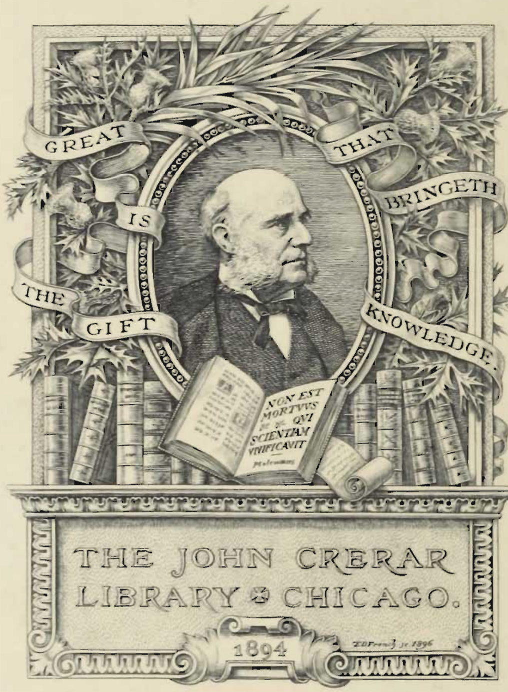
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UNITED KINGDOM.

ECONOMIC GEOLOGY

OF THE

ISLE OF MAN,

WITH SPECIAL REFERENCE TO THE

METALLIFEROUS MINES.

BY

G. W. LAMPLUGH, F.G.S.

[REPRINTED FROM THE MEMOIR ON THE GEOLOGY OF THE ISLE OF MAN, 1903.]

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PREFACE.

The following account of the Economic Geology of the Isle of Man deals principally with the metalliferous mines, and is a reprint of Part III. of the Memoir on the Geology of the Island. It is issued as a separate volume to meet the requirements of those who are especially interested in the mines.

The original paging is retained, together with the cross-references to other portions of the complete memoir. As stated in the preface to the larger work, our thanks are due to the managers of the mines throughout the island, without whose cordial co-operation it would have been impossible to collect the information contained in the following pages.

The Commissioners of the Woods and Forests also aided us by giving Mr. Lamplugh access to the documents in their possession, amongst which are the valuable manuscript reports of the late Sir W. W. Smyth. The particulars as to old workings have been principally obtained from these documents, and it is believed that these particulars will be of considerable local interest and value.

J. J. H. TEALL,
Director.

Geological Survey Office,
28, Jermyn Street, London,
13th March 1903.

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ECONOMIC GEOLOGY

OF THE

ISLE OF MAN.

CHAPTER XII.

THE METALLIFEROUS VEINS OF THE ISLAND.

Historical and Introductory.

In proportion to its area the metalliferous wealth of the Isle of Man has been great. Two of its mines have stood, for a long series of years, in the first rank in the British Islands for productiveness, respectively, of silver-lead and of zinc. These metals have constituted its principal riches, but copper-pyrites and hematite-iron have also been raised in marketable quantity. Of orés of nickel and antimony only minute quantities have been found, while of gold the reported occurrences are not well established (p. 549).

As veins yielding traces of the useful metals are frequently exposed in the cliff-sections, it is not surprising to find that they attracted attention at an early date, and are mentioned in the ancient records of the Island.

The great lode of Bradda Head (see p. 530), with its gangue of white vein-quartz cutting vertically through the cliffs of dark slate, stands up so conspicuously when viewed either from land or sea that it must have received notice as soon as this part of the Island became known to men acquainted with the use and mode of occurrence of its metals.

Hence, so far back as history goes we hear of this lode; and the miners of later days have found workings of unknown date in which the ore had been extracted by the use of 'feather-wedges,' a method abandoned upon the introduction of gunpowder.[1] These old workings have been vaguely assigned to "the Romans"; but though the Island was known to that nation the absence of Roman antiquities renders it improbable that any attempt was made by these invaders to colonise it.

[1] Cumming, "Isle of Man," p. 306; also Berger Trans. Geol. Soc., vol. ii., p. 51.

We are informed by Mr. A. W. Moore, the historian of the Island, that in the course of his researches[1] he finds the first mention of the Manx Mines in 1246. The island was at that time still under the dominance of Norway; and its King, Harald II, granted a charter by which the monks of Furness Abbey obtained the right to work the mines.[2] The previous existence of the mines is thus distinctly implied.

Cumming notes that "it is stated in Chaloner's 'Caledonia' (vol. iii., p. 372) that John Comyn, Earl of Buchan, obtained from Edward I. a license to dig for lead in the Calf of Man to cover eight towers of his Castle of Cruggleton in Galloway. In the course of the 15th, 16th, and 17th centuries, the noble family of Stanley appear to have sought for copper in the same neighbourhood; traces of their labours remain. The ore discovered, though not abundant, was rich in quality, producing six pennyweights of copper per ounce of ore."[3]

From Mr. Moore's researches we learn that in 1406 "mines of lead and iron" were included in the grant of the Island to Sir John Stanley by Henry IV.; and in 1422 it was ordered that the lord's mine should be managed by his "Lieutenant, Receiver, and Comptroller,"[4] who had to see that the miners did their duty. In the middle of the 17th century, Chaloner mentions that Capt. E. Christian found the Ore of Lead at "Mine-hough" [Mine-howe ?] or Bradda Head to contain much silver.[5] After the Restoration, mining was prosecuted more systematically; and from that time both lead and copper seem to have been diligently sought, the lord letting his rights in the mines on condition of receiving one-fifth of the produce. In 1668 a lease of all the mines in the Island, with leave "to erect a smelting mill, or more than one, for the smelting of the oar-mynes and minerals," was granted to two merchants, one of London, and one of Liverpool.[6]

In the following year Charles, the 8th Earl of Derby, at that time Lord of Man, "being by good reasons persuaded y^t there is plenty of coales" in the Island, ordered the Governor to institute a search for it.[7] In 1699 the lord's fifth of the lead and copper ore amounted to 32 tons 13 cwt. About this time also the hematite iron-ore of Maughold received attention, Mr. Moore finding it on record that in the year 1700 there was shipped from the mine at "Daunane" (Drynane, see p. 126) 227½ tons of this ore.[8]

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[1] Since this chapter was written, Mr. Moore has included an account of the progress of Manx mining in his "History of the Isle of Man" (2 vols. 8vo, London, 1900). Vol. ii., pp. 960-971.

[2] "Cott. MSS., Manx Soc., vol. vii., pp. 79-81."

[3] "Isle of Man," p. 307.

[4] "Statutes," vol. i., p. 19.

[5] See reprint by Manx Soc., vol. x., p. 8.

[6] "Loose sheets in Seneschal's Office" [A. W. Moore].

[7] *Ibid.*

[8] *Ibid.*

Governor Sacheverell, in his "Account" of the Island published in 1702, writes:—"I am informed, since I left the Island, they have discovered very good mines of Lead, Copper, and Iron, and great probability of Coal."[1]

The strenuous efforts made about this time to encourage mining are illustrated by the following notice, published in 1714 (for copy of which we are indebted to Mr. Moore).

'Forasmuch as our hon^ble Lord hath been pleased for the discovery and finding out mines within this Island . . . to send over an order . . . . that any person who shall find out any veines of Lead or Copper . . . . such as shall be thought fitt for working by the Steward or overseer of the said workes . . . . shall not only have paid down to them fourty shillings as a reward, but shall have the preference of working the said mines . : . . and three pounds a ton for every ton they shall get, delivering unto the Steward a fifth part of what oare they shall raise after the same is cleansed and made merchantable, provided they begin and prosecute the said work within three months."[2]

A few years later, Bishop Wilson wrote as follows:—"Mines of coal there are none, though several attempts have been made to find them; but of lead, copper, and iron there are several, and some of them have been wrought to good advantage, particularly the lead; of which ore many hundred tons have of late been smelted and exported. As for the copper and iron ores, they are certainly better than at present they are thought to be, having been often tried and approved of by men skilled in these matters: however either through the ignorance of the undertakers, or by the unfaithfulness of the workmen, or some other cause, no great matter has as yet been made of them."[3]

From this statement it appears that the metals were raised in the same relative proportions at that time as at present, excepting that the zinc-blende associated with the lead-ores, formerly of little or no value, is now a product of considerable worth. The repeated attempts since made to work the veins of copper and iron have met with no lasting commercial success, and it seems to have been demonstrated that those ores do not occur in sufficient quantity for profitably winning under current conditions of price.

In the above accounts the only localities actually mentioned are Bradda Head, The Calf, and Maughold, all places where the metalliferous veins are visible in the cliffs, though it is probable that trials had also begun on the richer deposits of the interior. Dr. Berger in his description of the mines in 1814 has the following note:—"Mr. Fitz-Simmons, who is preparing to publish an extensive work on the ancient History of the Isle of

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[1] Manx Soc. Reprint, p. 17.

[2] "'Lib. Scacc.'" [A. W. Moore].

[3] Bp. Wilson's "History, etc.," in Camden's "Britannia," 1772, p. 392, Manx Soc. Reprints, vol. xviii., pp. 94-5.

Man, states that mention is made of the mines of the Isle in the time of Sir Stanley 1st and 2nd." (*Foot note*—"The first Sir Stanley appointed King of Man, was by grant from King Henry 4th in the year 1407.") "Those at Brada, he believes, were first wrought; whether those at Foxdale were then opened may be doubted; those at Laxey were opened and wrought by a mining company of Cumberland, about the commencement of the last century . . . .

"Mr. W. Geneste informs me further that he lately found in some books (titled Charge of the Revenue) in the Duke's office in Douglass (called the Seneschal's office) that the last Earl of Derby had the mines wrought, paying the workmen at the rate of £3 Manx per ton for the ore (lead) raised. In 1709, he paid the miners for about 70 tons; from 1709 to 1713, about 30 tons yearly. A new smelting house was built in 1711. The workings of the mines was totally suspended about 3 years ago."[1]

Among the papers preserved in the Office of Woods and Forests in London relating to the mines of the Island are several relating to a grant, made in 1679 by King Charles II. to Charles, Earl of Derby, of a Lease of "all Mines Royal of gold or silver, or holding gold and silver to such a proportion as according to the Laws of the Realm of England doth make the same a Mine Royal." This lease had expired by the failure of the Heirs male of the grantee on the death of James, Earl of Derby in 1735, but was revived on the petition of John, Duke of Athol in 1780, upon a declaration made by P. J. Heywood, a former Deemster of the Island:—"That he is enabled to declare of his own knowledge and from what he hath heard, that there are not any mines of Gold or Silver in the said Island; that the only mines which now are or ever were wrought in the said Isle, as he hath heard and believes, are Mines of Lead and Copper. Except that he hath heard some Mines of Iron have been worked formerly, and that he hath been informed by persons experienced in the knowledge of mines that there is a proportion of silver in the Lead-mines now working, but so small as by no means to answer the expence of assaying and separating."[2]

Feltham, in 1798, describes the mining work then in progress at Laxey and Foxdale, but found the Bradda mines closed.[3]

Woods, in his account of the Island published in 1811,[4] gives some interesting data respecting the mines then existing. These were at Laxey, Foxdale, and 'Breda' Head; and he mentions also deserted shafts of lead-mines with rubbish-heaps between Port Erin and Kirk Arbory, no doubt referring to those since reworked as the Ballacorkish or Rushen mines (see p. 532). He speaks of Bradda as a copper mine, but did not visit it. Foxdale he found deserted and drowned (see p. 500). Laxey was being worked by two levels from the banks of the river and yielded

[1] Trans. Geol. Soc., vol. ii., p. 51.
[2] In a Report of the Surveyor-General to the Royal Commission.
[3] "Tour through the Isle of Man," pp. 213, 243.
[4] "Account of the Isle of Man," pp. 10-20.

silver-lead, blende and copper (see p. 519). He mentions that a small quantity of compact brown ironstone occurred immediately under the breccia (Carboniferous Basement Beds) in the Silverburn near the mill below Athol Bridge. The old level at that place to which reference was made on p. 197 was perhaps in connection with this ore.

Quayle also published details respecting some of the workings in 1812.[1]

Macculloch, in his work published in 1819, discusses the metalliferous veins of the Island at some length.[2] He notes that the mines were all abandoned, with no prospect of renewal —a statement which in view of the later highly successful results obtained from Foxdale and Laxey may afford some prospective encouragement to the hopeful adventurer on old workings in the Island. He speaks of Laxey, Brada Head and Foxdale as the three principal veins, but found that work had been carried on also at Ballacorkish and Glensash (Glenchass, see p. 536) near Port St. Mary; and some other small north and south veins near Port Erin were pointed out to him by old miners, (probably at Bay Fine and Calf Sound, see p. 532).

The following are the "Mines and Minerals" catalogued in the "Schedule of the Property" conveyed by the Duke of Athol to the Crown in 1827–8 (MS. in Office of Woods and Forests):—

LEAD MINES.

New Foxdale.
Old Foxdale.
Flappy Vein.
Balla Corkish Vein.
Silver Bourne Vein.
Glen Chass Vein.
Bradda Head Vein.
Laxey Vein.

COPPER MINE.

Bradda Head.

IRON STONE.

Maughold Head.

POLISHING POWDER.

Ballastole.

YELLOW OCHRE

Mallew.

LIME STONE.

Port le Mary.

BLACK LIMESTONE.

Pool Vasle [vash].

SLATE.

South Barrule.

STONE QUARRIES.

Gob e Valley.
Spanish Head.

COAL.

Among other papers relating to this transfer preserved in the Woods and Forests Office in London are copies of the leases under which the mines were worked, and plans showing the extent of the development of the more important mines up to that time. These plans will be referred to when the mines are separately described.

1 "General View of the Agriculture of the Isle of Man," pp. 9-10.
2 "Western Isles," vol. ii., pp. 574-577.

The third and fourth decades of the 19th century marked a great revival and development of the Manx mining industry. After that time its steady progress may to some extent be traced in the Mining Statistics published in an early memoir of the Geological Survey and in the Records of the School of Mines (see pp. 495–8).

Cumming gave a full account of the condition of the mines as he found them in 1845—1848.[1] He notes that the Foxdale mining ground, extending eastward across the northern side of South Barrule from Glen Rushen, had hitherto proved the most productive on the Island; and thinks that the proximity of the granite had very beneficially affected its mineral riches. The company then working this group of mines generally employed about 350 men and boys, and the average raising of silver-lead ore for the previous ten years had been about 2,400 tons per annum. Laxey also, he states, was being worked by a new company employing 300 men and raising 60 tons of lead, 200 tons of blende mixed with lead, and 5 tons of copper ore per month; the deepest working being 130 fathoms below the adit-level. The other mines which he mentions are the Ellerslie on the Bishop's Barony near Crosby (see p. 516), which was being worked without success; a Copper Mining Company in Maughold parish, also unsuccessful; and the iron mines in the same parish, in which about 70 men were employed and ore raised to the extent of about 500 tons per month.

During the ensuing twenty or thirty years the great prosperity of the Foxdale and Laxey companies led the investing public to take shares readily in Manx mining enterprises, and stimulated the search for metals in every part of the Island. Numerous new companies were formed, and mines established on the slenderest prospects, with of course almost uniform ill-success. In some cases no ore whatever was obtained; oftener the vein yielded a little lead, zinc, or copper, in quantity too small to be marketed; while in a few instances sufficient ore was found to be worth selling, but less than paid the working expenses. The wrecks of these mines, with their ruined buildings and plant, are strewn here and there over the whole area occupied by the Manx Slates. It is impossible at the present time to obtain in the Island definite information regarding many of these; but fortunately, through the courtesy of the Commissioners for the Woods and Forests, we have been allowed access to the reports made annually between the years 1857 and 1888 by the eminent mining authority, Sir W. W. Smyth, who, in his official capacity as Chief Mineral Inspector for that department, examined most of the workings at the period of their activity, and reported fully. We are also indebted to Mr. W. H. Rowe of Douglas, for placing at our disposal his collection of plans and details of old mines. From these and other sources duly acknowledged in the context, the descriptive accounts of these ventures given in the succeeding pages have been prepared.

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[1] "Isle of Man," Appendix K., pp. 306-311.

GEOLOGY OF THE METALLIFEROUS VEINS.

General Characters.

While the lodes which have been mined to commercial advantage in the Isle of Man are only two in number, viz., that of Foxdale and that of Laxey, it has been demonstrated by the numerous other workings that ores of lead, zinc, iron and copper are present in a minor degree in veins in almost every part of the Manx Slate Series. These veins have in all cases the character of infilled fissures which break across the stratification of the rocks. Relative displacement of the walls of these fissures has probably occurred in most cases, but usually only to a slight amount; and it is exceptional to find indications of considerable faulting along them. The principal vein is generally accompanied by rudely parallel veins and branches which are sometimes in themselves metalliferous, the whole forming a more or less complex group. Occasionally they are broken and displaced by later transverse faults, as will subsequently be described. Almost invariably they are inclined, at angles of from 5° to 30° or more degrees from the vertical, this "hade" varying in amount as the vein is followed downward, but usually constant in direction. In rare instances the "hade" is temporarily reversed, a change considered by the miners to be unfavourable to the productiveness of the lode.

The veins are subject to great and sudden variations in breadth and in mineral contents, the metalliferous deposits rarely form more than a small proportion of their infilling, the greater part of the fissure being occupied by crystalline quartz, calcite, dolomite, with sometimes a little barytes, fluor-spar, etc., and by breccia and decomposed material derived from the walls. Gas- or water-filled cavities known as "lochs" or "vughs" are likewise frequent. The valuable ores sometimes occur in definite ribs in the vein-stuff, and sometimes in disseminated crystalline grains, or in both forms combined. It is clear that the crystalline constituents, both metalliferous and non-metalliferous, have been slowly deposited in open cavities. In some cases, mostly in the Foxdale Lode, there are indications of movement of the walls after partial infilling of the fissure, causing portions of the vein-stuff to be displaced and brecciated. The fissures have been found to extend vertically, with or without ore, as deeply as the deepest mining works have gone, viz., not far short of 2,000 feet below the present surface at Foxdale and at Laxey; laterally, the Foxdale lode in one or another of its branches has been traced almost continuously for 2½ miles, and the Laxey Lode for over a mile; but in most cases the veins have been found to split up or otherwise become indistinguishable within much shorter distances.

Direction of the Lodes.

The main lode-system at Foxdale has a nearly east-and-west course, and the smaller veins at the old Cornelly Mine a mile north of Foxdale, and at the Bishops Barony Mine three miles east of Foxdale, have also this direction; but at Laxey, Snaefell, Ballacorkish, Bradda, and in fact at almost all the other workings from which ore has been obtained, the direction of the lode has been approximately north-and-south, or more strictly, a little (5°—30°) to the west of north and east of south. In only one or two unimportant instances has any ore been found in N.W. and W.N.W. veins; while apparently not a single case of a productive north-easterly vein is known, although this is the direction of strike of the rock-masses and of innumerable quartz-veins accompanying planes of cleavage, crushing and fracture (see pp. 86–7). It is true that the predilection of the miners for north-and-south veins has led to these being tested in far greater numbers than those in any other direction, and that this selection may in some degree have affected the result; but the extent to which veins of every kind have been cross-cut in underground workings on the productive lodes is sufficient to prove that the occurrence of the metalliferous ores in other than the recognised directions must be extremely rare.

The north-and-south veins are rather frequently dislocated by normal faults, known to the miners as 'slides,' which usually strike about E.20°N.—W.20°S., or approximately at right angles to the metalliferous vein. Several of these have been observed in the Laxey Mine (see p. 521) and others at Ballacorkish (p. 527), Snaefell (p. 535) and one or two other places (pp. 528, 532). The amount of vertical displacement which they represent is as a rule small; but if the disturbances by which the Laxey vein is lost southward, and by which the Ballacorkish vein is broken at the "Great Douk Lode," be due to faulting, these cases may be of great extent. It is not clear whether the north-and-south lodes received their metalliferous infilling before or after these transverse dislocations took place; with one supposed exception (p. 522) the 'slides' have never been found to contain ore, but some of the facts at Laxey suggest that the principal deposition of the metals took place there subsequent to the faulting of the lode (p. 522).

At Foxdale, while the chief productive lode strikes east and west, this intersects north-and-south metalliferous veins both in the central portion of its course, and farther west at Beckwith's Mine; and in the latter case the E.—W. lode is said to have thrown the N.—S. lode at the intersection (p. 505), thus playing the rôle of a 'slide.' In the Foxdale Mines slickensided surfaces are abundant, and the striations are generally nearly horizontal, showing that some degree of lateral movement has taken place along the line of the lode; moreover, the metalliferous vein-stuff is in places broken up, sometimes into partially rounded blocks, and recemented by undisturbed material subsequently introduced, showing that there has been movement along the fissure after an interval of quiescence.

It seems possible that the later movement may have taken place here at the time of the cross-faulting of the N.—S. lodes in other districts, and that the Foxdale vein was affected along, and not across its course because of its E.—W. direction.

A point of importance in regard to the position of the lodes is, that all the larger and more productive, including Bradda, Ballacorkish, Foxdale, Laxey, and Maughold Head, occur on or in the vicinity of the structural axis of the Manx slates, near where the dominant dips of the folded strata and of the cleavage form an anticline. As elsewhere shown (p. 118), this axis is probably the centre of a synclinorium of the slates as a whole; but it is remarkable that in many mining districts abroad, *e.g.*, in Nova Scotia and Queensland,[1] a close association of metalliferous deposits with anticlines of folded strata has been observed, though not in veins of the Manx character.

Age of the metalliferous lodes and relation to the Olivine-dolerite dykes.

While from the limited range of Manx stratigraphy direct evidence as to the period at which the metalliferous fissures were formed is not forthcoming, we possess sufficient data to show that it must have been comparatively late in the geological history of the Island. It was certainly later than all the Pre-Carboniferous earth-movements and dyke-injections described in a previous chapter (p. 71-2), by which the Slate Series was packed into folds, brecciated, foreshortened by overthrusts, and interpenetrated by basic and afterwards by granitic intrusions.

The segregation-veins of quartz and other minerals which were formed so abundantly during the later stages of these movements contain no metals of economic value; and the metalliferous fissures have been cleanly gashed through rocks in which all the above indications of earth-movement are present, and are clearly subsequent. The presence of copper pyrites in a vein in the Carboniferous Basement Conglomerate at Langness (p. 538), and of galena in a similar vein in the Carboniferous Limestone at Castletown (p. 537), brings down the date of, at any rate, some of the metalliferous deposits into Post-Carboniferous times. The only 'solid' rocks newer than Carboniferous accessible to observation above sea-level in the Isle of Man are the intrusive dykes of olivine-dolerite, which, on grounds already discussed (Chap. VIII, p. 327), are believed to be of Tertiary age. The study of the relationship of these dykes to the lodes has led me to the unexpected conclusion that, although the fissures were in existence before the date of these intrusions, some part of their metalliferous infilling was of later date. The grounds for this conclusion are fully stated in the descriptive details of the Bradda, Ballacorkish, Langness, East Foxdale and other mines, and will here be only briefly recapitulated.

At North Bradda, Ballacorkish, and Langness there is evidence to show that dolerite dykes, following the usual north-westerly

[1] Victoria Government Blue-book; Dept. of Mines; Reports on the Bendigo Gold-field, by E. J. Dunn, pp. 9-13 (Melbourne, 1896).

course, have been diverted northward for a short space on intersecting the fissures. In the first-mentioned place, where the lode is of great size and clearly revealed in the cliff, it is seen that the dyke is intrusive into the vein. But at Ballacorkish and East Foxdale, portions of the metalliferous lodes have been found in the underground workings to intersect the igneous rock (see Smyth's reports quoted on pp. 515 and 534), and the ores (sulphides) lie alongside the margin of the dyke-rock, in positions which they could not have occupied before or during the injection of the molten matter; and similarly at Langness, where the ore slightly interpenetrates the dolerite. Besides the places above mentioned, smaller quantities of the metalliferous ores have been found in the vicinity of olivine-dolerite dykes at Kerroo-mooar (p. 546), Glen Auldyn (p. 545), Maughold Head (p. 541), and Castletown Harbour (p. 537); but in all except the last case no evidence is now available as to the exact relationship.

It is of course possible that scattered ores already in existence in the fissures may have been displaced and concentrated into larger bodies by the invasion of the dykes; but it seems more likely that the deep-seated channels which permitted the upward egress of the molten rock may also have served, at a somewhat later stage of the same period of thermal activity, as conduits for the vapours and waters which supplied the crystalline infilling to the reopened fissures.[1]

It does not follow, however, that the whole of the Manx metalliferous veins are of this age; for it is only in a few instances, and these not of the first importance, that the connection between the dolerite and the ores has been observed; and, moreover, the majority of the olivine-dolerite dykes are not known to be accompanied by ore-deposits. All that can be learned from the evidence is that where the dykes of this late age are in contact with the metalliferous accumulations, the latter are the newer. As no association of olivine-dolerite dykes with ore deposits appears to be known in Western Scotland and Northern Ireland where these intrusions are so numerous, there must be some additional factor in the local conditions of the Isle of Man which has favoured the production of the metals in the veins. What this may be has not yet been discovered.

The outcropping of the metalliferous veins and of the dolerite dykes at the present surface shows how extensive must have been the erosion in the area during later Tertiary times, as the infilling of the fissures in both cases can only have occurred at some considerable depth.

I was not aware until after the above passages were written that my colleague, Mr. J. G. Goodchild, had some time ago reached a similar conclusion in regard to the metalliferous veins of another district by a different chain of reasoning. The

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[1] Sir W. W. Smyth's description of the quiet and undisturbed condition of the delicate fibres of Plumosite in the Foxdale lode, quoted on p. 503, has a direct bearing on this question.

following quotation from his suggestive paper entitled "Some Observations upon the Mode of Occurrence and the Genesis of the Metalliferous Deposits,"[1] will show that the Manx evidenc is in close agreement with his results.

"As bearing upon the age of the North of Eugland lead-veins one or two points remain to be considered. The faults wherein the veins occur probably date back in many cases to very remote geological periods. As zones of disturbance and of dislocation, many of them certainly may be referred to periods long anterior to the date of the rocks they now affect at the surface. There is plenty of evidence to show that, as zones of weakness, they have acted as faults again and again at various periods since. The fault breccias are scrunched and slickensided in a manner that points to the repeated exertion of powerful mechanical forces in times past. In remarkable contrast to this evidence of powerful grinding and crushing is that afforded by the crystalline contents of the veins. There may be, in a few instances, some kind of evidence of these vein-minerals having been disturbed since they were formed; but as a rule the evidence tends to show that since the date of formation of these minerals there has been no vertical displacement of the opposite cheeks of the fault. Large masses of crystals occur without the slightest sign of any break during their growth from first to last, and the crystalline faces of many of the minerals, such as Fluor, Baryte, Galena and others, are just as perfect as when the minerals were first formed. The significance of this very common feature of mineral veins does not seem to have been generally perceived."

"Another equally well-known feature in connection with mineral veins calls for remark here. This is the 'comby' structure of lodes, and the evidence of the deposition of vein minerals in successive layers. This clearly points to the fact that during the filling of the vein there were occasional interruptions of deposition, which were contemporaneous with more or less lateral disruption of the veins and their contents. After the formation of the earliest stages of the comby structure there has been no displacement along the plane of the fault."

"Such a condition of things, extending over a large area, can only have obtained under conditions of upheaval. This seems to indicate that the introduction of the lead ores of the North of England took place at, or about the close of, the last period of upheaval. This, by independent reasoning, I have inferred to be contemporaneous with the last manifestations of volcanic energy in Tertiary times; and all the evidence yet brought forward seems uniformly to support that conclusion" (pp. 56, 57).

In many other parts of the world it has been proved that certain metalliferous veins have received their infilling at comparatively late periods in geological history and in association with the intrusion of igneous rocks. If we take, for example, Part III. (Economic Geology) of the 18th Annual Report of the U.S.

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[1] Proc. Geologists' Assoc., vol. xi. (1888-9), pp. 45-68.

Geological Survey, which came to hand while this chapter was in preparation, we find an account (p. 69) of the celebrated Treadwell-Mexican Gold Mine on Douglas Island, Alaska, by G. F. Becker, in which it is stated that the mineralization of the lode is probably connected with the intrusion into it of a vein of analcite-basalt, the author concluding that " the basalt was injected after the mineralization began, but before it had ceased "; he adds, " so far as I know this is the first known case of an association of analcite-basalt with ore generation." The age of the intrusion is not definitely established, but is supposed to be either Late Mesozoic or Tertiary.

Moreover, in the same volume three out of the four other reports on mining districts, in widely separated parts of the Western States, embody the conclusion that the metalliferous infilling of the veins must be assigned to periods of eruptive activity in Tertiary (or in one case possibly Cretaceous) times: these are "On the Judith Mountains of Montana," by W. H. Weed and L. V. Pirsson (veins not older than early Tertiary, p. 463); " On the mining districts of the Idaho Basin," by W. Lindgren (veins probably Cretaceous or early Tertiary, p. 631); and " On the Telluride Quadrangle, Colorado," by C. W. Purington (veins not older than Late Tertiary, p. 825).

'Country'-rock of the Lodes.

The Manx metalliferous veins are developed principally in that portion of the Manx Slate Series which is intermediate in character between the grits on the one hand and the clay-slates on the other. Their usual matrix is the bluish-grey thin-bedded flags or flaggy slates which consist of a more or less intimate admixture of argillaceous and fine-grained sandy or silty material. In no case has a productive lode been found among the quartz-veined grits ("Agneash and other Grits," of published map); and where belts of this character have been encountered in underground workings, as at North Laxey and in the northern extremity of Great Laxey, the vein has been found to contract or become 'tight,' and to lose its value. On the other hand the homogeneous dark-blue "Barrule Slates" have been found equally barren; and where bands of this composition have been passed through, as at Snaefell and other places, the lode has become soft ('douky') and shattered, splitting up into small branches and losing its individuality. At Foxdale the main E. and W. lode, and also one of the N. and S. cross-courses (Magee's), has been followed downward from the slate into granite, and has been found equally as productive in the one rock as in the other, though the quality of the galena has shown a remarkable variation, that in the slate being richer in silver than that in the granite.

In this locality the opinion, alluded to by Cumming,[1] is commonly held that the metalliferous vein owes its riches to the

[1] " Isle of Man," p. 308.

granitic intrusion. But it is clear not only that the granite was consolidated, but also that its offshoots were affected by post-consolidation movements (p. 316) long before the lode was formed. Similarly at Laxey, the lode cuts across elvans given off from the Dhoon Granite, in which incipient cleavage had been produced by earth-movement subsequent to their consolidation (p. 521); and at the old Cornelly Mine, a mile N. of Foxdale, where massive granite was found beneath the slate (p. 517), the lode traversed both rocks. At Bradda, Ballacorkish, Snaefell, and North Laxey, considerable ore bodies occur in the slate-rocks where there is no reason to suspect the proximity of granitic intrusions; and the highly productive western portion of the Foxdale main lode, (Beckwith's Mine, p. 504), lies amid slates nearly 2 miles beyond the proved underground extension of the granite. The rich vein at Laxey, again, is about a mile distant from the nearest outcrop of the Dhoon Granite; while other veins in close proximity to that intrusion have proved barren or nearly so (p. 528). Hence the whole of the facts tell against the supposition that the metalliferous deposits were a direct result of the granitic eruptions.

In an indirect manner, however, it is possible that the Foxdale Granite, long after its consolidation, may have favoured the production of the lode, by affording a massive homogeneous rock-basement, in which a fissure produced by unequal earth-movement might descend to great depths and remain sufficiently open to permit the ascent along it of the vapours and solutions from which the empty spaces received their infilling. The broad shelving laccolitic outline of this granite (p. 166) would be more favourable to the production of such a fissure than would be the case in the Dhoon Granite, which appears to descend as an irregular pipe-like core with steep walls (p. 144).

The same explanation may be applied to the distribution of the veins in the sedimentary rocks. Where these were of a character to break cleanly to considerable depths, and to preserve an open space when fissured, as in the case of the firmly packed and welded mass of Lonan flags enclosing the Laxey lode, productive metalliferous veins have been formed: but where the rocks were, like the Agneash Grits, of such a character that regular fissures could not readily be produced in them; or, like the Barrule Slates, where if produced, such fissures would be filled with the broken débris of the walls, the conditions were unfavourable either for the percolation or deposition of the ore-bearing solutions, and the veins are consequently scanty and of no economic value. This explanation seems adequate for the known occurrences of ore in the Island; but fails to account for the fact that there are large tracts of the firm slaty flags apparently equally favourable for the production of lode-conditions, in which only inconsiderable quantities of ore have yet been discovered. Here again some additional factor in the deep-seated structure, to which we have no clue, is probably involved.

Association of the Ores in the Lodes.

On this point but little information has been obtained. The lead and zinc ores (sulphides) are usually found together, but the relative quantities are extremely variable; so that while at Laxey zinc-blende is by far the most abundant ore, at Foxdale the quantity present is too insignificant to be recognised commercially. Copper, in the form of pyrites, generally occurs, in very thin strings or finely disseminated around the outskirts of the other ore-bodies, as at Laxey, where its appearance in the southward drivings heralded the deterioration, of the lode (see p. 520); at Foxdale it is rarely found and in very small quantities (see Smyth's report in 1883 quoted on p. 511). Pyrites and chalybite are more or less present in all the lodes, the latter sometimes in large bodies at Foxdale.

The hematite ore of the Maughold veins, as suggested on p. 291, may have been introduced into the lode when the slates were overlapped by Triassic strata.

Lists of the minerals of the individual lodes and particulars respecting the rarer varieties are given in the subsequent detailed descriptions of the mines.

Notes on the Mineral Statistics since 1845.

After the close and systematic search which has been made in every part of the Island, we may presume that the relative importance of the various lodes has been well established, and that no considerable body of ore presenting surface indications can have been overlooked, though there is, of course, the possibility that such may remain still undiscovered beneath a superficial covering of drift. As previously mentioned, while the valuable ores have been found in small amount in many veins, the commercially successful mines are and apparently have always been confined to two lodes—that of Foxdale and that of Laxey, though considerable bodies of lead and zinc ore have been met with also in the mines of 'Snaefell,' 'North Laxey' in the Cornah Valley, and 'Ballacorkish'; and of hematite in Maughold parish. From all the other workings combined the total quantity is inconsiderable. From the depth to which the principal mines have now been sunk, we must also conclude that the average output of the last fifty years is unlikely to be maintained in the future.

LEAD-ORE.—The table given on pp. 495–8 shows that between 1845 and 1850 the average output of lead-ore was 2,300 tons per annum, of which at first six-sevenths, and afterwards two-thirds was contributed by the Foxdale group of mines, and practically the remainder by Laxey. A steady increase during the next five years brought the total output of this ore in 1855 up to 3,573 tons, of which three-fourths was from Foxdale, and the remainder from Laxey. A decrease then set in, so that until 1864 the annual output ranged, in round numbers, between 2,500 and 2,800 tons. In that year however the contribution from Laxey was greatly augmented; and in the following year equalled that of Foxdale, bringing the total up to 3,143 tons of lead-ore. In 1871 the grand total of 4,645 tons was reached, of which Laxey yielded a half, Foxdale rather over a third, and eight smaller mines the remaining sixth. There was a drop of 1,000 tons in 1872 owing to a decrease of that amount from Laxey; but from 1873 to 1877 inclusive the total annual output of the Island remained steadily between 4,200 and 4,400 tons, the Foxdale contribution maintaining, as for many previous years, remarkable regularity at about 1,600 to 1,700 tons. In 1878 the returns fell below 4,000 tons, Laxey sinking again, and permanently, to the second place as a lead-producer. But this deficiency was more than made up in succeeding years by Foxdale, which swelled the output to high-water mark at 6,868 tons in 1885, two-thirds of which was from this mine and less than a quarter from Laxey. From 1884 to 1893 inclusive the total yield of lead-ore remained between 6,000 and 6,700 tons, the decline of Laxey meanwhile continuing, so that in the last-named year its proportion was less than one-seventh, while Foxdale yielded three-fourths and three other mines the remainder. Since that date, though Foxdale has maintained its high productiveness—its yield of 4,800 tons of lead-ore for 1894 being the greatest in the history of the mine—the deficiency from the other mines has diminished the total output of the Island to 3,843 tons for 1900.

ZINC-BLENDE.—The only other metal deserving special notice is zinc; and its history is practically that of the Laxey Mine, as except during a short period of productiveness at Snaefell, the other sources of this substance in the Island have been unimportant. In 1854 the returns of blende from Laxey were 1,435 tons, rising suddenly in the following year to 3,989 tons, and from that time until 1861 ranging around 3,000 tons more or less. Then follow great fluctuations, so characteristic of this mine, the record for 1862 being 691 tons; for 1863, 2,298 tons; for the four following years, between 4,960 and 5,488 tons; in 1869, 7,208 tons; and so on, until in 1875 the returns show 11,753 tons of blende from this mine, and 11,898 tons from the whole Island, a quantity which has not been since attained.

During the ensuing decade, the average was about 6,000 tons, ranging from about 2,000 above to 2,000 below this figure. But since 1885 there has been a continued decline which brought down the total for 1896 to 1,180 tons of blende from Laxey and 1,489 tons from the whole Island, with a slight recovery to the total of 2,009 tons in 1897, 2,602 tons in 1899, and 2,124 tons in 1900.

The following table gives the total annual output of the Manx Mines recorded in official returns.

ISLE OF MAN MINING STATISTICS.

TABLE showing TOTAL OUTPUT OF MANX MINES.[1]

Year	1826	1827	1828	1829	1830	1831	1832	1833	1834	1835	1836	1837	1838	1839	1840	1841	1842	1843	1844
	Tons.	*Tons.*	*Tons.*	*Tons.*	*Tons.*	*Tons.*	*Tons.*	*Tons.*	*Tons.*	*Tons.*	*Tons.*	*Tons.*	*Tons.*	*Tons.*	*Tons.*	*Tons.*	*Tons.*	*Tons.*	*Tons.*
Lead ore (containing silver, as below).	—	—	—	—	—	—	—	No returns available before 1845.					—	—	—	—	—	—	—
Zinc ore	—	—	—	—	—	—	—	No returns available before 1854.					—	—	—	—	—	—	—
Copper ore[2]	33	—	28	161	238	283	341	249	268	77	89	69	121	183	278	368	406	207	46
Iron ore	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Umber, Ochre, etc.	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Silver, estimated quantity contained in lead ore	—	—	—	—	—	—	—	No returns available before 1851.					—	—	—	—	—	—	—

[1] Compiled from Mem. Geol. Survey, vol. ii. (1848), pp. 703-715; Records of the School of Mines, vol. i. (1853), pt. 4; Mineral Statistics, 1853-1898.
[2] The figures for the first twenty-two years are derived from "Sales at Swansea from English Mines," Mem. Geol. Survey, vol. ii. p. 715.

ISLE OF MAN MINING STATISTICS.—*Continued.*

Table showing Total Output of Manx Mines.

Year	1845	1846	1847	1848	1849	1850	1851	1852	1853	1854	1855	1856	1857	1858	1859	1860	1861	1862
	Tons.	*Tons.*	*Tons.*	*Tons.*	*Tons.*	*Tons.*	*Tons.*	*Tons.*	*Tons.*	*Tons.*	*Tons.*	*Tons.*	*Tons.*	*Tons.*	*Tons.*	*Tons.*	*Tons.*	*Tons.*
Lead ore (containing silver, as below).	2,259	2,316	2,575	2,521	2,826	2,175	2,560	2,415	2,460	2,800	3,573	3,218	2,656	2,457	2,464	2,810	2,718	2,508
Zinc ore - - -	—	—	—	—	—	—	—	—	—	1,435	3,990	3,000	2,917	2,777	—	3,181	3,255	691
Copper ore - - - -	79	92	60	—	—	—	—	—	—	64	—	125	260	403	354	350	785	942
Iron ore - - - - -	—	—	—	—	—	—	—	—	—	—	2,240*	—	—	566*	1,282*	1,671*	967*	647*
Umber, Ochre, etc. - -	—	—	—	—	—	—	—	—	—	164	—	151	—	120	—	—	116	—
							Oz.	*Oz.*	*Oz.*	*Oz.*	*Oz.*	*Oz.*	*Oz.*	*Oz.*	*Oz.*	*Oz.*	*Oz.*	*Oz.*
Silver, estimated quantity contained in lead ore.	—	—	—	—	—	—	33,980	36,700	47,105	52,262	52,203	60,382	48,016	46,985	56,974	60,170	67,282	70,592

* Hematite.

ISLE OF MAN MINING STATISTICS.—*Continued.*

TABLE showing TOTAL OUTPUT OF MANX MINES.

Year	1863	1864	1865	1866	1867	1868	1869	1870	1871	1872	1873	1874	1875	1876	1877	1878	1879	1880
	Tons.	*Tons.*	*Tons.*	*Tons.*	*Tons.*	*Tons.*	*Tons.*	*Tons.*	*Tons.*	*Tons.*	*Tons.*	*Tons.*	*Tons.*	*Tons.*	*Tons.*	*Tons.*	*Tons.*	*Tons.*
Lead ore (containing silver, as below).	2,561	3,118	3,143	3,494	3,799	4,290	4,302	4,604	4,645	3,529	4,371	4,204	4,429	4,353	4,464	3,920	4,358	5,119
Zinc ore - - - - -	2,298	5,363	5,488	4,960	5,361	3,278	7,219	4,177	5,768	3,123	5,520	7,010	11,898	8,669	9,043	9,569	7,427	7,507
Copper ore - - -	1,293	127	1,317	294	400	462	459	373	180	323	—	61	—	75	52	30	20	35
Iron ore - - - - -	339*	—	120*	—	—	220*	1,291*	—	75†	122† 872*	512† 2,256*	718† 425*	—	—	—	100†	230†	9†
Umber, Ochre, etc. - -	—	—	—	130	—	149	139	142	172	148	248	156	183	—	170	232	156	166
	Oz.	*Oz.*	*Oz.*	*Oz.*	*Oz.*	*Oz.*	*Oz.*	*Oz.*	*Oz.*	*Oz.*	*Oz.*	*Oz.*	*Oz.*	*Oz.*	*Oz.*	*Oz.*	*Oz.*	*Oz.*
Silver, estimated quantity contained in lead ore.	74,289	125,020	123,221	147,516	165,170	178,718	172,839	172,528	176,631	145,433	163,058	161,612	183,524	170,105	186,019	110,496	100,476	59,667

* Hematite. † Spathose iron ore.

ISLE OF MAN MINING STATISTICS.—*Continued.*

TABLE showing TOTAL OUTPUT OF MANX MINES.

Year	1881	1882	1883	1884	1885	1886	1887	1888	1889	1890	1891	1892	1893	1894	1895	1896	1897	1898	1899	1900.
	Tons.	*Tons.*	*Tons.*	*Tons.*	*Tons.*	*Tons.*	*Tons.*	*Tons.*	*Tons.*	*Tons.*	*Tons.*	*Tons.*	*Tons.*	*Tons.*	*Tons.*	*Tons.*	*Tons.*	*Tons.*	*Tons.*	*Tons.*
Lead ore (containing silver, as below).	5,675	5,494	5,828	6,007	6,868	6,257	6,560	6,356	6,433	6,141	6,682	6,698	6,427	5,624	5,287	4,953	4,273	3,948	3,924	3,848
Zinc ore	7,567	7,756	4,820	5,685	5,510	4,795	4,994	5,320	4,596	4,388	3,561	3,380	3,628	2,570	1,535	1,489	2,009	2,135	2,602	2,124
Copper ore	60	44	578	—	236	—	—	46	—	7	—	4	—	—	—	—	—	—	—	—
Iron ore	120†	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Umber, Ochre, etc.	207	171	188	—	—	—	—	—	—	No Re	turns.	—	—	—	—	—	—	—	—	—
	Oz.	*Oz.*	*Oz.*	*Oz.*	*Oz.*	*Oz.*	*Oz.*	*Oz.*	*Oz.*	*Oz.*	*Oz.*	*Oz.*	*Oz.*	*Oz.*	*Oz.*	*Oz.*	*Oz.*	*Oz.*	*Oz.*	*Oz.*
Silver, estimated quantity contained in lead ore.	84,865	1 9,769	125,940	123,251	132,315	135,456	134,353	138,033	139,304	129,124	125,350	124,949	122,010	111,325	120,302	107,643	91,710	76,419	72,181	66,067

† Spathose iron ore.

MINING DETAILS.

List of Mines and Mining Trials in their order as described in the following pages. The names of the more important are printed in small capitals.

FOXDALE GROUP.

The Mines of the Central or Foxdale Area.

HISTORICAL AND GENERAL NOTES.

From both the geological and economic points of view the Foxdale Mines stand pre-eminent in the Isle of Man ;—during the latter half of the past century they have indeed attained to the first rank among the lead-mines of the United Kingdom for productiveness, as well as for good management, which has enabled them to survive successfully the vicissitudes in the market value of their product that have extinguished the industry in many mining districts. They are situated in the interior of the southern part of the Island, close to the head-waters of the Foxdale River. The east-and-west lode which they explore traverses the northern slopes of South Barrule and Granite Mountain (formerly known as Slieau ny Clough), the present workings being confined to the portion intersecting the village of Foxdale, at an elevation of from 400 to 450 feet above sea-level.

The date of the first discovery of ore in this locality is not known, but was at any rate before the early part of the 18th century, as in a report made to Lord Derby in 1724 the governor of the Island mentions that "Foxdayle hath from the first been worked with the least success . . . . I shall be forced to give it up, for the longer we work it the worser it grows." [1]

Since the surrounding ground is more or less drift-covered, we may presume that the lode was first recognised in the bed of the Foxdale River, which crosses its richest portion. Old workings may still be traced in the vicinity of the stream; and it was probably these to which Feltham referred in 1798 as having produced rich and abundant ore,[2] and which Woods noticed early in the next century, in a deserted condition, "the rubbish from the shafts consisting almost wholly of fragments of slate, mixed with pieces of brown blende, a little lead glance and some sparry iron ore." ("Account of . . . the Isle of Man," 1811, p. 12.) Berger also found the mines inactive (in 1811?); he mentions that a "small-grained granite" had been found in one of the shafts, and that a productive north and south cross-vein (see p. 510) had been discovered, with richer ore at its junction with the main vein. He was informed that the granite was found in a shaft 40 yards deep, where it "formed the north side of the vein, the galena adhering to it, while the south side was a stratified rock." [3] Macculloch, a few years later, likewise found the workings deserted and inaccessible.[4]

Some information regarding these old workings has been obtained from documents preserved in the Office of Woods and Forests. In a schedule of the property purchased by the Crown from the Duke of Athol in 1827–1828, we find under the heading of Lead-mines "*New Foxdale*," "Old Foxdale," and "Flappy Vein" (the cross-course mentioned by Berger), given as three distinct mines; and it is mentioned that these are subject to a lease granted by the Duke to Michael Knott for a term of 31 years from November, 1823. There is also in the same office an old plan and section prepared by J. A. Twigg in 1826, the former lettered, "Section of the vein of lead-ore at the New Foxdale Mine, wrought by M. Knott, Esq., in the Isle of Man, showing the course of the levels (driven near the vein) and a view of the shafts at present sunk, and also some trials made upon the Head of the vein at the Surface." This plan shows the Engine Shaft to be 38 fathoms deep, with two levels west and five levels east from it; the longest level was that at 15 fathoms, which went 160 fathoms east and was reached by

[1] Knowsley (Loose) Papers quoted by A. W. Moore in "History of the Isle of Man," vol. ii. p. 964.
[2] "Tour through the Isle of Man," p. 213.
[3] Trans. Geol. Soc., vol. ii. (1814), p. 37 and p. 52.
[4] Western Isles," vol. ii., p. 577 (1819).

three air-shafts E. o Engine Shaft, and by one W. of it; and still farther E. were two more sinkings, to a depth of 15 fathoms, with short drivings. The ground-plan indicates the main lode, with a "south string" and "north string" [? = Magee's Lode, see p. 510], just east of Engine Shaft: and a "strong vein" [? = Flappy Vein] going off nearly N.–S. on the west of Engine Shaft; and also an E.–W. vein joining the "main vein" 33 fathoms west of that shaft, on which is the note "This vein contains manganese and other minerals not congenial to lead." It shows, moreover, the position of "shaft sunk by the old men," and "old workings wrought 40 years ago."

Soon after Mr. Knott obtained his lease he appears to have sold his interest to a company, who took up the working ; and thenceforward, on one part or another of the vein, mining has gone on continuously up to the present day. The following account of the progress of the mine up to 1848 is given by Cumming :—

"The chief workings at that time [*i.e.*, circa 1823] were upon what is generally termed the Foxdale vein, to the northward of the great granitic boss, crossed by elvans striking out from the nucleus of the granite. Very little except horse and water power had been employed, though there were at that time two small steam-engines also at work, and the depth reached was never more than 40 fathoms. The great workings are now carried on [circa 1848] at the eastern and western extremities of the district, at Cornelly or Jones vein [see p. 516] in the neighbourhood of Kenna, and at the Beckwith vein in Glen Rushen. The Cronck Vane [1] mine, more in the centre of the district, on the brow of the hill betwixt Slieauwhallin and South Barrule, a few years ago was worked with very great results. The miners appear to have fallen in with one of those great sops or masses of ore which I have noticed in the body of this work as generally characteristic of limestone districts, but which appears as a peculiar feature of this schistose country also."

"At the time of my visit, in company with Professor Ansted, three years ago, the depth attained into the body of ore was 88 fathoms, the width of the vein or mass at its centre being 24 feet, thinning off to the E. and W. to about 4 feet. The length of this body of productive ore was 14 fathoms. The vein had generally a southerly dip, the walls being very clean, and presenting in several places extensive appearances of slickenside. There is very little gossan upon these veins, and not in general any indication of their presence till the workman comes directly upon the body of lead. The prediction of Professor Ansted at that time, respecting the duration of the working at the Cronck Vane Mine, seems to have been fully verified, as I found on my last visit to the place the works abandoned."

"The number of men and boys employed at the mines of this company in different parts of the district is generally about 350, and the average raising of ore for the last ten years has been about 2,400 tons per annum. The product gives about 70 per cent. for lead and 9 ozs. silver per ton." [2]

Since the above was written, the operations on the eastern and western extremities of the Foxdale lode and on the Cornelly (afterwards known as Townsend) vein have gradually been suspended; and for many years past, work has been confined to deep mining on the site of the earliest workings close to Foxdale village. An admirable record of the later history of the mines of the district is contained in the series of reports made annually between the years 1857 and1888 by Mr. (Sir) W. W. Smyth, as the result of his personal examination ; these are preserved in manuscript at the London Office of Woods and Forests, and in the context will be largely drawn upon for information respecting workings which are now inaccessible.

In 1867, D. Forbes in describing [3] the occurrence of Polytelite (Silber

[1] This refers to Cross's Mine (Cross Vein of 6-inch Ordnance Map, Sh. 12 ½ mile west of Doarlish Head.

[2] "Isle of Man," p. 309.

[3] "Researches in British Mineralogy," Phil. Mag., 4th ser., vol. xxxiv., pp. 350-4.

fahlerz) from the Foxdale mines, gave a short account of the character of the lode. He stated, on the authority of Mr. J. L. Thomas, that the polytelite occurred in the most easterly workings of the mine where the lode ran out of slate into granite, the minerals associated with it being galena, chalcopyrite, iron-pyrites, zinc-blende, quartz, dolomite, chalybite and calcite. Mr. Forbes gave an analysis of the polytelite, showing it to contain 13·57 per cent. of silver. His remarks on the granite and on the reported occurrence of gold in the locality will be alluded to on a subsequent page (p. 549).

In 1880 Mr. (Sir) W. W. Smyth gave an account of the general features of the lode in a paper "On the occurrence of Feather Ore (Plumosite) in Foxdale Mine."[1] The following passages are quoted from this paper as supplying an excellent and authoritative description of the vein and its rare mineral, plumosite :—

"The masterly lode of Foxdale has been worked for some four miles, not quite continuously, on its east and west course, and to an extreme depth nearly approaching 200 fathoms" [since carried to 290 fathoms, see seq.]. "It varies in character, and often within short distances, to as great an extent as perhaps any lode that could be cited ; sometimes, as at Beckwiths, a body of more or less orey material of 5 or 6 fathoms in width, in other parts exhibiting powerful ribs of solid galena with several tons of ore to the running fathom, again parting into parallel branches of an ordinary lead ore on the south wall, and others of a highly argentiferous variety affecting the north side, and often with from 2 to 6 fathoms of lode material between them. Between the courses and shoots of ore is encountered (and sometimes unfortunately for very long distances) a quantity of unproductive ground in which detrital killas, or granite, and ribs of chalybite (carbonate of iron), and singular veins and seams of an indurated black clay, form the chief constituents. This latter material, cutting sharply against some of the other lighter coloured substances, gives rise to appearances very instructive as regards successive openings and fillings of parts of the lode, and reminds one of the so-called *glauch*, which plays a similar part in the small but rich veins of tellurium and gold at Nagyag in Transylvania."

"Furthermore, the variation in appearance is added to by the fact that whilst the country rock has mostly been killas, the Old Foxdale Mine encountered granite at a medium depth—in some places only on one wall, and is now opening in many successive levels in a solid mass of that rock. No sudden alteration has been produced by the change of 'country'; but fluor spar is abundant in some of the western drivings, and in the deeper levels the main or south part of the lode appears to be more frequently than elsewhere a matrix of grey quartz. In these deeper levels a new and unusual feature has been the emanation of a gas, probably carbonic acid, from the crevices of the south wall of the lode, which has the effect of instantly quenching the flame of the candle, and at times had interfered with the work for days together."

"The chief engine shaft is Bawdens, and to the west of this, 10 to 20 fathoms, about the 100-fathom level, in a series of 'pitches' extending up to the 86, soon above which the killas comes in as 'country,' is the part of the mine in which the Plumosite has been found. Its *habitat* appears to be on the north side of the south part of the great lode. In other portions of the mine, about the 'old shaft' further east than the above, the well known antimonial ore of copper, called fahlerz or tetrahedrite, has been met with in spots and branches, notably at the 100 and 115-fathom levels; and the frequent tendency of this mineral to contain a large percentage of silver has no doubt had something to do with the unusual value for silver of the galena of some of the northern parts of the lode. These have in fact assayed at times from 100 to above 200 oz. of silver to the ton of lead, and have thus in many places admitted of being worked in thin strings, and in hard ground, where common lead-ore would not have paid to work. It might have been expected that the two antimonial minerals, the fahlerz and the plumosite,

[1] Trans. Roy. Geol. Soc. of Cornwall, vol. x., pp. 82-89.

would stand in some relation to each other. It is true they both occur at nearly the same level; but where the latter has been found there is no trace of the former."

"The plumosite is associated with a fine-grained galena, and a vuggy or cellular quartz, with many transparent crystals; it occupies these vugs, seldom filling them up entirely, but usually attached by one portion, whilst the remainder floats loosely. Its appearance is much like that of a piece of dark cotton wool, sometimes like a little wreath of smoke. . . . . . A closer examination will reveal multitudes of the finest spiculae, bright grey metallic-lustred hairs confusedly flung together, and sometimes so felted into one plane, the prisms crossing in different directions, as to look like a bit of rag or woven cloth. The colour, however, is always grey, and hence differs at once from the *Zundererz* or Tinder ore of the German mines, in which a notable proportion of silver, about 2·56 per cent., is revealed by the reddish colour due to an admixture of the mineral, Ruby silver ore. One or two of the specimens had a slight touch of that dull red colour which characterises the *Zundererz*; but in view of the minute quantity of the mineral it is difficult to decide whether the redness may be due to one of the 'ruby silvers' or to kermesite."

"Under the microscope the prisms come out distinctly; but it is difficult to be satisfied about their terminal faces. Other very curious features are now discernible; the hairlike prisms often affect curvilinear forms; arcs of circles and parabolas are not infrequent, and in some cases a coil of the microscopic hairs forms a perfect ring of very uniform thickness. The long crystals are flexible and elastic, and those which are anchored at one end will be seen to wave to and fro in a current of air. Some of these are adorned with minute bright crystals set at intervals upon them like beads upon a string. These latter appear to be cubical, and may probably be pyrites. . . . . . I cannot but regard it as a singular circumstance, under the data which we at present possess, that this new occurrence of plumosite should be connected exclusively with galena, quartz, and their usual associates. . . . . . The plumosite is, in point of date of deposition, the last mineral which has been formed in the little caverns of the lode, *and its delicate fibres and webs seem to indicate, whatever process we may call in to explain their origin, a period of quiet and undisturbed action.*"[1]

The emanation of carbonic acid gas from the lode, referred to by Smyth in the above account, was more fully described by Dr. C. Le Neve Foster in 1883,[2] who noticed the phenomenon in a cross-cut in granite, 14 fathoms south, from the 185 fathom level of the mine. Dr. Foster mentions in this paper that there had been a similar issue for a fortnight from a vug in the sole of the 80 fathom level of the Townshend (Cornelly) Mine three years previously, and that small escapes of the same gas had been reported from 'lochs' in the Great Laxey Mine.

The further literature relating to the Foxdale mines includes a short general description of the lode in 1890 by Prof. W. Boyd Dawkins[3]; and the brief accounts to be found in most of the larger British text-books on Ore-deposits; *e.g.*, J. A. Phillips' "Treatise on Ore Deposits," pp. 304-6 (2nd ed., London, 1896); C. Le Neve Foster's "Text-book of Ore and Stone Mining," pp. 335-8 (Lond., 1894).

While this memoir was in the press a short note on the mines by Capt. W. H. Kitto of Foxdale, read in 1892 before the Isle of Man Nat. Hist. and Antiq. Society, has been published (Yn Lioar Manninagh, vol. ii., 1901, p. 32). The following is Capt. Kitto's description of the lodes:—"There are several lodes in Old Foxdale, but the two principal bearing ones called the North and South, are very dissimilar—the former hard, with all its ore highly charged with silver, ranging from 50 to 400 ounces per ton, and

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[1] Italics not in the original.

[2] Trans. Roy. Geol. Soc. of Cornwall, vol. x., pp. 175-6.

[3] "On the clay slates and phyllites of the South of the Isle of Man, and a section of the Foxdale Mine." Trans. Manch. Geol Soc., vol. xx., pp. 53-56.

at times having small quantities of Tetrahedrite or Fahlerz, an ore of copper and antimony averaging from 3,000 to 4,000 ounces of silver, whilst the South, or soft doukey lode, by its side yields comparatively little silver, but a greater quantity of lead ore."

With regard to the occurrence of Plumosite in the mine, Capt. Kitto gives the following additional information:—"Plumosite was first discovered in the western part of these mines at the 86 fathom level. It is associated with fine-grained galena, and a vuggy quartz, with transparent crystals; . . . . Recently we have discovered it in the eastern part of the mine, about 60 fathoms deeper, in grey quartz and killas, with both sides of the lode composed of granite. We have not found it in large quantities, and never entirely in granite, but always in the locality of lead rich in silver." (Op. cit. p. 33.)

The annual output of ore from the mines since 1845 has been published in "Mineral Statistics" and other official records, and from these sources the Table given on p. 512 has been compiled. The periodical reports of the managers of the mines, giving full details of the progress of the workings, have for some years past been reproduced *in extenso* in the local weekly newspapers published in Douglas. Files of these newspapers may be consulted in the Douglas Free Library.

DESCRIPTION OF THE WORKINGS.

The main Foxdale lode has been worked almost continuously, by a string of shafts extending from Glen Rushen on the west to a little to the eastward of Foxdale village on the east, a distance of about 2½ miles, with outworkings, on a supposed prolongation of one of its branches at Eairy ½ mile still farther eastward. Its leading characteristics have been given in the preceding general description and in the passages quoted from Sir W. W. Smyth's account of the mines. It has a persistent southerly underlie, and in the central portion of its course, where best defined, strikes in an average direction of E. 3° 5° N. to W. 3° 5° S. Both eastward and westward it splits into branches, and is lost in confused and broken ground. In spite of repeated searches (some account of which is given on pp. 546 and 548) it has not been traced west of the stream in Glen Rushen, and the most westerly working to yield a profitable quantity of ore is the Beckwith Mine, 400 yards east of that stream, at an altitude of about 650 feet above ordnance datum.

The diagram overleaf, based on the plans in the possession of the Isle of Man (Foxdale) Mining Company, will serve to show the position and depth of the shafts on the main lode, and the lie of its principal branches and cross-courses (Fig. 110.)

Beckwith's Mine.

The following account of the discovery of the riches of this temporarily productive portion of the vein was given by the late Mr. W. Beckwith under the date April 9th, 1881, and printed in the prospectus of the "New Foxdale Mining Syndicate" (Garth Trial, see p. 515):—

"The Beckwith vein was discovered by the driver of a hay-cart crossing the west side of South Barrule, who found a solid lump of lead-ore in the wheel-track; this induced me to make a search in the neighbourhood, when I discovered ore among the roots of the heather, and immediately put two men to work who, on the following day opened up the ore, and about 650 tons were raised before sinking was commenced. The ultimate result of this discovery was about 50,000 tons of lead-ore which realised about three quarters of a million sterling." . . . . "Like all veins in the Isle of Man this enormous yield was irregular in its deposit, from the surface down to the 70 fathom level the vein averaging from 10 to 15 feet wide and producing fully 15 tons of lead-ore to the fathom. In the next 20 fathoms the vein grew poor, but on persevering with the sinking the ore was again cut into at the 90-fathom level, this new deposit being more productive than before, in places fully 26 feet wide and yielding 30 tons ore to the fathom. This great productiveness continued for another 50 fathoms down when the mine again became poor, evidently from the same causes that existed in the levels above."

In spite of its magnificent commencement, the deeper part of the mine and the lateral workings proved entirely unprofitable and it was abandoned about 1866, though an attempt was made 15 or 20 years later to form a company to restart it. The main or 'Beckwith's' shaft attained a depth of about 185 fathoms from the surface, intercepting the 'old day-level' at 15 fathoms and the 'new day-level' at about 35 fathoms, with levels at 15, 30, 45, 60, 75, 90, 102, 117, 132, and 147 fathoms below the new day-level. The ore-body seems to have been very limited in lateral extent throughout, lying chiefly to the eastward of the main shaft, having a general trend westward, and disappearing in depth below the 102 fathom level. The vein appears to be a southerly branch of the Foxdale Lode, and strikes S. 10° W., with a southerly underlie. A supposed north branch, 200 to 300 yards north of Beckwith's, striking approximately E.-W., has been recognised by the miners as the 'North Gill Lode,' and tested in several places, but without profitable result. These converging branches are supposed to fall together in the vicinity of Cross's Mine (see below). Besides these E.-W. veins, a productive cross-course striking nearly north and south (N. 3° W.), named 'Wardell's North Lode,' occurs at the Beckwith Mine, and was worked by N.-S. levels from that shaft, yielding ore chiefly between the 60 and 90 fathom levels. In view of the importance of determining the relative ages of these veins, I made special inquiry as to their intersection, and was informed by Captain J. Kitto that the N.-S. (Wardell's) lode was found to be shifted about 3 fathoms eastward on the south side by the E.-W. (Beckwith's) lode. Their relations are thus the same here as in the Laxey, Snaefell, and Ballacorkish mines where the N.-S. veins are displaced by later E.-W. 'slides' or faults; with this difference, however, that whereas the 'slides' of those mines are almost invariably barren, in this case the E.-W. vein constitutes the most productive part of the mine.

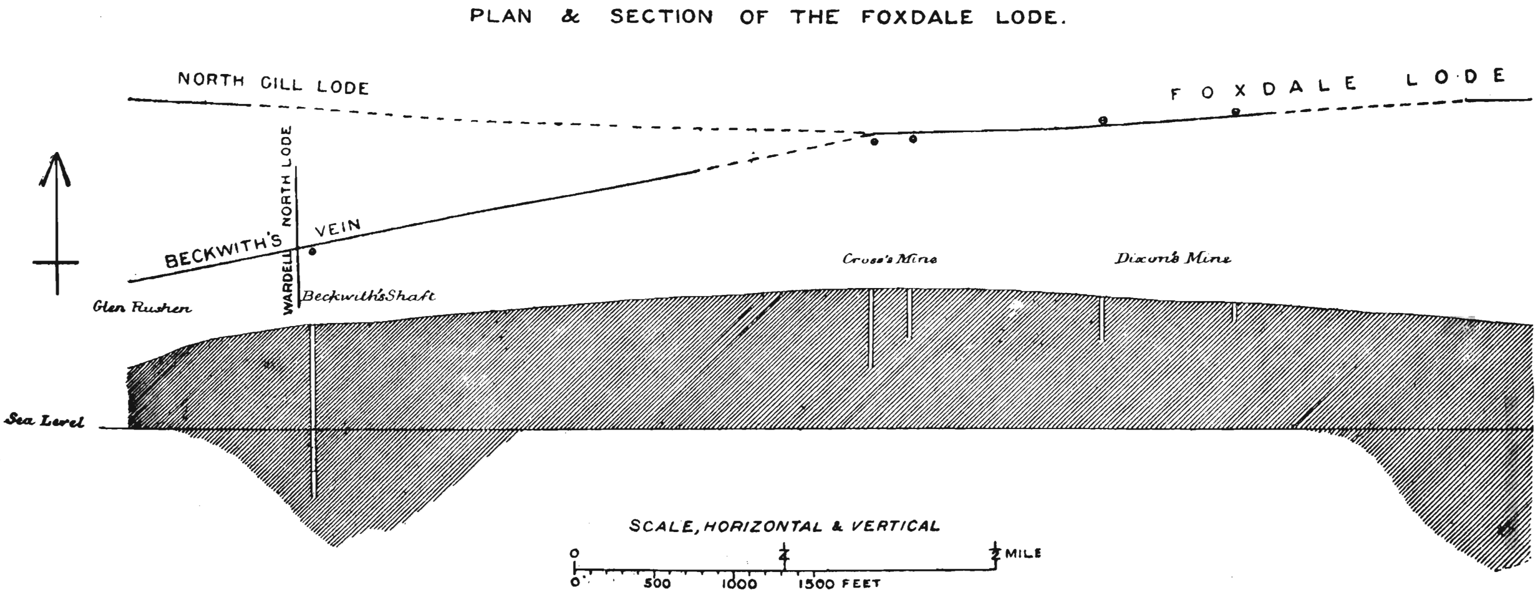
The 'country' rock of the mine is a highly sheared sericitic striped slate, which merges westward into the dark blue homogeneous 'Barrule Slate' (p. 53) of Dalby Mountain, and eastward into a belt of alternately slaty and gritty flags. The prevalent dip of these rocks is at a high angle towards N.N.W., but in the vicinity of the lode and between its two branches north-north-easterly dips occur in several places. In the spoil-heap were noticed fragments of one of the common basic ('older greenstone') dykes crushed into a schist, but no trace of the Foxdale granite or its elvans exists in this locality. The ground around the mine is more or less drift-covered (p. 458), and it is only in the glens that the rocks are well exposed.

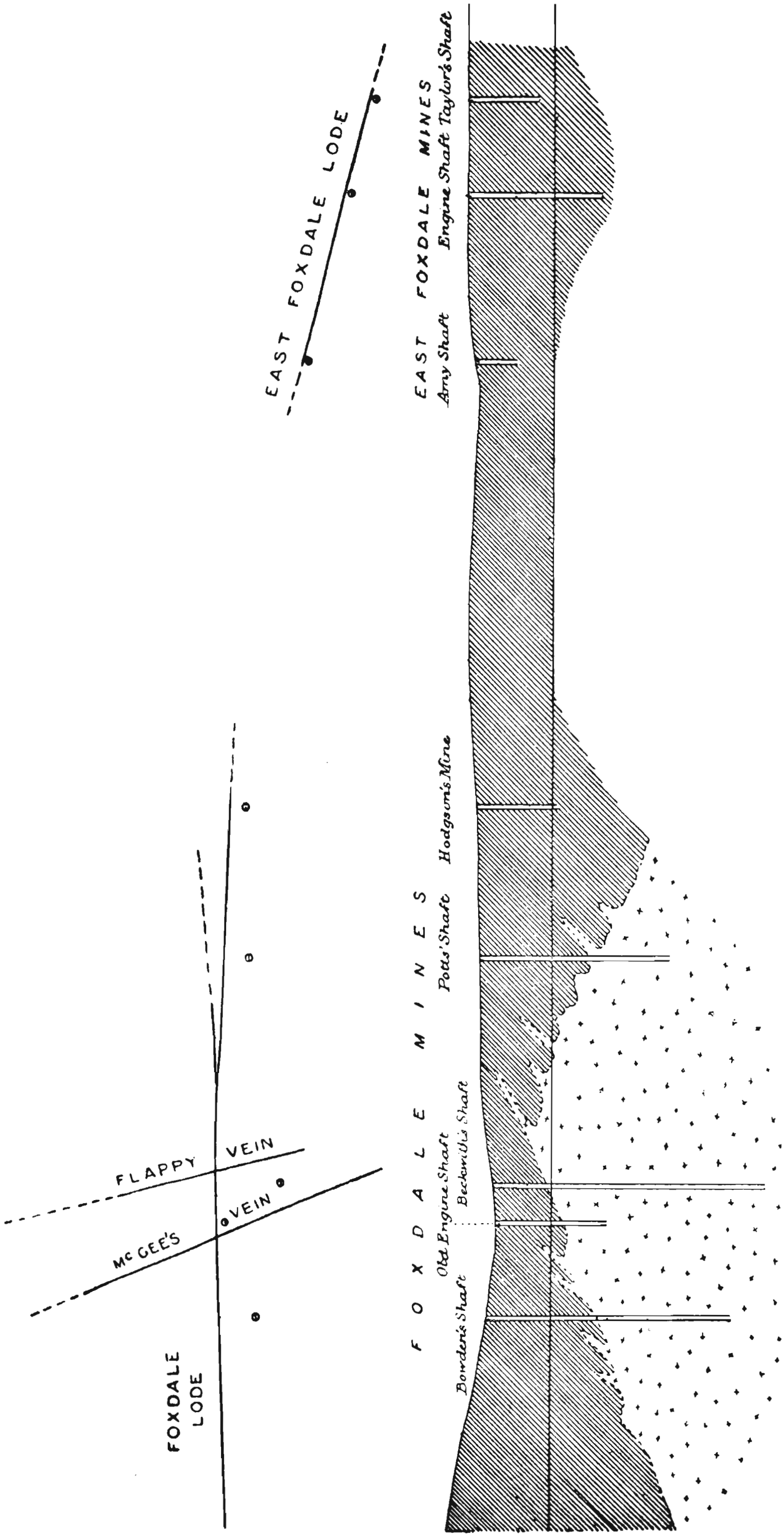
During the later stages of its activity the Beckwith mine was annually examined by Sir W. W. Smyth, and as it has now fallen to ruin and its workings are quite inaccessible, a few notes drawn from the MSS. reports of this authority may prove useful.

In the report for 1857 it is mentioned that down to below 90 fathoms the mine had been marvellously rich, but that the lower levels, at 117, 132, and 147 fathoms, had been driven on a lode showing hardly any trace of ore; and that a great drawback was found in the enormous amount of timber required and its rapid destruction by dry rot as well as by the heavy pressure of the strata. The N. and S. cross-vein had been opened to 160 fathoms S. of the shaft in the 75 fathom level, and a course of ore got in the same vein in the 60 fathom level N. In 1858 reference is made to a trial known as WEST BECKWITH'S at the western part of the Foxdale sett, where a shaft had been sunk 13 fathoms on a large lode filled with black clay-slate, but without ore. In 1859 it is noted that in the principal mine the total poverty of the lower levels had been a little relieved by

FIG. 110. *Diagrammatic plan and section of the Foxdale Lode.*

Manx Slates shown by oblique shading; Foxdale Granite and elvans by small crosses.




EAST FOXDALE LODE
FLAPPY VEIN
McGEE'S VEIN
FOXDALE LODE
EAST FOXDALE MINES
Taylor's Shaft
Engine Shaft
Amy Shaft
FOXDALE MINES
Hodgson's Mine
Potts' Shaft
Beckwith's Shaft
Old Engine Shaft
Bowden's Shaft

some small sprigs of galena at the 132 level in the west cross-cut, and that the 117 level had some very good ore on the N. part of the lode. On the "Wardell's" cross-course the 75 level was out 200 fathoms S., while the 60 and 75 N., both poor at the end, had passed through "a long run of tolerably good ground which will yield material for stoping." At WEST BECKWITHS a level had been driven E. for 50 fathoms "in black shale with a little quartz," and doubt was expressed whether it was in the lode at all. In 1862 it is stated that "great lengths of gallery have been opened beneath the formerly rich parts of the lode without finding any noticeable ore"; and detailed accounts of the 117, 132 and 145 fathom levels are given, showing a total length of unproductive driving of "about 317 fathoms." The reports for the ensuing years record the gradual cessation of all work except that of driving the adit eastward, according to covenant, to connect with Cross's Mine, 1,200 yards E. of Beckwith's. In 1877 the inspection of this adit is described; it was reached by descending the main shaft to 40 fathoms. and followed for 345 fathoms, to the end, which was in very confused ground "where the two lodes, the main one and the North Gill are closing together"; it was now within 50 fathoms of the old workings at Cross's Mine, and was barren of ore, nor was any seen in the numerous cross-cuts. This level is also referred to in the two following years, after which the mine is not again mentioned.

Cross's Mine.

This mine, the position of which has just been indicated, lies at an elevation of above 830 feet above O.D. This is evidently the 'Cronck Vane mine' described by Cumming in the passage above quoted (p. 501). Its history appears to have been a repetition of that of Beckwith's Mine on a smaller scale—a good but limited ore-body having been met with in the upper workings; and poverty below. It does not seem to have been worked since its abandonment at the date noted by Cumming. The mine consisted of two shafts 80 yards apart, viz., 'Engine Shaft' on the west and 'Whim Shaft' on the east; with levels at 20, 30, 40, 50, 65 and 80 fathoms. The ore-body described by Cumming lay mainly between the two shafts, and was lost below the 65 fathom level, and also in the drivings east and west of the mine. The longest or pioneer levels were the 80 fathoms, which went 79 fathoms west from 'Engine Shaft, and the 50 fathoms, which was driven 95 fathoms east of 'Whim Shaft' and ended in barren ground about 50 fathoms short of the most westerly driving from Dixon's Mine.[1]

Dixon's Mine.

This mine, lying to the east of Cross's at a distance of only 400 or 500 yards, was worked by two shafts 280 yards apart, with levels at 17, 32, and 47 fathoms in the 'Engine (western) Shaft,' and at 17 fathoms in the 'East Shaft.'[2] The day-level was reached by a cross-cut from the little valley north of the mine. As in the mine last described, the workings were wholly in slate; very little ore appears to have been found. Smyth mentions it in his report for 1857 as having been sunk to the 47 fathom level, but with nothing of promise in sight; and in the following year describes it as a "great disappointment," some productive ribs at the 17 fathom level having gone out in the 32, and on the south side there was similar deterioration below the adit level. In 1865 we learn on the same authority that after being for many years abandoned a shaft and adit were reopened. In 1867 the adit had been cleared for no less than 200 fathoms, and the 17 fathom level opened, with a little lead westward, but on the east for scores of fathoms without showing a speck of ore; from the 34 fathom level a cross-cut had been driven out

[1] Information from mining plans in the office of the Foxdale Company.
[2] *Ibid.*

in which it was difficult to recognise the limits of the lode; and only a few tons of ore in all had been raised from this new undertaking. In 1868 it is noted that only a cross-cut at the 44 level was driving; and this is the last mention of the mine in the reports.

Foxdale (Old Foxdale) and associated Mines.[1]

In following the lode eastward from Dixon's we descend into the Foxdale valley by a steep slope on which there have been a few shallow unproductive trials in the slates. The Foxdale Mines, from which by far the greater proportion of the mineral produce of the lode has been obtained, lie at the foot of this slope at altitudes of between 400 and 450 feet above sea-level. The principal shafts now in operation are—Bawden's the most westerly, with the bottom level at 260 fathoms; Beckwith's, with the bottom at 290 fathoms[2]; and Potts, the most easterly, with the bottom at 200 fathoms. The distance in a straight line between the first and last-mentioned is 750 yards, and the extreme length of the underground workings from end to end in 1897, was 1,510 yards; the pioneer level westward being the 170 fathoms, which went 320 fathoms west of Bawden's and approached within about 175 fathoms of the overhead position of the east shaft at Dixon's Mine; and the pioneer east, the 127 level, going 435 fathoms east of Bawden's. The above-mentioned shafts are sunk vertically on the southern side of the outcrop of the lode, and intercept it on the underlie. They commence in slate, but pass, at varying depths, into granite, as shown in the section (Fig. 110, p. 507), their lower workings being entirely in the igneous rock.

In the higher part of the mine the slate is traversed by elvans springing from the granite, which render the shelving upper surface of the intrusion ragged and uneven, just as it is seen to be at its outcrop on the hill-top south of the mines. Unfortunately the old upper levels which traversed the junction of the intrusive rock with the slate are now mostly inaccessible, and it is only at a few points that the contact can be studied. A few details respecting them may be gleaned, however, from Smyth's reports, quoted in the context. The junction was seen by the writer in 1896, in a cross-cut in the 115 fathom level, at the eastern end of the mine, and there showed distinct evidence of faulting, the granite being separated from the slate by a 'dowky' slightly slickensided vein an inch or two wide; but the vertical displacement did not appear to be great. As previously mentioned the lode, of which this vein seemed to form one of the 'branches,' is rarely a simple fissure but a belt of disturbed 'country,' with more or less parallel fractures showing nearly horizontal slickensides and containing brecciated rock, with vein-stuff and ore generally in ribs but occasionally also brecciated. The granite included in and adjacent to the lode has undergone partial decomposition, and it softens and 'bursts' on exposure to air in the workings; while the same rock exposed in cross-cuts outside the lode remains solid and very little altered. The rock thus affected is rendered somewhat 'platy' by numerous joints parallel to the vein, some of which exhibit traces of movement; and the miners appear to regard all material of this character as part of the 'lode,' ribs of ore being likely to occur anywhere within it. The 'bursting' of the rock-faces in the workings is probably due to the felspars having been decomposed while under restraint, rapid expansion taking place as soon as relief is obtained.

The ore-bodies have a general trend downward towards the west. The chief minerals associated with the galena in the vein-stuff have been enumerated in the passages already quoted. The western portion of the

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[1] Our thanks are due to Capt. W. H. Kitto and Capt. Lean for their courtesy in affording us facilities for studying the plans and underground workings of these mines and the plans of several abandoned mines in the neighbourhood; and to Capt. J. Kitto, sen., for information in respect to many of the older workings in this and other parts of the Island.

[2] Beckwith's Shaft has now a level at 305 fathoms, and is being sunk for a 320-fathom level. (August, 1902.)

mines is on the whole characterised by the presence of large bodies of coarsely crystalline galena poor in silver; and the eastern, by smaller quantities of fine-grained ore rich in silver. With regard to the occasional presence of the rarer minerals, silberfahlerz and plumosite, we learn from Sir W. W. Smyth's and Capt. Kitto's notes that these minerals are limited to that part of the vein which lies in the vicinity of the junction of the slate with the granite.

The seam of "indurated black clay" mentioned by Sir W. W. Smyth as a peculiar feature of the lode is rarely absent, serving the miners as an indicator where the vein is pinched or unproductive. It varies from a mere film to a thickness of 2 or 3 inches, and widens out into a 'dowky' mass in the vicinity of the ore-bodies; and in such places is reported sometimes itself to contain 'stones' of ore. It has probably been brought down by percolating waters from the overlying slate during one of the later expansion-movements along the fissure, perhaps at the same time as the detritus observed by Smyth in the 170-fathom level east, which exhibited "the peculiarity of fragments of killas or clay-slate in the breccia [of the lode], unexpected so deep in the granite." (MSS. Report for 1894. See also description of the 155-fathom level quoted in the context.)

Between Beckwith's and Pott's shafts the lode in going eastward splits into two branches, and to the eastward of the Pott's shaft becomes obscure and difficult to follow. The abandoned workings farther eastward will subsequently be described.

Regarding the cross-veins known as MAGEE'S VEIN and FLAPPY VEIN, which, as shown in Fig. 110, are about 140 yards apart and strike across the main Foxdale lode in the neighbourhood of Beckwith's shaft, little information is now procurable, as the places where they intersect the main vein in the upper levels are inaccessible, while in the lower levels they are not definitely recognisable. We may suppose that, like Wardell's North Lode at Beckwith's Mine (p. 505), they were formed at an earlier date than the E.—W. main vein, as otherwise some indication of displacement of the latter at the intersection would probably have been noticed. Both have yielded lead-ore in limited quantities. FLAPPY, the more easterly of the two and the one referred to by Berger (p 500), is shown on the mining plans as having a course of S. 22 deg. E., with a westerly dip. It was followed for 150 fathoms southward in a driving from the 20-fathom level E. of Old Engine Shaft of Foxdale Mines, and had also three levels, viz., adit, 20 and 30 fathoms, from a shaft on the lode; and was further tested by workings 650 yards north of Foxdale. MAGEE'S strikes S. 30 deg. E., with a westerly dip, and therefore converges towards Flappy, with which it is supposed by the miners to unite on the hillside south of Foxdale. It is no doubt the "strong vein" west of "Engine Shaft" shown on Twigg's plan of 1826 (p. 500). It was worked on a small scale as recently as 1878, by a shaft 300 yards S. of Foxdale, as described by Smyth in the reports quoted below. The vein is supposed to be visible at the surface, in the slate-quarry at the margin of the granite mentioned in a previous chapter (p. 165).

The following information illustrating the geology of the main lode in the older parts of the Foxdale Mines is abstracted from the annual MSS. reports of Sir W. W. Smyth, whose interest in this mine was always keen. In his report for 1857, we learn respecting "Old Foxdale" that in the 50 fathom level a part of the lode adjoining a dyke of granite was unusually rich in silver (up to 300 oz. per ton of lead) and that to the west of the [Old Engine] shaft large quantities of sparry iron-ore formed the bulk of the lode. In 1860, the Engine Shaft is stated to be about 4 fathoms below the 86 fathoms, in a very hard close-grained granite, and the lode brecciated on a large scale, but exhibiting no lead ore; while in the 72 level west there was an excellent lode, "the orey parts yielding silver in very variable proportions, but averaging 70 oz. to the ton of lead." In 1861, the last-mentioned level is described, in which "a cross-cut south near the end has entered a white granitic porphyry, and found a small south vein separating the latter from clay-slate;" and in the shaft, now at 96 fathoms, "all except the south side is in very hard granite; on that side a large amount of sparry carbonate of iron is visible, which I hope promises for the continued strength of the lode in descending." In the 72 fathom level east, some of the galena ran to the extent of 180 ounces per ton in silver. In 1862, the east and west driving of three levels—the 86, 72, and 60 fathoms—is described, "now against granite, and presently against slate"—"varying much in richness, but on the whole offering to view a noble lode of highly argentiferous lead ore." In 1865, the deepest level was the 100 fathom, which was 105 fathoms west from Engine Shaft in a fine lode 5 feet wide, between soft granite walls, and rich for lead ore, but was impoverished east of the shaft. In 1866, when the deepest level was still the 100 fathom, the report contains the following passage [regarding which we may note that the later workings have fully justified Smyth's judgment and confidence]:—"It becomes now an interesting question whether the vein will be as productive when entirely in the granite as when passing between alternations of that rock and slate. I myself see no *a priori* reason to doubt that it will be as good, and hence look forward with impatience to the driving of a deeper level." In 1867 we learn that the bottom or 115 fathom level west, all in granite, had a rib 2 to 8 inches wide of good lead ore, but not rich in silver; while specks and lumps of fahl-ore or tetrahedrite very rich in silver had been found in stopes on the 100 fathom east. [This concentration of the ores rich in silver in the northern side of the vein near the junction of the granite and slate deserves especial attention.] In 1868, it is noted that "this is the second year during which considerable quantities, amounting to 8 or 10 cwt. (in the rough) of highly argentiferous fahlerz have been raised from the mine." In 1872, the 72 fathom level west under the mountain [the pioneer level at that time] is described, in which a cross-cut north for 20 fathoms near the end was in hard white granite. The 115 fathom west showed in one place "ore of a gossany character with spiculæ of cerussite or white lead ore, rather a rare feature at such a depth." Bawden's Shaft, now 10 fathoms below the 127 fathom level, was sinking in hard granite, "the rock exceedingly obdurate, but showing a small vein of hard breccia with some steel-grained lead-ore." The 100 fathom level east was out 205 fathoms from "Old Shaft," and the lode in the end "full of clay slate." In 1873, it is mentioned in regard to the end of the 86 fathom level east that "here, too, the walls change again to soft clay slate." In 1880 "the 140 fathom has for a very long way been entirely sterile—large and conglomeratic in the end, with embedded stones of dark granite"; and the west ends of the 170, 155, and 140, all somewhat alike, show "a great lode of disintegrated white granite seamed by small veins of black indurated clay, and showing only specks of lead and zinc ore with a little quartz and traces of fluor." In 1881, the 84 fathom level east is described as containing "the finest regular rib of orey ground which I have seen in the mine, the lode very uniform and averaging 20 to 24 inches wide of very compact galena of medium richness and silver." In 1882, Beckwith's Shaft had been sunk 40 fathoms "in rather hard schist." In 1883, the 127 E. at 190 fathoms from Old Shaft had a lode 3 feet wide, "*with a copper-bearing branch* [unusual in this mine], and strings of dark quartz containing steel-grained ore, and a little of the silvery fahl-ore." The adit driven westward to prove the ground under the mountain was over 150 fathoms long, in 'douk' or argillaceous vein-stuff but uniformly poor. In 1885, it is noted that all the workings at less than 100 fathoms were stopped; the 140 E. showed a good deal of white barytes and chalybite, with several strings 6 to 10 inches apart of good silvery ore; the 200 W. had laid open "a magnificent lode of ordinary galena," "reminding the observer of the richest of the Spanish mines"; and surprise is expressed that the new shaft though in solid granite had required timber for half its length. In 1886, when some of the eastward deep drivings were getting out of the granite, we learn that the 127 level showed bunches and strings of dark ore, richer than the average in silver, and "very much like Mexican and Hungarian ores"; in the 140, E. end, there was "schistose rock on both sides, taking the place of granite"; the 170, cross-cut S. close to end, "again revealed a wide body of schistose rock of white hue, which towards the end lay almost flat upon granite" [possibly a highly sheared aplite dyke, see p. 165]; while the 185 level had granite for the 'country' on both sides. In 1887, the 155 level E. "presented the curious feature of contorted blue shiny slate, forming the body of the lode against a granite foot-wall, but without ore"; the 215 E. of Bawden's Shaft had "a marvellous lode" 6 to 9 feet wide, capable in places of yielding 8 to 10 tons ore per fathom. The last of these reports is for the year 1888. It states that the deepest level was the 230 fathom; that the 170 E., in soft killas or slate rock, had a cross-cut a little way back from the end, driven N. for 4 fathoms in granite, sometimes very pink; and that in the 127 E. on the N. branch of the vein, here a curious jumble of pyrites, lead ore and chalybite, a parallel vein with highly argentiferous fine-grained steel ore had been found by cutting 4 fathoms still further N. through slaty rock.

TABLE SHOWING ANNUAL OUTPUT OF SILVER-LEAD ORE FROM THE FOXDALE MINES BETWEEN 1845 AND 1900.

From Mineral Statistics in Mem. Geol. Survey, vol. ii. (for 1845 *and* 1847); *Records of the School of Mines, vol. i., pt.* 4 (*for* 1848 *to* 1852); *Home Office, Mineral Statistics* (1853 *to* 1900).

Year.	Lead-ore.	Silver contained in Lead-ore.	Estimated Value.	Year.	Lead-ore.	Silver contained in Lead-ore.	Estimated Value.
	Tons.	Ounces.	£		Tons.	Ounces.	£
1845	1,902	No data.	Value of Lead-ore not stated before 1874.	1873	1,433	57,727	—
1846	2,071	"		1874	1,673	67,868	31,562
1847	2,040	"		1875	1,722	73,564	37,804
1848	1,566	"		1876	1,607	65,183	33,284
1849	1,527	"		1877	1,727	87,700	32,314
1850	1,340	"		1878	1,959	53,453	29,753
1851	1,660	"		1879	2,766	55,319	37,363
1852	1,600	12,224		1880	3,486	49,799	42,993
1853	1,750	18,800		1881	3,419	69,080	39,145
1854	1,900	19,926		1882	3,211	48,807	36,356
1855	2,535	26,756		1883	3,700	48,100	35,100
1856	2,500	35,512		1884	4,020	51,525	33,500
1857	2,125	30,136		1885	4,670	59,851	42,400
1858	1,820	25,807		1886	4,013	51,435	43,000
1859	1,650	37,028		1887	4,322	55,396	41,500
1860	1,950	43,144		1888	4,009	59,397	44,600
1861	2,082	56,098		1889	4,185	62,010	44,400
1862	1,739	53,900		1890	4,160	61,640	44,500
1863	1,715	54,480		1891	4,700	69,641	45,200
1864	1,792	65,173		1892	4,650	73,550	40,250
1865	1,590	57,236		1893	4,650	73,550	35,400
1866	1,615	65,808		1894	4,800	85,522	34,430
1867	1,579	70,675		1895	4,600	00,359	39,200
1868	1,774	72,427		1896	4,250	188,473	36,700
1869	1,700	69,959		1897	3,775	76,697	34,100
1870	1,800	81,880		1898	3,610	66,125	34,000
1871	1,670	75,032		1899	3,610	62,515	39,800
1872	1,734	86,050		1900	3,610	58,905	43,100

Respecting MAGEE'S MINE, Smyth notes in 1859 that it was "on a north and south lode, in which a winze is sinking below the 40 fathom level. The veins are here in the midst of solid granite—mere strings, and but little ore is raising from them." The mine is not mentioned again until 1868, when it had three ends advancing, and was yielding some 10 to 13 tons of ore per month. In 1871, we learn that the 60 fathom level was driving south, and the 72 both north and south, and the shaft was being deepened; the lode, generally only a few inches wide and encased in very hard granite, had opened to 5 feet wide in one part below the 60, and also proved continuous beyond a dislocating cross-course. [The last-mentioned fact apparently furnishes another example of the displacement of N.-S. lodes by E.-W. faults, and lends strength to the supposition advanced above as to the relations of this vein to the main Foxdale lode.] In 1873 the mine had been deepened to 84 fathoms, but the vein was still the same small string, and work was soon afterwards abandoned.

Hodgson's, otherwise Faragher's or Louisa Mine.

This mine, the latest working of which took place over twenty-five years ago, lies immediately to the eastward of the present Foxdale Mines. The principal (Louisa) shaft is 260 yards east of Pott's Shaft, and one or two of the higher levels are connected with the corresponding levels of that mine, the two shafts having at one time been worked together, under the name of Faragher's Mine, on the south branch of the Foxdale Lode. The Louisa shaft was sunk to a depth of 82 fathoms, with levels at 10, 20, 38, 53, 67, and 82 fathoms, the pioneer eastward being the 20 fathom which was carried 110 fathoms east of the shaft. Two small pits, respectively 50 and 90 yards east of this shaft, descended only into the upper level of the mine.[1] None of these workings reached the granite, slate being the country-rock throughout the mine. A fair quantity of ore was obtained at an early period in its history, but the subsequent operations were unprofitable.

Sir W. W. Smyth's reports contain a few references to the latest working, from which the following details are taken. It was in operation in 1860 and 1861, but yielded no return. In 1863 Smyth notes that the 52 fathom level was driving east and west on a greatly improved lode, with an excellent rib of lead-ore. In 1865, the 67 fathom level had been opened east and west, with only an unsatisfactory quantity of ore. In 1870, the 67 and 82 fathom levels were equally poor at ends, but there were "stopes with a little good ore in the midst of soft killas rock." The latest reference to the mine is in 1874, when the 30 fathom east, having been cleared, showed a little ore here and there, but nothing regular; and in the 72 and 84 levels the vein was "too small."

To the eastward of this mine there is a belt of crushed sericitic slate, occupying the ground up to the depression half a mile distant in which the Santon River has its source. Numerous shallow trials have been made without success in this tract to find the prolongation of the lode. As suggested in a previous chapter (p. 166), there may possibly be extensive transverse faulting in this hollow, perhaps the continuation of the eastern boundary fault of the Peel Sandstone; and this may explain the isolation of the small outlier of granite ¼ mile south of Eairy (p. 166) and the shattered condition of the slates between this outlier and the main granite mass, a condition likely to render the ground unfavourable for the production of lode-fissures. At the hamlet of Eairy, immediately to the eastward of the hollow, however, some extensive mining work, known as the East Foxdale or Central Foxdale Mines, has been done on a vein supposed to represent the continuation of the south branch of the Foxdale lode. The identification is scarcely convincing, since the Eairy vein differs in many of its mineral characters, and in its more southerly strike, from any portion of the Foxdale lode above-described.

[1] Details from plans in Foxdale Co.'s Office.

East Foxdale, otherwise Central Foxdale Mines.

The East Foxdale workings comprise the Amy Shaft a few yards east of the bridge at Eairy; the Elizabeth, afterwards renamed Engine, Shaft, 350 yards farther eastward; and Taylor's Shaft, 200 yards east of the last. The first-mentioned appears to have been only once in operation since the early days of the mine (see Smyth's report for 1876 quoted below), and according to plans preserved in the Woods and Forests Office had only a depth of a little over 40 fathoms, with short drivings at 10, 30, and 40 fathoms. The other shafts have been reworked two or three times, after longer or shorter intervals of inactivity, the last working continuing up to 1889; by which time Engine Shaft had attained a depth of 145 fathoms, and Taylor's Shaft 74 fathoms, with levels at about every 10 fathoms down to 40 fathoms, and every 15 fathoms below. Although in the aggregate a considerable quantity of lead-ore averaging well in silver (about 35 oz. per ton) was obtained from the mine (see Table p. 515) it was insufficient to pay working expenses. The chief ore-bodies were found to the east of Engine Shaft. The ground was complicated and difficult, two or three separate lodes or branches of the same lode being recognised. Geologically the most interesting feature of the mine is the occurrence of an intrusive dyke of olivine-dolerite (supposed to be of Tertiary age, see p. 327) in association with the lode. Similar dykes occur in connection with north and south metalliferous veins at Ballacorkish, Bradda, Glen Auldyn and other places in the Island, as elsewhere described, but this is the only known instance in the Foxdale district, or in any other lode with an approximately east and west course. The significant bearing of this matter on the origin and age of the metalliferous infilling of the veins has been discussed in the introductory part of the present chapter. The mine-workings are now inaccessible, and the information which I was able to collect on the spot regarding the mode of the occurrence of the dyke was meagre and unsatisfactory; but fortunately Sir W. W. Smyth's reports, quoted below, contain many valuable details on this point and prove that the lode in this portion of its course is newer than the intrusion. There is a doubtful exposure of the dyke at surface on the steep slope immediately E. of the bridge at Eairy (see p. 169); in the spoil-heaps of the old mine 400 yards farther east the rock is present in abundance.

The mine was reopened, under the name of "East Foxdale," between 1860 and 1863, but beyond the statement that £11,000 were then expended without result, Smyth's reports contain no details of this working. In 1871 a new company commenced operations, and in Smyth's report for 1872 we read— "The old workings of the 30-fathom level and the newer ones of the 60 and 75 fathom levels show a great deviation from the regular course of the Foxdale Lode, and the presence of dykes and masses of a trap rock" rendered the mine a costly problem. In the following year a 15-fathom cross-cut from the 90 level showed "more or less confused appearance of vein-stuff," and in Taylor's shaft driving was going on in the middle lode of three which had been tested. In 1875 the name of the mine had been changed to "Central Foxdale," and the report states that the Engine Shaft was sinking below 90 fathoms in killas, and the 90 level had been driven "east about 40 fathoms from the shaft and, from the place where the lode was cut, is amid the black trap rock, in which mere strings of spar without any ore are seen. Where the grey killas or slate comes in again the lode improves, and a few stones of ore have been met with"; the 90 west was out 15 fathoms, in ground much disordered and not promising; "the 60 east has been driven east beyond the confusion caused by the trap, and looks for the last fathom or two as if in a wide body-mass with small occasional spots of lead ore, exhibiting as its most promising feature ribs of chalybite or spathose iron-ore." In 1876 Smyth notes that he descended to the 40 fathom level in Amy's Shaft "to see the driving west which has the black trap rock alongside the vein on the north, and altogether a very unpromising appearance." In 1877 the various drivings are described, including the 90 east, in which an exceptional body of rich orey ground had been found; and the difficulty of becoming acquainted with "the ramifications of these disordered lodes" is commented on. In 1878 the "hard black stone" is mentioned as making its appearance in the 105 level west.

Up to this time Smyth seems to have entertained the miners' opinion that the dyke cut out the lode, and his report for 1880 is therefore especially important in showing that he found this opinion no longer tenable. The passage in question reads:—"At the 120, the deepest level, a careful examination shows *that the 'black stone' or dolerite which it was feared might cut off the lode, is really intersected by it*, and in the eastern drivings the lode, divided into two parts, exhibits a considerable improvement." [Italics not in original.] Similarly, in his report for 1882 he mentions that in the deeper level then driving, at 135 fathoms, where the lode was in places very wide, between walls of clay-slate, there had been "a somewhat alarming appearance" of dolerite, but that it "seems really not to have injured the lode." In the previous year he noticed that in the 105 level east, where the lode had split into two branches, the north branch had got into "the volcanic rock of a rather pale tint."

In 1883 the mine was again standing, but was resumed by a new company in the following year. In 1886 the report states that 25 to 30 tons of ore per month were being raised, and that the 145-fathom level (the deepest point attained in the mine), driving east on the south lode, had met with some 'greenstone' on the north wall. In 1888, in the last of his reports, Smyth mentions that he did not go below, but gives the information that "spots of copper, with lead and zinc" had been found in a driving at 135 fathoms on the south lode; and adds that "some stones of granite which have appeared in the bottom level form a reminder of the bottom levels of Old Foxdale and give encouragement to further sinking." Under the circumstances it may be doubted whether the "granite" referred to was anything more than one of the granitic elvans by which the slates in the vicinity of the mine are traversed (p. 167); at any rate no confirmatory evidence has been obtained for the presence of massive granite in the mine.

Output of Lead-ore from East or Central Foxdale Mine (from "Mineral Statistics").

Year.	Lead-ore.	Silver.	Year.	Lead-ore.	Silver.
	Tons.	Ounces.		Tons.	Ounces.
1872	50	819	1881	400	5,362
1873	135	2,200	1882	450	10,440
1874	58	968	1883	530	15,900
1875	20	280	1884	330	9,839
1876	70	591	1885	325	6,447
1877	198	1,184	1886	319	10,149
1878	360	6,074	1887	418	11,625
1879	360	4,337	1888	250	6,953
1880	250	5,032	1889	92	2,559

From the above descriptions it is evident that even if the Foxdale Lode be prolonged in these mines it has lost its definiteness of character and direction; and it is therefore not surprising to find that all efforts to follow it still farther to the eastward have, up to the present, proved ineffectual. Traces of these old trials break the surface in several places on the Dreem Lang ridge east of Eairy, while in the valley near GARTH, one mile east of the EAST FOXDALE mines, a more extensive trial known as the NEW FOXDALE MINE was made in 1884–7 with no success.

The prospectus of this trial stated that the vein to be tested was 18 ft. wide and contained carbonate of iron, barytes, quartz, pyrites, galena and blende. The principal working consisted of a cross-cut adit on the right bank of the stream, driven about 30 fathoms to the lode; with a level from it for 30 fathoms westward on the lode; and three short cross-cuts south from the level; only "indications" of ore were obtained. The sericitic slate which forms the 'country' in this locality is traversed by an elvan of microgranite, which was cut in one of the workings (see p. 168).

Ellerslie, otherwise known as Bishops Barony, Great East Foxdale, or Darragh Mine.

This old mine is situated on the Bishops Barony on the south-western side of the central valley of the Island, ½ mile S. of Crosby, at the mouth of a little glen of the stream draining from Garth. It has been worked on an E. and W. vein supposed to be connected with the Foxdale lode. The mine has been reopened at various times, but always without commercial success, and is now in ruins. From Mr. A. W. Moore's researches it appears that the mine was commenced about 1825 by the orders of Bishop Murray, the site being fixed "by following the direction of that rich vein which had been wrought to such great advantage at Little Foxdale" (quoted from the "Manx Advertiser" newspaper). Cumming, in 1848, gave the following account[1] :—"It appears to have been commenced on a very thin even vein, consisting of a narrow thread of ore in veinstone, the outcrop being visible at the surface in a small burn . . . . The vein which has been pursued from its outcrop upwards of 300 fathoms, at a depth of 6 to 10 fathoms presents such a striking uniformity as greatly to discourage further working. At one or two points cross-courses have been met with, but they do not affect the value of the vein."

By the later workings a shaft was carried down to 75 fathoms, and a small quantity of lead obtained. In 1875 the mine, then recently reopened, was examined and reported on by Smyth, who described the principal level as 75 fathoms deep, "and in this a lode varying generally from 1½ to 3 feet in width opened occasionally, as in the present end E., to 5 feet, yielding promising ribs of ore."[2] In this report Smyth inclined to the opinion that the lode, from its "line of bearing and the character of the ores," might represent the prolongation of that of Foxdale; but in a later report (for 1885) he concluded that the mine was tolerably certain to be on a different lode from Foxdale. In 1878 he noted that some fine quality of ore was being obtained from pitches in the back of the 70 fathom level.

In "Mineral Statistics," returns of lead-ore are given from "Great East Foxdale Mine" in 1875 and the three succeeding years, amounting in the aggregate to 301 tons, and 8 tons in 1883 from "Glen Darragh Mine."

Cornelly or Townsend Mine.

This mine, abandoned since 1884, was worked on an east and west lode parallel with that of Foxdale, about a mile farther north, on the northern slope of Archallagan, at the head of a short deep glen—"Glion Darragh" of the 6-inch Ordnance map (Sheet 9), but now known to the country folk as Ballacurry Glen. The lode was of a curiously irregular character, and not easy to follow. Cumming mentions the mine as in operation in 1845-6; but respecting these early workings, when it was known as the "Cornelly Mine," no detailed information has been obtained; the later operations under the title of the "Townsend Mine," between 1874 and 1884, are described in Sir W. W. Smyth's reports (see below); and plans are also

[1] "Isle of Man," p. 310.
[2] MSS. in Woods and Forests Office.

preserved in the Woods and Forests Office and in the office of the Isle of Man Mining Company at Foxdale. From these plans it appears that at the cessation of the last workings, the mine consisted of two shafts 12 fathoms apart, with levels from the Engine Shaft (the deepest) at 20, 40, 50, 65, 80, 95, 110, 125, and 140 fathoms. The pioneer level was the 95 fathom, which was carried 360 yards east and 195 yards west of the shaft, with a cross-cut going 70 yards southward from it. The chief ore-bodies were found in the neighbourhood of the shafts. The lode was very steep, with a slight underlie southward in the upper 80 fathoms and in the opposite direction below that depth. It contained much chalcedony, and had been affected to even a greater degree than the Foxdale lode by recurring movements by which the vein-material as well as the country-rock had in places been fractured, rounded and afterwards re-cemented. Among the minerals noted by Sir W. W. Smyth [2] from this vein besides galena, chalybite, etc., are semi-opal or cacholong, hornblende ("mountain-leather"), a beautiful iridescent variety of galena, and a curious variety of zinc-blende in balls with a radiated structure. A considerable output of lead-ore was made from the mine, but not in quantity to pay the expense of working. As the returns were included with those of the Foxdale Mines, no statistics are available.

The chief geological interest of the mine lies in the fact that, as mentioned on p. 165, though nearly 1½ miles N. of the nearest outcrop of the granite, the shaft penetrated that rock beneath the slate at 300 to 400 feet below the surface. Judging from the material on the spoil-heaps, some part of the igneous rock reached in the mine possessed the massive boldly-crystalline character of the Foxdale intrusion, and was not like the micro-granite dykes which strike out from that mass. It is therefore probable that the granite represents a local protuberance on a deep-seated mass, and not merely a dyke. The rock seems to have occurred very irregularly in the workings, at first in detached strings and afterwards in a massive body; and the deeper levels both east and west were again in slate, though the cross-cut south was in granite. The evidence given below suggests that the intrusion formed a pipe-like mass inclining westward; the fine-grained material mentioned in the reports probably occurred around the margin, with the more coarsely crystalline rock described on p. 315 in the interior. The high degree of schistose and garnetiferous alteration in the slate-rock of this vicinity has been discussed in a previous chapter (pp. 111–2).

It is fortunate that Sir W. W. Smyth's reports contain descriptions of this interesting mine, as the workings are now inaccessible. The following passages have been selected from these reports as showing the general character of the lode and of the granitic intrusion.[3] In his report for 1875 Smyth states:—"The shaft is again sinking [below the 60-fathom level] and a peculiar phenomenon which somewhat links this mine with Old Foxdale is that veins or tongues of granite intersect the schistose rock, whilst a great difference is in the hardness of the rock, which scarcely requires any timbering." In 1877 we learn that in the 80-fathom E. level (then the deepest) "the lode is generally 2 or 3 feet wide, but carrying narrow vugs or caverns of great length lined with beautiful crystals of galena, but not enough to make a rich lode." In 1878, "the last 6 fathoms of the shaft [above 95 fathoms?] were in hard grey granite; the 95-fathom level had been driven about 30 fathoms, and was productive nearly all the way through; the lode a very singular one, vuggy, sometimes fragmentary with sharp angular country stone; the ore attached very generally in single or groups of cubical crystals to thin plates of quartzy veinstone with brown spar; and the better parts giving about a ton to the fathom. . . . . About the place where the east end [of the 80-fathom level east] was in 1877, granite had come in on the country and continues to the present

[1] For access to the later plans and much other information my thanks are due to Capt. W. H. Kitto, of Foxdale.

[2] In "List of Manx Minerals," op. cit., pp. 143-147.

[3] From MSS. in the Woods and Forests Office.

end [*i.e.*, for about 45 fathoms] where the lode is pinched to dimensions of 2 to 5 inches." It is also mentioned that a quantity of gas, probably carbon anhydride, had been given off for weeks together in this part of the mine, a feature likewise observed in the Foxdale lode in granite (see p. 503). In 1879 it is noted :— "the Townsend mine is proving to be a remarkable place, as having a distinct character from either of the other mines in the neighbourhood [*i.e.*, Foxdale and Central Foxdale], and as yielding a large amount of lead ore very little intermingled with vein-stuff or foreign substances. . . The 95-fathom level west shows a small but orey rib of 3 or 4 inches in mica-schist. A pitch above this level is in a wonderful group of parallel ribs and cavernous hollows studded with crystals of galena of all sizes up to 6 inches across; the whole occupying 3 fathoms in width, and having to be heavily timbered." The 65-fathom level east was driving— "the country intersected being micaceous schist, which in a large part of the deeper exploration is replaced by a granitello or unusually fine-grained granite." In 1881 the 95-fathom level east (which had commenced in granite) was visited, and "at 150 fathoms from shaft I found that for a long distance the level had been in a dark hard schist with an utterly sterile lode. . . . The 110-fathom level west was in a granitoid rock, very hard, with scarcely a vestige of a lode." In 1883 it is noted that the shaft was down below 140 fathoms, and that the 125-fathom level east had a poor quartzose lode of 3 feet, and a good rib, 4 to 6 inches wide, of beautifully iridescent lead-ore, while in the same level west the lode was a mere string an inch wide set in hard granite rock. The latest mention of the mine is in the report for 1884, where we learn, respecting the deepest level,—"the 140-fathom level which is again in the slate-rock, exhibited at first, on the east, the old 'Townsend' type of a hollow broken lode and with bold crystallisation of lead ore," but afterwards changed for the worse. The deepest level appears from this account to have been altogether in slate, but we are informed by Captain Kitto that the shaft itself was in granite to the bottom, though the ends of all the pioneer levels were in slate.

Traces of old trials are seen on the north side of Cooillingill near Crosby, 1 mile to the east of the above mine; and others, 1½ miles to the west of it, on the western slope of the lower part of Foxdale (see List, pp. 552-53.) These are said to have been on supposed prolongations of the Cornelly lode; no further information has been obtained in regard to them.

Trials South of Foxdale.

On the southern side of the watershed, south of Foxdale and South Barrule, traces of old mining trials are to be found in most of the little glens wherever any appearance of a vein is visible, and indeed sometimes where there seems to be nothing to have encouraged the search. Those in respect to which no special information is forthcoming are included in the List of Small Workings given on p. 553. In his report for 1858, Smyth mentions that the researches in progress on the south side of South Barrule were "very precarious," and that a small shaft had been sunk near Ballamoda farm-house where some surface-stones of ore had been found. Another of these trials was made between 1870 and 1874 on the left bank of the Santon River, 60 yards above Campbell Bridge near Ballanicholas (Sh. 13), rather over a mile south of the East Foxdale Mines. This was known as the BALLANICHOLAS MINE; it returned 3¾ tons lead-ore in 1872. It appears to have been worked at the junction of a granitic elvan with slate (see p. 167); the lode was supposed to have a N.N.W. strike, but seems to have been ill-defined. Smyth refers to the working in his report for 1871, stating that a discovery of ore of remarkably fine quality had enabled a large pile to be raised from 3 fms. of driving at the bottom of a 12 fm. shaft, but that it did not look like a lode. In 1873, he mentions that the shaft was being sunk below the 10-fathom level; and in the following year that work had been suspended with the loss of some hundreds of pounds.

LAXEY GROUP.

Laxey or Great Laxey Mines.

Standing in the first rank of British metalliferous mines, this great mine has been second only to Foxdale in the Island as a producer of lead-ore, while its output of zinc-blende for a long series of years surpassed that of any other in the kingdom, and indeed was sometimes greater than that of all the other British mines combined. At one period of its career the mine was also a producer of copper ore, though not to a large extent. As the Statistics given on a subsequent page will show, it has, however, of late years shown progressive decline, its annual output lately averaging less than half that of its palmy days.

The mine is established on a north and south lode (average direction about N. 10° W.), having an easterly dip, the country rock being the Lonan Flags of the Manx Slate Series. Although worked to within a mile of the coast, the lode has never been identified in the cliff-section, and was probably first discovered in the bed of the stream. According to an authority quoted by Dr. Berger, it was "opened and wrought by a mining company of Cumberland, about the commencement of the last [18th] century."[1] Mr. A. W. Moore ("History," vol. ii., p. 965) gives reference to documentary evidence of its having been worked about 1782. Feltham, in 1798 ("Tour, etc.," p. 243), mentions a "new level" 160 yards long, a mile and a half up the glen, which he examined. Woods, writing in 1811, gave a full description of the workings, which consisted of two levels from the banks of the river, the upper level, 100 yards long, following a vein nearly 4 feet wide consisting of quartz, blende, galena and some green carbonate of copper, blende being the most abundant; a small quantity of phosphate and carbonate of lead was also noted, and the lead reported to contain as high as 180 ounces of silver to the ton; but where the copper ore occurred, the lead was in small quantity and of poor quality [a feature subsequently found to characterise the lode in its deeper portions also]; in the new level, ¼ mile lower down the river, which was 200 yards long in 1808, carbonate of copper and blende alone had been discovered; only three men were employed in the workings.[2] The vein was again described by Berger in 1814[3] and by Macculloch in 1819;[4] but both observers found the workings abandoned; the latter author mentions the presence of calcareous iron ore (chalybite) and the steel-grained variety of galena. A plan of the mine by J. A. Twigg dated 1826, preserved in the Woods and Forests Office, shows the "Old level" as "wrought out," and a shaft, 34 fathoms deep, communicating with the "New level to unwater the mine."

Work was resumed a few years later on a more extensive scale, with profitable results; so that Cumming in 1847 found the adit to be 400 fathoms long, and two shafts, with drivings, down to 130 fathoms below the adit, employing 300 men.[5] Since that time the development of the mine has been carried on continuously, the details being published in the periodical reports of the managers which are reprinted in the Manx newspapers.[6] The principal underground workings of the mine are in the lower part of Glen Agneash (*Glen Mooar* : 6-inch, Sh. 8), where the three deep shafts are situated. At the time of my visit at the close of 1895, the most southerly, or Engine Shaft, had attained a depth of 247 fathoms; the next, or Welsh Shaft, 150 yards farther N., was down to 295 fathoms; and the third, or Dumbell's, 520 yards N. of the last, was 266 fathoms deep, all following the underlie of the vein. These shafts have levels at about every 10 fms. down to the bottom; the pioneer level S. was the

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[1] Trans. Geol. Soc., vol. ii. (1814), p. 51.
[2] "Account, etc.," op. cit., pp. 18-20.
[3] Trans. Geol. Soc., vol. ii. (1814), p. 51.
[4] "Western Isles," vol. ii., p. 577.
[5] "Isle of Man," p. 308.
[6] Files of these newspapers may be consulted in the Douglas Free Library.

235, which went 203 yards S. of Engine Shaft; and the pioneer N., the 255, which at the above mentioned date went 604 fms N. of Dumbell's Shaft; the length of the deep galleries from end to end of the mine is therefore over 1¼ miles. Shallow shafts communicating with the upper workings exist both N. and S. of those above mentioned.

MINERALS OF THE LODE.—The 'lode' varies greatly in breadth and character within short distances, both horizontally and vertically, being sometimes as much as 25 feet in width ('at the 190 fathom level near the shaft,' *vide* Smyth's report for 1857), and sometimes "gradually dwindled to a mere string without a speck of ore, hardly to be recognised by the unpractised eye" (in 110 N.; *ibid.* report for 1870). It usually presents clean well-defined and slightly polished walls of slaty flags, between which the infilling vein-stuff consists chiefly of quartz (with a little chalcedony) in ribs parallel with the walls, and calcite, mixed with more or less slate-breccia and with the metalliferous deposits. Zinc-blende and galena which constitute the principal ores occur alternating with quartz in ribs, and similarly in globular incrustations around 'vughs' or cavities in the lode. The copper-pyrites was mainly obtained in the southern part of the mine (south of Engine Shaft), "especially associated with dolomite,"[1] and occurred in thin strings after the ores of the other metals had dwindled down to an insignificant quantity; both here and in some of the deep levels farther north it seems to have formed a scanty ragged fringe to the great bodies of blende and galena of the central part of the mine, and its incoming was therefore looked upon with disfavour as indicating the proximity of the limits of these ore-bodies. The galena is of good quality, averaging 40 oz. to the ton of silver. Among other crystalline constituents of the lode are iron-pyrites, chalybite, pyrrhotine (northern part of adit, *vide* Smyth's report for 1882), barytes ("rare in Laxey"[2]) dolomite ("in perfect rhombohedrons"[3]) and calcite. Sir W. W. Smyth also notes the following in the old workings, or in the upper part of the lode: melanterite, sulphate of copper, melaconite, pyromorphite ("near Dumbell's shaft"); and steatite ("a white variety, spotted with crystals of zinc-blende, abundant at the 100 fathom level,") and anthracite ("a 3-inch band on the east wall of Laxey lode, 100 fathom level, S. of Engine Shaft, very pyritous").[4]

ANTHRACITE.[5]—The occurrence of the last-mentioned mineral is of peculiar interest, but the available information respecting it is meagre, and I have not been able to ascertain whether it was a constituent of the lode as Smyth appears to suggest, or belonged to the adjacent 'country' slate-rock. Mr. J. [E.] Taylor in describing the slates in 1864 mentioned the anthracite as occurring in 'thin veins,' and implied that it was interbedded with the sedimentary strata; but whether his description was based on personal observation or on miner's information is uncertain.[6] According to the recollection of Mr. Killip, the under-manager of the mine, the substance occurred as a vein, not more than an inch thick and a few inches long, in the "copper ground" between the "Engine" and "Corner" shafts, and formed part of the lode on the hanging or east wall. Captain J. Kitto, however, who also had personal remembrance of the circumstances, thinks that the anthracite lay between beds of the country-rock and like them went off from the lode. The significance of this undecided point is that if interbedded with the slates the anthracite must be regarded as the product of contemporaneous organic growths, like the coal-seams of later times; but if a vein-deposit it would presumably be akin in its genesis to plumbago and other carbonaceous substances sometimes found in veins. It should be mentioned that no interbedded seam of this character was anywhere observed at the surface in the Manx Slate Series.

[1] "List of Manx Minerals." Trans. I. of Man Nat. Hist. and Antiq. Soc., vol. i., pp. 143-147.
[2] *Ibid.* [3] *Ibid.* [4] *Ibid.*
[5] A specimen of this mineral from Laxey is preserved in the Museum of Practical Geology.
[6] Trans. Manch. Geol. Soc., vol. iv., p. 75.

GRANITIC DYKES AND AGE OF LODE.—The 'lode' appears to be a simple fissure-system extending down to an unknown depth, along which slight movement has taken place without causing much relative displacement of the opposite walls. As bearing upon its age it is interesting to find that in the northern part of the mine the lode breaks across the characteristic elvan-dykes of the Dhoon Granite. The nearest point of the surface-outcrop of this granite is on the hill-top, 1,050 yards east of the underground workings, and there is no indication in the bottom of the mine that the margin of the intrusion is any nearer than at the surface (p. 143). A dyke of micro-granite or quartz-porphyry 20 feet in width, striking S. 20°–30° W., probably identical with that seen in the stream in Glen Agneash (p. 144), is traversed by the 255-fm. level (at this point about 1,800 feet below the surface) at 490 yards N. of Dumbell's Shaft; and the lode, carrying a little blende, distinctly cuts across the intrusion without perceptibly displacing it. A second, smaller elvan, 4 feet wide, is seen under similar circumstances 154 yards farther north in the same level. In the southern part of the mine the lode similarly intersects a group of the 'older greenstone' dykes, which were injected into the slates at a period anterior to the intrusion of the granite (see p. 144).

It has already been shown that the sedimentary rocks had undergone extreme deformation before any of these greenstones or microgranites were intruded among them; and moreover, that both sets of dykes have been affected by later movements of great severity. The development of the fissure has clearly been subsequent to the latest of these crushing movements, and cannot have taken place earlier than Carboniferous times, while it may have been much later; so that its metalliferous infilling cannot in any case have begun until towards the close of Palæozoic times, and is more probably long subsequent.

'SLIDES.'—Another factor of much consequence in relation to the age of the lode is that it is displaced at intervals by transverse (E.–W.) 'slides' or dislocations, which are apparently true normal faults. At the southern end of the mine, south of 'Corner Shaft,' the vein seems to have encountered a close-set group of these 'slides' and to have been dislocated and perhaps terminated by them, the various attempts to recover it in the lower part of the glen by day-levels and cross-cuts (including the 'Glyn adit' about 175 fathoms in length) having proved unsuccessful. Farther north the slides have better-defined individuality, the same dislocation being recognised by the miners in the successive levels down to the bottom of the mine. Thus the 'Big slide' intersects the lode at 160 yards south of Engine Shaft, and carries it 10 to 20 feet westward on the south side, the dislocation dipping south at about 70° from the horizontal and splitting into two branches below 30 fathoms. 'Welsh Slide,' emerging at the surface near Welsh Shaft, has a slightly steeper dip in the same direction and affects the lode in a similar manner, displacing it about 6 feet laterally (the chief "copper-ground" of the mine lying between these two slides); but according to the mining plans it unites near the 200 fathom level with another dislocation hading in the opposite direction, known as 'Engine Slide,' the two enclosing a huge wedge of the lode between them. Farther north is 'Dumbell's Slide,' dipping south at 60°, and intercepted by Dumbell's Shaft at a depth of 12 fms.; and this is joined at 110 fms. by a slide with a slightly steeper dip in the same direction. In the explorations still farther north other dislocations were passed through, dipping in the opposite direction or northward, and consequently shifting the lode eastward on the south side; and these apparently form a rude northerly boundary to the ore-bearing ground. The average strike of these transverse faults is E 20°–30° N., which is also approximately that of the strata forming the 'country.' Wherever I was able to examine these faults in the mine-workings they presented a rather sharply cut joint-like aspect, generally with a little soft 'dowky' matter or crushed rock between the faces, but with no quartz. The direct vertical displacement which they have effected was estimated to range from 20 feet or less to about 70 feet, but this estimate is of uncertain value, as the movement has probably been oblique.

Though evidence was sought to show whether the deposition of the ore in the lode took place before or after its dislocation by these transverse faults, no very definite conclusion was attained. So far as I could learn, the only case of ore having been found in a slide was that reported to me by Captain W. H. Rowe, who remembered a little "steel-grained" galena being met with in the Agneash Slide between the adit and 12 fathom level. But this absence of ore may be due merely to the 'tightness' and lack of cavities in the fault-planes. The lode itself is usually impoverished in the immediate vicinity of the slides, consisting there chiefly of brecciated 'country rock' with very little quartz or metalliferous infilling; which suggests that it has been shattered by them before the formation of the ribs of quartz and ore within it. Hence, the indications do to some extent suggest a later date for the principal infilling of the lode; and it seems not improbable that the effect of the transverse faults may have been to reopen the older fissure and cause a slight gaping in it where the rocks were firmest and least liable to crumble, thus giving rise to empty spaces in which the crystalline constituents of the lode afterwards segregated. Unfortunately, owing to the absence of newer rocks than the Slates, the district affords no direct clue to the age of the faults; but it is worthy of note that on the Cumberland coast the N.E. to S.W. faulting has been shown to be Post-Carboniferous and Pre-Triassic (see p. 87).

While the metalliferous lode is for the most a single fissure, it is here and there complicated by minor 'branches' going off from it at a low angle, in which occasionally a little ore has been found; and other parallel but unproductive joints or fissures appear to traverse the slates in its vicinity, one of which, known to the miners as the 'East Lode,' has been reached by easterly cross-cuts about 70 yards E. of the main lode. The principal ore-deposits have been found in that part of the mine which lies between Engine and Dumbell's Shaft, occurring vertically in large irregular lenticular sheets showing a general tendency to descend northward. North of Dumbell's, the ore as yet discovered has been dispersed in smaller masses, with wider spaces of barren ground between, and in the most northerly drivings is reduced to mere specks.

THE 'COUNTRY-ROCK.'—In the principal part of the mine the strata belong to the Lonan Flags division of the Manx Slates and consist of firmly welded greyish and bluish sandy and slaty flags; and it is interesting to find that these extend without noticeable change of character from the surface to the bottom of the mine over 1,200 feet below sea-level (p. 33). Like most of the metalliferous veins of the Island, the lode is in the vicinity of the structural axis of the slate series; and the change in the direction of the dominant bedding, from S 20° E. to N. 20° W., may be observed in the mine-workings. South of Dumbell's Shaft the general dip of the contorted strata is at a high angle, usually between 60° and 80°, towards S. 20° E.; but in the 255-fathom level a short distance north of this shaft, the bedding ranges from vertical to 70° or 80° towards N. 20° W., and continues to dip in this direction, at a slightly lower angle, to the N. end of the level. In the deepest level (295 fathoms) the change sets in a little farther south, the N. 20° W. dip being found at about 450 yards north of Welsh Shaft. In both cases the obscure strain-slip cleavage is inclined in the same direction as the dip, but at a much lower angle, usually about 20°. The deep position of this structural anticline corresponds fairly well with its place at the surface. At about 700 yds. N. of Dumbell's Shaft the 255-fm. level passes into darker and more argillaceous strata for about 300 yds. and then into very hard sandy flags, which are probably the commencement of the Agneash Grits that outcrop on the mountain overhead; and as neither type of rock is so well fitted to develop an open fissure as the homogeneous flags farther south, it may be from this cause that the lode is pinched and impoverished in this part of its course. As the northward termination of the profitable part of the mine nearly coincides with the change in the direction of dip of the 'country,' the miners have come to regard this change as itself detrimental; but more probably it is because the N. 20° W. dip ushers in the unfavourable modification of the 'country' that it constitutes an untoward omen.

Precisely as the trials in Laxey Glen south of the mine, and on the coast, where an adit was driven 50 fms. into the cliff, have failed to discover the prolongation of the lode in that direction, so, also, trials have been made without success on the western bank of Glen Agneash, and again at the head of the glen (where it is known as Glion Ruy), to discover its northward extension. In this direction it would have approached nearer the outcrop of the Dhoon Granite than in any other part of its course; and the deterioration of the lode in the underground workings north of Dumbell's Shaft, as well as the poverty of the veins which have been tested at the Dhoon (p. 528) in close proximity to the igneous boss, tell strongly against the supposition that the presence of the metalliferous deposits is due to the contiguity of the granite (see also ante, pp. 491-2).

ANNUAL OUTPUT OF LEAD, ZINC, AND COPPER ORES FROM THE GREAT LAXEY MINE BETWEEN 1845 AND 1900.

(*From Mineral Statistics in Mem. Geol. Survey, vol. ii.* (*for* 1845 *to* 1847) *Records of the School of Mines, vol. i., pt.* 4 (1848 *to* 1852); *Home Office, Mineral Statistics* (1853 *to* 1900.)

Year.	Copper-ore.[1]	Zinc-Blende.	Lead-ore.	Silver contained in Lead-ore.	Total Estimated Value.
	Tons.	Tons.	Tons.	Ounces.	£
1845	79	—	327		Value of lead-ore not stated before 1874.
1846	92	—	220		
1847	60	—	375		
1848	—	—	695		
1849	—	—	815		
1850	—	—	810		
1851	—	—	900		
1852	—	—	800	32,400	
1853	—	—	698	28,130	
1854	64	1,435[2]	900	32,336	
1855	—	3,990[2]	800	24,400	
1856	94	3,000	700	24,675	
1857	169	2,909	500	17,625	
1858	403	2,777	600	21,068	
1859	354	—	800	19,826	
1860	333	3,181	800	16,936	
1861	731	3,255	600	11,184	
1862	942	691	700	16,380	
1863	1,263	2,298	800	19,440	
1864	127	5,356	1,250	59,000	
1865	1,317	5,488	1,500	65,293	
1866	294	4,960	1,800	81,054	
1867	400	5,362	2,100	93,365	
1868	412	3,278	2,300	105,020	
1869	400	7,208	2,200	101,244	
1870	300	4,067	2,130	87,760	
1871	100	5,718	2,300	98,221	
1872	300	2,973	1,300	52,316	
1873	—	5,370	2,355	94,870	

[1] In Mem. Geol. Survey, vol. ii., p. 715, the earlier statistics on next page are given respecting the annual sales of Laxey Copper-ore at Swansea. The output of the other ores for the same period is not recorded.

[2] Largest in the United Kingdom.

Year.	Copper-ore.	Zinc-Blende.	Lead-ore.	Silver contained in Lead-ore.	Total Estimated Value.
1874	—	6,925	2,100	86,268	£58,246
1875	—	11,753	2,400	107,420	90,915
1876	75	8,582	2,500	57,460	85,046[1]
1877	8	8,645	2,222	94,749	77,835
1878	30	9,411	1,395	49,898	52,947
1879	—	7,200	1,200	40,500	46,792
1880	35	7,425	1,300	24,745	53,474
1881	—	7,568	1,700	52,50[0]	59,188
1882	—	7,750	1,755	70,200	19,950[2]
1883	200	4,720	1,540	61,600	45,176
1884	—	5,625	1,537	61,188	43,408
1885	236	5,340	1,588	63,219	42,700
1886	—	4,715	1,765	72,030	47,622
1887	—	4,540	1,545	63,052	42,207
1888	46	4,600	1,535	62,643	42,158
1889	—	3,900	1,615	65,908	43,880
1890	—	3,844	1,430	58,359	48,328
1891	—	2,825	1,120	45,708	32,763
1892	—	2,390	943	39,427	24,763
1893	—	2,145	902	36,811	18,701
1894	—	2,040	527	21,507	13,042
1895	—	1,417	403	16,447	8,917
1896	—	1,180	399	15,884	8,762
1897	—	1,610	247	10,080	8,894
1898	—	1,575	138	5,632	9,404
1899	—	1,390	158	6,448	11,831
1900	—	1,216	95	3,877	7,471

Appendix—SALES OF LAXEY COPPER-ORE AT SWANSEA, 1828-1837.

Year.	Tons.	Year.	Tons.
1828	28	1838	121
1829	161	1839	183
1830	238	1840	278
1831	283	1841	368
1832	341	1842	406
1833	249	1843	207
1834	268	1844	46
1835	77		
1836	89	Total	3,412
1837	69		

North Laxey Mine.

The location of this mine is in the upper part of the Cornah valley, 1¾ miles west of Corrany (six-inch, Sh. 8). It has been in operation, with short intervals of quiescence, since 1856, and has produced in the aggregate a considerable quantity of lead-ore, but not as yet sufficient to repay the

[1] Plus value of copper, not stated.
[2] There is evidently an error in the statistics here; £30,000 should probably be added.

cost of working. The following description is based on my personal examination of the mine in 1895, and on information then kindly placed at my disposal by the manager, Mr. J. Corlett. Some details of interest regarding the earlier workings, which are now for the most part inaccessible are added from Sir W. W. Smyth's Reports.

The mine is worked on a lode which crosses the bottom of the valley in a nearly north and south direction, with an underlie or dip westward. Two shafts have been sunk, 70 yards apart, the South Shaft to the depth of 110 fathoms and the North Shaft (in December, 1895) to 174 fathoms. The mine has levels at 12, 27, 38, 50, 60 (the two last in South Shaft only), 73, 84, 96, 110, 121, 136, 146, and 170 fathoms; the longest or pioneer levels were the 146 northward, and the 60 southward. The 'lode' is mainly indicated by a quartz vein, bunchy in character, sometimes only 2 or 3 inches wide or even nipped out to a mere joint in the slate-rock, and sometimes swelling to a width of 3 or more feet, and then often full of crystal-lined 'vughs' or cavities which when first tapped discharge water, but soon dry up. It contains in places ribs and bunches of galena and scattered patches of other minerals, including barytes (in the deeper workings), pyrites, etc. The fissure does not appear to represent a fault of any consequence. The country-rock, which dips steeply north-westward, is a firm dark slate, interbedded at intervals with hard bands of quartz-veined grit (see p. 141), one of which, 3 feet in thickness, was well exposed at the bottom of the North Shaft at the time of my visit. The ore-bodies have shown a tendency to sink northward, being met with at shallower depths in the southern than in the northern part of the mine.

Turning to Sir W. W. Smyth's reports[1] we find mention in 1857 that at 10 fathoms there was a little ore, only a few inches wide; in 1860 the South Shaft was at 40 fathoms, and the lode still small and producing only a little ore; in 1865 some orey ground had been found in the 60-fathom level south, but the "end got into black ground, bedded rather flatly," and not promising; and in the following year it is noted that the same level had "poverty-stricken white quartz for its veinstone." In 1869, in the 110 level of the South Shaft the lode proved quite poor on the south, but bolder and better on the north; and the discovery of ore in the 96 and 84 north drivings, where there was "a really tolerable lode," led to the renewed sinking of the old [North] Shaft which had previously stopped at 38 fathoms. In 1872 the North Shaft was down 120 fathoms, and the lode there 4 or 5 feet wide, but quite worthless; and in the 110 level half-way between the shafts the vein was also of good size, but calcareous and unprofitable. In 1876, it is noted that the lode at 136 fathoms down was sprinkled with lead and zinc; and in the following year that at 146 fathoms it was "dull quartz with a few large crystals of calc-spar in the cavernous hollows."

In the annual "Mineral Statistics," returns of lead-ore from this mine are given for all the years between 1857 and 1878 inclusive; also for 1880–1, 1891–4, and 1897, amounting in the aggregate to 1,763 tons.

Glencherry Mine.

This name was given to a small mine in the bottom of the Cornah Valley 650 yards east of the North Laxey Mine, with which it has since been amalgamated. Work was carried on here, chiefly between 1865 and 1875, on a north and south lode with an easterly underlie, which yielded a small quantity of lead ore. Two shafts were sunk, the South Shaft to 15 fathoms, and the Engine Shaft to 35 fathoms, with levels at 15, 20 and 35 fathoms.[2] Sir W. W. Smyth describes the underground appearances in his reports as follows[3]:—In 1866, when the shaft was down 8 fathoms, it was "on a lode 5 or 6 feet wide yielding extremely promising stones of weathered galena with incrustations of green and of white lead ore;" in

[1] MSS. in Woods and Forests Office.
[2] Information from Mr. W. H. Rowe.
[3] MSS. in Woods and Forests Office.

1867, the 15 fathom level had been driven 12 fathoms north, and showed a little ore; in 1868, it is noted that the favourable symptoms had been of short duration, and the ground very changeable—the 20 fathom driving north had a little ore which dwindled away after a few feet; in 1869, the 20 and 35 fathom levels had been driven for some fathoms without finding more than a mere sprinkling of ore; and in 1871, the 35 fathom level had been driven some 15 fathoms, showing a lode 2 to 3 feet wide with no other mineral than a little pyrites in sight.

East Laxey Mine.

Under this title an unsuccessful trial for copper, on which many thousands of pounds were expended, was carried on between 1866 and 1869 in the Cornah Valley 600 yards west of the bridge at Corrany (Sh. 8). An adit was driven from the bank of the stream for 65 fathoms with a direction of N. 30° W. on a hard quartzose lode, underlying westward, said to contain little pockets of copper pyrites and iron pyrites; and a shaft was sunk to 20 fathoms, with a level at that depth for 40 fathoms northward. Another adit was driven, for a few fathoms only, into the south bank of the stream. No saleable quantity of ore was produced.[1] Sir W. W. Smyth refers in his report for 1867 to the driving of a level on "a miserable-looking hard vein with but a few specks of copper pyrites here and there"; and in 1868 states that he examined the 20 fathom level for 40 fathoms north, and found a lode all the way, without ore or promise.

East Snaefell Mine.

The company using this title was formed about the year 1864, to test the supposed extension of the Great Laxey lode in the upper part of the Cornah Valley, 650 yards above the 'North Laxey Mine.' A day-level (indicated on the six-inch ordnance map, Sh. 8) was driven S.S.E. into the hill-side, on a gossany clayey 'lode' underlying east, but no metal was found.[2] Smyth writes of these trials in his report for 1865, that "some short drivings and the sinking of a sump for a few feet have shown that there are lodes in this ground, but nothing of promising appearance, far less productive, has been seen." The company afterwards transferred its operations to the "Glencherry Mine."

Snaefell Mine.

This mine, on which work was seriously commenced about the year 1856 and has been continued, with some interruptions, up to the present time, is situated at the eastern foot of Snaefell on the north branch of the head-waters of the Laxey River, 3 miles N.W. of Laxey village. The lode, which was discovered in the bed of the stream, strikes about N. 20° W. from the mine, but swings to N. 30°–35° W. towards the northern extremity of the underground workings. Its underlie is eastward at about 75° from the horizontal. It consists of a belt of crushed slaty rock, often 'dowky,' interpenetrated by strings of quartz associated with dolomite, calcite, galena, zinc-blende, and a little copper-pyrites, iron-pyrites; and pyrrhotine ("in the form of acute hexagonal pyramids"). Sir W. W. Smyth also records[3] impure graphite ("100 and 130 fathom-levels") and manganese spar ("small crystals in small isolated 'vugs' or locks," found about the year 1876). The width of the space recognised as 'lode' varies from 6 inches to 60 feet or more; but its limits are generally ill-defined, and it is said to have 'branches' in places on both sides, with more or less broken country-

[1] From information obtained from Mr. W. H. Rowe.
[2] *Ibid.*
[3] "List of Manx Minerals," op. cit.

rock between; and the lode is considered to be most favourable where these 'branches' fall into it. This broken ground probably marks a line of faulting which may be of considerable magnitude, though the highly contorted and complex structure of the strata precludes any trustworthy estimate of the displacement. The mine is placed on the narrow belt of banded slates with gritty intercalations which form the passage beds between the Barrule Slates on the west and the Agneash Grits on the east, but the deeper northward workings appear to enter the Barrule Slates. At the time of my examination in 1895, it consisted of a single shaft, following the dip of the vein to the depth of 171 fathoms, with levels, below the adit, at 25, 40, 60, 74, 85, 100, 115, 130, 141, 158, and 171 fathoms, chiefly driven northward under the mountain. The most northerly point of the mine was the 130-fathom level, which was 530 fathoms out from the shaft; and the most southerly, the 141 level, out 60 fathoms. The levels communicate with each other by a series of winzes connecting with the adit-level which enters the hillside 100 yards N. of the shaft.[1]

While a little ore has been found in many places in the lode, the principal bunches hitherto discovered lay at 60 to 80 fathoms north of the shaft in the upper levels, and at over 250 fathoms north in the lower levels. Including 1900 the total output of ore from the mine since the year 1870 recorded in "Mineral Statistics," is 4,567 tons lead-ore and 8,926 tons zinc-blende.

The galena averages 14 to 16 ounces of silver per ton. The copper-pyrites is sparsely distributed, occurring chiefly where blende is most abundant. No payable quantity of ore has been discovered south of the shaft, either in the deep levels or in the trial adits in the valley below the mine. One of these trials, on the south bank of the Laxey River 200 yards below the confluence of its two main branches, was driven W.S.W. for 80 fathoms to cross-cut the lode, and then southward along the lode for about 80 fathoms farther.

Polished (graphitic?) and slickensided surfaces are very conspicuous in the vein, especially among the darker slates, the striæ on some faces being vertical, and on others horizontal or inclined. The 'dominant dip' of the rocks (see p. 145) in the neighbourhood of the mine is towards N.N.W.; but underground the dips were found to be variable, and frequently towards the unusual direction of N.E. or E.N.E., probably denoting local disturbance along the line of faulting. In one place the lode is cut by a 'cross-course,' which is clearly a later fault, striking N. 30° W. and hading southward, the effect of which is to shift the metalliferous vein 8 feet to the westward on the north side. The position of this 'cross-course' in the 141 fathom level (where I examined it) is about 205 fathoms N. of the shaft; the lode is somewhat enriched in its vicinity, especially in blende. One or two small sheared igneous dykes of the basic type so numerous in the Manx Slates were observed in the country-rock adjacent to the lode.

Block Eary and other Trials near Snaefell.

In the valley of the Block Eary feeder of the Sulby River, at the foot of the northern slope of Snaefell Mountain, an adit was driven for 100 fathoms south-eastward in the river-bank S. of the farmstead of Block Eary, and another in the opposite direction in the little glen 250 yards W. of the farm, on a vein which is said to have been similar in character to that of the Snaefell mine, with which it was supposed to be continuous; but no ore of value was discovered.[2] The Snaefell lode was also sought

[1] A plan and description of the mine is contained in the Official Report of Dr. C. Le Neve Foster to the Home Office on the accident in May, 1897, by which twenty men lost their lives through the poisonous gases engendered by a fire in the timbers of the 130 fathom level. (Blue Book. "Snaefell Lead Mine Accident." 1898.)

[2] From information furnished by Capt. J. Kewley.

for in the opposite direction, south of the valley of the Laxey River, but Sir W. W. Smyth noted in his report for 1871[1] that only some indistinct fragments of vein were found in these workings. Several other profitless trials were made in Laxey valley between the Snaefell and Great Laxey mines, one of which, known as the Glenfoss level, is briefly described in Smyth's report for 1865.[2]

Glen Roy Mine.

This mine, on which very large sums were expended both underground and at the surface, is situated in Glen Roy near Riversdale, 2 miles west of Laxey. It seems to have been begun about 1864 as an offshoot of the Great Laxey Company, but was subsequently worked by an independent company, with disastrous results. It was finally abandoned about twenty years ago. As the returns of ore from the earlier workings seem to have been combined with those of Great Laxey the data for estimating its total produce are not available. In the years 1877, 1878 and 1882, when separate returns were made, the aggregate (in "Mineral Statistics") is 9 tons 9 cwts. of lead ore, and 136 tons 9 cwts. of zinc ore. The shaft was sunk to a depth of about 122 fathoms, with levels at 10, 25, 40, 55, 65 [100?] and 108 fathoms, on a north-westerly lode, hading eastward.[3] The presence of a large dyke of greenstone in the vicinity of the lode has been noticed in a previous chapter (p. 160). The following excerpts from Sir W. W. Smyth's reports for the years between 1864 and 1882 will serve to show the principal features of the mine:—In 1864 the operations are referred to as a "small trial"; in 1867 we learn that at 18 fathoms there was a better lode of 2 to 3 feet wide, with a gossany leader or branch containing some good stones of lead-ore; in 1868 the 25-fathom level had been driven a few fathoms north-west on the lode, with about ¼-ton lead ore and 1 ton blende per fathom; in 1869 the same level, extended 30 fathoms, had yielded some good ore, and the 40-fathom level, driven some 9 fathoms, showed "a pretty little rib" chiefly of zinc blende, "but there is nothing that savours of more than distant promise." In 1873 the 50 [? 55] fm. level was a long way north, with one little bunch of ore, while the 65-fathom level had been driven 25 fathoms each way but showed no promise. In 1876 the mine had recently been reopened, and a little zinc-blende was found in the 40-fathom level by a cross-cut through what was supposed to be the wall. In 1877, at the bottom of the shaft below 65 fathoms the lode was only 4 inches wide at one end, and at the other showed two strings with 4 feet of ground between them, but not a speck of lead or zinc. The 65-fathom level had been driven 73 fms. [?] north and 80 fms. [?] south, and in the 25-fathom level a little blende had been found in a portion of the lode turning some 15° west of south. In 1879 the 100 [? 108] fm. level was 11 fathoms out on "some appearance of a vein, with a few cavities and crystals of dolomite, but utterly sterile for useful mineral." In the following year this level had come upon some good ribby lead ore, but it proved an isolated pocket. And finally, in 1881, we learn that the deepest level, at 108 fathoms, was out 70 fathoms with only one little blink of ore; that the shaft was deep enough for a 122 fathom level; and that an anomalous bunch of a few tons of very good ore had been found in the 25-fathom level in connection with a 'slide.' The next report mentions that the mine was dismantling.

Dhoon or Rhennie Laxey Mine.

The operations known by this name, on which many thousands of pounds were expended without any return, were made for the purpose of testing a supposed lode occurring in Dhoon Glen, 400 yards east of the main

[1] MSS. in Woods and Forests Office. [2] *Ibid.*

[3] There is some discrepancy in particulars between the plan of this mine deposited at the Home Office (No. 1509 in "List of Plans of Abandoned Mines") and our other sources of information. The Home Office Plan gives the shaft a depth of 108 fms. only.

road from Laxey to Ramsey. The early workings consisted of a shaft sunk in the glen on the 'lode,' from which a little lead ore was obtained. This shaft ultimately attained a depth of about 65 fathoms, with drivings at 10, 18 and 20 fathoms, in the last of which, north-west of the shaft, a little zinc-blende was revealed. All the workings were in the slate rocks. The most ambitious part of the later operations (between 1859 and 1869) took the form of a deep adit-level, starting low down in the great cliff of slate 500 yards S. of Dhoon Bay and going for 315 fathoms in a west-north-westerly direction as a cross-cut to intersect the vein, and afterwards pushed to within about 250 yards of the margin of the Dhoon Granite. The course of the lode is supposed to have been W. 10° to 20° N., with a southerly underlie.[1] The following excerpts from Sir W. W. Smyth's reports supply further information regarding these now inaccessible workings.[2] In 1858 the vein is described as 4 to 6 feet wide, with occasional spots of lead ore; in 1866 Smyth states, "I regretted to pass through a long series of workings at the 20 fathom level which have proved entirely unproductive; a few small strings only, which run W.N.W. carry some lead ore, but they seem unimportant." In 1868 it is mentioned that the shaft had been holed to the level, but only a little zinc-blende found in the process, and that all the way in the level (¼ of a mile) to its mouth, not an available spot of mineral had been seen. In 1869 this level had been advanced 110 fathoms beyond the shaft, and the end was following a vein through soapy grey slate, but not exhibiting a speck or sign of any kind of ore.

Minor trials in the same glen included a short cross (10 or 12 fathoms) in slate on the spur between two streams, 200 yards E.N.E. of the shaft; and another in the upper part of the glen, a few yards west of the high road, said to have a length of 35 fathoms, and to continue throughout in the tough boulder clay in which it starts.[3]

SOUTHERN GROUP.

Bradda Mines.

As stated in the introductory notes to this chapter, these mines are probably the most ancient in the Island, and were worked at a period anterior to the oldest records. They seem always to have been carried on fitfully and with long intervals of quiescence, just as during the 19th century. Copper and argentiferous galena have been the principal ores obtained, the latter especially in the northern part of the lode. Permission was asked in 1858[4] to raise iron-pyrites from the mine, but Sir W. W. Smyth gave the opinion in his report for that year that the mineral was not likely to occur in quantity.

Cumming remarks that these mines "seem to have been wrought to some extent at the beginning of the seventeenth century, but have latterly been almost abandoned."[5] Chaloner, in 1656, after mentioning the occurrence of lead-ore containing silver at this place, adds[6]:—"The Veins of this Mine, by it's brightnesse, may plainly be discerned in the Rock towards the Sea; but it seemeth not possible to be wrought, in regard the Sea beats upon it constantly at High-water, unlesse it may be done by Mining within the Land; a tryall whereof were worth the undertaking, in regard of the great benefit that possibly may ensue thereof." Feltham in 1798 ("Tour," etc., op. cit., p. 213) mentions that the mines though closed at the time of his visit, were worked and the ore brought from the shore in boats, and then carted to the smelting house at Port-le-Mary. Woods, Berger and

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1 Information chiefly from Mr. W. H. Rowe.
2 MSS. in Woods and Forests Office.
3 Information chiefly from Mr. W. H. Rowe.
4 Documents in Woods and Forests Office.
5 "Isle of Man," 1848, p. 165.
6 "A Short Treatise, etc." p. 8.

Macculloch, early in the past century, found them standing idle, the last-mentioned author stating (in 1819) that they had been abandoned "twenty years ago." A plan of the workings, dated 1826, is preserved in the Office of Woods and Forests.[1]

Work was resumed soon after Cumming wrote, as there is a return of 25 tons of lead ore from them in 1850; and similar small quantities are recorded intermittently between this date and 1863, the returns for the whole period showing 178 tons lead ore and 146 tons copper ore. The "South Manx Mining Company" which had been prosecuting the work seems then to have come to an end; but between 1866 and 1875 the "Bradda Mining Company" resumed operations, with a total output, as shown by returns between 1869 and 1874, of 364 tons lead ore and 193 tons copper ore. In 1881 the mine passed into other hands, and a new "Bradda Mining Company, Limited," was instituted, which ceased working in 1884. The returns of this company (1881–1883) give a total of 478 tons copper ore. The output from these mines seems never to have approximately reached the cost of production.

The lode, as already mentioned, is very conspicuous in the cliff on both sides of Bradda Head. On the south it occurs as a nearly vertical rib of white quartz and fault-breccia 30 to 50 feet wide, with well-defined walls rising over 120 feet up in the cliff. It strikes N. 5° E. across the headland for 700 yards and reappears on the coast opposite Creg Harlot (six-inch map, Sh. 15), forming in places the face of the high cliff until truncated by a sharp curve in the coast-line. It is to these sections that Sir W. W. Smyth referred in describing the Bradda Lode as "the noblest surface exhibition of a mineral vein to be seen in Europe."[2]

At its southern extremity the underlie of the vein is eastward at about 10° from the vertical. The quartz is full of cavities or 'vughs,' and the metalliferous contents are distributed irregularly in detached strings and patches. I am informed that at South Bradda the lode was found to 'pinch' rapidly in the workings below sea level, and that in the deepest part crushed slate rather than quartz was its chief constituent. The fissure appears to mark a fault cutting off the eastward prolongation of the flaggy grits of the headland; but the extremely contorted arrangement of the rocks in this vicinity hides the true relations of the strata. It is important to note that the vein, like most of the metalliferous lodes of the Island, lies close to the main structural axis of the slates (see p. 30).

At its northern outcrop the fissure is less sharply defined, and appears to have split into two or more branches with shattered rock between them, the western branch being distinguished as the 'Bulwark Lode.' In this part of its course a small dyke of (Tertiary ?) olivine-dolerite, 1 to 2 feet wide, is seen in the cliff to run along the lode, thus furnishing an especially interesting example of the association of the dykes of this type with the metalliferous deposits. In this case it is evident that the vein was in existence prior to the intrusion of the igneous rock; and no distinct indication is forthcoming to show whether the dyke has been the means of introducing or concentrating the ores in the fissure, as is suggested in some other instances (p. 488). The dyke is probably an offshoot from a broader intrusion visible at low tide on the shore 220 yards S. of Creg Harlot, which strikes away from the lode in the usual direction of the olivine-dolerite group, viz., W. 35° N. Apparently while the main part of the dyke has held to its original course, it has thrown off a branch northward on intersecting the lode. On the opposite or eastward side, the course of the main dyke is indicated by a small outcrop at the side of a fence 250 yards inland, in the same line of strike. The intrusion was seen in the North Bradda mine-workings by Sir W. W. Smyth, who in his report for 1873, after describing the 70-fathom level north of the shaft as being in a cavernous quartz lode with very little appearance of copper, remarks:— "the south driving of the same level has been strangely interfered with

[1] Of doubtful value; probably incorrect.

[2] Bevan's "British Manufacturing Industries," 2nd ed., p. 15. (London. 1878.)

by trap dykes, which in some places appear to border, but in others cut right across the lode, filling up a great portion of the space between the walls."

The workings on the vein are in three separate groups:—the South Bradda Mine, at the foot of the cliff at the southern outcrop; the North Bradda Mine, in a similar position at its northern extremity; and a set of workings at a higher level, on the top of the headland about half-way between, which connect with an adit-level driven in from the cliff.

At South Bradda the older workings were carried on by means of an adit about half-way up the cliff, driven northward along the lode and connected with shafts from the surface of the headland and with sinkings where the ground was productive. The largest patches of ore seem to have been found in this locality. The later operations include a level over 100 fathoms long, driven upon the lode at a little above high-tide, with a rise connecting with the higher workings; and a shaft sunk from the base of the cliff to a depth of 30 fathoms, with a level along the vein at 20 fathoms, which disclosed nothing of importance.

At North Bradda there is, similarly, a series of old galleries in the face of the cliff, with newer workings descending below sea-level. The shaft at the base of the precipice is stated to have been carried to a depth of 72 fms. with levels at 27, 40, 50, 60 and 72 fathoms, mostly driven northward on the lode. The longest of these levels was the 60 fathom, which appears to have been carried 70 to 80 fathoms N. of the shaft, with poor results. Some ore was won in the 40 and 50 fathom levels, and a little lead in the 72 fathom S. The mine made 200 gallons per minute of salt-water. One of the higher galleries of this mine was driven south to connect with the 'Spittals Shaft,' which was sunk from the upper surface of the headland. The plan of the mine prepared by J. A. Twigg of Chesterfield in 1826, now preserved in the Office of Woods and Forests, shows a through communication between North and South Bradda by an adit a little above sea-level, but this connection is not shown on the later plans to which I have had access. The workings above sea-level were the most productive of the mine both in the cliff and on the top of the headland; and Smyth notes (in his report for 1873), "It is a matter of reasonable disappointment that this great lode both here [North Bradda] and in the southern workings at Spitals Shaft has manifestly deteriorated in depth." The width of the lode in the upper part of the mine was in places between 10 and 11 fathoms.[1] The vein was everywhere 'streaky,' and without continuous ore bodies. A little native copper ('moss-copper') is reported to have occurred in the parts of the mines highest above sea-level. The following minerals from the lode are recorded by Sir W. W. Smyth:—Malachite; Cuprite ("in minute octahedral crystals at the 40 fathom level"); Melaconite; Copper Pyrites; Copper Sulphate (old workings); Atacamite ("copper-ore changed under action of the sea-water—Old Mine, North Bradda"): Galena (argentiferous); Cerussite; Marcasite; Chlorite ("with quartz"); Agate ("parts of the vein-quartz in the Bulwark lode, North Bradda"); Hydrated Oxides of Iron (Ochre and Umber; "sometimes as gossan of lodes as at Ballacorkish and Bradda").[2]

As the workings are now inaccessible, special value attaches to Sir W. W. Smyth's descriptive reports, from which, in addition to the passages already quoted, the following details respecting the character of the lode have been culled. In 1858, Smyth mentions that at North Bradda "the eastern part of this huge lode presents a rib, between 2 and 3 feet wide, of softer character, which was largely worked for lead ore under the Duke of Athol, and a little is still obtainable in the 'backs.'" In 1859, the workings at South Bradda are described, where the adit had been cleared, the lode cross-cut, and a 20 fathom level driven some distance below the adit, "but although copper-pyrites, galena, iron-pyrites, and carbonate of

[1] For the above details I am chiefly indebted to Messrs. R. Barkell, J. Kewley, and W. H. Rowe.

[2] See "List," in Transactions I. of Man Nat. Hist. and Antiq. Soc., vol. i., pp. 143-7.

iron are all there, they are in too small quantity to be of any value." It is also mentioned that three shallow shafts opened on the hill above, and levels driven or re-opened there, had discovered large workings of the 'old men,' but very little ore. In 1860, "from North Bradda, at last, some ore has been raised and sold," a very fair course of lead ore having been found in a winze down about 14 fathoms on the eastern lode. In 1868, we learn, "the Bulwark lode or farthest point W., under the sea, has so far been a disappointment, containing little else than quartz with an agate-like structure." In 1871, the North Bradda shaft was down 9 feet below 70 fathoms, and "here the lode is a great quartzose cellular mass of the hardest character, streaming on all sides with salt water, and containing only small spots of copper ore." In 1872, the workings at Spittals Shaft are described as being 25 fathoms below the adit from the cliff, which reached the shaft at 54 fathoms from the surface, the lode keeping its great size here "in all 50 or 60 feet wide, inclusive of the 'douk' or soft argillaceous lode, and the 'Bulwark' or western quartzose part," but copper ore occurred only in spots. On the last re-working of North Bradda, it is noted in the report for 1883 that the 40 fathom level, driven 50 to 60 fathoms N. of the shaft, had ore said to run 3 or 4 tons per fathom, but "a cross-course had disordered the lode in the end."

Coast south of Port Erin.

If the Bradda Lode be continuous southward in the same line of strike, it should be again intercepted by the coast about ¾ mile S. of Port Erin Bay; and we find in this locality a comparatively small but well-marked vein, with an easterly underlie, in the recess of Bay Fine, consisting of quartz and fault-breccia with iron pyrites. The strike of this vein, however, is N. 10° W., which is somewhat to the seaward of Bradda Head; it may possibly be a branch of the main fissure. At Aldrick, a similar recess ¾ mile farther south, another fracture is revealed, striking about N. 3° W. and hading eastward, which emerges again on the shores of Calf Sound near Carrick Nay (six-inch, Sh. 18) 500 yards farther south, where it forms a broad lode. This has been tested by an adit reported to be 15 to 20 fathoms in length, from which a little copper-ore was obtained. I was informed by a miner who had worked both here and at Bradda that this lode resembled exactly the Bradda vein, of which it is regarded as the prolongation. If the identification be correct, the Bradda vein must have been shifted for 600 or 700 yards to the westward of its strike, either by a change of direction or by cross faulting. It is more probable however that, as at Ballacorkish, the ground is gashed by a set of approximately parallel but discontinuous fissures. There are no doubt later east and west faults here, as in other localities; but it is scarcely likely that these are large enough to carry the Bradda vein to Aldrick.

Ballacorkish, South Foxdale, or Rushen Mines.[1]

Though not permanently profitable, these mines have made a considerable output of lead and zinc ore, of which they are the only workings in the south of the Island to yield an appreciable quantity. Their early history is obscure, but the vein appears to have been worked and abandoned prior to 1811.[2] It is also mentioned by Macculloch in 1819 as an abandoned working.[3] The mines lie in the Manx Slates, about half a mile W. of the village of Colby in the parish of Arbory, on the lower slopes of a spur from the hilly axis of the Island. Work was resumed

[1] Unless otherwise indicated, the account of this mine is based on my personal examination of the plans and part of the workings, supplemented by information supplied by Mr. F. Kitto, the manager of the mine.
[2] G. Woods, "An Account," etc., op. cit., p. 12.
[3] "Western Isles" vol. ii., p. 574.

about 1862 and carried on more or less intermittently at the one or other of two shafts until 1893, latterly under the title of the Rushen Mines. The aggregate returns, as given in "Mineral Statistics" between 1864 and 1894, show a total output of 3,693 tons lead ore, 2,869 tons zinc ore, and 138 tons copper ore.

The mines comprise two separate workings, not connected underground, the main shafts of which are about 600 yards apart. These workings appear to be on different lodes, or otherwise upon a lode which has suffered considerable lateral displacement. The lode or lodes have a general northerly strike, but while in the South or Ballacorkish mine the average direction is 2° to 5° W. of N., in the North or Rushen Mine it is about 10° E. of N. The hade or underlie is in both cases principally westward, at from 10° to 20° from the vertical, but with local deviations bringing it over in one part of the mines to the opposite quarter.

The South Shaft has been sunk to a depth of 75 fathoms, with levels at 12, 24, 36, 60, and 75 fathoms. The longest level is the 60 fathom, which has been driven about 490 yards north and 130 yards S. of the shaft. The North or 'Phosphate' Shaft had a depth at the time of my visit in 1893 of 60 fathoms, with levels at 15, 30, 45, and 60 fathoms, of which the 45 fathoms went 60 yards S. and 260 yards N., and the 60 fathoms about the same distance N, these being the pioneer levels of the mine. In the uppermost part of the mines a ltttle copper ore was obtained, while the lower levels yielded only galena and zinc-blende, the latter chiefly on the western side of the lode. The ores were 'bunchy' and irregular in their mode of occurrence throughout. In describing the uppermost level in the S. shaft in his report for 1869, Sir W. W. Smyth remarks "in the best part of this . . . . . the lode was as much as 5 or 6 feet wide, with more massive ribs of ore than were anywhere to be seen in the Island except only Foxdale and Laxey."

The galena of the south mine was richer in silver than that of the north, the former being stated to run 15 to 16 ounces to the ton and the latter only 3 or 4 ounces. The water percolating along the lode and pumped from the shafts averaged from 30 to 35 gallons per minute for each mine.

Besides the ores mentioned above, the following minerals are quoted in Sir W. W. Smyth's list[1] as occurring in the vein:—Pyromorphite [phosphate of lead, from which the N. shaft derived its name], Cerussite, Chlorite ("according to Captain Barkell"), and Ochre and Umber [decomposed dolerite?]. The country-rock chiefly consists of rather flaggy slate; thinly bedded grits with slate partings were revealed in a short cross-cut E. in one of the lower levels.

The main geological interest of the mine lies in the relation of the lode to a dyke of olivine-dolerite, and in the cross-faults by which the metalliferous vein is thrown. The olivine-dolerite is apparently one of the Tertiary dykes (see p. 327) which diverges from its W.N.W. course on encountering the lode and follows it for a short distance. It is probably identical with the intrusion revealed in the bed of the Colby River a few yards below the corn mill, and again in the little glen 400 yards W. of Colby under the garden of Ballasherlocke (see p. 185).

As previously stated, the relations of the metallic infilling of this lode to the intrusive rock afford important evidence as to the age of the ore-deposits, a study of the facts leading to the conclusion that although the lode existed as a rock-fracture previous to the intrusion, some part if not all of its metallic contents were subsequently accumulated, therefore attaining their present position at a comparatively late geological period (p. 489).

SOUTH MINE.—The dyke was first reached in the northward drivings of the South Mine within about 200 yards of the shaft and was more or less continuous thence to the end of the levels, accompanying and forming part of the lode, the ore lying sometimes to the east, but oftener to the west of it.

[1] Trans. Isle of Man Nat. Hist. and Antiq. Soc., vol. i., pp. 143-7.

This portion of the mine was inaccessible at the time of my survey, but is described, with especial reference to the intrusion, in Sir W. W. Smyth's official reports. The presence of the dyke is first mentioned in his report for 1870 [1]; in the following year Smyth notes the adit being stopped "on account of the apparent destruction of the lode by greenstone"; and in 1878, that in a deeper level the "black-rock or dolerite" made its appearance and seemed to militate against the productiveness of the vein. In 1879, he compares the intrusion to the [Carboniferous] igneous rock of Scarlet Point [from which it is, however, distinct, see p. 325] and describes its occurrence in the 60-fathom north level, at that time 210 fathoms out from the South Shaft, as follows:—"I regret to add that the dolerite or black igneous rock . . . . has for the last 35 fathoms completely overpowered the lode so that in the latter part hardly a trace of it is seen. Before that, it had accompanied the lode in a narrow band of 6 inches, which had appeared to do its productive qualities no harm. . . . . There are hitherto but few precedents to go upon with reference to this dolerite and basaltic rock, but it is evident it is a question of much importance in this part of the Island from its action here, as well as at Central Foxdale, and in a minor degree at Bradda." In 1880, in describing the further progress of this level, he mentions that the lode was a mere string, not yet out of dolerite in which it has "been encased for 80 fathoms length,"—thus distinctly implying that the 'lode' proper is newer than the intrusion.

NORTH MINE.—In the North Mine, where it was practicable in 1893 to examine the intrusion in the lower levels, I found the principal dyke to have a thickness of from 6 to 12 feet. Small fliers of the same rock occurred among the lode-stuff and were themselves sometimes dappled with lead-ore throughout, this association suggesting that part, at least, of the metalliferous contents of the vein had been introduced along with or later than the dolerite. In his earlier reports quoted above, Sir W. W. Smyth evidently inclined on the whole to the miners' opinion that the lode was intruded upon and cut out by the dolerite; but with the progress of the workings in the North Mine, and influenced, no doubt, also by evidence obtained about this time at Central Foxdale (p. 515) and Langness (p. 538), he abandoned this opinion; and in 1883 in describing the 30 fathom level of the new shaft he remarks that the ground was strongly invaded by dykes of dolerite, "the supposed prejudicial effect of which on the lode is, I think, not confirmed at this place, since there are parts in which a rib of this rock from 4 to 8 inches thick was flanked on either side by a branch of lode with lead and zinc ore."

We learn from the report for 1881 that in the upper level the lode was 4 to 8 feet wide, "having in places very beautiful examples of gossany lead-ore with white and green lead-ore;" and in 1883, that in the 30 fathoms the lode was difficult of definition, in places 14 feet wide, and two levels on it, though the branch usually opened on was about 2½ feet wide, mostly occupied by soft gossan with abundant minute crystals of white lead ore.

From information obtained at the mine, it appears that in these workings the dolerite was continuous southward to the end of the longest driving, 60 yards S. of the shaft; while northward it was lost, at about 90 yards from the shaft in the 45 fathom level; at 95 yards in the 60 fathom level; and at about 100 yards in the 75 or lowest gallery, probably striking off westward upon leaving the lode, with the same course that it held before intercepting the fissure, as it was not touched in the east and west cross-cuts made farther north. The dyke was disturbed and shattered in places, probably by transverse movements after its consolidation. It is not clear whether the intrusion is continuous from the South to the North mine, or whether we are dealing with separate and parallel branches. The end of the most northerly driving from the South Shaft lies about 240 yards east of the end of the most southerly driving from the North Shaft, and the character of the intermediate ground is unknown. It seems most probable that the lodes constitute

[1] MSS. in the Woods and Forests Office.

a group of roughly parallel discontinuous N.—S. fissures, and that the intrusion in traversing the tract from east to west broke across from one to the other, and followed each in turn for a short distance only. The greater portion of the metalliferous deposits appear to have been afterwards concentrated in the fissures around and a little beyond the places at which the dolerite crosses them.

In the South Mine two large transverse east and west displacements of the vein have been recognised by the miners. One of these, known as the 'Dowk Lode,' consists of a belt of crushed soft ground 66 feet broad, which sets in 15 yards north of the shaft and is said to shift the metalliferous vein 190 feet westward. The second, named 'King Slide,' occurs 130 yards north of the shaft,[1] and is supposed to displace the lode westward on the southern side. The miners' identification of their 'lode' beyond these breaks is of course open to doubt, and Sir W. W. Smyth refers to the workings north of the 'Slide,' in his report for 1875, as on "a new north and south lode at about 24 fathoms beyond the old one," and in 1880 mentions the "Blende lode," 52 fathoms east from the main lode. In Great Laxey and other Manx mines working north and south lodes, though east and west displacements, recognisable as normal faults, are not uncommon, they are never of this magnitude (p. 487).

Bellabbey or Ballasherlocke Mine.

The site of this extensive but unproductive trial is on the eastern bank of the little glen ¼ mile west of Colby (Sh. 16), 760 yards north of the main road to Port Erin, and about 700 yards east of the 'Phosphate Shaft' of the Ballacorkish Mine. The work seems at first to have been carried on in connection with the trial in the cliff at The Slock (p. 536) 2 miles farther north, under the designation of the "BELLABBEY AND FALCON CLIFF MINES." The earlier workings appear to have been the adit levels in the glen north of Bellabbey. These were referred to in Smyth's official reports for 1862 and 1869; we learn from the same source in 1870 that the adit level had been driven 87 fathoms and discovered only a string of mixed lead ore and blende 2 to 6 inches wide and a few yards in length. A shaft, ultimately attaining (in 1876) the depth of 72 fathoms, was then sunk and levels driven, mostly northward, from it at 12, 24, 36, 48, 60, and 72 fathoms, the longest being the 60 fathom which went 140 fathoms. Besides the ore in the day level above described, a little galena was found in the 36 fathom level north and in a few other places, but nowhere in profitable quantity. The supposed lode ran approximately north and south, with easterly underlie, and consisted of quartz (gossany at the top), crush-rock and 'dowk.' Water was raised from the mine by the pumps at the rate of 100 gallons per minute.[2] In Smyth's report for 1872, when the shaft was down 31 fathoms, it is stated that the driving had "met with a little copper pyrites and zinc blende, but scarcely any lead ore." In his report for 1876 there is the following passage:—"A very curious and exceptional little deposit of copper ore occurred in a 'warp' or loop of the vein in the 48 level north 60 fathoms from shaft; a bunch, only a few feet in length, and, as I fear, only some 9 fathoms in height, but reaching at its best 12 or 14 inches in thickness, assaying 13½ per cent."[3] It is also mentioned in this report that a cross-cut at the 72 level 9½ fathoms beyond the old lode had cut another lode also dipping east but at a steeper angle. In 1880, Smyth described a cross-cut at 60 fathoms going out west for 58 fathoms without attaining any results. This appears to have been the last work done in the mine.

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[1] These displacements have been indicated on the published geological map, but much exaggerated owing to the small scale of the map.

[2] For most of these details we are indebted to Mr. R. Barkell, the lat manager of the mine.

[3] MSS. in Woods and Forests Office.

Slock Trial (*apparently worked as the* Falcon Cliff Mine).

This consisted of a level driven into the face of the high precipitous cliff nearly opposite The Stacks, about a mile N. of Fleshwick (near Y Slogh, of six-inch map, Sh. 12). The country-rock is banded slate, and many dykes of microgranite of the Foxdale type, of greenstone, and of olivine-dolerite, are exposed in the immediate vicinity (see p.p. 150-1). The 'lode' consists of fault-breccia, which is said to have contained a little lead-ore at the mouth of the level but none farther in. Its direction is slightly N. of E. at the entrance of the adit, but is reported to have changed to S. of E. inside.[1] The trial was made between 1860 and 1870. Sir W. W. Smyth's report for 1866 contains the following comment on it:—" A fair amount of work done in the past year has only made appearances worse than before."

In " Mineral Statistics " the Bellabbey and Falcon Cliff Mines are credited with returns in 1872 and 1876 8, amounting in the aggregate to 59½ tons copper ore, 22 tons 17 cwt. lead ore, and 16 tons 8 cwt. zinc ore.

'Iron Spout' Mine.[2]

This name was applied to a small trial-shaft which was sunk, about the middle of last century, to a depth of 10 or 15 fathoms on the E. bank of a rivulet ½ mile E. of Colby and 300 yards N. of the highroad. No ore seems to have been found, but some of the weathered débris on the spoil-heap shows slight copper staining. The shaft has passed through a highly-sheared 'greenstone' dyke curiously dappled with the green stain.

Glenchass Mine.

The site of this mine is in the north-western corner of Perwick Bay ½ mile S.W. of Port St. Mary, where the vein is intersected by the cliff in the recess known as *Collooway* (six inch, Sh. 15). The date of the first working is uncertain, but was probably before the end of the 18th century; Macculloch in 1819 mentioned the place (" Glensash, near Port la Marie ") as being at that time abandoned.[3] Toward the middle of the past century operations were resumed, at first as part of the Bradda mining sett and afterwards as an independent company, but the mine did not at any time yield ore in paying quantity. The first workings consisted of an adit-level driven into the cliff along the course of the lode, which runs N. 18° to 20° W. with an easterly underlie. Afterwards, a shaft was sunk from the surface 200 yards inland, which reached a depth of 50 fathoms, with drivings, chiefly southward under the sea, at 15, 23, 38 and 50 fathoms, Some small 'bunches' of argentiferous galena of high quality, and kupfer-nickel (arsenide of nickel), are said to have been found in the sole of the day-level, this being the only known occurrence of the latter ore in the Island.[4]

From Sir W. W. Smyth's official reports[5] we learn that the mine was in operation in 1857; but working appears then to have been suspended until 1861 when the 15-fathom level was being driven north and south, exhibiting a little lead-ore in the latter direction; in 1862, the shaft had been sunk

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[1] From information supplied by Mr. Barkell.
[2] *Ibid.*
[3] " Western Isles," vol. ii., p. 575.
[4] Recorded by Sir Warington W. Smyth in his " List of Manx Minerals " (Trans. I. of Man Nat. Hist. and Antiq. Soc., vol. i., p. 146), where it is stated that the ore was " found in small quantities about 1858 to 1862 "; according to the same authority, Millerite (sulphide of nickel) occurred in "delicate capillary crystal vein-stuff at a trial shaft at Rhenas, south of Kirk Michael " (see p. 547).
[5] MSS. in Woods and Forests Office.

to 50 fathoms, and the "lode in the 38 fathoms [south] is of good size, but valueless"; in 1863, this level had cut a slide introducing water and a better-looking lode, 3 feet of which carried some steel-grained galena, while the 50-fathom level south showed nothing of promise. The report for 1865 records the collapse of the shaft "which had been put down among old workings, and appears to have been subjected to a sudden pressure by the fall of their walls." The accident brought the operations to a close, and the failure of the mine is locally held to have been due to this cause alone; it is important therefore to note that Smyth's report for the previous year (1864) contains the opinion that "this lode has always appeared to me a hopeless blank."

The Glenchass lode has been supposed to continue its course northward to the coast between Bradda Head and Fleshwick, where it has been sought for in some small trials in the vicinity of a branching dyke of olivine-dolerite at *Lhoob ny Charran* (Sh. 15). An intermediate trial in the interior, close to the hamlet of Bradda West, known as the WEST BRADDA MINE, consists of an adit driven 24 fathoms, with a sump of 5 fathoms, on a lode striking somewhat west of north and hading east, which showed traces of blende and lead.[1] In referring to this trial in his report for 1882,[2] Smyth states that the lode had been tested by the old Foxdale Company 40 years previously, and expresses doubts whether it really coincides with that of Glenchass.

Castletown Harbour.

The occurrence of a little galena at this place is not only interesting as affording the only known locality[3] for this ore in the Carboniferous Limestone of the Island, but also because the ore is associated, like the copper pyrites of Langness, with olivine-dolerite (Tertiary?) dykes. Cumming in 1845 described the circumstances as follows:—"This dyke has greatly altered the limestone, and more particularly in those places where it encloses a mass of limestone betwixt two of its branches. In this crystallised and altered limestone we meet with thin strings of galena."[4] During the mining excitement in the Island some 20 years later, a small trial was begun at this place which was alluded to by Sir W. W. Smyth, in his report for 1867 in the following terms:—"At Castletown, a great cry has been made about a discovery of ore in the limestone rocks bordering the harbour. A shaft is now sinking, but in it I found no trace of vein, and it remains to be seen by driving a cross-cut from it whether anything be there on which a mine can be opened."[5]

Langness Copper Mines.

The prolonged and expensive series of trials on the western shore of Langness on some small copper veins known to Cumming[6] in 1845 seems to have been commenced about 1875, as we learn from Smyth's report for that year,[7] that "some strings and vein-like deposits of occasionally 2 or 3 feet in depth have been opened upon the foreshore and yielded some very good

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[1] From information furnished by Mr. W. H. Rowe.
[2] MSS. in Woods and Forests Office.
[3] There is a local belief that lead ore occurs also in the limestone at Balladoole, a little to the north of the foreshore; but the evidence offered is unsatisfactory.
[4] Quart. Journ. Geol. Soc., vol. ii., pp. 331-2.
[5] MSS. in Woods and Forests Office.
[6] Cumming says, "I may also mention that along the side of the dike cutting the southern point of Langness, and in a narrow gully, I have met with fine veins of copper in the schist." Quart. Journ. Geol. Soc., vol. ii., p. 332.
[7] MSS. in Woods and Forests Office.

copper pyrites." The work was prosecuted at various spots from that time until 1880; and after being at a standstill for a few years, was, towards the end of the decade, resumed near the southern extremity of the headland, but has since been again suspended. The strings of ore were first discovered in the Carboniferous Basement Conglomerate, but most of the workings have passed into the underlying slate. As at Ballacorkish, North Bradda and Central Foxdale, the close association of the metalliferous deposit with intrusions of olivine-dolerite lends considerable geological interest to the matter. Unfortunately in spite of the heavy expenditure of capital the total quantity of ore yet obtained has been quite insignificant—only 10 tons 18 cwt. of copper pyrites standing to the credit of the mines in the official returns ("Mineral Statistics" for 1890 and 1892). The direction of the supposed lodes is approximately north and south, with an easterly dip. The strings of ore have been found alongside or in close proximity to small olivine-dolerite dykes that fill the fissures.

The most northerly working is a small trial-pit just above high-water mark on the foreshore of Castletown Bay 420 yards N. of Langness Farm; this has a depth of 26 feet, starting in Carboniferous Limestone, and ending in dark Basement Conglomerate.

The next is a shaft 320 yards S.W. of the above-mentioned farmstead, sunk to a depth of 12 fathoms, on the raised beach near high-water mark, the upper 50 feet being in conglomerate and the remainder in slate. From the bottom a cross-cut was driven westward under the shore, at first in slate but afterwards in conglomerate, and is described as follows in Sir W. W. Smyth's report for 1876:—"This passes through mottled slaty rock beneath the Conglomerate and at thirty fathoms out has intersected the vein of 2 or 3 feet thick including a 'black stone' or trap and with some good portions of yellow copper ore in it."

The most extensive trial of the series is situated on the top of a low cliff 225 yards farther south, where a shaft has been sunk vertically in slate to a depth of 44 fathoms, with drivings westward from it under the shore. The shaft is said to have intercepted the eastward dipping lode at 30 fathoms from the surface. The lower part of the mine was flooded during my stay in the neighbourhood, but I was able in 1893 to examine a cross-cut to the lode at 12 fathoms depth, in which the junction of the slate and conglomerate was seen to occur at a small fault striking N. 8° E., and to be accompanied by a rib of intrusive dolerite like the branching dyke so beautifully exposed on the foreshore above (p. 195). Strings of copper pyrites lay along the junction of the dyke with the conglomerate, and to a minor extent at its junction with the slate. On the opposite side the ore in places permeated the margin of the igneous rock, like the lead-ore at Ballacorkish (p. 534), and was most plentiful in a bifurcation of the dyke.[1]

The 40 fathom level was described by Sir W. W. Smyth in his report for 1878, as a cross-cut running S. of west for 35 fathoms in clay-slate, with short drivings along a string running N. and S. at 18 fathoms from the shaft, and along a second a little farther out having a slightly different course, both utterly barren and devoid of promise, leading to the conclusion that the bunch or two of ore in the overlying conglomerate were extinguished at this depth in the slate.

The evidence on the foreshore shows that the relation of the dyke to the lode is the same here as at Ballacorkish and North Bradda, an intrusion striking W.N.W. across the headland (p. 177) having been diverted northward for a short space by the fissure, but soon escaping from it and going off W.N.W. again. The ore in places impregnates the matrix of the conglomerate as well as the dyke-rock, and must have been concentrated in its present position either during or after the intrusion. It is important to note that both here and at Langness Point the strings of ore occur only in

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[1] Our thanks are due to the engineer and captain of the mine for facilities afforded on this and other occasions.

the proximity of the dykes; at the same time, there are many more of these dolerite dykes in the neighbourhood which are not accompanied by metalliferous veins.

The course of the 'lode' of the above mine after it is abandoned by the dyke is indistinct, and does not appear to give rise here to a displacement at the surface; though it may possibly be prolonged into the sharp anticline breaking northward into a small fault which brings up the oval inlier of conglomerate among the limestones on the foreshore N.W. of Langness Farm (p. 195).

Southward of the shaft, at a distance of 200 yards, an adit has been driven into the cliff through banded slates traversed by small sheared pre-Carboniferous dykes of 'greenstone;' and 300 yards south of this again, just beyond The Arches (p. 190), there is another adit 36 fathoms long, in the Carboniferous Conglomerate.

The remaining workings are in slate at Langness Point, east of the boundary of the Carboniferous rocks. Here, on the south shore of *Port Bravag* (6-inch, Sh. 19) 200 yards east of the extremity of the headland, a dyke of dolerite a foot or two wide, striking N. 8° to 15° E. along a fissure in slate, showed a string of copper pyrites along its western side. To test this, a shaft was sunk to 26½ fathoms on the ridge about 100 yards to the eastward, and a north-west cross-cut commenced to intercept the lode, but was not completed. Specks of galena were found on joint-faces in the slates of this level. A smaller pit was then sunk to 8 fathoms in close proximity to the fissure, and a short cross-cut driven from it to the dyke, but the result was discouraging. The present surface of the slate at this point is nearly identical with the ancient floor on which the Carboniferous Conglomerate originally rested (p. 191), so that the disappearance of the copper-ore downward in this place as well as in the previous workings suggests that these particular metalliferous strings tend to die out on passing down from the conglomerate into the slate-rocks.

The cliffs on the eastern side of Langness have been tested in several places by short excavations along planes of dislocation and crushing in the slate, but without revealing anything of promise.

NORTHERN HEMATITE GROUP.

Reference has been made in preceding chapters to the occurrence of hematite iron-ore in the veins which traverse the slate-rocks in the north-eastern part of the massif, and to the probability that it may indicate a former overlap of the New Red strata upon the Manx Slates in this quarter (p. 125 and p. 291). So far as is known, it is only in the north-eastern district that lodes of this mineral occur among the slates, though chalybite (carbonate of iron), and iron pyrites are abundant constituents of all the metalliferous veins, and pyrrhotine (magnetic pyrites) is also present in some places. The supposition that the hematite may, as in Cumberland, be connected with the former extension of the Triassic rocks over the area is greatly strengthened by the discovery in the deep borings in the extreme north of the Island (Chap. VII.), of Triassic rocks of considerable thickness, resting on the denuded edges of Carboniferous strata, the latter being always stained and veined with hematite.

From the conspicuous aspect of this red ore in considerable veins in the cliff on both sides of Maughold Head (p. 125), its presence must have been known in early times. As mentioned in the historical introduction to this chapter, we know that the mine at Drynane was working in the year 1700, but no particulars are forthcoming respecting the operations previous to the nineteenth century; they probably consisted of the older part of the adit-levels into the cliff, which have since been driven, at intervals, farther and farther inland. Though in the aggregate a large quantity of ore has been obtained from these mines (see Table, pp. 496–7), the output does not appear to have been sufficient, at any time of which we have trustworthy record, to meet the working expenses, and the mines have consequently been practically abandoned since about 1874.[1] Two separate lodes or sets of lodes have yielded the chief production, the first that which traverses Maughold Head, and the second running parallel inland 1½ miles farther westward, known as the Ballajora (Ballagorra of Ordnance map) or Magher-e-breck lode. Besides these, several minor trials have been made in the district, but all apparently without result.

Maughold Head Mines.[2]

On the northern side of Maughold Head, at Stack Mooar, a great vein of fault-breccia and quartz, with cavities containing hematite, strikes in a south-easterly direction across the foreshore and into the cliff, with an exposure almost equal to that of Bradda Head in size and interest (p. 125). Its width at the foot of the cliff is about 40 feet, and it hades or dips north-eastward at 15° from the vertical. The most important of the old workings at this point is said to have consisted of a deep adit-level driven in from a little above high-water mark for 95 fathoms, with cross-cuts for 5 or 10 fathoms both ways at the end, but it appears to have yielded no appreciable quantity of ore.

Better success attended another opening on the lode, known as the GLEBE MINE, about ½ mile S.E. of the above and close to Maughold village. At this place, about 100 yards N.W. of The Vicarage, a shaft and some shallower trials were sunk, and two levels driven on the lode, the lower going south-east for 196 fathoms and north-west for 212 fathoms. This work, according to Cumming, was principally done by a company formed in 1836; and a few years later, when a Glasgow gentleman became sole lessee of the Maughold Mines, the annual shipment of hematite from the district is stated to have been about 500 tons per month,[3] seventy men being employed. The south-eastward driving of the Glebe Mine appears to have passed about 100 yards to the north of Maughold Church, and if prolonged in the same direction would have emerged in the cliff above Traie Curn, close to the extremity of the headland. Hence the lode which was followed cannot directly coincide with that of the Southern or Dhyrnane Mine next to be described. Indeed, the veins of this district in spite of their apparent strength in the cliff-sections appear all to be of limited length, forming a group of impersistent converging or radiant fissures, of which those which strike towards points between north and west are more or less metalliferous.

Drynane Mine.

This term is applied to the workings on the southern side of Maughold Head, in a little inlet 500 yards east of Port Mooar (Sh. 8). As mentioned in the footnote on p. 126, the name Drynane, written Dhyrnane, is erroneously affixed on the 6-inch Ordnance map to another inlet 200 yards farther north, in which an adit has been driven to procure umber. The Drynane Mine proper consists of a level going in from the cliff for 320 fathoms in a N.N.W. direction on a lode dipping east, with sumps on ore bodies at 10 fathoms and 37 fathoms from the entrance, and connected with a shaft from the surface at 70 fathoms. A large quantity of hematite was obtained between the mouth of the level and the shaft, but very little farther in. The chief work was done between 1857 and 1874, and is described in Sir W. W. Smyth's reports to the Woods and Forests Office, from which the following abstracts are taken. The report for 1858 states that in driving north, the level passed through two bunches of ore, the first small, but the second 8 to 10 feet wide, and capable of remunerative work; but

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[1] Some exploratory work was done, on the old workings, a year or two ago, but has led to no result.

[2] For information regarding the old workings I am chiefly indebted to Mr. W. H. Rowe.

[3] "Isle of Man," p. 311.

in the two following years we learn that no more ore had been found, though a shaft had been sunk on the vein, and a 10 fathom level driven north and south. In 1861, the adit was 95 fathoms in [beyond shaft ?], but with "no appearance of promise, although the lode is some 15 feet wide. The south level has also been advanced a long way without any farther discovery of ore. The mineral is so evidently disposed in discontinuous 'bunches' that the prospects of the mine are extremely uncertain." In 1863, the adit was 250 fathoms in, but the lode had dwindled till there was scarce a vestige of it. In 1864 we read, "On careful examination I saw that the drift was really carried on in the lode, and that it oçcasionally formed a vein of a foot or two in width, but utterly valueless." The later reports contain only passing reference to the workings, until 1873 when it is noted that a long way in the old level and to the east of it, on climbing a rise some 7 fathoms up, a rib of ore of minor importance was seen, "not to compare with the old deposits worked away years ago."

The Umber Mine level mentioned above, which was last in operation between 1887 and 1893, appears to be driven on a decomposed dyke of olivine-dolerite having the usual north-westerly direction. On a plan in the possession of Mr. W. H. Rowe this is shown as intersecting the Drynane level a short distance from its northward termination, with indications that the dyke may have slightly displaced the lode. It is to be regretted that no further evidence is available as to their relations.

Ballajora Iron Mine.

These workings, from which a fair amount of hematite was marketed, were carried on between 1858 and 1874 on N. and S. lodes, dipping eastward, close to the farmstead of Margher-e-breck (*Magher* - of old one-inch Ordnance map, *Mangher* of new) in the parish of Maughold. There are two old shafts N. of the farm, one said to be 18 fathoms and the other about 30 fathoms deep, in the vicinity of which the chief bodies of ore were found; an adit connected with these workings has its mouth in a cross-cut 250 yards S. of the farm. The lode seems to have been very irregular, and in its northern portion to have consisted of two branches.[1] A few descriptive details have been gleaned from Sir W. W. Smyth's reports, as follows[2] :— In the report for 1859 it is mentioned that the lodes called No. 1 and No. 2 have proved large and capable of yielding a fair return of iron-ore, but "unfortunately a great proportion of this is carbonate of lime and iron yielding a percentage of iron [too small] to bear the expense of carriage." In 1861, the No. 1 level had been driven a long way "in a large lode of impure carbonate of iron," while "the 'School-house lode' has yielded some few cargoes of first-rate hematite, but where hitherto opened, averaging from 1 to 2 feet wide, is not large enough to insure a remunerative mine." In 1872 ("Ballajora and Maughold Head Iron Mine") it is noted that the adit level in the S. ground had opened in a new lode when 20 fathoms in and showed "2 to 5 feet wide of a fair quality of hematite"; and in the following year "two stopes and a sink below the adit" are mentioned in these workings which soon afterwards fell into abeyance.

Other trials for iron-ore, regarding which little or no information has been obtained, are indicated at several places in this neighbourhood; on the N. side of the Smithy at Ballasaig there is a large spoil heap, marked "Iron Mine" on the 6-inch map. (Sh. 5); similar though less conspicuous traces exist in a field 250 yards S.E. of the Wesleyan Chapel at Ballagorra; 350 yards N. of this chapel is the obliterated mouth of a level which was driven for 100 yards into the hill-side; and another level, marked "Iron Mine" on the 6-inch map opens into the cliff 500 yards S. of Gob ny Garvain. (See List at p. 552.)

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[1] The above information has chiefly been obtained from Mr. W. H. Rowe.

[2] MSS. in Woods and Forests Office.

MISCELLANEOUS TRIALS.

Abbey Lands Mine.

This designation was applied to a trial made between 1865 and 1872 on the banks of the tributary to the River Glass known as the *Sulby River*, 1,150 yards N.N.E. of the bridge at Abbey Lands (six inch, Sh. 10). It consisted of a shaft with drivings, on the east bank of the stream, and a short adit on the west bank. Smyth mentions it in his report for 1866 [1] as a "sinking on a lode coursing north-east." The supposed lode is probably the belt of crushed ferruginous slate still to be seen in the bed of the stream a few yards above the ruins of the mine. In his report for 1867, the same authority states that there was a single driving east at 28 fathoms, the vein containing calc-spar and copper pyrites; in 1868, we learn that the shaft was idle, but a trial adit 100 fathoms farther south showed another lode, of better character but with no metallic substances; in 1869, a 27-fathom level was being driven west to cut this (north-and-south) lode; in 1870, the 28 fathom level had been driven 40 fathoms on a lode north-westward, of which 13 yards in length had been slightly orey; in 1871, when only the 27-fathom south level was driving, Smyth refers to "the hitherto obscure character of this piece of ground"; in 1872, the 27-fathom level had apparently intercepted the second vein mentioned above, which proved to be a large lode but with no metallic substances of any value, and the work was then stopped. In reporting on a proposed assignment of the lease in 1883, Sir W. W. Smyth stated: "I have on several occasions examined these operations underground, and never yet saw anything of a promising character, or that would give ever so small an amount of saleable ore."[2]

Ballaglass or Great Mona Mine.

Large sums of money were expended upon this trial of a small north-and-south lode discovered in the bed of Cornah River 1,050 yards E. of the high road from Ramsey to Laxey. The workings commenced about 1854; and in 1857 Sir W. W. Smyth reported that much spirit was being shown in driving the 10 and 24 fathom levels, on a vein with small portions of copper, zinc and lead, but too narrow to warrant much further outlay. In same year there is a record of 9 tons of lead ore and 8 tons of zinc ore to the credit of the mine in "Mineral Statistics," which appears to be the only return made from it. The mine was then suspended for some years, but restarted by the Great Mona Mining Co. in 1866, with no better success. In 1867, Smyth noted that a few stones of ore had been raised; and in 1868, that the shaft was down to 50 fathoms, with no improvement. This appears to have been the depth attained when work was abandoned. The lode is said to have been nowhere more than 6 to 12 inches wide, and to have had an easterly underlie. A small uncrushed igneous dyke of peculiar character traverses an E.—W. joint or small fault in the slaty flags immediately to the westward of the mine (see p. 140), and must be intercepted by the lode. An intrusion of different character has been encountered in the workings, as shown by the fragments of sheared 'greenstone' contained in the spoil-heap.

Ballaskeg Mine.

The Great Mona Company also drove two levels (the longest said to be 60 or 70 fathoms) into the cliff 700 yards N. of Port Cornah, on an E.—W. lode containing traces of copper ore, which were known as the BALLASKEG MINE. Another level was driven, equally unprofitably, into the side of the valley near Corrany Bridge.

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[1] MSS. in Woods and Forests Office.
[2] *Ibid.*

Barony Mine.

This name was given to a small trial for copper made many years ago on a conspicuous N.—S. lode exposed on the foreshore 200 yards S.W. of Port Cornah, as described in a previous chapter (p. 129). The shaft, on the low cliff, is said to have been sunk 15 fathoms, and a level driven S. from it at 10 fathoms, until stopped by water, on a good gossany westerly dipping lode with some carbonates of copper. A cross-cut adit was afterwards driven from Port Cornah.[1]

Baldwin Mine.

This old mine, the site of a long and obstinate trial with the most meagre results, is located on the east bank of the River Glass opposite the hamlet of Baldwin. A plan of the mining sett in the Woods and Forests Office, dated 1864, shows two parallel lodes, "No. 2" and "No. 3," 40 or 50 yards apart, striking approximately N.N.W., intersected by other two ("No. 1" and "Wheelcase Lode") similarly parallel and the same distance apart, striking E.—W., but these lodes were probably more or less imaginary. From the papers accompanying this plan, it appears that a level had been driven in the first instance by the Isle of Man (Foxdale) Mining Company, and abandoned. Later, sometime between 1850 55, an attempt was made by other parties to sink a shaft; and finally, in 1862, a lease was granted to the "Baldwin Mining Company, Limited," and work commenced in earnest. In 1873, we find it stated that about £20,000 had been expended, and ore sold to the value of £168 3*s.* 3*d.* only, with some 5 or 6 tons more at the surface partially unwashed. Sir W. W. Smyth's reports contain many details of the workings. In the report for 1863 we learn:—"From the bottom of the shaft, now 17 fathoms deep, a cross-cut is driving N. and S. to intersect the three veins which have been seen at the surface. The southern one is without promise, but the ground looks more favourable in the direction of that lode which at a shallower level had last year yielded some large lumps of lead-ore." In 1867 the shaft was 66 fathoms deep, with drivings; in the 42-fathom S. level a little ore had been obtained on the hanging side. In 1868 the 42-fathom level was out no less than 140 fathoms from the shaft; and "one little course of ore is yielding lead and blende ores, rather in cwts. than in tons" and hardly worth the timbering. In 1870 the 66-fathom level on No. 2 lode is mentioned as having for about 14 fathoms yielded a fair amount of ore, but improvement was still needed. In 1871 a winze had been sunk 11 fathoms, and about 12 fathoms of a 77 fathom level driven "unfortunately finding only poverty beneath." The following year we learn that the capital of the company was exhausted.

Ohio, otherwise East Baldwin Mine.

The ruins of this mine may be seen in the East Baldwin valley on the east bank of river 50 yards north of the mill at Ballawyllin. It seems to have been commenced in 1866, and furnishes another example among Manx mines of long and costly working with the most insignificant result. It is mentioned in Smyth's report for that year as "a small shaft sinking on a not very pronounced vein," and reference is made in the following year to the unwarranted excitement in Douglas over a surface-discovery at the mine. In 1868 Smyth notes that a 10-fathom level showed the "lode of a very confused and ungainly appearance," and that no ore whatever was being raised. In 1869, the mine was down to 35 fathoms, "but there is here a junction of veins with an exceedingly puzzling piece of ground to unravel . . . . a little good ore had been met with in one place for 2 or 3 fathoms in length," in the 25-fathom level. In 1870, the lode was being cut in the 50-fathom level, but the little ore obtained was from a sump in

[1] From information obtained from Mr. W. H. Rowe.

the 35-fathom level, "which is the only exception to the mass of confused and broken black ground." In his next report Smyth states that the mine was sunk to 60 fathoms, and that a level at 50 fathoms was 25 fathoms long "with nothing of promise till close to the end, where came in a favourable looking branch of zinc-blende." In 1872, with the shaft at 70 fathoms, it is noted that much driving had been done, "but with the curious result that neither the E. and W., nor the N. and S. lode can be found ore-bearing except in the one limited bunch" previously recorded; and in 1873, the 70-fathom level had been driven some fathoms east and west "in black slate country, and showing not a spark of any useful mineral," while the 60-fathom level was driving north on a N.-S. lode, but without a trace of ore. After which it is not surprising to read in the following year that the mine had stopped. It was restarted, however, by "The Manx Silver-lead Mining Company, Limited;" and Smyth noted in 1876 that a little ore had been scraped up in the 36-fathom level from the skirts of the original bunch; and in 1878, that the shaft was down to 92 fathoms, and that it was intended to carry it down to 104 fathoms—an intention which does not appear to have been fulfilled.

The only returns from this mine published in "Mineral Statistics" are in the years 1872, 1874, and 1875, the total amount being 24½ tons lead ore and 39 tons 8 cwt. zinc-blende.

Douglas Head Mine.

Some utterly profitless mining work was done on Douglas Head (Sh. 13) between 1865 and 1871, consisting of a long adit driven in from the cliff at the southern side of the headland, and a shaft on the summit S.W. of Fort Anne Hotel. The character of the operations will be understood from the following extracts from Sir W. W. Smyth's reports:—In 1865 the report states that "a shaft had been sunk for 14 fathoms, and a couple of fathoms driven on a lode coursing N.E. and S.W. with 'umbery' gossan, but no appearance of ore; while a cross-cut adit was driving from 'Billy Gilbert's harbour,' which will have to be pushed from 60 to 70 fathoms in order to meet an expected lode." In 1866, the level driving in from the sea had "no appearance whatever of a promising character"; in 1868, it had a length of 80 fathoms in hard ground [Lonan Flags] costing £13 to £16 per fathom, "the vein a mere string without a speck of mineral in it the whole way"; and in 1870, the shaft had been sunk "24 fathoms on a course termed a lode but having a very problematical appearance and not a grain of any kind of ore."

Ellan Vannin Mine.[1]

Under this term an unproductive trial was made between 1870 and 1875 in the little glen locally known as Cartwright's Glen, which joins Glen Auldyn south of Skyhill farm. The workings were commenced on the strength of the discovery of lumps of lead-ore in a gossany north-and-south vein in the bed of the stream, which it was thought might be the prolongation of the Laxey lode. The favourable indications disappeared however in adits driven north and south on the lode. A level was then driven from the bottom of the valley 200 yards lower down, below the bend of the stream, to cross-cut the lode under the hill. This is said to have attained a total length of 104 fathoms, with branches. Sir W. W. Smyth notes in his report for 1874 that the long level failed to show the least sign of any vein on which to open workings. A shorter level, 30 fathoms long, driven north-north-westward from the fork of the streams due S. of Skyhill, to test another supposed lode known as the Douk Vein, was equally unsuccessful. The cost of the trials must have been considerable, and no ore was marketed.

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[1] From plans and information furnished by Mr. W. H. Rowe.

Glen Auldyn Lead Mine.[1]

This name was given to a series of trials in the upper part of the picturesque glen which falls into Glen Auldyn from the east at Balleigheragh (six-inch, Sh. 5). The earlier workings in the ravine, 500 yards west of the mountain road below North Barrule, consisted of sinkings and short levels on a vein striking N. 20° E., with a westerly dip. A dyke of olivine-dolerite (described on p. 136) is intercepted by the supposed lode at this point, but I have not been able to obtain definite information as to their relationship. A deep adit-level was afterwards started 200 yards lower down the valley, to cross-cut the lode; and was driven 69 fathoms, but is said only to have cut the 'flookan,' a subsidiary vein, and not the main lode. Sir W. W. Smyth refers to the workings in his report for 1866, describing the vein as a "soft lode on which adits are driving . . . . with small isolated stones of lead ore." No returns of ore were made.

In another branch of the same glen, 400 yards west of the above, at the place marked "Lead Mine" on the six-inch Ordnance map (Sh. 5), there is an old working regarding which no information is forthcoming; it appears to consist of a level driven south, but no lode is visible.

Glen Crammag.

An old adit may be seen in the east bank of this glen, 300 yards above its junction with the Sulby River (Sh. 7). It goes E. 20° N. on a dislocation at the margin of the "crush-conglomerate," the "lode" consisting of crushed slaty pyritous fault-stuff and quartz. This is probably the working mentioned by Smyth in his report for 1866 as being on a "very unpromising great dowk lode."

Glenfaba Trial.

Respecting the working on the south side of the Neb about 100 yards N. of Raggatt, Smyth reported in 1858, "a level has been driven a few fathoms from near where the road, at one mile south of Peel, crosses the river, but there is no lode at all."

Glen Meay or North Foxdale Mine.

A plan of metalliferous veins at 'Glen May,' dated 1826, is preserved in the Woods and Forests Office, showing two north and south "main veins," and three N.W.—S.E. "cross-veins" or "feeders,' with the note—"The whole of these veins, laders and feeders bear lead ore to the surface, and are in every way promising to be productive in that metal." The workings afterwards carried on, chiefly between 1857 and 1865, were situated 550 yards from the shore, or 150 yards higher up the glen than the position of the veins as shown on this plan which, however, may have been incorrect in scale.

In Sir W. W. Smyth's reports for 1858 and 1869 it is stated that small portions of ore were visible in the workings, but no appearance of a regular or strong vein. In 1861 we learn from the same source that drivings were being prosecuted "at 15 fathoms deep, in two lodes running pretty distinctly through clay slate and from 6 inches to 2½ feet in breadth, but unfortunately yielding no ore; traces of iron pyrites and carbonate of iron being all the metalliferous matter present." In 1865, "favourable stones of lead ore have been met with at various points, but not continuous enough to be of value." In 1866, a 14 fathom level had been driven a great many fathoms east to no purpose, as well as a cross-cut north; while "a short cross-cut south on the extreme west of the workings has laid open a very

[1] Information chiefly furnished by Mr. W. H. Rowe, to whom I am indebted for a copy of a mining plan of the locality.

promising appearance of lead ore, at the rate of several cwt. of ore to the fathom." In 1867, it is stated that in the last 3 fathoms of the shaft the vein had yielded stones of lead to make up 3 or 4 tons. In 1868, the workings are described as a 50-fathom inclined shaft, and a driving of 3 fathoms. In 1869, we learn that the 50-level had been driven 70 fathoms west and 30 fathoms east on an unkindly lode yielding nothing whatever; and his is the last mention of the mine in these reports.

Glen Rushen and Niarbyl (Isle of Man Antimony Mining Company).

In an old trial made about the middle of last century on the shores of Niarbyl Bay in search of the westward prolongation of the Foxdale lode, a small body of antimony ore (*antimonite*) was discovered. As it was currently believed that more of this ore might at that time have been obtained if it had been considered worth working, the ground was reopened in 1893-4 by an adit driven eastward into the cliff at Traie Vrish (Sh. 12), 400 yards S.E. of The Niarbyl, only to find that the ore-body had been merely a small pocket which had been entirely cut out in the previous workings.[1] Specimens of the ore may still be obtained from the old spoil heap at the foot of the cliff at this place. It is apparently the only occurrence of this mineral in the Island.

A renewed attempt was made under the same auspices to discover the Foxdale lode in Glen Rushen, west of Beckwith's Vein (p. 504), but without success.

Injebreck Mine.

Under this name a trial was made between 1872 and 1876 in the valley of the head-waters of the River Glass, 300 yards N.E. of Injebreck House, at the place marked *Lead Mine* on the six-inch Ordnance map (Sh. 10). Smyth described it in 1874 as consisting of a shaft 22 fathoms deep, with a bit of level east and a cross-cut south, revealing mere specks of ore of no value.

Kerroo-Mooar Mine.

This rather extensive mining trial was made between 1860 and 1870 in the steep bluff of slate at Kerroo Mooar, nearly a mile to the eastward of the village of Sulby. It consisted of three levels driven, one above the other, southward into the hillside on a somewhat uncertain 'lode' striking nearly due south with an easterly underlie. The lowest level was about 100 fathoms in length; the second 80 fathoms; and the highest 50 fathoms; the vertical distance between the first two being 16 fathoms, and, between the last two, 10 fathoms. In the two upper levels a little galena and blende, associated with barytes, was discovered, but not in marketable quantity. The lowest level for several fathoms from its entrance was in the boulder clay, which is banked thickly against the foot of the slope. The workings intercepted one of the olivine-dolerite dykes, and a shallow sinking on the dyke is said to have revealed; a little galena on the 'foot-wall' of the intrusion.[2] In an adjacent open quarry, as described on p. 59, one of the older 'greenstone' intrusions is worked for road-metal, and a thin dyke of olivine-dolerite, probably a 'flier' from the dyke found in the mine, is seen to traverse both the country-rock and the 'greenstone.'

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[1] Information supplied by Mr. Bawden, the manager of the recent workings.

[2] We are indebted to Mr. W. H. Rowe for most of this information.

Sir W. W. Smyth mentioned the operations in his report for 1866 as "a promising vein being driven on, but without farther discovery of ore;" and in 1867 noted that "a good deal of veinstone containing lead and zinc ore has been brought to the surface, but none yet dressed"

Kirk Michael Lead Mine.

References to preliminary operations in this locality are contained in Sir W. W. Smyth's reports[1] for the years 1858, 1859, 1860, and 1861, but the chief work on this small mine was effected at intervals between 1868 and 1883. Its total yield as given in "Mineral Statistics" between 1870 and 1883 was 222 tons of lead ore. It is situated in the deep glen which lies between Slieau Curn and Slieau Freoaghane, about 1½ miles S.E. of Kirk Michael, and furnishes the only known example of a metalliferous vein in the north-western district of the Island. The direction of the lode seems to have been about W. 40° N. E. 40° S., with a north-easterly underlie, but after being traced for 120 yards it was lost in both directions, apparently through cross-faulting, being intercepted by east to west slides, known respectively as "the Great Douk vein" on the S.E. and the "Cross lode" on the N.W. The mine was worked by three day-levels driven into the hill to intercept the lode, and by a shaft. Other trials were made on the steep slopes on both sides of the glen, but with no result.[2] In describing the workings on the productive part of the mine in his report for 1875, Smyth notes that in the No. 2 level, S. of the cross-cut, a shaft had been put down 6 fathoms, with drivings north and south from it, the lode 2 to 3 feet wide "consisting of two small strings of galena with killas between them, and yielding at most 8 or 10 cwt. of ore per fathom." We are informed that over £10,000 was expended on this property.

Laurel Bank and Wheal Michael.

In his report for 1863 Sir W. W. Smyth refers to a working of this name carried on by Mr. Ashe "in some singularly contorted 'country' in which were some irregular floors of quartz sparsely containing delicate stars of a rare nickel-mineral, 'Millerite,' but there was no lode at all." In his "List of Manx Minerals" (Isle of Man Nat. Hist. and Antiq. Soc., vol. i., p. 147) the same authority mentions the mineral as "delicate capillary crystal vein-stuff at a trial shaft at Rhenas, south of Kirk Michael." It is not easy to identify this locality; Laurel Bank is given on the 6-inch Ordnance map, Sh. 9, as the name of a house on the western side of the Neb Valley one mile below Glen Helen; Rhenas is two or three miles higher up the same valley just above Glen Helen. There are traces of a small mining trial between these places, 500 yards south-west of Lambfell Mooar, in the little gully which joins the Neb Valley just below Glen Helen; but Mr. Ashe's trials seem chiefly to have been carried on, under the title of the "WHEAL MICHAEL MINE," on the hill named Cronk ny Fedjag, about a mile north of Rhenas, where the traces of a shaft and other workings may still be seen. Either of these localities may be the place referred to by Smyth, but the former is the more probable. An old plan of the Wheal Michael sett in the possession of Mr. W. H. Rowe shows two supposed lodes; one coursing east-north-east, on which the shaft is sunk; and another, coursing north-north-east and intersecting the first, which was tested by a short level in Glion Cannell, 150 yards north of Shughlaigquiggin. Both lodes are said to have yielded samples of lead ore. An older working, apparently of greater extent but respecting which no information is forthcoming, occurs a little farther east, on the banks of the stream 350 yards north of Cronkbane Farm, in the vicinity of a mass of intrusive "greenstone" (p. 137); this is marked "*Lead Mine (Disused)*" on the six-inch map (Sh. 6).

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[1] MSS. in Woods and Forests Office.
[2] The above information has been furnished by Mr. W. H. Rowe.

Maughold Head Copper Mine.

This working, erroneously marked "*Lead Mine*" on the six-inch Ordnance map (Sh. 5), consists of an adit, stated to be 60 fathoms long, driven into the cliff on the south side of Gob ny Strona, the most easterly point of Maughold Head, on a dolomitic vein containing a little copper pyrites, striking in a west-north-westerly direction. Sir W. W. Smyth referred to it in his report for 1866 as "a lode 3 feet wide, promising in appearance, but in a place very difficult of access"; and in 1867 he mentioned that a shaft had been sunk for 10 fathoms at the base of the cliff, where the ore appeared to be cut out. The trial was abandoned without having produced any marketable ore. (Since this was written, work has been resumed here, the shaft deepened, and a level at 18 fms. driven towards low-water, where the lode is reported to widen out.)

Montpellier Mine.

This was a trial made about 1866 in the ravine of the western feeder of the Sulby River under Sharragh Bedn (Sh. 7) 600 yards N. of Croit. A line of disturbance and faulting traverses the slates in this glen in a W.N.W. direction, hading northward, which may have constituted the 'lode.' Some lumps of lead-ore are said to have been obtained, but nothing of permanent value; one of the levels is stated to have gone about 50 fathoms. Sir W. W. Smyth described it in his report for 1866 as "a level driven and shaft sinking with nothing to recommend it."

Mount Dalby Silver-Lead Mining Company, Ltd.

Under the auspices of this company some trials were made near Dalby about the year 1872 in the valley of the Lagg River, half a mile east of Barrane, but without attaining any useful result. Sir W. W. Smyth, in October 1872, after examining these workings, reported that "of the favourable appearances. . . . not a trace exists," and that the only facts were that the sett contained vein-like traces, in which no ore had yet been found, in the direction of the Foxdale lode. The statements which were made in the prospectus of this company must be read with astonishment by anyone knowing the ground.

Onchan (Douglas Bay) Mine.

This working, which appears in the list of Manx Mines in "Mineral Statistics" for 1891 and the succeeding years, consists of a sump and an adit in a direction of N. 10°—20° W., in the slate cliff on the northern side of Douglas Bay, 200 yards west of Derby Castle. From an account published in the "Transactions of the Manx Geological Society, Session 1891–92" (reprinted from "Mona's Herald" newspaper, 6th January, 1892), it appears that "a piece of almost pure plumbago was found upon the shore within a very short distance of the place," and the working seems to have proved the presence of that mineral in the lode. In the same account it is stated that "the adit so far shows a lode containing quartz, lead, baryta and oxide of iron, though as yet only in moderate quantities." A later newspaper report announced that ore had been found containing several pennyweights of gold per ton, but the discovery does not appear as yet to have assumed any economic importance.

Pen (Beinn) y Phot or Sulby River Mine.

The insignificant trial thus named consisted of a level and shaft (marked on the 6-inch map, Sh. 7) on the west bank of the headwaters of the Sulby River, one mile S.W. of the summit of Snaefell. Considerable sums must have been expended on the erection of a large wheel and other surface works, the ruins of which are still conspicuous. Sir W. W. Smyth refers to it in his report for 1866, as "on a north and south lode, dowky or with soft clay"; and in the following year mentions that it was started with fine plans, and then heart lost. In a later communication to the Woods and Forests Office (Sept., 1881), he remarks that no conclusive trial was ever made at this place.

The Ramsey or Northern Mine.

This trial, on which some thousands of pounds were expended, was made between 1866 and 1873, on a small north and south vein containing a little galena and blende, in the slate cliff at Gob Ago (Sh. 5) on the eastern side of Port e Myllin (*Vuyllin* of revised Ordnance map). The first workings consisted of an adit driven for about 50 fathoms southward on the lode; a shaft was afterwards sunk (26 fathoms?) and a driving under the sea northward commenced, where it was expected the vein would intersect the course of the broad belt of felsitic igneous rock exposed in the cliff 500 yards farther eastward (see p. 124).[1] No further discovery of ore was made however, and the total quantity produced was too small to be worth marketing. Another old level, a few fathoms in length, exists in the eastern corner of Port e Myllin 200 yards west of the above.

Sir W. W. Smyth makes brief mention of this trial in several of his reports.[2] In 1866 he notes there was "nothing more met with than pretty strings 1 to 3 inches wide with good galena"; in 1867 he refers to it as "a tempting vein of lead ore, but far too small to be important." In 1871, the shaft had been sunk 21 fathoms and was intended to go 5 fathoms deeper; in 1872, a cross-cut was being driven out; and in 1874, the mine was "idle."

NOTES ON OTHER VEIN-PRODUCTS.

Gold.

From the general character of the Manx Slates and some of its veins, it is not inherently improbable that a little gold should be found in the Isle of Man; but the evidence for its presence is, as yet, scarcely satisfactory. In 1867 D. Forbes in describing the occurrence of polytelite in the Foxdale Mine mentioned that the Foxdale granite is identical in composition with some auriferous granites, and that traces of gold were reported to have been found in the gullies and in quartz-veins contiguous to it.[3] Capt. J. Kitto, late of the Foxdale Mines, informed me that he also had heard that specimens of gold had been found, some time ago, in this district, but had not himself seen them.

Among Cumming's geological specimens preserved in King William's College at Castletown, are two water-worn fragments of slate showing specks of free gold, in the one specimen on a smooth cleavage face, and in the other in a crushed vein-streak. An almost illegible label on one of the specimens appears to read "Langness," and the rock is of the kind which occurs in that locality. The reported presence of gold in a vein mined on the northern side of Douglas Bay has been mentioned on p. 548[4].

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[1] From information and plan furnished by Mr. W. H. Rowe.

[2] MSS. in Woods and Forests Office.

[3] "Researches in British Mineralogy." Phil. Mag., 4th ser., vol. xxxiv., p. 354.

[4] A note of this supposed discovery appeared in "Nature" of Jan. 24th, 1895, vol. li., p. 299.

The metal is not included in Sir W. W. Smyth's published list of Manx Minerals.[1]

Since the above was written a small trial has been made near the Cluggid in Sulby Glen on a vein reported to contain gold; and another trial at Maughold. Both are however now suspended. (Aug., 1902).

Molybdenite.

This mineral occurs as a thin incrustation on joint-faces of the Dhoon Granite in the quarry on the west side of the high-road, half a mile north of Dhoon Glen, where, according to Smyth, it was mistaken for lead ore.[2] It has not been observed elsewhere in the Island.

Plumbago.

The presence of graphitic slate at two or three localities in the Manx Slate Series has been noted in a previous chapter (p. 94 and p. 134). No workable deposit of the mineral has yet been found in the Island. In Sir W. W. Smyth's "List of Manx Minerals" (op. cit., p. 143) graphite is recorded as occurring "impure in the Snaefell Lode 100 and 130-fathom levels"; and in some handbooks of Mineralogy (*e.g.*, that of Greg & Lettsom, 1858, p. 2), "Beary in the Isle of Man" is given as a locality for the mineral. Documents in the Woods and Forests Office throw light upon the last-mentioned reference. From these it appears that in 1852 leave was granted to the Rev. J. G. Cumming and Dr. T. Underwood to search for manganese and other minerals in the parish of German, east of the Neb and north of the Peel and Douglas highroad, and that "in the course of their searches they have discovered some plumbago, which they wish to have included in their licence," which was accordingly done. In February 1854, the resident Crown Agent reported that a day-level had been driven about 25 feet in this sett, with a side-cut to meet the opposite cheek of the vein; and that about 40 tons of raw stuff had been raised, but the samples were not sufficiently good in quality to command the attention of plumbago merchants and no sale had been effected; strings of copper had also been observed in the district. The site of this working appears to have been on the slope of Beary Mountain, but the exact locality has not been identified; Cumming no doubt refers to it in his "Guide to the Isle of Man" (1861, p. 27), where he states, "Plumbago has been discovered in Glen Helen."

The discovery of a piece of plumbago of good quality on the foreshore at Douglas, derived from a neighbouring lode, has already been mentioned (p. 548).

In connection with this subject the occurrence, under circumstances previously discussed, of a singular string of anthracite in the Laxey mines should not be forgotten (p. 520).

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[1] Op. cit., p. 146. [2] *Ibid.*

LIST OF SMALL MINING TRIALS NOT DESCRIBED IN THE FOREGOING PAGES.[1]

Sheet of 6 inch Ordnance Map.	Locality and Position.	Description of Working.
Sheet 4.	Hillside S. of Ballaugh, 400 yds. W. of *Corn Mill*[2]	Small shaft
	Glen S.W. of Sulby, in gully 400 yds. N.E. of Earykellue	Short trial along fault
	Glen S.E. of Sulby, in bank of stream 600 yds. S.S.E. of Ballamanaugh	Short adit going E. 15 N.
Sheet 5.	Steep slope 300 yds. S.E. of Glentramman East, marked *Lead Mine* on 6-inch map	Adit; stated to go 8 or 10 fathoms on an E.-W. "douk-lode"
	Near stream 700 yds. S.W. of Parkneakin	Small sinking on "douk-lode with spots of lead"
	Cliff 300 yds. W.N.W. of Port Lewaigue	Short adit
Sheet 7.	*Glen Shoggle*, 120 yds. S.E. of Nascoin	Adit into south bank of stream
	Stream 400 yds. E.S.E. of Stockfield	Adit into west bank (? part of *Wheal Michael* workings; see p. 547)
	W. slope of Sartfell, 900 yds. S.E. of Barrowgarroo Beg	Adit, marked "*Lead Mine*" on 6 inch map, but probably a slate-trial
	Head of *Glion Kiark*, S. of Slieau Freoaghane	Level in connection with slate-trial
Sheet 8.	Head of Glen Auldyn at slate-trials at upper fork of streams	Two levels (? for slate), marked on 6-inch map
	Head of Cornah Glen, between *North Laxey Mine* (p. 524) and *East Snaefell* trial (p. 526)	Adit in north bank marked on 6 inch map
	Cornah Glen, S. slope, 1,550 yds. W. of Corrany	Adit on hill-side marked on 6 inch map.
	Cornah Glen, S. slope, 1,100 yds. S.W. of Corrany	Adit near top of slope.
	Cornah Glen, in gully 150 yds. S. of Park Lewellyn	Short adit, E. 15 N.
	Cornah Glen, N. side of stream 200 yds. W. of Corrany	Adit 40 fathoms long, on a well-marked lode without ore
	Cornah Glen, S. slope, 250 yds. S.E. of Corrany	Small shaft; hematite-stained slate in spoil-heap
	E. bank of small stream, 250 yds. S.W. of Boileyvelt	Small shaft?; spoil-heap of hematite-stained slate

[1] This list represents the old trials noted on the working map during the Survey, respecting which no information was forthcoming. It does not profess to be exhaustive, as there have no doubt been many other trials of which there are now no distinct traces. It is intended to illustrate the extent of the exploratory work.

[2] Distances given as measured on the 6-inch map; place-names in italics will be found on the 6-inch map, but not on the 1-inch.

Sheet of 6 inch Ordnance Map.	Locality and Position.	Description of Working.
Sheet 8 (*cont.*).	Ballasaig, 200 yds. W.S.W. of *Smithy*, and again 50 yds. N. of *Smithy*	Small shafts (trials for hematite)
	Ballagorra, 400 yds. W.S.W. of Chapel at cross-roads	Small shaft
	Ballagorra, 350 yds. N. of Chapel at cross-roads	Adit, "50 fathoms long" (see p. 541)
	Ballagorra, 250 yds. S.E. of Chapel at cross-roads	Small shaft (obliterated)
	Cliff 500 yards S.W. of Gob ny Garvain	Short adit N. 15. W.; marked *Iron Mine* on 6-inch map (see p. 127)
	Cliff at Bulgham Bay, 300 yards S. of Dhoon Mine adit (see p. 528)	Short adit
	Dhoon, in small ravines east of high road.	Several short adits in granite, for 'polishing powder' (see p. 556)
	Head of *Glion Ruy* (Glen Agneash)	Adit (and shaft ?) marked *Lead Mine* on 6 inch map
	Glen Agneash	Several workings in search of N. prolongation of Laxey lode (see p. 523)
	Laxey Glen, east bank of *Stroan ny Fasnee*.	Adit N. 25 E.
	Laxey Glen, west bank, 150 yards above *Mill*.	Adit, starting in till
	Laxey Glen, lower part.	Several workings in search of S. prolongation of Laxey lode (see p. 521)
Sheet 9.	Cliff S. side of White Strand.	Adit along small fault in Peel Sandstone
	Cass Stroan, 150 yards inland.	Shaft in Peel Sandstone (see p. 274)
	N. corner of field 350 yards E.N.E. of Lambfell Mooar.	Spoil heap, small sinking ?
	Cliff 300 yards S. of Glen Meay.	Adit
	Gordon, 500 yards W. of high road.	Adit (and sinking ?) marked *Lead Mine* on 6 inch map
	Ballacoshnahan, near W. margin of valley 700 yards S. of *Ash Lodge*.	? small sinking
	N. slope of Slieau Whuallian, 300 yds. S.W. of Glen Aspet	Small shaft
	N. slope of Slieau Whuallian, 300 yds. S.E. of Glen Aspet	Adit in connection with slate-trial
	Lower part of Foxdale, west bank, 550 yds. E. of Slieau Whuallian Farm	Adit S.W. through till into slate
	Lower part of Foxdale, in small gully, 400 yds. E.S.E. of Slieau Whuallian Farm	Adit: marked *Lead Mine* on 6-inch map.
	West side of road at Ballaoates	Adit
	Slope 800 yds. N.N.E. of Ballagaraghan	Obscure spoil-heap ? : graphite-trial ? (see p. 550)

Sheet of 6 inch Ordnance Map.	Locality and Position.	Description of Working.
Sheet 10.	S. side of glen N. of Carn Gerjoil, in N.W. corner of field 200 yds. N. of mountain road	Obscure spoil-heap, probably adit
	Hillside S. of Greeba, 300 yds. W. of *Creg y Whualliam*	Spoil-heap : shaft or adit
	N. side of *Cooillingill*, 500 yds. S. of *Creg y Whualliam*	Shaft (see p. 518)
Sheet 11.	N. branch of Glen Roy, 350 yds. E. of Ballaquine	Adit E. 30 N. into bank of stream
	Cliff, 750 yds. S. of Laxey Harbour	Adit
	Cliff, 1,150 yds. S. of Laxey Harbour	Adit N. 10—20 W.
	Cliff, Garwick, on S. side of Glen	Adit, now called a cave
	Cliff, Garwick, 150 yds. S.E. of above	Adit, now called a cave
	Glen Gawne, Garwick, S. bank 350 yds. W. of shore	Adit and cross cut
	Glen Gawne, Garwick, S. bank 100 yds. W. of tram-line bridge	Adit S. 30 W.
Sheet 12.	Head of middle fork of glen east of Ballelby, near Dalby	Small trial (adit ?)
	Cliff on S. side of *Gob ny Gameren*	Small trials
	Glionn Maarliagh, 600 yds. E.N.E. of Ballavell, Glen Rushen.	Short adit
	Glen Rushen, W. side, in gullies 300 yds. N. of Glionn ny brack	Short adits (see p. 546 for other workings)
	Glen Rushen, in banks N. of high-road bridge	Short adits
	500 yds. N.W. of South Barrule Quarries	Adit in connection with slate-trial
	Beeal-feayn-ny-Geay, S.W. side of Cronk ny Arrey Lhaa	Adits along faults
	Summit of Cronk Fedjag	Adits in connection with slate-trials
	Gully 250 yds. N.E. of Garey Mooar	Adit along decomposed olivine-dolerite dyke (see p. 556)
	Mooney Mooar, in *Glion Cam*, 200 and 250 yds. below high road	Two adits, one in each bank, respectively N. 30 E. and W. 35 S.
	S.W. of Granite Mtn., 300 yds. E. of head of *Struan Barrule*	Spoil heaps of slate ; ? small sinking
Sheet 13.	Corner of field 300 yds. S. of Ellerslie farm	Shaft
	Hillside 500 yds. S.S.E. of Ballingan	Adit
	West bank of Santon River, on S. side of road 350 yds. N. of Ballacorris	Small shaft

Sheet of 6 inch Ordnance Map.	Locality and Position.	Description of Working.
Sheet 13 (*cont.*).	East bank of stream at *Ballalough*, 200 yards S.E. of highroad bridge east of Richmond hill	Small excavation : trial ?
	Cliff at Fiddler's Green 700 yards S.W. of Douglas Head	Adit (see p. 544)
	Cliff at *Slack Indigo*, 600 yards S. W. of last	Adit, obliterated ; marked *Lead Mine* on 6 inch map
Sheet 14.	Cliff on E. side of Onchan Harbour	Short adit ; marked *Lead Mine* on 6 inch map
	Cliff on E. side of *Port Jack*, 600 yards S.W. of last	Adit, obliterated ; marked *Lead Mine* on 6 inch map
Sheet 15.	Cliff in *Ghaw Dhoo* on N. side of Bradda Hill	Adit.
	Cliff 150 yards W. of last	Adit ? near olivine-dolerite dyke (see p. 171)
	Hillside 300 yards W. of "West Bradda trial" (see p. 537).	Small trial
Sheet 16.	Head of Colby River 300 yards W.S.W. of Ballacannell	Adit in E. bank
	West bank of Silverburn, 150 yards S. of *Cregg Mill*	Adit (see p. 197)
Sheet 17.	Cliff at *Traie ny Gill*, 300 yds. W. of Port Greenaugh	Adit
Sheet 18.	Cliff in recess W. of Baroo Ned	Adit (see p. 532)
	Cliff at *Rheboeg*, Bay Stacka	Adits, marked *Mine* on 6 inch map
Sheet 19.	Cliff on E. side of Langness, N. of *Tarrastack Rock*	Two short adits, 40 yds. apart ; (for trials on W. side of Langness see p. 538.)

CHAPTER XIII.

NON-METALLIC PRODUCTS.

Umber and Ochre.

The production of these colouring earths in small quantity in the Isle of Man dates back at least from the beginning of the nineteenth century. Macculloch, in 1819, mentions that "yellow ochre has been found in sufficient quantity in some of the mineral veins, to have become at one time a matter of export," but that the mines had long since ceased to be wrought.[1] The mines referred to were probably Bradda and Ballacorkish, as Smyth notes the occurrence of the substance in these lodes.[2] In the documents relating to the transfer of the mineral rights of the Island to the Crown in 1827-8, Mallew is the only locality given for Yellow Ochre; at the same time a report of the Crown Agent states that "of this oaker there is great abundance in the Island of excellent quality" but that the lessee had failed to make it pay. From the somewhat incomplete returns given in "Mineral Statistics," as shown in the Tables at pp. 496-8, the production since 1858 seems usually to have ranged between 100 and 200 tons per annum.

The substance has been obtained from two distinct sources. One variety, prepared in the village of Ballasalla, is derived from the decomposed black flaggy Carboniferous Limestone (Castletown or Lower Limestone), which is often weathered at the surface and along irregular pipes and veins into brown earth, as may be seen in the cliffs north of Ronaldsway and in the large quarries west of Ballasalla. This change is especially noticeable where the limestone is dolomitised.[3] During our survey of the district the principal supply was being obtained from shallow pits in the little outlier of Carboniferous rocks east of the fault near Athol Bridge, one mile N.N.W. of Ballasalla, at the place

[1] "Western Isles," vol. ii., p. 579.

[2] "List of Manx Minerals." Isle of Man Nat. Hist. and Antiq. Soc., vol. i., p. 145.

[3] Similar decomposition of dolomitic limestone into umber in Devonshire has been described by R. J. Frecheville in a paper on "The Umber Deposits at Ashburton." Trans. Geol. Soc. Cornwall, vol. x. (1884), p. 217.

marked U on the geological map. The 6-inch Ordnance map (Sh. 16) shows an "*umber pit*" near the boundary of the limestone at Billown, 600 yards west of the Ballahot quarries, but this is no longer worked and the section is obliterated. In preparing the substance, the raw material is pounded, washed and run into settling tanks in which the umber remains as a fine paste and is then dried and ground.

The other source of the material is from decomposed olivine-dolerite dykes and from rotten ferriferous slate adjoining veins, and sometimes apparently from the ferruginous portion of the vein-stuff itself. Near the surface, both the dyke and the country-rock, as well as the vein, are occasionally perished to a brown earth which furnishes the umber. The chief supply of this variety has of late years been drawn from the day-level in the cliff on the southern side of Maughold Head, mentioned on p. 126, which follows the course of an olivine-dolerite dyke that intersects the Drynane hematite-vein. This is known as the Baldroma Mine, and was last in operation between 1887 and 1893. In the upper part of the Silverburn basin, in a gully 250 yards S.W. of Garey Mooar, there is a similarly decomposed dolerite dyke, along which a short level has been driven, but whether for umber or in search of other ores has not been ascertained.

Rotten-Stone.

At the umber works at Ballasalla a small quantity of 'rotten-stone,' for use as a polishing agent, has also been prepared, the raw material being a fine argillaceous silt, which has accumulated, apparently by rain-wash, in a boggy depression on the moorland between South Barrule and Cronk Fedjag. Though used for the same purpose, this is, of course, an entirely different substance from the 'dun-earth' described below.

Fuller's Earth.

Information regarding the fine glacial clay which has been dug for this purpose in Glen Wyllin near Kirk Michael will be found in Chap. XI., pp. 428 and 447.

'Dun Earth' or 'Asbestos.'

The 'Asbestos' (fibrous tourmaline) which occurs in veins in the Dhoon Granite under conditions described in a previous chapter (p. 143) was mined for a time to a small extent, as a polishing powder, early in the past century. The material was mentioned by Woods, in 1811, as being in local use;[1] and Henslow, in 1821, described it as follows:—"Fibrous Actinolite occurs in a decomposing state near the Dun, in two veins, each about six inches broad, traversing the decomposed portion of the

[1] "An Account, etc., of the Isle of Man," p. 17.

granite and gneiss. It is accompanied by quartz, which it penetrates and frequently colours. It may be taken from the vein in fibrous bundles of three or four inches in length, but it is in general so much decomposed as to have assumed an earthy form. . . . . On pressing the fibres between the fingers they crumble to a harsh powder capable of taking away the polish from glass, and consequently very unfit to be used in cleaning plate, a purpose to which it has been applied. I found a single specimen in which the fibres were flexible. Specific gravity = 3·03."[1]

A plan of the workings, dated 1826, is preserved at the Woods and Forests Office, showing three short levels, one on the northern and two on the southern side of the stream, with a note in reference to the northern level that "the mineral substance called Asbestos or polishing powder disappears at the end of the workings." A lease had been granted by the Duke of Athol for the mining of this substance, but the Crown Agent in reporting on it in 1827–8 remarks, "Mr. S——— wrought this for a short period and paid 15 guin^s of Lordship, but he abandoned the work some years ago, but whether from its being unprofitable or for other reason, I know not."[2]

Vein-Quartz.

The broad vein of this substance quarried on the N.E. side of the Foxdale Granite has been described on p. 166. It has been exported on a small scale; and is in favour locally for ornamental rock-work. A smaller quarry has been opened in a similar vein on the north slope of Kerrowgarroo, ½ mile E. of Kennaa, near St. Johns (p. 164). The material occurs in strings and lenticular masses in every part of the Manx Slates, especially in the Barrule Slates (p. 320), but is generally more or less entangled with the country-rock and intermixed with small quantities of mica, chlorite, pyrites, etc.

Coal Trials.

The search for coal in the Island has been long and obstinate, and as yet fruitless. The earlier trials were foredoomed to failure, being for the most part ignorantly carried on in rocks older than the Coal-measures; while the later researches in the north, beneath the drift-covered plain, where alone some possibility of success existed, have, up to the present time, failed in their main object; though they have revealed a small salt-field which may prove of economic importance.

As previously noted (p. 481), we learn that, as far back as 1669, the ruling Lord of Man (Charles, 8th Earl of Derby) "being by good reasons persuaded that there is plenty of coales" in the

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[1] Trans. Geol. Soc., vol. v., p. 498.
[2] MSS. Athol papers in Woods and Forests Office.

Island, ordered a search to be instituted; and Bishop Wilson, early in the 18th century, referred to several unsuccessful attempts having been made to find them.

Dr. Berger discussed the subject at some length in his memoir published in 1814, and gives reference to some older records in Curwen's "Agricultural Report" (Workington, 1810). He says:—"While I was in the Isle (June, 1811), two or three spots in the north-western part were particularly pointed out to me as places where coals did *actually* appear, or were *cropping out.* But when the matter was strictly enquired, the reports turned out unfounded. . . . The only serious attempt, I believe, to find coals in the Isle was made at Derbyhaven [in Carboniferous Limestone] many years ago by a speculator from Cumberland. After having gone to a certain depth, not finding traces of them, he gave up the search as fruitless."[1] Macculloch, in 1819, mentions, but discredits, the report that coal had been found in the red sandstone near Peel; and he adds that since his visit to the Island he had received fragments of coal said "to have been found under the limestone or in the conglomerate of Derbyhaven where some expensive borings for that purpose were formerly made."[2]

It was no doubt the same supposed discovery which was referred to in the following terms in the "Manx Mercury" of 26th Nov., 1793[3]:—"We feel unspeakable pleasure in being able to announce to our readers that a stratum or bed of coal has been discovered near Derbyhaven in this Island, at a depth of about 60 feet from the surface of the earth." This statement was of course unfounded, but is still remembered and repeated in the locality.

From documents preserved in the Office of Woods and Forests it appears that the search was still fitfully continued during the first half of the present century. The resident Crown Agent, in reporting on the matter in 1836, says, "Many trials have been made and considerable sums expended, but always without success," and refers also to his "knowledge of many unsuccessful trials made by the late Duke [of Athol] to find coal." About this time a licence to search for coal was granted to E. Forbes, of Douglas (father of Professor Ed. Forbes)[4] and others; and it is mentioned that trials had previously from time to time been permitted on the Waste Lands (of The Ayre ?), but without result. In a "report of the Directors of the Isle of Man Coal Company," dated 22nd February, 1840 (quoted in the prospectus of a later company,) the following details of a boring at Ballasalla

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[1] Trans. Geol. Soc., vol. ii., p. 56.

[2] "Western Isles," vol. ii., p. 574.

[3] Quoted in the Prospectus of the "Isle of Man Coal Co., Ltd." (about the year 1870).

[4] In an article on Manx Geology contributed by Prof. E. Forbes to Quiggin's "Guide to the Isle of Man," it is stated that in several places, both in the limestone and slate, specimens of anthracite or blind-coal occur, and that these had been mistaken for bituminous coal and led to useless researches (p. 56, 4th ed., 1852).

are given:—"The measures gone through at Ballasalla are, first, 7 yards white sandstone; secondly, 24 yards of layers of limestone, varied from 2 to 7 feet thick, with intermediate layers of soft blue clay; thirdly, 23 yards of old red sandstone in layers from 3 to 12 yards in thickness, with three layers of clay; fourthly, 5 yards ferruginous bands." It is stated that these explorations "abandoned for a time for the purpose of searching at the north of the Island, were intended to be resumed, but in consequence of the Company breaking and losing the boring rods, they declined to further prosecute the work." The top "sandstone" is probably drift, the lower beds being, of course, the Carboniferous Limestone and its Basement Conglomerate (see p. 196). The northern boring alluded to was probably that made at the Craig near St. Jude's Church in 1839, described by Cumming in a passage quoted on p. 280. A document in the Woods and Forests Office, dated 18th February, 1843, mentions that upwards of £1,000 had been spent in this search, which had been suspended two years previously.

Another company, with the title of "The Isle of Man Coal Company, Limited," the prospectus of which has been quoted above, was organised about thirty years ago to make further search for anthracite coal in the neighbourhood of Ballasalla and Derbyhaven, but no information is forthcoming as to its actual operations. In 1873 renewed explorations were also set afoot in the Peel district. All that could be learnt respecting these and the earlier trials in the same neighbourhood has already been stated (Chap. VI, pp. 278–9). The systematic and thorough investigation in the extreme north of the Island commenced by Messrs. Craine Bros. of Liverpool in 1891, and still in progress, has been fully discussed in a preceding chapter (Chap. VII., pp. 280–95).

Salt.

Steps are being taken to make economic use of the salt deposits discovered in Triassic Marls of the Point of Ayre borings, described on p. 289. It is proposed to pump the brine and convey it in pipes to Ramsey for treatment. In "Mineral Statistics" for 1895, p. 101, a return of 10 tons from this source is recorded the first in the annals of the Island.

Peat.

Information regarding the distribution of peat and the places where it has been dug in the Island has been given in a foregoing chapter (pp. 415–6).

Roofing Slate.

Reference has previously been made (Chap. III., p. 50), to the many costly attempts to find roofing slate in the Island and to the uniform ill-success which has attended them. The unsuitable character of the cleavage and flow-structures (p. 73), as well as the prevalence of shear-planes and quartz-veins, and their combined detrimental effect upon the hardness and compactness of the slate-rocks sufficiently explain the failure of these attempts, and in most cases ought to have been a deterrent before the loss was incurred. These trials have been chiefly made in the Barrule Slates, but a few have taken place in slaty bands in the Niarbyl and Lonan Flags. In the aggregate probably not far short of £100,000 has been expended in this manner in the Island with scarcely any return.

Bishop Wilson in the middle of the 18th century referred to blue thin light slate as a matter of export[1]; and Berger, in 1814, mentioned roofing slate as being obtained at Peel Hill and Ballagawne.[2] The oldest of the systematic trials is probably that at the northern end of the ridge of South Barrule, which is included in the schedule of the property transferred from the Duke of Athol to the Crown in 1827-8. At that time the slate-quarries of the Island were under lease to Mr. Knott; but from the report of the Crown Agent it appears that the tenant had met with opposition from the natives "who at their own hand and without the authority or licence of the lord had been accustomed to work the same."[3] This custom is referred to by Cumming, who states:—"By the insular laws every person standing in need of limestone or building stone may enter on his neighbour's land and dig and carry away what is requisite for his own use, paying the occupier a reasonable satisfaction, which appears to be interpreted merely surface damage."[4]

Between 1860 and 1870 a very large amount of development work was done upon the South Barrule quarry; and about the same period more or less extensive openings were made, among other places, at the north side of Maughold Head near Port e Myllin (p. 124); at the head of Ballure Glen, south of Ramsey (p. 136); at several spots in Glen Auldyn; in Sulby Glen near the mouth of the Block Eary tributary (p. 133); in Glion Kiark on the northern slope of Sartfell (p. 138); in the valley of the Neb near the mouth of Glen Helen and lower down opposite Ballig (p. 157); on the coastward side of the hill south of Peel (p. 147); on the northern slope of Slieau Whuallian near Glenaspet; on the western side of Foxdale near Ballageay (p. 162); in the West Baldwin valley west of Awhallan (p. 157); on the western side of Greeba Mountain; on the east coast, at Bulgham Bay and a few other places; in Glen Rushen above Glen Meay (p. 163); and on Cronk Fedjag (p. 164). Numerous other localities where work was done on a smaller scale are mentioned among the topographical details in Chap. IV. The workings were mostly open quarries, but in a few cases shafts were sunk and galleries driven. Some produced a small quantity of slates, of inferior

[1] "History of the Isle of Man" (Cruttwell's ed. of 1786), p. 343.
[2] Trans. Geol. Soc, vol. ii., p. 38.
[3] MSS. in Woods and Forests Office.
[4] "Isle of Man," p. 311.

quality and in no instance good enough to compete with Welsh slates; the best seem to have been obtained from a narrow slaty band in the Niarbyl Flags south of Peel (see p. 147). For many years all these trials were abandoned, but work was resumed recently for a short time at the South Barrule quarry.

Sir W. W. Smyth's official reports contain many references to these quarries during the years of their activity, and as some of the workings are now filled with water or otherwise inaccessible, a few notes from this source may prove useful. In 1862, after describing several of the quarries, he remarks that he had seen no slate as yet opened in the Island good enough for exportation. In 1863, he notes that 120 men were at work in Glen Rushen on rock of a lamentably poor character; that South Barrule had some rather better slate; and that at Baldwin, where twenty men were employed, there was no rock at all like slate. In 1864, at South Barrule, with forty-five men, a fair quantity of material had been raised, and met with a ready local sale but was not good enough for an export trade. In 1865, the most effective trial was being made at Ballamoar [near St. Johns] by sinking a shaft; and in the following year it is noted that at this place a tunnel had been driven a long way into the hill, finding throughout the same even-splitting slate, too soft to be applicable; in the same year, workings at Peel, Sartfell, Sulby Glen, Glen Auldyn and Maughold are also mentioned. In 1867, Smyth remarks that speculation had greatly cooled; that at Maughold some slate had been got, but with too much waste; at Glen Auldyn the lower gallery might do for local consumption; and at South Barrule it was too clear that the middle part of the quarry was too bad to touch, and the north and south ends, which were better, must be worked into the mountain independently, and some good piles of second-class slate had been got from the north end. In the following year we read :—"I regret to record the almost total collapse of this branch of industry, buoyed up as it has been chiefly by ignorant hopes on one side and false representations on the other." Two or three quarries however were still carried on, including that of Rhenass (Neb valley), the rock of which is described in subsequent reports as coarse and full of quartz, fit only for rough local purposes; and that in the Sulby valley, regarding which it is noted in 1871 that better stone had been found in a cut 8 yards below the chief floor, "but there is much spar all through the quarry still, and the cleavage is so imperfect that the product would certainly not be saleable in England or Wales"; 95 men were employed in this quarry in 1873, but it seems to have been abandoned two years later. The report for 1876 describes a spirited trial near Peel, where twenty men had been at work on a vein, only 32 feet wide, narrowing inshore and with a high cliff above, which rendered difficult any system of economic extraction; "several cargoes amounting to perhaps 100,000 slates have been sent away," but the enterprise was to be abandoned. In 1877, two or three men were at work at South Barrule only, and in 1880 no work was being done, "not even on South Barrule."

Building Stone.

Quarry-stone is the common building-material in the Island, and is usually obtained from whatever source is nearest, whether Manx Slate Series, Peel Sandstone, or Carboniferous Limestone, while in the drift-plain of the north glacial boulders are largely used.[1]

[1] For special purposes, and for the more elaborate buildings, stone is occasionally imported from the mainland: Wood's notes (op. cit., p. 22) that the old Douglas Pier was built of stone from Runcorn, and Mona Castle of sandstone from Arran.

Manx Slate Series.

From the large area which they occupy, the Manx Slates furnish by far the greater proportion of the ordinary building stone, but the quality is inferior. It was adequately described long ago by Bishop Wilson as a "broken ragstone sometimes rising in coarse uneven flags, or in irregular lumps," which "an English mason would not know how to handle, or would call their walls, as one merrily did, 'a causey reared up upon an edge.'"[1] The material cannot be dressed, except very roughly, and is quarried in irregular slabs along whatever happens to be the dominant fracture-plane,—usually the bedding where the rock is somewhat arenaceous, and the shear-cleavage planes where it is argillaceous. The stone is best where the two structures are approximately parallel, but even then there is usually a cross-cleavage or close-jointing oblique to the dominant structure, which causes irregular acutely-angled edges to the blocks. All varieties of the slate-series are used, even including the crush-conglomerate (near Ramsey, p. 66), but the best stone is obtained from the Lonan and Niarbyl Flags and from some of the laminated passage-beds, while the quartz-veined grits are least in favour and are generally set aside for road-metal. In the north-western corner of the massif, north of Glen Wyllin and west of Glen Dhoo, and in a few other more limited tracts, the rock breaks up into faggot-like pieces along the intersecting structural planes (p. 131) and is of little use. In most buildings of rough slate, brick or dressed stone is employed at the angles and around doorways, windows, etc. On St. Michael's Island, Langness, the well-preserved walls of a fort built in 1650 contain many blocks of a schistose greenstone dyke which crops out in the vicinity (p. 181); and this stone, in spite of the exposed situation, has withstood the weather remarkably well—even better than the accompanying slate, which is itself very enduring.

A variety of the slate-rock which was formerly quarried, as described at p. 174, both on the crest and at the foot of Spanish Head was especially valued for its quality of raising in very tough and strong beams, somewhat flexible, and up to 15 or 16 feet in length, which were used for lintels, gate-posts, foot-bridges (p. 132), etc., and in Castle Rushen for flooring (p. 174). As previously mentioned, Macculloch states that a beam of this material 15 feet long and 2 inches thick was forced 5 inches out of the straight line before it broke. The top quarry seems to have been in working as late as 1858 (see "Mineral Statistics" for 1858, pt. ii., p. 269). The slate is of the banded argillaceous type, and its peculiar quality seems to have arisen from the compression of the rock in the trough of a fold, with the resultant intersection of flattish bedding by steeply inclined shear-cleavage. Under similar circumstances, in a quarry on the steep slope between Ballaugh and Gob y Volley, beams of the same kind of

[1] Bishop T. Wilson's "Description of the Isle of Man (Camden's Britannia ed., 1772), p. 392.

stone up to 24 feet in length have been raised, as described on p. 132; and probably these conditions might be likewise found in other places more accessible than Spanish Head. Though not at present worked, the material seems well fitted for various economic uses if it could be got at a reasonable cost.[1]

The building-stone quarries in the Slate Series are usually small, being opened as occasion requires, near the place where the material is needed. At Douglas, however, there are large quarries (in the Lonan Flags) on the southern side of the harbour and near the northern extremity of the Bay (p. 153); and openings in the hill-side south of Ramsey have also attained a considerable size. From the quarries working under the Quarries Act and giving returns to the Home Office, the output for 1897 (Mineral Statistics, p. 140) is stated to have been 17,560 tons of the value of £1,056; in 1898 (*ibid.*, p. 248), 21,508 tons, value £1,282; in 1899 (*ibid.*, p. 256), 19,005 tons, value £1,057; and in 1900, 13,524 tons, value £754.

Peel Sandstone.

This red sandstone, being the only 'freestone' available in the Island, has been extensively quarried at Creg Malin and Ballaquane, north of Peel. The characters of the formation have been fully described in Chapter VI., p. 263. Only a small part furnishes building stone, the thin and irregular bedding and the shaly and conglomeratic intercalations being detrimental in the greater portion. The stone is only moderately durable, as may be seen from the condition of part of the ruins at Peel Castle on St. Patrick's Island. The output for 1897 ("Mineral Statistics," p. 140) is given as 2,800 tons of the value of £166; for 1898, 1,240 tons, value £76; for 1899, 1,827 tons, value £112; and for 1900, 1,218 tons, value £101.

Carboniferous Limestone.

Besides affording the chief source of lime for the whole Island and being to some extent used for road-mending, the dark grey flaggy Lower or Castletown Limestone of the southern basin supplies the local building stone, both dressed and in the rough. For the last-mentioned purpose, when carefully selected it is structurally well adapted, though somewhat dingy in colour; the excellent state of preservation of Castle Rushen at Castletown bears testimony to the durable quality of this stone. The principal quarries at present working are those at Ballahot and Billown, three-quarters of a mile W. of Ballasalla (p. 206), and that near Scarlet on the W. side of Castletown Bay (p. 203). The output given in "Mineral Statistics" for 1898 (p. 230) i

[1] Berger (op. cit., p. 37) and Macculloch (op. cit., p. 532) also mention among the economic products of the Island a "hone slate" occurring "at a place called Montpellier." The latter author describes the stone as "of a whitish colour and soft texture better adapted for the polishing of metallic plates than the uses of the cutler. It has not been exported." This stone is no longer in use, and I have failed to identify the locality referred to.

12,372 tons, value £2,813; for 1899 (*ibid.*, p. 238), 9,272 tons, value £881; and for 1900, 9,315 tons, value £895.

The so-called 'black marble' of Poolvash was obtained from the harder courses in the black flaggy and shaly "Posidonomya Beds" on the eastern shore of Poyll Vaaish, as described on p. 224, but is not at present worked. The best stone seems to have been found immediately underlying the volcanic ash, where the rock has been indurated, probably by a slight over-thrust of the Volcanic Series (p. 224). Among other uses, it was wrought into chimney-pieces, tombstones and steps. Being too soft to take a natural polish, it was covered with a kind of black varnish, and in this way objects wrought out of it were "made to look not much inferior to the best Derbyshire black marble."[1] The tombstones made from it show rapid weathering. The "steps of St. Paul's Cathedral in London," so often mentioned in Manx topographical literature as having been supplied from this locality, seem to be no longer in existence (p. 220). The total extent of the 'black marble' quarrying has not been great.

Granite.

In the district S. and S.W. of the Foxdale Granite, where glacially transported boulders of this rock are numerous, they have been largely used in building, but have shown themselves subject to very unequal weathering. A quarry was opened some years ago on the northern slope of the granite outcrop, but was not worked to any great extent; the operations have however been recently resumed. The rock is massive and not too hard, but is somewhat liable to crumble after exposure. The granite was formerly raised in long beams and shaped into rollers for agricultural purposes, and it is worth mentioning that fragments of these broken rollers may readily be mistaken for boulders in parts of the island when there are no true boulders of this rock.

The Dhoon Granite, being much harder and closer in texture, has been quarried for road-mending and for making paving setts; the latter industry was revived recently on an extensive scale for a short time, but has now again flagged. The following note respecting the quality of the granite is quoted from the Journal of the Isle of Man Nat. Hist. and Antiq. Soc. for 1898 (Yn Lioar Manninagh, vol. iii., pt. x., p. 488). "The granite of the Dhoon has been tested for road setts and other purposes. The results under compression, such as percussion and attrition tests, show that it is a most excellent stone for all road purposes, and most durable as a building stone. If basalt average 6 or 7·2, Dhoon is 7·3: Aberdeen granite . . . . showing . . much . . below Dhoon."

The Oatland Granitite is at present used only for road material, for which purpose it is extensively quarried.

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[1] Cumming, "Isle of Man," p. 132.

Boulders.

In the northern drift-plain the absence of solid rock has led to the extensive use of glacial boulders both for road-mending and building. For the latter purpose the chief rock is the abundant Criffel Granite, the larger blocks of which are blasted into pieces and trimmed into shape; a good example of its use may be seen in Bride Church. Besides those found inland, large numbers of boulders are obtained from the shore, where they accumulate from the waste of the cliffs. Some have done duty over and over again in successive buildings, and the walls of old cottages in this tract are often interesting to the glacialist from the medley which they exhibit; but there is a striking rarity of limestone, this rock having been set aside for burning into lime.

In parts of the Island where the drift contains only ocal blocks these are sometimes also put to economic use.

Road Material.

Though subject to a brisk stream of carriage and waggonette traffic in the summer-time, the Manx high-roads are not often called on to bear heavy crushing loads, the vehicles used in agriculture being chiefly one- or two-horse carts and not heavy waggons. Consequently good results are obtained from stone of a quality unsuitable for more ponderous traffic, and a supply is usually got without much difficulty from a local source. Among the rocks thus laid under contribution are the quartz-veined grits and other hard beds of the Manx Slate Series, the Carboniferous Limestone, the Dhoon Granite and the Oatland Granitite. But the toughest and best material is furnished by some of the dykes, especially those of the 'newer greenstone' type (p. 297), intrusive into the Manx Slates: the only drawback being that these are usually narrow and discontinuous, and sometimes spoilt by shearing. These dykes, locally known as 'pot-metal,' have been quarried on a small scale here and there all over the slate area (for details see Chap. IV.); and at Poortown, 1½ miles east of Peel, a coarsely porphyritic boss of diabase is extensively worked (see p. 156). As a general rule the dykes lettered D and B^D on the map are, where thick enough, suitable for road-metal unless deeply decomposed; while those lettered B^G are usually too much altered by shearing to afford durable material

At Crosby a broad dyke of microgranite of the Foxdale type furnishes much road-material of fair quality (p. 168). Accessible exposures of this kind of dyke-rock also occur in the West Baldwin valley (p. 158); at the side of the road between Foxdale and Castletown (p. 167); and at other places shown on the map; but have not yet been tested. These elvans, like the older 'greenstones,' are, however, sometimes spoilt by the platy structure developed by earth-movement.

The dykes associated with the Dhoon Granite (pp. 144–6) have not been quarried in the interior, as their chief outcrops are rather inaccessible, but would probably supply material as good or better than the Foxdale elvans. The use of the granite itself for paving setts has already been mentioned.

Another dyke-rock which though not hitherto tested would probably yield tough and durable stone, is the mica-diorite of Port Groudle (p. 152): this could be conveniently excavated at its outcrop on the north side of Banks Howe; it occurs in a district where there is a comparative dearth of suitable stone.

The olivine-dolerites even where not too small are usually too much decomposed to be serviceable.

Boulders and gravel from the beach are made use of in many places near the coast, especially in the north of the Island where drift-material of this kind affords the only local supply.

Lime.

At present lime is prepared only in the Carboniferous Limestone tract of the south of the Island; but it was formerly burnt locally from a cornstone band in the Peel Sandstone near The Stack (p. 275); and at many places, especially in the north, from glacially-transported limestone boulders collected on the shore, the ruins of old kilns which one finds in unlikely places having generally been thus supplied. Berger, who quotes statistics showing that 84,992 barrels of lime had been sold from kilns in the south-eastern part of the island between the years 1807 and 1811, mentions that the northern farmers preferred the lime from the boulders to that from the southern limestone for manuring the land. The Manx Slates are essentially non-calcareous, the only portion possessing more than a mere trace of lime being certain fine-grained bands in the Niarbyl Flags, which contain up to 4·4 per cent. (p. 36), and a few sparingly calcareous nodules in the Lonan Flags (p. 34). The ruins of the ancient chapel on St. Michael's Island, Langness, show a very enduring mortar prepared from burnt sea-shells.

Brickearth.

At the time of the Survey, brick-making was being carried on only at three places in the Island—one in the N., on a very limited scale, at Regaby Beg (section described on p. 437); one in the W., in the valley of the Neb at Peel (described on p. 457); and one in the E., at Highton, one mile W. of Douglas (p. 455). The material in the first is weathered red boulder-clay; in the second, decomposed slate; and in the third, mixed slaty drift.

Disused brick-yards were noticed at West Craig, near St. Judes (p. 437); at Ballacoarey, 1¼ miles E.S.E. of Andreas; near Ballakelly, 1 mile W.N.W. of Andreas; at the northern end of the Mooragh at Ramsey; and at Port Lewaigue, 1 mile S. of Ramsey (p. 443), all in red boulder-clay: at Ballawyllin, a mile W. of St. Johns, in similar material (p. 458); and in the valley of the Neb, nearly a mile north of St. Johns, in slaty till (p. 453). Except near the surface, where it has been thoroughly leached the red boulder-clay appears to contain too much lime to make good bricks. The decomposed slate used at Peel furnishes a dense hard brick of a dullish colour. The operations in the Neb valley N. of St. Johns proved a costly failure, but whether from the nature of the material or from want of care in burning is not apparent.

In "Mineral Statistics" the Manx output of clay for brick for 1895 is given as 6,793 tons, value £339; for 1896 6,000 tons, £275; for 1897, 8,914 tons, £360; for 1898, 10,100 tons, £460; for 1899, 7,000 tons, £175; and for 1900, 8,000 tons, £500.

Sand and Gravel.

These materials are obtained from the glacial deposits of the extra-insular type (p. 335) on the flanks of the Island, where they are abundant, but are not found of serviceable quality where the drifts are entirely of the local type.

CHAPTER XIV.

AGRICULTURAL GEOLOGY AND WATER SUPPLY.

Soils, etc.

The glacial deposits are the chief factors in determining the character of the soil in the cultivated portions of the Island, as the principal tracts of solid rock occur on the mountains above the limits of cultivation. The northern plain, which constitutes the largest area of fertile land, exhibits the variability commonly found wherever drift has accumulated thickly, ranging from stiff clay to light sand and gravel, with peaty patches in the hollows. In this case, however, the boulder-clay rarely forms the stiffest soil, having a sufficient admixture of sand to work into loam at the surface; and the beds of laminated clay belonging to the stratified part of the drift make the heavier land. The difficulty of indicating the kind of soil under these conditions by the conventional methods of drift-mapping has been discussed in Chapter XI. (p. 430), where information will be found as to the localities where the map might seem misleading. The practice of 'marling' the lighter tracts was at one time universal in this area, but is now practically abandoned except on the blown-sands along the southern edge of The Ayre. As already described, the 'marl' usually consisted of boulder-clay or stratified glacial clay (p. 418), but occasionally of late-glacial or post-glacial fresh-water deposits (pp. 378–81); both contain some lime (pp. 464–5), but, as Cumming remarked, the benefit to the land was probably more on account of improved texture and general renovation than from this ingredient alone.[1] Berger mentions that "150 tons of marl are computed to be necessary for an acre of land," but this was probably an extreme quantity; he adds that the cost of the operation was £6 per acre if the cartage did not exceed a mile, and that "the cost of liming, a practice chiefly used in the southern part of the isle, is nearly the same," 90 bushels of lime to the acre being allowed.[2] Seaweed is still extensively used for manure in parts adjacent to the coast, and in this way, as well as by 'marling,' many pebbles etc. have been artificially introduced into the soil,—a fact to be borne in mind by the glacial geologist.

Next in importance to the northern plain as an agricultural tract is the southern lowland, overlying the Carboniferous rocks

[1] "Isle of Man," p. 306.
[2] Trans. Geol. Soc., vol. ii., p. 55.

and extending beyond them up the gentle slopes of slate to 600 feet or more above sea-level. The lower ground in this tract closely resembles that of the northern plain, excepting that sand-and-gravel soils are less prevalent and tend to be more loamy, and the boulder-clay soils are darker, tougher and more calcareous. On the upland slopes the drift is mainly derived from the local slates and, though mapped as 'boulder-clay,' gives rise to soil which is not, as a rule, stiff, but usually a deep stony loam full of subangular fragments of slate, with patches of thinner rubbly soil where bosses of the solid rock approach the surface. This kind of land is predominant all over the hilly tracts wherever agriculture is attempted. Where the soil consists entirely of loose slaty débris, derived either from the subjacent decomposed rock-surface or from slaty drift of the gravelly type, it is termed by the Manx farmers "shilly" land; this produces better crops than its extremely stony appearance would lead one to expect, especially of oats, turnips, and potatoes; but it loses moisture rapidly, and suffers in a dry season. The patches of cold wet clay-land, difficult to drain and difficult to cultivate, occurring on flats and depressions both on the uplands and at the foot of the hills,—the result of the rain-wash and weathering of the drift—have been described in a previous chapter (p. 453); such 'Colby wash' soil has usually a dark grey colour instead of the rusty brown of the mellower slaty land, and is generally full of bits of vein-quartz which have remained unaltered while the slate fragments have decomposed into mud.

On the eastern flank of the Island there is more or less cultivation on the hill-slopes from end to end, but on the western side the cultivated strip extends only as far south as Dalby. In the interior, south of the central valley the greater part of the drift-covered area is or has been tilled, but among the hills north of that valley a much smaller proportion is cultivated, and the area devoted to upland sheep-walks is constantly increasing at the expense of tillage. Macculloch as long ago as 1819 pointed out that the cultivation of elevated ground had in some places extended "further than prudence would have dictated or profit will ultimately justify";[1] and his dictum has been fully borne out, the uplands being everywhere dotted with the ruins of deserted cottages and small farmsteads; the little fields surrounding them, once under the plough, now producing only rough pasturage. This diminution in the proportion of arable land, as marked in the Island as in Great Britain and Ireland, is illustrated in the following statistics.[2] These figures also show to what an insignificant percentage the growth of wheat has shrunk, the grain

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[1] "Western Isles," vol. ii., p. 519.

[2] From the annual Parliamentary Blue books: "Agricultural Returns." In the Return for 1899, the quantity of "Mountain and Heath land used for grazing" (not included in the Table) is given as 23,110 acres, and "Woods and Plantations" as 826 acres.

crops now consisting almost entirely of oats and barley, with turnips and potatoes as the principal root crops.[1]

Year.	Total area of Land and Water.	Wheat.	Barley.	Oats.	Green Crops.	Clover and Grasses under rotation.	Permanent Pasture.
	Acres.	Acres.	Acres.	Acres.	Acres.	Acres.	Acres.
1866	145,325	8,075	7,736	11,010	12,208	25,309	9,762
1876	"	6,181	7,210	12,324	12,045	34,373	20,517
1886	"	1,128	9,256	13,485	11 859	42,026	19,948
1896	145,011	809	7.452	13,789	11,263	38,009	22,904
1899	"	1,018	7,258	13,268	10,993	38,670	20,141

Water Supply.

The water supply of the Island is practically all obtained from the surface-streams or from shallow wells, there being no available deep source. The slate-rocks are waterless, except for a slight percolation along the lodes (see description of mines, pp. 532–3, etc.) and along joints near the surface in the quartz-veined grits; consequently there are scarcely any true rock-springs, though water oozes out abundantly from the base of the rubbly local drift and shaken rock on the hill-slopes and in the valleys. The Carboniferous Limestone of the south is too thinly bedded and intercalated with shale to afford a good supply, and few wells have been sunk in it (pp. 207, 471); some deep quarries in this rock W. of Ballasalla are unwatered by wind and steam power, the discharge being of good quality, and estimated to average about twenty-six million gallons per annum[2]

All the towns possess organised water-systems supplied from reservoirs near the heads of the streams, Douglas thus utilising the Glass and the Groudle Rivers; Castletown, the Silverburn; Port St. Mary and Port Erin, the Colby River and a stream E. of Fleshwick; Peel, a stream from the Slieau Whuallian ridge and from

[1] Berger quotes (op. cit., p. 32) the following figures from J. C. Curwen's "Report of the Agricultural Society in the Isle of Man" (Workington, 1810):—

"Acres.	
100,400	of mountain.
69,045	for grazing.
30,158	in oats.
15,079	under barley.
14,761	under green crops, 710 of which may be considered as potatoes.
9,047	in wheat.
7,270	in roads, rivers, houses.
Total 245,760	acres."

But as this total greatly exceeds the actual acreage of the Island, the table is not of much use for comparison.

[2] We are indebted to T. Moore, Esq., for this information.

Glen Rushen; and Ramsey, the head of Ballure Glen. The country districts depend either upon the streams or upon small shallow wells, often very inadequately protected from contamination; the latter, on the low ground, are generally in water-logged beds of drift not far below the surface; and in the hilly districts are usually little basins excavated in the slate in a position to catch the percolation between the solid rock and the overlying rubble or drift. The conditions of supply on The Ayre and other parts of the northern plain have previously been discussed (pp. 285 & 417), and particulars of a few wells in other districts are given in Chap. XI.

APPENDIX I.

LIST OF MINERALS KNOWN TO OCCUR IN THE ISLE OF MAN.

(The Lode-Minerals are mainly on the authority of Sir W. W. Smyth's List, in Trans. Isle of Man Nat. Hist. and Antiq. Soc., vol. i., pp. 143-147.)

Name.	Localities and Remarks.	
	Lode-minerals.	Rock-forming minerals.
Actinolite	—	As alteration-product in dyke-rocks (p. 308).
Albite	—	In some igneous rocks.
Analcime	—	As decomposition-product in basalts.
Anglesite	Glenchass Mine (s)[1] - -	—
Anthracite	Laxey Mine (see p. 520)- -	—
Antimonite	Niarbyl Mine, (p. 546) - -	—
Apatite	In a vein near Foxdale Granite (Kendall)	In small crystals in many igneous rocks.
Atacamite	North Bradda, old workings (s)	—
Augite	—	Common in intrusive rocks.
Barytes	Foxdale; rare at Laxey (s); North Laxey	—
Biotite	—	Common in igneous rocks, and detrital in slates.
Calamine	Laxey (rare) (s) - - -	—
Calcite	Common in lodes - - -	Chief constituent of limestones, and alteration-product in basic igneous rocks, etc.
Cerussite	Glenchass, Rushen, and Bradda Mines (s).	—
Chalcanthite	Old workings, Laxey, Bradda (s)	—
Chalcedony	Cornelly Mine: as *Agate* in Bulwark Lode, North Bradda (s)	As pebbles, in Peel Sandstone and in Glacial deposits.
Chalco-pyrites	Laxey: Foxdale (rare); Maughold Head; Langness (s), and other places	—
Chalybite (Siderite)	Foxdale, Cornelly, and other mines	As decomposition-product in some igneous rocks.
Chlorite	Bradda and Rushen Mines (s), and common in quartz veins	Common as alteration-product.
Chloritoid (Ottrelite)	—	In altered elvan on Greeba Mountain (p. 318) and probably in other altered rocks.
Cuprite	Bradda Mine (s) - -	—
Dialogite	Snaefell Mine (s) - - -	—
Dolomite	Common in lodes - - -	In Carboniferous Limestone and sparingly in decomposed basic rocks.

[1] Localities marked (s) are from Sir W. W. Smyth's list.

Name.	Localities and Remarks.	
	Lode-minerals.	Rock-forming minerals.
Epidote	—	Common as alteration-product especially in basic dykes
Fahlerz (see Tetrahedrite)		
Felspar (see Orthoclase, Plagioclase, etc.)		
Fluor-spar	Old Foxdale (s) - - -	—
Galena	In many lodes: more or less argentiferous	—
Garnet	—	As alteration product; and detrital in grits.
Gold ?	see p. 549 - - - -	—
Graphite	Snaefell Lode (impure) (s). Beary (p. 550).	Graphitic slate in several localities: see p. 134.
Gypsum	Many veins in Triassic and Carboniferous rocks in deep borings on The Ayre.	—
Hematite	Maughold Mines - - -	—
Hornblende	Cornelly lode (s) - - -	Common in intrusive rocks (see p. 301).
Ilmenite	—	Common in many rocks.
Iron-pyrites	Common in lodes	Common in many rocks.
Kupfer-nickel	Glenchass (s) - - -	—
Labradorite	—	In basic igneous rocks.
Leucoxene	—	As decomposition-product in igneous and metamorphic rocks.
Limonite	Maughold Mines (s) -	
Magnetite	—	Common in igneous rocks.
Malachite	Bradda Lode (s) - - -	—
Malacolite	—	Variety of augite common in basic dykes (p. 301).
Manganese-spar (see Dialogite)		
Marcasite	Laxey, Bradda (s), etc. -	
Melaconite	Laxey and Bradda Mines (s) -	—
Melanterite	Old workings, Laxey, etc. (s) -	—
Mica (see Muscovite, Biotite, etc.)		
Microcline	—	In Dhoon Granite elvans and in granite at Cornelly Mine.
Millerite	Trial-shaft at Rhenas (s) -	—
Molybdenite	On joints in Dhoon Granite -	—
Muscovite	In many quartz veins (p. 320)	Common rock-constituent.
Nickel-ores (see Kupfernickel and Millerite)		
Ochre	Rushen and Bradda (s) - -	—

Name.	Localities and Remarks.	
	Lode-minerals.	Rock-forming minerals.
Oligoclase	—	Common in some igneous rocks.
Olivine	—	In basaltic dykes.
Opal	Var. semi-opal; Cornelly Mine (s)	—
Orthoclase	—	Common in igneous rocks.
Picotite	—	In Carboniferous diabase (*Hobson*).
Plumbago (see Graphite)		
Plumosite	Foxdale Mine (p. 503) - -	—
Pyrites (see Iron-pyrites and Chalcopyrites		
Pyrolusite	Upper part of several lead-veins (s)	—
Pyromorphite	Rushen and Laxey Mines (s) -	—
Pyrrhotite (Pyrrhotine)	Snaefell; Laxey (rare) (s) -	—
Quartz	Chief constituent of veins in slates	Common rock-constituent.
Riebeckite		In Ailsa-Craig boulders in the drift.
Rutile	—	Common in altered slates and in some igneous rocks.
Sericite	—	Common as alteration-product in sheared rocks.
Serpentine	—	As decomposition - product after Olivine.
Silver-ore (see Fahlerz and Plumosite)		
Sphene	—	As alteration-product in igneous and metamorphic rocks.
Staurolite	—	As alteration-product at margin of Dhoon granite; rare. (*G. Barrow.*)
Steatite	Foxdale and Laxey Mines (s)	—
Stibnite (see Antimonite)		
Tetrahedrite	Foxdale Mines (s) - - -	—
Tourmaline	In quartz-veins near granite (see p. 143).	Common as alteration-product in igneous and metamorphic rocks, etc.
Tremolite	—	Alteration-product in some dykes.
Uralite	—	Variety of hornblende, common in basic dykes (see p. 301).
Zinc blende (Sphalerite)	In many lodes - -	—
Zircon	—	Small grains in grits; also in igneous rocks.
Zoisite	—	As alteration-product in igneous rocks.

APPENDIX II.

SOME PUBLISHED ANALYSES OF MANX ROCKS.

Analyses from Dickson and Holland's paper:—on "An Examination of some Volcanic Rocks of the Isle of Man," in Proc. Liverpool Geol. Soc., vol. vi. (1889), pp. 126-129.

Specimen showing junction of microgranite dyke at Crosby with the slates.

"Analysis of Elvanite portion of specimen."
"Sp. Grav. 2·72.[1]

SiO_2	74·39
Al_2O_3	15·55
Fe_2O_3	1·35
MnO	0·22
CaO	0·48
MgO	0·33
K_2O	2·14
Na_2O	3·79
Combined water	1·18
	99·43

"Analysis of the slaty portion of the rock at the point of junction

SiO_2	49·03
Al_2O_3	24·83
Fe_2O_3	3·68
FeO	5·57
MnO	0·26
TiO_2	1·09
CaO	1·80
MgO	2·68
K_2O	5·09
Na_2O	2·96
Combined water	2·57
	99·56

"Not enough of the specimen remained to enable a satisfactory estimation of the carbonaceous matter to be made. P_2O_5 was detected in this specimen, but was not estimated, as also S.

"Thinking it would be interesting to have a specimen of the unaltered slate rock examined chemically so as to compare it with the rock near the point of junction, a specimen was kindly sent by Dr. Tellet of Ramsey, from Sulby, a place about 5 miles from Crosby."

[1] Mr. Hobson states that the sp. grav. of this rock is 2·62 (Quart. Journ. Geol. Soc., vol. xlvii., p. 439).

"Analysis of unaltered Silurian from near Sulby.
"Sp. Grav. 2·79.

SiO_2	57·25
Al_2O_3	21·51
Fe_2O_3	1·30
FeO	5·71
MnO	0·48
TiO_2	0·94
CaO	0·61
MgO	1·92
P_2O_5	0·13
S	0·22
K_2O	3·75
Na_2O	1·32
Combined water	4·32
	99·46

"Carbonaceous matter approximately 0·5 per cent.

"It seems remarkable that there should be 8 per cent. more silica in the unaltered than in the altered rock."[1]

"Specimen ['altered basalt'] from summit of Scarlet Stack.
"Sp. Grav. 2·62[2]

SiO_2	46·70
Al_2O_3	13·74
Fe_2O_3	5·43
FeO	9·88
MnO	a trace
TiO_2	1·94
CaO	3·95
MgO	6·24
K_2O	1·36
Na_2O	3·48
CO_2	1·68
Combined water	5·88
	100·26

"Specimen of gabbro from the most westerly quarry at Rockmount.
"Sp. Grav. 2·26[3]

SiO_2	47·13
Al_2O_3	8·48
Fe_2O_3	6·15
FeO	5·54
MnO	0·64
TiO_2	0·58
CaO	11·34
MgO	13·61
K_2O	0·22
Na_2O	1·28
CO_2	0·47
P_2O_5	0·32
Combined water	3·90
	99·66

[1] As the specimens were from widely separated localities, the disparity commented on may only indicate that the Sulby rock was originally more sandy than the other. [G. W. L.]

[2] Mr. B. Hobson re-determined the sp. grav. and found it to be 2·76. (Quart. Journ. Geol. Soc., vol. xlvii., p. 441.)

[3] Sp. grav. corrected by Mr. B. Hobson to 2·76.

"Carboniferous shale from a deep boring [Knock-e-Dooney] in the Isle of Man," by W. Maynard Hutchings (in "Clays, Shales and Slates"; Geol. Mag., July, 1896, dec. iv., vol. iii., p. 309).[1]

Silica	58·75
Alumina	19·15
Ferric Oxide	3·90
Lime	1·15
Magnesia	1·95
Potash	3·48
Soda	1·54
Carbon dioxide	1·36
Water and organic matter	8·87
	100·15

[1] The specimen analysed by Mr. Hutchings was from a depth of 805 feet in the above boring.

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MEMOIRS OF THE GEOLOGICAL SURVEY.

ENGLAND AND WALES.

THE GEOLOGY

OF THE

CHEADLE COAL FIELD

BY

GEORGE BARROW, F.G.S.

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PREFACE.

THE ground described in this Memoir is the small outlying portion of the North Staffordshire Coal-measures which lies around the town of Cheadle. It is only a portion of the area included in the one-inch map, 124; but it has been thought desirable to issue this Memoir previous to the publication of the whole sheet in order to complete the re-survey of the North Staffordshire Coal-fields. The original Geological Survey of this district was included in the old series one-inch map, 72, N.W., which was published in 1857, the Coal-measures having been mapped by Sir W. W. Smyth, the Permian and Trias by Professor Hull, the sub-divisions of the Millstone Grit having been added by Prof. A. H. Green in 1864.

In 1899, Mr. George Barrow commenced the re-survey of this Coalfield on the six-inch scale under the superintendence of Mr. Fox-Strangways, but the field work, owing to interruptions, was not completed till 1901. The results of this survey are now published on a one-inch map which accompanies this Memoir.

The physical character of the measures, and its relation to their mode of formation, has been noticed; but as this is a large subject it will be better to treat of it, as well as the classification of the coal seams, and their correlation with those of the more important North Staffordshire Coalfield, at greater length in the general district Memoir.

For much information with regard to the Coalfield we are indebted to the Colliery authorities, who have freely given access to plans and rendered other assistance. To Mr. E. E. Almond, owner of Park Hall Colliery, our thanks are especially due for getting information about old trial sinkings.

J. J. H. TEALL,

Director.

Geological Survey Office,

28, Jermyn Street, London,

12th March, 1903.

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OF THE

CHEADLE COAL FIELD.

CHAPTER I.

INTRODUCTION.

The area described in this small memoir is remarkable for the fact that its main features are of two widely different ages. What may be broadly called the northern portion is composed of Carboniferous rocks, forming a sloping tableland essentially of pre-Triassic age, though modified of course by later denudation. Upon this older land surface the Triassic rocks were deposited, but have since been denuded off all except a small portion of the northern area; thus restoring, as it were, the old pre-Triassic surface. In the southern area, however, these rocks have escaped denudation to a considerable extent, and now form a second and newer tableland, overlooking the first and older one. The true form of the older tableland is somewhat obscured locally by the hill of red sandstone at Cheadle, but from the summit of the hill it is at once seen that this isolated eminence is simply a detached portion of the newer Triassic plateau, and really serves to emphasise the fact that these rocks do form a tableland.

The highest ground occurs in the northern area, formed of Carboniferous rocks, attaining an elevation of 1,000 feet about Ipstones, and 800 feet in the neighbourhood of Wetley Rocks. The Triassic rocks do not attain so great an elevation; at the edge of the plateau overlooking Cheadle the ground maintains a fairly uniform height of 700 feet above sea-level, and the top of the hill at Cheadle is at the same height.

The drainage of the area is effected by the two rivers, the Churnet and the Tean, and their branches. Of these the Churnet is much the larger, and flows for the most part in a deep valley, often almost a gorge; and so regular on the whole is the plateau on both sides of the river that it is often possible to look across the deep valley without realising its existence. The chief branches of the Churnet are three in number, and flow through the Consall Woods, the valley between Ipstones and Froghall, and the beautiful gorge of Dimmings Dale. The gorge is renowned for its steep, craggy, and densely-wooded sides. It is cut in the Triassic rocks; the other two channels are in the Carboniferous. Though less gorge-like than Dimmings Dale they both have steep and craggy sides locally. The area about Cheadle is drained by small streams flowing in shallow hollows, which unite to form the Tean, and eventually flow into the Churnet to the south of this area.

Much of the ground is permanent pasture, and this is specially the case where the soil is formed of the heavy Carboniferous shales and clays. Of the lighter lands, formed of the sandstones and grits of this formation, a considerable portion is under the plough; and the same is true where the soil is formed of the dry Triassic sandstones. Even here, however, may be noted the same tendency to lay ground down to permanent pasture that is seen in many other parts of England.

Several minor industries are carried on in the district. Of these the silk-spinning at Cheadle is mainly due to local cheapness of production; though it is obviously an outlying occurrence of a widespread manufacture of which Leek may be taken as a centre.

Brick-making is also carried on to a considerable extent, though mainly for supplying local needs, the material employed being the Coal-measure shales or clays, which are of excellent quality and abundant in much of the area about Cheadle.

Considerable employment is also given by the large copper works of Messrs. Bolton, situated in the Churnet Valley, close to the railway at Froghall and Oakamoor. This industry is interesting as an illustration of the survival of a trade that owed its origin to local causes, which have long ceased to exist.

A large deposit of copper-ore was discovered in Ecton Hill on the Manifold, and this ore was brought down to Whiston on mules' backs, partly for the sake of the Woodhead coal worked near by, and partly to be near the canal, as a means of carriage. The copper-mine has been abandoned and coal from a distance has been used, while the Whiston works have fallen to decay. Nevertheless a local supply of skilled workmen and cheapness of living, aided by the proximity of the railway, have enabled the industry to be retained and extended when carried on at a more convenient site. In former days there were extensive brass works near Cheadle where the Delphouse coals were used for its manufacture, but no such favourable conditions being maintained, the works have fallen to decay. The brass from these works had a high reputation.

Coal-mining is the most important industry of the district and gives employment to a considerable number of men. At present there are six collieries at work; viz., Foxfield, Park Hall, Cheadle Park, Hazle Wall, Kingsley Moor, and Delphouse. Of these all but the Delphouse are working in the Woodhead seam. Only the Foxfield and the Delphouse are at present connected with a railway, so as to send coal out of the district; the others supply local needs only.

Although the number of coal-seams in the Cheadle district that are workable under present conditions is by no means large, still the district posesses a peculiar interest on account of the great antiquity of these workings. How old they are is not known, but they can be traced back as far at least as the reign of Richard III. This antiquity is essentially due to local geological conditions. The coal seams are not hidden under Boulder-clay or Drift, as in many parts of England; and the ploughing of the fields led to the turning up of a curious dark streak, which on being followed proved to be the outcrop of a bed of coal.

The art of level driving to unwater tracts of coal must have been discovered at a very early period, for in recent years an old level was accidentally found that must be at least 300 years old. This level was driven to unwater a specially good coal between Belmont Hall and Ipstones; and the records of Belmont Hall dating back to 300 years make no mention of it. When we consider that every tub full of dirt was pushed along a wooden plank (serving as the modern iron rail) the labour and cost must have been great, and the driving of it a great engineering feat. It would certainly have been mentioned if any records were kept when it was made.

In the majority of cases these old workings were started from the outcrop. As the coal occurred deeper, pits were sunk, but mining was greatly impeded by water percolating from the older surface workings. The further in the miners went, the more the trouble increased, till it has now become necessary to leave a fairly broad strip of coal to prevent the influx of this water. Until the Mines Regulation Act no accurate account of the workings was kept, and for safety's sake this strip of unworked coal is often unnecessarily broad, and is hopelessly lost. A considerable portion of the Woodhead Coal has in this way been rendered unworkable.

Consequently it may not be out of place here to point out a future source of similar danger. The Woodhead and Dilhorne Coals must certainly outcrop beneath the long strip of Bunter sandstone shown on the map of Cheadle. If these coals are followed to the actual outcrop beneath the Bunter, the vast body of water known to be present in this sandstone will be admitted into the mine and the workings drowned out. Indeed the water may invade other workings further to the dip. In the interest of the district, precautions should be taken to prevent this.

Table of Formations.

The rocks that occur in this area may be divided into four groups in descending order as follows:—

Alluvium.	
Drift.	
Trias - - -	Keuper Marls. Keuper Sandstones. Bunter.
Carboniferous	Coal Measures. Millstone Grit Series.

The superficial extent of the strata is shown on the one-inch map at the end of this volume. The six-inch maps of the area are sheets 13 (southern half) and 19 Staffordshire.

CHAPTER II.

CARBONIFEROUS ROCKS.

The Carboniferous rocks that occur within the area, consist of a portion of the Coal-measures and of the underlying Millstone-grit series. Natural outcrops of the latter and of the lowest part of the Coal-measures are abundant, and their nature can be accurately ascertained. But the higher rocks are confined to an area where sections are rare or entirely wanting, and we are forced to rely on mining information for most of our knowledge of these beds. Seams of coal occur throughout the whole series, but they vary much in quality and thickness, and in addition are more abundant or closer together at some horizons than at others. It has been found that black shales are abundant in the lower part of the series, and comparatively rare in the upper, while the strong grit bands are confined to the lower rocks.

By the aid of these characteristic differences, the coal-bearing rocks may, for convenience of description, be divided into the following five parts, or groups, in descending order:—

5. THE UPPER PALE GROUP with coal-seams fairly close together, most of which have been worked. The Four-foot Coal forms the base of this group. The most abundant rock in it is called grey shale. This does not weather as a shale in the sense in which the term is used by geologists, but decomposes into a nearly white clay that becomes almost fluid when wet. Even the sandstones from this part of the series disintegrate on exposure to the air. From the persistent whitish colour of all these rocks when weathered, it is both natural and convenient to call the group the pale-series.

4. THE LOWER PALE GROUP.—The same white clay material is almost as abundant as in the last group, but there is also a little dark shale. The coals are here further apart, and the top one alone, the Dilhorne Coal, has been extensively worked. Some dark shale and more coherent sandstones occur in the lower part of the series.

3. THE WOODHEAD COAL AND WOODHEAD SANDSTONES.—Associated with the Woodhead Coal both above and below is a considerable thickness of dark shale, which distinguishes this horizon from any higher one. The Sandstone which underlies this shale, consists of a great number of thin bands of sandstone, all of which are fine in grain and more or less flaggy. About the middle of the mass is a band cemented by carbonate of lime and probably some iron. When undecomposed this is an intensely hard rock and easily recognised.

2. THE LOWEST COAL-MEASURES.—The feature of this group are the thick masses of black or dark shales associated with coal seams and sandy bands, the latter tending to pass into gannister, often of excellent quality. Of the coal-seams, one the Crabtree

or Lower Stinking Coal is very persistent, and has been worked to a considerable extent. The others vary greatly in thickness and are often absent. There seems reason to believe that this group is the equivalent of the Lancashire Gannister Series, but it is not proposed to discuss these points in this small memoir.

1. THE MILLSTONE GRIT SERIES.—This is at once recognised over the greater part of the area by the size of the grains composing the body of the grits (the First and Third) as well as by their thickness. The grits continue to be strong to the east and north, but in the Dilhorne area, the First Grit becomes thinner and finer, and the Third Grit is only just recognisable, so much has it thinned away. A mass of black shale similar to that in the group above separates the two grits, and there is a seam of coal always present above the Third Grit; it varies however from little more than a smut to a good seam 2 feet 10 in. thick. Below the grit again is a mass of dark shales associated with red marls and sandy bands of a very variable nature.

There is a considerable variation in the thickness of these groups as we pass from one area to another, so that it is not possible to say what is the exact thickness of the whole series at any one spot. In the course of mining operations all but a small portion of these rocks has been proved in shafts or borings; from these we estimate the total thickness of the true Coal-measures in the Cheadle area to be about 1,600 feet, while the Millstone Grit Series has been proved to a depth of about 450 feet.

SECTION SHOWING ALL THE COAL SEAMS IN THE CHEADLE AREA.

	ft.	in.
Coal and Smut	2	6
Measures	42	0
Two-Yard Coal	5	6
Measures	76	0
Half-Yard Coal	2	6
Measures	61	0
Yard Coal	3	6
Measures	51	0
Littley Coal	2	9
Measures	33	0
Four Foot Coal	3	6
Measures	120	0
Coal (variable)	2	0
Measures	60	0
Dilhorne Coal	6	0
Measures	190	0
Stinking or Alecs Coal	3	9
Measures	55	0
Foxfield Coal	1	8
Measures	64	0
Coal 7 in. (Black Seat 2 ft. 6 in.), Coal 8 in., below	1	5
Measures	130	0
Cobble Coal	1	3
Measures	55	0
Coal (no name)	1	1
Measures	95	0

	ft.	in.
Rider Coal - - - - - - - - - - -	1	6
Measures - - - - - - - - - - - -	125	0
Woodhead Coal - - - - - - - - - -	2	9
Measures - - - - - - - - - - - -	500	0
Stinking or Crabtree Coal - - - - - - -	2	0
Measures (including First Grit 100 feet) - - - -	320	0
Coal. Third Grit or Roaches Seam (varies) - - -	2	0

1. The Millstone Grit and Associated Shales.

These rocks form a ring round the greater part of the Cheadle Coalfield, but the southern and south-western portion of this ring is buried under the Triassic rocks, and its exact position cannot be fixed. The symmetry and continuity of the ring are greatly broken by faults, which for short distances make the outcrops of the different beds somewhat difficult to trace; but over the greater part of the area these beds have such well-defined characters that even small outcrops can usually be recognised.

The series can be best studied in the Froghall and Ipstones area, where the rocks differ least from the well-known types of the areas to the north, such as that of the Roaches, etc. Shafts and borings in search of ironstone have proved the thickness of much of the series in this area—a borehole close to Abovechurch, north-west of Ipstones, passing through the total thickness of the Third Grit, and piercing about 100 feet of the underlying rocks. A number of trials were also made in the Oakamoor area in the beds below the Third Grit, proving a seam of coal some 10 inches thick, at a depth of about 95 feet below the grit. Other borings have proved still lower beds, but it is not possible to fix exactly the horizon at which these started. The following section shows the approximate thickness of the beds in this part of the series in the Ipstones and Churnet Valley areas, in descending order:—

	ft.	in.
First Grit, about - - - - - - - -	100	0
Dark shales with a little sandy marl in upper part - -	120	0
Third Grit - - - - - - - - - - -	140	0
Marls, thin sandstones and black shales, about 200 feet proved - - - - - - - - - -		

The First Grit in this area is a moderately fine-grained rock, rarely containing pebbles; it tends locally to weather red, distinctly colouring the soil. This rock occurs more often than is usually supposed on the east side of the Churnet, owing to repetition by faulting. Commencing at the north-east end of this area the First Grit is exposed in the little stream in Coalpit Wood, about a mile west of Belmont Hall. The Hall itself stands on the same rock repeated by a fault. The fine crags at the south end of the hill, evidently close to the fault face, enable the bed to be examined here. It is again brought up by a fault, and forms the hill of Noonsum Common, while another fault repeats the grit which forms the hills to the south on which Booth and Hermitage farms stand. A large fault throws the grit down beneath the Ipstones and Froghall Valley, and it does not crop out again till we reach the high ground east of the village of Ipstones. The village itself stands on grit, but it is not easy to say if this is the First or Third. The cause of this difficulty is the doubtful position of the large fault just referred to. If this passes on the west side of the village, then the south end of the latter is on the First, and the north end on the Third; if, however, the fault passes on the east side, the reverse is the case, for the mapping makes it clear there are two different grits here. The church undoubtedly stands on the First Grit. To the east of the Ipstones Valley another fault throws up the First Grit, which forms the small round outlier to the north of Foxt. Part of the hill on which Foxt stands is also formed of this bed, but the village may stand on the Third Grit if the fault, so clearly seen passing close to the inn further north, passes on the west side of Foxt; if it passes on the east side of the village the latter is on the First Grit. It was not found possible to settle this point owing to insufficient evidence.

The First Grit covers a large area in the neighbourhood of Whiston, and its base is seen in the old reservoir at the abandoned copper works. There is a gradual passage here from the grit to the underlying shales, and this gradual passage prevents the rock making the usual bold feature, the base being by no means easy to follow at times. As we approach Oakamoor, shafts have been sunk through the grit to reach the underlying coal, and from the depth of these shafts the grit must be about 90 to 100 feet thick. In the wood on the north side of the Churnet, opposite the western end of the tunnel, the grit makes an unusually bold escarpment. For a short distance on the south side of the river a similar escarpment occurs; it is, however, abruptly truncated by a fault just before these rocks are covered by the Bunter Sandstone.

Returning to the northern area, near the Churnet, the grit has a double outcrop for some distance to the west due to a fault, but the exact position of the fault is difficult to fix, as the hollow in which it occurs is covered with downwash. The large fault passing near Consall New Hall throws the grit up again, and it crops out in the sides of the valley and near the Hall farm. On the west bank of the Churnet a large quarry has been opened in this rock, which here forms an excellent building stone.

A large fault trending north-west repeats both these outcrops, as the map clearly shows. The shorter and more southerly outcrop is well seen in the side of the small stream in the Consall woods, and by its position and mode of ending off serves to show well the course of two of the faults. The more northerly outcrop is peculiarly clear about the sides of the stream that cuts right through this rock, and gives an excellent section of it. As we leave the stream and approach the faults shown on the map further west, the position of the bed is more difficult to fix. Close to the Wetley-rocks road this grit is faulted against the Third Grit, so as to make the whole appear a continuous outcrop of one grit. Further south its course is very difficult to trace continuously, partly owing to faults, partly to the fact that the grits begin to thin away rapidly in this direction. The bed of sandstone to the east of Hilltop Farm is probably this rock, as is also the sandstone exposed in the Foxfield railway, a little south-east of Stansmore Hall. The great east and west fault at Dilhorne throws down the Millstone Grit Series, and their further course west of the Cheadle basin is covered by Triassic rocks and measures between the First and Third Grits. The greater part of the rock between the two grits consists of dark shale. Close under the First Grit, however, the beds vary somewhat, being often lighter in colour and of a more sandy nature. Occasionally a thin band of sandstone occurs, but it is distinctly rare and impersistent. Owing to the occurrence of these beds between two much harder rocks, they are rarely seen except in stream sections or artificial openings. Toward the base of the shale is a seam of coal known as the Third Grit Coal or Roaches Coal. This seam occurs all over the eastern and northern part of the area, but there is some doubt if it exists in the western part.

IPSTONES AND FROGHALL AREA.—An excellent series of sections of these beds occurs in the little valley—almost a gorge—to the east of Booth Farm, rather more than a mile north-north-west of Froghall. In the eastern branch of this valley a small adit has been driven for a short distance immediately below a hard shale band that lies about half-way between the two grits. The section in descending order is as follows:—

Dark shales.
Dark hard shale band, about 1 foot.
Impure coal, a few inches.
Calcareous ironstone, a few inches.
Dark shales.

The hard shale band has been recognised at several localities, and though not a "goniatite-shale" band here, there can be little doubt it is at the same horizon as the band full of *Goniatites* near the Knypersley Reservoir. It must not, however, be confounded with the "goniatite-shale" band above the coal, lower down in this mass of dark shale.

This lower band occurs immediately above the Third Grit Coal, and fragments of it are seen in every tip-heap from the coal workings to the west and north of Ipstones Church. The coal has been extensively mined in this neighbourhood, and one shaft is still being worked, the coal being 2 feet 10 inches thick and of fairly good quality. It was to unwater this coal, in consequence of its good quality and thickness, that the old level, referred to in the introduction, was driven. About half a mile west of the church a borehole, known as the Abovechurch Borehole, was put down to see if any workable ironstone was present. A seam was found, but its quality was not such as to encourage its being worked. The exact position of the Third Grit Coal is shown by the boring, an account of which is as follows:—

Ipstones Area—The Abovechurch Borehole.

	ft.	in.
Soil and clay	9	0
Black shale. Goniatite shale band at base	22	0
Coal. The Roaches Seam	2	10
Fireclay	8	0
Sandstone rock. Third Grit	144	0
Hard marl	9	0
Red and brown rock	7	0

	ft.	in.
Roach or gritty shale	33	0
Grey shale	36	0
Black shale	27	0
Grey shale with red bands	1	6
Black shale with red bands	1	0
Red hydrate ironstone, said to be	1	5

Three shafts, which are shown on the map, were sunk through the lower portion of these shales to this coal; one three-quarters of a mile south-west of Ipstones, a second (New House) a little south of Ipstones, and a third half a mile south-east of the village.

These shafts appear to have been made under the impression that these dark shales were at the same horizon as those above the Froghall Ironstone, which they closely resemble. They proved a curious fact; in all cases the coal has passed to a mixture of coal and ironstone, closely resembling the higher one already referred to. In this special area this curious admixture occurs at three distinct horizons, for it is also met with in the Froghall Ironstone.*

In the small valley, rather more than a mile due north of Foxt and close to the fault shown on the map, the Third Grit Coal is exposed, and has been worked, as the ironstone is absent here. About the Lees, west of Whiston, the coal has again been worked; the goniatite shale is everywhere seen in the spoil heaps, and fragments of impure ironstone show that the mixed material also occurs in this neighbourhood. To the north-east of Whiston no old workings have been found, but as we approach Oakamoor the coal has been extensively wrought, and many old pits are still open in this neighbourhood. A considerable portion of the outcrop of the shales above this coal is faulted out in this area by a fault running along the foot of the escarpment of the First Grit. The tunnel at Oakamoor passes through the greater part of these beds, and a great quantity of the goniatite shale may still be seen in the spoil heap at the west end of the tunnel.

THE NORTHERN OUTCROP.—Close to the Churnet on the northern edge of the First Grit a shaft was sunk to the coal, and some of the overlying shales are exposed in the banks here. To the west and south-west, however, nothing is seen of these beds till we reach the ground between the outcrop of the two grits to the south of Consall village. This ground is intersected by small gorges, which give an almost complete section of these shales. In the wooded ravine—shown on the map—the hard shale band about the middle of this series is particularly well seen. This band is 4 feet thick with a coal smut below, but no fossils were found in the shale.

Owing to the faulted nature of the ground these shales are difficult to trace for some distance to the south, and the only good exposure of them occurs in the old marl pit close to Bank Top, about a mile north-north-west of Foxfield Colliery. A hard calcareous band associated with some traces of coaly matter

* See page 19.

seems to be the only representative of the Third Grit Coal, but the pit is too old for the section to be clearly understood. That there is no good coal here seems clear, for it would otherwise have been worked, as there is no other easily accessible coal in this neighbourhood. There are numerous openings for marl or shale to spread on the dry Bunter Sandstone soil, and some of them must have cut open the coal if it exists here. A little south of this area these shales are faulted down by the Dilhorne Fault and covered by the Bunter Sandstone.

THE THIRD GRIT.—Generally speaking, this grit is coarser and thicker than the First. There is no need to give a detailed description of the outcrop of this rock for it runs parallel to the First Grit, and its position may be defined as being invariably a little further off from Cheadle than the latter. In the Ipstones and Oakamoor area it is about 140 feet thick, and the thickness changes slowly and apparently evenly in definite directions. It has gradually thinned away from 190 feet in the Stocton Brook area, but the evidence shows clearly that these grits do not vary in thickness in comparatively short distances as is often supposed. They are really built up of a considerable number of lenticular beds of grit which often die away in a short distance. But the total thickness of grit built up of these lenticles varies very little over considerable areas, as the numerous shafts and borings through it show. The finest crag outcrops occur about the Caldon Low Tramway near Abovechurch (Ipstones area) and the Belmont gorge to the east of the Churnet. On the west side of the Churnet the most northerly outcrop near Park House is so obscured by Drift that it was missed in the former survey map. About Consall, however, it makes a bold feature, but begins to thin away to the south. It is still recognisable at Bank Top, the farm referred to above, but at Stansmore Hall, north-west of Dilhorne the rock is recognised more from its position above the thin hard sandstones (crowstones) near Stansmore Wood, than from its own characters. It is not known further south being covered by the Bunter.

BEDS BELOW THE THIRD GRIT.—The dark shales below the Third Grit are exposed in the cutting on the Caldon Low Tramway, and still lower beds are seen in the stream (Shirley Brook) that flows south towards the tramway in the neighbourhood of Foxt. At the point where this stream turns abruptly west a small brook joins it from the east, and in the low scar at their junction a curious small coal seam occurs, about 10 inches thick, apparently at the same horizon as the seam often met with in the borings about Oakamoor. The seam at Shirley Brook appears to be highly bituminous and pyritous, and is crowded with *Goniatites*. These at the outcrop crumble to pieces in the fingers, but a hand lens shows that even the most delicate markings are perfectly preserved. It would probably be worth while to make a small opening here to obtain fresh specimens, as well as to ascertain if the coal is sufficiently bituminous to possess any commercial value. A little north of this point an interesting bed of sandstone occurs in the Shirley

Brook, and can be followed for a considerable distance in the sides of the stream. At first it contains a few small pebbles in its upper portion, but further north these increase both in number and size till the rock resembles the Third Grit. Though thin it is very hard, and after rising from the sides of the hollow it makes a large spread about Lanehead. This bed occurs again, repeated by a fault, at the smithy north-east of Foxt. It is here still more like the Third Grit in appearance, but a shaft proved it to be only some thirty feet thick. This tendency of the sandy beds in this district to become thicker, coarser and more pebbly is not confined to this rock: the mapping of part of the Ipstones area made it clear that a number of thin pebbly grit bands are coming on and partly replacing the masses of shale so conspicuous in the Endon area.

On the opposite side of the Cheadle area, however, the reverse phenomenon is seen. There the beds below the Third Grit are mainly soft shales associated with thin crowstones, good examples of which may be seen to the west of Banktop Farm.

2. The Lowest Coal-measures.

This group consists essentially of dark shales separated by bands of fireclay and sandstone or gannister. The whole thickness of the group was pierced in the boring from the bottom of the pit at Park Hall Colliery,* but there is reason to believe the beds here are somewhat thinner than in the Froghall and Ipstones area. The section shows that several small seams of coal are present, but only one, the Crabtree or Stinking Coal, is of any thickness. The sandy bands in this series are liable to much greater variation than the dark shales, a phenomenon that is specially well shown by the beds beneath the Crabtree Coal, which may be either a pebbly grit, a series of thin fine sandstones, or a gannister of specially good quality. The change from one type of section to another will recur several times in quite a small area.

Owing to the fact that the three deep valleys of the district, that of the Churnet, Consall Woods, and Ipstones, are cut principally in this portion of the Coal-measures, exposures are numerous, more particularly at the points where small streams flow into these larger valleys.

Mr. John Ward, in his excellent work on this district†, draws attention to the fact that the dark shales of this and the underlying group of beds usually contain a different fossil fauna from that of the shale in the groups higher up in the series. In the latter the fossils are fish remains, *Spirorbis*, *Carbonicola*, and other shells of a fresh-water origin; while in these lower rocks the fossils have a more distinctly marine aspect, such as *Goniatites*, *Aviculopecten*, *Lingula*, etc. For this reason he proposed to restrict the term Lower Coal-measures to this group, classing the Woodhead Coal and overlying rocks of the Cheadle area as Middle Coal-measures. It is not at present certain that this distinction in fauna prevails over a sufficiently large area for this classification to be adopted.

* See page 57. † See page 58.

Ipstones and Froghall.—A long narrow strip of these beds occurs between Ipstones and Froghall, let down by two nearly parallel faults, and in this a number of boreholes were put down to prove the Froghall Ironstone, which in this area occurs at the base of the Coal-measures. Though the ironstone has been practically worked out, the borings are still interesting as showing the nature of the beds passed through. The exact position of these boreholes cannot now be fixed, as a series was made in each locality, and it is impossible to say to which of these series the separate boring-accounts refer.

A considerable number were made in the locality of Cloughhead, a farmhouse about a mile north of Froghall. These borings, while differing in minor details, show the persistent presence of certain beds of coal and bands of dark shale. They are, however, sufficiently in accordance with the section proved in the engine pit close by for it to be taken as fairly typical of the district.

Section of the Old Engine Pit near Cloughhead. (Froghall.)

		ft.	in.
15	Grey and black shale	37	0
14	Coal	0	4
13	Hard fireclay and rock, shale at base	20	0
12	Sweet or Split coal { Coal, 1 ft. 1 in. Shale, 6 in. Coal, 1 ft. 8 in. }	3	3
11	Grey and black shale (bass)	19	5
10	Coal	0	4
9	Grey and black shale	31	6
8	Coal (the Stinking or Crabtree)	2	3
7	Fireclay on white and grey rock	31	7
6	Grey shale	2	9
5	Coal	0	3
4	Grey and black shale (paper shale at base)	20	6
3	Coal	0	4
2	Grey and black shale passing to harder sandy shale	63	6
1	Black shale 1 ft., Ironstone 1 ft.	2	0

Below this the shaft was sunk, some 10 feet into grey marl.

All the strata recorded above are visible at some part or other of the deep ravines between Froghall and Ipstones. Close to Froghall the banks of the stream are formed of the dark shales above the Crabtree or Stinking Coal. On the east side of the valley, all the beds from this seam to the Kingsley sandstone are present, but there are only isolated exposures, and no details can be made out. Just at the lime-wharf the Crabtree Coal crops out at about the water level, and from this point rises faster than the stream as we go north, so that a little above the rude dam formed by the great shale-tip in the western valley, a foot-path to Ipstones passes over the sandy beds below the coal. At this point there is a good section in the stream below which shows:—

	ft.	in.
Dark shales (No 11 of above section)	20	0
Paper shale band	1	0
Coal, 2 in. Smut, 8 in. (12 of above)	0	10
White fireclay	5	0
Dark shale	10	0
Flaggy fine grit, having a cemented appearance at the base	10	0

This section is important, as the paper-shale band overlying the coal marks an horizon that is persistent over a very large area. Unlike the rest of the black shale it does not readily fall to pieces on weathering, but changes to a brown-paper colour, and in this condition it can be split open with a blunt knife, and thin sheets like stiff brown paper may be obtained from two to three feet long. At times fish scales and a small flattened *Lingula*-like shell are fairly abundant; but as a rule fossils are very sparsely distributed in the rock. It never contains, so far as we know, the masses of *Goniatites* and *Aviculopecten* so abundant in the other hard shale bands, and it differs also from the latter in the absence of pyrites. It is to the freedom from this mineral and the decomposition that accompanies its presence, that the paper-shale band owes its preservation. Once seen it is easily recognised, and forms, as stated above, an excellent horizon over the area here dealt with.

Following up the stream towards Ipstones the hard beds (No. 9) above the black shale and under the Crabtree Coal form the sides of the small ravine till we reach the first houses of the village of Ipstones itself. Here a quarry has been opened in the gannister that so often occurs at this horizon. It may be noted that in this section no trace was observed of the thin coal (No. 10) which experience shows to be liable to great variations in thickness, and at times to disappear altogether. It must not, however, be inferred that it never existed, for there seems a strong probability that many of these thinner coals were denuded after they were laid down, but this has not been proved. Only a short distance to the east of this stream a borehole passed through a hollow 2 feet deep due to the extraction of this very coal. The section also shows the variability of the hard beds that underlie the Crabtree Coal. At the south end of the section the bulk of the rock is a fairly fine sandstone, but close to the village it is mostly fireclay and gannister. This change in a short distance is characteristic of the whole area, the zone being specially liable to these changes. The gannister and fireclays when present are usually of excellent quality. Owing to the greater hardness of this zone it forms a step or feature in the stream banks, and this enables the position of the Crabtree Coal (No. 8) to be easily traced. To this fact is probably due the extensive nature of the workings in this neighbourhood. It was also pierced again and again in the shafts to the underlying Froghall ironstone, and was often worked for the engines at the numerous pits. The Crabtree Coal may be seen from the tip-heaps to be overlain by the persistent hard shale band so rich in *Goniatites*, etc., that assists in the identification of this Coal over a large area. The coal and shale together form the one persistent recognisable horizon in this part of the Lower Coal-measures. Though there must have been numerous outcrops of these bands in the ravine north of Froghall, they are now much obscured by the *debris* from the ironstone mines.

To the south-east of the shale-tip in the Ipstones Valley the Sweet or Split Coal above the Crabtree, and another seam below it, have been cut open in the steep bank, but owing to slips it is not easy to tell the exact thickness of either. They are too thin apparently to be worth working. Ascending the east branch of the main valley a fault is crossed which brings up the Froghall ironstone. The outcrop of this is marked for a considerable distance by a number of adits. Further north the sandy beds and gannister of the Crabtree Coal are seen close to the Mill-dam, and about 200 yards beyond this is another section of the Split seam, the thickness being the same as in the shaft given above. Higher up the stream the Crabtree again comes to the surface, close to an old adit, and the shales below the coal are also seen, but the ground beyond is much faulted and the exact horizon is difficult to fix. South and south-east of Froghall a considerable area of these rocks occurs on the north side of the Churnet. Sections are numerous, and borings and shafts have been put down to prove the ironstone and to work the Crabtree Coal. The ironstone is either too thin to work, or absent in this area, but the coal maintains its usual thickness. A little south of Eavesford the sandy beds below the coal form a grit with pebbles as large as those in the Third Grit, but the matrix is fairly fine. The outcrop of this is shown on the map. South of Whiston Eaves this rock is much finer and contains no pebbles. Over all this area the Crabtree Coal has been worked some distance in from the outcrop, and has always the Goniatite-shale roof. A shaft, about 500 yards south of Eavesford, passed through three seams of coal below the Crabtree. The section of this shaft is as follows.

Shaft at Ross Banks, Whiston Eaves :—

	ft.	in.
Sand and clay	9	0
Grey bands and shale	4	0
Blue shale	35	0
Stinking or Crabtree Coal	2	0
Fireclay and rock	29	0
Black shale	3	0
Coal	0	10
Fireclay	8	0
Hard band on red marl	7	0
Black shale	2	6
Coal (? Shaffalong)	0	9
Black shale	9	0
Grey roach	9	0
Coal (? Shaffalong)	1	6

A boring put down by Johnson of Ipstones in the dell close by gives 40 feet to the hollow where the Crabtree has been worked; then 31 feet to a hollow where the roof has fallen into another coal (see above); then 29 feet to a red sandstone. This is said to be the top of the First Grit, but it does not seem deep enough.

A small coal seam about 7 inches thick, apparently above the Crabtree Coal, is exposed in the bank of the little stream close to the first railway bridge south of Froghall, but its position is not easy to fix owing to the faulted nature of the ground. The stream flowing south-east from Whiston Eaves gives numerous sections of the shales below the Crabtree, but these possess no points of special interest. Due south of Crowtrees a small slag heap suggests the presence of the Froghall ironstone but it cannot be thick, for trials have been made in the neighbourhood without success.

Near the farm of Eastwell the outcrop of these beds crosses to the south side of the Churnet. The northern boundary is a natural one, but the southern is a fault throwing down south. In this outcrop sections occur in the streams east of Woodhead Hall, and again in the stream that flows down past Cheadle. The latter are in the black shale above the Crabtree Coal, while those to the east show clearly the beds associated with the Crabtree Coal, which has been worked here. In some calcareous nodules from the tip heaps numerous fine specimens of *Goniatites* were observed, but they are very difficult to extract. Dr. W. Hind kindly determined two of these as *Goniatites* (*Gastrioceras*) *Listeri* and *Goniatites* (*Dimorphoceras*) *Looneyi*. With the object apparently of proving if the Froghall ironstone was present or not, a boring was made from the bottom of one of these pits. This must have pierced the First Grit, as a large quantity of water was met with which still flows as a considerable stream in spite of the height above the base of the Churnet Valley. There could be no seam of ironstone present, but the water is markedly ferruginous.

Rather more than a mile east of Cheadle the shales of this part of the series are seen in the valley to the south of Hilltop Farm, and again in the hollow to the east; but as they pass in this direction under the Bunter Sandstone no outcrops are known further south.

Returning to the Froghall area and following these rocks round the margin of the coalfield, a curious outcrop of the Froghall ironstone with a thin cover of shale occurs on the summit of the hill to the north-west of the station. The occurrence of these outliers was not known for a long time, and this is the more remarkable owing to the great amount of slag left from ancient workings in the ironstone. All record or even tradition of these workings is lost.

To the south of this hill a large fault throws the ironstone and overlying beds down into the valley, but the downwash is so great that nothing is seen of the rocks till we approach the small stream to the north-west that rises near Ipstones. A little below the junction of this with the main river the ironstone comes to the surface, and is said to form the bed of the canal close to the adit, from which a small quantity of ironstone is still being mined for making red paint.* A little way up the small stream the First Grit comes to the surface, marking the position of the fault already referred to.

Further west many shafts were sunk to the ironstone, nearly all of which has been extracted. They proved the persistent presence of the Crabtree Coal, which remains fairly uniform in thickness, and also of several smaller seams, two of which are

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* Close above the adit is a little band of hard white grit or conglomerate; apparently that recorded in the Park Hall boring. (See page 57.) It has not been seen elsewhere.

very variable, but rarely as much as a foot thick. The harder beds above the Crabtree Coal form the edge of a flat-topped hill on which Hillhouse farm stands, and the outcrop of the coal can be fairly well traced. In the small valley on the east side of Belmont Hall numerous sections are met with showing the nature of the lower portion of the series. The ground is much affected by faults, one of which is well shown on the east side of the valley not far from Pettyfields. This fault brings the shales below the Crabtree against a sandstone above that seam. The shale has locally slipped away from the fault face, leaving a curiously isolated sandstone scar. To the north of this no such slip has occurred and the sandstone is consequently not seen, although it cannot be more than a few feet from the surface inside the bank face. To the west of Belmont Hall some good sections of the beds about the Crabtree Coal are exposed, and the gannister, which is of excellent quality, is quarried. A little further up the Churnet valley, on the same side, a small stream cuts through the basal shales of the series, and gives one of the very few natural sections of the Froghall ironstone, which has here dwindled to some three inches in thickness. An equally thin seam was met with in the trial-shaft a little east of the stream, and the limit of the workable ironstone in this neighbourhood is thus fixed.

On the southern and western side of the Churnet about and above Froghall the lowest Coal-measures form the greater part of the steep banks of the valley. For some distance, however, the slips and wash from above prevent any rock being seen *in situ* till the woods north of Hazlescross are reached, where the traces of an old tram line indicate the outcrop of the ironstone, into which levels have been driven at intervals as far north as the flint-mill. Sections about the ironstone are numerous, though slips are gradually obscuring these, and in time little bare rock will be visible. These slips occur at intervals all down the hill face, and a fresh one will of course leave a bare scar for a time. Several such scars occur in the banks here at present. They are most numerous just below the summit of the bank at the top of the dark shales below the Woodhead sandstone to be described later. A few occur much lower down in the harder bands associated with the Crabtree Coal, which has been worked to a small extent.

Specially good sections of these rocks occur on the south bank of the stream that flows through the Consall Woods and joins the Churnet at Consall Forge. Although the sequence is locally affected by faulting, still on the whole the stream flows almost exactly along the strike of the rocks, and thus as the valley deepens lower and lower beds are exposed. For some distance above the point, where the long north and south fault crosses, black shale is the dominant rock, and this contains lines of small ironstone nodules, with at times marine fossils These beds would repay a careful search. On the east side of the fault a good section of the Split or Sweet Coal is exposed, the section being as follows :—

		ft.	in.
Mixture of sandy marl and gannister		4	0
Pale sandy marl		10	0
Smut, 3 in.	Split seam	5	0
Coal, 8 in.			
Smut, 4 in.			
Clunch, 1 ft.			
Smut, 3 in.			
Clunch, 1 ft. 10 in.			
Coal, 8 in.			
Hard white clunch with lenticles of jet or coal		2	0
Hard clunch, base not seen		10	0

The clunch is a sandy material cemented by a little clay. It is coherent and devoid of bedding. Though softer than a sandstone it is much harder than an ordinary marly shale or clay.

A little further down the stream an excellent section of the Crabtree Coal with its Goniatite-shale roof is seen, and the coal can be followed till we reach a large scar in which the beds from some distance above the Split seam down to this coal are all laid bare. It is the most complete natural section in the district. The Split seam here consists of two bands of coal, each about 6 inches thick separated by 3 feet of fireclay and shale; a little further down the stream the beds above the Crabtree crop out, the section showing 30 feet of black shale with a Goniatite-band at the base. Under this is the Crabtree Coal resting on 3 feet of fireclay, succeeded by laminated and compact sandstones. These are totally unlike the harder material (gannister and fire-clay) worked on the west side of Belmont Hall referred to above.

The small scar formed at the angle in the bank where the Consall Valley joins the main valley shows the paper-shale bands some distance below the Crabtree Coal described on page 13, and which are so persistent in this area. It is here underlain by a thin smut of coal, while a little above it are several bands of sandy material closely approaching gannister in appearance and composition. A considerable distance up in the bank a shaft was sunk to the Froghall ironstone, which shows the absence of any seam of coal below the Crabtree. It also shows the great thickness (93 feet) of loose material that tends to accumulate on these steep banks, largely no doubt due to slippings as well as downwash.

On the north side of the Consall Valley there is a considerable area of the Lower Coal-measures, but only a few good natural sections occur in it. Owing to the fact that the beds below the Crabtree Coal are harder than the rest, they had often to be cut open to make the tram roads for the old ironstone mines. By the aid of these sections the coal can be traced over a considerable area. The ironstone was extensively mined here, and numerous shafts were sunk. The workings proved the area to be greatly faulted, and the majority of these faults are shown on the map. The Crabtree Coal was met with in every shaft deep enough to intersect the seam. It varied in thickness from 1 foot 6 inches to 2 feet, and was worked for the engines where convenient to do so. It was always highly pyritous, but gave a good heat, and coked well. This local mining of the seam has given rise to a number of patches of waterlogged ground, which will be a source of danger and difficulty if the seam be more extensively worked at some future time.

In addition to the shafts sunk to the ironstone, some borings were put down to prove it in Ladypark Wood, close to the stream, and west of the fault shown on the map. The first met with the ironstone at a depth of 95 yards, the stone being only 7 inches thick and too thin to work. The second, some distance further west, proved the seam absent altogether. Some additional borings were made in the fields near the road to Wetley Rocks, which proved a coal, said to be the Crabtree, at a depth of 12, 14 and 20 yards, but no ironstone was found.

The outcrop of the lowest Coal-measures on the western side of the Cheadle basin is difficult to understand, as the ground is faulted, and the rocks themselves rapidly change in character, which renders the faults difficult to trace. The high dip also produces a steep featureless country, which is further obscured by wash. The shales can be seen occasionally in a few stream sections, and have been excavated to a considerable extent for marling the fields. The Crabtree Coal was not met with in any of these pits, which extend almost to the Dilhorne fault. It seems reasonable to suppose that this seam, like the Third-grit Coal, has died away. To the south of this dislocation these rocks are covered by the Triassic beds, and nothing is known of their further course.

Summary of the Coal-seams.—From the above account, it will be seen that the Crabtree is the only seam of any thickness that is at all persistent over the greater part of the area. It has a thickness varying from 1 foot 6 inches to 2 feet 4 inches over all but the western district. It has been extensively worked at different times, and it is doubtful how much of it is left except as isolated patches surrounded by waterlogged "Old-man." In the area north of the Consall Valley a small portion has been worked for the hauling engines of the old mines, but the bulk of it is left. It is, of course, untouched over the greater part of the Cheadle area, but whether it would ever pay to work when coal becomes scarcer is a difficult matter to decide. It seems to be a hot coal and cokes easily. It may some day be possible to wash the pyrites out of it and coke the powder.

The Froghall Ironstone.—This seam of ironstone, which has been referred to above, lies either directly on the First Grit or may be separated from it by as much as 15 feet of shale. With the exception of a few patches that are worked for making red paint, the seam has been practically worked out. It was deposited in the form of an extremely thin lenticle of somewhat irregular thickness, which was roughly elliptical, the longer axis of the ellipse trending E. and W. The southern limit has been proved at the west end by borings already referred to in the Consall Valley, near the stream flowing north from Kingsley Moor. It was followed till it was too thin to work both at Hazlescross Pits, and at some pits close to Kingsley Village. A boring proved its southern termination again at Froghall, and only a trace of it was met with at Whiston. To the east of Ipstones it passes to a curious admixture of coal and ironstone, which did not pay to work. Beyond this for some considerable distance the limit to the north is the natural outcrop, but close to the Churnet it has been proved to die away to a few inches before reaching the outcrop. In order to prove if this seam came on again a boring was put down by Mr. Almond from the bottom of Park Hall Pit, and this corroborated the evidence already given that the seam does not extend south of the line described above.

That this seam owed its existence to local conditions, which tended to recur, seems to be shown by the fact that in the area where the seams become a mixture of coal and ironstone two other similar admixtures occur between the First and Third Grits, as noted above. This association suggests some special condition for its occurrence, and it seems that filtration may be partly the cause. For instance, if a delta be covered with a dense vegetation of a reedy or fern-like nature, the mass of vegetation will tend to filter off all sediment while allowing water to pass through. The coal may possibly be formed by decomposition *in situ* of the vegetable matter, the shells once present being completely decomposed by solution in water highly charged with carbonic acid, and the lime replaced by iron. As Mr. Sorby has so ably shown, lime produced from certain shells is peculiarly liable to be replaced by iron. It is a curious fact tending to confirm this hypothesis that not a single shell has been found in this ironstone, in spite of the thousands of tons of it that have been taken out.

Some details of the mode of occurrence of this ironstone are published in the "Iron Ores of Great Britain," by Warington Smyth, Part IV. pp. 277–279, and an analysis is given by Mr. Dick, p. 291.

3. Woodhead Coal and Woodhead Sandstones.

The rocks of this group possess such well-marked characters that it has been possible to trace them continuously over nearly the whole area, except, of course, where they crop out under the cover of Triassic rocks. A boring put down at the bottom of the shaft at Park Hall Colliery penetrated all the members of this group, and proved the succession to be as follows in descending order:—

	ft.	in.
Black shale or bass	10	0
Woodhead Coal	2	10
Pricking and Ouster Coal	1	0
Nodular sandy marl (Conglomerate rock)	10	0
Dark shales with harder bands in lower part	40	0
Flaggy sandstones with thin partings	170	0
Finely fissile grey sandstone	50	0
Fine grey sandy shale (dark shale below)	40	0

The peculiarly hard black shale or bass at the top of this group makes an excellent roof to the coal workings. It can be easily recognised in the field, both from its nature and from the band at its base, locally known as the Fish-bed, which is so peculiarly full of these remains. The amount of them may be best understood by walking along the line from the Foxfield colliery where the metals are ballasted largely with this band. About every third bit of shale, if not too decomposed, will be found to contain fragments of fossil fish. At the Kingsley Moor pit they are equally abundant, but further to the south and east, though still abundant, they are present in smaller quantity.

The Woodhead Coal is about 2 feet 10 inches thick, and of fairly good quality. It is essentially a non-bituminous coal and can be taken out in large blocks, as may be noted at any of the coal staithes, such as the Woodhead. At the base of the seam is some shale and shaly sulphurous coal, about 1 foot thick in all, which is taken out in working the coal.

The bed locally known as the Conglomerate-rock is a rather hard sandy shale, portions of which are cemented together so as to form ferruginous balls, harder than the rest of the bed. From the presence of these balls the rock has acquired its name. The shale on which this rests is softer and not quite so dark in colour as the bass. These dark shales above and below the coal serve to distinguish it at once from any seam at a higher horizon.

The rocks forming the lower members of the group may be briefly described as a thick mass of flaggy sandstone (the Woodhead or Kingsley sandstone), passing through the stage of a very shaly sandstone to a sandy shale. The whole, in fact, forms a perfect transition from sandstone to the dark shales of the group below. There is no other rock in the district at all like this Woodhead flaggy sandstone, and a good outcrop of it is unmistakable.

Natural Exposures or Outcrops of the Group.—The coal with its associated rocks are cut open in the side of the small stream that is crossed by the by-road from Dairy House Farm to Above Park, the road leaving the stream close to the point where the coal crops out. The latter is here 2 feet 9 inches thick; the top and base being clearly seen. A little further north a fault throws the beds down, and the coal is seen at the surface again higher up the stream, as shown on the map. Below the coal an excellent section occurs here of the flaggy sandstones. The group of beds can be traced in a southerly direction towards the by-road already mentioned, and the coal has been cut open in forming a drain. This outcrop ends against the fault referred to above, which brings up the flaggy sandstone against the coal. After crossing the fault the flaggy sandstone can be traced for some distance, and a trial shaft was sunk in it. The further outcrop of the coal to the south could not be traced, nor could the sandstone be followed far beyond the trial sinking.

A complete section of the Woodhead Coal and its associated rocks occurs in the small stream that rises on Kingsley Moor and flows north through Hollins Wood. It begins at a point about 500 yards north of the meeting of the three roads. After passing some fissile sandstone, soft sand rock, and the typical pale marly shale, a small adit is reached driven in the Woodhead Coal. The seam is still visible, but the underlying beds are covered with the tip from the adit. A few yards further on a fault is seen throwing down to the north and repeating the beds, so that at the junction with the next small stream the upper part of the bank is formed of the black bass above the coal, which is well exposed here, and is about 2 feet 9 inches thick. Below the coal is a few inches of cannel shale, like that under the Rider Coal. This is succeeded by the slicken shale and impure coal known as the "Ouster." The conglomerate rock described above occurs beneath this, and is about 6 feet thick. This is succeeded by shaly clunch and lumpy shale, which passes to a mass of dark shale some 30 feet thick. This rests on the typical flaggy Woodhead sandstone of which a complete section is seen, and the gradual passage from the base of the sandstone to the dark shale of the group below is well shown. By the aid of this section this group of rocks can be identified in any part of the area where reasonably good exposures occur.

To the east of this stream the rising ground, formed by the sandstone and the traces of old outcrop workings, enable the position of the coal to be traced as far as Hazles. Here the ground is somewhat obscured by faults, proved in working the Froghall ironstone, but nearer Kingsley the coal can again be traced by old crop workings. The village itself stands on the sandstone, of which there are numerous sections hereabouts. The typical thin-banded rocks are well shown in a quarry on the edge of the Churnet Valley at the south-west corner of the plantation due north of Kingsley.

Close to the brick bridge, where the footpath crosses from Kingsley school, the stream has cut open the dark shale below the coal. Between the bridge and the small plantation close by a band of indurated mudstone occurs in the shale, which contains numerous fragments of fossil fishes, as well as abundant specimens of *Carbonicola* and *Spirorbis*. A few feet above this mudstone is a ferruginous nodular band crowded with casts of *Anthracomya*. A little higher up in the series, but lower down the stream, is a lenticular speckled siliceous band containing numerous plant remains. The sandy material below the coal occurs a little further on, and then the coal itself crops out in the bank, succeeded by the black bass, and still further south by the grey shales of the group of beds above. A slight change in the dip brings the coal to the surface again, a little above the Cheadle and Froghall road. To the north-north-west the coal lies close to the surface for some distance and crops out again about 200 yards north-east of Shaw House. It here covers a rather broad strip of ground, and at its base is a thin band of cannel shale containing compressed shells, mostly *Carbonicola*.

The sandstone is seen in the sides and bed of the stream for some distance below the Cheadle road, after which it is faulted up and fragments are then seen in the hedge sides on the west side of the valley.

To the south of the fault that crosses by Woodhead Hall the black bass has been dug out to form the dam for the fish ponds, while fragments of the Kingsley sandstone cover the fields about Woodhead Farm and Abbotshay. In addition, small sections of the sandstone are seen in the sides of the old tram line near the hall. Further south the position of these beds is for a short distance completely obscured by the belt of Bunter sandstone; but to the south of this strip the Woodhead rock is repeatedly cut into by the small streams that rise about Hill-top to the north of the Alton Road. The outcrop workings of the coal can be traced over most of the area to the east and south-east of Cheadle. Close to the farm of Rakeway, on the Croxden Road, is a rather deep pit from which shale has been dug for marling the fields, and much coal is seen about the sides of this. The shale seems to be the Blackbass and the coal the Woodhead, but this was not clearly proved. Beyond this the coal and sandstone pass under the Bunter sandstone, and their further course is unknown.

In addition to the outcrop of these beds, which belongs to the Cheadle basin, there is a second outcrop due to a sharp syncline in the Churnet Valley, which corresponds to the ending off of the large north and south faults of the Froghall and Ipstones area. The outcrops of the sandstone and coal on the western edge of this syncline are shown on the map. The coal can be easily traced owing to the numerous sections shown in the small streams that drain east into the Churnet; indeed, some of the oldest workings in the Woodhead Coal occur in the neighbourhood of Woodhead Hall, and the seam has derived its name from this fact. Of the many sections north of Woodhead Hall one of the most interesting is that in the streams due east of Thornbury Hall, where the whole thickness of the sandstone is cut through. The rock is, on the whole, less flaggy than usual, though it forms a succession of features due to the presence of softer partings. In addition, parts of it are cemented by carbonate of iron or lime, and are then intensely hard. To the south of Woodhead Hall the coal forms a small outlier on the crest of the small anticline that separates the main Cheadle portion of the coalfield from that in the syncline to the east. This syncline has already flattened considerably before the red rocks close by are reached, and probably does not extend far under them.

Details of the Woodhead Coal.—This coal has an average thickness of about 2 feet 10 inches, and is of fairly good quality as a rule. Its extensive working is in part due to the nature of the beds immediately above and below it. These form an excellent roof and floor, and the cost of timbering is unusually small. In this respect it contrasts strongly with the seams above, most of which have either a bad floor or roof, or both, and the expense of timbering is much heavier. The workings near the outcrop in the northern and eastern area are of great antiquity, and, as a rule, no details of them can now be obtained. In the western and south-western part of the coalfield, however, the outcrop is largely obscured by wash, and possibly by faulting, and, in consequence, the coal is mostly untouched. The most south-westerly portion of the outcrop occurs under the Bunter, and still less is known about it.

The coal in the small detached area to the east lying in the syncline referred to above has been worked out. In the main basin, in the area north of the Dilhorne fault, most of the coal has either been won, or is in process of extraction by the Foxfield, the Hazelwall, Kingsley Moor, Parkhall, and Cheadle Park collieries. In the area intersected by the east and west faults to the south of Dilhorne, none of the coal has yet been touched, nor has any under the narrow strip of red sandstone at Cheadle. If the latter be worked, great care should be taken not to let the water in from this sandstone, as the workings all round might be flooded by the great quantity of water known to be present in that rock.

To the south of these faults in the Cheadle district, the coal has been won as far west of the outcrop as the Birches Colliery, where the workings were stopped by a large fault trending north-north-west not far from the shaft. About Cheadle Mill and Rakeway to the south-east of Cheadle, the coal deteriorates, and is apparently not worth working.

In addition to the area being worked, there is thus left the whole of the coal south of the Dilhorne fault, except the small part to the south and east of Cheadle. There must therefore be an area of at least two square miles still remaining. This calculation is based on the supposition that in the southern area the coal crops out to the west as it does in the Foxfield area. But it is quite possible that this may not be the case, and the coal may continue on into the Potteries coalfield. The extent of the seams in this south-westerly direction can only be proved by boring. In any case the coal must be overlain by a greater or less thickness of Triassic rocks, which in this district contain a quantity of water, and may prove a considerable obstacle to further workings in this direction.

4. Lower Pale Group.

To the north of the Dilhorne fault and the tongue of Bunter at Cheadle, these rocks cover a considerable area, roughly quadrangular in shape. The outer or basal limit is practically the Woodhead Coal, the outcrop of which is shown on the map. A few small exposures occur on the western part of the coalfield south of Dilhorne, but the Coal-measures here are for the most part buried under the Triassic rocks. On the east of the Tean and south of Cheadle another fairly large area is composed of these beds, but they are again buried under the Bunter in the vicinity of Huntley.

The greater part of the group is penetrated in the Foxfield shaft (see page 52), which starts practically at the Dilhorne Coal. This coal is some little distance below the top of the group, conveniently taken as the Four-foot Coal, and the top portion of the group has never been proved. But by the aid of the railway cutting at Cheadle and information obtained in working the Dilhorne Coal, the following section of the beds of this group, in descending order, may be given:—

	ft.	in.
Measures	120	0
Coal (good quality)	2	0
Measures	60	0
Dilhorne Coal (3 feet at Huntley)	6	0
Measures	190	0
Alecs or Upper Stinking Coal	3	9
Measures	65	0
Foxfield Coal	1	8
Measures	196	0
Cobble Coal	1	3
Measures	55	0
Coal	1	1
Measures	95	0
Rider Coal	1	6
Measures	125	0

Exposures of this Group at the Surface.—In the northern part of the outcrop of these rocks good sections are met with in several of the streams. Commencing with the one that flows between Dilhorne and Cheadle at Parkhall, and ascending the eastern branch, a good section of the Dilhorne Coal is seen not far from the farm. The whole of the seam is not exposed, but the base can be accurately studied. It consists of a 9-inch hard band, containing films of soft coal and jet. This rests on typical clunch composed of fine sand grains cemented by a small quantity of argillaceous material. It contains rootlets and is devoid of bedding. A little above Park Hall Colliery some of the typical pale-weathering marly shales, the dominant constituent of the group, are seen. North of Parkfoot there is an almost continuous section for some distance mainly in this material; the softer part contains numerous balls of impure ironstone that weather to hollow cases. Just below Holleygrove is a thin coal (4 inches) with a hard band above and clunch below. Grey and dark shales are seen some distance further up, and these must be close above the Stinking or Alecs Coal, as from the account of the shaft there are no such shales till we reach this coal. A fault proved in the Hazelwall Colliery repeats this shale, and it occurs again in the stream, and about the roads close to Above Park, where the old workings in Alecs Coal can still be traced. The peculiar pale weathering of the beds of this series is well shown about the banks of the brooks in this neighbourhood, and a specially good section occurs in the brickfield attached to the Hazelwall Colliery. The section here is grey shale, a few feet; Foxfield Coal, 18 inches; grey shale, 10 feet; sandstone, 14 inches; with soft grey shale below. The grey shale is a soft, marly rock that falls readily to very soft clay; as already noted, it is the typical and most abundant rock in the series.

Starting again from Parkhall and ascending the west branch of the stream (Godley Brook), typical pale rock is first seen, and then the south-west bank is occupied for some distance by the base of the Dilhorne Coal. Taking the right branch at Birchenfields some low mounds are seen on the west side of the brook, which the spoil-heap shows were workings in iron nodules and possibly the thin continuous band seen in the banks of the stream. At the base of this band are some much crushed shells resembling *Carbonicola*. This bed (? No. 8 of the Foxfield shaft) is repeated by a fault a little further on. The small seam of coal (? No. 9) is also exposed here. Above this is soft sandstone and sandy marl for some distance. Below Hatchley a few feet of dark shale is associated with a curious rock, composed of mud or shale cemented by brown ironstone material. Where the iron is at a maximum the bed is intensely hard, and in addition contains threads of jet. This rock is violently contorted, but no actual fault was observed, though it lies almost in line with a fault proved further east. No fossils were found in this rock, but it is worth a more careful search. After passing some more of the pale rocks a dark shale is reached, and numerous pits are seen round about. These were sunk to the Alecs or Stinking Coal, the top of which is exposed in the bed of the stream. The dip which hitherto has been to the south-west now turns round gradually to the south-east, and is at a rather higher angle. A little north of Dairy House the stream flows in a small gorge cut in the sandstone and shale above the Woodhead Coal. A fault crosses a little further north and repeats part of the series, for the Rider Coal is met with higher up the stream. Still higher up is the outcrop again of the Woodhead Coal, underlain by the typical flaggy sandstone. The two small streams that flow down through the woods at Foxfield Colliery, and unite to form the west branch of Godley Brook, both give good sections. In Pearcroft and Foxfield Woods the steady increase in dip as we go west from the colliery is specially well shown. At the shaft it is about seven degrees to the east. From this point it steadily rises till at the head of the little stream it is at least twenty degrees in the same direction. This increase in dip is even better shown in the next wood to the south (Broomyclose Wood), for here the section continues further to the west, and in the last rocks seen the dip is about forty degrees. In both woods the outcrop of the Stinking or Alecs Coal is exposed with the beds below and above; while the Foxfield Coal also crops out in Broomyclose, about 300 yards below the higher loop of the railway. To the south of this wood is a narrow plantation with a small stream flowing south to the fish ponds. On the west edge of this plantation a coal has recently been cut open in draining. From the nature of the dark shales associated with it this should be the Woodhead, but its identity is doubtful. It will be noted in examining the rocks in the woods, and still more the shales further west, that many of the beds have a pronounced red colour not observed in the rest of this area. It is possible that this is due to staining from the red rocks that once covered the whole district. In the streams that rise about Kingsley and Kingsley Moor and unite on the east side of Cheadle, numerous sections of the lower pale series occur, but they are disconnected, and the horizon in them is usually difficult to fix. In addition to the pale rocks, which are indistinguishable from one another, the grey shale above the Stinking Coal is seen close to Harewood Hall, and the coal is cut open in the bank of the small stream, about 500 yards north-west of Booth Hall. At this farm a bed of sandstone makes a good feature that can be traced for some distance, and in a small pond close by is a little band of dark shale, said to be some 15 feet above the Cobble Coal, and thus fixing the position of that seam.

In the stream below Booth a thin seam of cannel shale occurs at several points, but its position cannot be ascertained from the sections of the shafts. It should be some little distance below the Cobble Coal. Apparently the same bed is seen in the small sandstone quarry close to Shaw; it is here some eight feet above the sandstone. Numerous small exposures of the pale rocks occur on the sides of the fish ponds near Shaw, and a trace of coal seen on the edge of the most westerly may be the outcrop of the Rider Coal.

In the stream that flows down from Hazlescross, past Kingsley to Cheadle, numerous sections occur, the most interesting being those associated with the coal seams. Those involving the Woodhead have already been given. The Cobble Coal is twice seen. About Hazlescross it occurs about the bed and banks of the stream (see map), and is again repeated by faulting in the stream close to the footpath from Kingsley Moor shaft to Hazlescross.

Much further south another section is shown in the stream due east of Broadhay, which is as follows in descending order :—

Pale marls.
Coal, 1 foot.
Cannel-shale, 1 foot 6 inches.
Fireclay, 4 feet.
Sandstone, base not seen.

The cannel shale contains much bituminous matter, and parts of it can be lighted with a match. *Carbonicola* and allied fossils occur in it, as in the Kingsley area, but they are much flattened. The beds at the southern part of the section are flat, but to the north they rise rapidly, marking the position of a fairly large east and west fault. In the ditch on the north side of the long plantation that reaches nearly to Woodhead Hall, and close to the stream, the Rider Coal crops out for a considerable distance; it has been recently cut open in draining, and shows well the imperishable nature of the cannel shale. Between this locality and Huntley numerous exposures of the pale rocks occur both in the stream and in the brickfields, but unless there is some special band present it is impossible to tell their exact horizon. The cutting at Cheadle Station exposes perhaps the most important section in the whole district. At the west end, and dipping west, are some sandstone bands in marly shales, the latter containing some ferruginous nodules.

These beds are succeeded to the east by a considerable thickness of pale marls, with a two-foot band of dark shale below. The top of this shale is somewhat indurated, and contains numerous fossils, an account of which will be given in a general memoir on the North Staffordshire Coalfield. Below the dark shale there are some three feet of pale marl with another thin dark shale band at the base, resting on a coal seam. This is the Huntley Coal, and is about four feet thick. Below the coal there is more pale marly shale containing little ironstone nodules, and having a seam of cannel shale at the base. Close to the cutting on the north side are the old shafts (Majorsbarn) put down to work the Woodhead Coal, but which were sunk only to the Alecs or Stinking Coal. The depth to this seam proves clearly that the coal exposed in the cutting is the Dilhorne Coal, but it has thinned away so much that the fact has hitherto not been recognised.

Details of the Coals.—The Dilhorne or Six-foot Coal has been worked out north of the Dilhorne fault. In the course of these workings a shaft at Old Engine Farm proved a small two-foot seam of coal, of good quality, about 60 feet above the Dilhorne. This fact is of importance, as a similar seam was met with above the Huntley or the coal of the Cheadle cutting. The Dilhorne Coal is thrown down by the great east and west fault; but, owing to the fact that this fault corresponds nearly to the oncoming of the unconformable Bunter sandstone, the outcrop of the coal does not reach the surface for some distance to the south of the fault. South of Cheadle, there being no Bunter sandstone, the seam again comes naturally to the surface, and is the bed seen in the Cheadle cutting. Owing to its diminished thickness it was not recognised as such; but, as stated above, the Majorsbarn shaft shows that the Cheadle seam is at approximately the same height above the Alecs Coal as it is in the Foxfield shaft. The workings of this seam almost reached the Cheadle cutting, and proved it to be the Huntley seam. In working the Huntley Coal, a two-foot bed of good coal was met with corresponding to the two-foot seam in the Dilhorne area. Moreover, the Cheadle seam continues to thin towards Huntley, showing that the diminished thickness as compared with the Dilhorne area is what would be expected at Cheadle. Putting all the evidence together, there can be little doubt the Cheadle cutting or Huntley Coal is the same as the Dilhorne Coal. The observed dip in the railway cutting enables a rough estimate to be formed of the thickness of the beds between the Four-foot Coal, which crops out close to the Tean, and the Huntley seam; this must be somewhat less than 200 feet. The Huntley Coal was worked from shafts in the neighbourhood of Huntley, and followed almost to Majorsbarn. At the former place the seam is about three feet thick, but thickens slowly towards Cheadle. No faults of any size were met with, and the beds dip about two inches to the yard to the west-south-west.

With the exception of the portion taken out in these workings the Dilhorne or Huntley Coal is intact over the area south of the

Dilhorne fault. It must extend to the west of these old workings as far as a line drawn south from Dilhorne Church through Callowhill. South of the Cheadle road, it is difficult to say how far it extends to the south-west under the Triassic rocks; but it must certainly cover altogether an area of at least four square miles, and have an average thickness of about four feet.

For some reason this seam has been confounded with the Two-yard or Six-foot Coal at the top of the next group of beds; but the fact that the Dilhorne fault throws down to the south makes the idea impossible, and it is not easy to see how this view has been perpetuated. The fact that the Dilhorne Coal underlies the whole of the Delphouse area does not seem to have been suspected, and no effort has been made to work it.*

The next seam of any importance is the Alecs or Stinking Coal; the latter name being applied from the sulphurous smell it gives when burning. It has been worked in several places in this area near the outcrop. The most northerly workings are near Dairy House, and south of Hazlewall; and by their aid the outcrop can be traced for some distance. Some old shafts near Harewood Farm are said to have been in this seam, but no outcrop workings are visible. Traces of shallow pits are met with close to the Cheadle road near Harewood Hall, and trials of the coal were made close to the present Parkhall Colliery. It was here found that the underclay was so soft that it tended to swell up and close the workings, and the amount of timber required to keep them open was too great to enable the seam to be worked at a profit. In the neighbourhood of Foxfield and Dilhorne the coal has been worked to some extent, but the workings never penetrated far from the outcrop, showing that it did not pay to work at any considerable depth.

South of the Dilhorne fault, in the Dilhorne area, a shaft was sunk which reached this seam at a depth of 50 yards. The old shaft lies on the east side of the Forsbrook road, and about 500 yards west-north-west of Callowhill Farm. The beds were found to rise to the west at the rate of 1 in 7. This shaft is of considerable importance, as it shows that the Dilhorne Coal cannot extend as far west as this, while the Woodhead must extend considerably further. The coal in the shaft was of no better quality than usual, and the amount taken out was small.

Still further south, nothing is known of this seam, as its outcrop is entirely concealed by the Triassic rocks.

On the eastern side of the basin, near Cheadle, the outcrop is cut out for some distance by a fault proved in the Birches Colliery; but, as already stated, the coal was reached in the Majorsbarn shaft further west, where it was not considered worth working. Its outcrop was met with some 300 yards to the north-east of Huntley Hall, where it was worked to a small extent, being locally known as the Four-foot Slack. But as usual it was not followed far in from the outcrop.

* A boring has recently been put down south of the Dilhorne fault, to the N.E. of the Cheadle Gas Works, which has pierced the Dilhorne Coal and proved that it is thrown down by the fault.

The Small Seams between the Alecs and the Woodhead Coals.—Between the Alecs and Woodhead Coals, in the Foxfield shaft, four small seams were met with—viz., the Foxfield, the Mans, the Cobble and the Rider. Of these seams, only the Cobble has been worked to any extent.

The Foxfield Coal crops out in Foxfield Wood, near the Foxfield shaft, and again in the brickpit at Hazlewall. It has been proved in other shafts north of the narrow belt of Bunter sandstone, and appears to have an average thickness of some 18 inches. The fact that it has been so little worked, even when close to the surface, suggests that it is of moderate quality; and it is doubtful whether it will ever be worked, even when coal becomes much scarcer. It lies between the Stinking or Alecs Coal and the Woodhead, as already stated, and its extent and position can be roughly inferred from the outcrop of these two seams.

The Mans Coal.—This coal has not been identified at the surface, and there is no certain record of its having been worked anywhere.

The Cobble Coal.—This seam is somewhat thicker than the two previously mentioned, and moreover is usually of good quality. It has consequently been more extensively worked where not too far beneath the surface. So far as can be ascertained, the principal drawback to its working is the fact that it passes insensibly into a kind of cannel shale, to which the coal adheres, and this renders it somewhat troublesome and expensive to work. Its exact outcrop cannot be fixed, but in the northern part of the area this seam extends a little beyond the Kingsley Moor shaft; a line drawn from this shaft parallel to the outcrop of the Alecs Coal in a south-west direction gives a very fair idea of its extent and outcrop. To the south and east of Kingsley Moor the seam is just below the surface at the disused Longhouse shaft, and the outcrop must occur on the east side of the present tramway. South of the fault shown on the map near Booth Hall, the old shaft started just below the Cobble Coal, and the outcrop is at or a trifle west of the tram-line. It is not on at the old Ladywell shaft, but there are numerous traces of some very old workings near here that must have been in this seam. Further south the ground is much faulted, and it is not possible to fix the outcrop, but the old disused pit known as Rimmons, penetrated the coal at a depth of 14 yards from the surface. From this point there is a considerable area more or less dotted over with small mounds, showing the position of the numerous shafts sunk to this coal. The mounds extend to the Woodhead coal-staithes and some distance to the north, while they are bounded to the south-west by the little stream flowing past the staithes.

The position of the coal under the narrow strip of Bunter near Cheadle is not known, but to the south of the town the seam has been worked near the surface, and traces of some of the old shafts can still be made out. From these the approximate outcrop shown on the map has been determined. No record of any workings can be obtained further south till we reach the Eaves farm in the Huntley district, where the seam was worked for some years, and the outcrop workings, which can be easily traced, are shown on the map. It appears to have been followed some distance to the dip, and was last worked from a shaft about 50 yards deep, sunk at the back of the cottages opposite Mobberly: but the coal was followed only for a short distance. That this seam was the Cobble seems certain; for on the east side of the field opposite Huntley Lodge gate a shaft was sunk to a depth of seven yards to a seam locally known as the Four-foot slack. From its thickness and character, this could only be the Alecs or Stinking Coal, for the Eaves Coal is exactly the proper distance below, and possesses exactly the character of the Cobble. It was from 18 inches to two feet thick.

On the western side of the coalfield little is known of this coal. Owing to the high dips to the west of the Foxfield shaft there is some doubt if it is the seam seen in a drain recently cut open on the west edge of a small plantation, about a quarter of a mile north-west of the bend in the road at Dilhorne. There is so much dark shale about this seam that it appears at first sight to be the Woodhead, although so far as can be ascertained it is too thin to be that layer, and an old miner of considerable experience considers it to be the Cobble.

South of the Dilhorne fault the small shaft already referred to, west of Callowhill, shows that the seam extends some distance west of the Dilhorne and Forsbrook road; but further south nothing is known except that it must extend west of the Alecs Coal, but not so far as the Woodhead.

Extent of the Unworked Coal.—The uniform good quality of this coal makes it likely that as thicker seams become scarcer it may be more extensively worked. North of the Dilhorne fault it extends over the whole area within the outcrop of the Alecs Coal, and somewhat beyond. In the northern part it reaches to the road due north of Hazlewood Colliery.

The seam occupies an oval basin, the longer axis of which lies north-north-west and south-south-east, and is about four miles long; the shorter axis being some two-and-a-half miles long. Cheadle lies about the centre of the east margin of this basin, and only the fringe of the coal on this side has been worked.

The Rider Coal.—This seam is usually rather over a foot thick, and has a cannel-shale base. The outcrops of it have been noted already. It is thin and not easily separable from the shale below, into which it seems to pass gradually; consequently, so far as can be ascertained, it has never been seriously worked. It obviously covers the same area as the Cobble, but extends slightly further in all directions around Cheadle.

5. Upper Pale Group.

This group of rocks is confined to the western part of the Cheadle coalfield. Their occurrence is limited to the north by the large east and west fault that passes from Dilhorne to the northern edge of the Bunter at Cheadle. This throws down or brings on these higher beds, and for this reason they are sometimes locally known as the "deep measures." To the east, the small stream flowing past Park Hall Farm and Brookhouses to join the Tean at Huntley, approximately corresponds with the outcrop of the Four-foot Coal, though this seam frequently crops out a little on the east side of the stream. To the west the outcrop of the Yard Coal has been proved under the Bunter sandstone in the Dilhorne area, and of the Four-foot in the Delphouse area, as shown on the map. But south and south-west of Delphouse, although the workings in the Yard Coal have extended as far south as the middle of Huntley Wood, nothing is known of the outcrop of the lower coals beneath the cover of red sandstone.

The following section shows the thickness and nature of this part of the series:—

Section of the beds in the Delphouse area:—

	ft.	in.
Clay	4	0
Coal and smut	2	6
Marl	8	6
Roach (sandy shale) streaked with sandstone	20	0
Grey shale (falls to wet clay)	12	0
Coal, the Two-yard	5	0
Ouster coal and pricking	2	8
Clunch	6	1
Roach and rock binds	18	4
Fairly hard sandy rock, not bedded	27	0
Getley coal (useless)	2	0
Rock, compact sandy material	13	0
Soft grey shale, hard black film at base overlain by shell marl band	7	0
Coal, Half-yard	2	6
Clunch	6	0
Roach and rock binds	16	0
Hard white rock, black streaks	24	0
Grey shale, falls to clay	12	0
Black shale	0	6
Coal, the Yard	3	9
Fireclay	1	6
Hard clunch	6	0
Rock	15	0
Very hard white rock	8	0
Grey shale (seam of dark fossiliferous shale at base)	19	0
Coal, the Litley	2	9
Pricking, 3 in; Ouster coal, 2 ft.	2	3
Grey clunch	6	0
Rock	12	6
Grey shale	14	9
Coal, the Four-foot	3	6
Total	282	0

A great drawback to the working of the coals in this part of the series is the soft nature of the beds associated with them. While some of them have a fairly good roof, nearly all have a bad floor, formed by the white or pale measures already referred to. Even when dry this is soft, and tends to swell up and close the workings, particularly when water is encountered. Owing to the great extent of "Old Man" referred to above, it is at times almost impossible to keep the water out.

Two-Yard Coal.—This seam, which is about five feet thick, has been cut through in the siding from the Delphouse pits to the Cheadle railway, and from this point it can be traced to the margin of the Bunter on the hill above. Its outcrop under this sandstone was met with in the railway tunnel, and a little further south it must turn round and trend north toward the fault close to the road from Cheadle. Although the beds are thrown down to the north by this fault, the Two-yard Coal does not occur over much of the strip north of the road, as it is cut out by an old pre-Triassic valley. It is doubtful if there is any of this coal north of the next east and west fault.

The coal itself, though thick, is of poor quality, and the greater part of it has been worked out. Of the patches left it is probable that much is unworkable owing to their water-logged condition.

The Half-Yard Coal.—This seam varies somewhat in thickness, but the average may be given as two feet six inches. It is of fair quality. The outcrop south of the Cheadle road and east of the Bunter is shown on the map; but only the southern part of this can be ascertained from evidence at the surface. A section of the seam is seen above the mouth of the railway tunnel, where the hard black band with fossils could be recognised when the cutting was first made. This layer forms a fairly good roof to the workings, but the floor is of the usual soft nature. South of the cutting the outcrop passes under the Bunter, and no reliable evidence could be obtained as to how far south this seam extends; but, as in the case of the Two-yard, the outcrop must turn round somewhere under Huntley Wood, and then trend north; for the proved outcrops, under the Bunter, of the Yard Coal show that this seam cannot extend far beyond the ridge above the Delphhouse pits. Over this area south of the Cheadle road much of this coal has been got out. There are patches left, but no plans of these older workings can be found, if they ever existed. North of the fault the coal is thrown down about 20 yards; and, except in the pre-Triassic valley referred to above, the outcrop under the sandstone must extend further west. But there is good reason to believe that most of the Half-yard Coal has been worked out in this strip. Further north, so far as could be ascertained, only small patches of this coal are left, the bulk of it having been taken out.

The Yard Coal.—This is the best seam in the series, and consequently has been extensively mined. The outcrop, as far as is known, is shown on the map. On the eastern side, south of the Cheadle road, there is a double outcrop due to a fault that throws down some 35 feet, and may be seen in the cutting at the entrance to the tunnel. The area over which this coal extends is divided by faults into four parts. The first and most northerly of these lies immediately south of the Dilhorne fault, and a considerable number of pits were sunk to it, the remains of the more recent of which can still be seen. No record of the oldest, near the eastern outcrop, can be found. Close to the edge of the Bunter, at the Dale, south of Dilhorne, a shaft was sunk, from which this seam was followed to the outcrop under the sandstone, and there seems no reason to doubt that it has been worked out in this strip.

In the next strip several shafts were sunk, and one of these is still open. The coal to the east has been won, but whether the coal has been followed from the open shaft to the outcrop under the Bunter, I have been unable to ascertain. The fact of the pit being left open suggests that this was not the case.

The third strip lies between two faults. Close to the four cross roads a shaft was sunk to a depth of a hundred yards to the coal, which was taken out on the rise or west side. On the dip the workings do not extend far, and there is a strip left, the exact size of which could not be ascertained.

In the area immediately south of the fault at the Cheadle road much of the coal has been won; but further south, beyond the Wonder Pit, much of the coal is left. It is impossible to say how far south of the Draycott Cross ridge the seam extends, as nothing is known of it ; on the north side of the ridge it has been worked to some extent, but the workings are old, and no plans could be found.

The Litley and the Four-Foot Coals.—These seams have been mined to a considerable extent, but the workings are rather scattered. As the coals are of rather poor quality they do not seem to have been followed where difficulties were encountered. Close to Parkhall Farm a shallow shaft was sunk to the Four-foot, and it was followed to the fault already referred to as seen in the tunnel-cutting. On the opposite side of the stream these coals lie in a trough, and though they have been followed in from the outcrop on both margins of the trough it is not possible to find out exactly how far they have been worked. On the south side of Cheadle much of these coals has been won for a certain distance south of the fault, but beyond the Wonder Pit little is known of them, and they have probably not been mined.

The question now arises, how far south do the Yard, the Litley and the Four-foot extend under the red sandstone and marls ? As the map shows, the seams lie in a syncline the axis of which trends roughly north and south. This syncline is tilted up towards the south, thus producing a horse-shoe shaped outcrop similar to that of the Dilhorne Coal to the north. If this tilting of the syncline continues toward Tean, as the position of the Huntley, Cobble, and Woodhead seams appear to suggest, then the lower seams of the upper measures cannot extend beyond the south-east end of Huntley Wood. The Coal-measures in this district, however, so often suddenly change their dip that it is possible that these seams may continue further to the south-east, although it is not likely.

CHAPTER III.

TRIASSIC ROCKS.

In addition to the Carboniferous rocks already described, there are present in this district certain sandstones and marls which belong to the Triassic formation. These rocks are for the most part of a reddish colour, and are consequently often known as the red rocks. Their occurrence is partly dependent on the extent to which the older series had been previously denuded; for these Triassic rocks are largely of the nature of deposits in hollows in the Carboniferous strata. The Triassic rocks rest unconformably on the latter, and the map shows at a glance how great that unconformity is.

The Triassic rocks in this area may be conveniently separated into the following sub-divisions in descending order:—

3. Red marl. 2. Sandstones and marls.	Keuper.
1. Sandstones, more or less pebbly, with massed shingle beds or conglomerate near the top.	Bunter.

Bunter Sandstone and Conglomerate.

This division consists of moderately fine-grained sandstones with a rather thick and, over most of the area, persistent bed of conglomerate or masses of pebbles in the upper part. The sandstone itself usually contains some pebbles, but on the whole these are far less numerous here than in the Bunter of the Churnet Valley, or in the typical Bunter of this part of the Midlands. This comparative absence of pebbles can be noted in the hill at Cheadle where sections are numerous; the well sunk in this hill did not pass through a single one of the wedges of gravel or conglomerate that characterise the typical Bunter. The same is true of the sandstone to the east and south of Cheadle, but to the west pebbles are more numerous, and a few small conglomerate wedges occur about Dilhorne and also in the hill over the northern mouth of the railway tunnel. Even here, however, the shafts to the tunnel showed that the bulk of the rock was comparatively free from stones. These shafts also showed that much of the sandstone is almost white when unweathered.

The Bunter forms a horse-shoe shaped escarpment facing Cheadle from all points. There is a projection, however, from this escarpment, on the east, where the Bunter fills an old pre-Triassic valley, and the end of this projection forms the hill at the foot of which the northern part of the town stands.

Natural Outcrops.—As already stated, sections of the Bunter are numerous about Cheadle, especially along the high road. On the west side of the horse-shoe shaped outcrop good exposures occur at Dilhorne and also at the Madgedale Farm. A cutting occurs in the Cheadle Road further south, and there is a considerable amount of bare rock in the face of the escarpment above the Delphouse pits. A cutting occurs on the Uttoxeter Road at Huntley, which shows one rather gravelly band, while the rest of the beds are comparatively free from stones, the few that do occur being distinctly small. The dip can be accurately fixed here, and is about one in fifteen in a southerly direction. It is not easy to say if this is a deposition dip, or the result of slight movements of later age. Small sections are numerous all along the escarpment further east and north-east, but the downwash greatly obscures much of the hill face in this area. Specially good sections again occur on the road to Oakamoor, both ascending the hill and descending it to the Churnet Valley.

The unconformity between the Bunter and the underlying Carboniferous rocks is obvious from the map, but there are two cases in which it is specially interesting. The first of these is connected with the long narrow east and west strip of sandstone on which Cheadle partly stands. The well at the top of the hill is sunk some feet below the level of the stream to the east of the town, yet does not reach the base of the Bunter. Even the cellars of the houses on the north side of the High Street of Cheadle are entirely on the red sandstone; while the Carboniferous rocks are at the surface on the south side of the street. The openings for the town drains showed conclusively there was no fault between the two formations, but that the sandstone clearly lies against the steep side of a pre-Triassic valley; the base of the valley being far below the level of the road. This valley slopes in an easterly direction, joining a much larger old valley somewhere about Oakamoor. The sandstone at Cheadle is, therefore, connected with that of the escarpment, and acts as a great water channel, conducting much of the rain that falls on the latter to the bottom of the deep sand-filled hollow at Cheadle, and thus brings an excellent supply of water to the town. The ground about a mile or rather more north-west of Oakamoor, where the base of the Bunter rises and falls repeatedly, also shows the extremely irregular and hilly surface of Carboniferous rocks on which the Bunter rests.

In driving the Cheadle tunnel a curious rock was met with at the base of the Bunter, which is not seen at the surface. It consists of two beds of conglomerate separated by a thin marl parting. The beds, which are each some 25 feet thick, are composed of subangular stones cemented together by a markedly calcareous matrix. Were the pebbles a little more angular, it would pass well for a so-called Permian breccia. There is no discordance between this material and the rocks above, of the normal Bunter type. The calcareous rock evidently thins away before reaching the outcrop facing Cheadle, and is to some extent overlapped by the normal Bunter. In the hedge side, bordering the alluvium at Cecily Mill, to the east of Cheadle, is a mass of small angular pebbles, which may represent the same material with the lime dissolved out of it. It is not possible to speak confidently of this obscure outcrop, but the stones are exactly like those of the calcareous rock, and quite unlike those of the ordinary Bunter.

Close to the top of the Bunter, and, so far as is known, restricted to this area, is a curious deposit of massed shingle beds or conglomerate, which is quite unlike the wedges of conglomerate so abundant in many parts of the typical rocks. The latter are essentially discontinuous; while the former, as the map shows, form a continuous deposit over a very large area. The stones in it are the typical Bunter pebbles, and are well-rounded and pitted; but the pitting is not so common. There are thin bands of whitish sandstone in the conglomerate, which though only two or three feet thick are continuous for some distance. In many cases they become stony, the proportion of stones increasing till the bed passes to conglomerate indistinguishable from the rest of the rock. These massed shingle beds are extensively quarried for road-metal, their principal component being the quartzite, which forms so large a proportion of the Bunter pebbles. This quartzite forms a very good road-metal when not mixed with too large a proportion of softer material. The principal quarries are at Callowhill on the western escarpment, further south on the hill top overlooking the Delphouse pits, in the by-road that leaves the Uttoxeter Road at Huntley, and on the crest of the hill at every road going in an easterly direction out of Cheadle. There is also a long bare exposure of these gravels at the crest of the Oakamoor Road, which forms a feature in the scenery that can be seen from a great distance to the west.

It will be noted that if we stand on the top of almost any part of the Bunter escarpment these shingle beds keep at almost exactly the same height above sea-level over the whole area. The only exception to this occurs in the by-road referred to near Huntley, where the bed rapidly descends, but whether from a fault, or because it is sloping down into a deep pre-Triassic valley that apparently exists further south near Tean, it is difficult to say.

As we recede from the summit of the escarpment in a southerly direction these beds slowly sink, and give the impression that this fall is due to original deposition. As they do so, the sandstone partings appear to thicken at the expense of the shingle or conglomerate.

Above these massed shingle beds is a thin band of sandstone that is rarely well exposed; partly because it is very soft and easily decomposes; partly because if it occurs in a hill-face it is covered with downwash. It would be more convenient to take the top of the Bunter at the summit of the gravels; but as these are so local it would raise great difficulties in adjacent areas. Immediately above this soft band we reach more coherent material which is extensively quarried, and this is taken as the base of the next division of the Trias.

Keuper Sandstone.

Above the band of easily decomposing sandstone just referred to there are a series of beds of sandstone of a different nature.

The grains of which they are composed are, on the whole, distinctly sharper, and partially cemented by iron oxide; while the beds themselves are more coherent, and in consequence are often quarried for building stone. Though comparatively free from pebbles in some parts of the area, they are markedly pebbly as we approach the old pre-Triassic land surface in the Oakamoor area. But the pebbles are not nearly so rounded as in the Bunter, and there is good reason to believe that they are rarely, if ever, pitted. The pebbles give the impression of being either Bunter pebbles eroded under conditions not specially favourable for the production of a markedly rounded form, or else they were derived from the same source as the Bunter pebbles but under slightly different conditions. The pebbles in both the Keuper and the Bunter are essentially composed of the same material, quartzite being of course the most abundant.

The Keuper sandstone in this area varies much in different localities, according to its proximity to or distance from the old land surface. In the Oakamoor area the sandstone contains much oxide of iron cement, and numerous pebbles. The latter occur both scattered through the rock and also as thin bands of massed pebbles; which, though rarely more than two feet thick or perhaps less, are very persistent, and cemented together more firmly than the massed pebbles in the Bunter. These features are well seen in the head of Ousal Dale, and again in the hill face due north of this valley where the sandstone is quarried. Another quarry at the same horizon in the sandstone has been opened on the crest of the hill near Threapwood Head, on the opposite side of Dimmings Dale, where the rock is almost free from pebbles, and is a fine-grained compact sandstone, forming an excellent building stone, which the quarrymen assert is the same rock as the Hollington stone. No lines of massed pebbles are seen here, on the contrary the only persistent parting in the sandstone consists of fine red marl. The sandstone round about this district possesses a peculiar mode of weathering, forming nubbles or small hillocks that project from the general surface of the ground. This peculiar mode of weathering may be due either to the irregular hardness of the sandstone, or to the uneven surface on which the overlying marl once rested. The latter is probably the true cause, as the marl here rests on a very irregular surface of Keuper sandstone. These surfaces can be met with at intervals as far south-west as Gorstyhill, a little north of Tean.

Both in Dimmings Dale and in the smaller valley that trends south towards Hollington, the Keuper sandstones retain their hardness, and often form bold crags such as are never seen in the Bunter in this particular area. These crags are a well-known feature of Dimmings Dale, and indeed give the character to the Dale. A specially bold crag occurs on the south end of the tongue of sandstone that projects into the marl area south of Alton Common. Pebbles are fairly common, and thin lines of massed pebbles also occur here, but they are not so prominent as in Ousal Dale nearer the old land surface. Further south another conspicuous crag is seen above Lightoaks Farm, where the pebbles are in still smaller quantity. Further west the Keuper sandstone is not recognisable till we reach the ground on the south side of the Cheadle Tunnel. Here the beds are usually softer, and contain only minute and scattered pebbles in certain parts of the rock. Much of the stone is white when unweathered, as shown by the material taken from the shaft near the tunnel.

In a number of old marl pits to the west of the road to Draycott Cross, near the old shaft, soft marly sandstones associated with marly partings may be noted. These form a kind of passage from the sandstone below to the marl above and are included with the former. No such passage material occurs in the eastern area just described.

Keuper Marls.

These marls are of the usual red colour and character so well known in many parts of England. They are confined to two parts of the present area. The first, which lies between two faults, occurs about Cresswellford and Draycott; the second is shown on the south-eastern edge of the map, south of Alton Common. About Cresswellford the marl contains at times the typical hard thin skerry sandstones with casts of crystals of rock salt. It passes insensibly to the underlying Waterstones by a gradual increase in the amount of soft red marly sandstone present in the lower part of the marl.

The relation of the marl to the Keuper sandstone is different in the area of Alton Common, where there are no passage beds of any importance. Indeed, in this area, near the old pre-Triassic land area, there is a distinct local unconformity between the marl and the underlying sandstone. An excellent example of this unconformity may be seen in an old marl pit, near the farm on the south side of Threap Wood, where a nose of sandstone projects into the horizontal marl. Moreover, small patches of marl are often seen lying between the projecting nubbles of sandstone referred to above. On the north-east side of the bold crag, south of Alton Common, the marl appears to be banked against a cliff of Keuper sandstone. The junction at first sight suggests a fault, but no evidence of faulting was found on tracing this junction on the ground.

In both districts numerous pits have been opened in the marl, and as might be supposed these are most numerous in the neighbourhood of the dry sandstone areas.

CHAPTER IV.

PLEISTOCENE AND RECENT.

Glacial Drift—Boulder Clay.

The distribution of the Boulder-clay, or true Glacial-drift, will be best understood by the statement that all but the margins of the Cheadle table-land are now practically free from this deposit. To the north-west of the area true Boulder-clay occurs, and this forms the taper end of the great sheet of Drift that extends from the Cheshire Valley. About the head of the Consall Valley this Drift is not thick enough to map, but north of the village it gradually thickens, though even here the outcrop of the grits is clear. Still further north, about Parkhouse, the Drift is thick enough to completely obscure the western outcrop of the Third Grit, and in the former survey of the district this bed was missed. Foreign boulders are fairly abundant in the Drift here, the more common being fragments of Eskdale and Ennerdale granite, and the ash-rocks of the Lake District. Of the smaller pebbles by far the most common are the greenish greywacke, which probably comes from the southern part of the same district; but their origin has not been satisfactorily traced. The boulders may be examined in a little disused brick-pit close to the Consall Village road, and about quarter of a mile east of Wetley Rocks. On the edge of the by-road to Folly and Parkhouse farms, to the north of the pit just referred to, a small heap of fragments of these Lake District rocks gives an excellent sample of the more abundant types of these foreign boulders.

A very small patch of typical Boulder-clay occurs to the west of Dilhorne, on the extreme edge of the area here described. It forms a part of a small isolated deposit of Drift that has been banked up against the east side of the hill of Bunter sandstone. At the edge of the map, at Forsbrook, another small patch of this material occurs, which is also the edge of a good-sized mass of Drift to the west.

Doubtful Drift Deposits.—Bunter pebbles occur more or less abundantly over the whole of the area described; but it is doubtful whether these pebbles should be claimed as a true glacial deposit or are merely the stones left after the clay matrix had been washed away.

Every gradation is met with from isolated pebbles far apart, and which would almost escape notice but for artificial openings, to a deposit at times three feet thick composed of clay crowded with Bunter pebbles, but containing no far-travelled rock fragments. The view that they are simply a remnant of the Bunter that once undoubtedly covered the whole area, seems very unlikely when their position is noted, for in some cases these pebbles occur on the Keuper sandstone which contains no such well-rounded pebbles. They must, in such cases, have been distinctly lifted up to some extent in order to occupy the position in which they are now found.

A kind of connecting link between this wash-like stony material and the more normal Boulder-clay occurs in the long hollow through which the by-road passes from Dairy House to the farm north of Bank Top, in the north-western part of this area. The deposit seems to continue for some distance down the main valley keeping on the west side of the stream. It appears to merge into the typical "wash" so abundant in this district at the foot of long slopes. Bunter pebbles are abundant in the higher part of the deposit about the road, but they appear to decrease steadily close to the stream. Whether this material is a true glacial Drift or not is difficult to decide. It is difficult to believe, however, that it is not in some way connected with the breach or hollow in the outcrop of the grit that occurs at the fault shown on map. It is possible that either the ice sent a small tongue through here, or more likely still that a small sub-glacial stream carried the material through this hollow as the only means of egress of the water.

Another small area where these pebbles are present in great numbers occurs on the west side of the stream above the Cheadle Gas Works.

On top of the Bunter table-land here and there are small patches of clay material containing pebbles, many of which lie with their longer axes vertical. These deposits are not usually more than a foot or two thick, and can rarely be detected unless exposed in some artificial opening. Two instances of this material may be noted, the first at Callowhill, south of Dilhorne; the other at the small pit at Rakeway Head, south-east of Cheadle. A little south of the last pit there seems to be a similar deposit of clay on the rising ground at Cheadle Common; but there are no good openings in this.

On the Keuper sandstones to the north of the Alton Road, well-rounded pebbles occur scattered over the surface of the ground. These have undoubtedly come from the Bunter, for no such pebbles occur so high up in the Triassic rocks as this.

A possible explanation of the phenomenon of the occurrence of these Bunter pebbles unaccompanied by any far-travelled boulders is that they were collected from the Bunter on the immediate margin of this area (west and north-west) and were entangled in the upper layers of the ice sheet, while the far-travelled boulders were buried at lower levels in the ice. On reaching the margin of the table-land, owing possibly to waning strength of the movement of the ice, only the upper layers containing the locally-collected Bunter pebbles, were driven over. In a few places on its north-west margin, however, the lower layers were forced over the edge of the higher ground, and here alone the foreign boulders are found.

Area East of the Churnet.—To the east of the Churnet, the distribution of the boulders of Millstone Grit seems to show clearly that the whole district was once covered by a moving ice sheet capable of transporting large blocks of stone considerable distances. In this district many of the walls of the fields are built of blocks of the First and Third Grits. These are often a considerable distance from any outcrop of these rocks, and the shape of the stones in the walls is conclusive that they are broken up loose blocks, and have not been obtained from a quarry. A little consideration of the amount of material required shows how numerous these blocks of grit must have been before the fields were cleared. Such blocks are still numerous in the beds of the small streams from which, on account of their weight, it did not pay to lift them. The most conclusive evidence that these grit blocks are really a form of glacial Drift was shown in quarrying the fireclay below the Crabtree Coal close to the small stream below the little lane at the south end of Ipstones. Here the sloping surface of the rock in the bank-side is covered with a curious clay containing large blocks of grit, though these are not so well rounded as one would have expected. This deposit is overlain by wash, several feet thick in some places, with no grit boulders in it. The grit-bearing clay is thus older than the wash, and as the grit blocks have travelled some distance, the deposit is probably a true boulder-clay. There is, however, no deposit of similar clay on the flatter ground above the hollow in which the stream runs, the grit blocks alone being met with.

Patches of clay with Bunter pebbles occur here and there in the gently-sloping hollow between the old Whiston Works and Shirley Common, and though in some cases it is fairly easy to define the limits of this material, in many places it was impossible to do so, for it tails away till it is either too thin to map or disappears altogether. A small pit in this clay occurs close to the high road to the north-east of the works; while a much larger one is seen on Shirley Common where the Whiston Road crosses the Caldon Low Tramway. Part of this latter clay rests on a Grit, below the Third-grit, and from its position and composition can scarcely be of the nature of wash. Indeed it is difficult to see how this can be anything else than true glacial Drift. This, as noted above, leads to the conclusion that the Bunter pebbles scattered over the entire country are the remains of glacial Drift from which all the softer clay matrix has been washed away.

Rain Wash.

Any one familiar with the north of England or Scotland can scarcely fail to be struck with the amount of wash or material that has been accumulated in this area at the foot of slopes, even when these are at a comparatively low angle. Though this material is present in the more northerly districts, it does not attain anything like the thickness observed in this part of Staffordshire. It is derived partly from the soft shales and the Drift, but more especially from the Bunter, in which latter case it obscures the base of that sandstone. It also causes at times a difficulty in fixing the limit of the alluvium, for the very fine material of which it is composed is washed down over the edge of the equally fine alluvium, and conceals the true junction of this with the rock slope or Drift. It strongly suggests that the glaciation of this area must have ceased, and more modern conditions of denudation begun much earlier than in Northumberland and Scotland. As the remarks on the doubtful Drift show, this wash often bears a very close resemblance to the clay in which the Bunter pebbles occur; in most cases it is this resemblance that raises the doubt whether the stony clay is true Drift or not.

Alluvium.

Only in the bottom of the Churnet Valley does the alluvium attain any size. In the case of all the other streams it is so small as to be scarcely worth showing on a small scale map. Even in the case of the Churnet, where the river flows through the gorge-like hollow north of Consall Forge, the alluvium is almost too narrow to map; and further south as far as Froghall. it is still narrow as a rule. To the south of Froghall and to the north of the gorge, it attains some considerable breadth. This is due to the rocks of the valley being softer, and in consequence a deeper and broader hollow has been eroded. In addition the material of this alluvium is a very fine water-tight silt, and essentially of the nature of a material filling up a hollow, rather than the usual sand and gravel seen where a river is eroding its base. This is specially noticeable in the case of the northern area, where the Churnet has silted up what is practically a long lake-like hollow extending far to the north past Cheddleton, Leek, and Rudyard.

Terraces.—In its passage through the gorge the Churnet has formed a few very narrow river-terraces, but these strips have been so much interfered with in making the canal and the railway that they are now scarcely traceable.

CHAPTER V.

WATER SUPPLY.

A large quantity of water can be obtained in this area from both the Triassic sandstones and the Millstone grit, as proved by shafts and borings. The geological survey of this district enables us to fix on certain places specially suitable for borings or sinkings for water.

Triassic Water Supply.

The town of Cheadle is supplied with water obtained from a well sunk through the Bunter sandstone that forms the rising ground at Cheadle. The well is sixty-five yards deep, and the base of it is some yards below the bed of the stream at Cecily Silk Mill, which lies a little east of the town. The well does not reach the base of the Bunter, which fills an old pre-Triassic steep-sided valley. This valley has been proved to continue to the east, and the rock that forms Cheadle Hill is continuous with the main mass to the south-east. This narrow valley filled with porous sandstone acts as a great water channel carrying a considerable portion of the rainfall on the Bunter escarpment area to the base of the well at Cheadle. In order to test the amount of water available the pumps were worked continously for fourteen days, pumping at the rate of 120 gallons a minute, without lowering the surface of the water more than about two feet.

Immediately south of the Cheadle Railway Tunnel the Bunter lies at some distance below the surface, being let down by the two trough faults which are shown on the map. Not far from the tunnel a shaft was put down in search of coal, but the quantity of water met with was so great that after passing through the Keuper sandstone, a few yards only of the Bunter was pierced before the work had to be abandoned. For a considerable distance from this shaft, both in a north-western and south-eastern direction, between the two trough faults, a large quantity of water could be obtained, especially near Tean where there are indications of a locally deeper pre-Triassic valley.

Near the face of the horse-shoe shaped escarpment of the Bunter not much water is usually met with, because the surface of the underlying Carboniferous rocks usually slopes away from the escarpment, but further away from this of course the amount of water will steadily increase.

As might be expected, strong springs issue from the Bunter, where the base of this rock descends to the bottom of the Churnet Valley, as about Oakamoor and further to the north-west about Eastwell. About Alton the base of the Triassic rocks must be far below the level of the river, and an abundant water supply would be available; but some recent trials suggest that, as the Trias in this area is largely capped with red marl, the water may contain much sulphate of lime, and be unduly hard.

Millstone Grit Supply.

The old shafts sunk in the neighbourhood of Ipstones proved the presence of large quantities of water in these grits, especially the Third. These grits slope down toward Froghall in the Churnet Valley. A shaft or boring put down in the vicinity of the bridge, or anywhere between the two parallel faults bounding the Ipstones Valley, would tap a large volume of water which would probably rise to the surface, as there must be a strong head of it owing to the height of the gathering ground above Froghall. The First Grit has a large exposed outcrop to the north and east of Whiston, so that a copious supply could be tapped again in the Churnet Valley by a shaft or borehole put down due south of Dustystile. There is no doubt that the water would rise to the surface here, for a borehole at least fifty feet above the river and close to the little stream on the east side of Woodhead House was put down to this grit, from which the water has poured out at the surface for years without intermission.

About Consall Forge and Consall Valley, to the west, similar good sites can be selected for obtaining water from these grits, for there must be a large amount banked up against the west side of the long fault trending north-north-east which passes close to Consall New Hall.

The faulted nature of the country greatly aids at times in the circulation of water underground, and an excellent illustration of this occurs to the north-north-east of Foxt. The Third Grit is faulted against one of the lower grits which here begin to assume importance in this series. A boring sunk close to the fault taps not only the water of the thinner and lower grit, but also that from the far thicker Third Grit which is faulted against the smaller bed. The quantity of water thus brought into the boring is so great that it overflows at the surface and has been taken to supply the village of Kingsley, on the opposite side of the Churnet Valley.

Supply from the Coal Measure Sandstones.

Broadly speaking, water does not circulate freely in these rocks, and the amount available is often not more than sufficient to supply the needs of a house or farm. Indeed the Woodhead sandstone is the only bed from which any appreciable amount can be obtained. This so often forms the bearing rock of the Churnet Valley that a considerable part of the rainfall that sinks into it escapes at the base of this long outcrop, giving rise to the landslips, previously referred to, in the shales of the lowest Coal-measures.

CHAPTER VI.

STRUCTURE AND FAULTS.

There are really two structures in this area, one of which is pre-Triassic and affects the Carboniferous rocks only; the other post-Triassic, which locally modifies the older structure but mainly affects only the Triassic rocks.

Ignoring the uncontormable cover of the latter, the Carboniferous strata lie in what is usually called a basin; but a far more apt simile would be to compare it to a large fresh-water mussel shell. The long length of the shell lies north and south, and the hinge to the west. At this side are the steep dips, and it forms the deepest part of the shell, from which the beds rise gradually in all directions. The structure is modified by faults mostly of pre-Triassic age, but an important local modification has been produced by the two dislocations that affect the Trias in the Draycott area.

The Bunter sandstone was deposited upon the Carboniferous rocks, which were eroded after this shell-structure had been formed; and, in spite of the extreme irregularity of the base in many cases, the Bunter is built up of horizontal, though often lenticular beds. Though this horizontality has been locally destroyed by the three post-Triassic faults shown on the map, it is, on the whole, fairly well preserved, as is shown by the outcrop of the massed conglomerates or shingle beds, which occur at nearly the same height above sea-level over a large area. The most striking feature of the district is the bold escarpment of the Triassic rocks, which in horse-shoe form faces Cheadle. A subordinate feature is the outlying hill of Bunter at Cheadle, which serves to testify that this deposit once covered the whole area, and that the escarpment is the result of comparatively recent denudation.

Faults.

The area is greatly affected by faults, many of which have been proved in the course of mining the coal and ironstone. Those that occur in the ironstone area usually cut the grits of the Millstone Grit series and can be traced at the surface; but in the Coal-measure area it is impossible at times to see any trace of the dislocations unless they cut the well-marked Woodhead sandstone.

There are faults of two ages present; the majority are of pre-Triassic age, and, as the map often shows, they do not affect the outcrop of the Bunter sandstone; there are, in addition, a few faults of post-Triassic age. Some of the faults vary rapidly in the amount of their throw, while a few may vary little over a considerable distance. There is a certain tendency for these dislocations to occur in groups in one area, while the adjacent district may be comparatively free from them.

A group of faults occurs in the Ipstones, Froghall and Churnet Valley areas. In the neighbourhood of Ipstones the two parallel faults throw in opposite directions, and let down a long strip of Coal-measures between the Millstone-grits. About the middle of the deep hollow both of these faults must have a throw of more than 200 feet, but further south the throw slowly diminishes till at length they appear to die out. The fault trending north-west and south-east from Belmont Hall towards Froghall is well shown at the surface. Close to the hall it throws the First Grit against the Third, while in the lane south of Booth, the First Grit is brought against the Crabtree Coal, in which a small opening has been made. In the Churnet Valley the ironstone is much below the level of the river bed, while on the opposite side of the dislocation it is on top of the hill. The fault west of Pettyfields was proved in mining, but its further course is clearly marked by the displacement of the Woodhead and Rider Coals, which are thrown down to the east about 150 feet.

The fault on the west side of the First Grit about Belmont Hall is shown by the workings of the Crabtree Coal and gannisters in Coalpit Wood. These rocks are about 120 feet above the grit, but the fault has thrown them down to the west till they are considerably below the base of that rock.

In the Consall Hall area a large number of faults were proved in mining the ironstone, and these are shown on the map. The master fault of the series trends north-north-east and attains its maximum effect close to the Hall, where it must throw down to the west more than 200 feet, but from this point it diminishes in both directions.

About Wetley Rocks the beds are greatly disturbed and often on end. This disturbance seems connected with a fault that near Highfields throws the First Grit down to the west against the Third; quite at the edge of the map it throws the Coal-measures against the middle of the same grit. It cannot here have a less throw than 300 feet, and this dislocation must penetrate some distance into the Pottery coalfield area. No coals are being worked in this neighbourhood, and nothing is known further about this dislocation; for, being a pre-Triassic fault it does not affect the Bunter sandstone by which it is covered further to the south-west.

There are several faults in the neighbourhood of Bank Top, one of which, trending east and west, is well shown at the surface by the outcrop of the Rider and Woodhead Coals. At the stream north-west of Dairyhouse it has a downthrow to the north of about 150 feet. Further east it appears to break up into a number of small dislocations which were proved in the older workings at Hazlewall Colliery.

Numerous faults have been proved in the coal workings, of which no trace can be found at the surface till they cut the outcrop of the Woodhead sandstone, when their further course is usually clear. A typical example of such a fault is shown a little west of Hazlewall Pit. West of Parkhall shaft a fault was proved not only in the colliery, but in some shallow workings in the Four-foot Coal at Parkhall Farm, and again at the old pits near the disused brass works west of Cheadle. It was exposed in the cutting at the entrance to the Cheadle tunnel, and repeats the outcrop of the Yard Coal, throwing down to the east some 30 feet. This fault has a singularly uniform throw throughout its whole length, yet only in this artificial section is there any evidence at the surface to suggest a fault

The set of east and west faults in the Dilhorne and Cheadle district are in the main proved only from mining evidence. The most important of these is the fault at Dilhorne. This throws down to the south and brings on the highest beds of the area, conveniently called the Delphouse Series, or the Upper Pale Group. Shafts on the north side were sunk to the Dilhorne Coal, passing through a small seam above it. Close to the south side of the fault shafts were sunk to the Litley, and also apparently to the Four-foot seam, though there seems some dispute about the latter. The exact throw in the Dilhorne area is thus a matter of doubt. But just under the extreme north-west end of the Bunter near Cheadle, a level, starting in the Woodhead Coal, was driven through the fault till the Rider seam was cut, showing the fault here had a downthrow to the south of somewhat over 120 feet. This fault-level is of great importance for it shows conclusively that the Dilhorne Coal is thrown *down* to the south, and is below the Delphouse coals. It cannot possibly be at the top of these beds as is generally supposed.

A fault throwing down to the south-west about 90 feet was proved in the Birches Colliery, near Cheadle. It trends north-west and south-east, and was met with a little to the south-west of the shaft.

About Oakamoor there are a number of faults, some of which have a considerable throw. The clearest is the one at the foot of the First Grit escarpment, near Crowtrees and Moneystone. Here the coal of the Third Grit is on a level with the base of the First Grit, and there is a downthrow of about 100 feet to the west; further north it increases somewhat, for the two grits occur side by side. There seems to be a network of faults about Oakamoor station; one of these is well shown by the outcrop of the two grits on the south side of the tunnel.

Faults in the Triassic Rocks.

While most of the faults described above are of pre-Triassic age, there are some faults in the district that cut the Trias. Two of these are shown in the Draycott area. They throw in opposite directions, causing the Keuper marls and sandstones to lie in a trough between the two outcrops of Bunter. If the evidence obtained from the old shaft near the tunnel can be relied on, the more northerly of these faults must have a throw of at least 300 feet, but that of the more southerly is considerably less.

In the south-eastern part of the area there appears to be a fault of some throw between the Bunter and Keuper sandstones; but the amount is difficult to ascertain as it seems possible that the Keuper sandstone may here lie in an eroded hollow of the Bunter. Several small faults may be seen in the roadside on the face of the Bunter escarpment, but they have no structural importance. A fault of 15 feet throw occurs in the quarry in the Keuper sandstone on the north side of the Cheadle and Alton Road. It cuts the sandstone in a peculiarly clean manner, and does not easily catch the eye. This seems to be rather a feature of the smaller faults in the Triassic rocks.

The accompanying section (Fig 1) to the scale of six inches to a mile, and drawn roughly from west to east, gives a general idea of the structure of the Cheadle coalfield and of the position and outcrop of the various seams. The section starts on the west at an old shaft, about 300 yards east of the road from Dilhorne to Forsbrook, in a direct line with Callowhill Farm. This shaft was sunk 50 yards to the Alecs or Stinking Coal. It crosses the Cheadle Road near Boundary, where the old shafts fix the position of the Yard, the Litley, and the Four-foot Coals, and also prove the thickness of the overlying unconformable Bunter sandstone. After passing the exposed outcrop of the Two-yard Coal the section crosses the cutting at the mouth of the Cheadle tunnel, where the double outcrop of the Yard Coal occurs, owing to repetition by the fault. At this point the section takes a slight turn and trends a little north of east so as to pass through the Birches Colliery, where the Woodhead Coal was worked. Before reaching this the outcrop of the Huntley or Dilhorne Coal is passed, and a little north of the point shown on the section the Majorsbarn shaft proved the depth to the Alecs Coal, from which the depth of the Woodhead is also known. The fault close to the Birches was proved in the workings. At Cheadle Mill the Woodhead Coal was worked, while the outcrop shown further east can still be traced by the old workings close to Moss Lane.

West of the fault at the Birches Colliery, the Woodhead Coal is intact; while to the west of the Tean the Dilhorne or Huntley Coal is also intact. Of the seams above much has been taken out, but patches are left here and there.

A series of shaft sections is given on the plate (Fig. 2) in order to show the position of the seams in the Delphouse area relatively to those in the rest of the district.

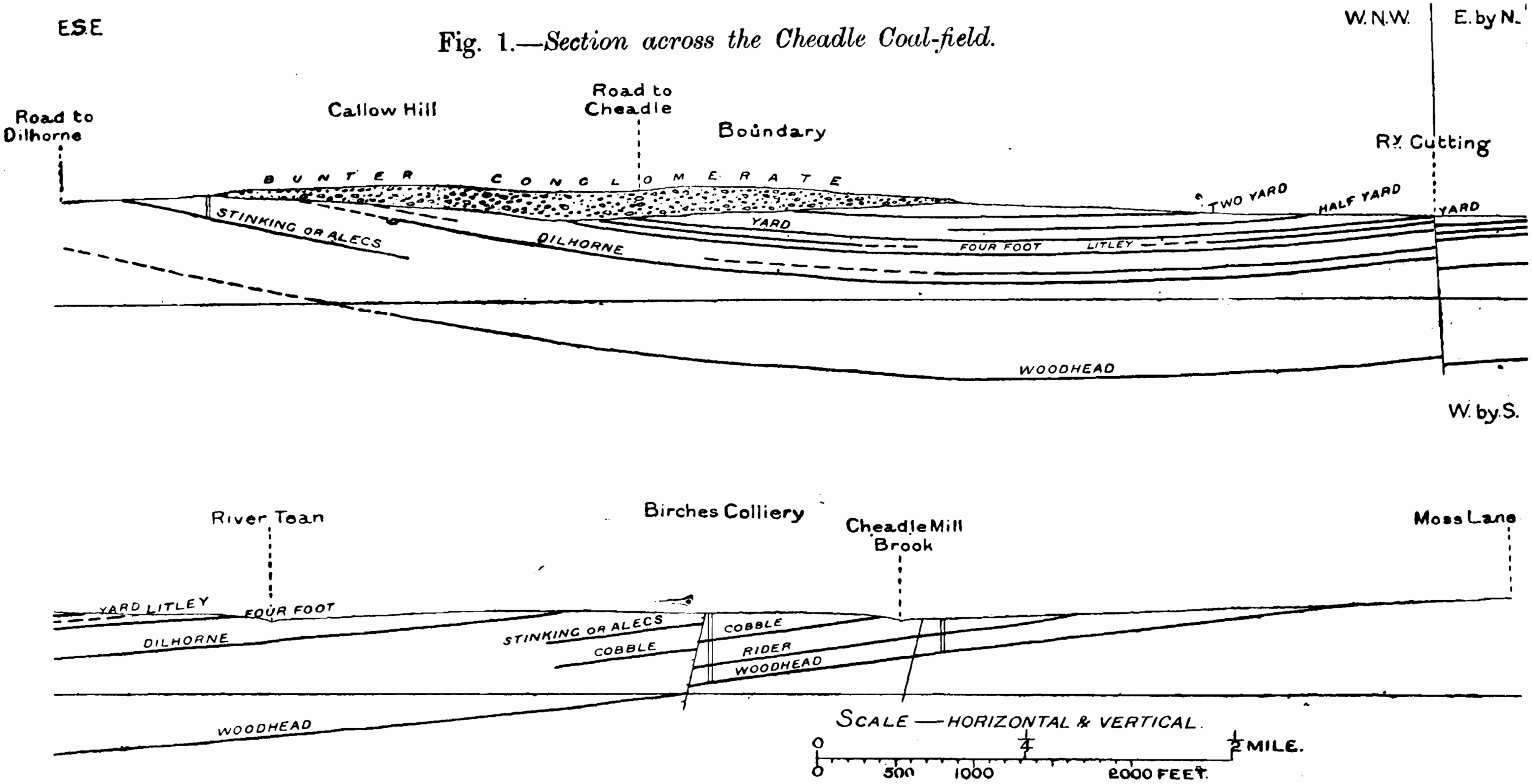

Fig. 1.—*Section across the Cheadle Coal-field.*

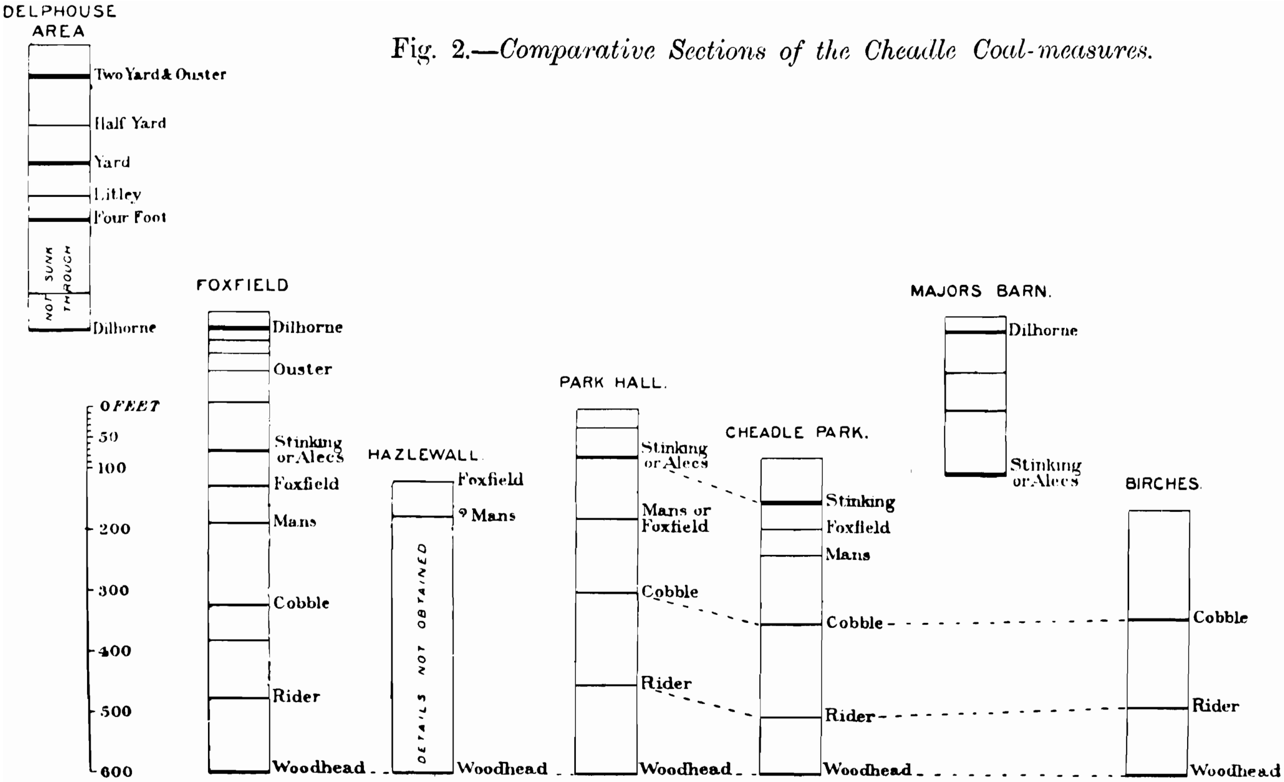

Fig. 2.—*Comparative Sections of the Cheadle Coal-measures.*

APPENDIX I.

Sections of Colliery Shafts.

1. Delphouse Collieries, Cheadle.

(Communicated by Mr. William Lockett.)

	Thickness.		Depth.	
	ft.	in.	ft.	in.
Coal and smut - - - - -	2	6	2	6
Marl - - - - - - - - - -	8	6	11	0
2 Yard rock - - - - - - - -	16	0	27	0
Grey shale - - - - - - - -	17	0	44	0
2 Yard **Coal** - - - - - - - -	5	6	49	6
Ouster coal and pricking - - - - -	2	8	52	2
Clunch - - - - - - - - - -	6	1	58	3
Roach and rock-binds - - - - - -	18	4	76	7
Sandy rock, not bedded, but hard - - -	27	0	103	7
Getley coal (useless) - - - - - -	2	0	105	7
Hard sandy rock - - - - - - -	13	0	118	7
Soapy grey shale (fossil marl and black bat roof) - - - - - - - - - -	7	0	125	7
Half-yard **Coal** - - - - - - -	2	6	128	1
Clunch - - - - - - - - - -	6	0	134	1
Roach and rock binds - - - - - -	16	0	150	1
Hard white rock with black streaks - - -	24	0	174	1
Grey shale - - - - - - - -	12	0	186	1
Black shale roof - - - - - - -	0	6	186	7
Yard **Coal** - - - - - - - -	3	9	190	4
Fireclay - - - - - - - - -	1	6	191	10
Hard clunch - - - - - - - -	6	0	197	10
Littley rock - - - - - - - -	15	0	212	10
Hard white rock - - - - - - -	8	0	220	10
Grey shale (fossil bed at base) - - - - -	19	0	239	10
Littley **Coal** - - - - - - - -	2	9	242	7
Grey clunch - - - - - - - -	6	0	248	7
Four-foot rock - - - - - - - -	12	6	261	1
Grey shale - - - - - - - -	14	9	275	10
Four-foot **Coal** - - - - - - -	3	6	279	4

2. Foxfield Shaft, two miles W.N.W. of Cheadle.

	Thickness.		Depth.	
	ft.	in.	ft.	in.
Clay and marl - - - - - - -	24	0	24	0
Dilhorne Coal - - - - - -	6	0	30	0
Seat - - - - - - - - -	4	6	34	6
Grey shale - - - - - - - -	4	9	39	3
Coal, 9 ins. Black clunch, 7 ins. **Coal,** 8 in.	2	0	41	3
Seat and rock binds - - - - - -	5	6	46	9
Grey shale - - - - - - - -	9	0	55	9
Dark brown shale and pebbles - - - - -	4	6	60	3
Black stone, 3 in. **Coal,** 5 in. - - - - -	0	8	60	11
Seat - - - - - - - - -	2	0	62	11
Strong rock binds - - - - - - -	5	0	67	11
Grey shale - - - - - - - -	9	0	76	11
Dark grey clunch - - - - - - -	3	2	80	1
Black shale and stone bands - - - - -	4	4	84	5
Grey shale - - - - - - - -	4	0	88	5
Ouster Coal, 5 in. Pricking, 3 in. - -	0	8	89	1
Hard grey rock - - - - - - -	2	0	91	1
Soft grey rock - - - - - - - -	2	6	93	7
Strong roach - - - - - - - -	4	6	98	1
Hard grey rock - - - - - - -	4	6	102	7
Roach - - - - - - - - -	20	0	122	7
Strong grey metal - - - - - - -	10	6	133	1
Black shales - - - - - - - -	7	6	140	7
Stone, **coal** and rattlecock (cannel shale) - -	1	5	142	0
Fireclay - - - - - - - - -	7	6	149	6
Dark shale - - - - - - - -	14	0	163	6
Grey shale - - - - - - - -	10	0	173	6
Rock - - - - - - - - -	9	0	182	6
Grey shale - - - - - - - -	18	0	200	6
Black shale - - - - - - - -	8	0	208	6
Grey shale - - - - - - - -	5	3	213	9
Moonshine (shale full of slickens) - - -	4	3	218	0
Coal, 1 ft. 3 in. Pricking, 6in. **Coal, 2 ft.** } **Stinking** or **Alecs Coal.**	3	9	221	9
Seat - - - - - - - - -	3	0	224	9
Strong binds - - - - - - - -	6	0	230	9
Strong rock - - - - - - - -	27	6	258	3
Strong binds - - - - - - - -	18	0	276	3
Foxfield Coal - - - - - -	1	8	277	11
Pricking - - - - - - - - -	0	8	278	7
Strong clunch - - - - - - -	3	0	281	7
Strong grey binds - - - - - - -	17	0	298	7
Red roach - - - - - - - -	13	6	312	1
Chocolate rock - - - - - - -	14	0	326	1
Chocolate metals - - - - - - -	7	0	333	1
Grey shale, black at base - - - - -	5	0	338	1
Mans Coal - - - - - - - -	1	5	339	6
Black seating - - - - - - - -	2	6	342	0
Coal - - - - - - - - -	0	8	342	8

2. Foxfield Shaft, two miles W.N.W. of Cheadle—*continued.*

	Thickness.		Depth.	
	ft	in.	ft.	in.
Clunch	3	0	345	8
Black shale	3	6	349	2
Strong clunch	5	0	354	2
Grey sandstone	2	0	356	2
Binds	4	0	360	2
Grey shale	5	6	365	8
Coal and shale	0	6	366	2
Clunch	3	0	369	2
Brown yards	5	0	374	2
Grey yards	25	0	399	2
Grey metals	18	0	417	2
Black shale	1	6	418	8
Grey shale	3	0	421	8
Rock (sandstone)	4	0	425	8
Grey shale	30	0	455	8
Black shale	1	3	456	11
Grey shale, black at base	15	3	472	2
Cobble Coal	1	3	473	5
Strong clunch, full of iron balls	7	6	480	11
Rock	4	0	484	11
Grey metals	7	6	492	5
Dark shales, black base	37	6	529	11
Coal	1	1	531	0
Strong clunch	9	6	540	6
Binds	10	6	551	0
Grey metals, full of iron balls	9	6	560	6
Black shale and slickensides	3	0	563	6
Clunch, flinty rock boulders	3	0	566	6
Rock binds	7	0	573	6
Grey metal, full of iron balls	31	0	604	6
Black shale and stone of coal	1	0	605	6
Dark clunch	4	0	609	6
Metals and binds	14	0	623	6
Grey shale	2	0	625	6
Rider Coal	1	6	627	0
Clunch, soft top	3	6	630	6
Grey binds	9	0	639	6
Grey sandstone	24	0	663	6
Dark shale on clunch	8	6	672	0
Hard rock	7	6	679	6
Strong grey metal, shale in middle	43	0	722	6
Grey shale	12	0	734	6
Black shale	14	0	748	6
Woodhead Coal	2	9	751	3
Pricking, 9 in. Ouster coal, 3 in.	1	0	752	3
Total	752	3		

3. Cheadle Park Colliery, one mile N. of Cheadle.

	Thickness.		Depth.	
	ft.	in.	ft.	in.
	8	6	8	6
Soil and clay - - - - - - - -	62	0	70	6
Strong fireclay - - - - - - -				
Alecs or **Stinking Coal** (two dirt seams of 9	6	0	76	6
and 5 inches) - - - - - - -	7	0	83	6
Soft clunch - - - - - - - -	11	0	94	6
Sandstone - - - - - - - -	20	6	115	0
Grey shale - - - - - - - -	1	4	116	4
Foxfield Coal - - - - - - -	8	0	124	4
Clunch - - - - - - - - -	11	0	135	4
Sandstone - - - - - - - -	22	0	157	4
Grey shale - - - - - - - -	1	0	158	4
Black shale - - - - - - -	1	0	159	4
Coal - - - - - - - - -	5	0	164	4
Clunch - - - - - - - - -	8	0	172	4
Sandstone - - - - - - - -	33	0	205	4
Grey roach - - - - - - - -	0	9	206	1
Coal - - - - - - - - -	2	0	208	1
Clunch - - - - - - - - -	15	0	223	1
Grey shale - - - - - - - -	13	0	236	1
Sandstone - - - - - - - -	18	0	254	1
Grey shale - - - - - - - -	1	6	255	7
Black shale - - - - - - -	15	0	270	7
Grey shale - - - - - - - -	2	2	272	9
Cobble Coal - - - - - - - -	1	0	273	9
Clunch, etc. - - - - - - - -	21	0	294	9
Clunch - - - - - - - - -	17	0	311	9
Dark shale - - - - - - -	18	6	330	3
Sandstone - - - - - - - -	7	0	337	3
Grey shale - - - - - - - -	0	3	337	6
Coal - - - - - - - - -	4	0	341	6
Clunch - - - - - - - - -	15	0	356	6
Grey shale - - - - - - - -	8	0	364	6
Sandstone - - - - - - - -	21	0	385	6
Grey roach - - - - - - - -	7	0	392	6
Grey shale - - - - - - - -	14	0	406	6
Sandstone - - - - - - - -	17	6	424	0
Grey shale - - - - - - - -	1	4	425	4
Rider Coal - - - - - - - -	3	0	428	4
Clunch - - - - - - - - -	6	0	434	4
Grey shale - - - - - - - -	21	0	455	4
Red sandstone - - - - - - -	41	0	496	4
Strong roach - - - - - - - -	13	6	509	10
Grey shale - - - - - - - -	9	6	519	4
Black shale or bass - - - - - - -	2	11	522	3
Woodhead Coal - - - - - - -				
Total	522	3		

4. Birches Colliery, S.E. of Cheadle.*

	Thickness.		Depth.	
	ft.	in.	ft.	in.
Soil and brick clays	12	0	12	0
Fireclay	3	0	15	0
Clunch and binds	162	0	177	0
Cobble Coal	2	10	179	10
Fireclay	6	0	185	10
Rock and rock-binds	6	6	192	4
White and red micaceous sandstone	105	0	297	4
Rider rock	12	0	309	4
Roach	12	0	321	4
Black shale	2	0	323	4
Rider Coal	1	6	324	10
Fireclay	1	0	325	10
White rock	29	0	354	10
Roach, fine laminated sandstone	63	0	417	10
Red and grey marl. Balls of red ironstone	9	6	427	4
Black shale. The Bass	7	6	434	10
Woodhead Coal	3	2	438	0
Total	438	0		

* Taken from the "History of Cheadle," by R. Plant, page 297. If the account is correct there is far more hard or sandy material present here than in the area to the west and north. The Cobble coal is unusually thick. The thickness of the Woodhead coal includes the pricking and ouster coal beneath, not usually reckoned in the thickness of the seam.

5.—Park Hall Colliery, Cheadle.

(Communicated by Mr. J. R. Haines, F.G.S.) to depth of 583 feet 10 inches, and by Mr. E. Almond, below that depth.

	Thickness.		Depth.	
	ft.	in.	ft.	in.
Pit top raised	9	0		
Clay	8	0		
Grey shale	13	0		
Coal, Sweet	0	9	30	9
Marl	4	0		
Hard rock	14	0		
Grey shale, with rock	78	0		
Coal, Stinking	3	9	126	9
Marl	4	0		
Rock	11	0		
Grey roach	39	0		
Coal, Man's	1	6	184	6
Strong clunch	4	6		
Grey roach	7	6		
Black shale	3	6		

5.—**Park Hall Colliery**—*continued.*

	Thickness.		Depth.	
	ft.	in.	ft.	in.
Clunch	5	0		
Grey roach	11	4		
Coal	0	2		
Rock	8	0		
Grey roach	16	6		
Grey rock	24	0		
Rock	12	0		
Roach	6	6		
Rock	2	6		
Grey roach	9	0		
Black shale	1	6		
Grey shale	9	0		
Coal, Cobble	2	6	307	0
Clunch	18	6		
Dark shale	15	0		
Black shale	17	0		
Coal	0	2		
Clunch	1	6		
Rock	6	0		
Grey roach	4	6		
Strong roach	7	6		
Strong roach	10	6		
Grey shale	4	6		
Grey shale	9	0		
Rock	9	0		
Roach	13	6		
Rock	7	6		
Rock, hard	3	0		
Grey shale	4	6		
Coal	0	6		
Clunch	4	6		
Rock binds	10	6		
Grey roach	3	0		
Coal, Rider	2	3	459	8
Clunch	6	9		
Rock	26	0		
Grey roach	37	0		
Rock, hard	4	0		
Rock, soft	5	0		
Grey roach	16	6		
Grey roach	4	6		
Grey shale	12	0		
Black shale	9	0		
Coal, Woodhead	3	0	582	8
Stone	0	9		
Pricking	0	2		
Ouster coal	0	3		

5.—Park Hall Colliery—*continued.*

Boring below the last Bed.

	Thickness.		Depth.	
	ft.	in.	ft.	in.
Bind	9	0	583	10
Black shale	26	0		
Strong bands and shale	5	0		
Black shale	9	0		
Grey rock and soft roche	173	0		
Slate rock	49	0		
Grey shale	40	0		
Black shale	22	0		
Dark clunch	8	0		
Grey rock	6	0		
Black shale	13	0		
Coal	0	4		
Grey rock	6	0		
Black shale with bands	45	0		
Soft grey rock and shale	28	0		
Coal	0	3		
Black shale	0	3		
Clunch	1	0		
Black soft shale	1	0		
Grey shale	4	0		
Black shale	38	0		
Grey rock full of spar	2	9		
Black shale	10	9		
Stinking coal	2	0		
Dark clunch	3	0		
Grey and white rock	19	8		
Light red shale	4	5		
Grey and white rock	3	3		
Conglomerate	1	3		
Red shale	4	0		
Black shale	12	0		
Smooth grey rock	9	0		
Red shale	3	8		
Grit bored into (said to be the First Grit)	8	4		
Total bored	567	11	1151	9

APPENDIX II.

LITERATURE.

GEOLOGICAL SURVEY PUBLICATIONS.

1857. SMYTH, W. W., & E. HULL.—Quarter-sheet 72 N.W. Additions by A. H. GREEN, 1864.

1859. HULL, E., & A. H. GREEN—Horizontal Section, Sheet 57. Across the Coal Field of Cheadle.

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OTHER WORKS.

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1863. WARDLE [SIR] T.—On the Geology of the Neighbourhood of Leek, Staffordshire (reprinted from John Sleigh's History of the Ancient Parish of Leek, Staffordshire). 8vo. Leek.

1881. MOLYNEUX, W.—Chapter on the Geology of the Cheadle Coal Field in R. Plant's History of Cheadle, pp. 277–311. 8vo. Leek.

1890. WARD, J.—The Geological Features of the North Staffordshire Coal Fields, their Organic Remains, their Range and Distribution; with a Catalogue of the Fossils of the Carboniferous System of North Staffordshire. *Trans. N. Staff. Inst. Mining Engineers.* Vol. x., pp. 1 189.

1892. BEASLEY, H. C.—The Bunter Conglomerate near Cheadle, Staffordshire. *Proc. Liverpool Geol. Soc.* Vol. vi., p. 439.

1892. BEASLEY, H. C.—The Trias of Cheadle and Alton, Staffordshire. *Trans. Liverpool Geol. Assoc.* Vol xii., p. 37.

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GEOLOGICAL SURVEY OF ENGLAND.

GEOLOGICAL MAP OF THE CHEADLE COALFIELD.

By George Barrow, F. G. S.

INDEX

		Alluvium	~
GLACIAL		*Boulder Clay*	
TRIAS	KEUPER	*Red Marl*	f^6
		Sandstone	f^5
	BUNTER	*Conglomerate*	$f^{2'}$
		Sandstone	f^2
COAL MEASURES		*Grit*	d^5
MILLSTONE GRIT SERIES		*1st Grit*	
		3rd Grit	d^4
		Crowstones	

6 ↓ Indicates dip of strata, the amount in degrees.
White lines are Faults, the downthrow being given in feet thus ―10

Coal Seams in descending order shewn by figures, thus

1. 2 Yard.
2. ½ Yard.
3. Yard.
4. Litley.
5. 4 Foot.

(1–5: *Coals of Delphouse Area.*)

7. Dilhorne or Huntley.
8. Alecs or Stinking.
9. Cobble.
10. Rider.
11. Woodhead.
12. Crabtree or Lower Stinking.
13. Third Grit or Roaches.

Scale of One Inch to One Statute Mile = $\frac{1}{63360}$

0 1 2 3 4 Miles

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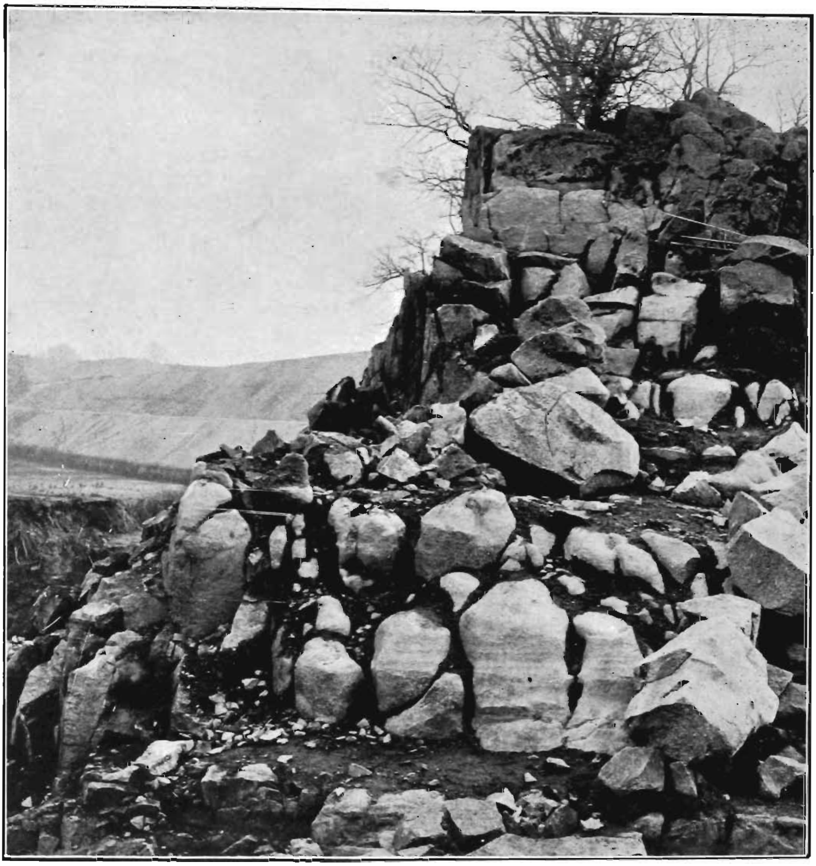
LEICESTERSHIRE,—53 NE, 62 NE, 63*, 64*, 70*, 71 SE, SW.
LINCOLNSHIRE†,—64*, 65*, 69, 70*, 83*, 84*, 85*, 86*.
MERIONETHSHIRE†,—59 NE, SE, 60 NW, 74, 75 NE, SE.
MIDDLESEX†,—1† NW, SW, 7*, 8†.
MONMOUTHSHIRE,—35, 36, 42 SE, NE, 43 SW.
MONTGOMERYSHIRE†,—56 NW, 59 NE, SE, 60, 74 SW, SE.
NORFOLK†,—50 NW*, NE*, 64*, 65*, 66*, 67*, 68*, 69.
NORTHAMPTONSHIRE,—64*, 45 NW, NE, 46 NW, 52 NW, NE, SW, 53 NE, SW, & SE, 63 SE, 64.
NORTHUMBERLAND,—102 NW, NE, 105, 106, 107, 108*, 109, 110. NW*, SW*, NE*, SE.
NOTTINGHAM,—70*, 71* NE, SE, NW, 82 NE*, SE*, SW, 86, 87* SW.
OXFORDSHIRE,—7*, 13*, 34*. 44*, 45*, 53 SE*, SW.
PEMBROKESHIRE†,—38, 39, 40, 41, 58.
RADNORSHIRE,—42 NW, NE, 56, 60 SW, SE.
RUTLANDSHIRE,—this county is wholly included within Sheet 64*.
SHROPSHIRE,—55 NW, NE, 56 NE, 60 NE, SE, 61, 62 NW, 73, 74 NE, SE.
SOMERSETSHIRE †,—18, 19, 20, 21, 27, 35.
STAFFORDSHIRE*,—54 NW, 55 NE, 61 NE, SE, 62, 63 NW, 71 SW, 72, 73 NE, SE, 81 SE, SW.
SUFFOLK,—47*, 48*, 49*, 50*, 51*, 66* SE*, 67*.
SURREY,—1 SW†, 6†, 7*, 8†, 12†.
SUSSEX,—4*, 5†, 6†, 8†, 9†, 11†.
WARWICKSHIRE,—44*, 45 NW, 53*, 54, 62 NE, SW, SE, 63 NW, SW, SE.
WESTMORLAND,—97 NW*, SW*, 98 NW, NE*, SE*, 101, SE*, 102.
WILTSHIRE —12*, 13*, 14, 15, 18, 19†, 34*, and 35†.
WORCESTERSHIRE,—43 NE, 44*, 54, 55, 62 SW, SE. 61 SE.
YORKSHIRE†,—85-88, 91 NE, SE 92-97* 98 NE* SE*, 102 NE, SE, 103 SW, SE 104.

See also *New Series* Maps.



HAWCLIFF HILL, MOUNTSORREL.
Crags of Granite, shewing horizontal grooving.
From a Photograph by W. T. Tucker.

156.

MEMOIRS OF THE GEOLOGICAL SURVEY.

ENGLAND AND WALES.

THE GEOLOGY OF
THE COUNTRY NEAR
LEICESTER.

(EXPLANATION OF SHEET 156.)

BY

C. FOX-STRANGWAYS, F.G.S.

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PREFACE.

THE area described in the present Memoir is contained in Sheet 156 of the New Series one-inch Map of England, and embraces parts of central and eastern Leicestershire, and of the adjoining county of Rutland. It includes most of the area represented in the quarter-sheet 63 N.E. of the Old Series Geological Survey Map, which was surveyed by Mr. H. H. Howell and published in 1855; also the northern part of quarter-sheet 63 S.E. surveyed by Mr. W. T. Aveline and Mr. H. H. Howell and published in 1859, together with a small descriptive Memoir published in 1860; and the north-western part of Sheet 64, surveyed by Prof. J. W. Judd and Mr. W. H. Holloway and published in 1872, together with a Memoir issued in 1875 on "The Geology of Rutland."

The area is also referred to in the Memoir on "The Triassic and Permian Rocks of the Midland Counties of England" by Prof. Hull published in 1869.

A comparison of Sheet 156 of the New Series with the former Sheets of the Old Series, which it replaces, will show that considerable changes have been made in the delineation of the geology of this part of the Midlands. The outcrop of the granite and other old rocks in the neighbourhood of Mountsorrel has been shown with more exactness than was possible with the smaller scale map. The outcrop of the Rhætic Beds in this part of the Midlands has now been traced, and slight modifications have been made in the mapping of the Keuper Marl. The use of larger scale maps has also enabled the sub-divisions of the Middle Lias to be traced with more precision.

The Drifts have been surveyed in detail, for the first time over much of the area, and the most striking feature of the map is the evidence which it affords of their plateau-like character.

The present map differs again from the old map so far as the alluvium is concerned; the lines have been traced with greater accuracy in the main valleys and extended into the smaller valleys, thus bringing out more clearly the drainage system of the country. The river terraces are also shown. A new feature is the insertion of a longitudinal section to show the general structure of the ground.

The whole of the area has been surveyed by Mr. C. Fox-Strangways, who has prepared the present Memoir. The catalogue of fossils has been revised by Mr. E. T. Newton.

Manuscript copies of the six-inch maps have been deposited in the Office for reference, and copies may be obtained on payment of the cost of copying.

The Drift edition only of the map is colour-printed, but hand-coloured copies without Drift may be obtained at a cost of 3*s*.

A bibliography of Leicestershire was published in the Memoir on the geology of the country between Atherstone and Charnwood Forest and is not, therefore, included in the present Memoir.

J. J. H. TEALL.

Director.

Geological Survey Office,
28, Jermyn Street, London,
11th February, 1903.

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LIST OF ILLUSTRATIO''S

GEOLOGY

OF THE COUNTRY NEAR

LEICESTER.

CHAPTER I.

Introduction.

The sheet described in this Memoir contains an area of 216 square miles, the greater part of which lies in the County of Leicester, but it includes also a small portion of the County of Rutland. It covers the larger part of the area shown in 63 N.E. of the old one-inch survey, but extends nearly three miles further to the south; it also contains a considerable portion (72 square miles) of the ground covered by Sheet 64.

Owing to the Drift, which overlies the solid strata, being shown, this map has far more detail than the former of these sheets; and, owing to six-inch maps being now used, the lines can be drawn in with greater accuracy than was possible in 1872, when the eastern part was surveyed. Since the old surveys were made much additional information has been obtained. For instance, in 1855, when the district surrounding Leicester was surveyed, the Rhætic beds were not recognised, and were consequently included with the Lower Lias, a part of the outcrop at Leicester being entirely overlooked.

The only large town in the district is the county town of Leicester, but there are several important manufacturing villages, such as Mountsorrel, Sileby, Syston, Thurmaston, Wigston, Blaby, Narborough, and others along the valley of the Soar. In the eastern part of the map, the ground being entirely agricultural, the villages are not so large, but all are fairly prosperous, from the district being near the centre of the most famous hunting country. On this side the largest place is Billesdon, but there are quite thirty other villages that are of considerable importance.

Although the greater part of the drainage of the district is within the Trent basin, a large part of the water on the east side passes away to the Welland, and thence into the Wash. The watershed dividing these two runs from Ranksborough Hill, by Cold Overton, Knossington, Whatborough Hill, Tilton, Billesdon, Rolleston, and Carlton Curlieu. It rises to an elevation of over 700 feet between Billesdon and Tilton, but declines to about 500 feet at Ouston, and at the southern edge of the map. Near Kibworth, to the south of this, it is below the 400 contour line.

The physical aspect of the country is greatly influenced by the Drift. This, in former times, appears to have completely covered the district, and to have obliterated its older features, so that the surface of the land gradually declined in one broad sheet from the line of watershed. Along the outcrop of the Middle Lias between Burrow and Billesdon there must have been a pre-Glacial feature as fine as the present escarpment, where the fall in the ground was somewhat rapid ; but beyond this there was a nearly uniform slope, which was so slight that the ground may be considered to have been nearly level. This plateau, which was lowest along the line of the present Soar valley, has been cut into by the tributaries of this stream; so that the present aspect of the country is that of a great plain intersected by numerous furrows, that have been carved out by the tributary streams. The same thing has taken place on the eastern side of the watershed, the present streams apparently flowing nearly along the same lines as they did before the deposition of the Drift, which they have cut through, leaving only patches on their flanks. The effect of this denudation is that the escarpment of the Middle Lias, forming the highest ground in the map, rises in a more or less abrupt bank, overlooking a general plain of lower ground to the west, which has been furrowed into a series of ridge-like hills by the numerous streams that flow down to the main Soar valley. To the east of the Middle Lias escarpment the ground falls away gradually towards the Vale of Catmos, in the centre of Rutland ; but this is principally along the valleys, as the ridges between maintain a fair altitude to beyond the limit of this map.

The following table gives a list, in descending order, of the subdivisions of the strata :—

RECENT AND PLEISTOCENE	Recent and Post-Glacial		Alluvium.
			River gravels.
	Glacial		Valley Drift.
			Chalky Boulder-clay with intercalated beds of sand and gravel.
			Older Boulder-clay (upper part).
			Quartzose Sand.
			Older Boulder-clay (lower part).
			Older Sand and Gravel (?)
JURASSIC	Inferior Oolite		Northampton Sands.
	Lias	Upper Lias	Shales.
		Middle Lias	Marlstone Rock-bed (zone of *Ammonites spinatus*).
			Sandy shales and clays with ironstone, &c. (zone of *Am. margaritatus*).
		Lower Lias	Lower Lias Shales with limestones in the lower part.
TRIAS	Rhætic		Rhætic Beds.
	Keuper		Keuper Marl with lenticular sandstone beds and bands of gypsum.
PRE-CAMBRIAN OR ARCHÆAN	Charnian		Granite of Mountsorrel, and associated rocks.
			Slates, hornstones, and agglomerates of Charnwood Forest.

The older formations that come to the surface within the limits of the map occupy a very small space, but they have been proved to extend further beneath the newer rocks at Leicester and elsewhere. They include a small outcrop of the Pre-Cambrian slates of Bradgate Park, and the intrusive granite and other rocks of Mountsorrel, which form the fringe of the Charnwood Forest district. The principal formations, however, are the Trias and the Lias, which practically cover the whole of the district.

The Keuper Marl crops out along the Soar valley, covering a considerable area, but the most extensive formation is the Lower Lias, which crosses the centre of the district; between these is a narrow band of Rhætic shales which has now been mapped for the first time. This is followed by the Middle and Upper Lias, which cover the eastern part of the district, and form the higher ground that is found in that direction. A few isolated hills of Inferior Oolite rise here and there above the general mass of the Upper Lias Clay. Finally, the whole of these strata are more or less covered by Boulder-clay and sands, which have somewhat altered the general character of the country.

The soil of the country, being in the main derived from the underlying formations, is mostly clay of a very retentive character. It is diversified here and there by beds of sand and gravel, which render it much lighter. This is particularly the case with the alluvial gravel that occurs along the margin of the Soar valley, especially about Syston. In the eastern part of the area the Rock-bed of the Middle Lias, where not covered by Drift, also forms a light rubbly soil, that is the best arable land in the district. In consequence of the large proportion of heavy clay land the greater part of the country is devoted to grazing purposes, and is noted for its extensive pastures and its renown as a hunting district.

Although there is no coal mining in the country now under consideration, the proximity of the coalfields to Leicester, and their early connection by one of the first railways made in the kingdom, has enabled that town to become an important manufacturing centre.

A large industry, and one which has greatly increased of late years, is the quarrying of roadstone. This is actively carried on at Mountsorrel, where the granite forms an excellent material both for mending roads and for pavements; it is also used in the preparation of artificial flagstones. These quarries are very extensive, and, being connected by branch lines with both the Midland and Great Central Railways, a large amount of road-metal is sent away to other districts.

The Keuper Marl is extensively used along the Soar valley for the manufacture of bricks, and has entirely superseded the Glacial and Liassic clays, which were formerly worked to a small extent locally for this purpose.

There are no minerals of any importance. The Rock-bed of the Middle Lias contains a certain amount of ironstone, which has been tried at Tilton: but, from the abandonment of the works, it does not appear to have been of much value. The Inferior Oolite is also very ferruginous, but the area covered by the rock is too small to be of any importance.

A thick bed of gypsum occurs in the Keuper Marl at Thurmaston, and other bands of this rock have been met with in borings; but it does not appear to have been used commercially in this district, although extensive works exist further north, between Kegworth and Gotham.

There is no building stone of any value. The soft white sandstone of the Keuper to the west of Leicester, the limestone bands in the Lower Lias, the Rock-bed of the Middle Lias, and the Inferior Oolite have been used, but they are generally too soft and friable for the purpose. Some of the new bridges on the Melton and Market Harborough Railway are built of the hard fossiliferous blocks ("jacks") of the Middle Lias, and appear to stand fairly well.

The limestone bands in the lower part of the Lias, from which the well-known cement at Barrow is made, are worked for lime at Kilby Bridge, but the beds are more shaly and impure than at Barrow. These beds have also been worked on the Crown Hills near Leicester, but the quarries are now abandoned.

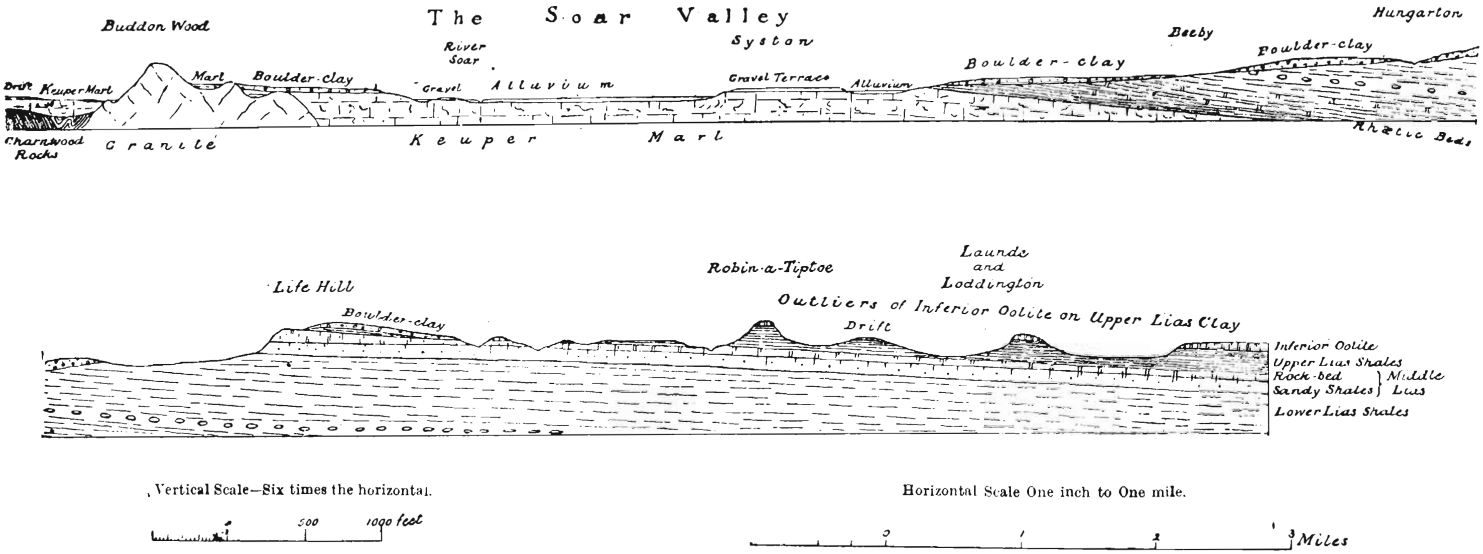
Beds of sand and gravel occur at numerous places throughout the area, especially along the Soar valley, about Knossington and Tilton, and further south. The gravel was formerly, in the country districts, the usual material for road-mending, but now it is entirely superseded by "granite," except for purely local purposes. The sand is, of course, still used for mortar, large quantities being excavated near Leicester, where the building trade is very active.

The water supply of a district like this, which has been derived chiefly from superficial deposits resting on impervious clays, is neither abundant nor good. For this reason the rapidly growing town of Leicester, which has been supplied by catchment reservoirs in the neighbourhood, is now seeking to obtain water from the far better but distant Carboniferous rocks of the Peak district of Derbyshire. When this scheme has been carried out the western portion of the area under consideration will have an admirable supply.

By considering the subject of the water-bearing properties of the rocks of this district we shall see why it has been necessary for Leicester to seek its supply from another source. The Keuper Marl with its subordinate bands of sandstone, when bored into, is usually found to yield a considerable amount of water; but, owing to the quantity of gypsum contained in these rocks, it is so impregnated with sulphate of lime as to be too hard for domestic purposes.

In the limestones and shales of the Lower Lias the supply of water is usually very scanty, and the shaly beds are so full of decomposing pyrites that the water is generally strongly impregnated with sulphuretted hydrogen.

FIG. 1.—*Section showing the general position of the strata across the area from north-west to south-east.*



The Rock-bed of the Middle Lias, being very porous, furnishes a copious supply, which is probably the best water in the district, but from the ferruginous nature of the rock it is liable to be strongly impregnated with iron ; so that it is usually a strong chalybeate rather than a good water for domestic purposes.

The Upper Lias, from its generally impervious character, gives the poorest supply of any formation, as the water is only held in thin limestone bands ; and from the pyrites in the shales it is not often fit to use.

The gathering ground covered by the Inferior Oolite is too limited to give a supply of any quantity, but good springs generally issue from this rock, although the water is liable to be rather ferruginous.

The sandy bands in the Drift frequently give good water, and no doubt may furnish a valuable source of supply ; but the springs being only shallow, and the water being often conveyed for some distance between enclosing sheets of Boulder-clay, it is very liable to be contaminated by surface pollution, and great care should be used in the selection of sites for wells.

CHAPTER II.

PRE-CAMBRIAN.

On the western margin a small portion of these old rocks just comes within the limit of the map. These rocks were described by Professor W. W. Watts in the explanation of the neighbouring sheet (155); so that we need not devote much attention to them here. They constitute the main mass of the Charnwood Hills, but only the extreme eastern outcrop, just as it becomes buried beneath the Trias, is seen here.

Professor Watts has divided these rocks into the following series, but only the Swithland Slates and a part of the Bradgate beds are exposed in this map:—

Pre-Cambrian Rocks of Charnwood.

(*c*) The Brand Series	(*c*) Swithland and Groby Slates.
	(*b*) Conglomerate, Grit, and Quartzite.
	(*a*) Purple and Green Beds.
(*b*) The Maplewell Series.	(*e*) Olive Hornstones of Bradgate.
	(*d*) Woodhouse Beds: Hornstones and Volcanic Grits.
	(*c*) Slate-Agglomerate of Roecliffe.
	(*b*) Hornstones of Beacon Hill.
	(*a*) Felsitic Agglomerate.
(*a*) The Blackbrook Series: Hornstones and Volcanic Grits.	

These rocks protrude through the Keuper Marl in isolated knolls in Swithland Wood and Bradgate Park; and extend across the reservoir at Cropston, where they are last seen in this direction.

The Olive Hornstones of Bradgate are well represented in the Park, just beyond the edge of the map. "They are fine olive-green hornstones, devoid of coarser seams, but ashy in composition, and more or less fissile or slaty."

The Swithland Slates were formerly quarried at Swithland Wood and in the neighbourhood of Woodhouse Eaves. They are much heavier and rougher than the ordinary Welsh slate; consequently they are not now used except in a few instances where a more picturesque aspect is desired. These slates, which have a coarse cleavage, are purple or green in colour, and the best of them have a satiny or glossy texture.

Mountsorrel Granite and Associated Rocks.

Intimately associated with these slaty rocks is the granite of Mountsorrel and the neighbouring hills. It was shown in the description of Charnwood Forest, by Professor Watts, that the rocks of that district were traversed by numerous masses of syenite, which had been injected through the older strata. Probably a still later intrusion is the Mountsorrel granite, which, although about two miles from the main mass of the Charnwood area, is nevertheless connected with rocks of this age, a junction with altered slates being shown at the extreme south-west and north-west corners of the Mountsorrel group, although everywhere else the relation to the older rocks is hidden by the overlap of the Keuper Marl.

The granite crops out in several isolated knolls, the largest of which is the fine wooded eminence of Buddon Hill. Around this are grouped several smaller hills to the number of about twenty-two, varying in size from conspicuous hills like that at Mountsorrel to small patches, just rising through the Boulder-clay, not more than a yard or two in diameter. The rock is a pink biotite-granite; a full description of its mineral constituents has been given by Prof. Bonney* and by Mr. J. J. H. Teall.† It varies somewhat in composition, the easternmost exposure, at Mountsorrel being the most acid, while the westernmost, at Brazil Wood, is the most basic. Besides the pink felsitic veins by which this rock is frequently traversed there are several dykes of a more basic character. The principal of these is that seen in the old Mountsorrel quarry. This dyke runs in an east and west direction (W. 15° N.) across the quarry, and is 22 feet thick at the west end. It is seen again in the small quarry near the Cottage Hospital, where it is only 4 inches thick and dips at an angle of 45°. In the opposite direction, at Cocklow Wood, which is on the same line, we could find no trace of this rock, so that it probably dies out in both directions from its maximum width in the large quarry. Other dykes occur at Buddon Wood and Brazil Wood. About 80 yards west of the latter there is a curious mound of diorite, now concealed by the water of the reservoir. This is no doubt a portion of another dyke, but there is not enough seen of the rock to indicate its direction. This remarkable rock, which is unique in the district, is a plagioclase-hornblende rock with some pyroxene. It is coarsely crystalline, with large plates of hornblende that are very conspicuous.

Where the granite is in contact with the older rock, as at the two spots mentioned on the west side, the latter is greatly altered, and full of minute garnets. At Brazil Wood the rock, which might be called a mica-hornfels, is split up by numerous dykes for a distance of about 20 yards or more from the granite, which was evidently intruded at a very high temperature. A good section of these rocks was exposed here in the trench connecting the two hills at the time the reservoir was made, of which Professor Watts has supplied the following notes:—‡

"The intrusive rocks are entirely separate from the metamorphosed slate, but along the trench the beds are too much cut up by dykes to throw much light on progressive contact metamorphism. No unaltered rock occurs in Brazil Wood.

* *Quart. Journ. Geol. Soc.* (1878), vol. xxxiv., p. 218.

† *British Petrography* (1888), p. 321.

‡ A fuller account will be given by Prof. Watts in his forthcoming Memoir on the Charnwood rocks.

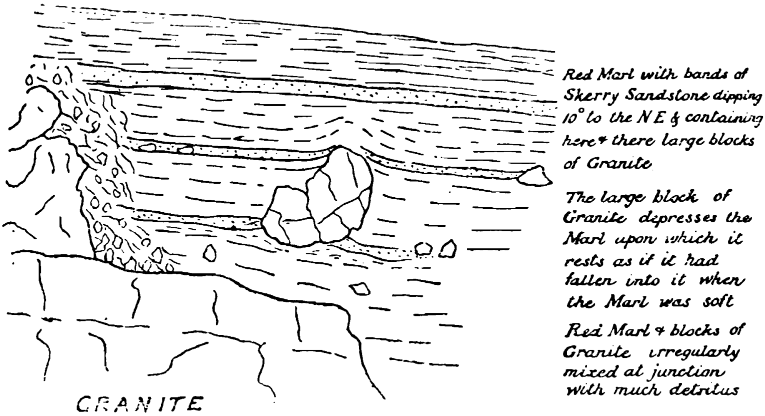
"The granitite of Kinchley is more basic than that of Mountsorrel, and contains plenty of hornblende in addition to brown mica. The rock of Brazil Wood is still more basic, and hornblende is always in excess of mica; it also contains much plagioclase (oligoclase or albite) in addition to orthoclase. The hornblende is in part brown and in part green—mostly compact, that is, not fibrous. The hornblende, mica, and felspar have consolidated before the quartz. Apatite and sphene are usually present. The dark rock is fine-grained, with porphyritic felspar set in a fine felspathic matrix. Hornblende and mica are present. The pink veins which seam this are chiefly micropegmatite, consisting of more acid 'mother liquor.' Some of the dark rocks contain so much hornblende and plagioclase that, if occurring alone, they would be called diorite. The contact rocks, which look like hard bands in the 'slate,' are fine-grained dykes from the granite. They contain felspar like the granite, but the matrix consists of rounded grains of quartz set in a very fine-grained felsitic matrix instead of irregular masses of interstitial quartz. The rock is almost devoid of hornblende or mica, and may be micropegmatite veins quickly cooled. The 'felsite' of the east end is of the same type. One of the hard veins in the slate is different, and contains abundance of crystals, probably of brown mica set in plagioclase with a little quartz, resembling the mica traps sometimes found in dykes from granite. The diorite differs in the deep brown colour of the compact hornblende and the presence of much fibrous actinolite, the small amount of orthoclase, and the absence of quartz.

"The altered rocks show no trace of the original clastic structure, and have been much altered. A few patches of aggregates of white mica occur, but not many recognisable crystals. The bulk of the rock is spotted and contains abundance of iron-ore dust. The lighter spots apparently consist of a felt of minute micaceous minerals separated by patches of brown matter also fibrous, which may be dark mica.

"The slate at the end of the trench is much more altered, and consists almost entirely of two kinds of mica with quartz in clear patches. All the minerals have been recrystallized. The spotted appearance is still preserved in places, but the light material consists of felted white mica passing into aggregates of larger crystals of the same, while the dark patches are now a pale olive brown pleochroic mica with inclusions of zircon, and passing in places into a dark brown mica. As the rock is not schistose it may be called (according to Mr. Teall) a mica-hornfels. No felspar has been detected. It is not more altered at the actual junction, except that the micas are larger and better formed. It also contains a brown biaxial mineral. The Buddon Wood contact-rock is full of minute garnets."

The junction of these isolated granite bosses with the surrounding Keuper Marl is found nearly everywhere to be very precipitous, and shows that they must have formed peaks and nearly vertical cliffs in the Triassic lake. At Mountsorrel, a well which is 50 yards from the edge of the granite, is sunk to a depth of 40 feet entirely in Keuper Marl.* At Hawcliff the edge of the granite goes sheer down to the bottom of the quarry, a depth of 20 feet or more. In the old brickyard at Nunckley there is a deep well within 30 yards of the granite. At the end of the reservoir embankment on the west side of Buddon Hill the edge of the granite was found to be very steep, and, in fact, wherever the junction of the two formations has been opened out it has been found to be of the same character.

FIG. 2.—*Junction of Keuper Marl and Granite at Mountsorrel.*



A curious feature of these granite cliffs was noted on the northern side of Hawcliff when the rock was first uncovered, a representation of which is given in the frontispiece.† The surface of the cliff here is scored with numerous horizontal lines and groovings, which are certainly not caused by glacial action, but are probably the result of the erosive power of sand driven by the wind, as is well exemplified in Iceland at the present time, where the lava is scored by sand-blasts in a similar manner.‡ These groovings are found beneath the undisturbed Keuper Marl as well as under Boulder-clay, thus showing that they must have originated in Triassic times.

* Professor Bonney gives the depth of a well here as 100 feet.—*Quart. Journ. Geol. Soc.*, vol. xxxiv., p. 218.

† It was first described by Professor Watts, *Brit. Assoc. Rep.* for 1899, p. 747; see also *Proc. Geol. Assoc.*, vol. xvii. p. 379.

‡ H. J. Johnston-Lavis, *Scottish Geograph. Mag.* (1895), vol. xi., p. 465.

CHAPTER III.

TRIAS.

Keuper.

Although the Rhætic beds are now generally included with the Trias, this formation consists in the main of two great groups—the Bunter and the Keuper; these have been further subdivided into the several minor divisions as given below:—*

Keuper	Upper Keuper. Marl and Sandstone with beds of Gypsum. Lower Keuper. Sandstone with bands of Marl (Waterstones) and Sandstone, and breccia (Basement Beds).
Bunter	Upper Red and Mottled Sandstone. Conglomerate or Pebble Beds. Lower Red and Mottled Sandstone.

It will be seen, however, that it is only the higher of these divisions that are present in this district; in fact only the upper member of the Keuper crops out in this area, although lower beds have been proved in borings near Leicester. From these borings we learn that the full thickness of the Keuper beds averages about 700 feet, of which about 100 feet, more or less, may be classed with the Lower Keuper Sandstone.†

The upper member of the Keuper Marl has been separated into three divisions—an Upper Gypseous Series, Upper Keuper Sandstone, Lower Gypseous Series, but it is doubtful if these really hold good to any extent. The Upper Keuper Sandstone appears to occur in more or less lenticular masses, which thin out in all directions, and there is no evidence that this bed is so continuous and regular in its character as it has been supposed to be; consequently we shall treat the Upper Keuper Marl as one formation, merely alluding to the included sandstones when they are of sufficient importance to notice.

The Keuper Marl covers the greater part of the western half of the map; and, although it is largely covered by superficial beds, still a considerable area is to be seen in all the valleys and depressions of the district. It consists of thick beds of red and grey or tea-green marl, with numerous thin bands of gypsum, and shaly sandstone, which latter occasionally thickens out into more prominent beds of rather coarse gritty sandstone. The red colour of the marls is frequently bleached by organic matter; and in some places, more particularly in the neighbourhood of Kirby Muxloe, the red marls

* This is the classification given by Professor Hull and adopted by the Survey, but of course it varies somewhat in different localities. See T. M. Reade, *Geol. Mag.*, 1889, p. 550.

† The details of these sections are given in the Appendix. The most reliable of them is that from the Crown Hills, near Evington, as this appears to have received a larger amount of attention at the time when the boring was made, and the cores are preserved in the Museum at Leicester.

are full of grey markings, which traverse the rock in vertical and diagonal lines, and are due to the infiltration of acidulated water, which has deoxidised the marl. Occasionally the marl contains some peculiar nodular lumps, which are very hard, and seem to be formed of aggregations of sand. They fracture in transverse radiating planes, which are filled with crystalline mineral matter after the manner of septaria. These lumps are very conspicuous in the pit of the Star Brick Works, near Thurmaston.

The thickest beds of gypsum are towards the upper portion of the series, as shown by the numerous wells and borings in and near Leicester. The only bed, however, which can be traced at the surface is that seen in the railway cutting at Thurmaston, which has a thickness of from 6 to 10 feet. Beds of gypsum are mentioned by Jukes as having been worked at the old pits at Regent's Road, Leicester* ; and they are recorded from most of the borings and well sections in and around the town. Gypsum has also been met with in considerable quantity beneath the Knighton Tunnel† and at the Humberstone Brick Works. In the borings at the foot of Spinney Hills several beds of gypsum are mentioned, one at Crown Hills being as much as 10ft. 6in. thick.‡

The principal bed of sandstone, which occurs a short distance below this horizon, is best exposed in the railway cutting of the branch line to Burton, where it has a thickness of over 14 feet, and in the quarry at Ashleigh House, near the Dane Hills, where there appears to be nearly 20 feet of this rock. This, however, is its maximum thickness, as it thins away from here in all directions. It is a massive false-bedded sandstone, but its separate grains are very loose and incoherent, so that on the Dane Hills it is quarried as a building sand. At Shoulder of Mutton Hill, on the Hinckley road, the rock is curiously pitted, and has dark spots, possibly manganese. At Buddon Wood it is full of drusy cavities filled with white crystals. In the quarry at Ashleigh House there is a good section in these beds, which has been figured and described by Mr. Montagu Browne.§

On the eastern portion of the Dane Hills, which is now built over, this sandstone is considerably thinner, and in the neighbourhood of the Fosse Road appears to die out almost entirely. An excavation at the corner of the Fosse Road and Hinckley Road, of which a representation is given below, showed this dying out of the sandstone and its passing into more marly beds very clearly, and proved that it does not pass beneath this portion of the town, as has been supposed.

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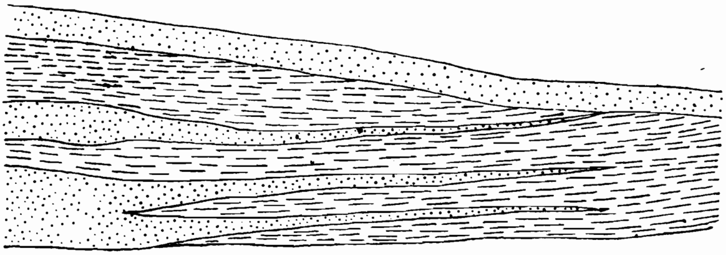
* Professor J. B. Jukes, the *Analyst*, vol. viii., 1838, p. 7. Montagu Browne, *Trans. Leicester Lit. and Phil. Soc.*, vol. iii., p. 123.

† Montagu Browne, *loc. cit.*, p. 196, note 89.

‡ See Appendix, p. 65. In the first boring at Lodge Farm there is a bed of gypsum said to be 20 feet thick; but we doubt the accuracy of this, as it is not mentioned in the second boring, which was only 3 feet distant.

§ *Loc. cit.*, p. 131.

FIG. 3.—Section about 50 yards east of the junction of Hinckley Road and Fosse Road, Leicester.



3. Soil, 1 foot.
2. Grey marly beds and flaggy "skerry" (thinning westwards).
1. White gritty sandstone (thinning eastwards).
Section about 6 or 7 feet deep.

The shales and flaggy beds mixed with marl and containing a few streaks of coarse sandstone, on which the main part of the sandstone rests, occupy most of the surface to the east, and are exposed in nearly every ditch, field-pond, or other excavation. In the new channel of the River Soar, which was made to carry off the flood water, these flaggy sandstones were so hard that the rock had to be blasted. These shaly beds, with the flaggy sandstones, locally called "skerry," were included, in the old survey, with the principal mass of coarse sandstone; but as the latter is of some economic importance, while the former is of no value whatever, we have considered it better, in the present case, to ignore them, and in mapping to group them with the red marl. They, however, occupy a fairly definite horizon, their outcrop in this map roughly following the course of the River Soar. These beds have been exposed in numerous excavations on the west side of the river at Leicester; they dip to the east, and pass beneath the main part of the town; where, having been met with in numerous borings, they have been mistaken for the coarse sandstone of the Dane Hills, the so-called Upper Keuper Sandstone. They are also seen to the south of the town, and in the brickpits at Sileby. In a number of sections beneath the town, given by Mr. James Plant in the Reports of the British Association for the years 1875, 1878, 1880, and 1889,* this sandstone is stated to vary from 20 to 45 feet in thickness, but there is no doubt that this is an error brought about by including the alternations of thin skerry sandstone and hard grey marl in one thick bed of sandstone, as pointed out by Mr. Browne in the following remarks upon this subject.† "[The sections in Leicester do not bear out the theory] that a certain definite horizon obtains for thick-bedded sandstones, emanating from the west, and passing under the town. Indeed, little or no thick beds

* See Appendix p. 75 *et seq.* † *Loc. cit.*, p. 153.

of sandstone occur after leaving the western district, and what little does occur is found at all levels, and would be, perhaps, better described as 'skerries,' by which is meant an impure sandstone charged with marl, or occurring as sandstone streaks between marls of any colour and which may be fairly thick, but, unlike pure thick sandstones, such as those of Dane Hills, are of no value for building. . . . Probably the explanation is that sandy 'skerries,' some little true sandstone, and hard grey cuboidal marls occur out of the sandstone district at any horizon, and that engineers, when well-sinking, cannot be expected to be very particular in their rendering of 'sandstone,' and that very often any hard grey substances do duty for actual rock, and are 'lumped' together to fancy thicknesses."

The coarse sandstone bed itself is seen at a few places along the line of outcrop, more particularly at Birstal, at Rothley, in the Fosse Road above Lewin Bridge, in the lane leading thence to Cossington, and in the village of Ratcliffe, where it again appears to be somewhat thicker. It also crops out at Narborough Wood House in the south-west corner of the map, where it covers an area of some extent, considering that the bed is stated to be only 1 foot 6 inches in thickness.

The sandstone, although very soft when first quarried, is said to harden on exposure to the air; and in former times appears, from the numerous old workings on the Dane Hills, to have been used to some extent as a building-stone, but it can never have been very well suited for this purpose, and at present is only employed as a building-sand.

At the top of the red marl there occurs from twenty-five to thirty feet of grey or tea-green marls, which were formerly included with the Rhætic beds above, but are now classed with the Keuper for the following reasons, as given by Mr. Strahan in a recent memoir on a part of the South Wales Coal Field* :—"In the first place, no line can be drawn between them and the Red Marls which does not include typical red beds in the green series, or green beds in the red series. The gradation from one to the other is perfect, even the green marls themselves being of the usual Triassic type except in colour. On the other hand, there is a definite plane of separation between the 'tea-green' series and the black shales in which the Rhætic fauna first appears. Marls of Triassic type, whether red or green, and the cavernous inorganic calcareous bands, occur below that place, while above it we find shales and thin limestones crowded with organic remains. The plane itself is not infrequently accompanied by an inch or two of conglomerate, consisting of quartz pebbles, rolled teeth and bone-fragments, which, without indicating an actual unconformity, points to an abrupt change of physical conditions. Taken in connection with the usually sudden appearance above it of the Rhætic fauna, it suggests the first complete invasion of the area by the Rhætic sea."

* A. Strahan, Explanation of Sheet 249 (*Survey Memoir*), p. 71.

The tea-green marls are well seen in the brickyard at South Wigston, and have been exposed in numerous excavations near the Spinney Hills at Leicester. North of the town they form the steep bank on the east side of the Soar valley extending from Humberstone Asylum to Barkby Thorpe; but north of this they have only been met with in a few obscure sections.

In this district no organic remains, with the exception of fish-scales, and an insect-wing recorded by Mr. Harrison,* have as yet been found in the tea-green marl, and there is always a sharp line of division between them and the overlying black shales.

Very few organic remains have been recorded from the Keuper, and most of these, as one would naturally expect, occur in the sandstone. Several forms of plants have been mentioned, but they appear to be very imperfect, and it is doubtful if some of them are organic. The same may be said of the doubtful coral *Gorgonia keuperi*, discovered by Mr. John Plant,† which Mr. Browne does not consider to be organic.‡ Besides these, there are a few worm-tracks, teeth, spines, and scales of fish, and other vertebrate remains. A full list of these is given in the Appendix of Fossil Species.

Rhætic Beds.

At the top of the tea-green marls last described there is always a sharp line of division separating them from the dark finely-laminated shales of the Rhætic beds. This line of junction is usually occupied by a thin band of conglomerate having a peculiarly gritty feel, known as the Bone-bed. This bed, although sometimes absent, generally varies in thickness from half an inch to two inches or rather more. When met with at a little distance from the surface it is usually very hard and pyritic, but nearer the outcrop it becomes decomposed and much more brittle. It has the character of being a highly pyritous and impure sandstone full of the fragmentary remains of saurians and fish, together with fragments of Triassic sandstones, pebbles, and coprolites. Mr. Montagu Browne, in describing the sections on the west side of the Spinney Hills, gives the following account of this bed:—"There is a well-defined but friable bone-bed, varying from half an inch to two inches in thickness, with a dip of about 2° to the east, from whence have been procured bones and teeth of saurians, teeth and scales of *Colobodus*, scales of *Gyrolepis alberti*, teeth of *Saurichthys acuminatus*, *Acrodus minimus*, and *Hybodus cloacinus*; some of these, it will be seen, [were] unknown in Britain until discovered by Mr. A. E. Baker from the old Spinney Hill section on the New Evington side, and by the present writer from the new cuttings."§

* Harrison, *Quart. Journ. Geol. Soc.*, vol. xxxii., p. 214.

† *Reports of the British Assoc.*, 1849, Trans. of Sections, p. 64.

‡ Browne, *loc. cit.*, p. 125, note 4.

§ Browne, *loc. cit.*, p. 174. In laying out the western slope of this hill for building during 1892 and 1893 numerous shallow sections in these beds were exposed, which have been described in great detail by Mr. Montagu Browne, p. 159, *et seq.*

The Bone-bed is succeeded by a thickness of about 17 feet of dark finely-laminated shales containing *Avicula contorta, Protocardium philippianum* (*P. rhæticum*), and other Rhætic bivalves in considerable abundance.

These pass up into a series of bluish or greyish shales having a thickness of about 20 feet, and which are not unlike the tea-green marls below.

The finest section of the Rhætic beds that occurs in this map is that seen in the brickyard at South Wigston, close to the Glen Parva Station, of which the following is a general account.

*Glen Parva Brickyard.**

		Thickness, approximate. Ft.	in.
Glacial	Boulder-clay with pebbles and Lias fragments. Very few, if any, flints.	20	0
Lower Lias -	Band of limestone (not on west side)- - -	2	2
Upper Rhætic Shales or White Lias	Bluish shales - - - - - - - -	20	0
	Band of limestone nodules - - - -	0	6
Lower Rhætic or *Avicula contorta* shales	Dark shales with a band of limestone nodules -	17	0
Keuper Marl	Grey marls - - - - - - -	15	0
	Red marl - - - - - - - - -	10	0
	Band of sandstone - - - - -	1	0

The outcrop of these beds, where it enters the map at its southern edge, is very obscure, and, were it not for this fine section, would be scarcely recognisable. The Boulder-clay is so thick near here that these beds were not seen in the deep cutting where they cross the Midland Railway; but a little beyond this the black paper-shales have been met with in wells near Wigston Fields, and also in the valley close to Knighton Church. In making the sewer along the valley here nearly the whole series of these beds was exposed, the dark shales at the church passing up into grey shales capped with limestone nodules, which were seen in the lane close to the vicarage. North of Knighton the outcrop winds along the higher ground by Clarendon Park and Victoria Park to the Spinney Hills, but is entirely obscured by the thick covering of Boulder-clay.

At Spinney Hills we come to the typical sections where these beds were first described near Leicester by Mr. W. J. Harrison.† These sections are now all hidden owing to the extension of the town, but while the ground was being prepared for building we were able

* More detailed measurements of this section are given by Messrs. Wilson and Quilter, *Geol. Mag.* Dec. 3, vol. i., p. 416, 1884. Also Montagu Browne, *Trans. Leicester Lit. Phil. Soc.*, 1901, p. 32.

† The occurrence of Rhætic beds here was first noted by Mr. J. J. H. Teall. See *Geol. Mag.*, 1874, p. 318.

to obtain many useful notes; among others the following section was exposed on the west side of the hill:

*Section west side of Spinney Hills, near the north end of Haddon Street.**

	Ft.	in.
Boulder-clay resting on a distinctly glaciated surface forming a marked line with striations. The Boulder-clay itself, with many striated surfaces or slickensides, contains mostly Lias fragments, a very few quartz pebbles, limestone fragments (striated), and one large sandstone block - - - - nothing to	8	0
Dark laminated shale with selenite crystals, and much sulphur; yellowish, rusty-looking band at intervals, small *Protocardium philippianum*, and *Avicula contorta*, occasional jet-like streaks. Limestone nodules at east end - - - - - about	6	0
Bone-bed, varying in thickness from half inch to nothing.		
Tea-green or grey marls -10 0 to	15	0

Dip, 3° E. A small fault throwing down to the north about 2 feet was observed on the west side.

The upper part of the Rhætic series, which has a thickness of from 6 to 10 feet, is composed of grey and buff sandy shales with very few fossils, it is a good deal stained by iron, and contains many small calcareous lumps (race). In the upper part of these shales there is usually one or more bands of cream-coloured nodular septariate limestone, from which *Estheria minuta* and a few other fossils have been obtained. The most complete section of the Rhætic beds in this neighbourhood was that afforded by the old brickyard at the northern end of the hill, of which the following account has been given by Mr. W. J. Harrison:—†

Section of the Rhætic Beds, Spinney Hills, Leicester.

	Petrology.	Thickness. Ft. in.	Organic Remains.
10.	Soil and drift - -	1 0	
9.	Nodular band of limestone -	0 6	*Estheria* (casts), *Avicula contorta.*
8.	Light-coloured shales with sandy partings - - -	4 0	*Modiola minima, Avicula contorta, Cardium rhæticum* [*P. philippianum*].
7.	Dark shales with sandy partings - - - -	1 0	*Ophiolepis Damesii, Pholidophorus Mottiana.*‡
6.	Finely-laminated black shales	2 0	*Avicula contorta, Cardium rhæticum.*
5.	Sandstone - - -	0 1	*Axinus*-bed. Worm-tracks.

*Compare woodcut on p. 47.

† *Quart. Journ. Geol. Soc.*, vol. xxxii., p. 213, 1876. The site of these brick-pits is now crossed by the streets known as Prospect Hill and Wood Hill.

‡ Doubtful species. See Table of Fossils.

Section of the Rhætic Beds.—continued.

	Petrology.	Thickness. Ft.	in.	Organic Remains.
4.	Black shales, coarsely laminated - - -	2	6	
3.	Bone-bed -	0	3	*Gyrolepis, Saurichthys apicalis* [*S. acuminatus*], *Hybodus minor, Ceratodus, Nemacanthus monilifer, Ichthyosaurus, Plesiosaurus, Coprolites, Sargodon tomicus, Acrodus, Axinus* [*Schizodus*] *elongatus, A. depressus.*
2.	Light buff sandy marls with hard courses ; bluish nodules in lower part - -	16	0	Fish scales, Selenite, Salt pseudomorphs.
1.	Red and blue Upper Keuper Marls - - - - -	10	0	Selenite, Salt pseudomorphs.

It has been considered that this section did not expose the full thickness of the Lower Rhætic beds, and that the nodular limestone at the top was not *in situ.** We see, however, no reason to doubt the position of this bed, having seen a similar limestone in small excavations on the west side of the hill, where it apparently occurs at about the same distance above the Bone-bed. If this band represents the lower nodular limestone of Wigston and other sections, the Lower Rhætic beds are here much thinner than in many other places, in fact not much more than half the thickness of what they are at Wigston, four miles to the south. It is also evident that in this locality the full thickness of these beds above the Bone-bed cannot be much more than 25 feet or so, as the outcrop of this bed in Dale Street† is only 20 feet below the top of the hill which is formed of the higher part of the Rhætic series. This is further shown by the shallow borings made in the south-western corner of Spinney Hill Park and by the deeper borings to the east.‡

The upper limit of the formation was met with in cutting the sewer along the Mere Road, between Diseworth Street and St. Peter's Road, of this Messrs. Bates and Hodges have given an account, from which the following is abbreviated :—§

* Wilson and Quilter, *Geol. Mag.*, 1884, vol. i., p. 417.

† Montagu Browne, *loc. cit.*, p. 170.

‡ See Appendix, pp. 67 and 72.

§ *Trans. Leicester Lit. Phil. Soc.*, 1886, p. 23.

Section on Spinney Hills, from Diseworth Street to St. Peter's Road.

	Petrology.	Thickness.	Organic Remains.
		Ft. in.	
	Glacial drift - -	2 5 to 10 0	
Lower Lias.	Decomposed and hard blue crystalline limestone - -	4 0	*Cidaris Edwardsi*, *Pentacrinus* sp., *Ostrea* sp., *Lima* sp., *Pecten* sp.
Lower Lias.	Yellow earthy limestone resembling the above, but less decomposed.	0 4 to 2 0	*Lima pectinoides*, *L. gigantea*, *Ostrea liassica*, *Pleurotomaria anglica*, *Am. torus*, *Am. catenatus*, *Nautilus striatus*, Wood, Spines.
Lower Lias.	Thickly-laminated cream-coloured shales, with a thin band of limestone containing *Pholadomya* - -	4 0	*Modiola lævis*, *Pecten* sp., *Ammonites* sp.
Upper Rhætic.	Light-coloured marl with reddish stains. Very calcareous at top, with a thin nodular limestone - -	4 10	
Upper Rhætic.	Blue marl - - - - -	6 3	*Axinus cloacinus* [*Isodonta Ewaldi*].

The band of limestone 2 feet thick, thinning out to 2 inches, is considered by Mr. Montagu Browne to have been a boulder,* but although the beds were no doubt much broken up by glacial action we do not see, taking into account the character of the surrounding country, any reason to doubt the fact of their being *in situ*, the palæontological evidence notwithstanding. This would rather imply that the beds are higher in the series than has been supposed.

In the low ground to the east of the Spinney Hills the Rhætic beds cover a wider area than is usually the case, but are a good deal covered by alluvium and valley deposits. The dark paper-shales have been met with in wells and other excavations in the district known as New Evington and New Humberstone, which has enabled the outcrop to be traced with some degree of accuracy. These shales were found in the borehole at Lodge Farm, in sewers near the Great Northern Station, and below Humberstone Village.

In building the new asylum at Humberstone the lower part of the Lias was exposed; and a well 60 feet deep, which appears to have gone into the tea-green marl, passed through a nodular limestone at 34 feet, thus showing that the Rhætic beds here are somewhere about 20 feet thick.

Beyond this point the outcrop follows the brow of the hill, but the beds are not seen till we get to the little valley below the Humber

* *Loc. cit.*, p. 172.

Stone. Here the outcrop is shifted by a small fault, so that dark shales are seen in the ditch below the farmhouse, while red marl occurs nearly to the summit of the rising ground to the north. Nothing is seen of the Rhætic beds in the valleys on either side of Barkby Thorpe, but on the intervening hill dark paper-shales were found along the ridge, which here forms a good escarpment. North of Barkby the Rhætic beds have not been seen, but from several exposures of red and grey marls it is evident that the outcrop runs back some distance up the Wreak valley, probably as far as Brooksby. Grey marls, which probably mark the top of the Keuper, are seen in the stream between Gaddesby and Queniborough, and in the hillside about a quarter of a mile north of the latter village. Grey marls and mottled clays are also exposed along the brook at Barkby, and about half a mile above the village, as well as at a few places in the fields between these two, close to the edge of the great mass of Drift which covers the country here. There is no doubt that the outcrop of the Rhætic beds follows the base of the Boulder-clay very closely along here, and that the greater part of the formation is just hidden by it.

North of the Wreak valley the outcrop is shifted about five miles to the west by a fault which brings in the Lias directly against the Keuper Marl along an east and west line running a little to the north of Thrussington and Sileby; so that Rhætic beds are not seen again till we reach the banks of the Soar at Barrow, in the next map. The absence of the Rhætic beds over the higher ground on the north side of the Wreak was proved in a well at the Roman Catholic college, where the Boulder-clay, which is about 80 feet thick, was found to rest directly on red Keuper Marl.*

* See Appendix, p. 91.

CHAPTER IV.

LIAS.

The Lias is separable both from its petrological character and the nature of its organic remains into three distinct horizons, Lower, Middle, and Upper, each of which is further divisible into zones characterised by particular assemblages of fossils.

Professor Judd, who surveyed the country to the east, estimated that the total thickness of the Lias was about 800 feet, but from evidence which has since been obtained the maximum thickness of all three divisions must be at least 1,100 feet; and, even where some of the divisions are thinner, it cannot be much less than 1,000 feet thick. The Lias covers nearly the whole of the area E. of the Soar and Wreak valleys, but it is so much covered over by Glacial beds that it is not exposed over a large part of this area.

Lower Lias.

This division consists of a series of thin argillaceous limestone bands and shales in the lower part, and a thick series of clays or shale in the upper. It occupies a broad stretch of country on the east side of the Soar valley, extending as far as a line drawn from Whissendine to Burrow on the Hill, Billesdon, and Illston on the Hill. Over a large part of this district the beds are completely hidden by Boulder-clay; it is, therefore, chiefly beneath the Middle Lias escarpment, and along the numerous small streams flowing into the Soar, that exposures in the rock are likely to be met with. In the description of the country to the north-east it has been shown that the Lower Lias is divisible into four principal horizons,* viz.:—

The Clays above the Ironstone (*Zones of A. capricornus, A. Jamesoni, A. armatus*, and *A. oxynotus*).
The Ironstone Beds (Zone of *A. semicostatus*).
The Clays below the Ironstone (Zones of *A. Bucklandi* and *A. angulatus*).
The Strenshami† or Limestone Series (Zone of *A. planorbis*).

In this map these divisions, owing to the thinning out of the Ironstone Beds, are not all of them so well marked, although the separation into the more numerous palæontological zones may be fairly carried out. These zones may be recognised wherever there are good sections; but the country, as we have said, is so thickly covered with "Drift" that it is only in a very few places that this can be done. Mr. H. E. Quilter, in describing the Lower Lias of the whole county, has divided it into the above eight zones‡; but, within the limits of this map, there are clear exposures of only three of these, although there are indications of the others.

The three highest of these, the zones of *A. capricornus, A. Jamesoni*, and *A. armatus*, have been by some authors included with the Middle Lias; but the reasons for and against this classification

* *The Geology of the south-west part of Lincolnshire* (Survey Memoir), p. 22.
† This name should not be used in future. See H. B. Woodward, *The Jurassic Rocks of Britain*, vol. iii., p. 146.
‡ *Geol. Mag.*, Dec. 3, vol. iii., p. 59.

have been so fully discussed in other places* that we need not enter upon the subject here.

In describing the outcrop of the Lower Lias it will be best to trace the lower portion first across the map, and then take the higher beds which are only exposed along a narrow tract of country below the Middle Lias escarpment.

The lower portion of the Lias is best seen just beyond the northern edge of the map, in the neighbourhood of Barrow, where the numerous pits that are constantly being worked for these valuable limestone bands afford a series of interesting sections. These pits, being opened nearly on the same horizon, are very similar to one another, and show the great uniformity there is in the character and thickness of the beds, the variations observed in them arising chiefly from their difference in position and depth. The following section, kindly supplied by Mr. Montagu Browne, gives a good idea of the general character of these beds at Barrow :—

General section of the lime pits at Barrow.†

Lithological character and local name.	Thickness. Ft.	in.	Organic Remains.
Soil and Drift - - - - -	3	0	
Argillaceous shale - - - -	5	0	*Schlotheimia angulata.*
Limestone (Bank Hurs) - -	0	3	*Cidaris Edwardsi. Schlotheimia catenata.*
Shale (The Roak) - - - -	16	0	Plesiosaurian remains.
Limestone (Rummels) - -	0	10	Angulata zone. *Lima. Pecten.*
Shale (Rummels Calf) - -	4	0	*Psiloceras Johnstoni*, very abundant.
Limestone (First floor) - -	0	6	*Psiloceras planorbe*, rare.
Shale (Second-floor Calf) -	1	0	Ichthyosaurian remains. Various Fishes and Saurians.
Limestone (Second floor)- -	0	6	*Palæotermes Ellisi.*
Shale (Hur Calf) - - - -	0	9	
Limestone (Hurs) - - - -	0	6	*Lima.*
Shale (Hog Calf) - - - -	1	6	*Dapedius.*
Limestone (Hog and Second Hog, sometimes including a shale of 2 inches)- -	0	8	*Psiloceras planorbe. Dapedius.*
Shale (Bottom-floor Calf) -	0	6	
Limestone (Bottom floor) -	0	6	*Dapedius* and various Fishes.
Shale (Good-for-nothing Calf)	1	0	Various Saurians, Fishes, and Invertebrates.
Limestone (Good for nothing)-	0	4	*Psiloceras planorbe*, abundant, and various Fishes.
Shale (Four-foot Calf) - -	2	6	Various Saurian remains and Fishes.
Limestone (Four foot) - -	1	0	*Psiloceras planorbe* commences.
Shale - - - - }	Rhaetic beds not worked.		
Limestone (Black Rummels) - - - - }			
Shale - - - - }			
Limestone (White Hurs) }			
Shale - - - - }			

* Judd, *Geology of Rutland* (Survey Memoir), p. 45. Blake, *The Yorkshire Lias*, pp. 14, 16. *The Jurassic Rocks of Britain* (Survey Memoir), vol. i. p. 28, by C. Fox-Strangways ; vol. iii., p. 187, by H. B. Woodward.

† Compare section by Harrison, Geology of Leicestershire and Rutland, p. 37.

Beds of limestone and shale are frequently exposed along the stream course between Sileby and Seagrave, but the strata are so much disturbed along this valley that the general sequence of the rocks is not very clear; they appear, however, for the most part to belong to this zone. The limestones were worked in former times at Seagrave, but the pits have long been closed.

Along the valley of the Wreak they again come out in the small streams near Thrussington and Hoby, and a strong band of limestone, with *Am.* [*Psiloceras*] *planorbis*, is seen in the railway cutting just north of Rotherby. Mr. Judd mentions that traces of the Fish and Insect Limestones, lower part of the zone of *A. planorbis*, were found in the railway cutting at Kirby,* which seems to show that if the beds are not repeated by faults they must be lying nearly flat along this part of the valley. This section is now, unfortunately, entirely obscured; and, not knowing of the above observation at the time, there was considerable difficulty in arriving at a conclusion whether it was cut in solid strata at all.

South of this valley there are no sections in the Lias till we get to the stream flowing past Gaddesby, where the solid strata begin to emerge from beneath the Boulder-clay, and may be followed along the bottom of the branching valleys to the east. Sections are, however, not very good. The limestone bands were at one time worked at Ashby Folville, but the quarry is now full of water. From the spoil-heaps here we obtained *Lima gigantea* and a *Pseudomonotis*, the limestone beds containing a good deal of fossil wood. About half a mile above the village some impure limestone bands, with small cement nodules, and shales containing *Pecten Thiollieri* and *Gryphœa arcuata*, crop out in the stream.

At Twyford Lodge there is a small scar showing blue shale and limestone with *Lima pectinoides* and a small *Pecten*; while between the village and the railway viaduct there are several small sections in shales, from which were obtained *Am.* [*Ægoceras*] *brevispina*, *Belemnites* (fragment), *Pecten lunularis*, *Gryphæa cymbium*, *Arcomya sp.*, and close to the viaduct, *Am.* [*Ægoceras*] *Jamesoni*, *Belemnites acutus?* (fragment), *Gryphæa cymbium*, *Gryphæa sp.*, and *Gresslya intermedia*, showing that here we are getting into higher zones.

In the next valley to the south, starting from Queniborough, we first observe Lower Lias beds about a mile east of the church, but nothing very definite is seen till we come to South Croxton. On the hill to the south-west of this village, about 300 yards from the fox-cover of Barkby Holt, there is an old pit which appears to have been worked for ironstone. This ironstone, we presume, is on the horizon of the *A. semicostatus* beds, which obtain some importance in the map to the north-east; but we were not able to obtain any evidence to verify the point. In the valley thin limestones and shales occur with *Gryphæa arcuata*, *Lima gigantea*, and a *Pinna*, so that these must be still in the *A. Bucklandi* beds.

* *Geology of Rutland* (Survey Memoir), p. 58.

Further up the valley, nothing definite is seen till we get nearly to Loseby, and reach the higher zones of the Lower Lias.

In the valleys, which run down on either side of Ingarsby Station, Lias beds are frequently seen, but there are no sections that call for particular notice. About 500 yards north-east of the station there is a steep bank above the stream showing shales with nodules of whitish limestone containing *Rhynchonella tetrahedra* and a large *Pholadomya*; while a little further down, at the old brick-yard, ironstone fragments are seen lying about, but the section here is now covered up. It is, however, very possible that this is about the horizon of the *A. semicostatus* beds. Following down the valley towards Beeby we pass over limestone bands with crinoids, and below the village reach shales with sandy bands containing *Gryphæa arcuata.*

In the valley to the south these beds are better seen, especially near Keyham, where we obtained *Am.* [*Ariet.*] *sauzeanus*, *Am.* [*Ariet.*] *semicostatus*, *Gryphæa arcuata*, and *Pecten* (fragment). At the viaduct near here there are some hard calcareous beds with *Am.* [*Aeg.*] *Bucklandi*, *Gryphæa arcuata*, *Lima gigantea* and many other fossils; so that it would appear that the higher ground about here is on the horizon of the *A. semicostatus* beds, while the valleys cut through into those of the *A. Bucklandi* zone. The lithological character of the beds is shown by the well at Ingarsby Station.* Further evidence of the *A. semicostatus* beds is given by the cuttings at the western end of the Ingarsby tunnel, where there is a considerable excavation in dark shales yielding—

Am. [*Arietites*] *Conybearei*, Sow.
,, [,,] *sauzeanus*, d'Orb.
,, [,,] *semicostatus*, Y. & B. Very abundant.
Belemnites (cylindrical form).
Amberleya Chapuisi, Terq.
Rhynchonella plicatissima, Quenst.
Gryphæa arcuata, Lam.
,, *cymbium*, Lam.
Modiola (fragment).
Serpula.

Along the railway between here and Thurnby there are several shallow cuttings in Lias shales, the spoil-heaps from which yielded to Mr. J. D. Paul, at the time the line was being made in 1882, the following list:—†

Ichthyosaurus (vertebræ).
Am. Bucklandi, Sow.
,, *Conybearei*, Sow.
,, *catenatus*, Sow. (one specimen only).
,, *obesulus*, Blake.
,, *sauzeanus*, d'Orb.
,, *semicostatus*, Y. & B.
Nautilus striatus, Sow.
Belemnites.
Eucyclus elegans, Münster.
,, *undulatus*, Phil.

* Appendix, p. 88.
† *Trans. Leicester Lit. and Phil. Soc.*, 1883, p. 50.

Chemnitzia.
Gervillia ?
Gryphœa arcuata, Lam.
Lima gigantea, Sow.
,, *pectinoides*, Sow.
Ostrea liassica, Strickl.
Pecten æquivalvis, Sow.
,, *lunularis*, Roemer.
Plicatula spinosa, Sow. (*Harpax Parkinsoni*)
Cardinia Listeri, Sow.
,, *cardioides* [? *Unicardium*].
Gresslya lunulata ?, Tate.
Leda æquilatera ?, K. & D.
Modiola hillanoides, Chap. & Dew.
,, *scalprum*, Sow.
Rhynchonella plicatissima, Quenst.
Serpula.
Hemipedina (spines).
Pentacrinites.

These no doubt indicate the greater part of the *A. Bucklandi* zone, with their passage into the *A. semicostatus* beds above.

Further west, where the railway crosses the Uppingham Road, there is a cutting in brown and grey shales and limestone bands with *Lima gigantea, Gryphæa arcuata, Modiola minima*, and a *Nautilus.* Mr. Quilter records *Am. catenatus* from here. From the general position we should think that this cutting is just at the junction between the *A. Bucklandi* and *A. angulatus* beds. To the south of this, at Crown Hills and Evington, 189 feet of Lias were proved in the deep boring there, containing no less than thirty-four bands of limestone, although most of them were very thin. In the quarry near here a portion of these beds is exposed, from which Mr. Quilter records the following list :—

Ammonites Charmassei, d'Orb.
,, *scipionianus* ?, d'Orb.
Cryptœnia.
Gryphœa arcuata, Lam.
Lima gigantea, Sow.
Pecten lunularis, Roemer.
Cardinia Listeri ?, Sow.
Leda.
Modiola ?
Unicardium cardioides, Phil.
Rhynchonella plicatissima, Quenst.
Cidaris ?
Pentacrinus briareus, Miller.

This section is now much worn down, but Mr. Plant has preserved the record of it* and several other sections that were made by the Evington Coal Boring Company between the years 1876 and 1881.

In the valley south of Evington, and near Knighton, there are a few exposures of Lias beds, but nothing of any importance. In the field below Ashfield House a sinking of 40 feet is reported to have been in fossiliferous shales, which from its position probably reached the Rhætic beds; and a well in Stoneygate also appears to have been sunk to the same

* Appendix, p. 74.

strata, but unfortunately the information is not very precise. More definite evidence of the base of the Lias was furnished in cutting the sewer that runs along the Knighton valley, which proved the *A. planorbis* beds at South Knighton, and entered the Rhætic beds, as we have noticed above, about 200 yards from Knighton Church. South of this some bands of white and buff flaggy limestone may be seen in the southern branch of the stream, and the wells at Wigston Fields appear to reach Rhætic beds at a very slight depth. In the railway cutting just beyond here we gather from Mr. Plant's MSS. that two or three beds of limestone were met with, but no fossils are recorded. The surface of the Lias appears to have been much disturbed by glacial action.

In the clay-pit at Glen Parva Station the base of the Lias is seen resting on the Rhætic beds. There is here, as we have noticed, a band of limestone 2 feet 2 inches thick, which we take as the base of the Lower Lias. It contains the usual characteristic Lias fossils, while the shales below are very unfossiliferous. These lower beds outcrop under most of the town of South Wigston, but the only exposures about here have been in shales. Thin limestone bands were seen along the Midland Railway at Wigston Station, and near Kilby Bridge and a few other places; but the best section is in the large quarry at Kilby Bridge, where these beds are worked. There are said to be twenty-one bands of limestone in this quarry, but only seventeen are worked. The bands of limestone are separated by soft crumbly shale, and not by hard and firm shale (slavin), as at Barrow. Very few fossils are found here, except *Lima gigantea*, which is fairly abundant.

The two streams which unite at Great Glen afford a few exposures in Lias shales. At Little Stretton these contain *Gryphæa arcuata*; and in a clay-pit at the side of the Uppingham Road there is some grey clayey shale, with a band of small ironstone nodules, which Mr. Quilter has referred to the zone of *A. oxynotus*; but this pit is not worked now, and we could not find any fossils.

In the north-east corner of the area the Lower Lias is exposed over most of the low ground below Burrow and Little Dalby, but there are very few sections at the present time, except along the stream flowing north past Leesthorpe. A band of limestone, with *Terebratula punctata* and two small species of *Pecten*, much crushed, was also seen in the stream near the Grange, north of Little Dalby. A little to the south of this Professor Judd records* *Am. Jamesoni*, Sow., *Hippopodium ponderosum*, Sow., *Gryphæa obliquata*, Sow., *Gryphæa cymbium*, Lam. (*G. Maccullochi*, Sow.), *Avicula* sp., *Belemnites*, and joints of *Pentacrinus*, from the west side of Little Dalby; and on the other side of the hill, *Am. Maugenesti*, d'Orb., *Am. armatus*, Sow., *Belemnites* sp., *Gryphæa obliquata*, Sow., *Plicatula spinosa*, Sow., and *Montlivaltia rugosa*, Wr.

Along the stream coming down from Ouston, and in the Marefield valley, there are many sections in the upper part of the Lower

* *Geology of Rutland* (Geological Survey Memoir), p. 61.

Lias, but the clearest exposures are at Loseby, a little south of this. In the old brickyard here there is the following section :—

Section at Loseby Brickyard.

		Ft.	in.
	Surface clay.		
6.	Shales with ferruginous nodules, very few fossils - - - -	6	0
5.	Obscured (? shale with *Ammonites*, &c.) - - - - - - -	8	0
4.	Nodular band decomposed to yellow clay (Large septaria of Judd)	0	3
3.	Shale, harder and more laminated - - - - - - - -	2	6
2.	Hard calcareous band with *Pecten* (Indurated stone of Judd) -	1	0
1.	Shale with small round nodules, *Gryphœa cymbium* - - - -	2	0

From here we obtained *Am.* [*Ægoceras*] *armatus*, *Am.* [*Ægoceras*] *densinodus*, *Gryphœa cymbium*, and *Homomya*. This section was again visited at a later date by the writer, in company with Mr. Montagu Browne, when by the help of some small excavations a somewhat fuller list was obtained. These, through the courtesy of Mr. Browne, we are able to give below, with the addition of those previously recorded by Professor Judd.

Fossils from Loseby Brickyard.

	——	Judd.	1.	2.	3.	4.	5.	6.
	Saurian vertebræ - - - - -	x	–	–	–	–	–	–
	Belemnites acutus, *Miller* - - -	x	–	x	x	–	–	-
	Am. [Oxynoticeras] Coynarti, *d'Orb.*	x	–	–	–	–	–	–
	,, [Phylloceras] Loscombei, *Sow.* -	x	–	–	–	–	–	–
	,, [Ægoceras] armatus, *Sow.* -	x	–	–	–	–	–	–
N	,, [,,] subplanicosta, *Oppel* †	–	x	–	x	x	–	–
N	,, [,,] densinodus, *Quenst.*†	–	–	–	x	x	–	–
N	,, [Arietites] Macdonnelli, *Portlock* (Am. nodotianus, *Wr. non d'Orb.*)† - - - -	–	–	x	–	–	–	–
N	,, [Psiloceras] aplanatus, *Hyatt* (Am. tardecrescens, *Blake non Hauer*) † - - -	–	–	–	x	–	–	–
	Nautilus truncatus, *Sow.* - - -	x	–	–	–	–	–	–
	Actæonina sp. - - - - - - -	–	–	x	–	–	–	–
	Cerithium sp. - - - - - -	–	–	–	–	–	–	x
	Pholadomya ambigua. *Sow.* - -	x	–	x	x	–	–	–
	Panopæa elongata, *Roemer* - -	x	–	–	–	–	–	–
	Unicardium cardioides, *Phil.* - -	–	–	x	–	–	–	–
	Gresslya (near to intermedia, *Simp.*) -	–	–	–	x	–	–	–
	Cardium truncatum, *Sow.* - -	–	x	x	–	–	–	x
	,, sp. - - - - - -	–	x	–	–	–	–	–
	Hippopodium ponderosum, *Sow.* -	x	–	x	–	–	–	–
N	Cardita multicostata, *Phil.* - -	–	x	–	–	–	–	–
	Cardinia Listeri, *Sow.* - - - -	–	x	–	–	–	–	–
	,, sp. - - - - - - -	x	–	–	–	–	–	-
N	Arca Stricklandi, *Tate* (A. truncata, *Buckm.*) - - - - -	–	–	–	–	–	–	x
	,, sp. - - - - - - - -	–	–	–	–	–	–	x
	Modiola scalprum, *Sow.* - - - -	x	–	x	–	–	–	–
	,, hillana, *Sow.* - - - -	–	x	–	–	–	–	–

† Species marked thus have been determined by Mr. S. S. Buckman. Those marked N are new records from this locality. The figures in the last six columns refer to the strata in the section given above.

Fossils from Loseby Brickyard.—continued.

	——	Judd.	1.	2.	3.	4.	5.	6.
	Avicula sp. - - - - - -	x	–	–	–	..	–	–
N	Pecten Thiollieri ?, *Martin* - -	–	–	x	–	–	–	--
	„ textorius, *Schloth.* - -	–	x	x	–	–	–	–
	„ calvus, *Goldf.* - - -	–	x	x	–	–	–	–
	„ sp. - - - - - -	–	–	x	–	–	–	–
	Limea acuticosta ?, *Münster* - -	–	x	–	x	–	–	--
	Lima pectinoides, *Sow.* - - -	–	–	x	–	–	x	–
	„ gigantea, *Sow.* - - -	–	–	x	–	–	–	–
	„ Hermanni, *Voltz.* - - -	x	–	–	–	–	–	–
	„ sp. - - - - - - -	–	–	x	–	–	–	–
	Plicatula sp. - - - - - -	–	–	x	–	–	–	–
	Gryphæa cymbium, *Lam.* - -	x	–	–	–	–	–	–
	„ obliquata, *Sow.* - -	x	–	–	–	–	–	–
	„ sp. - - - - - -	–	–	x	x	–	–	–
	Ostrea sp. - - - - - -	–	x	x	–	–	–	–
	Rhynchonella variabilis, *Schloth.* -	–	x	–	–	–	–	–
	Ditrupa ? etalensis. *Piette* - -	–	x	–	–	–	–	–
N	Extracrinus sp. - - - - - -	–	–	–	x	–	–	–
	Pentacrinus sp. - - - - - -	x	–	–	–	–	–	–

In and near the railway there are several sections in the zones of *A. Jamesoni* and *A. capricornus*. From the deep cutting at Cold Newton we obtained *Am.* [*Ariet.*] *sauzeanus*, *Belemnites*, *Avicula*, *Lima pectinoides*, *Pleuromya costata*, *Plicatula spinosa* (abundant), *Terebratula* (fragment), *Serpula*, *Pentacrinus*; and in ditches near Hamner's Lodge *Am.* [*Aeg.*] *capricornus*, *Belemnites sp.*, *Eucyclus imbricatus*, *Plicatula spinosa*, and *Serpula*. At the station there is a hard band of limestone with *Rhynchonella tetrahedra*, *Cardinia sp.*, etc., which is probably very near the junction between the Lower and Middle Lias.

Some hard beds of limestone crop out in the little stream on the north side of Billesdon; and, where the lane to Billesdon Coplow crosses, ferruginous shale and hard bands are exposed containing *Pecten æquivalvis*, *Arca Stricklandi ?*, *Modiola scalprum*, *Rhynchonella lineata*, and *Belemnites*. These beds must be very near to the top of the Lower Lias, and possibly should be included in the Middle Lias, but without further evidence it is impossible to say.

In this neighbourhood two borings have been put down into the Lower Lias, which show the great thickness these beds attain here. The first, which was sunk about the year 1833 on the south side of the hill at Billesdon Coplow, was made in search of coal. This boring, it is evident both from the depth sank and from the character of the strata penetrated, did not reach the base of the Lias, although supposed to have been sunk in true Coal Measures. Professor Judd (*Geology of Rutland*, p. 62) gives the depth of this boring as more than 600 feet, but the account given by Holdsworth, of which we give an abstract in the appendix, does not allude to so great a depth as this.* Another boring was put down

* See p. 88. This is the boring to which the anecdote of Professor Sedgwick related by Professor Jukes (*Life and Letters of J. B. Jukes*, 1871, p. 467, quoted by Harrison, *Geology of Leicestershire*, p. 3) is supposed to refer.

in 1897 close to the Billesdon Brook, three-quarters of a mile south-west of the village. This proved over 700 feet of Lias beds, and, as it commenced beneath the outcrop of the Middle Lias, the full thickness of the Lower Lias cannot be much short of 750 feet.

South of Billesdon the Lower Lias is brought up by a fault, so that its outcrop is shifted some distance further east. It crops out in the valleys to the south of Rolleston, and was met with in a well at Illston Hall, which is said to have been sunk 110 feet in grey shale with much selenite and pyrites. Dark shales were also thrown out of a well at Three Gates, but no fossils could be found to fix the horizon of the beds.

In the stream due east of Rolleston dark and grey shales with nodules containing *Am.* [*Aeg.*] *capricornus* were found, and a little lower down there are several sections in shales with ironstone nodules, showing that this valley is cut down into the upper part of the Lower Lias. The valleys further east—that is, the Eye Brook and the numerous small streams uniting at Hallaton—do not appear to have cut through the *A. margaritatus* shales of the Middle Lias. Prof. Judd * suggests that the *A. capricornus* beds may have been reached at the bottom of the clay-pit at Hallaton brickyard, but as the Rock-bed crops out at the road, there is not sufficient room for the full thickness of the *A. margaritatus* zone.

Middle Lias.

FIG. 4—*Village of Somerby, Rutland, situated at the head of one of the deep sinuous valleys of the great escarpment formed by the Marlstone Rock-bed.* (*F. Rutley.*)†

* *Loc. cit.*, p. 62.

† From *Geology of Rutland*, p. 53.

The Middle Lias consists of two important divisions, the Rock bed and the shales below, corresponding to the two palæontological zones of *A. spinatus* and *A. margaritatus*. These are easily recognised wherever the rock crops out free of Drift. As the beds are best exposed about the centre of the map, near Billesdon and Tilton, where they attain their greatest thickness and form bold escarpments, it will be as well to describe the section here before proceeding further.

At Tilton Station the whole thickness of the Rock-bed and a portion of the *A. margaritatus* shales are cut through in the following section :—

*Section in the Railway Cutting at Tilton.**

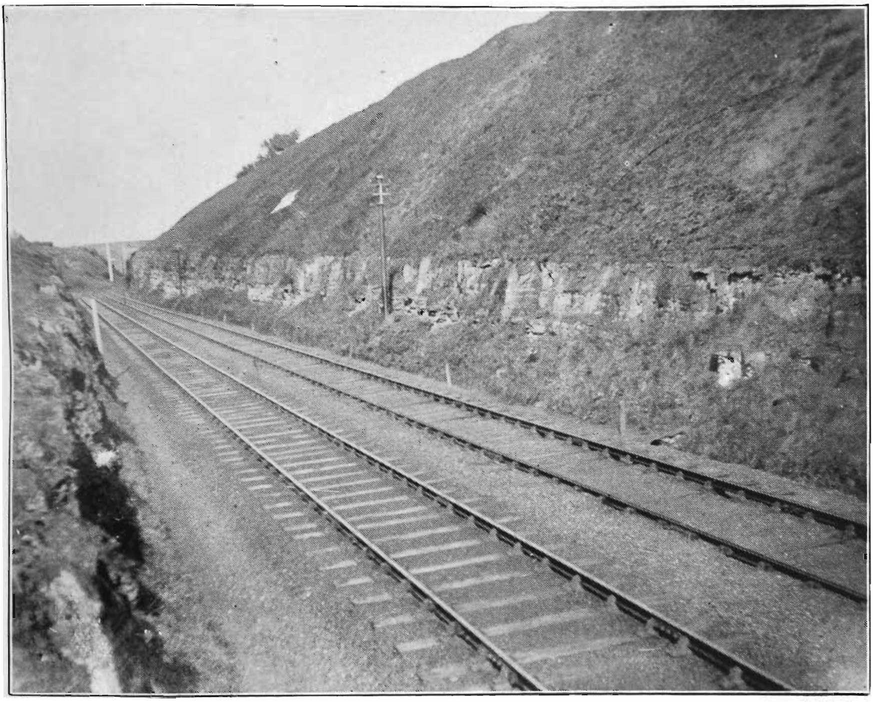
	Ft.	in.
Massive ferruginous sandy limestone with *Am.* [*Cœloceras*] *communis*, *Am.* [*Harpoceras*] *elegans?*, *Belemnites*, etc., very abundant in a matrix of white calcspar on the surface - - - - - - - - - - - - -	6	0
Soft sulphury line.		
Rock, much jointed and broken - - - - - - -	4	0
,, with hard grey lenticular patches full of brachiopoda-	4	0
Marked band of rock crowded with brachiopoda - - -	1	0
Massive rock with scattered brachiopoda - . - - -	2	0
Grey sandy shales - - - - - - - - - - - -	3	6
Sandstone - - - - - - - - - - - - -	2	0
Sandy shales (at the bridge and behind the signal-box) and limestone bands with pyrites. *Pentacrinus* - about	25	0
Sandy shales (in the stream) - - - - - - 10 0 to	15	0
Hard sandy bed below.		
Ironstone nodules and shale in the stream further down.		
Total thickness of Rock-bed about 18 feet.		

The Middle Lias enters the map in the north-east corner at Whissendine, the Rock-bed being seen in the road at the east end of the village,† just beyond the limit of this sheet. It has been quarried in the valley east of Houlback Lodge, where it forms a well-marked plateau. It again crops out in the valley on the other side of Ranksborough Hill, and makes a conspicuous feature on both sides of the lake, as well as in the other branch of this valley nearly a mile further west.

The general escarpment of the Middle Lias being completely covered by Drift between Whissendine and Pickwell, these are the only exposures of the Rock-bed between these villages, but the *A. margaritatus* shales crop out all along the valley, and at the time of the former survey were well seen in the brickyard where the Oakham road crosses this stream. From these dark blue clays with septaria Professor Judd gives the following list of fossils :—

* A very full account of this section is given by E. Wilson and W. D. Crick, *Geol. Mag.*, 1889, p. 296.

† Not west end, as stated in the Rutland Memoir.



RAILWAY CUTTING, TILTON.

Section showing Upper Lias Shales resting on the Rock-bed of the Middle Lias.

From a Photograph by A. W. Searley.

*Fossils from the Old Whissendine Brickyard at Rocott.**

Ammonites margaritatus, De Mont. Normal form; specimens very numerous, often of large size and great beauty.
Belemnites paxillosus ? Schloth. Very large.
Pecten sublævis, Phil.
Cardium truncatum, Sow.
Lima pectinoides, Sow.
Modiola scalprum, Sow. Very abundant and large specimens.
Myacites (Pleuromya) unioides, Röm., sp.
Terebratula punctata, Sow.
Rhynchonella tetrahedra, Sow.
Serpula sp.

At Pickwell the Middle Lias gets clear of the Drift, and the Rock-bed forms the marked tabular feature which is so characteristic of the rock. This table-land, which is bounded by a bold escarpment on the north and west, dips gently to the east; it extends as far as Somerby on the south and Burrow Hill on the west, where it attains a height of 689 feet above the sea, forming one of the most conspicuous landmarks of the district. The *A. margaritatus* shales crop out on the steep slopes below, both to the north and west, and in the deep ramifying valleys on either side of Somerby. They were also met with in a well at Burrow on the Hill.

Between Somerby and Ouston the outcrop is masked by Drift, and the rock is seen only at a few places; the most important exposure being at the old brickyard about half-way between the two villages, where the *A. margaritatus* beds have been worked a short distance below the outcrop of the Rock-bed. Of this section, which is now entirely obliterated, Professor Judd gives the following account:—

Section at Ouston Brickyard.

	Ft.	in.
1. Soil.		
2. Light-coloured clay only partially exposed.		
3. Band of ironstone - - - - - - - - - -	0	6
4. Blue, highly micaceous and pyritous clay -	3 0 to 4	0
5. Blue, sandy, calcareous and highly micaceous rock, crowded in places with fossils - - - - - -	2	0
6. Clay similar to 4, but with bands of septaria - - -	21	0 to bottom of the pit.

The fossils were beautifully preserved and are enumerated in the following list:—

Fossils from the Middle Lias Clays of Ouston Brickyard.

Ammonites margaritatus, De Mont., typical form, very abundant; many of the specimens attaining a great size.
Ammonites normanianus, d'Orb.
Belemnites elongatus, Mill.
Belemnites sp.
Helicina expansa, Sow. sp.
Ostrea sp.
Pecten æquivalvis, Phil.
,, *sublævis*, Phil.
Avicula inæquivalvis, Sow.

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* Rocart on the old one-inch map.

Mytilus hippocampus, Y. & B.
,, *scalprum*, Sow. Very variable in form; very abundant.
Cardium truncatum, Sow
Pleuromya unioides, Roemer., sp.
Pholadomya decorata, Hartm.
,, *ambigua*, Sow., var. ?.
Serpula sp.
Pentacrinus sp.

In the neighbourhood of the railway at Tilton the Middle Lias again becomes clear of Drift, and forms a series of bold headlands, which may be easily followed as far as Billesdon. At Life Hill, near Billesdon Coplow, where the outcrop extends furthest to the west, the Rock-bed rises to an elevation of 700 feet above the sea. At the foot of this the sandy shales of the *A. margaritatus* beds crop out. They consist of blue and yellow shales, with ironstone nodules and hard calcareous bands. These beds are found in the steep slope immediately below the escarpment of the Rock-bed, and rarely extend for any great distance beyond it. They may be followed from the Tilton cutting to Loseby Station, where they form the rising ground immediately to the south. It is doubtful whether a portion of the beds seen in the cutting here should not also be included in this zone.

Around Billesdon Coplow these beds form a rather more extensive outcrop, being seen in the lane going down to Ingarsby, and, in two or three shallow excavations west of the house. From a well near the farm, which was 47 feet deep, we obtained *Am.* [*Lytoceras*] *cornucopia*, *Pecten æquivalvis*, and *Arca Stricklandi* ?. The old boring here is also just within the outcrop of these beds, which it must have penetrated for a few feet.*

In the lane leading to Billesdon, close to the bridge, there is as we have noticed, a hard band of blue limestone with *Arca Stricklandi* (?), *Modiola scalprum*, *Rhynchonella lineata*, *Belemnites*, etc.; and some yellow sandy shales with ironstone nodules containing *Pecten æquivalvis* are seen a little further up the valley which, although probably representing the upper part of the *A. capricornus* beds, cannot be far from the base of the *A. margaritatus* zone.

In the brickyard at Billesdon is the most complete section we have of these beds. In 1890 the following details were measured here:—

Section in Brickyard at Billesdon.

	Ft.	in.
Dark, red, ferruginous, sandy limestone - - - - -	2	0
Grey marly beds, changing to ferruginous sandstone - -	5	0
Yellowish sand beds - - - - - - - - -	3	0
Hard, greyish shaly beds - - - - - - - - -	2	0
Break in measurements.)		
Grey shale - - - - - - - -	3	0
Ferruginous band with white efflorescence - - -	–	–

* Appendix, p. 88.

	Ft.	in.
Grey shale	4	0
Ferruginous band with large *Pecten æquivalvis*, etc.	–	–
Grey shale	4	0
Nodular band	–	–
Grey shale	2	0
Nodular band	–	–
Grey shale	5	0

About 15 feet more of shale with nodular bands are seen in the lower pit on the south side of the road.

Professor Judd, who saw this section many years before, gives a rather different account. It appears that this pit has been both deepened and cut further back in the interval, so that it now reaches the base of the Rock-bed, and there must be nearly 50 feet of measures exposed in the two pits. Fossils are not very plentiful, but Professor Judd records the following:—*

Fossils from the Billesdon Brickyard.

Ammonites margaritatus, Montf.
Belemnites paxillosus, Schloth.
Lima pectinoides, Sow.
Pecten æquivalvis, Sow. (*P. sublævis*, Y. & B.).
Plicatula spinosa, Sow.
Modiola scalprum, Sow.
Goniomya sp.

South of Billesdon the outcrop of the Middle Lias becomes much obscured, partly from the overlap of the Boulder-clay and other Drift deposits, but principally, we think, from the thinning out of the Rock-bed, which scarcely makes any feature in this country. Between Billesdon and the Ashlands there is no evidence for the outcrop of the Middle Lias, but from the general structure of the country it is probable that it forms the backbone of this ridge; although the beds seen at Illston and Rolleston may be outliers, and not connected with the main mass, as shown on the map.

The *A. margaritatus* beds are seen at Ashlands and Illston; in the road north-west of the latter village the following section was seen, but from the weathering down of the beds the account is very imperfect:—

Section in road on west side of Illston.

		Ft.	in.
Ferruginous clays with a little ironstone		10	0 (?)
Obscured		10	0 (?)
Very ferruginous rock	0 1 to	0	2
Yellow clays } Greyish shale with carbonaceous markings }		10	0
Flaggy sandstone	2 0 to	3	0
Grey and yellow shales, more ferruginous		5	0
		or more	

At the top of the hill, and in the pond at the north end of the village, ferruginous sandstone and ironstone are seen, forming the lowest portion of the Rock-bed.

Another isolated section of these beds is found in the little valley above Rolleston Wood, where the Rock-bed forms a small feature

* *Loc. cit.*, p. 69.

round the head of the valley. It consists of a thin bed of ferruginous limestone, with *Belemnites*, *Protocardium truncatum*, and other fossils. The blue sandy shales of the *A. margaritatus* beds were met with in the gasometer at Noseley Hall; but the Middle Lias about here is entirely covered by Drift, and there is no evidence to show how far it may extend to the south.

On the opposite side of the valley at Goadby the Middle Lias is free of Drift, and the Rock-bed forms a very marked feature. The rock is, however, very thin, so that it seems to be its unusually hard flaggy nature that enables it to form so regular a plateau. The outcrop is lost beneath the Drift about half a mile further south, but is seen to the east near the higher part of the interior valley going down from Keythorpe Wood, a little north of the footpath between Goadby and Hallaton. It is evident that the beds in this valley are lower than has been supposed, and that the outcrop of the Rock-bed does not run in the direct manner shown on the old map, but more probably extends much further to the west, in the direction of Staunton Wood, following the present contour of the ground much more nearly than was shown on the old survey.

The Rock-bed in this direction is evidently very thin, as shown by sections at Cranhoe and other places just beyond the edge of the map.

Since the previous survey of this country was published, the railway cutting through Slawston Hill, south of Hallaton, has been made. As this section gives a good idea of the character of the Middle Lias in the neighbourhood we give it here.

Section in Railway Cutting at Slawston Hill.

	Ft.	in.
*Massive sandy ironstone	3	0
	or more	
Sandy shales	4	0
Hard flaggy band	0	6
Sandy shales - about	12	0
*Dense red ironstone with *Belemnites* (many split longitudinally)	1	0
Sandy shales - about	7	0
* { Ironstone, shaly and nodular, with *Belemnites*	0	8
{ Band of ironstone, weathers with a very irregular surface	0	6
Shale with a nodule or two	3	8
Line of nodules some distance apart.		
Shale with a few nodules	5	0
Hard flaggy calcareous band - 0 0 to	0	4
Shale with nodules	15	0
Base of cutting.		

The Goadby plateau extends across by Old Keythorpe into the valley going down to Hallaton. The Rock-bed can be seen at intervals on both sides of this stream, but it is evidently very thin.

* These three beds stand out conspicuously from the grass slope of the cutting. The above details were measured in 1890, when the section had become much obscured. A somewhat different account, given by Mr. J. Marriott, is published in abstract in *Trans. Leicester Lit. Phil. Soc.*, 1884, p. 80.

It is 3 feet thick at Old Keythorpe; but a little lower down, where the bridle-road crosses the valley, the following section, which is now entirely obscured, was given by Professor Judd:—

UPPER LIAS:—

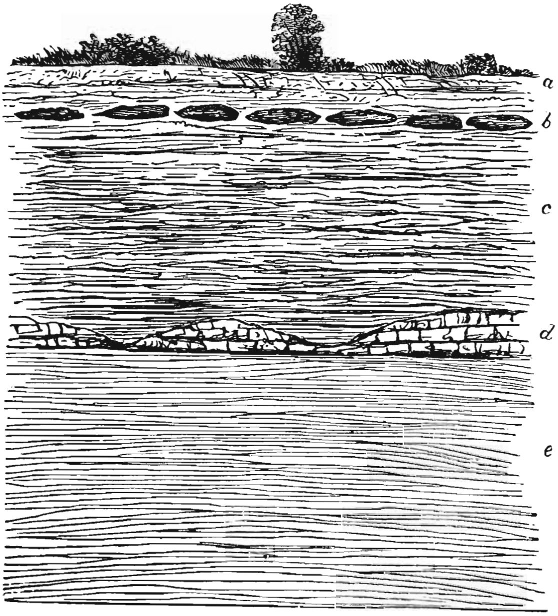
1. Laminated shales with traces of the "fish and insect beds" at the top - - 5 to 6 feet.

MIDDLE LIAS:—

2. Marlstone Rock-bed with usual characters, containing numerous *Belemnites*, *Ammonites annulatus*, *Terebratula punctata*, etc. As is often the case with this rock, it here contains numerous rounded pebbles and concretions - 1 foot seen.
3. Light blue clays passing down into—
4. Clays with bands and layers of nodules of ferruginous and micaceous rock.

The irregular mode of occurrence of the diminutive representative of the Marlstone Rock-bed is illustrated in the following sketch of a section seen at this point:—

FIG. 5.—*Section exhibited in a pit between Keythorpe and Hallaton (Prof. J. W. Judd).**



a. Soil, etc.
Upper Lias. { b. Nodular Fish and Insect Limestones.
c. Clays.
Middle Lias. { d. Marlstone Rock-bed.
e. Clays, etc.

The Rock-bed, although so thin, can be easily followed on both sides of the stream for its whole length down to the village. The

* *Geology of Rutland*, p. 73.

outcrop is in some places obscured by landslips, and there are several springs that deposit large quantities of tufa. *Am.* [*Amaltheus*] *margaritatus* was found in the ferruginous beds just at the junction of the Rock-bed with the shales below.

In the other valleys radiating from Hallaton the Rock-bed also forms a marked feature; it is cut into by the railway, which shows, at about 400 yards south of the tunnel, a limestone crowded with Brachiopoda, and which is about 1 foot 6 inches thick. All these valleys are cut for some depth into the *A. margaritatus* shales, but the only clear section is that at Hallaton brickyard, where the following section was measured:—

Section at Hallaton Brick Works.

	Ft.	in.
Yellow and grey shales with nodules - - - - -	5	6
Rubbly ironstone with *Terebratula*, etc. - - - - -	1	6
Shale - - - - - - - - - - -	1	0
Rubbly ironstone - - - - - - - - -	1	6
Shale - - - - - - - - - - -	3	0 seen.

Professor Judd records the following fossils from this place:—

Ammonites margaritatus, Mont.
Avicula inæquivalvis, Sow.
,, sp.
Pecten liasianus, Nyst.
,, sp.
Cardium truncatum, Sow.

These shales with ironstone nodules were also obtained from a well at Horninghold, but we were not able to find any fossils in them. At this last village the Rock-bed is seen along the sides of the stream and in the road; it is a brown sandy rock, with a little flaggy limestone, and contains, according to Professor Judd *Am. annulatus* and *Rhynchonella tetrahedra*.

The remaining exposures of the Middle Lias are in the three inlying valleys to the north, the Eye Brook, the River Chater, and the River Gwash. In the first of these valleys the Rock-bed is best seen at East Norton and at Loddington; but further up the valley to the west it is soon lost beneath Drift, so that the extent of the outcrop is very doubtful. It probably occurs along the higher part of Reddish Wood, and runs against the fault a little to the west of this, but there is no evidence of the rock beyond Loddington Mill. The same obscurity occurs on the south side of the valley, no rock being seen between Tugby and the little valley just south of Skeffington, where a ferruginous rock containing *Terebratula punctata* crops out. This ground is represented on the old map (64) as Lower Lias, but the section at Skeffington was not observed; and as the hill rises gradually from one village to the other it is much more probable that the outcrop of the Rock-bed is continuous.

The *A. margaritatus* shales crop out along the Eye Brook, but whether this valley is cut through to the Lower Lias is doubtful.

From the septaria in these shales at the Belton old brickyard Professor Judd obtained the following fossils :—

Ammonites margaritatus, Mont. Several varieties, and of all sizes.
Pleurotomaria Quenstedti, Goldf.
Myacites or *Panopæa* (fine specimen).
Leda complanata, Phil.
Cardium truncatum, Sow. (in masses).
Pecten demissus, Phil.
,, *æquivalvis*, Sow.
Lima pectinoides, Sow.
,, sp.
Plicatula spinosa, Sow.
Avicula inæquivalvis, Sow.
Rhynchonella tetrahedra, Sow. (one specimen).

Along the valley of the Chater the Rock-bed and the shales just below are very well exposed. Sanvey Castle, at the head of the valley, is formed almost entirely by the Rock-bed, which here stands up in an abrupt little cliff of well-bedded sandy limestone, full of Brachiopoda in the lower part, resting on softer sandy ferruginous beds; while a little lower down the stream the grey shales below with septaria are seen. There are 6 inches of rotten sandstone with ferruginous nodules at the junction. The rock has been quarried at Withcote, Launde, Coles Lodge, and Leighfield; it contains *Rhynchonella tetrahedra*, *Terebratula punctata* in great abundance, and also a *Cardinia*. When freshly quarried the limestone is bluehearted.

In the valley of the River Gwash the Rock-bed first comes to the surface at the point where the streams branch about three-quarters of a mile below Knossington; it forms a fairly good feature along the north side of the valley all the way to Braunston, where it is exposed in the village. On the south side of the valley, however, the outcrop is very obscure, and it is possible that it may be cut out by a fault ranging along the valley. The shale is much disturbed at several places, and it is curious that, although the outcrop is so good on the north side of the valley, the rock has not been observed on the south side; but the evidence is scarcely sufficient to warrant the insertion of a fault along this valley.

The rock is not now used as an ironstone anywhere in the area included in this map; it was at one time tried near Tilton, but apparently without much success.

Upper Lias.

The Upper Lias occupies the whole of the remaining part of the map to the east of the Middle Lias escarpment, except in those valleys that are cut through to this latter formation. Consequently all the ridges between these valleys are formed of Upper Lias shale, which is, however, generally covered in the higher part by Drift. These shales form large swelling pastures, and it is seldom that there are any sections to show their character. Formerly there were a few brickyards in them; but now, owing to the depression in agriculture, very few artificial sections for drainage or other purposes are made, and the brickyard at Knob Hill, east of Hallaton, is the only place where these shales are worked.* Therefore we have to gather our information of the Upper Lias principally from the old Survey memoir on the district, which was undertaken between the years 1867 and 1871, when the country was more prosperous, and consequently exposures of the shales much more frequent. Professor Judd divides the Upper Lias into the following five divisions† :—

e. "*Leda-ovum Beds.*" Clays with numerous bands of septaria (many fossils).
d. Highly pyritous clays, with much jet in places (few fossils).
c. "*Communis Beds.*" Laminated blue clays with bands containing numerous small fossils.
b. "*Serpentinus Beds.*" Clays with nodules of limestone, sometimes ferruginous (Ammonites abundant).
a. "*Paper-shales with Fish and Insect Limestones.*" ("Dumbleton series.")

The thickness of the Upper Lias is given by Professor Judd as about 200 feet, but it is not quite so much as this near its western edge. Below the outliers of Oolite at Ranksborough and Whatborough there is not more than from 110 to 120 feet, but below Robin-a-Tiptoes and at Belton there is as much as 180 feet or so.

At Knob Hill the finely-laminated shales, which contain crystals of selenite often 6 inches or more in length, are very unfossiliferous; and only a few decomposed bivalves were noticed in them. The only other section near here was in the bottom of a pond in the valley to the north, where there are some soft ferruginous beds with oolitic grains containing *Am.* [*Coeloceras*] *communis*. Professor Judd, in his account of this country, says‡—"On the left bank of the stream at Hallaton Ferns the junction of the Upper and Middle Lias was well seen in a number of field-drains. The succession of beds here is as follows :—

Upper Lias	1. Dark blue clays.
	2. Ferruginous beds with *Ammonites serpentinus*, Rein. (abundant), and *Am. bifrons*, Brug.
	3. Paper-shales, with Fish and Insect Limestones (usual fossils.)
Middle Lias	4. Sandy, ferruginous band with casts of shells. (Marlstone Rock-bed ?)
	5. Light-coloured clays with ironstone balls.

"Near the bridle road from Keythorpe to Hallaton, at the point where it crosses the brook, some old pits show the base of the Upper Lias, consisting of 5 or 6 feet of laminated shales, with traces of the nodular limestones, with fish and insect remains; these rest upon the Middle Lias beds, which have been already described at this place. (See page 73).

"Opposite to Moor Hill Lodge there is an extensive brickyard in the Upper Lias Clays. In this and a pond above we have a section

* There were also formerly brickyards in these shales at Launde and Moorhill.
† Memoirs of the Geological Survey. *Geology of Rutland*, p, 79.
‡ *Loc. cit.*, p. 83.

of at least 50 or 60 feet of the series. The highest beds seen consist of laminated, light-coloured clays, with irregular, brown, ferruginous bands in the lines of stratification. The lower part consists of blue clays with few septaria, but with much pyrites, both in nodules and disseminated through the mass, and, in consequence, the weathered beds exhibit much Selenite, often in very large and beautiful crystals. Fragments of *Belemnites* occur in this pit, and *Ammonites* are also found, but I saw none sufficiently well preserved for identification. The clays exposed in this pit probably belong to the middle portion of the Upper Lias, which is generally very unfossiliferous. In Keythorpe Park a pond, dug in the lower part of the Lias Clays, exhibited the richly fossiliferous bands crowded with small *Ammonites*, etc., which characterise that part of the series. I collected here—

Ammonites communis, Sow. (Very abundant.)
,, *annulatus*, Sow. (Very abundant.)
,, *Holandrei*, d'Orb.
,, *radians*, Rein. (Abundant.)
,, *bifrons*, Brug.
Belemnites compressus, Voltz.
Leda ovum, Sow. sp.
Inoceramus dubius, Sow.
etc., etc.

"The brickyard opened on the opposite side of the road to Tugby Hall exhibits the same beds, consisting of finely-laminated blue clays with a few septaria. These clays when dug show a few small crystals of Selenite. The beds are crowded with small fossils of the same species with those found at the last noticed locality.

"At several points about the village of East Norton, and also at Finchley Bridge, roadside cuttings and field-drains have exposed the fish and insect beds with the usual fossils. Small bivalves, such as *Inoceramus dubius*, Sow., and *Pectens* with dwarfed *Ammonites* occur in some of the bands of flattened limestone nodules.

"An interesting pit at Allexton exhibits the following section of the lower beds of the Upper Lias:—

		Ft.	in.
1.	Soil	1	0
2.	Blue laminated clay	6	0
3.	Irregular stony band ("kale") full of *Ammonites serpentinus*, Rein., *Belemnites* and other fossils - 1 to	2	0
4.	Laminated clay	0	6
5.	First, irregular bed of hard, argillaceous limestone	0	6
6.	Laminated clay	1	0
7.	Second, irregular bed of hard argillaceous limestone	0	6
8.	Laminated clay	1	0
9.	Third, or best bed of limestone - 0 3 to	0	6
10.	Laminated clay	0	4½
11.	"Kale"	0	6
12.	Marlstone Rock-bed full of the usual fossils; four course of stone - together	2	6

"In the clays large masses of wood, converted into jet, are found These, after being soaked in oil to prevent cracking, are used by the workmen and others for whetting razors.

"The three layers of limestone contain the usual fragments of fish, insects, and crustaceans with the following shells:—

Belemnites sp.
Ammonites serpentinus, Rein.
,, *elegans*, Sow.
,, *annulatus*, Sow.
,, sp.
Small univalves.
Ostrea (small species).
Inoceramus dubius, Sow.
Astarte sp.
Lima sp.
Pteroperna sp.
Other small bivalves.
Fragments of wood.

"The limestone, which is hard and fissile, and of a blue colour weathering white, occurring sometimes in continuous bands and at other times in nodules, is carried to Tugby, where it is burnt for lime. It is said to produce a hydraulic lime fully equal in quality to the celebrated "Barrow lime," which is made from the fish and insect limestones of the Lower Lias series.

"It is worthy of notice that the Serpentinus bed, which in many places is ferruginous, and has often, when attention has not been given to the fossils, been mistaken for the Marlstone Rock-bed, is at Allexton either not at all or only very slightly coloured with oxide of iron.

"At Deepdale traces of the fish and insect limestones of the Upper Lias are seen lying on the Marlstone. At several points about Loddington there are small exposures in the road-cuttings of the same beds."*

Along the railway north of Loddington there are some deep cuttings of about 40 feet or so in these shales, which, although now grassed over, afforded many fragments of *Am.* [*Harpoceras*] *falcifer* and other species.

A well near the Windmill at Billesdon was sunk in the lower part of the Upper Lias, the spoil-heap containing several specimens of *Am.* [*Harpoceras*] *falcifer* together with a *Nautilus*, and many fragments of the fish and insect limestone. In the road on the north side of Tilton on the Hill, and at Pickwell, Professor Judd records the presence of the fish and insect limestones, but these sections were not visible at the time of the present survey.

To the east of Somerby the Upper Lias is very free of Drift, and may be easily recognised from the nature of the soil; but there are no excavations in the beds, although a brickyard, now closed, was formerly worked about a mile from the village. There are also two small outliers between Somerby and Burrow Hill. To the north of Pickwell and Rocott the Upper Lias becomes entirely covered by Drift, and there is no evidence to fix how far it may extend in the direction of Whissendine.

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* *Loc. cit.*, pp. 83, 84.

CHAPTER V.

INFERIOR OOLITE.

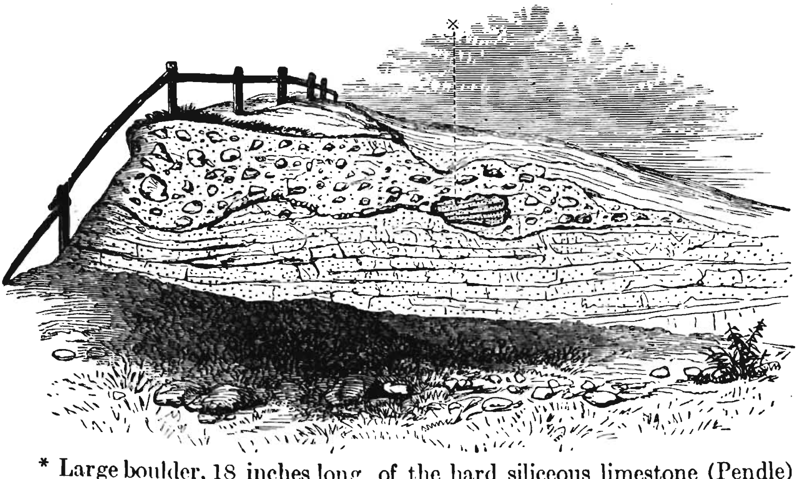
Northampton Sand.

The beds of the Inferior Oolite that are represented in this map are quite at the base of the formation, and merely represent a few scattered fragments that have so far resisted denudation. They are the equivalent of the Northampton Sand, which in some localities is very variable in character; but here, owing to the small thickness of rock that remains, and therefore to its greater exposure to the weather, very little calcareous matter is left, and we have a residue consisting almost entirely of soft ferruginous sandstone. This sandstone has a peculiar "cellular" structure, consisting of a casing of brown hæmatite enclosing a soft interior of blue and green carbonate and silicate of iron, or merely ferruginous sand. This structure, which is well shown at Launde Park Wood and other places, seems to be caused by the concentration of hydrated peroxide of iron along the bedding planes and joints that have split up the rock into roughly rectangular blocks.

The main escarpment of the Inferior Oolite lies between three and four miles beyond the eastern margin of the area now under consideration: therefore there are only a few small outliers of the rock that come within this area.

The first of these occurs to the north of Hallaton, but it is almost completely covered by Drift, so that the rock is only seen along its northern and western edge. The following sketch at this place is from the old Survey memoir:—

FIG. 6.—*Section in pit above Hallaton Ferns, showing a small outlying patch of Northampton Sand capped by Boulder-clay. (Prof. J. W. Judd.)*†



* Large boulder, 18 inches long, of the hard siliceous limestone (Pendle) of the Inferior (Lincolnshire) Oolite.

† *Geology of Rutland*, p. 107.

It is probable that the rock also occurs on the hills east of Hallaton and south of Allexton, where fragments of the Inferior Oolite are very conspicuous and the elevation sufficient to bring on this rock; but as the ground is entirely covered by Drift it has not been shown on the map at these places.

The largest outlier is that to the north-east of Belton, but only a very small portion comes into this map. It may, however, extend further along the ridge to the west, and be connected with that south of Launde Park Wood, the ground being sufficiently elevated but entirely covered by Drift. The western edge of this latter outlier is much depressed by a fault, so that it and the small outliers just north of Loddington are quite 50 feet lower. There is another small outlier at Launde Big Wood; but, both from their isolation and greater elevation, the most noted outliers are those at Robin-a-Tiptoes and Whatborough. These hills rise above the 700 contour line and form very conspicuous objects in the landscape. Colborough Hill also assumes the aspect of an Oolitic outlier, and it is probable that the rock is only just removed by denudation, as a careful examination of the hill revealed nothing but shale close to the summit.

Although it is possible that the Inferior Oolite may occur on the hills on either side of the Gwash and at Cold Overton, there is no evidence of its outcrop this side of Ranksborough Hill. Here two very small outliers occur, the ground between being only just denuded below the base of the rock. This hill has steep sloping banks of Upper Lias Clay on the west and south, but towards the north Drift clay soon comes on, and therefore it is not so conspicuous when viewed from the latter direction.

The beds of the Northampton Sand form a light rubbly soil, well adapted for the growth of corn; but the areas covered by the rock in this district are so small that the only place where its presence has any influence on agriculture is on the flat-topped hill east of Belton.

CHAPTER VI.

PLEISTOCENE AND RECENT.

Glacial.

The superficial deposits which come into this map are of considerable interest from the fact that they illustrate the character of these beds in one important branch of the great Trent basin. The nature of the Pleistocene succession in this large area has been ably described by Mr. R. M. Deeley,* who separated these beds into no less than eight sub-divisions in the following order :—

Newer Pleistocene Epoch.

Later Pennine Boulder-clay.
Interglacial River-gravel.

Middle Pleistocene Epoch.

Chalky Gravel.
Great Chalky Boulder-clay.
Melton Sand.

Older Pleistocene Epoch.

Middle Pennine Boulder-clay.
Quartzose Sand.
Early Pennine Boulder-clay.

Mr. Deeley drew his conclusions from a large number of isolated sections; but the detailed mapping of the ground does not entirely substantiate these ideas.

As yet the survey of this midland district has not been carried far enough to give a decided opinion on the subject, so that the classification adopted in this memoir relates only to the Soar valley, and may be subject to modification when a larger area has been examined. Many of the differences noted in the Boulder-clay and gravel appear to be due to merely local conditions, and it is probable that some deposits of slightly different character are really contemporaneous. The main fact drawn out from a study of the Drifts is that they are of two distinct ages; the one having its included fragments, consisting principally of quartzite pebbles derived from the west or north; the other, containing detritus of the Chalk and Oolite, from the east. These, as we have said, occupy the relatively higher ground throughout the district. There is also possibly a third series of clays and gravels which were laid down at a much later date, after the existing valleys had been cut out, and consequently it is only found at the lower levels. This is so intimately connected with the post-Glacial

Quart. Journ. Geol. Soc., vol. xlii., p. 437.

river beds, that probably it should be included with them. It may represent a passage of from one state of conditions to the other. With the exception of these doubtful beds, the general distribution of the Drift is that of one vast sheet rising gradually to the watershed and falling equally gradually on the other side. This sheet, which seldom has a thickness of more than 100 feet, is cut through by all the principal streams of the districts, so that the solid strata are exposed in nearly all the valleys, while the Drift is found capping all the ridges between them.

The following appears to be the order of succession of these beds in this district:—

Valley Drift.
Great Chalky Boulder-clay with intercalated beds of sand and gravel.
Older Boulder-clay (upper part).
Quartzose Sand.
Older Boulder-clay (lower part).
Older Sand and Gravel. (?)

Older Sand and Gravel.—Along the valley of the Wreak, fringing the modern alluvium of that river, there are a series of sands and gravels, the age of which is somewhat puzzling. At first sight these appear to be ordinary post-Glacial river terraces, and no doubt a good deal of the gravel along this valley is of this nature; but at the same time there are places where the gravel appears to pass under the older Boulder-clay, and consequently must be the oldest of the superficial beds with which we have to deal.

This appears to be the case more especially at Eye Kettleby, east of Kirby, at Rotherby, and at Rearsby, on the south side of the Wreak. On the north side the gravels at Hoby and Asfordby are probably also of this age, but the evidence is more indistinct. These beds consist of false-bedded sands and gravels, composed chiefly of quartzite pebbles and other rocks derived from the north and west, with few, if any, from the Chalk or Oolite. The sands generally contain streaks of coaly fragments, with intercalated clayey patches here and there. They rise usually from the level of the alluvium to from 30 to 40 feet above it, flanking the meadows on either side in the ordinary manner of river terraces, so that it is very difficult to distinguish one from the other. These gravels may be of pre-Glacial age in part, and, if so, it clearly shows that the present valley is excavated nearly in the same line as the old one.

The principal evidence for the position of these sands and gravels is chiefly in that part of the Wreak valley that is north of the present area, more especially at Eye Kettleby, Frisby, and Hoby. In this area they are seen at Rearsby, and apparently crop out along the valley towards Frisby Lodge, but their position is obscure.

The Older Boulder-clay.—The principal section of this Boulder-clay is in the brickyard at Thrussington, although it is also seen along the valley to the north, and in that to the north-east of Seagrave. It consists of a stiff marly clay of a variegated red and bluish-grey colour, with small pebbles of quartzite and other rocks, but containing few, if any, large boulders, nor any derived from the Chalk or Oolite. For this reason it appears to be the result of a glaciation derived entirely from the west, and thus is in strong contrast to the Boulder-clay containing Chalk and Oolite, which has come from the opposite direction. It however contains a considerable amount of limestone derived from the Lias, which is usually well striated, as also are most of the harder rocks.

The Quartzose Sand.—This name has been given by Mr. Deeley to the coarse sand lying on the Boulder-clay just described. It principally occurs along the sides of the larger valleys, and consists principally of false-bedded sand and gravel, the sand frequently containing great quantities of coal detritus.

This sand, being much used for building, is extensively worked near Leicester, both at Aylestone and near the Abbey.* At the latter place portions of the sand are frequently cemented together, so that the floor of the pit is a very hard sandstone, and there are pillars of the same kind of rock. The isolated block of stone known as St. John's Stone, which formerly stood near this place, was probably, as pointed out by Mr. J. D. Paul, a pillar of this sort.†

Similar cemented gravels are frequently met with at the base of the Drift, one very conspicuous instance being in the railway cutting near Rowley Fields. The long tunnel between Glenfield and Leicester is entirely cut in these sands, which are here full of water, so that if a hole is made in the brickwork it requires considerable force to close it again. Similar gravels occur at Oadby and other places.

This sand is seen resting on the Boulder-clay at Thrussington brickyard. It passes up into a laminated clay or brickearth which attains its greatest thickness and best development in the valley of the Wreak at Rotherby and to the north of Hoby.

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* This pit is now closed.

† *Trans. Leicester Lit. Phil. Soc.*, vol. iii., part v., p. 262.

In the brickyard at Rotherby, where these clays were formerly worked, they are about 26 feet thick, and pass down into a hard tough red Boulder-clay. The following is the section:—

Section in Rotherby Brickyard.

	Ft.	in.
Loamy soil, with Chalk fragments.		
Boulder-clay, containing mostly Lias fragments and quartzite pebbles, but with one or two Chalk fragments - - - - - - - - -	8 0 to 12	0
Stratified clayey sand with coaly matter and a few pebbles. Thin seam of clay in upper part - -	4 9 to 5	0
Laminated brick-clay or sandy loam of a reddish colour, with a pebble here and there (lower part proved by boring) - - - - - - - - - -	21	0
Hard, tough, red Boulder-clay, with small quartzite pebbles and a few bits of limestone, etc. (bored into) -	12	0

This brick-clay has a red Keuper-looking appearance, as if it had been deposited from tranquil water largely charged with the débris of that formation. It is usually underlaid and overlaid by sand, and frequently passes altogether into sand or gravel; so that the colour shown on the map denotes in some places a loamy clay, in others a sand or gravel. It appears, however, to be only on the outskirts of the area over which the brick-earth has been deposited, or among beds which occupy the same horizon—namely, between the Boulder-clay just described and the one above—that we find these coarser sands.

The area over which the brick-clay has been deposited is about five miles across in either direction, and consequently covers about 25 square miles, of which the village of Hoby is nearly in the centre. Beyond this lenticular patches of sand and gravel occur at the same horizon throughout other portions of the district. These in many places contain a large proportion of Chalk débris, in others there is not a Chalk fragment to be found; so that, although they seem to have been deposited at about the same time, they are probably the result of conflicting currents at the period when the country was passing from the glaciation which produced the older Boulder-clay to that which formed that next to be described. Whether they are all of this date is, however, doubtful.

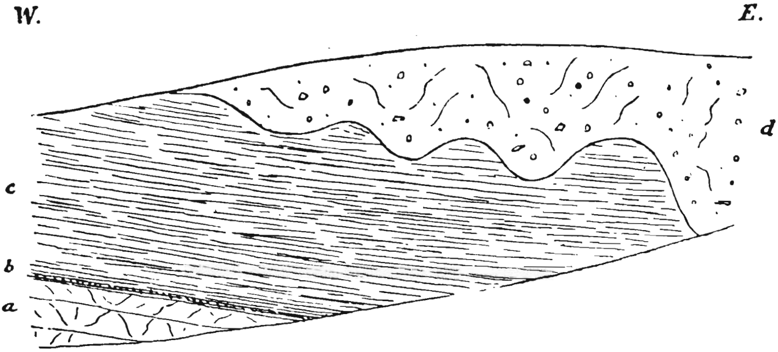
A similar brick-clay occurs at Melton, which has been described by Professor Judd, who considers it to be of pre-Glacial age.*

These sands and gravels occasionally join on to those previously described beneath the Boulder-clay, so that without clear sections it is impossible to distinguish one from the other: for this reason the colours used for Drift on the map indicate merely lithological differences without regard to their relative age.

* Geology of Rutland, p. 243.

The Older Boulder-clay (*upper part*).—Resting on these sands and laminated clays there is another Boulder-clay similar to that described above, in that it does not contain any fragments of Chalk or Oolite. This Boulder-clay rarely exhibits any trace of stratification, but near the base is frequently intersected by numerous striated surfaces or slickensides, which give the clay an irregular, jointed appearance. This was well shown in the section on Spinney Hills.

FIG. 7.—*Section on the west side of Spinney Hills, Leicester.*



d. Boulder-clay resting on distinctly glaciated surface with striations. The Boulder-clay, which is much slickensided, contains mostly Lias fragments, a few quartz pebbles, limestone fragments (striated) and one large sandstone block.

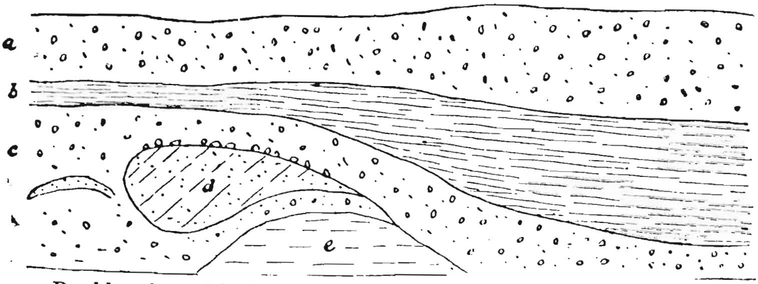
c. Dark laminated shale with selenite crystals and much sulphur. Yellowish rusty-looking band at intervals, and occasionally jetty-looking streaks. Small *Protocardium philippianum* and *Avicula contorta.* Dip 3° E. Limestone nodules at east end.

b. Bone bed, varying in thickness from half an inch to nothing.

a. Tea-green or grey marl.

A good instance of the great irregularity in Drift deposits of this age is shown in the following section :—

FIG. 8.—*Section on the Midland Railway, just south of the tunnel, Freeman's Common, Leicester.*



a. Boulder-clay with but few stones of any size, a few Chalk fragments and flints.

b. Laminated clay with a few very small stones ; 6 to 8 feet thick in thickest part.

c. Boulder-clay, a line of pebbles as large as the fist resting on (*d*).

d. Sand with much coaly matter, stratification highly inclined.

e. Keuper Marl with a little white sandstone.

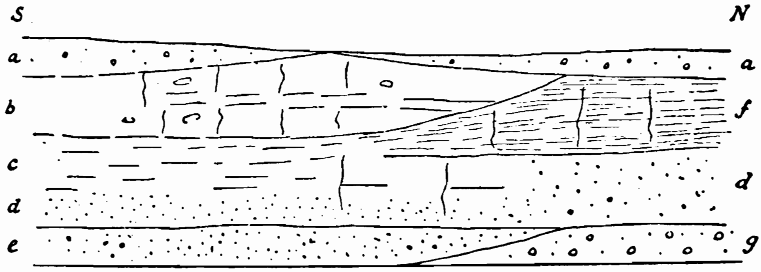
Height of section about 15 feet, more Boulder-clay above.

This Boulder-clay, which probably covers a large area, comes to the surface only on the flanks of the hills bordering the Soar and its tributaries, being nearly everywhere else hidden by newer beds, to be described presently. Its chief outcrop is along the spurs of the hills east of the Soar; but it does not appear to extend much north of Seagrave, as it is not traceable in the upper part of any of these valleys, nor was it met with in a well at the Lodge a mile north-west of Seagrave, which went through the overlying Boulder-clay directly into the Lias. Towards the east its outcrop also gradually becomes more and more obscure, so that probably in this direction it also soon thins out.

The outcrop of this Boulder-clay frequently forms a distinct feature which is easy to recognise in walking over the ground; but, as there would be much uncertainty in attempting to trace it continuously, it has not been separated on the map from the overlying Chalky Boulder-clay.

The Chalky Boulder-clay.—The Chalky Boulder-clay covers the whole of the higher ground between the numerous streams intersecting the district, except at a few places in the eastern part. It appears to attain its greatest development in the northern portion of the map, gradually diminishing in thickness towards the S.E.* It consists when unweathered of a darkish blue or grey clay, with fragments of chalk, flint, and other rocks; but on exposure to the air it becomes decalcified and of a reddish-brown earthy nature. The amount of included fragments varies considerably in different places, sometimes there is a clay with very few stones, at others the deposit is almost entirely made up of chalk and chalk flints with very little clay. The other rocks, which include sandstones, limestones, slates, quartzites, igneous rocks, etc., from various formations, are always in a distinct minority, being probably derived from older glacial beds, and not from the original glaciation of the country where they have their outcrop. An interesting section in the lower part of the Drift was seen in one of the cuttings of the Great Central Railway.

FIG. 9.—*Cutting on Great Central Railway, south-east of Stocking Farm, Leicester.*



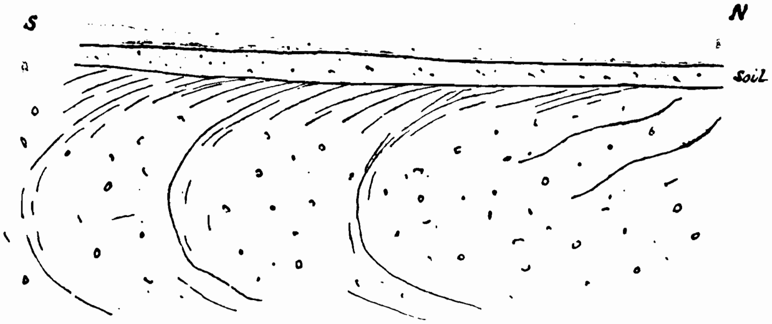
* A well about a mile west of Hallaton is said to have been sunk to a depth of 150 feet. The spoil-heap consisted of Boulder-clay only.

		ft.	in.
a.	Weathered Boulder-clay with scattered chalk flints - at N. end	4	0
b	Irregular, lumpy, soft, marly, sandy beds, and clay with incipient concretions	6	0
c.	Sand and loam with marly partings containing "race"	5	0
d	Loamy sand - at N. end	3	0
e.	Chalk gravel	2	0
f.	Stiff drab clay	3	0
g.	Gravelly, chalky Boulder-clay	3	0

(*b*) is very similar to unconsolidated Coal-measure clay.
(*c*) passes into dark brickearth in the centre of the section, and drab clay (*f*) towards the north.
The connection between the north and south ends of the section is not very clear.

Further evidence that the Boulder-clay has been subjected to subsequent movements after its deposition was shown at Enderby, where its upper portion has been bent over in the manner shown in the sketch given below. This curving over is towards the north, or from the summit of the hill, and may have been caused by accumulations of Drift slipping over that below.

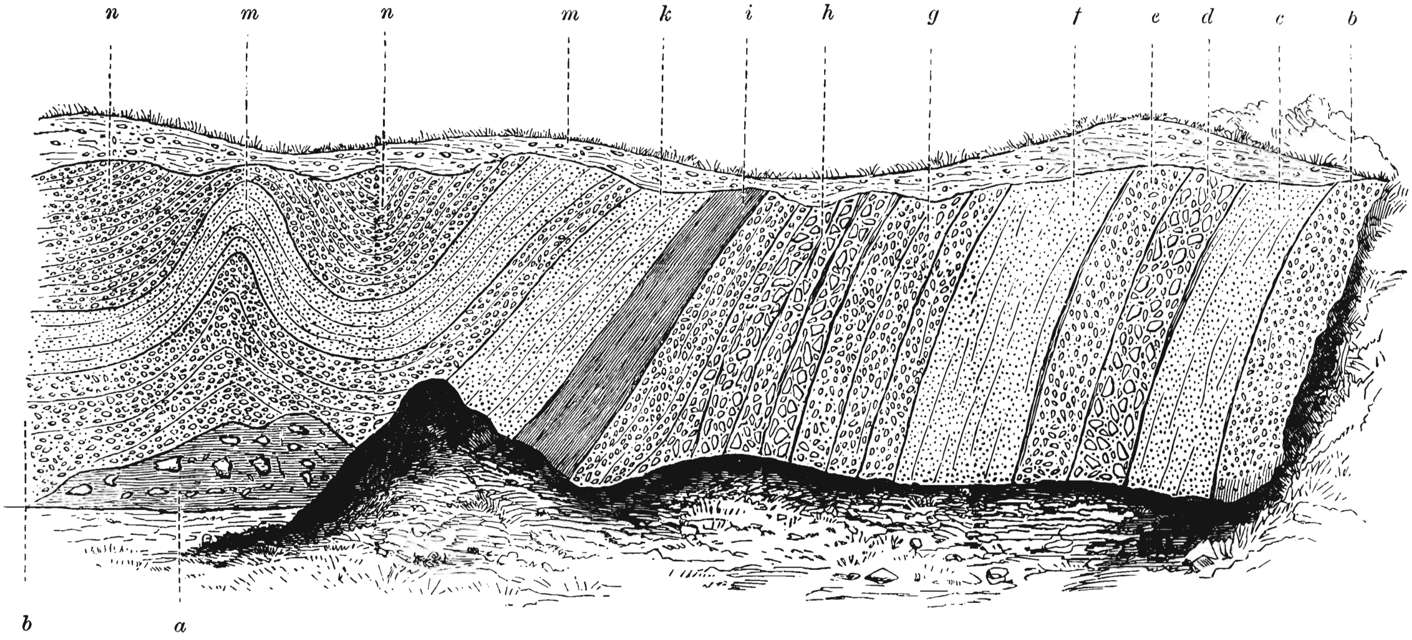
FIG. 10.—*Section in cutting west of Enderby Hill.*



The Boulder-clay contains mostly Chalk fragments, few sandstones, etc., and very few pebbles. It is bent over towards the north-west, or from the hill. The curved lines are streaks of sandy loam or clay. At the end of the cutting the Boulder-clay abuts against the rock at an angle of 30°. It is rather gravelly close to the junction. Height of section about 16 feet.

Intimately associated with this Boulder-clay are several lenticular patches of sand and gravel. Some of these, as we have mentioned, were deposited previously to the Chalky Boulder-clay; but others are of later age, and are intercalated in its mass or deposited over it. They are very well developed at Tilton, Skeffington, Cold Overton, Knossington, Ouston, Belton, and many other places. They are composed almost entirely of Chalk, Oolite, and Lias fragments, and are frequently very much disturbed and contorted by great lateral pressure, as shown in the accompanying sketch by Professor Judd.

FIG. 11.—*Pit in Glacial Gravels between Whatborough and Ouston* (*Prof. J. W. Judd*).*

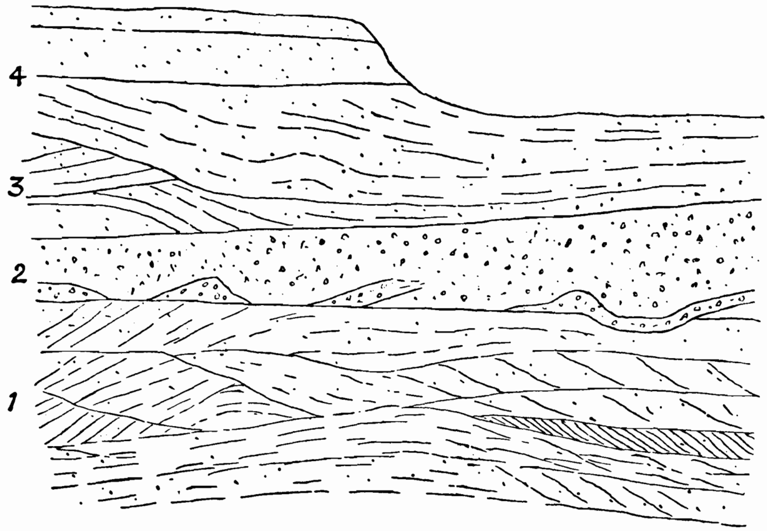


a. Boulder-clay. *b, e, g, l, n.* Fine gravel. *c, f, k, m.* Sands. *d, h.* Coarse gravel. *i.* Loam.

* Geology of Rutland, p. 248.

Another good section in these gravels was seen on the north side of the river at Blaby, of which we give the following rough sketch :—

FIG. 12.—*Sand Pit near Union Inn, Blaby.*

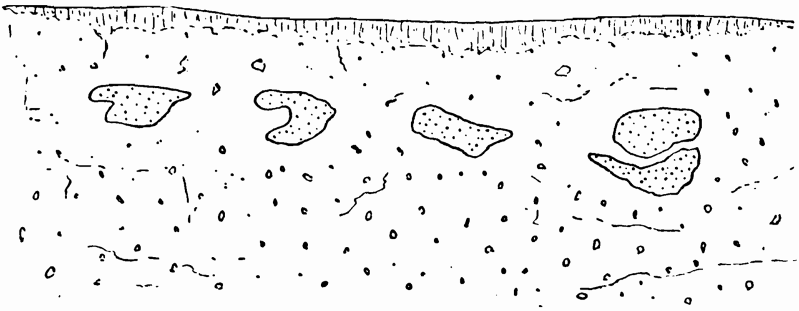


4. Sand and gravel mixed.
3. False-bedded sand - - - - - - - - - 15 0
2. Chalky gravel with patches of Boulder-clay at the base
1. False-bedded sand- - - - - - - - - - 10 0

A few granite boulders lying about.

Other instances of this contortion of the Drift have been noticed at Tilton Windmill, in the railway cutting near Marefield, and in the railway cutting south of Wigston, where the sands are thrust in under beds of Lias.

FIG. 13.—*Balls of sand in Boulder-clay, corner of Ratcliffe Road and Elms Road, Leicester.*



Excavation about 10 feet deep. The balls of sand are about two feet in diameter. The Boulder-clay is grey or mottled with fragments of soft sandstone and Lias limestone abundant. A good number of quartzite pebbles, but no Chalk or Flint. Weathered clay with a few stones on top.

In the upper part of the Boulder-clay, as shown in the above figure, there are frequently curious lenticular patches of sand, that seem to run at one definite horizon, which is usually not many feet below the surface of the ground. It is not very clear how these pockets of sand have originated, whether they have been washed into hollows in the Boulder-clay, or whether they were deposited as frozen masses.*

The Drift rises to 730 feet on Life Hill, north of Billesdon, which is the highest ground in the map, so that there is no evidence as to what its maximum elevation may have been; but probably it was not much greater than this, as on the Charnwood Hills the Drift never rises quite to this level. It descends towards many of the existing valleys, showing that the present lines of drainage nearly coincide with those in pre-Glacial times. In a few cases, as at Illston Grange, north of Rolleston, and north-east of Ouston Woods, the Boulder-clay has not been cut through by the present streams, but this is very exceptional, and we have found no evidence of a pre-Glacial drainage system differing from the present one. The absence of Drift along the escarpment of the Middle Lias is probably due to the greater force of denudation along this steep bank; but why it has been cleared off the three channels running east from Burrow Hill to Ranksborough, from Tilton to Belton, and from Goadby to Horninghold is not so clear.

The Drift occasionally contains enormous transported masses of Oolite, Chalk, and Marlstone, such as have been noticed in the country to the north-east in the neighbourhood of Corby,† to the south at Rugby,‡ and elsewhere. One of these transported masses occurs just beyond the N.E. corner of this map. It is a mass of Oolitic limestone; and, as far as can be made out from old quarries, and the fragments lying about, appears to be at least 300 yards long and 100 yards across. The nearest point from which this mass can have come is at Waltham, about five miles to the north-east. At about 1,000 yards north-east of Belton there are two small rounded hills that appear to be capped by Inferior Oolite. These possibly are also drifted masses; but, as their summits are 80 feet below the outcrop of the rock, which is only 300 yards distant, they may be due to landslips. As has been stated in the memoirs descriptive of this neighbourhood (Sheets 64 and 70), it is probable that such masses are the result of coast ice acting along the Oolite shore at a period when the country was partially submerged.

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* Mr. Paul has noted similar occurrences at other places in the neighbourhood. *Trans. Leicester Lit. Phil. Soc.*, 1885, p. 117.

† Memoirs of the Geological Survey. Explanation of Sheet 70, p. 79.

‡ *Quart. Journ. Geol. Soc.*, vol. xxxi., p. 355.

In connection with this subject, it is interesting to note the general disposition of the larger boulders in this part of the country. The following list has therefore been compiled from the reports of the British Association, with a few additions from other sources:—*

LIST OF THE MORE REMARKABLE BOULDERS RECORDED IN LEICESTERSHIRE.
Square brackets denote additions or alterations.

Locality.	Dimensions.		Character of Rock.	Reference to Authority.
	Maximum.	Minimum.		
Hugglescote	10 tons	Gravel	All Charnwood rocks except one Millstone Grit.	Brit. Assoc. Rep., 1873, p. 190.
Shakerstone	5·0×4·0×1·6	—	Porphyroid and other rocks of Charnwood.	,, ,, 1875, p. 88.
Carlton	—		Charnwood rocks	,, ,, 1880, p. 113.
Market Bosworth	4·0×3·0×2·0		Syenite and ashy conglomerate of Charnwood.	,, ,, 1880, p. 113.
[Leicester Forest]	6·0×4·0×4·6	Several smaller	Syenite	,, ,, 1883, p. 142.
Kirby Muxloe	4·0×4·0×5·0	2·0×2·0×1·0	,,	,, ,, 1883, p. 142.
Loughborough?	3·0×3·0×2·0		Millstone Grit	,, ,, 1883, p. 141.
Normanton-on-Soar.	—		Charnwood Forest rocks	,, ,, 1875, p. 88.
Burton-on-the-Wolds.	3·6×3·4×5·0	—	Grit.	
Stanton, Notts	4·6×2·0×1·0	—	Lias [limestone], Quartzite, Millstone Grit, Carboniferous limestone.	,, ,, 1875, p. 87.
Grimston	3·0×2·0×3·0		Jurassic limestone	Geological Survey.
	5·0×3·0×2·6	—	Coarse sandstone	,, ,,
Saxelby	4·0×3·1×1·6	—	Jurassic limestone	,, ,,
Kirby Bellars	3·0×2·0×1·6		Grit	,, ,,
Hoby	3·0×3·0×3·0	—	Millstone Grit.? Black basalt.	Brit. Assoc. Rep., 1875, p. 88.
Loseby	4·6×3·0×3·6	—	Granite, also flints and Quartzite pebbles.	,, ,, 1877, p. 89.
	5·3×3·5×2·4	—	Millstone Grit	,, ,, 1878, p. 190.
Syston, New York Farm "Moody Bush Stone."	[3·6×1·6×1·0]	—	Coarse, ashy conglomerate from Charnwood.†	,, ,, 1880, p. 112.
[Syston?] Lodge Farm.	2·6×2·0×1·6	1ft. cube	Granite of Mount Sorrel	,, ,, 1880, p. 114.
Rothley Temple	3·0×2·6×2·0	2·6×2·0×2·0	,, ,,	,, ,, 1881, p. 206.
Cropston	8·0×4·0	—	,, ,,	Geological Survey.
Ingarsby Tunnel	3·6×2·6×2·0	—	Coarse carb. sandstone	,, ,,
Bushby	2·0×1·9×1·4	1·6×1·3×1·3	Carb. limestone, Millstone Grit, &c.	Brit. Assoc. Rep., 1880, p. 112.
Thurnby	2·0×1·6×1·6	9in. cube	Granite, Syenite, Greenstone	,, ,, 1877, p. 89.
	4·0×3·0×1·0	—	Granite	,, ,, 1880, p. 111.
	6·0×2·0×1·6	1ft. cube	Carb. limestone, Millstone Grit	,, ,, 1882, p. 246.
Johnstone's Farm.	5·0×4·0×2·0	—	Conglomerate or Breccia	,, ,, 1880, p. 112.
Evington	3·0×2·3×1·6	1ft. cube	Granite, Millstone Grit, Limestone, Chert, Sandstone, &c.	,, ,, 1877, p. 89.
Coleman Road	3·3×3·0×2·6	1·3×1·0×1·0	Sandstone, Grit, Limestone from the N.W.	,, ,, 1878, p. 191.
Spinney Hill Road.	3·0×1·0×1·0	2·6×1·2×1·4	Granite of Mount Sorrel	,, ,, 1878, p. 192.
Lodge Farm	4·6×2·6×1·0	3·0×2·6×1·0	,, ,,	,, ,, 1881, p. 205.
Leicester	—	—	Dark, slaty, hornblendic rock	,, ,, 1874, p. 197.
	7·0×6·0×2·0	—	Granite of Mount Sorrel	,, ,, 1880, p. 113.
Rutland Street	4·0×2·0×3·0	—	,, ,,	,, ,, ,, ,,
	3·0×1·10×1·3	—	,, ,,	,, ,, ,, ,,
Near the Abbey‡ "St. John's Stone"	7 feet above ground.	—	Sandstone.†	,, ,, 1874, p. 197.
Abbey meadow	2·0×2·0×2·0	—	Chert from Derbyshire?	,, ,, 1880, p. 114.
	2·0×2·0×1·0	1·6×1·0×1·0	Granite	,, ,, 1881, p. 206.
North of Humberstone, "Holystone," or "Hellstone"	8·0×7·0×5·0 [8·0×7·10×3·6]	—	Granite of Mount Sorrel (longest axis 10ft., weight about 20 tons).†	,, ,, 1874, p. 197. 1878, p. 190; 1881, p. 207.
Victoria Road	2·9×2·1×0·10	1·8×1·6×1·0	Granite, Syenite, Carboniferous limestone, Chert, Millstone Grit, Oolite.	Brit. Assoc. Rep., 1878, p. 193; 1880, p. 113; 1886, p. 223.

* Since this memoir has been in the press Mr. Browne has published a list of boulders from the Beaumont Leys Estate. *Trans. Leicester Lit. Phil. Soc.* 1902, p. 34.

† The microscopical character of these rocks is given in the Appendix, p. 116.

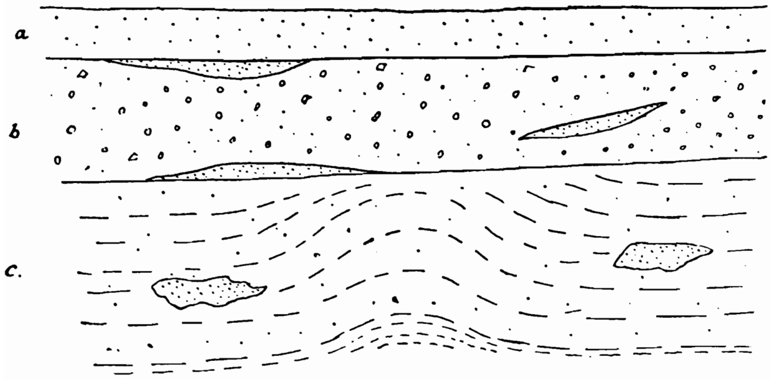
‡ Probably not a boulder. *See* p. 45.

Locality.	Dimensions.		Character of Rock.	Reference to Authority.
	Maximum.	Minimum.		
Victoria Park	1·6×1·0×1·0	10in. cube	Granite, Syenite, Slate, Grit, Sandstone, Coal, Carboniferous limestone, Oolite, Lias, Chalk flints.	Brit. Assoc. Rep., 1881. p. 206.
Evington Road	3·1×2·1×0·10	1·5×1·2×1·1	Syenite, Millstone Grit, Oolite	" " 1878, p. 192.
Saxe Coburg Street.	3·3×2·2×2·0	2·6×2·0×1·10	Granite of Mount Sorrel	" " 1878, p. 192.
	3·0×2·6×1·10	—		
Clarendon Park	2·6×1·5×1·7	1·5×1·9×0·10	" "	" " 1883, p. 141.
	5·0×4·6×3·9	4·0×3·1×2·3	" "	" " 1878, p. 193.
	3·6×2·0×1·6	—	" "	" " 1881, p. 205.
			Syenite	" " 1882, p. 245.
	2·6×2·0×2·0	1·6×1·6×1·0	Lias, Syenite, Granite, Greenstone, Millstone Grit.	" " 1882, p. 245.
Oadby	2·0×1·0×2·0	1·6×1·0×1·0	Granite of Mount Sorrel	" " 1880, p. 114.
Stoughton, Dairy Farm.	4·0×3·0×2·6	—	" "	" " 1881, p. 205.
Spinney Hills, Lodge Farm.	3·0×2·6×1·9	2·0×1·0×1·0	Granite and Millstone Grit	" " 1881, p. 206.
Spinney Hills	3·3×3·0×2·6	—	Granite, Grit and Oolite	" " 1888, p. 123.
Willow Brook	3·0×2·0×2 0	2·0×2·0×1·3	Granite, Grit and Slate of Charnwood.	" " 1881, p. 206.
Saffron Lane	4·0×3·6×2·0	1ft. cube	Granite, Basalt, Syenite	" " 1882, p. 246.
Newfoundpool	5·0×3·0×2·6	—	Syenite	" " 1888, p. 123.
Braunston	3·0×2·6	—	Sandstone	Geological Survey.
Knighton Church Lane.	3·0×2·0	—	Syenite	Leicester Lit. Phil. Soc., iii., p. 207.
Aylestone	3·0×2·10×2·10	2·0×1·0×0·10	"	Brit. Assoc. Rep., 1878, p. 191.
	2·6×2·0×1·10	1·0×0·10×0·9	"	" " " "
	7·0×6·0×4·0	—	Granite of Mount Sorrel	" " 1882, p. 245; Leicester Lit. Phil. Soc., 1882, p. 23.
	4·0×3·6×3·0	—	Syenite†	Brit. Assoc. Rep., 1880, p. 111.
	3·0×2·10×2·8	—	"	" " 1880, p. 114.
	4·0×3·0×1·6	—	"	" " 1881, p. 206.
	6·0×3·6×3·0	4·0×3·0×3·0	"	" " 1882, p. 246.
Beasley's Farm	3·0×1·9×1·3	1·9×1·3×0·10	Millstone Grit, Triassic sandstone.	" " 1882, p. 246.
Beasley's Pit	4·6×3·3×1·6	—	Millstone Grit	Leicester Lit. Phil. Soc., 1883, p. 24.
Aylestone Road	4 9×2·0×2·3	—	Syenite	Leicester Lit. Phil. Soc., iii., p. 208.
Hallaton	7·0×6·0×3 0	—	Marlstone	Brit. Assoc. Rep., 1883, p. 141.
Countesthorpe	2·6×2·0	—	Keuper sandstone, Oolite, Greenstone, Quartz.	" " 1880, p. 113.
Ashby Magna Station.	12·0×12·0	—	Marlstone	Geological Survey.

Valley Drift.—Besides the two Boulder-clays described above there is a later deposit which we have called the Valley Drift, from its occurring along the lower ground, and in the bottoms of valleys which have been denuded since the older glacial beds were formed. This Drift occurs along the small tributary valleys about Barrow and Sileby, and seems to be occasionally present beneath the river gravels, but no clear sections have been seen in this area. It is never of any great thickness, usually not more than about five feet or so, and appears to be largely made up of pre-existing Boulder-clays. It contains irregular lenticular patches of sand and gravel, which appear to have been thrust into the mass of the clay; but the most noteworthy fact in connection with this glaciation is that the upper portion of the Lias strata, on which it reposes, is nearly always more or less disturbed, and frequently violently contorted, with patches of gravel thrust into it for some depth. A good section of this was shown in the limestone quarry about a mile N.E. of Barrow Church, a diagram of which is given below.

† The microscopical character of these boulders is given in the Appendix, p. 116.

FIG. 14.—*Section in upper part of limestone quarry ("Darby's Pit") north-east of Barrow.*



		Ft.	in.
a.	Soil cap with Chalk fragments, etc. - - - about	1	0
b.	Boulder-clay with Chalk fragments and pebbles, and streaks of sandy gravel. Majority of stones are Chalk - - - - - - - - - - -	4	0
c.	Lias clay with specks of calcareous matter and bits of limestone; also patches of sandy chalk gravel here and there - - - - - - - - - - -	2	0
	Lias shales and limestones below		

It is very evident that a different state of things existed at the time of the formation of this Drift to that which obtained during the deposition of the two earlier Boulder-clays. The small thickness of this clay, the limited area over which it extends, and the disturbed stratification both of it and of the beds upon which it rests, seem to point to the conclusion that the climate must have been considerably milder, and the ice of a more local character, than that which prevailed during the two preceding periods of glaciation. We would, therefore, suggest that this newer deposit may be the result of a purely local glaciation which operated for a much shorter period, and during which the present valleys were occupied by glaciers or floating ice emanating from the central region of Charnwood.*

Sand and Gravel.—Besides the sands and gravels which are associated with the two earlier Boulder-clays there is a third series of these beds, which appears to have been deposited during this later period, although the age of these sands is always much more difficult to determine than that of the clay.

As shown in the section at the top of the Barrow lime-pit (Fig. 14), both the Drift-clay and the upper part of the Lias contain frequent pockets of sand. These may, in other places, spread out into thicker beds of sand and gravel, but they are not distinctive enough to be shown on the map.

* My colleague, Mr. H. B. Woodward, who accompanied me on one occasion to this pit, expressed his opinion that the glaciation belonged to the period of the Chalky Boulder-clay.

These sands and gravels, like the clay itself, are never found much above the bottoms of the present valleys; and for this reason are not easily distinguished from the post-Glacial valley gravels.

River Gravels and Alluvium.

Along the valleys of the Soar and Wreak there are well-marked terraces of river gravel flanking the modern alluvium of these rivers. These are about 20 feet above the present river flat; and, near the confluence of the two rivers at Syston, form considerable spreads of flat gravelly soil. They have evidently been deposited at a time when the rivers flowed at a higher level, and when there was a greater volume of water than at the present time. These terraces in many places extend up the lateral valleys, and in their upper part join on to the alluvium of those streams so that it is difficult to separate one from the other. This is the case at Leicester, where, the old town being built on one of these terraces, its later extension has obliterated all trace either of its connection with earlier valley deposits or with the alluvium of the Willow Brook, with which it becomes merged in the northern part of the town. Besides the modern alluvium of the main streams there are frequently deposits of loam which have generally been ignored, but in a few places have been included with the alluvium. This loam masks the outcrop of the later Drift beds, so that without sections it could not be mapped. A great number of mammalian remains have been found from time to time in the newer deposits near Leicester, of which the following species are recorded by Mr. Montagu Browne.

List of Vertebrate Remains found in Leicestershire, recorded by Montagu Browne ("*The Vertebrate Animals of Leicestershire and Rutland*," 1889).

PLEISTOCENE.

Species.	Localities.
Bison bonasus, var. *priscus*, Bojanus	Abbey Meadow, Archdeacon Lane, and Kegworth.
Bos taurus, var. *primigenius*, Bojanus	Abbey Meadow, Belgrave (?), Willow Bridge, West Langton.
Cervus elaphus, Linnæus	Abbey Meadow, North Bridge, and Barrow-on-Soar.
Elephas antiquus, Falconer	Barrow-on-Soar and Thorpe Arnold.
Elephas primigenius, Blumenbach	Valley of the Soar, Abbey Meadow, Belgrave, Humberstone, Thurmaston, Loughborough, Kegworth, and Melton Mowbray.
Rangifer tarandus, Linnæus	Grafton Place, Abbey Meadow, Belgrave, Aylestone.
Rhinoceros leptorhinus ?, Owen	Belgrave, Thurmaston.

PREHISTORIC AND RECENT

Species.	Localities.
Bos taurus, var. *longifrons*. Owen -	Abbey Meadow, Flood Works, Thurnby, Syston, Barrow-on-Soar, Loughborough.
Capra or *Ovis* - - - - -	Leicester, Syston, and Barrow-on-Soar.
Capreolus caprea, Grey *	
Cervus dama, Linnæus - - -	Town Hall Lane and Flood Works.
Cervus elaphus, Linnæus - - -	Abbey Meadow, North Bridge, and Barrow-on-Soar.
Equus caballus, Linnæus - - - -	Braunston Gate, Fosse Road, Belgrave, Birstal, Mountsorrel, Barrow-on-Soar, Loughborough, Kegworth.
Sus scrofa, Linnæus - - - -	St. Nicholas Church, Friar Lane, Abbey Street, Bede House Meadows.

* Recorded in error by J. Plant, *Leicester Lit. and Phil. Soc.*, 1874, p. 37. See Browne, L. Vert, p. 34.

CHAPTER VII.

FAULTS.

The solid strata in this district are, on the whole, nearly flat, with a slight dip towards the east; and, although the beds seen in the streams are frequently much disturbed, there do not appear to be many large faults. Owing to the covering of Boulder-clay there are probably more of these dislocations than are shown on the map, but they cannot cause any great displacement in the strata.

Barrow and Sileby Fault.

The principal evidence for this fault is between Barrow and Sileby, beyond the northern edge of the map, where it cuts out the Rhætic beds bringing in the Keuper Marl against the Lower Lias. At Sileby the effect of the fault is very striking from the close proximity of these strata, both at the back of the village and in the stream. Further east the exact position is not so clear; but it is evident that it must either turn more to the north-east or be met by another fault to the north of Ratcliffe R. C. College where the well was sunk in Keuper Marl without meeting with any Lias or Rhætic beds. From the exposure of Keuper Marl in the valleys on either side of Thrussington it is clear that the fault extends to the north of these sections, and is probably continued some distance up the Wreak valley. Although the exact position of the fault cannot be determined, owing to the covering of Boulder-clay, its general effect is very apparent, by the setting back of the Rhætic and Lias outcrop, and by the occurrence of the basement beds of the Lias at Kirby Bellars, far to the east of their normal position.

Billesdon Fault.

On the south side of Billesdon the Middle Lias; which forms so grand an escarpment to the north of the village, is cut off by an east and west fault. The strata that are brought up to the south are, however, so much hidden by Drift that it is not possible to estimate the amount of displacement, but the recent survey of the ground about Rolleston and Skeffington seems to indicate that it is not nearly so large as has been supposed. In Sheet 64 of the old Geological Survey this fault is continued to the north of Skeffington and Loddington, but there is so much Drift over the high ground east of Billesdon that, although this may be the same as the fault next to be described, it is better to treat them separately.

Loddington Fault.

The principal evidence for this fault is in the two streams coming down from Robin-a-Tiptoes, where the sandy beds of the Middle Lias are brought against the Lower Lias shales. At Loddington the effect of the displacement is to bring the base of the Inferior Oolite rather nearer to the Rock-bed of the Middle Lias than it usually is. The amount of throw is, however, small and a sharp roll of the strata would nearly produce the same effect. To the east of this the fault appears to soon die out.

The other faults that have been noticed are only quite small, although they cause a marked breach in the continuity of the strata. In a little valley north of Humberstone the Rhætic beds are seen in the stream on the south side of a fault running north-west and south-east, while on the north the Keuper Marl nearly caps the hill on the same line of strike. The throw may be from 30 feet to 40 feet.

On the north side of Burrow Hill there is a sharp drop in the base line of the Rock-bed, and the plateau formed by this rock is perceptibly higher to the north, towards Little Dalby, than what it is at the encampment.

South of Somerby there is another small fault that also throws down the Rock-bed to the south. The effect of this dislocation is very apparent on the roads to Ouston and to Knossington from the clear features formed by the Rock-bed, which is 30 feet or so higher to the north than what it is on the south side of the valley. This fault is probably continued some distance to the west, for in the valley on the east of Burrow the escarpment of the Rock-bed drops very rapidly to the south, falling as much as 100 feet in 400 yards. This seems to be the result of a sudden bending down of the strata on the line of fault rather than an absolute dislocation.

It is possible that there is a fault along the south side of the Gwash valley, but the evidence is not sufficient to warrant the structure being so mapped. On the north side of this valley the Rock-bed is fairly well exposed and makes a good feature; but on the south side the position of its supposed outcrop is entirely covered by Boulder-clay, either in place or in slipped masses. The stream, moreover, exhibits many sections in vertical or highly inclined strata, so that there is great probability of there being a disturbance of some sort along the valley. Possibly further evidence on the point may be forthcoming when the country to the east is surveyed.

APPENDIX I.

BORINGS AND WELL SECTIONS.

Leicester.

Willow Brook Boring.

On the estate of the Rev. F. G. Burnaby, at the foot of Spinney Hills, near where Green Lane crosses the brook. From Mr. Plant's MSS. :—

		Thickness.		Depth.	
		Ft.	in.	Ft.	in.
1	Marl	40	0	—	
2	Gypsum and grey skerry	11	0	51	0
3	Marl	9	0	60	0
4	Gypsum	1	0	61	0
5	Marl	2	0	63	0
6	Gypsum	2	0	65	0
7	Purple marl and gypsum	5	0	70	0
8	Gypsum and marl	10	0	80	0
9	Gypsum, marl, and skerry	20	0	100	0
10	Gypsum	3	0	103	0
11	Gypsum, marl, and skerry	17	0	120	0
12	Gypsum and grey marls	4	0	124	0
13	Purple marl	20	0	144	0
14	Skerry	4	0	148	0
15	Gypsum and marl	17	0	165	0
16	Sandstone	3	0	168	0
17	Gypsum, marl, and skerry	87	0	255	0
18	Grey sandstone	5	0	260	0
19	Gypsum, marl, and skerry	30	0	290	0
20	Red and grey marl	6	0	296	0
21	Hard grey marl	4	0	300	0
22	Grey marl	4	0	304	0
23	Red and grey marl	24	0	328	0
24	Grey marl	2	0	330	0
25	Red marl	10	0	340	0
26	Grey marl	1	0	341	0
27	Red marl	5	0	346	0
28	Red and grey marl	9	0	355	0
29	Gypsum	0	6	355	6
30	Sandy marl	14	6	370	0
31	Gypsum, skerry, and marl	30	0	400	0
32	Gypsum and a little marl	9	0	409	0
33	Grey skerry	7	0	416	0
34	Sandy marl and skerry	18	0	434	0
35	Gypsum	3	0	437	0
36	Sandy marl	10	0	447	0
37	Red marl	8	0	455	0
38	Hard grey marl	2	0	457	0
39	Sandy marl, skerry, and gypsum	21	0	478	0
40	Hard grey marl	2	0	480	0
41	Marl, skerry, and gypsum	12	0	492	0
42	Hard grey marl	1	0	493	0

WILLOW BROOK BORING.—*continued.*

		Thickness.		Depth.	
		Ft.	in.	Ft.	in.
43	Sandy marl and skerry - - - - -	32	0	525	0
44	Skerry with little marl - - - - -	11	0	536	0
45	Sandy marl and skerry - - - - -	18	0	554	0
46	Gypsum - - - - - - - -	2	0	556	0
47	Sandy marl and skerry - - - - -	24	0	580	0
48	Sandstone with mica - - - - -	2	0	582	0
49	Purple sandy marl with skerry - -	28	0	610	0
50	Sandy marl with mica - - - - -	3	0	613	0
51	Sandy marl with skerry - - - -	9	0	622	0
52	Marl with gypsum - - - - - -	2	0	624	0
53	Sandy marl* - - - - - - - -	16	0	640	0
54	Red sandstone - - - - - - -	10	0	650	0
55	Red sandy marl with skerry - - -	10	0	660	0
56	Sandy marl (spring of water at base) -	10	0	670	0
57	Sandy marl - - - - - - - -	20	0	690	0
58	Micaceous sandstone with black spots -	1	0	691	0
59	Running sand - - - - - -	43	0	734	0
60	Red sandstone - - - - - - -	7	0	741	0
	Tools broken in hole.				

Correlation of the above.

	Ft.	In.
Keuper Marl - - - - - - - - - - - - -	640	0
Lower Keuper Sandstone (proved) - - - - - -	101	0

LODGE FARM, SPINNEY HILLS. (BORING NO. 1.)

Began November 14th, 1877. Stopped December 1st.
From Mr. Plant's MSS.

	——	Thickness.		Depth.	
		Ft.	in.	Ft.	in.
1	Soil and drift clay - - -	5	0	5	0
2	Whitish yellow clay - - -	3	0	8	0
3	,, ,, ,, - - -	5	0	13	0
4	,, ,, ,, - - - - -	6	0	19	0
5	Reddish yellow clay - - - - -	9	0	34	3
6	Red clay - - - - - - - -	6	3	28	0
7	Red clay and gypsum (gypsum bed 20			70	3
	feet, 9 feet terra alba, 11 feet common)	36	0	89	3
8	Red clay and marl - - - - - -	19	0		
	Stopped Dec. 1st to prepare shaft.				

* Spring of pure water at bottom of running sand at 636 feet [?] rose 20 feet above top of borehole.

Lodge Farm, Spinney Hills. (Boring No. 2.)

Hole shifted to another part of 10 feet shaft, 8 feet in diameter, 3 feet south of No. 1 borehole, but in the same shaft. Began March 4th, 1878.* Copied from boring-book ; the particulars in brackets are from another account.

—	—		Thickness.	Depth.	Core obtained, 6in. Diameter of bore, 7in. Below 143ft. 3in. core obtained, 4in. Diameter of bore, 5in.	
		Ft. in.	Ft. in.	Ft. in.	Ft. in.	
	Limestone and shaly clay: Soil and earth	1 6				
	Gravel and sand	2 0	—	20 0		
Mar. 11	" " Clay	4 6	6 2	26 2		Broken up.
" 12	" " Grey-white sandy marl	20 5	2 3	28 5	2 3	
" 12	Red marl: Chocolate red marl	5 11	10 2	38 7	4 9	
	" " "	4 4				
" 13	Marl and gypsum: Chocolate-red marl	15 11	17 1	55 8	2 2	Marl.
	Pure solid gypsum	1 2			1 2	Gypsum
	Gypsum and marl: Red marl	3 4				
" 14	Gypsum, pure solid (pure terra alba)	– 9	7 7	63 3	– 6	Marl.
					– 9	Gypsum.
	Red marl mixedwith gypsum	3 6			3 6	Marl mixed with gypsum
" 14	Marl and inferior gypsum: Red marl mixed with gypsum	5 1	5 1	68 4	3 1	
" 15	Gypsum and marl: Gypsum, pure solid (pure terra alba)	– 7	—	—	– 7	
	Red marl (chocolate)	5 1	5 8	74 0	3 1	
	Gypsum and marl: Red marl (chocolate)	3 5			2 6	Marl.
" 15	Gypsum (pure terra alba)	– 7	8 0	82 0	– 7	Gypsum, good
	Red marl	4 0			4 0	Marl and gypsum.
" 16	Marl (Red marl)	11 7	11 7	93 7	6 7	
	Marl and gypsum: Red marl	2 5			1 2	Marl.
" 20	Gypsum (pure terra alba)	1 4	4 3	97 10	1 4	Gypsum, good
					– 6	Marl.
" 21	Marl	—	5 11	103 9		
" 21	Gypsum and marl	—	6 3	110 0	1 7	Gypsum with marl.
					1 5	Marl veined with gypsum.
" 22	Marl and thin gypsum	—	5 4	115 4	5 0	
	" "	—	3 2	118 6	3 0	
" 23	" "	—	6 7	125 1	6 0	
" 25	Marl with veins of gypsum	—	8 0	133 1	7 0	
" 26	" "	—	8 2	141 3	8 0	
" 27	" "	—	2 0	143 3	– 8	
April 1	Red marl	—	7 6	150 9	4 0	
" 2	"	—	10 0	160 9	7 0	At 165 grey-green marl.
					2 6	Red marl.
" 3	Blue marl with bands of sandstone	—	7 6	168 3	4 6	Blue marl with bands of sandstone.
" 4	" "	—	11 0	179 3	11 0	
" 4	" and red marl	—	10 9	190 0	8 0	
" 5	Red marl	—	4 8	194 8	4 0	
" 5	" with bands of sandstone	—	10 5	205 1	10 0	
" 6	Red marl and gypsum	—	10 6	215 7	9 0	
" 8	" "	—	10 0	225 7	10 0	
" 9	" "	—	14 5	240 0	13 10	
" 10	" "	—	16 2	256 2	15 8	252–253·4 grey rock.
" 11	" "	—	14 2	270 4	8 8	Broken ground
" 12	" "	—	9 3	279 7	6 2	" "
" 13	"	—	6 2	285 9	4 0	" "
" 16	Marl, grey rock and sandy marl	—	8 7	294 4	3 2	Marl.
					4 0	Grey rock.
					1 5	Sandy marl.
June 19	Marl and gypsum	—	7 2	301 6	3 6	
Aug.	" "	—	10 10	312 4	6 0	
" 21	Red marl and gypsum	—	2 8	315 0	2 0	
" 22	" "	—	16 6	331 6	11 0	
" 23	" "	—	10 9	342 3	10 6	
" 24	" "	—	7 0	349 3	5 0	

* Borer says began January 7. These dates are of some importance in reading the reports which were drawn up at the time, and in understanding the controversy which arose about the several borings of the Evington Coal Boring Company.

Lodge Farm, Spinney Hills (Boring No. 2.)—*cont.*

—	—	Thickness.	Depth.	Core obtained, 4in. Diameter of bore, 5in.	
		Ft. in.	Ft. in.	Ft. in.	
Aug. 26	Red mottled marls veined with gypsum	18 0	367 3	15 0	
" 27	" "	21 0	388 3	17 0	
" 28	" "	28 6	416 9	25 3	
" 29	" "	29 8	446 5	24 0	
" 30	" "	24 0	470 5	20 3	
" 31	" "	15 0	485 5	12 6	
Sept. 2	Sandy mottled marls and gypsum in thin veins	32 2	517 7	24 0	
" 3	" "	25 6	543 1	21 6	
" 4	" "	25 5	568 6	23 0	
" 5	" "	31 6	600 0	17 6	607ft. 10in. to 621ft. 8in. soft sandstones and water
" 6	" and sandstone	35 6	635 6	{7 9 {4 9	Do. and sandstone. Red sandstone and marls
" 7	Red sandstone and marls	29 6	653 0	5 0	
" 9	Marls and deep red sandstones	20 0	673 0	9 0	
" 11	Marls and sandstone	18 10	691 10	- 8	
" 14	Red and purple marl and sandstones	15 4	707 2	7 0	
" 16	Purple-brown sandstones and marl	16 5	723 7	11 0	
" 18	Breccia and sandstones	15 3	738 10	11 6	
" 19	"	5 1	743 11	4 0	
" 20	Purple shale	20 1	764 0	3 6	
" 21	"	4 0	768 0	1 0	
" 22	"	4 9	772 9	3 6	
" 23	Dark shale, hard and jointy	17 0	789 9	4 0	The strata here is a rocky shale splitting at a high angle and, falling down, grinds away.
" 24	"	4 3	794 0	—	
" 25	Dark shale of slaty character	10 3	804 3	3 6	
" 27	" "	10 5	814 8	2 10	
" 28	" "	4 5	819 1	3 0	

Crown Hills, Near Evington.

Copied from boring-book by Mr. Plant.

—	—	Thickness.	Depth.	Length of Core.	
		Ft. in.	Ft. in.	Ft. in.	
Nov.	Clay (dug out)	2 8	2 8	—	Diameter of bore, $7\frac{3}{16}$in.
" 20	" (light)	1 0	3 8	1 0	
" 21	- - -	4 0	7 8	—	
" 22	Light clay	3 0	10 8	1 6	
	Limestone } 3ft. 6in.*	—	—	- 2	
" 25	" }	—	—	- 3	
Dec. 1	Blue clay	2 0	12 8	1 6	
" 2	Limestone - 3in.	2 3	14 11	- 3	
	Blue clay	—	—	- 9	
	Limestone - 7in.	—	—	- 7	
" 3	Blue clay	5 1	20 0	- 11	Pebble found.
	Limestone - 2in.	—	—	- $1\frac{1}{2}$	
	Blue clay	1 5	21 5	{1 7 {1 1	
" 4	"	2 5	23 10	- 6	
	Limestone - 4in.	—	—	- $3\frac{1}{2}$	
	Blue clay	—	—	- 1	
" 5	Light clay	1 8	25 6	Not drawn.	
" 6	"	- 10	26 4	None.	
	Blue clay	- 2	26 6	- 2	
	Limestone - 6in.	- $5\frac{1}{2}$	26 $11\frac{1}{2}$	- $5\frac{1}{2}$	
	Blue clay	4 $10\frac{1}{2}$	31 10	None.	
	Limestone - 3in.	- 3	32 1	- 3	
" 9	Blue clay }	1 7	36 8	2 6	
	" } 12ft. 6in.	2 11	39 7	Not drawn	
" 10	" }	2 0	41 7	4 5	
	" }	3 0	44 7	2 7	
	Limestone - 2in.	- 2	44 9	- 2	
	Blue clay - 3in.	- 3	45 0	- 1	
	Limestone - 2in.	- 2	45 2	- 2	
	Blue clay - 8in.	- 8	45 10	- 5	
	Limestone - 2in.	- 2	46 0	- 2	

* The figures in this column are from another account, given on page 66, which was found among Mr. Plant's MSS. It is difficult to understand exactly what is intended, but the last column shows what was really brought up.

Crown Hills, Near Evington—*cont.*

Date	Strata		Thickness Ft.	Thickness in.	Depth Ft.	Depth in.	Length of Core Ft.	Length of Core in.
	Blue clay	2ft. 7in.	-	10	46	10	-	7
	"		1	9	48	7	1	5
	Limestone	2½in.		2½	48	9½		2½
	Blue clay	10in.		10	49	7½	-	5½
Dec. 11	Limestone		-	2	49	9½	-	2
	Blue clay		-	4½	50	2	-	3½
	Limestone		-	1¼	50	3¼	-	1¼
	Blue clay		-	2	50	5¼	-	0
	Limestone		-	1½	50	6¾	-	1½
	Blue clay		-	3	50	9¾	-	0
	Limestone		-	3¼	51	1	-	3¼
	Blue clay	6ft. 2in.	-	9	51	10	-	0
	"		4	11	56	9	4	2
	"		-	6	57	3	-	5
	Limestone		-	3½	57	6½	-	3½
	Blue clay	7ft. 9½in.	3	10½	61	5	3	0
	"		3	10	65	3	2	3
,, 12	"		-	1	65	4	-	0
	Limestone		-	1	65	5	-	1
	Blue clay		3	2	68	7	-	0
,, 13	"		1	3	69	10	-	6
	Limestone		-	1½	69	11½	-	1½
	Blue clay		2	6	72	5½	1	4
	Limestone		-	1	72	6½	-	1
	Blue clay		1	0	73	6½	-	2
	"		-	6	74	0½	-	3
	Limestone		-	1½	74	2	-	1½
	Blue clay		4	1	78	3	2	11
,, 16	Limestone		-	1½	78	4½	-	1½
	Blue clay		4	7	82	11½	4	0
	"		5	8½	88	8	5	1
	"		2	4	91	0	Not drawn.	
,, 17	"		3	4	94	4	4	10
	"		5	1½	99	5½	4	9
	"		1	6½	101	0	1	6
	Limestone		-	1	101	1	-	1
	Blue clay		3	7½	104	8½	1	7
	"		4	10	109	6½	2	8
,, 18	"		4	11½	114	6	5	2½
	"		4	10	119	4	4	2
	"		5	1	124	5	3	4
,, 19	"		5	3	129	8	5	6
	"		4	8	134	4	4	2
	Limestone		-	8	135	0	-	8
	Blue clay		2	11½	137	11½	2	6½
	Limestone		-	3½	138	3	-	3½
	Blue clay		2	0	140	3	1	8
	"		-	9	141	0	-	7
	Limestone		-	2½	141	2½	-	2½
	Blue clay		-	1	141	3½	—	
	Limestone		-	2	141	5½	-	2
	Blue clay		3	9½	145	0	—	
,, 20	Blue clay or blue shale		5	6	150	6	4	8½
	" "		3	0	153	6	2	8
	Limestone		-	4	153	10	-	4
	Blue clay		2	2	156	0	—	
,, 22	"		-	1	156	1	-	1
	Limestone		-	1	156	2	-	1
	Blue clay		1	0	157	2	-	7
	Limestone		-	4½	157	6½	-	4½
	Blue clay		-	3	157	9½	—	
	Limestone		-	3	158	0½	-	3
	Blue clay		-	9	158	9½	-	7
	Limestone		-	3½	159	1	-	3½
	Blue clay		-	3	159	4	—	
	Limestone		-	3½	159	7½	-	3½
	Blue clay		-	4	159	11½	—	
	Limestone		-	6	160	5½	-	6
	Blue clay		-	7	161	0½	—	
	"		-	6	161	6½	-	6
	Limestone		-	3	161	9½	-	3
	Blue clay		4	5	166	2½	4	0
	"		5	5½	171	8	5	4
,, 23	"		5	2	176	10	4	11
	"		5	3	182	1	4	10
	"		5	2	187	3	4	1
,, 24	"		1	10	189	1	1	7
	White limestone mottled or mixed with blue clay		3	7	192	8	3	5
	" " " "		5	4	198	0	4	8
1880.	" " " "		5	4	203	4	4	10
Jan. 6	" " " "		1	0	204	4	-	7

Crown Hills, Near Evington—*cont.*

—	—	Thickness.	Depth.	Length of Core.	
		Ft. in.	Ft. in.	Ft. in.	
	White limestone shale	1 6	205 10	2 9	
Jan. 7	Mottled and red marl with band of gypsum	2 6	208 4		
	White limestone shale	2 0	210 4	- 8	
	Red marl	- 9	211 1	- 8	
„ 8	„ and gypsum	- 3	211 4		
	White limestone shale and band of gypsum	3 9	215 1	2 0	
„ 14	Red marl, limestone shale, and veins of gypsum	12 3	227 4	8 0	
„ 15	Red marl and gypsum	12 11	240 3	11 7	
	„ „	3 6	243 9	13 3	
„ 16	„ „	10 2	253 11		
	„ „	3 0	256 11	9 6	
„ 17	Gypsum (pure)	10 6	267 5	2 3	
	Red marl and gypsum	—	—	1 1	
„ 19	„ „	6 4	273 9	- 10	
	Gypsum	—	—	1 1½	
	Red marl and gypsum	—	—	2 1	
„ 20	„ „	9 0	282 9	6 8	
„ 21	„ „	13 2	295 11	13 1	
	„ „	3 0	298 11	3 4	
„ 22	„ „	7 7	306 6		
„ 23	„ „	6 1	312 7	2 0	
„ 24	„ „	4 1	316 8	5 6	
„ 26	Blue marl and gypsum	11 4	328 0	11 3	
„ 27	Red marl and gypsum	2 0	330 0	1 11	
	„ „	- 11	330 11	—	
28	„ „	12 7	343 6	6 10	
„ 29	„ „	3 11	347 5	1 9	
	„ „	3 0	350 5	—	
„ 30	„ „	6 3	356 8	1 3	
	Red and blue marl and gypsum	7 6	363 11	12 11	
„ 31	„ „ „	10 10	374 9	6 6½	
Feb. 2	„ „ „	3 6	378 3	2 10	
	„ „ „	2 5	380 8	—	Diameter of bore, 3⅛in.
„ 3	Red marl and gypsum	6 0	386 8	1 10	
	„ „	5 2	391 10	1 7	
„ 4	„ „	7 1	398 11	4 0	
Feb. 5	Red and blue marl and gypsum	7 6	406 5	4 7	Broken ground.
	„ „	6 5	412 10	3 3	
„ 6	„ „	3 4	416 2	2 6	
	„ „	2 9	418 11	1 10	
„ 7	„ „	7 3	426 2	4 10	
Mar. 19	Red marl with veins of gypsum	7 7	433 9	7 3	
„ 23	„ „	3 10	437 7	3 1	
„ 24	Red and blue marl with gypsum	10 5	448 0	7 7	
Apr. 1	„ „	10 2	458 2	7 11	
„ 2	„ „	9 4	467 6	6 9	
„ 3	„ „	6 2	473 8	3 6	
„ 8	Red marl	9 8	483 4	1 6	
	Blue marl with bands of gypsum	—	—	4 8	
	Red marl with one band of gypsum	—	—	4 4	
„ 22	Red and blue marl and gypsum	9 3	492 7	4 2	
„ 23	„ „	8 10	501 5	7 6	
„ 24	Red marl	1 6	502 11	—	
„ 26	„	- 9	503 8	- 3½	
„ 28	„	5 0	508 8	- 7	
„ 29	Red and blue marl and gypsum	10 6	519 2	7 2	
„ 30	„ „	7 11	527 1	4 10	
May 1	„ „	9 4	536 5	6 10	
„ 3	„ „	9 3	545 8	7 2	
„ 4	„ „	3 0	548 8	Not drawn.	
„ 5	„ „	6 6	555 2	7 0	
	„ „	4 2	559 4	Not drawn.	
„ 6	„ „	7 2	566 6	11 1	
	„ „	4 3	570 9	- 6	
„ 7	„ „	12 6	583 3	8 10	
„ 8	„ „	10 1	593 4	10 6	
„ 10	„ „	12 3	605 7	10 4	
„ 11	„ „	6 4	611 11	Not drawn.	
„ 12	„ „	2 4	614 3	3 10	
	„ „	10 2	624 5	6 5	
„ 13	„ „	12 5	636 10	10 10	
„ 14	„ „	12 2	649 0	6 1	
„ 15	„ „	8 3	657 3	1 9	
„ 20	„ „	11 0	668 3	9 10	
„ 21	„ „	11 0	679 3	9 4	
„ 25	Red marl	9 3	688 6	2 0	
„ 29	Red and blue marl and gypsum	11 0	699 6	9 7	
„ 31	„ „	11 11	711 5	10 0	
June 1	„ „	11 3	722 8	8 0	
„ 2	„ „	12 0	734 8	6 3	Sandstone at 731ft (Plant).

CROWN HILLS, NEAR EVINGTON—*cont.*

—	——	Thickness.	Depth.	Length of Core.	
		Ft. in.	Ft. in.	Ft. in.	
June 3	Soft sandstone and marl	13 4	748 0	3 8	
„ 4	„ „	9 10	757 10	2 4	
„ 5	„ „	9 4	767 2	3 10	
„ 7	„ „	4 7	771 9	1 8	
„ 9	Soft sandstone	14 10	786 7	2 6	
	„	—	—	- 7	
	Red marl	—	—	- 1	
	Gypsum	—	—	- 2	
	Soft sandstone	—	—	1 3	
	Red marl	—	—	- 5	
10	Soft sandstone	15 5	802 0	- 3	
	Red and blue marl	—	—	- 8	
	Sandstone and gypsum	—	—	- 2	
	Red and blue marl	—	—	1 4	
	Sandstone	—	—	- 10	
	Red and blue marl	—	—	1 6	
	Sandstone	—	—	- 7	
	Red and blue marl	—	—	- 4	
	Coarse sandstone and red marl	—	—	- 8	
	Red and blue marl	—	—	- 4	
	Sandstone	—	—	- 3	
„ 15	Soft red and blue marl	14 5	816 5	4 7	
	Sandstone	—	—	- 2	
„ 17	Fine light red sandstone	19 2	835 7	- 4	
	Coarse dark red sandstone and gravel	—	—	- ½	
	Coarse light red sandstone and gravel	—	—	- 1½	
	Red marl	—	—	- 1	
	Fine white sandstone	—	—	- 2	
	Coarse white sandstone	—	—	- 1	
	Red marl	—	—	- 11	
„ 18	„	1 1	836 8	- 11	
	Hard purple rock with many veins at various angles.	5 6	842 2	5 4	
„ 21	Hard purple rock	6 3	848 5	2 9	
„ 22	Hard purple and black rock	1 10	850 3	- 2½	Struck at 848ft. 5in.
	Hard black rock	—	—	1 2	
„ 23	„ „	8 4	858 7	7 9	
„ 24	„ „	1 2	859 9	- 9	
„ 25	„ „	2 4	862 1	—	
„ 26	„ „	4 8	866 9	5 10	
„ 29	„ „	6 9	873 6	Not drawn.	
„ 30	„ „	3 0	876 6	8 6	
	„ „	10 0	886 6	9 3	
July 1	Deep black slaty rock with vertical and angular veins, white.	11 8	898 2	9 6	Struck at 885ft.
„ 2	Deep black slaty rock with vertical and angular veins, white.	9 7	907 9	6 6	
„ 3	Deep black slaty rock with vertical and angular veins, white.	10 6	918 3	10 1	
„ 5	Hard black slaty rock	14 0	932 3	9 9	
„ 6	„ „	14 2	946 5	11 9	
„ 7	„ „	13 0	959 5	11 6	
„ 8	„ „	10 5	969 10	10 3	
„ 9	„ „	15 2	985 0	10 5	
„ 10	„ „	9 11	994 11	5 10	
„ 12	„ „	5 4	1000 3	4 1	Rods measured by Mr. W. Howes, depth according to measure, 1,002ft. 3in.

Another account of the upper part of the above section, left in MS. by Mr. Plant :—

	Ft. in.
Soil	0 6
Light clay	8 8
Limestone	3 6
Blue clay	1 6
Limestone	0 3
Blue clay	0 11
Limestone	0 7
Blue clay	1 11
Limestone	0 2

CROWN HILLS, NEAR EVINGTON—*cont.*

	Ft.	in.
Blue clay	5	6
Limestone	0	4
Light clay	2	8
Limestone	0	6
Blue clay	4	11
Limestone	0	3
Blue clay	12	6
	44	8

Summary and Correlation of the Crown Hill Section.

—	Thickness.		Base reached at.	
	Ft.	in.	Ft.	in.
Lias, including soil and weathered clay at the surface	189	1	189	1
Rhætic beds, including the tea-green marls	16	9 or more	205	10
Keuper marl	525	2	731	0
Keuper sandstone	105	8	836	8

THE CO-OPERATIVE BOOT WORKS, KNIGHTON FIELDS.* (Chisel Boring.) Communicated by Messrs. Mather and Platt. Date of sinking, 1892.

—	Thickness.	Depth from Surface.
	Feet.	Feet.
Old well	57	—
Red marl	39	96
Blue shale and marl [grey shale and skerry sandstone]	12	108
Red marl and gypsum [bands of gypsum not more than one foot thick]	132	240
Very soft red and blue marl	20	260
Very hard marl	6	266
Red marl with thin bands of green sandstone	4	270
Red marl and gypsum	220	490
Hard grey sand rock	12	502
Red marl and gypsum†	55	557
Fine red sand rock	11	568
Hard sandy marl	15	583
Hard fine red sandstone with thin beds of marl	33	616
Coarse red sandstone with bands of white rock	6	622
Very hard dark blue and black shale	63	685
Very hard grey rock, limestone‡ [pyrites]	83	768
Soft black shale	57	825

*Other accounts of this boring are given by Mr. Paul, *Trans. Leicester Lit. Phil. Soc.*, 1893, p. 105; and by Mr. Montagu Browne, *op. cit.* p. 199.

† The presence of gypsum below 490 feet is doubtful, and, considering the character of the boring, may have fallen in from higher beds.

‡ See appendix pp. 117.

Vestry Street Baths.*

Sunk and communicated by Messrs. Legrand and Sutcliff, 1890.

——	Thickness.		Depth.	
	Ft.	in.	Ft.	in.
Basement floor below surface	–	–	10	0
Dug well	30	0	40	0
Red marl	18	0	58	0
Block marl	15	0	73	0
Red marl	4	0	77	0
Blue stone and clay [skerry sandstone and grey marl]	3	0	80	0
Red marl and gypsum [white sandstone]	14	0	94	0
Red marl	7	9	101	9
Red and blue stone	1	9	103	6
Gypsum	–	6	104	0
Mixture of marl and gypsum	61	0	165	0
Blue stone [mottled grey marl]	2	6	167	6
Red marl	41	6	209	0
Gypsum	1	0	210	0
Red marl	–	–	–	–

The additions in square brackets are from observation of the specimens. Mr. Paul states that the water-level is 17 feet below the surface.

London Road. Messrs Davis, Moore, and Co.†

Sunk and communicated by Messrs. G. Isler and Co., per Mr. W. Whitaker. Water-level 29 feet down. Supply abundant. Shaft 46 feet, the rest bored.

——	Thickness.		Depth.	
	Ft.	in.	Ft.	in.
Red marl	53	0	53	0
Hard grey stone	4	0	57	0
Hard red marl	20	6	77	6
Red marl and grey stone	7	6	85	0
Coloured marl	4	0	89	0
Blue marl	3	0	92	0
Rock	10	11	102	11
Red marl	2	0	104	11
Rock	5	0	109	11
Rock and marl	6	0	115	11
Gypsum and marl	7	6	123	5
Gypsum	3	0	126	5

* A slightly different account of this boring is given by Mr. Paul, *Trans. Leicester Lit. and Phil. Soc.*, 1891, p. 408, and by Mr. Montagu Browne, *Ibid.*, 1893, p. 152.

† The account given of a boring at this place by Mr. Plant, *Brit. Assoc. Rep.* for 1889, p. 74, copied on page 77, does not agree very well with this.

A slightly different account gives

	Thickness.		Depth.	
Dug well	50	0	–	–
Red marl	3	0	53	0
Hard grey stone	4	0	57	0
Hard red marl	30	0	87	0
Blue marl	3	0	90	0
Rock	17	9	107	9
Marl rock	3	9	111	6
Marl	9	6	121	0
Gypsum	3	0	124	0

51, CHARNWOOD STREET. LEICESTER BREWING AND MALTING COMPANY

Sunk and communicated by Messrs. Isler and Co. Boring made in 1895.

	Thickness.		Depth.	
	Ft.	in.	Ft.	in.
Dug well*	59	0	–	–
Red marl	10	6	69	6
Hard red and grey rock	4	0	73	6
Hard red rock	7	3	80	9
Stone	4	6	85	3
Red stone	3	0	88	3
Red marl stone	13	9	102	0
Blue shale and stone	3	6	105	6
Green rock	6	0	111	6
Blue rock	2	6	114	0
Green stone	3	6	117	6
Greyish stone	1	6	119	0
Very hard rock	4	7	123	7
Green and red shale and rock	2	9	126	4
Red sandstone and shale	3	0	129	4
Red sandstone	7	6	136	10
Sandstone	22	6	159	4
Red sandstone	3	0	162	4
Red stone	3	0	165	4
Red sandstone	3	6	168	10
Red stone	5	0	173	10
Sandstone	3	2	177	0
Red rock	11	6	188	6
Hard stone	11	6	200	0

Water-level, 36 feet below the surface. Supply, two barrels a minute.

*The details of this well are given on p 76

Messrs. Else and Frome.

Boring made in 1884. Sunk and communicated by Messrs. Legrand and Sutcliff, per Mr. W. Whitaker.

——	Thickness.		Depth.	
	Ft.	in.	Ft.	in.
Dug well - - - - - - - - -	50	0	–	–
Red and grey marl - - - - - - -	6	0	56	0
Hard shaly marl - - - - - - - -	17	0	73	0
Hard blue marlstone - - - - - - -	9	6	82	6
Blue marl rock - - - - - - -	3	0	85	6
Light [coloured] sandstone - - - -	4	6	90	0
Light [coloured] marl - - - - - - -	5	6	95	6
Red marl rock - - - - - - -	14	6	110	0
Hard red marl and gypsum - - - - -	30	0	140	0

Water-level, 45 feet below the surface. Supply, 15 gallons a minute.

Walnut Street.

Boring made in 1894. Sunk and communicated by Messrs. Tilley.

——	Thickness.		Depth.	
	Ft.	in.	Ft.	in.
Clay - - - - - - - - - - -	2	0	–	–
Gravel - - - - - - - - - - -	6	0	8	0
Light [coloured] marl - - - - - -	7	0	15	0
Red marl - - - - - - - - - -	21	6	36	6
Light [coloured] sandstone with water - -	2	0	38	6
Red marl - - - - - - - - - -	11	6	50	0
Light [coloured] sandstone with water - -	1	10	51	10
Red marl (veins of gypsum) - - - - -	24	10	76	8
Loamy sand with water - - - - - -	5	4	82	0
Red marl - - - - - - - -	17	0	99	0
Red marl with veins of gypsum - - - -	15	0	114	0
Mixed marl - - - - - - - - - - -	22	0	136	0
Red marl with one inch of hard sandstone at the top - - - - - - - - - - -	5	6	141	6
Sandstone - - - - - - - - - - -	1	3	142	9
Red marl - - - - - - - - - - -	1	0	143	9
Sandstone - - - - - - - - - -	–	6	144	3
Hard red marl - - - - - - - - -	5	9	150	0
Red marl and gypsum - - - - - -	4	0	154	0
Sandstone with water - - - - - -	–	4	154	4
Red marl mixed - - - - - - - -	15	8	170	0

All Saints' Brewery (Messrs. Langmore and Bankhart).

Sunk and communicated by Messrs. Legrand and Sutcliff, 1884, per Mr. Whitaker. Water-level, 27 feet down. Yield, 40 gallons a minute.

—	Thickness.		Depth.	
	Ft.	in.	Ft.	in.
Dug well (the rest bored)	–	–	45	0
Red marl	7	0	52	0
Soft blue stone	4	0	56	0
Purple marl and soft marl in layers	9	0	65	0
Sandstone	2	0	67	0
Soft red marl	3	0	70	0
Soft red sandy marl	15	0	85	0
Red marl and sandstone	9	0	94	0
Red marl and gypsum	13	0	107	0

Aylestone Road Gas Works.

Boring made in 1877. Sunk and communicated by Messrs. Docwra and Sons, per Mr. Whitaker.

—	Thickness.		Depth.	
	Ft.	in.	Ft.	in.
Alluvial beds, 11ft. 6in. { Black soil	–	6	–	6
Loamy clay	1	6	2	0
Sandy clay with stones	2	0	4	0
Red loamy sand	2	0	6	0
Red clay mixed with rock stones	3	0	9	0
Greenish sandy clay mixed with rock stones	2	6	11	6
Light grey rock	6	6	18	0
Light grey rock (soft)	3	0	21	0
Red sandy marl	22	0	43	0
Hard red rock	2	0	45	0
Soft red sandy marl	4	0	49	0

Corporation Waterworks, New Parks.

Boring made in 1895–96. Sunk and communicated by Messrs. Isler and Co.

—	Thickness.		Depth.	
	Ft.	in.	Ft.	in.
Dug well	18	0	–	–
Blue marl	7	0	25	0
Red marl	46	0	71	0
Stone	1	6	72	6
Red marl	39	6	112	0
Blue and red marl	10	0	122	0
Red marl	4	0	126	0
Stone	7	0	133	0
Red marl	7	0	140	0
Stone	14	0	154	0
Red marl	6	0	160	0
Stone	–	2	160	2

Water-level, 100 feet from surface.

Spinney Hills and Crown Hills.

Shallow borings sunk by T. R. Bosworth, between November 26th, 1878, and January 17th, 1879. From Mr. Plant's MSS.*

Bore No. 1.—[Spinney Hill Park, about 120 yards north-east of the south west gates.] Water at 19 feet.

	Ft.	in.
Soil	0	9
Yellow clay	2	3
Light Lias [Rhætic] shale, plastic clay	10	0
Tea-green marls (not penetrated)	17	0

Bore No. 2.—About 80 yards N.N.E. of No. 1. [Both Bore No. 1 and No. 2 are about 70 yards from the Mere Road.] Water at 23 feet.

	Ft.	in.
Soil	0	9
Yellow clay	4	3
Light Lias shale or Rhætic	22	0
Tea-green marls, Rhætic	16	0
Band of red clay	4	0
Rhætic [?]	3	0

Bore No. 3.—264 yards south-east of No. 4; 1,350 yards from No. 1 1,760 yards from Willow Brook [Boring]. [Near the old tramway in the field between the two Limestone Pits.]

	Ft.	in.
Soil	0	9
Red and yellow marls mixed	9	9
Yellow marl with small limestone	1	9
Blue Lias shale	3	0
Limestone in layers	0	4
Shale in layers	0	4
Limestone in layers	0	3
Shale in layers	0	3
Limestone in layers	0	4
Shale in layers	0	3
Limestone in layers	0	5
Blue Lias shale with irregular layers of limestone	40	0

Bore No. 4.—165 yards south-east of No. 5. [Near the summit of the hill in the same field as the old Limekilns.]

	Ft.	in.
Soil	0	9
Yellow clay	11	0
Light (Lias) shale	23	0
Dark blue Lias shale	5	0

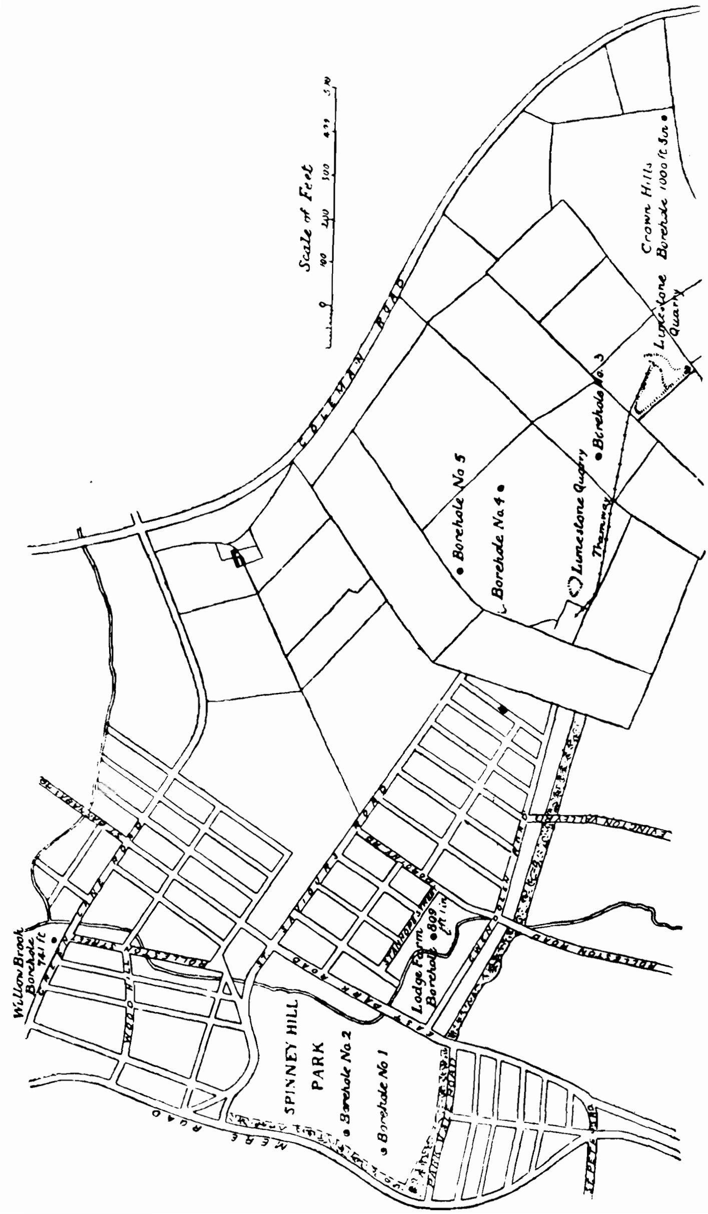
At 42 feet there was a strong rush of air (or gas), which continued for three days when the top of the bore was closed.

Bore No. 5.—560 yards south-east [? 840 yards due east] of Lodge Farm. [In the same field as the last, and 260 yards north of the Limekilns.] Water at 15 feet.

	Ft.	in.
Soil	0	9
Yellow marl	15	0
Dark (plastic) Lias clay, with scattered crystals of fibrous gypsum and selenite	10	0

* The positions of the boreholes as marked on a plan of the estate are given in square brackets.

FIG. 15.—*Plan of North Evington, Leicester. Showing position of bore-holes of the Evington Coal Boring Company.*



BORE.—Lodge Farm, 460 yards south-east of No. 2.

	Ft.	in.
Soil	0	9
Yellow clay	4	3
Light grey clay	14	9
Red (light) clay	15	6
Red marl with thin veins, vertical and horizontal, of gypsum; thin bands of gypsum and nodules of gypsum	23	6

CROWN HILLS (Quarry No. 1).
From Mr. Plant's MSS.

	Ft.	in.
Shale*	5	0
Limestone	0	9
Shale*	2	0
Limestone	0	6
Shale*	1	0
Limestone	0	5
Shale*	1	3
Limestone	4	7
Shale	0	0
Limestone	0	6
Shale*	1	6
Limestone	0	6
Shale	1	6
Limestone	0	5
Total depth	19	11

CROWN HILLS (Quarry No. 2.) Section of Pit near the Kilns.
From Mr. Plant's MSS.

	Ft.	in.
Shale	3	7
Limestone	0	3
Shale	0	6
Limestone	0	5
Shale	0	8
Limestone	0	3
Shale	0	6
Limestone	0	4
Shale	1	0
Limestone	0	4
Shale	0	8
Limestone	0	6
Shale	1	9
Limestone	0	3
Shale	1	0
Limestone	1	0
Total depth	13	0

Leicester.

The following are taken from the Reports of the British Association on the circulation of underground waters, with the omission of some of the correlations which are incorrect. The additions in italics are from Mr. Plant's MSS.; those in square brackets are our explanation of the statements:—

*These are called "Drift" in the original.

MESSRS. FIELDING AND CO. [? BOND STREET, 201 feet above O.D.]

B. A. Report, 1875, p. 134.
Well, 8 feet diameter. No borehole.
Water stands at 35 feet, reduced by pumping to 10 feet.

	Ft.	in.
Soil - - - - - - - - - 2	0 to 6	0
Clay and sand *and sharp sandy gravel* [valley deposit] - -	10	0
Red marl - - - - - - - - - -	30	0
Red and grey marl [with skerry and some] beds of sandstone, alternating and full of ripple marks - - -	29	0
Total depth - - - - - - -	75	0

MESSRS. FIELDING AND CO., BOND STREET, 214 [201 ?] feet above O.D.

B. A. Report, 1889, p. 74.
Well, 50 feet. Boring, 80 feet. *Sunk July, 1884.*
Water stands 20 feet from the top.

	Ft.	in.
Soil - - - - - - - - - - - - -	1	0
Boulder-clay [valley deposit] - - - - - -	14	0
Marl with two gypsum beds - - - - - -	35	0
Shales with gypsum [marls and skerry] - - - -	16	0
Sandstone - - - - - - - - - -	14	0
Shales [marls and skerry] - - - - - -	11	0
Red marl with four gypsum beds [and some] white sandstone - - - - - - - - - -	40	0
Total depth - - - - - - - -	131	0

MESSRS. HODGES AND SONS [? LOWER BROWN STREET, 200 feet above O.D.], 206 feet above O.D.

B. A. Report, 1875, p. 134.
Well, 90 feet, 9 feet diameter.
Water stands at 50 feet.

	Ft.	in.
Drift [valley deposit] - - - - - - - -	10	0
Red marl - - - - - - - - -	35	0
Sandstone [?] - - - - - - - -	45	0
Total depth - - - - - - - - -	90	0

MESSRS. PICKARD AND SONS [? OXFORD STREET, about 200 feet above O.D.] 206 feet above O.D.

B. A. Report, 1875, p. 135.
Well, 75 feet, 8 feet diameter.
Water stands at 30 feet.

	Ft.	in.
Drift [valley deposit] - - - - - - - - -	15	0
Red marl - - - - - - - - - -	25	0
Sandstone [? marl and skerry] - - - - - -	35	0
Total depth - - - - - - - - -	75	0

MESSRS. EVERARD AND CO., SOUTHGATE STREET BREWERY, 203 feet above O.D.

B. A. Report, 1875, p. 135.
Well, 50 feet, 7 feet diameter.
Water stands at 15 to 20 feet.

	Ft.	in.	Ft.	in.
Clay, etc. [made ground] - - - - - -	30	0	*20*	*0*
Sandstone [? marl and skerry sandstone] - -	20	0	*30*	*0*
Total depth - - -	50	0		

MESSRS. RUST AND CO. [St. NICHOLAS' SQUARE, 200 to 205 feet above O.D.

B. A. Reports, 1875, p. 135.
Well, 80 feet.
Water stands at 40 feet.

	Ft.	in.
Soil - - - - } [mostly made ground] { -	10	0
Clay, sand, and gravel - } [mostly made ground] {	30	0
Alternate bands of sandstone and red clay - - -	40	0
Total depth - - - - -	80	0

MESSRS. BATES AND SONS' BREWERY, UPPER CHARNWOOD STREET 203 feet above O.D.*

B. A. Reports, 1878, p. 387.
Well, 62 feet [?], 6 feet diameter.
Water stands at 30 feet.

	Ft.	in.
Drift - - - - - - - - - - -	8	0
Marl - - - - - - - - - - -	52	0
Total depth - - - - - - - - -	60	0

MESSRS. GIMSON AND CO. [VULCAN STREET, above 195 feet above O.D.], 212 feet above O.D.

B. A. Reports, 1878, p. 387.
Well, 64 feet, 6 feet diameter.
Water stands at 30 feet.

	Ft.	in.
Drift [?] - - - - - - - - - -	6	0
Marl - - - - - - - - - - -	58	0
Total depth - - - - - - - - -	64	0

MESSRS. W. GIMSON AND SONS, CHURCH GATE, Near St. Margaret's Church, 183 feet above O.D.

B. A. Reports, 1878, p. 388.
Well, 70 feet *from street level*, 8½ feet diameter.
Water stands at 55 feet.

	Ft.	in.
Gravel, sand, and clay -	10	0
Marls - - -	25	0
Hard blue rock stone -	35	0
Total depth - - - - - - -	70	0

* The lower part of this section is given on p. 69, under the heading 1, Charnwood Street.

MESSRS. COOPER, CORAH AND SONS, ST. MARGARET'S WORKS [CANNING STREET, about 174 feet above O.D.]. Sunk in 1876.

B. A. Reports, 1880, pp. 105, 106.

Well, 26 feet; diameter, 3 feet 6 inches. Bore, 58 feet; diameter, 4 inches.

Water stands at 72 feet, 6 feet below neighbouring canal.

	Ft.	in.
Gravel and soil	10	0
Marl	48	0
Layers of hard and soft sandstone	26	0
(Running sand at the bottom.)		
Total depth	84	0

MESSRS. SCOTT AND SONS, BAY STREET MILLS [177 feet above O.D.]. Sunk in 1860.

B. A. Reports, 1880, p. 106.

Well, 45 feet; diameter, 4 feet. Bore, 25 feet; diameter, 4 inches

Water stands 15 feet from the surface, about 8 feet below canal.

	Ft.	in.
Clay and gravel	12	0
Marl	36	0
Sandstone [probably marl and skerry]	22	0
Total depth	70	0

MESSRS. JESSOP AND CO., FRIDAY STREET [177 feet above O.D.]. Sunk in 1876.

B. A. Reports, 1880, p. 106.

Well, 33 feet; 4 feet diameter. Bore, 37 feet; 4 inches diameter.

Water stands at 50 feet.

	Ft.	in.
Clay and gravel	12	0
Marl	38	0
Sandstone [?]	20	0
Total depth	70	0

MESSRS. DAVIS AND CO., LONDON ROAD, 220 [209] feet above O.D.

B. A. Reports, 1889, p. 75.

Well, 70 feet; 6 feet diameter. Bore, 80 feet; 6 inches diameter.

Water stands at 20 feet.

	Ft.	in.
Drift [?]	20	0
Marl with gypsum beds	25	0
Sandstone and shales	45	0
Red marl with gypsum beds, and thin beds of sandstone	60	0
Total depth	150	0

MESSRS. RAVEN AND CO., WHARF STREET, 186 feet above O.D.

B. A. Reports, 1889, p. 75.

Bore, 120 feet, 7 inches diameter; 84 feet, 6 inches diameter.

Water stands 20 feet from the surface.

	Ft.	in.
Drift.* *Below the level of Wharf Street*	8	0
Marls. *Marl*, 10 *feet; chocolate marl*, 15 *feet*	25	0
Sandstone A. *White sandstone*, 59 *feet*	30	0

* The "Drift" is probably hypothetical. The boring appears to have commenced in the basement at a depth of 8 feet below the street. Mr. Plant's MS. notes, which are given in italics, differ considerably from the correlation published.

MESSRS. RAVEN AND CO.—*cont.*

	Ft.	in.
Middle sandstone B.	20	0
Lower shaly sandstone C.	22	0
Red marl with gypsum bands. *Marly beds with gypsum, 79 feet*	69	0
Red marl with bands of shaly sandstone. *Red marl with bands of sandstone, 33 feet*	30	0
Total depth	204	0

The following sections numbered 1 to 13 are from Mr. Plant's MSS.

(1) BAY STREET WHARF (boring).

	Ft.	in.
Soil and red clay	17	0
Soft silicious white sandstone* (of same character as thick bed at cutting)	2	0
Red clay	10	0
Total depth	29	0

(2) MIDLAND RAILWAY (Excavation at the Station).

	Ft.	in.
Drift clay and gravel	20	0
Hard green drab arenaceous clay, extends all over the excavation as a floor	3	0
Total depth	23	0

(3) HINCKLEY ROAD, JUNCTION WITH NARBOROUGH ROAD.

Keuper sandstone thins out, and is succeeded by a blood-red chocolate sandy clay.
Depth of grey sandy shales exposed, 10 feet.

(4) NEWFOUNDPOOL (boring).—Keuper, 1,000 feet.

(5) HUMBERSTONE (well).

	Ft.	in.
1. Soil, sand with rolled Oolite pebbles	2	0
2. Drift composed of Lias, Oolite with Belemnites, and blue shale with pyrites, blocks scored and grooved	66	0
3. Fine (grey pink) sands, appears to crop out in valley	9	0

(6) MOWMACRE HILL (boring).

	Feet.
Drift clay Gravel and sand with Oolitic boulders	120

(7) EVINGTON FIELDS Deep Sewer (Eastern).—St. Stephen's Road or Melbourne Road [?]. Depth 20 to 30 feet, stiff Boulder-clay with erratics.

*Cut through at Bowman's Well, Frog Island.

(8) Rust's Factory, Holy Bones (sinking).*

—	Thickness.		Depth	
	Ft.	in.	Ft.	in.
Made soil and black earth } mostly made ground	10	0	10	0
Alluvial clays, etc. } mostly made ground	35	0	45	0
Keuper sandy shales	3	0	48	0
Chocolate marls	3	0	51	0
Green marls	1	0	52	0
Chocolate marls	3	0	55	0
Alternate layers of sandy shales and green marls	20	0	75	0
Red clay	1	0	76	0

(9) Jarrom's Well, Freehold Lane, Stoneygate.

—	Thickness.		Depth.	
	Ft.	in.	Ft.	in.
Alluvium [?]	3	0	3	0
Lias shales and limestone	96	0	99	0
Keuper marls	6	0	105	0

(10) Bond Street.—Sewer in Clay and sand 14 feet.

(11) Newarke.—Sandstone reached.

(12) Newarke Street, into Newarke.—Thin bed of sandstone.

(13) Causeway Lane (Well).
Alluvium [?].
Marls.
Sandstone.

The following, numbered 1 to 30, are taken from notes made on a map of Leicester by Mr. Plant:—

(1) Grey Friars.

	Ft.	in.
Soil	2	0
Coarse gravel	4	0
Sand	2	0
Gravel	4	0
Red-clay	2	0
Total depth	14	0

(2) Grey Friars.—Angular erratics at 20 feet.

(3) Wharf Street.—Red and yellow sand from Russell Square to top of Wharf Street. Red marl and dark sand opposite Wharf Street, at top of Rutland Street. Thin clay underlies the sand.

(4) Granby Street and Rutland Street.—Elephant's teeth in Drift with large erratics.

* May be the same as that given on p. 76.

(5) GRANBY STREET AND HORSEFAIR STREET.—Red sand at 4 f t, 12 feet thick.

(6) CLOCK TOWER.—Red sand at 6 feet.

(7) BOND STREET.—Blue stiff clay mottled red.

(8) CHURCH GATE (North end).—Blue stiff clay mottled red.

(9) BAY STREET.—Keuper shales at 6 feet.

(10) LOWER BROWN STREET.—Keuper shales at 55 feet.

(11) OLD GAS WORKS.—Drift sand, red. Shales of Keuper at 55 feet below 5 feet red marl.

(12) UPPER TICHBORNE STREET AND ST. STEPHEN'S ROAD.—Erratic blocks. Sandy clay. Blue sandy mottled clay, rolled boulders and blue-grey partings.

(13) LEADENHALL STREET.—Earth and soil 2 feet. Blue coarse gravel and sharp red gravel with flints down to 12 feet.

(14) CEMETERY.—Stiff red clay with boulders up to two tons. Flints, etc. Gypsum bed at 10 feet.

(15) CATTLE MARKET.—Stiff red clay. Boulders, granite, one to three tons. Gypsum at 12 feet.

(16) DANE HILLS.—Middle bed of Keuper at surface.

(17) ST. NICHOLAS STREET.—Soi 2 feet. Grey clay, chocolate clay. Lower shales of Keuper.

(18) LUNATIC ASYLUM, field north of. Sand at 4 feet, 10 feet thick.

(19) RAWSON STREET.—Soil 1 foot. Fine red sand 11 feet. At bottom many erratics, not Leicestershire.

(20) REGENT'S ROAD, end of Salisbury Road. Soil 1 foot. Stiff blue mottled clay 6 feet, rolled erratics, flints, etc.

(21) VICTORIA ROAD.—Soil 1 foot. Stiff mottled blue and red clay with patches of sand. Boulders in profusion. Sand 35 yards wide, 10 feet deep.

(22) VICTORIA ROAD AND LANCASTER STREET.—Thick bed of sandstone 8 feet below the road.

(23) VICTORIA ROAD, field south of road, opposite corner of cemetery.—Soil 2 feet. Stiff red mottled clay. Flints numerous. Erratics. Block of granite (10 tons) at 12 feet.

(24) VICTORIA PARK.—Soil 2 feet. Clay mottled with sand to 30 feet.

(25) MARKET PLACE.—Angular erratics at 20 feet.

(26) ABBEY PARK ROAD (South end.)—Gravel with tusk of *Mammoth*, at base resting on red clay.

(27) ABBEY PARK ROAD, a little north of the south end.—*Rhinoceros* teeth' *Succinea*, *Lymnea*, etc.

(28) WELFORD ROAD, Opposite the Cemetery.—Boulder-clay 14 feet, with worn Lias limestone. Sand and blue clay with large and small pebbles much rounded and scratched.

(29) HUMBERSTONE GATE, Secular Hall.—Bed of red sand.

(30) ST. STEPHEN'S ROAD.—Drift 30 feet.

The following sections numbered 1 to 29 are taken from Mr. Montagu Browne's very detailed account of "The Geology of the Borough of Leicester."* In this account there are between 200 and 300 sections; from these we have selected those which have a bearing on the mapping, or illustrate special points in the geology of the country. Some of these in particular districts we have summarised, instead of giving each individual section:—

(1) HINCKLEY ROAD, 45 YARDS WEST OF FOSSE ROAD.

	Ft.	in.
Macadam and gravel	1	8
Grey shale and sandstone	2	5
White sandstone	1	0
Grey marl, hard	4	6
White sandstone, very hard (indef.)	1	5
Total depth	11	0

(2) JUNCTION OF HINCKLEY ROAD AND FOSSE ROAD.

	Ft.	in.
Macadam	0	3
Grey shale, soft	2	2
White sandstone	1	0
Skerry	4	1
White sandstone	0	7
Skerry	4	6
Red marl (indef.)	3	11
Total depth	16	6

(3) MIDDLE OF WEST STREET, BRAUNSTONE GATE.

	Ft.	in.
Filling	5	1
Black clay	1	5
Sandy gravel	4	10
Sand	3	11
Gravel (indef.)	0	0½
Total depth	15	3½

(4) BRITON STREET, HALF-WAY BETWEEN NARBOROUGH ROAD AND RIVER

[About 550 yards south-east of No. 2.]

	Ft.	in.
Soft grey marl	2	0
Hard grey marl	6	0
Soft grey marl	2	0
Red marl (indef.)	5	6
Total depth	15	6

(5) ON BOULEVARD, NEAR MILL LANE WHARF.

[Average of three sections.]

	Ft.	in.		Ft.	in.
Filling	5	10	to	7	11
Blue clay	2	0	,,	6	4
Gravel and sand	4	8	,,	7	9

* *Trans. Leicester Lit. Phil. Soc.* 1893, p. 123 *et seq.* Since this memoir has been in the press Mr. Browne has published several sections on the Beaumont Leys Estate. *Ibid.* 1902, p. 7 *et. seq.*

(6) JUNCTION OF MILL LANE AND BRUDENEL STREET.

	Ft.	in.
Made ground	3	11
Loamy gravel	3	0
Brown clay	0	6
Sand and gravel	5	10
Red marl	2	9
Total depth	16	0

(7) HAVELOCK STREET.

[Average of four sections.]

	Ft.	in.		Ft.	in.
Made ground	2	1	to	4	0
Dark clay and soil	2	5	,,	4	2
Yellow clay	1	0	,,	2	8
Sandy gravel	2	7	,,	5	1
Total depth of superficial beds	11	6	to	13	0

(8) JUNCTION OF ASYLUM STREET AND RICHMOND STREET.

	Ft.	in.
Filling	10	0
Skerry	1	0
Sandstone	2	0
Skerry	1	0
Sandstone	1	0
Skerry	3	0
Total depth	18	0

(9) CASTLE YARD, OPPOSITE CENTRE OF ST. MARY'S CHURCH.

	Ft.	in.
Filling	7	0
Soil, bones, etc.	3	0
Gravel, sand, and clay	6	0
Red marl	15	0
Total depth	31	0

(10) THE NEWARKE TO THE END OF GRANGE LANE.

[Average of four sections.]

	Ft.	in.		Ft.	in.
Filling	4	0	to	6	0
Loam, sand, and gravel	2	0	,,	4	0
Total depth of superficial beds	7	0	to	10	0

(11) INFIRMARY SQUARE AND ALONG LANCASTER STREET TO THE RAILWAY.

Several sections only showing filling over red marl.

(12) AYLESTONE ROAD, OPPOSITE END OF KNIGHTON STREET.

	Ft.	in.
Filling	2	9
Clay with stones	2	0
Sand	2	3
Total depth	7	0

13) Castle Street, Messrs. Everard and Co.'s Brewery.

Well sunk in 1886, 45 feet from the one given on p. 76.

	Ft.	in.
Cellar below roadway	10	0
Pump pit, stated to be excavated in "the ordinary town filling"	11	0
Red marls	10	0
Indurated red marls	29	0
Red marls and grey marls in layers, with harder "skerries"	5	0
Indurated grey marls and sandstone with grey marly partings ("skerries")	9	0
Grey marl	3	0
Red marl	14	0
Red and grey marls and "skerries" and a little gypsum	13	0
Red and grey marls with gypsum, apparently in considerable quantity	42	0
Reddish chocolate and grey, sandy, much indurated marls, with stainings of manganese	4	0
Total depth	150	0

(14) Bottrell's Yard, Southgate Street.

	Ft.	in.
Black soil and various filling	60	0
Roman wall (3 feet 6 inches in width)	9	0
Red marl	5	0
Total depth	74	0

(15) Abbey Lane.

[Average of five sections.]

	Ft.	in.		Ft.	in.
Sand and gravel, with clay in places	7	8	to	13	0
Red and grey marls below.					

(16) Eastern End of Sanvey Gate, Messrs. W. Gimson and Sons

[About 120 yards from the one given on page 76.]

Supply of hard water very abundant, stands at 17 feet.

	Ft.	in.
Filling	5	0
Gravels	20	0
Red and grey marls	7	0
Total depth	32	0

(17) Near the North-West Corner of Spinney Hill Park

Measured by Messrs. Hodges and Bates.

	Ft.	in.
Soil	0	6
Drift clay	3	0
Bluish clay	2	0
Shales, light-coloured	2	4
Darker shales	1	8
Still darker shales	1	10
Bone bed	0	1
Tea-green marls	0	10
Total depth	12	3

(18) Mere Road, in Man-hole about 320 Feet North of End of St. Peter's Road.

Measured by Messrs. Bates and Hodges.

	Ft.	in.
Soil and glacial drift, containing rolled pebbles, etc.	8	0
Rubble or decomposed limestone, containing spines of *Echinus* and plates of *Pentacrinus*	2	0
Band of fossiliferous limestone, containing *Ammonites Johnstoni*	0	4
(Further S.S.E. this bed increases to 2 feet.)		
Shales	3	10
Nodular band with overlying ferruginous seam	1	2
Total depth	15	4

(19) Mere Road, 8 Yards North of Kerb of Ashbourne Street

	Ft.	in.
Humus	0	9
Clay (rainwash), stiff, reddish, with a few pebbles	0	6
Yellowish-grey Rhætic clay, with impersistent rusty bands and small limy lumps [race]	3	0
Rhætic limestone, large, nodular, ovoid and septariform, with calcite; reported as being "horse-backed" - 0 5 to	0	6
Shales, reported as being of the same nature, but more "dicey"	9	4
Total depth	14	0

(20) Mere Road, Summit of Hill Opposite Park Gates.

	Ft.	in.
Boulder-clay	9	6
Rhætic "grey rock"	1	0
Total depth	10	6

(21) Dale Street, 89 Yards from Kerb in Mere Road.

	Ft.	in.
Lower Rhætic shales	4	0
Bone bed (indef.).		
Tea-green marls	3	0
Total depth	7	0

(22) South Knighton, University Road, 118 Feet from Kerb of Knighton Church Road.

	Ft.	in.
Sandy drift [valley deposit]	6	6
Yellow shales	2	9
Dark shales	2	0
Light grey fissile limestone, containing minute Ammonites —*Am. planorbis*	0	3
Total depth	11	6

(23) Sewer in Field South-west of End of Knighton Church Road, 145 yards West of Cross Hedge.

	Ft.	in.
Humus, rainwash	1	0
Stiff yellowish clays or marls	4	0
Lower Lias limestone, 3 to 4 inches	0	3
Dark shales, not proved.		
Total depth	5	3

(24) At Cross Hedge, 95 Feet West of the Preceding Section.

	Ft.	in.
Humus, rainwash	1	2
Stiff yellow clays or marls, showing but little lamination, and partly or wholly reconstructed	3	6
Rhætic shales, thickly laminated	4	4
Total depth	9	0

(25) Knighton Church Lane, in Line with Pond.

	Ft.	in.
Filling	1	0
Rhætic dark grey shales	3	0
Rhætic nodular limestone, 3 to 4 inches	0	4
Rhætic bluish-black shales	4	6
Total depth	8	10

Sections just above this show the commencement and gradual thickening of the drift.

(26) Aylestone Road, about 50 Yards North of Cat's Lane.

	Ft.	in.
Alluvium, very sandy, free from stones, apparently tinged with a little Keuper red marl	10	0
Alluvium, nearly black, apparently composed of vegetable matter. Rolled and subangular large flints at base	2	0
Sandy, reconstructed, Keuper marls	2	0
Total depth	14	0

(27) Richmond Road, Aylestone Park, 50 Yards from Landsdown Road.

	Ft.	in.
Filling	1	3
Sands and gravel, with large blocks of Carboniferous sandstone, containing plant-remains	6	0
Red marl	1	3
Total depth	8	6

(28) Aylestone Road Gas Works. [Trial hole about 200 yards from the road.]

	Ft.	in.
Made ground	4	0
Humus	1	0
Stiff clay (homogeneous, with no stones), changing in colour from yellow to grey	5	0

	Ft.	in
Stiff dirty clay, with flints and pebbles - - - - -	0	10
Dirty gravel, with flints and pebbles - - - - -	0	10
Rusty red band - - - - - - - -	0	1
Rather dark gravel, rather coarse and stony - - -	1	0
Rusty red band - - - - - - - - - -	0	1
Greyish coarse gravel and sand, with quartz pebbles - -	1	0
Rusty red gravel - - - - - - - - - -	0	1
Rather coarse gravel and sand, with quartz pebbles - -	0	10
Fine sand and quartz pebbles - - - - - - -	0	9
Rusty red gravel and boulders, with a few broken pieces of Upper Keuper Sandstone, and antler of Reindeer -	0	1
Upper Keuper grey and red marls.		
Total alluvial beds - - - -	11	7

(29) Flood-Works Basin, just North of the Viaduct on the Burton Railway.

	Ft.	in.
Humus - - - - - - - - - -	1	0
Stiff dirty clay, with flints and pebbles - - - - -	3	0
Dirty gravel, with flints and pebbles - - - - -	2	3
Greyish coarse silicious sand and gravel - - - -	0	6
Coarser gravel and sand with quartzites and other pebbles -	1	2
Grey marls ("skerries"), cuboidal, and apparently shattered - - - - - - - - - -	2	3
Sandstone, with stains of vegetable matter - -	1	3
Grey and red marls - - - - - -	20	0
Total depth - - - -	31	5

[The engineer's assistant states that a bed of flagstone in the lower part was so hard that it had to be blasted.]

The following sections numbered 1 to 20 are from information obtained during the making of sewers.

Communicated by Mr. Norman Scorgie.

(1) Church Gate and Sanvey Gate, near the Church.—Sand and gravel, 11 feet. Red marl.

(2) Sanvey Gate.—Made ground from 8 to 15 feet. Marl.

(3) Junction of Northgates and Sanvey Gate.—Soil, etc., 9 feet. Gravel, 1 foot 6 inches. Marl.

(4) Junction of Northgate Lane and Northgates.—Made ground, 12 feet. Marl.

(5) Friars Road (centre).—Made ground, 17 feet. Gravel.

(6) Northgate Street.—Made ground, 6 feet to 8 feet 6 inches.

(7) Charlotte Street.—Made ground, 10 feet. Gravel.

(8) Alexander Street.—Made ground, 10 feet. Gravel 2 feet. Marl.

(9) Sarah Street, opposite Ruding Street.—Made ground, 14 feet. Gravel.

(10) Bath Lane, opposite Orton Street.—Made ground, 16 feet. Marl.

(11) Bath Lane, 92 Feet South of Welles Street.

	Ft.	in.
Made ground	6	0
Concrete	5	6
Made ground (not bottomed)	9	6

(12) Bath Lane, Opposite Gonty's Dye Works.—Made ground, 18 feet. Marl.

(13) Friday Street, Corner of Watling Street.—Made ground, 6 feet 6 inches. Marl.

(14) Watling Street.—Made ground, 6 feet. Marl.

(15) All Saints' Road.—Made ground, 10 feet or more.

(16) Abbey Gate, Opposite Emerald Street.

	Ft.	in.
Made ground	0	9
Gravel	11	3
Marl	7	0
	19	0

(17) Littleton Street.

	Ft.	in.
Soil, etc.	8	0
Gravel	1	6
Marl.		

(18) Wood Gate.—Made ground, 8 feet. Marl.

(19) First Field South of Wood Gate.

	Ft.	in.
Soil	1	0
Gravel	4 feet to 10	0
Marl and blue shale	5 feet to 8	0

(20) Second Field South of Wood Gate, Near the Railway.

	Ft.	in.
Soil	1	0
Gravel	10	0
Blue shale	3	6
Rock	1	6

The following communicated by Mr. Smith.

Beaumont Leys.—Well 100 feet. Blue clay 97 feet into gravel. Plenty of water.

Beaumont Leys. Farm Nearest Anstey and Farm Nearest Gilroes Reservoir.—Blue clay 15 feet and 27 feet respectively. No water in either.

Mowmacre Cottage.—Blue clay, yellow in upper part, 9 or 10 yards. Not much water.

Ingarsby.

RAILWAY STATION.

Communicated by J. L. Pattison, 1882, per Mr. W. Whitaker.

----	Thickness.		Depth.	
	Ft.	in.	Ft.	in.
Made ground	3	0	3	0
Blue clay and sandstone	4	0	7	0
Blue clay and stone	12	0	19	0
Sand and blue clay	1	0	20	0
Blue clay and limestone	4	0	24	0
Sand	1	0	25	0
Blue clay and stones	69	0	94	0
Hard blue Lias stone	2	0	96	0
Blue clay and stone	13	0	109	0
Clay stones and pebbles	6	0	115	0

Stationmaster reports this is a well 50 feet and boring 50 feet. No water obtained. Have to use rain water.

Billesdon Coplow.

Abstract of account of boring by J. Holdsworth, *Phil. Mag.*, Ser. III., Vol. III., p. 77*:—

	Ft.	in.
Strong slaty bind, containing about 9 feet of excellent ironstone in beds from 3 inches to 10 inches thick	150	0
Dun marl or bands of freestone, alternating in layers from 1 inch to 3 inches thick	30	0
Grey rock	27	0
Hard grey or freestone bands, divided by thin bands of light blue and black shale, with two thin veins of coal†	120	0
Hard bastard dun, much impregnated with coaly matter	42	0
Very hard striped rock	2	6
Red dun, or, rather, shale	9	0
Rock beautifully striped with black, white, brown, and dun	21	0
Brown dun	18	0
Strong black shale, occasionally finely striped with white	–	–
[? Total depth	419	6]

Billesdon.

NEAR THE BROOK, BELOW FRISBY (boring).

Sunk and communicated by Messrs. Thomson Bros. Sunk in 1897.

*There is a criticism of this account by Conybeare, *Phil. Mag.*, Ser. III., Vol. III., p. 112, and a counter reply by Holdsworth, *Mag. Nat. Hist.*, Vol. VII., p. 42.

† The coal was obtained from washings of the material brought up, and is probably fossil wood or jet from the Lias.

——	Thickness.		Depth.	
	Ft.	in.	Ft.	in.
Surface soil	3	0	3	0
Clay and stones	16	0	19	0
Lias (weathered)	125	0	144	0
Lias (firm) [*Am. Bonnardi* at 240 feet.]	348	0	492	0
Lias with thin limestone beds	114	0	606	0
Lias, dark (no lime)	33	0	639	0
White limey sandstone [Effervesces strongly]	9	0	648	0
Light fireclay	3	0	651	0
Dark and broken fakes [shaly sandstone]	10	0	661	0
Brown dun [clay]	12	0	673	0
Dark fakes and blaes [shale]	38	0	711	0
Dark shaly blaes [with *Avicula contorta ?*]	5	0	716	0
Blue marl	15	0	731	0
Marly sandstone with thin gypsum beds	238	0	969	0

The following six sections are communicated by Mr. Preston, Wellsinker.

Asfordby.

(1) VILLAGE.—Blue dicey clay, 30 feet.

(2) HOLWELL IRONWORKS.—35 yards, all clay.

(3) RAILWAY STATION.—Gravel 5 feet.

Kirby Bellars.

(4) THE HALL.—Clay 9 yards, then sand.

Syston.

(5) RAILWAY PUMPING STATION.—Sand and gravel 6 yards ; clay 4 yards.

Rearsby.

(6) VILLAGE.—Shallow wells in sand.

Seagrave.

LODGE FARM.

Information from Wellsinker.	Feet.
Chalky Boulder-clay, rather darker, with less chalk towards the bottom	46
Band of limestone 4 inches thick at	102
,, ,, 7 ,, ,,	105
,, ,, 9 ,, ,,	108
Nodular band, with water, at	114

Total depth of well, 40 yards.

Wells in the village are reported to have from 12 to 15 feet of chalky (?) Boulder-clay, with seven or eight floors of limestone below. Total depth, about 20 yards.

The following six sections communicated by Pick and Wells, Wellsinkers.

Queniborough.

(1) THE COPPICE.—Marl free of stones.

Barkby.

(2.) East Side.—Heavy soil, no springs, badly off for water.

(3.)West Side.—Lighter soil.

(4.) Barkby Thorpe.—Sand 3 yards ; plenty of water.

(5.) New York Farm.—Black shale, 52 yards.

Beeby.

(6.) Near Beeby House.—Black shale.

Beeby.

Midland Brewery Company.

Sunk and communicated by Messrs. Isler and Co.

——	Thickness.		Depth.	
	Ft.	in.	Ft.	in.
Dug well	27	0	–	–
Blue Lias with stone	91	0	118	0
Rock and blue Lias	5	0	123	0
Blue Lias	17	0	140	0
Hard rock	2	0	142	0
Blue Lias	33	0	175	0
Rock	4	0	179	0
Black shale	8	0	187	0
Red marl	5	0	192	0
Red marl with gypsum	6	0	198	0
Red marl	5	0	203	0
Red marl and shale	5	0	208	0
Red and blue marl	50	0	258	0
Rock	4	0	262	0
Rock and red marl	3	0	265	0
Hard rock	2	0	267	0
Red and blue marl	3	0	270	0
Red marl and rock	15	0	285	0
Hard red marl	6	0	291	0
Hard rock	1	0	292	0
Hard red marl	16	6	308	6
[Omitted]	66	6	–	–
Hard rock	2	0	375	0
Hard red marl	15	10	390	10

Hoby.

Communicated by Mr. Shelton, Wellsinker.

Wells in the village generally.

Soil and loamy mixture, 4 feet.
Sand and sharp gravel, 9 feet or more.
Blue stone, solid.
Yellow clay.

Some wells in clay and gravel. In red clay at Hill House.

Frisby on the Wreak.

Communicated by Mr. Shelton.

Public House.—All quicksand.

The following three sections communicated by Mr. Smith, Wellsinker.

Swithland.

Wood Farm (on west side of wood).—Red marl 36 feet on to slate.

Groby.

Near the School.—36 to 50 feet into sand. Plenty of water.

Glenfield.

Land Society.—Deepest well about 60 feet. Blue and red clay 50 feet. sand below.

Anstey.

Papermill Company. [North side of the village] 225 feet above O.D.

B. A. Reports, 1875, p. 137.
Shaft, 102 feet; diameter, 8 feet; bore, 85 feet; diameter 3 inches.
No water; bottom of bore in gypsum.

	Ft.	in.
Drift, stiff brown Boulder-clay with rounded pebbles [with lumps of black clay (shale) and pyrites]	70	0
Red marl with layers of gypsum (6 inches to 12 inches) and white and blue clay (*dicey*). [Another account gives 80 feet red marl and 10 feet skerry]	117	0
Total depth	187	0

The boring ceased at a bed of gypsum so dry that a match could be ignited at the bottom.

Ratcliffe.

College, Quadrangle of. Sunk in 1843. 312 feet above O.D.

B.A. Reports, 1878, p. 387.
Well 156 feet, diameter 6 feet.
Water stands at 8 feet.

[There is no detailed section given, but the nature of the rock is stated to be "Lower Lias and Upper Keuper Marls and sandstone." This is erroneous, as shown by information obtained by the college authorities in 1893, and kindly communicated to us per the Rev. J. Cappella. In this year the well was repaired, and samples of the strata taken at about every 11 feet, with the following result:—

		Feet.
Clayey sand with small pebbles and specks of chalk	at	11
Clayeysand with small pebbles and specks or rather coarser	,,	33
Grey clay, probably dark when wet	,,	44
Gritty sand with clayey partings and small stones	,,	55
Grey (blue) clay with sandstone, chert, etc.	,,	66
Grey (blue) clay with chalk, etc.	,,	77
Coarse sand with fragments, little marl	,,	88
Red marl with a grey patch	,,	99
White quartzose sandstone	,,	102
Red marl streaked with grey	,,	110
Red sandy marl with grey specks	,,	121

From the above it will be seen that there is no Lias or Rhætic in this well, as stated in the Report, but that the strata passed through might be correlated according to the following summary.

	Ft.	in.
Boulder-clay with a parting of sand, and possibly a bed of sand at the base	88	0
Red marl with a bed of sandstone, probably the same as that which crops out in the village	68	0
Total depth	156	0

Mr. G. Hodson states that this well, which was 139 feet deep, was continued by boring to 241 feet; the Waterstones being reached at 220 feet.

Glen Parva.

New Barracks. About 300 feet above O.D.

B.A. Reports, 1878, p. 387.
Shaft 100 feet, diameter 6 feet; bore 150 feet, diameter 6 inches.
Very little water, hard what there is, and that is thought to be surface drainage.

	Ft.	in.
Drift	10	0
Lower Lias with thin limestone	40	0
Rhætic [mostly tea-green marl]	20	0
Chocolate marls	30	0
Red marls, chocolate colour	150	0
	250	0

Blaby.

Hospital about a Mile S.E. of the Village.

Communicated by Messrs. Simpson and Harvey.

Two wells, the one at the top of the field about 90 feet deep, one at the side about 35 feet deep.

	Ft.	in.
Soil	0	6
Brick clay	20	0
Bluish clay	70	0 ?

A vein or pocket of sand at the 35 feet depth.

Countesthorpe.

BORING AT THE COTTAGE HOMES.

Communicated by Messrs. Le Grand and Sutcliff. Sunk in June, 1892.

	Thickness.		Depth.	
	Ft.	in.	Ft.	in.
Well [Drift 87 feet]	103	0	–	–
Red marl	28	0	131	0
Red marl and gypsum	6	6	137	6
Marl and gypsum	41	6	179	0
Sandstone	1	2	180	2
Blue and red marl	9	10	190	0
Slate and blue marl [skerry]	6	6	196	6
Blue and red marl	3	6	200	0
Red marl and gypsum	102	0	302	0
Red marl	43	6	345	6
Sandstone	3	0	348	6
Red marl	8	6	357	0
Sandstone	0	3	357	3
Red marl rock	4	3	361	6
Red marl rock	31	4	392	10
Hard rock	0	6	393	4
Red marl	83	2	476	6
Rock	0	6	477	0
Red marl	72	0	549	0
Blue marl rock	2	6	551	6
Red marl	46	6	598	0
Red and blue marl and red sandstone	2	6	600	6
Red marl	4	0	604	6
Red sandstone	10	0	614	6
Marl and blue sandstone	8	0	622	6
Red marl	4	3	626	9
Granite*	2	9	629	6
Red marl	3	6	633	0
Granite	4	8	637	8

No supply of water.

Melton Mowbray.

Boring for town supply about 200 yards west of G.N.R. and L.N.W.R. joint station. About 260 feet above O.D.†

	Ft.	in.
Loam and gravel	14	0
Boulder-clay (?)	24	0
Lower Lias	230	8
Rhætic (dark shaly clay and stone)	16	4
Keuper Marl (Red and grey marls with bands of gypsum and bands of grey sandstone in the lower part)	247	10
	532	10

Water rises to 120 feet below the surface, from the gypsum beds as well as the sandstone.

* This is probably a similar rock to that described on p. 116.

† Details of this section are given in the Survey Memoir descriptive of Sheet 70. "The Geology of the South-west Part of Lincolnshire," p. 147.

Saxby.

Trustees of the late Earl of Dysart. Situated near the river, and half-way between north and south of enclosure No. 89, or 2,500 Plan No. XX. 8 of Leicestershire.

——	Thickness.		Depth.	
	Ft.	in.	Ft.	in.
Soil and blue clay	14	0	–	–
Nodular limestone rock	2	6	16	6
Blue clay	31	0	47	6
Rock	2	0	49	6
Blue clay	76	0	125	6
Rock (small supply of water from this rock)	7	6	133	0
Clay	92	0	225	0
Rock (water found here)	4	6	229	6
Clay and soft rock	2	0	231	6
Rock	8	6	240	0
Clay	36	6	276	6
Rock (a little more water found in this rock)	5	0	281	6
Clay	16	6	298	0
Rock	4	0	302	0
Clay	7	6	309	6

Oakham.

One mile west of the town. About 350 feet above O.D.

B.A. Reports, 1879, p. 161.

Sunk about five years before, and deepened several times. Shaft 80 feet. Diameter 7 feet. No driftways.

Water stands at about 40 feet level, not perceptibly reduced. Very sweet and pleasant water, used solely for brewing.

	Ft.	in.
Drift	4	0
Upper Lias clay	30	0
Marlstone rock	18	0
„ sands	28	0
	80	0

APPENDIX II.

CATALOGUE OF FOSSILS

RECORDED FROM THE

TRIAS, RHÆTIC AND LIAS FORMATIONS OF LEICESTERSHIRE AND RUTLAND, OR JUST BEYOND THE BORDERS OF THOSE COUNTIES.

This Catalogue of the Trias, Rhætic, and Lias Fossils of Leicestershire and the immediate neighbourhood has been compiled from the works of the different authors enumerated in the list given below.

The narrow columns give the horizon at which the species has been recorded, the several observations being noted by an initial. When the reference is not sufficiently explicit to determine at what particular zone the species occurs, the observation is entered in one of three columns denoting the general divisions of the Lias.

The names of species are printed in three forms of type: those now recognized being in **Clarendon** characters, the synonyms of these in *italics*; while the uncertain and doubtfully determined forms, as well as the MS. names of species which have not as yet been figured or described, are placed in SMALL CAPITALS.

Reference Initial.	Author or Museum.	Works referred to.
A.	D. T. Ansted.	Physical Geography and Geology of the County of Leicester, 1866.
B.	Montagu Browne.	The Vertebrates of Leicestershire, 1889. Leicester Lit. Phil. Soc. for 1893, p. 123. Brit. Assoc. Rep. for 1895.
Ba.	E. F. Bates and L. Hodges.	Rhætics at Spinney Hills, Leicester Lit. Phil. Soc. for 1886, p. 22.
Bm.	British Museum.	
J.	J. W. Judd.	Geology of Rutland. Geological Survey Memoir, 1875.
Jm.	Jermyn Street Museum.	
H.	W. H. Hudleston and E. Wilson.	Catalogue of British Jurassic Gasteropoda 1892.
Hn.	W. J. Harrison.	Quart. Journ. Geol. Soc., vol. xxxii., p. 212, 1876. Geology of Leicestershire and Rutland, 1877.
L.	Leicester Museum.	
M.	J. Morris.	Catalogue of British Fossils, 1854.
N.	A. J. Jukes-Browne, and others.	Geology of South-west part of Lincolnshire, with parts of Leicestershire and Nottinghamshire (Explanation of Sheet 70). Geol. Survey Memoir, 1885.
P.	J. D. Paul.	Section on the Gt. Northern Railway near Thurnby. Leicester Lit. Phil. Soc., 1883, p. 50.
Pl.	James Plant.	Leicester Lit. Phil. Soc. for 1875, p. 43. Quart. Journ. Geol. Soc. 1856, p. 369.
Q.	H. E. Quilter.	Leicester Lit. Phil. Soc. for 1883, p. 51, and 1884, p. 86. The Lower Lias of Leicestershire, Geol. Mag., dec. iii., vol. iii., p. 59, 1886.
S.	Geological Survey.	Collected and determined by the officers of the Survey.
W.	E. Wilson and H. E. Quilter.	The Rhætic Section at Wigston. Geol. Mag., dec. iii., vol. i., p. 415, 1884.
	E. Wilson.	British Liassic Gasteropoda. Geol. Mag., dec. iii., vol. iv., p. 193, etc. 1887.
	E. Wilson and W. D. Crick.	The Lias Marlstone of Tilton. Geol. Mag., dec. iii., vol. vi., p. 296, etc. 1889. The List given by E. Wilson in Mid. Nat. 1885, differs from this, but we take the later one as being the most correct.
Wo.	A. S. Woodward and C. D. Sherborn	Catalogue of British Fossil Vertebrata, 1890.
X.	Various authors.	Reference given in last column.

SPECIES.	Keuper Sandstone.	Rhætic Beds.	Lower. Am. planorbis.	Am. angulatus.	Am. Bucklandi.	Am. semicostatus.	Am. oxynotus.	Am. armatus.	Am. Jamesoni.	Am. capricornus.	Middle. Am. margaritatus.	Am. spinatus.	Upper. Am. annulatus.	Am. serpentinus.	Am. communis.	Lower Lias.	Middle Lias.	Upper Lias.	LOCALITIES AND REMARKS.
INCERTÆ SEDIS.																			
Onychites sp. Wilson, Geol. Mag. 1889, pl.x., fig 6.	–	–	–	–	–	–	–	–	–	–	–	W	–	–	–	–	–	–	Tilton East) Norton).
PLANTÆ.																			
ALGÆ ?	Pl	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	Leicester.
Echinostachys oblongus ? Brongn.	Pl Hn	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	Leicester.
Equisetites sp.	Pl	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	Leicester.
FOSSIL WOOD	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	L	L	–	
FUCOIDS	–	L	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	Crown Hill
PLANT REMAINS	L	–	–	–	–	–	–	–	–	–	–	–	–	–	–	L	–	–	
Pterophyllum brevipenna ? Heer	–	B	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	East Leake.
Voltzia sp.	Pl Hn	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	Leicester. Cast of leaves in red marl (Harrison).
FORAMINIFERA.																			
Cornuspira infima, Strickland	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	X	–	–	H. B. Woodward, Jurassic Rocks of Britain, Vol. iii.
sp.	–	–	–	–	–	–	Q	–	–	–	–	–	–	–	–	–	–	–	
Cristellaria sp.	–	–	–	–	–	–	Q	–	–	–	–	–	–	–	–	–	–	–	
Dentalina sp.	–	–	–	–	–	–	Q	–	–	–	–	–	–	–	–	–	–	–	
Frondicularia sp.	–	–	–	–	–	–	Q	–	–	–	–	–	–	–	–	–	–	–	
Involutina sp.	–	–	–	–	–	–	Q	–	–	–	–	–	–	–	–	–	–	–	
Lingulina sp.	–	–	–	–	–	–	Q	–	–	–	–	–	–	–	–	–	–	–	
Marginulina sp.	–	–	–	–	–	–	Q	–	–	–	–	–	–	–	–	–	–	–	
Miliola sp.	–	–	–	–	–	–	Q	–	–	–	–	–	–	–	–	–	–	–	Old Dalby Tunnel. Foraminifera of these genera were obtained by E. Wilson.
Nodosaria sp.	–	–	–	–	–	–	Q	–	–	–	–	–	–	–	–	–	–	–	
Nonionina sp.	–	–	–	–	–	–	Q	–	–	–	–	–	–	–	–	–	–	–	
Orbulina sp.	–	–	–	–	–	–	Q	–	–	–	–	–	–	–	–	–	–	–	
Planularia sp.	–	–	–	–	–	–	Q	–	–	–	–	–	–	–	–	–	–	–	
Pulvinulina sp.	–	–	–	–	–	–	Q	–	–	–	–	–	–	–	–	–	–	–	
Textularia sp.	–	–	–	–	–	–	Q	–	–	–	–	–	–	–	–	–	–	–	
CŒLENTERATA. (ACTINOZOA.)																			
GORGONIA KEUPERI, Plant	Pl	–	–	–	–	–	–	–	–	–	–	–	–	–	–		–	–	Probably not organic.
Lepidophyllia hebridensis, Dunc.	–	–	–	–	–	N Q	–	–	–	–	–	–	–	–	–	–	–	–	Redmile.
Montlivaltia Guettardi, Blainv.	–	–	–	N	Q	–	–	–	–	–	–	–	–	–	–	L	–	–	Bottesford, Kilby.

SPECIES.	Keuper Sandstone.	Rhætic Beds.	Lower. Am. planorbis.	Am. angulatus.	Am. Bucklandi.	Am. semicostatus	Am. oxynotus.	Am. armatus.	Am. Jamesoni.	Am. capricornus.	Middle. Am. margaritatus.	Am. spinatus.	Upper. Am. annulatus.	Am. serpentinus.	Am. communis.	Lower Lias.	Middle Lias.	Upper Lias.	LOCALITIES AND REMARKS
Haimei, Chap.&Dew.	–	–	N	–	–	–	–	–	–	–	–	–	–	–	–	L	–	–	Balderton, Old Dalby.
mucronata, Dunc.	–	–	–	–	–	–	Q	–	–	–	–	–	–	–	–	–	–	–	
papillata, Dunc.	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	N	–	–	Gainsborough. Duncan, Pal. Soc.
rugosa, Wright	–	–	–	N	–	–	–	–	J	–	–	–	–	–	–	–	–	–	Claypole, Dalby.
Thecocyathus sp.	–	–	–	–	–	–	–	–	–	–	–	W	–	–	–	–	–	–	Tilton.
ECHINODERMATA. (ECHINOIDEA.)																			
Cidaris Edwardsi, Wright	–	–	Ba W	–	Q	–	Q?	–	–	–	–	–	–	–	–	B L	–	–	Spinney Hills, Wigston.
spp.	–	–	–	–	Q?	–	–	–	–	–	–	–	–	–	–	L	–	–	Barrow. Crown Hill. *C. florigemma*, recorded by Quilter in error? Omitted in list of 1886.
Eodiadema granulata, Wilson	–	–	–	–	–	–	–	–	–	–	–	W	–	–	–	–	–	–	Tilton.
Hemipedina Tomesi, Wright	–	–	Q	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	Thurnby.
(spines)	–	–	–	–	P	–	–	–	–	–	–	–	–	–	–	B L	–	–	Barrow.
OPHIUROIDEA.																			
Ophioderma Milleri, Phil.	–	–	–	–	–	–	–	–	–	–	N	–	–	–	–	–	–	–	Middle Gonerby.
Ophiolepis Damesi, Wright	–	L W Hn Q	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	Wigston. Spinney Hills.
Ramsayi? Wright	–	L	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	Disc and ray.
CRINOIDEA.																			
Extracrinus britannicus, Schloth.; *Pentacrinus briareus*, Miller	–	–	–	–	Q	–	–	–	N?	N?	–	–	–	–	–	Hn	–	–	CrownHill, Barrow, Kilby Bridge.
subangularis, Miller	–	–	–	–	–	–	–	–	–	–	J	–	–	–	–	–	–	–	
Pentacrinus basaltiformis, Miller	–	–	–	–	–	–	–	–	–	J	–	–	–	–	–	–	–	–	MarketHarbro
briareus, Miller v. Extracrinus britannicus.																			
lævis, Miller	–	–	–	–	–	–	–	–	–	–	–	W J	–	–	–	–	–	–	Tilton.
psilonoti, Quenst.	–	–	W Q	–	Q	–	–	–	–	–	–	–	–	–	–	–	–	–	Wigston.
punctiferous, Quenst. v. P. scalaris.																			
robustus, Wright	–	–	–	–	–	–	–	–	–	Q J	–	–	–	–	–	–	–	–	
scalaris, Goldf.; *P. punctiferous*, Quenst.	–	–	–	–	–	–	–	–	J S Q	–	–	–	–	–	–	–	–	–	Stapleford. Loseby.
subangularis, Miller, v. Extracrinus.																			
spp.	–	–	Ba	–	P	N	–	–	S	N	J	–	–	–	–	–	–	–	

SPECIES.	Keuper Sandstone.	Rhætic Beds.	Lower. Am. planorbis.	Am. angulatus.	Am. Bucklandi.	Am. semicostatus	Am. oxynotus.	Am. armatus.	Am. Jamesoni.	Am. capricornus.	Middle. Am. margaritatus.	Am. spinatus.	Upper. Am. annulatus.	Am. serpentinus.	Am. communis.	Lower Lias.	Middle Lias.	Upper Lias.	LOCALITIES AND REMARKS.
ANNELIDA.																			
Ditrupa																			
capitata, Phil. (*Serpula*).	-	-	-	-	-	N Q	-	-	-	-	-	W	-	-	-	-	-	-	Tilton, Redmile.
etalensis, Piette	-	-	-	-	-	-	-	-	-	-	-	W	-	-	-	L	-	-	Tilton, Old Dalby.
quinquesulcata, Münster	-	-	-	-	-	-	-	-	-	-	-	W J	-	-	-	-	-	-	Tilton.
sp.	-	-	-	-	-	-	-	-	N	-	-	-	-	-	-	-	-	-	
Serpula																			
capitata, Phil. v. Ditrupa.																			
tetragona, Desl.	-	-	-	-	-	-	-	-	-	-	-	W	-	-	-	-	-	-	Tilton. Geol. Mag. 1889, p 342. ? *S. tetragona,* Sow. Unable to verify this.
tricristata, Goldf.	-	-	-	-	-	-	-	-	-	-	-	W?	-	-	W	-	-	-	Tilton.
spp.	-	-	W Q	-	P Q	S	Q	Q	J Q	S	-	-	-	-	-	-	-	-	
WORM-TRACKS	Pl Hn	Hn	-	-	-	-	-	-	-	-	-	-	-	-	-	-	L	-	
INSECTA.																			
Buprestis (Elytron of)	-	-	Q	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
Libellula (Wing of)	-	-	Q	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
INSECT WING	Hn	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	Spinney Hills. In the tea-green marl.
NEUROPTEROUS INSECT	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	L	-	-	Barrow.
Palæotermes																			
Ellisi, Woodw.; Geol. Mag., 1892, p. 193.	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	L	-	-	Barrow. Type specimen.
BRYOZOA.																			
Diastopora																			
oolitica, Vine	-	-	-	-	-	-	-	-	-	-	-	W	-	-	-	-	-	-	Tilton.
stomatoporoides ? Vine.	-	-	-	-	-	-	-	-	-	-	-	W	-	-	-	-	-	-	Tilton.
CRUSTACEA.																			
Archæoniscus																			
sp.	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	L	-	-	Barrow.
CRUSTACEAN REMAINS	-	-	-	-	-	-	Q	-	-	-	-	-	-	-	-	-	-	-	
Eryma																			
n.sp.	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	L	-	-	Fleckney. *Fide.* Dr. H Woodward.
Eryon																			
barrovensis, M'Coy	-	-	Hn Q	-	-	-	-	-	-	-	-	-	-	-	-	L	-	-	Barrow.
sp.	-	-	-	-	Q	-	-	-	-	-	-	-	-	-	-	-	-	-	
Estheria																			
minuta, Goldf.	Pl Hn B	N Hn	-		-	-	-	-	-	-	-	-	-	-	-	-	-	-	Kilvington, Casts in nodular limestone. Spinney Hills, Dane Hills. Aylestone.
sp.	L	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
Glyphæa																			
liassina ? Meyer	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	X	-	-	Barrow. ?=*G. liassica,* recorded by Brodie, Ann. Mag. Nat. Hist., 1867, ser. 3, vol. xix,. p. 31.

SPECIES.	Keuper Sandstone.	Rhætic Beds.	Lower.								Middle.		Upper.			Lower Lias.	Middle Lias.	Upper Lias.	LOCALITIES AND REMARKS.
			Am. planorbis.	Am. angulatus.	Am. Bucklandi.	Am. semicostatus.	Am. oxynotus.	Am. armatus.	Am. Jamesoni.	Am. capricornus.	Am. margaritatus.	Am. spinatus.	Am. annulatus.	Am. serpentinus.	Am. communis.				
Præatya																			
scabrosa, Woodward, Geol. Mag., 1878, p. 289.	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	Bm	-	-	Barrow.
BRACHIOPODA.																			
Discina																			
reflexa, Sow. - -	-	-	-	-	-	-	-	-	-	-	-	W	-	-	J N	-	-	-	Tilton. Grantham.
Lingula																			
metensis, Terq. -	-	-	-	-	-	-	-	-	N	-	-	-	-	-	-	-	-	-	Broughton.
Rhynchonella																			
acuta, Sow. var. **bidens**, Phil.	-	-	-	-	-	-	-	-	-	-	-	W J	-	-	-	-	-	-	Tilton.
amalthei, Quenst. -	-	-	-	-	-	-	-	-	-	-	-	W	-	-	-	-	-	-	Tilton.
calcicosta, Quenst.	-	-	-	-	P Q	-	Q	S Q	-	-	-	-	-	-	-	-	-	-	Crown Hill, Thurnby, Ingarsby.
fodinalis, Tate -	-	-	-	-	-	-	-	-	-	-	-	W N S	-	-	-	-	-	-	Tilton. Wellingore.
lineata, Y. & B. -	-	-	-	-	-	-	-	-	-	S	-	-	-	-	-	-	-	-	Billesdon.
plicatissima, Quenst. v. Rh. calcicosta.																			
tetrahedra, Sow. -	-	-	-	-	-	-	Q	-	N S	S	J	W H J N	-	-	-	L	L	-	Old Dalby, Holywell, Tilton, Hallaton, Edmondthorpe, Pickwell, Ingarsby, Loseby.
tetrahedra, var. **northamptonensis**, Dav.	-	-	-	-	-	-	-	-	-	-	-	W N	-	-	-	-	Hn L	-	Tilton, Holywell, Eastwell.
variabilis, Schloth.	-	-	-	-	-	N Q	-	-	J	-	-	-	-	-	-	Hn L	L	-	Barrow, Kilby, Thorpe Langton, Loseby, Redmile.
subvariabilis, Dav.	-	-	-	-	-	N	-	-	-	-	-	-	-	-	-	-	-	-	Plungar.
spp. - - - - -	-	-	-	-	-	-	-	-	N	N S	-	-	-	-	-	L	-	-	Old Dalby Loseby.
Spiriferina																			
rostrata, Schloth. -	-	-	-	-	-	-	-	-	-	-	-	W	-	-	-	-	-	-	Tilton.
verrucosa, Von Buch	-	-	-	-	-	-	Q	-	-	-	-	-	-	-	-	L	-	-	Old Dalby.
Walcotti, Sow. -	-	-	-	-	-	N	Q	-	J Q	-	-	-	-	-	-	L	-	-	Thorpe Langton, Loseby, Old Dalby.
Terebratula																			
furcillata, Theod. var. **lævigata**, Quenst.	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	L	-	-	Old Dalby.
punctata, Sow. -	-	-	-	-	-	Q? N	-	-	-	-	J	Hn W J N	-	-	-	-	L S	-	Holywell, Edmondthorpe, Pickwell, Keythorpe, Tilton, Skeffington.
punctata, var. **Edwardsi**, Dav.	-	-	-	-	-	-	-	-	-	-	-	W	-	-	-	-	L	-	Tilton, Belvoir.
punctata, var. **haresfieldensis**, Dav.	-	-	-	-	-	-	-	-	-	-	-	W	-	-	-	-	L	-	Tilton.
punctata, var. **radstockensis**, Dav.	-	-	-	-	-	-	-	-	-	-	-	W	-	-	-	-	L	-	Tilton,Holwell.
subpunctata, Dav.	-	-	-	-	-	-	-	-	-	-	-	N	-	-	-	-	L	-	Tilton,Holwell.
Walfordi, Dav. -	-	-	-	-	-	-	-	-	-	-	-	W	-	-	-	-	-	-	Tilton.
spp. - - - -	-	-	-	-	-	-	-	-	-	S	-	-	-	-	-	-	-	Q	Market Harbro'.
Waldheimia																			
indentata, Sow. -	-	-	-	-	-	-	-	-	-	-	-	W	-	-	-	-	-	-	Tilton.
numismalis, Lam.	-	-	-	-	-	-	Q	-	-	-	-	W J	-	-	-	L	-	-	Tilton, Edmondthorpe, Old Dalby.

SPECIES.	Keuper Sandstone.	Rhætic Beds.	Lower. Am. planorbis.	Am. angulatus.	Am. Bucklandi.	Am. semicostatus.	Am. oxynotus.	Am. armatus.	Am. Jamesoni.	Am. capricornus.	Middle. Am. margaritatus.	Am. spinatus.	Upper. Am. annulatus.	Am. serpentinus.	Am. communis.	Lower Lias.	Middle Lias.	Upper Lias.	Localities and Remarks.
perforata, Piette	-	-	-	-	Q	-	-	Q	N	-	-	-	-	-	-	L	-	-	Old Dalby, Kilby Bridge, Loseby, Woolsthorpe.
resupinata, Sow.	-	-	-	-	-	-	-	-	-	-	-	W	-	-	-	-	-	-	Tilton.
subnumismalis, Dav.	-	-	-	-	-	-	-	-	-	-	-	W	-	-	-	-	-	-	Tilton.
Waterhousi, Dav.	-	-	-	-	-	-	-	-	-	-	-	N	-	-	-	-	-	-	Wellingore
LAMELLIBRANCHIATA. (MONOMYARIA.)																			
Anomia numismalis, Quenst.	-	-	-	-	-	-	-	-	-	-	-	W	-	-	-	-	-	-	Tilton.
Avicula (*Cassianella*) contorta, Portl.	-	L W N B Hn	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	Barrow. Wigston. East Leake.
cygnipes, Y. and B.	-	-	N	-	-	-	-	Q	-	-	W J	-	-	-	-	-	L	-	Tilton, Harbro. Hallaton, Cranhoe.
decussata, Goldf. v. Pseudomonotis																			
inæquivalvis, Sow.	-	-	-	-	-	N	-	-	S	-	W J N S	W N	-	-	-	-	L	-	Tilton, Belton, Ouston, Harbro, Hallaton, Holt, Loseby.
novemcostæ, Brown v. Av. inæquivalvis																			
papyria, Quenst.	-	-	-	S	-	-	-	-	-	-	-	-	-	-	-	-	-	-	Thurnby. From a well.
spp.	-	-	-	-	-	-	-	-	N S	N S	-	-	-	-	-	L	-	-	Ashby Folville.
Cassianella v. Avicula																			
Crenatula v. Inoceramus																			
Gervillia spp.	-	-	-	-	P?	N	-	-	-	-	-	-	-	-	-	-	-	-	Thurnby, Plungar.
Gryphæa arcuata, Lam.; *G. incurva*, Sow.	-	-	W Q	Q	P Q N	N Q Hn	Q	N Q	S	N	-	-	-	-	-	Hn	-	-	Abundant.
cymbium, Lam.	-	-	-	-	-	-	Q	J	J S Q N	S N	-	-	-	-	-	S L	-	-	Abundant.
cymbium, Lam. var. depressa, Phil.	-	-	-	-	-	-	-	S	-	-	W	-	-	-	-	-	-	-	Loseby, Tilton.
cymbium, Lam., var. obliquata, Sow.	-	-	-	-	-	-	-	J	J Q	-	-	-	-	-	-	-	-	-	Loseby, Dalby, Staunton Wyville.
incurva, Sow. v. G. arcuata.																			
Maccullochi, Sow. G. cymbium.																			
obliquata, Sow. v. G. cymbium.																			
sp.	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	L	-	-	Barrow.
Hinnites abjectus, Phil.	-	-	-	-	-	-	-	-	-	-	-	W	-	-	-	-	-	-	Tilton.
tumidus, Ziet.; *P. velatus*, Münst.	-	-	-	-	-	-	-	-	-	-	-	J W S N	-	-	-	-	-	-	Tilton.
velatus, Münst. v. H. tumidus.																			
Inoceramus dubius, Sow.	-	-	N	-	-	-	-	-	N ?	N	-	-	J	-	W J	-	-	J	Barrowby, Keythorpe, Rockingham.
substriatus, Münst.	-	-	-	-	-	-	-	-	J	-	-	-	-	-	-	-	L	-	Eastwell.

SPECIES.	Keuper Sandstone.	Rhætic Beds.	Lower.								Middle.		Upper.			Lower Lias.	Middle Lias.	Upper Lias.	LOCALITIES AND REMARKS.
			Am. planorbis.	Am. angulatus.	Am. Bucklandi.	Am. semicostatus.	Am. oxynotus.	Am. armatus.	Am. Jamesoni.	Am. capricornus.	Am. margaritatus.	Am. spinatus.	Am. annulatus.	Am. serpentinus.	Am. communis.				
ventricosus, Sow. (*Crenatula*).	-	-	-	-	-	-	Q	-	-	J	-	-	-	-	-	L	-	-	Harbro, Old Dalby.
sp.; Geol. Mag., 1889, p. 338, pl. x., f. 4.	-	-	-	-	-	-	-	-	-	-	-	W	-	-	-	-	-	-	Tilton (East Norton).
sp. - - - - -	-	-	-	-	-	N	-	-	-	-	-	-	-	-	-	-	-	-	Plungar.
Lima																			
acuticosta, Schloth. v. Limea.																			Error for Limea.
duplicata, Sow. -	-	-	-	-	N	-	-	-	-	-	-	N?	-	-	-	-	-	-	Redmile, Eastwell.
eucharis, d'Orb. -	-	-	-	-	-	-	-	-	-	-	-	W	-	-	-	-	-	-	Tilton.
gigantea, Sow. -	-	-	W Ba N Q	Q	P Q	N Q	Q?	Q	S	N	-	-	-	-	-	Hn L	-	-	Abundant.
Hermanni, Voltz. -	-	-	Q	-	-	-	-	J Q	J Q	-	-	W	..	-	-	Hn	-	-	Loseby, Barrow, Tilton, Stapleford.
pectinoides, Sow. -	-	-	N Ba Q	-	P Q	N Q	Q	Q	S	-	J N	W J	-	-	-	S B L	Hn L	-	Cranhoe, Thurnby, Tilton, Spinney Hills, Billesdon, Rocart, Belton, Loseby, Twyford, Cold Newton.
punctata, Sow. -	-	-	-	-	-	N Q	-	-	-	-	-	N	-	-	-	-	-	-	Redmile, Plungar, Wellingore.
succincta, Schloth.	-	-	Q	-	Q	-	-	-	-	-	-	-	-	-	-	L	-	-	Barrow, Hoton.
spp. - - - -	-	-	Ba	-	-	-	-	-	-	-	-	-	-	-	-	Hn L	-	-	Spinney Hills.
Limea																			
acuticosta, Münst.	-	-	-	-	-	-	-	-	J Q	-	-	W	-	-	-	L	-	-	Thorpe Langton, Stapleford, Tilton, Loseby, Kilby Bridge. *Lima* of Judd, and Quilter.
juliana, Dum. -	-	-	-	-	-	-	-	-	-	-	-	W	-	-	-	-	-	-	Tilton.
sp. - - - - -	-	-	-	-	Q	-	-	-	-	-	-	-	-	-	-	-	-	-	
Monotis v. Avicula and Pseudomonotis.																			
Ostrea																			
arcuata, Lam. v. Gryphæa.																			
cymbium, Lam. v. Gryphæa.																			
Goldfussi, Brown; *O. irregularis*, Münst.	-	-	N	-	-	-	-	Q	-	-	-	-	-	-	-	-	-	-	Cotham.
irregularis, Münst. v. O. Goldfussi.																			
liassica, Strickland	-	-	W N Ba	Q?	P Q	-	Q	Q?	-	Q	-	-	-	-	-	Q Hn L	-	-	Wigston, Kilby, Spinney Hills, Thurnby, Barrow, Fleckney.
submargaritacea, Brauns	-	-	-	-	-	-	-	-	-	-	-	W	-	-	-	-	-	-	Tilton.
spp. - - - -	-	-	Ba	-	-	N	-	-	N	N	N	J	-	-	J	L	-	-	Spinney Hills, Tilton, Allexton.
Pecten																			
acutiradiatus, Goldf.	-	-	-	-	-	-	-	-	-	-	-	W	-	-	-	-	-	-	Tilton.
æquivalvis, Sow.; *P. sublævis*, Y. & B	-	-	-	-	P	N Q	-	-	N J	-	J	W J N	-	-	-	-	L	-	Abundant.
calvus, Goldf. -	-	-	-	-	-	-	-	-	-	-	-	W	-	-	-	L	-	-	Tilton, Loseby.
demissus, Phil. -	-	-	-	-	-	-	-	-	-	-	J	-	-	-	-	-	-	-	Belton.
dentatus, Sow. -	-	-	-	-	-	N	-	-	-	-	-	W J	-	-	-	-	-	-	Plungar, Tilton.

SPECIES.	Keuper Sandstone.	Rhætic Beds.	Lower. Am. planorbis.	Am. angulatus.	Am. Bucklandi.	Am. semicostatus.	Am. oxynotus.	Am. armatus.	Am. Jamesoni.	Am. capricornus.	Middle. Am. margaritatus.	Am. spinatus.	Upper. Am. annulatus.	Am. serpentinus.	Am. communis.	Lower Lias.	Middle Lias.	Upper Lias.	LOCALITIES AND REMARKS.
liasianus, Nyst. v. P. lunularis.																			
lunularis, Roemer; *P. liasianus*, Nyst.	–	–	Q	–	Q P	N Q	–	–	S	N	J	W S J N	–	–	–	–	Hn L	–	Crown Hill, Tilton, Twyford, Bowden.
priscus, Schloth.	–	–	–	–	–	–	–	–	–	–	–	W	–	–	–	–	–	–	Tilton.
sublævis, Y. & B. v. P. æquivalvis.																			
textorius, Schloth.	–	–	–	–	–	N Q	–	–	–	N?	–	W	–	–	–	L	L	–	Tilton, Loseby, Grantham.
Thiollieri, Martin	–	–	–	–	–	N	–	–	S	–	–	–	–	–	–	L	–	–	Rocart, Ashby Folville, Loseby.
valoniensis, Defr.	–	L B Q	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	East Leake, Wigston.
spp.	–	–	Ba W	–	–	–	–	–	–	–	–	–	–	–	–	L	–	N	Spinney Hills, Market Harbro.
Perna																			
infraliasica, Quenst.	–	–	–	–	Q	–	–	–	–	–	–	–	–	–	–	–	–	–	
Pinna																			
fissa, Goldf.	–	–	–	–	–	N	–	–	–	–	N?	–	–	–	–	–	–	–	Plungar.
folium, Y. & B.	–	–	–	–	–	–	Q	Q	–	–	–	–	–	–	–	L	–	–	Old Dalby.
spathulata, Tate	–	–	–	N	–	–	–	–	–	–	–	–	–	–	–	–	–	–	Redmile.
tiltonensis, Wilson	–	–	–	–	–	–	–	–	–	–	–	W	–	–	–	–	L	–	Tilton.
sp.	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	L	–	–	Barrow.
Placunopsis																			
sp.	–	–	–	–	–	–	–	–	–	–	–	J	–	–	–	–	–	–	Tilton.
Plicatula																			
lævigata, d'Orb.	–	–	–	–	–	–	–	–	J? Q	–	–	–	–	–	–	–	–	–	Stapleford.
spinosa, Sow.	–	–	–	–	P Q	–	J Q	Q	J N S Q	N S	J	W	–	–	–	L	L	–	Thurnby, Freeby, Dalby, Stapleford, Tilton, Thorpe Langton, Cold Newton.
sp.	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	L	–	–	Barrow.
Posidonomya																			
Bronni, Voltz	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	J N	Holt. Grantham
sp.	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	N	Grantham.
Pseudomonotis																			
decussatus, Goldf. (*Avicula*.)	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	L	–	–	
Pteroperna																			
sp.	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	J	Allexton.
LAMELLIBRANCHIATA. (DIMYARIA.)																			
Anatina																			
præcursor, Quenst.	–	B	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	East Leake.
Arca																			
elongata, Buckm.	–	–	–	–	–	–	–	–	–	–	N	–	–	–	–	–	–	–	MiddleGonerby
ferruginea ? Lycett	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	N?	Grantham.
Stricklandi, Tate; *A. truncata*. Buckm.	–	–	–	–	–	–	–	–	–	S?	N	–	–	–	–	S	–	–	MiddleGonerby, Billesdon, BillesdonCoplow.
truncata, Buckm. v. A. Stricklandi																			
spp.	–	–	–	–	–	–	–	–	–	–	–	–	–	–	J	L	–	–	Thornhaugh, Old Dalby.
Arcomya																			
elongata, Roem. (*Panopæa*).	–	–	–	–	–	–	–	–	J?	J	–	–	–	–	–	–	–	N	Grantham, Dalby, Loseby.
vetusta, Phil.	–	–	–	–	–	–	Q	–	–	–	–	–	–	–	–	–	–	–	
sp.	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	S	–	–	Twyford.
Astarte																			
striato-sulcata, Röm.	–	–	–	–	–	–	–	–	–	–	–	W	–	–	–	L	–	–	Tilton, Great Dalby, Loseby.
spp.	–	–	–	–	–	N	–	–	–	–	–	–	–	–	J N	B L	–	–	Rockingham, Holt, Allexton.

SPECIES.	Keuper Sandstone.	Rhætic Beds.	Lower.								Middle.		Upper.			Lower Lias.	Middle Lias.	Upper Lias.	LOCALITIES AND REMARKS.
			Am. planorbis.	Am. angulatus.	Am. Bucklandi.	Am. semicostatus.	Am. oxynotus.	Am. armatus.	Am. Jamesoni.	Am. capricornus.	Am. margaritatus.	Am. spinatus.	Am. annulatus.	Am. serpentinus.	Am. communis.				
Axinus v. Schizodus.																			
Cardinia																			
antiqua, Phil.	-	-	-	-	-	-	-	-	-	-		-	-	-	-	S?	-	-	Loseby.
attenuata, Stutchb.	-	-	-	-	-	N	-	-	J	-	-	-	-	-	-	-	-	-	Staunton Wyvile, Dalby.
CARDIOIDES, v. Unicardium.	-	-	-	-	P	-	-	-	-	-	-	-	-	-	-	-	-	-	Thuruby. Probably misprint for Unicardium.
concinna, Sow.	-	-	-	-	-	N	-		-	-	-	W	-	-	-	-	-	-	Tilton, Plungar, Redmile.
copides, de Ryck.	-	-	-	-	-	N Q	-	-	-	-	-	-	-	-	-	-	-	-	Redmile.
gigantea, Quenst.	-	-	-	-	-	N Q	-	-	-	-	-	-	-	-	-	Hn	-	-	Vale of Belvoir.
Listeri, Sow.	-	-	-	-	Q P	N	Q	-	-	-	N	-	-	-	-	Hn L	-	-	Vale of Belvoir, Thurnby, Crown Hill, Loseby.
Listeri, var. **ovalis**, Stutchb.	-	-	-	-	-	N Q	-	-	-	-	-	-	-	-	-	-	-	-	Redmile, Plungar.
var. **hybrida**, Sow.	-	-	-	-	-	N Q	-	-	J	-	-	-	-	-	-	-	-	-	Redmile, Staunton Wyvile
Slatteri, Walford. (*Isocardia.*)	-	-	-	-	-	-	-	-	-	-	-	W	-	-	-	-	-	-	Tilton.
spp.	-	N	-	-	-	-	-	-	-	-	-	-	-	-	-	L	-	-	Granby Barrow.
Cardita																			
multicostata, Phil.	-	-	-	-	-	-	-	-	N	-	-	-	-	-	-	L	-	-	Woolsthorpe Loseby.
Cardium v. Protocardium.																			
Ceromya																			
bombax, Quenst.	-	-	-	-	-	-	-	-	-	-	-	W	-	-	-	-	-	-	Tilton.
liassica, Moore v. C. petricosa.																			
petricosa, Simp.	-	-	-	-	-	-	-	-	-	-	-	N	-	-	-	-	-	-	Eastwell.
Corbicella																			
sp.	-	-	-	-	-	N?	-	-	-	-	-	-	-	-	-	-	-	-	Plungar.
Cucullæa																			
Munsteri, Ziet.	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	L	-	-	Old Dalby.
sp.	-	-	-	-	-	-	-	-	-	-	J	-	-	-	-	-	-	-	Cranhoe.
Cypricardia v. Trapezium.																			
Goniomya																			
heteropleura, Ag.	-	-	-	-	-	-	-	-	-	-	-	W	-	-	-	-	-	-	Tilton.
hybrida, Münst.	-	-	-	-	-	-	-	-	-	Q	N	-	-	-	-	-	-	-	MiddleGonerby
sp.	-	-	-	-	-	-	-	-	-	-	J	-	-	-	-	-	-	-	Billesdon.
Gresslya																			
donaciformis, Phil. (*Myacites*.	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	J N	Thornhaugh, Stoke, Grantham.
intermedia, Simpson	-	-	-	-	-	-	-	-	N S	-	N	W	-	-	-	-	-	-	Broughton, Tilton, John o' Gaunt.
lunulata, Tate	-	-	-	-	P?	-	-	-	-	-	N	W	-	-	-	-	L	-	Thurnby, Tilton.
Seebachi, Brauns	-	-	-	-	-	-	-	-	-	-	N	-	-	-	-	-	-	-	MiddleGonerby
sp.	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	L	-	-	Old Dalby.
Hippopodium																			
ponderosum, Sow.;	-	-	-	-	P	-	Q	J	J	-	J	-	-	-	-	Hn	-	-	Loseby, Saxelby Dalby, Thurnby, Ouston, Ingarsby.
Mytilus hippocampus, Y. & B.	-	-	-	-	Q	-	-	Q	-	-	-	-	-	-	-	L	-	-	
Homomya																			
sp.	-	-	-	-	-	-	-	S	-	-	-	-	-	-	-	-	-	-	Loseby.
Isodonta																			
Ewaldi, Bornemann; *Schizodus (Opis) cloacinus*, Quenst.	-	Ba W B Hn Q L	-	-	-	-	-		-	-	-	-	-	-	-	-	-	-	Spinney Hills, Wigston, East Leake.
Leda v. Nuculana																			
Lucina																			
sp.	-	-	-	-	-	-	-	-		-	-	-		-		-	-	N	Grantham.

SPECIES.	Keuper Sandstone.	Rhætic Beds.	Lower. Am. planorbis.	Am. angulatus.	Am. Bucklandi.	Am. semicostatus.	Am. oxynotus.	Am. armatus.	Am. Jamesoni.	Am. capricornus.	Middle. Am. margaritatus	Am. spinatus.	Upper. Am. annulatus.	Am. serpentinus.	Am. communis.	Lower Lias.	Middle Lias.	Upper Lias.	LOCALITIES AND REMARKS.
Macrodon Buckmani, Richardson	–	–	–	–	–	–	–	–	–	–	–	W	–	–	–	–	L	–	Tilton.
Modiola hillana, Sow.	–	–	N	–	Q	N Q	–	–	–	J	–	–	–	–	–	Hn L	–	–	Neville Holt, Harbro', Loseby.
hillanoides, Chap. and Dew.	–	–	–	–	P	–	–	–	–	–	–	–	–	–	–	L	–	–	Thurnby, Flecney.
lævis Sow.	–	–	Ba	–	Q	–	–	–	–	–	–	–	–	–	–	–	–	–	Spinney Hills.
minima, Sow.	–	Hn	N Q	–	–	–	–	–	–	–	–	–	–	–	–	L	–	–	Barrow.
Morissi, Oppel	–	–	–	–	–	Q	–	–	–	–	–	–	–	–	–	–	–	–	
numismalis, Oppel	–	–	–	–	–	–	–	–	–	–	–	W N	–	–	–	–	–	–	Tilton. Scalford.
ornata, Moore v. M. subcancellata																			
scalprum, Sow.	–	–	–	N	P Q	N	Q	J Q	N Q? S	J Q	J	W N	–	–	–	Q L	L	–	Abundant.
subcancellata, Buvig.; *M. ornata*, Moore.	–	–	–	–	–	–	–	–	–	–	–	N W	–	–	–	–	–	–	Woolsthorpe, Tilton.
spp.	–	–	–	–	Q	–	–	–	–	–	–	–	–	–	–	B L	–	–	Leicester.
Myacites donaciformis, Phil. v. Gresslya.																			
Myophoria inflata, Emmerich	–	B	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	East Leake.
Mytilus hippocampus, Y. & B. v. Hippopodium ponderosum.																			
Nucula claviformis, Sow.	–	–	–	–	–	–	–	–	–	–	–	–	–	–	W	–	L	–	Tilton, East Norton.
Hammeri, Defr.	–	–	–	–	–	–	–	–	–	–	–	–	–	–	W	–	–	–	East Norton.
ovum, Sow. v. Nuculana.																			
variabilis, Quenst. [? Sow.]	–	L	–	–	–	–	–	–	–	J Q	–	–	–	–	–	L	–	–	Wigston, Old Dalby, Neville Holt.
spp.	–	–	–	–	–	–	–	–	–	–	J	–	–	–	–	–	–	J N	Hallaton, Neville Holt, Grantham.
Nuculana (*Leda.*) **æquilatera,** Koch & Dunker.	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	L	–	–	Old Dalby.
complanata, Goldf.	–	–	–	–	–	–	Q	–	–	N	W J	–	–	–	–	–	–	–	Tilton, Belton, Holt, Cranhoe.
Galathea, d'Orb.	–	–	–	–	–	–	Q	–	–	Q	–	–	–	–	–	L	–	–	Great Dalby.
graphica, Tate	–	–	–	–	–	–	–	–	N	–	N	–	–	–	–	L	–	–	Woolsthorpe, Middle Gonerby, Old Dalby.
imbricata, S. & N. M.S., v. N. Quenstedti, Tate																			
minor, Simp.	–	–	–	–	–	–	Q	–	–	N	–	–	–	–	–	–	–	–	Peascliffe.
ovum, Sow. (*Nucula*).	–	–	–	–	–	–	–	–	N	–	–	–	–	–	J N Q	–	–	Hn L Q	Abundant.
Quenstedti Tate; *Leda imbricata*, Sharman & Newton, MS.	–	–	–	–	–	–	–	–	–	–	N	–	–	–	–	–	–	–	Middle Gonerby.
sp.	–	–	–	–	Q	–	–	–	–	–	–	–	–	–	–	–	–	–	Crown Hill.
Panopæa, v. Arcomya and Pleuromya																			
Pholadomya ambigua, Sow.	–	–	–	–	–	–	–	J Q	N	–	J	–	–	–	–	L	–	–	Loseby, Ouston, Broughton.

SPECIES.	Keuper Sandstone.	Rhætic Beds.	Lower. Am. planorbi	Am. angulatus.	Am. Bucklandi.	Am. semicostatus.	Am. oxynotus.	Am. armatus.	Am. Jamesoni.	Am. capricornus.	Middle. Am. margaritatus	Am. spinatus.	Upper. Am. annulatus.	Am. serpentinus.	Am. communis.	Lower Lias.	Middle Lias.	Upper Lias.	Localities and Remarks.
decorata, Zeit.	-	-	-	-	-	-	-	-	J Q	-	J	-	-	-	-	-	-	-	Dalby, Ouston.
glabra, Ag.	-	-	-	-	Q	-	-	-	-	-	-	-	-	-	-	-	-	-	
ventricosa, Ag.	-	-	-	-	-	-	Q	-	-	-	-	-	-	-	-	-	-	-	
sp.	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	L	-	-	Barrow.
Pleuromya																			
costata, Y. & B.	-	.	N	-	-	-	-	-	S	-	-	-	-	-	-	-	-	-	Cold Newton.
striatula, Ag.	-	-	-	-	Q	-	Q	-	-	-	-	-	-	-	-	-	-	-	
unioides, Roemer	-	-	N	-	-	N Q	-	-	-	-	N J	-	-	-	-	-	-	-	Ouston, Rocart.
spp.	-	-	-	-	-	-	Q	-	-	-	-	W	-	-	-	-	L	-	Tilton.
Pleurophorus																			
sp.	-	-	N	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	Cotham.
Protocardium																			
philippianum, Dunker; *C. rhæticum*, Merian		Pl W N B Hn Q L	-	-	-	-	Q	-	-	-	-	-	-	-	-	L	-	-	Wigston, East Leake, Loseby, Spinney Hills, Old Dalby, etc.
rhæticum, Merian v. P. philippianum.																			
substriatulum, d'Orb.	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	L	-	Harlaxton.
truncatum, Sow.	-	-	-	-	-	-	-	-	-	-	L W N S	W? N S	-	-	-	L S	-	-	Abundant.
spp.	-	-	N	-	-	N	-	-	N	-	-	-	-	-	-	L	-	-	
Pullastra																			
arenicola, Strickl.	-	N	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
Schizodus (*Axinus*) *cloacinus* Quenst. v. Isodonta Ewaldi.																			(? *Isodonta*)
depressus, de Kon.	-	Hn	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	Spinney Hills.
elongatus, Moore	-	Hn N	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	Spinney Hills. Cotham.
Tellina																			
gracilis, Dum.	-	-	-	-	-	-	-	-	-	-	-	W	-	-	-	-	-	-	Tilton.
Trapezium, (*Cypricardia*)																			
cordiformis, Desh.	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	N	Stoke.
cucullata, Münst.	-	-	-	-	-	-	-	Q	J	-	-	-	-	-	-	-	-	-	Stapleford.
Unicardium																			
cardioides, Phil.	-	-	-	-	P Q	N Q	Q	Q	J Q	N	N	-	-	-	-	L	-	-	Abundant.
subglobosum, Tate	-	-	-	-	-	-	-	-	-	-	-	W	-	-	-	-	-	-	Tilton.
SCAPHOPODA.																			
Dentalium																			
giganteum, Phil.	-	-	-	-	-	-	-	-	-	N	-	-	-	-	-	-	-	-	Peascliffe.
sp.	-	-	-	-	Q	-	-	-	-	-	-	-	-	-	-	-	-	-	
GASTEROPODA.																			
Actæonina																			
ferrea, Wilson	-	-	-	-	-	-	-	-	-	-	-	W H	-	-	-	-	-	-	Tilton.
fragilis, Dunker	-	-	-	-	-	-	-	-	-	-	-	W	-	-	-	-	-	-	Tilton.
ilminsterensis, Moore	-	-	-	-	-	-	-	-	-	-	-	W H	-	-	-	-	L	-	Tilton, Pickwell.
sinemuriensis Martin (*Actæon*).	-	-	-	-	-	-	-	-	-	-	-	W	-	-	-	-	-	-	Tilton.
Valleti, Stoppani	-	B	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	East Leake.
sp.	-	-	-	-	-	-	Q	-	-	-	-	-	-	-	-	-	-	-	
Amberleya (*Eucyclus*)																			
Æolus, d'Orb.	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	L	-	Pickwell.
capitanea, Münst.	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	H	Market Harbro'.
Chapuisi, Terquem and Piette	-	-	-	-	-	S	-	-	-	-		-		-	-	-	-	-	Ingarsby.
conspersa Tate	-	-	-		-		Q					-						-	

SPECIES.	Keuper Sandstone.	Rhætic Beds.	Lower. Am. planorbis.	Am. angulatus.	Am. Bucklandi.	Am. semicostatus.	Am. oxynotus.	Am. armatus.	Am. Jamesoni.	Am. capricornus.	Middle. Am. margaritatus.	Am. spinatus.	Upper. Am. annulatus.	Am. serpentinus.	Am. communis.	Lower Lias.	Middle Lias.	Upper Lias.	LOCALITIES AND REMARKS.
Dunkeri, Münster	-	-	-	-	Q	-	-	-	-	-	-	-	-	-	-	L	-	-	Ingarsby.
elegans, Münster	-	-	-	-	Q P	-	-	Q	-	-	-	-	-	-	-	H L	-	-	Old Dalby. Thurnby.
Fidia, d'Orb.	-	-	-	-	-	-	-	-	-	-	-	W H	-	-	-	-	-	-	Tilton.
gaudryana, d'Orb.	-	-	-	-	-	-	Q	-	-	-	-	W H	-	-	-	H	L	-	Tilton.
gaudryana var. **imbricata,** Sow.	-	-	-	-	-	N Q	Q	-	N J	N S J	N	W	-	-	-	-	L L	-	Tilton, Staunton Wyvile, Harbro'., Hamner's Lodge, Grimston.
undulata, Phil.	-	-	-	-	P	-	-	-	-	-	-	-	-	-	-	L	-	-	Thurnby, Great Dalby, Thorpe Satchville.
spp.	-	-	-	-	-	N	-	-	-	-	N	-	-	-	-	-	-	-	Middle Gonerby.
Ataphrus (*Monodonta*) **bullatus,** Moore	-	-	-	-	-	-	-	-	-	-	-	W H	-	-	-	-	-	-	Tilton.
lindecolinus, Wilson.	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	H	-	Medbourne.
Bourguetia (*Phasianella*) **turbinata,** Stol.	-	-	-	-	-	-	-	-	-	-	-	W	-	-	-	-	L	-	Tilton, Pickwell. *Pseudomelania,* Wilson.
sp.	-	-	-	-	-	-	-	N	-	-	-	-	-	-	-	-	-	-	Muston.
Cerithium																			
asperulum, Moore	-	-	-	-	-	-	Q	-	-	-	-	-	-	-	-	-	-	-	
camertonense, Moore.	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	H L	-	-	Old Dalby.
confusum, Tate v. Cerithinella.																			
costulatum? Desl.	-	-	-	-	-	-	-	-	-	-	-	W? H	-	-	-	-	-	-	Tilton.
ferreum, Tate	-	-	-	-	-	-	-	-	-	-	-	W H	-	-	-	-	L	-	Tilton.
ibex, Tate	-	-	-	-	-	-	Q	-	-	-	-	-	-	-	-	L	-	-	Old Dalby.
ilminsterense, Moore	-	-	-	-	-	-	-	-	-	-	-	W H	-	-	-	-	-	-	Tilton.
liassicum, Moore	-	-	-	-	-	-	Q	-	-	-	-	W H	-	-	-	L	-	-	Tilton. Old Dalby.
ligaturale, Tate	-	-	-	-	-	N H Q	-	-	-	-	-	-	-	-	-	-	-	-	Redmile.
reticulatum, Desl.	-	-	-	-	-	-	-	-	-	-	-	W H	-	-	-	-	L	-	Tilton. Pickwell.
ubfistulosum, Tate	-	-	-	-	-	N H Q	-	-	-	-	-	-	-	-	-	-	-	-	Redmile.
trigemmatum, Wilson v. Turritella.																			
varicosum, Moore v. Cryptaulax, cf. undulata.																			
spp.	-	-	-	-	-	-	-	-	-	N?	-	J	-	-	-	L	-	-	Tilton. Old Dalby.
Cerithinella **confusum,** Tate	-	-	-	-	-	-	-	-	-	-	-	W H	-	-	-	-	L	-	Tilton. Pickwell.
Chemnitzia																			
Berthaudi, Dum.	-	-	-	-	-	-	Q	-	-	-	-	-	-	-	-	-	-	-	Old Dalby.
Blainvillei, Münster	-	-	-	-	-	-	Q	-	-	-	-	-	-	-	-	L	-	-	Old Dalby.
carusensis, d'Orb.	-	-	-	-	-	-	Q	-	-	-	-	-	-	-	-	-	-	-	
citharella, Tate	-	-	-	-	-	-	Q	-	-	-	-	-	-	-	-	L	-	-	Old Dalby.
periniana?, d'Orb.	-	-	-	-	-	-	-	-	-	-	-	W	-	-	-	-	-	-	Tilton.
semitecta?, Tate	-	-	-	-	-	-	Q	-	-	-	-	-	-	-	-	-	-	-	Old Dalby.
undulata? Benz.	-	-	-	-	-	-	-	-	-	-	-	W	-	-	-	-	-	-	Tilton.
spp.	-	-	-	-	P	N	-	N	-	-	-	-	-	-	-	L	-	-	Thurnby. Old Dalby.

SPECIES.	Keuper Sandstone.	Rhætic Beds.	Lower. Am. planorbis.	Am. angulatus.	Am. Bucklandi.	Am. semicostatus.	Am. oxynotus.	Am. armatus.	Am. Jamesoni.	Am. capricornus.	Middle. Am. margaritatus.	Am. spinatus.	Upper. Am. annulatus.	Am. serpentinus.	Am. communis.	Lower Lias.	Middle Lias.	Upper Lias.	Localities and Remarks.
Cryptænia																			
compressa, Sow. (*Helicina*).	-	-	-	-	-	-	-	-	-	-	Hn	-	-	-	-	-	-	-	Ouston.
consobrina, Tate	-	-	-	-	-	-	Q	-	-	-	-	-	-	-	-	L	-	-	Old Dalby.
expansa, Sow. (*Helicina*).	-	-	-	-	-	Q N	Q	-	-	-	J H	W H	-	-	-	-	L	-	Tilton, Ouston.
rotellæformis, Dunker	-	-	-	-	-	N	-	-	-	-	-	W H	-	-	-	-	-	-	Plungar. Tilton.
solarioides, Sow.	-	-	-	-	-	-	-	-	-	-	-	W H	-	-	-	-	-	-	Tilton.
sp.	-	-	-	-	Q	-	-	-	-	-	-	-	-	-	-	L	-	-	Kilby.
Cryptaulax																			
cf. undulata Quenst.; *Cerithium varicosum*, Moore	-	-	-	-	-	-	Q	-	-	-	-	-	-	-	-	-	-	-	
Cylindrites																			
æqualis, Wilson	-	-	-	-	-	-	-	-	-	-	-	W H	-	-	-	-	-	-	Tilton.
Eucyclus v. Amberleya																			
Helicina v. Cryptænia																			
Littorina v. Amberleya																			
Monodonta																			
bullata, Moore v. Ataphrus.																			
humilis, Wilson	-	-	-	-	-	-	W H	-	-	-	-	-	-	-	-	L	-	-	Old Dalby.
lindecolina, Wilson v. Ataphrus.																			
Nortonia																			
patroclus, d'Orb. (*Purpurina*).	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	W	East Norton.
Palæoniso																			
monoplicus, d'Orb. (*Trochus*).	-	-	-	-	-	-	-	.	-	-	N	-	-	-	-	-	-	-	Middle Gonerby.
Phasianella v. Bourguetia.																			
Pleurotomaria																			
anglica, Sow.	-	-	Ba Q	-	Q	N	Q	-	-	-	-	W	-	-	-	Hn H	-	-	Spinney Hills, Saxelby, Tilton, Old Dalby, Plungar.
canalis, Münster	-	-	-	-	-	-	-	-	-	-	-	W H	-	-	-	-	-	-	Tilton.
helicinoides, Roem.	-	-	-	-	-	-	-	-	-	-	-	W H	-	-	-	-	-	-	Tilton.
precatoria, Desl.	-	-	-	-	-	N Q	-	-	-	-	-	-	-	-	-	-	-	-	Redmile.
princeps, K. and D.	-	-	-	-	-	N Q	-	-	-	-	-	-	-	-	-	-	-	-	Redmile.
Quenstedti, Goldf.	-	-	-	-	-	-	-	-	-	-	J	-	-	-	-	-	-	-	Belton.
rustica, Desl.	-	-	-	-	-	-	-	-	-	-	-	W H	-	-	-	-	-	-	Tilton.
Pseudomelania																			
brannoviensis, Dum. (*Chemnitzia*)	-	-	-	-	-	-	-	-	-	-	-	W H	-	-	-	-	L	-	Tilton.
turbinata, Stol. v. Bourguetia.																			
sp.	-	-	-	-	-	-	-	-	-	-	-	W	-	-	-	-	-	-	Tilton.
Rotella																			
expansa, Sow. v. Cryptænia																			
Trochus																			
Acis, d'Orb.	-	-	-	-	-	-	-	-	-	-	N	-	-	-	-	-	-	-	Middle Gonerby.
Æolus, d'Orb. v. Amberleya.																			
Ariel, Dum.	-	-	-	-	-	-	-	-	-	-	-	W H	-	-	-	-	L	-	Tilton.
dalbiensis, Wilson	-	-	-	-	-	-	W H	-	-	-	-	-	-	-	-	-	-	-	Old Dalby.
Fidia, d'Orb. v. Amberleya.																			

SPECIES.			Lower.								Middle.		Upper.						LOCALITIES AND REMARKS.
	Keuper Sandstone.	Rhætic Beds.	Am. planorbis.	Am. angulatus.	Am. Bucklandi.	Am. semicostatus	Am. oxynotus.	Am. armatus.	Am. Jamesoni.	Am. capricornus.	Am. margaritatus.	Am. spinatus.	Am. annulatus.	Am. serpentinus.	Am. communis.	Lower Lias.	Middle Lias.	Upper Lias.	
imbricatus, Sow. v. Amberleya.																			
lineatus Moore	–	–	–	–	–	–	–	–	–	–	–	W	–	–	–	–	–	–	Tilton.
monoplicus, d'Orb. v. Palæoniso.																			
northamptonensis, Wilson.	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	W L	Daventry, Tilton.
Œdipus ?, d'Orb.	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	L	–	–	Old Dalby.
pethertonensis, Moore.	–	–	–	–	–	–	–	–	–	–	–	W H	–	–	–	–	–	–	Tilton.
rotulus, Stol.	–	–	–	–	–	–	–	–	–	–	–	W H	–	–	–	–	–	–	Tilton.
thetis, Münster	–	–	–	–	–	–	W Q	–	–	N	–	H	–	–	–	L	–	–	Old Dalby. Tilton ?
spp.	–	–	–	–	–	N Q	–	–	–	–	–		–	–	–	Hn	–	–	Redmile, Saxelby.
Turbo																			
cyclostoma, Benz.	–	–	–	–	–	–	–	–	–	–	–	W H	–	–	–	–	–	–	Tilton.
Dunkeri, Münster v. Amberleya.																			
latilabrus, Stol.	–	–	–	–	–	–	–	–	–	–	–	W	–	–	–	–	L	–	Tilton, Pickwell.
rugiferus, Moore	–	–	–	–	–	–	–	–	–	–	–	W H	–	–	–	–	–	–	Tilton.
Theodori, Münster	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	W H	Tilton.
spp.	–	–	–	–	–	N Q	–	–	–	–	–	–	–	–	–	L	L	–	Old Dalby, Pickwell.
Turritella (*Cerithium*)																			
trigemmata, Tate	–	–	–	–	–	–	W	–	–	–	–	–	–	–	–	L	–	–	Old Dalby.
spp.	–	–	–	–	–	–	Q	–	–	–	–	–	–	–	–	–	–	–	
CEPHALOPODA.																			
AMMONOIDEA.																			
Ammonites.																			
[*Acanthopleuroceras* v. Cycloceras].																			
[Ægoceras]																			
armatus, Sow.	–	–	–	–	–	–	–	S J Q L	J	–	–	–	–	–	–	Hn L	L	–	Loseby, Dalby, Tilton, Bruntingthorpe.
Birchi, Sow.	–	–	–	–	–	–	–	–	N	–	–	–	–	–	–	–	–	–	Broughton.
brevispinus, Sow.	–	–	–	–	–	–	–	–	S J N Q	N	–	–	–	–	–	–	–	–	Dalby, Stapleford, Twyford, Woolsthorpe.
capricornus, Schloth.	–	–	–	–	–	–	–	–	–	S J Q N	–	–	–	–	–	Hn L	–	–	Abundant.
curvicornis, Schloenb.	–	–	–	–	–	–	Q	–	–	–	–	–	–	–	–	L	–	–	Dalby.
Davœi Sow.	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	L	–	–	Old Dalby.
densinodus, Quenst. v. A. obsoletus.																			
gagateus, Y. and B.	–	–	–	–	–	–	–	J	–	N? Q	–	–	–	–	–	L	–	–	Barrowby, Great Dalby.
Henleyi, Sow.	–	–	–	–	–	–	Q	–	–	N Q	J	–	–	–	–	–	–	–	Cranhoe, Peascliffe.
Jamesoni, Sow.	–	–	–	S	–	–	Q	–	J S Q	N	–	–	–	–	–	Hn	–	–	Saxelby, Dalby, John o'Gaunt.
Jamesoni, var. **Bronni** Roemer.	–	–	–	–	–	–	–	–	J	–	–	–	–	–	–	–	–	–	Stapleford.
Jamesoni, var. **confusus**, Quenst.	–	–	–	–	–	–	–	–	J	–	–	–	–	–	–	–	–	–	Stapleford.
latæcosta, Sow.	–	–	–	–	–	–	–	–	J Q	–	–	–	–	–	–	–	–	–	Stapleford, Dalby.

SPECIES	Keuper Sandstone.	Rhætic Beds.	Lower. Am. planorbis.	Am. angulatus.	Am. Bucklandi.	Am. semicostatus	Am. oxynotus.	Am. armatus.	Am. Jamesoni.	Am. capricornus.	Middle. Am. margaritatus.	Am. spinatus.	Upper. Am. annulatus.	Am. serpentinus.	Am. communis.	Lower Lias.	Middle Lias.	Upper Lias.	LOCALITIES AND REMARKS.
Leckenbyi, Wright.	–	–	–	–	–	–	–	L	–	–	–	–	–	–	–	–	–	–	Bruntingthorpe.
Maugenesti, d'Orb.	–	–	–	–	–	–	–	–	J	–	–	–	–	–	–	–	–	–	Dalby.
obsoletus, Simp.	–	–	–	–	–	–	–	–	J N S	N	–	–	–	–	–	L ?	–	–	Barrowby, Woolsthorpe, Loseby, Stapleford, Old Dalby, Twyford. Includes *A. densinodus* Quenst.
polymorphus, Quenst.	–	–	–	–	Q	–	–	–	–	–	–	–	–	–	–	L	–	–	Ingarsby, Old Dalby.
polymorphus, lineatus, Quenst.	–	–	–	–	–	–	–	–	J	–	–	–	–	–	–	–	–	–	Stapleford.
sagittareus Blake	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	S	–	–	Keyham.
striatus, Rein.	–	–	–	–	–	–	–	Q	–	–	–	–	–	–	–	L	–	–	Old Dalby.
subplanicosta. Oppel.	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	L	–	–	Loseby.
Taylori, Sow.	–	–	–	–	–	–	Q	–	–	–	–	–	–	–	–	L	–	–	Old Dalby.
[Amaltheus]																			
Engelhardti, d'Orb.	–	–	–	–	–	–	–	–	–	–	N	–	–	–	–	–	–	–	MiddleGonerby
margaritatus, Montf.	–	–	–	–	–	–	–	–	–	–	J W N	W J	–	–	–	–	Hn L S	–	Abundant.
spinatus, Brug.	–	–	–	–	–	–	–	–	–	–	N	J W	–	–	–	–	L	–	MiddleGonerby Tilton.
trivialis, Simp.	–	–	–	–	–	–	–	–	J	–	–	–	–	–	–	L S	–	–	Barrowby, Woolsthorpe, Old Dalby, Great Stretton.
[*Amblycoceras* v. *Ægoceras*]																			
[Arietites]																			
Bonnardi, d'Orb.	–	–	–	–	S	–	–	–	–	–	Y	–	–	–	–	–	–	–	Frisby borehole.
Brooki Sow.	–	–	–	–	–	–	–	–	–	N	–	–	–	–	–	–	–	–	Barkston.
Bucklandi, Sow.	–	–	–	–	P Q	N	–	–	–	–	–	–	–	–	–	–	–	–	Thurnby, Broughton.
Conybeari, Sow.	–	–	–	–	P Q	S	–	–	–	–	–	–	–	–	–	Hn L	–	–	Kilby, Ingarsby, Thurnby, Fleckney, Crown Hill.
Macdonnelli, Portl.	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	L	–	–	Loseby.
nodotianus, Wr. non d'Orb. v. Macdonnelli																			
obesulus, Blake	–	–	–	–	P Q	–	–	–	–	–	–	–	–	–	–	–	–	–	Thurnby.
ophioides, d'Orb.	–	–	–	–	–	–	–	Q	–	–	–	–	–	–	–	–	–	–	
raricostatus, Zeit.	–	–	–	–	–	–	N	–	–	–	–	–	–	–	–	S	–	–	Great Stretton.
sauzianus, d'Orb.	–	–	–	–	P Q	S	–	–	S	–	–	–	–	–	–	L	–	–	Ingarsby, Fleckney.
scipionianus d'Orb.	–	–	–	–	Q	–	–	–	–	–	–	–	–	–	–	–	–	–	Crown Hill.
semicostatus, Y. & B.	–	–	–	–	P Q	N S Q	–	N	–	N	–	–	–	–	–	Hn S L	–	–	Belvoir, Keyham, Ingarsby Houghton.
subnodosus Y. & B.	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	L	–	–	Ingarsby.
tardicrescens, Blake v. Psiloceras aplanatum.																			
Arnioceras v. Arietites																			
[Aspidoceras]																			
bispinosa, Ziet.	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	L	–	Twyford.
[*Caloceras* v. Psiloceras]																			

Species.	Keuper Sandstone.	Rhætic Beds.	Lower. Am. planorbis.	Am. angulatus.	Am. Bucklandi.	Am. semicostatus	Am. oxynotus.	Am. armatus.	Am. Jamesoni.	Am. capricornus.	Middle. Am. margaritatus.	Am. spinatus.	Upper. Am. annulatus.	Am. serpentinus.	Am. communis.	Lower Lias.	Middle Lias.	Upper Lias.	Localities and Remarks.
[Coeloceras]																			
annulatus, Sow. -	-	-	-	-	-	-	-	-	-	-	-	J	S J W	-	-	-	L	Hn J N	Abundant.
communis, Sow. -	-	-	-	-	-	-	-	-	-	-	-	J W	-	-	W J Q N	-	-	L	Tilton.
crassus, Y.&B. -	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	L W J N	Tilton, Holt Stoke, Grantham.
Desplacei, d'Orb.-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	N	Stoke, Grantham.
fibulatus, Sow. -	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	J N L	MarketHarbro'.
Holandrei, d'Orb.	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	J Q L	Abundant.
raquinianus, d'Orb. -	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	L	Tilton.
semicelatus, Simp. -	-	-	-	-	-	-	-	-	-	-	-	W	-	-	-	-	-	-	Tilton.
Cycloceras] Valdani, d'Orb. -	-	-	-	-	-	-	Q	-	J	-	-	-	-	-	-	L	-	-	Old Dalby, Thorpe Langton. *Am. bipunctatus*, recorded by Judd.
[*Dactylioceras* v. Cœloceras]																			
[*Deroceras* v. Ægoceras]																			
[*Grammoceras* v. Harpoceras]																			
Harpoceras] acutus, Tate - -	-	-	-	-	-	-	-	-	-	-	-	W	-	-	-	-	L	-	Tilton.
bifrons, Brug. - -	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	Hn W N J Q L	Abundant.
cæcilia, Rein. -	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	L	-	Tilton.
complanatus, Brug. -	-	-	-	-	-	-	-	-	-	-	-	-	-	-	N	-	-	-	Grantham.
concavus, Sow. -	-	-	-	-	-	-	-	-	-	-	-	-	-	-	J N	-	-	-	Grantham.
elegans, Sow. -	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	J N	Holt, Allexton, Stoke.
exaratus, Y. & B.	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	L	Market Harbro.
falcifer, Sow; *A. serpentinus*, Auct.	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	L N Hn J Q	Abundant.
cf. Levisoni, Simp.	-	-	-	-	-	-	-	-	-	-	-	S	-	-	-	S	-	-	Tilton, Holwell.
lythensis, Y. & B.	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	J N	
nitescens, Y. & B.	-	-	-	-	-	-	-	-	-	-	N	-	-	-	-	-	-	-	Middle Gonerby.
normanianus, d'Orb. -	-	-	-	-	-	-	-	-	J Q	-	J	-	-	-	-	-	-	-	Dalby, Stapleford, Ouston.
ovatus, Y. & B. -	-	-	-	-	-	-	-	-	-	-	-	W	-	-	-	-	-	-	Tilton.
radians, Rein. -	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	N J	Holt, Keythorpe, Scalford.
serpentinus, Auct. v. H. falcifer.																			

SPECIES.	Keuper Sandstone.	Rhætic Beds.	Lower. Am. planorbis.	Am. angulatus.	Am. Bucklandi.	Am. semicostatus.	Am. oxynotus.	Am. armatus.	Am. Jamesoni.	Am. capricornus.	Middle. Am. margaritatus.	Am. spinatus.	Upper. Am. annulatus.	Am. serpentinus.	Am. communis.	Lower Lias.	Middle Lias.	Upper Lias.	LOCALITIES AND REMARKS
subplanatus Dum.	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	L	Nassington.
Hildoceras v. Harpoceras]																			
[*Liparoceras* v. Ægoceras]																			
[**Lytoceras**]																			
cornucopia, Y.&B.	-	-	-	-	-	-	-	-	-	S	-	-	-	-	-	-	-	-	Billesdon Coplow. From a well.
fimbriatus, Sow.	-	-	-	-	-	-	-	-	-	J Q	-	-	-	-	-	Hn S	-	-	Holt. Loseby.
[*Microceras* v. Ægoceras]																			
[**Oxynoticeras**]																			
Coynarti, d'Orb.	-	-	-	-	-	-	-	J	-	-	-	-	-	-	-	-	-	-	Loseby.
guibalianus, d'Orb.	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	L	-	-	Loseby.
oxynotus, Quenst.	-	-	-	-	-	-	Q	-	-	N	-	-	-	-	-	L	-	-	Barrowby, Gt. Dalby.
[**Phylloceras**]																			
heterophyllus, Sow.	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	N J	Holt.
Loscombei, Sow.	-	-	-	-	-	-	Q	J Q	-	-	-	-	-	-	-	Hn L	-	-	Loseby. Old Dalby.
[**Psiloceras**]																			
aplanatum, Hyatt (*Caloceras*).	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	L	-	-	Loseby.
Johnstoni, Sow.	-	-	Ba N	-	-	-	-	-	-	-	-	-	-	-	-	L	-	-	Spinney Hills, Barrow.
planorbis, Sow.	-	-	W N B	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	Wigston, Knighton, Barrow.
tortilis, d'Orb.	-	-	Q	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
torus, d'Orb. v. P. Johnstoni.																			
[**Schlotheimia**]																			
angulata, Schloth.	-	-	-	B	Q	-	-	-	-	N	-	-	-	-	-	Hn L	-	-	Barrow, Barrowby, Knighton.
catenatus, Sow.	-	-	Ba	Q	P	-	-	-	-	-	-	-	-	-	-	Hn L	-	-	Barrow, Thurnby, Spinney Hills.
BELEMNOIDEA.																			
Belemnites																			
acutus, Miller	-	-	-	-	Q	N Q	Q?	J Q	-	-	-	-	-	-	-	-	-	-	Redmile. Loseby.
apicicurvatus, Blainv.	-	-	-	-	-	-	-	-	-	-	-	W	-	-	-	-	L	-	Tilton.
breviformis, Voltz.	-	-	-	-	-	-	-	-	-	-	-	W	-	-	-	-	-	-	Tilton.
clavatus, Blainv.	-	-	-	-	-	-	J	-	J	J Q	-	J	-	-	-	Hn	-	-	Freeby, Stapleford, Saxelby, Stanton Wyville, Harbro'. Edmondth'rpe
CLAVELLATUS, Bean?	-	-	-	-	-	-	-	-	-	-	-	W	-	-	-	-	-	-	Tilton. ? MS. name.
compressus, Voltz v. Bel. Voltzi.																			
elegans, Simp.	-	-	-	-	-	-	Q	-	J	-	-	-	-	-	-	-	-	-	Stapleford.
elongatus, Miller	-	-	-	-	-	-	-	-	J	-	N J	W J	-	-	-	-	L	-	Thorpe Langton, Tilton, Ouston, Belvoir.
infundibulum, Phil.	-	-	-	-	Q	N	-	-	N	-	-	-	-	-	-	-	-	-	Broughton
irregularis, Schloth.	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	J	
levidensis, Simp.	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	N	Grantham, Welbourn.
paxillosus, Schloth.	-	-	-	-	-	-	-	-	-	-	J	W J	-	-	-	-	L	-	Billesdon, Tilton, Rocart, Edmondthorpe

SPECIES.	Keuper Sandstone.	Rhætic Beds.	Lower. Am. planorbis.	Am. angulatus.	Am. Bucklandi.	Am. semicostatus.	Am. oxynotus.	Am. armatus.	Am. Jamesoni.	Am. capricornus.	Middle. Am. margaritatus.	Am. spinatus.	Upper. Am. annulatus.	Am. serpentinus.	Am. communis.	Lower Lias.	Middle Lias.	Upper Lias.	LOCALITIES AND REMARKS.
subtenuis, Simp.	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	W	Tilton.
Voltzi, Phil.	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	N J	Grantham, Holt, Manton, Keythorpe, Rockingham, Stamford, Uppingham.
vulgaris, Y & B.	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	N	Grantham.
spp.	-	-	-	-	P	-	-	-	N	N	-	-	-	-	-	Hn	Hn	-	
NAUTILOIDEA.																			
Nautilus *latidorsatus*, d'Orb. v. N. toarcensis.																			
lineatus, Sow.	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	N	Grantham.
semistriatus, d'Orb.	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	N	Grantham.
striatus, Sow.	-	-	Ba Q	-	P Q	-	-	-	-	-	-	-	-	-	-	Hn	-	N	Stoke, Barrow. Spinney Hills, Thurnby.
toarcensis, d'Orb.; *N. latidorsatus*.	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	N	Stoke.
truncatus, Sow.	-	-	-	-	-	-	-	J Q	-	-	-	W	-	-	-	L	-	-	Loseby, Tilton, Old Dalby.
spp.	-	-	-	-	-	-	-	-	-	-	N	-	-	-	-	Hn	-	S	Billesdon, Loseby, Middle Gonerby.
PISCES.																			
Acrodus **keuperinus**, Murchison & Strickland (*Hybodus*).	Hn P. B L	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	Aylestone, Shoulder of Mutton Hill, Leicester. Recorded by Harrison as teeth of Hybodus & Acrodus. "Ichthyodorulites" Plant.
minimus, Ag.	-	B W N Wo L	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	Spinney Hills, East Leake, Glen Parva, Barrow.
spp.	Hn	-	-	-	-	B N	-	-	-	-	-	-	-	-	-	-	-	-	Upper Keuper Sandstone (Harrison), Plungar.
ACTINOPTERYGIAN SCALES.	L	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
Belonorhynchus **acutus**, Ag. (*Belonostomus*.)	-	-	Q	H B	-	-	-	-	-	-	-	-	-	-	-	L	-	-	Barrow?. May be from Lyme Regis (Woodward).
Belonostomus v. Belonorhynchus.																			
Browneichthys **ornatus**, Woodward	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	Wo L	-	-	Barrow.
Ceratodus **latissimus**, Ag.; *C. altus*, Ag.	-	Q N Wo B L	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	Spinney Hills, Barnston.
Chondrosteus **acipenseroides**, Egerton, Ag. MS.	-	-	B Wo?	-	-	-	-	-	-	-	-	-	-	-	-	L	-	-	Barrow.
Colobodus **frequens**, Dames.	B	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	Aylestone, Spinney Hills. Scales.

SPECIES.	Keuper Sandstone.	Rhætic Beds.	Lower. Am. planorbis.	Am. angulatus.	Am. Bucklandi.	Am. semicostatus.	Am. oxynotus.	Am. armatus.	Am. Jamesoni.	Am. capricornus.	Middle. Am. margaritatus	Am. spinatus.	Upper. Am. annulatus.	Am. serpentinus.	Am. communis.	Lower Lias.	Middle Lias.	Upper Lias.	LOCALITIES AND REMARKS.
maximus, Quenst.	–	B	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	Spinney Hills.
Cosmolepis v. Oxygnathus.																			
Dapedius																			
dorsalis, Ag. (*Tetragonolepis*)	–	–	B	–	–	–	–	–	–	–	–	–	–	–	–	L	–	–	Barrow.
monilifer, Ag.	–	–	B M Wo	–	–	–	–	–	–	–	–	–	–	–	–	L	–	–	Barrow.
orbis, Ag.	–	–	B M A Hn Wo	–	–	–	–	–	–	–	–	–	–	–	–	L	–	–	Barrow.
striolatus, Ag. v. D. dorsalis.																			
spp.	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	L	–	–	Barrow.
Eugnathus																			
Hastingsiæ, Ag. (*Pholidophorus*).	–	–	Wo B	–	–	–	–	–	–	–	–	–	–	–	–	M A	–	–	Barrow. Spinney Hills, Wigston.
serrulatus, Egerton v. Heterolepidotus.																			
Gyrolepis																			
Alberti, Ag.	–	Hn Q Wc L B	–	–	–	–	–	–	–	–	–	–	–	–	–	L	–	–	Spinney Hills, Wigston, Barrow.
Quenstedti, Dames	B	B	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	Aylestone, East Leake.
Heterolepidotus																			
serrulatus, Ag. (*Eugnathus*).	–	–	Q Wo B	–	–	–	–	–	–	–	–	–	–	–	–	L	–	–	Barrow. *Leptolepis sprattiformis*, recorded by Quilter, may be this species. See Browne, Vertebrates of Leicestershire, p. 194.
Hybodus																			
cloacinus, Quenst.	–	L Hn Q B Wo	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	Spinney Hills. Crown Hills.
minor, Ag.	–	Hn W N Wo B L	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	Spinney Hills, East Leake, Barnston.
reticulatus, Ag.	–	N	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	Barnston.
spp.	–	B	–	–	B	–	–	–	–	–	–	–	–	–	–	L	–	–	Crown Hill.
Lepidotus v. Heterolepidotus.																			
Leptolepis																			
concentricus, Egerton.	–	–	Hn B	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	Barrow. ?=*L Bronni*, Ag.
sprattiformis, Blainv. v. Heterolepidotus serrulatus.																			
Mesodon																			
liassicus, Egerton.	–	–	M B Wo	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	Barrow ?
Nemacanthus																			
monilifer, Ag.	–	Pl Hn Jm L B	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	Wigston, *Asteracanthus* of Plant's list. See M. Browne, Leicester. Lit. Phil. Soc. 1893, p. 225.

SPECIES.	Keuper Sandstone.	Rhætic Beds.	Lower. Am. planorbis.	Am. angulatus.	Am. Bucklandi.	Am. semicostatus.	Am. oxynotus.	Am. armatus.	Am. Jamesoni.	Am. capricornus.	Middle. Am. margaritatus.	Am. spinatus.	Upper. Am. annulatus.	Am. serpentinus.	Am. communis.	Lower Lias.	Middle Lias.	Upper Lias.	LOCALITIES AND REMARKS.
Oxygnathus (*Cosmolepis*). **Egertoni,** Egerton, Ag. MS.	-	-	M A B Wo L	-	-	-	-	-	-	-	-	-	-	-	-	L	-	-	Barrow. S. Woodwa.. Ann. Mag Nat. Hist., 1890, p. 431.
Pholidophorus EGERTONI	-	-	Q	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	Mythical species.
Hastingsiæ, Ag. v. Eugnathus.																			
Higginsi, Egerton	-	L W Hn Wo B	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	Spinney Hills.
mottiana, Harrison v. Ph. Higginsi.																			
nitidus, Egerton, v. Ph. Higginsi.																			
tricklandi, Ag.	-	-	M A Hn Wo B	-	-	-	-	-	-	-	-	-	-	-	-	L	-	-	Barrow.
sp. (scales)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	B L	-	-	Knighton.
Ptycholepis minor, Egerton	-	-	M B Wo	-	-	-	-	-	-	-	-	-	-	-	-	L	-	-	Barrow.
Pycnodus liassicus, v. Mesodon.																			
Sargodon tomicus, Plien.	-	Q Wo B L Hn.	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	Spinney Hills.
Saurichthys acuminatus, Ag.	-	L Hn Q W Wo B	-	-	-	-	-	-	-	-	-	-	-	-	-	L	-	-	Wigston, Spinney Hills. Barrow?
apicalis, Ag. v. S. acuminatus.																			
sp.	-	N	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	Barnston.
SELACHIAN SPINES	X	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	Spinney Hills. A. S. Woodward, Leicester Lit. Phil. Soc., 1889, p. 18.
Semionotus Brodiei, Newton	Wo	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	Colwick Wood, Notts.
Sphenonchus sp.	-	Q	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	Spinney Hills. Spines recorded under this name are probably Hybodus.
Undina barroviensis, A.S. Woodward; Ann. Mag. Nat. Hist., 1890 p. 436.	-	-	Wo	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	Barrow.

SPECIES.	Keuper Sandstone.	Rhætic Beds.	Lower: Am. planorbis.	Am. angulatus.	Am. Bucklandi.	Am. semicostatus.	Am. oxynotus.	Am. armatus.	Am. Jamesoni.	Am. capricornus.	Middle: Am. margaritatus.	Am. spinatus.	Upper: Am. annulatus.	Am. serpentinus.	Am. communis.	Lower Lias.	Middle Lias.	Upper Lias.	LOCALITIES AND REMARKS.
REPTILIA and AMPHIBIA.																			
Eretmosaurus rugosus, Owen (*Plesiosaurus*).	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	Wo	-	-	Granby.
Ichthyosaurus communis, Conyb.	-	-	Hn Wo	-	-	-	-	-	-	-	-	-	-	-	-	L	-	-	Barrow.
Conybeari, Lyd.	-	-	B	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	Barrow ?
integer, Bronn	-	-	B	-	-	-	-	-	-	-	-	-	-	-	-	B	-	-	Barrow. Brit. Mus., 33,178.
intermedius, Conyb.	-	-	Hn B Wo	-	-	-	-	-	-	-	-	-	-	-	-	L	-	-	Barrow.
latifrons, Konig.	-	-	B Wo	-	-	-	-	-	-	-	-	-	-	-	-	L	-	-	Barrow.
platyodon, Conyb.	-	-	A B	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	Barrow ?
tenuirostris, Conyb.	-	-	Hn N B Wo	-	-	-	-	-	-	-	-	-	-	-	-	L	-	-	Barrow.
zetlandicus ? Seeley	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	B Wo	Vale of Belvoir.
spp.	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	B Bm. L	-	-	Seagrave. Oxford Museum.
(VERTEBRÆ, ETC.)	-	Hn	-	-	P	-	-	-	-	-	W	-	-	-	-	-	-	N	Spinney Hills, Thurnby, Tilton, Grantham
Labyrinthodon spp.	-	Hn B Jm	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	Spinney Hills, Wigston, East Leake.
FOOTPRINTS	x	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	Weston Cliff. In Keuper Sandstone, Hull, Geol. of Leicestershire Coalfield, p. 62.
Plesiosaurus Dewalquei ? Van Beneden.	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	B	-	-	Barrow, Bm. (R 1440).
Hawkinsi ? Owen	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	B Wo	-	-	Bennington Lincolnshire. Bm (R 45).
macrocephalus, Buckl.	·	-	A B Hn	..	-	-	-	-	-	-	-	-	-	-	-	L	-	-	Barrow. Recorded in error under the name *Pl. megacephalus* by Ansted and Quilter.
megacephalus v. Thaumatosaurus.																			
(VERTEBRÆ, ETC.)	-	Hn	B Q N	-	-	-	-	-	-	-	-	-	-	-	-	L	-	-	Spinney Hills, Barrow, Barnston.
Rysosteus Oweni W. and S.	-	B	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	East Leake.
TANYSTROPHŒUS, von Meyer, *See* Woodward and Sherborn, Fossil Vert., 1890.																			Error : Bone recorded by J. Plant from the Keuper of Leicester.
Thaumatosaurus megacephalus, Stutchbury (*Plesiosaurus*).	-	-	B	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	Barrow. Dublin Museum. May be *P. macrocephalus*. See Browne L. Vert., p. 180.

APPENDIX III.

On the Microscopic Character of some of the Boulders, and Rock Specimens from Borings, by Dr. J. S. Flett, M.A.

The Humber Stone, Holystone, Hellstone or Holstone. E.3408. —This is a biotite granite essentially composed of quartz, orthoclase, plagioclase and biotite, which last is often weathered into chlorite and epidote. It contains also a few crystals of a pale green, not very dichroic hornblende, some sphene, epidote, zircon, apatite and iron oxides. Orthoclase is abundant in large irregular crystals often perlitic and sometimes zonal. The plagioclase is near oligoclase. The structure is that which is usual in rocks of this group; but the felspars occasionally show a tendency to become porphyritic.

Aylestone. E.3410.—A rather decomposed syenite, the principal ingredients of which are felspar and hornblende. The felspar is to a large extent plagioclase, but orthoclase is also plentiful; both are much decomposed, and the former is in idiomorphic crystals with rectangular sections, the orthoclase more irregular in shape and often surrounding the plagioclase. There is fresh hornblende which shows the characteristic transverse section, and is brownish-green with exceptionally little dichroism. The abundant epidote and chlorite are probably mainly due to the decomposition of the hornblende. There is a small amount of interstitial quartz sometimes in rude graphic intergrowth with the felspar. In one or two places aureoles of micropegmatite surround felspar crystals. Epidote is present in grains and divergent fibrous aggregates. Accessories: apatite, sphene, magnetite, zircon. The rock is almost a quartz diorite.

St. John's Stone, Leicester Abbey. E.3411.—A calcareous grit which contains in a calcareous cementing matrix rounded and subangular grains of quartz, weathered felspar, flint or chert and other materials often stained red with encrusting oxide of iron. The grains are rather large (5 mm. across average), the calcareous cement very abundant.

The Moody Bush Stone, New York Farm, near Syston. E.3409 —A rather coarse-grained andesitic tuff. It contains a good deal of epidote which colours it green in spots, but is otherwise remarkably fresh and the felspars of the lapilli well preserved. These lapilli are of various kinds but may all be grouped under the term andesite, though some might possibly be better called trachytes. Their ferro-magnesian minerals have all decomposed into epidote, limonite, etc.

Countesthorpe Cottage Homes. (From a boring at 170 feet ?)* E.3412.—A fine-grained felsitic rock consisting principally of a microcrystalline or microgranitic aggregate of quartz and felspar. It is not porphyritic, the groundmass is filled with scales of secondary muscovite. It has in places a nodular character, recalling that of ash beds, but in the thinnest parts of the section

* From a core supplied by Mr. J. D. Paul, who states that it was obtained from a boring made at this place in 1884, and carried to a depth of 170 feet. [? yards.]

some of these nodules have a radiate structure, resembling devitrified spherulites. I think it is an old acid lava or intrusive vein.

Knighton Fields, Co-operative Boot Works. (From a boring at 690 feet.) E.3413.—This fine-grained soft grey rock, so far as is shown by the micro-sections, is composed of fine scaly muscovite, minute grains of quartz, spots of calcite or carbonates, and a diffused green mineral which is probably chlorite. In addition to these there is apparently a good deal of kaolin. From its composition it is a mudstone or clay rock, slightly calcareous but in no sense a limestone.

E.3414 (at 720 feet) and E.3415 (at 750 feet) have a spotted nodular character which suggest that the rock may be a fine-grained thoroughly decomposed tuff, but no volcanic minerals or structures are to be recognised in the specimens.

INDEX.

Names of Persons (authors, observers, and informants) are in Small Capitals.

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268.

MEMOIRS OF THE GEOLOGICAL SURVEY

ENGLAND AND WALES.

THE GEOLOGY OF

THE COUNTRY AROUND

READING.

(EXPLANATION OF SHEET 268.)

BY THE LATE

JOHN HOPWOOD BLAKE, Assoc. M. Inst. C.E., F.G.S.

With contributions by WILLIAM WHITAKER, B.A., F.R.S.

EDITED BY

H. W. MONCKTON, F.L.S., F.G.S.

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MEMOIRS OF THE GEOLOGICAL SURVEY.

ENGLAND AND WALES.

THE GEOLOGY OF

THE COUNTRY AROUND

READING.

(Explanation of Sheet 268.)

BY THE LATE

JOHN HOPWOOD BLAKE, Assoc. M. Inst. C.E., F.G.S.

With contributions by William Whitaker, B.A., F.R.S.

EDITED BY

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PREFACE.

The country described in this Memoir is situated in the western part of the London Basin. The Chalk and overlying Eocene strata are gently inclined to the S.E., and over their eroded surfaces have been spread during Pleistocene times various gravels and loams, of which the high level or plateau deposits have suffered considerable erosion.

The district is one in which the action of rivers and changes in their courses are conspicuously shown, a subject which has been dealt with by Mr. H. J. Osborne White and others, but which cannot be discussed without reference to a much larger area than that under consideration.

Geologically the area was the scene of some of the early labours of Prestwich, the fine sections of the mottled plastic clays so long worked as tile-earth having led him to adopt the name Reading Beds for the varied group of strata which here intervenes between the Chalk and London Clay. The subsequent researches of Mr. Whitaker and others who carried on the original one-inch survey, and of Mr. Jukes-Browne who gathered information relating to the Cretaceous rocks, have been supplemented by notes made by Mr. J. H. Blake and Mr. F. J. Bennett during the more detailed survey on the six-inch scale, which was carried on under the superintendence of Mr. Whitaker. Mr. Blake had nearly completed the MS. of this memoir at the time of his death in 1901.

Mr. H. W. Monckton then kindly offered to edit the MS. for publication, an offer gratefully accepted. He has retained practically all of Mr. Blake's notes, but has freely inserted additions from his own note book, many of the observations having been made in company with Mr. Blake. These additions relate more particularly to the chapters on the Superficial Deposits, for which Mr. Monckton is thus to a considerable extent responsible.

The map has not at present been printed in colours, but two editions, with and without Drift, were issued hand-coloured in 1898.

J. J. H. TEALL,
Director.

Geological Survey Office,
28, Jermyn Street, London,
25th March, 1903.

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LIST OF ILLUSTRATIONS.

GEOLOGY

OF THE COUNTRY AROUND

READING.

CHAPTER I.—INTRODUCTION.

Sheet 268 of the Geological Survey Map represents an area of 216 square miles; that portion on the north of the Thames being in Oxfordshire, and the remainder in Berkshire, with the exception of a somewhat irregular narrow strip along the south, which is in Hampshire.

Reading, the capital of Berkshire, is situated near the central part of the area; and the town of Wokingham stands on the eastern edge. The most important villages are Goring, Whitchurch, Mapledurham, Caversham and Shiplake in Oxfordshire; Streatley, Pangbourne, Bradfield, Theale, Burghfield, Aldermaston, Stratfield Mortimer, Swallowfield, Sonning, Twyford, and Wargrave in Berkshire; and Silchester, Stratfieldsaye, and Eversley in Hampshire.

The area is drained by the river Thames, and its tributaries, the Pang, the Kennet, and the Loddon, together with minor streams.

The *Thames* enters the district between Streatley and Goring, flows in a south-easterly direction to Reading, when it turns to the north-east and eventually to the north, and leaves the district soon after passing Wargrave.

The *Pang* enters a little north of Hampstead Norris, flows southerly, then in an easterly direction to Stanford Dingley, from there north-easterly to Tidmarsh, and northerly to its junction with the Thames at Pangbourne.

The *Kennet* enters near Thatcham Railway Station, flows in an easterly direction to Aldermaston, where it is joined by a tributary the *Enborne* flowing from the south-east; it then flows north-easterly to near Theale, and from there easterly to Whitley, where a tributary, the *Foundry Brook*, flowing from the south past Silchester and Stratfield Mortimer, with branches from near Mortimer and Burghfield Commons, unites with it; it then flows northerly and easterly through the town of Reading, on the north-eastern side of which it joins the *Thames*.

The *Loddon* enters at Stratfieldsaye Park, flows in a northerly direction for about a mile and a half, then north-easterly and northerly to its junction with the Thames between Shiplake and Wargrave, where it is divided into two streams. At Swallowfield Park it receives the united streams of the *Blackwater* and *Whitewater;* and further north is fed by a stream flowing from the south and west of Bearwood; and by another west of Hurst, flowing from the south of Wokingham.*

The following is a list of the geological formations which are shown on the map by distinctive colours:—

RECENT - - -	Alluvium. Tufa.
PLEISTOCENE - -	Loam. Valley Gravel. Clay-with-flints and Loam (overlying chalk). Plateau Gravel. Pebble Gravel.
EOCENE - - -	Upper Bagshot Beds. Bracklesham Beds. Lower Bagshot Beds. London Clay. Reading Beds.
CRETACEOUS - -	Upper Chalk. Middle Chalk.

* The history of some of the streams in the Kennet-Thames area has lately been dealt with by Mr. H. J. O. White, *Proc. Geol. Assoc.*, vol. xvii., p. 399.

CHAPTER II.—CHALK.

This formation is divided into Lower, Middle, and Upper Chalk, but only the Middle and Upper Chalk come to the surface in this district. At Winkfield, in Windsor Forest, however, a boring passed through the whole formation, and the thickness was found to be 725 feet, of which 219 feet was Lower Chalk, 169 feet Middle Chalk, and 337 feet Upper Chalk.*

The Chalk exists throughout our district, but is only found at the surface over a comparatively small part, for, in the southern half of the area and in parts of the northern half, it is covered by Eocene strata often of great thickness, and in other parts the Chalk is hidden under beds of Drift.

MIDDLE CHALK.

The Middle Chalk is divided into two zones, namely—

2. The Zone of *Terebratulina* (Fig. 2).
1. The Zone of *Rhynchonella Cuvieri* (Fig. 1).

FIG. 1.—Rhynchonella Cuvieri, *d'Orb.* (twice natural size).

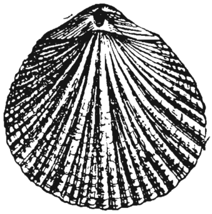

FIG. 2.—Terebratulina gracilis, var. lata, *Eth.* (thrice natural size).

The zone of *Rhynchonella Cuvieri* consists of a rubbly yellowish chalk in which nodules of flint seldom occur, and its base is usually marked by a hard, nodular, chalky limestone known as the Melbourn Rock, which does not, however, come to the surface in our area.

The zone of *Terebratulina* consists of smooth white chalk, and in it nodules of flint are occasionally to be found. It has been termed the zone of *Terebratulina gracilis*, but it is now known, through the researches of Dr. F. L. Kitchin, that this species does not occur below the uppermost division of our Chalk; the name to be used for the species of *Terebratulina* in the Middle Chalk has yet to be decided; it has been called *T. gracilis* var. *lata.*, by Mr. Etheridge.

The Middle Chalk runs down the Thames Valley from Goring and Streatley by Basildon to Pangbourne.

---

* "Water Supply of Berkshire," *Mem. Geol. Survey*, 1901, p. 95. *See* Whitaker and Jukes-Browne, *Quart. Journ. Geol. Soc.* vol. l., p. 496 (1894).

The following note of the details of exposures are by Mr. Jukes-Browne:—

No outcrop of Melbourn Rock could be found in this district or south of Moulsford, but the old quarry by the road-cutting through the ridge, about one and a half miles north of Streatley, exposed hard yellowish lumpy chalk, which is believed to belong to the zone of *Rhynchonella Cuvieri*, at no great distance above the Melbourn rock, although no fossils were discovered in it; the weathered face has a disintegrated rubbly appearance, and the bedding is indistinct, but the mass included large irregular lumps of very hard chalk; features which are also developed in the chalk of this zone at Cleeve near Goring.

It was therefore inferred that the Melbourn Rock came to the surface on the slope between this road and the river, passing thence below the gravel and reaching the level of the alluvium a little to the north of Streatley. A small pit in the field a quarter of a mile south-west of Streatley Farm exposed a few feet of similar hard chalk.

On the eastern side of the valley the lower part of the Middle Chalk is well exposed in the railway-cuttings a little out of this district to the north of Goring, and at several points along the river-bank also just north of the district. The first cutting north of Goring Station is about 30 feet deep; the lowest beds in the centre are hard and full of fragments of *Inoceramus*, and form regular courses from one to two feet thick; the higher beds are less hard, and about half-way up the face a single egg-shaped flint was found, but the whole of the chalk has a yellowish tinge and probably belongs to the zone of *Rhynchonella Cuvieri.*

On the same side of the valley the upper part of the Middle Chalk is exposed in a pit on the slope above Gatehampton Farm, which cannot be far below the Chalk Rock; it shows:—

	Ft.	in.
Tough white chalk without flints - - -	10	0
Soft and buff-coloured marl - - - -	0	6
Firm white chalk with nodules and seams of flint, and broken *Inoceramus* - - -	16	0

The surface of the bed underlying the marl is hard and nodular.

The uppermost beds, passing up into Chalk Rock, are also seen in the road-cutting east of Goring. (See p. 10.)

The outcrop of the *Terebratulina* zone was found in the road-cutting west of Streatley at a level of 315 feet. Thence it passes along the steep slope of Green Hill, its level gradually falling along the slopes to the southward.

Upper Chalk.

The Upper Chalk consists of soft white chalk, more or less evenly bedded, with numerous irregular nodules of flint along the planes of bedding and sometimes in the chalk between.

Thin seams of tabular flint occasionally occur along the bedding-planes, or fill fissures or joints inclined at various angles to them. At its base is the Chalk Rock, a cream-coloured limestone with glauconitic grains and many green-coated nodules.

The Upper Chalk is divided into several zones, only the three lower of which have been identified in our district, namely—

3. The Zone of *Micraster coranguinum*, Leske. (Fig. 3.)
2. The Zone of *Micraster cortestudinarium*, Goldf.
1. The Zone of *Holaster planus*, Mant. (Fig. 4.)

The following account is by Mr. Jukes-Browne, and will appear in his Memoir on the Cretaceous Rocks, vol. III.

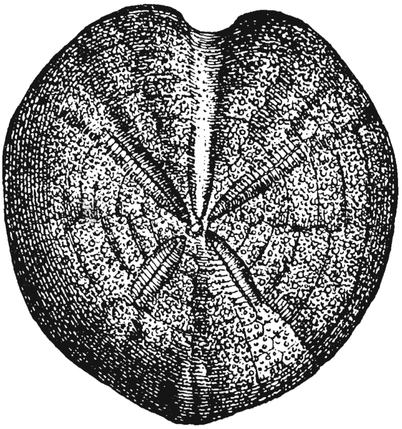

FIG. 3.—Micraster coranguinum, *Leske.*

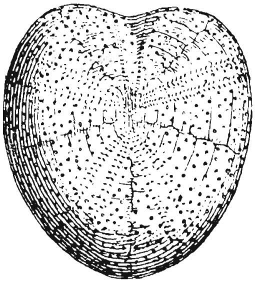

FIG. 4.—Holaster planus, *Mant.*

1.—Zone of Holaster planus.

The zone of *Holaster planus* includes the Chalk Rock, which, as has been said, forms the base of the Upper Chalk.

The average thickness of the zone in the Thames Valley is about 20 feet.

A good section of this zone was exposed in an old quarry facing the Thames in Harts-lock Wood opposite Basildon. The upper 30 feet of the quarry-face being inaccessible, only the lower part was measured, the rest being estimated by eye:—

				Feet.
		White chalk with flints - - - -	about	12
		Soft white chalk without flints - - -	,,	2
Zone of H. Planus.		Soft powdery chalk with hard lumps which weather out prominently; contains a few scattered flints and a layer of flints at the base. *Micraster* common - - - - - - - -	-about	16
	Chalk Rock.	Hard compact rock with a layer of green-coated nodules at top; below it passes into lumpy white chalk - - - - - - - - - - -		2
		Hard yellowish rock full of green-coated nodules in the upper six 6 inches, compact below but passing into nodular chalk - - - - - - -		3

		Feet
Middle Chalk.	Less nodular white chalk passing into massive white chalk	6
	Layer of grey marl just seen	
	Talus hiding lower beds	20

There was no sign here of any rock-bed at the summit of the lumpy chalk, but the soft white chalk may be regarded as the base of the zone of *Micraster cortestudinarium.* The Chalk Rock below has but few fossils.

Another good section, where every bed can be easily examined, is in the road-cutting on White Hill, east of Goring, and may, perhaps, be given though it is just beyond our district. Here the upper limit of the zone is marked by a thin bed of yellowish rock. The beds seen were as follows:—

		Ft.	in.
	Soft white chalk with a layer of flint about half an inch thick at the base	5	0
Zone of *Holaster planus.*	Hard yellowish rock in loose lumps, but without nodules. *Ventriculites.*	1	0
	Nodular chalk, consisting of hard limestone lumps embedded in loose powdery chalk with a few scattered flints	12	0
	Hard white limestone, without green grains, passing down into very hard compact yellowish rock full of green grains, with several layers of green-coated nodules (Chalk Rock)	5	0
Middle Chalk.	Hard rock without green grains passing down into rough nodular chalk	2	0
	Layer of soft shaly marl	0	3
	Firm bedded white chalk	4	0
	about	30	

Micraster is rare at this place, but *Echinocorys scutatus, Spondylus spinosus,* and *Terebratula carnea* occurred in the nodular beds.

2. Zone of Micraster cortestudinarium.

The average thickness of this zone in the Thames Valley is about 60 feet, and there seems to be some thickness of chalk, exposed in several pits, which is referable to it.

There is a quarry at Whitchurch which may possibly be in the Chalk of this zone, but no fossils have been obtained from it, and it is more likely to be in that of *M. coranguinum,* which continues thence to Reading.

Part of the zone is well exposed in the railway-cutting west of Pangbourne, where the beds are bent up into a slight anticlinal curve, as represented in Fig. 5. The fault is of small importance, having a throw of only about 2 feet. The flints are black inside, with a very thin rind, and some of them are cavernous. *Echinocorys scutatus* was the only fossil seen.

FIG. 5.—Sketch in the Railway-cutting west of Pangbourne.

		Ft.	in.
10. Chalk with some flints	- - - - - -	0 to 6	0
9. A continuous seam of flint	- - - - - -	0	3
8. Chalk without flints	- - - - - - -	4	0
7. Chalk with three layers of flint nodules	- - - -	5	0
6. Chalk with a few flints	- - - - - - -	10	0
5. Yellow rocky chalk, with some flints	- - -	0	9
4. Chalk with scattered flints	- - - - - -	4	0
3. Hard yellowish rocky chalk	- - - - - -	1	0
2. Rough chalk with flint nodules	- - - - -	2	0
1. Massive homogeneous chalk	- - - seen for	1	3
		30–34	0

3. Zone of Micraster coranguinum.

Along the valley of the Thames the thickness of this zone is about 200 feet. Exposures are numerous, and the following account has been drawn up from the records published by Professor Barrois,* supplemented by notes furnished by Mr. W. Hill, and Mr. J. Rhodes.

Being unable to indicate any particular bed as the top of the zone of *M. cortestudinarium*, and fossils being scarce in the beds which form the passage from it to the zone of *M. coranguinum*, we cannot be sure about the zonal horizon of some exposures. It is probable, however, that the chalk seen at Whitchurch belongs to the *M. coranguinum* zone, and, if so, then all the chalk seen in the numerous quarries along the Oxford side of the river from Whitchurch to Shiplake will belong to the same zone.

The exposure at Whitchurch is north of the village, behind the school-house on the main road, and in 1885 it showed a vertical face of chalk with many layers of flints. The chalk is firm, but not hard; the flints occur in layers, or courses, 4 to 6 inches thick, full of flints crowded together, and these courses are from 2 to 3 feet apart; there are also some scattered nodules between the courses, and some thin continuous seams of flint. I did not notice any fossils, but could not give time to the search. Dr. Barrois mentions a quarry " north of Pangbourne " which he refers to the zone of *M. cortestudinarium*; it can, however, hardly be this one.

* Recherches sur le Terr. Crét. Sup., p. 148. (1876).

Another quarry was visited by Dr. Barrois, one kilometre (0·62 mile) east of Whitchurch, and from his description it appears to be in similar chalk. He obtained the following fossils:—

Inoceramus involutus.	Echinocorys gibbus.
„ Cuvieri.	Micraster coranguinum.
Rhynchonella plicatilis.	Starfish remains.
Cidaris clavigera.	Porosphæra globularis.

At Mapledurham and at Chazey Farm, west of Caversham there are quarries which are unquestionably in the zone of *M. coranguinum*, the chalk being soft, white, with few perfect fossils, but many fragments of large *Inocerami;* the flints are in layers from 2 to 3 feet apart, and some of them have a cloudy white band, while others are cavernous and contain numerous Bryozoan remains. The quarry at Chazey Farm is about 80 feet deep.

At Caversham there is another large quarry, the chalk of which Dr. Barrois referred to the zone of *Marsupites*, which overlies the zone of *Micraster coranguinum*, but he did not find any plates of *Marsupites*, and Mr. Hill, who has recently visited it, saw no reason for separating this chalk from that of Chazey Farm, its general aspect being the same, the flints nearly as numerous, and no layer of yellow nodules nor any other special feature being visible in either quarry. Dr. Barrois describes the chalk of the Caversham quarry as "white and soft, with layers of flints from 3 to 6 feet apart. These flints are black, with a thin white skin; some are cavernous, others in tabular layers; their shape is irregular, generally flattened in the direction of the stratification." He found the following fossils:—

Inoceramus (rare).	Cidaris clavigera.
Lima Hoperi.	„ hirudo.
Spondylus.	Micraster coranguinum.
Rhynchonella plicatilis,	Bourgueticrinus ellipticus.
Serpula granulata.	Porosphæra globularis.

It will be observed that there is nothing here specially characteristic of the higher zone, no Belemnite nor *Offaster pillula.*

There are several pits between Caversham and Shiplake, and Mr. Hill reports them all to be in chalk with many layers of flints, with very few fossils, and without special features. He refers them all to the *M. coranguinum* zone.

South-east of Wargrave, in Berkshire, is a large quarry, 60 feet deep in similar chalk, and the same chalk can be seen at several places on the river slope between Wargrave and Park Place.

A. J. J.-B.

Returning to the Chazey Farm pit, it was noted that numerous irregular-shaped flints, and also some tabular flint, occurred along the lines of bedding, and a few flints here and there in the solid chalk between the bedding. The upper part was very rubbly and thinly bedded in places, whereas the lower part was rather thickly bedded, the beds averaging from 1 foot 6 inches to 2 feet or more in thickness.

A flint-cast of a large Ammonite of the [*Hapl.*] *leptophyllus* group from the chalk cutting on the Great Western Railway at Waltham, is in the collection of Mr. Ll. Treacher of Twyford.*

FOSSILS FROM THE UPPER CHALK.

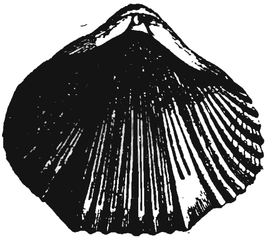

FIG. 6.—Rhynchonella plicatilis var. octoplicata, *Sow.*

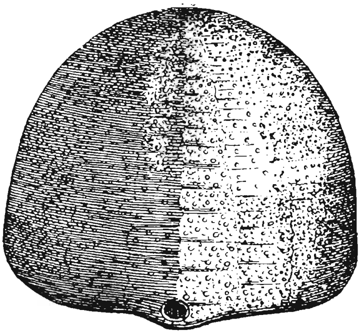

FIG. 7.—Echinocorys scutatus, *Leske* ($\frac{3}{4}$ natural size).

The Rev. W. Buckland gives the following account of the Chalk at Catsgrove [Katesgrove] Hill Brick Kilns, Reading:—

The chalk is quarried below the green sand containing oysters [Reading Beds] to the depth of about 25 feet, when the workings are stopped by water at a point nearly on a line with the level of the River Kennet. . . . In this thickness of 25 feet of chalk, there is but one regular and continuous course of flints, and in this they are disposed in tabular masses, for the most part of about two inches in thickness. (This bed is but a few feet above the water.) In the chalk that lies above this silicious stratum, the flints are disposed irregularly with their usual characters and eccentric forms, derived, in many instances, from the organic remains which they envelope. They are collected for the use of the porcelain manufactories. The chalk itself is extracted largely from under the sands and clays, by means of shafts and levels, to be burnt into lime.†

The following notes are by Mr. F. J. Bennett:—

The Upper Chalk with flints is seen at the surface in the north-western corner of the area, and disappears under the Tertiaries at Stanford Dingley, the river there being on the boundary.

Its thickness there has been estimated at 300 feet. A well at Woodrow's Farm south-west of Aldworth, at which place there is an outlier of Reading Beds, is 300 feet deep, and Chalk Rock seems to have been touched at that depth; and as there was no great thickness of Reading Beds this seems to agree fairly well with the estimate.

* H. J. O. White, *Proc. Geol. Assoc.*, vol. xvii (1901), p. 177.
† *Trans. Geol. Soc.*, vol. iv. (1817) p. 280.

At Applepie Hill, about a mile and a quarter west of Aldworth Church, a small pit shows some chalk with flints.

Chalk with flints is also seen in the road-cutting one and a quarter mile south-east of Aldworth and in a large pit just west of Hartridge Farm where there is 15 feet of it.

In the railway-cutting just south of Hampstead Norris Station there is greyish much broken-up chalk with nodular flints, with a yellow marly band in the middle, showing a dip of 7° S. A little east of Ealing Farm is a large chalk pit with nodular and tabular flints; a small fault is seen in the pit.

Chalk is exposed in most of the valleys in the north-western part of the area, and the fields are in many places thickly covered with flints.

There are several chalk pits near the junction of the Chalk with the Tertiaries: these have been opened for the purpose of getting chalk for dressing the heavy Tertiary clays. There are large pits near Stanford Dingley.—F. J. B.

Some extensive galleries were found in the chalk at Yattendon, in 1819. They are described * by W. H. Brewer as consisting "of various passages intersecting one another; the roof formed with no contemptible skill, and supported by square pillars hewn out of the chalk."

* The Gentleman's Magazine, 1822, p. 416.

CHAPTER III.—READING BEDS.

There is a great break in time between the Chalk and the Reading Beds which are here found resting upon it; for not only are the highest beds of the Chalk wanting in this area but a considerable series of Eocene strata which in other places is found below the Reading Beds is also absent. The Reading Beds accordingly here lie upon a greatly but evenly eroded surface of Chalk.

They consist of variously coloured mottled plastic clays and more or less loose sands, the former generally occurring in the upper part of the formation, and varying from about 30 to 50 feet in thickness, while the sands are found beneath with a thickness of from 20 to 40 feet. The " bottom-bed " consists of stiff dark bluish-grey clay, which is sometimes laminated, interstratified with brown and olive-green glauconitic sands. It is very persistent and usually from about 7 to 10 feet in thickness. The whole formation in this area varies from about 70 feet or less to 90 feet in thickness.

The main mass of the Reading Beds extends beneath the surface in the southern half of the district and at its outcrop forms a narrow band running nearly east and west.

Several outliers are found upon the Chalk to the north of the main mass. Four of them lie north of the Thames and will be first described; those south of the Thames will then be dealt with from west to east; and finally the main mass will receive attention.

Outliers.—North of the Thames.

Cray's Pond.—North of Whitchurch there is an irregular outlier, the northern part of which extends beyond the district. In that part, a little more than half a mile north-east of Cray's Pond, there was a brickyard in Claypits Wood which showed the following section:—

		Feet.
Reading Beds.	Mottled crimson, grey, and brown clay -	16
	White sand - - - - - - -	5
	Brown and grey clay interstratified with seams of sand (Bottom-bed) - - -	4
Chalk.		

Other sections also occurred north of the above on Greenmoor Hill; one showing a very even line at the junction of the bottom-bed (6 feet thick) with the Chalk.

In digging the well (331 feet in depth) at the cross-roads by Cray's Pond, in 1886, gravel, loam, and clay were passed through, and chalk reached, at a depth of 60 feet, according to information supplied by the well-digger, John Higgs.

At Little Heath, north-west of Cray's Pond, red and brown clay was exposed.

In the southern part of this outlier, there are many small exposures of light-coloured sands. South of Cold Harbour Farm, a section showed :—

		Feet.
Reading Beds	Crimson and grey mottled clay - -	1
	Buff sands, well-stratified - - -	6

Mapledurham.—With the exception of its south-eastern side, this outlier is covered with gravel; making its north-western limit doubtful. It is possible it may extend in that direction as far as Whittles Farm, where, in an excavation, 2 feet of red clay were exposed beneath the gravel. The doubtful boundary, as shown by a disconnected line south of Hodmoor Farm, has been drawn there as the bottom-bed, consisting of brown and green sand, was exposed 6 feet beneath the surface in cleaning out the pond near the fork in the road.

In the cross-roads west of Tokers Green, mottled plastic clay was exposed by the side of the road; and mottled yellow and grey clay in the road to the west of the Pack-saddle Inn.

"Just above the 'Pack-saddle' there is crimson mottled plastic clay; and in sinking chalk-wells in the fields near, about 20 feet of gravel, loam, and clay have been found above the Chalk." * W. W.

Emmer Green.—This outlier extends from Caversham Grove and Oakley House north-east to Rose Hill.

In Caversham Park Mr. Whitaker noted† "mottled plastic clay some distance below the house, and sand at a higher level eastward, whilst the hills on the eastern side of the valley consist of Chalk, at a much higher level than the Tertiary beds in the Park, thus indicating a fault with a downthrow on the west."

A well in the park passed through 30 feet of Reading Beds, the upper 24 feet being mottled clay and, at the bottom, there were 6 feet of sand on the Chalk.

At Rose Hill a well showed as much as 61 feet of Reading Beds.

In the eastern part of the outlier a patch of London Clay is brought in by three faults arranged in the form of a triangle, one of which is that running through Caversham Park, already mentioned.

Mr. Whitaker observed a section in a brick-field near Rose Hill showing London Clay thrown down by one of these faults against the variously coloured mottled plastic clays of the Reading Beds. He adds that in a Chalk well about 40 feet of

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*"Geology of the London Basin," *Mem. Geol. Survey,* vol. iv., 1872, p. 202.
† *Loc. cit.*

clay was passed through before the Chalk was reached and that immediately above the latter there was about 3 feet of clayey green sands (bottom-bed) with oyster shells at the base.*

Binfield Heath.—At the kiln, adjoining Comp Farm, the following section was exposed:—

		Feet.
Reading Beds	Mottled crimson and grey clay	25
	Sand	5

A well-defined fault, with a downthrow of the Reading Beds on the eastern side, and with the chalk coming to the surface on the western side, passes through the north-eastern corner of the wood south of Comp Farm, and continues in a south-easterly direction as far as Dunsden Green. The Chalk to the south-east of the wood is at a little higher level than the surface of the ground at the above section of Reading Beds, and within about 30 yards of the north-western corner of the section, and about 80 yards from the south-eastern corner.

Close to the north-eastern corner of the wood, a well was sunk in the Chalk to the depth of 72 feet, with galleries for obtaining the Chalk.

Referring to previous excavations at the same kiln, Mr. Whitaker gives the following description†:—

"In sinking a chalk-well at the Binfield Heath Brickyard the Chalk was reached after passing through about 20 feet of the Reading Beds, in which, as at Rose Hill, there was but little sand. Immediately above the Chalk was a clayey green sand. When the survey was being made, there was a small section showing three beds of mottled clay with a dip gradually increasing from 5° to 15°, about 20° west of south, in which direction, however, the Chalk comes to the surface at a higher level, proving the existence of a fault with a downthrow on the north-east. In a chalk pit just below the kiln the dip is 5° to the east, that is in a contrary direction to that of the Reading Beds on the down-throw side of the fault. In sinking a well at a house on the high road, opposite the road leading to the brickyard, plastic clay was again found at a lower level than the Chalk to the south-west."—W.W.

Many small exposures of the Reading Beds are to be seen on the eastern side of the fault. Thus in Sandpit Lane, sand and clay was exposed; in Tagg Lane crimson and brown plastic clay was seen; whilst on the western side of the fault there are chalk pits.

On the north-western side of the outlier, in a pit in the wood south of Dean Farm, clay was seen overlying Chalk; and loam and sand in a pit in the northern part of the wood east of Dean Farm.

On the north, exposures were seen at the pond, at Mays Green; also on the north-east of High Wood, where red sand occurs; whilst to the south-east of the same wood a sand-pit showed 9 feet of well stratified buff sand.

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* *Op. cit.*, p. 202. † *Op. cit.*, p. 202.

In the central part, mottled red and grey clay was exposed beneath gravel, on the south-eastern corner of Oakhouse Wood.

On the eastern side of the outlier, there are sand pits in the wood north of Shiplake Row known as Long Copse, where 15 feet in thickness of well stratified buff sand was exposed in one pit, and 6 feet in another. At Shiplake Kiln, south-east of the wood, the following section was seen on the west side of the excavation, south of the road:—

		Feet.
Reading Beds	Mottled clays - - - - - - -	25
	Bluish clay with shells (Bottom-bed) -	5
Chalk		

On the southern side of the same excavation, from 15 to 20 feet of mottled clays were exposed; and on the northern side of the road from 1 to 3 feet of gravel. Drift was seen to overlie 25 feet of mottled clays.

South of this brickfield, a good section showing from 15 to 20 feet of mottled clays was exposed in the road-cutting east of Shiplake Row. And in the road leading from Shiplake Row in a southerly direction to the main Reading Road, mottled red and grey clays were to be seen in the upper part; and sand and clay in the lower.

In the southern part of the outlier, red and grey mottled clays occur 2 feet beneath the surface in the road west of the Methodist Chapel; and in an excavation in the wood south of The Firs, a section showed 8 feet of brown loam and clay.

Outliers South of the Thames.

Bower Farm.— "A small outlier in the north-western part of the district, about half-a-mile north of Aldworth, consists of "a small thickness of the bottom-bed, with yellow sand above, in a hollow in the Chalk."*—W. W.

Streatley.—In Common Wood, on the hill to the south-west of Streatley, sand has been excavated in places.

The following note is by Mr. Bennett:—

Aldworth.—This outlier is a little south-west of Aldworth. As it is in a hollow in the Chalk it makes no feature. Small sections in it are to be seen in several places. Half a mile west of the church and just north of the road by Pibworth Farm a small pit showed a little mottled clay over 6 feet of yellow sand. A little south-west of this in a meadow is another sand-pit with 5 feet of sand. There are two ponds close to the farm house; the one north of the house shows 10 feet of mottled clay, and the other, east of the house, also shows clay. A pond close to Woodrow's Farm showed 5 feet of mottled clay, and I was informed that the excavation for a tank at the house showed 20 feet of clay.

**Op. cit.*, p. 194.

Ashampstead.—A little north-eastward of Ashampstead and east of Hartridge Farm there is an outlier composed largely of sand. It is also in a hollow in the Chalk, and makes no feature.

Upper Basildon.—This outlier is very well defined and the brickyard showed the following section :—

A little pebbly gravel	
A little mottled clay	
Brown mottled clay - - -	5 to 10 Feet.
Fine white sand - - - -	3 to 10 „

A shaft sunk in the wood close by to reach the chalk showed 20 feet of Reading Beds; and, as the ground above rose at least 10 feet, these beds must here be 30 feet thick.—F.J.B.

The following notes are by Mr. Whitaker*:—

Yattendon.—" The Yattendon outlier occupies the high ground between that place and Bradfield, and is capped in two [or more] places by London Clay. The projection on which Yattendon stands consists of the bottom-bed with a capping of sand; a long section of the former may be seen on the road south of the village, and it is also exposed in a chalk-pit on the road to Manstone Farm.

" In Lye Wood there is sand, and at its southern end, in an old chalk-pit now overgrown with trees, the bottom-bed is just visible. It contains green-coated flints, one that I found being a cast of a *Galerite.*

" At and near Burnthill Common there is sand, capped with gravel on the higher ground; and also at Strouds. South of the latter place, by Birchland and Hockley Woods, the boundary is obscure; but the swallow-holes serve as guides. In the fields north of Heath Wood [south-west of Bottom House Farm] there is sand a little distance above the Chalk; and along the road to Bottom [House] Farm a section of the bottom-bed consisting of some feet of bluish-grey clay and sand with green grains, with pebbles in the lower part. This bed is also to be seen in the fields west of the road. There is much gravel here, especially on the higher ground."—W. W.

Sir Joseph Prestwich has noted the beds shown in a brickyard at Red Hill, near Hewin's Wood,† and remarked that " the peculiarity of this section is the occurrence of a patch of angular chalk fragments and flints, resembling ordinary gravel, beneath the main mass of mottled clay." He gives the following section :—

		Feet.
Reading Beds	Red and purple clay passing down into red and green mottled clay, and then red clay	20
	Angular fragments of chalk, subangular flints, and flint-pebbles - - - -	1
	Mottled red and yellow sand - - -	0½
	Light-coloured sand - - - - -	6 (?)

* *Op. cit.* p. 195.

† *Quart. Journ. Geol. Soc.*, vol. x. (1854) p. 87.

Mr. Whitaker noted that "at Old Pit, west of Bradfield [3 furlongs north-east of Rushall's Farm] there is sand above the Chalk, and in the valley farther west is a swallow-hole. At the southern end of Hanger Copse [3 furlongs north-west of Rushall's Farm] there is a trace of the bottom-bed, and in the woods sand; at the old brickyard to the east of Yattendon the former is seen to be of considerable thickness, and in it I found an internal cast, in iron-pyrites, of a small *Nucula*. At King's Wood [probably in the small outlier east of Burnt Hill] light-coloured sand and clay overlie the bottom-bed." *

The following notes are by Mr. F. J. Bennett:—

"A section in Clack's Copse east of the fish-pond showed 5 to 12 feet of brown false-bedded sand. East of this in Gravelpit Copse a pit showed loam and angular gravel with masses of pebbles overlying coarse yellow sand, and I was told that silicified trunks of trees had been found in the sand. (See p. 68.)

The part of the outlier south of Burnt Hill, capped with London Clay, showed the following sections:—

Section at the Kiln north of Lucksall Farm.

London Clay	Rusty brown clay	8	46 feet.
Reading Beds	Red mottled clay	8	
	Sand and clay, said to be	30	

Section in a pit three-quarters of a milesouth-east of Lucksall Farm Kiln and east of the road:—

London Clay ?	Rusty brown clay	4	8½ feet.
Reading Beds	Brown and grey clayey sand	3	
	Pinkish-white sand	1½	

A little south of Stroud's or Mapleton's Farm (east of Burnt Hill) and west of the road is a large pit showing 10 feet of false-bedded coarse yellow sand capped in one place by brown loam.

The Reading Beds were seen in the cutting on the road leading from Burnt Hill to Stanford Dingley, and swallow-holes occur in the wood to the east of that road."—F. J. B.

The following is by Mr. Whitaker †:—

Frilsham.—"The hills between Frilsham and Stanford Dingley are formed by a large mass of the Reading Beds, with a thick and extensive capping of London Clay. . . . In the road near Frilsham House the bottom-bed is partly exposed, and above it are loams and mottled plastic clays. Thence to Frilsham the boundary-line is much hidden by Drift gravel and clay, though yellow sand may be seen occasionally; but it may be traced by the swallow-holes which occur in most of the hollows. On the slope of the hill east of Frilsham there is a spring of clear water, said to be constant, thrown out from the loamy basement-bed of the London Clay, by a crimson-mottled plastic clay immediately beneath. In a well, at a house on the

* "Geology of the London Basin," *Mem. Geol. Survey*, vol. iv., 1872, p. 195.
† *Op. cit.*, pp. 194, 195.

road south of this, light-coloured sand was found above the bottom-bed. In the brickyard close by there are several small pits, one showing the junction with the London Clay, a large mass of which has slipped down over the lower beds. Beneath the basement-bed of the London Clay there is crimson and green mottled plastic clay. The bottom-bed is not seen here, but the sand above it is well developed, being as much as 20 feet thick; the upper part is buff, the lower and greater part white, and above it there is clay.

"Just south-east of Hawkridge [Farm, not named on the map but marked south of Hawkridge Wood] a chalk-pit shows 2 or 3 feet of light-coloured sand, and about a foot of clayey sand, with green grains (bottom-bed) above the Chalk. Just west of the other Hawkridge [half-a-mile west of Field Farm] yellow sand comes on a little above the Chalk. At Rusdens [nearly half-a-mile south of west of Field Farm] there is sand, and at a higher level, mottled clay.

"By the road south of Hawkridge Farm [now Field Farm] there is some of the green sand of the bottom-bed, and also at the higher part of the large chalk-pit near the same place. North of this the boundary-line is much hidden by Drift; but sand may be seen near the farm; at Dods [half-a-mile north of Field Farm] where there is a swallow-hole, and around Maslin's wood [half a mile south-east of Frilsham House]. At the meeting of the three roads [also] half-a-mile south-east of Frilsham House, the following section was to be seen:—

		Feet.
Reading Beds	Light-coloured sand - - - - - -	3 or 4
	Bottom-bed, greenish throughout, the lower half of a brown colour, the bottom 6 inches darker than the rest - -	about 6
Chalk, with holes (made by boring molluscs ?)"		

W. W.

Mr. Bennett notes that at the Kiln on this outlier there were two sections, one showing 5 feet of red mottled clay, and the other 20 feet of sharp coarse yellow sand.

A little north of the Iron Foundry at Bucklebury, a pit shows a little gravel over brown sand; and another pit a little farther north, called the Warren Pit, showed 3 feet of Reading Beds over Chalk, the junction being piped and irregular.

At the eastern edge of the outlier there are some swallow-holes. F. J. B.

Upper Bowden Farm.—This outlier, south-west of Pangbourne, is apparently small and consists mostly of sand. In Franklin's Copse, east of Upper Bowden Farm, a pit showed well-stratified sand.

Ruscombe.—There is a small outlier to the north of this place nearly covered by gravel which overlaps its northern boundary on to the chalk. There was a section at its southern end half a furlong from the Twyford-London Road showing the junction of the Reading Beds with the Chalk.

The former consisted of grey clay, with green sand and green coated flints at the bottom.

Wargrave.—A little east of this place there is a large outlier of Reading Beds, but only a portion of it is in our district. Upon this portion there is part of a thick outlier of London Clay forming Bowsey Hill.

Mottled clay is worked in a brickfield north of Highfield House, and is also seen by the side of the lane towards Gibstrude Farm.

The well of the Wargrave and Twyford Waterworks at Tagg Lane, one mile east of the former place, passed through about 12 feet of Reading Beds consisting of mottled clay, loam, etc.*

Mr. Whitaker noted several swallow-holes. His account of the whole outlier may be referred to for further details.†

* "Water Supply of Berkshire," *Mem. Geol. Survey* (1901), p. 90.

† "Geology of parts of Middlesex," etc. *Mem. Geol. Survey* (1864), pp. 42-44; "Geology of the London Basin," *Mem. Geol. Survey*, vol. iv. (1872, p. 199; "Geology of London," vol. i. (1889), pp. 180-182.

CHAPTER IV.—READING BEDS.

THE TILEHURST-READING OUTLIER.

A large outlier of Reading Beds extends from the hill above Sulham into Reading, and most of the Castle Ward is built upon it or on gravel which overlies it.

On its western part there is a large patch of London Clay, and upon it the village of Tilehurst stands.

A well * at Newdams, Tilehurst, proved the full thickness of the Reading Beds to be 51 feet.

According to Prestwich † "at Sulham . . . the sands overlying the chalk are more than 20 feet thick."

In the upper part of Sulham Wood, about one and a half furlongs north-east of the church, and a little south of the road, a pit showed the following section:—

Mottled red and grey clay - - - -	6	16 feet
Well-stratified buff-coloured sand - - -	10	

On the sloping ground about six furlongs south-eastward of Sulham church, green sand of the bottom-bed was exposed in a dead well showing the junction of the Reading Beds with the Chalk.

At the limekiln and brickyard about three-quarters of a mile north-east of Theale railway-station, about 15 feet of Reading Beds overlying Chalk was exposed in 1887, the plane of junction being remarkably even. The top 12 to 15 inches of the Chalk was perforated in every direction with tube-like holes about one-half to three-quarters of an inch in diameter, filled with the greenish and brownish sand of the overlying beds. A few of these tubes reached to a depth of 18 inches from the top of the chalk. The following was the section exposed:—

			Feet.
Reading Beds.		Well-stratified brown sand containing a bed of grey clay about 8 inches thick in its upper part - - - - -	8
	Bottom-bed.	Well-stratified and laminated clays variously coloured grey, brown, and red, with seams of brown and greenish sands - - - - - - -	6
		Green-coated flints of a more or less sub-angular shape, intermixed with flint pebbles, in a matrix of brown and greenish sand - - - -	1 to 1½
Chalk at a depth of - - - - - - - - - -			15½

* "Water Supply of Berkshire," *Mem. Geol. Survey* (1901), p. 85.
† *Quart. Journ. Geol. Soc.*, vol. x. (1854), p. 87.

A man who had worked the pit for about thirty-five years, and who had observed fossils in the Chalk, stated that he had not noticed any oysters or other shells in the Reading Beds. There appeared to be a little carbonaceous matter in the laminated grey clays, but no impressions of leaves were found.

Mr. Whitaker gives the following section at this brickyard:—*

				Feet.
Reading Beds.			Light-coloured sands - - - - about	5
	Bottom-bed, about $6\frac{1}{2}$ feet.	a.	Blue and orange-coloured mottled clay - - -	$1\frac{1}{4}$
		b.	Blue and yellow clayey sand -	1
		c.	Light-blue clay, rather sandy, especially at the upper part where there are many dark grains - - - -	$1\frac{1}{2}$
			Blue and brown clay (ferruginous) - - about	$\frac{3}{4}$
		d.	Clayey sand, with green grains; green-coated flints at the base	1
		e.	Yellowish-brown sand at the lower part clayey, and with green grains and green-coated flints - - - - -	1

Chalk, with holes of boring molluscs (?)

The dip given by the junction, which is very regular, is 2° in a direction 30° E. of S.

In both parts of *c.* there are a few indistinct casts of small bivalves and a great many small flat radiating impressions, apparently casts of selenite crystals."—W.W.

Mr. Whitaker tells us that Mr. C. E. Hawkins showed him large specimens of impressions of the same sort in mottled clay at Rowland Castle Brickyard (Hants), and a like fact has been observed by M. de la Condamine in another part of this formation (not here present) at Counter Hill, Lewisham.†

Casts of fossils were found in beds *c*, *d*, and *e* of the above section.

The following species were recorded‡—Cerithium Lunni ? *Mor*, Arca, Cyrena cordata, *Mor.*, Psammobia ? Ostrea bellovacina, *Lam.*

Mr. Whitaker§ adds that "along the road above the brickyard there is sand with iron-sandstone and clay.

"Between Theale and Reading there is much valley-gravel, which hides the boundary-line; but sand may often be seen. Clay generally occurs at a higher level."—W.W.

At Calcot Kiln, south-westward of Calcot Park, the following section was exposed:—

Mottled red and grey clay - - - - -	3 to 5	20 feet.
Buff, white and brown sand indurated in places	15	

Mr. Whitaker notes that the upper part of the sands contains a slight admixture of clay, so that it is very tough, and may be quarried in blocks, which harden by exposure: the

* "Geology of the London Basin," *Mem. Geol. Survey*, vol. iv. (1872), p. 196.
† *Quart. Journ. Geol. Soc.*, vol. x. (1854), p. 123.
‡ "Geology of the London Basin," vol. iv., pp. 576-7. § *Op. cit.*, p. 196.

lower part is fine sand. He saw a small block of sandstone, of a light and somewhat varied colour, evidently out of the Reading Beds. The junction of the clay and sand dips in a westerly direction, down the slope of the valleyside.*

At Horncastle, south-east of Calcot Park, in the triangular space westward of the Inn, a sand-pit showed 10 feet of stratified buff and brown sand; and about 10 chains south of the Inn there was a pit where the junction of the Reading Beds with the chalk was well exposed in 1887. The following was the section:—

			Feet.
Reading Beds.		Soil and brown sandy loam - -	1 to $1\frac{1}{2}$
	Bottom-bed.	Brown sand with a little laminated grey clay in places - - -	1
		Laminated grey clay - - -	1
		Greenish sand, ferruginous for 3 to 6 inches at base, and containing numerous small green-coated flints averaging from 3 to 4 inches in size - - - - - -	$\frac{3}{4}$ to 1
		To chalk - -	$3\frac{3}{4}$ to $4\frac{1}{2}$
Chalk, rubbly and containing flints - - - - - -			8

The junction of the Reading Beds with the Chalk was even, but slightly undulating.

Mr. Whitaker notes† that "at the brickyard south-south-east of Tilehurst the order of the beds, as well as it could be made out, is as follows:—

Basement-bed of the London clay.	Brown and pale blue mottled sandy clay.
	Brown sand.
Reading Beds.	Light-coloured sands.
	Laminated iron-sandstone, 2 to 5 inches.
	Dark brown sand.
	Light-coloured sands.

"In a pit lower down there is more of the last, with a little light-coloured clay; and, according to a well-sinker, a great thickness of sand above the Chalk.

"In a chalk-pit about a quarter of a mile south of this there is a junction of the bottom-bed, partly in pipes, with apparently reconstructed chalk.

"Near Southcot is much sand."—W.W.

Passing now to the sections in this outlier in the town of Reading, we come first to Coley Hill, where bricks were made for many years on the site of the present recreation ground. On the western side of this Coley brickyard the following section was exposed in 1887 :—

		Feet.
Plateau gravel, consisting of subangular flints, flint pebbles, etc. -		4
Reading Beds.	i. Well-stratified greenish-grey clay and loam, and mottled red, brown, and grey clays and loams - - - - - - - - -	5
	ii. Variegated light-coloured sands - - -	16
	iii. White and ash-coloured sands exposed to -	12

* *See* "Geology of the London Basin," *Mem. Geol Survey*, vol. iv. (1872) p. 197.

† *Op. cit.*, p. 197.

The sands of bed ii. were variously stained and mottled: yellow, light pink, grey, fawn, buff, green, etc., in different shades. They were underlain by the very finely stratified white and ash-coloured sands of bed iii., streaked and stained in places by yellow, buff and orange colours. Numerous thin seams and small nodules of grey plastic clay ("clay galls") occurred interstratified with the sands. Many black specks and fragments of carbonaceous matter were observed in the white sands, also small angular fragments of white flint (resembling fragments of shells but decidedly flint), and fragments of black flint here and there, and occasionally a subangular flint from one to four inches or more in size, often coated with a greenish colour. These white sands are much false-bedded in places.

The section has at times been cut down to the Chalk, and an account by Professor T. Rupert Jones, F.R.S., and Captain C. Cooper King, R.M.A., will be found in the Quarterly Journal of the Geological Society for 1875.* The following abstract of their account is by Mr. Whitaker:—

		Feet.
	Red loamy gravel, chiefly of flints, with some quartz, quartzite, etc., resting on the whole horizontally, but pocketed in an eroded surface of the clay below, averaging - -	5
Reading Beds.	Mottled clays; buff, grey, white, and ochreous false-bedded sands; with layers of blue clay (sometimes peaty, and showing traces of the "leaf-bed"), "clay-galls" (rolled fragments of clay with included flints) some 18 inches in diameter, and occasional ferruginous nodules and subangular flints (one green-coated) -	18 to 30
	Bottom-bed; loamy and pebbly green sands; with oyster-shells, sharks' teeth (and a fragment of the palate of *Myliobatis*), carbonised woody matter, flint pebbles, sharp fragments of flint, a small pebble of schist, another of quartzite, and small angular pieces of chalk.	
	Chalk, junction even, with perforated surface.	

The authors remark that the sands, which are thickest on the west, "suffered considerable denudation eastward before the Mottled Clay was laid upon them," and they draw notice to certain other irregularities in the series, namely, the absence of oyster-shells in the bottom-bed in some places, whilst near by they are abundant; the absence of the leaf-bearing clay in some parts, probably from erosion rather than from thinning out; and the evidence of the partial destruction of some of the beds of the Reading Series before others were deposited that is given by the clay-galls, etc. "This goes to prove the greater complication of processes in the formation of the 'Reading Tertiaries' and adds to the length of time required for them. In any case not only does the rolling of the clay-galls bespeak a flat shore and neighbouring cliff, but their *enclosed flints* clearly indicate a beach, bank, or shoal of flint *débris* at no great distance, whether in fresh, brackish, or salt water."†—W.W.

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* Vol. xxxi., p. 451.

† *Op. cit.*, p. 456.

The bottom-bed of the Reading Series at Coley Kiln has yielded some fossils besides *Ostrea bellovacina*—the following are in the collection of Mr. R. S. Herries:—*

Odontaspis (Lamna) contortidens, *Ag.*	Tellina ?
Pycnodus.	Panopæa.
Cardium (large species).	Ostrea.
Trigonocœlia ?	Echinus.
Nucula Bowerbanki, *Sow.*	

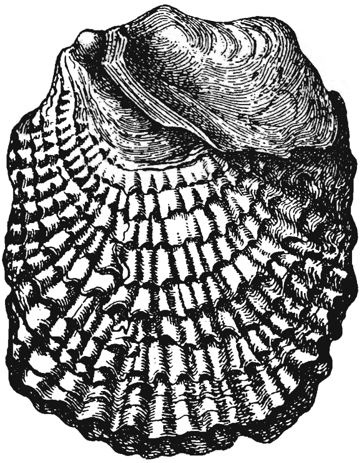

FIG. 8.—Ostrea bellovacina, *Lam.* (⅔ natural size.)

Mr. Whitaker† gives the following account of the sections at Castle Kiln, north of Coley Hill, obtained from two pits, one above the other. The top two beds were much hidden:—

			Feet.
Reading Beds. 33 feet.		Mottled clay, crimson, blue, and brown.	
		Light-brown and white sand, with a thin seam of mottled clay - - - - - - about	5
		Pale green and brown mottled clay, with bands of crimson clay - - - - - - - - -	3½
		White, grey, brown, and yellow sand, with a few blocks of iron-sandstone; at the base a few inches of bright orange sand. The lower part very coarse (a regular grit); false-bedded; pieces of flint in one bed; in a bed of clay about 5 feet from the bottom there are casts of leaves - -	20
	Bottom-beds 4½ feet.	Blue clay, laminated by thin seams of sand - - - - - - - - -	1
		Clayey sand, with green grains - -	1
		Sand - - - - - - - - -	1¼
		Bluish-grey and brownish clay, sandy towards the base; with green grains and grains of yellow sand, and a few green-coated flints - - - - -	1¼

Chalk.—The top part bored (by lithodomous molluscs ?) Junction horizontal and very even.—W.W.

**Proc. Geol. Assoc.*, vol. xiv. (1895–96). p. 412. *See* also W. H. Hudleston, "Excursion to Reading," *Proc. Geol. Assoc.*, vol. iv. (1874–76), p. 519.

† "Geol. of the London Basin," *Mem. Geol. Survey*, vol. iv. (1872), p. 197.

In the pit at the south-east corner of Castle Hill, Reading, and west of the new church (St. Saviour's) a section (in 1887) showed 20 feet in thickness of sand, whitish and ash-coloured, intermixed with a little buff. The whole was very finely stratified, and much false-bedded in the lower part for about six feet upwards from the bottom. A little plastic grey clay occurred in thin seams in places, and nodular lumps of grey and brown plastic clay ("clay galls"), varying in size from half an inch to nine inches in diameter. There were also numerous black specks in horizontal and oblique seams, due, probably, both to carbon and manganese. I was informed that green sand underlaid this white and buff-coloured sand, and then chalk—the foundations of the church reposing in places on the latter at depths varying from 4 to 9 feet from the present surface of the ground.

The following observations on Castle (David's) Hill were recorded by Buckland*:—

"In a hill called David's Hill, west of the town of Reading, on the opposite side of the Kennet to that of the Catsgrove brick kilns, and about one quarter of a mile distant from them, are other large quarries of brick earth, in which many of the subdivisions which have been noted at Catsgrove are not to be recognised, and the entire thickness of some of the pits is made up of the same sands and clays as on the opposite side, but more uniformly disseminated through the whole mass, forming a kind of loam more like No. 12 [of the Catsgrove Section, *see* page 37] than any of the other beds that have been there described; ochreous concretions and pyritical nodules abound in it as in No. 12. The total thickness of this deposition at David's Hill above the chalk is about 40 feet. Water occurs in the subjacent chalk, as soon as they sink 30 feet into it. It is separated from the incumbent brick earth by the bed of green sand, with the same oysters as at Catsgrove."

The section in the deep cutting on the Basingstoke and Newbury branch lines of the Great Western Railway was described by Prestwich† as follows:—

"A feature of considerable interest connected with this [Reading] series was exhibited in the railway cutting for the Newbury branch line through the hill west of and adjoining Reading. Under the mottled clays there were a few feet of sand, and then a local and lenticular mass of very finely laminated light greenish clay abounding in places, with the most beautifully preserved impressions of plants. Beneath this bed were strata of yellow sand succeeded by the bed of green sand with the *Ostrea bellovacina*. I give this section in full, both to show these points and also as a good instance of the irregular deposition of the mottled clay series."

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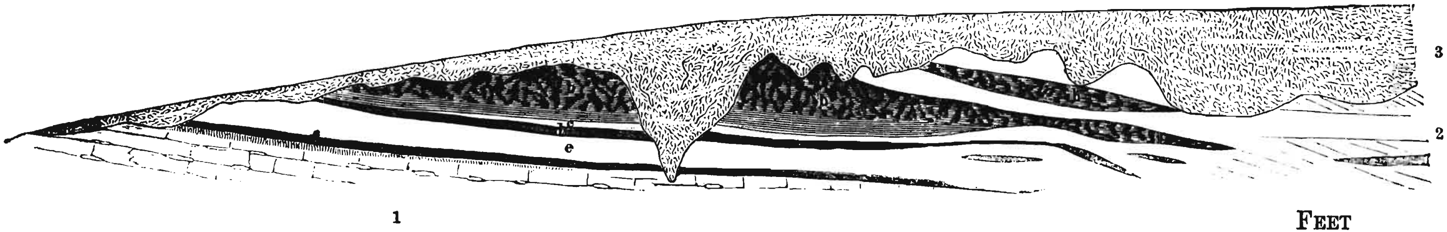
* "Description of a series of Specimens from the Plastic Clay near Reading, Berks." *Trans. Geol. Soc.*, ser. 1 (1817), vol. iv., pp. 277, 281, 282.

† *Quart. Journ. Geol. Soc.*, vol. x., p. 88 (1854.)

FIG. 9.—Railway-cutting west of Reading (Sir J. PRESTWICH).



		FEET
3. Drift Ochreous flint-gravel, varies greatly in thickness.—Averages		10
2. Reading Beds.	*b.* Mottled red and light bluish-grey clay, passing down into slightly laminated light grey clays	20
	c. Laminated yellow sands	2
	d. Thin layers of light grey and greenish clays more or less sandy, some of the seams consist of a very pure and fine clay, slightly mottled with a tinge of red. Extremely perfect and very numerous impressions of leaves are found in this bed	4
	e. Fine yellow sand with slight false stratification. Ferruginous clayey sand in patches —soft ferruginous casts of wood	8
	Green sand with a band of *Ostrea bellovacina* at *f*	2
1. Chalk, with tubular surface perforations filled with green sand		0

Mr. Whitaker* gives the following account of the same cutting:—

"In the railway-cutting west of Reading there was, at the northern end, in 1858, a long and good section, since turfed over. All the beds above the bottom-bed were very irregular; there were many wedge-shaped masses, and much waved bedding. Combining different parts of the section, the following general order was shown:—

			Feet.
		"Gravel, composed almost wholly of flints, 12 feet in extreme thickness, except in a large pipe more than twice that depth.	
Reading Beds.		Brown and blue mottled clay; a few feet.	
		Variously coloured sands, with occasional seams and lenticular masses of clay - - - from	20 to 30
	Bottom-bed.	Bluish-grey and brown clay, roughly laminated - - - - - -	1
		Dark bluish-grey laminated clay; sometimes sandy; casts of shells - -	1
		Bluish-grey and brown clay, roughly laminated clay; casts of shells - -	1
		Dark sands, mostly clayey; throughout of a greenish tint, owing to the presence of green grains; casts of shells and beds of oyster shells; green-coated flints at the base - -	5
		Chalk, with holes (of boring molluscs ?) filled with greensand from the bed above.	

"The junction is even, though slightly waved, and the bottom-bed a little varied in structure in different parts. * * * *

"This section is at the same spot as that given by Mr. Prestwich, [quoted above] that is, in the part of the cutting to the north of the Bath road. Since the time when Mr. Prestwich saw the section, it has been much widened in this part, which will account for any difference from that given above. The large pipe of gravel noticed by him was still to be seen; but I could not find any specimens of the leaves which he found in such numbers in layers of light-grey and greenish sandy clay in the middle of the sands.

"However, a few years afterwards, I saw a like bed with impressions of leaves at Castle Kiln [*see* p. 27] and at Shaw Kiln, Newbury; so that this leaf-bed is perhaps not so local as has been thought." W. W.

The bottom-bed has recently been well shown in a brickfield between this railway cutting and Tilehurst. The section was as follows:—

Section in Mr. Jesse's Pit, ¼-mile south-east of the Barracks, Reading.

			Feet.
Drift.		Gravel very coarse; subangular flints, many large quartzite pebbles and boulders, etc. -	14 to 16
Reading Beds.		Sand, buff and white, much false bedded - -	8 to 10
	Bottom-bed	Clay, bluish-grey, stratified - - - -	2 to 2½
		Oyster-bed - - - - - - - -	½ to 1
		Clay laminated, grey, with green sand -	1½
		Sand, green with clay and oysters, green-coated flints at base - - - - -	3 to 4
		Chalk, with tubular holes filled with green sand.	

* "Geology of the London Basin," *Mem. Geol. Sur.*, vol. iv., 1872, pp. 197, 198.

In this excavation an impersistent layer, about 10 yards in length, of subangular green-coated flints occurred in the lower part of the buff sands overlying the bottom-bed, and a similar bed has been noticed in a like position in a sand-pit a short distance to the east.

The upper oyster bed had been exposed on the floor of the pit over an area of about 60 by 20 yards. It seemed to thin out in a northerly direction. The shells were mostly *Ostrea bellovacina*, many having the valves united, but there were also a large number of shells identified by Messrs. Sharman and Newton as *Ostrea gryphovicina*. The largest specimens of *Ostrea bellovacina* occurred near the base of the bottom-bed, and continued upwards for about 3 or 4 feet in the glauconitic olive-coloured green sand.*

Mr. Ll. Treacher obtained from this pit the following fossils which have been identified by the Survey:—

Bottom-bed of Reading Beds.

Odontaspis (Lamna) contortidens, *Ag.*	Cytherea ?
" " macrota, *Ag.*	Modiola elegans ? *Sow.*
Cerithium ?	Nucula.
Dentalium.	Nuculana.
Natica.	Syndosmya.
Corbula ?	Tellina ? 2 sp.

West of this brickfield are the extensive excavations connected with Messrs. Colliers' Brick and Tile Works. The following was the section on the northern side of the Rookery, Prospect Hill Park, in 1898.†

		Feet.
London Clay.	Basement-bed, lower part only, stratified sand and clay - - - - - - -	4 to 5
Reading Beds.	Mottled crimson, grey, etc., variegated clay, about	30 to 40
	Buff and white sand, false-bedded in places not bottomed, about 10 feet exposed.	

Some indurated calcareous sand occurred in the buff sands.

At Westwood Kiln nearly the whole section shows mottled clays of considerable thickness with buff sand cropping out at their base.‡

At Norcot Kiln, close to Norcot Farm, the section shown in 1898 was as follows:—‡

			Feet.
Plateau gravel - - - - - - - about			6
London Clay.	Clay, mottled brown and grey - - - -		10
	Basement-bed.	Sand and clay interstratified. White and black flint pebbles in brown sand (in lower part), and casts of shells in ferruginous sand at, and near, base - - - - - -	9
Reading Beds.	Clay mottled crimson and grey - - -		7 to 10
	Sands, buff and white.		

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* See *Proc. Geol. Assoc.*, vol. xv. (1897-8), pp. 304-305.
† *Ibid.*, p. 306. ‡ *Ibid.*, p. 307.

CHAPTER V.—READING BEDS.

Main Mass.

The main mass of the Reading Beds forms an irregular and somewhat narrow band, along the sloping ground southward of the River Pang by Bucklebury, Stanford Dingley, Bradfield, and Englefield. The beds disappear beneath the valley deposits of the River Kennet, and continue underground north of Sulhampstead Park, Sheffield Bottom, to Whitley Manor Farm, where they re-appear at the surface, and form the escarpment westward and northward of Whitley Hill and Southern Hill. They continue through Reading northwards of Whiteknight's Park and westward of Earley Court by Holme Park and Sonning, then south-eastwards, disappearing beneath the valley deposits of the River Loddon at Whistley Green, and re-appearing at the surface at Stanlake Park, Twyford, and Ruscombe.

Southward of their outcrop the Reading Beds are continuous underground, beneath the London Clay, throughout the whole of the southern part of the district.

Mr. Aveline remarks that to the west of Bradfield the boundary line of the Reading Beds is indicated by the occurrence of numerous and large swallow-holes. At Bushnell's Green, a mile east of Bucklebury, he noted white sand.

A well at Jennet Hill, Stanford Dingley, passed through 42 feet of Reading Beds into chalk.*

Mr. Bennett notes a pit north of Bradfield Workhouse which gave the following section:—

		Feet.
Reading Beds.	Brown sandy clay - - - - - -	2½
	Brown clayey sand - - - - - - -	2½
	Buff sand, fine, evenly bedded, with some black spots, 7 feet shown but not bottomed.	

The following is from Mr. Aveline's note:—

"Less than three-quarters of a mile from Bradfield, on the road to Englefield, is a brickyard; here there are crimson, green, and blue mottled plastic clays, with a little light-coloured sand."†

At about the same place, mottled red, grey, and brown clay was recently exposed in a small pit on the western side of the road in Kiln Copse, a short distance north of the Crown Inn, north-westward of Bradfield Brewery.

Wells for the supply of Bradfield College show the full thickness of the Reading Beds to be about 70 feet in this part of the district.‡

* "Water Supply of Berkshire," *Mem. Geol. Survey* (1901), p. 76.
† "Geology of the London Basin," *Mem. Geol. Survey*, vol. iv. (1872), p. 186.
‡ "Water Supply of Berkshire," *Mem. Geol. Survey* (1901), pp. 30, 31.

In a sandpit in Englefield Common Wood on the sloping ground eastward of the Bourne, and a little south of Bradfield Brewery, the following section was exposed—

Reading Beds.	Mottled clay - - - - -	4	24 feet.
	Buff-coloured sand - -	15 to 20	

Between Englefield and Reading the Reading Beds are hidden to a large extent by Drift, but well-sections at Burghfield proved their thickness to be 70 and 76 feet.*

Red clay was noted near the bank of the Foundry Brook, south of Whitley Manor Farm, and a little to the north there are, or have been, very fine sections in the brickfields on the east bank of the River Kennet, known as the Rose Kiln, the Waterloo Kiln and the Katesgrove Kiln, the site of the last named of which is now built over and in the town of Reading.

At Rose Kiln Mr. Whitaker records a section, above ninety yards in length, showing wavy or disturbed bedding. (*See* Fig. 10, page 34.)†

In April, 1888, the following section was shown near the southern end of the brickyard at about 3 or 4 chains north of the hedge, where the beds are shown dipping towards the south:—

		Feet.
Soil and mottled clays worked up with gravel - -		6
Reading Beds.	Mottled clay, grey, green, brown, and crimson in upper part - - - -	6
	Sand, occasionally, ash-coloured, orange, fawn, and pinkish, but mostly white -	18
	More or less laminated grey clay in bands alternating with white and brown sands (in about equal proportions) the uppermost clay-bed being mottled in various colours - - - - - - - -	8
	White sand, loose but well stratified - -	6

Northwards there is a gentle anticlinal, and consequently an increase of thickness of the mottled clays by the reverse dip. At 2 chains north of the road leading eastwards to the Basingstoke main road, there was a fine section showing about 15 feet of mottled red, blue, grey, and brown clay overlying white and buff-coloured sands.

At the southern part of the excavation at Rose Kiln the following section was exposed:—

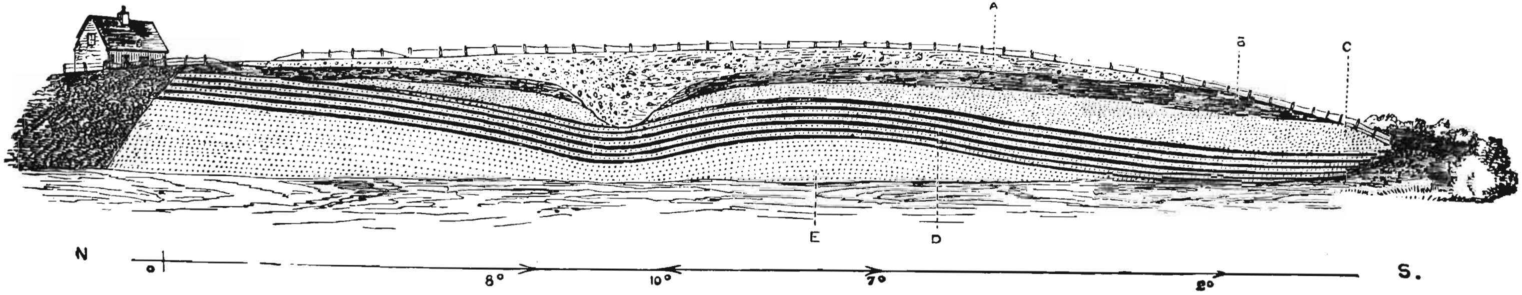
Reading Beds.	Mottled red and grey clay and loam	3	23 feet
	White sand with patches of red and brown in places, and with a few bands of grey clay in the lower part - - - - -	20	

A little to the north on the western slope of Southern Hill and on the low ground bordering the Kennet is the Waterloo brickfield, worked by Messrs Poulton. In it leaf-beds are occasionally

* "Water Supply of Berkshire," *Mem. Geol. Survey* (1901), pp. 34, 35.

† "Geology of the London Basin," *Mem. Geol. Survey*, vol. iv. 1872, pp. 186, 187.

Fig. 10.—Section at Rose Kiln, S. of Reading. (W. WHITAKER).



Note. The figures show the amount of the dip at the points above them. The 10° should be a little more to the right.

A. Gravel and clay, 22 feet deep in the pipe.

			FEET
Reading Beds	B.	Pale-blue and green clay, mottled with brown, passing into the bed below - - - - -	7
	C.	Light-coloured sands, chiefly white - - - - - - - - - - - - -	
	D.	White, pale green, and brown sands, alternating with beds of clay, for the most part mottled with red, crimson or rich lilac - - - - - - - - - - -	8
	E.	Buff sands, showing lines of bedding - - - - - - - - - - - -	18
			33

very well seen. They are in a similar position in the Reading Beds to those already noticed in the railway cutting and at Castle Hill on the opposite side of the River Kennet (pages 27 to 30). They occur near the base of the series above the greenish sandy bottom bed.

At the south-eastern corner of this brickyard, the following section was exposed in March, 1888, and extended northwards for about 5 chains:—

		Feet.
Reading Beds.	Light-buff and ash-coloured loamy clay with bands of brown sand, about -	10
	Dark mottled crimson and grey stiff clay - - - - - - -	15
	Dark red and crimson clay forming a very marked layer - - from	$1\frac{1}{2}$ to 2
	Greenish and greyish loamy clay mottled with red in places -	10 to 12
	Buff and white sand	

The beds dip at a slight angle southwards. The clay beneath the marked red band, gradually thins northward, and at about 5 chains distant is reduced to a thickness of 6 feet only, and is underlain by buff-coloured sand, 6 feet of which was exposed. This sand at a distance of about 2 chains further northward was shown to be from 10 to 15 feet thick and not bottomed. It was of various colours—green, white, brown, grey, pink, and other tints being shown; and was slightly loamy and indurated in places.

In the south-west corner of the brickyard an excavation on the low ground adjoining, and but little above the level of the Kennet marshes, showed a section in the lower part of the buff and whitish coloured sands (which occur here beneath the mottled clays), consisting of laminated grey loams and clays interstratified with buff sands. The loams and clays in places somewhat resembled fuller's earth, and contained numerous fossil leaves and a few ferns.* This part of the pit has been obscured for several years, but a new section showing what is probably the same leaf-bed was open in October, 1902, some 200 yards north of the old locality. The details were as follows:—

		Ft.	In.
Reading Beds 1.	Greyish sand, somewhat ferruginous in places, with many layers of laminated grey clay, containing leaves and other vegetable remains; one of these clay layers 9 inches thick, close to the bottom of the bed, yielded the best specimens of leaves. Greatest thickness - - - - -	3	6
" " 2.	Buff current-bedded sand, rather coarse, with a few very thin layers of clay here and there. Exposed to - - - - - -	4	

A note on the leaves from this place will be found at p. 40.

* *See also* W. H. Hudleston, *Proc. Geol. Assoc.*, vol. iv. (1876), pp. 520, 521.

As no complete analysis of the mottled clay from the Reading Beds at Reading appears hitherto to have been published, a sample of the clay was obtained from this brickfield.

The following analysis of the specimen was made in the Geological Survey Laboratory by Dr. W. Pollard* :—

SiO_2	53·43
TiO_2	·84
Al_2O_3	18·77
Fe_2O_3	9·42
CaO	·51
MgO	1·40
K_2O	3·39
Na_2O	·54
H_2O at 105	5·55
„ above 105	6·59
Total	100·44

Trace of Li_2O, MnO.

FeO cannot be estimated with any certainty, owing to the presence of a little organic matter All Iron calculated as Fe_2O_3.

Sand	21·9 %
Combined Silica	31·6 %
	53·5

The Katesgrove workings are a little north of the Waterlow kiln. They are very old, and the oyster-beds at the bottom of the Reading Beds long ago attracted attention. Dr. James Brewer, in a letter to Dr. Sloane, dated January 13th, 1699, mentioning sending oyster-shells to him, and, referring to the place where he dug them out says, "where for so many succeeding generations they have been found."

The following is a part of a second letter, from Dr. Brewer to Dr. Sloane† :—

"*Reading*,
"*January 25th*, 1699.

"Sir,

"In answer to your last, be pleased to take the following account, the observations which I personally made, were with all the exactness as the subject and place would admit. The circumference then, where these Oyster-shells have been digg'd up, and found, contains (as I before hinted to you) as is judg'd, between 5 and 6 Acres of Land. The foundation of these Shells is a hard Rocky Chalk, and above this Chalk the Oyster-shells lye in a bed of green Sand, upon a level, through the whole circumference, as nigh as can possibly be judged; this Stratum of green Sand and Oyster-shells is (as I measur'd) nigh 2 foot deep. Now, immediately above this Layre, or Stratum of green Sand and Shells, is a bed of a bluish sort of Clay, very hard, brittle, and rugged; they call it a pinny Clay, and is of no use. This Bed, or Layre of Clay, I found to be nigh a yard deep; and immediately above it, is a

*See also Whitaker, *Mem. Geol. Survey*, vol. iv., p. 101; T. Reeks and F. W. Rudler, "Catalogue of Specimens of British Pottery, &c.," Appendix, p. 288; and "British Clayworker" for 1901, p. 467.

† Published in "Philosophical Transactions," vol. xxii., p. 485, 1700–1.

Stratum of Fuller's-earth, which is nigh two foot and a half deep; This Earth is often made use of by our Cloathiers; and above this Earth is a Bed, or Layre, of a clear fine white Sand, without the least mixture of any Earth, Clay, etc., which is nigh seven foot deep: then immediately above this is a stiff red Clay, (which is the uppermost Stratum) of which we make our Tiles. The depth of this can't be conveniently taken, it being so high a Hill, on the top of which hath been, and is dug a little common Earth about two foot deep, and immediately under appears this red Clay, that they make Tiles withal; as the Gentleman that lives on the spot tells me: I should also have acquainted you that this very day with a Mattock I dug out several whole oysters with both their Valves, or Shells lying together, as Oysters before opened, in their Cavity there is got in some of the pre-mentioned green Sand. These Shells are so very brittle, that in digging for them, one of the Valves will frequently drop from its fellow, but 'tis plainly to be seen that they were united together, by placing the Shell that drops off to its fellow Valve, which exactly corresponds; but I dug out several that were entire; nay, some double oysters with all their Valves united. **** The account that I have here given you of these Shells, and strata's of Sand, Clay, etc., is what I yesterday and this day observed, and try'd on the spot, therefore you may depend on the faithfulness of it."

Dr. Buckland, writing in 1817, remarks that the section given above "differs as little as might be expected from that now exposed at Reading." *

The oyster-bed at "Cats Grove" near Reading is mentioned by Robert Plot in his *Natural History of Oxfordshire,* published in folio at Oxford, 1705 (*see* page 120).

Dr. William Stukeley in "Itinerarium Curiosum" (folio, London, 1724, at p. 59) also refers to this locality. He says that near the trench the Danes made between the river Kennet and the Thames is Catsgrove Hill, a mile off Reading; in digging there they find first a red gravel, clay, chalk, flints, and then a bed of huge petrified oysters, 5 yards thick, 20 feet below the surface; their shells are full of sea-sand.

Mr. Whitaker gives the following note on the section at this kiln † :—

"At Katesgrove kiln the lower part of the section was not so clear at the time when that neighbourhood was mapped by the Geological Survey as when it was measured by Dr. Buckland in 1814,‡ or by John Rofe in (or before) 1834 §; indeed neither the Chalk nor the bottom-bed were laid open. I therefore give Dr. Buckland's description, with Mr. Rofe's corrections for the bottom part.

	Feet.
13. Clay, sand, and gravel.	
12. Soft loam, lower part ironshot and sometimes with ochreous concretions and decomposing nodules of iron-pyrites (used for soft bricks) - - -	about 11

* *Trans. Geol. Soc.*, vol. iv., p. 277.

† "Geology of the London Basin," *Mem. Geol. Survey*, vol. iv. (1872) pp. 188, 189.

‡ *Trans. Geol. Soc.*, vol. iv., p. 277 (1817).

§ *Ibid.*, Ser. 2, vol. v., p. 127 (1837).

			Feet
11.	Dark red clay, partly mottled and mixed with grey	about	4
10.	Light ash-coloured clay, with fine sand of the same colour (used for bricks) - - - - - -	,,	7
9.	Fine sand, laminated and partly mixed with clay (used for tiles) - - - - - - - - -	,,	4
8.	"White vein." Fine ash-coloured sand with a little clay, in some parts passing into loose white sand (used for bricks) - - - - - -	,,	5
7.	Dark red clay mottled with blue (used for tiles) -	,,	6
6.	Lowest brick-clay, light grey, with fine sand - -	,,	5
5.	White sand (used for bricks) - - - - - -	,,	4
4.	Fuller's earth - - - - - - - . -	,,	3
3.	Yellowish quartzose sand - - - - - -	,,	5

"The continuation downwards had better be given from the later measurements of Mr. Rofe:—

		Inches.
2.	Clay parted by small seams of selenite-crystals - -	19
	Sand, with small green grains, and sometimes green nodules, flints (rolled and angular) and oyster-shells	14
	Brown clay, with oyster-shells (larger than those in the bed above) - - - - - - - -	13

1. Chalk, the uppermost foot with tubular hollows filled with sand.

The numbers of the beds are those in Dr. Buckland's paper.

No. 13 includes the Drift, and perhaps a little London Clay.

No. 12 may be the basement-bed of the London Clay.

Nos. 11 to 3 are the sands and plastic clays of the Reading Beds.

No. 2 is the bottom-bed.

"The upper part of this large pit, however, was fairly clear when I mapped the Reading District (1858) and showed the following beds:—

Gravel.

Basement-bed of the London Clay.	Brown and bluish mottled sandy clay, with a little ironstone, containing casts of shells and lines of greenish sand.
	Dull brownish sand and loam, with layers of ironstone, and sometimes of clay; at one part two beds of shells in greenish sand.

Crimson mottled plastic clay of the Reading Beds.

"The beds below were hidden at this spot; but near by, at a lower level, there was the section below:—

Light-coloured sands, with two beds of crimson plastic clay, and light-coloured mottled clays interspersed.

Green plastic clay."—W. W.

In June, 1888, the Chalk was worked by a well, and we were told by the workmen that the top of the Chalk was 30 feet below the floor of the pit. This well was on, or nearly on, the site of the proposed Church of St. Michael and All Angels. Now, in 1902, the working has been abandoned and the ground is being built over.

The Reading Beds, consisting of light-brown and grey loams and sands, were exposed in a section in Clover lane, 6 chains east of the Wokingham Road, Reading.

The following account of the Reading Beds near Sonning is from Mr. Whitaker's *Geology of the London Basin.** In a chalk-pit between the turnpike road and the Great Western Railway, near the thirty-fourth mile-post on the latter, there is the following section:—

		Feet.
Flint-gravel		8 or 10
Reading Beds.	1. Blue and red mottled plastic clay; only seen at one part	1
	2. Bottom-bed, chiefly consisting of clay; at the base green-coated flints, rounded and angular - about	4

Chalk; the uppermost 8 or 9 inches full of holes (? of boring molluscs).

The junction with the Chalk is rather uneven.

In sinking a well at Holme Park Farm the Chalk was not reached after sinking 30 feet, when the work was stopped. Below the wood on the west of the farm there is sand.

In the gravel pit at Sonning there is, at one part, between the gravel and the Chalk, a small trough of the bottom-bed.

In making the cutting for the Great Western Railway near Sonning, a good section was exposed. It is now quite hidden; but an account has been given by Prestwich, from which the following is taken †:—

		Feet.
Subangular ochreous flint-gravel, varies in thickness, averages		12
London Clay.	Brown clay with septaria	? 5
	Basement-bed, brown clay with irregular layers of yellow sand, patches of green sand, flint pebbles, and tabular calcareous concretions. Fossils throughout, but most abundant in the blocks of stone	4 to 5
Reading Beds.	Slightly mottled bluish and red clay, eastwards grey	10
	Irregular seam of sand, yellow or light bluish	2
	Mottled brown and blue clay } Dark grey clay } Mottled red and grey clay, the lower part of a lighter colour }	23
	Irregular seam of white sand	2½
	Red clay	1½
	Light-grey clay	½
	Very dark grey clay	6
	Red clay	2
	Light-grey clay	1
	Yellow sand with bands of brown clay	2
	said to be continued as follows:—	
	Dark clay	10
	Ash-coloured sand	5
	Green-coated flints, &c.	1
Chalk.		

* *Mem. Geol. Survey*, vol. iv. (1872), p. 189.
† *Quart. Journ. Geol. Soc.* vol. vi. p. 266, and vol. x. pp. 88, 89.

The basement-bed rests on a somewhat irregular and worn surface of the Reading Beds, and "this section also shows the peculiar waved and irregular lines of bedding of these strata."

W. W.

The Reading Beds are worked at the brickfield at Ruscombe, and in 1891 the section was as follows :—

		Feet
Plateau.	Gravel - - - - - - - - - -	3
Reading Beds.	Mottled clay on the south side of the working, not bottomed - - - - - about	30
	On the north side of the working the mottled clay was only about 17 feet thick and was underlain by yellow current-bedded sand, of which 10 feet was shown.	

In October, 1902, the section seen was more to the north than in 1891, and showed 12 feet of current-bedded sand on the south side, and greyish clay on the north side. Mr. Ll. Treacher told us that this clay had not been found below the sand.

The bottom-bed, dark clay, 6 feet, black stones and green-coated flints, 3 feet thick, was traversed by the well at Twyford Vicarage.*

The Reading Beds have been proved in several wells to the south of their outcrop.

At Woolhampton their thickness was found to be about 72½ feet.† At Oakfield, Stratfield Mortimer, a thickness of 69 feet was recorded,‡ and in other wells near that place beds of "stone" or "rock," probably indurated sand, were found in the Reading beds.§ At Bearwood the unusual thickness of 86 feet is stated to have been found,|| but possibly this is an error, for at Wokingham the thickness in one well was found to be 70 feet, and in another only 68 feet.¶

Note on Plants from Waterloo Brickyard, Reading.

By E. T. Newton, F.R.S.

The plants collected from the Reading Leaf Bed in the railway-cutting, Reading, and described by Sir J. D. Hooker in a "Note" following Prestwich's paper,** were not named; and I am not aware that they have since been determined; their fragmentary nature preventing any useful comparison with other specimens. A series of leaves, etc., were collected for Mr. J. H. Blake some years ago, by Mr. J. Rhodes, from these beds in the Waterloo Brickyard, and were examined by Mr. G. Sharman and myself. Certain of these are probably the same forms as were figured by Sir J. D. Hooker. Two or three fairly good fronds of a fern seem to us to agree precisely with the form

* "Water Supply of Berkshire," *Mem. Geol. Survey* (1901), p. 87.
† *Op. cit.*, pp. 101, 102. ‡ *Op. cit.*, p. 78. § *Op. cit.*, p. 77.
|| *Op. cit.*, p. 25. ¶ *Op. cit.*, pp. 98, 99.
** *Quart. Journ. Geol. Soc.* vol. x. p. 163 (1854).

figured by Saporta* as *Asplenium subcretaceum*, afterwards named by Mr. J. Starkie Gardner† *Anemia subcretacea*, and we have referred the Reading specimens to the same species.

FIG. 12.
Aralia ? cf. A. looziana, *S. & M.*

FIG. 11.
Anemia subcretacea, *Sap.*

FIG. 13.
Laurus ?

Several tripartite leaves more or less fragmentary resemble those of the Maple (*Acer*). Other triple forms more deeply divided and with serrated edges are evidently more nearly related to the *Aralia* as figured by Saporta and Marion,‡ and may be compared with their *Aralia looziana*. Some large ovate leaves remind one of the Laurel (*Laurus*), and have the general form and venation of *Laurus jovis*, de la Harpe.§ Other smaller leaves, narrower and more lanceolate, resemble those of the Willow (*Salix*). One example of the basal part of a leaf bears a very close resemblance to the *Litsaea* figured by Saporta and Marion,‖ and another fragmentary specimen has venations, so far as preserved, resembling the *Viburnum*.¶

There are two or three examples of what appear to be small cones with slender bracts broken across; but at present they remain undetermined.

Quite recently Mr. O. A. Shrubsole obtained a series of plant-remains from another part of Messrs. Poulton's pit (about 200 yards to the north, see p. 35), and these seem mostly to be referable to one or other of the forms above mentioned, but one or two may be different, and they have not yet been determined.

E. T. N.

* *Mem. Soc. Geol. Fr.*, Ser. 2., vol. viii., p. 315., pl. ii., fig. 4. (1868).
† *Brit. Eocene Flora*, p. 45., pls. viii. and xi., Pal. Soc. (1880).
‡ *Heersienne de Gelinden*, p. 77, pl. xiii., figs. 1–3 (1877).
Mem. Couronnés, L'Acad Royale Belg. (1878).
§ "Geology of the Isle of Wight," pl. vii., fig. 3, *Mem. Geol. Surv.* (1862).
‖ *Loc. cit.*, pl. xi., figs. 1–3. ¶ *Idem.*, pl. xii., fig. 1.

CHAPTER VI.—LONDON CLAY.

This great clay formation appears at the surface within the area occupied by the main mass of the Reading Beds, with Bagshot Beds and Drift-deposits overlying it in many places; and it also occurs on some of the outliers of the Reading Beds, where it is, in most cases, itself partially covered by Drift.

It consists of stiff brown and dark bluish-grey clay, with layers of concretionary masses of argillaceous limestone known as septaria. It is very uniform in character, excepting near the top, which is often sandy, and at the bottom, where there is a very well marked and persistent basement-bed from 6 to 18 feet in thickness.

This basement-bed consists of loam and clay interstratified with brown and olive-green glauconitic sand. It often contains septaria, nodules of concretionary argillaceous ironstone, flint pebbles, lignite, and iron pyrites, and sometimes the whole bed is blackish, owing to the presence of carbonaceous matter. It is often very fossiliferous.

The well at the Wokingham Waterworks * in the Finchampstead Road passed through 273 feet of London Clay, and the top of the well is about 19 feet below the level of the bottom of the Bagshot Beds, so that the London Clay is about 292 feet thick at Wokingham, on the eastern border of the district. It thins towards the west At the Poplars on Burghfield Hill a well passed through 205 feet of London Clay; and, as its site is close to the edge of the Bagshot Beds, that must be nearly the full thickness of the London Clay.† At Woolhampton the total thickness was found to be only 176 feet.‡

The following fossils from the top beds of the London Clay at Wokingham, were collected by Mr. Ll. Treacher, and identified by the Survey Palæontologists:—

Serpula bognoriensis, *Mant.*
Nucula Bowerbanki ? *Sow*, (internal cast).
Protocardium nitens, *Sow.*
Modiola elgans, *Sow.*
Cytherea tenuistriata, *Sow.* var.
Cyprina scutellaria, *Lam.* (= C. planata, *Sow.*)
Astarte rugata, *Sow.* var.
Turritella (internal cast).
Pyrula Smithi, *Sow.*
Pleurotoma teretrium, *Edw.*
,, sp.
Pisania (Buccinum) labiata, *J. de C. Sow.*
Natica labellata, *Lam.*
Fusus, sp.
Cypræa Bowerbanki, *Sow.*
Cassidaria nodosa, *Solander.*
Actaeon (Solidula) simulatus ? *Sow.*
Odontaspis elegans, *Ag.*
,, macrotus, *Ag.*

* "Water Supply of Berkshire," *Mem Geol. Survey* (1901), p. 97.
† *Op. cit.*, p. 35.
‡ *Op. cit.*, p. 101.

Outliers North of the Thames.

There is a small outlier of London Clay north-east of Emmer Green. As has already been stated it is brought in by three faults arranged in the form of a triangle, and is described by Mr. Whitaker as follows:—*

"The London Clay * * * * is mostly of a bluish-grey colour, but partly brown and containing *septaria* (with fossils) and ironstone.

"The basement-bed is not seen in the section; but I was told that in sinking in the orchard just by, and at the same level as the Reading Beds in the brickyard, below about 30 feet of blue clay, there was a sort of loam, with a little green sand and with shells. I saw some of the shells which belong to the basement-bed.****Some of the *septaria* lying about are very full of *Ditrupa plana* and probably come from the same bed. *Pectunculus brevirostris* is also abundant."—W.W.

Outliers South of the Thames.

Frilsham.—The following account of this outlier is also by Mr. Whitaker† :—

"The outlier of the Reading Beds near Frilsham, as before noticed, is capped with London Clay, the boundary-line of which is much hidden by gravel, as well as by the thick woods on the high ground. The basement-bed is exposed in the road-cutting to the west of Frilsham House; it contains flint-pebbles and ironstone, is underlaid by mottled clay, and dips to the south. On the hill, above Frilsham, by the spring before mentioned (p. 20), there are the remains of a small brickyard, with a shallow section in brown London Clay. Along the road, higher up, a few rounded flints occur in the clay. In the brickyard farther southward, by the hedge at the highest part, there is a little of the basement-bed above red mottled clay; and, lower down, in a mass that has slipped over the Reading Beds, are two small sections of the same, which consists of light brown loam, with a few scattered flints (rounded and sub-angular), and pieces of ironstone. In the eastern part of this irregular-shaped outlier there are no sections; but in the fields on the north-east of Rusdens [*i.e.* east of Field Farm] there are many of the large flint-pebbles of the basement-bed. Just above the kiln, nearly a mile to the south of Yattendon, there is mottled light-brown and grey sandy clay passing into the basement-bed, consisting of the usual brownish loam; the bottom of this was not shown."—W.W.

Yattendon.—There are two outliers of London Clay to the south of Burnt Hill on the Yattendon outlier of Reading Beds.

Mr. F. J. Bennett describes the larger outlier as a thin capping, and adds that the section at Luckshall Farm Kiln shows 8 feet of rusty brown clay resting on red mottled clay. The former being, he believed, London Clay.

* "Geology of the London Basin," *Mem. Geol. Survey*, vol. iv. (1872), p. 305.
† *Op cit.*, p. 300.

Tilehurst.—Much of the eastern part of the Tilehurst-Reading outlier of Reading Beds is covered by London Clay, which is, however, to a great extent hidden under Drift. A well gave 42¾ feet of London Clay including the basement-bed, which measured 12¾ feet.*

Sections at a brickyard south south-east of Tilehurst and at Norcot Kiln have already been described. (See pages 25 and 31.) At the last-named place, casts of shells were found in iron-sandstone in the basement-bed. The following list is from Mr. Whitaker's *Geology of the London Basin*, 1872. (See pages 198, 583–6)

Aporrhais Sowerbyi, *Mant.*	Cyprina Morrisi ? *Sow.*
Cassidaria.	Cytherea obliqua ? *Desh.*
Fusus.	Pectunculus terebratularis. *Lam.* ?
Natica.	Ditrupa plana. *Sow.*
Pyrula.	

A second patch of London Clay occurs on the Tilehurst outlier. It is in Prospect Hill Park, and a section, showing the basement-bed, has already been given at page 31.

Wargrave—Bowsey Hill.—A considerable portion of the Wargrave outlier of Reading Beds in this district is covered by London Clay, which must be of considerable thickness. Mr. Whitaker† notes the occurrence of the basement-bed along the road rather more than half-a-mile east of Chamberlain's Farm, which is apparently the place named Gibstrude Farm on the new series of the map. In it he observed a bed of flaggy sandstone at least a foot thick.

The basement-bed was also seen at the side of a field west of Bear Grove.

Main Mass.

The main mass of the London Clay extends practically over the southern half of the district. It is, however, largely covered by the Bagshot Beds and by Drift. The formation is so uniform in character that a detailed description of sections is unnecessary. The basement-bed is, however, of interest on account of its abundant fossils, and deserves more particular notice.

At Burghfield, when the serpentine road-cutting was made on the sloping ground to the east of Hosehill Farm, a little more than one mile and a quarter north-west of the church, a good section of London Clay was exposed. It consisted mostly of well-stratified brown loam and clay. No fossils were seen.

At the brickyard a quarter of a mile south-west of Hosehill Farm, many fossils, mostly fragile, were observed in 1886 in a thin bed in the London Clay, exposed in a section in the south-eastern corner of the brickyard, a little below the general floor of the working.

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* "Water Supply of Berkshire," *Mem. Geol. Survey* (1901), p. 85.

† "Geology of the London Basin," *Mem. Geol. Survey*, vol. iv. (1872), p. 300; and "Geology of London," vol. i., p. 251.

This is the locality noticed by Mr. Whitaker* as follows:—"At the brickyard at Woolwich Green, north of Sulhampstead Abbots, there is a large section in brown London Clay.* * * When I saw the section (in 1860), the basement-bed was just cut into at the northern end. It consists of the usual brown loam, and, although but little of it was to be seen, two or three beds of fossils were shown. It also contained a little clayey ironstone and some selenite, which latter I had not noticed in the basement-bed elsewhere." The fossils found here were as follows†:—

Actæon.
Aporrhais Sowerbyi, *Mant.*
Fusus.
Natica labellata, *Lam.*
Natica, sp.
Pleurotoma, sp.
Avicula, sp.
Cardium, sp.
Corbula, sp.
Cyprina Morrisi, *Sow.*
Cytherea obliqua ? *Desh.*
Modiola, sp.
Nucula, sp.
Glycimeris (Panopæa) sp.
Pectunculus brevirostris, *Sow.*
,, decussatus, *Sow.*
Tellina, sp.

The following section was exposed in 1886 in a small clay pit at the eastern end of Bennett's Hill Copse, at the foot of the slope, nearly one mile N.N.W. of Burghfield Church:—

			Ft.	In.
London Clay.		Brown loam and clay, more or less stratified	8	6
	Basement-bed.	Greenish sand interstratified with brown clay, with three beds containing numerous shells; and with black flint pebbles here and there at the base, some of which measured $2\frac{1}{2}$ inches in their longest diameter	3	6
		Brown sand	1	0

There is another clay pit one mile N.W. by N. of Burghfield Church, on the western side of the road, known as Bennett's Hill, adjoining the copse of that name. The following section was exposed in 1886:—

			Ft.	In.
London Clay.		Brown loam and clay, more or less stratified	9	0
	Basement-bed.	Brownish and greenish sand, interstratified with nine thin beds of brown and grey clay; and containing a mass of shells in a fragile condition, throughout	2	3
		Slightly indurated and laminated brown loam and clay, with indications of plant remains (?)	0	6
		White sand, finely stratified and containing irregular-shaped orange-coloured sandy concretions	2	0

* "Geology of the London Basin," *Mem. Geol. Survey*, vol. iv. (1872), p 295.
† *Op. cit.*, p. 583, etc.

			Ft.	Ins.
London Clay, (*cont.*) 20 feet.	Basement-bed, (*cont.*) 11 Feet.	Brown sandy loam with orange-coloured concretionary nodules at the top- - - - - -	4	0
		Hard greenish-grey and brown sandstone, the bottom very irregular. From 9 inches to	1	6
		Mottled brown and grey clay containing nodules of clay and a few scattered large oval flint pebbles, which measured from 4 to 5 inches in longest diameter - - -	0	9
Reading Beds ?		Loose brown sand, more or less stratified, and containing some greenish bands in places exposed to - -	3	0

The hard sandstone mentioned in the above section formed the floor of the pit, but it had been broken through in places in order to obtain some of the loose sand beneath it. The surface area of this hard bed exposed measured 24 by 8 feet.

Southern Hill, Reading, is formed of London Clay with a capping of Drift. The basement-bed with shells was exposed in Whitley Hill by the road side.

Mr. Whitaker* remarks that: "At Katesgrove Kiln, the basement-bed is shown, and has yielded many fossils. When paying a flying visit to this section in 1862 with my colleague, Mr. T. McK. Hughes, we found a slab of hard stone in the basement-bed; it was crowded with *Ditrupa* and other fossils, the most noteworthy being some dozens of specimens of the little *Hemiaster Bowerbanki*. Mr. R. Gibbs, our fossil collector, also found a number of the same. The species had not been recorded as occurring in this bed, unless as the *Spatangus*, got by Mr. Prestwich at Sonning."—W. W.

The following note of the basement-bed at Katesgrove Kiln was made in 1883 :—

	Ft.	In.
Hard ferruginous sand with a layer of shells - - - -	0	4
Sand - - - - - - - - - - -	0	3
Green sandy clay full of shells - - - - - -	0	6
Sand - - - - - - - - - - -	0	6
Green sandy clay full of shells - - - - - -	0	3
Dark clay - - - - - - - - - - -	1	0
Carbonaceous bands - - - - - - - - -	0	10
Dark clay - - - - - - - - - - -		

The hill in the side of which this excavation is made is known as Bob's Mount. At the northern end, the following section was exposed in March, 1888, during the building of the houses along the new street, at a spot situated two chains south of the end of Hill Street and exactly opposite to it.

**Op. cit.*, p 296.

Soil and Plateau Gravel	- - - - -	from 5 to 8 feet.
London Clay. Basement-bed, 10 feet.	Brown loam with numerous thin beds of grey clay in it, and concretionary nodules of brown ironstone. These nodules commenced at 18 inches from the top and occurred in layers along the thin grey clay bands throughout nearly the whole thickness of the bed exposed, with occasional iron nodules here and there as well. The section presented a stratified appearance, brown in colour, with the exception of the uppermost 18 inches, which was more or less mottled with red and grey - - - - - -	10 feet.

Another section of the basement-bed was exposed at the same time north-west of the above spot; and about two chains west of the end of Hill Street the section was as follows:—

		Ft.	In.
Soil and Plateau Gravel	- - - - - - -	3	0
London Clay. Basement-bed, $12\frac{3}{4}$ feet.	Brown loam with thin beds of grey clay and layers of iron nodules, similar to those in the above section but not so numerous - - - - - -	8	0
	Orange-coloured sand, greenish in places - - - - - - -	1 to 1	6
	Chocolate-coloured clay with bright green specks and patches in it, and black flint pebbles - - - -		3
	Buff and brown sand with flint pebbles, a few small pebbles of chalk, and a few nodules of mottled clay derived from the underlying Reading Beds; one measured 6 inches in longest diameter - - - -	3	0

The following fossils were obtained from the London Clay basement-bed at Bob's Mount and named by the Survey Palæontologists:—

Ditrupa plana, *Sow.*
Cytherea tenuistriata, *Sow.* (=C. suessoniensis, *Watelet*).
Pectunculus (Axinæa) brevirostris, *Sow.*
Protocardium sp.
Aporrhais Sowerbyi, *Mant.*
Fusus sp. (*cf.* Speyeri, *Desh.*).
Natica hantoniensis ? *Pilk.*
Natica labellata ? *Lam.*

Ostrea bellovacina, Lam. was obtained from the London Clay a few feet above the basement bed at the same place.

The following fossils from the London Clay (basement-bed) were obtained in drainage works in Redlands Road, Reading and determined by the Survey Palæontologists:—

Ditrupa plana, *Sow.*
Hemiaster branderianus, *Forb.*
Cytherea tenuistriata, *Sow* (=C. suessoniensis, *Watelet*).
Glycimeris (Panopæa) intermedia, *Sow.*
Modiola elegans, *Sow.*
,, simplex, *Sow.*
Nucula sp.
Ostrea bellovacina ? *Lam.*
Pectunculus (Axinæa) brevirostris, *Sow.*

Protocardium Laytoni, *Morr.*	Fusus sp. (cf. Speyeri, *Desh.*)
,, plumsteadiense ? *Sow.*	,, sp.
Aporrhais Sowerbyi, *Mant.*	Natica hantoniensis, *Pilk.*
Bulla sp.	,, sp.
Cassidaria sulcaria ? *Desh.*	Pyrula nexilis ? *Lam.*

The following is by Mr. Whitaker *:—

"At the brickyard [½ mile south of the cross roads at the Cemetery and] to the east of Redlands House, the following beds were to be seen in 1858, but the brickyard has since been given up and the section hidden (1862):—

Drifted clay and gravel.

London Clay.—Bluish-grey and brown stiff clay; the lower part rather sandy, and with a little ironstone; about 12 feet; passing into the bed below.

Basement-bed.—Brownish sandy clay, with a few small flint-pebbles and lines of ironstone (with fossils), more sandy towards the base, in fact passing into clayey sand. About 6 feet from the top there is a bed of shells, 5 feet below which is another bed, and between the two a few scattered shells. Not sunk through; greatest thickness about 12 feet.

"There are lying about some rather flat masses of limestone, which come from the lower part of the basement-bed."—W.W.

The basement-bed was exposed in some excavations for main drainage in Wokingham Road, Earley, to the east of Reading. The following fossils obtained there have been determined by the Survey Palæontologists:—

Wood (Lignite).	Protocardium Laytoni, *Morr.*
Ditrupa plana, *Sow.*	,, plumsteadiense, *Sow.*
Hemiaster branderianus, *Forbes.*	Actæon sp. (near to A. limneiformis, *Sandb.*)
Cytherea orbicularis, *Edw.*	Aporrhais Sowerbyi, *Mant.*
,, tenuistriata, *Sow.* (= C. suessoniensis, *Wat.*)	Buccinum ?
Cyrtodaria (Glycimeris) rutupiensis ? *Morr.*	Fusus (Strepsidura) turgidus, *Solander.*
Modiola elegans, *Sow.*	,, sp (*cf.* Speyeri, *Desh.*)
,, simplex, *Sow.*	Natica hantoniensis, *Pilk.*
Nucula sp.	,, labellata, *Lam.*
Ostrea bellovacina, *Lam.*	Pleurotoma terebralis, *Lam.*
Pectunculus (Axinæa) brevirostris, *Sow.*	,, teretrium, *Edw.*

At the brickyard (known as Mock Beggars') north of Whiteknights Lake, and nearly half-a-mile west-north-west of St. Peter's Church, Earley, an excavation made in February, 1887, showed the following section:—

		Ft.	In.
Valley Gravel, etc.	Brown loam - - - - 1 ft. 6 in. to	2	6
	Gravel, resting very irregularly on the London Clay - - - - - - - 1 ft. to	2	0
London Clay. Basement-bed.	Brown and grey sandy loam and clay, sometimes greenish, containing much white "race" in places, and numerous shells at different levels -	3	0
	Brown sand, in places pebbly and gravelly, with shells, from - - - 6 inches to	0	8

* "Geology of the London Basin," *Mem. Geol. Surv.*, vol. iv. (1872), p. 296.

		Ft.	In.
Reading Beds.	Greenish-grey stiff clay, slightly mottled with red and brown in places. At its junction with the bed above, there is an even but slightly undulating and well-marked plane -	2	6
	Dark grey and brown clay mottled with red, there being a large quantity of the latter or crimson in the lower part exposed to - -	7	0

In another portion of the same brickfield, but on higher ground, an excavation in 1886 showed 16 feet in thickness of London Clay, consisting of brown loam and clay.

This brickyard is at almost the same place as that described by Mr. Whitaker as about half-a-mile to the east of the one near Redlands.*

The following fossils were obtained from the basement-bed of the London Clay in this brickfield. They have been determined by the Survey Palæontologists.

Wood (Lignite).
Ditrupa plana, *Sow.*
Hemiaster branderianus, *Forbes.*
Cytherea orbicularis, *Edw.*
,, tenuistriata, *Sow.* (=C. suessoniensis (*Wat.*)
Glycimeris (Panopæa) intermedia, *Sow.*
Nucula sp.
Pectunculus (Axinæa) brevirostris, *Sow.*
Protocardium Laytoni, *Morr.*
,, sp.
Fusus sp. (*cf.* Speyeri, *Desh*).
,, sp.
Natica labellata, *Lam.*
,, sp.

Fossils from the London Clay a few feet above the basement-bed:

Lamna Vincenti, *Winkl.*
Odontaspis cuspidatus, *Ag.*
,, elegans, *Ag.*
Otodus obliquus, *Ag.*
Vertebra (Elasmobranch).

The following fossils, collected from the basement-bed of the London Clay at Sonning by Mr. Ll. Treacher and the author, have been determined by the Survey Palæontologists :—

Oculina raristella, *Defr.*
Ditrupa plana, *Sow*
Cyrena tellinella, *Fer. and Desh.*
,, sp.
Cytherea orbicularis, *Edw.*
,, tenuistriata, *Sow.* (=C. suessoniensis, *Wat.*)
Glycimeris (Panopæa) intermedia, *Sow.*
Modiola, sp.
Nucula venusta, *S. Wood.*
Ostrea sp.
Pectunculus (Axinæa) brevirostris, *Sow.*
Pholas Levesquei, *Wat.*
Protocardium plumsteadiense, *Sow.*
Tellina sp.
Aporrhais Sowerbyi, *Mant.*
Buccinum ?
Calyptræa sp.
Cassidaria sulcaria ? *Desh.*
Fusus sp.
Natica hantoniensis, *Pilk.*
,, labellata ? *Lam.*
Pseudoliva sp.
Odontaspis cuspidata, *Ag.*

Mr. Whitaker† saw a section of the basement-bed in a ditch on the western side of the road leading to Hurst Green, nearly three-quarters of a mile south-west of Haines Hill. "Near the

* *Op. cit.*, p. 297.

† *Op. cit.*, p. 297.

cross roads there was clayey sand with *Ditrupa, Ostrea, Pectunculus* and other shells, and flint pebbles; further towards the Green there was brown clay with "race" (irregular-shaped calcareous concretions); beyond this light bluish-grey and brown mottled loam; then brownish sand with flint-pebbles; and farther still the same without pebbles. [He] could not make out the super-position of the different members of the basement-bed, but it is clear that together they take up a great space at the surface."

In the brickyard south of Mortimer, *Nautilus centralis, Sow.* was found in the London Clay, and Mr. Ll. Treacher has collected teeth of *Lamna* as well as *Pectunculus, Cyprina,* etc., from the brickyard close to Wokingham Station

Fossils from the Basement-Bed of the London Clay.

Localities from which the fossils have been obtained, with references to the sources of information:—

1. Englefield Brickyard; Prestwich. *Quart. Journ. Geol. Soc.* vol. vi. (1850). p. 266.
2. Norcot Brickyard, Tilehurst; Whitaker. *Geology of the London Basin* 1872, p. 583.
3. Woolwich Green, Sulhampstead Abbots; Whitaker. (*Ibid.*)
4. Reading { Katesgrove Brickyard; Prestwich and Whitaker. (*Ibid.*) (*loc. cit. p.* 266.)
   Bob's Mount, close to Katesgrove; J. H. Blake. *See* above, p. 47. }
5. „ Redlands Brickyard; Whitaker. (*loc. cit.*)
6. „ Drainage Works, Redlands Road; J. H. Blake. *See* above, p. 47.
7. „ Do. do. Wokingham Road; J. H. Blake. *See* above, p. 48.
8. „ { Mock Beggars' Brickyard, Wokingham Road; J. H. Blake. *See* above, p. 49.
   Brickyard east of Redlands (same place), Whitaker (*loc. cit.*) }
9. Sonning Cutting, Prestwich (*loc. cit. p.* 267.) and Ll. Treacher and J. H. Blake. *See* above p. 49.

Basement-bed of the London Clay.

	1	2	3	4	5	6	7	8	9
Oculina raristella, *Defr.*	–	–	–	–	–	–	–	–	9
Ditrupa plana, *Sow.*	1	2	–	4	5	6	7	8	9
Hemiaster Branderianus, *Forbes*	–	–	–	–	–	6	7	8	–
„ Bowerbanki, *Forbes*	–	–	–	4	–	–	–	–	–
Spatangus sp. (? = Hemiaster)	–	–	–	–	–	–	–	–	9

Holoparia Belli, *M'Coy*	–	–	–	–	5	–	–	–	–
Astarte sp.	–	–	–	–	–	–	–	–	9
Avicula sp.	–	–	3?	–	–	–	–	–	–
Corbula sp.	–	–	3	–	–	–	–	–	–
Cyprina Morrisi, *J. de C. Sow.*	–	2?	3?	–	–	–	–	8	–
Cyrena tellinella, *Fer. and Desh.*	–	–	–	–	–	–	–	–	9
„ sp.		–		–	–	–	–	–	9
Cyrtodaria (Glycimeris) rutupiensis, *Mor.*	–		–	–	–	–	7?	–	–
Cytherea orbicularis, *Mor.*	–	–		4	–	–	7	8	9
„ tenuistriata, *Sow.* (=C. suessoniensis, *Wat.*)	–	–	–	4	–	6	7	8	9
Glycimeris (Panopæa) intermedia, *Sow.*	1	–	–	–	–	6	–	8	9
„ „ sp.	–	–	3?	–	–	–	–	–	–
Modiola elegans, *Sow.*	–	–	–	4	–	6	7	–	9
„ depressa, *Sow.*	–	–	–	–	–	–	–	–	9
„ simplex, *J. de C. Sow.*	–	–	–		–	6	7	–	–
„ sp.	–	–	3	–	–	–	–	–	9
Mytilus sp.	–	–	–		5?	–	–	–	–
Nucula venusta, *S. Wood*	–	–	–	–	–	–	–	–	9
„ sp.	1?	–	3	4	–	6	7	8	9
Ostrea bellovacina, *Lam.*	–	–	–	–	–	6?	7	–	–
„ pulchra, *Sow.* (? O. pulcherrima, *Wood*)	–	–	–	–			–	–	9
„ sp.	–	–	–	4	5	–	–	–	–
Pectunculus (Axinæa) brevirostris, *J. de C. Sow.*	–	–	3	4	5	6	7	8	9
„ decussatus, *Sow.*	–	–	3	4	–	–	–	–	–
„ plumsteadiensis, *Sow.*	1	–	–	–	–	–	–	–	9
„ terebratularis, *Lam.*	–	2	–	4	–	–	–	8	–
Pholas Levesquei, *Wat.*	–	–	–	–	–	–	–	–	9
Protocardium Laytoni, *Morris*	–	–	–	4?	–	6	7	8	–
„ nitens, *Sow.*	–	–	–	4	–	–	–	–	9
„ plumsteadiense, *Sow.*	–	–	–	4	–	6?	7	–	9
„ semigranulatum, *Sow.*	–	–	–	4	–	–	–	8?	9
„ sp.	1	–	3	4	5	–	–	8	–
Tellina sp.	–	–	3?	–	–	–	–	–	9
Venericardia ?	–	–	–	–	–	–	–	–	9?
Actæon sp.	–	–	3	4	–	–	7	–	–
Aporrhais Sowerbyi, *Mant.*	1	2	3	4	–	6	7?	–	9
„ n.sp.	–	–		–	–	–	–	–	9
Buccinum sp.	–		–	–	–	–	7	–	–
„ ?	–		–	–	–	–	–	–	9
Bulla sp.	–	–		–	–	6	–	–	–
Calyptræa aperta, *Solander* (= C. trochiformis, *Lam.*)	1	–	–	4	–	–	–	8	9
Cancellaria læviuscula, *Sow.*	–	–		–	–	–	–	8?	–
Cassidaria sulcaria ? *Desh.*	–	–	–	–	–	6?	–	–	9
„ sp.	–	2	–	–	–	–	–	–	–
Fusus sp. (cf. Speyeri, *Desh.*)	–	–	–	4	–	6	7	8	–
„ turgidus, *Solander*	–	–	–	–	–	–	7	–	–

Fusus sp. - - - -	—	2	3	4	5	6	—	8	9
Natica hantoniensis, *Pilk.* -	—	—	—	4?	—	6	7	—	9
,, labellata, *Lam.* - -	—	—	3	4	—	—	7	8	9
,, sp. - - - -	1	2	3	4	5	6	—	8	—
Pleurotoma terebralis, *Lam.* -	—	—	—	—	—	—	7	—	—
,, teretrium, *Edw.* -	—	—	—	—	—	-	7	—	—
,, sp. - - -	—	—	3	4	—	—	—	—	9
Pseudoliva sp. - - -	—	—	—	—	—	—	—	—	9
Pyrula nexilis, *Solander* - -	—	—	—	—	—	6?	—	—	—
,, sp. - . - -	—	2	—	—	—	—	—	—	—
Scalaria sp. - - -		—	—	4	—	—	—	—	9?
Voluta denudata, *J. de C. Sow.*	—		—	—		—	—	—	9?
Lamna (teeth) - - -	1		-	—		—	—	—	9
Odontaspis cuspidata, *Ag.* -	—			—	—	—	—	—	9

CHAPTER VII.

UPPER BAGSHOT, BRACKLESHAM, AND LOWER BAGSHOT BEDS.

The Lower Bagshot Beds rest more or less conformably upon the London Clay, there being apparently passage-beds in places. They consist of buff, brown, yellow, grey and white sands, with thin beds of pale grey pipe-clay and occasionally laminated white, grey, and liver-coloured clays. The sands are well stratified, very often current-bedded, frequently micaceous, in some places ferruginous, and contain occasional beds of flint pebbles. The full thickness is only found in the south-eastern corner of the district, and it is then probably nearly 100 feet.

They cover a large area in the southern part of the district, but are usually hidden by the Plateau Gravel. In most cases the Lower Bagshot Beds can be seen along the slopes of the hills beneath the level of the sheets of gravel. These beds, with their capping of gravel, form the Commons of Bucklebury, Crookham, Brimpton, Padworth, Burghfield, Silchester and Barkham.

Lower Bagshot Beds—Outliers.

The following notes on the western outlier are by Mr. Bennett:—

In the south-western portion of the district the Lower Bagshot Beds seem to be largely clay or sandy loam with occasional beds of sand, but sand seems to be the exception, for wherever it is found it is dug, and there are very few sandpits.

There seems to be a gradual passage from the London Clay into the Lower Bagshot Beds, though sometimes a bed of pebbles occurs at about the boundary.

Bucklebury Common.—On this large outlier sandy loam was noted in some of the road-cuttings leading from the Common, but only one good section was seen. It was at Midgham Kiln, and the section in 1887 was as follows:—

	Feet
Grey and brown mottled sandy clay - - - - - -	4
Brown clayey sand - - - - - - - - - -	1½
Stiff brown and grey mottled clay - - - - - -	3
Soft buff sand - - - - - - - - - - -	3

The section mentioned in "The Geology of the London Basin,"* at the kiln near Harts Hill no longer exists.

The Lower Bagshot Beds are stated to have consisted "of alternations of yellow and white sands, with pale blue clay and layers of iron sand-stone."

* *Mem. Geol. Survey*, vol. vi. (1872), p. 310.

At Upper Woolhampton the Bagshots have been found to extend farther than was shown on the old map, and this is in agreement with the record of the well sunk at St. Mary's College, Woolhampton. West of Midgham Green sandy loam and red sand may be seen, and reddish loam in the road west of the College. There is also a scattering of pebbles on the surface of the ground here and there. The road-cuttings north and south of the Blade Bone public house, Chapel Row, show mottled red and grey clay. Half-a-mile west of Hall Place Farm, and almost mid-way between it and Woolhampton Church, a small section showed five feet of reddish-brown bedded loam.

Four small outliers have been mapped near Woolhampton.

Crookham Common.—Only the eastern end of this outlier lies in our district. The gravel in some places covers up the Bagshot Beds, and no good sections were seen.

Huntsmoor Hill.—In the road-cutting at the north of this outlier brown sand and brown and red mottled clay may be seen. There are two small outliers near Ashford Hill.

Silchester.—A large outlier extends from Wasing to Sulhampstead and away south beyond our area. It is almost wholly covered by Drift, and the top is flat and mostly wood and heath land. Brimpton, Padworth, Mortimer, and Silchester Commons are upon it.

West of Brimpton Common the road cutting west of Blacknest Farm shows loam.

At Ashford Hill Kiln the section in 1887 was as follows:—

	Feet.
A little gravel.	
Stiff brown and grey clay, bedded, at bottom darker, and containing much iron - - - - -	5 to 6
Stiff dark-brown clay with iron-pan at bottom - -	1
Soft brown sand - - - - - - - - -	2 to 4

Below this there were alternations of loam and sand. This section is on the side of the valley and close to the top of the hill. Lower down the slope and near the stream another pit showed five feet of brown sandy clay with irony concretions.

South-east of the kiln loamy soil is shown on the sides of the valley.

The section at Inhurst Brickyard in 1887 showed.

	Feet.
Subangular gravel.	
Grey and red laminated clay with sandy partings -	7
Sand (base not seen).	

At Tadley there was a kiln close to the Fox and Hounds public house. It showed, in 1887, the following sections:—

Northern Pit.

	Feet.
Gravel.	
Rather coarse, yellow sand with seams of pipeclay -	9
Finer, yellow sand - - - - - - - -	3

Then I was told they came to clay and water.

Southern Pit.

	Feet.
Much contorted gravel in clay matrix. Grey and brown mottled laminated clay. Very dark shaly clay with much black, pyritised, woody matter - - - -	10

South-east of the Fox and Hounds, small pits showed gravel over pipe-clay; yellow sand; and gravel over sand.

About half-a-mile east of the Fox and Hounds a pit showed in succession gravel over clay and sand.

On Silchester Common, a third of a mile south-east of the Crown Inn, sand capped by gravel was seen, and nearly a mile north of the Inn at Hungry Hill there was a similar section.

The section at Mortimer West End Kiln showed stiff grey and brown mottled clay very much like the Ramsdell clay, up to 10 feet. West of this sand was dug, and the section in 1887 was thus:—

	Feet.
Gravel.	
Brown and grey laminated clay, becoming a pipeclay when wet - - - - - - - -	6
Rather coarse, yellow sand - - - - - - -	2
Finer yellow sand and pipe-clay - - - - - -	3

This pit seemed to be abandoned in 1897, and no section was to be seen.

A third of a mile east of the south gate of the Roman city of Silchester a small section showed ferruginous sandy clay over ferruginous clayey sand. North of this, and in the road north-west of Sheepgrove Farm, mottled laminated clay over sand was seen in the road-cutting. Half-a-mile westof Broca Lane Farm, in a new drain, ochre was seen in ferruginous clay and the like south of Sims Farm.

Half-a-mile due east of the school at Padworth, a pit in Ufton Park Wood showed 10 feet of bedded buff sand with pipe-clay.

F. J. B.

Brickelton Farm.—There is a small outlier north of this farm. In 1891 sand was seen in a ditch-section 10 chains south-east of the Silchester Arms.

Heckfield.—Only a portion of this outlier lies in this district. It is mostly covered by Gravel, but sand was dug in a pit a quarter of a mile north of the Wellington Monument, where the section was:—

		Feet.
Plateau Gravel - - - - - - - - -		5
Lower Bagshot Beds.	Buff sand, dug to a depth of -	5

Farley Hill.—This is a small outlier, and as usual has a gravel capping. A well at the Poplars passed through 32½ feet of Lower Bagshot Beds, consisting of sand, loam, and clay.*

A section in a gravel-pit to the west of Farley Castle showed 6 feet of Bagshot Beds consisting of yellow sand with many laminæ of white clay. This was covered by a few feet of gravel.†

At the south-western corner of the outlier there is a section in Sandpit Lane showing 9 feet of reddish sand with a little light-coloured clay.

* "The Water Supply of Berkshire," *Mem. Geol. Survey* (1901), p. 43.
† See *Quart. Journ. Geol. Soc.*, vol. xlviii. (1892), p. 53.

To the west of and close to Farley Hill, there is a small outlier of Lower Bagshot Beds forming a hill named Fir Grove, above Nutbean Farm. A section showed 12 feet of well stratified sand, for the most part reddish, but buff and white in places, and with many very thin seams of grey clay. In places the sand is indurated.

Arborfield Cross.—This is a long narrow outlier, and on it stands the village of Arborfield Cross. A sandpit ¼ mile south-west of the cross roads gave the following section:—

		Feet.
Lower Bagshot Beds.	Sand of a buff colour and ferruginous - - -	1½
	Clay of a grey and liver colour - - - -	5½
	Buff sand dug down to - - - - -	3

King Street.—Yellow and brown sand occurs close to Bearwood Lodge and the ground at Toutley Hall is sandy. There is, therefore, probably a thin capping of Lower Bagshot Beds. It may be, however, that only the sandy topmost bed of the London Clay is present here.

Wokingham.—The town of Wokingham stands upon a well-marked outlier of Lower Bagshot Beds, the greater part of which is in this district, though it projects slightly to the east. Judging by the elevation, the Bagshot Beds must be about 40 feet thick at the highest part of the outlier, and as usual there is a capping of Drift.

In the railway-cutting to the north of Wokingham Station and close to St. Paul's Church, well stratified buff and brown sand with thin seams of grey clay was shown to a depth of 15 feet.

A little north of the gas-works on the south of the town there was a pit in yellow Lower Bagshot sand, which must have been close to the bottom of the formation, for only 7 chains to the south on the opposite side of the gas-works, and at a very slightly lower level, there was a brickfield, the section in which was as follows in 1881:—

		Feet.
London Clay.	Sandy clay of a light brown colour - - -	4
	Stiff dark blue clay dug to - - - - -	9

In the cutting on the South Western Railway south of Wokingham the section was as follows *:—

		Feet.
Plateau Gravel.	Flint pebbles, subangular flints and Lower Greensand fragments, interstratified with beds of yellow sand up to - - - - - - - -	7
Lower Bagshot Beds.	Well stratified yellow and white sand with ferruginous concretions and seams of grey and liver-coloured clay, the lower part mainly white current-bedded sand, to - - - - - -	12

Lower Bagshot Beds—Main Mass.

A small portion of the main mass of the Lower Bagshot Beds extends into the south-eastern corner of the district.

South of Bramshill Common, and just outside the district, there is a sand pit in the Lower Bagshot Beds.

* *Quart. Journ. Geol. Soc.* vol. xlii. (1886), p. 409.

Yellow sand (Lower Bagshot Beds) was dug under 4 feet of gravel in a pit at the cross roads south of Wixenford.

Sandy clay was found beneath the gravel a little north-east of Glaston Hill House, and the boundary of the Bagshot Beds probably crosses the River Blackwater between Eversley and Eversley Cross, where it is covered by gravel and alluvium.

In a brickfield west of Fleet Hill Farm very sandy clay, probably the topmost bed of the London Clay, was worked, and in Fleet Hill Copse, at rather a higher level there was a pit in yellow sand with a few laminæ of light-coloured clay which belongs to the Lower Bagshot Beds.

At Webb's Farm a well is said to have been dug in 7 to 10 feet of sand with water.

There is a brickfield in London Clay at the western end of the Nine Mile Ride to the north of Shepperlands Farm. Close to it on the east the surface is very sandy, and yellow sand with clay laminæ (Lower Bagshot) is seen in a road-section south-east of Long Moor Lake, and also below gravel in a pit close to Warren Lodge.

There is a large sand-pit north of Dowles Farm, Barkham, showing 15 feet of yellow, white and buff sands well stratified, with slight current-bedding in places and numerous bands of light coloured clay, often an inch in thickness, but usually thinner.

Mr. R. Trench notes that: "About three-quarters of a mile north-north-west of Barkham, near Wokingham, there is light-brown fine micaceous glauconiferous sand, with thin layers of pipe-clay towards the top, about 12 feet thick, over a pebble-bed in whitish micaceous sand." *

In 1887 a working for road-metal was opened a little more than three-quarters of a mile rather west of north of Barkham Church, and probably at much the same place as the section above referred to. It was described by the Rev. Dr. Irving as follows †:—

		Feet.
"*a.*	Drift (coarse sand and flint fragments)	2
b.	Loamy sands	3
c.	Pebble-bed in greenish and brown sand	5
d.	Coarse brown loam	¼
e. (1.)	Clay, tough, hard, pale grey, laminated	2½
e. (2.)	Clay, more compact, chocolate-coloured	
e. (3.)	Clay, tough, hard, drab-coloured, laminated	
f.	Coarse irony sand with clay laminæ like *e*	½
g.	Coarse sand, irony	3½"

The strata below the Drift *a* in this section are probably Lower Bagshot Beds.‡ The bed *b*, is a yellow sand with many irregular and thin layers of light-coloured clay. The bed *c*, is a mass of

* "The Geology of the London Basin," *Mem. Geol. Survey*, vol. iv. (1872,) p. 314.

† *Quart. Journ. Geol. Soc.* vol. xliv. (1888), p. 176.

‡ The question of their age is discussed—*Quart. Journ. Geol. Soc.*, vol. xlviii. (1892), p. 53—under *Bearwood.*

flint pebbles; among them are a few minute pebbles of quartz not more than $\frac{1}{10}$th inch in diameter. This pebble-bed probably extends with more or less regularity for some distance in this part of the district, for the hill north-east of the Manor House is capped by a mass of flint pebbles which were dug for road metal in 1885.

The surface at Eastheath, near Wokingham, is also very pebbly, and there is a large proportion of flint pebbles in the gravels there.

A section near Sindlesham Church showed reddish-brown sandy and loamy clay, probably the topmost beds of the London Clay, and a little higher up the hill light buff loam and sand appears.—(Lower Bagshot Beds).

An excavation 32 chains south-east of Lucas's Hospital showed the junction of the Lower Bagshot Beds with the London Clay. The former consisted of brown sandy loam over brown sand with seams of grey clay, and the latter was a mottled grey and brown loamy clay.

The Bracklesham Beds.

The Bracklesham Beds lie conformably on the Lower Bagshot and have a thickness of about 40 feet. They consist of yellow, brown and olive-green glauconitic sands, all more or less clayey in the upper part, and of brown, grey and liver-coloured clay generally laminated in the lower part. The sands are sometimes current-bedded, and contain one or more layers of flint pebbles.

The Bracklesham Beds only occur in the south-east corner of our district.

No fossils have been recorded from the Bracklesham Beds of the area dealt with in this memoir.

A small outlier has been mapped to the west of Finchampstead. Mottled red and grey stiff clay appears at its southern edge.

The village of Finchampstead stands on the main mass of the Bracklesham Beds. Green glauconitic sand was noted in several places in ditch sections below East Court.

In the lane to the north-west of Finchampstead Church the junction of the Bracklesham and Lower Bagshot Beds was seen, the sections being as follows :—

Bracklesham Beds.	Brown fairly stiff clay.
	Dark green glauconitic sand.
	Grey laminated clay.
Lower Bagshot Beds.	Brown sand.

A clay pit in Wick Hill, about 7 furlongs north-west of Finchampstead Church, showed the following section* :—

		Feet.
Drift.	Yellow sand with flint pebbles - - - -	$1\frac{3}{4}$
Bracklesham Beds.	Green glauconitic sand - - - - -	$1\frac{3}{4}$
	Yellow and white sand with a little white clay in places - - - - - -	$4\frac{1}{2}$
	Green clayey sand with iron pyrites - -	5
	Dark blue clay with stalk-like markings and carbonaceous matter passing down into yellow laminated clay with ferruginous concretions, dug down to— -	$3\frac{1}{2}$

* See *Quart. Journ. Geol. Soc.* vol. xlii. (1886), p. 402.

At a brickfield at California, to the north of Wick Hill, the following was the section :—

		Feet.
Bracklesham Beds.	Yellow sand - - - - - - - -	2
	Grey clay and buff sand dug to - - -	10

A little to the north of the brickfield there was a pit in yellow and white stratified sand (Lower Bagshot Beds.) This brickfield is now disused.*

The Upper Bagshot Beds.

The Upper Bagshot Beds consist of buff, yellow and white sand with little or no sign of bedding: pebbles seldom occur above the bottom, where there is a fairly well marked and continuous pebble-bed. No fossils have been found in this district, but casts of shells were fairly numerous at the eastern end of the Finchampstead Ridges outlier in the railway cutting at Ambarrow, on the South-Eastern Railway.

Finchampstead Church stands upon a small outlier. On the south-west there was a section showing 15 feet of buff sand, and in the churchyard another section showed 10 feet of buff sand with a few green grains. In the lane to the north-west many pebbles were seen in the banks at about the 300 feet contour, and probably were from the basement bed of the Upper Bagshot.

The Ridges, Finchampstead, are on another outlier which extends just beyond the eastern edge of the district. A road cutting at North Court showed 15 feet of yellow sand with green grains, and other sections in yellow, buff or white sand of the Upper Bagshot Beds were noted in the lane to the east of Ridge Farm, in the road from North Court to Wick Hill, and in the wood north of Halls Farm.

The basement pebble-bed was very well shown in the cutting between Ambarrow and Wellington College Station, a little east of the margin of the district.†

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* An account of these sections by the Rev. Dr. Irving will be found—*Quart. Journ. Geol. Soc.*, vol. xliv. (1888), p. 172.

† See *Quart. Journ. Geol. Soc.*, vol. xxxix. (1883), p. 351. ; vol. xliv. (1888), p. 614.

CHAPTER VIII.

CLAY WITH FLINTS AND PEBBLE GRAVEL.

CLAY WITH FLINTS AND LOAM.—OVERLYING CHALK.

The name "clay with flints" was given by Mr. Whitaker to a deposit of stiff brown and reddish clay, with large unworn flints which occurs over the higher parts of the Upper Chalk tract.

It lies very irregularly on the Chalk filling pipes in that rock, and does not occur as an even overlying bed like the Reading Beds. At the base there is generally black clay a few inches thick, also with flints, in this case black-coated. It does not occur in the bottoms of the valleys, though often running some way down the upper part of their slopes.

Besides the unworn flints there are sometimes pebbles which may have been derived from Tertiary or Drift Beds.

Mr. Whitaker considers that the clay with flints is of many ages, and may be even forming at the present day, and that it is owing in greater part to the slow decomposition of chalk under atmospheric action.*

Above the clay with flints there is occasionally a loam, sandy clay or brick-earth, probably formed from the waste of the sands and clays of the Reading Beds.

The clay with flints and loam covers a considerable extent of the Chalk in the north-western part of the district, round Aldworth and Ashampstead, and extends to the hills above Hampstead Norris on the west and almost to the Thames on the north-east. Patches also occur on the Chalk east of Goring and north of Shiplake.

Mr. Bennett remarks that though the clay with flints is thin there is quite enough of it to affect the agricultural character of the district.

He adds that it is very irregular in thickness, as may be seen in some of the chalk pits, where deep pipes of the clay are often shown. These result from water percolating down lines of weakness in the Chalk dissolving it, and leaving the clay as a lining to the pipe.

Mr. Bennett also contributes the following note of the section at Buttonshaw Kiln. It is about a mile south-west of Aldworth, and a third of a mile south-east of Buttonshaw farm, and showed 6 feet of large unworn flints and sarsens resting irregularly on rusty brown and black-stained clay. A hole dug for clay near the kiln showed a mixture of plastic clay and coarse red sand, capped with clay with flints. The plastic clay seemed in process of conversion into the rusty brown clay.

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* "Geology of London," *Memoirs of the Geol. Survey* (1889), i. 281.

Near Aldworth well-sections give up to 11 feet of clay with flints,* and at Ashampstead the deposit was found to be 19 feet thick at the keeper's house on the common.†

Pebble Gravel.

The pebble gravel is probably the oldest Drift deposit of the district. As its name implies, it consists almost wholly of pebbles, and no fossils have been found in it. It is distinguished from the pebble beds of Eocene age by the presence of a considerable proportion of pebbles of quartz, whereas the Eocene pebbles are almost all of flint. On the other hand it is distinguished from the other Drift gravels by the scarcity of subangular flints, of which they are largely or mainly composed, and by the absence of red quartzite pebbles and other pebbles and boulders which, as will be explained later on, are believed to be derived from Triassic pebble beds.

Streatley.—There are small patches of gravel on the outlier of the Reading Beds in Common Wood, on the hill above Streatley. The level is rather over 540 feet; no good sections were seen, and the gravel seems to be thin. It consists largely of quartz pebbles, but does not appear to be a good example of pebble gravel for there are many subangular flints and some pebbles of red quartzite. Probably it is the debris of pebble gravel mixed to a certain extent with other Drift.

The same may be said of another patch of pebbles which occurs on the road from Streatley to Aldworth. It is on the Chalk, at a level of 548 feet. There is also a small pebbly patch on high ground one and a half miles west of Streatley. It has been coloured pebble gravel, but like the above is more probably a gravel formed mainly of the debris of that formation.‡

Cray's Pond and *Cold Harbour.*—Patches of pebble gravel have been mapped at Cray's Pond and Cold Harbour. They lie at a level of nearly 550 feet, upon an outlier of the Reading Beds.

At Greenmoor Hill, on the same outlier, there is another patch which is just outside our boundary. It has been described by Prestwich.§

Bowsey Hill.—Four small patches of pebble gravel have been mapped on the top of Bowsey Hill, Wargrave, between 400 and 460 feet above the sea.

A digging for road-metal in the highest patch showed 3 feet of stones and sand with little or no sign of stratification.

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* *Mem. Geol. Survey*, "Water Supply of Berkshire," (1901), p. 18.

† *Loc. cit.*, p. 22.

‡ *See* H. J. O. White, "On the Distribution, etc., of the Westleton and Glacial Gravels," *Proc. Geol. Assoc.*, vol. xiv. (1895), p. 21.

§ *Quart. Journ. Geol. Soc.*, vol. xlvi. (1890), p. 140 See also *Proc. Geol. Assoc.*, vol. xii. (1891), p. 113, and H. J. O. White, *ibid.*, vol. xiv. (1895), p. 15

The stones are mainly flint pebbles, many of which are as much as 3½ inches in longest diameter. There are a considerable number of subangular flints, many of which have been very little rolled or water worn. They are often large, stones of 7 inches in length being far from rare.

Next to flint, the most abundant constituent of the gravel is quartz. Pebbles over 2 inches in diameter are common, and pebbles over half an inch abound. The quartz is usually white, but pink quartz occurs. There are a few pebbles of white sandstone. Mr. Whitaker mentions a section, on the top of this hill, which showed 5 feet of gravel.*

* "Geology of London," *Mem. Geol. Survey*, vol. i. (1889), p. 293. Accounts of the gravel on this hill, by Prestwich, will be found—*Quart. Journ. Geol. Soc.*, vol. xlvi. (1890), p. 141, and by H. J. O. White, *Proc. Geol. Assoc.*, vol. xiv. (1895), p. 21.

CHAPTER IX.

PLATEAU GRAVEL.

The plateau gravel covers considerable areas in all parts of our district. It usually forms flat expanses at various levels, from about 160 to over 500 feet above the sea. Sometimes it forms a mere stony bed at the surface, but it is often 20 feet or more thick.

Its composition varies in different parts of the area, but it usually consists mainly of subangular flints and flint pebbles. The former are generally brown, much rolled and waterworn, and have probably in most cases been derived from still older gravels. The flint pebbles are nearly always from Eocene pebble beds or from the pebble gravel.

North of the Thames, and at some places near that river, though to the south of it, the gravel contains numerous pebbles or boulders of a reddish quartzite. Similar pebbles are found at many places in the higher parts of the Thames Valley, and have long attracted attention. They were noticed by Dr. Buckland in "Reliquiæ Diluvianæ" (1821, 4to., p. 279) and by Prof. John Phillips in his "Geology of Oxford and the Valley of the Thames" (Oxford, 1871).

Prof. Phillips says (at p. 458): "On a large portion of the Cotswolds, but not rising to their greater elevations, we find a scattered gravel deposit of a kind entirely different from that which is so common in the greater part of the Thames Valley. It is not accompanied by boulder clay, contains no large erratic blocks, but a considerable variety of stones of greater size than such as are commonly found in gravel. Two sorts of stone are the most common, one is quartz, usually in small white pebbles, the other hard reddish gritstone or quartzite, a metamorphic rock which corresponds with none *in situ* better than with that of Hartshill near Nuneaton. This kind of stone may be collected from half the ploughed lands of Oxfordshire, on the southward slopes of the oolites on the Chiltern Hills and in the Vale of the Thames about Oxford and Abingdon. I have never seen a fossil in it. It is probable that the new red conglomerates of Warwickshire and the midland counties may, with justice, be credited as the *immediate* source of the pebbles. Whence they came originally may be hard to determine, though *such* rocks as those of the Lickey Hills and Hartshill, metamorphic sandstones of some paleozoic kind, possibly destroyed in early mesozoic ages, are clearly indicated."

Mr. H. J. Osborne White, who has made a careful study of the gravel near Reading, has come to the conclusion that the red quartzite pebbles in them, like those noticed by Prof. Phillips, come from the Triassic rocks of the midlands.*

Prof. Bonney says that a fine grained quartzite pebble found

* *Proc. Geol. Assoc.*, vol. xv. (1897), p. 160.

in gravel at Rose Hill, near Caversham, appears identical with the liver-coloured quartzite of the Midland Bunter.*

Associated with the red quartzite pebbles, we find a varied collection of pebbles and boulders of quartz, sandstone, black chert or grit, and occasionally igneous rock, and probably much of this material has, like the red quartzites, been derived from the Bunter Beds of the Midland Counties.

In the eastern part of our district the gravel often contains a considerable proportion of light-coloured chert and ragstone derived from the Lower Greensand Beds of the Wealden area. These fragments of Lower Greensand rock are more especially abundant in patches of gravel near the River Blackwater and the lower part of the Loddon, and at Shiplake they are found in gravel north of the Thames.

In the south-western part of the area we neither find Triassic pebbles nor Lower Greensand fragments in the gravel, and it consists of flint with fragments of sarsens and a few ferruginous concretions from the Eocene Beds.

Plateau Gravel North of the Thames.

There is a considerable spread of Plateau Gravel on the high ground above Whitchurch up to a level of about, or rather over, 500 feet. Whitchurch Gate, Goring Heath, Cane End, and Kidmore End are on this gravel. It differs in composition from the pebble gravel which has been described as occurring at still higher levels, for it consists mainly of subangular flints. It contains many pebbles, often large, of red and brown quartzite and sandstone, and flint pebbles which form so large a part of the pebble gravel, are far less abundant.

The fields above the 400 contour south-east of Abbot's Wood are scattered with flints, quartz, and quartzite pebbles, etc.†

Between Stapnall's Farm and Gatehampton Farm, near Goring, the soil is gravelly, The stones are mostly subangular flints, but quartzite and sandstone boulders, 5 to 6 inches in diameter, and also quartz pebbles are common.

There is a pit in this gravel close to the Pack Horse Inn. Bardolph's Wood (300 feet O.D.). It is composed mainly of subangular flints, and there is a small proportion of flint pebbles. Reddish and white quartzite pebbles are common, and there are also pebbles of sandstone, etc.

There is another pit at Gallowstree Common, in the southern angle formed by the cross roads, a little more than half a mile north-east of Cane End. The section showed 5 feet in thickness of gravel of a similar character to that at the Pack Horse Inn pit. The stones were mostly of small size. The total thickness of the gravel was not shown. A sarsen-stone, 1 foot 6 inches in diameter, was seen by the side of the road, nearly 300 yards south-east of the pit. On the high ground between Gallowstree Common and Kidmore End, the gravel is pebbly, but is otherwise

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* *Quart. Journ. Geol. Soc.* vol. liv. (1898), p. 592.

† Mr. H. J. O. White has recorded the presence of many boulders of red and grey quartzite in the gravel N.E. of Goring Heath. *Proc. Geol. Assoc.*, vol. xiv. (1895), p. 18.

very similar in character to the above, though the stones are larger and more rounded in some localities than in others. There is apparently a little clay with flints in places between the gravel and the underlying chalk, as shown in the road section about half a mile south-east of the smithy at Cane End. In some places there is some loam intermixed with the gravel near the surface of the ground, and the soil is of that nature around Coldnorton Shaw, about midway between Gallowstree Common and Kidmore End.

About 8 feet of gravel was exposed in 1887 in a pit on the west side of the road about 8 chains west of Tanner's Farm between Kidmore End and Caversham. This gravel consisted mainly of subangular flints. Flint pebbles were tolerably numerous. There were also a few quartz pebbles and some small well-rounded boulders of red grit and sandstone, three or four inches in diameter.

Between Chazey Heath and Caversham there is a gravel-covered plateau with a level of between 200 and 300 feet.

A pit a quarter of a mile north of Blagrave's Farm gives a very good section at a level of 269 feet. The gravel is stratified. It consists mainly of subangular flints, which are mostly rather small. Flint pebbles are not very common. A few of the flints have not been rolled or waterworn. There is a great quantity of small quartz pebbles, and many pebbles of red quartzite—these last measuring up to 7 inches in longest diameter. Pebbles of black stone and of ironstone occur. The gravel contains very little sand, but there is some loam in places; a thickness of 18 feet was shown.

Another pit near the southern edge of the same sheet of gravel, and 150 yards to the east of Chazey Wood, at Gravel Hill, gives a good section, showing 10 feet of similar gravel. It was apparently not bottomed.

In another pit situated on the west side of Tokers Green Lane, at a little more than one mile and an eighth north north-west of St. Peter's Church, Caversham, and 200 yards south-east of Farthingworth green, a section showed 10 feet in thickness of gravel also of a similar character.

Gravel has been dug to a considerable extent in the field between Toot's Farm and St. Peter's Hill, Caversham. The level is about 235 feet above the sea. The gravel consists mainly of subangular flints—flint pebbles are not very abundant. Pebbles of white quartz and of variously coloured quartzite are common. A block of white quartz $7\frac{1}{2} \times 5\frac{1}{2} \times 3\frac{3}{4}$ inches in size was noticed.

Mr. O. A. Shrubsole has recorded that "in this pit a large number of flint implements have been found. They occur mostly in a definite zone which follows the bedding of the gravel, and is usually only 1 to 3 feet from the surface." *

In Mr. Ll. Treacher's collection there are some implements of red quartzite from this locality.

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* *Quart. Journ. Geol. Soc.*, vol. xlvi. (1890), p. 583. See also *Proc. Geol. Assoc.*, vol. ix. (1885-8), p. 209.

There are four small patches of Plateau Gravel around Emmer Green.

There was a section in the most westerly of them about 400 yards north-west of Caversham Grove, on the east side of, and close to, a plantation. It was a small pit, and 8 feet of gravel was exposed. It consisted mainly of subangular flints and flint pebbles.

In the patch on Caversham Hill, there was a pit about 150 yards east of Springfield House, and 200 yards north-west of the Independent Chapel, where a section showed 9 feet of flint gravel of a reddish-brown colour, containing erratics here and there. The stones were mostly of small size; and the excavation did not apparently show the total thickness of the gravel.

There is a third patch at Rose Hill Kiln, near Caversham, which has been described by Mr. Shrubsole.* He collected from it a considerable variety of pebbles of quartz, quartzite, felstone, and rhyolite, notes on which by Prof. Bonney are given in his paper.

The Binfield Heath outlier of Reading Beds is capped by patches of plateau gravel. A working above Shiplake Row, about 305 feet above the sea, showed 4½ feet of gravel of very much water-worn and broken flints, with a considerable number of pebbles of a dark red and brown quartzite.

Mr. Ll. Treacher observed† the occurrence of a few fragments from the Lower Greensand in this gravel. It is so far as we know the most westerly point in this district at which they have been found in gravel north of the River Thames.

There is a patch of gravel at Caversham a little below the 200 feet contour, which it has been found convenient to class with the Plateau Gravel.

A large quantity of gravel has been excavated from a pit in this patch on the north side of the road to Shiplake, one mile and a quarter east by north of St. Peter's Church, Caversham, and 200 yards south-east of The Elms. A section of the eastern side of the pit showed 9 feet of coarse gravel. Another section on the western side exposed chalk beneath the gravel.

The gravel consisted of subangular flints, flint pebbles, and also contained pebbles of quartz, quartzite and sandstone.

Two patches of gravel near Shiplake have also been coloured Plateau Gravel. They rise very little above the 200 feet contour, and extend some distance below it.

A gravel-pit is situated 350 yards west by south of the church, on the southern side of the road, south of the "Plough" Inn. A section showed 8 feet 6 inches of gravel overlying chalk, which latter was dug down to, at the eastern end of the pit.

Gravel has also been dug to a depth of 6 feet close to the cross-roads three furlongs north of the church. It is stratified

* *Quart. Journ. Geol. Soc.*, vol liv. (1898), pages 591–592.
† See *Proc. Geol. Assoc.*, vol. xiv. (1895), p. 20.

yellowish brown, and consists mainly of brown subangular flints with some flint pebbles. Red quartzite, sandstone, and quartz pebbles are common, and there are numerous fragments of Lower Greensand Rock.

PLATEAU GRAVEL BETWEEN THE RIVERS THAMES AND KENNET.

Passing now to the south of the Thames we find a small patch of gravel capping the outlier of Reading Beds at Upper Basildon. It is at the high level of 466 feet above the sea.

Mr. F. J. Bennett noted a section of 4 feet of pebbly gravel in a clayey matrix, and a similar bed has been worked near the cross roads above Kiln Farm.

The gravel consists of pebbles of flint, quartz, red and brown quartzite, and black chert with some subangular flints. The clay in which the stones lie is mainly mottled, and no doubt derived from the Reading Beds.

A sheet of gravel extends from Upper Basildon to the hill above Pangbourne. Its level varies from 250 to 404 feet above the sea, and it rests upon chalk excepting at one place where it slightly encroaches on the Upper Bowden Farm outlier of the Reading Beds. The gravel is very clayey, or loamy, in places. A well at New Town passed through 20 feet of gravel and loam to chalk,* and at Upper Bowden Farm the Drift in a well-section is described as 10 feet of brown clay.†

A road-cutting 4½ furlongs east of New Town showed 6 feet of clayey sand full of stones. Waterworn flints, more or less broken, were common, but the stones were mainly pebbles of brown and red sandstone, and quartzite, and of white quartz. There were only a few pebbles of flint.

At Lower Bowden Farm 18 feet of red clay were found in a well-section.‡

To the north of Lower Bowden Farm there is another sheet of similar gravel. A pit was noted in it a little to the west of Park Farm. The section showed 6 feet of gravel. Red and brown quartzite and quartz pebbles occur on the surface all over these patches of gravel.

Between Tidmarsh and Slade Gate there is another extensive patch of gravel rising from 220 feet to 404 feet. A well at Bere Park Farm passed through 18 feet of gravel to chalk. A pit was noted by the small wood north of Dark Lane Copse which showed 12 feet of gravel. There were eight sarsens in the pit, measuring from 4 to 9 inches in length.

Gravel has also been worked ¼ mile east of the cross roads at Blenheim Barn. It consists mainly of fragments of brown flint, with a few flint pebbles. No quartz and no quartzite pebbles were seen.

The Frilsham and Burnt Hill Eocene outliers are capped by patches of gravel which Mr. Bennett remarks is very pebbly,

* "The Water Supply of Berkshire," *Mem. Geol. Survey* (1901), p. 66.
† *Op. cit.*, p. 65.
‡ *Op. cit.*, p. 66.

much more so than most of the Plateau Gravel farther to the south. There is a patch of pebbly gravel on Frilsham Common. It is dug in shallow pockets here and there; the highest part is at a level of 413 feet.

East of Yattendon and north of Burnt Hill there is another small patch of pebbly gravel capped with loam. A section showed

		Feet.
	Loam clean and also mixed with gravel - -	2 to 3
Plateau Gravel.	Pebbly gravel, with patches of subangular gravel, sometimes found intermixed. The pebbles are occasionally very large - - - - - -	7

Reading Beds.—Coarse yellow sand with, it was stated, trunks of trees. See p. 20.

South of the Axe and Compass Inn, on Burnt Hill Common, a pit showed 4 feet of the pebbly gravel which caps the outlier there.—F. J. B.

The high ground between the rivers Pang and Kennet is covered to a great extent by sheets of gravel of a very uniform character, consisting almost entirely of subangular flints and flint pebbles. Blocks of sarsen are common, but there is an absence of the pebbles and boulders of quartz, quartzite, etc., which are so abundant in the gravels near the Thames. A flint implement was found in August, 1902, in a gravel pit, at a level of 283 feet, O.D., near Englefield House. It is now in the Reading Museum.*

The following notes are by Mr. Bennett:—

Bucklebury Common is covered by gravel, which varies from 4 feet to about 7 feet in thickness, and where seen in section generally has a clayey matrix. A pit a little north-east of Hart's Hill showed 5 feet of gravel, with a few sarsen stones in a clay matrix. This gravel weathers white. A pit a little north-east of the cemetery showed 6 feet of gravel in a clay matrix.

Half-a-mile south-west of Beenham Church a pit showed 6 feet of rather fine gravel. From 2 to 7 feet of gravel was seen capping the clay at Beenham Kiln.

At Mare Ridge there were two pits showing from 5 or 8 feet of clean shingly gravel.

To the south-west of Bradfield there are two patches of gravel resting on London Clay. Pits a little south-west of the workhouse showed 8 feet of rather fine gravel and sand. One of the well sections at South End recorded 15 feet of gravel, but all the rest about Bradfield, averaged from 6 to 7 feet.—F. J. B.

To the south-east of Bradfield there is a patch of Plateau Gravel on the Reading Beds. A pit 5 furlongs north of east of Bradfield Church showed gravel, composed of small subangular flints with flint pebbles, the whole weathering white. As in the case of the other pits south of the Pang already described, no quartz or quartzite pebbles could be found.

There are a number of patches of Plateau Gravel on the Tilehurst outlier of London Clay and Reading Beds, and on the north-west it extends on to the Chalk as far as Purley.

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* *Quart. Journ. Geol. Soc.*, vol. lviii. (1902). Proc., p. lxxxii.

There was a pit showing 3 to 5 feet of gravel nearly half-a-mile north-east of Purley Hall; another pit 3 furlongs east of south of the same house showed 6 feet of gravel and chalk beneath it. Quartzite pebbles abound on this part of the patch.

Another pit 2 furlongs east of Sulham Church, at a level of about 310 feet, showed 3 feet of gravel consisting mainly of brown subangular flints and flints pebbles. There were only a few pebbles of red quartzite and a few large quartz pebbles.

The quartzite and sandstone pebbles and boulders increase in number as we go eastwards, and in the small gravel patch at Chapel Hill the gravel consists mainly of quartz, quartzite and sandstone pebbles and boulders. Quartz pebbles over 6 inches long are not uncommon, and big blocks of sandstone occur.

Tilehurst Common.—The plateau gravel on Tilehurst Common is much intermixed with loam and seams of clay in places. It was proved to be 13 feet in thickness in a central position on the Common, at a point 350 yards south-east of the Independent Chapel.

In a clay pit a little more than three-quarters of a mile north-west of St. Michael's Church, Tilehurst, red and grey mottled clays of the Reading Beds are shown capped by coarse gravel. On the north side of the road, a little more than half-a-mile north of the church, a section extending for more than 100 yards showed similar gravel. The plateau gravel on the high ground five-eighths of a mile westward of the church is very pebbly in character, and contains many small quartzite and sandstone pebbles.

Gravel has been worked to a considerable extent above Norcot Kiln, the section at which has been already given (page 31). The level of the gravel is about 290 feet. Subangular flints, some of which are brown but many black and not much water-worn, form about half the deposit, and the other half consists of flint pebbles, quartz pebbles and blocks, red and liver-coloured quartzite pebbles, and pebbles of black chert, sandstones, iron-stone, etc. Boulders of igneous rock occur,* and rolled blocks of sarsen are common.

To the east of Tilehurst there is a large patch of Plateau Gravel with a level of from 180 to 200 feet. It lies upon Reading Beds excepting on the north-west, where a long spur projects and lies partly on the Chalk. This spur forms a well-marked terrace on the hillside above and south-west of Reading Barracks. There are, or have been several gravel-pits in this terrace.

There are gravel and chalk pits about 15 chains south of the Barracks. In one of them about 10 to 12 feet or more of gravel was exposed overlying the Chalk, the total thickness not being clearly shown. The gravel mostly consists of pebbly and subangular flints intermixed with many well-rounded sandstone quartzite and quartz pebbles. Immediately overlying the chalk on the south side of the pit were some green-coated flints, and from about 1 foot 6 inches to 3 feet of greenish and brownish sand, and mottled brown and grey clay. The above had every appearance of being

* *Quart. Journ. Geol. Soc.*, vol. xlix. (1893), p. 308.

in situ, and thus showing the junction of the Reading Beds with the chalk. From about 3 to 6 feet or more of brownish loamy clay overlaid the gravel at the northern part of the pit, where it thins out on the sloping ground. Here the gravel rested unevenly on the Chalk, being piped into it in many places, whereas on the southern side, where the sand and clay of the Reading Beds overlaid the chalk, the junction was even.

The gravel pit, known as Hill's Pit and sometimes as Grovelands, is also in this terrace. It is situated to the south-east of the Barracks, and a quarter of a mile south-south-west of Elm Lodge. The gravel consists mostly of subangular flints and flint pebbles, intermixed with many quartz, quartzite, and sandstone pebbles and boulders often measuring from 4 to 8 inches in size. One boulder of quartz measured 11 × 7 × 6 inches, and several boulders of quartzite from 8 to 10 inches. There is apparently a rough, irregular, horizontal stratification, which is sharply cut off at the slope of the valley to the north, showing denudation since the deposition of the gravel. A large quantity of gravel has been excavated from this pit for road metalling. Bones of Elephas antiquus, *Falc.*, and Cervus elaphus, *Linn.*, as well as flint implements, have been obtained from the gravel of this pit.*

In the town of Reading, about 12 feet in thickness, of coarse, subangular, and pebbly gravel, resting on brown loam, was exposed in 1887 in a large square pit, 10 chains north of the Bath Road, and 9 chains west of Turret House, or 17 chains westward of the centre of the railway-cutting (Basingstoke line). At 6 feet down from the surface there is a blackish irregular band from 6 to 9 inches in thickness, the gravel being stained there apparently with manganese. Two other similar bands occur beneath this, with a distance of 18 inches between them. This gravel consists almost entirely of flints, but well-rounded quartzites occur in places. The matrix is mostly sandy, with a little loam here and there. The colour of the gravel is generally brown, with whitish patches in places, similar to that exposed at Hill's or Groveland's Pit (described above), of which it is apparently a continuation. Several Echinoderms in flint have been found.

Plateau Gravel between the Rivers Kennet and Loddon.

In the south-west quarter of our district there are very extensive sheets of gravel capping the outliers of the Lower Bagshot Beds. In composition and general character they agree with the gravel of Bucklebury Common already described. They contain no red quartzite pebbles or Lower Greensand fragments, and quartz pebbles are very rare. When we pass into the eastern part of the district a change in composition takes place. Lower Greensand fragments are found, often in considerable abundance, as we approach the River Loddon, and red quartzite and variously-

* See also *Proc. Geol. Assoc.*, vol. ix. (1895-96), p. 211; vol. xv. (1897-8), pp. 305-6, and O. A. Shrubsole, *Quart. Journ. Geol. Soc.*, vol. xlvi. (1890), p. 585.

coloured sandstone pebbles and boulders in the gravels near the Thames. The following notes are by Mr. Bennett:—

On Crookham Common a pit north of the Traveller's Inn showed 6 feet of gravel. A pit close to the road, a little south-west of Brimpton church, showed 5 feet of clean coarse and fine gravel, with 10 per cent. of flint pebbles. Four sarsen stones were also seen, two of them large. At the bottom of the gravel was a bed of sandy loam.

A little north of Wasing Rectory, on Brimpton Common, 10 feet of ferruginous gravel was dug. North of Blacknest Farm another pit showed 8 feet of gravel. A little north-west of Inhurst House 6 feet of gravel in a clay matrix was dug, and south-east of the house 3 feet of gravel was seen in a small pit.

About one mile north of Borson two pits showed from 4 to 5 feet of gravel.

On Tadley Common, half-a-mile west of New Town, a small pit showed up to 4 feet of gravel in a clay matrix. Both the pits at the Tadley Kiln showed gravel resting irregularly on the Bagshot Beds, but in the south pit the junction was the more irregular, and the gravel and clay much intermixed.—F.J.B.

Gravel has been worked to a large extent on Silchester Common, the workings usually showing from 4 to 6 feet of gravel. The level is about 330 feet above the sea. As a rule the gravel is of a very light colour, often nearly white, not very sandy or clayey, and with but little sign of stratification. It consists of subangular flints, much weather-worn and broken, and of flint pebbles, together with a few blocks of sarsen. No Lower Greensand fragments could be found in it.* The Roman town of Silchester stands upon this gravel.

Near Padworth, Mr. Bennett notes that two pits east and west of Round Oak showed 4 to 5 feet of gravel in a clay matrix. South of Padworth Church 4 feet of gravel was dug, and near the schools 6 feet of rather fine gravel.

Numerous gravel workings were noted on Mortimer Common and showed gravel from 2 to 4 feet in thickness.

It consists of flint pebbles and of subangular flints very much broken and weather worn, often quite white, and usually small in size. Indeed, the small stuff might fairly be described as bleached chips of flint. There are a few blocks of sarsen, and very rarely a quartz pebble occurs. One 1½ inch in diameter was found in a working. No red quartzites or sandstones nor black chert nor fragments from the Lower Greensand could be found.

Sometimes the gravel is rather sandy, but usually it is a mass of stones with little or no sign of stratification.

On Burghfield Common there are several pits in a similar gravel.

The Lower Bagshot outlier at Brickleton Farm is capped by a small patch of plateau gravel with a level of 297 feet. Only a ditch-section was to be seen, and it seemed to show a gravel like that of Silchester; no Lower Greensand fragments could be found.

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* *Quart. Journ. Geol. Soc.* vol. xlviii. (1892), p. 37. *Proc. Geol. Assoc.*, vol. xvi. (1900), p. 514.

To the north-east of Stratfield Mortimer there are several small patches of plateau gravel, all of which lie at a lower level than either Mortimer Common or Silchester and rest upon London Clay.

The patch at Great Park Farm is at a level of 241 feet. That at St. Mary's Church, Beech Hill is at a rather lower level.

Near Crosslane Farm there are two small patches at a still lower level (about 190 feet). Gravel has been worked in the fields on both these patches: it appears to be about 4 feet thick. The gravel is like that of Silchester and no Lower Greensand fragments could be found.* Other patches of gravel occur at Bromfield Hatch and Reid's Farm.

About three quarters of a mile north-east of Crosslane Farm, and about 50 feet higher in level, there is another patch of gravel with a thickness of about 4 feet. There is a pit close to Whitehouse Farm which shows that the gravel consists of the usual subangular flints and flint pebbles but with the addition of many fragments of Lower Greensand chert and ragstone.

There are several patches of Plateau Gravel at, and near, Spencerwood Common and Shinfield, but they call for no special notice, and we may pass on to the patch on Southern Hill in the town of Reading which lies at a level of 230 feet above the sea. Christ Church occupies nearly a central position on this patch. The greatest thickness of this gravel appears to be about 16 feet, as proved in a well situated in a garden about 130 yards south of Christ Church. At the northern part of Bob's Mount, sections show it to be about 7 feet in thickness, with a very irregular line at its junction with the underlying basement-bed of the London Clay. In a pit 400 yards west-south-west of Christ Church—in a field south of Kingsclere Villas—8 feet in thickness was shown; and in two pits 300 yards south of Christ Church, 6 feet in thickness was exposed. The stones composing the gravel in these pits were mostly small.

They are mainly brown subangular flints and flint pebbles, but flints which have been scarcely at all rolled or water-worn occur. There are also a great number of pebbles of quartz and variously coloured quartzite. Black pebbles occur, one of which was found to be a tourmaline grit. This gravel consequently resembles that of Tilehurst, and is very different from that of Silchester. Some fragments which may have been derived from the Lower Greensand were noticed.†

To the east of Southern Hill, Reading, a group of patches of Plateau Gravel are found at levels of sometimes rather over and sometimes a little under 200 feet. They lie on London Clay, Reading Beds, and to a very small extent on Chalk, and form a flat topped tract of high ground projecting between the Thames and the Loddon.

In the South Eastern Railway cutting at Woodley Hill, Earley, the gravel was from 12 to 15 feet in thickness, and a pit at a level

* *Quart. Journ. Geol. Soc.* vol. xlviii. (1892), p. 37.

† See *Quart. Journ. Geol. Soc.* vol. xlix. (1893), p. 310.

of 214 feet, close to the railway and a little west of Earley station, showed that it contained a great many Lower Greensand fragments, but no quartzite pebbles could be seen.

Mr. Ll. Treacher has obtained numerous flint implements from the Gravel cut through by the Great Western Railway south of Sonning.

A pit in a field east of Wheeler's Green, about 2¾ miles east of Southern Hill, Reading, showed 6 feet of Plateau Gravel with rather indistinct stratification, agreeing in composition with the pit by the railway, for Lower Greensand fragments were very common, and the quartzites which are so abundant at Southern Hill were apparently absent. This pit is near the Loddon, but one and a quarter miles to the north-west, and nearer to the Thames there is another pit in gravel which contains quartzite pebbles in abundance.

The pit referred to is on the south-east side of the London Road Bridge over the Great Western Railway cutting. The section showed 9 feet of gravel with some loam in places resting on the clay of the Reading Beds. The gravel is stratified, but the stratification is indistinct in places. It consists mainly of the usual subangular flints and flint pebbles. Quartzite pebbles are common, and often measure as much as 4½ inches in longest diameter. Fragments from the Lower Greensand occur, but are not common.

Another pit, known as the Charvil Hill Pit, in the same sheet of gravel by the side of the Reading-Twyford Road, and 6 furlongs south-east of Sonning Church, gave a section in well stratified gravel with a little current-bedded sand in one place. The gravel resembles that in the last pit by the railway bridge. Quartzite pebbles are common, the red quartzite which has been noted at so many places near the Thames being abundant. A number of flint implements from this pit are in the collection of Mr. Treacher.

Plateau Gravel east of the River Loddon.

The Bagshot outlier of Heckfield Heath is capped by an extensive sheet of gravel usually some 6 feet in thickness, and at a level of 270 feet above the sea. It is thus some 50 feet lower than the gravel of Silchester, rather more than four miles to the west, and differs from it in several respects. It is much more sandy, is well and evenly stratified, the stones in it are less broken and weather-worn, and it contains fragments from the Lower Greensand.

There are numerous pits in Heckfield Heath; one in which the junction with the underlying Lower Bagshot Beds was seen has been already noted (page 55). The gravel, as usual, consists mainly of brown subangular flints and of flint pebbles. Lower Greensand fragments are quite common, and minute pebbles of quartz occur.

The Lower Bagshot outlier at Farley Hill is capped by a patch of Plateau Gravel of a character similar to that of Heckfield Heath. A block of white quartzite was found in a pit a little south of Farley Castle. Sept., 1902. It was of irregular shape, and weighed 5lb. 6oz.

A specimen of the rock has been examined by Dr. J. S. Flett, who reports as follows:—

> The rock is a milky white, worn quartzite with diffuse patches of ferruginous staining. It is somewhat granular or saccharoidal, but in the hand-specimen shows no gritty texture.
>
> Under the microscope it exhibits a mosaic of irregular interlocking grains of quartz, which vary greatly in size. All are filled with minute fluid cavities, in lines and streaks, which do not as a rule pass across the boundaries of the individual grains from one to another. Shearing has evidently taken place, as much of the quartz has undulatory extinction, and streaks of fine grained granulitic material are frequent. There is no evidence of original sedimentary character or of a cementing material between the grains, and the rock is apparently a mass of crushed vein-quartz.

There are small patches of similar gravel on the Lower Bagshot outlier of Arborfield Cross.

Another patch lies on the main mass of the Lower Bagshot Beds at Bannisters, near Eversley. A pit in Fleet Copse shows about 5 feet of gravel consisting of brown subangular flints, of flint pebbles and Lower Greensand fragments, with some ferruginous concretions probably from the Bagshot Beds. It is dark yellow, very sandy, well stratified, and with current-bedding in places. Here and there the gravel is consolidated into a ferruginous conglomerate.

The Upper Bagshot outlier of Finchampstead Ridges is capped by a sheet of Plateau Gravel with a level of rather over 300 feet, that is to say, about the same level as the Silchester plateau, nearly 10 miles to the west. The thickness of the gravel is sometimes as much as 13 feet. It consists of brown subangular flints, of flint pebbles, a good many small fragments of Lower Greensand rock, and a good deal of quartz in the form of very small pebbles usually under ½ inch in diameter. Blocks of sarsen are not common, but occur occasionally. Many flints of irregular shape, which have been but little water-worn, occur, and all are of a brown colour.

Mr. O. A. Shrubsole found a few pebbles of white quartz or quartzite in this gravel, the largest measured 31 × 24 × 17 inches. *

In it there is frequently a good deal of coarse quartz sand, sometimes with irregular white clayey layers, and the whole is often contorted, the contortion being most usual in the upper part.

Some stones found in this gravel, which have possibly been used as scrapers, have been described by Prof. Rupert Jones, F.R.S., as Eolithic Flint implements. †

The gravel is very ferruginous and is frequently consolidated

* *Quart. Journ. Geol. Soc.* vol. xlix. (1893), p. 320.

† Report of the Wellington College Natural Science Society, for 1901, published 1902, page 58.

into a hard conglomerate or grit. This is also the case in many, or most, of the patches of gravel in this part of the district, and the rock thus formed has been used as a building-stone. The tower of All Saints' Church, Wokingham, is mainly built of it.

On Barkham Common there are small patches of gravel resembling that of Finchampstead, and at Bearwood there is a patch where the proportion of Lower Greensand chert is higher than at Finchampstead.

At and near Wokingham are some more patches, the gravel of which consists very largely of flint pebbles probably derived from the Lower Bagshot Beds. (See p. 78.) Lower Greensand fragments are present in all these gravels.

No red quartzites could be found, but they occur in the two patches of plateau gravel at Twyford and Ruscombe. Some trial holes in a field 2½ furlongs south of Twyford station showed 6 feet of reddish gravel consisting of subangular flints, of flint pebbles with many pebbles of red quartzite, and an abundance of fragments from the Lower Greensand. The place is about 2 miles from the Thames and a little east of the Loddon. A section showing the gravel of this patch resting on clay and sand of the Reading Beds was noted (October, 1902) at a brickfield between Ruscombe and the Great Western Railway. The gravel resembles in character and composition that of Charvil Hill on the opposite side of the River Loddon (see p. 73) and like that gravel it has yielded flint implements.*

According to Mr. H. J. O. White a section in the north side of this brickyard in 1893 showed "a gravel of purely southern type [with Lower Greensand fragments but without the quartzites] underlying one of north-western facies."†

* See O. A. Shrubsole, *Quart. Journ. Geol. Soc.*, vol. xlvi. (1890), p. 591.
† *Proc. Geol. Assoc.*, vol. xvii. (1901), p. 177.

CHAPTER X.

THE VALLEY GRAVEL AND LOAM.

Valley Gravel of the River Thames.

The patches of Valley Gravel along the course of the Thames are of no great extent. They lie in nearly all cases on Chalk.

Mr. A. J. Jukes-Browne notes that at Goring, near the corner of a new road opposite the school, a bell pit was sunk (February, 1886) through soil and gravel into Chalk, the last being about 10 feet below the surface. There is also a large gravel-pit about half a mile north of Streatley.

Near the house built for Mrs. Stokes at the southern end of this road a pit was open for sand. Mr. Joseph White stated that the thicknesses proved were as follows:—

Gravel about 10 feet
Sand ,, 17 ,,
Chalk beneath.

There are patches of Valley Gravel at Basildon Whitchurch, and Pangbourne.

Much of the town of Reading stands on Valley Gravel. A broad strip runs from the Barracks to the County Gaol and Biscuit Factory. This gravel was found to be 15 feet thick at the Royal Albert Hotel.

There was for some time a pit on the east side of Elm Lodge, and more recently (1902) a pit has been worked close to the County Cricket Ground, Kensington Road. The sections showed from 17 to 18 feet of stratified gravel resting on Chalk. The gravel consists of much small chalk, of subangular flints, some being of large size and but slightly waterworn, together with a few large rounded quartzites. A few pieces of broken bone and some teeth of *Hippopotamus* have been recorded from this pit.*

In a small pit at Battle Farm, situated a little more than 300 yards east-north-east of the workhouse, 5 feet in thickness of light-coloured subangular flint gravel was exposed.

At the time when the excavations were made for the basements of the new buildings in the central part of Blagrave Street, on the western side near the *Reading Observer* Office, 14 feet in thickness of subangular flint-gravel was exposed resting on Chalk, which latter was penetrated to a depth of 8 feet, when water was reached.

An excavation made for drainage-purposes in the road in the Forbury, near the Assize Courts, exposed 8 feet in thickness of gravel and sand.

To the east of the Kennet there is a wide spread of Valley Gravel resting partly on Chalk and partly on Reading Beds. Most of Church Ward is built upon it.

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* *Proc. Geol. Assoc.*, vol. xv. (1897-98), p. 304, and vol. xvii. (1902), p. 381.

In the London Road, opposite Portland Place, an excavation showed 3 feet in thickness of brown subangular flint gravel.

At the north-western corner of the Alexandra Road, at a spot about 50 yards eastward of the Unitarian Chapel and adjoining the London Road, an excavation in 1887 showed 15 feet in thickness of brown subangular flint gravel resting on Chalk at one part; and at a point a few feet southward of the above, chalk was reached at a depth of 10 feet. The stones composing the gravel were for the most part very small, particularly in the upper portion; but towards the base, there was a large light coloured or whitish patch of coarse flint gravel lying at a considerable angle, and mostly made up of stones varying from about 4 to 8 inches in diameter. There were no indications of stratification.

Some sections in a gravel pit a little to the east of Reading School were described by Mr. E. B. Poulton in 1880, as follows.*

The Valley Gravel including the surface bed was about 12 feet thick, and beneath it was some 9 feet of clays and sands apparently derived from the Eocene Beds, containing mammalian remains and portions of trunks of trees a foot or more in diameter, and in some cases several feet in length.

The Valley Gravel has been extensively dug near the mouth of the River Kennet. A pit between the South Eastern Railway and Cholmeley Road showed 16 feet of well-stratified gravel resting on the Chalk. The gravel contained some flints not much waterworn and some small pebbles of chalk and fragments of shells from the Eocene Beds. Numerous pebbles of quartz and quartzite and a piece of quartz conglomerate were noticed. Amongst the small stuff were irony fragments many of which were bits of fossils probably from the Oolites. The bulk of the deposit was as usual formed of subangular flints and flint pebbles.†

Mr. O. A. Shrubsole mentions that mammalian bones have been found here.‡

There are some patches of gravel resting mainly on Chalk at Sonning, Twyford, Wargrave and Shiplake station.

A good section showing from 9 to 10 feet in thickness of subangular and pebbly flint gravel overlying Chalk, was exposed (1886) in the village of Sonning, in a pit 400 yards east-north-east of St. Andrew's Church.

The Twyford gravel consists of subangular flints, flint pebbles, quartzites, etc.

The Shiplake Station patch is coarse subangular flint gravel. It contains pebbles of quartz, quartzite, etc., like the patches of Plateau Gravel at Shiplake Church (see page 66), and, like them, it also contains many fragments from the Lower Greensand.

* *Quart. Journ. Geol. Soc.* vol. xxxvi., p. 296.
† *Quart. Journ. Geol. Soc.* vol. xlviii. (1892), p. 44.
‡ *Quart. Journ. Geol. Soc.* vol. xlvi. (1890), p. 590; 4. Kennet Mouth.

Valley Gravel of the River Pang.

The following note is by Mr. Bennett:—

From where this river enters the district gravel is seen all along its course.

Near Marlston House, Frilsham, are some patches of a high level Valley Gravel, and a large pit north-east of the house shows 9 feet of coarse gravel with very large flints in a clayey matrix.

Valley Gravel is also seen in the side valley west of Marlston House.

South-east of Coles Farm west of Bucklebury are two pits in fine and coarse gravel. One of the pits showed 12 feet of the gravel, with many pebbles in a clayey and ferruginous matrix, with a band of stiff loam in one place resting on Chalk.—F.J.B.

Valley Gravel of the Rivers Kennet and Enborne.

Mr. Bennett also contributes the following:—

In the valley of the Kennet on the western side of the district alluvium and peat hide a good deal of this gravel.

The course of the river Enborne is mostly marked out by gravel, there being little alluvium. The gravel is mostly derived from the high level gravel and so much resembles it, but is coarser contains more sarsen stones, and shows more stratification. There are some seams of sand and of loam in this gravel.

These remarks also apply to the gravel of the River Pang.

A pit at Calthrop Cottages, north of Calthrop Mill, showed brown loam over gravel. South of Midgham Bridge was a pit in a small patch of gravel where shell-marl was also seen.

At the junction of the river Enborne with the Kennet is a considerable spread of gravel, and there are indications here of a gravel terrace.

North of Wasing Park the gravel has a loamy surface, so that there may be beds of loam in it. At Aldermaston the gravel broadens out on the left bank of the river, whilst there is but little on the right bank, and that almost confined to small patches.—F.J.B.

Near Beenham a section showing 8 feet in thickness of fine gravel, was exposed to the east of Gravel Pit Farm, a little north of Aldermaston railway station.

There was another section, showing similar gravel in a pit about three-quarters of a mile north-east of the above, adjoining the road on the west side.

At Theale, in a gravel pit now (1887) ploughed over half-a-mile west of Holy Trinity Church, on the east side of the road, a section showed 5 feet in thickness of gravel (not the total thickness apparently), consisting of small subangular flints and pebbles.

Gravel similar to the above was to be seen in old pits on either side of the fork in the road, about five-eighths of a mile south-west of Holy Trinity Church, where the thickness of the gravel to the water-level is from 8 to 9 feet.

A large pit occurs about a quarter of a mile eastward of the above-mentioned fork in the road; here, a continuation of the same spread of gravel has been excavated to a depth of from 9 to 10 feet, and used apparently for ballast for the railway.

At Burghfield, flint gravel was exposed to a depth of 3 feet (not bottomed) in a pit on the north side of the fork in the road, one mile north-by-east of St. Mary's Church.

A similar thickness of gravel (3 feet) was shown on the sides of a pond and ditch immediately north of Field Farm, a little more than a quarter of a mile north-west of the above pit.

A section, showing fine whitish gravel, composed of subangular flints and with many black flint pebbles, is exposed around a pond about 50 yards north of Searl's Farm, nearly one mile and three-quarters north-east-by-north of St. Mary's Church, Burghfield.

Gravel similar to the above was exposed on the sides of a saw-pit situated 350 yards north north-east of Searl's Farm; and also along a ditch about 150 yards eastward of the farm, where it was shown to have a matrix of blackish sand.

In ditches around Knight's Farm, half-a-mile south-west of Searl's Farm, fine flint gravel, very similar to that mentioned above, was seen in section, also in ditches along the roads and elsewhere eastward of Amner's Farm, nearly three-eighths of a mile south-west of Knight's Farm.

Around Amner's Wood, situated half-a-mile south-eastward of Amner's Farm, there is a little loam overlying the gravel, which latter was well exposed in section in the ditch running eastward from near Amner's Wood to the railway.

A small stream flows by Silchester and Stratfield Mortimer to the Kennet, and there is a patch of gravel at Grazeley. A pit close to Grazeley Court showed 8 feet of well stratified gravel consisting mainly of subangular flints. There were some flint pebbles. One quartz pebble rather over an inch in length was noticed, but no quartzites or Lower Greensand chert could be found.

Valley Gravel of the Rivers Loddon and Blackwater.

With the exception of some small patches at Stratfieldsaye, there is very little gravel in the Loddon valley until that river is joined by the Blackwater. From that point to the Thames the sheets of Valley Gravel are extensive, and look like a continuation of the gravels of the Blackwater, with which moreover, they agree in character.

On the north side of the Blackwater there is an irregular strip of Valley Gravel. Near Lea Farm it is worked down to water which is reached at about 3 feet below the surface. The gravel is composed of brown subangular flints, of flint pebbles, and of fragments from the Lower Greensand.

On the south side of the river there is a much more extensive sheet of gravel running from the edge of the district to the junction of the Blackwater and Loddon at Swallowfield, and only broken by the alluvium of the Whitewater.

The surface of the ground rises from the river southwards, and the highest part of the Valley Gravel forms a terrace some 40 to 50 feet above the level of the Alluvium, and running from Glaston Hill House to Wixenford and across Riseley Common.

A section in the road by the schools near Glaston Hill House showed 4 feet of this gravel, with rough stratification and resembling in composition that of Lea Farm on the other side of the river.

Below the junction of the rivers Blackwater and Loddon there is a large sheet of gravel running from near Swallowfield to Schoolgreen, Shinfield.

Near the river the gravel is at the same level as the alluvium, but it rises gradually, and the highest parts of the sheet are about 20 feet above that level.

There was a section in a large pit a furlong south of Sussex Lodge, Swallowfield. It showed 12 feet of gravel stratified with seams of sand and with ferruginous staining here and there. It consists of subangular flints and flint pebbles, with occasional Lower Greensand fragments. The stones are mostly small, seldom as much as 5 inches in diameter. There was water at the bottom of the pit.

At the large gravel-pit to the north of Schoolgreen, Shinfield, and a quarter of a mile south-east of the church, the following section was exposed in 1887 :—

	Feet.
Soil - - - - - - - - - - -	1 to $1\frac{1}{2}$
Fine well-stratified gravel - - - - - -	9

The gravel was of a light-brown colour, but ferruginous in places, and here and there stained black with manganese. Occasional lenticular bands and seams of brown sand and loam also occurred, one measuring 6 inches in thickness. There were not many stones larger than 4 inches in size, and a very few measuring as much as that.

In places the gravel is cemented into a hard ferruginous conglomerate. It is composed of brown subangular flints mostly broken into fragments. There are some flint pebbles but no large proportion. Lower Greensand fragments are common, many pieces being over 2 inches in length.

In another patch of Valley Gravel a little north of Shinfield Grange there was a pit 5 feet deep in a similar deposit. A band of ferruginous conglomerate about 9 inches thick ran for some distance about a foot below the surface of the ground.

On the opposite side of the river Loddon there is a well marked terrace running from Arborfield to near King Street, and on it are several patches of Valley Gravel.

At Arborfield a patch of this gravel lies about 20 feet above the river. It is worked to a depth of 9 feet on the north of the lane which runs across the patch.

Arborfield Hall stands on another patch, and there is a pit showing 6 feet of gravel to the north of the Hall.

The next patch of gravel to the north rises 30 feet above the river.

There was a pit in the gravel of the patch at Carter's Hill, and several workings in the fields near Sindlesham.

All these sections show a gravel, more or less well stratified, consisting of subangular flints, flint pebbles and Lower Greensand fragments. Almost all the stones are much broken and water-worn; even the flint pebbles have often been broken and subsequently rolled.

From near King Street to near Twyford there is a fairly extensive sheet of Valley Gravel on the right side of the river and some small patches on the opposite side.

There were pits near Arbor Cottage, at Merryhill Green, and at Hurst Grove. In all the gravel was stratified and consisted of subangular flints, of flint pebbles, and of Lower Greensand fragments. No quartz or quartzite pebbles could be found.

Loam.

Several patches of Loam have been mapped in the Valley of the Thames between Pangbourne and Wargrave.

Along the southern bank of the River Thames between Norcot Scours and the Fisheries at St. Mary's Island, south of Chazey Farm, from 2 to 5 feet in thickness of brown loam was exposed in section over gravel.

Loam of a similar thickness, and also over gravel, is exposed along the southern bank of the Thames opposite Caversham Mill at Lower Caversham.

A large irregular-shaped mass of brownish and yellowish loam occurs in the valley north of the village of Sonning, at a slight elevation above the surrounding alluvium or meadow land. Along the banks of the stream, three-quarters of a mile north-north-west of Sonning Bridge, it was shown to be 5 feet or more in thickness.

Loam 4 feet in thickness is exposed along the northern bank of the Thames at the bend in the river westward of Holme Park.

A good section, showing from 4 to 5 feet 6 inches in thickness, of loam overlying subangular flint gravel, is exposed along the northern bank of the River Thames extending from near the French Horn Inn to a short distance beyond the timber tow-path bridge at Sonning.

About five-eighths of a mile north-north-east of the tow-path bridge above mentioned, a section along the northern side of the river—opposite Sonning Meadow—shows 6 feet in thickness of brown loam.

There are two patches of loam in the low-lying ground south of Sulham between the rivers Pang and Kennet. There are also some patches in the Valley of the Loddon, between Loddon Bridge and Shinfield.

CHAPTER XI.—RECENT.

Mr. Whitaker has remarked that "The alluvium, or modern river deposit, of the Thames, consists mostly of silt. That of the Kennet is more peaty: that of the brook running through Bucklebury and Bradfield consists, to the east of the latter place, of peat and peaty clay above silt; and along one of the small watercourses running through this alluvium the bottom is covered with spherical calcareous concretions, from half-an-inch to an inch in diameter."*

On the southern bank of the river Thames opposite Mapledurham, just south of the lock, a section extending to about 300 yards showed from 5 to 7 feet in thickness of brown loam.

On the same side, but north-westward of the lock, a section extending for a considerable distance showed a thickness of 5 feet of brown loam.

The following notes on the Alluvium, Peat and Marl or Tufa of the Kennet and Enborne Valleys are by Mr. Bennett.

Peat was once extensively worked round Midgham, so much so that very little, if any, of the thick beds can be left now. The peat in the Kennet Valley was dug and burnt, the ashes being used as manure, and this practice was carried on for over 150 years and only ceased about the middle of last century, so that we can only wonder if any should be left. The present osier beds mark the places where the peat was dug. Associated with the peat is a deposit of shelly marl, and this may be seen at Chamberhouse Farm and a little east of that place. South-east of Bank Farm a section where the peat was still dug for burning into ashes for manure was open in 1887; the section showed about 8 feet of peat and one part of the section also showed about an equal thickness of the shell marl, interbedded with the peat.

The marl forms a feature, rising above the peat as a rule and sometimes forming mounds in it.

South of Banks Farm a fair sized patch of the marl has been mapped, and in this part of the sheet it seemed to be confined to a spot east and west of the farm. A polished flint implement was found in the peat there.

In the valley of the Enborne, during the making of a bridge near Hyde End bones of ox, horse, and roe deer were found. They are now in the Blackmore Museum, Salisbury.—F. J. B.

Along the southern side of the Kennet, on the eastward side of the Reading and Basingstoke Railway, a section—just south of the seven weirs—showed 4 feet in thickness of brown loam overlying gravel, which latter was exposed to 4 feet.

At Plummery Ditch, Reading, bones of mammalia have been dug out. "Some of these occurred in a peaty deposit, along

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* "The Geology of Parts of Oxon. and Berks.," *Mem. Geol. Sur.*, Sheet 13, 1861, p. 57.

with fresh-water shells, below the river sands, and above a bed of gravel. Some came from the lowest gravel." *

The following quotation relating to Reading is of interest: the first sentence probably refers to Valley Gravel:—

"In the gravel, bones of ox, horse, and elephant have been sparingly met with, whilst in one pit upon the Redlands estate the trunk of a pine tree was found. . . . During excavations made in 1872, 1873, and 1874, in connection with the town drainage, and again recently by the Gas Company, immense quantities of bones have been taken from the bed of the Kennet, and from the silt and shell-marl underlying the peat in the meadow adjoining the river. Many tons of bones of various ages . . . have been upturned—some few are human; others belong to the horse, hog, wild boar [? same] beaver, wolf, dog, fox, red and fallow deer, *Bos primigenius, Bos longifrons,* and *Bos taurus* [? same] and goat. These are associated with pottery of recent, and of Roman, Saxon, British and mediæval date, numerous implements worked of bone, such as awls, shuttles, winders, and salmon gaffs, also a yoke made of the antler of the stag, and some twenty or more species of fresh water shells, all of existing species."†

Many animal and plant remains, and some other objects of geological interest, have been obtained from excavations on the site of the Roman city at Silchester. ‡

SARSEN STONES.

Sarsen stones or Greywethers which have been derived from Eocene strata, are not uncommon in the Chalk district and their occurrence in many of the gravels has been already noted. They are found all over the country in use as corner-posts, and blocks of sarsen stone may be seen in many buildings.

Sarsen stones are believed to have been used by the Romans as mile stones between Streatley and Aldworth. §

The Nymph, or Imp, stone on Silchester Common is a small block of Greywether sandstone about a foot square.||

During the construction of the roads at Earley Rise in 1887, a Sarsen stone was found about 2 feet beneath the surface, on the sloping ground at a spot about 8 chains south of the railway and 28 chains N.W. of the church. The stone was a whitish saccharoid sandstone of a triangular shape and measured 2 ft. 10 in. × 1 ft. 10 in. × 1 ft. 6 in. It presented a waterworn appearance, the edges being all much rounded, and rested on London Clay.

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* *Proc. Geol. Assoc.*, vol. iv., No. 8, p. 523 (1876).

† H. M. Wallis (of Reading), 1881, *Proc. Holmesdale Nat. Hist. Club* for 1879 and 1880, p. 56.

‡ See *Archæologia*, vols. lii.-lviii., 1890-1902.

§ T. Rupert Jones. History of Sarsens. *Geol. Mag.*, Dec. 4, vol. viii. (1901). p. 117.

|| Prestwich. *Quart. Journ. Geol. Soc.*, vol. x. (1854) p. 124, note.

APPENDIX.

List of Principal Works on the Geology of the District.

GEOLOGICAL SURVEY PUBLICATIONS.

1.—*Maps.*

Sheet 7. By W. Whitaker, T. R. Polwhele, and others. 1861. Drift Edition. By W. Whitaker and C. E. Hawkins. 1872.
Sheet 8. By T. R. Polwhele, and others. 1862. Drift Edition. By W. Whitaker, F. J. Bennett, and C. E. Hawkins. 1887.
Sheet 12. By W. T. Aveline, H. W. Bristow, and R. Trench. 1860.
Sheet 13. By W. T. Aveline, W. Whitaker, and others. 1860.
Sheet 268. New Series. By F. J. Bennett and J. H. Blake. Editions with and without Drift. 1898.

2.—*Memoirs.*

The Geology of parts of Berkshire and Hampshire (Sheet 12). By H. W. Bristow and W. Whitaker. 1862.
The Geology of parts of Middlesex.........Berkshire, &c. By W. Whitaker. 1864.
The Geology of the London Basin. By W. Whitaker. *Mem. Geol. Survey*, vol. iv. 1872.
The Geology of London. By W. Whitaker. 2 vols. 1889.
The Water Supply of Berkshire. By J. H. Blake, with contributions by W. Whitaker. 1902.

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1700. Brewer, Dr. J. Part of two letters concerning beds of Oyster-shells near Reading. *Phil. Trans.*, vol. xxii., No. 261, p. 284.
1813. Lysons, Rev. D. and S. Magna Britannia, vol. i., part 2. Berkshire (with a Geological description by Dr. Beke, and Note of Fossils, &c., pp. 187–193). 4to, Lond.
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On the main points of Structure and the probable Age of The Bagshot Sands. *Quart. Journ. Geol. Soc.*, vol. iii., p. 378.
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1861. Whitaker, W. On a Reconstructed Bed on the top of the Chalk and underlying the Woolwich and Reading Beds. *Quart. Journ. Geol. Soc.*, vol. xvii., p. 527.

1862. WHITAKER, W. On the Western End of the London Basin. *Quart. Journ. Geol. Soc.*, vol. xviii., p. 258.

1871. PHILLIPS, Prof. J. Geology of Oxford and the Valley of the Thames. 8vo. Oxford.

1873. JONES, Prof. T. R. The Geology of the Kennet Valley. *Trans. Newbury Field Club*, 1870–71, p. 21.

1875. JONES, T. RUPERT AND C. COOPER-KING. On some newly exposed sections of the Woolwich and Reading Beds at Reading, Berks. *Quart. Journ. Geol. Soc.*, vol. xxxi., p. 451.

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1893. MONCKTON, H. W. On the occurrence of Boulders and Pebbles from the Glacial Drift in Gravels south of the Thames. *Quart. Journ. Geol. Soc.* vol. xlix., p. 308.

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298.

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ENGLAND AND WALES.

THE GEOLOGY OF

THE COUNTRY AROUND

SALISBURY.

(EXPLANATION OF SHEET 298.)

BY

CLEMENT REID, F.R.S., F.L.S., F.G.S.,

WITH CONTRIBUTIONS BY H. B. WOODWARD, F.R.S., F. J. BENNETT, F.G.S., AND A. J. JUKES-BROWNE, B.A., F.G.S.

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MEMOIRS OF THE GEOLOGICAL SURVEY.

ENGLAND AND WALES.

THE GEOLOGY OF

THE COUNTRY AROUND

SALISBURY.

(EXPLANATION OF SHEET 298.)

BY

CLEMENT REID, F.R.S., F.L.S., F.G.S.,

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PREFACE.

THE country described in this Memoir includes a large part of Salisbury Plain and part of the Vale of Wardour. The original Geological Survey was made by H. W. Bristow, and published on the old series sheets 14 and 15, in 1856 and 1857, without any accompanying Memoir.

The re-survey on the six-inch scale was commenced by Mr. A. J. Jukes-Browne in 1890, and resumed by Mr. F. J. Bennett in 1894, under the superintendence of Mr. Whitaker. Mr. Bennett, who surveyed most of the ground, retired in 1899, and the field work in the Vale of Wardour was completed in 1900 by Mr. Clement Reid, to whom the preparation of the Memoir has been entrusted.

Few notes were left by Mr. Bennett, and Mr. Reid has availed himself of materials gathered by Mr. H. B. Woodward, and published in the General Memoir on the Jurassic Rocks, and of those by Mr. A. J. Jukes-Browne, some of whose observations have been published in the Memoir on Cretaceous Rocks, vol. i., or prepared for the later volumes.

As the Portland and Purbeck strata of the Vale of Wardour extend a little way beyond the limits of the map, it has been deemed desirable to include descriptions of all the sections in the present Memoir.

While recognising our indebtedness to previous workers notably to Fitton, whose early observations made the Vale of Wardour classic ground for geologists, as well as to Brodie, Prestwich, Mr. W. H. Hudleston, Prof. J. F. Blake, Dr. C. Barrois, and others, it is a satisfaction also to acknowledge the personal assistance rendered by the Rev. W. R. Andrews (formerly of Teffont Evias), and by Dr. H. P. Blackmore, of Salisbury, whose intimate knowledge of the Chalk, the Pleistocene, and later accumulations is so well known.

J. J. H. TEALL,

Director.

Geological Survey Office
28 Jermyn Street, London.

18th October, 1901.

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LIST OF ILLUSTRATIONS.

GEOLOGY

OF THE COUNTRY AROUND

SALISBURY.

CHAPTER I.

INTRODUCTION.

SHEET 298 of the Geological Survey Map takes in an area of 216 square miles, belonging to Wiltshire and including the southern part of Salisbury Plain, the Vale of Wardour, and part of the Avon Valley.* At its north-east corner the Map just overpasses the Hampshire boundary; but only takes in a quarter of a square mile belonging to that county. Salisbury and Wilton are within its limits, which extend westward to Tisbury, northward to Amesbury and Stonehenge, and eastward to East Grimstead. Most of the district is occupied by undulating Chalk Downs, which rise in a few places to 700 feet, and even reach 766 feet above the sea on White Sheet Hill. The Downs are deeply trenched by river valleys, all tributaries of the Avon, and one of these valleys, that of the Nadder, lays bare a few square miles of older Cretaceous and of Jurassic Rocks in the Vale of Wardour. These older strata give rise to scenery of a totally different character, with sandy heaths, clay flats, and outcrops of limestone; making bold scarps and flat-topped hills very unlike the rounded Chalk Downs. This difference of scenery marks off the Vale of Wardour as something apart from the remainder of our district. Another small area of distinct character—sandy or clayey, well-wooded land—is formed by the Tertiary syncline near Alderbury, which, however, only occupies about seven square miles.

This region is mainly devoted to agriculture, the Chalk Downs forming excellent pasturage for sheep, while the valleys are noted for their dairy-farming. Most of the area, even of the high and exposed Salisbury Plain, is now under the plough; but

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* For "List of Books, Maps, Papers, &c., on the Geology, Mineralogy, and Palæontology of Wiltshire" to the year 1873, by Mr. W. Whitaker, see *Wilts. Archæol. Mag.*, vol. xiv., p. 107.

the character of the land varies greatly, even over the same rock. Some areas of Upper Chalk, like that around Stonehenge, are dry, having only a few inches of soil; whilst others have five or six feet of stony loam, which makes a wet soil and supports extensive woods. The soils in the Vale of Wardour are so greatly mixed, through downwash from the scarps on each side, that in that region there is but little land the soil of which can be said to be the direct product of the rock on which it lies.

The other industries connected with geology are mainly the quarrying of Purbeck and Portland stone for building and road metal, of Chalk for lime and cement, and the digging of brick-earth and sand for building-purposes. Over great part of the area the loose Chalk-flints found in the fields are used for road-making. No ores are obtained in the district, the only underground workings being those for the extraction of the Portland stone around Tisbury.

The formations represented in Sheet 298 are as follows:—

Recent	Alluvium.
Pleistocene	Brickearth. Valley Gravel. Plateau Gravel. Clay with Flints.
Eocene	Bagshot Sand. London Clay. Reading Beds.
Upper Cretaceous	Upper Chalk. Middle Chalk. Lower Chalk. Upper Greensand and Gault (Selbornian).
Lower Cretaceous	Lower Greensand Wealden.
Upper Jurassic	Upper Purbeck. Middle Purbeck. Lower Purbeck. Upper Portland. Lower Portland. Kimeridge Clay.

The strata beneath the Kimeridge Clay have nowhere been reached within the area described in this Memoir. There seems reason to believe, however, that several thousand feet more of Secondary strata would have to be passed through before any Palæozoic rock could be touched. Under these circumstances it seems useless to discuss the possibility of Coal Measures being met with.

Before entering on the description of the strata above tabulated, it may be useful to say a few words on the underground structure of the district; for in this region the appearance of the rocks at the surface is due more to underground structure than to any strongly-accentuated system of hill and valley. If a general geological map of this part of England be referred to, it will be seen that two systems of disturbance dominate the whole area. There is, in the first place, a general uptilt toward the north-west, causing a strongly-marked north-east and south-west strike of the rocks from the Wash to the Devon coast. Every stratum has been so tilted that the newer rocks occur, in general, towards the south-east. But this uplift, which cuts off the London and Hampshire Tertiary Basins, and gives a general, though slight, south-eastward cant to the strata throughout the Salisbury area, is modified by a series of sharp folds with axes nearly east and west. These east and west folds are most strongly developed in the coast region between Brighton and Weymouth; but two of them enter the area described in this Memoir. On the east of Salisbury a synclinal trough extends from the Avon at Alderbury, through East Grimstead, to the River Test outside our district. West of Salisbury a well-marked anticline coincides with the Vale of Wardour and causes the Cretaceous rocks on either side to dip towards the north-north-east and south-south-east respectively. An older disturbance, which affects the Jurassic and Lower Cretaceous rocks, but does not affect the Upper Cretaceous, occurs in the same area; but this disturbance, though important, cannot easily be dealt with until the various strata involved have been described. It will be again referred to.

CHAPTER II.

KIMERIDGE CLAY.

The Jurassic rocks of the Vale of Wardour appear in succession from beneath a covering of newer strata. The two series dip in the same general direction, and have the same dominant strike; but the older rocks dip at a higher angle than the newer, so that newer and newer Jurassic strata appear as the valley is followed eastward. Three miles west of Tisbury, Upper Cretaceous strata rest immediately on the Kimeridge Clay; at Teffont they rest on Upper Purbeck rocks; at Dinton the Wealden clays come between. Perhaps, if the valley were deeper, we might find that a few miles to the east, near Salisbury, the rest of the missing Lower Cretaceous strata are preserved.

The exposure of the Portland and Purbeck rocks in the Vale of Wardour is so small and isolated that, though part of the outcrop lies without our district, it will be most convenient to complete their description in this Memoir, especially as it will only add a page or two to the bulk, and the Frome map cannot be finished for several years.

The Kimeridge Clay shown in the Salisbury map crops out only in the bottom of the valley near Tisbury; but it is so obscured by downwash from the hills on either side that little can be said about it. There is no clear section within the area here described, though a well on the alluvium immediately north of Wallmead Farm showed black, unctuous, shaly clay. Another well, close to the stream at the Chilmark quarries, is said also to have reached very black clay beneath calcareous sandy beds (Portland) at 39 feet from the surface.* It is not quite clear whether this may not have been a clay-bed in the Portland Sands: for the foreman told me that the well was still in sand at the bottom, and that the solid clay had not been touched. At any rate, the Kimeridge Clay cannot be far below the stream-bed at this point. (See p. 10).

West of the small area here described the outcrop of the Kimeridge Clay in the valley bottom gradually widens, until it merges into the extensive, undulating, well-wooded plain, which stretches in a wide belt from south-west to north-east almost across England.

* H. B. Woodward, "The Jurassic Rocks of Britain," vol. v., p. 204, Mem. Geol. Survey, 1895.

CHAPTER III.

PORTLAND BEDS.*

The Portland Beds comprise a very variable set of strata. In the upper part they include shelly limestones, oolite, chalky and compact limestones, with local layers and nodules of chert, and some beds of sand and calcareous sandstone. The lower beds comprise alternations of greenish-grey glauconitic sand with thin loams and clays. The thickness of the entire formation in the Vale of Wardour is about 100 feet, and it extends from near Donhead and East Knoyle on the west to Tisbury and Chicksgrove, where it sinks beneath the stream level. In the Chilmark valley, however, it again appears, and has been extensively worked. How far it extends eastward beneath the newer strata is still unknown.

The Portland Beds are essentially marine accumulations. Indications of estuarine conditions have been considered to occur in the so-called "*Cyrena*-beds" of the Vale of Wardour. The "*Cyrena*" is really a *Cytherea* or some allied marine genus, but Mr. Hudleston observes that the "shell, being frequently associated with *Cerithium*, represents a peculiar estuarine condition, which was the precursor of the Purbecks."† *Neritoma* and *Corbula*, which also occur, may be taken to afford similar testimony.

The following are the zones of the Portland Beds that are more generally adopted, together with a few of the leading fossils:—

Zone of Ammonites giganteus	Cytherea rugosa. Trigonia gibbosa. Ammonites boloniensis. Trigonia incurva.
Zone of Ammonites gigas	Trigonia Pellati. Cyprina Brongniarti. Exogyra bruntrutana. Astarte Sæmanni.

Ammonites gigas has not been very definitely recorded from this country, and abroad the zone is sometimes separated and put below the zone of *Cyprina Brongniarti*. Still the ranges of species in different parts of the Continent seem so variable, it is impossible to mark minor zones that will hold good over any extensive region.‡

Organic Remains.

Among the fossils of the Portland Beds there are occasionally found remains of Saurians, including species of *Cimoliosaurus*, *Pliosaurus*, and *Metriorhynchus*; and of the Chelonians, *Stegochelys* and *Pleurosternum*. The Fishes include *Ischyodus*, *Mesodon*, and *Lepidotus*.

* By H. B. Woodward, with additions, in square brackets, by Clement Reid.
† Proc. Geol. Assoc., vol. vii., p. 170 (1881).
‡ See J. F. Blake, Quart. Journ. Geol. Soc., vol. xxxvii., p. 497; see also Table by Fox-Strangways, Memoir on the Jurassic Rocks of Britain, vol i., p. 25.

Ammonites are fairly abundant, especially the large *Ammonites giganteus*, of which examples are obtained in considerable abundance at Portland. Closely related to this species is *A. boloniensis*. Belemnites are extremely rare.

Many of the Portland Stone fossils have lost their shells, and only casts or moulds are preserved, as in the Portland "Roach." Layers of this character occur on different horizons in the Upper Portland Beds. Thus the shells of *Cerithium, Neritoma, Trigonia*, &c., are removed, but *Pecten* and *Ostrea*, where present, retain their shelly matter.

The Portland Sands do not, as a rule, afford a rich field for the collector, but fossil-beds occasionally occur, from which *Ammonites, Pecten, Mytilus, Exogyra bruntrutana, Thracia, Trigonia*, &c., may be obtained. Brachiopoda and Crustacea are rare in the Portland Beds: of the latter, remains of *Eryma* and *Glyphea* have been found. No species of Polyzoa are recorded; Echinoderms are occasionally obtained.

One Coral, the Tisbury Star-coral, *Isastræa oblonga*, has been found in some abundance in the Vale of Wardour; and rarely in the Isle of Purbeck. It occurs in the Chert. Calcareous examples are not met with in England, but they occur in the Upper Oolites of Sutherlandshire. Sponge-remains (*Pachastrella*) are also found at Tisbury (See p. 10.) Remains of Plants (*Araucarites*) are but seldom obtained.

PORTLAND FOSSILS.

FIG. 1.

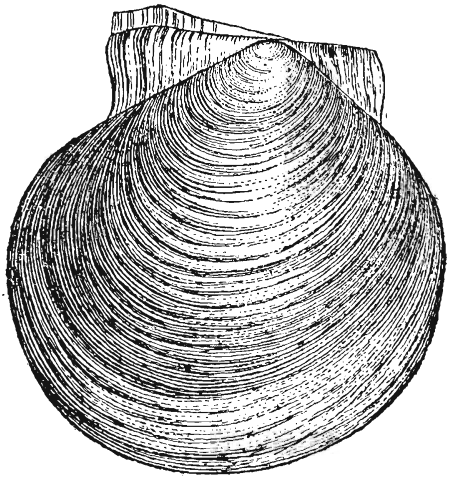


FIG. 2.

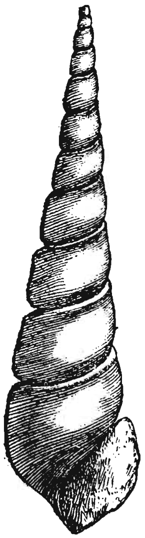


FIG. 1. Pecten lamellosus *Sow.* $\frac{2}{3}$.

FIG. 2. Cerithium portlandicum *Sow.* (cast).

Portland Fossils.

Fig. 3.

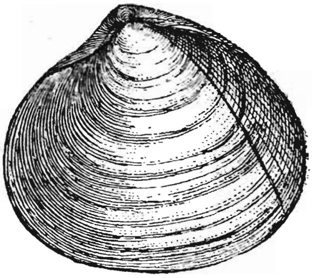


Fig. 4.

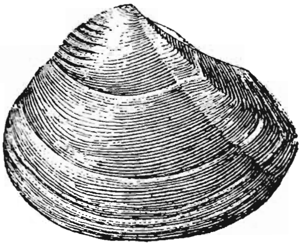


Fig. 5.

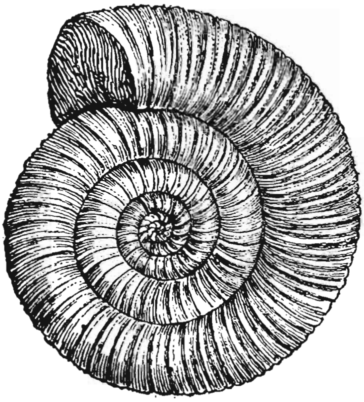


Fig. 6.

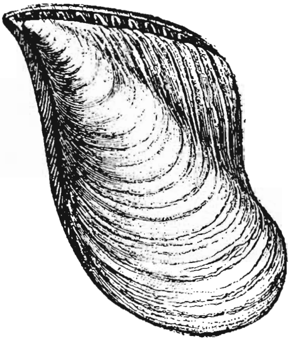


Fig. 7.

Fig. 11.

Fig. 8.

Fig. 9.

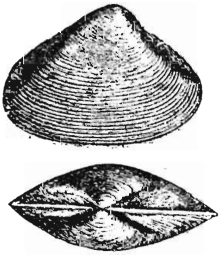


Fig. 10.

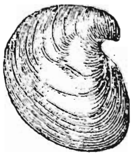


Fig. 3. Cardium dissimile, *Sow.* $\frac{2}{3}$.
" 4. Trigonia gibbosa, *Sow.* $\frac{2}{3}$.
" 5. Ammonites [Perisphinctes] giganteus, *Sow.* $\frac{1}{18}$.
" 6. Perna mytiloides, *Sam.* $\frac{1}{2}$.
" 7. Lucina portlandica, *Sow.* $\frac{1}{2}$.

Fig. 8. Cytherea rugosa, *Sow.*
" 9. Cyprina elongata, *Blake.*
" 10. Exogyra bruntrutana, *Thurm.* $\frac{2}{1}$.
" 11. Isastræa oblonga, *Flem.* $\frac{2}{3}$.

The more abundant and noteworthy fossils of the Portland Beds are as follows:—

	Lower Beds.	Upper Beds.
Ammonites [Perisphinctes] biplex	1	2
—— [———] boloniensis	–	2
—— [Olcostephanus] giganteus (Fig. 5)	–	2
Buccinum ? angulatum		2
Cerithium portlandicum (Fig. 2)		2
Natica elegans	1	2
—— incisa	1	2
Neritoma sinuosa		2
Pleurotomaria rugata	1	2
Cardium dissimile (Fig. 3)	1	2
Cyprina elongata (Fig. 9)	1	2
—— implicata	1	2
Cytherea rugosa (Fig. 8)		2
Exogyra bruntrutana (Fig. 10)	1	2
Lucina portlandica (Fig. 7)	–	2
Ostrea expansa	–	2
—— solitaria	1	2
Pecten lamellosus (Fig. 1)	1	2
Perna Bouchardi	1	2
—— mytiloides (Fig. 6)		3
Pleuromya tellina	1	2
—— Voltzi	1	2
Thracia tenera	1	2
Trigonia gibbosa (Fig. 4)	1	2
—— incurva	1	2
—— Pellati	1	2
Isastræa oblonga (Fig. 11)	-	2

The Vale of Wardour is one of the classic regions of the geologist. Large quarries have been opened in the Portland and Purbeck beds, many fossils have been obtained, and the district has been described by many observers. Pyt House, a few miles west of Tisbury, was the home of Miss Etheldred Benett, one of the earliest of lady geologists, who gave especial attention to the fossils of Wiltshire, and published the first detailed account of the strata.* They have subsequently been studied by Fitton,† Mr. W. H. Hudleston,‡ Prof. J. F. Blake,§ and the Rev. W. R. Andrews‖ (formerly of Teffont Evias).

The general section of the Oolitic strata in the Vale of Wardour is as follows:—

		Ft.	In.
Lower Purbeck Beds.	Flaggy limestones, dirt-beds, and peculiar oolitic beds. (See page 16.)		

* A Catalogue of the Organic Remains of the County of Wilts, 1831; (privately issued).

† Trans. Geol. Soc., ser. 2, vol. iv. pp. 251, 254.

‡ Proc. Geol. Assoc., vol. vii. pp. 167-170, and Geol. Mag. 1881, p. 387.

§ Quart. Journ. Geol. Soc., vol. xxxvi. p. 200.

Proc. Dorset Nat. Hist. Club, vol. v. p. 66.

General Section of Oolitic Strata in Vale of Wardour—*contd.*

			Ft.	In.
Upper Portland Beds.	Upper Building Stones.	Buff sandy and oolitic limestones, compact limestone, and occasional chert-seams in lower part - 10 to	16	0
	Chalky Series.	Soft white chalky limestone, with nodules and veins of black chert - 4 to	24	0
	Ragstone.	Brown, gritty, and shelly limestone, divided in places by seam of rubbly marl - - 4 6 to	5	6
		Pale shelly and oolitic limestones, with rubbly shelly marl at base - - -	3	3
	Building Stones.	Trough bed: Hard buff sandy and oolitic limestone, the surface covered with bivalves (*Trigonia gibbosa*), the bed merging into that below - -	2	8
		Glauconitic and sandy limestones; divided locally into:— Green Bed - 5 0; Slant Bed - 1 0; Pinney Bed - 2 0; Cleaving or Hard Bed - 1 0; Fretting Bed - 3 4; Under Beds - 3 0	15	4

Lower Portland Beds.
Kimeridge Clay.

The finest exposures of the Portland Beds are to be seen at the Chilmark ravine, about a mile south of the village, but there are a number of quarries near Tisbury.

The Oolitic series has a general inclination towards the E.S.E., but the beds are affected by undulations, which bring the Portland Beds to the surface at Chilmark. The Upper Cretaceous rocks extend across the denuded surfaces of the older strata and form a margin to the vale both north and south. (See Fig. 12.)

On the west side of the Chilmark ravine only the lower building-stones are worked, on the east side both Upper and Lower Beds are quarried, for the most part in underground workings. The overlying Purbeck Beds at the Teffont (Chilmark) Quarry are noted on p. 21. The lower building-stones are as follows:—

		Ft.	In.
Upper Portland Beds.	Chalky Series.		
	White Bed: gritty limestone, used for hearthstone - - - - 1 6 to	4	0
	Rubbly marl (Rag) - - - - -	0	6
	Shelly Limestones - - - - -	3	6
	Trough Bed: pale shelly oolitic limestone -	1	3
	Rubbly marl, passing into Roach - -	0	6
	Green Bed: hard buff or pale greenish-grey oolite merging into bed below - 2 6 to	2	9
	Pinney Bed: brown glauconitic and oolitic sandy limestone in three or four layers -	12	0

A well at the base of the Chilmark (Teffont) Quarry was sunk to a depth of 39 feet through clays and calcareous sandy beds to very black clay (Kimeridge Clay), and water rose to within 19 feet of the surface (see p. 4).

The thicknesses at this locality may be thus summarised:—

		Ft.	In.
Upper Portland Beds.	Upper Building Stones	16	0
	Chalky Series	24	0
	Ragstone	9	0
	Lower Building Stones	18	0
Lower Portland Beds		38	0
		105	0

The Lower (or Chief) Building Stones have yielded but few fossils. Prof. Blake records *Ammonites boloniensis* and *A. biplex*. The beds contain occasional cherty masses, and a quantity of sponge-spicules may, according to Mr. Hudleston, be found in some of them. He observes that *Trigonia gibbosa* is found in a state of chalcedonic replacement, and states that the Pinney Bed is penetrated by a small Serpula, from the appearance of which the name is derived.*

The names applied to these building-stones vary in different parts of this district, and other names besides those mentioned have been used.†

The Ragstone Beds are characterized by *Cytherea* ("*Cyrena*") *rugosa*, and they have been termed the "Lower Cyrena Beds." Gasteropods are fairly abundant, including the form known as *Cerithium concavum*, the small *Natica elegans*, *Pseudomelania teres*, *Neridomus transversus*, *Neritoma sinuosa* and *Actæonina signum*.‡ The beds yield also *Corbula*, *Cardium dissimile*, *Lucina portlandica*, &c.

Mr. Hudleston considered there was evidence of a break between these beds and those below. He noted at the base an irregular *Trigonia*-bed, with *T. gibbosa* and *Mytilus jurensis*. *Trigonia Manseli* also occurs in these beds. The shells in this division are well preserved. The absence of Ammonites is noteworthy, and the general assemblage is considered by Mr. Hudleston as suggestive of fluvio-marine conditions.

The Chalky Series calls to mind the similar beds at Upway. The fossils are marine and include *Ammonites boloniensis*, known as "Horns," *Pleurotomaria rugata*, *Turbo apertus*, *Cardium dissimile*, *Lucina portlandica*, *Ostrea expansa*, *Pecten lamellosus*, *Pholadomya tumida*, *Pleuromya tellina*, and *Trigonia gibbosa*.

The Upper Building Stones, termed by Mr. Hudleston the "Upper Cyrena Beds," yield fossils for the most part in casts, and the beds have been compared to the Roach of Portland. *Cerithium portlandicum* is characteristic, and among other fossils

* Proc. Geol. Assoc., vol. vii. pp. 171, 172.

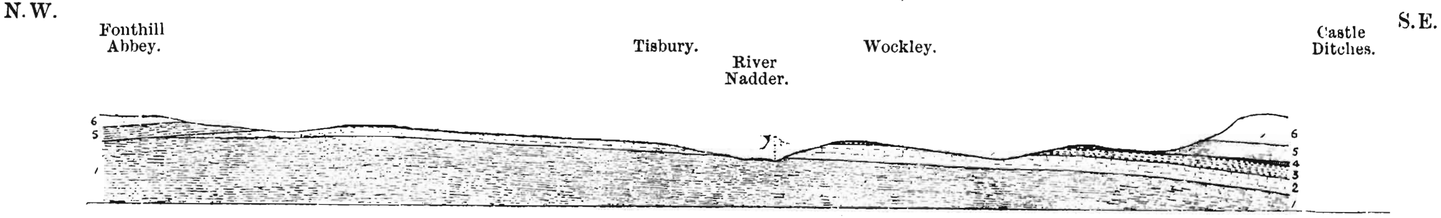
† See Section of Chicksgrove Quarry, by Miss E. Benett, Sowerby's Mineral Conchol., vol. ii. 1818, p. 58.

‡ See Hudleston, Geol. Mag. 1881, p. 387; and Proc. Geol. Assoc., vol. vii., pp. 167, &c.

FIG. 12.

Section across the Vale of Wardour.—(H. B. WOODWARD.)

Horizontal scale 2 inches to a mile. Vertical scale 1,200 feet to an inch.



3. Purbeck Beds.
2. Portland Beds.
1. Kimeridge Clay.

6. Upper Greensand.
5. Gault.
4. Wealden Beds.

there are *Neritoma sinuosa*, *Cytherea* ("*Cyrena*") *rugosa*, *Trigonia gibbosa* (not uncommon), *Cardium dissimile*, *Lucina portlandica*, and *Pecten lamellosus*.

Portland Beds, with usually some thickness of Purbeck Beds on top, were worked on the north side of River Nadder by Chicksgrove Mill, and there were other quarries (with underground workings) on the south side of the river. An account of one of these was published by Miss Benett in 1818.* The locality is that of Upper Chicksgrove, and pits were opened westwards in Quarry Copse, south of the railway. A cutting on the railway west of Chicksgrove Mill, and north of Wockley, showed the following section:—

		Ft.	In.
Upper Portland Beds.	Greenish sandy bed - - - - - - - -	1	0
	Hard grey sandy limestone, weathering white: *Trigonia*, *Ammonites* - - - - - -	1	3
	Greenish and grey beds of more or less calcareous sandstone or sandy limestone - -	2	6
	Shelly limestone: *Serpula* - - - - - - -	2	6
	Sandy and shelly limestone: *Serpula* - - -	2	6
	Sandy marl: *Ostrea*, *Serpula*, Spine of *Echinus* - - - - - - - - - -	0	4
	Grey shelly limestones - - - - - - -	4	0
Lower Portland Beds.	Brown and greenish-brown sand with clay seams and bands of indurated sand: casts of shells here and there, thin beds of stone near top - - - - - - -	15 0 to 20	0

The three uppermost beds merge one into the other, and are much shattered at the top in places. The fissures that sometimes traverse the rocks in this district are known as "lets."†

At Wockley, south-east of Tisbury, the beds are much reduced in thickness, and their character, especially in the lower beds, is altered, for we miss the Ragstones of Chilmark. (See Fig. 28, p. 22.) The individual layers of rock also vary much in thickness. On top there is from 18 to 20 feet of Lower Purbeck Strata, beneath which we find:—‡

		Ft.	Ft.	In.
Upper Portland Beds.	4. Bed of Roach, with lenticular mass of chert at top: *Trigonia gibbosa*. 3. Chalky limestones obliquely bedded, with *Ammonites biplex*, *Pleurotomaria rugata*, *Ostrea expansa*, *Pecten lamellosus*.	10 to	15	0
	2. Buff and greenish, glauconitic sandy limestone - - - - - - -	2 to	4	0
	1. Compact and very shelly limestone, passing down into sandy limestone (quarried for freestone) - - -	4 to	5	0

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* Sowerby, Min. Con., vol. ii., 1818, p. 58.

† Fitton, Trans. Geol. Soc., ser. 2, vol. iv., p. 255.

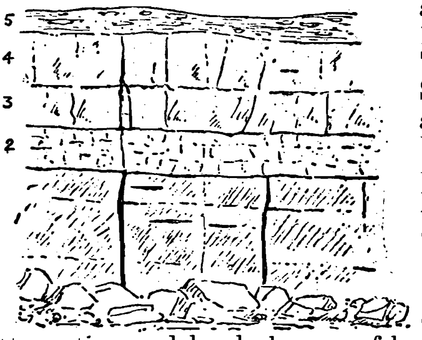
‡ See also Fitton, Trans. Geol. Soc., ser. 2, vol. iv., p. 253; and Hudleston, Proc. Geol. Assoc., vol. vii., p. 173.

A quarry south of Tisbury Station afforded evidence of the variable nature of the beds. The section was as follows (see Fig. 13):—

		Ft.		Ft	In.
Upper Portland Beds.	5. Rubbly stone and marl with seam of clay - - - - - - -	0	to	4	0
	4. Shelly limestone (Roach) with *Trigonia incurva*. 3. Impure shelly and tufaceous limestone - - - - - - -	4	to	5	0
	2. Compact, but rotten chalky limestone, much shattered, with Gasteropods	3	to	4	0
	1. Greenish glauconitic sandy limestone with lenticular seams of oolitic chert: three layers seen - - -	10	to	12	0

Fig. 13.

Quarry south of Tisbury, Wiltshire.



Beds of greenish sandstone, that become paler when dry, are dug to a depth of about 10 feet in a quarry between Tisbury and Newtown. Specimens of *Trigonia* are abundant on some of the blocks. Formerly much stone was obtained at Lower Lawn, and extensive old quarries are to be seen there.

Looking generally at the variations exhibited in the different quarries, to the attenuation and local absence of beds that may be classed with the Upper Building Stones, Mr. Hudleston remarked there was evidence of discordance between the Purbeck and Portland Beds in the Vale of Wardour.*

No doubt there are abrupt changes here and there between the formations, as there sometimes are between individual beds in the Portland series. There is, however, no discordance such as would imply upheaval and denudation of the strata. The phenomena may be attributed in part to contemporaneous erosion, in part to the attenuation and local deposition of certain sediments; while, again, the variations in the lithological characters of different layers serve to render the results of minute correlation very difficult and uncertain.

Tisbury has been long famous as the locality for the Star Coral, *Isastræa oblonga*, which occurs in the Portland chert, and polished specimens of which are to be found in most collections. The exact position of the bed yielding this "Siliceous Madrepore" has been a matter of some doubt. It was described in 1729 by John Woodward as the "Starr'd Agate." He says: "This was found, amongst several others, lying on Floors, like the

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* Hudleston, Proc. Geol. Assoc., vol. vii., pp. 170, 173, 174. See also J. F. Blake, Quart. Journ. Geol. Soc., vol. xxxi., p. 191.

common black Flints, amongst Chalk; * * * Underneath these Floors of starred Flints lay Strata of Sand stone, in a Quarry in *Tisbury* Parish."*

This position in the Chalky Series agrees with that assigned to it by the Rev. W. R. Andrews, who has found the fossil above the Ragstones at Newtown, Tisbury. Most of the specimens have, however, been obtained from ploughed fields to the north-west of Tisbury. The horizon also agrees with that noticed by Miss Benett, who states that the Coral was found above the Portland rock (*i.e.*, building-stone), in a well sunk at Burton's Cottage, near the Inn, at Fonthill Giffard; the same authority recorded the following section of a well at Butcher's Knap(field), Tisbury:—†

	Ft.	In.
Rubble of Portland Beds	10	0
Siliceous Madrepore	1	0
Portland Beds	42	0
(Water.)		

[In the course of the new Geological Survey (in 1900) several specimens of this silicified coral were discovered in place in the lane which runs westward from the main road half a mile north-west of Tisbury village. They occur imbedded in chalky limestone at its junction with the hard cherty limestone, worked in the quarry just below. The corals are in their position of growth.—C.R.]

Fitton mentions the finding of *Ammonites biplex* in chalcedonic flint, and states that many specimens of the Tisbury Coral had been obtained from "a continuous bed of flint, about 2 inches thick," exposed in one of the quarries formerly worked to the south of Fonthill Giffard.‡ It has been found also at Chilmark.

In a cutting on the road-side between Tisbury and Wardour, near Hazelton, and in other sections, Mr. Hudleston noted the following beds beneath the main building-stone:—§

		Ft.	In.
Upper Portland Beds.	3. Loose sands with doggers	7	0
	2. Greenish concretionary limestone grit, with occasional lydite; originally a Trigonia-bed	3	0
Lower Portland Beds.	1. Loamy sands and clays	21	0

From the hard band (2) he records the following species:—

Natica elegans.	Mytilus jurensis.
Avicula credneriana.	Pecten lamellosus.
Cardium dissimile.	Perna Bouchardi.
Exogyra bruntrutana.	Trigonia gibbosa.

Prof. Blake, who first noted these beds, identifies the *Trigonia* as *T. Pellati*.‖ The fauna, as remarked by Mr. Hudleston, seems

* Nat. Hist. Fossils of England, Tome II., p. 77.
† Cat. Org. Rem. Wilts, p. iv.; see also Hudleston, Proc. Geol. Assoc., vol. vii., p. 167.
‡ Trans. Geol. Soc., ser. 2, vol. iv., p. 255.
§ Proc. Geol. Assoc., vol. vii, p. 172.
‖ Quart. Journ. Geol. Soc., vol. xxxvi., p. 202.

very little different from that of the building-stones: "It is what one would call an average Portland stone fauna of the large type, somewhat modified."

The occurrence of the bed with lydites is interesting, as we find other such pebbly layers when we trace the beds over the exposures onwards to Buckinghamshire, and the horizon seems to be fairly constant. [These beds are probably the source from which are derived the similar pebbles found at the base of the Lower Greensand and Gault, and described in Chapters VI. and VII.]

CHAPTER IV.

PURBECK BEDS.*

The Purbeck Beds comprise a series of clays and shales with "Beef," marls, marly, tufaceous, and shelly limestones, and occasionally of granular oolitic beds, and sandy strata. In thickness the series varies from about 80 or 90 feet in Wiltshire to nearly 400 feet in Dorsetshire.

The term "Beef" applied by workmen to the seams of fibrous carbonate of lime, was so given from "the resemblance of its small and parallel fibres to the fibres of animal muscle."† It often presents a cone-like structure, similar to that known as "cone-in-cone."‡

Pseudomorphous crystals of rock-salt were noticed by H. W Bristow in the Lower Purbeck Beds of Durlston Bay and Lulworth Cove; and similar pseudomorphs have been observed in the Vale of Wardour. § Gypsum sometimes occurs, and here and there we find nodules of chert.

Nodules of chert occur in the Lower and Middle Purbeck Beds of the Vale of Wardour. A specimen of chert or flint from the lower part of the Purbeck Beds in Chilmark quarry, in the Vale of Wardour, was examined by Mr. W. H. Hudleston, who observed that it showed portions of marly limestone partially silicified, sealed together with purer chalcedony. The rock contained oolitic granules, a fragment of shell, and valves of *Cypris*: some of the oolitic granules of characteristic type were immersed in more or less pure chalcedony.‖ Hence the flint resulted from the silicification of calcareous matter. Another specimen of oolitic chert from Chilmark, examined by Mr. Teall, showed the oolitic grains to be partially silicified, the inner portions of the grains being calcareous.

The Purbeck Beds in most places rest comformably on the Portland Beds, and are overlaid conformably by the Wealden strata.

The junction with the Wealden Beds shows a much more gradual passage than that between the Purbeck and Portland Beds, and yet on the whole, as remarked by Sedgwick, the general lithological characters of the Purbeck Beds seem to unite them more closely with the stony Portland Beds.

Many authorities following Webster and Fitton, amongst whom are Godwin-Austen, Oppel, and Ramsay, grouped the Purbeck Beds

* By H. B. Woodward, with additions, in square brackets, by Clement Reid.

† Buckland and De la Beche, Trans. Geol. Soc., ser. 2, vol. iv., p. 11.

‡ See Memoir on the Lias of England and Wales, p. 308.

§ Andrews and Jukes-Browne, Quart. Journ. Geol. Soc., vol. l., p. 52.

‖ Proc. Geol. Assoc., vol. vii. p. 181, and Plate I., Fig. 1.

with the Wealden, for palæontologically, by reason of their freshwater fauna, they are more intimately connected with that formation.*

Edward Forbes, who made a study of the Purbeck Beds in 1849 and 1850 in company with Bristow, did not recognize any passage from the Portland into the Purbeck Beds in the Isle of Purbeck, and observed that the top beds of the Portland series were marine, the lowermost Purbeck Beds purely freshwater. At the same time he concluded that the Purbeck Beds were connected with the Oolitic group rather than with the Cretaceous, and he was evidently influenced by his discovery of the Echinoderm *Hemicidaris purbeckensis*, which he found in a layer above the Cinder Bed (with *Ostrea distorta*).† The same view is taken by De Loriol, and also by Coquand, Contejean, and others; while the more recent researches of Pavlow and others, on the marine equivalents of the Purbeck Beds, tend to show that their affinities are rather with the Jurassic than with the Cretaceous system.

On the whole it may be said that the marine fossils ally the Purbeck Beds with the Portland strata, and the freshwater fossils link them with the Wealden Beds. The vertebrate as well as the invertebrate remains have Jurassic as well as Wealden affinities.‡

Hemicidaris purbeckensis occurs in the zone of *Ammonites gigas*, Lower Portlandian, of Boulogne-sur-Mer.

The Purbeck Beds mark changing conditions; freshwater limestones, botryoidal and tufaceous in character, like beds of travertine, are succeeded in places by evidences of land vegetation in the now silicified remains of Cycads and Conifers. The Lower Purbeck Beds indicate freshwater and terrestrial conditions, which may have been marked by a lake or series of lagoons, for they were attended locally by the deposition of gypsum. Subsequently an irruption of the sea in Middle Purbeck times allowed the incursion of marine forms like the *Pecten, Thracia, Trigonia, Avicula*, and *Hemicidaris*. These were succeeded by a gradual change from brackish to freshwater conditions in Upper Purbeck times, when the *Unio, Limnæa, Physa, Valvata, Paludina*, and *Planorbis* flourished. The freshwater Purbeck Beds were succeeded gradually by the great accumulations of Wealden strata formed by river agency, but whether distributed over the bottom of a huge lake, or as a delta deposit, is a somewhat debatable subject.

Godwin-Austen remarked that "the changes in the Purbeck series are readily accounted for by reference to areas of water

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* Fitton, Trans. Geol. Soc., ser. 2, vol. iv. p. 159; Webster, *Ibid.*, vol. ii. pp. 40, 44, and Ann. Phil., vol. xxv. p. 47; Mantell, Geol. Isle of Wight, ed. 3, 1854, Table, p. 42; Marcou, Geologist, 1859, p. 1; Dr. C. Struckmann, Geol. Mag., 1831, p. 556. See also A. Strahan, Geology of the Isle of Purbeck and Weymouth, *Geol. Survey*, 1898, p. 72.

† Forbes, Decade III., Geol. Survey, Plate V.; and Rep. Brit. Assoc. for 1850, p. 80; P. de Loriol and A. Jaccard, Mem. Soc. Phys. Hist. Nat. Genève, vol. xviii. p. 112.

‡ Lydekker, Quart. Journ. Geol. Soc., vol. xlvi. p. 49. See also Judd, Rep. Brit. Assoc. for 1870, p. 77; and A S. Woodward, Proc. Zool. Soc., 1890, p. 346.

such as occur on the American coast at present, and which may be salt or brackish, according to the extent to which the sea-waters are excluded by sand-bars from mixing with the fresh waters flowing from the land."* Indeed, Forbes, in his early account of the Purbeck Beds, indicates nine or ten alternations of freshwater, brackish water, and marine conditions in the Purbeck Beds; and remarks that they are not marked by any striking physical characters or mineral changes.† Brackish water conditions were indicated by the occurrence of *Corbula, Cyrena, Cardium, Melanopsis,* and *Rissoa,* and perhaps by the *Ostrea distorta.*

The Purbeck Beds have yielded an exceedingly varied series of fossils. Perhaps of the highest interest are the Mammals, which at present have been obtained only from the base of the Middle Purbeck Beds of Durlston Bay—in a thin earthy or "Dirt" layer.

Among the fossils from the Purbeck Beds the Saurian remains are important. The Dinosaurs include *Iguanodon* and *Nuthetes;* then we have the "Swanage Crocodile," *Goniopholis crassidens,* and the dwarf Crocodiles known as *Nannosuchus* and *Theriosuchus.* Owen estimates the average length of a mature *Theriosuchus* at eighteen inches. Turtles have been obtained mostly from the quarrymen, as they occur in the stone-beds: they include *Tretosternum, Pleurosternum concinnum, P. Bullocki,* and *Chelone obovata.* The Fishes include *Asteracanthus verrucosus, Caturus, Coccolepis, Hybodus, Lepidotus, Macrosemius, Ophiopsis,* and *Pleuropholis,* and they are mostly found in the stone-beds worked at the quarries. Specimens occur at various horizons in the Purbeck Beds, and some of the best preserved examples have been obtained from the neighbourhood of Teffont Evias, in the Vale of Wardour.

It was the intention of Edward Forbes to publish an account of the Invertebrata of the Purbeck Beds of Dorsetshire; and he had assigned names to a number of new species of Mollusca, which he was the first to discover.‡ Some of these have been figured in Lowry's Chart of Characteristic British Fossils, and others in works published on the Continent. They all belong to living genera, and, taken by themselves, possess a Tertiary or even recent aspect. Reference has already been made to the principal genera of Mollusca found in the Purbeck Beds, but it may be mentioned that Mr. Carruthers has described, under the name *Teudopsis Brodiei,* a cuttle-bone from these strata in Dorset.§

Insects are represented very fully by remains referred to Coleoptera, Orthoptera, Diptera, Neuroptera, and Hemiptera.

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* Rep. Brit. Assoc. for 1872, Sections, pp. 92, 93. See also Meyer, Quart. Journ. Geol. Soc., vol. xxviii., p. 244; and Ramsay, Address to Geol. Soc., 1864, p. 32; and Physical Geology and Geography of Great Britain, ed. 6, 1894.

† Rep. Brit. Assoc. for 1850, p. 81.

‡ Some figures of Purbeck fossils will be found in the works of Fitton, Trans. Geol. Soc., ser. 2, vol. iv. Plates XXI. and XXII.; Mantell's Geological Excursions round the Isle of Wight, ed. 3; and Damon's Supp. to the Geology of Weymouth, &c., ed. 3, 1888.

§ Quart. Journ. Geol Soc., vol. xxvii. p. 448.

FIG. 14.

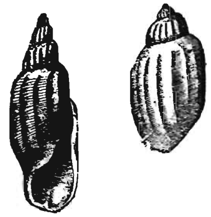


FIG. 17.

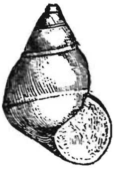


FIG. 15.

FIG. 16.

FIG. 20.

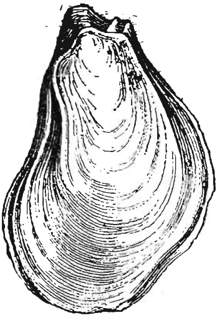


FIG. 18.

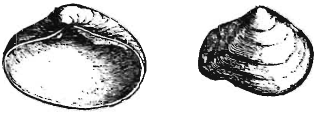


FIG. 19.

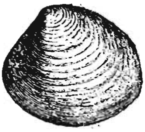


FIG. 22.

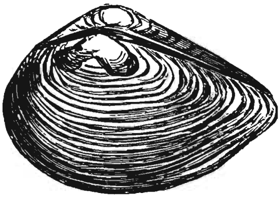


FIG. 21.

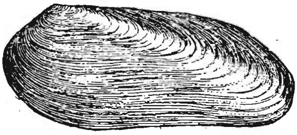


FIG. 23.

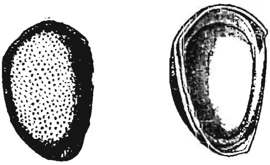


FIG. 26.

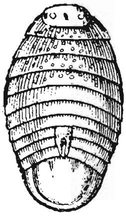


FIG. 24.

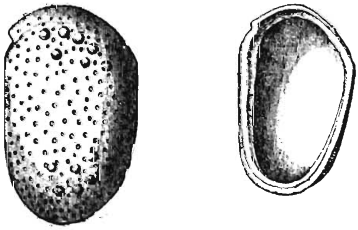


FIG. 25.

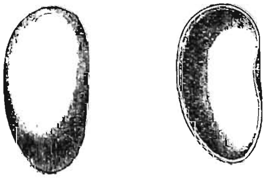


FIG. 14. Melanopsis harpæformis, *Dunk.*
,, 15. Physa Bristovii, *Forbes.*
,, 16. Paludina elongata, *Sow.*
,, 17. ——— carinifera, *Sow.*
,, 18. Corbula alata, *J. Sow.*
,, 19. Cyrena media, *J. Sow.*
,, 20. Ostrea distorta, *J. Sow.*
,, 21. Unio sp.

FIG. 22. Unio valdensis, *Mant.* $\frac{2}{3}$.
,, 23. Cypridea punctata, *Forbes.* $\frac{25}{1}$.
,, 24. ——granulosa, *Sow.* $\frac{25}{1}$.
,, 25. Cypris purbeckensis, *Forbes.* $\frac{20}{1}$
,, 26. Archæoniscus Brodiei, *M. Edw.*

At Durlston the Insect-remains occur most abundantly in the Lower Purbeck Beds: elsewhere they are found in Middle Purbeck strata.

Among Crustacea, the Isopod, *Archæoniscus* (Fig. 26) occurs in profusion in the Middle Purbeck Beds in the Vale of Wardour. It has been obtained, however, in the Lower Purbeck Beds of Wiltshire and Dorset. Among the Ostracods it is found that *Cypris purbeckensis* (Fig. 25), *Candona ansata*, and *C. bononiensis* are most abundant and characteristic in the Lower Purbeck Beds; *Cypridea granulosa* (Fig. 24) in the Middle Purbeck; and *C. punctata* (Fig. 23) in the Upper Purbeck.

Here and there at various horizons in the Middle and Lower Purbeck Beds a number of "Dirt Beds" occur. The name has been applied to layers of carbonaceous clay or shale, but it originated in Portland Island, where the Great Dirt Bed which occurs near the base of the Lower Purbeck Beds is especially noted for the silicified remains of Cycads and Coniferous trees which it has yielded. There great "Burrs" of siliceous and calcareous (tufaceous) material have been accumulated around the old tree stumps. Some of the more characteristic fossils of the Purbeck strata are figured on p. 19.

In the Vale of Wardour the Purbeck Beds are well shown in many quarries and cuttings, but we have no continuous section to enable us to estimate the full thickness with accuracy. The beds have been described by Fitton, Brodie, O. Fisher, J. F. Blake, Hudleston, W. R. Andrews, and A. J. Jukes-Browne.

The general succession of strata appears to be as follows:—

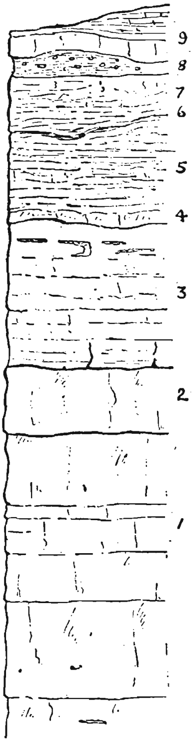
			Ft.	In.
Purbeck Beds.	Upper.	Shell-marls, clays and marls, with "beef," and sandy layers with bands of calcareous sandstone	20	0
	Middle.	Marls and sandy rocks, with "beef," limestone with *Archœoniscus*, Cinder Bed, and other calcareous bands - -	12	0
	Lower.	Limestones and shales ("Lias," &c.) - - - - - -	18	0
		Limestone, clay, and oolitic beds	15	0
		Fissile limestones, tufaceous beds and dirt-beds, with chert nodules, &c. - - - -		
			85	0

It is difficult to mark any divisional planes to correspond with the Lower, Middle, and Upper Purbeck divisions of the Dorset Coast. The occurrence of *Ostrea distorta* was noticed by Fitton, but the presence of an oyster bed equivalent to the Cinder Bed of Durlston Bay was first recognised by the Rev. O. Fisher.* The presence of Upper Purbeck Beds was generally questioned until, in 1894, Messrs. Andrews and Jukes-Browne described beds that belong to this division; but they included as Purbeck, strata here regarded as Wealden.†

* Quart. Journ. Geol. Soc., vol. x. p. 477. † *Ibid*, vol. l. p. 59.

The lowest Purbeck Beds are exposed in the great quarries of the Chilmark ravine.* A pit on the north-east side showed the following beds :—

FIG. 27.—*Section at Chilmark, in the Vale of Wardour.* (H. B. WOODWARD.)



		Ft. In.
Lower Purbeck Beds.	9. Flaggy limestone and marly clay - - - -	
	8. Dirt Bed, 1 ft. to 18 ins. thick, like the Great Dirt Bed of Portland, a carbonaceous clay with remains of Cycads, and with rounded lumps of limestone and decomposed chert - - - -	
	7. White marly rock and clay of irregular thickness -	8 0 to 10 0 (beds 9–4)
	6. Dirt Bed, marly and carbonaceous clay with stones -	
	5. Marly clay and irregular earthy limestone - -	
	4. Tufaceous and granular oolitic stone, irregular -	
	3. Earthy tufaceous limestone with chert seams, passing down into pale fissile and earthy limestone - -	6 0
Portland Beds.	2. Buff oolitic stone, forming roof-bed of mine, with marly band at base: *Cerithium, Cytherea.*	3 0
	1. Buff compact oolitic, and in places rather sandy limestones. (Upper Building Stones.) Seen to depth of 12 feet, the lowest bed containing chert - -	

Messrs. Andrews and Jukes-Browne record *Mantellia* (*Cycadeoidea*) *microphylla*; and in the layer above noticed as the upper Dirt Bed, they observed an upright and rooted stump of a tree, the stem standing about 6 feet high.

The Lower Purbeck Beds were observed by Fitton in some of the old quarries at Upper Chicksgrove. The details of the strata vary considerably from place to place, even in one quarry, as at Wockley. There the general section noted in 1885 was as follows :—

		Ft.	In.
	14. Loamy soil - - - 0 6 to	1	0
Lower Purbeck Beds.	13. Fissile limestones, some oolitic; and marls and clays with layers of sandy limestone and sand: about - -	8	0
	12. Hard marly limestone - - - - -	0	8
	11. Banded limestones and marls - -	2	0
	10. Dark clays - - - - - - - -	1	0
	9. Sandy limestone - - - - - -	0	9
	8. Earthy marl with irregular (? concretionary) masses of stone - - -	3	0

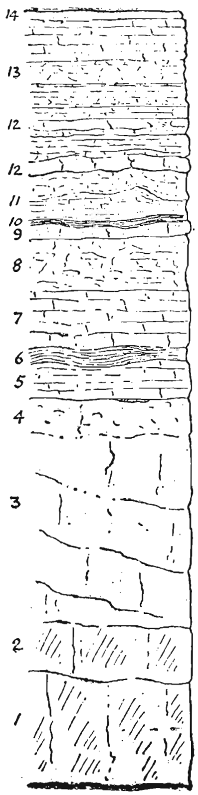
* See also J. F. Blake, Quart. Journ. Geol. Soc., vol. xxxvi. p. 200; and Andrews and Jukes-Browne, *Ibid*, vol. l. p. 48.

			Ft	In.
Lower Purbeck Beds.	7.	Fissile limestones - - - 2 0 to	3	0
	6.	Dark shaly clay, much squeezed up in places.		
	5.	Compact limestones - - - - -	2	0
Upper Portland Beds. (See p. 12.)	4.	Roachy bed with chert at top.		
	3.	Chalky limestones.		
	2.	Sandy limestone.		
	1.	Shelly and sandy limestone.		

The Purbeck Beds resemble in some respects the lower beds of Lulworth Cove and Worbarrow. They undulate, and are much broken up in places. Bed No. 6, which was best shown in the northern part of the pit, may represent one of the Dirt Beds, while Bed 8 reminds one of the Soft Burr and Bacon Tier of Portland.

Messrs. Andrews and Jukes-Browne* figure a curious disturbance in the beds, but we saw nothing so striking as they have represented (in a slightly diagrammatic manner), either in 1885 or on subsequent visits.

Fig. 28.
Section at Wockley, near Tisbury.
H. B. Woodward.



In the Museum of Practical Geology there is a "Large Block of Limestone, showing the Junction between the Portland and Purbeck formations from Oakley [Wockley] Quarry, near Tisbury." It was thus described by H. W. Bristow: "In the quarry from which the specimen was taken, the uppermost bed of Portland Stone is harder than the chalky limestone upon which it reposes, and is crowded with marine shells common to the formation, viz., *Trigonia, Cardium dissimile Ostrea*, &c. Immediately above this stratum is a bed of hard, grey, bituminous limestone the upper foot of which is fissile and used for flagstones. In the specimen, as in the quarry, the exact line of junction between the shelly bed and the fissile limestone is scarcely distinguishable to the eye, but when broken by a heavy blow the Portland Stone and the Purbeck split off from each other at the junction, along a smooth and even surface. The line of demarcation between the two strata is crowded with fish."†

In their section at Wockley Messrs. Andrews and Jukes-Browne group with the Portland Stone the hard flaggy limestone that we have included at the base of the Purbeck Beds. They state that the flaggy and shelly portions "are firmly welded together, and would yield a slab like that at the Museum of Practical Geology, in which Portland shells are visible in the lower and Cyprids in the upper part, but these Cyprids are not freshwater species, being, in fact, *Candona ansata* and *C. bononiensis* (which are estuarine forms). From

* Quart. Journ. Geol. Soc., vol. 1. pp. 49, 52.
† Catalogue of Rock Specimens, ed. 3, p. 139.

the flaggy portion two species of fish have been obtained (*Ophiopsis breviceps* and *O. penicillatus*) and also a large species of *Archæoniscus*." Furthermore, they obtained from the beds above, *Candona ansata*, *Cypridea*, *Cypris*, *Cardium* and *Corbula alata*.*

To be consistent, however, we must continue to regard the old plane of division as the best, and going again to the district with Mr. Strahan no difficulty was found in determining this junction in the quarries near Tisbury and Chilmark. The evidence of the fossils shows that the change of conditions was not so marked as in other localities where freshwater beds overlie those of a marine character. Here we have estuarine beds overlying marine beds, while in other places in the Vale of Wardour the "Cyrena-beds" of the Upper Portland Beds have been regarded as of a semi-estuarine character. (See p. 5.)

An interesting section to the south-east of Ridge has been noted by Messrs. Andrews and Jukes-Browne as follows:—†

		Ft.	In.
	Dark brown soil - - -	1	0
Lower Purbeck Beds.	Weathered marlstone or "lias" -	1	0
	Buff-coloured marl, with seams of grey clay - - - -	0	6
	Soft fine-grained, marly oolite, a mixture of oolitic particles with triturated shells, cyprids, &c.; with thin layers of harder compact marlstone in the lower part - -	2	3
	Soft yellowish calcareous oolitic sand -	0	9
	Very hard limestone, consisting of shelly layers alternating with seams of compact marlstone - - -	0	10
	Soft marl with yellowish oolitic stone	3	2
	Hard grey shelly limestone - -	2	4
	Oolitic stone with layers of marl -	3	3
	Soft calcareous stone passing down into hard limestone with pseudomorphous crystals of rock-salt: *Corbula alata*, *Perna*, *Cardium*, *Nuculana*, *Serpula*, &c.	3	3
	Grey laminated marl - - -	1	0
	Buff marlstone - - -	3	0
		22	4

To the west of Ridge the basement-bed exposed at the outcrop is a tufaceous limestone with large masses of wood. Many blocks of this limestone are ploughed up; but no section is now visible in it.

To the south-west of Teffont Evias Church there is a long excavation in the Purbeck stone-beds which present a general resemblance to Lower Lias limestones, and many beds are known

* Quart. Journ. Geol. Soc., vol. 1. p. 51. See also Fitton, Trans. Geol. Soc., ser. 2, vol. iv. p. 253.

† Quart. Journ. Geol. Soc., vol. 1, p. 52.

to the quarrymen as "Lias." The best section is near the Lime-kiln at the northern end of the workings; this was noted as follows:—

		Ft.	In.
	Brashy soil, brown sandy loam.		
Middle Purbeck Beds.	Cherty layer with many bivalves [*Cyclas*].		
	Cinder Bed: hard greyish brown limestone, much broken up; *Ostrea distorta*, [*Trigonia* allied to *gibbosa*, and spine cf *Hemicidaris*] - -	1	0
	Clay and rubble - - - - - -	0	8
	Hard grey limestone with dendritic markings - - - - - - -	1	2
	Grey shelly limestones, splitting up irregularly; the bottom bed called White Bed (6 ins. to 1 ft.) [Chelonian bones, *Hybodus*, Cyprides] - -	2	3
	Shaly limestone, with curious concretionary projections from base of White Bed, which disturb this stratum [*Modiola*] - - - - -	0	6
Lower Purbeck Beds.	Pale grey rubbly marls - - - -	0	4
	White Limestones [Lias No. 1] - -	1	6
	Sandy marl and clay [*Mesodon*, *Estheria* and Cyprides] - - - - - -	0	4
	Sandy shell-limestone Blue Rock [or Flagstone]; blue-hearted stone, weathering buff, with brown ferruginous base called Scale, showing tridactyl markings on under surface. *Cyrena* [Fish-remains] - - - -	2	3
	Clays and Shales with *Cypridea granulosa*, [*Cypris purbeckensis*] - -	1	0
	Hard white marl -	1	3
	Soft marl - - - [Lias No. 2]	1	0
	Hard marly limestone -	1	3
	Soft white marl - - - - - -	1	3
	Hard white marly limestone [Lias No. 3]	1	3

The above section has been described in more detail by Messrs. Andrews and Jukes-Browne, and we have added in square brackets some of the fossils recorded by them. They had an excavation made below the floor of the quarry, and their observations showed that the lowest bed of "Lias" (No. 3) above noted, was 3ft. 6in. thick, and beneath were nearly 8 feet of marls and marly limestones.

From the Lower Purbeck Beds, and especially from the bands of "Lias," Mr. Andrews has obtained many fish-remains, including *Caturus*, *Coccolepis*, *Leptolepis*, and *Pleuropholis*. Many of these are very beautifully preserved, but all are diminutive when compared with the Purbeck fishes of Dorsetshire.*

The Purbeck stone-beds, comparable with those of Teffont Evias, have also been quarried for road-metal and building-stone on the south of Lower Chicksgrove. There is a band of hard

* Quart. Journ. Geol. Soc., vol. l. p. 53; and A. Smith Woodward, Geol. Mag., 1895, p. 145.

grey limestone, like the Swanage stone, and compact smooth-grained limestone termed "Lias" (2 feet thick). These beds overlie shelly limestones and marls, with decomposed shelly layers and "beef"; with *Paludina* and *Modiola*. The Cinder Bed, as noticed by Messrs. Andrews and Jukes-Browne, occurs above these beds, and is surmounted by a marly oolitic limestone, and by clays with "beef," &c.*

Higher up occurs the Isopod Limestone discovered by the Rev. P. B. Brodie,† a band containing *Archæoniscus Brodiei* in multitudes here and there, although the stone may in places be split up without any specimens being observed. This fossil occurs also at other horizons, but the particular bed above-mentioned is a smooth-grained limestone that may be readily identified in the neighbourhood of Dinton.

About a mile west of Dinton Station, and extending north-westwards along the scarp into Teffont Park, there are traces of old stone-pits. Some of these must be at or near the spot where Fitton noted his section at Dallard's Farm. This showed about 12 feet of slaty stone and clay with *Ostrea distorta, Modiola, Corbula alata*, and Cyprides. Others are nearer the present line of railway, and are those described by the Rev. P. B. Brodie and the Rev. O. Fisher. Fitton mentions that on Ladydown, quarries have long been worked for the sake of tilestone—a fissile stone, yielding *Cyrena* and remains of Fishes.‡ One of these quarries is still open.

Somewhat higher beds probably were opened up at Dashlet, on the south side of the Nadder, to the north of Fovant, for there Fitton noted oolitic particles in the top layer of stone, and found *Ostrea distorta*, Fish-remains, &c., in a compact limestone at the base of the quarry. In these quarries no doubt the stone was obtained below the Cinder Bed. The quarry at Dashlet is now overgrown.

[A good exposure will be found in the stream-bank at the end of the wood, south-east of Teffont Mill. It shows:—

	Ft.	In.
Alternations of white clay and white earthy limestone	4	0
Harder light-coloured limestone with carbonaceous matter and fish-scales	0	10
White marl	0	4
Oolitic limestone (at water level)		

This section is difficult of access when the mill is working, and as no characteristic fossils could be found, there is some doubt as to the exact horizon.]

Clear sections of the strata from the Cinder Bed up to the junction with the Wealden Beds have been exposed in the two railway-cuttings to the west of Dinton Station. The second cutting west was described in detail in 1881 by the Rev. W. R. Andrews, who obtained from the Cinder Bed the new species *Trigonia densinoda*.

* Quart. Journ. Geol. Soc., vol. l. p. 54.

† Proc. Geol. Soc., vol. iii. pp. 134, 780; History of Fossil Insects, pp. 3, 18, 19; and Quart. Journ. Geol. Soc., vol. x. p. 474.

‡ Trans. Geol. Soc., ser. 2, vol. iv. pp. 249–251; see also Brodie, Proc. Geol. Soc., vol. iii. p. 780.

FIG 29.—*Section in the Railway-cutting west of Dinton Station, Wiltshire.* (H. B. WOODWARD.)

Distance about 155 yards.

The numbers indicate the same beds as those shown in Fig. 30, p. 27.

Mr. Andrews, then took Bed 19 as the top of the Middle Purbeck Beds, believing that they were overlaid unconformably by his "Wealden" Beds 20.* The clear connection with the overlying beds was not manifest, and when examining the sections in 1885 I (H. B. W.) noted the various strata that occurred above the Isopod Limestone onwards to the white and coloured clays on top of the series near Dinton Station. These white clays I took to be Wealden, and thought they were the beds so described by Mr. Andrews. The bed of hard eroded marl (19) described by him, is identical in character with Bed 27, and this caused my misinterpretation of his section.

In the meanwhile Messrs. Andrews and Jukes-Browne have given further particulars of the strata, and have included with the Upper Purbeck Beds, strata that I regard as Wealden.† In the spring of 1894 Mr. Strahan and I examined the area, and were fortunate in finding a fresh cutting near Dinton Station, the railway having been widened for the extension of the siding. We were thus enabled to measure all the strata from the base of the white clays, which we regard as Wealden down to the blue clay taken by Messrs. Andrews and Jukes-Browne as the base of the Upper Purbeck. Examining also the second cutting, where the Isopod Limestone is well shown, we were led to believe that that band would be met with a foot or two below the lowest bed exposed in the first cutting. Getting assistance in digging a hole, we were successful in finding this well-marked band of limestone No. 13, and thereby confirmed our previous inference that there was no discordance and no evidence of faulting between the two cuttings.

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* Proc. Dorset Nat. Hist. Club, vol. v., p. 68; Quart. Journ. Geol. Soc., vol. xxxvii., p. 251.

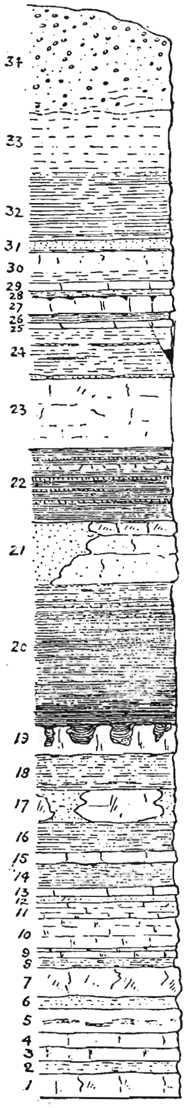
† Quart. Journ. Geol. Soc., vol. l., p. 55; and H. B. W., *Ibid.*, p. 71.

The following is the section exposed in the railway-cuttings west of Dinton railway-station (see also Fig. 29, p. 26):—

FIG. 30.

Section at Dinton.

(H. B. WOODWARD.)



			Ft.	In.
Wealden Beds.	34.	Irregular gravel passing down into whitish stony clay	5	0
	33.	White, grey, and mottled clay, passing down into white and ochreous clay with seam of greenish sand	3	0
	32.	Laminated yellow ochreous clay and sandy seams	2	3
	31.	Brown, black, and white sand, and thin layer of laminated clay	0	6
Upper Purbeck Beds.	30.	White marl passing down into clay: with Cyprides	1	4
	29.	Shelly calcareous grit — 0 1½ to	0	3
	28.	Gritty marl	0	3
	27.	White marl with black (carbonaceous?) matter on top — 0 4 to	0	8
	26.	Blue clay	0	5
	25.	Bluish-grey calcareous sandstone	0	3
	24.	Marls and clays, with thin bands of "beef," and thin impersistent layers of sandstone — 1 9 to	2	6
	23.	White shell-marl, with thicker bands of "beef"	3	0
	22.	Dark blue clays, with shell-marl, "beef," and ferruginous matter — 2 6 to	3	3
	21.	Blue-hearted shelly and sandy limestone with greenish earth in places, lignite, *Unio*, *Paludina*. Brown calcareous sandstone. The whole passing into sand with ferruginous layers	2	8
	20.	Yellowish sands and laminated sands and clays, passing downwards and laterally into stiff blue clay — 4 0 to	6	0
Middle Purbeck Beds.	19.	Hard-jointed white marl, the surface eroded and the hollows filled with clay (like Bed 27) — 0 1½ to	1	3
	18.	Thin laminated marl, with layers of clay and sand, shelly bands and "beef"	1	6
	17.	Calcareous sandstone passing into sand — 1 0 to	1	6
	16	Clay with shelly bands	1	3
	15.	Brown sandy rock with *Cyrena*	0	6
	14.	Shell-marl with greenish tinges	1	0
	13.	Smooth-grained grey limestone with *Archæoniscus*	0	3
	12.	Sandy shell-marl	0	3
	11.	Grey marly and ferruginous limestones	0	9
	10.	White limestones	1	3
	9.	Shelly and sandy limestones. Fish-remains	0	5
	8.	Shell-marl with "beef"	0	5
	7.	Cinder Bed: earthy limestone with *Ostrea distorta*	1	3
	6.	Marly and sandy layer with "beef"	0	5
	5.	Grey sandy and shelly limestone with marly seam	1	0
Lower Purbeck Beds.	4.	White limestone	0	8
	3.	White limestone	0	6
	2.	Marly bed	0	7
	1.	Brown sandy limestone	1	0

Still lower beds were noted as follows, in the adjacent quarries, by the Rev. O. Fisher in 1853:—*

		Ft.	In.
Lower Purbeck Beds.	Ribbon clays and sands, with compressed shells - - - - - -	1	0
	Hard crystalline limestone, with comminuted shells, *Cypris* and *Cyrena* -	1	6
	Brown sand, full of crushed bivalves and Serpulæ - - - - - -	0	9
	Blue and grey laminated clay with limestone nodules, thin "beef," and crushed bivalves - - - - -	1	0
	Hard grey marly limestone - - -	3	6
	Dirt-bed - - - - - - - -	0	3
	Laminated clay and soft and hard marls - - - - - - -	1	6
	Hard marl with conchoidal fracture -	0	8

These lower beds represent the "Lias" beds, &c., of Teffont; from the Middle Purbeck the following fossils were obtained:—

Lepidotus.	Cyrena ? gibbosa
Avicula dorsetensis.	——— media.
Cardium.	Modiola.
Corbula.	Mytilus.

The "Upper Marls" noted by Messrs. Andrews and Jukes-Browne were proved in the well at the cottages north of Dinton Station. This well was probably carried down through Wealden and Purbeck clays to the fossiliferous bed No. 21. The thin bands of calcareous sandstone above are, like the thicker beds, readily decomposed, and their presence would not have attracted the notice of the well-sinker. The water would have been obtained in the sandy beds on this horizon and below. Indeed, the same beds yielded water in a shallow well sunk by the old railway-siding, and the supply failed when the siding was extended.

In the material thrown out from this well Mr. Andrews obtained some Fish-scales, also the following fossils:—

Paludina carinifera.	Cypridea (cf.) valdensis.
Unio.	Cyprione Bristovii.
Cypridea punctata.	Darwinula leguminella.

The evidence clearly establishes the contention of Messrs. Andrews and Jukes-Browne that the Upper Purbeck Beds are represented, though I believe their "Upper Marls" are for the most part Wealden. In his original notes on the Vale of Wardour, the Rev. P. B. Brodie appears to have observed strata about as high as No. 23 in the Dinton section. [Since the above account was written the cutting has again been overgown; though a small quarry by the side of the rail still shows the beds up to No. 20.]

The hard marl (No. 19) and also the similar bed (No. 27) show evidence of local dissolution. The former layer, which sometimes is 15 inches thick, has almost disappeared in places, being reduced to 1½ inches.

* Quart. Journ. Geol. Soc., vol. x, p. 476; see also Andrews, *Ibid.*, vol. xxxviii, p. 251; Andrews and Jukes-Browne, *Ibid.*, vol. l, p. 55; and Geol. Mag., 1891, p. 292.

[The mapping of the Vale of Wardour on the six-inch scale in 1900 strongly supported the view taken in 1895 by Mr. Woodward as to the relation of the Purbeck Beds to the strata above. The thin marls and sands which form the Upper Purbeck were found to be continuous and to lie conformably underneath the Wealden strata. They were traced westward for over two miles to Chicksgrove, where they are overlapped, and lost just beyond the point where the Wealden sands disappear. Three outliers of Upper Purbeck age were also discovered; but there is no section beyond that seen in the railway-cutting at Dinton. The junction of the loamy Upper Purbeck with the Middle Purbeck limestones which lie below is commonly marked by a series of small swallow-holes. These are formed by the rainwater, which runs over and down the loamy surface till it reaches a porous rock into which it can sink, at the same time dissolving this rock if, as in this case, it happens to be soluble. Upwards, the Upper Purbeck strata seem everywhere to pass imperceptibly into the Wealden beds above, the only noticeable difference being that the Purbeck consist of decalcified marl and sand, and the Wealden of clay and sand which do not appear ever to have contained much lime. Probably both these deposits would appear very different if we could see sections which have not been subjected to the action of percolating water. The soil of the Upper Purbeck outliers is a brown sandy marl, unlike the retentive limestone-soil of the Middle and Lower Purbeck; but the main outcrop is so dominated by higher slopes of Cretaceous rock, that the character of the soil is not a satisfactory guide. C.R.]

CHAPTER V.

WEALDEN.

The Wealden strata, as shown in Figs. 29 and 30, rest conformably and seem to pass imperceptibly into the Upper Purbeck rocks seen in the cutting at Dinton station. Their outcrop extends for about three miles to the west to Sutton Row, on the south side of the valley, but only to Teffont on the north. The strike and dip coincide with those of the Purbeck strata; but only the strike corresponds with that of the Upper Cretaceous escarpment further west. The upward tilting towards the north-west, which affects all the Secondary rocks, had already begun in Lower Cretaceous times; but it seems to have continued to a much later period, probably as late as Miocene. Thus the older rocks have the higher dip, and various strata of Secondary and Tertiary date tend towards the west to rest on the upturned edges of older rocks.

In Dinton railway-cutting only some 10 feet of the lower part of the Wealden Beds can be examined, and the exact age of these deposits is, perhaps, not quite satisfactorily made out. At the cottages 300 yards north-east of this section, however, a well was sunk in 1884, and this showed, according to Messrs. Andrews and Jukes-Browne* :—

	Ft.
Yellow clay	3 or 4
Light-grey silty marl	11 or 12
Stiff grey clay	5 or 6
Very stiff grey and brown clays	about 20
Hard gritty stone	a few inches

This well, according to Mr. Woodward, penetrates both Wealden and Purbeck strata, the lower part being undoubtedly in Upper Purbeck, the upper part probably Wealden. The thickness of the Wealden strata at Dinton cannot be much over 30 feet; but on the south side of the river, near Sutton Mandeville, it may be somewhat greater. The only sections besides those already described will be found at Panthurst, where a deep cutting shows 10 feet of blue-black sand, the road above showing blue clay and sand. Near Sutton Mandeville Mill there are also shallow exposures of ferruginous sand and yellow sandstone.

Fragments of the peculiar wood known as *Endogenites erosa* have been found at several points in the Vale of Wardour; but this is the only characteristic Wealden fossil yet recorded. It is too doubtful a form to be of much value for correlation, though its presence supports the view that the strata containing it truly belong to the Wealden period, and are not, as supposed by Messrs. Jukes-Browne and Andrews, of Purbeck age.

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* *Quart. Journ. Geol. Soc.*, vol. l. p. 61. (1894) ; and "The Lower Cretaceous Series of the Vale of Wardour," *Geol. Mag.* dec. III., vol. vii. p. 292 (1891).

CHAPTER VI.

LOWER GREENSAND.

The interpretation of the Lower Cretaceous deposits in the Vale of Wardour has led to some debate; but the detailed mapping has now shown clearly that Fitton in 1827 had understood the true structure.* Fitton recognised that between the Wealden Beds and the Gault there occurs a thin deposit of greenish sand, very similar in character to the Upper Greensand above the Gault, and that this deposit represents the Lower Greensand of other districts. The Lower Greensand, however, is not shown on the old map of the Geological Survey, the sand described by Fitton being considered, apparently, too thin to be mapped separately.

The Lower Greensand of the Vale of Wardour consists usually of 15 or 20 feet of glauconitic sand with rare masses of cherty sandstone or chert. The only fossils I have noticed in it consist of sponge-spicules and of rare moulds of *Pecten* (*Neithea*) *quinquecostatus* and *P. orbicularis;* both species being common to the Upper and Lower Greensand. These fossils were found in loose blocks of chert picked up in a ploughed field, and this chert is so like one variety found in the Upper Greensand that it is impossible to be quite certain that any particular specimen may not have been washed down from the hills above. Messrs. Jukes-Browne and Andrews, however, record the more characteristic *Exogyra sinuata* from a well at Dinton.†

Exposures are so rare in the Lower Greensand that it will be convenient to follow the outcrop westward, first on the north side and then on the south side of the valley.

At Dinton a well sunk in 1890 gave Messrs. Jukes-Browne and Andrews the following section:—

		Ft.
Gault	Yellow, brown, and blue clay (with fossils) -	21½
	Sandy rock with a layer of small pebbles at the base (fossils) - - - - -	14½
Vectian (Lower Greensand)	Brown, grey, and yellow sands, with lumps and layers of ferruginous sandstone (*Exogyra sinuata*)	26½
	Light grey sandy clay, becoming darker and passing down into stiff black clay -	7

They remark that "in this well the base of the group is evidently not reached, but most fortunately it is completed by a brook section at Teffont, which begins in a black clay exactly like that found at the bottom of the well. This black clay is about six feet thick, and passes down into a nearly black sand, which has a green streak when cut, and consists mainly of dark-green grains of glauconite.

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* Observations on some of the strata between the Chalk and the Oxford Oolite, in the south-east of England. *Trans. Geol. Soc.* ser. II., vol. iv. p. 248 (1836).

† *Geol. Mag.* 1891, p. 293.

"Underneath this sand are mottled clays, which were recognised by Mr. Whitaker as similar to the 'catsbrain' clays of the Weald —their tints are yellow and white, mottled here and there with a rich claret-coloured stain, which imparts a special character to the clay. Below are yellow loamy clays. We consider these to be of Wealden age, and the dark sand to be the base of the Vectian; but as the section is not clear, and this sand has not yet been found elsewhere, we cannot say whether the sand is conformable to the clays or not." I cannot help feeling some doubt as to this correlation of the clays at Dinton and Teffont, and should be inclined to refer only the 26½ feet of sandy beds to the Lower Greensand. The Gault in the above well will be more fully described in the next chapter. It may be noted, however, that its fossils belong to a higher zone than that of *Ammonites* [*Acanthoceras*] *mammillatus*.

The Greensand first rises above the marsh-level near Dinton Mill as a coarse-grained glauconitic sand with concretionary masses of cherty sandstone, the whole deposit being apparently about 20 feet thick. Material of this sort was formerly dug over a piece of rough ground half a mile west of the Mill; but the section is now overgrown. To the south of Dinton Park and Teffont Magna Mr. Jukes-Browne has been able to follow the outcrop as a narrow belt of sandy land, though no section is visible. Immediately east of Teffont the Lower Greensand overlaps the Wealden Beds and rests on Upper Purbeck. Three-quarters of a mile farther west it rests on Middle Purbeck limestone, which has been dug close to the sand. At Ridge an uprooted tree, growing apparently just at the junction, brought up hard shelly limestone with oolitic grains, belonging to the Lower Purbeck. Some overgrown pits immediately south of Ridge Pottery are perhaps referred to by Fitton, who does not appear himself to have seen this part of the section which he describes, though he saw the pit in the Gault above and the quarry in the Purbeck limestone below. More probably he obtained the thickness and character of the Lower Greensand from the well which is noted in his section as occurring at the Tile-pits. His section gives:—

	Ft.
Gault - - - - - - - - - - - - - -	75
Sand; (perhaps the representative of the Lower green-sand) said to be like that of the hill-top. Masses of a calcareous conglomerate in the upper part - - - - -	15
Purbeck stone.	

I have not seen any calcareous conglomerate such as Fitton describes; but he probably refers to the thin pebble-bed which marks the base of the Gault wherever sections are visible, though it is not now exposed at Ridge.

Towards Fonthill the Lower Greensand becomes thinner and thinner, the last point to which it has clearly been traced in that direction being in the neighbourhood of Fonthill Abbey. In this area it is usually so dominated by higher slopes of Upper Greensand that it is difficult to recognise; but in some fields west of the Rectory it runs ou as a spur, capped only by Gault.

Here I saw traces of disturbed cherty sand, resting on Portland Stone, and found also a specimen of *Pecten* [*Neithea*] *quinquecostatus* in chert. The whole deposit does not appear to exceed five feet in thickness; though the tendency of the soft Gault to slip and flow down slopes no steeper than this, makes measurement impossible. The same cause prevents the tracing of the Lower Greensand any farther towards the west; but I think the deposit must be actually overlapped and cut out by the Gault close to Fonthill.

The south side of the Vale of Wardour shows still clearer evidence of the presence of the Lower Greensand, and we will now follow the outcrop from Dinton south-westward. Half a mile south-west of Dinton Mill blocks of coarse-grained glauconitic cherty sandstone were noticed in Compton Wood, a few feet below the base of the Gault. These correspond closely with the material from the opposite side of the valley, and appear to be almost in place, though the soil is full of a slightly different chert derived from the Upper Greensand slope above. Pieces of this glauconitic cherty sandstone are traceable here and there as far as the road to Catherine Ford, where is the exposure noted by Fitton; we can still see in that road traces of greenish sand between the Gault and the Wealden. Similar sand and cherty sandstone, with exceptionally large grains of glauconite, have been mapped by Mr. Jukes-Browne around Fovant, where it makes a somewhat wider spread, and at Sutton Mandeville. In them, at Panthurst, Fitton discovered a *Pecten* and the stem of a *Siphonia*; no section is now to be found, but on the outcrop there is a shallow overgrown pit, which was perhaps open in Fitton's day.

West of Sutton Row the Lower Greensand overlaps the Wealden Beds, and a small pit in coarse sand will be found immediately east of Haredene Wood. At the north-east corner of this wood some of the basement-bed, which here rests on Middle Purbeck limestone, is let down into a swallow-hole, in the sides of which three feet of coarse-grained greenish sand can be seen. North and east of Castle Ditches the Lower Greensand rests on Middle Purbeck, and there is some indication of a thin pebble-bed at the junction.

The occurrence of gentler slopes and wider outcrops, and the greater distance of the Upper Greensand escarpment, make the exposures south of Tisbury more satisfactory than any we have yet dealt with; for though sections are scarce, abundance of Lower Greensand material without much admixture of rock from the slopes above can be found. If the road from Tisbury to Ansty and Swallowcliffe past Wallmead is followed, it will be found to cross two spurs of Lower Greensand, one at Totterdale Cottage, the other nearer Ansty. Sections are not good, but the use of the spud and an examination of the ploughed fields shows that the Cretaceous rocks here rest on the lowest Purbeck Beds, that there must be a thin seam of quartz and lydite pebbles at the base of the Lower Greensand, and that the strata above are ferruginous or glauconitic coarse sands and cherty sandstones apparently with some intercalated seams of loam. Above these comes another thin pebble-bed in brown loam, forming the base of the Gault. In the ploughed fields I found several pieces of cherty sandstone with *Pecten quinquecostatus* and *P. orbicularis*; but was quite unable to find any characteristic fossils, though a large amount of material was broken up and examined. About a quarter of a mile south-east of Totterdale farm, a small section of the upper beds can be seen, brown sandy loam with numerous scattered pebbles (the base of the Gault) overlying ten feet of glauconitic sand. This section, unfortunately, does not show any of the harder fossiliferous rock, which seems to occur principally as irregular scattered nodules towards the base of the deposit. The total thickness of the Lower Greensand around Totterdale appears to be nearly 30 feet. To the west of this farm the outcrop is easily traced as a belt of sandy land, with loose masses of ferruginous sandstone; but no other section is visible within the area described in this Memoir. Outside our limits a sand-pit in Wardour Park shows:—

		FEET
Gault - -	Blue Clay - - - - - - -	10
	Pebbles - - - - - - - -	½
Lower Greensand.	Coarse gritty sand - - - - - -	10

The strata in this pit shows a dip slightly to the south of east.

There still remains for discussion the question of the probable age of the Lower Greensand of the Vale of Wardour, for its extreme thinness, the occurrence of a pebble-bed and unconformity at its base, and of a pebble-bed and overlap of the Gault above, do not favour the idea that we are dealing with an attenuated representative of the whole of the Lower Greensand. It seems far more probable that this thin coarse-grained deposit represents part only of the Lower Greensand of other districts; but what part the evidence found in the Vale of Wardour is insufficient yet to show.

Though in the Vale of Wardour itself it is difficult to find conclusive evidence to settle this point, there is a pit near Okeford Fitzpaine, about 12 miles to the south-west, which throws much light on the subject. The section and fossils of the lower part were thus described in 1896 by Mr. R. B. Newton* :—

		FEET.
Hoplites interruptus Zone.	Dark-grey coloured, micaceous, and sandy clay with phosphatic nodules; fossiliferous in the lower 4 feet	15
	Brown sandy rock, with fossils in the upper part.	4
Acanthoceras mammillatum Zone.	Argillaceous sandy beds, micaceous, and of a brown, grey, or yellowish colour; ferruginous and oolitic; siliceous pebbles interspersed; fossiliferous.	5
Aptian?	Pure sand.	3
Kimeridgian.	Stiff blue clay.	8 or 10
Corallian?	Sandy rock.	

* Geol. Mag. 1896, p. 198.

From the *Ammonites* [*Acanthoceras*] *mammillatus* Zone he records the following fossils :—

Acanthoceras mammillatum	Cucullæa carinata
Hoplites Benettianus	Ostrea Leymeriei
Pleuromya plicata	Exogyra sinuata

In the *Ammonites* [*Hoplites*] *interruptus* Zone were found amongst others the following :—

Hoplites interruptus	Mytilus subsimplex
——— splendens	Nucula pectinata
Nautilus clementinus	Ostrea canaliculata
Aporrhais carinata	Thracia simplex
Avellana inflata	Trigonia alæformis
Solarium ornatum	Trigonia archiaciana
Cucullæa carinata	— Fittoni

In this section a few feet of sandy beds lie between the clayey Gault and the Jurassic rocks, exactly as the sandy beds occur in the Vale of Wardour; but in the Okeford section both deposits contain characteristic zonal fossils, and we can prove the occurrence of the zone of *Ammonites mammillatus* below that of *Ammonites interruptus.*

The lowest fauna discovered in the Dinton well comes, however, not from the sandy beds described in this Memoir and mapped as Lower Geeensand, but from what I take to be the pebbly and sandy basement-bed of the Gault above; and this basement-bed yields the fauna of the *Ammonites interruptus* zone (see p. 38). As to this, Mr. Jukes-Browne remarks that, "It will be noticed that the basement-beds are here 8 feet 8 inches thick, and it might have been expected that they would yield the fauna of the zone of *Ammonites mammillatus,* but this does not seem to be the case."* I think, however, that the true zone of *Ammonites mammillatus* is probably represented by the 26 feet of sandstone below, not by the pebbly beds. This sandstone at present has only yielded *Exogyra sinuata ;* but further search should produce definite evidence.

As regards the classification of these strata, Mr. Jukes-Browne remarks that, "It has been customary in England to regard the Gault as commencing with clayey beds containing *Ammonites interruptus,* and to refer all beds below this horizon to the Lower Greensand. In France, however, the sands containing *Ammonites mammillatus* which underlie the clays with *A. interruptus* have always been included in the Gault or Albian of d'Orbigny."† In the Vale of Wardour the sands referred in this Memoir to the zone of *A. mammillatus* are certainly more closely related stratigraphically to the Gault above than to anything below; but as they can be mapped separately and have a markedly different lithological character they have been coloured as Lower Greensand on the map, and are still bracketed as Lower Cretaceous. At the same time they are placed in the Index to the Map at the base of the Gault, with a marked break between them and the Wealden beds. An additional reason for

* "Cretaceous Rocks of Britain," vol. i., p. 228, *Mem. Geol. Survey* (1900).
† *Ibid,* p. 43.

this treatment is found in the unfortunate circumstance that on the Continent the Gault is nearly always classed as Lower Cretaceous, while we class it as Upper Cretaceous. If we transfer the zone of *A. mammillatus* from the lower Greensand to the Gault, we make this discordance greater instead of less. At present British geologists do not seem disposed to adopt the continental division between the Upper and Lower Cretaceous rocks, which is certainly not a convenient one for Britain.

CHAPTER VII.

GAULT AND UPPER GREENSAND (SELBORNIAN).*

The Selbornian Group consists of clays and marls which are usually known as *Gault,* and of sands and sandstones which have been called *Upper Greensand;* but it must be remembered that though both exist in Wiltshire, the Gault clays of this county represent the Lower Gault of Folkestone only, the Upper Gault (which comprises two-thirds of the formation at Folkestone) being here represented by the so-called Upper Greensand.

The following is the succession of beds which make up the Selbornian in the Vale of Wardour:—

		Feet.
Zone of *Pecten asper.*	Green sand or sandstone - - - -	about 10
	Sands with layers of cherts - -	,, 25
	Glauconitic sandstone - - -	,, 15
Zone of *Ammonites rostratus.*	Greenish grey sands - - - - -	,, 40
	Fine buff-coloured sands - - -	,, 50
	Sandy malmstone - - - - -	,, 20
Zone of *Am. interruptus.* (Gault.)	Sandy micaceous clay - - - } Grey and brown clays - - }	,, 100
	Ironstone and pebble bed - - -	3 to 8
		About 265

GAULT.

The Gault of the Vale of Wardour is a bluish marly clay or loam, tending to become sandy above and below, and having a thickness of from 80 to 90 feet. Where sections are visible there is a sharp line, marked by a few small pebbles, at its junction with the sands below, but upwards it passes gradually into the Upper Greensand. Indeed, the relation of the Gault to the Upper Greensand is so intimate, that in his "Upper Cretaceous Rocks of Britain," Mr. Jukes-Browne has introduced the name "Selbornian" for the combined formations. The two make one palæontological whole, and are merely different lithological facies of one formation. The equivalents of the Upper Gault clay tend to become so sandy towards the west as to be scarcely distinguishable lithologically from the Upper Greensand. In this district the clay represents the Lower Gault only. It passes up into a kind of impure malmstone, or fine micaceous sandstone containing a variable quantity of colloid silica, and this in turn passes up into soft sands.

Our knowledge of the Gault within the area described in this Memoir is mainly derived from two sections, a brickyard and well at Ridge, and a well sunk at Dinton, north-east of the

* Mainly from Jukes-Browne's "Cretaceous Rocks of Britain," vol. i., chapter xvi. (*Memoirs Geol. Survey*), 1900.

church, in 1890. The Dinton well has already been referred to; the section given by Mr. Jukes-Browne is as follows:—

		Ft.	In.
	Surface soil	1	6
Gault clays	Yellow and grey clays	5	0
	Hard ferruginous stone	0	8
	Brown clays with a layer of brown stone	15	0
	Dark grey clay with selenite, some fossils and a few small phosphate nodules	5	0
Basement Beds	Hard grey ferruginous sandy rock, fossils	5	8
	Reddish-brown sandstone with scattered pebbles, fossils and fragments of wood	2	6
	Layer of small pebbles	0	6
Lower Greensand	Brown and grey sands and stone beds	26	8
	Grey and black clays	7	0
		69	6

The following fossils were obtained from the brown sandstone by the Rev. W. R. Andrews and identified by Messrs. Sharman and Jukes-Browne:—

Ammonites sp. (? Deshayesi or denarius).
Natica sp. (? Genti)
Arca (Cucullæa) carinata.
Cytherea sp. (? plana, young).
Inoceramus concentricus.
,, sp. (large).
Lima sp.
Modiola sp.
Mytilus sp.
Ostrea vesicularis.
Pecten orbicularis.
Pinna sp. (several).
Pleuromya mandibula.
Terebratula biplicata.
Holaster lævis.

From the overlying hard grey rock were obtained:—

Ammonites [Hoplites] sp.
Turbo sp. (not *munitus*).
Inoceramus sp. (large).
Cucullæa glabra.
,, sp.
Arca Raulini ?
Cardium raulinianum ? (not *sub-hillanum*).
Pleuromya plicata ?
Cyprina angulata.

In the clay above Mr. Andrews found the following:—

Am. interruptus (Fig. 31).
Trigonia Fittoni.
Pleuromya mandibula.
Pecten orbicularis.
Inoceramus sp.
Pinna sp.

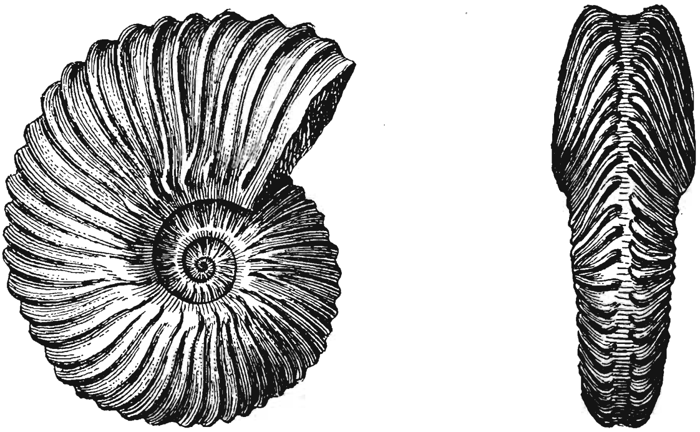


Fig. 31. Ammonites [Hoplites] interruptus, *Brug.*

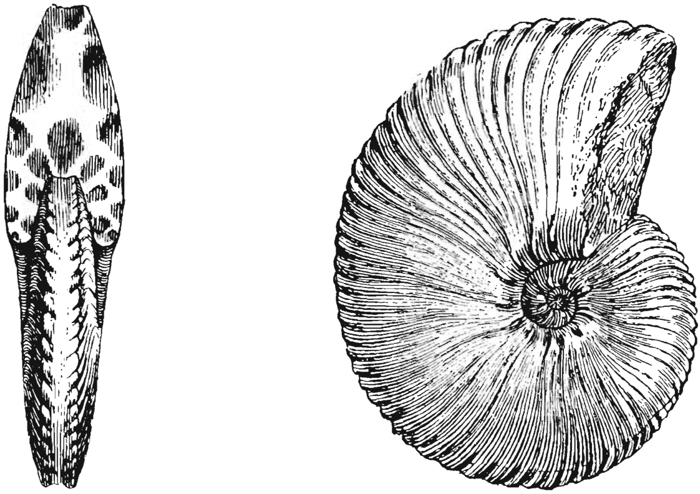


FIG. 32. Ammonites [Hoplites] splendens, *Sow.*

The only excavation in the Gault along the north side of the Vale is that of a brickyard at Ridge, west of Chilmark. Here about 40 feet of dark grey micaceous silty clay is seen containing a nearly continuous layer of dark grey argillaceous and calcareous mudstone or silty sandstone. Small ovoid dark-coloured septarian stones are scattered through the clay, and one of these was analysed for us by Prof. J. B. Harrison, F.G.S., of Demerara, the result showing the presence of much phosphate of lime (51·6 per cent.), carbonate of iron (6 per cent.), and carbonate of lime (19·38 per cent.), the latter probably being chiefly from the calcite-veins which traversed the nodule. These phosphatic nodules are common in the Gault throughout Wiltshire and the northern part of Dorset; they run from 3 to 5 inches in length, and are often 2 inches in diameter.

Fitton records the following fossils from this exposure:—

Ammonites Beudanti	Rostellaria carinata.
„ dentatus[interruptus]	Pectunculus umbonatus.
„ tuberculatus.	Cytherea parva ?
„ selliguinus (?)	Lima elongata (= parallela d'Orb).
„ varicosus [? an error]	Terebratula sp.
Avellana inflata.	Astacus [? Hoploparia].
Dentalum decussatum.	

The Rev. W. R. Andrews has himself obtained *Ammonites interruptus, Am. splendens* (Fig. 32), *Inoceramus sulcatus* and a large species of *Cucullæa,* probably *glabra.*

UPPER GEEENSAND.

The malmstone into which the highest part of the Gault passes is a fine-grained grey siliceous rock, containing a variable amount of colloid silica, but less than the typical malmstone of Hampshire; in other words it is an impure malmstone with considerable quantities of clay and fine sand in its composition. Some parts of it may contain 20 per cent. of colloid silica, but an argillaceous sample from Sutton Mandeville, analysed by

Prof. J. B. Harrison yielded only 11·4 per cent., with 31·84 per cent. of quartz and mica, and 34·19 per cent. of combined silica; this sample was remarkable for containing a large amount of magnesia (8·18 per cent.) and no carbonate of lime.

The malmstone passes up into fine micaceous sand which sometimes, as near Ridge, passes into a very soft and loose sandstone containing much colloid silica, a material which the French call *gaize*. These sands always weather to a buff or yellowish colour, but pass up into grey sands which have little or no mica, consisting entirely of small grains of quartz and glauconite. The highest part of these sands for 9 or 10 feet contain roundish concretions of calciferous sandstone, some as large as a man's head.

The next member of the group is a firm glauconitic sandstone of coarser grain than the beds below, and cemented by calcareous matter into a fairly hard rock. This stone has been quarried in many places for building-material and was formerly in much request. Along the northern outcrop, and perhaps on the southern side of the Vale, there is a layer about a foot thick in this sandstone almost entirely composed of *Ostrea vesiculosa*, and where the rock has been much decomposed at the surface, this shell-bed becomes a conspicuous feature in it. The rock also contains *Pecten asper* and *P. quadricostatus*.

The Chert Beds are a continuation of those which appear near Warminster; they consist of fine greyish sand, often almost a silt, containing large quantities of sponge-spicules, and enclosing layers of black or brown chert and of white porous siliceous-stone, with occasionally doggers of calcareous sandstone. Fossils of other kinds are rare.

The highest member of the series is seldom seen in the eastern part of the Vale, but appears to consist of sharp green sand without fossils.

The Upper Greensand of the Vale of Wardour is apparently no less than 150 feet thick, and includes two distinct zones, that of *Ammonites rostratus* (Fig. 33) and that of *Pecten asper* (Fig. 34); the older of these zones, that of *A. rostratus*, though here almost entirely composed of sand, is the equivalent of the Upper Gault clay of districts farther east.

There are many exposures of the beds composing the zone of *Ammonites rostratus* on both sides of the Vale of Wardour. It forms the mass of what is called the Upper Greensand, and the general succession is as follows:—

		Ft.	In.
Glauconitic sandstone (zone of Pecten asper) - - -			
Zone of *Am.* [*Schloenb.*] *rostratus.*	Soft greenish-grey sand with hard irregular calciferous concretions (no chert)	9	0
	Fine greenish-grey sand, often laminated and current-bedded - - about	30	0
	Buff-coloured sands, becoming micaceous below and passing into soft micaceous sandstone - - - -	50	0
	Impure sandy malmstone, from 15 to -	30	0
Gault (grey sandy micaceous marl) - - - - -			

The thicknesses given are approximate only, and the total probably varies between 105 and 120 feet.

FIG. 34.

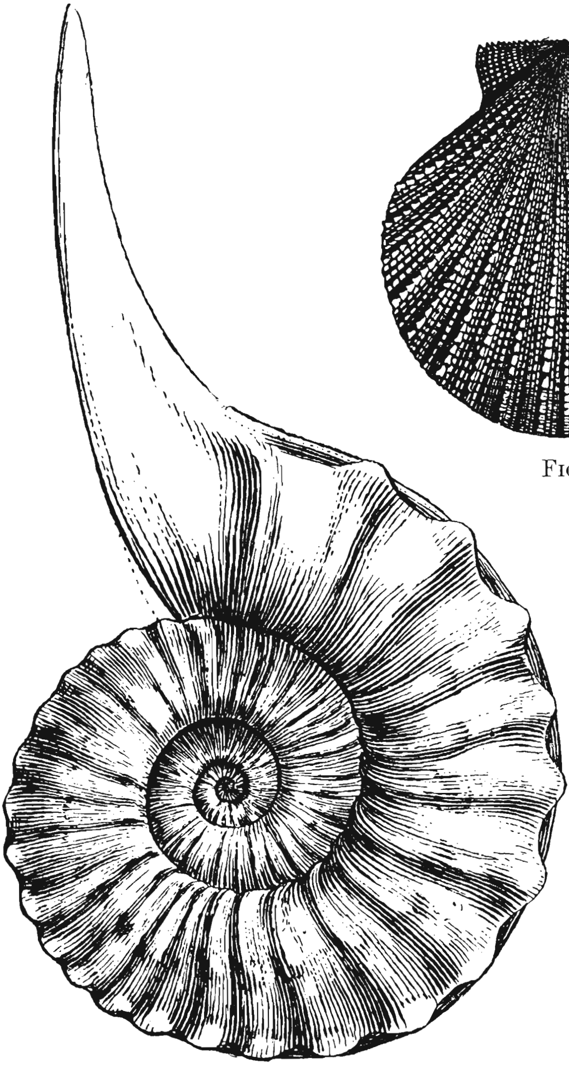


FIG. 33.

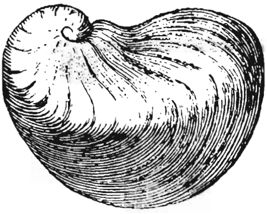


FIG. 35.

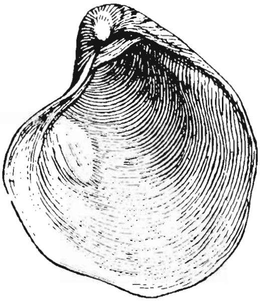


FIG. 36.

FIG. 33. Ammonites (Schloenbachia) rostratus, *Sow.* $\frac{1}{3}$.
35. Exogyra conica, *Sow.*

FIG. 34. Pecten asper, *Lam.* $\frac{2}{3}$.
,, 36. Ostrea vesiculosa, *Sow.*

On the south side of the Vale there is a good section of the malmstone in a deep fosse-way by Sutton Mandeville church. The beds dip to the south and the top is not seen, but there seems to be a thickness of about 30 feet; most of it is a light grey stone of small specific gravity, so that it feels light in the hand, but some of the beds are heavier and more argillaceous with spots and streaks of dark grey marl. The stone weathers into beds of 6 to 12 inches thickness. Another excellent section of these strata will be found in the sand-pit opposite the church at Ansty, which shows 35 feet of fine glauconitic sandy loam, with a few masses of concretionary sandstone, *Exogyra conica* (Fig. 35) occurring in the other part, and *Pecten (Neithea) quinquecostatus*, and a large *Serpula* in the lower. The bottom of this pit is probably 30 or 40 feet above the clayey Gault, which throws out strong springs around the pond below.

Along the north side of the Vale the sandstone is well exposed by Knap Farm near Ridge, where it has the character of a true "gaize" like that of Devizes; here it contains *Serpula concava* and impressions of bivalve Mollusca. It is also visible in the lane north of Dinton.

The best sections through the sands which form the higher part of the zone are:—

The lanes near Ridge.
A sand-pit in Upper Holt, north-west of Teffont.
The lane north of Dinton.
Large sand-pits by the road north-west of Dinton Manor Farm.
The railway cutting near Baverstock.
The lane down the north side of Fir Hill, near Fovant.

The zone of Pecten asper is well developed in the Vale of Wardour, and consists of the following beds:—

Green sand or sandstone, from 6 to 10 feet.
Chert Beds, from 20 to 30 feet.
Glauconitic sandstone from 9 to 16 feet.

the average thickness being probably about 45 feet.

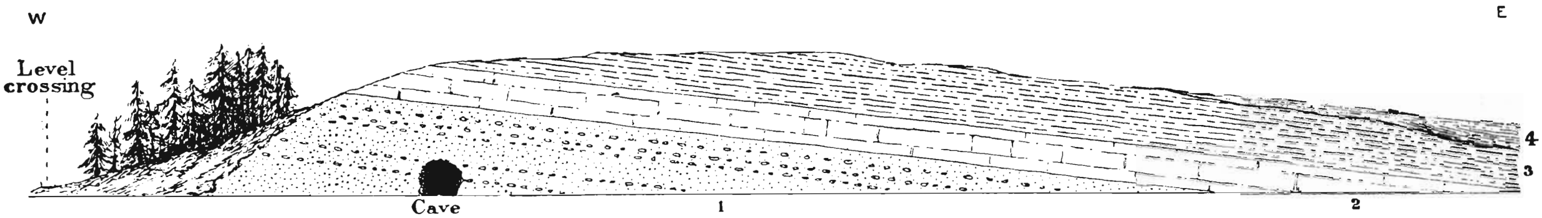
The glauconitic sandstone is exposed in many of the lanes and roadways on both sides of the Vale, and its thickness increases from 9 feet on the western side to 14 or 16 feet towards the eastern end. In the middle or upper part of it there is a layer about 12 inches thick which consists almost entirely of *Ostrea vesiculosa* (Fig. 36) shells, and where the rock has been decomposed into soft sand and sand-rock this bed of Oyster shells becomes a very conspicuous feature.

The stone has been quarried in many places for building-material, and was formerly in much request. Dr. Fitton says it was called "Greenstone" at Fovant, and adds "it is valuable from its not being affected by frost. It can therefore be dug at any season, and stands well in water as in the foundations of bridges, and in exposed situations as in copings, etc."* The Chert Beds are used for road-metal around Swallowcliffe.

The best section on the south side of the Vale is that of the old quarry at Fovant near the Pembroke Arms. Dr. Fitton gave

* Trans. Geol. Soc. Ser. 2, vol. iv., p. 246.

FIG. 37. *Section of railway-cutting at Baverstock, Wiltshire* (A. J. JUKES-BROWNE).
(Length of cutting about a quarter of a mile).



		Ft.
4.	Soil.	
3. Chert Beds	Fine grey sand with layers of black chert and white porous stone	6
	Fine grey sand, with irregular layers of porous stone, and doggers of hard calcareous stone	8
	Light greenish grey marly sand, with a layer of grey calcareous stone at the base	1½
2.	Firm greenish sandstone, with vertical joints. *Ostrea vesiculosa* abundant about the middle	13
1.	Soft grey sands with lenticular layers of hard siliceous stone in the upper part, seen for	25
	About	54

the succession here, and his account differs little from the following, which was taken in 1890:—

	Feet.
Soil and Rubble - - - - - - - - - - -	3
Fine grey silty sand, with layers of chert and white porous siliceous stone - - - - - - - - - -	8
Soft grey sand, with two layers of greenish calcareous stone -	4
Soft grey sand, with nodular lumps of calcareous grit, passing down into tough greenish sandstone with irregular lumps of hard grit - - - - - - - - - - -	6
Firm greenish sandstone, standing with a vertical face and weathering yellowish brown - - - - - -	10
	31

The only fossils seen in the sandstone were *Pecten orbicularis* and *Ostrea vesiculosa*, but Dr. Fitton also mentions Sharks' teeth. The beds are nearly horizontal, and form part of a plateau, which has a gentle slope to the southward. The stone is rather coarse in grain, the glauconite grains being large, dark green, and conspicuous.

The highest beds of the Greensand are well exposed near Baverstock. In the wood about half-a-mile east of the church is a small sand-pit, which shows marly glauconitic sand (about 3 feet) passing down into sharp bright green sand (about 8 feet). This must be just below the "Chloritic Marl." In the railway cutting to the south-eastward lower beds are seen with a dip of about 10° to the north-east, by which the succession shown in Fig. 37 is brought in.

At two other points within the area described in this Memoir the higher beds of the Upper Greensand are exposed at the surface, but there is no section visible. One exposure is at Alvediston, the other farther east, near Mead End. The last-mentioned outcrop is part of the Greensand inlier brought up by an anticline which runs through Bower Chalk; sections in this Greensand will be found in Bower Chalk village, which lies just outside our limits (*see* Ringwood Memoir and Map, sheet 314).

CHAPTER VIII.

CHALK.*

The Chalk, which occupies the surface over so large a part of the area described in this Memoir, forms a mass of such great thickness that it has been mapped in three sub-divisions—Upper Chalk (soft, with flints), Middle Chalk (harder and less flinty), and Lower Chalk (grey marly chalk without flints). In addition to these broad lithological divisions, various zones characterised by peculiar fossils have been recognised, though it has not been attempted to lay down these palæontological zones on the map. The zones usually recognised are as follows:—

	Zone.	*Thickness.* Ft.
Upper Chalk (with Chalk Rock at its base).	Belemnitella mucronata - - -	80
	Actinocamax quadratus - - -	170
	Marsupites testudinarius - - -	230
	Micraster coranguinum - - -	240
	—— cortestudinarium -	70
	Holaster planus - - - - -	
Middle Chalk (with Melbourn Rock at its base).	Terebratulina - - - -	80-100
	Rhynchonella Cuvieri (= zone of Inoceramus labiatus) - -	
Lower Chalk (with Chloritic Marl at its base).	Holaster subglobosus - - - -	90
	Ammonites varians - - - -	100
	about -	1070

The upper part of the series is incomplete, only the base of the *Belemnitella mucronata* zone being preserved, and this only in the neighbourhood of the Eocene strata.

LOWER CHALK.

The nodular and phosphatic Chloritic Marl, which forms the base of the Chalk in this part of England, is nowhere clearly exposed within our area; but the rest of the Lower Chalk forms a well-marked belt of undulating marly land, fringing the Vale of Wardour and running at the foot of the scarp which everywhere bounds the valley. Lower Chalk also appears in the bottom of the valley of the Wylye around Codford, and again on the southern limit of the district around Alvediston and Broad Chalk.

A good exposure of the alternating beds of soft marl and hard chalk forming the upper part of the *Am. varians* zone occurs in the chalk-pits by the side of the road leading up Buxbury Hill, on the south side of the Vale of Wardour, and is seen in the

* Mainly from the notes of Messrs. A. J. Jukes-Browne and F. J. Bennett,

lowest level leading to the door of the lime-kiln, the descending succession being as follows:—

	Ft.	In.
Two courses of hard rough grey chalk separated by loose marly chalk - - - - - - - - -	2	6
Dark grey argillaceous marl - - - - - - -	0	6
Loose grey marly chalk - - - - - - - -	1	3
Hard grey chalk - - - - from 9 inches to	1	6
Marly grey chalk, weathering into loose fragments, with here and there patches of darker blue grey chalk (many fossils) - - - - - - - - - -	14	0
Very hard rocky grey chalk, rising from below the last near entrance - - - - - - - - -	1	6
Dark grey tough marly chalk - - - - seen for	1	0
	22	3

These beds have a southerly dip of 4°, and contain many of the characteristic fossils of the Chalk Marl, such as *Rhynchonella Martini*, *Rh. grasiana*, *Lima globosa*, *L. aspera*, *Ammonites* [*Schloenbachia*] *varians*, etc.

A quarry to the south-east of the village of Fovant shows a similar set of beds, which must be at about the same horizon. The upper part of the quarry is in firm, massive, whitish chalk, of which about 50 feet is seen, and below this the following succession can be made out:—

	Ft.
Hard greyish-white chalk in layers, having alternately a rough and a smooth fracture - - - - - - -	6
Layer of soft grey marl - - - - - - - - -	0
Hard grey chalk - - - - - - - - - - -	3
Soft dark grey marly chalk - - - - - - - -	1
Dark grey sandy chalk, with visible grains of glauconite (many fossils) - - - - - - - - about	15
Very hard light grey limestone - - - - - - -	1
Soft grey marl below.	

The grey sandy chalk is not unlike Totternhoe Stone, and contains many of the same fossils, but there are no phosphatic nodules or fragments in it.

There are no good exposures of this zone on the north side of the Vale of Wardour.

By the road leading up to Buxbury Hill there are two excavations in the higher part of the Lower Chalk. The first of these is in the quarry above the exposure by the limekiln previously mentioned. This shows about 25 feet of firm blocky greyish-white chalk, breaking as usual along more or less curved surfaces, so that the real planes of bedding are obscured. The following fossils occurred: *Ammonites* [*Acanthoceras*] *rotomagensis*, *Inoceramus sp.*, *Ostrea lateralis*, *Pecten Beaveri*, *Terebratula semiglobosa*, and Mr. Rhodes subsequently found *Ammonites* [*Acanthoceras*] *Mantelli*, *Am.* [*Haploceras*] *Austeni* (?) (a fragment), *Ostrea vesicularis*, and *Pecten orbicularis*. These species and the absence of *Ammonites varians* suggest that these beds belong to the higher zone. If this is correct, the floor of the quarry nearly coincides with the transition from one zone to the other.

On the other side of the road, and at a little higher level, there is a second quarry, showing the following beds:—

	Ft.
Compact white chalk, weathering into courses with looser chalk between them - - - - - -	5
Rather rough greyish-white chalk - - - - -	6
Marly parting.	
Hard greyish chalk, with indefinite bands of very hard nodular grey chalk - - - - - - - - -	8
Massive compact blocky chalk, parting along curved surfaces - - - - - - - - seen for	7
	26

The lowest blocky chalk is evidently a continuation of that in the other quarry. The nodular beds contain *Ammonites Austeni* (?) and *Sussexiensis* (?). They show a dip of 6° or 7° to the south-east. The marls of the *Act. plenus* band cross the road about 100 yards farther up, and from them Mr. Rhodes got three specimens of the characteristic Belemnite.

A quarry by Pitchpenny Clump, north of the hamlet of Ridge, shows the Melbourn Rock resting on a layer of grey marl, with greyish chalk below, but the rest of the section was obscured by talus when visited in 1890.

A similar section is exposed in a chalk-pit about a mile north-east of Dinton, grey blocky chalk succeeded by a broken layer of grey marl passing below the Melbourn Rock, which dips north at about 20°.

No sections of Lower Chalk are visible in the part of the Wylye Valley that comes within our area, though immediately west of the limits two pits will be found.

At the southern margin of the area the Lower Chalk is again brought up by anticlinal folds, and is seen here and there in the Ebble Valley. In these inliers Mr. Bennett has noted a few sections. In the Broad Chalk inlier a pit will be found above Knighton Farm, and a road-section half a mile south of Croucheston. The Bower Chalk exposure shows several sections; the only ones which come within our limits are, however, those near Mead End. The spring-head south of that farm shows hardish grey flaggy chalk with *Ammonites varians*. A pit nearer the farm shows 10 feet of rather hard flaggy chalk, apparently higher in the series, having a northerly dip of 8°. No pits are now open at Alvediston.

MIDDLE CHALK.

The Middle Chalk, from its harder character, tends usually to form the lower part of the steep scarp which borders the valleys where the softer Lower Chalk occupies the bottom. In other places the contours where Middle Chalk appears at the surface are scarcely distinguishable from those of the rolling downs which characterise the Upper Chalk. The soil of the Middle Chalk is dry, and more fitted for pasture than for tillage, for where the slope is steep the soil tends to wash away during heavy rains. It is unfortunate that these steep slopes were ever ploughed, as the removal of the turf allowed the rain to wash away the thin soil which had taken centuries to accumulate; and now the absence of soil is severely felt.

The total thickness of this division is, as already mentioned, about 80 or 100 feet. At its base is a band of hard nodular rock, known as the Melbourn Rock, having a thickness of 5 or 10 feet. Two palæontological zones are included in the division, that of *Rhynchonella Cuvieri* above, and that of *Terebratulina* below; fossils, however, are not abundant in the Middle Chalk of this district, the most common being the fibrous fragments of an *Inoceramus*, probably the species variously known as *I. mytiloides* or *I. labiatus*. This shell is usually accepted on the continent as giving the name to the zone here known as that of *Rhynchonella Cuvieri*. The main outcrop of Middle Chalk within our area is that bordering the Vale of Wardour; but the rock covers also a considerable area in the valleys of the Wylye and Ebble.

In the Vale of Broad Chalk, many exposures of Middle Chalk can be found, but, according to Mr. F. J. Bennett, there are few large quarries in it. He saw the Melbourn Rock at Broad Chalk, at the top of a quarry north of Chalk-pit House, and again in the road south of Knighton.

Mr. Jukes-Browne visited Homington and Coombe Bissett in 1890; south of Homington he found a quarry in the Cuvieri zone, showing:

		Ft.
Hard chalk, broken and weathered, with two layers of greenish marl, *Inoc. mytiloides*		6
Hard whitish nodular limestone	seen for	6

In the lane leading out of the road from Homington to Coombe the top of the Lower Chalk (with the Belemnite marl) overlain by hard Melbourn Rock are well seen. At Coombe Bissett there is a large pit in the lower part of the Middle Chalk about 40 feet deep; the chalk at the bottom is hard, and contains *Inoceramus mytiloides;* higher up, it is tough and massive, with several layers of soft marl; and near the top are many grey flints. The beds are dipping to the north at about 4 deg.

The sections of Middle Chalk around Ebbesborne Wake and Alvediston are not important, though a pit by the road-side half a mile west of Alvediston church shows 10 feet of hard thick-bedded chalk with marly bands. A similar section can also be seen in a pit at Prescombe Farm.

There are no good quarry sections in this division along the south side of the Vale of Wardour, but the whole of the Middle Chalk can be traced in the roadway ascending Compton Down; first, the rough nodular chalk of the *Rhynchonella Cuvieri* zone, then the firm white chalk of the *Terebratulina* zone overlain by the hard rocky beds of the Chalk Rock.

South of Barford, in the road cutting leading to Hoop Side, the Melbourn Rock can be seen overlying the highest beds of the Lower Chalk.

Along the northern border of the Vale of Wardour there are a few places where the zone of *Rhynchonella Cuvieri* can be seen in spite of the high dips.

A quarry north-east of Baverstock shows about 25 feet of this zone, hard, rough, and nodular in the lower part, which cannot be far from the Melbourn Rock. The two common fossils were found in the upper beds, and the dip is about 33 deg. to the north-east.

The Melbourn Rock, passing up into hardish bedded chalk containing *Rhynch. Cuvieri*, and *Inoceramus mytiloides*, is also exposed in a small pit threequarters of a mile north-east of Dinton. The dip here is about 20 deg. north, and an old excavation close by must have shown the *Terebratulina* zone, as the Chalk Rock, which is still exposed at the northern end, dips at 45 deg.

A quarry half a mile north of the village of Ridge shows the following section:—

	Ft.
Hard bedded whitish chalk	15
Hard yellowish nodular chalk in regular beds, with several layers of marl	10
Marked layer of marly chalk	
Hard nodular yellowish chalk (Melbourn Rock)	5
Greenish grey marl and marly chalk	6
Talus concealing lower beds.	

The dip here appears to be about 15 deg. to the north.

Mr. F. J. Bennett states that the rock is seldom well exposed in the Wylye Valley, but he saw exposures of it in an old lane south of Boyton, and again south of Sherrington in an old trackway leading eastward. Hard bedded chalk, which probably belongs to the zone of *Rhynchonella Cuvieri*, is to be seen in the road-cutting at Deptford and in a chalk-pit by Deptford Field Barn.

UPPER CHALK.

Over more than half the area which is now being described the surface rock is Upper Chalk. This division is 700 or 800 feet thick, so that hills and valleys of considerable size can be carved out of it without any other rock being exposed. Most of the wide expanse of Salisbury Plain, only part of which comes within our area, is Upper Chalk, and this plain is continued eastward in the plains of Basingstoke and Winchester, which again stretch eastward to the sea in the two long tongues known as the North and South Downs. In the southern part of our area the continuity of the Downs is somewhat broken by the Alderbury syncline, the trough of which brings in Eocene strata; but south of this tongue the continuity of the Downs again stretches unbroken into Dorset and to the English Channel.

In its character and composition this great mass of rock is singularly uniform; nearly all of it is soft white chalk, with flint nodules scattered more or less in lines. One or two thin hard bands, known as Chalk Rock, occur at the base, and an occasional marl parting is found; but lithologically it is all one formation, and we have been obliged to map it as such. When we examine the fossils, however, it is found practicable to break up this mass into zones characterised by peculiar assemblages; but the limits of these zones are somewhat indefinite, for the species in most cases disappear one by one and are replaced equally gradually by the species of a higher zone. No sudden transitions from one fauna to another have yet been discovered in the district with which we are dealing. In other regions, however, breaks, marked by lines of nodules, which suggest either the non-deposition or the destruction of certain intermediate strata, can be found; and at the same points a sudden change in the fauna usually takes place.

The area occupied by the Upper Chalk is shown on the map, whereon the outcrop of the Chalk Rock has been delineated. It will be seen that this is an extremely irregular line, running for a long distance down the valley of the Wylye, and then westward till it climbs to a very high level on White Sheet Hill, north of Mere.

On the south side of the Vale of Wardour the lower beds of the Upper Chalk form the highest part of the ridge, which ends in another White Sheet Hill, east of Shaftesbury, a ridge which separates the Vale of Wardour from the Vale of Broad Chalk. The structure of the latter is clearly shown by the mapping of the Chalk Rock, and proved to be a succession of dome-shaped uplifts (three or four) arranged along an anticlinal axis. This axis is prolonged eastward across the valley of the Avon, and is continued in the tract of chalk which indents the boundary of the Eocenes north-east of Downton.

From this anticlinal axis the Upper Chalk dips northward under what may be called the Salisbury syncline, and southward into a wider main syncline of the Hampshire basin.

It is only in the eastern part of this area, near Salisbury and Downton, that any great thickness of Upper Chalk comes in. In most other parts of the district no higher zone than that of *Micraster coranguinum* is found. In describing the local development of the several zones, it will suffice to give particulars of some of the best exposures of the lower zones, and then to concentrate our attention on the neighbourhood of Salisbury.

In South Wiltshire the zone of *Holaster planus* has the true Chalk Rock aspect, always containing two or more beds of hard compact yellowish limestone with layers of green-coated nodules. It is not often, however, that the whole of the Chalk Rock beds are exposed in one section, and a visit to some localities might lead the observer to believe that there were only a few feet of such rock. More complete sections, however, show that the harder rock beds often pass down into less hard and more nodular chalk, forming a set of beds which are from 12 to 16 feet thick. In other places the group expands by the intercalation of separate beds of lumpy chalk, some of which are hard, and others consist of hard lumps in a soft mealy kind of chalk; the whole group is then from 20 to 26 feet thick, always having a hard rock-bed at the base and another at the top.

Above the uppermost bed of rocky chalk we find softer but still lumpy chalk containing many flints, and often thin seams of flint, while there are no flints in the Chalk Rock beds. These higher beds contain *Micrasters* of the *cortestudinarium* type, and may be referred to the zone of that species; but other fossils are few. There are few good exposures of this zone, and its upper limit has nowhere been satisfactorily fixed, but it is supposed to be 40 or 50 feet thick in the valley of the Wylye.

The succeeding zone of *Micraster coranguinum* is, as usual, of considerable thickness (more than 200 feet), and is believed to occupy the larger part of the surface area of Salisbury Plain; it also occupies some space west of Salisbury and north of the Vale of Wardour. Its lower beds contain many carious flints, often of a reddish tinge inside, its middle part black flints with a milky white band, and the upper beds grey flints with a thick white crust or rind.

The only part of South Wiltshire in which the higher zones of the Upper Chalk have been carefully studied is the neighbourhood of Salisbury. This was described in 1876 by Professor Barrois.* Dr. H. P. Blackmore, of Salisbury, has been collecting for many years from all the quarries within a radius of five or six miles, and has kindly placed the results of his labours at our disposal. Mr. Jukes-Browne had the further advantage of visiting most of the exposures near Salisbury under his guidance in 1890. It is from these materials that this account of the upper zones has been compiled.

The total thickness of Upper Chalk exposed in this district is between 700 and 800 feet. The following estimates of the thickness of the several zones are based on information communicated by Dr. Blackmore:—

		FEET.
Zone of Belemnitella mucronata - - -	about	70 to 80
„ of Actinocamax quadratus - - -	„	170
„ of Marsupites - - - - - -	„	230
„ of Micraster coranguinum - - -	„	230 to 250
Zones of Micraster præcursor and Holaster planus	„	70
	About	790

The facts on which these estimates are based are as follows, all the information being communicated by Dr. Blackmore. The zone of *Holaster planus* is seen to be over 20 feet thick near Homington, and 45 feet is probably a low estimate for the zone of *M. cortestudinarium*, so that the two together may be put at 70 feet.

The quarry on Camp Down, between the valleys of the Wylye and the Avon, is 200 feet above the rivers; this quarry is in the *M. coranguinum* zone, and the beds are horizontal, while its base is probably at about the level of the Avon stream. Hence there is over 200 feet of this zone.

* Recherches sur le Terrain Crétacé Supérieur de l'Angleterre et de l'Irlande, pp. 54, 64. *Mém. Soc. Géol. du Nord.* 1876.

From the top of Bishopsdown (north of Salisbury), where *Marsupites* are found, to the top of the well at the waterworks nearer the town is 100 feet; the well was sunk 70 feet, and bored for another 63 feet, and a good *Marsupite* plate was obtained from the lowest part of the boring; hence the thickness is at least 230 feet. This is confirmed by a well sunk at a spot about 2½ miles to the N.E. of Bishopsdown. This was sunk to a depth of 230 feet, and a *Marsupite* plate was obtained from the bottom.

With respect to the *Actinocamax quadratus* zone, two wells have been sunk between Harnham Hill and the river, through chalk with thin-skinned flints, and fossils like those at Highfield (*Marsupites* zone). From the top of the wells to the top of Harnham Hill is 170 feet, and there is reason to think, from the space elsewhere occupied by the *Act. quadratus* zone, that 170 is about its full thickness.

As to the *Bel. mucronata* zone, a well has proved 63 feet of it, and from the space it occupies it is not likely to exceed 100 feet, so that from 70 to 80 feet is a probable estimate.

Chalk Rock and Associated Beds.

The Upper Chalk is so thick, and extends over so wide an area, that it will be described most conveniently in successive stages or zones. We will therefore begin with the Chalk Rock and the associated beds of the valley of the Wylye, in which valley the outcrop has been traced for a long distance by Mr. Bennett, from whose notes the following description is mainly compiled.

One of the best sections, exposing 13 feet of chalk with flints, and 8 feet of yellowish rocky beds, can be seen in the yard of a barn north of Upton Lovell. There are other sections near Codford, Sherrington, and Wylye, but the most complete one in this valley is the quarry at Steeple Langford, about 360 yards E.N.E. of the church. We are indebted to the Rev. W. R. Andrews, F.G.S., for the following description, and for the photograph from which Fig. 38 has been drawn.

The upper part of the Chalk Rock can also be seen in the river cliff about a quarter of a mile north-west of Wishford church, 10 feet of the rocky beds with green-coated nodules being overlain by 12 feet of nodular white chalk containing five layers of nodular flints, and three continuous layers or flint floors. These 12 feet may be referred to the zone of *M. cortestudinarium*.

A quarry just east of the cross roads at Stapleford is probably opened in the latter zone. Mr. Bennett states that it is about 20 feet deep, and combining his account with that given of it by Dr. Barrois, the section, now much talused, appears to have been :—

	Ft.
Hard white chalk with a few black flints and several flint seams, *Cidaris subvesiculosa* and *Micraster cortestudinarium* - - - - - - - - - - -	10
Hard nodular chalk with yellowish stains - -	3
White chalk with flints, both nodules and continuous floors, talused, but dug for - - - -	7

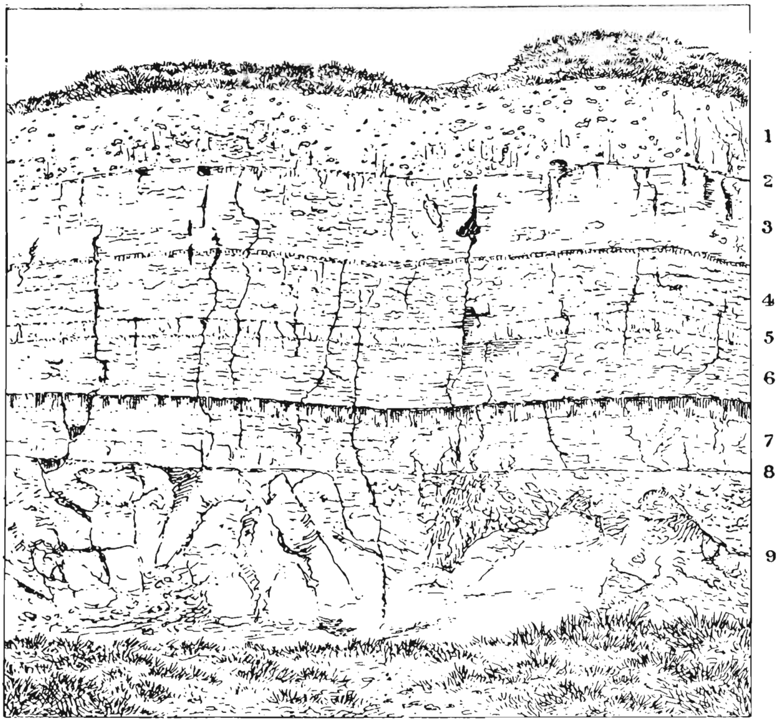


Fig. 38.—*View of Quarry at Steeple Langford.*

		Ft.	In.
1 & 2.	Soft white rubbly chalk with a few scattered black flints and a layer of such flints at the base - - - - -	5	0
3.	Very hard nodular yellowish limestone, with many green-coated nodules, passing down into less hard nodular chalk - - - - - - - - - - -	4	0
4.	Similar hard limestone with nodular chalk below - -	4	6
5.	Course of hard rocky chalk - - - - - - -	1	0
6.	Rock and nodular chalk, like No. 3 - - - - - -	4	0
7.	Rock as before, passing down into less hard nodular chalk	4	6
8.	Thin layer of grey marl - - - - - - - - -	0	3
9.	Massive white chalk - - - - - - seen for	6	0
	About	30	0

Nos. 8 and 9 belong to the zone of *Terebratulina.*

What appears to be the summit of this zone, and its junction with that of *M. coranguinum,* is exposed in a quarry at the north end of Wishford; the following is Dr. Barrois' account, with the thicknesses corrected by Mr. Bennett:—

	Ft.
Soft white chalk with many layers of flints and several flint seams, also joints filled with flint. *Echinocorys gibbus* and *Micraster coranguinum* - - - - - - -	15
Hard yellowish nodular chalk - - - - - - -	$\frac{1}{2}$
Rather hard chalk with scattered flints - - - - - -	6

Chalk which may be in or at the top of the same zone is exposed also in the valley of the Avon between Lower and Upper

Woodford. At Middle Woodford there is a large pit, which has been described by Dr. Barrois ("Recherches," p. 53), and of which Mr. Jukes-Browne took the following notes in 1890:—

	Ft.
Soft white chalk with many layers of flint nodules, and some large masses of flint - - - - - - -	24
Hard yellowish nodular chalk with marked plane of division at top - - - - - - - - - - - - -	2
Hard yellowish nodular chalk, with nodular upper surface, enclosing many flints of irregular shapes and often hollow, with *Doryderma ramosa* - - - - - - - - -	2
Softer white chalk with numerous flints and a seam of continuous flint - - - - - - - - - -	10

The beds are nearly level, with a slight inclination to the south. Fossils are fairly abundant, and from the nodular beds and the underlying chalk Mr. Jukes-Browne obtained a species of *Micraster*, *Cidaris clavigera* (spines), *Echinocorys gibbus*, *Terebratula semiglobosa*, and *Rhynchonella reedensis*. Mr. Bennett afterwards obtained a specimen of *Coscinopora infundibuliformis*. It is possible that the upper beds may belong to the zone of *Micraster coranguinum*, in which case the nodular chalk may be regarded as the top of the *M. præcursor* zone.

Another good series of sections in the zones of *Holaster planus* and *Micraster cortestudinarium* can be found along the north border of the Vale of Wardour from Mere to Barford, and have been noted by Mr. Jukes-Browne.

At the eastern end of the Vale, on the downthrow side of the fault, the Chalk Rock beds are well exposed in the railway cutting at Barford. The descending section here, taken about 90 yards from the west end of the cutting, is as below:—

	Ft.	In.
Hard lumpy chalk with scattered nodules of black flint, very gritty and yellowish in some places (? zone of *M. cortestudinarium*) - - - - - -	12	0
Hard and heavy nodular limestone with yellow stains, in two layers, the upper full of green-coated nodules -	1	3
Hard yellowish limestone passing down into hard rough nodular chalk - - - - - -	3	4
Parting of white shaly chalk.		
Hard nodular chalk - - - - -	1	3
Hard yellowish limestone with a layer of green-coated nodules at top, passing down rough lumpy chalk. *Ter. carnea* and *Micraster* - - - - -	7	0
Soft yellowish-grey marl - - - - -	0	3
Rough nodular chalk with yellow stains, very hard in places, same fossils - - - - -	4	6
Parting of buff shaly marl.		
Nodular white chalk with two layers of grey sandy and shaly chalk - - - - - -	4	6
Hard nodular limestone with a layer of green-coated nodules, probably the bottom bed of Chalk-rock seen for	3	0
	37	1

It will be seen that the zone of *Holaster planus* or Chalk Rock has here a thickness of over 25 feet. The thickness of the overlying lumpy chalk is uncertain, but in the cutting east of the bridge 5 feet of it are seen overlain by soft white chalk with four continuous layers of flint, and as the upper rock bed occurs at the base of this cutting there is probably from 15 to 16 feet of the lumpy chalk between, containing Micrasters of the *M. cortestudinarium* type.

Part of the same set of beds is exposed on the south side of the valley in the road cutting at the head of the "Punch Bowl," near Burcombe. Here the upper beds are much weathered, but the junction with the zone below is clearly exposed, the section seen in 1890 being as below:—

		Ft.	In.
Zone of *Hol. planus* (26 feet).	Hard compact yellow limestone - - -	1	6
	Hard rough nodular chalk - - - - -	10	0
	Layer of soft marl.		
	Hard rough nodular chalk with yellow stains -	6	0
	Tough gritty whitish chalk, splitting into flattish lumps with lenticular seams of greyish marl - - - - - - - - about	5	0
	Hard nodular rock with two layers of green-coated nodules; passes into next - - -	3	6
Zone of *Terebratulina.*	Tough and lumpy white chalk - - -	5	0
	Seam of light grey marl - - - -	0	4
	Bedded white chalk - - - - seen for	3	0

This section, therefore, gives the base-line which is wanting to complete that of the Barford cutting, and shows the full thickness of the *Hol. planus* zone to be just 26 feet.

The rocky beds of the *H. planus* zone are seen in several of the roadways which ascend the fine escarpment along the southern side of the Vale of Wardour, as, for instance, in the roads south of Compton and of Fovant, a pit by the latter exposing 11 or 12 feet of them.

Passing to the Vale of Broad Chalk by way of Compton Down, the outcrop is again passed through about three-quarters of a mile north of the village. Here Dr. Barrois noted 30 feet of hard nodular chalk overlying a bed of Chalk-Rock with green-coated nodules, and from the former obtained the following fossils:—

Micraster cortestudinarium.	Inoceramus Cuvieri?
,, corbovis? [Leskei]	Terebratula semiglobosa.

Mr. Bennett states that it is also exposed in a quarry west of Prescombe Farm, north-west of Broad Chalk.

It is also fairly well shown in the road-cutting north of Homington, where the hard, yellowish basement rock is seen to dip northward at about 8 deg., and to be overlain by about 20 feet of nodular rock, with some scattered flints and another hard bed at the top. From this exposure Dr. Blackmore has obtained the following species:—

Inoceramus sp.	Terebratula semiglobosa.
Ostrea vesicularis.	Rhynchonella reedensis.
Spondylus spinosus.	Holaster planus.
Terebratulina gracilis (? var. lata).	Parasmilia centralis.
,, striata.	

Zone of Micraster coranguinum.

The quarry at Middle Woodford, north of Salisbury, has been described on p. 54, and the probability of its being opened at the junction of the zones of *Micraster præcursor* and *M. coranguinum* was then mentioned. There is a small pit at Little Durnford, on the eastern bank of the Avon, which exposes chalk with many layers of thin-skinned flints, most of them stained red or reddish with iron oxide; this is certainly in the zone of *Micraster coranguinum*, that fossil and *Echinocorys scutatus* being common here.

A pit at the north end of the village of Stratford shows some 25 feet of firm but brittle white chalk, with layers of flints at intervals of from 1 to 3 feet; these flints have thin skins, and many are cavernous (caries), the hollows showing traces of *Doryderma ramosa*, and some have drusy cavities filled with quartz crystals. Several layers, however, consist of solid flints stained red or brown by iron. *Micraster coranguinum*, *Galerites albogalerus* (*Echinoconus conicus*), *Cidaris hirudo*, *Ostrea semiplana*, *Inoceramus Cuvieri*, and other fossils have been found here.

Another pit on the northern side of Old Sarum hill is about 80 feet above the floor of the other, and shows softer chalk with scattered flints, not in layers, and less numerous. These flints have thick rinds, which are banded in layers of white and grey, and are solid throughout; the smaller nodules have, in fact, only a small nucleus of clear black flint, but both the black and the white parts are equally hard. This chalk is probably near the top of the zone.

On Camp Down, between the valleys of the Avon and the Wylye, there is a large pit near the main road showing 25 to 30 feet of chalk with similar thick-rinded flints, many of them showing pink, white, and grey bandings, and being of very irregular shapes with knobby or cornute projections. Fossils are scarce, but twenty species have been found by Dr. Blackmore and Mr. E. Westlake, and prove it to be in the *M. coranguinum* chalk, though it must be near the top of that zone.

The zone of *Micraster coranguinum* probably occupies a large part of the surface of Salisbury Plain, and is deeply trenched by the rivers which traverse that plain.

West of Salisbury it also occupies some space round Quidhampton, Wilton, and Netherhampton.

At Quidhampton there is a large pit on the north side of the railway, showing between 50 and 60 feet of chalk. Flints occur in regular courses, which are from only about 2 feet apart in the upper 40 feet, but more distant in the lower part; most of them have very thin rinds, some hardly anything but a white skin, but a few have a definite white crust; some are large with irregular knobby surfaces. The bedding is nearly horizontal. From the lower beds Mr. Jukes-Browne obtained *Micraster coranguinum*, *Epiaster gibbus*, *Terebratula carnea*, *Inoceramus Cuvieri*, *Lima Hoperi*, and *Ostrea vesicularis*, and Dr. Blackmore has found a few other species.

The higher part of the zone is exposed in a pit by the Roman road south of Netherhampton. When seen in 1890, much of it was hidden by talus, but above this, chalk with numerous flints is seen like that at Camp Down; the flints have the same pink and white chalcedonic layers in the outer crust. Some of the usual fossils of the zone have been found here.

South-west of Salisbury, in the valley of the Ebble river, a portion of the central part of the zone is exposed a little south of Odstock, dipping to the north at about 9°. The chalk is firm, white and brittle; flints occur in frequent layers about 2 feet apart, and nearly all of them have a band or zone of cloudy white flint a little distance beneath the external surface, but little or no crust. Fragments of large Inocerami are common, but other fossils are rare.

In ascending Clearbury Hill from Charlton a definite succession of beds may be recognised from the characters of the flints seen in small pits and roadside banks. Thus a quarry opposite Charlton Farm is about 30 feet deep in rather hard chalk, with many solid plain black and dark grey flints, and fragments of *Inoceramus* shells are abundant. A pit about a quarter-mile to the south-west shows about 16 feet of chalk, with crowded layers of irregular shaped flints about 2 feet apart, and most of them have the cloudy white zone above mentioned, but some are stained red or pink by iron. Higher up on Clearbury flints with the same cloudy band are seen, but near the top of the hill they have thick crusts like those at Camp Down.

A quarry in the lower part of this zone, north of Ufford, shows some interesting features; it is about 20 feet deep in well-bedded chalk, which shows a dip of about 2° to the south-east. The descending succession is as follows:—

	Ft.	In.
Chalk, inaccessible - - - -	8	0
Continuous seam or floor of flint - - - - - -	0	1
Firm solid chalk without flints - - - - - - -	2	0
Soft loose marly chalk crowded with flints - - -	1	0
Solid bedded chalk, with few flints - - - - - -	4	0
Soft marly chalk - - - - - - - - -	0	6
Chalk with many scattered flints - - - - -	8	0
	23	7

The beds are broken by a small fault with an oblique hade and a throw of about 4½ feet. The flints, both large and small, have either a thin crust or none at all. Fossils found were *Micraster coranguinum*, *Galerites albogalerus* (*Echinoconus conicus*), and *Inoceramus involutus*.

The upper part of the *M. coranguinum* chalk is exposed in the rail cutting at Witherington, north of Downton, and the beds, which correspond with those at Camp Hill, dip at 14° to the south, and there are other places on the eastern side of the Avon. On the western side of that river its basset surface must occupy a considerable tract of country south of the Broad Chalk valley.

Zone of Marsupites.

The chalk of this zone occupies the higher ground in the immediate neighbourhood of Salisbury, as on Bishopsdown, Milford, and Fisherton.

The lower part of the zone is well shown in the quarry at the whiting-works at Fisherton; this is about 50 feet deep in pure soft white chalk; flints are not numerous, but occur sparsely along planes which are about 10 feet apart. Most of them are nearly spherical, from the size of bullets to that of cannon balls, are yellow outside, but have no crust, merely the yellow stain, and consist wholly of solid black flint. The workmen state that they have quarried about 12 feet below the then pit floor, and found the same kind of chalk. *Actinocamax verus*, small *Kingena lima*, and the ovate variety of *Echinocorys scutatus* are common here. *Uintacrinus* and a few of the brachial joints of *Marsupites* have been found, and twenty-five specimens of *Ammonites* [*Haploceras*] *leptophyllus*, with other fossils.

The higher part of the *Marsupites* zone is exposed in a pit on Bishopsdown, which shows soft white chalk, with more numerous flints, all having thick white crusts. Plates of *Marsupites* and joints of *Bourgueticrinus* are very abundant at this locality, and a specimen of *Am.* [*Hapl.*] *leptophyllus* about 2 feet in diameter was found in 1893. In that year also a well was sunk at the foot of Bishopsdown, and nearly 100 feet below the quarry; Dr. Blackmore informs me that the well is 70 feet deep, and traversed chalk with occasional layers of flints exactly like those of Highfield. The first layer met with was 45 feet from the surface, and one *Marsupites* plate was found in the lower 30 feet. This information is important, as proving the Highfield chalk to be inferior to that of Bishopsdown, and as giving a thickness of at least 170 feet for the *Marsupites* zone.

Zone of Actinocamax quadratus.

The *Actinocamax quadratus* zone forms the high ground to the east and north-east of Salisbury, and also the ridge which lies to the south of the villages of East and West Harnham. It consists of chalk, in which flints are rather more numerous than in the *Marsupites* zone, and in the lower part of it *Offaster pillula* is the most common fossil.

At East Harnham there is a fine quarry worked in two levels. The lower one shows about 50 feet of bedded white chalk, with only a few scattered flints; the upper level shows about 60 feet, with seven or eight layers of flints at varying distances, sometimes 6 feet, sometimes 10 or 12 feet apart, with only a few scattered flints in the intervening chalk. The beds are regular, and dip at about 2° to the south, unbroken by faults. The flints have white crusts, but not thick ones, and are all solid. Fossils are not abundant, but, through the workmen, Dr. Blackmore has obtained many species from this pit.

At West Harnham there is another large quarry from 60 to 70 feet deep. In the higher part the chalk is regularly bedded; in the lower part the bedding is less distinct, and it is probably a lower portion of the zone, for the flints, few and scattered, are stained yellow outside. *Act. quadrata* is fairly common in the upper part, but rare in the lower beds, though it has been found in them.

At Britford a quarry shows about 30 feet of the higher beds, bedded chalk, with layers of flints at intervals of about 3 feet, and sometimes less.

East of Salisbury there is a small exposure of the lower part of the zone at the cross-roads east of Milford, but, though only 10 or 12 feet of chalk are exposed, many specimens of *Offaster pillula* can at any time be obtained, with joints of *Bourgueticrinus* and a small *Rhynchonella* (? *reedensis*); the shelly plates which are usually regarded as the aptychi of *Ammonites* [*Haploceras*] *leptophyllus* and of *Am.* [*Pachyd*] *Portlocki*, and which Dr. H. P. Blackmore regards as shelly processes belonging to the guards of *Belemnitella lanceolata* and *Actinocamax quadratus*, have been found here as well as at the Harnham quarries, and are certainly as common in this zone as are the two characteristic Belemnites.

Part of the same zone, with flints like those of Harnham, is exposed in the railway at Ashley Hill, and in the pit below the level of the railway, north of Ashley Hill House, Dr. Blackmore has also traced the zone at intervals for some distance to the north-east, and has found a piece of *Act. quadratus* thrown out of a rabbit hole on the hill known as Thorny Bushes.

South-east of Salisbury there is a good section of it in the railway cutting at Whaddon, which shows soft white chalk, with irregular layers and scattered nodules of flint, and occasional seams of soft marly chalk dipping to the north at about 14°. The flints have thicker white crusts than those of Harnham, but there is the same assemblage of fossils. A quarry in the field near the railway is about 15 feet deep in similar chalk.

At West Grimstead, south of the brickyard, there is another pit in similar chalk dipping at 16° to the north. It contains, however, regular layers of flint at 3 or 4 feet apart, many of the nodules being large and smooth, with rounded protuberances; they have thick crusts, often pink and agaty, like those of Camp Down. Fossils did not appear common, but *Act. quadratus* was found.

Zone of Belemnitella mucronata.

This, the highest zone of the chalk in the Hampshire basin, is only found round the border of the area occupied by the Lower Eocene to the east and south-east of Salisbury. It is exposed in a chalk-pit at Shootend, north-west of Alderbury, between the branching of the roads to Downton and to Southampton. The Chalk here seen is very soft and white, with few flints, those that occur consisting of solid black flint without any crust—merely a yellow coating. *Belemnitella mucronata* is fairly common, with *Echinocorys scutatus*, *Terebratula carnea*, *Rhynchonella limbata*, a large variety of *Kingena lima*, and other fossils similar to those found in Norwich chalk. More recently Dr. Blackmore has found *Magas pumilus* and pieces of an Ammonite which seems to be *Am.* [*Lytoceras*] *Jukesi.*

Dr. Blackmore also states that in 1893 a well was sunk on the Southampton road above Shootend and a little beyond the second milestone from Salisbury: it passed through –

	Ft.
Clay and Sand - - - - - - -	12
Chalk of the *Bel. mucronata* zone - - - - - - -	63

and many fossils were obtained from the chalk which was brought up, including five examples of *Bel. mucronata.*

Still further east, near Clarendon, there are some pits in this zone. One near the keeper's house in Clarendon woods is about 10 feet deep in soft white brittle chalk, with a few scattered flints, which often occur on one plane, but at distances of 2 or 3 feet from one another. The flints here differ from those at Shootend in having an ordinary white crust, but just the same assemblage of fossils is found. There is another pit in similar chalk near the Clarendon brickyard, and here the beds show a dip of 3° to the east.

The fossils from the different zones of the Upper Chalk near Salisbury have been carefully collected and tabulated by Dr. H. P. Blackmore,* and the full list will be found in Mr. Jukes-Browne's Memoir on the Cretaceous Rocks of Britain, vol. ii.

* Some Notes on the *Aptychi* from the Upper Chalk. *Geol. Mag.* dec. 4, vol. iii, p. 529 (1896).

CHAPTER IX.

EOCENE.

Eocene strata are only preserved in the south-east corner of our area. The main Tertiary escarpment enters the district at the point where the Salisbury and Romsey roads fork; but only enters it for half-a-mile. Eocene strata, however, are again brought in by a fairly deep synclinal fold, which runs through Alderbury and Grimstead. In this trough three divisions are preserved, and we find Reading Beds, London Clay, and Bagshot Sand. A few miles further north, near Laverstock and Figsbury Ring, there are small outliers of Reading Beds. The total area of the Eocene strata is, however, only about 7 square miles.

READING BEDS.

These apparently consist in the main of red-mottled clay above and of glauconitic sand or loam below. Their thickness is estimated by Mr. Bennett at 50 feet, which is somewhat less than is found in the Ringwood area, where they average 80 feet. No sections are now visible in the narrow outcrop around Alderbury; but at the new house near the second milestone from Salisbury the drive was cut through these beds. At the house close to the junction with the London Clay, bores were put down 40 feet through mottled clay, and near the lodge green sand with a bed of oysters was met with. About 10 feet of this sand was passed through in sinking a well to the Chalk at the lodge belonging to the house close to the high-road.

Only the lower strata come into our area in the outcrop near Brickworth House, and these consist of sand and pebbles, in which pits were formerly open. The small outlier near Laverstock shows traces of red-mottled clay and a pebbly soil; the outlier near Figsbury Ring shows many old holes in loam and pebbles. It will be noticed that besides the exposures mapped as Eocene, much of the "Clay with Flints" consists of Eocene material; it is still doubtful, however, to what extent this material represents outliers of Reading Beds in the immediate neighbourhood broken up and weathered without being transported to any great distance.

LONDON CLAY.

The London Clay consists of grey or brown sandy clay, usually becoming more sandy and pebbly towards the base. It occupies an area of 4 or 5 square miles, and, according to Mr. Bennett, is probably about 150 thick. The lower 40 feet of this deposit was formerly well-exposed in the railway cutting through Clarendon Hill, north of Alderbury. Here Prestwich noted the following section:—

a. Ochreous flint-gravel.
b. London Clay; dark bluish grey sandy clays with numerous *Panopæa*, *Ostrea*, and *Pinna*.
c. Large tabular masses: composed, some of almost a pure green sand, and others of a coarse ochreous sand, with a calcareous cement. A few rather small round flint pebbles are scattered through these blocks.
d. Alternating thin beds of sand and thick beds of mottled clay; chiefly red.

"The chalk outcrops lower down the hill at a depth apparently of about 40 or 50 feet beneath '*c*'."*

This locality is celebrated for its fossils, which are in a better state of preservation than is usual in the London Clay. Mr. F. E. Edwards here made an extensive collection, and the list given below is compiled from the Catalogue of his collection, now in the British Museum (Natural History), the nomenclature there used being retained.†

Only two sections are now open in which the London Clay can be seen, and in each case it is only the basement-bed that is worked. The Brickyard at West Grimstead shows 8 feet of sandy clay, dipping north. At the Clarendon Kiln 8 feet of brown clay is seen, and here also fossils have been met with.

The fossils from Clarendon are mainly species known from the London Clay of other localities; but among them are several species peculiar to this locality. As the list of mollusca is of exceptional interest, it is given here in full:—

Bullinella uniplicata, *Sow.*
——— consors, *Desh.*
Scaphander parisiensis, *Orb.*
Solidula simulata, *Sol.*
Actæon turgidus, *Desh.*
Calyptræa suessoniensis, *Orb.*
——— aperta, *Sol.*
Sigaretus clathratus, *Gmel.*
Natica labellata, *Lam.*
——— hantoniensis, *Pilk.*
——— epiglottina, *Lam.*
Solarium pulchrum [var. primævum, *Edw.* MS.].
Solarium bistriatum, *Desh.*
Scalaria [Prestwichii, *Edw.* MS.].
Cingulina Bourdoli, *E. de Boury.*
Turritella terebellata, *Lam.*
——— Dixoni, *Desh.*
Bayania [linigera, *Edw.* MS.].
——— n. sp.
Cerithiella prælonga, *Desh.*
Eulima [similis, *Edw.* MS.].
Turbonilla sulcata, var. [clarendonensis, *Edw.* MS.].
Cancellaria [clarendonensis, *Edw.* MS.].
Cancellaria læviuscula, *J. Sow.*
——— [tenuiplica, *Edw.* MS.].
Pyrula Smithii, *Sow.*
——— [subcostellata, *Edw.* MS.].
Pisania curta, *Sow.*
——— [cymatodis, *Edw.* MS.].
——— [granulosa, *Edw.* MS.].
——— [Morrisii, *Edw.* MS.].
——— [transversaria, *Edw.* MS.].
Trophon tuberosum, *Sow.*
Typhis muticus, *Sow.*
Murex plicatilis, *Desh.*
Marginella gracilis, *Edw.*
Voluta depressa, *Lam.*
——— elevata, *Sow.*
——— muricina, *Brug.*
——— tricorona, *Sow.*
Pleurotoma acuminata, *Sow.*
——— crassa, *Edw.*
——— pyrulata, *Desh.*
——— stena, *Edw.*
——— terebralis, var. pagoda, *Edw.*

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* Quart. Journ. Geol. Soc., vol. vi., p. 257 (1850).
† Systematic List of the F. E. Edward's Collection of British Oligocene and Eocene Mollusca, by R. B. Newton, 8vo. (1891).

Pleurotoma terebralis, var. pulcherrima, *Edw.*
Pleurotama terebralis, var. revoluta, *Edw.*
Pleurotoma teretrium, var. tuberculata, *Edw.*
Pleurotoma gomphoidea, var. avita, *Edw.*
Pleurotoma tereticosta, var. soror, *Edw.*
Pleurotoma turpis, *Edw.*
Pleurotoma denticula, var. macrobia, *Edw.*
Pleurotoma Prestwichii, *Edw.*
——— simillima, *Edw.*
——— monerma, *Edw.*
——— pupoides, *Edw.*
——— variata, *Edw.*
Cassis substriata, *Edw.* MS.
Aporrhais Sowerbii, *Mant.*
Corbula costata. var. [clarendonensis, *Edw.* MS.].
Corbula [substriata, *Edw.* MS.].
——— [tenuisulcata, *Edw.* MS.].
Glycimeris intermedia, *Sow.*
Gari [clarendonensis, *Edw.* MS.].
Tellina [clarendonensis, *Edw.* MS.].
Meretrix bellovacina, *Desh.*
——— obliqua, *Desh.*
——— orbicularis, *Morris.*
——— [ovum, *Edw.* MS.].
——— suessoniensis, *Watelet.*
Protocardium [nitidulum, *Edw.* MS.].
——— subdiscors (?), *Orb.*
Lucina [clarendonensis, *Edw.* MS.].
Cardita Brongniarti, var. clarendonensis, *S. V. Wood.*
Astarte clarendonensis, *S. V. Wood.*
Nuculana partim-striata, *S. V. Wood.*
——— prisca, *Desh.*
Nucula curvata, *S. V. Wood.*
Axinæa (Pectunculus) decussata, *Sow.*
Arca tumescens, *S. V. Wood.*
Modiola [clarendonensis, *Edw.* MS.].
Pinna affinis, *Sow.*
Ostrea flabellula, var. modicella, *S. V. Wood.*
Ostrea pulchra, *Sow.*
Anomia anomialis, *Lom.*

BAGSHOT SAND.

The Bagshot Sand occurs as an outlier of about two square miles, extending from Alderbury to East Grimstead. It consists of false-bedded ferruginous sand, with lenticular masses of pipe-clay and with thin beds of ironstone. The thickness shown is about 50 feet, but this includes the lower part only of the formation, which reaches 200 feet in the district further south, where the whole is preserved. But few sections are now visible, the following notes giving the principal exposures.

On the top of Alderbury Hill, at the point where the road to Ivychurch leaves the Southampton road, a pit shows five feet of ferruginous sand with some pipe-clay and ironstone. At the south end of the same hill a large pit shows about 30 feet of false-bedded ferruginous sand with pipe-clay in the upper part, the lower part being much obscured.

At Whaddon, on the east side of the rail and close to the high road, a pit shows ten feet of brown sand, and this sand is also shown in the road cutting. Another pit, a quarter of a mile west of West Grimstead and close to the high-road, shows yellow and pinkish false-bedded sand with a lenticular layer of pipe-clay. The sections in the railway-cuttings are now all overgrown, as are several pits open at the time of the original one-inch survey. No fossils appear yet to have been found in the Bagshot Sand of our area.

CHAPTER X.

DRIFT.

No large area within the district dealt with in this Memoir is obscured by drift, and the drift that does occur is usually of no great thickness. The classification of the more ancient of these deposits is not altogether satisfactory, for the exact correlation of various outliers at different levels, having different compositions, and yielding no fossils, is by no means easy. To what extent the Clay with Flints overlying the Chalk is equivalent to the more pebbly Plateau Gravel which rests on the Eocene strata, remains to be worked out. We will, however, deal with the deposits according to their approximate date of formation.

CLAY WITH FLINTS.

Over many of the higher ridges and plateaus formed by the flinty Upper Chalk there is spread a sheet, sometimes five or ten feet in thickness, of unworn or shattered flints in a black or reddish clayey matrix. This deposit is unstratified, rests on a very irregular chalk-surface, and can often be traced to considerable depths as vertical cylindrical masses, which have sunk into pipes or pot-holes in the Chalk.

The origin of the Clay with Flints has been much discussed, and is probably composite; its age also is somewhat indefinite. Parts of the deposit are mainly composed of Eocene material, reconstructed almost in place, and dating from any period since the land last rose above the sea. Other parts are derived in large measure from the Chalk below, which has gradually been dissolved, leaving an insoluble residue of unworn flints mixed with a little fine clay: this also may be of many different dates. Everywhere, however, there is a considerable admixture of material that cannot have been derived from the strata immediately below. We find in it, for instance, chalk-flints belonging to zones which only outcrop some distance away on higher ground. It also contains pebbles derived from Tertiary deposits, which cannot have rested directly on the Chalk in that neighbourhood; on washing the matrix we obtain a sandy residue consisting of rounded grains of quartz such as could not have been derived from the Upper Chalk. Wind also seems to have played an important part in transporting the fine dust which now helps to make the matrix of the Clay with Flints so clayey and impervious. Another thing must be taken into account in estimating the date of any particular part of the Clay with Flints. It is highly probable that much of the deposit was to some extent disturbed and reconstructed during the Glacial period, when floods, caused by the melting of the snow or by rain falling on frozen soil, combined with creep or soil-cap motion further to mix material which had already been moved.

The distribution of the Clay with Flints is somewhat peculiar, and the reasons for its partial and irregular spread are not thoroughly understood. A glance at the Map will show that the chalk-plateaus over the southern half of our area are all capped with sheets of this deposit; whilst in the northern half, including the very level plains around Stonehenge, it is too thin and irregular to be mapped, Chalk being usually so near the surface as to be turned up by the plough.

PLATEAU GRAVEL.

At levels high above the present Avon, scattered deposits of flint-gravel are to be found, and these seem to represent a very early and much-eroded Alluvial flat of that river. It is not easy to make out the relations of these various isolated patches of gravel around Salisbury, and for an account of the ancient valley of the Avon and of its deserted river-terraces, the reader must be referred to the Memoir on the country around Ringwood. In that Memoir is described the lower Avon, with its wonderful series of ancient terraces, of which only mere traces extend into the Salisbury area.

Outliers of Plateau or High Terrace Gravel—for the gravel-covered plateaus, where well preserved, are seen to be merely parts of terraces bounded by still higher bluffs—have only been mapped in the south-eastern part of our area, in the country immediately around Salisbury. Two of doubtful extent have been mapped by Mr. Bennett on the west of the Avon, opposite Old Sarum, at a height of 450 feet above the sea. These now show no section; but the pebbly nature of the soil suggests that they may be reconstructed Eocene outliers.

The next outlier is one which caps Bishopsdown, a ridge lying between the Avon and the Bourne. This sheet occupies an isolated hill, rising to a height of over 300 feet above the sea, between Salisbury and Old Sarum. No section is visible; but Dr. H. P. Blackmore has here found rude flint-implements of "Eolithic" type. He has also found similar implements on Thorny Down (533 feet), Laverstock (486 feet), Burroughs Hill (319 feet); but, unfortunately, exposures are seldom visible in the higher outliers, and we cannot say to what extent implements found on or near the surface may belong to the gravel, or whether this gravel is truly of fluviatile origin.

The outlier of Plateau Gravel at Alderbury lies at a height of about 320 feet above the sea and nearly 200 feet above the gravel-flat of the river below. The best section is that seen in a large pit south-east of Ivychurch, where Mr. Bennett notes "12 to 15 feet of ferruginous gravel in a clayey matrix. The gravel is bleached in the upper part, and very ferruginous in the lower, and contains thin seams of sand and irregular beds of clay, brown at the top and grey and mottled below. Sometimes the clay occurs as a thin bed, at others as pipes up to eight feet deep. In the northern part of the pit the clay seems to end altogether." In this pit, Dr. H. P. Blackmore has found many rude eolithic implements at all levels in the gravel.* Mr. Bennett observes that the gravel contains 4 per cent. of pebbles, 3 per cent. of chert and ironstone, and 1 per cent. of sarsen stone. The pebbles are derived from the Eocene strata, as is, perhaps, some of the chert; but most of the Greensand chert, in all probability, comes direct from the Greensand of the Vale of Wardour.

Two outliers of Plateau Gravel at a somewhat lower elevation will be found further to the east, near West Grimstead. The only remark that they call for is that the material is more largely of local origin, the proportion of flint-pebbles rising to 15 to 25 per cent. When we return to the neighbourhood of the Avon and examine the gravel outliers at Standlynch, we notice that the proportion of flint-pebbles again falls and the proportion of Greensand chert from the Vale of Wardour becomes very large. It looks as if the gravels near the Avon were true Avon river-gravels, whilst those of Grimstead may belong to a small lateral tributary not crossing Greensand; in these latter, chert seems to be very rare.

Though no ancient river-gravels have been mapped at corresponding heights in the upper parts of the various valleys which combine at Salisbury, yet close search revealed numerous partially-worn fragments of flint and chert in fields 200 feet above the Nadder, near Tisbury. The exact locality is in the gap west of Lady Down, where the gravelly patches are found just north of Vicarage Barn (marked on the Map), and again a quarter of a mile north-west of the Tumulus. The outliers rest on Purbeck Beds at a height of 500 feet above the sea, and are now entirely cut off from the Greensand and Chalk by lower land; but the gap seems to correspond with an ancient north and south valley which runs up to Chilmark Down. The stones must have been transported at a time when the contour of the country was very different from that now seen; but nothing more definite can yet be said about them. Though the fields were searched for eolithic implements, I found none; but the locality is worth further examination.

VALLEY GRAVEL AND BRICKEARTH.

Between the Plateau or High Terrace Gravels and the series next to be described there occurs a local break of some importance; though in adjoining districts the gap seems to be filled up. The valleys appear to have been deepened considerably during this interval, so that the highest of the more modern river-terraces in this area is sharply cut off from the terrace above. The lower terrace, however, is often composite and readily separable into an upper and a lower terrace a few feet apart: in fact, in the lower part of the Avon valley, outside our area, the wide gravel flat is often seen to form several distinct steps.

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* *See also* Rev. R. A. Bullen, Eolithic Implements. *Victoria Institute Trans.* 1901.

As these old fluviatile and subaerial deposits are well developed in each of the valleys, it will, perhaps, be most convenient to commence our description with the central area around Salisbury. In this central area it happens also that the beds are fossiliferous, and in various ways noticeable; only here, and at one spot in Devonshire, have fossils distinctly characteristic of the Arctic regions yet been found near our south coast.

Sheets of clean-washed river-gravel a few feet higher usually border the low modern flood-plains of the existing streams; but above these, on the hill slopes in the immediate neighbourhood of Salisbury, occur alternating loams and earthy gravels, which, though probably of very similar date, may be of quite different origin. The most noticeable of these deposits is that worked in the brick-pits of Fisherton, where it occupies the lower part of the spur which divides the Nadder from the Avon valley. Quite an extensive literature has grown up relating to the Fisherton pits and their fossils, for the bones of large mammals were noticed at a very early date, and it was not long before it was discovered that among the mammals were several that now characterise regions far colder than ours.*

So much of the brick-earth has now been worked out, and so many of the sections are obscure, that it will be convenient to quote the account given by Prestwich, who wrote when the pits were in full work. His section of the strata in Harding's brick-yard, as exposed about the year 1854, is as follows :—

		Ft.
a.	Earth and flint-rubble, variable - - - - -	1 to 2
b.	Rubble of angular flints, fragments of chalk, and flint-pebbles, in clay and brick-earth - - - - - -	4 to 6
c.	Brick-earth, mixed with variable masses of flint and chalk-rubble, and containing bones and a few shells, chiefly in the lower part - - - - - - - - -	10 to 18
d.	Light-coloured fine marl, full of well-preserved shells, with a few bones - - - - - - - - - -	1 to 2
e.	Flint and chalk-rubble, with sand and clay, only upper surface exposed - - - - - - - - -	3 to 4 (?)
	Chalk.	

"The shells in the brick-earth, *c*, are here, as in the same drift in the other parts of the valley, few and irregularly dispersed; but in the underlying marl, *d*, they occur in the greatest profusion, in a very perfect state of preservation, and with traces of colour still discernible in some specimens. . . . . It is, however, in the brick-earth, *c*, that most of the bones are found. . . . . . The water-molluscs, with the exception of the *Succinea putris*, which is abundant . . . . , form a group such as we might expect to find in a spring or shallow pond rather than in a river."

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* Lyell, On Some Fossil Bones of the Elephant and other Animals, found near Salisbury, *Proc. Geol. Soc.*, vol. 1, p. 25 (1827); Prestwich and Brown, On a Fossiliferous Drift near Salisbury, *Quart. Journ. Geol. Soc.*, vol. xi, p. 101 (1855); Blackmore. List of Mammalia from Fisherton, *Geologist*, vol. vi, p. 395 (1863); Evans, On Some Recent Discoveries of Flint Implements in Drift-deposits in Hants and Wilts, *Quart. Journ. Geol. Soc.*, vol. xx, p. 188 (1864); Blackmore, in Stevens, Flint Chips, pp. 12—30 (1870); Evans, The Ancient Stone Implements. &c., of Great Britain, Ed. 2 (1897).

Since Prestwich made the foregoing observations, the mammalian remains have been most carefully collected and determined by Dr. H. P. Blackmore, of Salisbury, who has been so good as to provide us with the subjoined revised list of the species he has discovered:—

Bos bison	Hyæna crocuta
—— taurus, var. primigenius	Lepus variabilis ?
Canis lagopus	Microtus nivalis
—— lupus	—— ratticeps
—— vulpes	Myodes torquatus
Cervus elaphus	Ovibos moschatus
Elephas primigenius	Rangifer tarandus
Equus caballus	Rhinoceros antiquitatis
Felis leo	Spermophilus erythrogenoides

Nothing is yet known as to the plants which accompanied this Arctic fauna. The associated land and fresh-water mollusca call for no remark, they are all living British forms. With the mammals were found some bones and fragments of an egg of the wild goose (*Anser palustris*), a bird whose nesting is now restricted to more northern climes.

Several other sections of the brick-earth were formerly visible on the north side of the valley between Salisbury and Wilton, and descriptions of these will be found in the papers already referred to. It will be observed that wherever this brick-earth occurs it consists merely of masses of loam intercalated in the low terrace-gravel, with which it is intimately connected. The main part of the brick-earth seems to have been a subaerial wash of loam and flints, derived from the Chalk and Eocene bluff above, and deposited at the foot of the slope. This view as to its mode of origin is borne out by the discovery of so many skeletons of lemming, coiled up as though they had been smothered while hibernating in burrows in this talus-slope. Scree-material of similar nature accumulates rapidly under Arctic conditions, where vegetation is scanty and the rocks are readily broken up by the frost. Such Arctic conditions must have held when this group of high northern mammals occupied the south of England.

The gravels associated with the brick-earth are of wider extent, for they occupy much of the flat bottom of every valley of importance in the district. They also cover sloping terraces at considerable heights above the existing streams; but it is often very difficult to say to what extent these terraces are of more ancient date, or merely consist of talus which happens to have lodged on gentle slopes above the main gravel flat. The highest of these terraces are found near Salisbury, where they have yielded a good many Palæolithic implements, specimens of which will be found in the Blackmore Museum, in Salisbury. Bones of large mammals are occasionally found.

The distribution of the Valley Gravels is shown on the Map; their composition calls for little remark. They are usually made up in the main of broken or little-worn flints and chalk, around Salisbury mixed with a considerable proportion of flint-pebbles and greywether blocks derived from the Eocene deposits. In the valley of the Nadder, and in that of the Avon below Salisbury, they also contain a noticeable admixture of Greensand chert and some Purbeck and Portland chert derived from the higher reaches of the Nadder. The material of these gravels is therefore entirely of local origin, and derived from higher parts of the valleys in which it is now found.

No trace of erratics has yet been met with in this area, and it seems probable that the peculiar far-transported blocks seen in the middle of Stonehenge were brought from low-lands, now destroyed by or sunk beneath the sea, lying off the present mouth of the Avon. An erratic-strewn plain only rising a few feet above the present sea level seems in quite recent geological times to have fringed our south coast, though now it is only to be seen on the lee side of the Isle of Wight, especially in the Selsey Peninsula; whence P. J. Martin suggested that the igneous blocks in Stonehenge were derived.* That these erratics are not merely confined to the Sussex coast is proved by the abundance of similar far-transported blocks under the sea as far west as Tor Bay and the Eddystone. Three or four thousand years ago, which seems to be the approximate date of the erection of Stonehenge, a belt of flat land, like that of Selsey, probably existed under the lea of the Isle of Purbeck; and over such a flat, blocks of rock, originally from Brittany, Cornwall, and the Channel Islands, might be collected and carried up the Avon on rafts. The larger stones used in the building of Stonehenge are greywether sandstone, of local origin, and derived from Eocene strata, probably from the Reading Beds.

ALLUVIUM.

The Valley or Flood Gravel just described usually descends to the level of the Alluvium, into which it seems imperceptibly to merge. But this seeming transition in most cases is only apparent; for the Gravel is discovered by boring to pass beneath the Alluvial flat, and to sink considerably below the level of the bottom of the existing river. When the flood-gravel was being laid down, the land stood at a level considerably higher than the present, so that the valley-bottom was cut below the depth to which any floods of the modern river can excavate. We do not yet know the full depth of this ancient channel of the Avon near Salisbury; but it may lie fully a hundred feet below the present valley-bottom. All that we can at present say is, that the Avon, like every river in England, once had a steeper fall in its lower reaches, so that it could cut a deeper channel. Later subsidence of the land, or rise of the sea-level, pounded back the water, turned the lower part of the valley into estuary and lake, which were afterwards silted up by more modern gravelly and muddy Alluvium. In the region that we are here dealing with, this silting and levelling up is nearly complete; in Christchurch Harbour part of the ancient submerged valley of the Avon is still not entirely obliterated.

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* Phil. Mag., ser. 4, vol. xiii, p. 34 (1857). A Bibliography of Stonehenge and Avebury has lately been prepared by Mr. W. J. Harrison, *Mag. Wilts Arch. Soc.*, vol. xxxii. Reprinted 4to., Devizes, 1901.

Little is known about the thickness of the Alluvium, as we have no borings in the middle of the old channel. A boring put down by Sir Arthur Blomfield, in 1896, in the Cathedral Close, in order to ascertain the character of the foundations of Salisbury Cathedral, showed:—

	Ft	In.
Alluvial soil - - - - - - - - - - - -	4	0
White clay [marl ?] - - - - - - - - -	1	3
Gravel - - - - - - - - - - -	28	0
To Chalk - - - - - - - - - - - - -	33	3

This gravel is constantly full of water, which stood in the trial hole almost to the top of the Clay.

The Avon being a fairly swift and clear salmon stream, its Alluvium is largely composed of flint-gravel, which cannot always be separated from the more ancient river-gravel. The modern gravel, however, is usually smaller, and the stones are more worn and weathered than in the older deposit, which often contains large unworn masses of flint and greywether, probably transported by river-ice during the Arctic winter. The whole of the alluvial flats have been trenched and turned into water-meadows, this irrigation extending as far up the slopes as it is practicable to lead the water. Long-continued irrigation, and the occurrence everywhere of ancient mill-dams, have so altered the alluvial flat as to make it difficult to say what would be the character of the land under more natural conditions. Probably, however, the difference of water-level would not be great, for the numerous snags and fallen trees must have hindered the flow almost as much as do the mills, with their clean straight channels and mill-races. The water-meadows of the Avon do not appear to yield such good grass as do the corresponding meadows of the more muddy Stour. The water-meadows of the Nadder, which bring down a good deal of clay, have a stiffer soil.

CHAPTER XI.

ECONOMIC GEOLOGY.

Building Materials.

A considerable variety of building materials is used in the district; but the only building stones sent away are those from the Portland and Purbeck rocks of the Vale of Wardour. Brick is the building material over most of the area, the same parts showing also buildings of rough flint, or poor cottages of mud, or walls of sun-dried bricks made of a sort of concrete of flint and chalk. In the Vale of Wardour both stone and brick are used, many of the modern buildings being of brick, even where stone is close at hand. Perhaps the most convenient order of dealing with the building materials will be according to geological formations, for in this area the different strata yield stone of different character, and the geological and economic classifications happen nearly to coincide.

Mr. H. B. Woodward thus describes the Portland and Purbeck building stones of the Vale of Wardour* :—

"In the Vale of Wardour the Portland Beds, known as Wardour Stone or Tisbury Stone, are extensively quarried and mined for building stone near Tisbury, at Chilmark, Chicksgrove, and Wockley; and formerly there were old quarries at Lower Lawn, to the north of Tisbury.

"The lower beds of the Portland Stone are those chiefly worked as freestone—they consist generally of greenish sandy limestones or calcareous sandstones, which become paler when dry. They are used not only for building purposes, but for troughs, tombstones, &c. The most extensive quarries with galleries are those in the Chilmark ravine, where beds of variable character are present, passing from sandy and glauconitic limestones into calcareous sandstone. Mr. Hudleston notices how full of quartz grains these beds are, but they appear to be cemented to a certain extent by opaline silica.†

"The principal beds are, the *Trough Bed*, a sandy limestone about 2 ft. thick, considered the best weather-bed, and used for building stone steps, paviours, &c.; the *Green Bed*, a sandy and glauconitic limestone sometimes shelly, and about 5 feet thick; the *Pinney Bed*, a sandy and glauconitic limestone, a good weather stone, about 2 feet thick; and the *Fretting Bed*, a very sandy and partially calcareous rock, a little over 3 feet thick; the thicknesses above given being those of the merchantable stone.

"The Portland Stone of the Vale of Wardour was employed

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* The Jurassic Rocks of Britain, Vol. v. The Middle and Upper Oolitic Rocks . . . . pp. 312, 313, 317. *Mem. Geol. Survey*, 1895.

† Proc. Geol. Assoc., vol. vii. p. 171.

in the Cathedrals of Salisbury, Rochester, and Chichester, in Wardour Castle, Longford Castle, Fonthill Abbey, Wilton Abbey Romsey Abbey, Westminster Abbey (Chapter House), Christchurch Priory, Balliol College at Oxford, &c.

"An upper and oolitic freestone has been obtained by means of galleries at Chilmark; it was employed in the west front of Salisbury Cathedral, and has lately been again worked."

The specific gravity of the Chilmark stone is 2·48 (about 155 lbs. per cubic foot). The Tisbury stone weighs 153 lbs. per cubic foot, and absorbs 8·6 of its bulk of water. Analysis of the "trough bed" Chilmark stone gives*:—

Carbonate of lime	79·0
" magnesia	3·7
Iron, Alumina	2·0
Silica	10·4
Water and loss	4·2
Bitumen	trace
	99·3

In the Vale of Wardour, especially at Teffont Evias, the beds of hard smooth-grained Purbeck limestone are worked for building purposes, and other coarser beds are used for flagstone or rough tiles.

The sandstone in the Upper Greensand has been described at p. 42. It was formerly much used locally, but is now seldom worked. It has been employed in the building of St. Mark's Church, Salisbury.

Brick and tile-making depend so largely on the local demand that only some of the suitable clays have been worked. The Lower and Middle Purbeck clays are stiff and marly; but the Upper Purbeck and Wealden beds contain loams suitable for brick-making. The mass of the Gault is stiff and suitable for tiles and pipes; its upper part is loamy and makes good bricks. In the Eocene strata stiff tile-clay occurs in the Reading series, and the London Clay is loamy, especially towards the top. The Clay with Flints in other districts is used for brick-making, though the bricks are not very good; here the deposit is placed inconveniently for any market, and water is usually deficient on the hill-tops. The Valley Brick-earth in the neighbourhood of Salisbury has been extensively dug, and great part of it is now worked out or built over.

Lime.

As scarcely any of our area is distant a mile from limestone, lime can be procured without difficulty. The Purbeck Beds and Lower Chalk yield argillaceous limestones suitable for hydraulic lime; the Portland limestone and the Middle and Upper Chalk give ordinary lime.

* Report with reference to the selection of stone for building the new Houses of Parliament, 1839. Analysis by Prof. Daniell, p. 30.

Road Metal.

Over the greater part of the area flints gathered from the fields or dug in the Valley Gravel or the Clay with Flints, are used for road-making. Greensand chert and the hard cherty Portland beds are, however, extensively used in the Vale of Wardour.

Water Supply.

Over most of the district water is obtained without difficulty from the Upper or Middle Chalk. This water is good, but somewhat hard. The water from the Portland Beds is excessively hard, and owing to the fissured character of the rock, great care is needed to avoid surface contamination. The Purbeck Beds yield a little water of poor quality, and that found in the Wealden is also bad.

A good supply of excellent water is obtainable from the Upper Greensand, which often gives out copious springs at its junction with the Gault. Such springs will be noticed at Ansty and Swallowcliffe. A small amount of water is obtained from the Bagshot Sands. The water found in the Valley Gravel is largely derived from filtration from the adjoining river or from the Chalk. This source of supply is not a very safe one, for the gravel is very porous, and the gravel-flats are largely occupied by buildings and farms.

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(EXPLANATION OF SHEET 317.)

BY

CLEMENT REID, F.R.S., F.L.S., F.G.S.

With Contributions by

G. W. LAMPLUGH, F.G.S., and A. J. JUKES-BROWNE, F.G.S.

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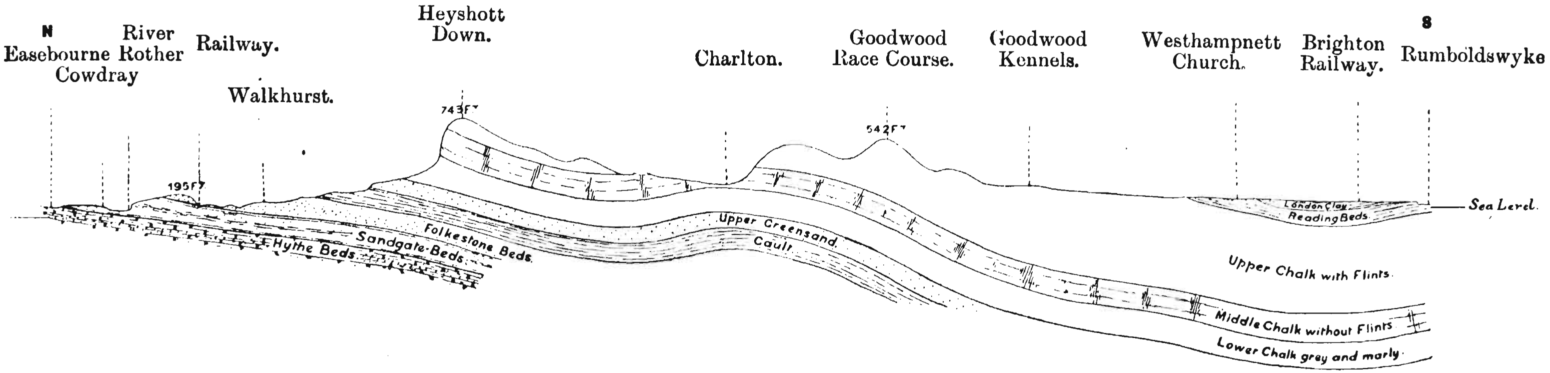

FIG. 1.—*Section from Easebourne across Heyshott Down to Rumboldswyke.*

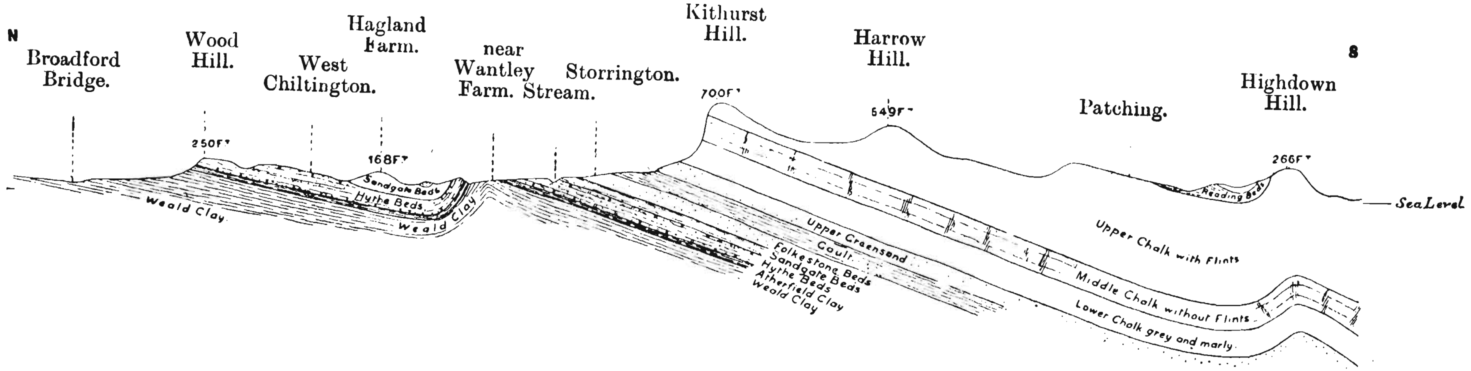

FIG. 2.—*Section from Broadford Bridge across Kithurst Hill to Highdown Hill.*

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With Contributions by

G. W. LAMPLUGH, F.G.S., and A. J. JUKES-BROWNE, F.G.S.

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PREFACE.

THE country described in this Memoir includes a large tract of the South Downs, which present a bold front of Chalk scarps on the north, overlooking the great Wealden area, a portion of which is represented on the map. Southwards the Chalk descends gradually to a low level, where it forms a syncline, in the hollow of which Lower Eocene strata are preserved. In this comparatively level tract the strata are extensively covered by Pleistocene deposits of brick-earth and gravel. Geologically the area has been described and illustrated in the works of Fitton, Frederic Dixon, P. J. Martin, and Dr. Charles Barrois, and it has been partially described in the Geological Survey Memoirs by Mr. William Topley and Mr. A. J. Jukes-Browne.

The original Geological Survey of this area on the one-inch scale was made by H. W. Bristow and Frederick Drew, and published in 1864. The re-Survey on the six-inch scale was carried on between the years 1884 and 1890 by Mr. Clement Reid, who mapped the southern area, including the Chalk Downs. The remaining portion was for the most part surveyed by Mr. G. W. Lamplugh in 1899 and 1900, a few square miles near Midhurst having been previously mapped by Mr. C. E. Hawkins.

In the course of the Survey, assistance has been rendered by Mr. William Hill, Mr. J. Vincent Elsden, and Mr. R. M. Brydone, while useful records of the strata have been furnished by well-sinkers.

J. J. H. TEALL,

Director.

Geological Survey Office,

28 *Jermyn Street, London.*

25th March, 1903.

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OF THE COUNTRY NEAR

CHICHESTER.

CHAPTER I.

INTRODUCTION.

Sheet 317 of the Geological Survey Map takes in an area of 216 square miles, all included in the county of Sussex. The central part of the district is occupied by the South Downs, which stretch from east to west as a wide belt of undulating southward-sloping uplands, bounded on the north by the high chalk-escarpment which overlooks the Weald. This escarpment rises to 818 feet at Linch Down. On the south the Downs usually end in a lower bluff, which marks the position of an ancient partly-obliterated sea-cliff; and below this is a flat coastal-plain, which extends continuously to the sea. These are the main features; the details will be described further on.

One river of importance, the Arun, traverses the country from north to south, and with its tributaries drains about two-thirds of the area. Over the remaining area most of the water escapes by underground courses to the Lavant, or drains into small streams which reach the sea near Bognor and Pagham.

Within the area lies the ancient town of Chichester, as well as Arundel, Midhurst, Petworth, Pulborough, and numerous villages. The position of the settlements has been decided mainly by the possibility of obtaining water, no place of importance lying on the Weald Clay or Gault, nor on the high Downs, where water can only be found in deep wells.

The district is mainly devoted to agriculture and sheep-pasture; but contains also much woodland, beech on the Downs and oak in the Weald. There are neither mines nor manufactures, and the mineral products raised, consisting of chalk, brickearth, tile-clay, gravel and sand, are almost entirely used within the district, for building purposes, agriculture, or road-making.

The formations represented on Sheet 317 are the following:—

Recent . . .	Alluvium.	
Pleistocene . . .	Brickearth. Valley Gravel and Coombe Rock. Hill Gravel and Flint-rubble. Marine Gravel (south of the Downs). Clay with Flints and Tertiary *débris* (overlying Chalk).	
Eocene . . .	London Clay. Pebble Beds. Reading Beds.	
Upper Cretaceous	Upper Chalk. Middle Chalk. Lower Chalk.	
	Upper Greensand. Gault.	Selbornian.
Lower Cretaceous	Folkestone Beds. Sandgate Beds. Hythe Beds. Atherfield Clay.	Lower Greensand.
	Weald Clay.	

Nothing is yet known about the strata which underlie the Weald Clay; but as far as can be judged from neighbouring areas, a great thickness of Lower Cretaceous and Jurassic Rocks would be met with. It is not probable that any minerals worth mining occur within several thousand feet of the surface.

A general southward dip is caused by the broad anticlinal arch of the Weald, on the southern side of which the whole of our district lies. By the destruction and planing down of the higher parts of this arch, rocks have been laid bare in the north which to the south are buried under a great thickness of newer strata; these newer strata form the northern edge of the broad syncline known as the Hampshire Basin. Not only does this great disturbance affect our area, but we have also various minor parallel folds, which form ripples on this big wave. It will be seen, on examining the Map, that several of these folds occur within the area. An anticline enters the district north of Storrington, bringing up Wealden strata; then it runs westward to Watersfield, where it dies out. Another anticline commences near Bury (south of Westerfield), and then brings up an inlier of Lower Chalk near Upper Waltham, and a long tongue of Middle Chalk, which extends as far as West Dean. West of that point the anticline causes two more inliers to appear, and then passes out of our district. Another sharper anticlinal fold brings up Chalk at Highdown, and can be traced westward to Barnham, with Eocene strata on either side. Still another commences near the termination of this one, but not in the same line, and brings up Chalk south of Chichester.

These sharp folds, in the southern part of our area, make, however, scarcely any sign at the surface, for they have nearly all been planed down to a uniform level and subsequently covered with Drift deposits. The streams which now cross the coastal plain follow courses decided by slight irregularities in the surface of the Drift; they quite ignore the anticlinal and synclinal structure below. Should the land again rise, the deeper trenching of the stream courses would cut across the folded strata below, and we should then see a series of valleys which, like those of the Weald, would seem to be independent of the hardness or softness of the strata through which they have been cut.

CHAPTER II.

WEALDEN.*

The Weald Clay, which is the only division of the Wealden strata occurring at the surface in the district, is brought up, as already described, to the north of Petworth, Pulborough, and West Chiltington. A tongue of it also appears along the axis of the minor anticline north of Storrington; but only the upper part of the formation is here exposed.

The area under consideration in this Memoir includes a considerable proportion of the tract mapped and described in detail, with remarkable accuracy, by P. J. Martin so long ago as 1828.† Martin noted the occurrence of definite courses of sand and of Sussex Marble in the Weald Clay of this district, by which the deposit could be divided into distinct belts, and although these courses may not be quite so regular and continuous as he believed, his statement of the general succession has been satisfactorily verified. The occurrence of the sandy horizons has some economic importance, as they are the main source of water-supply in the Weald Clay tract; and, moreover, by their admixture with the clay where near the surface, they change the character of the soil from a stiff intractable clay-land which, under present conditions, will not pay for cultivation, to a more readily arable loam which is still, for the most part, under tillage. Hence beds of this material underlie the major portion of the arable land in this part of the Weald, while the unmodified clay-belts are nearly all under grass or woodland. The beds of sand are, however, usually too thin or too much interstratified with clay to render the soil actually "light," especially as the clays tend everywhere to "creep" and become mixed with the sands along their outcrop. The water supply from wells in the sands is often tainted with mineral matter in solution, and is usually only sufficient in quantity for household supply, but is nevertheless important in a district where no other safe source is available.

The uppermost division of the Weald Clay, so far as the very scanty exposures enable one to judge, is a dark blue shaly clay, probably of the character of the Wealden Shales of the Isle of Wight. It weathers at the surface to a stiffly plastic brownish-yellow clay, and occupies the lower slopes beneath the bold escarpment of the Hythe Beds of the Lower Greensand and a broad belt of low ground to the northward. Beds of this description probably extend uninterruptedly at the same horizon all round the Weaden depression.

Below this division come more silty clays associated with thin beds of fine yellow loamy sand or sand-rock, with a little concretionary iron rag-stone in places. Owing to the insufficiency of

* By G. W. Lamplugh.

† "A Geological Memoir on a Part of Western Sussex."

the exposures it is not possible to assert with confidence that the sand-beds are absolutely continuous; they may, perhaps, occur in detached lenticles of irregular horizontal extent; but sand was found here and there at approximately the same horizon from the eastern to the western limits of the tract surveyed, and was apparently thickening westward. Usually only 4 or 5 feet of sand was visible in any particular section, but the full thickness would probably in most cases have been found to be greater if the exposure had been complete. The greatest depth was noticed a little to the north of the limits of the map in a road-cutting at Gunter's Bridge, one mile north of Petworth, where 10 feet or more of sand and sand-rock with thin clay-partings is exhibited, one seam being exceptionally coarse in grain for these beds. In an exposure in a gully in the woods south-west of Hawkhurst Lodge, three miles farther east (also in Sheet 301), the sand-rock contains a seam of pebbly conglomerate, apparently of local and contemporaneous derivation, made up of fragments of soft sandstone and pellets of clay, with fragments of bone and wood, resembling the conglomerate bands often associated with the sandstones of the Variegated Series of the Wealden in the Isle of Wight. On the eastern slope of the Arun Valley at Toat Wood and Toat Farm, just within the present sheet, a sand-rock of this belt has been dug in old quarries, probably as a sandstone. The clay which immediately overlies the sands of this as well as of the lower horizon is frequently of a bright red colour.

The sands generally form a gentle feature along their outcrop, but owing to their slight thickness and the above-mentioned "creeping" of the clays on the slopes and consequent mixing of the beds, it is rare that sand is visible in the feature, the exposures being found usually in gutters and ponds on the lower part of the dip-slope, under a thickness of 2 or 3 feet or more of clay. The dip, which is to southward, appears, from calculation, rarely to exceed 1° or 1½°, and the dip-slopes are therefore of great breadth in proportion to the thickness of the bed. Under these circumstances it was not found practicable to map the beds of sand separately from the accompanying clay and silt, and the plan was therefore adopted of mapping out approximately the limits of the zones wherein the clay is associated with sandy intercalations so that they may be distinguished from the zones in which such intercalations are absent. The same remarks apply also to the method adopted for indicating the horizon of the Sussex Marble next to be described. Difficulties were found in carrying out this plan towards the northern edge of the area in the vicinity of the Arun, and it remains to be proved by further survey whether the divisions can be followed beyond the ground already mapped. It would certainly be advantageous, in studying the detailed structure of the country, if the thick mass of the Weald Clay could thus be broken up into zones.

Below the silty clays with sands, we find in the eastern part of the district examined a belt of stiff, dark, shaly clay, probably somewhat pyritous, containing a bed of Paludina-limestone or Sussex Marble ("First course of Sussex Marble" of Martin) ranging from a few inches to 2 feet in thickness. This limestone was formerly much dug for road mending and building, and many of the farmsteads near its outcrop are partly built on it; it is still being raised on a small scale in fields one-third of a mile north of Broadfordbridge and near Oldhouse Farm. In going westward, however, all trace of this stone-band was lost before crossing the London, Brighton, and South Coast Railway at Adversane, and it was not again seen in the area examined, though, according to Dr. Martin, it is found west of the Arun to the northward of the ground at present mapped.

This division is the lowest seen in Sheet 317, where it occupies a little triangular tract only about a mile long from east to west and half a mile broad from south to north in the extreme north-eastern corner of the map.

It is succeeded farther north, in Sheet 301, by another sandy series consisting of laminated pale blue, dark blue, and grey clay and silt with layers of sand and a thin band of calcareous sandy flagstone ("The Second Sand" of Martin). A good section was obtained in this division in a new well at a cottage opposite to Marringdean Farm (Sheet 301), 1¼ miles south of Billingshurst Station, where it was penetrated to a depth of 40 feet. A seam of silty clay a few feet above the bottom of the well contained well-preserved plant-remains, and a collection of these was made from the spoil-heap and submitted to Mr. A. C. Seward, F.R.S., who kindly undertook their examination, and determined the following forms:—

Weichselia Mantelli, *Brongn.*
Onychiopsis Mantelli, *Brongn.*
Brachyphyllum sp. (?)

The flora of the Weald Clay, as distinguished from the Hastings Beds, is imperfectly known, so that the occurrence of these plants is of some interest, though they all belong to well-known and widely distributed Wealden forms. The horizon at which they occur is probably about midway in the Weald Clay of this part of Sussex.

The calcareous flagstone mentioned above is apparently at the most only a foot or two thick; it was formerly dug in several places between Marringdean Farm and Lording's Farm, but the present exposures are poor and scanty. The division as a whole was traced westward to the Arun at Lee Farm; west of the Arun it passed beyond the northward limits of the ground examined.

CHAPTER III.

LOWER GREENSAND.*

According to the classification of the original Survey Map, the uppermost portion of the clayey deposits which occur immediately beneath the Lower Greensand escarpment is supposed to represent the Atherfield Clay, though definite evidence on this point is rarely forthcoming. A few marine fossils were, however, found long ago in nodules from this clay at the brickyard at Harwood's Green, near Pulborough, which serve to differentiate it at this locality from the underlying Weald Clay of fresh-water origin; and during the new survey some further specimens were obtained from this place.

There are occasional indications that the clay becomes interstratified with silt and fine sand towards its junction with the overlying Hythe Beds, and that in passing southward the base of the latter strata contains an increasing proportion of clay.

The broad grounds for the subdivision of the Lower Greensand into the supposed equivalents of the Hythe Beds, Sandgate Beds, and Folkestone Beds of East Kent, are readily grasped in this part of West Sussex, though the exact boundaries of the sub-divisions are usually more or less vague, seeing that they rest entirely upon lithological differences which are subject to much local variation. The Hythe Beds are characterised, as in Kent, by irregular calcareous stone-bands among half-indurated loamy glauconitic sand, with the local development of impersistent layers or concretions of chert. The calcareous sandstone has been much used for building, and the chert is extensively dug for road-mending.

The Sandgate Beds are variable in composition, but contain more clay and silt than the underlying and overlying divisions. In the western part of the district a thick bed of sand near the base of this series is partly composed of smooth polished grains of brown iron-ore. It has been suggested that this ferruginous sand might be of some economic value, but the average percentage of iron (23%) is probably too low to bear the cost of carriage. The iron-sand disappears rather suddenly at a short distance to the eastward of Selham. The Sandgate Beds are for the most part destitute of fossils, but a richly fossiliferous band was found, consisting of ironstone crowded with the casts of marine shells, at the top of the iron-sand, in two hitherto unrecorded localities near Midhurst (June Lane, and the river bank due south of Cowdray Ruins). In the stream-bed east of Ambersham Common, some plant remains, including traces of *Weichselia*, were collected from a thin band of sandstone.

The Folkstone Beds consist of sharp sand, strongly current-bedded, with ironstone concretions and thin partings of pipeclay. Excepting the cast of a fragment of wood with teredo-like borings, no organic remains were found in these sands. At the top of

* From Mr Lamplugh's notes.

this division, immediately below the Gault, the sand is indurated into a hard grit-band, from 2 to 4 inches thick, of a deep red colour, which is persistent throughout the area examined.

A comparatively rapid thinning away southward of the Lower Greensand as a whole causes increasing difficulty in mapping the sub-divisions in working eastward, owing to the persistent southerly trend of the escarpments. This difficulty is especially felt on the southern side of the anticline near Storrington.

Atherfield Clay.

As already mentioned, there is much difficulty in obtaining definite evidence respecting the Atherfield Clay, which, on slender grounds, has been supposed to form a continuous base to the Lower Greensand series around the Weald. The best exposures of this clay observed in the district lie outside the margin of the present map, about a mile to the eastward of its boundaries, in Sheet 318, in road cuttings at Warminghurst and again two-thirds of a mile south of Warminghurst, on both sides of the Greenhurst anticline. In the latter section the sandy Hythe Beds are seen to pass down into clay, at first greyish-brown, but deep chocolate-brown below, containing small phosphatic concretions, with casts of marine shells. The thickness of the clay here apparently does not exceed 20 feet and may be less. Immediately below it there is dark blue shaly clay, evidently the topmost bed of the Weald Clay, and the junction appears, as usual, to be quite sharp. A few phosphatic nodules from the marine clay were seen in the spoil-heap from a small excavation at the spring 200 yards south-east of Thakeham Church, and at two or three other spots on the escarpment farther to the north-westward. Chocolate-brown clay was likewise observed in the same position in other localities, both east and west of the Arun, though without direct evidence for its marine origin. Hence it may be regarded as certain that the Atherfield Clay is present throughout the area examined, though probably of insignificant thickness. This confirmation of the old map in the matter is the more satisfactory since the new railway cutting at Redhill, in Surrey, on the opposite side of the Weald, showed an unexpected absence of the Atherfield Clay. The presence of the chocolate-brown clay in the Sussex sections is noteworthy, as a clay of precisely similar aspect forms part of the Atherfield Clay of the Isle of Wight, and was likewise found at the same horizon in the new colliery shafts at Dover.

Hythe Beds.

This division usually is characterised by the presence of irregular stone-bands in hassocky loam. Sometimes these are large, round, or tabular discontinuous concretions set in sand or soft sandstone—indeed, they would probably always appear as lenticles if we could see large sections. There are also limy grits, and in places, especially between Petworth and Bedham, irregular tabular sheets of chert, arranged one over the other in broken columnar fashion. Fossils are rare throughout. A few limas were noticed in the hassock, and occasional obscure casts of bivalves in soft sandstone; in one of the chert-pits between Brinksole and Bognor was a layer containing many badly preserved shells, but no cephalopods were seen. The presence of clay interstratified with the division is shown by the Midhurst Waterworks boring, and there appears to be a similar lenticular band of fine stiff unctuous clay 300 yards east of Little Common near Tillington.

The Hythe Beds contain no workable chert east of the Arun, and the sandstones which characterise their lower portion in the Pulborough district and farther westward are scarcely recognisable in the eastern part of the area examined, where the beds consist of sandy "hassock" with concretionary limestone in lenticular masses and sheets.

It is unnecessary to describe the numerous exposures of Hythe Beds, which can be examined in various natural sections and in quarries opened for the stone; we will merely mention the leading sections which illustrate the character and thickness of the deposits. The best section of the base is seen in the bank on the east side of the pond belonging to the Upper Mill at Little Bognor near Fittleworth. This shows:—

	Feet.
Hard sandstone with hard sands (cherty and loamy) -	5
Soft sandstone, rather harder than below - - -	3
Soft sand and sand-rock nearly black, banded pale and dark yellow and green - - - - - -	3
Lumpy, irregular, nodular sandstone, yellow and dark green, ferruginous in places; with soft loamy lenticles between the beds - - - - - -	9
Flaky hassock, with dark green, almost black, sandy layers, and impure loamy sandstone - - - -	5
passing into	
Yellow loam - - - - - - - - - - -	2
passing into	
Greyish and yellowish loamy clay - - - - -	1

In similar beds just below the road, casts of shells (*Avicula*, etc.) were noticed in a dark-green hassock, which also contained small soft brown bits like decomposed phosphate or bone, and rounded pebble-like bits of sandstone like neighbouring beds.

Another exposure, which exhibits the whole of the Hythe Beds in one section, will be found in the road-cutting at Jackets Hill, a place exactly at the eastern limit of our area and immediately north of Hills and Hamper's Farm. The section, which is worthy of more detailed study, is as follows:—

	Feet.
Like beds below, but hassock predominates (extends to the cottages at the north foot of the hill, where Sandgate beds probably come on)	50 to 55
Alternations of concretionary sandstone in badly stratified masses, with loamy hassock; sandstone predominant - - - - - -	40
Hassocky sandstone with pyrites - - - -	4
Knotty sandstone - - - - - - -	1
Rather clayey sand, as below - - - - -	7
A band of concretions 3 feet in diameter, concretionary sandstone bands and hassock (not well seen) - - - - - - - - -	9
Rather clayey sand, harder than that below, with soft sandstone with dark mottling - -	4
Soft loamy greensand - - - - - - -	3

At south side of hill at foot of bank, obscure: probably clayey loam. Below this water oozes out, and the base of the Hythe Beds is mapped - - - - - about	12
	130

The above section illustrates the eastward thinning of the beds, for only three and a half miles to the west-north-west, at Pulborough, a well sunk in 1900 by Messrs. Duke and Ockenden proved nearly 181 feet of strata belonging to this division. The well is in the corner of the field adjoining the churchyard, north-east of the railway station, on the top of the hill, close to the brickyard and sandpit. The well starts near the top of the Sandgate Beds: the dip is rather steep, apparently 10° or 15°, the thickness therefore will be slightly exaggerated. The descriptions given below are misleading, the loamy Hythe Beds (hassock) being called "clay." The Sandgate Beds probably extend to 83 feet, and all the rest is Hythe Beds: the bottom sandstone being probably that at the base of the Hythe Beds. The well-sinkers section shows:—

		Thickness. Feet.	Depth. Feet.
Sandgate Beds	[*Dug Well*] - - - -		30
	Sand-rock - -	8	38
	Sand with clay	40	78
	Hard clay - -	5	83
Hythe Beds	Clay and greensand -	14	97
	Clay - - - -	22	119
	Clay and sand - -	80	199
	Rock and clay - - -	19	218
	Clay and sand - - - - -	3	221
	Rock and clay - -	4	225
	Sand and clay - - -	3	228
	Rock and clay - - - -	15	243
	Layers of hard and soft sand-rock	21	264

Even if the dip amounts to 15°, the thickness of these strata will only be reduced by about 4 per cent.

SANDGATE BEDS.

This division forms a wide belt stretching nearly across our district, from Trotton, through Midhurst, Fittleworth, Pulborough, and Storrington. The Sandgate Beds, which are best exposed in the numerous sections around Pulborough, are characterized by the beds of silt and clay which they contain; but they include also some beds of sand which, in isolated sections, can scarcely be distinguished from the Folkestone Sand, particularly in the north-eastern part of the ground. The fossiliferous nodules which have long been known to occur in this division in two or three localities in the Pulborough district were observed in a few other unrecorded places also, as mentioned below. The horizon on which these fossils occur is probably roughly equivalent to that at Midhurst, described in 1899,* though the localities seem to have few species in common.

* Summary of Progress for 1899, pp. 136, 137.

The Sandgate Beds are so variable, and their upper and lower limits are so indefinite, that the most convenient method of description will be to mention the principal sections in order, passing from west to east.

Near the western limit of our area, and thence eastward to a little beyond Selham, the lower part of this group is a well-characterized coarse sand, full of polished flakes and grains of deep brown iron-ore. As this makes a good feature, with featureless ground below, it was at first taken as the base of the division, though the old map seemed to have taken a somewhat lower line. This bed disappears suddenly east of Selham, being last seen below Barnetts Mill, where it seems quite strongly developed. In connection with it, the above-mentioned fossiliferous ironstone nodules were found in June Lane, Midhurst, and in the river-bank at King John's Walk, Midhurst. The fossils are bivalves and univalves in the state of casts. The following forms have been named by Mr. E. T. Newton and Dr. F. L. Kitchin :—

June Lane, Midhurst :

Cardium ?	Tellina (Linearia) cf. concentrica, *d'Orb.*
Corbula striatula ? *Sow.*	Actæon sp.
Cytheræa ?	Aporrhais sp.
Nuculana scapha, *d'Orb.*	Trochus ?

River Bank due south of Cowdray Ruins :

Cucullæa sp.	Actæon sp.
Exogyra sinuata ? *Sow.*	Cerithium ?
Nuculana sp.	Trochus sp.
Trigonia sp. (group "Scabræ").	

Probably the dying out of this bed southward is indicated in the banks of the stream south-east of Ambersham Common, where a curious mixture of clay with coarse greenish grit passing into iron-grit is seen at the north-east corner of the Common. Farther south occurs a band of soft micaceous sandstone associated with clay, and in this sandstone are bits of ferns and other plant remains, perhaps including fragments of *Weichselia Mantelli*, Brongn. Perhaps the southern trend of the scarp brings the marine iron-grit to an end ; for, as already observed, there is a general tendency for the Lower Greensand to thin out in that direction.

Below this iron-grit, everywhere east of the place where it crosses the Rother at Midhurst, there is a band of clay or clayey loam. This clay was included in the Sandgate Beds in the old map, and was probably the reason for carrying their base below the iron-grit farther west. I (G. W. L.) should have preferred to leave this loam and clay with the Hythe Beds, as it is lithologically not much removed from them, and these beds undoubtedly do include lenticles of clay, while the coarse iron-grit betokens a change of conditions. I therefore held to the base of the grit as long as it lasted ; but then found that on going farther east it was necessary to go down to the bottom of the clay to make a division between the Sandgate and the Hythe Beds. Then, working backwards, a line was drawn below this clay up to Midhurst, and this line is that adopted on the map. A brickyard has been opened in the lowest bed of clay at Fittleworth; but there, according to the old map, it had been included in the Hythe Beds.

The upper parts of the Sandgate Beds in the Midhurst area are silts and black silty micaceous clay, with fine white sand and sand-rock. The top of the highest clayey band has generally been taken for the division between Sandgate and Folkestone Beds; but the line is not satisfactory, as all these clay beds are lenticular, and it is quite likely that they invade higher or lower horizons at different places.

In the eastern part of our area the best sections of Sandgate Beds are seen in lanes near Pulborough; at Park Farm, Pulborough Church; and Marehill ("Codmore Hill," of the Weald Memoir and old map, is at Hesworth Common, near Fittleworth, and is not the Codmore Hill north of Pulborough). The base seems to be clayey loam passing down into the hassock of the Hythe Beds. Above this comes fine sharp sand or sand-rock, white or stained red or yellow, making a bold feature east of Pulborough, and quarried for moulding sand. Apparently there are sometimes two beds of this sand, with a silty or clayey parting containing fossiliferous ferruginous nodules. Then follow dark shaly silts or muds. The lower clays and silts have large irregular concretions of ironstone, crowded with casts of marine fossils — *Trigonia*, *Terebratula*, etc. Fossils were noticed in these in a wood north of Park Mound (good); in the railway cutting (very much weathered); on the west side of Gravel-pit Plantation near Washington; at the edge of the wood east of Threal's Farm (one mile south of West Chiltington); and at Hurston Place. The best locality for collecting the fossils is, however, the lane mentioned in the Weald Memoir, at Park Farm, near Pulborough, and in the adjacent wood.

Folkestone Beds.

The sand and sand-rock immediately below the Gault is generally sharp and clean. Sometimes it is white and of very fine quality, sometimes yellow and rusty, and sometimes, especially in the upper part, crimson in patches, apparently from the decomposition of some iron nodules. It often becomes coarse, with pebbles up to a quarter of an inch diameter or larger in the lower part, and it is wonderfully cross-bedded. No fossils whatever have been seen in it in this area, except a trace of wood in the "carstone" (concretionary ribs of ironstone) by which it is traversed. Just below the Gault it is cemented into a hard band, two to four inches thick, of a crimson colour and coarse gritty texture, which forms an excellent line of division, and is generally traceable. This is dug occasionally for walling. Like the other divisions of the Lower Greensand, the Folkestone Beds become thinner as they are traced towards the south-east.

CHAPTER IV.

SELBORNIAN (GAULT AND UPPER GREENSAND).

The two divisions which are described in this Chapter have been grouped together by Mr. Jukes-Browne as one formation, named the Selbornian; for the old lithological division between Gault and Upper Greensand is not one that can be used in a classification depending on time. The line between the clayey Gault and the sandy Upper Greensand varies its position so greatly, that the Upper Gault of the east of England finds its true equivalent in the sandy strata known as the Blackdown Sands in Devon, and the Gault of Dorset represents only the Lower Gault of Folkestone.

The palæontological zones into which the Selbornian is divided are as follows:—

Upper Greensand and Upper Gault	Zone of Pecten asper.
	„ „ Ammonites rostratus.
Lower Gault . .	„ „ ——— lautus.
	„ „ ——— interruptus.
	„ „ ——— mammillatus.

It is doubtful, however, whether the lowest zone, that of *Ammonites mammillatus*, is represented in West Sussex.

GAULT.

The Gault stretches across West Sussex, forming a strip of low-lying heavy clay land, often a mile in width. Though so well represented in our area, but little can be said about it, for sections in this slippery clay are rare, and soon become obscured, and few wells penetrate it to any great depth. Its total thickness is probably between 200 and 300 feet. The part just above the grit-band mentioned in the last Chapter as occurring at the top of the Folkestone Sands is often seen; but above this there are few sections. Mr. Lamplugh noticed grit-grains mixed with the clay for a few inches above the base in the excellent section at Fittleworth station, and Mr. Jukes-Browne gives the following account of the basement-bed, with which, it will be observed, he classes the thin grit:— *

" How far the greensand with phosphatic nodules which forms the base of the Gault near Petersfield extends to the east is not yet known, but it does not reach to the outcrop south of Midhurst, for there, according to the late Mr. Topley, the junction of Gault and Lower Greensand is a red ferruginous grit without fossils or phosphate nodules.

" Topley observed the same bed of red grit farther east, 'in the road west of Burton Church, south of Petworth station; and also in many of the streams which cross the outcrop of the Gault, the hard grit often making a small fall in the stream-bed.'

* Cretaceous Rocks of Great Britain, vol. i. p. 114, Mem. Geol. Survey.

"Still farther east, at Sullington, between the valleys of the Arun and the Adur, the same red grit is seen again. Topley says, 'an excellent section is seen in the road north-east of Sullington, where the grit is [between] two and three inches thick. Here the land below the grit is clayey for a few inches.'

"This junction, as seen in a cutting on the railway, near Lower Fittleworth, was described in 1869 by Mr. G. Maw,* who gives the section as follows:—

FOSSILS OF THE GAULT.

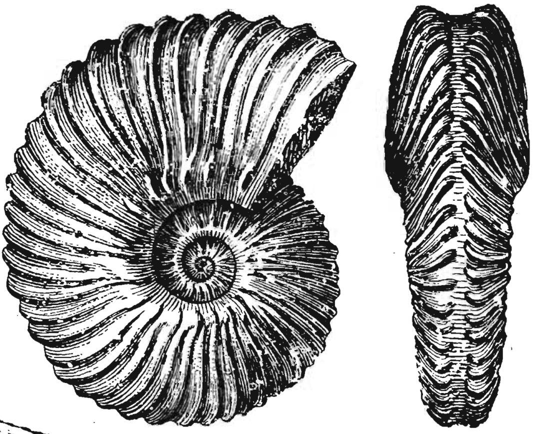

Fig. 3.

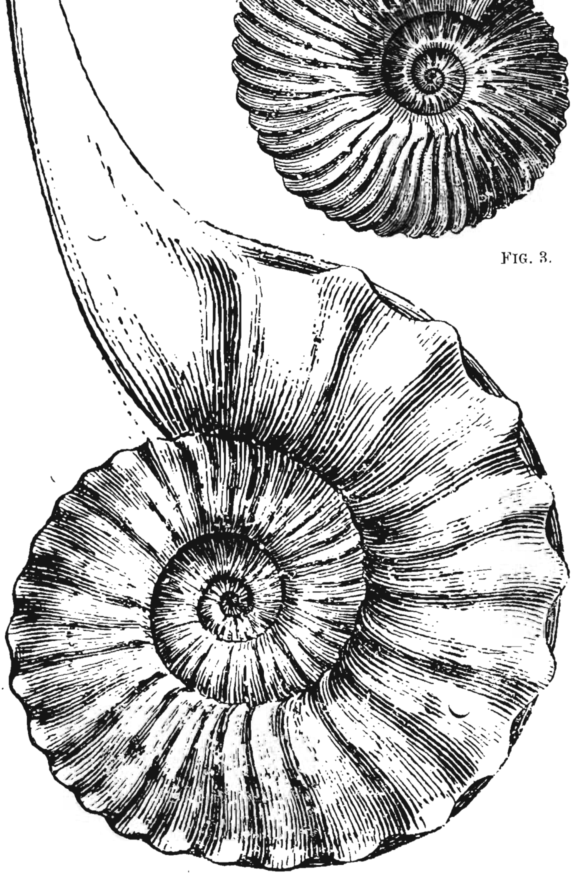

Fig. 4.

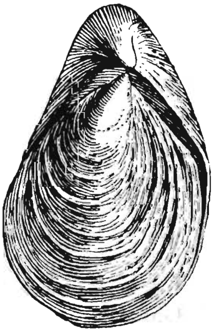

Fig. 5.

Fig. 3. Ammonites [Hoplites] interruptus, *Brug.*
Fig. 4. Ammonites [Schloenbachia] rostratus, *Sow.* (reduced).
Fig. 5. Inoceramus concentricus, *Park.*

* Geol. Mag. vol. vi. p. 335.

	Ft.	in.
Ferruginous gravel - - - - - - - - -	5 or 6	0
Gault clay - - - - - - - - -	10	0
Hard blood-red ferruginous conglomerate - - - -	0	4
Yellow and orange sands which for a few inches below the conglomerate are stained bright blood-red - -	30	0

"He describes the conglomerate as maintaining a uniform thickness of about four inches, and as abounding in small quartz pebbles, which are held together by the ferruginous matrix. He also remarks that the line of demarcation is remarkably definite, 'no gradation existing between the red stratum and the Gault above, or the Lower Greensand below.'

"Mr. R. M. Brydone informs me that about 20 feet of Gault clay can now be seen in this cutting, and that fossils are very scarce and badly preserved, being all converted into selenite, which is very abundant; also that the clay is much cracked, the surfaces of the cracks being coated with rust-coloured films.

"It would appear, therefore, that throughout the west of Sussex to the valley of the Adur the base of the Gault is formed by the grit-bed above described, which is not associated with any layer of phosphatic nodules. In this region, therefore, there does not seem to be any representative of the zone of *Ammonites mammillatus*.

"Mr. Brydone also communicates the following information (1898):—'Some years ago a well was sunk near the base of the Gault north of Graffham, the surface of the ground at the spot being about 30 feet above the horizon of the red ferruginous grit, which is visible in the bed of a stream close at hand. The clay brought up yielded *Inoceramus concentricus* (Fig. 5) in abundance, and a few other fossils.' The fossils were sent to me by Mr Brydone, but few were specifically determinable; they include the following:—

"Hamites intermedius or attenuatus.
Hamites punctatus?
Aporrhais carinata.
Bellerophina minuta.
Natica clementina?
Scalaria sp. (young).
Inoceramus concentricus.
Leda phaseolina?
And other obscure bivalves."

From brickyards in the Gault at Pitsham near Midhurst, and at Hardham near Pulborough, Mr. Lamplugh obtained fragments of Ammonites (probably all *Amm. interruptus* (Fig. 3) and varieties) but no other fossils.

The middle part of the Gault is thus described in Topley's Memoir on the Geology of the Weald (p. 150):—"In the railway cutting just west of Elstead Station there is a section of Gault which appears to be about in the middle of that formation. The clay here contains some hard calcareous nodules with phosphate of lime. In the road between Burton and Duncton, just opposite the road which goes off to Bound House, there are some nodular masses of clay-ironstone with the concentric structure exceedingly well marked. . . . . . This section also is about the middle of the Gault." The well in Bignor Park, mentioned by Martin in 1828 as 70 feet deep, was also most probably in these beds, though we have no details.

The upward limit of the Gault is very obscure, there being few exposures of the higher part. The only good section now visible is one noted by Mr. Lamplugh, in the road north of Sutton. The malm rock here seems to become more clayey downward and to pass into a rather sandy micaceous brown marl, which becomes more and more clayey below and merges into Gault. The clay about the junction has a brownish tint when weathered (and perhaps when fresh), and when dry has a whitish look. Lower down the clay is pale blue and very stiff, getting darker blue towards the base of the Gault. For proof that Upper Gault with *Ammonites rostratus* (Fig. 4) exists in West Sussex below the base of the malmstone we are indebted to Mr. Brydone, who found fossils in the marly clay forming the bed of the stream just below Duncton old church. These included *Ammonites rostratus, Belemnites minimus, Plicatula pectinoides, Pollicipes glaber?* and also the following among specimens sent to Mr. Jukes-Browne for identification: *Cardita tenuicosta, Nuculana vibrayeana,* and *Fusus.*

Upper Greensand.

The earliest description of the Selbornian in Sussex was that by P. J. Martin in 1828. He divided it into *Galt* and *Malm*, subdividing the latter into "Greensand" and "Malm-rock."* He says, "This [chalk] marl passes into the malm, of which there is a thin stratum [*i.e.* Chloritic Marl], succeeded by a bed of greensand, and that by the more indurated malm rock, which again gradually resolves itself into the galt clay beneath."

Speaking of the bed which he specialises as "the greensand," he says "the best sections of this stratum are to be found at Steyning, Amberley, Bury, and Barlavington . . . . at Bury it is from 15 to 20 feet in thickness."

He continues thus:—"The great body of the malm rock next succeeds, advancing in a bold and broad talus [? terrace], at the foot of the chalk hills, and it is worthy of remark that it is broadest on the eastern side of every remarkable salient angle of the Chalk. . . . The wells are from 30 to 100 feet, and the average depth of the whole stratum may be about 70 or 80 feet. . . . . In its most indurated state the malm rock has a conchoidal fracture, and is of a bluish colour when fresh broken, but becoming white by exposure to air."

Though small exposures of the Upper Greensand are common, few of them call for special note. We will therefore merely mention the best that are met with when this rock is traced along its outcrop from west to east.

Elsted, according to Mr. C. E. Hawkins, is on the malm rock, which may dip to the north at about 5°. Sections of the sandy marl, which occurs at the base of the Upper Greensand, may be seen in the road-cutting leading down to Elsted Green, and also at the foot of the scarp north of Elsted; it is also exposed north of Didling. At Grayets a shallow well has been dug in this sandy marl, which is here sufficiently firm to stand without steining. The water in this well is held up by the underlying Gault clay.

* Geological Memoir of a part of Western Sussex, p. 18.

The sections around Cocking are interesting, for just east of Sunwool Farm the passage from Greensand to Chalk is seen, glauconitic marl (base of the Chalk) passing down into soft glauconitic greensand. The beds below are also seen in various sections in the village; and Mr. Gould saw the lower beds well exposed in a drain at Sunwool Farm. The malm towards the bottom becomes a soft and rather sandy rock, with mica, ultimately passing rather suddenly into a marly clay, green mottled with red, which changes insensibly during the next 20 feet into Gault.

In the neighbourhood of Cocking, and perhaps continuously eastward to Beachy Head, a marked bed of dark-green glauconitic sand or sandstone occurs just below the junction with the Chalk. This sand is constantly exposed in the deep "hollow-ways" which descend the scarp; and though it usually contains only a poor fauna, its marked lithological character makes it a useful horizon and easy to trace. Many of the springs are given out at the junction of this bed with the malm rock, and not at the base of the malm rock.

At Graffham, a quarry south of Woodcut Farm shows 10 feet of massive malm rock, dappled with clayey streaks and containing pyrites. South-east of this quarry the junction of the Greensand with the Chalk can again be seen, though not clearly.

Near Barlavington, Sutton, and Bignor, where the outcrop turns southward, numerous exposures both of the greensand and malm-rock will be found, but neither the junction with the Gault below nor with the Chalk above is clear.

On the east side of the Arun a good exposure of the malm-rock will be seen in the river-cliff at Amberley; and south of Storrington this rock has been lately quarried for a new house. It will be noticed that in this part of the outcrop the springs are given out high up, apparently from a loose glauconitic sand only a few feet under the Chalk.

One other section within our area deserves special mention. A well made in 1844 at Gatehouse's brewery, Chichester, is said to have penetrated 84 feet of "Malm Rock containing Iron Stone Nodules," this rock being first reached at 970 feet below the surface, and 790 feet below the base of the Eocene deposits. It is difficult to understand this old section (which will be again referred to): but I cannot help doubting whether the Lower Chalk was really penetrated, and whether the so-called malm rock was not merely part of the Chalk Marl. The Chalk Marl along part of the escarpment of the South Downs is silty and micaceous, and might readily be taken for malm rock, when obtained blue and unweathered. If the Upper Greensand was really met within this well, the Chalk must be exceptionally thin. The new boring at Goodwood (see p. 32) leaves little doubt that the Chalk at Chichester must be more than 1,000 feet thick.

CHAPTER V.

CHALK.

More than a third of the area under consideration is occupied by Chalk, which forms the undulating hills known as the South Downs. These rise at their escarpment, which overlooks the Weald, to 700 or 800 feet above the sea, the highest points being found towards the west, where Linch Down touches 818 feet, and Duncton Down reaches 837 feet.. The South Downs fall naturally into two divisions, separated by the transverse valley of the Arun. East of the Arun they are mainly bare and treeless; west of the Arun beech-wood and copse form a conspicuous feature. This difference, however, is probably due more to climatic than to geological causes, for as the area of high down becomes wider, the average height greater, and we travel westward into moister regions, the hills are more and more often capped with mists.

The Chalk out of which these hills are carved is of considerable thickness, being more than 1,000 feet at Goodwood Park, though a good deal of the upper part of the formation had been destroyed before the overlying Eocene strata were laid down. Though the whole of this thick mass would ordinarily be spoken of as "chalk," yet a cursory examination is sufficient to show that it falls naturally into three divisions—a white soft Upper Chalk with many flints, a white harder Middle Chalk without flints, and a grey marly Lower Chalk, which last shows trace of a division into firm greyish-white and grey chalk above and marl below. Besides these three lithological divisions, and some subordinate beds of varying texture and hardness, which will be described further on, the Chalk is divisible into a series of zones, each characterised by a peculiar assemblage of fossils, and these zones remain constant over wide areas, notwithstanding considerable lithological changes. Palæontological zones, however, have not hard and fast boundaries, but tend to merge one into another as the fauna changes slowly with the lapse of time. In this particular area no sudden breaks have been noticed in the Chalk or in its successive faunas. The zones now commonly recognised in Britain are as follows:—

Zone of Ostrea lunata	Upper Chalk.
„ Belemnitella mucronata	
„ Actinocamax quadratus	
„ Marsupites testudinarius	
„ Micraster coranguinum	
„ Micraster.cortestudinarium	
„ Holaster planus	
„ Terebratulina	Middle Chalk.
„ Rhynchonella Cuvieri	
„ Holaster subglobosus	Lower Chalk.
„ Ammonites varians	

The uppermost two of these zones, however, and the greater part of the next one, that of *Actinocamax quadratus*, are believed to be missing in this part of Sussex.*

Lower Chalk.

On following the outcrop of the Lower Chalk from west to east, we find that it forms a belt of fairly uniform width throughout our district. This belt lies at the foot of the downs, or forms the lower and gentler slopes of the escarpment; it is undulating, marly and moist, forming excellent arable land, which changes into open down and sheep-pasture when the boundary of the Middle Chalk is passed. The change, however, does not coincide exactly with the geological boundary, for the large amount of wash and talus from the steeper hills above, tends to make the dryer soil of the Downs transgress some distance over the wetter Lower Chalk.

Owing to the wash from the hills above and other causes, continuous sections are seldom visible in our district, and it is difficult to obtain accurate measurements of the thickness. This difficulty is increased in another way, not usually taken into account, for it is impossible to place any reliance on the dips which can be measured. The general dip is southward; but nearly always the angle of the dip is increased by the weight of the hill above, which, pressing downward on the soft Lower Chalk, tends to tilt up its free edge, thus exaggerating the apparent amount of the dip. In the same way dips taken in soft deposits on a foreshore under high cliffs are never trustworthy; there is usually a tendency to dip inward toward the cliff. Making allowance for these uncertainties, the relation of the geological boundaries to the contour-lines suggests a thickness of 180 to 200 feet for the Lower Chalk, the deposit being apparently somewhat thicker in the east and south than in the west.

Along the western part of the outcrop of the Lower Chalk exposures are few, the old pits being much overgrown, and no clear section of either the top or the bottom of the division being now visible. Soft massive chalk seems to constitute the upper part, and marl more or less sandy and silty the lower part.

Around Cocking sections are clearer, and the basement beds are fairly well seen near Sunwool Farm, and in the road south of the village. Still further south there are several good sections in the massive grey chalk, which is worked for lime, and can also be seen around the spring at Crypt Farm. It appears as if this spring were given out at the junction of the grey chalk with the chalk marl below; but it may rise along a line of fault, for, at this point, there is an obscure disturbance, which may be either a small fault or one of the minor folds already mentioned.

The sections south of Heyshott are more satisfactory, road-

* The information on the Chalk is taken largely from Mr. A. J. Jukes-Browne's Memoir on the Cretaceous Rocks of Britain, vols. ii. and iii. (*in the Press*).

cuttings and old quarries giving the following succession, though the exposures do not admit of accurate measurements:—

Middle Chalk . . .	Melbourn Rock.
Lower Chalk . .	Belemnite marl.
	Coarse-grained chalk.
	Massive grey chalk.
	Chalk marl.
	Hard sandy glauconitic marl.
Greensand.	

The "coarse-grained chalk" was exposed in the roadway, but not seen in the quarries. The estimated thickness is here between 180 and 200 feet.

There are two quarries in the Lower Chalk south of Duncton Church. The lower of these is now disused and talused, but we are informed by Mr. R. M. Brydone that a good section of the Chalk marl was formerly exposed here, and that he obtained many fossils from it. He has kindly communicated the following information and list of fossils.

"The greater number of the fossils came from the lowest band in the pit, a bed of dark bluish-grey marl about 4 feet thick, soft when wet, but drying to a hard marl, and having a notably

FOSSILS OF THE LOWER CHALK.

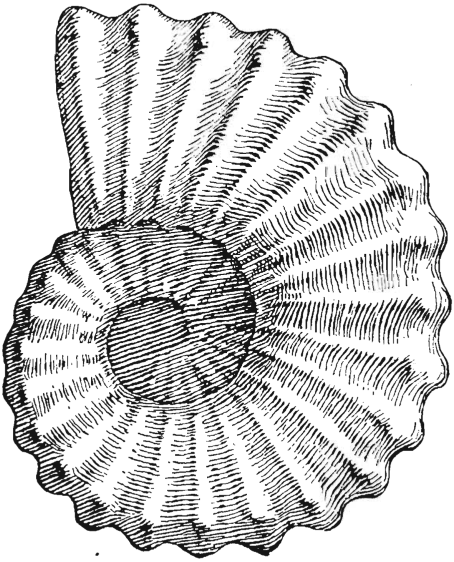

FIG. 6.

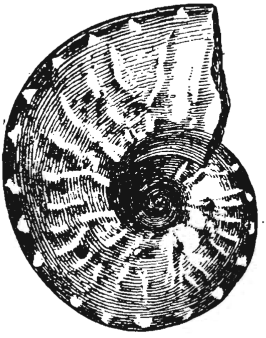

FIG. 7.

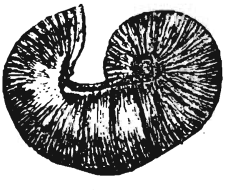

FIG. 8.

FIG. 6. Ammonites [Acanthoceras] rotomagensis, *Brong* ($\frac{1}{2}$ natural size).
FIG. 7. Ammonites [Schloenbachia] varians, *Sow.* ($\frac{3}{4}$ natural size).
FIG. 8. Scaphites æqualis, *Sow.*

conchoidal fracture. *Brachiopoda*, *Serpulæ*, and *Onchotrochus* were especially abundant in this marl; other fossils were less common. Above this is about 10 feet of lighter grey chalk with few fossils, succeeded by a bed of very hard chalk mottled in light and dark grey, and containing many *Cephalopoda*."

The floor of the pit from which these fossils came is probably about 50 feet above the base of the Chalk.

A little to the eastward, and about 100 feet higher up the slope, is another quarry and limekiln where about 60 feet of chalk are shown, belonging to the zone of *Holaster subglobosus*. Mr. Brydone has here found the species noted below, but says that fossils, except *Ostreidæ*, were scarce.

FOSSILS OF THE LOWER CHALK.

	A. varians Zone. Duncton.	H. subglobosus Zone. Duncton.
Cimoliichthys lewesiensis, *Leidy*	—	x
Enchodus lewesiensis, *Mant.*	x	—
Lamna appendiculata, *Ag.*	x	x
Ammonites [Acanthoceras] navicularis, *Mant.*	x	—
" " rotomagensis, *Brongn.* (Fig. 6)	x	—
" [Schloenbachia] varians, *Sow.* (Fig. 7)	x	—
" " Coupei, *Brongn.*	x	—
" sp.	—	x
Baculites baculoides, *d'Orb*	x	—
Scaphites æqualis, *Sow.* (Fig. 8)	x	—
Turrilites tuberculatus, *Bosc.*	x	—
Nautilus elegans, *Sow.*	x	
Cerithium ornatissimum ? *d'Orb*	x	x
Natica sp.	x	.
Pleurotomaria sp.	x	—
Solarium sp.	x	—
Exogyra haliotoidea, *Sow.*		x
Inoceramus striatus, *Sow.*	x	-
" sp.	—	x
Lima elongata, *Sow.*	x	—
" globosa, *Sow.*	x	x
Ostrea acutirostris, *Nilss.*	x	—
" vesicularis, *Lam.*	x	—
Pecten Beaveri, *Sow.*	x	—
" orbicularis, *Sow.*	x	x
" (Neithea) 5-costata, *Sow.*	x	x
Plicatula inflata, *Sow.*	x	x
Magas Geinitzi, *Schloenb.*	x	—
Rhynchonella grasiana, *d'Orb.*	x	—
" mantelliana, *Sow.*	x	—
" Martini, *Mant.*	x	—
Terebratula squamosa ? *Mant.*	x	—
Terebratulina striata, *Wahl.*	x	x
Pollicipes sp.	x	—
Serpula ampullacea, *Sow.*	x	x
" annulata, *Reuss*	x	—
" macropus, *Sow.*	x	x
" umbonata, *Sow.*	x	—
" plexus, *Sow.*	x	—
" " var. gordialis, *Schloth.*	x	—
Echinocyphus difficilis, *Ag.*	—	x
Holaster sp.	—	x
Pentacrinus sp.	—	x
Onchotrochus serpentinus, *Dunc.*	x	—

Again, in the lane leading up West Burton Hill, Mr. W. Hill saw beds of greyish-white chalk alternating with beds of marly chalk; *Ammonites varians* and *Am. Mantelli* occurred frequently at a spot considerably more than 100 feet above the base of the Chalk. Ascending the lane these beds give way to more massive lighter coloured chalk, and the top of the Lower Chalk is reached a little to the north of the tumuli, but there is no clear section, and the Belemnite Marls were not seen.

Immediately south of Bury some glauconitic sandy marl, seen in the roads to Bury Hill and to Houghton, must be very near the base of the Chalk. The middle of the Lower Chalk is not exposed: but a quarry at the foot of Bury Hill shows an excellent section of grey chalk, passing upwards into the "Belemnite marl" (here about 10 feet thick), which again is capped by Melbourn Rock. The characteristic belemnite of this marl (*Actinocamax plenus*) does not appear yet to have been found at this locality, and throughout our area the Belemnite marl is sparingly fossiliferous. At Bury the southward trend of the escarpment causes the level of the base of the chalk to sink rapidly, so that near Houghton the whole of the Lower Chalk is lost beneath the sea-level. This trenching of the Downs by a transverse valley, and the consequent change of direction of the geological boundaries, enables us to calculate the dip, which here appears to be about 4°, almost due south.

A curious point, not exactly geological though connected with geology, may be referred to in connection with the area just described. Some parts of the slopes are too steep for cultivation and are clothed, and seem always to have been clothed, with ancient hanging woods, locally known as "hangers," principally of beech, with some undergrowth of holly and hazel. So little of the primæval forest is anywhere left in Sussex, except on the heavy clay lands of the Weald, that it is interesting to find these small outliers still remaining. They contain rare woodland animals and plants such as one does not find in the forests of the Weald. Among the mollusca, both *Helix obvoluta* and *Clausilia Rolphii* are to be found, and among the plants Solomon's seal, and herb Paris. In one of these woods the zig-zag connecting the Roman Stone Street with the lowlands is well seen.

East of the Arun sections are more frequent, and there is less woodland and copse over the Lower Chalk. Though the actual base is not seen near Amberley, the railway cutting near the village shows some beds not much above. They consist of hard, bluish marl with small grains of glauconite and flakes of mica. The south end of this cutting is much overgrown, but shows sandy marl, which seems to mark the junction with the grey chalk above. The next few feet cannot be examined, but a quarry near by continues the succession, probably nearly up to the Belemnite marl; it is thus described by Mr. W. Hill: "Mr. Pepper's quarry, about a quarter of a mile north of Amberley Station, is about 80 feet deep; 60 feet of this is in massive smooth white chalk, passing down into greyer chalk, the lowest 10 or 12 feet being in courses divided by marly bands. In the floor of the quarry a narrow working disclosed about 20 feet more of grey chalk and grey marl in alternating courses. No fossils were seen, nor did the quarrymen possess any."

Between Amberley and Sullington Hill a grey siliceous chalk appears at various places, apparently on the same horizon as the sandy bed seen in Amberley cutting. In the road to the Downs from Amberley village this bed is a hard fine-grained calcareous sandstone with *Pecten*, and makes a noticeable feature, which has been traced eastward to the limit of our district. Near this limit a series of sections will be found, those below Chantry Hill and Sullington Hill being particularly good. At Chantry Hill the junction of the Middle and Lower Chalk can be seen. At Chantry Farm the road-cutting, probably about 30 feet up in the Chalk, shows fine-grained grey gritty marl, full of small brachiopods, among which Dr. Kitchin identified *Kingena lima*, *Rhynchonella grasiana*, *R. mantelliana*, *R. martini*, *Terebratula semiglobosa*?, *T. squamosa*, *Terebratulina striata*, and also *Serpula umbonata*. Above this comes grey marl or marly chalk, but the sections are obscure till the Belemnite marl and the Melbourn rock are reached. The total thickness of the Lower Chalk seems here to be 200 feet.

Middle Chalk.

This division consists of hard white irregularly bedded chalk, full of fragments of *Inoceramus*, but not usually yielding many other fossils. At its base it becomes still harder and more rocky, forming the Melbourn Rock, which, however, though sharply distinguished from the Belemnite marl below gradually merges upwards into Middle Chalk of the usual type. The thickness of the Melbourn Rock is about 10 or 15 feet; the total thickness of the Middle Chalk about 200 feet.

The Middle Chalk occupies a great part of the steep face of the escarpment of the Downs, its outcrop is also continued in a long spur through the middle of the Downs, from Upper Waltham to West Dean, and it reappears also as inliers in the valleys at Binderton and Stoughton. Notwithstanding this considerable exposure, good sections are not very common, most of our knowledge being derived from the large pits at Amberley and Houghton. We will trace this division also from west to east along the escarpment; afterwards describing the exposures in the interior of the Downs. The hard Melbourn Rock, resting on the exceptionally soft Belemnite marl, tends to make a distinct ledge or terrace in the face of the escarpment, especially in the eastern part of our area, where the difference in hardness is strongly marked. Towards the west this ledge is not so striking a feature, though there is seldom much difficulty in fixing exactly the position of the base of the Middle Chalk. Its upper limit, however, is much more difficult to define; for the Chalk Rock, which over wide areas divides the Middle from the Upper Chalk, is non-existent in this district, and a boundary has to be drawn at or near the level on which the first regular bed of flints makes its appearance. The fossils of the Chalk Rock, which can sometimes be found occupying a narrow zone even where the rock itself is missing, have not been recognised in our area.

In the escarpment near Treyford the Melbourn Rock does not seem to be noticeably different from the rest of the Middle Chalk; but there are no clear sections. The higher part of the division, however, is visible in the road-cuttings and pit east of Buriton Farm, where a few grey flints extend down into the Middle Chalk. The Chalk Rock was not recognized in the pit, but perhaps its fossils might be found there with longer search.

Below Linch Down hard chalk with *Inoceramus* is seen in the road-cutting; but neither top nor bottom of the Middle Chalk is quite satisfactorily defined. A mile to the east, however, the Melbourn Rock runs out in a bold spur on Bepton Down, and the transition from flintless to flinty chalk is also easy to trace in the road 200 feet higher. Here F. Sargent observed 3 or 4 inches of fuller's earth in the Chalk (*Geol. Trans.*, vol. i., p. 168).

At Cocking the Melbourn Rock makes a clear, well-defined feature, and the railway-cutting south of the tunnel shows an excellent section of the junction of the Middle with the Upper Chalk. A thin hard bed in the road to Cocking (West) Down may represent the true Chalk Rock; but this seam could not be found in the railway cutting. The Chalk Rock should appear also in the old pits and cuttings at the west edge of Cocking (East) Down, where chalk with thick-skinned black and grey flints seems to pass down into hard flintless chalk with *Inoceramus*; however, it could not be found.

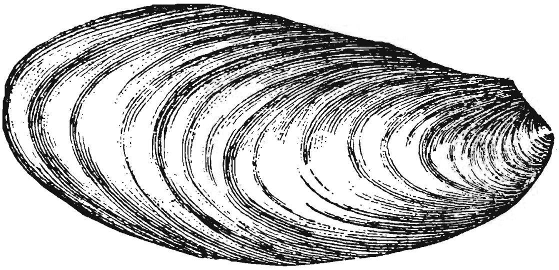

FIG. 9.

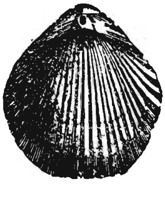

FIG. 10.

FIG. 9. Inoceramus mytiloides, *Mant* (half natural size.)
FIG. 10. Rhynchonella Cuvieri, *d'Orb*, (twice natural size.)

The next sections of interest are met with at Graffham, where, in the roads leading to the Downs and in the pit near by, the hard Melbourn Rock is well seen, while the gradual passage into flinty chalk can be traced in the roads 200 feet above. Here also no rock of exceptional hardness could be found at the junction with the Upper Chalk.

Barlavington Downs is one of the best places for examining the Middle Chalk; for the division has there an exceptionally wide outcrop, and pits expose a considerable part of the thickness. The cutting on the high road to Chichester exposes the Melbourn Rock, resting on Belemnite marl. A pit immediately above shows 40 feet of rough nodular chalk, which belongs to the zone of *Rhynchonella Cuvieri* (Fig. 10), that fossil and *Inoceramus mytiloides* (Fig. 9) being abundant. Another pit, in Duncton Hanger, which is a quarter of a mile south-east of

Duncton Church, exposes 90 feet of this chalk, including the top of the Melbourn Rock. A third pit, higher up and on the west side of the Chichester road, perhaps exhibits the junction with the Upper Chalk; but, unfortunately, the lower part of this pit is hidden by talus, and I am not sure that the Middle Chalk has been reached.

The best sections in our district are those in the large chalk-pits of Bury and Amberley. On the road from Bury to Arundel two pits will be found; the lower one showing Melbourn Rock resting on Lower Chalk, the higher showing hard chalk with marl seams and a few scattered flints. The upper pit seems nearly to reach the Chalk Rock. The shallow road-cutting above Houghton village shows a thin hard bed which may be the true Chalk Rock.

Rough nodular chalk which cannot be far above the Melbourn Rock is exposed in the most northern part of the large quarry by Amberley station, close to the main road. About 25 or 30 feet of this chalk is seen, and from it Mr. Hill obtained *Inoceramus mytiloides* and a few *Rhynchonella Cuvieri*.

The best section of the zone of *Terebratulina* in western Sussex is that in the large quarry by Amberley station. Writing of this quarry Dixon said:* "The large quarry on the opposite side of the River Arun (to Houghton) is called Balcombe-pit, and is of the Lower Chalk formation, or that without flints." Among fossils found here he mentions *Radiolites*, "bones of turtles and fishes in very good preservation, particularly *Beryx ornatus* and *Macropoma Mantelli*, Echinoderms and Crustaceans, especially *Enoploclytia Leachi*. The nodules of sulphide of iron here often contain a *Terebratula* or other small shell in the centre, which elsewhere is rare."

Professor Barrois has also described this pit, giving the following particulars †:—

	Feet.
5. Compact chalk with scattered flints.	
4. Shaly chalk with scattered grey flints, *Terebratula semiglobosa*, *Inoceramus sp.*	6½
3. Layer of yellowish nodules.	
2. Homogeneous white chalk, in courses separated by seams of grey marl	82
1. Hard compact white chalk, in beds about 3 feet thick separated by marly seams, which contain nodules (of chalk)	33
	About 121

Mr. W. Hill visited the quarry in 1897, and contributes the following note: Here about 110 feet of Turonian Chalk is traversed; about a third of the main face is now obscured by talus, but smaller cuttings to the right and left expose the lower parts. The chalk is for the most part soft and white; flints occur near the top, and there is at least one layer of large,

* Geology of Sussex, Second Edition. 1878, p. 130.

† Recherches sur la Craie d'Angleterre et de l'Irlande, p. 33.

massive flints. *Terebratulina gracilis* var. *lata* is fairly common, *Spondylus spinosus* and *Sp. latus* (?) also occurred, and in a fallen block containing some of the large flints a crushed Echinoderm, apparently *Holaster planus*, was found.

Mr. Jukes-Browne has compiled the following list of Middle Chalk fossils from Amberley and Houghton:—

	Zone of Rhynch. Cuvieri.	Zone of Tereb. gracilis.	Zone unknown.
Pisces.			
Beryx, see Ctenothrissa and Hoplopteryx			
Corax maximus, *Dixon*	—	—	x
Ctenothrissa radians, *Ag.*	x		
Enchodus lewesiensis, *Mant.*	—	—	x
Hoplopteryx lewesiensis, *Mant.* (ornatus, *Ag.*)	—	—	x
Lamna appendiculata, *Ag.*	x		
Oxyrhina Mantelli, *Ag.*	—	x	
Lamellibranchiata.			
Inoceramus Brongniarti, *Sow.*	—	x	
„ mytiloides, *Sow.*	x		
Ostrea semiplana, *Sow.*	x		
Plicatula sigillina, *Woodw.*	—		x
Radiolites Mortoni, *Mant.*	—	—	x
Spondylus latus, *Sow.*	—	x	
„ spinosus, *Sow.*	—	x	
Brachiopoda.			
Rhynchonella Cuvieri, *d'Orb.*	x	x	
Terebratulina gracilis, *Schloth.* var. lata, *Eth.*	—	x	
„ striata, *Wahl.*	—	x	
Terebratula semiglobosa, *Sow.*	x	x	
Crustacea.			
Enoploclytia Leachi, *Mant.*	—	x	
Echinodermata.			
Galerites subrotundatus, *Mant.*	—	x	
Holaster planus, *Mant.*	—	x	

The sections in the escarpment east of Amberley call for no remark.

On returning westward to Bignor and Barlavington we find a break in the escarpment, and a pass connecting with the Lavant valley, through which the high-road to Chichester is carried. For a considerable part of its course this valley nearly coincides with an anticline, which brings up the Middle Chalk all the way to West Dean. The sections in the upper part of this valley are poor; but there are doubtful indications of the hard Chalk Rock in the road west of Upper Waltham and in that north of East Dean. In the exposure at East Dean chalk with flints can be seen immediately above, and chalk without flints can be traced down to the village. More than half the thickness of the Middle Chalk must here be cut through by the valley. A pit on the south side of the valley, above Manor Farm, shows a section which may be entirely in Middle Chalk or may show the junction with the Upper Chalk. I do not think, however that the very hard chalk is the Chalk Rock. The measurements are:—

	Feet.
Chalk with marl seams	15
Very hard chalk	2
Chalk with marl and a seam of gray flints	5

The railway cuttings near Singleton and West Dean showed excellent sections of the hard chalk without flints; but none of them seem to reach beds more than 100 feet down in the Middle Chalk. A pit by the road side north-west of the Station shows 25 feet of hard chalk, and a few feet above flinty chalk crops out in the road. Another pit, on the road to Chilgrove, exposes a characteristic section of the upper part of the division:—

	Ft.	In.
Hard rubbly chalk	6	0
Grey clay	0	2
Hard chalk	2	0
Tabular flints	0	2
Hard chalk	7	0

Still lower there is hard chalk with a few flints, and it may be observed that as we travel westward, or perhaps rather south-westward, there is a noticeable tendency of flints to become more common and to extend further down into the Middle Chalk. The occurrence of tabular flint in this division is, however, unusual; but just beyond our limits, in the bottom of the valley west of Bow Hill, a thin tabular flint was noticed more than 100 feet down in the Middle Chalk. A pit about 100 feet above, and at the west end of Lambdown Hill, shows hard nodular chalk with a line of grey flints at the top, whilst the road between exposes only hard chalk without flints.

The Middle Chalk has also been reached in two wells, the one at Chichester, the other at Goodwood. The well at Gatehouse's Brewery in Chichester was made so long ago (1844) that the record is not easy to interpret. It can only be suggested that the 4-foot bed met with 600 feet down in the chalk and described as "crystallised carbonate of lime" represents the Chalk Rock, which is often markedly crystalline. A small fragment which happened to be preserved, shows it to be a very hard crystalline chalk.

Upper Chalk.

The greater part of the Downs is carved in the flinty Upper Chalk, which reaches a thickness of 600 feet, though several hundred feet of the upper strata, represented in adjoining counties, are here missing. The whole of the zone of *Belemnitella mucronata* and probably great part of that of *Actinocamax quadratus* are absent. Much, however, remains to be done before the palæontological divisions in this area can be considered as thoroughly known; at present our knowledge of the fossils is confined mainly to the valley of the Arun, and to the disturbed chalk of Highdown Hill. The following account of the Upper

Chalk of the Arun Valley is by Mr. Jukes-Browne (from notes taken by Mr. W. Hill and Mr. R. M. Brydone) :—

No good sections of the zone of *Holaster planus* (Fig. 13) were found near Amberley, but it is traversed by the cutting for the railway about half a mile south of the station, at the east end of a short tunnel. The chalk here is lumpy and of a creamy-yellow tint; no continuous section can be taken, but *Micrasters* are very numerous, and are all of the varieties termed "low-zonal" by Dr. A. W. Rowe; they are associated with *Echinocorys scutatus* (Fig. 14), *Rhynchonella plicatilis, Rh. reedensis, Terebratula carnea,* etc. These beds probably belong to the upper part of the *Holaster planus* zone.

Higher beds, including the greater part of the *M. cortestudinarium* zone, with part of the overlying *M. coranguinum* zone,

FOSSILS OF THE UPPER CHALK.

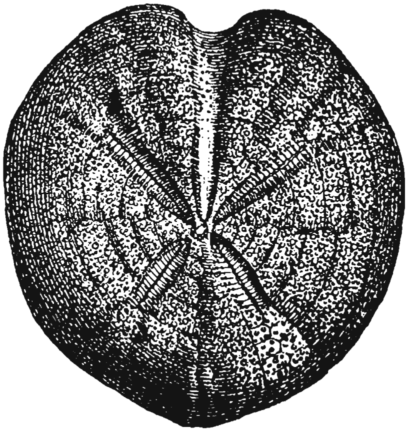

FIG. 11

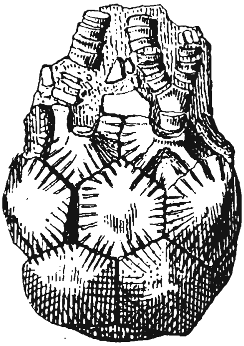

FIG. 12.

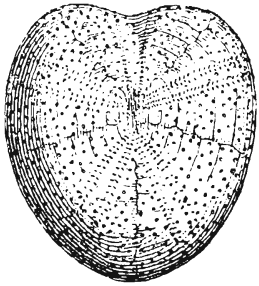

FIG. 13.

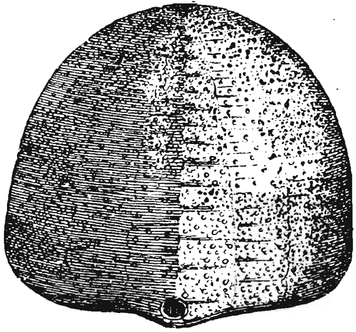

FIG. 14.

FIG. 11. Micraster coranguinum, *Leske.*
FIG. 12. Marsupites testudinarius, *Schloth.*
FIG. 13. Holaster planus, *Mant.*
FIG. 14. Echinocorys scutatus, *Leske.* (Three-quarters natural size.)

are exposed in the large quarry south-west of Houghton. The section here is given below. Mr. Rhodes obtained *Micraster cortestudinarium*, *M. præcursor*, *Holaster planus*, *Rhynchonella plicatilis* and *Lima Hoperi* from a bed of "greyish chalk" in this quarry.

Parts of these higher zones are exposed also in the quarry on Duncton Hill, about two-thirds of a mile south-west of Duncton church. The lower part was found to be obscured by *talus*, but the face above this exposed about 2 feet of hard nodular chalk, surmounted by 20 feet of chalk, with many flints, which are grey inside. This probably includes the junction of the zones of *H. planus* and *M. cortestudinarium*.

We are indebted to Mr. R. M. Brydone, for the following list of fossils which he has found in this quarry:—

Ostrea vesicularis.
Exogyra haliotoidea.
Inoceramus sp.
Plicatula Barroisi.
Terebratula semiglobosa.
Rhynchonella plicatilis.
„ reedensis.
Cidaris clavigera.
Cyphosoma sp.
Echinocorys gibbus.
Holaster planus.
Micraster sp.
Pentacrinus sp.

The lower part of the *M. coranguinum* zone and its junction with the *M. cortestudinarium* zone are exposed in the large quarry south-west of Houghton. The section here was taken by Mr. William Hill in 1897, and is as follows:—

		Ft.	In
	Chalk with layers of flints (inaccessible) - - - - (?)	50	0
	Seam of flint, nearly continuous, but breaking here and there into nodules - - - - - - - - - - -	0	2
	Rather hard white chalk with scattered flints, yielded a typical *Micraster coranguinum* (Fig. 11) - - - -	10	0
	Continuous seam of flint - - - - - - - - - -	0	3
	Rather soft white chalk with a few scattered flints near the base - - - - - - - - - - - - - -	5	0
	Soft mealy chalk, with lumps of hard yellowish compact chalk, with many Micrasters and other fossils - -	1	6
	Thin seam of marl - - - - - - - - - - -	0	1
	A massive bed of firm white chalk, with a few scattered flints near the base - - - - - - - - -	3	0
	Massive bed of rough lumpy chalk, hard creamy yellow lumps cemented together in a matrix of lighter colour, the whole course being hard - - - - - - - -	3	3
Zone of *M. cortestudinarium*.	Continuous seam of flint - - - - - -	0	2
	Hard white chalk veined with grey - - - -	2	6
	A conspicuous layer of large flints - - - - -	0	8
	Smooth and firm white chalk, rather broken up where measurements were taken, forming a sort of ledge in this part of the quarry - - - -	4	6
	Massive firm white chalk without flints - - - -	3	6
	Massive firm white chalk, with flints both scattered and in layers ; no fossils seen - about	50	0
	About - - - - - - - - - - - -	134	0

Owing to the scarcity of fossils the exact limit-plane between the zones cannot be determined, and it is possible that it should be taken rather higher up than we have placed it.

Other pits to the southward show white chalk with layers of black flints, featureless, but unquestionably belonging to the zone of *M. coranguinum*. From one half a mile west of South Stoke Mr. Rhodes obtained *Septifer* (*Modiola*) *lineatus*, *Micraster coranguinum* and *Ventriculites cribrosus*.

A large quarry at the back of the Black Rabbit Inn appears to show the junction of the *M. coranguinum* and *Marsupites* zones. Mr. Hill reports that the lower 60 or 70 feet here exposed consists of firm chalk with many layers of black flints; the upper 50 feet shows soft chalk with few flints; only a few sparsely scattered nodules or in lines at distant intervals.

Similar chalk with few flints is seen in the river-cliff at Burpham, on the eastern side of the valley. This was searched by Mr. Rhodes, who found *Marsupites* (Fig. 10) in a band, which is first seen about 50 feet above the river, but comes down to the water-level further south. About 15 feet above this band he found a bed of oysters like that at Burwells Farm, Lancing. Near the top of the cliff he noticed a layer of lumpy yellow-stained chalk, containing some *Serpula*, *Bryozoa*, and decomposed Sponges.

The section is continued in a pit by the high road west-north-west of Warningcamp Hill, of which pit Mr. Rhodes made the following note:—"About 10 feet above the floor of the pit is a bed of stained chalk, containing rotted sponges, *Serpula*, and a layer of flint nodules, which seems to be the same as that seen at the top of Burpham Cliff. Above this is chalk with few flints, and about 22 feet above the floor is a 4-inch layer of marl, succeeded by chalk with marly layers, for 12 feet, in which *Offaster pillula* is common." This may be regarded as the base of the *Act. quadratus* zone. The large pit on Warningcamp Hill shows chalk with some thin flint floors and frequent layers of flint nodules, and is probably in the *Act. quadratus* zone, though its base may be in the lower zone, as Mr. Rhodes found a *Marsupites* plate here. By the side of a small stream west of Arundel is a pit in chalk with layers of black flints, probably in the *Act. quadratus* zone, though no *Belemnite* was found.

The list of fossils collected by Mr. Rhodes from the quarries above mentioned is given on p. 32.

In the hope of finding softer water in the Lower Greensand than that obtained from the Upper Chalk, an old well near the Kennels at Goodwood has been deepened recently, and the boring has reached a depth of no less than 1,012 feet without penetrating the Chalk. As the Goodwood boring gives the only nearly complete measurable section through the Chalk of West Sussex, details are given below, as far as they can be ascertained. Unfortunately, at the time of my visit in December, 1902, the large cores had been exposed to the weather for several months, and the figures denoting depths had all disappeared. Only one core, from within 7 feet of the lowest point, could be identified. It has only been possible, under these circumstances, to draw up a section from details and small samples communicated by the well-sinkers, Messrs. Le Grand and Sutcliff, and from some additional information obtained on the spot, through the Hon. W. F. Dundas.

The well is situated half a mile north-west of Goodwood House, and is almost on the 200-feet contour line. It is distant about a mile and a-half from any Eocene strata, and some part of the Upper Chalk may therefore be missing. Probably the thickness of the missing Chalk, seen further south, does not exceed 200 feet; this would make the total thickness of the Chalk in West Sussex somewhere about 1,200 feet. Possibly the lateral pressure which formed the Chichester syncline may have slightly increased the apparent thickness of the softer parts of the Chalk, for the Lower Chalk is decidedly thicker than would have been expected at this point. The lowest bed reached would appear, from its lithological character, to be close to the base of the Chalk, and probably within ten feet of the Upper Greensand.

The particulars of this well are as follows, notes in square brackets referring to specimens examined:—

		Thickness. Feet.	Depth. Feet.
Upper Chalk.	Old dug well	0	134½
	Old boring (11-inch) shelled out in chalk with flints	0	412
	Chalk and flints	5	417
	„ „ „ free cutting, and water	22½	439½
	Very hard chalk	¾	440¼
	Chalk and flints	19¾	460
	„ „ „ hard	12	472
	„ „ „	26	498
	„ „ „ very hard	13	511
	„ „ „	43	554
	„ „ „ very hard	5	559
	Sticky chalk and flints	7	566
	Chalk and flints, very hard	8	574
Chalk Rock?	Hard rock chalk	12	586
	Softer chalk	2½	588½
	Hard rock chalk	9	597½
Middle Chalk.	Softer chalk	6½	604
	Hard „	31	635
	Softer „	2½	637½
	Hard „	16	653½
	Very hard chalk	4½	658
	Hard „	32	690
	Very hard „	2	692
	Hard „	5½	697½
	Very hard „	2½	700
	Hard „	110	810
Lower Chalk.	Grey „ [fish scales and pyrites at 823½ ft.]	13½	823½
	Hard grey „ [fish scales, pyrites, and a little mica at 889 ft. [Alternating grey chalk and soft grey marly chalk]	178½	1002
	[Darker grey hard rock with *Serpula plexus* and much insoluble residue of flinty silica, quartz, mica, and a little glauconite at 1,002 ft. [Lighter-grey hard rock with numerous fucoid-like impressions.]	10	1012

Between 445 and 500 feet a spring was met with in the Upper Chalk. It yielded over 40 gallons per minute, pumping 8 hours a day. No water was found below this spring, and the boring was abandoned at 1,012 feet.

——	Houghton.	Burpham.	Warningcamp.	Warningcamp Hill.	Arundel.
Ctenothrissa	—	x	—	—	—
Fish vertebræ	—	—	—	x	—
Inoceramus sp.	x	x	x	x	—
Lima Hoperi, *Sow.*	x	—	—	—	—
Ostrea acutirostris, *Nilss.*	—	x	—	—	—
„ normaniana, *d'Orb.*	—	x	—	—	—
„ semiplana, *Mant.*	—	—	—	x	—
„ vesicularis, *Lam.*	x	x	—	x	—
Pecten (Chlamys) cretosus *Defr.* = nitidus, *Mant.*	—	—	x	x	—
„ (Neithea) quadricostatus, *Sow.*	—	x	—	—	—
„ „ quinquecostatus, *Sow.*	—	x	—	x	x
Spondylus dutempleanus, *d'Orb.*	—	x	—	—	—
„ spinosus, *Sow.*	x	x	—	—	—
„ striatus ? *Sow.*	—	—	x	x	x
Crania sp.	—	x	—	—	—
Kingena lima, *Defr.*	—	x	—	—	—
Rhynchonella limbata, *Schloth.*	x	x	?	x	x
„ plicatilis, *Sow.*	x	x	—	—	—
Terebratula biplicata ? *Sow.*	x	—	—	—	—
„ semiglobosa, *Sow*	x	—	—	x	—
Terebratulina Rowei, *Kitch.*	—	x	—	—	—
„ striata, *Wahl.*	—	x	—	—	—
Alecto sp.	x	x	—	—	—
Bidiastopora sp.	—	x	—	—	—
Bernicea papillosa, *Reuss*	x	—	—	—	—
„ sp.	—	x	—	—	—
Entalophora obliqua ? *d'Orb.*	—	—	—	—	x
„ sp.	—	x	—	x	—
Eschara sp.	—	x	—	—	x
Escharina sp.	—	x	—	x	x
Idmonea sp.	—	—	—	x	—
Pustulipora (Hammia) pustulosa, *Goldf.*	—	x	—	—	—
Semieschara sp.	—	—	—	x	x
Pollicipes sp.	—	—	—	x	—
Serpula ampullacea, *Sow.*	—	—	—	—	x
„ plexus, *Sow.*	x	x	x	—	—
„ pusilla, *Sow.*	—	—	—	—	x
„ turbinella *Sow.*	—	—	—	x	x
Terebella lewesiensis, *Davies*	—	—	—	—	x
Bourgueticrinus ellipticus, *Goldf.*	—	x	—	—	x
Cidaris (spines)	—	—	—	x	x
Echinocorys scutatus, *Leske*	x	x	x	x	—
Galerites (= Echinoconus)	—	x	—	—	—
Goniaster (ossicles)	—	x	—	x	—
Marsupites testudinarius, *Schloth.*	—	x	—	x	—
Micraster coranguinum, *Klein*	x	?	—	—	—
„ sp.	x	—	—	—	—
Offaster pillula, *Lam.*	—	x	x	—	—
Parasmilia sp.	—	x	—	—	—
Porosphæra globularis, *Phil.*	—	x	x	—	x
„ urceolata, *Phil.*	—	—	—	x	—
„ Woodwardi, *Carter*	—	x	x	x	—
Callodictyon sp.	—	x	x	—	—
Placotrema cretaceum, *Hinde*	x	—	—	—	—
Ventriculites cribrosus, *Phil.*	x	—	x	—	—
„ impressus, *Smith*	x	x	—	—	—
„ sp.	—	—	—	—	x

CHAPTER VI.

EOCENE.

Eocene deposits occupy the southern part of our area, crossing it in a sharp synclinal fold, which runs east and west, being bounded on each side by the Chalk. Over the greater part of this region, however, the geological structure is somewhat obscure, and could only be worked out by piecing together every scrap of evidence, from ditch-sections to the numerous well-borings. The reason of this obscurity is that the greater part of the highly inclined Eocene and Cretaceous deposits were afterwards planed down to a nearly level surface, over which gravel has been spread, completely hiding the underlying rock, and suggesting anything rather than an area of high dips and exceptional disturbance. The only part of this region that suggests disturbance, and that yields clear surface evidence, is the extreme east, where the Eocene strata can be seen to lie in a trough or basin which separates Highdown Hill from the main mass of the Downs.

Reading Beds.

The Reading Beds between Highdown and Chichester are exceptionally uniform in character and in thickness. They consist almost entirely of stiff red-mottled clay, with a few flints at the base. The thickness is everywhere about 100 feet. No fossils have yet been found within our area, the nearest being two or three obscure marine shells discovered at Lancing, close to the base of the deposit. It is not uncommon in the Hampshire Basin for a little glauconitic sand with marine fossils to occur near the bottom of the Reading Beds; but in this particular district nothing of the sort has yet been noticed, even in continuous borings which penetrate to the Chalk. The red-mottled clays, which are here the only representatives of the period, seem to be of lacustrine origin; but it is unusual to find fossils in clays of this character.

At the time when the Survey was being made no pits were open in the Reading Beds near Highdown Hill, though abundant indications of the presence of the characteristic red-mottled plastic clay were discovered in the ditches. A well at Patching, communicated by Messrs. Duke & Ockenden, shows that these clays are at least 67 feet thick. Another well, at the Decoy Cottage, close to the ponds in Angmering, is said to have penetrated 149 feet of clay before reaching the Chalk; but no details could be obtained, and it is doubtful how much of this clay may belong to the London Clay. The upper part of the red-mottled clay can still be seen in the railway-cutting close to Arundel Station, though the section is much overgrown and obscured by landslips. A boring in the Station showed at least 88 feet of the clay, Chalk being reached, according to Messrs. Duke & Ockenden, at 106 feet from the surface. The upper beds in this boring, described as London Clay, may be marsh clay of the Arun.

Three small pits near Arundel were the first clear sections met with in travelling westward. The brickyard near the Gas Works showed 5 feet of red-mottled clay, and a small pit at the edge of the wood, east of Park Farm, exposed 7 feet of similar clay. In each of these cases the pit is in the lower half of the mass. Another pit at the north end of Tortington Common was in somewhat higher beds, but the character was the same.

West of Brinsted few clear sections are to be seen, though the Reading Beds occupy a wide area beneath the Drift. Various borings, however, penetrate to the Chalk. One of these, at Barnham Junction, shows a thickness of 108 feet of red and mottled clays, with a bed of flints a foot thick at the base. Another section, at Walberton Brewery, was communicated by Messrs. Ellis & Sons, who had also preserved a series of samples. As this gives a good idea of the general character of the deposits the details are here quoted; but the London Clay should probably be thicker, and the Reading Beds thinner, than is given. Unfortunately the first numbered sample was from 128 feet:—

		Feet
Drift.	Loamy sand - - - - - - - -	about 20
London Clay.	Blue clay - - - - - - -	about 30
Reading Beds.	Mottled clay, at about 50 feet (sample not labelled and doubtful). Red clay at 128 and 146 feet. Lignite and black clay, a thin bed between 150 and 160 feet. Grey clay, at 170 feet. Red clay, at 171, 171 and 173 feet. Hard grey sand, at 174 and 176 feet. Mottled sand and clay, at 183, and 185 feet. Red clay, at 187, 190, and 192 feet. Dark mottled clay, at 193, 194, 196, and 197 feet. Hard bed, at 198 feet.	148
Chalk	- - - - - - - - - - -	115

At Westhampnett the Brick Works, which lie in a shallow valley, cut through the Drift, and show a section of 13 feet of mottled red, blue and black clays. Several of these valleys around Chichester show indications of the same clay; but the only other pit is found at Fishbourne. Borings at Chichester and at Fishbourne prove, however, the total thickness of the Reading Beds; which in the former case are 97 feet, in the latter either 98½ or 106½, the uppermost 8 feet, described as light-grey clay, perhaps representing the base of the London Clay.

London Clay.

The London Clay of our area consists of dark-blue or grey clay with occasional septarian nodules, alternating, especially in the lower part, with beds of fine-grained sandy loam, or even of sand. These in one or two places apparently become hardened into a rock like that which forms Bognor Ledge. At the base of the London Clay there are usually a few perfectly rounded flint-pebbles, this seam becoming of sufficient thickness around Clapham to be dug for gravel and to be mapped separately.

Several pits in this gravel will be found on Clapham Common; but the maximum thickness appears to be less than 10 feet, and no fossils could be discovered in it.

The London Clay occupies two distinct outliers, the one extending westward only as far as Poling, the other commencing a mile to the north-west and stretching continuously in a narrow band nearly to the western edge of our district. Our knowledge of this division has been derived almost entirely from borings and well-sections; for the only exposure of any importance is that seen in the Arundel railway-cutting, which is now much overgrown and obscured by landslips.

At the southern limit of our district almost the whole thickness of the London Clay seems to have been met with in a trial-boring made at Merston for the Bognor Waterworks. The whole of the neighbourhood is obscured by Drift gravel and loam; but the great thickness of the London Clay met with in this boring, and the high dip proved by other wells, suggest that there may be an outlier of Bagshot Sand south of Drayton House. The details of the boring, supplied by Messrs. Docwra & Co., are as follows:—

		Ft.	in.
Made ground and Drift		13	6
London Clay 292½ ft.	Hard blue clay	4	0
	Soft clay with sand	12	6
	Blue clay	16	0
	Sandy clay	2	0
	Blue clay	95	6
	Green sand	1	6
	Hard rock		10
	Blue clay	88	2
	Hard rock	1	0
	Hard blue clay	65	0
	Blue clay	6	0
Reading Beds 99½ ft.	Mottled clay	8	0
	Hard red clay	91	0
	Flints		6
	Chalk and flints	244	6

The two rock-beds may represent the two which form respectively the ledges known as the Barn Rocks and Bognor Rocks on the coast.

No other section in the district equals the one just mentioned in completeness and interest, though a boring at Headhome Farm, in Aldingbourne, proved 235 feet of London Clay, and one at Barnham Junction proved 208 feet. A section and samples of this latter, communicated by the London, Brighton, and South Coast Railway Company, showed:—

		Ft.
Drift		12
London Clay 208½ ft.	London Clay	44
	Sandy loam, with water	thin
	London clay	56
	Rock	1
	Blue clay with septaria	38
	Rock	1
	Blue sandy clay with septaria (stiff at 170 feet)	68½
Reading Beds 109½ ft.	Red and mottled clays	108½
	Bed of flints	1
Chalk		105¾

It will be noticed that in this section again there are two thin beds of rock; but their positions do not correspond with the thin bands found at Merston.

No fossils have yet been recorded from the London Clay of our area, and I have only seen indeterminable fragments in the crushed material brought up by the boring-tools.

CHAPTER VII.

DRIFT.

The drift deposits of this part of Sussex occur in two areas, isolated from one another by the high range of the South Downs; the Downs themselves being free from drift. This isolation, the difference in the character of the deposits, their different mode of origin, and the absence of any clear evidence from fossils, makes any satisfactory correlation between north and south at present impossible. We must, therefore, deal with the two areas separately. Before speaking of the deposits, it will be convenient, however, to sketch in a few words the changes that can be shown to have taken place within the larger district, of which the area now treated is only part.

After the deposition of the Eocene deposits described in the last Chapter, and probably as late as the Miocene period, movements of the earth's crust threw the strata into the folds that have already been alluded to more than once. The principal wave raised the middle part of the Weald high above the area now occupied by the North and South Downs; consequently, the streams received a tendency to flow away from the Wealden axis northward and southward across the Chalk into the London and Hampshire Tertiary basins, each of which basins was drained by a main river, flowing towards the east in the synclinal trough. As time went on, the north and south streams deepened their valleys so greatly that they could not easily be diverted; though tributaries, working east and west along the outcrop of the softer strata, soon lowered their valleys far below the general level of the more slowly denuded chalk downs. Thus there still remain a few large streams, like the Arun, which cut from north to south, straight through the wall-like Chalk-escarpment, whilst many of their newer tributary valleys, which run east and west, would seem to offer a far easier mode of escape to the sea. The main valleys still retain their original course; the smaller valleys must continually shift southward and cut downwards as the Chalk-escarpment recedes.

In addition to the deep trenching of the country by river valleys, the Chichester area shows another feature, which is apt to be overlooked. On reference to the Map, it will be seen that the drift-covered plain around Chichester ceases abruptly at the foot of the Downs, with a nearly straight boundary for over ten miles. This line marks the position, approximately, of an ancient buried and much-destroyed sea-cliff. It will be noticed that the more abrupt rise or slight bluff that marks the cliff does not keep to one geological formation, as does the true sub-aerial escarpment of the Downs. Near Arundel the boundary curves to the east-south-east, so as to cross the Eocene strata and take in part of the Chalk at Highdown Hill, though the exactly similar Chalk and Eocene strata around Angmering and Ford have been planed down to one dead level.

Clay with Flints.

Before dealing with the truly stratified and transported Drift deposits, it will be well to refer to the sheets of stony clay and Tertiary *débris* which cap some of the flatter-topped hills and ridges of the Downs. This Clay with Flints may occur at any height above the sea and cannot be referred to any definite geological period. In this part of the Downs it is confined to areas over which Eocene deposits may have spread within comparatively recent times; it is sometimes very difficult to decide whether a particular patch should be called slightly disturbed Eocene, or mapped as Clay with Flints. It will be understood, from what has just been said, that the material of the Clay with Flints is mainly derived from the destruction of Eocene outliers, the flint pebbles, green-coated angular flints, sarsen stones, quartz-sand, and probably most of the clayey matrix, being of Eocene origin. A considerable number of the angular flints, and part of the fine clayey matrix, have been added, as insoluble residue from the underlying Chalk, which was gradually dissolved away by the percolating rain-water. This solution produces curious vertical hollow cylinders or cones in the Chalk, and these so-called pipes can often be seen in section in quarries. Within the pipe is a column of clay and flints let down from above, the centre of the column often being mainly composed of Eocene material, while the margin and bottom consists of true insoluble residue. It should not be forgotten that only a small part of the Upper Chalk is insoluble, and that this insoluble residue alone would consist mainly of loose flints, and would make a stony desert rather than stiff clayey land.

The distribution of the Clay with Flints will best be understood by reference to the Map. The matrix as a rule is a black or red sandy tough clay, much stained by oxides of iron and manganese, and the nearer the outliers are to Eocene strata the larger the proportion of Eocene pebbles found in them. The Clay with Flints where thick makes a cold wet soil, very different from the ordinary soil of the bare Downs. On it one finds areas of rough coarse grass, brambles, and low bushes. The total thickness seldom reaches 10 feet. A good deal of the weathered flint gravel found in the Valley Drift was probably derived from these sheets of stony clay, and need not represent the contemporaneous destruction of an equivalent amount of flinty chalk.

Southern Area.

We will commence the description of the stratified Drift deposits with the area south of the Downs; for in that area the sheets are nearly continuous, and can be connected with deposits of known date and yielding abundance of fossils not far from Chichester. We must begin with the ancient sea-cliff and the deposits which flank it; for unfortunately we have nothing of earlier Pleistocene date, though an occasional erratic block, washed out of older strata, can be found.

Marine Gravels.

The sea-cliff just mentioned enters the area near Highdown House, where it still makes a bold feature, though no pit shows the actual shore-line, which is hidden by later gravels. South of the stream some of the ancient marine deposits can be traced in the shingly gravel which there appears at the surface. A shallow well at Ferring (just outside the Map) gave still better evidence; for the shingly sand there found was full of periwinkles (*Littorina obtusata*); but the small sample I saw contained nothing else. A new chalk-pit on the south side of Highdown Hill may at any time lay bare the old buried cliff.

Between Highdown and the Arun the old coast-line cuts obliquely across the Eocene strata; and, as we should expect in such soft strata after so long a period, the actual cliff is not easy to trace, and the marine deposits seem to have been swept away by the rush of water from the Downs. The marine deposits found at Ferring have been preserved, it will be noticed by Highdown Hill, which has protected them from the land-water and diverted the floods to the right and to the left.

West of the Arun the marine gravels reappear on Tortington Common as masses of flint shingle at a height of 105 feet. A little nearer the Downs equivalent deposits are seen in two pits in a copse on the north side of the high road one and a half miles west of Arundel. These pits show:—

	Feet.
Angular flint gravel (Coombe Rock) - - - - -	2 to 6
Fine buff sand and a few pebbles - - - - - -	10 to 15
Chalk (touched)	

The sands reach a height of about 120 feet above Ordnance Datum and correspond closely with the sands at Waterbeach, still to be described. They perhaps represent an ancient sand-dune or sandy beach; but no fossils were observed at this point.

Three-quarters of a mile west of the pits just described, an outcrop of these sands will be found on the edge of the Brinsted valley, immediately east of Slindon Common. Two pits in this outcrop show similar sections, but the Coombe Rock is thicker; the level is about the same. Another smaller outcrop occurs in the little valley which exposes Chalk and Reading Beds south of Slindon Common. A small pit just on the 100 foot contour, and slightly farther from the buried cliff, here shows flint-shingle.

Near Boxgrove this marine sand appears at the surface for nearly three miles; but it only reaches a maximum elevation of 90 feet, and is cut off by the Coombe Rock both on the north and on the south. A pit on the east side of the park belonging to Aldingbourne House showed 20 feet of falsebedded shingle and sand, among the pebbles being found two of quartzite or greywether, one of a coarse purple grit, like that found among the Selsey erratics, and one of basalt. Other pits south of Boxgrove expose from 10 to 15 feet of this shingle and sand, which has all the appearance of a true sea-beach, though here the marine shells have been destroyed by percolating water.

Between this bank of shingle and the old chalk-cliff the fine sands again appear. There is a pit in them close to the road to Eartham, about a quarter of a mile south-west of Park Farm. The cliff must run between the pit and the farm. The top of the sand is here about 130 feet above Ordnance Datum; but of course if this sand, which contains no stones, is merely a sand-dune, it does not prove submergence to quite that extent. Another small patch of this sand will be found at the same level half a mile to the west-north-west, at the south end of Eartham Thicket.

Close to Waterbeach, at the south-east corner of Goodwood Park, will be found a large sand-pit, which is of exceptional interest, for it yields clear evidence of a submergence beneath the sea to the extent of at least 130 feet. This pit seems to lie within a few yards of the old cliff, though the actual cliff-face has not yet been touched. Large blocks of Pholas-bored and worm-eaten chalk are occasionally found in the sand, and part of one of these masses has been placed in the museum at Jermyn Street. The section measured at a time when the pit was exceptionally clear was as follows:—

	Feet.
Coombe Rock—unworn flints in a chalky paste, irregularly decalcified for about a third of its depth.	15
Coombe Rock—stratified and mixed with sand and chalk-pebbles	2
Fine buff quartz-sand, with coarser seams full of splinters of flint, and containing occasional small shells. *Balanus* (common), *Mytilus edulis* (fry only), *Tellina balthica* (one valve), *Trophon* (one full-grown) and numerous Foraminifera. Also a boulder of *Pholas*-bored chalk weighing about 2 cwt.	15
Tabular concretions of calcareous sandstone	$\frac{1}{4}$
Sand as above, a few flint-pebbles near the base	4
Large flat irregular concretions, in sand	1
Fine sand, becoming loamy, orange, and alternating with thin seams of reddish clay near the base	2
Waterworn irregular surface of Chalk and flints	

The top of this pit is about 157 feet above Ordnance Datum.

So few species of fossils have yet been found in the Waterbeach pit, that very little can be said as to the climatic conditions which then held. The climate does not seem to have been Arctic, and if, as I think, this beach-deposit is of the same age as the deeper-water clay with southern mollusca found at Selsey, we apparently must be dealing with a true interglacial deposit.*

Immediately south-west of Goodwood House the sands are said again to have been met with, and in Valdoe there is another small pit. At Lavant they seem to have been swept away, but reappear on the west side of the valley in the railway-cutting west of Chichester Barracks. They have not been noticed farther west for some miles, till Portsdown is reached.

* *See*, Geology of Bognor, *Mem. Geol. Survey* 1897; Reid, Pleistocene Deposits of the Sussex Coast, *Quart. Journ. Geol. Soc.*, vol. xlviii., pp. 344-361 (1892); and Prestwich, *Ibid.*, p. 271.

It is impossible to show on the Map the greater part of the outliers just described, for the sections are nearly all pits dug through newer deposits, or are else in outcrops too narrow to be engraved.

Coombe Rock, Valley Gravel, and Brickearth.

The term "Coombe Rock" is applied in Sussex to a faintly-stratified deposit of unworn or shattered flints mixed with chalk, which occupies the lower part of the valleys in the Downs, and spreads out in a wide sheet over the maritime plain. This deposit is very peculiar, and though it tends to merge into ordinary terrace-gravel when traced up valleys which still contain living streams, it is neither forming now nor is a quite similar deposit of common occurrence out of Sussex. Its probable mode of origin has been described elsewhere.* It seems to point to Arctic conditions affecting a region not actually smothered under ice, as so much of Britain was during the Glacial Epoch. It suggests violent spring floods, which rushed down the valleys, thawing, tearing up, and carrying away the chalk and spreading sheets of chalk and flint rubble over the plain in wide confluent deltas. At the present day most of the valleys are dead, never contain running water, and remain unchanged from year to year, except for the gradual accumulation in their bottoms of a layer of loose flints dislodged from the steep sides. This talus and rainwash, however, is unlike Coombe Rock, which is full of unweathered flints and of lumps of chalk, even at a distance of several miles from the Downs.

The Coombe Rock yields occasional teeth of horse and mammoth, usually much weathered, as though they had long lain on the surface before being swept down by the floods. In this region no other fossils have been noticed, except one or two worked flint-flakes. At Salisbury, however, a large Arctic fauna has been found. The stony brickearth, which so often replaces part of the Coombe Rock over certain areas, might yield fossils, were it not usually decalcified by the action of percolating water.

Coombe Rock is extensively dug for road-metal, part of the chalky matrix being screened away, the remainder helping to make the material bind. Or else the upper decalcified and the lower chalky material are mixed, so as to give the right proportion of chalk. The distinction between red and white gravel, which are often supposed to be different deposits,† is due merely to the subsequent dissolving away of the chalky matrix, leaving a mass of rusty flints and clay. The Coombe Rock has been dug to a depth of 15 feet in a large pit at Portfield, near Chichester, for ballast on the railway. Though this pit is constantly being worked, contemporaneous fossils do not seem often to be found. None could be procured from the men, who brought me only some echinoderms in flint, and a handful of coins, mostly Roman. Various other pits, always changing, will be found; the one at Waterbeach, already described, being of particular interest as

* *Quart. Journ. Geol. Soc.*, vol. xliii., p. 364 (1887).

† *See* Godwin Austen, *Quart. Journ. Geol. Soc.*, vol. xiii., p. 47

showing the relation of the Coombe Rock to the underlying stratified sands. An excellent section must once have been visible in the long cutting occupied by the branch canal near Chichester.

The Brickearth, which has been mapped as a separate division, is really a modified Coombe Rock; and passes both horizontally and vertically by imperceptible gradations into that deposit. In fact the transition is so gradual that great doubt was felt as to which areas should be included in each, much of the material being "shrave," a local name for such loamy gravels or gravelly loams as are too stony for brickearth and too earthy for use as gravel. Shrave was formerly of more importance as being a convenient material for building mud walls, an art now seldom practised.

The Coombe Rock, as already mentioned, when traced into the Arun Valley, tends to pass into material more like ordinary valley deposits; as though that valley was then occupied by a perennial stream, which however flowed at a somewhat higher level than the present channel. In the Arundel railway-cutting the gravel runs up 50 feet above Ordnance Datum. At Warningcamp its upper edge is slightly higher; but its lower edge seems to pass under the marsh. A pit in Warningcamp, about 30 feet above the marsh, shows a curious transition from Coombe Rock to ordinary washed river-gravel. The section is: —

	Feet
Coombe Rock — angular flints in a matrix of fine rolled chalk-gravel and a little marl, slightly bedded. This weathers irregularly and in pipes into angular unstratified flint-gravel in a blackish clayey matrix. No fossils yet found - - -	12
Finer, more worn, and distinctly falsebedded gravel, with nests of sand. In the lower half are numerous fragments of Greensand-chert and of Wealden ironstone, often large - - - -	4

Teeth of elephant are said to have been found at Warningcamp, but it is not clear from which bed they were obtained. In the small coombe north of Warningcamp there is a narrow terrace, apparently of Valley Gravel or Coombe Rock, about 15 feet above the bottom of the coombe and stretching for a quarter of a mile along the north side. The road-cutting north of this coombe passes through similar gravel to that seen in the pit; but only about 8 feet is seen. It contains Wealden stones, and rests on at least 10 feet of chalk-rubble in a marly paste, also containing occasional fragments of Greensand-chert. In this neighbourhood, therefore, clean river gravel would seem to alternate with Coombe Rock.

Wepham, Burpham, and Peppering are built on a terrace cut into the Chalk, and sloping upwards to about the 100 foot contour; but no gravel was observed on this terrace except at one point. In the steep river-bluff north of Peppering, close to the path, chalk has been dug, and in it is seen a pipe full of ferruginous sand with pieces of Lower Greensand ironstone. Another pipe in the Burpham cliff contains very fine white or buff sand. Elephant-teeth have been found at Burpham

Offham and South Stoke show gravelly terraces; North Stoke and Houghton are built on similar platforms, with merely a trace of gravel. The most northerly of these terraces rises about 45 feet above the marsh.

The reason for tracing thus minutely the terrace-features through the valley of the Arun, is that these terraces seem at present to offer the only means of connecting the drift-deposits south of the Downs with those on the north. The continuity, however, is not unbroken, and it is still doubtful whether the terrace just described is represented by the higher or by the lower series of gravels in the northern area, or by both. I suspect that none of the gravels coloured pink on the Map in the northern area are so old as the raised beach-deposits of Goodwood; and that the two series around Midhurst and Pulborough may be equivalent to the two Coombe Rock terraces at different levels seen at Lavant. The evidence thus far obtained in Sussex, suggests a considerable lowering by denudation of the floor of the Wealden area in late-Pleistocene times. Nowhere can the Pleistocene marine deposits be traced through the gorges of the South Downs or into the Weald, though much of the Weald lies below the level of the raised beach. Perhaps some of the higher plateau-gravels may be fluviatile deposits belonging to that period of depression.

The next section will describe the Pleistocene deposits and features of the northern area; it is mainly by Mr. Lamplugh.

Northern Area.

Within the part of our area which lies north of the Downs, Mr. Lamplugh finds that the oldest superficial deposit is a coarse flinty rubble, which forms an irregular capping on plateaux of limited extent on the Folkestone, and occasionally on the Sandgate Beds south of the Rother valley. These little plateaux, much dissected by erosion, slope gently northward (*i.e.*, away from the South Downs), but end off boldly above the depression occupied by the Gault in steep bluffs simulating an escarpment, sometimes 50 to 80 feet high. The rubble on these plateaux has an extreme depth of 9 or 10 feet in "piped" hollows, but is oftener a mere ragged film through which the underlying formation continually breaks. It is best developed on the commons of Heyshott, Ambersham, Graffham, and Coates and is much dug for road mending. It is again found, though in less quantity, on the higher ground occupied by the Folkestone Beds to the east of the Arun, at Rackham, Parham Park, Kithurst, Sullington Warren, and Longbury Hill, forming little plateaux at varying elevations, apparently the remnants of an old surface which sloped westward towards the Arun and also northward from the Downs. The remarkable persistence of this drift on the Folkestone Beds, while it is scarce or absent on the neighbouring formations, seems to be due to the greater height of the outcrop of that group, which, perhaps, thus alone preserves portions of the ancient surface on which the rubble was deposited. This material was a subject of discussion nearly fifty years ago by Sir R. I. Murchison,* and more recently by Mr. J. Vincent Elsden.† Its accumulation probably dates back to the glacial period, and must have taken place under peculiar physical conditions. That the plateaux have suffered very little surface-erosion since prehistoric times, is shown by the position of the tumuli on some of the spurs overlooking the Gault depression. There is great difficulty in distinguishing between the lower patches of this high-level drift and the higher of the true river gravels, though frequently the presence of fragments of chert, sandstone, etc., in the latter, is sufficient to identify them.

Where the escarpment of the Hythe Beds is high, as between Petworth and the Arun, patches of angular cherty rubble, derived from that source, occur as a thin capping on hills of Weald Clay below the escarpment, and sometimes half a mile or more distant from it. These usually lie opposite coombe-like indentations in the escarpment, and are probably equivalent to the flinty rubble which occupies a similar though more distant position in regard to the South Downs. Both would require peculiar physical conditions for their production, and are probably the relics of some stage of the glacial period.

Gravelly deposits, undoubtedly connected with the erosion of the present valleys, are found chiefly in the form of deltas around the junction of tributary streams with the main valleys, their materials being mainly derived from the high-level drifts. These gravels, in the absence of sections, are sometimes difficult to detect, owing to the deep covering of stoneless sandy wash in the Lower Greensand tract, and of clayey wash in the Wealden area, which form soils indistinguishable from those of the rocks below.

In the vicinity of the Arun, gravels of this class occur at varying elevations, even capping high ground adjacent to the river, as at Lee Farm in the Weald, and at Greatham on the Lower Greensand. They are then, as above stated, scarcely separable from the high-level drift. It is indeed evident that the subaerial erosion of the land has gone on without interruption since the period of the high-level drift; there is no trace here, as already remarked, of the marine stage recognised at corresponding elevations on the southern side of the South Downs, which therefore probably preceded the earliest drift now existing in the interior.

Alluvium.

The Alluvium of the Arun forms a wide and perfectly level plain, the marshes ending abruptly against rising ground on either side. It will be noticed that this flat does not change slowly into dry land and sloping bank, or form a curved valley-bottom like that of the Lavant. On drawing a transverse section across the Lavant valley the outline will be found to follow an unbroken sweeping curve. But a section across the Arun valley is different; the flowing curve of the hills on either side is not

* *Quart. Journ. Geol. Soc.*, vol. vii., pp. 351-361.
† *Ibid.*, vol. xliii., pp. 637-656.

continued by the present valley-bottom; but if the curves are continued they will be found to plunge beneath the Alluvium, to meet 100 feet or so beneath the present marsh-level. On examining the records of borings in the Alluvial flat of the Arun, it will be found that the curve of the rocky floor does follow the same law as in other valleys; but that the true bottom of this valley is now much below the level of the sea. The land at one time stood higher, so that the valley could be cut below the present sea-level; but since that time subsidence has turned this valley into a long harbour or fiord, which has gradually become silted up till at last the harbour has changed to a marshy flat raised nearly to the level of the highest tides. This deep trenching, subsequent depression, and ultimate silting up of the valleys is not confined to the Arun: it affects the whole of the estuaries and harbours round our coasts. The depression seems to have taken place at so recent a date that great part of the harbours are still only partly silted up, though many are rapidly becoming obliterated. The ancient fiord of the Arun is silted up; but Chichester harbour, which happens to receive no stream of importance, and therefore little mud, remains only partly filled.

Some borings for wells between Arundel Station and Arundel throw a great deal of light on the contour of the submerged valley-bottom. A boring at Arundel Station is said to have reached the chalk floor beneath 100 feet of marsh clay, and another boring at the Station Inn was 150 feet deep in marsh clay. The strike, however, suggests that possibly in each of these wells there may have been some Reading Beds included in the "marsh clay." Another well, at a new house on Arundel Causeway, about midway between the two bluffs, is open to no such question, and it shows 84 feet of marsh clay above the chalk. Another boring, at Warningcamp crossing, shows still deeper Alluvium, Chalk being reached at 117 feet below the marsh. On the Arundel side of the marsh a boring at the coal yard penetrated 38 feet of marsh deposits before reaching Chalk —showing that the steep bank must be continued downwards to below the level of low water. The superficial layers of the Alluvium, thrown up in digging the foundations of a new house on Arundel Causeway, were composed of estuarine warp full of *Scrobicularia* in the position of life.

CHAPTER VIII.

ECONOMIC GEOLOGY.

Within the area with which we are now dealing there are no mines, and no quarries of much importance, the economic applications of geology being almost confined to the supply of building materials for local use, of stone for road-making, to water supply, and to agriculture.

Building Materials.

Over most of the district brick is now the building material, though other materials, such as rough flint, sandstone, and dob, or mud mixed with stones, were freely used in the older buildings. The various building stones will be taken in order.

Hythe Beds.—These yield irregular bands of calcareous sandstone, which is much used for building around Pulborough. The stone is often hard and cherty, or passes into chert, which is dug for road-metal.

Folkestone Beds.—A little ferruginous sandstone is occasionally found, and has been used for walls, but it is of no economic importance.

Upper Greensand.—Neither the malm-rock nor the green sandstones are now quarried, both seeming to be too soft to be of any value in this area.

Grey Chalk.—A little of this rock has been used for interior work, as it is very easy to work. It will not stand the weather.

White Chalk.—The harder Middle Chalk has also been used for interior work, but it has an irregular curved jointing, and usually comes out in small pieces. The flints of the Upper Chalk, more or less trimmed, have been used extensively in the old buildings, especially in the churches. They are almost indestructible, and when carefully squared and built with close joints, they make a wall which is probably less affected by the weather than any other in Britain. Except occasionally in the churches, this fine squared-flint building is seldom used, the art of squaring flints needing special skill, and being quite unlike ordinary mason's or bricklayer's work.

Coombe Rock.—This deposit also yields abundance of large flints for building; but they are commonly more stained than those obtained direct from the Chalk. Flints from drift-deposits, or those that have long been exposed to the weather, are also more difficult to face or square.

Lime.

The Middle and Upper Chalk everywhere yield ordinary lime of very similar character. The Lower Chalk is more marly, and yields hydraulic lime. The custom of chalking the land has now almost been given up in this district, though lime is often used.

SAND.

Some of the best sand in the district is that obtained from the whiter parts of the Folkestone and Sandgate Beds; though there are sand-pits in various parts of the Lower Greensand. Sand from the Upper Greensand is usually full of green or rusty specks, and is not so clean. The southern part of the area is badly supplied, the only clean sands there found being the fine dust-like sands of Waterbeach and other localities near the old raised-beach.

ROAD-METAL.

For road metal the chalk-flints are the great source of supply, those collected from the fields being tougher and better than those obtained direct from the chalk-pits or from the gravel. In the area too far from the flints, the chert found in the Hythe Beds and the concretionary ironstone from the Folkestone Beds are used.

WATER SUPPLY.

Over the greater part of the area there is little difficulty in obtaining good water; for plenty is usually to be found in the Chalk, and the Upper Greensand may yield supplies of good quality. As this subject has been dealt with in a recent Memoir,* there is no need to go over the ground in detail; the areas where difficulty is felt should, however, be mentioned. On the Weald Clay the supply is often very uncertain, and the water not palatable; the only source (beyond the very unsafe surface wells) is the thin sand beds which occur irregularly in the clay. It is almost useless to make deep borings; though occasionally one may yield a moderate supply of water. The Gault yields no water; but a good supply can be obtained by boring to the Folkestone Beds; any small quantity found in the Gault should be carefully stopped out, and not allowed to mix with that from below—its flavour is very disagreeable.

Over the exposed Eocene clays, water is readily obtained by boring to the Chalk; the Eocene itself here yielding no water. Where the Chalk and Eocene are overlaid by Coombe Rock there is commonly plenty of water in the superficial deposits; but this source is very liable to surface contamination, and should not be used if it can be avoided. The water from the gravel is harder than that from the Chalk.

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* The Water Supply of Sussex from underground sources, *Mem. Geol. Survey*, 1899.

APPENDIX.

List of Principal Works on the Geology of the District.

1822. Mantell [Dr.] G. A. The Fossils of the South Downs, or Illustrations of the Geology of Sussex. 4to. London.

1826. Mantell [Dr.] G. A. On the Iron Sand Formation of Sussex. *Trans. Geol. Soc.*, Ser. 2, vol. ii., p. 131.

Murchison [Sir] R. I. Geological Sketch of the north-western Extremity of Sussex. *Ibid.*, p. 97.

1827. Mantell [Dr.] G. A. Illustrations of the Geology of Sussex. 4to. London.

Martin, P. J. On the Geology of the Vicinity of Pulborough, Sussex. *Proc. Geol. Soc.*, vol. i., p. 19.

1828. Martin, P. J. A Geological Memoir on a part of Western Sussex. 4to. London.

1833. Mantell [Dr.] G. The Geology of the South-east of England. 8vo. London.

1836. Fitton, Dr. W. H. Observations on some of the Strata between the Chalk and the Oxford Oolite in the south-east of England. *Trans. Geol. Soc.*, Ser. 2, vol. iv., p. 103.

1841. Martin, P. J. On the Relative Connection of the Eastern and Western Chalk Denudations. *Proc. Geol. Soc.*, vol. iii., p. 349.

1850. Dixon, F. The Geology and Fossils of the Tertiary and Cretaceous formations of Sussex. 4to. London. Ed. 2 in 1878.

1851. Martin, P. J. On the Anticlinal Line of the London and Hampshire Basins. *Phil. Mag.*, ser. 4, vol. ii., pp. 126, 189, 278, 366, 471. See also vol. xii (1856), p. 447 and vol. xii. (1857), pp. 33, 109.

Murchison [Sir] R. I. On the distribution of the Flint Drift of the south-east of England, on the Flanks of the Weald, and over the surface of the South and North Downs. *Quart. Journ. Geol. Soc.*, vol. vii., p. 349.

1855. Godwin-Austen, R. A. C. On Land Surfaces beneath the Drift Gravel. *Quart. Journ. Geol. Soc.*, vol. xi., p. 112.

1856. Martin, P. J. On some Geological Features of the Country between the South Downs and the Sussex Coast. *Quart. Journ. Geol. Soc.*, vol. xii., p. 134.

1857. Godwin-Austen, R. A. C. On the Newer Tertiary Deposits of the Sussex Coast. *Quart. Journ. Geol. Soc.*, vol. xiii., pp. 40-72.

1859. Prestwich [Sir] J. On the Westward Extension of the old Raised Beach of Brighton; and on the extent of the Sea-Bed of the same Period. *Quart. Journ. Geol. Soc.*, vol. xv., p. 215.

1869. Maw, G. [Letter] On a section of the Gault and Lower Greensand, at Lower Fittleworth, Sussex. *Geol. Mag.*, vol. vi., p. 335.

1875. Topley, W. The Geology of the Weald. (*Mem. Geol. Survey*). 8vo. London.

1886. Elsden, J. V. Superficial Geology of South Portion of Wealden Area. *Quart. Journ. Geol. Soc.*, vol. xlii., p. 637.

1887. Reid, C. On the Origin of Dry Chalk Valleys and of Coombe Rock. *Quart. Journ. Geol. Soc.*, vol. xliii., p. 364.

1892. Prestwich [Sir] J. The Raised Beaches, and "Head" or Rubble-drift, of the South of England. *Quart. Journ. Geol. Soc.*, vol. xlviii. The Sussex Coast Plain, pp. 271-273.

Reid, C. The Pleistocene Deposits of the Sussex Coast, and their Equivalents in other Districts. *Ibid.*, pp. 344-361.

1899. Whitaker, W., and C. Reid. The Water Supply of Sussex from underground sources. (*Mem. Geol. Survey*). 8vo. London.

1900. Jukes-Browne, A. J. The Cretaceous Rocks of Britain. Vol. I.—The Gault and Upper Greensand of England. With contributions by W. Hill. (*Mem. Geol. Survey*). 8vo. London. [Vols. II. and III. dealing with the Chalk are in the Press.]

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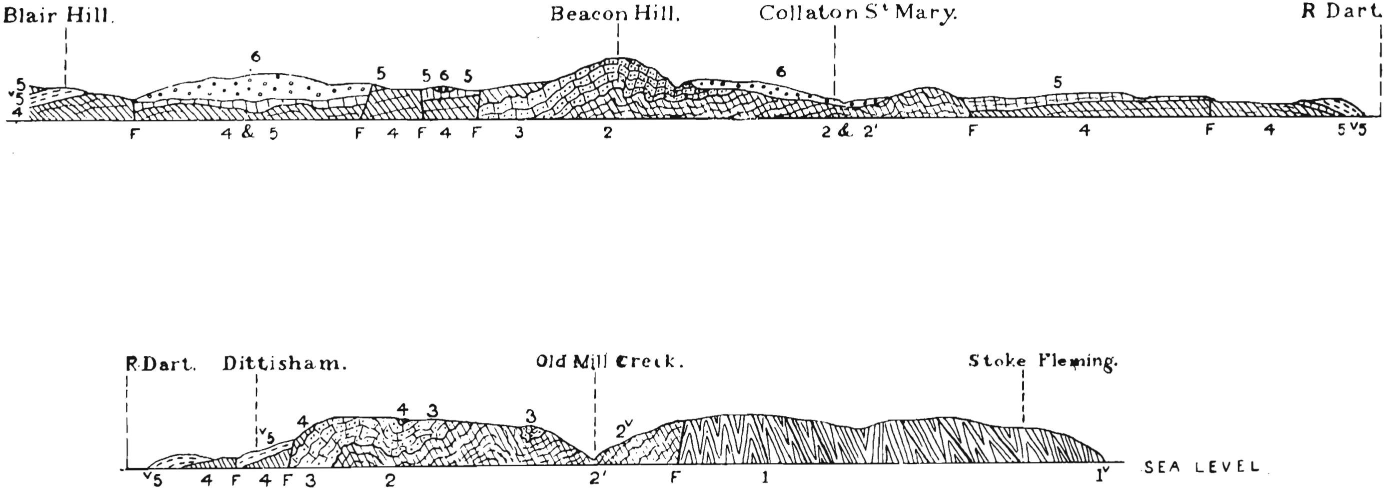
Fig. 1.—Section North and South through Dittisham to Stoke Fleming.



Lower Devonian = 1, 2′, 2, 3 { 1—Dartmouth Slates. 2′—Representatives of Looe Beds including Long Sands Grit. 2—Meadfoot Beds 3—Staddon Grits. 1 V.—Volcanic Rocks in or on Dartmouth Slates. 2 V.—Line on which igneous rocks occur in No. 2′ or 2.

Middle Devonian = 4, 5, V 5 4—Eifelian Slates. 5—Eifelian and lower part of Middle Devonian Limestone. V 5—Volcanic Rocks.

Lower New Red Rocks— 6—Conglomerate, Breccia and Sand. F—Faults.

350.

MEMOIRS OF THE GEOLOGICAL SURVEY.

ENGLAND AND WALES.

THE GEOLOGY OF
THE COUNTRY AROUND
TORQUAY.

(Explanation of Sheet 350.)

BY

W. A. E. USSHER, F.G.S.

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PREFACE.

The original geological map of this area which was published in 1840 was based on the field work of R. A. C. Godwin-Austen, whose Memoir "On the Geology of the south-east of Devonshire," may be regarded as the foundation of all subsequent geological work in the district. In 1868, Dr. Holl brought out a map in which additional details are given, and a few years later Mr. Arthur Champernowne commenced a careful survey of the neighbourhood of Totnes. The official re-examination of the area was begun in 1874-75 by Mr. H. B. Woodward, at Torquay, and Mr. Ussher, at Paignton.

Shortly before his death Mr. Champernowne generously handed over the results of his work to the Geological Survey, and the task of embodying these results in the official publications was entrusted to Mr. Ussher. About this time the six-inch ordance maps of the district were issued and it was found necessary to re-survey the whole area on this scale. This work has been carried out by Mr. Ussher, the results have been reduced to the one-inch scale and the map (New Series, sheet 350), was published in 1898. The present memoir is issued as an explanation of that map.

The district is one of exceptional difficulty, owing to the want of persistence in well marked lithological horizons and to stratigraphical complications of a most intricate character due to folding and faulting. Detailed work was therefore necessary before even the broader tectonic features could be made out. This work has, however, met with its reward. The three main divisions of the Devonian formation have not only been recognised, but their boundaries have been ascertained with at least approximate accuracy, and the rocks of the Torquay area have been brought into line with their continental equivalents.

Many workers have contributed to this result, and a general account of the extensive literature relating to the geology of the district is given in the introduction.

The six-inch maps have been deposited in the office for reference, and copies may be obtained at cost price.

J. J. H. TEALL,

Director.

Geological Survey Office,

28, Jermyn Street, London,

9th June, 1903.

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LIST OF ILLUSTRATIONS.

GEOLOGY

OF THE COUNTRY AROUND

TORQUAY.

CHAPTER I.

INTRODUCTION.

Sheet 350 of the Geological Survey Map embraces an area of about 102 square miles in the south-eastern part of Devonshire, with a coast line of about 20 miles extending from Petitor beach round the Torquay promontory, by Paignton, Brixham and Berry Head, to Dartmouth Harbour, Stoke Fleming and Matthew's Point. The area is replete with interest from an archæological and historical, as well as from a geological point of view, and it possesses in Torquay a watering-place unrivalled in the south of England. The scenery is extremely diversified; steep rounded hills, rising here and there above 600 feet, are intersected by narrow combes or stream-valleys, and at Torquay and south of Paignton, limestone plateaux abut against the higher land. The river Dart and its tributaries drain most of the inland districts, the coast lands being watered by small streams having direct outlets to the sea. The Dart enters the area near Staverton, a locality renowned for its orchards, and, following a rather sinuous course of thirteen miles by Dartington Park, Totnes, Sharpham House and Dittisham, it empties itself into the sea below Kingswear and the town of Dartmouth.

LITERATURE.

The earliest special references to the geology of the area embraced in Sheet 350, are to be found in the writings of De la Beche and Godwin-Austen, in the "Transactions of the Geological Society;" in De la Beche's "Report on the Geology of Cornwall, Devon and West Somerset," which was published in 1839, and in his "Geological Manual," second edition, 1832, page 401, and pages 496, 497. In the first section of "Memoirs of Geological Survey," vol. 1., 1846, page 89, he rightly places the Lower Devonian of Torquay and Paignton below the limestone. In 1829, De la

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Beche described the New Red rocks of Tor and Babbacombe Bays.* He regarded the Devonian limestones as Carboniferous limestone and the Lower Devonian grit as Old Red Sandstone In 1842, Godwin-Austen combined four of his previous papers into a connected description, entitled "On the Geology of the south-east of Devonshire." This Memoir may be regarded as the foundation on which all subsequent geological work in the areawas built; for, although De la Beche's Report antedated it, the Geology of South Devon, there described, was based on the field work of Godwin-Austen. The map accompanying Godwin-Austen's paper is, in many respects, a masterly production; as showing the general distribution of the Devonian limestones and the extension of the New Red rocks. It is a reduction from the old Geological Survey map done by him and presented to Government. In the text special references are made to the following phenomena:—The submerged forest ground of Torbay, the raised Beaches of Hope's Nose, the Thatcher rock and Brixham, Kent's Hole Cavern, the gravels of the Dart near Staverton, cleavage of slates and limestones in districts north of Totnes and near Brixham, the igneous rocks of Black Head and North Whilboro, the lateral forcing of large blocks of limestone into the slates at Petitor, disturbances at Petitor, Torquay, etc.†

Dr. Harvey B. Holl, in 1868, attempted the solution of the structure of the Older Rocks of South Devon and East Cornwall.‡ He placed the (Lower Devonian) grits of Cockington above the (Middle Devonian) limestones of Marldon, etc. In this error he was subsequently followed by Champernowne, although Mr. H. B. Woodward § had placed them in their true position some years previously.

The Cavern deposits of the area will ever be associated with the name of William Pengelly, and many references to the general and special geological phenomena will be found in the numerous papers contributed by him to the British Association, Devonshire Association, Royal Geological Society of Cornwall, Plymouth Institute, etc. A list of Pengelly's papers, and a digest of his scientific work, by Professor Bonney, will be found appended to the Biography by his daughter. In 1856, he called attention to the form of chalcedonic structure found coating limestone fragments in the New Red breccias of Torbay.|| In 1861, contributions appeared on Brixham Cavern, and on recent encroachments of the sea on the shores of Torbay.¶ In 1862, the distribution of Devonian Fossils of Devon and Cornwall, and the correlation of the rocks with the Old Red Sandstone of Scotland was treated of.** In 1861, and following years, the

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* *Trans. Geol. Soc.* Ser. 2. vol. iii., p. 161.
† *Trans. Geol. Soc.* Ser. 2. vol. vi., pp. 433 to 446, and 481 to 489.
‡ *Quart. Journ. Geol. Soc.*, vol. xxiv., p. 434.
§ *Geol. Mag.* for 1876, p. 576, and 1877, p. 449.
|| *Rep. Brit. Assoc.* for 1856, *Trans. of Sections*, p. 74. In full in *Trans. Roy. Geol. Soc. Corn.* vol. vii., p. 309.
¶ *Rep. Brit. Assoc.* for 1861, p. 123. *Geologist*, vol. iv., pp. 153, 447 and 456.
** *Ibid.* vol. v. pp. 10, 74 and 456. *Rep. Brit. Assoc.* for 1862, p. 86.

New Red rocks were described.* In 1865 the first Report of the Committee for exploring Kent's Cavern appeared,† and also a paper in the Proceedings of the Royal Institution. In his contributions to the Devon Association from 1865 to 1888 will be found many papers referring to the submerged forests, raised beaches and other signs of elevation, and to the caverns and fissures of this area, besides commentaries on references to the district in contemporary literature. The titles of those referring to the area will be given in the Appendix. The literature of Kent's Cavern is also associated with the name of E. Vivian. He edited MacEnery's notes, besides other papers.‡

The late E. B. Tawney in 1870§ noted the discovery of fossils in the Lower Devonian rocks of Smugglers Cove and the coast west of Hope's Nose raised beach. Mr. H. B. Woodward gave the true position of the Cockington grits in 1876.‖ The discovery of Upper Devonian fossils at Saltern Cove by J. E. Lee was announced in 1877.¶ The discovery of *Calceola sandalina* at the base of the limestones of Daddy Hole plain, and the inverted structures in that part of the coast were recorded by Champernowne in 1874.** In 1878 Champernowne published his adhesion to Mr. Woodward's opinion in regard to the Cockington beds.†† In 1881 he announced the discovery of *Homalonotus* in the Lower Devonian rocks of Lincombe Hill,‡‡ and in 1884, described some Zaphrentoid corals from the Middle Devonian rocks of Mudstone Bay and Dartington.§§ In 1889 Champernowne's latest views (in which he advocated the Upper Devonian age of the Cockington grits) appeared in a most important paper on the Ashprington Volcanic series.‖‖

The Dartmouth slates, so named by Sedgwick,¶¶ who classed them with the Morte slates of North Devon, were left undefined as to position by Champernowne. He seems to have regarded them as a type, locally, representing the Middle Devonian.∞ The classification of the Devonian rocks in the area, just before the Geological Survey began its work in 1888, is given by Mr. Woodward.*†

In Davidson's "Supplement to the British Devonian Brachiopoda," pages 4 and 8, the discovery of Lower Devonian fossils in the railway cutting near Saltern Cove, and at Goodrington

* *Trans. Plymouth Instit.* for 1861–1863 and 1864–1865.

† *Rep. Brit. Assoc.* for 1865, p. 16 and in succeeding years up to (and inclusive of) 1878.

‡ *Ibid* for 1847, *Trans. of Sect.* p. 73; *Ibid* for 1856, *Trans. of Sect.* pp. 78 and 119.

§ *Trans. Devon. Assoc.* vol. iv., p. 291, etc.

‖ *Geol. Mag.*, 1876, p. 576. *Ibid*, 1877, p. 449.

¶ *Ibid*, 1877, p. 100.

** *Trans. Devon. Assoc.* for 1874.

†† *Geol. Mag.*, 1878, p. 193.

‡‡ *Ibid*, 1881, p. 487.

§§ *Quart. Journ. Geol. Soc.*, vol. xl., p. 497.

‖‖ *Ibid* vol. xlv., p. 369.

¶¶ *Quart. Journ. Geol. Soc.*, vol. viii., p. 3.

∞ Ussher. *Proc. Geologists Assoc.*, vol. viii., p. 442.

*† Geology of England and Wales, 2nd edition, 1887, pp. 130–139.

Sands, by the Rev. G. F. Whidborne, is recorded. The bearing of this discovery on the age of the Cockington beds was overlooked, perhaps because the prevalence of faults, and the occurrence of New Red rocks in the intervening distance, may have been thought to render it inconclusive.

The palæontology of the Lummaton limestone, which occurs on the north border of Sheet 350, has been thoroughly worked by Mr. Whidborne, and is described in a Monograph in the Palæontographical Society's publications between the years 1888 and 1896. Ostracods obtained in the Eifelian Limestone near Daddy Hole, Torquay, by Mr. Whidborne were described by Prof. T. R. Jones.*

In 1888 Mr A. R. Hunt contributed an important paper on "The Raised Beach on the Thatcher Rock, its Shells and their Teaching."† In "Notes on Torbay," by the same author,‡ valuable information as to the character of the bottom and of the submarine rock reefs in the bay is given. See also a paper "On Exposures of the Submerged Forest Clays at Paignton and Blackpool Beaches in April 1881."§ The Torbay submerged forest and the Hope's Nose raised beach were also referred to by the late D. Pidgeon.|| Some of the pleistocene phenomena of the area have been incidentally referred to in a paper, "On the Chronological Value of the Pleistocene Deposits of Devon," by the writer. Amongst his papers the following have special reference to this area—"On the Age and Origin of the Watcombe Clay,"¶ "On the Geology of Paignton,"** "The Devonian Rocks of South Devon."†† The Devonian rocks of the area are also mentioned in classifications published in 1889‡‡ and 1891.§§

In an important paper "On the Microscopic Structure and Residues, insoluble in Hydrochloric Acid, of the Devonian limestones of South Devon," |||| Mr. E. Wethered refers particularly to specimens from Hope's Nose, Daddy Hole, and Lummaton. The most important paper bearing on the correlation of the Devonian rocks of the area with those of the Continent, was contributed by Dr. Kayser in 1889.¶¶ There are few parts of South Devon which present such a copious geological literature.

General Geology and Cartography.

The geology of Sheet 350 is very complicated. The impersistence and variation in lithological characters, as well as the

* *Annals of Nat. Hist.*, Oct. 1888., p. 295.
† *Trans. Devon. Assoc.*, for 1888.
‡ *Ibid* for 1878.
§ *Ibid* for 1881.
|| *Quart. Journ. Geol. Soc.*. vol. xli., p. 9, 1885, and *Ibid*, 1878, p. 451.
¶ *Trans. Devon. Assoc.* for 1877.
** *Ibid* for 1878.
†† *Quart. Journ. Geol. Soc.*, vol. xlvi., p. 487, &c., 1890.
‡‡ *Rep. Brit. Assoc.*, *Trans. of Sect.*, and *Proc. Somerset Arch. and Nat. Hist. Society.*
§§ *Trans. R. Geol. Soc., Corn.*, pp. 282-285, and 316, 317, and 324. *Quart. Journ. Geol. Soc.*, vol. xlviii., p. 377, 1892.
¶¶ *Neues Jahrb. für Mineralogie*, etc., 1889, Band 1, Zeitsch. 189.

restriction of faunas to certain favoured localities, would alone constitute obstacles to a rapid geological survey; but, as there are also numerous faults repeating or cutting out horizons in a series of rocks everywhere contorted, the original Geological Ordnance Survey Map of this district cannot be regarded in any but the most general sense as the foundation of the present Survey Map. The earlier map showed Devonian, or "grauwacke," with masses of limestone and some patches of greenstone, overlaid by the New Red rocks of Paignton and Cockington, the boundaries of the latter being well drawn. The necessity for broad generalizations, during the rapid original survey, in indicating limestone and greenstone boundaries, could not result in the production of anything more than a sketch map.

The late A. Champernowne devoted most of his leisure time during many years to a stratigraphical study of the area. He placed the limestones in one general series; separated the Lower Devonian of the Torquay promontory, and near Sharkham Point and Dittisham; attracted attention to the fossiliferous Middle Devonian slates; and proved the development of a great volcanic series, corresponding in character to the Nassau schalsteins. Champernowne generously placed his field maps at the disposal of the Geological Survey. In reconciling the different versions on his maps, where he entertained doubts as to the structure or succession of the Devonian rocks of the Torquay and Paignton area, during a careful survey made on the then new 6-inch maps, the present map was evolved.

The discovery of an Upper Devonian fauna, of the Büdesheim type, by the late J. E. Lee at Saltern Cove, also afforded an invaluable basis of research, by which the structure of many parts of the district and the distribution of the Upper Devonian rocks was determined.

Through the kind offices of Messrs. Gosselet and Kayser, who identified fossils collected in the Lower Devonian districts during the earlier stages of the survey, representatives of Upper and Lower Coblenzian horizons were shown to occur in the Cockington and Paignton area. Champernowne had regarded the Cockington grits as of doubtful age, but possibly the representatives of the *Psammites de Condroz* of Belgium, and therefore Upper Devonian. The Lower Devonian rocks of the Dartmouth and Kingswear area, under the name "Dartmouth Slates," were left undefined as to position by Champernowne and the author, in classifications of 1889.

The survey of the Devonian rocks, begun in Sheets 339 and 350 in 1887, on the basis of Champernowne's map, has been carried on throughout South Devon and in East Cornwall, as far as Looe and Liskeard. The Lower Devonian rocks have from the first occasioned the greatest difficulty. The absence of consecutive succession has necessitated very minute observation, the collection of many typical specimens, and the accumulation of problems, rather than of evidence for their solution. However, on reviewing all the work, it was found necessary to arrive at some general hypothetical succession which should be tested by its efficacy in explaining the apparently conflicting evidences as to the composition and succession of the Lower Devonian rocks in different areas. The last area surveyed, that of Looe, clearly demonstrated the necessity for a reconsideration of the relations of the Lower Devonian rocks of this and the intervening areas.

Since 1898 this work had been rapidly carried on when opportunity offered, but the Lower Devonian coast line, south of Brixham, was not revisited until March, 1902, when it was brought into direct and satisfactory relation to all the other Lower Devonian coast sections as far west as Fowey. Local names were used to denote lithological types which appeared to have definite stratigraphical value; but the progress of the survey tends to show that, although indispensable to the investigator, the retention of local names (many of them synonyms), is a needless tax on the memory; for it must be borne in mind that (except in North Devon and West Somerset) the British Devonian had never been subdivided prior to the commencement of the present survey; whilst in France, Belgium, Germany and Russia, the main subdivisions and the faunas which characterise them had been carefully worked out. It is in these divisions or stages that we have to group the British Devonian rocks.

Of the two principal Continental types—the Franco-Belgian and the German—the Devonian rocks of South Devon approximate most closely to the latter, although the lithological characters of the correlative horizons are in some cases quite different. Thus the Upper Devonian shales of Büdesheim are very unlike the red slaty mudstones of Saltern and Silver coves, although characterised by a similar fauna. Still less do the Upper Devonian slates of South Devon resemble the Upper Devonian shales of the Ardennes. As regards the Upper Devonian, the chief lithological resemblances are to be found in the calcareous beds near the base of the Upper Devonian, in the Chudleigh, Torquay and Paignton districts. In these districts the decomposed calcareous nodules, characteristic of the *Knollen Kalk*, are occasionally met with in the slates; beds made up of almond-shaped concretions of compact limestone recall the German *Kramenzel*, and the shaly red *Goniatite* limestones of Lower Dunscombe, Petitor, etc., represent the *Goniatiten Schichten*. In the limestone masses, parts homotaxeous with the *Rhynchonella cuboides* zone and the Middle Devonian *Stringocephalus* limestone in their lithological variations are identical with continental equivalents; as also in the case of the lower beds of limestone, corresponding to the Eifelian limestones (*Calcaires de Couvin*). As regards the Lower Devonian the Meadfoot beds correspond in character more or less with the Lower Coblenzian, and the grits above them are more or less similar in character to the Upper Coblenzian. The mottled red and green slates of the Gedinnien resemble the Dartmouth slates, though not necessarily on the same horizon. For purposes of comparison or reference the continental horizons may be summarized as follows:—

	Franco-Belgian.	German.
UPPER DEVONIAN	Upper part Fammenien	Cypridinen Schiefer
	Lower part Frasnien	Knollen Kalk, Kramenzel Goniatiten Schichten Iberger Kalk
MIDDLE DEVONIAN (including Eifelian)	Calcaire de Givet	Stringocephalen Kalk
	Calcaires et schistes de Couvin	Calceolen or Eifler Kalk Calceolen Schiefer
LOWER DEVONIAN	Coblenzien Superieure	Ober Coblenz
	Coblenzien Inferieure	Unter Coblenz
		Hunsruckschiefer
		Taunusien
	Gedinnien	Gedinnien

A further correlation is made by the correspondence of the Middle Devonian volcanic rocks, south of Totnes, named the Ashprington series, with the schalsteins of Nassau. The general correlation of the Devonian rocks in Sheet 350 with those of the Continent is unquestionable.

Dr. Kayser* thus refers to the correspondences of South Devon and West German Devonian horizons:—"We find first of all in South Devon a development which in every aspect most intimately connects it with West Germany. In the Upper Devonian we have the Knollen Kalk with *Clymenia*, Cypridinen Schiefer, Adorf *Goniatite* limestone, Büdesheim shales and Iberg Coralline and Brachiopod limestone; in the Middle Devonian, *Stringocephalus* limestone, *Calceola* limestone, *Calceola* slates, and possibly also Goslar slates; finally in the Lower Devonian, Upper and Lower Coblenz beds and Siegener grauwacke—that this crops out at Looe in Cornwall I have already proved through a small but typical fauna—(*Jahrb. d. Kgl. Preuss. Geol. Landesanstalt,* 1882–3). This widespread agreement is strengthened by the appearance of numerous greenstones which are accompanied, as in Nassau and the Harz, by schalsteins [slaty sheared volcanic rocks] and contact rocks."

On the other hand, no boundary can be drawn for representatives of the *Rhynchonella cuboides* zone, as the Lummaton fauna proves the co-existence of *Rhynchonella cuboides* and *Stringocephalus,* and there is no lithological distinction by which such a line could be traced, if this were not the case.

As regards the Lower Devonian, the boundaries between the Warberry and Meadfoot beds cannot be proved to be a division between Upper and Lower Coblenzian, or even to possess absolute stratigraphical value, and although the Looe rocks have their equivalents in the area to the north of the Dartmouth slates, they cannot be separated out.

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*Translated from *Neues Jahrb. für Mineralogie*, etc., 1889. Bd. 1. Zeitsch. 189.

TABLE OF FORMATIONS WITH FOREIGN EQUIVALENTS AND LOCALITIES.

PLEISTOCENE	Alluvium		Of R. Dart and tributaries, and of streams with seaward outlets.
	River Terrace Gravels		Dart Valley above Totnes; north of Paignton.
	Submerged Forests		Tor Abbey Sands, the Paignton Coast, Blackpool near Stoke Fleming.
	Head		Traces on Raised Beach Platforms at Hope's Nose, Churston Cove, &c., not shown on the Map.
	Raised Beaches		Hope's Nose, Thatcher Stone, Churston Cove, near Berry Head, Sharkham Point.
	Cavern Deposits		Kent's Cavern, Windmill Hill Cavern Brixham, Happaway Cavern, Anstey's Cove Cavern.
LOWER NEW RED (*Permian*)	Conglomerate and Breccia with beds of Rock Sand		Oddicombe Beach, St. Marychurch, W. of Torquay, Paignton.
	Clays with sandy beds, Brecciated Clays		Petit Tor, N. of Torre Station, Edginswell, N. of Compton, &c.
	Sandstone outliers and in fissures in limestone		Outliers near Waddeton, Brixham, Durl Head; fissures near Churston Cove and Berry Head.
UPPER DEVONIAN	Cypridinen Schiefer		Red and greenish slates with Entomostraca, Anstey's Cove, Goodrington.
	Büdesheim Schiefer		Red slates and slaty mudstone, Saltern Cove, Ivy Cove.
	Knollen-Kalk and Kramenzel		Slates, &c., with calcareous nodules, compact concretionary limestone, Saltern Cove, Ivy Cove, Ilsham.
	Goniatiten Schichten		Irregular liver-coloured shaly limestone, Petit Tor combe, Anstey's Cove, Ilsham.
MIDDLE DEVONIAN	Rhynchonella cuboides Zone		Pale massive sub-crystalline limestone, Lummaton, Petit Tor, Ilsham, &c. Bedded limestone, Goodrington, Elbury, &c.
	Stringocephalen-Kalk		Massive and bedded limestones mostly coralline, Babbacombe, Torquay, Brixham, Ipplepen, Marldon, Dartington.
	Stringocephalen-Schiefer		Slates replacing limestone in Dartington Park, Broadhempston, &c.
	Eifler-Kalk		Thin-bedded, slaty and shaly limestones, Hope's Nose, Redgate Beach, Daddy Hole, &c., Mudstone Bay, Harbertonford, &c.
	Eifler-Schiefer		Fossiliferous irregular, partly calcareous, slates, Berry Park; more even slates, Mudstone Bay anticline, &c.
LOWER DEVONIAN	Upper Coblenzien	Staddon Grits	Hard quartzose grits, red, dull green and grey grits, with slates and shales. Top beds west of Hope's Nose Raised Beach. Main outcrop from north end of Southdown Cliff westward, Warberry Hill, Lincombe Hill, Torquay, Cockington, &c.
	Lower Coblenzien and Taunusien (Siegener Grauwacke)	Meadfoot Beds, including Looe Beds	Dark grey slates, knubbly and irregular, with compact grit beds, and fossiliferous calcareous bands. Dark grey slates with silty films, occasional beds of grit, and lenticles of limestone. Beds of Looe and Ringmore type on coast, south of Man Sands locally red-stained.
	Gedinnien (?)	Dartmouth Slates	Variegated, purple, green, &c., glossy slates, grit shales (quartzo-phyllades), and occasional beds of hard grit. Scabbacombe Head to S.W. corner of map.

The Ashprington volcanic rocks, consisting of shalsteins, tuffs, and hard diabases, occupy a considerable area south and south-east of Totnes. The Eifelian limestones, which emerge from beneath them near Dittisham, Cornworthy, etc., prove that the earlier eruptions took place during, or immediately preceding, the deposition of the Eifelian limestones. The distribution of the Brixham and Yalberton limestone masses with reference to them justifies the inference that volcanic rocks in this area of maximum vulcanicity locally represent the Middle Devonian limestone masses. Although the Ashprington area furnishes no evidence of the date of the most recent eruptions, it is very probable that these were coeval with emanations from local foci, which in some cases, as at Black Head, Goodrington, etc., obscure the relations of the Upper and Middle Devonian, and may have been protracted to a stage as high as the Goniatite beds near the base of the former.

TABLE OF IGNEOUS ROCKS.

UPPER DEVONIAN		Calcareous Tuffs - - -	Ansteys Cove, Black Head.
		Diabase of Black Head?	(Carey Arms, Babbacombe?)
		Felspathic Tuffs in slates	Hookwells, West of Churston Cove.
UPPER AND MIDDLE DEVONIAN (About the Stage of Rhynchonella cuboides Beds)		Schalsteins, &c.- - - -	Black Head, Saltern Cove, Goodrington. Crabs Park, volcanic rocks in part. Ashprington, volcanic rocks in part.
MIDDLE DEVONIAN (including Eifelian Limestone)		Schalsteins, Tuffs, Diabases	Crabs Park, volcanic rocks in part. Ashprington volcanic area, Sharkham Point. Dartington Park, &c., Blair Hill, Babbacombe Cliff. Two Bands in Limestones of Hope's Nose.
LOWER DEVONIAN	In Meadfoot Beds or representatives of Looe Beds	Sheared Diabases (probably in part contemporaneous)	Southdown Cliff, S. of Crabrock Point. Near Nethway House, Sandquay. Townstal, Lower Norton, Bugford.
	In or on Dartmouth Slates	Sheared Diabases and Felspathic Tuffs?	Coast of Kingswear Promontory. Stoke Fleming Coast and Blackpool Valley; Brookhill (near Kingswear), Hansel, &c.

The boundary lines on the map, as regards the Devonian rocks, are only stratigraphical so far as the characters by which they were drawn may be regarded as persistent or reliable indications of stratigraphical horizons. The uncertain value of colour distinctions and lithological distinctions which may have been produced by secondary agencies must be taken into account. In parts of the area it is uncertain to what extent slates may represent the limestones, and this is of course naturally the case as regards volcanic rocks, there being no evidence to show the date of the upward limit of the Ashprington volcanic series. As regards the Lower Devonian, the darker tint on the map denotes the prevalence of grits in the Upper beds (the Staddon grit series) which may be regarded as roughly homotaxeous with the Upper Coblenzian; but it also includes red-stained Meadfoot beds, which cannot be separated in the Paignton area, and developments of grit in that series. The Dartmouth slate group does not occur in the Torquay and Paignton areas. The boundary between this series and the Meadfoot beds, west of Stoke Fleming, owing to the absence of marked lithological distinctions in the slates, and the danger in placing too much reliance on colour, the almost indefinite repetition of junction beds, and bad preservation of fossils and lack of time to search for them, is not satisfactory although carefully drawn.

STRUCTURE.

The district is cut up by numerous faults resulting from the compression and contortion of a complex group of rocks of different degrees of hardness, and the contortions exhibited by the older rocks, even where exposed in section, are often so broken by small slides and faults, that it is not easy to trace their effects with certainty. Owing to the shearing to which inverted contortions have been subjected, many small slides or thrusts have taken place throughout South Devon, and these, in homogeneous rocks, tend in some cases to obscure both bedding and cleavage. Sections prove that appearances of horizontal bedding are sometimes due to more or less sharp zig-zag plication, and this structure, accompanied by small thrusts and faults, may produce an apparent dovetailing between different members of the Devonian series; as in the Petitor syncline. Where junctions are not actually exposed, it is in many cases impossible to say whether they are faulted or natural. As the evidence for a comparatively trivial fault may be marked whilst an important one cannot be traced, the presence of fault lines on the map in one part of the district and their absence in another, as for instance in the Torquay area, and in the area south of the Dart, is no proof whatever of their prevalence in the one district more than in the other. In tracing a comparatively distinct boundary, such as that of the Lower Devonian grits, westward from Sharkham Point, which is almost invariably marked by feature (the older rock occupying the higher ground), there is a strong *à priori* reason for inferring fault and thrust boundaries, but their position, as south of Brixham, after the evidence had been completely exhausted, remains doubtful. Where the Lower Devonian is in contact with the Upper on the north of Goodrington, there is a reversed fault or thrust boundary of considerable magnitude, which is prolonged round a part of the Lower Devonian of the Paignton area and shifted by cross faults. In spite of these remarks it must not be inferred that the Devonian rocks are quite dismembered by thrusts. Thrusts and faults have taken place in consequence of the minor foldings and contortion of the rocks, producing numerous minor displacements, but the larger dislocations have a direct relation to the main structural curves as may be seen on either side of the Middle Devonian syncline between Paignton and Man Sands, and there is no proof of the rocks being anywhere thrust out of their true relative position.

A map on the one-inch scale is too small to enable us to depict the geology in a wholly satisfactory manner, as minutiæ of considerable local interest and importance cannot be adequately shown upon it.

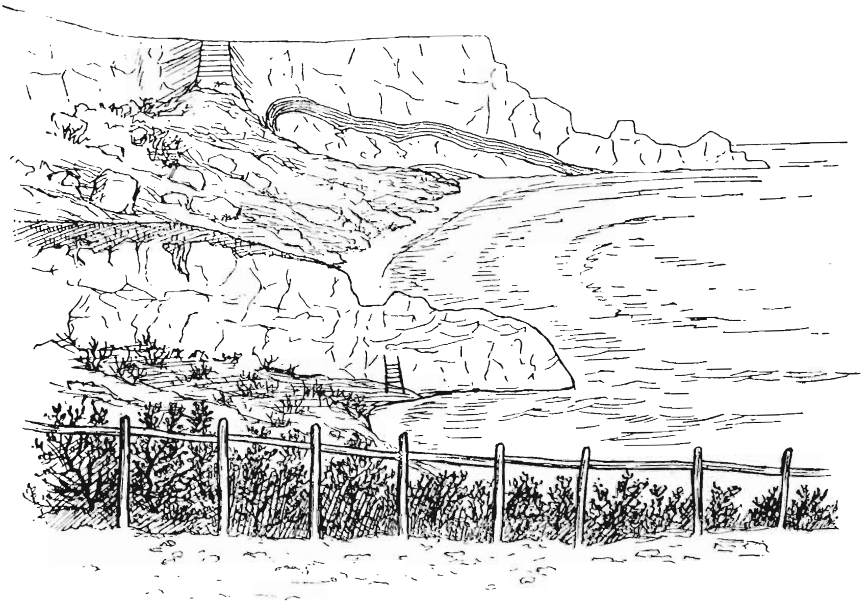
The map is not overburdened with dips, because their amount and direction are of little consequence in an area where the rocks are thrown into sharply inverted folds, and are seldom observable free from contortion or fault for many yards.

General Structure.

The indications of southerly dips, prevalent in the southern parts of the area, show that the axes of the folds are inverted toward the north. Although the constant evidences of disturbance and dislocation, met with in the area, naturally tend to obscure the true value and persistence of lithological and palaeontological horizons, their effect on the general continuity and structure of the rocks is less than might be supposed.

Striking east and west the main Lower Devonian outcrop terminates in Southdown Cliff, just south of Sharkham Point. It is separated on the north from the Lower Devonian (which bounds the New Red rocks of Paignton) by Middle Devonian slates, limestones and volcanic rocks; whilst, still further north, the Lower Devonian rocks of Torquay are separated from those of Cockington by Middle Devonian slates and limestones. Hence it follows that the limestone of Berry Head occupies a syncline troughing out eastward; the Paignton area, an anticline terminating westward, and the Torquay promontory, an anticlinal dome or offset from the Paignton anticline. The effect of these structures is to produce a great superficial representation of the Middle Devonian rocks, through the flattening or dying out westward of the great structural folds in a series of curves, repeating the beds with an endless accompaniment of small contortions. The map does not show this disposition of the Middle Devonian rocks because of the impersistence of the limestones, through their replacement by volcanic rocks ("The Ashprington series" of Champernowne) in the district south of Totnes, and by slates in the Dartington and Broadhempston districts. Another effect of the general structure is the greater dislocation and displacement of the rocks in the vicinity of the Lower Devonian anticlines. Thus, wherever Middle Devonian limestones are in contact with Lower Devonian rocks, a thickness of at least 170 feet of Eifelian slates has been cut out by fault or thrust; wherever Upper Devonian rocks, as at Saltern Cove, are in contact with the Lower Devonian, at least 400 feet of Middle Devonian rocks are missing. Upper Devonian rocks have been identified at Petitor, Anstey's Cove, and Ilsham, on the flanks of the Torquay anticline, and at Saltern Cove, Goodrington, Elbury and Silver Cove on the south of the Paignton anticline; yet in the district between Ipplepen and Totnes, away from the Lower Devonian rocks, we have no proof of the occurrence of Upper Devonian, and may, therefore, safely infer that—neither the dislocations nor the folds are of sufficient magnitude to trough them in.

Fig 2.—View across Redgate Beach.



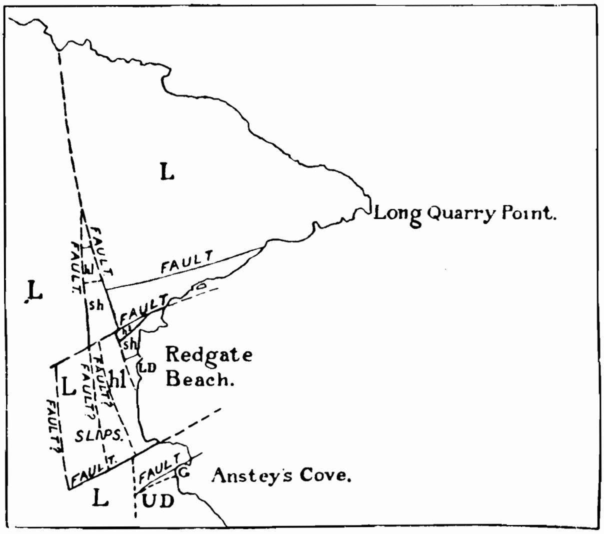
The sketch is taken from the path to Ilsham, looking across Anstey's Cove, Devil's Point and Redgate Beach, to Long Quarry Point. At the step-ladder red shale and shaly limestone (Upper Devonian) overlie the Devil's Point limestone, which may represent the *Rhynchonella cuboides* beds. On the further side of Devil's Point is Redgate Beach, at the foot of a tumbled slope of slips and debris from a cliff of contorted and faulted Middle Devonian limestone, there is a partial exposure of Lower Devonian shale and grit under dark Eifelian shales. Beyond is the limestone (Middle Devonian or *R. cuboides* beds) plateau of Babbacombe Downs. Along the cliff face dark Eifelian limestones, plicated with a mass of grey milestone, are shown; these beds slope outward from the face of the cliff which coincides with a fault by which they are brought up to the south. The cliff face is also broken by two cross faults, facing the spectator: between these red shaly limestones (probably Eifelian) are brought up, and appear to rest on the slates. The broken ground masks numerous faults slips, talus, and limestone blocks.

From what has gone before it may be regarded as a truism to point out, that comparative breadth of outcrop affords no indication of the thickness of any group in the Devonian series.

Fig. 2 has been selected as the best illustration of the complexity of structure and presence of faults in the vicinity of the great structural curves. The distance represented is not more than from twenty-three to twenty-five chains, and in it rocks of Upper, Middle, and Lower Devonian age occur. It also illustrates the character of the limestone plateaux and the erosion of the softer strata along lines of weakness.

The cliff face of contorted Middle Devonian limestone, parallel with Redgate beach, and coming toward the spectator, cannot, of course, be shown; but the tumbled masses of limestone and broken ground, at the foot of this cliff face, is due to slips, occasioned by faults and cracks on the down, parallel with

Fig. 3.—SKETCH MAP OF REDGATE BEACH, (Scale 6 inches=1 mile).



UD. Upper Devonian red and greenish slates and shales.
G. Apparently shaly Goniatite-limestone with calcareous tuff.
L. Middle Devonian limestone.
hl. Thin dark limestone (Hope's Nose beds apparently) faulted against the limestone cliff and folded round pale-grey rather thin-bedded limestone; and reddish thin-bedded limestone.
sh. Reddish and dark-grey shales (Eifelian).
LD. Lower Devonian, red shales and red-brown grit, and grey slates with occasional beds of grey grit. Largely concealed by talus.

the cliff edge, in beds of limestone dipping seaward at a comparatively low angle. Fig. 3 shows the locality in plan. Fig, 1 (Frontispiece) is a section drawn across the map due north from Stoke Fleming. It shows the Paignton anticline and main outcrop of the Lower Devonian rocks.

CHAPTER II.

LOWER DEVONIAN.

The Lower Devonian rocks of the area consist of slates and grits irregularly associated.

The slates vary from purely argillaceous to fine silty, more or less siliceous, sediment, and these varieties are frequently found interlaminated or interbanded. For instance, at the north end of Long Sands, at Scabbacombe Sand, etc., on the coast south of Berry Head. The siliceous slates locally become welded into masses of hard compact grit.

The slates, through coincidence of bedding with the prevalent southerly dips of schistosity, frequently present the appearance of shales, and, where associated with hard beds of grit, as in the coast north of Man Sands, or rendered intractable by silty admixture, they become shales; the tendency to cleavage in the latter case being often shown by the undulation or incipient gnarling of their planes. The grits vary from a fine grained rock to a hard silty mudstone; they are more or less felspathic. The relatively coarser grained and more distinctly quartzose grits are granular, or assume the character of quartzite. Of the former the red speckled grits of Warberry Hill constitute an easily recognizable type, which is met with here and there as the Lower Devonian rocks are followed along their strike into Cornwall. Of the latter typical examples are furnished by grit bands and masses associated with the variegated slates of Kingswear promontory. The more felspathic varieties, and the finer silty sediments form hard or dense grits or siltstones.

Strings, lenticles, or bands of limestone are found in the slates; they are mainly of organic origin and are often completely altered. by the dissolution of the lime, into brown friable compressed residues. The presence of these bands furnishes a much more reliable guide to the classification and structure of the Lower Devonian rocks than is to be obtained by a study of the character and distribution of the grits, and the distribution of colouring matter.

Looked at broadly, grits are of more frequent occurrence in the upper part of the Lower Devonian where the arenaceous or granular varieties prevail; lower down they usually occur in intercalated beds, bands, or seams, and are more close textured and silty. The arenaceous rocks are generally reddish, red-brown, or dull green, and the associated slates reddish or grey. The compact grits are more often grey or brown; where this is the case they have been called Meadfoot beds, but where red they cannot be separated from the overlying types. Champernowne gave to the upper series the name of "The Lincombe, Warberry and Smugglers Cove Grits," but the term "Staddon Grits" used by Holl is the best general term—they are developed on Staddon Heights south of Plymouth.

The term "Meadfoot Beds" was applied by Pengelly to dark slates and mudstones, with beds of compact grit and calcareous fossiliferous bands, which form the cliffs under Kilmorey and above the north part of Meadfoot Sands. These beds constitute a passage between the Lower Devonian rocks, where grits are prevalent, and the slates where they are of less frequent occurrence. The uppermost beds of the Meadfoot series are therefore sometimes mapped with the Staddon grits, and sometimes separated according to the vagaries of colour distinction. In the Paignton anticlinal the prevailing red colour prevents any boundary being drawn between the Staddon grits and Meadfoot beds. The main mass of this series consists of grey slates, locally red-stained, containing films or lenticles of limestone in places, occasional bands of hard grit and siliceous or silty interfilmings. In the area occupied by the group, it will be seen that grits have been mapped, notably the mass extending westward from Long Sands. These are coloured the same tint as the Staddon beds and they may be synclines of the basement beds of that group or of the grits in the upper beds of the Meadfoot series. Their occurrence is analogous to the grits of Looe and Beesands (Beeson) near Torcross (in sheet 356), in which rocks of the Warberry type are common. The rocks of the Torcross and Kingsbridge districts, as well as the various types of the Looe fossiliferous rocks, are all included in the Meadfoot series.

Below this group come the Dartmouth slates, a name given by Sedgwick to the glossy lilac, purple, and green variegated slates occurring south of Dartmouth and east of Kingswear. Beds of grit and quartzite occur in this group. Its relative position was unknown prior to the year 1898, during which the Looe area was surveyed and the Dartmouth slates proved to be continuous with the Polperro beds. When the map (350) was published, June 1898, the Dartmouth slates, although separated by a broken line, were not differentiated by colour. As in the case of the Staddon grits, the junction of the Dartmouth slates with the Meadfoot series is most uncertain. During the survey of the district a sharp colour distinction between dark slates (regarded as Meadfoot Beds) and lilac, red or purple, and green variegated slates, was taken as a boundary line, but on revisiting the Kingswear promontory (in 1902) it was found that red slates and grits with limestone of the Looe type had, through dependence on colour, been included in the Dartmouth slates, the boundary being further south than the broken line on the map.

There is no evidence of the presence of the Dartmouth slates at the surface in the Paignton and Torquay anticlines, and these are so broken up by faults that the structure of the Lower Devonian rocks can only be made out by a study of the main outcrop in the southern part of the map. In this area the coast section between Scabbacombe Head and Sharkham Point furnishes the best and most continuous exposure.

Proceeding northward along the coast, the greenish, purple, red and grey, partly siliceous slates of the Dartmouth group, with grey or green beds of hard grit or quartzite here and there, are associated with sheared igneous rock (perhaps originally a felspathic tuff of a type met with in the same series at Brook Hill near Kingswear, etc.) at a few chains north of Scabbacombe Head. At a few chains further north the red shaly grit and slate fragments on the surface contain fossils and brown friable seams which are the only indication that we have passed into the Meadfoot group. The coast being here inaccessible, it is impossible to say whether the junction is a natural one or faulted. The same beds are exposed at the Post Office, Kingswear. The cliff at the south end of Scabbacombe Sands consists of dark grey slates invertedly overlain by red, partly siliceous, slates with bands, films, and lenticles of red crinoidal limestone, in which irregular white streaks of calc spar replace organisms which were probably for the most part Monticuliporoid corals. A large fallen block of red limestone with the same white markings, is identical in every respect with red and dark grey limestone associated with the Looe grits on East Looe Beach and with the dark grey slates in junction with them at Millendreath. In the intervening coast sections there are similar limestones in the cliffs under Tregantle Fort; south of Plymouth between Crownhill Bay and Andurn Point; between Westcombe Beach and Armour (or Ayrmer) Cove near Ringmore, and by the River Avon between Sharpland and Cockridge Points.

Proceeding northward we encounter successively dark grey slates, contorted in places, grey slates with bands of grit and paler silty interlamination; a thrust fault bringing on dark slates with hard black patches, possibly fish remains, and limestone films with *Zaphrentis* and crinoids, then dark grey slates mottled with bright red (ologiste) splotches. These beds are succeeded by the Long Sands grits, dense, often thick bedded, arenaceous or silty rocks evidently much disturbed. In one spot small fossil markings, resembling Gasteropods, were observed in a hæmatitic patch on the surface of a bed. Small included fragments of buff slate or shale, are occasionally met with, particularly in one thin band. This is a phenomenon exhibited by the Looe grits and by the Staddon grits, and may be due to contemporaneous deposition or erosion.

The grits are associated with pale reddish slates, and apparently much contorted; they are continuously exposed in the low shore cliff, and make a vertically contorted junction with dark slates, in which a fragment of a Pachyporoid coral replaced by quartz was found. A little further north the slates exhibit silty interbanding; at the north end of the sands they contain small black patches, one of which revealed the structure of a *Pteraspis* plate. At the point, further on, limestone films with the (Monticuliporoid ?) markings previously described are to be seen, near dark slates with bands of pale coloured igneous rock similar to the rocks in the Torcross section. The prolongation of this horizon westward would connect it with the traces of igneous rocks found in the grey slates of the Nethway House Valley. Further north the slates become reddish, and contain films of crinoidal limestone, then dark grey, containing bands and lenticles of (Monticuliporoid ?) limestone similar to that in the red beds at the south end of Scabbacombe Sands; we next encounter traces of igneous rock of the Torcross type at the projection of Crabrock Point, round which it was impossible to proceed.

On the north side of Crabrock Point at the south end of Man Sands the section consists of dark grey slates with occasional seams of hard grit, veins of quartz and calcite, and interlaminated beds of Torcross and Tinsey Head types. Dark slates with occasional pyritous nodules prevail for about six chains beyond Man Sands Cottage, in the lower part of Southdown Cliff. The dark slates become blended with reddish coloured slates further north, and the schistosity is, in places, crossed by hard red decomposed fossiliferous bands, no doubt originally more or less calcareous, and occasionally forming bands or films of crinoidal limestone. A decomposed red-brown sheared igneous rock, about 2 feet thick, was noticed in these beds. At about twenty-five chains from Man Sands Cottage the section is broken by great tumbled blocks of hard grit, which occurs in thick bedded masses and in single beds in lilac-red and greyish slates, and both in the larger tumbled masses, and in low cliff exposures exhibits many inverted curves. These grits are very hard and compact, and in brown weathered patches there are traces of fossils, which, owing to the toughness of the rock, cannot be extracted by the use of an ordinary geological hammer. The appearance of these rocks connects them with the hard brown grits exposed in the New Drive near Hope's Nose, in which *Homalonotus* remains are abundant. The association of hard masses and beds of grit with reddish or grey slates continues for about ten chains north from the projection of the coast beyond Man Sands. Grey slates then prevail for about 60 yards, and overlie invertedly, reddish and grey slates with beds of hard grit, and red-brown shaly, more or less, micaceous sandstone. These show many inverted curves, and appear to constitute the base of the Staddon grit group, being cut off by a north-west and south-east fault, bringing up Aphanite and volcanic rocks of Middle Devonian (probably Eifelian) age.

In this section the obvious resemblance of the limestones, whether occurring as bands, films, or impersistent lenticles of some thickness, at the south end of Scabbacombe Sands to those south of Crabrock Point (whether the organisms are Monticuliporoid corals or not), leaves no doubt as to their being repetitions of the same horizon. There is every reason to conclude that the sequence from Man Sands northward is a gradually ascending one. Whether the hard grit beds and masses on the south of the Staddon grits should be embraced in that series, or in the upper part of the Meadfoot group, must remain a question awaiting the collection of characteristic fossils.

The discovery of *Pteraspis* at the north end of Long Sands, is a corroboration of similar finds in the dark slates of Looe above the variegated Dartmouth slates, and by Mr. Brook-Fox in the grey slates of Armour (Ayrmer) Cove (sheet 355). It is certainly suggestive of the proximity of the Dartmouth slates, but, on the other hand, the upward range of *Pteraspis* has never been ascertained in these rocks, and hard black patches are of common occurrence in the grey slates of the Plymouth section at higher horizons, and exactly similar to those in the slates on the north and on the south of the Long Sands grits.

The coast being inaccessible toward Scabbacombe Head (as previously mentioned), it is impossible to say whether the Dartmouth slate boundary is natural or faulted. Though the latter supposition is rendered probable by the usual intervention of dark slates between the Dartmouth slate and the red or grey fossiliferous beds of Looe, yet the local upward extension of red colouring matter would render such an intervening series indistinguishable from the rocks above and below.

As regards the Long Sands grits and dense silty mudstones, the boundaries and colouring on the map suggest a repetition of higher beds, which cannot be assumed in the face of the occurrence of masses of silty rock in association with the slates not far above the Dartmouth series in the Looe area.

The Lower Devonian rocks exposed in the River Dart sections appear to be in unfaulted relation to the Eifelian (or lower Middle Devonian) slates; consequently the Staddon grits are better developed than on the coast. Their normal type is greenish, dull purple, brown, and reddish, more or less micaceous sandstones or fine grits, in thick or shaly beds, associated in variable proportions with reddish or greyish slates. Hard grey and red quartzose grits, similar to the upper beds of the group, shown in the coast section near Hope's Nose Raised Beach, are also present. A few feet of peroxidated igneous rock, probably intrusive, was noticed in the Staddon grits at Lower Kilngate.

The junction of the Staddon and Meadfoot beds is concealed by Noss Creek, but the latter series is typically exposed in Higher Noss Point, consisting of grey slates with hard beds of compact grit in places, and bands and lenticles of fossiliferous limestone, more or less siliceous, and often decomposed to brown residua. Near Lower Noss Point brown weathered siliceous limestone bands yielded crushed Spirifers, regarded by Mr. E. T. Newton as similar to *Sp. primæva* or *Sp. Decheni*. On the west bank of the river, hard brown grits are more prevalent in the Meadfoot slates; they seem to be contorted impersistent developments similar to those on the south of the Staddon grits in the coast section, although not continuously traceable in the intervening district. The shores of Old Mill Creek exhibit bands and lenticles of limestone, and of decomposed fossiliferous material; and sheared igneous bands, probably volcanic, also occur in the grey slates. These are probably the westerly continuation of the calcareous beds near Lower Noss Point. At a spring on the south border of Sandquay Wood, near the Naval Establishment, variegated slates of the Dartmouth slate type are exposed. If this is not due to local staining in the

Meadfoot beds, they owe their position to faults and disturbances, to which the absence of a close correspondence in the sections exposed on either side of the Dart is no doubt due. On the east side disturbances are marked by developments of quartz in masses, and in veins interlacing grit beds, near the Old Rock Inn, Ferry. Further south, 25 to 30 feet of brown weathered grit is exposed. If dips can be relied on, this horizon is repeated further south in two bands, which coalesce, through the dying out of the folds in the intervening slate, to form the irregular mass shown on the map. These grits are probably a faulted continuation or a folded repetition of the grits of Long Sands, on the coast, which have been traced westward to Waterhead Brake, but do not appear to cross Waterhead Creek. On the west bank of the river the same horizon is represented in the north of Dartmouth by reddish slates with grits and sandstones, which are apparently in faulted junction with the Dartmouth slates. These have been traced westward for more than three miles.

On the north of this gritty development, igneous patches or impersistent bands occur in the slates, commencing at Sandquay quarry with rocks resembling sheared tuffs and with porphyritic diabase. Although the masses of Aphanite, etc., shown on the map may be intrusive, impersistent bands which cannot be shown suggest contemporaneous vulcanicity and co-relation with similar phenomena in the valley at Nethway House, and on the north of Long Sands.

A section taken across the strike of the Lower Devonian at Blackawton shows greater repetition of horizons than the Dart or Coast sections. The Staddon grits are repeated by a syncline at Blackawton, which can be traced to a connection with their main outcrop at Capton. The intervening anticline of Meadfoot beds is complicated by numerous folds, owing to the plicated repetition of the Staddon grits on the western border of the map. The grits mapped at Hutcherleigh may be a repetition of the Staddon group, or a continuation of the Long Sands grit horizon, as they appear to be connected with the latter by arenaceous mudstones and laminated gritty beds, visible in the slates at Washwalk, Millcombe Bridge and Pruston Barton.

Further south, the lower horizons of the Meadfoot group are kept at the surface by innumerable, apparently small, contortions. No fossils were obtained, although brown friable material was noticed in the slates in places. Green and purple slates belonging to the Dartmouth slates occur at Combe on the western margin of the map, and between America Wood, Higher Wallaton Cross, and Abbotsleigh, lilac and purplish slates prevail, also suggestive of anticlines of Dartmouth slates. Besides these there may be other anticlines which have escaped detection. The main boundary drawn by colour distinction is very irregular and so unsatisfactory that no attempt was made to separate out occurrences of grey slate in the Dartmouth slate areas in the Kingswear promontory, and near Stoke Fleming; although it is probable that the igneous rocks of these districts occur on the same geological horizon as those near Tor, Leader Wood and Buckland near the southern margin of the map.

This uncertainty cannot invalidate the conclusion that the groups are kept at the surface by shallow repeating curves or contortions in this part of the area, just as the Middle Devonian rocks are repeated at the termination of the great structural anticline of the Paignton area.

Through the sections across the main outcrop of the Lower Devonian we learn that the general descending sequence is as follows:—

1. Grits, sandstones, and gritty shales associated with slates and shales and generally reddish, greenish, or brownish in colour. (Staddon grits.)
2. Dark-grey, pale weathered slates and shales with beds of grit, occasional impersistent bands of siliceous limestone, and gritty films. In this series impersistent masses of grit occur. (Meadfoot group.)
3. Purple, lilac, buff and green glossy slates with beds of hard grit or quartzite. (Dartmouth slates or Polperro beds.)

The junction between 2 and 3 is so vague that, although very unlikely, it is by no means absolutely certain that the volcanic rocks in 2, near Dartmouth, may not be the same series as the volcanic rocks on the Kingswear and Stoke Fleming coasts, and in the Blackpool Valley.* This uncertainty is due to the absence of characters sufficiently marked to detect the basement beds of number 2, if present, in certain parts of the Dartmouth slate areas.

In general types the Staddon and Meadfoot groups correspond to the Upper and Lower Coblenzian of parts of Germany, and are homotaxeous with them. From this it must not be inferred that the lower part of the Meadfoot group may not correspond to strata older than the Lower Coblenzian, or that the upper beds of that group may not be in part Upper Coblenzian. The solution of this question involves a special search for fossils, for which there was no time during the survey of the area. In the following notes, commencing with the lower strata, we shall endeavour to keep each group separate as far as possible.

Dartmouth Slates.

The area was mapped in 1890–91 in entire ignorance of the connection of these beds with the variegated slates of Polperro, which was not clearly established until the survey of the Looe area in 1899. Taking the Looe district as the standard, both as regards lithological characters and relations, the Dartmouth and Polperro slates are identical. The variegated slates of Polperro and Downderry, where unfaulted, are in contact

* Such a correlation would make the grits between Long Sands and Cotterbury (near Blackawton), difficult to account for, except as an anticline of the upper beds of the Dartmouth slates.

with a dark slate series which separates them from grits. At Looe *Pteraspis* remains have been found on the coast in the dark slates, and these slates are often mottled with red (ologiste) splotches. It is, therefore, highly probable that there is an insensible passage from the *Pteraspis* beds to the Meadfoot group; and that a boundary drawn by colour characteristics may, in one place, exclude dark slates which belong to the Dartmouth slate series and, in another, include coloured slates which should be referred to the higher group.

In the Dartmouth slate districts between Scabbacombe Head and Stoke Fleming grey slates are frequently met with. Their presence suggests the occurrence of synclines of the basement beds of the overlying series which cannot be traced through the irregular distribution of colouring matter. Beyond all question, in the distinction of the different groups of the Lower Devonian colours are of great general value, but utterly unreliable, where unaccompanied by lithological distinction, as a guide to absolute stratigraphical boundaries. It is necessary to insist on this, as the boundaries of the Dartmouth slates west of Stoke Fleming are entirely dependent on colour distinctions. Guided by these alone the evidence in the south-western part of this area (and in the adjacent map, sheet 356) shows the gradual disappearance of this group westward through a series of anticlinal plications. This theory is borne out by the fact that, as a whole, the Dartmouth slate series is easily recognisable throughout its extension from Polperro in Cornwall to Modbury in Devon, but where in unfaulted junction with a grey slate series the boundary is nearly always more or less indefinite.

The Dartmouth slates are, as a group, characterised by the general prevalence of lilac, red, green and purple tints, often delicately blended with greys. Their glossy surfaces and reddish and purplish tints often exhibit much resemblance to varieties of the Gedinnien slates in the Ardennes. Siliceous shales (Quartzo-phyllades) are common in the series and, in the districts south of Dartmouth, may represent the grit intercalations which are often conspicuous in the Kingswear promontory. The grit beds vary from hard dense grit and more or less hackly fractured quartzose grit to quartzite. On the east of Ivy Cove hard grey grits intersected by quartz veins rest in inverted synclinals on glossy pink and lilac-grey variegated slates, and form crags on the summit. Between this and Scabbacombe Head a mass of similar grits forms a promontory. The local character of such grit masses is exemplified on the Revelstoke and Wembury coasts, at Bindown and Congorlan Tor in the Looe area and elsewhere throughout the extension of the group. On the hill above Kingswear, grey and blue slates, mottled red in places, are associated with shaly grit and rest on purplish, reddish and greenish grey slates or shales, with numerous films of brown friable material, usually in small knubbly patches or lenticles between their planes. Contorted beds of hard grit are shown at the south end of a quarry in the slate; beds of quartzose grit or quartzite are also shown in the south of Kingswear, where greenish and grey tints prevail.

Between Beacon House and Brookhill, the coast is accessible by a path and steps. Near this an igneous rock, probably a sheared felspathic tuff or lava, makes a contorted junction with the slates, crossing the cleavage of which both rocks partake. This sheared rock cannot be continuously traced, although it occurs near Scabbacombe Head and at Coleton. It forms a type here and there present throughout the extension of the Dartmouth slates.

At the cemetery west of Dartmouth a shaft was sunk to a depth of 59 feet, in pale lilac and reddish glossy slates with occasional films of soft brown powdery material. The occurrence of brown films, of which many more instances might be cited, suggests the decomposition of calcareous organisms.

Between Matthews Point and Landcombe Cove (in the adjacent map on the south, sheet 356) there are thin lenticles of limestone in the slates. One of these, a fine-textured red-purple band, seems to be wholly composed of small organisms, suggestive of fish-spines, etc., but not clear enough for identification. At Coleton and near Brookhill, east of Kingswear, the slates are often thickly studded with small bodies, which suggest scattered and crushed organisms. *Pteraspis* remains have not been found, but they have not been specially sought for, as the relations of the Dartmouth slates to the *Pteraspis* beds was not known until years after the mapping of the district. At Coleton, amongst the slates, sheared felspathic tuff may possibly occur, or cubes of pyrites decomposed and replaced by whitey buff material may have produced the effect. Near the Plymouth Brethren's Chapel at Blackpool the variegated glossy slates, in one place by the lane, resemble a highly sheared volcanic rock of the Brookhill type with felspars drawn out.

One of the chief difficulties in distinguishing sheared tuffs and lavas from sheared intrusive rocks is occasioned by the frequent coincidence in the direction of bedding and cleavage in the Dartmouth slates through the sharpness of the folds, the axes of which are often merely indicated by a thickening of the slate, and by the development of quartz veins. It is only when the series contains many intercalated beds of grit, as in the Revelstoke coast, that the eye can readily distinguish the constant over-folding of the beds, or where laminated grits traverse the cleavage in a wavy or puckered manner. In Mill Bay an appearance of unconformity in the series is probably due to a thrust. The igneous rocks occur in a way strongly suggestive of the plicated repetition of tuffs and lavas, either emitted from sources now beneath the sea or from local necks amongst or under them.

The character of the laminated grits as exemplified by a specimen obtained near Mill Hill Copse, west of Stoke Fleming, is thus described by Mr. Teall:—

3094 (130). Near Mill Hill Copse, west of Stoke Fleming.

A brownish grey puckered sandy Devonian shale containing small cubes of partially oxidized pyrite.

Under the microscope alternating laminæ of gritty and micaceous material. The micaceous laminæ show strain-slip cleavage exactly similar to that seen in the corresponding laminæ in the mica-schists. The strain-slips on opposite sides of an anticline dip outwards, and those on opposite sides of a syncline dip inwards.

The coarsest particles in the gritty layers are about ·1 mm. in diameter.

The micaceous layers are formed almost entirely of mica, which occurs both in the form of fairly large clastic flakes and also as extremely minute scales. The latter are associated with excessively fine micro- or crypto-crystalline material. Some of the gritty layers contain deep brown ferric oxide, which has probably been formed by the alteration of ferriferous carbonate. The micaceous minerals occur also in the gritty layers. This rock was evidently formed along the zone where fine sand shades into mud, and the conditions varied so as to give rise to alternations of finer and coarser sediment.

Meadfoot Beds and Staddon Grit.

For purposes of description the Lower Devonian rocks above the Dartmouth slates are naturally split up into the following districts—the southern district, or main outcrop, the Paignton anticline, and the Torquay anticline.

Southern District.

Meadfoot Beds.—These strata are so plicated and faulted that the appearance of the Dartmouth slates in anticlines in unexpected places may explain the following occurrences. Variegated slates on the south border of Sandquay Wood, near the Naval Establishment; a narrow strip of purple slates on the west of Uddern Copse (west of Ash and south of Paddlelake) at Hutcherleigh, and near Hoodown. As to the Long Sands, Dartmouth and Townstal grit, its boundaries, probably owing to the dying out of the grits in the reddish slates with which they are associated, are very indefinite near Nethway House. The faulted relation of these grits to the Dartmouth slates is nowhere seen, and the presence of rocks which might belong to the Dartmouth slates, and of grits in places (of Warberry and Looe types) renders the boundary uncertain. There seems to be, however, more evidence for regarding these grits as an impersistent development in the Meadfoot series than for their inclusion in the Dartmouth slates. The general succession of the Meadfoot beds on the west of the Dart seems to be as follows in descending order:—

1. * Dark slates with hard grey and brown grits and brown friable fossiliferous matter.
2. Dark grey slates with impersistent partly calcareous siltstone bands, films and lenticles.
3. Similar slates with volcanic seams impersistent.
4. Reddish slates and red and greenish sandstones, which may be continued by greenish grey sandy shales and banded mudstone westward from Cotterbury.
5. Dark grey slates with arenaceous films or gritty shales, possibly a repetition of the beds west of Cotterbury.

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* These are, no doubt, on the horizon of the fossiliferous Meadfoot bed disclosed in the New Drive (south of Hope Farm) in the Torquay promontory.

These arenaceous shales (5) are of frequent occurrence in the south-western part of the district. They form a common type met with near East Allington and in the Kingsbridge district. The laminæ are sufficiently coherent to enable the rock to be quarried out in large thick slabs (used for stiles, boundary fences, lidstones, &c.). This type is well shown between Bowbridge and Forder (south of Blackawton). Dark brown compressed friable material, apparently fossiliferous calcareous residue, is noticeable here and there in the slates between Newton Cross and Ford Corn Mill and on the south side of Millcombe. I think that the calcareous beds in Southdown Cliff are on or near the horizon of the limestone bands south of Lower Noss Point. These are continued by slates with shaly limestone lenticles and decomposed friable fossiliferous bands along Old Mill Creek. The westerly continuation of this horizon is shown by exposures of fossiliferous slates in quarries (on the 6-in. map) at West Norton Wood, between West Norton Wood and Bugford Lane End, and by the stream to the west of Bugford Lane End, near Lower Wadstray and at Lower Wadstray, where red-brown very fossiliferous friable matter is present. These all correspond to (2) in the above sequence. The following are apparently higher in the series and correspond to (1) in the sequence. Near Hole Farm, south of Bosomzeal, slates with hard grey grits and brown friable bands containing *Homalonotus* and Gasteropods are exposed in quarries near the top of the Meadfoot beds. Fragments from the same horizon south of Capton Cross contain *Homalonotus armatus* ?. North of Wood, west of Blackawton, Brachiopods, including *Chonetes* and *Rensselæria* ?, are met with in brown friable grit which, with some hard grit beds in the vicinity, have been included in the Meadfoot series. Northeast of Chipton, by the lane from Downton Cross to Old Mill, fossils resembling *Chonetes* and *Tentaculites* were found in red slates; these may, however, belong to the Staddon grits, as their junction beds with the Meadfoot group may be repeated by plication near Chipton.

Typical Meadfoot beds, probably on the same horizon as at Hole Farm, occur at Higher Noss Point, and contain hard brown fossiliferous beds. There are very fossiliferous lenticles, apparently with casts of Gasteropods, in the slates by the road between Noss Plantation and Furland. The grits just south of Furland may also belong to the upper part of the Meadfoot series. Between Furland and South Down Cliff the horizon cannot be continuously traced, and there are many faults, none of which can be located with certainty. Between Guzzle Down and Raddicombe there must be more than one fault to account for the absence of the Staddon grits and the junction of Eifelian slates and Meadfoot beds which cannot be approximately located. The upper beds of the Meadfoot group are apparently brought in by changing strikes between Forder and Southdown. In a brown grit surface stone north of Forder, at 25 chains east of Raddicombe Barn (see 6-in. map), fragments of *Homalonotus* and *Tentaculites* were found. Towards Southdown Cliff the relations of the Meadfoot and Staddon beds are not clear. The thin lenticular limestone bands and brown and yellow friable fossiliferous seams in the slates south of Lower Noss Point contain *Spirifera*, either *Sp. primæva* or *Sp. Decheni*, according to Mr. Newton. Near Old Rock Inn the slates contain brown friable matter. In a quarry in the irregular patch of grit south of Hoodown there are brown earthy bands evidently fossiliferous. A gritty micaceous shale in this quarry exhibits markings (*Chondrites* ?) also found in a dark slate at Long Sands. In Nethway Quarry (west of Woodhuish) dark grey slates with decomposed fossiliferous matter contain *Zaphrentis, Fenestella*, and crinoids. Near Woodhuish limestone lenticles, brown filmy fossiliferous bands, and gritty intercalations are met with in the slates. They are the prolongation of the calcareous horizons so well exposed in the coast section on the south of Crabrock Point. There is every reason for regarding these horizons as a repetition of the red beds with (Monticuliporoid ?) limestone bands and fossiliferous grits containing Brachiopods, which bound the Dartmouth slates between Scabbacombe Head and Scabbacombe Sands. The same horizon occurs at Kingswear. Casts of fossils, including *Rhynchonella daleidensis* ?, are met with in brown arenaceous shaly beds by Waterhead Creek, west of Waterhead Mill.

Staddon Grits.—Between Southdown Cliffs and Raddicombe the relations of these beds to the Middle Devonian rocks are everywhere obscured by fault. From Guzzle Down to the Dart, although the junction with the Eifelian slates appears to be a natural one, the exposures are insufficient. West of the Dart the junction is evidently faulted in several places near Kingston, and near Newhouse and Bickleigh there are no clear exposures. Around Higher Tideford grey slates, partly gritty and with grey grits, nowhere properly exposed, render the junction exceedingly uncertain. At Capton Wood,* south of Barberry Water Mill (on the 6-inch Map) grey slates occur in mass. There are also grey slates and mudstones between Allaleigh and Halwell Camp, and near Bosomzeal. There is no means of proving whether these slates belong to the Lower Devonian or to Middle Devonian (Eifelian) brought in by a syncline.

With these and similar local exceptions, the main outcrop of the Staddon group exhibits the usual characteristics of greenish, red and lilac grits and sandstones, often shaly, with the red speckled quartzose Warberry grit, and other local types, here and there. No fossils have been found in the main outcrop, although in the irregular synclinal tongue, between Capton and Blackawton, they have been detected in several places,† viz—in red speckled quartzose grits north-east and north of Hemborough Post, south of Stone Farm, where *Tentaculites* and Brachiopods (*Chonetes* ?) occur. In a quarry in purple and red grits east of

* West of Kingston.

† In the prolongation of the grit near Ritson westward into the adjoining map (349) *Bellerophon trilobatus* and *Homalonotus* occur, south-south-east of Stanboro House, south of Halwell. The same fossils have been found on Lincombe Hill, Torquay.

Quarry Head (between Oldstone and Blackawton) numerous badly preserved fossils are obtainable, including Gasteropods (*Pleurotomaria* ?). Near this, on the west side of Quarryhead Wood, white, red-speckled grit is exposed in quarries and contains badly preserved fossils (*Rensselaeria* ?). No fossils were obtained in this group between the Dart and Guzzle Down. Near Raddicombe (on south-east side) a grit fragment was found, apparently belonging to this group, and containing *Tentaculites scalaris* ?.

The Paignton Anticline.

On the north of Saltern Cove the Lower Devonian rocks consist of red slates with beds of quartz-veined grit overlain by New Red breccia; they are separated from red slaty Upper Devonian mudstones (The Büdesheim beds) by a reversed fault or thrust. The position of the fault is obscured by the similarity in colour, where grits are not evidenced; but it is certainly shifted northward by cross faults to Clennon Hill, whence it continues westward, frequently shifted by cross faults, throwing limestones and volcanic rocks down on the south, and cutting out the Eifelian slates completely. Toward Aish, washes from the high ground obscure the evidences of its position. Between Aish and Berry Park Lodge, Eifelian slates appear at Longcombe on the west of the fault boundary; they may also underlie the limestone of Lomentor Copse in a faulted tongue which indents the Lower Devonian.

A detached faulted mass of Lower Devonian is seen at Byrch Clump, on the 6-inch map: between it and Longcombe there are several limestone patches, some of which appear to be thrust over Lower Devonian grits and shales which occupy an irregularly faulted tract between the limestones on the west of the main fault boundary. Further north the main boundary separates Eifelian slates from the Lower Devonian. There is a strip of red slates, west of Borton Pines, which may belong to either group. There are no junction exposures, so that it is impossible to tell whether the boundary is anywhere unfaulted. Near Wildwood the northern boundary is a fault, and further east its position is rendered extremely uncertain through the prevalent lilac and red tints in the slates south of the Marldon limestone in proximity to the New Red rocks. This uncertainty is accentuated by the occurrence of *Pleurodictyum* in the red slates near Westerland House, by the presence of grey slates of the Berry Park type, apparently in faulted association with the red slates west of Westerland House and at Lower Westerland, by the prevalence of red slates in the Lower Devonian on the northern slope of Beacon Hill and south of Churscombe.

From Churscombe eastward the Lower Devonian rocks are partly in faulted, partly in natural unconformable relation with the New Red rocks. The prevalent red colouring in the Devonian rocks of the Paignton anticline renders the detection of the Meadfoot beds, as a separate series, impossible. That they are brought up by some of the numerous faults, and in anticlines, is certain. An abortive attempt was made to trace this group between Shortdown and Livermead. A small quarry (on the 6-inch map near Broomball Plantation), north-east of Windmill Hill Clump, displays slates and slaty grits exhibiting the characteristics of the Meadfoot beds. Fossils were obtained in a fine-grained lilac-brown grit in this quarry, and were kindly identified by Messrs. Gosselet and Barrois (unless otherwise stated) as follows :—

Pleurodictyum problematicum.
Homalonotus gigas.
Chonetes sarcinulata.
—— semiradiata.
Rhynchonella daleidensis (identified by Prof. Kayser).
—— hexatoma (near to Rh. daleidensis).

A *Leptæna* resembling *L. spathulata* was found in a grit fragment near Broomball Plantation on the west. These fossils point to the Lower Coblenzian age of the rocks.

In the red shaly beds with grit bands, exposed in Saltern Cove railway-cutting, *Chonetes sordida* and *Pleurodictyum problematicum* were found, besides the following which Davidson thought he could recognize amongst the fossils obtained from the cutting by the Rev. G. F. Whidborne :—

Leptæna looensis.
Orthotetes hipparionyx.
Rhynchonella pengellyana.
Spirifera lævicosta.

The natural inference from the above is, that these beds correspond to the fossiliferous rocks of Looe. This is, as far as I know, with one exception* the only recorded discovery of *Rhynchonella pengellyana* in Devon, the original specimen having been determined from the Looe rocks by Davidson. It is given by Sandberger as a distinctly Gedinnien species, and is, at any rate, strongly suggestive of the inclusion of lower horizons than the Lower Coblenzian in the Meadfoot series. Between the New Red outliers, south of Goodrington Sands, red slates, very irregularly associated with grit beds and much plicated, yielded *Tentaculites*, *Orthoceras*, *Spirifera*, *Zaphrentis*, and *Pleurodictyum*. Between Paignton and Torquay, near Hollowcombe Lake, north of Preston, the red slates and grits contain fossils too imperfect for identification. In this neighbourhood slates seem to underlie grits and sandstones, becoming intercalated with grit beds and resting on grits near Shortdown. *Spirophyton* † was found in red shaly grits near Shortdown. Red slates with grit by Seaway Lane, Cockington, yielded *Homalonotus*. In red grit fragments ploughed up on the margin of Staddon Plantation, Cockington, *Pterinæa* and a good example of *Spirifera hysterica*† were obtained.

On Paignton Windmill Hill, red slates and grits, cropping out by a hedge in a field near Ramshill Cross, furnished *Pleuro-*

* Viz., *Rh. pengellyana?* amongst Champernowne's fossils from New Cut, Torquay, identified by Etheridge, with doubt. *Geol. Mag.*, Nov. 1881, p. 490.

† Identified by Messrs. Gosselet and Barrois.

dictyum and *Homalonotus* ?.* On Beacon Hill, south of Westerland House, amongst the numerous grit fragments ploughed up, brown fossiliferous stones yielded *Homalonotus*, *Nucula* (near to *N. kahlebergensis*, Bausch., perhaps *Palæoneilo* of the Coblenzian), and indeterminable fragments of Gasteropods and Lamellibranchs. By the high road, south of Churscombe, 15 chains from the Ship Inn, *Spirifera speciosa*, *Streptorhynchus*, *Orthis*, and *Pleurodictyum problematicum* were obtained in rocks very similar to those in the Saltern Cove Railway Cutting. In a quarry by the road from Livermead to Cockington, traces of Brachiopods were noticed in red grit with numerous included fragments of shale.

The Torquay Anticline.

Better opportunities for the study of the characters of the Staddon and Meadfoot groups, and for obtaining fossils in them, are afforded in the Torquay promontory than elsewhere in this area, owing to many exposures in road cuttings supplementing the coast sections.

The structure is a complex anticline, cut up and displaced by innumerable faults and thrusts, and the strata are moreover exceedingly contorted. From Warberry Hill the Lower Devonian (Staddon grits) extends westward in a strip bounded by faults, one of which is well shown in Market Street, from the Western Hospital to Mudges Copse (Thurlow Road), where it is cut off by a fault. A bifurcation occupies the high ground between Warberry Hill and Babbacombe Church. If the main boundary is anywhere in unfaulted relation to Eifelian slates it would be so on the south of Babbacombe Church, but there are no junction sections. North of the Western Hospital some red and greenish slates and shales are exposed by a new road; they are open to the same doubt as the red slates round Westerland House, as to whether they are Lower Devonian or Eifelian.

Between the Warberry and Lincombe † Hills there are no exposures beyond a small mass of shattered limestone by Lower Warberry Road, just inside the grounds of Wellswood House, and indications of slates north-east of it, which may be Eifelian. It is not improbable that the grits of Warberry Hill are separated from those of Lincombe Hill by a synclinal tract of faulted Middle Devonian rocks; if not, the connection would be on the south of the patch of limestone mentioned above, *i.e.* between Lower Warberry Road, Erith House, and the faulted boundary of the Braddons Hill and Lisburn Crescent limestones.

Behind Hesketh Crescent there is a fault junction between the Middle and Lower Devonian; it is nowhere visible, but from very slight exposures of Lower Devonian rocks in Lower Lincombe Road and elsewhere, it appears to run in the direction shown on the map, toward Apsley House. The grits of Lin-

* Identified by Messrs. Gosselet and Barrois.
† Lincombe Hill is called Oxlea Hill on the map.

combe Hill are faulted against Middle Devonian limestones on the north, the fault boundary traced eastward cuts off the Black Head Diabase against Lower Devonian at Smugglers' Cove.

At Hope's Nose the Lower Devonian is separated from the Middle by a series of faults; but in the bay on the west of the Raised Beach, on the southern shore of the promontory, the uppermost grit beds of the Lower Devonian are visible at the base of a broken cliff composed of Eifelian slates, capped by irregular calcareous slates and slaty or shaly limestone. This section * commences at a well-marked fault, hading east and throwing down the limestones which form the southern horn of the promontory. Near this, proceeding westward, the lower part of the section is composed of dark slates or slaty shales, which are the basement beds of the Eifelian. In the lower parts of the cliff, a mass of grit, 10 feet thick, in beds of from two inches to two feet in thickness, terminates abruptly in the dark slates. Although in apparent horizontal intercalation, the grits are evidently sharply folded and connected with Lower Devonian grits on the beach; the connection being obscured by tumbled blocks of limestone. The grits are hard, fine-grained and quartzose, of pale grey or reddish grey colour, and with whitish surfaces, studded here and there with small black, glistening, argillaceous filmy patches. In the beach reefs the grits are in irregularly contorted association with the dark slates; they are laminated, and interlaminated with shaly films, in places. On the bed surfaces changes in colour, from grey to red with green mottling, are noticeable. Fossil casts are plentiful on some of the surfaces, but they are very badly preserved and impossible to extract. *Loxonema* and *Pleurodictyum problematicum* were recognised. Toward the end of the beach a sharp easterly tilt is observable in the Eifelian slates above, and the grits rise from the beach to a height of about 40 feet in the cliff. This sudden rise of the grits is probably accompanied by a fault, and they are cut off on the west by a fault, concealed by *débris* in a small gulley which descends to the beach, at its western end.

On the opposite side of the gulley the cliffs are formed of characteristic Meadfoot beds, consisting of dark slates with fossiliferous seams (in which *Zaphrentoid* corals are conspicuous) and brown-weathered even grit beds showing local contortion and disturbance. These beds form a strong contrast to the thick beds of grey grit on the east side of the gulley.

This section was noted by the late E.B. Tawney thus: †—"On the other side of Hope's Nose tongue of land we have merely the top part . . . the lower part is cut off by a fault which brings grey and red grits against beds of the Meadfoot series." In the red and grey (Eifelian) shales above the red grits he obtained *Favosites Goldfussi* and *Cyathophyllum*; in the red grits *Ten-*

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* See fig 6, on p. 51.

† *Trans. Devon. Assoc.* Vol. 4, p. 293, 1870.

taculites scalaris, *Homalonotus*, *Streptorhynchus gigas*, and other fossils, mostly Lamellibranchs.

If these fossils are undoubtedly from the uppermost grit beds of the Lower Devonian and not from the grits in Smugglers' Cove the presence of *Streptorhynchus gigas*—which occurs in the Onychien quartzite and Rhipidophyllen Schiefer—(the lowest horizons of the Gedinnien in Nassau), according to Sandberger,* and does not go up—is remarkable.

As there are no Eifelian slates on the north coast between Smugglers' Cove and Hope's Nose, the fault in the gulley on the south coast alone, or in conjunction with cross dislocations, in some undiscoverable way, cuts off the Eifelian slate tract between the north and south shores of the promontory. The uppermost beds of the Lower Devonian are also exposed in the exceedingly faulted tract bounding Redgate Beach (*see* Fig. 3 p. 13). Here tough broken fine grits of a chocolate red colour, in one spot exposed to a depth of eight feet, occur under red shales with grit bands, and are overlain by dark slates or shales, evidently Eifelian. The extension of both is effectually concealed by talus and limestone blocks; no fossils were found. It is impossible to correlate these beds with any special horizons in the Lincombe and Warberry grits. The tendency of the evidence in this, as in the Paignton and Southern district, is to prove that the character of the junction beds of the Lower Devonian with the Eifelian is variable, sometimes formed by grits, sometimes by slates or shales with intercalated grits, or grits and grit shales with intercalated shales or slates.

The boundary of the Staddon and Meadfoot groups is not a very reliable one to judge from the two sections in which it is exposed—viz. at the bend in the New Cut drive (north-west of Kilmorey) and by the New drive (south-east of Hope Farm and north-east of Kilmorey). In the New Cut the red slaty beds and grits become buff, mottled with purple, and seem to pass more or less horizontally into grey slates with bands of grit. There may, however, be a fault at the bend in the New Cut running towards Lisburn Crescent. The red beds of Lincombe Hill terminate at Torcello, Higher Lincombe road, in the manner shown on the map; but, between their termination and the faulted limestone of Apsley House, green grits (or sandstones) and grey slates are evidenced in places in Lower Woodbury Road and by the steps leading to it from Higher Erith Road, and in and between Lower and Middle Lincombe Road. These may be the upper or lower beds of the Staddon group. Greenish grits and grey slates are also faulted against the Asheldon Copse limestone by the Babbacombe road. On the slope below the New Cut, above Hesketh Crescent, greenish and grey grits are associated with dark grey slates.

In the New Drive, west of Hope Cove (the cove south of Smugglers' Cove) the peroxidated grits and slaty beds are shown to change colour and to become brown grits associated with grey

* *Jahrb. d. Nassau Ver. f. Nat.* Jahrg. 42.

slaty shales. Near this the fault shown in Hope Cove, and noted in Tawney's section, crosses the road, and for ten chains in a south-easterly direction the rocks exposed by the road would be classed as Meadfoot beds. There appear to be at least two fossiliferous horizons in them (perhaps roughly corresponding to those of Hole Farm and Higher Noss Point in the southern district). These beds are succeeded by dull green grits with occasional flakes of shale,* and hard grits, often flaggy, which are cut off by a nearly north and south fault along the crags overlooking the Hope's Nose promontory.

These grits, if lithological character is worth anything, belong to the Staddon group; indeed, they may be the upper beds of that series thrust over the Meadfoot beds. They occupy the highest ground between Kilmorey and Hope's Nose, on which, as their persistence is very doubtful, they are indicated by two patches on the map. The westernmost of these patches is evidently a very thin capping of flaggy greenish grit, occasionally red, judging by surface stones on the hill above Kilmorey. Traces of fossils including *Atrypa, Rhynchonella, Chonetes* and *Spirifera cultrijugata* were obtained. There is doubt about the last named owing to the imperfection of the specimen. Greenish sandstones associated with or overlying grey slaty mudstone and dipping in northerly and north-westerly directions are exposed in quarries near Kilmorey on the east. In stones in one of these quarries *Homalonotus, Chonetes, Spirifera* and *Pleurodictyum* were noticed. This westernmost patch has every appearance of an outlier, but between it and the easternmost mass there are hard and soft grey slates which are more or less fossiliferous, and as far as character goes might be Eifelian.

These slates contain *Pleurodictyum,* and *Cornulites* (identified by Mr. Whidborne) was also found in them. The green sandstones of the larger patch seem to dip under them near its south-eastern boundary. The upper parts of the cliffs bounding this tract are also suggestive of a newer slaty series overthrust on an older (the Meadfoot beds); the relations of the rocks between Kilmorey and the Eifelian of Hope's Nose are therefore exceedingly doubtful. The cliffs under Kilmorey are characteristic Meadfoot beds. In the same series from here to the gulley fault, west of Hope's Nose Raised Beach, there are many faults; one of these is well shown (marked by fault rock) in the cove on the east side of the southernmost point on the coast. It cuts off a mass of red grit forming the end of the point, apparently the axis of a uniclinal plication. The cliffs of the cove in the lower part are composed of dark grey, partly siliceous, slates, with fucoidal markings and *Chondrites* ?† and traces of

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* Lithologically identical with green grit in the Staddon grits near Plymouth.

† Similar to those in the quarry south of Hoodown, and in dark slate at Long Sands. A gritty shale with irregular surface markings, fucoidal ? noticed here has been observed on the Thurlestone Coast and in many Lower Devonian sections in Devon and Cornwall.

Gasteropods (*Pleurotomaria ?*) and other organisms. No absolute decision as to the position of these beds can be arrived at owing to the zig-zag contortions accompanied by thrusts (or axial displacements) and traversed by faults, which are everywhere met with; but the probability of their equivalence to the slates in contact with the grit of Long Sands may be hinted.

On the north coast, between Smugglers' Cove and Hope's Nose, a continuous section is visible; but the upper parts of the cliff slopes are almost invariably concealed by undergrowth, grass, and talus. The fault at Smugglers' Cove is marked by a deep depression separating the Black Head diabase, on the north, from red Lower Devonian rocks on the south. The latter consist of red slaty shales with thin grit beds, and intensely peroxidated hard fossiliferous bands, on pale lilac and greenish slaty shales, with hard massive grit beds (often interlaced with quartz veins) in the lower part of the cliff. On the beach thin beds of compact grit separate the above from grey buff-banded slaty rocks, which crop out near the fault, and were noted by Tawney as Meadfoot beds. In the next Cove (Hope Cove), through a southerly deflection in the strike, the beds above the thick grits occupy the lower part of the cliff; an oblique cleavage not affecting the grit beds is apparent. The following descending sequence, in a thickness of 8 feet, gives a fair sample of the section:—

Thin brown-red and green grit bed.
Red slaty shales.
Red and greenish slaty shales with impersistent bands of peroxidated fossiliferous grit with green shaly films.*
Grit, partly compact.

These beds are exposed for 24 yards in the cove, but beyond this the base of the section is concealed by tumbled blocks of red and grey rocks for 34 yards. A colour change probably takes place in this interval. Greyish and brown purple-stained grits with grey slates are then encountered, dipping south at 30°. The fault, noticed by Tawney, here traverses the section, bringing on a sharply folded axis (with lower limb horizontal) of brown and grey grits associated with knubbly irregular slates, which may be a repetition of those in the beach reefs of Smugglers' Cove. The partly decomposed fossiliferous slaty limestone† bed occurs at the base of the folded mass, but cannot be traced upward, as the whole is cut off by a tributary fault, or slide, joining the main dislocation above, and bringing on 10 feet of brown and grey hard grit beds (with purple surface mottling). These grits form the southern horn of Hope Cove, and dip under the following, in upward succession:—6 to 7 feet of grey slates

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* This character, already referred to as common to the Hangman grit series, the Looe grits, etc., was noted by Champernowne (*Geol. Mag.* Nov. 1881, p. 488) as characterising Ludlow rocks in the Usk district.

† *Zaphrentis* is recognisable, also black patches (fish traces ?). The latter are noticeable in similar rocks in the Meadfoot beds—at 23 chains west of Kilmorey, in Crownhill Bay, south of Plymouth (near Boveysand Bay), &c.

with hard thin brown shaly grit—an irregular bed of hard grit—20 to 25 feet of dark shales or slates, with hard thin brown weathered grit bands—a lenticular fossiliferous band. Above this the rocks may be the same as those in Hope Cove. The coast runs for about 13 chains from this, more or less coincidently with the strike. Grey slates with brown grits and thin grit bands are shown in sharp zig-zag plications, determining the surfaces of rock shelves at the base of the cliff, and occasionally broken by small faults. In places the section is red in the vicinity of joints or faults. For the remaining 9 chains the dips are often easterly. In the coves the grits and slates are red-stained for about 2 chains (*d* in Tawney's section). Beyond this, irregular dark grey slates, crossed at intervals by brown grits and partly calcareous fossiliferous bands, are in faulted junction with the Middle Devonian limestone of Hope's Nose Quarry.

This section is inconclusive as to the boundary between the Staddon grits and Meadfoot series. It proves that absolute reliance cannot be placed on colour distinction, and without that guide one cannot say in which group the peroxidated beds of Smugglers' and Hope Coves should be included.

In the following notes on the fossil localities in rocks classed as Meadfoot beds, and in rocks classed as Staddon grits, this separation is therefore often arbitrary.

Meadfoot Beds.

In decomposed fossiliferous bands and siliceous limestone, traversing the dark slates near their faulted junction with the limestone of Hope's Nose Quarry, the following fossils were obtained:—

Pleurodictyum problematicum.
Zaphrentis.
Homalonotus Rœmeri ?
Spirifera primæva.
Strophomena rhomboidalis (var. *analoga*, according to Whidborne).

At from 10 to 11 chains due south of Hope Farm, on the edge of a bramble brake, very fossiliferous decomposed brown beds and tough orange-brown bands are met with in grey slates. These beds can be more or less continuously traced along the contour to the New Drive, where they contain a bed of siliceous limestone, so that there is here a fossiliferous zone or zones extending continuously for a quarter of a mile. The fossiliferous beds are associated with irregular knubbly slates (of the Meadfoot and Lynton type) and beds of hard brown grit, in which remains (spined plates, portions of glabella, etc.) of *Homalonotus* are plentiful.

The following fossils were obtained from the beds in the New Drive:—

Spirophyton.
Homalonotus armatus ? (plentiful).
Chonetes (plentiful).
Leptæna laticosta (Tropidoleptus rhenanus)—plentiful.
Orthotetes hipparionyx.
Rensselæria strigiceps.

Rhynchonella (near to pugnus).
Spirifera cf. lævicosta.
— microptera.
Ctenodonta concentrica?
Pterinæa.
Tentaculites scalaris.

The following were found on the edge of the bramble brake:—

Homalonotus (comparatively scarce).
Chonetes.
Leptæna laticosta (plentiful).
Orthis hipparionyx.
Rhynchonella (large).
— sp
Spirifera (large).
Pterinæa.
Tentaculites.

This horizon is no doubt shifted by fault on the east; on the west it cannot be traced on the slope toward Kilmorey, where we should expect to find it below the western grit patch from the parallelism it exhibits to the northern boundary of the eastern grit mass, assuming these to be ordinary outliers. The cliffs and beach reefs under Kilmorey are composed of the irregular dark slates with hard grit beds and decomposed fossil bands characteristic of the Meadfoot series. Here *Pleurodictyum problematicum* was found. Dr. Kayser's* list from this spot is as follows:—

Zaphrentis oolithica (determined by Dr. Frech).
Rhynchonella daleidensis.
Chonetes sarcinulata.
Spirifera hysterica.
— paradoxa.
Strophomena cf. Murchisoni.
Pterinæa costata.

Mr. Whidborne† mentions the occurrence of *Strophalosia productoides* "in the *Pleurodictyum* beds at Meadfoot." Pengelly‡ recorded the discovery of a single scale of *Phillolepis concentricus* in coarse gritty slates at the base of the cliff under Kilmorey, and of a rather doubtful scale of *Holoptychius* from Meadfoot Sands. Salter in his monograph (Pal. Soc., 1865) gives Meadfoot Sands as the locality for *Homalonotus elongatus* (a species founded on the discovery of a tail). Phillips records (Pal. Foss.) *Orthoceras tentacularis, Spirifera costata, Orthis granulosa, O. plicata* and *Avicula anisota* from Meadfoot. Meadfoot Sands is too indefinite a term, as both Eifelian slates and Meadfoot beds are present in the cliffs on the west and on the east of Hesketh Crescent, respectively. The slates of doubtful character east of Kilmorey seem to overlie the green sandstones of the eastern outlier. On the southern border of the copses north-east of Kilmorey they contain many crinoid fragments and badly preserved fossils, amongst which were recognised the following:—

Pleurodictyum.
Zaphrentis.
Cornulites sp. (three specimens identified by Whidborne).
Spirifera lævicosta?
— speciosa.
Streptorhynchus.

* *Neues Jahrb. für Mineralogie*, &c., 1889. Bd. 1, p. 188.
† Pal. Soc. 1893, p. 156.
‡ *Trans. Devon. Assoc.* for 1868. History of the discovery of fossil fish, and *Ibid.* for 1874 in Notes on Recent Notices, &c., part 1.

By the easternmost copse, *Rhynchonella* and *Pleurodictyum* were found. The possibility of these slates being Eifelian and thrust over Meadfoot beds has been before referred to. They resemble slates included in the Eifelian of Ellacombe and near Warberry Mount.

Staddon Grits.

The exposures on Warberry Hill are slight, and this may be the reason why so few fossils have been obtained. The faulted strip of red grits and shales between the Western Hospital and Thurlow Road is better exposed, but no fossils have been obtained. In the wood near Warberry Reservoir red slates are exposed. If unfaulted, towards Babbacombe Church greenish slates at the base of the Eifelian are succeeded by red shales with beds of grit, over red grits presenting many examples of the white quartzose red-speckled variety. Amongst the materials turned out in the excavation of Warberry Reservoir, fragments of red-speckled grit containing *Tentaculites*, a cast of *Spirifera* (?) and *Beyrichia* were recently obtained; previously *Beyrichia wilckensiana* had been identified by Professor Rupert Jones in a fragment from this locality. If the green grits by the Babbacombe Road (near Asheldon Copse) and between Lincombe Hill and the Apsley House limestone were peroxidated, it is questionable if they could be distinguished from the red and red-speckled grits of Warberry Hill.

The reason the term given to this series by Champernowne "Warberry, Lincombe and Smugglers' Cove grits" has not been adopted, is, apart from its length, to allow for the probability of the Lincombe and Smugglers' Cove grits being in part stained Meadfoot beds, although the Warberry Hill beds are not open to this probability, as far as one can judge by the evidence.

In the field in which the round copse on the northern part of the summit of Lincombe Hill is situated, fragments of red, buff and red-speckled grit (and occasionally of banded rock of the Pigshill Wood type) are ploughed up. Some of these are fossiliferous, containing *Homalonotus*, *Chonetes*, *Orthis*, *Pentamerus* and *Pleurotomaria*. The following were specifically identified:

Pleurodictyum problematicum.	Bellerophon compressus.

On the south side of the copse grey and greenish slates and grits prevail. Further south near the 400-foot contour south of St. Raphael's Home, in pale buff, pale grey, and green tough hard and brittle grit stones, the following were obtained:—

Leptæna laticosta.	Streptorhynchus.
Spirifera primæva?	Bellerophon trilobatus.
— sp.	Tentaculites multiformis.

By the New Cut, within a hundred yards east of the spot where the red beds change colour, Champernowne* obtained

* *Geol. Mag.*, Nov., 1881, p. 487, &c.

the *Homalonotus* named *H. Champernownei* by Dr. Woodward, besides fragments probably representing two other species. Some of his fossils were identified by Mr. Etheridge. The rock is described as "red finely-sandy or silty beds, interstratified with grits" and "traversed by a coarse cleavage dipping south, which usually ignores the hard grit bands." The following, not included amongst Mr. Etheridge's identification, are also given by Champernowne:—

Tentaculites.
Chonetes sordida ("often crowded in certain layers.")
Cypricardites ?
Myalina. (Small)

Dr. Woodward's identifications:—

Homalonotus Champernownei.
Homalonotus sp.

Mr. Etheridge's identifications are:—

Petraia.
Pleurodictyum problematicum.
Chonetes.
Orthis.
Rhynchonella pengellyana ?
Spirifera cultrijugata.
Streptorhynchus umbraculum.
Pullastra.
Holopella or Loxonema sp.
Cyrtoceras.
Orthoceras.

The following were obtained during the early stages of the survey in 1888 in the New Cut, and in stones on the slope below:—

Pleurodictyum problematicum.
Avicula anisota, *Phil.*
Tentaculites.
Orthoceras.

Obtained in 1900:—

Homalonotus armatus ?
Chonetes sordida ?
Leptæna laticosta ?
Orthotetes hipparionyx.
Spirifera.

There is an appearance of a syncline in the red beds by the New Cut, noticed by Champernowne. Though the structure of Torquay is too complex to attach very much importance to it, it is consistent with the actual continuation of the red beds to Hope Farm and Smugglers' Cove. Near Hope Farm lilac-red and grey-lilac purple-mottled grits and slaty beds are exposed by the New Drive. The red-speckled grit type also occurs here, and a fossil resembling *Leptæna looensis* was found in it. At the bend in the new drive between Hope Farm and Hope Cove there is a contortion in the red grits, apparently in the vicinity of a fault.

In the hard peroxidated bands of Smugglers' Cove many fossils are to be seen, but it is extremely difficult to develop them sufficiently for specific identification. Tawney * considered the red beds of Smugglers' Cove to be about 150 feet thick; this estimate would be nearly correct if we could be certain that the cliffs afforded a direct succession, but the probability of zig-zag

* *Trans. Devon. Assoc.*, vol. 4, p. 292, 1870.

plication carrying the lower beds upward is much too strong to be overlooked. Champernowne obtained, "at Smugglers' Cove, with Mr. Lee," .... in reddish schistose masses slipped from the cliff, many casts of *Orthis*, *Spirifera*, and *Leptæna laticosta*. The bed effervesces, being an impure limestone." Tawney commented on the occurrence of *Tentaculites* and of *Cypricardiæ* in the red beds in Smugglers' and Hope Coves, and mentioned the discovery of *Pleurodictyum problematicum* in the faulted grey grits of the Meadfoot series in Hope Cove. According to Champernowne,* "Tawney's Smugglers' Cove list includes *Homalonotus* n. sp. (most like *H. Johannis* from the Wenlock beds)"; but this list is given in connection with the section on the southern coast of Hope's Nose promontory, and just after mention of fossils in Middle Devonian slates above the red grits. Although this list has already been given as obtained from the uppermost beds of the Lower Devonian, the possibility that the red grits were meant to include the Smugglers' Cove beds is suggested by Champernowne's remark. Our lists from the red beds of Smugglers' Cove and Hope Cove are as follow:—

Smugglers' Cove:	Hope Cove:
Pleurodictyum.	Pleurodictyum.
Chonetes plebeia.	Crinoids.
Edmondia.	Cyrtina or Spirferina.
Macrochilina.	Leptæna laticosta.
Pleurotomaria.	Spirifera.

Tawney's list, presumably from the uppermost beds of the Warberry group, West of Hope's Nose Raised Beach, is as follows:—

Homalonotus, n. sp. (most like H. Johannis from the Wenlock beds).
Orthis arcuata?
— (like Berthoisii).
Streptorhynchus gigas.
Cardiomorpha.
Ctenodonta.
Cypricardia lamellosa?
Modiolopsis?
Pterinæa ventricosa?
— (like bifida or anisota).
Natica.
Tentaculites scalaris (apparently most abundant).

Obtained by the Survey:—

Pleurodictyum problematicum.
Loxonema.

On the whole the Lower Devonian succession in Sheet 350 is rendered very unsatisfactory by the disturbed relations of the rocks and the utterly unsatisfactory character of the palæontological evidence.

In the Torquay and Paignton areas the main question is whether the Looe beds are represented or not. This is a purely palæontological question, for no objection on lithological or stratigraphical grounds can be urged. It seems to be answered in the affirmative by the identification of such fossils as *Spirifera primæva*, *Streptorhynchus gigas*, *Rhynchonella pengellyana* and *Orthotetes hipparionyx*.

* *Geol. Mag.*, Nov. 1881, p. 488.

The discovery of specifically recognizable fossils in the southern part of the area is necessary to enable one to piece together the more broken succession of Torquay.

The records of the occurrence of *Spirifera cultrijugata* are meagre and unsatisfactory *Pleurodictyum* is of no value whatever. The remains of *Homalonotus* are so numerous in the Torquay promontory that there is considerable scope for research as regards that genus alone. In fact, in bringing this chapter to a close, one can only deplore the paucity of specifically identified fossils, due to their bad state of preservation, but still more to the need for special search, even in unpromising localities, by which alone doubts as to the absolute position of certain rocks in the series could be satisfactorily solved. Whatever light may be cast on the Lower Devonian succession by such researches, it will be seen that they are minor points, and do not affect the general structure and disposition of the strata as set forth here.

Evidences of Contemporaneous Vulcanicity.

No igneous rocks have been detected in the Lower Devonian rocks of the Torquay and Paignton areas. In the main outcrop isolated traces of igneous rock, or of decomposed material probably of igneous origin, have been found in different places, and apparently in different parts of the series. The chief indications and those which point to horizons of vulcanicity are to be found in the Meadfoot beds from Sandquay Quarry westward to Paddlelake (east of Blackawton), and in the Dartmouth slate area along the southern shores of the Kingswear promontory and from the mouth of the Dart to the south-west margin of the map.

At about 20 chains north of the Coastguard Station at Man Sands a sheared igneous band, two feet in thickness, is noticeable in the cliffs in lilac and grey slates. Igneous rocks similar to those of the Torcross coast occur in the slates between Long Sands and Crabrock Point. In the valley between Nethway House and Woodhuish there are signs of igneous rocks in grey and bluish slates. Further west between Boohay and Waterhead Brake there is an irregular mass of very hard bluish or dark grey brown-weathered rock, probably an intrusive diabase. By the Dart, between Higher and Lower Noss Points two or three feet of igneous (probably volcanic) rock occurs in bluish grey slates.

On the shores of Old Mill Creek at Hermitage Castle, and by the tributary creeks near Great Copse and Rough Hole Barn, there are thin bands of volcanic rocks in the slates. By the Dart, at Lower Kilngate north of Old Mill Creek, a few feet of peroxidated materials, probably decomposed igneous rock, occurs in the Staddon beds. With this exception, the traces of igneous rock mentioned occur in the Meadfoot beds, and may possibly belong to the same series repeated by folds.

Further west there appear to be volcanic bands in the slates near their junction with the Staddon grits south-east of Higher Wadstray.

In Sandquay Quarry about thirty feet of quartz-veined porphyritic diabase occurs in grey sericitic-looking slates. At the Gymnasium north of the Quarry there appears to be a volcanic tuff band in the slates. The Sandquay rock cannot be traced more than a quarter of a mile westward, but between Mount Boone Farm and Norton there are seven masses of igneous rock, two of which resemble the Sandquay rock, and three are aphanites. These igneous patches occur in the slates which contain intercalated bands of tuff and slaty diabase near Townstal on the west, and near Norton on the south and south-east.

A small patch of igneous rock is visible in a quarry at Woodbury Farm. Further west, aphanite with cracks lined with asbestus is exposed in a quarry south of Bugford Lane End. Clay is said to have been encountered in the centre of the quarry under the aphanite. Between this rock and Norton no proofs of the occurrence of volcanic bands in the slates were obtainable, but between Bugford Lane End and Cotterbury Green soft tuffs, banded tuffs, and white shales with a steatitic appearance were noticed near Hillfield and Bugford Cross, and a small patch of diabase north of Paddlelake.

There is a small mass of diabase near Pasture Farm, south of Hutcherleigh, quite isolated.

Further south, near the south border of the map, we encounter the chain of diabase patches and volcanic rocks which belong to the Blackpool, Stoke Fleming and Kingswear coast series. These commence with a small patch near Lower Heathfield, a larger one south of Torr, and one near Buckland, apparently in the Dartmouth slates; a craggy mass on either side of the stream in Leader Wood and Burlestone Wood; several small patches, which do not appear to be connected, in and near Leader Wood and near Hansel and North Corn Mill, and at Orestone Cottage. Most of these are hard diabases, and probably intrusive, but it is possible that the last mentioned may be contemporaneous.

The next patch of igneous rock (diabase) is shown to a depth of twenty-five feet in a quarry at Combe Cross. The structure is suggestive of an anticline.

The igneous rocks of the Blackpool Valley consist of aphanites and slaty and sheared diabases. These seem to be in plicated association with grey slates which contain sheared rocks, probably tuffs and lavas, near Middle Blackpool Corn Mill and Venn Cross. The Quarry near Venn Cross is in rather soft sheared green rocks, with steatitic-looking material lining a crack in them. They cannot be traced beyond the quarry, there being no exposures, but they are probably continuous to Middle Blackpool Corn Mill. Hard igneous rock resembling the rocks of the Stoke Fleming coast is exposed in a quarry near Embridge Corn Mill. A band of sheared diabase crosses the valley at Blackpool, and there appear to be bands of sheared felspathic tuff in the Dartmouth slates (as between Kingswear and Brookhill) near Blackpool Bridge.

At the southern extremity of Blackpool Sands, a rhyolitic felsite is exposed in the cliff. It is thus described by Mr. Teall

(No. 3,076): "A compact pinkish felsitic rock showing a marked fluxion structure." Under the microscope, "a few small phenocrysts of plagioclase in an irresolvable felsitic matrix."

The volcanic rock is repeated in Matthew's Point on the south. As it cannot be traced in either case westward, its presence is evidently due to anticlinal folds. In Landcombe Cove there seems to be tuff in the slates.

At the east end of Blackpool Sands buff-weathered igneous rocks, with filmy bands of green hornstone near their junction with the slates on the north, occur in the cliff. These rocks, partly vesicular, alternate with the slates through plication, and are repeated at Leonard Cove, extending to Redlap House. On the east of Redlap Cove a mass of diabase, broken up irregularly by anticlines of red and green slates, forms the coast as far as Combe Point and on either side of Shinglehill Cove.

Between Compass Cove and Blackstone Point there appear to be impersistent volcanic bands in the rock reefs of grey and greenish slates. These rocks, with irregular volcanic intercalations, overlie a mass of slaty diabase in the cliff on the south side of Ladies Cove, the whole being cut off on the west by a fault which runs along the eastern cliff of Compass Cove. They may, therefore, be regarded as the continuation of the Stoke Fleming rocks shifted by fault. Between Venn Cross and Ladies Cove on the south of the high road and north of Little Dartmouth there is a quarry in hard diabase overlain by slates with sheared volcanic rocks. The rocks cannot be traced beyond the exposure. They may, for all one can tell, be the easterly continuation of those in the quarry near Venn Cross. Throughout this area in the grass lands there are no exposures, and those by roads are too meagre to afford any clues by which to trace the volcanic bands.

On crossing the mouth of the Dart we find that the igneous rocks are continued by three masses of diabase on the southernmost part of the Kingswear coast. One of these seems to occupy a syncline in grey slates; it is probably shifted by fault on the east, and continued by the two masses on either side of Old Mill Bay between Froward Cove and Kelly's Cove. North of Kelly's Cove igneous rocks are again encountered in Pudcombe Cove. Here hard sheared igneous rocks form a band about ten feet thick in reddish slates with some hard grit on the north shore, the west side being composed of dark grey igneous rock, resting irregularly on the slates which contain hard sheared igneous rock near its northern extremity. Sheared diabase and buff rocks, which may be tuffs, occur at the western cliffs of Ivy Cove. At ten chains north of Ivy Cove dark grey sheared igneous rocks extend a short distance westward from the coast. Although the continuity of these masses cannot be proved, their general alignment in strike with the igneous rocks of the Stoke Fleming coast scarcely admits of a doubt as to their being the same series, shifted by faults, repeated by folds and occurring in patches severed by denudation.

When the area was surveyed the true relations of the Dartmouth slates were unknown, and no time was specially devoted to a search for fossils. It is therefore uncertain whether higher beds may not be faulted or folded in, but even on this hypothesis the correlation of the volcanic rocks in the Meadfoot beds between Sandquay and Paddlelake with those of the Stoke Fleming and Kingswear coast is scarcely probable, except as belonging to the same general series. In this connection, however, it must be remembered that, although colour distinction is of great value in effecting a broad general separation of the main groups of the Lower Devonian, where unaccompanied by sufficiently marked lithological distinction it is a most unreliable guide to the position of stratigraphical boundaries, so that the occurrence of these igneous rocks in a red slate series or a grey slate series is of itself no proof that the horizons are different.

CHAPTER III.

MIDDLE DEVONIAN.

Under this heading are embraced all the slates, limestones and volcanic rocks between the Lower Devonian on the one hand, and the Upper Devonian shaly *Goniatite* limestones and slates on the other. The lower beds, therefore, represent the Eifelian slates * and limestones, and the uppermost are homotaxeous with, or equivalent to, the *Rhynchonella cuboides* zone, or basement beds of the Upper Devonian of the Continent. The sequence of deposits differs in different parts of the area, and to some extent even in the same district.

In the Torquay and Brixham districts, from the Eifelian slates upward, a continuous accumulation of limestone has taken place; yet in these districts proofs of contemporaneous vulcanicity are locally present, as in the Hope's Nose promontory, in the Babbacombe Cliffs, at Trumland's Quarry in St. Marychurch, and in the faulted limestone forming the south margin of the Mudstone Bay anticline. At Black Head, Torquay, we have proofs of contemporaneous vulcanicity higher in the series, and still better examples are afforded in the area between Torquay and Brixham, near Goodrington. These intercalations of volcanic material in the districts of maximum limestone accumulation are, so to speak, the thin edge of the wedges by which the limestone masses are broken up and replaced, in and on the borders of the areas of maximum vulcanicity.

South and south-east of Totnes the Ashprington volcanic series rests partly on Eifelian slates, partly on Eifelian limestones, and takes the place of the limestone masses, representing the Middle Devonian, and, in all probability, the lower beds of the Upper Devonian.

Volcanic rocks, either emanating from sources in this area of maximum vulcanicity, or from local vents outside it, seem to have partly replaced the Middle Devonian limestones on the east of Yalberton, in Dartington Park, and east of Staverton. About Waddeton, between the Ashprington volcanic development and the Brixham limestone, it appears as if the limestones had been largely replaced by slates, and volcanic rocks.

North and north-east of Totnes, the Berry Park slates † undoubtedly occupy an intermediate position between the Lower

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* Under the term Eifelian slates all the slates between the Eifelian limestones and the Warberry grit series of the Lower Devonian are necessarily included, but it does not therefore follow that the lower beds may not represent the uppermost part of the Lower Devonian, for this can only be proved by palæontological evidence.

† A local name given by Champernowne to this type of Eifelian slates, viz., irregular grey slates with brown friable fossiliferous lenticles, occasionally calcareous. He was led to regard them as below the Cockington grits and above the limestones through appearances due to inversion and fault.

Devonian rocks of the Paignton area and the limestones of Dartington, Marldon and Berry Pomeroy, and may therefore be regarded as Eifelian slates. The limestones of this area, however can scarcely be taken as representatives of the limestone developments of Torquay, Brixham and Ipplepen. If we assume that they represent the lower part of these masses, the upper part must either have been denuded or replaced by slates in a synclinal trough which terminates westward in Dartington Park. If denuded, these limestones must be everywhere newer than the slates that bound them, and the Dartington structure would be an anticlinal.

North of Staverton and west of the Ipplepen limestone, the main mass of the limestone is evidently replaced by slates, as there are no developments of limestone between Ipplepen and Yealmpton in the slates and volcanic rocks, which represent the Middle Devonian for a distance of thirteen miles or more along their strike.

It will thus be seen that the Middle Devonian succession differs much in different parts of the area, and is not always uniform in the same locality, although in all cases the Eifelian slates form the basement beds. Hence, whilst the relation of the Middle Devonian, as a whole, to the Lower Devonian clearly brings out the general structure (as shown on the map and sketched in the introductory chapter), the distribution of the limestones, as shown on the map, does not explain the structure of the Middle Devonian areas.

In consequence of variability and constant disturbance, and of the restriction of palæontological evidence to the very few localities that have been carefully worked, any attempt to treat the limestones, volcanic rocks and slates under general headings would be impracticable and misleading. As each district has its own peculiarities, detailed description is necessary, but the rocks will, as far as possible, be treated in ascending sequence. For this purpose it has been found desirable to divide the area into the following districts: 1. The Torquay district; 2. The Brixham district, and district west of Broadsands; 3. The Ashprington volcanic district; 4. The Dartington, Marldon, and Ipplepen district.

General Characters of the Slates.

The Eifelian slates vary from even grey, greenish-grey, and dark grey or blackish, compact or argillaceous sediments, to the irregular slates of the Berry Park type. In places where the Eifelian slates pass up into limestones, as under Daddy Hole Knoll (Torquay) and near Waddeton Boat House (by the Dart), they are red in colour, as also in places in the vicinity of Marldon, etc., where the staining may have been due to filtration through overlying New Red rocks. The slates replacing the limestones are grey or greenish-grey and in places black.

General Characters of the Limestones.

The limestones betray every gradation between a red or dark grey calcareous slate and a pale grey or dove-coloured compact massive limestone.

As a general rule, the calcareous slates and thin-bedded or slaty, dark, somewhat argillaceous, limestones are at the base of the series. Well-bedded limestones are developed in the main masses, and above the shaly basement beds. Massive or thick-bedded crystalline compact coralline limestones characterise the upper part of the masses, but are not confined to it, and may occur at almost any horizon (as at Hope's Nose and at Highlands, near Totnes). The thick-bedded limestones often present a slaty-jointed structure through contortion, as in the cliff bounding Redgate Beach (north of Anstey's Cove, Torquay) on the west. (See fig. 10, p. 63).

Dolomitic limestones occur here and there throughout the district, as at Trumlands Quarry (near St. Marychurch), in Lummaton quarries, at Charles Terrace (Ellacombe), in the Yalberton limestone, in the Ipplepen quarries, near Little Hempston, and in many other places. The massive limestones are often crushed and broken into small irregular pieces. Crinoidal limestones are not confined to any particular horizon, but are, as a rule, most frequent in the lower beds.

Mr. E. Wethered * gives the results of microscopical examinations of specimens of Devonian limestones taken from the Hope's Nose Quarry, the Quarry at Daddy Hole, Lummaton Quarry, and from three localities in the adjacent map Sheet 339, viz., Barton Quarry near Lummaton, Combe End near Kingsteignton, and from the Goniatite limestone (Upper Devonian) of Lower Dunscombe. "So far as the evidence warrants a conclusion being drawn, the Devonian limestones of South Devon appear to have chiefly originated from corals, crinoids, ostracoda, stromatoporoids and fragments of shell, while the Goniatite limestone alone contains foraminifera." "Some of the beds at Hope's Nose and Daddy Hole are almost entirely of coralline origin," and "represent accumulations of coral *débris*."

In most of the slides examined rhombohedral crystals of dolomite were found. "Sometimes they appear in aggregates, at other times as single crystals, and there is no doubt that they are of secondary origin." These crystals "are mostly associated with calcareous organic fragments. This may, perhaps, be explained by the greater solubility of the aragonite as compared with the other form of carbonate of lime of which shells are mostly constructed."

In the table of percentages of residues insoluble in hydrochloric acid, the thin-bedded (Eifelian) limestones of Hope's Nose yielded 13·5 and 18·6, the (Upper Devonian) Goniatite limestones 10·2, whilst the other specimens obtained from different parts of the limestone group between these horizons gave much lower percentages, from 0·2 to 3·5.

* *Quart. Journ. Geol. Soc.* for Aug. 1892. Vol. xlviii. pp. 377-387.

Slides of the thin-bedded limestone at the top of the Hope's Nose Quarry show under the microscope "a light grey finely crystalline ground mass traversed by fissures filled with calcite. In the ground mass are ferruginous patches and minute rhombohedral crystals, apparently of dolomite." Slides of the more massive limestone at the base of the quarry proved "to be composed of broken calcareous fragments, the structure of which has, for the most part, been obliterated." "Higher up in the quarry" the limestone "is largely made up of coral *débris*, polyzoa and stromatoporoids." "Toward the middle of the quarry" is "a series of beds very dark in colour. These sections show an almost structureless ground mass" in which crinoid ossicles, valves of ostracoda, and one or two shell fragments were found, traversed in all directions by calcite suggesting tubules, apparently forms of vegetation. The dark residuum was proved to be carbon with very little doubt.

The Eifelian slates vary in colour and character in different parts of the area, so that their recognition depends to a great extent upon their relations to the overlying limestones. For example, the red, grey and dark slates and shales on the south coast of Hope's Nose promontory, and the reddish grey and dark grey slates and shales which underlie the Daddy Hole limestones, are overlain by Eifelian limestones of a slaty or shaly character. The limestones with rugose corals, which represent the Eifelian limestone in impersistent patches at the base of the Ashprington volcanic series, overlie Eifelian slates; but it does not therefore follow that the basement beds of the various limestone masses are all on the same horizon, even where they rest on, or exhibit a downward passage by intercalation into, slates. Although from Eifelian limestone to slate a passage, more or less gradual but irregular, is shown in such sections as Hope's Nose and Daddy Hole, no such passage is apparent in many places where limestones rest more or less abruptly on slates, as at Upton Farm, Torre Chapel and Torre College, in parts of Ellacombe, in Torquay, and in the Marldon, Berry Pomeroy, and Ipplepen districts. In these cases it is not always easy to decide to what extent slates or shales may have replaced Eifelian limestones, and whether the limestones belong to the Eifelian or a higher stage. This uncertainty makes the correlation of isolated limestone patches, in the absence of distinct lithological and palæontological evidence, very unsatisfactory.

Torquay District.

The structure of the Torquay promontory is a complex anticline, so broken and shifted by faults that the Middle Devonian rocks on its flanks are very seldom found in their normal relative positions. The Lower Devonian may be an offshoot from the Paignton anticline, as before mentioned, or may be isolated by intervening Middle Devonian rocks. The limestone islets of the Shag Rock, the Thatcher, and the Oare

Stone, strongly suggest a barrier of Middle Devonian cutting off the Lower Devonian on the south.

It is, however, quite possible that the Lower Devonian of Torquay and Paignton may be connected between the Shag Rock and the Thatcher in Torbay. Mr. Hunt * remarks: "From the Shag, which is a limestone rock, a reef runs off in a south-easterly direction for some four hundred and fifty yards. This is composed of slate rock or grit, such as we find at Meadfoot, and does not correspond in that respect with the Shag Rock, of which it seems a continuation. From the south point of the 'Thatcher' the bottom is rocky in a westerly direction, and here (about four hundred yards from the 'Thatcher') . . . my dredge detached a large fragment of slate rock. . . . . . About one thousand yards south-east by south of the 'Thatcher' . . . the dredge . . . brought away a piece of grey grit." From these passages it seems likely that there is a connection between the Torquay and Paignton Lower Devonian areas in Torbay. The main structural curves of the Torquay area are obliterated through faults and constant irregular plication; but, notwithstanding this, the spurs of Lower Devonian extending to Babbacombe Church and to Thurlow Road (Torquay) from Warberry Hill prove the complex structure of the anticline, and account for the Eifelian slates and limestones of Ellacombe, as occurring in a syncline between these anticlinal spurs. The general tendency elsewhere has been the production of faults letting down the limestones against Lower Devonian rocks and cutting out the Eifelian slates altogether. The greater effects of faulting and of minor plications in the vicinity of the main structural folds have been pointed out in the introductory reference to the general structure of the area.

The limestones of Torquay and Babbacombe form portions of a plain or plateau which is also conspicuously shown in the limestones of Berry Head and Brixham.† As, with local exceptions, these limestones bridge over the entire interval between the Upper Devonian *Goniatite* beds and the Eifelian slates, it is a legitimate inference that all the slates in the Torquay promontory which are not included in the Upper or Lower Devonian are below the limestone masses, and may therefore be considered Eifelian.

As it has not been found possible to separate Middle Devonian (proper) from Eifelian limestones in the following descriptions, the lower beds of the former must be necessarily included, the remainder being reserved for another section, which embraces what are regarded as the upper beds of the masses.

Lower Part of the Limestone and Eifelian Slates and Limestones.

Localities.—1. Between Daddy Hole and Meadfoot Sands and The Strand, Torquay. 2. Hope's Nose and Redgate Beach.

* "Notes on Torbay," *Trans. Devon. Assoc.* for 1878.

† Pengelly "On the Lithodomus Perforations, etc." *Trans. Devon. Assoc.* for 1866.

3. Babbacombe, Ellacombe and St. Marychurch (open to question).
4. Hele, Upton and Torre.

Daddy Hole.

The Section at Daddy Hole was described by Champernowne in 1874* as follows:—"A mass of limestone between Daddy Hole Plain and Hesketh Crescent is separated from the main mass of limestone, and forms a conspicuous knoll above the west end of Meadfoot Beach, but it does not appear to have been generally recognised as a repetition of beds. If we descend to the little cove which we may call 'Daddy Hole' or 'Syracusa' Cove, leaving the base of the limestone of Daddy Hole Plain, we pass over a band of shales, which to all appearance are interstratified between that limestone and the beds constituting the knoll before referred to. The foot of the path, close to the beach, is over huge blocks of limestone fallen from the cliffs above, but immediately on the right we have a mass of the grey or olive-coloured shales (or slates) in which, although a cleavage is developed, the bedding is on the whole quite distinct. They contain a few crinoidal remains and Brachiopoda, not easy to get out complete, and the universal *Atrypa reticularis*, Linn., was all I could recognise. Beyond here, for some way, they are weather-stained red till near the limestone. Thin-bedded calcareous layers, brownish and reddish, pass gradually into the limestone above, and contain first a great number of Polyzoa, which, though fragmentary, are often beautifully preserved, with one or two peculiar forms of crinoidal joints, etc., and then immediately above, if not in the same layer, *Calceola sandalina*, Linn., in a thin-bedded red shaly limestone, in considerable numbers, together with simple corals (*Cystiphyllum* and others). . . . . The passage beds . . . . dip below the limestone at an angle of 35°. . . . . Recrossing to the east end of the little beach, we observe that it ends abruptly against a great face of limestone, which plunges under the sea at a mean angle of 40°. On approaching this limestone the slates are similarly reddened, and the passage layers of limestone can be seen in section immediately above the face just mentioned. There is no material difference between the appearance of the passage on the one side and that on the other. *Calceolæ* occur on this side as well, and are not uncommon in the red shaly limestone which forms the slope of the hill, where, it is worthy of remark, they were lying for the most part flat side up, which, if the beds be inverted, is what we might expect. I have looked for them, but so far without success, under the quarry on the north-east or Meadfoot side of the knoll,† underneath which are again shales, weather-stained red, which strongly resemble those we had before in the cove. Their fossiliferous character in Meadfoot Bay was long ago pointed out by Professor Phillips."‡

* "On a Contortion of the Limestone of Torquay and the Presence of Calceola Sandalina at its Base." *Trans. Devon. Assoc.* for 1874.

† I have obtained several specimens of *Calceola* in the red limestone shales on the Meadfoot side of the knoll.

‡ *Pal. Foss. Cornwall, Devon, etc.*, page 204.

"If, then, we are right in regarding this hill of limestone as the Rock End and Daddy Hole beds repeated by some means, we should expect to find that they possess many characters in common. Accordingly, we find that such is the case. Both lithologically and palæontologically they are, in fact, identical. The *Murchisoniæ, Favosites, Syringopora,* etc., besides many more of the common corals, occur in both. The two last mentioned are found associated near the Rock End wall and 'London Bridge,' on the west side of the cove, and on the east side at the point of limestone directly opposite the Shag Rock, known as Triangle Point. The *Murchisoniæ* I have found close to Rock End Wall, and Mr. Lee tells me he has found them in the old quarry on the east side of the cove.". . . . "The wrench which has formed the subject of this communication appears to be traceable from the coast by a boss of limestone overhanging Hesketh Mews, and another isolated piece near 'The College.' These may, however, owe their position to this twist, combined with a fault crossing from near the Post Office to Hesketh Crescent." The little promontory of limestone (Triangle Point) at the south end of Meadfoot beach is cut off from the limestone of Daddy Hole Knoll by a nearly east and west fault, which is filled with broken limestone and calc spar. This fault has a downthrow to the south, decreasing westward and passing out into two or three small dislocations visible in the cliffs on the west side of Daddy Hole. Traces of gold were met with in the calc spar of the fault rock, on the south side of the quarry, on the east of Daddy Hole, but the gold fever this discovery produced was speedily allayed by a small dose of unremunerative prospecting.

The succession under Daddyhole Plain is as follows in descending sequence:

1. Thick-bedded grey limestone.
2. Irregular thin-bedded grey limestone, partly slaty and shaly, and containing buff earthy matter, about 15 feet thick.
3. Dark grey slates, weathering greenish, with lenticles of limestone and fragments of corals and crinoids.
4. Dark grey slates, weathering greenish, with calc-spar veins, very fossiliferous in places, notably at about 30 feet below the limestone. In one part of Daddy Hole Cove (Daddy Hole) the slates are stained red for about 40 feet vertically downward from the limestone; the colour change has a breadth of about 20 yards. Herr Frech obtained *Monticulipora* allied to *M. fibrosa*, *Calceola sandalina*, *Pentamerus galeatus* and *Cyrtia Whidbornei*, Davidson, in Daddy Hole Cove, in 1888.

The Rev. G. F. Whidborne* notes the discovery of numerous specimens of a new genus of Ostracod, named by Prof. Rupert Jones *Kyamodes Whidbornei*, in a quarry on Daddy Hole Knoll. *Athyris concentrica* and a doubtful *Vermetus* were found in the same bed which forms one of several thin bands, alternating with shale and underlying thick-bedded grey limestones.

On the east side of Daddy Holl Knoll the descending sequence is as follows:—

1. Thick-bedded bluish grey limestone.
2. Rather thin and irregularly-bedded dark grey limestones.

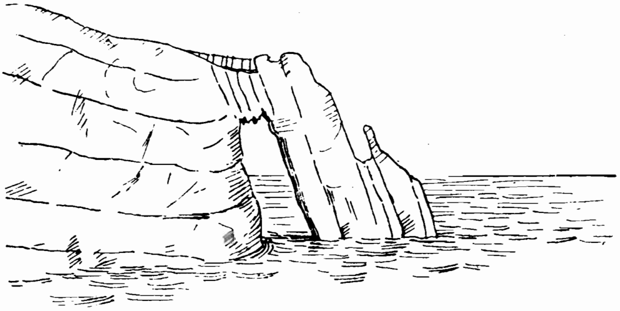
* *Ann. and Mag. of Nat. Hist.* for October, 1888, p. 299.

3. Red shaly limestone and partially calcareous shales in which several examples of *Calceola sandalina* were obtained, besides *Phacops*, *Atrypa*, *Leptœna*, *Orthis*, *Spirifera* and *Fenestella*.
4. Dark grey shales with occasional beds of limestone and small limestone lenticles, enclosing fossils such as *Spirifera* resembling *Sp. speciosa* and *Fenestella*.
5. Dark grey and greenish shales and slaty beds with calcareous patches.

Lower in the series the slates are very dark grey or blackish, and contain harder bands and lenticles of mudstone, as well as signs of interbanding with films of a coarser texture and paler colour. In places the reefs are of a vivid pale-green colour suggestive of the presence of copper ore, and a purple colour is noticeable in them by the steps leading up the low cliff from the beach to Meadfoot Road.

The Eifelian slates are evidently cut off against Lower Devonian rocks at the east end of Hesketh Crescent. The patch of limestone at Hesketh Mews* is on the south side of this fault—and on the north side of it is the college (Apsley House) limestone. Between the Hesketh Mews and Apsley

FIG. 4.—LONDON BRIDGE, TORQUAY.



House limestone patches a shaft was sunk during the construction of the Torquay sewer, near the junction of Middle Woodfield Road with Meadfoot Road. In it calcareous beds were encountered at a depth of 104 feet under the dark slates. Whether this phenomenon is due to the faulted junction of the Middle and Lower Devonian having so oblique a southerly hade as to allow of the superposition of Eifelian slates on Meadfoot beds at this spot, or to the occurrence of calcareous beds low down in the Eifelian slates, there is now no means of ascertaining.

The coast between Daddy Hole Cove and the Bath Saloons shows the contorted character of the Daddy Hole limestones. At Magwintons (Fig.5) the limestones exhibit an inverted syncline (with steep seaward dips from which the beds rise gently landward). The natural arch of London Bridge (Fig. 4), further west, is on the prolongation of this synclinal, the rocks forming the bridge being thin beds immediately on the seaward side of the axis from which the beds rise gently landward. The floor of Dyer's (or "the Old Land's End") Quarry "with its dense reef-like growth

* Compare limestone of Charles Terrace, Ellacombe.

of *Cyathophyllum cæspitosum*, and other corals*" is on the continuation of this axis. At Land's End *Cystiphyllum vesiculosum* has been found in the limestone. The cliff hard by bounding Petit Tor Cove † seems to be on the face of a fault, which, prolonged northward, probably shifts the limestone boundary near Engadina Villa, and in its further prolongation throws the Apsley House limestone on the east against Lower Devonian on the west. The cliff face at Petit (Peaked) Tor Cove shows a normal anticline in the limestones. The Bath Saloon is built upon rather massive-bedded grey limestone, but the cliffs eastward often consist of reddish shaly or slaty limestones, which might belong to the Eifelian. The Apsley House limestone is a triangular patch apparently bounded on all sides by fault. At the Presbyterian Church reddish, slaty limestones are exposed; they may belong to the Eifelian.

In the valley between Victoria Parade and Asheldon Copse the evidence is altogether insufficient to enable one to trace the relations of the rocks with approximate certainty.

FIG. 5.—CONTINUATION OF THE LONDON BRIDGE SYNCLINE AT MAGWINTONS, ¼ MILE TO THE EAST.

Behind the Torquay Natural History Society's Museum, and in the foundations, greenish-weathered fossiliferous ‡ slates were excavated. Near this, at the Winter Garden, reddish shaly limestone and shales were observed. These beds overlie the limestone of Braddons Hill, and are, no doubt, inverted Eifelian slates and limestones.

Pengelly informed the writer that the foundations of Lisburn Crescent disclosed limestone associated with slate. Behind the Crescent there is a cliff of compact crystalline pinkish and grey limestone shattered by irregular joints. This compact limestone is suggestive of beds higher in the series, although the limestones and the slates in the foundations may be Eifelian. The prolongation of the fault which throws the Braddons Hill limestone against Lower Devonian rocks in Market Street seems to cut off the limestones of Lisburn Crescent on the south side of Erinville.

A small mass of crushed and broken (dolomitic ?) limestone is exposed in a small quarry by Lower Warberry Road, just within

* Champernowne, *op. cit.*

† Or Peaked Tor, not to be confounded with Petit Tor near St. Marychurch, at the north margin of the map.

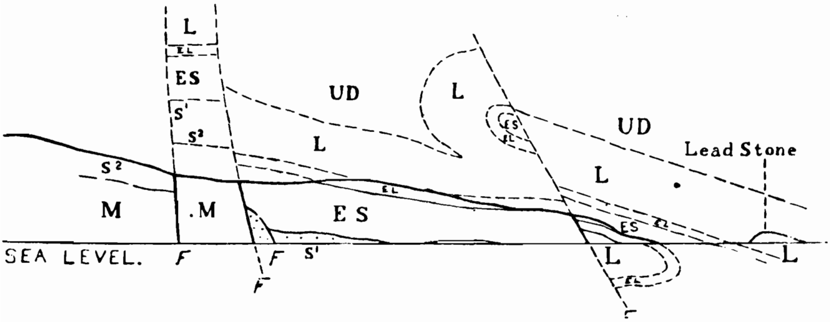
‡ The Rev. G. F. Whidborne has examined the fossils obtained in the excavations, and collected by the late Mr. Else. See *Geol. Mag.* for Dec. 1901.

the grounds of Wellswood House. This limestone probably occurs at the coalescence of faults, which, in the absence of evidence, cannot be traced. It may rest on Eifelian slates, as grey slates are evidenced at Wellswood Park, but their relation to the Lower Devonian grits and slates on the north is not visible.

Hope's Nose.

A fault roughly coincident with a line drawn from the west end of Hope's Nose Quarry across the promontory in a south-westerly direction cuts off the Lower Devonian rocks against Eifelian slates.* These rest on the top beds of the Lower Devonian, and are partly capped by slaty limestone (*i.e.*, the base of the Eifelian limestone). Therefore (unless partly cut out by thrust faults), we have here the whole thickness of the Eifelian slates—about 180 feet.

FIG. 6.—DIAGRAM SHOWING THE RELATIONS OF THE DEVONIAN ROCKS AT HOPE'S NOSE.



U D = Upper Devonian.
L = Middle Devonian limestone.
E L = Eifelian limestone.
E S = Eifelian slate.
S¹ S² = Upper and lower part of Staddon grits.
M = Meadfoot beds.
F F = Faults.

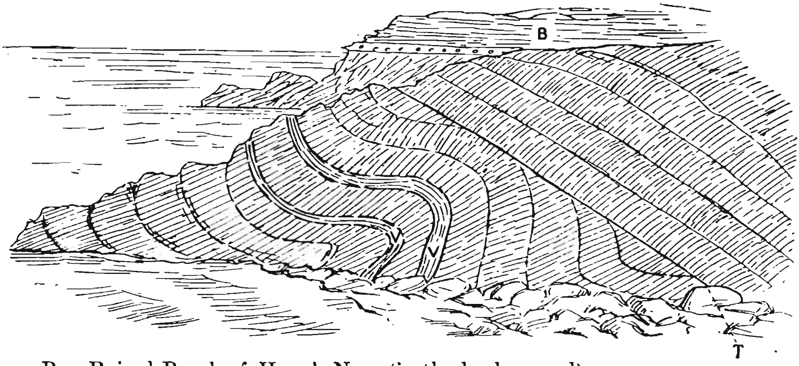
For some distance below the capping of buff-weathered slaty limestone, the shales are partially calcareous, very fossiliferous, and contain slaty limestone. They weather pale grey and buff-brown, but, toward the fault, are peroxidated for a considerable vertical thickness. These beds are underlain by blackish slates or shales,* with bands and lenticles of dark grey brown-weathered mudstone, and, occasionally, of dark limestone; they rest directly on the Lower Devonian grit. The relation of this section to the limestone of either horn of the Hope's Nose promontory is obscured by a fault, which is well shown near the Raised Beach, and has a distinct hade eastward. This fault meets the N.E. and S.W. fault, at the west end of Hope's Nose Quarry. The beds let down by it are thick-bedded grey limestones, overlain by thin-bedded and slaty limestones, which form the low cliff and foreshore reefs for most of the way between Hope's Nose

* Strictly speaking, the Eifelian slates are either slates or shales, or slaty shales according to the accidents of plication.

and the Raised Beach. These slaty and thin-bedded limestones are unquestionably Eifelian, and they are overlain by slates which occupy a shallow syncline. The succession here is, therefore, a reversal of that of Daddy Hole. It can only be explained by inverted structures, as shown in the accompanying diagram (Fig. 6).

We have thus, in the Hope's Nose promontory, a normal and an inverted succession, the inverted succession supplementing the normal one. Hope's Nose is composed ot massive or thick-bedded pale grey limestone, often compact and pinkish * (described by Kayser as a coral reef) containing *Stromatopora, Heliolites porosus*, simple *Cyathophylla, Cystiphyllum vesiculosum*, etc. In the quarry this limestone is exposed to a depth of about thirty feet, and is overlain irregularly by from twelve to twenty feet of thin dark grey limestone beds. On rounding Hope's Nose and proceeding southward, the reef composed of massive limestone is bounded by a low cliff of the thin-bedded limestones, which become slaty towards the Raised Beach. The thin lime-

FIG. 7.—SKETCH ON THE COAST AT HOPE'S NOSE.



B =Raised Beach of Hope's Nose (in the background).
T =Thrust fault.
V V=Volcanic tuff.

stones rest, as in the quarry, on an irregular hummocky floor of the massive rock, presenting appearances of truncation, etc., which Kayser attributed to deposition on and against the irregular surfaces of the reef. If this explanation is the only one, the beds cannot be inverted. It must, however, be remembered that in such an explanation as has been given the friction and pressure, at the junction of the massive and thin-bedded rocks would be likely to produce irregularities as well as sharp plication accompanied by thrusts, such as are exemplified further on.

The massive limestone platform dips under the sea-level a short distance to the south of the outfall of the Torquay sewer. From this to the Raised Beach the cliff and beach reefs are in slaty limestones, slates above them occurring in one place at the top of the cliff. The Raised Beach is on a platform of massive

* Compare the coralline limestone of Highlands Bridgetown, Totnes, which seems to be Eifelian, and the limestone behind Lisburn Crescent.

bedded limestone, which has emerged from beneath the slaty and thin-bedded limestones. On the summit near the Raised Beach the thin-bedded limestones are contorted and thrust over, or obliquely faulted against the massive rock.

In the slaty limestones a thrust is also visible at about 150 yards from the Raised Beach, but it is impossible to say whether it is a continuation of that above mentioned. Below this thrust (*see* Fig. 7) the slaty limestones are contorted, and contain two intercalated bands of volcanic tuff two feet apart. These bands, respectively eight and six inches thick, are visible for sixty or seventy yards.

The dark slaty limestones are intersected by calc-spar veins in places, and they appear to pass into slate. In the low cliff where the limestones are shaly they are often partly decalcified to buff indurated earthy material,* and contain numerous fossils. *Phacops latifrons* is said to be abundant in the shales above the limestone.† In the following list the fossils obtained by Dr. Kayser are supplemented by those identified by the Geological Survey palæontologists and by Mr. Whidborne, which are respectively distinguished by appended letters S. and W.

Cyathophyllum heterophyllum
Heliolites porosus.
Fenestella arthritica. W.
Hemitrypa oculata. W*
Rhabdomeson ? similis. W.
Athyris concentrica ? W.
— rugata. W*.
Atrypa aspera. S.
— desquamata. S.
— reticularis.
Bifida lepida. W.*
Kayseria lens.
Leptæna interstrialis.
Orthis arcuata. W.
Pentamerus galeatus.
Productus pustulosus ? W.
subaculeatus. S.
Rhynchonella parallelopipeda. W
— procuboides.
Spirifera curvata (typical shape).
— speciosa.
Streptorhynchus umbraculum.
Platystoma sigmoidale. W*.
Scoliostoma (Turbo) texatus. S.

The four fossils in the list with W* are referred to in Whidborne's Monograph, vol. i., p. 199 ; vol. ii., pp. 100, 102, 180.

Calceola sandalina has not been found in the Hope's Nose slates and limestones.

Redgate Beach.—The next place on the coast where the Eifelian is represented is Redgate Beach, a sketch of which is figured (Fig. 2). Here the Eifelian limestones are very dark grey, irregularly shaly and thin bedded, and apparently in plicated association with pale grey coralline, apparently massive, but really somewhat shaly, limestone. The dark beds have the appearance of folding round the pale grey limestone in much the same way that the Hope's Nose thin limestones are assumed to be folded round the massive beds, and they are brought up by a fault which runs coincidently with the massive limestone cliff behind them. In specimens obtained from the dark limestones Mr. Whidborne has identified

* The Eifelian limestone near Springville House, north of Totnes, is of the same type.

† Whidborne, "Monograph of the Devonian Fauna, etc." ; "Limestones of Lummaton, etc.," Part i., p. 7, 1889, Pal. Soc.

Alveolites suborbicularis, a small *Pachypora* (*cervicornis* ?), a *Cyathophyllum*, similar to *C. Roemeri*, and *Atrypa reticularis*.

Between two faults in the massive limestone cliff thin-bedded shaly reddish limestone, apparently resting on shales, are brought up. These also are probably Eifelian. The extensive under-cliff of slips, talus and limestone blocks, which bounds Redgate Beach, effectually conceals the faulted relations of the Eifelian slates and limestones; slates of the same dark character as the lower beds in the Hope's Nose and Daddy Hole sections are, however, exposed on the margin of the broken ground bordering the beach, and as grits associated with chocolate-coloured shales denote the occurrence of Lower Devonian, it is probable that, although cut up by faults, we might find the whole Eifelian slate series represented, if the slipped material and talus were removed. No systematic search for fossils was made in this locality.

Babbacombe.—The limestones of Babbacombe Cliff are evenly bedded in thin layers with occasional thicker beds. In the road to Oddicombe Beach they pass downward into slates with calc spar veins and, here and there, irregular beds of limestone. *Atrypa reticularis* was recognised amongst the badly preserved fossils in one of these beds. The further observation of the slates is prevented by slips and talus obscuring the surface between the cliff and the beach below. The slates are cut off against New Red rocks, on the north, by an east and west fault, which is exposed on the coast. From the fault to beyond the Half Tide Rock, where the limestones overlie them on the beach, dark slates or slaty shales are visible. Near the junction they are intersected by calc spar veins and contain hard bands, probably calcareous.

At the Half Tide Rock an irregularly intrusive igneous mass occurs in these slates, and a large mass, with less clear relations, is exposed near the fault. These are evidently the rocks described by Dr. Busz * as a Labrador porphyry rock (allied to the leucophyres, as the ground mass consists almost entirely of felspar) and a compact diabase.

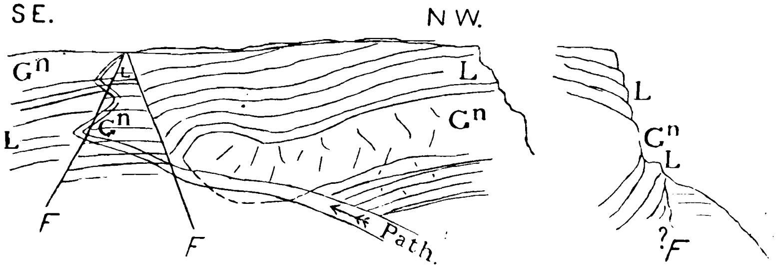
The Carey Arms is on purplish slates, apparently on decomposed red and brown weathered igneous rock (a granular diabase). This slate continues to the Glen, and it is possible that it may be either a stained continuation of the dark slates or even Upper Devonian cut off by fault.

In the Babbacombe Cliff the limestone is affected by zigzag plications, the axes of which run, more or less, coincidently with the cliff face; this, in consequence, gives at first sight the appearance of nearly horizontal bedding with an interbedded impersistent mass of igneous rock, mostly decomposed. Closer inspection, however, shows that the igneous mass is along the axis of a curve through which it has been exposed, by the denudation of the limestones which originally wrapped round it. (Fig 8).

* *Sitz. d. Niederrheinische Gesell. im Bonn.*, 1893, p. 85.

This mass is either an intrusive sill, perhaps connected with the rocks below, or a contemporaneous volcanic rock. It is shifted by a couple of faults crossing a path up the cliff and in line with its southernmost exposure. About sixty yards from this the zigzag contortions are very well shown (Fig. 9). With such a structure it is evident that the superposition of limestone on slate is quite inconclusive as to their relative position. In this

FIG. 8.—UPPER PART OF BABBACOMBE CLIFF NEAR THE ROYAL HOTEL.



Gn=Igneous rock at axis of a fold.
L =Limestone, even-bedded.
FF=Faults.

The same in profile on the north-west side of the faults.

case, however, the dark slates correspond in character to those in Dartington Park and in the Broadhempston area as well as to the lower part of the slates in the Daddy Hole and Hope's Nose sections. They cannot be Upper Devonian, so that the only alternative is one suggested for these dark slates from a cursory inspection by Dr. Kayser,* viz., that they may belong to the *Stringocephalus* horizon and correspond to the Wissenbach and

FIG. 9.—CONTORTIONS IN BABBACOMBE CLIFF.

Goslar slates. This would not apply to the Hope's Nose and Daddy Hole sections, and its application to this section would imply the local breaking up of the Torquay limestone mass by a series of intervening slates.

In a district so faulted and contorted the local separation of the lower from higher beds of limestone by the deposition of mud, in an interval attended by slight volcanic disturbance,

* *Op. cit.* p. 187.

would be very hard to prove. Such a theory might account for the difference in the character of the Ellacombe limestone and for the relations of the St. Marychurch limestones, and those of Torquay Cemetery, etc. This explanation, as will be seen further on, applies to phenomena in the Goodrington, Yalberton, Dartington, Broadhempston and Whilborough districts, otherwise difficult to explain.

The Babbacombe limestones are faulted against the Eifelian slates and Lower Devonian rocks on the west. Near Bishopstowe this boundary is shifted by a cross fault, on the north of which shaly irregular limestones, perhaps Eifelian, are exposed by the Babbacombe Road. There is no evidence of the nature of the rock between Asheldon Copse and Bishopstowe. At the east end of Babbacombe, opposite Bennetts' cottages, irregular dark grey red-weathered shaly limestones, with occasional intercalations of shale, are exposed in a small quarry.

Ellacombe.—The Eifelian slates of Ellacombe weather grey and greenish; their junction with the Lower Devonian of Warberry Hill, where not faulted or over thrust, seems to be inverted, as, for instance, south of Warberry Mount, and perhaps at, or near, the Western Hospital. In the new road, north of the Western Hospital, greenish and red slates or shales are exposed, but no characteristic fossils were obtained in them.

The position of many of the limestone patches can only be accounted for by fault, and it is possible that some of them owe their position to thrusts.

In Ashill Road a large patch of rather thick-bedded grey limestone is faulted against the Lower Devonian; it is exposed in a quarry face on its eastern border, and also at its southern extremity. There is no exposure between this and the neighbouring masses of Charles Terrace and the Maisonette, which are well defined by feature.

The Charles Terrace limestone is exposed in a quarry near its eastern extremity, where the rock has a saccharoid dolomitic aspect, and has been crushed into small pieces. In the centre of the quarry a dyke-like pulverised rock is conspicuous; it is probably due to the decomposition of the more crushed portion of the limestone. Bedding seems to be irregular and more or less horizontal, if the indications taken for it are not crush planes.

The Maisonette limestone is well exposed in quarries. The rock is pale grey and crystalline, and is broken by irregular joints; it appears to be faulted against the slates on the south. There are two small patches of limestone, bounded by fault on the east, in the market gardens at the foot of Warberry Hill. A small patch of grey massive, or thick-bedded, limestone is exposed at the bend in the Lower Bronshill Road, south of Homelands.

All the above may be placed in the same category, viz., limestones which show no appearance of passage into the underlying slates, and which, therefore, suggest basal thrusts or faulted boundaries.

Between these limestones is a larger mass. This is irregularly associated with schalsteins at its eastern extremity, both being probably cut off by fault. The south-eastern part of this mass consists of limestones with nearly vertical bedding, and is separated by a band of tuff from the main mass.

In a quarry near the Ellacombe National School the limestone is irregularly associated with grey slates. By lower Bronshill Road and by the lane to Hill Park (north of the St. Marychurch Road) dark grey limestone beds, associated with slates, were observed. The association with slates renders the boundaries of this limestone mass very indefinite, whilst it strongly suggests the normal Eifelian limestone type. On the north of the Charles Terrace limestone a trace of volcanic rock was noticed in the slates.

Upton Farm Limestone.—A mass of limestone, overlying the slates on the west, is well exposed in a quarry by the road in Upton Vale, on the north of Upton Farm. The rock is partly crinoidal and in tolerably thick beds, partly thin-bedded and shaly. East of Upton Farm, near Matchwood Terrace, lenticular limestone beds were seen in the slates.

The slates near Hill Park and Upton Cottage are dull greenish-grey, and contain vesicular igneous rock, probably intrusive. Near their junction with the Upton Farm limestone, on the south, and the Daisons limestone, on the north, the slates are red stained. The junctions may in both cases be faults. It is probable that the boundary with the Daisons limestone is a continuation of the fault on the south of Oddicombe Beach.

Daisons Limestone.—Near Daisons Farm, on the south side of the fault, pale grey limestone, apparently dolomitic, is exposed in a small quarry opened for gravel, as the rock is broken into small pieces by the crushing it has undergone.* Eifelian limestones probably make a natural junction with the slates from Daisons Farm eastward, but no indication of the nature of the rock could be obtained. The Daisons limestone is much plicated and faulted. The Daisons Rock crags indicate inverted plications with a northerly dip, and faults and crushed rock are shown in the large quarries by the Teignmouth Road. These disturbances probably counteract the fault in the direction of Oddicombe Beach, which has a downthrow to the north, and bring in Eifelian beds north of the Daisons House and Westhill Farm. Thin limestones, overlying slates with traces of tuff, and dipping north, are exposed near Westhill Farm, behind a house by the road to St. Marychurch (West Hill), and by the road to Hele (Black's Hill). The thin limestones and slates may be sandwiched between two nearly parallel faults between Hele and Windmill Hill, or they may be brought up by an anticline.

St. Marychurch Limestone.—From Cary Farm to Trumlands Quarry there are very occasional indications of the presence

* Compare the Charles Terrace limestone and the limestone patch near Wellswood House.

of tuffs and slate, on the slope below the broken, rubbly, grey limestone on which Cary Castle stands; its boundary with the New Red is exceedingly vague. In Trumlands Quarry, buff, grey-brown, and red, much decomposed, hard and soft calcareous tuffs rest on (partly dolomitic) limestone, which is thick-bedded in places, though for the most part in thin beds, and in parts irregularly shaly or slaty. The dip is northerly, at an angle of about 35°. In the corner of the quarry there appears to be a fault, and in another place irregular displacements or thrusts. *Heliolites porosus* and *Stromatopora Hüpschii* (in the *Caunopora* state) were obtained in this quarry, and identified by the late Prof. Nicholson. The tuffs are again encountered in Mount Pleasant quarry (in the north part of St. Marychurch). Here they are of a purplish colour, and contain hard, irregular masses of (apparently) dolomitic breccia. They dip northward at an angle of 55° under pale grey limestone beds, which are much shattered. From these quarries the tuffs would seem to be in a syncline, and therefore above the limestone. It should be mentioned that the Petit Tor faults, prolonged westward, may have something to do with this peculiar rock, and it is just possible that it may mark a line of excessive crush, along which dolomitization had subsequently taken place. The limestones of Mount Pleasant Quarry dip under red shales or slates. The boundary can be traced across the high road south of the Palk Arms Brewery to the lane between Barton Road and the Lummaton Quarries, where it is lost in the low ground. In an orchard west of the Palk Arms Brewery rather even-bedded limestones were observed dipping under hard shaly mudstones and shales, at an angle of 20°. Similar tuffs to those in Trumlands Quarry are associated with the shales. It appears, therefere, that these limestones are lower than those in the Lummaton mass adjacent, and if evidences of the superposition of shales and schalsteins upon them may be relied on, that there was here an interval during which local vulcanicity and muddy sedimentation took place. From the nature of the evidence it is impossible to connect this episode with other cases in the Torquay promontory to which a similar explanation may apply.

Hele, Upton, and Torre district.—Between Hele Cross, Hele, and Windmill Hill, dark grey irregularly-bedded limestones, of the Ellacombe Eifielian type, are exposed.

In the higher part of the Torquay Cemetery slaty and irregular broken limestone beds have been proved, in places, to a depth of twelve feet. In the path by the greenhouse, near the southern Mortuary Chapel, broken blue limestones (red stained on the surface) rest on red and lilac shales, with clay seams and lenticles of fossiliferous limestone containing *Atrypa reticularis* and *Spirifera speciosa*.* In the exposure, which was fourteen yards in length and about two feet in depth, the slates seemed to form an anticline. On the east side of the Cemetery grey slates and yellowish clay, with occasional beds of limestone, occur on the

* Identified by Messrs. Gosselet and Barrois.

higher ground, and dark slates on the lower. These are bounded by New Red clays on the west, and shifted by fault on the south. Beyond this the slates, with one small and one large mass of limestone (on the north side of the Cricket Ground), much crushed and broken, are surrounded by the New Red rocks, as are also two limestone inliers, at the Pavilion entrance to the Cricket Ground and near the Teignmouth Road. The New Red rocks are faulted on the south against the reddish and greenish (presumably Eifelian)* slates which separate the limestone masses of Stantaway's Hill, Torre College Hill, and Chapel Hill. The western boundary of the middle limestone mass (Torre College) is a fault. In the apex of the acute angle made by this fault with the faulted boundary of the New Red, on the west of the Cricket Ground, a knoll of crinoidal limestone, interpenetrated by vesicular diabase, is conspicuous.

The Torre College limestone, where exposed by the road to the Cemetery, is distinctly bedded; it overlies greenish slates on the east; these contain volcanic materials at the junction near Palestine Villa, and there are also traces of similar origin in the slates beyond the reservoir. Between the western fault boundary of this limestone and the grey limestone of Chapel Hill the slates are reddish.

The Stantaway's Hill limestone is well exposed in a long quarry behind Prospect Place. The quarry faces are in part faults, or crush planes, against which the lowest beds, consisting of thin-bedded broken limestones, dip westward. Reddish shales or slates, apparently dipping under the limestones, were exposed by the Teignmouth Road. Stantaway's Rock is a whitish massive limestone which dips east. It appears to be cut off by fault against the Windmill Hill limestones, which are exposed in a quarry exhibiting, in the lower part, shaly limestones intercalated with partly calcareous shales, dipping N. 35° W. at an angle of 35°, and perhaps representing the Eifelian limestones. On the east of Stantaway's Rock, by the Teignmouth Road, massive grey limestones are irregularly overlaid by reddish shaly limestones with an appearance of discordance. In this case the shaly limestones may be Eifelian thrust over the massive rock. In the absence of clear junction sections, and in the presence of faults and thrusts, there is nothing to contradict the supposition that the three limestone masses of Chapel Hill, Torre College Hill, and Stantaway's Hill contain in their lower beds representatives of the Eifelian limestones, and are parts of an originally continuous mass repeated by faults and folds. It is these horizons that seem to be represented by the Marldon and Berry Pomeroy limestones, and the Whilborough and Bulleigh Barton limestones may be embraced in the same category, viz., uppermost beds of the Eifelian, and lowest beds of the Middle Devonian.

* If not Eifelian, these slates would have to be considered as intercalated in the Middle Devonian and corresponding to those above the St. Marychurch limestones, roughly speaking.

Mudges Copse Limestone.—The limestone of Mudges Copse is probably the southerly continuation of the Stantaway's Hill mass; it is faulted against Lower Devonian on the east, and seems to overlie the Eifelian slates on the south of Upton Farm. A section, now concealed, behind a new house in the Lymington Road, showed reddish-stained shaly limestones associated with shales overlying red partly calcareous shales with lenticular limestone, cut off by a fault, or thrust, with a northerly hade at a low angle, against greenish slaty shales with limestone lenticles. Further south the limestone forms a grey broken rock, evidently higher in the series.

Tor Hill Road Limestone.—A cliff of limestone rises above the Torre Parish Church (St. Saviour's). By the Tor Hill Road it forms a conspicuous crest of white limestone, much fractured, and similar to Stantaway's Rock. The absence of exposures in Brunswick Square renders the northern boundary of the mass very uncertain. It appears to be a continuation of the Torre College limestone shifted eastward by fault. The alluvium of the Upton Valley probably conceals its faulted junction with the Lower Devonian. On the south, at Upton Parish Church, there are some slight indications of the association of slates with limestone beds. If not faulted on the south against greenish Eifelian slates, the latter form an inverted anticlinal; slates separating this mass from that of Waldon Hill. The most northerly exposure of the Waldon Hill mass, near the Coffee Tavern (in a narrow bye-street parallel with Union Street), is a cliff of thin even-bedded limestones and shaly limestones and shales, which dip northward at an angle of 36°.

From the foregoing notes it will be seen that no boundary between the Eifelian limestone and the *Stringocephalus* limestone (or Middle Devonian proper) has been defined. Although the lower beds of the limestones, where they exhibit a passage into underlying slates, have been certainly claimed as Eifelian, every attempt to limit their upward extension must be based on minute palæontological research. Where massive or thick-bedded limestones rest directly on the slates, the possibility of their being Middle Devonian limestones pushed out of position by thrust planes, or of the local replacement of thin-bedded or slaty Eifelian limestones by slates, is suggested.

Torquay District.

Upper part of the Limestones.

Hitherto the Middle Devonian limestones have been described in their relation to the Eifelian; in this section, they have to be considered in relation to the uppermost beds of the masses, which should be taken as homotaxeous with the *Rhynchonella cuboides* zone, constituting, on the Continent, the basement beds of the Upper Devonian.

Champernowne, in unpublished notes, alluded to the occurrence of "occasional *Stringocephali*" in the limestones of

Lummaton and Woolborough, where *Rhynchonella cuboides* is most abundant. As these limestones belong to the upper part of the masses of Torquay and Newton Abbot, he remarked that *Rhynchonella cuboides* "either lived earlier in Britain than the Continent, or the *Stringocephali* survived later."

Unfortunately, in Lummaton Quarry, the spots where these fossils are found are very restricted, and a similar shelly mass has not been elsewhere encountered in the Torquay limestones. It is therefore impossible to draw any palæontological boundary in them. If, however, the upper parts of the mass exhibited a uniformly massive character, and were succeeded regularly by distinctly bedded limestones, a line could be drawn to denote these characters, although it would have only a relative palæontological value. This, however, cannot be done, in view of the disturbed character of the rocks, and, if practicable, might not represent a definite stratigraphical horizon. It is necessary to include the upper beds of the limestone masses in the Middle Devonian on stratigraphical, as well as palæontological grounds, at the same time leaving the question of the representation of the *Rh. cuboides* zone perfectly open.

The only section which gives anything approaching to a clue to the thickness of the Middle Devonian limestones is the record of the Torquay Brewery Well, at No. 34, Fleet Street, given by Mr. H. B. Woodward,* and in White's Directory. The site of this well is in the valley between the limestones of the Braddons and Waldon Hills. As the uppermost beds are probably unrepresented, and part of the lower beds may be cut out at a faulted junction with the Eifelian slates, the total thickness of the Torquay limestones cannot be inferred from the section. The inclinations of the limestone and underlying slate at 70° (if not cleavage) and 45°, respectively, give the true thicknesses, approximately, as follows:—

	Feet
Varieties of Petit Tor Marble (in beds from 3 to 6 feet thick) -	35
Dark liver coloured shillety limestone with quartz veins; Blue, pink, and chocolate, plain limestone -	85
Limestone -	120
Soft tenacious red clay probably denoting a fault:	
Blue slate -	58
Chocolate slate -	46
Blue slate -	68
Slate -	172
Indurated red marl (probably Lower Devonian).	

From this it would appear that the section in the upper part consists of rock of the same character as that of Wallshill, north of Redgate Beach, upon slaty limestone similar to that in the

* *Geol. Mag.* for Oct. 1877, and White's 'History of Torquay.'—See also Well Sections, pp. 126, 127. There is a slight difference between Woodward's and White's sections in thicknesses. The latter is more detailed in description of the limestone.

cliff bounding Redgate Beach on the west, and to reddish slaty limestones in the Rock Walk Cliff, by the road to Torquay Station. Just as it is legitimate to infer that the limestones in connection with the Eifelian, embraced in the previous section, are the lower or middle parts of the limestone series, so it is reasonable to regard all limestones in unfaulted or slightly faulted contact with the Upper Devonian Goniatite-beds as the uppermost parts. The limestones of Ilsham and Devil's Point* and the Petit Tor limestones belong to this class, on direct evidence, and with them, on less direct evidence, are included the limestone of Wallshill (between Long Quarry Point and the Carey Arms), of Lummaton, of part of Waldon Hill.

It is probable that the higher limestone horizons are also present in parts of the Windmill Hill, Daison, and Braddons Hills; but there is no means of proving this, as the same horizon may be massive in one place and distinctly bedded in another. Each mass of any magnitude consists of different horizons brought irregularly to the surface by faults and contortion.

Braddons Limestone.—The Braddons Hill limestone is locally made up of corals. This character is well shown in exposures by the winding ascent to Braddons Street, where *Heliolites porosus*, *Favosites* (*Pachypora*) *polymorpha*, and probably *Striatopora denticulata* were recognised. (The rock on the west side of Petit Tor Knoll exhibits a similar character.). The limestone is stained reddish in places, and splits occasionally in a somewhat irregular shaly manner.

In the quarry on Stentifords Hill, bluish-grey and pale grey limestones, in beds of from five inches to a foot in thickness, exhibit zigzag contortion. In the southern part of the quarry pale grey compact limestones occur in a way suggesting a faulted anticline. At their faulted junction with the Lower Devonian shales and grits, in Market Street, the pale grey limestones are distinctly bedded, but so broken that contortions cannot be traced with certainty. The fault, which is well shown by the steps on either side of the street, has a normal hade. Near the Castle thick even-bedded limestones are associated with thin and shaly beds. These dip in a north-westerly direction, and may denote the proximity of the inverted anticline of Eifelian slates, which separates the Braddons and Waldon Hill limestones from the Tor Hill Road mass.†

Waldon Hill.—The Waldon Hill limestones are exposed in cliff sections by Rock Road and Warren Road, where they are, for the most part, pale grey, more or less compact in texture, massive or thick bedded, and broken up by numerous irregular joints. Behind Abbey Crescent, the cliff seems to be a slicken-side, along a faulted junction with the New Red rocks. In the Rock Walk cliffs the limestone is much plicated. Near Cumper's

* The Asheldon Copse and Kent's Hole limestone may belong in part or altogether to the upper beds, or be lower in the series.

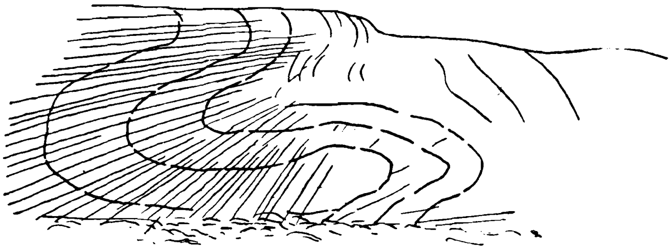
† The adjacent section near the Coffee Tavern at the north end of the Waldon Hill limestone has been referred to on p. 60.

Hotel, thick beds of slaty grey and reddish limestone (recalling the contorted limestone in the cliff on the west of Redgate Beach) dip toward the road below, so steeply that there is danger of masses of the rock becoming detached and falling.

The red colours of the limestones in White's account of the Brewery Well, describe a phenomenon met with, locally, both in the Middle Devonian and in the Eifelian limestones, and as the texture is in both cases similar, it constitutes a difficulty in distinguishing horizons where the exposures are insufficient to afford conclusive evidence. As bearing on this point, the locality depicted in Fig. 2, p. 12 is selected.

Wallshill.—Toward the south end of Redgate Beach, the cliff, facing east, consists of reddish or reddish-brown slaty limestone. The bedding is shown by a thick bed exhibiting a fine uniclinal plication (Fig. 10). The cleavage is evidently the result of con-

FIG. 10—NEAR THE SOUTH END OF REDGATE BEACH.



tortion, and near the top of the cliff there is an appearance of thin vertical bedding. The curve may be intersected by a fault. The cleaved limestone is probably subordinate to the massive grey limestone which forms the cliff near by on the north.

Where the cliff rounds toward Long Quarry Point, the massive grey limestones are (as previously mentioned) breached by two faults between which red shaly limestones, taken as Eifelian, are wedged in. These faults coalesce on Wallshill Down at a few chains from the cliff edge. Following their direction to the coast northward, the massive compact grey limestones of Shelter Cove seem to be much contorted, although persistent lines of bedding are not displayed. In a quarry west of Shelter Cove, reddish shaly crinoidal limestones are exposed under massive grey limestone, and are cut off by faults on either side. These shaly beds may be the top of the series of bedded limestones represented by the contorted bed in Redgate Beach cliffs. If Eifelian, massive limestones would, here, represent the whole of the Middle Devonian. This idea is, however, hardly consistent with the fact that the Wallshill limestones give place to bedded limestones towards Bishopstowe and Babbacombe. The exact relations of the Wallshill limestones to the Babbacombe Cliff limestones which are lower in the series, and to the red slates at the Cary Arms, which may be Upper Devonian, are not clear, and are, no doubt, obscured by faults.

Anstey's Cove and Ilsham.—In Anstey's Cove Upper Devonian slates, with representatives of the shaly *Goniatite* limestones, on either side, form a syncline separating the massive grey limestones of Ilsham and Devil's Point. The Ilsham limestones and the two patches on the south and south-east are often clearly bedded.

Asheldon Copse and Kent's Hole.—The slopes of the Ilsham and Asheldon Copse limestones are separated by a narrow tract of flat ground, suggestive of slate, which is in line with the north and south faults in the Redgate Beach cliffs, so these limestones are either on the same horizon, or, the Asheldon and Kent's Hole limestone is below that of Ilsham, and may even roughly correspond to parts of the Daddy Hole, Stantaways Hill, Torre College, etc., limestones. The quarry near Kent's Hole displays pale grey limestones in rather thick even beds dipping northward. A smaller quarry on the opposite side of the road presents an appearance of lenticular bedding, probably due to the intersection of an axis of uniclinal plication. *Actinostroma stellulatum,* Nich., obtained in this quarry, was somewhat doubtully identified by the late Prof. Nicholson, owing to distortion. He described the form as "abundant in the Middle Devonian of the Eifel (Gerolstein and Gees)." It occurs in the Dartington limestone. In the north of Asheldon Copse the limestones dip eastward at 26°.

Petit Tor.—Petit Tor Combe,* like Anstey's Cove, is a syncline of Upper Devonian slates, the grey and massive limestones on either side (Petit Tor Knoll on north, Petit Tor Hill on south) being in contact with traces of the shaly Upper Devonian *Goniatite* limestone. Petit Tor is a knoll of coralline limestone (recalling the Braddons Street limestone), and of pale grey limestone broken into large irregular blocks by uneven joints, and ramified by the peculiar fibro-crystalline form (organic ?) of carbonate of lime, to which Mons. E. Dupont applied the name "*Stromatactis.*" The limestone forms a cliff overlain by New Red, which it separates from the Upper Devonian slates. The cliff attenuates to a mere shell, or wall, terminating on the beach in a pinnacle of broken rock, interpenetrated throughout with New Red material.

Petit Tor Hill.—Petit Tor Hill, the southern wing of the synclinal, has an appearance of horizontal bedding, due, apparently, to crush planes consequent on sharp zigzag foldings. Here and there, masses of slaty reddish limestone, quite distinct from the massive grey rock, seem to have been dovetailed in at these axial crush planes. On the beach the evidences of crushing and distortion are so great that masses of the grey limestone have been jammed into the slates. *Stromatactis* is not so frequent in this limestone. It is faulted against the New Red of the Oddicombe Beach cliffs on the south. Near Petit Tor Point, the grey limestone is exposed in Petit Tor Quarry. Here also red shaly limestones occur, as if lenticular in the grey rock, either natu-

* See Fig. 15, p. 109.

rally, or through the dovetailing of a contiguous rock by contortion. In this rock large specimens of *Orthoceras* have been obtained in considerable numbers. The researches of the marble vendors have made the quest for these organisms somewhat unprofitable. In polished specimens the structures are well shown in a matrix of deep red marble.

It will be seen that, from their relations, the limestones of Anstey's Cove and Petit Tor are the counterparts of the Lower Dunscombe limestone (in sheet 339) and, therefore, are homotaxeous with the *Rhynchonella cuboides* beds.

Lummaton.—The Lummaton limestone is bounded by New Red rocks on the north and west. It is well exposed in the quarries on Lummaton Hill and consists for the most part of a pale grey or dove-coloured, finely crystalline, massive, coralline limestone, in which *Smithia Hennahi* is conspicuous. The rock appears to be partly dolomitic in the western quarries. In the large eastern quarry rubbly, broken, shelly limestone occurs in one or two places, extending from the surface at the top of the quarry, irregularly downward for a few feet, in the more massive rock. Mr. Whidborne* describes it as "apparently little else than a shell-heap, and which was probably a local and littoral deposit. This would explain the fact that the Trilobites are almost always found there in a fragmentary condition; for most likely they had decayed and fallen asunder before they reached the place of deposition." In another place † in notes on *Hemitrypa oculata*, Phill., he observes," Judging from the general facies of the Lummaton fauna, it did not inhabit deep water, and was exposed to the action of strong currents and tides." Thanks to Mr. Whidborne's labours the fauna of Lummaton, principally obtained from the shelly part of the limestone, is more prolific than any heretofore described from any part of the South Devon limestones.

Toward Hele the massive Lummaton limestones give place to a distinctly bedded rock. On Windmill Hill, south of Hele, the limestone, although rather flaky, may belong to the uppermost horizons, which it resembles in texture. The extreme restriction of the shelly limestone to Lummaton may possibly be more apparent than real,but no such rich shelly material has been hitherto detected elsewhere in the Torquay limestones. From the following list taken from Mr. Whidborne's monograph, it will be seen that the numbers of *Stringocephalus Burtini* and of *Rhynchonella* (*Wilsonia*) *cuboides* (which were for the most part obtained in the shelly material), deprive these forms of any real value in determining horizons in the upper part of the South Devon limestone masses.

List of Fossils from Lummaton.

(For convenience of reference the order and nomenclature of Mr. Whidborne's Monograph are followed).

The specimens of doubtful derivation, but which, from the nature of the matrix, may have come from Lummaton have been

* Pal. Soc., 1889. Whidborne's Monograph, p. 2.
† Pal. Soc., 1895. Monograph, p. 180.

omitted from the following list. The numbers in brackets after certain fossils denote the number of specimens collected.

Trilobita 17, Phyllocarida 1, Ostracoda 9, Entomides 2, Cephalopoda 16, Gasteropoda 48, Lamellibranchiata 30, Brachiopoda 72, Discina 1, Crania 1, Bryozoa 14, Echinodermata, 10.

Trilobita.

Phacops batracheus, *Whidb.*
Cheirurus Pengellii, *Whidb.*
C. Sternbergii? *Boeck.*
Acidaspis Robertsii, *Whidb.*
A. pilata, *Whidb.*
Lichas Devonianus, *Whidb.*
Cyphaspis ocellata, *Whidb.* (common).
Proëtus batillus, *Whidb.* (common).
P. subfrontalis, *Whidb.*
P. Champernowni, *Whidb.*
P. audax, *Whidb.*
Harpes macrocephalus, *Goldf.*
Bronteus delicatus, *Whidb.*
B. tigrinus, *Whidb.*
B. pardalios, *Whidb.*
B. alutaceus, *Goldf.*
B. granulatus, *Goldf.*

Phyllocarida.

Tropidocaris? sp.

Ostracoda.

Cypridina? 3 sp.
Cypridinella cæca, *Whidb.*
Cypridella?
Polycope simplex, J. and K.
P. Devonica, *Jones.*
P. „ var. major.
P. „ var. obliqua.
P. „ var. concinna.
P. Hughesiæ, *Whidb.*

Entomides.

Entomis peregrina, *Whidb.*

Cyprosinidæ.

Cyprosina Whidbornei, *Jones.*

Cephalopoda.

Goniatites fulguralis, *Whidb.*
G. Hughesii, *Whidb.*
Trochoceras pulcherrimum, *Whidb.*
Gyroceras tredecimale, *Phil.*
G. Leei, *Whidb.*
Cyrtoceras lineatum, *Goldf?*
C. Robertsii, *Whidb.*
Phragmoceras? ungulatum, *Whidb.*
Gomphoceras poculum, *Whidb.*
Actinoceras devonicans, *Whidb.*
Orthoceras eutrichum, *Whidb.*
O. Robertsii, *Whidb.*
O. Vicarii, *Whidb.*
O. „ var. eductum.
O. oryx, *Whidb.*
O. cf. acuminatum, *Eichwald.*

Gasteropoda.

Macrochilina subcostata, *Schloth.*
M. subimbricata, *D'Orb.*
M. elevata, *Whidb.*
Loxonema Rœmeri, *Kayser.*
L. priscum, *Münster.*
Littorina Ussheri, *Whidb.*
Natica? nexicosta, *Phil.*
Platystoma sigmoidale? *Phil.*
P.? deforme, *Sow.*
Capulus? invictus, *Whidb.*
C. pericompsus, *Whidb.*
C. rostratus? *Trenkner.*
C. compressus, *Goldf.*
C. puellaris, *Whidb.*
C. terminalis, *Whidb.*
C. uncinatus, *F. A. Röm.*
C. columbinus, *Whidb.*
C. squamosus? *Trenkner.*
C. tylotus, *Whidb.*
C. galeritus, *Whidb.*
C. contortus? *F. A. Röm.*
C. multiplicatus, *Giebel.*
Orthonychia costata, *Barrois.*
O. quadrangularis, *Whidb.*
Holopella tenuisulcata, *Sandb.*
H. duplisulcata, *Whidb.*
H. Hennahiana, *Sow.*
Philoxene philosophus, *Whidb.*
P. lævis, *d'Arch and de Vern.*
P. serpens, *Phil.* rather common.
Euomphalus Dionysii, *de Montf.*
E. Hecale, *Hall.*
E. circularis, *Phil.*
E.? araneifer, *Whidb.*
Phanerotinus militaris, *Whidb.*
Rotellina? helicina, *Münst.*
Pleurotomaria subclathrata, *Sdb.*
Pl. impendens, *Sow.*
Pl. Orbigniana, *d'A.* and *de V.*
Pl. trochoides, *Whidb.*
Pl. subimbricata, *Whidb.*
Pl. Shaleri, *Whidb.*
Pl. delphinuloides, *Schloth.*
Pl. victrix, *Whidb.*
Pl. Bischoffii, *Goldf.*
Bellerophon lineatus, *Goldf.*
B. mundus, *Whidb.*

Chitonidæ.

Helminthochiton papilio, *Whidb.*

Lamellibranchiata.

Allorisma dubium, *Whidb.*
Cypricardinia scalaris, *Phil.*
C. striatissima, *Whidb.*
C. reticulata, *Phil.*
C. ensiformis, *Whidb.*
Conocardium clathratum, *d'Orb.* common.
Con. pugnans, *Whidb.*
Con. Villmarense, *d'A.* and *de V.*
Con. frater, *Whidb.*
Protoschizodus ? trigonellus, *Whidb.*
Nucula Protei, *Münst.*
Myalina luna, *Whidb.*
Gosseletia ?
Plethomytilus retrorsus, *Whidb.*
Rutotia elliptica, *Whidb.*
Actinopteria ? Robertsii, *Whidb.*
Act. hirundella, *Whidb.*
Act. dilatata, *Whidb.*
Act. placida, *Whidb.*
Act. Justi, *Frech.*
Act. Wurmii, *F. A. Röm.*
Act. rudis ? *Phil.*
Act. texturata, *Phil.*
Act. crenatissima, *Whidb.*
Pterinopecten gracilinus, *Whidb.*
Pt. Cybele, *Barrande.*
Pt. consolans, *Barrande.*
Aviculopecten aviformis, *Whidb.*
Lyriopecten fibratus, *Whidb.*
Crenipecten ? comma *Whidb.*

Brachiopoda.

Magellania Whidbornei, *Dav.*
Mag. sp.
Mag. juvenis, *Sow.*
Centronella virgo, *Phil.* (common).
Meganteris inornata ? *d'Orb.*
Stringocephalus Burtini. (25).
Enantiosphen Vicaryi, *Dav.*
Merista plebeia, *Sow.*
Athyris Glassii, *Dav.*
Ath. concentrica, *Von Buch.* (71).
Ath. Newtoniensis ? *Dav.*
Bifida Huntii, *Dav.*
B. ? plana, *Whidb.*
Retzia longirostris, *Kayser.*
Spirifera Verneuilii, *Murchison.*
Sp. subcuspidata ? *Schnur.*
Sp. undifera, *F. Röm.* (73).
Sp. concinna ? *Hall.*
Sp. nuda, *Sow.* (68).
Sp. curvata, *Sow.* (175).
Sp. infima, *Whidb.*
Sp. simplex, *Phil.*
Spiriferina insculpta, *Phil.*
Cyrtia ? Whidbornei, *Dav.*
Cyrtina heteroclita, *Defrance.*
Cyrt. „ var. multiplicata, *Dav.*
Glassia Whidbornei, *Dav.*
Atrypa reticularis, *Linn.*
A. desquamata, *Sow.*
A. aspera, *Schloth.*
A. flabellata, *Goldf.*
Pentamerus brevirostris, *Phil.* (142).
P. biplicatus, *Schnur.*
P. sublinguifer ? *Maurer.*
Conchidium britannicum, *Whidb.*
Stricklandinia ?
Rhynchonella acuminata, *Martin.*
Rh. reniformis, *Sow.*
Rh. pugnus, *Martin.*
Rh. triloba, *Sow.*
Rh. triloboides, *Whidb.*
Rh. parallelopipeda, *Bronn.* (138)
Rh. implexa, *Sow.* (56).
Rh. angularis, *Phil.*
Rh. ? anisodonta, *Phil.*
Rh. ? Ogwelliensis, *Dav.*
Rh. (Wilsonia) cuboides, *Sow.* (106).
Rh. (Wilsonia) omega, *Whidb.*
Camarophoria ascendens, *Stein.*
C. protracta, *Sow.*
C. Lummatonensis, *Dav.* (91).
C. ? rhomboidea, *Phil.*
C. Phillipsii, *Dav.*
C. cf. megistana, *Le Hon.*
Skenidium areola, *Quenst.*
Orthis striatula, *Schloth.*
O. ? sp.
O. Eifeliensis, *de Vern.*
O. pulcherrima, *Whidb.*
Orthotetes umbraculum, *Schloth.*
O. distortus, *Barrande.*
Strophomena rhomboidalis, Wilckens. var. analoga, *Phil.*
Stropheodonta nodulosa, *Phil.*
S. irregularis, *F. Röm.* (1).
S. interstrialis, *Phil.* (70).
S. ? nobilis, *M'Coy.* (13).
Productella subaculeata, *Murchison* (33).
P. fragrina, *Whidb.*
P. sp.
Chonetes ? Hardrensis ? *Phil.*
C. Phillipsii ? *Dav.*
C. convolutus ? *Phil.*
Discina peltastes, *Whidb.* (1).
Crania proavia, *Goldf.* (1).

Bryozoa.

Fenestella fanata, *Whidb.*
F. delta, *Whidb.* (1).
F. arthritica, *Phil.*
F. sp.
F. subrectangularis, *Sandb.*
Polypora populata, *Whidb.*
P. pagana, *Whidb.*
Hemitrypa oculata, *Phil.*

Bryozoa—cont.
Isotrypa ? Gregorii, *Whidb.*
Diplopora pristina, *Whidb.* (1).
Ptilopora ?
Penniretipora.
Ramipora.
Batostomella oomorpha, *Whidb.*

Echinodermata.

Hexacrinus interscapularis, *Phil.* (20).
H. perarmatus, *Whidb.*
H. ornatus, *Goldf.*
H. quintangulus, *Whidb.*
H. ? aberrans, *Whidb.*
Thylacocrinus ?
Rhipidocrinus crenatus ? *Goldf.*
Haplocrinus decipiens, *Whidb.* (1).
Cupressocrinus Schlotheimi, *Stein.*
Sphærocrinus geometricus, *Goldf.*

The limestone of Lummaton is, like that of Barton (near it on the north), a coralline growth, and was doubtless a part of a reef which included the massive limestones of Petit Tor, Ilsham, Wallshill, etc. In the Upper Devonian slates of Anstey's Cove, near their junction with the massive limestone of Devil's Point, there are suggestions of the occurrence of similar tuffs to those of St. Marychurch. Again at the northernmost point of Black-head similar tuffs seem to be associated with shales and *Goniatite* limestone resting upon 20 to 30 feet of compact pale yellowish and grey finely crystalline limestone containing *Alveolites, Cyathophyllum cæspitosum,* and *Stromatactis*. This mass rests, or is overthrust, on schalsteins containing numerous pieces of similar limestone in the uppermost part, and impersistent bands and nodules of limestone below. In this section we have, I think, the evidence of the dovetailing of the uppermost part of the limestone reefs with volcanic materials, which, in incursions from local centres of vulcanicity, interrupted the coral growth at different stages, and in parts of the area prevented the formation of limestone altogether. The tuffs in the Eifelian of Hope's Nose, etc., in the Middle Devonian of St. Marychurch, and those in the earlier stages of the deposition of the Upper Devonian of the Black Head are comparatively feeble evidences of contemporaneous vulcanicity in comparison with the districts yet to be described.

Brixham and Yalberton District.

The Brixham limestones form by far the largest and most continuous mass in the area. The Upper Devonian slates of Ivy Cove (with the Büdesheim fauna) are in inverted junction with the upper beds, whilst the lower are seen to rest on the Eifelian slates of Mudstone Bay. Consequently all the horizons of the Torquay limestones are represented. Massive or thick bedded limestones corresponding to those of Wallshill, etc., are encountered in the northern part, and bedded limestones corresponding to those of Daddy Hole, Babbacombe, etc., in the southern part of the mass. The anticlinal structure of Mudstone Bay was figured by Champernowne, and the superposition of the plicated limestone on the volcanic rocks of Sharkham Point was beautifully illustrated. This southern wing of the anticline is, as we have seen, in faulted junction with the Lower Devonian.

The Sharkham Point Iron Mine is in a mass of red and purple brown rock, brecciated with slate fragments in places, exhibiting a wavy linear structure probably denoting bedding, and containing masses of hæmatite. This mass appears to be an anticline of the peroxidated volcanic rocks of the Sharkham Point shore, which invertedly underlie the limestone and are associated with slates. The same material appears to separate the limestone of Sharkham Point from that of Higher Brixham, but the relations of the Higher Brixham, to the Laywell limestone (which contains corals resembling *Clathrodictyum* and *Spongophyllum*) are not clear. From Laywell House westward volcanic rocks, apparently red and grey sheared lavas and tuffs and slaty diabase, occupy the position which we might expect the Sharkham Point limestones, if they had been persistent, to occupy. These volcanic rocks belong to the earlier eruptions of the Ashprington volcanic series, with which their continuity is only broken by denudation acting on the faulted area of Eifelian slates west of Lupton House. The anomalous position of the rocks on either side of the Mudstone Bay anticline is therefore due to the irregular incursion of volcanic materials on the margin of an area where limestone accumulation was in its earliest stages; so that the coral growth took place partly on the muddy bottom, partly overlapped the fringes of the earlier volcanic emissions, or formed banks against them. Between Waddeton, Yalberton, and Goodrington similar effects were produced by later eruptions emanating from local foci. Here, however, the relations of the rocks are rendered extremely complex by faults, and by the soluble character of the limestone surface. The largest tract of volcanic materials in this part of the area will be referred to as the Crabs Park volcanic district. As the consideration of the volcanic rocks involves a reference to the relations of the Upper Devonian they will be mentioned last in the following notes.

Eifelian Slates.

These slates extend westward from Mudstone Bay to the border of the map, their continuity being only broken south of East Cornworthy, where volcanic rocks are in faulted contact with the Lower Devonian. They also extend from Galmpton Creek to Port Bridge, and are brought up by fault near Stoke Gabriel, perhaps also forming a narrow strip on the north of that village. On either side of Mudstone Bay, more especially on the south, there are evidences of contortion where the slates pass up into the limestone. The transition is marked by red slaty and shaly limestone intercalated in beds and lenticles in red and lilac slates, which are, apparently, mixed with fine volcanic dust, on the south side of the bay, where *Phacops ? macropthalmus* (according to Whidborne) and a large coral resembling *Cyathophyllum bilaterale* were obtained. In the corresponding beds on the north side of the bay Champernowne * recorded the discovery of two corals, viz., *Zaphrentis calceoloides ?* and *Campophyllum ?*. Grey buff-weathered slates succeed these

* *Quart. Journ. Geol. Soc.*, vol. xl., Aug. 1884, pp. 497-499, pl. xxi.

intercalated beds and, in the centre of the anticline, seem to rest on dark grey slates with irregular lenticular brown-weathered bands of slaty limestone containing Cephalopods. These latter are the beds from which *Cyrtoceras bdellalites*, Phill., and *Gyroceras ornatum*,* Goldf. were obtained. The slates of Mudstone Bay have also yielded *Athyris concentrica*, *Streptorhynchus umbraculum* ?, *Cyathocrinus pinnatus*, Goldf., *Gorgonia repisteria*, Goldf. (*Polypora populata* ? Whidborne), *Spirifers* and *Zaphrentids*. Champernowne † figured *Zaphrentis Mudstonensis*, which he obtained in the grey slates. The *Cyrtoceras* fauna seems to occur in the lower parts of this slate series which have yielded no fossils at Meadfoot Sands and Hope's Nose. Taken in connection with the doubts as to the representation of the Lower Devonian by slates in its uppermost beds, expressed in the footnote on page 42, the occurrence of a Cephalopod fauna in the lower part of the slates under the limestone developments is suggestive of a representative of the *Orthoceras Schiefer* in South Devon. This is, of course, merely a tentative suggestion, and even if it should ever be proved correct, it would not be possible to draw any line with an approach to stratigraphical accuracy in the slates which represent the Eifelian slate group. At Laywell House, not far from the limestone patch, a well was sunk to a depth of sixty feet in the slates. At Lupton Farm there are grey and lilac slates; the grey slates contain fossils. Other places where indications of fossils were observed, usually in a very bad state of preservation, are as follows:—Higher Alston, crinoids; west of Higher Alston, south of Widemoor Barn; south-west and west-south-west of Higher Alston, at about thirty-two chains distance, traces of *Spirifers*, crinoids, and *Pleurodictyum* ? were noticed; south of Higher Greenway, very badly preserved fossils; Dittisham Waterworks, near Lower Devonian, south of Higher Dittisham; south of Foxhole Copse and in a slate (Berry Park type) quarry in Bullcombe Wood, and between Kingston and Downton Wood, where *Spirifera* and *Streptorhynchus* were recognised in partly calcareous slates. The Ashprington series here interrupts the outcrop. West of Combe crinoids are met with; the slates assume the Berry Park type in places. By Woodland Lane they have been quarried out in large flaggy blocks and are occasionally fossiliferous. Near Gitcombe, north-west of Higher Tideford, the slates contain fossils; also, near Grant's Hill Plantation, Lower Washbourne, and Higher Washbourne. The slates between Waddeton and Port Bridge occasionally present the Berry Park type, but more often resemble those of Mudstone Bay and Ellacombe. Brachiopods including *Streptorhynchus* occur in them on the west of Waddeton, and on the east of Port Bridge *Phacops* and an *Orthis*, near to *O. Eifelense* (according to M. M. Gosselet and Barrois) were noticed and *Phacops* cf. *latifrons* (according to Herr Frech).

* Whidborne, Pal. Soc., 1890, p. 95.
† Champernowne, op. cit. p. 502, pl. xxiii.

Limestones.

The Brixham limestone, notwithstanding frequent appearances of nearly horizontal bedding, is much contorted and, as shaly and slaty structures have been frequently developed, in the absence of distinctive fossils, it is often impossible to distinguish Eifelian limestones from higher beds. Between Durl Head and Mudstone Bay a strong cleavage dipping south-east traverses limestones dipping north-west. In the cliffs between Berry Head and the Mew Stone slaty limestones are contorted in the cliff. At, and near, Galmpton shaly Eifelian limestones are probably repeated by folds. At Churston Station red shaly limestones contain *Cyathophyllum cæspitosum*, *Favosites Goldfussi*, *Heliolites porosus*. At Galmpton Quay, on the south of the shipbuilding yard, the section corresponds more or less to those of Daddy Hole and Hope's Nose. Grey and dark grey very irregular limestones, with *Heliolites porosus*, show occasional brown earthy decomposition products and rest on irregular red slates with crinoids and lenticles and thin beds of limestone—the whole forming a passage from limestone to slate. By the Dart near Waddeton Boat House Quay the junction beds consist of red slates, intersected by quartz veins in places and much disturbed, with red concretionary nodules and irregular lenticular peroxidated limestones containing badly preserved corals amongst which *Favosites Goldfussi* is recognisable. Both here and at Waddeton the rocks locally assume the character of mudstones traversed by a fine secondary cleavage and splitting in prismatic fragments. Brachiopods, Crinoid ossicles, and traces of *Fenestella* occur in the slates.

The Brixham mass is evidently cut up by faults, and, except on the coast line, exposures are not sufficiently numerous to enable one to detect them or to trace horizons.

At the paint works near Brixham Station compact, bluish, massive-bedded, shaly-splitting limestones have been dissolved into irregular potholes and fissures containing New Red sand and brecciated loam. Blocks of New Red sandstone are met with here and there on the limestone plain. West of Brixham Station similar limestone to the above is exposed; it is pale buff and brown, and exhibits a dolomitic aspect in places. In Waddeton, just south of the large New Red outlier, no limestone is actually visible *in situ*. This outlier is inferred from a red clay soil with blocks and pieces of sandstone; it seems to be a mere soil on red and lilac slates, which are evidenced round the isolated masses of limestone, and up to the sinuous boundary of the limestone east of Waddeton and north of Galmpton Warborough. Near Galmpton Warborough, and by the high road to Paignton (west of Broad Sands), the limestone has a dolomitic aspect; this character is still more pronounced in the isolated mass on which the two small outliers of New Red sandstone are shown, here the rock, as exposed in an old quarry, is of a drab colour and saccharoid appearance. Masses of iron ore, probably in potholes, have been worked in this patch. The red slates in the irregular tongue which ramifies the limestone mass toward Galmpton are associated with felspathic tuffs. East of Waddeton Lane, and south of Crabs Park, red-lilac and purple slates are so imperfectly exposed that one cannot say whether they are associated with volcanic rocks or not, or tell their relations to the pale grey and pinkish compact limestone patches on the east side of Waddeton Lane. These limestones resemble the upper beds in the Broadsands railway cutting. As these slates are, either a replacement of the upper part of the limestone mass, or Upper Devonian, their proximity to, if not actual contact with, Eifelian slates at Waddeton can only be explained by the assumption that the limestone is almost cut out by faults at that hamlet. North west of Waddeton the Eifelian slates are bounded by limestone, the boundary of which is indefinite and its connection with the large Yalberton mass near it could not be proved; it is probably Eifelian. The limestone of the small outlier contains *Favosites Goldfussi.* The fossiliferous Eifelian slates of Port Bridge pass under the limestone on the north and east. At Castlepark Copse, near Lower Well Farm, the limestone is bounded by a nearly east and west fault, on the south of which a mass of limestone, partly thin bedded and slaty, partly dolomitized, occurs, probably in a syncline in the Eifelian slates.

The Yalberton limestone mass often exhibits a dolomitic appearance north of Higher Yalberton, and between Lower Yalberton and Aish. Between Aish and Stoke Gabriel, near its faulted junction with the volcanic series and a coralline limestone near Hoil,* compact grey limestone (partly dolomitic) is exposed. To the east of this, near an old shaft, dolomitic limestone has been dissolved into pipes and potholes filled with brown earth (umber ?). Further east, at Bitney Brake, there is a small outlier of New Red, and near it a red loamy soil is suggestive of the retention of overlying materials on an eroded limestone surface. The Yalberton limestone is doubtless a part of the same plain of Permian (?) denudation as the Brixham limestone, which would account for the sandstone fragments boulders, and other relics of the New Red found on the surface.

North of Lower Yalberton *Cyathophylla* and *Stromatopora* were noticed in the limestone. Near Brake Copse a bluish grey coralline limestone furnished *Paralellopora dartingtonensis* ? Carter, identified by Nicholson.

The boundary of the limestone with the Crabs Park volcanic series, from Higher Yalberton southward, is very sinuous and marked by feature up to a point east of Brake Copse, but further south it is extremely indefinite, so much so that it is very possible that the limestone may unite the two small patches, shown on the map, with the irregular mass on the south. South and southwest of Brake Copse red slates, tuffs, and schalsteins occur, either in dissolved depressions in the limestone, or under them; in the latter case, it is possible that they may disconnect the

* See Chapter iv., p. 83.

limestone near Lower Well Farm from the main mass, due east of Well Farm.

The Crabs Park Volcanic Series.—North of Waddeton the volcanic materials are chiefly tuffs and schalsteins. Between Lower Yalberton and Crabs Park, and west of Eight Acre Pens Linhay the lavas are represented by local masses of vesicular rock. Near the last named place there is a cluster of patches of diabase; one of these may be a neck; it is surrounded by coarse tuffs associated with altered fossiliferous mudstone. There are suggestions of limestone bands near the Linhay. Between this and Crabs Park Cottages (near the tenth milestone from Newton, by the road) on the north, thick, blue-grey, indurated slates either occur in the volcanic series, or are folded up from beneath it. In these, *Orthis* and *Pentamerus* were recognised by Dr. Kayser. The tuffs in the vicinity are often very coarse. North of, and near Crabs Park Cottages there is a mass of diabase, and a small patch of limestone which is probably bounded by a north-west and south-east fault. Near Higher Yalberton Cottages the tuffs are partly felspathic, partly fine (with no visible felspar). The Crabs Park limestone seems to be partly dolomitic; its junction with the volcanic rocks is ill-defined, and the irregularity on the north is apparently due to faults. At Crabs Park the eastern boundary is faulted against red slates (Upper Devonian ?). This fault cuts off the southern end of the limestone, and further south appears to form the eastern boundary of the volcanic rocks. At half a mile north of Waddeton, indurated lilac mudstones containing *Atrypa reticularis* were observed on the border of the volcanic rocks. A narrow band (probably thrust or faulted) of schalstein separates the Crabs Park limestone from the Clennon Hill limestone on the north. The latter is a pale grey compact rock, which is seen in the easternmost quarry to be irregularly associated with buff, red-mottled mudstone.

Goodrington Volcanic Rocks.—In Champernowne's words,* "The next patch of volcanic rocks brings us to the coast of Torbay. It lies east of Goodrington, forming the 'sugar-loaf' hill, of less elevation than the limestone plateau to the south. A hard, aphanitic rock protrudes for a short distance along the top, but does not reach the railway cutting close to the cliff, where it is flanked by tuffs. This patch throws off some beds of iron-shot limestone to the north, dipping north and exposed in the cutting. The face of Saltern Cove is a north and south line of fault, which has shifted the iron-shot limestone on the foreshore south of its exposure in the railway cutting. . . . It abounds in corals—*Favosites cervicornis*, Edw. and H., *Alveolites* sp. *Cyathophyllum cæspitosum*, Goldf., and simple forms, *Stromatopora* crinoids, and, more rarely, *Acervularia* (sp.). The layers are parted by a red clay. At the foot of the cliff in the main

* On the Ashprington Volcanic Series, *Quart. Journ. Geol. Soc.* for Aug. 1889, p. 374.

cove the tuff exposed is identical with a piece of schalstein from Weilburg, Nassau, in my collection." The limestone above mentioned is the Feather-stone of the Torquay lapidaries. For distinction it will be referred to as the Upper limestone. It is overlain by the Upper Devonian *Goniatite* slates of Saltern Cove. The persistence of this limestone could not be proved through Goodrington, but it is visible on the west, where it is separated from the main mass by grey vesicular schalsteins, with which it is cut off by fault against a triangular tract of slates, bounded on two sides by the main limestone. Further west the north boundary of the main limestone is a fault. In a quarry by the high road at Goodrington the limestone is altered, overlain by tuffs, and in irregular junction with aphanite, apparently intrusive.

In its faulted continuation on the coast, the Upper limestone strikes from the cliff seaward, and curving southward is again visible in an isolated patch resting on the volcanic rocks (which are intersected by veins of calc-spar), and in bold, thick-bedded masses in the seaward reefs at the southern horn of the bay. Just south of the point the cliff is composed of bedded tuffs, with veins of calc-spar, and patches and nodules of limestone on the bed faces, and intercalations of slate. Further south, in a small cove, the tuffs rest on red mudstones and slates interstratified with tuffs, beneath which is a boss of limestone, perhaps the top of the underlying mass. Further on, the volcanic rocks, probably repeated by fault or folding, form the cliff, and are seen to rest on red mudstones with limestone lenticles, mostly coralline. A mass of calc-spar marks the fault junction of these beds with the main limestone. This calc-spar represents the Upper limestone between two faults, viz., the fault boundary of the main limestone and a fault coincident with the trend of the coast, bounding New Red in the beach reefs and promontory, and cutting off the Goodrington Park limestone on the east.

The Goodrington Park limestone is faulted against slates on the south. It consists of blue-grey, irregularly-cleaved beds, separated by films of red mudstone, and is, I think, the representative of the Upper limestone. It rests, nearly horizontally, on red mudstones associated with fine tuffs, and these, in their turn rest on the main limestone, which forms the steep slopes of the valley spanned by the railway viaduct. From the viaduct northward the railway cuttings give the following section:—For four chains, compact grey and pinkish bedded limestone. Fault crack filled with New Red *débris*, and throwing down red mudstones, vesicular and indurated in places, associated with tuffs, and red slates with irregular masses of limestone and calc-spar in places: these beds occupy the cutting for five or six chains, and rest on compact grey and pinkish limestone containing *Stromatopora*, and exhibiting a tendency to flake off in shaly pieces. At four chains from their outcrop there is an appearance of disturbance, and at a chain further, irregularly bedded pink and grey limestones with dog-tooth spar overlie, or are faulted against, pale grey, more or less massive limestones rich in *Stromatopora*. Near their faulted junction with the Goodrington volcanic rocks, at eight chains further north, a lenticular slaty patch is noticeable in the limestone. (Compare Clennon Hill Quarry.)

In this section the limestones correspond to beds in the upper part of the Brixham mass, and to the Ilsham etc. limestones of Torquay; and the red mudstones faulted down are probably a repetition of those beneath the Goodrington Park limestone, and therefore representatives of the Goodrington volcanic series. Near its western extremity, where it is separated by volcanic rocks from the south end of the Crabs Park limestone, the main mass is dolomitic, as also in a large quarry near the high road at about half a mile south of Goodrington. Near Hookwells the limestone resembles that of Goodrington Park, and is bounded on the west by a faulted patch of volcanic rocks with diabase.

Along its very sinuous boundaries the main limestone is, no doubt, faulted in many places against the red and lilac slates on its flanks. These slates are seldom well exposed. South of Hookwells, they are associated with fine volcanic breccia and tuffs rich in felspar fragments. On the east of Galmpton Warborough turnpike; south of Elbury; in the faulted tongue on the Brixham limestone south and east of Silver Cove, and at Fishcombe Cove, the slates also contain red tuffs or schalsteins.

The Elbury limestone forms Galmpton Point (not named on the 6-inch maps). This limestone is composed of thin and fairly thick beds, separated by red mudstone, and repeated by innumerable small inverted plications. *Alveolites suborbicularis*, and other corals occur here. There is every reason to regard this limestone as equivalent to that of Saltern Cove and Goodrington Park, but the age of the slates on the south side of it has not been proved by fossil evidence, although we have near it on the coast the Upper Devonain red slates with *Goniatites*.

Comparing the Goodrington with the Black Head section, the succession is identical, although the Upper limestone differs in character, being a massive bed. *Goniatite* slates on limestone on schalstein is the sequence in both cases—but at Ilsham the *Goniatite* beds are in direct contact with the limestone mass, just as they appear to be near Silver Cove in inverted contact with the Brixham limestone. Moreover, there are signs of vulcanicity in the Upper Devonian above the *Goniatite* beds between Ilsham and Black Head, if indeed the Black Head diabase is not itself a lava plug. It appears, therefore, that the Upper limestone is an impersistent coral bank on volcanic rocks at Black Head; the coral growth being interrupted by repeated incursions of fine mud in the Saltern Cove, Goodrington, and Elbury limestones —and that sporadic showers of ash may have accompanied, or succeeded, the deposition of the Upper Devonian *Goniatite* mudstones in both places. The local eruptions which preceded the formation of the coral bank rendered the bottom on their margins unfit for coral growth by the extension over it of volcanic mud, or of muddy sedimentation; and, whilst all these events were taking place, in contiguous, but favourable, sites, the reef growth went on uninterruptedly. This hypothesis will, I think, explain the various phenomena displayed in the district south of Goodrington and west of Brixham. When the Upper limestone is absent, without fossils, it is obviously impossible to distinguish slates with occasional schalsteins or tuffs, which represent a stage of limestone in the upper part of the main reefs (such as those underlying the Goodrington Park limestone), from Upper Devonian slates with tuffs (such as the faulted band south of Ivy Cove is considered to be). There are schalsteins, probably Upper Devonian, at Fishcombe Cove, where the following fossils, identified by Professor Frech, were found in the upper part of the underlying limestone.

Alveolites suborbicularis, *Bl.*
Petraia decussata, *Münst.*
Cyathophyllum heterophylloides, *Frech.*

The Crabs Park volcanic series represents a much more extended period of local vulcanicity than that of Goodrington. The earliest eruptions may have begun shortly after the earliest stage in the formation of the Eifelian limestone, and the later ones may (as far as one can judge) have been coeval with those of Goodrington. The presence of fossiliferous mudstones, and of small limestone patches in the volcanic rocks, may be accounted for by intervals during which ordinary sedimentation was resumed. The transition from volcanic rocks, on the west, to red and lilac slates, on the east, may be due to the tailing off of the coarser volcanic ejectamenta in mud, etc., as in the case of the Goodrington eruptions, but at earlier stages, and for a more protracted period, or periods.

It is not probable that the upper horizons of the Brixham limestone are represented in the mass between Yalberton and Stoke Gabriel. It corresponds, I believe, to the limestones of Vane Hill and Daddy Hole, Torquay, and is continued in part by the limestones of Aish, Lomentor etc. (which mark its extension on the borders of the Ashprington volcanic series) to the Berry Pomeroy, and through them to the Marldon limestones.

The contemporaneity of the eruptive rocks of the Goodrington and Crabs Park volcanic districts with volcanic rocks of the Ashprington series is, generally speaking, certain; but, although an actual mingling of eruptive materials from the different areas is extremely probable, it is not actually provable The limestones connected with the Ashprington eruptive area will be described in the next chapter.

CHAPTER IV

MIDDLE DEVONIAN—*continued.*

Ashprington Volcanic Area.

As a component of the Middle Devonian, the Ashprington* volcanic series is far more persistent than the limestones it replaces; as tuffs and schalsteins, coeval with part of it, practically connect the limestones of Brixham with those of Ashburton and Plymouth in a stratigraphical horizon.

The name given to this volcanic group is amply justified by the fact that nowhere in Devon and Cornwall is there an equal extension of volcanic rocks to that surrounding the village of Ashprington. This extension seems to be due, primarily, to a more protracted and continuous volcanic activity, the later stages of which were doubtless prolonged into the Upper Devonian, (coeval with the schalsteins and felspathic tuffs south of Goodrington), but the flattening of the Paignton anticline westward contributes to it, by the repetition of the same horizons in shallow curves. This area of maximum vulcanicity extends from Totnes to Stoke Gabriel, Dittisham, Cornworthy, and Harbertonford.

The volcanic rocks embrace tuffs, schalsteins, hard slaty diabases, and patches of diabase, which may be subsequent intrusions, or pipes by which the later eruptions reached the surface.

The tuffs and schalsteins are so sheared and decomposed that it is frequently impossible to distinguish a schalstein lava from a schalstein tuff. They exhibit a variety of colours such as buff, purple, green, etc., but the prevalent colour is a deep red in which small white (zeolitic) patches are often conspicuous. The peroxidated materials are well exposed in the following places:—Near Cholwell Cross; near Langridge Cross; near Bowden Pillars; between Bowden House, Sharpham Barton and Ashprington Cross; between Cross Lanes and Ashprington; south of Sharpham House and near Ashprington point, where they contain amygdules with ferruginous coating. On the opposite side of the Dart—south of Weston House, east of the Rifle Butts, near Fleet Mill, west of Longcombe, north-east of Millcombe Barn, north and west of Hackney Creek, near Duncannon, south and south-east of Stoke Gabriel. Buff tints prevail, near Redworth, near True Street, south of Totnes, north of Bowden House, near

* The term Ashprington Volcanic Series does not occur on the map, and as it really denotes a special area of maximum vulcanicity, the general application of the term to volcanic rocks of Middle Devonian age outside this area can only be used with propriety in a restricted sense.

Luscombe Cross, north of Ashprington Cross, near World's End, east of Millcombe Barn, etc. In many places red and buff beds are intercalated.

Hard diabases, whether contemporaneous or intrusive, are distinguished by the darker tint on the map. These are marked by bold crag features on the slopes of the hills, but are generally indistinguishable by feature on the summit, where many of the patches shown have been inferred from surface fragments only. Near Torcombe sheared slaty diabase and massive diabase make fine craggy features. The rocks have an apparent southerly dip. Hard slaty porphyritic diabases make a bold ridge near the Lodge south of Sharpham stile. Slaty diabase occurs at Dundridge, west of Langridge Cross. A hard vesicular diabase is quarried at Peak Cross, north of Ashprington Cross, and west of Sharpham Barton a mass of diabase runs north-east and south-west; it is bounded by grey-brown vesicular rock, shaly where weathered. Highly vesicular rock is associated with peroxidated tuffs at Sharpham Barton.

A small patch of aphanite and bluish vesicular slaty rocks occur in Higher Gribble Plantation. Rocks from a quarry, by the Dart, near the Rifle Range butts, and from Byter Mill east of Stoke Gabriel, were pronounced by Dr. Hatch to be sheared amygdaloidal diabases with flattened chloritic amygdules. Slaty vesicular diabases are met with at fifty chains north of Fleet Mill, south of Fleet Mill, and east of Hackney Barn. South of Port Bridge there are three bands of hard slaty diabase, apparently intercalated in the tuffs and schalsteins, the northernmost can be traced to Stoke Gabriel.

At Ham Barn, east of Sharpham Point, bluish amygdaloidal rocks strike nearly east and west. East of Sharpham House pale greenish-grey schalsteins have been quarried. Near the Boat house of Sharpham House the amygdules are filled with calc spar. On the east of Ashprington, green, slaty and vesicular, fragments of igneous rock are scattered over the brown arable land.

Sheared vesicular diabase (melaphyr) occurs on the south of Tuckenhay Paper Mills. In a similar lava north of Higher Dittisham the amygdules are filled with quartz.

Many of the diabase patches, indicated by surface stones or insignificant exposures, may cover larger or smaller areas than is shown on the map, such as the large mass at Luscombe Cross the patches north of Stancombe, between Ashprington and Ashprington Cross, etc.

Most of the smaller diabase patches are aphanites, of which the rock forming the Sharpham Reach promontory, by the Dart is a typical example. There are several patches near Harbertonford, by the Dart north of Sharpham Park, at Pen quarry near Stoke Gabriel, on the north of Fleet Mill where the rock is veined with epidote, near Redworth, etc. Porphyritic diabase patches are met with on the north of Totnes Cemetery, south-east of Follaton House, near Broomborough House, and on Harper's Hill west of the northernmost lodge in Sharpham Park, etc.

The following notes are by Dr. Hatch:—

E. 1105. Pit west of Sharpham Barton Linhay plantation—Compact diabase, slightly porphyritic, consisting of isolated porphyritic crystals of plagioclase embedded in an altered ground mass composed of augite, felspar, iron ore, and chlorite. The structure of the rock is much obscured by the turbid alteration products of the felspar.

1159. From a small patch, north-west of Sharpham House—Altered diabase veined with secondary minerals : quartz, epidote, chlorite, etc.

1158. Quarry near Ham Barn, Hackney Creek Porphyritic diabase, rich in granular epidote and chlorite, resulting from the decomposition of augite and felspar; some iron ore.

E. 1106. Old quarry near Totnes Workhouse—Compact diabase slightly porphyritic, composed of small porphyritic crystals of felspar embedded in a ground mass of felspar and chlorite (the latter arising from the alteration of the augite). In the Chlorite are scattered numerous granules of titaniferous iron ore (ilmenite). Calcite in isolated patches.

E. 1108. Quarry by back road to Broomborough House, west of Totnes—Porphyritic diabase, much decomposed : plagioclase, chlorite, ilmenite, calcite, etc.

Hard compact buff rocks * occur in places in the volcanic series, as near Sharpham House boathouse, at Totnes Castle, near Dartan Moor (north of Bridgetown, Totnes), west of Redworth, etc. The specimen from Totnes Castle is thus described by Mr. Teall:—

3156. Totnes Castle—Compact rock mottled with pale greenish-grey and purplish tints. Weathers brown.

M. A few small phenocrysts of completely altered felspar in a matrix of similarly altered lath-shaped felspars, carbonates after augite and iron-ores.

1491. South of Dittisham Corn Mill.—A rock pronounced to be "ophitic dolerite" by Prof. Watts.

At Follaton House and in the lane south of Broomborough House there are whitish slates, of a steatitic aspect in the latter case. These may be of volcanic origin. Similar slate has been recorded in the Lower Devonian area near Bugford, west of Dartmouth. (See p. 39.)

Relations of the Volcanic Rocks.

No evidence of continuous intervals during which ordinary sedimentation took place has been obtained in the volcanic area, but some traces of slate may be accounted for by deposition between periods of eruption. Thus, bands of slate seem to be intercalated in the volcanic series in the following places:—purple slates at sixteen chains north of Langridge Cross; lilac slates east of Dundridge; a nearly north and south band of purple and buff slates east of Cholwell; a thin band of purple slate north of Cross Lanes, east of Ashprington; purplish slates between Lower Gribble Plantation, and Ashprington Cross. By the alluvium of the Dart, near World's End in Sharpham Park, ten feet of purple shales with traces of cherty limestone are exposed in the low cliff, and in a quarry by the avenue, fifteen chains south-west of it, purple slates in the volcanic rocks dip eastward at 15°. On the summit between Lower Longcombe and Millcombe

* Similar rocks occur in the volcanic series between Ugborough and Plymstock (Sheet 349).

Barn, east of Fleet Mill, there is an irregular patch of red, buff, and mottled slates, associated with quartz. Some buff slates overlying volcanic rocks in the valley on the north may be the continuation of this patch shifted by a north and south fault.

The above instances might perhaps be explained by the appearance of underlying sedimentary beds through faults and inverted plications, as in the following occurrences:—South of Totnes dark grey buff-weathered slates are exposed by the road near Gerston Cross, where they seem to be shifted by fault, and are seen to contain a little dark grey calc-veined limestone. Dark slates are also exposed by the road between Windmill Down and Tristford Cross; their extension towards Broomborough House is doubtful. At the end of a plantation, fifteen chains south-east from Follaton House, a small patch of limestone is met with; it is probably brought up by faults, accounting for springs which rise in the vicinity in the volcanic rocks. A small triangular patch of limestone, bounded by faults on the west and south, but apparently dipping under the volcanic rocks on the east, occurs on the hillside at thirty chains south from Weston House.

At Parkers Barn grey slates are exposed. They extend along the banks of the Dart for about eighteen chains, passing under volcanic rocks on the south (where they contain films of limestone) and east, and are cut off by a nearly east and west fault on the north. Following the direction of this fault eastward, on crossing the tributary valley south of Fleet Mill, it coincides with a tributary valley in which three tiny patches of limestone may be detected, at and west of Millcombe Barn. By the Fleet Mill valley, at eighteen chains east of Parkers Barn, a small limestone patch dipping under volcanic rocks on the south, is visible south of Hackney Barn. It is probably bounded by slates under volcanic *débris* on the north. A small, nearly circular, patch of limestone with south-easterly dip is noticeable at about a quarter of a mile north of Pen Quarry.

The boundaries of the volcanic rocks are not the fringes of the products of an eruption, or of a series of contemporaneous eruptions, from different vents, but of the emissions of many different eruptions taking place at different times and from different vents. There is, therefore, nothing anomalous in the different relations displayed by the volcanic rocks to the slates and limestones, as their boundary is traced round from Harbertonford to Totnes.

The absence of limestone along the southern boundary, except at Harbertonford (where a mass of dark grey slaty Eifelian limestone underlies the volcanic materials), is, perhaps, partly due to fault junctions with the Eifelian slates, as faults undoubtedly occur between Harbertonford and Washbourne, and near Combe, East Cornworthy, and Dittisham. The volcanic series is thus brought in contact with the Lower Devonian near Combe, and a great part of the Eifelian slates are cut out south of Dittisham.

In Champernowne's paper* "On the Ashprington Volcanic Series," the Greenway House coast from the Fishpond's inlet, near Greenway Viaduct, northward is thus described:—"Some grey slates with a few calcareous seams line the north side of this inlet and rising from below them a great mass of lavas and tuffs with some very hard rock forms the ledges until we round Greenway Quay and reach their base. Along the bank from here to near Galmpton Mill some beds of dark limestone and buff-coloured shale extend. They are exceedingly rich in corals, the prominent forms being *Alveolites compressa*? Edw. and H., large specimens of *Cyathophyllum damnoniense*, Phil., and others. *Cystiphyllum vesiculosum*, Goldf., also a specimen of *Hallia* occurred, the latter with a quantity of *Aulopora* hanging about it."

On the same side of the Dart, west of Waddeton Quay, the volcanic rocks are again encountered. They consist of red, purple, buff, and green lavas and tuffs, with occasional small masses of hard diabase. On the east they are bounded (apparently) by slates, but on the north limestone containing *Cystiphyllum vesiculosum* is encountered; the continuity of this limestone (as shown on the map) with that of Sandridge Park is inferred. South of Sandridge Park a quarry in grey coralline limestone afforded *Cyathophyllum cæspitosum* and *Cyath. helianthoides*. In parts the limestone is shaly, as by the Dart at Ladies Quay, where it is overlain by soft mottled fossiliferous shales, apparently fine tuffs. At Sandridge Point the limestones reappear under volcanic rocks partly fossiliferous, as above. Their junction with the limestone is irregular and ill-defined. Hard red crinoidal limestones are seemingly intercalated with the tuffs, and the dark-grey, red-weathered, lenticularly shaly limestones have soft red partings and bands. A volcanic breccia with limestone fragments is observable in one spot near hard diabase. The limestones yielded *Receptaculites*, *Alveolites compressa*, *Cyathophyllum* (possibly *C. obtortum*), *Strophodonta*? and *Zaphrentis*, kindly identified by Mr. Whidborne.

On the opposite bank of the Dart, a tiny patch of limestone is visible under the volcanic rocks at Redgate near Higher Gurrow Point. A similar patch of slaty blue and brown limestone (with *Cyathophyllum obtortum*) is met with at Blackness Point, near a band of slaty limestone with rugose corals, and gently undulating bedding (along the Dart shore). This band is repeated by plication along Dittisham Mill Creek. It reappears in the limestone patches of East Cornworthy which are shifted by fault on the west, and in a small patch on the southern margin of very fossiliferous grey Eifelian slates of the Berry Park type, exposed by the Dart. Recrossing the Dart between Stoke and Mill points, we again encounter the limestones, with occasional brachiopods and numerous corals, amongst which Mr. Whidborne recognised *Alveolites compressa*, *Cyathophyllum*

* *Quart. Journ. Geol. Soc.*, vol. xlv.
† Identified by Rev. G. F. Whidborne.

cœspitosum, *C. obtortum* (probably), *C. vermiculare*. These limestones are intermixed with buff material, and are in places much altered and decomposed. A chalcedonic film was observed in the decomposed brown rock. The connection between the limestone and volcanic materials is so intimate that the rocks display the appearance of schalstein-kalk in places. In one spot a hard, red rock, probably a peroxidated igneous dyke, seems to have penetrated the limestone. The rocks are evidently contorted. At the mouth of Bow Creek, south of Langham Wood Barn, there is a small patch of decomposed limestone and schalstein-kalk. On the south shore of Bow Creek, limestone underlies the volcanic rocks, forming two patches at from 20 to 50 chains east from Tuckenhay Creek. In the westernmost of these, thick bedded and slaty dark blue limestones are exposed, for about 50 feet, in a quarry.* They contain numerous corals amongst which Mr. Whidborne recognised *Cyathophyllum bilaterale*, Champ. In another part of the limestone, which occurs on the border of a small alluvial tract, *Spongophyllum* was noticed. East and south of Bow the bluish coralline limestones are again visible—by the creek in Crownley Wood under volcanic rocks—exposed to a depth of 20 feet in a quarry north of Crownley Wood, and between Lower Yatson and the River Harbourne. The connection between the two last exposures is inferred, along the strike of the limestone anticline. Near this between Bow, Beanleigh, and Luscombe, there is a considerable tract of Eifelian slates. Along its border limestone has only been proved to separate the slates from the overlying volcanic rocks in one place, viz., south of Torcombe, where there is a small patch of blue and greenish, irregular, slaty limestone, associated with slates and overlying slates of the Berry Park type.

Returning to the main boundary at Sandridge Park, we find the volcanic rocks, between that place and Port Bridge, bounded by Eifelian slates of the Mudstone Bay type. The junction appears to be an irregular north and south fault, throwing down the volcanic rocks on the west. North of Stoke Gabriel reddish and grey slates may separate the limestone mass from the volcanic series, as they occur on the margin of the limestone at Well Farm, and three quarters of a mile farther west.

The slates on the west side of Stoke Gabriel seem to be brought up by a fault. They are overlain by a large patch of slaty limestone, which seems to rest on purple volcanic rocks near Duncannon, and by a circular outlier of blue and buff weathered limestone farther north. Near its western termination the slate is faulted against limestone, of which the small patch near Ham Barn might be a faulted continuation.

There are numerous faults between Stoke Gabriel and Longcombe affecting the relations of the limestones and volcanic rocks, and the surface evidence is often unreliable.

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* Champernowne obtained the original specimen of *Cyathophyllum? bilaterale* described in *Quart. Journ. Geol. Soc.* vol. xl. p. 503. pl. xxiii. from a quarry "on the south bank of Tuckenhay Creek." No doubt this quarry was meant.

The limestones and schalsteins of Aish are cut off by a nearly north and south fault against the great mass of limestone north of Stoke Gabriel. On the west side of this fault there is a small patch of very coralline limestone, near a place called Hoil (on the 6 inch map), in which *Spongophyllum Sedgwicki*, identified by Professor Frech, is conspicuous. This limestone, as well as that of Aish, where unfaulted, is probably under the volcanic rocks. The limestones of Aish are exposed in a quarry south-west of Aish House to a depth of 20 feet; at Aish they seem to be horizontal.

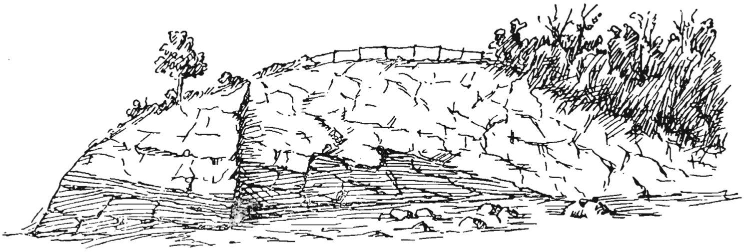
The limestones at, and south of, Longcombe occur between two faults which unite on the west side of Aish. The westernmost of these faults passes "Parliament House," the little house in which William of Orange held his first Council. The larger patch of limestone seems to pass under volcanic rocks on the south and to be bounded by a fault on the east, which coalesces with the main dislocations and cuts off the small patch of limestone on the west of Longcombe. The limestone patch faulted against Lower Devonian, south of Longcombe, seems to rest directly on Eifelian slates, and to be lower in the series than the other patches. South of Parliament House a band of limestone is cut off on the east by the fault. At its western extremity this limestone is exposed; the beds dip south and west, and are overlain by shaly yellowish-grey and purple volcanic materials much contorted. The persistence of this band is doubtful. The Lomentor limestone seems to be faulted on all sides, or overthrust on Eifelian, or Lower Devonian strata.

At Aish the volcanic rocks seem to overlie the limestone, and although their persistence to Higher Yalberton on the east is not ascertainable, owing to extensive washes of Lower Devonian *débris*, a connection between the Ashprington and the Crabs Park volcanic products is very likely to have taken place in this direction. The faulted limestone patches north of Longcombe are associated with red rocks, so imperfectly evidenced that I cannot say whether they are volcanic or Lower Devonian. If volcanic, the limestones, which are displaced portions of the same horizon, would be separated by them from underlying Eifelian slates. If Lower Devonian, their positions would have to be explained by thrust and step faults.

From Longcombe westward the volcanic rocks are bounded by slates, in faulted or unfaulted contact except—near Weston House; between Bridgetown and True Street; and at Totnes Cemetery—where limestones are met with. South of Berry Pomeroy, east of Weston House, a good sized mass of limestone, bounded on three sides by the volcanic series, yielded *Alveolites vermicularis*, *Favosites Goldfussi* and the following, identified by Herr Frech, *Heliolites porosus*, *Mesophyllum damnoniense*, *Syringopora crispa*. There are two patches of limestone, probably connected with this, on the opposite side of the stream. The relations of the limestone are probably affected by a fault prolonged in a south-easterly direction from True Street. Between True Street, Great Court, Bridgetown and Bourton the boundaries of the volcanic rocks, where in contact with slates, are invariably faults running east and west, and shifted by dislocations trending north by west and south by east; the only exception being a somewhat doubtful north-east and south-west fault between True Street and Bourton. South of True Street limestone dips under the volcanic rocks, but its extension is very doubtful, through lack of evidence between Highlands and True Street. Thin bedded limestones, associated with slates apparently dipping under volcanic rocks on the south, are visible at a quarter of a mile east of Bourton.

Similar limestones are imperfectly evidenced in an orchard south of Bourton. The volcanic rocks rest on limestone. At Redhill quarry by the Dart, Champernowne, in unpublished notes, thus describes the section—"Here the mass, which is scoriaceous at the base, rests on an eroded step-like surface of limestone beds dripping south-east." Godwin-Austen ascribed this step-like junction to faults, but Champernowne regarded it as "a case of contemporaneous erosion involving a disturbance of the reefs by the volcanic forces."

FIG. 11.—REDHILL QUARRY, NEAR TOTNES.



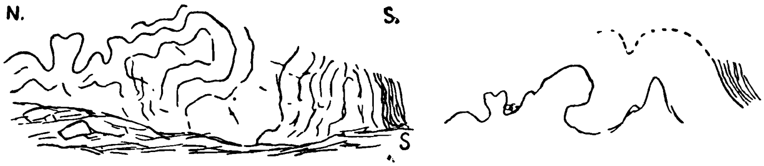
Greenish, buff brown weathered, decomposed igneous rock, resting on limestone, which dips at 15° to 20°.

To the south of this the limestone is again visible, underlying the volcanic rocks without any appearance of irregularity. Still farther south irregular buff and grey slates, with limestone lenticles containing *Cystiphyllum vesiculosum*, are exposed by the high road below the limestone. The limestone in the wood contains an isolated mass of igneous rock to the east of which it extends for some chains, probably faulted against the volcanic rocks on the north but passing under them on the south. In this extension the limestone is exposed in a quarry near Dartan Moor where it is partly massive, partly broken and slaty, and excessively contorted, as shown in the sketch (Fig. 12).

East of Dartan Moor limestone is exposed in an old quarry at Endsleigh, where buff schalsteins, so blended with limestone as to resemble a schalstein-kalk, rest on massive dark grey limestones, veined with calc-spar and with a lenticular peroxidated slaty seam. A coral obtained here was described by the late Professor Nicholson as "a *Caunopora* belonging to a common but undescribed Stromatoporoid of Devonshire. It is probably referable to the genus *Hermatostroma*."

The continuation of the Endsleigh limestone eastward is broken by two parallel faults, eight chains apart, by which it is shifted northward and forms a mass apparently in an inverted anticline in the volcanic rocks on the slope south-east of Bourton. The easternmost fault cuts off a mass of coralline limestone, of grey and deep red colours, on the west, near Highlands. Amongst the corals *Cystiphyllum vesiculosum* was obtained from this limestone. Nicholson identified *Alveolites suborbicularis*, *Clathrodictyum*, probably a new species, and Dr. Frech recognised *Favosites reticulatus* and *Mesophyllum damnoniense*. Farther south the fault cuts off a patch of thin-bedded limestone, resting in an inverted syncline on Eifelian slates, against volcanic rocks on the east. It may, therefore, be inferred that these isolated limestone patches formed a continuous mass, resting on the Eifelian slates and overlain by the volcanic materials. There is no reliable evidence for connecting these volcanic rocks with the main mass; they appear to be cut off by an east and west fault at Great Court, and may rest on limestone at a spring, west of that place.

FIG. 12—QUARRY NEAR DARTAN MOOR.



Massive limestone and broken limestone Schalsteins. General structure.

At Higher Weston farm, and in an orchard south of it, wells have been sunk just below the feature made by the volcanic rocks. One of these wells is said to be 160 feet deep. No volcanic materials were turned out, the strata penetrated being, apparently, dark grey slates, overlain near the surface by dark shaly limestone and buff fossiliferous (decomposed limestone) shaly beds. The limestone and buff shaly fragments, turned out, recall the Hope's Nose Eifelian limestones and contain numerous Brachiopods and corals. The Spirifers were pronounced by Professor Kayser to be *Spirifera aff.* (but not the true) *speciosa*, Schloth. Professor Frech identified the following:—

Atrypa reticularis, *Linn.*
Actinostroma verrucosum, *Goldf.*
Cyathophyllum cæspitosum, *Goldf.*
C. dianthus *Goldf.*
C. vermiculare, *Münst* (præcursor *Frech*).
Mesophyllum damnoniense, *M. E. and H.*
Favosites Goldfussi, *M. E. and H.*

Beds of dark grey limestone, containing similar Spirifers to those at the wells, are exposed at the border of the volcanic series in a narrow brook channel to the south of Lower Weston Farm.

At Rose Cottages, south of Totnes, there are lenticles of limestone in the buff slates on the volcanic boundary. There is a small patch of limestone between the volcanic rocks and the Eifelian slates, crossing the Great Western Railway at Totnes Cemetery. Near Longcause, lenticles of limestone occur in the slates near the volcanic boundary. In the high road at Redworth two small patches of highly altered limestone are visible in or under the volcanic rocks, which here appear to be faulted against Eifelian slates on the north and east.

Atrypa reticularis occurs in buff slates at their junction with the volcanic, just outside the map near Follaton House.

The well sunk by Isler and Co. at the Lion Brewery, High Street, Totnes, indicates the presence of shaly Eifelian limestones probably forming a syncline beneath the volcanic outlier of Totnes Castle. Beyond the Castle mound there are no exposures in the space indicated as volcanic on the map, and part of the made ground may be volcanic rock disturbed. The section thus interpreted is:—

	Ft.	in.	
Made ground and soil	21	0	Probably in part volcanic
Shaly rock	3	0	Eifelian limestone.
Blue limestone rock	2	6	
Blue slate rock	139	6	Eifelian slates.

Taken in connection with Weston wells, and the entire absence of evidences of volcanic intercalation in the Eifelian slates, it seems evident that the earliest eruptions of the Ashprington series took place during the later, or latest, stages of the deposition of the Eifelian slates. From the disposition of the volcanic materials indiscriminately on these slates, and on successive stages in the limestone formation which ensued, it seems clear that the earlier eruptions were so localized as to permit of these organic growths taking place and being overwhelmed at different stages by subsequent eruptions. On the margin of the eruptive foci, under favourable conditions, coralline growths would spread over the volcanic materials, as at Sharkham Point, and, perhaps, near Aish, etc., where subsequent disturbances may have entirely effaced the original relations of the rocks.

Dartington, Marldon, and Ipplepen District.

In the introductory notes the general character of this area has been roughly sketched. The New Red rocks west of Torquay conceal a tract between the Torquay and Paignton anticlines, in which the disturbances of the Middle Devonian rocks must have been considerable. As faults cannot be traced in the slate areas away from the limestones, and the dislocations affecting the latter were only shown where obvious, through displacement or shifting of the boundaries, it is not possible to say how far the structure may be influenced by faults which have not been detected, and consequently to distinguish slates which may have replaced limestones from the Eifelian slates which underlie them. North of Staverton the limestones are so feebly represented and so closely associated with the slates, that they appear rather to be impersistent and irregular developments in them than faulted remnants of a persistent horizon.

Looked at in a broad way, we may regard the slates on the south of the Dartington and Marldon limestones (the Berry Park slates of Champernowne) as Eifelian, or the lowest beds of the Middle Devonian. Above these come the bedded limestones, which include the Berry Pomeroy outliers, and extend from Marldon to Dartington, and thence to Fishacre. The Ipplepen limestone mass is either altogether above the Dartington limestones, or represents them in its lower beds south of Orley Common. In either case the Dartington limestone passes out into slates in the Broadhempston country, but it may be continued eastward in the Newhouse Barton, Yarneford Copse, Wrigwell House, Bulleigh Barton, and Whilborough limestones. The limestone bounded on the south by volcanic rocks on Blair Hill, north of Bulleigh Barton, is an upper limestone mass, in the same category with that of Ipplepen, the schalsteins being a development in the slates with occasional dark limestone bands and tuffs, which overlie, or replace, the Dartington limestones.

The replacement of the limestones by slates with contemporaneous volcanic rocks is conclusively proved (as already remarked) in the area on the west, in Sheet 349. The slates with tuffs in the area under description have been regarded as the commencement of this replacement. These would be above the Dartington limestone on the assumption entertained by Champernowne that the Dartington structure is a syncline, the limestone separating older from newer slates. If we assume the contrary hypothesis, the Marldon and Dartington limestones would be partially replaced or occur as outliers, and the volcanic materials would be associated with the uppermost beds of the Eifelian slates, or with slates representing the lower (locally even the higher) parts of the Eifelian limestone.

The volcanic rocks of this area are brought into relation with those of the Ashprington and Goodrington districts by Champernowne. Referring to a coarse tuff faulted against dolomitic limestone at Aish, north of Stoke Gabriel, he wrote:—* "This tuff consists chiefly of red slaty-looking patches, decomposed felspar crystals, and grains of quartz. A precisely similar rock resting on limestone occurs near Watton [Waddeton] village, and beds of like constitution, but not red, are interstratified with bluish slaty shales over the Dartington limestone, being well exposed in the Ashburton railway-cutting, also overlying the limestone of Bulleigh Barton, and south of the limestone of Clennon Hill near Goodrington. . . . These belong to a characteristic type . . . they are never amygdaloidal, and cannot have flowed, but seem to correspond to the Nassau

* On the Ashprington Volcanic Series, *Quart. Journ. Geol. Soc.*, Vol. xlv., p. 369, etc.

'porphyritic schalstein' so-called." In his unpublished notes the following passage occurs:—"In the broken and troughed country of Dartington and Little Hempston, the lavas appear to be absent, ash beds, both fine-grained and flaky, as well as coarser brecciated layers, alone representing this group. Blue-black slates intervene between them and the great limestone below, so full of Middle Devonian fossils. With the slaty beds above the ash, etc., many blue limestone layers are interstratified, apparently unfossiliferous. Dartington Hall and Little Hempston Parsonage are built on the latter, which are finely exposed in the railway cutting on the left bank of the Dart."

In allusion to the difficulty he experienced in distinguishing the slates above mentioned from those below the limestone, the paper on the Ashprington series concludes with the following sentences:—"But why should there not also be slates neither exactly above nor below the limestone, but replacing it? So that De la Beche's words would be true, viz., that the geological continuation of certain limestone appears to consist of slate." Dartington Parish Church is built on slates bounded by the Dartington limestone (along a north and south fault?) on the east, and by a mass of decomposed igneous rocks at Knoddy and Yarner on the west. The rock (No. 1084) of Yarner Beacon is a dolerite. These igneous rocks rest on the slates, but shaly limestone is exposed beneath them in an old quarry at Lownard, near Yarner.

Farther west, in Sheet 349, there is not the slightest evidence of the continuation of the Dartington limestone, so that we must conclude that its place has been taken by slates with schalstein; and that the isolated Eifelian limestone of Peloe (Paytoe on the old map) in which Champernowne obtained *Calceola*, and the limestones of Buckfastleigh, on the north and of Hazard, on the south, were not connected with it. North of Staverton and west of the Ipplepen mass there is not sufficient evidence to connect the various occurrences of limestone.

The strikes of the area vary between east and west, and north and south; this is partly due to the dying out of the Lower Devonian anticlines, partly to the prolongation southward of nearly north and south strikes from Newton Abbot. The consequence of these strike variations is to repeat the rocks indefinitely, and rather to discount the idea of the occurrence of any great structural curves. There are numerous examples of slaty limestones passing into slate, but these are seldom sufficiently distinctive in character, or fossil contents, to justify their correlation with the Eifelian limestone with any degree of certainty.

Eifelian slates seem to pass under the Dartington limestones on the south. They contain limestone lenticles near the junction on the south-east side of Dartington Park and have the appearance of passing into the limestone. *Aulopora* and other fossils occur in them south of the Vineyard, and *Fenestella*, north of Dartington Hill Copse. Near Hampstead a lenticular patch of limestone associated with slate occurs in the Eifelian slates; and on their southern border the Little Hempston limestones are slaty near Grattons. On the east of Little Hempston Wood *Phacops batracheus* (=*P. granulatus*) was found. The slates of Gatcombe Park are fossiliferous. These slates are regarded as Eifelian and below the faulted limestones on either side. Near Shadrack Cross they contain *Aulopora, Zaphrentis, Phacops, Spirifera;* and east of Shadrack, *Phacops* and *Spirifera speciosa.* At Netherton *Atrypa reticularis* was found in them. Between the limestone near Uphempston and the adjacent patch of New Park Hill plantation there is an interval occupied by slate; north of Shadrack Cross there is no representative of the limestone between these slates which do not contain tuffs and those of Penball Cross which do. If, therefore, these phenomena are not due to faults, which can only be inferred theoretically, it is impossible to separate the slates with tuffs from the Eifelian slates.

The Battleford Copse limestone is considered to belong to the same series as the limestones of New House and Yarneford Copse, and the slates from Red Post eastward, which are frequently red stained, may, or may not, be Eifelian. East of Weekaborough Oak Cross, grey fossiliferous slates contain *Spirifera speciosa, Atrypa reticularis, Streptorhynchus* and *Phacops.* At Aptor Barn the slates are red, they contain many distorted fossils, fragments of trilobites, *Streptorhynchus umbraculum, Spirifera,* etc.

In the lilac-red slates north of Westerland House *Spirifera speciosa, Cyathocrinus nodulosus, Pleurodictyum* and *Zaphrentis* were obtained.

Grey fossiliferous slates of the Berry Park type, exposed in a quarry west of Westerland House, yielded *Leptæna interstrialis, Spirifera speciosa, Streptorhynchus* and *Strophomena rhomboidalis.* To the north of this, by the lane to Culvertor Copse, the slates contain *Orthoceras* and a small gasteropod (*Pleurotomaria,* identified by Kayser). From Culvertor Copse to Totnes the prevalent types of Eifelian vary, from the irregular Berry Park type to that of Ellacombe and Mudstone Bay—fossils are of common occurrence, as decomposed and distorted casts or impressions. *Atrypa reticularis* was recognised in Blackpool Clump, near Berry Castle Lodge, and near Springville, north of Totnes.

Berry Pomeroy, Marldon and Dartington Limestones.

The limestones of this group are so seldom seen in unfaulted junction with the slates that the recognition of the shaly Eifelian passage limestones and slates at their base is naturally exceptional. They represent the bedded limestones of Daddy Hole, and although, where unfaulted, their lower beds would correspond to the Eifelian limestone, it it not possible to say how far they may be regarded as included in that series.

Near Springville House, north of Totnes, there are three contiguous patches of Eifelian limestone, possibly connected, but of this there was not sufficient evidence. The westernmost patches consist of dark grey limestone veined with calc-spar, under thin irregularly bedded limestone, overlain (invertedly ?) by papery shale; and of dark grey limestone associated with buff argillaceous material, very similar to the Hope's Nose limestones.

The larger mass, on the east, is composed of dark grey limestones, more or less slaty. These are well exposed in Mockwood Quarry where they exhibit a complex series of zigzag plications. This limestone is probably terminated by fault on the east. In a specimen labelled Mockwood Quarry, of pale grey compact limestone, Professor Frech identified *Cyathophyllum tinocystis*, Frech—an Iberger Kalk species. The character of the specimen suggests higher beds thrust or folded in.

The limestones south of Gatcombe Park are connected by a narrow, probably faulted, isthmus, On the south of this there are signs of limestone and schalstein bands in the slates. The larger mass is frequently slaty, and in one place (shown on the map) it may surround a plicated mass of slates. Contortions in the limestone are well shown in a quarry overlooking Gatcombe Park. Dark bluish-grey limestones associated with buff earthy matter (as at Hope's Nose) are exposed south-west of Combepark Cross. East of Little Hempston Wood the limestone is coralline and contains *Alveolites suborbicularis* and *Mesophyllum damnoniense* identified by Professor Frech. The faulted patches, near Netherton, point to the connection of these limestones with those of Berry Pomeroy on the south, and through them, with the limestones on the north border of the Ashprington series. In one of these patches, at Sandlane Copse south of Netherton, the limestone is cleaved, as in the Hope's Nose coast.

The surface evidence between the Berry Pomeroy limestone patches is, in many cases, so indefinite that it is impossible to say that they may not be connected by—and based on—slates with limestone bands or lenticles, representing the lower part of the Eifelian limestone. The most southerly mass, on the north of the Ashprington series, is exposed in a quarry in Southfield Wood showing pale-grey limestone, yellow-banded in places, weathering dark grey.

At Berry Castle Lodge, a triangular patch of contorted bluish-grey calc-veined limestone is exposed; it appears to be faulted on all sides. Near the end of the wood, on the west of Berry Castle Lodge, a small patch of limestone was also detected; relations not shown. These limestones were no doubt once connected with the faulted patches near Longcombe on the south, and the Afton and Marldon limestones on the north. The slates of Shadrack Cross lie between two nearly north and south faults. The westermost cuts off the Uphempston limestone. The eastermost cuts off the limestone south of Netherton, and forms the western boundary of a long patch of limestone with easterly dips in New Ground Copse. This mass may be connected with that on the east in which *Alveolites suborbicularis* was obtained in Park Corner Copse.

The third and largest mass occupies the high ground between Afton and Northtor Cottages. It is bounded on the south by a fault along the north-western walls of Berry Pomeroy Castle. There is every reason to conclude that the Afton limestone rests on the slates which separate it from the limestones of Aftontor Quarry on the north. From Aftontor Quarry the limestones extend to Marldon, their sinuous boundaries on the north, between Aftontor Wood and Butterball Copse, denoting a natural, but, no doubt, frequently inverted junction with the slates of Aptor and Weekaborough Oak Cross. On the south the boundary is a fault at Loventor. This is shifted by a cross fault at Afton, and forms the southern boundary of the Afton limestone at Berry Pomeroy Castle, already mentioned. Near its northern margin the limestone, east of Butterball Copse and south of Aptor, contains numerous corals including *Amplexus tortuosus* and *Cystiphyllum vesiculosum*, and the following identified by Professor Frech, "*Cyathophyllum cæspitosum*, Goldf. *Mesophyllum cylindricum*, Schlüt. *Cœnites* n. sp. (not occuring in Germany)."

At Burrowbottom Barn, south-west of Aptor, there are two small outliers of coralline limestone in which *Cyathophyllum cæspitosum* "immersed in a colony of *Alveolites*" (identified by Nicholson), *Cyathophyllum helianthoides* and *Cystiphyllum* were obtained.

At Hazelwood, where thin-bedded limestones have been quarried, the continuity of the limestone is broken and shifted by faults.

Near Strainytor Copse numerous inverted contortions with easterly dips are shown in an old quarry. At Higher Westerland Quarries bluish-grey limestones, mostly crinoidal and containing corals in places, are exposed. In one of the quarries, a sharply inverted syncline is shown. *Alveolites vermicularis*, *Aulopora*, *Favosites* and *Spirifers* are obtainable. At Marldon the limestones are bounded by faults; they exhibit various changes in strike. "*Alveolites suborbicularis*, Lam., associated with stems of a species of *Pachypora*," and a "rugose coral, partly immersed in a Stromatoporoid" were recognised by Professor Nicholson.

North of Marldon a fault-bounded inlier of distinctly bedded, partly crinoidal, limestone is exposed in the valley south of Compton, in the New Red area. It contains *Alveolites vermicularis*, *Heliolites porosus*, *Spirifera* sp., and "*Stromatopora Hüpschii*," Barg. (with "*Caunopora* tubes") which was identified by Nicholson.

A small limestone inlier occurs to the east of this; and further east is the Stantor Quarry inlier. In this quarry the even, mostly thin-bedded, limestones are excessively contorted. Numerous sections of Gasteropods are shown in some of the beds. *Stromatopora Bücheliensis*, Barg. was obtained here and identified by Professor Nicholson.

The Marldon limestones in their extension to Aptor seem to rest on red slates on the south. South of Marldon Tor Plantation there is no reliable surface evidence.

At Aptor Brake the limestone is shifted northward by faults. At Aptor the rock is coralline in places; one bed full of *Favosites*, etc., was noticed; the bedding is generally even. Between the Aptor limestone mass and that of Herhill Copse, grey slates are in faulted junction with the New Red. The Herhill Copse limestone is faulted against these slates on the east, but the shaly limestones on its southern border are indicative of a natural junction. Limestone is imperfectly exposed on the New Red boundary in a valley south of Higher Weekaborough, but beyond this there are no indications of limestone along the New Red boundary until Battleford Copse is reached. Between Battleford Copse and Red Post there seems to be a small patch of limestone associated with red slate.

From Uphempston the limestones in direct continuation with those of Dartington Park begin. The Uphempston limestone is faulted against slates on the east, west, and south. Near its southern boundary the dips are westerly, and the rock is partly dolomitic. On its northern border even-bedded, dark bluish-grey, white-weathered, hackly fractured limestones, locally full of corals, seem to rest on bluish-grey slates. Amongst the corals Nicholson recognised *Alveolites subæqualis*, Ed. and H., and a *Cyathophyllum*, (perhaps *C. ceratites*). Mr. Whidborne identified *Phillipsastræa* (*Smithia*) *Hennahi*. Between the western fault boundary of the Uphempston limestone and that of New Park Hill Plantation there is an interval of twenty yards, or so, of slate with some signs of tuff. Unless the slates with tuffs on the north are newer than the slates without tuffs on the south of it, the New Park Hill Plantation limestone (which is partly dolomitic) occupies an inverted syncline; if not, the interval between it and the Uphempston limestone must be bridged by a fault.

South of Little Hempston Church a nearly east and west fault cuts off the limestone on the north against dark slates. Both series are extremely contorted. The fault cuts off a small contorted patch of limestone at the north end of Little Hempston Quarry, and to the east the dark slates are well exposed in the road cutting descending the hill toward Little Hempston Bridge. On the north of the fault we encounter limestones in the dark slates (or shales) in four places. One of the limestone beds is cleaved and inverted, and in one spot nipped out. Further on, dark, partly calcareous slates, in places passing into limestone. are to be seen. A little lower down, dark grey tuffs with a southerly dip are exposed in the slates. These beds, although faulted against the limestone on the south, are in direct relation to it on the east. The problem to be solved is how far the phenomena may be due to an actual outward passage of the limestones into slates with occasional limestone bands, in an area of local vulcanicity, and to what extent local vulcanicity irregularly interrupted the upward growth of the limestone.

Near Parkhill, Little Hempston, the limestone is interstratified with dark blue and grey slates, and apparently overlain by dark slates, calcareous in places. In the wood east of Grattons, dark grey slates are intercalated with the limestone. On the summit between Grattons and the Dart the limestones enclose an irregular tract of slates bounded by fault on the north, and presumably an anticline of Eifelian slates. At Grattons, and near its southern boundary (which may be faulted), the limestone is slaty. Dolomitic limestone is encountered in the north part of the mass, west of Little Hempston, and on the west and south of the central slate patch.

The alluvium of the Dart and river terraces bordering it, in Dartington Park, conceal the connection of the Little Hempston and Dartington limestones. South and south-east of Dartington House, the boundaries ot the limestone are very indefinite, owing to the plication of bedded or flaggy limestones which pass, by irregular intercalation, into slates.

In the old quarries on the south of the river terrace (north of Dartington Hill Copse) rather thin-bedded dark bluish-grey limestones are exposed, apparently resting on shaly limestones, on Eifelian slates of the Berry Park type, and dipping east 15 south, at 18°. Traced northward, these limestones are found to pass into slates by intercalation on the east and west, and are cut off by the Little Hempston fault prolonged, east of Dartington House. Grey slates with limestone lenticles are exposed by the Dart at the Boat House. The Dart seems to run along the strike of an inverted anticline of slates and slates with shaly limestones, separating the Little Hempston limestone from the limestones in Dartington Park which belong to the same series.

On the south of Dartington Gardens flaggy limestones are exposed in a quarry, giving a south-easterly dip of 40°. In a copse on the summit, some chains south-west of this, the bedding is nearly horizontal. The connection of this limestone with the main mass in Nellie's Wood cannot be proved, and its relation to the limestones on the east is obscured by faults Between Nellie's Wood and Dartington Hill Copse, surface fragments suggest the presence of volcanic materials in the Eifelian slates, and there are signs of lenticular bands or lenticles of limestone in the slates on the east and south of Nellie's Wood. West of Nellie's Wood, a quarry in Symon's Tree Wood exhibits limestone, partly shaly and associated with reddish slate. The limestones appear to be shifted by fault on the south of Foxhole Copse, but toward Shinner's Bridge they are well exposed in the stream gorge. The road between Parsonage Cross and Dartington House exhibits even-bedded limestones, dipping at low angles northward, in the quarry near its western margin, and westward at Symon's Tree Barn. Unless indicative of strong zigzag plication, or near a faulted western boundary, these low dips denote a less thickness of limestone here than in the Shinner's gorge.

At six chains north of Symon's Tree Barn there are indications of slate with volcanic bands in the limestone; these terminate in a small mass of diabase, at 13 chains northward. The limestone on the west of the diabase is dolomitic. Just north of this, in Chacegrove Wood, there is a larger mass of diabase, apparently faulted on the south (perhaps by the westerly prolongation of the Little Hempston fault). Limestones seem to dip off the diabase on the east and north, but on the west there are only indications of the presence of irregular beds of dark limestone associated with slates. In fact, the continuity of the Dartington limestone round Chacegrove Wood is most uncertain. This cannot be properly shown on the one-inch map, on which a line has been drawn as the north border of a tract where slates and tuffs, etc., may take the place of the limestones. This indefinite tract terminates in a bold feature in Staverton Ford Plantation, made by a mass of diabase flanked by limestone on the north and west slopes, and also on the east and south-east. In one place there is a trace of schalstein interbedded in the limestone. In Park Copse the continuity of the limestone is nearly, or altogether, broken by a great mass of diabase which continues on the north side of the Dart to Reevacre Cross, bounded on the east by a continuation of the Dartington limestones from Thistlepark Plantation. On the west side of Park Copse there is not sufficient evidence to prove whether the diabase is bounded by limestone or by slates. A specimen of the rock from Park Copse Quarry (No. 1079) is an ophitic dolerite.

Champernowne * described the limestone in Pit Park Quarry, Dartington, as a light grey, highly crystalline rock. A small part friable and almost sandy. From this quarry he obtained *Alveolites, Favosites cervicornis*, var. *reticulata, Heliolites porosus, Cystiphyllum vesiculosum, Heliophyllum*, simple *Cyathophylla*, Crinoid joints, pelvic plates of *Hexacrinus* (rare), and occasional brachiopods among which Davidson recognised *Spiriferina cristata*, var. *octoplicata*. From a quarry in an adjoining field a specimen of *Uncites gryphus*, in the Jermyn Street Museum, was obtained.

About 30 chains north of Dartington House *Cyathophyllum cæspitosum* and *Smithia Hennahi*, Ed. and H., identified by Nicholson, were found in the limestone. Nicholson gave Dartington as the locality for *Actinostroma clathratum*, Nich. From its specific name, *Parallelopora dartingtonensis* was no doubt obtained here. The *Stromatopora* obtained by Champernowne in Pit Park Quarry were not specified.

East of Thistledown Plantation a broad river terrace conceals the continuation of the limestone, which is visible on its margin, by the alluvium, for a distance of 10 chains south from the underlying diabase. For 30 chains further south, slates are present. *Atrypa reticularis* was found in them on the west of the river terrace. A band of tuff is here shown on the map; it completes the elliptical strike over the interval where the limestones are absent.

Just north of the timber yard in Park Lane, Dartington House, a well was sunk to a depth of 30 feet in dark grey

* *Quart. Journ. Geol. Soc.* vol. xxxv., pp. 67–68, 1879.

slates, calcareous in the lower part. Between the timber yard and the outbuildings, behind Dartington House, limestone is exposed, but no evidence of its persistence, along the north-east and south-west direction of its strike, was procurable.

Felspathic tuffs are visible in the slates on the high ground north of Dartington House, in the band on the east of the House, above mentioned, and in the grounds south-west of the House.

The slates of Staverton contain a few beds of slaty limestone in the Ashburton Branch Line section, near their junction with the prolongation of the Park Copse diabase mass in Staverton wood. Beginning with these slaty limestones, the following beds are exposed in the railway, between the slates of Staverton and the Little Hempston limestone :—

1. Buff and grey slates, with a few beds of slaty limestone, junction with diabase not exposed.

2. Diabase for a distance of twenty chains.

3^1 and 3^2. Intercalated slates and limestones overlain by limestone, with occasional slaty partings, and bluish-grey distinctly-bedded partly crinoidal limestone, also exposed in a quarry in the wood above the Line. The limestone beds vary from two or three inches to two or three feet in thickness. *Favosites* and *Cystiphyllum* were noticed in the cutting. These beds form the cutting for 17 chains; they are the continuation of the Dartington limestones from Thistlepark Plantation.

4. Dark grey partly calcareous slates, similar to those turned out of the well on the north of Dartington House, exposed for four chains.

5. A hard grey felspathic tuff bed, well exposed in a quarry above the Line, overlies the dark slates, and is succeeded by slates with irregular bands of tuff here and there, which form the cutting for four chains and pass under.

6. Slates with beds of limestone, about a chain in breadth; and either overlain by, or faulted against, 7.

7. Slates for about 10 chains, dipping eastward under :—

8. Bluish grey limestones with intercalcations and partings of slate. This band may be No. 6 shifted by fault or fold; it cannot be traced further north than a point (south of Parsonage Farm) on the slope above the appearance of 6 at the base of the cutting.

9. Slates with bands of tuff separating the limestone horizon (8) from slates with limestone beds which form the border of the Little Hempston limestone.

Following the rocks along their northerly or north-north-easterly strike from the cutting, we find that the diabase (No. 2) and overlying limestone (3) attenuate and disappear at Reevacre Cross, whilst the overlying beds, Nos. 4 and 5, increase in breadth from eight chains in the cutting to twenty-two chains at Buckyett, tuffs being irregularly developed in them in a continuous mass, directly above the limestone (3), and in irregular patches near Buckyett. South of Buckyett the slates and tuffs are bounded by hard bluish limestone beds (with a south-easterly dip of 40°, in a quarry near Parsonage Lane). Similar limestones associated with slates are exposed north of Buckyett, and dip off the slates and tuffs in an easterly direction. The same calcareous band has been continued, on the evidence of an exposure, north of Longford Bridge, and of pits and slight indications, round the coarse and fine tuffs of Ford Cross as far as Fishacre Cross. Whether in a persistent limestone zone or not, these limestone occurrences are evidently on the same stratigraphical horizon, and they appear to be the northerly continuation of No. 6, and perhaps No. 8, the limestone horizons in the cutting. The attenuation of limestone No. 3 (continuation of the Dartington limestone mass), which is associated with slates near Reeveacre Cross, makes its correlation with the Buckyett calcareous band probable, and both are no doubt cut off by the east-north-east and west-south-west fault which throws the tuffs of Ford Cross against the limestone of Fishacre.

To return to the cutting, the slates and tuffs No. 9 have a breadth of only five chains, but tracing them along the border of the Little Hempston limestone, they are found to fill the increasing space between that limestone, which strikes in an easterly direction, and limestone No. 8 in the cutting which strikes northward; and continuing to Bycellar Bridge (on the 6-inch scale map) they exhibit patches of tuff here and there, and also coarse tuffs or volcanic breccia in places. These slates and tuffs are separated by blue-grey slates from the series near Buckyett. It seems certain that the tuff-bearing slates Nos. 5 and 9 are repetitions of the same series. Whether the calcareous horizons 6 and 8 are the same or not, there can be little doubt that they severally belong to the Dartington and Little Hempston masses in an area where showers of tuff and muddy sedimentation rendered continuous coralline growth impossible, or very partial.

In the railway cutting at Bycellar Bridge blackish contorted slates, with irregular beds of dark calc-veined limestone, are overlain by slates, or shales, with tuff in places; appearances of irregularity in the junction are probably due to the intersection of sharp plications along their strike. The calcareous beds cannot be traced southward by surface evidence, but an exposure in the railway cutting north of Little Hempston Bridge connects them with the dark slates and limestones exposed in the road section leading to Little Hempston Bridge (on the north side of the Little Hempston fault), which have already been referred to.

In the railway cutting, north of Little Hempston Bridge, dark slates are shown with beds of dark blue limestone, which are much contorted and seemingly impersistent. Near this tuffs are visible in the slates.

The road cutting in Penny's Wood opposite Bycellar Bridge, proceeding southward, shows successively:—

Pale greenish slates, or shales, for a few feet.
Lilac or Indian red slates, or shales.
Grey and greenish slates, or shales.
Even shales with beds and lenticles of limestone.

This calcareous horizon, of which limestones occupy but a small part, is from 15 to 20 feet thick. It cannot be traced far on its strike. It is bounded by irregular grey clay-slates in which, toward Red Post, traces of tuff are found.

East of Penball Cross masses of coarse tuff inosculate with thick slates, or mudstones, containing *Zaphrentis*, badly preserved brachiopods, etc. Between Bittam's Barn and Penball Cross there is an exposure of limestone associated with slate. This might be a continuation of the calcareous horizon in Penny's Wood shifted by fault. It cannot be traced north of Bittam's Barn.

North of a line drawn from Tallyho Bridge eastward to Red Post grey slates, apparently without limestone bands or traces of volcanic rock, occur between the Battleford Copse limestone and the tuffs and limestones of Fishacre.

Between Bittam's Barn and Penny's Wood red and green slates are visible. At Ford Bridge slates of an indian red tint occur. Between Bittam's Barn and Battleford Copse lilac tints are noticeable, in places, in the slates. In the road from Ford Bridge to Reevacre Cross grey slates, with a cleavage dip of 42° south-east, are shown to dip at 40° north-east by brown fossiliferous bands, in which small impressions of a shell (not unlike *Cardium palmatum*, but with no signs of ornamentation) were noticed.

Near its termination, the Dartington limestone is exposed to a depth of from 15 to 20 feet in quarries south of Reevacre Cross; the rock is partly red, and rests upon a few feet of red and buff tuffs which separate it from the hard diabase below. This is important, because there is not sufficient evidence in Dartington Park to prove whether the diabase is intrusive or contemporaneous, or partly intrusive partly effusive, and the presence of the tuff on it tends so show that the larger mass was probably a lava.

The slaty margins of the limestones and the obviously close relationship of the dark slates with limestone bands with the Dartington and Little Hempston limestones—whether they denote an upward, downward, or horizontal passage into them, and whether the tuff bearing slates are above or below the dark slates with limestone bands—certainly prove that the limestones in this area are largely replaced by slates, and that this was partly due to showers of tuff rendering the waters unfit for the extension of the coralline growth.

No distinction can be drawn between Eifelian slates and slates, etc., replacing limestones, in the district north and north-east of Staverton and between Battleford Copse and Fishacre Bridge.

At Fishacre dark grey thin-bedded limestones, partly shaly and with a local tendency to pass into slates, or shales, are faulted against tuff-bearing slates. These limestones can be traced for forty-five chains west from Fishacre. Their continuation with an adjacent band of similar dark limestone, on the north of Ringswell Cross, is very probable. The last-mentioned band is exposed in three quarries, in which the dark-blue calc-veined limestones occur in the slates, but cannot be traced to the Ambrook.

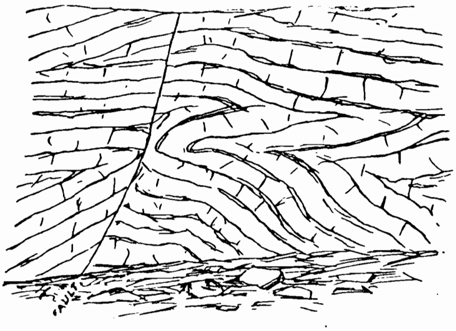
At Great Ambrook the slates contain traces of crinoids and *Fenestella*; west of Little Ambrook *Atrypa* and other brachiopods, very badly preserved, are to be found in them.

A little dark limestone is exposed in the slates on the south of the eastern termination of the band. North of its western termination there are some slight evidences of the continuation of the Fishacre limestones by slates with occasional beds and lenticles of limestone in a northerly direction to Broadhempston. These are indicated and greatly exaggerated by the band on the map.

At Bow Mill the slates are partly knubbly and calcareous. Blue slates, partly calcareous, have been turned out of a well south-west of Broadhempston Vicarage. Limestone lenticles occur in the slates in the west part of Broadhempston and at Sneydhurst, near the Vicarage. Thin bands of limestone were observed in the slates, near the sharp bend in the road to Torbryan, south-east of Broadhempston. The Broadhempston limestone is no doubt a development of these calcareous manifestations, so that its boundaries cannot be regarded as of much stratigraphical value. The limestone is exposed in three quarries.

On the south of Kiln Cottage dark-grey calc-veined, more or

FIG. 13—QUARRY SOUTH OF KILN COTTAGES, NEAR BROADHEMPSTON.



less crinoidal, thin-bedded limestone is exposed to a depth of 20 feet, but the beds are thrown into sharp zig-zag plications and, in one place, faulted. East of Elbridge Cottage thin-bedded bluish calc-veined limestones, partly shaly, are exposed to a depth of 25 feet. The only fossils noticed were crystalline crinoid joints. Here again the beds are plicated in sharp zig-zag folds, so that the true thickness is probably much less than half of the depth exposed. West and north of Broadhempston the slates are partly calcareous—perhaps also between Simpson and Torbryan Mill. North of Port Bridge, by the road to Beaston Cross, there appear to be traces of limestone in the slates. At twelve chains north of Kingston Barton signs of limestone beds in the slates were observed in a drain.

Champernowne's map shows limestone trending south-west to some springs on the south of Sparkwell Cottages. An old pit east of Sparkwell also suggests the presence of limestone. The patch shown on the map is merely meant to emphasize these slight proofs of calcareous beds, which could not (as in the case of the broad band south of Broadhempston) be shown otherwise than by lines, within which limestone may be sparingly, present in the slates At ten chains south-east of Kingston Barton, beds of crinoidal limestone dip in a south-easterly direction, but cannot be traced along their strike. On the south of Bow Bridge blue-grey slates, with veins of calc-spar and occasionally of quartz, are exposed in quarries. The dip of the schistosity varies from an easterly to a south-south-east direction. Further south, a thin brown band in the slates between Waddons and Waddons Cross suggests decomposed limestone. At a quarter of a mile south of Sparkwell an inacessible pit, filled with water, affords no evidence, but about ten chains further south (near Barntonhill Cross) slate with occasional limestone lenticles has been quarried. West of Barntonhill Cross, probably in line of strike with the above, bluish grey shaly limestones, associated with calcareous slates, are exposed in a quarry. South of this, bands of igneous rock occur in the slates in three places; but beyond the actual exposures they cannot be traced; near one of them, east of Fursdon, there is a pit in dark bluish grey shaly limestone in irregular laminæ, or beds, thickening in places from an eighth of an inch to three inches. The laminæ are contorted, pyrites is disseminated in cubes. Fossils are scarce and difficult of extraction; *Streptorhynchus* was noticed. These limestones, and calcareous manifestations, and the traces of igneous rock are probably parallel bands.

Fossiliferous brown lenticles occur in the slates west of Staverton. On crossing the Dart on the south of the village, there is a small patch of felsitic rock in the slates in the river bank.

A mass of igneous rock occurs on the hill north of Sparkwell. Torcorn Hill (on the north margin of the map) is capped by two patches of igneous rock; in the larger, porphyritic dolerite and sheared amygdaloidal rocks are exposed. At Well House and Houndhead, on the south side of Broadhempston, a small patch of igneous rock (tuff ?) is visible. There may be a patch on the west of Simpson. These may be connected with the igneous rocks of Coppa Dolla on the north (in Sheet 339).

On the east of the Ambrook patches of tuff, or schalstein. occur on the borders of the limestone of Newhouse Barton, and near the borders of the Ipplepen mass south of Orley Common.

At Newhouse Barton the limestone is shaly. Its northern boundary is a fault. The limestone of Yarneford Copse is faulted against the southern end of the Ipplepen mass; the lower beds seem to be intercalated with red slates. The limestones are exposed in a quarry north of Eastwell Barn; they seem to be much contorted. *Actinostroma Hebbornense*, Barg., indentified by Nicholson, was obtained in them. These limestones probably occupy inverted and faulted synclines in the slates, and the Battleford Copse limestone may be placed in the same category. They may therefore be regarded as a continuation of the lower parts of the Ipplepen limestones.

The Ipplepen quarries near Barton House exhibit 50 to 60 feet of grey and bluish, red-veined, limestone, intersected by calc-spar filaments, etc. The beds are of irregular thickness, in places furnishing blocks 12ft. × 4½ft. × 3ft., furnishing ornamental marble on being polished. No organisms were obtained, In one part the rock is of a dolomitic and saccharoid aspect, stained blackish (probably by umber or manganese). It has been dissolved in a large irregular pothole which was filled with clay and stones. This soluble character recalls parts of the Brixham mass. A few chains north of Barton House, compact shaly reddish limestones, traversed by a thrust fault, are exposed. Further west, near the borders of Orley Common, brown stained dolomitic limestones have been quarried. *Caunopora ramosa* was obtained in one of the quarries, and *Cyathophyllum vermiculare*, Goldf. identified by Professor Frech.

Between Barton House and Yarneford Barn grey limestones, partly crinoidal, partly of a saccharoid dolomitic aspect, are exposed. On the margin of the limestone, thin-bedded crinoidal limestones are exposed on the south of Orley Common, and below Orley Quarry where they are associated with red slates. West of Well Barn there are lenticles of limestone in the slates, and shaly limestones occur west of Wood Barn; these beds are apparently at the base of the Ipplepen mass, and above the slates on the west; they may be represented by reddish crinoidal limestones which crop out at the Wellington Inn, Ipplepen.

On Hannaford Hill and in Beltor Quarries pale grey limestone apparently unfossiliferous, form a mass, probably separated by denudation from the Ipplepen limestones; cut off by fault on the south along Edgelands Lane; and elsewhere overlying slates, with traces of volcanic rock east and south of Wrigwell Cross, and with a patch of igneous rock and a trace of limestone near Blackstone. Near Combefishacre Bridge there is another trace of volcanic rock in the slates.

Between Combefishacre Bridge and Bulleigh Barton there are three masses of limestone. The westernmost is exposed in the railway cutting on either side of Wrigwell Bridge. Commencing on the east, we encounter tolerably thick even-bedded limestones, with intercalations of shale and thin-bedded limestone; these may be faulted against slates, on the east, in which there are traces of tuffs at Cockleford Bridge. If not reduplicated by contortion these beds would be about 50 feet thick; they are succeeded on the west by about 15 feet of thin-bedded limestone and calcareous shales with occasional thicker beds of limestone, on about 30 feet of reddish shales with thin beds of limestone and occasional impersistent thicker beds. The face of Wrigwell Quarry is along a fault, marked by limestone breccia. At about twelve chains north of Wrigwell Quarry a well was sunk to a depth of 30 or 40 feet, without obtaining water, in reddish and grey slates and shales, partly calcareous, and associated with shaly limestones and occasional impersistent limestone beds. On the west of the well shaly limestone is exposed overlying slates. The calcareous beds are probably cut off by a west-north-west fault, on the north. South of the railway the bedded limestones form Wrigwell Hill, and in Hoster Wood Quarry exhibit an inverted anticline.

Between Wrigwell Quarry and Kittymore Linhay a small patch of limestone, containing *Pachypora cervicornis,* seems to rest on, and pass downward into, chocolate-red slates.

The beds penetrated in Dainton Tunnel are dark slates with bands of tuff. Tuffs are evidenced in the slates near Dainton Elms Cross and Bulleigh Elms Cross, and in the cutting at the southern end of the tunnel, where the slates are also fossiliferous and contain limestone lenticles.

The tunnel is apparently traversed by a fault which forms the eastern boundary of the mass of limestone on the south. This limestone is separated by greenish slates from the Wrigwell mass. Near its eastern margin alternating thin and thicker even beds of limestone, with a south-easterly dip, are exposed in a quarry. A quarry in the south-eastern part of the mass showed thin even-bedded, dark grey, calc-veined limestones sharply inverted. They contain *Heliolites porosus, Favosites cristatus,* and *Actinostroma verrucosum,* identified by Professor Frech. The dip is in a north-easterly direction. Near the north-eastern border grey and bluish-grey coralline limestone is exposed, containing *Pachypora cervicornis, Striatopora denticulata* and *Smithia Hennahi.* Near this, on the west, *Stromatopora concentrica* and *Caunopora* were obtained. The centre of this limestone mass consists of slates with intercalated thin beds of limestone; these may indicate an upward or downward passage into slates.

In the third mass, near Bulleigh Barton, from 40 to 50 feet of even-bedded limestone, dipping south-east, at 25° to 30°, is exposed in a quarry. At six chains to the north of this, *Pachypora cervicornis* was found in limestone dipping east at 15° The eastern boundary of this mass also appears to be a fault which, prolonged, forms the western boundary of the adjacent mass on the north. The latter is well exposed near Dainton Bridge, and is faulted against the Whiddon and Kerswell Down (in Sheet 339) mass at its north-eastern extremity

The schalsteins, tuffs and slaty green basic rocks of Blair Hill and North Whilborough are, no doubt, a development of the same general stage of vulcanicity denoted by the tuffs near Ipplepen, Bulleigh, Elms Cross, etc., and are below the limestone on the north margin of the map. This limestone (the Whiddon and Kerswell Down mass) is pale-grey, whitish, pinkish, and compact, and resembles the higher parts of the Brixham and Torquay masses.

The slates which bound the volcanic rocks on the south contain fossils, amongst which *Retepora repisteria* was recognised; *Streptorhynchus* and other Brachiopods are to be found in them between Bulleigh Cross and Bickley Pond. Stellate sponge spicules (?) were noticed in Mill Lane near Compton Mill, and in Windmill Lane, further east, *Phacops, Streptorhynchus,* and Crinoids.

The Whilborough limestones commence in Windmill Lane, where a small patch passes down into slates with brown fossiliferous lenticles. This patch seems to be shifted by fault about ten chains eastward, whence the slaty beds continue northward, the thicker limestones disappearing, unless shifted by fault to South Whilborough.

At South Whilborough dark grey even-bedded limestones, veined with calc-spar, shaly in part, and intercalated with shales, are exposed in a quarry. They are much contorted, being in part vertical and furnishing easterly and southerly dips.

CHAPTER V.

UPPER DEVONIAN.

Prior to 1889 the occurrence of Upper Devonian strata in the area was proved by Mr. J. E. Lee's discovery of the Büdesheim fauna, in red mudstones faulted against Lower Devonian rocks in Saltern Cove. Petit Tor Combe had always been considered as an example of anticlinal structure, the red slates in the centre being overarched by the limestones on either side, in De la Beche's sections. The inverted junctions of red slates with the Ilsham limestone, and in Elbury Cove, south of Paignton, with the Brixham limestone, had been regarded as natural junctions. The presence of Upper Devonian rocks in these localities has been proved by the discovery of fossils, by corresponding lithological characters, and by the working out of the stratigraphical relations. The lower zone of the continental Upper Devonian, characterised by *Rhynchonella cuboides*, cannot be separated out, and so the upper part of the limestone masses, which, no doubt, represent it, have been included in the descriptions of the Middle Devonian in the previous chapters. In the Lummaton limestone, where *Rhynchonella cuboides* is plentiful, *Stringocephalus* has also been found, but in the Petitor, Ilsham and Devil's Point limestones, and the limestone beds of Saltern Cove, Goodrington, Goodrington Park and Elbury, which are homotaxeous with the zone of *Rh. cuboides*, that fossil has not been found.

Petit Tor Combe.

Petit Tor is a boss of grey coralline limestone which descends to the beach in a cliff, separating New Red rocks on the summit from red slates at its base. On the face of this wall of rock patches of irregularly shaly, liver-coloured, limestone are occasionally met with. These resemble the Lower Dunscombe *Goniatite* limestone, and a diligent search was rewarded by the discovery of *Goniatites sagittarius* in them. The limestones on the opposite, or southern, side of the Combe are irregularly flanked by similar shaly limestones associated with red slates, here also, *Goniatites* were found. The grey limestones have here an appearance of nearly horizontal bedding, apparently due to planal cracks, or movements, traversing vertically zig-zagged bedding, and nipping in pieces of the liver-coloured *Goniatite* limestone. The soft red greenish-spotted slates, near their junction with the limestone, exhibit gently inclined cleavage dips, the bedding being indicated by vertically undulating greenish bands. These slates form the low cliff by the beach ;

their association with the massive limestone, on the south, is so irregular as to suggest severed masses of limestone squeezed into them.

The structure of Petit Tor Combe* is therefore clearly a syncline of Upper Devonian Slates, irregularly based by shaly *Goniatite* limestones, and in direct, but contorted, relation to limestones equivalent to the upper part of the zone of *Rhynchonella cuboides*.

Anstey's Cove and Ilsham.

The limestone of Devil's Point, on the north side of Anstey's Cove, seems to be faulted against red and greenish slates with irregularly lenticular red shaly limestone associated with calcareous tuff. The cliff under the Ilsham limestone is composed of red and greenish slates containing *Posidonomya venusta*, and *Entomis serratostriata* (identified by Prof. Rupert Jones). On the borders of the Ilsham limestone, compact, irregular, shaly, reddish, whitish and greenish limestones are found. They are the representatives of the *Goniatite* limestones of Lower Dunscombe, and of Petit Tor. Compact concretionary limestone (the *Kramenzel* of the Continent) also occurs in the slates, which contain friable nodules (the *Knollen Kalk*) in places. The concretionary limestone is well shown on the border of the grey limestone, near Stoodly Knowle, behind the barn of Ilsham Manor, where it rests on red and green slates. North-east of Ilsham Manor the slates exhibit spilositic alteration near a patch of diabase, not far from the Black Head mass. A small patch of diabase also occurs on the west of Ilsham Manor, but there is no evidence for the continuation of the Upper Devonian slates between the Ilsham and Asheldon Copse limestones.

De la Beche† figured a section on the coast near the northernmost projection of Black Head, rather more than a quarter of a mile north of Smugglers' Cove. In a distance of about 130 yards (see Fig. 14) a projection, at the foot of the partly overgrown cliff-slope of the diabase, is formed by a mass of grey, yellowish-weathered, fine-crystalline limestone, from 20 to 30 feet in thickness, containing *Alveolites*, *Cyathophyllum cæspitosum*, and *Stromatactis*. The limestone is intersected by a fault with a south-east downthrow of a few feet, from which it dips steeply toward the south-east, and exhibits a greater thickness than on the other side of the fault. It is here overlain by compact, knubbly, and thin shaly, limestone, identical with types of the *Goniatite* limestones. In this a badly preserved *Goniatite* was found. These materials, in association with purple and green schalstein, or calcareous tuff, and seams of limestone, pass up into red and green slates, or slaty shales, overlain by indurated dark grey and green slates at, and near, contact with the diabase, both rocks being intersected by calc-spar veins. These Upper Devonian slates attain a thickness of 10 feet or more, at the sea

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* See Fig. 15, page 109.

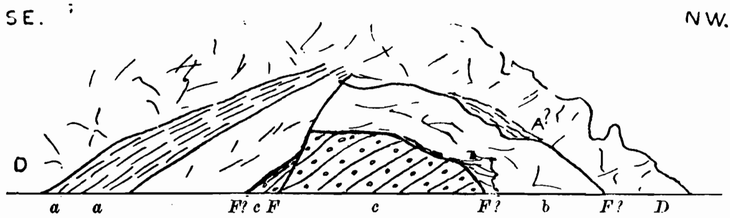
† "Geological Manual," 1832. 2nd Edit., p. 496.

level, but they attenuate rapidly upward, between the diabase and the limestone. On the north-west side of the fault the lower beds of the slates associated with the calcareous tuff and compact limestone seams and lenticles, are only partially (a') visible on the surface of the limestone, which is in contact with the diabase projection at the sea level.

On this side of the fault the limestone rests somewhat irregularly on (c)—buff, purple, and green schalsteins, full of pieces of compact reddish and grey limestone near the junction, and containing seams, impersistent bands, and (coralline?) nodules of limestone lower down. The upturned edges of the schistosity, which seems to be the bedding planes of the schalsteins, are cut off by the limestone above, so that the junction seems to be a fault, or thrust, which has been shifted by the fault that traverses the limestone, so as to allow very little of the schalstein to appear

Fig. 14. Northern Point of Black Head.

(Length of section about 6 chains).



a-. Dark grey and green slates or shales indurated at, and for a few feet below, contact.

a and *a*? Red and green slates and slaty shales, with occasional limestone seams, and purple and green schalstein, or calcareous tuff. At or near contact with *b*, compact knubbly limestone, and thin shaly limestone represent the Upper Devonian *Goniatite* beds

b b. 20 to 30 feet of grey fine-crystalline limestone with corals, weathering yellowish.

c c. Buff, purple and green schalsteins, full of pieces of compact reddish and grey limestone near junction with *b*, and containing, lower down, seams and impersistent bands and nodules (? corals) of limestone.

D D. Diabase.

F. fault. F? Apparently faults or thrusts.

above the water level on the south-east side. The limestone and overlying *Goniatite* beds and slates are probably separated from the diabase above by a fault, or thrust. These strong probabilities of displacement render the actual relations of the limestone to the diabase above, and schalsteins below, very doubtful.

The signs of schalstein above the limestone, here and in Anstey's Cove, prove that the emission of the diabase took place on the outskirts of a volcanic region, which was active during the deposition of the *Goniatite* beds. It is possible that the smaller patches of diabase were vents from which the Black Head mass flowed, its eruption being heralded by showers of ash, incorporated with the *Goniatite* beds, and that earlier eruptions, put a stop to the growth of the Ilsham coralline limestone for a time. In other words, the thick limestone bed in this section seems to represent the latest stage in the growth of the Ilsham limestone, and before this the schalsteins beneath it had put a stop to its growth for an unknown period. This is analogous to the Saltern Cove succession.

Saltern Cove.

At five chains north of Saltern Cove a mass of New Red breccia rests unconformably on red shales and grits of the Lower Devonian. These are faulted against chocolate-red, broken, and contorted slaty mudstones of the Upper Devonian. The fault, owing to talus, etc., is not clearly seen, either in the cliff or in the adjacent railway cutting, and further west the evidence is very unsatisfactory. Proceeding southward along the coast, a nearly vertical wall-like mass of limestone nodules, or flat ovoid lenticles, is encountered in the mudstones, the longer axes of the lenticles are tilted east 40° north, at an angle of 15°, which represents cleavage. Near this, at a few feet above the beach, the small *Goniatites*, *Bactrites*, and *Cardiolœ* of Büdesheim type are found. A little promontory separates this part of the coast from Saltern Cove; the slaty mudstones, of which it is composed, are in places thickly studded with irregular patches or lenticles of limestone; here also the characteristic fossils are to be found.

Mr. Lee's list* obtained from these places is as follows:—

Goniatites auris, *Quenst.* = Tornoceras auris.
G. retrorsus, *Quenst.* = T. simplex, *v. Buch.*
G. Ausavensis, *Stein* = T. Ausavense, *Stein.*
G. primordialis, *Quenst.* = Gephyroceras orbiculus, *Beyr.*
G. Gerolsteinus, *Stein* = Geph. calculiforme, *Beyr.*
G. prumiensis, *Stein.*
Orthoceras Schlotheimi, *Quenst.*
Pleurotomaria turbinea, *Stein.*
Mytilus priscus, *Stein.*
Cardium palmatum (Cardiola retrostriata).
Crinoidal stems.

A fault runs parallel with the railway along the inner cliff face of the cove, shifting the beds exposed in the railway cutting seven chains northward on the beach. In the railway cutting the red mudstones become intercalated with thin even beds of limestone, and rest on a mass of coralline limestone containing *Pachypora cervicornis.* On the beach this limestone is seen to rest on tuffs and schalsteins with limestone fragments, as already mentioned in the Middle Devonian chapters. Here we have, as at Black Head, *Goniatite* beds—on coralline limestones—on schalsteins; the two cases, but for the Black Head diabase mass, would be exactly parallel.

The Upper Devonian slates certainly extend westward for more than half a mile from the coast. *Entomis serratostriata*, identified by Prof. Rupert Jones,† was found in them, but,

* *Geol. Mag.*, 1877, p. 102.
† *Ann. and Mag. of Nat. Hist.*, 1890, p. 319.

although the coralline limestone is present, no signs of the Büdesheim fauna have been detected in this direction.

Elbury and Silver Cove Coast.

The cliff in Elbury Cove is 30 feet high, and composed of red slates which appear as if they dipped under the Brixham limestone, whilst on the north they overlie a series of contorted thin-bedded limestones with intercalated seams of red mudstone passing down into the limestone of Elbury, which may be the top of the Brixham mass. Following the coast from Elbury Cove eastward, nothing is visible but the contorted grey limestone for a distance of fourteen chains, when we encounter contorted limestone beds intercalated with slates, inverted over red mudstone full ot lenticles of red limestone (partly crinoidal). The lenticles sometimes occur in beds, as described near Saltern Cove. These beds are, here and there, intersected by veins of quartz and contain irregular masses of quartz, and of limestone partly replaced by quartz. A thick bed of limestone, intensely contorted, forms a noticeable feature in the section. In one place a band of contorted slate, a foot in thickness, marks a thrust plane. A careful search in the (inverted) lower part of the cliff revealed crushed *Goniatites* and *Bactrites*, and very good examples of *Cardiola retrostriata* (*Cardium palmatum*).

Between this section and Silver Cove the cliff, for about 60 yards, is composed of massive grey limestone, which forms also the eastern shoulder of Silver Cove. The centre of that cove consists of the same red beds, much fractured and contorted. They run inland from the top of the cliff for thirteen chains, flanked on either side by massive limestones. A north and south fault, shown at Ivy Cove, shifts them northward, but they continue from it eastward, for a distance of thirty chains, on the limestone plateau. In this extension the red slates seem to be associated with schalsteins, or felspathic tuffs.

In Fishcombe Cove red slaty mudstones, associated with tuffs, are wedged into the grey limestone by faults, and also form a narrow band running for some distance westward from the coast. No fossils have been found in the red slates west of Elbury Cove; felspathic tuffs, as already mentioned, occur in them in places, but, as elsewhere explained, it is impossible to distinguish slates above the Goodrington limestone from slates below it, without stratigraphical evidence of the presence and persistence of that limestone.

CHAPTER VI.

NEW RED SANDSTONE SERIES.

The interval between the deposition of the Upper Devonian and the accumulation of the basement clays, breccias and conglomerates of the New Red series is everywhere marked by a great unconformity. At Marychurch and west of Torquay the New Red rocks rest on Eifelian and Middle Devonian slates and limestones; at Cockington and in the Paignton district upon Lower Devonian strata.

Derivation.

The New Red rocks of the area are for the most part of strictly local derivation. The clays of Petit Tor and the fine breccia associated with them occupy the lower ground on the north margin of the area, and are distinguished by a lighter tint on the map, as far as the Compton Castle valley; although it is not possible to trace them further as a distinct series, it must not be inferred that they are necessarily elsewhere overlapped by higher beds, but simply that they are no longer lithologically distinguishable.

The Upper and Middle Devonian slates furnish a ready source of derivation for these beds. The name, Watcombe clays, has been given to them from the fact that the celebrated Watcombe ware is manufactured from the puddled clay obtained from them * at the head of Watcombe Combe. The coarser New Red beds consist of conglomerates and breccio-conglomerates—with fragments of Devonian limestone, grit and slate, and of igneous rocks, in a sandstone matrix, and with intercalated beds of sandstone—and of breccias with fragments of grit, slate and limestone, or of grit and slate, or of slate only, in sandy or loamy matrices. In every variety the source of derivation of the majority of the included fragments, and the local character displayed by the rocks, may be traced to the neighbouring Devonian limestones, grits and slates.

As regards the igneous fragments, more especially in the cliff-sections, doubtless many might be found which could not be traced to exposed sources within the present coast limits of the district.

The variability of the New Red rocks renders the tracing of faults in them a rather unprofitable task, but that such variability may be locally due to the faulted conjunction of different horizons is rendered probable by the frequent instances of faulted boundaries with the older rocks, and by the numerous small faults shown in the coast sections. Faults run in many directions. Those running north and south are evidently the latest, but there appear to be north and south faults affecting

* W. A. E. Ussher, on "The Age and Origin of the Watcombe Clay," *Trans. Devon. Assoc.* for 1877.

the Devonian only (viz., east of Aptor). The high dips locally observable in the New Red, as in Oddicombe Beach cliffs and at Petit Tor, are always accounted for by the proximity of faults.

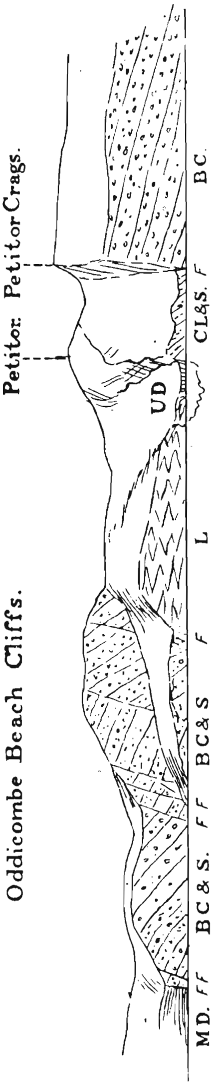
Watcombe Clays.

The Petit Tor section exposes lower beds of this series than those in Watcombe Combe; these consist of red clays, or shaly marls, with beds of sand (an argillaceous paste of comminuted slate fragments), and of rubbly breccia at junction with the Devonian limestone. The clays are cut off against the newer conglomerate by fault. The Oddicombe Beach New Red rocks are faulted on both sides. They consist of breccia, breccio-conglomerate, and sandstone, intercalated irregularly, and evidently belonging to the beds above the Watcombe clays.

On the south-west side of Torquay cemetery, the brick pits at Old Wood exhibit sections of dark red-brown, or purplish-brown, clunchy clay mixed with masses of sand, or very fine breccia, made up of comminuted Devonian slate. Here and there beds, or lenticles, of red clay containing fragments of Devonian limestone are intercalated. In one spot the beds appear to be faulted, and present a south-west dip of 35°.

From their junction with the overlying breccio-conglomerates and breccias in the Torre Railway cutting westward, the boundary of the Watcombe clays becomes more and more indefinite; the lines drawn for them near Whilborough and Compton Pool merely separate distinct conglomerates and breccias, from breccia with a more or less clayey and loamy matrix, which occupies the lower ground, and is very partially exposed. Further to the west, the junction of New Red with Devonian is much obscured by rainwash on the slopes. Near Combe Fishacre the breccias are clayey and loamy in places, but this character is often observable elsewhere, and there is no proof that it denotes any special stratigraphical horizon.

Fig. 15. Petit Tor (horizontal scale 6 inches=1 mile. Approximate vertical scale 1 inch=800 feet).



B C. Breccio-conglomerate. B C & S. Breccio-conglomerate and sand-rock. Cl & S. Watcombe clay (lower beds) with beds of sandstone. U D. Syncline of Upper Devonian slates. L. Upper or Middle Devonian limestones (also seen in Petitor). M D. Middle Devonian dark slates. *F.* Faults.

Conglomerates, Breccias, etc.

The conglomerates are finely exposed in Petitor Crags. In the Oddicombe cliffs the well-rolled limestone pebbles are less frequent, the rock more often presenting the appearance of breccia, or breccio-conglomerate, with beds of sandstone, which exhibit an irregular surface in places, the breccia filling hollows probably due to slight contemporaneous erosion. Conglomerates with large limestone pebbles occupy the high ground south of Whilborough; they are associated with breccio-conglomerate and breccia, the latter varieties prevailing to the west of the Compton Valley. The New Red, where limestone fragments are absent, sometimes presents a rubbly appearance with indistinct bedding, in colour much resembling the Lower Devonian grits and shales on its borders; as in the outlier south of Marldon, at and near Occombe, south-east of Marldon, in the outlier at Blagdon Cross, on the west of Collaton Kirkham, etc. An outlier is shown on the map between Occombe and Hollicombe, north of Paignton, which, not being exposed in section, is doubtful; the resemblance between the rubbly New Red gravelly soil and that of the Lower Devonian being very close. At Collaton Kirkham red-brown loam studded with fragments of Lower Devonian rocks, mostly small, represents the New Red breccia.

The coast sections at Corbon's Rock and Livermead show intercalation of sand-rock in breccia, or breccio-conglomerate, and brecciated sand. In Corbon's Rock beds of yellow and grey sand-rock are faulted against breccio-conglomerate, which is in its turn faulted against breccio-conglomerate upon yellow and grey sand-rock. On the north of Livermead breccio-conglomerate rests on red-brown, red, and occasionally grey, sand, with seams of breccia, over breccia or brecciated rock-sand. The limestone fragments on this part of the coast are often coated with the peculiar annulated form of chalcedony called beekite.*

In the railway cutting across Roundham Head red sand, with buff and grey patches and a clayey band, rests on conglomerate with numerous limestone fragments, affording many examples of beekite structure. A quarry near Paignton Quay shows purplish red grey-mottled loam—on thin even-bedded red grey-mottled sandstones—upon breccio-conglomerate; separated by faults from brown-red loamy breccia with seams of red sand—on reddish sand and loam, brecciated in places, on one side; and from purplish red grey-mottled loam with thin even-bedded red sandstones—on breccio-conglomerate, on the other. On the south side of Roundham Head (Fig. 16) the association of beds of rock-sand in breccia and breccio-conglomerate is very marked. The general dip is northerly, so that the beds on the north side of the Head are doubtless above these; they are brecciated sand and loam, with thin even-bedded sandstone, and breccio-conglomerates.

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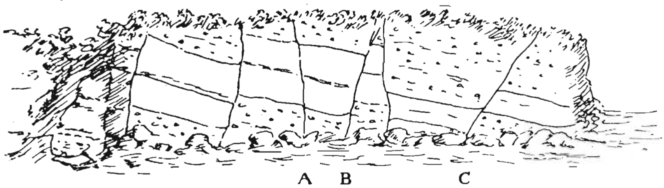
* Vide Pengelly, *Trans. Roy. Geol. Soc. Corn.* vol. vii., p. 309, and *Rep. Brit. Assoc.* for 1856, *Trans. of Sections*, p. 74; also Pengelly, "The Geology of the North-Eastern Coast of Paignton," *Trans. Devon. Assoc.* for 1878.

A quarry on Primley Hill shows red-brown bedded breccio-conglomerate dipping north at about 13°. In some parts stones of limestone and quartz predominate, in others, fragments of grit and lydian stone (or dark blue-grey fine slaty rock). The matrix of coarse sand is largely composed of comminuted slate. A large quarry, 50 feet in depth, in an orchard on the north-west of Paignton, shows rubbly brecciated loam and hard beds of brecciated sandstone for 15 feet from the surface, upon thick beds of breccio-conglomerate, some of the beds being 2 feet in thickness; the matrix consists of comminuted grit and shale, or slate, and coarse sand.

On the west of Paignton the hard thick-bedded breccia and breccio-conglomerate is exposed in a quarry. The contained fragments are of limestone, quartz, grit, and a few igneous, angular, sub-angular and well-worn, in a hard red sand matrix. Within 15 feet from the surface strips of red sand occur, and quartz fragments predominate, limestone being more plentiful below. The above observations will show the futility of attempting to divide the New Red rocks of the Paignton area into stratigraphical horizons.

FIG. 16. CLIFFS ON THE SOUTH SIDE OF ROUNDHAM HEAD.

(Horizontal and vertical scale 1 inch=120 feet)



A. Downthrow of 6 inches to the east.
B. Downthrow of 6 feet to the west.
C. Downthrow of 7 feet to the west. Faults shown by displacement of beds of sandstone in breccia and breccio-conglomerate.

Near Paignton Cross, by the side of the road leading to Goodrington Sands, nearly horizontal beds of red sand with bands of coarser sand, or of fine breccia, containing worn fragments of igneous rock, are exposed. There is a trace of breccio-conglomerate on the Devonian slate reef in the middle of Goodrington Sands. Further south the unconformity of the New Red on the Devonian is well shown on the coast. A fault which runs coincidently with the Broad Sands Coast cuts off a projection and coast reefs of New Red sand-rock with bands of breccio-conglomerate; at the southern extremity of the patch the sandstone is indurated and intersected by numerous calc-spar veins in proximity to the fault. Further south, on the west side of Galmpton Point, two very small patches of breccio-conglomerate occur on the beach.

Mr. A. R. Hunt discovered a trace of New Red breccia on a rock reef platform near Compass Cove, south of Dartmouth Castle. The extension of the New Red beyond its present limits over the Devonian area is also proved by traces of its former presence in small outliers, or in potholes and fissures in the Devonian limestone, in the following places:—

At half a mile north of Stoke Gabriel a small patch of red sand and sandstone occurs on the limestone; in its vicinity red and brown loam with slate fragments masks the surface of the limestone.

On the north of Waddeton a red clay soil with pieces, and occasional boulders, of hard New Red sandstone, here and there, suggests an outlier or the remnants of an outlier. Near this, on the east, there are signs of two small outliers of New Red sandstone on limestone.

In the quarry by the high road near Goodrington, and in two places in the railway cutting north of Broadsands, there appear to be pockets in the limestone filled with New Red materials.

In the Brixham limestone at Ivy Cove, near Fishcombe Point, at Berry Head, etc., vertical veins and dykes of hard red sandstone fill cracks and joints in the limestone.* They suggest the subsidence of New Red sand into lines of weakness, enlarged by the percolation of acidulous water, by which the infillings were cemented in the cracks. Some blocks of the sandstone occur on the summit of the limestone plain west of Fishcombe Point, and also near the Ropery and Paint works not far to the west of Brixham Station, where also sand and brecciated loam fill fissures and potholes in the limestone. There are similar traces between Brixham and Durl Head. Near Durl Head a small patch of New Red sandstone is shown on top of the cliff (*vide* map). On the west end of a narrow indentation, north of Durl Head, a trace of the sandstone (too small to indicate on the map) is visible.

The hard sandstones above referred to are similar to those which occur at the base of the New Red at, and near, Bishopsteignton. Beyond these proofs of the extension of New Red rocks over the Devonian limestone plateaux, there is no evidence to show that they ever covered the higher lands of the Lower Devonian in the south of the map.

The absence of signs of contemporaneous vulcanicity in the New Red rocks of the area is accounted for, by their evident attenuation through a conformable overlap, as they are traced northward toward Exeter, the volcanic horizon being higher in the series than the strata represented in the map.

Mr. Hunt's dredging operations in Torbay led him to conclude †: "The sunken limestone and slate rocks of Torbay prove also that where they exist the Triassic sandstones, which by the position of their remains appear to have formerly filled the greater part of the bay, can never have been present to any great depth."

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* *Vide*, Pengelly, "On Certain joints and dikes in the Devonian Limestones on the Southern Shores of Torbay," *Geol. Mag.* for 1866, pp. 19-22.

† "Notes on Torbay," *Trans. Devon. Assoc.* for 1878.

CHAPTER VII.

POST-TERTIARY AND RECENT.

Under this head are embraced cavern deposits, raised beaches, 'Head' or ancient talus shed on the old beach plane, submerged forests, fluviatile deposits comprising river terrace gravels, etc., and the more recent alluvial flats.

It is, of course, impossible to indicate the cavern deposits on the map, and as regards superficies the raised beaches and the submerged forests which are occasionally visible on the foreshore cannot be shown, yet these phenomena are well represented within the area embraced by Sheet 350. The indefatigable labours of the late W. Pengelly in the Torquay and Brixham caves have rendered them notable throughout the scientific world. Godwin-Austen, Mr. A. R. Hunt, and others have attracted an especial interest to the raised beaches of the Torquay promontory and its vicinity, and the researches of Mr. A. R. Hunt in submarine geology in Torbay, in carrying on the investigations of the late W. Froude, further contribute to the exceptional geological interest attaching to this map.

Cavern Deposits.

The facilities which the faulted, jointed, and contorted limestone masses of the district afford for the downward percolation of surface waters have resulted in the widening of joints and fissures into subterranean galleries, shafts and chambers. Into these, materials have been introduced from outside between, or during, periods of precipitation of calcareous matter in solution in percolating water which, dripping from stalactitic incrustations and protuberances, formed stalagmitic floors. Two fine examples of such caverns occur in the district, *viz.*, Kent's Hole, Torquay, and Windmill Hill Cavern, Brixham. Besides these the Happaway Cavern in Stentiford's Hill, Torquay, and the Anstis Cove Cave have been explored and described by Pengelly. It is probable that many more bone caverns have been dissolved in the limestones, which, through their apertures being choked up by limestone blocks cemented in stalagmite have escaped detection; as the existence of the Windmill Hill Cavern, Brixham, was only accidentally revealed by quarrying.

Kent's Hole is situated in a wooded limestone hill on the south of Asheldon Copse, and on the south side of the road from Torquay to Ilsham. There are two entrances to the cave fifty-four feet apart,* on the eastern side of the hill and nearly on the same level. They are situated at about 270 yards due east of

* See "Lecture on the Ancient Cave Men of Devonshire," by W. Pengelly.

St. Matthias Church, and at from 60 to 70 feet above the bottom of the adjacent valley.

The following information is gleaned from "A Short Account of Kent's Cavern," by Mr. A. R. Hunt.* The cavern has many ramifications from two main parallel passages, the northernmost of which exceeds 300 feet in length. The entrance now in use is 184 feet above meantide level, and was blocked by *débris* when the systematic explorations began in 1865.

The cavern was first explored by the Rev. J. McEnery in 1825. His researches established the existence of numerous bones of extinct mammalia with worked flints. McEnery's MSS. notes were subsequently published by Pengelly. The cavern was investigated by R. A. C. Godwin-Austen in 1840, and a small part of it by the Torquay Natural History Society in 1846. The systematic exploration of the cavern by the British Association, commenced in 1864 under the superintendence of Mr. Pengelly and Mr. E. Vivian, of Torquay, was continued without intermission until 1880, at a cost of more than £1,950. "When the Association began its work, three deposits only were known in the cave, *viz.*, a layer of black mould which rested on a floor of (granular) stalagmite, which in its turn rested on a bed of 'cave earth' of unknown depth. The method of exploration adopted was the removal of the stalagmite, whatever its thickness, with four feet of the subjacent deposit, the latter, in carefully numbered and recorded portions, three feet long, one foot broad, and one foot deep." In the fourth report of the Exploration Committee the discovery of a breccia of grit, stalagmite, and bones was announced, and, shortly afterward this breccia was found to be separated from the overlying cave earth by a local floor of crystalline stalagmite, which reached a maximum thickness of twelve feet.

"The breccia entered the cave from the west and thinned toward the east. The cave earth entered from the east and thinned toward the west. The true cave earth sometimes overlay the breccia; the breccia never overlay the cave earth." "The fauna of the cave earth included twenty-six species of mammalia," remains of hyæna being abundant. "That of the breccia consisted almost entirely of bears, with traces of lion, fox and deer." The flints of the cave earth were of two recognised palæolithic types, and were associated with implements of bone, "whilst those of the breccia were formed of flint nodules and chips struck off in the making."

Notwithstanding the exhaustive exploration of the cavern, the only plan of its ramifications extant is that drawn by Mr. A. R. Hunt, from every available material, for the guidance of the Geologists' Association, published in their Excursion Programme, 20th March, 1900. †

Probably the most succinct account of Kent's Cavern to be found amongst Pengelly's writings is furnished by the following

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* Presented by the Torquay Natural History Society to the members of the British Association visiting Torquay, September, 1898.

† See also *Proc. Geol. Assoc.* vol. xvi., p. 437.

table, extracted from "Notes on Recent Notices of the Geology and Palæontology of Devonshire,"* in which the scientific names of the species found were not given.

Deposits.	Contents.
Black Mould - -	Stones of various kinds; shells of hazel nuts; shells of snails, limpets, whelks, oysters, cockles, mussels, pectens, solens and cuttle-fish; bones of birds, seal, water rat, rabbit, hare, goat, sheep, red-deer, shortfronted ox, brown bear, badger, fox, dog, pig, and man. "Whetstones," angular and curvilinear plates of slate; pieces of smelted copper; bronze articles including rings, a fibula, spoon, spearhead, socketed celt and pin; flint "strikelights"; potsherds (including a piece of Samian ware); stone "spindle-wheels," a bone-awl, bone chisel, bone combs; amber beads; charred wood; a halfpenny of 1806; and a sixpence of 1846.
Granular Stalagmite. -	Stones of various kinds, impressions of ferns; shells of cockle and cuttle-fish; bones of bear, mammoth, hyæna, rhinoceros, horse, fox, and man. Flint-flakes and "cores."
Black Band. - - -	Bones of ox, deer, horse, badger, bear, fox, hyæna, and rhinoceros; 366 flint implements, flakes and chips; a bone awl, a bone needle or bodkin having a well-formed eye, a bone harpoon; burnt bones and burnt wood.
Cave Earth. - - -	Bones of lion, lynx, wild-cat, hyæna, wolf, fox, *Isatis* (?), glutton, badger, cave bear, grizzly bear, brown bear, mammoth, *Rhinoceros tichorinus*, horse, wild-bull, bison, Irish-deer, red deer, hare, pika, water vole, field vole, bank vole, and *Machairodus latidens*. "Whetstones," hammer stone, lanceolate and ovate flint *flake* tools, flint flakes, and "cores"; a bone pin, two bone harpoons, charred wood and bones.
Crystalline Stalagmite.	Bones of bears.
Breccia. - - -	Bones of bears of various species, including cave-bear; a very few of lion and fox. Flint *nodule* tools and flakes.

Happaway Cavern is situated in the limestone of Stentiford's Hill, Torquay, on the south-western slope overlooking the street at 271 feet above mean tide level. Pengelly † gives the deposits in descending order as follows:—

"1. Fine light chocolate coloured earth containing bones and bits of charred wood, but few stones, average depth about 6 inches.

2. Tenaceous moist dark coloured earth, with numerous bones, bits of charred wood and stones about 18 inches.

3. Coarse rather sandy brightish red earth with larger and more numerous stones, occasional limestone blocks and pieces of stalagmite. Charred wood and bones less plentiful."

Owing to the absence of separating stalagmite, the relative positions of the bones found are not certain. They consist of badger, deer, fox, pig, sheep, hare, rabbit, and smaller rodents, bat and man (human skull, bones, jaws), two parts of tooth of

* *Trans. Devon. Assoc.* for 1882, vol. 14, p. 694.
† *Trans. Devon. Assoc.* for 1886, p. 161.

rhinoceros, two molars of bear, one tooth of *Hyæna spelæa*, shells of cuttle-fish, a periwinkle and cockle valve, many of *Helix* one fish vertebra, a few bones of birds, and about 50 flint chips and flakes were also found.

Anstis Cove Cavern* is situated in the northern cliff face of the cove, three furlongs north-north-east from Kent's Hole. From M'Enery's Notes (1825) there is no reason to infer any evidence of an extinct fauna. The cavern is 63 feet in length, 9 feet high by 6 feet broad at its mouth, narrowing to 3 feet by 3 feet at the end. The downward succession of deposits seems to be :—

In one part	1.	Angular *débris* encrusted with stalagmite	14 inches.
In another part	„	Stalagmite - - - - - - -	6 inches.
Upon	2.	Stones, shells, teeth, and bones forming a compact breccia, containing shells of *Helices* and *Turbo* [*Cyclostoma*] *elegans*, fox's jaw and tusk, bears' tusks and teeth, one deer's horn, one young horse tooth, a few teeth resembling canines of hyæna, some slight long bones gnawed, probably by foxes -	about 1 foot.
Upon	3.	A second stalagmite - - -	2 inches.

"The mammals which appear to have been generically identified are bear, fox, deer, and perhaps hyæna," species in no case stated.

Windmill Hill† rises to a height of 175 feet above mean tide level, eastward from the principal street of Brixham leading to the harbour. In January, 1858, in quarrying in the upper part of the hill, the crowbar disappeared down a small hole in a north and south joint. On further excavation the owner was enabled to descend and recover the tool, when he found that the vertical chamber communicated with a "long narrow tunnel" extending "southward for about 50 feet, whence a second gallery extended westward." The natural entrance, sealed up by angular limestone fragments cemented by stalagmite, was soon afterward opened up, whereupon a lease was negotiated with the proprietor for the purpose of systematic exploration by a committee under the auspices of the Royal Society and the Geological Society of London, which was begun in Midsummer 1858, and completed (at the end of one year) by Midsummer 1859. In September, 1858, the results obtained, up to that date, were communicated at the British Association Meeting held at Leeds. They are summarized as follows by Mr. Pengelly :—

"The deposits were, first or uppermost, a floor of stalagmite varying from a few inches to upwards of a foot in thickness. Several bones were found on and in the stalagmite," including "a fine antler of a reindeer firmly cemented to the upper surface," and "a humerus of the extinct cave bear lying completely within the stalagmite."

"Second, cave-earth composed of red ochreous loam and angular pieces of limestone, and containing rolled fragments of quartz,

* Pengelly. *Trans. Devon Assoc.* for 1873–4, vol. vi., pp. 61, etc.
† Pengelly. "The Ancient Cave Men of Devonshire."

greenstone and brown hematite of iron. Though deposits capable of yielding the rounded materials exist in the Brixham district, none of them could have been derived from Windmill Hill; nor could they at present reach it without crossing one of the deep valleys by which it is bounded." "The bones in the cave-earth were those of the ordinary cave-mammals," "an entire left hind-leg of the cave bear," was discovered by Dr. Falconer.

"Third, or lowest, gravel, mainly consisting of well-rounded fragments of quartz and greenstone, having a tendency to become a more or less firm conglomerate." "None of the very few bones" found "were of any importance." "Except in one limited locality, all the objects lay in such a position with regard to the plane of the cave-earth bed, as to betoken the action of a small stream of water which must have flowed continuously through the cavern in one uniform direction," "at a time when the bottom of the valley was at or near the level of the external entrances," "at a time so remote that the valleys of the district were at least one hundred feet less deep than they are at present."

Pengelly also states that the flint implements and flakes found were obtained "at from 9 inches to upwards of 20 feet below" the under surface of the stalagmite, the greater number being in the cave-earth; "whilst nearly 40 per cent. of all the bones met with were above the uppermost implement or flake." The full report of the committee's exploration may be found in the volumes of the *Philosophical Transactions*. The following is taken from Professor Prestwich's Report* to the Royal Society. "When first opened all the galleries and chambers were found to be more or less filled with the following deposits in descending order:—

1st. A layer of stalagmite, varying from a few inches to upwards of a foot in thickness.

2nd. Reddish cave-earth, with angular fragments and blocks of limestone in places, generally averaging from 2 to 4 feet. [In places completely choking the galleries up to the ceiling.]

3rd. Waterworn shingle 2 to 6 feet. [Pebbles of limestone, quartz, greenstone, grit and shale.]

In addition to these a thin layer of peaty or carbonaceous matter extended on the cave-earth from near the entrance to a distance of 40 feet, and was overlain part of the distance by a limestone breccia."

"A few pebbles, the same as those composing the underlying shingle bed, were occasionally found in the cave-earth, together with fragments of stalagmite, portions apparently of an old destroyed stalagmite floor."

"No shells were found in any of the beds, but a considerable number of existing land shells, and one limpet shell were found on the surface, and a few in the stalagmite. They were most numerous near the external entrances."

"Mammalian remains were found sparingly in the stalagmite, in abundance in the cave-earth, and rarely in the shingle." "No coprolites were found in any part of the cave." Omitting bones

* From "Report on the Exploration of Brixham Cave" *Proc. Roy. Soc.* No. 137, 1872.

"of small rodents, no doubt of comparatively recent introduction," "the bones belong to twenty or twenty-one animals, referred by Dr. Falconer and Mr. Busk to the following species":—

Elephas primigenius.	Capreolus capreolus.	Lepus timidus.
Rhinoceros tichorhinus.	Felis leo (var. spelæa).	L. cuniculus.
Equus caballus.	Hyæna spelæa.	Lagomys spelæus.
Bos primigenius ?.	Ursus spelæus.	Arvicola amphibius.
B. taurus ?	U. ferox (priscus).	A—— ?
Cervus elaphus.	U. arctos.	Sorex vulgaris.
C. tarandus.	Canis vulpes.	

No tusks or teeth of mammoth met with, hence bones found probably brought in by carnivora. Remains of the woolly rhinoceros rather numerous. "Next to those of the Bear, the remains of the Reindeer are by far the most abundant," and next in abundance those of *Hyæna spelæa.* "Remains of the Cave Lion are scanty in number." "Not a single human bone has been found in Brixham Cave; but thirty-six rude flint implements and chips, "were met with in different parts of the cave." One of these is "a roughly-shaped flint hatchet." The implements were found in positions that prove the co-existence of man with the extinct mammalia.

Raised Beaches, etc.

Pengelly* draws the following inferences from a study of the raised beaches and submerged forests of Torbay etc.:—

1. "That the submerged forests are more modern than the raised beaches."

2. "That after the completion of the beach the entire district was uplifted at least 70 feet before the forest flora took possession of the soil which its remains now occupy."

3. "That subsequently to the forest era there was a general subsidence to the amount of certainly forty, perhaps of many more, feet."

4. "That the forests are of sufficient antiquity to have sheltered the mammoth and long-fronted ox, but that they fall very far short of the era of extinct molluscs."

5. "That the successive changes of level were at least tolerably uniform, and were effected gradually."

In the raised beaches of Hope's Nose and the Thatcher Rock the district possesses the best examples for the study of the molluscs of that period to be found in the south-west of England. The Hope's Nose raised beach has been described by many observers. Of these Godwin-Austen† was the first.

He gives the thickness of the stratified consolidated sand and underlying "conglomerate containing blocks of considerable size" as 17 feet, with an extension from east to west of not more than 50 feet, and the height of its base as 31 feet above high water.

* *Trans. Devon. Assoc.* for 1865, pp. 33, 34.

† *Proc. Geol. Soc.*, vol. ii, p. 102 (1834) and *Trans. Geol. Soc.*, ser. 2, vol. vi. p. 441 (1842).

Prestwich* describes it as "a projecting cornice overlain by three feet of sand and then by a few feet of angular local rubble in which" he "found a tooth of a horse. Many of the shells are entire, but they are mixed with a large proportion of comminuted shells."

Mr. Jukes-Browne supplies the results of his more recent investigations in the following notes taken in September, 1898:—

"This raised beach is at the south-eastern corner of the Hope's Nose promontory; its base is about 25 feet above what appears to be ordinary high water mark. It rests on an irregular surface of limestone, and its basement bed is from 12 to 16 inches thick, consisting of pebbles and large boulders in a matrix of coarse sand. The boulders are chiefly limestone and slaty rocks, mostly rounded, but some sub-angular, and they range up to over a foot in longest diameter. The material above this is a coarse sand, very regularly bedded, and cemented with carbonate of lime into a hard stone, which forms a projecting cornice. Here and there are softer places from which shells can be extracted, the commonest species being large and thick specimens of *Ostrea edulis, Mytilus edulis* and *Patella vulgata*, many of which are perfect though difficult to extract."

"This concreted sand contains some large stones and pebbles of local rocks, and it is noticeable that the lower foot or two consists largely of the *débris* of such rocks (limestone, slate, trap etc.), though quartz both in large and small grains is abundant and there is much comminuted shell. Higher up the quartz grains predominate and the sand becomes finer, though there are occasional layers of coarse sand with limestone and shell *débris* up to the top of the consolidated and unweathered portion of the beach, which is about 12 feet above its base."

"At the top it passes into soft loose sand, which is of very fine grain, and may be blown sand, but is probably as old as the beach sand below. Of this sand there is two or three feet, and it is overlain by sandy soil containing small angular rock fragments. This is hardly to be called 'head,' but is evidently soil and land wash from the slope behind, for the beach forms the top of the cliff, and the ground rises inland from it in a gentle slope of cultivated land."

"The following is a list of the shells which have been found in this beach by Messrs. Godwin-Austen, Prestwich, A. R. Hunt and myself":—

Cardium echinatum ? (recorded as *tuberculatum* by Austen).
— edule (common, but rotten).
Cyprina islandica (Austen, Prestwich).
Mytilus edulis (very common).
Ostrea edulis (very common).
Pecten maximus (Austen).
— varius (not uncommon).
— sp. (Jukes-Browne).
Tapes decussata ? (Austen only, as *Venerupis decussata*).
Littorina littorea (Austen and Prestwich).
— obtusata (Jukes-Browne).

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* *Quart. Journ. Geol. Soc.*, vol. xlviii, p. 279 (1892).

Littorina rudis (Prestwich, Hunt, Jukes-Browne).
Murex erinaceus (Austen and Prestwich).
Patella vulgata (common).
Purpura lapillus (not uncommon).
Trochus ziziphinus (Hunt).
Turritella terebra (Austen and Prestwich).

"Godwin-Austen mentions *Modiola vulgaris* (*M. modiolus*) and does not mention *Mytilus edulis.* The shells are large and have somewhat the aspect of *Modiola,* but are probably *M. edulis.* The umbonal end is generally wanting, and in most of them the inner shell is partially dissolved away. Mr. A. R. Hunt has also found the claw of a crab."

The Thatcher Stone is a small island of limestones, about 800 yards from the Hope's Nose raised beach in a direction south 32° west, but the nearest point of the mainland on the north is not more than 330 yards from it. There is a raised beach shelf, or platform, at from 10 to 15 feet above high water mark on the eastern side of the island, on which traces of raised beach and broken shells are to be found mixed with partially consolidated "Head" or ancient rubble. Mr. A. R. Hunt * found that "the portions of the beach deposit best preserved are on the northern shoulder of the rock facing the mainland." The site indicated is a higher part of the rock shelf, and disconnected from that on the east side of the rock. Mr. Jukes-Browne tells me that the "embedding material" of the beach "consists principally of quartz sand and comminuted shell, with many small fragments of slaty rock." The 43 species obtained by Mr. Hunt from the Thatcher Beach were identified by Messrs. Gwyn Jeffreys, J. T. Marshall and D. Pidgeon, and are as follows:—

Cerithium reticulatum.
Cylichna cylindracea.
Fusus gracilis.
— jeffreysianus.
Lacuna puteolus.
Littorina obtusata.
— rudis.
— litorea.
Murex erinaceus.
Nassa reticulata.
— incrassata.
Natica Alderi.
Patella vulgata.
Pleurotoma striolata.
— brachystoma.
— turricula.
Purpura lapillus.
Scalaria Turtonæ.
Trochus zizyphinus.
Trophon truncatus.
Turritella terebra.
Astarte sulcata.
Cardium echinatum.
— edule.
— Norvegicum.
Cyprina islandica.
Lutraria elliptica.
Mactra subtruncata.
Mya arenaria.
Mytilus edulis.
— modiolus.
Nucula nucleus.
Ostrea edulis.
Pinna rudis.
Saxicava rugosa.
Solen vagina.
Tellina balthica.
Venus exoleta.
— fasciata.
— gallina.
Adeorbis subcarinatus.
Aporrhaïs pes-pelecani.
Buccinum undatum.

Mr. Hunt singles out from the above *Trophon truncatus* and *Pleurotoma turricula* as evidence of a rather colder climate, the

* "The Raised Beach on the Thatcher Rock, etc." *Trans. Devon. Assoc.* vol. xx. pp. 225–252, 1888.

presence of *Pinna*, *Adeorbis* and *Fusus jeffreysianus* and the absence of *Astarte borealis* negativing the idea of any intensity of cold.

From the presence of the estuary-frequenting forms *Mya arenaria* and *Tellina balthica* and *Cardium edule*, the former extension of the mouths of the Teign and Exe, and a westerly drift from them, is suggested.

The absence of *Cardium aculeatum* from the raised beach, and its occurrence in the clayey and muddy bottom of Torbay, in view of the strong probability that the clay in Torbay is the seaward extension of the submerged forest clay deposited in a subsequent era to the raised beach, led him to infer that through lack of a congenial muddy sand bottom *C. aculeatum* was absent from the vicinity of what is now Torbay during the raised beach period.

"That the beaches on the Thatcher and at Hope's Nose were in one and the same little creek or bay is very evident." "But the stage of erosion indicated by the northern Torbay raised beaches" is, according to Mr. Hunt, prior to the excavation of Torbay, or in an early stage in its formation.

"The shell bearing remnant of the Thatcher beach is very insignificant in area. It is therefore improbable that any shell rare in the raised beach era should have been preserved in so small a deposit."

Godwin-Austen * first drew attention to the raised beach on the Thatcher, "rich in shells, particularly the *Turritella terebra*."

He also alludes to the occurrence of raised beaches near Brixham and Sharkham Point.

No reliable traces of raised beach are met with between Hope's Nose and Churston Cove. Opposite Churston Cove there is an old beach platform cut in (apparently) nearly horizontal limestones, on its irregular surface consolidated sand is visible in places adhering to the inequalities in the rock, and containing shells, mostly broken, of *Purpura*, *Littorina*, *Cardium edule*. The beach traces are partly mixed with earthy *débris*, or Head, containing fragments of limestone, which form a gentle slope below the 50-feet contour. At the Sharkham Point Iron Mine there is an old beach platform at 10 to 15 feet above high water. Amongst the mine rubbish with which it is covered are pieces of cemented sand composed of quartz and comminuted shells and containing small flint, slate and quartz, pebbles and sub-angular fragments, and occasionally large fragments of limestone, but the beach material was not exposed actually *in situ*.

Between Blackstone Rock and Compass Cove, south of Dartmouth Castle, traces of old beach sand are observable on a rock platform surmounted by Head. Further to the south, at Western Combe Cove, at about 15 feet above high water, an even slate platform, flush with the cliff at its edge, supports over 20

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* *Trans. Geol. Soc*, ser. 2, vol. vi., p. 442.

feet of Head consisting of igneous rock and slate fragments irregularly, but often linearly, dispersed in buff-brown sandy soil; in the lower part worn boulders occur at from 3 to 5 feet above the platform. This seems to be a case of admixture of Head and raised beach material.

FORMATION OF THE LIMESTONE PLATEAUX.

Pengelly* drew attention to perforations in the limestones at Petitor at about 235 feet above mean tide; near the northern entrance to Kent's Cavern, and in a small cliff in Asheldon Hill at about 200 feet above mean tide; on the northern slope of Sharkham Point, numerous, in a vertical zone extending from 95 to 165 feet above mean tide; in a small cliff between Brixham and Mudstone Bay slightly more than 200 feet above the sea, but since destroyed by quarry work. He ascribed their production to *Pholas dactylus*, *P. candida*, and possibly also *P. parva*, *Saxicava rugosa* and *Venerupis Irus* "whilst the district was undergoing a process of slow upheaval, which was broken by several protracted periods of intermittence." He connects these phenomena with the planing of the limestone plateaux in successive stages as follows—Babbacombe and Daison platform about 280 feet above the sea, Torquay plateaux, 240 feet, Brixham plateau, 200 feet; the two latter being represented by shelves at their respective levels on the flanks of Daison Hill.

Further stages are said to be evidenced by a natural arch in the limestone, probably of marine origin, by the Teignmouth Road between Torre and Upton, at base 176 feet above mean tide; by the planed surface of Roundham head at 75 feet above the sea; and by the raised beach platform at about 30 feet. The Petitor perforations are said to be coeval with the Torquay platforms, those of Kent's Cavern anterior to the introduction of the extinct cave fauna.

As direct evidences of Cretaceous and Eocene denudations are not forthcoming in the area under consideration, the further discussion of this interesting problem would necessarily introduce extraneous evidence.

SUBMERGED FORESTS.

The traces of submerged vegetation on the shores of Torbay have been long known.† Leland quaintly observes:—"Fisschar men hath divers tymes taken up with theyr Nettes yn Torrebay Musons of hartes, whereby men judge that yn times paste it hath been forest grounde." Godwin-Austen‡ mentions the submerged forest traces of Tor Abbey and Broadsands lying on lacustrine mud, in which at Broadsands *Paludina* shells were obtained; he also notes the occurrence of traces of lacustrine marl at Goodrington beach. Pengelly**noted that in some parts

* *Trans Devon. Assoc.* for 1866. † Leland's *Itin.* vol. iii. p. 545.
‡ "*Geology, S. E. Devon*" p. 439. ***Trans. Devon. Assoc.* for 1865, p. 30.

of Tor Abbey sands the vegetable matter is 10 feet in thickness. "In this and in the similar deposits of Goodrington and Broadsands bones of *Cervus elaphus, Sus scrofa, Equus caballus, Bos longifrons* and *Elephas primigenius* were found." "Considerable accumulations of vegetable matter with stumps and roots of trees firmly fixed in bluish clay, and evidently the remains of a forest which once grew on the spot, exist in all the inlets of Torbay." The molar of mammoth, considered to have come from submerged forest peat, was dredged in a trawl at about 5 fathoms on the southern side of Torbay. A part of a jaw of *Bos longifrons* was obtained by Pengelly from the Torre Abbey peat between high and low water. During the progress of the Geological Survey the peat with trunks and roots of trees and the blue clay associated with it was well exposed in the Tor Abbey Sands. In the flat now occupied by the Torquay Recreation Ground a thickness of 14 feet of peat upon New Red rock was disclosed in drainage operations; veins of sand were observable in the peat in places. Detached antlers and bones of *Cervus elaphus* were found in peat under red clay, lead coloured at base and from 1 to 1½ feet thick. At about 2 feet down in the peat there was a vein of fine red sand. Pengelly traced the Tor Abbey peat to about 40 feet above mean tide level, in a narrow tongue in the valley west of Torre Station. Under Preston Sands the occurrence of peat and blue clay has been proved.* Peat underlies the alluvium of the Paignton marshes between Torbay Cottage and Roundham Place, also the alluvium bordering Goodrington Sands, and that near Elbury House on the south of Broadsands. A low mound of blown sand fringes the seaward side of the Paignton alluvium.

Pengelly† described a submerged forest at Blackpool Sands which is very rarely exposed; he saw brownish drab-coloured clay crowded with small twigs, leaves, nuts, etc., and numerous prostrate trunks and branches of trees partly embedded in the clay. "Several large stumps projected above the clay in a vertical direction, and sent roots and rootlets into the soil." Mr. Hunt,‡ from a visit paid to the spot during a subsequent exposure, concluded that there are "at least two different deposits of vegetable *débris*."

River Gravels.

The outlet of the Hollicombe Lake stream, near the Torquay Gasworks, is well shown by gravels upon the New Red rocks forming the low cliffs. The cliffs have evidently been cut back since the deposition of the gravel. Fig. 17 represents a part of it.

The terrace gravels of the Dart north of Totnes are, as a rule, well marked by feature. They rise from a few feet, to over 30 feet, above the adjacent alluvium.

The river terrace at Staverton rises from about 15 feet above the alluvium to 30 feet above it. Coarse gravel of worn stones

* Pengelly, *Trans. Devon. Assoc.*, vol. x., p. 201. 1878, Hunt. *Ibid.* for 1881.
† *Ibid.* for 1869, p. 127.
‡ *Ibid.* for 1881, p. 344.

is exposed on its southern margin east of Staverton. The terrace on the east side of Dartington Park is well marked; its breadth decreases southward, and, like the Staverton terrace, its margin is separated from the alluvium by a low bank o Devonian rocks.

The terraces at Totnes Station, Hampstead, between the Dart and the Hems (the Little Hempston stream), and near Springville House rise gently upward from the alluvium.

By the Rifle Range, south-east of Totnes, the alluvium of the Dart is bordered by a river terrace making a bank about 12 feet in height. In this a gravel pit disclosed the following section:—

Buff soil.

Red and brown loam with volcanic stones, sometimes in distinct beds.

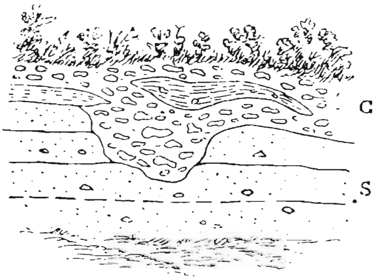
A band of purple on brown loam with very few stones.

Brown loam with volcanic stones and large unworn fragments of diabase, and some worn fragments, perhaps from the underlying gravel.

Gravel of fine dark grey slaty rock, granite, etc., well worn, in a matrix of small worn fragments. The gravel varies from one to three feet in thickness; the lie of the stones denotes current bedding in places, and a lenticular bed of coarse sand is shown at its base in one place. It rests irregularly on slaty volcanic rocks, exposed just above the alluvium, and up to a few feet above it.

The deposits overlying the gravel vary from six to twelve feet in thickness

FIG. 17.—CLIFF SOUTH OF LIVERMEAD.



G. Gravel of flat angular and sub-angular grit stones with small pieces of quartz (one flint pebble was obtained), with a lenticular patch of red clay containing a few stones and a strip of red loam. The base of the gravel is from 5 to 15 feet above high water mark.

S. Reddish brown sand rock containing occasional stones (Lower New Red).

CHANGES IN THE COAST.

White, in his "History of Torquay,"* tells us:—"Within the recollection of persons living, there were cottages and gardens outside the sea wall which bounds the road at Livermead House; and less than fifty years ago there was a grand sandstone arch at Corbon Head which vied in picturesque beauty with the more durable limestone arch on the other side of the bight, locally known as London Bridge. It is worthy of observation that the Torbay Road is at least the third defence which has been raised against the encroachments of the sea. The wall built by Mr. Cary was partially destroyed in 1884; and previously to the erection of that, the original wall was much further out."

* Pp. 159. 160, "Torquay." Printed at the *Directory* Office, 1878.

From the traces of New Red rocks mentioned in this Memoir, and from the presence of outliers, to the south, on the Slapton shore, and near Thurlestone (in sheets 355, 356), there is reason to think that the present coast-line was not far off the position of an old coast-line during the Lower New Red sandstone epoch, and that this circumstance has something to do with the configuration of the present coast, and therefore with the formation of Torbay and the more rapid waste of its inner shores.

CHAPTER VIII.

ECONOMICS.

Water Supply.

The water supply of the villages is from wells. Prior to 1858 Torquay was supplied from wells or private waterworks connected with a reservoir at Ellacombe. In 1856 the waterworks by which the town is now supplied were begun, and completed in 1858. The supply is obtained by impounding streams on the Dartmoor granite near Hennock, about 16 miles from Torquay. Owing to the elevation of the reservoir, the pressure being too great to allow of direct delivery from the mains, two reservoirs, one on Chapel Hill, the other on Warberry Hill, were constructed. The storage Reservoir (Tottiford) on Dartmoor forms a lake covering more than 35 acres, and is said to contain 60,000,000 gallons. The water is soft, having only 2° of hardness according to Shapter,* 0.61 (Clarke's) according to White. The latter gives an analysis by Mr. E. Smith, F.C.S., published in 1873. Referring to water derived from springs at Torre and near the summit of Braddons Hill, Torquay, Shapter, says:—"The waters conveyed from the above sources through iron pipes are clear and sparkling, strongly inpregnated with lime, and containing some little iron: their temperature at the fountain head is about 52°.

Dartmouth, Brixham, and Totnes are supplied from local sources and wells.

Borings, Well Sections, etc.

It is much to be regretted that records of the strata passed through in ordinary well sinkings are not kept, and verbal information obtained on that head is never sufficiently clear to be of much scientific value. An Artesian well boring made by the Diamond Rock Boring Company on the premises of the Torquay Brewery, 34 Fleet Street, was begun on February 3, 1875, and abandoned at a depth of 638 feet 7 inches on November 5 of the same year. The following is the section as given in "White's Directory":—

	ft.	in.	ft. in.
Varieties of Petitor marble, with beds of "Grey Harry" (Beds from 3 to 6 ft. in thickness)	93	0	329 8
Dark liver coloured limestone, with quartz veins, shillety; Plain limestone, varying colours of blue, pink, chocolate and liver coloured.	236	8	
Hiatus filled with tenaceous red mud	4	0	
Blue clay slates	82	9	246 4
Chocolate grey slate	65	7	
Second bed of blue clay slate	98	0	
Indurated marl, few cores obtainable	58	7	
	638	7	

* See White's "History of Torquay," pp. 204–211, and Shapter's "Climate of the South-east of Devon," London, 1842.

Mr. H. B. Woodward published the following account in 1877 :*

	ft.	in.
Petitor marble, about	92	0
Plain limestone „	247	8
(Hiatus of two or three feet filled with soft tenaceous red clay.)		
Blue slate	82	9
Chocolate slate	65	7
Blue slate	98	0
Indurated red marl	42	7

The shillety reference, in White's account, denotes a band or lenticle of slate or slaty limestone, of which the thickness is not given. The "Hiatus" is most probably a fault filled with clayey fault rock. The three slate horizons below are presumably Middle Devonian slates, and the indurated marl last encountered would appear to be the upper part of the Lower Devonian. Mr. H. B. Woodward gives the depth of the boring as 628 feet 7 inches, the total depth in limestone as 339 feet 9 inches. He adds: "The inclination (or 'natural cleavage,' as it was termed) of the limestones was about 70°, whereas the inclination of the slates was no more than 45°; and this difference, I am inclined to think, is due to a fault. Owing to this inclination the thickness of the beds passed through may be estimated as follows: Limestone 130 feet, slates 185 feet, red marl 25 feet. Concerning the so-called 'indurated red marl,' I saw a specimen which seemed to belong to one of the junction beds between the slates and red sandstones."

Since the failure of this attempt, White says that the Brewery Company have tapped a spring "rising in the old red sandstone formation, where it is thrown up by the rock of limestone on which the Castle College stands," and obtain their supply through pipes by gravitation.†

At the Lion Brewery, High Street, Totnes, an ineffectual boring for water made by Messrs. Isler & Co., 2 feet dug; 145 feet 4 inch boring, gave the following section :

	ft.	in.
Made ground and soil, etc.	21	0
Shaly rock	3	0
Blue limestone rock	2	6
Blue slate rock	139	6

At Lower Weston Farm, east of Totnes, a well said to have been sunk to a depth of 160 feet seems, from the material thrown out to have been sunk in nearly identical strata with the above, dark blue slates in the upper part of which thin beds of fossiliferous limestone (Eifelian) occur.

In all well sections the thickness of slates penetrated, even where dip of schistosity is given, can scarcely be estimated without ascertaining the true bedding.

The Torquay main sewer commences at a few yards in front of the Spanish Barn, whence it passes across the meadows and

* *Geol. Mag.* for October, 1877.
† "History of Torquay," p. 293.

through the grounds of the Belgrave Hotel, skirting the back of Abbey Crescent, where it joins the first tunnel under Waldon Hill. From this tunnel the sewage passes to the pumping station in Swan Street, where it is raised to a higher level sewer and proceeds through a tunnel from Fleet Street, under Higher Terrace, Apsley House, and Meadfoot Hill, to the sea road, along which it is carried by a barrel sewer and enters the third tunnel under Kilmorie, being finally discharged into the sea at Hope's Nose, a distance of three miles from Torre Abbey. The third tunnel proved the greatest obstacle, "owing to the extreme hardness of the rock, and the depth of working from the surface, and the large quantity of water which flowed in from the springs." The details procurable are, however, of very little value as far as the geology is concerned. One of the shafts was sunk by Middle Woodfield Road, near its junction with Meadfoot Road, through 104 feet of slates to calcareous beds. From Mill Lane to Torre Abbey the excavation was through peat to solid rock; from Belgrave Road to the foot of Waldon Hill partly tunnelled through sandstone easily excavated; between Babbacombe Road and the junction of Meadfoot and Hesketh Roads, the greater part of the tunnel was in limestone rock.* Taking the last-mentioned observation in conjunction with the thickness of slate penetrated in Middle Woodfield Road, it would appear that the slates are either above the limestone, or inverted for part of the distance between Babbacombe Road and Hesketh Crescent.

Mines, Quarries, etc.

The following notes are chiefly compiled from White's "History of Torquay," † Collins' "Mineralogy of Cornwall and Devon," ‡ a paper by R. N. Worth on "The Economic Geology of Devon," § and a paper by E. T. Appleton ‖ on "The Economic Geology of Devon."

Mines and Manufactures.—About the year 1680, the then Earl of Londonderry erected stamping mills, etc., at great cost in the brook near Westhill and that running by the Teignmouth Road, in the vain hope of finding tin lodes. In a lease dated 1720 mines between Torwood and Hope's Nose are mentioned. As late as 1850 an iron mine was worked at Torre, between the Infirmary and the first house in Higher Union Street on the hillside facing Upton, but in a few years the operations were abandoned. Rich samples of iron ore were raised in another part of Torquay about ten years later. Collins gives the following list of mines in 1871, worked for hematite and limonite:—Torquay, the Torbay Mine. Paignton, Gympton (Galmpton?). Brixham, Five Acre, Prosper Huel, Parkins and Sharpham (Sharkham?). Worth tells us that "Mr. Wolston, of Brixham, started a paint manufactory in connection with

* See Chatterton on "Torquay Drainage."

† Torquay, 1878. ‡ Truro: Heard & Sons, 1871.

§ *Trans. Devon. Assoc.* for 1875, pp. 209–233. ‖ *Ibid.* pp. 234–246.

his iron mines, in which the softer parts of the ore were made into ochreous pigments, and similar paints are still manufactured there." Brick and tile works have been opened in dark red brown clunchy clay belonging to the Watcombe clay series, but the clay from which the terra cotta is made is worked in the map to the north of sheet 350, although the same horizon occurs near Torre. Lime for manure or mortar has been afforded by the limestones nearly everywhere, but for hydraulic cement the only mention of suitable limestone is by Appleton, *viz.*, the small patch on the borders of the volcanic series at Harbertonford, although there are, no doubt, many patches of Eifelian limestones of the same character, and the admixture of shale with the Middle Devonian limestones would doubtless afford suitable material for the purpose.

Mineral Waters.—Worth mentions a chalybeate spring at Totnes, not, however, used medicinally.

Building Materials.

The limestones of Torquay and Brixham, etc., are extensively quarried for building stone. The more massive limestone rocks are used for sea walls, etc., often in association with large blocks of New Red conglomerate or breccia, which is also quarried for building purposes at Chelston and Paignton. The hard sandstones of the Waddeton and Brixham outliers, are mentioned by Appleton as being considered by workmen harder to dress than granite. The massive limestones of Ipplepen, Petitor, etc., when polished, form ornamental marble used chiefly in interior church architecture. Worth says: "The Ipplepen marble is chiefly characterised by a roseate dove-colour ground with reddish veins." The Torquay marbles vary much in colour and appearance, some being very distinctly coralline. Lapidaries have special names for the fossiliferous limestones; thus limestone full of *Favosites cervicornis*, such as that at Saltern Cove, is called "Featherstone." The Lower Devonian grits are locally used for building material, as also the slates where their planes are closely compacted. The volcanic rocks are either too hard or too soft to be largely used for building purposes.

Roofing Slate.—Slate has been quarried near Nethway House, south of Brixham, and in many parts of the slate district, for purely local purposes. The slate quarries of Harbertonford are just outside the limits of the map, on the west.

Road Metal.

The harder aphanites and diabases are largely used for road stone. Appleton says that "greenstone near Greenway, on the Dart, has long been used for the metropolitan roads," and in the "Report on the Building Stones of the United Kingdom" for the year 1858, by R. Hunt, trap rock at Dartmouth and metamorphic rock at Sandquay, near Dartmouth, are said to have been used for the same purpose. The Sandquay rock is a hard igneous rock.

The Devonian limestones are largely used for road metal, but for that purpose are inferior to the carboniferous limestone.

SOILS.

The volcanic rocks afford the richest soil in the district. The plum orchards at Dittisham are grown on this soil. The New Red rocks also afford rich soil suitable either for grazing or tillage, and varying, according to their constitititution, from comparatively light loamy or sandy soil to comparatively heavy clayey land. The Lower Devonian rocks also produce variable soils according to the local prevalence of grits or of slates. In the slate areas of the Upper, Middle, and Lower Devonian the more clayey and heavier soils are naturally most often encountered. The limestone soils are for the most part thin and clayey, and consequently much affected in seasons of drought.

The celebrated orchards of Staverton grow on the soil of Eifelian slates, partly covered by river terrace *débris.*

APPENDIX.

List of the Principal Works on the Geology of the District.

1829. De la Beche, [Sir] H. T. On the Geology of Tor and Babbacombe Bays, Devon. *Trans. Geol. Soc.*, ser. 2, vol. iii., part i., p. 161.

1839. De la Beche, [Sir] H. T. Report on the Geology of Cornwall. Devon, and West Somerset. (*Geological Survey*). 8vo. London, (Index by C. Reid, 1903.)

1840. Sedgwick, Rev. A. and [Sir] R. I. Murchison. On the Physical Structure of Devonshire, and on the Subdivisions and Geological Relations of its Older Stratified Deposits, &c. *Trans. Geol. Soc.*, ser. 2, vol. v., part iii., p. 633.

Lonsdale, W. Notes on the Age of the Limestone of South Devonshire. *Trans. Geol. Soc.*, ser. 2, vol. v., part iii., p. 721.

1841. Phillips, Prof. J. Figures and Descriptions of the Palæozoic Fossils of Cornwall, Devon, and West Somerset (*Geological Survey.*) 8vo. London.

1842. [Godwin-] Austen, R.A.C. On the Geology of the South-East of Devonshire. *Trans. Geol. Soc.*, ser. 2, vol. vi., part ii. (This includes the substance of papers printed in abstract in *Proc. Geol. Soc.* in 1834, 1836, 1839 and 1840).

Shapter, Dr. T. The Climate of the South of Devon and its Influence on Health. 8vo. London. (2nd Edition, 1862).

1846. De la Beche, Sir H. T. On the formation of the Rocks of South Wales and South-Western England. *Mem. Geol. Survey*, vol. i. (Many references to this district and to literature will be found in pp. 65-95 and p. 105).

1847. Vivian, E. Extract of a letter from Mr. E. Vivian of Torquay, respecting the Phenomena of Kent's Cavern. *Rep. Brit. Assoc. Trans. of Sects.*, 1847, p. 73.

1857. Pengelly, W. On the Beekites found in the Red Conglomerates of Torbay. *Rep. Brit. Assoc. Trans. of Sects.*, p. 74. In full in *Trans. Roy. Geol. Soc. Cornwall*, vol. vii., p. 309.

Vivian, E. Researches in Kent's Cavern, with the original MS. Memoir of its first opening, by the late Rev. J. MacEnery. *Rep. Brit. Assoc. Trans. of Sects.*, 1856, p. 79.

—— The earliest traces of human Remains in Kent's Cavern. *Ibid.*, 1856, p. 119.

1859. McEnery, Rev. J. Cavern Researches. Edited by E. Vivian. 4to. London.

1861. Pengelly, W. On a New Bone Cave at Brixham. (Brit. Assoc.) *Geologist*, vol. iv., pp. 153, 456.

1862. PENGELLY, W.
The Geographical and Chronological Distribution of the Devonian Fossils of Devon and Cornwall. (Brit. Assoc.) *Geologist*, vol. iv., pp. 10, 74.
—— Letter on Accumulation of Cave Deposits. *Ibid.*, p. 65.

1862, 3, 5, ——The Red Sandstones and Conglomerates of Devonshire. *Trans. Plymouth Institute*, Parts i., ii., iii.

1864, 5. DAVIDSON, T. A., Monograph of the British Devonian Brachiopoda. Parts i. and ii. *Palæontographical Soc.*, 4to, London.

SALTER, J. W. A Monograph of British Trilobites. Parts i. and ii. *Ibid.*

1865. PENGELLY, W. On the Beekites found in the Red Conglomerate at Torbay. *Trans. Roy. Geol. Soc. Cornwall*, vol. vii., p. 309.
—— Raised Beaches of Torbay. *Trans. Devon. Assoc.*, vol. i., p. 33.

1866. PENGELLY, W. Report on the Exploration of Kent's Cavern. *Proc. Roy. Inst.*, iv., p. 534.

—— On the Lithodomus perforations above the sea level in the Limestone Rocks in South-east Devonshire. *Trans. Devon. Assoc.*, vol. i., p. 82.

—— On Certain Joints and Dykes in the Devonian Limestones on the Southern Shore of Torbay. *Geol. Mag.*, vol. iii., p. 19.

1868. PENGELLY, W. History of the discovery of Fossil Fish in the Devonian Rocks of Devon and Cornwall. *Trans. Devon. Assoc*, vol. ii., part 2, p. 423.
HOLL, Dr. H. B. On the Older Rocks of South Devon and East Cornwall. *Quart. Journ. Geol. Soc.*, vol. xxiv., p. 400.

1869. PENGELLY, W. On a Submerged Forest at Blackpool, near Dartmouth, South Devon. *Trans. Devon. Assoc.*, vol. iii., p. 127.

1870. TAWNEY, E. B. On the occurrence of Fossils at Smuggler's Cove, Torquay. *Ibid.*, vol. iv., p. 291.

1873. CHAMPERNOWNE, A. On the discovery of a Species of Starfish in Devonian Beds of S. Devon. *Rep. Brit. Assoc.* xliii., p. 77.
PENGELLY, W. Anstis Cove Cavern. *Trans. Devon. Assoc.*, vol. vi., p. 61.

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ON THE

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OF

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AND

WEST SOMERSET.

By SIR HENRY T. DE LA BECHE, C.B., F.R.S.

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Unfortunately it was published without an Index, the want of which has been felt by everyone who has used the work. Some years ago Mr. Clement Reid prepared a MS. Index, and this has proved of so much service during the re-survey of Cornwall and Devon that it has been decided to print it for general use.

J. J. H. TEALL,
Director.

Geological Survey Office,
28, *Jermyn Street, London,*

17th November, 1902.

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10. Dumfriesshire. 6*s.*
11. Roxburghshire and Dumfriesshire. 4*s.*
12. Argyllshire (Kintyre, S. half of). 4*s.*
13. Ayrshire, Turnberry Point, and S. part of Arran. 4*s.*
14. Ayrshire, Central Districts. 6*s.*
15. Dumfriesshire, N.W.; Ayrshire, S.E.; and Lanarkshire, S. 6*s.*
16. Dumfries, Selkirk, Peebles, Lanark, and Roxburgh shires (parts of). 6*s.*
17. Roxburghshire, Selkirkshire, and Dumfriesshire (parts of). 6*s.*
18. Roxburghshire, E. part. 4*s.*
19. Argyllshire (S. part of Islay). 4*s.*
20. Argyllshire (Kintyre, Gigha I., part of Islay). 4*s.*
21. Argyllshire; Arran, Central and N. part; Bute, S. part; Cumbraes; Ayrshire (part of N.W.). 4*s.*
22. Ayrshire, Renfrewshire, Lanarkshire (parts of). 6*s.*
23. Lanarkshire, Central Districts; Ayrshire (part of W.). 6*s.*
24. Peeblesshire, Lanarkshire, Edinburghshire, Selkirkshire (parts of). 6*s.*
25. Berwickshire; parts of Roxburgh, Selkirk, and Edinburgh. 6*s.*
26. Berwickshire and Roxburghshire (parts of). 4*s.*
27. Argyllshire; parts of Islay and Jura, Oronsay. 4*s.*
29. Argyllshire, Ayrshire, Buteshire, Dambartonshire, and Renfrewshire (parts of). 6*s.*
30. Renfrewshire; parts of Dumbarton, Stirling, Lanark, and Ayr. 6*s.*
31. Lanarkshire, Stirlingshire, Linlithgowshire, Dumbartonshire, Edinburghshire (parts of). 6*s.*
32. Edinburghshire, Linlithgowshire, Fifeshire, Peeblesshire (parts of). 6*s.*
33. Haddingtonshire and parts of Edinburghshire and Berwickshire. 6*s.*
34. Eastern Berwickshire. 4*s.*
38. Perthshire, Stirlingshire, Dumbartonshire, Argyllshire (parts of). 6*s.*
39. Perthshire, Clackmannanshire, Stirlingshire, and Fife (parts of). 6*s.*
40. Fife and Kinross. 6*s.*
41. Fife, East part. 6*s.*
46. Perthshire, Argyllshire (parts of). 6*s.*
47. Perthshire. 6*s.*
48. Perthshire, Forfarshire, and Fifeshire (parts of). 6*s*
49. Forfarshire and Fifeshire (parts of). 4*s*
55. Perthshire. 6*s.*

View from top of Goatfell looking North. The so-called North top of Goatfell forms the prominent peak to the right, and to the left of this, in the distance, appears the deep rift of Ceum na Caillich. A basic dyke crosses the near ridge on the left.

MEMOIRS OF THE GEOLOGICAL SURVEY.

SCOTLAND.

THE GEOLOGY

OF

NORTH ARRAN, SOUTH BUTE,

AND THE

CUMBRAES,

WITH PARTS OF

AYRSHIRE AND KINTYRE.

(Sheet 21, Scotland.)

THE DESCRIPTION OF NORTH ARRAN, SOUTH BUTE, AND THE CUMBRAES by W. Gunn, F.G.S.; PART OF AYRSHIRE by Sir A. Geikie, D.C.L., F.R.S.; PART OF KINTYRE by B. N. Peach, F.R.S.; WITH CHAPTER ON THE PETROGRAPHY OF THE TERTIARY IGNEOUS ROCKS OF ARRAN, SOUTH BUTE, AND THE CUMBRAE ISLANDS by A. Harker, M.A., F.R.S.

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PREFACE.

THIS memoir describes the geology of the area included in Sheet 21 of the one-inch map of Scotland, which embraces the north part of Arran, South Bute, and the Cumbraes, with parts of Ayrshire and Kintyre. The ground in Ayrshire was surveyed by Sir A. Geikie, who also mapped a narrow belt along the east coast of Arran in 1872. Bute and the Cumbraes were surveyed by Mr. Gunn, and the small area in Kintyre by Mr. Symes. The survey of the southern part of Arran was commenced in 1892 by Mr. Gunn, who gradually traced his lines northwards till he completed the mapping of the whole island; the field-work being carried on under the supervision of Mr. B. N. Peach, F.R.S.

The geological description of North Arran, South Bute, and the Cumbraes has been written by Mr. Gunn, that of the Ayrshire coast by Sir A. Geikie, and that of Kintyre by Mr. Peach. Chapter XI., on the petrography of the Tertiary Igneous Rocks of Arran, South Bute, and the Cumbraes, has been supplied by Mr. Harker, F.R.S. In Part II. of the Appendix, the notes on the petrography of the Old Red Sandstone Igneous Rocks have been contributed by Mr. Kynaston, and those on the Carboniferous Igneous Rocks by Mr. Seymour. While the field-work was in progress, petrographical notes on various rocks from this sheet were also supplied by Mr. Teall, F.R.S., Dr. Hatch, Professor Watts, Professor Grenville Cole, and Dr. Flett.

The lists of Carboniferous fossils have been prepared by Mr. Peach, Dr. Crampton, and Mr. Tait, and the notes on the Mesozoic fossils found in the island of Arran have been supplied by Mr. E. T. Newton, F.R.S. Special thanks are due to Dr. Traquair, F.R.S., Mr. Kidston, F.R.S., and Dr. Wheelton Hind for their valuable assistance in the determination of the fishes, the plants, and the lamellibranchs respectively.

Part III. of the Appendix, which gives a list of publications relating to the geology of the areas included in this sheet, has been prepared by Mr. Gunn with the assistance of Mr. Harker and Mr. Tait.

The photographs reproduced in Plates I. to X. were taken by Mr. Robert Lunn of the Geological Survey.

The principal additions to our knowledge of the geology of Arran, made during the progress of the Geological Survey, may here be briefly summarised :—

1. The discovery of the former extension of Cretaceous, Liassic, and Rhætic deposits in the island from the presence of fragments enclosed in a volcanic vent.

2. The determination of the Triassic age of the sandstones, conglomerates, and marls of the southern part of Arran, and their unconformability to the Carboniferous Rocks.

3. The discovery of strata of Coal-measure age, though of limited development, in the island.

4. The identification of black schists, cherts, and grits probably of Arenig age in North Sannox.

5. The discovery of no less than six different sets of volcanic rocks, in addition to that formerly known in the Lower Carboniferous strata. Of these, one is probably of Arenig age; two belong to the Old Red Sandstone period; two are of Carboniferous age, and the last, forming a huge volcanic vent, is probably Tertiary.

J. J. H. TEALL,
Director.

GEOLOGICAL SURVEY OFFICE,
28 JERMYN STREET,
LONDON, *28th March 1903.*

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THE GEOLOGY OF NORTH ARRAN.

CHAPTER I.

INTRODUCTION.

CONSIDERABLY more than one half (about five eighths) of the area of this sheet is occupied by sea—the Firth of Clyde and its branches—and the land amounts to only about 161 square miles. The land area belongs to three different counties, and consists of no less than nine separate portions—seven of them being islands or parts of islands, and the other two belong to the mainland of Scotland.

In the north-west corner of the map is a small portion (about 13 square miles) of the peninsula of Kintyre in the neighbourhood of Skipness, Argyllshire. On the eastern border is a somewhat larger area, about 16 square miles, which is part of the county of Ayr. It embraces a strip of coast land stretching from Largs to near Ardrossan, together with the Horse Island opposite to its southern end. The six remaining portions belong to the county of Bute. Near the northern edge of the map occur four of these—the southern parts of the islands of Bute and Inchmarnock, the whole of the Little Cumbrae, and nearly all of the Great Cumbrae. The largest land mass is the northern portion of Arran, nearly three quarters of the whole area; and the northern end of Holy Island, which closes in Lamlash Bay, completes the list.

The extent of coast line in the sheet is about 91 miles.

Millport in the Great Cumbrae is the most important town, but a portion of Largs comes into the sheet on the Ayrshire side at the north-east corner. Lamlash, Brodick, Corrie, and Lochranza are important villages in the Isle of Arran, and so are Kilchattan in Bute, and West Kilbride in Ayrshire. Inchmarnock, Little Cumbrae, and Holy Island are but sparsely populated, while the Horse Island is an uninhabited rock.

PHYSICAL FEATURES.—Naturally, from the small size of the separate portions of land, there can be no large streams, but some of the ground rises to a great height, especially in the Isle of Arran.

The Kintyre portion is an undulating table-land rising rapidly from the sea level to a height of 500 or 600 feet, and the highest point is Cruach an t-Samhlaidh, which reaches to 849 feet above the sea. This area is drained by the Claonaig Water and the Skipness Water.

Inchmarnock is a low, rocky island of less than 200 feet in elevation.

The western side of Bute is of much the same physical character as Inchmarnock, but rises to 279 feet above the sea. The ground south of Loch Quien is below the 50-feet contour, and is part of a low, narrow valley which runs northward to Rothesay. East of Loch Quien the ground rises into a comparatively featureless area, the highest part of which, near Birgidale Butts, is 400 feet above the sea. To the south of this, and stretching across the island between Kilchattan Bay and Stravanan Bay, is a low, flattish, sandy tract which rises to a little above the 50 feet contour. In great contrast to this rises the ridged and rocky part which composes South Bute, between Kilchattan and the Garroch Head. Its highest points are Suidhe Chatain 517, south of the village, and Torr Mor 485, near Glencallum.

The Great Cumbrae is generally in character like that portion of Bute to the north of Kilchattan, and rises to about the same height above the sea—417 feet. Some intrusive igneous masses, however, diversify its surface considerably.

The Little Cumbrae, on the other hand, rising to 409 feet above the sea, is rocky, like the southern end of Bute, only that instead of marked ridges there is a series of gently sloping terraces.

On the Ayrshire side is the rocky promontory of Portincross rising to 456 feet above the sea, which is connected with the main mass of land to the eastward by ground less than 100 feet in elevation. To the east of the railway the land rises rapidly, as it does along the coast generally, much of the border of the sheet being over 800 feet, and in one place it exceeds 1000 feet.

The fine peaks of the northern granite mountains, with their deep-cut glens, are the dominant features in the scenery of Arran. These are contained within a nearly circular area about eight miles by seven across. All the principal streams take their rise in this mass, or from a smaller oval area near the centre of the southern edge of the sheet, which is belted by a granitic ring, and in which are the hills of Ard Bheinn 1676, A' Chruach 1679, and Beinn Bhreac 1649. The streams that flow eastward from this smaller mass of high ground are Benlister Burn and Glencloy Burn, while those which flow to the west are tributaries of the Machrie Water and the Black Water.

The larger granitic area is nearly divided into two equal parts by the glens of Iorsa Water and Easan Biorach, which coalesce at the watershed of Loch na Davie. The Iorsa stream, which is about eight miles long, is the largest in the island. Some of its branches drain the western part of the high ground, which is not so high and rugged as the eastern half, nearly all the highest hills being round or flat topped. Beinn Bharrain 2345, and Beinn Bhreac 2333—the highest points of a continuous ridge; Meall nan Damh 1870, and Meall Mor 1602, isolated conical hills; and another Beinn Bhreac 1881, west of Loch na Davie, are the most important summits in this part, which is partly drained by Allt Gobhlach and the stream which flows north down Glen Catacol.

From the masses of Caisteal Abhail 2817,* and Cir Mhor 2618, diverge ridges that embrace the glens of Sannox and North Sannox, which drain eastwards, and that of Rosie, which drains southward into Brodick Bay. One ridge with a gradual descent runs northwards from Caisteal Abhail to Creag Dubh, and bounds the valley of North Sannox on the west. Another, and very rugged, ridge runs eastward to the rift of Ceum na Caillich, and then in a smooth outline continues in a north-east direction past Suidhe Fhearghas, 2156. This ridge separates the two Sannox glens. A high col, the lowest part of which is 2046, joins Caisteal Abhail to Cir Mhòr. In a south-south-west direction from this peaky mountain we have successively A' Chir (the most difficult to traverse in the whole island), Beinn Tarsuinn 2706, and Beinn Nuis 2597. The height of A' Chir is not given, but is probably about 2335, and the pass to the south of it is over 2000 feet, while the pass on the north side is 1933. The highest point of Beinn a' Chliabhain, which is on the west side of Glen Rosie, is 2217 feet in height. Cir Mhòr is connected with the Goatfell range by the low col of the saddle 1414, which has a precipitous and difficult descent on the Sannox side. Goatfell, 2866, the highest summit in the island, is on a continuous range of high ground, over 2000 feet in elevation, which runs in a curved line from Cioch na h-Oighe, 2168, round the head of the White Water, past Goatfell, some half a mile down its southern spur. For three quarters of this distance the ridge is nearly everywhere over 2500, and only falls slightly below that height at one or two points. From its highest point north of Goatfell, 2716, a ridge which bounds the White Water on the north runs eastward to Am Binnein, 2172.

Holy Island, which is on the eastern side of Lamlash, is steep and rugged, and rises to above 1000 feet, but its highest point is outside the limit of this sheet.

Several freshwater lochs diversify the surface of Arran, and one, Loch Quien, comes into the portion of Bute with which we have to deal. Nearly all the lochs in Arran are in the western part of the island. The largest is Loch Tanna, which is a mile in length, but not particularly interesting, being immediately surrounded by low-lying, peat-covered ground. It is probably shallow, and drift-dammed. The Dubh Loch to the west of it is partly surrounded by rock, and may be a rock basin. Loch Nuis and Loch Iorsa are shallow lochs, probably in drift, as is also Loch na Davie. Two small lochs occur to the south-west of Sail Chalmadale, one of which is not on the ordnance maps. The finest of the lochs is Loch Chorein Lochain at a height of 1080 feet above the sea, picturesquely surrounded by granite crags between Meall nan Damh and Meall Biorach.

For sea lochs we have only Loch Ranza, and the bays of Brodick and Lamlash in Arran, for the coast is not much indented. Brodick Bay is the most interesting, for into it debouch the Cnocan Burn; the Rosie Burn, into which Glen Shurig Burn drains; the

* The highest point of Caisteal Abhail is not indicated on the one-inch map. It is about 200 yards east of the parish boundary where is the height, 2735.

Glencloy Burn, and the Allt Beidh. There are thus the openings of five separate glens diverging from this short sea loch. In Bute the principal indentations of the coast are at Scalpsie Bay and Kilchattan Bay; and Millport Bay is the only one of importance in the Great Cumbrae.

In the following pages an outline only can be given of the complicated geology of the northern part of the Isle of Arran, which forms the bulk of the land in the sheet, fuller details being reserved for a complete memoir on the island. In this forthcoming volume it is also proposed to give an historical sketch of the geological discoveries made in the island by the principal observers, with full references to the books and papers in which they are contained.

A separate short explanation of the rocks in the southern part of Arran to accompany Sheet 13 of the one-inch geological survey, will succeed the present publication.

Attention is here called to the following points, embracing the principal additions to our knowledge of the geology of Arran made during the progress of the survey:—

The discovery of the former extension of Cretaceous, Liassic, and Rhætic formations in the island from the presence of fragments of these rocks enclosed in a Tertiary volcanic vent.

The definite determination of the Triassic age of the sandstones, conglomerates, and marls of the southern part of Arran, and their unconformability to the Carboniferous rocks.

The restriction of the Carboniferous formation to an extremely narrow compass in the island—a much broken and faulted strip which does not extend to the west coast—and the discovery in it of strata of Coal-measure age.

The discovery of beds of probable Arenig age in North Glen Sannox in the form of black schists, cherts, and grits, associated with old lavas and volcanic tuffs similar to those occuring near Ballantrae in Ayrshire.

The discovery of no less than six different sets of volcanic rocks in addition to that formerly known as occurring in the lower part of the Carboniferous formation. Of these newly discovered volcanic series one is probably of Arenig age, two belong to the Old Red Sandstone period, two are of Carboniferous age, and the newest, which is a huge volcanic vent, is probably of Tertiary age.

In addition to these, the age and character of the numerous intrusive rocks both acid and basic have been more definitely fixed, and their distribution more accurately determined. While the majority of the intrusive rocks of the sheet are of Tertiary age, a considerable number belong to the Carboniferous period, and some to that of the Old Red Sandstone, while a few are as old as the Lower Silurian period, or even earlier in date than this.

When we take into consideration all these important additions to our knowledge of the island, we are more disposed to admit that the geology of Arran is, as it has often been said, an epitome of that of Scotland.

CHAPTER II.

Table of Formations occurring in the Sheet and general Geological Description.

The following Table gives a complete list of the various formations and subdivisions of formations that are found within the area, together with the varieties of intrusive igneous rock met with. The stratified formations are arranged first, beginning with the most recent and proceeding to the oldest. Next follow the contemporaneous volcanic rocks, and last of all the intrusive igneous rocks.

In the descriptive parts a somewhat different arrangement is followed, for we begin with the oldest rocks—the metamorphic schists—and end with the newest or most recent strata. In the description, also, of the different volcanic zones, it has been found more convenient to take them along with the aqueous rocks, with which they are associated, than to class them together as contemporaneous igneous rocks. An endeavour has also been made to describe together the intrusive igneous rocks that are known to belong to one and the same period.

AQUEOUS.

Recent and Post-Tertiary.	Sub-aerial and Fresh Water.	Blown sand.	
		Alluvium of stream terraces and old lakes	
		Peat	
	Estuarine and Marine.	Mud and sand of present beach .	
		Raised beaches (25 feet) . .	
		,, (intermediate) .	
		,, (100 feet) . .	
Drift series.	Sands, gravels, and stratified clays. Eskers and glacial shell-beds.		
	Erratic blocks.		
	Boulder clay or Till. Drumlins.		
	Ice markings on rocks.		
Cretaceous.	Limestone with siliceous concretions, occurring in volcanic vent . .		h
Lias.	Dark shale with many fossils, occurring in volcanic vent		g
Rhætic.	Black shale with ironstone and limestone, occurring in volcanic vent .		fg
	Pale-coloured mudstones, do.		

Trias.	Red marls and shales with white and yellowish sandstones.	$f^{x'}$
	Thick red, yellow, and whitish sandstones with masses of conglomerate . False-bedded red sandstones.	f
Carboniferous.	Coal-measures with contemporaneous lava . .	d^5
	Carboniferous Limestone Series. { Upper Limestone group. Edge-coal group. Lower Limestone group. }	d^2
	Calciferous Sandstones with intercalated volcanic series	d^1
Old Red Sandstone.	Upper Red Sandstones and conglomerates with volcanic series . . .	c^3
	Lower Red Sandstones, mudstones, and conglomerates with volcanic series	c^1
Lower Silurian.	Cherts, grits, and dark schists associated with a volcanic series (Arenig ?) .	b
Metamorphic.	Mica schist	𝔤
	Limestone	λ
	Slate	𝔩
	Gritty schists or schistose grits . .	𝔷

Igneous.

A.—Interstratified or Contemporaneous with the Formations among which they lie.

In Carboniferous System.	Basalt (in Coal-measures, Carboniferous Limestone and Calciferous Sandstone) as intercalated sheets of lava .	Bd^5, Bd^2, & Bd^1
	Andesite in Calciferous Sandstone	Po d^1
	Trachyte ,, ,,	Tr d^1
	Volcanic tuffs ,, ,,	Ts d^1
	Agglomerate in necks . .	Nd^1
In Old Red Sandstone	Basalt in upper Old Red Rocks .	Bc
	Basalt in lower ,, ,, ,, .	Bc^1
In Lower Silurian.	Epidiorite or Greenstone lava of Arenig (?) age — slightly schistose	Bb ?
	Tuff and agglomerate of do. .	Ts b ?

A¹.—Fragmental Volcanic Rocks subsequent in date to the strata among which they lie.

Tertiary.	Agglomerate and conglomerate in large vent probably of Tertiary age.	Ni

B.—Intrusive or subsequent in date to the rocks among which they lie.

Probably of Tertiary Age.	Gabbro	U
	Basalt and dolerite in dykes, sills, and bosses	B
	Andesite	Po
	Diorite and Hyperite	D
	Syenite.	S
	Felsite, Rhyolite, and Quartz-Porphyry in dykes and sills	F & F″
	Pitchstone	F′
	Quartz-diorite	G″
	Granophyre	G″
	Granite—fine-grained	G
	Granite—coarse-grained	G
Late Carboniferous.	Basalt and Dolerite in dykes and sills	B
Of Early Carboniferous Age.	Olivine basalt in dykes and sills	B
	Andesite in dykes	Po
	Porphyrite or Bostonite in dykes	F
	Trachyte in dykes	Tr
Probably Old Red Age.	Malacolite or Salite-Dolerite in dykes and sills	B
Lower Silurian ?—Epidiorite and Hornblende Schist		BG
Of Uncertain Age.	Serpentine	Σ
	Hornblende Schist	BG

General Geological Description.

Metamorphic rocks, as mica schists, etc., occupy the whole of the Kintyre area, the island of Inchmarnock, and the western part of Bute. In these areas the strike of the rocks is generally north-east and south-west, with a steep dip to the south-east, and prominent features or ridges often run in the same direction as the strike of the beds. These rocks, which are the oldest in the sheet, also form an incomplete ring round the granite in the northern parts of Arran where they occupy high ground generally, for though the formation is found on the sea coast from Dougrie to Newton the land rises rapidly from the sea level. These rocks often occupy a kind of plateau rising to over 1000 feet in the district reaching from Glenshant Hill to Whitefarland. In the north-east of Arran the formation attains a height of 1453 feet above the sea. Crags and minor features are common in the formation, both on the sea coast and inland, some of which are in a great measure due to joints or faults.

Separated from the metamorphic rocks by a fault, the Lower Old Red Sandstone forms in the main a curved, highly dipping strip, stretching from Corloch on the east side of Arran to Dougrie on the west coast. The conglomerates of this division form prominent hills in North and South Glen Sannox, but the highest point of this band is An Tunna, 1184 feet, north of the String Road. There is also a detached portion of this sub-formation to the east and south of the smaller granite area at the heads of Glen Dubh, Benlister Glen, and Clachan Glen. It rises to 1346 feet in Cnoc na Croise.

The main portion of the Great Cumbrae and a large portion of Bute consist of Upper Old Red Sandstone rocks, which are comparatively featureless except near the coast. This formation also occupies a portion of the Ayrshire coast.

In Arran these rocks occupy the shore between the Fallen Rocks (near Corloch) and Corrie, and they form a narrow band to the east and south of the Lower Old Red Sandstone and apparently conformable to that division. On the north side of North Glen Sannox the conglomerates of this division form a marked set of features with a northerly dip, and here they are unconformable to the lower division.

Carboniferous rocks (aqueous) form small portions of south Bute, Great and Little Cumbrae, and Ayrshire. They are also found in several places in north Arran, the principal area being between the Cock and the Fallen Rocks, where they occupy a narrow band dipping steeply northward and bounded on the west by a fault. On the south side of a great anticlinal we find these rocks with a southerly dip for a distance of half a mile along the shore at Corrie, and they form a narrow, interrupted band, stretching thence southward and inland to near the head of Benlister Glen.

The New Red Sandstone occupies a small area in the north of Arran near the Cock, and the whole eastern shore southward from Corrie. Inland, we find it as far west as Glen Ormidale and Gleann Dubh, and high up Benlister Glen. There are fine crags formed of this rock in Gleann Dubh. This formation rises to near 1000 feet above the sea close to the Cock of Arran, in Maol Donn to over 1200, and on either side Gleann Dubh to 1250. On the western side of the island it spreads over the vale of Shiskine on either side of the mouth of the Machrie Water.

The Rhætic, Lias, and Cretaceous formations are fragments found in a volcanic vent of Tertiary age.

Of the contemporaneous Igneous Rocks—the lavas and tuffs of probable Arenig age are only found in North Glen Sannox in Arran, where some bands form prominent crags.

The lavas of Lower Old Red age are only found on the west side of Arran in a narrow inconspicuous band, and those of Upper Old Red age occupy a much faulted strip on the east side of the island between the mouth of North Glen Sannox Burn and Corloch.

The Lower Carboniferous Volcanic Rocks occupy considerable areas in Ayrshire, Little Cumbrae, and South Bute. In the latter locality the lavas form a striking set of ridges, which dip steeply to the south-west; in the Little Cumbrae they are disposed in a shallow synclinal, and the beds form a series of gently sloping terraces, which feature caused the island to be named in ancient times *Cumbrae Deas.* These rocks are found in several parts of Arran, where they form few conspicuous features.

Intrusive rocks of Carboniferous age are numerous in Great Cumbrae, diversifying its surface and giving rise to crags in the interior. An intrusive mass of this period forms the conspicuous hill of Suidhe Chatain in the southern part of Bute.

Intrusive rocks of Tertiary age form all the marked features of the topography of Arran, and they comprise nearly one half the area of the island. The large granitic mass which has been already referred to as forming all the highest ground and the grandest scenery in the island belongs to this period, and in the southern part of the sheet nearly all the prominent hills are formed of intrusive rock, acid or basic, of Tertiary age; and Holy Island also. Ard Bheinn which overlooks the vale of Shiskine, is one of the most rugged hills of the island of Arran, and it consists of several varieties of intrusive igneous rock which have penetrated a Tertiary volcanic neck. The agglomerate of this vent forms marked crags on the eastern side of the Glenloig valley, the lower part of Glen Craigag.

The different forms of the hills in the northern part of Arran in the districts of the coarse and fine granites, has often been referred to, and generally ascribed to the different mode of weathering in the two rocks. But it is clear that in many cases the deep nicks crossing the ridges are due to more rapidly weathering basic and other dykes. Ceum na Caillich is a marked example, and A' Chir, the most serrated mountain in the island, is the one most traversed by dykes. Of course there are dykes in both granites, but the difference in weathering between dyke and granite, which gives origin to the nick, is greater in the case of the coarse than of the fine granite. In addition to this, the coarse granite is penetrated in places by veins of finer granite, and there are lines of weakness which occasionally give rise to hollows. It seems also probable that the original upper surface of the coarse granite was in the form of a dome (covered by schists, etc.). If such were the case, the coarser granite, after removal of the sedimentary cover by denudation, must have been exposed a long time to denuding forces before the finer granite appeared at the surface, and thus, whatever tended to produce the peaks and nicks, would have a longer time to operate in the case of the coarse than of the fine granite. It may be remarked, however, that some of the lower hills formed of coarse granite, like Meall nan Damh 1870, and Meall Mor 1602, are not unlike in form to the hills formed of fine granite.

Our admiration of this grand hill and valley system in Arran is by no means diminished on realising that it is all of recent geological date, and that none of it was in existence before the Tertiary Period. W. G.

AYRSHIRE DISTRICT.

The north-eastern part of Sheet 21 of the Geological Map of Scotland, on the scale of one-inch to a mile, includes a part of the coast of Ayrshire which extends from the southern outskirts of the village of Largs almost as far as the seaport of Ardrossan. This strip of country is about ten miles long, and at one point, where the land juts out into the Firth of Clyde, has an extreme breadth of nearly three miles. Stretching along the eastern margin of the broad firth, it includes a band of low ground next the shore, from which the land rises rapidly until it forms the great hilly plateau, which in the interior reaches a height of more than 1500 feet above the sea.

With this range of feature the tract of country unites considerable variety and interest of geological structure. The Upper Old Red Sandstone is well developed along the shore and on the lower slopes, and its component strata can be satisfactorily studied both on the beach and in the numerous ravines which have been eroded by the streams down the inland declivities. The passage of the red sandstone conformably upwards into the base of the Carboniferous system can be followed in these burn-sections, where the lowest sub-division of that system, known as the Calciferous Sandstones, is likewise displayed in the characteristic development which it assumes in the West of Scotland. Immediately above these sandstones comes the thick volcanic series which forms so notable a feature in the scenery and geology of Central Scotland. Only the extreme western edge of the plateau formed by the lavas and tuffs comes into the ground here described, but it includes excellent and typical illustrations of the general character and arrangement of these rocks and of their influence in the landscapes of the country. Good natural sections may be found along the craggy slopes of the hills, and also in the numerous gullies of the burns. The hillsides on the east of Noddisdale Glen, the gorge of the Gogo Glen above Largs, and Kelburn Glen near Fairlie, are particularly worthy of attention by those who wish to study the volcanic history of this district.

But the interest of this history is not confined to the sheets of lava and tuff of which the inland plateau is built up. Owing to the vast denudation which has removed the westward extension of the volcanic sheets, probably once continuous across the Cumbrae islands and the south end of Bute to the north-east of Arran, the underlying strata through which the erupted materials made their way have been extensively laid bare, and with them have been revealed many of the subterranean connections of the volcanic sheets. Sills and dykes traverse both the Carboniferous and Upper Old Red Sandstone strata, and may be examined in great numbers along the shore and in the ravines. But still more remarkable is the display of volcanic necks which mark the sites of some of the vents up which the eruptions took place. To the west of the edge of the plateau, between Largs and Ardrossan, at least a dozen of these necks may be counted. They generally form rounded, green hills, which rise conspicuously above the surrounding sandstone slopes.

Besides these memorials of Carboniferous volcanic action, the district includes some examples of the great series of younger basalt-dykes which plays so important a part in the geology of the West of Scotland, and may be assigned to an older part of Tertiary time.

The glacial phenomena of the tract of country here described, though not striking, furnish evidence that the whole of the ground was ground down by ice which moved in a southerly direction from the Highlands. The proofs of this movement are found in ice-worn rock-surfaces and in the contents of the drift-deposits.

Traces of raised beaches are found at various heights from the 100-feet Terrace down to the latest at about 15 feet above the present level of the sea. Of recent deposits the most extensive are the marine alluvia, which are laid bare in wide sandy flats at low water. The streams which descend from the hills have slopes too rapid to permit any marked deposition of sediment. There is consequently little fluviatile alluvium. Peat covers the depressions on the surface of the plateau, and in at least one place, Carlung Moss, forms a peat-moss on the lower ground. Some trifling accumulations of blown sand only suffice to indicate that the conditions for this variety of geological process are not here favourable. A.G.

CHAPTER III.

Metamorphic Rocks.

All the rocks to be described in this chapter have undergone some amount of deformation. They have been folded and cleaved, and mica or chlorite has been developed along the cleavage planes to a greater or less extent. The original grains or pebbles in the rock, such as quartz and felspar, have also been more or less drawn out or elongated in certain directions along the planes of foliation, so as to produce a schistose structure. Sometimes these planes of schistosity coincide with the original bedding of the rock, but very often they do not, and over considerable areas the true bedding is obscured by the superinduced structures.

These rocks are the oldest we have to deal with, but their exact age is still undetermined. They make up the whole of the Kintyre area included in this sheet, the island of Inchmarnock, and the part of Bute west of Loch Quien, and they form an incomplete ring round the central granite mass in the north of Arran, which varies much in width, but which at Dougrie and to the east of Lochranza is about two miles across.

In texture these rocks vary from very coarse, gritty, and pebbly varieties to fine-grained slaty rocks or phyllites. They are in this district a continuation (of course with sea intervals) of the schists on the southern margin of the Highlands which have been described in the Memoir on the Cowal district of Argyllshire, and in the main they have the same north-east and south-west strike as in the Dunoon district, but with some variations due apparently to the intrusion of the granite mass in Arran. Quartz veins, often coinciding with the foliation planes, are characteristic generally of these schists, but the amount of these varies much in different places; sometimes they are abundant, while in many districts in Arran few are to be observed. This paucity of quartz veins or the reverse, has, however, no relation to proximity to the granite, as the older writers supposed, for they were developed in the rock long prior to the intrusion of the granite. There is also great variation in the amount of mica developed in the schists. The term mica-schists, under which they have been referred to, is scarcely applicable to them as a whole, seeing that mica is sparingly developed in them except in the finer-grained varieties that appear along the coasts about Imachar, Pirnmill, and Thundergay, and the more gritty varieties in the neighbourhood of Lochranza. Along this north-western part of Arran, however, the rocks have been more than usually plicated, and contain numerous quartz veins. Along the eastern and south-eastern sides of the granite mass the schists contain little mica, and are little more than schistose grits. Generally the rock is a moderately fine-grained schistose sandstone, including occasional bands of a fine blue slate, and also rocks of a decidedly gritty character, schistose greywacke, and conglomerate with deformed pebbles.

No order of succession has been made out over a large part of the area. In Arran the rocks are much folded on the south-side of the Iorsa valley and along the west coast. To the north-east of the granite mass there is a fairly uniform dip to the south-east and east, and there appears to be a regular upward succession from the ordinary gritty schists east of Lochranza through a thick series of slates (Dunoon ?) into a thick series of alternating coarse grits and fine beds, which apparently includes in its upper part a contemporaneous volcanic group, presumably of Arenig age.

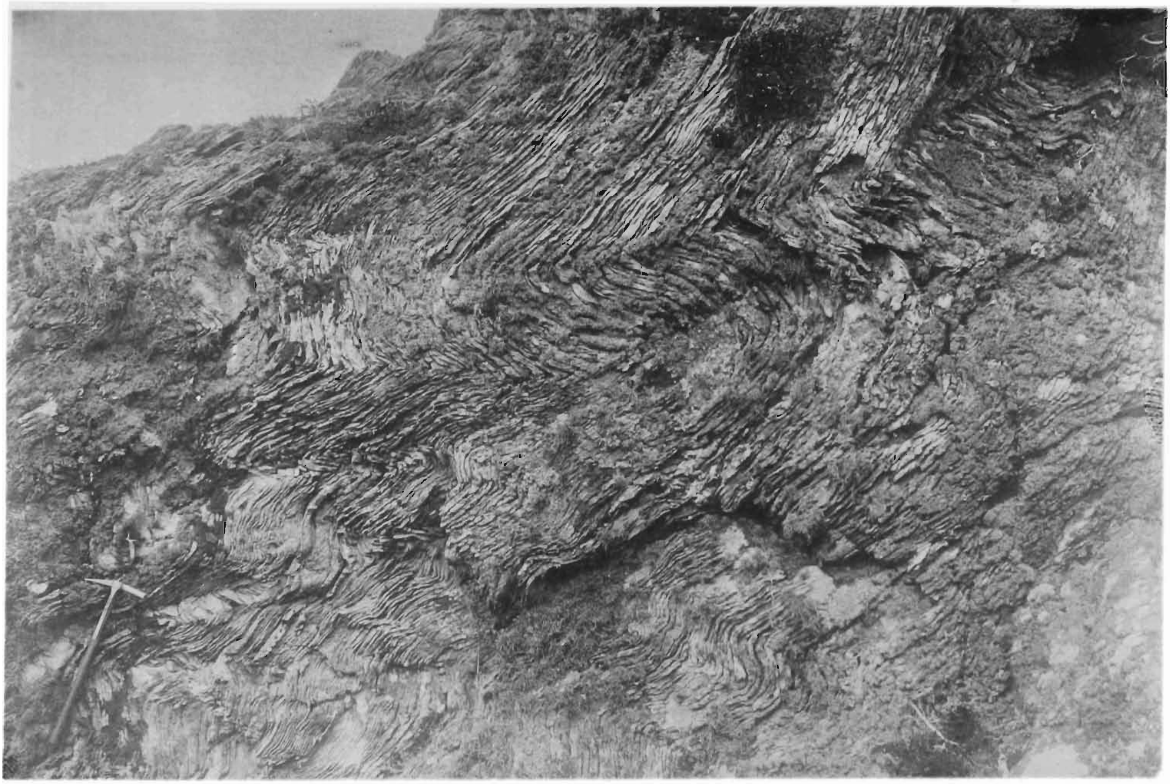
Detailed Description.—To the east of Glen Rosie there is a good exposure of schists all over Glenshant Hill. In the Cnocan Burn, below the mill dam, the true dip of the schists is to the S.E. or S.S.E. at a high angle, and the foliation dip is there coincident with that of the bedding. The rocks are mostly gritty and some are pebbly, and this type of schist prevails nearly all over Glenshant Hill. In Creag Rosie some alternations of thin gritty, and slaty bands show that the beds are vertical with a north-east strike. To the north-west of this the foliation strikes in one place to the N.N.E., while the bedding strikes E.N.E., so that the true dip is at a high angle to the S.S.E. Near the granite these rocks are considerably altered, and appear to be more contorted than usual. Much of the same type of schist prevails on the opposite side of Glen Rosie, about the hill called Cul nan Creagan, where thin quartz veins occur occasionally in the rock. In Gleann Easbuig, east side, and 950 yards north from the top of An Tunna, is a very coarse pebbly band of a slightly greenish tinge, which is about 30 feet in thickness. The deformed pebbles are of quartz and felspar, and the rock which contains them set in a slightly chloritic matrix, may be traced in a direction slightly north of west for about 200 yards, cutting across the foliation of the ordinary schist near. There is much gritty schist on the north-west side of Gleann Easbuig, but no rock so coarse as that described above was noticed there. On the hills called Beinn Chaorach and Beinn Lochain to the south of the Iorsa valley the schists are generally so plicated that it is difficult to make out any prevailing strike. Much of it is fine-grained with quartz veins. On the north side of the Iorsa the rock is altered by the granite, and the foliation rendered obscure in many places, the most prominent planes being joints, which seem the result of the granite intrusion. The rocks are well exposed in the lower part of Glen Scaftigill, and in the adjacent burn of Allt na h-Airidhe. In Glen Scaftigill the schist is moderately fine-grained, and bluish or grey in colour, the foliation is generally even and regular with little contortion and few quartz veins. The foliation dip is to the south or S.S.E. at a high angle; sometimes it is vertical, while the bedding as seen distinctly in one place strikes N.E., and dips steeply S.E. The foliation at this place dips

S.S.E. To the westward, about Cnoc Donn and between this hill and Dougrie Point, there is a strong band of gritty rock which is very slightly schistose, and is apparently overlying a thick band of black, bluish and grey phyllitic schist, which is much contorted. Some very coarse and pebbly bands of the gritty rock are exposed in the old sea cliffs three quarters of a mile north of Iorsa Foot, and the contorted slaty rock is exhibited in many places to the S.E. of Balliekine. Alternations of gritty and slaty schists, very much plicated, appear along the shore between Balliekine and Imachar, opposite which latter place the schists are more than usually contorted, with abundant veins of quartz (*see* Plate II.). On the hills nearly a mile E.N.E. of Imachar alternations of pebbly bands with rocks of a finer grain show that the strike of the foliation is from 10° to 15° farther west of north than that of the bedding. Both are practically vertical. North of Allt Gobhlach, along the shores of Penrioch and Auchmore, the schists are not so much plicated, but numerous faults crossing the alternations of fine and coarse rock are exposed on the shore. At North Thundergay, again, the rocks are as plicated as at Imachar. There are some very coarse bands about Penrioch, but they are usually thin and cannot be traced far. One of them contains pebbles from two to four inches long. There is also, east of North Penrioch, a band of light-coloured, schistose, micaceous limestone some four or five feet thick, which was formerly quarried and burnt for lime. It can be traced for a considerable distance to the northward. Some other very thin calcareous bands are intercalated in a dark-coloured schist.

In the lower part of the Pirnmill district the schist forms a remarkable series of ridges and hollows nearly coincident with the strike; higher up the hillsides other marked features are apparently due to joints or faults, as their direction makes an angle with the strike. Near the granite the schist is much hardened, and the finer varieties assume a bluish colour. A marked set of joints appears also to have been developed in this altered rock by the action of the granite. These joints are in places much more prominent than the foliation planes, which are nearly obliterated.

The ring of altered schist near the granite is here and there some two or three hundred yards in width. As the rock is less easily decomposed than the granite itself it occasionally forms a ridge at a higher elevation than the granite immediately adjoining. This is finely shown in Glen Catacol and Glen Easan Biorach, where the streams have cut narrow gorges through the altered schist.

On the north side of the stream Allt nan Eireannach, nearly half a mile S.S.W. of Catacol Bridge, there occurs a beautifully glossy, gritty mica schist with abundant sericite mica on the foliation planes. Along a great part of this burn runs a thick band of dark slaty schist, which is probably identical with that which appears near the foot of Abhuinn Bheag on the east side of Glen Catacol. And there is strong probability that the same band continues southward from Glen Catacol nearly parallel to the boundary of the granite, but at no great distance, as far as to Allt Gobhlach opposite Pirnmill.



Contorted mica-schist with quartz-veins in shore cliffs, opposite Imachar, 2 miles North of Dougrie, Arran.

North-westerly dips prevail in the schists in the districts between Catacol and Pirnmill, though, of course, there are many minor folds parallel to the general strike. On the eastern side of Catacol Bay there is a marked synclinal fold, which runs nearly parallel to and not far from the coast. The line of it crosses the loch a little north of Lochranza Castle, and it can be observed for some distance east of the loch but gradually disappears, so that from North Newton there seems to be a regular and apparently ascending series in the schists all along the edge of the high ground to the south-eastward as far as to Corloch, where we come upon the supposed Arenig lavas. On the shore at North Newton, where the rocks have a high dip to the south-south-east, the schists are gritty, somewhat greenish and chloritic, with alternating bands of finer slaty schist, more micaceous or chloritic and with more abundant quartz veins. Some bands outcropping to the east of the hamlet are very strong and coarse. Variable rocks of more or less gritty character prevail over Cnoc nan Sgrath and Torr Meadhonach till, near the road leading to the Cock, we come upon the edge of a thick slaty series, in which there are two old slate quarries about a quarter of a mile south of the road. In the larger and more easterly quarry there are rather coarse and thickly laminated bluish slates with some pale coloured or greenish, probably chloritic, bands. The slates are not glossy, and there is not much mica on the foliation planes. Dark bluish, fine slaty schist with quartz veins appears in Creag Ghlas Cuithe at the edge of the high ground, where the dip is almost due south. In Glen Chalmadale the dip is eastward, and between these two localities the strike describes a curve of a quarter of a circle. This slate band is most probably the Dunoon series described in the Memoir of the Cowal district. To the eastwards succeeds a strong, coarse, and thick gritty mass, which is probably the Kilcreggan series. It is a very massive grey and greenish greywacke, only slightly schistose, the bedding of which is as even and as regular as a sandstone. In one place there is interbedded a few feet of greenish slaty rock, which much resembles the green beds in character. Pebbly bands are common in this rock and show the bedding clearly, which dips from 30° to 50° E.S.E. This rock forms a very fine set of crags, some of which are bounded by straight faces running nearly across the strike. They appear to be due to joints, along which the rock has parted, and masses have fallen away. In the upper part of this series are alternations of slaty and gritty beds which give rise to strike features crossing the line of crags. These pass up into a greenish slaty series which forms the highest ground at the Ordnance Station 1453, and this is the highest point attained by the schists in the island. About half a mile south of this the gritty series below forms crags at Creagan a'Choilich, where a very coarse, pebbly, quartzo-felspathic band may be seen. Eastwards from the Ordnance Station another thick gritty series comes on above the finer band, the upper part of it being marked by a very coarse, quartzose pebbly band 100 yards in breadth. In various places along the course of this band it may be observed that the true dip as shown by the quartz pebbles is high, sometimes nearly vertical, while the planes of schistosity or foliation dip about 30° or 40°. At the southern exposure of this band there is a cross fault which shifts it westward 100 feet or more. The crag here is visible at long distances. The pebbly quartzose rock is white in colour, and is penetrated by conspicuous white quartz veins. A portion of the rock might be described as a conglomerate. Another band of dark and bluish slaty schist succeeds to the eastwards, and is some 200 yards across, but is little exposed except on the crags; and then comes a gritty series, variable in character, half a mile across, which continues till we arrive at the so-called Arenig traps. W. G.

SKIPNESS DISTRICT.

In that portion of Kintyre which enters into Sheet 21 the metamorphic rocks which floor the whole area consist of alternations of quartzose mica schists and phyllites, the former being greatly in excess of the latter. The microscopical examination of specimens [9545, 9546, 9547,] by Dr. Flett shows that the quartzose varieties exhibit every grade of alteration from schistose grits in which pebbles of blue quartz and cleavable felspar occur, which are only granulitized peripherally and set in a schistose matrix composed of a secondary granulitic mosaic of quartz and felspar traversed by wavy films of white mica and more or less chlorite, into schists in which the remains of pebbles are not readily detected, as the whole rock is converted into a granulitic mica-schist in which the pebbles are represented by flattened granulitic aggregates. There is a regular gradation from these quartzose schists into phyllites and mica schists by the increase in the proportion of mica to the other ingredients, evidently owing to original differences in texture and composition, the finer phyllites and mica schists doubtless representing the more argillaceous bands. When not stained these rocks are usually greenish-grey in colour, according to the amount of chlorite they contain, but the phyllites are leaden-grey coloured and slightly calcareous. Both sets of rocks are much traversed by quartz veins.

In a great many cases the original bedding is still readily made out, while the foliation for the most part does not coincide with the bedding planes. In some cases at least two sets of foliation planes can be seen to lie oblique both to the bedding planes and to one another.

The rocks in the area are evidently a continuation to the N.N.E. of the beds which make up the greater part of the eastern side of the peninsula of Kintyre. From their relation to "Green Beds" and to the "Loch Tay" Limestone, to which they behave in Kintyre in the same manner as the Ben Ledi grits do in the rest of Argyll and in Perthshire, there can be little doubt that these rocks in the present area represent the upper members of the "Ben Ledi grit" group.

The schists are much crumpled and wrinkled, and in the N.W. corner of the sheet they can be seen to be folded upon almost vertical axes, while over all the rest of the area they appear to dip towards the south-east; but this does not necessarily imply that there is an ascending order of succession in that direction. The apparent dip is due to their being isoclinally folded, the axial planes of the folds being inclined in that direction. That this is the case throughout the whole eastern side of the peninsula of Kintyre is shown by the behaviour of the overlying "Green Beds" and "Loch Tay" Limestone in the Campbeltown region. By following the outcrops of these beds it can be shown that the apparent axis which runs along the centre of the peninsula, away from which the rocks appear to dip on each side, is in reality an axis from which the axial planes of isoclinally folded beds dip away, and that in spite of the apparent easterly dip of the strata in the present area the beds which crop out at Skipness may actually underlie those exposed along the great central axial line. This is rendered highly probable, for in the adjoining region in Sheet 20, just out, of the present map, a fold of the "Green Beds" is found on the shoulders of Bhein Bhreac between the schistose grits which crop out on the shore at Cour and the central axis, the Cour rocks being a continuation of those that occur near Skipness.

The best exposures of rock are found along the coast, but owing to the coast-line coinciding more or less with the long axes of the folds, the same beds often form the coast-line for long distances. Inland, the principal streams do not as a rule expose rock-sections near their mouths, but flow over glacial deposits, raised beach material, or through their own alluvia. This is propably due to the land having stood at a higher level in pre-glacial times than at present, so that the rocky bottoms of these drift-filled valleys are actually below sea level at or near the coast, phenomena common around our shores. Further up the valleys the streams have cut down through the drift and exposed sections, but the best inland exposures are to be found on the hillsides, which are often rocky.

B. N. P.

CHAPTER IV.

Arenig (?) *Rocks.*

A strip of rocks that may be separated from the ordinary schists of the island is found in North Glen Sannox, It crosses the valley from south to north at a distance of rather over a mile from the sea. It is upwards of a mile and a half in length, and its width varies from 100 to 400 yards, being narrowest at its northern end. The rocks in this area, so far as can be ascertained, are not separated by any structural line from the ordinary schistose grits on either side of them, and they appear to be essentially a part of the metamorphic series of the Highlands. They differ much in character, however, from ordinary schists, in that they consist mainly of igneous rocks, both volcanic and intrusive, with which are intercalated bands of black shales or schists, and thin bands of chert.

The black shales and cherts are associated together, as they are in the Aberfoyle district along the Highland border, and in the band of similar deposits intercalated with volcanic rocks in the Arenig group of Ayrshire. The black shales are partly in the condition of phyllites, and are much contorted in places. The cherts are perceptibly granulitized, and in structure similar to those parts of the cherts which have been altered by the granite of the southern uplands. When in this condition, such rocks have generally lost all trace of their organic remains, and no radiolaria have yet been found in these Arran cherts. The most prominent members of this group of rocks are those of igneous origin, and it is now definitely ascertained that there is in Arran a very old volcanic series which includes undoubted lavas and volcanic tuffs. The lavas form bands of a dull-green, fine-grained rock, which may be conveniently spoken of as "greenstone." Like their associated sediments they have undergone a considerable amount of deformation, and are now in the condition of epidiorite. The whole of the rocks, both aqueous and igneous, appear to be in the same state of metamorphism as the schists to the east and west of them. They have an apparent dip to the east-south-east at high angles, and sometimes are practically vertical, and it is by no means certain which is the top or bottom of the series. They have also undergone much plication, which is particularly observable in the intercalations of black schist, and, as has been before observed, they are flanked on either side by schistose grits of the ordinary southern Highland type.

The strip of rocks thus defined is truncated at its southern end by the intrusion of Arran granite at the north-east end of the ridge of Suidhe Fheargħas, while its northern boundary is a fault which brings down against it a part of the Lower Carboniferous series. The schistose grits, which apparently underlie these rocks, are well exposed in the North Sannox Burn at the bridge, while another series of schistose grits, which apparently overlies these volcanic rocks, can only be observed in the main stream and on the south side of the glen, as they are cut out on the north side by the Highland border fault, which brings down the Lower Old Red Sandstone against the igneous rocks. This fault gradually crosses the line of strike of the igneous group, so that only the lower portion of it is represented at its northern end.

The general succession of the members of this group of rocks, together with the underlying and overlying sedimentary strata belonging to the Highland schists, is apparently, in descending order, as follows:—

1. Coarse schistose grits or gritty schists, grey in colour, and weathering with a smooth surface.

2. Thin bands of slaty schist, with traces of dark schist or shale, apparently alternating in places with thin bands of greenstone.

3. Upper bed of greenstone, generally fine-grained and quite schistose in places, with some lenticular bands of agglomerate.

4. Bands of light-coloured and dark chert, associated with bands of laminated black shale or schist. Lenticular bands of volcanic tuff and of schistose grit also occur on this horizon.

5. Lower bed of greenstone, often massive. It contains an agglomerate band on the north side of the valley.

6. Bands of black shale or schist, associated with chert, and with some fine-grained slaty schist. There are traces of agglomerate also.

7. Thick mass of strong and coarse schistose grit, sometimes greenish in colour and generally different in character from No. 1.

The whole succession may be observed in the North Sannox Burn, and on the hillside to the southward. On the north side of the glen the upper grit and greenstone are obscured by glacial drift for some distance till they are cut off by the Highland fault. Nos. 2 to 6 embrace the rocks supposed to be of Arenig age.

The gritty schists, No. 7, are well exposed in the stream where the road to Lochranza crosses, both above and below the bridge. They are here crossed by some basalt dykes. About 70 yards east of the bridge the coarser rock contains a band of fine-grained schist, and 80 yards further down the stream dark schists are seen to be associated with a brecciated rock like that which occurs in several places. It is composed of fragments of old lava, but is not exactly like a true volcanic agglomerate, and may have been produced by the brecciation of igneous rock in motion before final consolidation. Above these rocks in the main stream comes the lower mass of lava (No. 5), which occupies the burn for a hundred yards. It is for the most part a massive rock, moderately fine-grained, and of a greenish-grey colour. It exhibits well developed "pillow-structure" identical in character with that of the basic lavas of

Arenig age in the southern uplands, but not on so large a scale (*see* Plate III.). The chilled and rounded margins of these "pillows," and the numerous amygdales that are found a short distance inward from their surfaces are marked features. The dark schist that apparently overlies the pillowy lavas is much contorted in places, and is accompanied by a breccia or agglomerate similar to that previously described in No. 6, and also by some thin lava-like bands. The cherts that are associated with the black schists are well exposed about 200 yards up Allt Cairn Bhain, a small stream on the north side of the glen. Some of them are dark in colour, but the thickest and purest bands seem generally to be grey or light-coloured. High up on the south side of the valley there is associated with this black schist a strong gritty band, and immediately upon this rests the upper greenstone, No. 3. In the main stream this is but occasionally exposed, and the best sections of it are in the hillside to the southward. It much resembles the lower bed, but the pillowy structure is not so prominent. In its upper part the rock is often so schistose that it might be taken for the so called "green beds" of the southern Highlands. There is a good exposure of this upper lava on and about the two small hills called Cnocan Donna, where the doubtful Arenig rocks attain their highest point above the sea (944 feet). On each of the knolls a band of true agglomerate is interbedded with the greenstone. These bands are lenticular, and are made up of large angular fragments of fine-grained lava. Neither of them can be traced for more than 40 or 50 yards along the strike, and the more southerly is not more than 6-feet across at its widest part. The other is larger, and probably as much as 30 feet across in its broadest part.

The upper schistose grits, but partly exposed in the main stream, are a prominent feature on the hillside to the southward, where they form a strip of ground 200 yards in width. They can be followed in this direction along the strike to the eastward of Cnocan Donna till they in turn are cut off by the granite.

The lower greenstone forms prominent crags, one of which, about 300 yards south-south-east from the bridge, is a conspicuous object from the road. The same rock forms crags at Corloch, at the northern extremity of the area, and all the crags on the north side of the valley between Allt Carn Bhain and Allt Dornach, the next small stream to the west.

There can be little doubt that these bands which we have called greenstone are true lavas, and they show many points of resemblance to the lavas of the Arenig volcanic series of Ayrshire.

Two specimens from these doubtful Arenig lavas have been sliced and submitted to microscopical examination by Mr. Teall. One of these from Cnocan Donna on the south side of North Glen Sannox, is a fine-grained, greenish-grey massive rock (8666) composed of minute prisms of nearly colourless hornblende, epidote, leucoxene after iron ores, quartz, and chlorite.

It is evidently an altered basic igneous rock, a variety of epidiorite.

" Pillowy " structure in supposed Arenig lavas, Torr na Lair Brice. North side of North Glen Sannox, Arran.

Another specimen from Torr na Lair Brice on the north side of the glen (slide 8667) is a scoriaceous rock, the cavities of which have been filled by calcite. The main mass is formed of microlitic felspar, chlorite, leucoxene, and carbonates. It is an altered basic rock, but differs from the first in having recognisable felspar. It is closely allied to, but not identical with, the common forms of pillow lavas.

These two fine-grained rocks are highly altered greenstones, allied to those found in association with cherts in other areas.

Some additional specimens have lately been cut, and the slides are described by Dr. Flett. Three of these (9381, 9382, 9383) from Torr na Lair Brice, 550 yards N.E. of North Sannox Bridge, though differing somewhat in individual characters have a general resemblance to those described by Mr. Teall. A specimen (9384) from a small burn on the south side of the glen opposite Allt Carn Bhain is rather peculiar, being a grey-green rock with brown streaks and patches. It is a fine-grained basic igneous rock which has undergone much deformation. There is a band of this rock along the strike, and it may be seen also just south of the main stream. Two specimens of the supposed lavas altered by contact with granite (Nos. 9385 and 9386) are very different from the rest, and one of them (9386) appears to have lost all trace of its igneous origin (can it be altered black shale?) . The last of these new slides (9387) is taken from a fragmental rock of a tuffaceous character in the upper part of Allt Carn Bhain. Many of the fragments are fine-grained and not certainly igneous, but the band from which the specimen was taken is several feet thick and the coarser parts contain undoubted large fragments of the lavas. This band is associated with the black schists.

Intrusive Igneous Rocks, Probably of Arenig age.

At a distance of 600 yards north from the main stream in North Glen Sannox, and near Allt Dornach, is a rock which differs considerably in character from the lavas. It is coarser grained than these, and was probably a hornblende gabbro originally. It was the first of the igneous masses to be noticed in this area, and from the way in which it is associated with ordinary schistose rocks of a clastic origin it was regarded as an intrusive rock, which view has subsequently been corroborated by the result of a microscopic examination and also by its similarity to undoubted intrusive rocks associated with the Arenig lavas of Ayrshire. It forms a band some 15 to 20 yards in width, which is about 50 yards east of the small stream mentioned, and on the west side of the bedded lavas, and separated from the latter by a considerable band of black schists with chert. The intrusive band, however, as given above, includes some lenticular and irregular strips of schist. The best section occurs a few yards below the old track or road which was formerly the highway to Lochranza, and the intrusive rock there forms a small crag, but it cannot be traced far either way. A rock of a somewhat similar character is found on the west side of

Allt Carn Bhain (the next small burn to the east) between 100 and 250 yards north from the main stream of the glen.

EPIDIORITE OR HORNBLENDE SCHIST.

To the south of Scalpsie in Bute there is a considerable mass of epidiorite or hornblende schist which appears to form a sill or intrusive sheet in the schist. It is nearly 400 yards in length from north to south, and it occupies the hill called the Dun, on which is an old fort, and the edge of the high ground to the southward as far as the head of Scalpsie Bay. It is bounded by the sand and gravel of the raised beach on the east side, and the schists into which it is probably intruded are only seen to the west of it. On the south side of the Dun the rock is mainly a fine-grained, dark-green massive rock which may be termed an epidiorite. It is a confused aggregate of chlorite, hornblende, epidote, carbonates, felspar, and leucoxene. This altered basic, igneous rock varies considerably in character, passing southward and northward into a fine-grained hornblende schist with epidote.

There is strong reason for the view that this mass of epidiorite is closely related to that associated with the supposed Arenig rocks of Arran, and there is every probability that we are in this part of Bute just below the horizon of those contemporaneous volcanic rocks.

SERPENTINE.

On the west side of Scalpsie Bay in Bute serpentine occurs in two places in or near the large fault skirting the west side of the bay. In the first case it is about 75 yards from the head of the bay and just below high-water mark of the ordinary spring tides. It is apparently just at the edge of the fault, is much crushed, but can be traced for a little distance westward. No other rock is seen in contact with it. About 75 yards farther to the south-west, and nearly at the shore line, serpentine again occurs. This locality is 25 yards from the wall which here runs parallel to the shore, and nearly opposite a cross wall. Here again no rock is seen in contact with the serpentine, but a short distance to the south-east white carboniferous sandstone on the other side of the fault appears, dipping south-south-east at 30°. The serpentine is a compact pale-greenish rock, remarkably uniform in character, and the alteration so complete as to make it impossible to say what the original mineral was which makes up its aggregate of irregular scales, but it was probably not olivine. It must, however, have been some basic or ultra-basic rock intrusive in the schists, for similar rocks are thus seen west of Loch Fad, and near Innellan in the sheet to the north (29, one-inch).

CHAPTER V.

Old Red Sandstone.

A strip of the Old Red Sandstone occupies the eastern coast of Arran from the Fallen Rocks at Corloch southwards to near Corrie, and continues inland as far as the Brodick woods, whence it sweeps as a belt across the centre of the island to the western coast near Dougrie. A detached part of the formation is found on the eastern and south sides of the smaller granite area from Glen Dubh by Cnoc na Croise and the head of the Clachan Glen round to near Cnocan Biorach. This portion, which is some three miles to the south of the String Road, is invaded by intrusions of granite, granophyre, and diorite, by which all the surronnding strata are highly altered.

Lower Old Red Sandstone.

This subdivision of the formation does not appear on the eastern coast, but is well exposed in North and South Glen Sannox, partly in the streams and partly on the hillsides. It consists of course conglomerates, red mudstones, and purplish felspathic sandstones. The blocks in the conglomerates are well rounded, and many of them are of a pinkish or white quartzite, often associated with pebbles of andesite derived from the denudation of lavas belonging to a lower part of the formation. The conglomerates are associated with, or alternate with beds of red or purplish fine sandstone and mudstone, and generally form the lowest and most westerly part of the formation as exposed in these glens. The middle portion is composed largely of mudstones and flaggy sandstones, and the higher part is mainly felspathic sandstone, somewhat coarser and thicker bedded than that in the middle part. All these beds have a general easterly dip often at high angles.

A great series of purplish-red and chocolate-coloured sandstones, generally hard and micaceous, and often thin bedded, occupies Glen Shurig and strikes south-west, with a high dip to the south-east, across the String Road. These rocks have been quarried in places for road metal. They form, apparently, the highest portion of the lower division of the formation. As the dip is high, they must be between 2000 and 3000 feet in thickness. Although in places the dip is reversed there are no apparent contortions, so that the strata are probably occasionally inverted as they must be in the Cnocan Burn, and on the west side of Glen Rosie. It was in this group of rocks in Glen Shurig, in a burn near the String Road, that Sir A. Geikie and his students found a specimen of *Psilophyton* in the year 1882. From the same upper part of this subdivision in Glen Shurig about a dozen specimens of plants were obtained by Messrs. Macconochie and Tait, the fossil collectors of the Geological Survey, in 1897. Mr. Kidston, to whom these were submitted for examination, could only identify one of them specifically as *Psilophyton princeps*, var. *ornatus*, Dawson.* He, however, thinks that all the other specimens belong to this species, which is characteristic of the Perthshire and Forfarshire Old Red Sandstone, and is not known in the Caithness Flags. The strata in which these plants were found are hard, purplish, flaggy, micaceous sandstones, often weathering of a yellow tint, and they must be several hundred feet lower in the formation than those which yielded *Psilophyton* in 1882, but both belong to the same set of beds. The exact locality for the specimens collected by the Geological Survey in 1897 is in the main stream of Glen Shurig, about 200 yards above its junction with Allt Mor, which is its principal tributary on the south side. In the south bank of the stream at this point is a good shale band about three inches thick, and it was from this bed that the plants were obtained. Some fragments were also got on a somewhat higher horizon, some 100 yards lower down the burn and nearer Allt Mor, and it was in Allt Mor itself, but some distance up from its foot, that the specimen was obtained in 1882.

The thick masses of mudstone, interstratified with coarse conglomerates made up mainly of quartzite pebbles, so conspicuous in North and South Glen Sannox, are much attenuated in Glen Shurig, while the upper felspathic sandstones are much thicker.

In Glen Rosie, near the schists, a type of the formation occurs which is not red but grey in colour, and contains a different set of pebbles, which are mostly of quartz. It may be observed in a vertical position at the bend of the burn half a mile west of the wood. The rocks here have a north-north-east strike, and appear to have been confounded with the schists by some observers. Epidote is pretty common in these rocks, and also in some similar in character and position near the schists in Garbh Allt, north of Monyquil.

East of Dougrie there are fine sections in the Old Red Sandstone on the shore and in the old sea-cliffs, but a portion of the rocks there exposed probably belongs to the upper division of the formation. The Lower Old Red Division, which is characterised by thick bands of coarse quartzite conglomerate, alternating with red and purplish sandstones, must in places on this side of the island have a thickness of several thousand feet, with a high southerly dip ranging from S.S.W. to S.S.E. The coarse conglomerate forms a broken ridge of high ground east of Auchencar, and is apparently unusually thick in the hill of Garbh Thorr, near Monyquil, which is probably bounded on either side by a large fault. Below this mass of conglomerate is found a volcanic zone, composed of lavas

* These plants were obtained from Locality No. 49, given in Appendix A.

some 50 or 60 feet thick, which is elsewhere described (*see* page 26). These crop out in Auchencar Burn, to the north of the hill Baniorlach, one and a quarter miles farther east, and to the north-west of Garbh Thorr. Below this zone the rocks consist mainly of sandstone. The sandstones which overlie the conglomerate, mostly thin-bedded or flaggy, are exposed in the Machrie Burn, west of Cnoc na Ceille.

The boundary between these undoubted Lower Old Red Sandstones and the beds above which may belong to the upper division of the formation, is somewhat arbitrary and uncertain, as the dip and strike of the two set of rocks are, on this side of the island, everywhere the same, and no fossils can be obtained to assist us in the determination of the exact line. In the old sea-cliff, near the Dougrie schoolhouse, more than half a mile north of Auchagallon, there is a variegated marl bed covered with oval or round white and greenish spots, and there are also narrow bands of the same material along joints, some of which are also lines of movement. This bed, which is 12 to 15 feet in thickness, with some irregular sandstone on one side, contains doubtful traces of plants. This band is included in the lower division, and the rocks above are referred doubtfully to the upper or middle division. Similar greenish marl bands are found along the strike in the Machrie Burn, and in a smaller burn farther east, and some much thinner bands of the same kind also occur in the Machrie Water, so that the line given on the map seems to follow a definite horizon, if it is not an actual boundary between two sub-formations. Below these bands in the Machrie Water the rock is much hardened and jointed, for which alteration there is no visible cause except an intrusive basic dyke.

In the Clachan Glen, to the south of Beinn Bhreac, the rocks of this sub-formation have been intensely altered by the granophyre, so that now they are totally unlike Old Red Sandstones in character. They are, in fact, more like old silurian greywackes, very hard and tough, and of a bluish-grey colour. They are also apparently contorted in places, and the bedding cannot always be determined. A similar alteration in the rock has taken place on the north side of Gleann Dubh.

In the upper part of the Merkland Burn, outside the Castle woods at Brodick, there are some rocks of a peculiar type in this division. Near the edge of the wood, but inside, conglomerates with well rounded pebbles of the true Lower Old Red type may be observed in a vertical position and with a northerly strike. Succeeding to these, outside the wood we find sandy red mudstones in the stream for a hundred yards. They have the same vertical strike as the conglomerates, but the last visible strata of this kind have a strike directed somewhat west of north. These rocks are abruptly truncated at a waterfall by a totally different set which come on along a line running about north-north-east. The junction line may be a fault, and the rock which we first come to on the other side has somewhat the appearance of a dyke a few feet in width. North of this we seem to have recognisable purplish mudstones, altered, however, with another possible green dyke parallel to the stream on the west side. Below the first branch stream on the west side there appear to be fairly recognisable altered mudstones striking north-east and dipping south-west. All these rocks have a number of yellowish-green veins and patches of epidote.

Above this, in the main stream, for a long way, is a mass of apparently fine-grained, blue-grey rock with very indistinct traces of bedding, and not at all resembling the ordinary type of Old Red Sandstone. Similar rocks may be seen in both the branch streams on the west for a distance of about 200 yards up them, where rocks of an undoubted gritty character appear. In the upper branch stream this is a white hard-baked sandstone, almost a quartzite, which has evidently undergone considerable alteration. This has been microcopiscally examined by Mr. Kynaston, and is seen to consist principally of numerous small rounded grains of quartz and felspar, some of which is microcline and some plagioclase. The interstitial material often has the appearance of a fine quartzose mosaic, as if it had been recrystallized, but the larger grains show no perceptible alteration. There are some grains of epidote. The highest observed rock in the main stream, 700 yards above the wood, is clearly an altered sedimentary rock, a rather coarse grit with numerous fragments of andesite, more or less rolled, quartz-grains, felspar, epidote, etc.

The doubtful rocks, some of which have been sliced, will be referred to again (*see* p. 27) with some remarks on the probable cause of the alteration which is visible in the undoubted grits.

CONTEMPORANEOUS IGNEOUS ROCKS OF LOWER OLD RED SANDSTONE AGE.—In the Lower Old Red Series of Arran, on the west side of the island, is an interbedded volcanic series. It occurs near Auchencar as a band of lava, and may be traced eastward for about two and a half miles as far as to the north-west side of Garbh Thorr near Moniquil. Everywhere it dips steeply to the south and underlies the main mass of the conglomerates, while the strata below it consist principally of sandstones. Where this lava crops out at the surface it is largely amygdaloidal and apparently of a basic character, though the lower portion of it is in places more compact, and seems to be more basic than the rest. The best section of it occurs in the Auchencar Burn, about seventy yards east of the moor fence, where a thickness of from fifty to sixty feet is exposed. Here the rock is amygdaloidal above and compact below. As the band is nearly vertical it occupies but a narrow strip of ground, and, besides, it is a good deal concealed by drift. Still, traces of it may be found in several places to the eastward, and undoubted outcrops of it occur to the north of a conglomerate hill called Baniorlach, and also to the north-west of Garbh Thorr, where the band appears to be thicker than in the Auchencar Burn. For the appearance of these rocks under the microscope see Appendix.

In the conglomerates above this volcanic zone, pebbles of an andesitic rock, presumably derived from the lava, are common. It seems probable that the volcanic series was largely denuded before and during the formation of these conglomerates, which contain these basic igneous pebbles in various parts of the island where no other traces of the former presence of these contemporaneous rocks exist. Some of these pebbles from near Auchencar and from Glen Sannox have been microscopically examined, and descriptions of of them by Mr. Kynaston are in the Appendix.

INTRUSIVE IGNEOUS ROCKS OF LOWER OLD RED SANDSTONE AGE (?).—In Glen Rosie, about three quarters of a mile west of the hamlet, is an intrusive sill in the Lower Old Red Sandstone. It crops out in the southern bank of the stream, and may be traced up the hillside to the southward and over the moor for nearly a mile. Two prominent knolls formed by it are called Torr Breac and Torr Dubh, and at these places the sill is about 300 feet in width. The rock is very massive, fine-grained, grey in colour or pinkish, and contains in places veins of epidote. It is a peculiar rock, and seems of an intermediate rather than basic composition. It appears always to contain a pale-coloured augite, and is a salite diabase.

In the Lower Old Red Sandstone on the south side of Glen Sannox is a large dyke which forms a marked ridge trending west-south-west for nearly three quarters of a mile. It crosses the stream, Allt a' Chapuill (which enters the Sannox Burn near the old barytes workings), and runs toward the granite hill of Cioch na h-Oighe, but no trace of it is to be found in the granite. Its average width is about 150 feet. It is a coarse grained, brown-coloured rock, apparently a kind of salite-dolerite. See Appendix for the microscopical characters of these intrusive rocks.

DOUBTFUL ROCKS.—In Merkland Burn, Brodick, a mile and upwards from the sea, in the Lower Old Red Sandstone area, are some rather puzzling rocks, which seem at first sight a good deal like altered grits, in which the bedding is often very obscure. Some specimens from this locality, however, are very like felsitic tuffs or agglomerate, and some of the fragments have points of resemblance to the salite-diabase of Glen Rosie. But it must be remembered that in places the undoubted Lower Old Red conglomerates are largely made up of fragments of old basic lavas. Mr. Kynaston, however, has examined and reported on some microscopic slides cut from the rocks as well as some undoubted Old Red rocks from the immediate neighbourhood, and is inclined to the view that they are of pyroclastic origin, of the nature of tuffs or agglomerates. One of the specimens sliced was the supposed dyke at the edge of the mass, which is a fine-grained dark rock, apparently of a massive character. Under the microscope, however, it appears partly andesitic, and in a more or less fragmentary condition, and partly consists of small fragments of quartz and patches of calcite in a fine matrix. It is difficult to determine the exact nature of this rock, and it seems possible that it is essentially a massive rock which has been broken or crushed along or near a line of fault, which may be of later date than the alteration surrounding the doubtful rock, for there is no trace of such alteration on this side in the Lower Old Red Mudstones.

These doubtful rocks cannot be observed in the drift covered and peaty ground east of the main stream, but they would appear to be comprised in an oval area which is about 500 yards in length from north to south. As the rocks of this area differ so much in character from the genuine Lower Old Red Sandstone of the neighbourhood, and as they have many points of resemblance to tuffs or agglomerates of pyroclastic origin, it seems more probable that they belong to the latter class. It will be most convenient, then, to consider this small area as the site of a volcanic vent in the Lower Old Red Sandstone rocks, the age of the vent or the period when there was outpouring of either lavas or tuffs being still to be determined.

There remains to be considered the undoubted alteration in the surrounding rocks; at all events on the western border of the area. The large mass of granite suggests itself as the cause of the alteration; but the edge of the granite is half a mile distant, and metamorphism in the surrounding rocks cannot be traced so far away from its mass. Often in the case of Old Red Sandstone it only extends some 40 or 50 yards away from the boundary. On the contrary, the evidence, so far as it goes, favours the view that the alteration in the surrounding rocks came from within the doubtful area itself, and it seems extremely probable that the operating causes were gaseous exhalations and emissions of heated aqueous vapour in connection with a solfatara.

Upper Old Red Sandstone.

The rocks of this division of the Old Red Sandstone have been much studied in the island of Arran, where they occupy the shore from the old march of Achag (not Achab) Farm, north of Corrie, to the Fallen Rocks at Corloch, a distance of three miles. They were supposed to be typical of the whole formation of the island, but, as will be seen from the sequel, they only represent the upper part of the formation, while the Lower Old Red division is only seen in the interior on this side of the island. The equivalents of these beds in Great Cumbrae and in Bute were, while the survey of those islands was in progress, classed with the Lower Carboniferous rocks, with which they are in general perfectly conformable in the matter of dip and strike. In all three localities there are alterations of red sandstones, often false-bedded, with brecciated conglomerates, made up largely of fragments of quartz and schist derived from the denudation of the metamorphic rocks. Mingled with these, which are often more or less angular, are well rounded pebbles or blocks of quartzite derived from the conglomerates of the Lower Old Red division. Bands of shale, when they occur, are thin, but they form but an insignificant portion of the whole. As may be gathered from the name of the division the rocks are generally of a red colour.

No organic remains have been found in these rocks within the limits of this sheet, except doubtful fragments of plants found on the shore about a quarter of a mile south of Farchan Mor.

On the north side of North Glen Sannox there are two distinct sets of beds, separated by a contemporaneous volcanic series, which probably belong to the upper division of the Old Red formation.

Above the shepherd's house we find, along the hillside, a purplish-red felspathic sandstone which is pebbly in places. The pebbles are generally small, and are of coarse, reddish quartzite and white quartz, which are mingled together. Some thin bands of purplish and red mudstone, like the thick masses which occur lower down in the formation, are occasionally seen. The pebbles which occur in the sandstone are well rounded, especially those of quartzite. The dip of these rocks is clearly to the east-north-east, at angles of from 20° to 30°. These beds undoubtedly are the upper portion of the Lower Old Red Sandstone.

At the top of the slope where these beds are found a line of crags may be observed which consist of a very different type of rock, a whitish conglomerate nearly in a horizontal position, and with every appearance of being unconformable to the beds first described. The pebbles in this conglomerate are mainly of white quartz not well rounded, though a few of the well-rounded quartzite pebbles common in the lower division also occur. The numerous quartz pebbles give the rock a decidedly grey colour when seen from a distance, though the matrix is often somewhat tinged with red. Further west, beyond the first large fault, there are many rounded quartz pebbles and some of schist in the basement beds. The rocks in these crags must be considered as the lowest portion of the Upper Old Red division. They have a gentle dip to the northward and pass under a succession of massive, whitish conglomerates of like character, which alternate with reddish, flaggy sandstones. The whole forms a fine set of parallel escarpments much broken by faults. The dip gradually increases till it reaches 25° or 30° in the highest beds of the series, a set of whitish and somewhat flaggy sandstones which are pebbly occasionally and which underlie the contemporaneous igneous rocks. The beds as above described have a probable thickness of about 800 feet below the lavas. The latter are purplish-red rocks, often amygdaloidal and decomposed, which are elsewhere described (*see* latter part of this chapter). They are much faulted; their thickness is probably not more than 100 feet at the most, and they appear to thin away rapidly to the southward. Above them comes a series of red, flaggy sandstones which are surmounted by the ordinary red conglomerates and sandstones partly exposed along the adjacent coast, the highest bed of which has furnished the material for the Fallen Rocks. To the south-east of these rocks it is principally conglomerate we find on the shore for a distance of half a mile, when, after passing a fault ranging north-east, we come upon the flaggy sandstones which overlie the volcanic series. These occupy the shore for some 600 yards farther. They dip N.E. and N.N.E. at comparatively low angles, 15° on average, and at the south end are faulted against a coarse conglomerate, which occupies the shore for 200 yards, and is then cut off by a fault ranging E.N.E., which brings up much lower beds. From this point, which is 700 yards from North Sannox Burn, the section is very complicated and could not be described accurately without much detail. There are numerous faults and in one place irregular bands of impure cornstone, perhaps on the same horizon as one seen at Farchan Mor. There is no trace of the volcanic series, and nearer to North Sannox there is strong evidence for an unconformability, where in more than one place dull red sandstone abuts in a peculiar way against conglomerate. Perhaps this may be the reason for the absence of the bedded traps. As we approach the burn the dip tends more and more towards the east, and on the south of the stream it becomes south of east, and we have passed over the anticlinal line so called. The sandstones and conglomerates that lie immediately south of the burn dip about E.S.E. at angles of 30° to 40°. They strongly resemble the beds formerly described as lying below the lavas, and it is very probable they are a part of that series. Above them there appears to be an unconformability of the same kind as that occuring north of the burn. The rocks which succeed are a series of flaggy red sandstone with occasional pebbly bands, and these continue to the cross-wall, where comes on the thick conglomerate which extends a long way on the shore and which forms the fine crag called the Blue Rock. At the south end of the shore section, nearly a quarter of a mile from the South Sannox Burn, is an interesting section. A sharp line on the foreshore running N.N.W., which appears to be a joint and not a fault, divides sandstone from conglomerate for the greater part of its length, but near low-water mark sandstone is found on both sides of this line, beyond the point where the conglomerate is seen to overlap beds of sandstone. Near high-water mark, also, conglomerate occurs east of the line, wrapping round beds of sandstone. It is clear in this case there is a local unconformability. Somewhat similar cases occur south of Farchan Mor, one of which is near the Rocking Stone. The coarse conglomerate bed on which stands this stone overlaps beds of soft, shaly, red sandstone which lie below. This section was photographed and is reproduced in Plate IV. A large fault which runs nearly parallel to the coast truncates this conglomerate near high-water mark, perhaps a continuation of the fault which passes on the west of the Blue Rock; and some distance southward there are several smaller faults. Near these some curious hardened markings project from the surface of the sandstone ; some appear vertical like finger ends, and others resemble worm castings which are arranged into various patterns. The rocks to the southward are mostly red sandstones, sometimes false-bedded, which dip S.E. at angles from 20° to 30°. There are some beds of conglomerate, one of which forms the highest part of the formation, about a quarter of a mile north of the Corrie School-house. These higher beds are shown in the section of the Carboniferous rocks.

To the west of Corrie the ground occupied by the Old Red Sandstone is much faulted, and also obscured by glacial deposits, and the division between the upper and the lower parts of the formation is very uncertain. Most of the writers on Arran describe a narrow band of schist or slate along the eastern border of the granite for a distance of about three miles southward from Glen Sannox, but Old Red Sandstone certainly is the rock which

South of Farchan Mor. Sannox, Arran. Local unconformability in " Upper Old Red Sandstone." The coarse conglomerate on which rests the " Rocking Stone " overlaps, on the left, soft red shaly sandstone.

occupies this position excepting for a length of half a mile to the east of Cioch nah-Oighe, where a band of altered schist occurs next to the granite. It is mainly the lower division of the Old Red Sandstone that is in contact with the granite along this line, and it is doubtful if the upper division and the granite ever come together. The width, however, occupied by the whole formation as it is exposed at the surface is narrowed to 500 yards at the Locherim Burn, and is not more than 400 yards south of the White Water.

The lower boundary of the upper division to the south of Corrie is but an arbitrary line, as the dip and strike of both divisions are the same. It has been drawn, however, through the Brodick woods and up Glen Shurig, so as to include in the upper division rocks which could not be referred to the lower division. South of Gleann Dubh, where nearly all the Old Red rocks are much altered, the more felspathic rocks of the Lower Old Red become grey in colour, while the more quartzose rocks of the upper division are turned white, and this difference in colour assists one considerably in deciding on the boundary between them. Some of the rocks of the Upper Old Red are converted into quartzite.

In the Clachan Glen, to the south-west of Beinn Bhreac, there is a thick series of white sandstones and conglomerates which apparently occupy the position of the Upper Old Red rocks, though they do not much resemble them in character, and certainly not in colour. The white colour may be due, however, to the same cause which has so highly affected the Lower Old Red Sandstone of this district, viz., the intrusion of the granophyre and other rocks of Beinn Bhreac.

On the western side of the island the beds above the genuine Lower Old Red Sandstone are very variable. On the shore and in the old sea-cliffs north of Auchagallon they are mainly conglomerates with some pebbly sandstones. In the Machrie Burn the proportion of conglomerate to sandstone is not so great, and in the Machrie Water there is a great thickness of soft red sandstone with few or no pebbles in what has been taken as the lower part of the upper division.

GREAT CUMBRAE.

In the Great Cumbrae, as in Bute, the rocks which are now regarded as of Upper Old Red Age were formerly classed with the Lower Carboniferous. The upper limit of the formation as now defined follows the horizon of a cornstone band which may be traced at intervals from Doughend Hole, near the south-west end of the island, past Upper Kirkton, in a curved line by Terrach Hill to Ballykellet. Superficial accumulations and numerous intrusive rocks make the line somewhat uncertain in various places. On the west coast the dip is to the S.E., but becomes almost due south inland, and is never at a high angle. To the east of Ballykellet a large fault, which runs close to and parallel to the road, throws up lower beds of the Old Red Sandstone against the Carboniferous rocks, which are not found on the eastern side of the island.

From Doughend Hole the descending section in the Red Sandstone may be followed along the shore and in the old sea-cliffs. The rocks consist of alternations of false-bedded red sandstone and coarse conglomerate. The dip is at first to the south-west at 10° but soon changes, and afterwards continues steady towards S.E. or S.S.E. all along the west coast of the island. Much of the sandstone is coarse and pebbly, and false bedding is very marked in places. At the north side of Bell Bay the true dip is to the south-south-east, while the false-bedding dip is eastward. Many irregularities in the stratification may be observed, certain beds dying out and being replaced by others; and at one place, on the south side of Fintray Bay, a kind of local unconformability is seen, coarse beds overlapping on to fine.

Along the east side of the island the direction of the dip is not so constant, though the rocks are similar in character. On the eastern side of Millport Bay the rocks dip westward towards the line of fault, and the amount of dip near Farland Point is considerably greater than on the west coast, being from 20° to 25°. The westerly dip continues till we pass the Lion Rock, when it changes to east-south-east, and north of the Butter Lump to east-north-east, which is the prevalent direction as far as Clashfarland Point. The amount is as high as 30°-40° in places. On either side of Bessy's Port there is no rock on the foreshore for some distance. About Downcraig Ferry the dip is to north-east, which changes towards the north end of the island to almost due east.

Near the Glaid Stone on Minnemoer, the highest part of the island (Δ 417), there are numerous and rather large quarries in the massive red sandstone, which is not very coarse and occasionally weathers to nearly a white colour externally. The beds here dip almost due south at angles of 15°-20°.

The numerous intrusive igneous rocks of the island, the majority of which are of Carboniferous age, will be found noticed in Chapter VI.

It is somewhat difficult to estimate the thickness of this formation as exposed in the island, but it probably amounts to as much as a thousand feet. There is no sign that we anywhere are near the base of the division.

BUTE.

The conglomerates and sandstones in Bute are of the usual character. Inland sections are few and poor, and mostly confined to the burns, except in the small area bordering the road to the west of Cosson and Piper Hall, where the conglomerate is soft and much decomposed generally. The dip everywhere, both here and along the shores, where are the best sections, is generally to west-south-west, inclining to south-west in the peninsula south of Kilchattan, and to nearly due west along the northern edge of the map. The average amount is between 15° and 20°. It is impossible to give the exact thickness of the formation exposed in this island, as there is no long continuous section. The best is that on the shore between Little Kilchattan and Bruchag Point, which consists of alternations of sandstone and conglomerate amounting to about 1250 feet in thickness. The total thickness is probably more than double this amount, as there is a wide interval occupied by the sands of Kilchattan Bay before the upper beds are reached. The higher beds may be seen along the western coast where the best section, exposing probably 1000 feet of strata, occurs to the north of Lubas Port. Owing to faults small patches of these rocks appear among the Carboniferous traps to the southward, and in Dunagoil Bay the highest beds pass naturally under the Lower Carboniferous rocks. There is a good exposure of these upper beds of the subdivision along the shore to the south-east of Kilchattan, and their passage up into the Lower Carboniferous may be traced. The thick cornstone or dolomitic limestone, which has been largely quarried in former times, is regarded as the upper limit, but 300 yards S.E. of White Port a white cornstone three or four feet thick occurs among the red sandstones and several hundred feet below the horizon of the limestone quarried.

A peculiar tract of columnar sandstone is found on the shore about 400 yards east of the pier, which has been noticed by Mr. D. C. Glen*. The tract is about 20 yards wide on the shore at high-water mark, and it appears to run in a north-east direction parallel to the course of many of the intrusive dykes along this shore, for the columnar structure may be observed in the old sea-cliff 70 yards south-west of the shore-line at this point. The columns are fairly regular five and six sided prisms, some of them as much as seven inches in diameter. The dip of the sandstone and conglomerate is to the south-south-west at 30°, and the columns are arranged nearly at right angles to the planes of bedding, so that they incline steeply to north-north-east. The pebbly rocks or conglomerates appear to be as much altered as the finer sandstone; both are much hardened, in fact converted into a kind of quartzite, and they are much lighter in colour than the unaltered rock. It seems probable that this structure is due to a concealed dyke—one which does not reach the present surface—running in a north-east direction.

De la Beche ("Geological Manual," 3rd ed., pp. 471, 472) observes that some sandstones when kept in our furnaces at a heat insufficient to fuse them take a columnar form. A Coal-measure sandstone between Halifax and Huddersfield is thrown into kilns and burnt for road-making material, when it frequently becomes columnar. The columns are variable in the number of their sides, are generally curved, and about half-an-inch in diameter. Macculloch ("Quart. Journ. of Science," 1829) connected this altered structure in furnaces with the columnar character of sandstone occurring in nature, and he noticed prismatic structure in a hearth-stone taken from a blast furnace. Columnar sandstone occurs in the island of Rum, according to Macculloch.

In connection with this subject, reference may be made to a

* Trans. Geol. Soc. Glasg., vol. v., 154.

paper by Mr. James Haswell on "Columnar Structure developed in Mica Schist from a Vitrified Fort in the Kyles of Bute." [Trans. Geol. Soc. Edin., vol. i., p. 229.]

The faults in South Bute that affect both the Old Red Sandstone and Carboniferous rocks will be noticed in connection with the latter formation.

CONTEMPORANEOUS IGNEOUS ROCKS OF UPPER OLD RED SANDSTONE AGE.—The Upper Old Red Sandstone of Arran contains an interstratified and contemporaneous set of lavas on the north side of North Glen Sannox. The area in which these volcanic intercalations occur is much faulted, but the position of the interbedded igneous rocks is quite clear. The Old Red Sandstone of this part of the island consists of three distinct members, the lowest of which is made up of coarse, well-rounded conglomerates, alternating with felspathic sandstones and purplish mudstones. These are the undoubted Lower Old Red rocks. Above this set comes a middle series of light-coloured or reddish conglomerates and sandstones, the pebbles in which are mostly of quartz. This series is apparently unconformable on the lower. Lastly comes an upper series of red sandstones and conglomerates which occupy nearly the whole of the coast-section in which the Old Red Sandstone appears, and it is this series which has generally been supposed to be typical of the whole of the Old Red Sandstone of the island. The volcanic series is intercalated between the middle and the upper divisions above described, and it crops out in many places high above the hillside between the shepherd's house at North Sannox and Laggantuin, but is very discontinuous from being much faulted. It consists of dull-red or purplish lavas, in places soft, and often much decomposed. The general character of the rock is basic, but a specimen from near the Fallen Rocks which Mr. Teall examined was found to be too much altered for precise determination, though it was probably a basalt originally. No trace of these rocks is found along the coast, nor in any other part of the island of Arran.

Some additional specimens were afterwards collected, and examined by my colleague Mr. Kynaston. The description of these (slides 9394 and 9395) will be found in an Appendix to this chapter. W. G.

AYRSHIRE DISTRICT.

The strata which are included here as belonging to the Upper Old Red Sandstone, were formerly regarded as the lowest member of the Carboniferous System, and were so treated in the Map and Memoir (Sheet 22) immediately to the east. Subsequent investigation, however, has shown that they may more conveniently be classed in the older system, the line of demarcation between the two series being taken at a tolerably persistent zone of cornstone which, throughout a large part of the south of Scotland, appears to mark the cessation of the peculiar conditions of sedimentation in which the strata underlying it were accumulated.

The Upper Old Red Sandstone of this district consists of red and reddish-grey sandstones, red marls, and conglomerates. Its base is nowhere visible, and owing to frequent change of dip its thickness here is not easily computed. The inclination of the strata is tolerably continuous towards S.E. from the north of Ardrossan to Ardneil Bay, a distance of three miles, and the angle varies from 10° to 17°. If no serious faulting occurs there may be a depth of more than 2000 feet exposed on the beach without the appearance of either the upper or lower portions of the whole series.

Probably a line of anticlinal axis, possibly, also, a great line of dislocation comes to the surface about Farland Head. The strata there stand on end, with a nearly north and south strike, but immediately to the north they begin to dip towards N. and N.N.E. at high angles (30° to 60°) and continue this inclination at lessening angles for about two miles. Hence the oldest portions of the whole series are probably those exposed on the beach at Farland Head and Portincross. On the east side of Farland Head thin-bedded, ripple-marked sandstones and red marls appear from under the shingle of Ardneil Bay dipping westward at 25°. The strata soon become vertical, and have here undergone so much crushing and movement as to assume a fissile structure which externally resembles that of some of the Highland schists on the opposite side of the Firth. A well-marked dolerite dyke passes in an east and west direction through the strata at the promontory, and a much smaller dyke, running towards N.E., traverses the disturbed zone farther west. Pebbly and flaggy red and reddish-grey sandstones, cut by an occasional small basalt-dyke, succeed each other to beyond the Throughlet, their angle gradually rising northwards to 60°. Between the old and the new harbours of Portincross the conglomeratic sandstones include rounded and subangular pieces of different amygdaloidal and porphyritic igneous rocks, possibly derived from some of the volcanic ranges of the Lower Old Red Sandstone. At the gap of the Throughlet a large dolerite dyke descends from the interior to the coast, and has hardened and bleached the sandstones on each side of it.

The shore south of Ardneil Bay affords the most continuous section of the Upper Old Red Sandstone in this district. Thin-bedded red sandstones with occasional seams of red sandy marl form the lowest visible members of the series, and probably belong to the same series as the similar strata on the west side of the bay. As at Portincross, also, they here pass upward into false-bedded, red pebbly sandstones with bands of conglomerate. One of these bands, conspicuous on the shore west of Overtonshore, is marked by numerous layers and patches of white quartz-pebbles. Their marked false-bedding and abundance of fragments of white-quartz give these rocks some resemblance to the Triassic sandstones of Broadford Bay in Skye. Except for the abundant dykes by which they are intersected, the red and reddish-grey sandstones present little variety along the rest of the coast to Ardrossan. They may be followed from the shore up the courses of the burns. One of the best of these inland sections will be found in the Kirkland Glen, in which, from Ann's Lodge up to Tailorleap Bridge, a distance of a mile, a gorge has been excavated in the sandstones and in the boulder-clay.

No organic remains have yet been met with in any of the strata of the Upper Old Red Sandstone of this district. A. G.

CHAPTER VI.

Carboniferous Formation.

ARRAN.

One of the most remarkable results of the geological survey of Arran is the restricted area now assigned to the Carboniferous rocks which were formerly supposed to cover a large part of the island, and it may be as well before entering into details about these strata to remove certain misapprehensions as to their position, distribution, and thickness. The Carboniferous series, it has long been known, is typically developed and best studied along the eastern coast, where it forms a narrow strip which stretches for about three miles between the Cock and the Fallen Rocks. Its thickness here has been much exaggerated from no account having been taken of numerous faults by which the strata are repeated. A narrow band of the formation, 200 yards in width, also occurs on the north shore near the mouth of the burn east of North Newton. This strip lies between two large faults. Along the shore at Corrie, Carboniferous strata stretch for two-thirds of a mile, with a dip of 20° to 25°, until they are overlapped by the New Red Sandstone 250 yards south of the Corrie Hotel. The total thickness of the Carboniferous rocks on this shore may be as much as 1200 or 1500 feet, inclusive, as at Laggan, of a volcanic group 300 or 400 feet thick. Several thin red limestones occur near the upper part of the series, but the most prominent members are the volcanic group, the thick Corrie limestone, and the white sandstones immediately above that bed. It is by these well-marked bands that the series can be followed inland and recognised among the numerous faults, some of which bring up the Old Red Sandstone and confine the Carboniferous rocks to a comparatively narrow belt. One of these north-north-west dislocations, with a throw greater than the total thickness of the series, shifts the base of the volcanic group into the burn north of Maol Donn, and another large fault running along the west side of that hill has moved the main body of the Carboniferous rocks southward again for more than a mile. The strata reappear in the Clachland Burn, whence they can be traced to the south-west through the wood, and behind Brodick Castle, in a steeply dipping band altogether not more than 200 to 300 yards in width. Though they disappear under the Brodick alluvium, some of the sandstones and shales are visible in the Rosie Burn about the bridge, and the white thick sandstones are a conspicuous feature about the manse and church. Behind the churchyard the thick Corrie limestone was formerly worked. A little farther west a large fault throws the rocks up to the hillside where the thick white sandstone forms a marked feature, and the limestone immediately below has been worked. The Carboniferous band here is 200 yards wide only, and dips steeply to the south-east; the New Red rocks, extremely false-bedded as usual, forming the high bank above. The volcanic group crops out here and there at the base, and the whole series can be followed south-west to the Windmill Hill, where it becomes entangled among intrusive masses of various kinds, which, along with faults, have displaced the rocks so that they do not occur again till the south side of Glen Dubh is reached. This locality is more than a mile south-east of the Windmill Hill, where they were lost sight of. From Glen Dubh the Carboniferous formation may be traced in a broken way southwards by Benlister Glen to near Cnoc a' Chapuill in Sheet 13, being recognisable by the presence of the volcanic group, after the Corrie limestone has been overlapped by the New Red Sandstone. There is no trace of these rocks on the west coast, the Triassic rocks reposing directly on the Old Red Sandstone without the interposition of any Carboniferous strata.

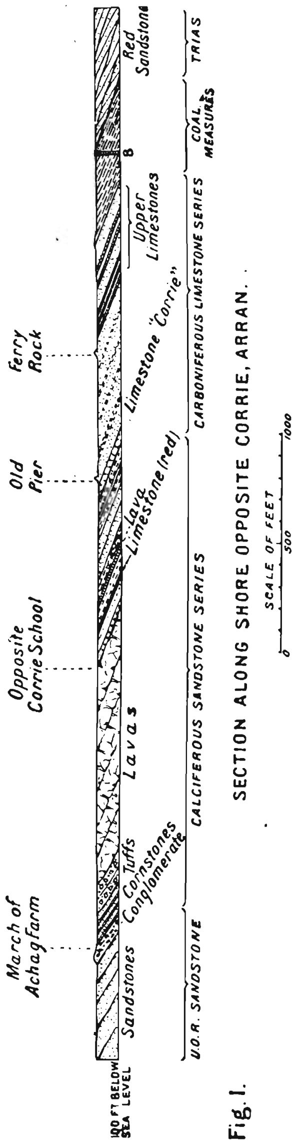


Fig. 1. SECTION ALONG SHORE OPPOSITE CORRIE, ARRAN.

Detailed Description.—It will be advisable to describe the Corrie shore-section in some detail, as it is easy to examine at low water, and is comparatively little faulted. (*See* No. 1 section, Corrie shore.) From the schoolhouse northward there is exposed on the shore, for a distance of 350 yards, the lower volcanic series, made up mainly of massive lavas, with a thick band of coarse volcanic agglomerate at the base or northern end. To the north of this for a distance of about 35 yards are various members of the lower Carboniferous rocks, including three limestones or cornstones, and below these projects a mass of red conglomerate which is the highest bed of the Old Red Sandstone. This is the locality called the March of Achag Farm by the older writers. The red conglomerate itself is 50 feet broad at high-water mark, but considerably less at low water, and the junction between it and the Carboniferous beds is peculiar. A joint or crush at the shore line, running N.N.E., appears to die out towards the sea, or is overlapped by sandstone and limestone, which abut against a nearly vertical face of the conglomerate, so that this is clearly an unconformable junction. This mass of calcareous sandstone and pebbly cornstone, several feet thick, may be faulted along a N.N.E. line against a few feet of overlying white sandstone which dips to the south-east at 25° to 30°. Above this lies red shale, and then comes a nodular cornstone, abont 15 feet thick, with a red argillaceous matrix. A gap of a few feet separates this from the uppermost cornstone, which is a whitish, irregular, calcareous sandstone somewhat mixed with reddish sandstone, and shaly below. It may be three feet thick. The 15 yards of distance between this and the base of the agglomerate is almost entirely occupied by white sandstone, the beds of which dip S.E. at 25° or more, so that it is probably as much as 20 feet thick. The whole thickness of strata between the volcanic rocks and the conglomerate cannot, however, be more than 45 feet.

The volcanic agglomerate itself is 45 yards in width on the shore, and must be 50 feet thick or more. It is a very coarse rock, made up of fragments of basic trap, sometimes as much as 6 feet in length. The lower beds of the lavas are massive, bluish, and fine-grained, and some of the upper are purplish in colour, but the whole is similar in composition, being a porphyritic olivine basalt. Near the big boulder called Clach an Fhionn, there are very fine examples of "pillow" structure in the lava. This mass of Carboniferous lavas, which are certainly contemporary with the sedimentary rocks adjacent, is probably 300 feet in thickness.

South of the school, for a distance of 75 yards, we find sandstones and shales that overlie the lavas. The dip is in the same direction as before, but only about 20°. Most of the rocks here are of a red colour, and the shales are specially so, and some are tuffaceous. Among these occurs a thin red limestone from one to two feet in thickness.

We now arrive at a projecting mass of purplish and much-veined trap 10 yards across. This is a lava bed, about 10 feet thick, and the last outflow from the old volcano in this locality. Above this is a gap of 20 yards or so, probably occupied by shales; to which succeed thick beds of white and pinkish stone, which have been quarried both on the shore and up the hillside to the westward. There is probably a thick mass of red shale above this and underlying the Corrie limestone, but it is poorly exposed on the shore.

The Corrie limestone, which occupies the old harbour, is probably the equivalent of the Hurlet. It is said to be 20 feet in thickness, and is crowded with innumerable specimens of *Productus giganteus*, well exposed on the under surfaces of many of the beds in the old quarry to the westward, which extends for nearly a quarter of a mile up the hillside. The beds of limestone are separated by thin partings of reddish shale, and from the calcareous shale immediately overlying the limestone were obtained by the fossil collector of the survey, Mr. Tait, about 60 species of organic remains, which are enumerated in the Appendix. Two basic dykes cross the limestone in a N.N.W. direction. One of these, just above the old lime-kiln, is 5 feet wide, and the other, nearly 50 yards higher up, is 4 feet in width. Several small faults also cross the quarry. One of these above the kilns coincides with one of the dykes just mentioned, and it throws down east 7 to 8 feet. A second fault a little farther up, throws down 2 feet to the west, and a third fault is down east 3 to 4 feet. Near the top of the quarry there is the following section:—

Thick Sandstone, ...	6 feet.
Shale and shaly sandstone, . , . .	3 ,,
Thick sandstone, ...	10 to 12 ,,
Shale and shaly sandstone (red), . .	3 to 5 ,,
Limestone, upper bed thick, . . .	16 feet visible.

There are slight calcareous shale partings where *Producti* are very numerous.

Between the two upper faults the *bearing* above the limestone is much less, being only 10 to 15 feet, but east of this there is probably 30 feet of sandstone and shale in the artificial cliff above the limestone. The two shale bands are variable, but the intermediate sandstone is not so thick and massive as near the top of the quarry, while 10-12 feet of the upper sandstone appears.

Headrick (op. cit. p. 344) gives some analyses of limestone at Corrie, from which it appears that the proportion of carbonate of lime varies from 90½ to 97 per cent. He also gives the following for South Currie Quarry:—

Carbonate of Lime, ...	98½.
Clay, ...	1½.

This is probably the old quarry at An Sgriob, north of Maol Donn, which is in the same bed as the Corrie Quarry, and which has also yielded a numerous suite of fossils. The beds between the Corrie limestone and the Index limestone are well exposed on the shore for 220 yards south of the old harbour, and consist mainly of alternations of thick white sandstones and flags, with occasional shale bands. The dip continues much the same in amount and direction, 20° to 30° towards the S.E. The sandstones have been much quarried for building material in the wood above the houses, and at the landing place. There is an ironstone band in one place, and fireclays, such as often underlie coal seams, occur, but there are no coals, though we are on the horizon of the coals worked at the north end of the island near the Cock. There are traces of coal plants however. The thickness of this part of the series must be about 250 feet.

A thin red limestone with *Productus latissimus* occurs about 25 yards south of the Ferry rock, and not far to the south of it occur two others, as in the following section in descending order:—

3.	Red limestone in one place, . .	1 foot thick.
	Shale and sandstone, some of the sandstone fine and like gannister, .	about 20 feet.
2.	Red limestone, ...	1 foot.
	Shale, red, ...	7 to 8 feet.
1.	Red limestone, ...	2 to 3 feet.
	Shale, argillaceous, red and mottled sandstone,	5 feet.

No. 1 of this section is the Index or *Productus latissimus* limestone (Loc. 26). No. 2 is in the locality lists described as a ferruginous band with many gasteropods (Loc. 27), and No. 3 band, which also is a *Productus latissimus* limestone, is locality 28. The fossils collected from Nos. 1 and 3 are pretty numerous, and will be given in the Appendix. We give here only those from No. 2 band.

Lingula squamiformis.
Pecten s.p.
Aclisina elongata.
,, striatula.
Dentalium ingens.
Macrocheilus acutus.
Macrocheilus imbricatus.
Metoptoma elliptica.
Murchisonia angulata.
,, quadricarinata.
Strepsodus striatulus.

There are numerous small faults about this part of the shore which in the main run parallel to the coast-line, crossing the beds nearly at right angles, and shifting their outcrops again and again for a few feet. A mass of sandstone now projects into the sea, and south of this, in front of the hotel, is a little bay in which occur two or three thin red limestones, from one to two feet thick, which are probably separated by shale, but the section is not clear. To the south of this bay there is a mass of sandstone with irregular shale bands. One of the shale bands, 8-10 feet thick at the shore-line, gradually thins away seaward, till at low-water mark it has almost disappeared. The thick sandstone underlies a mass of red and mottled clays, red and purplish shales, with occasional thin sandstones which occupy the larger bay south of the hotel. The beds in this bay are classed with the Coal Measures as they contain organic remains of Upper Carboniferous facies, but they and the equivalent beds elsewhere may possibly be Millstone Grit. About 25 yards south of the northern boundary of Cromla gardens, and near high-water mark, there was obtained a specimen of *Neuropteris gigantea*, and opposite the Cromla House the beds yielded *Lepidodendron* sp., *Carbonicola acuta*, *C. aquilina*, *Naiadites modiolaris*.

These Coal-measure strata also crop out in the lower part of Locherim Burn 200 yards from the sea, where in fine red shale 15 yards from the faulted New Red junction there were obtained :—

Mariopteris muricata.
Neuropteris heterophylla.
Carbonicola acuta.
Carbonicola aquilina.
Myalina sp. (? Verneuili.)
Naiadites sp.

Another locality near Corrie where these beds occur is on the north-west side of the Maol Donn cliff. In red sandy shale above the limestones were found :—

Artisia (Sternbergia) approximata.
Calamites ramosus.
,, sp.
Neuropteris gigantea.
,, sp.
Stigmaria sp.

There is another fossiliferous band up the Locherim Burn the existence of which was first made known by Prof. W. Ivison Macadam,* but it is in the Upper Limestone Series some 330 yds. from the sea, where the stream forks at a waterfall, and it is separated by a fault from the Coal-measure strata previously mentioned. Alternations of shale and sandstone occur with a thin limestone band. The beds above the limestone yielded the following plants to the Geological Survey Collectors :—

Asterocalamites scrobiculatus.	Rhodea sp.
Carpolithes sulcata.	Sigillaria Taylori.
Lepidodendron veltheimianum.	Sphenopteridium dissectum.
Lepidostrobus sp.	Stigmaria.

and the limestone and calcareous shale band underlying the plant bed afforded :—

Orthis resupinata.	Nucula gibbosa.
Orthotetes crenistria.	Nuculana attenuata.
Productus sp.	Protoschizodus axiniformis.
Allorisma sulcata.	,, obliquus.
Edmondia unioniformis.	Bellerophon sp.
Myalina Verneuili.	Macrocheilus canaliculatus.
,, s.p.	

In the Merkland Burn about three-quarters of a mile north of Brodick Castle there is a pretty continuous outcrop of the Carboniferous rocks, except that the section is obscured where the Corrie limestone should appear. The thick sandstones above it appear, and lower down the burn two of the Upper Limestones. From the lowest of these were collected :—

Crinoid ossicles.	Spirifera glabra ?
Athyris ambigua.	Allorisma sulcata.
,, Roysi ?	Edmondia Josepha.
Lingula mytiloides.	Lithodomus lingualis.
Streptorhynchus crenistria.	Nucula sp.
Productus costatus.	Pecten Sowerbyi.
,, longispinus.	Orthoceras sp.
,, semireticulatus.	

The limestone a few yards still lower down the stream yielded *Productus latissimus*. The more shaly beds still further down the stream are similar to the highest beds on the Corrie shore, and from them were obtained the following Coal-measure forms :—

Anthracomya modiolaris ?	Naiadites, periostracum of.
Carbonicola acuta.	Megalichthys Hibberti.
,, ,, var. rhomboidalis.	Rhizodopsis sauroides.
Naiadites quadratus.	

The same beds in a parallel burn nearly a quarter of a mile to the south-west of this gave *Carbonicola acuta*, *C. aquilina*, *Rhizodopsis* sp. All these beds have a steep dip to the E.S.E., and the dip increases towards Brodick Castle. The Corrie limestone was at one time quarried at the edge of the wood about half a mile north of the Castle,

* See his paper entitled "Notice of a New Fossiliferous Bed in the Island of Arran." Trans. Geol. Soc. Edin., vol. v., p. 316.

and there are traces of small limestone quarries west of the Castle. In the Sawmill stream 300 yds. S.W. of the Castle the beds are practically vertical. Here, a few yards above a foot-bridge, were collected the following:—

Productus latissimus.	Bellerophon Urei.
,, sp.	Euomphalus sp.
Edmondia Josepha.	Loxonema rugiferum.
Nuculana attenuata.	,, scalaroideum.
Parallelodon Geinitzi.	Natica sp.
Pecten dissimilis.	Pleurotomaria sp.
,, sp.	Orthoceras sp.
Bellerophon decussatus.	

They must belong to the Upper Limestone Series. In the mill-lade *Lingula squamiformis* was found. Shelly ironstone bands associated with shales and sandstones are found in the Rosie Burn on either side the bridge near Brodick Manse, and from one of these, a few yards above the bridge, a "musselband ironstone," there were obtained a Lycopod branch and a species of *Carbonicola*. Here we have the Coal Measures again.

The Corrie limestone was formerly quarried north-west of the church, just beyond the boundary wall of the kirkyard; and on the hillside a quarter of a mile S.E. of the String Road and half a mile and upwards west of the wood. The beds are nearly vertical in both localities and they yielded *Productus giganteus*. The Carboniferous rocks here have diminished to a band not more than 600 feet in thickness, and yet we have the Coal Measures above and the volcanic series below; bnt there is no trace in Glen Shurig of the Upper Limestones. We find a portion of the formation entangled in the intrusive masses of Windmill Hill and nearly dividing it into two. In a little gully nearly in the centre of the north side of this hill there is a section in sedimentary beds. The lowest part of the exposure contains a few feet of sandy shale, and above these there are several feet of rather thick yellowish sandstone, which dips south-east about 30°. Higher up dykes of felsite and basalt render the section somewhat confusing, but after passing these we find much red sandstone, thin-bedded and shattered, dipping like the beds below but at a higher angle; and still higher up some pebbly sandstone which is not red, but is not well exposed. The lower part of the section is certainly part of the Carboniferous, and probably the whole is. Near the highest part of the hill on the crags overlooking Glen Ormidale is a mass of red Carboniferous shale dipping steeply to the N.N.W. It contains some veins of calcite, and is a very conspicuous object when viewed from the high ground to the south, the colour of it being strongly contrasted with the light-coloured, intrusive quartz-felsite. It is certainly a portion of the cement-stone series.

By the disruptive action of igneous rocks and of faults the Carboniferous rocks are shifted more than a mile to the southward, and next occur on the south side of Gleann Dubh above a wood and north of a fine set of scars called Creag nam Fitheach. They form a triangular area bounded on the east and west by faults.

That on the east side throws down against them the Triassic sandstones and conglomerates of Creag nam Fitheach; that on the west brings up the Upper Old Red Sandstone. The volcanic series of the Carboniferous, dipping southward at angles of 25°-30°, rests on the Upper Old Red beds at the top of the wood. In the southern angle of the triangle massive white sandstone, which probably overlies the Corrie limestone, is seen, but the limestone itself does not crop out, and no other beds are to be observed. Near the west-end of Creag nam Fitheach another and still smaller Carboniferous patch occurs which is faulted on either side, but no other rock is visible than the volcanic zone.

South of this small isolated patch and beyond Brisderg, two other detached areas of Carboniferous rocks occur in Benlister Glen, on either side of a synclinal, the centre of which is occupied by Trias. It would seem that the unconformability between the two formations is more marked here than in any other part of the island yet described, for in one place beds containing plants and animals of Coal Measure age occur, while elsewhere the New Red rocks rest directly upon the Corrie limestone or even overlap that bed and repose on the shales below. On the western side of the synclinal the Corrie limestone may be seen at Benlister Burn, nearly half a mile S.S.W. from Brisderg. It appears to be repeated by a fault on the north side of the burn, but must be several feet in thickness, and from it has been collected numerous fossils, for which we refer the reader to the Appendix. Among them are six species of *Productus*. several of *Spirifera* and *Spiriferina*, and other well-known Carboniferous forms. This limestone is overlain by Triassic sandstone and conglomerate, while a few yards away, on the south side of the burn, the conglomerate rests immediately on red shaly clay, and the limestone has disappeared. However, nearly 300 yards farther to the south-west the *Productus* limestone appears again for a short distance, but in a very attenuated form (only 3 feet thick) under the conglomerate, but not immediately, and overlying a thick series of red shales and clays, with a few thin tuffaceous bands. The dip is high, being 50°-60° towards the south-east, and to the westward comes on the volcanic zone which underlies the red shales. All these rocks are much pierced by acid and basic dykes.

On the eastern side of the synclinal the limestoue appears in the southern bank of a small burn 400 yards due south of Brisderg. It is of considerable thickness, and is overlain by several feet of white blocky sandstone, on which rests the Triassic conglomerate. To the westward the conglomerate appears to overlap both the sandstone and limestone, and rests immediately on the red shales below. The greater part of the small valley to the eastward seems to be occupied by these red shales, though not many sections occur in them, owing to a thick deposit of drift, and the Triassic conglomerate appears to form the feature on the west side, which runs southward to a waterfall in the Benlister Burn, where it dips westward. No limestone here appears below the conglomerate, though red shales and sandstone, probably of Carboniferous age, are visible, dipping westward at 35°. However, by following the base of the conglomerate we come, some 200 yards to the southward, upon the limestone again, with the usual *Productus giganteus* and *Monticulipora tumida*, where a small stream occurs. The rocks here are much disturbed however. Lower down the main stream below a fall called Eas Geal (white water), at the bend of the stream there occur some shales and sandstones of a red colour, with a bed of shelly ironstone, dipping steeply to the south-east. This locality is 2¼ miles west of Lamlash Bay, and half a mile S.S.E. from Brisderg. These beds have yielded Coal-measure forms like those of Corrie, etc. There were collected here—

Calamites Suckowii.
,, sp.
Carbonicola acuta.
Edmondia Josepha ?
Naiadites crassus ?

These rocks on the west side appear to be faulted against the contemporaneous volcanic zone elsewhere described (*see* latter part of this chapter), and on the east they are thrown against Triassic rocks by a large fault which passes east of Brisderg. Another fault with a throw in the opposite direction passes west of Brisderg, and brings down the Triassic rocks on that side against the Lower Carboniferous zone, which is also bounded on the south side by a fault running eastward, throwing the red shale down against the traps.

Laggan Section of the Carboniferous Formation.—This stretches along the north-eastern shore of Arran, from the Fallen Rocks near Corloch for a distance of 3¼ miles to within 600 yards of the Cock of Arran. The shepherd's house at Laggan is 2 miles from the Fallen Rocks, while Millstone Point is a like distance from the northern end of the strip, the length of which, however, is only 3⅛ miles, as the coast-line is not straight. The width of the strip varies, but in general is not more than a quarter of a mile; it widens to half a mile at Cock Farm, but in two places south of Millstone Point it does not exceed 200 yards.

The dip is everywhere high, and nearly in the same direction; lowest at the north end, where it is about 30°, but for the greater part of the distance it is 40° or 50°, and even 60° in places. This high dip suggests an enormous thickness of beds, but it must be remembered that the general dip is in a direction to the east of north, while the trend of the coast is about 40° north of west, and is only 30 and 40 degrees removed from the general strike of the beds. In fact, there are parts of the coast-line where its direction coincides very nearly with the strike for some distance. In addition to this consideration it must be borne in mind that there are several large faults, especially in the lower part of the section, which repeat many hundred feet of the strata. Still, there is no doubt that we have here a much greater development of Carboniferous rocks than we have at Corrie; probably the thickness of the whole is twice as great, and if we confine our attention to the sedimentary beds alone the disproportion is still greater. The increased thickness is not confined to one part of the section. All the limestones are thicker than they are at Corrie, and they are more in number—there are coals which are absent at Corrie, and naturally there is a much greater development of sandstone and shale. The following is a comparative estimate of the thicknesses of the various subdivisons in the two sections:—

	CORRIE.	LAGGAN.
Coal-measures	150 feet.	250 feet.
Limestone Series	425 ,,	750 ,,
Calciferous Sandstone Series above and	275 ,,	575 ,,
below traps	75 ,,	700 ,,
	925 ,,	2275 ,,
Add thickness of Volcanic Series .	450 ,,	375 ,,
	1375 ,,	2650 ,,

The greatest difference is in the thickness of that part of the Calciferous sandstone series below the volcanic zone, which is less than 100 feet at Corrie contrasted with 700 feet in the Laggan section. It has been suggested that the trap at Corrie is a great dyke which conceals a very large fault, and that this accounts for the differences between the two sections; but the fault at Corrie, if it existed, would not explain why we have increased thicknesses at Laggan in all the sedimentary beds. Besides, we know that the thinning of the Carboniferous beds at Corrie as compared with those at Laggan is continued southward, so that in the neighbourhood of Brodick Castle and in Glen Shurig the total thickness is about 600 feet.

Some three hundred yards south of the Fallen Rocks the cornstone base of the Carboniferous rocks occurs in two places separated by a small fault. The cornstone is pebbly and adheres to the conglomerate below in an unconformable manner, like that described in the junction north of Corrie. This is separated by a considerable north-trending fault with a downthrow eastward from the main mass of the Carboniferous section which commences on the north side of the Fallen Rocks. The beds here have a fairly steady dip of 30°-40° to the northward, often inclining east of north sometimes as much as 15° or 20°. There are two cornstones of the usual light-coloured concretionary character, which are sometimes pebbly, and irregular in thickness. They are separated by a few feet of sandstone. There succeed to the northward a series of red clays with some lenticular calcareous bands, and red sandstone with quartz-pebbles. These are bounded on the north by a fault which crosses the foreshore in an easterly direction, and throws down on the north an alternating series of grey shales, thin sandstones, and calcareous bands. Among these Mr. James Thompson* discovered a brecciated or tuffaceous rock from which he obtained remains of plants and fish. At this locality, about 300 yards north of the Fallen Rocks, Mr. Tait, the collector for the survey, obtained the following species:—

Cordaites sp.
Fern rachis.
Sphenopteris sp.
Palæoniscid scales, (indet.)
Rhizodus Hibberti.
Rhizodus ornatus.
Strepsodus striatulus.
Fish-head plate.
Various bones and plates, (indet.

* See his paper in Trans. Geol. Soc. Glasgow, vol. xi., pp. 12–30.

Above these grey beds there come about 150 feet of an alternating set of white sandstones and red clays or shales, the clays containing several small, lenticular cornstone bands, the uppermost of which are fairly good continuous limestones, 1-2 feet thick, of the same character as the basal cornstones. These beds are surmounted by thick-bedded white sandstone, which continues for but a short distance, and then the section is lost for several hundred yards. Some 200 yards, however, beyond the most northerly Laggantuin Burn, white sandstones, with a northerly dip of 60° appear in the old sea-cliff, and these strongly resemble the pebbly sandstones of Millstone Point, a long way to the northward. In fact, there is not much doubt this is their position in the series. To the west of these is a large fault with a downthrow east of several hundred feet. On the west side of this the upper beds of the Old Red Sandstone, and all the lowest beds of the Carboniferous, including the cornstones, are exposed in a precipitous hill. The fault runs northward along the east side of of this hill, but on reaching the shore it, or a branch of it, runs along the foreshore in a north-west direction for 250 yards and then passes out to sea. On the inner side of this fault, along the foreshore, we again come upon the Millstone Point grits, but we do not find a continuous section up to the base of the volcanic series, for the beds immediately underlying that series are cut out by two parallel faults along the strike. Nearly a mile from the Fallen Rocks there is exposed on the shore a good section of the volcanic series, consisting of alternations of basic lavas with coarse and fine tuffs, the whole amounting in thickness to between 350 and 400 feet. These, which are elsewhere described in some detail (*see* latter part of this chapter), occupy the shore for a distance of over 200 yards, dipping steeply northward at 50° to 60°, but they do not appear in the old sea-cliff to the west, being cut off on that side by a large fault which runs in a northerly direction across the foreshore. This brings up again the beds below the trap, which are seen at intervals on the shore, the highest beds being grey cement-stones like those underlying the trap near Laggan. Above these comes a portion of the volcanic series again, which is bounded on the west by another large fault bringing up against it sandstones and shales of a much lower horizon.

To the northward come white sandstones, some of which are coarse, alternating with red shale and clay bands, and in one place some cement-stones and grey beds. These continue as far as the bay, south of Millstone Point, where there is a gap in the section. The rocks, however, are almost continuously exposed on the hillside to the south of this bay, and there can be no doubt whatever about the general order of succession. The dip is almost everywhere to the east of north, and between 50° and 60°. On the north side of the little stream called the Garbh Allt, white pebbly grits are well exposed at Millstone Point. In places the quartz-pebbles in the rock are large, some being as much as four inches in length. We cross a small and unimportant fault, and pass upward into alternations of white sandstone and dark shale with traces of coal. These are succeeded by grey sandstones and blue and grey cement-stones alternating with thin tuff bands, and in the upper part with two thin beds of lava. This is the spot, some 750 yards south-east of Laggan cottage, where Mr. E. A. Wünsch discovered trees and plant-remains, imbedded in trappean ash*, in the year 1865. It is interesting to note that these plant-remains, which are accompanied in this locality by thin coal-seams, occur on the same geological horizon as the coal which was formerly worked at Ambrisbeg, and at Ascog in the island of Bute, but in no other place within this sheet is a coal known to occur at the base of the volcanic series.

The following list of fossils was obtained from 750 yards south-east of Laggan cottage:—

Lepidophloios wünschianus.	Sphenopteris sp.
,, sp.	Stigmaria.
Rhacopteris sp.	Allorisma sulcata.
Sphenopteris (Rhodea) moravica.	Edmondia pentonensis.
,, ,, patentissima.	Sedgwickia gigantea.

These beds, which dip at a somewhat less angle, viz., from 35° to 40° are succeeded by the principal mass of trap, elsewhere described (*see* latter part of this chapter), and above this there is a thin cement-stone series again, alternating bands of grey beds, shales, cornstones, and sandstones with some tuffaceous bands. A thick series of blocky sandstones (white), alternating with thin bands of red shale, forms marked features west of the shepherd's house, and these continue till we reach the Corrie or Hurlet limestone, nearly 250 yards north-west of the house.

From a place 100 yards south-east of the cottage *Sphenopteris crassa* and another species (*Rhodea ?*) of *Sphenopteris* were obtained, and a few yards north of the cottage *Sphenopteris (crassa L. and H. ?)* and a species of *Stigmaria*.

The main or Hurlet limestone is here considerably thicker than elsewhere in the island, and is overlain at some distance by two other dark calcareous bands which are not represented at Corrie, and may be the equivalents of the Hosie limestone. The highest of these three limestones occurs nearly a quarter of a mile north-west of the shepherd's house, at a point where the shore-line bends westwards, and coincides with the strike of the beds. The section of these three limestones is as follows, in descending order:—

Black, hard calcareous shale and shaly limestone .	10–12 feet.
White sandstone, some of it coarse and pebbly . .	60 feet about.
Black, hard calcareous shale with limestone in middle	10–12 feet.
Coarse sandstone with a little black shale . .	30 feet.
Thick Corrie limestone with calcareous shale below	35 feet.
Blocky sandstone	

These beds all dip northward at 40°. All the limestone contains many fossils, and lists of the collections made from the three separate beds will be found in the Appendix. A fault trending north with a downthrow west crosses these limestones, the lowest of which can be traced as far as the footpath to the westward, but beyond this it is unknown. On the shore where the coast-line again trends N.W. there is a pretty example of a sharp syncline in

* See his paper in Trans. Geog. Soc. Glasgow, vol. ii., p. 97, and Geol. Mag. iv., 551.

sandstone with thin, dark shale bands. This extends for about 50 yards, and appears to be bounded by a N.E. fault. North of this the dip increases from 30° to 60°. The rocks are mostly sandstones with some bands of black shale and flags, and in one place there is a thin ironstone. South of the ruins of the old salt pans we come upon the crop of the coal or coals worked on this coast, and which have no representatives at Corrie. The coal was worked here upwards of a century ago, and there have been somewhat different accounts given of it. All agree, however, that it was a kind of blind or glance coal, which burned without much smoke or flame—an anthracite in fact. Headrick, who first described these workings* in detail, states—" there are three or four seams of coal running parallel from north to south; the principal or main seam being 14 feet in thickness," but this statement is hardly credible, especially when compared with an account of a working which he got from a Mr. Cowie who had wrought the coal. Mr. Cowie's description was as follows:—" The seam of coal at the Cock of Arran, wrought by James Cowie, is first about ten inches, then eight or ten inches of a dauchy till, then twenty inches of coal . . . . . the till between the two seams of coal seems to burn lime." The dauch or till was always mixed with the blind coal in burning lime. It seemed to kindle more readily than the coal; and the only difference was that the dauch always left a large *guest* (cinder), whereas the coal burnt into a fine white ash of very small quantity. The thicknesses above given are very much less than 14 feet, when added together, and in fact do not amount to 4 feet, which thickness we may confidently give as the utmost it attained. Two outcrops have been traced, but it seemed probable these were two sets of workings in one and the same coal separated by a fault. Near the salt pans *Lepidodendron veltheimianum* (?) was collected, and 140 yards N.W. of the old ruins there is a hard, brown weathering, argillaceous limestone in the position apparently of the Index or *Productus latissimus* limestone. This bed appears to be five or six feet in thickness, and has yielded the following forms:—

Archæocidaris Urei.	Streptorhynchus crenistria.
Retepora undata.	Productus latissimus?
Lingula mytiloides.	Gasteropod, small.
,, squamiformis.	

The section above this is a good deal obscured, but some 70 yards farther along shore, where the dip is N.W. at 50° or 60°, there is obscurely seen a thin band of dark-coloured limestone associated with hematite bands. This yielded the following list:—*Camarophoria* sp., *Streptorhynchus crenistria*, *Bellerophon Urei*. Some 450 yards, or a quarter of a mile N.W. of the salt pans, in a small bay, are tesselated ferruginous beds with an ironstone band where were collected:—

Productus giganteus.	Nuculana attenuata.
Rhynychonella pleurodon.	Pecten knockonniensis.
Edmondia sp.	Protoschizodus axiniformis.
Entolium Sowerbyi.	Sanguinolites tricostatus.
Myalina Verneuili.	Bellerophon hiulcus.
,, sp.	,, Urei.
Nucula gibbosa.	Orthoceras annulare.

* See his " View of the Mineralogy, etc., of the Island of Arran," pp. 212-219 (1807).

At the same spot in bands overlying the ironstone were collected :—

Allorisma sulcata.	Pecten (Streblopteria) lævigata.
Edmondia rudis.	Bellerophon Urei.
Entolium (young).	Orthoceras sp.
Nucula gibbosa.	Cladodus striatus.
Nuculana attenuata.	

The beds here dip northward at 20°-25°. Beyond these we pass over an alternating series of sandstones and clays on to a thick blocky sandstone which forms a kind of headland. The coast now trends more westerly, and we soon come upon a fault running at right angles to the shore which throws down on the east 20 to 30 feet. Beyond this we get a portion of the beds repeated, and soon we arrive at a red limestone in which *Productus latissimus* is abundant. This is more than a quarter of a mile south-east of the junction with the New Red rocks. It has bounded by a fault on the west side, which must be an upcast to the east, and is apparently some 15 feet in thickness. It has yielded .—

Monticulipora tumida.	Productus latissimus.
Zaphrentis sp.	,, longispinus.
Archæocidaris Urei.	,, semireticulatus.
Crinoid stems.	,, sp.
Fenestella sp.	Spirifera triradialis.
Athyris ambigua.	Spiriferina cristata var. octoplicata.
Chonetes laguessiana.	Phillipsia Eichwaldi var. mucronata.
Orthis resupinata.	
Streptorhynchus crenistria.	
Productus costatus.	

Nearly 100 yards west from this spot and 375 yards S.E. of the New Red junction occurs a thin "cephalopod limestone" about 2 feet in thickness, which yielded :—

Athyris sp.	Spirifera lineata.
Orthis resupinata.	Nautilus (Acantho-nautilus) bispinosus.
Streptorhynchus crenistria.	Nautilus (Pleuro-nautilus) nodiferus.
Productus giganteus.	Nautilus sp.
,, sp.	
Spirifera trigonalis var. bisulcata.	

A few yards west of this, in bands overlying the cephalopod limestone and 365 yards S.E. of the New Red junction, there were got :—

Streptorhynchus crenistria.	Terebratula.
Productus giganteus ?	Nucula gibbosa.
,, costatus var. muricatus.	Nuculana attenuata.
Spirifera ?	Orthoceras sp.

A few yards farther west and 350 yds. S.E. of the New Red rocks, there were collected :—

Carbonicola sp.	Nuculana attenuata.
Edmondia.	Sanguinolites clavus ?
Nucula acuta.	Solenopsis minor.

Above these beds comes a brecciated-looking limestone of considerable thickness, which is repeated by a fault ranging N.N.E. This only yielded *Lithostrotion Portlocki.* It has been called the Coral limestone.

Some of the upper limestones crop out on the hillside a quarter of a mile west of Cock Farm, and from one of these were obtained:—

Alveolites depressa.	Brachymetopus ouralicus.
Crinoid stems.	Allorisma sulcata.
Streptorhynchus crenistria.	Myalina Verneuili.
Productus latissimus.	

and a thin limestone occurs in the faulted strip of Allt Mor between North Newton and the Cock of Arran, which yielded Crinoid ossicles, *Orthis resupinata*, and a species of *Productus.*

Above the Coral limestone on the shore the beds consist largely of shales and red clays, with some rough and irregular sandstones. The highest marine band noticed was 100 yards S.E. of the New Red junction, and here were obtained:—

Crinoid ossicles.	Productus sp.
Lingula mytiloides.	Spirifera glabra.
Streptorhynchus crenistria.	,, trigonalis.
Productus fimbriatus ?	Lamellibranch.
,, muricatus ?	Bellerophon Urei.

Coal-measure plants were obtained from a spot 72 yards south-east of the New Red rocks:—

Calamites sp.	Lepidostrobus ?
Cordaites principalis.	

A longer and more important list was collected from a locality 20 yards S.E. of the New Red junction, and these are the following:—

Calamites ramosus.	Neuropteris gigantea.
,, varians.	,, sp.
Cordaites principalis.	Sphenophyllum myriophyllum.
Mariopteris muricata.	,, sp.

North Newton—unconformable section.—This remarkable junction of schists and newer rocks has often been described. It seems to have first been noticed by the celebrated James Hutton in the year 1785, and his description of it appears first in the 3rd volume of his "Theory of the Earth," which has remained in MS. till edited by Sir Archibald Geikie in 1899.* It may be worth while to quote a part of this description:—"Lochranza, at the north end of the island, is properly within the alpine schistus; but, in tracing the shore, upon the east side of the loch or bay, we come to the extremity of this schistus district. Here the first thing that occurs is the immediate junction of the inclined strata of schistus and the other strata, which here appear to be a composition of sandstone and limestone; these strata are equally inclined with the schistus, but in the opposite direction. Those two different kinds of stratified bodies rise to meet each other; they are somewhat confused at the immediate junction; but some of the sandstone or calcareous strata

* *See* "Theory of the Earth, with Proofs and Illustrations," by James Hutton, vol. iii., p. 235. Edited by Sir A. Geikie.

overlap the ends of the alpine schistus." Hutton made a drawing of the junction, which has been lost. Its place is supplied in the volume by a sketch from Sir A. Geikie. These beds of red and yellowish sandstone with lenticular calcareous bands, and distinct beds of white cornstone, we refer to the base of the Carboniferous formation. They stretch along the shore for nearly 400 yards, and project nearly halfway across the raised beach. At the south end they dip N.N.W. at 30°, and at the north end W.N.W. at 25°, so that the strike describes a curve of 45°. The schists on which they rest unconformably dip S.S.E. at 40°. (*See* Plate V.)

CATACOL CAIRN.—The coping of the wall in front of the police station, Lochranza, near the pier, is made of white Carboniferous freestone collected on the foreshore nearly a quarter of a mile north of Catacol, and the coping of the wall round the most easterly house in Catacol is from the same locality and of the same character. At first it seemed possible the materials might have been derived from ballast blocks or from scattered boulders on the shore, but on examining the ridge below high-water mark (called a "cairn"), whence the stones were obtained, it was found there were still remaining numerous large and not rounded blocks of the white Carboniferous sandstone, and also many blocks of red fossiliferous limestone belonging to the same formation. The sandstone blocks are much too large to have been used for ballast, and if there is not an outcrop of Carboniferous rock near, the ridge must be regarded as a kind of moraine. But the latter explanation does not appear very probable when we consider that the nearest place where rocks of this kind occur *in situ* is more than two miles away to the east of North Newton. It seems more likely that the blocks have been cast up by storms from an outcrop not far away, beneath the sea.

There are many limestone blocks in the old dyke by the roadside between Catacol village and the bridge over Catacol Burn, which must also have been derived from the foreshore.

Mr. D. Tait, the fossil-collector of the survey, has obtained the following suite of organic remains from the limestone blocks of the "cairn," and these were examined and named by Mr. B. N. Peach. The fossils apparently may all belong to the Upper Limestone group of the Carboniferous formation, and this lends support to the view that they have come from rocks *in situ* at a short distance.

FOSSILS FROM LOOSE LIMESTONE BLOCKS CAST ASHORE AT "THE CAIRN" BETWEEN TIDE MARKS NEAR $\frac{1}{4}$ MILE NORTH OF THE VILLAGE OF CATACOL.

Coral, rugose (Zaphrentis?).
Lithostrotion Portlocki.
Crinoid stems.
Phillipsia Eichwaldi.
Retepora sp.
Athyris ambigua.
Lingula squamiformis.
Orthis resupinata.
Productus cora.
Productus giganteus.
,, latissimus (abundant).
,, semireticulatus.
Spirifera bisulcata.
,, trigonalis.
Aviculopecten interstitialis.
Nucula gibbosa.
Discoceras (Discites) cariniferum.

Unconformability. North Newton Shore, North-East of Loch Ranza, Arran. The gently dipping cornstones and sandstones of Lower Carboniferous age repose unconformably on the Highland Schists, which are highly inclined and dip in a contrary direction. These last appear in the lower left hand corner.

BUTE AND THE CUMBRAES.

The Carboniferous rocks of Bute and the Cumbraes belong to the lower part of the Calciferous Sandstone division.

LITTLE CUMBRAE.

On the eastern side of the island sandstones which appear to be interbedded with the lower part of the volcanic series crop out. A rough, reddish sandstone is visible at low water on the eastern side of Castle Island dipping westward under the bed of trap that forms the island, and much jointed, roughly-bedded sandstone crops out in several places south of the houses on the main island. It is mostly of a reddish tinge, but the upper beds, which dip westwards at 10° to 12° under the main mass of the lavas, are whitish in colour.

GREAT CUMBRAE.

In this larger island the Lower Carboniferous rocks occupy a considerable area on the north side of Millport Bay, and the larger islands in the bay are formed of sandstones of the series. The lowest bed, which is a white cornstone, follows a curved line from Doughend Hole round to Ballykellet, nearly parallel to the curve of the bay on its northern side. This has already been described as the upper boundary of the Old Red Sandstone.

The rocks generally consist of white sandstones and red clays or shales, with occasional bands of conglomerate and some white cornstones. There are not many exposures in the interior of the island, except to the west of Ballykellet, and the best sections are along the coast from Doughend Hole southward to Portachur Point, and round the northern curve of the bay. The general direction of the dip of the beds is toward the S.S.W., which becomes due south towards the east end. The average amount is about 20°, but about Foul Port, west of the pier, it is between 30° and 45°, while on the islands of the bay the dip is about 10°. The eastern side of the bay is occupied by the Upper Old Red Sandstone, brought up against the Carboniferous rocks by the large north and south fault before referred to when treating of the Old Red Sandstone. It may be noticed that the sandstones of the islands, which are the highest beds visible, as well as the rocks on the shore to the northward, and those outcropping near Ballykellet, are all striking directly at this line of fault.

The sandstone of the islands has been a good deal quarried. It is generally thick-bedded, whitish in colour, and not very coarse, but in some places the bedding is irregular, and the rock is mixed with much quartzose conglomerate. On the shore of the New Town at the eastern end of the outcrop there are alternations of white sandstones and red clays with bands of white cornstone. Some of the sandstone is coarse and pebbly, with false bedding. Westward from this point the sandstone is generally white in colour and rather fine-grained, alternating with bands of red, purplish, and mottled clays, and occasional nodular limestone. On the west side of Foul Port near the West Bay there is a thick mass of red clays, with occasional thin sandstone bands. A great portion of this series does not appear on the east side of the little bay owing to two N.N.W. faults. There are several small faults along the shore to the southward, and in all this part west of the pier there are several bosses of intrusive igneous rock, besides dykes running in various directions. Several of these intrusive igneous rocks have altered the sandstones and clays in their vicinity. The prominent rugged hills about Upper Kirkton and to the eastward are all formed of intrusive igneous rocks, which are later in date than the Lower Carboniferous rocks which they penetrate. Some of these, as Sheughends and Playhill, are composed partly of trachyte and partly of olivine dolerite.

BUTE.

In the island of Bute the Lower Carboniferous rocks are found at Ambrisbeg, near Loch Quien, on the west side of Scalpsie Bay, and in the Garroch Head district south of Kilchattan.

Ambrisbeg.—The rocks here appear to form the southern end of a small synclinal, in the centre of which is the lowest bed of trap. Immediately beneath this bed there appears to be a seam of anthracitic coal about 18 inches thick, which was formerly worked, and there still exist remains of the old adits. A small sandstone quarry lies to the south of Ambrisbeg, and limestone, and white and red sandstone were found in a cut close by.

Scalpsie Bay.—Carboniferous Rocks are seen near the fault which runs along the west side of the bay. Some small sections in white sandstone appear near the northern end of the bay, and near Ardscalpsie Point there is a considerable exposure of Lower Carboniferous sandstones and conglomerates, some of which are reddish, others are white or yellow and calcareous, approaching to cornstone. There are two old limekilns here, and limestone is said to have been formerly burnt. The beds are undulating a good deal, and are penetrated by intrusive basic masses, both dykes and bosses, the latter being probably of Carboniferous age.

Kilchattan.—The Carboniferous district south of Kilchattan is complicated by faults, and much of the ground not occupied by the volcanic rocks is obscured by glacial drift. The limestone, which has been taken as the boundary between the Carboniferous and Old Red formations, also appears to be absent in places, and the volcanic series apparently overlaps or rests unconformably on the Old Red Sandstone.

The cornstone was at one time extensively quarried to the east and north of the ruins of Kelspoke Castle, but the quarries are now full of water. The rock is a kind of dolomite, containing from 17 to 34 per cent. of carbonate of magnesia, and it is remarkable that where the rock is in contact with intrusive igneous material the magnesia almost disappears. For interesting points connected with this fact we refer to Bryce.* The limestone is from 15 to 20 feet thick, and dips to the south-west at 25°. It may be followed south-eastward to its outcrop on the shore near to a mass of volcanic agglomerate, but its thickness appears considerably less than in the quarries. About 200 yards farther south a large fault having a W.N.W. course and downthrow north, brings up the Old Red Sandstone against the lower beds of lava. At the mouth of a small burn is a fault ranging north-east and throwing down on the south-east side, and a little beyond this, on the foreshore, we find the cornstone much invaded by basic igneous rocks. The white limestone crops out on the north side of the small burn, where it is also penetrated by igneous intrusions, and traces of it are found near Kelspoke Castle, but its repetition here is probably due to a fault ranging N.W., which appears to cut off the old quarry workings. The south-westerly dip at a high angle continues in the traps and other beds all across the peninsula, and yet we find at a distance of a mile and a half across the strike the same cornstone and associated beds at the south side of Dunagoil Bay on the west side of the island. It is manifest there must be some large fault or faults repeating the beds, but the difficulty is to find their exact position and direction. The base of the trap series is found at Port Dornach, and northward from this we see along the shore for more than a hundred yards beds of white sandstone and conglomerate, with bands of cornstone or limestone, some of which are pebbly or cherty. These beds dip to the S.S.W. at 25°, and are succeeded by the upper beds of the Old Red Sandstone of a red colour, somewhat streaked and mottled with white. A fault passes in a north-easterly direction along the edge of the raised beach, and by it the cornstone is shifted eastward, so that it appears again behind the isolated igneous mass, which is probably an old vent. Now we have the traps again on the north side of Dunagoil Bay, so that it seems clear they must be repeated by a downthrow fault which probably runs in a S.E. direction nearly in a line with the northern edge of the bay, turns S.S.W. by South Garrochty, and then turning S.E., again follows the hollow which strikes the southern shore near Port Uisg, which is south of Port Leithne. In Port Uisg we find again the base of the traps, and see dipping under them, but a good deal invaded by intrusions, a portion of the white Carboniferous sandstone.

Northward from Dunagoil Bay we find the traps on the shore, but after passing Barr Point we come again to the base of them at the southern end of Lubas Bay. Here, however, there are no traces of the cornstones, and the sandstones, which are generally red, seem to be portions of Old Red Sandstone dipping in a direction 30° west of south at angles of 20° to 25°. The trap appears to dip at a lower angle than the sandstones, and evidently transgresses the edges of their beds in places. If we look eastward from the trap at Barr Point towards the higher ground, which is upwards of 100 feet above the sea, we observe that the base of the Trap cliff has only a dip of about 10°. In front of it is a portion

* "Geology of Arran and other Clyde Islands," 4th ed., p. 325.

of an old beach, and below this is a cliff of red sandstone in which the beds dip about 25°. Now, if we examine the base of the trap on the shore we find clear evidence of an unconformability. The porphyritic trap, which is decomposed at the base, fills up in one place a hollow denuded out of the thin-bedded white and reddish sandstone on which it reposes.

We suppose that to the northward an east and west fault again repeats the beds of trap, and that the Dunstrone outcrop on the south side of Lubas Port is the same as that at Lubas, only shifted by a north and south fault. In both cases there is no cornstone, and the trap rests on red sandstone and conglomerate. Another north and south fault with a downthrow east separates the Lubas outcrop from that in Suidhe plantation, which is continuous with those on the east side of Glen Callum. The fault at the west end of Suidhe plantation is probably continued down this glen, and must have here a large downthrow on the north-east side, where there is a thick series of trap beds. The base of the traps appears on the west side, and sandstone below is visible at the northern end of the glen and in Glencallum Bay at its southern extremity.

Igneous Rocks of Carboniferous Age.

ARRAN, BUTE, AND CUMBRAE.

Contemporaneous Volcanic Rocks.

There appear to be within the limits of this sheet Carboniferous volcanic series belonging to three different periods. The most recent of these, which is probably of Coal-measure age, is found in Benlister Glen; another, which is of somewhat older date, and near the horizon of the uppermost limestones, occurs in the streams north of Brodick Castle; while a third, and by far the most important, is low down in the Calciferous Sandstone. This last occupies a considerable area in South Bute, forms nearly the whole mass of the Little Cumbrae, and in Arran is a conspicuous feature in the sections of the Carboniferous rocks on the north-east shore, at Corrie, and elsewhere in the island. Everywhere old lava-flows of basic composition make up the bulk of the volcanic material, while the fragmental portions vary from coarse agglomerates to the finest well-bedded tuffs. In a few places in the island of Bute we find the sites of volcanic vents now filled with coarse fragmental material, or with intrusive igneous masses of later date than the surrounding rocks.

i. Lower Volcanic Zone.

Arran.—On the north-eastern shore, near Millstone Point, the lower volcanic group occurs three times between Corloch and the shepherd's house at Laggan. The most northerly exposure occupies the shore for nearly a quarter of a mile, its southern boundary being nearly half a mile from Laggan. The greater portion of the outcrop consists of massive, fine-grained grey trap in which no dip is visible, but the whole series is inclined to the north at an angle between 30° and 40°, so that the total thickness must be over 300 feet. There are two fine tuff bands in the lower portion of the mass, and between these the rock is very scoriaceous, while the part below these fragmental bands is soft. Below the main mass are alternations of thin lava beds and fine shaly tuffs, in some of which Mr. A. E. Wünsch was the first to discover remains of Carboniferous plants (*see* Trans. Geol. Soc. Glasgow, vol. ii., pp. 97 and 160, "On the occurrence of Fossil Trees imbedded in Trappean Ash in Arran").

The ordinary Calciferous Sandstone and shales underlying the traps succeed to the southward, but owing to large faults we find repetitions of the volcanic series to the south of Millstone Point, where the old lavas again occur, but the tuffs are much coarser than in the last section and form a large proportion of the whole series, so that here we are probably nearer the site of a volcanic vent. Nearly half a mile south of Millstone Point we find the following section on the foreshore:—

The upper portion is for the most part a slaggy and amygdaloidal lava with a little tuffaceous material, about 150 feet in thickness. Succeed in descending order well-bedded greenish and red tuffs, 75 feet thick.

Lava.—slaggy above and with pillowy structure below, often an irregular mass in which are several red and dark flinty bands apparently filling up cracks in the lava-flow—75 feet.

Finer tuffs with some lava—few feet, perhaps 10.

Coarse volcanic agglomerate—75 feet.

The dip is slightly east of north at a high angle, 50° to 60°, and the total thickness must be near 400 feet.

These beds only appear on the foreshore and on the raised beach, being cut off on the west by a large fault running nearly due north with a downthrow east of some 500 feet. Some distance to the north, therefore, we find the volcanic zone again on the foreshore resting on the cement-stone series. It has the same steep northerly dip, but we only see a portion of it, the lower agglomerate band about as thick as before but intercalated with some finer tuff bands, and surmounting it a portion of the grey trap bed; and then another northerly-running fault with a large downthrow east destroys the continuity of the section.

On the south side of the North Sannox anticline this Lower Carboniferous volcanic band appears on the shore north of Corrie, where it is about 350 yards in breadth. It dips southward like the other Carboniferous rocks at an angle of about 20°, and the thickness is altogether about 350 feet probably. The lowest portion is a very coarse agglomerate containing some fragments of basic trap 6 feet in length. To the south of this, and overlying it, is a fine-grained bluish basalt, which opposite to and southward of the large granite boulder called Clach an Fhionn exhibits a remarkable pillowy structure, and it seems probable that many of the large rounded blocks on the foreshore and raised beach about here are simply detached pillows (*see* Plate VI.). The upper part of the mass near the schoolhouse is much reddened and veined with calcite, etc.

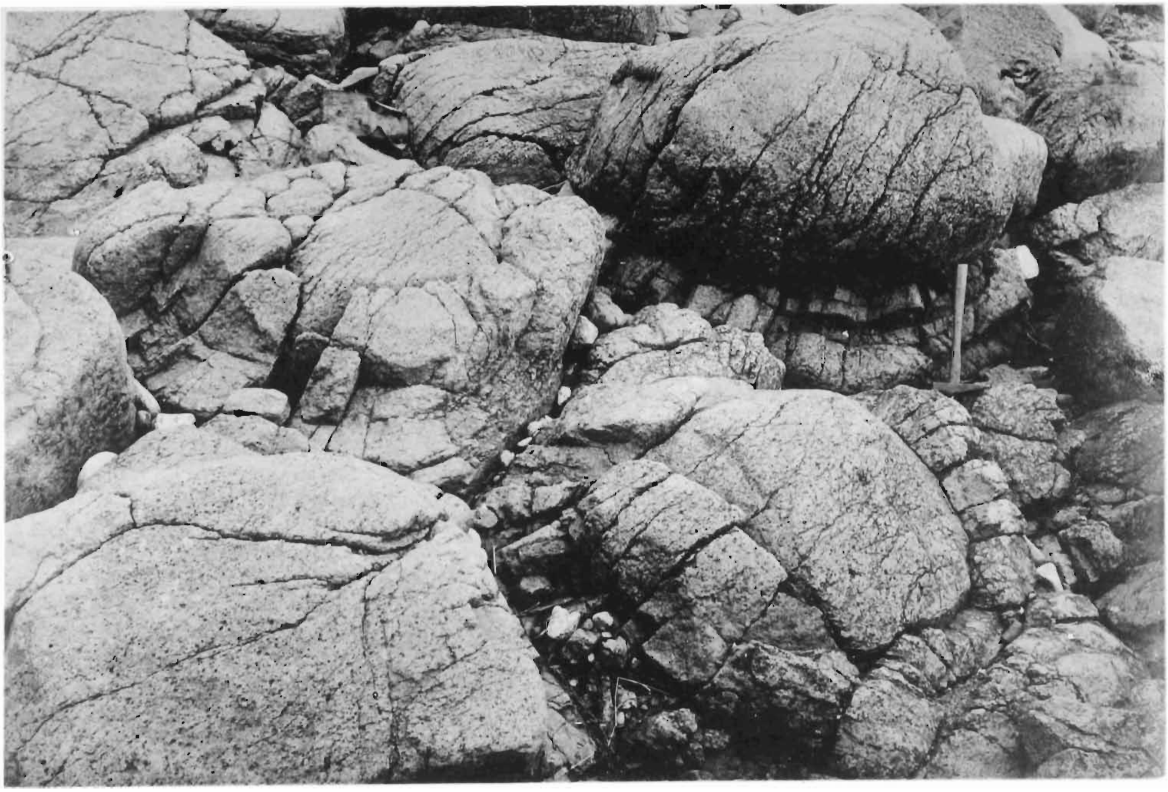
Seventy yards farther south and opposite the Established Church is a later lava-flow, a purplish and much veined bed, 10-12 feet thick, separated from the older by some 70 feet of shales, sandsstones, and cement-stones. Both beds are exposed in the burn that flows past the church, but the base of the lower volcanic mass is not seen here, for a large fault cuts off the outcrop 600 yards from the sea. This fault shifts the rocks to the southward, and both beds are exposed again in the Locherim Burn, where some intercalations of tuff occur in the lower and larger bed. Another large fault, which must have a throw of over 1000 feet, shifts the volcanic rocks again to the south, this time a distance of three quarters of a mile to the burn called Uisge nam Fear, which is the first stream north of Maol Donn. In the southern bank of this burn there is a fine section of the lower part of the series, for the most part a soft red or purplish decomposing lava of basic composition, overlying red shales, some of which are tuffaceous. All are much veined with calcspar, and several intrusive dykes of much later age (Tertiary) cut through both igneous and aqueous rocks. The large faults to the southward which cause the outcrops of this bed to be so disconnected are elsewhere described; it suffices to say that there are exposures of it in the burns in Brodick wood, north of the Castle; by the side of the road leading to Goatfell; along the southern side of Glen Shurig; in two places on the south side of Glen Dubh; and around Brisderg; from which last locality a continuous strip runs southward across the head of Benlister Glen to the southern edge of the sheet near the boundary of the two parishes. Throughout nearly the whole of its course southwards from Maol Donn it dips steeply towards E.S.E. or S.E., and the outcrop is generally but a narrow band. Bands of tuff occur here and there as in Benlister Glen and on the south side of Glen Dubh, and these sometimes merge into red sandstones or shales by a diminution of the amount of the volcanic material. The massive rocks consist of basic lavas generally of a red or purple colour, due to decomposition and oxidation of the iron ores and ferro-magnesian constituents. Those which have been sliced were originally olivine basalts, but they are now highly altered, and the ferro-magnesian minerals have almost entirely disappeared, and their place is taken by carbonates, chlorite, ferric oxide, and quartz. Owing to the great alterations these rocks have undergone it is sometimes difficult in hand specimens to distinguish between the massive rocks and the tuffaceous sediments.

The rock from Benlister Glen, east of Lag na Croise, is a highly altered olivine basalt of a dull, dark purplish colour, which when examined with a lens shows red spots in a greenish matrix.

The highly altered olivine basalt from 500 yards north-east of Windmill Hill is a fine-grained, dark purplish rock.

L i t t l e C u m b r a e.—The Lower Carboniferous Traps form the whole of the Little Cumbrae, except a small portion on the east side. The island is beautifully terraced; each separate lava-flow

Plate VI.



"Pillowy" structure in Lower Carboniferous lavas; about 300 yards North of Corrie Schoolhouse, Arran, and near the large granite boulder called "Clach an Fhionn."

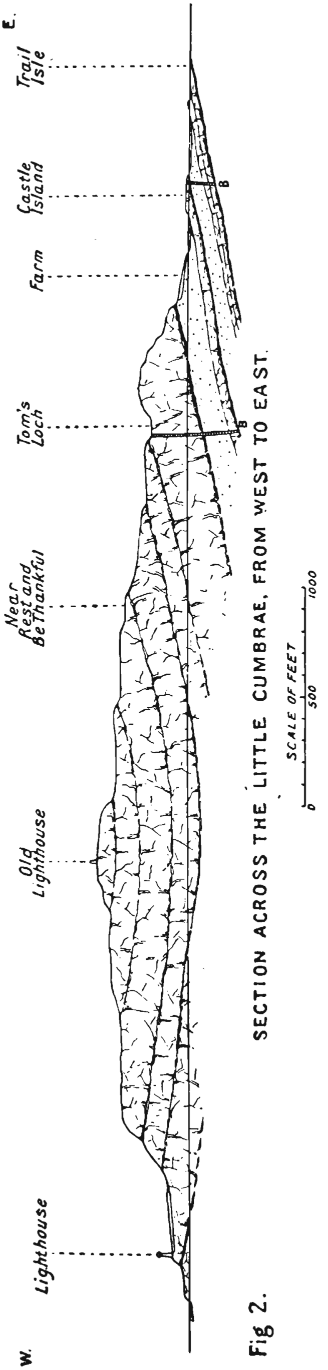


Fig 2. SECTION ACROSS THE LITTLE CUMBRAE, FROM WEST TO EAST.

making a distinct feature, often a crag, at the outcrop. The flows are often slaggy or scoriaceous at the top, but there is little real tuff. The beds are disposed in a shallow synclinal the axis of which ranges N.N.W. through the highest part of the island, where is the remains of the old lighthouse. As this axis is nearer to the west than to the east side, and the beds have also a less dip on the west side, the eastern limb of the synclinal gives the more complete section. The westward dip in this part is as much as 10 degrees or even more, and the thickness must be as much as 600 to 800 feet. The base of the main mass, which reposes on white sandstones, has a north and south course near the farmhouse, but older and separate parallel flows form Castle Island and Trail Isle to the eastward. See section across the Little Cumbrae.

All the specimens sliced are basalts, and the rock is often porphyritic in character and usually of a purple colour, though some beds are blue in colour and fine in texture. The slaggy or coarsely amygdaloidal varieties often contain much calcite in the cavities. In several places the flows exhibit a rather markedly columnar structure, as, for example, in the crags below the lighthouse.

Along the north-eastern shore in more than one place there occurs a coarse volcanic agglomerate with fragments reaching one foot in length. There appears nowhere any great thickness of this fragmental rock, and in all probability it is in each case a true volcanic tuff intercalated between sheets of lava.

South Bute.—In South Bute the same volcanic series forms a striking series of ridges ranging

N.W. with their scarped edges facing to the north-east. The dip to the south-west is on the average quite 30°, and the thickness must be great, probably much more than that exposed in the Little Cumbrae, notwithstanding that the beds are several times repeated by faults along the strike, elsewhere described. In neither locality, however, do we reach the upper limit of the series. One of the main lines of fault is along Glen Callum, while another passes by South Garrochty.

The flows vary in character and thickness. Some near the base of the series are fine-grained, bluish in colour, and weather with a marked columnar structure, but generally the rock is tinged red or purple and shows large porphyritic felspars. Many of the flows are scoriaceous at top as in Little Cumbrae, and most of them are basic in character like the olivine basalt of Dunstrone Fort, or the porphyritic dolerite that caps the ridge north of Tor Mor. Some beds may be more intermediate in character, like the basaltic andesite of Barr Point and the coarsely porphyritic andesite of Dunagoil Fort. One bed on the west side of Port Luchdach, half a mile west from Runnan Eun Point, is a brownish trachyte with a green pyroxene, and this bed can be traced nearly to North Garrochty.

Volcanic agglomerate and tuffs are found in several places, but form only a small portion of the series. A strip of coarse agglomerate runs for a long distance by the shore near South Garrochty, and is probably an intercalated mass; in one place it includes a block of sandstone four feet in length. East of Port Leithne are finer tuffs, beautifully laminated beds of ash and ashy sandstone, into which a late Carboniferous dolerite sheet is intruded. The tuffs dip to the south-west at 30°.

Ambrisbeg.—On the east side of Loch Quien at Ambrisbeg is a small area of this volcanic series. It forms a portion of a larger volcanic district which stretches between Lochs Quien and Fad, in Sheet 29, to the north. The rocks are old lavas, resembling in character those already described, and all apparently basic.

ii. Second Volcanic Zone.

There is a volcanic series nearly on the horizon of the Upper Limestones in the wood three quarters of a mile to the north of Brodick Castle. The lava, of which it mainly consists, is stained of a red colour, and in character closely resembles that of the lower group. In one place it attains a thickness of 25 to 30 feet. This bed is probably nearly contemporaneous with the lower part of the series at Sliddery Water Head and with some of the interstratified volcanic rocks in the higher part of the Carboniferous Limestone in Ayrshire.

iii. Third Volcanic Zone.

The best exposures of traps and tuffs of Upper Carboniferous or Coal-measure age occur at Sliddery Water Head in Sheet 13, and for a detailed description of these the reader is referred to the annual summary of the Geological Survey for 1897, pp. 112-123. It now seems probable from the evidence of the fossils that in this locality there is included in the one volcanic series representatives of both Coal-measures and of the Upper Limestones, and the volcanic action must have been prolonged during a portion of both geological periods.

In Sheet 21 there is an outcrop of Carboniferous trap at the fall called Eas Geal in Benlister Glen, 2¼ miles west of Lamlash. It occurs in a much faulted area and the age of it is somewhat doubtful, but as it is in conjunction with beds of red shale and and sandstone belonging to the Coal Measures it seems natural to suppose the trap to be of the same period. The volcanic rock appears to be faulted against the shales a little below the bend in the stream; it is there reddish and much decomposed. Above the fall the rock is fine-grained, grey in colour, and more like an intrusive rock, but it is probably another portion of the contemporaneous lava. It occupies the bed of the stream for about a 100 yards, and in one place is pierced by an intrusive basalt dyke. On the west side this mass is probably bounded by a fault which brings up the Lower Carboniferous rocks.

Intrusive Carboniferous Rocks.

Bute.—*Volcanic Vents.*—No intrusive igneous rocks of Carboniferous age have been noticed in Arran, but in South Bute these occur near the base of the Trap Series half a mile north of Runnan Eun Point; bosses, sills, and irregular masses of fine-grained dark basic rocks, and similar intrusions, are found a quarter of a mile east of the Garroch Head. The large oval mass of altered olivine-basalt which forms Suidhe Hill was probably intruded into an old volcanic vent, some of the fragmental material of the neck being still visible at the south-western end of the mass. This plug is some 600 yards long from north-east to south-west.

About half a mile north of Runnan Eun Point there is a crag formed of volcanic agglomerate which contains fragments of trap; also limestone and baked sandstone or quartzite. An intrusive basic sheet appears to occupy part of the site of this vent.

At Creag a Mhaid, 300 yards farther north, is another mass of coarse agglomerate, apparently of an oval form and about 150 yards in length, and here again the neck has been invaded by an intrusive mass.

On the south side of Dunagoil Bay is an isolated mass which may be the site of a vent, though there is not much fragmental material visible, and the rock is for the most part massive in character.

Great Cumbrae.—*Trachyte.*—There are at least four distinct groups of intrusive rocks in Great Cumbrae, and three of these are probably of Carboniferous age. The oldest of these is trachytic in character, and occurs both as sheets and dykes which have a general E.N.E. direction. The rock is usually of a pink colour, but is sometimes grey or purplish. A specimen from the dyke of the Hawk's Nest north of Farland Point was analysed by Mr. Teall, and was found to contain 11 per cent. of alkalies, principally potash, while the percentages of lime and iron were very low. Sometimes these rocks are fine in grain with but a few porphyritic orthoclase crystals visible, though numerous small crystals of this mineral are revealed by the microscope. These red trachyte dykes and sills are almost confined to the Upper Old Red Sandstone, rarely intruding into the Calciferous Sandstones, and being apparently older than the Carboniferous lavas of the Little Cumbrae and South Bute. Several of the sills form marked features in the interior of the island. Some bosses of rock in Millport Harbour, known as The Clach and the Miller's Thumb, which are described as porphyrite or bostonite, are probably of nearly the same age as the trachyte.

Olivine-basalt.—The next group has the same general direction but clearly cuts the trachytes, and must therefore be of later date. A fine example occurs on the shore near Craig nan Fitheach between Doughend Hole and Sheriff Port, where one of these dykes cuts a trachytic sill and both are crossed by a tertiary dyke running north-west.

The dykes of this set are the most numerous of the whole, and are found on every part of the island. On the north-east shore about 40 of them may be counted in half a mile of coast-line, and some of them are large. They appear to be all porphyritic olivine-basalts of the type of the Lion's Haunch on Arthur's Seat, Edinburgh. Generally they are bluish or grey in colour, and finer at the edges than in the centre, which is often coarsely porphyritic and amygdaloidal. Some of them, however, are much decomposed and stained. Olivine seems always characteristic, but has often been replaced by hematite and calcite. In Bute, a good many dykes occur on the north side of Kilchattan Bay and a few around Stravanan Bay, which have the same general direction as these basalt dykes in Cumbrae, and as their character is similar they probably all belong to the same geological period, which is probably that of the Lower Carboniferous lavas. Most of these dykes in Bute are much stained with hematite.

Dolerites.—The dykes of the third group are basalts or dolerites, with or without olivine, and they have, on the whole, an east and west direction like that of the Dunoon dyke, which belongs to this class. They cut the two sets of dykes previously described, and must therefore belong to a far later period of intrusion; probably they are not older than late Carboniferous time. One of these dykes in Great Cumbrae, about 50 feet in width, is a nodular basalt, and it can be traced westward from Ballykellet to the western shore. It traverses in its course many dykes and sills belonging to the two classes just described. Another dyke of this kind runs all across the island from Fintray Bay, where it is 100 feet wide, past Figgatoch to Downcraig Ferry, where its width is 75 feet. Its course, however, is not continuous; it is broken up into three detached portions, which remind one strongly of the similar behaviour of the Dunoon dyke and those near Rothesay, which probably belong to the same period. In Bute, a dyke to the south-east of Lubas and one at Kilchattan probably belong to this set, as does also a dolerite sill that traverses the Carboniferous traps in a north-easterly direction from Garroch Head to near Runnan Eun Point.

W. G.

Calciferous Sandstone Series.

AYRSHIRE.

The portion of this lowest subdivision of the Carboniferous system included in the present district follows continuously and conformably upon the Upper Old Red Sandstone, passes under the great overlying volcanic plateau, and attains a thickness of about 1500 feet. It consists mainly of yellowish sandstones, often pebbly, and including many zones of fine conglomerate. The cornstone at the top of the Old Red Sandstone has not been detected here, nor do we encounter more than a mere trace of the cement-stones, marls, and shales, which, farther north, emerge in considerable thickness from under the volcanic series. The Carboniferous strata are not exposed on the shore, but are well displayed in the numerous burns and on the inland slopes, Of these natural sections the best will be found in the channel of the Kippen Burn north of Fairlie, in Fairlie Glen, and in the Glen Burn a mile-and-a-half farther south.

The Fairlie Glen section may be described as typical for the whole district. The passage from the Upper Old Red Sandstone into the Carboniferous system is to be seen immediately above the ruins of Fairlie Castle. The red sandstones are there succeeded by intercalations of grey and yellow sandstone and fine conglomerate dipping up-stream. The hard conglomerate bands tend to form waterfalls in the course of the burn, of which a good example occurs at the line of the 250-feet contour. Red and reddish-grey sandstones still make their appearance, generally more or less pebbly, and often much false-bedded. At last the yellow sandstones prevail, generally full of false-bedding, and more or less conglomeratic. The conglomerates contain abundant white quartz-pebbles. The most important of them, crossed by the Fairlie Burn at the 1000-feet contour, not far below where the stream-section ends, is a well-marked conglomerate, with large pebbles of white quartz. It can be traced as a definite horizon for nearly a mile northward along the hill-slopes. Though thrown backward and forward by occasional faults it maintains its persistence until it comes against the large fault above Kelburn. It is probably the same band of conglomerate and pebbly sandstone which underlies and surrounds the outline of the volcanic plateau forming Kaim Hill, and which has been worked at the Kaimhill Millstone Quarry.

Above the conglomerate band in the Fairlie Burn a thin zone of reddish tuff marks the first beginnings of the volcanic series. It is immediately followed by mottled clays with dark sandy shales, which, however, have been greatly broken up by the invasion of an intrusive sill. These strata, of which only a small thickness is here displayed, present typical features of the Cement-stone group. The shales contain cyprids and plant-remains. They pass immediately under the lavas of the plateau.

Volcanic Group.

This important member of the stratigraphical series of Central Scotland lies between the Carboniferous Limestone, as represented by the well-known and persistent Hurlet seam, and the Upper Old Red Sandstone. In the western counties it does not descend so low as in the east of the country, for, as we have seen in the foregoing account of the section in the Fairlie Glen, a great thickness of the Calciferous Sandstones here intervenes between the base of the volcanic rocks and the top of the Old Red Sandstone. Only a few projecting and outlying parts of the volcanic plateau came into the present district, but they afford illustrations of most of its characteristic features. They show it to be built up of successive sheets of andesite, with occasional partings and bands of tuff. These rocks present the usual petrographical types, which are so well exhibited in the Little Cumbrae, and the south end of Bute, in the same Map. They vary from compact, finely-crystalline porphyritic masses, in which the characteristic andesite structure is manifest, up to coarse decomposing amygdaloids, which here and there furnish good agates and zeolites. The upper and under surfaces of the flows are frequently slaggy and brecciated.

The rocks are well exhibited in the courses of the burns, but perhaps the most instructive sections are to be found on the steep hill-slopes to the north of Largs, just beyond the northern limit of the present Map. On the face of the great escarpment a succession of sheets of andesite with occasional well-marked intercalations of tuff, can be followed up to the edge of the plateau, which stretches thence eastward into the great volcanic centre of the Misty Law. (Sheet 30.)

To the west of the escarpment a number of sills and intrusive bosses of a pinkish or yellowish felsitic or orthophyric rock form prominent ridges and detached hills. Some of these traverse the Old Red Sandstone, as in the case of the masses to the south-west of Hunterston and the sheet which runs along the slope behind Fairlie, as well as another to the south of The Glen. But most of them lie within the Carboniferous area. The chief mass occupies a breadth of about 800 yards immediately to the west of Glentane Hill. A little to the north it divides into two separate sheets, the lower or westmost of which can be followed for a mile-and-three-quarters nearly as far as Fairlie Glen. It, as well as the upper sheet, has been shifted by three faults, and both of them are pierced by volcanic necks. They not improbably belong to an early part of the volcanic history. There occur also numerous dykes of similar material, as well as of varieties of andesite and dolerite. The number of these intrusions must be vastly greater than is expressed on the map, for only a small proportion of them can actually be seen. Their multitude may be inferred from the profusion of them in the burns and along the shore. Most of these dykes, no doubt, belong to the Carboniferous volcanic period. But the dolerites and basalts, especially those which trend in a north-westerly direction, are more probably of Tertiary age.

Reference has above been made to the occurrence of at least a dozen volcanic necks which mark the sites of some of the eruptive vents connected with the plateau. These interesting features are dotted along the slopes between Ardrossan and Largs, and many more occur to the north of the latter village. They are filled with agglomerate or tuff, consisting of blocks and lapilli of various andesites, and porphyries with pieces of red and white sandstone or other sedimentary material imbedded in a dull green matrix of comminuted andesitic debris.

Beginning at the south end of the chain, we find the first of the series in the Tarbert Hill, a prominent, rounded, green eminence rising to a height of 445 feet above the sea on the sloping ground immediately to the east of Sea Mill. Like most of them, it is elliptical in form, measuring about 550 yards in length by 360 yards in breadth. In the centre it is composed of a yellowish or dirty green, fine, compact, sandy and granular tuff, with occasional quartz-pebbles, and here and there exhibiting traces of vertical stratification. Round its outer margin, and thus along what must have been the walls of the volcanic orifice, the material becomes a coarse agglomerate, mainly composed of rounded blocks and lapilli of various andesites, but enclosing also pieces of red sandstone some of which measure several feet in diameter.

Half-a-mile farther to the north-east stands the larger neck of the Law Hill, the summit of which is 551 feet above the sea. It has an irregularly oval shape, measuring about 850 yards from east to west, and about 450 from north to south. It is filled with a coarse agglomerate in which, besides red sandstone blocks, pieces of black shale may be observed. The date of this vent must thus be later than the time when the black shales of the Calciferous Sandstones began to be laid down. Only 160 yards from the eastern edge of this neck lies another, measuring 250 yards in its longest diameter, beyond which stands a third which, rising prominently into Blackshaw Hill (709 feet), measures 330 yards in its longer and 250 in its shorter diameter. It is specially remarkable in enclosing a lava-plug in the form of a dull, dark-grey, porphyritic andesite, which is much decomposed. This neck also includes black shale enclosing *Spirorbis*, together with pieces of a coarsely crystalline "greenstone."

A quarter of a mile to the north of West Kilbride a conspicuous vent forms Drummilling Hill (343 feet). It measures about 500 yards in length by 200 in breadth. Half a mile to the west two small necks occur on the estate of Carlung. The smaller of these appears on the little eminence called the North Mound, and measures only 100 by 65 yards. It is filled with a coarse, dirty-green agglomerate in which, among the volcanic materials, lapilli and larger fragments of the pale felsitic varieties of rocks are abundant. The other and larger neck, forming Crock Hill, is distinguished by possessing a small plug of compact purplish-grey andesite.

About a quarter of a mile to the south-east of Glentane Hill, and therefore just beyond the limits of the present map, two green eminences rising above the surrounding moorland mark the positions of two vents. One of these, known as Greenside Hill, about 800 feet high and filled with the usual coarse, green agglomerate, measures 300 by 200 yards. The other, only about 200 yards to the east, forms Lairdside Hill (850 feet), and measures about 230 by 180 yards. A mile to the north a smaller neck rises from the moor of Whiteside Hill, about 350 yards to the south of the Kaim Hill, of which the western edge comes into the present map.

A still more diminutive neck has pierced the edge of the escarpment of the intrusive sheet of Biglees Hill, a mile due east from Hunterston House. It measures no more than 100 yards from east to west by 50 from north to south. It is filled with the ordinary coarse agglomerate.

Next in order in our northerly course we come upon a small vent rising within tide mark at the promontory of the Black Rock on the south side of Fence Bay. In its coarse agglomerate sandstone fragments are abundant. Still farther north, on the declivity above St. Annan's Chapel, two good examples of vents may be seen. The lower or more westerly of these forms the eminence known as Diamond Hill (450 feet), and measures 400 yards in the longer axis and 325 in the shorter. The volcanic detritus with which it is filled is partly a coarse agglomerate and partly a compact tuff. This neck, as already mentioned, has broken through an intrusive sill, so that it cannot belong to the earliest phase of the volcanic activity. Immediately to the east the second and smaller vent pierces the upper of the two sills. Its line of junction with the contiguous sandstones may be seen in the watercourse, and exhibits there the usual signs of disturbance and disruption in the strata.

A. G.

CHAPTER VII.

New Red Sandstone or Trias.

The age of the red rocks which occupy so large a portion of South Arran was for a long time much disputed, and by various authors they had been regarded as of Old Red Sandstone, Carboniferous, or New Red age; while one author classed part of them with the Carboniferous and part with the New Red rocks. The question was definitely decided in the year 1894, when it was ascertained that these rocks are unconformable to the Carboniferous formation, though often at junction the two sets of rocks appear perfectly conformable. So long ago as 1874 Messrs. James Thompson and E. A. Wünsch had discovered derived Carboniferous fossils in these New Red conglomerates at the north end of Arran near the Cock; but apparently they did not see the importance of their discovery, as they were still disposed to class these rocks with the Carboniferous formation and to consider them as Millstone grit. This discovery of derived fossils in the overlying red rocks was confirmed by the Geological Survey in 1894. Near the Cock these strata rest upon the Lower Coal-measures, as they also do at Corrie and in the woods behind Brodick Castle. But towards the head of Benlister Glen they repose on the Corrie limestone, hundreds of feet lower down in the Carboniferous formation, while on the west coast, to the north of the mouth of the Machrie Water, they lie directly on the Old Red Sandstone, all the rocks of the Carboniferous system having disappeared.

No fossils, except some derived from the Carboniferous formation, have as yet been found in these newer red rocks, so that there must be a little uncertainty about their exact age. On account of the close resemblance of the lower false-bedded sandstones to those of Ballochmyle in Ayrshire, Sir A. Geikie was disposed to class them with the Permian formation, and in the map of the southern part of Arran all the newer red rocks were doubtfully lettered and coloured as of this age, but the general lithological character of the rocks is much more like the Trias of England, and the finding of a portion of the upper marls immediately connected with beds of of Rhætic age in a fragment in the Ard Bheinn volcanic agglomerate fixes pretty definitely the Triassic age of the upper division of the formation.

These unconformable and overlapping red strata may be divided into two great groups, as in the following Table :—

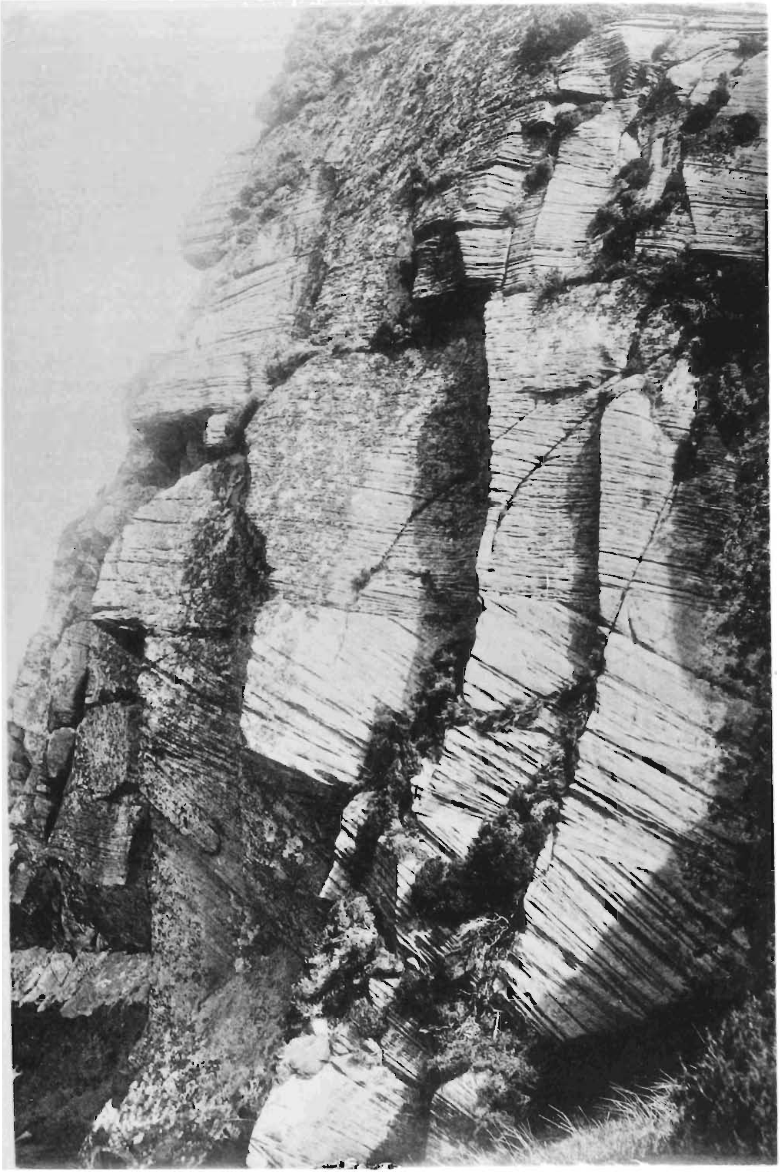
UPPER TRIAS—KEUPER?	Red and mottled shales or marls with thin beds of white, yellow, or grey sandstone, and occasional thin bands of nodular limestone.
LOWER TRIAS.	4. Light coloured and yellowish sandstones, sometimes red, with calcite in cavities. 3. Reddish sandstones with some conglomerates. 2. Conglomerates alternating with sandstones. 1. False-bedded red sandstones of Brodick and Corrie.

The upper group is poorly represented in this sheet, and its thickness cannot be estimated. In the southern part of Arran—Sheet 13—where it is well developed, its thickness is probably nearly 1000 feet.

LOWER DIVISION.—The lower group may for convenience of description be subdivided into four parts, as shown in the foregoing Table, but the subdivisions cannot be indicated on the map. Probably the total thickness of the Lower Triassic beds in Arran amount to as much as 2000 feet, of which the lowest subdivision—the false-bedded sandstone—occupies one-half.

1. The lowest subdivision is well exposed along the shore between Corrie and Brodick Castle, and consists of extremely false-bedded, bright red sandstones, traversed in many places by ridges formed of hardened joints and crushes, and in others full of ramifying hardened veins which cause the rock to weather with a honeycomb structure. Some of the crushes are certainly faults, but the rock is so uniform in texture generally that the amount of throw is not discernible. Numerous basic dykes cross the foreshore in various directions and discharge the red colour of the rock, making it white or yellow, and hardening it. Some of the ridges are probably in the line of dykes which end at the surface, and some may be due to dykes which have not reached the present surface. The false bedding conveys a very exaggerated idea of the real thickness of the series. Fine sections in the old sea-cliffs, and in caves, show that the true dip towards the S.E. is not more, generally, than 10°-15°, while the false bedding has an inclination of twice as much, and is, besides, very variable in direction. The great cliff on the north side of Maol Donn, which is formed of this sandstone, shows a similar gentle inclination of the beds. (*See* Plate VII.) This great scarp is largely due to an extensive slip, the material from which covers several acres to the northward. There are large quarries in this sandstone at Corrie and in Brodick wood at the back of the school. From the Corrie quarries much stone is shipped to Ayrshire and various parts for building purposes. This sandstone forms the ridge on the north side of Glen Cloy, where both the true and the false bedding dip to the southward or S.E. at a high angle, as they do also to the west of the old Brodick pier near the Castle. The boundary between this rock and the underlying Carboniferous series may be observed on the shore about 200 yards south of the Corrie Hotel, and it crosses the Rosie Burn a little below the bridge.

2. The alternating brecciated conglomerates and sandstones of the south side of Brodick Bay overlie the false-bedded sandstones just described, and the conglomerates of this division are so like in character to the Upper Old Red conglomerates north of Corrie as to be undistinguishable from them except in position; in fact, several observers have classed them with the older formation. They are largely made up of debris of the metamorphic rocks, such as pieces of vein-quartz and angular fragments of schist, with occasional pebbles of quartzite, like those characteristic of the Lower Old Red conglomerates.



False-bedding in the lower division of the New Red Sandstone Cliff on North face of Maol Donn, about 2 miles South of Corrie, Arran.

This subdivision strikes westward up Glen Cloy and forms the ridge between Glen Dubh and Glen Ormidale.

Near the heads of these glens it, along with the false-bedded sandstone below, has been much altered, being often converted to a white quartzite by contact with the intrusive igneous masses there. On the shore at Springbank the rock is pierced by two masses of agglomerate which appear to be of the nature of volcanic necks, though they contain no igneous material. The larger of these is about 150 feet in diameter and the smaller about 50 feet, though in neither case can the whole circumference of the mass be seen. The smaller is about 100 yards west of the hotel grounds, and the larger is some 150 yards farther west, and the breccia which composes both is entirely made up of fragments of the surrounding strata.

In this subdivision there is not much false bedding apparent, and the rocks at Springbank dip southward at about 15°. East of the pier numerous faults as well as dykes cross the outcrop, and the red conglomerate is seen to overlie false-bedded red sandstone of the same type as that on the north side of the bay. One of these faults ranging N. 25° E., which is 50 yards east of the pier, brings up the lower sandstones against the conglomerate. The sandstone occupies the foreshore for 300 yards eastwards when it is cut off by a fault, coincident with a dyke ranging N. 25° W., which throws down the conglomerate again on the east. For about 500 yards eastward from this point we see nothing but conglomerate on the foreshore till a north-west running fault, with a downthrow south-west, again brings the lower sandstone into view. This is continued for 300 yards farther in the most easterly part, being overlaid by conglomerate, when a fault ranging N. 25° E. causes the whole of the foreshore to be occupied by conglomerate, but this is only for a distance of 30 to 40 yards, when a powerful fault, N. 30° E., brings up the lower sandstones, which occupy not only the shore for a long distance but the cliffs also, which are much increased in height. Hitherto along this shore the conglomerate series could be seen either on the shore or on the boundary cliffs, but the effect of this large fault, which must have a downthrow west of several hundred feet, is to raise the conglomerate a long way above the top of the crags at this point, and it does not appear again on the shore till the southerly dip causes it gradually to descend and occupy the shore about Corrygills Point. Along this half mile of shore and in the cliffs bounding the raised beach the false-bedded lower sandstones are well exposed, with the same curious spires and ridges which we found characterising them on the north side of Brodick Bay. The southerly dip is everywhere nearly the same in amount, ranging between 10° and 20°, but as we proceed the direction gradually changes till, in the alternating conglomerates and sandstones on either side of Corrygills Point, it is nearly S.S.W.

This series is well exposed in the middle part of Benlister Burn where the conglomerates form occasional cascades, and it occupies a strip of ground to the northward (east of Brisderg) which is bounded by two large faults. The beds in this strip dip to the south-west, and their termination north is in the fine scar of Creag nam Fitheach, on the south side of Glen Dubh.

3. Along the South Corrygills shore the alternating conglomerates and sandstones pass gradually up into the beds of this subdivision, which consists almost entirely of red sandstones, moderately coarse, with only occasional pebbly bands, and with comparatively little false bedding. The dip inclines more and more to the west and generally increases in amount, so that in places along the shore east of the Clauchland Hills the dip is as high as 30° or 40° and the strike is parallel to the shore. Near Clauchland Point the dip is in one place as much as 60°, but this high dip is probably the effect of the intrusion of the great sill of dolerite there. On the south side of the Clauchland Hills the inclination of the beds is much more gentle, generally not more than 10°, and nearly coinciding with the slope of the ground to S.S.E. There are numerous sections in the small streams here, and along the northern shore of Lamlash Bay.

The beds of this subdivision occupy nearly all the area between Lamlash and Glen Cloy, and there is a fairly continuous exposure of them in the Birch Burn (Lag a' Bheith). They also form a marked feature above the wood to the south-east of Bruce's Castle in Gleann Dubh, and it is probably the higher beds of this series that appear beneath the thick sills of felsite along the west side and at the north end of Holy Island.

4. On the south side of Gleann Dubh the beds of the previously described subdivision pass up into white carious sandstones, which form the highest beds of the lower division of the Trias; but these cannot be everywhere distinguished as a separate subdivision and they might very well have been grouped as a variety of 3, from which they only differ essentially in possessing drusy cavities which once contained calcite.

The detached outlier of New Red Sandstone at the Cock of Arran, in the north part of the island, contains false-bedded, bright red sandstone like that of Corrie, and beds of conglomerate which mainly overlie the sandstone, though there are bands of conglomerate at the base of the sandstone in the lowest 40 feet of it. The mass of conglomerate is like that on the south side of Brodick Bay, and probably on the same horizon, so that we have in this small area representatives of the lower two subdivisions of the formation, with a total thickness of not less than 1200 feet. The beds generally dip northward and toward the sea, so that several landslips on a large scale have occurred, and the hillsides show gaping fissures.

On the western side of the island the Trias is found along the coast south of Auchagallon, and takes up the interior eastward to the foot of Ard Bheinn, but the subdivisions described as occurring on the eastern side of the island are not equally conspicuous here. The lower false-bedded red sandstones are well exposed in the Machrie Water; but there appears to be no equivalent of the conglomerate series, unless these are represented by some pebbly bands in the sandstone three quarters of a mile W.S.W. of Derenenach, near the main bend in the course of the stream. In this part of the island the Trias rests directly on the Old Red Sandstone and appears quite conformable to the older rock, so that it is extremely difficult to fix the exact boundary between them. The gently inclined New Red Sandstone in the Machrie Water when traced up stream gradually increases its S.S.W. dip from 10° to about 30° as far as the outcrop of a conglomerate band, which is doubtfully referred to the Old Red Sandstone. A similar difficulty is found in the section in the Machrie Burn and on the coast opposite Auchagallon. There is no fossil evidence to settle the question by fixing a definite line, but there is no doubt whatever about their being here two distinct formations and that the boundary between them is not far from the line drawn on the map. The soft, thick, and rather false-bedded sandstones near the top of this division, which are carious (having many cavities in places), have been quarried west of Traighliath, where they form a narrow gorge in the Ballymichael Burn, and by the side of the Machrie Water about a mile from its mouth. At the latter locality the cavities are of various shapes and sizes, some of them very irregular, and one was observed more than a foot in length and upwards of an inch in breadth. The natives call these cavities *moss-holes.* These upper beds are finely exposed along the Tormore shore for about a mile south of Leacan Ruadha. The sandstone varies from a deep or almost brick-red colour to yellow or white, and the changes, sometimes rather abrupt, are not easily accounted for. At the north end of the section the beds dip to the north-east at 10°, and this direction continues for some distance, so that as we advance southward lower and lower beds successively rise from the shore and form the cliff. Then the beds for some distance remain horizontal, but before reaching An Cumhann the strata begin to dip gently to the south-east, and we observe the rocks a second time as we proceed southward. The carious and false-bedded sandstones enclose lenticular masses which seem slightly calcareous, and the weathering of some of the rock is very curious and irregular, sometimes not unlike bunches of grapes. Much of the sandstone is quartzose and rather coarse, but the bunches and lenticles are formed of a finer and harder rock, concretionary in structure. The massive red and yellow sandstones in which the large caves are formed is the highest part of this series, and a short distance to the southward we find these beds passing under the marls of the Upper Trias (Keuper?).

DERIVED CARBONIFEROUS FOSSILS IN THE NEW RED SANDSTONE.

In the lowest part of the New Red Sandstone which immediately overlies the Carboniferous formation in the northern part of Arran, there are bands of conglomerate which contain pebbles of Carboniferous limestone from which several derived fossils have been obtained by the geological survey. Rather more than a quarter of a mile north-west of this spot, and about 100 yards east of the Cock of Arran, is another locality where derived fossils may be collected. There occurs a very irregular pebbly band, which appears to have accumulated in a hollow of the sandstone during the process of rock formation. It contains, among others, large blocks of trap and white quartz, etc., and from it the following collection was made:—

Lithostrotion irregulare.	Retzia ?
,, Portlocki.	Spirifera trigonalis.
Zaphrentis ?	Entolium Sowerbyi.
Crinoid ossicles.	Nuculana attenuata.
Rhabdomeson rhombiferum.	Protoschizodus axiniformis.
Orthis resupinata.	Bellerophon decussatus.

It was probably in the first-mentioned locality that derived Carboniferous fossils were obtained by Messrs. James Thompson and E. A. Wünsch, as reported in the Trans. Geol. Soc. Glasgow, vol. v., p. 313 (1874), and described in vol. xi. of the same Transactions, p. 30 (1897).

UPPER-DIVISION OF NEW RED SANDSTONE.—The red shales or marls of the upper division of the Trias (of Keuper age ?) are not well exposed in this sheet. They occupy but a small area, but are found in three separate localities, in one of which the rock is part of a fragment in the volcanic vent of Ard Bheinn, and is described in connection with the Rhætic beds. This section, though small, is interesting, however, as it presents us with what are presumably the very highest beds of the formation, which are nowhere else exposed in the island. In the two other localities only small portions of the lowest beds of this division occur. One of these is at the head of the Birch Burn to the south of Brodick and north of Cnoc Dubh. The rocks may be seen in both branches of the burn, but the longest branch yields the better section. Overlying the red sandstones rather more than half a mile north of Cnoc Dubh, we find beds of red and mottled clays or argillaceous shales with occasional thin bands of nodular limestone. The dip is first to the south at a low angle, but higher up the stream the dip is eastward or undulating, and the strata are traversed by dykes or sills of felsite, pitchstone, and basalt. Traces of the mottled shales or marls, variegated red and green, are found occasionally up to near the head of the stream where it issues from a peat moss. The size of this patch of the upper beds appears to have been limited by a fault on either side which brings up the lower sandstones.

The third locality where the rocks occur is on the western side of the island at Ballymichael, and they are exposed in three small streams on the east side of the road and south of Ballymichael Glen. The red shales or marls with occasional thin sandstones here seen, dip generally to the S.W. at 10°-20°, but sometimes the dip is easterly at a low angle or even S.E. They pass gradually down into the underlying sandstones.

These rocks form but a small portion of the division, which will be more fully described in the explanation of the southern part of Arran.

CHAPTER VIII.

Patches of Secondary Formations in Volcanic Vent.

The Rhætic, Liassic, and Cretaceous formations now to be described do not actually occur *in situ* in the island, but consist of fragments or masses of rock of various sizes which have fallen into a volcanic vent of post-Cretaceous (presumably Tertiary) age. The igneous rocks, both massive and fragmental, with which these fragments are associated are elsewhere described. As will appear from the detailed description of the fragments which contain fossils, they do not occur in close proximity, and sometimes as much as a mile intervenes between one fragment and another. In addition to the fossiliferous masses, there are others of limestone, of sandstone, and of shale, in which no organic remains have been found. It seems probable that these also are of Secondary or Mesozoic age, though it is not possible in each case to determine what formation they belong to.

In several instances the fragments have been much altered by intrusive igneous rock, and some of them have Tertiary dykes or sills traversing them. Especially is this the case with the largest of the fragments, which contains not only beds of Rhætic age but grey marls in the upper part of the Trias and a portion of the red marls which lie below.

Rhætic Rocks.

A short distance north of the farmhouse of Derenenach, two small streams which have cut gorges in the low lying mass of granophyre cross the road. The longer and more northerly of these two burns is called Allt an Dris, and is the only one of the two which is marked on the one-inch map. In the middle part of its course this stream traverses the largest of the identifiable fragments in the volcanic vent, which is of an irregular shape and extends over several acres. It is probably quite a quarter of a mile in length from north to south, and its width is at greatest about 150 yards. This patch contains the black shales and thin limestones of Rhætic age, which are exposed for a length of nearly 90 yards in Allt an Dris about a quarter of a mile north-east of Derenenach. The greater portion of this fragment, however, consists of grey and red Triassic marls, the red marls forming the bulk of it. One cannot be quite certain about the actual order of succession in this mass, as the rocks are broken, or faulted and disturbed, and we do not see the different subdivisions actually in contact, but the following is the probable arrangement in descending order.—

> Black shales and thin grey limestones of Rhætic age.
> Greenish-grey or pale-coloured compact marls—Upper Keuper.
> Red marls—Keuper.

These beds are bounded on the west by the granophyre before mentioned which occupies a strip of ground nearly a quarter of a mile in width between them and the road. They are best reached by following the burn upwards. On coming to the old sheepfold some of the red marls or mudstones may be noticed in the slope opposite with a high dip to the west, and they are also exposed in a small branch stream which we pass on the left. Soon the stream inclines more to the eastward, and we find in it a considerable section in the red marls, which appear to be nearly flat or have a gentle inclination eastward. The section is somewhat obscured, however, by several sills and dykes of felsite. Above this steep part the stream takes a sharp turn to the left and we lose sight of the rocks. A little higher up on the south side we observe the grey marls in the bank, lying nearly horizontal or with a gentle dip to the south-west, and a few yards farther we come upon the Rhætic black shales on the same side. They do not occur here, however, on the north-east side, but are opposed to the grey marls which on the north-east side are at a higher level than the Rhætic shales of the south-west side, so that there is manifestly a fault or break of some kind along the burn. Nearer to the sharp bend there occurs in one place a mass of the Rhætic shale containing thin limestone bands on the north-east side, and it was from this locality that all the best specimens were obtained. We do not, however, see the relation of this mass to the grey marls, and the junction is probably not natural.

The black shales on the south-west side of the stream here have yielded organic remains, but they are in a crushed and fragmentary condition. Altogether these Rhætic shales seem to be more disturbed than either the red or grey marls, and it is impossible to make out any order of succession in them. Often they appear to be nearly vertical, as in the fragment from which the fossils were obtained. The whole length of the exposure is in a small rocky gorge, and about 40 yards of it is below the sharp bend where the stream turns from a south-east to a due east direction. Above this bend the black shales may be traced for about 50 yards on the south side of the burn, but they do not extend so far on the north side. It seems probable, however, that they may occupy a considerable area to the south-west of the bend in the stream, where there is a smooth grassy slope, and excavations here might reveal other fossiliferous bands. The exposures above the bend in the stream have yielded no fossils.

The grey marls, as we have stated, appear on both sides of the stream, but the outcrops are not exactly opposite, as they are higher up on the north side, and opposed to the Rhætic beds on the south side.

These rocks were surveyed in the year 1899, and their peculiar characters, as being unlike anything occuring elsewhere in Arran, were remarked on. Specimens of the dark ferruginous shales were obtained, and were supposed to resemble certain rocks occuring in the Old Red Sandstone near Strathpeffer and elsewhere in the north of Scotland. In May 1900, however, the fossil collector of the Survey, Mr. A. Macconochie, who accompanied me to the locality, was successful in obtaining undoubted organic remains from the beds, and the collections made by him on being examined by Mr. Newton were referred to the Rhætic beds.

The following is Mr. Newton's determination of the specimens:—

FOSSILS FROM THE RHÆTICS OF SHISKINE, ARRAN.

Avicula contorta, *Portl.*
Pecten valoniensis, *Defr.*
Schizodus (Axinus) cloacinus, *Quenst.*
Protocardium philipianum? *Dunk.* (=C. rhæticum, *Merian.*)
Modiola minima? *Sow.*
Estheria minuta? *Goldf.*
Gyrolepis Alberti? *Ag.*

Nearly three-quarters of a mile distant from the Rhætic beds in Allt an Dris in a north-east direction, and about the same distance south of Glenloig, is a mass of unfossiliferous shale which may belong to this formation. It is about 35 yards in length from N.N.E. to S.S.W., and is nearly vertical or dipping steeply to E.S.E. The rock is much altered and hardened; is now of a blue colour and a kind of porcellanite, bounded on the east by volcanic agglomerate and on the west by an intrusive mass of quartz-felsite. The volcanic agglomerate has undergone much alteration as well as the shale, and there is not much hope of obtaining fossils from this locality.

Lias.

The locality in which the Lias fossils are found is about one mile south-east from that of the Rhætic patch in Allt an Dris, and nearly half a mile due south from the top of Ard Bheinn. It is 300 yards north of a fork in the Ballymichael Burn, and near the head of the glen in a dry gully on the north-west side of the stream. The patch consists of brownish, crumbling, calcareous shale and impure decomposed limestone, in some parts of which fossils are abundant, but mostly in the form of casts. The exact area occupied by this shale cannot be ascertained, but it is probably 100 yards in length and nearly 50 yards in breadth. Between it and the stream is found a yellowish granophyre, and on the north-east side occurs a fine, dark, basic rock. On the south-west side of it occurs the volcanic agglomerate, the boundary between which and the shale appearing to be vertical, and in one place the two rocks seem somewhat mixed.

My colleague Mr. B. N. Peach, to whom I showed this singnlar fragment of a formation, was the first to obtain fossils from it and to recognise their Liassic facies, and the joint collection then made by him and myself (June, 1900) was despatched to Mr. E. T. Newton, who fully confirmed Mr. Peach's observations. In October of the same year a further search at this locality was made by Mr. Macconochie, which resulted in considerable additions to the original list. The fossils all belong to the Lower Lias (*Ammonites angulatus* zone), and no traces of any beds that will fill up the gap between these rocks and the Cretaceous formation have been found, so that it is very probable they were related to one another in Arran as they are in Ireland, where the Cretaceous rocks repose unconformably on those of the Lower Lias. Mr. Newton has examined the whole set of fossils from this locality, and has furnished the following list of them :—

FOSSILS FROM THE LOWER LIAS (AMMONITES ANGULATUS BEDS), ARRAN.

Ammonites (Ægoceras) angulatus, *Schloth.*
Amberleya acuminata, *Chap. and Dew.*
Cerithium semele ? *Martin.*
,, sp. (*cf.* Falsani, *Dumortier.*)
Pleurotomaria tectaria, *Tate.*
Arca ?
Astarte sp.
Avicula lanceolata, *Sow.*
Cardinia Listeri, *Sow.*
Cardita Heberti, *Terq.*
Goniomya sp. (*cf.* rhombifera, *Goldf*; and sinemuriensis, *Oppel.*
Gryphæa arcuata, *Lamarck.*
Inoceramus (Crenatula).
Lima pectinoides ? *Sowerby.*
Lima succincta, *Schloth.*
Modiola sp.
Myoconcha psilonoti ? *Quenst.*
Nucula sp. (2 forms.)
Nuculana (Leda) Tatei N. (=L. Renevieri, Tate.)
Nuculana sp. (*cf.* Quenstedti, *Tate.*)
Ostrea irregularis ? *Quenst.*
Pecten subulatus ? *Goldf.*
Pholadomya ?
Protocardium truncatum ? *Sow.*
Tancredia ? Peachi, n. sp.
Unicardium cardioides, *Phillips.*
Ditrupa globiceps, *Quenst.*
,, sp.
Serpula sp.
Pentacrinus basaltiformis, *Miller.*
Wood.

CRETACEOUS.

Rather more than one mile to the east of the road Ballymichael Glen branches into two. A small stream comes in from the east, but the main valley continues in a north-east direction. A few yards above this fork there are lying at intervals in the bed of the main stream some blocks of a light-coloured limestone containing irregular lumps of chert or flint. They are not numerous, and have been apparently derived from the coarse volcanic agglomerate which forms here the western bank of the stream; for about 60 yards from the branch stream a small trail of these limestone blocks was observed on the slope. There is, however, no mass of the rock anywhere, and no fragment large enough to be indicated on a map of any scale. The limestone of these blocks is in character remarkably like to that of the chalk of Ireland, which is not a soft friable rock like that of England, but a hard and compact limestone, especially where it has come in contact with igneous rock. The siliceous concretions in the limestone are irregular in shape, and occur just like flints in chalk or like chert in cherty limestone. They are almost pure white, certainly lighter in colour than the limestone itself, and they project on a weathered surface. The limestone itself is compact, fine-grained, and of a grey colour.

This locality is only about 200 yards south of the patch or fragment of Lias already described, and the volcanic agglomerate occupies intervening ground.

These blocks were noticed by Mr. B. N. Peach in June, 1900, who remarked at the time on their resemblance in character to the Antrim chalk. They were afterwards, in October of the same year, searched by Mr. A. Macconochie, and the organic remains were examined by Mr. E. T. Newton, who has furnished the following list:—

FOSSILS FROM THE LIMESTONE AND CHERT OF BALLYMICHAEL GLEN, SHISKINE, ARRAN.

Inoceramus (piece of shell showing prisms).
Polyzoa (Entalophora ? and Escharina ?)
Echinoderm fragments.
Porosphæra globularis, *d'Orb.*
Hexatinellid sponge fragment (Plocoscyphia ?).
Tetractinellid and other spicules.
Globigerina cretacea, *d'Orb.* (and other species).
Textularia, &c., &c.

Rather more than a mile N.N.W. of this locality, and 1100 yards N.E. from Derenenach, a mass of cherty limestone of the same character occurs in a cave on Ard Bheinn, and some specimens of the limestone taken from this cave contain Cretaceous foraminifera. This "pigeon cave," as it has been called, can be traversed for many yards sloping downward in a W.S.W. direction. The arched roof of the cave, which slopes downward like the floor, appears to be composed entirely of basic igneous rock—one of the numerou intrusive masses of the vent. On the north side, near the entrance, occurs two to three feet of dark-coloured hardened shale, which dips westward at 20°-25°. Below this the section is somewhat obscure, but appears to be first basic igneous rock, then a light-coloured crystalline limestone—the Cretaceous rock—and afterwards a white baked sandstone or quartzite. These rocks on the north side are cut out on the south side by the arching over of the trap roof. Some of the limestone of this locality is converted to crystalline marble by igneous action, and all traces of organic remains have been destroyed.

Probably other patches of the limestone occur in the agglomerate of this neighbourhood, as there is a line of swallow-holes about 200 yards S.W. of the cave, and there is one about the same distance due south from the cave.

Three quarters of a mile north-east from the "pigeon cave" of Derenenach is another cave in which limestone occurs, about 500 yards south of Glenloig. The locality where this occurs is called Creag an Fheidh, and there is a steeply sloping hollow about 20 yards wide running in an N.N.E. direction and bounded by crags on either side. On the western side of the hollow, and running in the same direction as it, occurs a basalt dyke four feet in width, and there appears to be on the east side another dyke the width of which is not clear. The cave is on the western side of the hollow, and has a slanting opening some 12 to 15 feet high. It runs back at right angles to the hollow about 15 yards at the north end. It is at this part of the the cave that the limestone is visible, but it is very irregular in thickness, and only some two to three feet at the most, though, as the rock was once quarried, it may have been much thicker. It occurs in association with sandstone and some shale, and dips to the N.N.W. apparently from 30° to 40°. A patch of limestone may also be seen at the foot of the crag on the eastern side of the hollow. The limestone at this locality is much altered by contact with intrusive igneous rock which overlies it, and which has converted it into crystalline marble. There is no trace of chert in it and no organic remains, so that it is doubtful to what geological period it belongs. The cave has no doubt been enlarged by artificial means, but it is certainly to a great extent natural, and water sinks at the western end at a place now covered by loose stones. Probably this was at one time open.

An old road leads up to the cave.

Headrick* notices the occurrence of limestone at this place, but was mistaken as to its mode of occurrence, and in another part of his work he gives the following analysis of the limestone (p. 345):—

Glenluig Chalky Limestone.

Carbonate of lime, ...	98
Clay, ...	2
	100

Other Masses.

In addition to the above, there occur in the volcanic vent several large masses of a whitish, fine-grained sandstone, which probably are fragments of some Secondary formation. The largest of these is found in a line between the top of Ard Bheinn and the summit of Beinn Bhreac, and about 700 yards distant from the latter. It is some 250 yards in length and 15 to 20 yards in breadth, and forms a rather marked feature running in an E.N.E. direction. It is bounded on one side by agglomerate and on the other by granite, and it appears to dip nearly S.E. at an angle of 50°.

The next largest mass of the same kind is found about 200 yards south of the "pigeon cave" and is oval in form, and apparently about 70 yards in length. Smaller patches of the same kind may be seen about 100 yards S.W. of the same cave.

Other masses of sandstone occur about 150 yards north-east of the Rhætic patch in Allt an Dris, and 200 yards north of the old sheepfold on the same stream.

* *See* Bibliographical Appendix, p. 181.

CHAPTER IX.

Tertiary Igneous Rocks.

VOLCANIC VENT.

Reference has been made to the existence of a complicated area, composed of various igneous rocks, lying on the south side of the road leading from Brodick to Shiskine. It is of an oval form, between three or four miles in length, and embraces the high ground of Cnoc Dubh, A'Chruach, Beinn Bhreac, and Ard Bheinn, while its northern limit is the Machrie Water. The ring of acid igneous rocks which forms the exterior of this mass is elsewhere described, and we have here to deal with masses of conglomerate and agglomerate of very irregular outline which occupy for the most part the centre of the oval. For some time the age of these fragmental rocks was doubtful, but a more careful examination of some of the material found in them, and the discovery in various parts of the mass of separate portions containing Rhætic, Liassic, and Cretaceous fossils, established the post-Cretaceous or Tertiary age of the whole, which we must regard as of pyroclastic origin—fragments of various kinds of rock, both aqueous and igneous, that have fallen into the vent of an old volcano or have been forced up from below by explosive action. For the description of the Triassic marls, shales, and limestones of Rhætic age, the Lias shales, and the Cretaceous limestones, we must refer the reader to the foregoing chapter which treats of these rocks. In this place we can describe only the general character of the volcanic agglomerate and some of the igneous rocks which are intrusive in it. The fragmental material may be traced over an area two and a half miles in length by two and a quarter miles in breadth, and may have once extended farther. Masses of igneous rock, both acid and basic, penetrate the fragmental rock in all directions, isolating portions, and making a kind of patchwork, the separate parts of which have very irregular outlines. In many places the volcanic agglomerate has been intensely altered by the intrusive rocks, shale being changed into a flinty porcellanite rock, limestone into crystalline marble, and the matrix of the agglomerate generally profoundly modified. Probably quite one half of the area over which the agglomerate can be traced is occupied by these intrusive igneous rocks.

The general character of the agglomerate is not easy to describe, for it varies much in different places. The matrix of the fragments is very often arenaceous, much like that of an ordinary coarse sandstone, and in this are found pebbles and blocks derived from various sources, igneous rocks of an acid character often predominating.

To the west of Ard Bheinn the rock may be called a brecciated conglomerate, which weathers of a brown colour, and when broken is found to have a fine grey matrix. The included fragments are quartz pebbles (generally small), quartzites, acid igneous rocks such as granite and quartz felsite, schists, etc., all being rather angular in outline.

In Creag Shocach, to the east of Glenloig, the prominent pebbles and blocks in the rock are grits and sandstones of various kinds, more or less angular, small quartz pebbles, and quartzite pebbles generally well rounded, like those found in the Lower Old Red Conglomerates. In ascending the northern end of this crag we find many pebbles of quartz and quartzite in the coarse agglomerate, as well as several varieties of acid igneous rocks (but few of basic lavas) set in the ordinary grey paste. In the upper part of the crag is a quite different kind of rock, which is distinctly red in colour, with a sandy matrix containing only pebbles of quartz. All over the crag we find the nature of the rock varying. At one extreme is an agglomerate made up almost entirely of coarse angular or sub-angular fragments of sandstones, etc., of various shapes and sizes, with little or no matrix; while at the other the rock has a fine-grained appearance externally, and on a fractured surface is seen to consist principally of a bluish-grey hard paste imbedding small angular fragments. There is every gradation between these two extreme varieties. In no part is there any satisfactory indication of bedding. The rock weathers of the usual brown or rusty-brown colour where the grey matrix exists, but does not appear to be so much altered as in some other places—as in the burn to the west for example.

In several places besides Creag Shocach the rock is a coarse conglomerate, very like the characteristic quartzite conglomerate of the Lower Old Red formation, and there is no doubt that this formation has contributed a large part of the material which now fills the volcanic vent, though it has in most cases been broken up and mingled largely with fragments of granite, quartz-felsite, etc. It is only in a few places that the brecciated rock assumes the character of a true volcanic tuff or agglomerate made up of igneous fragments alone, and basic lavas are seldom represented in it. On the east side of the Rhætic patch in Allt an Dris the rock has generally a fine dark-grey matrix, which in places is calcareous and becomes carious on the brown-coloured weathered surface. It contains pebbles of white quartz (small), and quartzite, always well rounded. Rarely there are pebbles of quartz-felsite, and the schist fragments are always angular. Occasionally there are no prominent fragments, and the rock then has more the character of a fine tuff. A pebble of amygdaloidal andesite was got out of the rocks about 500 yards north-east of Derenenach, and pebbles of similar character are apparently not uncommon between this locality and Creag Mhor, where, near the edge of the granite, the rock has a chloritic and ferruginous matrix, probably from altered basic tuff-material. At the junction with intrusive basic rock 100 yards south-west of the Derenenach cave, a specimen showed a pebble of crushed and schistose grit (schist), besides the usual quartz grains, chips of andesite, etc. The agglomerate is much altered about three quarters of a mile south of Glenloig farm. One of the specimens collected from near the mass of altered shale described in Chapter VIII. has a large piece of micro-granitic quartz porphyry in a fine grey matrix much metamorphosed, with abundant new-formed biotite. To the west of this, and near the edge of the granophyre or granite, there is a vein one and a half inches wide of a fine-grained biotite granite traversing the matrix of metamorphosed tuff, apparently of trachytic composition, with new-formed biotite; there are also fragments of metamorphosed basic lava with much biotite.

Some pebbles collected from the agglomerate in Allt Ruadh to the east of Derenenach are of felsite, with small isolated spherulites. Others are much decayed, but may have been andesitic in character. A fairly large collection of pebbles was made from the agglomerate in various localities, and they quite bear out the statement that of the igneous fragments those of a decidedly acid character predominate, though basic material may have entered more largely into the formation of the matrix.

West of Creag Mhor the agglomerate comes probably directly into contact with the Lower Old Red formation, and there appears to be a break in the igneous ring.

Between Beinn Bhreac and Cnocan Biorach a portion of the fragmental rock appears to be surrounded by the later intrusive masses, and in two places we find the agglomerate outside the igneous ring, or only partly included in it. One of these is at the head of Benlister Glen, to the north of Cnoc na Croise. The extent of this cannot be ascertained, as it only occurs as a small section in the burn. A dark-greenish fragmental rock, apparently of a tuffaceous character, and considerably altered, occurs nearly close to the granophyre. The fragments are of quartz and of a felsitic rock, in a greenish matrix containing much hornblende (actinolitic) which has evidently been formed *in situ*. The other locality is at Cnoc an Biorach, on the south side of Ballymichael Glen, where a considerable mass of a dark, fine-grained, almost flinty rock, occurs around the Ordnance Station and to the south-west of it. Some of it is obviously fragmental, and portions which appear massive when examined under the microscope are found to consist of metamorphosed gritty tuff with much new biotite. Along the eastern margin of the mass a coarse agglomerate is visible in two places. This area appears to be bounded by granophyre and quartz diorite, except on the south-west side, where it adjoins the rocks of the Upper Old Red formation.

Some of the larger unfossiliferous masses included in the agglomerate are described with the secondary fragments.

The intrusive rocks of the vent have been generally described elsewhere, and some of the more important varieties, as granite, granophyre, quartz-diorite, diorite, hyperite, etc., have been more particularly noticed. There remain to be described here some of the more prominent intrusive masses that, together with the agglomerate, form the intricate patchwork of outcrops around Ard Bheinn. Two of the largest run along the western side of the hill in parallel bands; the outer a basic rock, and the more easterly a quartz-felsite, which becomes in places coarsely porphyritic. The basic rock, the course of which has been given elsewhere (*see* Chap. X.), is an ophitic dolerite which, 200 yards S.E. of Creag Mhor, is replaced by gabbro.

The quartz-felsite is a light-coloured rock, somewhat coarse textured, and very different in character from most of the acid intrusions that occur between Ard Bheinn top and Glenloig. It covers a considerable area, and has in places a width of outcrop amounting to nearly 400 yards.

The dark rock at the summit of Ard Bheinn is magnetic and affects the compass strongly. It appears to be a felsite with a fine-grained matrix containing whitish felspar crystals. Around the summit are some bands of a white weathering rock of a more acid character apparently. Two hundred yards S.S.E. of the summit is a grey rock banded with red; it is a rhyolite with strong flow structure, and may be connected with the mass of quartz-felsite that runs along the west side of the hill, but there is some doubt whether it is not a portion of a fragmental rock to which it is adjacent, as there are several fragmental masses in the intrusive rocks of this part of the hill.

A number of small, basic, intrusive masses occur about the Derenenach cave and around Binnein nah-Uaimh, and others are found near the Glenloig cave, but most of the intrusive rocks of the north side of the hill are of an acid character. Those which occupy the largest area, and which are most regular in their outline, are either granite or granophyre. The masses with such tortuous outlines consist generally of a fine-grained, grey felsitic rock, sometimes almost of a flinty character, minutely jointed and breaking up into splinters. It forms prominent scars at Creag Dhubh overlooking Glen Craigag. Sometimes the rock is of a darker colour and of a bluish cast. Quartz in small blebs is generally present in both varieties, and most of the rock is nearly white on the weathered surface. In places the jointing in this rock is beautifully close and parallel, and very striking. Good examples occur 300 yards south of the Glenloig cave and nearly a mile S.S.E. of Glenloig, both near the junction of felsite and agglomerate. The latter locality is about a quarter of a mile west of the main stream of Glen Craigag.

In several places in this burn about three quarters of a mile from Glenloig sections occur in a dark, almost black, fine-grained rock, which appears to alternate with masses of undoubted agglomerate. Some of the fine-grained rock is manifestly banded felsite, but here and elsewhere in this area it is almost impossible without the aid of the microscope to distinguish between the fine-grained massive rocks which are free from quartz and the highly altered matrix of the agglomerate where it is devoid of fragments. A pitchstone dyke pierces the agglomerate in a small stream two thirds of a mile south-east of Glenloig and nearly 300 yards west from the main burn. It is dark coloured, two to three feet in width, with a hade to the south-west. It runs in a south-east direction, and perhaps has contributed in the formation of the prominent scar of felsite there.

Intrusive dykes are seldom met with in Ard Bheinn, but a few occur in Glen Craigag. The deep and narrow gorge in which the stream runs, from 300 to 600 yards above Glenloig house, is occupied by a basic dyke which here pierces the agglomerate. Another gorge nearly one and a half miles from the house, is partly due to a basic dyke which invades the granite. Other dykes, both basic and acid in character, are found in a higher part of the stream penetrating both agglomerate and granite.

In many, if not most volcanic necks, the material forming them has often a more or less definite arrangement on a large scale, so that its different portions have an inclination towards the centre of the vent. There is, however, no approach to such arrangement in the case under consideration. In fact, the evidence we have, so far as it goes, points to an inclination in the reverse direction, *i.e.*, towards the circumference of the mass. This is noticeable in the material near both the caves, and in the edge of the agglomerate west of Beinn Bhreac.

CHAPTER X.

Tertiary Igneous Rocks—continued.

GRANITE.

Of the Tertiary intrusive rocks of Arran granite is by far the most important. It occurs in two detached areas, each of which has an oval form. The larger of these, which is the nucleus of the northern portion of the island, has been a subject of interest to geologists since the time of Hutton towards the close of the eighteenth century. Its form is nearly circular, being eight miles by seven, and its circumference, viewed on the large scale, is very even and regular, with no large projections or detached bosses, and generally its boundary is sharply defined. There are two varieties of the granite; one coarser-grained and earlier in age forms the exterior of the mass, while a finer-grained and newer variety is in the interior. The coarser kind is composed mainly of quartz and orthoclase felspar., with abundance of black or brown mica in certain places, but generally the mica is not conspicuous. Some plagioclase felspar also occurs in the granite. Here and there in the granite, dykes, sheets, and patches of a finer-grained rock occur, and these are not always later intrusions, but rather of the nature of segregations, for they may be seen sometimes to merge insensibly into the general mass. Patches of this kind are not uncommon near the junction of the granite with the surrounding rocks.

Many joints traverse the granite, and these in places are horizontal, or they dip at a comparatively gentle angle, so that the rock has a remarkably bedded appearance (*see* Plate VIII., No. 1). The most marked joints in other localities are vertical, or dip at steep angles into the glens, their inclination not seldom coinciding with the slope of the ground, and forming ground which is very difficult to traverse. Occasionally we find more than one set of joints developed in the same rock, *e.g.*, both horizontal and vertical joints, but the latter are generally most conspicuous near and parallel to the numerous intrusive dykes.

Some of the finest intrusive junctions of the granite with the older schists in North Glen Sannox were described by Hutton* more than a century ago, and these and other junctions at Tor Nead an Eoin, and elsewhere on the eastern side of the mass, have since been often referred to, but others quite as striking occur on the east side of Glen Catacol at Madadh Lounie, and in several places north of Meall nan Damh. The granite maintains generally its ordinary coarse character near its junction with the schists, but there are several places where it is fine-grained at the margin.

* See his "Theory of the Earth," vol. iii., p. 220.

Fine-Grained Granite.—Several writers have described the finer-grained granite in the interior without, however, defining its exact boundaries. It is intrusive in the coarser variety which surrounds it, and is evidently of somewhat later date, but both belong to the same geological period and are probably parts of the same igneous magma, for they have generally the same sets of joints, and are alike pierced by similar dykes of pitchstone, felsite, quartz porphyry, and basalt. The finer variety occupies nearly all the west side of Glen Iorsa, so that on this side of the island the coarser kind of granite is but a comparatively narrow strip varying from one mile in width to not more than a furlong at Iorsa Loch. On the east side of the Iorsa most of the granite is of the coarser variety, and the boundary between it and the fine is tortuous, some bays of the fine being almost detatched and surrounded by the coarse. The fine granite occupies about 14 square miles, which is one third of the whole granitic area.

All the peaky hills are formed of the coarse kind, the fine variety forming rounded or flat-topped hills, generally of lower elevation. (Plate I.). Usually the fine variety breaks up into small slabs, which often so entirely cover the surface of the ground that no solid rock is observable. The debris of this rock is nearly white in colour, while the decomposition of the coarse granite produces a coarse, brown sand. Occasionally, however, the finer granite becomes coarse-grained and massive; it then breaks up into larger blocks and forms crags. Good junctions of the two rocks are to be seen on the south side of Beinn Bharrain, on Sail Chalmadale, and in Glen Easan Biorach. South of Beinn Bharrain the junction of the two rocks is generally a vertical line which passes across the jointing, and both kinds of granite may be observed in one and the same slab. In Glen Easan Biorach also, the finest junction at the foot of the stream running north from Creag Dubh is vertical; but often in this glen the boundary line is not well defined for some yards, owing to admixture of the two kinds. There seems no evidence anywhere that the fine overlies the coarse granite, and the appearances west of Cir Mhòr relied on for the support of this view are certainly deceptive.

In addition to the main mass of finer granite, numerous small dykes and sheets of it have been intruded into the coarse in various places, but most of these are not large enough to be separately mapped. One of the largest detached masses occurs on the top of Beinn Nuis, between the Ordnance Station and the remarkable rock called Caisteal an Fhionn. It is apparently of an oval outline, and its greatest length from north to south about 300 yards. Another is found near the head of Glen Sannox on the south side of Caisteal Abhail, where the rock has a markedly jointed structure. In this is a closely laminated band of fine granite, about nine feet in width, which may be traced for a hundred yards or more. This is a peculiar rock, and differs from the fine granite which surrounds it in having an approach to a linear arrangement of the quartz in the rock, and it weathers into such thin plates or slabs that at first sight it reminds one rather of a schist than of a granite. Its laminæ, however, dip steeply to the west, exactly in the same way as do the joints in the neighbouring fine granite. In some places it has the appearance of an injected vein.

A specimen from Iorsa Water, 650 yards below Loch na Davie, may be taken as a type of the fine granite. It consists essentially of quartz and the two felspars (oligoclase and orthoclase), biotite and hornblende occurring as accessory constituents.

Drusy cavities containing smoky quartz and orthoclase crystals are common in both granites.

The alteration of the surrounding rocks by the intrusion of this great mass of granite is much less than might have been expected. Often the metamorphism seems to amount to little more than mere induration, and the adjoining rock is in some cases not more altered apparently than sandstone is near some of the dykes in the island. The fine-grained schistose rocks assume a bluer colour and break with a splintery fracture, while the Old Red Sandstone loses its purple or chocolate colour and becomes grey and very hard. Yet in most cases the bedding still remains distinct, though in some the bedding or foliation is rendered very obscure and a set of joints produced parallel to those in the granite itself. The alteration is perhaps greatest in Glen Rosie, where it seems to extend 300 yards into the schists from the junction. Between Glen Catacol and Glen Easan Biorach the altered and hardened schist band is 200 yards wide or more, and it forms a marked ridge which is higher than the granite adjacent, and it also gives rise to gorges in the two streams.

Under favourable circumstances certain minerals appear to have been developed in adjacent rocks by the action of the granite, as andalusite in the schists of North Glen Sannox, and epidote in the altered rocks at the White Water junction, and at Allt a Chapuill near Cioch nah-Oighe. Biotite has also been developed at the White Water by contact alteration. Perhaps the most marked instances of metamorphism are those which are found in certain basic dykes which are of earlier date than the granite intrusion. One of these, penetrated by granite or granophyric veins, is visible in the Cnocan Burn below the old mill-dam.* It is an altered dolerite in which the plagioclase felspars and the patches of iron ore have retained their original characters, while the augite has been converted into aggregates of pale-green hornblende, with which some brown mica is associated. On the opposite side of the mass of granite another example of the same kind of alteration is found in a dyke nearly half a mile north-west of Lochan a Mhill. This is described by Ramsay (Geology of the Isle of Arran, p. 49), who, however, thought that the dyke was intrusive into the granite. One of the most marked examples of alteration by the granite is found in Glen Iorsa, 400 yards W.N.W. of the boathouse, Loch Iorsa. A highly altered argillaceous schist seems totally reconstituted, and contains abundant andalusite in relatively large irregular crystals, and much finely-divided

* This dyke is described by Bryce ("Geology of Arran," 4th ed., p. 79), but he does not notice the alteration of it due to the granite.

biotite. This locality is nearly a quarter of a mile from the edge of the granite. In Glen Scaftigill, near the granite, a gritty schist is highly metamorphosed. There is new-formed biotite in large flakes, and there has been a recrystallisation of much of the finer-grained portion of the rock, with doubtful andalusite formed in places.

This large mass of granite comes into contact only with the schists and the Lower Old Red Sandstone, and is certainly of later date than the latter formation. That it is also more recent than any of the other formations which are found in the island—Upper Old Red Sandstone, Carboniferous, and Trias—seems very probable, from the fact that no fragments of granite are found in the rocks of these formations; and its similarity in character to the granite of the Mourne Mountains in Ireland, which is post-Cretaceous, lends support to the view that the Arran granite is of Tertiary age. This view is confirmed by the alteration observed in the dykes mentioned above, which are probably of Tertiary age. Further evidence on this point will be adduced in a subsequent page.

Area South of String Road.—The smaller granite area occurs south of the road leading from Brodick to Shiskine and occupies the highest ground in this part of the island, where are found the hills A'Chruach, Beinn Bhreac, and Ard Bheinn. The granite is here associated with granophyre and quartz-diorite (into which rock it appears to graduate), and with many other intrusive masses, both acid and basic, which have penetrated a large volcanic vent of post-Cretaceous age. This oval district, which is extremely complicated in structure, is 3½ miles in length from south-west to north-east, and 2¾ miles in breadth, and its area is about 7 square miles.

Granophyre passing into granite and quartz-diorite occupies the south side of Glean ant-Suidhe (through which the String road passes) and all the highest ground to the south, from Cnoc Dubh by A'Chruach and Beinn Bhreac round to beyond Ballymichael Glen.* A triangular detached portion runs along the east side of Ard Bheinn and takes up a great part of Glen Craigag. A smaller body of the rock runs westward from Glenloig and includes the granite of Creag Dubh, described by Bryce (Geology of Arran, 4th ed., p. 19). A detached area of granophyre occurs south-east of this, and another is found close to and due north of Derenenach. The common type of rock in most of the patches referred to, is a yellowish granophyre or granophyric granite, for in several places besides Ploverfield and Creag Dubh the rock may be called a granite, *e.g.*, in Ballymichael Glen; the burn north of Derenenach; the moss, half a mile due east of Ard Bheinn top; and on the east side of Glen Craigag, about three quarters of a mile E.S.E. of Glenloig. Granite is also found in veins which penetrate the more basic intrusive rocks within this area. Granite veins in this way may be seen in the diorite mass at the head of Gleann Dubh, three quarters of a mile W.N.W. of Brisderg; and in a burn 500 yards E.N.E. of Creag nam Mult, Gleann ant-Suidhe, granite with traces of

* The "Ploverfield granite" of Necker and Ramsay is a portion of this mass.

granophyric structure is intrusive into a fine-grained basic rock, resembling some of the rocks described as diorite.

Quartz-diorite is a very prominent rock in Gleann ant-Suidhe and in several of the streams that join it from the south, and it occupies a good deal of the high ground between A'Chruach and Beinn Bhreac, though here the exposures are not good as the hill-tops are covered with peat. There is a good exposure in Allt nan Calaman (which is the first stream to the west of Cnoc Dubh), and in the stream at Glenloig. It was probably in one of these streams that it was noticed and described by Zirkel 30 years ago (*see* his "Geologische Skizzen von der Westküste Schottlands," p. 30). The older writers, from Jameson in 1798* to Ramsay in 1841,† have described or included this rock under the head of syenite. It varies much in composition, in colour, and in grain. Sometimes the rock is light-grey, contains little hornblende, is very acid in character, and approaches granite in composition, as in a burn 150 yards north-east of Creag nam Mult, Gleann ant-Suidhe. The specimen described by Zirkel consisted of white felspar and greenish-black hornblende with some qnartz, plagioclase and orthoclase felspars being both present. The rock often contains finer and darker patches which are richer in horneblende and appear to be more basic than the general mass of the rock. In fact, the composition of the mass seems to be constantly varying, and occasionally we find that the most basic portions of it are penetrated by acid strings and veins approaching granite in composition, which are probably derived from the same magma which produced the more basic portions. Some attemps were made to map the quartz-diorite separately from the granite and granophyre, but the attempt was given up because the rocks are so intermingled, and because it was evident that there are transitional forms betweeen the quartz-diorite and the granophyre, and practically the rocks seem to be but different stages in the consolidation of one and the same molten mass. At all events, this is the impression one gets after examining the sections in the burns on the south side of Gleann an't Suidhe.

At the edge of the mass nearly half a mile south-west of the top of Beinn Bhreac, the granophyric rock is beautifully spherulitic. The same kind of structure occurs in a similar rock 300 yards north-east from the summit of Ard Bheinn. The rock forms here an oval patch about 40 yards long, the relations of which to the surrounding acid and basic rocks is not clear. The colour of it is nearly white on the weathered surface, but when broken it is seen to be a mass of spherules, each averaging half an inch in diameter.

In some places, as near the head of Ballymichael Glen, and between the heads of Glen Dubh and Glen Ormidale, the fine-grained granophyre of the edge of the mass appears to pass into a felsite-like rock. There is a great mass of this rock at the latter place, and the boundary between it and the granite and the granophyre to the west is not clear.

* R. Jameson, "An Outline of the Mineralogy of the Shetland Isles and of the Island of Arran, p. 84.

† A. C. Ramsay, "The Geology of the Island of Arran from Original Survey."

In Glenloig Burn, 200 yards west of the house, the rock is a granitite with traces of granophyric structure, and ferro-magnesian minerals are very scarce.

One of the most instructive sections occurs in Ballymichael Glen, rather more than half a mile above the road, where we come on to the mass of igneous rock. After passing over several yards of yellowish, crushed, felsitic rock, which probably represents a dyke, we approach a massive, dark-grey, basic-looking rock, probably a variety of diorite. Higher up this rock appears more distinctly acid, a quartz-diorite in fact; and just below the next sharp bend in the stream an irregular, yellow granitic band, four to five yards wide, which is intrusive in the diorite, crosses the burn. Some thin and still more acid veins penetrate both rocks alike. At the next bend above is a more basic-looking rock which may be a dyke, into which coarse granite intrudes, as also into granite or granophyre of the finer variety, while a thin acid vein or elvan runs along the burn in the darker and more basic rock. At the next bend to the north the rock is more decidedly an acid variety of quartz-diorite. Just above this is another intrusion of granite, and then the rock in the stream assumes a very massive character, weathering into large rounded masses, with marked joints inclined across the burn northward. This is a dark and coarse quartz-diorite. At the next bend to the north we come upon the main mass of light-yellowish acid granite, much jointed. The junction appears to be an intrusive one, the granite being the more recent rock of the two.

From the foregoing description it will be gathered that the granitic rocks form an almost complete ring on the outside of the oval complex. Various members of this acid series of rocks come into contact with both members of the Old Red Sandstone and also with the Triassic rocks, and the sedimentary formations are in every case altered, so that the intrusive rocks must be of later date than these formations. The granophyre at the head of Glen Dubh is also clearly intrusive into the mass of diorite there, which is nearly a mile in length, and there seems considerable evidence in favour of the view that this diorite is but a basic form of the quartz-diorite so often occuring to the westward. It is certainly very difficult to separate the two rocks by any definite boundary line, though an attempt has been made to do so on the map, and the diorite may conveniently be considered as part of the igneous ring.

The alteration effected by these igneous masses on the adjoining sedimentary strata is very great. Along the north side of the oval the actual junction of the igneous rocks with the Old Red Sandstone is not visible, and there is no opportunity of studying the altered rocks, but on the south and east sides the effects are marked. The red sandstones and conglomerates of the Trias and Upper Old Red Sandstone have their colour changed to white and the rocks are converted in quartzites, while the more felspathic sandstones of the Lower Old Red formation are changed from a chocolate to a grey or bluish colour, their bedding sometimes is nearly obliterated, and the rock is very tough and hard. The chocolate mudstones of the same formation are in like manner altered to flinty rocks resembling porcellanite.

If we now examine the inside of this igneous ring we find that its various members are intruded into the material, filling up a large volcanic vent which is known to be of post-Cretaceous age from the fossiliferous fragments included in it. There is thus a continuous chain of evidence in favour of the Tertiary age of this granitic tract, and this age must now be accepted.

Several writers have remarked on the resemblance of the granite of this outlying tract to the fine granite in the interior of the northern mass, and the evidence for their being contemperaneous is very strong. On the specimen before referred to from 650 yards south of Loch na Davie, Mr. Teall remarks that the rock is evidently the granitic phase of the magma which has elsewhere produced granophyre, so that both microscopic and field evidence agree in assigning these rocks to the same age. The coarser granite, as has been already shown, in all probability is only slightly earlier in date than the finer granite, and there is independent evidence for its being of Tertiary age. Hence, we arrive necessarily at the conclusion that all three granites are practically of one geological period.

If we look at the geological map of this northern portion of Arran we cannot help remarking on the nearly circular outline of each of the two areas in which granite is found, and that in both areas the sedimentary strata have been effected in the same way, having been upheaved so that their curved outcrops, especially on the eastern and southern sides of the masses, are roughly parallel to the edge of the igneous intrusions. May there not be a still further resemblance; and as the smaller area is proved to be a volcanic centre, may not the larger granitic area be the stump of an old volcano?

Granitic Dykes.—A dyke of pink-coloured syenite may be seen in a small burn called Allt nan Eireannach, about half a mile due south of Catacol. The point where the dyke is visible is 150 yards above the outlet of the stream, which flows into the Catacol Burn. The dyke has a course about W.S.W., and is here intrusive in dark phyllitic schists. Its width is at least 6-7 feet, but it may be a little more, as the exact contact with the schists is not exposed. This locality is about a quarter of a mile distant from the edge of the mass of granite, which the dyke does not much resemble in character.

A granitic or granophyric dyke occurs in Glen Chalmadale to the east of Lochranza, and appears to have an N.N.W. course. It crosses the main stream of the glen at a point nearly due north of the hill called the Clachan and 200 yards S.E. of the foot of a branch burn called Allt na Meanie which comes in from the north. The rock is light-coloured, of rather fine grain, has many small drusy cavities, and altogether much resembles some varieties of the finer granite of the interior or the granophyre of the southern tract. The dyke is from 25 to 30 feet wide, but only the central portion appears to be granitic; the edges are finer in grain and of a darker colour, and are probably of intermediate or basic composition. The dyke appears again in Allt na Meanie, but cannot be traced continuously. Rock, however, of the same character appears at the head of a burn a mile distant to the northwest and a little to the south of the most westerly of the old slate-quarries. This is quite three quarters of a mile distant in a straight line from the edge of the great granite mass.

The granite dykes which are found within the granite area are much finer in grain than even the fine-grained mass of the interior; they are, in fact, of the nature of elvans, and seem essentially composed of felspar and quartz.

FELSITE AND QUARTZ PORPHYRY, RHYOLITE, TRACHYTE, AND PITCHSTONE.

SILLS.—The larger sills and bosses of acid rocks other than granite are all in the southern part of the sheet. The most important of these are found at Dun Dubh near South Corrygills, near Cnoc Dubh north-west of Lamlash, the Windmill Hill on the north side of Glen Ormidale, Holy Island on the east side of Lamlash Bay, Torr Righ Beag on the west coast, and at Derenenach, and around Ard Bheinn. Many of the acid intrusions in the agglomerate on the north side of the latter hill are of a fine-grained, grey quartz-felsite, which is a white weathering rock. The quartz-porphyry of Windmill Hill is in general a rather fine-grained rock of a light-grey colour, and only here and there is it more largely porphyritic. It appears not to be pierced by any dykes of quartz porphyry or felsite, though there are several in the crags south of Glen Ormidale and in the adjacent stream, whose course might be expected to cross it. It is penetrated, however, by several basalt dykes, and crossed by faults that are of earlier date than these dykes. The rock has a yellowish, flesh-coloured, or grey, groundmass, with white quartz and orthoclase crystals imbedded in it. The rock of Dun Dubh is somewhat similar, and has been described as a rhyolite. It is disposed in fine nearly vertical columns on the north side, but these change to horizontal at the west end.

The felsite sheets, which have seldom free quartz and are not usually porphyritic in character, such as those of Holy Island on the one side of Arran and of Torr Righ Beag on the other, are probably of later date than the quartz porphyries. In the southern part of Arran we can see the felsite dykes and sheets piercing the porphyritic rocks, and in this area we have evidence that the felsite sills are about the most recent of all the intrusive igneous rocks, for we seldom find them pierced by the ordinary basalt-dykes. None have been met with in the Torr Righ Beag mass or in the felsite of Holy Island, though dykes are common in the adjacent rocks. A north-west running dyke on the South Corrygills shore does not penetrate the felsite sheet there, though it is traced for long distances on either side of it. The same felsite sheet appears two-thirds of a mile west from this place in a burn between North and South Corrygills, and here again it is clearly later in date than a basalt dyke which crosses the burn at the same spot. The larger felsite sheets in the southern part of Arran are often beautifully columnar, but examples are not common in this area, though one occurs on the north-eastern side of Holy Island.

The smaller felsite sheets, usually of a yellowish colour, are rather common near the head of the Birk Glen south of Brodick, and one which has been quarried appears by the side of the road to Lamlash, rather more than a mile south of Brodick pier. It is a somewhat fissile rock, fine-grained, of a pale-yellow colour, and minutely spherulitic. It has been described along with other felsites (Geol. Mag., vol. ix., p. 542) by Mr. S. Allport. Two sills of this character are found on the Corrygills shore on either side of Corrygills Point, and these have been described by several of the writers on the geology of Arran.

Dykes.—The dykes of quartz felsite which occur in Arran are not so numerous as those of basalt, and most of them occur to the south of the main granite area. Those which are found in the northern part of the island may be counted on one's fingers. Even in the southern part of the sheet where they are abundant in the interior, as in Benlister Glen, Gleann Dubh, Glen Ormidale, and Glen Shurig, they are seldom met with on the coast, where the basic dykes far exceed them in number. The largest dyke on the shore is at An Cumhann on the west coast. This is a coarsely porphyritic rock about 100 feet broad, running in a north-east direction. As a general rule the average width of these acid dykes exceeds that of the basic dykes. One of them is 150 feet wide on Beinn Tarsuinn, and has been traced southward for two miles or more, but in the southern part of its course it is not more than 50 feet in breadth. Another appears to extend from the west side of Caisteal Abhail into the corrie south-west of Cir Mhòr, and a third can be traced at intervals from the burn a quarter of a mile north of the Windmill Hill across Glen Shurig into Glen Rosie.

Comparatively few of these acid dykes are of the type of the smaller felsite sills, which are often spherulitic and contain little or no free quartz; they are nearly all quartz felsites, and some of them are like the An Cumhann dyke before mentioned, coarsely porphyritic.

Pitchstone.—Dykes and sills of Pitchstone, for which the Isle of Arran has long been celebrated, are pretty numerous in the island, and a good many of them occur in out of the way places in the interior which are not often visited. This glassy rock, which in some parts is called *bottle-rock* by the natives, is found of various shades of green from a light yellowish green through various dark shades of the same colour to a black rock. Yellowish-brown and brown varieties occur, and occasionally the rock is reddish. In composition the rock varies from an almost perfectly clear glass to a coarse pitchstone porphyry, and there are spherulitic and banded varieties which remind us of similar structures in the felsites.

Both the dykes and sills of this rock are, as a rule, much more irregular or inconstant than those of the basic rocks, or of the felsites or quartz porphyries, and we find sills changing into dykes, and *vice versa* without any apparent cause. None of the dykes or sills can be traced for very long distances, and any attempt to correlate rocks of this character at widely separated intervals is futile. One of the longest as well as earliest described dykes is that on the Tormore shore, which can be traced for about 500 yards. The dyke or sill at the Brodick schoolhouse can be followed for nearly 350 yards into the wood to the west, but its continuation is uncertain. The sill on the Clauchland shore so often described, can be followed southward with breaks, for about 330 yards, when it disappears on the foreshore. The dyke or sill south of Dun Fionn is traceable for 300 yards, and it may be continuous with the lower Corrygills sill, when its total length would be about 700 yards.

Altogether there are about 40 different pitchstone outcrops in this sheet, and there are also a good number in sheet 13.

LIST OF ARRAN PITCHSTONES IN SHEET 21.

LAMLASH.—A black pitchstone dyke is in the burn near Clauchland's Cottage. Its direction appears to coincide with that of the burn at the point.

DUN FIONN.—A dark pitchstone sill or dyke south of the fort accompanies a spherulitic felstone.

DUN FIONN, East of.—A green columnar pitchstone sill near the shore, which has often been described. It is visible near the base of the crags for 150 yards, and dips S.S.W. at 30°, nearly as the sandstone below it, but it clearly cuts the sandstone, though there is little alteration effected by it. Nearly 200 yards south of this it is visible on the foreshore for abont 50 feet in length.

DUN FIONN, West of.—Two dark pitchstones occur beneath the crags of the Clauchland Hills, between Dun Fionn and Dun Dubh. The lower of these, which may be continuous with that south of Dun Fionn, is about 15 feet thick.

SOUTH CORRYGILLS.—On the shore, 650 yards north of Dun Fionn, a pitchstone two to three feet thick accompanies the large felsite sill there on the north side.

SOUTH CORRYGILLS.—About 50 yards above the main road, and 200 yards west of the road leading down to the shore, a pitchstone is visible for 25 feet in length.

NORTH CORRYGILLS.—South side of branch stream close to main road, a pitchstone accompanies a felsite sill.

NORTH CORRYGILLS.—Same burn, 500 yards S.W. of road, a dark pitchstone dyke running N.W.

BIRK GLEN.—On old Lamlash road, dark-green pitchstone, often described. Also visible in the burn (Allt Beith).

ALLT BEITH.—Dark pitchstone occurs near the head of Allt Beith about one and three quarters miles south of Invercloy.

LAG A BHEIDH.—A dark pitchstone, probably a sill, about a quarter of a mile east of the Brodick and Lamlash road and 650 yards E.N.E. of the Birk Glen outcrop.

Carn Ban.—On the south-east side of this old cairn three-quarters of a mile south of Invercloy are many small fragments of a dark-grey pitchstone, probably nearly in place.

Glen Cloy.—South side of road, quarter of a mile north of Glenrickard, a black pitchstone, probably a sill; three to four feet visible.

Brodick School.—A dark green pitchstone sill with prominent felspar crystals. It is much laminated, and the lamination is parallel to its upper and under surfaces.

Glen Shurig.—A dark porphyritic pitchstone occurs half a mile west of the church in the road leading down to the highest house in the glen.

Beinn a' Chliabhain.—A composite dyke with basic sides and porphyritic pitchstone centre occurs 50 yards north of the highest point, 2217, and again 300 yards to the east.

Beinn Nuis.—A dark pitchstone dyke six feet wide is found about 500 yards south-east of the summit.

Beinn Tarsuinn.— A dark pitchstone is visible 150 yards south-west of the summit. There are probably other small outcrops on this hill.

The Saddle.—To the east of Cir Mhòr and nearly a quarter of a mile south-east of the Saddle is a greenish grey pitchstone, running nearly W.N.W. Some of it is columnar.

Cir Mhòr.—Green porphyritic pitchstone forms the centre of the composite dyke on Cir Mhòr, running east and west, described by Prof. Judd.*

Caisteal Abhail.—On the ridge between Cir Mhòr and Caisteal Abhail a dark pitchstone dyke occurs in the cliff a little south-east of the strong spring, and a quarter of a mile south of the point marked 2735 on the one-inch map.

Caisteal Abhail.—A dark columnar pitchstone occurs west of the highest point, and may be traced a considerable distance in a north-west direction by the loose fragments lying at the surface.

Another dark-coloured pitchstone dyke may be found under a crag about 100 yards north of the summit.

Creag Dhubh.—About a mile north of Caisteal Abhail a pitchstone dyke about six feet wide is visible for a short distance under the scars of Creag Dhubh.

Penrioch.—North-east of Penrioch and nearly half a mile E.S.E. of Auchmore or South Thundergay is a remarkable porphyritic pitchstone, only visible for about six yards.

Dubh Loch.—On the slopes of Beinn Bharrain a quarter of a mile N.W. of the Dubh Loch is a yellowish, streaky pitchstone, three to four feet wide, which may be traced to the W.S.W. for nearly 200 yards.

Iorsa Valley.—In a stream about one mile N.E. of the outlet of Loch Tanna there is a pitchstone dyke three to four feet wide with a course due north.

Iorsa Valley.—Near the heads of two small streams three-

* On composite dykes in Arran.—Quart. Jour. Geol. Soc., vol. xlix., p. 543.

quarters of a mile north of Loch Nuis dykes and sills of various kinds of pitchstone crop out in at least four places.

IORSA VALLEY.—About 600 yards S.S.W. of the outlet of Loch Iorsa a dark green pitchstone with a width of seven or eight feet is visible for about ten yards.

MACHRIE BURN.—A dyke of light-green pitchstone six feet in width crosses this stream in a N.N.W. direction about three quarters of a mile N.N.E. of Cnoc na Ceille. The stream here is called Allt Airidh Niall.

AUCHAGALLON.—In the stream a quarter of a mile north-east of the village there are two pitchstone dykes near together, and the more northerly of the two is accompanied by felsite. Both range somewhat north of east.

AUCHAGALLON.—A small pitchstone dyke occurs in the old sea-cliff to the west of the village on the north side of a sandstone quarry.

AUCHAGALLON.—A brown pitchstone also occurs on the shore about 80 yards south of the ferry.

GLENLOIG.—In a small stream on the west side of the main valley, two thirds of a mile south-east of Glenloig Farm, there is a dark pitchstone dyke two-three feet wide. It runs in a north-west direction and hades south-west.

TORMORE.—On the Tormore shore, opposite Torr Righ Beag, there are several dark pitchstone dykes. The largest and longest runs in a N.N.E. direction across the foreshore near An Cumhann, and then follows the shore-line in a more northerly direction a little above high-water mark. It can be traced altogether for about 500 yards. At its northern end another pitchstone dyke crosses the foreshore in an E.N.E. direction, but dies out in the old sea-cliff.

Two hundred yards south of this point a composite dyke running in a N.W. direction crosses the line of the larger dyke first mentioned. This composite dyke has banded pitchstone on its north-east side.

There are traces of pitchstone in more than one place to the south of Lecan Ruadh.

From the local distribution of these acid dykes and sills in Arran, as well as from the local occurrence of the other acid dykes and sills of felsite, quartz porphyry, etc., it appears to be pretty certain they are not due to the widespread cause which produced the numerous Tertiary basalt dykes all over the West of Scotland, but are intimately connected with volcanic action or vulcanicity in the island itself. The distribution of the numerous basic sheets and bosses in the southern part of the island is a confirmation of this view, and they are probably also the products of local volcanic action which did not reach the surface. Many of the basic dykes, especially those which are so numerous along the south coast, may also have had a local origin.

One of the surprising things connected with the intrusion of the acid sills is the little alteration they effect on the rocks which they have penetrated. There was much dispute as to the intrusive character of the pitchstone sill east of Dun Fionn on this account, and many other examples might be quoted.

INTERMEDIATE ROCKS.

Masses of intrusive rock of an altered basic character are found in connection with the smaller granite area, and seem to be of earlier date than the acid rocks adjacent to them.

Hyperite.—To the east-south-east of Glenloig, about three quarters of a mile, there is on the east side of a little tarn a projecting mass of rather coarse black rock. It is somewhat balloon-shaped in outline, and about 250 yards in length. The rock is a hyperite composed of labradorite, diallage, and hypersthene, with some insterstitial magnetite and biotite. It is surrounded by a granophyric rock, but no junction is visible.

About a quarter of a mile N.N.W. of this is Creag nam Mult, a prominent object from the road which runs through Gleann ant-Suidhe. The dark rock here forms a long and narrow outcrop with a steep face to the north, and consists of plagioclase, augite, hypersthene, and hornblende, with some interstitial quartz and micropegmatite. In the middle of this mass, which is 250 yards in length, is a gully where may be a basalt dyke. The surrounding rock is a granophyre which appears to have penetrated the hyperite in veins. There is a small detached area of a similar rock to that of Creag nan Mult 250 yards to the north-east.

Augite-Porphyrite.—About 500 yards east of Glenloig is a small section where two kinds of rock are seen—a coarse ophitic-dolerite, and an augite-porphyrite, which is probably intrusive in the former rock. This section is nearly close to the mass of volcanic agglomerate which is on the south of it. On the other side it is probably bounded by quartz-diorite, bnt no contact is visible.

Diorite.—The only mass of diorite of importance in the island is found at the head of Gleann Dubh (Glen Cloy). It is more than a mile in length (from N.E. to S.W.) by half a mile at its widest part, and it has an irregular outline, having penetrated the Old Red formation on its eastern margin, and being itself intruded into by granophyric and felsitic rocks on its western and northern edge. It is a massive, dark-coloured and generally coarse rock, with few prominent joints, forming crags on steep ground and rough rocky knolls on more gently inclined surfaces. Near its contact with the Old Red Sandstone it is often fine-grained, however. At its S.W. end, between the branches of the burn, a district known as Tir Dubh, the massive rock of the knolls is pierced with many little acid strings and granite veins. A specimen from one of the bosses near the burn is a dark green rock composed of plagioclase and green hornblende in grains and patches, with iron ores and a little biotite. Near its northern edge the rock is coarsely crystalline, with large crystals of diallage. Veins of granophyre and felsite penetrate the diorite in many places, especially near its north-eastern margin, in the crags on the north side of Gleann Dubh, where the rock is often a light-coloured quartz-diorite. At the head of Glen Ormidale are several long, narrow strips of a fine-grained greenish rock, which is probably derived from the same magma as the larger mass of diorite, and several small dykes of a similar kind of rock occur in the crags between the heads of the two glens.

BASIC ROCKS.

SILLS.—The largest mass of basic rock is that which forms the Clauchland Hills, and runs out to sea at Clauchland Point. It is a great intrusive sill, and fine intrusive junctions are visible near Clauchland Point (west of) and at several other places along its southern margin, the adjacent red sandstone being changed to a white, hard, quartzose rock. Reference may here be made to descriptions of this rock by Zirkel (Zeit. d. deutsch. Geol. Ges., 1871, p. 38) and Allport (Quart. Journ. Geol. Soc., 1874, p. 563). It is often a coarse gabbro-like rock with large crystals of augite, olivine, and plagioclase, and without any groundmass. This coarsely crystalline rock passes into a more compact rock of a basaltic character, which is the type of the rock that prevails over a large part of its extent. Allport describes a specimen from Dun Fionn as containing plagioclase crystals, beautifully striated, augite and olivine in a remarkably fresh condition, magnetite, a few plates of brown mica, a little apatite, and a clear amorphous glass in the interstices of the constituents. This sill crosses the Lamlash road to the south of the Stone Circle, and shortly after narrows considerably, and then separates into two dyke-like portions, with sandstone between. It cannot be found in the most westerly branch of the Birk Glen stream.

To the southward another considerable sill of coarse-grained dolerite, often much decomposed, is found at Cnoc Dubh, spreads over a wide extent southward, crosses Benlister Glen, and in Sheet 13 forms the prominent hill called The Ross. The rock much resembles in character the sill of the Clauchland Hills. The hills called Sheeans to the N.W. of Cnoc Dubh, which form marked features in the view up Glen Cloy from Brodick, are composed of a finer and harder variety of basic rock. In the western Sheean the dark-coloured rock is variegated with numerous white acid strings and irregular veins, which appear to be segregations. Southward from the Sheeans are some smaller basic intrusions of a like character, and other masses are found round Brisderg intrusive in the Carboniferous and Old Red rocks.

South of the String road at the summit occurs a mass of dark basic rock under the granitic crags. It is exposed in several small gullies, and appears to be an altered, coarse-grained, ophitic dolerite in which the augite has been replaced by green hornblende. This alteration is probably due to contact with the granite or granophyre, which is a late intrusion.

In the north-eastern part of the island a considerable mass of basic trap, nearly a quarter of a mile in length, is found to the west of Millstone Point. It is probably intrusive, but its boundaries are not well defined, and it is by no means clear that it may not be of Carboniferous age.

A considerable number of separate basic masses are found around Ard Bheinn intrusive in the agglomerate of the volcanic vent. One of the most conspicuous of these forms a craggy ridge called Creagan Liatha na Cluain Monaidh between the two branches of the stream near the head of Ballymichael Glen. At its eastern end this dark basic rock is highly magnetic. The largest mass runs from the west side of Ballymichael Glen in a north-west direction to above Derenenach, and then bends towards the north-east. It is altogether one and a half miles in length and more than 200 yards wide where it is broadest, and the rock of which it is composed is similar to that last mentioned and also highly magnetic in places. At a point 550 yards E.S.E. of Derenenach the rock is a natural magnet, possessing polarity. This basic mass is certainly earlier in date than the granophyre. Another mass of a somewhat different character, but also magnetic, is found round and at the top of Ard Bheinn, but this is rather a felsite. It has a fine-grained dark matrix which encloses felspar crystals, but there are no quartz grains.

Perhaps the most interesting of all the Tertiary sills is that which traverses the Carboniferous volcanic rocks in the southern part of Bute, and also cuts through a dolerite sill of late Carboniferous age. This remarkable compound sheet rises from the sea at Roinn Clumhach on the west side of Glencallum Bay, and after a winding course of nearly two miles enters the sea again on the east side of Uamh Capuill. Thus its general course is from east to west across the successive outcrops of the Carboniferous lavas, which dip steeply to the south-west and form marked features striking north-west. The intrusive mass inclines southward, and forms prominent crags at its northern side, which are in striking contrast to those formed by the Carboniferous lavas. This sheet rises to over 300 feet above the sea south of Torr Mor, where it cuts through the older intrusive sill, falls to about 100 feet near Loch na Leighe, and rises in St. Blane's Hill to 400 feet, which is the highest point it reaches.

This peculiar sill has a basic centre with fringes or selvages of an acid rock above and below. A specimen from the central portion near Loch na Leighe is an enstatite dolerite, while the lower part is a quartz porphyry having magnificent crystals of quartz and sanidine imbedded in a crypto-crystalline groundmass. The quartz grains are corroded, and the felspar slightly kaolinized.

The acid borders accompany the basic sheet throughout its whole extent, as far as can be ascertained, though in some places they must be thin. Generally the quartz porphyry forms the actual boundary of the intrusive mass, but in one place west of Loch na Leighe, where the lower acid sheet is 10 feet thick, there is from 18 inches to two feet of amygdaloidal pyroxene andesite of a basaltic type interposed between it and the Carboniferous Traps. The rock contains numerous derived quartz grains with pyroxene envelopes.

A little basic rock is also seen below four feet of quartz porphyry near the top of St. Blane's Hill on the north side. The greater part of the basic intrusion seems fairly uniform in character—a true dolerite, occasionally weathering in a nodular or spheroidal form, and sometimes rudely columnar. It is apparently only near its edges that it becomes an intermediate rock.

The quartz porphyry is pretty uniform in character throughout, and always a coarsely crystalline rock. Rhyolite or eurite seem also to be names for this kind of rock, but the most appropriate is *quartz-sanidine-trachyte.* A specimen from the upper acid border near Roinn Clumhach is a good fresh rock with traces of derived basic matter. There is a spherulitic groundmass, and spherulitic aggregations round the porphyritic quartz crystals. In the small outlier of this upper sheet east of Uamh Capuill the rock has a fibrous, delicate, spherulitic ground, which has broken up into granular crystals, as in the spherulitic felsite of Arran. Sometimes the rock contains dark objects which are probably pyroxene, and these may have been derived from a foreign source.

At the base of the dolerite sheet, north-east of Uamh Capuill, the rock assumes variable characters. The more normal kind is an enstatite-augite-andesite of basaltic type, with a little minute biotite among the chloritic products of decomposition. These are derived quartz grains with augite prisms forming an envelope about them. Another variety is a glassy rhyolitic andesite, including some much corroded crystals. It is probably a rock of mixed origin, its rhyolitic character being due to absorption of highly silicated materials. Minute biotite and pyroxene prisms occur, with much tufty chlorite. Other specimens contain porphyritic orthoclase of sanidine type and also porphyritic quartz, and the rock approaches the rhyolites in composition, but its porphyritic crystals may be derived.

There seems evidence from the foregoing description that both the acid and basic portions of the intrusive mass contain foreign material; or do these last mentioned specimens indicate a passage from the basic into the acid rock? The association is somewhat like that described by G. S. Corstorphine in the rocks of Benan Head in the southern part of Arran (*see* his paper—" Ueber die Massengesteine des Südlichen Theiles der Insel Arran," Tscherm. Min. u. pet. Mitth. xiv., pp. 453-463 and 469). In both localities there is strong evidence for the view that the acid and basic rocks are practically contemporaneous.

A specimen showing the junction of the acid and basic rocks from the south side of Barr Hill, east of Uamh Capuill, is called granophyre and dolerite [2612].

DYKES.—Basic dykes are very numerous in the Isle of Arran, but are not uniformly distributed. In some places they are abundant, as along the shore about Brodick from Invercloy eastward to Corrygills Point, while they are few in number between Corrie and Sannox; in the Carboniferous formation on the north-east shore between the Fallen Rocks and the Cock; and again between Lochranza and Catacol. They are much more numerous in the interior than would be inferred from an inspection of the geological map, as their outcrops are often covered by debris and glacial drift, and it is only in clear sections in burns that many of them can be observed, and then only for a distance of a few yards.

These dykes vary in composition. Some of them are true olivine-basalts, while others, such as those described by Prof. Judd,* are augite-andesites. It was found impossible, however, to divide the dykes of Arran, which may be counted by hundreds, into these two classes, and they must all be coloured alike as basic. The amount of olivine in a dyke varies much, and it seems quite possible to obtain from one and the same dyke rock specimens containing olivine, and others without that mineral.

As regards the direction of the dykes, there is a general tendency towards a north-westerly course, but there are many exceptions. Along the Brodick shore several of the dykes have a trend nearly north, and several of those found between Sannox and the Fallen Rocks have a similar direction with a tendency towards north-east. They do not often keep one direction for a long distance, for we observe them bending about in a zigzag fashion, separating into two or more portions, enclosing clastic rock and uniting again. Generally their sides are vertical, and sometimes they project above the general surface of the ground; but often they decompose more readily than the surrounding rocks, and form hollows along the shore and rifts in the cliffs. Examples of the latter may be observed in the ivy-clad rocks of the Corrygills shore, while marked examples of projecting dykes are found along the northern shore of Lamlash Bay, and in the Lion Rock and the Devil's Dyke of Great Cumbrae, east of Millport Bay.

The dykes vary much in width. Some are but a few inches broad, while a great many, perhaps the majority, are less than ten feet wide. The dyke that has a W.N.W. course between Imachar and Balliekine on the west side of Arran is in places 100 feet or more in breadth. At Rudha Ban, North Penrioc, a dyke with a course parallel to the last is about 50 feet wide. On the south side of Brodick Bay the largest is from 30 to 50 feet; it runs nearly N.W. from the Birch Burn, near the Free Church, to the shore at Invercloy.

The absolute lengths of the dykes can only be determined in a very few cases where they are seen to die out on the foreshore or in inland cliffs. Probably a good many of the small dykes, which are only visible in burn sections, have a very short course, at all events above ground. As regards others mapped for some distance, we can but say how far they have been traced. The large Imachar dyke can thus be said to have a course of about one mile, and the North Penrioc dyke can be traced for three quarters of a mile. In the granite area west of Loch na Davie, a north-west running dyke has been followed over Beinn Bhreac for one and a quarter miles, and some W.N.W. dykes near Goatfell can be traced almost as far. One of the longest and most remarkable is that which

* "On Composite Dykes in Arran." Quart. Journ. Geol. Soc., Vol. 49, pp. 536-565.

1. Jointing in the coarser granite, near top of Goatfell, Arran.

2. Tertiary dolerite dyke traversing "New Red Sandstone." The cross jointing is well shown. East of Brodick Pier.

forms the deep rift of Ceum na Caillich, east of Caisteal Abhail, crosses in a southerly direction the head of Glen Sannox, makes a gorge on the north side of the Saddle by no means easy to traverse, and runs for some distance down Glen Rosie, being altogether more than two miles in length. Probably it extends much farther in both directions; a dyke which appears in the bed of the Rosie Burn for some distance about three quarters of a mile above the Garbh Allt being a probable continuation to the south. This dyke is 24 feet wide at Ceum na Caillich, 12 to 15 feet at the rift in the Saddle, and farther south in Glen Rosie about 10 feet.

Dykes are perhaps nearly as numerous in the granite as in the other rocks of the island. There are a great number about a'Chir and Beinn a'Cliabhain, but many of the dykes in the granite are small and might easily be overlooked. Some of them also, in addition to those above described, form deep, narrow rifts in the mountain sides, which require an expert mountain climber to negotiate.

The alteration effected by these basic dykes on the adjacent rock is best seen where they traverse red sandstones, when we always find that the rock is considerably hardened and the red colour discharged, so that the sandstone is white for a variable distance from the edge of the dyke. One of the most remarkable instances of this may be seen about 100 yards east of Brodick pier, where on the eastern side of a dyke running N.N.E. the sandstone is whitened for a distance of 30 to 40 feet from the edge of the dyke (*see* Plate X-2).

These numerous basic dykes appear to be nearly all of one age, though some, as we have seen, are older than the granite. Most of them, however, are more recent than the granite; they penetrate the coarse acid and basic sills, are less numerous in the fine grained basic sills, and are almost entirely absent from the felsite sheets. W. G.

AYRSHIRE DISTRICT.

Brief allusion may here be made to the younger dolerite or basalt dykes which are probably referable to the Tertiary series. Several of these may be observed on the shore. The largest and most continuous has been already noticed running down to the coast at Portincross. It can be traced interruptedly for four miles, but it is lost before it crosses to the eastern margin of the volcanic plateau. As shown on the map, this dyke displays a feature not infrequently to be observed among the Tertiary system of dykes—the occurrence of short parallel dykes at no great distance from the main dyke. It will be noticed that the dyke is lost after it enters the west front of Law Hill above West Kilbride, but that two smaller dykes, a little to the north, continue the general line, while one dyke in the same line is found a short distance farther east on the south side of Blackshaw Hill. These interruptions probably point to parallel fissures, the uprising lava sometimes forsaking one for another.

A second and still broader dolerite dyke runs from the raised beach on the southern side of Largs for more than two miles up the slopes of the volcanic plateau. A. G.

KINTYRE DISTRICT.

A few basalt and dolerite dykes with well-defined margins and having a N.W. trend cut the schists at nearly right angles to their strike. These are of the ordinary type of the Tertiary basic dykes of the region. As might be expected, they are best seen on the shore. A small dyke is thus exposed at about half a mile N. of Skipness Point. No fewer than seven of these dykes are found between the mouths of the Skipness and Claonaig Waters. Most of these are thin and of fine-grained basalt, none exceeding four feet in width, but one which occurs at about 400 yards N.E. of Sgeir na Luinge (Skerry of the Long-boats) is 20 feet across and is composed of coarse dolerite. Three more dykes are seen between the Cleonaig Water and the mouth of Allt a Bhuic (Burn of the Bucks), and other two are exposed in the bed of the latter stream a little way above the public road. A group of four dykes, varying from 10 to 20 feet thick, occur within a half mile on each side of Port Alasdair Ruadh (Port of Red Alexander), near the point where the coast is cut by the edge of the map.

Inland, although they probably continue their course, the dykes more readily escape detection, owing to superficial deposits and the coating of turf-peat. In addition to those mentioned as visible in the Allt a Bhuic a dyke is exposed in the Larach Mòr Burn (Big Sheiling Burn), a tributary of the Skipness Burn, a little below Garveoline, while a small dyke is seen at the head of a stream on the eastern slopes of Cnoc a Moine Raibert, about one mile N. of Skipness.

Although they cannot be traced inland, groups of similar dykes appear to occur together in such a manner as to suggest that if they could be followed they would be seen to branch and anastomose.

B. N. P.

CHAPTER XI.

Petrography of the Tertiary Igneous Rocks of Arran, Southern Bute, and the Cumbrae Islands.

The following notes are based upon specimens collected by Mr Gunn during the progress of the survey, with some collected by Sir A. Geikie at an earlier time:—

(i.) VOLCANIC AGGLOMERATE.

A number of specimens have been examined of the volcanic agglomerate of the large vent, and of the various rocks enclosed as fragments in it [9421-9430, etc.]. In general they show a *gritty-looking matrix*, stained of various colours, in which are imbedded pebbles and fragments of quartzite, vein-quartz, and other rocks. The matrix itself consists largely, and often principally, of quartz-grains, angular and subangular; but there is also finely divided instertitial matter, which is probably to be interpreted as representing basic igneous material, too much altered for identification. Often it is largely chloritic; in other cases there is a ferruginous or a ferruginous and calcareous cement [9423 and 9421]. In addition to quartz-grains, we find sometimes little crystals and fragments of felspar [9424], grains of partially epidotized augite, and little chips of fine-textured basalt and especially of a pyroxene-andesite.

Among the *larger elements enclosed* in the general matrix we may remark especially fragments and rounded pebbles of quartzite and vein-quartz. Numerous other rocks are represented in fragments of all sizes. One specimen has cavities which probably represent destroyed limestone pebbles [9423]. A piece of crushed and schistose grit occurs, showing films of sericitic mica, strain-shadows in the quartz, and a characteristic mylonitic structure [9424]. Especially noteworthy are the fragments of igneous rocks, including andesites [9426, 9427], microgranitic quartz-porphyry [9428], and biotite- or biotite-hornblende-granite [9479-9481].

The intrusive rocks which break through the agglomerate mass are various. Besides gabbro and granite, they include quartz-porphyries, an ophitic dolerite with pleochroic purplish-brown augite, pitchstone, and other rocks, all of types to be described below. The *metamorphism produced in the agglomerate* by these intrusions is evident in some of the specimens. One, traversed by a granite vein, is apparently a trachytic or rhyolitic tuff, in which biotite has been developed by metamorphism, while denser patches richer in biotite represent enclosed fragments of andesite [9429]. Other specimens, representing the gritty tuff which is the most usual matrix of the agglomerate, show in varying degree the same development of new-formed biotite, resulting presumably from the metamorphism of the chloritic matter mentioned above [9430, 9428]. In another specimen, from the edge of the mass, the chief product of metamorphism is a pale-green fibrous hornblende, often with partial radiate arrangement [6387].

(ii.) GRANITE AND OTHER PLUTONIC ROCKS.

The first microscopical investigation of the Arran granites was made by Prof. Zirkel,* whose account of the rocks was published in 1871. Mr Teall† has added to this some particulars, and, like Delesse, has compared the Arran granites with those of the Mourne Mountains in Ireland, doubtless also of Tertiary age. Several writers have recorded the occurrence of special minerals in the druses of the granites.

Although the *northern area of granite* has been separated into coarser and finer varieties, the rocks do not differ in any important particular, excepting texture. They are biotite-granites, with some tendency to granophyric modifications. A specimen of the coarse type from the top of Goatfell [9469] shows crystals of felspar up to ½-inch long and quartz-grains and mica-flakes up to ¼-inch. The rock of the central part of the area is of considerably finer texture; and the same is true of apophyses, in which also there is sometimes a porphyritic tendency, indicated by the occurrence of a few relatively large crystals of felspar [9476]. It can be seen in the hand-specimens that the quartz tends to form grains, which are sometimes enclosed in the felspar; also that the biotite, which occurs only sparingly, is often in very irregular shapes, having crystallized after part of the felspar. Another feature, very conspicuous in most of the rocks, is the occurrence of numerous little drusy cavities of irregular form, on the walls of which the quartz and felspar assume good crystal-faces.

Thin slices reveal no other mineral, except an occasional grain of magnetite and some minute crystals of zircon enclosed in the biotite. The felspar is partly striated oligoclase, but chiefly what more resembles orthoclase. Much of the latter, however, has a fibrous appearance, becoming more evident with incipient alteration, and probably indicating a microperthitic intergrowth. The quartz contains many minute fluid-pores with bubbles, and in some of these cavities Zirkel detected minute cubes of salt. The mineral is generally idiomorphic towards the orthoclase and microperthite, but it also tends to be intergrown in an irregular fashion in those felspars. In the finer-grained type of rock the micrographic intergrowth is sometimes more regular, and one specimen from Glen Catacol, at the foot of Allt-nan-Calman, is a very beautiful granophyre [9471]. It contains much micropegmatite of a very

* *Zeits. deuts. geol. Ges.*, vol. xxiii, pp. 6–9; 1871.
† *Brit. Petrography*, p. 328; 1888. See also *Ann. Rep. Geol. Sur.* for 1896, pp. 75, 76.

delicate kind, which is often grown round the felspar crystals, and, when it surrounds orthoclase, has its felspathic element in crystalline continuity with the crystal itself.

The granites of the northern and larger area, coarse and fine together, belong thus to a well characterised type. The British rocks with which they compare most closely are undoubtedly those of the Mourne Mountains. The other British Tertiary granites—such as those of Skye and Mull—are usually hornblendic or augitic, and they run more frequently than these into granophyric varieties. An interesting point in common between the Arran and the Mourne rocks is the occurrence of special minerals in the druses. Albite, beryl, topaz, and garnet have been recorded in the druses of the Arran granite, besides stilbite (Macculloch).

A specimen from an isolated area of coarse granite in North Glen Sannox is found to be identical with the rock of the main mass [9475]. Some dykes traversing the mica-schists show a very different micro-structure. Two examples have been examined, one from Glen Chalmadale and the other from S.W of the Cock slate-quarry [9482, 9483]. They are fine-textured but still drusy rocks of pale colour. Both are found to be typical spherulitic granophyres. Crystals of quartz and felspar of small dimensions are enclosed in the spherulitic groundmass and have often served as nuclei for the spherulites. The inclusions in the quartz are here of glass, not of liquid.

The *granitic rocks of the more southerly area*, forming part of the ring surrounding the volcanic vent, have many points in common with the preceding, and especially with the finer-grained variety of the northern area; but there are also points of difference which are probably significant. There is the same tendency to rude micrographic intergrowths and sometimes a frankly granophyric structure, the same abundance of quartz, and sometimes very clear indications of microperthitic intergrowth in the untwinned part of the felspar. There is, however, a somewhat larger proportion of the coloured silicates, and these embrace not only biotite, often as before of allotriomorphic habit, but also green hornblende accompanying it, or even almost excluding it. Granules of sphene come in occasionally, and in some slices there are conspicuous little crystals of zircon, in addition to the minute ones enclosed here and there in the mica. This description applies not only to the rocks intrusive in the volcanic agglomerate, but also to granite pebbles contained in the agglomerate itself and therefore derived from an older rock. It is interesting to find that here, as in the Isle of Skye, the fragments in the agglomerate preserve evidence of the existence of older plutonic rocks which are not elsewhere exposed, and that these concealed rocks were of closely the same type as those subsequently intruded in the immediate neighbourhood.

The ring of plutonic rocks surrounding the volcanic vent consists in part of granite, but in part of more basic rocks which have been termed quartz-diorite, diorite, and gabbro. The granite itself shows by its mineralogical constitution a certain range of variety in chemical composition, the most obvious difference being in the amount of the ferro-magnesian minerals. The increasing amount of hornblende observed in a series of specimens, with other differences developed concurrently, corresponds presumably with the transition noted in the field between normal granite and the type styled *quartz-diorite*. This latter was first described by Zirkel,* whose account is as follows:—" . . . A fine-grained aggregate of white felspar and greenish-black hornblende, which, in spite of the smallness of the individual crystals, stand out clearly from one another, and quartz, which is first seen in the thin slice; plagioclase preponderates, but, as is common in similar rocks, there is some orthoclase present; green epidote borders the hornblende in places; the quartz is very rich in fluid-inclusions; except magnetite and apatite needles, often of surprising slenderness with great length (*e.g.*, a needle 0·9 mm. long and only 0·008 mm. thick), felsitic matter is not present. Here and there occur roundish dark concretions, in which the constituents are still finer-grained and the hornblende predominates strongly, like the concretions rich in dark mica in the granites. The rock is thus a beautiful quartz-diorite, the only one of its kind known from Arran, and essentially different from the augite-bearing diabasic traps."

Some of our specimens answer very well to this description. One from Glen Dubh, north side, for example, has all the characters of a typical quartz-diorite. It has not the fine texture of Zirkel's specimen. A thin slice [7447] shows that it consists principally of plagioclase felspar and abundant idiomorphic crystals of green to greenish-brown pleochroic hornblende. The plagioclase, as in most quartz-diorites, shows strong zonary banding between crossed nicols, indicating a great difference in composition between different coats of the crystal. It can often be verified that the interior and principal part is of labradorite, while towards the margin this passes successively through andesine and oligoclase to albite. Orthoclase is quite subordinate. Quartz too is not abundant, and always occurs interstitially, either by itself or in micropegmatite. The other minerals are magnetite, in fairly plentiful crystals and grains, and apatite, here building rather stout prisms to as much as 0·01 inch (0·25 mm.) in thickness.

Examining and comparing other specimens, however, we find unmistakable indications that at least part of these rocks are of abnormal nature, in that they have not originated simply by the consolidation of an ordinary rock-magma. Almost all the slides show in the interior of many of the hornblende crystals a core of colourless augite, with a highly irregular and intricate boundary between the two minerals which proves that the hornblende has replaced augite by a process which ate its way inwards into the crystal. Nevertheless it is not a case of the simple conversion of augite crystals into hornblende, which might be a secondary change, for the crystals have always the external forms proper to hornblende. We may infer that the augite was transformed (in great part) to hornblende in a still fluid magma, and the crystals

* *Zeits. deuts. geol. Ges.*, vol. xxiii, p. 30; 1871.

thus transformed, wholly or in their external parts, continued to grow as hornblende, assuming the proper crystal forms. This suggests that the augite was of *foreign derivation,* and other peculiarities leave no doubt that this conclusion is the correct one. The proportion of the ferro-magnesian element in the rocks is variable, and this even in one specimen, a mottled or patchy appearance being often very evident to the eye. Further, there occur in some parts of the mass numerous ovoid dark patches, an inch or less in diameter, of finer texture than their matrix. These are the "concretions" of Zirkel, but they are to be interpreted as representing the débris of a basic rock almost completely digested by the originally acid magma in which they were enveloped. Thin slices show that these "*xenoliths*," or enclosed foreign fragments, have been totally reconstituted, not merely by metamorphism but by interchange of material between them and the surrounding magma. The mineralogical composition of the dark patches, and especially the occurrence of a noteworthy amount of quartz and alkali-felspars, denotes a certain degree of acidification; and this is the case even when the patches appear quite sharply defined to the eye on a hand-specimen [7524]. The richness of the matrix in ferro-magnesian elements results from the correlated process of basification of the magma, which, however, results also in great part from bodily dissolution of the xenoliths, as proved by their rounded form. The mottled rocks without defined inclusions represent a further stage of intermingling between matrix and xenoliths, and the homogeneous-looking rocks, such as the quartz-diorite first noticed, represent complete amalgamation.

A full petrographical account of these interesting rocks cannot be given in this place. The interpretion set forth is arrived at in the light of very similar phenomena displayed at numerous localities in the Isle of Skye, where they have been studied in detail. One case of the modification of a granophyre by incorporation of a large amount of gabbro débris has already been described.* This is near Kilchrist in the parish of Strath, and it presents a special point of resemblance to the Arran occurrence, in that the rocks are intruded in the form of a broken ring at the edge of a large volcanic vent filled with coarse agglomerate.

Our observations are not sufficient to warrant the assertion that the basic rock represented by the highly altered xenoliths in Arran has been, as in Skye, a gabbro; but perfectly typical *gabbros* are found in the neighbourhord, and are in all respects comparable with those which form larger masses in Skye, Mull, etc. Two specimens of rocks intrusive in the agglomerate of the vent illustrate this: they are from 200 yards S.E. of Creag Mhòr Derenenach [9435, 9436]. The rocks are of average texture, and consist essentially of felspar, sub-ophitic light-brown augite, and irregular grains of black iron-ore. The felspar is a labradorite, with extinction-angles up to 34° in symmetrically cut sections. The

* Harker, "On Certain Granophyres, modified by the Incorporation of Gabbro-Fragments, in Strath (Skye)." *Quart. Journ. Geol. Soc.*, vol. lii, pp. 320–328, pl. xiii, xiv; 1896.

augite has a strong striation and schiller-structure parallel to the basal plane. Olivine is apparently not present. A rock from another locality has all the appearance of a gabbro in which the augite has been completely transformed to green hornblende [7536].

One of the most interesting of the Arran rocks is that which has been designated hyperite. It is a very fresh rock of dark aspect and of moderately coarse texture, the pyroxene and felspar being clearly distinguishable in a hand-specimen. An example from three-quarters of a mile E.S.E. of Glenloig Farm [7530] gave the specific gravity 2·97. In a thin slice it is seen that by far the greater part of the pyroxene is of the rhombic kind, though some augite is also present. The rock might therefore be termed *norite*. The dominant pyroxene is of pale colour, but always decidedly pleochroic, varying from a reddish to a greenish tint. It may therefore be called bronzite. Both this and the augite show schiller structures, parallel to the pinacoidal and basal planes, but not constantly developed. It is especially noticeable that these minerals have the ophitic habit, a circumstance not common in rhombic pyroxenes. The felspars are perfectly fresh, but show, except at the border of each crystal, a dirty appearance due to very minute inclusions. Carlsbad and albite twinning are found, and the extinction-angles in symmetrically cut sections rise to 33° or 34°, indicating labradorite but not one of the more basic varieties. Grains of black iron-ore occur, moulded on the felspar, and occasionally little scraps of biotite clinging about the iron-ore.

Specimens from Creag-nan-Mult show many points of resemblance with the preceding, but also certain differences, and they may be termed *quartz-hyperite* [7531, 7532]. Here the accessory iron-ore is idiomorphic, and apatite becomes a noticeable constituent. Augite is abundant as well as bronzite, and there is also a considerable amount of strongly-coloured hornblende, varying from brown to green. The browner kind has proper crystal outlines, and is therefore a primary constituent of the rock, but it often contains a core of pyroxene, about which it has grown with the usual crystallographic relation. The greener hornblende, on the other hand, is evidently formed at the expense of pyroxene, usually if not always of augite, and relics of the latter mineral, of highly irregular form and with intricate boundaries, are often preserved in the interior. Not only the pyroxene, but the felspar also has a well-marked schiller-structure, the arrangement following the two pinacoid planes and the basal. Finally, and especially characteristic of this rock, there are interstitial patches consisting of delicate micropegmatite.

It seems possible that the conversion of augite to hornblende in these latter rocks may be an effect of metamorphism due to the neighbouring granophyre, but this is not a necessary supposition.

(iii.) SYENITE DYKES.

A very unusual type of rock forms an E.-W. dyke 150 yards up Allt-nan-Eireannach, on the south side of Glen Catacol. It is a *hornblende-syenite.* It has a medium texture, the greenish hornblende and pinkish felspar being clearly distinguishable. A specific gravity determination gave the figure 2·76. In a thin slice [9419] the abundant crystals of hornblende are seen to be well shaped, with the usual habit. They are usually $\frac{1}{100}$ to $\frac{1}{50}$ inch in diameter, and are of brown colour, a character not usually found in syenites excepting those rich in alkalies. These idiomorphic crystals of hornblende are set in an allotriomorphic aggregate of felspar, twinned and untwinned; apparently oligoclase and orthoclase, the latter predominating. The only other constituents of the rock are small scattered crystals of magnetite and rather abundant needles of apatite.

About 600 yards south of the above dyke is another parallel one, which is *highly metamorphosed* by the granite. This dyke is mentioned by Ramsay, who, however, mistook its relation to the granite. The specimen [9414], traversed by a $\frac{1}{4}$-inch vein of granite, shows a rock of somewhat coarser texture than the preceding, the little black crystals contrasting sharply with the white felspar in which they are imbedded. Under the microscope the rock shows, however, a very decided resemblance to the other. The hornblende crystals, here often $\frac{1}{10}$-inch long, show the same well-shaped outlines, but each is wholly converted into an aggregate of biotite-flakes. There are in addition some rather irregular crystals of pale augite, not found in the former dyke, and these show a partial conversion to biotite but never complete replacement. The felspathic element of the rock has much the same characters as before, though it has apparently been recrystallised, and the little needles of apatite are also seen. Imbedded in the clear felspar, but clustering thickly in the neighbourhood of the biotite-aggregates, are a vast number of minute rods, apparently of augite, doubtless a new-formed mineral. Those rods which are actually attached to the biotite-pseudomorphs after hornblende have a parallel arrangement.

Excepting only the original accessory augite, this rock must prior to metamorphism have been practically identical in character with the other, and the two seem therefore to represent a special group of dykes, certainly older than the granite and not known to cut any other rocks than the schists. The type being quite unlike anything known among British Tertiary igneous rocks, it seems not unlikely that these dykes belong to a much older suite of intrusions.

(iv.) QUARTZ-PORPHYRY SILLS AND DYKES.

A suite of specimens from the acid sills of the district shows comparatively little variety among the different occurrences. The commonest type is a *quartz-porphyry rich in porphyritic elements*, which are quartz and felspar, the former usually $\frac{1}{8}$ to $\frac{1}{4}$ inch in diameter, and the latter with a length of $\frac{1}{4}$ to $\frac{1}{2}$ inch. These are often rather closely crowded in the grey groundmass, which is of fine-texture, no other mineral being evident to the eye except in some examples an occasional flake of dark mica (Drumadoon, etc.). Thin slices show that the felspar is commonly sanidine, though often accompanied by some oligoclase in addition, Both quartz and felspar, but especially the former, contain abundant minute glass-inclusions, and sometimes larger inclusions of the groundmass, besides having often a rounded or irregular outline indicative of magmatic corrosion. The biotite is often considerably altered, and its presence is sometimes only to be inferred from brown ferruginous patches. In no case is it abundant. Rarely a little crystal-grain of augite is seen [6396]. The groundmass is always micro-crystalline, sometimes having the felspar in little crystals upon which the interstitial quartz is moulded, but more usually with a granular structure and with varying degrees of fineness of texture. There is in this common type little or no approach to spherulitic or other intergrowths, though exceptionally we may see a tendency to micropegmatite in a narrow fringe on the border of a felspar crystal [6396]. Rocks answering to the above general description constitute the large sills at Drumadoon Point and Corrygills and numerous others.

A less common type shows a more evidently crystalline, though still fine-textured, appearance in a hand-specimen, and is without conspicuous porphyritic elements. A thin slice of one of these is seen to have the character of an ordinary microgranite [6384]. This rock is from the west branch of Urie-Loch Burn in Arran.

There remain the *spherulitic varieties*. These, as represented in the specimens, are not conspicuously porphyritic, though the microscope shows a few small crystals of quartz, $\frac{1}{100}$ to $\frac{1}{30}$ inch in diameter, and occasionally a small sanidine. The spherulites are very evident to the eye, owing to their assuming a pale tint with weathering. They are usually not more than $\frac{1}{20}$ inch in diameter, but in some specimens as much as $\frac{1}{8}$ inch. Two specimens [6406, 6407], from near Tormore, have very perfect spherulites exhibiting the black cross with polarised light. They tend to grow round such porphyritic elements as are present. In the former of the two rocks the spherulites are isolated and surrounded by a finely crystalline or cryptocrystalline groundmass. In the second rock the spherulites are more closely packed, with a smaller proportion of interstitial groundmass, which is here microcrystalline, probably owing to recrystallisation. There has been some ferro-magnesian mineral, probably augite, now destroyed and represented only by rather abundant chloritic matter, which shows as little dark patches on the hand-specimen.

It seems probable, from comparison, that a microcrystalline groundmass in these spherulitic rocks is in general the result of secondary changes. The spherulites themselves seem to have been less readily affected, but in a number of cases these too appear to have been recrystallised. The radiate structure is not quite lost in the process, but the excessively slender fibres have been destroyed, giving place to irregular narrow sectors, each of which polarises uniformly throughout its extent. A good example of this is furnished by a rock from near the head of Sliddery

Water [6372]. Another specimen [6398] from the neighbourhood of Sliddery Water, illustrates a further stage of alteration and a more complete disguise of the original nature of the rock. The little round spots representing the spherulites are still very apparent on the hand-specimen, and they are seen as relatively clear areas in a thin slice, but all trace of their radiate structure has been destroyed by the recrystallisation as a granular aggregate.

The type of quartz-porphyry first described seems to be characteristic of the larger sills, while the spherulitic type is exemplified by sills of smaller dimensions. Corstorphine* has a like observation.

The acid dykes have not been studied in such detail as the acid sills, but it is clear that they present petrographically a general correspondence with them. The quartz-porphyry rich in phenocrysts, which appears to be the general type among the large sills, is also represented among the dykes. A specimen [2455] from King's Cove is in all respects identical with those described above, having abundant corroded crystals of quartz, $\frac{1}{8}$-inch in diameter, and of sanidine, often more than $\frac{1}{4}$-inch long. Another dyke-rock [6381], from Allt Dhepin, a mile south of Loch na Leirg, is essentially similar, but with smaller porphyritic crystals.

Besides these rocks, there are other acid dykes belonging to a different set of intrusions. They are closely associated with the pitchstones, and some of them have arisen by the alteration of rocks which were originally pitchstones. These will be noticed below.

(v.) DOLERITE SILLS, INCLUDING TESCHENITE.

The basic sills of Arran present some variety of petrographical characters, and doubtless of composition. Zirkel† states that the sills, with the dykes which fed them, are mostly free from olivine, and often carry quartz; contrasting with the later basic dykes, which are usually olivine-bearing and never contain quartz. Allport,‡ who, like Zirkel, believed the sills to be of Carboniferous age, described an olivine-dolerite from Dun Fion, besides other doleritic rocks from Kildonan and Dippin. Corstorphine§ has also given descriptions of some of the basic sill-rocks in the southern portion of the island, including some quartz-bearing examples.

While quartz in these rocks is certainly often of foreign origin, it is in some cases a normal constituent. A good example of these normal *quartz-dolerites* comes from the north side of Glen Dubh. It is of quite coarse texture, and, like some other rocks in this collection, might be equally well named gabbro on petrographical grounds. It closely resembles some of the gabbros of Carrock Fell in Cumberland, or the coarsest portion of the Whin Sill of Teesdale. The augite and felspar are very evident, but the quartz is visible

* *Tscherm. Min. Petr. Mitth.*, vol. xiv, p. 455 ; 1895.
† *Zeits. deuts. geol. Ges.*, vol. xxiii, p. 21 ; 1871.
‡ *Quart. Journ. Geol. Soc.*, vol. xxx, pp. 562–564 ; 1874.
§ *Tscherm. Min. Petr. Mitth.*, vol. xiv, pp. 460–469 ; 1895.

only here and there in small spots. The specific gravity of the rock is 2·87. In a thin slice [2458] the felspar is found to be labradorite, with carlsbad and albite twinning and with strong zonary banding in polarised light, this being a constant feature in normal quartz-gabbros and quartz-dolerites. The pale-brown augite shows occasional striation and schiller-structure, parallel sometimes to the orthopinacoid (diallage-structure), sometimes to the basal plane (salite-structure). Needles of apatite and irregular grains of black iron-ore occur as accessories ; and there is occasionally a flake of dark biotite intergrown with a fibrous light-green hornblende, which in places has been formed at the expense of the augite. Quartz is fairly abundant, partly in interstitial grains, but chiefly in interstitial patches of micropegmatite. The felspathic element of the latter is probably orthoclase, but is so turbid as to be almost opaque.

It is probable that some of the coarse doleritic rocks which are free from quartz contain orthoclase. A rock from Cnoc Ballygown is an example [6389]. It shows interstitial patches of a very turbid, apparently untwinned, felspar moulded upon the zoned plagioclase crystals. In this rock the augite is idiomorphic. Apatite needles and crystals of magnetite are found as usual. Another specimen [6390] has little augite, and is much richer in orthoclase, as if graduating into a felspar-porphyry.

Other coarse *dolerites* are of types familiar in many districts. Ilmenite, with encrusting patches of leucoxene, is sometimes found instead of magnetite [6375]. In the more altered rocks the augite is sometimes replaced by a scaly aggregate of green chlorite. In other cases it has been converted into green hornblende, still preserving a partial diallagic structure [7536].

Olivine-dolerites are also found among the sills, as recorded by Allport, though, if our collection is representative, they are in a minority. An example comes from near the bend of Allt Cul-na h-Eildor [6374]. It has not the ophitic, but rather the granulitic type of structure, and consists essentially of little striated "lath-shaped" crystals of labradorite, with a tendency to parallelism in places, pale brown augite, and serpentinous pseudomorphs after olivine. There are a few larger and broader crystals of felspar, and some magnetite and apatite are present. This rock, forming only a thin sill, is of finer texture than those described above.

A peculiar rock is that which forms a large sill in the south-eastern corner of Arran, and may be termed *teschenite.* It has been described (under the name olivine-bearing analcime-diabase) by Corstorphine,* but is of sufficient interest to be noticed here. It is represented in our collection by five specimens from Dippin and Kildonan.

In hand-specimens the rocks appear as ordinary coarse-textured diabases, dark in colour, but with some variation in the relative proportion of black augite and white felspar, etc. A specimen [6361] gave the specific gravity 2·89. Thin slices show a

* *Tscherm. Min. Petr. Mitth.*, vol. xiv, pp. 463-465 ; 1895.

typical ophitic structure. Olivine is abundant in irregular crystal-grains, sometimes fresh [6361], but usually replaced by green or yellow-brown serpentine. Apatite is always abundant in little prisms about 0·01-inch long, or varying from 0·005 to 0·02 inch. Black iron-ore is also rather plentiful in grains and imperfect or skeletal crystal shapes; probably magnetite for the most part, but in some cases with outlines suggestive of ilmenite. The felspar is in crystals which give elongated rectangular sections, with Carlsbad and albite twinning. It is labradorite, but not usually of a very basic variety. The ophitic plates of augite show in thin slices the light purple colour and decided pleochroism often seen in the augite of nepheline-dolerites and other rocks rich in alkali, and probably indicating a certain content of soda and titanic acid in the mineral. Rotating over a Nicol's prism, the colour is often seen to change from a purplish or pale claret tint to pale apple-green or pale brownish-yellow. In natural light the ruddy colour is sometimes seen to pass gradually in one crystal into a pale apple-green, which is also pleochroic. Most of the crystals show, though imperfectly, the hour-glass structure which is so generally associated with augite of this kind. Small flakes of brown mica occur rather rarely in the rock.

In addition to the foregoing minerals there are abundant wedge-like and irregularly-shaped spaces occupying the interstices between the felspar and other crystals, and often enclosing numerous needles of apatite. These spaces consist in general of analcime, clear, colourless, feebly refringent, and isotropic, rarely with obscure traces of cleavage. In other cases we find patches of zeolites partly or wholly taking the place of the analcime, forming a yellowish aggregate* with more or less pronounced radiate-fibrous structure [6361, 6887, etc.] and, if not too fine, showing brilliant interference-colours. Corstorphine identifies natrolite and scolezite: the former might be derived from the analcime, but the latter would have to come from the felspar. In our slices the fibrous zeolites seem clearly to be formed at the expense of the analcime, and are found only in association with other secondary changes in the rock. The analcime itself has all the appearance of an original constituent of the rock. It is most abundant in the freshest specimens, and is there perfectly pellucid and unchanged; in other specimens it is seen in process of conversion to what is probably natrolite. Corstorphine recognises that the analcime cannot be derived from the felspar, which is often quite fresh, but he supposes it to represent vanished nepheline. While this is possible, there is nothing whatever to indicate the former presence of nepheline, and the supposition seems to be based merely upon reluctance to admit analcime to the rank of an original product from a rock-magma. Various researches on the monchiquites and allied rocks during late years render it difficult to maintain this attitude, and

* Zirkel seems to have observed, but not identified, this aggregate. He also notes quartz-grains (presumably of foreign origin) in a rock from Dippin Head. *Zeits. deuts. geol. Ges.*, vol. xxiii, p. 36; 1871.

the balance of probability in the case of our rock is decidedly in favour of the view that the analcime is merely the latest product of consolidation of the magma.

Specimens from another sill, on Auchenhew Hill, may also have contained analcime, interstitial patches of a radiate-fibrous zeolite being seen in the slices [6886, 6887]. This rock has, however, been altered by crushing and perhaps otherwise, and contains a certain amount of quartz. The augite here has a pale-green or greenish-yellow colour, with in places a basal striation and schiller structure. This rock seems to be the "salite-diabase" of Corstorphine.

(vi.) MODIFIED BASIC SILLS, WITH XENOCRYSTS, AND COMPOSITE SILLS.

It has been remarked above that most of the quartz which is found in some of the dolerite sills is to be regarded as of extraneous origin and foreign to the normal composition of the rocks. This is most evident as regards the quartz which occurs in the form of grains or rounded and corroded crystals. Derived crystals, or "*xenocrysts*," both of quartz and of felspar (oligoclase and orthoclase), are found in not a few of the basic sills of Arran, and they present the peculiarities which attach to such a mode of occurrence. The quartz-grains are surrounded by an envelope of granular augite formed by reaction between the quartz and the basic magma in which it became involved. Most usually this is only a thin crust, but sometimes it attains a more considerable thickness, equal perhaps to half the diameter of the quartz-grain which it surrounds. In this case the augite-granules take on a rather elongated form with a radiate arrangement [6376]. The felspar xenocrysts have usually a very turbid appearance in a thin slice.

The reactions between the xenocrysts and the enveloping basic magma necessarily occasioned not only a corrosion of the former but a certain modification of the composition of the latter, in the general sense of acidification; and there is often sufficient evidence that this action has proceeded far. There has resulted a corresponding modification in the products of final consolidation of the magma, which appears in the formation of relatively acid felspars, in a diminished proportion of augite as compared with felspar and iron-ore, and in an excess of silica crystallising as interstitial quartz. The micro-structure of the rock is also modified, the texture often becoming rather fine and the ophitic structure being usually lost. These peculiarities are seen in varying degree in a number of the basic or quasi-basic sills, or in portions of them. Rocks originating in this way may be regarded as in a certain sense abnormal, and they often refuse to range themselves under recognised petrographical types.

Closely connected with the frequency of xenocrysts in these rocks, and, like that phenomenon, pointing to a peculiarly intimate relationship as regards origin between the acid and basic rocks of the district, is the occurrence of *composite sills and dykes*, in which

* *Loc. cit.*, pp. 467–469.

acid and basic rocks form parts of a single intrusive body, and seem to have been intruded almost contemporaneously. The existence of such composite intrusions in Arran seems to have been recognised more or less clearly by Boué* and Delesse,† who describe a sill of quartz-porphyry resting upon, and apparently passing into, one of dolerite at Drumadoon Point (named "Rue Varey"). In late years Corstorphine‡ has described what is probably a composite dyke in Glen Struey. Composite sills and dykes are known among the Tertiary intrusions of other parts of the Western Isles of Scotland, and it will be sufficient in this place to refer briefly to two examples.

The first is a composite sill at Kildonan Castle, which consists of a central acid member with upper and lower members of basic composition. A specimen from the lower part is a grey, fine textured rock, without evident porphyritic crystals, and gives the specific gravity 2·68. In a thin slice [6358] it is found that the felspars, in little "lath-shaped" sections about $\frac{1}{100}$ inch or less in length, constantly gives quite low extinction-angles. Many of the crystals are striated, and the dominant felspar must be near oligoclase in composition, though orthoclase may perhaps be present in addition. The augite preserves its ophitic habit, but is in great part destroyed. In addition there are abundant little crystal-grains of magnetite, and in places a little interstitial quartz. The rock presents the characters of a partially acidified dolerite, the low density being very significant in this respect.

A specimen of the middle part of the sill, taken in the same quarry, is a compact-looking rock of light-grey colour, showing scattered slender felspars up to $\frac{1}{4}$-inch long, and containing ovoid druses also about $\frac{1}{4}$-inch in length. A specific gravity determination gave 2·48, to which some small addition must be made to allow for the druses in the interior of the specimen. A slice [6359] shows that the rock consists essentially of a plexus of little felspars giving "lath-shaped" sections $\frac{1}{200}$ to $\frac{1}{100}$ inch long, simple or once twinned, and with sensibly straight extinction. These must be orthoclase, and the rock is in composition a trachyte. Besides the scattered felspar phenocrysts there are a few irregular grains of quartz and a rare crystal-grain of augite, now decayed.

The other composite sill to be mentioned is the large one in the southern part of Bute. This differs from all other composite sills and dykes recorded in that it has the basic rock forming the interior part and the acid rock the upper and lower borders. The acid rock seems to have little about it that is abnormal. An example of the upper member, taken east of Uamh Capuill, is of the type already described as characteristic of the larger quartz-porphyry sills of the district. It is rich in porphyritic elements, set in a compact-looking light-grey groundmass. The porphyritic minerals are felspar, (chiefly sanidine) in rectangular or rather rounded crystals up to $\frac{1}{2}$-inch long, and crystals or crystal-grains

* *Essai géologique sur l'Ecosse,* p. 296, pl. iv, fig. 20 [1820].
† *Ann. des mines* (5), vol. xiii, pp. 349, 350 ; 1858.
‡ *Tscherm Min. Petr. Mitth.*, vol. xiv, pp. 460–465 ; 1895.

of quartz about $\frac{1}{8}$-inch in diameter [4640]. A specimen from south of Barr Hill shows a sharp junction between the acid and the basic rock [2612]. The former has to the eye the same appearance as before, but a thin slice shows that the groundmass is here spherulitic, the spherulites being of the cryptographic type.

The basic or quasi-basic portion of this large composite sill is variable in character, and a full description of it is outside our present scope. The normal dolerite constituting the central part has not been examined, but some specimens have been sliced from the modified variety which prevails towards the junction with the acid rock. These are from south of Loch-na-Leighe [4637] and from north-east and east of Uamh Capuill [4639, 4642, 4643]. They show the turbid xenocrysts of felspar and corroded quartz-grains with envelopes of granular augite, as already described. They illustrate also the other peculiarities which we have noticed as accompanying the presence of abundant xenocrysts, viz., abnormally acid felspars, some interstitial quartz, an altered micro-structure, and a finer texture. We may add also another peculiarity often observed in similar hybrid or mixed rocks in other districts, viz., the occurrence of microscopic druses lined with crystalline quartz and filled in with calcite, sometimes also enclosing little needles of actinolite [4637]. A very beautiful rock from the scar at the east end of Loch-na-Leighe deserves more particular notice [2610]. It is a dark evidently crystalline rock without conspicuous porphyritic elements, though small quartz-grains may sometimes be detected. A slice shows that it is mineralogically a bronzite-dolerite. The rhombic pyroxene forms abundant idiomorphic crystals, $\frac{1}{100}$ to $\frac{1}{50}$ inch in length, clear and distinctly pleochroic, with change from a pale rose to a pale apple-green : it is therefore a bronzite rather than a enstatite. The felspar is partly in idiomorphic striated crystals, partly in more shapeless crystal-grains with strong zonary banding between crossed nicols. Augite is seen to be quite subordinate in the general mass of the rock, where it forms little sub-ophitic patches. Needles of apatite and grains of black iron-ore are accessory constituents. A remarkable feature in this rock is the unusual development of the augite-fringes which surround the enclosed quartz-grains. These have a breadth of from twice to four times the diameter of the quartz-grain itself, and show a very marked radiate arrangement.

The phenomena of composite sills and dykes in Arran, seem, so far as they have been observed, to be very closely comparable with those in the Isle of Skye, which will be fully described in another place. A special interest, however, attaches to Arran in this connection, from the fact that the peculiar conditions which determine the almost simultaneous intrusion of basic and acid rocks have here been realised at two distinct epochs. Besides the intimate associations of dolerite and quartz-porphyry which have been mentioned, there are similar associations of augite-andesite and pitchstone (including certain felsitic rocks closely related to pitchstone). The best known examples of these are the composite dykes of Cir Mhòr and Tormore, which have been noticed from an early time,* and have been fully described by Prof. Judd.†

(vii.) DOLERITE AND BASALT DYKES.

The few specimens of basic-dykes chosen for examination scarcely include representatives of more than one type. Four are *ophitic olivine-dolerites,* from the following localities:—

Quarry at E. end of Suidhe Plantation, Bute [2592]; "Rough part of dyke," E. of Port Uisg, Bute [4624]; W. of Runnan Eun Point, Bute [4635]; E. of Rinn-à-Chrubain, Corrie Cravie, Arran [6364].

They are dark medium-grained dolerites of thoroughly basic composition. The first specimen gave the specific gravity 2·98. Thin slices show the following minerals:—abundant olivine-grains, almost always converted to serpentine, green, yellow, or yellowish-brown; labradorite in little striated crystals giving elongated rectangular sections, usually about 0·03 inch long, but varying in different rocks from 0·02 to 0·05 inch; irregular grains of black iron-ore, often wrapping round the felspars; and light brown ophitic plates of augite. In one rock [6364] the augite is of a stronger brown colour, with a purplish tone and distinct pleochroism. A rock from "smoother part of dyke," E. of Port Uisg, Bute [4623], differs from the above type only in having the augite in granules instead of in spreading ophitic plates.

Some dolerite-dykes of the same general type as those described, but apparently devoid of olivine, are older than the granite, and have been *metamorphosed* by it. One such occurs in the Cnocan Burn, below the old mill-dam. A specimen taken in actual contact with the granite shows in a hand-specimen no noticeable peculiarity, but in a thin slice [7442] it is seen that each ophitic plate of augite has been transformed into an aggregate of green hornblende. Occasionally a flake of brown mica is seen, usually clinging about a grain of magnetite. There is no indication that either the felspar or the iron-ore of the original rock has suffered any change, and the metamorphism is thus not of an extreme kind. Two dykes 60 or 70 yards from the granite in Glen Sannox Burn, one a dolerite, the other probably an augite-andesite, show a lower grade of metamorphism, the augite being replaced partly by little blades of green hornblende but partly by chlorite [9416, 9417].

Although the very numerous basic dykes in Arran have attracted attention from an early time, there is very little published information concerning their petrographical characters. Some observations, however, are of sufficient interest to be briefly noticed.

Among the most interesting of the basic dykes are those which pass at the margin into tachylyte, presenting thus a *black vitreous*

* Jameson, *Mineralogy of the Scottish Isles,* vol. i, pp. 81, 102-105; 1800. Necker, *Edin. Phil. Trans.,* vol. xiv, pp. 677–698; 1840. Ramsay, *Geology of the Island of Arran,* p. 26; 1841. Bryce, *Geology of Clydesdale and Arran,* pp. 81, 82; 1859. Zirkel, *Zeits. deuts. geol. Ges.,* xxiii, p. 41, pl. ii, fig. 6; 1871. Allport, *Geol. Mag.,* 1872, pp. 5, 541. Bryce, *Geology of Arran and the other Clyde Islands,* p. 164; 1872.

† *Quart. Journ. Geol. Soc.,* vol. xlix, pp. 536–565, pl. xix; 1893.

selvage, which, however, is usually less than an inch in thickness. An instance in the south-eastern part of Lamlash was noticed many years ago by Delesse,* and the microscopical and other characters of the glassy rock have been described by Professors Judd and Cole.† Delesse's chemical analyses, quoted in columns I, II, show a practical identity in composition between the basalt and its glassy modification. Another basalt-dyke with tachylyte selvage is found in the Castle grounds at Brodick (see column III.).

In the memoir just referred to (Etudes sur le métamorphisme) Delesse makes some interesting remarks upon the metamorphic effects produced by the basic dykes of Arran in their immediate vicinity, more particlarly upon the granite. Boué‡ had already remarked how the dykes have sometimes broken irregularly through the granite and caught up fragments of it; and he had regarded

	I.	II.	III.
SiO_2 . . .	55·20	56·05	53·96
Al_2O_3 . .	16·98	17·13	..
Fe_2O_3 . .	11·00	10·30	..
MnO . . .	traces	traces	..
MgO . . .	0·52	1·52	..
CaO . . .	6·80	6·66	..
Na_2O . . .	5·65	3·29	..
K_2O . . .	by diff.	0·98	..
Ignition . .	3·85	3·50	..
	100·00	99·43	..
Specific gravity .	2·649	2·714	2·83

I. Basalt, centre of dyke 8 inches wide, S.E. of Lamlash Is.; anal. A. Delesse, *Ann. des. mines* (5) vol. xiii, p. 369; 1858.
II. Tachylyte, selvage an inch thick on edge of same dyke; anal. A. Delesse, *ibid.* The total is given in the original as 99·53.
III. Tachylyte, selvage less than ½-inch thick on edge of dyke at Brodick Castle; Judd and Cole, *Quart. Journ. Geol. Soc.*, vol. xxxix, p. 462; 1883.

the stilbite crystals found in the druses of the granite in Garbh-choire and Glen Rosa as a result of infiltration from the basalt-dykes. Delesse§ found that the basaltic magma had penetrated and injected the fissures and druses of the contiguous granite and even the microscopic fissures of its constituent minerals, imparting a greenish colour to the rock. The orthoclase has thus had its specific gravity raised from 2·532 to 2·591, and its content of water is as much as 3·10 per cent., comparing with about one per cent. at a distance from the dyke. The dyke itself was found to contain 3·85 of volatile matter (water with a trace of carbon dioxide) and to have a specific gravity 2·829. It is not quite clear from Delesse's account that the injection of the granite with basic material, as

* *Ann. des mines* (5) vol. xiii, pp. 368–370; 1858.
† *Quart. Journ. Geol. Soc.*, vol. xxxix, pp. 444–464, plates xiii, xiv; 1883.
‡ *Essai géologique sur l'Ecosse*, pp. 19, 499; pl. v., figs. 25, 26; 1820.
§ *Loc. cit.*, pp. 366–368.

described, is anything more than infiltration of chloritic decomposition-products.

(viii.) AUGITE-ANDESITE DYKES AND SILLS.

Among the specimens selected for petrographical examination a well-marked type of sub-basic composition is illustrated by five examples from dykes in the Cumbrae Isles and Arran. The localities are:—

Devil's Dyke, Great Cumbrae [4581, 4582]; W. of Craig nan Fitheach, Great Cumbrae [4585]; Broad Island, Little Cumbrae [4595]; Dyke in intrusive sill, roadside, Dippin Quarry [6362].

These rocks are nearly black and of fine texture, with small scattered felspar crystals or sometimes more abundant crystals and crystal-groups up to $\frac{3}{8}$-inch long. Nos. 4582 and 6362 both gave the specific gravity 2·70.

Thin slices show that these rocks are *augite-andesites with a glassy base.* The porphyritic crystals are labradorite. The little felspars of the groundmass, presenting striated "lath-shaped" sections usually about 0·01-inch long, are acid labradorite or andesine-labradorite. Augite, of light-brown colour, occurs in little granules, and there may be a few crystals of an earlier generation with perfect outlines and a length of 0·02 or 0·03 inch. Little granules of magnetite are found, but not abundantly. Occurring interstitially among these elements is a considerable amount of glassy base of a brown colour. Sometimes it is merely a globulitic glass [4581]; more usually it encloses abundant minute crystallitic elements in the form of felspar fibres and little rods and granules of opaque iron-oxide. Very noticeable is the uneven distribution of the glassy base, which shows a tendency to collect in patches in certain places.

These dykes clearly belong to the "younger augite-andesites" of Prof. Judd,* a group which that geologist assigns to a late epoch in the history of Tertiary igneous activity in Britain. He has described† one rock of this group from Cir Mhòr in Arran, and has given a chemical analysis of it, which we quote below (column VII., p. 124). This rock forms the two marginal members of a triple composite dyke, of which the central member consists of pitchstone; and in general this group of augite-andesites seems to have a peculiarly intimate relationship with the pitchstone group, which points to community of origin. The glassy base of the andesites has probably a composition similar to that of the pitchstones, and there are, as Prof. Judd has remarked, many indications of a tendency for this glassy residue to become in part separated from the crystalline portion of the rock.

A somewhat different type is represented by a conspicuously porphyritic andesite from a dyke in Millport Harbour, Great Cumbrae [4575]. This contains closely-set porphyritic elements

* *Quart. Journ. Geol. Soc.*, vol. xlvi, pp. 371–381 ; 1890.
† *Ibid.*, vol. xlix, pp. 547, 548, pl. xix, fig. 2 ; 1893.

$\frac{1}{8}$ to $\frac{1}{4}$ inch in length, mostly of felspar, but including also black or dark-green pseudomorphs, which are seen in the slice to be augite crystals replaced by green chlorite. The porphyritic felspars are of medium labradorite. The ground-mass consists of little striated felspars, decayed augite, rather abundant granular magnetite, and a light-brown interstitial mass, which seems to have been a globulitic glass full of felspar fibres and other crystallites, but is now considerably altered. There are little irregularly-shaped amygdules, lined with chlorite and occupied by chalcedonic quartz or by calcite. This rock is probably to be attached to the augite-andesites rather than to the basalts, and represents one of the varieties richer in crystallised elements, and therefore more basic in composition than the foregoing.

One specimen only among the collection of sill-forming rocks seems to belong to the andesites. It is a dark close-grained rock from near the head of Allt-na-Slaic in the southern part of Arran; and, as it is described as intrusive in a felsite, it is presumably to be referred not to the epoch of the basic sills but to a later time, probably that of the andesite dykes. In seems to have had a fair amount of glassy base, but is now too much altered for any close examination [6379]. We may further note an andesite intruded in the form of a thin band in the schists west of Creag Rosie, in Glen Rosa [9405].

(ix.) PITCHSTONES AND DEVITRIFIED PITCHSTONES.

Since Jameson* more than a hundred years ago gave descriptions, in the Wernerian fashion of the time, of several varieties, the *pitchstones* of Arran have become more widely known than any other group of rocks in the island. This is owing especially to their very beautiful micro-structure, which has been made familiar to all geologists by the descriptions of Sorby,† Zirkel,‡ Allport,‖ Vogelsang,§ Teall,¶ Judd,** Rosenbusch,†† Corstorphine,‡‡ and others. Since the rocks are so well known, and specimens are to be found in most collections, a brief account will be sufficient in this place.

The specimens selected for examination are dark-grey or greenish-grey rocks, sometimes almost black, with the characteristic resinous lustre. They show usually only small crystals visible to the naked eye, rarely more than $\frac{1}{8}$-inch in length, and often rather sparingly scattered. There are, however, some conspicuously porphyritic pitchstones in the island, as described from Brodick Castle, Invercloy, and Cir Mhòr. Thin slices show under the microscope

* *Outline of the Mineralogy of the Shetland Islands and of the Island of Arran,* pp. 76–82; 1798.

† *Quart. Journ. Geol. Soc.*, vol. xiv, pp. 476, 477, pl. xviii; 1858.

‡ *Sitz. Akad. Wiss. Wien.*, vol. xlvii, pp. 260-262., pl. ii, iii; 1863. *Zeits. deuts. geol. Ges.*, vol. xix, pp. 785-788, pl. xiv; 1867. *Ibid.*, vol. xxiii, pp. 42-46; 1871.

‖ *Geol. Mag.*, 1872, pp. 1–10, pl. i, and pp. 536–545. *Ibid.*, 1881, p. 438.

§ *Die Krystalliten*, pp. 122 126, pl. xiii, xiv; 1875.

¶ *British Petrography*, pp. 344-347, pl. xxxiv; 1888.

** *Quart. Journ. Geol. Soc.*, vol. xlix, pp. 536-564; pl. xix.

†† *Mikroskopische Physiographie der massigen Gesteine*, pp. 699–702, of 3rd ed.; 1896

‡‡ *Tscherm. Min. Petr. Mitth.* (2) vol. xiv, pp. 448-451; 1895. [Sheet 13.]

that the general body of the rock consists of a glass more or less crowded with minute crystallites. These are of two orders of magnitude, the larger easily visible, the smaller appearing with a low magnifying power only as a pigment, colouring and rendering turbid the glassy matrix. There are thus four sets of elements in the rocks—the porphyritic crystals, the larger crystallites, the smaller crystallites, and the glassy base, the last enclosing the rest and constituting the principal part of the bulk.

The porphyritic crystals embrace quartz, felspars, augite,* and magnetite, all with idiomorphic outlines, excepting only when they are aggregated in groups, as is frequently seen. In this case the later crystallised minerals are moulded upon the earlier, and it is seen that magnetite has preceded augite, and both have preceded the quartz and felspars. Apatite is found rather rarely. The quartz is in pyramidal crystals, sometimes rounded at the angles and often having considerable inlets of the groundmass. Both quartz and felspars also contain glass-inclusions, and the glass often encloses minute crystallites.† The felspar is partly striated oligoclase, partly what looks like sanidine; but the latter, as remarked by Prof. Judd, has sometimes a vague appearance of very fine lamellation which is suggestive of cryptoperthite. The augite is in crystals with the usual octagonal cross-section, and is of a light-green colour.

The larger *crystallites* are in the form of minute rods (microlites) or needles, tapering at one end (belonites of Zirkel), and are constantly transparent and of green colour. The belonites are often aggregated into radiate groups, joined at the base, but not so regularly developed as to form perfect stars. Again, they grow attached to, and set perpendicularly upon, the faces of the porphyritic crystals, so as to appear in the slice as a thick fringe. These larger crystallites themselves have in turn served as starting-point for the growth of the much smaller crystallites of what we have styled the second order, and in this way have been built up elaborate fern-like and arborescent growths which give a very remarkable appearance to a thin slice of any of the Arran pitchstones. The mineralogical nature of the green microlites and belonites in these rocks has been the subject of some discussion. In the specimens examined by us the mineral, whenever sufficiently characteristic, seems to be hornblende. The extinction-angles observed were in all cases low, and pleochroism is often to be detected. It is possible that augite occurs in some of the Arran rocks not examined, and indeed Rosenbusch has noted in some cases, though rarely, extinction-angles up to 35°. The largest crystallites show in cross-section characteristic crystal outlines, which are those of hornblende. They are, as Mr. Teall‡ has remarked, hollow, the glassy core corresponding in shape with the exterior. In size these larger crystallites vary in different

* Corstorphine records a rhombic pyroxene as occurring, subordinate to augite, in a pitchstone in An Sloc, in the southern part of the island.

† *See* Sorby, *l.c.*, pl. xviii, figs. 57–63; Teall, *British Petrography*, p. 19 (in felspar) and Zirkel, *l.c.*, 1867, pl. xiv, figs. 16–22 (in quartz).

‡ *L.c.*, p. 345, pl. xxxiv, fig. 4.

rocks and also within a certain range in a given rock. In different specimens they have a length of ·005 to ·01 inch or ·01 to ·02 inch, with a width rarely more than ·0002 or ·0003 inch. There are often, however, a few rather larger rods, up to ·04 or ·05 inch in length. As a rule, these largest crystallites do not, like the rest, act as the trunks of arborescent and other complex growths.

The much more minute crystallitic growths, which represent the latest effort of crystallisation in the pitchstone magma, occur in two ways—disseminated uniformly through the glassy matrix and clustered thickly upon the larger and earlier crystallites to form complex arborescent and other aggregates. In the former case they impart to the general matrix a yellow colour and a somewhat turbid aspect in a thin slice. an appearance resolved by the use of a higher magnification. It is then seen to be due to the presence of an immense number of excessively minute bodies usually in the shape of short rods. With the short rods there may be still smaller bodies in the shape of globulites, and less commonly the globulites occur alone or almost alone [2448, 2451]. The complex growths built up by the aggregation of the minute crystallitic elements about the larger ones assume various forms. A very characterisric one resembles exactly a pine-tree, of which the trunk is made by a belonite and the foliage by a vast number of the smaller bodies. Another beautiful shape is made up by two or three rather small rod-like crystallites of the first order, crossing one another at their middle points, with their four or six extremities bearing complex plumose growths, which unite to form in section a feathery circle having the little rods as diameters. These two forms are well illustrated by specimens from Corrygills and Tormore respectively, and have frequently been figured*. The mineralogical nature of the more minute crystallites cannot be investigated directly, for, excepting their greenish-yellow colour, they do not exhibit any optical properties. It may be inferred, however, with high probability, that they are of the same nature as the larger crystallites, and therefore of hornblende. Those which take part in the complex growths have the same appearance as the trunks of the same growths. Further, it cannot be doubted that the minute crystallites disseminated through the glass are identical with those in the aggregates; for an invariable feature of these rocks is a ring of clear colourless glass surrounding each complex growth, as if the fine crystallitic matter which would otherwise have been scattered through this space had been abstracted to make up the aggregate in the centre.

The glass itself, apart from the minute crystallitic bodies with which it is charged, is always clear, colourless, and structureless. It does not, as a rule, show any perlitic structure. Indeed the "pitchstones," such as those of Meissen in Saxony, which show best this breaking up by minute curving fissures due to contraction, are mostly lava-flows, while these Arran rocks occur exclusively in the form of dykes and intrusive sills. There are, however, exceptions. A specimen [2451] from a dyke at Caisteal Abhail shows very

* See, *e.g.*, Cohen's *Sammlung von Mikrophotographien*, pl. iv., fig. 1 of 3rd ed., 1899.

perfect perlitic fissures, which mostly occur immediately surrounding phenocrysts of quartz and sometimes of felspar.

Many of the rocks show no evident indication of flowing movement in the magma subsequent to the beginning of crystallisation ; but in others fluxional phenomena are seen, and are of various kinds. Sometimes the porphyritic crystals of felspar are arranged with their long axes parallel to the direction of flow; less commonly the larger crystallites and crystallitic aggregates exhibit a like orientation [111, 6392]. Again, in some examples from Tormore [5656, 5657] and elsewhere the matrix of the rock is finely banded, the narrow bands following flow-lines, and being visible as an alternation of fine darker and lighter stripes upon a hand-specimen. In the slices this appearance is seen to arise from the unequal distribution of the crystallites through the glassy matrix. Stellate, plumose, and other groupings occur abundantly in certain bands and only sparsely in others. The more minute crystallitic elements are perhaps equally plentiful in the two cases ; bnt in the former they are aggregated, leaving the glassy matrix clear, and in the latter they are dispersed, producing a cloudy yellowish appearance.

The pitchstones of Arran, with those of the other western islands of Scotland and of the north of Ireland, differ from all other known acid rocks in their richness in crystallites of a ferro-magnesian silicate. Though always present, these are not always equally abundant, and the differences may be connected with differences of chemical composition. It is also to be remarked that some of the rocks do, and others do not, carry porphyritic quartz. The analyses which we quote of pitchstones and rocks closely connected with them from Arran show a certain range of chemical composition, some of the rocks being acid and others sub-acid. Our specimens selected for examination probably belong for the most part to the truly acid type, but one, picked out from the rest on account of its richness in the ferro-magnesian element, is perhaps a *sub-acid* rock. It is from a sill at Brodick school [7537]. It does not differ notably from the rest in appearance in a hand-specimen, except that it has a more decided black colour; but its specific gravity is found to be at 2·45, while a more ordinary variety from Corrygills [110] gives only 2·34. In a thin slice this Brodick rock shows a plexus of closely packed fine fibres imbedded in a brown glass. The fibres seem to be, at least in general, of felspar, and the larger ones show a central core of glass. The smaller are arranged in parallel groups attached to the larger and grown nearly at right angles to them, but there is no special orientation of the groups thus built up. The crowding of these crystallitic elements makes it difficult to examine the interstitial glass, but the brown colour is probably proper to the glass itself and not merely due to globulites.

Doubtless other pitchstones of sub-acid and intermediate composition occur in Arran. Delesse* mentions a thick sill in the red sandstones which gave the specific gravities 2·532 and 2·548 in the

* *Ann. des mines* (5) vol. xiii, p. 356 ; 1858.

	I.	II.	III.	IV.	V.	VI.	VII.	VIII.	IX.	X.
SiO_2	63·500	72·6	66·03	72·50	72·37	75·31	55·79	73·84	77·99	78·17
Al_2O_3	12·736	12·4	12·55	11·53	11·64	13·62	15·97	10·10	11·17	11·42
Fe_2O_3	. .	0·7	2·75	2·06	1·42	2·31	12·50	trace	trace	. .
FeO	3·796	1·1	not det.	not det.	1·08	. .	not det.	1·24	1·12	1·64
MnO	. .	. .	. .	. .	. .	. .	. .	1·17	0·16	. .
MgO	not det.	trace.	2·33	2·72	0·52	0·20	2·22	trace.	trace.	trace.
CaO	4·460	0·9	2·80	1·79	1·30	0·97	7·06	. .	0·93	0·13
Na_2O	6·220	1·7	5·02	3·37	4·15	3·02	2·21	2·65	4·93	7·67
K_2O	not det.	4·7	4·13	5·24	3·98	4·07	1·86	2·43	trace.	0·20
H_2O, etc. (ign.) . . .	8·000	5·2	4·20	0·70	4·86	1·48	2·88	8·18	3·58	1·47
	98·712	99·3	99·81	99·91	101·32	100·98	100·49	99·61	99·88	100·70
Specific gravity . . .	. .	2·340	. .	. .	2·36–2·37	2·52–2·53	2·70–2·71	. .	. .	. .

I. Pitchstone, Arran ; anal. T. Thomson, *Outlines of Mineralogy*, vol. i, p. 392 ; 1836.
II. Pitchstone, Arran ; anal. J. H. Player, in Teall's *British Petrography*, p. 347 ; 1888.
III. Pitchstone, Tormore, probably the N.-S. dyke ; anal. M. M. Tait, in Bryce's *Geology of Arran*, p. 203.
IV. Felsite ("claystone"), Tormore, probably from the southern composite dyke ; anal. M. M. Tait, *ibid.*
V. Porphyritic Pitchstone, centre of Cir Mhòr dyke ; anal. F. C. Thomson, *Quart. Journ. Geol. Soc.*, vol. xlix, p. 545 ; 1893.
VI. Quartz-Felsite, centre of same dyke ; anal. J. A. Schofield, *ibid.* Contains a trace of sulphur (in pyrites).
VII. Augite-Andesite, outside of same dyke ; anal. J. A. Schofield, *ibid.* The last item in the column includes 0·45 of sulphur.
VIII. "Hornstone" nodule in pitchstone dyke, King's Cove ; anal. J. A. Phillips, *Geol. Mag.* 1872, p. 540. The mean of two analyses ; of the water 2·37 was moisture.
IX. Red Felsite or "hornstone" forming part of the same dyke ; anal. J. A. Phillips, *ibid.* The mean of two analyses ; of the water 1·32 was moisture.
X. Spherulitic Felsite, dyke on Corrygills shore ; anal. J. A. Phillips, *ibid.* The mean of two analyses ; of the water 0·65 was moisture.

centre and at the margin respectively. The corresponding percentages of water were only 1·65 and 1·75, which are remarkably low figures.

Numerous geologists have noticed the occurrence in Arran of *felsitic rocks* in close association with pitchstones. In the older literature these rocks figure usually under the names "hornstone" and "claystone." Some which have been analysed (see columns IV, VI, VIII, IX, above) have a chemical composition not essentially different from that of the pitchstones, and the intimate association of the two rocks decidedly suggests that they are closely cognate and are in some cases parts of the same rock-body, the one having assumed a finely crystalline and the other a vitreous state. Assuming this, it remains a question to be considered in any given case whether the finely crystalline texture is original or is the result of devitrification of a pitchstone. In an example on Cir Mhòr carefully studied by Prof. Judd, that writer arrived at the former conclusion,* but the other alternative may be entertained in other instances. The remarkable micro-structure of the pitchstones may not improbably become obscured or obliterated by secondary changes when the glassy character is lost, and the absence of perlitic fissures in most of the Arran pitchstones usually precludes a criterion which has often been relied upon in other districts as indicating a formerly vitreous condition in rocks now cryptocrystalline or microcrystalline.

There are nevertheless specimens in our collection which give many indications of having originally been pitchstones and having lost their glassy texture, though the alteration evinced has been in general of a more radical kind than mere devitrification.

An interesting specimen comes from a quarter of a mile N.E. of Kilmichael, Glen Cloy [7539]. It is a dull-grey, compact rock, with numerous minute white spots, which look like spherulites.

* *Quart. Journ. Geol. Soc.*, vol. xlix, p. 551 ; 1893. The expression "primary devitrification" in this connection seems to be confusing, since devitrification is predicable only of what was once a glass.

A thin slice shows in natural light a vast number of little needles answering exactly to those seen in the pitchstones (Zirkel's belonites), but replaced by some chloritic or ferruginous substance. There are also abundant relics of the more minute crystallitic bodies attached like branches and twigs to these trunks, though the delicate arborescent growths which have probably been present have been in great measure destroyed, and clotted patches of the same ferruginous material represent the destroyed crystallites. Polarised light shows that the groundmass is not glassy, but consists of irregularly interlocking and interlacing crystalline areas. An imperfect radiate arrangement is seen in places, but no complete spherulites. The rock has probably been a pitchstone, and has undergone devitrification and other changes. Some little interstitial areas of clear quartz must be regarded as of secondary origin.

A specimen from a dyke north of Tor Righ Mòr [6405] is a dull compact rock mottled with pink and white streaks and with little scattered quartz crystals. It has something of a fissile structure, corresponding with very evident fluxion-lines. In the slice we see well developed perlitic fissures traversing the rock everywhere, and, with other circumstances, leaving little doubt that it has been originally a pitchstone. There are still little irregular brown patches which are dark between crossed nicols, and are crowded with what have presumably been crystallites, now replaced by reddish-brown ferruginous matter. The rest of the slice shows double refraction in a blotchy irregular fashion. In natural light there are clearer spots, often coalescing with darker yellowish interspaces. The spots often polarise as individuals. Another rock, comparable with this, comes from Tormore [6404]. This also shows marked flow-structure, with bands of pale green and pale yellow. It has a very compact, almost porcellanous, appearance, and is one of Jameson's hornstones. There are here no perlitic fissures, except occasionally surrounding the little porphyritic crystals. In natural light the appearance is otherwise very similar to that of the preceding rock, the clearer spots and yellow interspaces being strongly marked. Between crossed nicols, however, the groundmass breaks up into a much more fine-textured aggregate than before. The blotchy or spotted appearance of these and similar rocks seems to be connected with changes other than mere devitrification. There are, however, rocks which show no such peculiarity, and in which the only noticeable change from the presumed original pitchstone is the resolution of the glass into minutely crystalline elements.

There are other cases of the association of felsitic rocks with pitchstones in which the two rocks must be considered to represent distinct intrusions. An instructive example is a rock from a dyke in Glen Dubh, 100 yards above its junction with Glen Ormidale. This is a light-grey, compact rock with minute quartz-grains, enclosing rounded patches up to $\frac{3}{4}$-inch diameter of a darker grey colour. These patches are seen in the slice [7540] to be of the same general character as the matrix, both having a very finely crystalline texture, though with rather different structures. The grey matrix includes, however, other and smaller dark patches, which have all the appearance of a pitchstone under the microscope, except that the glassy base is devitrified, and only the larger and stouter crystallitic bodies retain their shape and groupings.

One well-known dyke on Corrygills shore may be mentioned here as being associated with the pitchstones, though there is nothing to indicate that it has itself been vitreous. Since the rock has been described and figured more than once,* no detailed account is necessary here; the chemical composition is shown above in column X. It is a spherulitic felsite of dull-grey aspect, the little spherulites appearing in our specimen [3323] as dead white spots $\frac{1}{40}$ to $\frac{1}{8}$ inch in diameter, often with a dark nucleus and a dark border. There is a flow-structure, partly marked by lines of spherulites. The appearance in a thin slice, and especially the blotchy or spotted character already remarked in other rocks, are well shown in Mr. Teall's coloured plate, and the rock seems to have suffered alteration of the kind already pointed out in other cases. The spherulites, which make up most of the bulk, have had their radiating fibres replaced by irregularly interlocking narrow sectors, or in the central portion by a merely granular aggregate. This latter structure is seen also in the interspaces between the spherulites. In our specimen, from the edge of the dyke, the flow-lines are seen to run uninterruptedly through the spherulites.

* Allport, *Geol. Mag.*, 1872, pp. 540, 541 ; Bonney, *Geol. Mag.* 1877, p, 506, with fig. ; Teall, *British Petrography*, plate xxxix, fig. 1 ; 1888.

A. H.

CHAPTER XII.

Faults.

We can notice here only the most important of the numerous faults, some of which have been treated of in the descriptions of the various formations.

Great Cumbrae Fault.—This fault runs almost due north from the eastern margin of Millport Bay to the northern end of the island, and has a large downthrow to the west, probably of more than a thousand feet. It affects both the Carboniferous and Old Red Sandstone formations and is a marked feature in the geology of the island in that its position coincides almost exactly with one of the important roads. This happens because the road has been formed in a kind of depression of the ground, no doubt due to the fault. In the northern part of its course the western or downthrow side forms the higher ground, while in the opposite direction it is the eastern side that is most prominent, and this line of higher ground is prolonged to near Farland Point. To this line of fault we owe the straight eastern boundary of the bay, and it seems clear that its age is subsequent to that of most of the intrusive igneous rocks of the island.

Highland Border Fault in Bute.—This crosses the island of Bute from Rothesay to Ardscalpsie Point in a valley a great part of which is occupied by lochs at a low elevation. It has a large and variable downthrow on the south-east side, and in the part with which we have to deal throws down on the the west side of Scalpsie Bay Lower Carboniferous rocks against the schist, so that the fault is, in part at least, later than Old Red Sandstone times. On the upthrow side of the fault is a remarkable relic of the denudation of the district in a conical hill called the Haystack. This is surrounded by the raised beach due south of Ardscalpsie House, and is about 20 yards in diameter and 25 feet high, composed of coarse conglomerate, mainly of large angular schist and of vein-quartz fragments. There is not much indication of bedding, but on the east side the blocks are arranged as if dipping to N.N.W. This is the basement portion of the Old Red Sandstone, resting unconformably on the schists and mainly composed of the debris of those rocks.

Boundary Fault in Arran.—There is not clear evidence that the boundary between the schists and the Old Red formation in Arran is everywhere a fault, but the general evenness, and in some cases straightness, of the line of junction is not in favour of its being natural. On the other hand, there is a general absence of signs of great disturbance or crushing along the line of junction except in a few places. It is pretty clear that the line is a faulted one at Dougrie, and in the small burn south of Beinn Lochain there appears to be a fault breccia. Then in the Garbh Allt above Moniquil the rocks of Old Red Sandstone are striking at the line of junction, as they do also to some extent on the south side of Glen Rosie. In the Cnocan Burn the junction is hidden under glacial drift. North of Maol Donn the boundary must turn almost at right angles and run nearly north-west for about three miles, but it has been obscured by the intrusion of granite except for a short distance east of Cioch nah-Oighe. From the north side of Glen Sannox the junction runs almost due north to Corloch, and here it is undoubtedly a fault, for there occurs on the upthrow side a mass of brecciated rock, triangular in outline, some 150 yards in the side. This rests unconformably, dipping at a gentle angle northward, on the highly dipping lavas of supposed Arenig age, and is opposed to the ordinary sandstones and conglomerates of Old Red age dipping at a steep angle on the eastern side of the fault. At the foot of the crag several other faults occur and the district is very complicated. A large north-west fault throws out the Old Red Sandstone entirely and brings down the Lower Carboniferous beds against the old lavas and schists. Farther north-west, and between two faults with a northerly trend, we find the upper beds of the Old Red formation brought up again, and also the cornstones and lowest beds of the Carboniferous formation in a very striking hill. These two faults, which have each a large downthrow to the east, disappear northwards under the sea, and may be connected with the Ardscalpsie fault in Bute. Westward we appear now to have two large faults running to the north-west, one of which is entirely in the schist and the other, which is nearest to the sea, forms the boundary between the schists and the Carboniferous rocks exposed on the coast. The strike of the latter brings in succession higher and higher beds of the formation against the fault, till at last, west of the Cock, we have not only the Coal-Measures but also the unconformable Triassic sandstones brought down by the fault against the metamorphic rocks. This main fault runs out to sea at the foot of the stream called Allt Mor, east of North Newton, and on the eastern side of the stream is another and nearly parallel fault. Between the two is a narrow strip of the Upper Limestone series of the Carboniferous formation.

Sannox Faults.—There are many faults large and small in the Old Red Sandstone of the Sannox district, but only a few of them can be noticed here. Perhaps the most important of these is that which passes west of the crag from which the Fallen Rocks have come. Towards the north it joins the boundary fault as already described, and near the Ordnance Station 664 it is joined by a fault which comes southward from the shore and there repeats the cornstone at the base of the Carboniferous formation. It is the largest fault which crosses the Upper Old Red Trap. United, these two faults run southward as one to North Glen Sannox, forming a marked feature for a considerable distance. The fault is probably prolonged to South Sannox, as the mudstones of the Lower Old

Red formation appear everywhere faulted against the felspathic grits which naturally overlie them. West of Farchan Mor, along this line the large dolerite dyke is apparently shifted some 200 yards to the north on the downthrow side; the grits and mudstones so far as can be observed have not the same strike, and the mudstones near the line have a higher dip than is usual.

Corrie Faults.—There are three large and important faults in the Corrie district which have nearly parallel courses in a N.N.W. direction, and all throw down eastward. The most easterly of these is visible in Corrie Church Burn, where it throws the Carboniferous Traps against the Upper Old Red rocks. It shifts the outcrop of the trap half a mile to the southward and must have a downthrow of several hundred feet, but in a southerly direction it divides into several branches forming a series of step faults. The next large fault shifts the trap about three quarters of a mile farther south, and has a downthrow greater than the total thickness of the Carboniferous formation—probably as much as 1500 feet. The nearly parallel fault west of Maol Donn throws out nearly the whole of the Carboniferous rocks for a long distance, but it is more nearly in the direction of the strike than the other two.

Brodick Church Fault.—West of the church at Brodick a large fault with a southerly course shifts all the Carboniferous Rocks on to the hillside to the southward. It has a large throw down eastward greater than the thickness of the formation, but as this is here much attenuated and probably not greater than 600 feet in thickness, the fault is not so great as it at first sight appears.

Gleann Dubh Faults.—The N.N.W. fault at the east end of Creag nam Fitheach has a large downthrow east, perhaps 1000 feet, and brings a high part of the Trias against lower beds. Its course southwards is somewhat uncertain, but northwards it is probably joined by other faults from the west, and increasing in throw becomes connected with the east and west fault north of the glen which throws down the Trias against the Lower Old Red rocks. The New Red Sandstone of Creag nam Fitheach is striking against the triangular patch of Carboniferous rocks and must obviously be separated from it by a fault, while that which bounds the Carboniferous on the west is visible in the stream at the west end of the crag formed by the volcanic zone. The fault with large downthrow east, at the west end of Creag nam Fitheach, passes southward to Benlister Glen where several faults running north are visible in the stream to the east of the small Coal-Measure area. The main throw down east, however, appears to be in the fault which goes off to the southward.

Corriegills Fault.—Several faults have been noticed in the account of the Corriegills shore section. The largest of these which throws down the Springbank conglomerates on the west against the lower false-bedded sandstones on the east is visible on the shore and in the cliff. Its south-westerly course inland is inferred from the fact that conglomerate bands which crop out on the north side of the Clauchland Hills appear to be cut off on the west and do not reach the Birk Glen, and the patch of Keuper-marls cannot have a natural boundary on the east side. It also appears to be faulted on the west side.

Ard Bheinn Fault.—The large fault on the west side of Ard Bheinn is a continuation of one in the sheet to the south which has a large downthrow west, bringing Triassic rocks against Old Red Sandstone. By it the outcrops of various subdivisions are shifted a long way to the northward on the west side, but the actual position of the fault has been subsequently obscured by the intrusive rocks of the volcanic vent.

Monyquil Faults.—The great mass of Old Red conglomerates forming the hill of Garbh Thorr is bounded by faults on either side, and both have large downthrows to the west. The most easterly of these is probably near the Garbh Allt, though nowhere visible. The conglomerates dipping at high angles are striking against the rocks in the stream which apparently belong all to the lower series of beds which underlie the trap. The more westerly large fault shifts the outcrop of the volcanic zone and the conglomerates, and has probably a downthrow south-west of 1500 feet. Though its direction is somewhat different it may be connected with the Ard Bheinn fault before mentioned.

Ages of Faults.—Some of the faults which affect the metamorphic rocks may be of very old date, but their age cannot be proved. Reference has been already made to physical features due to faults in the Pirnmill or Penrioc neighbourhood. There are others south of the Iorsa valley about Beinn Lochain. Such features are common in the schists of the Cowal district of Argyllshire.

From what is known of the Highland boundary fault elsewhere, it is possible, or even probable, that the portion of this in Arran, which is south of the large granite area, may be pre-Carboniferous or even of earlier date than the Upper Old Red rocks, and some of the faults which affect the Lower Old Red formation about Monyquil and in the Sannox glens may be of a like date.

In the quartz porphyry of Windmill Hill there are faults and crushes which are of older date than basalt dykes which pierce it.

None of the large faults in the Corrie and Sannox districts, some of which are undoubtedly post-Triassic, are found to affect the granite in any way, and the even outline of the latter is a clear demonstration that the large faults must have been formed previous to, or during, its intrusion, and not subsequently.

The anticline of North Sannox is much broken by faults, but is manifestly later than the Carboniferous and Triassic periods, for we find rocks of both these dates on either side the anticline dipping in opposite directions. Strange to say, however, the anticline does not affect the schists, and their strike has no relation to that of the newer rocks. Hence it appears that the metamorphic rocks had nearly their present strike before Old Red times, and the boundary faults along the north-east shore are contemporaneous with the formation of the anticline. It follows that many, if not most, of the faults are post-Triassic.

On the southern side of the great granite mass, if we compare the dip and strike of the rocks near Brodick Castle and in Glen Shurig with those in the Shiskine district, we find that the Upper Old Red, the Carboniferous, and the Lower Triassic beds have all been nearly equally affected by upheaving or disturbing movements, so that these movements must have been very considerable since the Triassic period. And when we notice a general parallelism between the successive outcrops of these beds and the edge of the great granite mass we are driven to the conclusion that the intrusion of the latter has been the principal factor in causing the present arrangement of the strata in question.

The effect of the southern granitic mass in truncating all these three formations, and causing the outcrops to be carried a long distance southward, as far as to the Clachan Glen, is remarkable. Of course the result is partly due to faults, as we have shown, but there is a tendency, as in the case of the larger granite mass, for the strike of the rocks to become more or less parallel to the edge of the intrusions, and this, as was before observed, is noticeable in the metamorphic rocks on the western side of the northern granite region.

CHAPTER XIII.

Glaciation and Glacial Deposits.

NORTH ARRAN, SOUTH BUTE, AND THE CUMBRAES.

A great part of the land area in this sheet was at one time covered by an ice-sheet which moved generally from north to south. This is evident not only from the distribution of erratic boulders in various parts of the district, but more particularly from a study of the glacial striæ on the solid rocks. The direction of these is almost due south in many examples on either side of the Little Cumbrae* and near Ardscalpsie in Bute. Sometimes there is a deviation towards the east as on the rock called Miller's Thumb in Millport Harbour, where the direction is about 15° east of south, and near Barr Buidhe, South Bute, where it is S.S.E. In other cases it is west of south, as in Bute to the east of Barefield (S.S.W.). It is clear, then, that the ice-sheet from the north moved over the comparatively low ground of Bute and the Cumbraes without let or hindrance, but the high hills of Arran divided the stream of ice as a rock in a running stream divides its current. For along the western side of the high ground south of Catacol we find almost universally the direction of the striæ parallel to the edge of the granitic mass. At first the direction is nearly S.W., as near Lochan a'Mhill. From Penrioc to Imachar the general trend of the ice-markings gradually changes from S.S.W. to almost due south, and about Balliekine it becomes east of south. Thus we have clear evidence that the ice-sheet *coasted* the high ground instead of going over it. The striæ on the granite inland to the west of the Iorsa valley have the same southerly tendency, but as the direction of these coincides with that of the valleys there it is not clear whether they are due to the great ice-sheet or to local glaciation. Portions of the great sheet may have gone over the watersheds at the heads of Catacol Burn and Easan Biorach, which are both under 1200 feet in height, and been augmented by local shed from the neighbouring hills.

The larger granitic mass east of the Iorsa caused a much greater deviation in the direction of the ice-sheet, for from Torr Meadhonach, in the north of the island, all along the skirts of the mountains we find the general direction of glaciation to have been between E.S.E. and due E. This continues at least as far as Farchan Mor on the south side of Glen Sannox. It now becomes pretty clear that the high mountains of Arran were not overridden by the general ice-sheet, but they must, both before and at the time of greatest glaciation, have been covered by a local ice-cap which

* Most of the groovings on the Little Cumbrae are within tide range, and it seems surprising at first sight that they are so fresh where exposed to tidal action. It must be borne in mind, however, that they have been so exposed for a comparatively short time, for till the last upheaval of the land they were "full fathom five" below water.

shed material all round to increase the general mass of ice. The high ground south of Gleann an't Suidhe may have formed a local ice-sheet also. At all events we have evidence that to the south of this the general ice-sheet moved south-westward over Arran towards Kintyre. It may be mentioned that glacial striæ are particularly numerous and good on the west side of Arran near the road between Whitefarland and Imachar; a particularly fine example of a grooved and polished surface of schist may be observed by the roadside at the former place.

To the east-south-east of Auchencar ridges of drift or drumlins which are parallel to the general direction of the glacial striæ are very prominent. They trend somewhat to the west of south, and in several cases are evidently examples of the phenomenon called crag and tail, for each of them is under the lee of a crag behind which the glacial material has accumulated.

Erratic Blocks.—At the north end of Great Cumbrae schist boulders which must have travelled from the north are found in several places, and blocks of gritty schist occur on the east side of the island near Bessy's Port. In South Bute schist blocks are fairly numerous. There is one on the foreshore of Kilchattan Bay called the Black Rock. Another west of the old quay measures 8 feet by 7 by 5, and there is a pebbly schist boulder 7 feet long to the west of the pier. A large block of quartzose pebbly schist veined with quartz 350 yards W.S.W. of Lubas is 8 feet long, and large fragments of a similar rock are near the seashore half a mile west of Quochag. A gneiss boulder also occurs in Quochag plantation, and there is a large boulder of gritty schist south of the west end of Suidhe plantation. A boulder of grey granite 3 feet 6 inches long, but partly buried, is found three quarters of a mile W.N.W. of Quochag. These are all far-travelled blocks, and a few erratics are also found in Arran, but most of the boulders of that island are of local rocks. A well-rounded boulder of coarse granite with large crystals of pink felspar is on the shore about half a mile west of the Cock of Arran. It is probably an example of the granite of Glen Fyne which has been carried from the north. About three quarters of a mile west of Lochranza pier there is at a height of about 200 feet above the sea and reposing on the schists a large boulder of brecciated conglomerate very like the kind so common in the Upper Old Red rocks of Bute. Its dimensions are 12 feet long by 9 feet broad, and it is four feet high. This block of coarse rock is composed mainly of fragments of quartz and schist. It may have travelled across from Bute. Rock of much the same character occurs also in Arran, but it would not be easy to account for its position here unless it came from outside the island.

The largest of the local erratics are of granite. The heaviest is probably the Clach Mhor, on the highest raised beach south of the the Corrie Burn and about three quarters of a mile south of the hotel. It is 30 feet square at the base, about 15 feet high, and must weigh about 400 tons. A block stilll longer than this (36 feet) but probably not so heavy, occurs among the moraines north of Ceum na Caillich. Clach an Fhionn, a split boulder north of Corrie by the roadside, measures 17 feet by 10 by 7, and Clach a Chait, 600 yards farther north, is 18 feet long, 6 to 9 feet wide, and about 15 feet high. There is a large granite boulder on the Corrygills shore, and large blocks of granite are numerous on the Clauchland shore on the north side of Lamlash Bay, and a few occur high up on the northern slopes of Holy Island. They are abundant on the Old Red Sandstone slope east of Moniquil, where one was measured 17 feet by 8 feet 6 inches ; and on the hill-slopes north of Dougrie and on the seashore to the west, where several are as much as 10 feet long. The numerous large boulders of granite and schist that encumber the shore for a distance of a mile and a half north-west from the Iorsa Water have been derived from the denudation of the boulder-clay during the process of cutting back the cliff to form the present raised beach, and the Clauchland shore boulders have probably in like manner been derived from the denuded till of the neighbourhood.

Glacial Deposits.—Till or Boulder-clay.—This well known, irregularly accumulated deposit is often tinged of a red colour and is very unevenly distributed, being mostly confined to the valleys and low-lying ground. Probably the best exposure of it in this area is on the north side of Ballymichael Burn, nearly half a mile above the road, where reddish till or stony clay appears from 40 to 50 feet in thickness. Thick masses of grey till may be seen in the banks of the Cnocan Burn, Brodick, about half a mile above the wood, and compact red till appears in the south bank of Glencloy Burn near Knowe. The general drift of the granite area is less clayey and more loosely aggregated, sometimes much like morainic material in character, though not in form. Thick masses of loosely-constructed brownish drift, with large blocks in it, are exposed in the banks of Allt Gobhlach, Pirnmill, half a mile from the sea, and fine exposures of this loose granitic drift are found by the stream called Allt ant Siorraim which issues from Loch Tanna. In places on the west side of the stream the drift would appear to be from 50 to 100 feet thick.

Moraines.—Relics of a later and more local glaciation also occur in nearly all the valleys in the shape of moraines. They are especially conspicuous in the valleys at the head of the North Sannox stream on the north side of Caisteal Abhail, and in the upper part of Glencloy in both its branches, Glen Dubh, and Glen Ormidale. In the three valleys into which North Sannox stream divides the moraines are generally an irregular assemblage of small mounds composed of huge blocks of granite, but in addition to this there is a fine example of a lateral combined with a terminal moraine on the eastern and north-eastern sides of the heaps S.E. of Creag Dhubh. There is also a linear moraine in the eastern valley—Coire nan Ceum—in addition to the formless heaps. In South Glen Sannox there is a well-formed lateral moraine, more than half a mile in length, which forms a sloping ledge nearly parallel to the stream on the north side of the valley, under Ceum na Caillich. In Coire nan Larach to the north of Am Binnein there is a beautifully-formed lateral moraine strewn with granite blocks, and there is another in Coire Làn at the head of the White Water. A well-marked linear moraine, which is at a low level to the north of Maol Donn, can be easily discerned from the high road south of Corrie. It has a north-east trend. Moraines are common in the Iorsa valley, and there are fine examples near the head of the Garbh Choire Dubh west of Cir Mhor. In Glen Rosie they are found less than half a mile west of the wood and below the upper limit of the 100 feet beach, and they are prominent again two miles farther up the valley where it divides into three. The upper part of the Garbh Allt branch glen, for a distance of a mile from the head of the valley, is almost one sea of moraines. In Gleann Dubh (Glen Cloy) there is a magnificent series arranged for the most part in concentric curves round an alluvial flat at the foot of the crags which must at one time have been a glacial lochan, or a tarn, dammed by moraines (*see* Plate IX).

ESKERS.—In the valley of the Machrie Water, about Monyquil and Glaister, and also up the Machrie Burn, mounds of detritus occur which at a distance might be mistaken for moraines, but which when closely examined are found to consist of washed sand and gravel. They are, threfore, more of the nature of eskers or kames. On the Machrie Burn they are conspicuous to the west of Cnoc na Ceille, where they form an irregular group stretching for a quarter of a mile parallel to the burn on its east side. On the west side, a line of them, almost a continuous ridge, may be traced to the north-westward for nearly half a mile. On the Machrie Water the best examples of them are found between Monyquil and Machrie Bridge on the west side of the river, and mounds of much the same character are found near the road which runs past Derenenach and Ballymichael to Shiskine. East of Ballymichael these mounds are very striking, and pits have been opened in them in several places for gravel and sand. Pits have also been made in the long mound between Machrie Bridge and Glaister. One of these mounds of a curved shape, south-west of Monyquil, is known as "The Serpent Mound," and is supposed to be artificial.

LAMINATÉD-CLAYS AND SANDS WITH GLACIAL SHELLS.—These are found in Bute at the Kilchattan Tileworks, and they occur also in the Great Cumbrae. The beds at Cumbrae College have been described by the Rev. H. W. Crosskey and D. Robertson in Trans. Geól. Soc. Glasgow, vol. iii, p. 113 (1868). The same observers describe the Kilchattan beds in the 4th vol., p. 128, of the Glasgow Geol. Soc. Trans. (1872); and these have also been described by (Sir) A. Geikie in his paper "On the Phenomena of the Glacial Drift of Scotland," Trans. Geol. Soc. Glasgow, vol. i, part 2, p. 132 (1863); and by James Coutts in the Proc. Nat. Hist. Soc. Glasg., vol, ii, p. 33 (1870).

AYRSHIRE DISTRICT.

In the part of Ayrshire described in this memoir the movement of the ice of the Glacial Period has been persistently from north

Moraines in Glen Dubh (Glen Cloy), near Brodick, Arran. They in great part surround an alluvial flat which was once a moraine-dammed lake.

to south, the actual direction varying slightly with the form of the ground or from other causes. If we take the observed striæ on the rocks at the greatest distance from the heights which would influence the motion of the ice, we find them at the Portincross beach as a well ice-worn surface of pebbly red sandstone, running towards S. 25° E. As the ice which engraved them must have come from N.N.W. across the Firth of Clyde we may assume that this was the general trend of ice-movement here. But the steep volcanic escarpment could not fail to affect the flow of at least the lower portions of the ice-sheet. Consequently on bare surfaces of andesite on the south side of the Gogo Burn above Largs the striæ are found to have been turned round and to point to S. 25° W. But a little farther south they run towards S. 20° E.

That the ice moulded itself upon the surface of the rock over which it moved and that it was pressed up hill is well shown at several places in this district. Thus, in the ravine of the Gogo Burn, 1000 yards due east from Gogo Bridge, a well ice-ground face of andesite, with an inclination of 60°, has been scored from bottom to top by the ice that was driven upward out of the hollow. Again, on the east side of the smaller of the two necks which rise from the slopes to the south of Fairlie, the surrounding sandstone has been striated from below upward by a mass of ice that was here moving towards S. 9° E.

The boulder-clay is abundantly spread over the surface of the slopes between the edge of the volcanic plateau and the sea. It is full of local stones, but contains also many from the Highlands. Sections of the deposit may be seen in almost any of the watercourses. It likewise forms the smooth grassy bluffs that rise from the inner edge of the platform of the raised beach. The large number of boulders everywhere strewn along the beach afford good material for studying the march of the ice-sheet, and remain as evidence of the contents of the boulder-clay which has been removed from so much of the lower ground. A. G.

KINTYRE DISTRICT.

Although the nature of the rocks in the area is not favourable to the preservation of Glacial striæ, the track of the ice which enveloped Skipness is indicated by the nature and disposition of the Boulder-clay and the carry of material. These indicate that during the period of maximum glaciation this part of the peninsula shared in the general movement of the great ice-sheet which crossed Kintyre approximately from east to west. As shown in the Report of the Committee on the High-level Shell-beds of Kintyre to the British Association in 1896,* striæ pointing westwards are found on the watershed at elevations of over 1200 feet to the north-west of Carradale, just outside the present area, and boulders of Arran granite have been traced in the drift across the peninsula from Carradale to the west coast.

* Report Brit. Assoc., 1896, pp. 386-389.

The Boulder-clay found over the Skipness area is red in colour and contains a large amount of red sandy matter and boulders of red sandstone and conglomerate entirely foreign to the area. It everywhere lies on the western slopes of the rising grounds, while the eastern slopes are bare. It fills the valleys of the Skipness and the Claonaig waters to great depths, and in the former case to over 200 feet in places, and both streams down a great part of their lower courses are cutting their present trenches between the Boulder-clay and their ancient western rocky sides, so that they have rocky banks on the left and high Boulder-clay bluffs on their right, and do not appear to have as yet reached the bottom of their old pre-glacial channels. The Skipness Water, however, appears to leave its old valley to cut into its rocky side for half a mile below Coalfin close to Skipness.

It is singular that the colour of the Boulder-clay in Skipness should be red. It cannot be of local origin, as the rocks of the region could not give rise to a deposit of that colour; nor can it have derived its colour from the rocks now seen on the shores of Loch Fyne, as the Boulder-clay found on the shores further up are described in the Memoir on Cowal as greenish-grey or pale-buff in colour.* Red boulder-clay, however, is common in the south part of Cowal.† It occurs throughout Kintyre south of this region, and is continued across Islay. It is highly probable that the redness is due to the rocks over which this part of the ice-sheet passed having been stained by an extension of Triassic rocks which may have filled the Clyde Basin and only been removed in late Tertiary times. The discoveries connected with the great Tertiary neck already described, give great support to such a supposition. It may be that even yet outliers of Triassic rocks occur in the Clyde to the east of Skipness, for Triassic rocks pass out to sea at the Cock of Arran,‡ and stained carboniferous limestone blocks full of characteristic fossils form a bank at the mouth of Catacol Bay § in such a manner as to suggest that they are not far out of place.

No moraines have been with certainty detected in this area.

B. N. P.

* "Geology of Cowal," Mem. Geol. Soc. Scot., p. 255.
† *Ibid.*, p. 255.
‡ See *ante*, Chap. vii.
§ See *ante*, Chap. vi.

CHAPTER XIV.

Raised Beaches and Recent Deposits.

RAISED BEACHES.—The 25 feet raised beach is a marked feature on the long coast-line of this map. Though often very narrow it is very persistent. It may disappear for a time at a rocky promontory but shortly re-appears. Sometimes it is but a shelf cut in the rocky shore with no deposit of gravel on it, and occasionally, as in the case of the Scriden and the Fallen Rocks in Arran, the original shelf has been obliterated by a comparatively recent landslip. The rocky shores of South Bute and of the Little Cumbrae show the least traces of it. The marine shells found in the sand and gravel of this lower raised beech or lying loose on its surface, appear all to be of species now living in adjoining seas, and are a testimony to the recent elevation of the land. A list of some found in a field about a mile south of Corrie is given by Ramsay in his "Geology of Arran," p. 19. In the southern part of Great Cumbrae, west of Millport, the shells in places are so numerous as to form a kind of shell marl. A separate beach at the height of the "40 feet" seldom occurs, except at the mouths of the large streams or in sheltered bays. In fact, both the 25 and 40 feet beaches are represented by the continuous marine terrace above described, which is often bounded by high sea-cliffs in which water-worn caves occur at various levels. These latter are conspicuous between Brodick and Corrie on the eastern side of Arran in the New Red Sandstone; and several are found hollowed out of the schist on the north-west coast. The remarkable group associated with the King's Cove near An Cumhann are just at the south-westerly edge of the map.

The higher and older marine terraces have evidently suffered much denudation by the action of the sea along the exposed part of the coast, and by streams at their mouths, and in the bays of Brodick and Lamlash, where several burns enter the sea. In these latter situations the marine and freshwater alluvia are mingled so that it is difficult to class them separately. We have evidence, however, of several beaches at different levels rising from 40 or 50 feet to over 100 feet above the sea, which are beautifully exhibited near the mouths of the Iorsa and Machrie streams in Arran, and in the extensive tract of low lying land, west of Kilchattan, in Bute. At the time of greatest depression, when the highest beaches were formed, Inchmarnock was separated into two islands, and the portion of Bute included in this map was divided into three; the northern part of Great Cumbrae was in like manner a separate island from the rest. In Arran the sea penetrated far up into many of the valleys; Glen Rosie and Glen Cloy were sea lochs, each one and a half miles in length; Lochranza was lengthened by one mile, and Lamlash Bay extended one mile farther to the west. North Glen Sannox was a long narrow sea loch, and at Catacol and South Sannox there were broad, short lochs. Perhaps the greatest changes in Arran would be on the western coast, where not only was there a sea loch at the mouth of the Iorsa but in the plain of Shiskine the sea penetrated in an irregular way to more than two miles eastward of its present boundary, and the hilly ground of Torr Righ Beag and Torr Righ Mor formed a separate island. Good sections of the gravel and sand of the higher beaches are exposed in the north bank of the Rosie Burn one mile from the sea, the south bank of Sannox Stream opposite Mid-Sannox House, the east side of the Iorsa Water above Dougrie Lodge, and in a gravel pit at Lochranza above the junction of the two main streams and west of Ballarrie. W. G.

The coast-line between Ardrossan and Largs affords a typical example of the raised beaches of the Firth of Clyde. These terraces form a platform of level ground along which the coast-road runs, and on which the maritime villages are built. On the seaward side of this platform lies the present sea-beach; on the inland side the ground rises steeply as a grassy bank, or occasionally as a wooded cliff, according to the nature of the material out of which it has been eroded. The smooth slopes usually mark the position of the Boulder-clay, while the more cliffy faces indicate the outcrop of harder rock.

At least four terraces may here and there be discriminated, but their boundaries are apt to become so faint that they seem to merge into each other, and they cannot, therefore, be continuously shown on the map. The lowest and youngest of the beaches has a height of about 15 feet along its inner margin. It forms the platform on which the seaward part of Largs stands, where its limits can here and there be readily traced. The gentle bank which marks its landward edge may be seen on the south side of the mouth of the Gogo Burn, on the flat to the south of Broomcraig Park, and to the south of Fairlie. It is on this terrace that most of the coast-road runs between Largs and Fence Bay, and again between Seamill Bridge and Ardrossan.

The next beach, usually known as the 25-feet terrace, covers a broader, more continuous, and more easily recognised space. Its inner margin runs, on the whole, tolerably parallel with the contour-line of 25 feet above ordnance datum, at a little higher elevation, but occasionally it sinks below that line or rises farther above it. These variations, which recur at frequent intervals, may be due to irregular local differences in the accumulation of littoral detritus. It should be noted that this terrace is fundamentally a platform cut out of the rocks underneath and with a variable thickness of sand and gravel spread over these rocks. At the same time it is unfortunately true that no careful levelling has yet been undertaken in the basin of the Firth of Clyde, or indeed anywhere in Scotland, to ascertain if a recognisable increase or diminution of the height of any of the marine terraces can be detected, such as might indicate inequality of movement between one part of the country and another.

The terrace continues as a well-marked platform about 200 yards broad to beyond Seamill Bridge. From its inner border a steep bank rises to more than 100 or even 150 feet above the sea, and shows here and there outcrops of red sandstone on its declivities, as in the "braes" of Boydston, Glenhead, and the Bank. Beyond Seamill Bridge, where the road quits the shore, the 25-feet beach continues towards the north-west with its wooded landward banks, which probably consist mostly of drift. At Portincross, however, it is interrupted by the projecting promontory formed by the broad and long dolerite-dyke already mentioned. Immediately beyond this point the platform reappears in its most characteristic form. It is here in places less than 70-yards broad, and is bounded inland by a range of wooded cliffs which rise to a height of 300 feet. The contrast between the dark rocky wall behind, and the strip of level green fields at its base, with the blue sea in front, forms a singularly striking piece of coast-scenery. After a distance of about a mile the cliffs sink down into sloping ground which makes a curve inland for three-quarters of a mile to Hill House, where it forms a promontory and then turns abruptly southwards away from the coast. By this disposition of the topography bays were formed in the old shore-line; the marine accumulations were there laid down under more sheltered conditions, and now cover a wider area and attain a greater development than elsewhere along this coast. To the south-west of Hill House the 25-feet beach expands into a fertile platform 1400 yards long, and with an extreme breadth of of 750 yards. Its inner margin follows the line of a low bank to the north of the grounds of Hunterston House. To the southward a higher platform makes its appearance, which will be further referred to immediately. The 25-feet beach stretches north by Fairlie to Largs, and for many miles beyond, carrying with it the same type of scenery which has now been described. Here and there it seems to merge insensibly into higher and older terraces especially where a stream, descending from the high grounds of the interior, has mingled its alluvium with that of the marine terraces, as in Kelburn Park, where the Kel Burn enters the sea, and at Largs where the Gogo Burn has carried down a large quantity of detritus from the hills above.

The next beach in succession is that to which the name of 50-feet terrace has generally been given, though its average height is probably rather less than that number of feet. At one time it was no doubt well developed along this part of the Ayrshire coast, but it has been in great part cut away during the prolonged period when the 25-feet beach was in course of formation. The only considerable portion of it that can be recognised is that which fills up the deep and broad hollow that extends from Poteath, beyond Hunterston, for a mile and a half to the south, with a breadth of more than half a mile. There can be no doubt that this was once a sheltered sea-bay where marine deposits might accumulate, and where they would be more likely to escape subsequent demolition than on the exposed coast-line to the north and south. Unfortunately there are hardly any sections to be seen of the deposits of this terrace. They include fine clays, which have been worked at Carlung for the making of tiles. That these clays lay at the surface over considerable spaces may be inferred from the position of Carlung Moss, which is an extensive tract of peat lying immediately on the marine platform and filling a small bay at its northern end. No marine organisms are known to have yet been obtained from these clays.

The highest beach which is generally recognisable in this part of Scotland is that to which the name of the 100-feet terrace has been assigned. Being older than the others it has been much longer exposed to denudation and has consequently been much more extensively demolished, so that for the most part only fragments of it now survive in such sheltered places as could afford it protection. The high gravel platform behind Largs appears to belong to this terrace.

Marine alluvium of younger date is well displayed along the shore from Largs southward. At low tide the Southannan and Hunterston sands present a plain of wet sand extending for nearly a mile out towards Fairlie Roads.

As already stated, the conditions have not been favourable for the formation of blown sand. But a small patch of this deposit may be detected here and there as, for instance, on the promontory close to the volcanic neck at the south end of Fence Bay. A. G.

Fragments of the 100-feet raised beach terrace are found near the mouth of Skipness Water above Skipness Castle, and overlooking the eastern angle of Claonaig Bay, as well as at Escairt, just above Escairt Point. A lower terrace, probably representing the 50-feet beach, is also found at the same localities. Relics of a still lower terrace, probably the 25-feet beach, are found all along the coast bordered by a steep bluff of cliff often cut in the rock or pierced with caves, forming a feature which easily arrests the eye.

Present Beach.—As already stated, the coast-line for the most part is rocky and no beach is being formed on these exposed parts, but the material abstracted by the sea is carried forward and heaped up in the sheltered bays. The higher raised beaches also occur in the same places, showing that a similar action took place during their accumulation. In Skipness Bay the marked deflection of the Skipness Water towards the west by the beach shows plainly that the greatest wave-action along this shore is by waves from the east.

B. N. P.

Freshwater Alluvia.—As might be expected from the small size of the streams the patches of freshwater alluvium are generally small and unimportant. The largest are found in the plain of Shiskine, on the Machrie Water above the old bridge, in the Iorsa valley above Iorsa Loch, and at the mouths of the Iorsa, Catacol Burn, Easan Biorach, the two Sannox Burns, and those which enter the bays of Brodick and Lamlash. The alluvium at the debouchure of the streams has been to a great extent formed from the denudation and rearrangement of the material forming the raised beaches. In the Shiskine district the alluvium of the swift running streams on the east side has been spread out in fan-like or delta forms over the marine material. The alluvial sand and gravel of the Machrie is two miles in length and nearly half a mile broad in places, and has been accumulated by several swift running streams of considerable size. At first sight it might be supposed that the material has filled up an old loch, but the fact that there is a rise of quite 100 feet between the foot and the upper end rather militates against this view. The patch of alluvium in Glen Iorsa is nearly as broad as the last and is three miles long, and here there must have been at one time an extensive sheet of freshwater which, including the present Loch Iorsa, may have been three and a half miles in length. For a distance of more than a mile above the last-named loch the alluvial flat is studded with small lochans, and the rise in level is but 7 or 8 feet. Even at a distance of more than two miles above Loch Iorsa the alluvial flat is only 30 feet higher than the loch. A beautiful example of a filled-up lochan, an old moraine-dammed tarn, occurs in Gleann Dubh (Glen Cloy) at the foot of the steep crags. The present extent of the alluvial flat shows this lochan was about 400 yards long and 300 broad. Old lochans or tarns which have been filled up are now generally peat-bogs, like Branzet Moss in Glencallum in Bute, and a bog east of Breckoch in Great Cumbrae. There were several on a small scale in Little Cumbrae. It is evident that several of the streams have changed their courses in the low-lying ground near the sea. In an old manuscript map of the latter part of the 18th century the Rosie Burn is represented as taking a sweep round to the eastward in what is now the deer-park, and the Cnocan Burn came southward towards it. The marked bank in the park south-west of the cottages shows where the old stream ran. At that time there was a project to make an artificial channel connecting the Rosie Burn with the mouth of the Cnocan in order to form a harbour opposite the castle. The lower part of the Cnocan Burn is now an artificial cut. There is still trace of a large bend, an old course of the Rosie, west of Strabane. The mouth of this stream has undergone several changes. At one time it ran along the sands towards the Cnocan, and afterwards changed to a straight course out to sea. Then it turned to the north again and its outlet, when the Ordnance Survey was made, must have been nearly 700 yards north of what it is now. The present run straight out to sea is, however, said to be owing to an artificial cut having been made. It has been in existence many years, but strange to say is not on the revised ordnance map. The greater part of the water of Ballymichael Burn is now carried by an artificial channel into the Machrie Water, to the east of the Stone Circles of Tormore, and this having been made a good many years ago ought to have appeared on the revised ordnance map.

PEAT.—The peat of the old lochans has been already noticed, and only the moor or hill peat will be described here. The higher granite hills are almost bare of vegetation, and the higher ground on which peat accumulates is in the southern part of the map, from

Beinn Bhreac to A'Chruach. There is a good deal of peat, however, on the lower granite area from Glen Catacol eastward to An Tunna, and it is abundant on the high plateau-like or gently sloping ground formed of schists, nearly all round the granite district. It is found, in fact, over the rocks of all formations in Arran, from the oldest to the Boulder-clay of the Glacial period.

Blown Sand.—Low hillocks of blown sand, but of no great extent, may be observed on the raised beaches at the north end of the Great Cumbrae, near Millport east of Breckoch, and coasting Scalpsie Bay and Stravanan Bay in the island of Bute. A more extensive area of blown sand, a typical sea-side links, occurs at Machrie Bay, Arran, to the south of the Machrie Water.

Landslips.—Probably the largest area covered by a landslip in Arran is that which is found in the hollow north of Maol Donn, between it and An Sgriob. Large masses both of Carboniferous and Triassic rocks are scattered over an area which is 600 yards in length from S.W. to N.E., and on an average more than 200 yards in breadth. The extent of this slip must be quite 25 acres. Other notable landslips, which have often been described, are those which form the Fallen Rocks and the Scriden. The former make a striking debacle of large blocks, from a height of 500 or 600 feet down to the sea level between North Glen Sannox and Millstone Point. The slipped masses are all of Upper Old Red Conglomerate (*see* Plate X.). The Scriden covers a larger area at the most northerly part of the island. It is formed of large blocks of Triassic sandstone and conglomerate which fell, it is said, some two hundred years ago. The concussion shook the earth, and the fall was heard in Argyllshire and Bute. In addition to the masses which have actually fallen several parts of the hill above have moved slightly from their position and left deep and narrow rents, one of which is known as the Fairy Dell. W. G.

No fresh-water alluvium exists in the Ayrshire district of sufficient importance to find a place upon maps on so small a scale as one inch to a mile. The slopes are too steep to permit of the deposit of sediment, and when the bottom of the declivities is reached the water-courses are within a stone-cast of the edge of the Firth. The only tract of fresh-water accumulation that may be referred to here is Carlung Moss already noticed. Considerable tracts of peat and peaty moor occupy the hollows of the volcanic plateau just beyond the present district. A. G.

Small alluvial plains are found along the course of the Kintyre streams, the broadest and most continuous being found on the Claonaig Water. High terraces showing stages in the lowering of the valleys are well shown along the same stream, especially where it runs through boulder-clay. They also occur in the Skipness Water where the river has cut deep down into the boulder-clay above the rocky gorge of Coalfin close to the village of Skipness. Small patches of alluvium occur along the smaller streams, but they are two small to be shown on the one-inch map.

Cultivation is mainly confined to areas covered by boulder-clay, the raised beaches, and the alluvial terraces, the best

Plate X.

Landslip of Upper Old Red Sandstone Conglomerate, which goes by the name of "The Fallen Rocks," East Coast of Arran, nearly 4 miles North of Corrie.

land being found on the two latter formations, as owing to their arrangement of the materials they afford natural drainage. The areas where the rock is not covered by these deposits are either bare, or, where the rocks readily decompose, are covered by a thick coating of grassy or heathery turf, while peat, thick enough to be worked, occupies hollows both overlying boulder-clay and decomposing rock debris. B. N. P.

CHAPTER XV.

Economic Geology.

Coal.

At Ambrisbeg, in Bute, some 200 or 300 tons of coal were said to have been got out many years ago. The seam is in the same position as that once worked at Ascog, and is probably of the same character, a kind of anthracite, locally called "blind coal." In Blain's History of Bute the Ambrisbeg coal is said to have been from a foot to 16 or 20 inches thick, but the field of it being small and the dip great combined with the thickness of the seam to occasion it being neglected. Several attempts have been made at various times to find a thicker seam, but invariably without result. There are traces of the old adits to the south and also to the north-west of Ambrisbeg.

The coal formerly worked on the shore of the Cock Farm in Arran is referred to by most of the older writers on the island. All agree that the seam or seams belonged to the type of blind or glance coal. It was difficult to work, and principally used for the purpose of making salt from the sea-water. (The old salt pans are close to the old workings.) It was probably also used for burning the limestone near Laggan. Two or three seams are said to have been worked, the principal seam being three or four feet thick; but though more than one seam may have been found it seems probable that the workings were almost entirely confined to the thickest seam. They are very old and were discontinued considerably more than 100 years ago, probably before 1773, as under that date in the estate accounts there is a record of boring at Cock for coal. In the same year a boring for coal was made on the north side of Lamlash Bay on the Clauchland shore to a depth of 114 feet 5 inches, which naturally proved unsuccessful.

It is remarkable that no coal is found at Corrie or elsewhere in the island in the strata corresponding to those at the Cock in which coal has been worked; nor has any coal been discovered in the highest Carboniferous beds in Arran which, on the evidence of their fossil contents, are assigned to the Coal-measures.

Peat.

There are extensive tracts covered with thick peat in the island of Arran, mainly on the higher plateau-like ground between 700 and 1700 feet above the sea, but occasionally it is found at lower levels, as on the old raised beaches on either side the lower part of the Machrie Water. It was formerly much used for fuel all over the island, and almost everywhere old peat roads to the hills still exist, though they are not marked on the ordnance maps. On the east side peat for fuel has almost entirely been replaced by coal, but on the west side it is still cut and largely used in the Shiskine district and northwards to Imachar and Lochranza.

Ironstone.

To the north of the landing-place at Corrie is a thin band of clay-ironstone which crops out also to the westward on the hillside, where it is from four to six inches in thickness. It appears to be of good quality, and we were informed that some hundreds of tons of it were formerly exported. Probably it was not mined for, but was collected during the working of the white freestone quarries. A similar band occurs in the section on the Cock shore. A number of old bloomeries exist in the island which have been described by Mr. W. Ivison Macadam.* Three of these are on the farm of Glenkiln near Lamlash, and in one case there is evidence that bog-iron ore was used. Two sites occur in Glencloy to the south-west of Glenrickard, and there were two near the road leading from Brodick to Lamlash, in one of which the slag was utilized for road-making. Another was at Coillemore near Lochranza. In all these cases charcoal appears to have been the fuel used for smelting, and the slag remaining is of the dense black type characteristic of the early period when the smelting process was very imperfect, and a large percentage of iron still remains in the slag.

Barytes.

A vein of sulphate of barytes which was formerly worked crosses Glen Sannox Burn in a northerly direction about three quarters of a mile from the sea. The workings above ground extend for a distance of about 100 yards, mostly on the north side of the burn, and shafts have been sunk within the opencast workings. One shaft also is found 70 yards south from the burn. At the northern end of the workings the vein is from 12 to 15 feet wide, and purest on the west side. In the river the worked part of the vein is four to five feet wide, and there is about as much more mixed with sandstone on the west side, and also a little on the east side. The general direction of the vein is a few degrees west of north, but it has a rather wavy course. South of the stream, about 125 yards, a small cross-cut was made at the surface, apparently as a trial to find the vein. In a burn to the S.S.E., another, or the same, vein occurs having a course towards the north-west. It is two feet or more wide in places and fairly pure, and has a hade to the south-west. The barytes occurs in a massive form, sometimes almost pure white but occasionally with a pinkish or yellowish tinge. Ramsay gives an account of the manufacturing process† carried on at the old mill of which traces still exist.

* "Notes on the Ancient Iron Industry of Scotland." Proc. Antiq. Soc. Scotland, 1886, pp. 89–132.

† "Geology of the Island of Arran," p. 24.

Building Stone.

There are extensive old quarries in the white Carboniferous freestone of Corrie which was much wrought a century or more ago. It was used in the construction of the Crinan Canal, and is said to have been shipped to the Isle of Man for building purposes. At present the red freestone of the Triassic rocks is the principal building stone in Arran, and there are large quarries in it at Brodick and Corrie. The stone is soft and easily worked, and is said to harden by exposure to the air. Large blocks of it can be obtained, and from Corrie the stone is largely exported to various parts of the Clyde district, and some going much farther away—a mansion in Rum being built of it. Troon harbour is said to have been built out of the material from the northern quarry. In the neighbourhood of Lochranza a tough, gritty schist is used for building purposes. At Millport the white freestone of the islands in the bay is quarried for like purposes, and the Upper Old Red Sandstone is largely worked south of Figgatoch.

Slate Quarries.

Slate has been worked in small quarries on Inchmarnock, both on the eastern and the south-west side of the island, the two extremities of a band that crosses the island in a N.N.E. direction. The slate is of a rough kind, grey in colour, and resembles that formerly worked at the quarries south of the Cock Farm in Arran. In the Brodick estate office there are records of these last workings, from which we learn that between 1773 and 1776 between two hundred and three hundred thousand were sold at prices of £1 per thousand and upward. Work was also carried on here between 1776 and 1781. Most of the slates from this locality have disappeared from the house-roofs of the neighbourhood, but some still remain in Lochranza and North Newton.

Limestone.

There are extensive old limestone quarries at An Sgriob, to the north of Maol Donn, and at Corrie. The latter are much the largest; they extend up the steep hillside for a quarter of a mile, and the limestone has been much wrought in artificial caves, besides having been worked at the outcrop towards the dip till in places there was nearly 30 feet of cover. Much lime was formerly exported, but very little is now burnt in the island, and on the Shiskine side lime is imported from Ireland. The only other large limestone quarries in this sheet are to the south of Kilchattan in the island of Bute. They are old workings, and are now filled with water and used as a reservoir, but a portion of them is newer than any of the Arran workings. According to an analysis of the rock given by Bryce* it is a species of dolomite, one specimen contain-

* Notes on the altered dolomites of the Island of Bute, Phil. Mag. xxxv, pp. 81-91, and Geology of Arran, etc., 2nd ed., 1859, pp. 56-59 (4th ed., pp. 326-330).

ing 33·72 per cent. of carbonate of magnesia. Another specimen was analysed by Dr. R. D. Thomson with the following result:—

Silica and Alumina	9·70
Protoxide of Iron	1·12
Carbonate of Lime	67·42
Carbonate of Magnesia	17·31
Water, Coaly Matter, and Carbonic Acid	4·45
	100·00—Spec. gravity, 2·679.

It is remarkable that where the rock has been converted into crystalline marble by the action of a dyke it loses nearly all its magnesia, the altered rock containing only from one to two and a half per cent. of it.

Road Metal.

The numerous igneous intrusions, especially the basic dykes and sills, afford abundance of excellent material for road-making almost everywhere. The acid rocks are not so much used for this purpose. However, a felsite sill is so used near the Brodick and Lamlash road, and a granitic mass near Derenenach on the Shiskine side of Arran. The hard sandstones of the Lower Old Red formation are used for road material in one or two places, as on the String road in Glen Shurig, and the gravel from a raised beach near Ballarrie, Lochranza, is taken for a like purpose.

Clay or Tileworks.

At Kilchattan in Bute is found a laminated fine clay which has been much worked for tilemaking. At the tile sheds it was about 14 feet thick resting on red till, but to the eastward it dies out and gravel is found reposing on the red till. Sometimes there are stones as big as one's fist in the laminated clay. Fine red sand, apparently without lamination, irregular in occurrence, but sometimes 10 to 12 feet thick, generally overlies the clay. The clay at the west end of the working has a ridgy upper surface, and also contains shells, and is useless for tilemaking purposes. This clay belongs to the glacial series.

Population.

The distribution of the people has little connection with the geological formations, the population being confined in Arran to the neighbourhood of the coast and to the lower parts of some of the glens. The district of Shiskine, on the west side, is the only exception, and here a few scattered farms are found some distance from the sea. In Bute and the Great Cumbrae we find scattered farms in the interior of the islands. The resident population of Arran is small but is much increased in the summer months by an influx of visitors, so that the inhabitants are probably doubled in number. Many of the natives find employment in the summer in catering for the visitors in various ways, but the majority of the people are engaged in agriculture, and the cultivated parts of the island are practically those in which the people reside. The remainder, and by far the larger portion, is devoted to sheep and deer.

The fishing industry is almost extinct, and chiefly confined to that of herrings on the west coast of Lochranza and Pirnmill.

Soil and Agriculture.

The alluvial flats and raised beaches at the mouths of the principal streams afford the best soil, and the narrow terrace or raised beach round the island is in general carefully cultivated. The upper limit of enclosed and cultivated land is between 400 and 500 feet above the sea, but the greater portion is below 300. As the ground rises steeply from the sea almost everywhere the arable land is necessarily but a narrow belt along the coast and even there is not continuous, though apparently more land was formerly cvltivated in the olden times. In the Millstone Point district there were at one time 14 families residing at Cock, Cuithe, Laggan, and Laggantuin, where there are now but a farmer and a shepherd. In North Glen Sannox there was once a large population where is now but a solitary shepherd's house. Several deserted farmsteads in the high fields above Corrie, at North High Corrie, and elsewhere, tell of former cultivation where all is now pasture land.

We also find evidence that it was at one time the general custom in the island to take the cattle to mountain pastures in the summer-time, and remains of the summer shielings or *airidhs,* as they were called, are common in nearly all the high glens.

The old runrig system of cultivation, which was general 100 years ago, still exists at Balliekine.

Wood.—There is much natural wood in Arran, mostly of birch, alder, hazel, rowan, and willow, with some scrubby oak. Belts of these trees are found along the sea coast from Dougrie to Lochranza on the west coast, and on the east coast between Sannox and Brodick. There is a good deal of natural wood also in the lower parts of some of the glens, especially in Lag a Bheidh and in Glen Cloy, also in the Shiskine district near the Machrie Water, and in the lower part of Glen Rosie. In Glen Dubh (Glen Cloy) the wood grows up to about 800 feet above the sea, and to nearly the same height in Coire Fhraoich (Glen Rosie), and on the higher ground west of Corrie. Along several of the smaller streams trees flourish up to nearly 1000 feet, especially if the streams run in ravines, but the only locality where there is a small forest at this height is at Doire na Ceardaich, to the east of the summit of the Corrie and Lochranza road. One or two stunted specimens of the rowan tree were observed on the north side of Glen Sannox at a height of about 1500 feet near Suidhe Fhearghas.

There are many artificial fir plantations in Bute and a few in

Great Cumbrae. In Arran the largest are around Brodick Bay; and up the Merkland Burn and in Glen Shurig these trees flourish up to nearly 700 feet above the sea. There are plantations also at Whitefarland, Sannox, South Corrygills, etc. Suidhe plantation in Bute rises to above 500 feet. Glen Iorsa in Arran is almost treeless, and the granite district generally is comparatively bare of wood.

Water Supply.

The rainfall in this west country is heavy, some 40 inches per year and upward; and the water supply from springs and streams is almost everywhere abundant. The water from the northern granite area is beautifully fresh and clear, and several of the springs which supply the streams are very powerful. One of these, three quarters of a mile from the shore at Corrie, rises near the edge of the granite and furnishes the greater part of the water of the Locherim Burn. Another strong spring is found near the head of North Sannox at the foot of Garb Choire, south-east of Creag Dubh. It rises at the edge of a moraine, and strong springs rise in a like position in the Corrie west of Cir Mhòr. One of the most remarkable of the springs is that which rises on the ridge south of Caisteal Abhail at a height of nearly 2400 feet. The hillside west of Caisteal Abhail is called from it Leac an Tobair, or the Slope of the Well. One famous well at Mid Thundergay on the west side of Arran, Tobar Challumchille, takes its name from St. Columba. Several shallow wells have been sunk for water in the gravel and sand of the raised beach at Tormore. Another at the most southerly house by the roadside is about 14 feet deep. The greater part of it is in rubble and clay (glacial drift), but the lower part is sunk two and a half feet in yellowish sandstone like that seen at the King's Cove. W. G.

APPENDIX.

PART I.—PALÆONTOLOGICAL.

Note by B. N. Peach, F.R.S.

A.—List of Localities from which Fossils have been obtained.

B.—General List of Fossils from the Carboniferous Rocks of North Arran.

C.—Special List of Fossils found in each of the Sub-Divisions of the Carboniferous System.

D.—Notes on the Mesozoic Fossils found in the Island of Arran.

PART II.—PETROGRAPHICAL.

Notes on the Petrography of Old Red Sandstone Igneous Rocks, by H. Kynaston, B.A.

Notes on the Petrography of the Carboniferous Igneous Rocks of Arran, Bute, and the Cumbraes, by H. J. Seymour, B.A.

PART III—BIBLIOGRAPHICAL.

APPENDIX.

PART I.—PALÆONTOLOGICAL.

The following lists of fossils are based entirely on collections made by the Geological Survey, chiefly by Messrs. Macconochie and Tait.

The Carboniferous fossils have been named by Mr. B. N. Peach and Dr. C. B. Crampton, with assistance from the following specialists, viz.:—Dr. Traquair, who has determined the Fishes; Mr. Kidston, the Plants; and Dr. Wheelton Hind, the Lamellibranchs.

The Secondary Fossils found in the masses of strata preserved in the great volcanic vent have been determined by Mr. E. T. Newton, who has supplied special notes and lists.

The lists of Carboniferous fossils have been drawn up by Dr. Crampton and Mr. Tait, under my supervision.

BEN. N. PEACH.

A. LIST OF LOCALITIES FROM WHICH FOSSILS HAVE BEEN OBTAINED BY THE GEOLOGICAL SURVEY IN NORTH ARRAN (Sheet 21).

Cretaceous.

(*a*) Ballymichael Glen, 1½m. E.N.E. of Ballymichael. Blocks in Volcanic Agglomerate.

(*b*) Dove Cave on Ard Bheinn, 1½m. N.E. of Ballymichael. Masses in Volcanic Vent.

Liassic.

(*c*) Ballymichael Glen, on north slope above stream, about 100 yards above locality (*a*); 1½m. E.N.E. of Ballymichael. Masses in Volcanic Vent.

Rhætic.

(*d*) Stream gully, ¼m. N.E. of Derenenach. Mass in Volcanic Vent.

Triassic.

1. Cock Shore, derived Carboniferous blocks in Red Conglomerate, 100 yds. east of the Cock of Arran.

Carboniferous and Old Red Sandstone.

2. Allt Mor, between North Newton and Cock of Arran.
3. Hill slope, 500 yds. west of Cock Farm, Lochranza.
4. Cock Shore, north of Cock Farm, 20 yds. south-east of junction with Triassic Rocks, and 620 yds. south-east of Cock of Arran.

5. Cock Shore, north of Cock Farm, 72 yds. south-east of junction with Triassic Rocks.
6. Cock Shore, north of Cock Farm, 100 yds. south-east of junction with Triassic Rocks. (Highest marine band observed.)
7. Cock Shore, north of Cock Farm, 220 yds. south-east of junction with Triassic Rocks ("Coral Limestone").
8. Cock Shore, 350 yds. south-east of junction with Triassic Rocks.
9. Cock Shore, 365 yds. south-east of junction with Triassic Rocks. (Band overlying "Cephalopod Limestone.")
10. Cock Shore, 375 yds. south-east of junction with Triassic Rocks. ("Cephalopod Limestone.")
11. Cock Shore, 460 yds. south-east of junction with Triassic Rocks. (*Productus latissimus* limestone.)
12. Cock Shore, ironstone band, 450 yds. north-west of Saltpans. (In the small bay here, are tessellated ferruginous beds.)

12*a*. Cock Shore, as above, bands overlying.

13. Cock Shore, opposite Cock Farm, 225 yds. north-west of Salt Pans. (Dark-coloured limestone associated with hæmatite beds.)
14. Cock Shore, 140 yds. north-west of old Salt Pans.
15. Salt Pans, sandstone at.
16. Laggan Shore, 170 yds. west of Hurlet Limestone (? Hosie Limestone).
17. Laggan Shore. This band overlies the Hurlet Limestone and is separated from it by 30 ft. of coarse sandstone, black alum shale and 1½ ft. impure limestone.
18. Laggan Shore. Hurlet Limestone, 220 yds. north-west of Laggan Shepherd's cottage.
19. Laggan Shore, a few yards north of Laggan Cottage.
20. Laggan Shore, 100 yds. south-east of Laggan Cottage.
21. Laggan Shore, 750 yds. south-east of Laggan Cottage ("Wünsch's beds").
22. Laggantuin Bay, Corloch, 300 yds. north-west of "Fallen Rocks." (J. Thompson's fish band.)
23. South Glen Sannox Burn, at footbridge, about ½ mile from mouth. (Lower Old Red Sandstone.)
24. Sannox Shore, about ¼ mile south of Farchan Mor. (Upper Old Red Sandstone.)
25. Corrie Limepits, Corrie. (Band above Hurlet Limestone.)
26. Corrie Shore, between Post Office and Ferry, 1st limestone south of the sandstone at Ferry. (*Productus latissimus* limestone.)
27. Corrie Shore, a few yds. south of *P. latissimus* limestone. (Ferruginous band with many small gasteropods.)
28. Corrie Shore, between Post Office and Ferry, five or six yds. south of preceding locality.
29. Corrie Shore, opposite Post Office, dark shale below the massive sandstone opposite the Post Office garden.
30. Corrie Shore, opposite Cromla House, near low-water mark, 20 yds. west of massive grey sandstone which underlies the Triassic Sandstone.
31. Corrie Shore, near high-water mark, and 25 yds. south of northern boundary of Cromla garden.
32. Locherim Burn, lower part, 200 yds. from sea, and 15 yds. up stream from junction with Triassic Sandstone.
33. Locherim Burn, at waterfall, 330 yds. from sea. (Professor Ivison Macadam's locality.)

34. Maol Donn, old quarries at An Sgriob, $\frac{1}{4}$ mile north of Maol Donn cliff. (Shale below Hurlet Limestone.)
35. Maol Donn, higher on the slope and nearer the cliff than loc. 34. (In red sandy shale above the limestone.)
36. Merkland Burn, $\frac{3}{4}$ mile north of Brodick Castle. No. 1 loc., lowest limestone seen in stream.
37. Merkland Burn, $\frac{3}{4}$ mile north of Brodick Castle. No. 2 loc., a few yards down stream from No. 1.
38. Merkland Burn, $\frac{3}{4}$ mile north of Brodick Castle. No. 3 loc., a few yards down stream from No. 2.
39. Brodick Castle Policies, streamlet $\frac{1}{2}$ mile north of Brodick Castle.
40. Brodick Castle, streamlet 300 yds. S.W. of, a few yards above bridge.
41. Brodick Castle Sawmill, in mill lade.
42. Glen Rosie Burn, a few yards above the bridge near Brodick Manse ("Musselband Ironstone").
43. Glen Rosie, about 1 mile west of Glen Rosie Cottages, at streamlet descending hill slope on the south side of the Glen, not far from junction with schist. (Lower Old Red Sandstone.)
44. Brodick Church, limestone north-east of.
45. Glen Shurig, hill slope $\frac{1}{4}$ mile south-east of String road. Old quarries about $\frac{1}{2}$ mile west of wood.
46. Benlister Burn, in bed of main stream below waterfall, $2\frac{1}{4}$ miles west of Lamlash Bay and $\frac{1}{2}$ mile S.S.E. of Brisderg.
47. Benlister Glen, shale below Hurlet Limestone, $2\frac{3}{4}$ miles west of Lamlash Bay, and nearly $\frac{1}{2}$ mile S.S.W. of Brisderg.
48. Benlister Glen, streamlet entering from S. and 620 yds. south-east of preceding locality. Hurlet Limestone.
49. Glen Shurig, main stream, about $1\frac{1}{2}$ miles from mouth and 200 yards above junction with Allt Mor. (Lower Old Red Sandstone.)

[LIST B.

B. GENERAL LIST OF THE FOSSILS OBTAINED BY THE GEOLOGICAL SURVEY FROM THE CARBONIFEROUS ROCKS OF NORTH ARRAN (Sheet 21).

Species.	Lower.				Upper	Locality Numbers.
	Calciferous Sandstone Series.	Carbon. Limestone Series.			Coal Measures.	
		Lower Limestones.	"Edge Coals."	Upper Limestones.		
Filicales and Cycadofilices.						
Cardiopteris, *Schimper*						
,, nana, *Eichw.*		×				16
Mariopteris, *Zeiller*						
,, muricata, *Schloth.* ...					×	4, 32.
Neuropteris, *Brongniart*						
,, gigantea, *Sternb.* ...					×	4, 31, 35.
,, heterophylla, *Brongniart*					×	32.
Rhacopteris, *Schimper*						
,, sp.	×					21.
Sphenopteridium, *Schimper*						
,, dissectum, *Göpp.*				×		33.
Sphenopteris, *Brongniart*						
,, crassa, *L. and H.* ...	×					19 ?, 20.
,, (Rhodea) moravica, *Ett.*	×					21.
,, ,, patentissima, *Ett.* ...	×					21.
,, sp.	×			×		20, 21, 22, 33.
Stems of Ferns indt.	×				×	4, 22.
Equisetales.						
Calamariæ.						
Asterocalamites, *Schimper*						
,, scrobiculatus, *Schl.*				×		33.
Calamites, (*Suckow.*) *Schlotheim*						
Group I., Calamitina, *Weiss.*						
,, varians, *Sternb.*					×	4.
Group II., Eucalamites, *Weiss*						
,, ramosus, *Artis* = nodosus, *L. and H.*					×	4, 35.
Group III., Stylocalamites, *Weiss.*						
,, Suckowi, *Brongniart* ...					×	46.
,, sp. ? indt.					×	4, 5, 32, 35, 46.
Sphenophyllales.						
Sphenophyllum, *Brongniart*						
,, myriophyllum, *Crepin*					×	4.
,, sp.					×	4.
Lycopodiales.						
Lepidodendron, *Sternberg*						
,, veltheimianum, *Sternb.*		×	× ?	×		15 ?, 33, 34.
,, sp.	×	×		×	×	17, 18, 21, 30, 33.
Lepidophloios, *Sternberg*						
,, wünschianus, *Carr.* ...	×					21.
,, sp.	×					21.

Species.	Lower.				Upper	Locality Numbers.
	Calciferous Sandstone Series.	Carbon. Limestone Series. Lower Limestones.	"Edge Coals."	Upper Limestones.	Coal Measures.	
LYCOPODIALES—*continued.*						
Lepidostrobus, *Brongniart*						
,, sp.				×	×	5, 33.
Sigillaria, *Brongniart*						
,, Taylori, *Carr.*				×		33.
Stigmaria, *Brongniart*						
,, sp.	×	×		×	×	16, 19, 21, 33, 35.
GYMNOSPERMÆ.						
Artisia, *Presl.*						
,, approximata, *Brongniart* ...					×	35.
Carpolithes, *Brongniart*						
,, sulcata, *Lindl.*				×		33.
Cordaites, *Unger*						
,, principalis, *Germar* ...					×	4, 5.
,, sp.	×					22.
PORIFERA.						
Sponge spicules in chert nodules ...		×				48.
ACTINOZOA.						
Alveolites, *Lamarck*						
,, depressa? *Flem.*				×		3.
Lithostrotion, *Lhwyd.*						
,, Portlocki, *M. Edw.* ...				×		37.
Syringopora, *Goldfuss*						
,, ramulosa, *Goldf.* ...		×				34.
,, sp.		×				18.
Zaphrentis, *Rafinesque*						
,, sp.		×		×		11, 16?, 18.
Incertæ sedis.						
Monticulipora, *d'Orbigny*						
,, tumida, *Phill.* ...		×		×		11, 47, 48.
,, sp.		×				25.
ECHINODERMATA.						
Archæocidaris, *M'Coy*						
,, Urei, *Flem.*		×	×	×		11, 14, 16, 17, 18, 34, 47.
,, sp.		×				48.
Asteroid, part of?		×				25.
Crinoid ossicles		×		×		2, 3, 6, 11, 17, 25, 26, 34, 36, 47.
Echinoid plates and part of lantern...		×				16, 47.
ANNELIDA.						
Spirorbis, *Lamarck*						
,, sp.		×				34.
Worm tubes?		×				18.
ARTHROPODA. *Ostracoda.*						
Beyrichia, *M'Coy*						
sp		×				25.

Species.	Lower: Calciferous Sandstone Series.	Lower: Carbon. Limestone Series: Lower Limestones.	Lower: Carbon. Limestone Series: "Edge Coals."	Lower: Carbon. Limestone Series: Upper Limestones.	Upper: Coal Measures.	Locality Numbers.
ARTHROPODA—*continued.*						
Trilobita.						
Brachymetopus, *M'Coy*						
,, ouralicus, *de Vern.*				×		3.
Phillipsia, *Portlock.*						
,, Eichwaldi, *Fischer* var. mucronata, *M'Coy* ...		×		×		11, 25.
,, sp.		×				47 ?.
POLYZOA.						
Fenestella, *Lonsdale*						
,, plebeia, *M'Coy*		×				25, 47.
,, sp.		×		×		11, 25, 26, 34.
Glauconome, *Goldfuss*						
,, sp.		×				25.
Polypora, *M'Coy*						
,, sp.		×				18.
Retepora, *Lamarck*						
,, undata, *M'Coy*			×			14.
Rhabdomeson, *Young*						
,, rhombiferum, *Phill.*		×		×		28, 34.
,, sp.		×				17.
BRACHIOPODA.						
Athyris, *M'Coy*						
,, ambigua, *Sow.*		×		×		11, 16, 26, 36, 47.
,, lamellosa, *Léveillé*		×				18 ?.
,, Roysi, *Léveillé*				×		36 ?.
,, sp.		×		×		10, 18, 25, 47.
Camarophoria, *King*						
,, crumena, *Martin* ..				×		26.
,, sp.			×			13 ?.
Chonetes, *Fischer*						
,, buchiana, *de Kon.*... ...		×				16 ?.
,, laguessiana, *de Kon.* ...		×		×		11, 16, 18, 25, 26, 34, 47.
Discina, *Lamarck*						
,, nitida, *Phill.*...		×				16, 17.
Lingula, *Bruguière*						
,, mytiloides, *Sow.*		×	×	×		6, 14, 16, 17, 18, 36.
,, squamiformis, *Phill.* ...		×	×	×		14, 16, 17, 27, 29, 41.
Orthis, *Dalman*						
,, resupinata, *Martin*		×		×		2, 10, 11, 18, 33.
,, sp.		×				48.
Productus, *Sowerby*						
,, aculeatus, *Martin* ...		×				18.
,, costatus, *Sow.*				×		11, 36.
,, fimbriatus, *Sow.*		×		?		6 ?, 25, 34, 47.
,, giganteus, *Martin* ...		×	×	×		9 ?, 10, 12, 13, 17, 18, 25, 34, 44, 46, 47, 48.
,, latissimus, *Sow.*		×	?	×		3, 11, 14, 25, 26, 28, 37, 40, 47.
,, longispinus, *Sow.*		×		×		11, 16, 34, 36, 47.

Species.	Lower. Calciferous Sandstone Series.	Lower. Carbon. Limestone Series. Lower Limestones.	Lower. Carbon. Limestone Series. "Edge Coals."	Lower. Carbon. Limestone Series. Upper Limestones.	Upper. Coal Measures.	Locality Numbers.
BRACHIOPODA—*continued.*						
Productus mesolobus, *Phill.* ...				×		26.
,, muricatus (?), *Phill.* ...				×		6 ?, 9 ?.
,, proboscideus, *de Vern.* ...		×				34.
,, punctatus, *Mart.* ...		×				25, 47.
,, pustulosus, *Phill.* ...		×				34.
,, scabriculus, *Mart.* ...		×				25, 34.
,, semireticulatus, *Mart.* ...		×		×		11, 18, 25, 34, 36, 47.
,, youngianus, *Dav.* ...		×				18, 34.
,, sp.		×		×		2, 3, 6, 9, 10, 11, 16, 17, 18, 25, 33, 36, 40, 47.
Retzia, *King*						
,, radialis, *Phill.*		×				16.
,, sp.		×				25, 47.
Rhynchonella, *Fischer*						
,, acuminata, *Mart.* ...		×				34.
,, pleurodon, *Phill.* ...		×	×	×		12, 17, 25, 26, 34.
,, pugnus, *Mart.* ...		×				34.
,, sp.		×				17, 47.
Spirifera, *Sowerby*						
,, duplicicosta (?), *Phill.* ...		×				34.
,, glabra, *Mart.*		×		×		6, 16, 36 ?, 47.
,, grandicostata (?), *M'Coy* ...		×				34.
,, lineata, *Martin*		×		×		10, 18, 25.
,, trigonalis, *Mart.*		×		×		6, 16, 17, 18, 25, 34, 47.
,, ,, var. bisulcata, *Sow.*		×		×		10, 16, 17, 25 ?, 48.
,, triradialis, *Phill.*				×		11.
,, sp.		×				17, 25, 47.
Spiriferina, *d'Orbigny*						
,, cristata, *Schloth.* ...		×				17, 18, 25, 34, 47 ?.
,, ,, var. octoplicata, *Sow.*		×		×		11, 18, 25, 47.
,, laminosa (?), *M'Coy* ...		×				34.
,, sp....		×				17.
Streptorhynchus, *King*						
,, (Orthotetes), crenistria, *Phill.* ...		×	×	×		3, 6, 9, 10, 11, 13, 14, 16, 18, 25, 26, 33, 36, 47.
Terebratula, *Lhwyd.*						
,, (Dielasma), hastata, *Sow.*		×				34, 47.
,, sp.				×		9.
LAMELLIBRANCHIATA.						
Actinopteria, *Hall*						
,, (Pteronites), sulcata, *M'Coy*	×					16.
Allorisma, *King*						
,, sulcata, *Flem.*	×	×		×		3, 16, 18, 21, 26, 28, 29, 33, 34, 36.
,, sp.			×			12a.
Anthracomya, *Salter*						
,, modiolaris, *Sow.* ...					×	38 ?

Species.	Lower.				Upper.	Locality Numbers.
	Calciferous Sandstone Series.	Carbon. Limestone Series.				
		Lower Limestones.	"Edge Coals."	Upper Limestones.	Coal Measures.	
LAMELLIBRANCHIATA—*continued.*						
Aviculopecten, *M'Coy*						
,, cœlatus, *M'Coy* ...		×				48.
,, dissimilis, *Phill.* ...				×		40.
,, fallax, *M'Coy* ...		×				17 ?, 25, 34.
,, Hardingi, *M'Coy* ...		×				17 ?.
,, knockonniensis, *M'Coy*		×	×			12, 12a, 16 ?, 18, 25.
,, semicircularis, *M'Coy*		×				25.
,, textilis, *de Kon.* ...		×				17.
,, sp.		×				1, 12, 16, 25, 27, 29, 34, 40.
,, with colour bands ...		×				17, 18.
Carbonicola, *M'Coy*						
,, (Anthracosia), acuta, *Sow.*					×	30, 32, 38, 39, 42 ?, 46.
,, ,, var. rhomboidalis, *Hind.*					×	38.
,, ,, aquilina, *Sow.*					×	30, 32.
,, sp.				×		7, 8, 42.
Cardiomorpha, *de Koninck*						
,, parva, *Hind....* ...		×				34.
Ctenodonta, *Salter*						
,, pentonensis, *Hind.* ...		×				16.
Cypricardella, *Hall*						
,, rectangularis, *M'Coy*		×				34.
Edmondia, *de Koninck*						
,, Josepha, *de Kon....* ...		×		×	?	16, 17, 18, 26, 36, 40, 46 ?.
,, pentonensis, *Hind.* ...	×	×				17, 18, 21.
,, rudis, *M'Coy*		×	×	×		12a, 16, 17, 26, 28.
,, scalaris, *M'Coy*		×				16 ?, 34.
,, sulcata, *Phill.*		×				17, 18, 34.
,, unioniformis, *Phill.* ...		× ?		×		33, 34.
,, sp.		×	×	×		8, 12, 16, 25, 34.
Entolium, *Meek*						
,, (Pecten) Sowerbyi, *M'Coy*		×	×	×		12, 16, 17, 18, 34, 36.
,, ,, young of ...			×			12a.
Leiopteria, *Hall*						
,, (Avicula), lunulata, *Phill.*		×				25, 34.
,, ,, recta, *M'Coy...*		×				34.
,, ,, squamosa, *Phill.*		×				25, 34.
,, ,, sp.		×				25, 28.
Lithodomus, *Cuvier*						
,, lingualis, *Phill.* ...		×		×		16, 25, 36.
Myalina, *de Koninck*						
,, Flemingi, *M'Coy*		×				17, 25, 34.
,, peralata, *de Kon.*		×				25.
,, Verneuili, *M'Coy*		×	×	×	× ?	3, 12, 17, 32 ?, 33,
,, sp.		×	×	×		12, 25, 28 ?, 33, 34.
Naiadites, *Dawson*						
,, (Myalina) crassa, *Flem.* ...					×	46 ?.
,, modiolaris, *Sow.*					×	30.
,, quadrata, *Sow.*					×	38.

Species.	Lower. Calciferous Sandstone Series.	Lower. Carbon. Limestone Series. Lower Limestones.	Lower. Carbon. Limestone Series. "Edge Coals."	Lower. Carbon. Limestone Series. Upper Limestones.	Upper. Coal Measures.	Locality Numbers.
LAMELLIBRANCHIATA—*continued.*						
Naiadites (periostracum of)					×	38.
,, sp.					×	32, 46 ?.
Nucula, *Lamarck*						
,, gibbosa, *Flem.*		×	×	×		9, 12, 12a, 26, 33, 34.
,, luciniformis, *Phill.*				×		26, 28.
,, scotica, *Hind.*				×		28.
,, sp.				×		11, 36.
Nuculana, *Link.*						
,, acuta, *Sow.*				×		12.
,, attenuata, *Flem.*		×	×	×		8, 9, 12, 12a, 18, 26, 28, 29, 33, 40.
,, brevirostris, *Phill.* ...		×				16, 18.
Parallelodon, *Morris and Lycett*						
,, Geinitzi, *de Kon.* ...				×		40.
Pecten, *Linnæus*						
,, (Streblopteria) lævigata ? *M'Coy*			×			12a.
Pinna, *Linnæus*						
,, flabelliformis, *Martin* ...		×		×		16, 17, 28, 34.
,, mutica, *M'Coy*		×				34.
,, young form		×				18.
Protoschizodus, *de Koninck*						
,, axiniformis, *Portl.*...		×	×	×		12, 17, 28, 33, 34, 40 ?.
,, obliquus, *M'Coy* ...		×		×		25, 33, 34.
,, sp.		×		×		26, 34.
Sanguinolites, *M'Coy*						
,, clavatus, *Eth. Jr.* ...				×		8 ?.
,, striatus, *Hind.* ...				×		26.
,, tricostatus, *Portl.* ...		×	×			12, 16, 17, 34.
,, ,, (very short form)		×				17.
,, variabilis, *M'Coy* ...		×		×		16, 17, 26, 34.
Sedgwickia, *M'Coy*						
,, gigantea, *M'Coy* ...	×	×				17, 21.
Solenomya, *Lamarck*						
,, primæva, *Phill.*				×		29.
Solenopsis, *M'Coy*						
,, minor, *M'Coy*				×		8.
GASTEROPODA.						
Aclisina, *de Koninck*						
,, elongata, *Flem.*				×		27, 28.
,, (Murchisonia) striatula, *de Kon.*				×		27.
Acroculia, *Phillips*						
,, (Capulus) trilobus, *Phill.*...		×				17.
Bellerophon, *Montfort*						
,, decussatus, *Flem.* ...		×		×		25, 26, 28, 29, 34, 40.
,, striatus, *Flem.* ...		×				25.
,, hiulcus, *Martin* ...		?	×			12, 16 ?.
,, Urei, *Flem.*		×	×	×		6, 12, 12a, 13, 16, 25, 26, 34, 40.

Species.	Lower. Calciferous Sandstone Series.	Lower. Carbon. Limestone Series. Lower Limestones.	Lower. Carbon. Limestone Series. "Edge Coals."	Lower. Carbon. Limestone Series. Upper Limestones.	Upper. Coal Measures.	Locality Numbers.
GASTEROPODA—*continued.*						
Bellerophon sp.		×		×		33, 34, 45 ?.
Dentalium, *Linnæus.*						
,, (Entalis) ingens., *de Kon.*		×		×		26, 27, 34.
,, inornatum, *M'Coy*				×		3.
Euomphalus, *Sowerby*						
,, carbonarius, *Sow.* ...		×		×		16, 26, 34.
,, catillus, *Sow.*		×				16.
,, nodosus, *Sow.*		×				34.
,, pentangulatus, *Sow.* ...		×				25.
,, sp.		×		×		17, 34, 40.
Loxonema, *Phillips*						
,, constrictum, *Sow.* ...		×		×		26, 34.
,, Lefebvrei, *Lév.*				×		26.
,, rugiferum, *Phill.* ...				×		40.
,, scalaroideum, *Phill.* ...				×		40.
,, sp.		×				25.
Macrocheilus, *Phillips*						
,, (Macrochilina) acutus, *Sow.*		×		×		3, 16, 26, 27, 28.
,, (Macrochilina) canaliculatus, *M'Coy* ...				×		33.
,, (Macrochilina) imbricatus, *Sow.* ...				×		26, 27, 28.
,, sp.		×				25, 48 ?.
Metoptoma, *Phillips*						
,, elliptica, *Phill.*				×		27, 28.
Microdoma, *Meek and Worthen*						
,, (Trochus) biserrata, *Phill.*		×				34.
,, ,, serrilimba, *Phill.*				×		40.
Murchisonia, *d'Arch. and de Vern.*						
,, angulata, *Phill.* ...		×		×		26, 27, 28, 34.
,, cincta ?, *Donald* ...				×		28.
,, (Hypergonia) quadricarinata, *M'Coy*				×		27.
Narica, *Recluz*						
,, variatá, *Phill.*		×				34.
Naticopsis, *M'Coy*						
,, canaliculata, *M'Coy* ...		×				16.
,, plicistria, *Phill.*		×				17, 25.
,, sp.		×		×		25, 40.
Pleurotomaria, *Defrance*						
,, (Ptychomphalus) atomaria, *Phill.* ...				×		26.
,, monilifera, *Phill.* ...		×				25.
,, tumida, *Phill.* ...		×				25.
,, sp.		×		×		25, 40.
,, (Baylea) Yvani, *Lév.*		×				25.
Porcellia, *Léveillé*						
,, Puzosi, *Lév.*		×				25.

Species.	Lower: Calciferous Sandstone Series.	Lower: Carbon. Limestone Series: Lower Limestones.	Lower: Carbon. Limestone Series: "Edge Coals."	Lower: Carbon. Limestone Series: Upper Limestones.	Upper: Coal Measures.	Locality Numbers.
PTEROPODA ?						
Conularia, *Miller*						
,, quadrisulcata, *Sow.* ...		×				17.
CEPHALOPODA.						
Actinoceras, *Brown*						
,, sp.		×				25.
Cyrtoceras, *Goldfuss*						
,, sp.		×				25.
Nautilus, *Breynius*						
,, (Acanthonautilus) bispinosus, *A. H. Foord* ...				×		10
,, (Planetoceras) globatus, *Sow.*				×		26.
,, (Cœlonautilus) subsulcatus, *Phill.*		×				16, 25.
,, (Stroboceras) (Dixcites) sulcatus, *Sow.*		×				17.
,, (Pleuronautilus) nodiferus, *Armstrong*				×		10.
,, sp.		×				17, 25.
Orthoceras, *Breynius*						
,, annulare, *Flem.* ...		×	×			12, 34.
,, inæquiseptum, *Phill.* ...		×				34.
,, sp.		×	×	×		9, 12A, 16, 17, 25, 34, 36. 40.
Trigonoceras, *M'Coy*						
,, meyerianum, *de Kon.*		×				25.
PISCES.						
Selachii.						
Cladodus, *Agassiz*						
,, striatus, *Ag.*			×			12A.
Cochliodont tooth *s.n.*		×				25.
Pœcilodus, *Agassiz*						
,, Jonesi, *M'Coy*		×				25, 48.
Polyrhizodus, *M'Coy*						
,, magnus, *M'Coy* ...		×				25.
Xystrodus, *Agassiz*						
,, striatus, *M'Coy* ...		×				25.
Teleostomi-Crossopterygii.						
Megalichthys, *Agassiz*						
,, Hibberti, *Ag.* ...					×	38.
,, sp.		×				16, 25, 48.
Rhizodopsis, *Huxley*						
,, sauroides, *Will.* ...					×	38.
,, sp.					×	39.
Rhizodus, *Owen*						
,, Hibberti (*Ag. and Hib.*) ...	×					22.
ornatus, *Traq.*	×					22.

Species.	Lower.				Upper	Locality Numbers.
	Calciferous Sandstone Series.	Carbon. Limestone Series.			Coal Measures.	
		Lower Limestones.	"Edge Coals."	Upper Limestones.		
PISCES—*continued.*						
Strepsodus, *Huxley and Young*						
,, Portlocki (*ex Ag. MS.*)		×				18.
,, striatulus, *Traq.* ...	×			×		22, 27, 29.
Actinopterygii.						
Acrolepis, *Agassiz*						
,, sp.				×		29.
Elonichthys, *Giebel*						
,, Robisoni (*Hib.*) ...		×				25.
,, sp.		×				17.
Rhadinichthys, *Traquair*						
,, ornatissimus (*Ag.*) ...		×				25.
Palæoniscid scales	×	×		×		16, 22, 29.
,, clavicle		×				34.
Fish remains, indt.	×			×		22, 36.

C. SPECIAL LISTS OF THE FOSSILS FOUND IN EACH SUBDIVISION OF THE CARBONIFEROUS SYSTEM.

Calciferous Sandstone Series.

Cordaites sp.
Fern rachis.
Lepidodendron sp.
Lepidophloios wünschianus.
,, sp.
Rachopteris sp.
Sphenopteris crassa.
,, (Rhodea) moravica.
,, (,,) patentissima.
,, sp.
Stigmaria sp.
Allorisma sulcata.
Edmondia pentonensis.
Sedgwickia gigantea.
Palæoniscid scales.
Rhizodus Hibberti.
,, ornatus.
Strepsodus striatulus.
Fish bones, teeth, scales, indt.

Hurlet Limestone.

Lepidodendron veltheimianum.
,, sp.
Chert nodules with sponge spicules.
Monticulipora tumida.
,, sp.
Syringopora ramulosa.
,, sp.
Zaphrentis sp.
Crinoid stems.
Asteroid, part of.
Archæocidaris Urei.
Echinus plates.
Spirorbis sp.
Worm tubes.
Beyrichia sp.
Phillipsia Eichwaldi.
,, ,, var. mucronata.
,, sp.
Fenestella plebeia.
,, sp.
Glauconome sp.
Polypora sp.
Rhabdomeson rhombiferum.
,, sp.
Athyris ambigua.
,, lamellosa.

Hurlet Limestone—*continued.*

Athyris sp.
Chonetes laguessiana.
Lingula mytiloides.
Orthis resupinata.
,, sp.
Productus aculeatus.
,, fimbriatus.
,, giganteus (abundant).
,, latissimus.
,, longispinus.
,, proboscideus.
,, punctatus.
,, pustulosus.
,, scabriculus.
,, semireticulatus.
,, youngianus.
,, sp.
Retzia sp.
Rhynchonella acuminata.
,, pleurodon.
,, pugnus.
,, sp.
Spirifera duplicicosta.
,, glabra.
,, grandicostata.
,, laminosa.
,, lineata.
,, trigonalis.
,, ,, var. bisulcata.
,, sp.
Spiriferina cristata.
,, ,, var. octoplicata.
,, sp.
Streptorhynchus crenistria.
Terebratula hastata.
Allorisma sulcata.
Aviculopecten cœlatus.
,, fallax.
,, knockonniensis.
,, semicircularis.
,, sp.
,, (very tumid species).
,, (with colour bands).
Cardiomorpha parva.
Cypricardella rectangularis.
Edmondia Josepha.
,, pentonensis.
, scalaris.
., sulcata.
,, unioniformis ?
,, sp.
Entolium (Pecten) Sowerbyi.
Leiopteria (Avicula) lunulata.
,, ,, recta.
,, ,, squamosa.
,, ,, sp.
Lithodomus lingualis.
Myalina Flemingi.
,, peralata.
,, sp.
Nucula gibbosa.
Nuculana attenuata.
,, brevirostris.
Pinna flabelliformis.
,, mutica.
,, sp.
Protoschizodus axiniformis.
,, obliquus.
,, sp.
Pteronites latus.
Sanguinolites tricostatus.
,, variablis.
Bellerophon decussatus.
,, ,, var. striatus.
,, Urei.
,, sp.
Dentalium ingens.
Euomphalus carbonarius.
,, nodosus.
,, pentangulatu
,, sp.
Loxonema constrictum.
,, sp.
Macrocheilus sp.
Microdoma biserrata.
Murchisonia angulata.
Narica variata.
Naticopsis plicistria.
,, sp.
Pleurotomaria monilifera.
,, tumida.
,. Yvani.
,, sp.
Porcellia Puzosi.
Actinoceras sp.
Cyrtoceras sp.
Nautilus (Discites) subsulcatus.
,, sp.
Orthoceras annulare.
,, inæquiseptum.
,, sp.
Trigonoceras meyeranium.
Elonichthys Robisoni.
,, sp.
Megalichthys tooth.
Pœcilodus Jonesi.
Polyrhizodus magnus.
Rhadinichthys ornatissimus.
Strepsodus Portlocki.
Xystrodus striatus.
Cochliodont tooth ?

Hosies Limestone.

Cardiopteris nana.
Sphenopteris ?
Stigmaria sp.
Archæocidaris Urei.
Echinoid lantern tooth.
Athyris ambigua.
Chonetes buchiana ?
Chonetes laguessiana.
Discina nitida.
Lingula mytiloides.
,, squamiformis.
Productus longispinus.
,, sp.
Retzia radialis.

Hosies Limestone—*continued.*

Spirifera glabra.
,, trigonalis.
,, ,, var. bisulcata.
Streptorhynchus crenistria.
Allorisma sulcata.
Aviculopecten knockonniensis.
Ctenodonta pentonensis.
Edmondia Josepha.
,, rudis.
,, scalaris?
,, sp.
Entolium (Pecten) Sowerbyi.
Leiopteria (Pteronites) sulcata.
Lithodomus lingualis.
Nuculana brevirostris.
Pecten sp.
Pinna flabelliformis.
Sanguinolites tricostatus.
,, variablis.
Bellerophon hiulcus?
,, Urei.
Euomphalus carbonarius.
,, catillus.
Macrocheilus acutus.
Naticopsis canaliculata.
Nautilus (Discites) subsulcatus.
Orthoceras smooth sp.
,, sp.
Megalichthys sp.
Palæoniscid scales.

Edge Coal Series.

Lepidodendron veltheimianum.
Archæocidaris Urei.
Retepora undata.
Camarophoria crumena.
Lingula mytiloides.
,, squamiformis.
Productus giganteus.
,, latissimus?
Rhynchonella pleurodon.
Streptorhynchus crenistria.
Allorisma sulcata.
Aviculopecten knockonniensis.
Edmondia rudis.
,, sp.
Entolium (Pecten) Sowerbyi.
Myalina Verneuili.
,, sp.
Nucula gibbosa.
Nuculana attenuata.
Pecten (Streblopteria) lævigata.
,, sp.
Protoschizodus axiniformis.
Sanguinolites tricostatus.
Bellerophon hiulcus.
,, Urei.
Orthoceras annulare.
,, sp.
Cladodus striatus.

Index Limestone.

Monticulipora tumida.
Zaphrentis sp.
Crinoid ossicles.
Archæocidaris Urei.
Phillipsia Eichwaldi, var. mucronata.
Fenestella sp.
Athyris ambigua.
,, Roysi?
Camarophoria crumena.
Chonetes laguessiana.
Lingula mytiloides.
Orthis resupinata.
Productus costatus.
,, latissimus (abundant).
,, longispinus.
,, mesolobus.
,, semireticulatus.
,, sp.
Rhynchonella pleurodon.
Spirifera glabra.
,, triradialis.
Spiriferina cristata, var. octoplicata.
Streptorhynchus crenistria.
Allorisma sulcata.
Edmondia Josepha.
,, rudis.
Entolium (Pecten) Sowerbyi.
Lithodomus lingualis.
Nucula gibbosa.
,, luciniformis.
,, sp.
Nuculana attenuata.
Protoschizodus sp.
Sanguinolites striatus.
,, variablis.
Bellerophon decussatus.
,, Urei.
Dentalium ingens.
Euomphalus carbonarius.
Loxonema constrictum.
,, Lefebvrei.
Macrocheilus acutus.
,, imbricatus
Murchisonia angulata.
Pleurotomaria atomaria.
Nautilus globatus.
Orthoceras sp.
Fish remains.

Limestones and Shales above Index Limestone.

Lithostrotion Portlocki.
Crinoid ossicles.
Athyris sp.
Lingula mytiloides.
Lingula squamiformis.
Orthis resupinata.
Productus fimbriatus?
,, giganteus.

LIMESTONES AND SHALES ABOVE INDEX LIMESTONE—*continued.*

Productus latissimus.
,, muricatus ?
,, sp.
Spirifera glabra.
,, lineata.
,, trigonalis.
,, ,, var. bisulcata.
Streptorhynchus crenistria.
Terebratula sp.
Allorisma sulcata.
Carbonicola sp.
Edmondia rudis.
,, sp.
Myalina sp.
Nucula gibbosa.
,, luciniformis.
,, scotica.
Nuculana acuta.
,, attenuata.
Pecten sp.
Pinna flabelliformis.
Protoschizodus axiniformis.
Sanguinolites clavus.
Solenomya primæva.
Solenopsis minor.
Aclisina elongata.
,, striatula.
Bellerophon decussatus.
,, Urei.
Dentalium ingens.
Macrocheilus acutus.
,, imbricatus.
Metoptoma elliptica.
Murchisonia angulata.
,, cincta.
,, quadricarinata.
Nautilus nodiferus.
,, (Acanthonautilus) bispinosus.
Orthoceras sp.
Acrolepis sp.
Strepsodus striatulus.
Palæoniscid scales.

Coal Measures.

Artisia approximata.
Calamites ramosus.
,, Suckowi.
,, varians.
,, sp.
Cordiates principalis.
Lepidodendron sp.
Lepidostrobus sp.
Mariopteris muricata.
Neuropteris gigantea.
,, heterophylla.
,, sp.
Sphenophyllum myriophyllum.
,, sp.
Stigmaria sp.
Anthracomya modiolaris ?
Carbonicola acuta.
,, ,, var. rhomboidalis.
,, aquilina.
,, sp.
Edmondia Josepha ?
Myalina sp. (? Verneuili).
Naiadites crassa ?
,, modiolaris.
,, quadrata.
,, (periostracum of).
,, sp.
Megalichthys Hibberti.
Rhizodopsis sauroides.

D. NOTES ON THE MESOZOIC FOSSILS FOUND IN THE ISLAND OF ARRAN, BY E. T. NEWTON, F.R.S.

The history of the discovery, under peculiar circumstances, of Mesozoic Fossils in Arran has already been fully described in the earlier part of this Memoir.

It was in the beginning of the year 1900 that Rhætic fossils were first discovered near Shiskine by Messrs. Macconochie and Gunn, and submitted to me for examination. Some remarks upon them will be found in the Director-General's "Summary of Progress" for 1899 (published 1900), and a further account of them and of more recent discoveries of Mesozoic fossils in Arran appeared in the Quarterly Journal of the Geological Society.[1]

i. Rhætic.

The following is a list of the Rhætic fossils found at locality d, near Shiskine. The species marked with an asterisk (*) have also been found

[1] Quart. Journ. Geol. Soc., vol. lvii. (1901), p. 229.

in the *Avicula contorta* beds of the North-east of Ireland,[1] and it is evident that this series of fossils must represent the *Avicula contorta* zone.

*Avicula contorta, *Portlock*
*Pecten valoniensis, *Defrance*
*Schizodus cloacinus, *Quenstedt* (— Isodonta Ewaldi, *Bornemann*).
*Protocardium philippianum? *Dunker* (= G. rhæticum, Merian).
*Modiola minima? *Sowerby* (= C. minuta, *Goldf.*).
Estheria minuta? *Goldf.*
Gyrolepis Alberti? *Agassiz*

ii. Lower Lias.

Another and larger series of fossils was obtained somewhat later from Ballymichael Glen, and forwarded to me. These were in a much decomposed rock, and the fossils were only represented by internal and external casts; but by means of wax impressions a considerable series of determinable species was reproduced, the Liassic age of which is clearly demonstrable. A careful examination led to the conclusion that the fossils correspond most nearly with those of the *Ammonites angulatus* beds of the North-east of Ireland (*see* Tate, referred to above), as will be clearly seen from a study of the following list of species.

List of Liassic Fossils from Ballymichael Glen (Locality c). Those marked with an asterisk have been found also in the North-east of Ireland.

CEPHALOPODA.

*Ammonites (Aegoceras) angulatus, *Schlotheim*

GASTEROPODA.

Amberleya acuminata, *Chapius and Dewalque*
*Cerithium semele? *Martin*
,, sp. (*cf.* C. Falsani, *Dumortier*).
*Pleurotomaria tectaria, *Tate*

LAMELLIBRANCHIATA.

Arca sp.
Astarte sp.
Avicula lanceolata, *Sowerby*
*Cardinia Listeri, *Sowerby*
*Cardita Heberti, *Terquem*
*Goniomya sp. (*cf.* G. rhombifera, *Goldf.* and sinemuriensis, *Oppel*).
*Gryphæa arcuata, *Lamarck*
Inoceramus (Crenatula) sp.
*Lima pectinoides? *Sowerby*
* ,, succincta, *Schlotheim* (— L. antiquata, *Sow.*).
Modiola sp.
*Myoconcha psilonoti? *Quenstedt*
Nucula sp. (two forms).
*Nuculana (Leda) Tatei, *Newton* (L. Renevieri, *Tate*).
,, ,, (*cf.* L. Quenstedti, *Tate*).
*Ostrea irregularis? *Quenstedt*
Pecten (Chlamys) subulatus? *Goldfuss*
Pholadomya?
Protocardium truncatum? *Sowerby*
Tancredia? Peachi, *Newton*
*Unicardium cardioides, *Phillips*

ANNELIDA.

Ditrupa globiceps, *Quenstedt*
,, sp.
*Serpula sp.

CRINOIDEA.

Pentacrinus basaltiformis, *Miller*

PLANTÆ.

Wood.

[1] *See* Tate, "Irish Liassic Fossils," Report Belfast Nat. Field Club, Appendix I., 1870.

iii. Cretaceous.

The following list of Cretaceous fossils is based upon the examination of blocks of grey limestone and chert found in the volcanic agglomerate in Ballymichael Glen, not far from the fossiliferous Liassic masses (Localities a and b). A series of specimens having been forwarded to me, sections for the microscope were prepared, and these showed such a close agreement with examples of Chalk from the North of Ireland that there could be little doubt as to the Arran specimens being of a like age. This was confirmed by the detection of the organisms detailed in the following list. It is satisfactory to be able to say that Dr. G. J. Hinde, who is so well acquainted with the fossils of the Chalk, fully agrees with the reference of these specimens to that formation.

Inoceramus (piece of shell showing prisms).
Polyzoa (several specimens, perhaps *Entalophora* and *Escharina*).
Echinoderms (fragments of).
Porosphæra globularis, d'Orbigny.
Hexactinellid sponge fragments (? *Plocoscyphia*).
Tetractinellid and other spicules.
Globigerina cretacea, d'Orbigny (and other species).
Textularia, etc.

iv. Conclusion.

The following remarks on these collections of fossils from Arran is taken from the Quarterly Journal of the Geological Society, vol. 57, p. 239 :—

"The island of Arran is far from any locality where strata of Jurassic or Cretaceous age are now found in place, the nearest locality being in the North-east of Ireland, which is about 40 miles away, where there are strata corresponding in a remarkable degree with the masses met with in Arran.

"The Secondary rocks of the North-east of Ireland, which had already been made known by Portlock,[1] were described more fully by Prof. Tate in 1863,[2] and in still greater detail in 1867.[3] In these papers it is shown that Rhætic beds, including the *Avicula contorta*-shales and the White Lias, rest upon older Triassic rocks and are overlain by Lower Lias, in which four distinct zones have been distinguished, namely, those of *Ammonites planorbis, Amm. angulatus, Amm. Bucklandi,* and *Belemnites acutus.* The uppermost of these zones is succeeded by Upper Cretaceous beds, Greensand, and hard Chalk,[4] and this again by basalt. Prof. Tate[5] has recorded undoubted Middle Liassic fossils from Ballintoy, but apparently from Drift, as hitherto they have not been found in place.

"In 1870 Prof. Tate[6] published a revised list of the Liassic fossils of Ireland, and from this it will be seen that nearly all the Rhætic and Liassic species found in Arran have been met with likewise in the neighbourhood of Belfast. The Rhætic fossils of Arran indicate the former existence of strata corresponding with the *Avicula contorta*-shales, but at present there is nothing to represent the White Lias in particular.

"That the Liassic fossils of Arran are from the earlier beds of that

[1] "Report on Geol. of Londonderry, &c.," 1843.
[2] Quart. Journ. Geol. Soc. vol. xx. (1864), p. 103.
[3] *Ibid.* vol. xxiii. (1867), p. 297.
[4] *Ibid.* vol. xxi. (1865), p. 15.
[5] *Ibid.* vol. xxvi. (1870), p. 324.
[6] "Irish Liassic Fossils," Rep. Belfast Nat. Field Club, App. i. (1870).

formation is evident, and broadly speaking, they are equivalent to the Lower Lias of the Belfast area; but I think that we may take another step with almost equal certainty. There seems no valid reason for supposing that the Liassic specimens hitherto found in Arran belong to more than one bed; for although some of the specimens are very friable and others tolerably hard, this is due to different degrees of decomposition. Now, among the fossils collected are several examples of *Ammonites angulatus*, while the characteristic ammonites of the *Amm. planorbis*- and *Amm. Bucklandi*-zones have not been met with; neither is there any fragment of a belemnite to indicate the 'Belemnite-shales.' It seems evident, therefore, that our Arran specimens belong to the *Ammonites angulatus*-zone. Many of the species range into higher or lower zones, but all of them have been met with in *Amm. angulatus*-beds elsewhere. Quite possibly representatives of the other Liassic zones of the Belfast area may yet be found in Arran; but, as it is the *Ammonites angulatus*-zone which attains the greatest thickness around Belfast, so it may have been in Arran. The similarity of the Chalk of Arran to that of Antrim has already been remarked upon.

"But for the preservation of the remnants above described the presence of Mesozoic strata in Arran, other than the New Red rocks, would have been unknown, and their preservation is due to the accident of portions of the rocks having fallen into the neck of a volcano. Being thus removed to some distance below the surface of the country, they escaped the denuding influences that have so effectually removed the other parts of the parent rocks which there is every reason to believe formerly spread over the island of Arran, and were doubtless continuous to the south-west with the corresponding strata of the North-east of Ireland: forming also a link between that district and the Liassic and Cretaceous areas of the Western Islands of Scotland and the small Liassic district near Carlisle. The still further extension of Cretaceous deposits in Scotland is indicated by the well-known remains of Greensand age near Moorseat (Aberdeenshire).

"The Liassic and Cretaceous rocks of the Western Isles of Scotland are perhaps 100 miles north-west of Arran, and have been noticed in part by the earlier writers mentioned in the more recent works of Sir Archibald Geikie,[1] Thomas Wright,[2] and Prof. Judd[3]; but the fossils of the Lower Lias which have been recorded from that area do not correspond so nearly with the Arran specimens as do those from the neighbourhood of Belfast. The zone of *Avicula contorta* does not seem to be distinctly developed in the Western Isles, according to Prof. Judd, although he had seen some indications of its presence, and only last year, under Mr. Horace B. Woodward's directions, some obscure fossils were obtained from Skye which it is thought may represent these beds. The numerous other horizons of Jurassic strata described in the Western Isles, having no representatives among the Arran fossils, need be no further alluded to. Above them, however, are Cretaceous rocks which Prof. Judd refers to the Lower, Middle, and Upper Chalk; the last-named horizon being that of *Belemnitella mucronata*, and apparently corresponding with the White Limestone of Antrim. If this correlation be correct, it seems highly probable that the Arran limestone will prove to be on the same horizon."

[1] Quart. Journ. Geol. Soc., vol. xiv. (1858), p. 1. [2] *Ibid.* p. 24.
[3] *Ibid.* vol. xxxiv. (1878), p. 696.

PART II.—PETROGRAPHICAL.

ARRAN.

NOTES ON THE PETROGRAPHY OF OLD RED SANDSTONE IGNEOUS ROCKS, BY H. KYNASTON, B.A.

UPPER OLD RED SANDSTONE.

6370. (93) Near Fallen Rocks, Arran. A dark purplish, fine-grained rock, apparently considerably decomposed. The microscope shows numerous small pseudomorphs after idiomorphic olivine, consisting of a pale yellowish, and sometimes almost colourless, serpentine (?), which appears almost isotropic, and is surrounded by a deep opaque border of iron-oxide (reddish-brown by reflected light), which also fills cracks in the pseudomorphs. A few felspar phenocrysts appear to have been present, but are too highly altered for satisfactory recognition. The groundmass is much obscured by decomposition products, though numerous small lath-shaped plagioclases may be recognised. Iron-ores lie scattered throughout the slide, and fill narrow branching cracks. The rock is probably an *altered olivine-basalt.*

9394. (267) Near Fallen Rocks, on hillside. A dark purplish rock with somewhat greenish patches. Too decomposed for satisfactory description. In its main features the rock is similar to the last. Olivine pseudomorphs are common, and the groundmass is of similar type. Black opaque iron-ores, leucoxene, and pyrites (?) may be seen, and calcite in patches. Altered basalt (?).

9395. (268) Hill side above Laggantuin. The microscope shows numerous pseudomorphs after olivine, some consisting in part of a reddish-brown to pale yellow, slightly dichroic, mineral resembling iddingsite; some calcite pseudomorphs after a more or less idiomorphic pyroxene (probably augite); and a groundmass of unorientated felspar microlites, carbonates, and interstitial matter. Altered olivine-basalt.

LOWER OLD RED SANDSTONE.

Volcanic Series.

In this series the rocks occurring in the field as lava flows are of a decidedly basic facies, and appear to be more closely allied to the basalts than to the typical andesites. It is probable, however, that typical andesites also occur. On the other hand, an examination of some of the fragments from the conglomerate, which is found overlying these lavas, shows that they belong to the more acid class of andesites, and may be referred in part to hornblende-andesite. It thus appears that a more acid series of andesites were undergoing denudation at the time of the formation of the conglomerate, while the earlier outpourings partook of a more basic character. A similar range in the composition of the lava-flows is exemplified in many other Lower Old Red volcanic areas and the sequence from basic to more acid is common and characteristic.

In the more basic series pseudomorphs after olivine are often very common, but in no case has the unaltered mineral been observed. Augite is frequent in both types. In the more basic rocks phenocrysts of felspar appear to be almost entirely absent, while in the more acid series they are exceedingly numerous. The groundmass of the basic rocks consists mainly of felspar microlites, amongst which pyroxene granules may sometimes be distinguished, and occasionally a small quantity of interstitial matter. In the more acid series the matrix usually shows felspar microlites together with a varying proportion of felsitic matter.

9388. (261) Auchencar burn, 70 yards east of the moor fence. The microscope shows numerous pseudomorphs after olivine in a groundmass of small lath-shaped felspars, sometimes showing a tendency to flow-orientation, grains of altered pyroxene (?), and iron-ores. Small scattered flakes of biotite are also seen in the groundmass. Altered basic lava—*olivine-basalt (?).*

9389. (262) 300 yards north of Creagan Geala, Garbh Thor, Monyquil. Pseudomorphs, mainly of iron-oxide, after olivine, and grains and crystals of augite occur in a groundmass mainly composed of felspar microlites and iron-ores, with some small ill-defined patches of secondary quartz. Altered basic lava, probably *basalt.*

9390. (263) Same loc. Purplish lava with well-defined amygdules. The microscope shows pseudomorphs of iron-oxide after idiomorphic olivine, grains of augite, mostly more or less altered, and amygdules of calcite in a groundmass of small lath-shaped felspars, pyroxene granules, iron-ores, and some interstitial matter. Altered basic lava. Basalt (?).

9391. (264) Scar, east of Creag Mhor, Auchencar. Pebble in Lower Old Red conglomerate. A reddish purple lava with irregular amygdules of calcite, and showing small porphyritic felspars. This is evidently a more acid type of rock than any of the preceding. The microscope shows numerous idiomorphic crystals and crystal-groups of brownish hornblende, for the most part now almost entirely replaced by pseudomorphs of iron-oxide. Sometimes the inner portion of the crystal retains some of the original brown colour, but there is invariably a deep opaque border of iron-oxide. Pleochroism is scarcely noticeable. The characteristic cleavages of the original hornblende may be seen in one or two cases. The felspar phenocrysts are fairly numerous. They are evidently mainly plagioclase, probably an acid variety, though some individuals only show the Carlsbad twinning. Apatite is accessory, and of a brownish tint. The matrix consists mainly of small felspar microlites (trachytic type), though a good deal obscured by small flecks of iron-ore. *Hornblende-Andesite.*

9392 (265) Sannox Burn, one mile west of mouth. Boulder in Lower Old Red conglomerate. A dark bluish-grey lava, with patches of epidote. Shows phenocrysts of turbid plagioclase, and pseudomorphs after a ferromagnesian constituent, some of which suggest hornblende, and some biotite, in a groundmass mainly formed of epidote, chloritic (?) matter, and iron-ores. The rock is rather decomposed and characterised by an extensive liberation of iron-oxide, and development of epidote. Altered *Andesite.*

9393 (266) A and B. Sannox Burn, one mile west of mouth. Boulder in Lower Old Red conglomerate. A dark purplish lava, showing what appears like an inclusion of a paler colour. The microscope shows numerous idiomorphic plagioclases of two generations, grains and aggregates of epidote and chloritic (?) matter, sometimes in the form of pseudomorphs after a ferromagnesian mineral, in a groundmass of felspar microlites, iron-ores, and felsitic matter. A portion of 9393A has the appearance of an inclusion of a more acid rock, but the microscope shows that there is no difference between the two portions except in the relative poverty in disseminated iron-ores of the lighter portion, the high proportion of which in the darker part gives it a black appearance in the hand-specimen. Moreover, felspar phenocrysts may often be observed lying partly in one portion and partly in the other. Scattered throughout both portions of the slide are some small colourless flakes resembling white mica, doubtless secondary, seen perhaps more frequently in the paler portion. Apatite is accessory. 9393B shows a portion of the matrix of the conglomerate, consisting chiefly of fragments of altered andesite, quartzite, quartzose-schist, quartz grains, felspars, chlorite, and a considerable quantity of epidote. Altered andesite.

Intrusive Rocks.

9401. (274) East end of big dyke—west of Farchan Mor.
9402. (275) 200 yards west of Allt-a-Chapuill.
9403. (276) West end of dyke near Cioch-nah-Oighe.

A fairly coarse-grained holocrystalline rock of doleritic appearance.

The microscope shows more or less lath-shaped turbid plagioclases, grains of pale augite (malacolite or salite), of earlier consolidation than the felspar, patches of pale greenish—(sometimes yellowish in the more weathered parts of the rock)—secondary fibrous amphibole, with some chlorite, and occasionally [9401] a little brown hornblende may be seen associated with the augite. There is also some interstitial alkali-felspar and quartz. Magnetite, ilmenite, and apatite needles are accessory.

The rock appears to be intermediate between the typical dolerites and the augite-diorites. It may be termed a *malacolite (salite)—dolerite.*

7444. (162) Torr Breac, Glen Rosie.
7519. (186) Torr Breac, Glen Rosie.
7520. (187) Rosie Burn, Glen Rosie, 400 yards north of wood.

These three specimens closely resemble one another. They are dark greenish-grey fine-grained rocks, and are practically merely finer-grained varieties of the intrusive rock already noticed. They consist essentially of more or less lath-shaped felspars, grains and aggregates of pale augite, patches of chlorite, and some secondary quartz. Apatite and iron-ores are accessory. Grains of epidote are sometimes seen, and the rock is occasionally traversed by narrow veins of epidote and calcite. Malacolite-dolerite (or diabase).

Doubtful Tuffs.

7542. (224) Merkland Burn, west branch, 500 feet above junction. A dark greenish rock, in which numerous small irregular fragments are easily seen with the naked eye. The microscope shows numerous small fragments of andesite and felsite (?) up to about $\frac{1}{8}$-in. in diameter, broken plagioclases, and quartz grains, grains of epidote, chlorite, etc., in a fine matrix consisting apparently of smaller fragments of a similar nature, though much obscured by greenish alteration products and iron-ores. The quartz and epidote often tend to form in patches and irregular veins

7542. (225) Merkland Burn. Similar to the preceding, but consisting of larger fragments, which are mainly andesitic, and showing very little matrix. These rocks do not resemble the matrix of the conglomerate as seen in 9393B; but suggest rather rocks of pyroclastic origin, such as tuffs or agglomerates.

LIST OF SLIDES FROM OLD RED SANDSTONE OF ARRAN (SHEET 21).

UPPER OLD RED SANDSTONE.

Volcanic Series.

	Locality.	Name and Remarks.
6370 - -	Near fallen rocks - - - - - - - -	Altered olivine-basalt.
9394 - -	Near fallen rocks, on hill-side - - - - - -	Do. do.
9395 - -	On hill-side above Laggantuin - - - - - -	Do. do.
	LOWER OLD RED SANDSTONE.	
	Volcanic Series.	
9388 - -	Auchencar Burn, 70 yds. E. of Moor dyke - - - -	Altered basic lava—olivine-basalt (?).
9389 - -	300 yds. N. of Creagan Geala, Garbh Thor, Monyquil - -	Altered basic lava—? basalt.
9390 - -	Same locality - - - - - - - - -	Do. do. do.
9391 - -	Scar E. of Creag Mhor, Auchencar - } Boulders in	Hornblende-andesite.
9392 - -	Sannox Burn, 1 mile W. of mouth - } Lower Old Red	Altered andesite, near hornblende-andesite.
9393 A & B	Same locality - - - - - } Conglomerate	Altered andesite.
	Doubtful Tuffs.	
7541 - -	Merkland Burn, W. branch, 500 feet above junction - -	? Tuff.
7542 - -	Merkland Burn - - - - - - - - -	? Tuff or agglomerate.
	Intrusive.	
9401 - -	East end of big dyke W. of Farchan Mor - - - - }	Malacolite-dolerite (diabase).
9402 - -	200 yds. W. of Allt-a-chapuill - - - - - - }	
9403 - -	West end of dyke near Cioch-nah-oighe - - - - }	
7444 - -	Torr Breac, Glen Rosie - - - - - - - }	Malacolite-dolerite (diabase), fine-grained variety.
7519 - -	Torr Breac, Glen Rosie - - - - - - - }	
7520 - -	Rosie Burn, Glen Rosie, 400 yds. N. of wood - - - - }	

Notes on the Petrography of the Carboniferous Igneous Rocks of Arran, Bute, and the Cumbraes, by H. J. Seymour, B.A.

(1) Late Carboniferous Sills (2609, 4633, and 4634) and Dyke 4592.

These rocks are medium to coarse grained *olivine dolerites*, showing a well-developed *ophitic structure* between the augite and plagioclase. They contain a good deal of hypidiomorphic olivine crystals usually under 0·5 mm. in longer diameter, which are more or less altered along their edges and cracks into serpentinous material, their central parts remaining clear. Augite occurs as brownish pink faintly pleochroic granules and allotriomorphic crystals moulded on the olivine and sometimes completely enclosing it (4633). Some of those crystals intergrown with the plogioclases are up to 2 or 3 mm. in length. The plagioclases (1·5 mm. average length) show repeated twinning and give symmetrical extinction angles up to 27°, indicating labradorite. Magnetic iron ore is present in small quantity Secondary products are chlorite, actinolite, and serpentinous material. These rocks are like tertiary dolerites. Sills.

4592. Is a much altered rock. The plagioclase is still fairly fresh and contains abundant apatite needles. The orginal ferro-magnesian constituents are almost completely altered to secondary chloritic material. Vesicular structure is noticeable, and the rock probably originally possessed a more or less glassy base.—Basalt. Dyke.

(2) Carboniferous Volcanic Series, "Upper."

Nos. 6371, 6994, 7051, and 7738 to 7743 inclusive.

These include two types of rocks—viz., basalts Nos. 7051, 7739, 7740, and 7741, and volcanic tuffs and grits Nos. 6371, 6994, 7738, 7742, and 7743. All these rocks occur in or near the burns at Sliddery Water Head, Arran (Sheet 13). The basic rocks have already been described in the Summary of Progress for 1897, pp. 119 and 120, as basaltic andesites. They are all much altered and stained red with ferric oxide, and original ferro-magnesian constituents (olivine and augite) are merely suggested now by the shapes of the iron-stained pseudomorphs noticeable in the sections. Basic rocks. The tuffs and volcanic grits or sandstones are also stained red with ferric oxide, and the compact varieties present a very close resemblance to some of the igneous rocks. In section they are seen to consist of very numerous quartz granules, mostly sub-angular, associated in different slides with a greater or less amount of basic volcanic lapilli. The latter are mostly in a glassy (altered) and scoriaceous or pumiceous condition, and less seldom finely crystalline. Pieces of quartzite and a few odd plagioclase crystals are also noticeable, the whole being cemented into a compact mass with ferric oxide. Tuffs and grits.

(3) Carboniferous Volcanic Series, "Lower."

Nos. 2148?, 2463?, 2603 to 2607, 4593, 4594, 4596, 4616 to 4622, 4625, 6373?, 6995 to 6997, and 9396 to 9398.

Of the above rocks the great majority are basic, two of them are porphyritic trachytes (2606 and 4617), and one (6996) is a tuff.

These include olivine basalts with and without plagioclase phenocrysts, porphyritic dolerites, and diabase. The olivine basalts without Basic rocks.

plagioclase phenocrysts are compact and fine grained as a rule, and do not differ essentially from the basic types described already except that they are much fresher and their constituents more readily determinable. No. 6995, from Benlister Glen, may be taken as representative. This in section is seen to be finely crystalline, and contains abundant olivine crystals altered to iddingsite. The other ferromagnesian constituent is chloritized, and the plagioclase crystals are mostly coated with nearly opaque calcareous matter. The rock from the west side of St. Blane's Hill (4625) is the most basic type examined, containing much less felspar than usual. It contains phenocrysts of augite and olivine (iddingsite), the former being much corroded by the ground and frequently forming "glomero-porphyritic" groups. The ground, which is very minutely crystalline, consists chiefly of more or less idiomorphic augite micro-crystals, with a good deal of magnetic iron ore, a subordinate proportion of the ground being composed of plagioclase microlites and some glass. Specimen No. 4621, from east of Port Uisg, South Bute, is a basalt, veined with a little calcite and a good deal of red stilbite or heulandite.

The basalts with plagioclase phenocrysts contain on the whole a smaller proportion of olivine crystals, and approximate closely to the Lion's Haunch type. The specimen from the east side of Port Luchdach, South Bute (4618), is fairly representative. This contains numerous phenocrysts of a basic plagioclase giving rather high extinction angles, and being probably labradorite. These frequently have included in them portions of the glassy base. The ground is made up of a finely crystalline aggregate of abundant hypidiomorphic augite crystals and plagioclase laths with a good deal of magnetite. A little interstitial glassy matter occurs here and there. Numerous greenish pseudomorphs after olivine are noticeable in the section, also several augite phenocrysts, the larger ones (2 mm. diameter) being much corroded.

The rock (2463) south of Millstone Point is an altered dolerite or diabase. It is somewhat amygdaloidal, the amygdales being now filled in with calcite. The ferromagnesian minerals are completely altered to a greenish chloritic product. The remaining basic rocks of this series are porphyritic dolerites (2603–2605, 2607, and 4622), similar generally in composition to those rocks above described, but with a ground more definitely and coarsely crystalline. The coloured phenocrysts (augite and olivine) are almost completely altered to secondary materials, but the plagioclases are quite fresh. Olivine phenocrysts are rather scarce, and augite also is not very conspicuous. The ground, which is of the anamesite dolerite type, is much finer in grain than the ophitic dolerite described above, *e.g.* 4633 or 4634. It usually contains abundant partially chloritized augite, plagioclase, magnetite, and a little secondary *biotite*, with abundant accessory apatite, as inclusions in the felspathic constituents.

Acid rocks.

The acid rocks (2606 and 4617) of this group are pale greyish and slightly porphyritic trachytes. The phenocrysts are pinkish coloured simply twinned orthoclases about 0·5 cm. long. The specimen (4617) from the west side of Port Luchdach is the most typical. In section it consists of a plexus of simply twinned felspar micro-crystals, in the form of long laths, and showing well-marked flow orientation. Many of them are stained slightly with red iron oxide. Between the crystals occur abundant specks of hematite, some of which appears to be pseudomorphic after an original ferromagnesian mineral, traces of which in the form of minute green granules are still noticeable in the ground. The section of the other rock (from the east of North Garrochty) is similar generally, but the flow structure is not quite so typically developed.

The remaining rock included in this series is (No. 6996) one from the north of Creag-na-Fitheach (?), Glen Dubh, Arran. This rock is a *quartzose tuff* indentical with those described from the "Sliddery Water" area.[1] The quartz grains contain abundant fluid cavities with a moving bubble in each. Tuff.

(4) Sills or Bosses of Early Carboniferous Age.

Nos. 4573, 4574, 4576, 4583, 4588, 2608, 4587, and 4627 to 4629.

These include examples of trachytes (4576, 4588, and 4583) and basalts (2608, 4587, 4627–4629) and two rocks (4573 to 4574) which are tentatively referred to the Bostonite type. Another rock included in this set (4626) is a tuff.

Trachytes. These are reddish and yellowish coloured rocks, which are considerably altered and stained with iron oxide. One of the rocks (4583) is porphyritic, the phenocrysts being altered orthoclase or sanidine. In the ground, which is typically trachytic, occur greenish pseudomorphs in grains and ophitic patches, after augite (ægirine) probably. Some interstitial secondary quartz is also present. These rocks recall the types described by Hatch from the Garlton Hill, Haddingtonshire. (*Trans. Roy. Soc. Ed.*, Vol. 37, also Vol. 29.)

Bostonites? Two specimens (4573 and 4574) from Millport Bay, Great Cumbrae. These are creamy brown coloured, slightly porphyritic, rocks. In section they consist of small felspar laths, which are much altered and kaolinized on their surfaces. The porphyritic mineral is an untwinned felspar with a low refractive index, and is probably orthoclase. Some of the small felspars of the ground are repeatedly twinned, but have a lower refractive index than Canada balsam, and hence are alkali varieties. The majority of the felspar laths show simple twinning. In the absence of any analyses the rocks are tentatively referred to the bostonites, as they correspond very closely with the type of that rock described by Kemp and Marsters (in the *Bulletin of the U.S. Geol. Survey*, No. 107), both macroscopically and microscopically.

Basalts. These rocks occur at Suidhe Hill (2608 and 4627–4629) and at Sheughends, Great Cumbrae (4587). They are porphyritic olivine basalts verging towards compact dolerites. They are quite similar to types already described, and do not call for any special remarks here. Most of the ferromagnesian constituents are altered, but the plagioclase is quite fresh usually.

(5) Dykes of Early Carboniferous Age.

Nos. 4577 to 4579, 4586, 4589 to 4591, and 2595 to 2600.

Of these rocks two are trachytes (4577 and 4578) and the remainder basalts and dolerites.

Trachytes. The trachytes are fine-grained types, consisting of a felt of orthoclase laths somewhat stained with ferric oxide, and showing very typical flow orientation. Orthoclase phenocrysts are scarce, and some interstitial and secondary quartz is noticeable in the sections. The rock from top

[1] Summary of Progress, 1897, pp. 119 and 120

of crag near Hawk's Nest, Great Cumbrae (4578), contains a few flakes of biotite mica orientated in the same direction as the felspars of the ground.

Basic rocks.

The basic rocks are chiefly *altered* basalts and compact dolerites, usually with olivine, and generally porphyritic (Lion's Haunch type). The phenocrysts are usually labradorite, and less often augite or olivine. A good many of the rocks show the lateritic type of weathering, which characteristic is shared with many of the trachytes of this area.

List of Sliced Rocks from One-inch Sheets 21 and 13 (Scotland), with Localities and Determinations.

Reg. No.	Locality.	1″ No.	Name.
2148	Bed above red tuffs, south of High Corrie, Arran, . . .	21	Altered olivine basalt.
2463	South of Millstone Point, east side of Arran, ...	,,	Diabase.
2595	South of Bruchag Point, Bute, .	,,	Dolerite.
2596	Same locality	,,	Dolerite.
2597	Wood, south of Kerrylamont, Bute, ...	,,	Dolerite altered.
2598	North of Lubas Point, Isle of Bute,	,,	Diabase.
2599	Dyke on Kerrytonlia shore, Bute,	,,	Olivine dolerite.
2600	Dyke on Kerrytonlia shore, Bute,	,,	Porphyritic dolerite.
2603	West of Dunstrone Fort, Bute, .	29	Porphyritic dolerite.
2604	From west of Branzet?, Bute, .	21	Porphyritic dolerite or andesite.
2605	North of Tor Mor, Bute, . .	,,	Porphyritic dolerite.
2606	East of North Garrochty, Bute, .	,,	Porphyritic trachyte.
2607	Garroch Head, Bute, ...	,,	Porphyritic dolerite.
2608	Suidhe Hill, Bute, ...	,,	Porphyritic dolerite.
2609	East of Tor Mor, Bute, . .	,,	Olivine dolerite.
4573	The Clack, Millport Bay, Great Cumbrae, ...	,,	Bostonite?
4574	Miller's Thumb, Millport Bay, .	,,	Bostonite?
4576	Barbay Hill, Great Cumbrae, .	,,	Trachyte.
4577	Farland Point, Great Cumbrae, .	,,	Trachyte.
4578	Top of crag near Hawk's Nest, Great Cumbrae, . . .	,,	Biotite-trachyte.
4579	South of the Hawk's Nest, Great Cumbrae, ...	,,	Porphyritic basalt.
4583	Shore west of Creag nan Fitheach, Great Cumbrae, . .	,,	Porphyritic trachyte.
4586	West of Creag nan Fitheach, Great Cumbrae, ...	,,	Porphyritic basalt.
4587	Sheughends, Great Cumbrae, .	,,	Porphyritic olivine basalt.
4688	Terrach Hill, Great Cumbrae, .	,,	Porphyritic trachyte.

Reg. No.	Locality.	1″ No.	Name.
4589	Dyke, Little Skate Bay, Great Cumbrae, ...	21	Altered basalt.
4590	Dyke, Little Skate Bay, Great Cumbrae, ...	,,	Altered basalt (porphyritic).
4591	Dyke, Little Skate Bay, Great Cumbrae, ...	,,	Altered basalt (porphyritic).
4592	North side of Fintray Bay, Great Cumbrae, ...	,,	Basalt.
4593	South end of Little Cumbrae, .	,,	Basalt.
4594	Rest and be Thankful, Little Cumbrae, ...	,,	Porphyritic basalt.
4596	Little Cumbrae, ...	,,	Basalt.
4616	Dunagoil Fort, South Bute, .	,,	Porphyritic basalt.
4617	West side of Port Luchdach, South Bute, ...	,,	Porphyritic trachyte.
4618	East side of Port Luchdach, South Bute, ...	,,	Porphyritic olivine basalt.
4619	Dunstrone, South Bute, . .	,,	Porphyritic olivine basalt.
4620	South of Barr Hill, South Bute,	,,	Altered porphyritic basalt.
4621	East of Port Uisg, South Bute, .	,,	Porphyritic basalt.
4622	Barr Point, North of Dunagoil Bay, South Bute, . . .	,,	Porphyritic dolerite.
4625	West side, St. Blanes (?) Hill, South Bute, ...	,,	Basalt.
4626	South-west end of Suidhe Hill, South Bute, ...	,,	Tuff.
4627	South-east side of Suidhe Hill, South Bute, , ...	,,	Porphyritic olivine basalt.
4628	West side of Suidhe Hill, South Bute, ...	,,	Porphyritic olivine basalt.
4629	South-east side of Suidhe Hill, South Bute, ...	,,	Porphyritic olivine basalt.
4633	On shore south of Barr Hill, .	,,	Ophitic olivine dolerite.
4634	South-west of Barr Buidhe, South Bute, ...	,,	Ophitic olivine dolerite.
6371	Head of Sliddery Water, Burn B, Arran, ...	13	Sandstone.
6373			
6994	Sliddery Water Head, Burn B, Arran, ...	13	Tuff.
6995	Benlister Glen, east of Lagna Croise, Arran, . . .	21	Olivine basalt.

Reg. No.	Locality.	1″ No.	Name.
6996	North of Creag na Fitheach, Glen Dubh, Arran, ...	21	Tuff.
6997	500 yards north-east of Windmill Hill, Arran, ...	,,	Olivine basalt.
7051	Sliddery Water, Burn B, 400 yds. north-west of Cnoc Dubh, .	13	Altered basalt.
7738	Sliddery Water, Burn C, . .	..	Tuff.
7739	Sliddery Water Head, upper part of Burn C, ...	..	Basaltic andesite.
7740	Sliddery Water Head, Burn B, .	..	Olivine basalt junction with quartz-felsite.
7741	"Trap" bed in shale, Burn B, Sliddery Water, . . .	,,	Basaltic andesite.
7742	"Coarse ash" in Burn B, Sliddery Water, . . .	,,	Tuff.
7743	Fossiliferous ironstone horizon, Burn B, Sliddery Water, .	,,	Tuff or ash ?
9396	Base of Carboniferous "trap," north of Corrie, Arran, . .	21	Porphyritic olivine basalt.
9397	Top of Carboniferous "trap," near Corrie, Arran, . .	,,	Porphyritic olivine basalt.
9398	Small "trap" bed opposite Corrie Established Church, . .	,,	Porphyritic olivine basalt (altered).

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