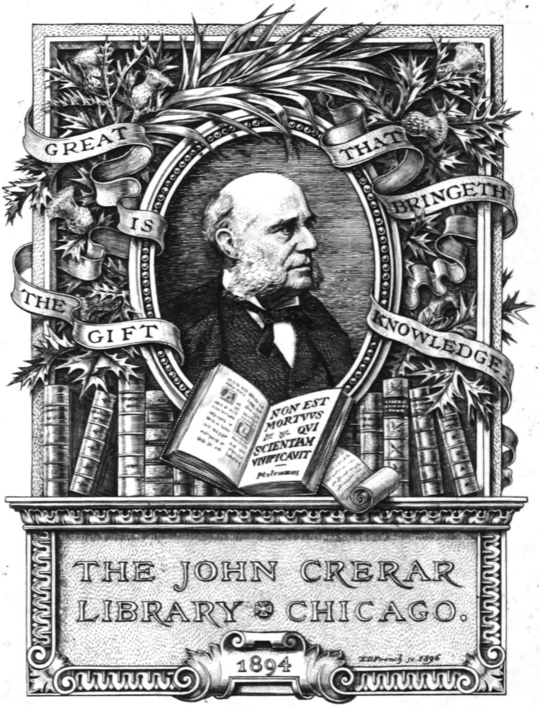

GREAT
IS
THE
GIFT
THAT
BRINGETH
KNOWLEDGE
NON EST
MORTVVS
QVI
SCIENTIAM
VIVIFICAVIT
THE JOHN CRERAR
LIBRARY CHICAGO.
1894

MEMOIRS OF THE GEOLOGICAL SURVEY.

SUMMARY OF PROGRESS

OF THE

GEOLOGICAL SURVEY

OF THE

UNITED KINGDOM

FOR

1899.

PUBLISHED BY ORDER OF THE LORDS COMMISSIONERS OF HER MAJESTY'S TREASURY

DIEU ET MON DROIT

LONDON:
PRINTED FOR HER MAJESTY'S STATIONERY OFFICE,
BY WYMAN AND SONS, LIMITED, FETTER LANE, E.C.

And to be purchased, either directly or through any Bookseller, from
EYRE & SPOTTISWOODE, East Harding Street, Fleet Street, E.C.; or
JOHN MENZIES & Co., Rose Street, Edinburgh, and
90, West Nile Street, Glasgow; or
HODGES, FIGGIS, & Co., Limited, 104, Grafton Street, Dublin.

1900.

Price One Shilling

LIST OF MAPS, SECTIONS, AND OTHER PUBLICATIONS OF THE GEOLOGICAL SURVEY OF ENGLAND AND WALES.

THE Maps are those of the Ordnance Survey, geologically coloured by the Geological Survey of the United Kingdom, under the Superintendence of Sir ARCH. GEIKIE, D.C.L., LL.D., F.R.S., Director General.

(For Maps, details of Sections, and Memoirs issued by the Geological Survey, *see* "Catalogue.")

ENGLAND AND WALES.—(Scale 1 inch to a mile.)

Maps marked * are also published as Drift Maps. Those marked † are published only as Drift Maps.

Sheets 3*, 5, 6*, 7*, 8*, 9, 11 to 22, 25, 26, 30, 31, 33 to 37, 40, 41, 44, 47*, 64*, 65†, 69†, 70*, 83*, 86*, price 8*s.* 6*d.* each.

Sheet 4, 5*s.* Sheets 2*, 23, 24, 27 to 29, 32, 38, 39, 58, 84†, 85†, 4*s.* each.

Sheets divided into quarters; all at 3*s.* each quarter-sheet, excepting those in brackets, which are 1*s.* 6*d.* each.

1*, 42, 43, 45, 46, NW, SW, NE*, SE*, 48, NW†, SW*, NE†, (SE*), (49†), 50†, 51*, 52 to 57, (57 NW), 59 to 63, 66 SW†, NE†, NW*, SE†, 67 N†, (S†), 68 E†, (NW†), SW†, 71 to 75, 76 (N), S, (77 N), 78, 79, NW*, SW, NE*, SE*, 80 NW*, SW*, NE*, SE*, 81 NW*, SW, NE, SE, 82, 83*, 87, 88, NW, SW*, NE, SE, 89 NW*, SW*, NE, SE*, 90 (NE*), (SE*), 91, (NW*), (SW*), NE*, SE*, 92 NW*, SW*, NE, SE, 93 NW, SW, NE*, SE*, 94 NW†, SW†, (NE†), SE†, 95 NW*, NE*, (SE*), 96 NW*, SW*, NE*, SE*, 97 NW*, SW*, NE*, SE, 98 NW, SW, NE*, SE, 99 (NE*), (SE*), 100*, 101 SE, NE*, NW*, SW*, 102 NW*, NE*, SW*, SE*, 103*, 104*, 105 NW*, SW*, (NE*), SE*, 106 NW*, SW*, NE*, SE*, 107 SW†, NE*, SE* 108 SW*, NE*, SE*, 109 NW*, SW*, SE*, 110 (NW*), (NE*), SE*, SW*.

New Series.—I. of Man*, 36, 45. 46, 56, 57, 8*s.* 6*d.* I. of Wight, with Mainland*, 330, 331, 344, 345, 8*s.* 6*d.* 155*, 203†, 231*, 232*, 248*, 249*, 263*, 267†, 268*, 282†, 283†, 284†, 299†, 300†, 315†, 316†, 325†, 328†, 329*, 339†, 330*, 331*, (332*), (333*), 334*, 339†, (340†), (341†), 342†, 343†, 349†, 350†, 355†, (356†). Price 3*s.* each, excepting those in brackets which are 1*s.* 6*d.* each.

GENERAL MAP:—(Scale 4 miles to 1 inch.)

ENGLAND AND WALES.—Sheet 1 (Title); 2 (Northumberland, &c.); 3 (Index of Colours); 4 (I. of Man); 5 (Lake District); 6 (E. Yorkshire); 7 (N. Wales); 8 (Central England); 9 (Eastern Counties); 10 (S. Wales and N. Devon); 11 (W. of England and S.E. Wales); 12 (London Basin and Weald); 13 (Cornwall, &c.); 14 (S. Coast, Torquay to I. of Wight); 15 (S. Coast, Havant to Hastings). *New Series, printed in colours,* sheet 1, 2s.; sheets 2 to 15, 2*s.* 6*d.* each.

HORIZONTAL SECTIONS.

1 to 140, 146 to 148, England, price 5*s.* each.

VERTICAL SECTIONS.

1 to 82, England, price 3*s.* 6*d.* each.

COMPLETED COUNTIES OF ENGLAND AND WALES, on a Scale of 1 inch to a mile

Old Series.

Sheets marked * have Descriptive Memoirs. Sheets or Counties marked † are illustrated by General Memoirs.

ANGLESEY†,—77 N, 78.
BEDFORDSHIRE,—46 NW, NE, SW†, SE†, 52 NW, NE, SW, SE.
BERKSHIRE,—7*, 8†, 12*, 13*, 34*, 45 SW*.
BRECKNOCKSHIRE†,—36, 41, 42, 56 NW, SW, 57 NE, SE.
BUCKINGHAMSHIRE,—7*, 13*, 45* NE, SE, 46 NW, SW†, 52 SW.
CAERMARTHENSHIRE†,—37, 38, 40, 41, 42 NW, SW, 56 SW, 57 SW, SE.
CAERNARVONSHIRE†,—74 NW, 75, 76, 77 N, 78, 79 NW, SW.
CAMBRIDGESHIRE†,—46 NE, 47*, 51*, 52 SE, 64*.
CARDIGANSHIRE†,—40, 41, 56 NW, 57, 58, 59 SE, 60 SW.
CHESHIRE,—73 NE, NW, 79 NE, SE, 80, 81 NW*, SW*, 88 SW.
CORNWALL†,—24†, 25†, 26†, 29†, 30†, 31†, 32†, & 33†.
CUMBERLAND,—98 NW, SW*, 99, 101, 102, NE, NW, SW*, 106 SE, SW, NW, 107.
DENBIGH†,—73 NW, 74, 75 NE, 78 NE, SE, 79 NW, SW, SE, 80 SW.
DERBYSHIRE†,—62 NE, 63 NW, 71 NW, SW, SE, 72 NE, 72 SE, 81, 82, 88 SW, SE.
DEVONSHIRE†,—20†, 21†, 22†, 23†, 24†, 25†, 26†, & 27†.
DORSETSHIRE,—15, 16, 17, 18, 21, 22.
DURHAM,—102 NE, SE, 103, 105 NE, SE, SW, 106 SE.
ESSEX,—1*, 2*, 47*, 48*.
FLINTSHIRE†,—74 NE, 79.
GLAMORGANSHIRE†,—20, 36, 37, 41, & 42 SE, SW.
GLOUCESTERSHIRE†,—19, 34*, 35, 43, NE, SW, SE, 44*.
HAMPSHIRE,—8†, 9†, 10*, 11†, 12*, 14, 15, 16.
HEREFORDSHIRE,—42 NE, SE, 43, 55, 56 NE, SE.
HERTFORDSHIRE,—1† NW, 7*, 46, 47*.
HUNTINGDON,—51 NW, 52 NW, NE, SW, 64*, 65.
KENT†,—1† SW & SE, 2†, 3†, 4*, 6*.
LANCASHIRE,—79 NE, 80 NW*, NE, 81 NW, 88 NW, SW†, 89, 90, 91, 92 SW, 98.
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, 83, 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.

MEMOIRS OF THE GEOLOGICAL SURVEY.

SUMMARY OF PROGRESS

OF THE

GEOLOGICAL SURVEY

OF THE

UNITED KINGDOM

FOR

1899.

PUBLISHED BY ORDER OF THE LORDS COMMISSIONERS OF HER MAJESTY'S TREASURY

DIEU ET MON DROIT

LONDON:
PRINTED FOR HER MAJESTY'S STATIONERY OFFICE,
BY WYMAN AND SONS, LIMITED, FETTER LANE, E.C.

And to be purchased, either directly or through any Bookseller, from
EYRE & SPOTTISWOODE, East Harding Street, Fleet Street, E.C.; or
JOHN MENZIES & Co., Rose Street, Edinburgh, and
90, West Nile Street, Glasgow; or
HODGES, FIGGIS, & Co., Limited, 104, Grafton Street, Dublin.

1900.

Price One Shilling

PREFACE.

THE following pages contain an account of the more important results obtained by the staff of the Geological Survey during the year 1899 in the field, the museum, and the laboratory. As far as possible, the account of the work of each member of the staff appears as it has been reported by himself. In regard to the field-work, a preliminary statement is given to show the general distribution of the mapping in each of the three kingdoms. This is followed by a narrative of the work of the past year in the various geological formations, beginning with the oldest.

Among the more noteworthy of these researches the following may here be referred to:—The investigation of the igneous rocks of part of Argyllshire, and particularly the examination of the olivine-monzonites and other more or less basic rocks round the Beinn Bhuidhe granite; the detection in the island of Arran of what are probably Arenig rocks with volcanic intercalations, such as have been already observed at various places along the southern edge of the Highlands; the establishment of the eruptive nature of what were believed to be tuffs and agglomerates in the south-east of Ireland; the closer determination of the stratigraphy of the probably Silurian rocks of Cornwall; the application of the knowledge obtained during the revision of the North Staffordshire coal-field to the recognition of the stratigraphical position of the Coal-measures under the younger formations of the centre of England; the important discovery of Rhætic strata and fossils in the island of Arran; the petrographical researches among the volcanic rocks of the Exeter district and among the so-called "ashes," "greenstones," and "felstones" of the east and south of Ireland; and

4 3371. Wt. 26682. 500—8/00. Wy. & S. a 2

the detection of phosphatic nodules with traces of probable cell-structure in the Torridonian rocks—the earliest indications of organised existence yet met with in Britain.

Some of these results have important economic bearings. The practical application of the work of the Survey continue to be much sought after by public bodies and by the public generally. A brief reference to this branch of the work, to which a large amount of time and labour is devoted by the officers of the staff, will be found in Part IV. of the present Summary.

Attention may likewise be called here to the Catalogue of Fossil Types and Figured Specimens, inserted as an Appendix. This list is the first of a series which is in preparation to illustrate the contents of the Palæontological Galleries of the Museum.

ARCH. GEIKIE,
Director-General.

Geological Survey Office,
Jermyn Street, London.
15*th May*, 1900.

CONTENTS.

SUMMARY OF PROGRESS

OF THE

GEOLOGICAL SURVEY

FOR 1899.

Several changes have taken place in the staff of the Geological Survey in the United Kingdom during the past year. MR. H. H. HOWELL, who joined the service as far back as 1850, when SIR HENRY DE LA BECHE was Director-General, reached the age-limit of sixty-five years on 13th July, and then retired. His office of Director for Great Britain has not been filled up, pending a consideration of the future organisation and work of the Survey, but in the meantime MR. H. B. WOODWARD, F.R.S., is provisionally entrusted with the duties of Acting-Director for England and Wales, and MR. JOHN HORNE, F.R.S., with those of Acting-Director for Scotland.

MR. F. J. BENNETT, who entered the Survey in 1868, has had to resign his appointment in consequence of ill-health. The vacancy thus caused among the Assistant Geologists has been filled up by the appointment of MR. E. E. L. DIXON, B.Sc., A.R.C.S.

In order to press forward the revision of the North-Staffordshire coal-field and the country around it, which is much required in the interests of the coal industry, MR. POCOCK was transferred last year from Scotland to take part in that work, and has been engaged continuously upon it since the spring.

I.—FIELD WORK.

The field-work in each of the three branches of the Survey has been continued along the same lines and in the same districts as were described in the *Summary of Progress* for 1898. A brief outline of its general distribution will first be given here, and the detailed results obtained will be more fully stated in subsequent pages (p. 6, *et seq.*).

ENGLAND AND WALES.—The revision of the coal-fields and of the counties where the superficial formations had not previously been mapped has been steadily prosecuted.

Leicestershire, North Staffordshire, Derbyshire, Cheshire, and Shropshire.

Thus in the counties of Leicestershire, North Staffordshire Derbyshire, Cheshire, and Shropshire, considerable progress has been made with the examination of the coal-fields, and with the mapping of the surrounding tracts which come into the sheets of the one-inch map that contain these coal-fields. The work has been carried on under the general supervision of MR. FOX-STRANGWAYS, by MR. GEORGE BARROW, MR. W. GIBSON, MR. T. I. POCOCK, and MR. C B. WEDD. An area of 199½ square miles has been mapped, with 1,341 miles of boundary-line, of which 789 represent the sub-divisions of the superficial formations, or Drifts. The Survey of the North Staffordshire coal-fields is now nearly completed. That of the Pottery coal-field is finished, and the map is being prepared for the engraver. The Survey of the Cheadle coal-field has also been finished, with the exception of a few patches of obscure ground. The re-survey of eastern Leicestershire has likewise been extended into a tract where the Drifts had not previously been mapped.

Middlesex, Hampshire, Dorset, Wilts.

The revision of the southern counties and the mapping for the first time of the superficial deposits of that wide region has been continued along the same lines that were sketched in the last *Summary of Progress.* The additional duties at present undertaken by MR. WOODWARD have rendered it expedient to relieve him of some of the supervision of field-work hitnerto entrusted to him. Accordingly the mapping in Dorsetshire, Hampshire, and Middlesex has been placed under the charge of MR. CLEMENT REID, F.R.S. MR. CAMERON has continued his work in the Thames Valley. MR. DIXON, who entered on his duties in July, was first trained in the Survey methods of field-work by MR. REID, and since then has been engaged on the Chalk, Eocene, and Drifts of the County of Dorset. MR. REID himself, besides supervising the work of his colleagues, has continued his revision of the Hampshire Tertiary Basin and of the surrounding tracts of Wilts and Dorset The total area surveyed by him and his colleagues amounts to 181½ square miles, with 562 miles of boundary-lines, of which 407 relate to the Drift.

Oxfordshire.

In Oxfordshire, MR. J. H. BLAKE, from Oxford as a centre, has surveyed an area of 48 square miles, with 192 miles of boundary, including 167 miles of Drift-lines.

Devon and Cornwall.

In Cornwall and Devonshire the re-survey has been continued by MR. S. B. WILKINSON, MR. W. A. E. USSHER, and MR. J. B. HILL. They have surveyed an area of 135½ square miles, and have traced 397 miles of boundary, whereof 152 miles belong to the Drift. The work has been carried on westwards from Plymouth to the neighbourhood of Liskeard and Looe. Near Falmouth the coast and creek sections have been studied in detail along an extent of 68 miles, and the sections along the railway to Truro, and eastwards towards St. Austell have been examined in order that the stratigraphy of the district may be more clearly understood. A large part of the Land's End region has now been surveyed. Both MR. WILKINSON and MR. HILL were occupied during part of the year in the survey of certain areas in Scotland, on which they had been engaged previous to their transference to Cornwall, and which it is desirable that they should themselves complete.

Sussex.

MR. G. W. LAMPLUGH, having completed the mapping and the Memoir of the Isle of Man, was transferred to the south of England, where his intimate knowledge of the Lower Cretaceous rocks of Yorkshire and Lincolnshire can be made available in the revision of these formations in Sussex and Kent, and in the preparation of a monograph descriptive of the Lower Cretaceous rocks of England. He has accordingly begun the re-survey of Sussex, where he has mapped an area of 50½ square miles, with 197 miles of boundary, including 66 miles of Drift-lines. Much of his time in the early part of the year was occupied with his Memoir on the Isle of Man, which has now gone to the printer. He was engaged also in an examination of the cores obtained from the deep borings and shafts that have been made in the search for coal in the south-east of England

In the South Wales coal-field the re-survey has been carried on under the general supervision of MR. STRAHAN, with the co-operation of MR. R. H. TIDDEMAN, MR. W. GIBSON, and MR. T. C. CANTRILL. An area of 104 square miles has been mapped, with 577 miles of boundary-line (263 Drift). As MR GIBSON, during the greater part of the year, was occupied in the re-survey of the North Staffordshire coal-field, his services were only given for a short time to the South Wales Coal-field in order to complete some colliery information. In future he will be engaged continuously in the re-survey of the Midland coal-districts. In South Wales the field-work has been carried on as far westwards as the neighbourhood of Swansea. The first memoir on the district, being the Geology of the country around Newport, in Monmouthshire, written by MR. STRAHAN, has now been published.

In England and Wales the total area surveyed in 1899 has amounted to 719 square miles, and the number of miles of geological boundaries to 3,266, of which 1,844 belonged to the mapping of the superficial deposits. The ratio of area to boundary-lines is thus almost exactly similar to that of the previous year, every square mile of surface having involved, on the average, the tracing of about four miles and a half of boundary-lines.

MR. JUKES-BROWNE has been occupied in revising the proofs, in slips and in pages, and in preparing the index, of the first volume of his Memoir on the Upper Cretaceous Rocks of England. He has, moreover, completed the MS. of the second volume dealing with the various divisions of the Chalk.

MR. WHITAKER, F.R.S., has been good enough to communicate records of nineteen wells and borings, representing 3,867 feet of strata.

A number of note-books containing records of pits and quarries and of well-sections, together with some MS. geological maps, which belonged to the late SIR JOSEPH PRESTWICH, have been presented by LADY PRESTWICH.

SCOTLAND.—The amount of field-work in Scotland has been somewhat reduced owing to several causes, among which the chief are the loss of MR. POCOCK'S services by his transference to the English staff, the detention of MESSRS. PEACH and HORNE in the office until the end of June in connection with the completion of a large Monograph on The Silurian Rocks of Scotland, and the removal of MR. HORNE in the autumn from the field to take charge of the office-work in Edinburgh. The mapping has been continued in the same districts as were mentioned in the last *Summary of Progress*.

Aberdeenshire. In Aberdeenshire, MR. BARROW mapped 34 square miles, with 121 miles of boundary; and in the same county MR. CUNNINGHAM-CRAIG reports $49\frac{1}{4}$ square miles, with 268 miles of boundary.

Argyllshire. In Argyllshire, MR. SYMES surveyed 31 square miles, with 204 miles of boundary; in the island of Jura in that county MR. WILLIAMSON mapped 31 square miles, with 69 miles of boundary, and in Islay he traced 119 miles of new boundaries in ground previously surveyed. In the same county also MR. WILSON mapped $7\frac{1}{2}$ square miles, with 14 miles of boundary, and MR. KYNASTON $61\frac{3}{4}$ square miles, with 414 miles of boundary.

Arran. In the island of Arran, MR. GUNN surveyed $9\frac{1}{2}$ square miles, with 84 miles of boundary

Dumbartonshire. In the county of Dumbarton, MR. CRAIG traced 72 miles of new boundaries in ground mapped some years ago.

Inverness-shire. In the county of Inverness, MR. HORNE in Strath Nairn mapped $3\frac{3}{4}$ square miles, with 11 miles of boundary; in the west of the same county, south-east of Glenelg, MR. CLOUGH surveyed $37\frac{1}{2}$ square miles, with 416 miles of boundary. MR. WILSON, stationed in the Fort William district, completed an area of $42\frac{1}{2}$ square miles, with 137 miles of boundary, and MR. HINXMAN, with Beauly as a centre, an area of 30 square miles, with $168\frac{1}{2}$ miles of boundary. In the island of Skye, MR. HARKER mapped $29\frac{1}{4}$ square miles with $540\frac{1}{4}$ miles of boundary, or upwards of 18 miles of boundary in every square mile surveyed.

Perthshire. In Perthshire, MR. WILSON surveyed 15 square miles with 20 miles of boundary, and MR. CUNNINGHAM-CRAIG traced $105\frac{1}{2}$ miles of fresh boundaries in ground previously mapped.

Ross-shire. In the county of Ross, with Kinlochewe and Dingwall as centres, MR. PEACH mapped $52\frac{3}{4}$ square miles and 267 miles of boundary; MR. HORNE in the west part of the Fannich Forest surveyed $6\frac{1}{4}$ square miles with 36 miles of boundary; and MR. GUNN, in the mountainous part of the Braemore and Fannich Forest, mapped $10\frac{1}{2}$ square miles with 87 miles of boundary. In the eastern part of the same county, from his station at Beauly, MR. HINXMAN surveyed 29 square miles with $102\frac{3}{4}$ miles of boundary.

Stirlingshire. In the county of Stirling, MR. CUNNINGHAM-CRAIG traced $29\frac{1}{2}$ miles of new boundary-lines along the border of the Highlands.

The total area surveyed in Scotland during the year has been $480\frac{1}{2}$ square miles, and the total aggregate length of boundary-lines traced amounts to $3,285\frac{1}{2}$ miles. Each square mile mapped has thus involved on the average the tracing of 6·84 miles of boundary.

IRELAND.—The whole of the one-inch map of this country having been completed and published, the field-work of the small staff retained for the purpose consists in revising the sheets of the map, and bringing it abreast of the present state of our knowledge of the structure of the country. Many years have elapsed since the maps of the eastern and southern counties were completed, and much new light has been thrown on the rocks during the interval.

The first revision has consisted in a re-examination of all the Silurian tracts in Ireland, with the view of separating the Lower from the Upper division, and of bringing the petrography of the ground up to date. It has also included the tracing of the superficial deposits in certain counties which were mapped at the beginning of the history of the Survey, but in which, as in England at the same time, these deposits were neglected.

In Wicklow MR. NOLAN has continued the mapping of the Drifts and the peat. In the same county, as well as in Counties Dublin and Wexford, some interesting and important re-examinations of the igneous rocks have been made by MR. EGAN and MR. MCHENRY, assisted in the petrographical work by MR. SEYMOUR. In addition to this region, further attention was given to some of the ground to the north of Dublin, with the view of obtaining material for completing the petrographical determinations necessary to allow the revised edition of the maps to be prepared and published. Thus the tracts of igneous rocks in the districts of Slane and Balbriggan were examined by MESSRS. MCHENRY and SEYMOUR, while a careful study on the ground was made of the dykes along the coast of Co. Down by MESSRS. EGAN and SEYMOUR.

In Co. Waterford MR. KILROE has completed the task assigned to him of tracing the boundary between Lower and Upper Silurian rocks. He has necessarily been much occupied by the eruptive rocks which form so large and important a part of the geological structure of that part of Ireland, and he has been able to effect changes of consequence in the representation of them upon the maps.

In connection with the revision of the Silurian rocks, MR. CLARK has continued to search the strata for fossils with the view of furnishing palæontological evidence for the mapping. Last year he was engaged in the Counties Clare, Tipperary, Kilkenny, Wexford, and Waterford. Near the granite of Leinster the rocks proved unfossiliferous, but near Now Ross and Duncannon fossils were found that pointed to a Lower Silurian age. The well-known fossiliferous localities of Waterford had already been fully examined, and collections of specimens from them have long been displayed in the Survey cases in the Dublin Museum of Science and Art.

In the following account of the chief scientific and economic results obtained by the Survey during the past year, the various geological formation of the British Isles will be taken in succession, beginning with the oldest.

PRE-CAMBRIAN.

Ross-shire.

The mapping of the displaced masses of Lewisian gneiss and the crystalline rocks embraced in the "Moine series," which was described in last *Summary of Progress*, has been continued in the counties of Ross and Inverness. The district around Loch Fannich, westwards to Loch Maree, and eastwards beyond Lochs Luichart and Garve, has been further investigated by MESSRS. PEACH, HORNE and GUNN.

MR. PEACH, to whom was assigned the more westerly and easterly portions of the ground, has furnished the following report of his field-work.

Kinlochewe and Fionn Bheinn (Mr. Peach.)

From the station of Kinlochewe on Loch Maree he worked out some of the details of the complex folds into which the Lewisian gneiss, the basement beds of the Torridonian, and the Cambrian formations are thrown in the mass of rock which overlies the "Glen Logan" thrust plane to the north of Kinlochewe. Besides being much puckered and folded, these strata are also traversed by minor thrust-planes and faults, which add greatly to the difficulty of unravelling their structure. Two small dykes of lamprophyre were mapped, which have been intruded since the period of the movement.

From the same centre Mr. PEACH also completed an area of about twelve square miles, between Loch Rosque and the River Bran on the south, and the Leckie Burn which joins the Kinlochewe River on the north. The western part of this ground is a high table land, with an average height above sea-level of over 1,000 feet, but deeply trenched by valleys, while the eastern part rises into the mountain mass of Fionn Bheinn, which attains a height of over 3,000 feet, and forms a conspicuous landmark.

The rocks of the tableland consist chiefly of quartzose granulitic Moine-schists many of which are of the typical micaceous flaggy character so well developed in the original Moine district of Sutherland. Towards the east, however, they occur in more massive beds. They alternate in varying degrees with dark biotite-schist over the greater part of the tableland. Fionnbheinn, on the other hand, so far as it has yet been mapped is almost entirely composed of muscovite-biotite-gneiss or schist, together with subordinate bands and lenticles of quartzose granulitic schist, and a few thin sill-like layers of garnetiferous epidiorite or hornblende-schist. The line of junction of the more quartzose Moine-schists and biotite-schists with the muscovite-biotite-gneiss has been traced across the ground now referred to. To the north it joins up with the line which was drawn by MR. POCOCK, and was referred to in the *Summary* for last year.* The continuation of the same boundary has been traced by MR. HORNE and MR. GUNN far to the north along the western slopes of the Fannich Hills into the plain beyond.

Kinlochewe and Fionn Bheinn (Mr. Peach.)

The ground mapped last year by MR. PEACH has a length of about five miles from west to east across the strike of the beds. Throughout its extent the apparent dip of the strata is towards the east, at angles varying from 20° to 40°. This arrangement arises from their being thrown into a series of isoclinal folds. Many of the minor folds can be seen in dip section, while the existence of others of greater amplitude can be demonstrated by following the layers of biotite-schist round the ends of the folds, where the "pitch" allows, so that what might appear to be successive outcrops of different bands of biotite-schist have thus been proved to belong to one and the same band. Further, there is strong presumptive evidence that, notwithstanding that the dip of all the structures is towards the east, there is a generally descending order of succession of the strata in that direction. The apparent dip of the quartzose granulites beneath the muscovite-biotite-gneiss of Fionn Bheinn is due to their forming the western limb of a much-compressed and overthrown anticlinal fold of great width. In the mountain itself, no core of rock of the type of the Lewisian gneiss has been observed; but granulitic, hornblendic and biotitic gneisses, like those which have already been described from Sgurr Mhuillin and Loch Luichart,† and surrounded by Moine schists and muscovite-biotite-gneiss, crop out in the stream which drains the southern slopes of Meall an Thuim Bhain at the extreme eastern limit of the area surveyed last year.

Loch Luichart and Garve. (Mr. Peach.)

From Dingwall as a centre MR. PEACH was able to reach the ground between Auchterneed and Loch Luichart and to continue the work well into the southern flanks of the Ben Wyvis mountains. The same groups of rock as were mapped in the previous year‡ were again met with—(*a*) a series of granulitic, hornblendic and biotitic gneisses, which, with dyke-like masses of peridotite, occur on the crests of some of the anticlines, and are presumably Lewisian; and (*b*) an overlying series made up of schists or gneisses of two types, the prevailing one being a granulitic quartzose schist with more or less mica (Moine-schist) and muscovite-biotite gneiss. Thin bands of garnetiferous epidiorite and hornblende-schist, that occur as sills both in the Moine-schist and the muscovite-gneiss, appear to have been intruded into the rocks prior to their foliation and certainly before their plication, since they follow the numerous folds into which these are thrown. In addition to the sills of hornblende-schist the only other foliated igneous rock associated with the schists is a sill-like mass of augen-gneiss or granite like that mentioned in the last *Summary*. This sill may possibly be

* *Summary of Progress* for 1898, pp. 15–17.

† *Op. cit.*, p. 7.

‡ *Op. cit.*, pp. 7–11.

Loch Luichart and Garve. (Mr. Peach.)

continuous with one of those crossed by the railway near Loch Luichart, though the actual connection between them, if it exists, is masked in the intervening ground by drift. Its outcrop has been traced from near the road between Loch Luichart and Corriemoillie north-eastwards under the Old Red Sandstone outliers of Ben a Bhric and Ben nan Cabag across the watershed towards the outcrop mapped by MR. GUNN, who has followed it into the well-known exposure at the bridge which crosses the Blackwater, near Inchbae. From its prominence, its mode of weathering, and its prolonged extent, it has supplied a vast number of boulders which have been dispersed far and wide over the basin of the Moray Firth, and afford excellent evidence of the movement of the ice which transported them.

One thin dyke of lamprophyre, nowhere more than 10 feet broad, has been traced in an east and west direction for several miles a little to the north of Loch Luichart. This is the only unfoliated igneous rock met with. Although the date of its intrusion cannot be directly determined, it may be inferred from the fact that a mica-trap of somewhat similar type was found to cut an outlier of the breccia of the Old Red Sandstone to the east of Loch Garve.* It is probable that the lamprophyres of this district are of later date than the basement beds of the Old Red Sandstone.

Fannich Forest. (Mr. Horne.)

The mapping of the mountainous region of the Fannich Forest, of which some account was given in the last *Summary of Progress*,† was again resumed by MESSRS. HORNE and GUNN, the former working southward, the latter northwards towards Loch Broom.

MR. HORNE reports that from his station at Cabuie to the west of Loch Fannich he surveyed ground along the southern slopes of Sgurr Breac and A'Chailleach (3,276 ft.), the western peaks of the Fannich group, westwards to near An Groban and southwards to the Cabuie river. This tract lies to the south of the area mapped by MR. GUNN, and to the north of that mapped by MR. POCOCK during 1898. The crystalline schists met with in it belong to the same well-defined groups, which have been previously described, but of which a brief enumeration may be here repeated for the sake of clearness in the following descriptions of the latest results of the field-work.

1. Acid gneiss, with basic lenticles and bands of hornblende-schist, epidiorite and garnetiferous hornblende-rock, resembling certain types of Lewisian gneiss.
2. Massive biotite-gneiss, highly garnetiferous in places with irregular masses of garnetiferous hornblende-rock. (Meall an't Sithe and Meall Dubh gneiss.)
3. Granulitic quartzose schist or gneiss quartz-biotite-granulite or Moine schist. (Meall a' Chrasgaidh rock.)
4. Flaggy biotite schist with small garnets.

GROUP 1.—The members of Group 1 enter the area mapped by MR HORNE in 1899, along the western slope of A'Chailleach

* *Summary of Progress* for 1898, p. 11.

† *Op. cit.*, pp. 11 17.

Fannich Forest. (Mr. Horne.)

between the contour-lines of 2,250 and 2,750 feet, where the pink granulitic acid gneiss with folia and eyes of felspar, and bands of epidiorite and hornblende-schist form a well-marked belt, readily distinguished from the garnetiferous muscovite-biotite-gneiss (group 2) both above and below it. Here the acid gneisses and the associated basic masses have a gentle easterly dip at angles varying from 10° to 15°. Owing to so gentle an inclination the members of this group present a highly sinuous outcrop for about six miles in the mountainous tract lying to the north-west of Cabuie. Along this outcrop numerous stream-sections show the lithological characters of the rocks. Upon the crest of the dividing ridge (An Sguman) for nearly a mile the overlying garnetiferous muscovite-biotite-gneiss has been removed by denudation, and the acid gneiss with its basic bands is laid bare in gentle undulations; the more prominent basic bands being repeated in the successive folds on the crest. There can be little doubt that the more massive basic bands, which here consist of green hornblende and plagioclase felspar, are intrusive in the acid gneisses, for they seem to transgress its foliation planes. In addition to the larger basic masses, thin strips of hornblende-schist and small lenticles and knots of hornblende-rock in the acid gneiss recall familiar features in the Lewisian gneiss of the north-west Highlands. The acid gneiss associated with these basic masses is coarsely granulitic and highly quartzose, with folia and eyes of felspar, as well as some biotite and muscovite. Sometimes it is finely striped and granulitic, with marked linear foliation, approaching the quartzose granulites of the Moine type. This latter type is frequently developed along the line of junction with the coarse garnetiferous muscovite-biotite-gneiss (group 2).

Group 2.—The characteristic muscovite-biotite-gneiss of this sub division both overlies and underlies the belt of acid gneiss just described, in the tract to the north-west of Cabuie. Both outcrops are believed to be repetitions of the same band due to folding. The overlying mass is well exposed on the higher part of A' Chailleach, and two small outliers of the same material are visible on the crest of An Sguman, between the Cabuie river and Abhuinn Nid. The underlying outcrop has been traced from the western slope of A' Chailleach, where this rock is exposed between the contour-lines of 2,000 and 2,250 feet south-eastwards to the mouth of the Cabuie river and the shores of of Loch Fannich. Throughout this ground the rock varies considerably in character. The normal type consists of large plates of biotite and muscovite with garnets and quartzo-felspathic material in thin veins and knots, presenting the characters of a coarse biotite-gneiss. Sometimes along the same line of outcrop the pegmatites disappear, the plates of mica become smaller, and the rock merges into a schist in which biotite and muscovite are the chief constituents, or a fine-grained mica-schist. Occasionally irregular masses of garnet-hornblende-rock appear in the garnetiferous gneiss, as for instance near the base

Fannich Forest. (Mr. Horne.)

of the more easterly outlier on An Sguman, and in the outcrop underlying the belt of acid gneiss.

Group 3.—The flaggy granulitic quartz-schists, which are the distinguishing feature of this group, appear on the col to the west of A' Chailleach where they rise from underneath the garnetiferous gneiss (group 2), and dip to the east at an angle of 10°. The boundary line between these two groups is there well defined, and it has been traced south-eastwards along the south slope of An Sguman to a point on the Cabuie river about a mile west from Loch Fannich, where it enters the ground mapped in 1898 by Mr. Pocock. It was last year followed by Mr. Peach along the west slope of Fionn Bheinn towards Achnasheen.

Group 4.—Not far below the junction line of the quartz-schists with the garnetiferous muscovite-biotite-gneiss, on the south-west slope of An Sguman, a band of flaggy biotite-schists with small garnets appears, with a similar gentle dip to the east. These schists are likewise underlain by flaggy quartzose schists of the Moine type. At present it is uncertain whether this group corresponds to the biotite-schists of Sgurr Mor Fannich, though lithologically the rocks resemble each other. The result of the mapping of the Fannich mountains proves that the groups of crystalline schists identified by Mr. Gunn on the northern slopes of that range are repeated on both limbs of a fold of great amplitude, in which the various groups seem to preserve the same relative position towards each other. It further appears from the gentle inclination of the various groups in the western part of the area, at least, that the axial planes of the folds must lie at comparatively low angles.

One instance of intrusive rocks later than the movements which determined the foliation and plication of the schists was found in the corrie at the head of Abhuinn Nid. It consists of a thin dyke of lamprophyre.

Loch Fannich to Loch Broom. (Mr. Gunn.)

The ground surveyed last year by Mr. Gunn lay near the watershed between Loch Fannich and Loch Broom. High, craggy, and difficult of access, it rises for the most part to a height of more than 1,500 feet, while three of the hills included in it exceed 3,000 feet. The greater part of his mapping lay around Loch a' Bhraoin. The same four groups of rock which he had established in previous years, and which, as above stated, were followed by Mr. Horne on the southern side of the watershed have been further traced by Mr. Gunn on the north side. He furnishes the following notes of the development of these rocks in the ground mapped by him last year.

The Biotite-schist of Sgurr Mor Fannich (No. 4) makes up but a small portion of the area. In several places it appears to be much more plicated than the quartz-schists which border it on either side. This difference may be due to the rock having been of a softer nature, so that it yielded more readily to pressure than the hard siliceous rocks. In the streams to the north-west of the head of Loch a' Bhraoin, a fairly thick band of biotite-schist probably represents this rock or is a part of it. This band,

Loch Fannich to Loch Broom. (Mr. Gunn.)

however, has not yet been traced continuously over Creag Rainich, and connected with the biotite-schist near the Fain Inn. On the watershed to the south-west of A'Chailleach a band of biotite-schist, apparently much thinner than the last, which has been followed northwards into the streams that run into the head of Loch a' Bhraoin from the south, is not only much thinner than the Sgurr Mor rock appears to be, but also lies apparently on a much higher horizon, not far below the upper boundary of the Meall a' Chrasgaidh rock (No. 3). This band of biotite-schist has been followed by MR. HORNE for a long distance on the south side of the watershed. Its relation to the Sgurr Mor rock cannot yet be decided.

The band of flaggy quartz-schist of Meall a' Chrasgaidh (No. 3) presents a typical Moine-type, and occupies the upper part of the valley of the Strathbeg River which runs into Little Loch Broom. Its component members dip to the east-south-east and south-east, but near Creag Rainich, at the head of the valley, they curve round and run across the ridge to the south, while the inclination changes to a northerly direction along the north side of Loch a' Bhraoin, so that the band forms a synclinal fold, in the centre of which, and forming the highest ground, lies the garnetiferous gneiss (No. 2). Numerous sections of these flaggy quartz-schists may be seen in the small streams (which are far more numerous than would appear from the map) on the north side of Loch a' Bhraoin. The numerous streams on the south side of the loch, near its head, run for the most part in glacial drift and do not afford good sections of the rocks below. No intrusions of igneous material have been met with in the Meall a' Chrasgaidh rock, and it seems also to be almost entirely devoid of pegmatites.

The garnetiferous gneiss of Meall an't Sithe (No. 2) forms an outlier on the ridge north of Loch a' Bhraoin, extending for three miles, from Meall an't Sithe nearly to Creag Rainich. As just mentioned, it lies in the centre of a syncline, which is probably broken by a fault along its south-eastern side near the loch. The rock is often massive in appearance, and is largely made up of small bands of white or light-coloured pegmatites, which for the most part coincide with the foliation-planes. Irregular bosses and sills of a basic rock, for the most part hornblendic, are often met with. They are crowded with garnets, while large garnets are likewise distributed generally through the mass of the gneiss.

Near the northern edge of the mass, bands of a very acid schist or gneiss occur, quite different in character from the bulk of the rock. The largest and most important of these, seen about a mile west of the top of Meall an't Sithe, is almost certainly an infold of the siliceous rock (No. 3) below. Good sections occur in the crags all along this northern boundary, but perhaps the finest continuous exposure has been laid open in the crag on the south side of Loch a' Bhraoin from near the burn called Allt a' Goibhre, which issues from Toll an Lochain, round to Allt Brebaig. At the latter locality, the rock near its upper boundary

Loch Fannich to Loch Broom. (Mr. Gunn.)

is in places comparatively free from garnets, is more evenly foliated than usual, and contains abundance of white mica, with very little biotite. A good exposure of the garnetiferous gneiss is visible in Allt na Goibhre, but to the westward the boundary between it and the siliceous flags is much obscured by drift for a long distance, only small isolated sections occurring till, on the west side of A'Chailleach, the rock again appears at the surface.

In Allt na Goibhre above the uppermost of two thick bands of acid gneiss, the Meall an't Sithe garnetiferous gneiss, or a rock very similar to it, again comes out in great force. It occupies the whole of the valley, spreads over the bounding ridges on either side, and forms all the upper parts of A' Chailleach and Sgurr Breac with the high ground between them, thus occupying all the watershed for a distance of two miles. On these hills, owing to the comparative absence of the small pegmatitic bands, the rock occasionally approaches more in character to an ordinary biotite-schist.

Considerable additions were made last year to our knowledge of the physical structure and composition of the acid gneiss (No. 1) in the area mapped by MR. GUNN. The rock is typically developed at the head of Allt Brebaig, between Sgurr Breac and Sgurr nan Clach Geala, where the coarse-grained grey acid gneiss has a marked north-west strike. In general, it is of a very acid type: some granulitic parts of it, indeed, might at first sight be confounded with the siliceous Meall a' Chrasgaidh rock, were it not for the basic bands associated with the gneiss. A grey granulitic rock with marked linear foliation, which occurs in the eastern branch of Allt Brebaig, 1,500 yards north-east of Sgurr Breac, has been found by MR. TEALL, on microscopic examination, to be composed of quartz, felspar, and two micas, with sphene as an accessory. Not far to the west, in the burn, called Allt nan Eilig, a well-banded grey and cream-coloured rock occurs, which MR. TEALL calls a fine-grained granulitic schist. His description of its appearance under the microscope is—No. 7509:—Epidote (grains and crystals of uniform dimensions in the different directions and occasionally containing brown cores, orthite ?), pale green pyroxene, hornblende (scarce),water-clear felspar, and quartz, forming an irregular mosaic (individuals varying in size), sphene as an accessory: epidote pyroxene-granulite.

About a quarter of a mile farther up the same stream a specimen from one of a group of broad bands of black, coarse-grained, massive rocks of a basic character is described by MR. TEALL as a granitoid aggregate of green or greenish-brown hornblende and plagioclase (oligoclase); sphene as an accessory. These basic bands appear to have all the characters of true intrusive dykes and bear the same relation to this acid gneiss as the epidiorite dykes do to the normal Lewisian gneiss. They have been traced for about two miles in a north-west and south-east direction. Their total width varies between 100 and 200 yards, and in some places seems to consist wholly of dyke-material, while in others thin strips of acid gneiss

Loch Fannich to Loch Broom. (Mr. Gunn.)

divide the whole into distinct bands. A somewhat different type of basic rock is also met with in the same ground; lenticles of basic material—irregular lumps, and thin bands of hornblende-schist which apparently bear the same relation to the acid gneiss of the district as the earlier basic rock does to the Lewisian gneiss.

The rocks of this area are much plicated. A beautiful example of folding on a rather large scale occurs in the crags to the south-west of Sgurr nan Clach Geala. In ascending a stream three quarters of a mile south-south-west from the hill-top, we come upon a band of diorite about 30 yards broad, and 300 yards farther up, upon another band, 70 yards wide, having a strip of gneiss 50 feet wide in the middle of it. The foliation of all the gneiss hereabouts dips uniformly and steeply towards east-north-east. As the broader band is traced northwards for about half a mile in the great precipice of Creag a' Fhuarain, the included strip of gneiss disappears and the whole then becomes one dyke, 100 yards or more in width. The smaller band widens out somewhat also as it is followed northward into the same crag, where the two bands are seen to form the two separate limbs of one isoclinal fold which curves round and spreads out over the crag. The foliation of the adjoining gneiss and the occasional foliation in the dyke itself show this clearly. In one part of the crag the width of the mass of diorite is as much as 800 feet. At the head of Coire Breac, so intense is the folding that the acid gneiss is felted with the garnetiferous gneiss, and both are shot with numerous pegmatites.

No basic igneous rocks have been noticed in the acid bands under A' Chailleach, but two acid bands seen in Allt na Goibhre contain dark basic material. In the uppermost of them some of the basic masses are foliated, and in one striking section the foliation of the acid gneiss cuts that of the included basic rock nearly at right angles—an almost exact parallel to the structure found in the Lewisian gneiss of the Gruinard district.

It is not necessary to allude further to the intrusive igneous rocks as they have been for the most part included in the foregoing account of rocks in which they occur. Those in the acid gneiss are generally diorites or hornblende-schists, while the bosses and sills of basic material associated with the garnetiferous gneiss are generally hornblendic in composition and crowded with garnets. The small pegmatites so generally diffused through the latter rock must generally be considered as segregations from the adjacent rock, and as the results of extreme metamorphism, but it is doubtful if some of the larger pegmatites have had the same origin. On the east side of Toll an Lochain and elsewhere masses of coarse pink and white pegmatite have a dyke-like character, several of them being many feet in breadth and stretching for a considerable distance. They generally run along the strike of the foliation, but some are seen to penetrate both the garnetiferous and acid gneisses. A specimen from Druim Ruadh is composed of large pinkish

Loch Fannich to Loch Broom. (Mr Gunn.)

microcline felspar. Traces of a red lamprophyre found in two places at the northern end of Druim Ruadh, probably belong to a sill or dyke, similar in character to those previously described from this district. Rocks of this character, however, are not common: they have as yet been found in only three localities.

Although in the siliceous and granulitic Meall a' Chrasgaidh rock, no intrusions of igneous rock, and few or no pegmatites are met with, when the upper boundary of this band is crossed, they make their appearance both in the garnetiferous and acid gneisses. The coarsely crystalline character of the rocks and the abundance of pegmatites in them appear to be closely connected, and to result from the same cause—extreme metamorphic action—and only very slightly, if at all, from direct intrusion of igneous rocks. But the metamorphism, if, as is usually taken for granted, it was induced from below, can hardly be due to any alteration of the rocks in their present positions, for highly altered masses overlie others which are less altered. The garnetiferous and acid gneisses, for example, come above the Meall a' Chrasgaidh rock. The metamorphism would thus appear to have occurred when the acid gneiss and the garnetiferous gneiss were below the Meall a' Chrasgaidh rock, and in that case it will follow that notwithstanding the apparently regular order of succession now existing, the rocks are really inverted. Another possible explanation may be offered, viz., that the more highly altered rocks owe their present abnormal position to a lateral thrust, but no trace of anything of this kind has been noticed by MR. GUNN.

Inverness-shire.

District of Glenelg. (Mr. Clough.)

The examination of the ground between the Gleann Beag of Glenelg and Loch Hourn has been continued by MR. CLOUGH, who supplies the following notes of his work:

Like the ground to the north, already described,* the tract surveyed last year, is composed in the main of rocks which seem to belong either to the Lewisian gneiss series or to the Moine-schists. Those believed to form part of the Lewisian gneiss series present very varied characters. They include a considerable proportion of hornblende-schist, hornblende-biotite-schist, eclogite, highly felspathic pink granulitic gneiss, and also some serpentinous and other rocks, which may be of igneous origin. Mixed intimately with these varieties are bands of limestone, kyanite-schist, graphitic calc-silicate seams, and other rocks probably of sedimentary origin. The limestone makes unusually broad outcrops on the south side of the Gleann Beag near Corrary and Balyraid. It is also well seen at other places. Various new localities for the spinels, which occur in the limestone,† have been noticed.

* *Summary of Progress* for 1897, p. 36.

† See *Quart. Journ. Geol. Soc.*, vol. lv. (1899), p. 372. "On Spinel and Forsterite from the Glenelg Limestone." By C. T. Clough and W. Pollard.

District of Glenelg. (Mr. Clough.)

In the part of the Lewisian gneiss series between Rudha Mor and Rudha Buidhe a considerable proportion of pale acid gneiss which in hand-specimens greatly resembles some highly-altered felspathic grits, is so much mixed with hornblende-schist, in sill-like bands, lenticles and knots, and also with thin streaks and knots of pegmatitic material, that its true origin is difficult to determine. Some parts of it which can hardly be distinguished from the rest wind round the hornblende-schist lumps. There is likewise occasionally in these lumps a banded structure which ends rather sharply at their sides, as if the pale gneiss, or part of it, had once been in a state of flow since the formation of the banded structure. The intermixture of pegmatitic material is generally less on the coast between Eilean Chlamhuinn and Rudha Buidhe than it is further north-west, and at the same time the sedimentary aspect of the pale gneisses is greater. The pegmatite streaks between Rudha Mor and Rudha Caol, each rarely more than a few inches thick, are so numerous that they make up about half the bulk of considerable exposures of the rock. They consist chiefly of felspar, and often present a granulitic condition. In some parts of the district, particularly near the Moine-schist, between Eilean Mor and Ellanreoch and near Allt a' Ghearr Oir, broad bands of pink granulitic gneiss bear considerable resemblance to the thin granulitic pegmatites just referred to.

In most parts of the area in which the rocks occur that may belong to the Lewisian gneiss, the hornblende-schists and also the eclogites, take the form of sill-shaped sheets and lumps like small laccolites, rarely if ever showing clear evidence of intrusion. In some plaees, however, certain bands of hornblende-schist behave like dykes. Some of the rocks cut by these dykes are themselves also hornblende-schists, but of a more variable type, and generally coarser in grain than those of the dykes. The earlier hornblende-schists resemble in many respects certain members of the Lewisian gneiss which, when they were mapped in Sutherland were known in the Geological Survey by the name of "early basic rocks," while the later dykes of hornblende-schist more closely resemble foliated dykes of the well-known "Scourie" type. There are also one or two foliated dykes which consist chiefly of hornblende and biotite with little or no felspar. None of the dykes of hornblende-schist have yet been traced up to the edge of or into a Moine-schist outcrop, and therefore it is uncertain what their age may be in respect to the Moine-schist.

The most common rock in the Moine series is a granulitic siliceous schist. A more micaceous variety is mixed in thin parallel seams with the siliceous schist, and in some places forms the predominant rock in outcrops as much as 100 yards wide. Calcareous streaks and lenticles, an inch or two thick, are not uncommon. Thin streaks which contain a considerable proportion of magnetite may likewise be observed. As a rule the Moine rocks contain decidedly less epidote, whether in the form of strings or in small grains scattered through the matrix, District of Glenelg. (Mr. Clough.)

than the Lewisian gneiss rocks, but in a few places they include thin bands so rich in epidote grains as to acquire in consequence a pale yellow colour. Garnets usually abound in the more micaceous bands. One of these bands, extending between Eilean Mor and Rudha a' Chamais Bhain, is full in many places of thin plates of actinolite lying across the foliation and apparent bedding. Many of the more micaceous bands, for example, this band with the actinolites, and another about a mile south of Ellanreoch, occur next to rocks of the Lewisian gneiss type, but we cannot assert that they all do, and in many places the siliceous granulitic Moine schists are seen in direct contact with the gneiss rocks. It is noteworthy that up to the present time no kyanite has been observed in the micaceous schists which can with certainty be referred to the Moine series of this district, though the mineral is by no means rare in the Lewisian gneiss series.

The Moine rocks which occur in the west part of the area are almost free from pegmatitic material, while many of the Lewisian gneiss rocks of the same district, as already stated, largely consist of, or are permeated by, such material. This contrast, and the absence of bands of hornblende-schist, eclogite, &c., in the Moine rocks of the district, render it comparatively easy in most places to separate the two groups of rocks. In the more easterly districts the Moine rocks are often permeated through and through by pegmatites. The felspar of these pegmatites is not usually in a granulitic condition, but the quartz often is. In some places the pegmatites are as much as 10 or 20 yards wide; in others the pegmatitic material never appears in thick bands, but forms innumerable thin streaks and lenticles from about $\frac{1}{4}$ inch to 2 inches thick, and makes up perhaps half the mass of the rock. The Lewisian gneiss series, where it comes near these pegmatitic Moine rocks, also contains pegmatites of the same kind.

Both in the Lewisian gneiss and in the Moine rocks, occasional bands of biotite granite-gneiss cut the banding of the rocks in which they occur, and these granite-gneisses are also frequently "pegmatised." None of the bands yet observed exceeds 12 or 14 yards in breadth. Their foliation sometimes strikes against their margins and is in the same direction as the foliation in the rocks at their sides.

While the Moine rocks in the western part of the area contain no hornblende-schist, in the eastern part they not uncommonly include partially foliated hornblendic intrusions. Some of these intrusive bands are foliated parallel to their sides and cut both the banding and the foliation of the rocks in which they occur. They are more variable in composition, and generally coarser in grain, than the hornblende-schist dykes, already noticed, which may represent "Scourie dykes." They differ, too, from these inasmuch as they cut all the pegmatites with which they have been seen in contact. They are, therefore, probably of later date. Of three thin slices of these hornblendic intrusions which

District of Glenelg. (Mr. Clough.)

have been examined by Mr. Teall, he calls two biotite-amphibolite, and the third hornblende-biotite-schist.

As noticed in preceding years, the difference between the strike of the Moine rocks and that of the Lewisian gneiss rocks is rarely sufficiently great to admit of recognition in individual sections, but when exposures at a little distance from one another are compared, the Lewisian gneiss rocks which lie next the Moine rocks are often found at different places to present distinct types. At one locality, about one-third of a mile east-south-east of Rudha na h' Airde Beithe, there is also a distinct difference, amounting, perhaps, to about 12°, between the strikes of the two series of rocks. As the ground there is almost free from drift, in one section the Moine rocks are seen to be lying close to a certain band of hornblende-schist; but to the north-east a pink felspathic gneiss comes in between the Moine rock and the hornblende-schist, and gradually increases to a thickness of perhaps 40 or 50 feet. Still further in the same direction another band of hornblende-schist intervenes between the pink felspathic gneiss and the Moine-schists. These appearances, Mr. Clough believes, suggest either that the line between the Moine series and the Lewisian gneiss series here represents a thrust-line, or else that the former is younger than the latter and unconformable to it. Although good indications of stretching have been observed in all the rocks, no important thrust-line has been detected. During the different plications which have affected the district, the junction-line of the two series of rocks may, perhaps, have formed a line of special weakness, but this does not necessarily imply a visible displacement along it.

One of the most remarkable features in Mr. Clough's field-work last year was the discovery of a band,—perhaps never more that 20 feet thick—which has a considerable resemblance to a highly-altered conglomerate or boulder-bed. Most of the larger fragments in it consist of a pink felspathic gneiss, like that which forms a great part of the Lewisian gneiss series in the neighbourhood. The examination of the band is not yet concluded and it would be premature to speak confidently of its character. It lies at the junction of the two great groups of rock near Rudha na h' Airde Beithe.

The prevalent folds in the district are isoclinal, and have limbs hading east or east-south-east, but with frequent twists in the strike into east and west, or north-west and south-east directions. Where the strike is east and west the limbs of the folds hade south. The long extension of the Lewisian gneiss rocks up Gleann Beag, past Balyraid, is owing to the east and west strike in that district. On either side of the gneiss area in this part of the glen extensive outcrops of Moine schist also strike east and west. These can be traced westwards until they twist and acquire a nearly north and south strike. Examples of rocks with north-west and south-east strike occur on the south-east side of Druim Fada, rather more than half a-mile north of the head of the Dubh Lochain of Arnisdale, and on Sgurr na Laire Brice.

District of Glenegl. (Mr. Clough.) Other folds also occur in which the limbs hade in opposite directions. These less acute examples appear often to twist the limbs of isoclinal folds, and consequently to be of later date. For instance, two sets of folds are seen together on the north side of Eilean Tioran, and on the side of the new road nearly half a mile east of Rarsaidh. The earlier folds in both these places are isoclinal with limbs dipping west-north-west or north-west, while the later folds have axial planes dipping gently east. It seems quite possible that the present hade of the limbs of the early isoclines in these localities may have been acquired during the later folding, and that their original hade was east or south-east, like the hade of the limbs of most of the isoclines in the district.

An important group of faults crosses the district in a south-west—north-east direction, from a little west of Eilean Rarsaidh to near Strathchomair. The Moine rocks of Ben Sgriol are thus brought against the Lewisian gneiss rocks on their north-west side for a distance of about a mile and a half. Near Loch na h'Oidhche, the Moine rocks of the eastern part of Beinn a' Chapuill on the north-west side of the faults, come near the Moine rocks of Ben Sgriol on the south-east side. The former are, as already stated, in an excessively altered condition, and thoroughly permeated by pegmatitic material, but the latter are less altered and contain fewer pegmatites. It seems probable, therefore, that the effect of the faults has been either to cause a considerable downthrow to the south-east, or else a large lateral shift which has moved the outcrop of the rocks on the south-east side of the faults, so that they now lie considerably to the north-east of the corresponding rocks on the north-west side.

Since the folding and the production of foliation many intrusions of eruptive material have taken place, chiefly in the form of dykes. The intruded material consists of (1) quartz-felsite, camptonite, mica-trap, or other variety of lamprophyre; (2) basalt, dolerite, and a rock allied to trachyte. About half a mile east of Rudha Mor a small oval boss of gabbro has also been observed. The dykes included in Group 1 have a general east and west or west-south-west and east-north-east direction.* In a considerable number of the lamprophyre dykes apatite crystals are large enough to form a feature in hand-specimens, some of the crystals being about ¼ inch long.

Beauly District. (Mr. Hinxman). From his station at Beauly Mr. Hinxman has extended the mapping of the crystalline rocks through new areas of the counties of Inverness and Ross, lying between Strath Conan and Strath Glass. The greater part of the ground surveyed by him is occupied by the Highland schists, with their accompanying igneous intrusions, of which he has prepared the following notice:—

As in the regions already mapped to the south, the schistose rocks of the Beauly district can be separated into two chief

* It may be remarked that the general direction of the same class of dykes on the north side of the Glen More of Glenelg is west-north-west and east-south-east.

groups :—(1) The Muscovite-biotite-gneiss ; (2) the Moine schists ; representing respectively an originally argillaceous and siliceous series. There is now little doubt as to the sedimentary origin of these rocks, in which the original bedding planes, or colour-bands indicating differences in sedimentation, can still often be traced ; while in some of the finer-grained rocks lines suggestive of current-bedding can even be detected. Beauly District. (Mr. Hinxman.)

The Muscovite-Biotite-Gneiss varies in character from a tolerably fine-grained, flaggy, or schistose rock to a coarse, flakey gneiss with corrugated and crumpled folia. The coarser varieties contain much quartzo-felspathic material—possibly of segregative origin—disposed in eyes and strings along the planes of foliation. The rock is also characterized in many parts by large rounded flakes of muscovite lying at various angles to the bands of felted micas (the "spangle-schist" of Badenoch). Garnets are generally abundant, and often of large size. Considerable deposits of garnet sand are found in the streams flowing through areas where these rocks occur. Bands of kyanite-gneiss seen on the spur which runs east from Carn nam Pollan in the north-west corner of the Erchless Forest, lie near the edge of the main mass of muscovite-biotite-gneiss, and are met with also as narrow infolds with the Moine-schists a short distance from the eastern edge of that mass. The kyanite combines with quartz, garnet, and biotite, to form prism-shaped aggregations which project at different angles from the weathered surfaces. The kyanite is clearly a secondary mineral, and as there is apparently no mass of intrusive igneous rock at the surface in this locality, it is probable that the presence of this mineral is due to regional rather than to contact-metamorphism.

The Moine-schist group is composed of a series of fine-grained, thoroughly granulitic, schists and granulites. The relative amounts of quartz and mica (usually biotite) present in the rock continually varies, and the resulting gradation of one variety into another, makes it difficult to draw satisfactory boundary lines between the different types of rock in the field. An attempt, however, has been made to separate out the more siliceous bands—coloured as quartzite on the map—leaving a residuum of undifferentiated quartz-biotite-granulites, gneissose flagstones, and biotite-schists. These granulitic quartzites form lenticular masses with an irregular outline in the gneissose flagstones north-west of Struy, and are also largely developed about Scatwell in Strath Conan. On the summit and slopes of Beinn a Bh'ach Ard several lenticular bands of quartzite, infolded with the coarse muscovite-biotite-gneiss, differ somewhat from the ordinary type. They are highly siliceous, contain little or no mica or felspar, and weather with a snow-white crust. The structure of the rock is coarsely granular and highly crystalline, and very similar to that produced in the siliceous Moine-schists of N.E. Sutherland by igneous intrusions. The rock has the appearance of being in an advanced stage of thermo-metamorphism, and its present condition may possibly be referable to the same causes which have produced the

Beauly District. (Mr. Hinxman.)

extreme metamorphism of the coarse garnetiferous muscovite-biotite-gneiss and the kyanitic bands which are found in its immediate neighbourhood. With regard to the structure of the ground over which these rocks have been recently mapped, it may be remarked that the schists of Strath Glass are arranged in a series of folds, whose long axes run in a N.N.E.-S.S.W. direction. The folding is almost invariably isoclinal, both limbs of the fold being inclined to the south of east. The quartz-granulites and flagstones that appear from beneath the old red conglomerate W. of Aigas are rapidly folded at high angles, and here, as in several other localities cleavage-planes passing through these minor folds can be detected. These rocks contain thin seams and bands of the muscovite-biotite-gneiss, which is brought in by a major fold at Craigdubh and extends in a line of irregularly lenticular masses northwards to Glen Goibhre. The gneissose flagstones again appear on the further side of this fold and alternate with numerous infolds of granulitic quartzite. These are followed by the main outcrop of the coarse muscovite-biotite-gneiss which crosses the river Farrar at Culligran Falls, and continues northward, forming the high mountain ridge of Beinn a' Bh'ach Ard. The western edge of this belt of gneiss has not yet been mapped, but there is good reason to suppose that it is succeeded by a series of highly siliceous rocks. In the Strath Conan and Glen Orrin district the long axes of the folds seem to be less regular in their disposition and the pitch more variable; so that the boundary-lines will, no doubt, prove to be more complicated than in the region just described.

The only fault of importance in this area is that which has determined the strong line of feature which runs N.N.E. from Erchless Castle along the course of the Allt Mhòr, and the deep hollow in which lies Lochan Fada and the stream at its head. The line of this fault is approximately parallel to the strike of the schists and does not produce any recognisable displacement; but at various points along its course, and especially in the upper part of the stream flowing into Lochan Fada, the rocks are much crushed and brecciated. Its course to the north of Urchany is concealed by peat and drift, but is possibly continued in the line of dislocation which crosses the River Orrin four miles further north, and throws down the Old Red Conglomerate against the schists at Muirton Falls.

The oldest intrusive rocks observed in the Beauly district appear to be a set of bands or sills of amphibolite and hornblende-schist, more or less lenticular in character, which occur on two horizons in the Moine-schists. Their trend is approximately parallel to the general strike of the schists, and the foliation-planes of the latter are continued into the amphibolite. These divisional planes are, however, constantly crossed by the edge of the basic rock, the marginal portion of which is invariably finer-grained and more schistose than the centre. The coarser bands are often highly garnetiferous, and show a tendency to *augen*-structure in the hornblende crystals. These bands may hence be regarded as representing masses of basic igneous material intruded into the Moine sediments before the development of their present schistose structure. The most easterly group of them is associated with the gneissose flagstones of Strath Glass. A second group has been mapped about Scatwell, in Strath Conan, among the quartzites and quartz-granulites of the siliceous zone. They appear to be more numerous here than in Strath Glass, but in both localities the repetition is probably in a large degree due to rapid folding. A particular sill can often be traced round the end of a fold, and it is possible that at each horizon the number of original intrusions may have been small.

Beauly District. (Mr. Hinxman.)

The acid intrusions in Strath Glass take the form of veins or sills of granite, pegmatite, and felsite. These appear to be later than the movements, which produced schistosity in the Moine-schists, and, except in a very few instances, do not exhibit any parallel structure. The veins of granite and pegmatite are most abundant in the ground between Erchless Castle and Farley Wood, where they form a belt of parallel intrusions running east-north-east, and cutting obliquely across the strike of the schists and hornblende-sills. The smaller branch veins which they give out, often, however, follow the foliation planes of the schists as lines of least resistance. These intrusions, which often measure 20 or 30 yards in breadth, are coarsely crystalline and generally more or less pegmatitic in structure. They are composed of abundant oligoclase, alkali-felspar, quartz, and muscovite. Vermicular pegmatite has been detected under the microscope in a specimen taken from a vein north-north-east of Urchany. The veins here described show no foliation; but a single vein, similar to them in composition, but with marked flaser-structure, occurs at Creag Ard Bheag, 1¼ miles north of Erchless Castle. A sill of compact, very hard, brick-red felsite, with the same east-north-east trend, has been traced continuously for nearly 3 miles through the Moine-schists to the north of Struy.

A new point in the work of the past year has been the discovery of a considerable area of solid granite in Glen Orrin, about 4 miles west of Fairburn House. The appearance of numerous granite veins in the schists of Glen Orrin heralds the on-coming of the main mass, which forms an irregular area about a mile and a-half in extent, on the north side of the river. The rock is a medium-grained white or grey granite, wherein the mica, which is not abundant, is usually biotite, muscovite being also sometimes present in small quantity. Near the southern margin of the mass the amount of mica greatly decreases, and the normal granite appears to pass into a border of aplite. A typical specimen of the rock examined under the microscope by Mr. Teall, is described by him as composed of oligoclase, alkali-felspar, quartz, biotite, and muscovite (scarce). The alkali-felspar shows traces of microcline-structure, and vermicular pegmatite is present. Though there is sometimes a tendency towards a parallel arrangement or orientation of the flakes of mica, the rock cannot be said to be foliated.

Beauly District. (Mr. Hinxman.)

The junction of the rock with the surrounding schists is, as is usual with the intrusive masses of the central Highlands, exceedingly complex and irregular. The granite is fringed with innumerable apophyses and detached veins traversing the schist, while fragments of the latter are thickly scattered as inclusions within and near the margin of the mass. Neither in the main body of the rock nor in its apophyses is there any appearance of a chilled edge, the rock in the smaller veins being as coarsely crystalline as in the interior of the mass. It may be further observed that the trend of the boundary of the granite, and of its fringing veins, as well as the disposition of the inclusions, has a marked tendency to conform to the strike of the surrounding schists. The inference may be deduced that the intrusion of the granite may not have been accompanied by any great disruption of the rocks, but that it rather took the form of a sill, which has made its way more or less along the planes of schistosity. The absence of any distinct foliation in the rock, even in its smallest apophyses, seems to differentiate the Glen Orrin Granite from the granites of East Sutherland, in which foliation of the margin and offshoots is a marked feature. Not improbably this mass may belong to the period of intrusion of the newer granites of Strathspey, to which it bears a considerable resemblance in character and composition.

A comparison of the Glen Orrin granite with the granite and pegmatite of Strathglass, above described, shows a striking resemblance in composition, and even in minute structure between the two rocks, the Strathglass pegmatites being slightly the more acid of the two. It seems therefore reasonable to assume that these veins of acid material may possibly be due to a later phase of the intrusion of the same magma.

DALRADIAN OR YOUNGER SCHISTS OF THE SCOTTISH HIGHLANDS.

For some years past the Geological Survey, while prosecuting the mapping simultaneously in the north-western counties and in the central, eastern, and southern Highlands, has refrained from any attempt to correlate the great series of schists of the region to the west of the line of the Great Glen with those to the east of that line. It has long been abundantly evident that in the north-eastern, central, and south-western Highlands the schists represent a great succession of truly sedimentary rocks. The age of these rocks and the date of their metamorphism remain still to be ascertained, though some progress towards the solution of these problems has already been made. But there can be no doubt that the phyllites, quartzites, grits, conglomerates, and limestones which extend from the shores of Elgin, Banff, and Aberdeen to those of Islay and Jura have had a sedimentary origin, and may yet find a definite place either among pre-Cambrian or post-Cambrian formations. The occurrence among them of igneous rocks which have shared in their metamorphism, and of later eruptive masses which have not been touched by the alteration, has been recognised not to affect that fundamental conclusion, even though in some places granitisation and foliation have been carried so far that it may be difficult to decide where a line should be drawn between what was originally eruptive and what was originally sedimentary material.

To the west of the line of the Great Glen, however, another kind of problem arose for consideration. In Sutherland and Ross the rocks that were found to have been pushed by vast overthrusts above the highest visible Cambrian limestones presented structures of extreme complexity, and for a time little light was obtainable as to their true succession and probable origin. Even now, after some years of careful scrutiny, it cannot be said that we have advanced far towards the removal of the difficulties with which any attempted interpretation of the ground is at once confronted. But there is a general agreement among the various officers who have been engaged in the research that the crystalline schists east of the great thrust-plane that destroys the continuity of the Cambrian succession of strata, include slices of the old or Lewisian gneiss, which have been dragged up from the east, and have been thrust westward towards the great rampart of unmoved ground which extends from Cape Wrath to Applecross. Some of these slices are of vast size. One, of which only a portion has yet been mapped, in the south of Ross-shire, must far exceed fifty square miles in area, and must be several thousand feet in thickness. These moved masses have had new structures developed in them by the mechanical deformation to which they have been subjected, but the traces of their original characters as part of the Lewisian gneiss have not been wholly effaced.

Much more difficulty has been encountered in the endeavour to trace the structure and history of the vast mass of crystalline granulitic schists, which have been grouped under the general name of "Moine-schists." Probably various groups of rock have been crushed and metamorphosed to make up these schists. As the mapping has advanced southwards, evidence has increased that much of the Moine-schists consists of material that was laid down as sediment. Probably the Torridon sandstone was largely drawn upon in the process of the manufacture of these schists, and there may also have been Cambrian or even later sediments which underwent the same conversion into a foliated crystalline condition.

The recent progress of the Survey in the Central Highlands and in Eastern Ross-shire has shown that the peculiar granulitic structure and composition of the Moine-schists, with their traces of colour-banding and even false-bedding, and their intercalated bands of muscovite-biotite gneiss, are precisely reproduced among the rocks of the Central Highlands. The two types of quartzose-flagstones and banded muscovite-biotite gneisses recur under similar conditions in Sutherland and Ross and in Inverness and Perth. The one suggests that they were originally sandstones, grits, or arkoses, while the other may have been of a more complex and argillaceous composition.

How far this identity of petrographical character can be taken to imply geological synchronism may be matter for discussion. Without at present attempting to decide this question, we may, in the meanwhile, conveniently retain the provisional name "Dalradian" for the younger schists of the region east of the line of the Great Glen. If it shall be shown, as seems probable, that the Moine-schists of the north-west pass into and form part of the Dalradian series of the Central Highlands, a step will be gained towards the solution of the problem as to the age and origin of the schists of both regions. We know that the Moine-schists of the north-west have been pushed into their present positions, and probably have acquired their present crystalline characters since Cambrian time. The Survey has detected bands of what appear to be Arenig rocks wedged in among the schists and grits along the southern border of the Highlands. It thus seems possible that the plication and metamorphism of the Highland schists were not concluded until Lower Silurian time, and that these schists may have originally consisted partly of older Palæozoic as well as Pre-Cambrian sediments.

Aberdeenshire.

Bynack District. Deeside. (Mr. Barrow.)

The area surveyed last year by Mr. Barrow lay around the Bynack, near the western source of the Dee. The mapping of the basin of Deeside is now complete, with the exception of a few small and rather inaccessible patches. For convenience of description the Bynack district may be divided into two parts, separated by a great fault—a continuation of the Glen Tilt fault, which has now been proved to continue far into Aberdeenshire. Not only does this line of dislocation correspond for a great distance with a marked dissimilarity in composition of the rocks on either side of it, but to a considerable extent it also coincides with a line marking a rapid decrease in their metamorphism.

The area west of the fault is composed entirely of crystalline gneisses, varying in tint from rather dark grey to nearly white, the change in tint being mainly due to the varying amount of brown mica present. By far the greater part of the series is highly quartzose, and possesses a typical mode of weathering. In the streams these rocks form massive pavements, admirably shown in the bed of the Geldie above its junction with the Dee. On the hillsides, free from drift, they form long ribs or terrace-like lines. Both in their dominant grey tint and in their mode of weathering they are substantially identical with the grey Moine-schists or gneisses of the north-west Highlands. Some subordinate bands of highly micaceous gneiss associated with them are characterised by a softer mode of weathering than the angular forms of the rest of the rocks. These bands alone contain abundant white mica; in most of the others this mineral is con-

Bynack District, Deeside. (Mr. Barrow.)

spicuously absent. As in other similar areas, this absence of white mica is accompanied by a total absence of the lenticular or overthrust structure, so characteristic of nearly all the true schists in the southern Highlands that have resulted from the alteration of sedimentary rocks. The perfect parallelism of the bands of different coloured material in many specimens is no doubt original bedding. It strongly recalls the curious intensification of the bedding produced in many banded rocks by contact or thermometamorphism. The splitting faces are often coated with brown mica, which imparts a bronzy aspect to the rock. From the highly quartzose nature of these gneisses alumina-silicates are not common in them, although with a hand-lens minute garnets can often be made out, which possess the clear port-wine colour shown by the same mineral in the sillimanite-bearing rocks close to the Galloway granite. These little garnets are most abundant in a white rock in which the quartz-grains are embedded in a paste of white felspar. By the aid of this rock, which can be easily recognised, the great spread of gneisses is seen to result from the complicated folding and subsequent metamorphism of a comparatively thin group of strata.

The microscopic examination of the gneisses shows that some of them possess remarkable structures. In addition to the common granular structure, from which they are usually classed as granulites, they present two others. The one which can easily be made out with a hand-lens, and may be conveniently called quartz-bleb structure, has the quartz embedded in a matrix of felspar, which often extinguishes in fairly large sheets. The other can only be made out with the aid of a microscope, and may be termed "pseudo-igneous," for structurally some of the rocks of this type are identical with many granites. They contain abundant micro-pegmatite of the vermicular type, and are specially rich in alkali-felspar, mostly potash. It may be that the original presence of the potash-felspar gave rise to these structures so characteristic of rocks that have been in a state of actual fusion. The large proportion of potash may have enabled these rocks to attain a state at least approaching pasty fusion, while the other bands in which potash is not so abundantly present were unable to do so. In the Southern Highlands, rocks possessing such igneous structures have been met with at only one other locality among the lowest known rocks in Dee-side, where again the rock is rich in potash-felspar. A striking feature of the whole area west of the great fault is the singular uniformity of the metamorphism. The rocks about Loch Tilt are just as highly crystalline as those six miles off, close to the edge of the great mass of the Cairngorm granite.

Over the entire district pegmatite occurs in two forms, either as little sills, which are of local occurrence, or as little dykes which, while never absent over any large area, tend to form a perfect network in the districts where they are specially abundant. The sills have a pronounced white colour, and are composed of *augen* of white potash-felspar, surrounded by

Bynack District, Deeside. (Mr. Barrow.)

quartz-felspar material. With the latter muscovite, and at times garnet, are abundantly associated, and the whole rock possesses an intensely "flaser" aspect, not a vestige of which is seen in the newer granites of this region. The small dykes have a very distinct aspect. They often possess an outer margin of coarsely crystalline felspar, within which is a finer and greyer material. The grey colour of this inner material is due to the presence of brown mica. White mica and garnet are also present, but this part of the dyke is of very variable composition. These rocks possess the intense hardness of the similar dykes of the Cairnshee magma so abundant in the Banchory area, and there can be little doubt that these pegmatites represent a portion of that intrusion. The field-work of previous years has shown that the Cairnshee magma reaches the surface along a belt of ground stretching from the coast at Aberdeen, where it is specially abundant, to a point some distance above Aboyne, and its occurrence in Upper Dee-side in a direct line with the belt already referred to, serves to confirm the conclusions arrived at in the case of the muscovite-biotite-gneiss of the area to the south. Here the pegmatites of the Cairnshee type continue in a gradually narrowing belt for at least 40 miles, though the granite itself never reaches the surface. These phenomena accord with those recorded from the study of the Brittany Granites, by Dr. Barrois, who has shown that there is a long and a short axis to a series of granite intrusions. Along the long axis the granite is met with repeatedly, and even when when it sinks beneath the surface its presence at no great depth is often shown by the alteration of the overlying rocks. In the direction of the short axis, the metamorphism steadily decreases as a rule, and further exposures of the granite are rarely met with. The older granites exactly reproduce these conditions in the great distances through which the granites make their presence evident by their pegmatites, and the extreme slowness with which the metamorphism decreases along these belts. In a direction at right angles to the longer axis the pegmatites usually disappear rather rapidly, and a steady decrease in metamorphism is well marked. Around the head of the western branches of the Dee the pegmatites are specially abundant along a belt stretching from a point a little west of Loch Tilt to the Chest of Dee, and running roughly parallel to the line of decreasing metamorphism. Where they disappear to the north and north-east is not yet exactly known, but to the east and south-east they rarely cross the stream flowing from the head of the Tilt to join the Dee at its junction with the Geldie. The line marking the limit of uprise of the pegmatites corresponds exactly with the line of rapid decrease to the east and south-east in the crystallisation of the schists, and thus while the highly crystalline character of these Moine-gneisses has not been induced by the newer granite, its connection with the pegmatites seems specially clear. That these pegmatites do not belong to that granite may be inferred from the fact that not only do they not increase in number towards the great intrusive

Bynack District, Deeside. (Mr. Barrow.)

mass, but on the contrary frequently decrease. as may be clearly seen from the sections in and about the bed of the Dee. The pegmatites are specially numerous near the Chest of Dee and for some distance further up the river. They then decrease in number, and are rare near the granite. The actual junction of the Moine-gneisses and the Cairngorm granite lies in the bed of the Dee, and the marginal phenomena of the granite can be clearly studied. The hard pegmatites, if present at all, are there represented by two minute veins in the whole section.

At the southern end of this section in the Dee the pegmatitic material that really does belong to the newer intrusions may be seen. It consists of a red friable material, of variable composition, but always rich in potash-felspar, together with quartz, garnet, and muscovite. Occasionally it is pale in colour and sometimes must be broken before it will disclose its true nature. In addition to its friability, it possesses the distinctive character that no large block is ever free from drusy cavities. On the margins of these cavities the rock is coarsely crystalline, and the minerals have some of their crystalline faces more or less well developed. It is in such cavities that the well-known "Cairngorms" occur. This drusy character, everywhere present, is seen in the veins in the granite about Loch Muick, on the margins of the Ballater mass, and on the border of the Cairngorm granite in the Invercauld Forest. In the last-named ground this material also occurs well away from the main mass of the granite, where, having no longer a high temperature environment, it consolidated in fine-grained garnet-bearing dykes. The composition of these rocks about the head of the Dee makes it evident they must be newer than the main mass of the Cairngorm granite. They frequently cut that rock. It is needless to state that the hard white pegmatites never occur within the granite. A remarkable feature of the Cairngorm mass in this district, as in others, is the fine grain of many of the intrusions within it. Indeed, when free from druses, they are mostly fine-grained. In this respect there is a remarkable contrast between the small acid intrusions in the granite and those in the diorite. Similar material, occurring even on the outer edges of the diorite, is invariably coarsely crystalline.

In the area east of the great fault above referred to, surveyed by Mr. Barrow, the Moine-gneisses are abruptly truncated by the dislocation, and with one exception an entirely different set of rocks lies on the east side. The observer suddenly enters upon the domain of the well-known Highland quartzite and limestone. Between these two members of the series a lenticle of altered sedimentary rocks of very variable composition and thickness is observable. In some places, however, though rarely in Upper Deeside, the limestone lies in direct contact with the quartzite, as so often happens in the Ben-y-Glo area. The lithological variations of this intercalated lenticle forcibly remind us of those so frequent and conspicuous at the base of any of the limestones of the Yoredale

Bynack District, Deeside. (Mr. Barrow.)

series. As in that Carboniferous succession, there may originally have been a shale, a sandy shale, or a sandstone at the base of the Highland limestone. The mapping has shown that, on the whole, the most common material was probably a dark shale containing a small band of dark, somewhat carbonaceous limestone a foot or so thick. The intense plication which this lenticle has undergone gives the deceptive impression at first of a thick mass of strata, but it has been known for some years that the dark shale was really a thin band. The repeated folding and reduplication of the little dark limestone enables this structure to be clearly determined, as the Moine-gneisses already noticed are shown by the incessant folding of the curious white garnet-bearing rock to have acquired their apparent thickness by intense plication.

The great fault that gives to Glen Tilt the aspect of a huge furrow driven by a gigantic plough is not an isolated line of fracture. It is simply the master-fault of a great series. This series of parallel faults is crossed by a set of minor dislocations, which can rarely be traced far, though so great is their number and so potent have been the effects of their production, that in special localities it is almost impossible to find a specimen of rock not more or less decomposed by shattering. The main lines of fracture are often taken by dyke-like intrusions of newer granite material which occasionally attain the breadth of nearly a mile. The intrusive material may be entirely unaffected by the fault, all movement having ceased before consolidation; it may show a foliated or flow structure due to final movement during consolidation; or it may be actually crushed by post-consolidation movement. The last phenomenon is rarer than might be supposed, and is always confined to the margins of the dyke or special thin bands within it. Microscopic sections prove that specimens showing flow-structure and others showing post-consolidation crush may be found within a foot of one another. Indeed, all three phases may be at times met with in the same dyke at different parts of its course. That these faults are in the main older than the granite in them is obvious; it is equally clear that they are post-metamorphic; for not only do they completely destroy the crystallisation of the unbroken rocks, but, in addition, they bring the broken and decomposed material into a specially favourable condition for being acted upon by the intrusions. From an examination of thin slides made from a decomposed garnet-schist along the side of one of these faults in and about which the newer igneous intrusions were specially abundant, it appears that a new, very fine criss-cross micaceous structure has been developed, closely resembling that produced by the action of the great whin-sill in the North of England. Though a purely contact-structure, it bears no resemblance to the coarsely crystalline structure of the "hornfels" of the district; which is both cut by these faults and contains numerous intrusions of similar material. The more the evidence afforded by these dykes is examined the more clear is it, in Mr. Barrow's opinion, that the metamorphism of the whole region took place before the uprise of the granite, any local small alteration that may occur being at the expense of this older crystallisation and of a very low type.

After leaving the upper Dee-side district, MR. BARROW and MR. CUNNINGHAM-CRAIG made an effort to finish the field-work in the district about Balmoral. This, however, they were unable to do as the ground proved to be of a more complicated nature than had been anticipated. Instead of a simple mass of normal granitite, the intrusions of the age of the newer granite have proved extremely variable and complicated. They range from a distinctly basic diorite to a pale acid rock rich in potash-felspar. The latter occurs chiefly in small patches and veins on the margins of the diorite. At times the two rocks are sharply distinct; at others there is an insensible passage from one to the other. Balmoral District. (Mr. Barrow.)

Standing on any elevated point outside the main mass of the Lochnagar Granite, this intrusion is seen to rise abruptly from the lower ground generally supposed to be composed of metamorphic rocks. Detailed mapping has now shown that close to the foot of the rising ground lies a series of patches of diorite of all sizes, which no doubt indicates the top of a large mass, more or less continuous under ground. Where these break through the metamorphic rocks the diorite is often fine in grain. The conviction from the field-work grows that fineness or coarseness of texture in such cases is largely due to the proximity to, or depth below, the original top of the mass.

The cordierite-hornfels has proved to possess a greatly wider extension than was formerly supposed. Exceptionally large masses of it occur on the north side of the Dee, about Inver. The actual tracing out of this type of alteration shows that, while often found close to the granite, it also often occurs at a distance of at least three miles from any large mass of that rock, the highly aluminous rocks that intervene being intensely foliated sillimanite gneiss.

The district of Braemar, in which MR. CUNNINGHAM-CRAIG has been engaged for several years, was revisited by him last year, and he spent rather more than three months there, partly in the western part of the Glen Ey Forest, partly further north among the Cairngorm Mountains, and partly in the Forest of Balmoral. But the necessity of completing some scattered outstanding areas in the southern Highlands required him to pass the early and the late part of the working season in the counties of Perth, Stirling, and Dumbarton. He has supplied the following notes regarding the chief results of his recent field-work in the Braemar district:— Braemar District. (Mr. Cunningham-Craig.)

While generally confirming the work of previous years, which has been described in former *Summaries of Progress*, MR. CUNNINGHAM-CRAIG, in the course of mapping the black schist, limestone, and quartzite to the west of Glen Ey, has obtained new evidence bearing on points of special interest in the geology of the district. Among these the question of the order of succession of

Braemar District. (Mr. Cunningham-Craig.)

the rocks may be specially mentioned. In the *Summary* for 1897 (page 54), reference was made to indications of considerable local contemporaneous erosion and deposit between the limestone and the quartzite, and, though the order of succession was not definitely stated, attention was called to the fact that the bed of limestone nearest to the quartzite is occasionally absent, as indicated by the sections near the head of Glen Ey. The adjoining ground to the northward has now been surveyed, and the evidence, while fully bearing out what has already been stated, is much clearer and more definite. The band of limestone which appears nearest the quartzite is there, as in Glen Ey, a pure saccharoid marble, which is occasionally almost in actual contact with the marginal beds of the quartzite, while, where it is absent, the quartzite comes in contact with certain variable schists often observable between the saccharoid bed and the less pure or "ribbed" limestone beds. These schists are frequently associated or intercalated with the latter. In sections in Coire Bhourneasg the quartzite, with bands of the "Coire Neid beds," seems to transgress the bedding of the variable schists, which occasionally intervene between it and the limestone, and in one or two instances it may be seen striking obliquely at and transgressing the beds of the limestone. Further down Glen Connie the quartzite lies in contact with the black schist, the limestone not being present, though in Coire Bhourneasg it occurs in a thick folded mass between the two rocks. In the Allt an t'Sionnaich specimens of what may be described as a calcareous quartzite show the bedding and banding of the quartzite, but contain a considerable quantity of carbonate of lime; the rock may have been originally a calcareous sandstone, formed by the deposition of arenaceous material contemporaneously with the erosion of a limestone.

Observations of the "pitch" of the folding give confirmatory evidence. At the head of Coire Bhourneasg a folded mass of limestone is seen distinctly "pitching" under a belt of biotite-schist, and the latter in turn "pitches" beneath the rusty "Coire Neid beds," *i.e.*, the lower part of the quartzite, which distinctly surmounts them in this section. From these data it may be inferred that the order of succession in this district is as follows in descending order:—

1. Quartzite—Rusty and thin-bedded "Coire Neid beds" (not always present).
2. Local unconformability.
3. Variable schists (frequently absent).
4. Limestone.
5. Black schist.

The black schist, as typically developed in the district, must be distinguished from the fine biotite-schists which frequently appear above the limestone and often closely resemble the former rock. This distinction has been noted on the field-maps wherever possible, but as the limestone appears to be developed in lenticular beds and is occasionally absent, especially where the black schist attains its greatest development, confusion between the two horizons is liable to arise. Braemar District. (Mr. Cunningham-Craig.)

In this connection the fact may be recalled that the conglomeratic deposit discovered in Corriemulzie glen (*Summary of Progress* for 1897, page 53), and considered as possibly representing the "boulder bed," contains numerous subangular and rounded pebbles of the typical fine purple biotite-schist and other variegated schists which have been frequently observed between the "ribbed" limestone and the saccharoid marble band. The horizon of this conglomeratic deposit lies between the quartzite and limestone, and the bed, though never well exposed, occurs actually on the margin of the quartzite.

In the northern part of Glen Connie, and in the ground between that valley and the Dee, flaggy and granulitic biotite-gneisses form the country-rock, to the exclusion of all other deposits, with the exception of bands of quartzite, which become more frequent and more massive to the southward. In this district, and in the area of metamorphic rocks north of the Dee, surveyed during the past season, the folding is flattened, and shearing movements have been relatively severe. North of the Dee, in this series of granulitic gneisses, zones or belts, consisting wholly or in great part of quartzite, can be mapped out along the hillsides for considerable distances. No evidence of unconformability between the bands of quartzite and flaggy gneisses has been detected, and so far the evidence bears out the suggestion (*Summary* for 1898, page 24) that these rocks may be the equivalent of the granulitic gneisses and quartzite of the Banffshire series, though they differ considerably from them in lithological characters.

West of the entrance to Glen Ey a felted muscovite-biotite-schist, conspicuous on Creag a' Chait among the flaggy biotite-gneisses, resembles closely the felted schist with quartz and albite segregations, described in the *Summary* for 1897 (p. 53), as occasionally appearing between quartzite and limestone. The same rock may be seen in the Ey section, south of the Colonel's Bed, in contact with a much sheared greenish amphibole-schist, which may be a crushed epidiorite, but is more probably the impure edge of a calcareous band, sheared and affected by thermometamorphism.

The western margin of the diorite, which has now been mapped, follows the eastern side of Glen Derry, where it comes in contact with the granite, and is pierced by several minor intrusions and tongues of granitic and pegmatitic material. In the course of the season, 20 square miles of the Cairngorm granite were surveyed, but nothing of importance can be added to what has already been published (*Summary* for 1898, pp. 25 *et seq.*) with regard to that intrusion. Variations in the texture of the rock are frequent, but, as a rule, without any clearly defined boundaries. Thin quartz-reefs and crush-reefs are noticeable, especially on the high ground; zones in which these are common may be seen near the summit of Beinn Muich Dhui. The

Braemar District. (Mr. Cunningham-Craig.)

crush-veins have probably originated during movements in the granite mass, after its upper part had consolidated. The latest phase of the residual material, which has crystallised in cavities and in fissure-veins, caused by the contraction of the solidifying mass of granite, may be described as a muscovite-pegmatite. It is sometimes very coarse, and shows frequent graphic intergrowths of quartz and orthoclase.

About 17 square miles of the Lochnagar granite mass have also been surveyed. The rock forming this intrusion, though generally similar to the Cairngorm rock, presents many minor points of difference. It is never so coarse in grain as the main mass of the northern intrusion, and never attains on weathering such a deep red colour. Biotite is in some cases more conspicuous in it, while the rock apparently contains more oligoclase, and is, in consequence, hardly so acid in character. The residual material in veins is, as a rule, less coarsely crystalline, and also less acid in composition than in the Cairngorn mass, biotite being frequently present.

In the area west of Glen Ey, large irregular intrusions of a remarkable porphyritic rock are exposed, which can be traced to the Perthshire border. The principal intrusion attains a length of three miles, with a breadth varying from one-third to two-thirds of a mile, while other masses of lesser area, together with small dykes and sills of similar material appear in burn-sections. The largest mass stretches from the ridge north-west of Allt-an-Odhar shieling, over the top of Cairn Creagach, and along the ridge between Glen Connie and Allt Sionnaich in a north-north-easterly direction to the hill-top west of Aucherrie, and is never observed at a lower level than 1,600 ft. At several points this intrusion has vertical or highly-inclined margins, but it spreads out in a sill-like mass over the hill-tops, and is capped in one instance by a cake of metamorphic rocks. A similar but smaller mass of rock occurs on the westward side of a tributary of the Connie, at a distance of 300 yards from the main intrusion, while the same rock appears on Geal Charn on the Perthshire boundary as an extension of masses mapped in Perthshire some years ago by Mr. Dakyns. The main mass evidently acts as a somewhat irregular sill, as is shown by its mode of occurrence and form, especially the V-shape of the margin in the Allt Sionnaich glen. The material of these intrusions presents several differences from the other igneous rocks of the area. The rock is essentially porphyritic, and usually consists of phenocrysts of plagioclase, quartz, and biotite in a matrix which varies from holocrystalline to cryptocrystalline.

Mr. Teall describes one of the coarser-grained specimens (8498) as containing "idiomorphic plagioclase (oligoclase-labradorite), orthoclase (scarce), quartz, biotite (more or less replaced by chlorite), and iron ores. The rock is intermediate between a granite and a porphyrite; but rather more allied to the former that the latter." Another specimen, taken from the heart of the mass, contains a little microcline, and interstitial micropegmatite. It is thus seen that these intrusions are more basic than the normal acid intrusions of the Braemar area, but resemble on the one hand the Glen Tromie porphyry described by Mr. HINXMAN, and on the other hand the Newbiggin dyke described by MR. BARROW. It is remarkable that, although in the centres of these intrusions the structure approaches that of a granite, the rock being holocrystalline throughout with no groundmass, in the marginal areas a groundmass is well developed, and frequently quite compact in appearance, while the phenocrysts maintain their normal size and appearance in it, with rather more distinctly idiomorphic outlines. Thus it is evident that the intrusion of these rocks has taken place when the surrounding rocks were at a comparatively low temperature and that the margins of the mass consolidated more quickly than the centre. The difference of texture is especially noticeable where the intrusions have a sill-like form, while where a vertical margin is observed, the effects of rapid cooling are not so conspicuous.

Braemar District. (Mr Cunningham-Craig.)

Small dykes and irregular intrusions of the more quickly cooled variety of the granitoid porphyrite are observed in the Allt Cristie Mor and Allt Cristie Beg to the northward of the main masses, and it is remarkable that in these instances the igneous rock only appears at a comparatively low level. It is not clear how far the larger masses have been intruded along previously existing fault-lines. One of the masses upon the Perthshire border (Geal Charn) may have been so intruded, and this is also probably true of an ill-defined mass of finer and more acid material (the normal quartz-porphyry of the Braemar area), which appears on the ridge north-west of Glen Connie; but the main intrusion does not appear to follow any line of dislocation. On the contrary, the igneous rock has been crushed and shattered by fault-movements in at least two localities, viz., on the south-east side of Glen Connie and in the lower part of the section in Allt Sionnaich. MR. TEALL describes a specimen (8501) from the former locality as "a crushed igneous rock. The original rock was probably similar to those described above (8498)." The quickly-cooled edge of part of the large intrusion is described as follows by MR. TEALL: "8502, Phenocrysts of plagioclase, corroded quartz, hornblende, and biotite, in a micro- or crypto-crystalline matrix. Carbonates, chlorite, and epidote as accessories. Quartz-porphyrite."

The more acid of the lamprophyre sills and dykes—fine-grained, dark-coloured rocks, containing phenocrysts of red plagioclase, and occasionally hornblende—are frequently found in the neighbourhood of the granitoid porphyrite intrusions, but no inference of a common origin can be adduced from this association. Included in the main mass, however, on the north side of Allt Sionnaich occurs a patch of basic diorite, of which MR. TEALL supplies the following description: "Brown hornblende, augite and altered plagioclase, with apatite and iron ores as original, and carbonates and chlorite (after augite) as secondary accessories; augite-diorite." This rock is probably of earlier date than the porphyrite.

Braemar District. (Mr. Cunningham-Craig.)

The latest phase of these remarkable porphyritic intrusions is seen in fine quartz-porphyries which are very noticeable near the edge of the larger masses, and which radiate out from the margins. These resemble in all respects the quartz-porphyries of the Braemar area, having invariably a fine micro- or crypto-crystalline ground mass, containing idiomorphic phenocrysts of quartz and potash felspar. In some cases, where these late intrusions being small very quickly cooled, the rock is a fine felstone with a well-marked banding due to flow.

Taking the whole area into consideration, we have a belt of country characterised by the presence of intrusions of a composition intermediate between the lamprophyres and the acid granites and quartz-porphyries: in some cases the intrusion may have taken place along fault-lines, but the rocks have also been considerably affected since their consolidation by the north-east to south-west fault-movements. In the northern part of the district the igneous rock has not reached to such high levels on the present surface of the ground, as in the southern part. Lastly, the latest and most acid phase of the injected material is indistinguishable from the Braemar quartz-porphyries, while the larger masses of the intermediate rock appear to be of more recent date than the diorites and some of the lamprophyres. From these facts Mr. Cunningham-Craig infers that he is dealing here with a phase of the newer granite magma, intruded at a locally intermediate stage in the differentiation, which has given rise to basic diorite and lamprophyres, highly acid granites and quartz-porphyries in contiguous areas. The intrusion has taken place while the surrounding rocks were at a comparatively low temperature, as evinced by the fine-grained chilled margins. The source of the igneous material may be looked for in an underlying magma, the existence of which has been previously suggested by the evidence in neighbouring areas. As the latest of the granitoid porphyrite intrusions have been shown to resemble closely the quartz-porphyries associated with the Auchindryne granite, it may be assumed that the latter intrusions are somewhat later in date than the granitoid porphyrites—an assumption borne out by the fact that the Auchindryne granite and its apophyses have been intruded since the north-east to south-west fault-movements, while the granitoid porphyrites have been more or less affected by these movements. The distinctly less acid composition of these remarkable intrusions also favours this suggestion.

Specially interesting evidence bearing on the question of thermometamorphism has been met with in the tract west of Glen Ey, from which the rocks can be traced continuously eastward into an area of greater metamorphism, while outcrops of black-schist, limestone, and other deposits capable of showing clearly the effects of alteration occupy a large part of the surface, and can be examined to great advantage both in burn- and hill-sections. Kyanite is commonly observed in the black-schist, and staurolite more rarely; but the crystals, which have been developed since all shearing movement ceased, are not so large and conspicuous as those seen in Corriemulzie Glen. The tremolite-rock and the garnetiferous sill of hornblende-schist are well seen, though the former is never so highly crystalline as in the metamorphic area east of Glen Ey. Braemar district. (Mr. Cunningham-Craig.)

But the most interesting feature is the entire absence of the production of hornfels, except at the contact with igneous intrusions; it is evident that in Glen Connie we are beyond the hornfels area, and have entered a belt of country in which the metamorphism has not attained to that relatively intense degree of alteration. The limestones appear very little affected, except where in contact with the granitoid porphyrite intrusions. The metamorphic effects of these intrusions are of greater interest. It has been pointed out that though these igneous masses attain to considerable dimensions, they have quickly cooled margins, so it cannot be expected that any very extreme type of metamorphism should be observed in the sedimentary rocks along the lines of contact. A certain amount of alteration, however, has undoubtedly taken place. Where the granitoid porphyrite comes in contact with impure limestone bands in Allt Sionnaich, the latter are converted into a compact banded hornfels. Mr. Teall describes a specimen (8503) as follows:—

"Compact banded hornfels.—The specimen contains a band of dark-purplish hornfels between bands of grey and pale green hornfels. The dark purplish hornfels owes its colour to the presence of minute scales of biotite. The other constituents are granules of pyroxene and a colourless mineral, the grains of which are too small for precise identification. They are probably either quartz or felspar. The grey bands are devoid of biotite but richer in pyroxene. They also contain grains of the colourless mineral and large individuals of a mineral belonging to the scapolite group (dipyre). The scapolites are crowded with inclusions of pyroxene in the form of minute grains. The grains in the scapolite are distributed in exactly the same manner as in the rest of the rock, so that the outlines of the crystals can only be distinguished in polarized light. Similar rocks have been described from the Pyrenees as 'cornéennes compactes" by Professor Lacroix. They are there regarded as Lias altered by contact with lherzolite."*

Purer bands of limestone, in Glen Connie, are found near the igneous rock as white saccharoid marble, with traces of calc-silicates, which have not been determined.

No contact between the true black schist and the porphyrite is exposed in this area, as the intrusions are for the most part confined to the neighbourhood of the limestone, but a thin fold of black schist seen in Allt Cristie Mor among minor intrusions of the granitoid porphyrite, has been converted into an andalusite-hornfels, which Mr. Teall describes as "(8506) Micaceous aggregates with cores of unaltered andalusite, quartz, and biotite. Andalusite-hornfels (altered)."

* Etude Minèralogique de la lherzolite des Pyrénées et de ses phenomènes de contact. *Nouvelles archives du Muséum d'Histoire Naturelle*, 3rd ser., pp. 209-302.

Braemar district. (Mr. Cunningham-Craig.)

The "purple schist," so frequently seen associated with the banded limestones, is also much affected near the junction with the intrusive rocks. It is essentially a quartz-biotite rock, but by the development of minute plates of "contact" biotite, it has been converted into a hard biotite-hornfels, the bedding being completely obliterated. Two specimens of the rock from different localities are thus described by MR. TEALL: "(8504) Black compact rock showing junction with porphyrite. It is composed of numerous quartz-grains in a matrix containing small scales of biotite and minute opaque dusty particles (? carbonaceous). The rock has the structure of fine grit."

"(8505) Very fine grained, almost compact, purplish hornfels. Minute scales of biotite and some larger crystals of white mica in a colourless mosaic, largely, if not entirely composed of quartz. Biotite-hornfels." The zone of alteration round these porphyrite intrusions is narrow, and little trace of the alteration can be detected in hand-specimens taken at a distance of a hundred yards from the igneous rock; the specimens examined microscopically were all taken from within 100 feet of the porphyrite, some from the actual junction.

Perthshire and Stirlingshire.

District between Brig o' Tuirc and Loch Lomond. (Mr. Cunningham-Craig.)

In continuation of his previous survey in these counties for the completion of Sheet 38 of the one-inch map of Scotland, MR. CUNNINGHAM-CRAIG has mapped the "Green-beds" in the neighbourhood of Brig o' Tuirc, and from that ground south-westward in a zone reaching through Loch Katrine and Loch Chon into Rowardennan on the eastern shore of Loch Lomond. As stated in last *Summary of Progress*, the mapping of these epidotic grits, by affording a reliable horizon, has sufficed to explain the nature of the folding, and to make clear many points in the structure of the district, which could not previously have been detected.

North of Brig o' Tuirc in Glen nam Meann and Glen Finglas the "Green beds" are found in simple outcrops resting upon the coarse pebbly grits of Ben Ledi, and dipping beneath the massive grits and schists, which at a higher level contain the main intrusion of epidiorite. Nearer to the mouth of Glen Finglas, what might be described as "corrugated outliers" of the epidotic grits, are seen upon the hill-tops. In these outliers the folding is distinctly shown; the plication, though it may be described as isoclinal, is in no sense comparable to the deep isoclinal folding of the central Highlands, the limbs of the folds being nowhere of any depth. Thus, in these outliers, the actual folding has no appreciable effect upon the form of the outlier.

As these rocks are followed south-westward, they appear on the high ground of Beinn Aan in shallow synclinal folds which rapidly become deeper, till on the shores of Loch Katrine the rocks are "packed" into a vertical isocline. The folding in this part determines the form of each outcrop. It is observable, District between Brig o' Tuirc and Loch Lomond. (Mr. Cunningham Craig.)

however, that the folds are, as a rule, shallow and undulating upon the hill-tops, while in the lower ground the " limbs " of the folds become longer, so that the pitch of the folding—*i.e.*, the actual dip of the folded beds—is often difficult to distinguish. This structure is again complicated by a cleavage observable in the fine-grained and more homogeneous beds, but which does not greatly affect the coarser grits. In the vertical limbs of folds, this cleavage coincides with the bedding, but where the folding is shallower, the bedding crosses the cleavage obliquely, and the former structure is frequently almost obliterated, so that a false appearance of isoclinal folding is given.

Observations of the "pitch of the folding" have been made where possible, and from these it appears that the pitch undulates considerably; this has a marked effect upon the outcrops of the "Green beds" betwen Loch Katrine and Loch Lomond. The effects of the rolling "pitch" are especially well seen about Loch Chon, the axes of the folds sloping towards the loch from both north-east and south-west, so that four or five synclinal outcrops appear on the shores of the loch, while the folds pinch out towards the hill-tops, and an outlier on the watershed is sometimes the only representative of a particular outcrop.

The effect of the isoclinal folding is to repeat the outcrop of the "Green beds" seven times on the southern shore of Loch Katrine. The compound synclinal folds in which these outcrops lie may be regarded as the westward extension of the trough which has been mapped from Balquhidder and Strathyre. Each outcrop is essentially a folded syncline. On the south-east side, the great trough is flanked by an anticlinal axis of the coarse pebbly grits of Ben Ledi, packed together in a vertical isocline, that seems to have acted during the folding movement as a line of resistance, against which the folding of the less massive beds took place. The pebbly grits make their appearance here and there in minor anticlines between the outcrops of the "Green beds," and their occurrence in this manner is confirmatory evidence of the fact that in this area there is only one series of epidotic grits, which is continually repeated by folding. The small thickness of the rocks, relative to the area of ground which they cover, is also strikingly shown.

To the north-west of the trough containing the "Green beds," the folding becomes shallow and irregular, the beds being rather "puckered" than folded, and the metamorphism is of a different type. Shearing has had greater effect, and the gritty beds appear chiefly as micaceous schists, with less trace of their clastic origin. This may be partly due to an original difference in lithological character, the coarser grits attaining their maximum development to the south-east of the trough, and the sediment becoming finer in grain to the north-west. But the chief determining reason is, doubtless, the change in the character of the folding, which has led to a different degree of dynamic metamorphism. Where the folding is shallow and irregular, differential movement under horizontal stress may be expected to take place more easily, and the greater dynamic metamor-

District between Brig o' Tuirc and Loch Lomond. (Mr. Cunningham Craig.)

phism would result in the total or partial obliteration of original structures. These phenomena hold good as far as the great trough can be followed. Tracing it into Stirlingshire, the trough is seen to be affected by faults, and to become shallower towards the south-west; the outcrops of "Green beds" become fewer in number, and the folding less regular and less deep, till, near Rowardennan, at a distance of about a mile from Loch Lomond, a fault cuts off the "Green beds" entirely, the upthrow being on the western side of the dislocation.

Dumbartonshire.

The portion of Dumbartonshire between Loch Lomond and Loch Long has been searched unsuccessfully for outliers of the "Green beds"; it seems that their horizon is never actually reached, the ground being occupied by rocks of a lower horizon folded into shallow and irregular undulations, and showing no trace of the great synclinal trough.

The Luss Slates.—Boundary lines for these deposits had not previously been mapped. In tracing the outcrops, it was found necessary to map in detail certain characteristic bands of grit. The grit of Meall Garbh in the Pass of Leny, and that which makes such a remarkable feature at Anie near the foot of Loch Lubnaig, have been found to afford admirable horizons for mapping. The data obtained by the detailed survey of these grit bands has made the structure of the district clear; numerous faults have been detected, and their effects have been shown, while the somewhat irregular arrangement of the rocky islands near Luss has been explained by the presence of roughly north and south faults concealed by the lake-basin, but the existence of which can be demonstrated.

The slate-bands have been quarried for roofing material at Luss for upwards of two hundred years, but the profitable beds have now been exhausted in the present quarries. Fresh openings in the neighbourhood have failed to find workable slate in sufficient quantity. Mr. Cunningham-Craig's examination of the ground soon disclosed the reason for this failure. He found that a north and south fault cuts off the workable slate, bringing against it a mass of fine and coarse cleaved grits with some softer slaty beds. The general similarity of these gritty beds to the true slates deceived the quarrymen, who continued working further into the mass of grits in the hope of winning workable slate.

The fault, which splits into several branches among the finer beds, has been traced for upwards of a mile. It shifts the outcrop of the slate-band—the same band that is being worked at Aberfoyle—a quarter of a mile to the southward, Veins of quartz and calcite with some chlorite are common in the neighbourhood of this fault and its branches, frequently rendering the slate unworkable.

Inverness-shire.

In the district of Strath Nairn MR. HORNE continued the mapping of the schists, and found them divisible into two well-marked groups: (1) Flaggy, quartzose biotite-gneiss of the Moine type; and (2) Extremely coarse biotite-gneiss, with highly-contorted folia, containing quartzo-felspathic materials, arranged in parallel folia or lenticles. With the latter are associated bands of garnetiferous hornblende rock.

Strath Nairn. (Mr. Horne.)

In the district which includes both sides of the southern end of the Great Glen, MR. GRANT WILSON continued the survey described in last *Summary*. He has now completed the mapping of Glen Loy. The schists which occupy the greater part of that valley are of the ordinary Moine-schist type or gneissose flagstones with quartose bands more or less felspathic and micaceous. The boundary of the diorite, part of which has been already described,* has now been traced all round. The mass, which is found to occupy an irregular area of about five square miles, appears to have been intruded more or less along the foliation-planes of the flagstones, for its eastern margin conforms closely to the changes in the direction of the foliation of these rocks. Half a mile to the west of Inverskavulin, on the banks of the Loy, where a good contact junction of this rock is seen, the granulitic flags next the diorite are much baked and shattered, while the igneous rock in close contact with them has a close-grained or chilled edge. A specimen from this place is thus described by MR. TEALL:—

South end of Great Glen and Glen Spean District. (Mr. J. S. Grant Wilson.)

"[8489.] Coarse-grained, massive rock. Under the microscope, plagioclase (Andesine-labradorite) biotite and garnet, with apatite and iron ores as accessories. A diorite-rock in which biotite takes the place of hornblende: garnetiferous biotite-diorite."

Few granite dykes† like these mentioned in last year's report seem to cut that portion of the diorite which lies to the north of the river Loy.

On the east side of the Great Glen, or Glen Albyn, the work of last year was continued by MR. GRANT WILSON up both sides of the Spean valley as far as Roy Bridge; round the western slopes of Ben Nevis to the limit of the driving road in Glen Nevis and the greater part of the Mamore Forest.

The most important section in this area is that laid open by the River Spean from the falls of Mucomir to the junction of the River Roy, the bed and the rocky ravine of the stream affording an almost continuous exposure of the zones of schist between the rivers Spean and Lochy described in last *Summary*.‡

(1.) Sericitic mica-schist. At the falls of Mucomir a crushed and contorted green schist, slightly calcareous in places, with a few quartzite bands, is cut by several small epidiorite-sills. In

* *Summary of Progress* for 1898, p. 42.

† *Op. cit.*, p. 43.

‡ *Op. cit.*, p. 44.

South end of Great Glen and Glen Spean District. (Mr. J. S. Grant Wilson.)

the road deviation at the Free Church Manse epidiorite-sills compose over two-thirds of the section, and to the east of the Manse, both in the river and in the railway-cutting, the green contorted schists are pierced by a large mass of gabbro, which in turn is cut by a porphyrite-dyke. On the railway below the cross-roads at Torr an Eas the rock, which is well exposed, consists mainly of dark grey and green schists with thin bands of quartzite, and a few small sills of foliated epidiorite constantly repeated by being thrown into folds. In the next railway cutting further east thin brown bands are interlaminated with green and grey schists, which appear to have been originally impure limestones.

(2.) The same narrow belt of black schist traced in 1898 by the Ben Nevis Distillery to Auchindaull, a distance of four miles, is not seen further to the north-east, and is not represented in the Spean section.

(3.) Below Coneachan dark grey flaggy micaceous schists with quartzite bands succeed the sericite-schists just described. They are isoclinally folded to east-south-east at an average angle of 50°, the same bands being frequently repeated. The epidiorite sills and dykes so characteristic of the sericite-schists still continue in this zone, though less abundantly. About 100 yards to the north of the High Bridge and in the railway-section, steel-grey flaggy schists are seen to include thin zoisite-schist partings a few inches thick. A specimen from one of these bands submitted to Mr. Teall is thus reported on by him :—

"[8559.] Hornblende and garnet in a white saccharoidal matrix. Under the microscope both hornblende and garnet are micro-poikilitic. The white matrix is a granulitic aggregate of quartz, felspar, and zoisite : hornblende-zoisite-granulite (garnetiferous)."

From this point to Spean Bridge the river section presents an alternating series of grey micaceous flags with flaky and quartzose bands. To the west of the railway viaduct the constant repetition of this series by folding on a large scale is well seen in the rocky gorge of the stream. The same group of rocks continues for a mile above Spean Bridge, either with their foliation planes on end or highly inclined to the east.

From Tirandrish for 600 yards up to the railway viaduct fine phyllites and flaky schists alternate with thin quartzose bands. Above the bridge a belt, 140 yards broad, of strong pink spotted and white quartzite with micaceous partings makes its appearance. Its relationship to the rocks on either side of it, though at present obscure, will in all probability be explained by the future mapping of the ground to the north. This quartzite is succeeded to the east first by soft grey phyllites with calcareous bands; next by a narrow belt of corrugated black schist with garnets, followed by a strip (75 yards broad) of blue crystalline limestone, with a few partings of black schist and phyllite.

To the east of this limestone, phyllites and black schist, identical in every respect with those on its west side, are repeated by numerous folds to within 280 yards of the Cour water when solid grey and slaty limestone with actinolite extends for a breadth of 166 yards. This belt of limestone is succeeded by calcareous phyllites which can be traced to about 150 yards beyond the mouth of the Cour water.

South end of Great Glen and Glen Spean District. (Mr. J. S. Grant Wilson.)

The general strike of the foliation of the whole of this calcareous series is north-east and south-west, and the planes are either vertical or else inclined to the south-east at a high angle. The detailed mapping clearly proves that the same limestone band, with black schist on either side of it, is twice repeated, and that between these belts of limestone, and on their east and west sides, a series of similar grey phyllites and schist with calcareous bands, evidently indicates a repetition of the same zone. This calcareous series comprises the (4) limestone and (5) black schist zones, already described as extending from Lismore to Glen Nevis.*

The calcareous series is last seen at thè foot of the Cour water: thence to the River Roy it is succeeded by silvery-grey phyllites and mica-schists, often garnetiferous. A specimen from Achnafraschoille, microscopically examined by MR. TEALL, is described by him is as follows:—

"[8560.] Both biotite and garnet are micro-poikilitic. The former occurs in large irregular plates, which are not arranged parallel with the schistosity. The matrix is composed of quartz and white mica with small grains and crystals of iron-ore—garnet-biotite-phyllite."

These schists, although lighter in colour, appear to be the representatives of the (2) dark-grey, flaggy mica-schists on the west side of the limestone and black schist. This identification is confirmed by the interlamination, both at Croft Ninner on the Spean and at Auchaderry on the Roy, of bands of zoisite-schist similar in every respect to those already described as occurring near the High Bridge. In close proximity to the zoisite-schist in the River Loy several belts of grey phyllite appear, which contain large feathery crystals of hornblende, occasionally seven inches long, and covered with crystals of a pale rose-pink garnet not yet determined.

A large number of broad dykes traverse the calcareous series in the Spean section. Some of these exceed 20 feet in width and all have fine-grained chilled edges. MR. TEALL has examined several of these, and finds that they belong to the lamprophyre group, and may be described as dioritic lamprophyres. On both sides of the Spean limestone, similar dykes cut the mica-schists of Glen Roy and Glen Spean, with a general trend of E. 30°—40° N. On the west side of Glen Nevis a similar group of dykes traverses the same series of strata (black schist and limestone) on Bidean Bad na h' Iolaire† to the south-east of Fort William.

In the burn section between Lochan Meall ant' Suidhe and the river Lochay the Ben Nevis granite is cut by a few aplite

* *Summary of Progress* for 1898, p. 45.

† *Op. cit.*, p. 48.

South end of Great Glen and Glen Spean District. (Mr. J. S. Grant Wilson.)

and lamprophyre dykes. In Glen Nevis and around Poll Dubh the biotite-schist, which lies to the south of Ben Nevis, is intersected by numerous lamprophyre dykes. Further north the binary granite of Mullach Nan Coirean is cut by a series of similar dykes. Their direction is the same as that of those by the biotite-schist, and many were observed to have chilled edges. A specimen of one of them from the Choire Deirg is thus described by MR. TEALL:—

"[8488.] Under the microscope it shows prismatic hornblende in a matrix of plagioclase more or less lath-shaped.—Camptonite."

This granite area is also intersected by several coarser dykes, which in all probability are closely allied to the camptonites. A specimen of one of these from the falls at Poll Dubh, submitted to MR. TEALL, is thus described by him:—

"[8563.] Medium to fine-grained pinkish rock containing hornblende. Under the microscope hornblende, biotite (mostly altered to chlorite) in a matrix mainly composed of idiomorphic plagioclase: a little interstitial quartz—Lamprophyre.

On the Moor of Rannoch, where a small tract has been mapped by MR. WILSON, between the head of the Tulla Water and the River Ghoir, a fine-grained biotite-granite has been found in place between Loch Laidon and the viaduct of the West Highland Railway. Traced to the south over the moor, this rock becomes more hornblendic and less micaceous till about half a mile from its edge it becomes a typical diorite. Several large lamprophyre dykes cut both the granite and diorite while the surrounding flagstones are intersected by diorite dykes.

Argyllshire.

District between Loch Fyne and the Black Mount. (Mr. Kynaston.)

During the past year MR. HERBERT KYNASTON continued the mapping of the Dalradian schists in the neighbourhood of Dalmally and Inveraray. From Dalmally the work, begun some years ago by MR. J. B. HILL, was carried on up to the eastern margin of Sheet 45 (one inch), and the boundary lines of the different series were joined up with their corresponding lines along the western margin of Sheet 46. In a northerly direction the work was pushed forward to the high ground at the head of Glen Strae, whence it was carried on during July to the north-east corner of Sheet 45 from Clais-gobhair in the Black Mount deer-forest. To the south of Dalmally the mapping was continued from Inveraray during September and October in the area drained by Glen Shira. The following notes of his field-work have been furnished by MR. KYNASTON:—

The sediments mapped consist of part of the garnet-schists, the Ardrishaig series, or calc-sericites, and the black slates, limestones, grits, and quartzites of the Loch Awe series. On the east side of Glen Shira a considerable tract is occupied by the calc-sericite series, which towards Ben Bhuidhe are thrown into numerous small folds and plications with accompanying lithological changes. The beds become harder and stand out in bold crags and ridges, while on the main ridge of Ben Bhuidhe itself the rock has evidently been converted into a true hornfels. Two or three small patches of granite appear on the Ben Bhuidhe range, resembling the finer-grained type of Glen Fyne; but the visible exposures of granitic rock seem too small to have caused the amount of alteration observed in the surrounding sediments. Since, however, this alteration is of a local character, and identical with the contact-type of hornfels-alteration in other areas, it would appear to be due in great part to a larger extension beneath the surface of the Ben Bhuidhe granite. It is possible that a considerable mass of granite may exist here, only small portions of which have as yet been tapped.

District between Loch Fyne and the Black Mount. (Mr. Kynaston.)

To the north of Glen Shira, in the neighbourhood of Ben Bhreac, Ben Bhoidheach, and Ben Bhalgairean, the calc-sericite group has a fairly uniform lithological character, consisting of hard, often intensely puckered, greenish and grey phyllites, in which occasionally calcareous and quartzose zones may be observed. These Ardrishaig schists have here a decidedly more metamorphosed appearance (of the regional type) than further west. This fact and all Mr. Kynaston's observations during the course of the mapping fully confirm Mr. Hill's view on the progressive metamorphism of these sediments.* From this area the Ardrishaig schists can be traced in a highly altered state to the west of Meall nan Tighearn, whence they curve round into Sheet 46 along the northern flanks of Ben Laoigh. Typical calc-sericites—greyish and greenish sericitic phyllites with numerous calcareous zones—are found at Ciochan Ben Laoigh, where they form a fine feature, and in the crags of Fireach na Moine.

To the east of the calc-sericites come the garnet-schists. As the latter are entered the calc-sericites become gradually less calcareous as well as more siliceous and highly micaceous, until they are succeeded by massive and flaggy quartzose mica-schists, thickly studded with garnets.

On the west side of Glen Shira the boundary-line between the calc-sericites and the Loch Awe series was followed in a general north-north-east direction as far as Bealach nan Cabrach, whence it turns westward and was traced to the shore of Loch Awe close to Inistrynich. The Loch Awe series between Glen Shira and Loch Awe maintains similar features to those described in former Reports. The black schists (belonging to this series) were again met with east of Dalmally and were followed as a comparatively narrow zone along the south side of Glen Lochy to the margin of Sheet 45. In this more altered area they have the appearance of black phyllites with micaceous partings and often with quartzose bands. They are also frequently garnetiferous.

To the north of the Strath of Orchy and Glen Lochy the black schists and limestones become restricted to insignificant zones until they gradually die out altogether, and a large area is then

* *Quart. Journ. Geol. Soc.*, vol. lv. (1899), p. 470.

District between Loch Fyne and the Black Mount. (Mr. Kynaston.)

occupied by quartzose schists and quartzites. The evidence of increased regional metamorphism is here again striking and apparently comes in somewhat suddenly. In fact, a considerably greater degree of metamorphism is observed in tracing the rocks for four miles from Dalmally in a north-easterly direction than in the course of the succeeding ten miles along the same line. The increase in this direction after the first four or five miles is comparatively slight as far as observations have yet gone. Near the southern boundary of the quartzose series rocks which appear quite gritty, and in which the individual grains can be easily distinguished by the naked eye, may be frequently observed, but further to the north-east the gritty nature of the rocks becomes gradually obliterated, the schistose structure grows more and more marked, until a quartzose schist is reached, which is often flaggy and maintains a uniform character over a large area, and in which the original clastic structure is almost, if not completely, lost.

Well within the altered area highly micaceous schists, often with both black and white micas and frequently garnetiferous, are not uncommon. Thus, garnetiferous mica-schists are well developed in Glen Orchy at Catinnis Bridge, and they again form a strong band near Clais-gobhair in the Black Mount, and are well seen on the south-eastern slopes of Ben Sroine. Lithologically they often bear a strong resemblance to the garnet-schists below the Calc-sericite group about Ben Laoigh and in the Glen Fyne area, but here they occur well within the quartzite area and are succeeded both above and below by quartzites and quartzose schists. The following section, observed near Clais-gobhair, may help to illustrate the relations of these garnetiferous schists. In apparently ascending order the subdivisions are:—

(1.) The quartzites and quartzose schists, in the immediate neighbourhood of Clais-gobhair. Then, in a burn section of rather more than a mile in length,

(2.) A green hornblendic schist or gneiss, the nature of which is at present doubtful.

(3.) Dark grey biotite-gneiss,—the biotite often developed in elongated leaf-shaped patches, irregularly distributed on the foliation planes,—passing into a schist with two micas, often gneissose, and with some small pegmatite veins.

(4.) Garnetiferous mica-schist, with two micas, garnets numerous.

(5.) Pale grey flaggy quartzites,—a narrow zone.

(6.) Silvery grey mica-schists, with two micas, only occasionally with small garnets. These rocks become very quartzose, and show, also, eyes and bands of quartzose material, which does not apparently represent extravasated quartz, but rather puckered and drawn out bands of recrystallised coarse grit. These rocks are again well seen about the east end of Loch Dochart. Near the top of this zone fine quartzite bands become more frequent and pass into

(7.) The series of flaggy quartzites and quartzose schists, which spread over a large area.

District between Loch Fyne and the Black Mount. (Mr. Kynaston.)

The green hornblendic schist (2) is a peculiar rock, regarding the nature of which a definite opinion cannot at present be given. Parts of it recall the epidiorite sills, so numerous in the Loch Awe area, but it does not seem to behave like one of these in the field. It appears to consist of a complex containing hornblendic, epidotic, and pyroxenic gneisses, sometimes with sphene, while some portions are calcareous. MR. GRANT WILSON, who mapped a portion of this schist, compared it to the scapolite gneiss, though it does not contain scapolite. Both this rock and the succeeding biotite-gneiss frequently contain small pegmatite veins. The biotite-gneiss is seen under the microscope [slide No. 8618] to be fine-grained in texture, and to consist mainly of biotite and quartz, with a small proportion of felspar, and occasionally eyes of granular quartz and small garnets. The garnet-schist [8619] is considerably coarser, but intensely puckered and well foliated. It is very quartzose and contains both white and brown micas, the former being slightly in excess, and a certain amount of felspar. The garnets have been broken up and show but little of their original substance, being now mainly represented by chloritic alteration products, biotite flakes, and granular quartz.

Almost throughout the whole area of the quartzite series surveyed, from the Strath of Orchy to the Black Mount, small pegmatite veins [are fairly common. On both sides of Glen Strae and in the tract between that glen and Glen Orchy they are numerous in the quartzose schists, especially noticeable in the neighbourhood of faults. They occur chiefly as small veins and strings of coarse red felspar, usually associated with quartz, along the joint planes and other lines of weakness in the schists. Some veins consist mainly of quartz. Besides these veins, isolated pockets and grains of felspathic material, already noticed by MR. HILL,* are well seen on the west side of Glen Strae, grains and patches of red felspar frequently occurring to such an extent as to give the rocks as a whole a reddish appearance. This MR. HILL has attributed to the presence of the Ben Cruachan Granite; that is to say, either the felspathic material has been derived from the granite, or it represents an original constituent of the quartz-schist recrystallised owing to direct contact-action. There can be no doubt that "granitisation" of this kind has taken place in many parts of the Highlands. In the region around Ben Cruachan, however, MR KYNASTON'S work in the field and with the microscope has led him to doubt whether the evidence might not be better explained in another way. As a general rule, as far as his experience of the Cruachan granite has gone, secondary felspar, which can be shown to be due to the direct contact-action of the igneous mass, is only found in the immediate neighbourhood of the

* *Op. cit.*, pp. 485, 486.

District between Loch Fyne and the Black Mount. (Mr. Kynaston.)

actual contact, *i.e.*, in the inner zone of hornfels alteration and such secondary felspar will usually present a fresh appearance under the microscope. The fact of the quartzites having a reddish colour, due to the disseminated felspathic grains, cannot be taken as any guide to the origin of such felspar. The majority of these quartzites and quartzose schists, throughout the ground surveyed, are rich in original felspar grains. They were at first fine-grained quartz-felspar grits, and they have frequently been observed to assume a reddish colour, due presumably to the weathering of the contained felspar, at distances from the granite very much greater than Glen Strae, and especially in the neighbourhood of faults or lines of crush, where the rocks are much shattered and decomposed. On the other hand, grey quartzose schists, containing abundant clastic felspar, may often be observed close against the margin of the granite, without any accompanying change of colour. Again, isolated grains or crystals of felspar, similar to those seen on the west side of Glen Strae, may be observed, up to quarter of an inch in diameter, in the quartzose-schists of Ben Donachan, three miles and a-half from the nearest exposure of granite, while veins and pockets of red felspar, up to three or four inches in breadth, are common in Glen Orchy in the neighbourhood of Catinnis, more than five miles from the granite. These felspar grains have always a very turbid appearance under the microscope, and are usually corroded, and often broken, and they are not restricted, as we have seen, to the zone of hornfels around the granite, but may be found several miles away from it. It is not always easy to draw the line between veins, pockets, small patches, and apparently isolated grains of felspathic material. A similar reddish colour might easily prevail in both secondary and original felspar; but there is no doubt that the rocks here considered are highly felspathic quartz-schists, which contain a large proportion of unquestionably original felspar, and these schists are traversed by felspathic veins, and structures of a similar nature. These structures cannot be referred to direct contact-action, nor can they have been injected from the granite. According to Mr. Kynaston, they belong to the same set of phenomena as ordinary quartz-veins, which form a common feature in the district. Veins and pockets precisely similar to those in the quartzose schists are found in the granite itself, especially in the coarse Black Mount type. From these considerations, Mr. Kynaston would refer this vein felspar and the occurrence of secondary felspar of a similar nature, though not necessarily in the form of a true vein, not to the presence of the granite, but to the same causes which give rise to the normal quartz and pegmatite veins, so common in igneous rocks and highly metamorphic regions, such as we are dealing with. Isolated reddish grains he would regard as original clastic material. That these should have escaped obliteration from the forces which produced the schistosity of the rocks, is not, perhaps, so surprising in view of the resisting nature of the rock, and the fact that the porphyritic felspars of the epidiorite-sills are frequently well preserved even in an area of garnetiferous mica-schists. **District between Loch Fyne and the Black Mount. (Mr. Kynaston.)**

The sills of epidiorites and hornblendic schist are already well known from previous Reports, and those mapped during the past year do not call for any special notice. It may be remarked, however, that as the mapping advances into the more highly metamorphosed area, to the north and east of Dalmally, sills, which would be designated epidiorites and chloritic schists further to the south, have now become recrystallised, and are true hornblende-schists and hornblende-gneisses, in which the hornblende is usually dark and fresh, and biotite is frequently present, with occasional garnets. Porphyritic felspars are often well preserved and conspicuous, as in some of the sills on the Glen Lochy side of Ben Sroine. Where sills are large they sometimes vary from a fine-grained hornblende-gneiss to a fairly coarse hornblende-rock showing scarcely any traces of foliation. These sills, however, are not nearly so common in the more altered area as in the district about Loch Awe.

Intrusive Rocks later than the Foliation of the Argyllshire Schists.

Various large masses of granite and innumerable sills and dykes of basic as well as acid material have invaded the schists of the south-western Highlands since the time of the production of the foliation. The question of the age of these intrusions is one of considerable difficulty. They not improbably belong to different periods of hypogene activity. Some of them no doubt belong to the time of great volcanic activity when the lavas of the Lower Old Red Sandstone of Lorne were poured forth. In the *Summary of Progress* for 1897 and also in that for 1898 reasons were given to show that the granite of Ben Cruachan not impossibly belonged to that volcanic period. No new evidence has been met with to impugn or to confirm this suggestion. On the present occasion it will be more convenient to discuss the occurrence of these eruptive rocks apart from the consideration of their geological date. They have recently been studied afresh both by Mr. Hill and Mr. Kynaston, and the observations of these two geologists will here be given in connection with their notes on the schists through which the intrusive rocks have been erupted.

At the time of Mr. J. B. Hill's transference from Scotland to Cornwall, a large tract between Inveraray and Dalmally, on which he had been engaged was not finished. The completion of this area as well as the northerly extension of the work from Dalmally was assigned to Mr. Kynaston. As the different sedimentary series of the Loch Awe region often shade into one another imperceptibly, a more or less arbitrary divisional line had to be adopted, and in order to secure that these lines should be drawn uniformly on the same horizon, it was desirable that both surveyors should visit the ground in company so as to run **District between Inveraray and Loch Awe. (Mr. J. B. Hill.)**

District between Inveraray and Loch Awe. (Mr. J. B. Hill.)

the boundary lines continuously from the one part of the district into the other. MR. HILL was accordingly instructed to join his colleague for a short time for this purpose, and they conjointly completed the joining up of their boundary-lines along the limits of their respective areas—a total length of 40 miles. MR. HILL took advantage of the opportunity to revisit the mountainous country between Glenfyne and the Shira River for the reexamination of the igneous rocks of Beinn Bhuidhe, and, as this work would probably have a bearing on the future survey of the ground to the northwards, he was accompanied by MR. KYNASTON.

The following description of the interesting and peculiar eruptive rocks of this district is supplied by MR. HILL. It is inserted here for convenience, but the age of the rocks must be much later than that of the Dalradian sediments which they traverse. MR. KYNASTON is of opinion that the Ben Cruachan granite not improbably belongs to the Lower Old Red Sandstone volcanic series of Lorne; while MR. HILL is disposed to regard it as of greater antiquity.

The occurrence of olivine-monzonite—a rock new to Britain—has been reported by MR. HILL in previous years from various parts of Argyllshire. He first mapped rocks of this kind in 1892 among the igneous masses forming the Beinn Buidhe complex, and apparently related to the great granite mass of Glenfyne. The following year he met with a rock identical in character on the western side of Loch Awe, close to the village of Kilchrenan. In 1896 he mapped a similar mass near Loch Avich about nine miles south-west of Kilchrenan, and described it briefly in the *Annual Report* for that year.* In the same *Report* a fuller account was given of a similar rock which MR. GRANT WILSON had mapped in the neighbourhood of Ballachulish.† During the past season MR. R. G. SYMES has met with another monzonite dyke in the Kilmelfort district (*postea*, p. 64), near MR. HILL's mass at Loch Avich, while MR. KYNASTON has mapped an example in Glenorchy. Doubtless other instances of them may be found as the mapping of the South-Western Highlands advances. With the exception of those in the Beinn Bhuidhe area, the mode of occurrence of these rocks is too isolated to throw much light on their origin. At Beinn Bhuidhe, however, an assemblage of igneous rocks can be studied which merge into one another, and among which a definite relationship can be observed both in the field and by microscopic investigation.

The extensive granite masses of Glenfyne and Ben Cruachan are separated by a space of nine miles. In the intervening ground small bosses of granite, diorite, and olivine-monzonite appear, besides sills and dykes of orthophyres, porphyrites, and lamprophyres. The granite masses of Glenfyne and Ben Cruachan are similar in character, while the occurrence of smaller bosses of granite and diorite between them may indicate an underground

* Annual Report of the Geological Survey for 1896, p. 23

† *Op. cit.*, p. 21.

District between Inveraray and Loch Awe. (Mr. J. B. Hill.)

connection between them—a connection further indicated by the enormous amount of the hornfels type of alteration on the Beinn Buidhe slopes, which is far in excess of what would be likely to be brought about by the small granite intrusions that appear on the surface. The western boundary of the Glenfyne granite is roughly coincident with Glenfyne. The dykes of orthophyre and porphyrite occupy a zone about a mile in breadth, and extend to about six miles south-west from this granite. None of them are seen to pass into the granite, but the porphyrites bear such a strong petrographical resemblance to it that there can be little doubt that they represent the dyke phase of that rock.

The distribution of the small igneous bosses, however, is somewhat different. They are scattered westwards from the Glenfyne granite over a broad tract of mountainous country extending to Glen Shira. If we except two small bosses of diorite which occur somewhat outside of this zone at about six miles south-west from the Glenfyne granite, it may be stated generally that the granite and diorite bosses occupy the part of the belt nearest to the granite, while the olivine-monzonites occur in the outer zone, the central part of the belt being more or less common to both, so that while the monzonites extend to a distance of about four miles from the granite, the small bosses of granite and diorite are restricted to a zone extending about two miles from the Glenfyne granite. Again, the lamprophyres of monzonite type are most strongly developed in the monzonite area, but also extend in a northward direction as far as Dalmally, helping still further to bridge over the interval between the main granite masses of Glenfyne and Ben Cruachan.

Before entering further into a description of these olivine-monzonites and their allied rocks, it will be convenient to state briefly the sense in which the term monzonite is here used. While this group of rocks bears marked affinities to the rocks described by Brögger as monzonites from the district of Monzoni, the Argyllshire type-rock is more basic, and always contains olivine, and while the olivine-bearing monzonites would represent only a basic variety of Brögger's group, in Argyllshire this represents the type-rock. But in other respects they resemble so closely the monzonites of Brögger that the term olivine-monzonite, first applied to them by MR. TEALL,* has been adopted. As shown by MR. TEALL,† these rocks are allied to both picrites and to monzonites, the amount of augite and olivine linking them with the former, and their proportions of silica, alumina and magnesia with the latter. MR. TEALL further pointed out that the augite from the rock mapped by MR. GRANT WILSON near Ballachulish was of the same type as that occurring in the "augite-syenites" of Monzoni. While, again, some of the rocks from the Loch Awe and Inveraray district exhibit a more or less equal amount of orthoclase and plagioclase, and in this respect approach closely to the monzonites of

* *Op. cit.*, p. 23. † *Op. cit.*, p. 22.

District between Inveraray and Loch Awe. (Mr. J. B. Hill.)

Brögger; this character is by no means persistent in them. In some good olivine-monzonites, fairly typical of the Argyllshire rocks, orthoclase has diminished to a very small proportion as compared with the plagioclase, and this diminution holds good whether or not the rock is rich in olivine.

In the field these monzonites present a characteristic appearance. They occur as more or less lenticular-shaped masses, like coarse dolerite, with a strong tendency to weather into cup-shaped depressions or deep hollows. In decomposition, however, they bear a striking contrast to dolerites; their outer surfaces are remarkably fresh, and ring somewhat like phonolite when struck with the hammer. They are dark in colour, and their constituent minerals can be readily detected with the naked eye. Pale green olivine in fairly large rounded grains can be seen amongst the more conspicuous dark augite and brown biotite, the felspar being less conspicuous. Perhaps the most characteristic mineral which strikes the eye is the biotite, in a discontinuous, patchy condition, but with the patches in optical continuity. When hypersthene is present, it can generally be readily detected without the assistance of a lens. Sometimes large patches of the rock are almost entirely felspathic, but these bear an insignificant proportion to the mass as a whole, which is generally fairly uniform throughout.

In this Beinn Bhuidhe region there are two well marked examples of the typical olivine-monzonites. One mass occurs in the Brannie Burn a mile south-south-west of Beinn Bhuidhe, the other in the Allt an Sithein, a tributary of the Shira River, about $2\frac{1}{2}$ miles west of Beinn Bhuidhe. The olivine-monzonite in the Brannie Burn extends for a length of about half a mile in a broad lenticular mass. Its boundaries are largely obscured by drift, but its general outline can be sufficiently made out by its junctions with the schist seen in the main burn and its tributaries. It has been intruded in the well-marked zone of garnetiferous mica-schist, which has been traced across the Highlands, occupying a position between the Loch Tay limestone and the Ardrishaig series. This is a typical olivine-monzonite, dark grey in colour, medium-grained in texture, and with the usual rugged type of weathering. Olivine in good-sized grains is conspicuous; the biotite is likewise prominent amongst the augite and felspar; while ophitic orthoclase is exceptionally well developed. The rock has produced well-marked contact alteration in the garnet-schist, good hornfels having been developed for a distance of 15 or 20 yards from its margin. In the hornfels zone fresh bright red garnets are seen, which appear to have resulted from the re-crystallisation of the garnets that were present in the schist before the monzonite intrusion. The eruptive rock is fairly uniform throughout, but contains inclusions about six inches wide of very much finer grained material. There is also a zone about six feet wide within the mass, mainly made up of felspathic material, which probably represents the more acid condition of the magma; it passes insensibly into the normal rock, and is not unlikely to be of sedimentary origin, as it differs both in composition and in the absence of the hornfels alteration from the sediments on the margin of the mass.

District between Inveraray and Loch Awe. (Mr. J. B. Hill.

Perhaps the most interesting point in connection with this olivine-monzonite is the occurrence of a granite in the heart of the rock, as exposed in the small burn that flows through the northern part of the mass. The precise outline of the granite cannot be determined owing to the presence of drift, but the distance of its two outer margins from each other, as exposed in the burn, amounts to about 170 yards. It is a fine-grained hornblende-biotite-granite, of the type common in the Beinn Bhuidhe district. Its intrusive character into the monzonite is unmistakable, as it sends veins into it from its margin, while veins of granite six to nine inches wide traverse the monzonite.

The next exposure of the rock occurs at An Sithein, and this mass is rather smaller than that of the Brannie Burn, since it is little more than a quarter of a mile in length and about one-sixth of a mile in width. It has been intruded into the Ardrishaig series—a zone of calcareous sericite schists. Here the conditions for regional metamorphism were less favourable than in the schists at Beinn Bhuidhe, and the rocks therefore were neither so indurated nor so crystalline when the intrusive rock was injected into them. As a consequence the monzonite has been able to effect greater contact-alteration; the change into hornfels extends to about twenty yards from the intrusion, and is specially marked. In general character this dark grey, medium-grained olivine-monzonite is similar to that just described. It contains, however, not only olivine, but hypersthene, and is therefore a connecting link between the monzonites and the hyperites. Like the rock of the Brannie Burn it incloses small zones of more highly felspathic material. At its eastern boundary it is much coarser, owing to the augites being much larger than in the normal rock, and occurring in a porphyritic condition. This rock, like that already described, has been cut by a later intrusion; while the Brannie Burn mass was invaded by a granite, this mass has been pierced by a lamprophyre dyke.

A rock which, in the field, can be seen at once to belong to the monzonite group, occurs half a mile north-west of Clachan Hill, and about a mile from the Brannie Burn mass on the steep slope between that hill and stream. It is a large sill-like intrusion, about half a mile in length, and one-eighth of a mile in width, and strikes at the Brannie Burn rock, from which it is separated by a space of three-quarters of a mile. This mass, while closely allied to the olivine monzonites, is an augite-diorite. Mr. Teall, who examined it under the microscope, describes it as being composed of nearly colourless augite, biotite, hornblende (green), plagioclase and a little interstitial quartz. Alkali felspar has not been definitely recognised, and only a very small quantity can be present. The augite is of the type occurring in the monzonites. Although not itself a monzonite, the rock belongs to that group.

District between Inveraray and Loch Awe. (Mr. J. B. Hill.)

A small sill close to the mass just referred to evidently belongs to the same group. It contains no augite, and has been determined by Mr. Teall from microscopic examination to be a biotite-camptonite, exceptionally rich in ferro-magnesian constituents. There can be little doubt, however, that it is closely related to the rock last described, and represents a more basic intrusion from the same magma. Further, this rock must be regarded as a connecting-link between the lamprophyres and the monzonites. In the Brannie Burn ground the monzonite and augite-diorite are associated with large numbers of lamprophyres, which immediately succeed them and extend in a westerly direction to Glen Shira. These rocks occur in close proximity to the augite-diorite and monzonite, and many of them shade so indefinitely into them that we must suppose them to represent the dyke phase of the monzonite group.

Two small lamprophyre sills on the slope of Ceann Garbh, about two miles to the north-east of Beinn Bhuidhe, are in some respects peculiar. They occur near one another, are dark in colour and medium-grained, but contain porphyritic crystals of augite and platy plagioclase, and are undoubtedly allied to the monzonites. They are, however, distinctly more porphyritic than the typical monzonites, and in mode of occurrence are more closely akin to the lamprophyre division of the monzonite group. Under the microscope they are seen to contain fairly large phenocrysts of colourless augite and plagioclase, in a matrix of felspar, biotite, and magnetite (accessory), with which chlorite and other secondary minerals are associated.

Another example of a lamprophyre sill of monzonite type appears a little to the south of Dalmally. It closely resembles both the two examples just described from Ceann Garbh and the augite-diorite from Clachan Hill. It is an augite-lamprophyre that clearly belongs to the monzonite group. As the two sills from Ceann Garbh might equally be classed with the monzonites or with the lamprophyres, so this sill might be placed either with the augite-lamprophyres or the augite-diorites, seeing that it occupies a position somewhat intermediate between the two, the rocks from all these localities being unmistakably members of the monzonite group.

In like manner a passage may be traced between the lamprophyres of pronounced monzonite type and the lamprophyres of the typical camptonite type. These intermediate stages can be favourably studied amongst the numerous lamprophyres of the Brannie Burn. In some instances augite is as conspicuous as hornblende, while in others hornblende only occurs, and we get the typical camptonite or hornblende-lamprophyre of this district. In some sills phenocrysts of altered augite and brown hornblende may be seen in a matrix of the lamprophyre type, while in others, by the absence of augite and the addition of biotite, we get a biotite-camptonite. Some of the sills, again, are made up of material similar to the ground-mass of these camptonites, and by the gradual diminution of the hornblendes we reach a type of lamprophyre prevalent in the district.

District between Inveraray and Loch Awe. (Mr. J. B. Hill.)

The monzonites, although most common amongst the more basic rocks of the district, are not wholly confined within such range. An instance will now be described in which a monzonite forms a portion of a mass which, taken on the whole, is a hornblende granite or a tonalite. About a mile and three quarters south of Beinn Bhuidhe two small bosses occur at rather more than a mile from the boundary of the Glenfyne granite, but not more than a third of a mile from the schist which is veined by the granite. The larger mass is about a quarter of a mile in length and one eighth of a mile in width. The smaller and more northerly mass, only separated from it by a distance of 100 yards, is about 200 yards long and about 100 yards wide.

These masses of fine-grained granite are slightly variable in composition and texture. In some parts the material is a grey biotite-granite or granitite, containing zonal plagioclase and interstitial quartz and orthoclase, in other parts hornblende appears. Moreover, the outer portion which is finer-grained is much darker and the amount of hornblende in it must be greater. Indeed it would appear that the margin of the mass is probably more basic than the interior, and since plagioclase felspar is in excess, parts of the mass might be more fittingly called diorite. Besides hornblende, augite is sometimes present. The specimen which Mr. Teall examined was composed of more or less idiomorphic augite, biotite, lath-shaped plagioclase, interstitial quartz, and orthoclase, with some accessory magnetite and secondary hornblende and chlorite. This rock is allied to both olivine-monzonite and to hyperite. Augite diorites occur in the monzonite group. Mr. Hill believes that the group may have a still further extension and embrace the more acid diorites and hornblende granites.

The district includes rocks still more acid than those now described. They consist of grey fine-grained biotite granites, forming small protrusions on the ridge and flanks of Beinn Bhuidhe, one of which has already been referred to as an intrusion in the olivine-monzonite of the Brannie Burn. There is every reason to suppose that these biotite-granites and hornblende-granites are of the same age as the Glenfyne granite, on the border of which they occur, and the finer-grained portions of the Glenfyne granite is identical in character with the material of these smaller intrusions.

While the instances here cited of a monzonite being pierced by granite and by a lamprophyre afford an indication of the relative ages of the rocks, they supply no evidence to determine the relation of the granite and lamprophyre to one another. This, however, has been apparently settled on the northern flanks of Beinn Bhuidhe, where a granite pierces a lamprophyre. The lamprophyre sill is distinctly seen to be veined by the granite which has produced great contact-alteration on it. Under the microscope the older rock is found to be composed of small scales of contact-brown-mica and water-clear plagioclase crystals, and crystalline patches of hornblende are also seen.

From the occurrences and behaviour in the field of this in-

District between Inveraray and Loch Awe (Mr. J. B. Hill.)

teresting group of rocks, we may now proceed to consider how far they help in determining the relations of the various igneous rocks apparently scattered at random over the wide district of rugged and somewhat precipitous hills, amongst which the highest peak, Beinn Bhuidhe, rising out of Glenfyne, attains within the space of 2 miles from its base an elevation of over 3,000 feet. The rocks enumerated in the foregoing pages range from acid to basic in composition, including granite, quartz-diorite, augite-diorite, augite-camptonite, camptonite, lamprophyre, and olivine-monzonite, which are so closely connected from a petrological standpoint that they pass by insensible gradations into one another. We have seen that the monzonite type prevails over the entire series, linking them together as a connected whole. This prevailing monzonite type, embracing rocks so varying in composition, is strong presumptive evidence that the rocks represent various phases of material which has been derived from a common magma. Further direct proof has been obtained of the intrusion of different members of the group into one another, thus affording an indication of the order of the successive phases of injection. If this apparent order accurately represents the true sequence of events, the olivine-monzonites would appear to have been intruded first, followed by the lamprophyres, and finally by the granite, or in other words, that the more basic material was intruded earliest, and the most acid latest. Whether the smaller igneous masses of the Beinn Bhuidhe area coincide in age with the large granite mass of Glenfyne cannot be with certainty maintained, but, as stated already the smaller granite masses appear to be identical with the finer-grained portions of that granite, and the porphyrites which occur amongst them are so closely allied to it, that there can be little doubt that they represent its dyke phase. On the whole there are strong grounds for supposing that all these granite masses are approximately of the same age.

The study of this group of rocks throws some light on the age of the lamprophyre-dykes so generally scattered over the Highlands. So far as the lamprophyres of this district are concerned, the evidence is ample that, like the olivine-monzonites, they have been derived from the more basic portions of the magma, which afterwards supplied the material for the granites. It is not suggested that all the lamprophyre-dykes are necessarily of the same age, nor that each granite mass was intruded at precisely the same time. Some of the lamprophyres are possibly later than some of the granites, but we have no reason to doubt that the order of succession here described holds good generally—at any rate the evidence is absolutely conclusive that some lamprophyres have preceded the granite of their vicinity.

Allusion has been made on a previous page to a group of porphyrite-sills extending to the south-west of the Glenfyne granite, some of which undoubtedly represent the dyke-phase of that rock. They are of three types, viz., orthophyres, porphyrites, and mica-porphyrites. The orthophyres are not so strongly developed as the porphyrites. They are rather unsatisfactory in

District between Inveraray and Loch Awe. (Mr. J. B. Hill.)

character, the decomposition of their felspars having proceeded so far that it is not always possible to decide whether this mineral is orthoclase or plagioclase. The porphyrites are of two types and of different age. The mica-porphyrites are sometimes cut by the hornblende-porphyrites. They were themselves originally hornblende-porphyrites, in which the hornblendes are now represented by pseudomorphs of biotite and epidote. MR. TEALL has suggested that the alteration has been brought about as a result of contact or thermo-metamorphism, as hornblendes frequently decompose to aggregates of chlorite and epidote, while chlorite may be converted into biotite by contact or thermo-metamorphism. Certainly the evidence previously adduced of the alteration of a lamprophyre by contact-metamorphism is suggestive, the hornblende-lamprophyre being converted into a rock made up of water-clear felspar and contact-brown-mica. As regards the porphyrites there is no evidence of such contact-metamorphism, except that they occur amongst schists, in which the regional metamorphism is beginning to be rapidly increased, and it is possible that thermo-metamorphism may have been the agency responsible for this increase of regional metamorphism, and that the porphyrites were affected at the same time.

The rocks of the later group of hornblende-porphyrites are comparatively fresh, and vary largely both in their texture and porphyritic characters. The finer-grained varieties are hornblende-porphyrites, containing sphene; the porphyritic felspars are plagioclase, similar to the idiomorphic felspars in the Glenfyne granite, which also contains sphene. They generally also contain free quartz, sometimes in considerable quantities. As they become coarser in texture, they pass into quartz-diorite or hornblende-granite, and it may be noted in this connection that the coarser and more granitic varieties enter the zone of the monzonite group, the true dyke-rocks being most prevalent to the south-west, at and beyond the limits of this zone. A sill which occurs on Clachan Hill, about three miles south-west of Beinn Bhuidhe, is composed of hornblende, biotite (idiomorphic), and more or less lath-shaped plagioclase, alkali felspar, and quartz with sphene, apatite and iron ores as accessories. This rock is richer in ferro-magnesian minerals and plagioclase than a specimen selected as typical from the Glenfyne granite, and is somewhat intermediate in structure between granite and porphyrite. This group of hornblende-porphyrites somewhat differs in character from the porphyrite-dykes of the Loch Awe district, which MR. KYNASTON supposes to represent the dyke phase of the Cruachan granite. On the whole, the rocks which it embraces are more acid and contain a larger amount of quartz which is clearly distinguishable without the aid of a lens.

Although the Glenfyne granite has its own assemblage of smaller intrusions, dykes, and sills distinct from those belonging to the Cruachan granite, there are well-marked resemblances between these two great granite masses. Thus MR. KYNASTON has recorded augite-diorite from the district of Ben Cruachan, while according to MR. HILL's observation, the igneous masses of the Beinn Bhuidhe area are suggestive of an underground connection between the granites of the two mountains. As regards the age of the Glenfyne granite, no definite statement can be made, except that it must be later than the foliation of the schists.

Glen Etive and district between Black Mount and Glen Shira. (Mr. Kynaston.)

The mapping of the Glen Etive granite was completed, and its boundary line was carried from Glenkinglass past the western end of Loch Dochart and thence in a general north-westerly direction to Lairig Dochart, where the line was joined up with that traced from Glen Etive in 1898. The rock has not presented any new features. The completion of the boundary-line shows that this granite forms a well-defined oval mass, almost completely surrounded by the Ben Cruachan type. It includes an area of approximately 60½ square miles, and is only covered to an insignificant degree by morainic material and other superficial accumulations. It is characterised by a wild and imposing type of mountain scenery, embracing no less than five peaks more than 3,000 feet in height.

The Ben Cruachan type of granite was found to die out against the Glen Etive mass in Glenkinglass, about a mile east of Doire-nan-Saor. Following, however, the margin of the latter type north-eastwards for two miles, we again find the Cruachan type about a mile south-west of Loch Dochart. It rapidly widens from a breadth of only a few yards to nearly half a mile, and assumes a fairly coarse texture. It is a pinkish hornblende-granitite, becoming fine-grained and dioritic in appearance at its junction with the quartzose schists to the east. North of Loch Dochart the boundary-line was traced in a general north-easterly direction to within a hundred yards or so west of the summit of Stob Ghabhar (3,565 feet). This portion of the Cruachan granite is continuous with that already mapped in Glen Etive, and it still maintains characters similar to those previously described from the Ben Cruachan district. In some places, for example, on the east side of the Dochart Burn, it appears to pass gradually into the Glen Etive granite. Its texture does not change as the margin is approached and the two types of rock pass gradually into one another, so that no hard-and-fast line can be drawn between them. A similar passage has already been noticed as occurring to the west of Loch Etive.*

Outside the eastern margin of the Cruachan granite a separate mass, of a similar general type, has been mapped in the immediate neighbourhood of Clais-gobhair. It is exposed for a mile and a half in the Clais-gobhair Burn, and is continued north-eastwards as a narrow strip to the north-western margin of Sheet 46. The rock is a medium-grained greyish, and sometimes pinkish, hornblende-granite—or, perhaps more strictly speaking, a diorite of the tonalite type. Close to Clais-gobhair an oval mass of a coarse very hornblendic diorite occurs within it, and doubtless represents a basic modification; while another small mass of a more basic diorite occurs among the schists close to its eastern

* *Summary of Progress* for 1898, p. 79.

Glen Etive and district between Black Mount and Glen Shira. (Mr. Kynaston.)

margin. Under the microscope the normal type of the hornblende granite [Slide, No. 8620, half a mile north-west of Claisgobhair] is seen to consist of plagioclase felspar, green hornblende, biotite, and a small proportion of alkali felspar and interstitial quartz; sphene, apatite, and iron ores occurring as accessories. The basic modification which occurs within this mass varies from a fairly coarse rock, containing about equal proportions of hornblende and plagioclase, to a coarse hornblende rock in which scarcely any felspar is visible to the naked eye. The former variety is seen under the microscope [8621] to be in great measure made up of large plates of green hornblende, which include small idiomorphic plagioclases and some small flakes of altered and ragged biotite. A few small pyroxene grains are also present, while hornblende and plagioclase likewise occur interstitially between the large plates of hornblende. There is no quartz. The other intrusion occurring outside the hornblende-granite is a similar rock, though the proportion of felspar to ferro-magnesian constituents is apparently more uniform. Further to the east again lies the diorite of Rannoch Moor, which doubtless, when more fully investigated, will turn out to have close affinities with the hornblende-granite and diorite of Ben Cruachan and the Black Mount.

As regards the age of the Cruachan granite, which has been referred to in the Reports of former years,* no fresh facts of any importance have come to light this year. Mr. Kynaston has examined microscopically the andesite which occurs in the Pass of Brander at a distance of about three-quarters of a mile from the nearest exposure of granite, but could detect in it no positive signs of contact-metamorphism. The andesite is not found in this district any nearer to the granite than this point, and it never occurs on the north-east or Cruachan side of the Pass of Brander fault. It is to be hoped, however, that more definite facts concerning the chronological relations of these two rocks will be forthcoming as the work in this and other parts of the district advances.

In connection with basic modifications of the larger masses of intrusive rocks attention may be called to the occurrence of olivine-monzonite on the west side of Glen Orchy. An elongated patch of this rock, almost a mile in length and an eighth of a mile in breadth, besides two smaller oval patches, probably connected with it, was mapped about a mile north of Catinnis in Glen Orchy, and seven miles from Dalmally. The rock varies from a medium grain, weathering like dolerite, and consisting apparently in large measure of augite, to a coarse-grain, in which the constituent minerals, olivine, augite, and biotite are easily seen with the naked eye. This coarse rock forms the greater part of the mass, and weathers into the characteristic small cup-shaped depressions already noticed by Mr. Hill. Under the microscope [8614] the olivine is seen to occur mostly in rounded grains, and seldom shows crystal outlines. It is fairly fresh, is traversed by

* *Summary of Progress* for 1897, p. 85; for 1898, p. 76.

Glen Etive and district between Black Mount and Glen Shira. (Mr. Kynaston.)

numerous anastamosing veins of magnetite, and often occurs as inclusions in the augite. Augite and olivine appear to be present in about equal proportions, and, together with biotite, form the main mass of the rock. The augite chiefly occurs as large individuals with well-defined crystal outline, frequently showing a marked zonal structure under crossed nicols. It also appears in smaller grains and granular aggregates of irregular contour scattered throughout the slide. The biotite is strongly pleochroic and occurs in ragged flakes and patches, and several detached flakes are often seen to be in optical continuity. Felspar, together with some biotite and small augite-grains, fills up the interspaces between the larger individuals. Both orthoclase and plagioclase are present, the latter being distinctly idiomorphic, while the former is interstitial. Magnetite fills the veins in the olivine, and appears also as grains associated with both the olivine and biotite. Mr. Kynaston has likewise visited the Beinn Buidhe district described by Mr. Hill (p. 48), and agrees with his colleague that so far as the present known evidence goes, it may not be unreasonable to conclude that the monzonites have been derived from the basic portion of the magma which supplied the granites, and are, therefore, approximately of the same geological age.

Throughout the whole area surveyed by Mr. Kynaston last year a large number of dykes and sills, having petrological affinities with the larger granitic masses, have been mapped. These show a wide range of variation both in composition, structure, and the relative proportion of the different constituents. They include quartz-porphyries, felsites, porphyrites, diorites, and lamprophyres, and these pass into one another through intermediate varieties. As regards distribution it is noticeable that the more acid types of sills are almost always found nearer the granite than the more basic varieties. The lamprophyres, however, frequently occur in the neighbourhood of the Ben Bhuidhe granite, and diorites occasionally cut that of Ben Cruachan.

The quartz-porphyries are found on Ben Mhic Monadh, about the head of Glen Strae, and in the Black Mount district. They traverse the schists and the Cruachan type of granite, but are not seen to cut the Glen Etive type. The usual type is a biotite-bearing quartz-porphyry, containing a certain amount of plagioclase as well as orthoclase. These, by an increase in the amount of plagioclase relatively to orthoclase and the disappearance of the quartz, will pass into porphyrites.

The porphyrites are common in the Glen Strae and Black Mount portion of the district surveyed, and also occur, but more sparingly, in other parts. They comprise both biotite and hornblende-porphyrites. The former pass occasionally through intermediate varieties into orthoclase-porphyries or orthophyres and quartz-porphyries, and the latter merge into diorites. Good examples of the more acid type of porphyrite are found in the neighbourhood of Clais-gobhair, and some of these are so crowded with phenocrysts as to have the appearance at first

Glen Etive and district between Black Mount and Glen Shira. (Mr. Kynaston.)

sight of a granitic rock. A specimen from Meall Buidhe shows abundant phenocrysts of felspar, biotite, hornblende, and small quartz-grains in a fine greyish matrix. Under the microscope [8624] all the larger phenocrysts of felspar are seen to be plagioclase, and to be in excess of orthoclase which occurs in smaller crystals. Quartz occurs sparingly in small, rounded grains. The biotite is seen as plates with ragged outline, and is also scattered throughout the rock in peculiar groups and patches of small flakes. These groups are frequently associated with hornblende, and would appear to be replacing it owing to some secondary action. The hornblende is pale green and occurs in irregular patches and grains, which never show crystal outlines, and the patches appear as a granular aggregate beneath crossed Nicols. Occasionally these patches have a more defined form, but they are always associated with numerous small flakes of biotite and grains of magnetite. Apparently there has been a gradual breaking down of the hornblende, and it is now partially replaced by secondary biotite and magnetite. Both the original biotite and hornblende occasionally occur as inclusions in the felspar. The groundmass is a micro-crystalline quartzo-felspathic aggregate with small disseminated grains of biotite and hornblende. Magnetite is an accessory. Another variety of hornblende-porphyrite with acid tendencies is common in the Cruachan granite on the ridge to the west of Stob Ghabhar, near Clais-gobhair. Elongated crystals of hornblende and plates of biotite are easily seen with the naked eye, while the felspar phenocrysts sometimes range up to an inch in length. The microscope shows [8623] that some of these latter are evidently orthoclase, though the larger proportion of the felspar phenocrysts are plagioclase. The hornblende is fresh and occurs in well-defined elongated crystals. The biotite is in about the same proportion as the hornblende and frequently occurs in hexagonal plates. Quartz occurs as an accessory; but is not visible to the naked eye, and only appears in occasional small rounded grains. The groundmass may be described as micro-dioritic. It shows much idiomorphic plagioclase, small greenish hornblendes, and biotite, with interstitial felspar and quartz. Porphyrite of this type has already been noticed from the same district.* These rocks appear to have closer affinities with the Glen Etive type of granite than with that of Cruachan.

Diorites and micro-diorites, in which plagioclase and hornblende may often be porphyritic, are common as sills in the Glen Orchy part of the district and in the Black Mount. These appear more frequently in the schists than in the granite. An unusual type, but well-marked when it occurs, is found on Meall an Laoigh, three miles south of Clais-gobhair. It is an augite-diorite with conspicuous and well-defined porphyritic augites, giving the rock a peculiar spotted appearance. Sills of a similar rock have also been mapped on the high ground separating Glen Strae from

---

* *Summary of Progress* for 1898, p. 39.

Glen Etive and district between Black Mount and Glen Shira. (Mr. Kynaston.)

Glen Kinglass.* The intrusions of this rock usually form larger sills than the porphyrites. In one instance, on Ben Larachan a plug-like mass of the rock was mapped, roughly circular in outline. This porphyritic type of augite-diorite is not known to cut the granite. The proportion of felspar to augite and hornblende often varies considerably; it is in the more felspathic varieties that the spotted appearance above referred to is so marked. Under the microscope, a specimen [8622] from Meall an Laoigh, shows large porphyritic augites resembling the augite of the monzonites, though not so fresh, with well-defined crystal outlines and zonal structure seen under crossed Nicols. Marginally they are partially replaced by greenish hornblende. The rest of the rock is dioritic in appearance, and consists of plagioclase, green hornblende, biotite, and some accessory magnetite. The biotite appears in scattered flakes, often in groups in optical continuity, recalling a similar feature in the monzonite. This appearance seems to be due to the biotite being moulded on the felspars. The plagioclase is mostly idiomorphic, and there would appear to be also a certain amount of interstitial orthoclase, though all the felspar is so turbid from decomposition that this point cannot be definitely determined. It is interesting to note certain apparent points of relationship between this type of augite-diorite and the monzonites. The addition of olivine and the elimination of the hornblende would give a rock resembling the olivine-monzonite of Glen Orchy. Its mode of occurrence also resembles rather that of the monzonites than that of the ordinary porphyrite and diorite sills. The sill-like mass of this rock on Meall an Laoigh is cut by two small intrusions of quartz-porphyry.

The lamprophyres constitute a rather ill-defined group, between which and the diorites and porphyrites there seems to be no hard and fast line. They are found in large numbers in the Glen Shira and Ben Bhuidhe parts of the district, but in a northerly and north-westerly direction from the upper end of Glen Shira they gradually die out, and only occasionally occur among the hills between Glen Orchy and Glen Strae. Many of them have already been mapped and described by Mr. Hill. Frequently they are highly micaceous, resembling typical mica-traps. Varieties containing a large proportion of hornblende are common. A sill, previously mapped by Mr. Hill, north-north-west of Corryghoil, near Dalmally, is seen under the microscope [8615] to be a typical camptonite. It contains abundant idiomorphic brown hornblendes in elongated crystals, plagioclase, orthoclase, interstitial quartz, and accessory magnetite. Sills of this type are numerous in Glen Shira, Glen Orchy, and on Ben Sroine, between Glen Orchy and Glen Lochy.

Kilmelfort district. (Mr. R. G. Symes.)

During the past year Mr. Symes has continued his survey of the district between Oban and Loch Melfort. To the south of the area of the Lorne volcanic rocks, from Kilmelfort as a centre, he has mapped the schists and other crystalline rocks, which

---

* *Summary of Progress* for 1897, p. 92.

emerge from under the Old Red Sandstone series. In the Duchara Burn dark calcareous slates are met with, which display a metamorphosed character. They have been converted into calc-silicate hornfels, and they are associated with epidiorite and limestones. Interbedded with these strata at least one sill of intrusive epidiorite may be observed, but as the sedimentary rocks are very much folded, it is quite possible that the successive exposures of epidiorite may be due to the reappearance of the same sill owing to folding. Above the second bend of the stream grey and black slates are succeeded by the great sill of epidiorite which caps Carn Duchara ($3\frac{1}{2}$ miles south-east from Kilmelfort), the highest point of the ridge. The fact that limestones and black slates are found on one side of this sill, and grey slates and quartzites on the other, seems to point to an order of succession; and as MESSRS. HILL and POCOCK have detected shale fragments in the quartzites, it may be inferred that the succession is an ascending one from the limestones to the quartzites. Kilmelfort district. (Mr. R. G. Symes.)

On the shore between Kames Bay, two miles south-west of Kilmelfort and Rudh'an Roin on the east, the schists have not been so much changed into hornfels as nearer the granite, to be afterwards referred to, but occur for the most part as phyllites with calcareous bands, which at one point swell out into bands of limestone, or perhaps dolomite, folded upon themselves so as to be repeated over and over again. Sometimes these folds are isoclinal, though they often appear to be regular, the direction of cleavage seeming to be almost invariable with a high south-easterly dip. South-east of Tralaig, three miles to the north-east of Kilmelfort, thick limestones without shales are folded with the epidiorites. These strata reappear to the east of Loch a' Chaoruinn and of Loch a' Mhinn, where they form a small escarpment on which lies the basal breccia of the Lower Old Red Sandstone. East of Loch na Sringe, seven miles north-east of Kilmelfort, thick limestones folded up with siliceous schists, epidiorite, and black slates, are overlain unconformably towards the north-west by the andesitic sheets of the Lorne volcanic series. Most of these limestones could be used for economic purposes. West of Loch a' Chreachain (three miles east from Kilmelfort), and of Loch a' Chaoruinn, numerous thin bands of limestone again form rapid folds with epidiorite and black schists, and on the south pass under the Lower Old Red Conglomerate, from which they again emerge at the southern outcrop of the conglomerate in Gleann Mor Burn. The calcareous members of the schistose series have a wide extension in this region. Ten miles to the south of Kilmelfort, in the road east of Salachary, limestones with pebbles of quartz sometimes an inch in diameter are flanked with schistose epidiorite.

Besides the limestones, the sills of epidiorite form conspicuous features in the geology of this district. Thus, the great sill of Carn Duchara, already referred to, is a thick sheet, which seems to be repeated in rather sharp folds. The rock of this sill is highly basic and rather fine-grained, so that it has been

Kilmelfort district. (Mr. R. G. Symes.)

susceptible of marked cleavage over the greater part of its extent, the cleavage-planes being nearly vertical, but inclined to the south-east. Near the top of the hill in several places grey slates are seen to be folded with the epidiorite, and again further to the north, beyond Loch a' Ghille, thin cakes of slate are seen adhering to the surface of the sill, and minutely crumpled along with it. If, as is probable, this marks the upper surface of the sill, it conforms almost exactly to the form of the ground. About quarter of a mile north-east of Loch a' Ghille a second sill, or perhaps a branch of the one under consideration, is quite like the first in texture, having porphyritic crystals scattered through the fine light-green groundmass. Along the north face of the hill the denudation of the folds in the epidiorite has exposed the underlying dark slates, which coincide with hollows, whilst the edges of the epidiorite sheets form crags. The first few feet of this sill lying next to the dark slates present a highly vesicular and amygdaloidal texture, the cavities being small and globular, and only elongated where they have been affected by the pressure which has been applied subsequent to the consolidation of the rock and the infilling of the vesicles. Where the kernels have weathered out the rock is so cellular as closely to resemble a lava, which the rock may possibly have been. The vesicular band follows each of the folds along which the black slates are exposed. On the south-western face of the hill the foldings seem to be more intense, for the upper porphyritic layers of the sill which make up the greater part of the ridge plunge at once vertically downwards, and are succeeded by grey flaggy slates, like the rock that adheres to the surface of the epidiorite, but quite unlike the underlying black slate associated with limestones. As to the rock of the hill itself, it is basic, fine-grained both above and below, and coarse-grained in the middle. In many parts the fine-grained rock has been cleaved into chloritic and epidotic slates or flags. Even where the rock is not much deformed by cleavage, it is highly epidotic and chloritic, which gives it a light sage-green colour. It also supports a crust of light-coloured lichen, which makes its crags conspicuous.*

To the east of Loch Pearson, close to Kilmelfort, epidiorites are again seen to be folded with quartzites, siliceous schists, and occasional phyllite bands. The quartzites dip about 15° east, their schistosity is inclined at an angle of about 80°. Mr. Teall, to whom specimens were submitted, remarks regarding the epidiorites of this place, "that they are not typical epidiorites, but being so closely allied to them must be grouped along with them." One of the specimens he describes as epidiorite (amphibolite, with zoizite and epidote), and of another he writes that "it contains chlorite, biotite, water-clear felspar, and a little quartz." Around Kilmelfort the epidiorites form great ridges,

* It may have been this highly epidotised rock, or some similar mass, especially the very vesicular part that has been the source of certain vesicular epidotic basic rock-pebbles in a conglomerate on the Island of Kerrera. See *Summary of the Progress of the Geological Survey* for 1897, p. 83.

Kilmelfort district. (Mr. R. G. Symes.)

that stretch in the direction of the schistosity of the metamorphic rocks, the phyllites, quartzites, and limestones having been denuded on the lower ground. The tops of the ridges are strewn with massive angular blocks of the epidiorite.

The most novel and interesting feature in MR. SYMES' recent surveys has been the discovery of a number of previously unobserved bosses of granite rising through the schists in the Kilmelfort district. These granites may be of the same age as that of Ben Cruachan, and they have produced a similar metamorphism in the surrounding sedimentary rocks.

Up to the present time six exposures of granite have been mapped to the south, east, and west of Kilmelfort. These are not improbably all extrusions from the same magma underneath. One of them occurs on the high ground four miles south-west from Kilmelfort, between Kames farm and Asknish on the south side of Loch Melfort. Another appears in the low ground at Tullich Farm, near Kilmelfort. Two hundred yards east of the manse a small exposure may be seen in the road leading to Loch Avich. Two other outcrops were noted in Gleann Domhain, four miles to the south-east of Kilmelfort, while one was found on the north shore of Loch a' Chaourinn three miles east from that village. Besides these bosses numerous veins cut the schists and epidiorites, and convert the former into hornfels. The granite, in all cases, is fine grained, with a preponderance of biotite, and the occasional occurrence of hornblende. In no part of this district has the granite been observed to make its appearance close to the Lower Old Red Conglomerate, nor have any blocks of it been found in that formation. MR. PEACH, who inspected the ground surveyed by MR. SYMES, found that "the Tullich granite is remarkably like some of the small bosses which occur about the Loch Doon granitic mass in Galloway." The phyllites as they approach the granite become a dark micaceous hornfels, and the calcareous beds are altered into calc-silicate-hornfels. Near the granite some of the strata assume a coarse gneissose structure, and probably contain cordierite.* At the south-east corner of the Tullich mass a dyke-like projection of the decaying granite appears to truncate a sill of felsite, showing flow-structure, intercalated between the bedding planes of the hornfels. The form of the granite mass suggests that the visible rock is the top of a boss from which the schists have not been entirely removed. In its centre a patch of schist may be seen adhering to the granite, while the schists are pervaded in every direction by strings of fine-grained granite, and, moreover, fragments of the schists have been floated off into the granite. The fine-grained character of the eruptive rock favours the supposition that nowhere is the granite now exposed far from its original margin.

On the hill-slope above Tullich, near the northern edge of the granite, a dyke of porphyrite about two feet across, and showing chilled edges, cuts the granite. A little farther down

*See *Summary of Progress* for 1898, p. 86.

Kilmelfort district. (Mr. R. G. Symes.)

the slope a sill of felsite with flow-structure has been intruded along the bedding planes of the schists (here altered into hornfels), and appears to be truncated against the margin of the granite. As this sill, like that on the south-east corner, does not penetrate the granite, the granite would seem to be later than the felsite. It may be added that a vein of the granite occurs in the hornfels near the farm of Tullich on the west side of the felsite sill, as if the sill were cut by the granite, though the actual junction of the two rocks is not observable. The little isolated granitic mass on the road two hundred yards east of the manse changes the phyllites into hornfels, and the limestone into marble.

In all the area surrounding the several granite masses, the schists have been converted into hornfels. The limits of this metamorphism are not easily definable. In some cases hornfels may be observed without the visible presence of any granite; it may therefore be inferred that there may be considerable bodies of granite below ground, which, though they have affected the overlying strata, have not yet been laid bare by denudation.

Among the various instances of the occurrence of monzonite already referred to (*ante*, p. 48), allusion was made to one observed by Mr. Symes. It forms a dyke twenty feet broad, running in a north-west and south-east direction south of Lochan a' Bhailis, six miles north-east of Kilmelfort. No other example of the rock *in situ* has yet been detected in the district. A large erratic, probably from the same dyke, but not from the same locality, is to be seen on the Avich road, a little north-east of Lagalochan.

Two masses of highly crystalline porphyrite were mapped east of Kilmelfort. One of these occurs on the north shore of Loch Losgainn Beg, and the other more to the east of Loch a' Mhinn. It may be inferred that from these sources the blocks were derived which form the bulk of the undermost layers of the Lower Old Red Conglomerate in that neighbourhood. At Rudh 'an Tighe Loisgte, east of Kames Bay, several sills of pink porphyrite may be noticed which do not quite follow the bedding of the schists, but often pass obliquely across from bed to bed. These rocks present close-grained or chilled edges against the schist, and at least one of them is vesicular in the centre. Porphyrite-dykes are rather uncommon in this district in comparison with the enormous number of Tertiary basalt-dykes. Three examples of them can be traced from the south-east of Kilmelfort, in a north-north-east direction, cutting first the limestones, phyllites, and epidiorites, further north rising through the Lower Old Red Sandstone and its volcanic series, then once more through the schists and epidiorites east of Loch Tralaig, whence they hold on to the north, again traversing the Lorne andesitic lavas near Oban, and then striking for Loch Etive. Nearly all the porphyrite dykes, but more especially those seen cutting the Lorne andesites and Lower Old Conglomerate, have a north-north-east and south-south-west direction. A mile and a quarter north of Kilmelfort a porphyrite-dyke that cuts both the

Kilmelfort District. (Mr. R. G. Symes.)

epidiorites and andesites assumes a columnar structure, where it traverses the lava sheets.

Nearly all the margins of the porphyrite dykes show under the lens flow-structure. For instance, in a gully half a mile south of Loch Losgain Beg the porphyrite dykes are edged with "fluxion-felsite." A large mass of felsite rises on the hill south of Kames Farm, near to the granite already referred to. Numerous dykes radiate from this felsite mass, which cut the metamorphic sedimentary series; but no felsite dykes have been found intrusive in the granite or Lower Old Red Conglomerate. On the east side of Loch nam Ban a rock has been noticed which has been identified by MR. TEALL as a lamprophyre, but its relations to the adjacent mass of porphyrite or felsite are not observable. Another dyke of lamprophyre cuts the epidiorite mass which bounds the felsite half a mile south-east from Loch nam Ban, and which has already been referred to as underlying the conglomerate, but here again the relations of the lamprophyre to the felsite are not shown. In the road section north of Lagalochan a dyke of lamprophyre as well as several of porphyrite are seen to cut through the epidiorite and the hornfels-rock in connection with it.

Island of Jura (Mr. S. B. Wilkinson.)

With the view of continuing and completing the survey of the Island of Jura in which MR. WILKINSON was engaged at the time of his transfer to England he was moved for a part of the year to Argyllshire, and he succeeded in mapping a considerable additional portion of Jura leaving no more than it is hoped will be finished during the present year.

The part of Jura surveyed by MR. WILKINSON last year lay chiefly on the western side of the northern half of the island, and embraced an area of thirty-one square miles. No new feature of importance has been noted by him among the rocks recently examined. The quartzite continues to display the same uniform appearance of the bedding, concealing the system of folds by which the strata are no doubt often repeated. The apparently continuous inclination is towards the south-east at between 30° and 40°. On the western coast line, however, from Ruintallain Point, the strata lie at a lower angle, and are seen to be rolling about considerably. Fine cliffs and crags of these rocks rise on the higher ridges such as at Rainberg Mor, Dhu Bheinn, and Bheinn Breac. The fine grained epidiorite dykes, formerly noticed on the eastern side of the northern area of Jura, have been found to extend westwards into the area surveyed during the past year. The three more or less parallel east-and-west dykes stretch across Gleann Cloisdale, and can be traced to Gleann Dorch where they seem to die out. The dyke of similar material which traverses the island from Ardlussa on the east across the top of Beinn Bhreac does not quite reach the western shore, but stops beyond the south-western slopes of a hill called Ceann Min na Beinne Brice, where it is joined by a basalt dyke which is in contact with it for a few yards. Another epidiorite occurs almost on the summit of the hill just mentioned, running in a north-west and south-east direction. As formerly stated, although these epidiorite dykes have the same direction as the dolerite dykes of the Tertiary series, they are doubtless of much greater age.

Island of Islay. (Mr. Peach & Mr. Wilkinson.)

Great difficulty having been experienced in the determination of the geological structure of the Island of Islay, especially of its central and northern parts, a strong effort was again made to discover the key to this complicated district before the publication of the map. Accordingly Mr. Peach joined Mr. Wilkinson in a critical examination of the more important sections. Their re-examination was highly successful, as will be seen from the following account which they have prepared of the results obtained by them.

The coast section between Portaskaig and Bonahaven, which had been mapped in great detail, was again critically examined. Between Bonahaven on the north and Na Feamindean on the south (a point on the shore about a mile north of Portaskaig) the strata were found to comprise five groups in the following descending order:—

5. Sandy shales and flags with ripple-marks and worm-casts (like the "Fucoid Beds" of Sutherland and Ross), with massive beds of cream-coloured dolomite.

4. False-bedded blue and white quartzite with ripple-marks and vertical annelid-pipes—thickness 100 feet.

3. Sandy, rusty, ripple-marked and worm-tracked shales and flags, with a thin band of dolomite.

2. Quartzites with a band of conglomerate locally developed near the top, containing well-rounded pebbles of granite and other rocks similar to those in the Portaskaig Conglomerate.

1. Portaskaig Conglomerate, charged with well-rounded pebbles of granite, gneiss, quartzite, limestone, &c., in a sandy dolomitic and sometimes shaly matrix; with intercalations of rusty-weathering dolomite and bands of quartzite.

A small fault or line of crush appears on the shore near the junction of Groups 1 and 2, which probably does not seriously affect the original relations of the rocks.

The section from Na Feamindean, south to Portaskaig, is almost a counterpart of the sequence given in the foregoing table; the members of the highest Group 5, being visible at Na Feamindean, and the Portaskaig Conglomerate at Portaskaig. The local band of conglomerate at the top of Group 2 is, however, absent, and a fault, probably of no great amount, occurs on the shore near the junction of Groups 1 and 2. It is apparent, therefore, that an important structural fault runs inland from the shore at Na Feamindean, whereby the highest beds (Group 5 of table) are thrown down against the exposure of the Portaskaig Conglomerate to the north. In various sections between Portaskaig and Bridgend, the Portaskaig Conglomerate rests unconformably on the Islay limestone and the associated blue and black slates; indeed, the Islay limestone and slates have furnished a large proportion of the pebbles present in the exposures of the Portaskaig Conglomerate of that region.

From the evidence here given, it appears that calcareous rocks appear on at least three horizons in Islay in the following descending order:— Island of Islay. (Mr. Peach & Mr. Wilkinson.)

(*a*) Dolomites in Group 5 of table.
(*b*) Lenticular bands of dolomite in Group 1 of table.
(*c*) Limestone (Islay limestone) associated with blue and black slates, and unconformably overlain by the Portaskaig Conglomerate.

Sixty-nine specimens of calcareous rocks, taken from these horizons in Islay, have been tested by Dr. Pollard, who reports regarding them that the bands in Groups 1 and 5 are dolomites, while those associated with the slates beneath the Portaskaig Conglomerates are limestones.

The two confirmatory sections between Portaskaig and Bonahaven appear to indicate the original order of succession of the strata. After Mr. Peach's departure, several weeks were spent by Mr. Wilkinson in tracing the various subdivisions above enumerated over the inland area between Bridgend and Ruadh a' Mhail. The groups were found to be remarkably persistent, and to furnish valuable aid in working out the structure of that region. In general, it may be said, that they are repeated by a series of sharp folds, the long axes of which run north-east and south-west. In some cases, owing to faulting, only one limb of the fold is represented.

Island of Arran.

Probable Arenig Rocks of the Highland Border.

In former Annual Reports of the Geological Survey reference has been made to the discovery of a band of rocks, possibly of Lower Silurian age, which have been wedged in along the fault at the Highland Border between the Lower Old Red Sandstone and the crystalline schists and grits.* These rocks have been traced at intervals from Kincardineshire to Dumbartonshire. They consist of graphitic shales, slates, or schists, black, grey and red cherts, and various dull green rocks of igneous origin, some of which are probably lavas, while others are intrusive. This association of black shales, cherts and volcanic and intrusive rocks, so closely a repetition of that which characterises the Arenig series over the Silurian uplands of southern Scotland, led to the suspicion that these Highland Border rocks might prove to be of Lower Silurian age. The suspicion was further strengthened by the finding of *Radiolaria* in the cherts, precisely as these organisms occur in the cherts of the Southern Uplands. A much more extensive development of probably the same belt of rocks has been detected far to the south-west in County Tyrone, where the igneous accompaniments are particularly conspicuous, embracing lavas, agglomerates and tuffs.†

* See *Annual Reports* for 1893, 1895, and 1896.

† A. Geikie, *Ancient Volcanoes of Britain*, vol. i., p. 240.

North Glen Sannox. (Mr W. Gunn.)

During the past year another link in the long chain of evidence has been found by MR. GUNN in the island of Arran, which thus connects the Stirlingshire section with those of Ireland. Though there is the strongest presumption that the rocks in question should be regarded as of Lower Silurian age, this account of an additional development of them is meanwhile retained in the present section descriptive of the Dalradian rocks, but further allusion will be made to them at the end of the account of the Silurian rocks (p. 82). MR. GUNN has supplied the following notes regarding their occurrence in Arran.

A strip of rocks that can be separated from the ordinary schists of the island, has been found to be well developed in the valley known as North Glen Sannox. It crosses the glen from south to north at a distance of rather more than a mile from the sea. It is upwards of a mile and a-half long, and from 100 to 400 yards broad, having its narrower width at the northern end. The rocks in this strip of ground, so far as can be seen, are not separated by any structural line from the ordinary schistose grits of the Highland series, which they follow with no apparent break. Nor do they differ in degree of metamorphism from the contiguous Highland schists. A closer examination, however, reveals some characteristic features which have not been met with among the schists, but which precisely resemble those already detected in the supposed Arenig rocks of the Highland border. They consist of black shales or schists and cherts, with some bands of igneous rock, which probably include both volcanic and intrusive bands.

The black shales and cherts are associated together as they occur in Stirlingshire, and also 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 much corrugated in places. The cherts are appreciably granulitized, and resemble in structure those portions of the cherts which approach the granite of the Southern Uplands. In this condition such rocks have usually had their organic remains obliterated. No trace of *radiolaria* has yet been found in the Arran cherts. The most prominent members of this group of rocks are those of igneous origin, and the important fact has now been definitely ascertained in Arran, that they include undoubted lavas and volcanic agglomerate. They occur intercalated with the black shales or schists, and cherts, as bands of a dull-green, decomposing material, which may be most conveniently named in the meantime "greenstone." Like their associated sedimentary accompaniments, they have undergone some deformation, and have passed into the condition of epidiorite. So far as the examination of the rocks has yet advanced, the whole of them, igneous and aqueous, are in the same condition of metamorphism as the schists to the north and west of them. They have an apparent dip to the east or east-south-east, stand at high angles, even as much as 90°, but there is no means of deciding which is top or bottom of the series. They have undergone much plication, which is specially observable in the intercalations of black schist. They are flanked on either side by schistose grits of the ordinary Southern Highland type. The strip of rocks now described, is cut off at the southern end by the intrusion of the Arran granite, at the north-east end of Suidhe Fhearghas, while their northern boundary is a fault, which brings down against them 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 overlie them, 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 great Highland Border fault, which brings down the Lower Old Red Sandstone against them. This fault gradually crosses the line of strike of the igneous group, of which consequently only a portion is represented at its northern end. **North Glen Sannox. (Mr W. Gunn.)**

The general succession of the members of this group of rocks, together with the overlying and underlying sedimentary strata of the Highland series, is apparently as follows, in descending order:—

1. Coarse schistose grits or gritty schists, 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, and a band of schistose grit.
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.
7. Thick mass of strong and coarse schistose grit, sometimes greenish and 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 valley, the upper grit and greenstone are at first almost entirely concealed by glacial drift, and eventually cut off by the Highland Border fault. In the lower part of the section, the gritty schists are well exposed in the stream, both above and below the bridge, where the road to Loch Ranza crosses. They are here traversed by a few basalt dykes. About 70 yards to the east of the bridge, the coarser rock contains an intercalated band of fine-grained schist, and 80 yards farther down the stream, dark schists are seen to be associated with a brecciated rock, the like of which is met with in several places. It is composed of fragments of greenstone, but is not exactly like a true volcanic agglomerate. It may possibly have been produced by the brecciation of igneous rock while still in motion before complete consolidation. Above these rocks in the main stream comes the lower greenstone (5 in Table), which occupies the burn for a hundred yards. It is for the most part a massive rock, moderately fine-grained and of greenish-grey colour. It exhibits a well-developed "pillow-structure," identical with that of the basic

North Glen Sannox. (Mr. W. Gunn.)

Arenig lavas of the Southern Uplands. The chilled and rounded margins of these "pillows," and the numerous amygdules, a short distance in from their surfaces, are marked features. The dark schist that apparently overlies the lower greenstone is much contorted in places, and is accompanied by a breccia similar to that just mentioned, and also by some bands of igneous material. The cherts which are associated with this black schist are well exposed, about 200 yards up the Allt Carn Bhain. Some of them are dark in colour, but the thickest bands seem generally to be light-coloured or grey. On the south side of the valley, the upper greenstone rests immediately on a strong gritty band; the former much resembles the lower bed, but with the "pillow" structure not so prominent. Its upper part is here and there so schistose that it might be taken for the so-called "green beds" of the Southern Highlands. A good exposure of the upper greenstone is to be seen on and about the two small hills called Cnocan Donna, where the doubtful Arenig rocks attain their highest point above the sea. On each of the knolls a band of true agglomerate is interbedded with the greenstone. These bands are lenticular, and are made up of angular fragments of fine-grained greenstone. Neither of them can be traced for more than 40 or 50 yards along the strike, and the more southerly is but five or six feet across at its widest part. The other is larger, and may be as much as 30 feet broad in one place. The upper schistose grits, only partly exposed in the main burn, form a prominent feature on the hillside 300 yards to the southward, and can be examined along the strike for a considerable distance in this direction till they in turn are cut off by the granite.

The lower greenstone forms prominent crags, one of which is a conspicuous object from the road, about 300 yards south-south-east from the bridge. The same sheet of rock is also conspicuous in the crags of Corloch, at the northern extremity of the strip, and it composes all the crags on the north side of the valley. There can be little doubt that these bands of greenstone are true lavas. They present many points of resemblance to the lavas of the Arenig volcanic series of Ayrshire.

At a distance of nearly 600 yards north from the main stream, and near the Allt Dornach, a rock which differs much in character from the lavas was the first igneous mass noticed in this part of the island, and was regarded as intrusive. This view has subsequently been corroborated by the results of petrographical examination. The rock, however, is probably nearly of the same date as the lavas. Only a few specimens of the rocks of this presumably Arenig band in Arran have yet been examined microscopically by Mr. J. J. H. Teall, who adds the following notes regarding them:—

"[8666.] Crocan-Donna, North Sannox. Fine-grained, greenish-grey massive rock, composed of minute prisms of nearly colourless hornblende, epidote, leucoxene after iron ores, quartz, and chlorite. This is evidently an altered basic igneous rock, a variety of epidiorite. [From the upper lava, No. 3 on the Table on p. 69.]

"[8667.] Torr na Lair Brice, North Sannox. A scoriaceous rock, the cavities of which have been filled with calcite. The main mass is formed of microlitic felspar, chlorite, leucoxene, and carbonates. This, again, is an altered basic igneous rock. It differs from the above in containing recognisable felspar. It is closely allied to, but not identical with, the common forms of pillow-lavas. [This is the lower lava, No. 5 of the Table.]

North Glen Sannox. (Mr W. Gunn.)

"[8688.] Torr na Lair Brice, near Allt Tornach. Moderately coarse-grained rock composed of patches of fibrous hornblende, relics of original deep brown hornblende, chlorite, plagioclase, epidote, and leucoxene. The original rock was probably a hornblende-gabbro. It may be termed uralitic gabbro. I have little doubt that this rock is intrusive. [This is the rock found near the Allt Dornach and referred to above as probably intrusive.]

"[8669.] Allt Carn Bhain, North Sannox, 200 yards from foot of burn. Similar to the last, but more highly altered. Chlorite and carbonates abundant. [There is not sufficient evidence on the ground to decide whether this rock belongs to the lavas or is intrusive.]

"The two fine-grained rocks [8666 and 8667.] are highly altered basic 'traps' (greenstones) allied to those found in association with cherts in other areas. The two medium-grained rocks are altered gabbros or diabases [8668 and 8669]."

SILURIAN.

The chief field-work of the past year among Silurian formations has lain in the east and south of Ireland, where the revision described in previous *Summaries of Progress* has been continued. Much attention has necessarily been given to the igneous masses which in these regions are associated with the Silurian rocks. Hitherto a large proportion of these masses has been mapped as consisting of lavas and tuffs contemporaneous with the formation in which they are intercalated. But as the revision has advanced, an ever-increasing body of evidence has been accumulating to show that rocks which have been mapped as "ashes" are often of intrusive origin, while some of them are grits or arkoses.

Counties Dublin and Wicklow.

District West of the Leinster Granite. (Messrs. Egan and McHenry.)

In resuming field-work to the south of Dublin, Messrs. Egan and McHenry began by a study of the ground lying to the west of the great range of Leinster granite, where on the published maps a number of strips of "greenstone ash" are shown as intercalated among the Silurian strata. A careful examination of these rocks failed to disclose a single band of volcanic tuff, all the outcrops so represented on the map being either true felspathic grits or more or less crushed basic sills and dykes. Where the rocks have escaped deformation their true nature has generally been recognised, but the influence of terrestrial movements in inducing new parallel structures has only been recognised in recent years, so that it need not be matter of surprise that even portions of the Leinster granite were in some instances mapped as sedimentary material.

Among the principal localities at which ordinary sedimentary strata were mistaken for "ashes" may be mentioned the Deer-

District West of the Leinster Granite. (Messrs. Egan and McHenry.)

park area west of Blessington, the river Liffey between Ballymore Eustace and Pollaphuca, and other places in the adjoining parts of the county Wicklow. Many other sections occur (Sheet 129), as, for example, in large quarries east of Dunlavin; also near Rathbran, west of Stratford, and in the country lying west and north-west of Baltinglass.

The crushed basic igneous rocks (in Sheet 129) were in all cases taken either for "greenstone ash" or, in the more intensely sheared portions, for Silurian sediments. Examples of both these identifications occur at Ballymooney, north of Donard; at Deerpark, south-south-west of Donard; and within the granite area at Colvinstown. Those at Ballymooney and Deerpark present features of special interest, seeing that some contain large crystals of felspar (Lambay porphyry type), while others pass gradually into amphibolite. The varied effects of the underground movements that gave rise to the deceptive appearance of bedding are well displayed there.

The results of his study of the microscopic structure of the grits and igneous rocks lying to the west of the Leinster granite has been prepared by MR. HENRY J. SEYMOUR, and will be found on p. 176.

In the portion of the county Wicklow west of the granite, acid igneous rocks do not occur. In the adjoining part of county Dublin, however, near Rathcoole (Sheet 111), dykes of felstone (mapped as "elvan") cut across the beds of slate. These resemble many of the felstones associated with the basic rocks east of the granite.

District East of the Leinster Granite. (Messrs. Egan and McHenry.)

On the east side of the granite (in Sheets 120, 130, and 139) rocks which have hitherto been regarded as occurring in the form of contemporaneous "ash" have been found by MESSRS. EGAN and MCHENRY to be either crushed igneous rocks or occasionally non-pyroclastic sediments. So far as these observations have yet gone, this correction has invariably had to be made. As the revision is carried southward in detail into the County Wexford, it remains to ascertain how far other areas really include contemporaneous "ashes." From a cursory examination it is surmised that true tuffs may possibly occur in the igneous area stretching south-west from Carrigadaggan* (north-west corner of Sheet 169) towards Waterford.

The oldest igneous rocks east of the granite are the basic varieties, which occur as ordinary diorites or as andesites. In Wicklow, examples are met with in the Bray Head railway-cutting, and at Greystones (Sheet 121). Southwards (Sheet 130) they exist a short distance south of Roundwood, and in the mountain overhanging the north side of the Upper Lake at Glendalough. Near Roundwood the rock is a variolite, slightly altered, the variety at Glendalough being partly amphibolite. and partly fine-grained diorite.

These rocks are largely developed in the south-east part of

* The name Carrigadaggan, which is not on the one-inch map, is that of a fossil locality, as published in the memoir of Sheet 169. It is a townland about seven miles east-south-east from New Ross.

Sheet 130, especially in the Avonmore River valley south of Rathdrum, and in the vicinity of Westaston and Kilmacrea Upper, about three miles east and south-east respectively of Rathdrum. They also form knobs in the hilly ground near the coast in the vicinity of Rockfield House and Brittas. Many minor dykes of diorite also occur along the coast southward from Wicklow Head.

District East of the Leinster Granite. (Messrs. Egan and McHenry.)

As a rule the true intrusive character of these basic rocks has been fairly recognised and expressed on the published maps; but where they have acquired a fissile structure from crushing and deformation they have been mistaken for sediments.

The microscopic characters of these rocks as developed near to, and at some distance from, the Leinster granite, have been studied by MR. SEYMOUR and will be found summarised on p. 176.

The acid rocks were less accurately treated by the older observers. Hence considerable modification of their mapping has been necessary. In all the cases hitherto examined the supposed "felstone ash" has been found to consist of crushed felstone of intrusive origin. Not only so, but in a large number of instances what have been regarded and mapped as interbedded sediments are really portions of true eruptive felsite, excessively crushed. Abundant evidence of both these conditions is found in the Kilmacoo mining district, south-south-east of Rathdrum (Sheet 130); also in the railway cuttings near that village, and along the river valley to the south. Fine sections occur on the coast at Ardmore Point; at The Castle: near Rockfield House; also in the Kilmacoo district just now mentioned. In many of these sections the rocks have a banded structure showing fine and coarse materials made up of broken felsites and pieces of sedimentary material. In some instances portions of pumice and lapilli have been detected by MR. SEYMOUR with the aid of the microscope, though the evidence on the ground indicates an intrusive origin. Instructive sections exist on the coast at Arklow Head, where many dykes of acid and basic rocks are exposed. The petrographical characters of the felsitic rocks of this region are discussed on pp. 179, 180.

An interesting and probably important point bearing on the age of the so-called "ashes" and acid "lavas" is the connection which MESSRS. EGAN and MCHENRY believe they have established between these rocks and the great granite ridge of Leinster. In many places masses which are mapped as "elvan," but are really granite, and some of which are acknowledged to be offshoots from the main granite mass, pass into the "felstones" and "ash," as at Lewis Vale, two miles north of Arklow, and at Rock Little, two miles south of that town. The same transition is seen on a larger scale in the Croghan Kinshelagh district south of Aughrim, where a granitic rock, mapped as "ash," graduates into felstone on the hill at Kilmacrea Upper, east-south-east of Rathdrum. The Leinster granite was intruded into the Silurian formations before the time of the Carboniferous Limestone, and is thus presumably of the age of the Old Red Sand-

District East of the Leinster Granite. (Messrs. Egan and McHenry.)

stone. The sheets of "felstone" connected with it cannot therefore be "lavas" of Silurian date. In the Croghan Kinshelagh district the shearing forces have affected the granite as well as the basic intrusions, and to such an extent that in many places the rock has actually been mapped as grey grits and slates.

One of the most novel features in the recent work of revision in Ireland has been the discovery of a number of cases of intrusive felsites, which present an internal finely brecciated structure so exactly simulating that of true volcanic tuffs that in hand specimens they would be unhesitatingly pronounced to be unquestionably of pyroclastic origin. The process by which they were produced is not yet satisfactorily explained, but this much may at least be asserted regarding them, that they form irregular eruptive bosses or dykes, and have been injected in veins and threads into the contiguous rocks. As far back as 1896* Mr. McHenry expressed an opinion that certain conglomerates in County Dublin, supposed to be of volcanic origin, had really been produced by intense crushing within the earth's crust, and at the same time he suggested that this might also have been the mode of formation of other masses in Wicklow and Wexford, which had always been looked upon as composed of truly volcanic detritus. During subsequent years this suggestion has been verified by the field-work of Messrs. Egan and McHenry in County Wicklow, and also by the microscopic study of the rocks by Mr. Seymour. Remarkable sections of these brecciated felsites are to be seen at Arklow Head, where their intrusive nature is shown. They are displayed still more clearly on the shore near Rockfield House (Sheet 130) between Mizen Head and Wicklow Head. They have always been regarded as tuffs, and appear as such on the Survey maps. An account of their minute structure by Mr. Seymour will be found on p. 179. Similar rocks were met with by Mr. Kilroe on the south coast of County Waterford and will be referred to in subsequent pages (see pp. 77–81, and 180). It may be added that in no instance have Mr. Egan and Mr. McHenry succeeded in detecting any volcanic detritus in the sedimentary strata near the igneous rocks, whether the latter are crushed or not.

Counties Dublin, Meath, and Down.

Slane, Bellewstown and Balbriggan. (Mr. McHenry.)

In order to prepare for the engraver the maps of those parts of the East of Ireland of which the Silurian tracts have been revised, it was necessary to re-examine the igneous rocks of these districts that the nomenclature might be brought up to date. In the counties of Dublin and Meath, towards the end of the past season, Mr. McHenry re-visited some special points in the Slane, Bellewstown, and Balbriggan districts, and was accompanied by Mr. Seymour, with a view to the petrographical study of the rocks. Mr. McHenry has supplied the following notes

* *Nature*, March 6th, 1896.

of his re-examination. His recent work has confirmed him in the conclusions which he had formed in 1896, that the rocks which have hitherto been mapped as "ashes" in those districts are not of contemporaneous origin with the Silurian strata, but are really intrusive rocks, though in external and internal characters, closely resembling tuffs and breccias. The igneous rocks and associated breccias and "ashes" that occur along the coast at Balbriggan, and to the west of it at Herbertstown, are, in his opinion, basic intrusive rocks of one period, but of many varieties. They must at least be later in age than the Upper Silurian strata, which they penetrate, and, like the similar masses in South Dublin, Wicklow, and Wexford, they may belong to the great volcanic and plutonic series of the time of the Old Red Sandstone. In the Bellewstown Hill and Ardcath areas, respectively five and seven miles south of Drogheda, both acid and basic varieties occur, the basic being similar to those at Balbriggan in their general characters and mode of occurrence, while the acid varieties closely resemble those of Wicklow and Wexford. Again, a mass of igneous rock at Craig Barron, west of Slane (Sheet 91), mapped as felstone, has been ascertained to be really of basic composition (dolerite, etc.).

Slane, Bellewstown and Balbriggan. (Mr. McHenry.)

To the west of Slane various acid masses, mapped as felstone and felstone ash, have hitherto been regarded as contemporaneous with Lower Silurian strata. As some of them, however, are distinctly intrusive in the fossiliferous Upper Silurian series, they cannot be of Lower Silurian age, but from their very close resemblance in every respeet to the Wicklow and Wexford types they not improbably belong to the same late period.

The two long east and west masses of rock mapped as "felstone" at Grangegeeth, three miles north of Slane, are now determined not to be igneous at all, but merely an arkose, composed of broken-up and disintegrated felspathic detritus in a fine green sandy matrix, which contains fossils in places.

In County Down a similar re-examination was undertaken by Mr. Egan of the abundant intrusions of igneous rock along the shore to the north of the mouth of Strangford Lough. He was accompanied by Mr. Seymour, whose notes on the petrographical results of the examination will be found on p. 180.

Co. Down. (Mr. Egan and Mr. Seymour.)

County Waterford.

Co. Waterford. (Mr. J. R. Kilroe.)

The revision of the Silurian ground in the County of Waterford has been continued during last season by Mr. Kilroe, who has prolonged to its southern limit the line of boundary between the Lower and Upper Silurian formations. In this mapping the available evidence was entirely lithological as far as Kilmeadan, four miles west from Waterford, the strata proving barren of organic remains until, near that place in the railway cutting at Mount Congreve, they were found by the Fossil

Co. Waterford. (Mr. J. R. Kilroe.)

Collector, MR. R. CLARK, to contain double graptolites, probably indicative of Bala or Caradoc age. The boundary is crossed obliquely by bands of felsite, which, being highly cleaved, were represented as slate and grit on the published maps.

Caradoc strata in great variety, interspersed with igneous bands, are to be seen throughout the southern part of the County of Waterford (Sheets 178 and 179). They extend to the coast-line, and pass beneath the Old Red Sandstone of the Comeragh Mountains on the west, and of Dunmore and Brownstown Head on the east. Near the Upper Silurian area the strata consist of rapidly alternating grey grit and dark grey slate bands.

Similar slate and grit in larger bands are common further south; and black slate, containing, as at Garrarus, Caradoc trilobites, appears in many places. Green grits and epidotic slates, frequently calcareous and fossiliferous, occur in small isolated areas surrounded by igneous rocks in a triangular tract, which extends from Ballynamona southward to the coast and westward towards Durrow. These rocks have peculiar interest, as they are associated with the only true, scantily-represented volcanic tuffs that MR. KILROE has been able to detect in the region. The Bala or Caradoc strata also contain red grits, which are seen in a stream two miles west of Tramore, and associated with green grit and tuff at Sheep Island and at Knockmahon. Earthy limestones and calcareous grits rise into cliffs some 80 feet high at Dunabrattin, and 100 feet near Tramore, this group of strata attaining a visible thickness of 400 feet at the former place, and 650 feet at the latter. It appears also at Green Island near Annestown, and at several other points along the coast. The prevalence of Bala fossils at Tramore and Dunabrattin has long been considered to fix the stratigraphical horizon of these lime stones; and it is doubtful whether the interesting occurrence of Russian and Scandinavian Llandeilo forms, recently pointed out by MR. COWPER REED,* should be accepted as subversive of the conclusion.† The section seen at Carrigaghalia referred to later on, which MR. REED gives as corroborative of his opinion, is of very doubtful value, having regard to the great disturbances which have affected the region.

Black slate, which appears from beneath the limestone near Tramore and at Dunabrattin, may on account of its position, on lithological grounds and in the absence of fossil evidence, be assumed to be of Llandeilo age, like the black slates so distinctive of the Llandeilo formation all over Ireland. Similar black slate found in many other places in the district may in some cases be of the same age; in others, however, it belongs to a Bala

---

* *Quart. Journ. Geol. Soc.*, vol. lv., p. 766.

† Especially in the absence of such forms from the Llandeilo limestone of Wales—a difficulty which the author admits. If the existence of these forms near Tramore be the result of migration westward, it would be reasonable to assume that they reached the Waterford area at a later epoch than the Llandeilo. Instances bearing out the presumption have been indicated by MR. MARR, and are referred to in MR. C. REED's Paper, page 770.

horizon, as is shown by its fossils. The relation of the black strata to the limestone is rarely manifest.

Co. Waterford. (Mr. J. R. Kilroe.)

MR. COWPER REED reports the occurrence of *Dicranograptus* in black slate, which, dipping at an angle of about 80°, at present overlies limestone at Carrigaghalia, 450 yards south of the boat pier at Lady Elizabeth's Cove, near Tramore. In order fully to appreciate the bearing of this section it should be noticed that a continuous series of limestones and grits, visible in Newtown Cove, half a mile to the north of Great Newtown Head, runs inland for about 250 yards, and that the strike of these strata is fairly regular along the cliffs northward. A corresponding succession of limestones and grits might be expected to appear at Carrigaghalia, forming the cliff, and probably also proceeding inland. Instead of this development, however, the limestone is only seen at the base of the cliff, the cliff itself being formed of igneous rocks and the black slate, which is faulted. A thin felsite-sill and a massive basic one separate the limestone from the slate above, the slate being further penetrated by felsite higher up in the cliff, which is here crowned by another basic sill. The structure, therefore, is not regular and normal, so that any conclusion based upon the present position of the slate, relatively to the limestone, can hardly be well founded. The *Dicranograptus* slate would otherwise have to be taken to represent the fossiliferous calcareous grits of the glen at Newtown Cove, where no black slate occurs. The black slate at Carrigaghalia may be considered as in all probability a detached mass, caught in a group of igneous intrusions and carried upward out of its natural stratigraphical position. This view of its relations finds ample illustration in sections along the coast from Newtown Head westward, where similar detached masses of sedimentary rocks are to be seen, surrounded by igneous rocks.

IGNEOUS ROCKS OF THE WATERFORD COAST.

The igneous rocks of the County of Waterford have long attracted attention. Their varieties of composition, structure, and mode of occurrence have been noted, as well as the difficult problems which these varieties present to the geologist. Some notes on the petrography of these rocks by MR. SEYMOUR will be found on p. 180. The following petrographical types have been recognised in the field by MR. KILROE.

(1.) The oldest of the whole series appear to be light and dark-green andesites and other more basic rocks, such as diorites and diabases. The andesites are usually epidotic, and sometimes porphyritic, with crystals of augite.

(2.) Volcanic tuffs associated with Silurian grits, seen at Sheep Island, and other points along the coast. The contained fragments consist chiefly of felsite, sometimes perlitic, glassy or highly vesicular, with pieces of andesite and other more basic rocks and fragments of black shale.

(3.) Compact light-grey and pink potash-felsites, frequently vitreous and showing flow-structure, occasionally containing detached pieces of lime-

Co. Waterford. (Mr. J. R. Kilroe.)

stone as in the sea-stack west of Sheep Island. At this point of the coast, the pink felsite is seen to break into a "breccia" which belongs to the next series.

(4.) Breccias—forming, for the most part, the coast between Great Newtown Head and Annestown, described on the published map in certain places as "felspathic ash" and "greenstone ash" and more recently regarded as "volcanic agglomerates." They are, however, intrusive rocks as will be more fully explained a little further on.

(5.) Green plagioclase-felsites, passing into andesites, and in certain places into "diorites." These prevail in the western part of the district, while the foregoing group predominates in the eastern. Similar rocks, however, form great dykes and sills to the east of Annestown, and may be seen along the coast as far as Great Newtown Head. At Sheep Island, offshoots from the dark green felsite of this group penetrate the breccia of Group 4, and massive sills of the same material invade and include between them an important lenticular band of strata consisting of fine tuff and green and red grit, the tuff graduating upward into the grit. The lower part of the upper sill displays a remarkably well-developed spherulitic structure in a band several feet thick on the south end of the island.

These green rocks—felsites, andesites, &c.—frequently assume a fragmental form like those of the previous group which are grey. They contain pieces of felsite of various kinds from small chips up to large blocks. In one remarkable instance, a little to the west of Ballydowane Bay, a sill consisting almost wholly of partially-rounded masses (the matrix being very scanty), includes some blocks more than two feet in diameter. Many of the lenticular bands in this group are cleaved, which no doubt led to their being mistaken for "greenstone ash."

(6.) Grey potash-felsite, usually porphyritic, which occurs in massive sills near Tramore and is recognisable along the coast to Ballyvoyle Head, near Dungarvan. It is probable that grey granite, similar to that of the Wicklow range, which occurs in lenticular areas trending south-westward, belongs to this stage of intrusion, inasmuch as one of the areas, north of Ballydowane Bay, seems continuous with that of a grey porphyritic felsite seen on the roadside near that bay. To this stage also belongs a striking porphyritic felsite with red felspar embedded in a green matrix, which occurs in two localities, north-east and south-west from Stradbally. Prismatic, spherulitic, and perlitic structures are occasionally to be seen among these felsites.

Green epidotic grits and fossiliferous slate of Bala age are seen to overlie the andesites of Group 1 north of Ballyscanlon Lough; while conglomerates, which form the base of the sedimentary series here and at Munmahoge, nearly three miles north-by-west of Tramore, contain pebbles almost wholly derived from similar andesitic rocks. It is, therefore, obvious that the Ballyscanlon andesites are more ancient than a portion of the Bala group, though there is no evidence that they were erupted contemporaneously with that group. No such satisfactory evidence of stratigraphical position is available for the determination of the age of the other andesites of the district; for while rocks closely resembling those of Ballyscanlon are to be seen in many places, they may be suspected to be of later date than the green Silurian strata. Some masses, however, to the west of Ballyscanlon, such as those of Corrig Castle Hill, near Ballylanneen, are at least older than the brecciated felsites of Group 4.

The tuffs forming Group 2 have been found in widely scattered patches, none of which perhaps exceed a few hundred square yards in area. They seem to be everywhere surrounded by later felsites.

Of the section at Sheep Island, the Director-General, who inspected the ground last summer with MR. KILROE, has furnished the following notes:—"A mass of pinkish-grey felsite rising out of the sea is surmounted by about 18 to 20 feet of well-bedded alternations of a fine breccia and of thin green shaly layers. The fragments enclosed in the breccia consist of small chips of highly vesicular felsites, andesites, and probably some more basic rocks. These materials are obviously of igneous origin. The most abundant of them are lapilli of a fine dull-green extremely minutely cellular pumice, which recalls the familiar basic lapilli of the Carboniferous tuffs of the basin of the Forth. They include also fragments of pink felsite with exquisitely perfect flow-structure. Many of the strata of this breccia are coarser at the bottom and become finer towards the top. There can hardly be any doubt that these strata are true tuffs. They pass upward at one place into some red shales and grits, the bedding of which is parallel with that of the tuffs below. Co. Waterford. (Mr. J. R. Kilroe.)

"Above this fragmental band comes another felsite, which is particularly conspicuous for the great perfection and beauty of its spherulitic and flow-structures. These structures are grouped parallel with the under surface of the sheet. The lower band of the rock is remarkably spherulitic. Some of the spherulites, composed of a very flinty pink felsite, measure three inches in length and many of them enclose a nucleus. Higher up in the sill bands of fine spherulitic material may be observed, the spherulites being small and round like peas, and scattered sparingly through the matrix. The lower portion of this felsite is traversed by a dyke two feet six inches broad, of a grey compact finely vesicular felsite."

The most important part of MR. KILROE's revision of the igneous rocks associated with the Silurian formations of the south of the County of Waterford has reference to the remarkable brecciated masses of that region. As in Wicklow and Wexford, these rocks have hitherto been considered as tuffs and agglomerates, but close re-examination of the remarkable coast-sections where the rocks are so well exposed, has led MR. KILROE to the same conclusion as his colleagues—MESSRS. EGAN and MCHENRY (*ante* p. 72). He believes that the main mass of the igneous rocks is of intrusive origin, and that most of the so-called agglomerates and breccias are not truly volcanic masses, but have been produced by a process of brecciation during the prolonged period of igneous intrusion. At the same time the microscopic study of the rocks by MR. SEYMOUR has shown that some of them are true felsitic tuffs, with glassy and vesicular lapilli.

The fragments enclosed in these "intrusive breccias," to use the term originally employed by MR. MCHENRY, consist principally of various felsites and other igneous rocks, but include also, sometimes abundantly, angular pieces of black slate and grit, derived from the surrounding Silurian formations The felsite fragments often show flow-structure, and have obviously been derived from a rock such as that which may here and there be seen in veins and sills traversing both the igneous

Co. Waterford. (Mr. J. R. Kilroe.)

and sedimentary masses of the coast-cliffs. Some specially instructive sections showing the character and relations of these rocks may be seen at Sheep Island, two miles west of Great Newtown Head, and on the adjacent part of the shore. Here the observer may follow, as it were, the successive stages in the process of the production of the brecciated structure in an intrusive molten rock. The original felsite has been broken up, and its fragments have been carried forward in a fresh inroad of similar material. The newer matrix sends veins into the included fragments, as may be well seen where the pale greenish grey felsite traverses a block of black slate. In some places, as at St. Ronan's Bay, south of Tramore, the quantity of included fragments sometimes amounts to about three-fourths of the whole mass, only one-fourth part being the matrix in which they are enveloped. It is difficult to realize how an intrusive rock so charged with foreign material could have been injected into cracks and fissures of the crust.

That this breccia moved as such, and was forced into irregular apertures or rents in previously solidified rocks is well displayed at many points of the coast-line. A remarkable section occurs on the cliff immediately behind Sheep Island, of which the Director-General has supplied the accompanying figure and notes :—

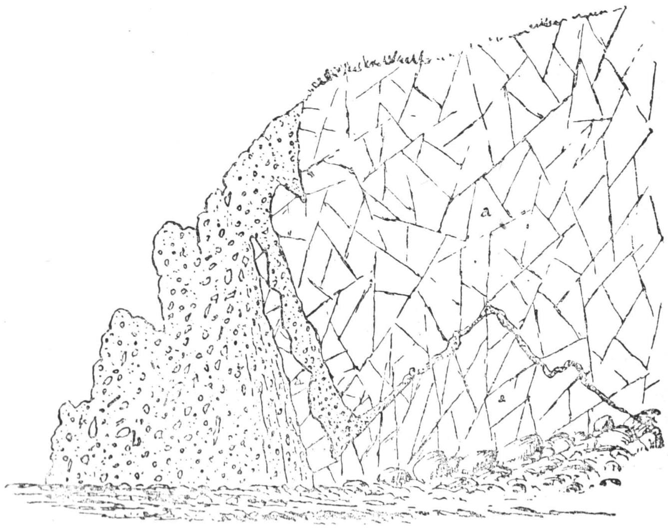


FIG. 1.—Section of Intrusive Breccia (b) in Felsite (a), shore opposite Sheep Island, south of Tramore, Co. Waterford.

"The older rock (a) of this section is one of the usual pinkish felsites which have so abundantly invaded the igneous and sedimentary masses of this coast. The younger rock (b) is a green 'breccia' of the prevailing type, but with a less proportion of included stones than may often be seen in other similar masses. The fragments which, however, are sufficiently numerous, consist largely of felsites, some having a beautiful flow-structure and others showing a vesicular texture. They include also pieces of a reddish limestone. It will be observed from the figure here given (Fig. 1) that this breccia is intrusive in the felsite It sends a long dyke or vein downward in the latter rock, of which it thus separates a strip at the margin. A little above the beach this dyke or vein bends sharply upward and rapidly lessens in thickness, but continues in a sinuous course through the felsite until it dies off in a narrow finger or thread. From the sharp bend just mentioned to the extreme end of the vein is a distance of seventeen feet. In the thicker dyke or vein to the left, the size of the stones is less than in the body of the breccia, and these are still smaller in the attenuated vein that strikes off to the right. But they continue to be present even up to the end. Co. Waterford. (Mr. J. R. Kilroe.)

"The matrix is a fine felsite, about the true origin of which as a molten rock there could be no doubt if it were considered in itself and apart from the problem presented by its included stones. It has been obviously intruded here into an irregular rent, and its load of fragments has been as it were strained off by the narrowing of the passage until only fine chips were borne along to the end."

Petrographical notes on some of these interesting rocks have been prepared by Mr. Seymour, and will be found on pp. 179, 180.

If the majority of the igneous rocks of the Waterford coast, hitherto regarded as volcanic sheets intercalated contemporaneously among the Lower Silurian sediments, are now to be regarded as really intrusive in, and therefore later than these formations, the important questions remain of (1st) the geological era to which the prolonged injection of this enormous series of eruptive masses is to be assigned, and (2nd) the stratigraphical relations and age of the volcanic eruptions represented by the tuffs. As the intrusions have invaded all parts of the Lower Silurian series of the district, they are clearly of later date than these. North of Kilmacthomas Mr. Kilroe has found cleaved felsites closely adjacent to Upper Silurian strata. The sections are not conclusive as to the relations of the two groups of rock, but if the felsite is not brought in by faulting or folding but is really intrusive in the surrounding strata, it will follow that some at least of the protrusions cannot be older than some part of the Upper Silurian period. But the date may be more nearly defined by the evidence of the coast-line at Ballydowane Bay to which fuller reference will be made in the account of last year's field-work in the Old Red Sandstone (*postea*, p. 101). It will be shown that there is a high probability that the igneous protrusions of County Waterford belong to that remarkable period of hypogene and volcanic activity which witnessed the injection of so many of the chief granitic masses of the British Isles and the outpouring of such vast sheets of andesitic lavas and volcanic agglomerates and tuffs.

Island of Arran.

An account of Mr. Gunn's interesting discovery of another exposure of the cherts and black schists on the Highland border has been already given in the section on the Dalradian rocks (*ante*, p. 68). But as these strata may with the highest probability be relegated to the Silurian system, a brief allusion to them again may not be inappropriate at the end of the foregoing narrative of recent progress among the Silurian formations of Ireland. Mr. Gunn, in his report of his year's work, justifiably stated that the most important addition to the geology of Arran is the discovery in North Glen Sannox of a volcanic series associated with the schistose grits of that region. This set of lavas occurs in connection with volcanic agglomerate, with cherts and with dark shales or schists, like the rocks of Ballantrae in Ayrshire, and the whole is probably of Arenig age. No organisms have yet been discovered, however, either in the cherts or in the dark schists, but it is to be hoped that when the rocks come to be thoroughly searched by the fossil collectors, organisms will yet be found. Great interest attaches to the rocks in this area because they appear to be intercalated in the Highland schists, the whole forming apparently a regular and conformable succession. By this discovery the number of distinct volcanic series in Arran is increased to six.

These igneous rocks were first noticed in the month of June, but very little was then done in working out their relations to the associated schists. Specimens, however, were obtained of several varieties of the rock, and on these being shown to Messrs. Peach and Horne, they at once remarked on their resemblance to the lavas of Arenig age near Ballantrae. It was not till late in the year that the survey of the district was resumed, and the area occupied by these volcanic rocks was mapped in detail After this was done Mr. Peach spent a day on the ground with Mr. Gunn, seeing most of the principal sections, and he had no hesitation in identifying these rocks with those of Arenig age at Ballantrae.

As has been already pointed out, no structural line of separation can be detected between these presumably Lower Silurian rocks and the ordinary Highland schistose grits between which they are intercalated. The question is thus again raised as to how far the Silurian age of the rocks is to be extended into the Highlands. It has been impossible to find any lithological difference in the condition of the strata that are almost certainly Arenig, and the schistose grits alongside of them. They have undergone the same plication and the same degree of metamorphism, and they undoubtedly seem to form parts of one continuous and unbroken series. We are not yet in a position to solve this difficult problem. But important data are accumulating for its solution. There now seems to be every probability that both Lower Silurian and Cambrian formations enter largely into the composition of the great mass of the Highland schists.

DEVONIAN.

Cornwall.

The field-work of the Survey among Devonian rocks last year has been confined to the County of Cornwall, where it has been carried on in the Eastern border by MR. USSHER, in the Falmouth district by MR. HILL, and around Penzance and the Land's End by MR. WILKINSON.

Districts of Liskeard and Looe. (Mr. W. A. E. Ussher.)

MR. USSHER has mapped Upper, Middle, and Lower Devonian rocks in the districts of Liskeard and Looe (Sheet 348). The larger part of the area surveyed consists of Lower Devonian rocks. These make a natural junction with the Middle Devonian slates south of Liskeard, but are cut off against Upper and Middle Devonian slates with volcanic rocks on the east by a fault that runs in a south-easterly direction from the vicinity of Clicker Tor near Menheniot Station. By this dislocation and others parallel to it near Mount Edgecumbe, the Lower Devonian outcrop has been shifted to more northerly positions.

The Lower Devonian rocks are greatly disturbed by numerous contortions, thrusts, and faults, which obscure the relations of the divisions at crucial points. Their uppermost strata consist of sandstones with argillaceous slates and shales (developed south of St. Keyne), which seem to be practically unfossiliferous, and are usually of a dull greenish and grey colour. Owing to repetition by plications they exhibit a greater development on the west than on the east of the East Looe river. They are succeeded by grey slates, occasionally siliceous, and with local beds of hard grit. Thus far the Lower Devonian succession is perfectly clear, but beyond this point it is obscured by the manner in which the remaining components of the series are distributed. These embrace the Looe beds and the Polperro beds.

The fossils recorded from the Looe grits and shales are said to characterise the "Gedinnian" group of the Continent, that is to say, they indicate a lower fauna than any other found in Devonshire. The rocks with which the organisms are immediately associated include limestone in no persistent quantity, but in character, and seemingly in fossil contents, identical with beds in the Plymouth section. They comprise also interlaminated beds similar to those of Torcross and Tinsey Head. These are well shown in the coast-sections. The calcareous bands seem to occur at different horizons, but are most apparent near to or actually in contact with the red or buff shales and grits of the Looe beds. The slate series, although to a great extent identical in character with the slates which succeed the St. Keyne sandstones, is more variable, containing irregular grits, compact grits, and fossiliferous partly siliceous, irregularly cleaved grey slates, closely similar to characteristic types of the Meadfoot beds of Torquay. This similarity is so strong that were it not for their Gedinnian fossils the Looe grits and shales might well be regarded as a part of the Meadfoot beds (Lower Coblenzian) with distinctive, Districts of Liskeard and Looe. (Mr W. A. E. Ussher.)

locally recurrent, but impersistent lithological and palæontological characters. The classic fish-beds of Polperro lie among dark slates and hard grits, which are no doubt a part of the slate series that includes the Looe beds, but the distribution of the organisms is more general in the purple green and buff slate series of Polperro, Talland and Downderry. These variegated strata are precisely like the Dartmouth and Kingswear slates and also the slates and grits of the Revelstoke and Wembury shores. At Piskeys Cove on the Revelstoke coast MR. USSHER found remains of *Pteraspis*. Although a boundary has not been continuously drawn for the Dartmouth slates in Devonshire, their persistence and identity with the variegated slates of Polperro has been clearly proved. The Dartmonth slates of Polperro, although faulted on the north, are shown in places in unfaulted junction with the dark slates which contain traces of fish. As far as can be judged from the evidence the calcareous beds in contact with the Looe grits and shales give place to these dark slates. The latter comprise intercalated beds of hard grit or quartzite which, where present, often show intense plication. These slates form the coast-section for five miles westward from Portwrinkle, where they are faulted against Looe beds. The dislocation at first escaped notice, the red beds of the Looe series between Crafthole and Cawsand having been very naturally confounded with those of the Dartmouth slates. In the Seaton River Valley, below Hessenford, the grey slate series, with its associated grits and calcareous bands and patches of Looe beds, presents many points of resemblance to the strata above the slates of the Kingswear promontory which correspond to the Meadfoot beds of Torquay. These grey slates, which are the inland continuation of those in the East Looe coast, are bounded on the south by the Dartmouth slates of the Downderry coast, the boundary being in part at least a fault, and on the north by a mass of the Dartmouth slates which north of Hessenford extends over the ridge of Bindown to the East Looe River Valley. This mass is shifted by a fault between Bindown and Congorlan. On Bindown and above Congorlan very tough grits, containing *Pteraspis* remains, are present in association with quartzite and grey slates. On the north border of this mass, at Wringworthy, a small patch of Looe grits occurs, but with this exception there is no proof of the representation of the Looe beds in the slates on the north which come directly below the St. Keyne sandstones. In the district west of the East Looe River, the Dartmouth slates may occur in small patches. Grits resembling those above Congorlan have been detected, which may owe their position either to a prolongation of an anticlinal axis from Bindown and Congorlan, or to a fault. The slates under the St. Keyne sandstone may perhaps form the upper part of a great series, in the middle or lower part of which the Looe grits and shales and calcareous beds occur, and the dark slates, with fish remains and quartzite beds, may lie at the base of this series, directly above the Dartmouth slate group.

The chief problem of the geological structure of the Looe district

Districts of Liskeard and Looe. (Mr. W. A. E. Ussher.)

is centred in the mass of Bindown and Congorlan. This mass is most probably an anticline. If it be regarded as a single outcrop the almost entire absence of Dartmouth slates on the west of the East Looe River will have to be accounted for by faults cutting out the whole of these slates, a view which would place the Looe beds below the Dartmouth slates, and would well accord with their presumed Gedinnian age. The evidence as to the Lower Devonian succession afforded by the Looe district alone must be confessed to be quite inconclusive. Taken in connection with the data derived from previous Lower Devonian exploration, the balance of evidence inclines Mr. Ussher to the simpler view that the downward succession is as follows:—

Staddon grits -	St. Keyne sandstones.	
Meadfoot Beds	Beeson, Churchstow and Ringmore beds -	Grey slates, with occasional grit
		- Looe grits and shales.
	Torcross and Tinsey Head beds.	Grey slates, with limestone and grits.
		Dark-grey slates, with interlaminated beds, and quartzite bands.
Dartmouth slates	Revelstoke Beds -	- Purple, green, and buff slates, with quartzite or compact grits and arenaceous beds.

South of Pelynt the direction of dip of the schistosity is nearly always northward. The change in the prevalent southerly dip of this structure takes place along an irregular line drawn from the fault in Portnadler Bay toward Pelynt, which has no connection with any particular geological horizon. De la Beche alludes to the rounding of the strike near Pelynt.

The Middle and Upper Devonian rocks in the district recently surveyed consist of slates and slaty mudstones, in which volcanic rocks occur. Their lower portions comprise argillaceous slates or slaty mudstones, often splitting prismatically, and with cleavage planes that dip generally at low angles, the bedding being frequently shown by vertically undulating, suture-like lines. Calcareous slates may be seen in the new railway line south of Liskeard Station, but there is no persistent limestone. The irregular distribution of the volcanic rocks in the tract of slate seems to be due to their lying in troughs of the higher Middle Devonian slates, and also to the fault-boundary of the Lower Devonian rocks, which cuts off the Middle and Upper Devonian series on the west, and is probably prolonged in the Middle Devonian area toward Liskeard. No boundary can be even approximately drawn between the Upper and Middle Devonian groups. Purple and green slates of the Upper group occur at Menheniot, and *Entomostraca* were obtained from them near Doddy Cross and Padderbury.

The Middle and Upper Devonian volcanic rocks consist of schalsteins and brown and greenish vesicular rocks, of which a good example is afforded by the mass on Padderbury Top. The Clicker Tor "Serpentine" is an ophitic dolerite, probably intrusive. A coarse-grained, probably intrusive basic rock occurs near Cartuther, and in the valley between that place and Menheniot.

Districts of Liskeard and Looe. (Mr. W. A. E. Ussher.)

In the Lower Devonian area igneous rocks occur in many places, but so sparingly developed and so decomposed that they cannot be indicated on the map without exaggeration. Although in places resembling sheared tuffs, their true origin remains uncertain. They are most frequently to be met with in the calcareous parts of the grey slate series associated with the Looe beds, but they also occur in the Dartmouth slates. Sheared diabases have likewise been found. The most interesting igneous rock yet encountered in the district is a highly silicified trachyte or andesite, which is quarried for road-metal on the southern slope of Bindown. It runs in an east and west direction, and is of small superficial extent. Mr. Teall has furnished the following notes regarding it:—

"[E. 3254 and 3255.] Bindown, S.S.W. of Menheniot. Grey or bluish-grey, highly quartzose rocks, traversed by veins of quartz and pyrite. Under the microscope they are seen to be highly silicified vesicular igneous rocks. Quartz has been deposited not only in the veins but also in the vesicles. The greater part of the rock is composed of quartz, but a certain amount of altered igneous material occurs as a matrix between the amygdaloids. This consists of a few rare phenocrysts of felspar in a groundmass of felspar-microlites and ill-defined interstitial matter. The nature of the original rock cannot be determined with certainty from these specimens. It appears to have been either an andesite or trachyte—most probably the latter."

Penzance District. (Mr. S. B. Wilkinson.)

In continuation of his previous mapping, Mr. Wilkinson has surveyed the tract lying to the north-west and south-west of the town of Penzance. The district is almost entirely occupied by granite, but sedimentary rocks, highly altered and traversed by masses of "greenstone," rise on its eastern margin. The boundary-line between the two groups of rocks is well defined on the coast at the fishing village of Mousehole, whence it runs inland and then circles round behind Madron and Gulval. On the coast at Mousehole the sedimentary series has been very much altered. The granite is there seen to have been intruded into bluish, flaggy, fine-grained strata, which it has baked and altered almost into hornfels. Nowhere else along the inland boundary has the actual contact of this intrusive mass been observed, but the sedimentary rocks, which are cleaved red shales, all show evidence of alteration. A large band of "greenstone" stretches from Mousehole to Newlyn among the sedimentary rocks which are there changed into hard and compact hornfels. Close examination of them indicates that they have been much puckered and plicated, and that they suffered their chief metamorphism, together with the "greenstone" mass, during the period of the granite intrusion. No evidence has been obtained as to the age of these sedimentary rocks.

The best-known mass of "greenstone" in this district is that which extends from Mousehole to Newlyn. It is much used for road-metal and for the manufacture of artificial pavement. At the Penlee quarries, which give employment to a large number of men, the rock is blasted out of the face of the quarry and is afterwards broken up by the hand and by machinery. It is an exceedingly hard and tough material, and on that account cannot be worked with tools for building purposes. What is probably a continuation of this mass crosses the stream at Newlyn and crops out behind the church and at Mount Misery, extending in a northerly direction to Castle Horneck and Rosehill. The town of Penzance appears to have been built on a mass of this rock, which crops out at Lescudjack Hill and Coombe Quarry, extending in an easterly direction towards Gulval. In all these masses an extreme toughness of character is maintained. A large quantity of the rock is used locally for road-metal under the name of *blue elvan*.

Penzance District. (Mr. S. B. Wilkinson.)

The granite of the Land's End district is seen to great advantage round the coast from Mousehole to the Land's End and thence northwards. In the interior the rock is not well exposed owing to the readiness with which it weathers and crumbles away, while round the coast, the weathering of the material along the joints gives rise to singularly artificial-looking masses. Inland the same kind of weathering occurs, but the rock appears there on the hill-tops in the form of huge mushroom-shaped bosses. Along one set of nearly horizontal or gently undulating joints the rock decays more readily than on the flat or rounded surfaces. Another set of joints which has a more or less vertical direction has not the same importance in determining the architectural aspect of the rock, but is effective in allowing it to weather into columns and obelisks.

The granite is a porphyritic rock, its most conspicuous constituents being crystals of grey felspar, which possess a beautiful pearly lustre, and are often three to four inches long and more than an inch in breadth. The ground mass through which the crystals are dispersed consists of quartz, felspar, and mica. Schorl also occurs at Castle Trenecen, where the Logan Rock stands, and which is cited by De la Beche as a good example of the occurrence of this mineral.

This beautiful granite is worked in several quarries. It is dressed on the spot, and sent away sometimes in enormous blocks. Besides the contact junction of the granite with the sedimentary rocks at Mousehole, already referred to, another is exposed further round the coast to the west at Tater-du-Point.

At Mousehole the granite penetrates and alters the sedimentary rocks into which it sends veins and tongues in every direction, and encloses portions of them. It is noticeable that the crystals of felspar (several inches long) are as large at the contact as they are in the interior of the mass. No "chilled edge" is here to be seen. On the other hand at Tater-du-Point, where the granite surrounds an inlier of "greenstone," it becomes gradually finer in grain for some six to eight yards from the contact, and at the actual junction presents a good example of the close texture so usual where masses of eruptive material have been rapidly cooled by coming against older and much colder rocks.

Veins of fine-grained granite have been observed at several places. At Mousehole fine-grained granite-veins pierce both the coarse porphyritic mass and the sedimentary rocks, while at Tater-du-Point similar veins cut across the main granite, and also the "greenstone." At Whitesand Bay innumerable veins of granite, very fine in texture, and varying from an inch to several feet in thickness, cut the coarse porphyritic mass in every direction.

Falmouth District. (Mr. J. B. Hill.)

Though there is reason to suspect that the rocks in the Falmouth district, long recognised to be Lower Silurian, are not by any means the only representatives of that system in this part of Cornwall, and that eventually it may prove that there are really no Devonian strata there, an account of the recent work of the Geological Survey in that district is inserted in the present section of this volume, in accordance with the order followed in previous *Reports*. Further research may justify the definite relegation of a considerable tract of ground in the south-west of the county to Silurian formations.

While the occurrence of Lower Silurian strata on the southern coast of Cornwall has been well known for so many years, the relations of these strata to the rest of the "killas" or "grauwacke" of that part of the country have never yet been ascertained. The structure of the ground is exceedingly complicated and can probably only be unravelled by patient examination with the aid of large-scale maps. This is the task which has been assigned to Mr. Hill, who, from his station at Falmouth, has continued the Survey, of which some account was given in last *Summary of Progress*. He has made a perceptible advance during the past year, as will be seen from the following narrative which he has furnished:—

The field-work has been carried well into the interior. The various estuaries which diverge from Falmouth Harbour and the Helford river penetrate deep into the heart of the country, and afford more or less continuous sections of the strata. Their courses are so tortuous that the examination of them has involved the mapping of 68 miles of coast sections in addition to what was reported for 1898. These deep indentations have allowed the strata to be continuously followed without a break from the sea-coast at Falmouth to practically midway across the breadth of Cornwall. Advantage has also been taken of the numerous cuttings along the line of the Great Western Railway. All these natural and artificial sections have been mapped in detail, and have been of considerable service in the working-out of the stratigraphy of the district, since generally over the surface of the interior the rocks are only to be seen in isolated exposures and usually in an advanced state of decomposition.

It was mentioned in last *Summary* that, in the absence of palæontological data Mr. Hill had separated the slates of the district lithologically into the following divisions * :—

1. Veryan beds.
2. Portscatho slates.
3. Variegated (Falmouth) slates.
4. Mylor series.

* *Summary of Progress* for 1898, p. 97.

Falmouth District. (Mr. J. B. Hill.)

These groups succeed one another in the order here given from east to west, and their persistence over wide areas as distinct stratigraphical horizons has been confirmed by the work of last year. The eastward extensions of the Portscatho slates in Veryan Bay were coloured by DE LA BECHE as Lower Silurian, and the same strata, after striking into Gerrans Bay, make their appearance again south of the Helford River. The part of the district to the south of Falmouth has now been examined, and the results of the work will here be briefly stated.

In order to determine the relations between the Portscatho slates (No. 2) and the strata south of Helford River the coast-section was examined in detail between Falmouth Bay and the Nare Point. From Maen Porth, where the Variegated Slates (No. 3) are last seen, the coast, as far as the Helford River, presents an uninterrupted section of the blue slates and fine sandy beds of the Portscatho slate series in their normal condition. South of the Helford River they are well exposed as far as St. Anthony Creek. As they are followed southward, however, they have suffered more severely from the stresses which have induced the folding and cleavage of the rocks. At Dennis Head the structures set up by these movements have been carried a step further. The strata have been, as it were, subjected to mylonisation (or crushing) of a coarse type, insomuch that they have been reduced to a mass of coarse lenticular patches of rock, the lenticles being several feet, in some cases yards, across, and the whole presenting the character of a gigantic breccia. These lenticles, when they have been torn from quartzose beds, resemble huge boulders; in other places the apex of a folded limb has been detached and isolated from the parent mass. This extremely coarse type of brecciated structure is more or less continuous along the coast as far as Porthalla, where the northern edge of the Lizard "complex" appears.

Between Dennis Head and the Nare Point a conglomerate is interbedded with blue slates. Near the Nare Head a quartzite appears, and further south, nearer Porthalla, a small limestone band. The limestone and quartzite, as well as the conglomerate, are found associated with the blue slates.

The conglomerate was described by DE LA BECHE,* who recognised in it fragments of hornblende-slate in addition to the material supplied from local sources. It is well seen on the shore east of Men-aver Point where it has an outcrop of nearly a third of a mile. Still farther east, at the Nare Point, conglomerate is again exposed for a few yards. As the strata are highly folded it is probable that the successive outcrops are parts of the same mass. Before the main body of the conglomerate comes on, thin seams of fine conglomerate may be observed to be intercalated in the slates. These seams vary from six inches to a foot in thickness. Commencing next the slates as sandstone, they rapidly become coarser, occasionally including fragments three or four inches across. The fragments are made up of black slate

* *Report on the Geology of Devon and Cornwall*, 1839, p. 94.

Falmouth District. (Mr. J. B. Hill.)

and greyish green slate, rounded and sub-angular, together with angular pieces of white quartz. This part of the rock is generally fine-grained. The coarse conglomerate begins with a fringe of similar material, which also forms the matrix of the coarse mass. The larger boulders are made up of slate, quartzite, and vein-quartz. Many of the quartzite-blocks are of huge size; the smaller boulders of this material are generally well-rounded, as are also many of the fragments of white quartz. In addition to these fragments, which have been derived from rocks in the immediate neighbourhood, boulders of foreign material are also present, consisting of granitic and felsitic rocks, some of which are foliated; quartz-felsite and green schistose fragments, some of which are probably referable to the hornblende schists of the Porthalla district to the southward, while granitic and felsitic fragments may have been derived from the older rocks of the Lizard; at least they do not resemble the granite and associated rocks that lie to the north of this part of Cornwall. These far-derived materials are generally in a highly decomposed condition; they have also suffered brecciation from the stresses to which the Conglomerate has been subjected in common with the rest of the rocks of the district. Amongst the fragments of green rocks in the Conglomerate, one which was very serpentinous but highly fissile, unfortunately could not be extracted from the rock. Whether it should be associated with the Lizard serpentines, must remain doubtful. Boase, indeed, has stated that fragments of serpentine and diallage-rock occur. De la Beche observed hornblende slate, but could not detect serpentine or diallage-rock. Since the time of De la Beche's survey the existence even of pieces of the hornblende-slate has been doubted, no subsequent observer having detected it. Mr. Hill's observations tend to confirm De la Beche's statement. If the fragments of foliated granite have, as is probable, been derived from the Lizard district, serpentine may perhaps yet be found included in it. It must be borne in mind, however, that the granite and other igneous fragments, supposed to have been derived from that district, are generally much decomposed, so that the chances of so soft a rock as serpentine surviving attrition during transport might not be great. Although better able to resist severe movements of the terrestrial crust than the slaty rocks among which it lies, the Conglomerate has undoubtedly experienced similar stresses. Its upper layers have yielded to the movements as completely as the slates on either side of it. Moreover it is traversed by planes along which shearing has taken place, so that its constituent boulders have sometimes been broken across. Thin quartz-veins occasionally traverse both boulders and matrix. The quartzite boulders are sometimes almost welded into the gritty parts of the Conglomerate. A mica-trap dyke rises in the Conglomerate, in which it is no doubt intrusive, although its junctions with that rock are not seen. No fragments of it occur in the Conglomerate. The mica-trap is of the normal type of the dykes which in this district cut the Portscatho slates.

The quartzite is first seen on the south side of Nare Point, but on account of the coarse brecciated structure that has been previously described as occurring in this neighbourhood, it cannot be continuously followed. It occurs here as a lenticle about 10 feet long and 5 or 6 feet wide. A little further south, between Nare Point and Nare Head, the quartzite seen a little inland above the cliff probably represents the parent mass from which this large lenticle has been isolated. It is a grey compact rock which has suffered a great deal from the brecciation of the district. Its interstices are filled with vein-quartz, consequently it is a mixture of quartzite and secondary-quartz. Except that it is more brecciated, it is similar in character to the quartzite of Carne in Gerrans Bay. The thin limestone seen near Porthalla also resembles the limestone at Gidley Well in Gerrans Bay. Falmouth District. (Mr. J. B. Hill.)

Besides the quartzite of Carne and the limestone of Gidley Well, the Veryan series of the Gerrans Bay district also contains a conglomerate, and is thus brought still further into relation with the strata between Dennis Head and Nare Point south of the Helford River. Indeed, the evidence furnished by a study of the two sections is ample for the correlation of the rocks in the two areas. De la Beche clearly recognised the probability of their identity,* although the Veryan beds were coloured on his map as Lower Silurian, while what must be regarded as their equivalents south of the Helford River were coloured as Devonian. As the Veryan beds have been determined by palæontological evidence to be Lower Silurian, it is clear that strata of Lower Silurian age extend still further to the south-west, and that they form the northern boundary of the Lizard mass of eruptive rocks. Gerrans Bay. (Mr. Hill.)

The positions of the four groups of strata enumerated in the table on p. 88 were given last year mainly as they appear on or near the coast line. But as these strata have since been traced well into the interior of the county, a better idea of their geological range can now be afforded.

The Veryan group, as we have already seen, after being lost in Gerrans Bay, reappears on the Meneage Peninsula to the south-west. It is then succeeded further west by the Portscatho group, which is well exposed along the coast line from Gerrans Bay to the Zoze Point. On the west side of the Carrick Roads, the Portscatho slates occupy the country between Falmouth Bay and the Helford River, from which they continue in a south-westerly course. From Pendennis Point they have an average north and south strike as far as Truro, and occupy the broad tract of country between that place and Gerrans Bay. The Mylor series (No. 4) covers an area of perhaps equal extent west of a north and south line between Truro and Falmouth. The Variegated Slates (No. 3), which lie between the Portscatho slates and the Mylor series, have been ascertained by the recent mapping, as far as this district is concerned, to be of much smaller extent than the two divisions

* *Op. cit.*, p. 95.

Gerrans Bay. (Mr. Hill.) which it divides. Some further particulars may be given in addition to what was stated last year in reference to the several groups.

In respect to the Portscatho slates, indeed, little has now to be added to the former description. They are almost continuously exposed along the whole line of coast from Gerrans Bay to the head of Helford River, and the greater part of the estuaries that strike inland from the Carrick Roads traverse this series of strata, so that, as it can be followed in continuous coast-sections across the strike from the mouth of Falmouth Harbour to Truro and Tresilian, unusual facilities are afforded for its detailed examination.

The Variegated Slates which form a well-marked belt at Falmouth cannot be so continuously traced. Between Falmouth and Truro they appear in lenticular strips, either as infolds within the Portscatho series or else as partitions between the Portscatho and Mylor series, while occasionally they may be seen as infolds within the area of the Mylor series. The axes of the isoclinal folds into which all the groups of strata have been thrown, do not correspond with the general strike of the stratigraphical zones but cross it rather obliquely, so that the mapping brings out several more or less parallel lenticular masses of the Variegated Series along a zone oblique to their longer axes, the several repetitions being due to isoclinal folds. These infolds are never found very far from the general boundary of the two adjoining series, except near Ruan Lamhorne, where two such patches occur within the Portscatho series, but indicating probably the upward limit of the Portscatho series at that place The ground southwards from Falmouth affords similar evidence. The large belts at Falmouth and Maen Porth, apparently, " nose out," and the section along the Helford River which crosses the strike shows numerous zones of this series interfolded with the Portscatho slates. So close are these intercalations that in many cases it is quite impossible to separate the stratigraphical divisions on the map.

It was pointed ont in last *Summary* that the Variegated Slates of Falmouth are more arenaceous than the series at St. Mawes, and as these are carried still farther to the south-west, they are found to be mainly arenaceous, almost to the total exclusion of argillaceous material, so that at Helford River they are represented almost entirely by buff sandy beds. Hence the alternations in colour from the green argillaceous to the buff sandy type are also lost, and consequently, instead of being variegated they are here of a uniform buff tint. Within this series of strata, both at Falmouth and at St. Mawes, narrow zones of sharply-contrasted purple and green slates have been observed, likewise to the north of St. Mawes, between Mesack Point and Turnaware Point, where rocks of this character are strongly developed in the Variegated series.

The Mylor series of finely-striped slates has been found to present a remarkable brecciated structure, to which brief allusion was made last year. So uniform was this character of the series over large areas, that this particular structure was supposed to be due to original conditions of deposit, rather than to secondary processes of deformation. The field-work of last season, however, has revealed that the brecciation is not so common as was believed from the mapping of the strata between Falmouth and Restrongult Point. The structure in question seems to be more or less confined to the latter locality, the outcrops further west and north being practically free from it. It is probably the result of the stresses to which the beds have been subjected. Its extent may be gathered from the fact that in some places it may be continuously followed across the strike for over half a mile, the strata being made up of a mass of fragments from the size of peas up to 5 or 6 inches in length, enveloped in a slaty matrix and with their flat sides lying in more or less parallel planes. These breccias clearly consist of the same material as the non-brecciated part of the same group, which is composed of inter-laminations of pale and dark argillaceous, occasionally pale siliceous material. The fragments are, as a rule, angular, but some are well rounded. Although direct evidence of their origin is not often forthcoming, yet, occasionally, stages may be detected in the process of manufacture which if carried a step further would have resulted in the production of isolated fragments. Besides having been thrown into numerous isoclinal folds, these strata throughout their whole material have been affected. The Mylor series, from the varying nature of its interlaminations and the corresponding variations in their ability to resist crushing, appears to have been unable to overcome the main strains without this process of brecciation. Still, for the most part, this structure is evidently rare; it occurs only in the neighbourhood of faults, and is evidently the last stage after the folding. The separation of the fragments has been due to the limbs of folds being isolated by the movements, which have produced a structure somewhat similar to the coarser lenticular structure in the section between Falmouth Bay and the Nare Point. There has been a combination of minute over-folds and thrusts. Instances may occasionally be seen where the disruption of the folds is not quite complete, and where the almost isolated folded limb precisely resembles the separated fragments. The phenomenon appears to be related to that described by MR. LAMPLUGH in his paper "On the Crush Conglomerates of the Isle of Man." In the Cornish examples, however, there can be no doubt that the alternating materials of which the strata are made up has been a potent factor in this type of deformation.

Gerrans Bay. (Mr. Hill.)

The brecciated structure now described as so prominent a feature in the Mylor series is not confined thereto. A similar structure on a large scale may be seen south of Helford River, even in the Mylor series itself at a distance from the brecciated areas. Feebly brecciated zones are met with in the neighbourhood of faults. Minor zones of brecciated material can likewise be seen in the Portscatho series, generally in thin bands near a fault where small angular fragments of slate may be found enclosed in a matrix of similar material.

Gerrans Bay. (Mr. Hill.) In Gerrans Bay in one of these bands of brecciated dark slate a crinoid stem was seen to be apparently unbroken. It would be almost impossible to separate this band from similar strata where the brecciated origin is clear. The rock seems to have been able to undergo considerable deformation as a whole while small portions were unaffected. The isolation of the fragments has sometimes been produced without folding; instead of faulting succeeding the folding, the stresses have resulted in the direct formation of movement-planes, which have isolated the fragments from the main mass.

The igneous rocks of the Falmouth districts, besides the granite and the quartz-porphyry dykes, are of the types consisting of greenstones and mica-traps. The former, many of which are schistose, are confined to the Mylor series, while the latter are found in the other stratigraphical divisions. These are especially numerous along the Fal actions of the Portscatho series.

The margin of the granite being everywhere obscured, the ground has proved highly unsatisfactory for the study of the effects of contact-metamorphism on the slates. Although the boundary of the eruptive rock has been followed for nine miles, the actual junction of the granite and slates has only been observed at one place. Besides the knotted structure, referred to last year, muscovite and biotite have also been developed in the slates. The mica increases in abundance towards the granite and has been observed as far as half-a-mile away from the line of contact. It occurs in minute scales but in considerable quantity, and both micas in about equal amount, but white mica is more confined to the immediate neighbourhood of the granite, whereas black mica occurs equally over the whole aureole where a micaceous constituent is present. The knotted slates have sometimes been observed at a distance of a mile and a-half from the nearest visible granite.

As pointed out in previous Reports, the structures of the stratified formations in the south of Cornwall are identical with the structures of crystalline schists. In the Falmouth district, so far as yet examined, true slates have not been met with. The strata have been thrown into a series of isoclinal folds accompanied by small faults. With these folds and faults minor structures have been set up until the whole rock has often become a mass of minute folds and thrusts with their accompanying strain-slip cleavages. These processes, as we have seen, have been carried so far that "crush-conglomerates" have been produced on a large scale. It is evident from a study of this district that had the rocks been subjected to these stresses at a greater depth and below the zone of fracture where they would not have been so free to move, they would have been converted into true schists. They possess now every structure of schists, but the mineralization has been wanting.

The visible dip of the rocks is of no value, except as registering the inclination of the limbs of folds. As an illustration of this fact, it may be pointed out that although the strata have a steady dip to the south-east between Falmouth and Truro, and we are apparently crossing the strike from the coast to the heart of the county, yet instead of getting deeper in the stratigraphical series we are on precisely the same geological horizon at Truro as at Falmouth, the intervening ground being made up of a succession of isoclinal folds. Gerrans Bay (Mr. Hill.)

Age of the Stratified Rocks in the Falmouth District.—The limestones and quartzites of the Veryan Series contain fossils which determine these beds to be Lower Silurian, and they were recognised as such by De la Beche, and coloured accordingly in his map. The Conglomerate already alluded to as occurring at Nare Head in Gerrans Bay, and at a headland bearing the same name south of the Helford River, contains boulders and pebbles of quartzite and not improbably marks a break between the Upper and Lower Silurian formations. Although the succession from the Veryan series to the Mylor series is apparently a descending succession, the true position is probably the reverse, and the Portscatho, Falmouth, and Mylor series may be Upper Silurian. At present no palæontological evidence is available to settle the stratigraphical position of these strata, which in the meantime can only be provisionally determined by their relations to the Lower Silurian rocks. If this interpretation should prove to be correct, the Devonian system is not represented in this part of Cornwall.

OLD RED SANDSTONE.

Ross-shire and Inverness-shire.

A few additional particulars have been collected during the past year regarding the lower division of the Old Red Sandstone of the basin of the Moray Firth. It has long been known that detached outliers of the formation are scattered over the schist-country of Sutherland and Ross. A number of previously unobserved outliers of this nature have been met with in the progress of the Geological Survey through these counties. Two of them which were detected by Mr. Gunn to the north-east of Loch Luichart in the east of Ross-shire* have now been mapped by Mr. Peach. They consist of breccia which caps the two mountains Beinn a Bhric and Beinn nan Cabag. In placing the details of their structure on the maps Mr. Peach has noticed further evidence of the exceedingly uneven surface of schists on which these breccias and conglomerates were deposited. In particular the remarkable augen-gneiss which forms so conspicuous a feature in the geological structure of that district rose as a ridge above the rest of the crystalline rocks in the waters of the Old Red Sandstone basin. Loch Luichart. (Mr. B. N Peach.)

Further progress was made by Mr. Horne in mapping the Old Red Sandstone in the Valley of the Nairn to the East of Strath Nairn Inverness-shire. (Mr. Horne.)

* Annual Report of Geological Survey for 1896, p. 53.

Inverness. In tracing its boundary along the west side of the valley he observed that the basement conglomerate contains pieces of the surrounding granulites and biotite-gneisses, and also blocks of porphyrite and felsite.

Beauly District. (Mr. Hinxman.)

In the same basin a further tract of Old Red Sandstone has been mapped by MR. HINXMAN from his station at Beauly. He has traced the western limits of the formation northwards to the Conon at Torrachilty. Above Clachuile Inn the river flows for some distance over a series of gently-inclined grey micaceous shales and flagstones, the general direction of dip being east-south-east. At Newton, a short distance below the rapids, the beds roll over towards the west, and rest at much higher angles. Immediately below the fall the shales are intercalated with and pass up into a well-bedded conglomerate, composed of rounded stones of moderate size, and altogether different from the coarse tumultuous breccia of Glen Orrin and the Beauly river.

The junction between the conglomerate and the Moine schists at the fall is a faulted one, and is accompanied by a considerable amount of disturbance and brecciation in the schists. The line of this fault can be followed through the woods of Coille Mhor to Glen Orrin, where it leaves the conglomerate, and passing into the muscovite-biotite-gneiss has determined the northerly course of the Orrin above Strathan for a short distance.

The outcrop of the grey shales is marked by a line of sulphurous wells of varying strength. Some of these springs rise in the bed of the river, and are only seen when the stream is at a low level. Others appear at Muirton Mains, Coul of Fairburn, and in the river Orrin at Balno. There is also a well-known spring of this nature just outside the village of Beauly, indicating the presence of the shales at this point beneath the thick covering of recent marine alluvium.

Lorne, Argyllshire.

In the *Summary of Progress* for 1897, and in that for 1898 accounts have been given of the interesting discovery of remains of fishes and other organisms in the sedimentary strata associated with the volcanic series of Lorne. The occurrence of *Cephalaspis* definitely proved these strata to belong to the Lower Old Red Sandstone. During the past year further information has been obtained regarding the fauna that was contemporaneous with the *Cephalaspis* in the ancient water-basin of Lorne. Remains of Ostracod crustaceans have been detected, and though their state of preservation is not as perfect as could be wished, their forms are at least generically recognizable. Possibly some layer of stone may yet be met with in which not only these, but other organisms have been more perfectly preserved. Palæontological notes on this subject will be found on p. 186.

Oban and Kilmelfort District. (Mr. R. G. Symes.)

In the Lorne basin of the Lower Old Red Sandstone further field-work by MR. R. G. SYMES has added to our knowledge of the extension of the sedimentary portion of the formation in that region, and at the same time has brought to light fresh points of interest in connection with the remarkable volcanic phenomena of this basin. Thus he has detected several previously unrecorded outliers of the conglomerate in the neighbourhood of Kilmelfort. One of these, of considerable size, lies a mile and a-half east of Kilmelfort Hotel, and to the east of Loch a' Mhinn. The material of which it consists is entirely different from that of any other conglomerate in the Oban district. It is made up at its base of large blocks, chiefly of porphyrite, epidiorite, limestone, schists, slates, and some quartzites, with but little matrix. At first it was supposed to be an agglomerate from the angularity of its constituents, but when the ground was more fully examined the upper portion of the mass was found to be similar to other parts of the Old Red conglomerate. North-east of Loch nan Ban, where the conglomerate rests on a floor of felsite which in places is highly porphyritic, the greater proportion of its blocks consists of that rock. On the west side of the exposure the lower part of the mass lies on thick limestones, phyllites, and epidiorites. Occasional pebbles of vein-quartz are met with in the higher layers, but bedding is not apparent, nor any trace of intercalated sandstones or shales. The greater number of the blocks in this rock near Loch a' Mhinn consists of a pink felspathic porphyrite. The conglomerate is there cut by a pink felspathic porphyritic dyke similar to those found elsewhere, rising through the Lower Old Red Sandstones and their associated andesites. These dykes trend from north-north-east to south-south-west. The strata exposed in this outlier must in some places be as much as 400 feet. The conglomerate here has no andesite capping, nor have andesite blocks been noted among its constituents.

North-east from Loch Losgain Beg another outlier of conglomerate extends from Loch a' Mhinn westward, and is found adhering to the quartzites and epidiorites on the east side of Barr Kilmhealaird. It is composed almost entirely of decomposed felsite-blocks, set in a matrix of comminuted material of the same kind. On the southern shore of Loch a' Mhinn a third small outlier has the same composition as that last mentioned, both of them being totally different in their ingredients from the mass east of Loch a' Mhinn, which is only distant a couple of hundred yards. From the considerable area covered by the conglomerate to the south and east of Loch Fear, near Kilmelfort, the rock might be supposed to be well developed there, but as it lies horizontally, and has had its protecting cover of andesitic lavas removed by denudation, its thickness in some places does not exceed a few feet.

At the foot of the waterfall from Loch Fear the basement-beds of the Lower Old Red Sandstone consist of thin purple shales lying below the conglomerate and resting on siliceous schists and limestones. Such an intercalation is most unusual throughout

Oban and Kilmelfort District. (Mr. R. G. Symes.)

the Oban district. It may be remarked in passing that under the shallow waters of Loch Fear a beautiful ice-polished surface of the conglomerate may be seen wherein, as in a kind of mosaic pavement, the pebbles of quartzite, pink porphyrites, vein-quartz, and epidiorite are displayed. The irregular floor on which the conglomerate was laid down is well seen to the west and north of Loch Losgain Beg, a mile east of Kilmelfort, while on the western slopes of Barr Kilmhealaird, the way in which the conglomerate passes down into cracks in the schists and epidiorites is conspicuous. These prolongations of the conglomeratic material downward might here and there be mistaken for actual intercalations of the conglomerate in the schistose series underneath. This series here consists of schists (phyllites) with calcareous bands, quartzite, epidiorite, porphyrite, and felsite with flow-structure. All these rocks are represented among the pebbles in the conglomerate, which are mostly sub-angular, and never quite well rounded. Here, as usual, they are local in origin. Near the outcrop of the porphyrite, blocks of that rock more than two feet long are found in the conglomerate. No fragments of andesite like that of the true lavas have been observed in this exposure.

The general local derivation of the materials in the conglomerates is well shown all over the Kilmelfort district. Thus on the hill side above Loch nam Ban, two miles east of the village, the rock is so much made up of the pink felsite upon which it rests that, but for some rounded pebbles of quartz that stand out on weathered surfaces, it might easily be mistaken for an igneous mass. The same close relation to the underlying material may be observed further to the east, in the stream which joins the Duchara Burn, near Lagalochan. At both places the compact conglomerate is the highest bed exposed in the section east of Loch a' Mhinn. About a quarter of a mile above the road, crossing the stream already alluded to, the conglomerate has been derived from the white decomposing felsite on which it rests, while nearer the road it is fine-grained and hard, resembling the conglomerate seen above Loch nam Ban. Along this stream a large north-north-east and south-south-west fault runs, with a downthrow to the east, whereby the compact conglomerate on the top of the series is thrown down against the epidiorites on the west side of the stream.

A further illustration of the uneven and cleft surface on which the Old Red conglomerates of this district were deposited may be observed on the shore, about a mile and three-quarters to the south-west of Kilmelfort close to the old Fort, and a little west of a porphyrite sill there exposed. The schists are here traversed along their planes of schistosity by a series of cracks now filled with a brecciated conglomerate similar to that which occurs on the hill side to the north of Loch Losgain Beg above mentioned. Although the overlying conglomerate has disappeared there can hardly be any doubt that these veins of its material belong to it, and represent the local base of the Old Red Sandstone, of which so large a part has been removed from this area by denudation.

North of Loch Tralaig, about three miles north of Kilmelfort, and to the east and west of Innie farm-house, thin beds of conglomerate appear from under the andesite. Again, to the north-west of Corrielorne, beds of conglomerate form the floor on which the andesites rest, while east of Tralaig, and north-east from the farm-house of Druimnashallag some red and purple shales intervene between the lavas and the epidiorites. These are the only exposures of the sedimentary representatives of the Lower Old Red Sandstone to be met with in that part of the district for a distance of six miles from east to west. In the Pass of Melfort, at the sharp angle in the road, some red, horizontally-stratified deposits, with black layers, about four feet thick, may possibly fill an enormous sand-crack. MR. TEALL found them, on examination of specimens, to be composed of disintegrated andesite.

Oban and Kilmelfort District. (Mr. R. G. Symes.)

To the north of Loch Avich, seven miles east of Kilmelfort, and west of Drissaig, the conglomerate dips to the east, underneath the lavas, and attains some thickness. It here differs from the conglomerates previously enumerated inasmuch as its chief constituents are fragments of andesite and epidiorite. The surface of the blocks in this mass has been well polished by ice, the direction of striation being east and west. This outcrop of fragmentary material may belong to a somewhat later part of the series than those conglomerates which have derived their constituents entirely from the schist-platform below; at least, it was not deposited until the eruption of the andesites had begun, whereas in the other examples referred to, no fragments of these lavas have been as yet detected.

A large part of the southern outcrop of the andesitic lavas of the Lorne region has been mapped during the past year. The margin of this volcanic area presents an irregular east and west line of escarpments rising above talus-slopes. The only gap or road through this area in a north and south direction is that of the pass of Melfort, formed by the River Oude, which has cut its way through the thick mass of lavas. At the southern limit of the andesites exposed in the road in the Pass of Melfort, close to the avenue gate to Melfort House, the volcanic sheets are seen to rest upon phyllites and epidiorites, with no intervening layer of sedimentary deposits. No outliers of the andesites have been noted to the south of Kilmelfort, or beyond the southern edge of the volcanic area.

When the mapping of the andesite-flows was in progress in the neighbourhood of Loch Tralaig, it was difficult to decide whether a large east and west fault runs along the southern shore of the lake, throwing down the volcanic rocks on the south against phyllites and epidiorites on the north, or whether denudation had removed all the lavas on the west side of the loch, so as to expose the schists, quartzites, epidiorites, and intrusive dykes. The section of the lavas to be seen south from the lake shows them to be almost horizontal. No trace could be found here of tuffs like those north and south of Loch Etive, nor are there any acid lavas such as have been found near Taynuilt and Airds Bay, in the north-east portion of the Oban district.

Oban and Kilmelfort District. (Mr. R. G. Symes.)

The greatest thickness of the entire series of andesitic lava-sheets between Tralaig and Kilmelfort is possibly not more than 500 feet. It has now been ascertained that the greatest development of these lavas occurs between Lochs Etive and Creran, and that the thickness of the sheets gradually lessens towards the south. About half a mile south-east of the shepherd's house of Maolachy, four miles east of Kilmelfort, an irregular mass of intrusive acid igneous rock in all probability belongs to a neck or volcanic vent. It is elongated in an east and west direction, and is about a quarter of a mile long and about half as broad. Mr. Peach, who twice visited the ground, has furnished the following notes on the field relations of this mass:—"It consists of an acid igneous rock, probably a very acid andesite, or perhaps a rhyolite, in which evidence of flow while the rock was in a very viscid state is everywhere conspicuous, the whole rock being now quite platy and its layers so highly crumpled as to simulate a puckered schist. The planes which separate these plates conform in a remarkable manner with the outward edges of the mass, and are either more or less vertical or dip inwards at high angles. Often near the edge the mass includes numerous blocks of the surrounding dark slates or epidiorite sills. It also contains broken-off portions of material similar to itself, which show flow-structure in a marked degree. So numerous are these fragments in some places that the rock looks like a brecciated conglomerate or agglomerate. The nature and the source of this breccia are well exhibited in the stream which skirts its north-western limit, where its contact with the sedimentary rocks is best exposed. Here the line of contact with the dark schists and limestones can be followed for about 200 yards. The rocks are much shattered, and their junction with the igneous mass is somewhat irregular, but the latter rock is seen to have flowed upward, conforming to the uneven surface, and catching up innumerable fragments of the black slates and limestones, as well as bits of its own chilled outer layers, and involving them in the still flowing viscous rock. This is in all probability a neck or vent which may have supplied the material of the more acid lavas and tuffs of the volcanic platform of Lower Old Red Sandstone age in Lorne."

Near Loch nan Losgain Beg several other masses of a similar flow-breccia are to be seen. Some parts of these contain more broken up fragments than matrix. But that they are truly of eruptive origin can be shown in many cases where they act as dykes or sills, and cut both the rocks of sedimentary origin and the epidiorite sills. They are in turn cut by the tertiary basalt-dykes. They are all probably of the age of the Lower Old Red Sandstone, and belong to the later phase of vulcanicity in the history of the lavas of Lorne. They are usually associated with "porphyrite" dykes, and may be regarded as not improbably continuations of such dykes as have continued to flow after having cooled to a very viscid condition and partially solidified. Flow-structure is also exhibited at the edge of some of the porphyrite sills.

County Waterford.

Bunmahon District. (Mr. J. R. Kilroe.)

While the revision of the Silurian areas has been in progress it has occasionally been necessary to carry the investigation into the surrounding tracts of other rocks. This prolongation has been especially imperative in the south of the County of Waterford on account of the complexity of the coast-sections and the accumulating evidence that much of the igneous material there developed, though enclosed within the area of the Silurian rocks, belongs to a later than the Silurian period.

The age of the red sandstone ,grits, and conglomerates, exposed on the coast at Bunmahon, has long been in dispute. The strong resemblance of these strata to the Old Red Sandstone of the neighbouring Comeragh region induced the original surveyors to consider them of corresponding age, and they were so represented upon the first edition of the one-inch sheet (No. 178), published in 1857. Their apparent interstratification with supposed volcanic tuffs and lavas of Silurian age, subsequently led to the abandonment of this view, and to the relegation of these red rocks to the Lower Silurian group, under which colour they appear on the edition of the map issued in 1863, which has not since been changed. A more recent examination of the district led the present Director-General of the Survey to question the correctness of the alteration and to express the opinion that the original view would not improbably prove to be correct. Believing that the igneous rocks to the east had been truly assigned to a Lower Silurian date, he thought it probable that a second set of igneous rocks existed which could not be older than the Old Red Sandstone.* Still more recently MR. COWPER REED has concurred in the original view. He mentions the superposition of the red rocks upon denuded igneous masses which were supposed by the authors of the revised edition of the map to be interbedded and contemporaneous. He bases his opinion as to the age and position of the conglomerates upon their relation to the igneous rocks, conjointly with their having undergone great disturbance and dislocation after Old Red Sandstone times. As the basal conglomerates at Ballydowane Bay—the principal place in which the red rocks are to be seen—contain pebbles of igneous material identical in character with that which forms the greater part of the perplexing intrusion-breccia at Bunmahon Head, it is not difficult to account for these differences of opinion. Accordingly MR. KILROE has devoted some time to a careful examination of the perplexing evidence, and he has supplied some notes of the results which he has so far obtained.

Occurring in five small isolated tracts, and usually showing high dips or set on end, the red rocks seem to lie in deep synclinal basins, the longer axes of which correspond with the trend of the neighbouring igneous bands, with the general

* *Ancient Volcanoes of Britain*, vol. i., p. 251

Bunmahon District. (Mr. Kilroe.)

direction of cleavage, and with the strike of the highly inclined Old Red Sandstone near Dungarvan. Though much faulted the strata present a clear succession at several points along the coast.

An important section on the cliff in the middle of Ballydowane Bay shows the following succession in ascending order, viz.:—

(*a*.) Basal deposit, several feet thick, consisting wholly of igneous detritus green and grey felsites and some basic (?) rocks; pebbles for the most part well-rounded. The beds rest at about 80° against igneous rocks similar in character to most of the pebbles, and weathering, specially near the junction, into a conglomerate-like mass, so that the line of demarcation between the two rocks is not distinctly traceable. No true tuffs or other truly volcanic rocks have been recognised either in the material of or near the basal deposit.

(*b*.) Red argillaceous grit, with massive bed of grey grit.

(*c*.) Conglomerate, consisting chiefly of white quartz-pebbles embedded in a red sandy matrix.

On the shore at the west end of the bay the adjoining igneous rocks are to be seen invading green grits and epidotic and serpentinous fossil-bearing Silurian limestone. On the east side of the bay the argillaceous grit, which as usual passes up into quartz-conglomerate, rests directly upon igneous rock, which, at this point, also penetrates green calcareous grit. The boundary here seems to be a thrust-plane, and though the hade (38°) corresponds closely with the dip of the immediately over-lying strata (38 to 45), the dislocation may have cut out the conglomerate which elsewhere occurs at the base of the series, and appears at the other side of the same synclinal basin. A vertical fault, almost parallel to the break just mentioned, cuts out the basal deposit at one point, but leaves a small thickness of it resting against igneous rocks, where it is seen to consist, as at other points, of fairly well-rounded igneous materials.

Close to Bunmahon Head the red grits are faulted against green felsites, and pass up into quartz-conglomerate. At the ore-yard and site of engine-house, Knockmahon, quartz-conglomerate overlies red grits, which commence with a fine breccia of igneous detritus, resting upon and against green felsite, which in the immediate vicinity penetrates Silurian fossil-bearing calcareous grit.

The section of undoubted Old Red Sandstone, near Ballyvoyle Head, presents a series of strata closely resembling those now described. Red argillaceous grit is there seen to intervene between quartz-conglomerate and the base of the series; while local blocks scattered on the beach, and probably detached from the basal beds at present concealed, show that these beds consist of conglomerate formed of igneous materials similar to those at the base of the Bunmahon series. This fact is all the more significant since the Old Red Sandstone floor in the Ballyvoyle coast section is formed of dark-grey and black slate, penetrated by a few felsite dykes. The Bunmahon conglomerates may therefore, with little hesitation, be regarded as belonging to the same series as the strata near Dungarvan, which are known to be of Upper Old Red Sandstone age. The igneous rocks which preceded the red rocks at the one place also preceded those at the other; and as these igneous rocks have invaded Lower Silurian strata, while fragments of them abound in the overlying conglomerates, their intrusion must date between the Lower Silurian and Upper Old Red Sandstone epochs. **Bunmahon District. (Mr. Kilroe.)**

But not only do the red strata contain abundant detritus of eruptive rocks, they have themselves been invaded by some of these rocks. At the southern end of the little promontory at Bunmahon Head they are penetrated by an intrusion which is seen to cross obliquely some twenty feet of quartz-conglomerate and red grit, within a distance of about 100 yards. Both igneous and sedimentary rocks at the junction are crushed, but not to such an extent as to obliterate the evidence of intrusion. The red strata, moreover, near the junction contain injections of a green igneous rock; and the adjoining igneous mass, includes fragments which resemble, if they are not, those of red grit. Like some of the rocks further east, to which reference has already been made, this mass is composed of green felsites, and perhaps andesites, in rounded lumps, which are embedded in and cut up by, a more basic material. The rock is now a coarse aggregate, which might readily be taken for a volcanic agglomerate.

A close resemblance is noticeable between this basic rock at Bunmahon Head and another which contains numerous quartz-pebbles near Mount-Kennedy, eight miles to the north-west. This highly vesicular rock afforded material to the Old Red strata overlying it. Pebbles of similar material were observed in local blocks taken from the base of the Old Red Sandstone at Ballyvoyle Bridge.

CARBONIFEROUS.

The field-work of the Survey among Carboniferous rocks during the past year has lain in the coal-fields of North Staffordshire and South Wales. In each of these regions satisfactory progress has been made in mapping not only the coal-fields, but also the surrounding areas, which, though largely covered by younger formations, must be surveyed in order to allow of the publication of the various one-inch sheets in which the coal-bearing tracts are represented.

North Staffordshire

The revision of the North Staffordshire coal-field and surrounding country has been continued under the supervision of Mr. Fox Strangways by Messrs. Barrow, Gibson, Pocock, and Wedd. Mr. Fox Strangways has himself been mainly engaged upon the Jurassic tracts that lie to the east of the **Rushton Spencer. (Mr. Fox Strangways**

Rushton Spencer. (Mr. Fox Strangways.) Leicester coal-field, his share in the North Staffordshire having been mainly that of taking general charge of the mapping by his colleagues. He reports that at Rushton Spencer, five miles to the north-west of Leek, a group of sandstones and shales which is there developed, has been considered to represent the Permian rocks of that district,* but that the strata precisely resemble the sandstone and shales which further south have been mapped as part of the Carboniferous system. He thinks that there can be little doubt that they belong to the "Yoredale series," an opinion which is shared by his colleagues, MR. BARROW and MR. GIBSON.

Leek District and Cheadle Coal-field. (Mr. George Barrow.) Resuming work near Leek in the spring, MR. BARROW completed the mapping of the inlier of Bunter strata through which the Churnet flows. In addition, so much of the Carboniferous shales and grits was examined as sufficed to finish the area allotted to him. The examination of the Cheadle coal-field was then commenced, and the same plan was followed as in the previous season. The grit-bands immediately below the Coal-measures were first traced, as it has been found that they indicate clearly the presence and direction of faults, which are so much more difficult to trace in the softer coal-bearing strata. Starting from this basal group, the examination of the overlying groups was proceeded with, and a higher and inner zone was completed, including the Woodhead coal. The tracing of the coal-seams above this horizon has proved difficult and tedious owing to the soft nature of the strata, and the almost featureless character of the country. Indeed some portions of the work could not be done without the assistance of mining information as to the ascertained structure of the ground, and this information has been willingly afforded by those connected with the collieries. The base-line of the Bunter formation which forms the southern limit of the visible coal-field has also been traced, and only a few patches of obscure ground now remain to complete the survey of this area.

Beginning with the oldest or Carboniferous series of strata, MR. BARROW reports that these fall naturally into five groups, which have probably only a comparatively local value. They are as follows in descending order :—

1. The White-weathering group with numerous coal seams. Thickness, 1,200 feet.

2. The Woodhead coal with accompanying dark shales and the Kingsley sandstone below. Thickness, 230 feet.

3. The Dark Shale and Gannister group. Thickness, 300 feet.

4. The first and third Grits with the intervening dark shales ; thickness, 300 feet. (Millstone grit in part.)

5. Dark shales with marls and thin sandstones, the latter passing to coarse grits in a south-easterly direction ; thickness not yet known. (Yoredale beds on the maps.)

* See Green, "Geology of Stockport." *Mem. Geol. Survey*, 1866, p. 36.

1. *The White-weathering Group.*—As no complete account of this group has yet been published, the following section of this part of the Coal-measures in descending order may be given here:— Leek District and Cheadle Coal-field. (Mr. George Barrow.)

	Ft.	In.
Two yard Coal	5	6
Measures	54	0
Getley Coal	2	0
Measures	20	0
Half yard Coal	2	6
Measures	61	0
Yard Coal	3	9
Measures	60	0
Litley Coal	2	9
Measures	35	0
Four-foot Coal	4	0
Measures	60	0
Coal	1	6
Measures	80	0
Dilhorne Coal	6	0
Measures	190	0
Alecs or Stinking Coal	3	9
Measures	55	0
Foxfield Coal	1	8
Measures	64	0
Coal	1	5
Measures	130	0
Cobble Coal	1	3
Measures	55	0
Coal	1	1
Measures	95	0
Rider Coal	1	6
Measures to Woodhead Coal	125	0

Though numerous seams of coal occur in this group, the Yard and the Dilhorne are the only thick seams of good quality. Of the thinner seams the Half-yard and the Cobble are always of fairly good quality, while the others either vary locally or are persistently of a poor character. The strata of this group are characterised in the field by their white weathering, their principal constituent being a pale marly shale or clay. When under pressure this is a fairly hard rock, but when once wetted it rapidly swells up and tends to close up the workings, thus adding greatly to the cost of winning the coal. All coals above the Dilhorne suffer more or less from this disadvantage.

Fresh or brackish-water lamellibranchs occur in thin grey bands throughout the group, while fish-remains, *Spirorbis* and *Carbonia*, are locally abundant. The strata, as a whole, may be claimed as essentially of fresh-water origin.

2. *The Woodhead Coal and Kingsley Rock or Sandstone.*—While the dark shales associated with the Woodhead Coal resemble the beds of the uppermost group in the fresh-water nature of their organic remains, they differ from them greatly in lithological character. In place of being soft, these shales are distinctly hard. In particular, the black shale immediately above the coal has a massive aspect when seen in stream-sections, and forms an excellent roof to the workings. As the floor is also a hard rock,

Leek District and Cheadle Coal-field. (Mr. George Barrow.)

this coal can be worked cheaply, and it is consequently the only seam at present worked to any extent in the Cheadle coal-field. About eight feet below the coal comes another black shale some thirty feet thick, which rests on the Kingsley rock, an alternation of thin sandstones and laminated hard sandy shales. This rock forms on the surface of the ground an excellent topographical feature, recognisable at a considerable distance. As it passes into the dark shales of the third group below, its limits can hardly be precisely fixed. But its distinctive characters are of great local value, for, as it can be easily recognised, it has supplied the key to the geological structure of the district.

3. *The Black-shale and Gannister Group* is characterised by its great amount of black shale which contains an essentially marine fauna, and thus differs from the higher shales, which otherwise closely resemble it. With the shales of this third group are associated numerous thin coal-seams. Of these all but one are either not persistent, or become so thin as to have often escaped notice. One, however, which is very persistent, is known as the Crabtree or Stinking (pyritous) Coal. It invariably possesses a hard shale roof containing abundant *Goniatites* and other marine fossils. There is reason to believe this coal, with its shale roof, to be continuous into Lancashire, and to regard this portion of the Coal-measures as the equivalent of the Gannister series of the country to the north. This view is strengthened by the fact that the sandstones of this zone often have a gannister-like aspect. Indeed the sandy beds below the Crabtree Coal often pass into a high-class gannister, which is now being worked in two places. At the base of this group lies the well-known Froghall Ironstone, which has been extensively worked in the Consall, Froghall, and Ipstones district. Detailed examination shows this seam to have been lenticular in form; practically the whole of the lenticle has been worked out. A feature worth noting in it is the fact that near Ipstones lenticles of coal occur in its upper part. The same phenomenon has been noted in connection with two ferruginous bands in the horizon below.

4. *Millstone Grit* (in part).—This group consists of the First and Third Grits, with the mass of dark shale between. In the area about Froghall and Ipstones these bands show much the same character and thickness as about Leek; the grits are probably slightly thinner, but the difference is not great. The shales between the grits are interesting, as they contain two hard shale-bands closely resembling the shale above the Crabtree Coal. The first lies about half way between the two grits, and is underlain by a mixture of coal and ironstone, the exact thickness of which has not been ascertained. The second shale-band lies about 10 feet above the Third Grit, and is underlain by the well-known Roaches Coal, which appears to extend like the Crabtree seam over a very large area. Unlike the latter seam, however, it thickens and thins locally, and in some places becomes little more than a smut. To the west of Ipstones this Roaches Coal is 2 feet 10 inches thick, and of fairly good quality.

Leek District and Cheadle Coal-field. (Mr. George Barrow.)

A level which was driven into it to drain the water may be at least 300 years old. At the time when this level was made its construction must have been a feat of engineering. The fact that mining operations long ago attained a high standard of excellence in this part of Staffordshire is borne out by the discovery of extensive workings in the Froghall ironstone in the course of the more recent mining operations. All record of these workings is lost, yet it is clear that at least several thousand tons of ironstone must have been extracted from them. As the coal above the Third Grit is traced southward an association of interlaminated coal and ironstone is met with, similar to that in the two instances just mentioned. It is remarkable that the same somewhat exceptional conditions should have been repeated three times in the same area on different horizons. Such an association of coal and ironstone has not been met with on these horizons in any other part of the region.

On the west side of the Cheadle coal-field a very different development of these strata is met with. Starting from the cross-roads south of Wetley and proceeding towards Dilhorne, we find that the first grit thins away with great rapidity and indeed is no longer recognisable. The third becomes much thinner, though still sufficiently coarse to be distinguishable from an ordinary Coal-measure sandstone. It this rate of thinning were continued, in a short distance there would be little or no grit left. The cover of Bunter sandstone which comes on further south makes it impossible to say whether or not such a diminution takes place.

5. *The Zone below the Third Grit.*—A small portion of the rocks below the Third Grit has been mapped on both the east and west sides of the Cheadle coal-field. To the east, across the Churnet Valley, where the grits above are still thick, we find below the Third Grit, first a mass of dark shales associated with bands of marl and thin sandstone. Below these lie a number of comparatively thin bands of coarse grit. As this area is much faulted, these grits gave considerable trouble in the mapping, for they seemed to be parts of the Third Grit repeated by faulting. Fortunately the thickest of them has been sunk through and found to be only 30 feet thick, so that it could not be that bed. The detailed survey of the area has proved these grits to occupy the horizons of the thin hard sandstones (crowstones) of the Leek and Endon district, and it is now seen that the great mass of shale and sandstone of that district is a somewhat local phenomenon, for to the south-east these rocks revert to their more normal condition of coarse grits. On the east side of the Cheadle coal-field, however, where the grits are thinning away, no such coarse rocks occur in this lower zone. Though hardly so fine as the typical "crowstones" the sandy rocks are still fine in grain.

The progress of Mr. Barrow's field-work has once more impressed upon him the great vertical range of individual fossils in the Carboniferous system, and he contrasts the *Goniatites* of that system with the *Ammonites* of the Yorkshire Lias. If the rate of biological variation remained fairly uniform we must suppose that the Carboniferous strata were laid down with comparative rapidity. In the case of the grits and shales this acceleration of sedimentation may not present any serious difficulty, but it is not so credible in the case of the great mass of Carboniferous Limestone.

North Staffordshire Coal-field. (Mr. W. Gibson.)

The continued prosecution of the resurvey of the Pottery coal-field has been carried on by Mr. Gibson, partly with the assistance of Mr. Wedd, while the surrounding Triassic areas have been mapped by Messrs. Pocock and Wedd. The following narrative of the work has been drawn up by Mr. Gibson:—

Among the Carboniferous rocks, several observations of scientific interest and commercial value have been made. At Weston Sprink, on a horizon between the Moss and Yard Coal, some purple shales, marls, and thin limestones are exposed in a marl pit. The shales have been traced some distance northward and found to be overlain by a red sandstone similar in appearance and texture to the Keele sandstone at the top of the Coal-measures. Mr. John Ward, of Longton, has obtained an interesting set of marine forms from this place. The fossils include *Aviculopecten papyraceus*, *Discina nitida*, *Lingula mytiloides*, *Pleuronautilus* sp., also a mytiliform shell and a small estheroid shell. The occurrence of *Aviculopecten papyraceus*, etc., high up in the Coal-measures is new to science.

Mention was made in the last *Summary of Progress* (p. 127), of the discovery by Mr. Gibson of an ironstone in Fenton Park marl pit, of which Dr. Pollard made an analysis from a carefully selected set of examples. A similar ore was found during the past year underlying the Chalky Mine Ironstone at the Clanway Colliery, Tunstall.

By the courtesy of Mr. W. B. Clive, an analysis of this ore by Mr. W. Jackson, A.R.C.S., is here given:—

Ferrous oxide -	38·88 per cent.	= 30·24 per cent. iron.
Manganous oxide -	0·89 „	= 0·69 „ manganese.
Lime - - -	6·09	
Magnesia - -	3·34	
Alumina - -	7·90	
Silica - - -	12·10	
Phosphoric acid -	0·53	
Carbon dioxide -	27·52	
Water (lost at 100°)	0·85	
Combined water -	2·78	
	100·88	

On calcined stone 41·33 per cent. iron.

The ore lies directly under and contiguous to the Chalky Ironstone bands. This position makes it a valuable ore, since although of comparatively low grade, it can be got with the valuable Chalky Ironstone at little extra cost. It is hoped, therefore, that the ore will ultimately be used in the local blast-furnaces.

In the difficult region of Talke and Audley, MR. WEDD has found that the lowest productive Coal-measures are brought to or near the surface in anticlines which trend in a north-north-east direction, from Woodlane on the south to Harecastle on the north. The Ten Feet Rock, a thick sandstone above the Ten Feet Coal, and sometimes in conjunction with the "rock" associated with the Seven Feet Banbury Coal, plays a large part in the formation of the anticlinal ridges. As the highly-inclined seams are traced on the western limb of the anticline they are found at a comparatively shallow depth to bend sharply upward, and to assume an almost horizontal position up to a large fault, which can be followed from Madeley Manor to Audley Station, and has been variously estimated to have a downthrow of more than 300 yards to the west. On the downthrow side of this dislocation the strata are gently inclined to the west. This inclination has been proved by mining operations to hold for the lower coals, and can also be seen at the surface in the upper measures.

North Staffordshire Coal-field. (Mr. C. B. Wedd.)

West of Leycett and Audley Station the Etruria marls and Newcastle-under-Lyme series, as described in last *Summary of Progress*, dip to the west at a gentle angle. The field-work during the past year thus enables us to define more clearly the area occupied by Upper Coal-measures to the west of the Staffordshire anticline. The area exposed may be taken at two square miles. Under this tract the Bassey Mine Ironstone lies at a depth of 1,000—1,300 feet.

A band of limestone containing *Entomostraca* has been found in the Keele series at Moddershall. This band most likely lies at a higher horizon than those described in the *Summary* for 1898. A cream-white limestone has also been found in the Keele series in the Keele Park railway cutting, 311 feet above a dark limestone containing Entomostracan remains; obscure forms of plants have also been found in the same cutting. During the progress of some excavations in Keele Park, a coal one foot six inches thick was found in the red series. Some good, but unnamed, specimens of plants from the Keele Sandstone of Hartshill, from the collection of the late DR. GARNER, are preserved in the Museum of Stoke-upon-Trent. These, at MR. GIBSON'S request, have been examined by MR. KIDSTON, F.R.S.E., who has kindly furnished the following list of them :—

Sigillaria tessellata, Brongn, decorticated and showing fructification zone.
Calamites undulata, Sternb, &c.
„ *Schutzei*, Stur.
„ *Cistii*, Brongn.?
„ *Suckowii*, Brongn.

These additional facts tend to show that the Keele Sandstone series, as already suggested, is intimately connected with the Coal-measures.

A thin band of grey limestone with *Entomostraca* has also been found near the base of the Etruria marls in the Grange Marl Pit. Eleven distinct bands containing *Entomostraca* are

North Staffordshire Coal-field. (Mr. W. Gibson.)

now proved to exist in the Upper Coal-measures of North Staffordshire. They are distributed as follows through the several sub-divisions of that assemblage of strata :—

KEELE SERIES :—Four bands at different horizons :—*Carbonia, Spirorbis.*

NEWCASTLE-UNDER-LYME SERIES :—Two bands near the base :— *Carbonia, Spirorbis, Anthracomya calcifera.** Fish-remains.

ETRURIA MARL SERIES :—Two bands near the summit and base :— *Spirorbis, Carbonia.*

BLACK BAND SERIES :—Three bands near the base, and thin bands of black shale with *Entomostraca* at several horizons :— *Carbonia, Spirorbis, Anthracomya Phillipsi, Carbonicola Vinti.** Fish-remains.

While examining the cores from the bore-hole at Thurgarton, near Nottingham, MR. GIBSON has made an important observation. He has found that the marls with *Productus horridus* rest on some red sandstones, identical in lithological character with the Keele Sandstone. The base of the Permian marls is a breccia, suggestive of a break between the Zechstein and Red Sandstone and Marls. Plant-remains are common at one horizon among the red sandstone and marls in the bore, and some of them have been sent to MR. KIDSTON for identification. The red sandstones have a dark calcareous shale with *Entomostraca* at their base, and are underlain by grey measures resembling the sandstones and shales of the Newcastle-under-Lyme Series. This is confirmed by the occurrence below these grey measures of mottled red marls, containing thin bands of coarse green grits like those so characteristic of the Etruria Marl Series in North Staffordshire. These red marls at Thurgarton pass down into grey measures containing Coal-seams. The recognition therefore of the divisions into which the Upper Coal-measures of North Staffordshire can be divided has thus great economical importance, as it enables us to detect the coal-bearing strata, and to fix their stratigraphical position under the Permian and younger formations of the centre of England.

Cheshire.

Macclesfield District. (Mr. Pocock.)

In order to complete the one-inch map which contains the northern part of the North Staffordshire Coal-field (No. 110) it has been necessary to revise the ground that stretches northward into Cheshire. Accordingly MR. POCOCK was stationed at Macclesfield with instructions to revise the Carboniferous tract to the east of that town. The district, which during the past year has been examined by him, lies between Macclesfield and the anticlinal fault described by the late PROF. GREEN as running in a north and south direction, four miles further east.

The general structure of the ground has been well described by PROF. HULL and PROF. GREEN in their Memoir "On the Geology of Stockport, Macclesfield, Congleton, and Leek," but

* Dr. Wheelton Hind. *Quart. Journ. Geol. Soc.*, vol. lv. (1889), p. 367.

some modifications of detail have been found necessary, in order to bring the mapping into harmony with the revised ground further south. The outlier of the fifth Grit, represented on the published map to the north-west of Forest Chapel, and the band of the same rock between Walker Barn and Tup Close Farm proved, after careful examination, to form really one continuous outcrop with the Yoredale Grit immediately to the east. This outcrop is repeated by a set of cross faults, one with a northerly trend, and the other pointing a little north of east. Half a mile west of Forest Chapel the strata arch over to the west, and the same grit appears with a westerly dip, succeeded by another, which crops out on the edge of Langley reservoir. The latter band is referred to in the Memoir as the Yoredale Grit, but is not shown on the published map. A mile further west, the escarpment of Tugg's Nose, which rises abruptly 550 feet above the valley, clearly represents three grits, and not merely the third and fourth, as shown on the map. The succession between this place and Forest Chapel, as well as on the west side, is complicated by faults. The belts of shale separating the different members of the grit series appear to be faulted out on the high ground east of Macclesfield, though they can be seen in the deep brook-sections to the north.

Macclesfie District. (M Pocock.)

South Wales.

During the past year the field-work in South Wales has lain chiefly in the region between Swansea and the northern edge of the coal-field (Sheets 230 and 247), but has included also the eastern part of the Gower peninsula, and a small tract near Bridgend (Sheet 262). Mr. Tiddeman, having completed the area assigned to him at Bridgend, commenced the examination of the Limestone and Coal-measures of Gower. Mr. Strahan surveyed the ground east of the Tawe from Swansea to Ystalyfera, and part of the north crop, while Mr. Cantrill carried on the examination of the north crop, and of the Millstone Grit and Limestone beyond it. Mr. Gibson was engaged for a short time in completing an area near Neath, upon which he had been engaged before his transference to Staffordshire.

S. Wales. (Mr. Strahan.)

The following account of the past season's work of the staff in South Wales has been drawn up by Mr. Strahan, to whom his colleagues have supplied notes regarding the ground surveyed by them.

Carboniferous Limestone.—The limestones of Gower are described by Mr. Tiddeman, so far as his investigations have gone, as being similar to those of the anticline between Cowbridge, Bridgend, and Porthcawl. They consist chiefly of grey rock, more often dark than light, with also shades of buff. Some of the oolitic bands weather white. Crinoidal limestones are not common among them. The greater part of the rock consists of fine current-bedded organic *débris*. Another common type shows an almost black stone, containing small organisms and

S. Wales. (Mr. Tiddeman.)

larger nests of white crystals, which may represent the remains of shells or corals. The oolitic limestones range in tint from almost black to nearly cream colour.

A curious set of limestones occurs along the north side of Mumbles Head. There are at least three which assume the appearance of a breccia. But the fact that the interstices between the apparent fragments are sometimes occupied by dolomite suggests that the rock is not a true breccia, but has been dolomitised along cracks. The surfaces of some other bands are marked with a number of small pits, most of which contain an irregular nodule, also apparently of dolomite. The edges of these pits frequently rise above the surrounding surface, as though there had been some obstacle to regular deposition. Similar strata were noticed by MR. TIDDEMAN at Newton Nottage, fourteen miles to the east of Mumbles.

A limestone known as "Black Lias," which forms a rampart-like scarp on the seaside of Oystermouth Castle, closely resembles the normal form of Lower Lias, but contains Carboniferous fossils. It is used for building and road-metal, and will make cement. It is black, but becomes coated with a fine white powder on exposure to weather. Occasionally, between strong joints, the stone has decayed to a kind of rotten stone, and MR. TIDDEMAN suggests that it may be represented by some white clays with *Fenestella* and casts of crinoids, and some thin bands of disintegrated chert, which crop out further west. The clay was formerly worked at the Croft on Langland Road, on the opposite side of the glen, and south of Newton.

The general structure of the area of Carboniferous Limestone in Gower may be described as that of a great compound anticline, striking generally W. 16° N., and broadening to the west, where eventually the Old Red Sandstone comes to the surface. The anticline is crossed by many small faults, ranging from north-north-west to N. 10° E. in direction, but it is also greatly folded and traversed by faults which run along the strike, and even coincide for long distances with the bedding, only here and there showing their true nature by a slight transgression. Notable instances where the beds are nearly vertical, and where evidently a fault strikes along a compound anticline, occur at Three Cliffs Bay and Sheer Cwm.

One of the largest folds of the compound anticline is that of Oystermouth, which is enclosed between the main mass of the limestone of the Mumbles Head and the road to Newton. The soft strata overlying the limestone are let in here. A fault running nearly along the road brings up to the north the limestone on which Oystermouth Castle stands. On the south side the boundary is probably natural, but the strata are vertical. Much of the Gower limestone has undergone dolomitisation, a change of composition for the investigation of which the services of a chemist were needed. DR. POLLARD was accordingly instructed to make a careful examination of the extent and mode of occurrence of the dolomitisation, and to collect such specimens as might be necessary for analysis. So far as the observations have gone at present, MR. TIDDEMAN infers that all the limestones are liable to the change; that the alteration takes place along both planes of bedding and faults; that it occurs at all elevations, but apparently reaches its greatest development low down by the sea. S. Wales. (Mr. Cantrill.)

The Carboniferous Limestone of the neighbourhood of Cowbridge, the surveying of which has now been completed by MR. CANTRILL, forms part of the Cowbridge-Cardiff anticline. The shales which underlie the main mass of the limestone appear to crop out in the bottom of the valley of the Dawen, while the overlying rock forms the precipitous western side. The greater part of the main limestone is concealed under Secondary rocks, but it seems to consist in the lower part of dark crinoidal limestone, succeeded upwards by light-coloured oolite.

In the north crop Mr. CANTRILL has continued for some miles the tracing of the highest subdivision of the series, namely some shales with their black limestones. The rotten-stone, into which the limestones weather at the outcrop, becomes less pure westwards, and the whole band grows less important, but the workings have been continued, wherever the outcrop is sufficiently free from drift or grit *débris.*

Millstone Grit.—The pebbly conglomerate which forms the lower part of the Millstone Grit of the north crop continues to be well developed as far westwards as the field-work has been carried. Its rugged grit-scarps are excellently shown on the eastern side of the Twrch Valley at Tyle Garw, and here may be seen, not far from its base, a thin band of black pyritous shale with thin black limestones containing brachiopoda. The rock has at times decomposed into loose *débris*, apparently through the dissolving out of a siliceous cement. This incoherent or friable material has been dug for silica for lining steel furnaces, and the Black Mountain Company is now quarrying a bed of soft grit for the same purpose. Hard unweathered grit is also ground up and used for the same purpose, the multitude of boulders in the bed of the Twrch being thus turned to account.

The middle or shaly portion of the Millstone Grit, exposed in several of the moorland ravines, passes up into a set of thin impersistent sandstones with shales, which form a poor representative of the Farewell Rock. The line of division between the Millstone Grit and Coal-measures is purely arbitrary.

The strata lying next above the Carboniferous Limestone of Gower consist of black, thinly-bedded shales with *Posidonomya*, *Goniatites*, *Euomphalus*, &c. These were shown in the original edition of the map as Coal-measures, but they more nearly resemble shales associated with the Millstone Grit. To this formation also may be probably assigned some hard olive-coloured sandstones and shales, with some siliceous rootbeds which crop out near Liliput. The siliceous bands, which are not unlike Cockshot rocks, were proved by DE LA BECHE to be the floors of thin coal-seams.

Coal-measures.—The examination of the Coal-measures has been continued as far west as Cwm Llynfell on the north crop,

S. Wales. (Mr. Strahan.)

and up to the east side of the Tawe between Pontardawe and Swansea. The surveying of the Cwmavon district having been completed, that of the Coal-measures which traverse Gower has been commenced.

In the north crop, where MR. STRAHAN was engaged with MR. CANTRILL in tracing the outcrops of the lower seams, the disturbances which have been already alluded to* acquire special importance from the fact that they here affect the lower portion of the Coal-measures. Not only are the seams over-folded and over-thrust, but the whole mass of sedimentary material has undergone deformation. The few shaft-sections which are obtainable do not therefore give the normal distances between the seams, and we have to rely upon estimates obtained by averaging data collected over a considerable area. The following table is based upon the consideration of a number of workings extending from Ystradgynlais to Gwaun-cae-gurwen:—

COMPARATIVE SECTIONS ALONG THE NORTH CROP, FROM GARNANT TO THE VALE OF NEATH.

—	Garnant and Brynamman.	Ystradgynlais and neighbourhood.	Dulais and Neath Valleys.
	Yards.	Yards.	Yards.
Stwrain Coal			
Measures - -	10	—	15
White Vein			Upper or White Four-Feet Vein.
Measures - -	5 to 9	8	19 (for 8 and 21†)
Black Vein			
Measures - -	22†	21†	
Little or Four-Feet Vein			Eighteen-Feet Vein
Measures - -	10 to 18	24†	15 Cornish Vein. 13
Harnlo Vein			Harnlo Vein.
Measures - -	19 to 22	25	11
Big Vein			Nine-Feet Vein.
Measures with a Black Vein -	31 to 45	28 to 20	20
Brass Vein			Yard Vein.
Measures - -	18	19	21
Trigloin Vein			Two Feet Vein.
Measures with Brynlloi, Little Brass, Middle, and Lower Veins	15 (supposed)	34 (supposed)	Measures with the Bluers, Enoch, Rhyd, and Grey (?Cnapiog) Veins, 78 (supposed).

All of these seams are anthracitic. The Four Feet or Little Vein, the Big, and the Brass, have been the most extensively worked. The first-named was raised principally in connection

* *Summary of Progress* for 1898, pp. 116-119.
† This figure is arrived at by averaging several sections.

with some noted ironstone, and is now scarcely being touched. The veins below the Brass Vein are worked in Cwm Twrch, but not further to the east. S. Wales. (Mr. Strahan.)

The disturbances take the form of acute folds which range in direction from about north-east at Cwm Llynfell to nearly east at Palleg. They thus cross the north-and-south system of normal faults almost at right angles. It seldom happens, however, that one of these "slip-faults" can be traced far in the disturbed ground. Sharp as many of the folds are, the coal has proved hard and workable both over the anticlines and down into the synclines, except on small strips upon the apices of the folds. Not infrequently the compression has reached a stage at which folding no longer sufficed to afford relief, and in such cases fracture ensued, and an overthrust or "overleaf" was produced. Many small and large examples of such structures may be examined in the old patch-works above Gyrnos, but one of the most instructive has been worked out in detail at the Palleg Colliery by Mr. H. Huxham, from whose paper* the materials for the accompanying figure have been taken by his kind permission. The fold shown in the upper section is exposed to view in the precipitous side of the valley; in the second and third sections, which were drawn about 100 and 200 yards respectively further west, this fold has passed into an overthrust, which was fully explored in working the Brass Vein. The quantity of Brass Vein available was considerably increased by the overthrust, and the Big Vein, which had been previously worked, is said to have been thrice overthrust, so as to occur in three "overleaves," in this same ground.

To some such structure as this must be attributed a repetition of the outcrops at Ystradgynlais for which no explanation has hitherto been forthcoming. The Four Foot, Big, and Brass Veins crop out in the hillside between Ystradgynlais Colliery and the Hendre-ladis branch railway, with a steady dip to the south-east. Yet in the Giedd, more than half-a-mile to the north-west, where their position should be high in the air, these veins crop out a second time. The repetition would be accounted for by a fault running about south-west with a downthrow northwards of upwards of 200 yards, and it has been generally assumed that such a fault exists and runs under Ystrad-fawr, near the Hendre-ladis New Pit, by Penrhos and up the Tawe Valley to the Lamb and Flag Inn. This Cwm-ddu Fault, as it is called, must, however, be supposed to cross the outcrops of the Four Foot, Big, and Brass Veins near the Castle Inn, where there is no break in their continuity, while to the south-west it would range for a part of the Tawe Valley, where the crop of the Red Vein seems to disprove the existence of a fault of any magnitude.

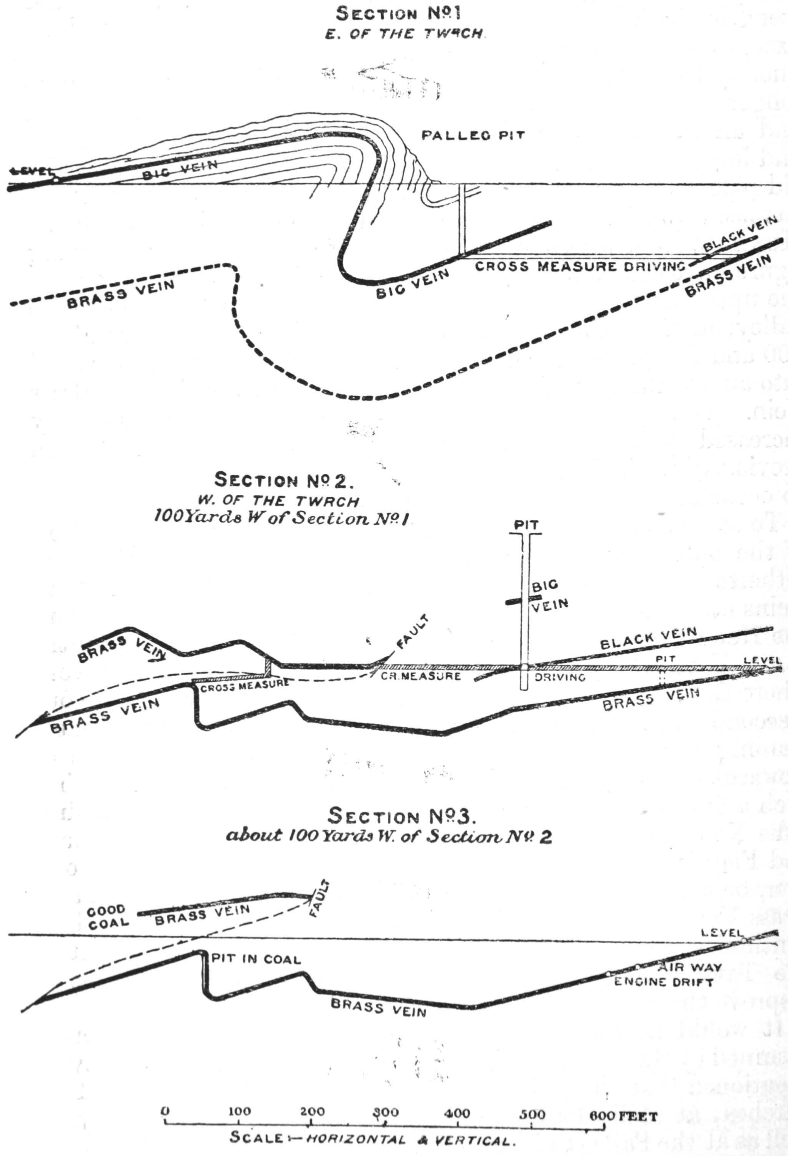
It would be impossible to describe in detail all the forms assumed by the strata in the disturbed belt of ground, but it may be mentioned that sharp folding may be seen in the old Cwm Phil patches; at Melin Palleg and in the Twrch Valley close by, as well as at the Palleg Colliery; in the Gwys Valley near Tir-y-gof;

---

* *Proc. South Wales Inst. Eng.*, vol. xx., p. 189, and vol. xxi., p. 2, 1898.

Sections shewing the passage of the Palleg Monocline into the Bryn Morgan Overthrust.

Re-drawn by permission from a paper by Mr H. Huxham. Proc. S. Wales Inst. Eng. Vol. XX.



in the Twrch Valley from Bryn Henllys to near the silica-works; and in Cwm Llynfell. Similar rolls occur in the old patch-works at Brynamman and in the Garw Valley, while some parallel disturbances have been noted by MR. CANTRILL in the Millstone Grit of Gareg-lwyd and Tair Carn. S. Wales. (Mr. Cantrill.)

The largest of the north-and-south faults which cross this part of the north crop is known as the Cwm Llynfell or Bryn-llefrith Fault. It is a downthrow to the west of about 240 yards, and falls into line with the Rhydding Fault so far as that has yet been traced. Another important fault crosses the Twrch river near the silica-works, and has been proved in the workings of the Brass Vein across the mountain to near the Gwys river. This also is a downthrow to the west, and forms the eastern limit of the field of the Brass Vein. Two important faults have been shown by MR. CANTRILL to throw down the trough of Millstone Grit which forms Esgair Hir.

The folding of the strata here described is almost wholly confined to the outcrop of the lower measures, and the Red Vein crops with great regularity round hill after hill. It would not be prudent, however, to assume that the lower strata are not similarly folded under those hills, for experience gained in other parts of the Coal-field has taught that soft measures of this type though highly contorted themselves may be directly overlain by strata in which no disturbance is manifest.*

The Red Vein, which is about $3\frac{1}{2}$ feet thick, lies about 170 yards above the Stwrain Vein, the highest of the seams mentioned in the table given above. It is worked at the Farteg Colliery, Ynysygeinon and Ystalyfera. At the Ynysygeinon Colliery it is thrown down westwards by two faults of forty and sixty yards respectively, one on each side of the level. The former dies away southwards, but the sixty-yard fault runs just east of Daren Wyddon and traverses the mountain for some distance. A branch of it with a westerly downthrow of about twenty yards is well seen in the southern angle of Daren Wyddon. The veins above the Red Vein consist in ascending order of the Welsh, the Pinchin and the Ynysarwed, none of which are at present worked in the area surveyed last year. The last-named represents No. 2 Rhondda, and lies at the foot of a conspicuous rock-feature; as at Crynant, there is a conglomerate band with pebbles of quartz and ironstone, a yard or two above the coal. The seam is visible in Daren Wyddon and Taren-y-gigfran, and it has been worked at the outcrop as far as Cwm Clic. In that ravine it has been recently driven into for about 200 yards, but being in troubled ground and the coal being a bastard-anthracite for which there was no good market, the workings were not profitable. The distance from the Ynysarwed Vein to the Red Vein can be calculated at the old pit at Ynysygeinon Junction. The Ynysarwed crops out 310 feet above the pit, and the Red Vein was reached in the pit at about 130 or 140 yards. Making

---

* *Summary of Progress* for 1898, p. 116.

S. Wales. (Mr. Strahan, Mr. Gibson.)

allowance for the dip we get about 260 or 270 yards as the distance between the veins, as compared with 270 yards in the Dulais Valley.

Above the Ynysarwed, or No. 2 Rhondda, lies a great mass of almost unproductive measures, chiefly composed of Pennant Grit, with subordinate beds of shale, and a few bands of quartz-rock. This barren zone has hitherto proved a complete barrier between the productive upper measures of Swansea and those which have been described above. These productive upper measures may be considered to commence with the vein which is variously known as the Esgirn at Cwmavon, the Hughes Vein at Swansea, and the Wenallt at Neath and east of it, and the determination of the distance from the Ynysarwed to the Hughes Vein thus becomes of the greatest importance in view of the probability of deep explorations being carried out in the central parts of the Coal-field. An estimate therefore has been made from more than one source.

In the Neath Valley, the Clyne Shaft started 500 feet below the crop of the Wenallt Seam, and at a depth of 209 yards reached a coal, 2 ft. 10 in. thick, which was supposed to be No. 1 Rhondda. The crop of the Wenallt seam is 2,000 feet distant from the pit, and allowing a dip of 5° we get 434 yards as the true distance from the Ynysarwed to this supposed No 1 Rhondda. This distance, however, is too great, and the seam was probably No. 2 Rhondda, for in Cwm Cregen in the Cymmer Valley, Mr. Gibson finds the Wenallt to be 332 yards above No. 1 Rhondda, and 432 yards above No. 2 Rhondda. Again in the Cadoxton Pit, which starts twenty yards below the Gellia (Wenallt) Seam, and extends to a depth (including a borehole of 403½ feet) of 397 yards below that seam, no representative of No. 2 Rhondda has been found. Lastly a section has been plotted through Mynydd March Hywell, under which the Wenallt seam has been almost continuously worked under the name of the Gellia Vein* to the crop of the Ynysarwed Vein at Cwm Clic, with the result of showing that there must be not less than 420 yards of strata between the two veins. We may assume then that the actual distance from the Wenallt to the No. 2 Rhondda seam in the Tawe and Neath valleys lies between 420 and 440 yards.

The Wenallt or Hughes Vein is one of a group which has been extensively worked near Swansea. The group includes, in descending order, the Dirty, the Rhesog, the Slaty, the Curly, the Bodwr or Rotten, and the Hughes. Of these, one only exists in workable form at Neath and in the Tawe valley above Llansamlet, and whether that one represents the Hughes or the Bodwr is open to doubt.

The distance from the Graigola to the Hughes Seam has

---

* This seam is locally called the Graigola. During the past year, however, Mr. Strahan has found that the true Graigola Vein lies about 230 yards higher up. A passage in last year's *Summary of Progress*, p. 115, in which the Graigola is correlated with the Wenallt requires modification. It is the so-called Graigola of Mynydd March Hywell which may be so correlated.

S. Wales. (Mr. Strahan.)

recently been proved by a shaft at Waun-y-coed near Pontardawe. The sinking commenced 20 yards below the crop of the Graigola and proved the Hughes at 216 yards. Allowing for a small dip we may take 234 yards as the distance between the two seams.

From the Graigola upwards the section has been proved at the Dyffryn Main and Primrose Collieries. We may, therefore, proceed to construct a table showing the thicknesses of the measures of the Neath Trough, from the highest existent down to the lowest which may be inferred to exist from what can be seen at the North Crop.

——	Thickness.		Depth below Bryn Coch Vein.	
	yds.	ft.	yds.	ft.
Bryn Coch Vein				
Measures	152	2	152	2
Wernffraith or Primrose Seam				
Measures about 105 yards } at Dyffryn				
Greenway or Court Herbert Seam, impersistent } at Dyffryn	226	0	378	2
Measures about 130 yards } at Dyffryn				
Little Tyr Edmond Seam				
Measures	2	0	380	2
Lower Tyr Edmond or Victoria Seam (the Hard and the Brithdir Vein)				
Measures	25	2	406	1
Graigola or Greenway Vein of Gnoll				
Measures, 37 yards } at Waun-y-coed				
Upper Maesmelyn Vein } at Waun-y-coed				
Measures, 50 yards } at Waun-y-coed	234	0	604	1
Lower Maesmelyn } at Waun-y-coed				
Measures } at Waun-y-coed				
Wenallt or Hughes Vein				
Measures	420	0	1,060	1
No. 2 Rhondda or Ynysarwed Vein				
Measures - 260 to	270	0	1,330	1
Red Vein				
Measures - about	200	0	1,530	1
Four Feet, Little, or Pencraig Vein				
Measures - 33 to	40	0	1,570	1
Big Vein				
Measures from 20 to 45 yards - say	35	0	1,605	1
Brass Vein				
Measures with Trigloin, Bryn-lloi, Middle, and Lower Veins - about	100	0	1,755	1

It must be borne in mind that in this Table the measurements given for the strata below No. 2 Rhondda were obtained in the North Crop and that, in accordance with the general rule that the Coal-measures thicken southwards and westwards in South Wales, they would be considerably thicker under Neath. Further light may be thrown on the point when the South Crop has been more fully examined.

S. Wales. (Mr. Strahan.)

The Neath section differs materially from that of East Glamorganshire. The No. 1 Llantwit, which may be taken to be the equivalent of the Mynyddislwyn of Monmouthshire, probably corresponds to the Wernffraith. Hughes Vein corresponds to the Wenallt, which, as was pointed out in the *Summary of Progress* for 1898 (p. 115), is probably the Pen-y-groes Vein of Llantwit Fardre. The Stwrain of Cwm Twrch is believed to be the Two Foot Nine Seam, while the Big Vein corresponds to the Nine Foot or Ras-las.

At Llantwit the No. 1 Llantwit lies 115 yards above the No. 3 Llantwit;* No. 3 Llantwit 60 yards above the Pen-y-groes Vein. At the Glyn Colliery the Tydu Vein, which is probably the Pen-y-groes Vein, may be estimated to lie about 270 yards above the No. 2 Rhondda, the distance between the two outcrops being 360 yards and the dip varying from 40° to 52°. The distance from the No. 2 Rhondda to the Two Foot Nine Seam has been proved in the Rhondda Valleys to average 300 yards, while in the same district the distance from the Two Foot Nine to the Big Vein ranges from 60 yards near Aberdare to 113 yards at Clydach Vale. We are thus able to construct the following comparative sections to illustrate the thickening of the measures in a horizontal distance of 20 to 25 miles. The most rapid expansion shows a rate of 1 in 116, which is by no means improbably great.

Neath Trough.	Yards.	Rhondda Valleys and Llantwit Fardre.	Yards.
Wernffraith Seam		Llantwit No. 1	
Measures 454 yards	488	Measures - - -	175
Graigola Seam			
Measures 234 yards in the Tawe Valley			
Hughes Vein		Tydu Vein	
Measures - - -	420	Measures - - -	270
Ynysarwed Vein		No. 2 Rhondda	
Measures - - -	440	Measures - - -	300
Stwrain Vein		Two Feet-Nine Seam	
Measures - - -	70 to 80	Measures - - -	60 to 113
Big Vein		Nine Feet Seam	
Measures - - -	20 to 35	Measures - - -	—
Brass Vein			

In the neighbourhood of Swansea only the Hughes and the veins above it are worked. The various seams are identifiable without much difficulty as far west as the Gardener's Fault, a downthrow of more than 300 yards to the west, which runs up Cwm Crymlyn by the Birchgrove Pit to Glais. The seams which are thrown in at Llansamlet on the west side of this fault are commonly stated to be bituminous, while those on the east are steam-coals, a statement which is true to the extent that, owing to the large displacement of the fault, seams belonging to the more highly bituminous upper part of the Coal-measures are thrown face to face with those belonging to a lower and more

* See Vertical Section of the Geological Survey Sheet, No. 81, section No. 6.

anthracitic zone. The correlation of the seams has been attended with some difficulty, partly owing to the fact that every shaft on the west of the fault has been sunk on a fault, and that for many years the true sequence of measures remained unknown, and partly in consequence of considerable changes undergone by the seams in that neighbourhood. The following table gives the most probable identification:— S. Wales. (Mr Strahan, Mr. Tiddeman.)

LLANSAMLET (West of the Gardener's Fault).	Yds.	NEATH TROUGH (East of the Gardener's Fault).	Yds.
Drew's Vein		Bryn Coch Vein	
Measures - - - - -	165		152
Four Feet Seam		Wernffraith Vein	
Measures - - - - -	118		
Five Feet Seam			254
Measures - - - - -	118		
Six Feet Seam		Graigola Seam	
Measures - - - - -	20		
Three Feet Seam			
Measures - - - - -	44		
Two Feet Seam		Not proved, but about	240
Measures, including four or five workable seams in their lower part - - - -	271		
Hughes Seam		Hughes Seam	

It would appear, therefore, that the Brithdir or Tyr Edmond Seam is absent on the west side of the fault, while, on the other hand, the group of seams which at Swansea occurs close above the Hughes Vein, is represented by one, or perhaps by two seams at Neath.

The surveying of the Bryn and Cwmafon district has now been completed by MR. TIDDEMAN. He finds that the strong rock-feature which he traced through much of the Maesteg district under the name of the Llynfi Rock is the same as that called the Tormynydd Rock further west. The Wernpystill Seam, which lies above that rock, and not the Tormynydd which lies below it, will therefore represent the No. 2 Rhondda Seam, which has been selected as the base of the Pennant series. The Cockshot Rock, another distinctive horizon, has been traced to the foreshore near Baglan School.

The series of coal-seams below the representative of No. 2 Rhondda is as follows:—

The Tormynydd, which proves well from Cwmafon to Bryn.

The Jonah is thin throughout.

The White Seam is about 4 feet thick, and is regular from Cwmafon to Maesteg.

The Clay Seam proves well with a thickness of about 2 ft. 4 in.

The Cwm Mawr Seam is thick near Cwmafon, but thin from Bryn to Dyrysiog. It is considered to correspond to the Victoria Seam of Maesteg.

The Golden Vein has been worked by level from Cwmafon to Bryn collieries, and is about 3 feet thick. It is believed to correspond to the Two and a half Feet seam of Maesteg.

The Cockshot Seam rests upon or close above the Cockshot Rock and consists of two coals, 2 ft. and 2½ ft. thick. It represents the Caedefaid o **the Llynfi, Ogmore, and Garw valleys**

S. Wales. (Mr. Strahan.)

The Finery Seam was formerly worked at Bryn on the anticline adjoining the Moel Gilau Fault, at Bryn Gyrnos and also at Cwmafon. It was much esteemed for copper-smelting.

This is followed in descending order by the Upper Four Feet, the Big Seam, the Coal and Mine Seam, the Lower Four Feet, the Four and Five Feet Seam and the Yard Seam, some of which have been worked about Cwmafon.

The Park Colliery Shaft at Baglan struck the Big Vein at 90 yards depth, but the ground was much disturbed owing to the nearness of the Moel Gilau Fault.

FAULTS.—*The Gnoll Fault.*—This great fault runs from the South Crop near Cwmafon to the Neath Valley near Llantwit by Neath. At Cwmafon it was proved in the working of the lower coals to be a downthrow to the west of about 70 yards, but at the Gnoll its throw must be between 400 and 500 yards, for at this point it brings the Court Herbert Seam nearly on a level with the Glyngwilym. Now the Court Herbert Seam is the Greenway Seam of Dyffryn, which lies 150 yards above the Graigola, and therefore about 390 yards above the Hughes or Wenallt. The Glyngwilym lies about 50 yards below the Wenallt, giving the total distance between the Court Herbert and Glyngwilym Seam as 440 yards.

The direction of the Gnoll Fault from Cwmafon to Gnoll is almost due north, but at the latter place it was proved in the workings of the Graigola Seam, and may be seen on the surface also, to turn to the north-west, the furthest point to which it has been proved being nearly under the Neath Workhouse. Its course from this point has been the subject of much dispute. It certainly does not cross the Gellia (Wenallt) workings of Cadoxton, and Mynydd March Hywell, nor can there be a large displacement if any between the Wenallt outcrops on the north and south sides of the Neath Valley. We are compelled to assume therefore that the Gnoll Fault must continue to head westwards so as to keep clear of the southernmost workings in the Gellia Vein, and must run into the Rhydding Fault. The bend is unusually abrupt for so large a fault, but can be matched to a certain extent both in the Rhydding and Dyffryn Faults further north. Moreover, it is a fact that the Rhydding Fault greatly increases in its throw at Cadoxton, as would happen if it had been joined by another large westerly downthrow, a fact, however, which is capable of another explanation.

The Rhydding Fault.—This fault is recognisable in the South Crop near Baglan House, and becomes an important downthrow to the west near Neath, its throw at Eaglesbush amounting to 140 yards. Near Cadoxton on the north side of the Neath Valley, it throws the Wernffraith Seam nearly on a level with the Gellia, which means a displacement of about 500 yards, *i.e.*, an increase in throw of 360 yards in about a mile and a half. Two miles further north the throw increases to nearly 800 yards, but at Cwm Clic, nearly five miles north of Cadoxton, the fault throws No. 1 Rhondda on a level with the Graigola, which means a displacement of only about 340 yards. Thence the dislocation runs northwards and probably becomes the Bryn

Lleffrith Fault previously mentioned. Two facts may be noted with respect to this fault. Firstly, it splits near Letty-sac so as to effect its throw by two steps; the easternmost step throwing in a small patch of the Graigola Vein (which is now being worked) on a level with the Gellia and being therefore about 240 yards, while the second step which lies between 300 and 400 yards further west, throws the Graigola down a further 500 yards, or more, to the position in which it has been worked at the Dyffryn Main Colliery. The second point is that the fault on approaching the Tawe Valley at Cwm Clic makes a sharp bend to the west, but after crossing the valley resumes its normal trend. The bend, though much less abrupt, resembles that made by the Gnoll Fault. S. Wales. (Mr. Strahan.)

The Dyffryn Fault, which runs nearly parallel to the Rhydding Fault, lies at an average distance of about a mile to the west of it. It is a downthrow to the east, and with the Rhydding Fault forms the well-marked trough of Dyffryn. It crosses the south crop on the west side of the Neath at Briton Ferry, and from Skewen can be traced northwards almost continuously both by old workings and on the surface past the Tawe Valley. This fault also on crossing that valley makes a bend similar to that made by the Rhydding Fault. At Skewen the Dyffryn Fault throws the Greenway down nearly on a level with the Graigola Seam, and may be taken to be a shift of 100 yards; near Dyffryn House it is believed to have a throw of 380 yards and at Wernddu of 440 yards, the Graigola of the west side being at a higher elevation than the Bryn Coch Vein of the east side. Here the fault is at its maximum, for near the Tawe Valley it throws the Graigola on the east a short distance only below the Hughes Vein on the West, a shift of less than 300 yards. Both here and at Llangiwg, however, it is accompanied by strong flexure which makes it difficult to estimate the shift effected by the fracture alone.

It will be seen that the Rhydding and Dyffryn Faults attain their maxima in the same region, namely near Bryn Coch; the measures dropped down in the trough between the two faults assume in fact a synclinal form, the deepest part lying at the spot named. The strata composing Mynydd March Hywell on the east side of the Rhydding Fault show no such synclinal structure, and the increase in the throw of the Rhydding Fault from Neath northwards is thought by some authorities to be sufficiently explained by the difference in inclination of the strata on its two sides, without the assistance of the Gnoll Fault, as discussed above. The supposition appears to involve a confusion between cause and effect; the synclinal form of the trough measures is the necessary result of so large a subsidence between two fractures of limited length.

The Gardener's Fault.—This important westerly downthrow runs from Jersey Marine by Glan-y-wern and up the Crymlyn Dingle. Here it throws the Llansamlet Four Foot Vein on a level with the Macs Melyn Vein. The Four Foot Vein we believe to be the Wernffraith, which lies 236 yards above the

S. Wales. (Mr. Strahan.)

Graigola at Llansamlet, while the Maes Melyn lies about 87 yards below that vein, the throw of the fault therefore being 323 yards. The fault intersects the outcrop of the Graigola at the old Heol-ddu Colliery, and passes through the Birchgrove and Sister's Pits to Glais, whence its course is still under investigation.

The Brother's Fault.—This may be regarded as a branch of the Gardener's Fault, springing from it between Heol-ddu Drift and the Emily Pit. At the Brother's Pit it was found to consist of three steps of 40, 50, and 60 yards, all down to the west. It appears to have been touched from the Garth Pit and to range for the Midland Railway bridge at Clydach.

The Bethel or Parc Pit Fault.—This is also a downthrow to the west, and has been traced at present through Pentre-dwr, the New Pit and the Parc Pit at Trallwyn to the Gwern Pit. Here its throw is said to be 100 yards. The fault has been touched also in the workings both of the Drew's and Four Feet Seams from Brother's Pit, but its throw has not been determined, though it seems to be diminishing northwards. What may be a continuation of it was touched 200 yards south-west of the Garth Pit.

The Six Pit Fault traverses the pit of that name and the Marsh Pit, and is a downthrow to the west.

The Pwll Mawr Fault is a downthrow to the east of 80 yards at the Pwll Mawr Colliery, but is supposed to be rather less south of Bon-y-Maen. Its effects on the configuration of the ground are most marked, however, where it crosses the outcrops of the Hughes group of veins at Tir-isaf, and throws the soft measures associated with them against the Pennant of Carn Nicholas Farm The fault runs out to sea at the Crown Spelter Works.

TRIASSIC.

As already mentioned, various tracts of formations younger than the Carboniferous series have been revised in connection with the resurvey of the Coal-fields, so that the one-inch sheets might be everywhere brought up to date. In North Staffordshire and the surrounding country this revision has been carried on by MESSRS. BARROW, GIBSON, POCOCK, and WEDD. In South Wales the work has been mainly done by MR. TIDDEMAN and MR. CANTRILL.

North Staffordshire Region.

In North Staffordshire MR. BARROW has mapped two separate areas of Bunter Sandstone and Conglomerate. The first of these lies to the north of Leek, and forms the north end of the long inlier that fills the old pre-Triassic valley through which the Churnet now flows. This valley has been eroded in the mass of soft shales underlying the Third Grit. In shape it recalls the form of some of the longer lakes of Scotland, from which, however, it essentially differs in that the water must have flowed out through the breaching of one side of the valley. This outflow not improbably occurred at the hollow south-west of Rudyard, as is suggested by the occurrence of the patch of Bunter at Endon, some miles down this lateral valley.

Cheadle District. (Mr. Barrow.)

In the other or Cheadle area of Triassic rocks only their margins have been at present mapped, so that little can yet be said regarding them. Evidence has been accumulated as to the very uneven nature of the surface of the Carboniferous floor on which the Bunter strata rest. Thus, the mass of New Red Sandstone on the north side of Cheadle, shown on the published map as an outlier, resting apparently on a comparatively flat surface of Coal-measures, proves to be in reality merely the end of a thick mass that fills an old, steep-sided valley. This mass and the valley which it fills is continuous eastward to the Churnet valley, in which direction the water flowed. The breadth of this sandstone at Cheadle arises from the valley having here been cut out of soft shales. Further east the valley passes through the much harder Kingsley rock already referred to, and there, together with its infilling Bunter Sandstone, it becomes much narrower. This connection of the Cheadle outcrop with the main mass to the east is of considerable practical importance to the town of Cheadle, for instead of their water supply being obtained from a catchment area of only one square mile, it in reality taps the water that is accumulated in the great mass of sandstone to the south-east. The supply will thus be more than enough for the town for many years to come.

To the west of Cheadle and in a direct line with the old valley just referred to, another ancient hollow existed which drained westward, and has likewise been filled up with Bunter Sandstone Its position is indicated on the map by the tongue that projects eastward from the main outcrop of that rock. The coincidence in direction of these two valleys suggests a common origin for them. The southern end and side, and in some cases the northern, correspond approximately with a rather large fault in the Carboniferous rocks, whereby the position of the valley was probably determined. This influence on the topography dates from a time anterior to the deposition of Bunter strata, as the mining evidence clearly proves. While the Two Yard Coal has been met with on the upthrow side of the fault under the Bunter Sandstones, it does not exist in the bottom of the old valley, even although it has been thrown down 25 yards. After its dislocation and subsidence, this coal-seam was obviously eroded out of the bottom of the valley before the red sandstone was deposited. It has been further ascertained that when a small easterly or westerly projection of the Bunter Sandstone is met with, it fills a small steep-sided pre-Triassic valley, whether or not a fault may there traverse the Carboniferous rocks.

Nearly all the faults in the Cheadle coal-field are of pre-Triassic age; they all trend either due east and west, or north and south. No such faults have been met with in the Bunter series in this area. There are, however, a few faults in the red rocks. They are, in the main, parallel to the trend of the steep-sided old valleys. The absence of any such faults in the Coal-measures, so far as known, raises the question as to what extent these faults cut the Carboniferous rocks, or are restricted to the overlying Red Sandstones. It seems probable that the latter supposition is really true in at least a number of instances. The pitting of the pebbles in the conglomerate shows that a great amount of compression has taken place, and these faults may represent the subsidence upon contraction of the incoherent sands into the deep and steep-sided valleys. They may thus have been quite superficial movements.

Stoke-on-Trent and Crewe Districts. (Messrs. Pocock and Wedd.)

Considerable difficulty has been experienced in establishing satisfactory divisions for the Trias in the Stoke district. The Keuper basement-beds are not sharply marked off from the underlying Bunter division and overlying Waterstones, and the latter graduate up into the Red Marls. It is doubtful, indeed, if the basement-beds are really represented there. Three divisions can be roughly made out. The lowest constitutes the Bunter group, consisting of red false-bedded sandstones and pebbly sandstones, with bands of shingle at several horizons; the middle includes even-bedded brown and white sandstones passing up into thin flaggy, thin-bedded sandstones with marl; the upper consists of red marl, with occasional thin bands of white and red flags, (skerries).

In the tract round Fulford Mr. Pocock has found the Trias subdivisions to be feebly represented. Not only are the Upper and Lower Mottled Sandstones absent there, but the Keuper Sandstones, which form the dominant features of the landscape in the Cheshire hills, occupy a subordinate position along the flanks of the plateau of Bunter Conglomerate, nor is there any clear division between the basement sandstones and the Waterstones. Thin sandstones of the waterstone-type are found interstratified with the coarser basement-sandstones, and though they are more common in the upper part of this division, it is not practicable to separate them on the map.

The Keuper Sandstones extend for about a mile south of Fulford, but in the Hilderstone valley they are absent and the Keuper Marl rests directly on Bunter Conglomerate. In the Triassic areas surveyed by Mr. Wedd, between Market Drayton and Betley, the same difficulty has been encountered in accurately subdividing the Trias. The broad divisions of Bunter, Keuper building-stones, flaggy waterstones and red marl can be recognised. The red marl passes downwards by a gradual increase of sandy material into flaggy waterstones These, again, in their lower part alternate with, and perhaps pass laterally into, soft false-bedded red sandstones and harder coarse white and brown building-stones, which are even-bedded in the west of the district, but are often markedly false-bedded at Blythe Bridge in the east. They sometimes contain a few pebbles, and it is often difficult to separate them from the Bunter group. This group in the ground mapped last year consists, as elsewhere, of red sandstone and pebble-beds, but it is uncertain whether these two types occupy separate horizons. At Merelake Hall, near Alsager, the Bunter group contains a considerable quantity of barium-sulphate as a cement, and narrow veins of baryto-celestite also occur. Barium is frequently found in the Keuper Sandstones of the western part of the district.

Stoke-on-Trent and Crewe Districts. (Messrs. Pocock and Wedd.)

At Linleywood, near Talke, a small triangular patch has been represented as Coal-measures upon the published map, on the down throw side of the Red-Rock-fault, two faults being introduced to account for its unusual position. This patch, however, seems to be really Keuper Sandstone. It closely resembles the Keuper Sandstone of Beeston Castle in Cheshire, and that of Bearstone, near Norton in Hales. The rock seen in Linleywood passes up into red flaggy sandstones, and on the same strike in an adjoining field red flaggy waterstones are exposed. Moreover, a minimum thickness of some 400 feet of Bunter strata has been proved in the workings of Bunkers Hill Colliery only about 200 or 300 yards to the south-west.

South Wales.

Of the eastern half of the broad tract of Secondary Rocks which extends from Cardiff to Porthcawl some account has been given in previous reports of the work of the Survey.* The western half has now been completed by MR. TIDDEMAN and MR. CANTRILL, under the supervision of MR. STRAHAN, who, from the reports supplied by his colleagues and from his own notes, has supplied the following general statement:—

The description of the Secondary Rocks extending from Cowbridge to Pyle was held over last year until the examination of the whole tract had been completed. All the strata in this part of the region, especially the Rhætic, assume so abnormal an aspect and change so rapidly in lithological character that only by continuous mapping could the change be realised and the stratigraphical horizons be identified. The eastern part of the district was surveyed by MR. CANTRILL, and the ground from Pen-llin westwards by MR. TIDDEMAN. In company with these two officers a complete traverse of the district was made by MR. WOODWARD and MR. STRAHAN for the purpose of checking as far as possible the correctness of the identification of the Rhætic strata in their abnormal form.

Triassic and Rhætic.—The Triassic conglomerate at Llanharry was found by MR. CANTRILL to lie unconformably upon Carboniferous Limestone, Millstone Grit, and Coal-measures. It seems to be of Upper Keuper age, and earlier than the uppermost green marls. It usually consists of a mass of pebbles of Carboniferous Limestone (ranging up to two feet in length), chert, and grit possibly derived from the Old Red Sandstone. These

* *Annual Report* for 1896, pp. 66–68: *Summary of Progress* for 1897, pp. 125, 126; *Id.* for 1898, p. 138.

materials are embedded in a ferruginous calcareous matrix in which iron occasionally so far predominates as to yield an ore which has been extensively worked.

It has been shown in previous *Reports* that all horizons of the Keuper Marl assume a littoral character in one place or another. At Penarth there is a considerable thickness of normal red marl, at the base only of which any conglomerate occurs; at Pendoylan the upper part also becomes littoral, while at Bonvilston, Llantrithyd, and St. Hilary the overlying green marls also pass into breccias. At Llandough the lower parts of the Triassic breccia are red, while the upper are yellow and evidently belong to the time of the green marls. In spite of these repeated evidences of the neighbourhood of a shore-line, the Keuper Marls on the whole preserve their typical aspect as far west as they extend. The green marls are well shown in a clay-pit near Pencoed, three miles north-east of Bridgend, behind the Old Pyle Inn, and to the south and south-west of Pyle Station. In these sections they present no essential difference from the green marls of the Penarth region, though the Rhætic strata above them have assumed a totally new aspect.

RHÆTIC BEDS.

South Wales. (Messrs. Tiddeman and Cantrill.)

The remarkable change which affects the Rhætic strata between Cowbridge and Pyle consists in the replacement of shales by sandstones and coarse grits, together with some increase in thickness. The thin group of soft shales and thin limestones which constitutes the formation at Penarth passes gradually into a massive rock which occasionally produces a moorland scenery rivalling that of the Millstone Grit. The change sets in near Cowbridge, but it is more fully developed near Bridgend and Pyle in the area surveyed by MR. TIDDEMAN. Its first appearance in the neighbourhood of Cowbridge is thus described by MR. CANTRILL:—

The lithological type as presented by the Rhætic rocks at Penarth persists for some ten miles westwards. At several points, even where they overlap the Keuper and rest directly upon the Carboniferous Limestone, the black *Avicula*-shales and the White Lias preserve their normal aspect, and manifest none of the signs of littoral deposition which usually characterise the Keuper under such conditions. Thus a roadside section near Bonvilston shows clays and thin *Pecten*-limestones resting directly on the Limestone.

Two railway-cuttings near St. Mary Church Road Station reveal a few feet of the upper Rhætic strata under the *Ostrea*-beds of the Lias. One bed, which is exposed for eight feet, is oolitic, an unusual feature in Rhætic limestone, and one not previously observed. In the cutting south of Cowbridge Station, limestones of Rhætic age, but not richly fossiliferous, with a few inches of breccia, probably of Keuper age, rest unconformably upon Carboniferous Limestone. They are overlain by a very hard Liassic limestone, containing bands of the shelly rock known as Sutton Stone, which seems to be a modified representative of the *Ostrea*-beds.

South Wales. (Messrs. Tiddeman and Cantrill.)

At Tregyff, near Llantrithyd, the sandy type of Rhætic first appears. The *Avicula contorta* series is there represented by blue sandy marls with *Pecten*-limestone and a conglomerate containing pebbles of Carboniferous Limestone and chert, overlying sandstone with casts of *Cardium* and *Avicula contorta*. Similar sandstones prevail north of Tregyff and are associated with bands of limestone composed of shell-fragments and resembling the Sutton Stone variety of the Lias. The proportion of sandy material increases northwards towards the Carboniferous ground, and the Rhætic sandstones have been quarried near Cowbridge, at St. Hilary, and at Llandough.

At Pencoed, from which point westwards this account is founded mainly on notes by Mr. Tiddeman, the Rhætic sandstones are let down between two faults. They are extensively worked for building, and have been used for silica firebricks. The rock is a rather fine freestone, white but with bands of a light greenish hue. *Pullastra arenicola* and scales of *Gyrolepis Alberti* have been collected from this sandstone. The presence of these fossils taken in connection with their superposition upon the uppermost green Keuper Marls exposed in characteristic form close by, as mentioned above, proves that the rocks belong to the *Avicula contorta* zone.

Near the top of the hill of Coed Mwstwr there is a small faulted outlier of this sandstone, together with yellow and green limestone-conglomerate which may represent the green marls under shore-conditions.

In approaching St. Mary Hill from Coychurch we pass over in descending order the *Ostrea*-beds of the Lower Lias, some compact limestone, which no doubt represents the Cotham Stone, some green marls with what appears to be an interbedded red marl, Rhætic sandstone, a space probably marking the outcrop of the Keuper green marls, and Keuper conglomerate. The sandstone at the brow of the hill has yielded to Mr. Tiddeman obscure casts of mollusca and scales of *Gyrolepis Alberti*. St. Mary Hill Down, which is covered with huge blocks of Rhætic sandstone, is formed by a compound anticline, much broken by strike-faults. Towards the south, where the sandstone dips away to the lower ground, the edge of the moor is followed by a depression, probably marking the outcrop of the upper part of the Rhætic group, and this by an escarpment of the *Ostrea*-beds of the Lias. These beds, however, are not quite of their usual type, and close by pass into a beach of shore-deposits.

In Coity a road-section west of the Castle exposes alternations of these sandstones and shales with greenish colouring and a little red mottling. The strata at first sight much resemble Keuper, but yield *Modiola minima* in abundance, a fossil which is plentiful in the upper part of the Rhætic group.

South Wales. (Mr. Tiddeman.) In the well-known Quarella quarries, where a white and pale-green building-stone is obtained, MR. TIDDEMAN has noted the following section:—

		Ft.	in.
	Blue limestone, with *Ostrea liassica* - -	0	2
Rhætic Beds	Clayey limestone, representing the Cotham Stone, variable.		
	Grey and green clay, with variable calcareous bands. *Lima* sp. - - - - - -	2	6
	White and pale-green sandstone, seen to -	35	0

The same rock was formerly quarried near the Angeltown Asylum, and Rhætic fossils may be obtained in the quarry rubbish.

The railway-section at Cwrt Coleman, which was described in detail by MR. TAWNEY in 1865,* is now partly obscured, but some of the beds, to which he refers as containing fish-remains on the south side, can now be seen on the north side of the line. A field-road south of Melin Cwcw shows a succession differing somewhat from that in the railway. We here obtain in descending order:—

	Blue limestone with *Ostrea liassica*, *Pleuromya crowcombeia*, and a coral.
Rhætic Beds	Buff marlstone, weathering white, probably representing the Cotham Stone.
	Green marls with a band of red marl, closely resembling Keuper Marl.
	Calcareous sandstone, several feet thick.
	Tough tufaceous limestone.

The strata exposed in the railway-cutting on the north side of the line evidently rise from below these, and themselves rest upon the thick Rhætic sandstone which forms the crest of the hill of Cwrt Coleman. The road-section therefore confirms the observation made in Coity that there is red and green marl associated with the upper part of the Rhætic group.

Higher up the valley some old pits show black shales resting on green limestone and white marly limestone. The green limestone is full of shells, which however cannot be broken out, but there is little doubt that the strata belong to the upper part of the Rhætic series.

The "Pyle Inn" quarry, which has been opened of late years to get stone for railway-viaducts, &c., gives the following sections:—

	Ft.	in.
Sandstone with *Natica pylensis*, *Cylindrites oviformis*, *Myophoria* - - - - -	12	0
Ochreous bed - - - - - - - - -	0	4
Fine sand - - - - - - - - - -	1	3
Green and grey clay - - - - - - -	3	6
Calcareous nodular bed, *Acrodus minimus* -	0	3
Shales - - - - - - - - - - -	1	3
Calcareous nodular bed, with fish-remains - -	0	3
Shales - - - - - - - - - - -	1	8
Fine whitish sandstone, with plants and at top a seam of quartz pebbles, with remains of *Hybodus* and *Acrodus*, seen to - - -	12	0

* *Quart. Journ. Geol. Soc.*, vol. xxii., p. 70.

The slopes below expose characteristic Keuper green marls. South Wales. (Mr. Tiddeman.)

The Rhætic sandstone has also been much quarried west of Pyle Church, the outcrop being followed for a considerable distance. Near the entrance to the quarries a white sandstone is seen with casts of *Pullastra arenicola* near its base. Above it was a band of green and red marl of typical Keuper aspect. Further on in the quarry the sandstone, where it has been more lately worked, shows bright green marly partings with ripplemarks, and yields *Anatina præcursor*, *Myophoria*, *Axinus cloacina*, while *Natica* has been obtained from the quarry-rubbish. The occurrence of the red and green marls next above this sandstone suggests that that rock lies high in the Rhætic group, and probably corresponds to the upper of the two sandstones in the "Pyle Inn" quarry, which also yielded *Natica*, etc.

Of the many scattered openings on Stormy Down the greater number have been made in search of sand for silica-bricks. One of these, lying south-west of the works, shows about 20 feet of massive sandstone, much like a Carboniferous sandstone, but resting on and containing thin seams of green clay. A little further west a swallow-hole shows that below it lies a limestone devoid of organisms and apparently of chemical origin, which is probably Keuper. The sandstone is thought by MR. TIDDEMAN to represent the lower sandstone of the "Pyle Inn" quarry. Further east, sandstones with green and yellow clays are exposed in a long line of excavations. They are occasionally green and ripple-marked, and yield casts of *Avicula contorta*. These probably represent the upper sandstone of "Pyle Inn" quarry.

The "Little Cement Quarry" on the edge of the Down, south-south-east of the Stormy works, shows a bed of shelly white limestone, resembling those seen in the old Rhætic pits west of Cwrt Coleman. From the material thrown out in deepening a spring close by, MR. TIDDEMAN obtained *Natica pylensis*, *Myophoria* sp., and *Cylindrites oviformis*.

The thick Rhætic sandstones form an escarpment of coarse white and yellow conglomerate near the top of Stormy Down. On some of the big blocks casts of lamellibranchs may be seen, but in other respects the stone might be taken for Millstone Grit. Such blocks are scattered all across the Down, and it was in one of these that the jaw of *Zanclodon cambrensis* was discovered.* It can now be stated with confidence that the *Zanclodon* occurred in true Rhætic strata of the zone of *Avicula contorta*.

In reference to the sections above described, MR. TIDDEMAN remarks that two points will strike anyone familiar with the typical aspects of Rhætic rocks in this country. One is the great preponderance of sandstone, the other is the occurrence of red beds above the sandstones, a colour which it is usual to associate with the Keuper Marl. From the abundance of sandstone he infers that the sediment was derived from a near source, probably the

* *Summary of Progress* for 1898, p. 202. See also E. T. NEWTON, *Quart. Journ. Geol. Soc.*, vol. liv., p. 646.

South Wales. (Mr. Tiddeman.)

sandstones of the Carboniferous or even of the Old Red Sandstone, while the remains of plants in them, and of land-reptiles such as the *Zanclodon*, to which we may perhaps add ganoid fishes, all point to an estuarine origin. The red beds suggest a land-locked area in which copious evaporation and chemical precipitation could go on. The silting up of an estuary might furnish some of the conditions necessary for the deposition of strata of this nature. The evidence shows that in the area around Bridgend in Glamorganshire, the Rhætic beds are intimately linked with the Keuper Marls. They exhibit, in fact, a local recurrence of the sedimentary conditions which attended the deposition of the Keuper Marls.

Mr. Tiddeman believes further that it is not altogether impossible to recognise some of the limits of such an estuary as that in which these deposits may have been laid down. One fairly defined shore may be recognised at St. Mary Hill Down. It is generally, though not invariably, the case that where the upper Rhætic beds have been deposited, a normal succession can be traced up into the Lias, but that where the Lias is conglomeratic no Rhætic strata lie below. The presence of conglomerates in the Lias thus furnishes a clue to the original limits of the Rhætic area. Another point on the south side of the estuary can be fixed between Tythegston and Merthyr Mawr, where the Lias overlaps the Rhætic formation, and rests as a shore-deposit upon Carboniferous Limestone. The northern shore of the estuary is obscured by faulting, but the high ground of the Coal-field must certainly have formed an extreme limit in that direction. Near the southern side of the supposed estuary Mr. Tiddeman notes that shell-banks, calcareous tufas, and sandstones permeated by carbonate of lime occur at points which are almost certainly near what were shores of Carboniferous Limestone. Coarse grits and sandstones containing quartz-pebbles prevail in the Rhætic series, near where the Millstone Grit no doubt forms the underlying rock.

Isle of Skye.

In the *Annual Report of the Geological Survey* for the year 1896 some particulars were given of the Passage-beds, which occur between the Lower Lias and the New Red rocks in Skye and Raasay. In Skye the strata, which comprise some six or eight feet of calcareous sandstones, limestones, and micaceous shales, are exposed in situations rather difficult of access, in the banks of Allt a' Mhuilinn, south-west of Broadford Free Church, at the cascade of Allt an Daraich, on the eastern side of Heast, and on the foreshore at Lusa (Lussay). These Passage-beds have been regarded by Mr. H. B. Woodward as the only portion of the Secondary series of this region likely to be of Rhætic age, but he failed to find any recognizable fossils in them in Skye and Raasay, or at Applecross, in Ross-shire, where similar strata occur. Last summer Messrs. A. Maccono-

CHIE and DAVID TAIT were instructed to make a diligent search for fossils at the above-mentioned localities in Skye, and they were rewarded by the discovery of a number of fossils, which have been submitted to MR. E. T. NEWTON and DR. F. L. KITCHIN.

At Ob Lusa, about eight feet beneath the famous coral-bed, which rests on a band of *Ostrea*-limestone (Lower Lias), there were obtained *Pleuromya? Nerita?* and *Cerithium cf. semele*, d'Orb. At Heast there were found some doubtful plant remains, together with *Ostrea*, *Mytilus*, and a fish-scale. At Allt a' Mhuilinn a number of Lamellibranchs were found, some of which closely resemble the Rhætic form *Myacites Escheri*, figured by Dumortier.*

The fossils are poorly preserved and crushed, so that they cannot be satisfactorily determined. In the opinion of both MR. NEWTON and DR. KITCHIN all the forms are such as might be expected to occur in the Rhætic Beds, and MR. WOODWARD, who has collected from the Rhætic Beds in many localities, is of the same opinion.

Isle of Arran.†

The most important observation recently made by the Geological Survey in Scotland is the discovery of fossils of Rhætic age in a streamlet about a quarter of a mile to the north-east of Derenenach, above the String Road, five miles to the south-west of Brodick in the Island of Arran. The rocks there have been mapped by MR. GUNN, who found them to be considerably disturbed. It was at first thought that they might belong to some part of the Old Red Sandstone. But eventually MR. MACCONOCHIE found in them a series of fossils which left no doubt that some of them are Rhætic. The specimens were first submitted to MR. PEACH, who recognised such characteristic forms as *Avicula contorta*, *Pecten valoniensis*, and *Cardium rhæticum*. They were subsequently placed in the hands of MR. E. T. NEWTON, who has supplied the following note regarding them :—

Avicula contorta, Portl. Several specimens clearly referable to this species leave no doubt as to the beds from which they came being of Rhætic age.

Pecten valoniensis, Defr. Two or three fairly good specimens agree with the shells from Rhætic beds, which have been called *P. valoniensis*.

Schizodus (*Axinus*) *cloacinus*, Quenst. One or two examples of shells with a sharp posterior keel are believed to be this species.

---

* *Études Pal. sur les dépots Jurassiques du Bassin du Rhone*, 1864, Plate I., figs. 5 and 6.

† The discovery of the fossils was made after this *Summary of Progress* had been sent to the printer. Subsequently as these pages were passing through the press, Mr. Peach and Mr. Gunn ascertained that the strata containing the Rhætic fossils are not *in situ*, but are enclosed in a coarse conglomerate that fills a volcanic vent, probably of Tertiary age. The same observers also found masses of limestone containing Lias fossils and fragments of chert containing *Foraminifera* which may possibly be Cretaceous.

Protocardium philippianum? Dunker (=*P. rhæticum*). There are two or three specimens which are in all probability *P. philippianum*, but none are so perfect as to make their identity certain.

Modiola minima? Sow. (=*minuta*, Goldf.). A specimen about $\frac{3}{4}$ in. long is referred to this species with some doubt.

Estheria minuta? Goldf. An imperfectly preserved impression of an oval shell may perhaps be this form, but it is very uncertain.

Gyrolepis Alberti? Ag. A broken fish scale showing a few ridges may be provisionally referred to this species.

The lithological characters of the strata containing the Rhætic fossils resemble those which are so persistent at the top of the Triassic system all through England and Wales. The red marls recall the well-known marls of the Keuper group; the grey marls seem to come in here as they do in South Wales, immediately below the fossiliferous black shales; and the latter again, though somewhat hardened, closely correspond with the equivalent strata in the same region. Fragments of decayed limestone which occur in the agglomerate have yielded what appear to be Lower Lias forms. They are not well preserved, but MR. NEWTON believes that they probably include such characteristic forms as *Ammonites angulatus* (?), *Cerithium semele* (?), *Gryphea arcuata* (?), *Pentacrinus basaltiformis* (?), and *Ditrupa globiceps*.

The importance of this fresh discovery in Arran is at least twofold. In the first place it probably gives a definite stratigraphical horizon for the red rocks of the southern half of the island, suggesting, if it does not absolutely prove, that these strata, in at least their upper portions, belong to the Keuper group, and are probably all of Triassic age. In the second place, the intrusive igneous rocks which disrupt these strata, and which form only a part of the great system of bosses and sills in the southern half of Arran, are now proved to be post-Liassic, or even post-Cretaceous, if the cherts should eventually prove to contain Cretaceous *Foraminifera*. Thus a further interesting and valuable piece of evidence is obtained to prove the comparatively late date of the younger igneous rocks of Arran.

JURASSIC.

Leicestershire and Rutland.

Hallaton and Burrow-on-the-Hill. (Mr. Fox Strangways).

The only tract of Jurassic rocks which has come within the range of the field-work of the Survey during 1899 lies to the east of the town of Leicester, on the borders of Leicestershire and Rutland, where MR. FOX STRANGWAYS has pushed the mapping eastward, so as to complete Sheet 156 (new series of the one-inch map). The district which he has so far completed lies between Burrow-on-the-Hill and Hallaton. It consists mainly of Upper and Middle Lias, with here and there thin coverings of Drift, which in a few places attain considerable importance. This part of the country was originally surveyed by PROFESSOR JUDD, but its revision on the six-inch scale allows considerably more detail to be put on the maps, and shows that the boundaries that have been drawn on Sheet 64 (old series) are merely approximate. The chief alterations to the published map, so far as the revision has advanced, appear to be at Skeffington and Noseley, where the Middle Lias has been found to extend much further than was supposed. In the first case, the Middle Lias probably stretches along all the high ground from Tugby to Skeffington, as strata of this age have been found at the latter village. It is not seen in the intermediate area owing to the thick covering of Drift. On the western side of the large valley between Goadby and Noseley an extensive outlier of Middle Lias was entirely overlooked in the former survey. This mass probably reaches from Noseley to the west side of Illston, and thence north to the fault at Billesdon, but its component strata are only seen at Rolleston and Illston, the rest of the ground being thickly covered with Drift. This western extension of the Middle Lias somewhat modifies the published view as to the size of the Billesdon Fault,* which is probably not nearly as large as was supposed. Although there seems to be an east and west fault there, it is probably not of any great magnitude. The outcrop of the Middle Lias south of Goadby is also incorrectly shown on Sheet 64, the Drift not being nearly so thick as the map would lead one to suppose.

Hallaton and Burrow-on-the-Hill. (Mr. Fox Strangways.)

The principal topographical feature that attracts notice in this district is the striking tabular forms assumed by the Middle Lias and Inferior Oolite over all the country from Somerby to Billesdon. Further south the Middle Lias becomes much thinner, and except at Goadby, it is only obscurely seen peeping out here and there from beneath the Drift.

CRETACEOUS.

Hampshire, Wiltshire, and Dorset.

In the counties of Hants, Wilts, and Dorset a small Cretaceous area has been examined by MESSRS. REID and DIXON, but the whole of the Chalk within it belongs to the Upper division, and is similar to that found in the surrounding country. Though much of the upper part of the Chalk is missing in the Cranborne district, represented on Map 314, there is no clear evidence of irregular folding or tilting before the deposition of the Eocene strata. In the absence of marked beds it is difficult, however, to speak with confidence on this point, especially as the junction of the Chalk and Tertiary formations is usually much "piped" as well as eroded.

Sussex.

For the purpose of securing the early completion of Sheet 317, which embraces the district between Petworth and Chichester,

Midhurst District. (Mr. G. W. Lamplugh.)

* Geology of Rutland, *Mem. Geol. Survey*, p. 66.

Midhurst District. (Mr. G. W. Lamplugh.)

the mapping of the Cretaceous rocks was assigned to MR. LAMPLUGH, who, during the summer and autumn, carried forward the revision from the margin of the ground previously mapped by MR. HAWKINS, two miles west of Midhurst, eastward to the transverse valley of the Arun at Pulborough. The strata above the Upper Greensand had already been surveyed by MR. CLEMENT REID, so that the work consisted in tracing on the six-inch Map the outcrops of the various divisions of the Lower Greensand, Gault and Upper Greensand, together with the superficial deposits by which they are in places overlain.

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 MR. LAMPLUGH obtained some specimens 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 may contain an increasing proportion of clay.

The broader grounds for the classification 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 characterized, 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 MR. LAMPLUGH found a richly fossiliferous band, consisting of ironstone crowded with the casts of marine shells, at the top of the iron-sand, in two apparently new localities near Midhurst (June Lane, and the river bank due south of Cowdray Ruins). In the stream-bed east of Ambersham Common, the same observer collected from a thin band of sandstone some plant remains, including traces of *Weichselia*, The Folkestone Beds consist of sharp sand, strongly current-bedded, with ironstone concretions and thin partings of pipe-clay. Excepting the cast of a fragment of wood with teredo-like borings, no organic remains were found in these sands. At the top of this division, immediately below the Gault, the sand is indurated into a hard grit-band, from two to four inches thick, of a deep red colour, which is persistent throughout the area examined.

Midhurst District. (Mr. G. W. Lamplugh.)

The Gault and Upper Greensand maintain the same character as in the country farther westward, and require no especial comment here. A few fragments of Ammonites, apparently *A. interruptus*, were collected in a brickyard in the Gault at Pitsham, near Midhurst, and the same species was also found in a new brickyard at Hardham. Both sections would probably yield better specimens if examined during the excavation of fresh clay.

Among the fossils collected by MR. LAMPLUGH during last season's work the following have been named in the Palæontological Department of the Survey by MR. E. T. NEWTON and DR. F. L. KITCHIN :—

JUNE LANE, MIDHURST, SUSSEX. (Sandy Ironstone ; Sandgate Beds.)

Cardium ?
Corbula striatula ? Sow.
Cytheræa ?
Nuculana scapha, d'Orb.
Tellina (Linearia), cf. concentrica, d'Orb.
Actæon sp.
Aporrhais sp.
Trochus ?

COWDRAY RUINS (RIVER BANK DUE SOUTH OF).
(Sandy Ironstone; Sandgate Beds.)

Cucullæa sp.
Exogyra sinuata ? Sow.
Nuculana sp.
Trigonia sp. (of the group " Scabræ ").
Actæon sp.
Cerithium ?
Trochus sp.

STREAM-BED SOUTH-EAST SIDE OF AMBERSHAM COMMON, 200 YARDS NORTH-EAST OF HOYLE FARM. (Sandgate Beds.)

Cf. Weichselia Mantelli, Brongn.

HARWOOD GREEN BRICKYARD, NEAR PULBOROUGH, SUSSEX. (Nodules, Atherfield Clay.)

Exogyra conica, Sow.
Pinna sp.
Thetis ?
Natica sp.

TERTIARY.

The revision of the Tertiary areas of the Hampshire and London Basins has been continued under the superintendence of MR. CLEMENT REID.

Hampshire Basin.

(Mr. Clement Reid and Mr. E. E. L. Dixon.)

With regard to the ground already reported as re-surveyed, considerable progress has been made in the reduction and publication of the revised maps. The sheet of the map (No. 315), showing the country around Southampton, has been engraved and published during the past year. Sheet 316 (Fareham) is partly engraved; but has been kept back to allow of the insertion of information obtained during the progress of a new railway. The memoir on sheet 328 (Dorchester) has been revised and published. Sheet 314 (Ringwood), which it was hoped could be completed and engraved during the year, was delayed owing to the unexpectedly late appointment of Mr. Dixon, who only commenced work in July; and also owing to necessity of Mr. Reid's presence at the office during part of the summer and again throughout December. The small area left over in this map (only about 14 square miles) will be finished early in the present year, and the map will then be sent to the engraver.

Hampshire has now been surveyed upon maps on the scale of six inches to a mile, with the exception of the north-east corner, around Aldershot. Half of Wiltshire has now been surveyed, mainly the eastern and south-eastern part. Dorset has advanced till about half the county has also been surveyed. In each of these counties the work of the past two years has consisted in completing and connecting scattered areas already partly mapped. The policy of completing defined areas will lead to the maps being more quickly available to the public, and ought to enable the work to be done more satisfactorily and more economically.

The recent field-work in the Hampshire Basin has been confined to the western border of the New Forest, the Avon Valley, and the adjoining parts of Dorset, all this ground being comprised in sheet 314. The area was almost entirely surveyed by Mr. Reid, who mapped the Forest, the Avon Valley, and part of the Chalk in Dorset. The newly appointed Assistant Geologist, Mr. E. E. L. Dixon, was placed under Mr. Reid's care, but as he only joined the staff in July, he could not contribute largely to the area of ground surveyed. He mapped the parts around Horton and Verwood. Much of Mr. Reid's time in the field was necessarily spent in training his new colleague.

The scientific results of the past season's work in the Hampshire Basin have not been striking; for the area on which Messrs. Reid and Dixon were engaged was surrounded on every side by ground already carefully revised. In Hampshire Mr. Reid found less than usual to alter in the Eocene boundaries of the published map (drawn by Joshua Trimmer), and though there were a good many points of scientific interest, not much of economic value was found. The principal novelties were, the discovery that the mass of pebbly gravel on Ashley Heath (west of Ringwood) was of Eocene age, and corresponded to the shingle seen in the cliff east of Bournemouth. The irregular appearance

(Mr. Clement Reid and Mr. E. E. L. Dixon.)

and disappearance of a mass of pebbles at the base of the marine Bracklesham Beds is not surprising; but it is noteworthy that on Ashley Heath this shingle is full of perfectly rounded pebbles of a peculiar siliceous sandstone, which corresponds exactly in its curiously waved bedding, and in the abundance of vertical root-cavities with the larger angular greywether blocks found loose, or in the Drift nearer to Salisbury Plain. In *Summaries* for previous years it has been shown that abundant evidence exists in the Hampshire Basin of an overlap westward and southward of the Reading Beds and of the Lower Bagshot group, till at last they rest on Palæozoic strata. We have now discovered evidence that the Bracklesham Beds also must overlap the lower horizons to a certain extent, for the pebbles of greywether must be derived from eroded strata of Reading age. A few fragments of Greensand-chert, which occur in the same pebble-bed, may have been derived from the chert-bearing fluviatile gravels of Bagshot or Reading age; they need not have been derived immediately from the Greensand.

New fossiliferous localities have been discovered in the Reading Beds, London Clay, Bagshot Sands, Bracklesham Beds, and Barton Clay; but within the area here alluded to fossils are badly preserved and not abundant. The most interesting change in the fossiliferous strata is the reappearance of a bed of marine fossils in the Woolwich and Reading series, this district being a long way from any other in which the Woolwich type, as distinguished from the Reading, is represented. The marine bed, already known through the labours of other observers, especially of Mr. Ernest Westlake, occurs at Rockbourne, and from that place extends south-westward through Wiltshire. It has also been discovered by Mr. Dixon at several new localities near Horton. The deposit is usually a glauconitic sand or loam, full of oysters, but containing little else. It now seems probable that the glauconitic loam without fossils, met with in the Dorchester sheet (No. 328) is a continuation of the same marine bed.

The Eocene deposits in the Dorset area surveyed last season are similar to those to the north-east and south-west. Mr. Dixon, as just mentioned, has discovered some new fossiliferous localities in the Reading series, though the fluviatile deposits of that age still remain barren. It is interesting to note, however, that subangular gravels containing Greensand-chert and fragments of Palæozoic rocks make their appearance as far north-east as Downton, though they are scarcely so angular as they become nearer Dorchester. Mr. Dixon has also obtained London Clay marine fossils at Verwood, and badly-preserved leaves in the Bagshot Sands not far from that place. He attempted to map out the clay-beds which often form marked features in the Bagshot series; but these proved to be as impersistent and irregular there as they are in other districts, and no one bed could be traced far. The clays dug around Verwood are not sufficiently good even for the coarse pottery there made, and the ware is consequently manufactured from the plastic clays of the Reading series, carted from other places.

LONDON BASIN.

(Mr. Clement Reid and Mr. A. C. G. Cameron.)

A considerable area in Middlesex has been surveyed by MR. A. C. G. CAMERON during the past season under MR. REID'S supervision. The greater part of it is underlain by London Clay, seldom containing fossils, and of the ordinary type. During an inspection, however, of the Stanmore district, in company with MR. CAMERON, MR. REID was struck by the marked resemblance of the supposed "high-level Pleistocene gravel" to undoubted Eocene gravels in the Hampshire Basin, and to the pebble-beds exposed some years since at Highgate, in the grounds of St. Joseph's Retreat, and in the deep trench of the Steep-grade Tramway. The Highgate deposit certainly belongs to the top of the London Clay or to the base of the Bagshot Sands, and on closer examination it was found that the Stanmore gravel also presents all the characteristics of an Eocene deposit. Its flint-pebbles are nearly always well-rounded, they have undergone zonal alteration to the centre (Pleistocene alteration does not extend nearly so deep), and mingled with them are rare fragments of Greensand-chert, hard sandstone, black grit with quartz-veins, and a few quartz-pebbles. Their composition thus closely resembles that of Eocene gravels described in former *Summaries.**

The unexpected result of this examination must lead to a reconsideration of the geological age of the whole of the supposed high-level Pleistocene gravels around London. It now seems doubtful whether outside the glaciated area any Plateau Gravels (*i.e.*, gravels more than about 150 feet above the Thames), are to be found that are not either of Eocene age, or derived wholly from Eocene deposits at a higher level. Stanmore is the highest hill (503 feet) in Middlesex, and dominates a considerable area down which the Eocene material has travelled.

Hungerford District. (Mr. J. H. Blake.)

At the western end or apex of the London basin, some fresh information has been obtained by MR. J. H. BLAKE as to the thickness of the Tertiary formations near Hungerford. It was derived from a boring made by MESSRS. CALLAS, SONS, and MAY in July last, at Kirby House, about a mile and a quarter east of Inkpen, and nearly two miles and a-half south of Kintbury. From specimens and detailed information supplied to him during the progress of boring, and from inspection of the material brought up at the place, MR. BLAKE was enabled to prove the occurrence and thickness of the following strata:—

	Feet.
Bagshot Beds	90
London Clay	52
Reading Beds	75
To Chalk	217
Chalk	103
	320

* See for example *Summary* for 1897, p. 130. *Annual Report* for 1895, p. 11.

A well was dug to the depth of eleven feet, and the rest was bored. The clean-cut section of the well showed the Bagshot Beds to be well stratified, and to dip north at an angle of 26°. This steep inclination brings up the Upper Greensand from beneath the Chalk to form the "Shalbourn inlier," south-west of Inkpen, as shown on the Geological Survey Map. The information obtained by this boring, satisfactorily clears up what was previously obscure. The published maps show no Bagshot Beds at the site of this boring; the omission having perhaps arisen partly from a certain similarity of the variegated coloured sands and loams of the Bagshot Beds in this district, to those of the Reading Beds, and partly also from the absence of sections.

The Igneous Rocks of Skye.

The survey of the Tertiary igneous rocks of the Island of Skye has been continued by MR. HARKER, who has been engaged in the district of the Cuillin Hills and the surrounding parts of the great plateaux of basalt. He has prepared the following notes regarding his work of the past season. **(Mr. A. Harker.)**

The basaltic plateaux.—More than twenty square miles of the moorland country have been mapped, lying to the north-west, west, and south-west of the Cuillin Hills. The general nature of the ground is that of small plateaux or flat-topped hills, rarely reaching 1,500 feet above sea-level. The slopes are conspicuously terraced, the salient features being always due to the numerous hard intrusive sills intercalated among the softer lava-flows. The latter, in contrast with the sills, are in general amygdaloidal. The prevalent type is basalt not rich in olivine, graduating into rocks which might perhaps be more accurately styled augite-andesites, but no such discrimination has been found practicable in the field. Conspicuously porphyritic varieties occur in a few localities only, *e.g.*, below Coire Labain. Approaching the gabbro boundary at the foot of the mountains, the lavas become harder, in consequence of metamorphism, and, the intrusive sills at the same time dying out, the details of the surface-relief assume a new character.

The metamorphism imparts to the basaltic lavas a tougher consistency and a more splintery fracture. The attendant mineralogical changes are most evident in the amygdules, which here contain felspar (formed at the expense of zeolites), hornblende (from chloritic substances), quartz (from chalcedony), epidote, and other new-formed products.

Conglomerates, with subordinate banded tuffs, are interbedded among the basalts at several places on the slopes above Glenbrittle House and elsewhere, while breccias and agglomerates occur more frequently among those relics of the basalt group entangled in the gabbro of the mountains. The pebbles in the conglomerate are chiefly of Jurassic sandstones, well rounded, while basalt, gabbro, and granite occur more sparingly.

Isle of Skye. (Mr. A. Harker.)

The only place where the base of the basalt group has been reached in the course of the season's mapping is along the coast facing the Isle of Soay. The underlying rocks are here for the most part Torridonian (Applecross grit). The base of the volcanic group, which is about 400 feet above sea-level at the western point of Loch Scavaig, sinks gradually westward to only a little above high tide at the outlet of Allt nan Leac, the stream draining Coir' a' Ghrundda. Here a small strip of Lias limestones is exposed on the shore, while the Trias conglomerate, rising from beneath these limestones, forms a small promontory 200 yards east of the mouth of the stream, as recorded last year.* Farther west the basalts come down below sea-level. There is another locality within the area mapped where the base of the volcanic group must be very near the surface, viz., on the shore of Loch Harport, near Carbost. Some years ago piles were sunk for a new pier about 500 yards beyond the Talisker Distillery, and the cores preserved in the yard of the distillery are of sandstone, presumably Jurassic. It is stated that the borings were only six or seven feet deep, under ten feet of water at low tide (about twenty-one feet at high tide).

The gabbro of the Cuillins with its associated patches of basaltic lavas.—The survey of the Cuillin Hills has been nearly completed during the past season by the mapping of some nine or ten square miles of the main (western) range, with its subsidiary spurs. The detailed study of this part of the ground has brought out more clearly the complexity of its structure, and especially the very considerable part played by portions of the basaltic lavas entangled in the gabbro and highly metamorphosed. These enclosed patches have lenticular or less regular forms, with dimensions ranging from a few yards to more than a mile. When their inclination can be detected, it is usually found that they dip eastward, *i.e.*, towards the interior of the mountains, agreeing generally in this respect with the other elements of the complex. The metamorphism is usually most intense in patches of small or moderate size, and the basalt thus indurated offers quite as much resistance to erosion as the gabbro itself, so that it occurs on the ridges rather than in the valleys. Some portions of these highly-altered lavas have a thoroughly coarse texture, and specimens would be unhesitatingly set down as gabbro, did they not still preserve relics of the characteristic amygdaloidal structure. This peculiarity may be taken as indicating that those rocks at least which exhibit it have not suffered bodily fusion in connection with the intrusion of the highly-heated gabbro; but the apparent gradual transitions from metamorphosed basalt to gabbro, though illusory, render the drawing of precise boundaries in some places a task of much difficulty. This difficulty is enhanced by another circumstance. It appears that the basaltic lavas so intimately associated with the large gabbro mass do not in general belong to the same part of the series as those developed on the adjacent moorland country.

* *Summary of Progress* for 1898, p. 137.

They are much less generally amygdaloidal, and what was there so distinctive a feature ceases to be available as a ready criterion on the more difficult ground. It is probable that in the northern and north-eastern parts of the Cuillins, mapped in former seasons, some rocks have been set down as intrusive diabases and fine-grained gabbros, which would be more correctly regarded as metamorphosed basaltic lavas. **Isle of Skye. (Mr. A. Harker.)**

Some of the central and highest mountains (such as those unnamed on the Ordnance map, but known to climbers as Sgùrr Alasdair, Sgùrr Tearlach, and Sgùrr Mhic Coinnich) consist in their upper parts almost wholly of basalt, with subordinate volcanic breccias, penetrated only by a few tongues of gabbro from below. From the extent and thickness of these lavas, they seem probably to be outliers of the rocks above the upper surface of the great gabbro laccolite, which, on this supposition, has a maximum thickness of about 3,000 feet or more.

The gabbro itself undoubtedly consists of numerous distinct intrusions in the form of wedges, sheets, and tongues, but their petrographical differences are not such as enable us to map them separately, even if the scale of the map permitted their delineation. An exception in this respect is the peculiar orange-crusted rock mentioned in the last report as remarkable for its extreme toughness, and for its containing innumerable xenoliths of a more normal gabbro. This rock occupies a considerable area in the western Cuillins, forming the peak at the junction of the Sgùrr Dubh ridge with the main range, and extending along the valley named An Garbhchoire. Here it is penetrated and enveloped by the normal coarse gabbro to the N.E., which is clearly of later date. On the other hand, the orange-crusted rock occurs at two places on the border of the gabbro area, viz., at An Sgùman and on the southern slope of Garsbheinn, and in both places is clearly posterior to the normal gabbro in contact with it. If the several masses of this peculiar rock are to be assigned to one epoch, we may draw the inference, on other grounds a likely one, that the normal gabbro on the border of the tract consolidated at a somewhat earlier time than that in the interior. Petrographical examination shows that the tough orange-weathering rock is of ultrabasic composition. It is usually a picrite, but passes into a pure olivine rock (dunite), and has also bands of troctolite associated with it.

Basic Dykes, Sills, and Sheets.—The intrusive rocks of the western part of the Cuillins and of the basalt country farther west are exclusively of basic (including sub-basic) composition. Acid dykes occur, as already recorded in the eastern part of the Cuillins, and occasionally on the moorlands to the north, but they do not extend westwards, a fact which tends to connect them genetically with the granite of the Red Hills to the east. It may be remarked too that granite veins in the gabbro, as well as independent acid intrusions, are wholly wanting in the western mountains; and even veins of pale felspathic gabbro, aplitic or pegmatoid, traversing the normal gabbro are comparatively rare except in a few places, such as the summit ridge of

Isle of Skye. (Mr. A. Harker.)

of Sgùrr Dearg. The most westerly independent intrusions of acid rock occur on the north-west slope of Sgùrr Thuilm, and consist of a biotite-bearing felsite—a type not elsewhere encountered.

As before, *basic dykes* were met with in great numbers on the ground mapped during the season. They are least numerous on the higher parts of the plateaux, formed by groups of thick sills. This may be due in part to the fact that some of the dykes supplied the material for individual sills and terminated at them; but the general explanation must be that the sills often presented an impenetrable barrier to dykes of later date than themselves. In many parts of the Cuillins the dykes are quite as numerous as on any portion of the basalt-ground. There are, however, in places considerable tracts of uniform coarse gabbro remarkable rather for the paucity of minor intrusions. Apparently some members of the complex body of gabbro have offered effective resistance to the passage of the dykes,

Comparing the dykes of the mountain district and the belt immediately surrounding it with those of the more distant parts of the basalt-country, and of Skye in general, we find a difference in their direction which seems to be of significance. In the basalt area the great majority of the dykes do not usually depart much from a direction north-north-west—south-south-east. In the mountains and the adjacent belt of country many of the dykes conform to the same law, but the general bearing has been governed by other factors, the principal group of dykes having a roughly radial disposition. They do not point accurately to a single central point, but the dominant set are so directed that, if produced, they would pass near the centre of the gabbro tract, or perhaps through one or other of several points situated within a central area. Further, the strong tendency of a dyke to run on in a straight line often causes it to be prolonged into a part of the tract where it makes an acute angle with the general direction in that place. In addition to the dominant radial set of dykes, there is a conjugate set approximately at right angles to them, the departure from rectangularity sometimes observed being due apparently to the same tendency to prolongation in straight lines. The conjugate set is usually subordinate to the radial, though locally it may attain almost equal importance. A noticeable hade is more frequent here than in the former set, especially in the outer belt of the tract, the inclination being very generally outward from the centre. In those parts of the mountains where the phenomena are most regular and most clearly displayed, we can distinguish by their bearing three sets of dykes: (i.) The radial; (ii.) the conjugate; and (iii.) the north-north-west set. The first two must be considered peculiar to the mountain district, while the third set is part of a much larger system, affecting an area which extends far beyond the limits of the Isle of Skye. It does not seem to be possible to distinguish the dykes of the several sets on petrographical grounds. One peculiar type, however, may be mentioned, consisting of an exceedingly hard and tough rock with an orange-yellow or rusty surface. Such dykes are frequent on some of the western mountains, especially in the neighbourhood of the orange-crusted picrite already referred to, with which they are sometimes in visible continuity. They have the same profusion of xenoliths remarked in that rock. Isle of Skye. (Mr. A. Harker.)

The *basic sills* intruded among the lavas make up collectively a considerable proportion of the total thickness. They vary somewhat in petrographical characters. The thicker ones are usually of a medium-grained diabase; others are of finer texture, often with something of a fissile structure. A few are amygdaloidal, but with characters quite distinct from those of the lavas, the vesicles being larger and more sporadic, and often empty. Fragments of the basalt lavas are sometimes enclosed.

The sills are always found to die out in the direction of the mountains, rarely approaching within 500 yards, and often not within 1,000 yards of the main gabbro boundary. Then follows a zone within which dykes are the only minor intrusions. Nearer to the mountains the *inclined sheets of basic rock* which form so prominent a feature of the Cuillins begin to make their appearance, traversing alike the gabbro and the enclosed patches of the volcanic group associated with it. These sheets may occur quite at the edge of the gabbro, or even in the metamorphosed basalts bordering it, but in most parts of the western Cuillins they do not become numerous at less than three-quarters of a mile or a mile from the outer boundary of the gabbro, or at altitudes of less than about 1,500 feet. They are thus quite distinct from the sills which follow the bedding-planes of the basaltic lavas. They are intimately linked with the gabbro, not only by their distribution, but by their inclination, which is always inwards towards the centre of the gabbro area. A greater variety of petrographical types among the inclined sheets also serves to separate them genetically from the sills. Which of these two groups of intrusions is the earlier is a question not easily solved. Both are evidently later than the large plutonic masses of gabbro and granite. Both are sometimes seen to cut through dykes, but this is far more frequent with the inclined sheets than with the sills. This observation, however, is not very conclusive, since we have reason to believe that the dykes in the gabbro area are in great part distinct from those of the moorland country.

Inverness-shire and Argyllshire.

In the progress of the mapping through the west of Scotland innumerable basalt-dykes are met with, having a general north-westerly trend, and presumably belonging to the third group in Mr. Harker's classification. During the past season many examples of this series of intrusions have been noted and marked on the maps. The following illustrations of their occurrence will suffice:—

Glenelg District. (Mr. Clough.) Reference has already been made to two series of dykes observed by MR. CLOUGH in the district between Glenelg and Loch Hourn. Those of the one group have been mentioned in connection with the crystalline schists. Those of the second group are no doubt of much later age, and, as they have a general north-west or north-north-west direction, and are of the same character as those of Skye, already alluded to, they may with some confidence be considered to belong to the Tertiary igneous protrusions of the west coast. They include basalts and dolerites and also some trachytic varieties. The latter are seen in several sections to be later than others of dolerite, and, as has been recorded in other districts, they show, near their sides, parallel rows of spherulites and greatly elongated amygdules.

Southern end of Great Glen. (Mr. Grant Wilson.) In the district at the southern end of the Great Glen, surveyed last year by MR. GRANT WILSON (*ante*, p. 39) both the granulitic flagstones and the Glen Loy diorite are traversed by numerous basalt-dykes of presumably Tertiary age. These vary in breadth from one to twenty feet, and have a general easterly and westerly trend. They are more numerous on the south than on the north side of Glen Loy. It is possible that they may be connected with the volcanic "necks" on the dividing ridge to the south of the glen.*

Dalmally District. (Mr. Kynaston.) A few additional examples of this late series of dykes have been noticed by MR. KYNASTON in the course of his work among the older rocks in the region already referred to (p. 42). Several dykes of dolerite, having an east and west direction, were mapped by him in the Ben Laoigh area, and between the lower portions of Glen Lochy and Glen Orchy. A dolerite near the head of Glen Shira also apparently belongs to the same series. It is a typical dolerite of medium grain, with a very fresh appearance under the microscope [8626].

Oban and Kilmelfort. (Mr. Symes.) In the Oban district numerous dykes, evidently belonging to the Tertiary series, have long been known. During his field-work last season, MR. SYMES came upon a number of additional instances around Loch Melfort. The rocks along the southern shore of that inlet are cut by a series of these basalt dykes, which are numerous and well exposed. They include examples of compound dykes, like that of which an account has already been published (*Summary of Progress* for 1898, p. 155). Two of these may be seen where a stream enters the sea at Kames Bay on the east shore. A couple of olivine-basalt dykes are there split up longitudinally by basalt dykes of a less basic nature, the edges of the latter being chilled against the earlier rock, and showing a margin of black basalt-glass. Another similar illustration occurs at Kilmelfort pier, on the north side of the loch. Close to Kilmelfort and east of the Manse, the basaltic dykes are especially numerous. They stand out there in great vertical walls, rising among the schists, granite, limestone, epidiorite, &c., and as a rule running in a north-west and south-east direction. At a distance of about five miles from Kilmelfort, on Carn

* As described in the *Summary of Progress* for 1898, p. 152

Duchara, the dykes tend to assume an east and west direction, and vary in composition from a fine-grained compact basalt to a highly crystalline olivine-dolerite. Although they run in numerous parallel lines, no compound examples have been noted among them. West of Loch Losgain Beg, the Tertiary dykes are seen to cut through the felsite dykes at right angles to the lines of flow.

Isle of Jura (Mr. Wilkinson.)

Nowhere on the West Coast do the late basic dykes offer a better contrast to the rocks which they traverse than they do on the western shores of the Island of Jura where the dark ribs of basalt rise through white or pale-grey quartzite. During the past season MR. WILKINSON has mapped a number of them in the portion of the island lying north of Loch Tarbert, where, however, he has found them not quite so numerous as they are further south. They are common on the northern shores of that sea-loch, and are more especially conspicuous at the western headland of Ruantallain, where at least eight dykes rise through the quartzite close to each other. At one part of the coast a dark sill has been thrust between the beds of the quartzite, which dips towards the east, and some of the dykes rise vertically through this sill.

Isle of Arran.

(Mr. W. Gunn.)

The survey of the remarkable succession of igneous rocks in the Island of Arran has now been nearly completed by MR. GUNN. During last season he was engaged in tracing dykes of basalt, pitchstone, and felstone in the central granite area among the crags of the highest hills, a task of some difficulty, as many of the dykes occur in almost inaccessible places, and form deep clefts that are not easy to traverse. The more minutely the granite is examined about the heads of Glen Rosie and Glen Sannox the more numerous do these dykes appear to be. MR. GUNN indeed has been led to believe that they are on the whole quite as numerous in the granite as in any other rocks of the Island. Basalt is the commonest rock among them, but dykes of pitchstone and of quartz-felsite are also abundant. With the exception of those of quartz-felsite, most of the dykes are comparatively small, many being less than ten feet in width. Composite dykes are far from uncommon. They generally consist of felstone with edges of basalt. An interesting example on Cir Mhor has been described by PROFESSOR JUDD.

In the area surveyed from Shedog, including the hill called Ard Bheinn, the rocks form part of the oval complex mentioned in a previous Report as occurring south of the String road between Brodick and Shiskine.* The geology of Ard Bheinn is about the most complicated in the island, but as none of the rocks recently collected there have been sliced for microscopical

* *Ann. Rep. Geol. Survey* for 1896, p. 75. As these pages are passing through the press a great volcanic vent in that district has been discovered by Mr. Peach and Mr. Gunn. (*Ante*, p. 133.)

(Mr. W. Gunn.) examination only a general description of the ground can at present be given. Indeed, only an exceedingly detailed description could give any idea of the extreme complexity of the area. The acid rocks embrace granite, granophyre, quartz-diorite, coarse quartz-porphyry, and fine-grained quartz-felsite. There are also basic rocks of several kinds that appear generally to be of older date than the acid rocks, besides later dykes. The number of separate intrusions of these rocks is very great. The rock into which they are intruded is the Lower Old Red Sandstone, which is generally here a conglomerate, but so highly altered as to have quite lost its ordinary character. Some of the basic rocks are highly magnetic, and at one place 550 yards east-south-east from Dereneneach the rock is a natural magnet, and possesses polarity. The characters, relations and age of these rocks remain to be determined.

PLEISTOCENE, INCLUDING GLACIAL.

Though no new facts of importance in the investigation of the Pleistocene deposits of the British Isles have been elicited during the past year by the field-work of the Geological Survey, much additional information has been collected regarding the distribution and local character of these deposits. In the following brief summary of the observations a geographical order will be followed, beginning with the English Midland and Southern Counties, then passing to South Wales, taking the districts of Scotland in order from north to south, and concluding with those of the south-east of Ireland.

Midlands.

Leicester and Rutland. (Mr. Fox Strangways.) In the portions of the counties of Leicester and Rutland examined by Mr. Fox Strangways he has found the distribution of the boulder-clay and gravel to be somewhat irregular. As a rule, these materials cap most of the higher ground, while the valleys are free from them. There are, however, exceptions to this rule, as over the high ground about Burrow and Somerby these deposits have been almost entirely removed, and also along the ridge from Whatborough Hill to the south-east. A large area free of Drift extends from between Tugby and Goadby eastwards to the north of Hallaton and Horninghold. Besides these tracts nearly all the valleys are devoid of drift in their lower part, except in two instances near Skeffington Vale and near Illston Grange, where boulder-clay is seen in the stream sections. The boulder-clay attains its greatest thickness along the southern edge of the map, a well west of Hallaton being said to be 150 feet deep, and apparently entirely in this deposit. Such a depth, however, must be exceptional, as elsewhere the drift does not appear to be of great thickness. The chief deposits of gravel are at Tilton, Skeffington, Rolleston, Tugby, and Belton. The revised edition of the map will show considerable changes in the mapping of the superficial deposits.

Reference was made in last *Summary of Progress* to some interesting particulars regarding the distribution of the boulder clays and boulders in the North Staffordshire region, which were gathered during the revision by MR. LAMPLUGH. In the work of last season, MR. BARROW obtained some fresh corroborative evidence of the same facts in the Leek and Cheadle district. He appears to have traced a portion of one of the marginal lobes of the ice-sheet that moved out of the Irish Sea, and carried with it the boulders from the Lake District. It will be remembered that MR. LAMPLUGH noticed that the ground between Cheadle and Uttoxeter was marked by an absence of these boulders, and he conjectured that the lower layers of the north-western ice, in which these stones were chiefly lodged, were arrested by the steep Bunter escarpment south of Cheadle. MR. BARROW, in confirming this surmise, has found that the arrest took place rather further to the north, but was effected by another prominent topographical feature of a similar kind. He has traced the north-western drift, with its abundant blocks from the Lake country, in great force over the ground to the north of Leek. This drift contains a great number of chips of flint, a characteristic feature of the boulder-clays of the Irish Sea basin. The blocks of igneous rocks from the Lake District cease to be visible a little south of Wetley Rocks. Roughly speaking, a line may be drawn in an easterly direction from this point, south of which these boulders have not been met with. Starting again from the same locality the further limit is no longer an east-west line, but a north-south one. In other words the limit of the drift is marked by a line that forms a right angle at a point a little south of Wetley. The position of this line is shown on a geological map to correspond through a considerable part of its course with the foot of the escarpment of the third grit—the rock that makes the most pronounced topographical feature in the whole area, and would obviously present the most persistent obstacle to the advance of the ice. The area beyond this line often contains no drift except a few Bunter pebbles, which are as ubiquitous in this part of England as chalk-flints are in other areas. On the east side of the Churnet there is no appreciable cover of drift. But the materials used in the construction of walls bear record of the transport of local boulders by ice, for these consist largely of the First and Third Grits, the outcrop of which is often not more than a mile distant. The bottoms of the small but deep valleys in the shales are often full of boulders of these local rocks. It was obviously economical to clear the fields of these blocks and use them for building walls, but it did not pay to undertake the great labour of hauling them out of the beds of the streams, and there they remain to attest the great number of boulders that have been transported by ice, though no drift now remains that can be represented on a map.

North Staffordshire. (Mr. Barrow.

In the western part of North Staffordshire, which has been revised by MR. C. B. WEDD, little can be added to what was said

(Mr. C. B. Wedd.

(Mr. C. B. Wedd.) of the Drift in last year's *Summary of Progress.* In the Audley and Talke district the drift terminates against the anticlinal ridges of the Coal-measure sandstones on the east, but where these ridges are broken by transverse valleys the drift passes southwards and south-eastwards up these valleys. On a belt of ground about a mile and a half broad, immediately west of these ridges, the drift is thin, except in valleys, while ridges of Triassic and Upper Coal-measure strata often rise from the midst of it. Beyond this it thickens to the west. It consists here as elsewhere of clays, sands, and gravels. The occurrence of shell-fragments in these deposits, which was referred to in last *Summary of Progress,* has been further proved by MR. WEDD during the past year. He has now found these fragments at 46 localities in the district, but few, if any, forms have been noted in addition to those given in the list published in that *Summary.* In the neighbourhood of Caverswall and Blythe Bridge little drift occurs, except in and north of the Blythe Valley, but no shell-fragments have been found in it. Many large boulders of some five or six types occur on the high Bunter ground of this part of the district. In the more westerly ground several peat-mosses occur, resting in hollows in sand, or closely associated with it.

(Mr. W. Gibson.) In the centre of the Pottery Coal-field, MR. GIBSON has observed that the drift deposits are thin and sparsely distributed, though they are developed in considerable quantities in the Trent Valley round Bucknall. At Kidsgrove another example of the edge of an ice lobe may be seen. The highly-inclined Coal-measures there rise abruptly above the Plain of Cheshire, and the drift deposits end off abruptly against the Carboniferous strata at an elevation of 500 feet, but drift sand and gravel occur at Trubshaw at an elevation of 700 feet.

Cheshire. (Mr. T. I. Pocock.) In the district of Crewe and further to the north-east in the country around Macclesfield the Drifts have been mapped by MR. T. I. POCOCK. It is well known that on the west side of the Pennine chain these deposits reach a height of 1,300 feet above the sea. Some patches of this high-level drift have been recently examined by MR. POCOCK. They consist of false-bedded sands with courses of pebbles (derived for the most part from the Lake District and Scotland), and rest here and there on boulder-clay. The amount of boulder-clay at the high levels is, however, small. The best known of these patches (that which yielded the marine fossils discovered by PROFESSOR PRESTWICH), runs for nearly a mile at the foot of an escarpment of grit north-east of Walker Barn. Others have been seen by the brook side east of Forest Chapel. The tops of the ridges above are plentifully strewn with boulders from the Lake country and Scotland, which afford conclusive evidence that some portion of the ice-sheet covered the spur of the Pennine Hills east of Macclesfield. The occurrence of drift and boulders by the brook which flows through Wild Boar Clough shows that the ice passed between Shutlingslow and the main ridge of the Pennine Hills. The peak of the Shutlingslow (two miles south from Forest Chapel), may have been a "nunatak" in the stream of ice. No erratics appear to have been recorded from the top of the main ridge, and probably the long escarpment formed by the third grit, which rises to a height of more than 1,800 feet at Shining Tor, barred the progress of the ice to the east. Cheshire. (Mr. T. I. Pocock.)

Besides the isolated patches of drift at high levels a series of mounds of sand and gravel was met with in the Langley Valley, two miles south-east of Macclesfield, about 700 feet above the sea. They are composed of the same materials as the drift at higher levels and take the form of conical heaps or undulating ridges, more or less parallel with the trend of the valleys. Their form, and mode of occurrence, at the point where the valley opens out on to the lowlands of Cheshire, recall the kames of the South of Scotland. They appear to have suffered little denudation since they were deposited. They may have been formed by torrential waters at a time when the ice-sheet barred the mouth of the valley, and the pressure from the north was not strong enough to force it over the tops of the hills.

In the Hilderstone district drift occurs sparingly on the tops of the hills, which rise to 700 feet above the sea, and also in the bottoms of the valleys, but the slopes are generally free from it. Ice-worn surfaces were met with near Fulford which indicate that the ice passed down Fulford Dale in an east-south-east direction. The drift, which is of the type described by Mr. Lamplugh,* is mainly composed of *débris* of Bunter pebble-beds with a mixture of red clay where its rests on the Keuper Marl. The occasional presence of striated pebbles from the Lake country clearly indicates its glacial origin.

In the Crewe district the drift is of the type common all over the Cheshire Plain. It is not more than 40 feet thick near Crewe, but is much thicker elsewhere. The false-bedded sands, which occupy a larger area than the clay in this district, can be traced continuously from Crewe Park through Weston and Wybunbury to Willaston. Here and there in brook-sections they may be seen to occupy a position between an upper and a lower boulder-clay. But as a rule this is not the case.

The three-fold succession described by Mr. De Rance in his Memoir on the Drift of South-west Lancashire, where the upper clay rests on an irregular surface of middle sands, or of a lower clay which closely resembles the upper, may hold good in the Crewe district. But the difficulty of distinguishing the two clays makes it impracticable to establish such a relation, or at least to use it for purposes of mapping.

Of the erratic boulders found in the course of Mr. Pocock's work last season the great majority belong to the same rocks as those described by Mr. Harker in the *Summary of Progress* for 1898. Some of the others were submitted to Mr. Peach, and were considered by him to belong to the Silurian grauwackes and granites of the south of Scotland. Another may have been derived from the Calciferous Sandstones of the Border-country.

---

* *Summary of Progress* for 1898, p. 160.

Hampshire Basin.

(Mr. Clement Reid.)

The Drifts mapped by Mr. Clement Reid in the Avon Valley consist in the main of tier above tier of gravel terraces, the highest of which rises fully 300 feet above the Avon, and not improbably dates back to Newer Pliocene times. These higher gravels are mainly preserved on the east side of the river, and, as is the case in all the Hampshire Basin, the gravels nearly cease where the Chalk crops out. The reason why the ancient valley gravels are so commonly confined to the Eocene area, and scarcely cross over to the Chalk, is by no means obvious, though it is probably due to the peculiar type of denudation which took place under an Arctic climate, when the undulating surface of the Down was frozen and no longer pervious. The 100 foot terrace (about 100 feet above the Avon) is the lowest of the gravel terraces here referred to. It is a continuation of the Bournemouth sheet, and contains, like that sheet, Palæolithic implements.

The Valley Gravels can sometimes be divided into two or three terraces, as Mr. Westlake has already shown; more commonly they form a continuous slope, rising 40 or 50 feet above the river, where the terrace abuts against the steep bluff which everywhere borders the Avon flat. These gravels yield remains of Mammoth, and also rare Palæolithic implements; but, like the older series, they are usually decalcified, and show no trace of fossils.

In the adjoining Dorset area, mapped by Mr. Dixon, a few outliers of the high terraces are to be found; but the highest is only 240 feet above the river, and is probably somewhat newer than the sheet over which the Downton and Southampton road passes.

Sussex.

(Mr. Lamplugh.)

In the area of Sussex, which has already been referred to (p. 135) as having been mapped last season by Mr. Lamplugh, 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 nine or ten 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 Heyshot, Ambersham, Graffham and Coates, and is much dug for road-mending. This material was a subject of discussion nearly fifty years ago by SIR R. I. MURCHISON,* and more recently by MR. J. V. 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.

South Wales.

(Mr. Strahan Mr. Tiddeman and Mr. Cantrill.)

The following summary of work of MESSRS. STRAHAN, TIDDEMAN and CANTRILL last season among the Pleistocene phenomena of South Wales has been drawn up by MR. STRAHAN. In previous Reports reference has been made to the Brecknock escarpment of Old Red Sandstone as having been no less important as an ice-parting in Glacial times than it is as a water-parting at the present day, but in the *Summary of Progress* for 1898 several facts were cited which suggest that the western end of that escarpment was crossed by the ice by way of the Crai and Tawyneu valleys. Further evidence of such crossing has been obtained by MR. CANTRILL in Cwm Garw. He finds that in that valley the ice, as shown by striæ on rock in place, moved in a general southerly direction, and that the valley contains many boulders of Old Red Sandstone, although the outcrop of that rock occurs beyond the head of the valley and on the other (northern) side of the water-parting. He infers that the ice overflowed the range southward by the pass of Pen rhiw wen, at a height of 1,618 feet, and that this overflow must have been due to the Vale of Towy having been filled with ice to at least that height.

MR. CANTRILL notes also the occurrence of many striæ, *roches moutonnées*, and bevelled crags on the Millstone Grit west of the Gwys. Tyle Garw shows numerous glaciated surfaces, the striæ indicating an ice-flow down Cwm Twrch in a south-south-west direction. The high Millstone Grit plateau lying between the rivers Tarch and Llynfell is glaciated right across its summit (1,656 ft.) in a direction towards south 15° west, by ice which must have moved up from somewhat lower ground to the north.

Along the north-west flank of the ridge known as Tair carn isaf, striæ have been recognised up to a height of 1,371 feet, with a direction ranging from south 60° west to south 15° west, indicating a general south-west flow parallel to the Llwchwr Valley.

The undulating plain underlain by the lower part of the Coal-measures is thickly overspread by a tough blue till full of large and small glaciated boulders, chiefly of Millstone Grit, but with abundant pieces of Old Red Sandstone and Carboniferous Limestone also. Through this deposit the rivers Giedd, Gwys, Twrch, and Llynfell have cut steep-sided ravines down into the under-

* *Quart. Journ. Geol. Soc.*, vol. vii., pp. 351-361.
† *Quart. Journ. Geol. Soc.*, vol. xliii., pp. 637-656.

(Mr. Strahan, Mr. Tiddeman, and Mr. Cantrill.)

lying rocks. These post-glacial ravines run about south 10°-15° west, and cut obliquely across the gentle ridges into which the Drift was piled, which run west 10° to 30° south. The direction assumed by these ridges prepares us for the fact that the main mass of the Brecknock Drift travelled along the north crop westwards, though some also certainly found a way down the Upper Clydach and Egel valleys past Rhyd-y-fro.

The Tawe Valley, like that of the Neath, formed one of the main outlets for the Brecknock Drift. Boulders of Old Red Sandstone and Limestone abound along its whole course, and are even piled up high on the hillsides around Swansea Bay. Striæ have been noticed in a paving quarry on Allt-wen, 400 feet above the bottom of the valley at Pontardawe, and at about the same elevation on the top of a sandstone-crag west of Ynysmeudwy. On Kilvey Hill, east of Swansea, there are many glaciated rock-surfaces, but none on which striæ were sufficiently preserved to be recorded. The Brecknock Drift runs up to a height of 550 feet at least on this hill; it is doubtful, in fact, whether there is any ground around Swansea which was not overflowed by the ice. The Drift in the upper part of the Tawe Valley may be described as a till, but in accordance with the usual rule it gets more gravelly farther from its source. The boulders, which are chiefly angular near the source in Brecknock, get steadily rounder, until at Swansea they are all true pebbles. The whole deposit also changes its character and assumes a rough stratification, in which sands alternate with pebble-gravels, while at the same time it has been heaped up into the ridge-and-hollow form so characteristic of glacial gravels. This form is admirably illustrated from Glais downwards. At that place a great dam of coarse gravel, reaching to a height of about 100 feet above the alluvium, extends far out in the valley, deflecting the river and leaving a narrow outlet for it at Clydach. Llansamlet also is situated among mounds of sand and gravel, the hollows between which have been filled up by flood-deposits of the Tawe and partly by peat.

The Drift-dam at Glais reproduces the phenomena already referred to* with respect to the Vale of Neath. The sands and gravels seem to have been the work of effluents from the ice-foot, and their development, especially in the form of a conspicuous ridge such as that at Glais, points to the ice-foot having lingered at that spot. It may be remarked of that ridge also that it presents a fairly gentle slope towards the north, but an extremely steep face to the south. It therefore has exactly the form which has been noticed in ice-foot accumulations at the present day, the gentle slope being produced by the advance and retreat of the ice over the rubbish, and the steep face by the extrusion of the material from the ice-foot.

The examination of the superficial deposits of Gower by Mr. Tiddeman has enabled him to prove a fact of much importance with respect to the relative age of the Raised Beach and the

* *Summary of Progress* for 1898, p. 165.

Glacial Deposits of the neighbourhood. This relation had been discussed, especially by Falconer* and Prestwich, but in consequence of the researches having been carried on chiefly in connection with the exploration of caves, and in a part of the coast where the evidence was obscure, Prestwich found himself unable to form a decided opinion. From an examination of the coast between Bacon Hole and Mumbles Head, MR. TIDDEMAN has satisfied himself:— (Mr. Strahan, Mr. Tiddeman, and Mr. Cantrill.)

1. That the Raised Beach is pre- or inter-glacial.
2. That the bone-beds which rest upon it in the caves are continuous with a layer of angular débris ("head") which lies upon it.
3. That the Glacial Beds lie upon this.
4. That these in turn are often covered with a deposit of angular débris of post-glacial age.

The lowest bed seen so far consists of a mass of pebbles, more or less crowded with shells of such species as are living on the coast at the present day. The pebbles consist of limestone, with an occasional specimen of Old Red or Carboniferous sandstone. There are also a few fragments of yellow flint or chert of doubtful origin. The conglomerate is firmly cemented. This deposit is overlain by a foxy-red sand, which, though impersistent, often runs for some distance. It is evidently a sand blown up from the foreshore and sometimes contains land-shells (*Helix*), which abound on the modern blown sands. The presence of this bed implies a sandy foreshore in some parts where no sands are found at low water now.

The next deposit rests on the sand, or, in its absence, on the beach or on the solid rock. It is to all appearance made up entirely of broken and angular limestone from the crags above. Its thickness varies greatly according to local circumstances. The glacial drift which rests upon the last-described band offers a remarkable contrast. It contains but little limestone, while Carboniferous sandstones and pebbles of Old Red Sandstone abound. This drift, which sometimes reaches a thickness of 40 feet, is in some places made up of rounded boulders and gravel, while in others semi-angular débris is more common.

Ross-shire and Inverness-shire.

Dingwall District. (Mr. B. N. Peach.)

During the past working season fresh proofs have been collected by MR. PEACH in the eastern parts of Ross-shire of the magnitude of the later glaciation of that region, to which allusion has alreadybeen made.† Both from the direction of the striæ on the bare rock-surfaces, and from the distribution of the boulders, especially those of the conspicuous Inchbae

* *Pal. Memoirs*, vol. ii., pp. 357, 358, 535.
† *Summary of Progress* for 1898, pp. 174, 175.

augen-gneiss, it is manifest that the ice was developed on such an enormous scale that the eastern margin of the great confluent glacier of the Blackwater and Conan rose high up the flanks of Ben Wyvis, and that on its emergence upon the low ground to the south of that mountain the ice must have fanned out towards the east. The southern slopes of the hill are terraced with successive lateral moraines strewn with boulders of the Inchbae rock, which mark successive stages in the decrease of the glacier.

Beauly District. (Mr. L. Hinxman.)

The glaciation of the region lying to the south of MR. PEACH's ground has been studied by MR. HINXMAN, who has observed that in the district between Strath Conan and Strath Glass most of the glacial phenomena are again found to belong to the later phases of the Glacial Period, few traces having been detected of the earliest glaciation since these have been in large measure effaced by the gigantic glaciers of later time.

On the summit ridge of Bheinn a' Bh'ach Ard, in the Struy forest, large erratic blocks of muscovite-biotite-gneiss and granite are forced up to heights of 2,800 feet. These must have been deposited by an ice-sheet coming from the west and over-riding the general surface of the country. Hard grey till, filled with angular blocks, underlies the later moraine deposits in the upper part of Glen Orrin near Aradie; and isolated patches of a similar early boulder-clay are found on the slopes of the higher hills north of Struy. On the ridge between Scatwell and Glen Orrin a few striæ pointing south-south-east have been observed. These indicate an ice-movement across the main valley system, and may possibly be due to the early ice-sheet. They may, on the other hand, have been produced by a branch of the Strath Bran glacier coming from the north through the narrow glen at the foot of Loch Luichart.

The lower hilly ground to the east of Erchless is for the most part bare of drift, and the rocks are well glaciated. The numerous striæ point north-east to east-north-east, a direction slightly oblique to the trend of the valley. The glaciation of this area and of that adjoining it on the north may be assigned to an early period of the valley glaciation—the period of the confluence of the Conan, Orrin, and Strathfarrar glaciers on the comparatively low ground to the east of Erchless and Corriechallie.

It is the last phase of the valley ice—that of small individual glaciers shrinking up the glens—that has produced the most striking glacial phenomena in the district. In the lower parts of Glen Orrin and Glen Goibhre the terraced lateral moraines, produced by the shrinking ice, are well displayed; and a particularly fine example encircles Cnoc Judais, the steep hill of conglomerate that rises west of the farm of Auchmore. East of this point they merge into the lateral moraines formed along the southern edge of the Strathconan glacier on the hill slopes above Balavulich and Ord Mains, and descending to the lower ground about Ord, pass into a series of flat-topped mounds and ridges of fluvio-glacial gravel, the latter finally spreading out into a fan and merging into the deposits of the 100 feet beach between High-field and Muir of Ord. Higher up Strathconan, the terminal moraines of the retreating glacier cover the bottom of the valley about Scatwell, and immediately west of Muirton Mains can be seen surrounded by, and no doubt resting upon, the 100-feet beach.

Beauly District. (Mr. L. Hinxman.)

Large boulders of the Inchbae augen-gneiss, together with blocks of gneiss, schist, and amphibolite, are found in great numbers about Arcan on the smooth drift-covered ridge between the Conan and the Orrin. The latter river seems to form the southern boundary of the dispersion of these augen-gneiss erratics. Eastwards, blocks of the same rock are numerous on the southern slope of the Black Isle, as mentioned in last *Summary of Progress* (p. 174). The stone circle at Carnurnan is formed of blocks of this gneiss, together with a few of mica-trap which enclose pebbles out of the Old Red Conglomerate. Mr. Peach has described a rock of this nature as occurring on Creag a Chaoruinn, south of Loch Garve, 12 miles to the west-north-west, from which place these erratics have not improbably been derived.

Among the glacial deposits of Scotland must be reckoned the older strand-lines or raised beaches which form so marked a feature on the eastern and western coastlines of the country. Some of these terraces are admirably developed among the northern firths from Inverness to the borders of Sutherland. One of the most marked of them, known as the 100-feet terrace, has been traced by Mr. Hinxman up the valley of the Conon to the extreme limit of the 100 feet contour opposite Torrachilty. Between Marybank and Clachuile Inn it is much denuded and sometimes obscured by river gravel. Immediately west of Muirton Mains it forms a considerable feature, and nearly surrounds a promontory of morainic material which, as mentioned above, appears to have been laid down upon the pre-existing beach. At this point the beach is composed of finely-laminated blue and grey estuarine clay, in which marine shells, not at the time identified, were obtained during draining operations.

The hollows and hill-slopes in Glen Goibhre and the Erchless Forest, and the plateau between Scatwell and Glen Orrin, are occupied by peat mosses of considerable extent and thickness. Most of the more accessible of these are dug for fuel.

In continuation of his previous work in the district of Fannich Forest Mr. Horne mapped some well-marked groups of valley moraines in the Abhuinn Nid and Cabuie Valley. When later in the year he transferred his station to Strath Nairn he found good evidence of the north-easterly movement of the great mass of ice which emerged from the Great Glen and spread out over the low grounds of the Moray Firth. This evidence consists of rock-striæ, the transport of materials in the boulder-clay and the dispersion of erratic blocks. The phenomena of the later glaciation were observed to be well represented by a fine development of valley moraines.

Fannich Forest and Strath Nairn. (Mr. Horne.)

In the west of Inverness-shire Mr. Clough has gathered

Glenelg District. (Mr. Clough.)

further information regarding the glaciation of the mountainous region to the south of Glenelg. In the area west of Beinn a'Chapuill and Ben Sgriol he has not observed much drift, but many of the glens to the east show extensive tracts of morainic heaps. Near the tops of Ben Sgriol (3,196 feet) and the Saddle (3,317 feet), and some other hills, he has observed flats and slopes which are chiefly covered with angular or subangular slabs of Moine-rocks like those which occur *in situ* near at hand, but without any admixture of stones, which must necessarily have been transported from a great distance. On the south slopes of the Saddle ice-striæ, pointing west and south-west, were noticed at a height of about 2,500 feet. The tops of Beinn a' Chapnill (2,421 feet) and of Sgurr na Laire Brice (2,326 feet) seem to have been covered by the ice, for ice-stræ may be seen close to the top of each; the direction of the striæ on Beinn a' Chapuill is south-east, and on Sgurr na Laire Brice north-east or east-north-east.

The terrace of the 100-feet raised beach is well seen on the south side of Gleann Beag of Glenelg. It runs for nearly a mile and a half above the mouth of the glen, and appears also on the coast near An Gurraban and Rudha Mòr. The hamlets of Arnisdale and Corran are built on a raised beach which, along the sea margin, reaches in places to a height of about forty feet. But the continuation of this beach inland in a terrace-form at the sides of Arnisdale river reaches a considerably greater height. On the north side of the river, about half a mile east-south-east of Arnisdale House, within the area of the high terrace, various banks and mounds are to be seen which resemble moraines. They seem all composed of well-rounded gravel.

On the south side of the same river, opposite to these mounds a terrace-shaped deposit of fine, stoneless, laminated, sandy clay, and sandy gravel lies at a height of perhaps 200 feet above the sea. At least one other terrace-shaped deposit occurs at a greater height, but its materials are not seen in section. Possibly these sediments were laid down at the side of an ice-tongue, which still filled most of the valley.

On the west side of Allt Coire Utha a large landslip has taken place. It appears to have at first dammed the burn back and given rise to a small lake. But the site of the lake is now filled up with gravel brought down by the stream. Other landslips have occurred on the south side of Gleann Beag (near Balyraid), and on Druim Fada.

Argyllshire.

Glen Spean and the Great Glen. (Mr. Grant Wilson.)

The glacial phenomena of Glen Spean and the Great Glen have long been classic in geology. They have never been actually mapped, however, in a detailed survey on such a scale as that now employed in the field-work of the Geological Survey. Mr. Grant Wilson, to whom this region has been assigned, has now made some progress with the mapping of the

Glen Spean and the Great Glen. (Mr. Grant Wilson.)

superficial deposits, and has furnished the following notes regarding the results obtained last season. One interesting feature of his mapping is the discovery of evidence for the former existence of a succession of lakes at various levels below the famous "Parallel Roads," during the time of the shrinkage of the ice-barrier that gave rise to them.

No characteristic of the region stands out more strikingly than the proofs of the enormous magnitude of the ice-streams during the later glaciation, especially on the west side of the Great Glen. At that time the ice while at its greatest extension, must have formed a large confluent glacier or ice-sheet over the ground between Loch Eil and Loch Arkaig. It moved eastward descending into the wide glen, and leaving traces of the successive stages of its decrease in the form of large lateral moraines which still terrace the slopes of the hills, and the sides of the valleys from top to bottom. So vast was this body of ice that it actually crossed to the south-east side of the Great Glen.* Round the township of Brackletter south of the mouth of the river Spean, the direction of the rock-striæ is from east 15° north to east 25° north; also on the east side of Loch Lochy to the south of Glenfintaig House, the striæ vary in direction from south 5° east to south 25° east. Two miles inland on the south-west shoulder of Sròn nam Bà, a fine series of striæ has been recorded These generally indicate a movement in the direction of east 15° to 35° S, and that the ice from Glen Arkaig had passed over the hollow now occupied by Loch Lochy and the Dochanassie district on its eastern side. From the direction of these different sets of striæ it appears that part of the ice from Loch Eil and the whole of that from Glen Arkaig converged towards the Spean valley.

That the movement of the ice of the later glaciation was from west to east over this district of Lochaber is further indicated by an analysis of the contents of the moraines. On the Fort Augustus Railway, below the Free Church of Kilmonivaig, a cutting has recently been made through sand and gravel resting on packed morainic detritus. As the material was removed the boulders of the moraine were placed on one side. A careful examination showed that fully 95 per cent. of them consisted of various rocks that occur *in situ* towards the west. A similar result has been obtained from an examination of the moraine sections exposed on the roadside that leads from Torlundy to Linachan.

Farther proof of the same general trend of the ice has also been collected in a study of the morainic detritus which fills the bottom of the valley of the Allt a' Mhuilinn, on the north-west slope of Ben Nevis. From the foot of the hill, for some miles to the east of the watershed, the underlying rock is granite, while the moraines are almost entirely made up of rocks from the Loch Eil basin and the country to the west. The ice has here not only carried the morainic detritus across the wide valley from Corpach to Inverlochy, but also up the slopes of

* See Mr. T. F. Jamieson's paper, *Quart. Journ. Geol. Soc.*, vol. xix., p. 235.

Glen Spean and the Great Glen. (Mr. Grant Wilson.)

Ben Nevis to a height of at least 2,000 feet above sea-level. It is evident that during this period of glaciation the local glaciers that emanated from the Ben Nevis range could only have been insignificant in size. Indeed, at no time could these glaciers have been large, seeing that the *nevé*-field of this range is so limited in extent.

During the past season numerous observations have been made by Mr. Grant Wilson in illustration of the later stages of the ice as it melted back towards the west, and the physical features that it gave rise to in Glen Spean. To the north of Spean Bridge the 855-feet Parallel Road is not correctly laid down on the one-inch Ordnance map. It should end about half a mile further to the east than is there represented. To the south of this point a well-marked terrace at the level of 420 feet extends from behind the house of Tirandrish to the foot of Glen Collarig in Glen Roy. This terrace is composed either of fine sand or of glacial silt, and where the Allt-na-Grudiareach has cut a deep trench across it, the following section is exposed :—

	Ft.	In.
Sandy soil - - - - - - - - - - -	21	5
Light brown glacial silt, laminated ,with a few stones -	2	0
Fine clean gravel, stones up to the size of peas - -	0	5
Very fine clean sharp sand - - - - - - -	1	6
Gravel, sharp and clean - - - - - - -	0	6
Sand with gravel bands - - - - - - -	0	9
Light brown glacial silt, laminated with stones - -	1	0
Gravel, sharp, bottom not seen - - - - - -	3	0
	10	8

A similar terrace at the same level has been traced on the south side of the River Spean from a point opposite Tirandrish round by Killiehonnet, thence up the Cour Valley and Allt-an-Loin till it merges into the flat which marks the site of Loch Lianachan. Fringing the south-side of the Allt-an-Loin, this terrace forms an extensive flat to the south of Dalnabie and continues up the valley as far as a point opposite the Roman Catholic Chapel of Glen Spean.

At many points around Dalnabie numerous landslips and cuttings show the terrace to be composed of fine glacial silt or sand, and in some cases these rest upon morainic detritus. Between the Roman Catholic Chapel and the foot of Glen Collarig, a well-marked flat-topped, broad terrace lies around the west foot of Meall Dhoire with its shore margin reaching to a height of about 420 feet. At the roadside below Auchaderry* its slope towards the deep water of the lake is seen to consist of 20 feet of fine white glacial sand in thin horizontal layers.

These three portions of a terrace appear to mark the site of another glacial lake in Glen Spean, which stood at a height of 420 above the present sea-level. When the ice which formed the barrier of the 855-feet lake had sufficiently diminished, its waters would find their way out in the direction of the valley of

* *Op. cit.*, p. 251.

the Lundy, at the same time depositing the large accumulation of false-bedded sands and gravels which are found at the head of the River Lundy between Torr Sonnachain and Sgor a' Pheanais. The 855-feet lake of Glen Spean and Glen Roy would thus be reduced to the 420-feet lake of Glen Spean, with its ice barrier stretching across the Spean Valley at Tirandrish. The surplus water of this lower lake would escape over the Col 420 feet at the south-west corner of Lake Lianachan. The barrier at Tirandrish must have been entirely composed of ice, for no terminal moraine extends across the valley at this point. Glen Spean and the Great Glen. (Mr. Grant Wilson.)

The next stage in the retrocession of the ice sheet from the Spean Valley is marked by the lowering of the 420-feet lake and its replacement by that of 300 feet. This later sheet of water was about 5½ miles long with an average breadth of half a mile. It stretched from Brackletter to the foot of Glen Roy. On the north side of the railway viaduct the line passes into a cutting* 250 yards long, which gives the following section of the materials deposited at the bottom of this lake.

	Ft.	In.
Fine gravel - - - - - - - -	3	0
Fine laminated brown silt with a few stones -	20	0
Fine laminated blue silt (contorted by shore ice) bottom not seen - - - - - - - -	3	5
	26	5

Both the brown and blue silt are arranged in fine horizontal laminæ, and through both are scattered a few glaciated pebbles. At the foot of the sloping bank the silt has been contorted and folded, possibly by the effects of the stranding of ice during the period of deposition. Around the church and the house of Blairour, numerous pit-sections show that the waters of the lake here deposited bands of fine glacial silt and sand with scattered glaciated pebbles. From the road-section below the church the thickness of the lacustrine deposit is seen to be about 50 feet.

On the south side of the river around Dalnabie, the finer deposits left by this lake have been denuded by the River Spean, and are replaced by the coarser and more recent alluvial gravels, but on the north side between Inveroy and Roy Bridge a broad, well-marked terrace with its shore-edge reaching to the 300-feet contour-line has been preserved.

When the lake at a level of 420 feet was superseded by this lower lake, the River Roy at the foot of its glen cut away a portion of the deposit laid down on the floor of the higher sheet of water, and left a long sloping terrace of silt covered by a thin deposit of gravel, now found midway between the two benches which mark the limit of the respective lakes.

A good part of the silt and sand deposited by the muddy waters of this lower lake has since been wholly or partially removed by the stream which has laid down in its place at a

* *Summary of Progress* for 1898, p. 171.

Glen Spean and the Great Glen. (Mr. Grant Wilson.)

lower level terraces of coarse alluvial gravel. This change is well seen in the railway cutting on the south side of the Spean, which passes through one of the upper river-terraces, showing current-bedded stream-gravel resting unconformably on a denuded surface of horizontally-bedded glacial silt. The barrier which impounded the waters of this lake extended from Bracklетter to Torr-an-Eas, and was partly composed of ice and partly of moraine-detritus. At the cross-roads below Torr-an-Eas, the moraine has a height of 361 feet. On the opposite side it is represented by the flat-topped hill of Bracklетter (371 feet), and in all probability once stretched right across what is now the deep river-gorge. This large accumulation of morainic detritus has an average breadth of about 500 yards.

In a railway cutting below the Free Church of Kilmonevaig, and on the west side of the barrier, it is seen that the portion which has been removed by the river consists of hard, packed morainic detritus, containing large boulders. The moraine in this cutting reaches a height of 230 feet above sea-level, and on its denuded top there rests a capping of false-bedded sand and gravel, about 15 to 20 feet thick. The dam would thus appear to have been lowered to the top of the moraine, while the outflowing water deposited the sand and gravel. The surplus water of the lake found its way into the Allt Achadh na Dalach, to the south-west of Spean Bridge. The present level of the col is a little over 270 feet, but when the lake overflowed in this direction, there may have been a considerable body of ice resting on the col, for the bottom of the gap is covered with small moraines, and below Auchnabobanne the valley is crossed by three large ridges, composed of morainic detritus. These mounds more nearly resemble kames than ordinary terminal moraines. They rise above the usual moraine hillocks, cross the valley with a serpentine course, and creep up the rising ground on both sides to at least 100 feet higher than in the centre of the valley. They are possibly due to the water, which must have circulated upon, within, or beneath the melting ice-sheet.

After the ice finally retreated from the foot of the Spean gorge, a large glacier would seem to have still issued from Glen Arkaig, and to have pushed its terminal face from Clunes to the braes on the west side of Bracklетter. This ice-barrier would raise the surface of Loch Lochy. That the lake did really stand at a higher level is proved by the well-defined terraces, 35 feet above the present level of the water between Muconir and Glenfintaig House, and around Blar-an-lochain.

Dalmally District. (Mr. Kynaston.)

From Dalmally Mr. Kynaston was able to map the drifts and other glacial phenomena, both southwards across the watershed towards Loch Fyne, and northward in the glens that drain into Loch Awe. From that part of Glen Shira nearest to the Cladich Burn he traced a continuous series of morainic mounds across the intervening divide and down to Loch Awe-side. The ice from the Ben Bhuidhe ground, no doubt, in part at one time travelled in this direction, and spread completely over the hills between Glen Shira and Glen Aray. The presence of a large boulder of monzonite, of the Ben Bhuidhe type, at the head of Glen Aray is of interest in this connection.

Dalmally District. (Mr. Kynaston.)

In Glen Lochy the morainic drift is well marked and extensive, and good sections of the mounds of loose material may be seen in the railway cuttings.

In the Glen Orchy area the larger burns (*e.g.*, Allt Corrie Bhiacar) have often cut their channels through more than 40 feet of mixed morainic material. Continuous morainic deposits may be traced from the head of Glen Strae down into Glen Orchy to the east, into the Black Mount on the north, and over into Glenkinglass on the north-west. In this district boulders of rocks, possessing characteristic and easily recognisable features, such as monzonite and the porphyritic augite-diorite, show that their dispersion has mainly followed the lines of the greater glens. Occasional large boulders of the Glen Orchy monzonite occur at Dalmally, while in the more immediate neighbourhood of the parent rock a line of boulders may be followed in a south-westerly direction, up a branch of the burn in which the rock occurs in place, and up the hill slopes between that branch and Glen Orchy, to a height of nearly 1,500 feet, or about 600 feet above the exposed parent rock.

Kilmelfort District. (Mr Symes.)

In the district around Kilmelfort Mr. Symes has observed that the striation on the ice-worn rock surface has a general east and west direction, varying up to as much as W. 45° S., which is the trend of striæ a mile to the south-west of the village. The ice is thus shown to have moved westwards, and to have inclined to the south of west, and even to south-west, according to the form of the ground. The most noticeable departure from this general trend was observed in the Pass of Melfort, which runs north and south, and where the striæ follow the same direction. As a rule these ice-markings have usually disappeared from the exposed surfaces of the knolls and crags of andesite, owing to the weathering of these volcanic rocks. But along the sides of the sea-lochs between tide-marks they are often well preserved. They abound on the eminence Carn Duchara, trending towards W. 20°–25° S.

Island of Jura. (Mr Wilkinson.)

A few additional particulars regarding the glaciation and old sea-margins of the Island of Jura have been gleaned by Mr. Wilkinson. Further evidence has been obtained by him of the westward movement of the ice-sheet by which the island was overridden. This consists both of rock-striæ and of the materials of the boulder-clay. Polished and striated surfaces of rock are common at all heights. There are indications of later glaciers in the moraines that have ponded back the drainage at higher elevations, and have thus given rise to numerous small tarns. The more ancient and extensive glacial drift consists of boulder-clay, which is widely distributed, and is banked up against the sides of the higher hills. The matrix of this clay is exceedingly tough, and is often of a red colour, which bleaches white or grey on the surface. It is plentifully charged with well-rounded, sometimes striated, boulders of quartzite.

Island of Jura. (Mr. Wilkinson.) epidiorite, dolerite, and red porphyry rocks, which are all found in place on the island. But there occur also pieces of red sandstone and andesite, which may have come from the volcanic district of Lorne. The west coast of Jura has long been celebrated for the number and admirable freshness of its raised beaches. To the north and south of Shian Bay they form a striking feature, also at the entrance of Loch Tarbert, and for some little distance along its northern shores. These terraces vary in elevation from the present beach up to the 200 feet contour line, which they do not pass. They consist of well-rolled shingle, which extends in patches for many miles; 90 per cent. of their stones are quartzite, which have been bleached by weathering into a dazzling white. In spite of their low elevation, they thus form a land-mark for a considerable distance at sea. They stretch out either into plateaux of bare shingle or moss-covered flats, behind which the ground rises rather abruptly along their inner margin. They extend inland in some instances for a mile. Occasionally one of the lower terraces has been a storm beach which has ponded back the drainage and now appears as a rampart of shingle with a small lake behind it.

Aberdeenshire.

Deeside. (Mr. Cunningham Craig.) The survey of the high grounds in the upper part of Deeside has included tl e mapping of the various glacial deposits of that region by Mr. Cunningham Craig. In the portion of the Cairngorm mountains recently examined, he has found later glaciation to be well-marked, especially in Glen Luibeg, where the moraines are noticeable for their size and regularity of form.

In the Lochnagar district, on the ridge dividing Glen Gelder from Glen Girnock, evidence of an abnormal drainage has been obtained. More than half-way up Glen Gelder, at the lowest parts of the ridge, broad flat cols may be observed. They are triangular in shape, with their apices to the eastward, where they terminate in steep dry gullies, which form the heads of small burns, that traverse the flat hollow of Glen Girnock and flow into the main stream of that valley. These gorges in the granite are not in lines of faults or crushes, and under present conditions could not have been cut by running water, as they do not drain any appreciable area. It seems probable that the explanation of them may be somewhat as follows. The ice-sheet, moving from the north-west, has overridden and completely filled the great open hollow of Glen Gelder, which probably owes its wide and shallow shape in great part to glaciation. During the decline of the cold a great mass of ice may have remained in the hollow, leaving the upper part of the glen comparatively clear, and diverting the drainage over the cols to the eastward and northward, where a similar gully is seen. Possibly a lake, or a number of small lakes, was formed in the upper part of the glen, about the sides of the mass of ice as it melted. Drainage to the westward was barred by the high ground of Lochnagar. If such conditions were maintained for a sufficient period, the escaping water, pouring over into Glen Girnock, would have been enabled to cut the gorges referred to. The material brought down in this manner would be spread over the open expanse of Glen Girnock, which may have been in great part free from ice. In confirmation of this suggestion, it may be mentioned that the superficial deposits, which mask the hollow of Glen Girnock are almost entirely composed of granite *débris* near the western ridge. That the northern ice must have swept into Glen Gelder in great volume is proved by the numerous fragments of schistose rocks in the drift of that glen, even in its upper part, where no sedimentary rocks can be detected *in situ*. The irregular and often ill-defined morainic mounds, which are scattered over the glen, consist almost entirely of granite *débris*, and were probably formed on the surface of the ice, and were deposited as the mass melted. Deeside. (Mr. Cunningham Craig.)

Dumbartonshire.

While the revision already noticed (p. 38) was in progress in the district of Loch Lomond an opportunity was afforded to examine with some care the marine deposits which have long been known to exist along the margin of that lake. Attention was first called to these deposits as far back as 1823,* and their enclosed fauna has more recently been studied by MESSRS. CROSSKEY and ROBERTSON.† In his recent revision of the district MR. CUNNINGHAM CRAIG traced the deposits where they have been preserved at intervals along the western shore and on several of the islands. They usually lie below the 50 feet contour-line, but on Inch Lonaig apparently rise to 100 feet above sea level; they are much denuded and cut into by streams, and are frequently covered by river-alluvium or the present lake-beaches. Their upper part usually consists of sandy gravel, which varies in coarseness locally, and sometimes contains erratic boulders of considerable size. Underneath this coarser material a fine yellowish or grey clay frequently occurs, with a few well-rounded pebbles and marine mollusca, which are sometimes found in the position of the living organism. This clay is frequently found in a somewhat denuded state under more recent deposits, *e.g.*, at Rossarden, where it is covered by one foot of recent lake-beach gravel. (Mr. Cunningham Craig.)

Inch Moan and Inch Cruinn are denuded remnants of a sea-beach which apparently stretched almost across the arm of the sea, which is now Loch Lomond. Inch Tavannoch and Inch Conachan consist of several ice-worn hummocks of rock, joined

* Adamson, *Mem. Wern. Soc.*, vol. iv.
† *Trans. Geol. Soc., Glasgow*, vols. ii. and iii.

(Mr. Cunningham Craig.) together by and rising through these marine deposits, which are here and there breached and denuded, and cut into miniature cliffs by the wave action of the present lake.

Rossarden and the northern part of Inch Lonaig are the best localities for the marine fauna. MR. ALFRED BROWN, of Broomfield, Luss, has kindly supplied the following list of species, which he collected on Inch Lonaig and identified.

Mya truncata.
Cyprina islandica.
Pecten islandicus.
Mytilus modiolus.
Tellina tenuis.

Though the fossiliferous clay has only been observed at levels below the 50-feet contour-line, the fauna points to cold-weather conditions, and the deposits probably belong to the time of the 100-feet beach.

North of Luss no traces of the marine deposits have been observed on the western shore of the lake. It is possible that the narrower upper reaches of the Loch Lomond were occupied by ice at the time when these sands, gravels, and clays were laid down.

County Wicklow.

(Mr. Nolan.) At such intervals as could be spared from the work of the office in Dublin, MR. NOLAN has continued the mapping of the superficial deposits in the region to the south of Dublin. He finds that the district immediately west of the high ground that extends in a southerly direction from Ballygobban south-east of Lugnaquillia mountain to the heights west of Tinahely is in general a rather flat, moory tract, gently sloping from the hills, at an elevation of from 700 to 800 feet above the level of the sea. Most of it is covered with scattered stretches of peat-bog over drift of local origin, containing pieces of granite and schist. This deposit is sandy or somewhat clayey, passing into a sandy boulder-drift, which, in some of the narrow stream-courses, has been heaped up to a considerable depth. The surface is often encumbered with blocks of granite, particularly in the vicinity of Moyne Church, north of Sandy Ford, and westwards to the borders of Co. Carlow. The limestone-gravel of the plain is met with to the west at High Park, three miles north of Hacketstown, whence it extends southwards, seldom in this district attaining a greater height than about 600 feet.

On the opposite or south-eastern side of the ridge, where there is far less moor and peat-bog, the local drift is usually thicker, and forms long, smooth slopes, well cultivated, and diversified with trees and plantations. In the valley traversed by the railway, between Aughrim and Tinahely, sand and gravel prevail, and a section through these deposits showing rude stratification was noticed at Tinahely railway station. These sands and gravels are of local derivation and contain no limestone fragments.

Although the rocks in this district are chiefly granite, and consequently little calculated to retain ice-markings, yet some striæ are occasionally seen. In the valley of the Ow, or Aughrim River, one mile south-east from Aghavannagh, striæ may be observed that bear north and south, while at Ballymanus Hill, near Aughrim, and on the heights above Ballinglen, the trend is towards south-east. These scorings, corresponding generally with those observed in northern Wicklow, confirm the conclusion that the direction of the ice flow in this part of Leinster was southerly, inclining to south-east. (Mr. Nolan.)

RECENT.

In the foregoing pages references have been made to some of the Recent formations met with in the course of the field-work last year. In addition to these the following brief notes are here given.

Sussex. (Mr. Lamplugh.) In the district of Sussex between Midhurst and Pulborough, recently mapped by Mr. Lamplugh, it is noted that as the Lower Greensand of that tract does not afford much gravel-making material, the plateau-drift has formed the chief source of the later valley-gravels. Consequently, although terraces of erosion are sometimes well-marked along the principal valleys, there is usually very little gravel upon them except around the mouths of tributary streams which have eroded the plateau-drift. Impersistent valley-gravels occur here and there along the course of the Rother, at various elevations up to 40 or 50 feet above the present stream. Eastward, towards the junction of the Rother and the Arun, these terrace-gravels attain a wider development, and as the plateau-drift sinks to lower elevations in this direction, there is some difficulty in distinguishing between this drift and the higher patches of valley-gravel.

Falmouth District. (Mr. J. B. Hill.) While mapping the older rocks of the south coast of Cornwall, Mr. Hill has likewise traced the superficial accumulations which in post-Tertiary time have been formed more especially in the inlets by which these shores are indented. He notes that the upper parts of the tidal estuaries are mostly filled with a deposit of brown mud, formed from the decomposition of the slates, and carried seaward by streams. Amongst these deposits, that of the estuary of the River Fal calls for special notice on account of its being likely to turn out of considerable economic importance. The Fal, for part of its course, cuts through the mass of the St. Austell granite, and receives the drainage of its western portion. As this granite is in a highly decomposed condition, it readily lends itself to the processes of denudation, in striking contrast to the neighbouring slates, which, in comparison, disintegrate slowly, so that the detritus from the granite forms the principal part of the deposit. The decomposition of the felspar has resulted in the formation of deep deposits of argillaceous material, which is mixed with the sand

Falmouth District. (Mr. J. B. Hill.)

and gravel of the estuary, and includes beds of impure kaolin, the deposit of which is now considerably accelerated by the drainage of the waste water from the china-clay works. This water, having a white, milky look, is charged with kaolin of the very finest texture, which has escaped in suspension. The clay of the estuarine deposit is of a white and pale yellow-grey colour. The beds of sand and gravel with which it is mixed consist of the coarser granitic detritus, and are most frequent at the head of the estuary, and along the borders of its channel. A factory has been established on the banks for the manufacture of bricks, which are largely used in the locality, and works are at present being started for the manufacture of earthenware, which, if remunerative, will create a new industry in the district. The clay suitable for this purpose extends for at least a mile along the estuary, and its thickness varies with the shelving of the bottom. It is at present being extracted to a depth of at least 12 feet below high-water mark, and this depth in many parts may be considerably exceeded.

Wicklow. (Mr. Nolan.)

While tracing the Drift-deposits in County Wicklow Mr. Nolan has likewise mapped the extensive tracts of peat-bog of that region. It has already been mentioned that much of the Drift in the moory uplands between Aghavannagh and Tinahely is covered with peat. A good deal of it is thin, and of poor quality, but there are some deep bogs where excellent fuel is obtained. Large tracts of peat-bog cover most of the floor of the valley between Aughrim and Tinahely, that near the latter town and at Ballinglen being much utilised. A considerable extent of mountain bog caps the hill of Ballymanus, at an elevation of 1,200 feet above the level of the sea. Roots and branches of trees, especially of the common birch, are met with in these bogs.

An extensive deposit of river alluvium spreads over all the lower parts of the Aughrim and Tinahely valley, sending arms into the subsidiary valleys. As just mentioned much of its surface is covered with peat.

II.—PETROGRAPHICAL WORK.

Some of the petrographical work of the Survey during the past year has been embodied in the foregoing pages in connection with the narrative of the field-work in the different districts whence the rocks examined have been obtained. But some further account of special petrographical researches has been reserved for the present section of this *Summary*. These researches have embraced both microscopical and chemical investigation. The specimens of which the investigation have been required for the purposes of the maps and memoirs of England and Wales and Scotland have been studied at this museum by Mr. Teall for the microscopical, and by Dr. Pollard for the chemical analyses. Those needed for the Irish branch of the Survey have been examined by Mr. H. J. Seymour at the office of the Survey in Dublin. The chief additions to the rock collections of the Survey have been made in Scotland where the Collectors gathered 136 rock specimens in illustration of the geology of the counties of Argyll, Inverness (Skye), Ross, and Sutherland. A number of the rocks collected in Scotland by members of the staff were sliced for microscopic examination, and have been examined and described by MR. TEALL and MR. HARKER.

Jermyn Street Museum. (Mr. Teall.)

The total number of sliced rocks added to the petrological collection at Jermyn Street under MR. TEALL'S charge during the past year is 456. Of these 79 are English, 348 Scottish, and 29 foreign. The foreign rocks have been sliced for comparison or to assist in answering enquiries addressed to the petrological department by public institutions or private individuals.

Detailed reports on 235 rocks have been furnished to the field officers. The remaining specimens have either been dealt with by the field officers or utilised for the purpose of labelling Museum specimens.

The English collection of rock-slides at Jermyn Street now numbers 3,265, the Scottish 8,678, and the foreign, 451.

The final revision and preparation for the press of the petrographical work on the Lewisian gneiss has been completed.

A series of microscopic slides of rocks from British Guiana, forwarded by PROFESSOR J. B. HARRISON, of the Government Laboratory, Georgetown, has been examined and reported upon.

The gradual substitution of the New for the Old Series of one-inch maps has rendered necessary the reclassification of the English petrographical collection. This has been done by MR. RHODES, assistant in the Fossil Department during the past year. All the English and Welsh rocks are now classified according to the New Series of maps.

The principal work in the Rock-room of the Jermyn Street Museum has been the relabelling of the Silurian rocks of Ayrshire and Dumfriesshire, and of the Carboniferous volcanic rocks of Scotland. This work, which has been carried out by MR. RHODES, under MR. TEALL'S supervision, necessitated the preparation of many new and thinning down of old sections, which were unsuitable for precise petrographical determination.

A series of specimens illustrating rock-structure in the Isle of Man, collected by MR. LAMPLUGH, has been added to the structure case in the rock-room.

MR. A. W. CLAYDEN, M.A., F.G.S., Principal of Exeter University College, has presented to the Museum a series of specimens of the Permian volcanic rocks of the Exeter district.

Dublin Office. (Mr. H. J. Seymour.)

In the Dublin Office of the Geological Survey during the past year, MR. H. J. SEYMOUR has examined and reported on 234 thin slices of rocks, while 170 new slides were prepared and added to the Irish collection, which now numbers 2,351. In order to facilitate the preparation of a "rock type" catalogue, he also examined and named nearly 100 slides in the collection which had not previously been determined. The report of his work, given on p. 176, is based on the examination of a number of slides selected as representative of about 750 specimens collected in the various districts referred to.

The following summaries of some of the more interesting or important researches of a petrographical kind carried on in the Survey during the past year, have been supplied by the officers who have been engaged in them :

INSOLUBLE RESIDUES OF CHALK.

(Mr. Teall.) Insoluble residues, prepared by MR. WILLIAM HILL from various horizons in the chalk, have been examined. The results are in accordance with those established by DR. HUME for the English, and by M. CAYEUX for the French Chalk. Quartz and alkali felspars are the principal clastic constituents; but whenever a sufficient quantity of material is available many heavy minerals, such as rutile, zircon, tourmaline, cyanite, and garnet may be detected.

No volcanic minerals and no traces of pumice or volcanic ash were observed; and the general character of the sedimentary material of mechanical origin, so far as composition is concerned, was found to be the same from all horizons. The amount and size of the mineral particles will be dealt with by MR. HILL as a part of his important work on the comparative petrology of the Upper Cretaceous rocks.

THE VOLCANIC ROCKS OF THE EXETER DISTRICT.

The preparation of an Explanation of Sheet 325 of the New Series of one-inch maps, embracing the district around Exeter, made it desirable that the petrography of the interesting volcanic rocks lying at the base of the red sandstone of that part of Devonshire should be more fully worked out. This research devolved on MR. TEALL, who has furnished the following summary of the results obtained by him :—

The general relations of these rocks to the sedimentary series has been described by SIR A. GEIKIE in his work on the "Ancient Volcanoes of Great Britain," and the same work contains also some particulars as to the petrographical characters of the rocks, based on observations by DR. HATCH and MR. WATTS. Further petrological details are contained in an important paper by MR. HOBSON, "On the Basalts and Andesites of Devonshire."* The general results of the re-examination may be briefly summarised as follows :—The rocks range in composition from trachytes or orthophyres to basalts or melaphyres. Many of them represent effusive forms of the minette-magma, and they

* *Quart. Journ. Geol. Soc.*, vol. xlviii. (1893), p. 496.

are thus brought into relation with the mica-trap dykes, which (Mr. Teall.) have been so well described by Mr. Collins.*

Most of them are in an advanced stage of decomposition, especially as regards the ferro-magnesian constituents. Augite is often represented by pseudomorphs in carbonate, and olivine has been converted into iddingsite or, in extreme cases, into carbonates and ferric oxide. The oxidation of the iron-bearing compounds gives a predominating red colour to the rocks. Much of this decomposition is of Permian age. It appears to be of the lateritic type so common in tropical regions, and the washing down of the red material by the Permian torrents has contributed largely to the formation of many of the basal rocks of the New Red Sandstone series.

The rock of Killerton Park near Exeter, is a biotite-trachyte or orthophyre having marked affinities with the euselite (Rosenbusch) of Rhenish Prussia and the orthophyre associated with the lower Rothliegende of Thuringia.

Another type of orthophyre containing numerous pseudomorphs of olivine occurs at Knowle, Spencecombe, near Crediton. Both these rocks have been analysed by Mr. Grant Wilson. They are closely allied to minettes in composition.

The well-known rock of Pocombe, so largely used for building in Exeter, is intermediate between orthophyre and basalt. It is composed of numerous red pseudomorphs after olivine, in a matrix composed of more or less lath-shaped microlites of felspar, a few grains of augite or carbonates after augite, and particles of iron-oxide. Both plagioclase and orthoclase are present, the relative proportion varying in different specimens. The minute and more or less altered laths of plagioclase form kernels in the orthoclase as they do in the absarokites of Iddings.†

The more typical basalts occur in the neighbourhood of Ide and Dunchideock. They frequently contain quartz, and are closely allied to the quartz-basalts of American authors. Mr. Hobson's paper contains a full description of these rocks and a discussion as to the origin of the quartz which he regards as foreign to the magma.

In comparing the Exeter maps with their Continental equivalents, the fact that they are but feeble representatives of the Permian volcanic episode is strongly emphasised. In bulk they are insignificant in comparison with the Permian igneous rocks of Rhenish Prussia (Saar-Nahe-district), the Thuringerwald, and Les Grandes Rousses. Not only is the amount of igneous material much larger on the Continent, but the rocks are also of a much more varied character. In Rhenish Prussia quartz-porphyries, porphyrites (andesites) and melaphyres (basalts) occur in great abundance and in rich variety. Under these circumstances, it is interesting to note that the Permian breccias of

---

* *Jour. Roy. Inst., Cornwall,* part ii., vol. iii. (1884).
† Absarokite-shoshonite-banakite series. *Jour. Geol.,* vol. iii., p. 935.

(Mr. Teall.) South Devon contain, as MR. WORTH has shown, quartz-porphyries, rhyolites, spherulitic felsites, and andesite in addition to the rocks above described. The Exeter traps and the Permian breccias taken together probably contain representatives of all the Continental types occurring on this horizon.

CHEMICAL INVESTIGATION OF ROCKS AND MINERALS.

The work of the chemical laboratory at the Jermyn Street Museum has continued to make good progress. DR. POLLARD was instructed, in addition to his duties there, to visit the officers in the field in South Wales in order to study on the spot the phenomena of dolomitization which are developed in the Carboniferous Limestone of that region. Accordingly, he studied these phenomena in the district of the Mumbles and collected material which awaits further treatment. He has conducted in the laboratory a series of quantitative analyses, and has likewise made a considerable number of qualitative examinations for petrographical purposes, or the identification of specimens. He has furnished the following notes of some of the more important researches on which he has been engaged :—

Tertiary volcanic rocks of Skye. (Dr. Pollard.) During the course of his survey of the Tertiary volcanic region of the Island of Skye, MR. HARKER has met with groups of rock of which it was highly desirable to know the complete chemical composition. He accordingly selected the following series of typical specimens, and submitted them for investigation by DR. POLLARD. The results of the inquiry are here given :—

[7064.] Granophyre, hornblendic, of Beinn a' Chairn sheet, in tributary of Allt Braigh Bhlain, 1,200 yards south-west of triangle on Beinn a' Chairn.

[8057.] Olivine Basalt (sill), Brochbeinn, 500 yards north of small tarn and south-east of larger loch.

[8043.] Olivine Gabbro, west bank of Sligachan River, just below junction with Allt Coire Riabhaich (the northerly burn of that name).

[8194.] Gabbro, Coire a' Mhadaidh.

[7124.] Hornblendic Granophyre, typical drusy variety, south end of Druim Eadhan Da Choire, west side of Coire na Aulg.

[8185.] Olivine Basalt (lava), Altt Feionn Fharadid, Drynoch.

[7854.] Olivine Diabase, sill in bedded basalt lavas, summit of Ben Lee.

[7862.] Porphyritic Olivine Dolerite or Basalt, 7 feet dyke cutting granite on south-east slope of Ciche na Beinne Deirge.

Nos. 7064, 8057, and 8043 were analysed in detail (most of the ingredients mentioned by CLARKE and HILLEBRAND* being looked for). The analytical methods used were those described by these chemists. The remaining five rocks were not analysed in

* *Bull. U. S. Geol. Survey*, No. 184.

quite so much detail, very small quantities not being determined quantitatively.

Tertiary volcanic rocks of Skye. (Dr. Pollard.)

Special precautions were taken as to the purity of reagents, and it was occasionally found necessary to purify some of them. Potassium bisulphate was always prepared in the laboratory owing to the difficulty of obtaining it of a satisfactory quality. Again, hydrofluoric acid has always been redistilled with permanganate before ferrous iron determinations. As it was suggested that some of the rocks from Skye contained metallic iron, Nos. 8057 and 8043 were examined for it by treating with a strong solution of mercuric chloride. The samples for this examination were crushed roughly, wrapped in cartridge paper to avoid any chance of contamination with iron. After all paper scraps had been picked out with care, the coarse powder was crushed and finally ground to a very fine powder in an agate mortar.

Blind experiments with rock-powder + a small weighed quantity (·05 to ·1g.) of pure iron wire were made. These gave good results [the greatest deviation being ·0771g. Fe taken = ·0763g. found], and as 2 to 5g. of rock-powder were taken, the error would be negligible. No iron could be detected in either of these rocks. It might, however, be of interest at some future time to examine a larger number of gabbros and basalts from Skye.

—	7064.	8057.	8043.
S.G.	2·63	2·91	2·85
SiO_2	71·98	46·13	46·39
TiO_2	·37	3·60	·26
ZrO_2	—	Trace ?	—
Al_2O_3	13·13	17·07	26·34
Fe_2O_3	1·33	6·61	2·02
Cr_2O_3	—	Trace ?	Trace
FeO	1·64	8·20	3·15
MnO	·14	·28	·14
CaO	1·15	7·15	15·29
BaO	Trace	—	—
MgO	·56	4·38	4·82
K_2O	4·93	1·19	·20
Na_2O	2·98	3·58	1·63
P_2O_5	·19	·09	Trace
Cl	Trace ?	—	—
H_2O 105°	·39	·59	·10
H_2O above	1·38	1·71	·48
Total - -	100·17	100·58	100·82

[NiO, CoO, Li_2O, S, F were not found.]

Tertiary volcanic rocks of Skye. (Dr. Pollard.)

—	8194.	7124.	8185.	7854.	7862.
S.G.	2·90	2·66	2·87	2·85	2·95
SiO_2	47·28	70·34	46·61	45·24	44·01
TiO_2	·28	·46	1·81	2·26	1·66
Al_2O_3	21·11	13·28	15·32	15·63	12·69
Fe_2O_3	3·52	2·65	3·49	5·56	3·62
Cr_2O_3	—	—	Trace	Trace	Trace
FeO	3·91	2·24	7·71	7·19	8·75
MnO	·15	·19	·13	·23	·21
(CoNi)O	—	—	Trace	Trace	Trace
CaO	13·42	1·24	10·08	9·38	10·57
MgO	8·06	·40	8·66	7·82	12·86
K_2O	·29	4·90	·67	·72	·49
Na_2O	1·52	3·61	2·43	2·01	1·68
P_2O_5	Trace	Trace	Trace	·20	·17
CO_2	—	—	Trace	·49	Trace
S	—	—	—	—	·11
H_2O 105°	·13	·46	1·10	1·12	·89
H_2O above 105°	·53	·76	2·07	2·21	2·73
Total -	100·20	100·53	100·08	100·06	100·44

No. 7124 contains a trace of BaO and Li_2O.

Culm-measure manganese. (Dr. Pollard.)

An analysis of a manganese deposit of Culm Measure Age from a limestone quarry, Hookworthy, Devonshire, gave the following results :—

Res. insol. in concentrated hydrochloric acid	64·64
CuO	·15
Fe_2O_3	13·10
Al_2O_3	·72
(NiCo)O	·11
MnO	9·98
CaO	·55
MgO	·20
O (Peroxide Oxygen)	2·05
H_2O at 105°	5·72
„ above 105°	3·21
Total	100·43

The insoluble residue is composed of—

SiO_2	63·3	of which 2·0% is colloid silica.
Fe_2O_3	·2	
Al_2O_3	·9	
CaO	·3	
	64·7	

The substance was a dark-brown friable powder which required no grinding, but only thorough mixing to get a uniform sample.

The small quantities of copper, nickel, and cobalt are interesting, as traces of these ingredients were found in the manganese nodules described in the "Challenger" reports. Culm-measure manganese (Dr. Pollard.)

MR. TEALL gives the following account of this specimen:— "The specimen analysed by DR. POLLARD was collected by me, from a Limestone Quarry in the Lower Culm series close to the village of Hockworthy, Devonshire. It was taken from one of several black bands, measuring two or three inches in thickness, regularly interstratified with grey shales, and apparently overlying the limestone. The insoluble residue is a fine white powder, mainly composed of cryptocrystalline silica in minute grains and irregular amorphous patches. A few grains of quartz measuring less than ·1 mm. in diameter, and probably of clastic origin occur, but the amount of mechanical sediment is extremely small. The cryptocrystalline silica is probably of organic origin. The specimen was analysed in the hope that it would be found to be much richer in oxide of manganese than actually proves to be the case. The limestone in the same quarry is dark, bluish-grey, and finely crystalline. Cherty portions of this limestone consist of cryptocrystalline silica associated with calcite which often takes the form of idiomorphic rhombs."

A sample of the clay already referred to as deposited in the estuary of the Fal and as probably of economic importance was sent up by MR. HILL. It was taken from a ford across the Fal, half a mile west of Ruar Lamhorne. A complete analysis of the clay gave the following results:— Falmouth Clay Deposit. (Dr. Pollard.)

AIR DRIED SAMPLE.

SiO_2	49·67
TiO_2	·19
Al_2O_3	33·43
Fe_2O_3	1·92
CaO	Trace
MnO	Trace
MgO	·37
K_2O	3·32
Na_2O	·29
Li_2O	Trace
SO_3	·07
Cl	·37
H_2O 105°	1·30
H_2O above 105° + some organic matter	9·64
	100·57
Less O for Cl	·17
Total	100·40

The chlorine and sulphuric acid are due to sea water.

The soluble salts amounted to ·83 per cent., the sand + acid silicates to 24·7 per cent.

Among the rocks met with by MR. CLOUGH in the Glenelg district is an eclogite, regarding the chemical constitution of one of the minerals of which further information was desirable. Accordingly from a specimen sent up for examination by MR. Eclogite of Glenelg. (Dr Pollard.)

Eclogite of Glenelg. (Dr. Pollard.)

CLOUGH the garnet was separated and analysed. The locality given by MR. CLOUGH for the specimen is "½ mile + 60 yards slightly east of north of Beinn a Chapuill," and the following is MR. TEALL's description:—

"[8449.] Medium-grained dark coloured massive rock, composed of garnet and omphacite, with rutile as an unimportant accessory. This rock is a typical eclogite."

The specific gravity of the garnet was 3·74, the composition as follows:—

SiO_2	40·3
TiO_2	Trace
Al_2O_3	21·6
FeO	18·0
Fe_2O_3	1·3
MnO	·7
CaO	7·2
MgO	11·2
Total	100·3

Rock analyses. (Mr. Grant Wilson.)

During the winter of last year MR. GRANT WILSON in Edinburgh made eleven analyses of rocks. The details of these investigations will appear in the memoirs of the Survey.

PETROGRAPHICAL RESEARCH IN IRELAND.

Reference has already been made in previous pages (pp. 71–81), to the petrographical assistance given by MR. H. J. SEYMOUR to the officers who have been engaged in revising the Silurian areas of the south-east of Ireland. The following more detailed and connected summary of his observations has been prepared by him.

Silurian Rocks West of the Leinster Granite. (Mr. Seymour.)

In the account of the work of the Geological Survey for 1898* a brief statement was given of some general results of a preliminary examination of the igneous rocks and so-called "ashes" in the district lying to the west of the range of the Leinster granite. Early in the past year a more detailed investigation of the rocks of that district was made (Sheets 111, 112, 120, 128, and 129 of the one-inch map), which has confirmed the conclusion that the so-called ashes in this district, which occur within a zone about a mile in width next the granite, are really more or less metamorphosed basic igneous rocks, while those which lie further west are without exception schistose grits or greywackes. The main road which starts just north of "Brittas Big" (top of Sheet 120) and runs southwards through Blessington, Poulaphuca, Annalecky, and Stratford, may serve as boundary line between the two classes of rock. The grits (greywackes) belong to one type and vary only in degrees of coarseness; most of them show a schistose structure. A thin section of a coarse variety, such as occurs near Poulaphuca, is seen under the microscope to consist essentially of quartz-

* *Summary of Progress* for 1898, p. 64.

grains, showing strain-structure, and forming eyes which are wrapped round by shaly bands of a greenish (chlorite) colour. Pieces of plagioclase crystals are almost always present, but only sparingly: and also rounded and lenticular fragments of finely crystalline basic rocks of the andesite type. The average diameter of the quartz-grains and other component fragments is nearly 4 mm. for this coarse variety, but elsewhere descends to microscopical dimensions.

Silurian Rocks West of the Leinster Granite. (Mr. Seymour.)

The igneous rocks which have been mapped as "ashes" may be classed together as altered basic andesites (frequently porphyritic) or dolerites without olivine. Where they lie close to the granite mass, they have been metamorphosed into hornblende-schists and amphibolites, while their outcrops at a greater distance appear as mostly epidiorites. This latter type is extensively developed in the north-east corner of Sheet 120 and in the adjoining areas in Sheets 111 and 112. The rock (I. 1848) at Ballinascorney Gap (Sheet 112) may be regarded as representative. It is an altered dolerite of medium grain. Though it looks fairly fresh in the hand-specimen, yet in section the ferro-magnesian mineral is seen to be mainly of secondary origin. The felspars occur in rather fresh lath-shaped sections which are repeatedly twinned. The interior of the crystals of felspar is more basic than the exterior and extinguishes at a higher angle, the passage between the two being sometimes quite gradual and occasionally abrupt. The central portion seems to be labradorite, while the exterior corresponds probably to andesine. The porphyritic constituent is a felspar too highly altered for determination. The augite when fresh is of a pale, reddish-brown colour, but it is for the most part altered into a greenish hornblende. It forms rounded grains, and sometimes fairly large crystals in which the felspar laths are set ophitically. Skeleton crystals of ilmenite occur, but no olivine could be detected.

The hornblende-schists and amphibolites are of the usual type, and call for no special remark. They are extensively developed in the district, and no doubt represent originally pyroxenic varieties. Near Colvinstown a basic mass (Ds, "Greenstone-ash" on Map) occurs, completely surrounded by granite, which sends numerous veins into it. A hornblende-schist which is seen here is composed of alternating narrow bands of actinolite and felspathic material, the whole rock being much folded and contorted. Near Donard (Sheet 129) an interesting outcrop occurs illustrating the effects of dynamo-metamorphism. Ballymooney Hill, north of Donard, and Deerpark Hill, south of the same place, are composed of a coarsely porphyritic rock mapped as "Greenstone-ash." Sections prepared from different parts of the masses show the following characteristics:—

Slide I. 1860 (Deerpark Hill) is the least altered of the series of rocks, but at the same time is considerably metamorphosed as compared with its original condition, when it was most probably a porphyritic basic andesite or aphanite, similar to the well-known Lambay porphyry. In the hand-specimen the por-

Silurian Rocks West of the Leinster Granite. (Mr. Seymour.)

phyritic plagioclases, which stand out conspicuously on a weathered surface, either singly or in groups of several individuals, form stumpy, flattened prisms of all sizes up to about 2 cm. × 1 cm. × ·5 cm. They seem fairly fresh, show parallel twin striae, and are brownish in colour, owing to various inclusions. In section the ground is mostly made up of minute brown mica-flakes (secondary biotite), along with some uralitic hornblende, embedded in a clear granular felspathic mosaic. Both the mica and the hornblende are oriented in the same direction by pressure, which has given the ground a schistose structure, and caused it to flow round the porphyritic plagioclases, and even penetrate them along cracks. The felspars are much clouded by opaque whitish inclusions. In all cases they show strain-slip, and are usually surrounded by a mylonitic envelope derived from themselves. Chlorite and iron-ore are present, but sparingly. Alteration is too far advanced to determine the plagioclase, but the presence of secondary calcite would seem to indicate a lime variety, very probably labradorite. (This is the felspar in the Lambay rock.)

I. 1861 shows a further stage in the metamorphism of the rock. The bronzy brown mica is still more conspicuously developed. Hornblende is practically absent, and the felspars are beginning to assume a parallel position with regard to one another. Continued strain has made the fragments into which they were broken slide over one another, producing schistose felspathic zones along the gliding planes, and also wavy extinction under crossed Nicols. Weathered specimens now show the felspars up to 3 cm. in length, but with the cross section considerably reduced in area, and arranged with their longest axes parallel to one another, and to the direction of schistosity.

I. 1862 is practically identical with the last, but contains some apatite. The plagioclases become more and more elongated, till the original stumpy crystals are drawn out into lenticles up to 8 cm. long, 1 cm. wide, tapering at each end, and from 1 to 1·5 mm. thick.

I. 1859 is a section of a rock in this stage which is accompanied by the formation of numerous secondary minerals. The brown mica occurs in knots, the individual crystals of which are considerably larger than usual. The felspar has partly recrystallised in water-clear granules, whilst most of the area formerly occupied by it is now crowded with minute prisms of epidote and zoisite. The original ilmenite is represented by sphene which occurs in numerous strongly pleochroic reddish crystals. In this final stage the rock is a banded gneiss or schist composed of white (felspathic), and dark (biotite) bands. The light bands vary in dimensions, according as they represent a single crushed felspar or a group of several individuals, being naturally larger in the latter instance. This case is a remarkably clear demonstration of the effects of metamorphism, and seems to throw some light on the production of banded gneisses. Although the outcrops occur close to the granite mass, no evidence of injection of the latter rock into the basic variety was noticed in this particular case.

With such clear evidence of pressure metamorphism, there can be little doubt that the hornblende-schists in this locality owe their origin to the same cause, especially as many of them are obviously crumpled and contorted (*e.g.*, at Colvinstown).

County Wicklow. (Mr. Seymour.)

The revision of the igneous rocks in county Wicklow was continued during the year, and some eighty-five slides from Sheet 130, and forty-two from 139 were examined and reported on. Many of the felsites are compact, schistose, and altered; so that their determination is rather difficult and unsatisfactory. As the microscope frequently fails to give much assistance, reliance has to be placed entirely on the field-evidence and on physical and chemical observations. The varieties met with include potash- and soda-felsites, diabases, diorites, dolerites, and basalts, all of which occur both in the uncrushed and crushed condition. The felsites vary much in physical characters, often closely resembling cherts. Thin sections, however, usually reveal the presence of minute plagioclases, in a ground presenting a devitrified aspect. Soda-felsites or keratophyres frequently occur in the area examined. They appear to be the latest rocks in the igneous series, as where typically developed they penetrate the ordinary (potash) felsite, which is known to be later than the basic rocks with which it is associated.

Reference has already been made to the field-observations by MESSRS. EGAN and MCHENRY regarding the occurrence of a remarkable brecciated structure in some of the intrusive felsitic rocks in the East of Ireland. MR. SEYMOUR contributes the following description of one of these which appears near Rockfield House, on the shore south of Wicklow Head. (Sheet 130, I. 1760 and 1761.) Here a greenish trachytic (soda) felsite is seen to penetrate, in numerous veins, a pale-coloured felsite, somewhat more acid perhaps in composition, and which weathers to a pinkish colour. The older rock has been shattered and in one part of its mass, occurs in angular fragments embedded in a greenish base composed of the later intrusive rock, the whole forming an eruptive or intrusive breccia. Continued pressure has subsequently fractured both this base and the included fragments. Microscopically, the greenish "ground" is remarkable. It contains numerous clear fragments (devitrified glass) with concave outlines and hour-glass forms, exactly similar in appearance to the lapilli of volcanic glass so characteristic of tuffs. Figure 48, p. 262, in Rosenbusch's "Elemente der Gesteinslehre" exactly represents the structure developed in the ground of this rock, and could have been drawn from a thin slide of it. There can be little doubt here, however, that the tuff-like structure has been produced by the brecciation in situ of the intrusive veins which had consolidated in a glassy condition, the resulting pieces of fractured glass being similar in shape to volcanic lapilli. Similar "intrusion breccia" occurs also at Arklow Head, Co. Wicklow, where a brecciated rock undoubtedly behaves as a dyke. It consists of pieces of lavender-grey felsite, embedded in a greenish porphyritic and brecciated soda-felsite, the phenocrysts being albites and soda-orthoclase. Though these crystals show evidence

County Wicklow. (Mr. Seymour.) of being fractured in situ, it is remarkable that in one of the slides an irregularly-shaped piece of pumice occurs, which could hardly have escaped destruction if it existed during the period of strain to which the rock has certainly been subjected. It seems difficult to account for its presence unless it be regarded as of secondary origin, and possibly somewhat analogous in its formation to the pumice which BERGEN and BEUDANT have shown to be occasionally formed when volcanic glass is gradually fused in a Bunsen flame. The light coloured felsite-fragments, which occur as inclusions, contain sphene, and this has given rise to anatase, which in some of the rocks abounds in crystals of minute size.

As mentioned in last *Summary of Progress*, the rocks mapped as tuffs (Fs or Ds), to the east of the Leinster granite, were found to be sheared varieties of acid and basic rocks respectively. This has again been found to hold for all the ground examined last year. Up to the present no true tuff of any description has been met with in County Wicklow (Sheets 130 and 139).

County Waterford. (Mr. Seymour.) Some account has been given at p. 79 of the igneous rocks of the coast of Waterford, mapped last year by MR. KILROE. Their petrography has been partly studied by MR. SEYMOUR, who during a visit to the ground with MR. KILROE collected a representative series of the rocks. These have subsequently been examined microscopically, and have been found to be in general similar to those in County Wicklow. Typical soda-felsites occur, some of which in the field closely resemble basic rocks. In section these are seen to be very trachytic in structure, they contain orthoclase (soda ?) phenocrysts, embedded in a crystalline felt of felspar microlites, showing flow-orientation. Secondary chlorite is also present in the slides. The soda-felsite at Ballydowane Bay seems to approach to the pantellerite type. The felsites also frequently show beautifully developed flow, perlitic, and spherulitic structures, being thus rather a contrast to the Wicklow specimens, where these characteristics are only rarely met with.

Another peculiar feature in the rocks of this district is the abundance of secondary epidote which many of them contain. This mineral often forms close on 40 per cent. of the bulk of some of the sedimentary rocks; it also occurs in oval concretions up to 3 in. in longest diameter in a crystalline rock, apparently an altered andesite, near Carrickbarrahane House. A coarsely porphyritic felsite occurs near Ballyvoyle Railway viaduct, containing well-formed, reddish-coloured orthoclase crystals in a greenish felsitic base. The andesites in this area are usually much altered, and the porphyritic mineral, when present, is augite, and not a felspar, as is usually the case in more northerly localities.

Coast of County Down. (Mr. Seymour.) As already stated, MR. SEYMOUR accompanied MR. EGAN to the east coast of Co. Down, in order to revise the igneous geology of that district (Sheets 37, 38, and 49). Almost every outcrop was visited by them, and a representative series of specimens was collected. These have now been sliced and examined by MR. SEYMOUR, who finds them to be all lamprophyres, the varieties differing from one another in the fact that the predominating ferro-magnesian constituent is sometimes biotite, sometimes hornblende, less often augite. In the last case the augite accompanies the biotite or the hornblende, but does not occur to the exclusion of either of these minerals. The felspar, as is usual in these rocks, is much altered and calcified, and is on the whole plagioclase, though a little may be referred doubtfully to orthoclase. The mica varieties are, therefore, Kersantites and augite-Kersantites, and the hornblende varieties Camptonites and augite-Camptonites

Coast of County Down. (Mr. Seymour.)

One of the rocks occurring as a dyke on the shore of South Bay, 3 miles E. of Portaferry (Sheet 49) is specially noteworthy. It is a hornblende-kersantite containing a blue amphibole, allied to riebeckite or arfvedsonite. It belongs to a class of minerals (soda-amphiboles) not hitherto known to occur *in situ* in Ireland, and is now recorded for the first time. The mineral in question occurs as a secondary addition to the terminal edges of the primary green hornblende. A nearly identical occurrence has been described by DR. WHITMAN CROSS in the case of a rock from Colorado.*

Ox Mountain District. (Mr. Seymour.)

An examination of the interesting rocks of the Ox Mountains undertaken by MR. SEYMOUR last year was continued at intervals. Owing, however, to the necessity of completing more urgent work it was not found possible to examine more than a small part of the collection. It is hoped that during the present year the work may be resumed and extended. The varieties examined included felspathic eclogites, garnet amphibolites, schistose diorites, biotite- and hornblende-gneisses, and granites with microcline. They are similar to the rocks described by MR. TEALL from the Ballyshannon area, in the Appendix to the Memoir on the Sheets 31 and 32.

Photographic Work. (Mr. Seymour.)

During his visits to the field in the past year MR. SEYMOUR took a number of photographs of geological interest. One series illustrates some of the typical features exhibited by the rocks along the coast of Waterford, from Stradbally to Annestown. Copies of these are preserved in the office for reference. Some photo-micrographic work has also been done during the year in the case of slides of special interest in the Irish petrographical collection.

III.—PALÆONTOLOGICAL WORK.

The Palæontologists of the Geological Survey at Jermyn Street have charge not only of the palæontological work of the Survey, but also that of the Museum. They determine all fossils collected by the staff in England and Wales and Ireland. The Scottish palæontological work is done at the Survey Office in

* *American Journ. Science*, vol. xxxix., p. 359.

Edinburgh. Mr. E. T. Newton has supplied the following notes of the more important examinations made by him and his staff last year.

Museum, Jermyn Street.

The constant need of revision and rearrangement of the fossils exhibited in the Museum of Practical Geology, as well as their maintenance in a satisfactory condition, together with the specific determination of such fossils as are presented, received from the field officers, or obtained from other sources, necessarily occupies the greater part of the time of the Palæontological Department. This routine work, however important in itself, is not usually of such a nature as to call for any special remarks; but it may be mentioned that of the fossils received during the year, a large part has already been specifically determined by Dr. F. L. Kitchin, who has likewise named a series of Carboniferous Limestone Cephalopoda, from the Isle of Man, kindly lent to the Survey by Miss Birley and Mr. Robt. Law, to whom our thanks are due for their courteous assistance. We have also to acknowledge our indebtedness to Mr. G. C. Crick of the British Museum for his valued help in the determination of these Cephalopoda.

The results of much of the detailed work of the past year will be seen in the Memoir by Mr. A. J. Jukes Browne on the Gault and Upper Greensand, and in that by Mr. G. W. Lamplugh on the Geology of the Isle of Man, now in the hands of the printer, as well as in other Memoirs which have appeared during the year.

The revisions and rearrangements which have been made in the Museum have chiefly been the work of Mr. H. A. Allen, who has also named a large number of the new fossils added to the collection. The need for a catalogue of the many valuable *figured* specimens contained in this Museum has long been felt; but the pressure of other work has hitherto prevented its being attempted. A beginning, however, has been made by Mr. Allen, who has prepared a catalogue of the *figured* specimens from the Eocene and Oligocene formations. This catalogue includes many of the Types described by Prof. Morris in Forbes's "Tertiary Fluviomarine Formations of the Isle of Wight"; by Prof. Forbes, in "Note on Fossil Leaves from Ardtun"; by De la Harpe and by Mr. Starkie Gardner, in their works on the Plant Remains of the Isle of Wight and of the South Coast. (See Appendix to the present volume, p. 195.) Although but a small instalment, it will serve to show the nature of the work; and being complete, so far as it extends, will, it is believed, be found useful to those working at Tertiary Palæontology.

Three series of Graptolites have been received from the Irish Survey, and reported upon by Mr. Newton. One series was from numerous localities in the Keeper Hill district. The chief forms noticed were of the *Monograptus Flemingi* and *M.*

Hisingeri types, with some indistinct specimens which appeared to be *Cyrtograptus hamatus*, thus indicating beds of Wenlock or Tarannon age. A few specimens from a cutting on the Waterford, Dungarvan, and Lismore Railway proved to be *Diplograptus* allied to *D. pristis*, and probably indicate the presence of Llandeilo rocks at this place.

A second series from Balyhelly, Co. Clare, too poorly preserved to give positive evidence, seemed to include *Monograptus Flemingi* and *M. priodon*, making it probable that the beds are of Upper Silurian age, and perhaps Wenlock.

A third series, chiefly from the neighbourhood of Belvoir, Co. Clare, were apparently from one horizon only. The absence of any Monograptids made it unlikely that these beds were of Upper Silurian age, and as there were no examples of Didymograptids they could scarcely be so low as Lower Llandeilo. The forms recognised were *Diplograptus pristis, D. foliaceus, Climacograptus scalaris,* and *Glossograptus Hincksi*, all species of Glenkiln or Hartfell age. It seems almost certain, therefore, that the strata belong to the Lower Bala or Upper Llandeilo series.

Application is constantly being made to this Department for assistance in work of a palæontological nature, and the officers do their best to render such help as is possible. As examples of this co-operation the following cases may be mentioned:—

SIR THOS. WARDLE, of Leek, desired information respecting a series of bones, which he had unearthed while exploring a cave at Red Hurst, near Wetton. Two consignments of these remains were examined by MR. NEWTON; they proved to be largely human and of comparatively modern origin; perhaps Romano-British, or Neolithic; but there were indications of Pleistocene gravels underlying the more modern deposits. An account of this cave was published by SIR THOS. WARDLE in *The Leek Post*, February 25, 1899.

A collection of bones from a deposit at Skitts Hill, Braintree, Essex, was critically examined by MR. NEWTON, at the request of the Essex Field Club, as it was deemed desirable to have the specific identification of the bones verified before publication. An account of these remains is included in a paper by the REV. J. W. KENWORTHY on this "Supposed Neolithic Settlement at Skitts Hill," just published in the *Essex Naturalist*.

A series of fossil shells and rocks was received from JUDGE MIDDLETON of Nicosia, Cyprus, through the secretary of the Royal Societies' Club. The rocks were examined by MR. TEALL, and the fossil shells by MR. NEWTON. The deposit from which the shells were obtained appears to be of late Pliocene age. Among the species recognised were many like those found in similar deposits in Italy and Sicily, as well as at other places around the Mediterranean coasts.

The Museum collection of fossils has been largely made use of by workers for the purpose of illustrating their Memoirs, and many specimens have been figured in various publications, as shown in the subjoined list of figured specimens published during 1899:—

Specimens figured in the Palæontographical Society's volume for 1899, by PROF. RUPERT JONES and DR. H. WOODWARD in their "British Palæozoic Phyllopoda":—

Gastric teeth of Dithyrocaris.
Dithyrocaris tricornis, Scouler.
„ *Colei*, Portlock.

Specimens figured in the Palæontographical Society's volume for 1899, by DR. WHEELTON HIND, in the "British Carboniferous Lamellibranchiata":–

Edmondia oblonga, Portlock.
„ *laminata*, Phillips. Two specimens.
„ „ var. *sublævis*, Hind.
„ *scalaris*, M'Coy.
„ *MacCoyi*, Hind.
Scaldia benedeniana, de Ryckholt.
Cypricardella parallela, Phillips.

Specimens figured in the Palæontographical Society's volume for 1899, by HENRY WOODS, ESQ., in his "Cretaceous Lamellibranchiata of England":—

Nucula speetonensis, Woods.
„ *pectinata*, Sow. var. *cretæ*, Gardner.
„ *obtusa*, Sow. Two specimens.
„ *albensis*, d'Orb.
Anomia lævigata, Sow. Three Specimens.
„ *cf.*, *pseudoradiata*, d'Orb.
Barbatia marullensis, d'Orb. Two specimens.
Grammatodon carinatus, Sow.
Isoarca obesa, d'Orb.
Pectunculus sublævis, Sow.
„ *umbonatus*, Sow.

Specimens figured by Dr. A. SMITH WOODWARD, in the "Proceedings of the Geologists' Association," vol. xvi., 1899:—

Notidanus serratissimus, Agassiz.

Specimens figured by E. T. NEWTON in the "Quarterly Journal of the Geological Society, London," vol. lv., 1899:—

Amia anglica, Newton.
„ *Colenutti*, Newton.
Zanclodon cambrensis, Newton.
Mustela robusta, Newton.

Specimens figured by MISS DONALD in the same journal:

Hormotoma ? gracillima, Salter.
„ *? dubia*, Donald.

Specimens figured by H. BOLTON, ESQ., in the "Memoirs of the Manchester Literary and Philosophical Society," vol. xliii., 1899:—

Palæochorda minor, M'Coy. Three specimens.
„ *major*, M'Coy.
Chondrites informis, M'Coy. Three specimens.

SCOTLAND.

The Palæontological Department in Scotland has been carried on as hitherto by MR. B. N. PEACH, assisted by MESSRS. A. MACCONOCHIE and D. TAIT. As usual the collections made during the year, after a preliminary investigation by MR. PEACH, have been partly distributed among specialists for identification and description. Thus DR. TRAQUAIR has determined the fish-remains, MR. KIDSTON has undertaken the naming of the plants, MR. KIRKBY has examined the ostracods while DR. J. WHEELTON HIND has examined the lamellibranchs.

The number of fossils gathered by the Survey Collectors in Scotland during 1899 amounted to 913. These comprise 479 specimens from the Cambrian rocks of Skye, Sutherlandshire, &c.; 20 from the Ludlow rocks of Lanarkshire; 112 from the Downtonian strata of Ayrshire and Lanarkshire; 8 from the Lower Old Red Sandstone of Arran; 39 from the Carboniferous Limestone of Arran; 99 from the Coal-measures of Arran and Dumfries-shire; 154 from the Jurassic rocks of Skye, and 2 specimens from Islay.

MR. PEACH has supplied the following digest of the palæontological work of the staff in Scotland for the past year.

Torridonian.—In view of the forthcoming Memoir on the North-West Highlands a further determined search was made by MESSRS. MACCONOCHIE and TAIT in the Torridonian rocks of Skye, chiefly in the dark carbonaceous Shales of the Kinloch sub-division of the Diabeg group. Though the material searched seems eminently favourable for the preservation of organisms, as ripple-marked and rain-pitted surfaces are plentiful, no vestige of a fossil was obtained. The same collectors also made another exhaustive search of the dark calcareous shales of the Cailleach Head in West Ross-shire, the highest visible members of the formation. The only indications of life they there exhumed are some doubtful specimens of annelid castings (" Worm pipes,"), but these are not sufficiently definite for identification. The shales of the Diabeg Group at Stoer in West Sutherland, which had already afforded some traces of organisms, were also searched bed by bed with the result that only the curious radiating bodies resembling some sponge spicules were obtained. The further study of some of the specimens, however, throws some doubt upon the organic character of these bodies. They may not be organic, but may be due to aggregations of crystals that had formed in the clays before their consolidation, but had been subsequently dissolved out and replaced by calcite. It is unfortunate that hitherto the Survey Collectors have been able to obtain no more definite organic remains than " worm pipes " from these practically undisturbed sediments.* (Mr. B. N. Peach.)

Cambrian.—A further collection of fossils was made by MESSRS. MACCONOCHIE and TAIT from the Durness limestones and dolomites in the Strath district of Skye. The search was made chiefly for the purpose of obtaining remains of trilobites

* Since the above notes were written, certain phosphatic nodules occurring in the dark micaceous shales at Cailleach Head have been examined by MR. TEALL. From their chemical composition these nodules are presumably of organic origin, an inference which is confirmed by the fact that MR. TEALL has determined under the microscope certain spherical cells and brown-coloured fibres in them, which appear to be débris of organisms.

(Mr. B. N. Peach.)

that might have a zonal value for the determination of the exact geological horizon of the members of the Durness Limestone series. Although a considerable collection of fossils was obtained no trilobite remains were found among them. The fossils add little or nothing to the list furnished in last year's *Summary*. A search was likewise made in the Durness area of Sutherland, where the collectors succeeded in finding several fragments of trilobites. From the preliminary study of the material thus acquired, the fossils would seem to indicate that the Croisapuill group of the Durness Limestone, the bed in which they chiefly occur, is of Middle or Upper Cambrian age—a conclusion to which the study of the other fossils from this band has already led.* Fragments of *Olenellus* were obtained from the cleaved 'Fucoid Beds" near Heilim, on Loch Eireboll, by MESSRS. MACCONOCHIE and TAIT. This is the first record of trilobites from this region, which is classic in the history of the rocks of the North-West Highlands.

Silurian.—A further search was made by MR. TAIT in the Ludlow and Downtonian rocks of Ayrshire and Lanarkshire, with the result that fragments of the fish *Birkenia elegans*, hitherto only obtained from the Downtonian rocks, was got in the *Ceratiocaris*-band of the Ludlow rocks on the Logan water above Lesmahagow. The materials obtained from the Downtonian rocks have been studied by DR. TRAQUAIR, and the results have been embodied in a paper published by him.† He remarks that, "Two additional specimens of *Lasanius*, collected by MR. TAIT at Seggholm since my notes at p. 567 were in type, indicate a new species distinguished from *L. problematicus* by the considerably greater proportional size and length of the spurs or thorns borne by the median scutes, and which I propose to designate *Lasanius armatus*. In one of these two examples the rays of the acutely bilobate heterocercal tail are preserved, the arrangement of which furnished the long desired clue to the position of the median row of scutes, proving that they were placed along the ventral margin of the body. Consequently it is now very improbable that the gridiron-like arrangement of ossicles in the anterior part of the body had anything to do with the support of the branchiæ."

Old Red Sandstone.—Further remains of plants were obtained from a new locality in the Lower Old Red Sandstone of Arran on the south side of Glen Rosie not far from the boundary fault. In going over the material obtained by him last season from the Lower Old Red Sandstone exposed in the railway cutting about a mile from Oban, MR. TAIT observed the casts of what appeared to be ostracods. Some specimens were sent to MR. JAMES W. KIRKBY, who confirmed this identification. The fossils were subsequently submitted to PROFESSOR RUPERT JONES who refers them to the genera *Aparchites, Isochilina,*

* *Summary of Progress* for 1898, p. 55.

† *Transactions of the Royal Society of Edinburgh*, vol. xxxix., pp. 827-861.

and *Beyrichia* (?), or *Drepanella*, one of the latter being curiously like the *Beyrichia* (?) *Holli*, Jones. Along with these casts occur the remains of *Cephalaspis* and *Pterygotus*. Although ostracods are plentiful in the Devonian Rocks of the South of England and the bivalve phyllopod *Estheria* is common in the Caithness flags, this is the first recorded instance of undoubted ostracods having been found in the Lower Old Red Sandstone of Scotland. (Mr. B. N Peach.)

Carboniferous.—A further collection of Carboniferous fossils from the streamlet flowing into the Sliddery Water at Sliddery Water Head was made by MR. TAIT last season. The discovery has already been announced of *Carbonicola* (*Anthracosia*) *acuta*, together with fish remains in this section,* the general facies of the organisms indicating the horizon of the true Coal-measures. With these remains there were also discovered fragments of plants characteristic of the Lower Carboniferous subdivisions. The fossils collected this season help to define more precisely the boundary-line between the Upper and Lower Carboniferous rocks in this section. The evidence afforded by the various bands exposed in the Sliddery Water may be tabulated as follows in descending order.

4. Fine · red mudstones, with numerous specimens of *Neuropteris heterophylla*, a characteristic Coal-measure form, and a specimen of *Spirangium carbonicum* (Schimper), supposed at one time to be a plant, but now thought to be the egg capsule of a placoid fish, and known as *Palæoxyris carbonicus*. This form has hitherto been recorded from only one other locality in Scotland, Woodhead Quarry, near Kilmaurs, Ayrshire, in strata belonging to the lowest members of the Coal-measures.

3. Thin mussel-band ironstone (2-3 inches) charged with *Carbonicola* (*Anthracosia*) *acuta* and *C.* (*A.*) *robusta*.

2. Grey and red shale yielding the following fishes :—*Platysomus parvulus*, *Megalichthys Hibberti*, *Rhizodopsis sauroides*, *Strepsodus sauroides*, *Diplodus sp.* *Pleuroplax sp.* *Helodus sp.* together with the plants *Lepidodendron veltheimianum*, *Lepidostrobus*, *Stigmaria*, and *Calamites*.

1. Red tuff, containing chiefly calamites, the most abundant form being *Astrocalamites scrobiculatus*, a characteristic Lower Carboniferous form.

It thus appears that, the fossils of bed or zone 1 are characteristic of the Lower Carboniferous formations (*i.e.*, Calciferous Sandstone and Carboniferous Limestone series); those of bed or zone 2 show a commingling of forms belonging partly to the Lower and partly to the Upper Carboniferous divisions, while those in beds or zones 3 and 4 are confined to the upper division (*i.e.*, Millstone Grit and Coal-measures). It is evident, therefore, that bed or zone 2, represents palæontologically the passage-zone between the two great divisions of the Carboniferous system.

Rhætic.—The specimens obtained from these zones in Skye by MESSRS. MACCONOCHIE and TAIT, were forwarded to Jermyn Street, where they have been examined by MR. NEWTON and DR. KITCHIN as stated on p. 133.

The palæontological collections of the Survey of Scotland have

---

* *Summary of Progress* for 1897, p. 113.

(Mr. B. N. Peach.) been freely placed at the disposal of experts engaged in working out any of the groups of fossils there represented. These collections are, as far as possible, displayed to the public in the gallery assigned to the Survey in the Edinburgh Museum of Science; some of the specimens are necessarily still retained at the Survey Office for purposes of study and comparison. Among those who have made use of the Scottish specimens collected by the Survey, reference may be made to MISS DONALD, who has figured and described (*Quart. Journ. Geol. Soc.*, vol. lv., 1899), several specimens of Cambrian gasteropoda from the Durness limestone. These are :—

Ectomaria pagoda, var. *Peachi.* Plate xxi., figs. 1 and 2.
,, ,, var. *orientalis.* Plate xxi., figs. 3 and 4.
Hormotoma antiqua. Plate xxii., fig. 9.

DR. WHEELTON HIND has named for the Survey a large number of Lower Carboniferous lamellibranchs from Liddesdale, and has also figured and described in a Monograph of the British Carboniferous Lamellibranchiata (*Palæontographical Society's Publications,* 1897), the following species :—

Myalina sublamellosa. Plate v., figs. 6, 7, 8.
Nuculana Sharmani. Plate xv., figs. 19–22.
,, *stilla.* Plate xv., figs. 24, 25.

DR. TRAQUAIR, in addition to writing the important Memoir on the Silurian fishes belonging to the Geological Survey already referred to, has revised the nomenclature of the specimens of fossil fishes exhibited in the Museum. He also transferred on loan from the Natural History section to the Geological Survey cases several duplicate specimens of fossil fishes from the Caithness flagstones. These form a useful supplement to the specimens already in the Survey collection. DR. TRAQUAIR has also presented to the Survey a set of his figures of the new Silurian fishes, while MR. NEWTON has given copies of the plates that illustrate his Memoir on the Elgin Reptiles.

MR. KIDSTON has revised the nomenclature of the Carboniferous plants exhibited in the Survey collection in the Museum.

IV.—PRACTICAL APPLICATIONS OF THE WORK OF THE GEOLOGICAL SURVEY.

Applications for information on geological matters have, as usual, been numerous at the offices of the Survey in London, Edinburgh, and Dublin. From the London Office assistance has been afforded to the Local Government Board, the Colonial Office, and the Agent-General for New Zealand. Advice on various subjects connected with mining, well-sinking, soils, sites for houses, &c., has been given as far as possible, personally and by letter, to those who have sought for information.

It has been suggested by the Local Government Board that it would be much to the public advantage if arrangements could be made whereby, on the request of the Board, officers of the Geological Survey should be sent to examine and report on any district where particulars might be required by that Department relating to water supply, the pollution of springs, sites for burial-grounds or sewage-farms, or other subjects where precise geological information is necessary. The matter is now before the Lords of the Committee of Council on Education, and it is hoped that the suggestion will be carried into effect.

At the Edinburgh Office of the Survey the number of applications by the public for information of a practical kind where geological knowledge is involved have been larger than in preceding years. They comprise enquiries relating to the position of coal-seams, limestones, ores, suitable building stones, &c., and also questions of water-supply, and the character of subsoils. As an illustrative example reference may be made to enquiry by Dr. Aitken, Medical Officer of Health, Brighton, regarding the nature of the rocks and sub-soils of Edinburgh in connection with a Report on the comparative prevalence of diarrhœa on certain soils in several of the larger towns of the country. The desired information was prepared and furnished.

At the Dublin Office also, constant applications continue to be made in regard to geological information of an economic kind. Many of these have reference to mines and minerals, especially to coal and metalliferous ores. But in Ireland, as in the sister kingdoms, the most frequent subject of enquiry is that of water-supply. During the past year the reports in answer to these demands have sometimes been necessarily of a detailed character, and have involved the drawing of sections in explanation of the geological structure of the ground. Among the public departments that have availed themselves of Survey assistance in such matters were the War Department and the Congested Districts Board of Ireland.

V.—MAPS, MEMOIRS, SECTIONS, &c., PUBLISHED DURING 1899.

A.—OFFICIAL.

I.—MAPS.

1.—*England and Wales.*

New Series of One-inch Maps.—Seven sheets of the New Series of one-inch maps have been published during last year, viz.:—

Sheet 155, Atherstone. Two editions with and without Drift. By C. Fox-Strngaways and W. W. Watts (Charnwood).

Sheet 282, Devizes. One edition with Drift. By F. J. Bennett and A J. Jukes-Browne.

Sheet 315, Southampton. One edition with Drift. By W. Whitaker and C. Reid.

Sheet 325, Exeter One edition with Drift. By W. A. E. Ussher.

Sheet 339, Newton Abbot. One edition with Drift. By H. B. WOODWARD, W. A. E. USSHER, and C. REID.

Sheet 340, Otterton. One edition with Drift. By W. A. E. USSHER.

Sheet 349, Ivybridge and Plymouth. One edition with Drift. By W. A. E. USSHER.

Old Series of One-inch Maps.—Sheet 19. Revised with Additions, by H. B. WOODWARD and A. STRAHAN.

The following One-inch New Series maps are in the hands of the engravers:—187, 203, 231, and 316.

Plans for printing these maps in colours are under consideration.

Six-inch Maps.—Northumberland. — Sheet 104, Whittonstall. By H. H. HOWELL.

Yorkshire.—Sheet 19, Hinderwell. By G. BARROW.

Six-inch Reference Maps.—96 MS. Coloured Copies of six-inch sheets and quarter-sheets have been made from the field-copies and deposited in the office for public reference. These are as follow:—

Brecknockshire.—31 S.E.; 32 S.W.; 37 N.E., S.E.; 38 N.W., S.W. 43 N.E., S.E.; 50 N.W.
Derbyshire.—57 N.E., S.E., N.W., S.W.; 58 N.E., S.E., N.W., S.W.; 60 N.W.
Devonshire.—105 N.E, S.E.; 106 N.E., N.W.
Dorset.—30 S.E.; 39 S.E.
Glamorganshire.—9, 11, 16, 41, 44, 45, 48, 49.
Hampshire.—48, 57, 64, 65, 66, 67, 73, 74, 75.
Leicestershire.—5 S.W.; 10 S.E., N.W., S.W.; 15 N.E., S.E., S.W.; 16 N.E., N.W.,, S.W.; 17 N.E., N.W.; 22 N.E.; 37 N.W.
Middlesex.—10 N.E., S.E.; 11 S.W., S.E; 15 N.E., S.E., S.W.; 16. N.E., N.W., SW.
Shropshire.—3 S.E., S.W.; 9 N.E., N.W.
Staffordshire.—8 S.W.; 10 S.E.; 11 N.E., S.E., N.W., S.W.; 12 N.E., N.W., S.W,; 13 S.W.; 16 N.E., S.E.; 17 N.E., S.E., N.W., S.W.; 18 N.E., S.E., N.W., S.W.; 22 N.E.,* S.E.,* N.W., S.W.*
Wiltshire. 67, 74, 75.

* Revised editions.

2.—*Scotland.*

Two sheets of the one-inch map of Scotland have been published during the past year, viz.:—

46, embracing part of south-west Perthshire, extending from Loch Voil on the S.E. to Loch Tulla in the N.W., and the valleys of the Fillan, Dochart, and Lochay.

86, including parts of Aberdeenshire and Banffshire, extending from Grange east to Fyvie, and south to Huntly, and embracing a large part of the valley of the Deveron.

The following sheets of the one-inch map are in preparation.

27, containing the north part of Islay.

37, including the district on both sides of the upper part of Loch Fyne.

38, containing parts of Argyllshire, Dumbartonshire, Perthshire, and Stirlingshire.

55, showing part of Perthshire, including Blair Athole and Dalnaspidal.

15, new edition, embracing part of the Southern Uplands to the N.E. and S.W. of Sanquhar.

Manuscript copies of the following six-inch maps have been made and deposited in the office for public reference

Caithness, 11-17.
Skye, 38.

3.—*Ireland.*

It was found necessary to delay the issue of the revised editions of Sheets 37 and 38 until the igneous rocks had been re-examined as stated on p. 5. The revision has been completed, and these sheets are now published. Most of the other sheets of the Silurian districts which have been revised to the north of Dublin are now being prepared for engraving, and will be issued, it is expected, in the course of the present year.

The following duplicate copies of six-inch maps have been made, and are deposited in the office for reference by the public :—

County Antrim. Parts of Sheets 4, 5, and 9.
" Down. Parts of Sheets 45, 46, 50, 51.
" Mayo. Sheets 82, 93, 114, and parts of Sheets 61, 65, 66, 67, 68, 74, 81, 92, 93, 105, 106, 115.
" Tyrone. Part of Sheet 15.
" Wicklow.—Sheets 15, 22, and 29.

II.—MEMOIRS.

A. — OFFICIAL.

1.—*England and Wales.*

During the past year the following six Memoirs have been published :—

✓ "Summary of Progress of the Geological Survey of the United Kingdom for 1898," pp. vi., 216. Price 1s.

✓ "The Geology of Belford, Holy Island, and the Farne Islands, Northumberland." (Explanation of Quarter-sheet 110 S.E., Old Series; 4 New Series.) By WILLIAM GUNN, pp. iv., 155. Price .

"The Geology of the Country around Carlisle." (Explanation of Sheet 107, Old Series; 16 and 17 New Series.) By T. V. HOLMES, pp. iv., 64. Price 1s. 3d.

"The Water-supply of Sussex from Underground Sources." By W. WHITAKER and CLEMENT REID., pp. iv., 123. Price 3s.

"The Geology of the Country around Dorchester." By CLEMENT REID., pp. iv., 52. Price 1s.

✓ "The Geology of the South Wales Coal-field." Part I., The country around Newport, Monmouthshire. By AUBREY STRAHAN, pp. vi., 97. Price 2s.

The following Memoirs are in different stages of progress :—

"The Cretaceous Rocks of Britain," vol. i. The Gault and Upper Greensand of England. By A. J. JUKES-BROWNE. (*In the Press.*)

"The Geology of the Isle of Man." By G. W. LAMPLUGH. (*Partly in type.*)

"The Geology of the country between Atherstone and Charnwood Forest." By C. FOX-STRANGWAYS. (*Nearly ready for the printer.*)

"Guide to the Geology of London." By W. WHITAKER. 6th edition. (*In preparation.*)

"The Geology of the country around Kingsbridge and Salcombe. By W. A. E. USSHER. (*Nearly ready for the printer.*)

"The Cretaceous Rocks of Britain," vol. ii. Chalk of England. By A. J. JUKES-BROWNE. (*MS. nearly ready for the printer.*)

"The Geology of the country around Reading." By J. H. BLAKE. (*In preparation.*)

"The Water Supply of Berkshire." By J. H. BLAKE, with contributions by W. WHITAKER. (*Nearly ready for printer.*)

"The Geology of the South Wales Coal-field":—

Part 2. The country around Abergavenny. By A. STRAHAN, J. R. DAKYNS and W. GIBSON. (*Nearly ready.*)

Part 3. The country around Cardiff. By A. STRAHAN and T. C. CANTRILL. (*In preparation.*)

Part 4. The country around Pontypridd. By A. STRAHAN, R. H. TIDDEMAN and W. GIBSON. (*In preparation.*)

2.—*Scotland.*

The large Memoir on the Silurian Rocks of Scotland referred to in previous *Annual Reports* was published last summer. It forms an octavo volume of 749 pages, with twenty-seven plates and 121 figures in the Text; also a coloured map and sections. It forms the first of the series of Stratigraphical Monographs, which has been entirely devoted to the geology of Scotland.

Another not less important contribution to the geology of the country is that on the North-West Highlands, to which allusion was made in the last *Annual Report*. As the literary work can only be undertaken during the season when field work has to be abandoned, the progress of so voluminous a Memoir as this must be necessarily slow. But so much of it has now been completed that the MS., it is confidently hoped, will be ready to be sent to the printer before the autumn of this year.

In connection with the preparation of the Memoir on the North-West Highlands it may be added that MR. ROBERT LUNN, of the Edinburgh Office, has, during the past season, visited the ground, and has taken fifty photographs of rock-sections and of escarpments of Torridon Sandstone, a selection from which will be used as illustrations of the Memoir. While in the north he also took thirty photographs of sections of Jurassic rocks in the district of Brora, Sutherlandshire, for the illustration of these rocks in a Survey Memoir.

No explanatory Memoir of Sheet 40 (Fife and Kinross) having hitherto been prepared, and no member of the staff being available for this duty, the Director-General undertook the work himself, and before the end of the year completed it. The MS. is only waiting for the completion of the Appendix of Fossils, and it will be sent to the printer as soon as that can be prepared. Another Memoir explanatory of Sheet 41 (Eastern Fife) will be taken in hand by the Director-General during the spring. Other Memoirs are in progress, including one on Cantyre by MESSRS. SYMES and HILL, and one on Islay by MR. WILKINSON.

III.—SECTIONS.

Three Sheets of Vertical Sections to further illustrate the South Wales Coalfield had been arranged during the early part of the year by MR. STRAHAN, and they were drawn to scale by MR. GILBERT WILLIAMS. Unfortunately, when the work was almost completed by the lithographers, the building in which the stones and the original drawings were placed, was destroyed by fire, and no portion of the work was preserved. Steps have been taken to re-draw the sections and to issue them at as early a date as may be practicable.

B.—NON-OFFICIAL.

The following is a list of the non-official publications of the members of the staff during the year 1899:—

CLOUGH, C. T., and ALFRED HARKER.—"On a Coarsely Spherulitic ('Variolitic') Basalt in Skye." Trans. Edin. Geol. Soc., vol. vii., pp. 381-389.

CLOUGH, C. T., and DR. W. POLLARD.—"On Spinel and Forsterite from the Glenelg Limestone (Inverness-shire)." Quart. Journ. Geol. Soc., vol. lv., pp. 372-380.

GEIKIE, SIR A.—Hutton's "Theory of the Earth, with Proofs and Illustrations." Vol. iii. Edited by SIR A. GEIKIE. 8vo, London.

GEIKIE, SIR A.—"Presidential Address. Section C., Geology, British Association. Dover, 1899." Rep. Brit. Assoc. for 1899 (1900), pp. 718–730.

GIBSON, W.—"Some Recent Work among the Upper Carboniferous Rocks of North Staffordshire and its Bearing on Concealed Coalfields." Rep. Brit. Assoc. for 1899 (1900), pp. 738, 739. Geol. Mag., Dec. iv., vol. vi., pp. 505, 506.

GIBSON, W., and DR. WHEELTON HIND.—"On the Agglomerates and Tuffs in the Carboniferous Limestone Series of Congleton Edge." With Appendix by H. H. ARNOLD-BEMROSE. Quart. Journ. Geol. Soc., vol. lv., pp. 548-559.

GOODCHILD, J. G.—"The Bedshiel Kaims." Proc. Berwick Nats. Field Club, pp. 295–312.

GOODCHILD, J. G.—"On the Genesis of some Scottish Minerals." Proc. Roy. Phys. Soc. Edin., vol xiv., pp. 181–220.

GOODCHILD, J. G.—"Guide to the collection of Scottish Agates." Edin. Mus. Science and Art, 1899.

GUNN, W.—"Notes on the rocks about Berwick-upon-Tweed." Proc. Berwick Nat. Field Club, vol. xvi., p. 313.

HARKER, ALFRED.—"Chemical Notes on Lake District Rocks." *Naturalist*, pp. 53-58, 149–154.

HARKER, ALFRED.—"Glaciated Valleys in the Cuillins, Skye." Geol. Mag., Dec. iv., vol. vi., pp. 196–199.

HARKER, ALFRED.—"On the Average Composition of British Igneous Rocks." Ibid., pp. 220 222.

HARKER, ALFRED.—"Notes on Subaerial Erosion in the Isle of Skye." Ibid., pp. 485-491.

HILL, J. B.—"On the Progressive Metamorphism of some Dalradian Sediments in the Region of Loch Awe." Quart. Journ. Geol. Soc., vol. lv., pp. 470–493.

HILL, J. B.—"The Lower Palæozoic Rocks of the South of Scotland, viewed in connection with the Lower Palæozoic Rocks of Cornwall." Trans. Roy. Geol. Soc., Cornwall.

JUKES-BROWNE, A. J.—"The Submerged Platform of Western Europe." Geol. Mag., Dec. iv., vol. vi., pp. 94–96.

JUKES-BROWNE, A. J.—"Zones and 'Chronological' Maps." Ibid. pp. 216–219.

JUKES-BROWNE, A. J.—"The Association of *Schlœnbachia inflata* with *Hoplites interruptus*." Ibid., pp. 234, 235.

KYNASTON, H.—"Contributions to the Petrology of the Cheviot Hills." Trans. Edin. Geol. Soc., vol. vii., p. 390.

NEWTON, E. T. "On Remains of Amia from Oligocene Strata in the Isle of Wight." Quart. Journ. Geol. Soc., vol. lv., pp. 1 10.

NEWTON, E. T.—"On a Megalosauroid Jaw from Rhaetic beds near Bridgend (Glamorganshire)." Quart. Journ. Geol. Sc., vol. lv., pp 89–96.

NEWTON, E. T.—"Additional Notes on the Vertebrate Fauna of the Rock Fissure at Ightham (Kent)." Ibid., pp. 419–429.

NEWTON, E. T.—"Remarks on *Mus Abbotti*." Proc. Zool. Soc., 1899 p. 318.

NEWTON, E. T.—"Note on the Mammalian Remains found at Carshalton." Trans. Croydon Micros. Nat. Hist. Club, 1899, p. 292.

NEWTON, E. T.—"Report upon series of Bones obtained by Sir Thos. Wardle from a Cave at Red Hurst, near Wetton, Leek." See Account of the researches at this Cave by Sir Thos. Wardle The *Leek Post*, Sat. Feb. 25th, 1899.

NEWTON, E. T.—"Notes on the Fossils collected by Colonel H. W. Feilden in Novaya Zemlya, 1897." "Beyond Petsora Eastward," by Henry J. Pearson, 8vo, London, 1899, p. 287; see also pp. 236, 242.

NEWTON, E. T.—"Notes on Fossils of Carboniferous Age, collected by Mr. Wm. S. Bruce, at Cape Cherni, Novaya Zemlya, in 1898." "Beyond Petsora Eastwards," p. 294.

NEWTON, E. T.—"On the Osteological specimens collected at Skitts Hill, near Braintree." See paper on "A supposed Neolithic Settlement at Skitts Hill, near Braintree," by Rev. J. W. Kenworthy, *Essex Naturalist*, vol. xi., p. 94.

PEACH, B. N.—"On some New Myriopods from the Palæozoic Rocks of Scotland." Proc. Roy. Phys. Soc. Edin. vol. xiv., p. 113.

REID, C.—"The Origin of the British Flora." 8vo, London, pp. vi, 191.

STRAHAN, A.—"The Age of the Vale of Clwyd." Geol. Mag., Dec. iv., vol. vi., pp. 111–117.

TEALL, J. J. H.—"The Natural History of Cordierite and its Associates. Presidential Address to Geologists' Association." Proc. Geol. Assoc., vol. xvi., pp. 61–74.

WEDD, C. B.—"Note on Barium Sulphate in the Bunter Sandstone of North Staffordshire." Rep. Brit. Assoc. for 1899 (1900), p. 740; Geol. Mag., Dec. iv., vol. vi., p. 508.

WOODWARD, H. B., and W. A. E. USSHER.—"Excursion to Seaton, Sidmouth, Budleigh Salterton, and Exeter." Proc. Geol. Assoc., vol. xvi., pp 133 153.

APPENDIX.

CATALOGUE of TYPES and FIGURED SPECIMENS from the EOCENE and OLIGOCENE SERIES preserved in the Museum of Practical Geology.

By H. A. ALLEN, F.G.S.

N.B.—The letter **T** *indicates that the specimen is the type of the species. The identity of some few specimens is not quite certain; these are marked* [**Doubtful**].

EOCENE.

PLANTÆ.

Alnites ? MacQuarrii, Forbes. **T.**
E. Forbes, Quart. Journ. Geol. Soc., vol. vii., 1851, pl. iv., f. 3, p. 103.
Eocene. Ardtun, Mull.

Andromeda reticulata, Ett.
O. Heer, Phil. Trans., vol. 152, 1863, pl. lxviii., figs. 10, 11, p. 1067.
Bagshot Series. Bovey Tracey, Devon.

Anona cyclosperma, Heer.
O. Heer, Phil. Trans., vol. 152, 1863, pl. lxx., f. 4, p. 1072.
Bagshot Series. Bovey Tracey.

Anona ? devonica, Heer. **T.**
O. Heer, Phil. Trans., vol. 152, 1863, pl. lxx., figs. 1, 2, 3, p. 1071.
Bagshot Series. Bovey Tracey.

Apeiobopsis Symondsii, De la Harpe. **T.**
De la Harpe, Mem. Geol. Survey, Isle of Wight, 1862, pl. vi., f. 5, p. 116.
Bagshot Series. Creech Barrow, Corfe Castle, Dorset.

Aralia primigenia, De la Harpe.
De la Harpe, Mem. Geol. Survey, Isle of Wight, 1862, pl. vii., f. 4, p. 117.
Lower Bagshot Series. Alum Bay, Isle of Wight.

Aralia primigenia, De la Harpe. **T.**
De la Harpe, Mem. Geol. Survey, Isle of Wight, 1862, pl. vii., f. 5, p. 117.
Lower Bagshot Series. Alum Bay.

Buds. **T.**
J. D. Hooker, Quart. Journ. Geol. Soc., vol. x., 1854, pl. iv., f. 25, p. 163.
Reading Series. Reading.

Cæsalpinia æmula, Heer.
De la Harpe, Mem. Geol. Survey, Isle of Wight, 1862, pl. v., f. 6, p. 118.
Lower Bagshot Series. Alum Bay.

Cæsalpinia Bowerbanki, De la Harpe. **T.**
De la Harpe, Mem. Geol. Survey, Isle of Wight, 1862, pl. v., f. 10, p. 119.
Lower Bagshot Series. Alum Bay.

Cæsalpinia ? brevis, De la Harpe. **T.**
De la Harpe, Mem. Geol. Survey, Isle of Wight, 1862, pl. v., figs. 12, 13, p. 119.
Lower Bagshot Series. Alum Bay.

Cæsalpinia ? mollis, De la Harpe. **T.**
De la Harpe, Mem. Geol. Survey, Isle of Wight, 1862, pl. v., f. 14, p. 119.
Lower Bagshot Series. Alum Bay.

Cæsalpinia Salteri, De la Harpe. **T.**
De la Harpe, Mem. Geol. Survey, Isle of Wight, 1862, pl. v., f. 11, p. 119.
Lower Bagshot Series. Alum Bay.

Carpolithes exaratus, Heer. **T.**
O. Heer, Phil. Trans., vol. 152, 1863, pl. lxx., figs. 24-27, p. 1079.
Bagshot Series. Bovey Tracey.

Carpolithes lividus, Heer. **T.**
O. Heer, Phil. Trans., vol. 152, 1863, pl. lxx., figs. 30 and 31, p. 1080.
Bagshot Series. Bovey Tracey.

Carpolithes vinaceus, Heer. **T.**
O. Heer, Phil. Trans., vol. 152., 1863, pl. lxx., f. 28, p. 1080.
Bagshot Series. Bovey Tracey.

Carpolithes Websteri (Brongn.), Heer.
O. Heer, Phil. Trans., vol. 152, 1863, pl. lxx., fig. 6, p. 1075.
Bagshot Series. Bovey Tracey.

Cassia Ungeri, Heer.
De la Harpe, Mem. Geol. Survey, Isle of Wight, 1862, pl. v., figs. 7, 8, 8*a*, p. 118.
Lower Bagshot Series. Alum Bay.

Cinnamomum lanceolatum, Heer.
O. Heer, Phil. Trans., vol. 152, 1863, pl. lxvii., figs. 1, 2, 4 ; pl. lviii., f. 14 p. 1063.
Bagshot Series Bovey Tracey.

Cinnamomum Rossmässleri, Heer.
O. Heer, Phil. Trans., vol. 152, 1863, pl. lxvii., figs. 17, 18, p. 1062.
Bagshot Series. Bovey Tracey.

Cinnamomum Scheuchzeri, Heer.
O. Heer, Phil. Trans., vol. 152, 1863, pl. lxvii., figs. 11, 14, 16, p. 1063
Bagshot Series. Bovey Tracey.

Cyperites deperditus, Heer. **T.**
O. Heer, Phil. Trans., vol. 152, 1863, pl. lx., f. 54, p. 1056.
Bagshot Series. Bovey Tracey.

Daphnogene Ungeri, Heer.
O. Heer, Phil. Trans., vol. 152, 1863, pl. lxv., figs. 1, 2, p. 1064.
Bagshot Series. Bovey Tracey.

Dalbergia ? Salteri, De la Harpe. **T.**
De la Harpe, Mem. Geol. Survey, Isle of Wight, 1862, pl. v., f. 9., p. 118.
Lower Bagshot Series. Alum Bay.

Dryandra acutiloba (Brongn.)
De la Harpe, Mem. Geol. Survey, Isle of Wight, 1862, pl. vii., figs. 6 and 7, p. 115.
Lower Bagshot Series. Alum Bay.

Dryandra Bunburyi, De la Harpe. **T.**
De la Harpe, Mem. Geol. Survey, Isle of Wight, 1862, pl. v., f. 4, p. 115.
Lower Bagshot Series. Alum Bay.

Echitoneum cuspidatum, Heer.
O. Heer, Phil. Trans., vol. 152, 1863, pl. lxiv., f. 5, p. 1068.
Bagshot Series. Bovey Tracey.

Elæodendron ? Heeri. De la Harpe. **[Doubtful] T.**
De la Harpe, Mem. Geol. Survey, Isle of Wight, 1862, pl. v., f. 5, p. 114
Bagshot Series. Bournemouth.

Equisetum Campbellii, Forbes. **T.**
E. Forbes, Quart. Journ. Geol. Soc., vol. vii., 1851, pl. iii., figs. 6*a*, 6*b*, p. 103.
Eocene. Ardtun, Mull

Ficus Bowerbankii, De la Harpe. **T.**
De la Harpe, Mem. Geo. Survey, Isle of Wight, 1862, pl. vi., figs. 1 and 2, p. 112.
Lower Bagshot Series. Alum Bay.

Ficus eucalyptoides, Heer. **T.**
O. Heer, Phil. Trans., vol. 152, 1863, pl. lxv., figs. 3, 4, p. 1061.
Bagshot Series. Bovey Tracey.

Ficus Falconeri, Heer. **T.**
O. Heer, Phil. Trans., vol. 152, 1863, pl. lxiii., f. 1*a* ; pl. lxiv., fig. 7, p. 1060.
Bagshot Series. Bovey Tracey.

Ficus Forbesii, De la Harpe. **T.**
De la Harpe, Mem. Geol. Survey, Isle of Wight, 1862, pl. vi., f. 4, p. 113.
Bagshot Series. Creech Barrow, Corfe Castle, Dorset.

Ficus granadilla (Massal.).
De la Harpe, Mem. Geol. Survey, Isle of Wight, 1862, pl. vi., f. 3, p. 113,
Lower Bagshot Series. Alum Bay.

Ficus Pengellii, Heer. **T.**
O. Heer, Phil. Trans., vol. 152, 1863, pl. lxv., f. 8, p. 1061.
Bagshot Series. Bovey Tracey.

Filicites ? hebridicus, Forbes. **T.**

E. Forbes, Quart. Journ. Geol. Soc., vol. vii., 1851, pl. ii., figs. 2*a*, 2*b*, p. 103. Refigured as **Onoclea hebraidica,** J. S. Gardner, "Eocene Flora," Mon. Pal. Soc., 1882, pl. xiii., figs. 5, 5*a*, p. 68.
Eocene. Ardtun, Mull.

Gardenia Wetzleri, Heer.
O. Heer, Phil. Trans., vol. 152, 1863, pl. lxix., f. 1, p. 1069.
Bagshot Series. Bovey Tracey.

Goniopteris stiriaca. *Vide* **Lastræa stiriaca.**

Lastræa (Goniopteris) Bunburii, Heer.
O. Heer, Phil. Trans., vol. 152, 1863, pl. lxiii., figs. 1 *b*, *c*, *d*, p. 1046.
Bagshot Series. Bovey Tracey.

Lastræa (Goniopteris) stiriaca, Heer.
O. Heer, Phil. Trans., vol. 152, 1863, pl. lvi., figs. 9, 10, 11, 14, 15, p. 1046. Refigured as **Goniopteris stiriaca,** J. S. Gardner, Mon. Pal Soc., 1880, p. 40, f. 20 (Woodcut).
Bagshot Series. Bovey Tracey

Laurus Jovis, De la Harpe. **T.**
De la Harpe, Mem. Geol. Survey, Isle of Wight, 1862, pl. vii., f. 3, p. 114.
Lower Bagshot Series. Alum Bay.

Laurus primigenia. Unger.
O. Heer, Phil. Trans., vol. 152, 1863, pl. lxv., f. 6, p. 1062.
Bagshot Series. Bovey Tracey.

Laurus ? Salteri, De la Harpe. **T.**
De la Harpe, Mem. Geol. Survey, Isle of Wight, 1862, pl. vii., f. 1, p. 115.
Lower Bagshot Series. Alum Bay.

Nymphæa Doris, Heer. **T.**
O. Heer, Phil. Trans., vol. 152, 1863, pl. lxx., figs. 32–37, p. 1072.
Bagshot Series. Bovey Tracey.

Onoclea hebraidica. *Vide* **Filicites ? hebridicus.**

Palmacites Dæmonorops (Unger).
O. Heer, Phil. Trans., vol. 152, 1863, pl. lv., figs. 8, 9, 10 ; pl. lxii., figs. 3, 6, 8, p. 1056.
Bagshot Series. Bovey Tracey.

Pecopteris (Hemitelia ?) lignitum, Giebel.
O. Heer, Phil. Trans., vol. 152, 1863, pl. lvi., figs. 3, 5, 7, 8, 9, 10 ; pl. lvii., f. 1, p. 1047.
Bagshot Series. Bovey Tracey.

Platanites hebridicus, Forbes. **T.**
E. Forbes, Quart. Journ. Geol. Soc., vol. vii., 1851, pl. iv., f. 1, p. 103.
Eocene. Ardtun, Mull.

Platanites hebridicus, var. ? Forbes. **T.**
E. Forbes, Quart. Journ. Geol. Soc., vol. vii., 1851, pl. iii., f. 5, p. 103.
Eocene. Ardtun, Mull.

Pteris eocænica, Ett. and Gard. **T.**
Gardner and Ettingshausen, "Eocene Flora." Mon. Pal. Soc., 1882, pl. xii., f. 11, 11*a*, pp. 32 and 62.
Bagshot Series. Bournemouth.

Pterocarya denticulata ? Heer.
O. Heer, Phil. Trans., vol. 152, 1863, pl. lxx., fig. 5, p. 1074.
Bagshot Series. Bovey Tracey.

Quercus eocenica, De la Harpe. **T.**
De la Harpe, Mem. Geol. Survey, Isle of Wight, 1862, pl. vii., f. 2, p. 112.
Lower Bagshot Series. Alum Bay.

Quercus Lyelli, Heer.
O. Heer, Phil. Trans., vol. 152, 1863, pl. lxiii., figs. 3, 5, 6, 7, 8 ; pl. lxviii., figs. 4, 6, p. 1058.
Bagshot Series. Bovey Tracey

Rhamnites ? multinervatus, Forbes. **T.**
E. Forbes, Quart. Journ. Geol. Soc., vol. vii., 1851, pl. iii., f. 2, p. 103.
Eocene. Ardtun, Mull.

Rhamnites ? major, Forbes. **T.**
E. Forbes, Quart. Journ. Geol. Soc., vol. vii., 1851, pl. iii., f. 3, p. 103.
Eocene. Ardtun, Mull.

Sequoia Couttsiæ, Heer.
J. S. Gardner, Mon. Pal. Soc., 1883, pl. vi., figs. 14 17, pp. 36 and 90.
Middle Bagshot Series. Bovey Tracey.

Sequoia Langsdorfii. *Vide* **Taxites ? Campbellii.**

Taxites ? Campbellii, Forbes. T.
E. Forbes, Quart. Journ. Geol. Soc., vol. vii., 1851, pl. ii., figs. 1*a*, 1*b* p. 103. Refigured as **Taxus Campbelli,** J. S. Gardner, "Eocene, Flora," Mon. Pal. Soc., 1885, pl. x., figs. 1, 1*a*, p. 101.
Eocene. Ardtun, Mull.

Taxus Campbelli. *Vide* **Taxites ? Campbellii.**
"Affinities doubtful."
E. Forbes, Quart. Journ. Geol. Soc., vol. vii., pl. iv., f. 2, p. 103.
Eocene. Ardtun, Mull.

ANIMALIA.

PROTOZOA.

Nummulites elegans, J. C. Sow.
Rupert Jones, Quart. Journ. Geol. Soc., vol. xliii., 1887, pl. xi., f. 1, p. 142.
Barton Series. Whitecliff Bay, I.W.

ECHINODERMATA.

Astropecten ? Colei, Forbes. T.
E. Forbes, Mon. Pal. Soc., 1852, pl. iv., figs. 3 *a*, *b*, p. 30.
London Clay. Sheppey.

Astropecten crispatus, Forbes. T.
Ansted, "Geology," vol. ii., 1844, p. 66 (Woodcut).
E. Forbes, Mem. Geol. Survey, vol. ii., part 2, 1848, p. 479.
E. Forbes, Mon. Pal. Soc., 1852, pl. iv., figs. 2 *a*, *b*, p. 29.
London Clay. Sheppey.

Astropecten crispatus, Forbes.
E. Forbes, Mem. Geol. Survey, Decade I., 1849, pl. iii., figs. 3 *b*, *c*.
London Clay. Sheppey.

Cainocrinus tintinnabulum, Forbes. T.
E. Forbes, Mon. Pal. Soc. 1852, p. 33 (Woodcut).
London Clay. Hornsey.

Cidaris websteriana, Forbes. T
E. Forbes, Mon. Pal. Soc., 1852, pl. iii., f. 4, p. 22.
Barton Series. Barton, Hants.

Cœlopleurus Wetherelli, Forbes T.
E. Forbes, Mon. Pal. Soc., 1852, pl. iii., figs. 1 *a*, *b*, *c*, p. 24.
London Clay. Sheppey.

Echinopsis Edwardsi, Forbes. T.
E. Forbes, Mon. Pal. Soc., 1852, pl. iii., f. 2, p. 23.
Bracklesham Series. Bracklesham.

Echinus dixonianus, Forbes. T.
E. Forbes, Mon. Pal. Soc., 1852, pl. iii., f. 3, p. 22.
Barton Series. Barton, Hants.

Eupatagus Hastingiæ, Forbes. T.
E. Forbes, Mon. Pal. Soc., 1852, pl. iii., f. 7, p. 26.
Barton Series. Barton, Hants.

Goniaster (Astrogonium) marginatus, Forbes. T.
E. Forbes, Mem. Geol. Survey, vol. ii., part 2, 1848, p. 475.
E. Forbes, Mem. Geol. Survey, Decade I., 1849, pl. 3, f. 2.
E. Forbes, Mon. Pal. Soc., 1852, pl. iv., f. 4, p. 31
London Clay. Sheppey.

Goniaster (Astrogonium) Stokesii, Forbes. **T.**
E. Forbes, Mem. Geol. Survey, vol. ii., part 2, 1848, p. 475.
E. Forbes, Mem. Geol. Survey, Decade I., 1849, pl. 3, figs. 1 *a*, *c*, *d*.
London Clay. Sheppey

Goniaster tuberculatus, Forbes. **T.**
E. Forbes, Mon. Pal. Soc., 1852, pl. iv., f. 5, p. 31.
London Clay. Sheppey

Hemiaster Bowerbanki, Forbes. **T.**
E. Forbes, Mon. Pal. Soc., 1852, pl. iii., f. 6, p. 24.
London Clay. Sheppey.

Hemiaster branderianus, Forbes. **T.**
E. Forbes, Mon. Pal. Soc., 1852, pl. iii., figs. 8 *a*, *b* *c*, p. 25.
Barton Series. Barton, Hants.

Hemiaster branderianus, Forbes. **T.**
E. Forbes, Mon. Pal. Soc., 1852, pl. iii., figs. 8 *d*, *e*, p. 25.
London Clay. Haverstock Hill.

Hemiaster ? Prestwichii, Forbes. **T.**
E. Forbes, Mon. Pal. Soc., 1852, pl. iii., figs. 5 *a*, *b*, *c*, p. 25.
London Clay. Sheppey.

Ophiura Wetherelli, Forbes. **T.**
E. Forbes, Mon. Pal. Soc., 1852, pl. iv., f. 7*b*, p. 32.
London Clay. Highgate.

Pentacrinus subbasaltiformis, Miller.
E. Forbes, Mon. Pal. Soc., 1852, pl. iv., figs. 9, 10, p. 34.
London Clay. Hornsey.

Spatangus Omalii, Galeotti.
E. Forbes, Mon. Pal. Soc, 1852, pl. iii., figs. 9 *a*, *c*, p. 28.
Barton Series. Barton, Hants.

LAMELLIBRANCHIATA.

Cytherea incurvata, Edw. **[Doubtful.]**
Lowry's Chart of the British Tertiary Fossils, 1866.
Bracklesham Series.

Modiola ? tubicola, S. V. Wood. **T.**
S. V. Wood, Mon. Pal. Soc., 1859, pl. xiii., f. 12, p. 73.
London Clay. Whetstone ?

Nucula proava, S. V. Wood. **T.**
S. V. Wood, Mon. Pal. Soc., 1862, pl. xx., figs. 3 *a*, *b*, p. 117.
London Clay (Basement Bed). Near Bishopstone, Herne Bay.

Nucula striatella, S. V. Wood. **T.**
S. V. Wood, Mon. Pal. Soc., 1862, pl. xx., fig. 9, p. 123.
London Clay (Basement Bed). Herne Bay.

Ostrea tabulata, J. C. Sow.
S. V. Wood, Mon. Pal. Soc., 1861, pl. iv. f. 1*b*, p. 31.
Bracklesham ? Bognor.

Perna croydonensis, Newton. **T.**
E. T. Newton, Proc. Geol. Assoc., vol. viii., 1883, p. 249.
Woolwich and Reading Series. Park Hill, Croydon.

Vulsella deperdita? Lam.
S. V. Wood, Mon. Pal. Soc., 1861, pl. ix., f. 2c, p. 35.
Barton Series. Barton, Hants.

GASTEROPODA.

Camptoceras priscum, Austin. **T.**
H. H. Godwin-Austen, Quart. Journ. Geol. Soc., vol. xxxviii., 1882, pl. v., figs. 1-5, p. 220.
London Clay. Between East End Lane and Hensbrook, Sheppey.

Fusus nitidus, Price. **T.**
F. G. H. Price, Proc. Geol. Assoc., vol. iii., 1874, pl. ii., fig. 2.
London Clay. Law Courts Area, Strand, London.

Pleurotoma varicosa, Price. **T.**
F. G. H. Price, Proc. Geol Assoc., vol. iii., 1874, pl. ii., fig. 1.
London Clay. Law Courts Area, Strand, London.

VERTEBRATA.

Arius crassus, (Koken) Newton. **T.**
E. T. Newton, Proc. Zool. Soc., 1889, pl. xxi., figs. 1-3, p. 206.
Barton Series. Barton, Hants.

Notidanus serratissimus, Ag.
A. S. Woodward, Proc. Geol. Assoc., vol. xvi., 1899, pl. 1, f. 7, p. 6.
London Clay. Sheppey.

Emys delabechei, T. Bell. **T.**
T. Bell in R. Owen, Mon. Pal. Soc., 1849, pl. xxviii., p. 74.
London Clay. Sheppey.

Agnopterus ? hantoniensis, Lyd. **T.**
R. Lydekker, Cat. Foss. Birds in Brit. Museum, p. 97.
Middle Eocene. Hordwell.

Gastornis Klaasseni, Newton. **T.**
E. T. Newton, Trans. Zool. Soc., vol. xii., 1886, pl. xxviii., xxix., p. 143.
Lower Eocene. Park Hill, Croydon.

Proherodius Oweni, Lyd. **T.**
R. Lydekker, Cat. Foss. Birds in Brit. Museum, fig. 75, p. 364.
London Clay. Admiralty Building, St. James's Park.

Coryphodon croydonensis, Newton. **T.**
E. T. Newton, Proc. Geol. Assoc., vol. viii., 1883, pl. iii., p. 250.
Lower Eocene. Park Hill, Croydon.

OLIGOCENE.

PLANTÆ

Andromeda reticulata, Ett.
O. Heer, Quart. Journ. Geol. Soc., vol. xviii., 1862, pl. xviii., f. 13, p. 373.
Hamstead Series. Hamstead, I.W.

Chara Lyellii (Forbes MS.), Salter. **T.**
J. W Salter in Forbes, Mem. Geol. Survey, Isle of Wight, 1856, pl. vii., f. 10, p. 160.
Bembridge Series. St. Helens, I.W.

Chara tuberculata, Lyell, var. **Morrisii**, Salter. **T.**
J. W. Salter in Forbes, Mem. Geol. Survey, Isle of Wight, 1856, pl. vii., f. 14, p. 159.
Hamstead Series. Hamstead, I.W.

Cyperites Forbesii, Heer. **[Doubtful] T.**
O. Heer, Quart. Journ. Geol. Soc., vol. xviii., 1862, pl. xviii., figs. 20, 21, p. 373.
Hamstead Series. Hamstead, I.W.

Limnocarpus headonensis (Gardner). Type of the genus. **T.**
Clement Reid, Journ. Linn. Soc., vol. xxxiii., 1898, p. 465 (woodcut).
Lower Headon Series. Hordle Cliff, Hampshire.

Nelumbium Buchii, Ett.
O. Heer, Quart. Journ. Geol. Soc., vol. xviii., 1862, pl. xviii., figs. 19 *c*, *d*, *e*, p. 374.
Hamstead Series. Hamstead, I.W.

Sabal major, Unger.
J. S. Gardner, Rep. Brit. Assoc. for 1887, pl. v., f. 5, p. 423.
Bembridge Series. Hamstead, I.W

Sequoia Couttsiæ, Heer.
O. Heer, Quart. Journ. Geol. Soc., vol. xviii., 1862, pl. xviii., figs 1–7, p. 372. Refigured as **Athrotaxis Couttsiæ,** J. S. Gardner, "Eocene Flora," Mon. Pal. Soc., 1884, pl. vi., figs. 3 and 8, pp. 36 and 90.
Hamstead Series. Hamstead, I.W.

CŒLENTERATA.

Madrepora anglica, Dunc. **T.**
P. M. Duncan, Mon. Pal. Soc., 1866, pl. viii., figs. 1–7, p. 51.
Middle Headon Series Brockenhurst.

Madrepora Roemeri, Dunc. **T.**
P. M. Duncan, Mon. Pal. Soc., 1866, pl. viii., figs. 8, 10, 11, p. 51.
Middle Headon Series. Brockenhurst.

Solenastræa cellulosa, Dunc. **T.**
P. M. Duncan, Mon. Pal. Soc., 1866, pl. v., f. 7, p. 41.
Middle Headon Series. Brockenhurst.

Solenastræa granulata, Dunc.
P. M. Duncan, Mon. Pal. Soc., 1866, pl. vi., f. 14, p. 45.
Middle Headon Series Brockenhurst.

Solenastræa Koeneni, Dunc. **T.**
P. M. Duncan, Mon. Pal. Soc., 1866, pl. v., figs. 8, 9, p. 42.
Middle Headon Series. Brockenhurst.

Bryozoa.

Membranipora Buski, Gregory. **T.**
J. W. Gregory, Trans. Zool. Soc., vol. xiii., 1895, pl xxix., f. 12, p. 229.
Headon Series. Colwell Bay, I.W.

Lamellibranchiata.

Arca Websteri (Forbes MS.), Morris. **T.**
J. Morris in E. Forbes, Mem. Geol. Survey, Isle of Wight, 1856, pl. iii., f. 8, p. 150.
Bembridge Series. Isle of Wight.

Corbula pisum, J. Sow.
J. Morris in E. Forbes, Mem. Geol. Survey, Isle of Wight, 1856, pl. i., f. 1, p. 145.
Hamstead Series (Upper Beds). Hamstead, I.W.

Corbula vectensis (Forbes MS.), Morris.
J. Morris in E. Forbes, Mem. Geol. Survey, Isle of Wight, 1856, pl. i., f. 2, pp. 46 and 145.
Hamstead Series (Upper Beds). Hamstead, I.W.

Cyclas Bristovii (Forbes MS.), Morris. **T.**
J. Morris in E. Forbes, Mem. Geol. Survey, Isle of Wight, 1856, pl. ii., f. 3, p. 146.
Hamstead Series. Hamstead Cliff, I.W.

Cyrena deperdita, Lam.
J. Morris in E. Forbes, Mem. Geol. Survey, Isle of Wight, 1856, pl. vi., figs. 11, 11 *a*, *b*, p. 156.
Headon Series. Isle of Wight.

Cyrena gibbosula, Morris. **T.**
J. Morris in E. Forbes, Mem. Geol. Survey, Isle of Wight, 1856, pl. vi., figs. 13, 13 *a*, *b*, p. 156.
S. V. Wood, Mon. Pal. Soc., Supp. 1877, pl. B, figs. 6 *a*, *b*, p. 14.
Headon Series. Colwell Bay.

Cyrena obtusa (Forbes MS.), Morris. **T.**
J. Morris in E. Forbes, Mem. Geol. Survey, Isle of Wight, 1856, pl. iii., figs. 4, 4 *a*, *b*, p. 149.
Bembridge Series. Hamstead Cliff, I.W.

Cyrena pulchra, J. C. Sow.
J. Morris in E. Forbes, Mem. Geol. Survey, Isle of Wight, 1856, pl. iii., f. 1, p. 148.
Bembridge Series (Green Marls). Isle of Wight.

Cyrena semistriata, Desh.
J. Morris in E. Forbes, Mem. Geol. Survey, Isle of Wight, 1856, pl. iii., f. 2, p. 148.
Bembridge Series. Isle of Wight.

Cyrena semistriata, Desh.
J. Morris in E. Forbes, Mem. Geol. Survey, Isle of Wight, 1856, pl. ii., f. 2, p. 146.
Hamstead Series (Corbula Beds). Hamstead, I.W.

Cyrena semistriata, Desh., var.
J. Morris in E. Forbes, Mem. Geol. Survey, Isle of Wight, 1856, pl. i., f. 3, p. 145.
Hamstead Series (Upper Beds). Hamstead, I.W.

Cyrena transversa (Forbes MS.), Morris. **T.**
J. Morris in E. Forbes, Mem. Geol. Survey, Isle of Wight, 1856, pl. iii. f. 6, p. 149.
Bembridge Series. Hamstead Cliff, I.W

Cyrena Wrightii (Forbes MS.), Morris. **T.**
J. Morris in E. Forbes, Mem. Geol. Survey, Isle of Wight, 1856, pl. iv., figs. 11, 11 *a*, *b*, p. 153.
Headon Series. Isle of Wight.

Cytherea incrassata, J. Sow.
J. Morris in E. Forbes, Mem. Geol. Survey, Isle of Wight, 1856, pl. iv., f. 10, p. 153.
Headon Series. Colwell Bay.

Cytherea incrassata (cast of), J. Sow.
J. Morris in E. Forbes, Mem. Geol. Survey, Isle of Wight, 1856, pl. iii., f. 10, p 150.
Bembridge Series. Isle of Wight.

Cytherea (Venus) Lyellii (Forbes MS.), Morris. **T.**
J. Morris in E. Forbes, Mem. Geol. Survey, Isle of Wight, 1856, pl. i., f. 4, p. 145.
Hamstead Series (Upper Beds). Hamstead, I.W..

Modiola Prestwichii, Morris. (**M. nystiana**, Forbes, on plate.) **T.**
J. Morris in E. Forbes, Mem. Geol. Survey, Isle of Wight, 1856, pl. ii., f. 5, pp. 46 and 147.
Hamstead Series. Hamstead Cliff, I.W.

Mya (Panopæa) minor (Forbes MS.), Morris, 1856. **T.**
J. Morris in E. Forbes, Mem. Geol. Survey, Isle of Wight, 1856, pl. iii., f. 3, p. 149.
Bembridge Series. Isle of Wight.

Mya (Panopæa) minor, var. (Forbes MS.), Morris. **T.**
J. Morris in E. Forbes, Mem. Geol. Survey, Isle of Wight, 1856, pl. ii., f. 4, p. 146.
Hamstead Series. Hamstead, I. W.

Nucula headonensis (Forbes MS.), Morris. **T.**
J. Morris in E. Forbes, Mem. Geol. Survey, Isle of Wight, 1856, pl. vi., figs. 12, 12 *a*, *b*, p. 156.
Middle Headon Series. Colwell Bay.

Nucula similis, J. Sow.
J. Morris in E. Forbes, Mem. Geol. Survey, Isle of Wight, 1856, pl. iii., f. 5, p. 149.
Bembridge Marls. Isle of Wight.

Ostrea callifera, Lam.
J. Morris in E. Forbes, Mem. Geol. Survey, Isle of Wight, 1856, pl. i., figs. 5, 5*a*, p. 145.
S. V. Wood, Mon. Pal. Soc., 1861, pl. v., f. 1*a*, p. 18.
Hamstead Series (Upper Beds). Hamstead, I.W.

Ostrea vectensis (Forbes MS.), Morris. **T.**
J. Morris in E. Forbes, Mem. Geol. Survey, Isle of Wight, 1856, pl. iii., figs. 9, 9*a*, 9*b*, p. 150.
S. V. Wood, Mon. Pal. Soc., 1861, pl. vii., figs. 5*a*, 5*b*, p. 32.
Bembridge Series. Isle of Wight.

Unio Austenii (Forbes MS.), Morris. **T.**
J. Morris in E. Forbes, Mem. Geol. Survey, Isle of Wight, 1856, pl. ii. f. 7, p. 147.
S. V. Wood, Mon. Pal. Soc., 1864, pl. xx., f. 12, p. 133.
Hamstead Series. Hamstead, I. W.

Unio Gibbsii (Forbes MS.), Morris.
S. V. Wood, Mon. Pal. Soc., 1864, pl. xx., f. 14, p. 133.
Hamstead Series. Isle of Wight.

Unio Gibbsii (Forbes MS.), Morris. **[Doubtful]. T.**
J. Morris in E. Forbes, Mem. Geol. Survey, Isle of Wight, 1856, pl. ii., f. 6, p. 147.
Hamstead Series. Hamstead Cliff, I.W.

GASTEROPODA.

Ancillaria subulata, J. Sow.
J. Morris in E. Forbes, Mem. Geol. Survey, Isle of Wight, 1856, pl. vi., figs. 1, 1*a*, p. 155.
Headon Series. Hordwell.

Borsonia sulcata (Edwards MS.), Morris. **T.**
J. Morris in E. Forbes, Mem. Geol. Survey, Isle of Wight, 1856, pl. v., figs. 3, 3*a*, 3*b*, p. 154.
Headon Series. Colwell Bay.

Cerithium Austeni, Morris. **T.**
J. Morris in E. Forbes, Mem. Geol. Survey, Isle of Wight, 1856, pl. iii., f. 11, p. 150.
Bembridge Series. Hamstead Point, I.W.

Cerithium concavum, J. Sow.
J. Morris in E. Forbes, Mem. Geol. Survey, Isle of Wight, 1856, pl. iv., f. 9, p. 153.
Headon Series. Isle of Wight.

Cerithium elegans, Desh. **[Doubtful]**
J. Morris in E. Forbes, Mem. Geol. Survey, Isle of Wight, 1856, pl. ii., f. 10, p. 147.
Bembridge Series. Headon, I.W

Cerithium inornatum, Morris. **T.**
J. Morris in E. Forbes, Mem. Geol. Survey, Isle of Wight, 1856, pl. ii., f. 13, p. 148.
Hamstead Series. Hamstead, I.W.

Cerithium margaritaceum, J. Sow. var. Morris.
J. Morris in E. Forbes, Mem. Geol. Survey, Isles of Wight, 1856, pl. iii., f. 13, p. 150.
Bembridge Series. Hamstead, I.W.

Cerithium mutabile, Lam. var. ? Desh.
J. Morris in E. Forbes, Mem. Geol. Survey, Isle of Wight, 1856, pl. iii., f. 12, p. 150.
Bembridge Series. Isle of Wight.

Cerithium mutabile, Lam. var. ? Desh.
J. Morris in E. Forbes, Mem. Geol. Survey, Isle of Wight, 1856, pl. iv., f. 6, p. 152.
Headon Series. Isle of Wight.

Cerithium plicatum, Brug.
J. Morris in E. Forbes, Mem. Geol. Survey, Isle of Wight, 1856, pl. i., f. 7, p. 146.
Hamstead Series (Upper Beds). Hamstead, I.W.

Cerithium plicatum, Brug.
J. Morris in E. Forbes, Mem. Geol. Survey, Isle of Wight, 1856, pl. ii. f. 11, p. 147.
Hamstead Series (Upper Beds). Hamstead, I.W.

Cerithium pseudocinctum, d'Orb. [Doubtful]
Morris in Forbes, Mem. Geol. Survey, Isle of Wight, 1856, pl. iv., f. 7, p. 153.
Headon Series. Colwell Bay.

Cerithium Sedgwicki, Morris. [Doubtful] T.
J. Morris in E. Forbes, Mem. Geol. Survey, Isle of Wight, 1856, pl. ii., f. 12, p. 147.
Hamstead Series. Hamstead, I.W.

Cerithium trizonatum, Morris. T.
J. Morris in E. Forbes, Mem. Geol. Survey, Isle of Wight, 1856, pl. iv., f. 8, p. 153.
Headon Series. Isle of Wight.

Cerithium ventricosum, J. Sow.
J. Morris in E. Forbes, Mem. Geol. Survey, Isle of Wight, 1856, pl. iv., f. 2, p. 152.
Headon Series. Isle of Wight.

Fusus Edwardsii, Morris. T.
J. Morris in E. Forbes, Mem. Geol. Survey, Isle of Wight, 1856, pl. ii., f. 15, p. 148.
Hamstead Series (Upper Beds). Hamstead, I.W.

Melania Forbesii, Morris. T.
J. Morris in E. Forbes, Mem. Geol. Survey, Isle of Wight, 1856, pl. iii., f. 15, p. 151.
Bembridge Series. Hamstead, I.W.

Melania inflata, Morris. T.
J. Morris in E. Forbes, Mem. Geol. Survey, Isle of Wight, 1856, pl. ii., f. 8, p. 147.
Hamstead Series. Hamstead Cliff, I.W.

Melania inflata, Morris, var. **lævis**, Morris. T.
J. Morris in E. Forbes, Mem. Geol. Survey, Isle of Wight, 1856, pl. ii., f. 9, p. 147.
Hamstead Series. Hamstead Cliff, I.W.

Melania muricata (S. V. Wood MS.), Morris. T.
J. Morris in E. Forbes, Mem. Geol. Survey, Isle of Wight, 1856, pl. iii., f. 16, p. 151.
Bembridge Series. Isle of Wight.

Melania muricata, Wood, var. **costata** (Sow. sp.), Morris.
J. Morris in E. Forbes, Mem. Geol. Survey, Isle of Wight, 1856, pl. ii. f. 14, p. 148.
Hamstead Series. Hamstead, I.W.

Melania muricata, Wood, var. **excavata**, Morris. T.
J. Morris in E. Forbes, Mem. Geol. Survey, Isle of Wight, 1856, pl. iii., f. 17, p. 151.
Bembridge Series. Bembridge, I.W.

Melania per-acuminata (Charlsw MS.), Morris. T.
J. Morris in E. Forbes, Mem. Geol. Survey, Isle of Wight, 1856, pl. iv., f. 5, p. 152.
Headon. Isle of Wight.

Melania turritissima, Forbes. T.
J. Morris in E. Forbes, Mem. Geol. Survey, Isle of Wight, 1856, pl. iii., f. 14, p. 150.
Probably the specimen figured in Lyell "Manual of Geology," 5th Edition, 1855, p. 209 (Woodcut).
Bembridge Series. Hamstead Cliff, I.W.

Melanopsis brevis, J. C. Sow.
J. Morris in E. Forbes, Mem. Geol. Survey, Isle of Wight, 1856, pl. vi., f. 10, p. 156.
Headon Series. Colwell Bay, I.W.

Melanopsis carinata, J. C. Sow.
J. Morris in E. Forbes, Mem. Geol. Survey, Isle of Wight, 1856, pl. vi., f. 8, p. 156.
Headon Series. Headon Hill.

Melanopsis carinata, J. C. Sow.
J. Morris in E. Forbes, Mem. Geol. Survey, Isle of Wight, 1856, pl. vi., figs 9, 9*a*, p. 156.
Headon Series. Colwell Bay.

Melanopsis fusiformis, J. Sow.
J. Morris in E. Forbes, Mem. Geol. Survey, Isle of Wight, 1856, pl. vi., figs. 7, 7*a*, p. 156.
Headon Series. Colwell Bay.

Melanopsis subcarinata, Morris. **T.**
J. Morris in E. Forbes, Mem. Geol. Survey, Isle of Wight, 1856, pl. vi., f. 5, p. 156.
Headon Series. Headon Hill.

Melanopsis subcarinata, Morris. **T.**
J. Morris in E. Forbes, Mem. Geol. Survey, Isle of Wight, 1856, pl vi., figs. 6 and 6*a*, p. 156.
Headon Series. Headon Hill, I.W.

Melanopsis subfusiformis, Morris. **T.**
J. Morris in E. Forbes, Mem. Geol. Survey, Isle of Wight, 1856, pl. vi., figs. 2, 2*a*, and 3, p. 155.
Headon Series. Isle of Wight.

Melanopsis subulata, J. Sow. **[Doubtful]**
J. Morris in E. Forbes, Mem. Geol. Survey, Isle of Wight, 1856, pl. vi., figs. 4 and 4*a*, p. 155.
Headon Series. Headon Hill.

Natica labellata, Lam.
J. Morris in E. Forbes, Mem. Geol. Survey, Isle of Wight, 1856, pl. i., f. 6, p. 146.
Hamstead Series (Upper Beds). Hamstead, I.W.

Pleurotoma headonensis (Edw. MS.), Morris. **T.**
J. Morris in E. Forbes, Mem. Geol. Survey, Isle of Wight, 1856, pl. v., f. 4, p. 155.
Headon Series. Colwell Bay.

Pleurotoma innexa (Sol.).
J. Morris in E. Forbes, Mem. Geol. Survey, Isle of Wight, 1856, pl. v., f. 5, p. 154.
Headon Series. Colwell Bay.

Pleurotoma plebeia, J. C. Sow.
J. Morris in E. Forbes, Mem. Geol. Survey, Isle of Wight, 1856, pl. v., figs. 1, 1 *a*, *b*, p. 154.
Headon Series. Colwell Bay.

Pleurotoma plebeia, var. Morris (var. *b* Forbes MS.), Morris. **T.**
J. Morris in E. Forbes, Mem. Geol. Survey, Isle of Wight, 1856, pl. v., f. 2, p. 154.
Middle Headon Series. Isle of Wight.

Rissoa (Hydrobia) Chastelii ? (Nyst) (*Hydrobia* on plate.)
J. Morris in E. Forbes, Mem. Geol. Survey, Isle of Wight, 1856, pl. iv., f. 3, pp. 148 and 152.
Headon Series. Isle of Wight.

Scalaria lævis, Morris. **T.**
J. Morris in E. Forbes, Mem. Geol. Survey, Isle of Wight, 1856, pl. iv., f. 1, p. 151.
Headon Series. Isle of Wight.

Vertebrata.

Amia anglica, Newton. **T.**
E. T. Newton, Quart. Journ. Geol. Soc., vol. lv., 1899, pl. i., figs. 1–5, p. 1.
Bembridge Marl. Hamstead, I.W.

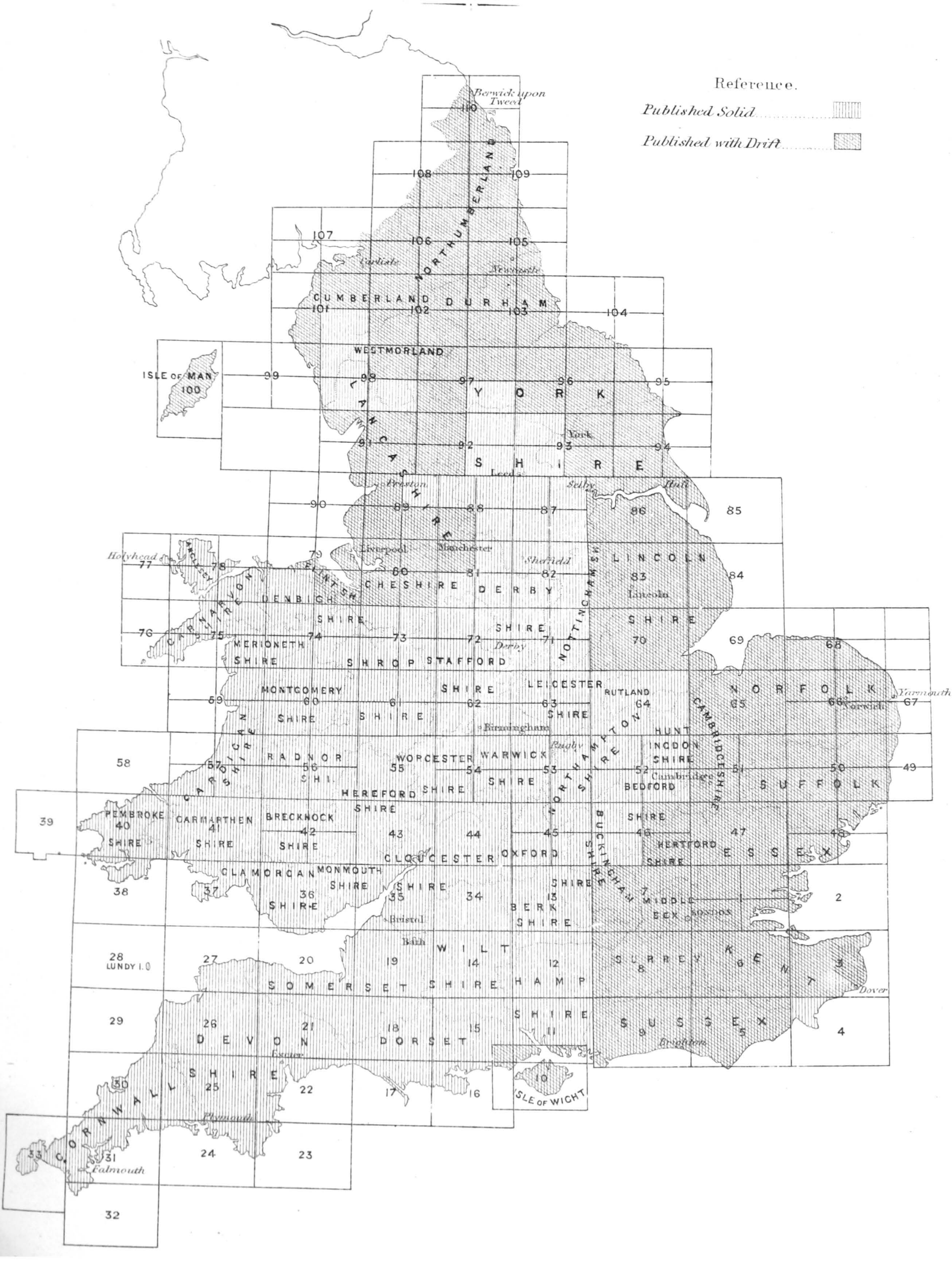
Amia anglica, Newton.
E. T. Newton, Quart. Journ. Geol. Soc., vol. lv., 1899, pl. i., fig. 19, p. 1.
Osborne Beds. Ryde House, Ryde, I.W.

Amia Colenutti, Newton. **T.**
E. T. Newton, Quart. Journ. Geol. Soc., vol. lv., 1899, pl. i., fig. 22, p. 8.
Osborne Beds. King's Quay, I.W.

Hyopotamus sp.
W. Kowalevsky, Phil. Trans., vol. 163, 1873, pl. xxxix., fig. 7, p. 30.
Hamstead Series. Hamstead, I.W.

INDEX.

INDEX
to the
GEOLOGICAL MAP OF ENGLAND AND WALES
Published on the Scale of One Inch to a Mile
OLD SERIES



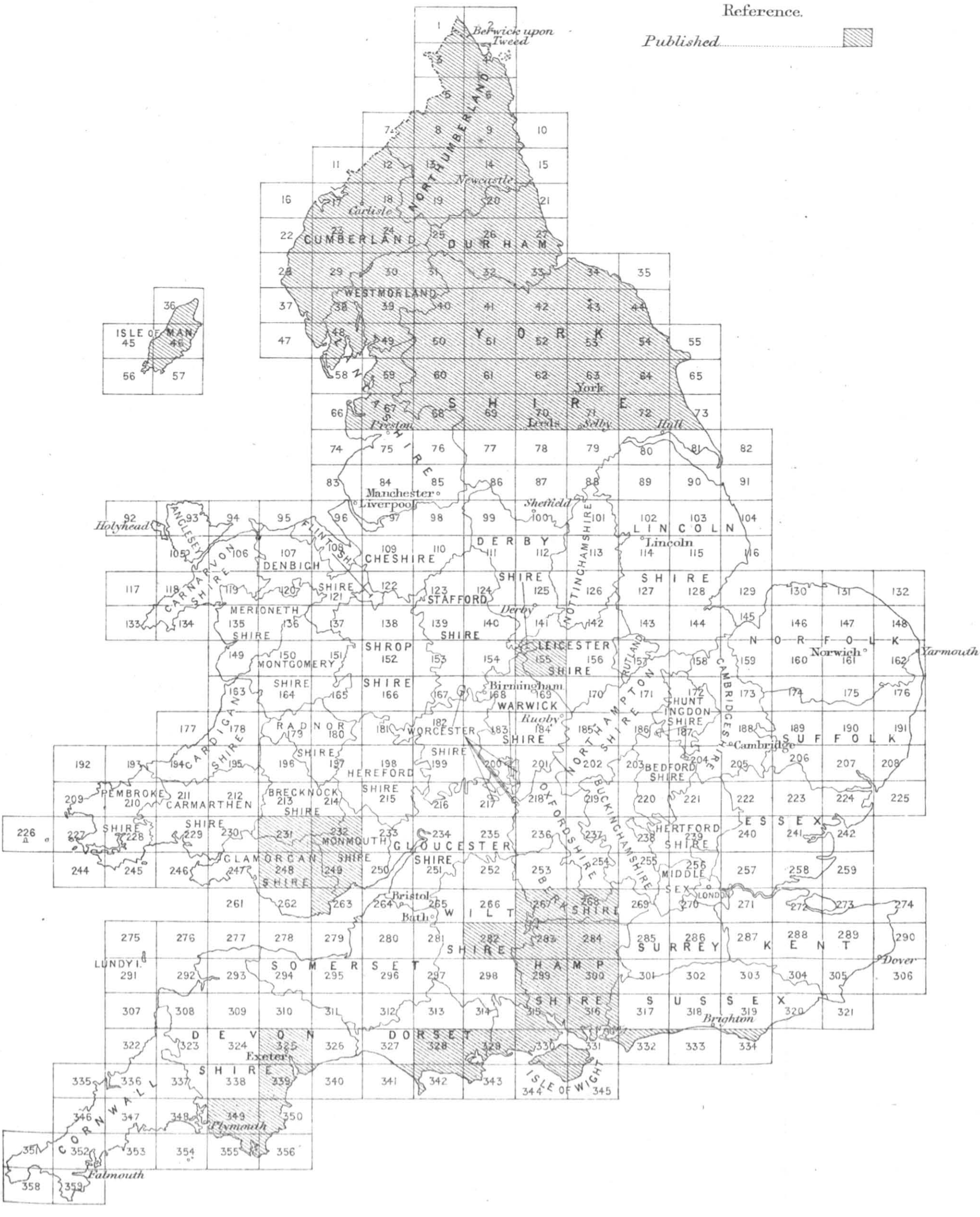
INDEX

to the

GEOLOGICAL MAP OF ENGLAND AND WALES

Published on the Scale of One Inch to a Mile

NEW SERIES



INDEX

to the

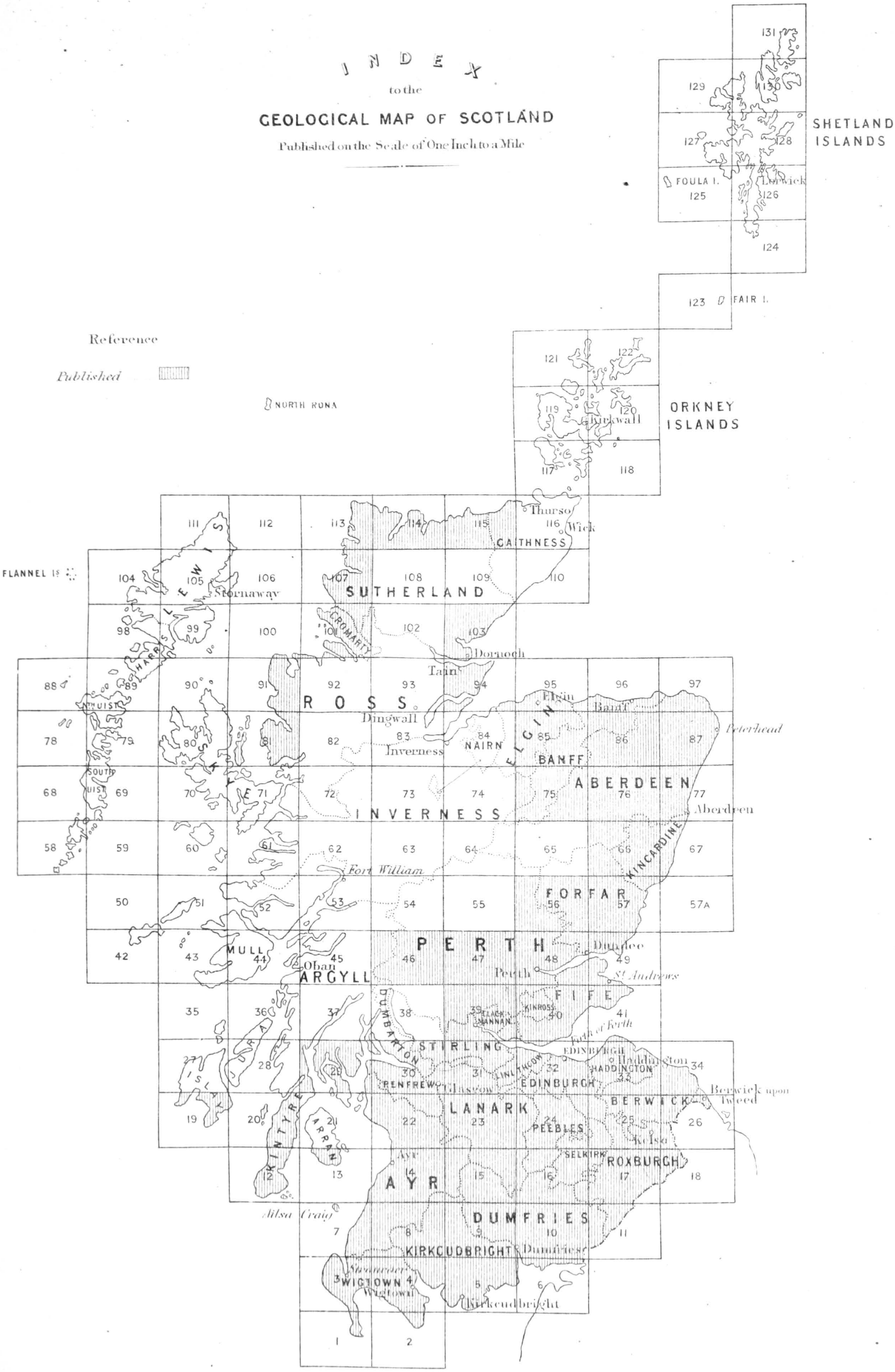
GEOLOGICAL MAP OF ENGLAND AND WALES

Published on the Scale of Four Miles to One Inch.

INDEX
to the
GEOLOGICAL MAP OF SCOTLAND
Published on the Scale of One Inch to a Mile

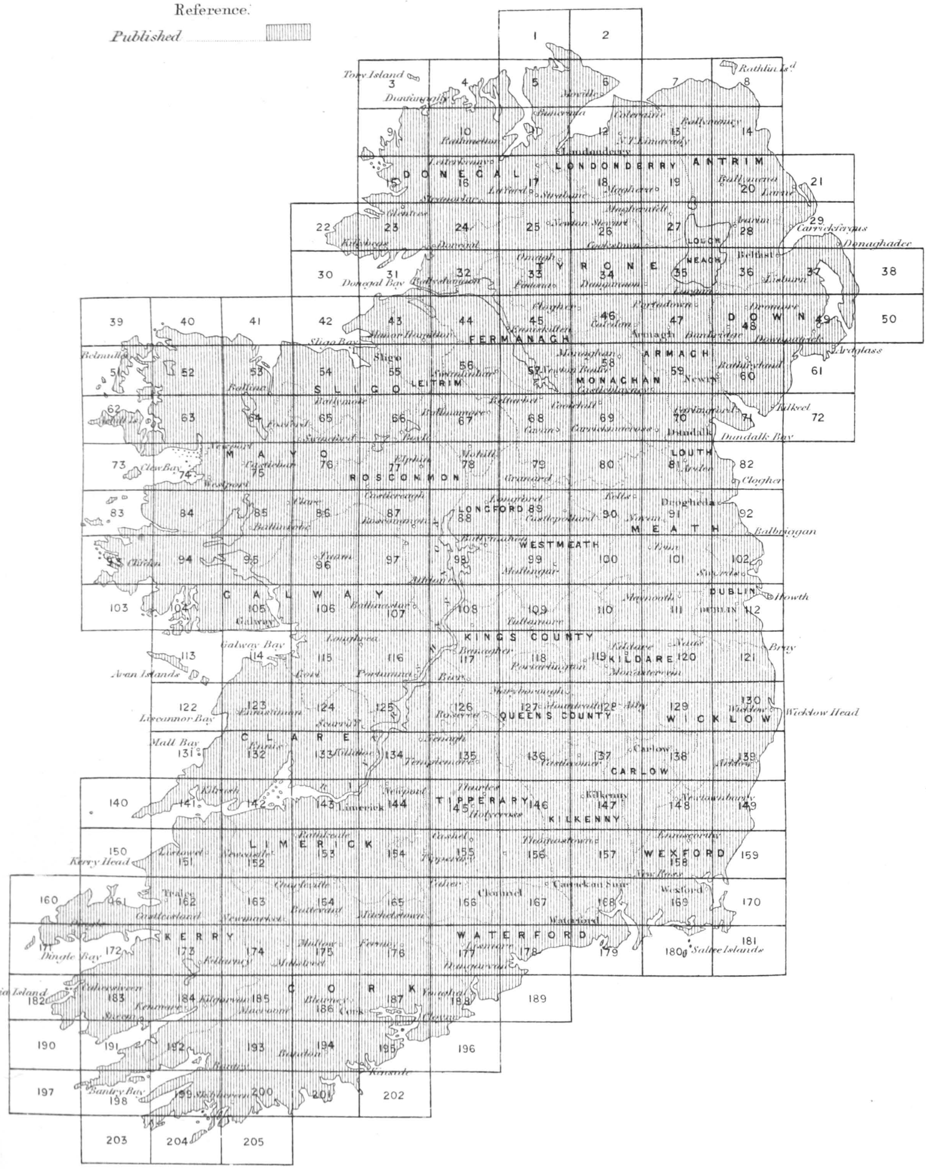
Reference

Published



INDEX
to the
GEOLOGICAL MAP OF IRELAND
Published on the Scale of One Inch to a Mile

Reference.
Published



GENERAL MEMOIRS OF THE GEOLOGICAL SURVEY.

SUMMARY of PROGRESS of the GEOLOGICAL SURVEY for 1897, 1898, and 1899. Each 1*s*.

The MEMOIRS of the GEOLOGICAL SURVEY of GREAT BRITAIN. Vol. I., 21*s*.; Vol. II. (in 2 Parts), 42*s*. N. WALES By SIR A. C. RAMSAY. App., by J. W. SALTER and R. ETHERIDGE. 2nd. Ed. 21*s*. (Vol. III. of Memoirs, &c.)

Guide to the GEOLOGY of LONDON and the NEIGHBOURHOOD. By W. WHITAKER. 5th Ed. 1*s*.

TERTIARY FLUVIO-MARINE FORMATION of the ISLE of WIGHT. By EDWARD FORBES. 5*s*.

The ISLE OF WIGHT. By H. W. BRISTOW. New Ed. By C. REID and A. STRAHAN. 8*s*. 6*d*.

The ISLE OF PURBECK AND WEYMOUTH. By A. STRAHAN. 10*s*. 6*d*.

The WEALD (PARTS of the COUNTIES of KENT, SURREY, SUSSEX, and HANTS). By W. TOPLEY. 17*s*. 6*d*

The TRIASSIC and PERMIAN ROCKS of the MIDLAND COUNTIES of ENGLAND. By E. HULL. 5*s*.

The FENLAND. By S. B. J. SKERTCHLY. 36*s*. 6*d*.

The MANUFACTURE of GUN FLINTS. By S. B. J. SKERTCHLY. 16*s*.

The SUPERFICIAL DEPOSITS of SOUTH-WEST LANCASHIRE. By C. E. DE RANCE. 10*s*. 6*d*.

NORTH DERBYSHIRE. By A. H. GREEN, C. LE NEVE FOSTER and J. R. DAKYNS. 2nd. Ed. By A. H. GREEN and A. STRAHAN. 5*s*. 6*d*.

BURNLEY COAL FIELD. By E. HULL, R. H TIDDEMAN [and Others]. 12*s*.

YORKSHIRE COALFIELD. By A. H. GREEN, R. RUSSELL [and Others]. 42*s*.

EAST SOMERSET and BRISTOL COALFIELDS. By H. B. WOODWARD. 18*s*.

WARWICKSHIRE COAL-FIELD. By H. H. HOWELL. 1*s*. 6*d*.

LEICESTERSHIRE COAL-FIELD. By EDWARD HULL. 3*s*.

ERUPTIVE ROCKS of BRENT TOR. By F. RUTLEY. 15*s*. 6*d*.

FELSITIC LAVAS of ENGLAND and WALES. By F. RUTLEY. 9*d*.

HOLDERNESS. By C. REID. 4*s*.

SOILS and SUB-SOILS from a SANITARY POINT of VIEW. By H. B. WOODWARD. 2*s*. 6*d*.

The WATER SUPPLY OF SUSSEX. By W. WHITAKER and C. REID. 3*s*.

The PLIOCENE DEPOSITS of BRITAIN. By C. REID. 5*s*. 6*d*.

The JURASSIC ROCKS OF BRITAIN.—Vol. I. YORKSHIRE, 8*s*. 6*d*., Vol. II. YORKSHIRE, Fossils, 12*s*. By C. FOX STRANGWAYS. Vol. III. LIAS OF ENGLAND (Yorkshire excepted). 7*s*. 6*d*. By H. B. WOODWARD. Vol. IV. The Lower Oolitic Rocks of England. 10*s*. By H. B. WOODWARD. Vol. V. The Middle and Upper Oolitic Rocks of England. 7*s*. 6*d*. By H. B. WOODWARD.

BRITISH ORGANIC REMAINS. DECADES I. to XIII., with 10 Plates each. Price 4*s*. 6*d*. each 4to; 2*s*. 6*d*. each 8vo.

MONOGRAPH I. On the Genus PTERYGOTUS. By T. H. HUXLEY, and J. W. SALTER. 7*s*.

MONOGRAPH II. On the Structure of the BELEMNITIDÆ. By T. H. HUXLEY. 2*s*. 6*d*.

MONOGRAPH III. On the CROCODILIAN REMAINS found in the ELGIN SANDSTONES. By T. H. HUXLEY. 14*s*. 6*d*.

MONOGRAPH IV. On the CHIMÆROID FISHES of the British Cretaceous Rocks. By E. T. NEWTON. 5*s*.

The VERTEBRATA of the FOREST RED SERIES of NORFOLK and SUFFOLK. By E. T. NEWTON. 7*s*. 6*d*.

The VERTEBRATA of the PLIOCENE DEPOSITS of BRITAIN. By E. T. NEWTON. 4*s*.

Museum Catalogues, &c.:—

HANDBOOK to the MUSEUM of PRACTICAL GEOLOGY. 6*d*.

HANDBOOK to the COLLECTION of BRITISH POTTERY and PORCELAIN. 1*s*.

FOSSILS:—CAMBRIAN and SILURIAN, 2*s*. 6*d*.; CRETACEOUS, 2*s*. 9*d*.; TERTIARY and POST-TERTIARY, 1*s*. 8*d*.

SHEET MEMOIRS OF THE GEOLOGICAL SURVEY.

1, 2, 7	GEOLOGY OF LONDON, &c. By W. WHITAKER. Vol. I., 6*s*. Vol. II., 5*s*.
4	FOLKESTON and RYE. By F. DREW. 1*s*.
34	PARTS of WILTS, and GLOUCESTERSHIRE. By A. C. RAMSAY, W. T. AVELINE, and E. HULL. 8*d*.
44	CHELTENHAM. By E. HULL. 2*s*. 6*d*.
45	BANBURY, WOODSTOCK, and BUCKINGHAM. By A. H. GREEN. 2*s*.
45 SW	WOODSTOCK. By E. HULL. 1*s*.
47	N.W. ESSEX & N.E. HERTS. By W. WHITAKER, W. H PENNING, W. H. DALTON, & F. J. BENNETT. 3*s* 6*d*.
48 SW	COLCHESTER. By W. H. DALTON. 1*s*. 6*d*.
48 SE	EASTERN END of ESSEX (WALTON NAZE and HARWICH). By W. WHITAKER. 9*d*.
48 NW, NE	IPSWICH, HADLEIGH, and FELIXSTOW. By W. WHITAKER, W. H. DALTON, & F. J. BENNETT. 2*s*.
49 S, 50 SE	ALDBOROUGH, &c. By W. H. DALTON. Edited, with additions, by W. WHITAKER. 1*s*.
49 N	SOUTHWOLD. By W. WHITAKER. 2*s*. 6*d*.
50 SW	STOWMARKET. By W. WHITAKER, F. J. BENNETT and J. H. BLAKE. 1*s*.
50 NW	DISS, EYE, &c. By F. J. BENNETT. 2*s*.
50 NE	HALESWORTH and HARLESTON. By W. WHITAKER and W. H. DALTON. 1*s*.
51 SW	CAMBRIDGE. By W. H. PENNING and A. J. JUKES-BROWNE. 4*s*. 6*d*.
51 SE	BURY ST. EDMUNDS and NEWMARKET. By F. J. BENNETT, J. H. BLAKE, and W. WHITAKER. 1*s*.
51 NE	PARTS of CAMBRIDGESHIRE and SUFFOLK. By W. WHITAKER [and Others]. 2*s*.
53 SE	PART of NORTHAMPTONSHIRE. By W. T. AVELINE and RICHARD TRENCH. 8*d*.
53 NE	PARTS of NORTHAMPTONSHIRE and WARWICKSHIRE. By W. T. AVELINE. 8*d*.
64	RUTLAND, &c. By J. W. JUDD. 12*s*. 6*d*.
65	S.W. NORFOLK and N. CAMBRIDGESHIRE. By W. WHITAKER S. B. J. SKERTCHLY, and A. J. JUKES-BROWNE. 3*s*.

66 NE, SE - NORWICH. By H. B. WOODWARD. 7*s.*

66 SW - - ATTLEBOROUGH. By F. J. BENNETT. 1*s.* 6*d.*

67 NW - - E. DEREHAM. By J. H. BLAKE. 1*s.* 6*d.*

67 - - - YARMOUTH and LOWESTOFT. By J. H. BLAKE. 2*s.*

68 E - - CROMER. By C. REID. 6*s.*

68 NW, SW - FAKENHAM, WELLS, &c. By H. B. WOODWARD. 2*s.*

69 - - - BORDERS OF THE WASH. By W. WHITAKER and A. J. JUKES-BROWNE. 3*s.*

70 - - - S.W. LINCOLNSHIRE, &c. By A. J. JUKES-BROWNE and W. H. DALTON. 4*s.*

71 NE - - NOTTINGHAM. By W. T. AVELINE. (2nd Ed.) 1*s.*

79 NW - - RHYL, ABERGELE, and COLWYN. By A. STRAHAN. (Notes by R. H. TIDDEMAN.) 1*s.* 6*d.*

79 SE - - FLINT, MOLD, and RUTHIN. By A. STRAHAN (Parts by C. E. DE RANCE). 4*s.* 6*d.*; *Supplement* 2*d.*

80 NW - - PRESCOT, LANCASHIRE. By E. HULL. (3rd Ed. With additions by A. STRAHAN.) 3*s.*

80 SW - - CHESTER. By A. STRAHAN. 2*s.*

81 NW, SW - STOCKPORT, MACCLESFIELD, CONGLETON, & LEEK. By E. HULL and A. H. GREEN. 4*s.*

82 SE - - PARTS of NOTTINGHAMSHIRE and DERBYSHIRE. By W. T. AVELINE. (2nd Ed.) 6*d.*

82 NE - - PARTS of NOTTINGHAMSHIRE, YORKSHIRE, and DERBYSHIRE. (2nd Ed.) By W. T. AVELINE. 1*s.*

83 - - - LINCOLN. By W. A. E. USSHER, A. J. JUKES-BROWNE, and A. STRAHAN. 3*s.*

84 - - - EAST LINCOLNSHIRE. By A. J. JUKES-BROWNE. 3*s.* 6*d.*

86 - - - N. LINCOLNSHIRE and S. YORKSHIRE. By W. A. E. USSHER [and Others]. 2*s.*

87 NW - - WAKEFIELD and PONTEFRACT. By A. H. GREEN. 6*d.*

87 SW - - BARNSLEY. By A. H. GREEN. 9*d.*

88 SW - - OLDHAM. By E. HULL. 2*s.*

88 SE - - PART of the YORKSHIRE COAL-FIELD. By A. H. GREEN, J. R. DAKYNS and J. C. WARD. 1*s.*

88 NE - - DEWSBURY, &c. By A. H. GREEN, J. R. DAKYNS, J. C. WARD, and R. RUSSELL. 6*d.*

89 SE - - BOLTON, LANCASHIRE. By E. HULL. 2*s.*

90 SE - - The COUNTRY between LIVERPOOL and SOUTHPORT. By C. E. DE RANCE. 3*d.*

90 NE - - SOUTHPORT, LYTHAM, and SOUTH SHORE. By C. E. DE RANCE. 6*d.*

91 SW - - The COUNTRY between BLACKPOOL and FLEETWOOD. By C. E. DE RANCE. 6*d.*

91 NW - - SOUTHERN PART of the FURNESS DISTRICT in N. LANCASHIRE. By W. T. AVELINE. 6*d.*

92 SE - - BRADFORD and SKIPTON. By J. R. DAKYNS, C. FOX-STRANGWAYS, R. RUSSELL, and W. H. DALTON. 6*d.*

93 NW - - NORTH and EAST of HARROGATE. By C. FOX-STRANGWAYS. 6*d.*

93 NE - - The COUNTRY between YORK and MALTON. By C. FOX-STRANGWAYS. 1*s.* 6*d.*

93 NW - - N. and E. of LEEDS, and near TADCASTER. By W. T. AVELINE, A. H. GREEN (and others).

93 SE, 94 W - COUNTRY between YORK & HULL. By J. R. DAKYNS, C. FOX-STRANGWAYS, and A. G. CAMERON. 1*s.*

94 NW - - DRIFFIELD. By J. R. DAKYNS and C. FOX-STRANGWAYS. 9*d.*

94 NE - - BRIDLINGTON BAY. By J. R. DAKYNS and C. FOX-STRANGWAYS. 1*s.*

95 SW, SE - SCARBOROUGH and FLAMBOROUGH HEAD. By C. FOX-STRANGWAYS. 1*s.*

95 NW - - WHITBY and SCARBOROUGH. By C. FOX-STRANGWAYS and G. BARROW. 1*s.* 6*d.*

96 SE - - NEW MALTON, PICKERING, and HELMSLEY. By C. FOX-STRANGWAYS. 1*s.*

96 NE - - ESKDALE, ROSEDALE, &c. By C. FOX-STRANGWAYS, C. REID, and G. BARROW. 1*s.* 6*d.*

96 NW, SW - NORTHALLERTON and THIRSK. By C. FOX-STRANGWAYS, A. G. CAMERON, and G. BARROW. 1*s.* 6*d.*

97 SW - - INGLEBOROUGH. By J. R. DAKYNS, R. H. TIDDEMAN, W. GUNN, and A. STRAHAN. 2*s.*

97 NW - - MALLERSTANG. By J. R. DAKYNS, R. H. TIDDEMAN (and others). 3*s.* 6*d.*

98 SE - - KIRKBY LONSDALE and KENDAL. By W. T. AVELINE, T. MC K. HUGHES, and R. H. TIDDEMAN. 2*

98 NE - - KENDAL. By W. T. AVELINE and T. MC K. HUGHES. 2nd Ed. by A. STRAHAN. 2*s.*

101 SE - - NORTHERN PART of the ENGLISH LAKE DISTRICT. By J. C. WARD. 9*s.*

102 SW - - APPLEBY, ULLSWATER, and HAWESWATER. By J. R. DAKYNS, R. H. TIDDEMAN, and J. G. GOODCHILD. 1*s.* 6*d.*

104 SW, SE - NORTH CLEVELAND. By G. BARROW. 1s. 6d.

107 - - CARLISLE. By T. V. HOLMES. 1*s.* 3*d.*

108 SE - - OTTERBURN and ELSDON. By HUGH MILLER. 2*s.* 6*d.*

108 NE - - CHEVIOT HILLS. By C. T. CLOUGH. 1*s.* 6*d.*

108 SW - - PLASHETTS and KIELDER. By C. T. CLOUGH. 1*s.*

110 SW - - WOOLER and COLDSTREAM. By W. GUNN and C. T. CLOUGH. 1 . 6*d.*

100 NW - NORHAM and TWEEDMOUTH. By W. GUNN. 6*d.*

110 NE - - COAST south of BERWICK-ON-TWEED. By W. GUNN. 9*d.*

110 SE - - BELFORD, HOLY ID., and FARNE ISLANDS. By W. GUNN. 2*s.* 6*d.*

249 (New Series) NEWPORT, MON. By A. STRAHAN.

328 („) DORCHESTER. By C. REID. 1*s.*

329 („) BOURNEMOUTH. By C. REID. 4*d.*

332 („) BOGNOR. By C. REID. 6*d.*

334 („) EASTBOURNE. By C. REID. 6*d.*

COAL-FIELDS AND OTHER MINERAL DISTRICTS.—Scale, six inches to a mile.

The Coal-fields and other mineral districts of the N. of England are in part published on a scale of six inches to a mile, at 4*s.* to 6*s.* each. M.S. Coloured Copies of other six-inch maps, not intended for publication, are deposited for reference in the Geological Survey Office, 28, Jermyn Street, London.

THE IRON ORES OF GREAT BRITAIN.

Part I. The North and North Midland Counties of England (*Out of print*). Part II. South Staffordshire. Price 1*s.* Part III. South Wales. Price 1s. 3*d.* Part IV. The Shropshire Coal-field and North Staffordshire. 1*s.* 3*d.*

MEMOIRS OF THE GEOLOGICAL SURVEY.

ENGLAND AND WALES.

THE GEOLOGY OF THE SOUTH WALES COAL-FIELD.

PART II.

THE COUNTRY AROUND

ABERGAVENNY,

BEING AN ACCOUNT OF THE REGION COMPRISED IN SHEET 232 OF THE MAP.

BY

AUBREY STRAHAN, M.A., F.G.S.,

AND

WALCOT GIBSON, F.G.S.,

WITH NOTES BY

J. R. DAKYNS, M.A., AND PROF. W. W. WATTS, M.A., SEC. G.S.

PUBLISHED BY ORDER OF THE LORDS COMMISSIONERS OF HER MAJESTY'S TREASURY.

LONDON:

PRINTED FOR HER MAJESTY'S STATIONERY OFFICE,

BY WYMAN AND SONS, LIMITED, FETTER LANE, E.C.

And to be purchased, either directly or through any Bookseller, from

EYRE & SPOTTISWOODE, EAST HARDING STREET, FLEET STREET, E.C.; or

JOHN MENZIES & Co., ROSE STREET, EDINBURGH, and

90, WEST NILE STREET, GLASGOW; or

HODGES, FIGGIS, & Co., Limited, 104, GRAFTON STREET, DUBLIN.

1900.

Price Two Shillings.

LIST OF MAPS, SECTIONS, AND OTHER PUBLICATIONS OF THE GEOLOGICAL SURVEY OF ENGLAND AND WALES.

THE Maps are those of the Ordnance Survey, geologically coloured by the Geological Survey of the United Kingdom, under the Superintendence of Sir ARCH. GEIKIE, D.C.L., LL.D., F.R.S., Director General.

(For Maps, details of Sections, and Memoirs issued by the Geological Survey, *see* "Catalogue.")

ENGLAND AND WALES.—(Scale 1 inch to a mile.)

Maps marked * are also published as Drift Maps. Those marked † are published only as Drift Maps.

Sheets 3*, 5, 6*, 7*, 8*, 9, 11 to 22, 25, 26, 30, 31, 33 to 37, 40, 41, 44, 47*, 64*, 65†, 69†, 70*, 83*, 86*, price 8*s.* 6*d.* each.

Sheet 4, 5*s.* Sheets 2*, 23, 24, 27 to 29, 32, 38, 39, 58, 84†, 85†, 4*s.* each.

Sheets divided into quarters; all at 3*s.* each quarter-sheet, excepting those in brackets, which are 1*s.* 6*d.* each.

1*, 42, 43, 45, 46, NW, SW, NE*, SE*, 48, NW†, SW*, NE†, (SE*), (49†), 50†, 51*, 52 to 57, (57 NW), 59 to 63, 66 SW†, NE†, NW*, SE†, 67 N†, (S†), 68 E†, (NW†), SW†, 71 to 75, 76 (N), S, (77 N), 78, 79, NW*, SW, NE*, SE*, 80 NW*, SW*, NE*, SE*, 81 NW*, SW, NE, SE, 82, 83*, 87, 88, NW, SW*, NE, SE, 89 NW*, SW*, NE, SE*, 90 (NE*), (SE*), 91, (NW*), (SW*), NE*, SE*, 92 NW*, SW*, NE, SE, 93 NW, SW, NE*, SE*, 94 NW†, SW†, (NE†), SE†, 95 NW*, NE*, (SE*), 96 NW*, SW*, NE*, SE*, 97 NW*, SW*, NE*, SE, 98 NW, SW, NE*, SE, 99 (NE*), (SE*), 100*, 101 SE, NE*, NW*, SW*, 102 NW*, NE*, SW*, SE*, 103*, 104*, 105 NW*, SW*, (NE*), SE*, 106 NW*, SW*, NE*, SE*, 107 SW†, NE*, SE* 108 SW*, NE*, SE*, 109 NW*, SW*, SE*, 110 (NW*), (NE*), SE*, SW*.

New Series.—I. of Man*, 36, 45. 46, 56, 57, 8*s.* 6*d.* I. of Wight, with Mainland*, 330, 331, 344, 345, 8*s.* 6*d.* 155*, 203†, 231*, 232*, 248*, 249*, 263*, 267†, 268*, 282†, 283†, 284†, 299†, 300†, 315†, 316†, 325†, 328†, 329*, 339†, 330*, 331*, (332*), (333*), 334*, 339†, (340†), (341†), 342†, 343†, 349†, 350†, 355†, (356†). Price 3*s.* each, excepting those in brackets which are 1*s.* 6*d.* each.

GENERAL MAP:—(Scale 4 miles to 1 inch.)

ENGLAND AND WALES.—Sheet 1 (Title); 2 (Northumberland, &c.); 3 (Index of Colours); 4 (I. of Man); 5 (Lake District); 6 (E. Yorkshire); 7 (N. Wales); 8 (Central England); 9 (Eastern Counties); 10 (S. Wales and N. Devon); 11 (W. of England and S.E. Wales); 12 (London Basin and Weald); 13 (Cornwall, &c.); 14 (S. Coast, Torquay to I. of Wight); 15 (S. Coast, Havant to Hastings). *New Series, printed in colours,* sheet 1, 2s.; sheets 2 to 15, 2*s.* 6*d.* each.

HORIZONTAL SECTIONS.

1 to 140, 146 to 148, England, price 5*s.* each.

VERTICAL SECTIONS.

1 to 82, England, price 3*s.* 6*d.* each.

COMPLETED COUNTIES OF ENGLAND AND WALES, on a Scale of 1 inch to a mile
Old Series.

Sheets marked * have Descriptive Memoirs. Sheets or Counties marked † are illustrated by General Memoirs.

ANGLESEY†,—77 N, 78.
BEDFORDSHIRE,—46 NW, NE, SW†, SE†, 52 NW, NE, SW, SE.
BERKSHIRE,—7*, 8†, 12*, 13*, 34*, 45 SW*.
BRECKNOCKSHIRE†,—36, 41, 42, 56 NW, SW, 57 NE, SE.
BUCKINGHAMSHIRE,—7*, 13*, 45* NE, SE, 46 NW, SW†, 52 SW.
CAERMARTHENSHIRE†,—37, 38, 40, 41, 42 NW, SW, 56 SW, 57 SW, SE.
CAERNARVONSHIRE†,—74 NW, 75, 76, 77 N, 78, 79 NW, SW.
CAMBRIDGESHIRE†,—46 NE, 47*, 51*, 52 SE, 64*.
CARDIGANSHIRE†,—40, 41, 56 NW, 57, 58, 59 SE, 60 SW.
CHESHIRE,—73 NE, NW, 79 NE, SE, 80, 81 NW*, SW*, 88 SW.
CORNWALL†,—24†, 25†, 26†, 29†, 30†, 31†, 32†, & 33†.
CUMBERLAND,—98 NW, SW*, 99, 101, 102, NE, NW, SW*, 106 SE, SW, NW, 107.
DENBIGH†,—73 NW, 74, 75 NE, 78 NE, SE, 79 NW, SW, SE, 80 SW.
DERBYSHIRE†,—62 NE, 63 NW, 71 NW, SW, SE, 72 NE, 72 SE, 81, 82, 88 SW, SE.
DEVONSHIRE†,—20†, 21†, 22†, 23†, 24†, 25†, 26†, & 27†.
DORSETSHIRE,—15, 16, 17, 18, 21, 22.
DURHAM,—102 NE, SE, 103, 105 NE, SE, SW, 106 SE.
ESSEX,—1*, 2*, 47*, 48*.
FLINTSHIRE†,—74 NE, 79.
GLAMORGANSHIRE†,—20, 36, 37, 41, & 42 SE, SW.
GLOUCESTERSHIRE†,—19, 34*, 35, 43, NE, SW, SE, 44*.
HAMPSHIRE,—8†, 9†, 10*, 11†, 12*, 14, 15, 16.
HEREFORDSHIRE,—42 NE, SE, 43, 55, 56 NE, SE.
HERTFORDSHIRE,—1† NW, 7*, 46, 47*.
HUNTINGDON,—51 NW, 52 NW, NE, SW, 64*, 65.
KENT†,—1† SW & SE, 2†, 3†, 4*, 6*.
LANCASHIRE,—79 NE, 80 NW*, NE, 81 NW, 88 NW, SW†, 89, 9[illegible], 91, 92 SW, 98.
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, 83, 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.

MEMOIRS OF THE GEOLOGICAL SURVEY.

ENGLAND AND WALES.

THE GEOLOGY OF THE SOUTH WALES COAL-FIELD.

PART II.

THE COUNTRY AROUND

ABERGAVENNY,

BEING AN ACCOUNT OF THE REGION COMPRISED IN SHEET 232 OF THE MAP.

BY

AUBREY STRAHAN, M.A., F.G.S.,

AND

WALCOT GIBSON, F.G.S.,

WITH NOTES BY

J. R. DAKYNS, M.A., AND PROF. W. W. WATTS, M.A., SEC. G. S

PUBLISHED BY ORDER OF THE LORDS COMMISSIONERS OF HER MAJESTY'S TREASURY.

LONDON:

PRINTED FOR HER MAJESTY'S STATIONERY OFFICE,
BY WYMAN AND SONS, LIMITED, FETTER LANE, E.C.

And to be purchased, either directly or through any Bookseller, from
EYRE & SPOTTISWOODE, EAST HARDING STREET, FLEET STREET, E.C.; or
JOHN MENZIES & Co., ROSE STREET, EDINBURGH, and
90, WEST NILE STREET, GLASGOW; or
HODGES, FIGGIS, & Co., Limited, 104, GRAFTON STREET, DUBLIN.

1900.

Price Two Shillings.

A.P.

TABLE OF CONTENTS.

3610. Wt. 3230. 500—9/00. Wy. & S.

LIST OF ILLUSTRATIONS.

EXPLANATION OF PLATE I.

Figs. 1 and 2. Dark oolite below the white oolite, near Blackrock, Clydach Valley. Crinoid ossicle and oolitic grains in crystalline carbonate of lime (p. 29). Magnified 31 diameters. Oolitic grains enclosing nuclei of calcite, shell-fragments, &c. Magnified 21 diameters.

Fig. 3. Sandy oolitic limestone above the Llangattwg Quarries. Oolitic grains with angular grains of quartz as nuclei (p. 30). Magnified 26 diameters.

Fig. 4. Partially dolomitised oolite. West end of Clydach Tunnel (pp. 32–34). Magnified 21 diameters.

Figs. 5 and 6. Completely dolomitised oolite, Cwm Ifor, near the Tumble (pp. 34, 35). Magnified 21 diameters.

Figs. 7 and 8. Fine-grained oolite, partially dolomitised, near Clydach Quarry (p. 35). Magnified 27 diameters.

PREFACE.

THE first part of the Descriptive Memoir on the Geology of the South Wales Coalfield, embracing the country around Newport, was published last autumn. In the Preface to it some account was given of the history of the mapping of South Wales by the Geological Survey. The present publication forms the second part of the same Memoir. It describes the extreme north-eastern corner of the coal-producing area, and includes also a considerable portion of the great tract of Old Red Sandstone which extends over the counties of Hereford, Brecknock, and Monmouth. It has been written mainly by Mr. A. Strahan, who surveyed the south-eastern part of the map (Sheet 232) and supervised the mapping of the rest of the ground. His colleagues who were associated with him in the field-work have supplied him with descriptions of parts of the districts mapped by them. Thus, Mr. W. Gibson, among other contributions, has furnished an account of the important mining district which extends from Blaenavon to Rhymney, while Mr. Dakyns' notes describe the evidence on which his mapping of the Carboniferous Limestone and Old Red Sandstone of the northern part of the map was founded.

The subdivision of the strata which was adopted for Part I. has been continued through the area described in the following chapters. The Old Red Sandstone includes two main subdivisions, the lower consisting chiefly of marls with their "cornstones," and the upper of red sandstones and conglomerates in which "cornstones" are less common. The conglomerates, however, so abound in the upper part of the sandstone-subdivision that they have been separately distinguished on the map by colours, though it is doubtful whether this distinction will be practicable in the region lying further west.

This classification agrees in the main with that adopted by the Rev. W. S. Symonds in his admirable work the "Record of the Rocks." To the same observer also we are indebted for much of our information concerning the fossils by which it is proved that this part of the kingdom contains representations of both the Upper and Lower Old Red Sandstone, though their existence had already been demonstrated by Murchison. The great unconformability, however, which separates these groups in Scotland and Ireland has not been detected in Monmouthshire and South Wales, insomuch that it is even a matter of doubt where to draw a line between them.

The Carboniferous Limestone, as developed in this part of South Wales, displays the phenomenon of dolomitisation with unusual clearness. By collecting specimens at definite intervals, every stage in the alteration of an oolitic limestone into a crystalline dolomite has been illustrated. The examination of thin sections of these rocks under the microscope was one of the last of the many important investigations carried out by Prof. W. W. Watts while engaged on the staff of the Geological Survey.

The Millstone Grit has long been known from the researches of Mr. W. Adams and Dr. G. P. Bevan to yield an interesting marine fauna. The partial survival of marine forms in the lower part of the Coal Measures, and their gradual replacement by estuarine forms, throws an interesting light on the change of conditions which led to the deposition of the coal-bearing strata in this part of the country.

The Coal Measures, in the lower part of which the argillaceous ironstones so much in request in the early part of the century abound, lie at a gentle angle, and are accessible over broad outcrops. The ores were readily worked, therefore, in open-air excavations or "patch-works," the great size of which bears witness to the former importance of the industry. Though these local ores are no longer worked, a short account of them is given in the following pages, in view of the possibility of their being again used at some future date. The coals, on the other hand, are more extensively worked now than formerly, and are being followed southwards under the deeper parts of the basin. The northern margin of the Pennant Grit forms one of the most conspicuous physical features of the district, and in its deep indentations contrasts strongly with the escarpment formed by the more highly inclined strata of the south crop.

Two editions of the map are issued. One of these represents the older formations; the other shows also the Superficial Deposits (Drift Edition). The distribution of these drifts indicates that the principal water-partings of the present day formed ice-partings in the Glacial Period, but the fact that the watersheds have been overridden by the ice in places points to the extensive scale of the glaciation. Small but interesting moraines in the deeper cwms remain as relics of the latest glaciers.

Copies of the original field-maps, on the scale of six inches to a mile, are deposited in the Geological Survey Office here, where they can be consulted, or whence MS. copies can be supplied if desired.

The principal shaft-sections in the area described in the present instalment of the Memoir have been drawn to one scale and arranged to form Sheet 81 of the Vertical Sections, published separately by the Geological Survey.

We have again to thank Colliery Managers, Mining Engineers, and Surveyors for free access to plans and for their unvarying courtesy in placing at our disposal their great store of mining information.

ARCH. GEIKIE,
Director General.

Geological Survey Office,
28, Jermyn Street, London,
16th June, 1900.

GEOLOGY

OF THE COUNTRY AROUND

ABERGAVENNY.

CHAPTER I.

INTRODUCTION.

Physical Features.

This sheet includes about 60 square miles of the north-eastern corner of the South Wales Coal Field, and a length of about 18 miles of the north crop of the Millstone Grit and Carboniferous Limestone. The remainder of the area is occupied by Old Red Sandstone and by the northern part of the Usk Inlier of Upper Silurian Rocks. Unlike the south crop, the strata rise at a gentle and fairly uniform angle from the great syncline of the Coal Basin towards the north, and present a series of bold and characteristic escarpments in that direction. The small portion of the Black Mountains of Old Red Sandstone which falls within the region includes the Sugar Loaf, 1,955 feet; and the outlying hills of Skirrid-fawr, 1,596 feet, and Skirrid-fach, 886 feet. The outcrop of this formation, however, which is generally marked along the north crop by high unenclosed moorlands, is here deeply trenched by the valley of the Usk.

On its south side the Usk Valley is overlooked from a height of 1,000 to 1,500 feet by the escarpment of the Carboniferous Limestone and Millstone Grit. The northward face of this great feature is extremely bold, but to the south the Millstone Grit forms long and gentle dip-slopes descending to the margin of the Coal Measures. The slopes, which are uncultivated, lie wholly above the 1,200-foot contour, and include as their highest points Blorenge, 1,834 feet; Mynydd Llangattwg, 1,694 feet; Mynydd Llangynidr, 1,750 feet; and Cefn Pyllau-duon, 2,000 feet. Except at Clydach, where it is breached by a stream descending eastwards from Brynmawr, the escarpment maintains a fairly even curve round the north-eastern end of the Coal Basin.

Within this escarpment, and strongly contrasting with it in the form of its margin, we encounter the mountain-land formed by the Pennant Grit. In elevation these moorlands scarcely fall short of those of the Millstone Grit, for they include Coity Mountain, 1,905 feet; Mynydd Carn-y-cefn, 1,806 feet; Cefn Manmoel, 1,511 feet; Bedwellty Mountain, 1,607 feet: Cefn-y-Brithdir, 1,460 feet; and Gelligaer Common, 1,570 feet. But, unlike the outer escarpment, this inner range of moorlands has been so deeply indented by a series of north and south valleys that it may be described as dying away northwards in a long series of narrow, flat-topped hills. The sides of the ridges, however, are remarkably free from side-valleys, and the outcrops scarcely waver from a straight line in their descent southwards..

The drainage of the area is effected partly by the Usk, which skirts the northern margin of the Carboniferous area, and gathers the streams from the Old Red Sandstone area. The Carboniferous tract is drained by a series of rivers which take their rise on the back of the Millstone Grit escarpment and flow southwards across the Coal Field to the Bristol Channel. These include the Afon Lwyd, the Ebbw-fach, the Ebbw, the Sirhowy, the Rhymney, the Bargoed Rhymney, and the Bargoed Taff. It may be noticed that these rivers persist in their southward courses regardless of the geological structure. Thus the Usk traverses the centre of the dome of upheaval which brings the Silurian rocks to the surface, while the others cut directly across the great Pennant scarp and the syncline of the Coal Field, and, moreover, cross the great north-north-westerly system of faults obliquely without making any attempt to follow it. The Clydach, a small tributary of the Usk, gives an interesting example of the robbing of a watershed of an old river by a cross-stream of more recent date, as described on p. 93.

Classification.

Though the thickness of strata exposed within the limits of this map can hardly fall short of 6,000 feet, we have failed at present to find any important break. A fairly sharp plane of demarcation divides the Silurian and Old Red beds, but there is apparently no want of parallelism; and again, though there is no doubt that the red strata include representatives of both the Upper and Lower Old Red Sandstone, we have found no trace of the great discordance which separates those two groups in other parts of the Kingdom. In their upper part the red sandstones graduate up into the Carboniferous, and in that great system there is a perfect passage from the lowest limestone to the highest Coal Measures. In the following table will be found the subdivisions into which this great mass of sediment has been split up, together with such Superficial Deposits as are shown upon the map:—

Table of Strata.

Alluvium Peat River Gravels (Terraces)	RECENT AND POST-GLACIAL.
Boulder Clay or Gravelly Till and contemporaneous Sand and Gravel	GLACIAL.

Sandstones and Shales with the Mynyddislwyn Vein at their base Pennant Grit with the Tillery Vein at its base Lower or Steam-Coal Series with the Garw (Rough) Coal at its base	COAL MEASURES.
Grit (Farewell Rock) Shale Grit	MILLSTONE GRIT.
Limestone with thin impersistent sand-stones Shale, Limestone — Lower Limestone Shales	CARBONIFEROUS LIMESTONE.
Red sandstones with grey grits and quartz conglomerates Red sandstones with an occasional limestone (cornstone) Red Marls with some bands of cornstone	OLD RED SANDSTONE.
Ludlow Group Wenlock Limestone Wenlock Shale	UPPER SILURIAN

CHAPTER II.

UPPER SILURIAN ROCKS.

The Usk Inlier of Silurian Rocks appears to be truncated towards the north-west by a fault or a belt of faulty ground, but the rock is so thickly overspread by glacial gravels that the details of the structure will never be ascertained. About the fault which throws Old Red marls against the Ludlow and Wenlock beds south of Littlemill there is no doubt, for it can be traced yard by yard through the upper part of the thick woods which clothe the red marl slopes, both in Sheet 249* and in the present map. Again between the small exposure of fossiliferous shales and sandstones in the railway to Abergavenny and the red marl of Littlemill there is probably a south-easterly downthrow, for red marl has been dug within 100 yards of the cutting. Lastly, the high easterly dip of the Silurian rocks of this cutting would carry them far over the red marl of Mamhilad and Goytre, and proves the intervention of a fault. The line of disturbance thus indicated is a direct continuation of the great upturn which passes through Pontypool Road Station and thence along the south-eastern lip of the Coal Basin.† It varies but little from a direction S. 32 W., which is almost exactly at right angles to the great system of N.N.W. faults.

The rocks consist chiefly of mudstones, more or less sandy in parts, or even interbedded with fine-grained olive-green sandstones towards the top.‡ There is perfect conformity from top to bottom of the series exposed in this inlier, but an impersistent limestone which is supposed to represent the Wenlock Limestone provides the means of dividing it into two groups which would thus correspond to the Ludlow Beds and Wenlock Shale of other districts.

Wenlock Limestone and Shale.

The limestone was formerly used extensively for lime-burning, but the kilns are abandoned, and a few only of the old quarries are kept open for road-metal. At Ton the stone was followed underground in a series of picturesque caves and galleries. It is overlain by mudstones more or less packed with oval concretions of limestone; these pass down into a rock containing but little mud, and which may be described therefore as a nodular limestone, or even into a pure calcite-rock devoid of nodular structure. The base of the rock is rarely visible, but its thickness in the present area seems not to exceed 15 feet, and is often much less. Unlike the limestones in the Old Red Sandstone it is crowded with organic remains, among which fragments of crinoids and corals are the most abundant.

---

* Geology of Newport, Mon. (Geol. Survey Memoir), p. 8. † Ib., p. 19.

‡ A fact which led to part of the strata of the Usk Inlier being originally classed as Caradoc. This was shown to be erroneous by J. Phillips. Geol. Survey Memoirs, vol. ii., part i. pp. 201, 202.

In the absence of the limestone, the boundary between the Ludlow and Wenlock strata becomes indefinite. At Rhadyr the horizon seems to be marked by a thin impure encrinital band, and north of Trostrey by mudstones with numerous layers of nodular limestone from 1 to 2 inches thick and 2 to 4 inches apart. These can be traced by the help of old limestone-pits to the banks of the Usk, and are then lost to sight under Glacial gravels.

LUDLOW BEDS.

The strata assigned to this group crop on either side of the main anticlinal axis of the Usk Inlier. The fine-grained sandstones already referred to are confined to the upper part of the group; downwards the mudstones contain nodular concretions of limestone and thus graduate into the Wenlock Limestone, which however is itself impersistent and may be regarded rather as a series of lenticular masses appearing more or less exactly along one horizon. In the Glascoed outcrop the best sections of the upper part of the group occur along a lane close to the red marl fault; the lower beds are repeatedly exposed to view along the line of old limestone-quarries which passes near Ton Church.

The eastern crop of the Ludlow group crosses the Usk at Rhadyr Mill and runs up to Clytha. There are many old pits showing mudstones with oval pebble-like nodules of limestone and a good section of even-bedded sandy shales and mudstones in the high road at Clytha Castle. These lie near the top of the group, but gravels hide the actual junction with the Old Red Sandstone, and an obscure exposure 300 yards south of the road shows merely a rubble of red and yellow sandstone above the Ludlow mudstones. The top of the group occurs again at Hill Farm on Trostrey Hill, just outside the margin of the map, where there is a small outlier of Old Red Sandstone.

It was considered by Phillips that "the Silurian series of Usk presents interesting points of research, in the very easy gradation by which it changes into the Old Red series."* This observation rested on the fact that some of the Upper Ludlow sandstones are brown and micaceous, and not strikingly dissimilar to the sandstones included in the Old Red marls. Jukes writing later did not endorse this view, and in fact stated that the Usk strata contained no red beds and showed no gradation up into the Old Red Sandstone.† The result of the resurvey has been to confirm Jukes, and to show that there is a well-defined plane up to which a Ludlow fauna and a Ludlow type of sediment extends, while above it the Old Red type with Lower Old Red fossils only have been recognised. So far as the Usk Inlier is concerned there is no alternation of the two types of sediment or fauna, nor even a gradation from one to the other.

A complete list of the fossils from the Silurian Rocks of the Usk Inlier is given in the Memoir on the Geology of Newport, Mon., pp. 9–15.

---

* Memoirs of the Geological Survey, vol. ii., pt. 1, pp. 202, 203.
† *Brit. Assoc. Rep.* for 1857, Trans. Sects. p. 74.

CHAPTER III

OLD RED SANDSTONE.

The characteristic features presented by the Old Red Sandstone are well exhibited in the neighbourhood of Abergavenny (Fig. 1). The formation consists generally of two groups of strata, the upper composed chiefly of sandstones and the lower chiefly of marls. To the upper is due the escarpment which forms so to speak the pedestal on which the Carboniferous Limestone stands, and the moorlands which extend northwards from Abergavenny; while the marls, more or less overspread by Drift, underlie the pastoral land south and east of that place. A third subdivision, however, seemed feasible, for some quartz-conglomerates formed a marked feature in the upper part of the sandstone-group in parts of the South Crop, though they become insignificant westwards and even disappear altogether. The prevalence, moreover, of conglomerates of this type and of certain yellow and grey sandstones in the upper part of the formation is not without significance, for it was in them that all the Upper Old Red fossils yet recorded from South Wales occurred. They may be presumed, therefore, to correspond to the "yellow flags" or Kiltorcan Beds of Ireland and the Dura Den beds of Scotland.

But as will be shown later on the South Wales sequence includes representatives of both the Upper and Lower Old Red Sandstone of Scotland and Ireland. The two groups are violently unconformable in those countries, yet no break in the Welsh sequence has been detected. Whether therefore the "grey grits and conglomerates" exactly correspond to the Upper Old Red Sandstone, or whether some of the underlying red sandstones should also be included, remains a matter of doubt.

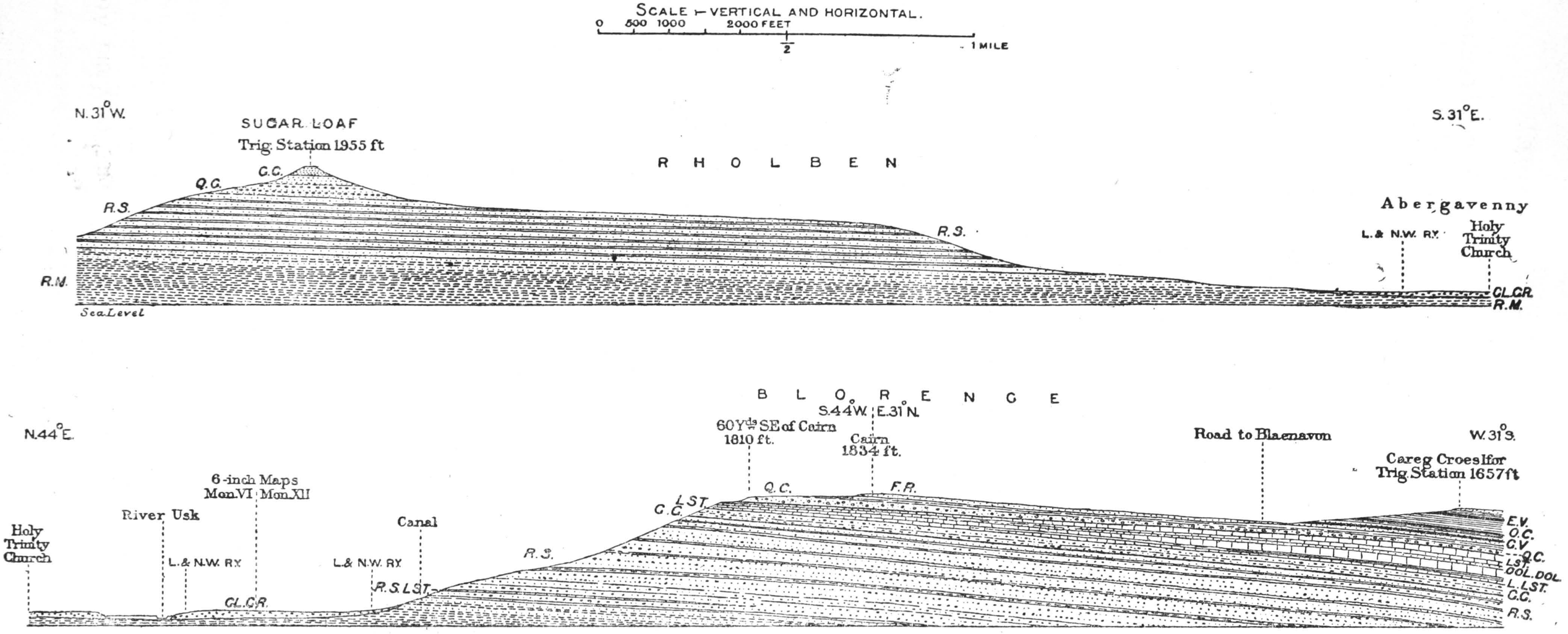
The "cornstones" or concretionary limestones, so well-known in the Old Red Sandstone, prevail chiefly in the lower marly subdivision, but are not uncommon in the red sandstones, even

FIG. 1.—*Explanation of Abbreviations.*

E. V.	= Elled Vein (with Big and Three Quarter Veins).	Coal Measures.
O. C.	= Old Coal	Coal Measures.
G. V.	= Engine Vein	Coal Measures.
Q. G.	= Quartz conglomerate	Millstone Grit.
LST.	= Limestone	Carboniferous Limestone.
OOL. DOL.	= Oolitic limestone, dolomitised at times.	Carboniferous Limestone.
L. LST.	= Lower Limestone Shales	Carboniferous Limestone.
G. G.	= Grey grits	Old Red Sandstone.
R. S.	= Red sandstones	Old Red Sandstone.
R. M.	= Red marls	Old Red Sandstone.

Figure I.—Section from Abergavenny northwards through the Sugar Loaf, and south-westwards through Blorence.

By A. Strahan, M.A.



towards their top. They are lenticular seams of compact structureless carbonate of lime, rarely exceeding 6 feet in thickness or a mile in horizontal extent. They frequently take the form of conglomerates of nodules of carbonate of lime imbedded in a gritty matrix, as though the calcareous concretions which abound in some of the marl-beds had been freed from their muddy surroundings by some change of current and swept together into one bed. Evidences of such deposition and subsequent washing up are frequent, for not only are the surfaces of the marls eroded but the grits resting upon them contain lumps of marl rolled into pebbles. The marls associated with the compact non-conglomeratic form of cornstone are usually loaded with calcareous concretions, which sometimes become so abundant along some bedding plane as to coalesce and form a thin continuous limestone. Drifted remains of fishes occur in the conglomeratic cornstones, but no molluscan remains or microscopic organisms have been detected in any of the Old Red limestones, which are therefore not comparable with the limestones of the great marine formations. Two possible sources of the carbonate of lime have been suggested. Professor Sollas has pointed out that it may have been in the form of calcareous mud in suspension, and instances the occurrence of lenticular beds of calcareous chalk-débris in the Barnwell gravels.* On the other hand, it is more probably either of chemical origin, or due to the action of algæ, all traces of which have perished.

The thickness of the Grey Grit and Conglomerate subdivision is about 120 to 150 feet in the eastern part of this area, but somewhat less in the western part. That of the Red Sandstones as measured down the face of Blorenge is 1,200 feet (Fig. 1, p. 7). The base of the Red Marls is not seen, but their thickness in the area adjoining on the south was estimated to be 2,800 feet.†

The Red Marl Subdivision.

The narrowness of the outcrop of the Old Red Sandstone where it enters this area on the south is due to the powerful movement which runs from near Risca (Sheet 249) to the Usk near Llanfihangel. Not only are the marls thrown on end, or even inverted in the region of greatest compression near Pontypool, but they are faulted against the Silurian rocks of the Usk Inlier in a manner which suggests overthrusting. The scarcity of clear exposures precludes our ascertaining the exact nature of the fractures, but the general result is to bring red marl into direct contact with the fossiliferous Silurian mudstones, and to cut out whatever there may be in the nature of passage-beds between the two great formations. For this reason the grit which forms the base of the Old Red series in Sheet 249† does not appear in Sheet 232, except in the form of occasional fragments.

---

* *Quart. Journ. Geol. Soc.*, vol. xxxv., p. 492, 1879, and ***Geol. Mag.*** for 1900, p. 249.

† Geology of Newport, pp. 17 and 20.

The red marls round Mamhilad are almost bare of superficial deposits, and are repeatedly exposed. Near Littlemill Junction they are made into bricks, pipes, and tiles, for which they are well suited, except for the presence of small calcareous nodules in some of the bands. The pit shows these together with some red marls containing thin layers of sandstone, but devoid of the nodules. Being between two faults the strata are rolling, and in part highly inclined. Other old pits in the neighbourhood show a monotonous repetition of mottled marls with deep-red highly micaceous sandstones, always dipping westward at angles varying from 20° to 50°.

The top of the marl-subdivision runs at the foot of the bold hill-side which marks the outcrop of the red sandstones and conglomerates, but the exact horizon at which the line should be drawn is a matter of doubt. The sandstones set in in force along the lower line of woods, and a band of limestone can be traced at their base for a couple of miles, partly by old limestone-quarries, where it was got for road-metal. Lithologically this band serves to separate the portion of the Old Red Sandstone in which marls predominate from the upper rocky subdivision, but our fossil evidence is at present too scanty to enable us to say that it forms the upper limit of the Lower Old Red fishes referred to later on. The northernmost exposure of the limestone occurs in a dingle north-west of Mamhilad House; thence for some miles there is no clear view of the top beds of the marl-series.

The Old Red Sandstone of the northern part of this sheet of the map was surveyed by Mr. J. R. Dakyns, who furnishes the following account of the marly subdivision:—

The north-eastern corner of the map (with the exception of Skirrid-fawr which is an outlier of higher beds) is occupied by the lowest division of the Old Red Series, namely the mottled marls, clays, shales, and sandstones. The marls or clays have been worked for bricks near Abergavenny, and the Skirrid-fach seems to be almost entirely composed of them, but in many places there is much sandstone associated. Both in this subdivision and in the lower part of the next there are several brecciated mudstones and cornstones, which, however, are seldom more than two feet thick. Many of the streams descending eastwards from Skirrid-fawr give excellent sections of these strata, but to the south of the road from Abergavenny to Llanvetherine there is much detritus.

Over all this area the beds roll about a good deal. At Llanvapley and at Cymmerau (one mile north-east of Llanvetherine) dips of 10° to the north-east were observed, and all along the lane between Pant-glas (one mile south of Llanvetherine) and Crossway the rocks consisting of marls and sandstones dip to the south-west at 25° to 30°, while on the east of Skirrid-fawr there is purple sandstone dipping west-south-west at 20°, though in a quarry close by the beds are nearly flat. Faults are not easily detected in such rocks, and two only were actually seen, namely, one in an old quarry at Mynach-du and another in Nant Bwch north-west of Llanvetherine.

The following sections of some of the cornstones have been observed:—

In the stream above Little Skirrid Farm.

	Feet.
Sandstone	—
Limestone	about 3
Marl	—
Limestone	—
Sandstone and marl	—
Limestone	about 3 or 4

In the Gavenni below the Lunatic Asylum.

	Feet.
Limestone, its base at the weir	3
Shale	4
Limestone, its top just seen in the bed of the stream	—

Further up nodular marls are exposed in the bed and banks of the stream, and just below Maincliff Bridge a limestone, 2 or 3 feet thick, crosses the river. Between 70 and 100 yards above the bridge a bed of cornstone crops out, and there are numerous sections in shale, marl and sandstone as far as Brookland.

The streams flowing from the north end of Skirrid-fawr show alternations of similar strata with thin cornstones. Over this series come the rocks forming Skirrid-fawr, which consist mainly of sandstone with subordinate shales and cornstones. The following estimates were made along the north-western spur of the hill:—

Skirrid-fawr.

	Feet.
Sandstone	174
Calcareous conglomerate	0 to 3
Sandstone	3
Calcareous band	½
Shale	8
Sandstone	42
Conglomerate, feebly calcareous	3
Shale	16
Sandstone	18
Conglomerate	1½
Sandstone	5
Conglomerate	3

At this horizon is drawn the provisional base of the sandstone-subdivision of the Old Red Sandstone. It seems to run to a spring at the north end of the hill, and thence to a crag 175 yards north-east of the summit where the section is:—

Skirrid-Fawr, North End.

	Feet.
Conglomerate and sandstone	12
Sandstone	6
Conglomerate	9

These probably correspond to some breccia and sandstone, 15 feet thick, which crop out in the hill-side east of St. Michael's Chapel.

The rocks in the Skirrid-fawr have a slight dip to the west-south-west, owing to which the west side of the hill has slipped away, so as to form two huge scars and hollows cumbered with masses of tumbled sandstone.

West of Abergavenny there are several exposures on the north side of the Usk on the hillsides and in the streams flowing from the Sugar Loaf. By these means an approximate top to the red marl subdivision has been drawn. A line of strong springs near Great House and a change in the ground form the only guide to its position north of Abergavenny. In the Llangenau Valley also it is doubtful where to take this line; a considerable thickness of sandy shales near Pendarren House ought perhaps to be included in the red marl series, but to do so would involve difficulties in carrying on the line, which therefore was drawn lower down.

J. R. DAKYNS.

The Red Sandstone and Quartz-Conglomerate Subdivisions.

This series of red sandstones, grits, and conglomerates not only rests conformably on the marls but is linked on to them lithologically, for it contains beds of marl and cornstones not distinguishable from the main mass below. Upwards also the quartz-conglomerates graduate into softer buff or grey sandstones with thin bands of red marl, which are succeeded rapidly but with perfect conformity by the Carboniferous Limestone. The occurrence of yellow sandstones at this stage is noteworthy, when we remember that the topmost beds of the Old Red Sandstone, the Kiltorcan beds of Ireland and the Dura Den beds of Scotland, are chiefly composed of yellow flags. The red sandstones and the quartz-conglomerates being so closely linked may conveniently be described together.

The conglomerates are characteristically developed on the north side of the Trevethin Fault, much more so than on the south side, and are dug for road-metal, being so crammed with well-rounded pebbles of vein-quartz, as to look like old shingle-beaches. Except for a slight red tinge in the matrix, and the fact that they lie under instead of over the limestone, they could scarcely be distinguished from Millstone Grit. This bed of pebbles, some of which are four inches long, runs continuously under Mynydd Garn-wen (or Mountain of the White Ridge), to which, no doubt, they give the name, but are there imbedded in a hard gritty matrix. Thence they continue in varying force all along the brows of the mountains to Gilwern. Above the conglomerates there may be detected occasionally the soft buff sandstones and red, yellow, or white clays above alluded to.

The Old Red Sandstone comes to the surface as a narrow inlier two-thirds of a mile long in the Afon Lwyd Valley (Fig. 5, p. 55). Yellow and green sandstone is exposed in the bed of the river for 500 yards below Cwm-afon House and a fine white micaceous sandstone, calcareous in parts, underlies the reservoir 600 yards above the house. The northernmost exposure occurs in the river 200 yards above the reservoir, where the base of the overlying limestone with a thin sandstone is exposed. The inlier exposes the upper part only of the uppermost subdivision of the Old Red Sandstone.

In the main outcrop there are exposures of these strata near Twyn-gwyn, 500 yards south of the Trevethin Fault; near Nant-y-gollen, 300 yards north of it; in Cwm Lascarn; and in the crags east of Mynydd y Garn-fawr. Here the following section was noted:—

Craig y Cwm.

		Feet.
Carboniferous Limestone (p. 21) containing quartz-grains at its base.		
Grey grit and conglomerate subdivision 97 feet.	Green and grey micaceous sandstone	10
	Red shale	1
	Green and grey sands with a red shale 14 feet above their base, about	50
	Pebbly grit stained red in the upper part	14
	Concretionary calcareous band	1 to 2
	White quartz-grit	10 to 20
	Dull red sand-rock.	
		97

East of Carn y Defaid, on the same hillside, the limestone, sandy and pebbly at its base, rests on soft white sand, 3 feet thick, underlain by coarse pebbly grit. The sand is probably a decalcified limestone.

In Blorenge (Fig. 1, p. 7) encrinital and partly oolitic limestone (p. 22) rests upon—

	Feet.
Hard calcareous sandstone seen to	4
Sands and sandstones, not well seen	60
Quartz-conglomerate forming the lowest conspicuous rock-ledge below the brow; base not seen	20
Beds not seen	20
Grey grit	12
Fine-grained white even-bedded sandstone on grey shale.	

The lowest limestone of Cwm Llanwenarth also becomes sandy and cherty at its base (p. 22), and rests upon a hardish buff current-bedded sandstone, and this upon hard grey grits with a band of red and grey shales. Below these come quartz-conglomerates and grey grits with occasional red and grey shale, and at their base quartz-conglomerates with pebbles up to three inches in length. Near Tila on the County Boundary the following sequence can be made out:—

Near Tila.

	Feet.
Limestone.	
Fine white gannister-like sandstone	2
Red shales, about	6
Grey sandstone	8
Quartz-conglomerate seen to	3

On the east bank of the Clydach there is a conspicuous band of grey grit crammed with quartz-pebbles. It is exposed in the railway by Tanker's Row, and a grey grit below it, upwards of 45 feet thick, is quarried by the railway-side 200 yards further north. Below the grey grit is red shale.

Cwm Ifor, which traverses the Tumble, and Cwm Dyar, which runs past Clydach Station, give good views of the same strata. In the latter the viaduct is built on the top of the lowest bed of the Carboniferous Limestone, and the section reads as follows:—

Cwm Dyar, Clydach Station, L. and N.W. Railway.

		Ft.	in.
Carboniferous Limestone (p. 23).			
Old Red Sandstone (part of)	Hard grey grit - - - - - - - - -	0	8
	Greenish grey clay - - - - - - -	0	6
	Soft white sandstone - - - - - - -	9	0
	Mottled red and green clay - - - - - -	3	0
	Hard white grit, forming a waterfall - - -	6	0
	Red marl with calcareous nodules - - -	2	0
	Beds not seen - - - - - - -	5	0
	Grit with quartz-pebbles - - - - - -	3	0
	Green and grey grit with some bands of red marl	8	0
	Fault.		

These strata belong to the conglomeratic subdivision, but are thrown by the fault against massive red grits which belong to the sandstone-subdivision below. Following the stream down we reach some waterfalls and a gorge in red sandstone; the uppermost waterfall is caused by a conglomeratic band, which contains pebbles of red marl up to six inches in length in a grit-matrix. At Pont-yr-Efail, still lower down, there are bands of coarse grit with quartz-pebbles in the red sandstones.

At the Tumble and to the west of it soft current-bedded buff or grey sandstone lies next below the limestone. Below it there are quartz-grits with two or more bands of quartz-conglomerate, and then red sandstone with shale-partings, which forms the top of the sandstone-subdivision. The quartz-conglomerates form conspicuous ledges on the steep face of Blorenge and other hills, but the softer strata between them are generally concealed.

The great mass of red sandstones and grits which form the flanks of these hills is repeatedly exposed to view in the streams, but offers little variety. A marked terrace which may be noticed in the lower part of the hillside from near Trevethin to Blorenge is due to the interstratification of a thick marl-bed in the red sandstones, but this and other soft bands are seldom actually visible in consequence of the lodging of rainwash on the terraces. There are two or more thin cornstones in the red sandstones of Coed Person, near Llanfoist.

The Clydach brook gives an almost continuous exposure of these strata. Below the old Clydach Ironworks Mr. Gibson noted the occurrence of the usual purple sandstones with thin red marls; these passed up into coarse grey grits with quartz-pebbles seen in the bed and banks of the stream to the west of Glan

Sychnant. At the waterfall to the south of the Rock and Fountain Inn the upper part of the red sandstone contained marls with calcareous concretions resembling cornstone. The grey grits were well exposed in Craig Amy, to the north of Clydach Village, but further west, were found by Mr. Dakyns to lose their distinctive characters.

The same intimate connection between these subdivisions of the Old Red Sandstone was found by Mr. Dakyns (from whose notes the following account is taken) to hold good in the hill-district north of Abergavenny also. On the slopes of the hill three miles north of that town he found illustration of the occurrence of cornstone among the grits and breccias of the sandstone subdivision:—

Bryn-aro.

		Feet.
Red Sandstone Series.	Grit.	
	Breccia	2 to 4
	Grit	1
	Breccia	$1\frac{1}{2}$
	Limestone (cornstone)	2
	Breccia	3
	Grit.	
	Breccia	2
	Grit, nearly	100
	Breccia	5
	Grit	3
	Breccia	4
	Grit	9
	Breccia and limestone	3

The base of the sandstone-subdivision lies about 250 feet below the strata enumerated in the above section.

Generally speaking, the series may be described as consisting of purple and grey grits and sandstones, often flaggy, with partings of red shale or mudstone. The outcrops of such strata are marked on the hillsides by features and lines of springs, but never can be traced far. They generally conform in their gentle and uniform dip to the outcrop of the Carboniferous Limestone, but between the Sugar Loaf and the Table Mountain there must be a syncline and possibly a fault also, for the base of the grey grits lies at 1,800 feet elevation on the former, and at only 1,360 feet on the Table Mountain. This mountain probably stands in the axis of the syncline, for the strata are nearly horizontal at its south end, though on the whole they rise to the north-west. The clearest proof of the existence of the syncline lies further north (in Sheet 214), where an outlier of Carboniferous rocks occurs at a level of about 1,750 feet, in just such a position as the rise of the Table Mountain would indicate.

There are no sections in solid rock along the Usk between Abergavenny and Crickhowell, the first exposures up the river being at an elbow near Glan Usk, and west of a bridge leading into the park. Thence for four miles sandstone is almost continuously visible in the bed and steep banks.

The sandstones have been quarried in many places, both for building and as flags or tiles, and are still being worked for the former purpose on the Deri, by the canal between Llanfoist and Govilon, by the side of the railway near Gilwern, and at Daren south of Llangattwg.

On the Sugar Loaf, and again north of Crickhowell, the upper part of the series consists of soft friable red grits easily weathering into sand and clay. Over these beds there comes a massive grey grit which forms the summit of the Sugar Loaf (Fig. 1, p. 7) and the Table Mountain. In the latter hill this rock contains many quartz-pebbles and precisely resembles Millstone Grit in appearance.

The sandstone below this grey grit is not everywhere friable as on the Sugar Loaf, but more generally graduates upwards, simply getting lighter in colour and more pebbly upwards. Consequently the line taken as the base of the grey grit is in many places merely a rough approximation, and cannot be considered as indicating a good horizon. This is particularly the case at Waun Llech near Llangynidr, where the grey type appears among the red sandstones below the general horizon of the grey grit proper.

The grey grit has been quarried, but not extensively, between Pant-y-Rhiw and the Clydach.

FOSSILS OF THE OLD RED SANDSTONE.

Reference has been made in the foregoing pages to the fact that the presence of both Upper and Lower Old Red Sandstone is proved by the fossils. The evidence is scanty in consequence of the difficulty of finding specimens, but, so far as it goes, is conclusive.

Upper Old Red Sandstone.

The existence of Upper Old Red Sandstone, which would be inferred from the conformable relations of the Carboniferous to the red rocks of South Wales, is confirmed by the occurrence of two fossils. *Anodonta* (*Archanodon*) *Jukesi* was obtained in the region between Newport and Chepstow in the uppermost beds of the Old Red Sandstone, as described in a previous part of this memoir.* In the district now under description, *Holoptychius*, a characteristic Upper Old Red Sandstone fish, was discovered by Murchison. His description of the spot enables us to say that the specimen was obtained in the upper part of the Old Red Sandstone, and probably in the uppermost

* Geology of Newport, Mon., p. 20. It seems likely that this fossil has been found in the Forest of Dean also, for Dr. Watson, writing in 1858, states that "there are also some impressions of shells in a thin bed of sandstone, about a foot in thickness which immediately subtends the limestone-group." *Geologist*, vol. i., p. 242.

grey grit or conglomeratic subdivision. "The bold scar called the Daren, two miles north of Crickhowell, offers a fair vertical section of a portion of this subdivision. We there see a greenish, fine-grained, thick-bedded sandstone (an excellent building-stone) alternating with purple, red and green, finely laminated, marls and other thin courses of hard sandstone and fine conglomerate. In the latter I detected the scale of a large fish."* On p. 588 he refers to this specimen as an undescribed *Holoptychius,* and on p. 601 says, "I have now no doubt that the large scale . . . . is identical with the scales which occur in Perthshire, Morayshire, and Caithness."

The Daren lies one mile west-north-west of the Table Mountain, and therefore just outside the northern margin of Sheet 232. The hill on which it is situated is capped by Carboniferous Limestone, and about 200 feet of the underlying strata are assigned by Mr. Dakyns to the grey grit subdivision. This thickness includes all the strata exposed in the cliff of the Daren and referred to by Murchison. We may assume, therefore, that the *Holoptychius,* like the *Anodonta,* occurred in the "grey-grit subdivision." The crag, according to Mr. Dakyns, displays in descending order massive greenish-grey grit with a thin band of breccia; mudstones and grit; hard grey grit; purple and red sandstones about 15 ft. thick and throwing out water; soft purple grit; and grey grit. From Murchison's description it would seem that the fossil occurred in a fine conglomerate in the lower part of the crag.†

Lower Old Red Sandstone.

Cephalaspis Lyelli, Ag. (*C. Agassizi*, Lank.), Abergavenny (British Museum, *Catalogue of the Fossil Fishes*, part ii., p. 181).

Cephalaspis Salweyi, Eg., east side of Skirrid-fawr, Abergavenny (British Museum, *Catalogue oft he Fossil Fishes*, part ii., p. 182. A photograph of this specimen (a fine large shield) forms the frontispiece of the *Trans. Woolhope Nat. Field Club*, 1868, and a figure is also given in the *Geol. Mag.*, New Series, vol. viii., pl. vi., 1881. Two imperfect cornua of the same species were found in the same quarry and were used by Lankester with the shield mentioned above in his outline-restoration in *Fishes of the Old Red Sandstone* (*Pal. Soc.*), p. 53, fig. 26).

Climatius (*Ctenacanthus*) *ornatus*, Ag., "North of Abergavenny," *Silurian System*, 1839, p. 597.

Eukeraspis, Newport. Geology of Newport, Mon., p. 17.

Palæaspis (*Holaspis*) *sericea*, Lank. (British Museum, *Catalogue of the Fossil Fishes*, part ii., p. 169. This unique specimen is described as

---

* *Silurian System*, 1839, p. 172.

† *Holoptychius* is recorded also from the top beds of the Old Red Sandstone at Portishead (*Proc. Bristol Nat. Soc.* N.S., vol. ii., p. 78 (1867), and N.S., vol. vii., p. 34 (1892)), and from a grey quartz-conglomerate at Tortworth, where it was associated with *Glyptolepis elegans*. Baily, *Rep. Brit. Assoc.* for 1864, Trans. Section, p. 49, and *Geol. Mag.*, vol. i., p. 293 (1864). Scales of a small *Holoptychius* and a detached plate of *H. giganteus* occurred with fragments of *Conulariæ* in a yellow sandstone at the top of the Old Red Sandstone at Farlow in Shropshire (Morris and Roberts, *Quart. Journ. Geol. Soc.*, vol. xviii., p. 94, 1862. The same locality yielded *Sauripterus anglicus* and *Bothriolepis macrocephala*, Eg. (*Pterichthys*), both Upper Old Red fishes.

being from the "Grey Cornstone" of the neighbourhood of Abergavenny. "The bed in which it occurs has furnished also shields of *Scaphaspis Lloydi*, *Pteraspis rostratus*, and *Pteraspis Crouchi* in excellent preservation," *Geol. Mag.*, vol. x., pp. 241, 331, pl. x., and woodcut).

Pteraspis Crouchi, Lank., Asylum Quarry, Abergavenny, and from a boulder in a railway-cutting, Main Cliff, Abergavenny (British Museum, *Catalogue of the Fossil Fishes*, part. ii., p. 168; also at Newport).

Pteraspis rostrata, Ag., Skirrid-fawr Quarry, Gethlellydd, Llanthewy, and Pandy, near Abergavenny (British Museum, *Catalogue of the Fossil Fishes*, part ii., pp. 162-165; also at Newport (Geology of Newport, Mon., p. 21), at Llangwm, Star Pitch, and Newbridge, Glamorganshire).

Psammosteus, Newport (Geology of Newport, Mon., p. 21).

Ptychacanthus dubius, Ag. (?), "Two doubtful onchus-shaped fossils from the Lower Old Red Sandstone of Abergavenny" (British Museum, *Catalogue of the Fossil Fishes*, p. 97; *Sil. System*, 1839, p. 597).

Plant-remains have been obtained from the Lancaster Arms Quarry at Pandy, near Abergavenny, Llanvetherine and Kemeys. Many of the bedding-planes of the brown grits which are quarried on the southern slopes of Deri, near Abergavenny, are crowded with fragments of plants.

I am indebted to Dr. A. S. Woodward, by whom the Catalogue of the Fossil Fishes in the British Museum was compiled, for much assistance in collecting the information concerning the Old Red Fishes of this part of South Wales. It is much to be regretted that the localities of these fossils have been so loosely recorded by their finders that for stratigraphical purposes much of their value is lost. Skirrid-fawr, for example, rises to a height of nearly 1,600 feet, and to describe a fossil as from Skirrid-fawr scarcely fixes its horizon within 1,000 feet. It seems extremely probable, however, that all the fishes enumerated above occurred in the upper part of the marl-subdivision of the Old Red Sandstone, that being the part to which nearly all the cornstones near Abergavenny belong. The Rev. W. S. Symonds, in his admirable description of the geology around Abergavenny,* divides the Old Red Sandstone into four groups which may be approximately correlated with the grouping now adopted on the map as below:—

[Grey Grits and Quartz Conglomerates.]	Yellow and grey sandstone and Old Red Conglomerate.
[Red Sandstone sub-division.]	Brownstones, which form the upper part of the Sugar Loaf and Skirrid and the middle part of Blorenge. Upper cornstones and sandstones, which form the lower part of the Deri, Rholben, and Blorenge.
[Red Marl subdivision.]	Lower flagstones and cornstones around Abergavenny.

Symonds knew the district at the time when the collectors of these fossils were still living and had opportunities of ascertaining the horizon. According to him no fossils have been

* *Records of the Rocks*, London, 8vo, 1872, p. 234.

obtained from the "Brownstones," but many occurred in the "Lower flagstones and cornstones," among which the strata near the Asylum may be included. The *Cephalaspis* (*Zenaspis*) *Salweyi* was found, according to him, "in higher Flagstones and Cornstones at the base of the Skirrid." This would indicate that it occurred in or near the cornstone which Mr. Dakyns takes as the top of the marl-subdivision; according to the mapping this horizon lies at the foot of and not some distance up in Deri and Rholben, as shown in Mr. Symonds' list of subdivisions given above. While, therefore, we can say that fishes of Lower Old Red type occur throughout the marl-subdivision, we cannot state positively that they are absent in the red sandstone, and thus are left in doubt both on palæontological and stratigraphical evidence exactly on what horizon to draw a line between Upper and Lower Old Red Sandstone.

While differing from normal marine formations in its irregular bedding, in being charged with the red oxide of iron, in containing many fragments of terrestrial plants with a peculiar assemblage of fishes, and lastly in the almost total absence of molluscs or microscopic organisms, the Old Red Sandstone was not necessarily purely lacustrine or fluviatile. As pointed out by Mr. Symonds,* *Eurypterus*, *Stylonurus* and other Old Red crustaceans have been found associated with *Linguliæ*, while *Holoptychius* and *Pterichthys* occur in the same beds with *Conulariæ* at Farlow in Shropshire. *Serpulæ* have been observed in the upper Old Red beds on Caldy Island. The *Anodonta* occurred in Northumberland in the same series of beds, though apparently not in the same stratum, with stunted forms of *Athyris* and *Nautilus*.† Lastly Professor Lankester, speaking of Kner's figured specimen of *Scaphaspis Kneri*, says "an *Orthoceras* is lying almost against the fish-shield, which is very perfect, and there are two *Lamellibranchs* in close proximity. We must not conclude, therefore, from the cornstones and Scotch beds that the *Cephalaspidæ* were exclusively lacustrine or fluviatile."‡ That some of the Lower Old Red fishes first appeared in the underlying strata, in association with an abundant marine fauna, has long been known.

It is possible, however, that many of the fish-remains may have been swept into marine or estuarine areas by the same currents which transported the plant-remains, so common through the sandstones of the whole formation.

---

* *Records of the Rocks*, p. 256.
† *Trans. Manchester Geol. Soc.*, vol. xvi., p. 249, 1882,
‡ *Geol Mag.*, vol. vii., p. 399, 1870.

CHAPTER IV.

CARBONIFEROUS ROCKS.

Carboniferous Limestone.

This formation exhibits in a marked degree, within the limits of the area under description, a change which is noticeable in all the members of the Carboniferous system. From a thickness of upwards of 500 feet in the western part it dwindles to scarcely more than 100 feet in the eastern part of the area, at the same time that it almost entirely loses the massive character which gives the escarpment its characteristic features, and becomes an inconspicuous group of shales with little more than thin slabs of muddy limestone. It reaches its *minimum* near the north-east corner of the Carboniferous basin, for it expands not only westwards but less rapidly southwards also.

It is a significant fact that the attenuation is no less marked in the outlier of Pen Cerig-calch (north of Crickhowell and just outside the limits of Sheet 232), than it is in the extreme north-east corner of the Coal Field, for it suggests that there may be some connection in shape between the present Carboniferous basin and the area of subsidence in which the maximum development of the Carboniferous Rocks took place. It will be remembered that the limestone develops again still further east in the Forest of Dean, but that we have no evidence of its having attained any great thickness in a northerly or north-easterly direction, through Herefordshire, Worcestershire, and Shropshire. On the contrary there is proof that it was never deposited over parts of those Counties, and that that region was not submerged until a late stage in the Carboniferous epoch. In Pembrokeshire also the limestone is overlapped northwards by the Coal Measures.*

The limestone displays the following sequence over most of the area under description. As it dwindles north-eastwards the massive beds disappear, but there still remain representatives of the two main subdivisions:—

		West to East.
Massive blue or brown limestones, with occasional impersistent sandstones or quartz-conglomerates. Some of the rock is oolitic, and towards the middle it contains one or two thick bands of almost white oolite of great purity - - - - - - - -		400 to 70 ft.
Lower Limestone Shales.	Shales with irregular and impersistent limestones - - - - - - -	70 to 20 ,,
	Limestone sometimes oolitic and usually encrinital; generally dark and impure, and shading down into the Old Red Sandstone - - - - - -	40 to 10 ,,

* On this subject see De la Beche, Memoirs of the Geological Survey, vol. i., pp. 112, 131, 132.

The downward passage of the limestone into Old Red Sandstone has already been described (pp. 11–13). Upwards also it is conformably succeeded by the Millstone Grit, though there are indications here and there that the sudden increase of movement in the water which led to the distribution of the pebbly grit washed away some of the latest of the calcareous deposits. Certain appearances which might at first sight be taken to indicate a strong discordance between the two formations are due merely to the solvent action of underground water on the limestone. Some large tracts of grit, more or less in a state of ruin, have thus been let down far below their proper geological horizon. (See also p. 45.)

In the neighbourhood of Trevethin the Lower Limestone Shales are well defined. The main mass of limestone above them is generally a blue or grey rock of earthy texture, with a little chert, but associated with much thin-bedded platy limestone. It is quarried at intervals up the Afon Lwyd Valley, and is frequently exposed to a thickness of upwards of 60 feet. Generally it is thickly overspread by fallen blocks of Millstone Grit, but near Farteg Hill its top, with twenty feet of grit upon it, is exposed in the railway, and its base can be fixed sufficiently nearly to show that its thickness is about 150 feet. A good view of the junction of the limestone and Millstone Grit may be obtained in the Graig quarry also, where flaggy sandstone rests on pale-blue shale, six feet thick, under which a yellowish dolomitic-looking limestone has been quarried to a depth of 30 feet.

The shales below it are rarely visible in that valley, but make a feature on the hillside, and throw out the abundance of water which sinks into the numerous swallow-holes on the slopes above. The limestone below them is repeatedly seen in the river, together with the narrow inlier of Old Red Sandstone alluded to on p. 11. The thickness of the Lower Limestone Shales is about 80 feet, giving a total for the Carboniferous Limestone of 230 feet at Farteg.

These lower strata are well shown in Cwm Lascarn, where the shale is underlain by a thin-bedded smooth-textured limestone, exposed to 20 feet in the quarry, a brown crystalline limestone, and then by Old Red Sandstone (p. 12). Further north the shale becomes indefinite, but it probably runs at the base of a dark oolitic rock, in which a number of small quarries have been opened in old days all along the eastern slopes of Mynydd Garn-clochdy. Above this oolite there are seen only thin platy limestones and shales, overlain apparently by a shale with thin grit of Millstone Grit age. The total thickness of the Carboniferous Limestone does not exceed 150 feet at Garnllech, on the east side of Mynydd Garn-clochdy, which indicates a loss of 80 feet in 1¼ miles in an eastward direction from Farteg Hill. (Fig. 5, p. 55.)

As we proceed northwards the deterioration of the limestone becomes more marked. The upper part of the formation becomes chiefly shale with thin blue shelly limestone and pisolitic or oolitic bands, and it is only in the lower part that any bands of limestone could be found workable for farm-purposes. The lowest limestone of all becomes a massive oolitic rock at the head of Craig-y-cwm. (See p. 31 for microscopic characters.) In the following section the exact position of the top of the limestone-series could not be fixed in consequence of the local absence of the basement-grit of the Millstone Grit, the line between the shales of the Millstone Grit and those of the upper part of the limestone being wholly concealed.

Craig-y-Cwm, east side of Mynydd y Garn-fawr.

		Ft.
Carboniferous Limestone (part of).	Blue shale with nodules and thin bands of very fossiliferous Limestone: *Fenestella* abundant—top not seen	12
	Red oolite, partly converted into hæmatite (p. 31)	2
	Thin sandy and shaly limestone, irregular; partly ferruginous	6
	Massive blue oolite	6
	Shaly beds forming a terrace below the uppermost quarries	8
	Dark laminated calcareous shales and bands of smooth dark-blue limestone; all weathering white	12
	Harder blue limestone with some shales	6
	Massive blue limestone	4
	Dark shale and impure limestone with plant remains	6
	Black shale	1
	Massive blue earthy limestone	6
	Shales forming a second terrace about	6
	Massive brown oolite, forming a crag	15
	Shaly beds, about	6
	Earthy blue and brown limestone, with quartz-grains in the base (p. 31)	4

Old Red Sandstone (p. 12).

The fine scarp to the east of Carn y Defaid on Mynydd y Garn-fawr is double. The upper crag consists of light-coloured sandy limestone resting on pale shale, the latter forming a slope loaded with fallen blocks of Millstone Grit. The lower crag shows the passage down into Old Red Sandstone as below:—

Near Carn y Defaid, Mynydd y Garn-fawr.

	Ft.
Limestone	12
Do. in part smooth-textured ("china-beds") with shale	8
Do. very hard and brown in the lower part	40
Do. very sandy, with quartz-pebbles	1
Soft white bedded sand, probably decalcified limestone	3
Coarse grit with quartz pebbles, seen to	3

A rushy terrace between the highest visible benches of limestone and the basement Millstone Grit on Blorenge marks the outcrop of a considerable thickness of shales at the top of the limestone-series, but the strata are nowhere exposed. A mile further on they return to their normal condition of limestones.

The brow and north-east face of Blorenge (Fig. 1, p. 7).

		Ft.
Millstone Grit.—	Two scarps of pebbly grit close together -	60
Carboniferous Limestone 107 feet.	Strata concealed, apparently shale - -	41
	Fine-grained buff and earthy limestone, irregular - - - - - - - - -	3
	Massive dark oolite: the highest line of quarries - - - - - - - - -	5
	Platy limestone - - - - - - -	3
	Shale, &c. - - - - - - - - -	3
	Smooth blue limestone with bands of pale calcareous marl, weathering into spheroidal lumps - - - - - - - - -	16
	Blue shale and smooth blue limestone - -	15
	Dark-blue sandy limestone - - - -	6
	Shale - - - - - - - - - -	2
	Dark, very sandy limestone - - - -	2
	Shale - - - - - - - - - -	2
	Dark encrinital limestone, in part oolitic, with quartz-grains in its lowest part - - -	9

Old Red Sandstone (p. 12).

At Pwll-du there may be obtained a grand view of the lower part of the Millstone Grit and of the limestone down to the base of the oolite :—

Old Quarry, East of Pwll-du House.

		Ft.
Millstone Grit—	pebbly grit, top not seen - - - - -	30
Carboniferous Limestone (part of)	Green clay with lumps of limestone in the lower part - - - - - - - - - - -	6 to 8
	Hard blue and brown limestone, thin bedded and containing some bands of close-grained cream-coloured oolite and a little smooth blue limestone ("china-bed") - - - - - - - - about	40
	Greenish shale - - - - - - - - - -	4
	Fine cream-coloured oolitic limestone - - - -	40

At the east end of this quarry the rock is concealed by scree for about 10 yards. In that space the oolite passes into dolomite as described on p. 33. Barytes is common in the joints of the limestone in the neighbourhood.

An exposure of the Lower Limestone Shales in Cwm Llanwenarth shows that the lowest limestone is a dull-blue or grey earthy rock, sandy and cherty at its base, and that the shale above it contains as much thin platy limestone as shale. The same strata are shown in a tributary stream descending from the School.

All along this hill-side the white oolite makes itself conspicuous. Above it the limestone is generally blue and hackly but contains bands of light-coloured oolite here and there. The oolite itself becomes creamy or pinkish in an old quarry west of Upper Cwm Farm; the ooliths are very small and the stone breaks with a roughly conchoidal fracture. It passes down into a coarsely crystalline blue shelly limestone. The base of the Millstone Grit is shown just above this quarry, and below it we find, as at

Pwll-du, about 8 feet of clay containing many lumps of limestone in the lower part and so passing down into solid limestone. The clay is yellow, green and purple, and the whole bed resembles a decomposition-product, such as might be produced by the action of underground water on muddy limestones and shales.

An old quarry south of Tila (on the County Boundary) was worked in two stages, the combined section being :—

Tila, near Tile.

	Ft.
Blue thick-bedded limestone - - - - - -	–
Smooth blue limestone ("china-beds") - -	2 to 4
Dull red and green clay with lenticular limestone -	6
Massive white oolitic limestone (worked in the lower stage of the quarry) - - - - - - - -	40

From the County Boundary westwards the white oolite is worked continuously for about 500 yards by the Blaenavon Iron Company for use in the blast furnaces.

At Clydach Quarries the white oolite, with parts of the blue limestone above, are burnt for lime, while some hard blue and brown limestones are worked for road metal. The following measurements were made by aneroid along a line running in an east-south-easterly direction and as nearly as possible in the line of strike :—

Cwm Dyar and Gilwern.

			Feet.
Carboniferous Limestone (419 feet).		Limestone, blue and brown, with hackly fracture, but with bands of smooth blue limestone ("china-beds") weathering conspicuously white and a pisolitic band about 20 to 30 feet above its base - - -	130
		Smooth blue limestone as above - - -	4
		Green clay, with lumps of limestone ("rubble-bed") passing down - - - - - -	6
		Massive white oolite - - - - - -	34
		Dark thin-bedded limestone with chert -	140
	Lower Limestone Shale.	Shale with some limestone - -	65
		Limestone, dull-blue and brown, sandy, with some smooth-textured blue bands - - - - - -	40
		Calcareous grit, crammed with rounded grains of quartz and small pebbles - - - - - - -	$\frac{1}{3}$

Old Red Sandstone (p. 13).

At this point we enter the area surveyed by Mr. Gibson, who furnishes the following account :—

In the gorge of the Clydach and the numerous large quarries on either side of it, the complete sequence from the Millstone Grit through much of the Old Red Sandstone is exposed. The total thickness of the limestone-series ranges from 400 to 450 feet. It includes the following lithological subdivisions in descending order :—

Clydach Neighbourhood.

	Feet.
1. Thick-bedded blue limestone with brachiopods and corals; it contains occasional thin bands of gritty limestone and is generally less pure than the beds below	250 to 300
2. A band of greenish clay with nodules of limestone, and black shales with occasionally a coal-smut at their base	8 to 10
3. Limestone	10
4. White oolitic limestone	20
6. Coarse rubbly limestone in a marly matrix ("rubbly bed")	—
7. White oolite passing down into dark-blue or black oolite	30 to 40
8. Shale	0 to 10
9. Limestone	30

The lowest bed of limestone (9) is an impure blue rock with conchoidal fracture, and can be seen resting on the Old Red Sandstone at a waterfall below the Rock and Fountain Inn. The shales (8) above it are thin and impersistent; though 20 feet thick at the Clydach Station Tunnel, they are absent or have passed into limestones in the river. The separation of the lowest limestone from the main mass above in such cases became impracticable.

The rocks immediately above this shale are not well shown except in the river. At the junction of the Llammarch Brook with the main stream a thin shale with thin-bedded limestone above and below it separates the oolite (7) from the lowest limestone (9), though elsewhere these intervening strata may consist either wholly of shale or wholly of limestone.

The lower part of the oolite (7) is dark-blue or nearly black, and contains occasional bands of pisolitic rock. It is quarried below the Black Rock Limeworks, on the north side of the Clydach, and forms the bed of that river above the Llammarch Dingle. Above it a white oolite is extensively quarried on both sides of the valley, the best section being obtainable in the quarries on the south side near the railway.

Quarry half a mile west of Clydach Station.

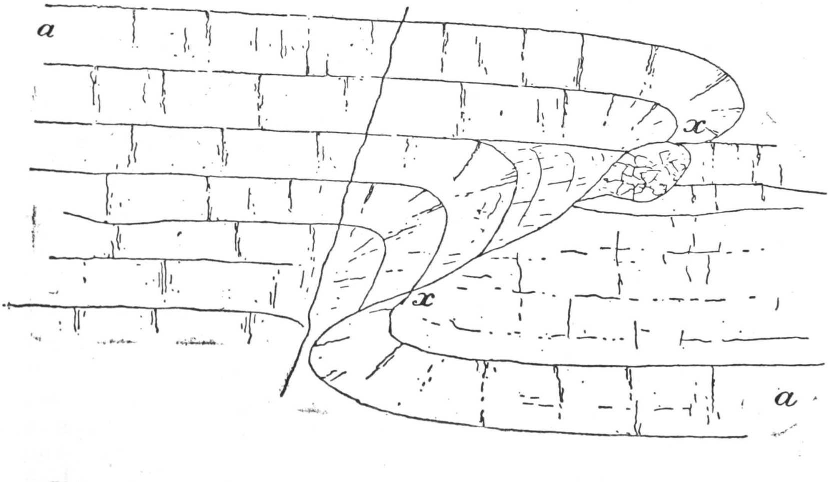
	Feet.
1. Dark limestone with conchoidal fracture	15
2. Green clay with nodules of ironstone and thin bands of carbonaceous shale	8
3. Light-blue limestone with conchoidal fracture	5
4. White oolite	4
5. Limestone, as above	12
6. Nodules of limestone in a marly matrix ("rubble-bed")	—
7. White oolite, seen to	25

The white oolite (7) is the rock which has already been referred to as being extensively quarried at Clydach and Pwlldu. In its normal condition it is an exceptionally pure carbonate of lime, but has undergone conversion into dolomite (carbonate of lime and magnesia) at intervals along this outcrop, and especially along the pathway leading eastward to the tunnel, as described on p. 33. The "rubble-bed" (6) above the oolite corresponds to the green clay of the Gilwern section (p. 23) and persists for a long distance at this horizon. Another green clay-bed (2) was also conspicuous in this quarry; it contained small hard nodules of limestone such as frequently enclose fish-remains, and in the carbonaceous shale there were indefinite plant-remains. This band can be traced westward to Llammarch Dingle and to the railway-cutting close by. The white oolite was formerly quarried in Pant Droenog Wood; it is there slightly gritty and yields casts of *Bellerophon*, *Productus*, and other fossils in abundance.

Above the green clay (2) comes a great thickness of massive impure limestones. Their lower part is well-bedded in the quarries at the back of the Crown Inn, Blackrock, and is purer than the upper part, the quarrying of which has been abandoned. In one of these quarries some thin-bedded limestones, lying between two massive strata, illustrate the effects of pressure on rocks of different resistance. The more yielding bands, partly by bending and partly by fracture, have been thrust over one another to a distance of nearly 10 feet. The massive rocks above and below show no disturbance.

Fig. 2.—*Overthrust-fault in western end of Blackrock Quarry, Clydach.*

From a sketch by W. Gibson



We pass now from Mr. Gibson's area into that surveyed by Mr. Dakyns, who continues the account as follows:—

On the north side of the Clydach valley there appears to be unbroken limestone from the top of the grey grit (Upper Old Red Sandstone) to the top of the white oolite (7), but generally the lowest bed of the limestone-series is separated from the main mass above by shale with more or less limestone, while it is itself often impure or even a calcareous sandstone, but often also an oolitic limestone. It has been traced to the west edge of the map though not continuously, for east of Pant-y-Rhiw it is not seen at all for nearly a mile, and here too the base of the main mass of limestone above is quite obscure. At the head of Cwm Claisfer also it is completely hidden by débris. Near Pant-y-Rhiw oolitic limestone with five or six feet of red concretionary mudstone and shale below is seen resting on conglomerate. Along part of the Crawnon valley the lowest limestone becomes double for about a mile. The shales are visible in a few places only, namely, obscurely under the limestone - cliff facing Llangattwg; on the side of the road from Llangynidr to Beaufort; near the north-westerly fault which shifts the boundary of the Millstone Grit on Mynydd Llangynidr; east of the waterfall at the head of Dyffryn Crawnon; and best of all along the stream above the waterfall.

Over the shales comes a great thickness of calcareous beds which may be broadly described as consisting of a lower series of massive limestones, generally light-coloured though in some places dark, and often oolitic, overlain by an intermediate series of thin-bedded limestones and "plate" with thin seams of sandstone, often calcareous, the whole succeeded by a higher set of limestones, dark-coloured and not oolitic.

The lowest of these strata is the great Llangattwg limestone; the actual base is in many places a band of dun limestone, but it is too thin and too frequently concealed to be mapped separately. The Llangattwg limestone is a massive rock, about 75 feet thick, which has been extensively quarried for about five miles. The lowest 20 to 25 feet or more are generally white or grey and markedly oolitic; the upper part is also light-coloured, but not characteristically oolitic. It is overlain by a curious rubbly bed and band of "plate" and of red shale, seen nearly opposite the tramway to Llangattwg. In the Llangattwg Quarries there occurred the green pebble-like inclusions in the oolite described on pp. 28, 29.

The limestone maintains its character to the western edge of the map. The oolitic character of the lower part which dies out west of the Blaen-Onnen Quarries sets in again at the head of Cwm Claisfer, and is visible to a thickness of ten feet close to a strong spring which issues probably near the base of the limestone. Further west the oolitic character is maintained in the lower thirty feet, but the rock sometimes assumes a dark tint. At the large quarry of Blaen-dyffryn the rock is crystalline and encrinital, but some oolite was seen further west again. Near the Clydach valley the Llangattwg limestone is succeeded by a white oolite of great purity (7 of the table on p. 24). It is about 18 feet thick, but seems to die out westwards.

A little higher up in the series there occurs a remarkable band of oolitic limestone, from 10 to 20 feet thick, containing grains (sometimes angular) and pebbles of quartz up to one inch long. Many of the oolitic grains have been formed round quartz-grains (p. 30 and Plate I., Fig. 3). This rock forms a little scar, by means of which and its peculiar character, it has been traced beyond

Blaen-Onnen where it coalesces with the great limestone. Thin bands of sandstone are sometimes associated with it. Thus there are two and a-half feet of grit at its base on Daren, and in a quarry on Daren Disgwylfa alternations of sandstone and pebbly limestone in beds from two to four feet thick. Between the Llangattwg quarries and Craig-y-Castell it is overlain by a grit as shown as below:

Near Llangattwg Quarries.

	Feet.
Black limestone with thin bands of calcareous grit -	–
Grit - - - - - - - - - - -	9
Space in which the rocks are hidden - - -	21
Grit - - - - - - - - - - -	12
Pebby limestone - - - - - - - -	–

South-east of Pant-y-Rhiw a bed of calcareous grit, one to four feet thick, in dark limestone, was traced for about half-a-mile in the measures above the pebbly limestone; the dark limestone itself contained a few quartz-grains.

In the valley which crosses the limestone west of Chwar Mawr a calcareous grit from three or four feet thick occurs at some little distance above the pebbly limestone (which at this spot is not oolitic), while much higher up a sandstone about eighteen feet thick occurs in the limestone-series. It cannot actually be traced, but is probably the same as a sandstone six feet thick seen on the hillside a little to the north-east. The latter ends abruptly against limestone, but in a manner that could not be explained by a fault.

Another curious section occurs in this neighbourhood to the north-west of the eighteen-foot grit. A mass of grit about forty feet high is to be seen on the hillside, apparently surrounded by limestone.

Similar thin bands of grits in dark limestone appear in several other places above the horizon of the pebbly limestone. One of them, near Blaen-Onnen, is big enough to be shown on the map.

On the plateau between the heads of Cwm Claisfer and Cwm Crawnon a sandstone, belonging to the limestone-series, occupies an area about a mile long and from a quarter to half-a-mile wide, but whether this is the same bed as on Blaen-Onnen is not known. The rock is fine-grained and not pebbly. It is overlain by a thin limestone under Garn Caws and by what seem to be two small outliers, while a small boss of fossiliferous limestone protrudes through it as a faulted inlier. The overlying limestone, which is very thin, is itself overlain by the pebbly grit which forms Garn Caws. If, as we suppose, this outlier is Millstone Grit, the limestone series must vary greatly in thickness, a fact of which we have plenty of evidence elsewhere. Southwards the sandstone-area mentioned above is bounded by a bank of limestone. There is no evidence to show whether the sandstone passes under the limestone or is banked against it.

A curious fragmentary structure was observed in two places in the great limestone. The rock seemed to be made up of broken bits of limestone cemented together in a calcareous matrix. This was seen four hundred yards west-north-west of Garn Caws, and above Cwm Claisfer east of Garn Caws, close to the pebbly limestone.

At the western edge of the map complications set in which will be more suitably explained in the description of Sheet 231.

The top of the limestone-series is irregular, and the rock appears to vary enormously in thickness, and no doubt does so. But how much of this is due to atmospheric decomposition and dissolution, and a consequent subsidence of the overlying grits it is impossible to say. That atmospheric weathering has gone on to a great extent is shown by the prodigious amount of broken grit that cumbers the ground and often entirely conceals the limestone.

Though it is so far not capable of direct proof, it seems to me that the upper surface of the limestone consists of ridges and hollows, due either to original inequality of deposition or to erosion, which hollows were filled in subsequently with sandstone and grit. Perhaps in some cases such hollows may have been filled up with calcareous as well as sandy sediment before the final deposition of sand, which now forms the Millstone Grit, began. Thus there is no proof that the intercalated sandstone south-west of Garn Caws passes under the limestone-bank to the south. It may, so far as I could see, have been deposited against it.

J. R. DAKYNS.

The higher beds of the series described above by Mr. Dakyns project southwards in three valleys into the area surveyed by Mr. Gibson. At Trefil he describes them as highly fossiliferous blue limestones, extensively quarried for the Tredegar and Ebbw Vale Ironworks. The quarry shows the basal conglomerate of the Millstone Grit with five feet of oolitic chert beneath it resting on limestone. The chert is a silicified limestone, as described on p. 36. It contains *Modiola megalober*, *Avicula* sp., *Nucula* sp., *Axinus* sp., as identified by Mr. Sharman.

The tongue of limestone that stretches southward to Odynfach lies in a well-marked hollow, with lines of swallow-holes on either side.

Microscopic Characters of the Limestones.

At the Llangattwg Quarries a compact dark-green rock occurred imbedded in white oolitic limestone in the form of rounded pebble-like masses from one to three inches in length. There were many of them at this spot in the blocks thrown down by the quarrymen, but they have not been noticed elsewhere. Under the microscope the rock is seen to be composed of minute colourless grains of quartz and possibly felspar, more or less separated by a green mineral, probably chloritic. The margins of the masses are penetrated by carbonate of lime, frequently in the form of oolitic grains, as though the material had been in a soft condition, such as a scarcely coherent mud, when it was

Fig. 1 × 31.

Fig. 2 × 21.

Fig. 3 × 26.

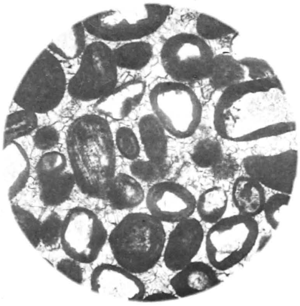


Fig. 4 × 21.

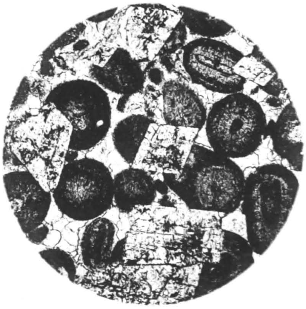


Fig. 5 × 21.

Fig. 6 × 21.

Fig. 7 × 27.

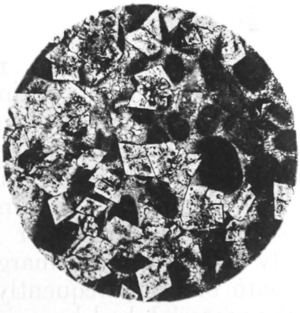
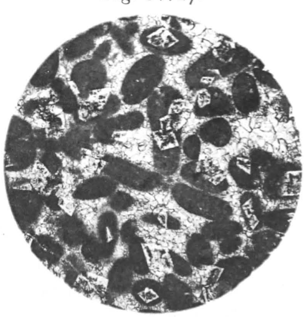


Fig. 8 × 27.



MICROSCOPIC SECTIONS OF CARBONIFEROUS LIMESTONE.

included in the limestone. We have no clue as to the source of these lumps, and can only suggest that they were floated to the spot by a raft of vegetation.

The following descriptions of some of the oolitic bands in the Carboniferous Limestone are furnished by Prof. W. W. Watts:—

Dark Oolite below the White Oolite, near Blackrock, Clydach Valley.—Plate I., Figs. 1 and 2. [E 2,439.]

A dark oolitic limestone, with the coats of the grains lighter in colour than the centres and the cement between.

This is a characteristic oolitic limestone. The grains are occasionally seen in contact. The interspaces are filled with crystalline carbonate of lime generally in single crystalline patches, which often include a patch of fragmental crystalline calcite, with which the infilling is in optical continuity, the cleavage and twinning passing through both; a bit of a crinoid stem is treated in this way. The interspaces enclosed by several grains are often lined with minute dog-tooth crystals which clearly *line the cavity*, and so have been deposited after the grains were in their present position. The crinoid ossicle, for instance (Plate I., Fig. 1), is edged in this way, although deposition obviously takes place most easily on the oolitic grains.

There appear to be no sand-grains in the rock, and the centres of the grains are usually calcite in irregular aggregates, relics of foraminifera, and bits of calcite-organisms, probably the ossicles of crinoids and the plates of echinids (Plate I., Fig. 2).

The shape of the grain varies with the shape of the nucleus, and is often oval and elongated. The interiors are sometimes filled with an inorganic crystalline aggregate of calcite almost certainly later than the grain in date.

A few grains show a perfect radial and concentric structure, especially in the interior and the outer coat, with a shell between of the same nature as the bulk of the other grains.

The majority of the grains, however, show only a roughly radiate arrangement, due to wandering clear canals passing outward through semi-opaque substance. When cut tangentially, such canals appear as clear circles amongst the opaque matter as if they were the sections of tubes.

The outer coat of the grains is often separated in places from the grain, the interspace being filled with crystalline calcite.

The average size of the grain is ·02 in. The larger grains are about twice this length, while smaller grains are about ·01 in. in length. The tint of the rock appears to come from the larger amount of dark granular material in the grains and from the fact that there is a little iron-ore round the grains or sparsely scattered about the matrix.

To this account Mr. E. T. Newton adds the following:—

"The oolitic granules sometimes have a nucleus formed by some foreign body. Such granules consist of extremely fine concentric layers and radiating lines partly obscured by irregular patches of coarse granular matter. In those granules which possess no foreign nucleus the coarse granular matter extends inwards and forms towards the centre an irregularly radiating spongy mass, which sometimes has the appearance of irregularly radiating tubes surrounded by the darker granular matter. These non-nucleated granules strikingly resemble some said to be now forming in the Great Salt Lake.

"Between the granules and sometimes forming their nuclei are fragments of Echinoderm spines and plates, brachiopod or other shells, polyzoa, entomostraca and foraminifera."

The White Oolite, Clydach Quarry. [E. 2,440.]

A white oolite with smooth fracture, the grains being lighter in tint than the crystalline matrix.

I do not recognise any important microscopic distinction between this rock and the dark oolite. [E 2,439.] The grains are about the same size, but the granular matter within is paler than in that specimen, and iron-ore seems to be altogether absent. There is less intermediate matter between the grains, and it is made of rather smaller crystals of calcite. The same dogtooth crusting of the grains is present.

Small round bodies are present between the grains which possess a very perfect radial structure.

The grains appear to have the same structure as in the dark oolite [E 2,439], but this is less easily observed.

Sandy oolitic Limestone above the Llangattwg Quarries.
Plate I., Fig. 3. [E. 2,324.]

This is a sandy oolitic limestone, the centres of many of the grains being occupied by angular grains of quartz, which are, as a rule, parts of single crystals, but are sometimes crystalline aggregates. The concentric structure of the oolitic grains is good, but the radial structure indistinct. The grains are fairly even in size, whether built on grains of quartz or not, so that in the case of the larger quartz-grains the calcite-coating on them is very thin. The infilling between the grains is of the usual crystalline character.

Lumps of Limestone in the Marl-bed at the top of the White Oolite, Clydach Quarries. [E. 2,442].

Apparently a breccia of dark and pale limestone-fragments embedded in a yellowish marly matrix.

The slide looks like a limestone-breccia. The fragments are angular, and from ·08 inch to ·05 inch in diameter.

The bulk of them consists of a minutely granular aggregate of carbonate of lime with holes filled up by larger crystalline calcite, This aggregate varies in translucency and also in the size of its constituent grains. The interspaces are filled with a mechanical aggregate of calcite-grains, ·001 inch in diameter on an average, the interspaces of which are again filled with still finer calcareous mud.

One of the fragments contains what looks like chambers of foraminifera. Some are traversed by a vague arrangement of tubules (?) and one grain at least consists of a lot of polygonal grains of calcite fitting one another's interstices exactly. This may be a tangential section of a shell. A few minute quartz-grains are present in some of the fragments.

Ferruginous Limestone in the Upper Part of the Carboniferous Limestone, Craig-y-Cwm, 3½ miles South of Abergavenny. [E. 2,315.]

This rock consists of small fragments of crinoids converted into iron-oxide, embedded in calcite. There is no oolitic growth on the fragments.

Ferruginous Limestone in the Lower Part of the Carboniferous Limestone, Craig-y-Cwm, 3½ miles South of Abergavenny. [E. 2,323.]

This rock consists of large shell-fragments and of small fragments of organisms enclosed in oolitic grains, embedded in calcite. The grains and organisms are slightly ferruginous. Small grains of quartz are scattered through the rock, but do not form the nuclei of oolitic grains.

Ferruginous Limestone in the Upper Part of the Carboniferous Limestone, Cwm-y-nant, four miles South of Abergavenny. [E. 2,319.]

This rock consists of fragments of crinoids and polyzoa (larger than in E. 2,315), converted into iron-oxide and embedded in calcite. There is no oolitic growth. Some of the organic structures are partly preserved in a yellowish-green mineral, probably glauconite.

These three rocks, and especially the first and third, make microscopic slides of exceptional beauty. They may be compared with the Rhubina Iron-ore, in which also the crinoids and polyzoa have been replaced by iron-oxide.*

Pisolitic Limestone in the Lower Limestone, Nant-y-gollen, Trevethin. [E. 2,443.]

A dark limestone-breccia or pisolite.

The matrix of this contains abundant angular quartz-grains, the largest about ·012 inch long, the smallest ·003 inch. Some of the grains are complex, and many strained as though they had been derived from gneissic rocks (one larger fragment ·13 inch long).

Oolitic grains and fragmentary or entire organisms occur in abundance, all embedded in a fine calcareous mud or cement.

The larger grains are mostly rounded, but do not show any clear radiating or concentric structures. They are many of them traversed quite irregularly by tubes of circular section. The

* Geology of the South Wales Coal Field, part i, The Country Around Newport, Mon., p. 26 and plate.

tubes seem to have a tendency to run at right angles to the bounding surfaces, and they frequently branch again and again. They may be *polyzoa*, and in one case at least they spring from a central point and radiate out from it. Bits of shells and other organisms are present.

A gritty polyzoan limestone. Some fragments with less perfect tubular structure are of the same character as those seen and remarked in the lumps of limestone in the marl-bed [E. 2,442].

Of this rock, Mr. E. T. Newton remarks that most of the larger granules are masses of the tubules which have been called *Girvanella*. Two or three different sizes of tubule may be seen in different granules.

The Lowest Limestone, near the Beaufort and Crickhowell road.
[E. 2,441.]

A grey oolitic limestone, somewhat like the White Oolite. [E. 2,440], but the oolitic grains look very slightly larger.

This limestone, like the others [E. 2,440 and 2,439], appears to be entirely destitute of either sand or mud. The intermediate matter is entirely crystalline calcite and the grains are like those in the dark oolite [E. 2,439] in structure, while intermediate between that and the white oolite [E. 2,440] in depth of colour.

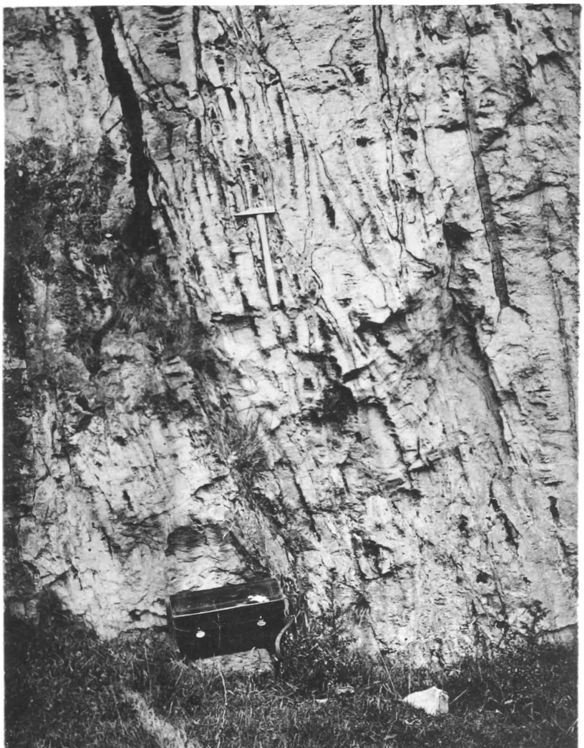
The size of the grains varies from ·02 to ·04 inch in diameter. There are only a few particles of iron-ore.

W. W. WATTS.

Dolomitisation of the Limestone.

In describing the stratigraphy of the northern margin of the Coal Field, allusion was made to the fact that the white oolitic limestone which is so conspicuous near Clydach and Gilwern undergoes some sudden changes in mineral character. The change, when complete, consists in the replacement of a portion of the carbonate of lime (about 30 per cent.) by carbonate of magnesia and in a recrystallisation of the whole rock, which obliterates all organic structures. The change takes place gradually, both horizontally along the outcrop and vertically from one part of the bed to another, but as a rule more abruptly across the bedding than along it. As will be seen from the analyses by Prof. Watts, the proportion of carbonate of magnesia increases steadily towards the area of dolomitisation, while examination of the same specimens under the microscope has revealed the fact that the carbonate of magnesia makes its appearance as isolated crystals scattered through the mass of the oolite (Plate I., Figs. 4, 7, 8). These crystals, which show no organic structures, cut across or into the oolitic grains, and eventually, as they increase in abundance, obliterate the oolitic structure and bring the rock to the condition of a true crystalline dolomite (Plate I., Figs. 5 and 6).

These changes can be nowhere better studied than along the escarpment from Blorenge to the Clydach. The ravine known as Cwm Ifor, which traverses The Tumble, shows that the upper part of the limestone includes a thick mass of crystalline



DOLOMITISED OOLITE.
CARBONIFEROUS LIMESTONE.
CLYDACH.

dolomite [E. 2,438], well exposed in the old tramway. Five hundred yards west of the ravine we enter the quarry near Pwll-du, described on p. 22, and find the dolomite passing horizontally in a distance of not more than ten yards into the white oolitic limestone for which the quarry was worked. Whether as dolomite or oolite, the stratum stands out in the hillside, and can be followed step by step; the change is unaccompanied by any fault.

From the Pwll-du Quarry the oolite keeps its character westwards through a long range of quarries (p. 23) to the Clydach Quarries at Clydach Station, but in the ravine of Nant Dyar is dolomitised again for a few yards. Here there is a well-marked fault which is clearly exposed to view in the Old Red Sandstone and lower beds of the limestone. The dolomitisation sets in about 100 yards east of the fault on its downthrow side; on the west side of the fault, within eighty yards' distance, the rock has recovered its normal oolitic character:

A still more instructive case occurs a few yards further west. The prominence of Twyn-y-Dinas, south of the Clydach Tunnel, consists of white oolite; but this same rock on the west side of a small fault, where it is thrown down to the level of an old tram-line, becomes a true dolomite. The change may be followed step by step from unaltered oolite into a rock dotted through with rhombohedral crystals of dolomite, and finally into a pure dolomite. By following the tram-line a few yards further westwards we observe the same changes in reverse order, and get back into pure oolite in the quarry 300 yards west of the tunnel entrance.

The dolomitised limestone is so conspicuously jointed and veined in a direction slightly west of north as to convey the impression that there must be a fault close by (Plate II.). Subsequent investigation showed that there could be no more than a most trifling displacement of the strata, but that there was a fracture in the underlying limestone running in the expected direction. Still more significant is the fact that the Blaenavon Fault, which has a downthrow east of 83 yards in the coal and ironstone measures, has been traced from Coity Mountain to the Millstone Grit at this very point. In the Farewell Rock the fault is recognisable, but small; in the lower part of the Millstone Grit and in the limestone it has ceased to shift the strata, but still makes its effects felt by fissuring. As a conduit, therefore, for underground water it was as effective as though it still kept its large displacement.

The white oolite is partially and locally dolomitised again in Llammarch Dingle, but the alteration is nowhere more clearly shown than at the spot last described.

The connection between the dolomitisation of the limestone and the faulting is obvious in some of the cases mentioned above, and is not disproved by the fact that we have failed to detect faults in all of them. It is to be noted that the faults enter the Coal Measures within half-a-mile of the limestone outcrop, and that those strata must formerly have overlain that crop at a height of less than 600 feet. Salts of magnesia are common in

Coal Measure waters, and salts of barium have been recorded in several cases.* By forming a channel for water containing such salts in solution the faults might account both for the dolomitisation and for the infilling of the cracks and joints with barytes.

To illustrate the change from dolomite to oolite a series of specimens was taken along the same bed. No. 1 [E. 2,311] represents the composition of the rock which seemed in the field to have recrystallised throughout and to have lost all oolitic structure. No. 2 [E. 2,312] was collected four yards east of No. 1, and represents the composition of a rock in which the oolitic structure had partially been destroyed (Plate I., Fig. 4). No. 3 [E. 2,313] was collected six yards east of No. 2 as a good specimen of normal white oolite. Nos. 4 and 5 were taken as one hand-specimen, three inches long, at the west end of the dolomitised belt to illustrate the vertical change into dolomite. No. 4 [E. 2,330 A] is at the dolomitised end of the specimen. No. 5 [E. 2,330 B] is the undolomitised oolite forming the other part of the specimen. The dolomitisation therefore sets in far more rapidly in a vertical than in a horizontal direction. The analyses were made by Prof. W. W Watts.

Dolomitised and non-dolomitised oolite, Clydach.

——	No. 1 [E 2,311]	No. 2 [E 2,312]	No. 3 [E 2,313]	No. 4 [E 2,330 A]	No. 5 [E 2,330 B]
Residue - -	·10	1·20	·18	[1]‡	[1]‡
†Carbonate of iron - -	3·11	6·13	1·15	2·26	2·19
Carbonate of lime - -	66·20	78·90	95·80	71·60	92·70
Carbonate of magnesia -	30·04	13·70	1·60	23·00	1·70
	99·45	99·93	98·73	97·86	97·59

† Fe. and Al. are both estimated as Fe CO_3.
‡ The residue is roughly estimated, not weighed, which may account for part of the loss.

The appearance under the microscope of the completely dolomitised rock, to which No. 1 in the above table approximates, is thus described by Prof. Watts.

Crystalline cream-coloured Dolomite, Cwm Ifor, near The Tumble· Plate I., Fig. 5 [E. 2,438 A & B].

M.—This rock consists almost entirely of crystalline dolomite the crystals being generally about ·02 in. long. Little drusy cavities are of frequent occurrence, sometimes empty and often

* Clowes. *Roy. Society Proc.*, vol. xlvi. See also "The occurrence of Barium Compounds in Artesian Well Water," by J. White. *The Analyst*, vol. xxiv., p. 67, 1899.

filled as noted below. Into these the edges of the dolomite crystals project (Plate I., Fig. 6). Some of the crystals show complete rhombohedral outlines, and one or two crystalline edges are invariably present; neighbouring crystals are generally joined along such edges.

The larger crystals or grains are often built upon skeleton crystals of a yellowish-brown substance which is insoluble in acetic and hydrochloric acids; the outline of the outer part of the grain may be more or less irregular (Plate I., Fig. 5).

On acting on the slide with weak hydrochloric acid the material into which the rhombohedra project, and which fills the drusy cavities, is dissolved entirely, while the rhombohedra themselves are only slightly acted on after a considerable time. This proves that the crystals are dolomite, while the infilling material is calcite.

There are no traces of organisms in the rock, and it would appear to be the product of the alteration of a limestone.

W. W. WATTS.

The following analysis by Dr. Pollard shows the composition of a rock in which the dolomitisation appears to be theoretically complete, as will be seen by the ratio of lime to magnesia. The specimen (E 2,314) was collected on the tramroad, 200 yards east of the easternmost oolite quarry at Pwll-du, close by and from the same bed as the one last described (E 2,438). It shows no trace of oolitic structure under the microscope:—

Sp. Gr. 2·83

Residue insol. in dil. Hydrochloric Acid	1·10
Ferrous oxide	1·03
Ferric oxide	·33
Alumina	·25
Manganous oxide	·34
Lime	29-91
Magnesia	20·56
Carbonic acid	45·64
Water at 105^0	·10
Water above 105^0	1·01
	100·27

Calculating lime and magnesia as carbonates:—

Carbonate of lime	53·41
Carbonate of magnesia	42·97

Thin slices of the specimen, yielding analyses Nos. 4 and 5, were found by Professor Watts to "show at one side a true oolitic limestone with occasionally a few rhombohedra of dolomite, generally inside the oolitic grains, but sometimes outside them (Plate I.,Figs. 7 and 8.). These rhombohedra increase in size and number so that the opposite side of the slide (Fig. 7) is made up almost entirely of them, leaving, however, some traces still of the oolitic structure, the grains being quite unaltered except where eaten into by the dolomite-crystals. Horizontally [Nos. 1, 2, and 3 of the table of analyses] a similar but less rapid transition is to be seen and every stage of the change can be observed; the rhombohedra attain a considerable size until at last the rock is entirely made up of them except a little calcite mostly occurring in the angular interspaces between the crystals. This is easily demonstrated by the action of hydrochloric acid diluted with glycerine. In its last stage the rock contains 30 per cent. of magnesium carbonate. Inside the dolomite-crystals are more or less perfect skeletons of some yellowish matter insoluble in strong hydrochloric acid (Plate I., Fig. 5): similar material is left when the oolitic limestone is similarly treated. It may represent the impurity originally present in the oolitic grains."

Silicification of the Limestones.

The oolitic chert which was described on p. 28 as intervening between the base of the Millstone Grit and the limestone at the Trefil Quarry is thus described by Professor Watts :—

Chert, Trefil Quarry. [E. 2,435.]

A grey chert with good oolitic structure on its cut face. There is no effervescence with acid.

The rock is most probably the replacement of an oolitic limestone. The structure of the original grains, both concentric and radial, is fairly preserved and accentuated by the deposit of iron-ore (probably limonite), which occurs inside and at the edge of the grains and especially in certain bands. A chalcedonic deposit occurs between the grains banded parallel to the enclosing walls of the spaces between the grains.

Occasionally an organic fragment is replaced by silica, but no other clastic grains are present.

I think the general staining of the grains is due to limonite and not to any siderite or other carbonate left behind in replacement.

Chert, Trefil Quarry. [E. 2,436.].

A dark chert bleaching towards the exterior, also oolitic on the cut face but losing this aspect where quite bleached. This bleached portion does not seem to occur in the slide. Very slight local effervescence with acid.

This is also a siliceous oolite, but different from the last in the fact that the silica of the grains is coarser and clearer than that of the matrix which is finer-grained and fuller of limonite. In parts the oolitic structure would be almost invisible but for the rings of specks of iron-ore on the edge of the granules. The point mentioned above about the coarseness and clearness of the silica is of no importance, for the facts are reversed in other parts of the slide. W. W. WATTS.

CHAPTER V.

CARBONIFEROUS ROCKS (*continued*).

Millstone Grit.

The massive quartz-grits of this subdivision form the barren moorlands which include the Mynydd Llangynidr, Llangattwg, Blorenge, Garn-fawr and Garn-clochdy. In this part of its outcrop the Millstone Grit consists of three fairly distinct sets of strata in descending order:—

Massive sandstone with lenticular shale (the Farewell Rock), which though extremely variable may be considered to range from 40 to 80 feet in thickness.

Shales with lenticular sandstones. This group contains nodules of ironstone and thin impersistent seams of coal. A band of dark mudstone with thin argillaceous limestones containing marine fossils occurs in this group at many localities from Clydach westwards.

Pebbly grits insignificant in the south-east, but expanding and becoming highly conglomeratic westwards along the North Crop. Shales are quite subordinate.

These groups not only vary rapidly in character as they are traced along their outcrop, but graduate vertically one into the other. It is difficult therefore to give precise measurements, but taken as a whole the Millstone Grit may be stated to be about 250 feet thick near Abersychan, 200 to 240 feet at Clydach, and about 245 feet near Rhymney.

It will be noticed that the most conspicuous member of the Millstone Grit of the North Crop is the pebbly grit at its base; in the South Crop, on the other hand, that rock is impersistent and insignificant, while the Farewell Rock forms the dominant feature and is the only conspicuously conglomeratic grit.* The pebbles in these conglomerates consist almost exclusively of vein-quartz, and the rock strongly resembles the upper conglomeratic subdivision of the Old Red Sandstone.

The middle subdivision varies much as it is traced westwards. As far as the Rhymney River it both contains and graduates down into grits, but beyond that it consists wholly of shale. The mudstones with marine fossils previously alluded to occur in association with some shales with ironstones, which were formerly worked under the name of the Rosser Veins, about the exact horizon of which, however, some confusion has arisen.

---

* Geology of Newport, p. 27.

That the Rosser Veins from which Dr. Bevan collected his fossils occurred in and not above the Millstone Grit is clear from his description. In the Geologist, vol. i., p. 53, he gives a section of that formation, and mentions the thin coals, the fossiliferous shale with ironstone, and the basal conglomerate in proper order; on p. 129 he gives a list of marine fossils obtained by him from the thin coals and the shale, and lastly, on p. 507, states that the ironstones are termed the Rosser Veins.

In 1861 an account of the Fossils of the South Wales Coal Field by J. W. Salter appeared in the Iron Ores of Great Britain (Memoirs of the Geological Survey), p. 219. The lists were drawn up from two collections only, namely, those of Mr. Adams and Dr. Bevan, and the collections were distinguished by letter. The first list gives the specimens found in the "Rosser Veins, under the Farewell Rock."

The fact, however, that these argillaceous ironstone measures closely resembled Coal Measures, and that the thin coals were being worked at the time of the original survey of the district, led to their being included, together with the Farewell Rock above them, in the Coal Measures on the Geological Map, although both were classed as Millstone Grit in other districts where the coals were not worked. The matter was further complicated by the fact that some ironstones which lie next below the Garw Coal, and therefore above the Farewell Rock, in the Hirwaun and Merthyr district, were also worked under the name of Rosser Veins. These were rightly included in the Coal Measures on the map, whereas the Rosser Veins of the Blaenavon and Rhymney district should have been, and now are, referred to the middle subdivision of the Millstone Grit. The marine fossils of the Rosser Veins of Blaenavon, Beaufort, and Rhymney must therefore be kept distinct from those which have been obtained from the Coal Measures at a much higher horizon (p. 84).

The outcrop of the shales of the Millstone Grit, though far from obvious on the monotonous moorlands, is important from an economic view, for it forms the site of the various reservoirs by which the surface-water is collected for several towns and works.

Commencing in the southern part of the map, we find a picturesque cliff of Millstone Grit in the Church Wood near Trevethin. The stream descending from near that place, and a quarry, furnish a descending sequence as below:—

Church Wood.

	Ft.	In.
Grit, seen to	6	0
Beds not seen, probably shale	20	0
Shaly sandstone (this and the beds below seen in the quarry and the road to it	5	0
Sandstone	4	0
Massive grit	12	0
Black coaly parting with tree-trunks	0	4
Massive grit	4	0
Irregularly bedded shale and sandstone about	40	0
Grit at the level of the river, seen to	6	0

Another quarry, 100 yards south-west of the Baptist College, shows the black coaly parting as a coal two inches thick. Another thin seam crops out in a road 300 yards east of Trevethin Church; this may be the seam opened out in the Twmpath Level.* The Millstone Grit of the tract is bounded on the north by the Trevethin Fault, and along the south side of the fault the lower grit is tilted up at an angle of 45° and forms a bold little ridge.

From Pont-newynydd northwards the Millstone Grit forms a narrow outcrop in the steep western side of the Afon Lwyd valley. Its uppermost member, the Farewell Rock, frequently shows itself, the top lying at about 30 feet below the Old Coal. The lower part is generally covered with detritus, but a railway cutting on the L. & N.W. Railway, half a mile south of Cwm-afon Station, shows 20 feet of grit, resting directly upon limestone and overlain by shale. The middle part of the subdivision consists of irregular alternations of shale and sandstone, the latter with threads of drifted coal in the planes of current-bedding. On the east side of the valley at Abersychan there is an outlier of Millstone Grit in the last stage of dissolution; though none of the rock can be seen actually in place, the top and sides of the ridge are densely overspread for nearly a mile with loose blocks of the lower grit.

The section forming Fig. 5 (p. 55) has been plotted across the valley from Farteg Hill to Byrgwm along a line where repetition of the outcrop gives an opportunity for exactly determining the inclination of the strata. It shows that the total thickness of Millstone Grit falls a little short of 250 feet in Farteg Hill. On the mountain east of the valley the section passes through a large swallow-hole known as Pwll Gwyn, and at this point indicates a thickness of about 100 feet of strata above the limestone. The swallow-hole commences in shale, while to the north and south of it there is rising ground, consisting of outliers of one of the overlying grits.

Proceeding northwards towards Mynydd y Garn-fawr we pass along a narrow neck occupied by the shales, cross an outcrop of a pebbly grit interstratified in them, and gain a broad plateau formed by the upper rocky division of the Millstone Grit. The edge of the plateau is notched at Blaenavon by the stream of Nant Llechan, and here may be seen about 18 feet of grit with a coal-smut eight feet from the base, resting on dark shale with *Carbonicola*. Eight hundred yards to the north-east of the spot a thin seam of fine-grained quartz-rock is being quarried as a gannister for the Blaenavon Furnaces. The rock is about two feet thick, and is overlain in the quarry by eight feet of grit. Its appearance under the microscope is thus described by Professor Watts:—

Blaenavon Iron Company's Pit, Gwaun Felen. [E. 2,437.]

M. A hard, cream-coloured, very fine-grained siliceous grit. The grains in this grit are very even in size, the bulk of them

* Geology of Newport, p. 27.

measuring ·0045 in. in greatest diameter; a few measure as much as ·01 in., while the smallest measure as little as ·002 in.

They are all sharply angular, and packed very closely into one another. *Almost all* of them are of *quartz*, generally filled with minute inclusions, probably of fluid. Grains of felspar are not at all of common occurrence, but there are fairly frequent grains of a rock—probably a *chert* or a felsite. Particles of *tourmaline*, opaque iron-oxide and probably altered ferromagnesian minerals occur, but there is no mica.

The rock appears to be mainly made of minute granitic *débris*, after the mica and kaolin have been washed off.

W. W. WATTS.

The plateau of Blorenge (see Fig. 1, p. 7) is formed chiefly by the upper grit or Farewell Rock, the shales and lower grit appearing as an ill-defined terrace just above the limestone outcrop. A seam of house-coal, known as the Engine Vein, with a maximum thickness of 2 ft. 4 in., has been worked at the southwest end of the plateau; it was reached at a depth of 26 yards by a shaft which is almost upon the crop of the Old Coal at Pwll Mawdy, and it crops out in the road 600 yards further east. Both the lower and upper grits are pebbly on Blorenge, but the lower appears to be impersistent, for it makes no show on Cefn-y-Galchen. Westwards, however, it is continually in evidence, and in the old quarries above Tumble there may be seen 30 feet of pebbly grit superimposed upon the limestone.

At Gilwern the so-called Engine Coal is said to have been proved in a well at the Prince of Wales' Inn at a depth of eight yards; the crop must cross the top of Cwm Dyar, though the coal is not visible. In descending the Cwm we traverse the following section:—

Cwm Dyar, Gilwern.

		Ft.
Coal Measures—Mine-ground worked at Pwll-du		–
Millstone Grit, 200 feet.	Farewell Rock; thick grit, coarse but rarely pebbly; it forms a waterfall and the crag of Careg Gwyr; at its base a coal-smut	35
	Shale, not all visible, but about	40
	Pebbly grit, about	20
	Shale, fossiliferous	15
	Pebbly grit	18
	Micaceous sandy shale and sandstone	6
	Pebbly grit with subordinate shales 45 feet above its base	66
Carboniferous Limestone, see p. 23.		
		200

From this point westwards the description of the Millstone Grit is continued by Mr. Gibson:—

In Llammarch Dingle a nearly complete sequence through the lower part of the Coal Measures, Millstone Grit, and Carboniferous Limestone is laid open. The section forming Fig. 6 (p. 59) passes a few yards west of the dingle.

Llammarch Dingle.

			Ft.	In.
Coal Measures, see p. 58				
Millstone Grit.	Farewell Rock, massive grit	about	51	0
	Coal, very irregular	0 to	1	0
	Grits and shales		15	0
	Fireclay		2	0
	Coal, locally called Engine Coal		1	10
	Grits and shales		73	0
	Black shale		5	0
	Massive grit		8	0
	Shale with nodules of ironstone		6	0
	Grit, pebbly in the lower six feet		77	0
Carboniferous Limestone, see p. 24				
			239	10

The upper of the two coals here mentioned crops out under the waterfalls formed by the Farewell Rock at the tops of Cwm Dyar and Cwm Dyar Fach, as well as in Llammarch.

The Engine Coal which was being worked in Llammarch in 1894 lies 17 feet lower down, and agrees in position with a coal formerly much worked in Cwm Carno, mentioned below.

The Clydach gorge shows a similar sequence between Ffynnon Gilfach and Coal Tar Houses. The *Ffynnon* is a strong spring issuing from the limestone; about 30 yards west of it the limestone is thrown against the Millstone Grit by what seems to be a crush rather than a fault of any considerable displacement.

A waterfall on the north bank of the Clydach near Coal Tar Houses shows, immediately under the Coal Measures, grits irregularly interstratified with shales, and containing, at about 33 feet from their top, some dark mudstones with thin bands of laminated mud full of plant-remains. The mudstone, however, is not the same as a band exposed by the side of an old tram-line, 250 yards further east, which abounds in small brachiopods. This marked fossiliferous bed is well shown in Nant-yr-Hafod, 400 yards north of a tram-line which runs to the south of Pen-y-lan-fach; it there contains a dark earthy limestone, in which *Discites*, *Spirifera*, *Productus*, and other fossils, are common. It not improbably corresponds to the fossiliferous shale referred to in the section of Cwm Dyar on p. 40, and to the fossiliferous horizon of the Rosser Veins of the Rhymney and Blaenavon districts.

At Garn-lydau (Fig. 7, p. 59), the Farewell Rock forms a bare rock-surface, and is directly overlain by the Garw Coal and its underclay, as may be seen in a level 200 yards to the south of the Heathcock Inn. The deep ravine of Cwm Carno lays bare both the whole of the Farewell Rock and the shales below, with a coal 1 ft. 6 in. thick, in which there are several old levels. On the east bank of Cwm Carn-eilw, the north-westerly continuation of Cwm Carno, a small gully 900 yards south-east of the Ebbw Vale Reservoir reveals black mudstones containing a marine fauna similar to that of Nant-yr-Hafod. This is probably the locality given in his list by Salter as "Beaufort." *

* Memoirs of the Geological Survey, Iron Ores of Great Britain, p. 221.

The long slope of Twyn Bryn-march is formed by the Farewell Rock, an extensive surface of which, lying east of Trefil Station, is bare of vegetation. This rock and the shales below it form the sides of Cwm Mil Gatw, a stream which joins the Sirhowy at Blaen-y-Cwm. Opposite Mil Gatw Farm, 200 yards above the junction, there is an outcrop of a black mudstone, rich in the marine fossils common at this horizon.

The slopes of Trefil-las are composed of the lower member of the Millstone Grit, the quartz-conglomerate. In the Trefil Quarries the conglomerate rests directly upon the limestone, part of which has been converted into the silicified oolite described on p. 36.

From Blaen-y-Cwm to a mile north of Trevil the Sirhowy Valley follows the Tredegar (or Pen-y-fan) Fault (p. 84). At Trefil this fault throws down the lower member of the Millstone Grit on the west more than 300 feet below its position on the east side of the valley.

On Cefn Pyllau-duon, a broad and barren plateau separating the Sirhowy and Rhymney rivers, the three members of the Millstone Grit are well developed. The lowest forms the low crags and bare glaciated pavements of quartz-conglomerate of Twyn Ceiliog, and repeatedly comes into view in the sides of swallow-holes. The holes are extremely numerous on the outcrop of the lowest grit, and occur even in the upper part of the shaly subdivision, where there would appear to be 180 feet or more of shales and grits on top of the limestone, but are absent in the area occupied by the Farewell Rock. They serve to conduct a large proportion of the rain which falls upon this moorland to underground channels in the limestone.

Above the basal quartz-conglomerate there lie some 30 feet of grey shale which is exposed at intervals on Cefn Pyllau-duon, but is better seen at the reservoir near Blaen Rhymney. Above this comes a thick mass of grit, followed by shales. These are difficult to trace across the moor, but can be recognised with little doubt at the head of Nant-y-Cesyg, a small tributary joining the Rhymney from the east, south of Blaen Rhymney. At the head of this streamlet a level has been opened on a coal 1 ft. 6 in. thick, lying in black shales.

Some old patchworks in the lowest Coal Measures to the north of the railway furnish almost the only clue to the position of the top of the Farewell Rock from Nant-y-bwch to Rhymney Bridge. At the former place the Coal Measures are thrown down on the east against the Farewell Rock by the western Tredegar Fault. The exact displacement of this fault is not known, and its course northwards obscure; probably it splits into the two shown in the limestone north-west of Trefil-ddu.

The Rhymney River and its tributary, the Pitwellt, exhibit a nearly complete sequence of the Millstone Grit. The latter shows what appears to be a great thickness of black unfossiliferous shales, and though the appearance is partly due to the fact that the stream-bed cuts the bedding at a gentle angle and partly to some faults at the head of the stream, there is certainly a greater development here than to the east. In both rivers these shales are separated from the main mass above by grits more or less split up by shales, but westward at Dowlais no such separation exists.

Near Lower House, Blaen Rhymney, black mudstones with numerous fossils, among which good specimens of *Discites* abound, are exposed in the banks of the river.

A few yards south of Rhymney Bridge the Garw, Rough or Bottom Vein Coal, with its underclay, is seen resting on the Farewell Rock. The following generalised section has been constructed by combining the observations made in the localities named above.

Section of the Millstone Grit in the Rhymney Valley.

		Feet.
Coal Measures; Bottom Vein Coal		—
Millstone Grit.	Sandstone (Farewell Rock)	48
	Shale with a thin coal	78
	Sandstone	18
	Shale, supposed horizon of the marine fossils	9
	Sandstone	30½
	Shale	7½
	Sandstone and quartz conglomerate	54
Carboniferous Limestone (p. 28).		
		245

The northern part of the Millstone Grit tract was mapped by Mr. Dakyns, who furnishes the following notes:—

The best section of the lower part of the Millstone Grit group is to be seen above the Llangattwg Quarries. Here the topmost limestone is immediately overlain by a pebbly grit; this is succeeded by sandstone and shale surmounted by a grit which forms the top of the cliff overlooking Cwm Onnen-fach. A feature on the moor running from Twyn Pen-rhiw indicates a third bed, also a pebbly grit, and over this comes the fossiliferous shale mentioned in the foregoing pages. The shale is exposed to view under Mynydd Pen Cyrn, at the north end of a pool lying west of Pwll Gwy-rhoc, on the roadside between Beaufort and Llangynidr, and a swallow-hole near Pwll-coch, where it contains a smut of coal and a little ironstone. The best exposure, however, is at the Ebbw Vale Reservoir, one mile south-west of Pwll-coch; on the south side of the reservoir a coal ten inches thick has been dug for use in the neighbouring cottage, while ironstone was once got from the shales in the valley above the reservoir. The Farewell Rock forms a bold feature on Mynydd Pen Cyrn.

J. R. D.

Swallow-holes.

The swallow-holes which are thickly clustered over parts of the outcrop of the Millstone Grit, bear an important part in the drainage of the district and sometimes attain a great size. On a bare limestone-outcrop they often take the form of open fissures, but wherever there is much "cover" upon that rock, whether of Glacial Drift or Millstone Grit, the visible part of the swallow-hole becomes a funnel-shaped depression. Such depressions vary from a foot or two to upwards of 60 feet in depth, and may be 100 yards or more in diameter.

Swallow-holes may take a linear arrangement along faults, but on the moorlands are more generally arranged along the depressions or what have been lines of drainage; while they occur sporadically also all over the slopes and tops. They occur, in fact, wherever there happens to be a crack or joint in the limestone and wherever surface-water happens to gain access to it. For these reasons they habitually appear in such situations as to intercept the natural surface-drainage.

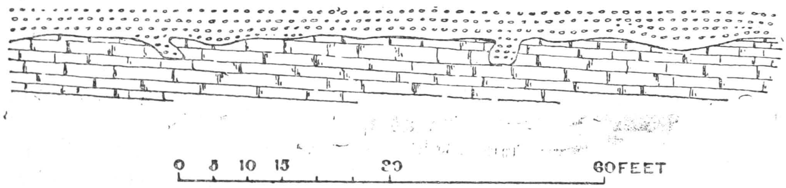
Some of them get blocked with débris and remain half-filled with water, but the majority allow the descent of large streams, as may be seen during any wet day. The exact course pursued by the water after it has gained the innumerable passages in the limestone is usually open to doubt, but it is a familiar feature in that rock that it gives egress to great springs, or what may be better described as streams, and that such issues occur in a region to which the dip of strata would naturally conduct the water entering by the swallow-holes. It is obvious that such streams, though usually clear and always cool, are open to contamination. Dead sheep are not unknown in the swallow-holes on the mountains, while in cultivated regions these holes are used by the farmers for the disposal of the carcases of horses and cattle, as well as of sewage.

The deep valley of the Afon Lwyd cuts down through the whole thickness of the Carboniferous Limestone between Abersychan and Blaenavon, and taps a series of such underground streams. They are thrown out chiefly at the base of the formation and along the east side of the valley, where the strata dip from the hill. Mynydd Garn-clochdy (excepting the outliers of upper grit) and the limestone-outcrop round it are dotted over with swallow-holes, and may be regarded as the source of the water. On the west side of the valley where the strata dip into the hill the springs are fewer and smaller. There are a few swallow-holes in the lower beds of the Millstone Grit on the hillside above, which, no doubt, communicate with the sources. Some are used as receptacles for refuse.

On the broad dip-slopes of the Llangattwg and Llangynidr Mountains swallow-holes abound and attain a great size. The large pool, 600 yards west of Pwll Gwy-rhoc, is stated by Mr. Dakyns to be a blocked swallow-hole, while Ogof Fawr, a little north of Llyn y Garn-fawr on Mynydd Llangynidr is a cave worn through grit into the underlying limestone. To the east of the Trefil Quarries the ground was found by Mr. Gibson to be riddled with swallow-holes, which tend to assume a linear arrangement parallel to the Tredegar Fault to the south of the quarries. Trefil-ddu and Cefn Pyllau-duon are dotted all over with them, excepting the southern part of the moorland which is occupied by the Farewell Rock. This distribution gives a clue to the thickness of measures through which the effects of the honey-combing of the limestone can make itself felt. On the outcrop of the basal pebbly grit, where the thickness of Millstone Grit ranges from nothing to upwards of 60 feet, the holes abound; they occur in greater size, but in smaller numbers over the outcrop of the shaly subdivision where the thickness probably ranges up to 150 feet or more, while they are absent in the upper beds where the thickness of underlying Millstone Grit exceeds 180 feet. Most of the holes are circular, though two may coalesce and form an oval. The water draining northwards falls into an elongated hole 750 yards east of Twyn Ceiliog, and reappears as Nant-y-Llechau, 350 yards to the east. A large swallow-hole (indicated on the map by an arrow north of Twyn Ceiliog) communicates with an open cave in the limestone, and 200 yards to the N.N.E. there is a chasm, a few feet wide but several yards long, which leads into a cave hollowed out in some 20 feet of pebbly grit. The shallow depression in the limestone known as Odyn-fach is drained by a number of swallow-holes, in many of which the limestone is exposed, and in one of which there are the ruins of a lime-kiln, whence came the name.

The solution of limestone by surface-water is manifested not only by swallow-holes but by the removal of the upper beds of the formation over wide tracts. In such cases the overlying Millstone Grit has subsided to a lower level in a state of ruin, which caused great difficulty in determining its true limits. It gave, moreover, an appearance of unconformity between the grit and the limestone, which from general considerations we believe to be false. An excellent example occurs in the Llammarch

FIG. 3. *Millstone Grit (Quartz Conglomerate) cutting into the top of the Carboniferous Limestone, Llammarch Dingle.*



Dingle. The pebbly basal grit there rests upon thinly and evenly bedded limestone. In a distance of about 35 yards the grit not only overlaps about six feet of the limestone, but it lies in holes and even sends tongues down into that rock. The appearances suggest that the surface of the limestone was eroded by the currents which distributed the pebbles, but they may be partly due to subsequent dissolution. On this subject Mr. Dakyns remarks that he has often found the grit-blocks which abound upon much of the limestone-area arranged in lines streaming down to the swallow-hole, as though such streams were the result of caves having broken in and let down the overlying grit. He notes also that the limestone-escarpment though generally bold is interrupted in places, and the rock concealed by masses of grit-débris, as if old valleys, now choked up, have breached the escarpment. Such is the case south of Wern, above Pant-y-Rhiw, and at both ends of Craig-y-Castell. In some of the swallow-holes, as at the head of Nant Trefil, there is nothing to be seen but decomposed Millstone Grit.

A part of the rainfall is diverted from the swallow-holes by artificial channels and conducted to the reservoirs. That which disappears in the swallow-holes at the heads of the Rhymney and Sirhowy rivers tends to travel down the beds southwards or to escape along them laterally. Towards the south where it is held down under less permeable strata it acquires a considerable "head," and tends to burst up violently wherever vent is provided. Thus some fissures in or near the bed of the stream, 350 yards above Blaen Rhymney, overflow violently in wet weather, but are dry at other times. Another such issue, but more constant, exists at Blaen Sirhowy, and is used for the drinking supply of the Sirhowy Valley. The yield is said to be 500,000 gallons per 24 hours at the minimum.

The part which escapes laterally finds egress in Nant Trefil; along the sides of which there are many copious limestone-springs. On the other hand the springs are small and few along the northern face of the limestone-escarpment, the dip being uniformly southward and into the hill-face.

No doubt the limestone under the Coal Measures is charged with water under pressure, if any underground channels extend so far from the outcrop. No satisfactory trial of this source of supply has yet been made, but the capability of the Millstone Grit was unintentionally tested in the Elliot Colliery in 1891, as described by Mr. E. M. Hann.* The west pit was sunk 440 yards to the Red Vein and 450 yards to the Ras-las Vein, and the east pit 530 yards to the Lower Four Foot. In November, 1891, after some coal had been worked off, the floor burst up and an outburst of water took place which yielded 60,000 gallons per hour for three weeks, and was running a month afterwards at the rate of 36,000 gallons per hour, five months afterwards at the rate of 21,000 to 22,000 gallons per hour, and a year afterwards at the rate of 16,000 gallons per hour. Renewed workings then caused a fresh crack, and the water rose to 38,000 gallons per hour, but in six weeks fell again to 22,000 gallons. Analyses were taken at intervals, and it was inferred from them that the water could not have come from the limestone, but presumably was derived from the Millstone Grit, the Farewell Rock lying about 38 yards below the Lower Four Foot Coal. In the same district, however, the Rosser Veins had been worked without trouble from water, though they lay only six feet above the Farewell Rock.

It was thought that the "feeder" had been permanently reduced to 22,000 gallons per hour, but in the two following years fresh outbursts occurred, and the total quantity ran up to 72,000 gallons per hour. At the same time a great increase in the proportion of carbonate of lime and sulphate of soda in the

* *Proc. S. Wales Inst. Min. Eng.*, vol. xix., p. 143.

water took place, and it was inferred by Mr. Hann that the limestone was the source of supply.*

A similar influx of water is stated to have taken place in working "the lower seam" at Ebbw Vale.†

Fossils.

The grits contain rolled fragments of *Calamites, Sigillaria, Stigmaria* and *Lepidodendron* everywhere, but the fauna of the period is preserved only in the shaly middle subdivision, and chiefly in the lower part of it. Generally speaking the fossils are purely marine in the lower beds and tend to become estuarine in the upper; such forms, for example, as *Productus, Spirifer*, and *Discites* predominating in the one, while the estuaro-marine *Carbonicola* (*Anthracosia*) alone survives in the other.

The following list has been made up from the collection of Dr. G. P. Bevan and Mr. W. Adams, as given by Mr. J. W. Salter in the Iron Ores of Great Britain,‡ to which have been added some specimens collected of late years by Mr. S. Trump, and identified by Messrs. Sharman and Newton, and those mentioned by Dr. Wheelton Hind in his Monographs on Carbonicola, etc., and on Carboniferous Lamellibranchiata.§ The list includes also the specimens preserved in the Museum of Practical Geology, as well as some collected during the recent re-survey.

Millstone Grit Fossils.

A = Adams Collection.
B = Bevan ,,
H = Wheelton Hind, Pal. Soc., vols. 48 *et seq.*
M = Museum of Practical Geology, Collections of 1861.
S = Survey Collections of 1893.
T = Trump.

—	Beaufort and Clydach.	Cwm Bryn-ddu.	Glan Rhymney.	Valley north of Dowlais Big Pond.
Poteriocrinus - - - - - -			T	
Rhodocrinus - - - - - -			T	
Encrinite stems - - - - -	B			
Athyris sp. - - - - - -			M	
Chonetes laguessiana (hardrensis, *Ph.*)			A, B, M, T	
Discina nitida, *Phill.* - - -			M, T	
Lingula mytiloides, *Sow.* - -				A, B, M
Orthis Michelini, *Lev.* - - -			A, B, M, T	
,, resupinata, *Sow.* - - - -			A, B, T	
Productus semireticulatus, *Martin* -	B, M		M, T	
,, hemisphæricus, *Sow.* - -	B			
,, sp. - - - - - -			T	
Spirifera *bisulcata*, *Sow.* (*see* trigonalis).				

* *Proc. S. Wales Inst. Min. Eng.*, vol. xxi., p. 248.
† *Ib.*, vol. xxi., p. 376.
‡ Mem. Geol. Survey, 1861, p. 221.
§ Pal. Soc., vols. 48 *et seq.*

—- -	Beaufort and Clydach.	Cwm Bryn-ddu.	Glan Rhymney.	Valley north of Dowlais Big Pond.
Spirifera glabra, *Sow.* - - -			B, M, T	
„ trigonalis var. bisulcata, *Sow.* - - - - -	M		B, M, H	
„ Urii, *Flem.* - - -			A	
Streptorhynchus crenistria, *Phill.* -	B, M			
Arca (striate sp.) - - - - -			B	
Aviculopecten gentilis, *Sow.* - -	B, M			
„ papyraceus, var. rigida	M			
„ scalaris, *Sow.* - -		A, M		
„ sp. - - - - -	M			
Carbonicola (*Anthracosia*) acuta, *Sow.*		H		S*
Ctenodonta (*see* Nucula) - - -				
Edmondia oblonga, *Portl.* - -	B, H		B, H	
„ (Myacites) sulcata, *Phil.* -	B		B, M	
„ „ *unioniformis* (*see* E. oblonga).				
Myacites (*see* Edmondia) - - -				
Naiadites (*Myalina*) triangularis, *Sow.*	B			
Nucula æqualis, *Sow.* - - -		A	T	
„ gibbosa, *Flem.* - - -			B	
„ undulata, *Phill.* - - -			B	
Schizodus axiniformis, *Phill.* - -		B, H		
„ carbonarius, *Sow.* - -		B, H, M		
„ *sulcatus* (*see* axiniformis) -				
„ sp. - - - - - -	M			
Littorina (?) *obscura* (*see* Natica).				
Loxonema (?) - - - - - -		M		
Macrochilina (minute) - - -		B		
Natica obscura, *Sow.* - - -	B, M			
Pleurotomaria (Luciella) limbata, *Ph.*			B	
Bellerophon apertus, *Sow.* - -		A		
„ decussatus, *Flem.* - -	B, M			
„ hiulcus, *Sow.* - -	B			
Conularia quadrisulcata, *Sow.* - -			B, M	
Cœlonautilus (Nautilus) quadratus, *Flem.* -			T	
„ „ sp. - -	S		M, S	S
Discites falcatus (*see* Pleuronautilus).				
Gastrioceras (Goniatites) Listeri, *Sow.*			A, B, M	
Glyphioceras (Goniatites) reticulatum, *Phill.*			M	
Orthoceras - - - - - -			B	
Pleuronautilus (Nautilus) falcatus, *J. de C. Sow.*			A, B, M, T	
Temnocheilus (Nautilus) concavus, *J. de C. Sow.*	B			
Megalicthys Hibberti, *Ag.* - -	B	A.		

* The Carbonicola usually occurs above the marine fauna given in this list, but in this locality was obtained a few feet below it.

CHAPTER VI.

CARBONIFEROUS ROCKS (*continued*).

COAL MEASURES.

The map under description includes the eastern margin of the Coal Field from Pont Newynydd to Blaenavon, and the north crop nearly to Dowlais. The measures being gently inclined everywhere, the physical features due to the different resistance offered to denudation by the Pennant Grit and the soft measures beneath it are developed in great perfection. Thus it will be seen that between each of the seven valleys which traverse this part of the Coal Field, there is a long plateau of Pennant Grit rising gently northwards until it terminates in a bold brow dominating the outcrop of the lower measures.

The Coal Measures have been subdivided during the progress of the resurveying into three great groups, all of which are represented in this area.

1. The Mynyddislwyn Vein, a noted house-coal, forms a convenient base to an upper series of soft sandstones and shales. These measures, of which a small part only falls within the area under description, are more fully treated in the Memoir on the Geology of Newport.
2. The Pennant Grit, to which the characteristic *Mynydd* of the Coal Field is due, consists in the main of highly felspathic grits, occasionally pebbly. Shales are not absent but are subordinate, and coals are few and unimportant. A remarkably constant house-coal, known in different parts of this district as the Red Ash, Tillery or Brithdir occurs at the base of the main mass of grits. The thickness of the group of measures separating the Mynyddislwyn and the Tillery Veins ranges from about 212 yards in the eastern to about 327 yards in the western part of the district.
3. The lower or Steam Coal Series consists in the upper part of nearly as much sandstone as shales, but in the lower part, where also the most valuable seams are clustered, almost wholly of shale. In this lower part also occurred the "mine-ground," or shales with nodules and bands of argillaceous iron-ore, the working of which formed the most important industry of South Wales in the early part of this century. The "mine" is now scarcely touched, whereas the coals which were formerly left are worked energetically. The thickness of this lower series ranges from about 250 yards in the eastern to about 560 yards in the western part of the district.

The lowest workable coal-seam is that known as the Old Coal, but an unimportant seam called in various districts the Garw or Rough, the Bottom or Big Vein Coal forms a more approximate base to the Coal Measures, inasmuch as it is preceded immediately by the Farewell Rock, the uppermost band of the Millstone Grit.

From Abersychan to Blaenavon the outcrop of the Steam Coal Series runs northwards and is confined to a narrow belt on the steep side of the Afon Lwyd Valley, but at Blaenavon it turns westwards along what has been the most thoroughly exploited parts of the district. The gentle dip and long slopes cause the outcrops to be widely spaced out and keep each bed near the surface for a long distance, and thus have led to a great development of the system of open-air working known as "patchwork." These great excavations were made chiefly in the extraction of the nodules and bands of clay-ironstone, known to the early miners as "balls and pins of mine," but such coal as was required for the local works was raised at the same time. This local ore alone was used and the furnaces were arranged along the outcrop of the mine-ground, the principal being Abersychan, Farteg, Blaenavon, Clydach, Blaina, Ebbw Vale, Tredegar, and Rhymney. The Jack and Balls Mine, which lies 8 yards below the Old Coal and $2\frac{1}{2}$ yards above the Bottom Vein Mine (Vert. Sects., Sheet 81, No. 7), was being worked in 1895 at Farteg Hill for the Blaenavon Furnaces, and some was being raised at the Hill Pit and near the Prince of Wales Inn, Pwll-du, but with these exceptions all the ore now used is imported. The patchworks, with their vast heaps of rubbish, run almost continuously along the crop of the lower measures from Blaenavon westwards, and bear witness to the importance of this almost defunct industry.

In turning westwards we take a direction in which the well-known thickening of the measures becomes most noticeable. The thickening takes place both southwards and westwards, and leads eventually to a great development of all the Carboniferous Rocks in West Glamorganshire. So far as our present area is concerned, it is illustrated by the following table. The two series of measurements run along approximately parallel lines in a direction about W. 10°–12° S., with the exception of the Pochin Pit, which lies $1\frac{1}{4}$ mile north of the general line. The thicknesses are given in yards.

	Harris' Navigation.	Bargoed.		Aberbyg	Cwm-du	
From the Mynyddislwyn to the Tillery or Brithdir Vein	327	342		254	212	
	Bedlinog	Elliot Pit.	Pochin Pit.	Marine Pit.	Vivian Pit.	Farteg.
From the Tillery to the Ras-las or Bydylog Vein	450	430	392	359	328	183

The thickness of the whole of the lower of Steam Coal Series, that is of the measures lying between the Tillery Vein and the top of the Farewell Rock, ranges from about 270 yards at Abersychan to 251 yards near Blaenavon, 449 yards in Ebbw Vale, 541 yards near New Tredegar, and 559 yards at Bedlinog. At Fochriw, which lies $2\frac{1}{4}$ miles north of Bedlinog, and where a slight decrease might have been expected, the distance from the Tillery to the Ras-las Vein is said to be 492 yards,* which would indicate a thickness of 601 yards for the whole of the lower series.

The distance from Cwm-du to Harris' Navigation is 10 miles, and the rate of expansion is consequently 1 in 153; the distance from Vivian Pit to Bedlinog Pits is 8 miles, and the rate of expansion 1 in 117. In the case of the measures between the Tillery and Ras-las Veins the expansion has been found by Mr. Gibson to be accompanied by the wedging in of grits in the Bargoed Taff districts, there being 130 yards of grit at Bedlinog as compared with 71 yards at the Marine Pit.

It is worthy of note that the rate of expansion is especially rapid along the eastern margin of the Coal Field, as though the present limit of the Coal Field, as determined by denudation, bears a not distant relation to the original limit as determined by deposition. For example, the distance from the Tillery Vein to the Old Coal at Aber Tillery is 373 yards; at Farteg Hill, three miles away in a north-easterly direction, the distance between the same two seams is 238 yards, the rate of attenuation thus being 1 in 39. It will be remembered that the limestone thins away no less rapidly under Mynydd Garn-clochdy (p. 20) and under Blorenge (p. 19).

The Monmouthshire Coal Field yields both House and Steam Coals, the latter, however, being as a rule more bituminous, technically less "dry," and not as hard as those of the Rhondda Valleys. It is a general rule throughout the South Wales Coal Fields that the upper seams are more bituminous than the lower, and that the same seams are more bituminous in the eastern than they are in the western part of the Coal Field. Thus the Mynyddislwyn, Tillery, or Red Ash Veins, are "house-coals" thoughout the area of this map; while the lower seams range through the intermediate stages of "flaming steam" and "steam-coal," the Elled, however, being regarded as a house-coal in the eastern part of the field.

Analysis of the iron-ores, made when they were in demand, will be found on pp. 78–82.

The Lower or Steam-Coal Series.

Afon Lwyd Valley.

These measures at the point where they enter the map under description are intersected by the Trevethin Fault, a downthrow south of 50 yards. They are illustrated by the Shaft-sections of Llanhilleth, Tirpentwys, and the Glyn Pit, published in Vert.

* Section supplied to the Coal Commission of 1871.

Sects., Sheet 80, Sects. 11, 10, and 9; and of the Cwm Tillery and Varteg Hill Collieries, published in Vert. Sects., Sheet 81, Sects. 8 and 7.

At the Tranch Colliery* a slope has been driven in on the crop of the Old Coal, but at present the Meadow Vein only is worked, the section being as follows:—

Tranch Colliery.

		Ft.	in.
Meadow Vein	Top coal (not worked)	2	6
	Holing clod	0	8
	Middle coal (worked)	6	0
	Cannel coal (separated and used for gas)	0	3
	Rubbish about	1	0
	Bottom coal (not worked)	2	6
Fireclay, rock, and sandstone		12	0
Old Coal (very inferior)		5	0

From the Meadow Vein a boring was put upwards for 50 yards in search of the Rock Vein, and proved it to be absent, presumably in consequence of one of the "washes" common in this vein. It passed through 30 feet of clift next above the Meadow Vein and the Yard Vein, a good coal, at 54 feet above it. The Elled, or New Vein, is a good coal, 5 feet thick, and has been opened in a level about 400 yards west-south-west of Tranch Colliery. Three yards beneath it lies the Droideg or Big Vein, 5 ft. 6 in thick. At the Plas-y-coed Brick Works the Soap Vein was worked.

The Trevethin Fault runs 140 yards north of the slope, and throws the strata down south 50 yards, though it soon dies away westwards.† Its effects in tilting the strata are apparent in the cuttings of a mineral railway, and in the crop of the Tillery Vein at Cwm-ffrwd-oer.

On the north side of the Trevethin Fault the Meadow Vein crops along the stream of Cwm-nant-ddu, within the loop of the L. and N.W. Railway. It has been opened in Harper's Level and runs thence by Heol-pen-twyn to the British Iron Works. The Old Coal, which is still being worked here and there for local household use, crops about 80 yards further east, and between the two there may be seen an impersistent quartz-grit. West of Snatchwood the Old Coal consists of a top coal 1 ft. 6 in. and a bottom coal 1 ft. 8 in. thick, with about 2 ft. of parting between. The Rock Vein crops just below Ty-troed-rhiw Ffranc, while the Elled or Red Vein rises under that house and runs thence to a level 250 yards south-east of Pistyll-gwyn, where it is being raised with its fire-clay for use at Cwm-bran. Above it are old patches in the Black Pins Mine-ground, surmounted by quartz-grit and conglomerate, known as the Black Pin Rock.

---

* For the information concerning this colliery I was indebted to Mr. W. J. Rees.

† Geology of Newport, p. 60.

The outcrop of the Tillery or Red Ash Vein is complicated by landslips and by the Greenland Fault, a downthrow west of 12 yards at the Roman road. There are old levels upon it in Craig-ddu, a slope now working at Cwm-serchan, and levels, also in work, at the Cwm-nant-ddu (Llannerch) Colliery, while near the Blaen-serchan Colliery, as named on the map, a shaft has been sunk to it at a depth of 120 yards. The vein is impersistent, and under parts of the mountain south of Cwm-nant-ddu was absent or too thin to work. North of the Roman road the crop runs through the great Pant-glas Landslip, which took place about 1866, to the level of the Cwm Byrgwm Colliery, and thence below a massive grit to the reservoir in Cwm-sychan, where it is said to have been proved.

The occurrence of red beds below the Tillery Vein has been noted in the Pontypool neighbourhood.* They crop out south of the Roman road and west of the Greenland Fault, and extend thence far to the north and west, as may be seen by consulting the shaft-sections published in Vert. Sects., Sheets 80 and 81.

At Tranch the Tillery Vein must lie about 250 yards above the Old Coal, if the dip of 1 in 12 in the latter coal continue beneath the outcrop of the former. It would, therefore, be about 200–210 yards above the Black (Rock) Vein at Tranch, as compared with about 188 yards at the Glyn Pit and 231 yards at Llanhilleth.

The Greenland Fault, where it crosses the crop of the Tillery Vein, throws the Elled and Meadow Veins 26 yards down west, and its effects are obvious on the surface, where it cuts through some strong grits below the Tillery Vein in Ty-beili Wood. There the following section was noted:—

Below the Tillery Vein, west of Golynos.

	Ft.
Very coarse grit, crammed with pebbles - - - -	10
Soft yellow sandy shale - - - - - -	6
Deep-red clay - - - - - - - - - -	2
Soft red and yellow sandy shale - - - - -	6
Massive pebbly grit, seen to - - - - - -	9

Further on up the Nant Ffrwd there are upwards of 12 feet of red clay, with pebbly grit above and a brown quartz-grit below, and the same beds are recognisable round much of Mynydd Farteg. The Tillery Vein gives the following section in and south of Nant Ffrwd:—

Under Gwastad.

		Ft.	in.
Tillery Vein.	Top Coal - - - - - - - - -	0	6—8
	Stone - - - - - - -	0	4 12
	Middle Coal - - -	0	6
	Stone - - - - - - - -	0	4
	Coal - - - - - - - - - -	0	5
	Holing - - - - - - -	0	6
	Bottom Coal - - - - -	2	0

* Geology of Newport, pp. 34, 36' 38.

Old Level under Craig-ddu Quarry.

		Ft.	in.
Tillery Vein.	Coal	0	6
	Clod	0	6
	Coal	1	0
	Holing	0	2
	Coal	1	10

In descending Nant Ffrwd we find an old level in the Soap Vein, 300 yards north-east of Craig-ddu, and another in the Black Pins, 100 yards lower down. Just above the Lower Varteg Colliery there are old levels in the Elled and Three Quarter Seams, and just below it one in the Rock (Black) Vein. A few yards above the Elled there lies a coarse quartz-grit, which forms the Mynydd Farteg-fach.

The Varteg Hill Colliery* is situated on the east side of Mynydd Farteg-fach below an old patch, in the lower part of which the Rock Vein may be seen cropping out, while in the upper part the Elled or Red and Three Quarter Seams are visible. The last-named seam crops just over the arch of the Varteg Slope, which lies 700 yards north of the Colliery. The Spotted Pin Mine-ground has been patched 150 yards east of the slope, and there is an old slope on the Old Coal on the south side of the Varteg incline. The Jack and Balls Mine which lies 8 yards below the Old Coal and $2\frac{1}{2}$ yards above the Bottom Vein Mine was being worked here in 1895 for the Blaenavon furnaces, a survival of an almost defunct industry. The complete section of the measures from above the Soap Vein down to the Bottom Vein Mine is given in Vert. Sects. Sheet 81 Sect. 7.

Nothing is known yet of the faults under Mynydd Farteg. Presumably the Blaenavon Fault, which has a downthrow east of 83 yards, must cross its western side, and it is believed that an

Figs. 4 and 5. Explanation.

Myn. V.	= Mynyddislwyn Vein	Coal Measures.
P. G.	= Pennant Grit	
T. V.	= Tillery Vein	
Q. C.	= Quartz Conglomerate	
S. V.	= Soap Vein	
E. V.	= Elled Vein with Big and Three Quarter Veins	
R. V.	= Rock Vein	
M. V.	= Meadow Vein	
O. C.	Old Coal	
F. R.	= Farewell Rock	Millstone Grit.
LST.	= Limestone	Carboniferous Limestone.
L. LST.	= Lower Limestone Shales	
G. G.	= Grey Grit	Old Red Sandstone.
R. S.	= Red Sandstone	
R. S. LST.	= Cornstone	
R. M.	= Red Marls	

* For the information concerning this colliery I was indebted to Mr. F. H. Davies.

Figure 4.—SECTION FROM MYNYDD LLANHILLETH TO NEAR MAMHILAD.
By A. Strahan, M.A.

SCALE — VERTICAL AND HORIZONTAL
0 500 1000 2000 FEET $\frac{1}{2}$ 1 MILE

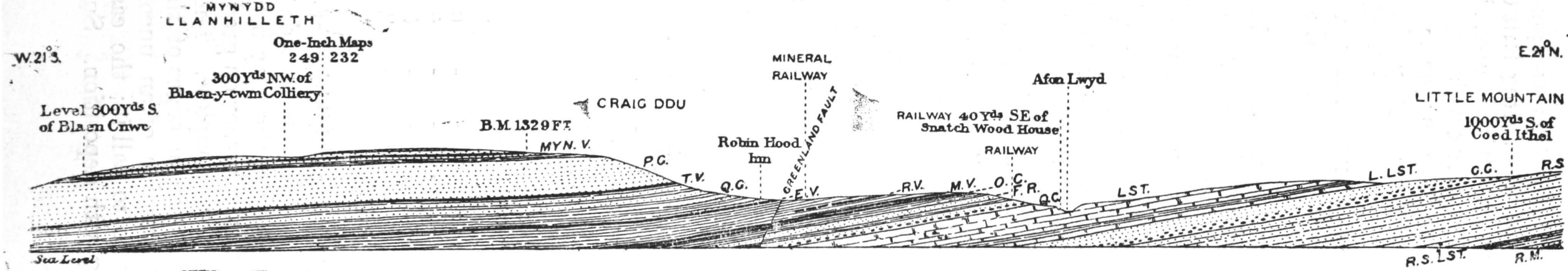
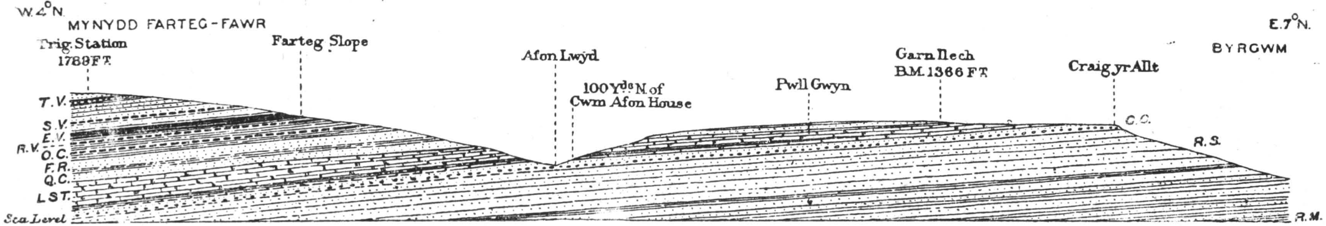


Figure 5.—SECTION FROM MYNYDD FARTEG-FAWR TO BYRGWM.
By A. Strahan, M.A.



easterly downthrow having the right direction was proved in the Rock (Black) Vein 600 yards west of the Varteg Hill Colliery in Cwm Ffrwd. But there seems to be little, if any, shift in the outcrop of the Tillery Vein, nor has any continuation of such fault been met with in the Tillery workings under Twyn Du.

Two faults with downthrows west of 6 and 26 yards have been proved in the Three Quarter Coal on the south side of Cwm Ffrwd; they run considerably west of north, and would cross the supposed line of the Blaenavon Fault near the Craig-ddu Quarry.

The crop of the Tillery Vein near Blaenavon can be traced by the usual massive Pennant Crag above it, and by an old level under the Coity-mawr Quarry. It is crossed by the Blaenavon Fault in Pant-mawr, 800 yards south-east of the quarry, and though the exact position of the coal can not be fixed in the *Pant* without opening the ground, it seems impossible that there can be anything like a shift of 83 yards. Yet that is said to have been the throw of the fault in the Bottom Vein Mine under the L. and N.W. Railway. The same difficulty arises with reference to the crop of the Three Quarter Coal. On the west side of the fault this crop runs from the Garn-yr-erw Colliery nearly along the L. and N.W. Railway to near the Coity Pit; on the east or downthrow side of the fault the crop is repeated and runs under the Iron Works to a point 500 yards south-south-west of Blaenavon Station (L. and N. W. Railway), where the seam was proved in a trial-shaft at 5 yards depth. The displacement indicated by these two crops falls considerably short of 83 yards. It has already been shown that the fault dies out in the limestone (p. 33); it would seem, therefore, to be at its maximum at Blaenavon, and to be larger in the lower than in the higher measures.

The crop of the Old Coal crosses the river 400 yards west of Blaenavon House, and runs thence under the blast-furnaces north of that house. Here it is cut by a fault with a downthrow west of 11 yards. East of the fault it can be traced up to a clay-pit south of the road at Pwll Mawdy.

Pwll Mawdy.

	Ft.	In.
Shale and sandstone	6	0
Coal	0	4
Clay	8	6
Old Coal	2	9
Clay, seen to	6	0

The pit is remarkable for its complete exhibition of a "wash-out." The shales which form the top of the pit-side cut down through the four-inch coal and well into the clay below it in a long gentle curve, and about 50 yards further on gradually rise again until the sequence is once more complete. Their base is sharply defined, and as it passes over the edges of the underlying strata presents a perfect illustration of an unconformity. It would, however, be a misnomer so to call it; the case is one merely of local erosion alternating with deposition. Such washouts unfortunately abound, but they are rarely laid open to view.

The following section was taken in a patch upon the crop of the Old Coal, 400 yards south-east of Old Pwll-du:—

	Ft.	in
Sandstone	2	0
Coal	1	8
Rashings	0	3
Coal	0	6
Rashings	0	6
Fireclay	8	0
Coal	1	2
Underclay	4	0
Coal	1	3
Underclay	5	0
Shale with thin rock-bands, seen to	8	0

The Yard Vein, which lies 21½ yards above the Old Coal is repeatedly visible in the top of a patch at Upper Brick Yard, as well as in the entrance to the tramway-tunnel. Thence it runs to an old clay-level, 400 yards south of Pen-y-ffordd-goch, where the section ran as below:—

	Ft.	in.
Sandstone	2	0
Coal (Little Vein)	1	0
Clay	5	0
Shale and sandstone	3	0
Coal	1	3
Black shale	0	9
Clay, seen to	6	0

The Yard Coal is said to be in the roof of the level.

The Meadow Vein crops in the upper part of the cutting which leads to the tunnel, and the Bydylog comes to the surface above a line of patch-works just north of the tunnel-entrance. The Three Quarter Coal is no longer visible in any of the old patches, but a strong rock above it, which forms Careg Croes Ifor (Fig. 1, p. 7) makes a conspicuous feature round the hill as far as the Blaenavon Fault. The Black Pin Mine-ground lies above this rock, and is itself surmounted by another sandstone. These sandstones die away westwards. The following section is exposed in an old patch-work 500 yards west of New Pit, 1½ miles north-west of Blaenavon:—

	Ft.	in.
Rashings	1	0
Coal	4	0
Fireclay and rashings	5	0
Coal	0	4
Parting	0	3
Coal	0	2
Clay	0	5
Coal	0	2
Fireclay and shale	5	3
Coal	0	3
Fireclay	3	0
Rashings and clay	2	6
Coal	6	0
Fireclay	2	0
Rashings	0	2
Fireclay with nodules of ironstone, seen to	6	0

The coals belong to the group which comprises the Elled, Big and Three Quarter Seams, but their precise identification is doubtful.

For Shaft-sections of the Blaenavon neighbourhood reference should be made to Vert. Sects., Sheet 81.

The following account of the Measures of the North Crop from Blaenavon to the Bargoed Taff is furnished by Mr. Gibson :—

Clydach Valley.

The details of the measures from the Elled Vein downwards near Waun-afon will be found in the section of the Mulfran Colliery given in Vert. Sections, Sheet 81, No. 1. The coals there proved crop out about a mile to the north of the pit and with the associated ironstones have been patched almost continuously between Llammarch and Brynmawr, but are now mostly covered by the crumbling of the strata. The crop of the Garw Coal, the lowest seam of the Coal Measures, is said to have been proved in a level at the head of Cwm Dyar-fach, but is obscured thence to the Llammarch dingle; some old workings 300 yards south of the Jolly Colliers Inn, Waun-llapria, are stated to have been in the Red Vein Ironstones which lie close above the Garw seam, and there is a level in the coal near the roadside at Llammarch waterfalls. The Old Coal and Meadow Vein Coal were formerly won by drifts 150 yards south of the Red Vein workings. South of this there are some old levels and patches on the Bydylog Coal, and still further south at Waun-wen some extensive patches and numerous old levels give sections of the Elled Coal and its associated measures. The plateau of Cefn garn-yr-erw to the south of the "Elled Patches" is composed of a coarse grit (Elled rock), which is exposed to view near Waun-afon House. From here the grit can be traced into the patch works in the Elled Coal 200 yards north of Pwrcas. In the banks of Llammarch dingle, and in old levels close by, several of the coals from the Garw to the Three-Quarter Seam are exposed at intervals, but large portions of the sequence are concealed

Figs. 6 and 7. Explanation.

P. G.	= Pennant Grit	Coal Measures.
T. V.	= Tillery Vein	
Q. C.	= Quartz Conglomerate	
Q. G.	= Quartz Grits	
E. V.	= Elled Vein	
R. V.	= Bydylog or Ras-las Vein	
Y. C.	= Yard Vein	
O. C.	= Old Coal	
G. V.	= Garw Vein	
F. R.	= Farewell Rock	Millstone Grit.
LST.	= Limestone	Carboniferous Limestone.
LST. OOL. and DOL.	= Oolitic limestone, dolomitised at times	
L. LST.	= Lower Limestone Shales	
G. G.	= Grey grits	Old Red Sandstone.
R. S.	= Red sandstones	

Figure 6.—Section from the Old Red Sandstone near Clydach, to the Pennant Grit of Cefn-coch.
By W Gibson

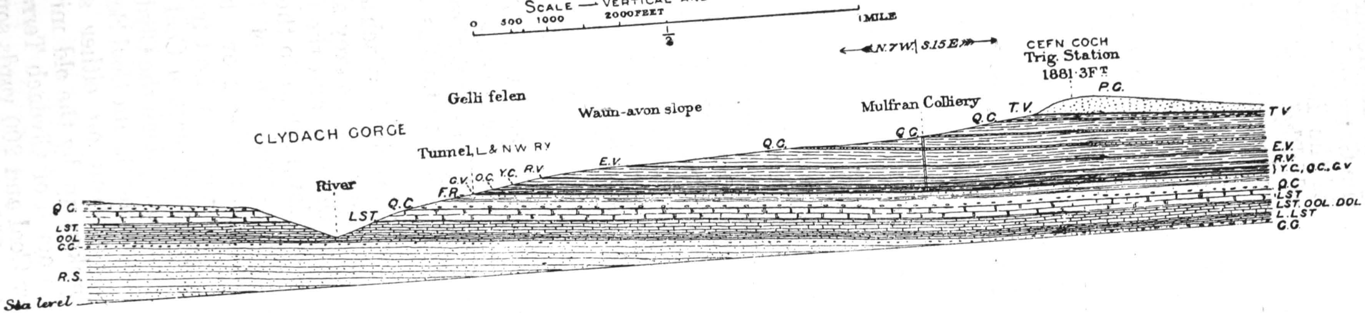
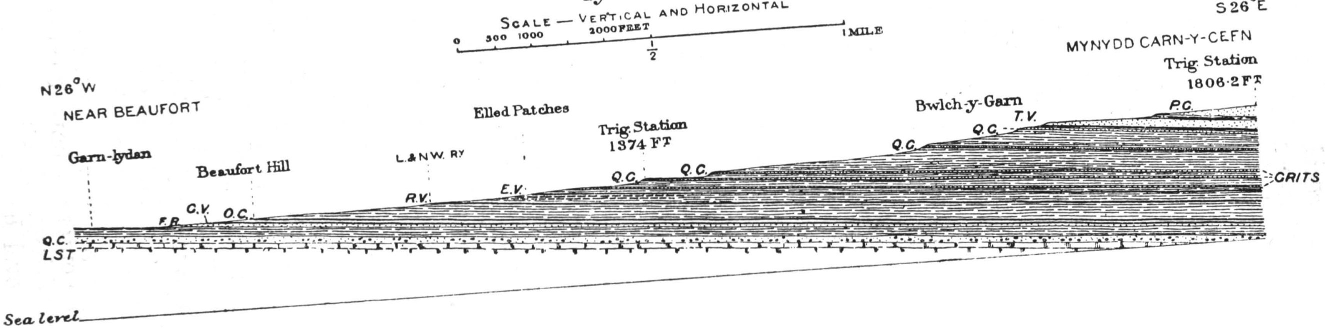


Figure 7—Section from the Millstone Grit near Beaufort to the Pennant Grit of Mynydd Carn-y-cefn
By W. Gibson



beneath talus, so that it is impossible to give measured details, though the section is one of the best in the neighbourhood.

West of Llammarch the crops of the Garw and Old Coals are traceable by means of levels south of the London and North-Western Railway, and between Mynydd Rheinallt and Pontclydach the railway cuts through the following measures:—

Section in the L. and N.W. Railway-cutting near Pontclydach.

	Ft.	in.
Black shale	5	0
Coal, full thickness not seen. Old Coal?	–	–
Grey and black shales with pins and beds of mine	12	0
Grey sandstone		–
Grey shales and beds of ironstone	15	0
Shaly sandstone		–
Big Vein ironstone	0	$2\frac{1}{2}$ 3
Mudstones	5	0
Sandy grey shales	1	0
Big Vein (Bottom Vein) Coal	1	$3\frac{1}{2}$

The Three-Quarter Coal, Big Coal, and Elled Vein can be seen at intervals in the old open workings between Clydach Colliery and the junction of the Blaenavon and Abergavenny Railways. The Soap Vein Coal and Mine were patched from close to Waunavon Station to Twyn Blaen-nant, a distance of over a mile.

The somewhat gentle declivity of the western slopes of Twyn-Carn-Canddo is broken near the base by a slight grit-feature, which becomes more marked to the west and near Waun-y-pwll-dwr furnishes walling-stone and inferior flags. Further up the hill there are four well-marked features, each due to an outcrop of grit, the one forming the main mass of Twyn-Carn-canddo being coarsely conglomeratic.

The Tillery Coal occurs at the foot of the steep ascent o Cefn-Coch, and in an old level 400 yards south of Mulfran Colliery rests directly on a hard grit instead of on a shale or fire-clay, as is more usual. The vein crops out 175 feet above the top of the Mulfran shaft in which the Bydylog or Ras-las Seam lies at a depth of 188 yards.

The banks of Cwm Nant Melyn, which joins the Clydach at the waterfalls near Coal Tar Houses, are formed of the grey shales and mudstones which lie between the Old Coal and the Garw Vein, the latter being visible in some old levels close to the disused tram-line from Brynmawr to the Camp. East of Nant Melyn the Farewell Rock is brought against the grey shales above the Garw Coal by a small fault which crosses the Clydach at a marked break in the steep banks 450 yards east of Coal Tar Houses. Between Clydach Bridge and Blaenclydach the Clydach river deeply trenches the lower portion of the Steam Coal Series and gives good sections, but on the plateau on either side the outcrops have been completely broken up by the old mine-workings. About a quarter of a mile north of Clydach Terrace a level has been opened on the Garw Coal and 200 yards south of this some grey flags overlying the Old Coal break out in conspicuous crags.

Ebbw-fach Valley.

The Ebbw-fach rises in a small alluvial flat 100 yards south of Rhes-fach, and for its entire course runs over Coal Measures. On the eastern side the coals and ironstones between the Old and Ras-las Coals were extensively "patched" in past years, and the outcrops have been so interfered with in the old workings that they have been omitted on the published map.

The shaft-sections published in Vert. Sects., Sheet 81, Nos. 2, 8, 9, illustrate the measures south of Brynmawr. They can be supplemented by the following shaft-section of the Cwm Celyn Pits.

Cwm Celyn Pits, Ebbw-fach Valley.

(Abstract of section communicated by Mr. T. Vachell.)

—	Thickness.			Depth from surface.		
	Yds.	ft.	in.	Yds.	ft.	in.
Soil and clay - - - - -	9	0	10	—	—	—
Court Coal - - - - -	0	1	0	9	1	10
Measures - - - - - -	8	0	7	—	—	—
Upper Soap Vein Coal and bast	0	2	5	—	—	—
Measures - - - - - -	9	0	10	—	—	—
Soap Vein Mine - - -	4	1	10	—	—	—
Soap Vein Coal and fireclay -	2	1	1½	34	2	7½
Shale, mine-ground and thin coals - - - - -	37	1	11	—	—	—
Elled Coal - - - - -	0	2	11½	73	1	6
Thin coals, clod and fireclay -	4	0	0	—	—	—
Big Vein Coal - - - -	1	2	4	79	0	10
Measures - - - - -	6	2	9	—	—	—
Three-Quarter Coal - -	2	0	5	88	1	0
Measures - - - - - -	35	0	10	—	—	—
Bydylog [Ras-las] Coal -	1	1	4	125	0	2
Measures, chiefly mine-ground	34	1	3	—	—	—
Yard Coal - - - - -	0	2	6	160	0	11
Measures - - - - -	17	0	7	—	—	—
Old Coal - - - - - -	1	2	0	179	0	6
Rock - - - - - -	2	0	4	—	—	—
Spotted Vein Mine-ground -	1	1	0½	182	1	10½
Measures - - - - - -	10	1	10½	—	—	—
Red Vein Mine- - - -	0	0	5	193	1	2

Little is seen of the strata between the Bydylog and Elled Coals, the outcrops being buried under the refuse-heaps of the Coal Pits and Blast-furnaces. The Soap Vein Coal and Mine were "patched" to the south of Cwm Crachan, and the sandstones above them form a slight feature between Groes-y-ceiliog and Coed-cae. The features formed by the grit-bands between this horizon and the Tillery Coal are broken or rendered obscure by the Brynmawr fault (p. 83) on the western slopes of Mynydd Mulfran, but are distinguishable on the hill-sides north of Cwm Celyn village. Towards the head of Cwm Celyn the stream cuts through four distinct bands of grit, each underlain by shale, and the highest lying about 40 feet below the Tillery Coal. The marls and shales are of a mottled red colour and agree both in this and in stratigraphical position with some red marls passed through in the Ebbw Vale Marine Colliery, No. 2 Pit, and in many others (see Vert. Sect., Sheet 81, Nos. 10, 13, 14, 15). The red strata persist as far at least as the Albion Colliery in the Taff valley and are conspicuous in the South Crop near Pontypool; the colour appears to be original, as stated in a previous memoir,* and not due to subsequent staining.

The crop of the Tillery Vein can be traced with ease from Blaen-y-Cwm to a little north of Blaenau-Gwent by the aid of a conspicuous escarpment above it and by a series of levels, one of which, 200 yards north of Hafod Farm, shows three feet of coal with shale above and below it. The summit of Mynydd Mulfran is formed of a small outlier of Pennant, separated from the main mass on Cefn Crib by the Cwm Celyn Valley. The relics of old trials exist near the Grouse and Snipe Inn, but, judging from the small size of the shale-heaps, the seam of coal was not followed for more than a short distance.

On the west side of Cwm Tillery, the chief affluent of the Ebbw-fach, the exact position of the Tillery Coal is difficult to fix, as there are no levels and the ground is covered with débris; a line of springs, however, probably marks the position of the crop north of Llanerch-Padarn. Along the east side of the Cwm there are old levels and the coal is visible in a quarry 400 yards to the east of Gwrhyd farm. It crops out at the foot of a bold feature, formed by a thick mass of Pennant. From Cwm Tillery to Green Meadow House the crop is not so obvious, but a level 200 yards south-east of Oak Cottage, starting below the outcrop, intersects the coal seven chains from the mouth. From Green Meadow to Rhiw Parc the crop has been proved in several levels, but from the latter to Six Bells it is concealed under Boulder Clay. At Six Bells the coal was worked by levels near the Six Bells Inn.

On the west side of the valley the strata below the Elled Coal are nowhere seen at the surface. The Soap Vein Mine and Coal were patched to the west of Nantyglo House, and it is worthy of note that the flaggy sandstone which commonly overlies them changes locally into a massive felspathic sandstone remarkably like Pennant. It is at this horizon that a great development of grits takes place in West Glamorganshire.

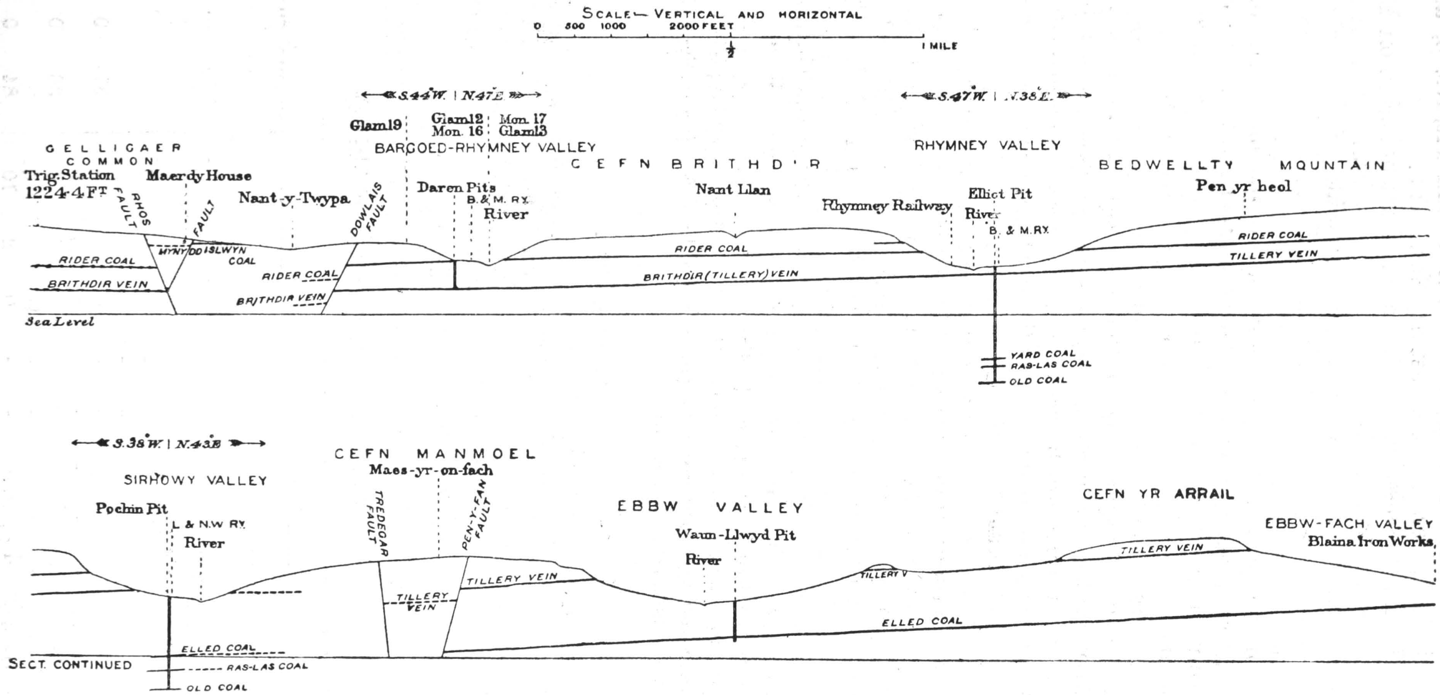
The Old Man's Coal, which lies 111 yards above the Soap Vein, was worked by levels in a plantation west of the Trostre Pit; it is of inferior quality, but is used locally during strikes. The features formed by the grits between this and the Tillery Coal are strongly marked on Bwlch-y-garn (Fig. 7), but cannot be followed on the steep eastern slopes of Mynydd Carn-y-cefn.

South of Blaina, where the valley contracts, the measures below the Tillery Vein are seldom exposed, but they are illus-

---

* Geology of Newport, pp. 34, 38, and Vert. Sects. Sheet, 80, No. 18.

Figure 8.—SECTION FROM THE BARGOED-RHYMNEY TO THE EBBW-FACH VALLEY, SHEWING THE MYNYDDISLWYN, PENNANT AND LOWER MEASURES
By W Gibson.



trated by the shaft-sections of the Griffin Pit, No. 3, and the Vivian Pit, Vert Sect. Sheet 81, Nos. 2 & 9.

The Tillery vein lies at the foot of the usual crags on Mynydd Carn-y-cefn and Cefn-yr-Arrail and was formerly much worked by a series of levels on the mountain-side. One of these, 500 yards south-west of Rose Heyworth Colliery, shows the coal to be two feet six inches thick with a sandstone-roof and shale-floor.

In Craig-yr-Arrail, south of the Abertillery Tin-works, the crop is thrown down westwards by the Llanhilleth fault. On the downthrow side of the fault between the tinworks and the air-shafts, 450 yards north-east of Pant-yr-Arrail, it is considered locally to be on the 800-feet contour, that is, only 535 feet below the Mynyddislwyn Coal of Coedcae, while only a mile away at Aberbyg the thickness of strata separating these coals is 761 feet (p. 77). Consequently we must either assume an unusually rapid northward attenuation of the Pennant, or suppose the crop to be lower down than is generally believed.

The section forming Fig. 8 has been drawn across the Ebbw and the other valleys west of it to the Bargoed-Rhymney for the purpose of illustrating the form of the ground and the steady increase in thickness of the lower measures westwards. The direction of the section being a little south of that of level course the measures are shown as descending gently westwards until there is ground not only for the whole of the Pennant, but for a small thickness of Mynyddislwyn measures in the trough between the Dowlais and Rhos faults. The section is drawn through the Waun Llwyd, Pochin, Elliot, and Daren Pits, the shaft-sections of which serve as reliable data for estimating the thickness of the measures.

Ebbw Valley.

The Steam Coal Series of Ebbw Vale is illustrated by the shaft-sections of the Bwlch-y-Garn Pit, Waun Llwyd Colliery and Ebbw Vale Marine Colliery No. 2 Pit (Vert. Sect., Sheet 81, Nos. 3, 4, 10). The following is an abstract of the shaft-section of No. 5 Pit, Ebbw Vale and Victoria properties.

Ebbw Vale and Victoria Properties, No. 5 Pit.
(Communicated by Mr. J. F. Tallis.)

——	Thickness.			Depth from surface.		
	Yds.	ft.	in.	Yds.	ft.	in.
Elled Coal	1	0	2	24	1	0
Measures	5	0	2½			
Coal (Big Vein Coal)	0	2	7			
Clod (Big Vein Coal)	0	0	5½			
Coal (Big Vein Coal)	0	2	1	31	0	4
Measures	3	2	9			
Three Quarter Coal	1	0	0	36	0	1
Measures	47	0	5			
Bydylog [Ras-las] Coal	0	2	10	84	0	4

—	Thickness.			Depth from surface.		
	Yds.	ft.	in.	Yds.	ft.	in.
Measures - - - - - -	34	2	9			
Engine Vein Coal with six feet of clod in six beds - - -	3	2	9	122	2	10
Measures - - - - - -	29	0	1			
Coal } Yard Vein Coal - -	0	1	7½			
Clod } Yard Vein Coal - -	0	0	6			
Coal } Yard Vein Coal - -	0	1	7	153	0	7½
Measures - - - - - -	0	2	3			
Coal } Old Coal - - -	0	2	3			
Clod } Old Coal - - -	0	1	2½			
Coal } Old Coal - - -	1	0	3½	156	0	7½
Measures - - - - - -	12	1	2½			
Ironstone } Red Vein - -	0	0	2½			
Clunch } Red Vein - -	0	2	10½			
Ironstone } Red Vein - -	0	0	2			
Clunch } Red Vein - -	0	1	5			
Ironstone } Red Vein - -	0	0	2½			
Clunch } Red Vein - -	0	2	5½			
Ironstone } Red Vein - -	0	0	3			
Clunch } Red Vein - -	0	0	8½			
Do. } Red Vein - -	0	2	5			
Ironstone } Red Vein - -	0	0	1½			
Clunch } Red Vein - -	0	2	6½			
Ironstone } Red Vein - -	0	0	4	173	0	6½
Clunch - - - - - -	0	2	0			
Fireclay - - - - - -	0	2	0			
Clunch - - - - - -	0	0	6			
Ironstone - - - - - -	0	0	3			
Clunch - - - - - -	0	0	6			
Ironstone - - - - - -	0	0	3			
Clunch with balls of ironstone -	4	0	10			
Ironstone - - - - - -	0	0	2			
Clunch - - - - - -	0	2	1½			
Ironstone - - - - - -	0	0	1½			
Clunch - - - - - -	0	2	9			
Ironstone - - - - - -	0	0	2			
Clunch - - - - -	0	2	11	182	0	1½

The coals worked at Ebbw Vale are in descending order:—The Tillery, Elled, Big, Three Quarters, Gwar-y-cae, Little Bydylog, and Old Coal. The Bydylog (Black, Ras-las, or Nine-Foot) Seam is too irregular and contains too much dirt to yield a profit, though it was worked to a thickness of 3 feet 4 inches at the Marine Pit. All the coals with the exception of the Tillery are classed as Steam Coals. The Rock (Black), Yard and Three Quarter Veins are "washed out" for about 1,200 yards at the Llannerch Pit. The Engine Vein of the Marine Colliery is considered to be the Meadow Vein. The best brick-clay lies on the top of the Soap Vein on the east side of Ebbw Vale, and the best fireclays lie about 12 yards above the Elled Vein and under the Old Man's Coal. Gannister has been worked just above the Old Coal.

* For this information we are indebted to Mr. J. F. Tallis.

The Old Coal crops out in the banks of the river 300 yards south of the ruins of the Beaufort Ironworks. In No. 15 Shaft, Ebbw Vale, it lies at a depth of 129 yards; in No. 6 Shaft, 1,470 yards further south, it lies at a depth of 228 yards. Allowing for the fact that the top of No. 6 Shaft is 23·3 feet above that of No. 15, it may be calculated that the dip of the Old Coal amounts to 2¼ inches in the yard. The inclination is the same also 1,400 yards north of No. 15 Shaft, and in fact varies but little throughout the top of the Ebbw Valley. The direction also, which is 20° west of true north, remains unchanged.

The crop of the Ras-las Vein has been proved in an old level 100 yards north of Newtown, and just below the old tram-line from Newtown to Newchurch. From here its course, as shown on old mining plans, brings it 25 yards east of Pant-y-fforest Pit and 25 yards west of the Cinder Pit.

In the old "patchworks" west of Llwydcoed the rock above the Elled Mine forms the top of the section. It is a hard sandstone, over 10 feet thick, and rests on grey shales containing the Elled Balls. A sketch of these excavations, accompanied by a description of the methods of working the mine-ground is given by Dr. Bevan in the "Geologist," vol. i., p. 126. Four hundred yards to the south "patches" in the Soap Vein give the following section:—

Patchworks in the Soap Vein, Llwydcoed, Beaufort.

	Ft.	in.
Hard siliceous grit - - - - - -	0 to 4	0
Sandstone - - - - - - - - - -	6	0
Black shales - - - - - - - - -	10	0

The grit dies away southwards, and the sandstones become more flaggy and even degenerate into sandy shales. They are overlain by the following rocks, well shown in some large brick-pits:—

Brick Pits 400 yards East of Newtown.

	Ft.	in.
Shales (used for manufacture of red bricks) -	15	0
Coal - - - - - - - - -	1	4
Sandy clay - - - - - - - -	8	0
Coal - - - - - - - - - -	1	6
Fireclay (used for manufacture of buff bricks) -	5	0

The bands of grit between the Soap Vein and Tillery form prominent features on the north-west slopes of Mynydd Carn-y-Cefn, and can be traced some distance down the valley. One band, a coarse pebbly grit more than eight feet thick, which occurs ten feet below the Old Man's Coal, has been quarried 500 yards north of the Bwlch-y-garn Colliery. The levels about the 1,000-feet contour in Coed Tyllwyn and Coed Tyn-y-fyd have been opened on the Old Man's Coal.

The old tram from the Red Ash (Tillery) Levels on Mynydd Carn-y-Cefn to Bwlch-y-garn Colliery cuts through a coarse grit 300 yards from the bottom of the incline. This rock makes a most conspicuous feature on Bwlch-y-garn, and probably corresponds to the highly siliceous grit that has been extensively quarried in Garn Wood.

The Tillery Coal in the Red Ash Levels on Mynydd Carn-y-Cefn gives the following section; the parting of shale is unusually thick:—

Red Ash Level, Mynydd Carn-y-Cefn.

		Ft.	in.
Tillery Vein	Coal	2	0
	Shale	12	0
	Coal	3	0+

From here the crop is easily traced round Daren-y-Trwyn by means of the characteristic Pennant feature, and from the head of Nant Merddog to Llandafal it is marked by numerous old levels, many of which give views of the coal. At Tor-Crug the Tillery Vein forms a small outlier 400 yards long and 120 yards wide. The coal is visible in the roadside near Pen-y-crûg, and the overlying Pennant in a small coppice to the south.

On the west side of the valley the crops of the Old, Ras-las, and Elled Coals have been laid down on the map from the positions marked on old mining plans, for at the present time there is nothing at the surface to mark them.

The Soap Vein measures are exposed in large excavations north and south of the main road from Ebbw Vale across the mountain to Tredegar. The Soap Vein Rock does not make much show on the ground, but has been quarried near Ysgubor Blaen-y-cwm Farmhouse. A few yards south of the house the overlying shales and mudstones are used for bricks. The succeeding measures contain several bands of grit, not appreciably thicker than on the east side of the valley, but forming bolder features. Some of them are more compact and siliceous than the bands on the east and have consequently been largely used as building-stones. In appearance they closely resemble quartzites except when coarsely conglomeratic.

The Old Man Coal crops out in the plantation west of Briery Hill. It is 2 feet 5 inches thick. The underlying grit is seen in some shallow excavations on the mountain road, 200 yards south-east of Mountain Air Inn.

A nearly complete sequence of the grits and shales between the Old Man's Coal and Tillery Vein is afforded by the road-cuttings and quarries on either side of the mountain-road leading from Briery Hill to the plateau on Cefn Manmoel. Each bed of grit is underlain by a thin coal. The old incline from the Tillery Level on Cefn Manmoel to Victoria intersects the same series, and a quarry opposite Glan Ebbw House on the north side of the incline gives the following sequence for its lower portion:—

Quarry opposite Glan Ebbw.

	Ft.	in.
Grit	10	0
Black shales	12	0
Grit	5	0
Coal	0 to 1	0
Fireclay	1	0
Shales		

The Tillery Coal (sometimes called the Troed-rhiw-clawdd in this valley) on Cefn Manmoel is overlain by the usual thick mass of Pennant, by means of which the crop can be traced from level to level as far as Cwm. South of this village it is concealed under glacial deposits and débris, but a level by the riverside, 200 yards south of the Marine Colliery, has been opened on the crop.

Sirhowy Valley.

The Steam Coal Series of this valley is illustrated by sections of the Whitworth, Mountain, Bedwellty, and Pochin Shafts (Vert. Sect., Sheet 81, Nos. 5, 11, 12, 13). The valley is crossed obliquely by a well-marked trough thrown down between the two Tredegar faults (p. 84).

In the Whitworth Shaft the Ras-las Coal lies at a depth of 625 feet above Ordnance Datum, and in the Pochin Pit at a depth of 268 feet below that Datum. This gives an inclination of 2½ inches in the yard in the direction of nearly full dip. The same dip has been proved in the Tillery workings of the Abernant Colliery, 4½ miles south of the Whitworth Shaft, and prevails generally throughout the Sirhowy Valley.

At Tredegar the Yard, Big and Old Seams are the most reliable, the Elled being incontinuous and the Ras-las absent for about a mile in consequence of a "wash out."

Between Trefil Station and the road leading to Hirgan-fâch the Garw Coal is hidden under débris, but in the railway-cutting between the bridge at Hirgan-fâch and the viaduct, shales associated with it are seen resting upon the Farewell Rock. Between the two Tredegar faults west of Blaen-y-cwm, where there is a thick cover of Boulder Clay, some old surface-workings near the Mountain Air Inn give the position of the Bottom Vein Mine, from which it may be inferred that the crop of the Garw Coal is not many yards to the north. Workings in the crop of the Old and Yard Coal extend from 700 yards east of Pant-y-poplar south of Rassa to 300 yards south of Penmarc. A gannister associated with the Old Coal is being worked.

The Little Vein Coal, which lies about 16 yards above the Old Coal, crops out in the bed of the Sirhowy 160 yards south of the main road from Dukes Town to Nantybwch. The crop of the Ras-las, as shown on the map, is taken from old mining plans.

The following section in the Mine Ground (Darren Pins) was obtained in old open workings north of Bryn-serth.

Patchworks north of Bryn-serth, Sirhowy.

	Ft.	in.
Sandstone - - - - - - - - -	10	0
Sandstone and shale bands - - - -	10	0+

Fault.

Black shales and bands of ironstone to bottom of section.

The fault occurs in the western portion of the workings and throws black shale with ironstone against a hard grit. It is probably a fault of 6 yards' throw proved in the Old Coal Three faults of small throw are proved in the underground workings in the Old Coal between Capel Waun-y-pound and Bryn-pica, but further east as far as the Ebbw-fach the coals are but little disturbed.

The Elled Coal and Mine were extensively patched to the south of the main road from Capel Waun-y-pound to Sirhowy. The excavations are now much obscured, but the following section gives the general characters:—

Patchwork in Elled Coal and Mine 700 yards east of Sirhowy.

	Ft.	in.
Sandstone	2	0
Black shale and ironstone	—	—
Coal	0	4
Sandstone	2	0
Black shales	—	—
Coal	1	0
Shales	0	3
Sandstone	0	10
Coal	0	6
Shale	2	0
Coal	0	8
Fireclay	—	—
Black shales with nodules, bands of ironstone, seen to	12	0

The Soap Vein workings lie 200 yards to the south of the Elled Patches, and run parallel with them as far as the Tredegar No. 1 or Pen-y-fan fault, a little north of George Town. The Soap Vein rock caps the steep side of the excavations and preserves it from destruction. The following section was measured in the patch to the east of the road leading from Bryn-pica to Cefn Manmoel.

Section in Soap Vein Patch, Sirhowy.

	Ft.	in.
Flaggy sandstone	10	0
Coal	1	4
Black shales and ironstones, seen to	15	0

A lower portion of the mine-ground was measured in a cliff-face close by:—

Section in Soap Vein Mine, 300 yards north-east of No. 4 Shaft.

	Ft.	in.
Shales	10	0
Coal	0	8
Grey shales	3	0
Nodules of ironstone, some large	—	—
Grey shales	12	0
Coal	0	6
Black shales with ironstone-nodules.		

The rock below the Old Man's Coal has been extensively quarried 100 yards to the south of the Mountain Air Gate. It is a hard, white and yellow, highly siliceous stone. The higher bands of grit come to the surface to the east of the workhouse, and plainly exhibit the shift due to the Tredegar No. 1 fault.

The Tillery Coal crops out in the opening of a quarry in Pennant Sandstone 500 yards north of Armageddon Chapel, Troed-rhiw-gwair; then for a distance of 900 yards in a south-east direction the coal is practically on the fault-face of the Tredegar No 2 fault.

On Graig Llwyn the outcrop, as marked by the massive crags of Pennant, is at a slightly lower elevation than on the western side of the valley (see Fig. 8, p. 63). In Coed Pen-rhiw over three feet of the coal can be seen in the levels east of Hollybush Station.

The Elled and Big Coals have been patched to the west of Tredegar, but of the lower coals nothing is seen at the surface. The patchworks to the north and south of the Mountain Pit are in the Soap Vein Mine and Coal. The strata above the Soap Vein are not well exhibited, but a seam of house-coal 1 ft. 2 in. thick has been patched to the west of Ysgubor-fawr.

The Tillery or Pontygwaith Coal has been considerably worked in the past under Bedwellty Mountain by means of the Daren and Bedwellty levels and is regarded as a good smith's and house-coal. It is overlain by the massive sandstone of Darenddu. At the Abernant Colliery, near Argoed, the vein is 2 ft. 10 in. thick and was reached at 163 yards depth, the Tillery Rider, 2 feet thick, having been passed through at 83 yards.

Rhymney Valley.

The town of Rhymney was the scene of much activity in the past when the mine-ground and coal-pits in the immediate neighbourhood were being worked, but the collieries, and much of the population with them, have gradually been removed lower down the valley as the coals near the north crop became exhausted, while the use of local ironstones has been entirely abandoned.

The chief collieries are the Pontlottyn and Rhymney Pits near Pontlottyn, and the Powell Dyffryn and East Elliot Pits near New Tredegar.

The shaft-sections of the Pontlottyn and Elliot Pits are given in Vert. Sect., Sheet 81, Nos. 6 and 14, and some others in Sheet 9. The section forming Fig 8, p. 63, passes through the Elliot Pit and shows the position of the Brithdir and some of the lower coals. The dip of the strata below the Brithdir Vein is 4 inches to the yard between the Pontlottyn Pits and Rhymney, and $2\frac{1}{4}$ inches to the yard between the Pontlottyn Pits and the Elliot Colliery. Between Troed-y-rhiw-fuwch and the Cefn-y-Brithdir Colliery the inclination of the Brithdir Coal is slightly under 2 inches to the yard. The dip in the top of the valley near Rhymney is a few degrees east of south, and between the Cefn Brithdir Colliery and the Rhymney Bargoed Valley a few degrees west of south.

The Old Coal, called in this district and to the west the Lower Four Feet, is seen at intervals in old levels and patchworks to the south of the L. and N.W. railway between Nant-y-bwch and Princetown. North of the railway the relics of extensive workings in the mine-ground below the Old Coal still remain, while the railway cuts through the same strata to the south-west of Princetown. In the bed of the Rhymney River there is a considerable development of dark-grey sandstone below the Old Coal. The coal forms the ledges by the stream-side, and gives the following section near Carno Bute Houses.

Section in the Old Coal, Rhymney River.

	Ft.	in.
Coal	0	6
Clod	1	0
Coal	2	2
Clod	0	6
Coal	2	6
Clod	2	1
Coal	4	0

A cutting on the main road from Rhymney to Rhymney Bridge exposes the Little, Clay and Yard Veins 300 yards south of Rhymney House. The Ras-las was formerly worked by levels 160 yards south-south-east of the Brewery; at the Bryn-oer Level, Susannah Row; and 330 yards north-east of Nant Melyn Pit. The mine-ground between the Upper Four Feet and Upper Soap Coals has been extensively patched from Tredegar to Rhymney, the long lines of cliff-like excavations forming prominent features in the landscape. The Upper Four Feet Seam was met at a depth of 151 yards in the Rhymney Pits near Rhymney Station.

The Soap Vein Rock caps Rhymney Hill as well as giving rise to a well-marked feature on its northern and western slopes. As seen in a quarry 600 yards east of Gwaun-fawr Pits it is a flaggy grey sandstone over 30 feet thick. It is succeeded by black and grey shales overlain by a coarse pebbly grit, with a coal over one foot thick at the base, all admirably exposed in a dingle 400 yards north-east of Maerdy Houses. A seam which forms a small outlier on Twyn Aber-tysswg is probably the Old Man's Coal of the Ebbw Valley. Blocks from an underlying coarse pebbly grit cover the hill-side and recall the talus-heaps on a slope of Millstone Grit. In Cwm Tysswg a series of levels have been driven on a thin coal which is probably one of the coals seen in the Sirhowy Valley, west of Ysgubor-fawr House (p. 70). The following section was obtained in the banks of the stream 500 yards north-north-east of the spot where it crosses the Brecon and Merthyr Railway.

Section in Cwm Tysswg, Rhymney Valley.

	Ft.	in.
Rashings	0	3
Coal	2	0
Fireclay	1	10

Two or more bands of hard, siliceous pebbly grits intervening between this seam and the Brithdir (Tillery) Vein can be traced round the north end of Bedwellty Mountain, but cease to be distinguishable on the eastern slopes. Taken as a whole the bands of grit between the Soap Vein and Brithdir are considerably thicker in the Rhymney than in the Sirhowy or Ebbw Valleys.

The Brithdir Coal is visible in several levels on Cefn-y-Rhychdir. In the mouth of one level 850 yards west of Mount Pleasant it is 3 feet thick, and rests on fireclay. Extensive landslipping has taken place at this horizon to the east of Powell's Dyffryn Colliery, and has entirely buried the crop of the coal. The seam, however, forms the bottom of a quarry 200 yards north-east of Puddler's Farm, where it is 3 feet thick. From New Tredegar to a level by the riverside 150 yards north-west of the Elliot Pit its crop is concealed beneath thick glacial gravels.

Between Rhymney Bridge and Dowlais Top the base of the Coal Measures is concealed under Boulder Clay. The Garw Coal, however, was obtained in the patchworks and old levels close to the reservoir 500 yards north of the main road from Rhymney Bridge to Dowlais Top. The Old Coal comes into sight in the mouth of a level 100 yards south of Cwm Carno, where it is overlain by a hard sandstone. The Ras-las crops out at several points in the patches south of the Rhymney Limestone tramway, where the following section was taken:—

Section in Patchworks 400 yards N.N.W. of Nant-llesg Colliery, Rhymney.

	Ft	in.
Sandstone - - - - - - - - - -	10	0
Ras-las coal - - - - - - - - -	4	1
Shales seen to - - - - - - - -	6	0

The Big and Upper Four Feet Coals have been extensively patched from Bryn-pwllog to near the Pitwellt Colliery. The strata are much false-bedded and variable, the sandstones showing a marked tendency to break down into sandy shales within a horizontal distance of a few feet. The following section in the Black Pins Mine and Upper Soap Vein measures was obtained in the extensive patchworks which extend from the Brecon and Merthyr Railway east of Ras-las pond to the New Dyffryn Pit north of Pontlottyn:—

Section in Patchworks 600 yards west of Pitwellt Colliery.

	Ft.	in.
Thin flaggy sandstone - - - - - - -	10	0
Sandy shales - - - - - - -	5	0
Coal - - - - - - - - - - - -	2	1
Black shales and nodules of ironstone seen to -	15	0

Good sections are also exposed in the gully south-south-west of the Pitwellt Pits.

There are several thin seams of coal, two of which have been worked on the hillside south of Pontlottyn, between the Brithdir and Soap Veins. They are overlain by bands of coarse grit, which form the feature and crags to the south of the Gwrhyd Pit. The Brithdir Seam crops out at the foot of the crags west of Troed-y-rhiw-fuwch and Tir Phil. In the Cefn Brithdir Colliery it lies at a depth of 113 yards.

Bargoed Rhymney Valley.

The Bargoed Rhymney rises on the northern slopes of Gelligaer Common, and passes over no portion of the Steam Coal Series older than the Black Pins Mine. The chief colliery is the Fochriw, the shafts of which commence 200 feet below the Brithdir Coal. The following is an abstract of the Shaft-section:—

*Fochriw New Pits, Dowlais Coal and Iron Company.**

—	Thickness.			Depth from Surface.		
	Yds.	ft.	in.	Yds.	ft.	in.
Measures - - - - - -	74	1	6	74	1	6
Coal - - - - - - -	0	2	10	75	1	4
Measures - - - - - -	37	1	5	112	2	9
Fochriw Coal - - - -	0	2	3	113	2	0
Measures with thin Coals - -	57	0	10	170	2	10
Old Man's Coal - - - -	0	2	3	171	2	1
Measures with several thin coals and fireclays - - - -	108	0	3	279	2	4
Soap Vein Coal - - - -	0	1	4	280	0	8
Measures with thin coals and ironstones - - - - - -	45	0	7	325	1	3
Coal } Elled Coal -	0	1	1	325	2	4
Shale and Clod } Elled Coal -	0	1	8	326	1	0
Coal } Elled Coal -	0	0	5	326	1	5
Clod } Elled Coal -	0	0	7	326	2	0
Coal } Elled Coal -	0	1	0	327	0	0
Measures - - - - - -	29	2	0	356	2	0
Upper Four Feet Coal, not regular - - - - - - -	0	1	0	357	0	0
Measures - - - - - -	15	2	6	372	2	6
Coal } Big Coal - - - -	0	0	3	372	2	9
Clod } Big Coal - - - -	0	0	4	373	0	1
Coal } Big Coal - - - -	1	0	6	374	0	7
Clod } Big Coal - - - -	0	2	1	374	2	8
Coal } Big Coal - - - -	0	0	7	375	0	3
Clod - - - - - - -	0	0	4	375	0	7
Coal - - - - - - -	1	0	5	376	1	0
Measures - - - - - -	41	2	1	418	0	1
Coal } Red Vein - - -	1	2	1	419	2	2
Clod } Red Vein - - -	0	0	10	420	0	0
Measures - - - - - -	1	1	0	421	1	0
Coal } Ras-las Vein - -	2	2	3	424	0	3
Clod } Ras-las Vein - -	1	0	1	425	0	4
Measures - - - - - -	10	0	8	435	1	0
Coal } Brass Vein - - -	0	2	2	436	0	2
Clod } Brass Vein - - -	0	0	1	436	0	3

* Abstracted from a tracing supplied to the Coal Commission, 1871.

There are no shafts to the Steam Coal Series south of Fochriw and the coals as yet remain untouched over a considerable area.

The deep railway-cutting to the east of Ras-las Pond gives the following approximate measurements in the Upper Soap Vein measures.

Brecon and Merthyr Railway-cutting west of Rhymney.

	Ft.	in.
False-bedded fine grey sandstone	—	—
Coal	1	1
Sandstone with nodules of ironstones	30	0
Coal	1	1
Black shale and inferior fireclay	2	0
Hard grey sandstone	2	0
Black shale and mine courses	20	0
Coal	1	11
Clift and course of mine	20	0
Coal	1	0
Grey sandstone	3	0
Clift	20	0
Coal	1	1
Hard grey sandstone	5	0
Black shale	—	—

Three thin coals are exposed in the railway-banks at distances of 100, 400, and 550 yards south of the deep cutting, the coal at 550 yards being overlain by a hard grit pebbly in its upper portion. Higher up in the series four more hard grits can be distinguished, each giving rise to a more or less definite feature on Mynydd Fochriw. The lowest two are underlain by thin coals, which are evidently at a higher horizon than the Old Man's Coal.

The Tillery Vein has been entirely worked out beneath Cefn-y-Brithdir. In the mouth of an old level 250 yards north-west of Brithdir-uchaf, the seam is over three feet thick. In the Daren pits (Fig. 8, p. 63) it lies at a depth of 110 yards, the ground between it and the Rider Coal, which lies at the top of the shaft, consisting wholly of rock. The seam under the rock-roof consisted of 4 to 8 inches of bastard coal at top, 7 inches of Engine Coal, and 2 ft. 10 in. of Bottom Coal.

Bargoed Taff Valley.

The Bedlinog Shaft of the Dowlais Coal and Iron Company illustrates the sequence in this valley (Vert. Sect., Sheet 81, No. 15).

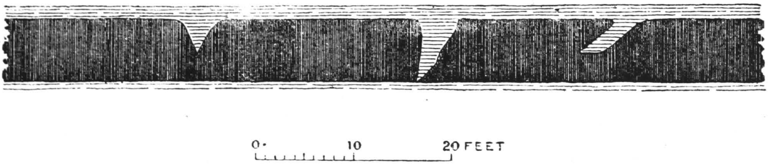
The Ras-las Vein becomes known here as the Nine-Feet Seam, a name which it keeps through the Rhondda Valleys and westwards. It did not prove well in the shaft-section, but presents the following details elsewhere in the workings:—

Red and Ras-las Veins, Bedlinog.

		Ft.	in.
Coal, dirty		1	0
Shale		0	3
Coal, dirty		0	10
Shale		0	1½
Red Vein	Coal, dirty	0	10
	Clod	1	0½
	Coal	1	6
Shale		0	3
Ras-las (Nine Feet) Vein	Coal, dirty	1	7
	Coal, good, with lumps of brass	5	2
	Black Shale	0	10

The Ras-las was rendered worthless in places by numerous wedge-shaped masses of shale cutting down to the base of the coal, or nearly so, but never below it. A little seam below was not similarly affected. The wedges run in no definite direction and appear to be runlets cut by water in the coal and filled up with

Fig. 9. *Shale cutting down into the Ras-las Coal, Bedlinog.*



mud before the overlying measures were deposited. A syncline over 200 yards broad has been proved to exist in the Nine-Feet Coal, though it did not appear in the Four-Feet Vein.

The Upper Four-Feet Seam at Bedlinog includes partings as below:—

		Ft. in.		Ft. in.
Upper Four-Feet Seam	Coal	0 9	to	1 10
	Clod	0 1	,,	3 10
	Coal	1 5	,,	1 11
	Clod	0 5	,,	4 7
	Bottom Coal	1 8	,,	2 0

When the two clods exceed four feet in thickness the two lower coals alone are worked.

The thin coals and associated strata between the horizons of the Old Man's Coal and the Fochriw Coal are cut through by Nant Gyrawd and form the deep gully of Cwm-goleu. In Nant Ffin, about a mile south-east of Bargoed Station and at a spot a few yards to the south of where it crosses the Great Western Railway, the following section was obtained in measures above the highest proved in the Fochriw pit:—

Section in Nant Ffin, Bargoed Taff.

	Ft. in.
Coal	1 0
Yellow sandy shales	8 0
Coal	2 6
Fireclay	3 0
Sandy shales	

The Bargoed Taff gives poor sections, the bottom of the valley being mostly filled with Glacial Drift, but at a spot 700 yards south of its junction with Nant Gyrawd, some ten feet of red cliff with courses of ironstone rest on blue and red marl. The red strata lie at about 150 feet below the Brithdir Vein, and no doubt correspond to the red and blue ground represented in the Bedlinog section and in Cwm Celyn (p. 62) at that same horizon.

The Tillery Vein has been mostly extracted from under Mynydd Fochriw, Pen Garn Pigau and Coly-uchaf. The coal is visible in the cutting of the Great Western Railway west of Pen Garn Pigau. On Coly-uchaf it is brought on a level with the Rider Coal by the influence of the Rhos Fault (p. 84). In this neighbourhood it is known as the Brithdir, Gwrhyd, or Coly Seam. It includes the following bands at Coly:—

		Ft.	in.
Brithdir Seam	Coal intermixed with shale	0	4
	Shale	0	1
	Coal	0	6
Soft Clod		0	1
Coal		3	7
Shale		0	1
Coal		0	11

On the west side of the valley the crop of the seam is concealed beneath landslip.

W. GIBSON.

Pennant Grit and supra-Pennant (Mynyddislwyn) Measures.

The Pennant Grit of Monmouthshire consists principally of thick felspathic sandstone, blue when fresh, but rusty-brown after exposure. It contains occasional conglomeratic bands, the included fragments consisting of small well-rolled quartz-pebbles and partially-rounded lumps of ironstone, coal, and other Coal Measure rocks. Generally it is highly current-bedded, but in parts is evenly bedded and yields flags which are in great request for paving purposes. Such bands occur usually in connection with shaly strata, and a well-known zone of them, worked at Pen-rhiw-fid, lies a few yards below the Mynyddislwyn Vein.

Shales are quite subordinate to the grits in the Pennant of the eastern end of the Coal Field, and are rarely seen except in underground workings. Such coals as occur are thin and not worth working. In these respects the Pennant Grit of Monmouthshire differs from what we may term the Pennant Series of the western half of the Coal Field, where the measures not only expand greatly, but especially in their upper part contain almost as much shale as sandstone and many valuable coal-seams. This change, taken in connection with the development of grits below the base of the Pennant Series westwards tends to destroy the individuality so well-maintained by that series in Monmouthshire, and to make its separation from the measures above and below somewhat arbitrary. So far as our present district is concerned the Mynyddislwyn and Tillery Veins form the most convenient top and bottom respectively to a subdivision of a perfectly conformable sequence of measures.

The thickness of the Pennant Grit as thus defined ranges from 212 to 342 yards within the limits of the map under description. A direct measurement can be made on the south side of Cwm-du, near Abersychan. The Tillery Vein crops out in the Cwm Serchan Level, while the Mynyddislwyn Vein comes out on the brow of the hill 480 feet above. After making allowance for the dip we get a distance (vertical to the bedding) of 208 yards between the two veins. A small fault of 4 yards has been proved in the Meadow Vein under the line of measurement, and may, if the fault reaches the surface, have to be added, making the true distance 212 yards. At Tirpentwys, 1¼ miles further south, the distance was ascertained to be 265 yards (Vert. Sects., Sheet 80, Sect. 10).

At Aberbyg the depth of the Tillery Vein on the east side of the Aberbyg Fault is 100 yards, and the colliery is 539 feet above Ordnance Datum. The Tillery Vein, therefore, lies at 239 feet above that Datum. The Mynyddislwyn Vein of Llanhilleth intersects the 1,000-foot contour in the direction of "level course," and, therefore, lies 761 feet above the Tillery Vein, or 254 yards as compared with the 212 yards estimated 2½ miles further east.

Near Bargoed the distance from the Mynyddislwyn to the Brithdir (Tillery) Vein is 342 yards, and at Harris' Navigation 327 yards (Geology of Newport, p. 53, and Vert. Sects., Sheet 80, No. 16).

The only coal-seam worthy of mention in the Pennant of the area under description is known as the Tillery Rider or the Rhondda No. 1 Seam of Glamorganshire. It is impersistent, but tends to reappear at about the same horizon, namely, about 80 yards above the Tillery Vein. Its occurrence in the Glyn Valley at that level has been noted elsewhere*; at Llanhilleth it lies 69 yards above the vein and is 1 feet 4 inches thick, but at Aberbyg we have no note of its occurrence, though the Tillery Vein lies at a depth of 100 yards on the east side and 78 yards on the west side of the shaft (on either side of a small fault), and there would therefore be ground for the Rider. In a cwm east of Aber-Tillery there is a coal-seam which doubtless represents it, and at the head of Cwm Tillery, where it crops on the eastern side of a fault with a downthrow west, it was found by Mr. Gibson to have been used locally by the farmers; on the eastern side of this Pennant range it is either non-existent or unrecognisable. Its further occurrences westwards are thus noted by Mr. Gibson:—

"On Mynydd Carn-y-cefn a level, 100 yards west of Llannerch-y-pant, shows the rider to be 1 foot thick with a shale-floor and with a sandstone above it which forms a low overhanging crag, the first noticeable feature above that formed by the rock overlying the Tillery Vein. On Domen-fawr the shale can be traced, but it is doubtful whether the coal exists.

"On the northern part of Bedwellty Mountain two marked sandstone-features, each with a coal at its base, occur at about 30 and 80 yards above the Tillery Vein. The first-named is exposed on some crags on Cefn-y-Rhychdir, 300 yards to the north-east of Powell's Dyffryn Colliery, where the following section was noted:—

Quarry on Cefn-y-Rhychdir,

	Feet.
Sandstone	20
Coal	1
Shale	3
Sandstone, seen to	20

* Geology of Newport, pp. 33, 51.

"The latter, which is the Rider, can easily be traced round the mountain to a level near Dafolog Farm.

"The shaft of the Cefn-y-Brithdir Colliery started in the Rider, and reached the Brithdir (Tillery) Vein at 113 yards. From here the rider can be traced round the Cefn by its characteristic rock-feature.

"The Daren Pits also started in the Rider, and proved a depth of 110 yards to the Brithdir (Tillery) Vein. Thence the crop of the Rider runs to the Dowlais Fault west of the Fochriw Reservoir, which has been excavated in the shales below the coal.

"On Gelligaer Common the Rider is thrown against the Brithdir Vein by the Rhos Fault; it has been worked in Craig Wood, east of Bedlinog.

"The sandstones above the Tillery or Brithdir Vein and the Rider are the most massive of the Pennant grits. The overlying strata are more thinly bedded and contain more shale, the result being that these outcrops rarely attain the boldness of those due to the sandstones associated with the two coals."

The Mynyddislwyn Vein of the small tracts which fall within this map has almost been worked out. The vein was double, the parting showing a general tendency to thicken southwards. At Blaen-cyffin the two parts were separated by 2½ feet only of shale, whereas further south the parting swelled out to 15 feet. The top coal is said to have been 4½ feet, and the bottom coal 2½ feet thick in the southern part of Cefn Crib. There is said to be a rider 30 yards above the vein near Llanhilleth, and on Mynydd Llanhilleth there is a sandstone-feature with traces of a coal beneath it at about that height above the Mynyddislwyn outcrop (Fig. 4, p. 55).

On Mynydd Pen-y-fan the section of the measures is said to be:—

		Yds.	ft.	in.
Big Rider		0	2	9
Rock		54	2	0
Rider		0	1	0
Rock		35	0	0
Mynyddislwyn Vein	Top Coal	0	3	6
	Shale	0	0	10
	Bottom Coal	0	2	7

The Big Rider, however, does not seem to have been proved on Mynydd Pen-y-fan, and its existence is probably inferred from the section at the Old Rhos Colliery, mentioned in the Geology of Newport, p. 63. For a description of the remainder of these tracts of Mynyddislwyn measures the reader is referred to that memoir.

Iron Ores.

The extraction of the "mine" or local iron-ore, both in the Coal Measures and the Carboniferous Limestone, has ceased with the few exceptions mentioned on p. 50. The ore was obtained chiefly by huge open excavations and levels, assisted sometimes by the process of "scouring," which consisted of damming up the surface water and letting it rush over the outcrop of the mine-ground. The nodules, or "balls," of ore were left exposed to the weather and were freed by frost and rain from any adhering shale. Ironstone from shallow workings parted from the shale more readily than that obtained from a depth. The following notes are condensed from the Iron Ores of Great Britain (Memoirs of the Geol. Survey), pp. 165–199, published in 1861 when the ores were being worked. Some additional information taken from a paper by Mr. Thomas Joseph (Proc. S. Wales Inst., Eng., vol. xii., p. 264, 1880–81), and from "The Coal and Iron Industries of the United Kingdom," by R. Meade, 1882, p. 588, is placed in square brackets:—

The industry is old, but is said to have become nearly extinct in South Wales in 1740 in consequence of the scarcity of wood, but in 1755 Mr. Antony Bacon erected at Merthyr a furnace for smelting iron with pit coal; this plan was adopted elsewhere: the trade revived, and before the end of the century it was of such importance that canals and tramroads were made from the works to the sea-ports, all the materials having hitherto been carried on the backs of mules. In 1858 the make of iron in South Wales was 886,478 tons, and the produce of coal 7,495,289 tons.*

The ironstones are richer in metal to the east, and poorer though thicker to the west. The principal works therefore lay in the eastern part of the Coal Field, and on the North Crop where the mine-ground lay near the surface over large areas.

The highest workable band occurs above the Mynyddislwyn Coal, and being sufficiently carbonaceous to support combustion was known as a Black Band (see also Geology of Newport, p. 64).

The next, also a "black band," occurs over the Old Man's Coal, and a similar ore was worked above the Charcoal Seam at Abercarn (Geology of Newport, p. 51).

In the lower series there are many courses of mine-ground, most of which have been worked in one part or another. The patches upon the Elled Mine-ground and coal are among the most extensive. The "Three Quarter Balls" were remarkable throughout the eastern part of the Coal Field, for the fact that they abounded in fissures and cracks which contained needle-shaped crystals of sulphide of nickel (Millerite), a hydro-carbon or mineral tallow (Hatchettine†), quartz-crystals, calc-spar and spathose iron-ore. The cavities were often filled with water of a saline taste. The lowest course of ironstone occurs locally in the Millstone Grit north of Beaufort, and was worked under the name of the Rosser Veins; these must not be confounded with the Rosser Veins of the district further west, which belong to the Coal Measures (p. 38).

The lowest ironstone of the Coal Measures is the Pin Garw overlying the Garw Coal; it is titaniferous. In the eastern part of the area this is represented by the Big or Bottom Vein

* Hunt's Mineral Statistics, 1858.

† Conybeare, Rev. J. J. *Ann. Phil.*, Ser. 2, vol. i., p. 136, 1821, and Johnston, J. F. W. *Phil. Mag.*, Ser. iii., vol. xii., p. 338, 1838.

Coal and the Big Vein Ironstone. The latter includes six inches of ironstone in two courses, and yields 1,700 tons per acre according to Meade.

The Old Coal was associated with a Blackband Ironstone, of good quality but limited extent, which was in great request near Beaufort and Nant-y-glo.

The ironstone measures of Cwm Celyn and Blaina contained the following ores in ascending order*:—

RED VEIN MEASURES.

	in.	
Upper Pin	1½	Of grey colour.
Red Vein	3 to 4	Accompanied by some 6 in. of "jack,"† or argillaceous stone, containing a small percentage of iron, and exhibiting "cone-in-cone" structure. [Average yield in the north-eastern crop 1,800 tons per acre.‡]
Pins or cakes	2 to 4	Having numerous cracks filled with carbonate of iron and lime.
Black Mine	3 to 4	This, as well as the Red Vein above, contains Hatchettine in the cracks and hollows.

These ironstones lie in about six feet of ground.

SPOTTED VEIN.

	Ft.	in.
Pins	0	7
Ground (shale, etc.)	2	3
Pin	0	2
Ground with balls	1	10

[Average yield in the north-eastern crop 1,200 tons per acre.‡]

BLACK PINS.

	Ft.	in.	
Black Pin	0	4	A darker stone than most of those which follow.
Ground	1	2	
Yellow Pin	0	4	Dark-grey stone, breaking with very regular smooth joints.
Ground	3	4	
Pin *ammed*	0	3	
Ground	1	3	
Pin *goch* (red)	0	2½	In shorter lenticular forms than the yellow pin.
Ground	2	11	
Holkin	0	3	
Ground	1	1	
Double Pins	0	2	
Ground	0	6	
Pilsen (pills)	0	3	
Ground	1	8	
Grey Vein	0	2	
Ground	0	10	

* From a section supplied by Mr. Levick in 1860, and published in the Iron Ores of Great Britain (Memoirs of the Geological Survey), 1861, p. 193.

† On Jackstones see a paper by J. Dickinson, *Quart. Journ. Geol. Soc.*, vol. ii., p. 131, 1846. They appear to be composed largely of carbonate of lime.

‡ Meade, Coal and Iron Industries, p. 585.

	Blaenavon. By Mr. A. Dick.			Red Vein Measures, Cwm Celyn and Blaina. By Dr. Noad.				Black Pin Measures, Cwm Celyn and Blaina. By Dr. Noad.			Soap Vein Measures, Cwm Celyn and Blaina. By Dr. Noad.	
—	Spotted Vein Mine.	Three Quarter Balls.*	Black Pins.	Red Vein.	Black Vein.	"Jack" in Red Vein.	Grey Vein.	Black Pin.	Red Pin.	Yellow Pin.	Top Soap Vein.	Bottom Soap Vein.
Protoxide of iron	45·22	36·10	41·22	–	–	–	–	–	–	–	–	–
Carbonate of iron	–	–	–	73·790	80·220	51·120	70·500	71·700	57·990	48·300	59·610	77·340
Protoxide of manganese	1·05	0·76	1·07	0·920	1·020	–	not determined	1·420	0·640	0·327	–	0·530
Alumina	0·58	0·48	0·59	5·650	5·600	7·370	6·000	5·150	8·520	16·400	7·850	6·960
Silica		–	–	8·310	4·600	8·130	15·240	12·000	15·400	25·200	20·000	9·540
Lime	1·63	1·07	2·89	–		–	–		–	–	–	
Carbonate of lime	–	–	–	2·950	4·650	19·800	1·980	2·640	3·450	1·200	4·500	none
Magnesia	3·04	4·52	3·38		–	–	–	–	–	–	–	
Carbonate of magnesia	–	–	–	3·800	2·910	11·880	3·900	4·230	8·580	6·000	4·800	0·900
Carbonic acid	31·58	27·33	30·07	–	–		–	–	–	–	–	
Phosphoric acid	0·38	0·18	0·76	0·530	0·427	–	0·217	0·482	0·750	0·214	0·424	0·576
Sulphuric acid	trace	trace	trace	traces	trace	–	trace	trace	trace	trace	trace	trace
Bisulphide of iron	0·71	0·11	0·15	0·170	0·123	–	0·119	trace	0·241	0·124	0·246	0·192
Water	0·66	1·06	1·21									
Potash	–	–	–	2·840	not determined		not determined	2·134	2·790	1·709	1·886	2·770
Organic matter	0·64	0·79	0·82									
Insoluble residue	14·50	27·58	17·27	–	–	–	–	–	–	–	–	
	99·99	99·98	99·43	98·960	99·550	98·300	97·956	99·756	98·361	99·474	99·313	98·802
Total Iron	35·48	28·55	32·44	35·625	38·75	24·650	34·000	34·600	28·000	23·300	28·750	37·300

* Minute traces of copper and lead.

	Ft.	in.	
Tobacco Pins - - -	0	2	Showing a succession of variously coloured laminæ.
Ground - - - -	0	6	
Black Pin - - - -	0	1	
Ground - - - -	1	0	
Grey Pin (*Pin glas bach*) -	0	3	

This last is accompanied by "jack," sometimes both above and below, and exhibits numerous vertical cracks or joints with crystalline quartz and, not unfrequently, Hatchettine.

[Average yield per acre 4,500 tons according to Meade, *op. cit.* According to Joseph the Black Pins had a high reputation for making the best bar-iron, but yielded only 25 per cent. metallic iron. *Proc S. Wales Inst.*, vol. xii., p. 264.]

SOAP VEIN.

Top Mine :			
Vein - - -	0	2	Brownish stone, which, as well as the next below, is somewhat poor.
Ground - - - -	1	10	
Two-inch Pin - - -	0	2	
Ground - - - -	2	1	
Tobacco Pin - - -	0	1	Thin, but excellent stone, formed of thin layers, looking like cakes of Cavendish tobacco; contains Millerite.
Ground - - - -	0	2	
Snuff Pin - - - -	0	0½	
Ground - - - -	2	0	
Bottom Mine :—			
Rashin - - - -	0	3	Contains Hatchettine in the cavities.
Rashin mine ground - -	2	0	
Pins - - - - -	0	1½	
Soap Vein Coal - - -	1	0	

[Average yield per acre 2,000 tons according to Meade, *op. cit.*]

For further sections the reader is referred to Vert. Sects., Sheet 81.

Faults in the Coal Field.

We have elsewhere noted the fact that the Coal Field owes its structure to two sets of disturbances differing in both character and age. An east and west set of flexures, accompanied by some faulting, traverses the field from end to end, and in certain parts of South Wales betrays its age by the fact that it passes under Secondary Rocks without producing any effect upon them. The other set consists of a long series of normal faults, accompanied by little or no folding, and ranging N. 5°—30° W., approximately at right angles to the first set. The age of this north and south system can be determined in certain parts of the district to be partly, if not wholly, post-Liassic, while, from other considerations, it is not unlikely to be post-Cretaceous.*

In the map now under description, beyond the fact that the general shape of the coal-basin is partly due to the earlier flexures, we are but little concerned with them, the Trevethin Fault alone falling into the right direction (p. 52). Of the north and south set, however, there is a good illustration; they cross the

* *Geol. Mag.* for 1899, pp. 113, 114.

Coal Field at fairly regular intervals, maintaining their direction obliquely across hill and dale with great constancy.

The faults of the north and south system are so arranged that the field is traversed by a series of narrow wedges or troughs, each dropped down between two faults, most of the faults taking their places as one side or the other of such troughs. Taken in order from east to west they may be enumerated as follows, each pair enclosing a trough :—The Blaenavon Fault; the Clydach Bridge and Brynmawr Faults; the Greenland Fault; the Pen-y-fan or Tredegar No. 1 Fault and another, also known as the Tredegar No. 2 or simply the Tredegar Fault; the Dowlais and Rhos Faults.

The Blaenavon Fault has already been discussed (p. 56); the remainder, which traverse the area surveyed by Mr. Gibson, are thus described by him :—

The Clydach Bridge Fault ranges N. 30° W., and has a downthrow west of 32 yards in the Old Coal under Twyn-Carn-canddo and slightly less southwards. It appears to start in the Millstone Grit, and at Pont Clydach, where it is visible, throws the Old Coal against measures lying below the Bydylog Seam; it then breaks through the outcrops of the grits below the Tillery Vein, and shifts the outcrop of that vein no less than 700 yards. The next clue to its position is afforded by the shattered condition of the Pennant at the head of Cwm Tillery, and by a strong spring near Gilfach Green, which appears to be thrown out in consequence of the fault bringing the shales of the Tillery Rider against massive sandstones. The position usually assigned to it lies about 200 yards further to the south-west, and the Clydach Bridge Fault is supposed to join the Greenland Fault, but the direction given to it as above suggests that it more probably runs by Varteg Hill Colliery, at the head of Nant Ffrwd (p. 56).

The Brynmawr Fault chiefly affects the lower measures near that town, and dies away southwards. As far as Cwn Celyn its underground position in the Old Coal almost coincides on the map with its surface position, the hade being high. South-east of Newtown, Brynmawr, it has a downthrow east of 40 yards, which decreases to 20 yards under Mynydd James, and to 8 yards near the South Wales Colliery, but increases to 27 yards near Palace Row, Cwm Tillery, south of which it appears to die out. Its surface-position is shown by a break in the escarpment to the east of Glyn-milwr Farm. The Clydach Bridge and Brynmawr Faults enclose a trough about half a mile wide from Brynmawr for about two miles southwards, but then diverge and lose connection.

The only faults in the Ebbw-fach and Ebbw Valleys are those proved at Llanhilleth and Aberbyg. The former is a downthrow west of 20 yards in the Mynyddislwyn Vein,* and ranges to Aber-Tillery, north of which its existence has not been proved. The Aberbyg Faults have been proved in the Tillery Vein; one of them passes through the shaft.

The Tredegar Faults start in the Millstone Grit (p. 42), cross

* See also Geology of Newport, p. 51.

the Sirhowy at Tredegar, and traverse the Pennant plateau of Cefn Manmoel to the Mynyddislwyn outlier of Pen-y-fan, where the more eastern of the two assumes that name. They not only preserve a long straight course, but especially keep a remarkable parallelism, the enclosed wedge only varying in width from 210 to 500 yards along a course of about 8 miles. The more eastern of the two has a downthrow west of 40 yards in the Old Coal at Tredegar, and seems to be nearly vertical. It shifts the outcrop of the Tillery Vein 700 yards, and throws down the Mynyddislwyn Vein 51 yards, from which it is inferred that it keeps its course across the featureless plateau of Mynydd Manmoel, as shown on the map. South of Pen-y-fan it either dies away or ceases to be distinguishable in the faulted ground near Trinant (Sheet 249).

The more western of the two is known as The Tredegar Fault. It is a downthrow east of 40 yards in the Old Coal 550 yards north-west of the Old Globe Pit; of 35 yards 200 yards west of that pit; and of 55 yards 600 yards south-south-east of that pit. On Mynydd Pen-y-fan the throw is estimated to be 51 yards, but, like its complementary fault, the Tredegar Fault dies away south of that mountain.

The Dowlais and Rhos Faults form a no less striking example of a trough. The Dowlais, or more eastern of the two, starts in the Old Red Sandstone; under Pen Garn Pigau it throws the Upper Four Foot Coal down west 72 yards, but dies out 150 yards north of Cwm-bargoed Farmhouse. In the same line, but a little further north, a fault with a downthrow west of 40 yards has been proved in the Upper Four Foot workings from Cwm Bargoed, but its relation to the 72-yard fault has not been ascertained.

The Rhos Fault, north of Coly-uchaf, throws the Rider on the east down nearly on a level with the Brithdir Seam on the west, which indicates a displacement of about 100 yards. Three-quarters of a mile to the north-west it is said to die out in highly inclined measures.

Fossils.

We have already observed that while the fauna of the lower part of the Millstone Grit is marine and closely allied to that of the limestone, yet that of the upper part shows itself sensitive to the gradually changing conditions in the comparative scarcity of the common brachiopods and in the comparative abundance of mud-loving lamellibranchs such as Anthracomya and Carbonicola.

In the Coal Measures, the separation of which from the Millstone Grit is quite arbitrary, the story is continued. Though a few of the brachiopods survive and reappear at intervals for upwards of 100 yards above the base of the formation, yet the great majority of fossils consist of lamellibranchs of the genera named above.

Though differing from the open-sea deposits which preceded them, the Coal Measures were almost certainly not fresh-water. The Anthracomya is known to have lived side by side with true marine molluscs, and the Carbonicola, though allied to a great fresh-water family, is always found in close attendance upon the Anthracomya. In no part of the Coal Measures has a true lacustrine fauna, such as characterised lakes of later age, been observed; not only are fresh-water gasteropods absent, but all the fossils are such as could have thrived in brackish water. A comparison with older formations leads to the same conclusion; the Old Red Sandstone, which there is reason to think was in part a delta-formation in fresh water, yields the large thin-shelled Anodonta, closely resembling the recent fresh-water mussel, but unlike any Coal Measure lamellibranch.

The gradual transition from the purely marine formation of limestone devoid of estuarine organisms, up into a mass of coal-bearing sediments generally devoid of purely marine organisms, is repeated in every English Coal Field, and is, moreover, always attended by the same sequence of lithological changes, the limestone being always succeeded by a mass of more or less conglomeratic grits (Millstone Grit), and the grits by coal-bearing strata largely composed of mud. Consequently a broad correlation of one Coal Field with another is easy, but no precise comparison of zone for zone has yet been found possible. Having regard, however, to the general sequence of events, we may say that about the same proportion of marine forms occurs in the lower measures of other fields as in the lower measures of South Wales, and, to take an example, that the Millstone Grit and lower part of the Steam Coal Series of Monmouthshire is comparable from that point of view with the Millstone Grit and Gannister Beds of Lancashire.*

The following list has been compiled from various sources:—(1) The Iron ores of Great Britain (Memoirs of the Geological Survey), part iii., in which Salter enumerates the specimens identified by himself and collected by Mr. Adams and Dr. Bevan; (2) from Monographs on Carbonicola, &c., and on the Carboniferous Lamellibranchiata by Dr. Wheelton Hind (Pal. Soc., vols. 48 *et seq*).; (3) from a collection made by Mr. S. Trump of Rhymney, and identified by Messrs. Sharman and Newton; (4) from specimens preserved in the Museum of Practical Geology.

The original specimens on which Salter's lists were founded are not accessible, and the identification cannot be checked. A long list of plants from the Elled Balls, quoted by Dr. Bevan in the Geologist, vol. i., p. 128, is omitted, the authority for their identification not being given. The more recent determinations are those by Dr. Hind and the Survey, and come under the letters H, S, and T. The authority and locality of each specimen is indicated by letters and numbers as on pp. 86, 87:—

---

* Salter in the Iron Ores of Great Britain, p. 223, correlated the Bottom Vein ironstone with a fish-bed which occurs in Lancashire in the roof of the Cannel Coal (not Arley Mine as stated), and, on p. 234, the Rosser Vein with the Pennystone and strata below it in the Coalbrookdale Field. This correlation is more precise than is justified. As an illustration of the danger of too minutely correlating the measures of different fields, it may be mentioned that in North Staffordshire a rich marine fauna has been found far higher up than in Lancashire or South Wales. Ward, *Trans. N. Staff. Inst. Min. and Mech. Eng.*, vol. x., pp. 43, 49.

A. Adams. B. Bevan. H. Hind. S. Geological Survey. T. Trump.

Localities. 1. Pontypool. 2. Clydach. 3. Cwm Celyn and Blaina. 4. Beaufort. 5. Ebbw Vale (including Gantre and Victoria). 6. Sirhowy. 7. Rhymney. 8. Dowlais.

	Bottom Vein Mine.	Blue or Big Vein.	Red Vein.	Mine over Engine Coal	Darran Pins.	Mine over Raslas Coal.	Cliff above Upper Four Foot Coal.	Mine above Three-quarter Coal.	Mine over Big Coal.	Black Pins and Soap Vein.	Roof of Brithdir Coal.	Black Band
Annularia sphenophylloides? *Zenk.*		–	–	–	–	–	–	–	–	–	T 7	–
„ stellata, *Schloth.*	–	–	–	–	–	–	–	–	–	–	T 7	
Lepidodendron, sp.	–	–	–	–	–	–	–	–	–	–	T 7	
Mariopteris muricata, *Schloth.*	–	–	–	–	–	–	–	–	–	–	T 7	–
Sphenophyllum cuneiforme, *Sternb.*	–	–	–	–	–	–	–	–	–	–	T 7†	–
Spirorbis carbonarius, Martin [= *pusillus*, Martin]	–	B 6	B 4*	–	–		–	–	–	–	–	
Athyris planosulcata, *Phill.*	–	–	–	–	–	B 4	–	–	–	–	–	–
Productus scabriculus, *Martin*	–	–	–	A 1	–	–	–	–	–	–	–	–
Spirifera bisulcata, *Sow.* [= *trigonalis*, var.]	–	–	–	A 2	–	–	–	–	–	–	–	–
Anthracomya Adamsi, *Salt.*	–	–	–	–	–	–	–	–	T 7	A 5, H‡	–	
„ modiolaris, *Sow.*	–	–	–	–	–	T 7	T 7	–	–	–	–	–
„ pulchra, *Hind*	–	–	–	–	–	–	–	–	T 7	–	–	–
„ pumila, *Salt.*	–	–	–	–	–	–	–	A H 5	T 7	–	–	–
„ senex, *Salt.*	–	–	–	–	AS 5	–	–	–	–	–	–	–
„ subcentralis, *Salt.*	–	–	–	–	–	–	–	A 5	H §	–	–	–

„ Wardi, *Salt.* MS.	–	–	–		–	–	–	–	T 7	–	–	–
„ Williamsoni, *Brown* (var.)	–	–	–	–	–	–	–	–	–	–	–	–
„ sp. near to dolabrata, *Sow.*	–		–	–	–	–	T 7	–	–	–	–	–
Carbonicola (*Anthracosia*) acuta, *Sow.*	H 6	B 5, T 7	A 5 ‖	–	–	T 7	–	–	–	B 5	–	–
„ aquilina, *Sow.*	–	–	–	–	S 5	–		–	–	–	–	–
„ *centralis* (see ovalis)	–	–	–	–		–		–	–	–	–	
„ nucularis, *Hind*		–	–	–	–	T 7	–	–	–	–	–	
„ ovalis, *Martin* (= *centralis*)		S 5	B 5 ‖	–	S 5	–		A 2	–	–	–	
„ turgida, *Brown*	H 5	–	–	–	B 6	–	–	–	–	–	–	–
„ sp.		T 7	–	–	–	–	T 7		T 7	–	–	–
Edmondia ?	–		B 4	–	–	–	–		–	–	–	
Modiola (or Anthracomya)	–		–	–	–	–	–		B 5¶	–	–	A B 3
Myalina (see Naiadites)	–		–	–	–	–	–		–	–	–	–
Naiadites, carinata, *Sow.*	–	H 6, T 7, S 5	–	–	B 6, H 6	T 7	T 7	–			–	
„ elongata, *Hind*			–	–	–	–	–	–	T 7	–	–	
„ modiolaris, *Sow.* (var.)	–			–	B 5	T 7	–	–	–	–	–	
„ quadrata, *Sow.*	–	–		–	–	T 7	–	–	S 5	–	–	
„ triangularis, *Sow.*	–	H 5		–	–	–	–	–	–	–	–	
Amblypterus [? Elonichthys]	A 5	–	–	–	–	–	–		–	–	–	–
Byssacanthus ?	B 5		–	–	–	–	–	–	–	–	–	–
Helodus simplex, *Ag.*	A 5	–	–	–	–	–	–	–	–	–	–	–
Megalichthys Hibberti, *Ag.*	A 5, B 8	–	–	–	–	–	–	–	–	–	–	A 3
Palæoniscus sp. [? Elonichthys]	A 5, B 4, 6	–	–	–	–	–	–	–	–	–	–	–
Pœcilodus angustus, *Ag.* [? Pleuroplax Atheyi, *Barkas*]	B 5	–		–	–	–	–	–	–	–	–	
„ sp.	B 5	–		–	–	–	–	–	–	–	–	–
Pleuracanthus gibbosus, *Binney* (Diplodus, *Ag.*)	A 5	–	–	–	–	–	–	–	–	–	–	–
Pleuroplax Rankinei (Pleurodus affinis, *Ag.*)	A**	–		–	–	–	–	–	–	–	–	–
Rhizodus granulatus *Ag.* [= Rhizodopsis sauroides, *Williamson*]	A, B 5	–	B 5 ‖	–	–	–		–	–	–	–	A 3

* Spotted Vein above the Red Vein. † Black Band below the Brithdir Coal. ‡ Soap Vein of Pen-y-cae. § Elled Balls of Brynbach.
‖ In the Old Coal. ¶ In the Elled Coal. ** Mentioned and figured by Salter in the Iron Ores, but locality not given.

CHAPTER VII.

SUPERFICIAL GEOLOGY.

Glacial Deposits.

These deposits, which are shown in colour on the edition of the Map for Superficial Geology, consist in part of gravels with well-rounded pebbles, and in part of clay or clayey gravel packed with almost angular boulders. In accordance with the practice prevailing in other parts of the kingdom these two types of Drift have been distinguished by colour, but there is here a perfect gradation from one to the other, nor are we able to state that either one habitually overlies the other. On the contrary, the few clear sections that occur indicate that the two have been inextricably jumbled up, apparently by ice-pressure, subsequently to their deposition. Two general laws, however, having reference to their relative distribution have been established. Firstly, the Boulder-clay type prevails near the source of the ice-flow, while the pebbly gravel-type is developed in areas where the ice-foot lingered. Secondly, the gravel-type is developed chiefly along what are main lines of drainage now, and what must have been the main line of the effluents formerly. In accordance with the former law, the Drift of the part of the Usk Valley described in this Memoir is loaded with well-washed gravel, while the Coal Measure valleys, with the heads only of which we are dealing, contain Boulder Clay.

With regard to the distribution of the Glacial Deposits as a whole, it has become clear that the existing water-partings formed the main ice-partings also, though they were over-ridden in places. In the map now under description the escarpment of the Carboniferous Limestone formed an insuperable barrier to the ice-flow of the Usk Valley from Llangynidr eastwards. The distribution of the Drift may, therefore, be dealt with in two distinct sections. The one comprises a portion of the Usk Valley, with Drift derived from a comparatively distant northern source; the other includes the series of Coal Measures valleys, with Drift of strictly local origin, mingled in a few cases with material of a northern source.

(1.) *North and East of the Carboniferous Limestone.—The Usk Valley.*

The great mass of well-rolled gravel which overspreads the lower part of the valley terminates at the Berthin Brook. The boulders consist chiefly of Old Red Sandstone, derived, no doubt, from the Monmouthshire Black Mountains, mixed with a variable proportion of Millstone Grit *débris*, from the north crop of the

Coal Field. Limestone boulders occur, but never abundantly. This composition makes it certain that the direction of transport has been down the valley, and from other indications, such as the occasional presence of coal-dust, but more especially from the direction of the Drift-ridges, we may state that it was south-eastwards.

Around Monkswood the gravel forms low terraces, undulating gently, but rising imperceptibly to considerable heights above the river, and in one place or another assuming the moundy form so characteristic of glacial deposits. In addition to Old Red Sandstone, it contains much Millstone Grit, and is sparingly dotted over also with large boulders of pebbly grit, sometimes glaciated. The Usk, in swinging to and fro, cuts deeply into this tumultuous accumulation, and shows that it varies from a red clay to a coarse, well-rolled gravel. The bank east of Llancayo consists of sand and rocky red clay exposed to 40 feet; at Trostrey coarse gravel with boulders of grit, Millstone Grit conglomerate, and a few of Silurian Limestone, more or less stratified, is banked against a cliff of Silurian rocks. Half a mile further up, but on the west bank, there are 8 to 10 feet of sand over gravel, containing a few boulders of Carboniferous Limestone, in addition to the usual grits; the gravel is cemented in places into a hard rock, and forms a cliff 70 feet in height. Kemeys Commander and St. Mary's stand on a similar deposit, cut into by the river in the latter case for upwards of 50 feet. Between St. Mary's and the church there are several deep old pits in sand and coarse gravel, and a river-cliff close by shows upwards of 90 feet of the same deposit.

At Bettws Newydd the gravel assumes a more characteristically moundy form, and encloses many of the little water-logged hollows which always accompany the mounds. An unsuccessful well * sunk here to a depth of 100 feet reached the underlying Silurian rocks, but the total thickness of the gravel was not ascertained.

The tract of gravel around Goytre consists of an almost interminable succession of low ridges, ranging about S.E.—parallel, that is, to the general trend of the Usk Valley, but diverging southward from the great scarp on its west side.

At Llangattoch, Llanfihangel and Clytha we at length reach the northern (or eastern) margin of this great mass of gravel. It ends somewhat abruptly upon a gently rising slope of Old Red Marl, but at its very margin rises into the characteristic little ridge, or esker, upon which stands the Twyn-y-Cregen. Here a pit for road-metal is worked in upwards of 20 feet of pebble-gravel with seams of sand.

At Llangattoch-on-Usk both mounds and hollows are excellently shown. There are several small hollows near the church and village, but one unusually large one, still partly occupied by water, lies close to Pen-pergwm Station, to which it gives the name

* The site was chosen by a diviner, who predicted a supply at 50 feet depth.

Four hundred yards west of it there is another small but deep hollow, which also forms a lake. Castle Arnold, on the other hand, stands on a small isolated esker or gravel-mound. The river here and for two-thirds of a mile northwards has cut a deep trench in a platform of gravel. On the east side the gravel is cemented into a conglomerate, and forms a steep cliff.

Continuing northwards along the east side of the river we find a conspicuous esker, partly dug away for road-metal and sand, close to Nant-oer, while in the river-bank there are upwards of 50 feet of gravel exposed. On the west side, at the Race Course, there is an excellent example of the way in which a river meandering across a hummocky plain of glacial gravel establishes a gradient, partly by the flood-waters silting up the hollows and partly by the washing away of the intervening ridges. In this case there is a succession of hollows occupied either with peat or silt, according as they are accessible to the floods or not, whereas the intervening ridge on which Lower Llanfoist stands has been cut through to a depth of 40 feet. The chief work of the river has been to fill up, whereas below Llanelen it has been to excavate. The bank of the river at the Grand Stand shows patches of gravel resting on 10 feet fine red laminated clay and loam with an occasional gravelly seam. The gravel wedges into the underlying beds, and the whole mass is slightly contorted.

In a large recess in the escarpment west of Llanover there is a remarkable development of a morainic form of Drift. The recess runs from Blaen-ochram north-westwards to the Malps, about 1½ miles, and is shut in on the east by the great rock-shoulder of Coed-y-Prior Common. In its western side there are two large cwms, which we may call respectively Craig-y-Cwm and Cwm-mawr, the latter being below Carn y Defaid. Their rock-sides are somewhat precipitous, and in the bottom of each is an alluvial flat, once a shallow tarn but now naturally drained by a small ravine.

The rock-shoulder which encloses Craig-y-Cwm on the north ends at Pen-twyn-y-lladron, but from it there starts a narrow moraine-like ridge, with steep sides and narrow top. After a course of 200 yards in a north-east direction the ridge turns round to the south and gradually loses form. On the south side of the Cwm there is a somewhat similar ridge, which, however, is compound and less conspicuous. The two tend to meet eastwards, and enclose between them a tumultuous assemblage of mounds devoid of either definite shape or direction.

In Cwm-mawr a large morainic ridge starts from the hillside at Craig-yr-hafod and runs east and south-east for about 500 yards. At the farm of the Malps it throws off a spur to the south-east about 250 yards long, which encloses one of the alluvial flats referred to. The ridge ends in a mass of hillocks which trend generally south-eastwards, but end at the farm of Cwm-mawr in a steep declivity, and it is noticeable that this declivity continues along the foot of the rock-slope west of Cwm-mawr, so that between it and the hill there is a narrow valley, not due to denudation, but a relic of the form of deposition. Similarly, between this declivity and the ridge of Pen-twyn-y-lladron, there is a tract of low ground terminating eastwards against the flank of Coed-y-Prior. Ochram Brook in descending from the higher level to these low meadows has cut a deep notch in the declivity.

The material composing these ridges is all such as may have come from the rock-walls of the cwms. It consists of angular masses of red sandstone, with much Millstone Grit here and there, and with a few boulders of limestone. Many of the red sandstone boulders must be of two or three tons weight. No pebbles or pebble-gravels occur, but the material merges into the pebble-gravel of the Usk Valley at Blaen-ochram.

The pronounced form and the rudely crescentic shape of many of the ridges, taken with the character of their contents, leave no room for doubt that they are of morainic origin. Though small as a feeding-ground for a glacier these cwms seem to have contained a snowfield of sufficient size to have had a proper motion of its own and to have been capable of piling the rubbish which fell upon it into lateral and terminal moraines. Presumably this was proceeding simultaneously with the accumulation of the ridges of pebble-gravel in the Usk Valley. So far as could be ascertained it was not possible to draw any line between the Drift in the recess and that in the main valley.

It may be mentioned here that the two cwms referred to above are characteristic of this part of the escarpment of Old Red Sandstone. One of the best known is the Punch Bowl, a beautifully symmetrical hollow in the east side of Blorenge. The north-eastern end of Blorenge tends to assume a similar form.

Cwm Llanwenarth, on the north side of Blorenge, contains an abundance of gravel, more or less hummocky in form. The Clydach Valley on the other hand shows a stiff dark Boulder Clay with striated boulders of limestone, which must have been derived from the outcrops at the head of the dingle. In the lower part of the valley this deposit graduates into the gravel of the Usk Valley.

Abergavenny and Llanfoist are built upon characteristically hummocky Gracial Gravel, trenched by the alluvial flat of the Usk, and well shown in the riverside west of The Brooks, as also in a railway-cutting near Llanfoist. These localities lie within the area surveyed by Mr. Dakyns, who furnishes the following notes:—

"The general aspect of the country [lying north of an east and west line drawn through Llanfoist] is that of one free from Drift. The soft sandstones and marls of the Old Red Sandstone, however, weather away so much that the solid rock is often hidden by a mass of detritus not readily to be distinguished from beds of glacial origin. With the exception of some moundy gravels there is but little unquestionably Glacial Drift."

After referring to the undoubted Boulder Clay of the Clydach he remarks that towards Gilwern gravel is seen in several places along the canal, and that a lot of gravel-mounds extend thence down to the river, but that there is absolutely nothing to show where the change from Boulder Clay to gravel takes place. It is quite probable that the one passes insensibly into the other.

"Below the Llangattwg Quarries, overlooking Cwm Onnen-fach there is a conspicuous curved mound like a moraine in shape, and near its head the valley is blocked by another mound which may be a moraine.

"At the head of Cwm Claisfer there is a lot of detrital matter quite concealing the solid rocks, like sandy till or morainic detritus. The limits are uncertain as there is much stony débris that may be due merely to atmospheric denudation. Similar detritus, mostly derived from the Millstone Grit, covers the Carboniferous Limestone at the head of Nant Trefil. Lower down the Cwm Claisfer there is material much like Boulder Clay.

"Gravels, generally of a dirty character and sometimes mixed with masses of clay like Boulder Clay, line much of the valley of the Usk like terraces of a higher level than the more recent alluvial deposits. In many places they are of a moundy character and enclose hollows; in others they extend up the hillside, as between Gilwern and Gofilon.

"With respect to the outlying patches of Drift to the north of the Usk, a sand-pit near Llantilio Pertholey, and a gravel-pit near Wern-ddu prove the existence of the two there marked; their limits are uncertain. Sand and gravel are exposed in the railway-cutting at Llanfihangel. In the valley of Afon Cibi, one of the streams draining the Sugar Loaf, there are a number of mounds probably of morainic origin.

"In the Llanbedr Valley gravel of the usual dirty character occurs by the roadside above Lower Cwm Bridge, and also on the east side of the valley below Upper Cwm Bridge. Further up the Grwyne Valley both gravel and sand are to be seen near Dyffryn, in all cases with most indefinite limits. Similar gravel occurs in Glyn Collwng near the western edge of the map.

"Though no glacial deposits have been recognised in the country which drains into the Trothy (on the eastern margin of the map) boulders of grit and quartz-conglomerate occur not unfrequently. Pebbles also may be found scattered about in many places where there is no deposit of gravel."

(2.) *Within the Escarpment of the Carboniferous Limestone.*

Of the seven main valleys traversing that portion of the Coal Field with which we are dealing the two to the east, namely the Afon Lwyd and the Ebbw-fach, are almost clear of Drift, while the others contain deposits of Boulder Clay, narrow as represented on a map, but often attaining a considerable depth. For the most part the material is such as may have been derived from the watersheds of the rivers, but in the Sirhowy and Rhymney Valleys there occur blocks of Old Red Sandstone, which must have been carried over the present water-partings from a more distant source.

The comparative absence of Drift in the two eastern valleys is accounted for by the fact that the ice was diverted by the

Clydach gorge. This deep ravine carries off the drainage of the depression which characterises the outcrop of the lower coal-series. It runs eastwards, at right angles to the main drainage system, and leads into the Usk Valley at the north-eastern corner of the Coal Field. It is believed by Mr. Gibson to be in part at least of more recent origin than the main system, and to have stolen some of its watershed for the following reasons.

The gap in the Pennant escarpment traversed by the Ebbw-fach is more comparable in its great width and depth with those of the Ebbw, Sirhowy, and Rhymney, than with those of the Rhymney Taff and Bargoed Taff. The Ebbw-fach river, on the other hand, is more comparable with the Rhymney-Taff and Bargoed-Taff rivers in the fact that it rises within the area of Coal Measures, whereas the others derive much of their water from the Millstone Grit moorland. This disproportion in size of river to valley suggests that the gap owes its origin to a larger flow of water than that which now passes down it.

A general view of the surroundings of the existing source of the Ebbw-fach shows that they have not the form of an original source, but that the valley actually continues on to the Millstone Grit, although the waters from this part no longer find their way into the Ebbw-fach. At the present time the drainage from the Millstone Grit runs past Clydach Bridge along a gorge the narrowness and steepness of which indicates its recent origin. Thence it descends by the rocky ravine of the Clydach, which we know from the fact of its containing Boulder Clay to be of pre-glacial age. That the gorge above Clydach Bridge is post-glacial we are unable to say for certain, but the fact that there is evidence of there having been Drift on the low water-parting between it and the Ebbw-fach (p. 94), while there is no Drift in the gorge itself, suggests that it is so. At any rate it seems certain that the cutting-back of the Clydach drainage-system has tapped that of the Ebbw-fach and diverted its upper waters. The diversion must have commenced as the Coal Field began to assume its present outline, and had proceeded so far in pre-glacial times that the Drift from Brynmawr travelled down the gorge eastwards and only in part, if at all, southwards.

The Ebbw, Rhymney and Sirhowy Valleys on the other hand still take the drainage from the Millstone Grit moorland, and in glacial times received the contents of the iceflow there generated. The occurrence of far-travelled boulders in some of them points to an overflowing of the local water-parting, such as we have obtained proof of in other parts of the Coal Field.* In this case we know that there was a great accumulation of ice on the Old Red Sandstone moorlands on which the Taff and its tributaries rise. Much of it escaped by the valley of that river, but that it did not all do so is proved by the existence of striæ on the Millstone Grit near Dowlais (just beyond the margin of this map) pointing not to the Taff Valley, but south-eastwards towards the Bargoed-Taff and Rhymney Valleys.

---

* Summary of Progress of the Geological Survey for 1897, pp. 141, 142, and for 1898 p. 166.

The greater part of the area within the limestone-escarpment was surveyed by Mr. Gibson, who furnishes the following account of the Glacial phenomena:—

The Glacial Deposits spread over considerable tracts on the dip-slopes and in the shallow valleys north of the railway from Abergavenny to Merthyr, but are hemmed into narrow strips in the deep valleys which penetrate the Pennant area. Pebbles of limestone and Old Red Sandstone occur to the north of the railway, but are scarce to the south of it, limestone especially being very rare. The material everywhere may be described as Boulder Clay, except in the bottoms of some of the deep valleys, some distance southwards, where it becomes a sand and gravel.

On the eastern slopes of the Ebbw Valley, near Beaufort, there are small isolated patches of Drift, often consisting merely of a sprinkling of small fragments of limestone and Millstone Grit. They probably travelled no further than from the Mynydd Llangattwg and Llangynidr, in a direction somewhat west of south, as indicated by some striæ one mile south-west of Pwll-coch. But the scarcity both of striæ and other signs of glaciation generally shows that the ice-sheet was of no great thickness.

An interesting example of a transported mass of rock was met with in the excavations for the Sirhowy Reservoir at Blaen-y-cwm. A mass of grit forming a small hill upwards of 200 yards in length, and which might well have been mistaken for rock-in-place, was found to be based on a stiff till consisting of clay with streaks of sand, fragments of coal and many blocks of grit. The hill therefore is merely a huge boulder, bearing witness to the great carrying power of the ice. In the accompanying sketch, which has been made by Mr. H. W. G. Williams from photographs taken while the reservoir was in construction, the Boulder Clay lying below the grit can be seen rising from behind three trucks towards the upper part of a timbered excavation. It should be remembered that the Sirhowy rises in the limestone-area, and makes a wide breach in the escarpment north of Trefil, which may have served for the passage of a lobe of ice from a more northern area. It was in this valley, some miles further down, that Old Red Sandstone boulders occurred in some numbers.*

On the wide plateau separating the heads of the Sirhowy and Rhymney Valleys, and known as Cefn Pyllau-duon, the signs of glaciation become more definite, while the composition of the Drift and the direction of a few striæ show that the ice over-rode this escarpment in some force. The abundance of scratched boulders of limestone and Old Red Sandstone on the broad sheet of Boulder Clay near Rhymney Bridge shows that we are dealing here with an ice-flow of northern origin, and the south-easterly direction of some striæ on Twyn Ceiliog shows that the direction of flow was locally influenced by the Rhymney Valley.

Within the Coal Field we find the same evidence of the glaciation having been purely local in the valleys to the east of the Rhymney. In all of them the Drift is mainly composed of

* Geology of Newport, p. 79.

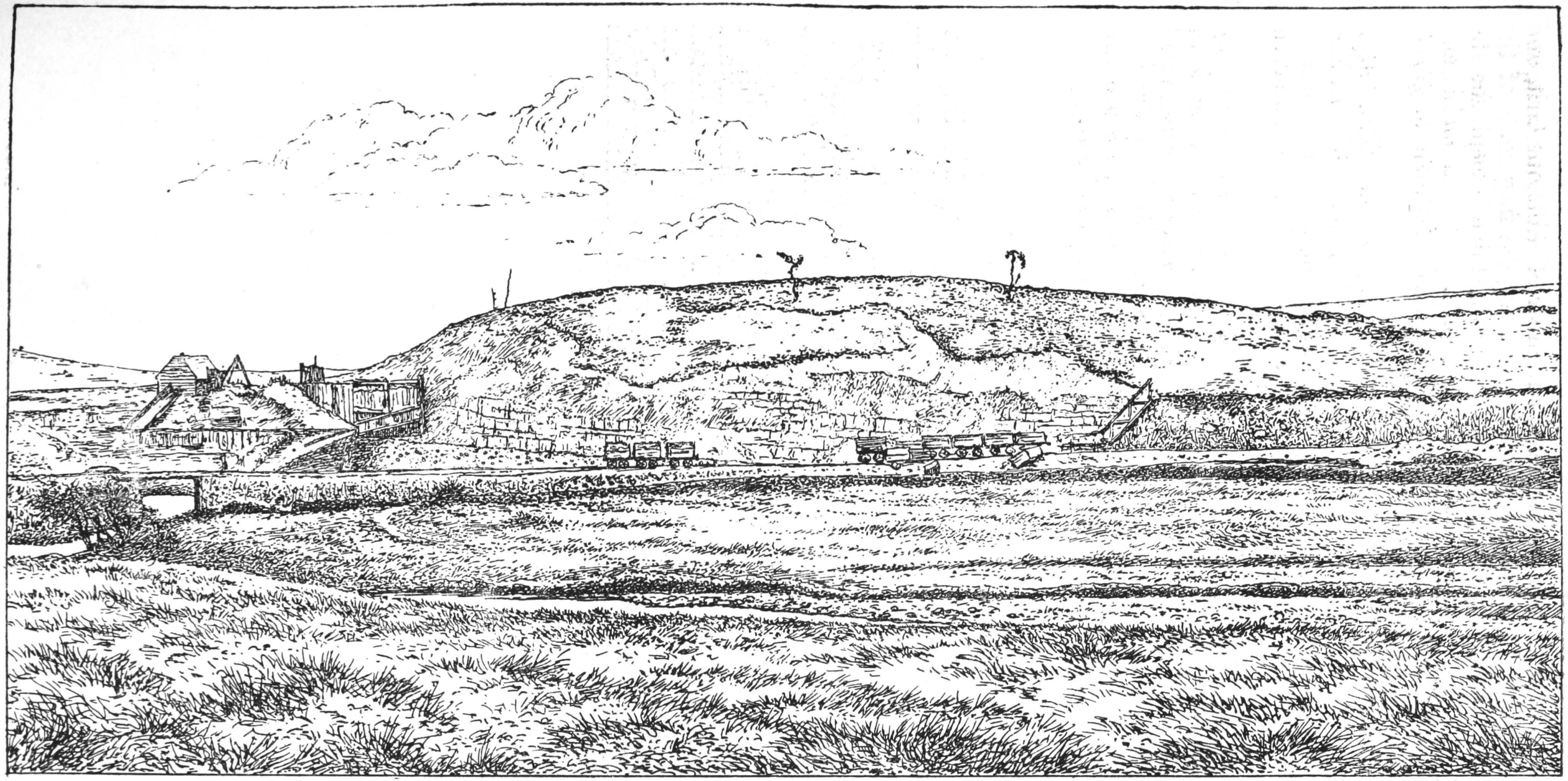


Fig. 10. *View of a transported mass of grit resting on Boulder Clay, Sirhowy Reservoir, north of Nant-y-bwch Station.*

blocks of Pennant with a smaller number of Millstone Grit, and frequently is so exclusively made up of angular fragments of the former as to be indistinguishable from talus except for the occasional occurrence of striated blocks. At Llandafal and Aberbyg, in the Ebbw valley, there are small deposits of gravel and rudely stratified sand.

In the Rhymney Valley the Boulder Clay between Pontlottyn and Cefn Brithdir Colliery contain many fragments of Old Red Sandstone, but rarely one of limestone, though loose blocks of both occur at an elevation of over 1,000 feet near the reservoir 500 yards west of Pontlottyn.

In the Boulder Clay of the Rhymney Bargoed Valley also blocks of Old Red Sandstone abound between Brithdir and Deri. Near the latter place this clayey Drift passes into a coarse gravel.

The same description applies also to the Drift of the Taff Bargoed Valley. It becomes a gravelly clay near Pwll-glâs, and contains some large conspicuously striated blocks of grit.

PEAT.

With the exception of a few small patches occupying some Drift-hollows near Llanfoist, the occurrence of peat is chiefly confined to the Millstone Grit outcrop, and especially to the north crop.

The swamps and peat-bogs form the sources of most of the rivulets which form the main supply of the reservoirs, and the occurrence of sufficient peat to colour the water is of some consequence.

There is a considerable area around Pwll Gwy-rhoc or Mynydd Llangattwg, and a sufficient number of irregular patches around the Bryn-mawr Reservoir to give the water a deep-brown colour. On Twyn Bryn-march and Mynydd Llangynidr there are patches of peat in hollows on the grits, and it occurs irregularly on Cefn Ceiliog. The outcrops of the shales of the Millstone Grit are generally marked by peaty swamps.

CHAPTER VII.

Water Supply.

The district comprised in this map is supplied wholly from springs or by the impounding of surface-waters, deep wells being unnecessary or futile. Most of the springs have been mentioned in the description of the strata. Those from the conglomerates and sandstones of the Old Red Sandstone are probably the purest, and are fairly copious. Several break out on the steep face which extends from near Trevethin northwards past Abergavenny, and have been utilised to a small extent. Abergavenny is supplied by gravitation from springs which issue from these strata on the south side of the Sugar Loaf plateau.

The springs from the limestone are more copious, but less free from suspicion. Allusion has already been made to the possible sources of contamination in the water breaking out in the sides of the Afon Lwyd Valley (p. 44). A spring in the Clydach ravine, known as the Ffynnon Gilfach, is safe from such pollution, and though issuing from limestone is said to be not a hard water; at present it runs to waste. Some of the most copious in the district issue from the limestone in the sides of the Trefil Valley or from the Millstone Grit lower down (p. 46). Some of the colliery-villages are supplied from local sources, such as springs from the Pennant; Fochriw, New Tredegar, and Bedwellty, for example, take a spring which issues from the No. 1 Rhondda seam at a point where it is intersected by a fault. The old levels in No. 2 Rhondda frequently yield abundant supplies, which are generally, however, contaminated or too hard to be suitable.

The larger towns on the North Crop are supplied by reservoirs constructed on the outcrop of the middle and shaly division of the Millstone Grit, and in which is collected as much of the rainfall as can be diverted from the swallow-holes. Such water is very soft—so much so, it is said, as sometimes to lead to corrosion of lead-pipes. A futile attempt to get water by sinking a well in the Upper Silurian rocks has been mentioned on p. 89. In such areas springs from the Drift-gravels or shallow wells are relied upon.

INDEX.

[*Only those fossils mentioned in the text are entered.*]

GENERAL MEMOIRS OF THE GEOLOGICAL SURVEY.

SUMMARY of PROGRESS of the GEOLOGICAL SURVEY for 1897, 1898, and 1899. Each 1s.

The MEMOIRS of the GEOLOGICAL SURVEY of GREAT BRITAIN. Vol. I., 21s.; Vol. II. (in 2 Parts), 42s. N. WALES By SIR A. C. RAMSAY. App., by J. W. SALTER and R. ETHERIDGE. 2nd. Ed. 21s. (Vol. III. of Memoirs, &c.)

Guide to the GEOLOGY of LONDON and the NEIGHBOURHOOD. By W. WHITAKER. 5th Ed. 1s.

TERTIARY FLUVIO-MARINE FORMATION of the ISLE of WIGHT. By EDWARD FORBES. 5s.

The ISLE OF WIGHT. By H. W. BRISTOW. New Ed. By C. REID and A. STRAHAN. 8s. 6d.

The ISLE OF PURBECK AND WEYMOUTH. By A. STRAHAN. 10s. 6d.

The WEALD (PARTS of the COUNTIES of KENT, SURREY, SUSSEX, and HANTS). By W. TOPLEY. 17s. 6d

The TRIASSIC and PERMIAN ROCKS of the MIDLAND COUNTIES of ENGLAND. By E. HULL. 5s.

The FENLAND. By S. B. J. SKERTCHLY. 36s. 6d.

The MANUFACTURE of GUN FLINTS. By S. B. J. SKERTCHLY. 16s.

The SUPERFICIAL DEPOSITS of SOUTH-WEST LANCASHIRE. By C. E. DE RANCE. 10s. 6d.

NORTH DERBYSHIRE. By A. H. GREEN, C. LE NEVE FOSTER and J. R. DAKYNS. 2nd. Ed. By A. H. GREEN and A. STRAHAN. 5s. 6d.

BURNLEY COAL FIELD. By E. HULL, R. H. TIDDEMAN [and Others]. 12s.

YORKSHIRE COALFIELD. By A. H. GREEN, R. RUSSELL [and Others]. 42s.

EAST SOMERSET and BRISTOL COALFIELDS. By H. B. WOODWARD. 18s.

WARWICKSHIRE COAL-FIELD. By H. H. HOWELL. 1s. 6d.

LEICESTERSHIRE COAL-FIELD. By EDWARD HULL. 3s.

ERUPTIVE ROCKS of BRENT TOR. By F. RUTLEY. 15s. 6d.

FELSITIC LAVAS of ENGLAND and WALES. By F. RUTLEY. 9d.

HOLDERNESS. By C. REID. 4s.

SOILS and SUB-SOILS from a SANITARY POINT of VIEW. By H. B. WOODWARD. 2s. 6d.

The WATER SUPPLY OF SUSSEX. By W. WHITAKER and C. REID. 3s.

The PLIOCENE DEPOSITS of BRITAIN. By C. REID. 5s. 6d.

The JURASSIC ROCKS OF BRITAIN.—Vol. I. YORKSHIRE, 8s. 6d., Vol. II. YORKSHIRE, Fossils, 12s. By C. FOX-STRANGWAYS. Vol. III. LIAS OF ENGLAND (Yorkshire excepted). 7s. 6d. By H. B. WOODWARD. Vol. IV. The Lower Oolitic Rocks of England. 10s. By H. B. WOODWARD. Vol. V. The Middle and Upper Oolitic Rocks of England. 7s. 6d. By H. B. WOODWARD.

BRITISH ORGANIC REMAINS. DECADES I. to XIII., with 10 Plates each. Price 4s. 6d. each 4to; 2s. 6d. each 8vo.

MONOGRAPH I. On the Genus PTERYGOTUS. By T. H. HUXLEY, and J. W. SALTER. 7s.

MONOGRAPH II. On the Structure of the BELEMNITIDÆ. By T. H. HUXLEY. 2s. 6d.

MONOGRAPH III. On the CROCODILIAN REMAINS found in the ELGIN SANDSTONES. By T. H. HUXLEY. 14s. 6d.

MONOGRAPH IV. On the CHIMÆROID FISHES of the British Cretaceous Rocks. By E. T. NEWTON. 5s.

The VERTEBRATA of the FOREST RED SERIES of NORFOLK and SUFFOLK. By E. T. NEWTON. 7s. 6d.

The VERTEBRATA of the PLIOCENE DEPOSITS of BRITAIN. By E. T. NEWTON. 4s.

Museum Catalogues, &c. :—

HANDBOOK to the MUSEUM of PRACTICAL GEOLOGY. 6d.

HANDBOOK to the COLLECTION of BRITISH POTTERY and PORCELAIN. 1s.

FOSSILS:—CAMBRIAN and SILURIAN, 2s. 6d.; CRETACEOUS, 2s. 9d.; TERTIARY and POST-TERTIARY, 1s. 8d.

SHEET MEMOIRS OF THE GEOLOGICAL SURVEY.

1, 2, 7 - - GEOLOGY OF LONDON, &c. By W. WHITAKER. Vol. I., 6s. Vol. II., 5s.

4 - - - FOLKESTON and RYE. By F. DREW. 1s.

34 - - - PARTS of WILTS, and GLOUCESTERSHIRE. By A. C. RAMSAY, W. T. AVELINE, and E. HULL. 8d.

44 - - - CHELTENHAM. By E. HULL. 2s. 6d.

45 - - - BANBURY, WOODSTOCK, and BUCKINGHAM. By A. H. GREEN. 2s.

45 SW - - WOODSTOCK. By E. HULL. 1s.

47 - - - N.W. ESSEX & N.E. HERTS. By W. WHITAKER, W. H PENNING, W. H. DALTON, & F. J. BENNETT. 3s. 6d.

48 SW - - COLCHESTER. By W. H. DALTON. 1s. 6d.

48 SE - - EASTERN END of ESSEX (WALTON NAZE and HARWICH). By W. WHITAKER. 9d.

48 NW, NE - IPSWICH, HADLEIGH, and FELIXSTOW. By W. WHITAKER, W. H. DALTON, & F. J. BENNETT. 2s.

49 S, 50 SE - ALDBOROUGH, &c. By W. H. DALTON. Edited, with additions, by W. WHITAKER. 1s.

49 N - - SOUTHWOLD. By W. WHITAKER. 2s. 6d.

50 SW - - STOWMARKET. By W. WHITAKER, F. J. BENNETT and J. H. BLAKE. 1s.

50 NW - - DISS, EYE, &c. By F. J. BENNETT. 2s.

50 NE - - HALESWORTH and HARLESTON. By W. WHITAKER and W. H. DALTON. 1s.

51 SW - - CAMBRIDGE. By W. H. PENNING and A. J. JUKES-BROWNE. 4s. 6d.

51 SE - BURY ST. EDMUNDS and NEWMARKET. By F. J. BENNETT, J. H. BLAKE, and W. WHITAKER. 1s.

51 NE - - PARTS of CAMBRIDGESHIRE and SUFFOLK. By W. WHITAKER [and Others]. 2s.

53 SE - - PART of NORTHAMPTONSHIRE. By W. T. AVELINE and RICHARD TRENCH. 8d.

53 NE - - PARTS of NORTHAMPTONSHIRE and WARWICKSHIRE. By W. T. AVELINE. 8d.

64 - - - RUTLAND, &c. By J. W. JUDD. 12s. 6d.

65 - - - S.W. NORFOLK and N. CAMBRIDGESHIRE. By W. WHITAKER S. B. J. SKERTCHLY, and A. J. JUKES-BROWNE. 3s.

21

SHEET MEMOIRS OF THE GEOLOGICAL SURVEY—*continued*

66 NE, SE - NORWICH. By H. B. WOODWARD. 7*s*.
66 SW - - ATTLEBOROUGH. By F. J. BENNETT. 1*s*. 6*d*.
67 NW - - E. DEREHAM. By J. H. BLAKE. 1*s*. 6*d*.
67 - - - YARMOUTH and LOWESTOFT. By J. H. BLAKE. 2*s*.
68 E - - CROMER. By C. REID. 6*s*.
68 NW, SW - FAKENHAM, WELLS, &c. By H. B. WOODWARD. 2*s*.
69 - - - BORDERS OF THE WASH. By W. WHITAKER and A. J. JUKES-BROWNE. 3*s*.
70 - - - S.W. LINCOLNSHIRE, &c. By A. J. JUKES-BROWNE and W. H. DALTON. 4*s*.
71 NE - - NOTTINGHAM. By W. T. AVELINE. (2nd Ed.) 1*s*.
79 NW - - RHYL, ABERGELE, and COLWYN. By A. STRAHAN. (Notes by R. H. TIDDEMAN.) 1*s*. 6*d*.
79 SE - - FLINT, MOLD, and RUTHIN. By A. STRAHAN (Parts by C. E. DE RANCE). 4*s*. 6*d*. ; *Supplement* 2*d*.
80 NW - - PRESCOT, LANCASHIRE. By E. HULL. (3rd Ed. With additions by A. STRAHAN.) 3*s*.
80 SW - - CHESTER. By A. STRAHAN. 2*s*.
81 NW, SW - STOCKPORT, MACCLESFIELD, CONGLETON, & LEEK. By E. HULL and A. H. GREEN. 4*s*.
82 SE - - PARTS of NOTTINGHAMSHIRE and DERBYSHIRE. By W. T. AVELINE. (2nd Ed.) 6*d*.
82 NE - - PARTS of NOTTINGHAMSHIRE, YORKSHIRE, and DERBYSHIRE. (2nd Ed.) By W. T. AVELINE. 1*s*.
83 - - - LINCOLN. By W. A. E. USSHER, A. J. JUKES-BROWNE, and A. STRAHAN. 3*s*.
84 - - - EAST LINCOLNSHIRE. By A. J. JUKES-BROWNE. 3*s*. 6*d*.
86 - - - N. LINCOLNSHIRE and S. YORKSHIRE. By W. A. E. USSHER [and Others]. 2*s*.
87 NW - - WAKEFIELD and PONTEFRACT. By A. H. GREEN. 6*d*.
87 SW - - BARNSLEY. By A. H. GREEN. 9*d*.
88 SW - - OLDHAM. By E. HULL. 2*s*.
88 SE - - PART of the YORKSHIRE COAL-FIELD. By A. H. GREEN, J. R. DAKYNS and J. C. WARD. 1*s*.
88 NE - - DEWSBURY, &c. By A. H. GREEN, J. R. DAKYNS, J. C. WARD, and R. RUSSELL. 6*d*.
89 SE - - BOLTON, LANCASHIRE. By E. HULL. 2*s*.
90 SE - - The COUNTRY between LIVERPOOL and SOUTHPORT. By C. E. DE RANCE. 3*d*.
90 NE - - SOUTHPORT, LYTHAM, and SOUTH SHORE. By C. E. DE RANCE. 6*d*.
91 SW - - The COUNTRY between BLACKPOOL and FLEETWOOD. By C. E. DE RANCE. 6*d*.
91 NW - - SOUTHERN PART of the FURNESS DISTRICT in N. LANCASHIRE. By W. T. AVELINE. 6*d*.
92 SE - - BRADFORD and SKIPTON. By J. R. DAKYNS, C. FOX-STRANGWAYS, R. RUSSELL, and W. H. DALTON. 6*d*.
93 NW - - NORTH and EAST of HARROGATE. By C. FOX-STRANGWAYS. 6*d*.
93 NE - - The COUNTRY between YORK and MALTON. By C. FOX-STRANGWAYS. 1*s*. 6*d*.
93 NW - - N. and E. of LEEDS, and near TADCASTER. By W. T. AVELINE, A. H. GREEN (and others).
93 SE, 94 W - COUNTRY between YORK & HULL. By J. R. DAKYNS, C. FOX-STRANGWAYS, and A. G. CAMERON. 1*s*.
94 NW - - DRIFFIELD. By J. R. DAKYNS and C. FOX-STRANGWAYS. 9*d*.
94 NE - - BRIDLINGTON BAY. By J. R. DAKYNS and C. FOX-STRANGWAYS. 1*s*.
95 SW, SE - SCARBOROUGH and FLAMBOROUGH HEAD. By C. FOX-STRANGWAYS. 1*s*.
95 NW - - WHITBY and SCARBOROUGH. By C. FOX-STRANGWAYS and G. BARROW. 1*s*. 6*d*.
96 SE - - NEW MALTON, PICKERING, and HELMSLEY. By C. FOX-STRANGWAYS. 1*s*.
96 NE - - ESKDALE, ROSEDALE, &c. By C. FOX-STRANGWAYS, C. REID, and G. BARROW. 1*s*. 6*d*.
96 NW, SW - NORTHALLERTON and THIRSK. By C. FOX-STRANGWAYS, A. G. CAMERON, and G. BARROW. 1*s*. 6*d*.
97 SW - - INGLEBOROUGH. By J. R. DAKYNS, R. H. TIDDEMAN, W. GUNN, and A. STRAHAN. 2*s*.
97 NW - - MALLERSTANG. By J. R. DAKYNS, R. H. TIDDEMAN (and others). 3*s*. 6*d*.
98 SE - - KIRKBY LONSDALE and KENDAL. By W. T. AVELINE, T. MC K. HUGHES, and R. H. TIDDEMAN. 2*s*.
98 NE - - KENDAL. By W. T. AVELINE and T. MC K. HUGHES. 2nd Ed. by A. STRAHAN. 2*s*.
101 SE - - NORTHERN PART of the ENGLISH LAKE DISTRICT. By J. C. WARD. 9*s*.
102 SW - - APPLEBY, ULLSWATER, and HAWESWATER. By J. R. DAKYNS, R. H. TIDDEMAN, and J. G. GOODCHILD. 1*s*. 6*d*.
104 SW, SE - NORTH CLEVELAND. By G. BARROW. 1s. 6d.
107 - - CARLISLE. By T. V. HOLMES. 1*s*. 3*d*.
108 SE - - OTTERBURN and ELSDON. By HUGH MILLER. 2*s*. 6*d*.
108 NE - - CHEVIOT HILLS. By C. T. CLOUGH. 1*s*. 6*d*.
108 SW - - PLASHETTS and KIELDER. By C. T. CLOUGH. 1*s*.
110 SW - - WOOLER and COLDSTREAM. By W. GUNN and C. T. CLOUGH. 1 . 6*d*.
110 NW - NORHAM and TWEEDMOUTH. By W. GUNN. 6*d*.
110 NE - - COAST south of BERWICK-ON-TWEED. By W. GUNN. 9*d*.
110 SE - - BELFORD, HOLY ID., and FARNE ISLANDS. By W. GUNN. 2*s*. 6*d*.
249 (New Series) NEWPORT, MON. By A. STRAHAN. 2*s*.
328 („) DORCHESTER. By C. REID. 1*s*.
329 („) BOURNEMOUTH. By C. REID. 4*d*.
332 („) BOGNOR. By C. REID. 6*d*.
334 („ EASTBOURNE. By C. REID. 6*d*.

COAL-FIELDS AND OTHER MINERAL DISTRICTS.—Scale, six inches to a mile.

The Coal-fields and other mineral districts of the N. of England are in part published on a scale of six inches to a mile, at 4*s*. to 6*s*. each. M.S. Coloured Copies of other six-inch maps, not intended for publication, are deposited for reference in the Geological Survey Office, 28, Jermyn Street, London.

THE IRON ORES OF GREAT BRITAIN.

Part I The North and North Midland Counties of England (*Out of print*). Part II. South Staffordshire. Price 1*s*. Part III South Wales. Price 1s. 3*d*. Part IV. The Shropshire Coal-field and North Staffordshire. 1*s*. 3*d*.

155.

MEMOIRS OF THE GEOLOGICAL SURVEY.

ENGLAND AND WALES.

THE GEOLOGY
OF
THE COUNTRY BETWEEN
ATHERSTONE AND CHARNWOOD FOREST.

(EXPLANATION OF SHEET 155.)

BY

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

WITH

NOTES ON CHARNWOOD FOREST BY

PROF. W. W. WATTS, M.A., F.G.S.

PUBLISHED BY ORDER OF THE LORDS COMMISSIONERS OF HER MAJESTY'S TREASURY.

LONDON:
PRINTED FOR HER MAJESTY'S STATIONERY OFFICE,
BY WYMAN AND SONS, LIMITED, FETTER LANE, E.C.

And to be purchased, either directly or through any Bookseller, from
EYRE & SPOTTISWOODE, EAST HARDING STREET, FLEET STREET, E.C.; or
JOHN MENZIES & Co., ROSE STREET, EDINBURGH, and
90, WEST NILE STREET, GLASGOW; or
HODGES, FIGGIS, & Co., Limited, 104, GRAFTON STREET, DUBLIN.

1900.

Price Two Shillings.

LIST OF MAPS, SECTIONS, AND OTHER PUBLICATIONS OF THE GEOLOGICAL SURVEY OF ENGLAND AND WALES.

THE Maps are those of the Ordnance Survey, geologically coloured by the Geological Survey of the United Kingdom, under the Superintendence of Sir ARCH. GEIKIE, D.C.L., LL.D., F.R.S., Director General.

(For Maps, details of Sections, and Memoirs issued by the Geological Survey, *see* "Catalogue.")

ENGLAND AND WALES.—(Scale 1 inch to a mile.)

Maps marked * are also published as Drift Maps. Those marked † are published only as Drift Maps.

Sheets 3*, 5, 6*, 7*, 8*, 9, 11 to 22, 25, 26, 30, 31, 33 to 37, 40, 41, 44, 47*, 64*, 65†, 69†, 70*, 83*, 86*, price 8*s.* 6*d.* each.

Sheet 4, 5*s.* Sheets 2*, 23, 24, 27 to 29, 32, 38, 39, 58, 84†, 85†, 4*s.* each.

Sheets divided into quarters ; all at 3*s.* each quarter-sheet, excepting those in brackets, which are 1*s.* 6*d.* each.

1*, 42, 43, 45, 46, NW, SW, NE*, SE*, 48, NW†, SW*, NE†, (SE*), (49†), 50†, 51*, 52 to 57, (57 NW), 59 to 63, 66 SW†, NE†, NW*, SE†, 67 N†, (S†), 68 E†, (NW†), SW†, 71 to 75, 76 (N), S, (77 N), 78, 79, NW*, SW, NE*, SE*, 80 NW*, SW*, NE*, SE*, 81 NW*, SW, NE, SE, 82, 83*, 87, 88, NW, SW*, NE, SE, 89 NW*, SW*, NE, SE*, 90 (NE*), (SE*), 91, (NW*), (SW*), NE*, SE*, 92 NW*, SW*, NE, SE, 93 NW, SW, NE*, SE*, 94 NW†, SW†, (NE†), SE†, 95 NW*, NE*, (SE*), 96 NW*, SW*, NE*, SE*, 97 NW*, SW*, NE*, SE, 98 NW, SW, NE*, SE, 99 (NE*), (SE*), 100*, 101 SE, NE*, NW*, SW*, 102 NW*, NE*, SW*, SE*, 103*, 104*, 105 NW*, SW*, (NE*), SE*, 106 NW*, SW*, NE*, SE*, 107 SW†, NE*, SE* 108 SW*, NE*, SE*, 109 NW*, SW*, SE*, 110 (NW*), (NE*), SE*, SW*.

New Series.—I. of Man*, 36, 45. 46, 56, 57, 8*s.* 6*d.* I. of Wight, with Mainland*, 330, 331, 344, 345, 8*s.* 6*d.* 155*, 203†, 231*, 232*, 248*, 249*, 263*, 267†, 268*, 282†, 283†, 284†, 299†, 300†, 315†, 316†, 325†, 328†, 329*, 339†, 330*, 331*, (332*), (333*), 334*, 339†, (340†), (341†), 342†, 343†, 349†, 350†, 355†, (356†). Price 3*s.* each, excepting those in brackets which are 1*s.* 6*d.* each.

GENERAL MAP :—(Scale 4 miles to 1 inch.)

ENGLAND AND WALES.—Sheet 1 (Title) ; 2 (Northumberland, &c.) ; 3 (Index of Colours) ; 4 (I. of Man) ; 5 (Lake District); 6 (E. Yorkshire) ; 7 (N. Wales) ; 8 (Central England) ; 9 (Eastern Counties) ; 10 (S. Wales and N. Devon) ; 11 (W. of England and S.E. Wales) ; 12 (London Basin and Weald) ; 13 (Cornwall, &c.); 14 (S. Coast, Torquay to I. of Wight) ; 15 (S. Coast, Havant to Hastings). *New Series, printed in colours*, sheet 1, 2s. ; sheets 2 to 15, 2*s.* 6*d.* each.

HORIZONTAL SECTIONS.

1 to 140, 146 to 148, England, price 5*s.* each.

VERTICAL SECTIONS.

1 to 82, England, price 3*s.* 6*d.* each.

COMPLETED COUNTIES OF ENGLAND AND WALES, on a Scale of 1 inch to a mile.

Old Series.

Sheets marked * have Descriptive Memoirs. Sheets or Counties marked † are illustrated by General Memoirs.

ANGLESEY†,—77 N, 78.

BEDFORDSHIRE,—46 NW, NE, SW†, SE†, 52 NW, NE, SW, SE.

BERKSHIRE,—7*, 8†, 12*, 13*, 34*, 45 SW*.

BRECKNOCKSHIRE†,—36, 41, 42, 56 NW, SW, 57 NE, SE.

BUCKINGHAMSHIRE,—7*, 13*, 45* NE, SE, 46 NW, SW†, 52 SW.

CAERMARTHENSHIRE†,—37, 38, 40, 41, 42 NW, SW, 56 SW, 57 SW, SE.

CAERNARVONSHIRE†,—74 NW, 75, 76, 77 N, 78, 79 NW, SW.

CAMBRIDGESHIRE†,—46 NE, 47*, 51*, 52 SE, 64*.

CARDIGANSHIRE†,—40, 41, 56 NW, 57, 58, 59 SE, 60 SW.

CHESHIRE,—73 NE, NW, 79 NE, SE, 80, 81 NW*, SW*, 88 SW.

CORNWALL†,—24†, 25†, 26†, 29†, 30†, 31†, 32†, & 33†.

CUMBERLAND,—98 NW, SW*, 99, 101, 102, NE, NW, SW*, 106 SE, SW, NW, 107.

DENBIGH†,—73 NW, 74, 75 NE, 78 NE, SE, 79 NW, SW, SE, 80 SW.

DERBYSHIRE†,—62 NE, 63 NW, 71 NW, SW, SE, 72 NE, 72 SE, 81, 82, 88 SW, SE.

DEVONSHIRE†,—20†, 21†, 22†, 23†, 24†, 25†, 26†, & 27†.

DORSETSHIRE,—15, 16, 17, 18, 21, 22.

DURHAM,—102 NE, SE, 103, 105 NE, SE, SW, 106 SE.

ESSEX,—1*, 2*, 47*, 48*.

FLINTSHIRE†,—74 NE, 79.

GLAMORGANSHIRE†,—20, 36, 37, 41, & 42 SE, SW.

GLOUCESTERSHIRE†,—19, 34*, 35, 43, NE, SW, SE, 44*.

HAMPSHIRE,—8†, 9†, 10*, 11†, 12*, 14, 15, 16.

HEREFORDSHIRE,—42 NE, SE, 43, 55, 56 NE, SE.

HERTFORDSHIRE,—1† NW, 7*, 46, 47*.

HUNTINGDON,—51 NW, 52 NW, NE, SW, 64*, 65.

KENT†,—1† SW & SE, 2†, 3†, 4*, 6*.

LANCASHIRE,—79 NE, 80 NW*, NE, 81 NW, 88 NW, SW†, 89 90 91, 92 SW, 98.

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, 83, 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.

PLATE I.

HANGING ROCKS, WOODHOUSE EAVES.

CRAG OF WOODHOUSE BEDS, SHEWING BEDDING AND CLEAVAGE IN HORNSTONES.

From a Photograph by Dr F. J. Allen.

MEMOIRS OF THE GEOLOGICAL SURVEY.

ENGLAND AND WALES.

THE GEOLOGY

OF

THE COUNTRY BETWEEN

ATHERSTONE AND CHARNWOOD FOREST.

(Explanation of Sheet 155.)

BY

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

WITH

Notes on Charnwood Forest by

Professor W. W. Watts, M.A., F.G.S.

PUBLISHED BY ORDER OF THE LORDS COMMISSIONERS OF HER MAJESTY'S TREASURY.

LONDON:
PRINTED FOR HER MAJESTY'S STATIONERY OFFICE,
By WYMAN AND SONS, Limited, Fetter Lane, E.C.

And to be purchased, either directly or through any Bookseller, from
EYRE & SPOTTISWOODE, East Harding Street, Fleet Street, E.C.;
JOHN MENZIES & Co., Rose Street, Edinburgh, and
90, West Nile Street, Glasgow; or
HODGES, FIGGIS, & Co., Limited, 104, Grafton Street, Dublin.

1900.

Price Two Shillings.

A.P.

PREFACE.

THE ground described in the present Memoir is contained in Sheet 155 of the New Series of the one-inch-scale map of England, and embraces the western part of Leicestershire, with adjacent portions of Warwickshire, Staffordshire, and Derbyshire. It nearly coincides with the area represented in Sheet 63 N.W. of the Old Series map of the Geological Survey, which was surveyed by Mr. H. H. Howell and Prof. E. Hull, and published in 1855. A memoir descriptive of this ground, prepared by Prof. Hull, was published in 1860 under the title of "The Geology of the Leicestershire Coal-field and of the Country around Ashby-de-la-Zouch." A small portion of the area depicted on the new map (Sheet 155) was comprised in the quarter-sheet 63 S.W. of the Old Series, and was illustrated in the Memoir on "The Geology of the Warwickshire Coal-field" by Mr. Howell, which appeared in 1859. Another smaller Memoir on "The Geology of part of Leicestershire," by Mr. W. T. Aveline and Mr. Howell, which described the quarter-sheet No. 63 S.E., was published in 1860.

The whole region having to be re-examined for the mapping of the superficial deposits, which were not shown upon the old maps, advantage was taken of the opportunity to revise the survey of the underlying formations. A comparison of Sheet 155 of the New Series with the former quarter-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 employment of the Ordnance maps on the scale of six inches to a mile has made it possible to introduce more detail and to ensure greater accuracy than was attainable with the smaller scale. For the first time the ancient rocks of Charnwood Forest, so carefully studied by Prof. Bonney and the Rev. E. Hill, have been worked out in such a manner as to allow their various sub-divisions to be represented on a published map. The Cambrian rocks of Nuneaton, formerly supposed to be of Carboniferous age, but proved by Professor Lapworth to be of much older date, were revised by Mr. A. Strahan in 1886. The main sandstones in the Coal-measures near Atherstone have been mapped, while the thin-bedded character of the Keuper Sandstone is now more clearly represented. The Trias is shown to have buried the ancient peaks of Charnwood Forest much more widely than was represented on the older maps.

Some doubt remains regarding the correlation of the deposits coloured on the map as Permian. Some of the sandstones in the extreme south-west corner of the map, hitherto shown as Permian, are for the present bracketed with the Carboniferous formations, but when a larger area of them has been mapped they may possibly require to be relegated to the

Trias. In like manner the age of the breccia that surrounds the Leicestershire and South Derbyshire Coal-field has not been determined.

For the first time the superficial deposits in this central part of England have been surveyed in detail and are shown upon a published map. Their plateau-like character forms a striking feature in the region. The alluvia of the various streams are now represented on the map, which thus brings out with great clearness the drainage-lines.

The whole of the map has been surveyed by Mr. C. Fox-Strangways, except the area of Charnwood Forest, which has been mapped by Mr. W. W. Watts. The present Memoir has been prepared by Mr. Fox-Strangways, Mr. Watts supplying the brief account of the pre-Cambrian rocks of Charnwood Forest, which forms the second Chapter.

It is intended that fuller descriptions will afterwards be given of some of the rocks enumerated in the present Sheet-Memoir. Thus, Mr. Fox-Strangways will prepare an account of the Leicestershire Coal-field, and Mr. Watts, who has resigned his position in the Geological Survey to become Assistant Professor of Geology in the Mason University College, Birmingham, has kindly undertaken to supply a full narrative of his researches in Charnwood Forest.

It should be mentioned that manuscript copies of the six-inch field maps are deposited in the Geological Survey Office. For much information with regard to the Coal-fields we are indebted to Mining Engineers, Colliery Managers, and Surveyors, who have freely given access to plans and sections.

ARCH. GEIKIE,
Director-General.

Geological Survey Office,
28, Jermyn Street, London.
9th July, 1900.

CONTENTS.

LIST OF ILLUSTRATIONS.

THE GEOLOGY

OF THE COUNTRY BETWEEN

ATHERSTONE AND CHARNWOOD FOREST.

CHAPTER I.

INTRODUCTION.

This sheet comprises an area of 216 square miles, the larger part of which lies in the County of Leicester, but it contains also portions of Derbyshire, Warwickshire, and a small part of Staffordshire. It includes the greater part of the area shown in 63 N.W. of the old survey, but extends somewhat farther to the east, west, and south, although not so far to the north as that map.

Owing to the Drift, which overlies the more solid rocks, being now shown, this sheet has far more detail than the older maps. Some of the other formations are also further sub-divided, particularly the older rocks of Charnwood, showing the structure of this region in a manner that has not previously been attempted.* Six-inch maps being now employed for the fieldwork, it has been possible to trace the boundaries with greater detail. Since the old survey several new collieries have been established, and the workings of the old mines have been considerably extended, so that much additional information has been obtained, that has in all cases been readily put at our disposal. This has thrown much new light on the structure of the rocks, and has enabled many points to be determined with greater accuracy than was possible nearly fifty years ago.

There are no very important towns in this sheet. The principal places are Ashby-de-la-Zouch, Coalville, and Atherstone. It also includes the old town of Market Bosworth, and there are numerous villages, many of which, especially near the mining districts, are of considerable size.

The drainage of the country is entirely within the basin of the Trent, but locally it is separable into two districts drained by the tributaries of that river; the one by the Soar and its branches flowing east; the other by the Mease and the Anker, which flow

* The Charnwood rocks were very fully described by Messrs. Hill and Bonney in the "Quart. Journ. Geol. Soc.," vol. xxxiii., p. 754; vol. xxxiv., p. 199; xxxvi., p. 33; vol. xlvii., p. 78; but no attempt was made to map the structure of the country until the present survey was undertaken. The first results of which were brought before the Brit. Assoc. at Liverpool in 1896 by Mr. W. W. Watts, and published in the "Geol. Mag.," dec. iv., vol. iii., p. 485, 1896.

west. The watershed dividing these two areas passes first in an easterly direction across the map from the high ground east of Ashby by Coalville and Bardon Hill to Copt Oak; and then more southerly by Ellistown, Bagworth, Cadeby, Stapleton, Barwell, and Hinckley.

The highest ground is over the Charnwood Forest district, which at Bardon Hill attains an elevation of 912 feet above the sea. At the foot of these hills, which rise abruptly, there is an extensive plain gradually declining from about 600 to about 400 feet above the sea, which is deeply cut into by the numerous small streams intersecting this plateau. In the western half of the map, between the two Coalfields, where the Drift has been denuded, the plateau-like character has been destroyed, and sharp escarpments are formed by the harder beds of the Permian, Bunter, and Coal-measure sandstones.

The greater part of the surface is covered by the Keuper Marl; which, over the higher ground, is much hidden by Boulder-clay and gravel. The Coal-measures, which cover the next largest area of surface, are separated into two portions forming part of the Warwickshire and Leicestershire Coalfields respectively: the connection between them is hidden beneath a broad belt of Lower Keuper Sandstone. The only other strata, that cover any considerable extent of ground, are the old rocks of the Charnwood Forest district. These, which form some of the most lofty ground in the Midlands, have been denuded into a series of isolated hills; the hollows between which have, in nearly all cases, been filled in with Keuper Marl. The other rocks which crop out, the Permian and Bunter sandstones, and the Cambrian shales of Atherstone with associated igneous rocks, do not occupy any large extent of surface.

The following formations occur in the area:—

PLEISTOCENE and RECENT.	Recent and Post-Glacial -	Alluvium. Loam and Peat. Valley Drift.
	Glacial -	Newer Boulder-clay, Sand and Gravel. Older Boulder-clay, Sand and Gravel.
TRIAS.	Keuper -	Keuper Marl with lenticular sandstone beds. Lower Keuper Sandstone with marl bands.
	Bunter -	- Pebble Beds or Conglomerate, and Sandstones.
PERMIAN -	-	Breccias with Marls.
CARBONIFEROUS	Upper Coal Measures	Sandstones and Marls*. Shales with *Spirorbis* Limestone.
	Lower Coal Measures—	Clay and shales with beds of Sandstone and Ironstone, and numerous coal seams.
CAMBRIAN-	-	Shales with intrusive igneous rocks.
PRE-CAMBRIAN or ARCHÆAN -		Slates, hornstones, and agglomerates with intrusive igneous rocks.

The soil of the country is mainly dependent upon the underlying formations. Thus the alluvium and some of the Drift beds form the best pastures, while the best corn land is found over the Keuper Marl. Owing to the large proportion of friable soil,

* These beds were formerly regarded as of Permian age. See page 28. They are represented on the map by a mixture of the Permian and Coal-measure colours.

especially over the Keuper Sandstone and the Pebble Beds, there is a much larger extent of arable land in this part of the country than in the east, and we do not find the large grazing districts that occur on the Lias. In the Charnwood Forest area, owing to the rocky character of the ground, only the valleys and flanks of the hills can be cultivated, the summits being either woodland or rough moorland.

The principal industry of the district is coal mining, which is now being vigorously carried on in the three separate districts of Baddesley and Polesworth; Moira, Donisthorpe, and Netherseal; and between Whitwick and Bagworth. Other important industries are the quarrying of the igneous rocks for road-stone and pavements, which is carried on at Whitwick, Bardon Hill, Cliffe Hill, Markfield, Groby, Enderby, Narborough, Croft, and south of Atherstone, while flagstones are made of this material at Groby and Croft. The output from these quarries has enormously increased during recent years, very large quantities of broken stone being sent away for macadamising roads, and the manufactured flagstone is rapidly superseding the natural material.

There are important brick and terracotta works in the Lower Keuper beds at Coalville, Ellistown, Ibstock, Heather, and Measham, and in the pot and fireclays of the Coal Measures to the north of Moira. These latter have of late years come into very extensive use, and a large industry in the making of sanitary pipes has arisen throughout the district between Moira and Swadlincote.

A rough slate is obtained from the Charnwood rocks at Swithland and Groby, but it is much inferior to the Welsh slates, and since the introduction of railways these workings have been entirely abandoned except to a very small extent at the latter place.

Manganese was formerly worked in the Stockingford Shales to the south of Atherstone; and limestone in the Coal-measures near Baddesley, but never to any extent. There is no building-stone of any value. The soft sandstones of the Lower Keuper, the Bunter, Permian, and Coal-measures have been used for this purpose; but, except in a few cases, they are far too soft to stand the weather. The slates and igneous rocks of Charnwood are occasionally used for rough or irregular walling. The use of the Drift gravel, which occurs over a large area, is now almost entirely superseded by that of "granite" for road mending; but the Pebble Beds of the Bunter are still worked, to a small extent, at Polesworth for this purpose.

The chief water-bearing stratum of the district is the Lower Keuper Sandstone, the porous divisions of which contain a very large amount of pure water. At Ellistown these rocks yield as much as 390,000 gallons a day. There are also many large springs issuing from the glacial gravels throughout the district. These also yield a very pure water, but in populous districts it is more liable to contamination than that from the deeper-seated sandstone.

CHAPTER II.

PRE-CAMBRIAN.

Pre-Cambrian Rocks of Charnwood Forest.

By Professor W. W. Watts.

On the north-east corner of sheet 155, scattered over an area of about seventeen square miles, there occur a number of rock-masses which are the summits of an old mountain range, whose base is buried deeply under the Trias. These rocks rise to their highest point in Bardon Hill, 912 feet above sea-level, but there are other hills of considerable height, such as Birch Hill and Beacon Hill, both over 800 feet, and Peldar Tor, over 700 feet.

This region is Charnwood Forest and its rocks are the oldest known in the district. They consist of a thick mass of clastic volcanic rocks, with overlying grits and slates; they are intruded upon in places by several types of igneous masses, and the whole of them are of pre-Cambrian age.

SUCCESSION.

The chief local divisions, several of them first indicated by the Rev. Edwin Hill and Prof. T. G. Bonney, and subsequently established and mapped by the Survey, are the following, given in descending order :—

(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.

The succession is clearest in the eastern part of the district, but it becomes much confused in the north-west, partly on account of the increased faulting and disturbance, but chiefly on account of the fact that the focus of volcanic activity appears to have been situated in or near this region.

STRUCTURE.

The general structure of the Forest is an elongated semidome with its major axis directed N.W. and S.E.; round this the chief beds can be followed and mapped. This simple structure is, however, much complicated by faulting, which follows on the whole the lines established by mapping and mining in the

Leicester Coalfield. The main set of faults course N.W. and S.E. and the most important of them is the well-known anticlinal fault, extending from near Charley Knoll, through Bawdon Castle, Benscliffe, and near Warren Hill (W.) into Hallgate Hill spinney. East and west of this are other thrust-faults which repeat the beds, showing that the flanks of the arch have been thrust over its keystone. One of the faults following this course from north of Woodhouse Eaves and through the Brand, is a normal fault, concealing some of the higher beds in the Maplewell series. The cross faults run N.E. to S.W., or E.N.E. to W.S.W.; the chief of them skirts the north side of Bardon Hill; a smaller one occurs south of Birch Hill and appears to run out north of Woodhouse Eaves; and a third forms the southern margin of Peldar Tor.

The principal beds, especially Cc, Cb, Bc, and Ba can be traced from their first entry into the area, between Whittle Hill and the Hanging Rocks near Woodhouse Eaves, round the southern side of the anticline to Timberwood Hill and Warren Hill (W.), where their individuality becomes lost. Their outcrop is frequently shifted by faulting, and the beds are often lost sight of altogether on account of faulting or the overspread of Trias, but, where one bed is lost, another one near to it can usually be followed. The structure sketched out in the foregoing paragraph seems to be that which best explains the position, dip, and strike of the exposed rocks, and it is confirmed by an attentive study of the local succession which may here and there be obtained among the crags and scarps.

SUB-DIVISIONS.

The Blackbrook Series.—It has not been found possible to subdivide this series, partly on account of the paucity of exposures, and partly because of the monotony in type of the rocks. Immediately under the Felsitic Agglomerate of Whittle Hill come some exceedingly fine-grained, hard, tuffs, which are quarried as the far-famed Charley Forest "Hone-stones." Under it there is a thick set of fine buff or green ashes, often beautifully banded, fine-grained and flinty, so that they have almost the aspect of felsites, and were considered to be quartzites by Jukes. One coarse band of conglomeratic grit is traceable for some miles in the sheet north of 155, but it is only seen in this sheet near the farm called Rock Villa. The joints in the rocks of this series are generally stained red with oxide of iron, and some bands contain well-developed cubes of hæmatite, pseudomorphous after pyrites.

The Maplewell Series.—These rocks are best seen extending from about Beacon Hill, through the grounds of Maplewell Hall, and thence to Bradgate Park. They admit of the following subdivisions.

The Felsitic Agglomerate.—At Whittle Hill a coarse agglomerate is found below the Beacon Hill Hornstones, which contains fragments of felsite as well as andesite, and but very few or no slate fragments. This we have called the Felsitic Agglomerate. Probably owing to faulting it is soon lost, but fragments of it are abundant all about Black Hill, and it probably occurs *in situ* in a spinney near the road just a quarter of a mile west of Bawdon Castle. It is caught in the anticlinal fault in Green Hill and Benscliffe Wood, and shattered to pieces in bending round the curve of the dome. It is found also near Chitterman Hills, and probably runs through Irish Farm towards Abbot's Oak. Faulted back from this point, it appears in force on the east margin of Timberwood Hill, and from thence it is traceable through Collier Hill to the margin of the map on Flat Hill. A peculiar character of the rock is that wherever it is exposed it has an exceedingly rough surface, which, however, is not due to the picking out of the fragmental constituents of the rock ; indeed, its fragmental nature is best seen on a freshly fractured surface. It is generally jointed at right angles to the bedding and breaks up into pillar-like masses. This rock forms a convenient base to the Maplewell Series.

The Beacon Hill Hornstones are fine green or cream-coloured ashes with occasional grit-bands a few feet thick, generally quartzose and epidotic. They give rise to very characteristic exposures on Beacon Hill and to the northward, and they may be traced round at intervals to Ulverscroft. They are not well exposed on the south-west side of the Forest, and when traced to the north-west and beyond the Bardon Hill fault they appear to pass into a great series of coarse breccias and volcanic agglomerates, in which it is not possible to trace out a sequence in consequence of the absence of all bedding below the higher hornstones and breccias of Warren Hill (W.). These rocks, however, appear to be the equivalent in time of the Beacon Hill Series, but they must have been deposited quite close to the volcanic vent, while only the finer materials drifted on the wind so far away from the vent as the eastern and southern sides of the Forest. If the correlation of the rock on the south of the great quarry on Bardon Hill with the Slate-Agglomerate is correct, the mass of rocks in the Hill, so largely quarried for road-metal, must also be the equivalent of the Beacon Hill Hornstones and of the great agglomerates of Charnwood Lodge and the rest of the district between Timberwood Hill and Warren Hill (W.). The Bardon Hill rocks appear to be in the main of clastic origin as, even in those varieties which are most like lavas or intrusive rocks, bombs or angular fragments can usually be detected: the only exception known to me is the "porphyroid" of the north flank of the Hill and quarries. It is possible that some lavas or intrusive rocks may occur here, but it has not been found possible to separate or recognise them, with the exception of the porphyroid just mentioned.

The Slate-Agglomerate.—Underlying the last division there is a marked band of volcanic agglomerate, named by Messrs. Bonney and Hill the Slate-Agglomerate, because of the abundance of slate fragments which are mixed with lapilli of andesitic rocks, and with broken felspar and quartz crystals. Some of the slate fragments seen in Bradgate Park and Warren Hill (E.) are from four to six feet long, and they are often folded. This band is traceable at intervals from the foot of the Hanging Rocks through the Brand, Roecliffe, Bradgate Park, the "Altar Stones" at Markfield, the Hollies, probably to Bardon Hill and the western flank of Warren Hill (W.).*

The Woodhouse Beds consist of alternations of coarse and fine volcanic ashes, the former giving rise to grits, highly felspathic and often quartzose, the latter to fine, banded, green, siliceous hornstones generally weathering to a cream colour. They are well exposed in the grounds of the Hanging Rocks north of Woodhouse Eaves,† and after sweeping through Bradgate and the country near Markfield they are well exposed in the crags above Rice Rocks Farm.

The Olive Hornstones of Bradgate.—The highest rocks of the Maplewell series occur in force in Bradgate Park, whence they extend into the area of the adjoining map to the east. They are fine olive-green hornstones devoid of coarser seams, but ashy in composition, and more or less fissile or slaty. They appear to be faulted out of the eastern side of the district from Woodhouse Eaves to Roecliffe and the Brand. It is likely that these rocks are several times seen on the west side of the Forest as in the old quarry below Rice Rocks Farm.

The Brand Series consists largely of rocks deposited under water, the materials being chiefly terrigenous, and derived from the denudation of sedimentary and volcanic rocks, but volcanic intercalations are not at all frequent.

The Purple and Green Striped Slaty Beds are only recognised in a few localities such as Woodhouse Eaves and the Brand, and they are mapped with the Maplewell Series, the conglomerate being used as the most convenient base for mapping the Brand series.

The Conglomerate and Quartzite division is well seen in the Hanging Rocks, the grounds of the Brand, and the N.E. entrance of Bradgate Park. The conglomerate occurs in beds from a few inches to a couple of feet thick; the pebbles may be three or four inches long, but they are usually smaller, and they are made of quartzite, vein-quartz, and slaty rocks; the whole rock is much crushed and cleaved, the long axes of the pebbles being often parallel to the cleavage planes. Above the conglomerate there is usually a thick band of purplish black grit, very rough to the touch and easily recognised. Some bands of this are highly quartzose, and pass into quartzite at Woodhouse Eaves and the Brand. The quartzite gains in strength and importance in Bradgate Park, Lady Hay Wood, and in New Plantation, about a quarter-mile W. of Bradgate House.

The Swithland Slates are purple or green in colour, often satiny and glossy, but the cleavage is somewhat coarse, and the slates, which were at one time much worked for roofing and slabs, are thick and heavy but very durable. The chief quarries were at Woodhouse Eaves, The Brand, Swithland Wood, and the

* *See* Plate II. † *See* Frontispiece.

country between Groby and Markfield; similar slates were also worked near Bardon Lodge.

FOSSILS.

The only fossils hitherto collected from the area are some worm burrows, the first of which were found by Professor Lapworth in beds on about the horizon of the quartzite or lower slates of the Brand Series in Bradgate Park. Mr. Rhodes has subsequently found other specimens in the same locality.

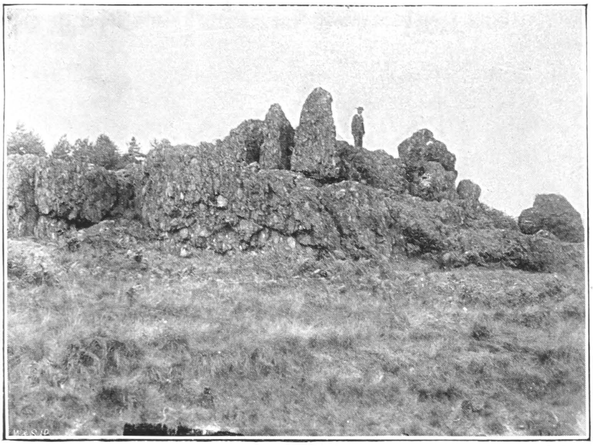
INTRUSIVE ROCKS.

Three or four types of intrusive rocks are met with in the part of Charnwood Forest included in this sheet.

Porphyroids.—These rocks occur in their most typical aspect at Peldar Tor and Spring Hill, and on the northern flank of Bardon Hill. The dominant type of rock is a porphyritic quartz-andesite or dacite, with large crystals of quartz and plagioclase in a fine-grained matrix. Its relationship to the other rocks in the Peldar area is not clear, but the difficulties which surround its method of occurrence would probably be best explained by supposing it to be intrusive. Messrs. Bonney and Hill regard it as a contemporaneous set of lavas. Whatever may be the relations of the rock of Peldar Tor, the precisely similar rock on Bardon Hill is undoubtedly intrusive, as its junctions with the compact agglomerate of Bardon are exposed along the north side of the great quarries. The junction is irregular, the rock has a chilled margin, it has reddened and altered the Bardon rock in contact with it, and it includes pieces of that rock. A close-grained felsitic rock, much crushed, is found on the Warren Hill Moorland, just south of Charnwood Forest Farm. A porphyroid without quartz, but with porphyritic felspar, occurs at Birch Hill; and another near Alderman's Haw, and at one or two other localities quite near to it on the north flank of Beacon Hill. These rocks appear also to be intrusive, though certain proof of this relationship is wanting. All the porphyroids are crushed and sheared by the main N.W. and S.E. movements, and they were intruded before this movement began. Fragments undistinguishable from some of the varieties of the porphyroids are to be found in many of the agglomerates of the north-west region.

Augite-Syenite.—Another important group of intrusive rocks are augitic granophyres or augite-syenites. They are generally found along the N.W. and S.E. fault planes as at Bawdon Castle and Hammercliffe, or else swelling out into large kernel-like masses such as those of Newtown Linford and Bradgate Park, Groby, Bradgate Woods, Markfield, Cliffe Hill, and Stanton-under-Bardon. The rocks are much altered and full of epidote, but they appear to have originally contained hornblende, augite, orthoclase, and plagioclase, embedded in a granophyric ground-mass. They consolidated under plutonic conditions and appear to bear no direct relationship to the porphyroids or the con-

PLATE II.



Volcanic agglomerate in Charnwood Forest. The large bombs have been turned on end or squeezed flat by the pressure which has cleaved the rock.

From "Geology for Beginners," by W. W. Watts (Macmillan & Co.), 1898, Fig. 104, p. 153.

Section in Charnwood Forest; showing unconformable junction of Triassic marl (*f*), resting in an old valley excavated through the ancient (pre-Cambrian) slates (*x*).

From "Geology for Beginners," Fig. 155, p. 222.

3288.
(*To face page* 9)

stituents of the agglomerates. The southern group of syenites is somewhat more acid than the northern, and the rocks bear evidence of having suffered from earth-movement, so that the thinner masses are much crushed. The northern group is more basic, darker, denser, and harder, and as it came up along the fault-planes it is later in date and is not affected by the movement; indeed it has come up along the fault-planes developed in the later stages of the movement. Similar syenites emerge from beneath the Trias at Enderby, Croft, and elsewhere to the south, and near the former place they are in contact with slates of Charnwood type. These rocks are much quarried everywhere for paving setts and road metal. They must be distinguished from the diorites or camptonites of the Warwickshire district, with which they have little or nothing in common.

AGE AND CORRELATION.

The Charnwood rocks are not at all like the Cambrian rocks of the Nuneaton district, nor are they like the felspathic tuffs and breccias which underly them. It is useless to parallel them with anything more recent than the Cambrian System and they are not like the Uriconian or Torridonian rocks, unless we except the grits and conglomerate of the Brand series, which have some resemblance to the Torridonian rocks. On the other hand, they have nothing in common with the gneisses and schists of the North-west or Central Highlands of Scotland. Many of the individual bands are like those of the Longmynd, in Shropshire, and, indeed, if we could imagine the pyroclastic materials from the Charnwood volcano dropped far from the vent and sorted and stratified in water, they would be likely to produce a group of rocks much like those of the Longmynd. It is impossible at present to push the comparison further, and meanwhile it may be better to be content with naming the whole group the *Charnian System*, and to refer it to some unascertained position in the great pre-Cambrian sequence.

RELATIONSHIP TO THE TRIAS.

In the sheet under consideration the Keuper Marl is the only newer rock found in contact with the ancient rocks of the forest. The unconformable junction is seen at several places. At Bardon Hill and elsewhere, the ancient rocks plunge down with a steep slope under the marl. A small breccia fringe is sometimes seen at the junction, but it never extends far from the old rock; some of the bands of skerry are made up of Charnian débris. At Bardon Hill, in the slate quarry at the south end of the Hanging Rocks, and in the slate quarry in Swithland Wood, near the Brand, the marl is found filling up old valleys in the slates or agglomerates. One of the junctions is shown in the annexed figure.*

* *See* Plate II.

LANDSCAPE.

The earth-movement which folded, faulted, and cleaved the rocks of Charnwood Forest, and guided the intrusion of igneous rocks into them, appears to have been of pre-Cambrian date, as no such effects are produced in the neighbouring Cambrian rocks of Nuneaton. After this mountain-making movement, which in places has converted the porphyroids into augen-chlorite-schists, the region was subjected to marine and sub-aerial denudation, possibly several times before the Carboniferous Period. During Carboniferous Limestone times some submergence and deposition took place on the northern skirts of the Forest, but it was not until Triassic times that the whole of the old mountain chain was completely enveloped in sediment. It is quite possible that the very highest summits were not even then covered. But the finishing touches to the landscape forms of the rocks were executed in Triassic times, and as the majority of the rocks are only just now being uncovered they still present a scarcely altered Triassic landscape. To this day many of the summits are as rugged and precipitous as when they were mountain-tops overlooking a Triassic desert or just submerged beneath the waters of a Triassic lake.

W. W. W.

CHAPTER III.

CAMBRIAN.

Besides the great mass of strata which form the Charnwood Hills, there is another small area of old rocks, which just comes into the map to the south of Atherstone. This is the northern extremity of the outcrop that extends along the hill from Bedworth, south of Nuneaton, to Waste Hill, beyond Atherstone, a distance of nine or ten miles.

These beds, known as the Stockingford Shales*, were originally mapped as Carboniferous, having been supposed to represent the lower or unproductive part of the Coal-measures; but in 1882 Prof. Lapworth brought forward convincing proof that they must be of Cambrian age.† The history of this error, how it arose, and the views entertained by authors at different times, has been clearly given by Mr. Strahan in his account of these rocks,‡ so that we need not pursue the subject further here.

The Cambrian rocks of this district consist of red, purple, olive-green, and grey shales, with a few dark carbonaceous bands; and, allowing an average dip of a little over 20°, have a thickness of about 2,000 feet. They are separable into two main subdivisions: a lower series of purple, green, and grey shales, with many small Brachiopoda of the genera *Lingulella* and *Obolella*, and an upper series of grey shales, with black bands, containing *Agnostus* and *Olenus*. These shales are well laminated, but not in the least cleaved, and dip to the south-west at angles varying from 15° to 35°. They are traversed by numerous parallel dykes of diorite,§ which give rise to the broken, undulating ground south of Atherstone, forming some of the prettiest scenery in the map.

These sheets of igneous rock, although they are really intrusive, follow the line of strike so closely that at first sight they appear to be interbedded with the shales. That they are intrusive, however, may be seen by the baked nature of the shales near the line of contact, and more clearly in the quarry south of Merevale Church, where the shales are dipping 15° to the south-west, while the igneous rock inclines at an angle of 35° in the same direction.

---

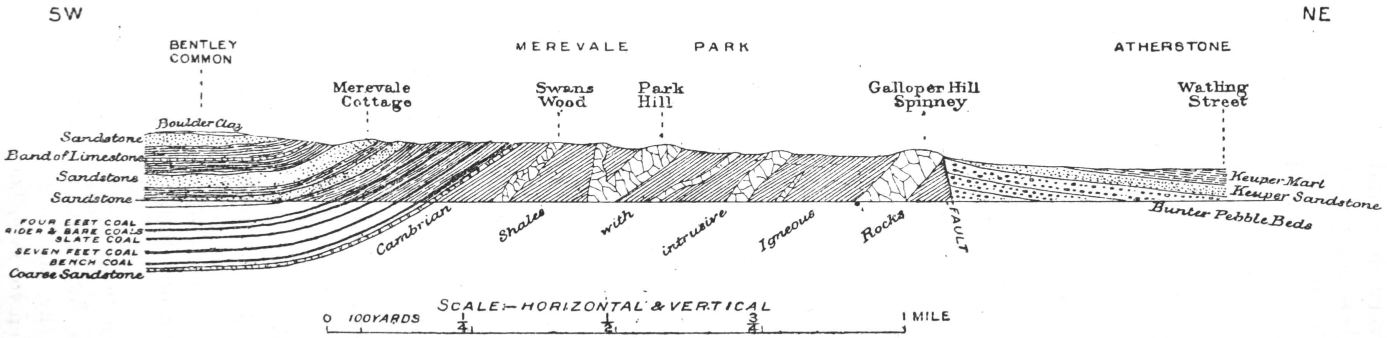
* This name was first suggested by Mr. W. Jerome Harrison, from the locality where these beds are best shown.

† Geol. Mag. dec. ii., vol. ix., p. 563, 1882; and dec. iii., vol. iii., p. 319, 1886. There is also a full account of these rocks by Prof. Lapworth, with an appendix by W. W. Watts in Proc. Geol. Assoc. for August, 1898, vol. xv., part ix.

‡ Brit. Assoc. Rep. for 1886, Trans. of sections, p. 624; and Geol. Mag. dec. iii., vol. iii., p. 540, 1886.

§ For description of this rock see Allport, Quart. Journ. Geol. Soc., vol. xxxv., p. 637, 1879.

FIG. 1. Section across the northern edge of the Warwickshire Coalfield



The outcrop of the Stockingford shales is, from the absence of Drift, generally very clear, and may be followed without much difficulty. The best sections, are, however, just beyond the edge of the map at the quarry below Oldbury Reservoir, and in the lane and new drive at Purley Park.

Professor Lapworth has separated these shales into three series. The Lower, or Purley Shales, formed of brightly coloured *purple* mudstones and shales, occur along the lower part of the Outwoods; the Middle or Oldbury Shales, formed essentially of *black* shales, enter the map in Merevale Park; and the Upper or Merevale Shales, formed of *grey* shales, are found near the road south of Merevale Abbey.*

The sheets of igneous rock vary from dykes, having a thickness of 200 yards or so, to mere strings of rock which cannot be traced. They obtain their greatest development in Merevale Park, in the thick mass immediately south of the hall; but the outcrop is not so extensive, and is more split up into thin sheets and strings, than shown in the old map. It is not, however, easy to follow the outcrop of these thin beds in the woods south of the park.

The composition of the diorite (camptonite) has been so ably described by Allport,† Teall,‡ and Watts,§ that it is needless to give a detailed description of it here. The predominant and characteristic constituents are a triclinic felspar and hornblende, together with a little magnetite and apatite; a glassy or felspathic matrix is also nearly always present.

The following fossils have been obtained from the shales:—

LIST OF FOSSILS FROM THE STOCKINGFORD SHALES.

Sponges.

Hyalostelia [=Pyritonema].
Protospongia fenestrata, *Salt.*

Crustacea.

Agnostus cf. cyclopyge, *Tullberg*
,, pisiformis, var. socialis, *Linrs.*
Beyrichia Angelini, *Barr.*
,, cf. nana, *Brög.*
Conocoryphe ? coronata, *Barr.*
Ctenopyge pecten, *Salt.*
Leperditia cf. primordialis, *Linrs.*
Olenus nuneatonensis, *Sharman*
,, cf. Salteri, *Call.*
Sphaerophthalmus alatus, *Boeck.*

---

* Proc. Geol. Assoc., vol. xv., p. 345.

† Quart. Journ. Geol. Soc., vol. xxxv., p. 637.

‡ British Petrography, pp. 133, 251, and Plate xxix.

§ Proc. Geol. Assoc., vol. xv., p. 394.

‖ This includes all the species given by Prof. Lapworth in his amended List (Proc. Geol. Assoc., vol. xv., p. 348, 1897), where details of the localities will be found.

Bryozoa.

Dictyonema sociale, *Salt.*

Brachiopoda.

Acrothele granulata, *Linrs.* [=Obolella granulata, *Sharman*]
Acrothele cf. A. intermedia, *Linrs.*
„ sp. cf. Kutorgina ? pusilla, *Linrs.*
Acrotreta sp. [=Obolella Sabrinæ ? *Sharman*]
Kutorgina cingulata, *Billings*
„ labradorica, *Billings*
Lingula sp. [=L. lepis ? Lingulella Nicholsoni, and L. pygmæa of earlier lists].
Obolella cf. sagittalis, *Salt.*
„ Salteri, *Holl.*
Orthisina cf. transversa, *Wahl.*

Mollusca.

Coleoloides typicalis, *Walcott*
Hyolithus cf. lenticularis, *Holm*
„ „ obscurus, *Holm*
„ „ princeps, *Billings*
„ „ tenuistriata, *Linrs.*
Orthotheca communis, *Billings*
„ corneola ? *Holm*
„ de Geeri, *Holm*
„ Johnstrupi, *Holm*
„ cf. teretiuscula, *Linrs.*
Stenotheca rugosa, *Walcott*
„ var. abrupta, *Walcott*
Scenella sp.

CHAPTER IV.

CARBONIFEROUS.

Coal Measures.

THE NORTHERN OUTCROP OF THE WARWICKSHIRE COALFIELD.

The Coal-measures which outcrop in this map form two separate districts, one comprising a portion of the northern part of the Warwickshire coalfield, the other the southern part of the Leicestershire and South Derbyshire coalfield. These will be described at greater length, when the whole ground has been surveyed, in special memoirs treating of these two coalfields respectively, so that in the present case we propose merely to give an outline of the structure of as much of the ground as falls within the limits of this map.

Whether these two coalfields are connected beneath the overlying Trias is at present scarcely decided, but the evidence, as far as it goes, is against the supposition that such is the case, or that coal will be found over much of the intervening ground.

That portion of the Warwickshire Coal-measures with which we have to deal is the eastern side of the northern half of the coalfield, and includes an area of about seven square miles in the south-west corner of the map. It contains at the present time four working collieries, which have afforded six or seven sections of strata and other information, that has enabled the general structure of the ground to be made out with greater accuracy than was possible when the old survey was undertaken.

These measures, which have a thickness of about 1,000 feet, consist of an alternating series of sandstones and shales, with several beds of ironstone and seams of coal and fireclay, and near the top one or two beds of limestone. At the base there is a bed of coarse false-bedded ferruginous sandstone, with quartz pebbles, which rests unconformably on the Stockingford shales.

This sandstone, which was first pointed out by Mr. Strahan, is of a buff or yellow colour, and so soft as to be readily used as a building sand. It is of great assistance in tracing the junction between the Cambrian and Carboniferous formations across the country, the white quartz pebbles being very conspicuous, and at once arresting the attention where this junction might be overlooked. This rock is best seen along the lane and in some old quarries on the east side of the Monk's Park Wood, where the unconformity is very marked, the sandstone, which is nearly flat resting on the Cambrian shales, dipping at an angle of 38°. It may be followed across the wood to the north side, where there is a small quarry in it. After crossing Merevale Park it makes a good feature as far as Waste Hill, where it comes against the boundary fault, but appears to be continued as a less coarse, but thicker, sandstone nearly as far as Suckle Green.

The Coal-measures lie in a flattish synclinal trough or basin, having its longer axis in a north and south direction, which turns up rather rapidly as it approaches the western, northern, and eastern margins. It was formerly supposed that, in the extreme northern part of the coalfield, about Shuttington, the workable seams of coal would be found at some considerable depth; recent workings, however, at Tamworth Colliery have shown that this is not the case, but that the beds turn up somewhat rapidly as they approach the large boundary fault, the Seven-feet coal not being more than 70 yards deep on the north side of the road to Polesworth, while it is 170 yards deep at the Colliery. The southerly dip seen in the lane to Shuttington also shows that the beds are rising towards the village.

The thicker seams of coal are all in the lower part of the series, and comprise about a dozen seams that have received names, besides several thinner beds of coal. Since the number of pit sections has been increased it has become easier to correlate the various seams than was formerly the case; but it is still probable that some of them which have received distinct names at different collieries are really the same beds.

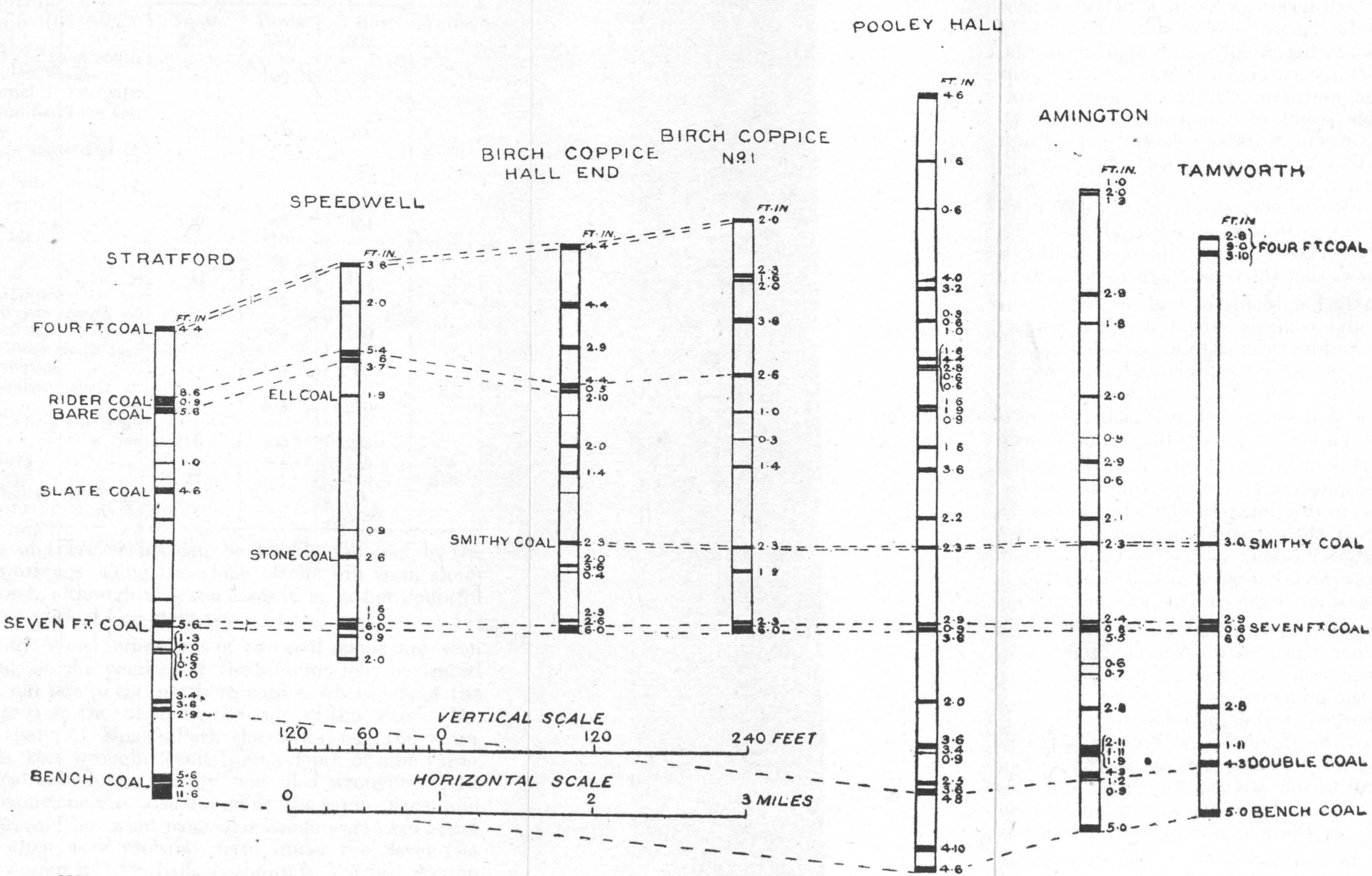
Mr. Howell, in his description of this coalfield, gives a comparative section showing the splitting up of the coalseams and the increase in the thickness of the measures between Hawkesbury Colliery in the extreme south of the coalfield and Stratford Pit on Baxterley Common in this map.* The same thickening of the measures takes place, although in a less degree, further to the north-west, as is shown by the accompanying section.

The principal seams in this part of the coalfield are the Four-feet, Rider, Bare, Slate, Seven-feet, and Bench, all of which have in old times been worked either in shallow pits or at the outcrop; but at the present time the Seven-feet coal is the seam principally worked at the collieries. The Bench coal is said to be inferior throughout the greater part of the district. The fireclays associated with these coals are not used at any of the pits in the map, but further west at Amington and Glascote the clay under the Seven-feet coal is mixed with another clay, and used for fire-bricks. At Dordon clays higher in the series are used.

It is in the measures immediately above the Four-feet coal that the principal beds of sandstone are met with. They consist of irregular masses which as a whole can be readily traced across the country, although the separate beds frequently thin out in short distances. They form the abrupt edge that runs from Merevale to Polesworth, and along which they have been quarried at a few places.

* Memoirs of the Geological Survey. The Warwickshire Coalfield, p. 10.

Fig. 2. Comparative Section of Coal Seams in the extreme north of the Warwickshire Coalfield.



3288.

[To face page 16]

The following depths of the Coal at the different pits throughout the district will help to show the general position of the seams :—

	Four-feet Coal.	Rider Coal.	Seven-feet Coal.	Bench Coal.
	Yards.	Yards.	Yards.	Yards.
Stratford Pit - - - - -	231	250	308	
Waste Lane, 200 yds. from south corner of Grendon Wood - -	–	90 (?)		
Baddesley Common, 150 yds. south-east of the Red Lion Inn	50			
Baddesley Church - - -	60 (?)			
Well just outside north end of Grendon Wood - - -	—	—	40	
Old shaft, 400 yds. west of Church - - - - - -	—	--	200	
Speedwell Pit - - - -	140	163	234	
Old Grave Yard Pit - - -	--	110		
Snibson's Wood - - - - -	—	30		
White House - - - -	60	—	170	
Bassett's Bridge, Polesworth -	—	—	110	170
Butt Lane, 450 yds. south of Polesworth Station - - -	—	—	100	
Pit at side of railway south-east of Polesworth Station - -	--	—	60	
Birch Coppice Colliery (shaft at Hall End) - - - - -	173	209	270	
Birch Coppice Colliery (shaft at Birch Moor) - - - - -	159	200	265	
Pooley Hall Colliery - - -	—	—	155	185
Tamworth Colliery - - -	71	·	170	218
1,000 yds. north-east of Tamworth Colliery - - -	—	—	65–80	

The outcrop of these seams can be readily followed by the lines of old workings along the slope of the hill from Merevale to Polesworth, although in some cases it is rather doubtful what seams were worked in certain pits.

In Monk's Park Wood indications of two coal seams are seen in the stream at the old ponds, and the outcrop may be traced by the lines of old pits to the northern corner, where one of the upper beds is seen in the ditch by the side of the wood. Mr. Howell states that "At Monk's Park the Seven-feet, the Slate, and Rider coals were wrought formerly to a depth of nine yards, and another coal called the 'Smithy' was also wrought to the same depth. Ironstone was also raised at the same place, and smelted by charcoal; but what particular bands were used is not stated, though they were probably from under the Seven-feet coal, where they occur in large balls, as shown in Vertical Section No. 6, Sheet 21."* The slag heaps from these old furnaces may be seen near where the old ponds were in the lower part of the wood.

In the road on the north side of the wood there are several indications of coal, and also across Merevale, one or other of the seams being seen in several places. At Colliery Farm the workings

* *Loc. cit.* p. 17.

to the Seven-feet coal are very apparent, as well as those to some of the higher beds. In Grendon Wood there are a large number of old pits, especially to the Seven-feet coal; but the outcrop of the higher beds, which leaves the wood and crosses the northern side of the village of Baddesley Ensor, is not quite so clear. North of this the Seven-feet and Bench coals outcrop in Baddesley Wood; and there are indications of the higher beds in the fields above and about Snibson's Cottage. In the valley of the Penmire Brook there is an east and west fault running nearly along the line of the Watling Street, which has been proved in the Birch Coppice Colliery to have a downthrow to the north of twenty-five yards. This fault must shift the outcrop of the coal seams somewhat to the east, but on account of the high westerly dip its effect is not very marked. In Birch Coppice old coal pits are again very frequent, but to which seams some of them were sunk is not very clear. North of this wood the double seam, known as the Rider and Bare coal, is stated by Mr. Howell to die out. He says, "As the workings here have been some time abandoned I could not obtain any very accurate information as to the exact point where the Rider and Bare coal disappeared, or the way in which this 'double coal' terminated; but as far as I could make out from the description given me of the last workings by Mr. Scarrot, of Polesworth, there was no large fault, using that term in its correct sense, but the place of the coal seems to have been taken by a bed of fireclay; and according to the accounts I obtained from the old miners, the coal terminates quite abruptly, the strata, however, not being shifted up or down. That it was not a *slip* fault was proved by the other coals, both above and below, being found to continue further north without any interruption."*

At Dordon Brickyard the following thin coals are seen:—

	ft.	in.
Sandstone	several feet.	
Dicey coal	1	4
Measures	20	0
Coal		10
Measures	4	0
Coal	4	0
Measures	2	0
Smut		
Measures	1	0

The beds dip at an angle of 15° to the west, but they are said to turn over and to be found again on the east side; so that it is probable that the thicker seam is the Four-feet coal, which outcrops a little lower down.

Between here and Polesworth nearly all the seams appear to have been worked at the outcrop, but there is not much evidence for identifying the different beds. In the railway cutting south of Polesworth Station two seams of coal 4ft. or more in thickness are to be seen. The identity of these coals is now much obscured, but probably was much clearer at the time the following statement was written:—"The Four-feet, Slate

---

* *Loc. cit.* p. 15.

and Seven-feet coals crop out in the railway cutting between Polesworth Station and the bridge, and the Bench coal on the south-east side of the bridge. The measures are much broken and disturbed where exposed in this cutting, and have a general dip to the west at an angle of 45° to 50°, and the unusually high angle at which the strata are inclined is accounted for by the close proximity of the boundary fault, which here runs along the east side of the railway." *

We feel rather sceptical as to the absence of the Rider coal and the great thickness (7ft. 3in.) given for the Slate coal about Polesworth. At Pooley Hall Colliery, which is only just on the other side of the river, the section of the different coal seams does not at all correspond with that of the old Polesworth Colliery.† We, therefore, cannot help thinking that in this latter pit the seams were wrongly identified. It is difficult to correlate the several seams in these two sections; but if the seam at the bottom of the old Polesworth shaft is taken as the Double Coal, the Slate Coal (7ft. 3in.) would be the Seven-feet Coal of other collieries; and the character of the intervening measures seems to correspond better on this hypothesis.

Again, it is very doubtful if the Rider Coal really dies out altogether, as stated by Mr. Howell. This coal is worked at Birch Coppice, and is 2ft. 6in. thick in the old shaft on Birch Moor, which is a good deal north of where it is said to die out. The measures in the colliery sections north of this have altered so much that at present it is impossible to correlate these thin seams; but probably there will be further evidence on this point when the rest of the coalfield is surveyed.

To the east of Polesworth and Dordon the Coal-measures roll over and dip to the east into the great boundary fault, so that the outcrop of the different seams is repeated along a strip of ground parallel with the fault between the Anker and the Penmire Brook. There are indications of the lowest of these seams in the lane 170 yards west of St. Helena, and in the ditch 250 yards south of that farm. Other seams are to be seen near St. Helena, in the lane 400 yards west of Dordon Hall, and in the fields near Hare Parlour. A five-feet seam of coal was met with in the well at St. Helena; and in the California Pit, which was about 200 yards to the north-east, a coal was reached at fifteen yards. There are also the remains of old coal workings at two or three different horizons in the eastern part of the Hollies. Mr. Howell, in writing of this part of the coalfield, says: "The coal has never been worked to any extent on this easterly dip, being much broken and faulted. Attempts were, however, made to work the Seven-feet coal by the side of the lane between Polesworth and Dordon, and the bed was followed in from the crop for a considerable distance, but was found to be so much

* *Loc. cit.* p. 13. The recent widening of the railway shows that the beds are very much disturbed here. Three coal seams crop out between the two bridges, and there are three thin coals a little east of this which may represent the Bench Coal.

† Hor. Sections, Sheet 21, No. 4.

shattered by small faults as to be altogether unprofitable. These faults were described to me by Mr. Scarrot, the manager of the colliery at Polesworth, as continually throwing down the coal to the east, sometimes many yards, and all running parallel with the boundary fault of the coalfield. It was in consequence of these numerous dislocations that the working of the coal was abandoned, as it was considered that they would most probably continue till the great boundary fault was reached, which would throw the coal down on the east to an unknown depth beneath the New Red Sandstone."*

In the upper part of the Coal-measures there are apparently two beds of limestone; we say apparently two beds, because from the outcrop it is not very clear whether this is the same bed repeated by a fault or roll of the strata, or whether there are really two distinct bands. At present no sinking has been made above the higher bed which would at once prove the case.† This limestone has a thickness of about three feet, and contains the small serpula *Spirorbis pusillus*, Mart. (*Sp. carbonarius*, Murch.); it varies in colour from buff or light grey to a dark slaty blue. It has only been seen *in situ* in the stream in Monks Park Wood; but it was met with in a well on Bentley Common, and in the Stratford Pit on Baxterley Common, at both of which places it was about a yard thick. Although it is not seen to the north of this its outcrop may be traced by the old workings to it north of Long Wood and Cowper's Grove. At the latter place the feature formed by the outcrop terminates abruptly, and there is not much evidence for it further in the same line of strike. Further south, however, at the base of the sandstone escarpment, the limestone appears to be again in force, having been worked in a line of pits between Ash Spinney and Lower Ridding. Fragments of the rock are again seen around the promontory at Baddesley as far as the plantation at the edge of the map, called the Dumbles, where there are old workings. At first we were inclined to think that the outcrop of limestone at Cowper's Grove was broken by a fault: but on further consideration it seems more probable that there are two bands of limestone along the foot of the escarpment between Baddesley and Baxterley.

* *Loc. cit.* p. 14.

† A pit has lately been sunk near Kingsbury Wood, on the other side of the Baddesley promontory, which reached a limestone conglomerate nine feet thick at about fifty yards below the outcrop of the limestone that has been mapped, but the Survey has not been carried far enough yet to show the connection between the two.

CHAPTER V.

CARBONIFEROUS—(*Continued*).

Coal Measures—(*Continued*).

THE SOUTHERN PART OF LEICESTERSHIRE COALFIELD.

The Leicestershire and South Derbyshire coalfield comprises an area of between seventy and eighty square miles, of which only the southern portion comes within the limits of this map.

This part of the coalfield is divisible into two areas: the Eastern or Coleorton coalfield, and the Western or Moira coalfield. These are separated from each other by an anticlinal arch of lower unproductive measures, containing only a few thin seams of coal, which rise up fiom below, and come to the surface near Normanton, Packington, and Ashby. One of these coal seams is seen in the railway cutting at Breach Hill: and there are indications of two or three other seams to the north of Normanton.

On the west side, close to the Boothorpe Fault, there are two or three seams seen in the railway cutting north of Wilkesley Wood, one of which is probably the representative of the Rafferee coal that crops out at Woodville, and will be further referred to in the description of that country.

These measures dip to the east on the east side of Ashby and Packington, and to the west on the west side of these places, which are nearly on the line of axis. Mr. Coleman states that their thickness is at least 1,000 feet, but what was the evidence upon which this statement was based we do not know.*

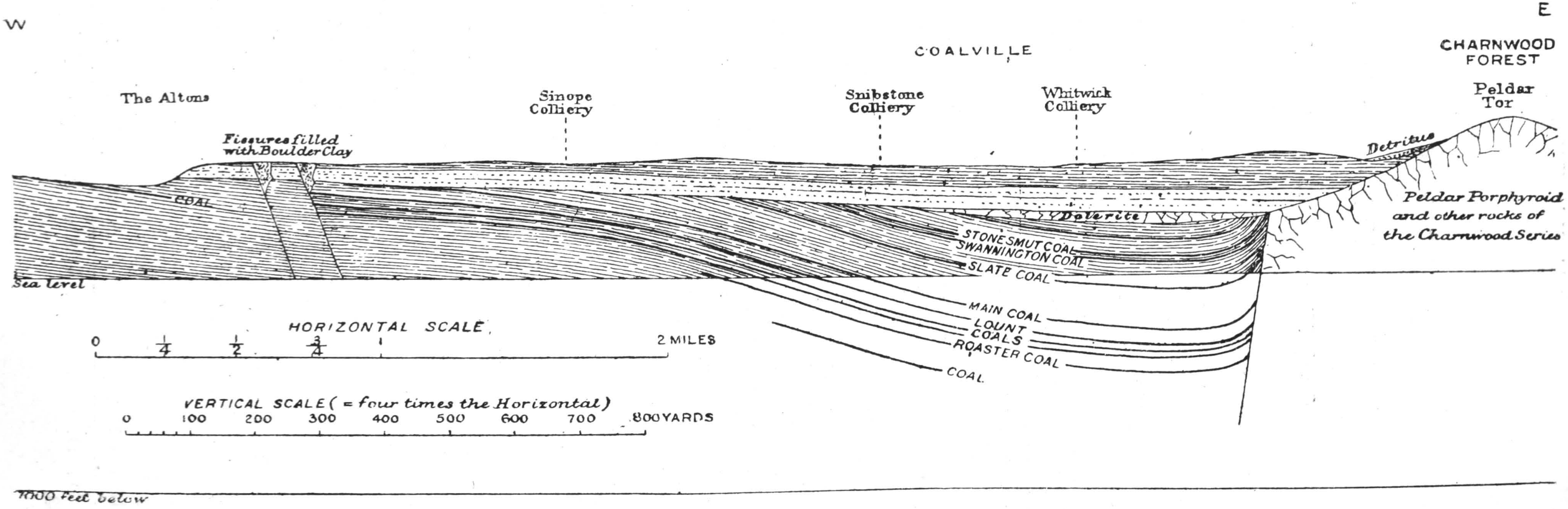
Coalville District.

The eastern or Coalville portion of the coalfield is almost entirely concealed by the overlying Triassic rocks, so that it is only over a small area at Heather and along the bank below Alton Grange that the Coal-measures come to the surface, and are shown by colour on the map. They have, however, been proved by collieries and borings to extend as far south as a line drawn from Heather to Desford, and may be found a little beyond this, but it is not likely that they extend very much further, as borings in the neighbourhood of Market Bosworth have proved the absence of Coal-measures: neither do they extend east of a line drawn from Whitwick through Thornton to near Desford.

This area is bounded on the west by the outcrop along the bank running from Alton Grange southwards, although beyond Normanton it is completely masked by the overlying Trias. On

* Rev. W. H. Coleman in White's History of Leicestershire. Ed. 2, p. 92, 1863.

FIG. 3. Diagram showing position of strata on the east side of the Ashby anticline.



the east the boundary is formed by the large fault which brings up the Charnwood rocks, and against which the Coal-measures turn up at a sharp angle. This fault has been proved in the Whitwick Colliery to run from the western side of the village of Whitwick to Broom Leys, and it is probably continued by Bardon Hill Station to Thornton and the eastern side of Desford.

This portion of the coalfield contains about eight workable seams of coal, varying in thickness from three to nine feet. Some of the higher seams have been worked at Bagworth, Ibstock, and elsewhere in old times; but the principal seams now used are the Upper Main or Coleorton Coal and the Lower Main or Roaster Coal.

The general dip of the beds is to the east at about 4°, they are therefore deepest about Ellistown and Bagworth, and crop out to the west beneath the New Red Sandstone; so that the higher seams, which occur in these shafts, are absent in those of Nailstone and Ibstock, while at Heather only the lowest seams are present.

Over the Coal-measures to the south of Whitwick there is a sheet of dolerite*, which has been ejected in a molten state from the line of the boundary fault, and run over them probably before the Triassic rocks were deposited, as where the rock is found in contact with the coal seams the latter are burnt to cinders, while the sandstone above does not appear to have been subjected to heat.

This rock is 81 feet thick in the eastern shaft (No. 6) of Whitwick Colliery, but thins out towards the north-west and south, being absent in the Snibston Pits (Nos. 2 and 3), as well as those at Ibstock, Nailstone, and Bagworth, but occurs at South Leicestershire and Ellistown. Its general extent and thickness may be gathered from the diagram given on the following page.

Moira District.

The western or Moira portion of the coalfield occupies a large part of the north-west quarter of the map. The Coal-measures over this area are much more exposed than in the Coalville district; and it is only along the western and southern portions that they are covered by Trias. The strata in general dip to the west, but along the western and southern margins they turn up, as well as to the north beyond the limits of the map; they therefore form an irregular basin, of which the deepest part is about Moira. On the east they are cut off by the great Boothorpe Fault, which brings up the unproductive measures of the Ashby district.

These Coal-measures have been proved to a depth of over 1,600 feet; they contain many valuable seams of coal, the details of which will be given in the special memoir on the coalfield. A general idea, however, of the seams and the thicknesses of the intervening measures may be gathered from the following table:—

* See S. Allport, Geol. Mag., vol. vii., pp. 159 and 435, 1870, and Quart. Journ. Geol. Soc., vol. xxx., p. 540, 1874; also J. J. H. Teall, British Petrography, p. 211, 1888.

Fig. 4. Plan of the East Leicestershire Coalfield, showing supposed extent of the Whinstone

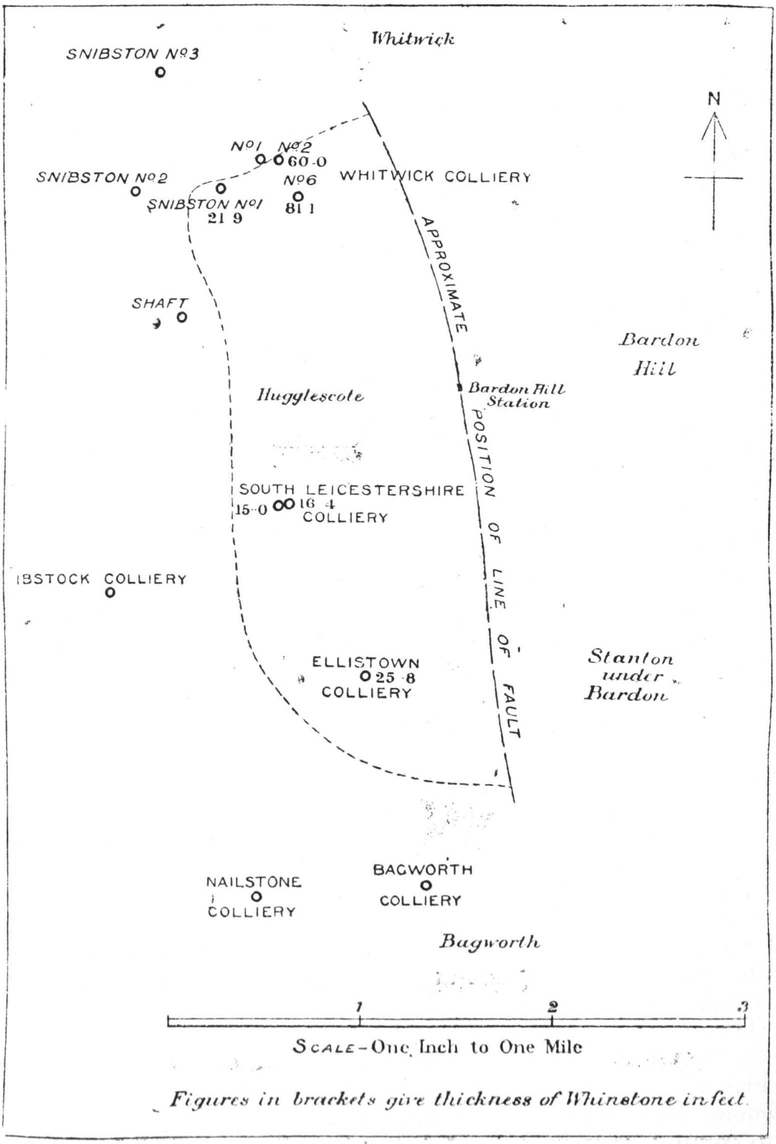
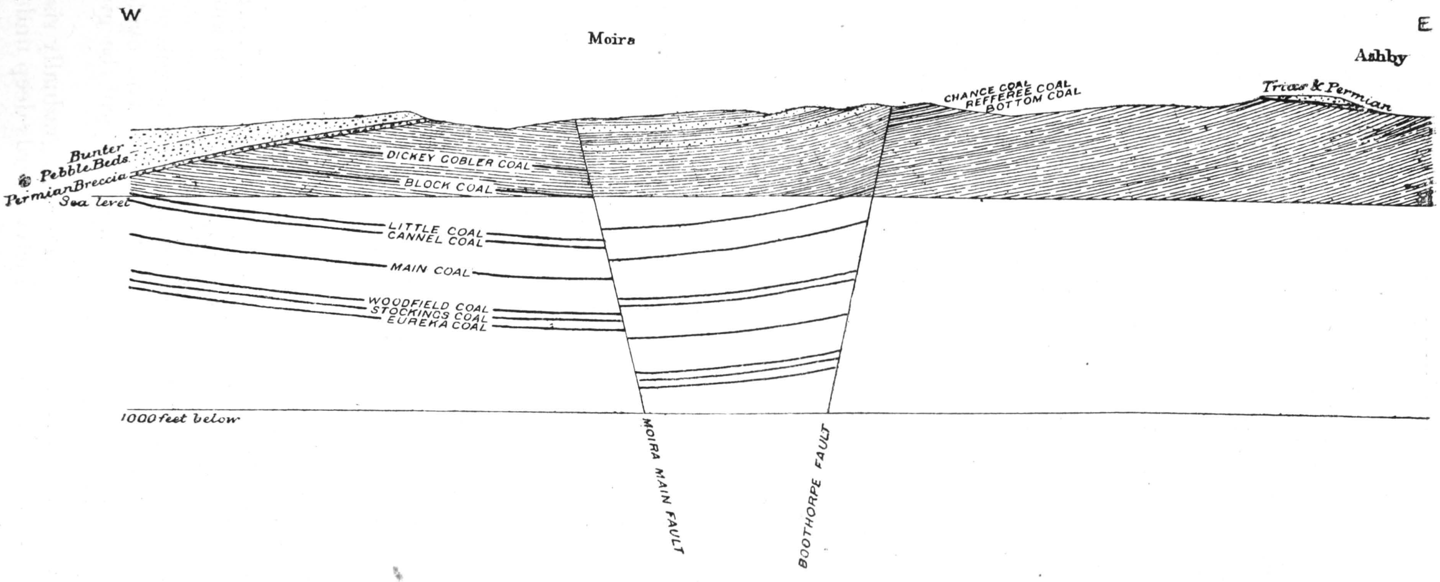


FIG. 5. Diagram showing position of strata on the west side of the Ashby anticline



Thickness of the Coal seams and intervening measures in the Moira District.

	Average thickness of Coal seams.	Thickness of intermediate measures.
	ft. in. ft. in.	Yards.
Ell Coal	3 11	
Measures		70 0 to 75 0
Dickey Gobbler Coal	3 0	
Measures		40 0 to 44 0
Jack Dennis Coal	3 8	
Measures		70 0 to 80 0
Little or Five-feet Coal	*4 6	
Measures		50 0 to 60 0
Main Coal - average	15 0	
Measures		10 0
Toad Coal	3 6 to 4 0	
Measures		20 0 to 23 0
Slate Coal	3 8 to 4 0	
Measures		18 0 to 20 0
Woodfield Coal	6 4	
Measures		15 0 to 21 0
Stockings Coal	8 4	
Measures		12 0 to 15 0
Eureka Coal	4 0 to 5 0	
Measures		30 ?
Stanhope Coal ?	4 7	
Measures		95 ?
Kilburn Coal ?	4 6	

* Four-feet Coal of Prof. Hull and his maps and sections.

The principal of these seams, and the one most generally worked is that known as the Moira Main Coal, which is wrought at every colliery in the district, and is now exhausted over a large area. Besides this seam the Five-feet or Little Coal, the Stockings and the Eureka are worked at some of the pits.

In the upper part of the measures are a series of valuable pot-clays, and one or more beds of fireclay, which have been worked in the neighbourhood of Woodville for a number of years for making sanitary pipes and other purposes. These are now being utilised in the Moira district, and the expansion in this trade has been so great that several new works have been established here during the last few years.

The Main Coal and some of the neighbouring seams outcrop to the north of Measham, but are thrown in again by a north-east and south-west fault, so that the Main seam is at a depth of 42 yards below the village. It will be noticed that the position of this fault is somewhat different from that shown on the old map. The reason for this alteration is that additional evidence has been obtained as to the position of the coal seams on the west side of the village, which shows that the run of this fault is rather different than formerly supposed. The evidence for the somewhat obscure mapping about here will be given in the general memoir on the coalfield.

South-east of Measham the measures gradually rise again, the Main coal being only about nineteen yards deep under Measham

Field, south of which it appears to be thrown out entirely. Higher seams of coal crop out in other parts of the district, but as they have not been considered worth working they are seldom exposed to view, and it is not possible to map them with any certainty. A coal about three feet thick, said to be the Dickey Gobbler, is seen in the railway cutting at Donisthorpe, and other seams are seen in the clay works about Moira, but they cannot be traced across country. In fact, it is so long ago that any coals have been worked near the surface, and all the men that worked at them being long since dead, that it is very difficult now to trace their outcrop, consequently the lines drawn for the coal crops near Measham have been mainly put in from information obtained during the old survey in 1854.

On the east these Coal-measures turn up very rapidly against the Boothorpe Fault, and a series of thickish sandstone beds crop out, which form a line of features that may be traced in a north-westerly direction from Willesley to Boothorpe. There are also indications of these same sandstones to the south of Willesley, but their outcrop is more obscure. There is no doubt that these beds are the same as the grit at Boothorpe. They are perfectly conformable to the Coal-measures, dipping beneath the upper part of that formation, and are not of Permian and Trias age, as was formerly supposed.

CHAPTER VI.

PERMIAN.

On the old survey of this district the Permian rocks are represented in two distinct areas—in Warwickshire and in Leicestershire. Later work in other districts, however, has thrown some doubt as to the Permian age of these Warwickshire rocks, and it is very probable that when a larger area of this county has been surveyed, they will be found to have more affinity with the Coal-measures. They outcrop in the south-west corner of the map, where they rest apparently almost conformably on the underlying Coal-measures; and form the northern part of the large patch, which has its southern termination in the neighbourhood of Warwick.

These beds were assigned by Prof. Ramsay to the Permian from their similarity to the beds of South Staffordshire*, which had been classed by Jukes as Permian. It has lately been shown, however, by Mr. Cantrill in South Staffordshire†, and by Mr. Gibson in North Staffordshire‡ that these beds are more nearly allied to the Coal-measures. If this is the case it is probable that the Warwickshire beds should also be classed with that formation. The small area of these beds that comes into this map has not furnished any evidence on the point; so that at present it must be left an open question, until the country to the south has been more thoroughly examined. In the explanation of this map it is, however, more convenient to include them under the Permian. They consist of thick beds of reddish sandstone separated by bands of purple marls and clays with here and there thin bands of limestone and calcareous breccia. Both the sandstones and the calcareous beds are very impersistent, and as a rule cannot be followed any great distance; although the former often form conspicuous features. The general dip of the beds is southerly at about 4°, but it frequently becomes more east or west over short distances. The thickest beds of sandstone are towards the base of the formation, and their outcrop forms the abrupt bank running from Bentley and Baxterley Commons westwards to beyond White's Farm, and

* Quart. Journ. Geol. Soc., vol. xi., p. 197, 1855. They had previously been assigned to the Bunter Sandstone. Trans. Geol. Soc., ser. 2, vol. v., p. 331.

† Quart. Journ. Geol. Soc., vol. li., p. 528, 1895.

‡ Summary of Progress of the Geological Survey for 1898, p. 123.

thence northwards to the western part of Baddesley Ensor; here the escarpment curves round, and continues westerly again for some distance. This sandstone has been quarried at numerous places along the escarpment, while some of the higher beds have been worked at Wickson Hill, near Baxterley Church, and elsewhere.

A thin band of limestone has been worked at Boultbee's Farm, but the outcrop does not appear to extend very far before passing into sandstone. It is possible that a good deal of the lime has been dissolved out of these beds, and that they would be found to be more calcareous at a greater depth. Calcareous beds are also seen near Lower Ridding, and in the stream below Hurley Hall.*

North of Polesworth these beds are thrown down by the great boundary fault, and crop out in the lower ground just north of the railway. Purple marls, sandstone, and breccia are exposed in the right bank of the river just east of the viaduct, and in the road a little further north. The marls appear to have been worked in old pits at the side of the footpath to Bramcote Hall and near Warton Barn; but the best exposure of the sandstone is in the quarry to the south-west of the Hall.

There are also smaller quarries on the other side of the stream; and a borehole at the Polesworth Waterworks, which are situated close to the stream, was sunk for fifty feet in sandstone. From these sections it is seen that the beds are dipping about 10° to the east, and consist of thick-bedded massive sandstones with a band of breccia in the upper part, over which there are fifty feet or more of marls before we come to the pebbly beds of the overlying Bunter.

At Bramcote these beds are cut off by a fault bringing in the Keuper sandstones, so that beds of Permian age do not appear again until we reach the margin of the Leicestershire coalfield in northern part of the map.

In this northern district these so-called Permian beds are found flanking the Coal-measures in a narrow and somewhat irregular band, and coming up through the Trias in one or two obscure inliers.

The character of the rock is very different from what it was in the south. Instead of the thick sandstones and marly bands with their intercalated calcareous beds, the rock is here mainly composed of coarse angular breccia with little marl or sandstone. These breccias, according to Mr. Horace Brown, who has made very complete analyses of the rock,† are composed mainly of fragments derived from the old Palæozoic rocks, consisting of felspathic grits and quartzites, together with slates and igneous rocks, but comparatively few carboniferous fragments. The rock from its deep purple colour, and the subangular character of the included fragments, is, when the beds are thick enough, not

* These places are just beyond the south edge of the map.

† Quart. Journ. Geol. Soc., vol. xlv., p. 24, 1889.

difficult to recognise, or to trace across the country. At the south end of the coalfield, however, these breccias appear to be thinning out, and are probably near their original limit; so that in many cases the outcrop is obscure.

Commencing on the east side, the first indications of these breccias are two small patches below Normanton. Whether the outcrop here is larger than represented we cannot say; the rock is only seen in ditch sections, and appears to have been previously overlooked. From this point it has not been observed until we reach Packington, a mile further north, where there are several sections of the breccia, in the roads near the Inn, in the stream to the south-east, in the quarry on the north side of the village, and in the conduit 350 yards north of this. Beyond this the outcrop is obscure, but may be followed on the other side of the Ashby stream as far as the north end of Willesley Park. Here the outcrop turns round to the south, and forms a fairly conspicuous feature throughout the whole length of the Park; until at the south end it either passes underneath the Trias, or is cut off by the Boothorpe Fault, which occurs is not very clear.

From this point the rock has not been observed until we get to Measham, a distance of a mile. Here it forms a considerable spread over Measham Field; but there are no sections, and the rock can only be traced from the fragments in the fields, although it has been proved in the several coalpits and borings over this ground, which show that its thickness here varies from 25 to nearly 50 feet.*

At Measham 18 yards of this rock have been proved in a well, and there is a good section of the breccia in an old quarry at the side of the Canal on the west side of the village. In an old brickyard behind the church marls have been worked, which we have classed with the Trias, but their age is somewhat doubtful. Mr. H. T. Brown gives the following section in a well at this place†:—

Well at Measham, 320 *yards east of the Church.*

	Feet.
Red clay - - - - - - - - -	9
Sandstone - - - - - - - - -	4
Clay parting - - - - - - - - -	a few inches
Breccia - - - - - - - - - -	3
Red marl, with brecciated fragments - - -	18
Blue Coal-measure clay.	

Mr. Brown calls the sandstone Lower Keuper, but there is no reason why it should not be of Permian age.

Between here and Oakthorpe the outcrop is rather uncertain, but a good deal of light has lately been thrown on the structure of this district by the borings and shafts put down by Mr. S. H. Leech for the Measham Terra Cotta Works, who has found the breccia and marl to have a thickness of 27 feet or more. From these shafts, which are between 600 and 700 yards west of the north end of Measham, the breccia may be traced by the nature

* These sections will be given in the general memoir on the coalfield.

† *Loc. cit.* p. 11.

of the soil to the Springfield shaft at Oakthorpe, where 18 feet of the rock were proved. At this village it again forms a hard compact rock, and crops out along the Canal, the wall of which has been built of this stone.

On the opposite side of Saltersford Brook the breccia is seen at the spring, and in the railway cutting near Hall Farm ; and the outcrop may be followed across the village of Donisthorpe to the Hooborough Brook, on both sides of which it forms a conspicuous feature.

South of Overseal the outcrop is broken by a fault, but, passing to the east of the village. the rock forms a good feature along the crest of the hill, that may be followed for some distance. Wells in the village show a considerable thickness of breccia.

CHAPTER VII.

TRIAS.

Bunter Sandstone and Pebble Beds.

The only representative of the lower part of the Trias which occurs in this district is that of the quartzose Conglomerate or Pebble Beds, which further west, in Staffordshire, constitutes the middle portion of the formation. These Pebble Beds consist of partially consolidated quartzose gravels, which pass upwards into alternations of more or less pebbly sandstone. The pebbles are covered with numerous small indentations caused by pressure or chemical action, where they are in contact.* They are, for this reason, easily distinguished from the Drift pebbles, which are never so indented. The latter also frequently have their longer axes vertical, which is not the case with those in the Bunter. The matrix of these old gravels is, in many cases, so hard and consolidated that they fracture more readily across the pebbles than between them.

These beds probably have a maximum thickness of about 1,000 feet (854 feet were found in the boring at Chilcote); but over most of the ground, where they crop out, the thickness does not appear to be so much, and towards the east they gradually thin away altogether. The upper part of the formation consists mainly of coarse sandstone with only scattered pebbles or lumps of quartz; which it is difficult to distinguish from the overlying Keuper Sandstone, and consequently the upper limit of these beds is somewhat arbitrary.

In the southern part of the map the only outcrop of these beds is an area of about a square mile between the faults at Warton and Polesworth. They are, however, well exposed over this ground and sections are frequent. The best exposure is that in the railway cutting at Hoo Hill east of Polesworth, where there is a continuous section nearly half a mile in length. The Bunter here consists of thick beds of conglomerate with several bands of sandstone; the lower part of the formation consists almost entirely of conglomerate, while in the upper part the sandstones gradually become less pebbly until they seem to pass into the higher sandstones, almost devoid of pebbles, which have been classed with the Keuper, although no actual junction is seen.†

On the north side of the river these beds form the somewhat conspicuous hill called Bury Hill.‡ Here the pebble beds and soft sandstones are seen at frequent intervals along the different roads and in the quarries round the hill. The general dip of the

* Figures of these pebbles are given by W. S. Gresley and T. Mellard Reade. Geol. Mag., dec. iv., vol. ii., pp. 239 and 341, 1895.

† The recent widening of the railway here shows that the whole cutting is in Bunter, and that the junction is further east, as shown on the map.

‡ "The Round Berry" on the new Ordnance Survey.

beds is south-east at angles varying from 9° to 25°, except at the north end of the hill, where they turn over towards the north, and dip at a rapidly increasing angle into the fault, which bounds them on this side. North of this they disappear under the overlying formations for some distance until they crop out again along the valley of the Mease between Netherseal and Measham.

At Measham these sandstones are seen in the railway at the station, and in quarries to the south; but both their upper and lower boundaries are here rather obscure. They are, however, not very thick here; it is probable that this is near their limit, and that they thin out a short distance to the east.

There are indications of these beds on the south side of Oakthorpe, but their outcrop is not very clear until we reach the stream coming down from Willesley. Beyond this the Pebble Beds become much thicker, and are very conspicuous over the hill to the south of Donisthorpe, and thence across the Hooborough Brook to Netherseal and Overseal. Here they form a range of gravelly hills, in striking contrast to the more clayey measures on either side.

West of Overseal there is a sharp junction with the Keuper sandstone and included marl bands, which was formerly supposed to be a line of fault, but which we now consider to be due to the unconformable overlap of the newer formation. The Pebble Beds rise up again to the west, and form the poor land at Seal Wood, where the junctions with the Keuper are equally sharp.

At the time of the old survey these abrupt terminations to the outcrop of the Pebble Beds were thought to represent mostly lines of fault, and that the Keuper was let down by three more or less parallel faults. Since then mines have been driven under a large part of this ground, and it has been found that the coals are not broken at these places. This being the case, these sharp lines of boundary must be caused by the Keuper lying unconformably in hollows of the Pebble Beds, and abutting against the ridges formed by them.

Lower Keuper Sandstones and Marls.

This formation has an average thickness of about 100 feet on the east side; but on the west it appears to be about 150 feet thick, although in places it may be somewhat greater. It consists of massive beds of soft sandstone, sometimes white but generally stained red or brown. These sandstones are split up by numerous beds of marl; they are generally false-bedded, and frequently ripple-marked. In the country to the north at Castle Donington, and also to the south in the neighbourhood of Warwick, footprints of *Labyrinthodon* have been found in these beds, but we are not aware of such being the case in the area now under consideration. The basement beds of these sandstones contain many quartz pebbles, and in some places hard beds of conglomerate. The following section in Heather brickyard shows the general character of the lower part of the formation.

Section in Heather Brickyard (*north of station*).

	Ft.	In.		Ft.	In
Drift Gravel - - - - - - - - - -					
Red marl - - - - - - - - - - -				10	0
Sandstone - - - - - - - - - -	1	0	to	3	0
Hard red marl with specks of mica - - - - - -	10	0	to	11	0
Yellow sandstone - - - - - - - - - -				3	0
Hard red marl (becomes more sandy further east) - -				3	0
Yellow sandstone - - - - - - - - - -				1	0
Hard red marl - - - - - - - - - -				6	0
Conglomerate, very hard in the centre of the pit, soft and decomposed to the east - - - - - -				1	0
Sandstone - - - - - - - - - - -				3	0
White and grey shales of the Coal-measures - - -					

The beds undulate and split up. There is more sandstone on the whole in the south-east part of the pit.

The upper beds pass very gradually into the overlying marls, so that the boundary between them is difficult to fix, especially in pit sections or borings.

In the south of the map the Lower Keuper Sandstone comes to the surface in a narrow strip along the line of the fault south of Atherstone. It is seen in an old sand pit at the edge of the Outwoods, and in others in Merevale Park. The beds here are so soft and unconsolidated as to be dug for building sand; they are also very coarse, especially in Sand Hole Spinney, where some of the pebbles are as much as two inches in diameter.

The beds in both these places have been worked up against the fault; by which they have been turned up very sharply and dip at 20° to the north.

On the west side of Merevale Park the sandstones have also been worked in Old Lane Spinney and at the Church, but the beds are not nearly so coarse as they are in Sand Hole Spinney.*

Beyond the Merevale Valley the Lower Keuper Sandstone is covered by marls, which here abut against the fault for a short distance; but it appears again just beyond the Watling Street and is seen at many places about Dordon Farm and Dordon Hall.

At Warton the sandstones are tolerably massive, and were formerly somewhat extensively quarried. They dip at the rather high angle of 9 to the north-east and east, which is probably caused by the proximity of the fault on the south side of the village. Beyond this the beds become flatter and the outcrop widens out considerably, covering the whole of the low ground between Austrey and Seckington, although much hidden by the later deposits of the Austrey Meadows. The lower and more massive beds are well seen at Seckington and Newton Regis; in the latter village great floors of rock are exposed near the Church.

At Austrey the flaggy upper beds are seen in many of the lanes, and the gradual passage into the marls may be followed up the stream to the east. In consequence of this gradual passage

* It is possible that these latter are a portion of the Pebble Beds brought up by the fault.

it is not very easy to fix the line of boundary with the true Keuper Marl; and we have drawn it between here and Appleby, at a somewhat higher horizon than that shown on the old map, which appears to cross the line of strike. The measures which we now include with the lower formation contain thin bands of sandstone that are somewhat different in character from those occurring in true Keuper Marl. Moreover, the Keuper Marl, east of Austrey and No Man's Heath, rises in a sharp bank above these measures, and forms a good physical feature, that is very abrupt and easier to follow than the horizon formerly adopted.

Between Shuttington and the Mease the Lower Keuper Sandstone covers a large area of country, and consists of beds of sandstone and marl, which occasionally form good features; but frequently, the sandstones becoming thinner, these die out, and no divisions can be drawn. In many places the marl predominates to such an extent as to give the country the aspect of that of a true Keuper Marl. This was, no doubt, the reason for the greater area of this formation shown on the old map.

North of the Mease the outcrop splits up into two horns flanking the Coal-measures on either side. The western of these forms a somewhat narrow outcrop to the west of Netherseal, which is broken by the Gunby Lea fault at Grange Wood, and fills the hollow between here and Overseal. This was shown on the old map as Keuper Marl; but, although in places the ground is very marly, there is a considerable amount of sandstone to be found over the area, certainly far more than ever occurs in the Keuper Marl.

At Netherseal Colliery the upper limit of the sandstone is obscured by Boulder-clay, but it probably runs against the large north and south fault somewhere to the south-west of the pit.

The outcrop on the eastern side of the coalfield covers a broader area to the east of Measham, part of which runs up in a promontory to the high ground above Willesley Park, while part passes by Snareston and Swepstone to the escarpment at Normanton, and thence by Alton Grange to the Midland Railway at Breach Hill. The formation here resting principally on Coal-measures, its base is better defined; and, the passage of the marls not being quite so gradual, the upper boundary is also more distinct. These sandstones are seen in some of the brickyards at Measham, in Willesley Park, and along the bank from Snareston to Breach Hill, where there is an extensive section in the railway showing the usual pebbly beds at the base.

Keuper Marl.

The Keuper Marl covers the largest area of surface of any formation with which we have to deal. It overlaps unconformably the rocks beneath; and, although along its junction with the Lower Keuper Sandstone, it succeeds that formation quite regularly, in fact, the one passes into the other by almost insensible gradations; still, where the oldest rocks come to the surface as around Charnwood Forest and at Enderby and Croft, it abuts directly against them without any intervening beds of

Lower Keuper Sandstone, showing that these older rocks must have stood up as islands in the waters by which the Trias was deposited.

These beds consist of red and mottled marls with thin beds of grey and white sandstone, known as skerry; which at two horizons, one near the top the other near the base of the series, thicken out locally into sandstones of some importance. Thin beds of gypsum also occur at intervals throughout these marls, as shown by several of the borings in them; but these bands are not so thick as in the higher part of the formation which crops out to the east, and consequently they are not very apparent at the surface.

The Keuper Marls occupy principally the southern and eastern portions of the map, but being largely concealed by Boulder-clay and other Drift deposits they are mainly to be found along the valleys which have cut through these later beds; although they also come to the surface somewhat extensively around the Charnwood Hills and in the low ground north and east of Atherstone, where there is very little Drift.

At Orton-on-the-Hill the sandstones near the base of the marls thicken out for some distance to the north and south of the village. There is not one mass of sandstone here, as shown on the old map, but there are five or six different bands separated by beds of marl, which form distinct features that may be followed from the low ground near Sheepy to Orton, and thence along the escarpment behind Austrey to No Man's Heath, where they turn round and gradually thin out again in the bank to the south of Appleby. There are indications of this sandstone at Norton, Shackerstone, and at Carlton Bridge, but it cannot be traced across the country from these places.

In the upper part of the marls a similar bed of sandstone is seen in the Leicester and Burton Railway just beyond the edge of the map. This is much more massive than that at Orton, but it also appears to thin out very rapidly in all directions. There is a considerable spread of sandstone at Narborough Wood House, and a band of from six to ten feet thick is seen in the quarry at Croft, which are probably the continuation of this upper sandstone.*

Over the area between the two coalfields of Warwickshire and Leicestershire the Keuper Marl has been entirely denuded for an average breadth of about three miles. It comes on again in the north-west of the map about Thorpe Constantine, Clifton Campville, and to the west of Netherseal, where it forms the eastern edge of the great mass of marl that stretches away to the Trent and beyond. Here it forms very similar country to what it does in the east, the higher ground being capped with thin Drift, while the valleys are cut in a uniform red marl without much sandy material of any kind.

* This has been called the "Upper Keuper Sandstone"; but, as in this district the bands of sandstone are very inconstant and occur at different horizons, they do not deserve a special name.

CHAPTER VIII.

PLEISTOCENE AND RECENT.

Glacial.

The Glacial beds, which come into this map, are in general not so thick and important, nor are the sub-divisions so clearly defined as they are further to the east along the valley of the Soar. Near Leicester there are three distinct Boulder-clays and associated gravels which are easily distinguishable from one another. An older clay containing quartzite and pre-Carboniferous pebbles mixed with fragments derived from local rocks; a newer clay, containing fragments of Chalk and Oolite, also mixed with local fragments; and lastly a still newer clay which is much more gravelly than the other two, and occurs along the valleys and lower ground, while the two older clays generally occupy that above.

In this district the same divisions probably to a certain extent exist, but the Drift being generally thinner the distinction between the several divisions is not so marked and they cannot be made out with any approach to accuracy. The Drift over this ground as a whole is more sandy or gravelly than further to the east, and, except along a north and south line across the centre of the map, there are no very thick deposits of Boulder-clay. Very few fresh sections in Boulder-clay have been exposed during the progress of the Survey; but from what has been seen it appears that the clay principally consists of local materials mixed with well-rounded quartzite and other pebbles; and generally contains, but not always, some fragments derived from the Jurassic rocks and Chalk, the latter in many places being so numerous as to form a regular Chalky Boulder-clay.

The thickest mass of Boulder-clay is, as we have said, along the centre of the map from the neighbourhood of Market Bosworth southwards. There is also a considerable amount at Hugglescote; where in a well over thirty feet of Chalky Boulder-clay was found resting on the gravel. Whether these two deposits originally occupied the same valley or depression in the Keuper Marl is not very clear, but they are probably more or less connected, as the Drift occurs at a lower level than elsewhere along a line running from the flanks of the Charnwood Hills near Coalville, by Hugglescote, Heather, Carlton, Market Bosworth, Shenton, and Stoke Golding. From Market Bosworth southwards it sinks below the present level of drainage, and appears to attain its maximum thickness. At the Cowpasture boring, to the north-east of that place, there was 40 feet of Boulder-clay, at Bosworth Wharf there was 27 feet, and at Kingshill over 100 feet, which shows that it descends considerably below the bottom of the present valleys. At all these places it also occurs along some of the lowest ground near the railway from Shenton southwards; it is also of great thickness to the eastward as far as Stapleton and Barwell, and southwards as far as Hinckley*, the solid rocks not having been seen at the surface anywhere throughout this region, although the present valleys are fully 60 feet below the general level of the country.

At Bosworth Wharf, Shenton, Stoke Golding, and further south a great part of the clay is free of stones, and is more of the character of a brickearth, containing sandy and loamy bands and a great profusion of the small calcareous lumps known as "race." Sections in this clay are exposed in the brickyards at Osbaston Lount, Hoo Hills, Bosworth Wharf, and Shenton, and in the railway cuttings near here and further south. At Osbaston Lount the clay is said to have been proved for 40 feet beneath the present valley. Intercalated in the clays are many beds of sand and gravel, which crop out along the flanks of the hills, or cap their summits, as shown on the map. These are sometimes dovetailed together with the clays, and are very irregular in their outcrop, more especially at Hugglescote, Barleston, Hoo Hills, Coton, Stoke Golding, and Stapleton.

West of this there is a broad tract of country occupying the greater part of the west half of the map, over which there is little or no Drift except along the flanks on either side.

This ground, which extends from Atherstone to Ashby-de-la-Zouch, is formed mainly by the outcrop of the Lower Keuper Sandstone, flanked on either side by the overlying marls, except at the northern and southern extremeties, where the Coal-measures crop out. Along the centre of this axis there is no Drift; but on either side isolated patches of gravel and gravelly clay are found over the higher ground, that on the east being clearly the attenuation of the thicker Drift mentioned above, while that to the west apparently belongs to deposits occupying the Trent Valley, although the Survey has not as yet been extended far enough in that direction to show the connection. These latter beds, which cap most of the hills in the north-west corner of the map, consist mainly of gravel; but there is one section at Netherseal Colliery which shows good chalky Boulder-clay interbedded with laminated clay or brickearth.

On both sides of this axis there is a good deal of thin Drift which is not light enough to be mapped as gravel, and is, therefore, shown as Boulder-clay. It is probably, in many cases, merely a remnant of gravel on a clay subsoil.

The principal areas of gravel in the eastern part of the map occur along a line running from Ravenstone to Heather, Nailstone, Barleston, Newbold Verdon, Desford, Peckleton, Kirkby Mallory, and Earl Shilton. This nearly coincides with the watershed between the Soar and Anker.

There is also a considerable amount of gravel at Twycross, Dadlington, and near Ratby.

* At Hinckley the Drift is stated to be 150 feet thick.—Brit. Assoc. Reports for 1875, p. 136, and 1879, p. 160.

These gravels, when they occupy a low position relative to the Boulder-clay, are generally composed of quartzite pebbles and other rocks derived from the west; but the older gravels were so irregularly distributed, or were so greatly denuded before the deposition of the overlying Drifts, that their position is often occupied by gravels of more recent date derived from the east. At the present time, owing to the general use of many of the older rocks for road material and ballast, there are very few good sections of gravel; and without a clear exposure, from the mingling of the overlying beds with those below, it is very difficult to determine one set of gravels from the other. The pebbly gravel principally occurs at Ravenstone and Heather, in the north of the map, and at Newbold Verdon, Desford, Kirkby Mallory, Peckleton, Earl Shilton, Huncote, Kirkby Muxloe, Ratby, and Ambion Hill in the south; while the more or less chalky gravel is found at Bagworth, Market Bosworth, Dadlington, Stoke Golding, East Leicester Forest, Enderby, and Narborough. The best section in the former is in Heather brickyard, and in the latter at Dadlington.

In the west of the map there are patches of gravel at Warton, Shuttington, west of Thorpe Constantine, Clifton Campville, Lullington, and Coton Park. These, with the exception of that at Coton Park, which contains flints, are all composed of pebbles without any admixture of eastern rocks. When they overlie the Pebble beds of the Bunter, as at The Round Berry, near Warton, they are rather difficult to separate from that formation: but the pitting of the older pebbles, as mentioned in Chapter VII., is a fairly safe guide by which to distinguish them.

In the north of the map there are two curious troughs or erosions in the solid strata that have been filled with Boulder-clay. These were crossed by the railway north of Ravenstone, and are well shown in the cuttings 500 yards and 840 yards west of the bridge at Sinope. They are from 100 to 150 yards in breadth, and contain beds of gravel, composed of Chalk flints and Oolite fragments mixed with pebbles, which have been cemented into a hard conglomerate, that is seen in the railway cutting where it crosses the eastern trough. This latter appears to coincide with the position of the Coleorton Fault; and it probably owes its existence to erosion or subsidence along that line.

Besides the Boulder-clays and gravels derived from the west and east just described there is a later Drift, which is found along the existing valleys. This varies from a clay to a sand or gravel; but is generally a mixture of the two, which can scarcely be called either a clay or a gravel. It is never of any great thickness, frequently forming little more than a stony soil over the underlying strata, and constantly merely filling pipes and hollows in these beds; so that, when there are few sections, its thickness is very deceptive. It contains materials derived from both the older Drifts; and when it abuts against these it is impossible to separate one from the other.

These beds form the more or less detached patches shown along the principal valleys of the district; and were deposited when these were nearly cut down to their present level. They evidently mark a very late period merging into the time when the terraces of the existing rivers were laid down; and consequently the separation of them from the river beds, in some cases as along the Anker and the other larger streams, is purely arbitrary. They, in fact, form a connecting link between beds of truly glacial age and the alluvial deposits of the present rivers.

River Gravels and Alluvium.

Intimately associated with the beds last mentioned are the deposits of gravel and loam which have been left along the courses of the main streams. These are found in the valleys of the Anker, the Soar, and their principal tributaries; where they form more or less distinct terraces above the modern alluvium of the river.

Along the flanks of the Anker there are two or perhaps three of these terraces, marking the level of the river in former times. The distinction between the several terraces is usually well-marked towards their upper end, but lower down the valley they are blended with one another, and it becomes difficult to separate them.

The higher of these terraces is the most indistinct, and, as we have said, joins on to beds of apparently late glacial age, so that it is doubtful how they should be represented on the map. Of this character are the patches of clay and gravel shown along the valleys near Shackerstone, Sheepy, Newtown Unthank, north of Earl Shilton, near Measham and elsewhere.

Besides the narrow strips of modern alluvium, which flank the larger streams, and are liable to be flooded by them, there are some considerable tracts of alluvial loam and peaty soil, which occupy depressions that were formerly lakes or swamps, but have been drained by the cutting down of the small streams, which connect them with the main valleys. The principal of these is that known as Austrey Meadows, which has a length of over two miles, and covers an area of about 1,300 acres. There are also smaller patches near Orton, Sheepy, and along the higher reaches of many of the streams, as around Shenton and other places.

CHAPTER IX.

FAULTS.

The Polesworth Fault.

We have given this name to the large fault that forms the north-east boundary of the older rocks of Warwickshire, in order to distinguish it from that other large dislocation which forms the north-east boundary of the Leicestershire coalfield; and on account of its existence at Polesworth as a fault being clearer there than elsewhere. This fault runs in a north-westerly direction from beyond Nuneaton to Atherstone, and thence to Polesworth and Shuttington. There is no means at present of estimating the displacement caused by this fault, as the thickness of the strata to the north-east is not known. It is, however, probably greater here than to the south-east about Nuneaton, where Mr. Strahan has stated that it is not of the importance that was supposed.* The nearest places at which the underlying measures have been proved is at Lindley Hall, which is two miles from the line of fault at Caldecote. Here the base of the Trias is supposed to have been reached at 660 feet. In the town of Nuneaton, close to the line of fault, the depth was 110 feet; whereas at Stretton Baskerville, and Hinckley Wharf, further to the east, it was 623 feet and 744 feet respectively. South of Atherstone this fault cuts off the Cambrian shales and intrusive igneous rocks very sharply, and brings down the sandy beds of Trias against them. The line of junction may be seen in the sand pit at the edge of the Outwoods, and in that in Merevale Park on the west side of the drive to the Hall; both of which have been worked up against the shales on the south side. At the latter place the line of fault makes a very sharp bend, almost at right angles, although it soon recovers the same general direction; and, passing in a well-defined line through Merevale Church, is continued to the north of Waste Hill. Its course through Dordon is more northerly; but its position is still sharply defined, especially at Dordon Hall, where the Coal-measure shales and Triassic sandstones are seen on opposite sides of the lane.

At Polesworth, Mr. Howell states that "this fault was proved in working the Seven-feet coal in a pit, which was sunk close to the barn, on the east side of the railway cutting between Polesworth station and the bridge over the railway between Polesworth and Waverton. The coal was here sixty yards deep, and was wrought up to the 'Red Rock fault,' which cuts off the coals

* Geol. Mag. dec. iii., vol. iii., p. 553. At Nuneaton the junction between the Keuper and the older rocks is very probably, to a great extent, a line of unconformity.

altogether to the east."* North of this it passes Woodside Farm, and is lost beneath the Drift capping the hill at Shuttington.

Bramcote Fault.

We give this name to a small branch of the last which passes to the south of Warton, and brings the Permian and Bunter beds against the Lower Keuper Sandstone, the general displacement of the beds near Bramcote Hall being very striking. To the west this fault probably joins with the Polesworth fault, and terminates the outcrop of the Coal-measures at Shuttington; but its exact position cannot be fixed, beyond the fact that Coal-measures are seen at the village, and red marls a little to the north. On the old survey this fault is represented as curving round to the south, and uniting with the main line of fault near the Watling Street. We could find no evidence of this; the Pebble Beds appear to dip quite regularly beneath the Lower Keuper Sandstone, and this latter beneath the marls: while the high dips in the quarries at Warton are probably caused by the proximity to this fault.

Monk's Park Fault.

There is probably a north and south fault intersecting the Cambrian beds at the Lake to the east of Merevale Hall. The principal evidence for this is, however, in the next map in Monk's Park Wood, where it throws down the Coal-measures to the west. "Its direction is about north and south, and the coals are thrown down to the west nineteen yards, the whole of the coals on the west side of the fault being shifted considerably to the north. This fault was proved in the workings of the Four-feet coal at Oldbury, which coal was found to have been thrown down to the west nineteen yards. The position of the fault further north was proved by numerous borings, all of which were on faulted measures. It also affects the Permian rocks in a similar manner, and can be seen in a quarry by the side of the lane between Monk's Park and Spodes Rough."†

Baddesley Fault.

In the south-west corner of the map we have shown a fault, about which we have some doubt. The principal evidence for there being a fault here is the sudden termination of the outcrop of the bands of limestone, and the disruption there also appears to exist in the "Permian" sandstones. The limestone, which forms a conspicuous feature from Baxterley Park as far as Cowper's Grove, suddenly terminates at this point; and the outcrop, which is probably in lower ground beyond, is not traceable. Similarly the base of the sandstones forms a good feature as far as Ash Spinney below White's Farm, where it is suddenly thrown down to lower ground, and the line of strike changes. At this point there are some old pits in which the limestone has been worked against the edge of the sandstone, which a little further on in the quarry near the old barn is seen to be dipping at 4° towards the fault.

* Warwickshire Coalfield, Survey Mem., p. 13.

† Ibid. p. 51. Mr. Smallman informed us that a pit, lately sunk south of Spodes Rough, shows that this fault is rather further west than drawn on the map (63 S.W.).

It is probable that the evidence for this dislocation will be clearer when the country further to the south-west, about Hurley, is surveyed.

Hall End Fault.

In Birch Coppice Colliery, at Hall End, a fault has been proved running almost in the position of the Watling Street, and having a throw of 25 yards down to the north. This must shift the outcrop of the coals in the valley south of Birch Coppice; but, owing to the general high dip here, its effect is not very conspicuous.

Several other faults, varying in throw from 10 to 30 yards, have been proved in the mines between here and the river Anker; while in the Baddesley Pits the measures are almost undisturbed, thus showing that the Coal-measures are much more broken as they approach the great east and west boundary faults enclosing the apex of this coalfield.

The short branch fault shown at Polesworth, having a down-throw to the west of from 10 to 40 yards, has been transferred from the old survey. The coal pits here have been abandoned many years, and all evidence in the matter has been lost.

The fault shown on the old map (62 N.E.) as running west from Polesworth has been found by the workings at Pooley Hall to have no existence at the Hermitage, and is consequently now omitted.

The great fault which bounds the Warwickshire Coalfield on the west side is probably continued as far as the valley west of Shuttington, and meets the east boundary fault; but there is no evidence for its being continued further north past Seckington, or for its being the same as the Stonewall Fault in the Donisthorpe coalfield as supposed by Coleman*. If these faults are connected they do not appear to have affected the overlying Trias. The marl at Seckington rests quite regularly on the thick sandstones beneath, and is not faulted against them as has been supposed.

In the northern part of the map the principal faults all run in a north-west and south-east direction parallel with the axis of the Charnwood Hills. There are also many running at various angles to these, but they are not so large or important as the former.

The Eastern Boundary or Thringston Fault.†

The largest fault in this district is that which bounds the Coal-measures on the east side. It enters the map at Whitwick, and has been proved on the east side of the colliery as far as Broom Leys, from whence it probably continues by Bardon Hill Station to Thornton and Desford, although the collieries near here have not as yet worked far enough east to obtain any

* White's History of Leicester, p. 93.

† We have adopted this name from Coleman. It is called the Coleorton Boundary Fault by Prof. Hull (Leicestershire Coalfield, p. 52), but as there is another fault much nearer Coleorton we reserve that name for the latter.

evidence of it. It may, however, have been touched in the Lindridge sinking, where the Coal-measures were much shattered, and "slaty rocks" were met with. In the Whitwick Colliery this fault is reached at about 1,000 yards to the north-east of the pit, where the measures begin to rise very rapidly until they become almost vertical. This fault causes a displacement of over 2,000 feet. The bending up of the Coal-measures caused by it is very rapid; as only about sixty yards from where they are nearly vertical they begin to rise in the opposite direction at about 5°, forming a synclinal trough parallel with this disturbance.* A large fault, shown on Hor. Sect., Sheet 46, called by Mr. Coleman the Hugglescote Fault, has been supposed to run at right angles to this fault along the northern foot of Bardon Hill. If such a fault exists it is of a pre-Carboniferous age, and does not appear to affect the Coal-measures in the least. In the South Leicestershire Colliery, which has worked across this line, there is no evidence of such displacement; and the coal seams in the other collieries on either side are more or less at about the same level.

The Coleorton Fault.†

This fault appears to bound the eastern division of the coal-field on its western side. It is more easily traceable in the map to the north, where it has been found to sharply cut off the outcrop of the coal seams. In this map it is entirely concealed by the Trias and Drift; but its direction is probably indicated by the troughs filled with Boulder-clay which are seen in the railway cutting west of Sinope.‡ At about 900 yards south-west of the colliery here the coal was found very tender and full of water, probably owing to the proximity of the fault; but its throw cannot be very much here, if we are right in supposing that the coal worked at Alton was the Roaster seam. The faults at Heather of 20 to 25 yards and 9 yards are possibly the continuation of this fault. They were proved in the colliery here, and their effect at the surface is to bring down the Keuper Sandstone into the stream for a short distance.

The Ashby or Anticlinal Fault.

Prof. Hull, in the old map of this district, has shown the axis of the anticlinal as a doubtful line of fault, and the same idea is entertained by Mr. Coleman. It is very probable that this is the case, but during the present survey we have not been able to obtain any evidence to prove whether the strata are really shifted along the axis or not.

The Boothorpe Fault.

This is the second largest disturbance in the district, and is estimated to have a throw of at least 1,000 feet. It forms the boundary between the workable seams of

* Hull, loc. cit., pp. 37, 45, 53. Mr. Coleman, loc. cit., p. 82, mentions an outcrop of Bardon rock considerably to the west of this fault. This may have been a drifted mass, as we could find no trace of such a rock at the place named.

† Heath End Fault of Hull, loc. cit., p. 52.

‡ See p. 39. Also Coleman, loc. cit., p. 89.

Moira and the more or less barren measures of Ashby. It is best seen at Woodville, just beyond the edge of the map; but is not difficult to trace in this sheet, having caused considerable disturbance in the measures that are exposed in the railway cutting north of Willesley Wood. It runs near the southern edge of Willesley Park, where the Main Coal, which probably crops out beneath the Triassic Sandstone here, is found to be sharply bent up. This fault probably bounds the workable seams of coal a short distance north of Measham House, but there is no evidence as yet to fix its exact position.

Moira Main Fault.

Throughout the Moira Coalfield there are a large number of faults that have been proved in the different collieries. The principal of these is that known as the Great Moira, Moira Main or Mammatt's Fault, which in the Rawdon pit has been proved to have a downthrow to the east of ninety-four yards. This fault, to the north of the railway, runs nearly parallel with the Woodville Road; but south of this curves round more to the south towards Donisthorpe, and appears to become split up in the large number of faults which occur about there. It does not continue on in a south-easterly direction towards Oakthorpe and Measham, as was formerly supposed This ground has now been worked under, and no throw of any size has been met with.

Stone Wall Fault.

Near the cross-roads east of Donisthorpe, there is a fault running in a south-west direction, which is probably the same as that to which the above name has been given. This fault is stated by Prof. Hull to have been proved in the Donisthorpe old mines, where it had a downthrow to the north-west of 100 yards. Mammatt, in one of his sections, shows a fault in about this position having a throw of from 120 to 140 yards up to the east; but the later colliery workings have not gone through it, so that we are unable to verify these statements. This fault probably runs from the much broken ground near Brambro Farm down the valley, between Oakthorpe and Donisthorpe.

Over the ground to the west of Overseal faults are shown on the old survey, which recent mining operations have proved do not exist; and therefore the sharp junctions here between the several divisions of the Trias are not due to faulting, but are rather the result of the unconformity of the Keuper Sandstone on the Pebble Beds of the Bunter. The principal faults, over this area, which have been proved in mining or by boring, are a large north and south fault, a little west of Netherseal Colliery, which has a downthrow to the west of 250 yards or more; another between this colliery and Overseal, which has a downthrow to the west of seventy-four yards, and a third east and west fault, which we have called the Gunby Lea fault.

The Gunby Lea Fault.

This runs nearly along the road at the south of Grange Wood, and has a downthrow to the north of 96 yards. It appears to shift the boundary of the Triassic beds, as shown on the map, and it is interesting from the effect it has on the waterbearing capacity of the Keuper Sandstone. At Gunby Lea this fault is exactly in the line of the road, and forms an impervious wall to the water, so that a well 29 feet deep on the north side of the road is full of water almost to the surface, while one recently sunk to a depth of 40 feet exactly opposite is completely dry.

At the south end of the village of Overseal there is a fault which is probably the continuation of this last. It has been proved in the mines to have a downthrow to the north of 20 yards, and its effect at the surface on the Trias and Permian is very marked.

Measham Fault.

Between Oakthorpe and Measham the old survey shows an east and west fault called by Prof. Hull the "Oakthorpe Fault."* Subsequent working in this district have afforded evidence that this fault has not the direction shown on the map, but that it runs more southerly and closer to the village of Measham. At a point about 500 yards west of the village the Main Coal has been found at the surface and dipping to the north, whereas it is stated to be 42 yards deep at the village.† It is, therefore, evident that there must be a considerable fault to the north and west of Measham, but running in a more southerly direction than shown on the old map.

Oakthorpe Fault.

On the south side of the village of Oakthorpe there is a north-west and south-east fault which cuts off the Coal-measures in the low ground beyond the railway. It has not been proved in any working, but the juxtaposition of the Coal-measure shales and the sandy beds of the Trias near the railway bridge seem to show its direction pretty clearly. This fault probably joins that of the Stonewall Fault mentioned above somewhere in the valley of the Saltersford Brook.

On Measham Field the borings along the old tram road‡ proved a fault which threw out the Main Coal to the south. This may be a continuation of the Oakthorpe Fault, as other borings tend to show that the coal is absent to the south of Measham.

There are several other faults throughout the Moira and Donisthorpe coalfield, which have been proved in the various mines and are shown on the six-inch maps. One very large one, the throw of which is doubtful, occurs in the Donisthorpe Colliery. This coalfield is very much disturbed and broken up, the disturbance evidently increasing towards the west, as the measures in the Netherseal Colliery are excessively irregular, and the direction of the dip changes about in a marvellous manner.

---

* Memoirs of the Geological Survey. The Leicestershire Coalfield, p. 49.

† Further evidence on this point will be given in the general memoir on the coalfield. Mr. S. H. Leech, of the Measham Terra Cotta Company, has given us much valuable information on this district.

‡ The details of these will be given in the general memoir.

APPENDIX I.

*Sections in the Northern Part of the Warwickshire Coalfield.**

Baddesley Colliery, Baxterley.

Stratford Pit.

From Rev. W. H. Coleman's MSS.†

—	Thickness.		Depth.	
	Ft.	In.	Ft.	In.
Soil	1	0		
Clay	4	0		
Bind	6	0		
Clunch bind	7	6		
Stone	2	3		
Clunchy marl	6	0		
Ironstone		3		
Clunch	9	0		
Stony bind	19	6		
Marly bind	16	6		
Stony bind	12	0		
Marly bind	7	6		
Open stone	15	0		
Sharp stone Stone and cank balls	5	4		
Coarse rock	13	6		
Hard stone	15	0		
Tender bind	6	0		
Limestone	2	6	148	10
Clunchy stone	5	0		
Sharp stone	10	0		
Sandy rock	30	6		
Dunns	16	6		
Strong bind	4	0		
Hard stone	22	2		
Clunchy bind	11	6		
Strong clunchy bind	7	0		
Stone		7		
Bind	4	1		
Stone	10	4		
Sharp stone	14	0		
Stone bind	1	0		
Cank	30	0		
Stone	8	0		
Clunchy bind	10	0		
Stone	12	8		
Tender bind	14	3		
Red stone	10	6		
Bind	16	9		

* The sections in the Leicestershire Coalfield will be given in a general memoir on that district.

† We are indebted to Mr. P. B. Mason, of Burton-on-Trent, for the use of these manuscripts.

—	Thickness.		Depth.	
	Ft.	In.	Ft.	In.
Stony bind - - - - -	4	6		
Dunns - - - - - -	7	3		
Clunchy bind - - - - -	5	6		
Stony bind - - - - -	10	3		
Hard stone - - -	6	0		
Tender dunns - - - - -	4	0		
Stone and cank - - - - - -	7	0		
Stony bind - - - - - -	4	8		
Grey stone - - - - -	14	0		
Stone - - - - - -	5	0		
Stony bind - - - - -	9	0		
Fireclay - - - -	3	0		
Bind - - - - - - -	1	3		
Stony bind - - -	6	0		
Stone and cank - - -	6	7		
Blue bind - - - - -	4	0		
Stone bind - - - -	10	0		
Stone and cank - - - - -	8	4		
Hard stone - - - -	6	0		
Clunchy bind - - - - -	3	0		
Stone and bind - - - -	4	0		
Rattlejack - - - - - -		9		
Stony bind - -	2	0		
Hard stone - - -	3	0		
Clunchy bind - - - -	4	8		
Fireclay - - - - - -	6	0		
Coal, soft - - - - - -	1	6	534	11
Bat and sloom - - - - -	1	6		
Coal, soft - - - - - -	1	3	537	8
Tender bat - - - - - - -	1	3		
Dunns - - -	4	6		
Sharp stone - - - -	1	0		
Stony bind - - -	4	10		
Ironstone balls - - - - - -		4		
Stony bind - - - - - -	6	0		
Bind - - - - - -	2	0		
Dunns and bat - - - -	3	8		
Coal, soft - - - - - - -	1	6	562	9
Dunns - - - - - - - -	1	0		
Coal, soft - - - - - - - -	1	0	564	9
Dunns - - - - - - - -	6	6		
Measures* - - - - - - -	112	6		
Coal, Four Feet Coal - - - -	4	4	688	1
Measures - - - - -	49	2		
Coal, Rider Coal - - - -	8	6	745	9
Parting - - - - -		9		
Coal, Bare Coal - - - - -	5	6	752	0
Measures - - - - - - -	58	0		
Coal Slate Coal - - - -	4	6	814	6
Measures - - - - - - - - -	102	0		
Coal, Seven Feet Coal - - - - -	5	6	922	0
Fireclay (Dark grey tender dunns)† - -	3	0		
Blue bind (Clunchy bind) - - -	9	0		
Coal (Soft dicey) - - - - - -	1	3	935	3
Fireclay (Dunns and bat) - - - -	4	0		

* The details of the section below here are not given by Mr. Coleman but may be found in the vertical sections of the Geological Survey, Sheet 21.

† The additions within brackets are from the sinker's account.

——	Thickness.		Depth.	
	Ft.	In.	Ft.	In.
Coal (Soft)- - - - - - - -	1	6	940	9
Fireclay (Soft light grey sloom) - -		3		
Coal (Soft dicey) - - - - - -	1	0	942	0
Fireclay (Drab and grey sloom or duns) -	3	0		
Ironstone balls (large brown and shot with white spar) - - - - - -	1	0		
Bind and ironstone (Sharp hard blue bind with yellow ironstone) - - -	21	7		
Ironstone balls (brown) - - - - -		4		
Blue bind - - - - - - - -	3	8		
Grey and blue stone - - - - - -	1	6		
Bind and ironstone (Dark blue bind with brown ironstone) - - - - -	5	0		
Coal (soft) - - - - - - -	3	4	981	5
Bind (dark blue) - - - - - -	3	6		
Coal (soft and tender) - - - - -	2	9	987	8
Fireclay (Dunns or bat) - - - - -	3	0		
Coal (tender) - - - - - - -		10	991	6
*Dark blue bind and clunch with ironstone 2 in. - - - - - - - - -	15	4		
Light brown ironstone - - - - -		2		
Dark blue bind - - - - - - -	17	9		
Brown ironstone balls - - - - -		4		
Dark blue bind with streaks of greystone-	11	3		
Tender blue and grey bind and dunns -	1	1		
Coal with a seam of pyrites. Like the Seven Feet Coal but burns to white ashes - - - - - - - - -	5	6	1042	11
Dark grey tender dunns - - - - -	2	0		
Coal, Very tender and friable. Full of bright batty slips - - - - -	11	6	1056	5
Very soft and tender dunns - - -	4	0		
Black curly ironstone balls - - -		3		
Very tender black shale or dunns - -	4	0		
Very curly black ironstone balls - -		5		
Very tender bright black shale with ironstone balls, from 1 in. to 6 in. - -	3	0		
Bright black shale with very tender ironstone - - - - - - - -	3	2		
Rather stronger black shale to dark blue tender bind - - - - - -	5	6		
Slate coloured ironstone with white spar -		6		
Blue bind, bored into - - - - -	10	6	1101	7

* The section below this is from the sinker's account.

Baddesley Colliery, Baxterley.

SPEEDWELL PIT.

From Rev. W. H. Coleman's MSS.

—	Thickness.		Depth.	
	Ft.	In.	Ft.	In.
Rise of bank	12	0		
Soil and clay	7	2		
Grey ramelly stone	12	0		
Sand rock	8	0		
Brown sand rock	40	8		
Hard stone, Boulders	13	8		
Blue bind	4	6		
Grey cank	5	11		
Sandstone	2	9		
Clunchy bind	7	10		
Sandstone	3	0		
Stony bind	4	0		
Clunch bind	4	3		
Strong clunchy bind	3	3		
Stone and cank	1	6		
Stone and strong bind	9	0		
Stone and cank	6	0		
Clunchy bind	8	0		
Clunchy grey stone	10	0		
Light blue bind	3	0		
Stony bind	6	0		
Stone and cank boulders	8	0		
Stony clunch	6	0		
Hard stone and cank	16	0		
Stony bind	4	0		
Hard stone	2	0		
Hard stone and cank	4	0		
Stone and cank	3	3		
Grey clunch	3	0		
Tender clunch	10	6		
Stronger clunch	4	0		
Clunchy bind	2	0		
Stony bind	2	0		
Good stony bind	2	4		
Stony bind	3	0		
Hard stone and cank	2	6		
Bat and clunch	4	0		
Stronger [clunch]	2	9		
Bat	1	0		
Clunch or fireclay	2	0		
Blue bind	3	0		
Hard stone and cank	3	8		
Stony bind	3	5		
" "	4	0		
Hard stone		9		
Stone bind	1	0		
Sharp hard stone	1	0		
Cank	1	0		
Close stone	2	0		
Stony bind	2	6		
Porous sandstone	6	6		
Coarse stone	3	0		
" "	1	6		

——	Thickness.		Depth.	
	Ft.	In.	Ft.	In.
Clunch or fireclay	4	0		
Clunch bind	4	3		
Sharp gritstone	3	6		
Cank	1	0		
Stone with sharp hard boulders	3	0		
Coarse stone	5	0		
Sloom		6		
Clunch and coal sheds	3	9		
Clunch or fireclay	2	9		
Bat or rattlejack		6		
Grey clunch		9		
Fireclay	1	0		
Clunch or fireclay	3	9		
Tender bat		6		
Coal, batty		6	322	11
Tender bat		3		
Tender clunch	5	0		
Fireclay	2	6		
Clunch or fireclay	5	6		
Hard stone		6		
Batty clunch	5	0		
Bind or shale	1	0		
Ironstone balls		3		
Bind or shale	1	0		
Coal, tender		2	344	1
Shaly bind	2	4		
Broad bind	3	6		
Clunchy bind and bat	1	0		
Hard clunch	2	4		
Hard stone	10	0		
Close hard stone	6	0		
Batty bind with pebbles	3	6		
Close hard stone	10	0		
Tender bat	1	0		
Bind, ironstone balls	1	6		
Strong bind	2	0		
Hard stone		6		
Stony bind	2	6		
Hard stone		6		
Stony bind	3	0		
Hard close stone	1	3		
Strong broad bind	2	0		
Kind broad bind	3	0		
Ironstone		1½		
Strong bind	2	0		
Ironstone		1½		
Kind bind	3	0		
Ironstone		1½		
Kind blue bind	3	0		
Blue bind	2	0		
Ironstone		2		
Tender bind	1	8		
Ironstone		2		
Blue bind	1	0		
Tender bat	1	0		
Coal, soft	3	6	417	10½
Bat	2	6		
Hard stone	1	0		

—	Thickness.		Depth.	
	Ft.	In.	Ft.	In.
Bind -	6	0		
Stone -		4		
Kind bind -	3	8		
Lighter bind	1	0		
Kind bind -	8	6		
Ironstone -		1		
Bind -	1	10		
Ironstone -		0½		
Rattlejack -	1	3		
Bind -		2		
Coal -	2	0	446	
Tender clunch -	2	0		
Fireclay	4	8		
Clunchy bind -	1	0		
Strong bind	1	0		
Kind bind -	2	0		
Tender bind	2	0		
Ironstone -		2		
Strong bind	3	10		
Strong light bind	7	0		
Strong bind	5	0		
Very strong bind	2	0		
Strong bind	1	0		
Close hard stone		9		
Strong bind	2	0		
Broad bind		10		
Bat or bind	1	3		
Coal, Rider Coal	5	4	488	1
Bat -		6		
Coal, Bare Coal	3	7	492	
Tender clunch -		6		
Strong clunch -	1	6		
Hard stone	4	6		
Stony bind	1	0		
Ironstone -		5		
Bind -		7		
Hard stone	5	0		
Strong bind	1	8		
Stony bind	3	0		
Stone	5	3		
Tender bind	1	4		
Coal, Ell Coal	1	9	518	8
Sloam		6		
Coal -		3	519	5
Clunch	3	0		
Stone	4	6		
Bind -	2	0		
Strong bind	3	0		
Fireclay	6	0		
Clunchy bind -	1	0		
Strong bind		11		
Cherty bind	6	0		
Ironstone -		4		
Bind -	2	8		
Ironstone -		5		
Stone	1	7		
Strong bind	5	0		
Stone		10		
Hard bind -	7	0		
Stony bind	3	0		

——	Thickness.		Depth.	
	Ft.	In.	Ft.	In.
Strong bind - - - - - - - -	2	0		
Strong bind - - - - - - - -	4	0		
Hard stone - - - - - - - -	4	3		
Hard cank - - - - - - - -	7	9		
Flinty stone - - - - - - - -	8	3		
Strong bind - - - - - - - -	2	0		
Sharp bind - - - - - - - -	5	6		
Stone bind - - - - - - - -	5	0		
Ironstone - - - - - - - - -		$2\frac{1}{2}$		
Hard stone bind - - - - - -	7	3		
Stone bind - - - - - - - -	10	$7\frac{1}{2}$		
Coal - - - - - - - - - -		9	624	3
Stone - - - - - - - - -	2	9		
Clunchy stone - - - - - - - -	3	0		
Stone - - - - - - - - - -	1	0		
Kind bind - - - - - - - - -	7	11		
Coal, Stone Coal - - - - - -	2	6	646	5
Clunchy stone - - - - - - - -	9	6		
Stony bind - - - - - - - -	3	0		
Hard stone - - - - - - - -		6		
Bind with sheds - - - - - -		$1\frac{1}{2}$		
Stone - - - - - - - - - -	1	5		
Cank - - - - - - - - - -	3	5		
Kind bind - - - - - - - - -	1	6		
Bind - - - - - - - - - -	5	0		
Ironstone - - - - - - - - -		1		
Bind - - - - - - - - - -	4	0		
Ironstone - - - - - - - - -		2		
Bind - - - - - - - - - -	3	11		
Shale - - - - - - - - - -	1	2		
Ironstone - - - - - - - - -		2		
Bind - - - - - - - - - -	2	6		
Ironstone - - - - - - - - -		$1\frac{1}{2}$		
Bind - - - - - - - - - -	5	8		
Ironstone - - - - - - - - -		$1\frac{1}{2}$		
Bind - - - - - - - - - -	3	7		
Strong bind - - - - - - - -	1	0		
Coal - - - - - - - - - -	1	6	694	$10\frac{1}{2}$
Bat - - - - - - - - - -	1	0		
Coal, Seven-Feet Coal - - - - -	6	0	701	$10\frac{1}{2}$
Clunch - - - - - - - - -	1	6		
Bat - - - - - - - - - -	1	3		
Tender bat - - - - - - - -	1	5		
Duns - - - - - - - - - -	1	0		
Coal, Trencher Coal - - - - -		9	707	$9\frac{1}{2}$
Duns or bat - - - - - - - -	2	6		
Shale - - - - - - - - - -	1	0		
Bind - - - - - - - - - -	2	6		
Clunchy stone - - - - - - - -	1	0		
Bind - - - - - - - - - -	5	0		
Stony bind - - - - - - - -	3	0		
Bat - - - - - - - - - -	1	0		
Coal - - - - - - - - - -	2	0	725	$9\frac{1}{2}$
Duns - - - - - - - - - -	2	0		
Stone - - - - - - - - - -	1	5		
Bat - - - - - - - - - -	4	0		
Clunchy bind - - - - - - - -	2	4		
Clunch - - - - - - - - -	7	6		
Clunchy bind ; ironstone - - - -	1	0		
Cank - - - - - - - - - -	8	0		
Stone - - - - - - - - - -	3	0	755	$0\frac{1}{2}$

Merevale.

From Rev. W. H. Coleman's MSS.

—	Thickness.		Depth.	
	Ft.	In.	Ft.	In.
Stony ratchet	14	0		
Coal, smut	3	0	17	0
Clunch	2	0		
Stone		9		
Bind	26	0		
Ironstone		7		
Coal	2	5	48	9
Clunch	9	9		
Bind	18	3		
Coal, Seven-Feet Coal	5	0	81	9
Clunch	2	7		
Bind	5	4		
Coal		4	90	0
Clunch	7	0		
Stony bind	6	0		
White stone	2	0		
Bind	3	0		
Coal		4	108	4
Clunch	7	0		
Bind and ironstone	50	0		
Coal	2	0	167	4
Clunch and ironstone	6	0		
Bind	13	10		
Coal	4	8	191	10
Clunch and ironstone	15	6		
Bind and ironstone	24	0		
Bind	5	6		
Duns	2	0		
Coal, Bench Coal	6	2	245	0

Merevale.

Pit near mouth of the higher tunnel.

From Rev. W. H. Coleman's MSS.

—	Thickness.		Depth.	
	Ft.	In.	Ft.	In.
Clay	24	0		
Coal	1	0	25	0
Sloom		6		
Coal		9	26	3
Sloom		6		
Coal		6	27	3
Clunch	15	8		
Sandstone	2	0		
Black bind	1	3		
Sandstone	26	6		
Black bind	4	0		
Clunch	4	0		
Sandstone	3	4		
Coal		6	87	6
Sloom	1	0		

—	Thickness.		Depth.	
	Ft.	In.	Ft.	In.
Coal		10	89	4
Clunch	3	0		
„ and ironstone	2	0		
White sandstone	6	0		
Stone bind	2	0		
Stone "Four-Foot"	13	7		
Bind	15	9		
Ironstone		3		
Coal, FOUR-FEET COAL	3	10	135	9

Merevale Common.

BORING BELOW THE BENCH COAL.

From Rev. W. H. Coleman's MSS.

—	Thickness.		Depth from Surface.	
	Ft.	in.	Ft.	in.
Clunch	2	0		
Coal smut	12	0	14	0
Clunch	7	6		
Bind	9	0		
Ironstone	1	0		
Bind	5	0		
Clunch	5	0		
Cank	2	8		
Blue bind	6	0		
Ironstone	1	0		
Bind	13	0	64	2

Birch Coppice Colliery, Hall End, Polesworth

From Mr. G. Fowler.

—	Thickness.		Depth.	
	Ft.	in.	Ft.	in.
Rise of ground	6	0		
Soil		10		
Sand mixed with sandstone	6	8		
Dark brashy rock	2	1		
Brown rock	3	11		
Blue clay	2	0		
Very hard grey rock	4	0		
Brown brashy rock (water 20 galls. a min.)	2	6	28	0
Blue [clay], mild	4	6		
Blue clay, very strong and gritty	13	6		
Grey rock	37	6		
Cank and pebbles	4	0		
Grey rock, very strong	9	0		
Cank, pebbles and limestone (Water 200 galls. a min.)	6	6	103	0
Strong dark clay, with rock	8	0		
Blue and red clay with balls of ironstone	4	7		
Grey sandstone	60	0		

—	Thickness.		Depth.	
	Ft.	In.	Ft.	In.
Cank, pebbles and limestone - - -	15	1	190	8
Strong rocky bind - - - - - -	11	11		
Very strong grey rock - - - - -	15	6		
Red marl and fireclay, good - - -	5	0		
Rocky bind - - - - - - - -	7	0		
Very strong grey rock, red in joints - -	3	6		
Very strong dark grey rock - - -	16	6		
Strong dark rocky bind - - - - -	10	4		
Red marl, good - - - - - - - -	15	0		
Light blue marl, strong - - - - -	4	8		
Light clunchy fireclay - - - - -	3	3		
Rocky bind - - - - - - - -	2	6		
Light clunchy fireclay - - - - -	16	1		
Dark bind - - - - - - - - -	2	2		
Coal, No. 1 - - - - - - - -		3	304	4
Dark fireclay - - - - - - - -		3		
Red marl, good - - - - - - -	6	0		
Light fireclay - - - - - - - -	6	7		
Strong light rock - - - - - -	11	0		
Fireclay - - - - - - - - -	2	6		
Blue rock - - - - - - - - -	12	6		
Light blue rock, very strong - - -	41	5		
Rocky bind - - - - - - - -	7	0		
Grey rock - - - - - - - - -	6	1		
Rocky bind - - - - - - - -	3	0		
Grey rock - - - - - - - - -	2	6		
Very rough light rock, mixed - - -	6	0		
Strong grey rock - - - - - -	9	3		
Red fireclay - - - - - - - -	2	3		
Blue rock - - - - - - - - -	20	5		
Coal, No. 2 - - - - - - - -	2	2½	443	3½
Black bat - - - - - - - - -	3	0½		
Rocky bind - - - - - - - -	9	2		
Black bat - - - - - - - - -		3		
Coal, No. 3 - - - - - - - -	1	2	456	11
Dark prickings - - - - - - - -		2		
Strong rocky bird - - - - - -	13	6		
Rock, cank and bind mixed, very strong -	12	0		
Grey rock - - - - - - - - -	3	0		
Dark bind, very greasy - - - - -	14	6		
Coal, No. 4 - - - - - - - -		6	500	7
Dark bat - - - - - - - - -		6		
Fireclay - - - - - - - - -	1	0		
Light fireclay - - - - - - - -	3	8		
Black bat - - - - - - - - -		4		
Dark brown rock, very strong - - -	10	8		
Coal, The Four-Feet Coal - - -	4	4	521	1
Dark prickings - - - - - - - -		4		
Dark clunchy fireclay - - - - -	5	0		
Grey rock, very strong - - - - -	21	0		
Black bat - - - - - - - - -		3		
Blue bind, very strong - - - - -	4	6		
Dark bind - - - - - - - -	7	6		
Light ironstone - - - - - - - -		2		
Blue bind - - - - - - - - -	3	0		
Ironstone - - - - - - - - -		1		
Dark smutty bat - - - - - -		3		
Coal, soft dicey coal - - - - - -	4	4	567	6

——	Thickness.		Depth.	
	Ft.	In.	Ft.	In.
Soft dark bind - - - - - - -	2	9		
Brown rock - - - - - - -	2	6		
Dark bind - - - - - - - -	13	7		
Brown ironstone - - - - - -		2		
Dark bind - - - - - - - -	7	5		
Dark shale and rattlejack - - - - -	2	4		
Coal, THIN RIDER COAL - - - - -	2	9	599	0
Dark prickings - - - - - - -		7		
Very strong light clunch mixed with ironstone balls - - - - - - -	7	6		
Rocky bind, dark - - - - - -	15	5		
Light stone - - - - - - -		6		
Rocky bind, dark blue - - - - -	1	6		
Dark slume - - - - - - -	1	0		
Coal, RIDER COAL - - - - - -	4	4	629	10
Pricking - - - - - - - -		5		
Coal, BARE COAL - - - - - -	2	10	633	1
Black bat - - - - - - - -		2		
Light clunchy fireclay - - - - -	6	2		
Strong dark bind - - - - - -	3	10		
Coal and dark clunch mixed - - -	7	0	650	3
Blue clunchy bind - - - - - -	3	0		
Brown rock, very strong, mixed with ironstone balls - - - - - -	14	6		
Rocky bind - - - - - - -	5	6		
Blue bind - - - - - - -		3		
Coal, inferior - - - - - - -	2	0	675	6
Blue bind - - - - - - - -		6		
Strong white rock - - - - - -	3	6		
Blue bind, mixed with ironstone balls -	2	5½		
Black shale - - - - - - -	1	6		
Rocky bind, mixed with ironstone balls -	3	10		
Blue flaky bind - - - - - -	7	2		
Coal, good - - - - - - -	1	4	695	9
Grey rocky bind with streaks - - -	9	3		
Blue bind - - - - - - - -	1	6		
Coal and black bat - - - - - -	4	3	710	9
Dark pricking - - - - - -		4		
Light clunchy bind, very strong, with balls of ironstone - - - - - -	10	2		
Black bat mixed with grey bat - -	4	6		
Dark clunch with ironstone balls - -	2	0		
Light flint rock - - - - - -	5	4		
Blue bind - - - - - - - -		4		
Strong rocky bind mixed with stone - -	11	4		
Blue bind - - - - - - - -	3	0		
Black bat - - - - - - - -	1	0		
Coal, SMITHY COAL - - - - -	2	3	751	0½
Dark clunch - - - - - - -	1	4		
Strong rocky clunch with balls of white stone - - - - - - - -	3	2		
Dark clunch mixed with ironstone balls	11	3		
Dark pricking - - - - - - -		3		
Coal - - - - - - - - -	2	0	769	0½
Black shale - - - - - - -	2	9		
Dark pricking - - - - - - -		9		
Coal - - - - - - - - -		4	772	10½
Clunch - - - - - - - -		5		

——	Thickness.		Depth.	
	Ft.	In.	Ft.	In.
Black bat - - - - - - - -		4		
Clunch - - - - - - - -	1	4		
Strong white rock - - - - - -	5	7		
Rocky bind with flakes of ironstone -	4	0		
Ironstone, not regular - - - - -		2		
Grey rock, very strong - - - - -	2	7		
Blue bind - - - - - - -	2	11		
Ironstone, not regular - - - - -		2		
Blue bind - - - - - - -	1	10		
Ironstone bed - - - - - - -		2½		
Blue bind - - - - - - -	1	7½		
Ironstone bed - - - - - - -		2		
Blue bind - - - - - - -	2	5		
Soft clunchy bind - - - - - -		2		
Ironstone bed - - - - - - -		5½		
Dark bind - - - - - - - -	3	0		
Dark pricking - - - - - - -		2		
Dark bind with flakes of ironstone - -	8	11½		
Coal - - - - - - - - -	2	3	811	7½
Soft bind - - - - - - - -	2	6		
Coal, Seven-feet Coal - - - - -	6	0	820	1½
Pricking - - - - - - - -		3		
Clunchy bind with ironstone balls - -	1	0		
Strong clunchy bind - - - - - -	4	1		
Clunchy bind with ironstone balls - -	5	3	830	8½

Birch Coppice Colliery, Polesworth.

Old Shaft. No. 1 of Ordnance Map.

From Mr. G. Fowler.

——	Thickness.		Depth.	
	Ft.	In.	Ft.	In.
Brown sandstone - - - - -				
Blue marl - - - - - - - -				
White sandstone - - - - - -				
White rag stone - - - - - -				
Brown sandstone - - - - - -				
Brown sandstone, with gravel - - -				
Fireclay - - - - - - - -				
Bind - - - - - - - - -				
Grey rock - - - - - - - -				
Coal - - - - - - - - -		3	322	2
Grey rock - - - - - - - -				
Blue bind - - - - - - - -				
Grey rock - - - - - - - -				
Coal - - - - - - - -		4	389	1
		8	391	11
Coal - - - - - - -		9	415	3
Coal - - - - - - - - -		5	446	4
Black ball, coal and grey rock - - -				
Coal, Four-feet Coal - - - - -	2	0	479	5
Grey rock - - - - - - - -				
Bind and ironstone - - - - - -				

—	Thickness.		Depth.	
	Ft.	In.	Ft.	In.
Coal - - - - - - - - -	2	3	522	8
	1	6	524	2
	2	0	526	2
Dark bind - . - - - - - -				
Coal, Thin Rider Coal - - - - -	3	6	558	5
Blue bind - - - - - - -				
Coal, Rider Coal - - - - - -	2	6	601	5
Brown skerry rock - - - - - -				
Coal - - - - - - - - - -	1	0	628	11
Clunch and ironstone - - - - -				
Coal - - - - - - - - - -		3	649	8
Blue bind - - - - - - - - -				
Coal - - - - - - - - - -	1	4	671	3
Coal, Smithy Coal - - - - - -	2	3	735	0
Coal - - - - - - - - - -	1	9	753	3
Blue bind and ironstone - - - - -				
Blue bind - - - - - - - - -				
Coal, The Thin Coal - - - - -	2	3		
Coal, Seven-feet Coal - - - - -	6	0	800	1

Pooley Hall Colliery, Polesworth.

From Mr. W. Hill.

—	Thickness.		Depth.	
	Ft.	In.	Ft.	In.
Raised top and soil - - - - - -	4	0		
Clay, chiefly yellow and strong - - -	2	6		
Blue marl - - - - - - - - -	4	0		
Blue marl - - - - - - - - -	7	6		
Sand and loam - - - - - - - -	2	6		
Post - - - - - - - - - -	1	6		
Coal (soft) - - - - - - - -	4	6	26	6
Dark seggar - - - - - - - -	1	3		
Dark seggar - - - - - - - -	1	0		
Post - - - - - - - - - -	3	6		
Blue clunch - - - - - - - -	11	6		
Bastard seggar - - - - - - - -	7	10		
Post (water 300 to 400 galls. per min.) -	1	0		
Post, very jointy - - - - - - -	22	0		
Coal - - - - - - - - -	1	6	76	1
Bastard seggar - - - - - - - -	3	0		
Seggar - - - - - - - -	1	0		
White post - - - - - - - -	8	0		
Kind bind - - - - - - - -	2	4		
Bastard bind - - - - - - - -	10	0		
Bind with layers of post - - - -	7	8		
Dark fireclay - - - - - - - -	5	0		
Coal - - - - - - - - - -		6	113	7
Dark fireclay - - - - - - - -	2	0		
Dark fireclay mixed with layers of bind and ironstone balls - - - - -	6	0		
Kind flaky binds - - - - - - -	4	6		
Kind blue binds - - - - - - -	40	3		

——	Thickness.		Depth.	
	Ft.	In.	Ft.	In.
Coal, in the southern half of the shaft, but running out to a thread on the other side	4	0	170	4
Black shale		2		
Bastard fireclay	2	3		
Fireclay mixed	1	4		
Coal	3	2	177	3
Fireclay	1	0		
Blue ground with ironst. balls (some water)	4	6		
Bind	2	0		
Light sandstone	7	0		
Rock bind	3	0		
Rock bind	4	9		
Black parting		2		
Coal		9	200	5
Black parting		6		
Coal	1	0	201	11
Bat		5		
Dark fireclay	3	0		
Black shale		1		
Bastard fireclay with ironstone balls	5	2		
Light binds	19	0		
Coal and bat mixed	1	6	231	1
Fireclay with ironstone balls	4	4		
Coal, coarse and hard	2	8	238	1
Fireclay		6		
Coal		6	239	1
Fireclay, good	1	6		
Bastard fireclay	1	6		
Light rock binds	1	5		
Grey sandstone	3	0		
Light blue bind	1	0		
Grey sandstone	10	0		
Kind blue bind	3	0		
Mixed grey and white sandstone	5	0		
Kind bind	2	0		
Coal	1	6	269	0
Strong patch	1	0		
White fireclay		9		
Coal		9	271	6
White fireclay with ironstone balls	5	9		
Bastard fireclay with ironstone balls	4	6		
Bastard rock		9		
Bastard fireclay	2	9		
Black rock	3	0		
Kind binds	10	6		
Bat		6		
Coal	1	6	300	9
Bastard fireclay	5	0		
Sandstone		6		
Binds with layers of stone	6	0		
Black ground	4	0		
Coal	3	6	319	9
Fireclay	3	8		
Smut and coal		6		
Fireclay with ironstone	2	6		
Blue bind with layers of stone	9	0		
Coal		2		
Grey sandstone, hard	18	10		

—	Thickness.		Depth.	
	Ft.	In.	Ft.	In.
Coal - - - - - - - - - -	2	2	356	7
Dark pricking - - - - - - -		4		
Bastard fireclay ironstone balls - -	3	0		
Grey post - - - - - - - -	2	3		
Bind - - - - - - - - - -		6		
Dark grey post - - - - - - -	1	3		
Dark bind with layers of stone and ironstone balls - - - - - - -	13	6		
Coal, inferior burning - - - - -	2	3	379	8
Black ground - - - - - - - -	1	0		
Dark fireclay - - - - - - - -	5	6		
Dark rock with layers of stone - - -	5	3		
Grey peldon - - - - - - - -	6	9		
Blue rock bind with stone - - -	1	9		
Blue bind with bands of stone - - -	11	6		
Rock - - - - - - - - - -	1	0		
Dark bind - - - - - - - -	8	6		
Dark bind - - - - - - - -	9	10		
Dark bind with little stone - - -	6	7		
Coal - - - - - - - - - -	2	9	440	1
Fireclay - - - - - - - - -		9		
Gob. Seven-feet Coal - - - - -	3	6	444	4
Light fireclay - - - - - - -	1	6		
Coal. Trencher Coal - - - - -		6	446	4
Fireclay - - - - - - - - -	3	6		
Strong brown fireclay - - - - -	1	6		
Strong rock bind with stone balls - -	25	10		
Dark ground with stone balls - - -	1	8		
Rock bind with stone balls - - -	19	6		
Bat - - - - - - - - - -		3		
Coal, bright - - - - - - -		9		
Coal, hard - - - - - - - -	1	3	500	7
Dark fireclay - - - - - - - -	5	3		
Dark fireclay - - - - - - - -	2	0		
Dark broken clay - - - - - -	2	6		
Whin - - - - - - - - -	4	0		
Rock bind - - - - - - - -	2	0		
Grey post - - - - - - - -	2	6		
Grey post - - - - - - - -	5	0		
Rock bind with stone balls - - -	6	6		
Black shale - - - - - - - -	2	9		
Coal - - - - - - - - - -	3	6	536	7
Dark fireclay - - - - - - - -	3	4		
Coal - - - - - - - - - -		9	540	8
Dark fireclay - - - - - - - -	3	10		
Blue rock bind with stone balls - -	17	10		
Coal - - - - - - - - - -	2	5	564	9
Dark fireclay - - - - - - - -	3	6		
Coal, Double Coal - - - - - -	4	8	572	11
Light fireclay - - - - - - - -	6	6		
Grey post - - - - - - - -	4	4		
Blue bind - - - - - - - -	1	2		
Light rough rock - - - - - -	3	2		
Blue rock bind - - - - - - -	3	6		
Grey peldon - - - - - - - -	2	6		
Blue rock bind - - - - - - -	5	6		
Blue rock bind - - - - - - -	1	6		
Grey peldon - - - - - - - -	2	0		
Bind parting - - - - - - -		2		

—	Thickness.		Depth.	
	Ft.	In.	Ft.	In.
Grey peldon	2	0		
Light rock	1	0		
Blue bind with layers of stone	5	0		
Fireclay		2		
Black shale		6		
Coal	4	10	616	9
Dark fireclay	2	1		
Black ground		6		
Ring of coal		4		
Dark fireclay	1	0		
Black bat	2	0		
Dark bind with layers of stone	5	8		
Coal, BENCH COAL	4	6	632	10
Dark fireclay	7	0		
Black ground	2	6		
Black ground	6	6		
Fireclay rock	5	0		
Strong blue bind with balls of stone	10	6		
Blue bind jointy with balls of stone	8	0		
Black bind with balls of stone	2	7		
Black bat	3	4		
Coal	1	6	679	
Dark fireclay	1	6		
Peldon				

Polesworth Colliery.

From a paper by the Rev. James Yates in the Geol. Trans., 2nd Series, vol. ii., p. 261. The section was furnished by Dr. Power, of Lichfield.

—	Thickness.		Depth.	
	Ft.	In.	Ft.	In.
Soil and clay	37	6		
Brown rocky clunch	12	0		
Smut		6		
Fireclay	5	6		
Pimply	4	0		
Bind	9	0		
Bind ; ironstone	4	0		
Blue bind	4	0		
Coal, ELL OR FOUR-FEET COAL	4	6	81	0
Fireclay	3	0		
Blue bind	14	0		
Rock	25	0		
Coal, UPPER SOUGH COAL	2	6	125	6
Clay and clunch	4	0		
Rock	3	0		
Coal		3	132	9
Fireclay	2	0		
Bind	5	9		
Black clod		8		
Ironstone bind	11	8		
Coal and clot. HALF-YARD COAL	2	0	154	10
Fireclay	2	3		
Rock	3	4		
Ironstone bind	11	8		
Coal, SLATE COAL	7	3	179	4

—	Thickness.		Depth.	
	Ft.	In.	Ft.	In.
Fireclay and pimply	7	0		
Scurry	12	3		
Bind and slums	7	6		
Coal, SMITHY COAL	2	4	208	5
Pimply	14	0		
Black clod with ironstone	3	2		
Coal, STONE COAL	3	0	228	7
Fireclay	1	2		
Mainstone	3	0		
Blue bind	9	0		
Ironstone		10		
Blue bind	2	6		
Ragstone		8		
Blue bind	3	0		
Coal, THIN COAL	1	8	250	5
Soft fireclay	9	0		
Strong bind	21	0		
Coal, MAIN OR SEVEN-FEET COAL	6	0	286	5

Polesworth Colliery.

MESSRS. SHAW AND CO.'S PIT NEAR THE RAILWAY STATION.
From Rev. W. H. Coleman's MSS.

—	Thickness.		Depth.	
	Ft.	In.	Ft.	In.
Soil		9		
Gravel and sand	16	0		
Blue bind	1	6		
Coal smut	2	0	20	3
Clunch	6	0		
Blue bind	11	0		
Stony bind	7	6		
Strong blue stone	2	3		
Blue bind	10	6		
Coal	1	4	58	10
Stony clunch	6	6		
Stony bind; ironstone balls	9	6		
Clunch and bat; ironstone balls	7	3		
Strong bind	6	6		
Soft bind	1	6		
Coal		3	90	4
Strong bind	10	3		
Soft bind	1	6		
Clunch and bat	3	0		
Stony clunch	6	6		
Blue bind; ironstone	12	10		
Coal. SMITHY COAL	2	4	126	9
Clunch	4	6		
White sandstone	3	6		
Stony bind	7	3		
White stone	1	6		
Blue bind; ironstone	21	6		
Ragstone	2	6		
Soft blue bind	10	0		
Coal	1	3	178	9
Dun-coloured clunch	5	0		
Dark-coloured clunch	6	0		
Coal. MAIN OR SEVEN-FEET COAL	6	0	195	9

Tamworth Colliery.

From Messrs. Langford and Ridsdale.

——	Thickness.		Depth.	
	Ft.	In.	Ft.	In.
Surface clay	4	0		
Measures	6	0		
Coal	1	6	11	6
Fireclay	15	6		
Measures	21	6		
Sandstone (water)	5	6		
Measures	27	6		
White rock (water)	10	0		
Measures	108	0		
Coal	2	8	202	2
Fireclay or clod	9	0		
Coal	3	10	215	0
Measures	221	10		
Ironstone	3	2		
Coal, Smithy Coal	3	0	443	0
Measures	26	2		
White ironstone	4	10		
Measures	26	9		
Coal	2	9	503	6
Parting		6		
Coal	6	0	510	0
Fireclay	6	0		
Measures	51	4		
Coal	2	8	570	0
Measures				
Coal	2	11		
Fireclay				
Measures				
Coal	1	11	600	0
Measures				
Coal. Deep or Double Coal	4	3	615	0
Measures				
Coal, Bench Coal	5	0	654	0

Glascote Colliery.*

From Rev. W. H. Coleman's MSS.

——	Thickness.		Depth.	
	Ft.	In.	Ft.	In.
Ground	20	0		
Yellow clay	7	6		
Coal	1	8	29	2
Fireclay	1	2		
White pipeclay	2	6		
Blue bind	11	0		
Coal		6	44	4
Fireclay	4	1		
Red fireclay	7	3		
Blue bind	1	8		
Sandstone	16	0		
Bind and fireclay	9	3		
Sharp stone	1	2		
Blue bind	19	6		
Coal	2	1	105	4

* Mr. Grayston has furnished us with the details of the shaft at Amington belonging to this Company, but has requested us to withhold its publication for the present.

—	Thickness.		Depth.	
	Ft.	In.	Ft.	In.
Black fireclay	2	6		
Black fireclay	4	0		
Black fireclay	3	6		
Blue bind	49	6		
Coal. Ell or Four-Feet Coal	3	6	168	4
Blue bind	32	0		
Coal		6	200	10
Fireclay	1	0		
Sandstone	9	0		
Clunchy bind	18	0		
Coal, soft	1	9	230	7
Fireclay	2	0		
Bind and ironstone	21	0		
Fireclay	1	6		
Coal	2	3	257	4
Grey rocky bind	12	0		
Blue bind	6	0		
Coal, Half-Yard Coal	2	0	277	4
Fireclay		6		
Blue bind	21	9		
Coal, Slate Coal	2	0	301	7
Fireclay	4	6		
Coal (Bat)	4	0	310	1
Blue bind	10	8		
Sandstone (skerry)	18	0		
Blue bind (ironstone)	21	0		
Bind	2	0		
Coal, Stone Coal	1	3	363	0
Fireclay		9		
Mainstone rock	12	0		
Blue bind (ragstone)	34	0		
Blue bind	20	6		
Coal, Thin Coal	2	3	432	6
Duns	2	0		
Coal, Seven-Feet Coal	6	0	440	6
Fireclay	6	0		
Clunch	18	0		
Coal	2	3	466	
Grey rocky bind	6	0		
Sharp stone	3	0		
Stony bind	14	6		
Black bat	1	6		
Coal	2	0	493	9
Sharp rock	3	0		
Blue clunch		11		
Coal		6	498	2
Fireclay	3	5		
Rock	31	8		
Rocky bind	4	6		
Black bat (ironstone)	3	0		
Coal	4	0	544	9
Fireclay	2	6		
Bat	2	4		
Coal	2	0	551	7
Clay		8		
Coal, Bench Coal	5	4	557	7
Blue bind	28	6		
Coal	9	0	595	1
Clunchy bind	19	6	614	7

Lindley Hall.

Boring No. 1.

By Mr. Hemming.

From Rev. W. H. Coleman's MSS.

—	Thickness.		Depth.	
	Ft.	In.	Ft.	In.
Soil	7	0		
Red clay and marl	4	6		
Mottled ground	2	6		
Blue skerry	1	0		
Rock marl	99	0		
Blue skerry		6		
Blue bind		6		
Hard blue rock		6		
Rock marl and gypsum	41	6		
Hard blue rock	1	0	158	0
Rock marl and blue skerry	6	0		
Rock marl	14	0		
Hard blue rock	9	0		
Strong mottled ground	9	0		
Rock marl and blue skerry	42	0		
Rock marl and gyspum	24	6		
Hard blue rock	2	6		
Mingled ground	9	0		
Red marl	17	6		
Gypsum. Marl partings	3	0	294	6
Red mottled rock	2	6		
Rock marl	3	6		
White gypsum		6		
Mingled ground	6	0		
Red clunch	1	0		
Rock marl	6	6		
Red clunch	2	0		
Mingled ground	8	0		
Blue clunch	0	6		
Hard mottled rock	7	6	332	6
Hard stone or peldon		6		
Blue and mottled ground	7	6		
Rock marl	2	6		
Hard blue rock	2	6		
Blue and mottled ground	9	6		
Rock marl	14	6		
Hard blue rock		6		
Mottled ground	5	6		
Hard blue rock	4	0		
Blue and mottled ground	3	0	382	6
Rock marl	12	0		
Grey rock and peldon	4	0		
Dark red rock	2	0		
Blue rock and bind	1	6		
Blue and mottled rock	19	6		
Blue rock and bind	10	6		
Rock marl and gypsum	1	6		
Blue bind and clunch	9	0		
Red and mottled ground	17	6		
Blue bind and clunch	3	0	463	0

	—	Thickness.		Depth.	
		Ft.	In.	Ft.	In.
	Rock marl and gypsum	7	6		
	Strong mottled ground	8	6		
	Brown rock with marl	10	0		
	Rock marl	1	6		
	Blue and mottled rock	6	0		
	Blue rock	3	0		
	Mottled clunch	2	0		
	Brown sandstone	6	0		
	Blue rock and smut	6	6		
60	Mottled rock	8	0	522	0
	Blue rock, with partings	3	0		
	Blue clunch	0	6		
	Light rock	1	0		
	Mottled rock	5	6		
	Light peldon	1	6		
	Red and mottled rock	19	0		
	Blue bind	1	6		
	Red and mottled rock	10	6		
	Hard blue bind	2	0		
70	Close red sandstone	18	0	584	6
	Mottled rock	13	6		
	Blue rock and bind	1	6		
	Mottled partings	1	9		
	Light peldon		6		
	Red and blue rock	14	3		
	Blue bind	1	6		
	Red sandy rock	3	6		
	Strong light blue bind	4	6		
	Peldon, with smut	2	6		
80	Brown rock	1	0	629	0
	Rock marl	3	0		
	Hard brown rock	4	0		
	Rock marl and sandstone alternating	24	6	660	6

Lindley Hall.

Boring No. 2.

From Rev. W. H. Coleman's MSS.

	—	Thickness.		Depth.	
		Ft.	In.	Ft.	In.
	Soil and clay	4	0		
	Rock marl and skerry	14	0		
	Sandstone	1	6		
	Blue skerry		6		
	Rock marl	16	6		
	Blue marl	1	6		
	Rock and marl	21	0		
	Hard grisly rock	2	0		
	Red sandy marl	33	6		
10	Rock marl and gypsum	7	0	101	6
	Hard grisly rock	1	0		
	Strong marl	5	0		
	Blue rock or skerry	2	0		

	——	Thickness.		Depth.	
		Ft.	In.	Ft.	In.
	White gypsum	1	6		
	Red sandstone	1	0		
	Rock marl and gypsum	32	6		
	Hard brown grisly rock	4	0		
	Gypseous marl and skerry	9	8		
	Blue mottled clunch	1	0		
20	Rock marl with gypsum	22	0	181	2
	Hard variegated rock	7	0		
	Gypseous marl and sandstone	20	4		
	Blue mottled rock	1	6		
	Rock marl and sandstone	12	0	222	0

Lindley.

Boring in a Field called Barn Close, between Chads Lane and Watling Street, near Lindley.

From Rev. W. H. Coleman's MSS.

	——	Thickness.		Depth.	
		Ft.	In.	Ft.	In.
	Soil	2	0		
	Gravel		6		
	Blue marl and skerry	3	6		
	Red marl	2	6		
	Blue sandy marl	3	0		
	Red rock and marl	8	0		
	Blue marl	1	0		
	Strong red marl	7	9		
	Blue sandy marl	4	6		
10	Red marl	9	0	41	9
	Blue marl	1	0		
	Strong red marl	8	3		
	Variegated rock	29	0		
	Sandy rock	2	0		
	Rock marl	4	6		
	Mottled rock	2	6		
	Rock marl	16	6		
	Mottled ground	2	0		
	Blue sandstone	1	6		
20	Sandy rock marl	37	6	146	6
	Rock marl and gypsum	19	6		
	Dark mottled ground	1	6		
	Rock marl and gypsum	51	6		
	Blue and mottled rock	4	0		
	Rock marl and gypsum	11	0		
	Red rock	3	0		
	Brown peldon	1	3		
	Red rock and marl with gypsum	28	0		
	Brown and grisly rock		9		
30	Marl		9	267	9
	Dark shaly lines	1	0		
	Rock marl and gypsum	15	6	284	3

Lindley.

BORING ON THE OLD POND SIDE OF LINDLEY WOOD.

	—	Thickness.		Depth from Surface.	
		Ft.	in.	Ft.	in.
	Soil and clay	3	0		
	Sandy clay	1	6		
	Marl and sandstone	4	0		
	Blue sandstone	4	6		
	Red sandstone and marl	14	0		
	Blue rock	7	0		
	Brown rock	4	0		
	Red sandstone and marl	11	0		
	Mottled rock	5	0		
10	Red sandstone and marl	5	0	59	0
	Sandstone	1	6		
	Red sandstone	8	0		
	Mottled clunch	3	6		
	Red sandstone and marl	7	6		
	Blue rock	1	6		
	Sandy marl	3	6		
	Mottled rock	1	6		
	Blue and red sandstone and marl	20	0		
	Mottled rock	5	0		
20	Marl	4	0	115	0
	Red sandstone	3	0		
	Marl and sandstone	36	0		
	Blue and mottled rock	9	0		
	Marl and sandstone with gypsum	39	0		
	Blue rock	4	0		
	Gypseous rock	18	0		
	Mottled rock	6	6		
	Blue rock	4	0		
	Brown rock	12	0		
30	Gypseous marl and sandstone	12	6	259	0
	Blue rock	3	0		
	Rock marl and gypsum	20	6		
	Rock and peldon	1	6		
	Marl and gypsum	5	0		
	Blue and mottled rock	7	6		
	Rock marl	2	0		
	Blue and mottled rock	4	6		
	Brown rock	19	6		
	Blue rock and smut	2	0		
40	Mottled ground	9	0	333	6

APPENDIX II.

LIST OF WORKS ON THE GEOLOGY OF LEICESTERSHIRE,

INCLUDING A FEW REFERRING TO THE IMMEDIATE NEIGHBOURHOOD.

By C. Fox-Strangways, aided by W. Whitaker, F.R.S.

LIST OF AUTHORS.

The figures refer to the dates of publication, those in brackets indicating the Maps and Sections of the Geological Survey.

A.

Adams, A. Leith, 1877-1881, 1879.
——— W., 1877.
Allport, S., 1870, 1874, 1879.
Allsop, C., 1842.
Ansted, Prof. D. T., 1863, 1866.
Atkins, A. F., 1883.
Aveline, W. T., (1859), 1860, 1877.

B.

Bakewell, R., 1812, 1819.
Bates, E. F., 1886.
Bauerman, H., 1858.
Beasley, H. C., 1890, 1892.
Bemrose, H. H. Arnold, 1896.
Bennett, Dr. F. W., 1899.
Berry, E. E., 1882.
Binns, J. G., 1897.
Blake, C. C., 1862.
—— , J. F., 1891-1894, 1892.
Bonney, Rev. T. G., 1876, 1877, 1878, 1879, 1880, 1885, 1887, 1890, 1891, 1892, 1893, 1894, 1895, 1900.
Bragge, G. S., 1886.
Bristow, H. W., 1858.
Britton, J., 1807.
Brodie, Rev. P. B., 1857, 1867, 1874, 1875, 1876, 1881, 1884.
Brown, E., 1862.
———, H. T., 1887, 1889.
Browne, A. J. Jukes, 1885, 1888, 1890.
————, M., 1888, 1890, 1891, 1892, 1893, 1894, 1895, 1896, 1897.
Buckland, Rev. Prof. W., 1823.
Burton, W., 1622.

C.

Callaway, C., 1881, 1889, 1895.
Carr, J. W., 1896.
Clifford, J., 1880.
Coke, G. E., 1896.
Coleman, Rev. W. H., 1846, 1863.

L.

M.

N.

O.

P.

Q.

R.

S.

MAPS AND SECTIONS OF THE GEOLOGICAL SURVEY.

Maps.—Scale 1in. to a Mile.

Quarter-sheet 53 N.E.—[Rugby] W. T. AVELINE and H. H. HOWELL. 1859.

Quarter-sheet 62 N.E.—[Tamworth] H. H. HOWELL. 1856.

Quarter sheet 63 N.W.—[Ashby-de-la-Zouch and Market Bosworth] H. H. HOWELL and E. HULL. 1855.

Quarter-sheet 63 N.E.—[Leicester] H. H. HOWELL. 1855.

Quarter-sheet 63 S.W.—[Hinckley] H. H. HOWELL. 1855. New edition by A. STRAHAN. 1886.

Quarter-sheet 63 S.E.—[Lutterworth and Market Harborough] W. T. AVELINE and H. H. HOWELL. 1859.

Sheet 64.—[Melton Mowbray to Market Harborough] J. W. JUDD, W. H. HOLLOWAY, and S. B. J. SKERTCHLY. 1872.

Sheet 70.—[Grantham] W. H. HOLLOWAY and others. 1886.

Quarter-sheet 71 S.W.—[Derby to Ashby-de-la-Zouch] E. HULL. 1855.

Quarter-sheet 71 S.E.—[Nottingham to Loughborough] E. HULL. 1855.

Sheet 155 New Series, *Solid and Drift*.—[Atherstone to Charnwood Forest] C. FOX-STRANGWAYS and W. W. WATTS. 1899.

Horizontal Sections.—Scale 6in. to a mile.

Sheet 46.—No. 1. Section from North-West to South East, from the Trent near Repton to Bardon Hill, Leicestershire, crossing the New Red Sandstone, the Coleorton Coalfield by Whitwick and Swannington Collieries and the Millstone Grit and Carboniferous Limestone near Ticknall, by E. HULL. No. 2. From Nailstone Church, through Bagworth Colliery, south end of Charnwood Forest, Woodhouse Eaves, Buddon Wood, to the Lias Limestone quarries near Barrow-on-Soar. By. H. H. HOWELL. 1858.

Sheet 48.—Section from Lazy Hill across the Permian and New Red

Sandstone to Glascote; the North end of the Warwickshire Coalfield, through Glascote Colliery, Hermitage Hill, and Poleswortli to Grendon; from Grendon through Orton-on-the-Hill, Gopsall Park, Heather Mill, near Whitwick Colliery, North end of Charnwood Forest, Garendon Park, near Stanford Hall, to Wysall. By H. H. HOWELL. 1858.

Sheet 49.—No. 1. Section from Barr Beacon across the New Red Sandstone, Permian Strata, and Warwickshire Coalfield, through Sutton Park, Kingsbury, Hurley, Baxterley, and Merivale to Radcliffe Culey, near Atherstone. No. 2. From the New Red Sandstone, Bodymoor Heath, near Kingsbury, across the Warwickshire Coalfield through Cliff, Hockley, and Wilnecote to Shuttington, from Shuttington across the New Red Sandstone by No Man's Heath and Donisthorpe, the Leicestershire Coalfield, by Moira, the Carboniferous Limestone of Ticknall, to the Red Marl of Chellaston Hill, Derbyshire. By H. H. HOWELL. 1858.

Sheet 52.—No. 1 Section North and South from the Trent at Newton Solney to Swepstone, crossing the Ashby-de-la-Zouch Coalfield (Leicestershire) at Newall, Gresley, Moira, and Measham Hall. No. 2 Section from West to East, crossing the New Red Sandstone by Linton, the Coal Measures of Ashby Woulds and Coleorton Common, the Carboniferous Limestone of Grace Dieu and the Cambrian rocks of the North part of Charnwood Forest. By E. HULL. 1858.

Sheet 122.—Section from the Three Shire Stone, four miles N.W. of Kimbolton (Hunts), through Thrapston, Rockingham Forest (Northamptonshire), Uppingham (Rutland), and across Burrow Hill to the River Eye, west of Melton Mowbray (Leicestershire). By W. H. HOLLOWAY and W. H. PENNING. 1879.

Sheet 124.—Section from Buddon Wood across Mount Sorrel, Burrow Hill (Leicestershire), The Vale of Catmos, through Oakham and Ketton (Rutland), to the Fenland at Peterborough (Northamptonshire). By W. H. HOLLOWAY and W. H. PENNING. 1887.

Vertical Sections. Scale 40 *feet to* 1 *inch.*

Sheet 19.—Sections in the Leicestershire (Ashby-de-la-Zouch) Coalfield, Eastern or Coleorton District: Bagworth, Ibstock, Snibston No. 2, Snibston No. 1, Whitwick, Heather, Swannington, Peggs Green, Coleorton, Lount, Heath End, Rough Park Wood, and Woodville. By E. HULL. 1856.

Sheet 20.—Sections in the Leicestershire (Ashby-de-la-Zouch) Coalfield, Western or Moira District: Donisthorpe Old Colliery, Hastings and Grey Shaft and Rawdon Shaft Moira, Granville Colliery, Gresley Wood, Whitehouse, Oakthorpe, Woodfield, Swadlincote, Arthcote, New Stanton, and Gresley Common. By E. HULL. 1857.

LIST OF WORKS.

1622.

BURTON, W.—The Description of Leicestershire; containing Matters of Antiquity, History, Armorye, and Genealogy. [P. 2, soils.] 4to. *London.* Ed. 2, 1777.

1740.

SHORT, DR. T.—An essay towards a Natural, Experimental, and Medicinal History of the Principal Mineral Waters of......Leicestershire......particularly those of Neville Holt......etc. 4to. *Sheffield.*

1748.

HILL, J.—A General Natural History [Gypsum at Mt. Sorrel, p. 114]. 3 vols. Folio. *London.*

1765.

ANON. [DR. T. SHORT].—A General Treatise on various Cold Mineral Waters in England, but more particularly those at......Neville Holt, etc. 8vo. *London.*

1781.

Jones, W.—Physiological Disquisitions; or, Discourses on Natural Philosophy of the Elements [Figure of Fossil Fish from Barrow, p. 412]. 4to. *London.*

1790.

Marshall, W.—The Rural Economy of the Midland Counties, etc. [Soils, etc., vol. i., pp. 6, 26, 28, 188; vol. ii., pp. 2, 87.] Small map. 2 vols. 8vo. *London.*

1794.

Monk, J.—General View of the Agriculture of the County of Leicester. With observations on the means of their Improvement. Drawn up for the consideration of the Board of Agriculture and Internal Improvement. [Soils, etc., p. 8.] pp. 75, Map, etc. 4to. *London.*

1795 1815.

Nichols, J.—The History and Antiquities of the County of Leicester. [Soils, minerals, and fossils, vol. ii., pp. 4, 5, 6, 144, 235, 504, 639, 700, 769; vol. iii., pp. 61, 81–84, 90, 133, 134, 143, 298, 402, 439, 614, 615, 659, 687, 739, 895, 981, 1032, 1050, 1123, 1125; vol. iv., 129, 204, 462, 815.] 4 vols. 2 pts. in each. Folio. *London.*

1807.

Anon.—[Account of the finding of the remains of a bull? at Bottesford near Grantham.] *Phil. Mag.*, vol. xxvii., p. 93.

Britton, J.—A Topographical and Historical Description of Leicestershire. *Beauties of England and Wales*, vol. ix., p. 313. 8vo. *London.*

Pitt, W.—A General View of the Agriculture of the County of Leicester, etc. [Soils, p. 3; Minerals, p. 7; Water supply, p. 10.] 8vo. *London.*

1810.

Farey, J.—Stratification of England and France. [Gypsum.] *Phil. Mag.*, vol. xxxv., p. 135.

————On the supposed Fresh-water Origin of the Gypsum Strata in the Environs of Paris; on the Geological Characters and Relations of the Alum Shales on the Northern Coasts of Yorkshire; and on the Orbicular Blocks of Sienite on Mount-Sorrel Hill, in Leicestershire. *Phil. Mag.*, vol. xxxv., pp. 256–261.

————A List of about Five Hundred Collieries in and near to Derbyshire. *Ibid.* p. 431.

1811.

Farey, J.—A List of about 280 Mines of Lead—some with Zinc, Manganese, Copper, Iron, Fluor, Barytes, etc., in and near to Derbyshire. *Ibid.* vol. xxxvii., p. 106.

————A List of about 700 Hills and Eminences in and near to Derbyshire with the Stratum that occupies the top of each, and other Particulars. *Ibid.* pp. 161–175. (Errors at p. 443.)

1812.

Bakewell, R.—Reply to Mr. Farey's Geological Observations. *Phil. Mag.*, vol. xl., p. 45.

1812–1846.

Sowerby, J.; continued by J. de C. Sowerby.—The Mineral Conchology of Great Britain. [Leicestershire, vol. i., pp. 33 and 128, 1812; vol. v., p. 64, 1825.] 8vo. *London.*

1813.

Farey, J.—Observations in Objections to some new Arrangements and Simplifications of the strata of England proposed by Mr. Bakewell.—A Defence of the Reality and Circumstances stated, respecting three great Faults or Dislocations of the Strata in and near Derbyshire.—On Mr. Silverwood's intended Section of all the Derbyshire Strata.—On Mr. Hall's Survey and Models of the high Peak of Derbyshire.—The slate of Charnwood Forest not stratified, etc. *Phil. Mag.*, vol. xlii., pp. 103–116.

PITT, W., and R. PARKINSON.—A General View of the Agriculture of the Counties of Leicester and Rutland drawn up for the consideration of the Board of Agricultural and Internal Improvement, with a Map and Plates. 8vo. *London.*

1815.

SMITH, W.—A Delineation of the Strata of England and Wales, with part of Scotland, etc. [Map of the Strata in fifteen sheets (scale five miles to an inch), accompanied by a "Memoir" of fifty-one quarto pages.] *London.*

1819.

BAKEWELL, R.—An Introduction to Mineralogy; and the Elements of Crystallography. [Leicester Coalfield, 5th Ed., pp. 196–199, etc.] 5th Ed. under different title, 1838. 8vo. *London.*

1821.

SMITH, W.—A New Map of Leicestershire divided into hundreds exhibiting its Roads, Rivers, Parks, etc., by JOHN CAREY, Engraver, 1821. [The above geologically coloured by W. Smith.] *London.*

1822.

CONYBEARE, REV. W. D., and W. PHILLIPS.—Outlines of the Geology of England and Wales. Part i. [Ashby Coalfield, pp. 403–406.] 8vo. *London.*

1823.

BUCKLAND, REV. PROF. W.—Reliquiæ Diluvianæ; or Observations on the Organic Remains contained in Caves, Fissures, and Diluvial Gravel, and on other Geological Phenomena, attesting the action of an Universal Deluge. [Leicester pp. 196, 250. Alludes to gravel at Houghton-on-the-Hill, Hinckley, and Market Harbro'.] 4to. *London.*

PHILLIPS, W.—On the Occurrence of Cleavelandite in certain British Rocks. *Ann. Phil.*, ser. 2, vol. vi., p. 448.

1824.

PHILLIPS, W., and S. LUCK KENT.—Observations on the Rocks of Mount Sorrel, of Charnwood Forest, and of the Neighbourhood of Groby in Leicestershire. *Ibid.* vol. vii., pp. 1 19. One plate.

1827.

YATES, REV. J.—Observations on the Structure of the Border County of Salop and North Wales; and of some detached groups of Transition Rocks in the Midland Counties [p. 263 refers to Enderby and Croft]. *Trans. Geol. Soc.*, ser. 2, vol. ii., pp. 237 264.

1829.

FORSTER, F.—Extract from a Report made on the 29th of September, 1827, on the probability of finding Coal near Leicester. [Drift coal at Birstall. Small map Leicester to Ashby, 5 miles = 1 inch.] *Phil. Mag.*, ser. 2, vol. v., pp. 347–350.

1830.

DAUBENY, DR. C.—Memoir on the occurrence of Iodine and Bromine in certain Mineral Waters of South Britain. [Leicester, p. 229.] *Phil. Trans.*, vol. cxx., p. 223.

1833.

CONYBEARE, REV. W. D.—On the alleged Discovery of Coal at Billesdon, Leicestershire. *Phil. Mag.*, ser. 3, vol. iii., p. 112.

HOLDSWORTH, J.—Notice of the Discovery of Coal-Measures and of Fossil Fruits at Billesdon Coplow, in Leicestershire. *Ibid.* p. 76.

1834.

CONYBEARE, REV. W. D.—On the probable future extension of the Coalfields at present worked in England. [Leicester, pp. 346 348.] *Phil. Mag.*, vol. iv., pp. 161 and 346; vol. v., p. 44.

CONYBEARE, REV. W. D.—Inquiry how far the theory of M. Elie de Beaumont concerning the parallelism of Lines of Elevation of the same Geological Æra is agreeable to the phenomena as exhibited in Great Britain. [Charnwood, p. 409.] *Phil. Mag.*, vol. iv., pp. 404–414, concluded from vol. i., p. 126.

HOLDSWORTH, J.—A Notice of some important Geological Discoveries at Billesdon Coplow, Leicestershire, with Observations on the Nature of their Relations to the Modern System of Geology. *Mag. Nat. Hist.*, vol. vii., p. 38.

MAMMATT, E.—A Collection of Geological Facts and Practical Observations, intended to elucidate the formation of the Ashby Coal Field, in the parish of Ashby-de-la-Zouch and the neighbouring district; being the result of forty years' experience and research. [Map and profiles, coloured sections, and 102 plates of fossils. Noticed in *Proc. Geol. Soc.*, vol. ii., pp. 163, 357.] 4to. *Ashby-de-la-Zouch* and *London.*

SEDGWICK, PROF. A.—[Abstract of a paper on the Rocks of Charnwood Forest.] (Cambridge Phil. Soc.). *Phil. Mag.*, ser. 3, vol. iv., pp. 68, 69. See also C. ALLSOP, 1842.

URE, DR. A.—Analysis of Moira Brine Spring, near Ashby-de-la-Zouch, Leicestershire; and Researches on the Extraction of Bromine. *Phil. Trans.*, vol. cxxiv., p. 577.

1837.

ANON.—Abstract of a Paper on the Fossil Ichthyosaurus, from Barrow-on-Soar. *Analyst*, vol. vii., p. 233.

1838.

JUKES, J. B.—A Popular Sketch of the Geology of the County of Leicester. *Analyst*, vol. viii., p. 1.

1842.

ALLSOP, C.—Brief account of the Geological Visit of Professors Sedgwick, Airy, and Whewell to Charnwood Forest. [Written in 1833, but published posthumously in 1842 as an appendix to J. B. Jukes' account of the Geology of Charnwood in POTTER's History and Antiquities of Charnwood Forest.] 4to. *Nottingham.*

JUKES, J. B., and others. Appendix on the Geology, Botany, and Ornithology of the District, in POTTER's "History and Antiquity of Charnwood Forest." 4to. *Nottingham.* [A cheap and popular edition published by Allen, *Nottingham.*] See ANON., 1857.

1843.

MORRIS, J.—A Catalogue of British Fossils, comprising the Genera and Species hitherto described; with references to their geological distribution and to the localities in which they have been found. 2nd Ed. 1854. 8vo. *London.*

1846.

ANON. [W. H. COLEMAN]. Sketch of the Geology of Leicestershire pp. 24–27 of W. WHITE's History, Gazetteer and Directory of Leicestershire, and the small county of Rutland, together with the adjacent towns of Grantham and Stamford, etc. With a map. 12mo. *Sheffield.* See also 1863.

1849.

M'COY, F.—On the Classification of some British Fossil Crustacea with Notices of New Forms in the University Collection at Cambridge. [*Eryon Barrovensis* from Barrow, pp. 172, 173.] *Ann. Mag. Nat. Hist.*, ser. 2, vol. iv., pp. 161, 330, 392.

1850.

PLANT, JOHN.—Notice of the Discovery of Beds of Keuper Sandstone containing Zoophytes in the Vicinity of Leicester. *Rep. Brit. Assoc.* for 1849, Sections, p. 64.

1853.

TRIMMER, J.—Notes on the Geology of the Keythorpe Estate, and its relations to the Keythorpe System of Drainage. *Journ. Roy. Agric. Soc.*, vol. xiv., pp. 96–105.

1854.

EGERTON, SIR P. DE M. G.—On some new Genera and Species of Fossil Fishes. [*Pycnodus liassicus* from Barrow, p. 436.] *Ann. Mag. Nat. Hist.*, ser. 2, vol. xiii., p. 433.

1855.

EGERTON, P. DE M. G.—*Pycnodus liassicus* from Barrow-on-Soar. *Mem. Geol. Survey*, dec. viii., no. 10, pl. x.

1856.

PLANT, JAMES.—On the Upper Keuper Sandstone (included in the New Red Marls) and its Fossils at Leicester. *Quart. Journ. Geol. Soc.*, vol. xii., p. 369.

1857.

ANON. [J. B. JUKES].—Geology of Charnwood Forest. Pp. i–xxii., plate (sections). Appendix to "An Illustrated Hand Book to Charnwood Forest," by R. ALLEN. 8vo. *Nottingham and London.* Also later editions.

BRODIE, REV. P. B.—Remarks on the Lias of Barrow in Leicestershire compared with the lower part of that Formation in Gloucestershire, Worcestershire, and Warwickshire. *Ann. Mag. Nat. Hist.*, ser. 2, vol. xx., pp. 190–192; and *Proc. Cotteswold Nat. Club*, vol. ii., pp. 139–141. [Republished with but little alteration in 1867.]

FAIRBAIRN, W.—On the Comparative Value of various kinds of Stone, as exhibited by their Powers of Resisting Compression. [Mount Sorrel Granite.] *Mem. Lit. Phil. Soc. Manchester*, ser. 2, vol. xiv., pp. 31–47.

1858.

ANON. [? J. PLANT].—Report of the Geological Section. [Trias.] *Rep. Leicester Lit. Phil. Soc.*, 1858, pp. 17-22.

PLANT, JAMES.—[Letter on the] Geology of Ashby-de-la-Zouch. *Geologist*, vol. i., p. 309.

————.—[Letter on the] Triassic Strata [of Leicestershire]. *Ibid.*, p. 310.

RAMSAY, A. C., H. W. BRISTOW, H. BAUERMANN, and A. GEIKIE. A Descriptive Catalogue of the Rock Specimens in the Museum of Practical Geology, with Explanatory Notices of their Nature and Mode of Occurrence in Place. 2nd Ed., 1859; 3rd Ed., 1862 (pp. 19-21 Charnwood). 8vo. *London.*

1859.

DAVIDSON, T.—A Monograph of the British Fossil Brachiopoda. Part V. The Carboniferous Brachiopoda. [Breedon, pl. ix., p. 64; Ashby, pl. xiv., p. 69, 70.] *Palæontograph. Soc.* 4to. *London.*

HOWELL, H. H.—The Geology of the Warwickshire Coalfield. *Memoirs of the Geological Survey.* 8vo. *London.*

MARSHALL, J. G.—On the Geology of the Lake District in reference especially to the Metamorphic and Igneous Rocks. [Charnwood Forest Granite, p. 93.] *Rep. Brit. Assoc.* for 1858, p. 84.

PLANT, JAMES.—Notice of the Occurrence of Mammalian Remains in the Valley of the Soar, Leicestershire. *Geologist*, vol. ii., p. 174.

————Blocks of Lower Oolite in the Drift-Clay at Leicester. *Ibid.*, p. 176.

1860.

AVELINE, W. T., and H. H. HOWELL.—The Geology of Part of Leicestershire. (Description of Quarter Sheet 63 S.E.) *Memoirs of the Geological Survey.* 8vo. *London.*

HULL, E.—On the Geology of the Leicestershire Coalfield and the Country around Ashby-de-la-Zouch. *Ibid.*

1861.

ANON. (J. H. W.).—On a Skull found in the Valley of the Trent, near Newark. *Geologist*, vol. iv., p. 415.

DRAKE, F.—Human remains found with bones of extinct animals in the Vale of Belvoir. *Ibid.*, p. 246.

DRAKE, F.—Human remains in the drift of the Vale of Belvoir. *Ibid.*, pp. 349-352.

HULL, E.—The Coal Fields of Great Britain; their History, Structure, and Duration. With Notices of the Coal Fields of other Parts of the World. [Leicestershire, 4th Ed., pp. 238-244.] 8vo. *London.* Ed. 2, 1861; Ed. 3, 1873; Ed. 4, 1881.

PLANT, J.—Human remains in the Trent Valley. *Geologist*, vol. iv., p. 495.

1862.

ANON. (T. R. J.).—Fossil Mammalia [in Leicester Museum, found at Keyworth and Leicester Infirmary]. *Geologist*, vol. v., p. 471.

BLAKE, C. C.—On Crania of the most ancient races of men. [p. 215 refers to Leicester]. *Ibid.*, pp. 205-233. Further Notes on Human Skulls from the Heathery Burn Cave, Weardale, Durham; with a Notice of the River-bed Skeleton from Leicester. *Ibid.*, pp. 313-316.

BROWN [E.].—On an Ancient Bed of the River Trent. *Mid. Scientific Assoc.*

FOWLER, GEORGE.—On the Method adopted in working the Main Seam of Coal at Moira, in Leicestershire, particularly with reference to spontaneous combustion. *Trans. N. Inst. Mining Eng.*, vol. x., pp. 161-165, 167-182.

HULL, E.—On Isodiametric Lines as means of representing the Distribution of Sedimentary Clay and Sandy Strata as distinguished from Calcareous Strata, with special reference to the Carboniferous Rocks of Britain. [Leicester, p. 137.] *Quart. Journ. Geol. Soc.*, vol. xviii., p. 127.

HUXLEY, PROF.—Notes upon Human Remains from the Valley of the Trent, and from Heathery Burn Cave, Durham. *Geologist*, vol. v., pp. 201-204.

JONES, PROF. T. R.—A Monograph of the Fossil Estheriæ. [Leicester, pp. 58, 63, 73.] *Palæontograph. Soc.*

MACKIE, S. J.—Human Bones at Leicester [supposed associated with *Bos primigeneus*]. *Atheneum*, Nos. 1810-1835, p. 23.

PLANT, J.—Discovery of a Human Skeleton and other Remains in the bed of the River Soar, at Leicester. *Geologist*, vol. v., p. 260.

1863.

ANSTED, PROF. D. T.—On the Metamorphic origin of the Porphyritic Rocks of Charnwood Forest. *Geologist*, vol. vi., p. 371; Abstract in Rep. Brit. Assoc. for 1863, p. 64.

COLEMAN, REV. W. H.—Geology of Leicestershire. In *W. White's History Gazetteer and Directory of the Counties of Leicester and Rutland.* 2nd ed. pp. 77-111. 8vo. *Sheffield* and *London.*

DRAKE, F.—Mammoth Remains at Leicester. *Geologist*, vol. vi., p. 457.

PLANT, J.—Remains of the Mammoth at Leicester. *Athenæum*, No. 1882, p. 683.

SORBY, H. C.—On the Microscopical Structure of Mount Sorrel Syenite artificially fused and cooled slowly. *Proc. Geol. Soc. W. Riding of Yorkshire*, vol. iv., p. 301; Abstract in *Geol. Mag.*, vol. ii., p. 448, 1865.

1864.

ANON. (W. D.).—The Skin of Reptiles preserved in a Fossil State. [*Ichthyosaurus tenuirostris* from Barrow.] *Geol. Mag.*, vol. i., p. 248.

RAMSAY, PROF. A. C.—The Breaks in Succession of the British Mesozoic Strata. (Presidential Address.) *Quart. Journ. Geol. Soc.*, vol. xx., p. xl.

1865.

ANON. (T. R. J.) [T. RUPERT JONES.].—Sorby on Microscopical Structure of Mount Sorrel Syenite.....[Notice of Sorby, 1863, and Marshall, 1859]. *Geol. Mag.*, vol. ii., p. 448.

ANON. (D. M.).—Geological Anecdote of Mr. George Stephenson [Piercing the igneous rock at Coalville]. *Geol. Mag.*, vol. ii., pp. 528 and 570.

GREEN, A. H.—Letter on finding the igneous rock at Coalville. *Ibid.*, p. 571.

MACKINTOSH, D.—Notes on Charnwood Forest. *Geol. Mag.*, vol. ii., p. 498.

OWEN, PROF. R.—Monograph of the Fossil Reptilia of the Liassic Formations. Part 1. *Palæontograph. Soc.*

PLANT, JAMES.—Are the [Slate] rocks of Charnwood Forest Laurentian? *Geol. Mag.*, vol. ii., p. 233.

1866.

ANSTED, PROF. D. T.—Physical Geography and Geology of the County of Leicester. 4to. *Westminster.* Review and Abstract. *Geol. Mag.*, vol. iv., p. 162. 1867.

FOSTER, C. LE N. –On the Occurrence of Molybdenite in Leicestershire ......*Geol. Mag.*, vol. iii., p. 525.

HOLL, DR. H. B.—On the Pre-Cambrian Rocks of Central England. *Rep. Brit. Assoc. for* 1865, *Sections*, p. 59.

MOSCROP, W. J. A Report on the Farming of Leicestershire [Account of soils, etc.]. Small geol. map. *Journ. Roy. Agric. Soc.*, ser. 2, vol. ii., pp. 289–337.

STARTIN, A.—On some special deposits of drift in the Parish of Exhall near Coventry, and also a few remarks on the drift of the surrounding district generally. *Proc. Warwickshire Geol. Soc.*, pp. 26-33.

1867.

BRODIE, REV. P. B.—On the Correlation of the Lower Lias at Barrow-on-Soar, in Leicestershire, with the same strata in Warwickshire, Worcestershire, and Gloucestershire; and on the occurrence of the remains of Insects at Barrow in Yorkshire. *Ann. Mag. Nat. Hist.*, ser. iii., vol. xix., p. 31–34; Abstract in *Brit. Assoc. Rep.* for 1866, *Sections*, p. 51; also under different title in *Proc. Warwickshire Field Club*, p. 1, 1868; *Trans. Woolhope Nat. Field Club* for 1866, p. 207, 1867; *Trans. Dudley and Midland Geol. and Sci. Soc.*, 1868.

MURCHISON, SIR R. I.—On the parts of England and Wales in which Coal may and may not be looked for beyond the known Coalfields. *Rep. Brit. Assoc.* for 1866, pp. 57–63.

TIMMINS, REV. J. H.—On the Chemical Geology of the Malvern Hills [contains two analyses of Mount Sorrel trap, p. 364]. *Quart. Journ. Geol. Soc.*, vol. xxiii., p. 352.

1868.

ESKRIGGE, R. A.—Geological Notes made during a Tour in Leicestershire. *Trans. Manchester Geol. Soc.*, vol. vii., pp. 51 57.

HALL, T. M.—The Mineralogist's Directory; or a Guide to the Principal Mineral Localities in the United Kingdom of Great Britain and Ireland. [Minerals from Staunton Harold.] 8vo. *London.*

HULL, E. Observations on the Relative Ages of the Leading Physical Features and Lines of Elevation of the Carboniferous District of Lancashire and Yorkshire. [Coleorton Fault, p. 331.] *Quart. Journ. Geol. Soc.*, vol. xxiv., pp. 323 335.

LEWIS, G. –On the Coleorton District of the Leicestershire Coal Field. *Trans. S. Wales Inst. Eng.*, vol. v., pp. 33-44.

MAW, G.—The Trias of Charnwood Forest. *Geol. Mag.*, vol. v., pp. 197, 198.

MOTT, F. T.—Charnwood Forest: its . . . . Natural Curiosities, &c. [Geological Map one mile to an inch. Notes, pp. 11—23.] Ed. 3. 8vo. *London.*

PLANT, JOHN.—Baden Powell and Charnwood Forest. *Geol. Mag.*, vol. v., p. 199.

POWELL, PROF. BADEN. On the Igneous Rocks of Charnwood Forest and its neighbourhood. *Geol. Mag.*, vol. v., p. 111.

WOODWARD, HY.—Third Report on the Structure and Classification of the Fossil Crustacea. [New Lower Lias Crustacea from Barrow-on-Soar, p. 45.] *Rep. Brit. Assoc.* for 1867, p. 45.

1869.

DRAKE, F.—[Note on human bones found at 16 feet below the surface in a gravel pit at Hinckley, near Leicester.] (Midland Scientific Association.) *Geol. Mag.*, vol. vi., p. 377.

——— Human Remains in the Gravels of Leicestershire. [Tusk of Elephant at Leicester.] (*Rep. Brit. Assoc.* for 1869, p. 130, title only.) *Anthrop. Rev.*, vol. vii., p. 427.

HULL, E.—The Triassic and Permian Rocks of the Midland Counties of England. Memoirs of the Geological Survey. 8vo. *London.*

MOLYNEUX, W.—Burton-on-Trent, its History, its Waters, and its Breweries. [Map of the town with geol. section, also section in Bretby Colliery Railway. Geology, pp. 147-213.] 8vo. *London* and *Burton.*

PLANT, JAMES.—On the so-called Pseudomorphous Crystals of Chloride of Sodium, found in the Upper Triassic rocks of Leicestershire, and the adjoining counties. (Mid. Scientific Assoc.) *Geol. Mag.*, vol. vi., 377.

STARTIN [A.].—[Account of an Excursion to Charnwood.] *Proc. Warwicksh. Field Club*, p. 31.

1870.

ALLPORT, S.—On the Basaltic Rocks of the Midland Coalfields. *Geol. Mag.*, vol. vii., pp. 159 162, 431–435.

ANON.—Short Account of Mountsorrel and the working of its Granite Quarries. [Comparison of weight, specific gravity, etc., with other Charnwood rocks.] 8vo. *Leicester.* Extracted from *The Building News* of July 8 and *The Builder* of November 12, December 10, and December 24, 1870.

HULL, E.—On the extension of the Coalfields beneath the newer formations of England, and the successive stratigraphical changes to which the carboniferous rocks have been subjected. *Rep. Brit. Assoc.* for 1870, Sections, pp. 74, 75. Printed separately under different title. 8vo. *London*, 1870.

LUCY, W. C.—Notes upon the Occurrence of Post-Pliocene Drift of Charnwood Forest. *Geol. Mag.*, vol. vi., p. 497.

MUSGRAVE, R. M.—On the Drift Gravel of Lutterworth, Kilworth, etc. *Proc. Warwickshire Field Club*, pp. 11 23.

WILSON, J. M.—On the Drifts and Gravels and Alluvial Soils of Rugby and its Neighbourhood. *Rep. Rugby School Nat. Hist. Soc.* for 1869, pp. 16–35.

——— On the Surface-deposits in the neighbourhood of Rugby. *Quart. Journ. Geol. Soc.*, vol. xxvi., pp. 192 202.

1871.

REPORTS.—Report of the Commissioners appointed to inquire into the several matters relating to Coal in the United Kingdom. [Leicester. vol. i., pp. 30, 132; vol. ii., pp. 326, etc.; vol. iii., p. 89, Ap. p. 28.] 3 vols. Folio. *London.*

RAMSAY, PROF. A. C.—On the Physical Relations of the New Red Marl, Rhætic Beds, and Lower Lias. *Quart. Journ. Geol. Soc.*, vol. xxvii., pp. 189 199.

1872.

FISHER, O.—On the Phosphatic Nodules of the Cretaceous Rocks of Cambridgeshire. [Erratic pebbles from Charnwood, p. 62.] Abstract, *Quart. Journ. Geol. Soc.*, vol. xxviii., p. 396; in full, vol. xxix., pp. 52–63.

HULL, E.—A Treatise on the Building and Ornamental Stones of Great Britain and Foreign Countries, arranged according to their Geological Distribution and Mineral Character. [Bardon Hill, p. 81; Chellaston, p. 162; Mount Sorel, pp. 37, 60.] 8vo. *London.*

1874.

ALLPORT, S.—On the microscopic structure and composition of British Carboniferous Dolerites. [Coalville]. *Quart. Journ. Geol. Soc.*, vol. xxx., pp. 529–567. Plate.

Anon.—Another Discovery of Coal near Leicester. [Lindridge.] *Coll. Guard.*, vol. xxvii., p. 757.

Brodie, Rev. P. B.—Notes on a Railway section of the Lower Lias and Rhætic between Stratford-on-Avon and Fenny Compton; on the occurrence of the Rhætics near Kineton, and the Insect-beds near Knowle in Warwickshire, and on the Recent Discovery of the Rhætics near Leicester. *Quart. Journ. Geol. Soc.*, vol. xxx., pp. 746–749.

———— The Distribution and Correlation of Fossil Insects, and the supposed occurrence of Lepidoptera and Arachnida in British and Foreign strata, chiefly in the Secondary Rocks. [Insect wings, Barrow.] *Proc. Warwicksh. Field Club*, pp. 12, 16–38.

Crosskey, Rev. H. W.—First Report of the Committee appointed for the purpose of recording the position, height above the sea, lithological character, size, and origin of the Erratic Blocks of England, Wales, and Ireland, reporting other matters of interest connected with the same, and taking measures for their preservation. [Charnwood Boulders at Hugglescote.] *Rep. Brit. Assoc. for* 1873, p. 190.

Irving, Rev. A.—On the Geology of the Nottingham District [Rhætic at Barrow and Spinney Hills.] *Geol. Mag.*, dec. ii., vol. i., pp. 314–319. In full in *Proc. Geol. Assoc.* 1875, vol. iv., pp. 45-90.

Kerr, C. M.—An Excursion of Mr. Wilson's Geological Class to Mount Sorrel. *Rep. Rugby School Nat. Hist. Soc.* for 1873, pp. 7-9.

Mann, E.—Geological Expedition to Atherstone and Nuneaton. *Ibid.*, pp. 19-22.

Plant, J.—Geology of Leicestershire. [Rhætic, etc.] *Rep. Leicester Lit. Phil. Soc.*, pp. 37–41.

Reports.—Sixth Report of the Commissioners appointed in 1868 to enquire into the best means of preventing the pollution of rivers. The Domestic Water Supply of Great Britain. [Bitteswell, pp. 10, 79; Hugglescote, pp. 76, 116, 356; Leicester, p. 46; Thurmaston, p. 403; Whitwick, p. 73.] Folio. *London.*

Woodward, H. B.—Rhætic Beds near Newark. [Barrow.] *Geol. Mag.*, dec. ii., vol. i., p. 480.

1875.

Brodie, Rev. P. B.—On the Lower Lias at Eatington and Kineton, and on the Rhætics in that neighbourhood, and their further extension in Leicestershire, Nottinghamshire, Lincolnshire, Yorkshire, and Cumberland. [Rhætics of Spinney Hills, p. 14.] *Proc. Warwicksh. Nat. Hist. Soc.*, pp. 6–17.

Crosskey, Rev. H. W.—Second Report . . . . on Erratic Blocks, etc. [Leicester and Hoby.] *Rep. Brit. Assoc. for* 1874, p. 197.

Hudleston, W. H.—Excursion to Charnwood Forest, Leicestershire. *Proc. Geol. Assoc.*, vol. iv., pp. 307–317.

Irving, Rev. A.—(Note on section of Rhætic Beds between Melton Mowbray and Nottingham.) *Quart. Journ. Geol. Soc.*, vol. xxxi., pp. lxxxi., lxxxii.

Judd, J. W.—The Geology of Rutland, and the parts of Lincoln, Leicester, Northampton, Huntingdon, and Cambridge, included in Sheet 64 of the One Inch Map of the Geological Survey, with an introductory essay on the classification and correlation of the Jurassic Rocks of the Midland Districts of England. *Memoirs of the Geological Survey.* 8vo. *London.*

Plant, J.—Geology of Leicestershire. [Report on Leicestershire specimens.] *Rep. Leicester Lit. Phil. Soc.*, pp. 42–46.

1875–1889.

Whitaker, W., and others.—The Geological Record for 1874, 1875, 1876, 1877, 1878, 1879, 1880, 1881, 1882, 1883, 1884. 8vo. *London.*

1876.

Anon.—The Ammonite. [Notes on finding Ammonites in the Upper Lias Clay at Glen Magna.] *Spencer's Illustrated Leicester Almanack*, p. 24.

BONNEY, REV. T. G.—The Age of the Rocks of Charnwood Forest. *Nature*, vol. xv., pp. 97 and 137.

BRODIE, REV. P. B.—On the further extension of the Rhætic or Penarth Beds in Warwickshire, Leicestershire, Nottinghamshire, Yorkshire, and Cumberland; and on the Occurrence of some supposed Remains of a new Labyrinthodont and a new Radiate therein. *Rep. Brit. Assoc. for* 1875, Sections, p. 64; *Proc. Warwicksh. Nat. Club*, pp. 1-11.

CROSSKEY, REV. H. W.—Third Report . . . . . on Erratic Blocks [Shakerstone, Normanton, Hoby]. *Rep. Brit. Assoc. for* 1875, p. 88.

DE RANCE, C. E.—First Report of the Committee appointed for the purpose of investigating the Circulation of the Underground Waters in the Permeable Formations of England; and the Quality and Quantity of the Water supplied to various Towns and Districts from these formations [General, Leicester, Hinckley, Elmsthorpe, Desford, Anstey, Hathern, Chilwell, Humberstone]. *Rep. Brit. Assoc. for* 1875, p. 118.

GREEN, A. H.—The Age of the Rocks of Charnwood Forest. *Nature*, vol. xv., p. 97.

HARRISON, W. J.—On the Occurrence of Rhætic Beds in Leicestershire. *Quart. Journ. Geol. Soc.*, vol. xxxii., pp. 212-218, two woodcuts; *Rep. Brit. Assoc. for* 1875, Sections, pp. 66, 67; also *Trans. Cardiff Nat. Soc.*, vol. viii., pp. 99-106 (1877).

———The Age of the Rocks of Charnwood Forest. *Nature*, vol. xv., p. 97.

———Notes on the Geology of the North Midland Counties. Kelly's Post Office Directory for Notts, Derby, Leicester, and Rutland. 4to. *London.*

———Notes, Bibliography, and Abstracts of several papers relating to the Geology of Leicester. MSS. in Leicestershire Free Library. 4 vols.

HULL, PROF. E.—The Age of the Rocks of Charnwood Forest. *Nature*, vol. xv., pp. 78 and 116.

———A Scheme of Water Supply for Villages, Hamlets, and Country Parishes of the Central and Eastern Counties. *Quart. Journ. Sci.*, n.s., vol. vi., pp. 304-317; and *Rep. Brit. Assoc.* for 1875, Sections, pp. 249, 250.

IRVING, REV. A. The Geology of the Nottingham District. [Leicester, pp. 81 and 83.] *Proc. Geol. Assoc.*, vol. iv., pp. 15-90.

WOODWARD, H. B.—The Geology of England and Wales. A concise account of the Lithological Characters, Leading Fossils, and Economic Products of the Rocks: with notes on the Physical Features of the Country. 8vo. *London.* Ed. 2. 1887.

1877.

ADAMS, W. On the Penarth or Rhætic Beds of Glamorganshire, Leicestershire, etc. [Contains reprint of Harrison's account of the Rhætic beds, 1876.] *Trans. Cardiff Nat. Soc.*, vol. viii., pp. 96-98.

AVELINE, W. T. The Magnesian Limestone and New Red Sandstone in the neighbourhood of Nottingham. *Geol. Mag.*, dec. ii., vol. iv., pp. 155, 156, 380.

ETHERIDGE, R.—Report on the probability of finding Coal under the Estate of the Evington Coal Boring Company, Limited, at Evington, near Leicester. Pp. 4. Fol. Privately printed.

HARRISON, JONATHAN. Notes on the Whitwick Collieries. *Proc. Dudley Geol. Soc.*, vol. iii., pp. 91, 92.

——— The South-East Leicestershire Coalfield and the Geological Formations of the Surrounding District. *Trans. Chesterfield Inst. Eng.*, vol. iv., pp. 319-326, plate xx. (section). Discussion, vol. v., pp. 134 135.

HARRISON, W. J.—The Leicestershire Coalfield. *Proc. Dudley Geol. Soc.*, vol. iii., pp. 84 87.

——— The Geology of Charnwood Forest. *Ibid.* pp. 88 91.

——— On the Rhætic Section at Dunhampstead Cutting, near Droitwich, and its Correlation with the same Strata elsewhere. [Figures, Leicester specimens.] *Ibid.* pp. 115-125. 2 plates (plans, sections, fossils).

HARRISON, W. J.—A Sketch of the Geology of Leicestershire and Rutland. Reprinted from White's History, etc., of the Counties. Pp. 67, 12 photographs. 8vo. *Sheffield.*

——— On the Geology of Leicestershire. *Proc. Geol. Assoc.*, vol. v., pp. 126 136, 2 woodcuts (sections).

——— Excursion to Leicestershire. *Ibid.* pp. 142–148.

——— Practical Geology in the Town of Leicester. [Notes on minerals used in the town.] *Spencer's Illustrated Leicester Almanack*, pp. 32–35.

HILL, REV. E., and [PROF.] T. G. BONNEY.—The Precarboniferous Rocks of Charnwood Forest. Part I. *Quart. Journ. Geol. Soc.*, vol. xxxiii., pp. 754-789; 6 woodcuts.

———The Rocks of Charnwood Forest. *Nature*, vol. xv., p. 470.

HUTCHINSON, REV. T. N.—Geology of Charnwood Forest. *Rep. Rugby School Nat. Hist. Soc.* for 1876, pp. 34-41, pls. i.-iii. Map and rock sections.

PLANT, J.—Report on the Boring for Coal on the Estate, near Evington, Leicestershire, of the Evington Coal Boring Company, Limited. Pp. 3. Fol. May 7. Printed privately.

———The Rocks of Charnwood Forest. *Nature*, vol. xv., p. 548.

WILSON, E.—Short Notice of a new Exposure of Rhætics near Nottingham. [Barnstone.] *Quart. Journ. Geol. Soc.*, vol. xxxiii. Proc. p. 1.

1877-1881.

ADAMS, A. LEITH.—Monograph of the British Fossil Elephants. [Teeth of *Elephas antiquus* from Barrow, p. 6, and *Elephas primigenius* from Kirby, p. 95.] *Palæontograph. Soc.*

1878.

CROSSKEY, REV. H. W.—Fifth Report . . . . on Erratic Blocks, etc. [Loseby, Evington, Thurnby.] *Rep. Brit. Assoc.* for 1877, p. 89.

DE RANCE, C. E.—Third Report . . . . on Circulation of Underground Waters, etc. [General.] *Rep. Brit. Assoc.* for 1877, p. 61.

GRAYSTON, F. A.—The Correlation of the Leicestershire, Warwickshire, South Staffordshire, and Shropshire Coalfields. (*Tamworth Nat. Hist. Soc.*) *Mid. Nat.*, vol. i., p. 112.

HARRISON, W. J.—Digging out a boulder. *Ibid.*, pp. 153-155.

———A Scheme for the Examination of the Glacial Deposits of the Midland Counties of England. *Ibid.*, pp. 242-245. Also *Proc. Dudley Geol. Soc.*, vol. iv., pp. 46-49, 1880.

———On the Study of Local Geology, with Illustrations from Leicestershire [Free Evening Lectures of Science and Art Department]. 8vo. *London.*

———Practical Geology [Alludes to Leicester]. 12mo. *London.*

HILL, REV. E., and PROF. T. G. BONNEY.—On the Precarboniferous Rocks of Charnwood Forest. *Quart. Journ. Geol. Soc.*, vol. xxxiv., pp. 199–239. Pl. x. (map), 2 woodcuts.

Minutes of Evidence taken in shorthand on the case Richardson *v.* The Evington Coal-boring Company, Limited. 8vo. *Leicester.*

MOLYNEUX, WILLIAM.—On the Occurrence of *Aviculopecten* and other Marine Shells in Deposits associated with Seams of Coal containing Salt Water in the Ashby Coalfield. *Rep. Brit. Assoc.* for 1877, Sections p. 73.

MOTT, F. T. Report of the Geological Section. *Rep. Leicester Lit. Phil. Soc.*, pp. 25–28.

STOKES, A. H.—Economic Geology of Derbyshire. [Leicester Coal Seams, etc.] *Trans. Chesterfield Inst. Eng.*, vol. vi., pls. i., ii.; also 8vo. *London* and *Derby.*

WOODWARD, DR. H. On a new and undescribed Macrouran Decapod Crustacean from the Lower Lias, Barrow-on-Soar, Leicestershire. [Same as 1868, but figured here.] *Geol. Mag.*, dec. ii., vol. v., pp. 289-291, pl. vii.

1879.

ADAMS, A. LEITH.—Monograph on the British Fossil Elephants. [Mammoth from Kirby Park. Part ii., p. 95, pl. xiii.] *Palæontograph. Soc.*

ALLPORT, S.—On the Diorites of the Warwickshire Coalfield. *Quart. Journ. Geol. Soc.*, vol. xxxv., p. 637.

——— On the Rocks of Brazil Wood, Charnwood Forest. *Geol. Mag.*, dec. ii., vol. vi., p. 481.

——— and W. J. HARRISON.—On the Rocks of Brazil Wood, Charnwood Forest. *Mid. Nat.*, vol. ii., pp. 243-245.

ANON. [M. B. G.].—The Midland Coalfield. *Coll. Guard.*, vol. xxxvii., pp. 141-256.

ANON. [W. J. HARRISON].—The Geology of Leicestershire. (*Leicester Daily Post.*) *Spencer's Illustrated Leicester Almanack*, pp. 15 18.

BONNEY, PROF. T. G.—The Pre-Cambrian Rocks of Great Britain. *Proc. Birmingham Phil. Soc.*, vol. i., pp. 140-159.

CROSSKEY, REV. H. W.—Sixth Report . . . . on Erratic Blocks, etc. [Humberstone, Loseby, Evington, Aylestone, Leicester.] *Rep. Brit. Assoc.* for 1878, p. 190.

DE RANCE, C. E.—Fourth Report of the Committee . . . . on the Circulation of Underground Waters, etc. [General, Ellistown, Ratcliffe, Glen Parva, Leicester, Newtown Unthank.] *Rep. Brit. Assoc.* for 1878, p. 386.

——— Notes on some Triassic Borings. *Trans. Manchester Geol. Soc.*, vol. xv., pp. 90-112.

HARRISON, W. J.—Annual Excursion. *Rep. Leicester Lit. Phil. Soc.*, pp. 17, 18.

——— Garnets in Charnwood Rocks. *Mid. Nat.*, vol. ii., p. 77 ; also *Spencer's Illustrated Leicester Almanack, etc.*, 1880, p. 48.

——— Rambles with a Hammer. [Charnwood.] *Ibid.*, vol. ii., pp. 117-122.

——— Excursion to Charnwood Forest. *Ibid.*, p. 174.

——— Fossiliferous Bunter Pebbles in the Drift. [Countesthorpe] *Ibid.*, p. 283.

PLANT, JAMES.—Report (to the Local Board of Health) on the Water Supply for the Town of Hinckley, Leicestershire, from the Underground Sandstones of the Triassic Formation. Pp. 12. 8vo. *Hinckley.*

1880.

ANON.—Recent Sciences : Geology. *Spencer's Illustrated Almanack, etc.*, for 1880, pp. 29-35. 8vo. *Leicester.*

——— Charnwood Forest : A Gossiping Picnic. *Ibid.*, pp. 35-38.

BONNEY, PROF. T. G.—The older Rocks of Charnwood Forest. [Abstract of a lecture.] *Mid. Nat.*, vol. iii., p. 207.

CLIFFORD, JOHN.—Barrow Limestone : A Geological Gossip. *Spencer's Illustrated Almanack* for 1890, pp. 38, 41.

DE RANCE, C. E.—Fifth Report of the Committee . . . . on the Circulation of Underground Waters, etc. [Hinckley, Oakham.] *Rep. Brit. Assoc.* for 1879, p. 160.

HARRISON, W. J.—The Syenites of South Leicestershire. *Spencer's Illustrated Leicester Almanack*, &c., for 1880, pp. 42-46. 8vo. *Leicester ; Mid. Nat.* vol. vii., pp. 7-11, 41, 42. 1884.

HARRISON, W. J.—A Starfish bed in the Rhætic Formation. *Sci. Gossip*, p. 56.

——— Another Boulder. [Mount Sorrel granite near Ratby.] *Mid. Nat.*, vol. iii., p. 92.

HILL, REV. E., and PROF. T. G. BONNEY.—The Precarboniferous Rocks of Charnwood Forest. Part III. *Quart. Journ. Geol. Soc.*, vol. xxxvi., pp. 337-350; 3 woodcuts.

MACKINTOSH, D.—On the Correlation of the Drift Deposits of the North-west of England with those of the Midland and Eastern Counties. *Ibid.* pp. 178-188; 3 woodcuts.

1881.

BRODIE, REV. P. B.—On certain Quartzite and Sandstone Fossiliferous Pebbles in the Drift in Warwickshire, and their probable Identity, lithologically and zoologically, with the true Lower Silurian Pebbles with similar Fossils in the Trias at Budleigh Salterton, Devonshire. *Quart. Journ. Geol. Soc.*, vol. xxxvii., pp. 430-435.

CALLAWAY, C.—How to work in the Archæan Rocks. [Charnwood, p. 421.] *Geol Mag.*, dec. ii., vol. viii., pp. 348-353; 420-427.

CROSSKEY, REV. H. W.—Eighth report . . . . on Erratic Blocks, &c. [Ayleston, Thurnby, Syston, Market Bosworth, Carlton, Leicester, Countesthorpe, Oadby.] *Rep. Brit. Assoc.* for 1880, p. 111.

DE RANCE, C. E.—Sixth Report of the Committee . . . . on the Circulation of Underground Waters, &c. [Leicester, Fleckney.] *Rep. Brit. Assoc.* for 1880, p. 105.

QUILTER, H. E.—Exposure of the Middle Series of the Bucklandi Beds in Leicestershire. [Fleckney.] *Mid. Nat.*, vol. iv., p. 265; section.

REPORTS.—Report of the Royal Commission on Agriculture. [Leicestershire, vol iii., p. 370.] 3 vols. Folio. *London.*

WOODWARD, C. J.—The Minerals of the Midlands. [Stanton Harold, p. 89.] *Mid. Nat.*, vol. iv., pp. 87-90, 112; vol. v., pp. 11-13, 202-207.

1882.

BERRY, E. E.—Analyses of five Rocks from the Charnwood Forest District. Communicated, with Notes, by PROF. T. G. BONNEY. *Quart. Journ. Geol. Soc.*, vol. xxxviii., pp. 197–199.

CROSSKEY, REV. H. W.—Ninth Report . . . . on Erratic Blocks, etc. [Leicester, Stoughton, Aylestone, Rothley, Humberstone.] *Rep. Brit. Assoc.* for 1881, p. 205.

DE RANCE, C. E.—The Water Supply of England and Wales; its Geology, Underground Circulation, Surface Distribution and Statistics. 8vo. *London.*

HARRISON, W. J.—Geology of the Counties of England and of North and South Wales. (Leicestershire pp. 151–162. 7 woodcuts.) 8vo. *London.*

——— On the Quartzite Pebbles contained in the Drift, and in the Triassic Strata of England, and on their Derivation from an Ancient Land Barrier in Central England. *Proc. Birmingham Phil. Soc.*

HULL, E.—On the two British Types of the Lower Cambrian Beds, and the Conditions under which they were respectively deposited. *Quart. Journ. Geol. Soc.*, vol. xxxviii., pp. 210–215. 2 woodcuts; and *Rep. Brit. Assoc.* for 1881, pp. 642, 643.

——— Contributions to the Physical History of the British Isles. Illustrated by twenty-seven coloured maps. [Charnwood pp. 13, 60.] 8vo. *London.* Also under different title in *Trans. Roy. Dublin Soc.*, n.s., vol. i., pt. xix., pp. 257–296.

LAPWORTH, C.—On the Discovery of Cambrian Rocks in the neighbourhood of Birmingham. *Proc. Birmingham Phil. Soc.*, vol. iii., pp. 234–238; *Geol. Mag.*, dec. ii., vol. ix., pp. 563–566.

PAUL, J. D.—Report of the Geological Section [Croft quarry, etc.]. *Rep. Leicester Lit. Phil. Soc.*, pp. 23–26.

PLANT, J.—Vestiges of the Ice Age in Leicestershire. *Leicester Mercury*, March 1; Abstract in *Rep. Leicester Lit. Phil. Soc.* pp. 33, 34.

——— The Coal Formation [Statistics, etc.]. *Rep. Leicester Lit. Phil. Soc.*, pp. 295, 296.

WILSON, E.—On the Rhætics of Nottinghamshire. *Rep. Brit. Assoc.* for 1881, pp. 637, 638; *Quart. Journ. Geol. Soc.*, vol. xxxviii., pp. 451–456, cut; *Mid. Nat.*, vol. vi., pp. 193–199.

1883.

ANON. — Geology of Charnwood. *Spencer's Illustrated Leicester Almanack*, pp. 18–22. 8vo. *Leicester*.

CROSSKEY. REV. H. W.—Tenth Report . . . . on Erratic Blocks, etc. [Leicester, Aylestone, Thurnby, Hallaton, Loughborough.] *Rep. Brit. Assoc.* for 1882, p. 245.

DE RANCE, C. E.—Eighth Report of the Committee . . . . on the Circulation of the Underground Waters, etc. [Croft, Hinckley Wharf.] *Rep. Brit. Assoc.* for 1882, p. 226.

PAUL, J. D.—On a section exposed on the Great Northern Railway near Thurnby and Scraptoft. [List of Lias Fossils.] *Trans. Leicester Lit. Phil. Soc.*, pp. 50, 51.

——— and A. F. ATKINS.—Excursion to Aylestone and Blaby. [List of Boulders.] *Ibid.*, pp. 24, 25.

QUILTER, H. E.—On an exposure of Lower Lias on the Crown Hill in a pit of the Evington Lime Company. *Ibid.* pp. 51, 52.

——— The Diorite of Charnwood Forest. *Mid. Nat.*, vol. vi., pt. 70, pp. 237, 238.

1884.

BRODIE, REV. P. B.—An account of the discovery, by Prof. Lapworth, of Cambrian and pre-Cambrian Rocks in North Warwickshire, formerly supposed to be of Carboniferous Age. *Proc. Warwickshire Nat. Arch. F. Club* for 1883, pp. 13–16.

CROSSKEY, REV. H. W.—Eleventh Report . . . . on Erratic Blocks. etc. [Leicester, Kirby Muxloe.] *Rep. Brit. Assoc.* for 1883, p. 141.

DE RANCE, C. E.—Ninth Report of the Committee . . . . on the Circulation of Underground Waters, etc. [Melton.] *Ibid.*, p. 154.

HARRISON, W. J.—The Syenites of South Leicestershire. *Mid. Nat.*, vol. vii., pp. 7–11, 41, 42.

——— Rambles with a Hammer . . . over Charnwood Forest. *Knowledge*, vol. vi., pp. 516–518. [? same as 1879.]

——— Leicestershire Rocks and Scenery. *Trans. Leicester Lit. Phil. Soc.*, p. 362. [Abstract.]

MARRIOTT, J.—The beds exposed in the railway cutting at Slawston Hill. *Trans. Leicester Lit. Phil. Soc.*, pp. 80, 81.

MOORE, C. A.—The Railway Cutting north of Market Harborough Station. *Ibid.*, pp. 82, 83.

PAUL, J. D.—The Cores from a Boring made near Evington. *Ibid.*, pp. 83–86.

PLANT, JAMES.—On the Map of South-east Leicestershire, just issued by the Government Geological Survey. *Ibid.*, p. 327.

QUILTER, H. E.—The Rhætic Beds of the Spinney Hills. *Trans. Leicester Lit. Phil. Soc.*, pp. 8 and 82.

——— The Cutting near Market Harborough Station. *Ibid.*, pp. 86, 87.

QUILTER, H. E.—On a Slaty Conglomerate in the rocks of Charnwood Forest. [Bradgate.] *Mid. Nat.*, vol. vii., pp. 140, 141.

WILSON, E., and H. E. QUILTER.—The Rhætic Section at Wigston, Leicestershire. *Geol. Mag.*, dec. iii., vol. i., pp. 415 418.

In the High Court of Justice, Chancery Division. Burnaby *v.* The Leicester and Evington Lime Company, Limited, 1884, B. No. 620. Particulars and Conditions of Sale of the Leicester and Evington Lime Works, Leicester. [Contains plan of estate and two vertical sections.] Ed. 2. Folio. *London.*

1885.

ANON.—Excursion to Leicester. *Chesterfield Mid. Inst. Eng.*, vol. xiv., p. 177.

————Patent Victoria Stone Works, Groby Quarries, near Leicester. *Ibid.*, p. 190.

————Bardon Hill Quarries, near Leicester. *Ibid.*, p. 197.

BONNEY, PROF. T. G.—On the Archæan Rocks of Great Britain. *Rep. Brit. Assoc.* for 1884, p. 529.

BROWNE, A. J. JUKES.—The Geology of the South-west of Lincolnshire, with parts of Leicestershire and Nottinghamshire. Explanation of Sheet 70. *Geological Survey Memoir.* 8vo. *London.*

EVERARD, J B. Report on the Water Supply of the Borough of Leicester. [Geological Features, pp. 5–7] 8vo. *Leicester.*

GRESLEY, W. S. On the Occurrence of Quartzite Boulders in a Coal Seam in Leicestershire. *Geol. Mag.*, dec. iii., vol. ii., pp. 553–555.

———— Some Inaccuracies upon the Geological Survey Maps and Sections of the Leicestershire Coalfield. *Mid. Nat.*, vol. viii., p. 342.

———— On certain Fossiliferous Nodules and Fragments of Hæmatite (sometimes Magnetite) from the (so-called) Permian Breccias of Leicestershire and South Derbyshire. *Quart. Journ. Geol. Soc.*, vol. xli., Proc. p. 109.

HARRISON, J. W.—On the Pre-Carboniferous Floor of the Midlands. *Mid. Nat.*, vol. xiii., pp. 38 40, 69 73, 100 104, 131–135, 163 167, 194–198.

IRVING, A.—Report on Permian and Trias. *Internat. Geol. Congress* (English Committee), pp. 107 120. Ed. 2 in 1888.

MARTIN, R. F. Mountsorrel Granite Quarries and Works. *Chesterfield Mid. Inst. Eng.*, vol. xiv., p. 199.

MOTT, F. T.—The Geological History of Charnwood Forest. Map 1 mile to an inch. *Chesterfield Mid. Inst. Eng.*, vol. xiv., pp. 213–224, 259 261 ; also 8vo. *London.*

PAUL, J. D. –The Valley of the Soar. *Trans. San. Inst.*, vol. vii.

———— The Drift at the Countesthorpe Brickyard. *Trans. Leicester Lit. Phil. Soc.* for 1885, p. 115.

QUILTER, H. E.—The Rhætic Beds as exposed at Wigston. *Ibid.*, p. 119.

WILSON, E. The Lias Marlstone of Leicestershire as a source of Iron. *Mid. Nat.*, vol. viii., pp. 61 66, 94 97, 123 127, 152–158.

WRIGHT, J. Groby Granite (or Syenite) Quarries near Leicester. *Chesterfield Mid. Inst. Eng.*, vol. xiv., p. 188.

1886.

BATES, E. F., and L. HODGES. Notes on a recent exposure of the Lower Lias and Rhætics in the Spinney Hills, Leicester. *Trans. Leicester Lit. Phil. Soc.* for 1886, p. 22.

BRAGGE, G. S.—The Geology of the South Derbyshire and East Leicestershire Coalfields. *Trans. Chesterfield Mid. Inst. Eng.*, vol. xv., pts. iii. and vii., pp. 198–214, 225–235. Supplement in 1887, with two sheets of sections.

DEELEY, R. M.—The Pleistocene Succession in the Trent Basin. *Quart. Journ. Geol. Soc.*, vol. xlii., 437-480. Abstract in *Geol. Mag.*, dec. iii., vol. iii., pp. 284–285.

DE RANCE, C. E.—On the Occurrence of Brine in the Coal Measures, with some remarks on filtration. *Trans. Manchester Geol. Soc.*, vol. xviii., pt. iii., pp. 61 81, 140.

GRESLEY, W. S. Note on C. E. De Rance's paper on Brine in the Coal Measures. *Ibid.* pt. vi., p. 140.

——— On the Occurrence of Fossiliferous Hæmatite Nodules in the Permian Breccia of Leicestershire, together with some account of their economic value. *Mid. Nat.*, vol. ix., pp. 1–8, 33–37, 64–69, 92–99. Abstract in *Proc. Geol. Soc.* 1885, p. 109.

HARRISON, W. J.—Faults in the Drift (at Kibworth, Leicestershire). *Mid. Nat.*, vol. ix., p. 138.

LAPWORTH, C.—On the Sequence and Systematic Position of the Cambrian Rocks of Nuneaton. *Geol. Mag.*, dec. iii., vol. iii., pp. 319–322.

QUILTER, H. E.—The Lower Lias of Leicestershire. *Ibid.*, pp. 59 65.

RUTLEY, F.—The Igneous Rocks, etc., of the Neighbourhood of the Warwickshire Coalfield. [Croft, etc.] *Ibid.*, p. 557–565.

SHARMAN, G. On the New Species *Olenus Nuneatonensis* and *Obolella granulata*, from the Lower Silurian ("Cambrian," Lapworth), near Nuneaton. *Ibid.*, p. 565.

STRAHAN, A.—On the Rocks surrounding the Warwickshire Coalfield, and on the base of the Coal Measures. [Borings at Hinckley, Lindridge, etc.] *Ibid.*, pp. 540 557. *Rep. Brit. Assoc.* for 1886, p. 624.

WALLER, T. H.—Preliminary Note on the Volcanic and Associated Rocks of the Neighbourhood of Nuneaton. *Ibid.*, pp. 322–325.

1887.

BONNEY, PROF. T. G.—Presidential Address (Section C.). [Charnwood, p. 608.] *Rep. Brit. Assoc.* for 1886, p. 601.

BROWN, H. T.—A Chapter in the Physical Geography of the Past. [Leicester Coalfield, Charnwood Forest, etc.] Presidential Address. *Trans. Burton-on-Trent Nat. Hist. Arch. Soc.*, vol. i., pp. 37-67.

CROSSKEY, REV. H. W.—Fourteenth Report . . . . on Erratic Blocks, etc. [Leicester.] *Rep. Brit. Assoc.* for 1886, p. 223.

——— On the Glacial Phenomena of the Midland District. [Charnwood erratics.] *Rep. Brit. Assoc.* for 1886, pp. 224-226.

GRESLEY, W. S.—Notes on the Formation of Coal-seams, as suggested by evidence collected chiefly in Leicestershire and South Derbyshire Coalfields. *Quart. Journ. Geol. Soc.*, vol. xliii., pp. 671-674.

LAPWORTH, C.—On the Geology of the Birmingham District. *Rep. Brit. Assoc.* for 1886, Sections, p. 621.

———The Cambrian Rocks of the Midlands. *Ibid.*, p. 622.

PAUL, J. D.—Shearsby, the Cheltenham of Leicestershire. *Trans. Leicester Lit. Phil. Soc.*, ser. 2, pt. iii., pp. 9-12.

STOOKE, T. S.—On a Borehole in Leicestershire. [Hinckley Wharf.] *Proc. Inst. Civ. Eng.*, vol. xc., p. 28.

TUCKWELL, REV. W.—On the Glacial Erratics of Leicestershire and Warwickshire. [Dispersion of Mt. Sorrel granite into Warwickshire, etc.] *Rep. Brit. Assoc.* for 1886, Sections, p. 627.

WALLER, T. H.—On the Petrology of the Volcanic and associated Rocks of Nuneaton. *Ibid.*, p. 623.

WILSON, E.—British Liassic Gasteropoda. *Geol. Mag.*, dec. iii., vol. iv., pp. 193-202, 258-262.

1888.

BROWNE, A. J. JUKES.—The Correlation of the Midland Glacial Deposits with those of Lincolnshire. [Reply to Mr. Deeley.] *Geol. Mag.*, dec. iii., vol. v., p. 332.

BROWNE, M.—Evidences of the Antiquity of Man in Leicestershire. *Trans. Leicester Lit. Phil. Soc.*, vol. i., pt. ix., pp. 7-37.

DAWKINS, W. BOYD.—On the Geography of Britain in the Carboniferous Period. *Trans. Manchester Geol. Soc.*, vol. xix., pt. ii., pp. 37-47 ; under different title, *Rep. Brit. Assoc.* for 1887, Sections, p. 684.

DE RANCE, C. E. Thirteenth Report of the Committee . . . . on the Circulation of Underground Waters, etc. [Hinckley.] *Rep. Brit. Assoc.* for 1887, p. 364.

DEELEY, R. M. Correlation of the Lincolnshire Pleistocene Deposits with those of the Midland Counties. *Geol. Mag.*, dec. iii., vol. v., pp. 153-155.

GRESLEY, W. S.—On the Occurrence of Boulders and Pebbles in the Coal Measures. *Trans. Manchester Geol. Soc.*, vol. xix., pt. xviii., pp. 488-504.

———— The Occurrence of Variegated Coalmeasures, Altered Ironstones, etc., at Swadlincote, Derbyshire. *Geol. Mag.*, dec. iii., vol. v., pp. 115-117.

LAPWORTH, C.—On the Discovery of the Olenellus Fauna in the Lower Cambrian Rocks of Britain. *Geol. Mag.*, dec. iii., vol. v., pp. 484-487.

TEALL, J. J. H.—British Petrography: with special reference to the Igneous Rocks. [Leicestershire, pp. 211, 250, 251, 270, 271, 321, 322, 341, 388.] 4to. *London.*

1888 1890.

LYDEKKER, R.—Catalogue of the Fossil Reptilia in the British Museum. [Barrow.] 8vo. *London.*

1889.

BROWN, H. T.—The Permian Rocks of the Leicestershire Coalfield. *Quart. Journ. Geol. Soc.*, vol xlv., pp. 1-40.

BROWNE, M.—The Vertebrate Animals of Leicestershire and Rutland. 4to. *Birmingham* and *Leicester*.

———— On a Fossil Fish (*Chrondrosteus*) from Barrow-on-Soar, hitherto recorded only from Lyme Regis. *Trans. Leicester Lit. Phil. Soc.*, vol. ii., p. 17.

CALLAWAY, C.—The Present State of the Archæan Controversy in Britain. *Geol. Mag.*, dec. iii., vol. vi., pp. 319-325.

QUILTER, H. E. The Rhætics of Leicestershire. With Notes on Fossil Fish Remains by A. SMITH WOODWARD. *Trans. Leicester Lit. Phil. Soc.*, vol. i., pt. xi., pp. 14-17.

————. The Life-Zones of the British Lias. *Research*, vol. ii., pp. 97-99.

READE, T. MELLARD. Physiography of the Lower Trias. *Geol. Mag.*, dec. iii., vol. vi., pp. 549-558. Abstract. *Rep. Brit. Assoc.* for 1889, p. 566.

WILSON, E., and W. D. CRICK. The Lias Marlstone of Tilton, Leicestershire. *Geol. Mag.*, dec. iii., vol. vi., pp. 296-305, 337-342.

WOODWARD, A. S.—On Some Remains of Fossil Fishes from the Rhætic Beds of the Spinney Hills, Leicestershire. *Trans. Leicester Lit. Phil. Soc.*, vol. i., pt. xi., pp. 18-21.

WOODWARD, A. S.—Note on a species of *Pholidophorus* from the Rhætic paper shales of Wigston. *Ibid.*, pp. 22, 23.

1889—1895.

——— Catalogue of Fossil Fishes in the British Museum (Natural History). [*Dapedius orbis*, from Barrow. Part III., pp. 138, 139.] Part I., 1889. Part II., 1891. Part III., 1895. 8vo. *London.*

1890.

BEASLEY, H. C.—The Life of the English Trias. *Proc. Liverpool Geol. Soc.*, vol. vi., pt. ii., p. 145.

BONNEY, T. G.—Mr. Mellard Reid's Interpretation of the Lower Trias Physiography. *Geol. Mag.*, dec. iii., vol. vii., pp. 52 and 235.

BROWNE, A. J. JUKES.—The Physiography of the Lower Trias. *Ibid.*, p. 220.

BROWNE, M.—A Supplementary Contribution to the History of the Fossil Fishes of the Rhætics of Leicestershire. *Trans. Leicester Lit. Phil. Soc.*, vol. ii., pp. 178, 179.

——— Revision of a genus of Fossil Fishes, *Dapedius*. *Ibid.*, p. 196-202.

——— A Contribution to the History of the Lias and Rhætics in Leicestershire (Abstract). *Ibid.*, p. 147.

DE RANCE, C. E.—Fifteenth Report . . . . on the Circulation of Underground Waters, etc. [Leicester, p. 74.] *Rep. Brit. Assoc.* for 1889, p. 71.

GRESLEY, W. S.—Evidence furnished by the Quaternary Glacial-Epoch Morainic Deposits of Pennsylvania, U.S.A., for a similar mode of formation of the Permian Breccias of Leicestershire and South Derbyshire. *Quart. Journ. Geol. Soc.*, vol. xlvi., Proc. p. 114.

HULL, E.—Our Coal Resources. *Trans. Edinburgh Geol. Soc.*, vol. vi., p. 76.

QUILTER, H. E.—[Ammonites collected from the Lower Lias of Barrow-on-Soar by Mr. Montagu Browne.] *Trans. Leicester Lit. Phil. Soc.*, n.s., vol. ii., p. 147.

READE, T. M.—Physiography of the Lower Trias. *Geol. Mag.*, dec. iii., vol. vii., pp. 155-157.

RÜCKER, A. W., and T. E. THORPE.—On the Relation between the Geological Constitution and the Magnetic State of the British Isles. [Melton Mowbray.] *Rep. Brit. Assoc.* for 1889, p. 586. Under different title. *Proc. Roy. Soc.*, vol. xlvii., p. 443, and *Nature*, vol. xli., p. 598.

WOODWARD, A. S.—Notes on some new and little known British Jurassic Fishes. [*Browneichthys ornatus*, from Barrow.] *Rep. Brit. Assoc.* for 1889, p. 585; *Geol. Mag.*, dec. iii., vol. vi., p. 455.

——— Notes on some Ganoid Fishes, from the English Lower Lias. [*Undina barroviensis*, from Barrow.] *Ann. Mag. Nat. Hist.*, ser. vi., vol. v., p. 436.

——— and C. D. SHERBORN.—A Catalogue of British Fossil Vertebrata. 8vo. *London.*

1891.

BONNEY, T. G.—Note on a Contact Structure in the Syenite of Bradgate Park. *Quart. Journ. Geol. Soc.*, vol. xlvii., p. 101.

BROWNE, M.—[Note on Lias Fossils from Loseby.] *Trans. Leicester Lit. Phil. Soc.*, vol. ii., p. 349.

——— On the Geology of the Keuper in the vicinity of Leicester. *Trans. Leicester Lit. Phil. Soc.*, vol. ii. [misprinted vol. iii.], p. 385.

BROWNE, M.—Note upon *Colobodus*, a genus of Mesozoic Fossil Fishes *Geol. Mag.*, dec. iii., vol. viii., pp. 501, 502 ; *Rep. Brit. Assoc.* for 1891, Sections, p. 644.

DE RANCE, C. E.—Sixteenth Report. . . . on the Circulation of Underground Waters. [Trent Valley, Castle Donington, Moira.] *Rep. Brit. Assoc.* for 1890, p. 352.

HILL, E., and T. G. BONNEY.—On the North-west Region of Charnwood Forest, with other Notes. *Quart. Journ. Geol. Soc.*, vol. xlii., pp. 78–100.

JEFFS, O. W.—Report of the Committee. . . . to arrange for the Collection, Preservation, and Systematic Registration of Photographs of Geological Interest in the United Kingdom. [Leicestershire, Nos. 29, 28, p. 435.] *Rep. Brit. Assoc.* for 1890, pp. 429 444.

MILLS, M. H.—A few Notes on the Ironstone Deposits of Leicestershire. *Proc. Chesterfield Mid. C. Inst., Eng.*, vol. xviii., p. 64 ; also *Trans. Fed. Inst. M. Eng.*, vol. ii. (1890–1891), pp. 28–30. Discussion, p. 525 (1892).

PAUL, J. D.—Recent Geological Notes. [Beaumont Leys Farm, Minerals, Boring in Leicester.] *Trans. Leicester Lit. Phil. Soc.*, vol. ii., p. 405.

RÜCKER, A. W., and T. E. THORPE.—A Magnetic Survey of the British Isles for the Epoch of Jan. 1, 1886. *Phil. Trans.*, vol. xlix., B. pp. 53–328, pls. i.–xiv.

WOODWARD, A. S., and C. D. SHERBORN.—A Catalogue of British Fossil Vertebrata. Supplement for 1890. [Leicester species, pp. 27 and 31.] *Geol. Mag.*, dec. iii., vol viii., pp. 25 34.

1891–1894.

BLAKE, J. F.—Annals of British Geology for 1890, 1891, 1892, 1893. 8vo. *London.*

1892.

ANON. (M. E.). General Notes on the Yorkshire, Leicestershire, and Warwickshire Coal Fields. *Coll. Guard.*, lxiv., p. 144.

BEASLEY, H. C.—The Life of the English Trias (Presidential Address). *Proc. Liverpool Geol. Soc.*, vol. vi., pp. 145 165.

BLAKE, J. F.—Excursion to Nottingham. [Breedon and Chellaston.] *Proc. Geol. Assoc.*, vol. xii., pp. 386–392.

BONNEY, T. G.—On specimens from the Permian Breccia of Leicestershire, collected by W. S. GRESLEY. *Mid. Nat.*, vol. xv., pp. 25–35, 49 57, pls. ii., iii.

BROWNE, M. Notes upon the Mesozoic Fossil Fish (*Ceratodus*), and its living representative, *Epiceratodus* (*Ceratodus*) *Forsteri* (Teller), with exhibition of palatal and mandibular teeth, from the Rhætics of Aust Cliff, Gloucestershire, and Spinney Hills, Leicestershire. *Trans. Leicester Lit. Phil. Soc.*, vol. ii., p. 559.

GRESLEY, W. S. A typical section, taken in detail, of the "Main Coal" of the Moira, or Western Division of the Leicestershire and South Derbyshire Coal Field. *Trans. Manchester Geol. Soc.*, vol. xxi., pp. 520–535, with two plates. Discussion, pp. 551 563. Reply to discussion, vol. xxii., pt. iii., pp. 74 85.

——— Geological History of the Rawdon and the Boothorpe Faults in the Leicestershire Coal Field. 8vo. *Newcastle.* Also *Trans. Chesterfield Inst. Eng.*, vol. xix., pl. iv., 1893 ; and *Trans. Fed. Inst. M. Eng.*, vol. iv., pp. 431–436, pl. xx., 1893. Discussion, vol. vi., pp. 402, 403. 1894.

HATCH, F. H.—Text Book of Petrology. [Analysis of Markfield Diorite, p. 147.] 8vo. *London.*

Hudleston, W. H., and E. Wilson.—A Catalogue of British Jurassic Gasteropoda. 8vo. *London.*

Woodward, H.—On a Neuropterous Insect from the Lower Lias, Barrow-on-Soar, Leicestershire. *Geol. Mag.*, dec. iii., vol. ix., p. 193-198 pl. v.

1893.

Bonney, T. G.—On the relation of the Bunter Pebbles of the English Midlands to those of the Old Red Sandstone Conglomerate of Scotland. *Rep. Brit. Assoc.* for 1892, p. 719.

Browne, M.—A Contribution to the History of the Geology of the Borough of Leicester. *Trans. Leicester Lit. Phil. Soc.*, vol. iii., pp. 123-240. Five plates.

Deeley, R. M.—The Glacial Succession. *Geol. Mag.*, dec. iii., vol. x., p. 31.

De Rance, C. E. On the relation of geology to the population and agriculture of England and Wales. [Statistics, etc.] *Trans. Manchester Geol. Soc.*, vol. xxii., pt. iii., pp. 85-112.

Everard, J. B.—Coalville Water Supply. 8vo. *Leicester.*

Hodson, G.—A consideration of some of the conditions requisite for obtaining underground water supplies ; illustrated by a description of the works for supplying Long Eaton and Melbourne (Derbyshire), and Castle Donington (Leicestershire). *Assoc. of Municipal and County Eng.*, vol. xix.

Hull, E.—On the Discovery of a concealed ridge of pre-Carboniferous rocks under the Trias of Netherseal, Leicestershire. *Geol. Mag.*, dec. iii., vol. x., pp. 552, 553. *Rep. Brit. Assoc.* for 1893, p. 745, 746. *Trans. Fed. Inst. M. Eng.*, vol. viii., pp. 90-92, 1894.

Paul, J. D.—Boring at Knighton [Wheatsheaf] Co-operative Shoe Works. *Trans. Leicester Lit. Phil. Soc.*, vol. iii., pp. 105, 106.

——— St. John's Stone. *Ibid.*, p. 263.

Woodward, H. B.—The Jurassic Rocks of Britain, vol. iii. The Lias of England and Wales (Yorkshire excepted). [Leicestershire pp. 23, 166 174, 231 239, 280 283, 290 293, 305.] *Memoirs of the Geological Survey.* 8vo. *London.*

1894.

Bonney, T. G.—A Comparison of the Pebbles in the Trias of Budleigh Salterton and of Cannock Chase. *Rep. Brit. Assoc.* for 1893, p. 655.

Browne, M. On some Vertebrate Remains not hitherto recorded from the Rhætic Beds of Britain. [Teeth of *Termatosaurus crocodilinus*, Quenst.] *Rep. Brit. Assoc.* for 1893, pp. 748, 749.

Lewis, H. Carvill.—Papers and Notes on the Glacial Geology of Great Britain and Ireland. Edited from his unpublished MSS., with an Introduction by H. W. Crosskey. 8vo. *London.*

Metcalfe, A. T.—On the Gypsum Deposits of Nottinghamshire and Derbyshire. *Rep. Brit. Assoc.* for 1893, p. 760. Abstract in *Quart. Journ. Geol. Soc.*, vol. lii., p. 461 (1896).

Woodward, H. B.—The Jurassic Rocks of Britain, vol. iv. The Lower Oolitic Rocks of England (Yorkshire excepted). [Leicestershire, pp. 28, 180, 496.] *Memoirs of the Geological Survey.* 8vo. *London.*

1895.

Bonney, T. G.—Supplementary note on the Narborough district (Leicestershire). *Quart. Journ. Geol. Soc.*, vol. li., pp. 24-34.

——— A Comparison of the Pebbles in the Trias of Budleigh Salterton and of Cannock Chase. *Geol. Mag.*, dec. iv., vol. ii., pp. 75-79. *Rep. Brit. Assoc.* for 1894, p. 655.

BROWNE, M.—On an exposure of Glacial beds in a cutting, for the M. S. and L. Railway, at Birstall Hill. *Trans. Leicester Lit. Phil. Soc.*, vol. iv., p. 25.

——— On a recent exposure of Rhætic and Lias beds on the M. S. and L. Railway, at East Leake. [Also on cemented gravel at Aylestone.] *Ibid.*, pp. 27, 28, 52.

CALLAWAY, C.—Professor Hull and the Cambrian age of the Charnwood Clastics. *Geol. Mag.*, dec. iv., vol. ii., pp. 142, 143.

GRESLEY, W. S.—Ice-plough Furrows of a Glacial Period. Abstract. *Quart. Journ. Geol. Soc.*, vol. li., p. 494.

HARRISON, W. J. Bibliography of Midland Glaciology. *Proc. Birmingham Nat. Hist. Soc.*, vol. ix., pt. ii., and 8vo. *Birmingham.*

HULL, E.—Geological age of the Rocks of Charnwood Forest. *Geol. Mag.*, dec. iv., vol. ii., p. 92.

——— The Leicestershire Coalfield. *Coll. Guard.*, vol. lxix., p. 272.

JEFFS, O. W. Fifth Report of the Committee on . . . . Photographs of Geological Interest, etc. [Leicestershire, Nos. 927-957, p. 278.] *Rep. Brit. Assoc.* for 1894, pp. 274-283.

PAUL, J. D. Cutting at the Swithland Reservoir. *Trans. Leicester Lit. Phil. Soc.*, vol. iv., p. 10.

——— Note on a Glacial Block recently exposed on the eastern side of King Richard's Road. [Leicester.] *Ibid.*, p. 27.

RANDALL, J.—The Midland Coalfields and superimposed rocks. *Coll Guard.*, vol. lxx., pp. 652, 782.

WATTS, W. W.—Notes on some Specimens collected in the Trench, Brazil Wood, Charnwood Forest. *Trans. Leicester Lit. Phil. Soc.*, vol. iv., p. 12.

WOODWARD, H. B.—The Jurassic Rocks of Britain, vol. v. The Middle and Upper Oolitic Rocks of England (Yorkshire excepted). [Bibliography with many Leicestershire titles.] *Memoirs of the Geological Survey.* 8vo. *London.*

1896.

ANON. The boring at Ruddington [Notice of excursion]. *Coll. Guard.*, vol. lxxii., pp. 823 and 1111.

ANON. The Leicestershire Coalfield. [Ibstock, South Leicestershire and Whitwick Collieries.] *Ibid.*, pp. 538, 584, 631.

ANON. (M. E.). The Warwickshire Coalfield, VI. Baddesley Colliery. *Ibid.*, p. 393.

BEMROSE, H. H. ARNOLD, and R. M. DEELEY. Discovery of Mammalian Remains in the Old River Gravels of the Derwent near Derby. *Quart. Journ. Geol. Soc.*, vol. lii., pp. 497-510.

BROWNE, M. Preliminary Notice of an Exposure of Rhætic Beds, near East Leake, Nottinghamshire. *Rep Brit. Assoc.* for 1895, p. 688.

COKE, G. E. Southern Limit of the Nottinghamshire Coalfield. (Map 1 inch to 3 miles.) *Trans. Fed. Inst. M. Eng.*, vol. xi., p. 339. *Coll. Guard.*, vol. lxxi., p. 1111.

————. J. W. CARR and W. W. WATTS. Excursion to Nottingham and Leicester. *Proc. Geol. Assoc.*, vol. xiv., pp. 430-433.

GRESLEY, W. S. Remarks on some interesting Coal Measure sections in the Leicestershire and South Derbyshire Coalfield. *Trans. Manchester Geol. Soc.*, vol. xxv.

HULL, E.—The Eastern Limits of the Midland Coalfield. *Trans. Fed. Inst. M. Eng.*, vol. xi., p. 9.

LAPWORTH, C., and W. W. WATTS.—[Note on the *Olenellus* zone of Nuneaton.] *Quart. Journ. Geol. Soc.*, vol. lii., Proc. p. vi.

TUCKER, W. T.—Archæological and Geological "Finds" of the M. S. & L. Railway. [Mammoth, &c., at Loughborough.] *Nottingham Daily Guardian*, Feb. 17, 1896.

WATTS, W. W.—Notes on the Ancient Rocks of Charnwood Forest. *Geol. Mag.*, dec. iv., vol iii., pp. 485-487; *Rep. Brit. Assoc.* for 1896, pp. 795-797.

1897.

ANON. Diorites of Atherstone and Nuneaton. *Coll. Guard.*, vol. lxxiii., p. 688.

BINNS, G. J., and G. HARROW.—On the occurrence of certain minerals at Netherseal Colliery, Leicestershire. *Coll. Guard.*, vol. lxxiii., p. 674. *Trans. Fed. Inst. M. Eng.*, vol. xiii., p. 252.

BINNS, G. J., C. FOX-STRANGWAYS, and W. W. WATTS.—Notes on borings at Netherseal, Ashby-de-la-Zouch, Leicestershire. *Ibid.*, pp. 595-598, 599, and vol. xv., p. 209.

BROWNE, M.—Fifth Contribution to Rhætic Literature. The Rhætic Bone-bed of Aust Cliff, and the Rock-bed above it. *Rep. Brit. Assoc.* for 1896, pp. 804, 805.

GEIKIE, SIR A.—Annual Report of the Geological Survey of the United Kingdom. 8vo. *London.*

——— The Ancient Volcanoes of Great Britain. 8vo. *London.*

JEFFS, O. W., and W. W. WATTS. Report. . . on Photographs of Geological Interest, etc. [Leicestershire, Nos. 1262 1310, pp. 361 362.] *Rep. Brit. Assoc.* for 1896, pp. 357-365.

WOODWARD, H. B.—The Chalky Boulder-clay and the Glacial Phenomena of the Western-Midland Counties of England. *Geol. Mag.*, dec. iv., vol. ix., pp. 485-497. *Rep. Brit. Assoc.* for 1897, p. 649.

1898.

ANON.—The Warwickshire Coalfield. *Coll. Guard.*, vol. lxxv., p. 747.

ANON. (M. E.).—The Leicestershire coalfield. VII. Bretby Colliery. *Coll. Guard.*, vol. lxxvi., p. 829.

ANON.—The Leicestershire Coalfield. [General account of strata.] *Ibid.*, p. 1154.

GEIKIE, SIR A.—Summary of Progress of the Geological Survey of the United Kingdom for 1897. 8vo. *London.*

GRESLEY, W. S.—Clay veins vertically intersecting Coal-measures. [Sections at Netherseal, Donisthorpe and Rawdon.] *Bull. Geol. Soc. America*, vol. ix., pp. 35-58.

——— Cone-in-Cone: Additional Facts from Various Countries. [Examples from Ashby said to be formed subsequently to the deposition of the Permian.] *Quart. Journ. Geol. Soc.*, vol. liv., p. 196. *Geol. Mag.*, dec. iv., vol. v., p. 236.

HARRISON, W. J. The Ancient Glaciers of the Midland Counties of England. *Proc. Geol. Assoc.*, vol. xv., pp. 400 408.

LAPWORTH, PROF. C. A Sketch of the Geology of the Birmingham District. *Proc. Geol. Assoc.*, vol. xv., pp 313 316.

SHRUBSOLE, G. A. On some High-level Gravels in Berkshire and Oxfordshire. [Analysis of gravel at Repton, p. 594.] *Quart. Journ. Geol. Soc.*, vol. liv., p. 585.

WATTS, PROF. W. W. Notes on the Petrology of the Birmingham District. *Proc. Geol. Assoc.*, vol. xv., pp. 389 400.

——— Report on the long excursion to the Birmingham District. *Ibid.*, pp. 417-428.

——— Report . . . . . on Photographs of Geological Interest, etc. [Leicestershire, Nos. 1419, 1617-1622.] *Rep. Brit. Assoc.* for 1897, pp. 298-332.

——— Geology for Beginners. 8vo. *London.*

1899.

ANON (M. E).—The Leicestershire Coalfield; viii., Nailstone Colliery; ix., Moira Collieries. *Coll. Guard.*, vol. lxxvii., pp. 58, 106.

ANON.—The Silurian and Carboniferous Rocks of the Midlands. *Ibid.*, p. 264.

ANON.—Excursion to the Cadley Hill Coal-pit and Church Gresley. *Trans. Leicester Lit. Phil. Soc.*, vol. v., p. 308.

BENNETT, DR. F. W.—[Charnwood Forest.] *Ibid.*, pp. 195–197.

GEIKIE, SIR A.—Summary of Progress of the Geological Survey of the United Kingdom for 1898. 8vo. *London.*

STRANGWAYS, C. FOX.—Excursions to Burrough-on-the-Hill; Melbourne and Repton; Swadlincote, Ticknall, and Melbourne; and Nuneaton and Atherstone. *Trans. Leicester Lit. Phil. Soc.*, vol. v., pp. 239, 241, 303, 307.

WATTS, PROF. W. W.—Report . . . on Photographs of Geological Interests, etc. [Leicestershire, Nos. 1840, 1841.] *Rep. Brit. Assoc.* for 1898, pp. 530–546.

——— Note on the surface of the Mount Sorrel Granite. *Geol. Mag.*, dec. iv., vol. vi., p. 508.

——— Excursion to Charnwood Forest. *Trans. Leicester Lit. Phil. Soc.*, vol. v., p. 309.

1900.

BONNEY, T. G.—The Bunter Pebble-beds of the Midlands and the Source of their Materials. *Quart. Journ. Geol. Soc.*, vol. lvi., pp, 287–306.

GEIKIE, SIR A. Summary of Progress of the Geological Survey of the United Kingdom for 1899. 8vo. *London.*

HALL, W. J.—[Note on a landship at Leire, Leicestershire.] *Trans. Leicester Lit. Phil. Soc.*, vol. v., p. 372.

PAUL, J. D. The Valley of the Soar. *Ibid.*, p. 426.

STRANGWAYS, C. FOX.—Excursions to Atherstone and Polesworth; Ashby-de la-Zouch and Melbourne; and Ashby-de-la-Zouch and Measham. *Ibid.*, pp. 477–483.

WATTS, PROF. W. W. Report . . . . on Photographs of Geological Interest, etc. [Leicestershire Nos. 2284, 2285. Furrowing and smoothing of Granite.] *Rep. Brit. Assoc.* for 1899, pp. 377–397.

——— Note on the Surface of the Mount Sorrel Granite. *Ibid.*, p. 747.

INDEX.

N.B.—Names of Persons (authors, observers, and informants) are in small capitals.

C.

D.

E.

F.

T.

U.

V.

W.

GENERAL MEMOIRS OF THE GEOLOGICAL SURVEY.

SUMMARY of PROGRESS of the GEOLOGICAL SURVEY for 1897, 1898, and 1899. Each 1*s*.

The MEMOIRS of the GEOLOGICAL SURVEY of GREAT BRITAIN. Vol. I., 21*s*.; Vol. II. (in 2 Parts), 42*s*. N. WALES By SIR A. C. RAMSAY. App., by J. W. SALTER and R. ETHERIDGE. 2nd. Ed. 21*s*. (Vol. III. of Memoirs, &c.)

Guide to the GEOLOGY of LONDON and the NEIGHBOURHOOD. By W. WHITAKER. 5th Ed. 1*s*.

TERTIARY FLUVIO-MARINE FORMATION of the ISLE of WIGHT. By EDWARD FORBES. 5*s*.

The ISLE OF WIGHT. By H. W. BRISTOW. New Ed. By C. REID and A. STRAHAN. 8*s*. 6*d*.

The ISLE OF PURBECK AND WEYMOUTH. By A. STRAHAN. 10*s*. 6*d*.

The WEALD (PARTS of the COUNTIES of KENT, SURREY, SUSSEX, and HANTS). By W. TOPLEY. 17*s*. 6*d*.

The TRIASSIC and PERMIAN ROCKS of the MIDLAND COUNTIES of ENGLAND. By E. HULL. 5*s*.

The FENLAND. By S. B. J. SKERTCHLY. 36*s*. 6*d*.

The MANUFACTURE of GUN FLINTS. By S. B. J. SKERTCHLY. 16*s*.

The SUPERFICIAL DEPOSITS of SOUTH-WEST LANCASHIRE. By C. E. DE RANCE. 10*s*. 6*d*.

NORTH DERBYSHIRE. By A. H. GREEN, C. LE NEVE FOSTER and J. R. DAKYNS. 2nd. Ed. By A. H. GREEN and A. STRAHAN. 5*s*. 6*d*.

BURNLEY COAL FIELD. By E. HULL, R. H. TIDDEMAN [and Others]. 12*s*.

YORKSHIRE COALFIELD. By A. H. GREEN, R. RUSSELL [and Others]. 42*s*.

EAST SOMERSET and BRISTOL COALFIELDS. By H. B. WOODWARD. 18*s*.

WARWICKSHIRE COAL-FIELD. By H. H. HOWELL. 1*s*. 6*d*.

LEICESTERSHIRE COAL-FIELD. By EDWARD HULL. 3*s*.

ERUPTIVE ROCKS of BRENT TOR. By F. RUTLEY. 15*s*. 6*d*.

FELSITIC LAVAS of ENGLAND and WALES. By F. RUTLEY. 9*d*.

HOLDERNESS. By C. REID. 4*s*.

SOILS and SUB-SOILS from a SANITARY POINT of VIEW. By H. B. WOODWARD. 2*s*. 6*d*.

The WATER SUPPLY OF SUSSEX. By W. WHITAKER and C. REID. 3*s*.

The PLIOCENE DEPOSITS of BRITAIN. By C. REID. 5*s*. 6*d*.

The CRETACEOUS ROCKS OF BRITAIN.—Vol. I. GAULT AND UPPER GREENSAND OF ENGLAND. By A. J. JUKES-BROWNE and W. HILL. 9*s*.

The JURASSIC ROCKS OF BRITAIN.—Vol. I. YORKSHIRE, 8*s*. 6*d*., Vol. II. YORKSHIRE, Fossils, 12*s*. By C. FOX-STRANGWAYS. Vol. III. LIAS OF ENGLAND (Yorkshire excepted). 7*s*. 6*d*. By H. B. WOODWARD. Vol. IV. The Lower Oolitic Rocks of England. 10*s*. By H. B. WOODWARD. Vol. V. The Middle and Upper Oolitic Rocks of England. 7*s*. 6*d*. By H. B. WOODWARD.

BRITISH ORGANIC REMAINS. DECADES I. to XIII., with 10 Plates each. Price 4*s*. 6*d*. each 4to; 2*s*. 6*d*. each 8vo.

MONOGRAPH I. On the Genus PTERYGOTUS. By T. H. HUXLEY, and J. W. SALTER. 7*s*.

MONOGRAPH II. On the Structure of the BELEMNITIDÆ. By T. H. HUXLEY. 2*s*. 6*d*.

MONOGRAPH III. On the CROCODILIAN REMAINS found in the ELGIN SANDSTONES. By T. H. HUXLEY. 14*s*. 6*d*.

MONOGRAPH IV. On the CHIMÆROID FISHES of the British Cretaceous Rocks. By E. T. NEWTON. 5*s*.

The VERTEBRATA of the FOREST BED SERIES of NORFOLK and SUFFOLK. By E. T. NEWTON. 7*s*. 6*d*.

The VERTEBRATA of the PLIOCENE DEPOSITS of BRITAIN. By E. T. NEWTON. 4*s*.

Museum Catalogues, &c.:—

HANDBOOK to the MUSEUM of PRACTICAL GEOLOGY. 6*d*.

HANDBOOK to the COLLECTION of BRITISH POTTERY and PORCELAIN. 1*s*.

FOSSILS:—CAMBRIAN and SILURIAN, 2*s*. 6*d*.; CRETACEOUS, 2*s*. 9*d*.; TERTIARY and POST-TERTIARY, 1*s*. 8*d*.

SHEET MEMOIRS OF THE GEOLOGICAL SURVEY.

1, 2, 7 - - GEOLOGY OF LONDON, &c. By W. WHITAKER. Vol. I., 6*s*. Vol. II., 5*s*.

4 - - - FOLKESTONE and RYE. By F. DREW. 1*s*.

34 - - - PARTS of WILTS, and GLOUCESTERSHIRE. By A. C. RAMSAY, W. T. AVELINE, and E. HULL. 8*d*.

44 - - - CHELTENHAM. By E. HULL. 2*s*. 6*d*.

45 - - - BANBURY, WOODSTOCK, and BUCKINGHAM. By A. H. GREEN. 2*s*.

45 SW - - WOODSTOCK. By E. HULL. 1*s*.

47 - - - N.W. ESSEX & N.E. HERTS. By W. WHITAKER, W. H. PENNING, W. H. DALTON, & F. J. BENNETT. 3*s*. 6*d*.

48 SW - - COLCHESTER. By W. H. DALTON. 1*s*. 6*d*.

48 SE - - EASTERN END of ESSEX (WALTON NAZE and HARWICH). By W. WHITAKER. 9*d*.

48 NW, NE - IPSWICH, HADLEIGH, and FELIXSTOWE. By W. WHITAKER, W. H. DALTON, & F. J. BENNETT. 2*s*.

49 S, 50 SE - ALDBOROUGH, &c. By W. H. DALTON. Edited, with additions, by W. WHITAKER. 1*s*.

49 N - - SOUTHWOLD. By W. WHITAKER. 2*s*. 6*d*.

50 SW - - STOWMARKET. By W. WHITAKER, F. J. BENNETT and J. H. BLAKE. 1*s*.

50 NW - - DISS, EYE, &c. By F. J. BENNETT. 2*s*.

50 NE - - HALESWORTH and HARLESTON. By W. WHITAKER and W. H. DALTON. 1*s*.

51 SW - - CAMBRIDGE. By W. H. PENNING and A. J. JUKES-BROWNE. 4*s*. 6*d*.

51 SE - - BURY ST. EDMUNDS and NEWMARKET. By F. J. BENNETT, J. H. BLAKE, and W. WHITAKER. 1*s*.

51 NE - - PARTS of CAMBRIDGESHIRE and SUFFOLK. By W. WHITAKER [and Others]. 2*s*.

53 SE - - PART of NORTHAMPTONSHIRE. By W. T. AVELINE and RICHARD TRENCH. 8*d*.

53 NE - - PARTS of NORTHAMPTONSHIRE and WARWICKSHIRE. By W. T. AVELINE. 8*d*.

64 - - - RUTLAND, &c. By J. W. JUDD. 12*s*. 6*d*.

65 - - - S.W. NORFOLK and N. CAMBRIDGESHIRE. By W. WHITAKER S. B. J. SKERTCHLY, and A. J. JUKES-BROWNE. 3*s*.

3

SHEET MEMOIRS OF THE GEOLOGICAL SURVEY—*continued*

66 NE, SE - NORWICH. By H. B. WOODWARD. 7*s*.
66 SW - ATTLEBOROUGH. By F. J. BENNETT. 1*s*. 6*d*.
67 NW - E. DEREHAM. By J. H. BLAKE. 1*s*. 6*d*.
67 - YARMOUTH and LOWESTOFT. By J. H. BLAKE. 2*s*.
68 E - CROMER. By C. REID. 6*s*.
68 NW, SW - FAKENHAM, WELLS, &c. By H. B. WOODWARD. 2*s*.
69 - BORDERS OF THE WASH. By W. WHITAKER and A. J. JUKES-BROWNE. 3*s*.
70 - S.W. LINCOLNSHIRE, &c. By A. J. JUKES-BROWNE and W. H. DALTON. 4*s*.
71 NE - NOTTINGHAM. By W. T. AVELINE. (2nd Ed.) 1*s*.
79 NW - RHYL, ABERGELE, and COLWYN. By A. STRAHAN. (Notes by R. H. TIDDEMAN.) 1*s*. 6*d*.
79 SE - FLINT, MOLD, and RUTHIN. By A. STRAHAN (Parts by C. E. DE RANCE). 4*s*. 6*d*. ; *Supplement* 2*d*.
80 NW - PRESCOT, LANCASHIRE. By E. HULL. (3rd Ed. With additions by A. STRAHAN.) 3*s*.
80 SW - CHESTER. By A. STRAHAN. 2*s*.
81 NW, SW - STOCKPORT, MACCLESFIELD, CONGLETON, & LEEK. By E. HULL and A. H. GREEN. 4*s*.
82 SE - PARTS of NOTTINGHAMSHIRE and DERBYSHIRE. By W. T. AVELINE. (2nd Ed.) 6*d*.
82 NE - PARTS of NOTTINGHAMSHIRE, YORKSHIRE, and DERBYSHIRE. (2nd Ed.) By W. T. AVELINE. 1*s*.
83 - LINCOLN. By W. A. E. USSHER, A. J. JUKES-BROWNE and A. STRAHAN. 3*s*.
84 - EAST LINCOLNSHIRE. By A. J. JUKES-BROWNE. 3*s*. 6*d*.
86 - N. LINCOLNSHIRE and S. YORKSHIRE. By W. A. E. USSHER [and Others]. 2*s*.
87 NW - WAKEFIELD and PONTEFRACT. By A. H. GREEN. 6*d*.
87 SW - BARNSLEY. By A. H. GREEN. 9*d*.
88 SW - OLDHAM. By E. HULL. 2*s*.
88 SE - PART of the YORKSHIRE COAL-FIELD. By A. H. GREEN, J. R. DAKYNS and J. C. WARD. 1*s*.
88 NE - DEWSBURY, &c. By A. H. GREEN, J. R. DAKYNS, J. C. WARD, and R. RUSSELL. 6*d*.
89 SE - BOLTON, LANCASHIRE. By E. HULL. 2*s*.
90 SE - The COUNTRY between LIVERPOOL and SOUTHPORT. By C. E. DE RANCE. 3*d*.
90 NE - SOUTHPORT, LYTHAM, and SOUTH SHORE. By C. E. DE RANCE. 6*d*.
91 SW - The COUNTRY between BLACKPOOL and FLEETWOOD. By C. E. DE RANCE. 6*d*.
91 NW - SOUTHERN PART of the FURNESS DISTRICT in N. LANCASHIRE. By W. T. AVELINE. 6*d*.
92 SE - BRADFORD and SKIPTON. By J. R. DAKYNS, C. FOX-STRANGWAYS, R. RUSSELL, and W. H. DALTON. 6*d*.
93 NW - NORTH and EAST of HARROGATE. By C. FOX-STRANGWAYS. 6*d*.
93 NE - The COUNTRY between YORK and MALTON. By C. FOX-STRANGWAYS. 1*s*. 6*d*.
93 NW - N. and E. of LEEDS, and near TADCASTER. By W. T. AVELINE, A. H. GREEN (and others).
93 SE, 94 W - COUNTRY between YORK & HULL. By J. R. DAKYNS, C. FOX-STRANGWAYS, and A. G. CAMERON. 1*s*.
94 NW - DRIFFIELD. By J. R. DAKYNS and C. FOX-STRANGWAYS. 9*d*.
94 NE - BRIDLINGTON BAY. By J. R. DAKYNS and C. FOX-STRANGWAYS. 1*s*.
95 SW, SE - SCARBOROUGH and FLAMBOROUGH HEAD. By C. FOX-STRANGWAYS. 1*s*.
95 NW - WHITBY and SCARBOROUGH. By C. FOX-STRANGWAYS and G. BARROW. 1*s*. 6*d*.
96 SE - NEW MALTON, PICKERING, and HELMSLEY. By C. FOX-STRANGWAYS. 1*s*.
96 NE - ESKDALE, ROSEDALE, &c. By C. FOX-STRANGWAYS, C. REID, and G. BARROW. 1*s*. 6*d*.
96 NW, SW - NORTHALLERTON and THIRSK. By C. FOX-STRANGWAYS, A. G. CAMERON, and G. BARROW. 1*s*. 6*d*.
97 SW - INGLEBOROUGH. By J. R. DAKYNS, R. H. TIDDEMAN, W. GUNN, and A. STRAHAN. 2*s*.
97 NW - MALLERSTANG. By J. R. DAKYNS, R. H. TIDDEMAN (and others). 3*s*. 6*d*.
98 SE - KIRKBY LONSDALE and KENDAL. By W. T. AVELINE, T. MC K. HUGHES, and R. H. TIDDEMAN. 2*s*.
98 NE - KENDAL. By W. T. AVELINE and T. MC K. HUGHES. 2nd Ed. by A. STRAHAN. 2*s*.
101 SE - NORTHERN PART of the ENGLISH LAKE DISTRICT. By J. C. WARD. 9*s*.
102 SW - APPLEBY, ULLSWATER, and HAWESWATER. By J. R. DAKYNS, R. H. TIDDEMAN, and J. G. GOODCHILD. 1*s*. 6*d*.
104 SW, SE - NORTH CLEVELAND. By G. BARROW. 1*s*. 6*d*.
107 - CARLISLE. By T. V. HOLMES. 1*s*. 3*d*.
108 SE - OTTERBURN and ELSDON. By HUGH MILLER. 2*s*. 6*d*.
108 NE - CHEVIOT HILLS. By C. T. CLOUGH. 1*s*. 6*d*.
108 SW - PLASHETTS and KIELDER. By C. T. CLOUGH. 1*s*.
110 SW - WOOLER and COLDSTREAM. By W. GUNN and C. T. CLOUGH. 1*s*. 6*d*.
110 NW - NORHAM and TWEEDMOUTH. By W. GUNN. 6*d*.
110 NE - COAST SOUTH of BERWICK-ON-TWEED. By W. GUNN. 9*d*.
110 SE - BELFORD, HOLY ID., and FARNE ISLANDS. By W. GUNN. 2*s*. 6*d*.
232 (New Series) ABERGAVENNY. By A. STRAHAN and W. GIBSON. 2*s*.
249 („) NEWPORT, MON. By A. STRAHAN. 2*s*.
328 („) DORCHESTER. By C. REID. 1*s*.
329 („) BOURNEMOUTH. By C. REID. 4*d*.
332 („) BOGNOR. By C. REID. 6*d*.
334 („) EASTBOURNE. By C. REID. 6*d*.

COAL-FIELDS AND OTHER MINERAL DISTRICTS.—Scale, six inches to a mile.

The Coal-fields and other mineral districts of the N. of England are in part published on a scale of six inches to a mile at 4*s*. to 6*s*. each. M.S. Coloured Copies of other six-inch maps, not intended for publication, are deposited for reference in the Geological Survey Office, 28, Jermyn Street, London.

THE IRON ORES OF GREAT BRITAIN.

Part I. The North and North Midland Counties of England (*Out of print*). Part II. South Staffordshire. Price 1*s*. Part III. South Wales. Price 1*s*. 3*d*. Part IV. The Shropshire Coal-field and North Staffordshire. 1*s*. 3*d*.