35. *The* Upper Eocene, *comprising the* Barton *and* Upper Bagshot Formations. By J. Starkie Gardner, Esq., F.G.S., F.L.S., Henry Keeping, Esq., and H. W. Monckton, Esq., F.G.S. (Read March 28, 1888.)

The introduction of the Oligocene stage into our classification has necessitated a partial revision of the grouping of our older British Tertiaries. Whether this introduction of a new primary division into the Tertiary system was necessary or expedient may still be questioned; but it has been generally adopted and is, for the time being, established. The division does not coincide in England with a marked change in either fauna or flora, though the series seems nevertheless tolerably complete and well developed; its limits, however widely stretched, show that the Oligocene stage compares neither with the Eocene nor the Miocene in importance.

Opinions have differed as to where the line of division should be drawn; whether this should be as low down as the top of the Barton Beds or at the base of the Headon Beds, or even higher. For our part, we think it desirable to uphold the view which places the demarcation between the top of the Bagshot Sands of Alum Bay and the base of the Lower Headon Series, though it is perfectly obvious that any such line in the midst of our series must be a purely artificial one.

An almost necessary consequence of the change in the classification has been the readjustment of the divisions of our truncated Eocene, only the middle and lower division remaining, so that the term "Middle" without an Upper Eocene would no longer be an appropriate one. But the Middle Eocene, embracing as it does such formations as the Nummulitic and the *Calcaire grossier*, has a literature of immense importance, which it appears to us in the highest degree inexpedient to disturb or render obsolete. We therefore propose to adopt the view which reconstructs an Upper Eocene from the Barton and Upper Bagshot Beds, and to show that they form a sufficiently natural and well-marked group*. Neither the Upper nor the Middle Eocene, however, will then continue to equal the Lower Eocene in importance, and we cannot but look on the necessity for any revision as unfortunate. The Eocene, as it stood, was a compact, useful, and by no means unwieldy group, with a literature and history that should have preserved it from dismemberment. The Upper Eocene was by no means so preponderating or so distinct as to render its removal expedient, and the transition beds were either satisfactorily located or might easily have been so. Finally the flora of the Oligocene, on which some stress has been laid, is so

* A paper by Prof. Prestwich has been published (Quart. Journ. Geol. Soc. vol. xliv. p. 88) since this was written. He treats the classification we propose here as the one already established, *vide* table p. 88. This would render further insistance on its expediency unnecessary, did he not propose, *l. c.* p. 108, to suppress this classification by totally abolishing the Middle Eocene.

distinctly Eocene in facies that the flora of Bournemouth, which is at the base of the Middle Eocene, may be said to be the typical flora of the Oligocene in Europe.

The Upper Eocene in England will, according to our views, comprise the Barton Series and the Upper Bagshot Series, the inferior limit being the Bracklesham, and the superior limit the Headon Beds. We have gathered conclusive evidence that the Upper Bagshot Series of the London basin is, to a large extent, the equivalent of the Barton Series of the Hampshire basin, and represents, indeed, rather its lower than its upper bed. This fact, again, has rendered revision necessary, and the classification which, we submit, best meets the requirements is the following:—

Upper Eocene.

	London Basin.	Hampshire Basin.
Upper Bagshot Series.	Unrepresented.	Becton-Bunny Beds. *Chama*-Beds.
	Upper Bagshot Sands.	Barton Beds. Highcliff Beds.

The base-line of the formation is, it must be confessed, not too well marked, but it almost coincides with the disappearance of Nummulites in our area, and with a considerable change in the character of the fauna, through the disappearance of a number of subtropical forms. Deposition was so continuous here during the Eocene time that it is not always easy to draw strongly marked lines of division, for such, in this case, would only occur where there had been great changes of level, or where an arm of the sea became landlocked and dry. It would thus be perfectly easy, say, to distinguish between early Pliocene deposits in Italy and those forming in historic times along the margin of the Adriatic; but if the whole basin of the Adriatic were upheaved, and escarpments cut through it, as in Hampshire, it might be very difficult to draw satisfactory lines between the Pliocene and the recent beds.

Literature.—We have not compiled any list of works on the Upper Bagshot Beds, as those of importance are referred to further on. The splendid preservation and abundance of the fossils in the Barton Beds attracted the attention of Mr. Brander, Curator of the British Museum, and, in 1766, a work upon them was so admirably illustrated that all the 85 species of Mollusca described in it by Dr. Solander can readily be identified. Professor Prestwich communicated descriptions of the Barton Beds to this Society in 1847–1854; and a Geological Survey Memoir on the Isle of Wight, dealing with the Barton Beds at Alum and Whitecliff Bays, appeared in 1862. Prof. Prestwich also described the Bagshot Beds of the London area in 1847*, placing the Upper Sands provisionally somewhere between the Bracklesham and Headon Series; and Trimmer included both the Barton and Bracklesham Beds in the Middle

* Quart. Journ. Geol. Soc. vol. iii. p. 384.

Bagshots*. But Prof. Prestwich, when again dealing with the subject in 1856, still considered the question unsettled; for he says:—"How far the Upper Bagshot Sands are related to the Bracklesham series it is difficult to say. The few fossils I have found in those sands are not sufficiently distinctive to enable me to pronounce a decided opinion. As, however, the fossiliferous Middle Bagshot Sands are very thin, and represent apparently only the lower or middle part of the Bracklesham Series, I think it probable that it is the upper beds of sand and clay of the latter which pass northward into the thick sands of the Upper Bagshot Sands. Still, it is possible that part of them may represent the Barton Series; for we see at Barton how shifting the upper part of that series is, how clay predominates at one place and sands at another" †. The Geological Survey Memoir of 1872 on the London basin contributed little further evidence as to the age of the beds under consideration, and to the present day Prof. Prestwich regards it as an open question ‡. Dumont, however, classed the Barton Beds with the Upper Bagshot Sands, and they have been generally regarded as more or less equivalent in age.

Area.—The Upper Bagshot Sands are chiefly restricted in the London basin to what is termed the "main mass" of the formation at and around Bagshot Heath, and extend from the eastern end of Berkshire into Surrey and Hampshire. In the Hampshire basin the Barton Beds occupy the coast-section in Christchurch Bay for about three miles; they have been traced inland to a little east of Ringwood, near the village of Powner, and the *Corbula*-zone has been recognized in brick-pits at Bramsgrove, not quite halfway between Powner and the coast. The *Chama*-beds have been seen at Binstead Manor, on the Compton estates, a mile north of Lyndhurst § (by the Rev. J. Compton, Rev. O. Fisher, and by Mr. Keeping). In the Isle of Wight they crop out and are well exhibited at Alum Bay, and are equally present at the other extremity, Whitecliff Bay. Mr. Bristow records that he met with Barton fossils at Gunvelle, north of Carisbrooke, and the clays without fossils have been identified at one or two other spots in the island. The area over which they extend is remarkably limited, considering their importance. Prof. Prestwich correlated them with the Sables de Beauchamp in France ‖ and the Laekenian system in Belgium ¶, and the accuracy of his views in this case has never been disputed.

Thickness.—The thickness of the Upper Bagshot Sand in the London basin nowhere greatly exeeeds 200 feet, and is usually much less, owing to denudation. It is, except the gravels, the highest formation in the area. In the Hampshire cliffs the whole series, from the pebble-bed at the base to the top of the Long-Mead-

* Journ. Royal Agricult. Soc. vol. xii. p. 445 (1851).

† Quart. Journ. Geol. Soc. vol. xiii. p. 132.

‡ In his latest works, Quart. Journ. Geol. Soc. vol. xliv. (1888), p. 107, and Geology, vol. ii. p. 363, he still regards the question as unsettled.

§ Mem. Geol. Surv. I. of Wight, Bristow, 1862, p. 46.

‖ Quart. Journ. Geol. Soc. vol. iii. (1847) p. 354. "On the probable Age of the London Clay and its relations to the Hampshire and Paris Basin Tertiary System."

¶ *Ibid.* vol. xiii. (1857) p. 107.

End beds, is about 200 feet thick. Our first measurements gave a total of 190 feet, and our second of 200 feet. Dr. Wright made a total of 210 feet. Prof. Prestwich's measurements agree, except that he makes the Middle Barton Clay 150 feet instead of 50 feet. Prof. Judd underestimated the thickness of the upper part, for he implies that the whole of the Headon group at Hordwell *, including everything above the Barton Beds (presumably the top of the *Chama*-bed), is only 100 feet thick, whereas our measurements, to the top of the Lower Headon only, show 144 feet. The thickness of the Barton and Upper Bagshot Series at Alum Bay is 380 feet, according to Prestwich; but Mr. Fisher subtracts 40 feet from the base to add to the Bracklesham, and the sands were not actually proved to be 100 feet thick, and may, from the position they occupy, have been folded or contorted.

At Whitecliff Bay the entire formation is nearly 350 feet thick.

Deposition.—The series, like the entire British Eocene, is distinctly fluviatile and estuarine, and in correlating it we must bear in mind that it is physically impossible for any one quality of sediment to have been deposited synchronously over any very extended area by such agencies. Though the beds of the Hampshire, the London, and the Paris basins present a broad similarity, the resemblance in most cases disappears when we come to detailed comparisons, and we have to rely rather on the faunas and floras contained in them. When these are alike, we regard the beds as synchronous, or on the same horizon, but with such deposits we should not perhaps trust too implicitly to fossils. The Upper Bagshot Sands of the London basin are such as might have been accumulated in a large bight or bay of open sea; but in Hampshire the series was evidently laid down within the influence of a considerable river †. It commences with a sand-and-shingle bank with much floated wood, and ends in the silts of the higher reaches of a river. In working through the beds, we start among the breakers of a bar far out to sea, and gradually make our way up into the smooth and purely freshwater reaches of a tidal river. The succession could only have been brought about by a sustained movement of upheaval, and we can best interpret the meaning of the repeated changes in the quality of sediment to be described by endeavouring first to realize what would be exposed if the sediments now forming at the mouth of such a river as even the Thames were similarly upheaved.

If a slow, sustained elevation set in between the Isles of Thanet and Foulness, the first effect would be an inward movement of the littoral zones of sand and shingle, which would overcreep the previous homogeneous sea or estuarine mud, the thickness of the former, of course, depending on the rate of upheaval. Unless this

* Judd, Quart. Journ. Geol. Soc. vol. xxxvi. (1880) p. 171.

† Mr. Sorby came to this conclusion many years ago, and believed the currents which deposited the Barton Clay near Muddiford to have been N. 76° E. and S. 74° W. In the upper part of the Barton Beds (at Alum Bay) he found no traces of currents, and inferred that the sea was too deep for the sediment to be moved (Edinb. New Phil. Journ. n. s. vol. v. p. 289).

were very gradual, the passage from blue or greenish mud or clay to coarse sand would be abrupt, but if very gradual indeed, every gradation from fine clay to sand, and from a relatively deep-water to a between-tide fauna, might be preserved. If the river continued to discharge its waters in the same direction, these would keep channels open in which no deposit formed; and as the water continued to shoal, banks and shoals would accumulate like those of the Nore, through which fresh channels are perpetually being cut and old ones silted up, presenting, when upheaved, a drifted, changeable, and confused bedding. The same kind of beds, but less in area, and with a fauna gradually passing from marine to more and more brackish, would extend a long way up the tideway of the river. They would also become more muddy in character, like the deposits off Sheerness and the Medway, because relatively more sheltered from the sifting action of rough and disturbed water. Still higher the more contracted channel would be kept open, but be flanked by extensive sheets of sediment evenly and distinctly bedded, because deposited intermittently by overflowing water, and perhaps interstratified with beds full of decayed vegetation, such as were seen in the section in Tilbury Flats. Most of this vegetation was rush-like, but in still higher reaches the brackish-swamp plants would be replaced by deciduous and other kinds of leaves &c., which might extend up the river as far as the influence of the tides and the lowness of the banks permitted. A transverse section across a valley once occupied by such a river would present a centre core of lenticular bedding, where the actual channel had been filled in, margined by horizontal beds of clay with stratified layers of vegetable débris and, probably, distinct layers of differing animal remains.

With our hypothetical very gradual but sustained elevation, each of these descriptions of sediment would in turn be laid down over the same spot, presenting a vertical sequence strikingly similar to that met with at Barton at the present day*. That this is so relatively simple and easily interpreted is truly remarkable when we consider that had the channel shifted and the river meandered greatly, all the first deposits might have been cut away and altered, while if there had been great oscillation of level the bedding must have become infinitely complicated.

The Barton Series, in fact, commences with a great mass of white sand, with lines of well-rolled pebbles, indicating raised banks in shallow water; and since the main mass of the underlying Bracklesham seen at Hengistbury was undoubtedly formed in more open

* In the London Clay it is easy to realize that deposition took place in a broad estuary or tract of sea, such as the German Ocean 50 or 100 miles off Harwich. We can trace where great drifts of fruits and seeds, such as those met with by Moseley, 70 miles from the mouth of the Amboynah river, New Guinea, became habitually water-logged and sank, how far beyond this macerated twigs alone floated, where certain types of Crustacea and Mollusca lived and died, the various depths of the water and proximity to shore at different localities, the main-channels strewed with terrestrial débris, and the wider regions into which these were never wafted.

sea, as indicated by the prevalence of sharks' teeth and fish-palates in it, the period ushering in the Barton must have been one of upheaval. We cannot expect to trace our base-line of sand and shingle in all localities, because the same amount of upheaval taking place in deeper water would merely result in a diminution of depth with, perhaps, but a slight change in the character of the sediment and nature of the fauna. The passage in the Isle of Wight, and probably in the direction of the New Forest, between the Barton and Bracklesham Series is, in fact, an almost imperceptible one, and in some places they appear a practically continuous formation. This mass of sand and shingle is, at Highcliff, followed by dark green sandy clay, similar to that of the Bracklesham beds, but full of drifted wood, fruits, and fir-cones, and coniferous twigs, and comprising a thin band with *Nummulites elegans*, fish-teeth, and, more rarely, bony plates of Chelonians and Crocodiles. This assemblage, confined, apparently, so far as vegetation goes, to objects with considerable powers of flotation, should give a great insight into the conditions of deposition, were observations of the necessary kind in existing estuaries not so scanty. A ferruginous band marks, perhaps, a considerable shift when the deposition of mud was almost suspended, and preceded a change which ushered in the stiff drab clay of the Highcliff Beds proper. That the water still remained shallow is apparent, since the shells, unless minute, are broken into small fragments and drifted with sand into pockets. A shore-crab, described by Dr. Woodward, was probably from a zone of pinkish clay in this part of the series. A small Echinoderm is abundant near the base, and first *Psammobia* and then *Pholadomya* become common, and are always found in the vertical position assumed by them in life. Next we have the Middle or true Barton Clay, at first glauconitic and then plastic, with its rich assemblages of shells, many of large size, and ending with great and wide-spread drifts of shell-matter, chiefly comminuted and in an irony matrix. This is succeeded by a mass of sand crowded with Chamas and a peculiar fauna, which appears for the first time and as suddenly disappears, giving place to the truly estuarine Becton-Bunny Beds, which in turn pass upward into the brackish Long-Mead-End Beds, and then into the fluviatile Lower Headons.

Great interest attaches to the Barton Series on account of its fauna, which is both rich and, to a large extent, peculiar. Prof. Prestwich long since remarked on the more northern character of its Mollusca, contrasted with those of the Brackleshams*. The submergence implied by him seems, in fact, to have destroyed some narrow barrier or isthmus which for a long period had kept the Southern Eocene sea, of which the Brackleshams are the earliest

* "The Barton-clay sea seems again to have been more connected with water opening to the northward than did that of the Bracklesham Sands; for several species of the London-clay sea . . . that had disappeared in the intermediate Bracklesham period, reappear in the Barton series. In fact, the fauna of this group, together with that of the Sables Moyens, has not so southern an aspect as that of the Calcaire grossier and Bracklesham period." (Quart. Journ. Geol. Soc. vol. xiii. p. 131.)

British representatives, isolated from the more northern basin in which the London Clay was formed. The mingling of the seas apparently lowered the temperature of the water to an extent sufficient to drive away such essentially tropical forms as the larger Cones, Cowries, Bullas, Harps, &c.*, without, however, greatly affecting the character of the contemporary land vegetation.

We cannot say that the whole period was one of sustained and continuous elevation, but the drifts of broken shells at the close of the Middle Bartons indicate an upheaval and the presence of strong currents. These shell-drifts thicken and become more numerous to the east and north. The protracted elevation soon afterwards forced back the sea, and converted the former estuary into a brackish-water reach of our great Eocene river. The Middle and Lower Bartons were evidently deposited in almost pure sea-water, though the considerable number of rare freshwater shells occurring in Edwards's list, even from Highcliff, would imply a river-current strong enough to have carried them along. Prestwich, moreover, mentions the occurrence of *Cyrena obovata* and *Potamides cinctus* in them at both Alum and Whitecliff Bays. It seems almost superfluous to point out that if the Barton Beds were estuarine, quite different deposits would be forming synchronously in the higher reaches of the river as well as further out to sea. Something not very different in quality from the freshwater Eocenes, which occur below as well as above them, must, in fact, have been forming in their vicinity or at no great distance; while the oceanic deposits of this period are probably preserved in the bed of the Atlantic, and have not been exposed to view. In dealing with our Eocenes it neither follows that distant beds are synchronous because they are similar, nor that they were separated by any intervals of time because they are dissimilar.

Description of the Beds.

The Barton Section (fig. 2, facing p. 594).

Of all the sections exposed, by far the most important and the classic one is that occupying the fine open bay of Christchurch, facing the Needles, and terminated westward by Hengistbury Head, and eastward by Hurst Castle. Towards the centre of the bay, where the Bartons are developed, the cliffs average little short of, and in places exceed, one hundred feet in height. Their summits are nearly level, and they terminate rather abruptly near Muddiford to

* The following are the principal types driven away or extinguished, and all of them have a highly tropical aspect:—*Cypræa Bowerbankii*, *C. tuberculosa*, *C. globularis*; *Voluta cithara* and *V. muricina*; *Conus deperditus* and *C. diadema*; *Pleurotoma attenuata*; *Harpa*, all sp.; *Cassis gigantica*; *Natica cepacea*, *N. hybrida*, *N. ponderosa*, *N. pachycheila*; *Turritella sulcifera*; *Dentalium grande*; *Cerithium giganteum*; *Bulla Edwardsii*; *Hipponyx cornucopiæ*; *Sanguinolaria Hollowaysii*, *Cardita planicosta*, *Arca Branderi*; also the corals *Oculina*, *Siderastræa*, &c. Some of the more temperate of the London-clay genera, such as *Trivia*, reappear, but not *Astarte*, *Cyprina*, *Verticordia*, *Vermetus*. The only species of large size to appear for the first time in the Bartons is *Voluta luctatrix*.

the west, and sink more gradually on the east. In composition they are clay or sandy clay, capped by gravel-deposits, twenty and even thirty feet thick in places, which constantly founder and partially obscure the Eocene beds below. The beds forming this coast-line begin well in the Bracklesham series to the west, and end in the Middle Headon, at Paddy's Gap, to the east. The cliffs occupied by the true Barton Series form ruined terraces, and the beds, with few exceptions, can only be seen *in situ* here and there along the sea-margin. The sea, however, which is rougher than at Bournemouth, regularly washes the base of the cliffs in the middle of the bay, and exposes an unending succession of fossils. On the other hand, the Hampshire Avon, which for several years swept along the base of Highcliff and threatened to undermine the Castle, has again shifted the direction of its outfall, and left such vast masses and bars of shingle behind, that the sea no longer reaches the cliffs under Highcliff; and these are consequently assuming an angle of repose, and becoming so overgrown that their stratigraphy, formerly clearly defined, cannot now be made out. This fact helped to decide us to redescribe the Barton Beds without delay.

The section has been frequently described and measured. There are some slight discrepancies in the thicknesses arrived at, but absolute identity cannot be hoped for in dealing with beds whose thickness may vary within a few feet. Our measurements were checked on each occasion, the second time by Mr. Geo. Harris, F.G.S. The results are tabulated below, and, for easier comparison, we have taken the *maxima* and, in some cases, bracketed two or three subdivisions of other authors together. We have adopted a tripartite system, each division of which is characterized by peculiar fossils and distinct lithological characters.

	Wright.	Prestwich.	Gardner and Keeping.	Gardner and Harris.	
Becton-Bunny Beds { Clay, no. 18, Wright	25	30	23	26	Upper Barton, *b* of Prestwich.
Becton-Bunny Beds { Sand, no. 19, Wright	20	30	19	26	
Chama-bed, no. 20, Wright	15	20	15	18	
Barton Clay, no. 21, Wright	50	150*	50	53	Middle Barton, part *a* of Prestwich.
Highcliff Beds, nos. 22, 23, 24, base according to Wright	80	70	50	49	Lower Barton, part *a* of Prestwich.
Green sandy clay and pebble-bed	—	15	14	10	
Total	190	315*	171	182	
Bracklesham	...	...	...	45	

The Bracklesham Beds at Highcliff form a vertical escarpment 45 feet high, of compact white sand, with an admixture of carbo-

* This measurement appears due to a *lapsus calami*.

naceous matter and a band of ironstone Septaria throughout a part of their horizontal extent. The base is not visible here, but can be seen at Hengistbury Head*. Eight feet above the beach there is a scattered line of typical Bracklesham pebbles, and another more considerable layer of the same capping the white sand†. The flints are moderate in size, either quite white or black, and mixed with small quartz-pebbles and grains, and lignitic matter abraded and worn into pellets. The upper layer is imbedded in warm-drab loamy sand, with pale green grains and sulphur-yellow partings and pipes, giving a green streak to the tool. Casts of bivalves abound in the upper pebble-bed, and, like the pebbles themselves, are most numerous at the base. The pebbles extend upwards throughout nearly 3 of the 4 feet of loamy sand composing the bed. Mr. Osmond Fisher looked on the upper pebble-bed as indicating a natural physical break, though he added‡, "the division is probably in reality one of convenience only, the two groups forming a continuous series, changing gradually throughout in its lithological character and fauna." Prestwich considered that there was no break between the two formations. A dozen fossils were determined by Fisher from the sand, and 18 from the pebble-bed, only 4 of which are Gasteropods. The last 10 feet is very green, stiff, sandy clay, rifle-green when fractured, but of a bright green colour when scraped. It abounds with wood, mostly *Teredo*-bored, and well-preserved fir-cones are not uncommon in it. Its angle of repose is very steep, and the abundance of green grains enables it to be distinguished easily from the overlying series. Casts of Mollusca abound in this part of the series, and are seen to belong to species that pass into the Bracklesham below as well as the Barton above §.

At this horizon there is a band 9 inches thick of ferruginous loam or imperfectly formed ironstone, mottled with green and containing grains and small pebbles of quartz. It was described by Prestwich as a band of tabular soft Septaria mixed with green-sand ‖;

* "Description and correlation of the Bournemouth Beds.—Part I. Marine Series, by J. S. Gardner," Quart. Journ. Geol. Soc. vol. xxxv. (1879) p. 214.

† This is coarse quartz-sand of largish subangular to rounded grains, mixed with very minute grains.

‡ Quart. Journ. Geol. Soc. vol. xviii. (1861) p. 88.

§ Osmond Fisher, *l. c.*, gives the following list:—*Fusus pyrus*, *Pyrula nexilis*, *Voluta nodosa*, *Dentalium*, *Cardium semistriatum*, *Cardita* (small ribbed), *Cytherea* (a Barton species), *Crassatella costata*, *Corbula pisum*. An analysis of the beds is also given, p. 86:—

Water	10·02
Silica	50·11
Iron protoxide	25·04
Alumina	6·12
Magnesia	3·14
Potash	5·17
	99·60

‖ Quart. Journ. Geol. Soc. vol. v. (1849) p. 45.

and is the "foxy" band of Fisher, underlying and defining the zone of *Nummulites elegans**.

The Lower Barton, or Highcliff Beds.

The Nummulite-band forming the base of the Barton Series is only 8 inches thick, and green sandy clay, identical with that of the Bracklesham Series beneath, continues upward, with fewer casts of fossils, for another 10 feet, when it passes insensibly into a fine and stiff, very plastic, drab clay, mottled darker and paler, and with a peculiar pinkish band, as if burnt, about 4 feet from the top. The *Goniocypoda Edwardsi*, H. Woodw., described as a true Shore-crab, and said to be from "the Red Marl of the Plastic Clay of Highcliff," must have been from this band †. Casts of an Echinoderm, whole and broken up, abound, together with otolites, spines, teeth, and other fish-remains. Ledas and Corbulas are very commonly drifted with quantities of broken shell-matter; and the Mollusca generally seem, like the casts below, to be of species common to both the Barton and Bracklesham Series. Among the more frequent are *Turritella*, *Voluta athleta*, *Cancellaria*, *Cassidaria ambigua*, *Rostellaria ampla*, *Trochita*, *Cardita*. The most distinctly Barton form is, perhaps, *Pleurotoma rostrata*. About 20 feet above the Nummulite-band the bed gradually becomes of a paler drab, rather plentifully mixed with patches or drifts of sand, the latter causing it to founder and form the conspicuous lower terrace at Highcliff. This latter condition of the bed is 13 feet thick.

The Highcliff Beds end in the Highcliff sands, a fairly well-marked division, consisting of a glauconitic clayey sand, interrupted by lines and pockets of very compact fine sand, composed of fine-grained and angular quartz, crowded with small and beautifully preserved shells. The sands are intermittent, often reduced to a mere trace, but swelling again and again into pockets, which never exceed 2 feet in thickness. The variety of the species in them is large, particularly among the genera *Bulla*, *Odostomia*, *Rissoa*, *Turbonilla*, *Bayania*, *Eulima*, *Pyramidella*, &c. The green grains soon disappear, leaving the clay palish drab, but the pockets of sand continue scattered through it for a thickness of 10 feet, with this important difference to the collector, however, that the higher ones are merely filled with *Corbula* and, occasionally, *Ditrupa*, mixed with the comminuted remains of larger shells, some of which also appear in the clay itself

* "I find a bed containing *Nummulina Prestwichiana* [*elegans*] at High Cliff, analogous to that at Alum Bay. I believe it has hitherto been overlooked, but it may easily be recognized by the following indication:—There will be observed, extending along all the central portion of High Cliff, not far overhead, as you walk upon the beach, a narrow band of hard marly clay, not quite a foot thick, weathering of a reddish foxy tint, and projecting slightly beyond the general face of the cliff. Immediately above this, in marked contrast of colour, is a narrow green band of coarse sandy clay, about 8 inches thick. This is the *Nummulina Prestwichiana* [*elegans*] bed. It is much thinner than at Alum Bay, and the Nummulites are less profusely scattered in it. At this place they are pyritized."—Fisher, *l. c.* p. 87.

† Geol. Mag. vol. iv. p. 529, pl. xxi. fig. 1 (1867).

in a more or less perfect state. *Psammobia* occurs in it in the position assumed by the shell when living, and *Ophiura* is met with, but not very commonly. Among the species that do not ascend beyond this horizon are *Cassidaria ambigua* and *Fusus errans*.

The Highcliff or Lower Barton Series closes with a dark drab sandy clay, mottled with glauconitic sand*, 4 feet thick, which weathers a rusty colour. It was tenanted when forming by numerous *Pholadomyæ*, and includes many dead shells of *Cytherea elegans*. The actual line of separation between it and the Middle Barton is drawn at a dotted layer of large, round, dark-coloured Septaria, which become more dispersed in proceeding west†.

Except in the terrace and the green clays at the base, the beds usually maintain an angle of about 35°. The fauna of this division of the Barton Series is very rich, numbering between 300 and 400, and, possibly, a considerably greater number of species. For those peculiar to it we have to search among the more minute shells of the Highcliff sands, foremost among them being the well-marked *Strombus bartonensis* and *Buccinum canaliculatum*, *Acera striatella*, *Volvaria acutiuscula*, &c. *Cassis ambigua* is confined to it in the Barton Beds, but reappears in the Middle Headon. We may also mention *Schizaster d'Urbani* and the *Ophiura* as characteristic species. There is a host of species which come up from the Upper Bracklesham, but do not pass beyond the upper limits of the Lower Barton, among such being the typical *Terebellum fusiforme*, *Fusus errans*, *F. interruptus*, *Cerithium angulatum*, *Nucula lissa*, *Cytherea elegans*, *Nummulites elegans*, &c. These species, taken together, are sufficiently abundant to furnish in the field an undeniable index as to the division of the Bartons we are in.

The Middle Barton, or Barton Clay proper.

Within 5 feet of the Septaria-band last mentioned, and taken as the base of the Middle Barton, a second and more strongly marked one occurs, the Septaria being equally dark in colour, and round and massive in appearance. Both bands are fossiliferous. Though

* Mr. Grenville Cole describes the sand as fairly rounded, the grains containing liquid-enclosures with moving bubbles. The dark green grains are very numerous, and there are also agglutinated sand-grains. The clay effervesces somewhat in cold acid.

† The section of the Highcliff Beds, according to Prestwich, Quart. Journ. Geol. Soc. vol. xiii. (1857) p. 108, is as follows:—

	ft.
Grey clay with seams of yellow sands and shells ...	20
Grey sandy clay, with *Echini*, *Cassidaria*, &c.	50
Mixed clay and green sands, impressions of shells .	14
Bed of flint pebbles in sand, size moderate	1
	85

Dr. Wright omits the two lowest of these beds from the Barton Series, and gives the remainder a slightly greater thickness (8 feet more), distinguishing them as beds 22, 23, 24 (Proc. Cotteswold Naturalists' Club, vol. i. pp. 129–133, 1853). Our first measurement came to 64, and our second to 59 feet, after accurately reducing them to the vertical.

the clayey matrix between them remains the same, the important species *Voluta suspensa* and a *Fusus* are confined to this particular horizon, and several fruit-spikes of a peculiar kind have quite recently been met with in it by Daniel Flynn, of the Coastguard, a very keen and good collector of Barton fossils. Above the Septaria the clay becomes glauconitic and sandy, with few and generally much crushed and eroded fossils, but about 30 feet up we come suddenly on two particularly rich zones, 18 inches apart, from which the coast-guardsmen collect in heavy weather. Chief among the fossils are *Rostellaria ampla*, *Voluta luctatrix*, *Fusus pyrus*, *F. longævus*, *Murex minax*, *Cassidaria nodosa*, and *Ostrea gigantea*. A few feet below these zones is a conspicuous band of larger, flattened, light-coloured Septaria, which dips beneath the shingle opposite the Coastguard Station. Succeeding this is dark gritty clay, quickly passing into a fine unctuous pale slate or dark-coloured clay, free from grit and green grains, but weathering slightly rusty and greenish at the partings. Most of the shells in it are small and delicate, and collected into pockets, *Corbula pisum* and *Turritella* in particular abounding. The bed is 10 to 12 feet thick, and includes another less well-marked zone of flat, light-coloured Septaria, 4 feet from the top. The Middle Barton Clays end in a very distinct shell-bed, made up of comminuted fragments, mainly of *Turritella*, in a rusty matrix, with occasional fragments of larger shells. In the cliffs it appears as a fulvous band, but it sets, under the influence of salt water, into a very hard stone, and when in this state the flat slabs, a foot or more thick, are hauled up the cliffs and used for the foundations of houses. Perfect specimens of *Tellina ambigua* and *T. Branderi* are not uncommon on their upper surfaces. The shell-beds are only a foot or two thick at Highcliff, and increase eastward to possibly as much as 15 feet.

The Middle Barton Clays include all the Septaria-bands that occur in the Barton Series, the lowest of these forming a good landmark for the inferior junction, and the shell-bed an unmistakable line of demarcation for the superior limit. They are about 50 feet thick*, relatively homogeneous, and form the slopes represented in the figure (fig. 2). The middle terrace is formed in the more sandy clay above the lower line of Septaria.

The fauna of the Middle Division of the Bartons is nearly as rich as that of the lower, and far more characteristic, consisting of upwards of 250 species. Very few of those peculiar to this stage are, however, either common or conspicuous, and perhaps the only one worth citing is *Fusus lima*. Some of the grandest species, as *Rostellaria ampla*, *Fusus longævus*, and *Murex minax*, range from the Bracklesham right through the Barton, but attain their finest development here. Others, such as *Cassidaria nodosa*, *Ficula nexilis*, *Triton argutum*, and *Fusus regularis*, pass upward from the Bracklesham, but do not range beyond the limits of this division. The finest

* This division is the "Barton Clay" of Dr. Wright, who regards it as 50′ thick, our measurements being respectively 50′ and 53′, but it appears as 150′ thick in Prestwich. It is described as a "mass of compact bluish-grey clay with Septaria."

specimens of the strictly Barton fossils, *Voluta luctatrix*, *Crassatella sulcata*, and *Limopsis scalaris*, are obtained here, while others, such as *Voluta ambigua* and *Pleurotoma rostrata*, cannot be collected at all above this zone. Finally, several small but well-known species, such as *Conus dormitor* and *Buccinum desertum*, make their first appearance here.

The Upper Bartons, or Chama and Becton-Bunny Beds.

Between the shell-bed with *Tellina ambigua* and *T. Branderi* and the *Chama*-bed, there are a few feet of buff sandy clay, breaking up into cubes from 3 to 9 inches square, which are full of a peculiar variety of *Turritella*. It is in this bed that *Scalaria acuta*, *Fusus turgidus*, and *Voluta subambigua* are found.

The *Chama*-bed is a mass of steel-grey (commonly called blue) sand, with a slight mixture of clay, the proportion of the latter decreasing upwards. Mr. Grenville Cole describes it as angular and sometimes very minute sand, with much fine brown mud and a few green grains. It forms almost a running sand in the cliff, at a very low angle, and is therefore invariably buried under masses of gravel and mud fallen from above, and exceedingly difficult to measure. Dr. Wright found it to be from 10 to 15 feet thick, and Prestwich estimated it at 20 feet. Though we failed to obtain any measurement at first, we subsequently found the base resting on the shell-bed in a drain cut under the Coastguard Station, and were able to get a fairly satisfactory measurement, showing a thickness of 18 feet. A perhaps even more accurate measurement was obtained by taking the outcrop along the shore, between the uppermost Septaria-zone and the top of the *Chama*-bed, a distance of 268 yards, at a dip of $2\frac{1}{2}°$, when, after making all allowances, the thickness also came out at 18 feet*.

The beds are unfossiliferous everywhere, unless capped by the stiff clay of the Becton-Bunny Beds, and they dip under the beach somewhere about 100 yards east of the fence dividing the lands of Col. Clinton from the Hinton-Admiral estates. Where fossiliferous, the Chamas occur in extraordinary profusion, especially towards the top, with the valves most frequently united, while Turritellas abound no less towards the base. Chamas are excessively rare in the lower, and none are found in the middle division of the Barton, and this is the last appearance of the genus in England. Their presence is very remarkable, and suggestive of a change in the physical condition of the sea-bed, for they inhabit tropical seas, especially among coral reefs. Many interesting and beautiful shells make their first, or almost first, appearance in the 7 or 8 feet of clayey sand at the base of this bed, such as *Typhis fistulosus*, *Conus scabriculus*, *Voluta costata*, *V. humerosa*, *Murex defossus*, *Mitra scabra*, *Trochus nodulosus*, and *Cypræa bartonensis*. Above these we find *Terebellum sopitum* and *Vulsella*. Still higher, in the more sandy bed, among

* 268 yds. at $2\frac{1}{2}°=35'-15'$, of Middle Barton$=20'-2'$, difference of level at the two extremities$=18'$.

the Chamas, an assemblage of splendidly preserved bivalves comprises many species of *Tellina*, *Lucina*, *Axinus*, *Anomia*, *Cardium* (*porulosum*), *Panopæa*, *Solen*, *Terebratula*, &c., most having the valves united, as if they had died *in situ*. On the other hand, nearly all the vast array of Barton species of *Pleurotoma* and *Scalaria*, most of the *Fusi*, together with all the species of *Ficula*, *Terebra*, *Triton*, *Littorina*, *Cassidaria*, and many others are absent from it. Other species become scarce and stunted, such as *Murex asper*, *Typhis pungens*, *Fusus porrectus*; others, again, like *Voluta luctatrix*, are represented by modified forms, whilst others, like *Murex minax* and *Voluta athleta*, seem to be derived and water-worn. It contains, moreover, hardly any of the minute species which so abound in the lower beds, except some of the *Bullæ* and their allies. The fauna contains altogether 170 known species, and differs, as a whole, more from that of the Lower and even Middle Barton than does that of the Lower Barton from the Upper Bracklesham. The change is, indeed, far greater than appears in the tabulated list; for though stray specimens of so many species lingered on or are derived, and therefore occur in the column of Upper Barton fossils, practically the entire fauna, except some bivalves, is different. The bulk of what may be considered the typical Barton species, including such forms as *Fusus longævus*, *Rostellaria ampla*, *Voluta luctatrix*, *V. ambigua*, *V. athleta*, *Murex minax*, *Cassidaria nodosa*, &c., have disappeared. It is difficult to say positively whether the change was from deeper to shallower water or the reverse; but the shell-bed preceding the *Chama*-bed plainly indicates a long period when no mud was being deposited, and the *Chama*-bed itself was formed in clear water. The fact of the bed being crowded throughout with full-grown, thick-shelled Mollusca, is corroborative evidence that it was formed very slowly. The river, with its turbid water, must therefore have been diverted, and the previous fauna, fitted to rest on an oozy bottom, suddenly gave place to one requiring bright water and cleaner sand. The *Chama* and Cowry are preeminently such; and the substitution of fresh species of *Voluta*, *Typhis*, *Murex*, &c. for those preexisting may be taken to mean an immigration of species consequent on this change, rather than evolutionary progress. The bed is altogether as remarkable as any in the Eocene, and cuts into the series as unexpectedly as the Lower Bracklesham Beds, or the coral zone at Brockenhurst. It shows, like so many other abrupt transitions in the Eocene, that a relatively slight change in physical conditions makes a far greater impression on the succession of life in a formation, than would be occasioned by an enormous lapse of time without such a change.

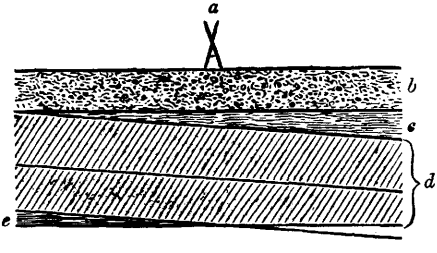
The *Becton-Bunny Beds* mark another change, so abrupt that opinions have been divided as to whether the Barton series should end here, excluding these and the overlying sands, hitherto called Upper Bagshot in Hampshire. Prestwich* agreed with Wright, and included the latter in the Barton Series, because they are highly

* Quart. Journ. Geol. Soc. vol. xiii. (1857) p. 109.

fossiliferous here and at Whitecliff Bay, and contain many Barton types. Judd, on the other hand, while admitting that "these beds graduate so imperceptibly into the underlying Barton Clays that it is difficult to fix the exact limits between them"*, decided to separate them on account of their more estuarine character, and would have them called the "Headon Hill Sands." They seem to us, however, to be more closely related to the Barton below than to the Headon above, and we prefer to retain them in the former, distinguishing them locally as the *Becton-Bunny Beds*.

They are divisible into an upper and a lower division. The latter rests on the *Chama*-bed, the separating line being well marked, and consists of a mass from 20 to 25 feet thick, of fine, at first ashy grey, piped, unfossiliferous, very angular sand, in which Mr. Cole detects numerous flakes of Muscovite mica, becoming almost pure white and then pale grey, mottled with darker grey. This sand contains much alum, is feebly plastic, maintains itself at a high angle, and is not loosened and blown by the wind. Its upper surface is very uneven, and it is piped throughout, as if it had been thickly inhabited by large bivalves and Annelids. It is overlain by sand of an earthy colour, full of casts of shells, and then by a stiff sandy clay of blackish or bluish colour†, becoming more and more sandy and full of shells. Towards the bottom the prevailing forms are *Oliva Branderi*, *Cerithium variabile*, *Vicarya*, *Ancillaria*, *Natica*, *Cardita*, *Lucina*, *Mactra*, *Tellina*. In the upper part of the bed a more distinctly brackish-water assemblage appears, including *Cerithium* and *Marginella*, *Cyrena*, *Mytilus*, *Dreissena*, and *Potamomya*. The accompanying diagram (fig. 1) will enable them to be identified

Fig. 1.—*Section of Becton-Bunny Beds.*



a. High fence between Col. Clinton's and the Hinton-Admiral estate.
b. Gravel. *c*. Long-Mead-End Bed.
d. Becton-Bunny Beds: *Oliva-Branderi* zone. *e*. *Chama*-bed.

in the cliffs themselves. The bed terminates with a band, 10 inches thick, of dark olive-green sandy clay, containing some of the above fossils, together with *Neritina concava*, *Lucina*, &c. This part of the

* Quart. Journ. Geol. Soc. vol. xxxviii. (1882) p. 475.

† Mr. Grenville Cole describes this as a very fine, sticky clay, when not containing minute plates and rod-like particles, with some angular grained sand.

series has been described in some detail by Tawney and Keeping*. The zone of *Oliva Branderi* can be traced half a mile west of the boundary; but as soon as it overlaps the protecting clay above, it becomes unfossiliferous. The underlying sand-bed also, in its turn, loses its alum and plasticity and becomes loosened and carried away by the wind as well as stained by the gravel as soon as it passes beyond the limits of the clay. The *Chama*-bed likewise becomes altered by percolating water as soon as the dip brings it near to the top of the section, and it is then undistinguishable from the beds above. The Upper Bartons continue in this state, in considerable thickness under the gravels, to at least Barton Lane End, the curve in the bay moderating the dip and causing them to maintain their position for so great a distance †.

Dr. Wright drew the line between his Lower Marine Formation and Estuary Formation at this horizon; but Prof. Prestwich included the overlying 15 or 20 feet of sands with the Barton Beds, because, where fossiliferous, as here and at Whitecliff Bay, they continue to contain Barton types. We entirely endorse this view, believing it to be impossible to draw any line of division at this particular point, and greatly preferring to take the Lignite-band at the base of the Lower Headon just above, as the limit of the Barton Series.

The *Long-Mead-End Sands* rest upon these, and we found their vertical thickness to be 20 feet, and their angle 46°. The base is slightly clayey, white sand, with mixed roundish and fractured grains, some of which, as Mr. Cole observes, still show surfaces of conchoidal fracture. The bed becomes purer and tawny for 15 feet and is without fossils; but towards the top shells become abundant, and are drifted into pockets. *Psammobia rudis* is the first to appear, followed by *Cerithium concavum*, *Ancillaria perita*, *Oliva Branderi*, *Lucina gibbosula*, *Cyrena gibbosula*, *Melania fasciata*, and remains of large and small turtles. There is an uneven junction, followed by rather more than 2 feet of darker tawny sand, also highly fossiliferous. The series closes with a little less than a foot of very dark olive-green sandy clay, with *Cerithium*, *Marginella*, *Natica*, *Lucina*, *Cyrena*, &c.

These beds have been described as "Upper Bagshot" and "Headon Hill Sands," and the measurements taken vary from 15 to 20 feet. A list of works bearing upon them was given by Tawney ‡ when he dissented from a proposal to place them in the Headon

* Quart. Journ. Geol. Soc. vol. xxxix. (1883) p. 573.

† The lower of the two Becton-Bunny Beds is Wright's no. 19, grey sand without fossils, 20 feet thick. It is present from west of Becton Bunny to beyond the Coastguard Station. The upper bed is no. 18, tea-green coloured clay, about 25 feet thick, with *Oliva*, said to differ from all other qualities of bed. It rises on the shore near Long Mead End, and maintains itself to a quarter of a mile east of Becton Bunny, near Barton Gang. Wright, Ann. & Mag. Nat. Hist. ser. 2, vol. vii. (1851) p. 441, and also Proc. Cotteswold Naturalists' Club, vol. i. pp. 129–133 (1853). It is section *b* of Prestwich, Quart. Journ. Geol. Soc. vol. xiii. (1857) p. 108.

‡ Proc. Cambr. Phil. Soc. vol. iv. part iii. p. 140.

Series, laying stress on the presence of *Oliva Branderi* and other Barton types in their fauna, and maintaining that the so-called *Cerithium concavum* of this zone is really Lamarck's *C. pleurotomoides*. From a table appended to his paper, it appears that of 28 species 15 are Barton and only 8 Middle Headon. Eliminating those which are common to both these formations, there remained 4·34 % of the Long-Mead-End species common to the Barton Beds and only 21·3 % to the Middle Headon. "As far as fossil evidence is concerned, therefore, these sands are more related to the Barton Beds than they are to the Headon." The fossiliferous beds rise 300 yards west of Mead End, and run out at Becton Bunny; and the unfossiliferous sand rises a quarter of a mile east of Becton Bunny, and disappears beyond Barton Gang. They are the estuary formation of Wright, beds 16 and 17*, and the yellow and white siliceous sands in *b* of Prestwich†. Their most distinctive fossils may be considered to be *Cerithium pleurotomides*, *Melania hordeacea*, and *Corbula Edwardsii*‡.

The Barton Series ends at this horizon, where all that is most characteristic of the Barton fauna finally disappears. It is, indeed, at this point, if anywhere in England, that any approach to a separating line between Eocene and Oligocene can be drawn.

We do not propose to describe the remainder of the Hordwell section in detail, but as the cliff-line is continuous, we have given a section with measurements of the Headon Beds in fig. 4. The beds change with the dividing line from brackish to fluviatile, the junction being a bed of black stratified, lignitic clay, 4 feet thick, containing *Potamomya*, *Dreissena*, *Cerithium pyrgatum*, &c. Some 17 feet higher up is the *Leaf-bed*, the exact position of which is not well known, and which we are anxious to take this opportunity of identifying with regard to forthcoming notices of its flora. It was known to Dr. Wright as a slate-coloured clay, with impressions of Dicotyledons in considerable number and variety of species, and with fossil fruits and the stems of plants, but no shells. He described it as a well-marked bed, 18 inches thick, rising nearly opposite Hordwell House, and running out at Long Mead End. In the Mammal-bed underneath he had also detected a "small black capsular seed with a corrugated integument," as well as *Chara medicaginula*, *Carpolithes ovulum*, and *C. thalictroides*§. Wise also describes it as 18 inches thick‖; but where we have made excavations it has exceeded 3 feet. The flora comprises *Equisetum*, *Salvinia*, *Chrysodeum*, Rushes, large Feather-Palms, *Arthrotaxis Couttsiæ*, a leaf known as *Populus Zaddachi*, the latter and some very abundant fruit-spikes being identical with Reading forms.

* Ann. & Mag. Nat. Hist. ser. 2, vol. vii. (1851) p. 441.

† Quart. Journ. Geol. Soc. vol. xiii. (1857) p. 108.

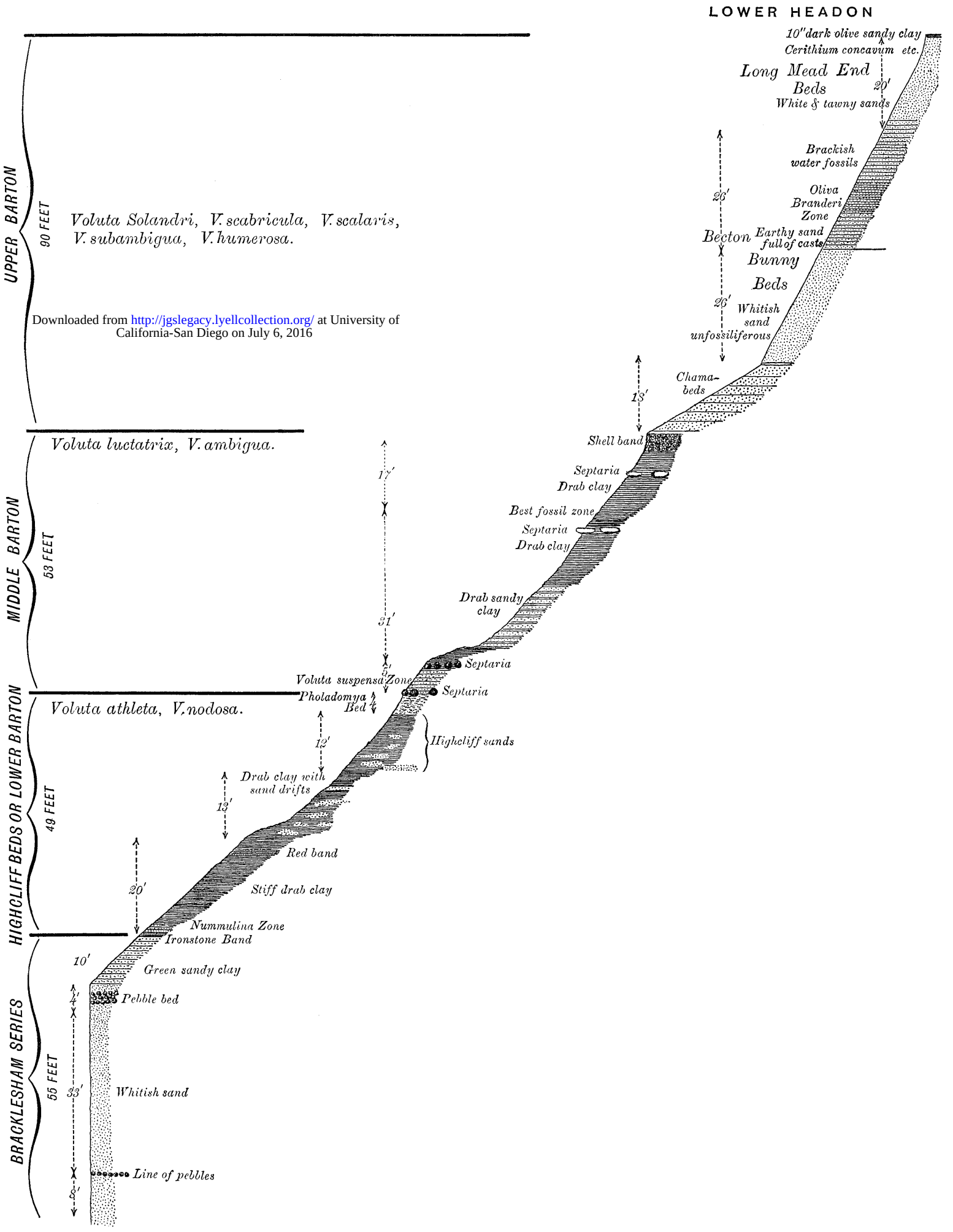
‡ Among the Barton species are *Buccinum lavatum*, *Oliva Branderi*, *Trochita aperta*, *Bulla Lamarckii*, and *Cytherea tenuistria*; other forms are *Melania hordeacea*, *Melanopsis fusiformis*, *Ringicula ringens*, *Nucula tumescens*, and *Strigilla colvellensis*.

§ Ann. & Mag. Nat. Hist. ser. 2, vol. vii. (1851) p. 441.

‖ Wise, New Forest, 1867, p. 239.

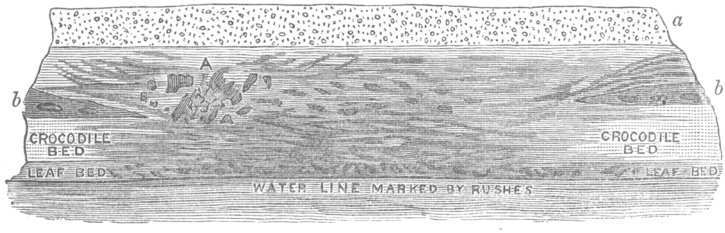
[To face. p 594

Fig. 2.—*Section of the Barton Cliff.*



We would also call attention to the singular interruption to the bedding which occurs a little west of Long Mead End, where the Leaf-bed and Crocodile-bed are cut through, and replaced by a confused mass of clay and sand with drift-wood, a large piece of which is seen to have been anchored vertically in the mud (fig. 3).

Fig. 3.—*Section at Hordwell (just west of Long Mead End).*



a. Gravel; *b*. Green clay with iron.

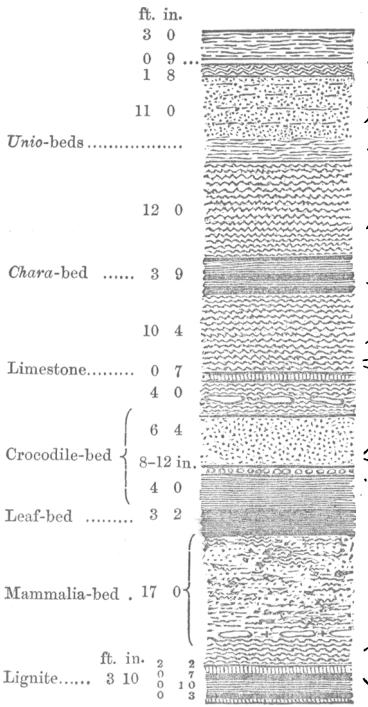
This section of an old channel occurs a little west of Long Mead End, and is about 200 yards in length. The green clays thin out, but the Crocodile-beds are dovetailed into the lignitic sands and clays. All zones are lost, and the whole cliff looks like black or dark ash-coloured sand. It is very shaly, full of wood for the higher 16 feet, and becomes more sandy towards the base. A band of white concretionary clay-stone, with pieces of wood imbedded in white plastic clay occurs, 16″ thick. The sands are rather false-bedded and twisted, but seldom dip more than 10°, and the whole is very full of wood, especially towards the base. At A, the mass of wood is vertical, and gives the appearance of vertical bedding at that spot. The green clay is also penetrated by wood in the same direction. A good many ligneous fruits are to be found near the two extremities after rain.

This is obviously the channel of an old river, similar to the estuary channel, filled with oysters, which cuts through the "Venus bed," between Colwell and Totland Bays, and such can frequently be traced in estuaries and fluviatile beds when these are of any extent*.

Note explanatory of Section through the Lower Headon at Hordwell (fig. 4).—The section from the top as far down as the *Chara*-bed was made nearly due south of Hordwell House. The rest, to the Lignite at the base, was measured about 450 feet east of Long Mead End. At that point the 10 feet or so of beds visible above the *Chara*-zone, and immediately under the gravel, are considerably

* Mud-beds, teeming with molluscous life, such as those of the Headons, could only be formed on the banks of a tidal river or estuary with extensive flats subject to overflow. Any change of level, whether by modifying the depth of water, making it more or less salt, or altering the quality of sediment deposited, might profoundly modify the fauna; and a section through such an area might disclose many minor, but constant, parallel zones of sediment, differing from each other and characterized by quite peculiar forms of life. So long as the section coincides with the direction of the flow of the estuary, the beds are continuous for long distances, but when it becomes transverse we find a channel of confused bedding, with a recurrence of the regular bedding on each side.

Fig. 4.—*Section through the Lower Headon, at Hordwell.*



Marl stained with gravel.
Limnean marl 9 in.; dark line with serpents' vertebræ, rodents' teeth, &c., above, 1 in. thick.
Greenish rusty marl, with broken turtle- and mammal-bones.

Laminated sand, with grey partings of clay, darker towards base.

Unio, *Paludina*, *Melania turritissima*, in nearly slate-coloured clay.
Line of seeds.

Bright green marly clay with crusted *Limneæ*.

Lignite and drab clays, with roots, rushes, &c.
Lignite with roots, full of yellow sand, rushes and seeds at base.

Greenish mottled clay and marl, various kinds, with a black band 4 in. near base,
2 feet fossiliferous, with *Dreissena*, *Limnea*, &c.

Limnea-limestone.
Black band 1 in.
Mottled green marly clay, with masses of clay and ironstone up to several tons in weight.

Very fine pale grey sand, becoming darker at base and more clayey. Zones of *Potamomya plana* at top and bottom.
The Crocodile-bones with *Cerithium pyrgatum* one third down.
Coprolite-bed, with rolled bones and comminuted shells.
Thin black layer.
Stiff marly clay, becoming clunchy.

Dark sandy clay, slightly mottled with yellow, and with roots in yellow sand.
Drab pipe-clay, with black roots and partings.

Bright green marl, with roots in drab sand.
Paludina drifted in pockets.

Iron band 8 in. thick.
Mottled green marly clay.
Impure friable lignite and clay, 2 feet 2 in.
Black clay, with *Potamomyæ*, *Dreissena*, *Mytilus*, and *Cerithium pyrgatum*, 7 in.
Black clay, with roots and occasional broken *Potamomyæ*, 10 in.
Lignite with fish-scales, sand base ½ in. thick, with *Cyrena* 3 in.

altered and appear of a whity and ochreous colour, very sandy, and without fossils, except some layers of *Paludina* quite at the base. The Lignite Beds themselves were measured at Long Mead End. The beds appear to be very variable, as the detailed measurements differ considerably from those previously made, though the principal beds remain as land-marks. The thicknesses have been variously recorded:—Marchioness of Hastings 78 ft. to 94 ft. 10 in.; Dr. Wright 64 ft.; Tawney and Keeping (Quart. Journ. Geol. Soc. vol. xxxix. (1883) p. 567) 83½ ft.

SECTION ALONG THE NEW LINE FROM BROCKENHURST TO CHRISTCHURCH (fig. 5).

The cuttings for the new line from Brockenhurst to Christchurch present us with a second section in some degree parallel with the coast-line, but several miles inland. Our friend, Mr. George Harris, after checking with us our previous measurements along the coast, aided in measuring the entire length of this cutting, and our section is prepared from the notes taken concurrently by each of us on the spot. The new exposure shows that the shell-beds are greatly thickened and maintain their character and position above the Septaria for a long way inland. It further enables us to check off the thickness of the *Chama*-bed, which, though unfossiliferous, is unchanged as to its matrix *. The Becton-Bunny Beds seem, however, to disappear

* Mr. Cole has examined this, and reports that it is a bed of very angular rather coarse sand with some few green grains. There is some clay with it, but less than would be expected from its general appearance.

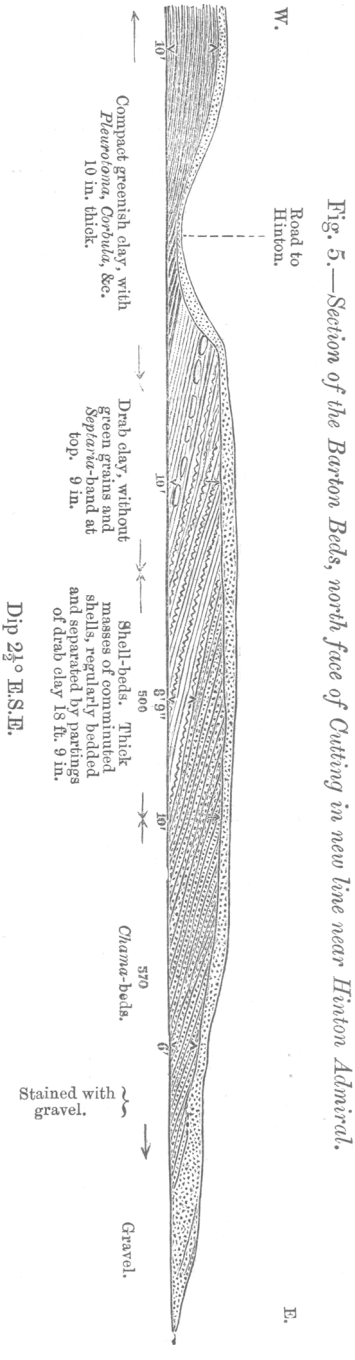


Fig. 5.—*Section of the Barton Beds, north face of Cutting in new line near Hinton Admiral.*

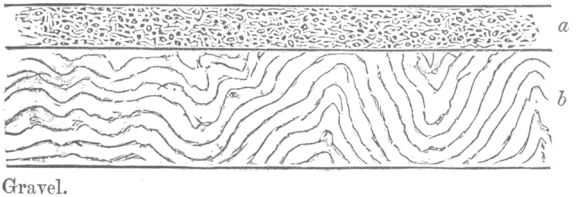
as at Alum Bay, and the whole series of Upper Bartons above the *Chama*-beds is obscured by weathering and by gravels. The vertical section is:—

	ft.	in.
Chama-beds, partly stained by gravel, about	18	0
Drab clay	1	6
Shelly bed	22	0
Septaria	1	0
Drab clay	9	0
Greenish compact clay, no base seen	10	9
	62	3

The fossils met with were numerous, but small, most of them being species common to the Middle and Lower Bartons. Among them, however, were *Pleurotoma exorta* and *P. macilenta*, two of the most characteristic shells of the Middle Barton. If the bottom bed is Lower Barton, as appears probable, the Middle Bartons are reduced to a little over 30 feet thick.

The outcome of the true Bartons is limited to a relatively short distance, but it is probable that the Becton-Bunny and Long-Mead-End Beds may occupy a tract between two and three miles wide. They only show in the cutting for a distance of over 1200 yards as yellow sands, rising from 1 to 8 feet, under a capping of 20 or more feet of gravel; but these are succeeded in the next hill by a greater thickness of whity-drab clays, extending for a further distance of 2700 yards. The *Paludina*-beds of the Lower Headon appear in a depression beyond this point, but their actual junction could not be traced at the time of our visits. The beds must be nearly horizontal, for they extend for the next 2 miles with little change, except that they are violently squeezed and contorted for a distance of 400 yards out of the last half-mile (fig. 6).

Fig. 6.—*Contorted Lower-Headon Beds, about* 2330 *yards west of the Brockenhurst Road.*



a. Gravel.
b. Light steel-grey clay, with shelly bands of crushed *Paludinæ*, &c.

Nothing further is visible, except gravel, for about a mile, when some white sand, some small patches of lignite and crimson-mottled clay are visible; but the bedding is disturbed and confused, as if thrust up from below, and we can only conjecture that the sand may represent the horizon of the Crocodile-beds. They extend horizontally for 500 yards, the lignites occurring close to the bridge over which the Brockenhurst Road is carried. The section ends with 18

feet of green clay mottled with shells, and 6 or 7 feet of compact pale green sand, the combined horizontal extent being 700 yards. This must, we believe, represent the beds immediately below, as well as partly the *Unio*-beds of our Hordwell section, for the Middle Headons occur somewhere in the next rising ground on the Brockenhurst side.

THE ALUM-BAY SECTION (fig. 7).

The section at Alum Bay is but 6 miles from Barton, and being through lofty cliffs with vertical bedding, is extremely easy to measure and understand. Measurements taken by Prof. Prestwich were published in his "Memoir on the Isle of Wight Tertiaries," in 1846, the entire series forming the 29th and 30th beds of his section, with a thickness of 380 feet*, inclusive of 100 feet of siliceous sand. In 1857 he separated the formation into three not very well characterized beds as group *a*, and made the overlying siliceous sands his division *b*. Mr. Bristow, with Mr. Gibbs, measured it again, the results published in the Survey Memoirs of 1856 and 1862 showing a total thickness of 300 feet, exclusive of the siliceous sands. We think that this is a little over-estimated and that the measurement of 380 feet is nearly correct. Mr. Fisher, in 1861, reduced the thickness shown by Prestwich by 43 feet, placing the beds below the *Nummulites elegans*, var *Prestwichiana*, in

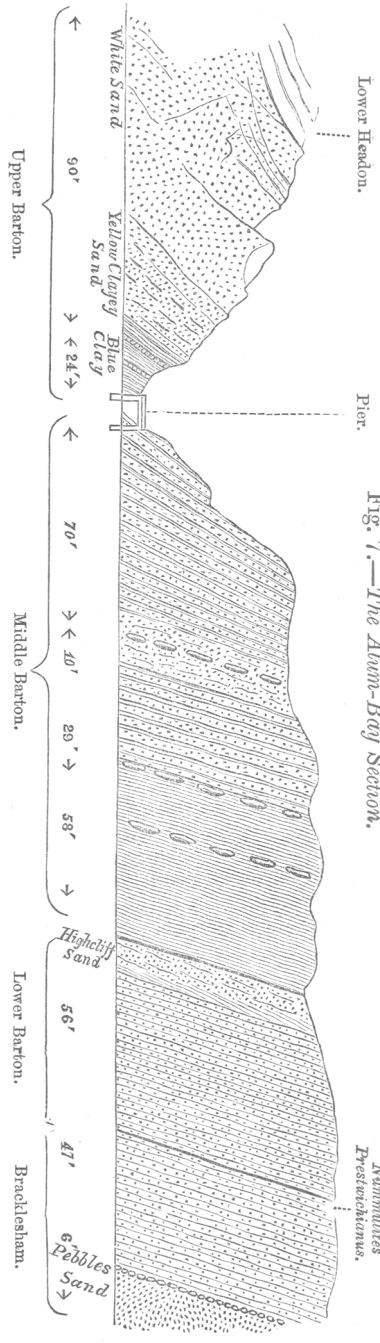


Fig. 7.—*The Alum-Bay Section.*

* Quart. Journ. Geol. Soc. vol. ii. p. 109.

the Bracklesham series. We make the section (fig. 7) to be as follows :—

		ft.	in.
Upper Barton.	White sand, becoming clayey and yellow towards the base, about	90	0
	Dark-blue clay, with one band of ironstone a foot thick, 6 feet from top, and a similar band 4 feet lower down; numerous fossils *	24	0
Middle Barton.	Pale and ferruginous yellow sandy clays, green in the upper part, Lignite, Corals, *Dentalium*, *Ostrea*, *Corbula*, *Pleurotoma*, common, and of several species, pale yellow sand at base †	70	0
	Layer of tabular Septaria, with many sharks' teeth, pebbles, fragments of wood, &c., and layer of scattered pebbles beneath in green sand	10	0
	Grey and brown sandy clay, with numerous casts of fossils of Middle Barton species, the shells being preserved in the lower 7 feet only	29	0
	Drab clay, with band of Septaria at top, and a second one 16 feet lower down. *Corbula*, sharks' teeth, and lignite †	58	0
Lower Barton.	Dark bluish-green clay, with sands in patches at the top, containing *Buccinum canaliculatum*, *Volvaria acutiuscula*, *Mitra parva*, &c. The whole capped with 9 feet of pale grey loamy sand	56	0
	The same with *Nummulites elegans*, var. *Prestwichiana*	1	0
Bracklesham.	Glauconitic sandy clay, the upper 10 feet with *Corbula*, &c., then about 15 feet in which casts of fossils are numerous, and the rest unfossiliferous ‡	47	6
	Pebble bed	0	6
	White sand.		
		386	0

(inclusive of 48 feet of Bracklesham).

The white sands at the top of this section have been quarried for glass-making, and as the change from the vertical position, in which the Bartons occur, to the nearly horizontal bedding of the Lower Headons takes place within the thickness of these sands, they cannot now be very accurately measured. They were estimated by Prestwich to be 100 feet, and by Bristow at as much as 140 to 200 feet, but we doubt if they even reach the former estimate. Though quite unfossiliferous, they represent the Becton-Bunny and Long-Mead-End Beds of the opposite coast.

The *Chama*-bed should appear beneath them, and one of us has found something very like it, but rarely exposed, at low water, just

* These agree almost precisely with Bristow's observations, Mem. Geol. Survey I. of W. p. 48.

† Bristow, *l. c.*, adds a band of small pebbles of white quartz and with sharks' teeth, 2 inches thick, 3 feet below the Septaria, and a third large layer of Septaria 5 feet from the base. Also a band of fossils 13 feet from the base, and a band of lignite 10 feet from the base. His base is, however, 9 feet above ours, the latter thickness being separated as pale grey, loamy sand, thinly laminated.

‡ Bristow mentions that a fossiliferous bed of indurated marl, 6 inches thick, occurs 30 feet 6 inches from the top; lignite bands at 1 foot 3 inches and 19 feet, and a layer of Septaria 28 feet from the upper part.

north-west of the pier, with *Turritella* and *Chama squamosa*, but not massed together. We could not trace it in the cliff, though the iron-bands seem to occupy the proper horizon of the shell-beds. The Middle Bartons seem abnormally developed, being more than three times the thickness seen at Highcliff, and nearly twice that at Whitecliff; but our junction is only 9 feet above the Highcliff sands, perhaps considerably (12 to 20 feet) too low down. We have taken the Survey measurement for the lowest bed of the Upper Barton and to some extent for the Upper Bed of the Middle Barton, as the road to the pier has been so considerably widened that these divisions are now cut out, only three beds of Septaria being now visible, and no lignite. Many rare species, not met with on the mainland, are confined to these beds. The Lower Bartons maintain their normal thickness and physical features, the pockets of sand, with drifted shells, occurring precisely as at Highcliff, with the chief characteristic species; but the beds being vertical and squeezed are not so favourably situated for collecting*. The shells in it are small and confined to the upper part, gradually giving place to casts for a few feet, after which the beds become unfossiliferous. The last distinct zone of fossils is the *Nummulites-elegans* bed. The quantity of ferruginous and carbonaceous matter indicates, perhaps, shallow water. In comparing the section generally we are unable to recognize any of the subdivisions of the Upper Barton on the mainland, the beds having become, perhaps owing to their vertical position, more uniformly sandy and unfossiliferous; the Middle Barton maintains its characters, but is enormously thicker, even making some allowance for the obliquity of the section: the Lower Barton has not increased to any appreciable extent.

The Section at Whitecliff Bay (fig. 8).

The most perfect section through the Eocene formation in England, and perhaps in Europe, is exhibited at Whitecliff Bay, in the Isle of Wight. The only beds at all concealed are those of the Barton Series, which have been hidden for years by slips and growths of herbage and brambles.

It is apparent, in glancing along the cliffs, that if the strata had chanced to have been plotted out into divisions on this spot, instead of elsewhere, a very different arrangement from that which exists would have been arrived at. All the Brackleshams above the drab clay, with seams of lignite and rootlets, must have been included in the Bartons, and the Brackleshams, as a marine formation, must have been limited to the beds with *Nummulites lævigatus*, &c., 66 feet lower down than the *Pecten-corneus* zone. It is far from certain that such a division would not have proved more natural than that which obtains, for not only is there evidence of intervening dry land and freshwater deposits, but the fauna of the Lower Brackle-

* Bristow mentions *Dentalium striatum*, *Fusus longævus*, *Voluta spinosa*, *Solarium*, *Cardium*, *Natica* (2 sp.), *Fusus pyrus*, *Rostellaria*, *Cancellaria*, *Pleurotoma*, *Mitra*, from this bed.

shams, with its giant Nummulites, Bullas, and Cowries, and its wealth of corals, differs far more from that of the Upper Bracklesham, than the latter does from that of the Bartons. Had the Barton Series been described from the Highcliff section first, and then been followed from west to east, taking first Alum Bay and then Whitecliff Bay, the entire Upper Bracklesham Series would have found a place in it, and the base-line been drawn where a decided physical change existed. The accidental circumstance that Mr. Fisher began to plot the Bracklesham Series at Selsey, led him to place their limits very high instead of very low. The whole of the strata on both sides of the Bill down to the London Clay were placed in the Bracklesham, perhaps chiefly because the thick freshwater sands and clays, which cut them in two, are unfossiliferous and seldom or never exposed on the shore. The highest beds at Selsey were traced to the New Forest, where still higher beds with similar species overlay them, and, finally, a small zone, containing a particular variety of *Nummulites elegans*, was fixed upon as the upper limit of the Bracklesham Series. That the line is drawn in "passage beds" is admitted by Prestwich and by Fisher himself, and it is thus less satisfactory than one coinciding with a physical break. As no better line of separation can be found, however, without trenching very considerably on the Bracklesham, we propose to retain the base-line in the zone of *Nummulites elegans*, var. *Prestwichiana*. In retaining the present divisions of the Bracklesham, we must remember that the lower is very different from the upper, and that the latter passes insensibly into the overlying Bartons.

The section at Whitecliff Bay (fig. 8) commences with mottled clay resting on chalk; then follows an eroded surface with scattered pebbles; some loamy sand and the *Ditrupa*-bed ushering in the London Clay. This is nearly 400 feet thick, and at 50 feet from the top we can recognize layers of soft concretions, crammed with *Pectunculus*, representing the Bognor Beds. It is capped with 100 feet of buff sand with a few bands of scattered pebbles. The section is very oblique to the outcrop, so that all these beds have an exaggerated thickness. The Lower Bagshots consist of 137 feet of finely laminated clays and sands with vegetable impressions, and end a little below a bed of *Cardita planicosta*, marking the base of the Lower Brackleshams. These consist in turn of 56 feet of greenish sandy clay, evidently marine; 52 feet of laminated clays, with some lignite of doubtful origin; 90 feet of greenish sand, marine; 37 feet of the same with *Nummulites lævigatus*; 66 feet of clay, with belts of lignite and underclay with roots; and then the *Pecten-corneus* zone of the Upper Bracklesham. The "Brook Bed" of Fisher follows, 23 feet thick, greenish marine sandy clay; sandstone 5 feet; *Nummulites-variolarius* zone 34 feet 6 inches; 93 feet of Huntingbridge Beds, not very well exposed; terminating with the zone of *N. elegans*, var. *Prestwichiana*, taken as the line of junction with the Barton Series.

The Barton Beds were not separated by Prestwich in 1846,

when he described the section *, but are given as "Headon-Hill Sands," 202 feet; 37 feet of laminated clayey sand; 44 feet of bright yellow sand; 162 feet of imperfectly exhibited brown and grey clays, &c.; 32 feet of fossiliferous brown clay resting on 4 feet of sandstone. The latter is placed in the Bracklesham by Fisher, and the junction somewhere in the 162 feet of clays (Quart. Journ. Geol. Soc. vol. xviii. (1861) p. 68). The artificial nature of the dividing line is shown by the fact that no observer previous to Fisher had ever thought of dividing up the almost homogeneous mass of fossiliferous clay which is now classified as 93 feet of Bracklesham Beds and 60 feet of Bartons.

Whilst preparing this communication, one of us visited Whitecliff Bay and found the Barton Series exposed between tide-levels in an unusual, if not an unprecedented, manner. The section was measured, and the corresponding beds subsequently exposed by digging at the base of the cliff, when the first measurements were checked off. The result was published in the Geological Magazine †. It must be remembered that the section is not quite at right angles to the outcrop, and a diagonal direction may somewhat exaggerate the thickness. The measurements are for the most part reproduced from the work cited, as we believe them to be more accurate in the case of the Barton Beds proper than those

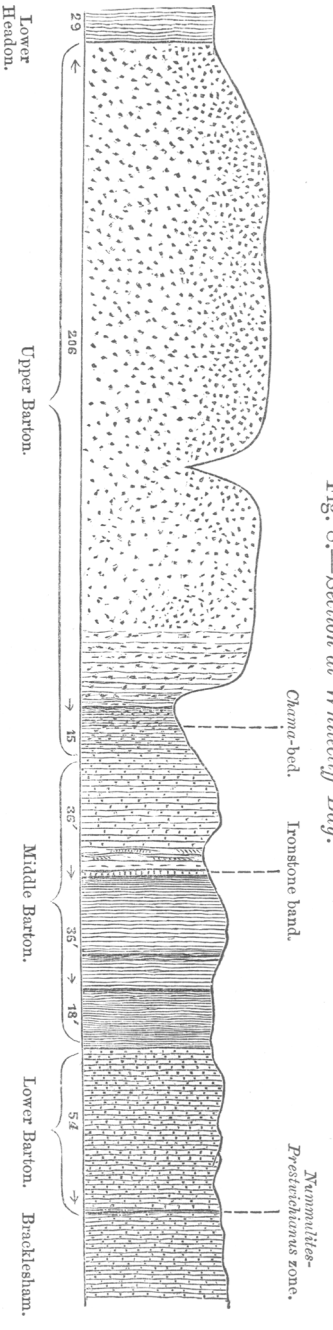


Fig. 8.—*Section at Whitecliff Bay.*

* Quart. Journ. Geol. Soc. vol. ii. p. 224. The Barton series is comprised in beds 17–20.

† "On the Discovery of the *Nummulina-elegans* zone at Whitecliff Bay, by H. Keeping," Geol. Mag. Decade iii. vol. iv. p. 70.

arrived at subsequently by two of us under less favourable conditions, and which we found to differ. The total is within a very few feet of that arrived at by Prestwich in 1846 and 1857. We have further grouped and correlated the beds with the three divisions seen in our typical section (fig. 2, facing p. 594).

SECTION AT WHITECLIFF BAY (fig. 8).

		ft.	in.
Lower Headon	Lower Headon	29	0
Upper Barton	Buff sand, with darker clayey beds towards base	206	0
	Bluish sandy clay, with *Chama squamosa*, *Terebellum sopitum*, *Voluta humerosa*, &c.	15	0
Middle Barton	Blue sandy clays, with mottled-brown patches of soft earthy ironstone and ironstone band 3 feet thick at base	38	0
	Greyish-blue clays, with fawn-coloured bands near base	36	0
	Stiff laminated clay, with few, if any, fossils	18	0
Lower Barton	Blue and yellow sandy clays, with few badly preserved fossils	54	0
	Dark green glauconitic sandy clays, crowded with *Nummulites elegans*, var. *Prestwichiana*	1	1
	Total	368	1
Upper Bracklesham	Coarse earthy sand, with *Ostrea plicata*	0	7
	Dark green glauconitic sandy clays	70	0
	Ditto, crowded with *Nummulites elegans*, var. *variolaria*	20	0
	Grey sandstone or "*Tellina*-bed" of Selsey	5	0
	Brook Bed	—	—

It will be seen that the Upper Bartons have enormously thickened since we last saw them at Alum Bay; but it is by no means certain that they are so uniform in character as they appear. The buff colour is probably greatly due to weathering, as these beds assume a precisely similar appearance when exposed for any length of time in the Barton section. By digging some distance in, the more or less clayey nature and darker colour of some of the beds become revealed, but no clean siliceous sands appear. At 66 feet from the top we found casts of *Cardita oblonga* and *Cytherea* *. The junction between this and the *Chama*-bed cannot be made out clearly in the cliff without digging to some depth; but it is very distinct at low water when the beds are visible. Still the *Chama*-bed is less sharply separated than at Highcliff, and the matrix is darker and more clayey and the Chamas far less abundant. The fossils collected from it were as follows:—

* Prof. Judd (Q. J. G. S. vol. xxxvi. (1880) p. 171) believes that they represent the Lower Headon. Prof. Forbes also found an abundance of impressions of marine shells which he considered might be Barton species.

Terebellum sopitum.
Voluta humerosa.
Ficula nexilis.
Natica, sp.
Trochita aperta.
Ostrea plicata.
Pecten carinatus.
——, sp.
Lima, sp.
Avicula media.
Arca, sp.
Pectunculus deletus.
Limopsis scalaris.
Nucula bisulcata.
Chama squamosa.
Cardium porulosum.
Lucina gibbosula.
Crassatella tenuisulcata.
Anisocardia, sp.
Cardita oblonga.
Cytherea.
Tellina ambigua?
Corbula ficus?
Panopæa corrugata.
Schizaster D'Urbani.
Ditrupa.

The ironstone band at the base of the next division seems to occupy somewhat the position of the shell-band at Barton. The total thickness we assign to the middle Barton here is 90 feet; but the subdivisions cannot be exactly correlated, and we were not able to make any collection of fossils from this part of the series. The thickness, 55 feet, assigned to the Lower Barton approximates to that measured at Highcliff, and the beds yielded a considerable fauna, though nearly all the species collected also range up into the Middle division. The *Nummulites-elegans* zone, taken as the base, is very distinct and the fossils in good preservation. It is 13 inches thick, and contains the following fossils:—

Typhis pungens.
Fusus pyrus.
Buccinum Solandri.
Pleurotoma exorta.
Voluta luctatrix.
—— scabricula.
Mitra parva.
Trochita aperta.
Dentalium striatum.
Bulla, sp.
Corbula pisum.
Crassatella sulcata.
Nemocardium turgidum.
Leda minima.
Ostrea plicata.
Nummulites elegans.

There is scarcely any lithological change in the beds as they pass into the Bracklesham, and the first break occurs at the bed of sandstone 90 feet lower down.

The Bracklesham, Stubbington, and Huntingbridge Sections.

The highest bed that can be identified at Selsey is the *Nummulites-variolarius* bed, locally known as the "Clibs." Higher beds certainly exist, but there is no record of their having been seen by any geologist. The transition in the fauna seems to commence in the "*Cypræa* bed" of Dixon, in which a large proportion of Barton species occur, such as *Cassidaria nodosa*, *Triton argutus*, *Pleurotoma inarata*, *Fusus pyrus*, *Rimella rimosa*, *Littorina sulcata*, *Voluta athleta*, *V. scabricula*, &c. With these are *Conus diadema*, *Cypræa Bowerbankii*, and *Pleurotoma attenuata*. The bed is remarkable as being fairly studded with the remains of *Posidonia*, a marine Monocotyledon which rooted in the sand. This is valuable as an indication of depth; for the existing Mediterranean species, hardly distinguishable from it, grows in the *bas-fonds* in from 10 to 20 feet of water. Above this is the "Hard Bed," in which *Tellina*

textilis, *T. plagia*, &c. abound with their original colouring distinctly preserved, together with *Solen obliquus*, *Mactra compressa*, *Cardium porulosum*, a few broken univalves, and *Belemnosepia*. Lastly, we have the *Nummulites-variolarius* bed. At Stubbington Mr. Fisher was able to trace the beds upward for another 30 feet, and at Huntingbridge still further up*. The Huntingbridge fauna† is truly transitional ‡, but contains among many Barton forms *Pseudoliva ovalis*, *Voluta labrella*, *Fusus Noæ*, and *Cassidaria coronata*, with a few others distinctive of the Upper Bracklesham Beds. A section through much of the overlying Barton Beds could probably be obtained by excavating in this vicinity.

The Barton Series in the London Area.

The Barton, or Upper Bagshot Series, in Hampshire, is separated from that in the London basin by an interval of no less than about 60 miles. We are of opinion that this break is due to Post-Eocene denudation, and see no reason to doubt that they once formed a practically continuous deposit.

The exact correlation of the sands, or very slightly clayey beds, which alone represent the clayey series of Hampshire in the London basin, is more difficult to determine; but the fauna precludes the idea that the sands of the latter at all correspond to the sandy beds of the Upper Barton of Hampshire. The application of the term Upper Bagshot to them, if implying anything newer than and distinct from the Bartons, is misleading. The clayey green sand, which occurs some 10 or 20 feet below the pebble-bed at their base, is undoubtedly Bracklesham, and probably Lower Bracklesham, for *Nummulites lævigatus* has been found with casts of other Lower Bracklesham forms §. Most of the fauna is of species common to Barton and Bracklesham alike; but a few, such as *Buccinum canaliculatum*, *Volvaria acutiuscula*, *Bulla orbicula*, and *Strigilla Rigaultiana*, are confined to the former, the first three being quite peculiar to the Lower Barton. Taking the fauna as a whole, we find three species, particularly *Dentalium grande*, peculiar to the Upper Bracklesham; thirty-one species common to the Bracklesham and the Barton; nine species peculiar to the Barton, of which three are peculiar to the Lower, and only two, *Nucula similis* and *Strigilla*, to the Upper Barton, the former being perhaps a not very reliable determination, since it might almost equally well be *N. lissa*.

There may thus be room for doubt, remembering the great thickness of these beds in Hampshire, as to whether the beds of the London basin are not partly, or even mainly, of Upper Bracklesham age, but there can be none whatever as to their being Lower Barton, if they are Barton at all. The bulk of the species, being

* Quart. Journ. Geol. Soc. vol. xviii. (1862) p. 79.

† Discovered by Henry Keeping.

‡ Mr. Fisher described the beds as possessing a Barton matrix with Bracklesham fossils; but the latter are actually in the minority in the highest beds.

§ See lists in Quart. Journ. Geol. Soc. vol. iii. p. 390, vol. xxxix. p. 349.

common to both formations, do not help to settle the question, except that some of the species are more distinctive of the latter than of the former. If we take the 12 to 20 feet of green clayey sand of the London basin, with *Nummulites lævigatus*, to represent the 37 feet of green clayey sand with the same fossils, and which is altogether undistinguishable from it, in the Whitecliff-Bay section, we should have the following thickness to account for in the London basin before reaching the base of the Barton series, supposing the two series to be all uniform in thickness :—

Hampshire Basin.

	93 ft.	Huntingbridge Beds, sandy clays, various.
Upper Bracklesham.	5 ft.	Sandstone.
	23 ft.	Brook Bed, greenish sandy clay.
		Pecten-corneus zone.
	66 ft.	clay with belts of lignite.
	187 ft.	

Towards this we have in the *London Basin* :—

Between 70 and 80 ft. of loamy sand passing into pure sand up to the horizon at which the determinable fossils have been found.

1 ft. pebble-bed.

10 to 20 ft. of loamy sand and clays overlying the green sand.

So that, even allowing for very considerable thinning, we should have no difficulty in placing the fossiliferous horizon in Tunnel Hill beneath the base of the Barton Series in Hampshire. The palæontological evidence, which has been sifted with care, almost precludes this, however, the list containing nine species which are peculiar to or are not known to pass beneath the Barton in this country. Against this we have to set the four Bracklesham species and two or three undeterminable casts which are more like *Cerithia* of that age than anything else. But, practically, we are bound to take the pebble-bed as a base, since there is nothing above it which would furnish any recognizable dividing line; and to put the whole of the 200 feet of Upper Bagshot sand into the Bracklesham, against the weight of evidence, such as it is, is out of the question.

The area occupied by the formation in the London basin is comprised in sheets 8 and 12 of the Geological Survey Map, and with the exception of a small possible outlier at Highclere, near Newbury, it only exists in the main mass of the Bagshot Beds. Easthampstead Plain, Finchampstead Ridges, Chobham Ridges, Fox Hills, Hartford Bridge Flats are formed of it. The surface is usually barren heath, or is covered with plantations or woods of self-sown Scotch fir, whilst the more clayey Bracklesham supports beech, alder, birch, &c., and is to a far greater extent under cultivation. In our sketch map (fig. 11, p. 616) the shading represents the Upper Bagshot as mapped by the Geological Survey, and the numbers refer to the various localities mentioned in the present paper. The dividing line between the Upper Bagshot and the Middle Bagshot is drawn at a higher level than that fixed on by Professor Prestwich on the ground that the yellow sands contain

green grains; but, judging from what occurs in the Hampshire basin, this reason is unsatisfactory, and the difficulty of drawing a line in the middle of a sand-bed has prevented the mapping being executed with consistency *.

It has been recently suggested that a bed of pebbles which occurs very persistently over the whole area, some 10 to 20 feet above the green sand with Bracklesham fossils, should be taken as the base of the Upper Bagshot, and in this opinion we concur †.

Taking the pebble-bed as the base, the greatest proved thickness of the Upper Bagshot is 228½ feet at the Albert Asylum Well (15 on sketch map), and this may be far from the original thickness, as no overlying beds but drift are present.

The various levels at which the pebble-bed is found show that the formation rests in a syncline of the Bracklesham Beds, and, probably, is conformable with them.

The Upper Bagshot Beds consist of whitish-yellow sands, a little loamy in some places. Faint bands of colour denote the original bedding with occasional iron concretions, pipings, and small blotches, the latter having once been fossils. Sometimes, as at Tunnel Hill, between Aldershot and Brookwood, the original forms are preserved as ferruginous casts, either of the interior or retaining the markings of the exterior of the shell. Recognizable fossils have only been found at this locality in beds of sand ranging from 70 or 80 to 118 or 128 feet above the base of the series, so that the overlying beds, nearly 100 feet thick, may represent a higher portion of the Barton Series.

It has recently been suggested that sands at Aldershot, Bearwood, Wokingham, Buckhurst, Bracknell, and Ascot are Upper Bagshot, though mapped as Lower Bagshot (see Q. J. G. S. vol. xli. p. 492, vol. xliii. p. 374); but, after considering the evidence, we have no doubt that the mapping is in these instances correct. Our reasons are stated in the Quart. Journ. Geol. Soc. vol. xlii. p. 402.

The point marked 1, near Ascot, on our sketch map, is the railway-cutting, the section of which is published Quart. Journ. Geol. Soc. vol. xxxix. p. 349, and from which large quantities of Bracklesham fossils have been obtained. The pebble-bed at the base of the Upper Bagshot is well seen about 13 feet above the fossiliferous green sand.

Pebbles derived from this bed are found in great abundance capping Hagthorn Hill, to the north of Tower Hill, also at the point marked 2 on the sketch map, and at Red Lodge, above the 300-feet contour-line. There are good sections in the Bracklesham clays at a brickfield in the northern slope of Tower Hill, (3) on the same contour, and there are good sections in Upper Bagshot yellow sands at the point marked 6, at Gravel Hill, 4, and at Cæsar's Camp, 5, whence we have two casts of shells. In Duke's Hill there is a satis-

* See Mem. Geol Surv. iv. pp. 329, 330, 333.

† See Quart. Journ. Geol. Soc. vol. xxxix. pp. 348, 353, vol. xli. p. 492, vol. xlii. p. 402; Proc. Geol. Assoc. vol. iv. p. 334, vol. viii. p. 149.

factory Upper Bagshot section (7). These sections prove that the base of the Upper Bagshot rises up to the 300-feet contour-line at this northern end of the main mass.

Passing eastwards to Chobham Common the following beds are exposed on a road at the point 8.

1. Capping of pebbles on hill top (remains of Upper Bagshot pebble-bed).
2. Yellow sandy clays, say 10 to 15 feet.
3. Green sand, with *Cardita planicosta*, *Corbula gallica*, &c., in abundance.

} Bracklesham Beds.

The clays of bed 2 were worked for bricks half a mile north of Chobham Place, and the same clays and underlying green sand are exposed in another disused brickfield near Titlarks Farm (9) (details given Q. J. G. S. vol. xlii. p. 404). The low hill just above this section (10) is capped with pebbles from the Upper Bagshot pebble-bed. These sections prove that the surface of the higher part of the Chobham-Common plain is Middle Bagshot, and the round-topped hills which rise above it are Upper Bagshot. In two of them there are good sections in characteristic Upper Bagshot sand (11, 12). At Long Down there must be over 50 feet of Upper Bagshot, and it appears to extend slightly further than is shown on the map.

A brickfield has quite recently been opened close to Chobham Place (13) and at about the same level. In March 1887 some 3 or 4 feet of stiff grey clay (Bracklesham) was shown, and this together with the former sections leads us to believe that Chobham Place is correctly mapped Bracklesham, so that we cannot confirm Professor Prestwich's section in which 100 feet of Upper Bagshot are represented overlying the Middle Bagshot at that place (Q. J. G. S. vol. iii. p. 384, fig. 4).

Several of the hills east of Chobham Place, at Ottershaw, and towards Chertsey are capped with pebbles, for the most part probably derived from the Upper Bagshot basement-bed; and the great pebble-bed at the top of St. Ann's Hill, Chertsey, in all probability is on the same horizon, though, unfortunately, the fossils which occur in it are not sufficiently perfect for identification.

Chobham Ridges attain a height of over 400 feet, and are composed of Upper Bagshot sand capped with gravel; and if the pebble-bed is taken as its base, it extends much further to the east than is shown on the map.

The well at the Albert Asylum (14), on the top of the ridges, furnishes the greatest recorded thickness of Upper Bagshot, viz., 226 feet of sand and 2½ feet of pebbles. The surface is about 400 feet and the level of the Bracklesham beds 171½ feet above O.D.

A little to the north and west of this well very fine sections were opened on the railway from Bagshot to Camberley (15). They showed sands of different tints of yellow and brown in broad bands of varying shades, and casts of badly preserved shells were very abundant. In our collection there are over 100 specimens from the

cutting at Crawley Hill*. Mr. Herries has found similar casts on the Lightwater Road, near Windmill Hill †.

All these fossils are from beds more than 100 feet above the Bracklesham.

There are several good sections in the lower beds of the Upper Bagshot in this district, mapped as Bracklesham. There are two large sand-pits at New England Hill (16) (close to "three Barrows" on the Survey Map), $2\frac{1}{2}$ miles east of the road running along the top of Chobham Ridges, and the pebble-bed crops out at the Gordon Boys' Home, a little below the level of the pits. It again occurs at Bisley (17), and there are two fine Upper Bagshot sections close to Cowshot Manor (18), and several small ones at the Guards' Camp, Pirbright.

We therefore believe that not only the high ground of Chobham Ridges, but also the low hills between Cowshot Manor and New England Hill and the boggy ground covered with heath between them and the Ridges, form part of the main mass of the Upper Bagshot.

There is a small outlier of Upper Bagshot close to Knap-Hill Asylum, and pebbles from the Upper Bagshot basement-bed are found at the top of many of the hills around, possibly, in some instances, they may be *in situ*.

Professor Prestwich obtained the greater number of his Upper Bagshot fossils from the railway-cutting on the main line of the South-western Railway through the northern end of the Fox Hills (19) (see list, Quart. Journ. Geol. Soc. iii. p. 393), and there are two in Mr. Herries's collection from a pit (20) close to the ruined windmill on the top of the hill. One, a *Tellina*, was in a red, hard sand, just below the gravel which caps the hill.

At about the middle of the Fox Hills there is a fine series of sections on the Woking-Aldershot line. The railway tunnels under the highest part of this ridge, known as Tunnel Hill; but at each end are deep cuttings, giving the following section (21, and fig. 9).

The fossils in beds 1, 2, and 3 can, in many cases, be named with certainty. The list is given on page 616.

The Upper Bagshot extends considerably beyond the limit shown in the map, probably as low as the 200-feet contour on the east of Tunnel Hill. To the west there is a small sand-pit in Upper Bagshot yellow sand, close to Mitchet Lake (23), at the level of about 237 feet above O. D.

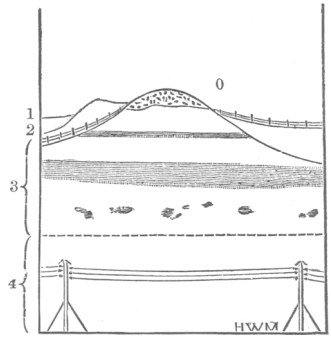
The strata under Tunnel Hill appear to have a slight dip to the north, so that the level of the pebble-bed under the hill must be under 237 feet above ordnance datum, *i. e.* from 70 to 80 feet below the

* Described Mem. Geol. Surv. iv. p. 334. The shells are *Terebellum fusiforme*; *Voluta*, sp.; *Natica*, sp.; *Turritella imbricataria*; *Trochita aperta*; *Xenophora umbilicaris*; and two other species of univalves; *Protocardium*, sp.; *Cardita sulcata*?; *Tellina scalarioides*; *Corbula*, sp.; two other species of bivalves and *Serpula*.

† Geol. Mag. dec. 2, vol. viii. p. 171. Those from the latter are *Turritella imbricataria*, *Ostrea*, sp., and three bivalves.

bottom of the highly fossiliferous beds, and giving a total of 130 feet of Upper Bagshot sand at Tunnel Hill.

Fig. 9.—*Section at Tunnel Hill on the West of Pirbright Common, Surrey, on the east of the railway north of the Tunnel.*



The shaded portions represent dark bands of yellow sand.

0. Angular flint-gravel, containing many pebbles.

Upper Bagshot.

1. Dark yellow, passing down into ochre-sand, numerous casts of fossils, mostly small univalves, in irony concretions, scattered throughout the bed. About 20 feet.
2. A well-defined line of bright yellow sand. 8 inches.
3. Whitish sand. Light yellow sand, passing down into nearly white sand, with a line of irregular patches of more ferruginous yellow sand, with lines and concretions full of casts of shells, many large bivalves, *Cardium porulosum*, *Protocardium parile*, &c. A few flint pebbles. 27 feet.
4. Alternate bands of dark and light brown and yellow sands, many iron-sand concretions, but very few fossils. Nearly 40 feet exposed on the north side of the tunnel. Though this is nearly a quarter of a mile long, the bright yellow line 2 and the line of irregular patches in bed 3 are seen at both ends.

The base of the fossiliferous beds is shown by the broken line, and is a little above the tops of the telegraph-poles.

There are several good Upper-Bagshot sections near North Camp Station, S. W. R., one on the railway and others at the rifle-ranges (24), from which Mr. Herries has obtained numerous fossils.

At the southern end of the Fox Hills, near Ash (22), Lieut. Lyons has found the pebble-bed cropping out at a little over the 300-feet contour with the Bracklesham and Lower Bagshot Beds below to the north (Q. J. G. S. vol. xlii. p. 413, vol. xliii. p. 435).

A large outlier of Upper Bagshot is mapped to the north-west of Pirbright, and the northern end of it, on the hills in the cemetery close to Brookwood Station, is correctly mapped; but we doubt whether the Upper Bagshot extends far to the south-east of the station, for at the point marked 25 on our sketch map the pebble-bed crops out, and the Bracklesham greensand comes to the surface

a little to the east. There is a pit in nearly white Upper Bagshot sand close to an arch under the railway (26) from which Mr. Herries has also obtained fossils.

At Bakersgate Farm pebbles abound on the surface of the ground, showing that there is no more Upper Bagshot in that direction.

The Bagshot Beds, which are usually fairly horizontal, rise sharply to the south as we approach the Chalk (Mem. Geol. Surv. vol. iv. p. 376, fig. 89), so that the base of the Upper Bagshot, which is but little over 200 feet above ordnance datum at North Camp Station, S. E. R., has risen to 300 feet at Thorn Hill (29) and to more than 560 feet at Cæsar's Camp (Q. J. G. S. vol. xliii. pp. 431, 440).

Near Farnborough Station, S. W. R., there are good sections in the Upper Bagshot yellow sand in a railway-cutting (28) and in road-sections, and the same beds were recently exposed in digging the crypt for the Imperial Mausoleum. Fossils are recorded from these sections (Mem. Geol. Surv. vol. iv. p. 334; Q. J. G. S. vol. xli. p. 500).

In a well at the Farnborough waterworks pebbles were reached at 135½ feet and 153¼ feet below the surface, and above the upper pebble-bed were 128½ feet of loamy sand (Q. J. G. S. vol. xli. p. 495).

At Thorn Hill, South Camp, Aldershot, are shallow fortifications and a sandpit at the top of the hill (29). All are in yellow Upper Bagshot sand, and in one Mr. Herries found a cast of a bivalve. The pebble-bed crops out 62 feet below the top of the hill (Q. J. G. S. vol. xlii. p. 410, vol. xliii. p. 431). Its exact limits in the Long Valley have not been worked out; but Lieut. Lyons says that the Brackiesham beds can be traced across the valley, overlain occasionally by the Upper Bagshot with the pebble-bed at its base (Q. J. G. S. vol. xliii. p. 439).

Mr. Herries has found casts of shells in abundance * in yellow Upper Bagshot sand at the steeplechase-course (30) near Long Hill. We have a single valve of a large shell, probably a *Cardium*, and other fossils, from the same bed at Beacon Hill (31).

At Gally Hill, named Curley Hill on the Geological Survey Map, though the whole is mapped Bracklesham, there is the following section in Upper Bagshot in a sandpit (32):—

	ft.	in.
1. Nearly white sand, with a little white clay in very small patches, and numerous green grains	6	0
2. Dark yellow sand, with about as much clay	4	0
3. White and orange-coloured sand	2	0
4. Line of pebbles in yellow sand.		

The beds 1 and 2 contain casts of shells. On the opposite side of the hill and at a rather lower level the Bracklesham clays are worked for bricks. In the Hartford Bridge Flats outlier there are

* 1 specimen of *Dentalium*, 6 of *Xenophora*, and 23 other specimens of univalves, 4 bivalves.

numerous sections in yellow sands of Upper Bagshot age. We have not found fossils in them, but Prof. Prestwich says fossils occur there. There is a good road-section (33) close to Minley Manor Chapel, and on the opposite side of the outlier there is a very good Upper Bagshot section (34) in a sandpit at the rifle-range. It is about 20 feet deep and shows yellow, irregularly-bedded sand, becoming nearly white at the bottom of the pit.

Small roadside sections (35) on the side of the Flats just above Eversley Church show the following series of beds:—

Section 1. Gravel at the top of the Flats.
Section 2. Yellow sand, with numerous green grains, either the bottom of the Upper Bagshot or the top of the Bracklesham.
Section 3. Green sand (Bracklesham) shown in good section some 10 or 15 feet below Section 2.

At Hazley Heath, to the south-west of Hartford Bridge Flats, is a good brickfield-section in Bracklesham clays; and above it, at the top of the heath, there is a pebble-bed in loose yellow sands beneath and distinct from the gravel which caps the heath. If this is the Upper Bagshot basement-bed, as it probably is, Hazley Heath is the most westerly point to which we have traced it.

There are numerous sections in the Upper Bagshot round the Staff College, Sandhurst, and here and there small sections occur on the commons to the north-east. From one (44) we obtained a cast of a bivalve, and from another on Olddean Common a *Xenophora*, another univalve, and a bivalve.

In the neighbourhood of Wellington College the Upper Bagshot extends further than is shown on the Survey Map, so that Finchampstead Ridges is not an outlier but a portion of the "main mass" (they are stated to be mapped Upper Bagshot, with some doubt, Mem. Geol. Surv. iv. p. 335).

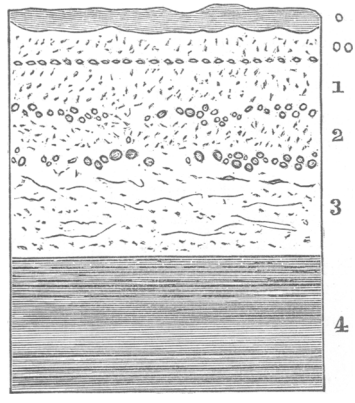
At Ambarrow hill there is a small section on the South-Eastern Railway (36), from which we have obtained many fossils, all very badly preserved. *Natica*, *Xenophora*, and *Voluta* are abundant, and we have an impression of *Turritella imbricataria* and many species which are undeterminable.

There are small pits in whitish sand at 37, and a deep cutting has recently been made for a road at 38 in yellow sand, also clearly Upper Bagshot.

The small outlier at Finchampstead Church (39) is also undoubtedly Upper Bagshot. There are two good sections in characteristic yellow sand at the top of the hill, and the Bracklesham green sand is shown in a road section on the northern slope.

The greater part of the Wellington-College estate is mapped Bracklesham, but there is a large extent of Upper Bagshot there, and the pebble-bed can be traced over a large area. It is well seen in the following section (40, and fig. 10):—

Fig. 10.—*Section on the South-Eastern Railway, ¼ mile to the south of Wellington-College Station at point* 40 *on Sketch Map*, p. 616.



0. Surface earth, 6 inches.
00. Sand, with a line of small angular flints at the base, 9 inches.

	ft.	in.
Upper Bagshot.		
1. Light yellow sand	1	3
2. Pebble-bed in greenish sand, the pebbles in two irregular lines	1	6
Bracklesham.		
3. Yellow sand, with irony concretions; a few casts of a *Turritella*-like univalve	2	6
4. Yellowish, reddish, and light-green sand, with laminæ of nearly white clay	3	0

The Bracklesham green sand and dark clays crop out along the line to the north of the station (see Q. J. G. S. xlii. p. 407, fig. 1).

The well at Wellington College (41) passed through 22 feet of Upper Bagshot sand before reaching the pebble-bed at the base (Mem. Geol. Surv. iv. p. 425; Q. J. G. S. xli. p. 494). There are several good sections in Upper Bagshot near the College, from one of which, at the butts in Edgebarrow hill, we obtained a cast of a bivalve. There is a small Upper Bagshot section at the point marked 42 (Crowthorne), and several good ones in Lodge Hill round the Broadmoor Lunatic Asylum, from one of which Mr. Whitaker informs us casts of shells have been obtained.

There is also a good section at Sandhurst, on the South-Eastern Railway (43), and from it we have several casts of univalves and bivalves.

Attention has been called to a small and very detached Upper Bagshot outlier close to Highclere Station by Mr. Irving, and a sand-pit on the 500-feet contour-line a little to the south-west of the Station furnishes a good section in it. The sand is yellow, irregularly bedded, with little or no clay, and with many irony concretions. Mr. Herries has found several casts of shells in the sand, unfortunately not sufficiently well preserved to be specifically identified, but very like the usual Upper Bagshot casts.

The reasons for believing this sand to be Upper Bagshot and not Lower Bagshot, as mapped, are as follows :—

The chalk is about ½ mile to the north, and there is a high dip to north. Along the railway north of the Highclere Station the following beds are exposed :—

1. Yellow sand, close to the Station.
2. Greenish, very clayey sand. } (Bracklesham.)
3. Yellow sand, rather clayey, a considerable thickness. (Lower Bagshot.)
4. Judging from wet fields below the level of the line, there appears to be a considerable thickness of clay here. (London Clay.)
5. Yellow and mottled clay.
6. Yellow sand.
7. Green-coated flints and *Ostrea*. } (Reading Beds.)
8. Chalk with high dip to north.

The sands in the pit in question resemble the Upper Bagshot of the chief mass, and they differ from the ordinary Lower Bagshot in the following particulars :—

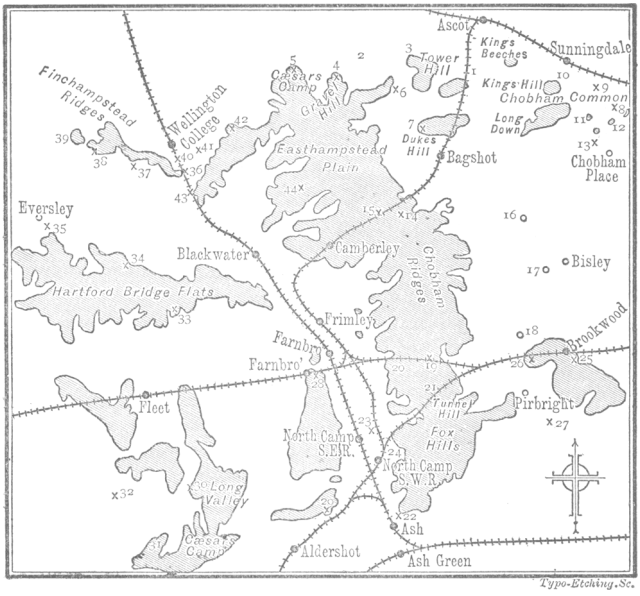
1. Absence of clay laminæ.
2. Presence of green grains.
3. Absence of current-bedding.
4. Presence of casts of shells in sandy concretions resembling those found in known Upper Bagshot.

We think we have now said enough to show the character of the Upper Bagshot beds, and the persistence of the pebble-bed at their base. As previously stated, they lie in a slight syncline of the Bracklesham, and are probably conformable to them. At Cæsar's Camp, Easthampstead (5), the base of the Upper Bagshot is above the 300-feet contour; at Wellington College (41) it is 264 feet above ordnance datum, at the Albert Asylum (14) about 165 feet, at Tunnel Hill (21) rather under 237 feet, and at Ash (22) it has again risen above the 300-feet contour.

The Upper Bagshot beds are thus distinguished by the elevation they attain and their barren aspect, the chief and almost only vegetation they support being scanty heather, whortleberry, stunted gorse, and Scotch pine; while the lower-lying Middle Bagshots are of a more swampy nature, and support deciduous trees and shrubs. The presence of the dividing pebble-bed can almost always be detected, however overgrown, if carefully searched for. Though now consisting solely of whitish-yellow sands, a little loamy towards the base, faint bands of colour denote the former bedding, while occasional irony concretions, piping, and small blotches testify to the extreme changes induced in their composition by percolating water. Richly fossiliferous and varied as we know the Upper Bartons to be in Hampshire, when covered and protected by impervious beds of clay, we have seen them assume the same monotonous and unfossiliferous condition the moment the outcrop

brings them to the surface and permits water to percolate through them. It appears perfectly certain that the Upper Bagshots in the London area were once at least as fossiliferous as those of Hampshire, and the beds and what can still be recognized of their fauna are such as might have been found in an open sea of considerable depth.

Fig. 11.—*Sketch Map showing the Upper Bagshot Sand, of the Bagshot Area.* (Scale $\frac{1}{4}$ inch to 1 mile.)



The numbers refer to localities noticed in the paper.

Fossils from the Upper Bagshot Sand.

(All are from Tunnel Hill, marked 21 on the sketch-map. The * indicates where a species is most abundant.)

	Upper Bracklesham.	Lower Barton.	Middle Barton.	Upper Barton.
Ancillaria canalifera	—	*	—	
Buccinum canaliculatum	...	*		
Bulla attenuata	—	—	?	*
Bulla elliptica	—	*	—	—
Bulla, sp.				
Bulla orbicula	...	*		
Cancellaria evulsa	—	—	—	—
Cassidaria nodosa	*	—	*	

Fossils from the Upper Bagshot Sand (continued).

	Upper Bracklesham.	Lower Barton.	Middle Barton.	Upper Barton.
Cerithium, sp.				
Dentalium grande †	*			
Dentalium striatum	—	—	*	—
Dentalium, sp.				
Fusus interruptus	*	—		
Littorina sulcata	—	*	—	
Melanopsis, sp.				
Natica ambulacrum	—	—	—	*
Natica labellata	—	*	*	—
Natica patula	—	—	*	—
Natica venusta?	—			
Natica, sp.				
Pleurotoma biconus	...	*	—	
Rimella rimosa	—	*	*	*
Sigaretus clathratus	—	*	—	
Solarium crenulare	—	—	*	
Terebellum fusiforme	—	*		
Trochita aperta	—	—	—	—
Trochus, sp.				
Turritella imbricataria	*	*	*	*
Serpuloides cancellatus	*	...	—	
Voluta, sp.				
Volvaria acutiuscula	...	*		
Xenophora umbilicaris	—	—	*	—
Cardita sulcata	...	—	*	—
Cardium porulosum	*	—	—	—
Clavagella coronata	—	—	—	—
Corbula gallica	*	—	—	
Corbula Lamarckii	—	—	*	—
Corbula longirostrum	—	—	—	*
Corbula pisum	*	*	*	—
Crassatella sulcata?	...	—	*	—
Cytherea obliqua	—			
Cytherea, sp.				
Lucina elegans	—	...	...	*
Nemocardium turgidum	—	—	*	?
Nucula similis?	...	?	?	*
Nucula, sp.				
Ostrea plicata	—	—	—	*
Pecten carinatus	...	—	—	*
Pecten reconditus	—	...	—	—
Pectunculus deletus	—	—	—	*
Strigilla Rigaultiana	...	...	...	*
Tellina scalarioides	*	—		
Serpula.				
Corals, 2 species of *Turbinolia*.				

† Not Barton, but found in the equivalent Sables Moyens of the Paris basin.

The preceding list contains 52 species of Mollusca †, for the collection of which we are largely indebted to Mr. Herries. Of these, 43 could be determined specifically, 9 generically only, and there was a considerable *residuum* which we were unable to identify. Thirty-one are common to the Upper Bracklesham and Barton, only 3 are absolutely unknown in the Barton, and there are 9 Barton species unknown in the Bracklesham. We must not attach undue importance to these, however, because a considerable distance separates Barton from Tunnel Hill; and we see that as far off as the Paris basin, many of what are our most distinctive Barton shells in Hampshire, such as *Volvaria acutiuscula*, *Strombus bartonensis*, *Solarium plicatum*, become distinctive of the Calcaire Grossier, and are quite unknown in the Sables Moyens, where we should expect to find them. On the other hand, we may instance *Dentalium grande* as a purely Bracklesham species in Hampshire, ranging into the Sables Moyens in the Paris area. If we take the * species, which are the most typical and abundant, we find that only 4 of those common to the two formations are more at home in the Bracklesham than in the Barton, while the reverse is the case with no less than 28. Though more of the Barton species belong to the Lower than to either the Middle or Upper divisions of the formation, the Lower Barton facies is not so apparent as we should expect it to be, probably because the sandy bottom favoured species which could not exist in the muddy bottom of the Hampshire basin. Making allowance for this the palæontological evidence agrees with the stratigraphy, the presence of the few Bracklesham forms leading us to place the Tunnel-Hill horizon a little below that of Highcliff.

The Barton Fauna.

The fauna of the Barton Series is the richest in our Eocene, and contains probably more species than have ever before been met with in a single locality. The splendid preservation of the fossils and their striking character attracted attention in very early times, and the work by Brander in 1766 is one of the very earliest in which a large series of fossils was accurately figured and described. They seem to have been collected assiduously ever since, the recurring wash of the waves against the base of the cliffs exposing fresh specimens with every tide, whilst new crops of these delicate fossils seem sprinkled over the dark slopes between Highcliff and Hordwell after every shower.

Prof. Prestwich was able to enumerate 209 species from Barton in his first paper, and in his second the number was increased to 301‡,

† Only 15 forms are given in the Survey list, in the "Geology of the London Basin," p. 600; and of these very few are determined specifically. At least 4 must be different from any in our list.

‡ In 'Geology,' vol. ii. p. 369, Prestwich says "The Barton Clay contains 310 species of Mollusca' and 28 of corals; "*Nautili* have not yet been met with there."

of which 252 were Mollusca. The collection of the Geological Survey, as shown by their catalogue in 1865, comprised 182 species, whilst Morris enumerated 219. Prof. Judd, when writing of "the richly fossiliferous marine deposits of the Barton Clay at the base of the Fluvio-marine series" remarks (Q. J. G. S. vol. xxxvi. p. 151):—"So long ago as 1857 Prof. Prestwich was able to enumerate no less than 300 species of Mollusca from this formation; and when all the known forms contained in the numerous collections in this country come to be described, the number of species from this deposit will probably exceed 1000." A somewhat critical examination of the Edwards collection shows about 527 varieties of Mollusca from the Barton Beds entitled to specific rank, and we are not of opinion that this number will ever be greatly exceeded. Fossils belonging to other groups bring the fauna to a possible total of 600.

The original basis of the tabulated list appended is the catalogue of the Edwards collection in the British Museum. To this we have added as much as possible on the one hand, whilst removing on the other all forms of doubtful specific value. In tabulating the range of the species, we have endeavoured to distinguish their occurrence in each division of the Barton Series; and we believe that the long residence of one and the repeated visits of two of us to the locality, for the purpose of collecting, enable us to deal with the question of the horizons to which species are confined, with a practical experience that it is scarcely probable any other workers have exceeded. Many, especially of the minuter forms identified by Edwards, are almost, if not quite, unique, and we have no means of ascertaining their horizons with certainty. We regard the record of some of the Barton species from other formations as doubtful, but do not suppress them, as we have ourselves discovered several fresh Barton species in Bracklesham Beds whilst preparing this paper. We endeavour to obviate the inconvenience arising from giving extended ranges to species, upon the occurrence of stray and even doubtfully recorded specimens, by placing an asterisk in the columns under which a species is most at home. We have also endeavoured to separate species of the Upper Bracklesham Beds from those of the Lower; and, though necessarily imperfect, this arrangement cannot fail to be of value in showing the passage of the fauna in a truer light than hitherto.

A formidable obstacle was presented by the extensive synonymy in use. No less than 42 species from Barton, out of 182 in the catalogue of the museum at Jermyn Street, cannot be traced under the same names in Edwards's list, whilst in the latest of the lists given by Prestwich 65 additional names of Barton fossils occur which are ignored by Edwards. Similarly we find 60 names in Morris's catalogue unrepresented, and 24 out of the 86 species recorded from the Barton Beds of Alum Bay in the Survey Memoir on the Isle of Wight of 1862. We have taken every precaution that no species should be omitted, but have not thought it necessary to state our reasons for changing or excluding names. Finally, we have not given MS. names of Edwards *in extenso*, but have noted the number

of undescribed species under each genus. No doubt many of them have been described on the continent; but to examine each case critically would be equivalent to monographing the entire series of Barton Mollusca. We have contributed to the clearing up of the synonymy by exchanging as many species as possible with M. Cossmann, who is now engaged in revising and supplementing Deshayes's work on the Mollusca of the Paris Basin, and thus assuring ourselves that the correct names are in use. M. Lefèvre, of the Société Malacologique of Brussels, has also kindly certified a number of the species for us, and we believe that the list, if not faultless, will yet be of considerable use to collectors.

We have met with no record of the discovery of any Mammalian remains in the Bartons, though they are far from uncommon in the Lower Headon of Hordwell, except that of *Zeuglodon* by a coast-guardsman named Addow, on the shore, in stiff tenacious clay of the Middle Barton. It was purchased by Dr. Wanklyn, and has not been seen since his death some years ago.

Fragmentary remains of Crocodiles and Chelonians are quite abundant in the lowest beds of Highcliff, but have not been determined specifically. For the extensive list of fish-remains we are mainly indebted to Mr. Davies, of the British Museum; most of them are the teeth and spines of Sharks and Rays, and the species, as a rule, have a wide range.

The Molluscous fauna is by far the most important, and may be divided into three great groups. That comprising the largest number of species is peculiar to the Lower Bartons and occurs in the small pockets of fine grey sand known as the Highcliff Sands. Mingled with the fry of larger species is a great number of minute but adult shells, some of which occur in such incredible profusion that an ounce of the sand may contain hundreds of individuals of a species, whilst others are so rare that only solitary examples are known. The relative prevalence of the species varies in samples from different pockets, but by far the most abundant, *Corbula pisum* perhaps excepted, is *Mitra parva*, the next being *Marginella bifido-plicata*. Next come *Bulla elliptica*, *Bayania delibata*, *Volvula lanceolata*, *Strombus bartonensis*, and then, but in rapidly decreasing numbers, several other *Bullæ*, *Volvaria acutiuscula*, *Sigaretus clathratus*, *Actæon Cossmanni*, *Bayania rudis*, *Eulima goniophora*, *Marginella pusilla*, *Teinostoma dubium*, and *Adeorbis elegans**. Most of the remaining minute forms may be considered rare, but the fact that

* The number of shells I have extracted from a single pocket, some ¼ peck of sand, is as follows:—of *Mitra parva* 400, *Bayania delibata* 326, *Marginella bifido-plicata* 190, *Volvula lanceolata* 140, *Orthostoma crenatum* 138, *Natica Noæ*, *N. labellata*, and *N. perforata* together 124, *Buccinum Solandri* 90, *Strombus bartonensis* 72, *Bulla elliptica* 70, *Buccinum*, sp., 58, *Cerithium filosum* 50, *Actæon Cossmanni* 41, *Bayania rudis* and *Rissoa bartonensis* each 40, *Bulla conulus* 37, *Bulla pseudo-elliptica* 20, *Sigaretus clathratus* 18, *Actæon simulatus* 16, *Volvula acuminata* 14, *B. angystoma* 13, *Eulima macrostoma* 13, *Nummulites elegans* 12, *Ringicula ringens* 7, *Eulima munda*, *E. goniophora*, *Bulla anomala*, *B. Sowerbyi*, and *Actæon*, sp., 4 each, *Marginella pusilla* and *Nerita inornata* 3, *Bulla ovulata* 2, and the rest 1 each. Corals 35.

they are entirely confined to a special horizon is no doubt due to the absence elsewhere of any similar pockets into which such small shells were drifted and have been preserved. A tiny coral and the fingers of small crabs' claws are mingled with them in equal profusion. Many of the species are exceedingly like living shells from Australia and Japan, and seem to indicate a considerable depth of water with light drifting currents. Many rare freshwater shells are met with in this fauna, the larger of them being almost invariably abraded, as if brought from long distances.

The second fauna is best represented in the Middle Barton, though few of the species are actually confined to it. The shells are of large size, and comprise the bulk of the typical Barton forms figured by Brander. Most of the striking ones are extinct, but others, such as *Ficula nexilis*, *Cassidaria nodosa*, and the species of *Pleurotoma* and *Natica*, are so nearly identical with living forms, that representatives of them may be said to exist.

The third fauna is that of the *Chama*-beds, comprising a number of exquisite and entirely distinct shells of moderate size, whose sudden appearance is to be attributed less to an interval of time than to a change in the outfall of the river, by which the muddy water and silt of an estuary gave place to clear water and a sandy bottom. An enormous colony of *Chamas* and the ubiquitous *Turritella* took possession of the area; but not the least remarkable circumstance is that the old representative species of several genera were suddenly replaced by others that, though quite distinct, seem closely allied. Thus *Voluta humerosa* replaces *V. maga*, *Murex tripteroides* supersedes *M. asper*, *Typhis fistulosus* displaces *T. pungens*, &c., while nearly the entire tribe of *Pleurotoma* give way to clear-water Cowries, Cones, *Mitræ*, *Murices*, &c. The survival of stray and often water-worn specimens of Middle Barton species does much, however, to rob the *Chama*-beds of the peculiar facies of their fauna when tabulated, and renders the break far less apparent than it actually is in the field.

The fauna from the Long-Mead-End Sands is again very distinct indeed in its general facies from those which precede it. Its most noticeable feature is the large proportion of *Cerithia* and of *Oliva Branderi*. It possesses a peculiar *Natica* and *Marginella*, and species of *Melania* and *Melanopsis* similar to those of the Headon Beds above, while, owing probably to an influx of brackish water, the whole group of *Volutæ*, *Pleurotomæ*, and *Murices* so characteristic of the Lower and Middle Bartons have disappeared. About a dozen of its commonest species are, in fact, indicative of brackish, if not of fresh water, while an equal number of hardly less abundant, truly marine forms pass up from below.

The list of Barton fossils comprises 23 Vertebrates, 47 Invertebrates other than Mollusca, 257 Gasteropods, and 150 Bivalves, exclusive of over 120 undetermined species. Twenty-eight of the Mollusca first appear in the London Clay and range for the most part above the Lower Barton, though 7 of them are absent in the Lower and 3 in the Upper Bracklesham. A further 37 species first appear

in the Lower Bracklesham, only 11 of which do not range above the Lower Barton. These are reinforced by no less than 108 additional species in the Upper Bracklesham, 35 of which die out with the Lower and 24 with the Middle Barton. Thus of the 407 species, 175 range below the Barton, against 56 that pass up into the Headon; but of the latter 30 are also Bracklesham and London-Clay species. The upper limits of the Barton formation are thus much more sharply defined, palæontologically, than the lower; but we must remember that in the former case the passage into fluviatile beds is abrupt, and the marine beds next above are separated by a considerable thickness of freshwater deposits, while in the latter the transition lies everywhere in marine deposits. The reason for drawing the line between Oligocene and Eocene in our area, here if anywhere, is quite obvious if our statistics are at all reliable.

The close connexion between the Upper Bracklesham and Lower Barton is rendered very striking by these tables, no less than 35 species being quite peculiar to the two horizons when combined. This contrasts with the 12 which are peculiar to the Lower and Middle Barton combined, and the less than half a dozen peculiar to the combined Middle and Upper Barton. The upper limits of the Bracklesham should obviously, on palæontological data, have been drawn much lower down. Only 16 are peculiar to the Upper Barton and Headon combined, and these are mostly freshwater or brackish-water stragglers.

Of the tabulated Mollusca, 124 are absolutely peculiar to the Barton formation in this country, though we must not lay undue stress upon them, as we have seen that many of those most rigidly limited in range in our area have a more extended or a different range in the Paris area. Of these, 15 range through the three divisions, 12 through the Lower and Middle, 5 are confined to the Lower and Upper, 3 to the Middle and Upper. This somewhat capricious distribution may be partly due to the extra turbidity of the water in the Middle period. There are 51 species absolutely confined to the Lower, 10 to the Middle, 28 to the Upper divisions.

The distribution by genera is equally instructive; but in order to have made an analysis, we must have introduced subgeneric names, which would have lessened the value of the list for general comparison. We have for the same reason retained many familiar generic names which, on the ground of priority, must disappear. The general resemblance between the facies of much of the Barton fauna and that of the London Clay is not apparent in the table, perhaps because species which did not hold their ground during the Bracklesham period, but emigrated, were so considerably modified during the interval that they can be distinguished as new species on their reappearance; while the modifications undergone by those that remained were so slight that in the presence of connecting links they are specifically inseparable.

If we confine our attention to the species whose range is marked

by * in the table, we find, excluding a few cosmopolitans, that 7 London-Clay or Lower Bracklesham and 32 Upper Bracklesham species merely straggle up into the Barton formation, only 7 or 8 actually belonging as much to one as to the other. There are 85 distinctively Lower, 39 Middle, and 50 Upper Barton species; only 3 or 4 species distinctive of all 3 stages, without being distinctive of any beds other than Barton; and only 2 distinctively common to the Middle and Upper stages alone. There are 13 characteristic Headon species in the Barton and only 5 that belong equally to Headon and Barton without passing into the Bracklesham.

Vertebrata.

The species which have all the columns left blank are from the Barton Series; but their precise horizon is not known.	London Clay.	Lower Bracklesham.	Upper Bracklesham.	Lower Barton.	Middle Barton.	Upper Barton.	Headon.
Zeuglodon Wanklyni, *Seeley*	...	...	...	...	—		
Crocodilus, sp.	—	—	—	—			
Chelone, sp.	—	—	—	—	—		
Lamna contortidens, *Ag.*	...	—	—	—	—	—	—
—— elegans, *Ag.*	—	—	—	—	—	—	—
—— (Odontaspis) Hopei, *Ag.*							
Otodus macrotus, *Ag.*	—	—	—	—	—	—	—
—— obliquus, *Ag.*	—	—	—	—	—	—	—
Myliobates †nitidens, *Ag.*	—	...	...	—			
—— goniopleurus, *Ag.*							
—— toliapicus, *Ag.*	...	...	...	...	...	—	
—— punctatus, *Ag.*							
—— marginalis, *Ag.*							
Aëtobatis rectus, *Dixon*							
—— subarcuatus, *Ag.*	—						
Pristis Hastingsiæ, *Ag.*							
—— †acutidens, *Ag.*	...	...	...	...	...	—	
Edaphodon leptognathus, *Ag.*	...	...	...	—	...	*	
—— Bucklandi	...	...	...	...	...	—	
Sphyrænodus, sp. ined.							
Cœlorhynchus rectus, *Eg.*	...	—	—	—	—		
Silurus Egertoni, *Dixon*	...	—	—	—	—		
Notidanus serratissimus, *Ag.*	—	...	...	?	?		

† Recorded by Agassiz, but not since authenticated.

Invertebrata.

The * in the columns denotes where the species is most at home. The † prefixed to a name indicates that the shell is unique. The species which have all the columns left blank are from the Barton Series; but their precise horizon is not known.	London Clay.	Lower Bracklesham.	Upper Bracklesham.	Lower Barton.	Middle Barton.	Upper Barton.	Headon.
Nautilus, sp.	...	...	...	—	—	?	
†Pedipes glaber, *Edw.*	...	...	...	—			
Cypræa bartonensis, *Edw.*	...	...	...	...	...	*	
Trivia platystoma, *Edw.*	...	...	...	—	—		
Marginella bifido-plicata, *Charlesw.*	—	...	—	*	—		
—— †gracilis, *Edw.*‡	...	...	...	—			
—— pusilla, *Edw.*	...	...	...	*			
—— simplex, *Edw.*	...	...	...	...	...	*	
Voluta luctatrix, *Sol.*	...	...	...	—	*	—	
—— ambigua, *Sol.*	...	...	...	—	*		
—— ——, var. subambigua	...	...	...	...	...	*	
—— nodosa, *Sow.*	*	...	*	—			
—— scalaris, *Sow.*	...	...	...	...	—	*	
—— spinosa, *Linn.*	...	...	*	—	—		
—— ——, var. depauperata, *Sow.*	...	...	...	...	...	...	*
—— scabricula, *Sol.*	...	...	—	—	—	*	
—— Solandri, *Edw.*	...	...	...	—	...	—	
—— athleta, *Sol.*	...	—	—	*	—		
—— maga, *Edw.*	...	...	*	—	—	...	—
—— suspensa, *Sol.*	...	...	...	...	*		
—— decora, *Beyr.*, var. maga, *Edw.*	...	...	...	...	...	—	*
—— humerosa, *Edw.*	...	...	...	...	...	*	
—— costata, *Sol.*	...	...	...	...	—	*	
†Mitra volutiformis, *Edw.*	...	...	...	...	—		
—— scabra, *Sow.*	...	...	...	...	...	*	
—— parva, *Sow.*	—	...	*	*	*	—	?
—— fusellina, *Lam.*	...	...	*	*	—		
—— †obesa, *Edw.*	...	...	...	—			
Conus scabriculus, *Sol.*	...	...	...	...	...	*	
—— lineatus, *Sol.*	...	...	...	...	...	*	
—— dormitor, *Sol.*	...	...	...	...	—	*	—
Pleurotoma rostrata, *Sol.*	...	...	...	—	*		
—— exorta, *Sol.*	...	...	—	—	*		
—— macilenta, *Sol.*	...	...	—	—	*	*	
—— lanceolata, *Edw.*	...	...	...	?	—		
—— lævigata, *Sow.*	...	...	...	—	—	?	
—— microdonta, *Edw.*	...	...	—	*			
—— desmia, *Edw.*	...	...	...	—	*		
—— innexa, *Sol.*	...	...	—	—	*		
—— coarctata, *Edw.*	...	...	...	*			
—— microcheila, *Edw.*	...	...	...	*	?		
—— dissimilis, *Edw.*	—	...	...	*			
—— gomphoidea, *Edw.*	—	...	...	*	—		
—— acuticosta, *Nyst*							
—— biarritziana	...	...	*	—			
—— §hemileia, *Edw.*							
—— §vicina, *Edw.*							
—— §dilinum, *Edw.*							

‡ Apparently a variety of above.
§ These species occur in the Barton Beds at Alum Bay only.

Invertebrata (continued).

	London Clay.	Lower Bracklesham.	Upper Bracklesham.	Lower Barton.	Middle Barton.	Upper Barton.	Hendon.
Pleurotoma pupa, *Edw.*	...	...	—	*	—		
—— §turgidula, *Edw.*							
—— §curta, *Edw.*							
—— scabriuscula, *Edw.*	...	...	...	—			
—— verticillum, *Edw.*	...	...	...	—			
—— constricta, *Edw.*	—	...	...	—	—		
—— bracheia, *Edw.*	...	...	—	*			
—— rotella, *Edw.*	...	...	...	—	—		
—— granulata, *Lam.*	...	...	—	*	—		
—— conoides, *Sol.*	...	...	...	—	*		
—— biconus, *Edw.*	...	...	...	*	—		
—— helicoides, *Edw.*	...	...	...	*	—	?	
—— aspera, *Edw.*	...	...	...	?	—		
—— †mixa, *Edw.*	...	...	...	...	—		
—— gentilis, *Sow.*	...	...	*	—			
—— denticula, *Bast.*, var. odontella, *Edw.*	—	...	—	—	—	...	—
—— callifera, *Edw.*	...	..	...	—			
—— monerma, *Edw.*	—	...	...	—			
—— varians, *Edw.*	...	...	...	*			
—— lima, *Edw.*	...	...	...	—	?	—	
—— reticulosa, *Edw.*	...	...	—	—	—		
—— cedilla, *Edw.*	...	...	...	—			
—— †puella, *Edw.*	...	...	...	—			
—— turbida, *Sol.*	...	...	...	*	*	*	
—— zonulata, *Edw.*	...	...	...	*			
—— prisca, *Sol.*	—	—	—	—	*	—	
—— subfilosa, *Edw.*	...	...	...	—	—		
Daphnella sulcata, *Edw.*	...	...	...	...	—	?	*
—— semicostata, *Edw.*							
—— lineata, *Edw.*	...	...	...	—			
—— citharella, *Lam.*	...	...	...	...	*		
Terebra plicatula, *Lam.* (and 5 other species).	...	...	*	—	—		
Strombus bartonensis, *Sow.*	...	...	...	*			
Rostellaria excelsa, *Gieb.*?							
—— ampla, *Sol.*	—	—	—	—	*	—	
Rimella canalis, *Lam.*	...	...	*	—	—		
—— rimosa, *Sol.*	...	...	—	*	*	*	—
Terebellum sopitum, *Sol.*	...	...	...	...	...	*	
—— fusiforme, *Sow.*	...	...	—	*			
Murex asper, *Sol.*	...	?	*	—	*	—	
—— bispinosus, *Sow.*	...	...	—	...	?	*	
—— tripteroides, *Lam.*	...	...	—	...	...	*	
—— defossus, *Pilk.*	...	...	...	...	...	*	
—— crispus, *Lam.*							
—— subrudis, *D'Orb.*	...	...	...	...	...	*	
—— minax, *Sol.*	...	—	*	*	*	—	—
—— obtusus, *Desh.*	...	...	...	...	—	—	—
—— raricostatus, *Desh.*							

§ These species occur in the Barton Beds at Alum Bay only.

Invertebrata (continued).

	London Clay.	Lower Bracklesham.	Upper Bracklesham.	Lower Barton.	Middle Barton.	Upper Barton.	Headon.
Typhis pungens, *Sol.*	...	...	—	—	*	—	—
—— fistulosus, *Sow.*	...	...	...	...	...	*	
Turbinella parisiensis, *Desh.*	...	...	*	...	—	—	
Fusus interruptus, *Sow.*	?	...	*	—			
——, sp. n.	...	...	...	...	...	—	
—— porrectus, *Sol.*	...	...	—	—	*	—	
—— aciculatus ?, *Lam.*	...	...	...	...	—		
—— longævus, *Sol.*	...	—	*	*	*	*	*
—— regularis, *Sow.*	...	—	—	—	*		
—— lima, *Sow.*	...	...	...	...	—		
—— errans, *Sol.*	...	...	—	*			
—— pyrus, *Sol.*	...	...	*	—	*	—	
—— juncea, *Sol.*	...	...	—	—	*	?	
—— turgida, *Sol.*	...	—	*	—	—	*	
(about 12 other species).							
Buccinum lavatum, *Sol.*	...	...	...	...	...	*	—
——, sp. n.	...	...	...	*			
—— desertum, *Sol.*	...	...	...	...	*	*	—
—— canaliculatum, *Sow.* (Fusus)	...	...	...	*			
Oliva Branderi, *Sow.*	...	...	—	—	—	*	
—— Salisburiana, *Sow.*	...	...	—	*	—		
—— aveniformis, *Sow.*	...	...	...	*	—	—	
Ancillaria perita, *Sol.*	...	...	—	—	—	*	*
—— olivula, *Desh.*	...	...	?	—	—	—	
——, sp. n.	...	...	...	...	—	—	
—— canalifera, *Lam.*	...	...	—	*	—		
Cassis ambigua, *Sol.*	...	...	...	*	...	...	—
Cassidaria nodosa, *Sol.*	...	...	*	—	*		
Nassa obtusa, *Edw. MS.*	...	...	—	—			
§Pseudoliva fissurata, *Desh.*	—	...	...	—			
Triton argutus, *Sol.*	...	...	—	—	*		
——, sp. n.	...	...	*	...	...	*	
(and 2 other species).							
Ficula nexilis, *Sol.*	—	—	—	—	*		
Ampullina mutabilis, *Sol.*	...	...	*	—	—		
Natica ambulacrum, *Sow.*	...	...	—	—	—	*	
—— hantoniensis, *Pilk.*	*	...	—	—	*	—	—
—— patula, *Desh.*	...	—	—	—	*	—	
—— grossa, *Desh.*=depressa	...	...	—				
—— Edwardsi, *Desh.*	...	—	*	—	—	—	*
—— sigaretina, *Desh.*	—	—	—	—	—		
—— labellata, *Lam.*	*	—	—	*	*	—	*
—— Noæ, *D'Orb.*	...	...	—	*	...	...	—
—— perforata	...	...	...	*	...	...	—
—— abscondita, *Desh.*	...	...	...	...	...	—	
Sigaretus clathratus, *Récluz*	?	—	—	*	—		
Cancellaria evulsa, *Sol.*	...	...	—	—	—	—	—
——, sp. n.	...	...	...	...	...	*	
—— elongata (?), *Nyst*	...	...	...	—	—	—	—
—— massæformis, *S. Wood*	...	...	—	—	—	*	

§ Only known as a Barton fossil from Alum Bay.

Invertebrata (continued).

	London Clay.	Lower Bracklesham.	Upper Bracklesham.	Lower Barton.	Middle Barton.	Upper Barton.	Headon.
Cancellaria, sp. n.	...	...	...	...	*		
—— quadrata, *Sow.*	...	...	—	*	...	—	
—— microstoma, *Charlesw.* (and 3 other species).	...	...	*	—			
Mesostoma cancellaroides, *Desh.*	...	...	—	—	*		
——, sp. n.	...	...	—	—	—		
Pyramidella (9 species, all from Lower Barton).							
Odostomia miliola, *Lam.* (and 18 other species from Barton or Highcliff).	...	...	—	*	—	—	
Turbonilla (12 sp.).							
Bayania delibata, *Cossm.*	...	...	...	*			
—— rudis, *Charlesw.* (and 2 others).	...	...	...	*			
Syrnola Bernayi, *Cossm.*	...	...	...	*			
Paryphostoma minus, *Desh.*							
Eulima goniophora, *Cossm.*	...	...	—	*			
—— munda, *Desh.*	...	...	—	*			
—— macrostoma, *Charlesw.* (and 4 species from Highcliff).	...	...	...	*			
Niso, sp.	...	—	*	—			
Solarium Dumonti, *Nyst.*	...	...	...	*			
—— plicatum, *Lam.*	...	...	...	*	?	—	
—— crenulare, *Desh.*	...	—	—	—	*		
——, sp. n.	...	...	...	...	...	?	
§Eumargarita trochiformis, *Desh.*	...	—	*	—			
—— §spiratum, *Lam.*	...	...	—	—			
§Discohelix patellatus, *Sow.*	...	...	*	—			
Scalaria primula, *Desh.*	...	...	...	*			
—— reticulata, *Sol.*	...	...	—	—	*	—	
—— acuta, *Sow.*	...	...	...	—	—	*	
—— undosa, *Sow.*	...	...	—	—	*		
—— cerithiiformis, *Wat.*	...	—	—	*			
—— tenuilamella, *Desh.*	...	...	...	—			
——, sp. n. (and 3 MS. species from Highcliff).	...	...	—	—	*		
Cerithium Gardneri, *Cossm.*	...	...	...	—	*		
——, sp. n.	...	...	...	*			
—— lima, *Desh.*	...	...	—	—	...	*	
—— Gravesii, *Desh.*, var.	...	...	...	—			
—— conarium, *Bayan*	...	—	*	—	—		
—— submarginatum, *D'Orb.*	...	...	*	—	...	...	—
——, sp. n.	—	—	*	—			
—— angulatum, *Sol.*	...	...	...	*			
—— variabile, *Desh.*	...	...	...	...	...	—	*
—— pleurotomoides, *Lam.*	...	...	...	...	...	*	
—— concavum, *Sow.*	...	...	...	...	...	—	—
—— ventricosum, *Sow.*	...	...	...	...	...	—	*
—— perditum, *Bayan*	...	...	...	...	...	—	

§ Only known as Barton fossils from Alum Bay.

Invertebrata (continued).

	London Clay.	Lower Bracklesham.	Upper Bracklesham.	Lower Barton.	Middle Barton.	Upper Barton.	Headon.
Cerithium filosum, *Charlesw.* (and 7 MS. species).	...	...	...	*			
Triforis, sp.	...	...	—	*			
Diastoma costellatum, *Lam.*	...	—	*	—	?		
Pirena rigida, *Sol.*	...	...	...	*	—		
Turritella imbricataria ‡, *Lam.*	—	*	*	*	*	*	
—— granulosa, *Desh.*	...	...	—	*	—	—	
—— concinna, *Edw.*	...	...	—	*			
Strebloceras cornuoides, *Brown*	...	...	...	...	...	—	
Serpulorbis cancellatus, *Desh.*	...	...	*	...	—		
Melania fasciata, *Sow.*	...	...	...	...	...	*	
——, sp. n.	...	...	...	*			
—— hordeacea, *Lam.*	...	...	—	—	...	*	
Melanopsis sigillata, *Edw.*	...	...	...	*			
—— fusiformis, *Sow.*	...	...	...	...	...	—	*
Littorina sulcata, *Pilk.*	...	—	—	*	—		
—— subangulata, *Desh.*	...	—	—	*			
Lacuna, sp. n. (and 8 other rare species).	...	...	...	*	—		
Stylifer, sp.	...	...	...	*			
Rissoina, sp. n. (and 3 other species).	...	...	—	*			
Rissoa nana, *Lam.*	...	...	...	*			
—— bartonensis, *Charlesw.*	...	...	...	*	—		
—— carinata, *Charlesw.*	...	...	...	*	...	—	
——, sp. n. (and 4 other rare species).	...	—	—	*			
Hydrobia anceps, *S. Wood*	...	...	...	*	—	—	*
—— sextonus, *Desh.*	...	...	...	*			
Truncatella, sp.	...	...	...	—			
Trochita aperta, *Sol.*	...	—	—	—	*	—	*
Capulus squamæformis, *Desh.*	...	...	—	—	*		
——, sp. n.	...	...	...	—			
Xenophora discoidea, *Sow.*	...	...	...	*	—		
—— umbilicaris, *Sol.* (and 3 MS. species).	...	—	*	—	*	—	
Trochus nodulosus, *Sol.*	...	...	...	...	...	*	
Teinostoma dubium, *Desh.*	...	...	...	—	—		
Delphinula canalifera, *Lam.*	...	—	—	—			
—— callifera, *Desh.*	...	...	—	—	—	?	
Adeorbis elegans, *Charlesw.*	...	—	—	*	—		
—— tricostata, *Desh.*	...	...	...	...	—		
——, sp. n. (and 8 other species).	...	...	...	...	...	—	
Neritina concava	...	...	...	...	...	—	*
Nerita, sp. n.	...	...	...	—			
—— hantoniensis, *Pilk.*	...	...	...	*	—		
Nacella, sp.	...	...	...	...	...	—	

‡ Several species are probably comprised in this.

Invertebrata (continued).

	London Clay.	Lower Bracklesham.	Upper Bracklesham.	Lower Barton.	Middle Barton.	Upper Barton.	Headon.
Actæon, sp. n.	...	...	—	*	—		
—— simulatus, *Sol.*	—	—	—	—	?	*	
—— elongatus, *Sow.*	...	...	—	—	?		
—— crenatum, *Sow.*	—	...	...	*	...	—	
Ringicula ringens, *Lam.*	*	*	...	*	...	—	
Volvaria acutiuscula, *Sow.*	...	...	...	*			
Etallonia, sp.	...	...	...	...	...	—	
Bulla attenuata, *Sow.*	—	—	—	—	?	*	*
—— Sowerbyi, *Nyst*	...	—	—	*	*		
—— constricta, *Sow.*	...	...	...	—	*	—	
—— elliptica, *Sow.*	...	...	—	*	—	—	—
—— pseudo-elliptica, *Edw.*	...	...	...	*			
—— producta, *Edw.*	...	...	—	—			
—— angystoma, *Desh.*	...	...	...	*			
—— conulus, *Desh.*	...	...	...	*			
——, sp. n.	...	?	—	*	—		
—— Lamarckii, *Desh.*	...	...	...	...	...	—	—
—— sp. n.	...	...	...	*			
—— coronata, *Lam.*	...	...	...	—	—	?	
Volvula lanceolata, *Sow.*	...	—	—	*	?	—	
—— acuminata, *Charlesw.*	...	...	...	*	?	?	
Acera striatella, *Lam.*	...	...	...	*			
Scaphander Defrancei, *Sow.*	...	...	...	*	...	—	
——, sp. n.	...	...	...	*			
Bullæa, sp. n.	...	...	...	...	...	*	
Dentalium pellucens, *Desh.*	...	—	*	*			
—— striatum, *Sol.*	...	—	—	—	*	—	
Anomia tenuistriata, *Desh.*	*	—	—	—	—	*	—
Ostrea oblongata, *Sol.*	...	—	—	—	*		
—— plicata, *Sol.*	—	—	—	—	—	*	—
—— gigantea, *Sol.*	...	...	—	—	*		
Vulsella deperdita, *Lam.*?	...	...	—	...	...	*	
Pecten corneus, *Sow.*	—	*	*	—	—		
—— carinatus, *Sow.*	...	...	...	—	—	*	
—— reconditus, *Sol.*	...	...	—	...	—	—	
Lima compta, *S. Wood*							
—— soror, *S. Wood*							
Avicula media, *Sow.*	*	—	—	—	—	*	—
Pinna margaritacea, *Lam.*	*	...	—	—	—		
Mytilus strigillatus, *S. Wood*	...	...	...	...	...	—	
—— affinis, *Sow.*	...	...	...	...	...	—	*
Modiola sulcata, *Lam.*							
—— Searlesi							
—— diversa, *S. Wood*							
—— eximia, *S. Wood*							
—— nodulifera, *S. Wood*	...	...	...	...	...	...	—
—— pygmæa, *S. Wood*							
—— bartonensis, *S. Wood*							
—— dimidiata, *S. Wood*	...	...	...	*			
—— seminuda, *Desh.*	...	...	...	*	...	—	

Invertebrata (continued).

	London Clay.	Lower Bracklesham.	Upper Bracklesham.	Lower Barton.	Middle Barton.	Upper Barton.	Headon.
Modiola hastata, *Desh.*	—	...	*	...	?		
—— elegans, *Sow.*	*	...	—	—	—	—	
—— subcarinata, *Lam.*	*	...	...	...	?	—	
Arca globulosa, *Desh.*	...	—	—	*	—		
—— lissa, *Bayan*	—	—	*	*	...	—	—
—— Lyelli, *Desh.*	...	...	...	—	—		
—— appendiculata, *Sow.*	...	—	—	—	*	—	—
—— biangula, *Lam.*	...	*	—	...	...	—	—
Pectunculus deletus, *Sol.*	...	—	—	—	—	*	
—— proximus, *S. Wood*	...	...	...	...	..	—	
Limopsis scalaris, *Sow.*	...	...	...	—	*	—	
Erinacria curvirostris, *Cossm.*	...	...	...	...	...	—	*
Nucula similis, *Sow.*	...	...	...	?	?	*	
—— tumescens, *Edw.*	...	...	—	...	...	*	
—— lissa, *Edw.*	...	...	—	*	...	...	—
—— prælonga, *Edw.*	...	...	...	...	...	*	
—— bisulcata, *Sow.*	...	—	—	—	*	—	
—— ampla, *Edw.*	...	..	...	...	...	*	
Leda minima, *Sow.*	...	...	—	*	—	...	—
Cardita sulcata, *Sol.*	—	...	...	—	*	—	
—— ——, var. pectinata, *Edw.*	...	...	...	—			
—— Davidsoni, *Desh.*	...	...	...	—			
—— pulchra *Edw.*	...	...	*	—			
—— trapezoidalis, *S. Wood*	...	...	...	—			
—— oblonga, *Sow.*	...	...	—	...	...	*	—
Crassatella sulcata, *Sol.*	...	...	...	—	*	—	
—— tenuisulcata, *Edw.*	...	...	...	...	...	*	
—— plicata, *Sow.*	...	...	...	*			
—— grignonensis, *Desh.*, var. anglica, *S. Wood*	...	...	*	—			
—— sinuosa, *Desh.*	...	...	—	—			
—— subquadrata, *Edw.*	...	...	—				
—— Bronnii, *Merian*	...	...	—	*			
—— pumilis, *S. Wood*	...	...	...	—			
—— bartonensis, *Edw.*	...	...	...	—			
—— dilatata, *Desh.*							
Woodia crenulata, *Desh.*							
Lutetia parisiensis, *Desh.*	...	...	—	*			
Chama squamosa, *Sol.*	...	...	...	...	...	*	
—— selseiensis, *Edw.*	...	...	*	—			
Lucina concentrica, *Lam.*							
——, sp. n.	...	...	...	—	—	*	—
—— gigantea, *Desh.*	...	...	...	...	...	*	
—— gibbosula, *Lam.*	...	...	—	...	...	—	—
—— elegans, *Defr.*	...	—	—	...	...	*	
—— concava, *Defr.*	...	...	...	...	...	—	*
—— § Menardi, *Desh.*							
——, sp. nov.	...	—	—	—	—		
—— § ambigua, *Defr.*							
—— § callosa, *Lam.*	...	...	...	...	...	—	

§ These species occur only in the Barton Beds of Alum Bay.

Invertebrata (continued).

	London Clay.	Lower Bracklesham.	Upper Bracklesham.	Lower Barton.	Middle Barton.	Upper Barton.	Headon.
Strigilla colvellensis, *Edw.*	...	...	...	...	...	*	
—— Rigaultiana, *Desh.* (= Lucina divaricata, *Sow.*)	...	...	...	...	...	*	—
Diplodonta, 9 sp.							
Cardium porulosum, *Sol.*	...	*	*	—	—	—	—
—— obliquum, *Lam.*	...	...	...	*	...	...	*
Nemocardium turgidum, *Sol.* (C. semigranulatum, *Sow.*, P. parile, *Desh.*)	—	—	—	—	*	?	
Erycina tenuicula, *Desh.*	...	...	...	—			
—— breviuscula, *Desh.*	...	...	...	—	?		
—— habilis, *S. Wood*	...	...	—	—			
Scintilla lata, *S. Wood*	...	...	...	—			
—— angusta, *S. Wood*	...	...	...	—			—
Lepton, 3 sp.							
Hindsia inæquilobata, *Desh.*	...	...	...	—			
Kellia delicatula, *S. Wood*	...	...	...	—			
Sportella, 2 sp.							
Levicardium parisiense, *D'Orb.*	...	...	—	...	—		
Anisocardia isocardioides, *Desh.*	...	...	...	...	—		
—— pectinifera, *Sow.*	...	...	...	...	...	—	*
Coralliophaga chartacea, *Bayan*	...	...	...	...	—		
—— vaginoides, *Desh.*							
Cyrena deperdita, *Desh.*	...	...	...	—	—	—	
—— gibbosula, *Morr.*	...	...	...	...	...	—	—
Cytherea sulcataria, *Desh.*	...	...	...	—	...	—	—
—— suberycinoides, *Desh.*							
—— transversa, *Sow.*	...	...	...	...	—	—	
—— Solandri, *Sow.*	...	...	—	*	...	...	—
—— elegans, *Lam.*	...	...	—	*	—		
—— nitidula, *Lam.*							
—— polita, *Lam.*	...	...	*	...	—		
—— cuneata, *Desh.*	...	...	*	—			
—— lævigata, *Lam.*	...	*	—	—	—		
—— parisiensis, *Desh.* (= lucida, *Sow.*)	...	*	—	—			
Psammobia rudis, *Lam.*	...	...	...	...	...	—	*
—— compressa, *Sow.*	...	...	—	*			
—— debilis, *Desh.*	...	...	...	...	—	—	
Donax trigonula, *Desh.*	...	...	...	—			
Tellina ambigua, *Sow.*	...	...	...	...	*	?	
—— ‡ lamellosa, *Desh.*	...	...	—	—			
—— Branderi, *Sow.*	...	...	*	—	—		
—— canaliculata, *Edw.*	...	...	—				
—— hantoniensis, *Edw.*	...	...	...	...	...	—	
—— filosa, *Sow.*	...	...	—	—	...	—	
—— tenuistriata, *Desh.*	...	...	—	—	—	?	
—— donacialis, *Lam.*	...	...	—	—	?		
—— lamellulata, *Edw.*	...	...	...	—	—		
—— squamula, *Edw.*	...	...	...	...	—		

‡ Barton *fide* Deshayes.

Invertebrata (continued).

	London Clay.	Lower Bracklesham.	Upper Bracklesham.	Lower Barton.	Middle Barton.	Upper Barton.	Hendon.
Tellina virgo, *Edw.*	...	...	...	—			
—— truncata, *Edw.*	...	...	...	...	?	—	
—— scalaroides, *Lam.*	...	—	*	—			
—— lævis, *Edw.*	...	...	*	...	—	*	—
—— textilis, *Edw.*	...	...	—	...	—		
—— granulosa, *Edw.*, and 4 sp.‡							
Syndosmya, 6 sp.							
Mactra compressa, *Desh.*	...	—	*				
Cardilia radiata	...	...	*				
Solen gracilis, *Sow.* (and 2 sp.)	...	—	—	—	—	—	—
Siliqua ovalis, *Edw. MS.*							
Cultellus bartonensis, *Edw.*	...	...	—	—	—	—	—
—— affinis, *Sow.*	—	*	*	—	—	—	
Solecurtus Deshayesi, *Des Moulins*	...	*	—	—	—		
Mya bartonensis							
Sphenia angulata, *Desh.*	...	...	...	—			
Corbula anatina, *Lam.*							
—— Lamarckii, *Desh.*	...	—	—	—	*	—	
—— gallina (Venus), *Sol.*	...	...	—	—	*	?	
—— longirostrum, *Desh.*	...	—	—	—	—	*	
—— costata, *Sow.*	...	—	—	—	—	—	
—— cuspidata, *Sow.*	...	...	...	...	...	—	*
—— pisum, *Sow.*	...	—	*	*	*	—	—
—— ficus, *Sol.*	...	...	...	*	—	*	
—— gallica, *Lam.*	...	*	*	—	—		
—— Edwardsii, *Tawney*	...	...	...	...	...	*	
—— globosa, *Sow.*	—	—	—	—			
Neæroporomya argentea, *Desh.*	...	...	—				
Neæra serrata, *Edw.*							
Panopæa corrugata, *Sow.*	...	—	—	—			
Thracia, 2 sp.							
Pholadomya margaritacea, *Sow.*	*	—	—	*			
Gastrochæna contorta, *Desh.*	...	...	...	—	—		
—— corallium, *Sow.*	...	...	—	...	—		
Clavagella coronata, *Desh.*	...	—	—	—	—	—	—
Martesia elegans, *Desh.*	...	...	...	—			
—— conoidea, *Desh.*	...	. .	...	—			
Teredo, sp.	...	—	—	—	—		
Teredina personata, *Lam.*	—	—	...	—			
Terebratula bisinuata, *Lam.*	—	—	...	...	...	*	
Palæastacus [robustus, *Carter*, *MS.*]	...	...	...	...	—		
Goniocypoda Edwardsi, *Woodw.*	...	...	...	—			
Balanus unguiformis, *Sow.*	...	...	...	...	—	—	—
Serpula exigua, *Sow.*							
—— extensa, *Sol.*	...	—	—	—	—	—	
—— crassa, *Sow.*							
—— heptagona, *Sow.*	—	—	—				
—— ornata, *Sow.*	...	...	—				

‡ Deshayes gives 4 other species.

Invertebrata (continued).

	London Clay.	Lower Bracklesham.	Upper Bracklesham.	Lower Barton.	Middle Barton.	Upper Barton.	Headon.
Ditrupa incrassata, *Sow.*	—	...	—	—	—	—	—
Schizaster D'Urbani, *Forbes*	...	...	—	—	...	—	
Ophiura Wetherellii, *Forbes*	—	...	...	—			
Cidaris Websteriana, *Forbes*	—						
Echinopsis Edwardsii, *Forbes*	...	...	—				
Echinus Dixonianus, *Forbes*							
Hemiaster Branderianus, *Forbes*	?						
Eupatagus Hastingsiæ, *Forbes*							
Spatangus Omalii, *Forbes*							
Turbinolia humilis, *M.-Edw.*	...	—	—	—	?		
—— Bowerbankii, *M.-Edw.*							
—— Fredericiana, *M.-Edw.*							
—— minor, *M.-Edw.*							
—— firma, *M.-Edw.*							
Holaræa parisiensis, *Mich.*	...	...	...	...	...	—	
Graphularia Wetherelli, *M.-Edw.*	—						
Entomostraca (Ostracoda ‡).							
Cythere striato-punctata, *Röm.*	...	...	—	—	—		
—— consobrina, *Jones*	...	...	...	...	—		
—— plicata, *Münst.*	—	...	—	—	—	...	—
—— Wetherellii, *Jones*	...	...	...	—	—	...	—
—— attenuata, *Jones*	...	...	...	—			
Cythereis horrescens, *Bosq.*	...	...	—	...	—		
Cytheridea Muelleri §, *Münst.*	...	...	...	—	—	...	—
—— perforata, *Röm.*	—	...	...	—	—	...	—
Krithe bartonensis, *Jones*	...	...	...	...	—		
Bairdia subdeltoidea. *Münst.*	...	...	...	—			
—— contracta, *Jones*	...	...	...	...	—		
Cytherella Muensteri, *Röm.*	...	—	—	...	—		
Foraminifera.							
Biloculina ?	...	...	...	...	—		
Quinqueloculina Hauerina, *D'Orb.*	...	...	...	—	—		
Miliola, spp.	...	...	...	—	—		
Cristellaria rotulata, *Lam.*	...	...	...	...	?		
Marginulina Wetherellii, *Jones*	...	...	...	...	—		
Truncatulina lobata, *W. & J.*	...	...	...	...	—		
Planorbulina rosea (?), *D'Orb.*	...	...	...	...	—		
Discorbina trochiformis, *Lam.*	...	...	...	...	—		
Nummulites variolarius, *Lam.*	...	...	*	—			
—— elegans, *Sow.*	...	...	—	*			

‡ Monogr. Tert. Entom. Pal. Soc. 1856, and Geol. Mag. for September and October 1887.

§ Taken in the Woolwich and Reading Beds.

Discussion.

The President referred to the numerous communications to the Society relative to the Eocenes of Hampshire, and complimented Mr. Gardner on being able to say something new.

Mr. Whitaker observed that in point of fact but little had been written about the Barton Beds of Barton Cliff, attention having been mostly drawn to the Headon Series. He spoke of Mr. Trimmer's section, 20 in. to 1 mile, executed in 1849; there was also one at Southampton by Mr. Keeping. The Barton section had hitherto been difficult of access.

Commenting on the cliff-section, he regarded the whole as one great series; there were no great gaps in the succession, the changes being local only. There was some difference of opinion as to the base-line of the Headon Series. The sandy beds below constitute a large portion of the material coloured as Upper Bagshot. In this occurs a clay bed, which he regarded as exceptionally intercalated; do the fossils connect it with the Barton Series? There was no gap of importance between the Barton and Bracklesham Series. The pebble-bed was exceptional in containing some subangular flints and quartz. The oscillations in the area had not been of great importance. He thanked Mr. Gardner for the care he had taken over the lists of fossils.

Mr. Irving recognized a general resemblance to the beds of the London basin, the changes of level being chiefly local. He would like to know if the fauna discovered by Mr. Monckton in the sandy Upper Bagshots occurred in exceptionally argillaceous beds.

Mr. Monckton remarked that this bed was quite as sandy as the others.

Mr. Irving expressed his doubts as to the possibility of specific identification of these fossils. Such a large number of genera were common to the two divisions, that he doubted any great difference in the fauna of the Upper and Middle Bagshots.

Mr. Herries said that the Pebble-bed was a convenient line of separation between the Upper and Middle Bagshots of the London basin, though perhaps at a lower horizon than the division-line in the Hampshire area. He assured Mr. Irving that in the London basin the fossils of the "green earths" (Middle Bagshots) were quite distinct from those in "Tunnel Hill" (Upper Bagshots), in which he believed only one purely Bracklesham form had been found, and of that but a single specimen.

Mr. Gardner had no desire to favour either the Headon or the Barton Series. He placed the upper boundary of the latter where the marine shells cease. The sands, therefore, to which Mr. Whitaker alluded belonged to the Barton Series. The lower boundary of that series was pretty distinct, though at Selsey the beds shade into each other. But the subtropical forms do not occur above the Nummulite-zone. Above this the fauna is of a more temperate character, with a partial recurrence of London-Clay forms. The upper beds in the section were far above the Upper Bagshots

of the London basin, and he indicated on the diagram the approximate horizon of Mr. Monckton's "Tunnel-hill" fossils. He assured Mr. Irving that they were not thrown back on genera in regard to these, as the species could be determined. He allowed the whole to be one series, and the changes only local, but he believed the land movements to have been considerable. He thought there were no subangular flints in the Pebble-bed at the base of the Barton.