

16. DESCRIPTION *and* CORRELATION of the BOURNEMOUTH BEDS.—  
Part I. UPPER MARINE SERIES. By J. STARKIE GARDNER,  
Esq., F.G.S. (Read February 20, 1878.)

DESCRIPTIONS of the coast-section between Highcliff and Bournemouth, with which the present paper deals, have already appeared in the publications of the Society. That by Sir Charles Lyell\*, in 1826, was written when the strata included in this section were still supposed to belong to the Plastic Clay underlying the London Clay. In it the different beds forming Christchurch Head are carefully distinguished, and their superposition illustrated in a somewhat idealized section. The description of the eight miles of cliff from a mile beyond White Pits to Poole Harbour is, however, dismissed in a very few words:—The “section presented by the cliffs is continued so precisely in the line of bearing of the strata, that no new beds rise up, and it is unnecessary to describe them in detail. . . . The prevailing character of the strata throughout this extent of coast is fine white sand; but yellowish and pinkish beds of sand occur, and thinly laminated clays in great abundance, resembling in appearance many of the light-coloured argillaceous marls of Montmartre near Paris; but in none could I discover any organic remains, except vegetable impressions, and these very indistinct.” The proofs of origin, whether marine or freshwater, are considered equivocal. The total thickness of the series, nowhere exposed to view, is put down at “not less than 150 feet.” It is also suggested that the argillaceous strata with shells of Alum Bay “are probably concealed here at some of the interruptions of the section.”

The next description of these cliffs is by Professor Prestwich† in 1848, written principally with the view of determining “the exact position which they bear with reference to the Barton Clay” (*l. c.* p. 43). He begins, however, with the assumption that Barton Clay is found to the west of Christchurch Harbour, and thence is led to place the strata of Christchurch Head higher in the section than I am inclined to do. He compares a section of the Head with that of the Barton Cliff near its western termination, and concludes that the beds with septaria common to both are upon the same horizon. A mile and a half to the west of the Head a small lens-shaped section is considered to be “a slight throwing in of an overlying stratum,” and evidently presenting “in a small depression the base of the Barton clays” (p. 47). The Eocene pebble-beds taken for diluvium by Lyell are carefully separated from the overlying angular gravel by Prestwich; but it seems that he thought them to be more continuous than they now appear to me.

In 1861, the Rev. Osmond Fisher wrote‡ defining the horizons into

\* Trans. Geol. Soc. ser. 2, vol. ii. p. 279.

† Quart. Journ. Geol. Soc. vol. v. p. 43.

‡ *Ibid.* vol. xviii. p. 65.

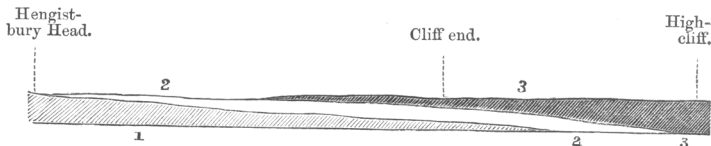
which the Bracklesham beds can be divided. His description of Highcliff stopped short E. of Christchurch Harbour; but it is of value in connexion with the present subject, since he shows that a pebble-bed at the top of the white sand at Highcliff is the equivalent of one of the higher beds of the Bracklesham series. Assuming the correctness of this determination, we have a defined horizon to start from; and as it can be shown that the sequence across the valley is uninterrupted and the dip regular, it seems to me that the position of the rest of the beds can be fixed with great accuracy.

The views I venture to put forward diverge from those of Prof. Prestwich. Although beds on the headland and on the coast almost immediately to the east of it both contain septaria, I believe them to be on different horizons, the former belonging to a separate series unrepresented elsewhere on the coast except at Alum Bay. Again, the slight throw-in of Barton Clay west of the promontory is, for me, only the most easterly of numerous and identically similar patches of the Bournemouth beds.

My views also differ slightly from those of Mr. Fisher. I think that the lower 123 feet of strata included by him in the Bracklesham series at Whitecliff may probably represent in time the *Lower Bagshot* beds. The Bracklesham beds are supposed by him to thin to only 43 feet at Alum Bay, and 35 feet at Highcliff. Even if, as he says, the 35 feet of sandy clay and the pebble-bed at Highcliff represent the whole uppermost strata of the series 130 feet thick at Whitecliff Bay, and we deduct the 123 feet placed in the Lower Bagshot, there are still some 400 feet unaccounted for. These 400 feet are, I think, not only well represented at Christchurch Head, where the strata are mapped as Bracklesham by the Survey, but also by the marine beds thence to and even beyond Boscombe, and at Alum Bay as well. I also find myself at variance with the Geological Survey, since I believe that the so-called *Upper Bagshot* beds of the London basin do not belong to that series, but are the equivalents of beds which I shall refer to as the Boscombe Sands. These Boscombe Sands and the marine Bournemouth beds are, I believe, the western equivalents or extreme shore-conditions of the Bracklesham sea.

My especial object in bringing this paper before the Society is, however, to prove that the Bournemouth leaf-beds immediately underlie

Fig. 1.—*Restored Section between Highcliff and Hengistbury Head.*



1. Hengistbury-Head beds of the Middle Bracklesham.
2. White Sands at the base of Highcliff and capping Hengistbury Head.
3. Barton and Upper Bracklesham beds.

the Bracklesham series and are, unlike those of Alum Bay, of *Middle* and *not Lower* Bagshot age, as had, I believe, been hitherto supposed. I have also ascertained that a great portion of the cliffs between the Head and Bournemouth are of marine origin and highly fossiliferous, and these I describe in detail. These marine beds are of two distinct characters; and both of them I have traced across to Alum Bay, where they are well represented.

The strata forming the promontory are higher in the series than those on the west, but below the Highcliff beds; and they can also, as divided by Lyell, be separately traced across to Alum Bay. No detailed correlation has, I believe, been previously attempted.

*Highcliff Sands*—At Highcliff (fig.1), nearly under Rothsay Castle, the section is substantially as given by Mr. Fisher\* :—

		ft.	in.
Barton.	Coarse, green, sandy clay, with grains of quartz. "The tool gives a bright green streak." .....	8	
	Indurated marly clay with "tabular soft septaria." .....	7	
	Dark green, coarse, sandy clay, "giving a bright green streak with the tool." .....	9	0
Bracklesham.	"Pebble-bed towards the W., changing E. into soft, dark, sandy clay, with scattered pebbles and impressions of fossils" .....	1	6
	Sands, clayey at bottom. Very variable W. "There is a band of ironstone-septaria in these sands which is not persistent" .....	33	0
	Band of flint pebbles ..	6	
	White sand; the bottom not seen.....	6	0

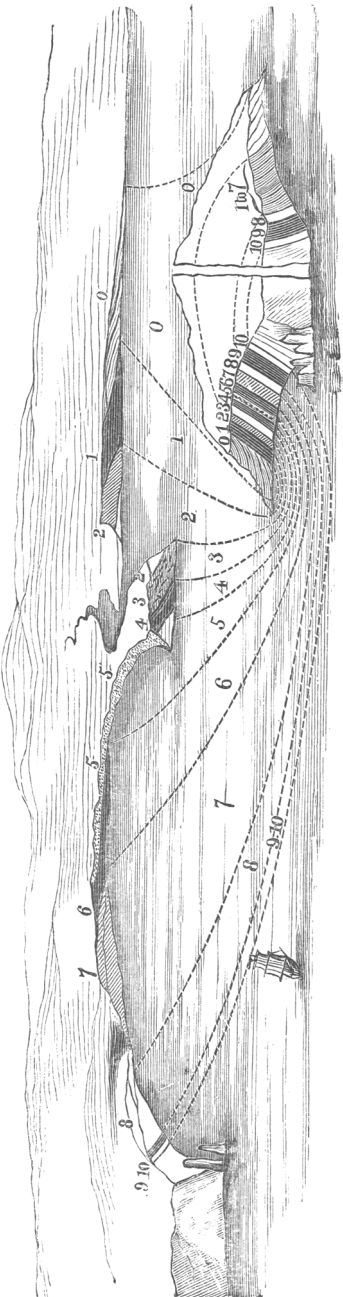
Fifty yards from the western termination of the cliffs, where they are still 50 feet high, the section has no septaria-layers; but at the base of the cliff we have coming in

	ft.	in.
Loose white sand.....	10	0
Hard, dark clayey sandstone with scattered pebbles at base .....	1	0
Hard yellow mottled sand shading to white .....	6	0

These sands dip conformably with the Barton and Hordwell series  $1\frac{1}{2}^{\circ}$  to  $2^{\circ}$  E. The curious turn the water flowing from Christchurch Harbour has taken within the last few years, known as the Run, has fortunately revealed the section to the very sea-level; and it is now seen that these sands rest upon another and lower series of dark sandy clay with ironstone nodules. These and the overlying sands can be almost directly traced to the headland, where they form the cliffs; for at the ferry, about midway between them, the landing-place is on hard compact clay, upon and about which are lying a few identically similar ironstone nodules. The sands themselves, however, have not resisted denudation and, like the Boscombe Sands on the other side of the Head, have been removed for the space of a mile.

\* *L. c.* p. 88. The woodcut, however (p. 87), is incorrect, showing too great a dip and a sudden curve in the strata.

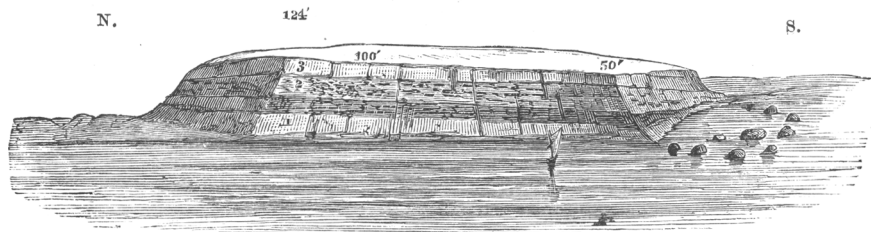
Fig. 2.—*Ideal View of the Isle of Wight and the adjacent Land, with dotted lines connecting the nearly horizontal beds of the mainland with the vertical beds of the island.*



- |   |  |                                   |
|---|--|-----------------------------------|
| 0. Upper Eocene.                                    | 3. Upper Hengistbury-Head beds, with iron-stone. | 7. Bournemouth Freshwater Series. |
| 1. Barton Beds.                                     | 4. Lower Hengistbury beds, with green grains.    | 8. Lower Bagshot.                 |
| 2. Upper Bracklesham and Highcliff white-sand beds. | 5. Boscombe Sands.                               | 9. London Clay.                   |
|   | 6. Bournemouth Marine Series.                    | 10. Woolwich and Reading beds.    |

*Hengistbury Head.*—The curious promontory of Hengistbury Head is mainly composed of strata which form the uppermost portion of a local and shore series, contemporaneous with the Bracklesham, which we may for convenience call the Bournemouth beds. It is a particularly interesting spot, as it reveals the presence of beds whose existence between the base of the Highcliff beds and the white sands of Double Dykes would probably have been otherwise unsuspected. The compact nature of the strata forming it has preserved it during the denudation of the surrounding area; and the layers of iron septaria, falling into the water, have made a reef stretching a quarter of a mile seawards, and thus saved it from being entirely swept away by the sea. The contour of these rocks, known as the Beerpan rocks, is in almost all weathers sharply defined by the smoother water within their barrier, and probably marks the original extent of the headland. The dip of the beds would take them, just beyond these rocks, out of the reach of the sea. The general shape of the promontory is a parallelogram with its northern extremity obliquely truncated; it is three quarters of a mile long, by about a quarter broad, the longer-side running N.W. by S.E. The cliffs facing the sea are about 50 feet high at their S. point, increasing N. to 100 feet. N. and E. they present bold escarpments to the sea; S. and E. they rise from a plain of blown sand, which forms the banks of the harbour and stretches one mile to Mudeford. The dip and strike of the strata follow the contour of the land, and are about  $3^{\circ}$  S.,  $2^{\circ}$  S.E.,  $3^{\circ}$  E.

Fig. 3.—*Hengistbury Head, west side,*



1. Boscombe Sands
2. Lower bed with green grains, and Upper bed with ironstone.
3. White Highcliff sand.

The form of the Head must have rendered it a position of great importance to an invading or beaten army in early times; and its advantages were not neglected, as the ancient walls and fosses known as Double Dykes, defending it from the mainland, prove. It should be, with its barrows and legendary name, a place of interest to the antiquary; it possesses many attractions to the artist, whilst its heather, to judge from the abundance of birds, is little disturbed by the gun.

The highest beds met with in the headland are undoubtedly, according to my thinking, the continuation of the white sands at the base of Highcliff. They extend almost all over it and at the highest

point, the watch-house, are 25 feet thick. In various places sections are exposed, as at the N. corner of the Head, where under 3 feet of peat we see 12 feet brown and yellow sand; yellowish sand with four thin layers of pipeclay, 2 feet 5 inches; white sand shading to orange, 1 foot 3 inches; deep orange-mottled clayey sand, 11 inches, resting upon brownish sandy clay with septaria. At the S.E. corner we notice 6 feet whitish sand shading to orange, with 1 foot 9 inches orange sandy clay at base. The S.E. extremity presents a good section of the white sands:—

		ft.	in.
High-cliff Sands.	White sand with a few yellow bands .....	7	0
	Hard white sand .....	1	0
	Yellowish and orange clayey sand .....	1	4
Hengistbury-Head Beds.	Hard white sand (local patch) .....	10	
	Dark clays and light sand in irregular layers .....	1	9
	Hard white sand (local patch) .....	3	3
	Brownish sandy clay with ironstone.....	44	0
	Débris concealing 12-feet bed of greensand.		

The white sands are 30 feet thick at Highcliff, having thinned out from 42 feet at Alum Bay, and are therefore probably originally even less in thickness here. At Alum Bay and at the Head the junction or base bed is strongly ochreous in colour.

*Hengistbury-Head Bed.*—The next stratum does not, so far as the coast-line of the mainland is concerned, extend beyond the Head itself. It is composed of brownish-drab, laminated, sandy loam, about 45 feet thick, with from 3 to 5 nearly parallel layers of large tabular ironstone\* concretions. It is well exposed on the S.W. and S.E. sides, and in an extensive quarry which nearly cuts the headland in two, E. and W. These septaria are conspicuous objects in the cliffs and form a reef running out to sea. They sometimes contain sharks' teeth, of both the *Otodus* and *Lamna* type, and vertebræ. Frequently, also, compressed tree-stems of considerable size traverse them; one of these, according to Sir C. Lyell, measured  $4 \times 2\frac{1}{2}$  feet with  $\frac{1}{4}$  in. of bark like black shining coal; I have measured others 5 feet in length, but not so wide. All the wood is riddled with *Teredo*-borings of large size. Prof. Prestwich records the occurrence of seeds in the septaria; but I have looked in vain for them, although layers of washed and fragmentary lignitic matter are not unfrequent. It is probable that the dicotyledonous leaves in the list of fossils from Hengistbury Head on the Geological Survey map were from this stratum; since although I have failed to discover any trace of such here, I have found a tolerably perfect leaf at St. Catharine's Hill in the same beds further inland. The four bivalve shells in the same list are probably, like the *Modiola* found by Prestwich "in the lower part of the clay," from the greensand next described, in which I some years ago met with a few casts of bivalves.

Succeeding the 45 feet of ironstone-bearing sandy clay, and at about 7 feet 6 inches below the bottom line of nodules, is a distinct

\* Mr. Tylor, Quart. Journ. Geol. Soc. vol. vi. p. 133, gives a brief account of these blocks.



and compact bed, 12 feet thick, of glauconitic sandy clay, with green grains and with occasional lignitic layers, very similar in appearance to some of the Highcliff beds described by Mr. Fisher\*. This bed rises at the S.E. corner of the promontory, and at its N.W. end is at least 30 feet above the beach. It includes scattered, round, black flint pebbles throughout, and has a continuous layer of them at its base. This and the succeeding beds rise at an angle of  $2^{\circ}$  or  $3^{\circ}$ . Like the preceding, it does not extend along the coast beyond the Head itself. At Alum Bay the position of the two beds last described is occupied by similar sandy clays, 71 feet thick, becoming more sandy towards the base and containing five layers of lignite, and capped by a thin seam of red sandy clay, answering probably to the orange-coloured bed at the base of the Highcliff sands.

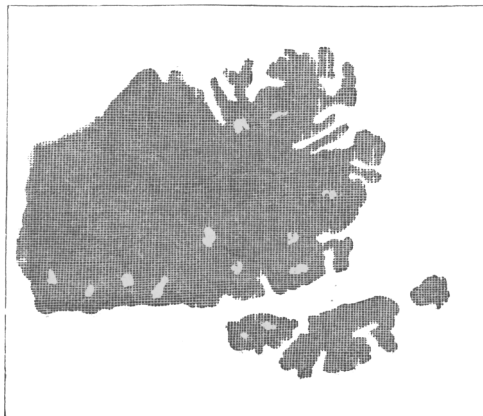
*Boscombe Sands.*—The next series is perfectly distinct and may be called the Boscombe Sands. It represents the principal mass, 148 feet thick, of brilliant-coloured sands at Alum Bay (numbered 25 to 26 in Prestwich's section, see fig. 6), containing thin straggling layers of flint pebbles with small rounded fragments of quartz. These beds, at Hengistbury Head, are only seen in the longest or S.W. range of cliffs, towards the centre of which they gradually rise from the beach. From the point at which they rise until a thickness of 7 feet or 8 feet is exposed, they are whitish or ash-coloured sand, containing much scattered lignitic matter, with layers of pebbles about 3 feet apart. The layers are, however, not persistent, and we find within a few yards a 3-feet bed of sand between two pebble-layers thickened to 12 feet, and including four layers of pebbles; nor are the pebbles always confined to layers. Under the white are pinkish, black, and deep chocolate-coloured sands 17 feet thick, again underlain by 7 feet of white sand. The junction between the dark coffee-coloured sands (which become black after a few minutes' exposure to the air) and the upper white sands is remarkable, the white sands having cut through and imbedded angular pieces of the darker sand of all sizes up to 4 or 5 feet diameter. The surface of the dark sand as well as some of the larger detached pieces have been bored by *Teredo* or *Pholas* before being imbedded (fig. 4, p. 216). The dark sand has basin-shaped patches of pinkish ash-coloured sand at the top, the pink sand sometimes forming a layer 1 foot 6 inches thick above the pebbles, so that the latter do not always mark the junction. Nearer the neck of the headland the bottom white beds become thicker and more compact, and contain iron layers and small concretions. The dark beds are very variable and change colour within short distances.

For half a mile the cliffs are very low, being but 17 feet high near Double Dykes, and composed of shingle, showing here and there at their base the uneven and eroded surface of the Boscombe Sands, which are now yellowish white. Here these loose sands and pebble-beds have been a prey to subsequent denudation, which, however, had not force to remove the included heavy shingle, but has left it in solid masses 12 and 15 feet thick, mixed with the

\* O. Fisher, Quart. Journ. Geol. Soc. vol. xviii. p. 86.

more recent angular gravel. Both supply material to the present beach.

Fig. 4.—*Mass of Black Sand imbedded in matrix of white siliceous sand and bored by Mollusca.*



A little over 3 miles due north of the Head there is another hill or, rather, range of hills of similar contour to that of Hengistbury Head. This, St. Catharine's Hill, 160 feet high, possesses, like the headland, a flat top and abrupt escarpments on all sides, and was also chosen as a strong place in ancient British times, as the remains of a camp, fort, four watch-towers, and numerous tumuli sufficiently prove.

From the singular resemblance which the hill bears in outline to Hengistbury Head, and from its relative position, it seems certain that it must be composed of a second mass of identical strata. Although it is completely overgrown, except where a brick-pit has dug slightly into it at its northern end, the evidence there is alone almost conclusive. The following section is exposed:—

	ft.	in.
Highcliff Sand? Orange sand and clay .....	3	0
Hengist- bury Beds. { Ash-coloured clay .....	3	0
{ Drab clay with iron concretions exactly as at Hengist- bury Head .....	5	0
{ Dark and very lignitic sand .....	2	6
{ White and yellow sand with layers of light clay almost white at base .....	3	0

Notwithstanding that the Hengistbury-Head beds have thus perhaps thinned out, there can be but little doubt of their identity. The valley of the Avon on the east is probably scooped out of the yielding Highcliff Sands; and that of the Stour to the W. has been worn through the Boscombe Sands. The beds seen in the pits are again very variable, there being a lenticular patch of whitish sand with iron stains, 10 feet thick, on the east side of the pit. The dip



is S.E. and E. about  $7^{\circ}$  and N.N.E.  $6^{\circ}$ . The laminated drab clay evidently contains well-preserved dicotyledons, but the other beds appear unfossiliferous. A pit higher in the hill-side confirms the supposition that the overlying beds are sand.

We have thus at Hengistbury Head (fig. 3), in the first place, the Highcliff Sands; white sand with a maximum thickness, under the watch-house, of 25 feet; next, the Hengistbury-Head beds, composed of 45 feet, or perhaps a little more, of clay with ironstone concretions, and 12 feet of clay with green grains; lastly, 30 or 40 feet of Boscombe Sands, whose base is not exposed. At Alum Bay, the first is represented by 42 feet of yellow and white sand, ochreous at base, like these, No. 28 in Prestwich's section\*. The Hengistbury-Head beds are equivalent to No. 27 of the Alum-Bay section, 71 feet in thickness, and are confined to this Head as far as the coast of the mainland is concerned. Their position is between 150 and 200 feet down in the Bracklesham series. The Boscombe Sands extend to beyond Boscombe, and are the equivalents of beds Nos. 26 and 25 at Alum Bay, where they comprise 147 feet of sand with occasional layers of pebbles. These, although on the mainland of plain white, buff, or chocolate-colour, are the most brilliantly coloured of all the sands at Alum Bay.

A careful examination of the cliffs in the bay from this point to Bournemouth shows conclusively that there is a general sequence, and that the strata, although nearly horizontal, have a slight dip, sufficient, however, in so great a distance, to pass through two complete series of beds. The upper series is the continuation of the Boscombe Sands just noticed, and has a probable thickness of at least 100 feet, but is here entirely composed of sands shading from orange to white and enclosing heavy shingle-beds. The second series is composed of sands and dark clays of marine origin, which we may provisionally call the *Bournemouth Marine Beds*, and which contain numerous and interesting fossil remains. Both these series extend to within a third of a mile of Bournemouth pier, the lower one partly thinning out and being partly replaced by freshwater beds.

Passing over the irregular patches of white sand which are seen underlying the shingle already mentioned as forming low cliffs between Hengistbury Head and the main coast-line, we find the first regular rise of the beds at a place called the Cellars, exactly 1 mile west of the Head, and about 700 yards E. of the Coastguard flag-staff. The lowermost beds are chocolate-coloured sands and dark sandy clays with vegetable remains, belonging to the Bournemouth Marine Beds, which rise in successive layers at angles of about  $5^{\circ}$ . At a distance of 110 yards west of the Cellars they have risen but 5 feet, and are frequently obscured by heaped-up shingle. The overlying white sand beds rise with them and are here 10 feet thick. 176 yards further west we have a small patch of dark clay 25 feet across, presenting a lenticular section, underlain by shingle, a very unusual arrangement. I am particular in noticing this clay patch, as I have no doubt it was a similar patch, if not this very one, which

\* Quart. Journ. Geol. Soc. vol. ii. p. 258.

Prof. Prestwich took for a "slight throw-in of an overlying stratum" of the Barton beds. The shingle is imbedded, as usual, in white sand, and underlain by yellow and grey sand in layers, and then by darker clayey sand. The cliffs are here 30 feet high with an easterly dip of  $7^{\circ}$ , and are more than half composed of gravel; 260 yards further the dip decreases to  $5^{\circ}$ , and we have in descending order ash-coloured sand and clay, a narrow seam of pink clay, white sand shading to fawn, a thin line of dark clay, lemon-coloured sand, and 23 feet white sand with laminated pale drab clays. A little westward a layer of iron sandstone appears; and 100 yards further the dip decreases again to  $3^{\circ}$  or  $4^{\circ}$ . At this point we find irony and fawn-coloured sands irregularly bedded under the gravel, then sandy laminated clay with two layers of orange-coloured clay, succeeded by three layers of black clay between lignitic sand. Under the flagstaff is an important shingle deposit comprising two nearly horizontal and parallel layers at its base, and several masses bedded obliquely at an angle of some  $25^{\circ}$  above. The whole of the shingle-beds appear to have been mistaken for diluvium by Lyell, but were recognized by Prestwich and distinguished from the surface-gravel. They consist, he says\*, "uniformly and solely of perfectly rounded smaller or larger flint pebbles, mixed with more or less sand, and always, when the latter predominates, showing distinct though rough stratification." A section by Prestwich appears to have been taken from this spot, where the flints are very large and round. For 400 yards there is no change of importance; but the base-beds show clearly defined stratula, which prove, like the slope of the old shingle beaches, that they were thrown down by water advancing from the eastward. At this point occur more dark lenticular clay patches of the Bournemouth beds; and through the increased height of these more of the overlying Boscombe Sands seem to have escaped denudation. The line of separation between these latter and the beds below may be distinctly traced, as a thin but more or less persistent clay seam checks the downward percolation of water, and throws it out in numerous tiny springs, the wet uniformly darkening the beds below even where they are composed of white sand. The clay patches continue without change for 150 yards. The cliffs are then 65 feet high, 40 feet belonging to the lower series and 20 to the Boscombe Sands, with little or no gravel capping. The upper beds exhibit stratula at reversed angles, showing cross currents, or that the prevailing set of the tides was often changed. The lower beds change frequently from dark clays to buff or white sands, sometimes within 10 yards, and contain great lenticular patches scooped out of them and filled in with white sand, marking probably former channels parallel with the shore, such as we see to-day on the same spot. The damp surface of the cliffs, to which blown sand clings, obscures, however, most of these changes, and they must be bared with a spade or pick to be visible. They are most distinct after heavy rain. About 400 yards beyond a little chine in which the coastguard boats are sheltered, the junction line is temporarily lost, and the whole cliff is composed of yellow sand,

\* Prestwich, Quart. Journ. Geol. Soc. vol. v. p. 46.

soon again diversified in its lower portion by a fresh series of small black lenticular patches. That these lenticular patches are cross sections of ancient channels parallel with the old shore seems probable; and that they are of considerable length may be argued from the fact that both Prof. Prestwich's sections\* show an arrangement which can be identified by certain peculiarities with two existing patches, notwithstanding that, in the 30 years that have elapsed since these figures were drawn, there is reason to believe 100 yards of coast may have been washed away. One coastguard'sman estimated that as much as 60 yards had gone in about 16 years, and all testimony points to a rapid waste. That this is much feared is clear from the great distance from the cliff at which the coastguard buildings are erected, and a monument on Double Dykes has had to be shifted further inland.

Wet brings down large masses of mud and sand in a few hours; wind produces continuous streams of sand; the falling pebbles compel you to give the cliffs a wide berth; and perpetual slips cause anxiety to the nevertheless fortunate proprietors of the lands bordering the sea. 250 yards to the east I detected a bean-like single-seeded pod with indistinct leaves, and other seeds in one of the lenticular patches. Here seems to be inserted a fresh series of laminated sands, 6 feet thick, with much wood and lignite; but with this exception the cliffs, 77 feet high, are all sand with only occasional darker lenticular patches, and with very few pebbles in thin small layers. The dip decreases 150 yards W. to  $1^{\circ}$ , and E.S.E. by S.E. The bottom-beds, 12 feet thick, contain distinct impressions of leaves in a liver-coloured clay; among them an ovate and a strongly serrate leaf are recognizable. 44 yards on we have several layers of black clay under the line of damp already mentioned as separating the two series of beds, then white sand, and only 10 feet dark sandy clay. The Bournemouth beds, here 40 feet thick, form, as a rule, a nearly vertical base to the cliff; whilst the Boscombe Sands, frequently nearly pure white and fit for glass-making, always slope back at a considerable angle. 130 yards W. we have another curious series of parallel shingle-beds; and in the base-beds, which are of liver-coloured clay, a large laurel-shaped leaf is abundant, associated with a pod as large as and resembling an ordinary pea-pod; 66 yards W. the cliffs again become wholly sand with a dip of  $3^{\circ}$ , the white sand showing fine examples of stratula; 154 yards further on, lenticular patches again appear, 40 feet from the beach. I will not, however, describe too minutely the details of the cliffs, and therefore pass over the changes occurring in the next quarter of a mile, and come to a concrete road constructed up the face of the cliff by Lord Portman, who has also gone to considerable expense in pile-driving at its foot, it is to be feared, unavailingly. Even the road itself, unless constantly cleared, will be filled by blown and falling sand, which forms great dunes at the top of the cliff. The cliff here shows, in descending order, gravel, ochreous sand, white sand in stratula, white sand with iron stains, iron-coloured sand, pinkish clayey sand not holding water, orange sandy clay and sand, thick black lignitic sand, mottled white

\* *L. c.* p. 46. fig. 3, p. 47. fig. 4.

and yellow sand, and, finally, much twisted black clay, the latter holding the water whose mischief Lord Portman endeavours to remedy. A little eastward the pinkish clayey sand ceases, the lignitic sand passes into pure glass-sand, and there are thick shingle-beds at the top. For 200 yards further we find the lower half of the cliffs composed of white sand, the upper of orange sand; 90 yards further we meet with very regular layers of shingle and curiously twisted lignitic sand and clay at the base. The cliffs are now 100 feet high; 380 yards further on we reach the first really palæontologically interesting spot. This is an obliquely bedded lignitic sand, some 16 feet thick, containing very perfect and almost uncompressed limbs of all sizes of an American form of *Cactus* \*, described by Heer from Bovey Tracey as *Palmacites daemonorops*. Together with this, and even more abundant, are branches of a *Sequoia*-like conifer †. The upper part of the cliff is nearly pure white sand, the rest (the Bournemouth beds) being composed of greyish sand and clay in layers. It is singular that these *Cactus* and coniferous branches should have been deposited in this place in abundance, and only here, in company with fragments and branches of wood (riddled by *Teredo*) and sharks' teeth. A few yards E. or W. we may search in vain for them; and it is difficult to understand why they are so completely separated from the fruits and seeds elsewhere so abundant.

120 yards beyond this are the Honeycomb Chines, the sides of which are upwards of 100 feet high and of most picturesque appearance. The ridge separating them, deprived of its gravel capping, and formed of snow-white sand, looks quite Alpine with its sharply cut peaks and water-worn gullies, which may be magnified by imagination into chasms and crevasses. The ribbon-like and netted surface, produced by weathering, produces a singular and striking effect. Lyell represents 3 chines at about the same spot; but it is hardly conceivable that any trace of those should remain at this day, as over fifty years have since elapsed. Last spring the face of the buttress separating the two fell away like an avalanche, which will take many a rough sea to remove. The production of these chines is marvellously rapid; a week's rain sometimes goes far to produce one where a few days before not even an indentation was visible. But their picturesque aspect is not their only charm to the geologist. The beds towards the base are full of interest. A section taken on the east side of the eastern chine shows, in descending order:—

- feet.
  - 20 Yellow sand and gravel.
  - 38 White sand.
  - 5 Whitish sand with lignitic matter.
  - 1 to 3 Dark reddish ash-coloured lignitic sand crowded with *Nipadites*, but almost without other recognizable fruits.
  - 6 Whitish and ash-coloured lignitic sand, with occasional fruits resembling *Petrophiloides*, *Cucumites*, and *Hightea* of Bowerbank.
  - 2 White-sand matrix, black with rolled lignite.
  - 3 White sandy clay bored by *Pholas*.
- Sand 10 or 12 feet to beach.

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\* Identified by Carruthers.

† *Sequoia Sternbergii*?

This section varies considerably in different parts of the two chines; but the *Nipadite*-zone is constant in both. The thick sands of the upper series enclose no shingle here. No reliable dip inland can be obtained, as the bedding is somewhat confused; but in most of the faces running N.N.E., N.N.W., W.N.W. the beds appear horizontal, the principal dip appearing to be towards W.S.W. The horizon of the *Nipadite*-bed at the extremity of the chines is 42 feet above sea-level, top of lignitic sand 47 feet, top of white sand 85 feet, with a capping of about 20 feet yellow sand and gravel. At the entrance to the chine the *Nipadite*-bed is but 25 feet above sea, and the top of the lignitic sand 50 feet. The base of a fine palm-stem was found in sand 15 feet above sea-level, near the entrance to the second chine. The bark and woody structure are in perfect preservation, and the roots still entangle the white clay in which the tree was imbedded before it was washed, in Eocene times, from the older beds nearer to Poole.

It is singular that the *Nipadites*, which are so abundant in the chines that after rains twenty or thirty may be collected in an hour, cannot be traced either east or west of the chines. I have met with them in only one other locality nearer Bournemouth, where they are comparatively rare. No specimen has the base preserved, all exhibiting the characteristic predisposition to dissolution\*.

The husks are mixed with masses of rounded and carbonized pellets of vegetable matter, occurring in layers, which have evidently been subjected to attrition by tidal water. It seems clear that they must have floated, or they would have been pulverized, like the more solid remains with which they are mingled; their deposition in layers renders it probable that they were periodically stranded by the winds and in great numbers.

Bowerbank, in his 'Fossil Fruits and Seeds from Sheppey,' gives some curious particulars respecting the *Nipadites* found at Sheppey and the recent genus *Nipa*. The principal habitat of the latter appears to be near large rivers and in watery and marshy places where the soil is black mud or clay frequently covered with water. "It is observed at the mouth of all the great and rapid rivers, and also in such places as are overflowed by the sea or by brackish water; for this tree grows best in soil impregnated with salt."

The Bournemouth species most resembles *N. crassus*, Bow. They appeared to have completed germination, and the exhausted and hollow fruit is filled with white sand with little trace of vegetable matter. The pericarp is present, and the endocarp is sometimes preserved, but equally filled with the same sand. This want of variety in the vegetable remains shows that they were deposited near to where they grew; the variety of form at Sheppey indicating, on the contrary, an assemblage brought together from a large area.

Returning to the cliffs: 220 yards to the west is Boscombe Chine, at the east corner of which is a small patch of hard greenish clay which may be designated the *Dryandra*-bed, as it is filled with tufts

\* See Bowerbank, 'History of Fossil Fruits of the London Clay,' pp. 4, 7.

of leaves of a small acutely-lobed Proteacean (which differs from those of Alum Bay) and with compressed coniferous branches. Under this patch is a compact bed of hard whity-brown and ash-coloured sand with more coniferous branches and seeds. A few feet east, in 16 feet of liver-coloured clay under  $8\frac{1}{2}$  feet of greenish clay, we meet, for the first time, so far as I have observed, in these beds, with casts of oysters in great masses. At the corner of the chine, close to the beach, the grey sand contains branches of trees 3 or 4 feet long, with more perfect *Teredo*-borings than any met with elsewhere on this coast.

The eastern side of Boscombe Chine is overgrown; but the western side is well exposed for nearly a quarter of a mile, and shows that the beds are quite as variable in a transverse as we have seen them to be in the longitudinal section, and that they here rise inland very rapidly. The W. corner presents a curious instance of denudation by wind which has taken place within my own recollection. For 50 yards the upper beds have been swept off, the top of the lower and more compact beds now forming a plateau of that extent. Proceeding W. the lower beds for 150 yards are dark and compact, forming a perpendicular cliff 25 feet in height, the junction between these and the upper series, now of an orange-colour, being sharply defined. The masses of lignitic sand forming the upper beds of the lower series appear to enclose none of the seeds which we sometimes find sparsely scattered in the sands below. These beds dip  $8^\circ$ , and under them rises greensand with casts of oysters, sometimes coated with Bryozoa. 60 yards eastward a clay patch occurs as many yards in length, and of a drab and irony hue at the base, emitting a sulphurous smell when divided. It has indistinct leaf-remains, and is penetrated by fossil roots or sedges. For the next 200 yards the sections are obscured by slips, but the dark beds appear occasionally and are seen to be full of oysters.

Next to this is the iron-ladder path, where the cliffs are about 80 feet high, with the addition of a capping of nearly 30 feet of blown sand. We here find the following section:—Lower beds: base very sandy clay obliquely bedded, 3 feet; dark sandy clay getting more decidedly clayey towards the top, the last foot being very stiff black clay shading to lead-colour, 30 feet; over this are whitish-grey sands with grains of lignite and a few seeds, 8 feet; total about 40 feet. Upper beds: principally white glass-sand, but yellow towards the top and base, 40 feet. A very few yards west, however, the obliquely bedded sandy clays rise and attain a thickness of 30 feet, and are then replaced by hard white sand, unconformable to the obliquely bedded clays. At the end of 200 yards these again become first more yellow and then interlace with nearly black sands, which soon entirely replace them. Here *Nipadites* are again found, but very sparingly, together with fruits, which are rare, resembling *Hightea minima*, Bow., and *Anona*. Heer For another 250 yards dark yellow and grey sands 50 feet thick alternate, the upper beds consisting of orange or white stratulated sands of nearly equal thickness; but at this point a small patch



quite at the base of the cliff deserves especial notice, as it is literally crowded with seeds and fruit, supposed of *Hightea* and *Cucumites*, and more rarely fruits of *Petrophiloides*. The patch is situated between the extremities of two unconformable sandy clay-beds. [So local, however, are these seeds that within the last year a shift of a small streamlet 2 or 3 yards to the east has caused them but rarely to be washed out.] They appear at the time of deposition to have been caught in an eddy, and are mixed with stems and leaves, the latter, although they cannot be worked out, being so perfect when weathered out by spray as to seem like freshly decayed leaves blown on to the face of the cliff\*. This new base-bed soon changes to sand of a white or ash-colour, full of lignitic grains and occasional slightly bored logs of wood, without fruits, but containing in one place an included mass of jet-black clay crowded with broken pinnæ of *Osmunda*. The section of the lower series is at this spot:—black clay at base, 8 feet; then white, drab and white sand with lignite, 44 feet; capped with a thin water-holding seam of clay. The upper series is unchanged. We now approach the point of final disappearance of the marine series of beds, which within about 100 yards gives place to beds of freshwater origin. Before their disappearance, which is due partly to the rise of lower beds and partly to their passage into the freshwater beds, they become greatly disturbed, and have been much broken up and redeposited; while the changes in their composition are so rapid that the most minute and careful examination is required to understand their sequence. They are mostly highly fossiliferous and of the greatest interest. Within less than 50 yards of the last section we have the following, in ascending order:—

			ft.
	1	Coarse quartz grit .....	3
		Light drab clay .....	
		Liver-coloured clay with pyritized stems penetrating.	
		Angular lumps of unfossiliferous hard dark bands	
		redeposited in a matrix of light lignitic sand .....	25
Lower Series.	2	Lignitic sand with slightly rounded blocks of a redeposited leaf-bed .....	
	3	Light grey sand .....	15
		Greenish sand with oysters, <i>Flustra</i> , &c. ....	4
	4	Pink and drab clay .....	1
		Lemon and ochreous clayey sand .....	3
Upper Series.		White sand .....	14
		Orange and yellow sand .....	about 20
		Total about	85

\* About fifteen distinct forms only are at present known from these beds, and they are mostly of small size. These fruits, although not rivalling in variety and importance those from Sheppey, are nevertheless of the highest possible interest, as should their supposed identity with the latter be sustained, the fruits of Sheppey would assist in the determination of the Bournemouth leaves in an unlooked-for manner. If these fruits, which are *above* the horizon of the leaves, are identical with or even similar to those from the London Clay *below*, we have there the strongest reason to infer that the leaves lying between them were leaves belonging to the same groups of plants to which the fruits belonged, and grew on the same land. We may thus find in the Sheppey fruits

A new bed, about 3 feet thick, of compact dark clay, next rises, containing abundant seeds and fruits\*, which are compressed, not so well preserved as in the former fruit-bed, and containing, in addition, various dicotyledonous leaves, including a *Dryandra*, and also *Cactus*-spines, as well as fragments of a broad, apparently Musaceous leaf.

From a point a very few yards west of the last section, and in the marine beds numbered 4 in the preceding section, were obtained several Crustaceans. The beds here show extremely well the passage from marine to brackish and freshwater, and are as follows, descending :—

1. Dark sands with green grains, broadest and lightest at the top, containing masses of *Ostrea dorsata*? (coated with *Flustra*), an *Arca* (apparently *A. appendiculata*), a *Modiola* (probably *M. Nystii*), *Tellina tenuistriata*, and more rarely *Calyptraea trochiformis*?, *Phorus agglutinans*, *Natica labellata*, and a *Cerithium*.
2. Liver-coloured clay (turning black on exposure) with abundant remains of *Callianassa*, and, more rarely, a shore-crab. Bryozoa, first detected by Carruthers, also abound†. A *Unio*-like shell is also abundant, together with some smaller bivalves and a minute and very rare *Planorbis*? 15 feet. [The surface of the succeeding bed is eroded for about 6 inches, and filled in with the overlying clay, which has also formed small pipings.]
3. Stiff black clays passing into lighter liver-clays at bottom, and, after a break, into liver-clay with ferns. Very dark sandy clay. White or ash-coloured sand with lignitic bands. 30 feet.

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a great help to the correct determination of the leaves; as in cases where the form and character of a leaf would leave it doubtful to which of several genera it should be referred, the presence of fruits of any one of the genera to which the leaf might be referred would assist us to determine its genus, with a far greater approximation to certainty than if no such fruit existed.

\* The likeness of these to the Bovey-Tracey seeds called *Anona* is so extraordinary that if specimens from both localities were mixed they could not again be separated with certainty.

† Mr. Waters, who has kindly examined the specimens of Bryozoa obtained here, writes to me as follows, about them :—

“The fossil Bryozoa from Bournemouth which you kindly allowed me to examine are (with the exception of one impression) all merely casts of horny species, and therefore do not permit any investigations into the shell-structure to be brought to bear.

“A few of the specimens are *Flustra*, but, as none of the characteristic points are preserved, cannot be determined, since the only comparison that is possible is the size of the cells.

“There are, however, three specimens of great interest. These are casts of *Diachoris*, of which the lateral tubular connexions can be seen, and these are frequently broken off at the diaphragm, as is often the case in recent *Diachoris*. There are two protuberances in the cast, one on each side of the oral aperture, and these show that there were two rather large avicularia. The Bournemouth *Diachoris* has the distal and proximal ends in direct contact, as in *Flustra* and *Carbasea*, while in most *Diachoris* they are joined by a tubular connexion similar to the lateral tubes.

“This, I believe, is the first time that a fossil *Diachoris* has been found, which on that account is of much interest. There are a few species now living in the Mediterranean; but it is apparently much more common in the southern hemisphere. The *Diachoris magellanica*, Busk, is the most common in the Mediterranean. It has one or two avicularia placed slightly more laterally than those in your specimen.

“This mode of tubular connexion is not confined to *Diachoris*; for *Membra-*

The marine bed last described occurs on the east side of a slight indentation of the cliff, some 30 yards across, formed by a spring. Owing to this spring, which has of late years caused frequent landslips, the section is seldom to be seen; but it was visible after much digging during the summer, great cracks threatening all the time, however, a fresh slip. No description can render intelligible the complicated structure of this part of the series, the broad lines of which are sketched in fig. 5. On the west side of this landslip occurs the first leaf-bed which bears evidence of having been deposited in fresh water. It is made up of thin layers of a pinkish clay between films of sand, and in one place contains nothing but leaves of ferns belonging to *Polypodium*, *Chrysodium*, *Pteris*, and *Osmunda*.

Other beds contain a few dicotyledonous leaves mixed with the ferns, among them a *Eucalyptus*; whilst some of the dark beds contain branches of *Sequoia*, leguminous pods and leaves, &c. Over this, and to the east of the landslip, the last shingle-beds of the Boscombe Sands occur in lenticular, sometimes truncated patches. About 100 yards further west the marine beds finally thin out and end in a point, the cliffs being nearly all composed of white sand with short irregular patches of vegetable matter. The lowering of the cliffs and the rise of the underlying beds terminate the upper or marine series at this point.

*nipora circumcincta* of Heller is also connected by short tubes, which are more numerous than in *Diachoris*.

"I think your specimen might well be called *Diachoris intermedia* if it is allowed to remain with *Diachoris*.

"There is also a cast of *Membranipora*, which in shape much resembles *Membranipora pilosa*, which is common on the seaweeds all round our coast; but as there are fossils with similar-shaped cells and great variation in other points, no specific determination is possible from casts.

"There is an impression of an *Eschara* or *Leprelia*, which, I fear, cannot be determined."

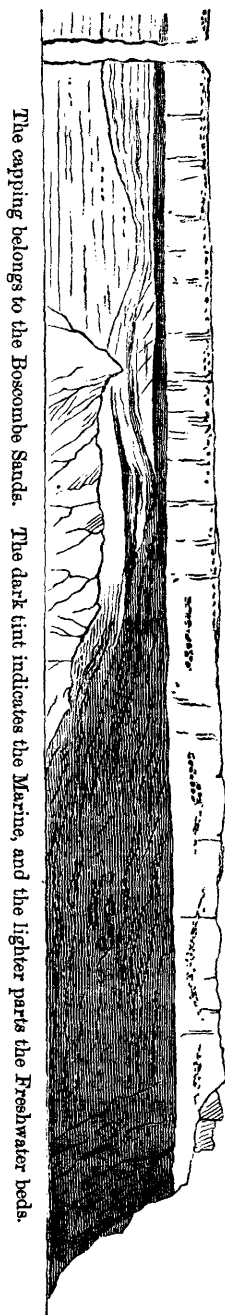
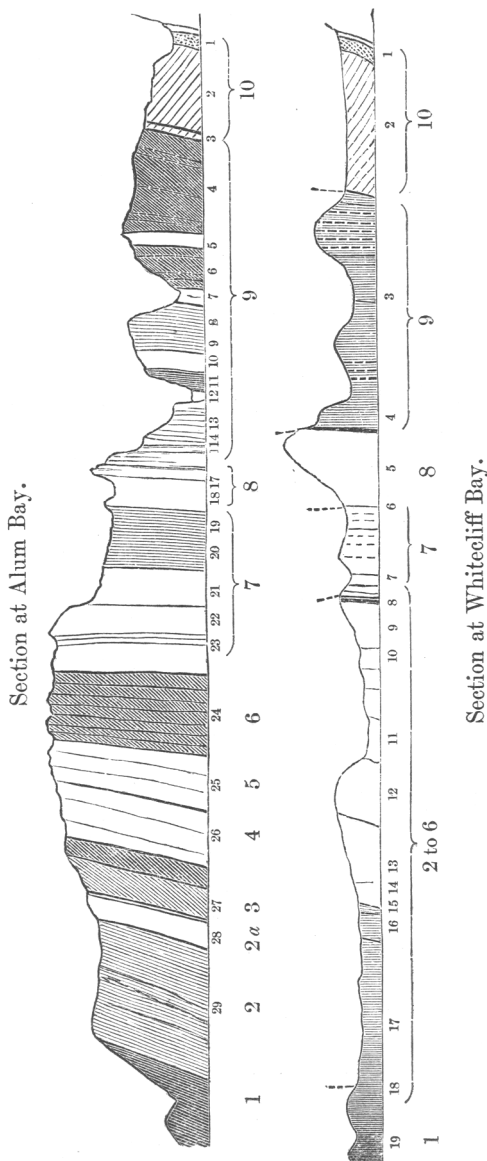


Fig. 5.—Western termination of the Bournemouth Marine Series.

Fig. 6.—*Reduced copies of Prof. Prestwich's Sections of the vertical section in Alum and Whitecliff Bays.*



The small numbers used are according to Prestwich, the larger numbers accord with my new nomenclature. The dotted lines indicate the correlation of the beds. The large numbers correspond with those used in fig. 2. 1. The Barton beds. 2. The Upper Bracklesham and Highcliff Sand. 3. The Hengistbury-Head beds with ironstone. 4. The Hengistbury-Head beds with green grains. 5. The Boscombe Sands. 6. The Bournemouth Marine series. 7. The Bournemouth Freshwater series. 8. The Lower Bagshot beds. 9. The London Clay. 10. The Woolwich and Reading series.

The extraordinarily shifting and rapidly changing character of the beds both horizontally and vertically, the marshy character of the vegetation, as represented by ferns, *Eucalyptus*, Aroids, &c., the frequent patches of drab clay (which evidently once formed an oozy soil in which the ferns and perhaps water-plants rooted), the local patches of ironstone, the marine beds, as well as the character of the fauna, shore-crabs and *Callianassa*, mingled with Unios, clearly show that this was the actual debatable margin betwixt sea and river, beyond which, to the west, it seems clear the encroaching sea never in these ages penetrated.

With regard to the correlation of the Bournemouth Marine beds with those of the London Basin, it is clear, upon reading Prof. Prestwich's description of the Middle Bagshot series in that area, that the beds are lithologically very similar. He ascribes to it a thickness of from 40 to 60 feet, and considers it to be a division of distinct mineral character and persistent range and structure. Whitaker, in the Geological Survey Memoir\*, adopts Prestwich's divisions, and quotes largely from his work. The lower part consists of laminated clays and sands; above these there is "green sand, generally very pure and of a dark bottle-green colour," 12 to 20 feet thick, succeeded by other sands and clays, with occasional layers of rolled flint pebbles. The presence of glauconite grains is a distinctive feature of the Middle Bagshot division, and the fossils that have been found are Bracklesham species. There can, I think, be no reasonable doubt that these beds represent the same stage of the Bracklesham series in the London Basin. When we come, however, to the Upper Bagshot beds in the same area, considerable doubt exists. These sands are described in the Survey memoir as "loose, generally whitish, and without signs of bedding or pipeclay, and are 250 to 300 feet thick." Considering that the Bournemouth marine beds are overlain by heavy deposits of white sand in every respect answering to this description, and that the Hengistbury-Head beds are also under a thick mass of whitish sand, and in the absence of palæontological evidence, it seems far more likely that these belong to Middle than Upper Bagshot time. On this supposition we have neither the very sudden thinning of the Middle Bagshot nor the absence of any indication of the Barton Clay to account for. I am therefore of opinion that no Eocene beds younger than the Brackleshams are met with in the London Basin. There is one other point upon which I wish to remark. The fossil plant-remains met with in the Bournemouth beds, especially those in the marine series, are so strikingly similar to the Bovey-Tracey fossils as to make it clear to my mind that the latter have been wrongly assigned to the Miocene. I believe, in fact, that they are simply an outlier of the Bournemouth series, from which they are but eighty miles distant. Whether we compare the ferns, as *Osmunda* (*Pecopteris*) *lignita*, *Lastrea Bunburyi*, the Cactus\* (*Palmacites daemonorops*), the fruits, conifers, or dicotyledons, it is seen that by far the larger proportion are not only specifically identical, but occur

\* Mem. Geol. Surv. vol. iv. p. 329.

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exactly in the same combinations and manner of preservation. The synchrony of the Bovey with the Hempstead beds has been inferred on the most slender grounds, and scarcely deserves attention now that it is opposed by strong evidence pointing in another direction.

DISCUSSION.

Mr. WHITAKER asked if the author regarded the fruits of Sheppey and those of Bournemouth as coming from the same horizon, and called attention to the thickness of strata deposited between the London Clay and the Bracklesham Series. He questioned the rejection of the older nomenclature, but admitted the great difficulty of correlating the Middle Eocene deposits of the London and Hampshire basins.

Mr. CHARLESWORTH remarked on the interest attaching to the discovery of fossil fruits at Bournemouth, and inquired whether *Nipadites* occurred, and if the fruits were in the same state of mineralization as at Sheppey.

The AUTHOR replied that the Bournemouth fruits were generally similar to those of Sheppey, and several belonging to the latter locality also occurred at Bournemouth. He defended his correlation of the beds.

Mr. WOODWARD stated that he had not yet been able to study the Crustacea collected by Mr. Gardner, which were not well preserved, and he feared would prove incapable of specific determination. He had recognized among them some Spider-Crabs, apparently of the genus *Stenorhynchus*, a *Xanthopsis*, and what appeared to be a *Cullianassa*.