Fig. 1.

SECTION OF ALUM BAY, ISLE OF WIGHT.

Eocene Series.

Fig. 2.

SECTION OF WHITE-CLIFF BAY, ISLE OF WIGHT.

Eocene Series.

THE
QUARTERLY JOURNAL
OF
THE GEOLOGICAL SOCIETY OF LONDON.

PROCEEDINGS
OF
THE GEOLOGICAL SOCIETY.

FEBRUARY 25, 1846.

G. E. H. Vernon, Esq., and Julius Jeffreys, Esq., F.R.S., were elected Fellows of the Society.

The following communications were read :—

1. *On the TERTIARY or SUPRACRETACEOUS FORMATIONS of the ISLE OF WIGHT as exhibited in the Sections at ALUM BAY and WHITE CLIFF BAY.* By JOSEPH PRESTWICH, Jun., Esq., F.G.S.

PLATE IX.

IN the London tertiary district there are but few good sections of the middle and upper Eocene strata; and there is no part of it in which the order of superposition is so well shown, or can be so conveniently studied, as in the coast sections of Hampshire and of the Isle of Wight. Owing to this better and more permanent stratigraphical evidence, it may be desirable, before treating of the London tertiaries, to fix the subdivisions of the contemporaneous Hampshire series, in order that they may serve as types and points of reference. I therefore beg to submit to the Society the following observations made in the autumn of 1839, which I should have brought forward at an earlier period, had I not hoped to have rendered them more complete by a further examination of the district, which however I have not had leisure since to resume.

The general details of this subject are well known. I will briefly note the results obtained by former observers, and then examine in succession the development and nature of the organic remains, conjointly with the changes of lithological characters and of dip, and I hope these may tend to remove some of the uncertainty and doubt which seem still to exist, particularly on the continent, on the subject of the fauna of these strata, and on the period of the disturbance by which they have been affected. Their age and synchronism with the Paris groups also require, I think, some material revision.

In 1766 Brander* published his descriptions and beautiful drawings of the London clay fossils of Barton and Hordwell Cliffs.

In 1802 Sir Henry Englefield† noticed the disturbance affecting the chalk and adjacent strata of the Isle of Wight.

In 1803 Lamarck‡ inferred, from a comparison of the fossils of the calcaire grossier of Grignon and Courtagnon with those figured by Brander, that these beds were of the same geological epoch.

In 1811 Dr. Berger§ gave several good mineralogical details and barometrical heights of parts of Hampshire and Dorsetshire, but his geological descriptions are defective.

In 1813 Mr. Webster|| detected the analogy of the geological structure of the tertiary rocks of the Isle of Wight with those described by Cuvier and Brongniart in the neighbourhood of Paris, and, following their classification, he grouped them into the formations of—1, sands and plastic clay; 2, London clay; 3, lower freshwater; 4, upper marine, and 5, upper freshwater.

In 1816 Dr. Buckland¶ noticed the strong resemblance between the London and Hampshire basins, inferred their former continuity, and traced the range of the plastic clay in the Hampshire basin.

In 1816 Sir Henry Englefield** published some excellent coast sections of the Isle of Wight and Dorsetshire, after drawings by Mr. Webster, who in the text gave a further geological description of the island. He states that in the lower dark brown clay (stratum *d*) of Alum Bay he found fossil shells, but he considered them as rather resembling those of the Woolwich beds than of the London clay. He did not consider the evidence that the elevation of the London clay took place prior to the deposition of the freshwater formation quite conclusive, but expressed his willingness to admit of any modification in his views which subsequent discoveries might render necessary.

In 1821 Mr. Webster†† gave an account of Hordwell Cliff and its freshwater beds.

In 1821 Mr. G. Sowerby‡‡ pointed out the occurrence of London clay fossils and *Septaria* in stratum "*d*" of Mr. Webster's section of

* Fossilia Hantonensia.

† Trans. Linnean Soc. vol. vi.

‡ Annales du Muséum, tom. i.

§ Trans. Geol. Soc. vol. i. p. 249.

|| Trans. Geol. Soc. vol. ii. p. 161.

¶ Ibid. vol. iv. p. 276 to 304, and 2nd Series, vol. ii. part i. p. 119.

** Sir H. Englefield's Isle of Wight.

†† Trans. Geol. Soc.

‡‡ Annals of Philosophy, vol. xviii. p. 216.

Alum Bay, and of the mixture of freshwater and marine shells in the so-called upper marine formation, which he considered to be of estuary origin. The sands, plastic clay, and London clay, he groups in one formation.

In 1822 Professor Sedgwick* confirmed the general correctness of the divisions introduced by Mr. Webster, and noticed that in stratum "d" the fossils rather resembled those of the Bognor rocks than those of Barton Cliff; he also found marine shells in the most northern vertical strata of White Cliff Bay agreeing in character with those of the sandy and overlying beds, which repose upon the London clay at Hordwell Cliff. In this notice Professor Sedgwick gave a detailed account of the nature and range of the freshwater beds over the north of the Isle of Wight, and showed the mixture and passage of the marine and freshwater exuvia, and the passage of indurated calcareous marls into clays and argillaceous marls.

In 1822 Dr. Mantell† noticed the great extent of the Bognor rocks, described their organic remains, and gave full details of the Newhaven plastic clay beds.

In 1824 Dr. Buckland‡ announced the discovery by Mr. Allan of the remains of the "*Anoplotherium commune*" in the lower freshwater limestone of Binstead.

In 1826 Mr. Lyell§ gave a detailed account of the beds underlying the London clay between Muddiford and the chalk at Stutland, and also of the beds above the London clay at Hordwell Cliff. He showed the paucity of organic remains in the former, and their great abundance in the latter, which he considered to belong exclusively to the lower freshwater formation.

In 1829 Mr. P. J. Martin|| contributed some interesting observations on the anticlinal line of the London and Hampshire basins.

In 1830 Mr. Pratt¶ discovered in the quarries of Binstead remains of the *Palæotherium* and of a new species of ruminant allied to *Moschus*.

In 1831 Professor Sedgwick** stated that he considered the anticlinal axis of the Isle of Wight to have been formed subsequently to the deposition of the lower beds of the freshwater formations, a portion of which he had discovered to be in vertical position in the cliffs of White Cliff Bay. He considered Mr. Webster's minor divisions not tenable, but the main ones he thought held good.

In 1832-33 Mr. Lyell†† coincided with these views of Professor Sedgwick, and traced the probable period and duration of the anticlinal disturbance of the Isle of Wight. He concluded that it was gradual and prolonged.

* Annals of Philosophy, vol. xix. p. 339 to 355.

† On the Geological Structure of Sussex.

‡ Annals of Philosophy, vol. xxvi. p. 360.

§ Trans. Geol. Soc. 2nd Series, vol. ii. part ii. p. 279 to 285.

|| Philosophical Magazine and Annals of Philosophy, 1829.

¶ Proceedings Geol. Soc. vol. i. p. 239.

** Ibid. vol. i. pp. 289 and 294.

†† Principles of Geology, Art. *Eocene strata*.

In 1833 Dr. Mantell* gave a further description of the Bognor rocks, and a more complete list of their organic remains.

In 1834 M. Elie de Beaumont† entered into the theoretical considerations of the period of the disturbance of the Isle of Wight, and the hydrographical state of the district during the Eocene period. He considered the strata to have been elevated after the accumulation of the freshwater formation, and contemporaneously with the elevation of the main axis of the Alps. The lignites of Alum Bay he thought synchronous with those of Soissons.

In 1835 Mr. Woodbine Parish, jun.‡, gave a list of the organic remains of the Bognor rocks.

In 1838 Mr. Bowerbank§ carefully measured some of the lower freshwater beds of Headon Hill, and noticed their want of organic remains.

In 1838 M. d'Archiac|| grouped the strata of the Isle of Wight into subdivisions parallel with those he has so well introduced in the French series, but still adhering to the divisions of Webster. He did not consider the period of the anticlinal disturbance to be satisfactorily proved.

In 1839 Mr. Bowerbank¶ described the strata at White Cliff Bay, and showed the great vertical range and abundance of the London clay fossils. He added a list of the organic remains he found in stratum "d" of Alum Bay, and these he considered to be of well-known London clay species. He viewed the sands, plastic clay and London as alternations of one group.

In 1839 the Rev. Mr. Clark** detailed the coast section from Poole harbour to the chalk at Stutland.

And in 1840 Mr. Bowerbank†† described several new species of shells and corals from Bracklesham Bay, and showed that species characteristic of the calcaire grossier were there common‡‡.

The details of the lithological characters of the different strata I have given in the sections, Plate IX. figs. 1 & 2, and need not here recapitulate. In these sections the strata are numbered, but I have also used the letters affixed to them in Mr. Webster's section of Alum Bay. There are a few points however connected with this subject to which I beg to call attention.

Both at Alum and White Cliff Bays the surface of the chalk on

* Geology of the South-East of England.

† Mémoires pour servir à une description géologique de la France, vol. iii. p. 153.

‡ Trans. Geol. Soc., 2nd Series, vol. vi. p. 313.

§ Mag. Nat. Hist., New Series, vol. ii. p. 674.

|| Bulletin de la Soc. Géol. de France, tome x. p. 168.

¶ Trans. Geol. Soc., 2nd Series, vol. vi. p. 169.

** Mag. Nat. Hist., New Series, vol. iii. p. 390.

†† *Ibid.* vol. iv. p. 23.

‡‡ Since the above was written, Professor Edward Forbes and Capt. Ibbetson have, at the last Meeting of the British Association at York, given an excellent account of the strata at White Cliff Bay, noticing particularly the great vertical range of organic remains and their abundance in stratum "d."—See Report of Brit. Assoc. for 1844.

which the tertiary beds repose is as usual much worn, and overlaid by a few feet of sand with green-coated slightly rolled flints, and some small flint pebbles. To this succeeds also, in both places, a considerable thickness of bright-coloured mottled clays, and then an important bed ("d") of sandy brown clay with *Septaria*. So far the sections are nearly identical in character, but above this bed a considerable difference of lithological structure exists. At Alum Bay we find a series of variously coloured siliceous sands with some greensands and carbonaceous clay, the whole almost free from calcareous matter. At White Cliff Bay, on the contrary, we have much less siliceous sand and carbonaceous clay, and more greensands, marls and calcareous sands. In the overlying freshwater, or rather, as they might probably be better termed, the fluvio-marine series, limestones are, on the contrary, more developed at Headon Hill than at White Cliff Bay. At Alum Bay as many as ten or eleven layers of pebbles may be traced in the vertical beds; they are marked "P" in the sections (Plate IX. fig. 1 & 2). In White Cliff Bay they are also numerous, but their number cannot be well ascertained owing to the many breaks in the cliffs. An unusual condition connected with this subject may be here noticed. In the lower limestones and sandstones, which, thin and unimportant at White Cliff Bay, swell out and become in places conglomeratic at Bembridge, not only do we find the common small round black flint pebbles imbedded in the rock, but also numerous angular flints, but little rolled, just as they are found in the common flint gravel. The following is a section of a block of this calcareous sandstone.

Even within small distances the lithological changes of some of the strata are considerable. The short projecting outcrop of the vertical beds precludes the exhibition of this fact at Alum and White Cliff Bays, but in the horizontal strata it may be constantly seen. Thus the thick bed of earthy limestone (No. 39) at Headon Hill passes in its range northward into a bed of sand; the thin limestones below this bed appear, on the contrary, to become more important in their range north-east. In the upper part of the series at Headon Hill, eighteen feet of hard limestone and indurated marl (71 and 72) almost entirely thin out before reaching Colwell Bay, so that the upper part of the freshwater or fluvio-marine series in its range northward and eastward loses much of its limestone, and presents thick masses of marls and clays—to this Professor Sedgwick has alluded.

At Hordwell Cliff, on the top of the London clay, there is a bed of sand fifteen feet thick overlaid by a few inches of grey clay; tracing

the range of these two strata a few hundred feet to the eastward, the sand is found to pass from yellow to ash colour and to thin out, whilst the overlying clay swells out and attains a thickness of twelve to fourteen feet.

The beds below the London clay from Barton to Poole harbour and Stutland consist almost entirely of sands: the same beds at Alum Bay show nearly equal proportions of clay and sand, whilst at White Cliff Bay the clays are to sands about as two to one. The thick strata of mottled clays and brown clays ("b and d") at Alum Bay are not exhibited at Stutland; or if, as I rather presume them to be, they are hidden by the slope and talus of the cliff, their thickness must be very inconsiderable.

On the whole, it is evident that siliceous sands preponderate to the westward and clays to the eastward, and that in the fluvio-marine deposits calcareous and siliceous rock strata are, in the lower division, most fully developed on the north side of the Isle of Wight, and, in the upper division, at Headon Hill.

Another point that may be further briefly noticed in connexion with the changes in lithological character is the frequent and considerable variation in the thickness of most of the strata. At Alum Bay the mottled clays "b" are 90 feet thick, and at White Cliff Bay as much as 140 feet. So also at the former place stratum "d" is 195 feet thick, whereas at the latter place it is about 300 feet thick. The succeeding sands and London clay at Alum Bay are 1020 feet in thickness, and at White Cliff Bay 820 feet. The Lower Headon Hill sands at the former place measure 120 feet, and at the latter 195 feet. At Headon Hill the lower division of the fluvio-marine series is but seventy feet thick, whereas at White Cliff Bay it attains a thickness of 350 feet. The upper division of this last group is more important at Headon Hill, but not being in either case complete, will not admit of accurate comparison. The result of two measurements of the series included between the chalk and the upper division of the fluvio-marine group (known as the upper marine formation) gave at Alum Bay 1500 feet, and at White Cliff Bay 1800 feet. My object in alluding to these facts is to show the irregular and active conditions prevailing during the accumulation of these tertiary strata, which it is important to bear in mind in examining their organic remains, whose distribution exhibits material corresponding modifications.

Organic Remains.

Neither in the thin bed of sand immediately overlying the chalk, nor in the succeeding thick beds of mottled clays "b," have any animal remains been hitherto found, so far as I am aware, either at Alum Bay or White Cliff Bay. But at both places the mass of brown sandy clay "d" overlying the mottled clays is well-characterized by peculiar fossils. At Alum Bay their existence has been long known. Mr. Webster noticed them in 1816, Mr. Sowerby in 1821, Prof.

Sedgwick in 1822, and in 1839 Mr. Bowerbank enumerated fourteen species*.

From this locality I procured the following twenty species, besides teeth of *Squalus* :—

Dentalium (<i>Ditrupa</i>) planum.	<i>Pyrula tricostata</i> ?
<i>Pectunculus brevirostris</i> .	<i>Lutraria oblata</i> ?
<i>Pholadomya margaritacea</i> .	<i>Rostellaria lucida</i> ?
<i>Panopæa intermedia</i> .	<i>Cerithium</i> , sp.
<i>Rostellaria Sowerbii</i> .	<i>Fusus</i> , sp.
<i>Turritella imbricataria</i> .	<i>Cytherea</i> , sp.
<i>Vermetus Bognorensis</i> .	<i>Ostrea</i> , sp.
<i>Pinna affinis</i> .	<i>Corbula</i> , sp.
<i>Calyptrea trochiformis</i> .	<i>Venericardia</i> , sp.
<i>Pleurotoma undata</i> ?	<i>Natica</i> , sp.

At White Cliff Bay this stratum is considerably thicker, but the fossils in it are neither so abundant nor so well-preserved. I believe they have been hitherto overlooked†. Owing to the very rainy weather during my stay there, I found it difficult to preserve specimens. They are sufficient however to prove the identity of the bed with that at Alum Bay. The species which most abound are characteristic, such as

Dentalium (<i>Ditrupa</i>) planum.	<i>Panopæa intermedia</i> .
<i>Pectunculus brevirostris</i> .	<i>Rostellaria Sowerbii</i> .
<i>Turritella imbricataria</i> .	<i>Pholadomya margaritacea</i> .

In the 750 feet of varied and brilliantly coloured strata between this stratum and stratum "B" at Alum Bay, no animal remains have, I believe, yet been found. Traces of vegetable matter in the shape of lignite, and some few impressions of leaves are however common‡.

Without a careful examination of this part of the series at various points in its range from Alum Bay to White Cliff Bay, it would be premature to decide whether these beds thin out or whether they become fossiliferous, and are represented by strata Nos. 5 to about 16 at the latter place§. This is a point which, if I could have found leisure, I had purposed to investigate more fully; I beg however to direct attention to it as one of considerable interest.

* The species enumerated by Mr. Bowerbank (*Geol. Tr. 2nd Ser. vol. vi. p. 172*) are as follows :—

<i>Venericardia planicosta</i> .	<i>Nucula amygdaloides</i> .
— <i>margaritacea</i> .	<i>Turritella conoidea</i> .
<i>Mya</i> (<i>Panopæa</i>) <i>intermedia</i> .	— <i>elongata</i> .
<i>Ostrea</i> , sp.	— <i>edita</i> .
<i>Venus</i> , sp.	<i>Murex innexus</i> .
<i>Cardium semigranulatum</i> .	<i>Buccinum desertum</i> .
<i>Nucula similis</i> .	

He also mentions that he found a well-preserved specimen of the *Cancer Leachii*, and I have since seen in his collection the *Cardium semistriatum*, *Natica labellata*, *Rostellaria Sowerbii*, *R. rimosa*, and two species of *Pleurotoma*.

† Since the above was written they have been fully noticed by Prof. E. Forbes and Capt. Ibbetson; and a notice concerning them was read at the York meeting of the British Association.

‡ Mr. Pratt has recently obtained some beautiful impressions of leaves in a bed of white and red clay, corresponding, as well as I can make out, with the stratum 17 of my section.

§ The latter case is the more probable.

In the greensands and brown clays of stratum "B" at Alum Bay organic remains abound, dispersed in distinct masses and groups. The lower part of the stratum, where it is much mixed with greensand, contains very few shells with some vegetable remains. At about twenty-seven feet from the bottom the clay becomes almost free from greensand, and contains numerous patches of the small *Nummulites elegans*. Above these the *Corbula pisum* abounds. The clay then again passes into a clayey greensand, a change accompanied by the almost entire disappearance of organic remains. A layer of Septaria and small flint pebbles then form an abrupt line of separation to a dark grey clay full of fossils, of which the principal are *Pleurotoma colon*, *Voluta luctator*, *Fusus longævus*, *Conus dormitor* and *Nummulites lævigatus*. The fossils again become scarcer in ascending, occurring only in irregular patches, and almost disappearing before the top of the stratum is reached.

The other fossils of this stratum "B" are well-known as common London clay species, and need not here be enumerated. In addition to the usual species I may however mention, that I found one specimen of the *Cyrena obovata*, and a *Spatangus* resembling the large one of the calcaire grossier (see description of Plate).

At White Cliff Bay, where the non-fossiliferous strata are limited to the sands No. 5, about 100 feet thick, we find a great vertical development of animal life, corresponding however only in part with that of stratum "B" at Alum Bay. At Alum Bay its vertical range is about 250 feet, and the species are not much grouped; whereas at White Cliff Bay its vertical range is about 600 feet, and the species are for the most part distinctly grouped, forming frequent bands of the *Venericardia planicostata*, *Turritella imbricata* and *Ostrea*. The *Venericardia* and *Turritella* abound in the centre of this group, in one part of which also Foraminifera are common, and in one part of it I have found a few *Miliolites* resembling the *M. saxorum* of Lamarck (*Trinocularia*, D'Orb.) and some *Gyrogonites*. The following are among the species I obtained from these strata:—

<i>Venericardia planicostata</i> .	<i>Solen obliquus</i> .
— <i>globosa</i> .	<i>Fusus longævus</i> .
<i>Turritella sulcifera</i> .	<i>Calyptrea trochiformis</i> .
<i>Nummulites elegans</i> .	<i>Corbula pisum</i> .
— <i>lævigata</i> .	<i>Turbinolia sulcata</i> .
<i>Nucula similis</i> .	<i>Pyrula</i> , 1 sp.
<i>Sanguinolaria Hollowaysii</i> .	And a <i>Natica</i> and <i>Cerithium</i> of the
<i>Pecten corneus</i> .	same species as occur in the over-
<i>Ostrea flabellula</i> .	lying freshwater deposits.

Mr. Bowerbank was the first to notice the fossils of these beds, which he, I think, justly considers to be the equivalent of the Bracklesham Bay strata, from which he and Mr. Edwards have procured a much larger and a very beautiful series of fossils. The upper beds of this division corresponding with stratum "B" of Alum Bay are most indistinctly exposed at White Bay, and have yielded fewer fossils: consequently the fauna above-mentioned, occurring low down in this division, must not be considered the equivalent in time of that at Alum Bay, where, as at Barton, the large development of

organic remains is in the top beds of this group. At Alum Bay these clays are succeeded by about 150, and at White Cliff Bay by about 200 feet of sands, in which no organic remains have yet been found at either place.

We next arrive at a series of considerable interest formed at Alum Bay, or rather Headon Hill, by a group of green marls and earthy limestones, about 150 feet thick, containing in its lower part but very few fossils, apparently only a few *Cytherea incrassata*; but in the upper part it is full of *Planorbis obtusus*, *Limnæa fusiformis* and *Melanopsis carinata*, and the other shells of the so-termed lower freshwater formation.

At White Cliff Bay this series attains a thickness of about 300 feet, and is characterized by singular groups of fossils. In the lowest bed we find the *Voluta spinosa*, and another species of *Voluta*, *Ostrea flabellula*, *Natica sigaretina*, *Pleurotoma colon*, *Cytherea incrassata*, *Calyptrea trochiformis*, and other London clay and marine species, associated with the *Cyrena obovata*, *Fusus labiatus*, *Melania fasciata*, *Neritina concava*, *Potamides acutus*, and *Paludina lenta*, species common to many of the overlying beds.

Next follow strata Nos. 23 and 24, containing fewer marine and more estuary and freshwater shells, but still with the same characteristic species of *Voluta*, *Turritella*, *Fusus*, *Cyrena*, *Potamides* and *Paludina*.

The marine species gradually disappear, and we find stratum No. 26 characterized by the *Melania fasciata* and *Cyrena obovata*.

In Nos. 27 to 30 occur the *Potamides acutus*, *Cyrena obovata*, *Paludina lenta*, and *Potamomya plana*.

And in the marls and limestones, Nos. 31 to 35, ending the series, the organic remains are almost, if not altogether, freshwater; they consist almost entirely of several species of the *Limnæa* and *Planorbis*.

At Headon Hill this division is succeeded by about twenty feet of marl (No. 60. Pl. IX.), with rounded flint pebbles, and containing

<i>Fusus labiatus</i> .	<i>Neritina concava</i> .
<i>Melania fasciata</i> .	<i>Melanopsis fusiformis</i> .
<i>Potamides</i> or <i>Cerithium</i> , several sp.	<i>Cyrena obovata</i> .
<i>Ostrea</i> .	<i>Corbula</i> .
<i>Natica</i> or <i>Ampullaria</i> .	<i>Nucula</i> ,—and many others (see p. 246).

The following characteristic species will serve, I think, to identify stratum 36, at White Cliff Bay, with this so-called upper marine of Headon Hill. Here also the beds are slightly conglomerate.

An <i>Ostrea</i> —the same as that which abounds at Colwell Bay.	<i>Melania fasciata</i> .
<i>Potamides cinctus</i> .	<i>Neritina concava</i> .
	<i>Melanopsis fusiformis</i> .

These are the most abundant species in these strata, but many other species occur, of which a large portion are yet undescribed.

At Headon Hill this bed is overlaid by a series of nearly 200 feet of marls and earthy limestones, containing principally the

<i>Paludina lenta</i> .	<i>Limnæa longiscata</i> .
<i>Cyrena obovata</i> .	<i>Planorbis euomphalus</i> .
— <i>cuneiformis</i> .	— <i>obtusius</i> .
<i>Potamides concavus</i> .	<i>Melanopsis</i> .
— <i>ventricosus</i> .	<i>Melania fasciata</i> .
— <i>cinctus</i> .	

and at White Cliff Bay by 100 feet of clays and marls, containing also almost exclusively the *Paludina lenta*, *Melanopsis carinata*, *Melania fasciata* and *Cyrena obovata*, and only a few specimens of *Limnæa* and *Planorbis*.

At Headon Hill I found in one of the limestones of this series (No. 69) a few teeth and bones. The former have been identified by Professor Owen as belonging to the *Palaotherium crassum* and *P. medium*.

Some of the bones were those of the Turtle, remains of which I met with also in stratum No. 74 of Headon Hill.

The distribution of the organic remains of this division will be more fully noticed at the end of this paper*.

In introducing local subdivisions and groups it may be convenient not only to consider the strata, with regard to their palæontological and lithological characters, but also to attend to those traces of minor disturbances effected during their accumulation, which may often usefully serve as lines of separation to the different groups. Inasmuch also as the effects resulting from these minor disturbances afford evidence of greater or lesser changes in the hydrographical condition of the district during the period when the formations were in course of accumulation, making slight breaks, but not destroying the continuance of like genera and species, although modifying their distribution, they may, I think, conveniently serve as points of division in the series. This is more especially the case, since these disturbances having been greater in one part than in another, the changes effected necessarily differ in importance, the condition of the fauna varying in the ratio of the amount of change, of which the effects are likewise almost always more or less visible in the lithological character of the beds.

There has been great difference of opinion with regard to the theoretical arrangement of the tertiary series of the Isle of Wight; some agreeing with Mr. Webster (to whom we are indebted for the first systematic attempt at classification), that they can be divided into "sands and plastic clays and London clay, with two freshwater and one upper marine formations;" others, on the contrary, contending that all the members of the lower part of the series alternate, rendering a division into London and Plastic clays impracticable, and considering that the upper freshwater and marine strata also alternate.

Now I do not think that Mr. Webster intended to separate the plastic and London clays into two formations, as we now understand

* See also the sections and their explanations at p. 252. In the preceding paragraph only the general grouping and most marked phenomena are noticed.

the word. He merely gave them as two divisions of the same formation, the former always underlying the latter and exhibiting a distinct character; and in this view I fully agree with him. He was doubtful however where the line of separation should be drawn, and hesitates where to place the brown clay stratum "*d.*" In lithological character he found it resemble the London clay, but its organic remains, *which he distinctly notices*, he considered as resembling those of the Woolwich beds. In fact, in his accounts of the tertiary formations of the Isle of Wight, both in the work of Sir Henry Englefield and in the Transactions of the Geological Society, he has well and ably described the geology of Alum Bay and Headon Hill, and soundly established such subdivisions as the then existing state of our palæontological and stratigraphical knowledge warranted. He proposed no fixed and positive system, but rather pointed out the analogies of the series with the classification then recently introduced by Cuvier and Brongniart into the Paris basin, and left it to be modified and completed as further observations might render necessary.

I purpose to restrict the term plastic clay solely to the mottled clays (which term would probably be preferable) marked "*b*" at Alum and White Cliff Bays. They are in both instances separated from the chalk only by a layer of a few feet of sand, pebbles, and large green-coated flints; but this bed, though unimportant here, is the representative, as I hope to show on a future occasion, of important fossiliferous beds at the east of the London basin, and at the north and east of the Paris basin. This layer may be called the lower sands. It is singular, that of all the varied beds of the tertiary series of England and France, the most persistent in its range, the most uniform in its composition, and the most regular in its organic remains (at present, I believe, it is only known to exhibit, and that rarely, traces of vegetable remains), are these mottled plastic clays. The whole of the beds below stratum "*B*" at Alum Bay have been considered as a great development of the limited series of sands and clays exhibited under the London clay at Woolwich, Lewisham, &c. I do not however think that their synchronism can be maintained; it is limited, I conceive, to the lower part only of Alum Bay. Cuvier partly limited the term "*Argile plastique*" to the variable and mottled clays without fossils occurring very generally below the "*Calcaire grossier*." The lignites and fossiliferous clays which occasionally intervene between this and the calcaire grossier he considers as subordinate, and designates them "*fausses glaises*." M. d'Archiac makes the clays and lignites together subordinate in his first and lowest group of the Eocene formations.

In France the geological position of these clays is constant over the larger portion of the Paris basin. It is represented, I conceive, solely by stratum "*b*" in the Isle of Wight, and underlies the whole of the London basin west of London, ranging north to Hertford and Bishops Stortford. The uniform absence, or at all events, the extreme rarity of animal remains in this division throughout its entire range, is a singular feature. The reasons for assuming the synchro-

2. GENERAL SECTION of the PARIS BASIN with reference to the conditions most resembling the HAMPSHIRE BASIN.

Arrangement according to M. d'ARCHIAC*.			Divisions of CUVIER, C. PRE- VOST, C. d'OR- BIGNY, etc.			Hampshire Basin.			
Subdivisions.									
MIOCENE.	6th Group. Calcaire lacustrine supérieur.	2. F. limestones (Calc. à Helix). 1. Clays and millstones.				Travertin supérieur.	U.F.W. Form.		
	5th Group. Grès et sables supérieurs.	3. Sandstones. 2. Sands. 1. Marls.				Grès de Fontainebleau.		Upper Marine Formation.	
		4th Group. Calcaire siliceux, ou Calc. lacustre moyen.				5. Millstones and clays. 4. } Freshwater marls and limestones. 3. }	Travertin moyen. Terrain gypseux.		Lower Freshwater Formation.
						3rd Group. Grès et sables moyens.	2. Gypseous series. 1. Freshwater marls and limestones.		
	2nd Group. Système calcaire.						3. Limestones. 2. Sandstones. 1. Sands.	Grès de Beauchamp.	
EOCENE.			4. Marls. 3. Upper Calc. grossier. 2. Calc. grossier. 1. Glauconie grossière.	Calcaire lisse. Calcaire grossier. Calcaire chlorité.	Lower Marine Formation.				
	1st Group. Sables et grès inférieurs.	6. Sands and clays. 5. Shelly beds (Lits coquilliers). 4. Sands. 3. Conglomerates & sands (Grès et poudingues). 2. Clays, lignite, etc. F. limestone.	Sables glauconifères. Terrain de l'argile plastique.	Plastic Clay Formation.					
		1. Sands (Glauconie inférieure) and calc. pisolitique.			Calcaire pisolitique.				
		CHALK							

nism of these non-fossiliferous beds, and for limiting this subdivision to the lower portion only of the Alum Bay section, will be shown more fully in treating of stratum "d."

In the meantime I beg to refer to the accompanying sections.

The first of these (2) is a general section of the Paris basin, viewed with reference to the maximum development of marine conditions in the lower groups, as being the conditions approximating the most closely to those of the Hampshire basin. In this diagram the divisions are taken from Brongniart and Cuvier, D'Archiac, Constant Prevost, Ch. d'Orbigny, &c., and the strata are represented of the average thickness on a scale of one inch to a hundred feet.

3. SECTION between KINGSCLEERE and HUNGERFORD *.

The next diagram, No. 3, drawn on the same scale, shows the extension of the mottled clays, in diminished importance, at the western extremity of the London basin.

4. SECTION between BASINGSTOKE and ODIHAM *.

No. 4 shows the same division in greater thickness at a point in the London basin further to the east; while No. 5 shows that these beds also range in the northern part of the basin.

5. SECTION near HERTFORD *.

The "lower sands" and the "mottled clays" with the thin over-

* The references in these diagrams are as follows :—

6. Bognor beds.	3. Mottled clays.
5. Pebble beds; frequently with ironsand.	2. Sand.
4. Sands (light-coloured).	1. Conglomerate of flints, green and ochreous sand.

The Bognor beds in (3) consist of brown and dark clays with *Panopæa intermedia*, *Pectunculus brevirostris* and *Dentalium planum*. In (4) they are brown or reddish clays, and contain *Pholadomya margaritacea*, *Vermetus Bognorensis* and *Dentalium planum*. In (5) they are brown sandy clays with *Pectunculus brevirostris* and *Panopæa intermedia*.

It seems proved by the distinct superposition of these beds that all of them are of the same age; namely, that of the lower group in the Isle of Wight.

lying bed of sand "c" at Alum Bay, may be considered as the first and lowest group of the Eocene strata of the Isle of Wight (Pl. IX.). They appear to me to mark a distinct period in the hydrographical condition of the tertiary epoch. Similar causes, judging from like results, were then evidently in operation over the greater part of the Paris, Isle of Wight and London basins. Whether the condition in the Isle of Wight basin were a deep sea-bottom or shallow waters, or whether the strata were accumulated rapidly or slowly, there is no evidence here to decide.

A careful examination shows that the surface of the upper thin sand "c" of the last group at Alum Bay has been worn and eroded, but in a much less degree than the surface of the chalk, by the action of water, and that on it are deposited strata differing both in lithological character and in their fauna from the preceding group, and indicating, by its underlie of coarse sand and large rounded flint pebbles, a considerable and sudden increase in the transporting powers of the water.

The organic remains of this division are extremely well-characterized, and form in the Isle of Wight and London basins an excellent geological horizon. Mr. G. Sowerby, as well as Mr. Bowerbank, have noticed the fossils of this bed as being well-known London clay fossils, and so far back as 1822 Prof. Sedgwick thought that they resembled the fossils of the Bognor rocks. Dr. Mantell and Mr. W. Parish have enumerated 30 or 32 species of fossils from the Bognor rocks. Of the 20 species I have found in stratum "d" at Alum Bay, 15 agree with those from Bognor. They include the most typical forms and groups, such as a species of *Pholadomya*, the *Panopæa intermedia*, *Pinna affinis*, *Pectunculus brevis*, *Dentalium planum*, *Vermetus Bognorensis* and *Rostellaria Sowerbii*. If the preceding mottled clays maintained a striking constancy of lithological character over a very wide area, these Bognor beds present a no less remarkable constancy in their palæontological character in the Hampshire and London basins. The fossils above enumerated characterize them equally at Alum Bay, Bognor, Basingstoke, Newbury, Sunning, Watford, Hertford, and many other places in the neighbourhood of London. See sections 3, 4 and 5, *ante*, p. 235.

The uniformity of characters prevailing in the first divisions of sands and mottled clays, which form the base of the tertiary formations throughout large areas of the Paris, Hampshire and London basins, indicating a widely-spread and continuous sea, and suggesting the origin of the detritus to have been probably from few and like sources, ceases at the end of that period, after which the increasing variety of the synchronous strata in the different basins proves the increasing disruptions and severance in the original connexion. Whatever may have been the depth and character of the waters at this epoch in the Isle of Wight basin, a subject that we shall be able to enter upon more fully in treating of the important fossiliferous beds of this age in the north of France and south-east of England, that a sudden change of some importance took place is

evident; first, from the considerably increased transporting power of the waters for a short time, the result of which has been to cover large areas of the London and Hampshire basins with a layer of from six inches to three or four feet thick of rolled flint pebbles, varying in size from a pea to an egg; secondly, from the sudden appearance (without transition or alternation) of a lithological structure not exhibited in any of the underlying tertiary strata, and evincing by its continuance the permanent nature of the change; and thirdly, by the presence of a distinct group of organic remains differing considerably from that of the beds below.

On examining the fossils of the Bognor beds at Alum Bay, it will be noticed that the deep-sea mollusca are absent; and that, on the contrary, their most characteristic and widely-spread genera form a group indicating marine waters of very moderate and tolerably uniform depths (e. g. *Pinna*, *Vermetus*, *Calyptrea*, *Panopæa*, *Pholadomya*, *Turritella*, &c.).

Sir Henry De la Beche, in his 'Theoretical Geology,' assigns, on the authority of Mr. Broderip, a depth not exceeding about twelve to sixteen fathoms to the genera constituting this group; and Prof. E. Forbes, in his Report on the Testacea of the Ægean Sea, gives further evidence to the same point; whence we may assume the predominating littoral and shallow-sea character of the testacea of this period. At the same time all the genera are essentially marine, unless we except the *Ostrea* and *Cerithium*, which also inhabit estuaries; but as the species of these genera occurring in this division are found so constantly associated with well-known and essentially marine families, their presence does not invalidate the argument. The weight of evidence is, I think, so far as the Hampshire basin is concerned, in favour of these beds having been deposited in an open and not a deep sea; whence, as these beds are here from 200 to 300 feet thick, and they are further overlaid by a great thickness of other marine strata, it follows that to have retained a constant fauna throughout so considerable a vertical range, the conditions under which they were formed must have changed progressively in adaptation to the prolonged existence of the same animal life. If therefore these Bognor beds exhibit throughout nearly their entire thickness a group of testacea, indicating a sea-bottom not often attaining a depth of thirty to forty fathoms, and averaging more probably not more than ten to twenty fathoms, this would clearly be insufficient for the accumulation of the mass of detritus necessary to form strata, which when desiccated are 200 to 300 feet thick. At the same time their lithological character denotes a tranquil and uniform deposit during some length of time: and as the evidence of fossils proves that the condition of animal life was similar at the end to that which existed at the commencement of this period, it follows that there must have been throughout its duration a quiet and gradual subsidence of the bed of the sea, immediately preceded, as before mentioned, by a disturbance sufficiently powerful and sudden partially to interrupt the continuity of deposit with the Paris basin, a circumstance rendering the recognition of the foreign

equivalents of the Bognor beds more difficult than with the preceding division.

In the third division of his first group of 'Sables inférieurs' M. d'Archiac places an irregular and variable deposit, termed by him 'Grès et poudingues,' and consisting of siliceous sands, imperfect sandstones and pebble beds, which immediately overlie the 'Argile plastique' and lignites. These conglomerate beds are overlaid successively by three other divisions, which complete his first group of the Eocene strata, a group succeeded by the 'Glaucanie grossière' and 'Calcaire grossier,' which he places in his second group (section p. 234). The three divisions above named he terms, in ascending order, 'Sables divers,' 'Lits coquilliers,' and 'Sables et glaises.' They consist of a very irregular mixture of siliceous and calcareous sand, concretions and imperfect earthy impure limestones, with frequent greensands and a good deal of clay. These beds pass one into another, rarely occur together, and are very irregular in their range and thickness. Taking the base of the Bognor beds as the diverging point in the mineral composition of the Paris with the Hampshire and London basins, it will be observed, that in the ascending series calcareous sands and limestones predominate in France, and argillaceous beds in England. It is not however until a later period that the lithological characters present their greatest dissimilarity.

The four above-mentioned divisions (3 to 6, section p. 234) of M. d'Archiac's lowest Eocene group do not hold in the English series; but it is probable that taken together they are represented partly by the Bognor beds. This appears to be the case for several reasons. In the first place the superposition is in the same order. Secondly, the commencement of both series indicates some change and disturbance in the Eocene seas. Thirdly, some similarity of mineral structure is traceable, and this in a somewhat marked manner, since the calcareous and sandy character of these beds at Bognor is well-known, and at White Cliff Bay they contain much greensand; whilst in France, in contrast with the general character of the French marine Eocene strata, they are also much mixed with greensands, yellow and brown clays, which frequently form compact and tenacious beds, and give rise to numerous springs from the percolation of water through the sands and limestones of the calcaire grossier. It is also probable, fourthly, by the analogy of organic remains; for notwithstanding that the fauna of the Bognor beds in England is very limited in species, it everywhere presents a very typical and constant group of fossils. In France the series is more developed than in England, and the organic remains are confined almost exclusively to the 5th division, viz. the 'Lits coquilliers,' a deposit almost as rich in fossils as the calcaire grossier. Most of the species are the same as those found in the calcaire grossier; but those which are distinct are in sufficient number to entitle the bed to be considered as a separate division. M. d'Archiac* enumerates 197 species from the 'Lits coquilliers,' and describes twenty seven of them as characteristic of

* Mém. de la Soc. Géol. de France, vol. v. p. 268.

these beds. M. Melleville's* distinctions are still more positive. I do not pretend to say that the Bognor beds are the exact equivalents of the 'Lits coquilliers'; but as these latter exhibit a varied and large marine fauna in part peculiar to the lower Eocene group in France, so in England do the Bognor beds maintain a fauna, certainly more restricted, but nevertheless equally distinctive and characteristic of that epoch.

As before mentioned, the Hampshire series exhibits a group of genera rich in individuals, but few in species, such as *Vermetus*, *Pinna*, *Pholadomya*, &c., indicating a marine littoral or a shallow sea deposit. The French beds, on the contrary, in the north and north-east of the Paris basin (in the central and southern districts this group thins out), contain many more genera, mostly rich in species, and show an admixture of freshwater shells of the genera *Melanopsis* and *Paludina* with numerous estuary shells, such as *Cerithium*, *Ampullaria*, *Cyrena*, &c., associated with marine forms, many of them inhabiting greater depths than those found in the Bognor rocks. As we have, therefore, evidence of conditions varying from a river-mouth to a tolerably deep sea-bottom, it follows that, from the more numerous zones of depth thence resulting, we might expect a greater variety of testacea than we meet with in the more uniform shallow sea deposit of the Bognor rocks. As corroborating this view of the influx of fresh waters into a sea, for the most part shallow, may be noticed an interesting fact mentioned by Professor E. Forbes in his Report on the Invertebrata of the Ægean Sea†, namely, that, with few exceptions, individuals of the same species are there dwarfish compared with their analogues in the Western Mediterranean, and he attributes this fact to the influx of the brackish waters of the Black Sea. Now the very same result is observable in the 'Lits coquilliers'; for M. d'Archiac, in his valuable paper on the Geology of the Département de l'Aisne (Mém. de la Soc. Géol. de France, vol. v. p. 271), states that they are distinguished, not only by distinct fossils but by varieties, constantly smaller, of species occurring in the calcaire grossier.

Of the species of testacea found in the Bognor beds in Hampshire and Sussex (thirty to thirty-two in number), the following eighteen occur in the 'Lits coquilliers' and 'Sables inférieurs'‡:—

<i>Anomia lineata</i> , Sow. (? <i>A. tenuistriata</i> , Lam.)	<i>Globulus sigaretinus</i> , Sow. (<i>Natica sigaretina</i> , Def.)
<i>Cassidaria carinata</i> , Lam.	<i>Infundibulum trochiforme</i> , Sow. (<i>Calyptræa trochiformis</i> , var. Lam.)
<i>Fusus rugosus</i> , Lam.?	

* Annales des Sciences Géologiques, vol. ii.

† Report of Brit. Assoc. 1843, p. 152.

‡ One of the most constant and characteristic fossils of the lower beds of the 'Lits coquilliers' is the *Nummulites planulatus* of M. d'Archiac (*N. elegans*, Sow.). Another characteristic species is the *Bifrontia laudensis*. In this country they have only been found higher in the series, and the latter is common at Bracklesham; but this at present is an anomaly. The *Panopæa intermedia*, a characteristic species from the Bognor beds, is I believe identical with the *Corbula dubia* of Deshayes, a fossil of this series in France.

- Nucula similis*, Sow. (*N. margaritacea*, Lam.) *Teredina antenautæ*, Sow. (*T. personata*, Lam.)
Ostrea flabellula, Lam. *Turritella edita* and *T. conoidea*, Sow. (*T. imbricata*, var. Lam.)
Panopæa intermedia, Sow. (? *P. remensis*, Mel., *Corbula dubia*, Desh.) *Venericardia planicostata*, var. Lam. (? *V. Suessonensis*, d'Arch.)*
Cardium semistriatum, Desh. *Pleurotoma undata*, Lam.
Pholadomya margaritacea, Sow. *Natica labellata*, Lam.
Pectunculus pulvinatus, Lam.
Pinna affinis, Sow. (*P. margaritacea*, Lam.)
Pyrula tricostata, Lam.

In Belgium also, M. Galeotti† mentions the *Pholadomya margaritacea*, a *Pectunculus*, (apparently *P. brevirostris*) *Cassidaria carinata*, a *Calyptrea* and a *Teredina*, as occurring amongst the fossils of his lowest group (système inférieure).

Combined with the other characters, this list affords strong presumptive evidence that the 'Lits coquilliers' and the Bognor beds are members of the same group, and nearly synchronous. The number of species common to the two is considerable, and gives a percentage equal to, or greater than, that of the species common to the calcaire grossier and the London clay. The difference of seabottom, clays predominating in the one and calcareous sands in the other, would, even under conditions otherwise similar, develop a somewhat different fauna. At the same time, amongst the fossils found in this group in England and France, there are a few, such as the *Pholadomya margaritacea*, *Ostrea bellovacina*, *Rostellaria Sowerbii*, *Panopæa intermedia*, &c., which rarely or never occur in either country in any of the overlying strata; but as some of these species range down to the chalk in parts of the Paris basin, further evidence is probably necessary before we can draw exact parallels. A greater number of English fossils are needed, and a more accurate comparison of the species of the two countries is still required, but there are sufficient indications to form in both countries a lower Eocene group characterized by a partially peculiar fauna; and whatever may be their foreign equivalents, it may I think be presumed, that the strata Nos. 4 to 6 at Alum Bay and Nos. 3 and 4 at White Cliff Bay are synchronous with the Bognor rocks, forming together a distinct and well-marked division. (See Pl. IX. and the description of the plate p. 252 *et seq.*).

It may be objected that the fossils of the Bognor rocks are those of the London clay. Some few of them no doubt are so, but as a group they are perfectly distinct and singularly constant; and it is from the circumstance of these two divisions occurring in common superposition in the London basin, that the fossils of the two have been constantly given without distinction as London clay fossils‡.

Now if the Bognor beds were accumulated in a shallow sea, any additional and thick marine deposit over them would not have

* I have since seen this species in M. d'Archiac's collection. It appears to be identical with the species I have found in the Isle of Wight, and apparently also with the one from Bognor.

† Mém. de l'Acad. Roy. de Bruxelles, vol. xii.

‡ This has been much the case formerly in France with regard to the 'Lits coquilliers,' the 'Glaucanie grossière,' the lower calcaire grossier and the upper calcaire grossier, and renders the present question still more difficult to determine.

been practicable without a further hydrographical change; whereas at both Alum Bay and White Cliff Bays we find them overlaid by several hundred feet of marine beds: it therefore follows that a considerable deepening of the sea must have taken place subsequent to the formation of the Bognor beds, and prior to or during the accumulation of the overlying sands and clays forming the mass of the London clay in the Isle of Wight, and at Bracklesham Bay and Barton.

That this disturbance was of greater importance than any of the preceding ones in the Eocene period, is evident from the more greatly altered palæontological and lithological conditions of the deposits. In France the preceding argillo-siliceous system is succeeded by the well-known calcareous system of the *calcaire grossier*, and in England by the argillaceous system of the London clay. The change however is not sudden; the lower beds, both in France and Hampshire, still continue to exhibit some evidence of similar origin, and in the former country the '*Glaucanie grossière*' underlies the *calcaire grossier*; while in the latter we find at the Isle of Wight a like predominance of argillaceous and calcareous greensands in the lower London clay beds.

The period in question was one of slow but considerable transition; and as such it is characterized by coarse drift sands and variable strata, resulting from the repeated change of land and sea levels. Whether the whole of the series between the Bognor beds and the Headon Hill sands at Alum Bay and White Cliff Bay are synchronous, is a point which requires for its elucidation a careful examination of the district between these two places. I think it is probable however that they will be found to be so. At Alum Bay no animal remains have hitherto been discovered in the lower part of this series, although at White Cliff Bay they abound; and at both places the remains of vegetables and plants are common. Should a further palæontological examination confirm the view that the Bognor beds are synchronous with the '*Lits coquilliers*,' then the superposition of the strata between them and the upper London clay will agree with that of the *glaucanie grossière*. In both cases the action of strong currents in the production of coarse sand and gravelly beds is exhibited, accompanied always by more or less green-coloured sand. Although perfectly distinct in lithological appearance, the fossils of the *glaucanie grossière* can scarcely be distinguished from those of the lower *calcaire grossier*, into which it passes; and of these two divisions this series of beds in the Isle of Wight may therefore prove to be the equivalents, although in greater development. The *Venericardia planicostata*, *Turritella sulcifera* and *Nummulites lævigatus*, &c., abound alike in both countries in the coarse sandy lower beds.

It is notwithstanding the case, that in this lower part of the series the number of species at present found in the Isle of Wight is not sufficiently great to establish an extensive comparison. In the range of these beds further to the eastward they become however highly fossiliferous; for although their superposition is not exhibited, there can be, I think, little doubt that the Bracklesham Bay beds belong to this period, as the mineral composition is the same; and

all, or almost all, the fossils which occur at White Cliff Bay, in the strata marked 9 to 11, are met with at Bracklesham; but at this latter place they are associated with numerous other species, identical for the most part with those of the glauconie grossière and lower calcaire grossier. More than sixty or seventy species have already been identified as common to the Bracklesham beds and the calcaire grossier (moyen), and Mr. Edwards and Mr. Bowerbank are daily adding to the list*.

In addition to the greater vertical range of organic remains in this series at White Cliff Bay than at Alum Bay, the fauna of these two localities presents some differences both in genera and species. As the superposition is however identical, the beds being in both cases overlaid and underlaid by similarly characterized strata, there can be little doubt of their synchronism; and the difference of the faunas must be attributed to the different hydrographical conditions under which they were accumulated.

In further evidence of the gradual changes in operation during this period, it may be noticed, that in the London clay at White Cliff Bay and Alum Bay we meet with indications of those fluviomarine conditions, which at a later period prevailed in fuller development; for I have found in the upper London clay at Alum Bay the "*Cyrena obovata*," and in the same division at White Cliff Bay the "*Potamides cinctus*," or if not that species, at all events a species identical with one in the overlying freshwater deposits, and a *Natica* or *Ampullaria* also analogous with one occurring in the overlying beds. Of the freshwater deposits the *Cyrena obovata* is one of the most characteristic shells.

Again at Alum Bay in the centre of stratum No. 29 may be seen a well-defined line of separation, marked by a sudden passage from clayey greensands to tough brown clays accompanied by a drift of pebbles underlying the latter. These two divisions of stratum No. 29 are also marked by different groups of testacea; the *Pectunculus*, *Sanguinolaria*, *Solen*, *Pecten*, &c. of the lower division being succeeded in the upper one by *Voluta*, *Pleurotoma*, *Conus*, &c. These latter constitute a deeper sea group than the former, showing a depression of the sea-bottom, and delaying for a period those freshwater conditions to which this locality was tending; for it was in the former or lower part that the *Cyrena obovata* occurred. Such is also the case with *Potamides cinctus* at White Cliff Bay; but the division of the strata is not there so well exhibited, as that portion of the cliff is much covered and broken. There is however there an evident difference, both palæontological and lithological, in the upper and lower strata of the London clay, although it is not so visible as at Alum Bay, which appears to have been nearer the centre of disturbance, as all the changes are there more abrupt and marked than at White Cliff Bay, where they exhibit more gradual transitions, indicating a disturbing force decreasing in effect as we proceed

* Since writing the above I have seen in M. A. d'Orbigny's collection a series of specimens from the glauconie grossière of Chaumont. As a group they present a strong analogy with those from Bracklesham Bay; and the same remarkable abundance of the *Venericardia planicostata* characterises both localities.

eastward, and ending possibly in a point of comparatively slight change and of nearly uniform deposit,—conditions applicable to the contemporaneous strata of the central and eastern portions of the London basin.

We now enter upon what may be termed, for the sake of distinction, the Fluvio-marine deposits, forming lithologically a distinct local group, exhibiting divisions of condition, but not of age, and palæontologically connected with and passing into the group below. These beds have therefore no relation with those similar ones partly of freshwater origin, which are known as the lower and upper freshwater and intervening marine formations of the Paris basin (groups 4, 5 and 6 of diagram 2).

The argillaceous strata last described are suddenly succeeded by a thick bed of sand without organic remains, but this bed is apparently of marine origin, since Professor Sedgwick has shown that the equivalent bed at Hordwell contains marine shells, and also that in the lower part of Hempstead Cliff marine or estuary fossils predominate. Further, the lower marls and clays of the overlying formations described as freshwater contain marine fossils. As this sand bed is well-exhibited and well-known at Headon Hill, where it forms the base of the hill, it may be convenient to term it the Headon Hill sand. It was formed during a period when the sea became shallow, estuaries replacing the open sea, and at a time also when a drift was deposited different from that previously accumulated; marls and earthy limestones succeeding the quartzose and green sands and pure clays.

At White Cliff Bay we find in stratum No. 21, immediately overlying the Headon Hill sands, an assemblage of fossils, presenting a singular mixture of marine, estuary and freshwater shells. Amongst them are the following species: *Cytherea incrassata*, *Voluta spinosa*, *Pleurotoma colon*, *Calyptræa trochiformis*, and other marine shells, associated with the *Potamides cinctus*, *Cyrena obovata*, *Paludina lenta*, *Melania fasciata*, &c. (and *Planorbis* according to Prof. E. Forbes and Captain Ibbetson).

In stratum No. 24 we have the same estuary and freshwater shells, with only the *Voluta* and *Cytherea* among marine forms, and, in addition to those species already quoted we find *Neritina concava*, and a *Natica* identical with an unnamed species from the calcaire grossier of Damery.

In 26 I only observed *Cyrena obovata* and *Melania fasciata*.

In 28 the *Potamomya plana* occurs with the *Potamides cinctus*, *Cyrena obovata*, and *Paludina lenta*.

In 29 and 31, *Paludina lenta* and *Serpula tenuis* are found; and in 32 the *Limnæa* and *Planorbis*.

At Alum Bay, or rather Headon Hill, this part of the series (Nos. 31 to somewhere about 56) is much less developed, and, as I have before mentioned, it affords only slight evidence of the partially marine conditions of the lower part, ending however, as at White Cliff Bay, with well-characterized freshwater marls and earthy limestones with *Limnæa* and *Planorbis*.

The palæontological changes exhibited in this series may have taken place without any further change of level. The slightly varying mineral composition, and the gradual change in the fauna, result probably from the tranquil filling-up of the estuary and the eventual barring-out of the salt water.

With reference to the so-called upper marine formation, the strata No. 56 to 61 in the Headon Hill, and No. 36 (which I consider its equivalent) in the White Cliff Bay section, it overlies the preceding group, from which it is not to be distinguished by stratification or mineral character, except that it contains some small flint pebbles. This however is a difference of some importance, as showing an increased moving force of water, and it indicates therefore an influx of the sea resulting probably from a slight further subsidence, and again restoring for a time, as evidenced by the organic remains, the conditions of the former estuary. The marine and estuary testacea, which had disappeared in the beds immediately preceding, now re-appear in considerable abundance, accompanied by some new species.

At White Cliff Bay the change has not been so important as at Headon Hill. At the former place one or two species of *Ostrea*, with the *Potamides cinctus*, *P. ventricosus*, *Melania fasciata*, *Cyrena obovata*, *C. cuneiformis*, and *Melanopsis* are common. At the latter place, however, a greater number of species occur, of which the most characteristic are, in addition to those just mentioned, *Fusus labiatus*, *Potamides acutus*, *Neritina concava*, a *Cerithium* and a *Natica* identical with species from the calcaire grossier of Damery, and probably also *Ampullaria Willemetii*.

At White Cliff Bay these beds pass upwards into thick strata of green marls and clays, of which almost the only fossils are *Paludina lenta*, *Cyrena obovata*, *Melania fasciata*, *Melanopsis* and *Potamides*. This does not indicate so much of a freshwater condition as does occasionally its equivalent at Headon Hill, which has been termed the upper freshwater formation. As before observed, the estuary fauna at No. 56 succeeds suddenly to the freshwater one, but in ascending order the change is more gradual, several estuary species, such as *Melania fasciata*, *Melanopsis fusiformis*, *Potamides ventricosus*, and *P. concavus*, appearing in No. 61. No. 62 is a thin bed full of *Planorbis* and *Limnæa*; and in the thick mass of earthy limestones marked Nos. 67 and 68, the several well-known species of these genera abound, and are associated with some teeth of the *Palæotherium* and bones of a Tortoise.

Slight changes of subsidence have again modified the higher beds to a small extent:—the upper part of the last stratum is partially a conglomerate, and in the marls which succeed we find the *Cyrena obovata*, and in stratum 70 *Melania fasciata*; in 71 the *Planorbis* and *Limnæa* again appear; in 72 bones of the Tortoise, with *Paludina lenta* and *Neritina concava*; in 73 *Cyrena obovata*; and in the bed No. 75 at the top of the series, and immediately underlying the gravel and sand, we find, in a brown clay having traces of lignite, *Melania fasciata*, *Potamides cinctus*, and *Cyrena obovata*, estuary

testacea, which we have therefore traced throughout the entire series of these fluvio-marine strata, both at Headon Hill and White Cliff Bay. It will be observed, however, that, on the whole, marine conditions are more predominant at the latter than at the former place.

In these remarks, having merely in view the unity of the series, I have only given the characteristic and more abundant fossils, worked out and marked on the spot from the different beds. The sequence appears complete and unbroken, the whole series consisting of deposits more or less marine and estuary, with interpolated freshwater beds, all characterized respectively by the same organic remains, varying only according to the variable conditions of the waters; at one time the abode of the *Potamides*, *Melania*, *Cytherea*, *Neritina*, *Cyrena*, and *Fusus*; and at another, more particularly, of the *Planorbis* and *Limnæa*. All these fossils range at intervals throughout the series, associated, when under predominating marine conditions, with other marine and estuary genera, and exhibiting no break in the sequence beyond that which would result from a contemporaneous fauna, subject to variations of marine and freshwater agencies.

With respect to the age and synchronism of these fluvio-marine deposits, I feel considerable hesitation in hazarding an opinion. We still want further evidence, and we especially require a more extended and careful comparison of the marine testacea with those of the Paris basin. At an early period in the history of tertiary geology they were considered to represent the lower freshwater, upper marine and upper freshwater formations of Cuvier and Brongniart; and this was assumed, first, from a supposed unconformable superposition on the London clay; secondly, from their having been accumulated, like the Paris series, under predominating freshwater conditions, and exhibiting a very similar sequence of strata; and, thirdly, from analogy of organic remains.

With respect to the first reason, there can, I think, be little doubt, as I shall endeavour to prove further on, that all the beds of the series, from the chalk to the top of the fluvio-marine beds, are in conformable stratification.

With regard to the second reason, it is now known that analogous freshwater conditions prevailed to some extent in the Paris basin prior to this period; for the upper strata of the calcaire grossier are frequently argillaceous, and contain subordinate beds of white and green freshwater marls, sands, and fine earthy limestones, closely resembling some of the overlying freshwater deposits, and, like them, containing also several species of *Paludina*, *Limnæa*, *Planorbis*, and *Melania*, showing evidence therefore of the commencement of freshwater conditions in the upper calcaire grossier—conditions traceable also occasionally in the grès de Beauchamp, and subsequently increasing in force, and ranging, with slight interruptions, to the completion of the Paris beds*.

* Constant Prevost has ably argued in support of his theory of affluents, that

The third reason, the subject of organic remains, requires a more lengthened notice. On this point, the main evidence on which the contemporaneity of the beds was considered to be established, consisted in the occurrence of the following fossils in the Isle of Wight and at Hordwell:—

<i>Limnæa columellaris</i> , Sow.	<i>Potamides concavus</i> , Sow.
— <i>longiscata</i> , Brongn.	— <i>duplex</i> , Sow.
— <i>minima</i> , Sow.	— <i>margaritaceus</i> , Sow.
— <i>maxima</i> , Sow.	— <i>plicatus</i> , Sow.
— <i>pyramidalis</i> , Sow.	— <i>ventricosus</i> , Sow.
— <i>fusiformis</i> , Sow.	— <i>rigidus</i> , Sow.
<i>Planorbis cylindricus</i> , Sow.	<i>Fusus labiatus</i> , Sow.
— <i>eumphalus</i> , Sow.	<i>Murex sexdentatus</i> , Sow.
— <i>lens</i> , Brongn.	<i>Helix globosus</i> , Sow.
— <i>obtus</i> , Sow.	<i>Cerithium funatum</i> , Sow.
— <i>rotundatus</i> , Brongn.	<i>Bulimus costellatus</i> , Sow.
<i>Ancylus elegans</i> , Sow.	— <i>ellipticus</i> , Sow.
<i>Ancillaria subulata</i> , Sow.	<i>Cyrena obovata</i> , Sow.
<i>Melanopsis brevis</i> , Sow.	— <i>cuneiformis</i> , Sow.
— <i>carinata</i> , Sow.	— <i>pulchra</i> , Sow.
— <i>fusiformis</i> , Sow.	<i>Corbula nitida</i> , Sow.
— <i>subulata</i> , Sow.	— <i>cuspidata</i> , Sow.
— <i>ancillarioides</i> , Desh.	<i>Venus incrassata</i> , Sow.
<i>Paludina lenta</i> , Sow.	<i>Mytilus affinis</i> , Sow.
— <i>concinna</i> *, Sow.	— <i>Brardii</i> , Fauj.
— <i>angulosa</i> , Sow.	<i>Nucula deltoidea</i> , Lam.
— <i>minuta</i> , Sow.	<i>Potamomya plana</i> , Sow.
<i>Melania costata</i> , Sow.	— <i>gregaria</i> , Sow.
— <i>fasciata</i> , Sow.	<i>Psammobia solida</i> , Sow.
— <i>minima</i> , Sow.	<i>Tellina ambigua</i> , Sow.
— <i>truncata</i> , Sow.	<i>Pollicipes reflexus</i> , Sow.
<i>Nerita aperta</i> , Sow.	<i>Unio Solandri</i> , Sow.
<i>Neritina concava</i> , Sow.	<i>Serpula tenuis</i> , Sow.
<i>Potamides acutus</i> , Sow.	<i>Balanus unguiformis</i> , Sow.
— <i>cinctus</i> , Sow.	

To these I have to add the following:—

<i>Infundibulum trochiforme</i> , Lam.	<i>Voluta spinosa</i> , Sow.
<i>Melania marginata</i> , Lam.	<i>Ostrea flabellula</i> , Lam.
<i>Venericardia</i> (globosa?), Sow.	— (crepidula?), Desh.
<i>Pleurotoma colon</i> , Sow.	<i>Dentalium entale</i> , Sow.

In Mr. Bowerbank's collection I have also seen *Sanguinolaria compressa*, Sow., *Globulus depressus*, Sow., *Modiola elegans*, Sow., and a *Pupa*; in Mr. Edwards's collection the *Cancellaria evulsa*, Sow., *Mitra pumila*, Sow., *Psammobia solida*, Sow., *Lucina divaricata*, Lam., with species of *Scalaria*, *Turritella*, *Tellina*, *Nematura*, *Helix*, new sp., and other genera; and in the collection of the Geological Society presented by Mr. S. Wood, we have *Melanopsis buccinoidea*, *Cyrena deperdita*, *Buccinum desertum*, *Neritina uniplicata*, and *Natica glaucinoides*.

The former of these two lists appears at first sight sufficiently di- in the Paris basin all the marine formations have their synchronous freshwater deposits—that they are interpolated and not superimposed. For numerous cases in point see his "Essai sur la Formation des Terrains des Environs de Paris," Acad. des Sciences, 1827, and his numerous papers in the Bull. de la Soc. Géol. de France.

* Probably the young of *P. lenta*.

stinct and characteristic. The great bulk of the specimens are named by English naturalists, and few foreign species are given by their foreign synonyms, those which are so being precisely the ones, such as *Limnæa longiscata*, *Planorbis rotundatus*, *P. lens*, &c., which at the period of publication were supposed to be peculiar to the fresh-water formations of the Paris basin.

But in reality we have in the seventy-eight species quoted above, (taking also their synonyms) twenty-three French species.

- Limnæa pyramidalis*, Brard and Sow. (*L. cornea*, Brongn.)
- *longiscata*, Brongn. and Sow.
- Planorbis lens*, Brongn. and Sow.
- *rotundatus*, Brongn. and Sow.
- Melanopsis ancillarioides*, Desh. (*M. buccinoidea*, Fer.)
- Corbula nitida*, Sow. and Desh.
- Nucula deltoidea*, Lam.
- Cerithium funatum*, Sow. (*Cerithium variabile*, Desh.)
- Potamides cinctus*, Sow. (*C. cinctum*, Desh.)
- *acutus*, Sow. (*C. acutum*, Desh.)
- *plicatus*, Sow. (*C. plicatum*? Lam.)
- *ventricosus*, Sow. (*C. ventricosum*, Desh.)
- Ancillaria subulata*, Sow. (*Ancilla subulata*, Lam.)
- Globulus depressus*, Sow. (*Natica depressa*, Desh.)
- Infundibulum trochiforme*, Lam. and Sow. (*Calyptrea trochiformis*, Desh.)
- Melania marginata*, Lam.
- Voluta spinosa*, Lam.
- Ostrea crepidula*, Desh.
- *flabellula*, Lam.
- Psammobia solida*, Sow. (*P. rudis*, Lam.)
- Lucina divaricata*, Lam.
- Natica glaucinoides*, Desh.

NOTE. It is doubtful whether the *Venus incrassata* of Sowerby is synonymous with the *Cytherea incrassata* of Deshayes, a well-known fossil of the lower part of the 'Grès de Fontainebleau.' M. Nyst of Brussels in his recent work * says distinctly that they are not the same species, but that the English species agrees rather with a Belgian one from the sandy calcareous beds of the middle Eocene period.

In addition to these foreign species found in the Isle of Wight, eight English species, viz. *Paludina lenta*, *Cyrena cuneiformis*, *C. deperdita*, *Mya* (*Potamomya*) *plana*, *Tellina ambigua*, *Dentalium entale*, *Pleurotoma colon* and *Cancellaria evulsa*, occur also in France.

Let us now examine the distribution of these thirty-one species in the French strata. Of the whole number I believe that only *Planorbis lens* and probably also *Limnæa cornea* are limited in their range to the 'Calcaires lacustres.' The *Planorbis rotundatus* has been found in some of the divisions of the 'Argile plastique'; and, according to M. d'Archiac, it occurs associated with *Limnæa longiscata* in the upper beds of the calcaire grossier†, but characterizes more especially the overlying freshwater deposits. The *Cyrena cuneiformis* and *Melanopsis buccinoidea* are characteristic of the 'Argile plastique' of the department of the Aisne‡ and the

* Description des Coquilles et Polyptères Fossiles des Terrains Tertiaires de la Belgique, p. 181.

† Mém. de la Soc. Géol. de France, vol. v. p. 236; also the Mém. of Constant Prévost.

‡ Mém. de la Soc. Géol. de France, vol. v. p. 303.

Marne*; and in the same formation the *Potamomya plana*, *Tellina ambigua*, *Paludina lenta* and *Melanopsis uncillarioides* occur occasionally; they rarely or never extend higher in the series.

The *Melania marginata*, *Natica depressa* and *N. glaucinoides* range from the 'Lits coquilliers' to the upper calcaire grossier†. The *Corbula nitida*, *Psammobia rudis* and *Voluta spinosa* are well-known calcaire grossier species, but occasionally the latter two range rather higher; the *Cancellaria evulsa*, *Pleurotoma colon* and *Cerithium ventricosum* are met with in the 'Lits coquilliers'; and the *Nucula deltoidea*, *Ancilla subulata*, *Calyptrea trochiformis*, *Lucina divaricata* and *Ostrea flabellula* are found in all the beds from the lower sands to the upper marine and freshwater deposits, and the *Cyrena deperdita* in the 'Grès moyens.'

The relations of the several species of the genus *Potamides* of Sowerby to those of the *Cerithium* of the French authors are rather ill-defined, and, from the great number of unnamed species, the subject requires further investigation. The *Cerithium cinctum* and *C. plicatum* are rather characteristic of the upper marine and freshwater deposits; whilst *C. acutum* and *C. concavum* are common in the upper 'Calcaire grossier,' *C. acutum* and *C. ventricosum* in the 'Lits coquilliers,' and *C. variabile* in the lignites of the 'Argile plastique‡.'

In addition to these recognised species, I have found in the calcaire grossier of Damery a species of *Natica* and a *Fusus*, not distinguishable from specimens from Headon Hill.

Thus the representative forms of the period of the 'Sables inférieurs' are more abundant even than those of the formations above the 'Calcaire grossier,' and as a group the forms of this latter deposit evidently predominate.

Referring again to the first list with regard to their geological range in this country, we find the following thirteen in the London clay of Barton, Alum Bay, or Bracklesham Bay:—

Dentalium entale.	Sanguinolaria compressa.
Ancillaria subulata.	Lucina divaricata.
Cancellaria evulsa.	Infundibulum (Calyptrea) trochiforme.
Mitra pumila.	Globulus (Natica) depressus.
Pleurotoma colon.	Modiola elegans.
Voluta spinosa.	Buccinum desertum.
Ostrea flabellula.	

Again, the *Melanopsis fusiformis*, *Paludina lenta*, *Cyrena obovata*, *C. cuneiformis* and *C. deperdita* are well-known and common fossils at New Cross and Woolwich in the beds under the London clay, and the *Cerithium funatum* at Newhaven; and Mr. Sowerby quotes the *Fusus labiatus* as occurring at Woolwich or Plumstead, *Potamomya plana* at Plumstead, and *Neritina concava* at Charlton.

It thus appears that nearly all the species which are known elsewhere show relations with the earlier Eocene strata.

Of the new species (nearly forty in number) at present confined

* Annales de l'Acad. de Rheims, Mém. of Rondot, p. 15.

† Mém. de la Soc. Géol. de France, vol. v. pp. 236, 261 and 272.

‡ Deshayes (Coq. Foss.) quotes the *Melania inquinata* and *Helix dubius* from the Isle of Wight, and M. d'Archiac (Bull. Soc. Géol. vol. x. p. 212) the *Ostrea crepidula*.

to the Isle of Wight, it is to be hoped that a more extensive comparison with the numerous French species which have yet to be described, will establish many analogues. In the meantime they do not of themselves afford sufficient evidence, since they are as likely to be new species of the age of the calcaire grossier as of the Fontainebleau sandstone. It is not from them that we can fix the age of the deposit; but the superposition of the deposit, as determined by their known associates, will on the other hand prove their date. They must therefore for the present be excluded from the scale, and our conclusions must be founded solely upon the evidence of the species which are known in other strata whose position is recognised.

With regard to the vegetable remains of these fluvio-marine strata, they cannot be taken in exact evidence. The *Gyrogonites* occur, it is true, in large numbers in the upper freshwater beds of Paris; but they are also common in some of the plastic clay beds of Epernay, and they occur likewise in the calcaire grossier. The *Carpolithes* also cannot be looked on as characteristic, nor can the animal remains be any longer considered in this light, since the remains of *Palæotherium*, *Anoplotherium* and *Lophiodon*, at first supposed to be characteristic of the period of the freshwater gypseous marls of Montmartre, have been found by M. Robert in the upper calcaire grossier at Nanterre, and since then by others in several places in the calcaire grossier. I have also met with remains of the *Lophiodon* and Crocodile in the sands above the plastic clay of Epernay*, and M. Ch. d'Orbigny has found them in the calcaire pisolitique at Meudon.

It is therefore, I think, very problematical whether the present grouping of the Isle of Wight tertiary formations, with reference to their foreign equivalents, can be maintained. The evidence is slightly conflicting, but still the weight of it is very considerably in favour of their being on the whole of an older date than that usually assigned to them. The occurrence of a bed of London clay ("B.") supposed to represent the calcaire grossier, succeeded by sands referred to the grès de Beauchamp, and then, as is the case with these formations in the Paris basin, overlaid by a series of freshwater green marls and earthy limestones, countenanced the hypothesis of a like chronological order, by exhibiting a very analogous lithological sequence. But according to M. d'Archiac, about half the fossils found in the grès de Beauchamp are peculiar to it†; and of the other half, which are common also to the calcaire grossier, only about nine species, or not quite three per cent. of the whole, are met with in the lower tertiary beds. In ascending through the lower freshwater, the upper marine and the upper freshwater formations of the Paris basin, a further departure from the fauna of the lower tertiary beds is perceptible, and very few species of the calcaire grossier are met with.

* Bull. de la Soc. Géol. de France, vol. ix., and others. Mr. S. Wood has a fine lower jaw of a Crocodile from Hordwell, and Mr. Bowerbank a palate of *Myliobates* from Headon Hill.

† Ibid., vol. ix. p. 69. The only one here characteristic is the *Cyrena deperdita*.

To view in its strongest light the palæontological evidence in favour of the supposed synchronism of the Isle of Wight freshwater or fluviomarine strata with the freshwater strata of the Paris basin, let us now, without breaking the fossils into groups according to the several divisions of these deposits, consider generally all the fossils of this series in the two countries, and see what identity can be established between them. About 400 species are known in these groups in France, and we have found about eighty in England. Now out of this number it appears that not more than ten or twelve species are common in these strata to the two countries; that not one-half of this small number can be regarded as characteristic of the beds over the calcaire grossier, while the majority of these common species range downwards, some into the calcaire grossier and some as low as the plastic clays: whereas a comparison of the fauna of these Isle of Wight fluviomarine strata with that of the calcaire grossier has shown that out of the thirty-one species having French analogues, as many as twenty-four are found in and below the calcaire grossier, and some of these are characteristic forms. It has also been shown that as many as twenty-two or twenty-three species of this fluviomarine fauna have been found in and below the London clay; that several of the species most common in the upper group at White Cliff Bay are met with in the middle group; and that no positive line of separation can be drawn there between the London clay and overlying beds, but that they pass palæontologically one into the other.

From this evidence, I am therefore inclined to consider the freshwater and estuary strata of the Isle of Wight to be synchronous or nearly so with the upper calcaire grossier. It may be objected, that, as these strata contain a considerable number of fossils peculiar to them, such cannot be the case. I have already stated why we should refuse to receive these new species as evidence of change of formation. Might we not, in fact, expect that the different geographical position and more freshwater condition of the strata in this locality would cause material modifications in the fauna, although still, as a whole, it may assimilate far more to that of the calcaire grossier and lower beds than to that of the more recent beds of the Paris basin, notwithstanding the prevalence during the accumulation of the latter of hydrographical conditions very similar to those existing during the formation of the Isle of Wight upper Eocene group?

That a parallelism of strata accompanied by identity of organic remains should exist over a sea-bottom subject to constant and variable but slow changes of subsidence and elevation is not probable: the greater deepening in one part than in another would allow both a greater thickness of deposit and a greater development of testacea; a littoral fauna might continue in one place, exhibiting little or no change, and at a distance it might gradually pass into others representing various zones of depth; or again, a rich and nearly constant marine fauna might exist in one part, whilst in another part a slow movement of subsidence or elevation of the same sea-bottom would destroy some genera and species and introduce others, either decreasing their number and bringing in genera of a wider geographical

range as the sea deepened, or else by a contrary movement gradually replacing the deep-sea testacea by others inhabiting shallow waters, estuaries and fresh waters. When the sea was once more deepened, the original fauna which had been preserved in a part of the neighbouring seas not subject to the same disturbances might again be distributed over the sea-bottom, so that there might be formed a deposit of small thickness and uniform palæontological character, the equivalent of a series of greater thickness and very variable fauna, but exhibiting nevertheless, as a condition of synchronism, and at each return to similar conditions, a tendency to the development of similar animal life.

With regard to the disturbances which have affected the Isle of Wight tertiary deposits, I have endeavoured to show the probability that a slow and quiet subsidence of the sea-bottom was taking place, commencing at least as early as the deposit of the Bognor beds, and continuing throughout the overlying marine sands and clays, gradually diminishing or ceasing as we reach the fluvio-marine strata, and at that period filling up the estuary and occasionally barring out the sea.

On the subject of the effects of the powerful disturbance by which the strata at Alum Bay and White Cliff Bay have been placed in a vertical position, it is evident that no unconformability of superposition has thence resulted. Commencing at the chalk, the strata are at first inclined at an angle of about 75° . This inclination shortly increases to 88° ; and at the upper part of the Bognor beds the strata are slightly reversed. They then continue nearly vertical to the fossiliferous clay stratum "B," where their dip is 80° . From this point upwards through the 250 feet of the London clay a gradual decrease in the dip may be observed. At a distance of 100 feet from the bottom of this bed it is 75° ; eighty feet further it is 70° ; it then rapidly decreases, first to 68° , and then to 60° . At the junction of the London clay and Headon Hill sands it is only 55° ; twenty feet higher it is 45° ; and 100 feet above this last point the green marls and limestones have a dip of 21° in the same direction. (See Pl. IX. fig. 1.) It is clear, therefore, that although not affected to the same extent, they are so in equal ratio, the force of the disturbance acting laterally from the chalk at the present sea-level to the lower part of the green marls and limestones. In further evidence of this it will be observed that the end of the green marls and limestones nearest to Alum Bay dips at 21° for a short distance, and that the strata are then fractured—the disjointed edges of the mass nearest to Alum Bay being eight feet below the level of the mass from which it is separated, this mass being prolonged northward at a very slight and uniform dip. (See Pl. IX. fig. 1.) Now this detached mass bears in itself evidence of having experienced the action of a protruding force; for if we prolong the plane of the larger and less-disturbed portion of Headon Hill, we shall find it intersect the plane of this small mass at angles of about 16° , and that the angle of depression, below the principal plane, subtends northward, and that of elevation

southward. Since however no general movement of depression of the strata on the north could have produced the corresponding angle of elevation, with the sands below as a fulcrum, it follows that this angle of elevation must have resulted from an elevatory force acting from the south, and consequently must have been the one passing through the Alum Bay strata.

At White Cliff Bay the effects of this disturbance are far more distinctly marked in the fluvio-marine beds. All the lower green marls and limestones exhibit through a thickness of 300 feet a dip varying from 80° to 85° . The operation of the disturbance ends rather abruptly about the centre of the series. At this point the limestone strata Nos. 32 and 34 outcrop at an angle of 82° , but curve immediately and rapidly, and resume, without break, and at a short distance to the northward, a position nearly horizontal. (See Pl. IX. fig. 2.)

It appears therefore that this important disturbance took place subsequently to the formation of the whole of the Isle of Wight tertiary series, but that there is no evidence to show its exact age*. Unlike the slow and comparatively tranquil changes of level in progress during the period we have treated of, this last and great change appears to me to have been one of active agency and of comparatively short duration.

EXPLANATION OF PLATE IX.

Fig. 1. SECTION EXHIBITED AT WHITE CLIFF BAY, AT THE EASTERN END OF THE ISLE OF WIGHT.

Description of Strata.		Thickness of the beds.	Association of genera and characteristic species in the chief fossiliferous beds.
		Feet.	
Upper Group. Headon Hill marls and limestone. (Fluvio-marine series.)	Gravel on the top.		37.
	38. Striped yellow, grey, brown and greenish clays with marly sands and a thin layer or two of hard indurated marl and a few seams of shells.	50?	Melanopsis fusiformis. Paludina lenta. Melania fasciata. Cyrena obovata.
	37. Green, and mottled red and green clays and marls.	45	36. Ostrea, 2 sp. Melania fasciata. Cyrena obovata.
	36. Dark grey clay beds and light-coloured indurated marl with <i>Ostrea</i> . A few rolled flint pebbles.	10	C. cuneiformis. Potamides acutus.
	35. Very light-coloured marl passing upwards into dark green marl.	5	P. cinctus. Melanopsis. Serpula.
		110	

* In the absence of data in our island to prove the age of this disturbance, we may refer to the opinion of Elie de Beaumont, who considers it to belong to the period of the elevation of the western chain of the Alps, with which it is parallel. This system of elevation, according to the same authority, took place at the end of the tertiary period, and immediately preceding the period of the diluvium and drift. (*Recherches sur quelques-unes des Révolutions de la Surface du Globe*, p. 65.)

Description of Strata.		Thickness of the beds.	Association of genera and characteristic species in the chief fossiliferous beds.
		Feet.	
<p>UPPER GROUP, continued.</p> <p>Headon Hill marls and limestone (Fluvio-marine series).</p> <p>Lower division.</p>	34. Hard light-coloured limestone with numerous fossils.	110	34-31.
	33. Dark grey marls passing upwards into very light-coloured greenish white marls.	9	<i>Limnæa longiscata</i> .
	32. Light yellow earthy limestone—lower part soft and porous, upper part hard.	5	<i>Planorbis euomphalus</i> .
	31. Beds scarcely exposed, apparently light green marls passing upwards into laminated grey marls with a few shells*.	12	— <i>rotundatus</i> .
	30. Light yellow limestone.	80?	29-28.
	29. Indistinct. Apparently light green marls, sometimes mottled with red, and containing a few shells and nodules of ferruginous clay.	1½	<i>Potamides cinctus</i> .
	28. Alternating beds of striped brown clays and striped greenish grey marls with a few layers of iron sandstone: shells numerous but friable, and much broken.	40?	<i>Cyrena obovata</i> .
	27. Striped ash-coloured and yellow sand.		— <i>cuneiformis</i> .
	26. Light green and grey marls, with a few subordinate central layers of ash-coloured and ochreous sands,—a few seams of shells.	24	<i>Potamomya plana</i> .
	25. Yellow and light coloured sands.	7	<i>Paludina lenta</i> .
	24. Alternating brown, grey and greenish grey sandy clays and marls—in places full of shells and small crystals of selenite—passes upwards into a fine ash-coloured sand with impressions of shells.		<i>Serpula tenuis</i> .
	23. White and ochreous sand.		<i>Melanopsis</i> .
	22. Compact thick-bedded light greenish grey marly sand with light yellow and brown partings—contains numerous tolerably firm casts and impressions of shells very delicately marked, but no shell remaining.	24	26.
	21. Light greenish marl with one bed of lignite, crystals of selenite, and numerous fossils—passes upwards into a laminated brown clay without shells, which again passes upwards into 22.	7	<i>Cyrena obovata</i> .
			<i>Melania fasciata</i> .
			24.
			<i>Fusus labiatus</i> .
<p>MIDDLE GROUP.</p> <p>London Clay series.</p> <p>Upper division †.</p>	20. <i>Headon Hill Sands</i> .—Fine light yellow sand, with a few ochreous and ash-coloured bands:—passes upwards into a light yellow sand with occasional tinges of red colour, and in the upper part alternating with beds of ironsand. It contains a thin seam of small black flint pebbles, and no fossils.	39	<i>Ostrea flabellula</i> .
		8	<i>Cytherea incrassata</i> .
			<i>Potamides cinctus</i> .
			<i>Melanopsis</i> .
			<i>Neritina concava</i> .
			<i>Melania fasciata</i> .
			<i>Cyrena obovata</i> (frequently bored).
		22	
		4	<i>Natica</i> .
			<i>Voluta</i> .
			<i>Turritella</i> .
			Fishes, bones, and scales.
			21.
			<i>Terebellum</i> .
		36	<i>Voluta spinosa</i> .
			<i>Pleurotoma colon</i> .
			<i>Ostrea flabellula</i> .
			<i>Potamides cinctus</i> .
			<i>Neritina concava</i> .
		52	<i>Calyptrea</i> .
			<i>Cytherea incrassata</i> .
			<i>Venericardia</i> .
			<i>Fusus labiatus</i> .
			<i>Melania</i> .
			<i>Paludina lenta</i> .
			<i>Ostrea</i> .
			<i>Planorbis</i> .
			Bones and scales of fishes.
		202	<i>Dentalium entale</i> .
			<i>Cyrena obovata</i> .
		751	

* And *Gyrogonites*, found by Prof. E. Forbes and Captain Ibbetson.

† This division may be above or below No. 20.

		Description of Strata.		Thickness of the beds.	Association of genera and characteristic species in the chief fossiliferous beds.
				Feet.	
MIDDLE GROUP, continued. London Clay series.	Upper division.	19. Laminated brown clay passing upwards into massive clayey sand of a greenish-grey colour.		751	
		18. Fine bright yellow sand with a few thin seams of ash-coloured clay.		37	16.
		17. An imperfectly exhibited series of brown and grey clays, finely laminated with brown and yellow sand, containing subordinate green clays and marls. In the upper part the sand predominates. A few small flint pebbles scattered throughout. Fossils.		44	Fusus longævus. Corbula revoluta. C. pisum. Dentalium entale. Calyptræa. Turritella.
		16. Brown clay. Numerous <i>Foraminifera</i> , with <i>Ostrea</i> and <i>Venericardia</i> :—passes upwards into dark greenish marly sand perforated in places by tubes of green-coloured sand containing a few shells and small crystals of selenite.		162	Anomia striata. Natica. Nummulites elegans. Cerithium or Potamides (cinctum). Venericardia planicostata.
		15. Light-coloured, compact and fine-grained sandstone.		32	Ostrea, 3 sp. Flustra.
		14. Imperfectly exhibited. Apparently grey, brown and greenish clays with a few shells—passes upwards into a light yellow sand.		4	14–12. Venericardia planicostata.
		13. Brownish grey clay and calcareous greensands with a layer of pebbles and numerous shells, but the junction with upper bed not shown.		86	— ? globosa. Turritella sulcifera. Calyptræa trochiformis. Ostrea.
		12. Finely laminated brown clay passing upwards into grey sand, and then into dark grey clay with vegetable impressions. A thin layer of shells about eighteen feet from the bottom.		54	Corbula globosa. — revoluta. Anomia. Natica. Dentalium entale. Pectunculus. Nummulites lævigatus. Nucula.
		11. Massive light and dark-coloured slightly calcareous greensand with small soft white calcareous concretions. In the upper half numerous shells and teeth of fishes.		62	Miliolites (Triloculina). Tellina. Turbinolia sulcata. Voluta spinosa. Cytheræa. Teeth of Squalus.
		10. Laminated grey clay with some beds of calcareous greensand, a few layers of ironsand, and one or two beds of lignite about one or two feet thick. A strong ferruginous spring issues from the junction with 11, converting part of the beach into an ironstone conglomerate. ? A few pebbles. Passes into 11.		76	11. Pecten cornea. Turritella sulcifera. Nummulites elegans. N. scabra (? lævigatus). Sanguinolaria Holloyi.
	Lower division.	9. Calcareous clayey green and ironsand, with numerous shells. Upper part greensand only, with only one seam of shells. Shells grouped in genera.		52	— compressa. Anomia striata. Dentalium.
		8. Alternating beds of greensand and finely laminated grey and brown clay. A few thin seams of lignite—passes into the overlying bed (9.).		18	Venericardia planicostata.
		7. Yellow sand.		10	Nucula similis.
		6. Grey sandy clay and brown clay finely		1288	Solen obliquus.

Description of Strata.		Thickness of the beds.	Association of genera and characteristic species in the chief fossiliferous beds.
		Feet.	
MIDDLE GROUP, cont. (London Clay series.)	Lower division.	1288	
	laminated with yellow sand. A few subor- dinate beds of impure greensand and seams of iron-sandstone, and a few imperfect septa- ria. At the bottom ten inches of flint pebbles about the size of a swan's eggs. Vegetable impressions. Few or no shells. 5. Broad striped sands of various shades of yellow passing upwards into nearly white sand. Two feet of iron-sandstone at the bottom.	95	4. <i>Pectunculus brevisrostris</i> . <i>Venericardia</i> . <i>Panopæa intermedia</i> . <i>Nucula</i> . <i>Rostellaria</i> . <i>Fusus</i> . <i>Pholadomya margari- tacea</i> .
LOWER GROUP.	Bogor beds.	98	
	Mottled clays.	75	3. <i>Dentalium (Ditrupe)</i> <i>planum</i> . — ? <i>entale</i> . <i>Venericardia</i> . <i>Pecten</i> ? <i>Cytherea</i> . <i>Turritella</i> . <i>Ostrea flabellula</i> .
		232 ?	
		140	No animal remains dis- covered.
		2	
		1930	

CHALK, in vertical beds. Many fossils, especially small corals. Strike S. 8° E.

FIG. 2. SECTION EXHIBITED AT ALUM BAY, ON THE NORTH-WESTERN SIDE OF THE ISLE OF WIGHT.

GRAVEL, consisting of rather angular chalk flints imbedded in a small quantity of loose yellow sand—passes downwards into yellow and whitish sand with patches and irregular layers of the same gravel.

UPPER GROUP. (Fluvio-marine series.) Headon Hill marls and lime- stones—Upper division.	75, 74. Whitish sand and thin calcareous sandstone irregularly interstratified with a few hard conglomerates. About ten feet from the underlying clays occurs one foot of brown clay and imperfect lignite, and one foot of greenish marl with shells.	40 ?	75-72. <i>Paludina lenta</i> . <i>Cyrena obovata</i> . <i>C. cuneiformis</i> . <i>Melania fasciata</i> . <i>Potamides concavus</i> . <i>P. ventricosus</i> . Turtle.
	73. Red clay mottled with yellow and green coloured clay and marls and layers of whitish sand.		
	72. Greenish grey, brown, grey and yel- low laminated sandy clays and marls :—in the upper part numerous very imperfect	20	
		60	

* Prof. E. Forbes and Captain Ibbetson state that they have observed *Cyprina planata* in these beds (3 & 4).

Description of Strata.		Thickness of the beds.	Association of genera and characteristic species in the chief fossiliferous beds.
		Feet.	
UPPER GROUP, continued. (Fluvio-marine series.)	Headon Hill marls and limestones—Lower division.	52. Striped grey clay and whitish sand.	190
		51. Light grey clay.	10
		50. Light yellow sand.	1
		49. Light brown clay.	3
		48. White and yellow sand.	2
		47. Brown laminated clay with irregular patches of lignite.	3
		46. Light green marl interlaminated with grey and yellow sand.	1½
		45. Soft light yellow earthy limestone with shells—contains a central layer of three inches of marl full of shells.	4
		44. Light greenish marl with shells.	5
		43, 42. Earthy limestone with a few shells, and underlaid by six inches of calcareous sand full of shells.	1½
		41. Green marl passing into striped greyish sand and grey clay: very irregular. Shells numerous. One inch of green and black clay underlies it.	1½
		40, 39, 38. Light-coloured sands underlaid by two inches of dark clay full of shells, and then three inches of a brown calcareous band full of shells. An irregular seam of lignite.	6
		37, 36. Olive-green clay and marl passing into bright green with bands of white sand in the lower part. Few shells.	1
		35. Green marl passing into grey, with an irregular and thin underlying band of lignite.	3½
		34. Sandy and dirty green clay.	6
		33, 32. Sand, speckled brown and white, passing into light brownish white sand.	1
		31. Mottled green, yellow and red clay, passing into bright ochreous sand; very irregular.	2
			4
		MIDDLE GROUP. (London Clay.)	Upper division.
29. Commencing at the top is a black clay with a very few shells in seams and patches—in descending it becomes browner, and very fossiliferous. At point X (see Pl. IX. fig. 1) is a layer of large septaria underlaid by a seam of small flint pebbles, immediately below which is thirty feet of greensand, in which fossils are extremely scarce—this then passes gradually into a brown clay with numerous shells and remains of <i>Foraminifera</i> , and then again into green sands with a few very small flint pebbles and traces of vegetable matter, but with few shells. In these beds we find six or seven layers of septaria. (Stratum "B" of Webster.)			

		Description of Strata.	Thickness of the beds.	Association of genera and characteristic species in the chief fossiliferous beds.	
			Feet.		
Middle Group, continued. (London Clay.)	Lower division.	28. Yellow sands passing successively into sands of white, yellow and ochreous tints, with six inches of large pebbles at top.	626		
		27. Tough light bluish clay, capped by a thin seam of dark red clay, and passing downward into a brown sandy clay with five layers of lignite, varying in thickness from six inches to two feet.	42		
		26. Bright-coloured sands successively ochreous, striped white and red, white, ochreous, brown (with pebbles), yellow, white, red, striped white and yellow.	71		
		25. Whitish sands succeeded by yellow and yellow and red-striped and brilliant red sands. Three straggling layers of small flint pebbles.	77		
		24. Dark grey clay with a seam of lignite one foot thick. Laminated dark clay with whitish sand and thin lignites. Very light grey lumpy clay with peculiar vegetable remains, and an underlying bed of fifteen inches of finely laminated light grey sandstone. Laminated dark grey clay with lignite and a layer of septaria.	70		
		23. Brown, yellow, white, yellow and brown striped sands. Red and yellow sands.	98		28-7. No organic remains of animals yet discovered.
		22. White sands striped with brown.	41		
		21. Pale and bright yellow sands.	24		
		20. Black and brown clay laminated with brownish and whitish sand. The weathered upper edges light-coloured for many yards. Traces of lignite.	13		
		19. Light grey clay.	60		
		18. Whitish light yellow, reddish bright yellow, ochreous and yellow striped sands.	5		
		17. White foliated clay, very fine and compact, and spotted and striped with red.	39		
		16. Yellow sand with a little red. Three inches of iron-sandstone underneath.	4		
		15. Light green sand.	11		
		14. Ochreous sand.	9		
		13. Black clay, passing into whitish sands with seams of lignite, and this again into black clay. Grey sand with partings of grey clay and seams of lignite.	10		
		12. Finely laminated tough brown and grey clay.	59		
		11. Thick-bedded black sand. Passes into (10).	17		
		10. Ash-coloured sand with greenish-coloured stripes. Passes into (9).	16		
		9. Finely laminated grey sand and clay; the clay preponderating.	17		
		8. Grey sand and clay resembling (9), but more sandy.	29		
		7. Bright yellow sand with underlying iron-sandstone.	14		
			24		
			1376		

Description of Strata.		Thickness of the beds.	Association of genera and characteristic species in the chief fossiliferous beds.
		Feet.	
LOWER GROUP.	Bognor beds.	6.	6-4.
		1376	Panopæa intermedia. P. virgula. Pectunculus brevirostris. Vermetus Bognorensis. Rostellaria Sowerbyi.
		40	Pholadomya margaritacea. Turritella imbricata, var.
		18	Pinna affinis. Ostrea, 2 sp. Dentalium (Ditrupe) planum. Venericardia planicostata, var. ? Suessonensis. Pyrula. Calyptraea trochiformis. Natica. Fusus. Corbula. Cerithium. Pleurotoma. Lutraria.
	Mottled clays.	135	
		4	
			No organic remains of animals yet discovered.
	Lower sands.	86	
		3	
		1664	

CHALK, with flints. Upper surface worn and uneven.

NOTE.—Mr. Webster's sands and plastic clay include strata Nos. 1 to 28 at Alum Bay, and the London clay of that author is No. 29. The strata are more subdivided at Alum Bay than at Whitecliff Bay, chiefly on account of their being more perfectly exhibited in the former. It should be understood that the lines of separation between the upper and lower divisions of the upper group at Headon Hill are only approximative, and that the lists of organic remains do not include all those found, but are intended to intimate that such species or genera occur in some part of the series associated with others, which are either less abundant or more necessary to the argument, and which therefore in the latter case are mentioned in the text.