1. *On the probable Age of the LONDON CLAY, and its Relations to the Hampshire and Paris Tertiary Systems.* By J. PRESTWICH, Jun., Esq., F.G.S. &c.

It is not intended on the present occasion to enter generally upon the subject* of the London clay, nor yet to describe its structure and fauna further than may be necessary to prove the argument of this paper, which is, that the London clay of Highgate, Sheppey, and other places in the neighbourhood of London, apparently is not, as it has hitherto been considered, synchronous with the Calcaire grossier of Paris, nor yet with the clays of Barton, and the clays and sands of Bracklesham; but that it is of older date than these, and consequently occupies a lower position in the Eocene series.

* For previous descriptions (Mr. Webster's especially) of the *Hampshire Tertiaries*, see my paper in the Journal of the Society for August 1846, pp. 224 to 226. Since then Mr. Charles Wood has contributed some important information to our knowledge of Hordwell Cliff. His list of the organic remains from its freshwater and fluvi-marine strata is far more complete than my own.

The following are the additional species given by Mr. Wood:—

Marine Beds.

Acteon.	Cytherea obliqua, <i>Desh.</i>
Arca elegans, <i>S. Wood, MS.</i>	Cytherina.
Cæcum.	Gastrochæna.
Cancellaria muricata, <i>S. Wood, MS.</i>	Lucina pulvinata, <i>S. Wood, MS.</i>
— elongata, <i>S. Wood, MS.</i>	Melania angulata, <i>S. Wood, MS.</i>
Cardium.	— muricata, <i>S. Wood, MS.</i>
Cerithium terebrale, <i>S. Wood, MS.</i>	Melanopsis minuta, <i>S. Wood, MS.</i>
Chemnitzia, 2 species.	Natica epiglottina, <i>Lam.</i>
Cristellaria.	Odostomia subulata, <i>S. Wood, MS.</i>
Cyrena cycladiformis, <i>Desh.</i>	

Freshwater Beds.

Cyclas exigua, <i>S. Wood, MS.</i>	Melania circincta?, <i>Lea.</i>
Cyrena obliquata, <i>Desh.</i>	Paludina unicolor, <i>Swainson.</i>
— pisum, <i>Desh.</i>	— ? impurata, <i>S. Wood, MS.</i>
Dreissena Brardii, <i>Faujas.</i>	Planorbis hemistoma?, <i>Sow.</i>
Helix labyrinthicus, <i>Say.</i>	— planulatus, <i>Desh.</i>
— striatella, <i>Anthony.</i>	— platystoma, <i>S. Wood, MS.</i>
Lymnea strigosa, <i>Brong.</i>	Potomomya subangulata, <i>Sow.</i>
— elodes, <i>Say.</i>	Potamides funatum, <i>Sow.</i>
Melania carinata, <i>S. Wood, MS.</i>	Succinea imperspicua, <i>S. Wood, MS.</i>
— subulaspira, <i>S. Wood, MS.</i>	

Besides these, Mr. Wood found a magnificent lower jaw of an *Alligator*, for which he proposes the specific name of *Hantoniensis*; also remains of the following Vertebrata—*Dichobune*, *Palæotherium*, *Seal*, *Lepidosteus fimbriatus*, *S. Wood*,—two new genera, for which he proposes the names of *Microchærus erinaceus* and *Spalacodon*, and a Rodent allied to *Anomalurus* and *Sciurus*. (See Charlesworth's London Geol. Journal, Nos. 1 and 3, 1846–47.)

To the Marchioness of Hastings we are also indebted for some valuable palæontological discoveries in the freshwater beds of Hordwell Cliff, including a new species of extinct *Pachyderm*, which Prof. Owen has named *Paloplotherium*, and a Crocodile, named by Prof. Owen *Crocodylus Hastingsii*. (See Report of the Meeting of the Brit. Assoc. for 1847, in the 'Athenæum' of the 3rd of July.)

These further observations confirm the views expressed in my last paper, that these strata are not the equivalents of the freshwater formations of Paris, but are rather of the age of the Upper Calcaire grossier. The evidence however is yet far from being sufficiently positive.—September 1847.

Old terms are altered with difficulty; they have the sanction of usage and weight of successive authorities, and are in geology occasionally apt, by their theoretical signification, to stand in lieu of proof. In the case before us, considering up to a late period the contemporaneity of the marine strata of London, Bracklesham, Barton, and Paris well established, I thought it scarcely necessary to investigate the data on which their identification rested; or rather, proceeding under the full impression of its correctness, I yielded to it facts, and endeavoured to conform to it phænomena, which, had I allowed them their due influence, would have earlier led to independent inferences. The differences known to exist in the fauna of these groups had been attributed solely to changes of condition and distance—causes, which as they produce effects whose limits are not easily assignable, sometimes prevent inquiry by offering an apparently available solution to anomalies in the faunæ, that might otherwise lead to further and more correct investigation.

I allude more particularly to this point, because in my paper on the Tertiaries of the Isle of Wight, following the usually received nomenclature, I applied the term "*London clay*" to the clays of Barton, the sands of Bracklesham, and their associated strata, and designated the group below them the "*Bognor beds*," in consequence of the typical fauna of the Bognor rocks occurring in this portion of the Hampshire series. If however the evidence which I shall lay before the Society this evening be conclusive, these terms must be changed.

Either the clays of Barton and Bracklesham are the *London clay*, and the clays of Highgate and London are not the *London clay*; or else we must restrict the term to the marine clay of the neighbourhood of London and its equivalent elsewhere: in which case its application to the clays of Barton and the clays and sands of Bracklesham must, as I shall endeavour to show, be discontinued.

With this exception, I adhere to the arrangement introduced in my former paper. In lieu of the term *London clay* in the sections of Alum and White-Cliff Bay, I propose that the terms *Barton clays* and *Bracklesham sands* be used. Below these divisions are the *Bognor beds*,—the strata which I conceive to be the sole equivalent of the *London clay*; and then the *mottled clays and sands*, the latter resting immediately upon the chalk. (See tabular arrangement of the strata at the end of these papers, and Plate XIV.)

Comparison with the "Calcaire grossier."

Let us first examine the present received hypothesis, that the beds of Barton, Bracklesham and London are synchronous with one another as well as with the *Calcaire grossier*, and see upon what grounds it is established.

In the immediate neighbourhoods of Paris and of London the tertiary series commences with variable strata of sands and clays reposing upon the chalk; these are for the most part unfossiliferous, but contain occasionally subordinate beds with fluviatile and estuary shells*.

* In France, and more especially in England, these are only local conditions; the lowermost beds of the series are as frequently marine.

To these succeed around Paris, whence the first points of comparison were obtained, a deposit of a soft light-coloured calcareous freestone abounding in marine exuviae; whilst in the vicinity of London we find, in resembling superposition, a thick mass of tough, tenacious, brown and dark grey clays, also with marine remains, but in far less abundance, and not so well preserved. Measuring the strata by their relative importance and general bearing, there appears to be an analogy of position and condition. As masses they are equivalent; but our question is with time, and that has but a very uncertain relation to masses.

From the frequent and almost constant variations of thickness which tertiary strata so generally exhibit, and from the comparatively local and limited expansion of many divisions, we ought to examine carefully the thinner as well as the thicker beds of the singularly-varied series of the Paris tertiaries; to trace the thinner ones in their greater development, and the thicker ones in their decreasing importance, and to note the variations and progress of their faunas. In all cases where considerable differences present themselves at distant points in beds of the same presumed age, we may most usually expect to meet at intermediate localities with intermediate characters, providing always that we have reason to suppose any connexion of original sea-bottom, such as probably existed at the first tertiary period. Thus the thick argillaceous deposit of *London clay*, at London, on the one hand, and the nearly pure calcareous deposit of *Calcaire grossier* at Paris, on the other hand, might be expected to show in their range towards each other, provided they were synchronous, some indications of a common origin. At the same time, the groups of organic remains should, notwithstanding the difference of chemical and mechanical conditions, exhibit some of the analogies dependent upon like conditions of age and of approximate geographical position.

Passing over for the present the beds between the *chalk* and the *London clay*, we will confine ourselves to the examination of the question of the latter being the equivalent of the *Calcaire grossier*. To understand how it came to be so considered, we must begin with the excellent work which first brought the fossils of this period prominently under notice.

Long before any systematic arrangement of the English and French tertiaries was attempted, the abundance and good state of preservation of the fossil shells found in the clay-cliffs of Barton had attracted the attention of Brander, by whom figures and descriptions of them were published in 1766*. When next, in 1803, Lamarck examined the shells of the *Calcaire grossier* of Grignon, he met with many which agreed with those figured by Brander from Barton, and with these he inferred them to be coeval†. In 1811, Parkinson‡ examined the fauna of the London clay of London and Sheppey; and in the same year the cutting of the Highgate tunnel enabled Mr. Sowerby and Mr. Wetherell to add considerably to the list of the London clay fauna.

A general resemblance of lithological character between the strata

* Fossilia Hantoniensia.

† Annales du Muséum, tome i.

‡ Trans. Geol. Soc. 1st Ser. vol. i. p. 324.

of Barton and Highgate, and the discovery of several species common to the two localities, led to the belief that they were contemporaneous. The more material differences in the fauna were then and afterwards attributed to differences dependent upon distance, and on the separation of the two seas at the period of the deposition of the strata; and the finding, at Kew, of several species common, some to Highgate, and others to Barton, was supposed to remove any doubts as to the identity of the two groups.

Having thus associated the London clay with the Barton beds, and afterwards, by the same reasoning, with the beds at Stubbington and Bracklesham, the organic remains occurring at these various places were taken as belonging to one and the same deposit; and they were then compared "*en masse*" with those of the *Calcaire grossier*. The consequence was, that the supposed relation of the *London clay* and the *Calcaire grossier* appeared to be confirmed by the discovery of a considerable number of French species at Barton and at Bracklesham: the beds at these localities were therefore supposed to present an intermediate fauna corresponding with their intermediate geographical position, and thereby gave some verisimilitude to the hypothesis of the synchronism of those divisions of the London, Hampshire, and Paris groups. Let us now inquire how far, independently of the aid it has received from Barton and Bracklesham, the *London clay* of the London district* agrees in its organic remains with the *Calcaire grossier*.

The Testacea of the *Calcaire grossier* have been variously estimated at from about 800 to 1000 species; whereas the *London clay* proper, apart from *Barton* and *Bracklesham*, exhibits apparently less than 250 species†. I am however inclined to think that the number of the Testacea of the *Calcaire grossier* has been over-estimated, from the circumstance of specimens from beds both above and below it, and cropping out at the same localities, having been, before the distinction of the beds was well ascertained, quoted indiscriminately as *Calcaire grossier* fossils. There is unfortunately no complete recent list published; and the same fact, which causes doubt as to the number of species, renders also their chronological value problematical.

We have however the excellent, but only local, lists of the Eocene fossils of the Département de l'Aisne given by M. D'Archiac‡, and his shorter but more general lists in his paper on the relations of the French, Belgian and English Tertiaries§. There are also numerous papers by Constant Prevost, Elie de Beaumont, M. C. D'Orbigny

* I have used the terms *London* or *Hampshire tertiary districts*, in preference to *London basin* or *Hampshire basin*, as denoting the areas occupied by the tertiary deposits. The map in Plate XIV. shows the relative position of the two districts.

† Of these not three-fifths are described. (See list at the end.)

‡ In this district M. d'Archiac enumerates from the Sables et Grès moyens, or Grès de Beauchamp 61 species of Testacea.

Calcaire grossier	{ Upper.....	101	"
	{ Lower.....	239	"
Lits Coquilliers		190	"
Étages des Lignites		40	"

All these divisions have many species in common.—Mémoires de la Société Géologique de France, vol. v. part 2.

§ Bulletin de la Société Géologique de France, vol. x. p. 168.

and others in the 'Mémoires' and 'Bulletin' of the French Geological Society. The fine work of Deshayes is the standard for the organic remains*, and for general descriptions and details the works of Cuvier and Brongniart.

Taking the number of described *Calcaire grossier* species at a moderate estimate of 600, I can only, after carefully excluding all the Barton and Bracklesham fossils, determine the following 20 as occurring also in the *London clay* of the London district †:

<i>Anomia lineata</i> , Sow. (<i>A. striata</i> , Desh.)	<i>Pecten corneus</i> , Sow.?
<i>Beloptera belemnitoidea</i> ??, Blainv.	<i>Pseudoliva obtusa</i> , Sow.?
<i>Cassidaria carinata</i> , Desh.	<i>Rostellaria macroptera</i> ?, Lam.
<i>Fusus bulbiformis</i> , Lam.	<i>Sigaretus canaliculatus</i> , Sow.
<i>Infundibulum trochiforme</i> , Sow. (Calyptrea trochiformis, Desh.)	<i>Solarium canaliculatum</i> , Lam.
<i>Globulus depressus</i> , Sow.?	— patulum, Sow. (? patulum of Desh.)
<i>Natica glaucinoides</i> , Sow.	<i>Triton viperinus</i> , Desh.
<i>Nucula similis</i> , Sow. (<i>N. margaritacea</i> , Lam.)	<i>Teredo personata</i> ?, Lam.
— minima, Sow.?	<i>Turritella imbricataria</i> , Desh.
<i>Ostrea fiabellula</i> , Lam.	— sulcifera, Lam.?

Thus it appears that not quite four per cent. of Testacea of the *Calcaire grossier* are found in the *London clay* of London: and even this small number is of little chronological value; for, with few exceptions, all these species have a wide vertical range in the Eocene series of France, twelve of them descending to the "*Sables inférieurs et Lits coquilliers*," and several of them ranging upwards to the "*Grès de Beauchamp*," and scarcely any of them being of characteristic *Calcaire grossier* species ‡. (See the works of Deshayes and D'Archiac.)

In the general character of the Testacea of the *London clay* and *Calcaire grossier*, the differences observable are as great as in the species. Thus in the former, Cephalopoda, Phytophagous Gasteropoda, and Lamellibranchiate Dimyaria preponderate; and in the latter, Zoophagous Gasteropoda and Lamellibranchiate Monomyaria.

If we compare the fishes, the plants, the Foraminifera, the Crustacea, and the Zoophytes of the *London clay* and *Calcaire grossier*, the same marked distinctions between them are traceable throughout. The *Calcaire grossier* abounds in Foraminifera, and possesses many Zoophytes. The former are almost unknown, and the latter very scarce, in the *London clay*, which however exhibits fine groups of Fishes§, Reptiles and Crustacea, together with a Flora || of remarkable variety and beauty, whilst in the *Calcaire grossier* ¶ such fossils

* Coquilles Fossiles des Environs de Paris.

† Future comparisons of the organic remains will, no doubt, considerably modify this list.

‡ This can only, from the want of revised lists and more complete descriptions, be a rough approximate estimate. An exact value must not be attached to it.

§ Agassiz's Report on the Fossil Fishes of the London Clay.—Reports of the Brit. Association for 1843 and 1844.

|| Bowerbank, Fossil Fruits of the London Clay.

¶ A local case will exemplify the general bearing.

	Foraminifera.	Zoophytes.	Fishes.	Reptiles.	Crustacea.	Plants.
<i>Calc. gross. dep. de l'Aisne</i> (D'Ar.)	45	15	1	0	0	2
<i>London clay</i> (Morris, Brit. Foss.)	1	3	53	16	4	107

The number of undescribed species of London clay Crustacea is very considerable. Alex. Brongniart enumerates thirteen species of plants from the *Calcaire grossier*, and Agassiz but 12 species of fishes.

are extremely rare. The per-centage of species in all these classes common to the two deposits will not, I think, average more than in the Testacea.

Where therefore is the affinity of these formations? Where the proofs of their synchronism? Are we to be satisfied with an assumed analogy of position,—with a community of apparently not more than forty or fifty species of organic remains, out of probably 1000 to 1200 or more, and attribute so wide a variation of fauna merely to geographical position and differences of conditions?—or is not rather the *primâ facie* evidence sufficient to render it probable that they differ in age as well as in origin, and to lead us to investigate more closely their relative superposition? If then the hypothesis which has referred them both to the same period is insufficiently grounded, the question arises, in what relation do they stand one to the other?

For an answer to this question, it is necessary to recur to the Hampshire tertiary series, and to search there for the intermediate and connecting types, without which it would be difficult to institute a comparison.

DIVISIONS OF THE TERTIARY SERIES.

Lowest—Sands and Mottled Clays.

In determining the synchronism of any portion of the London and Hampshire series, we should endeavour to establish by a good base-line the earliest point of contemporaneity. The lower part of the Hampshire tertiaries presenting at first sight considerable apparent differences from those of London, has caused the base-line, if it may be so termed, to be placed near the top of the series, viz. in the *clays of Barton*, making them parallel with the *London clay*, and thus forcing the strata above and below into an order bearing the same relation to the one as to the other*.

* The following is a sketch of the present arrangement of the Tertiary series of England and France, with the order of superposition and co-relation of the strata.

<i>London Basin.</i> Feet ¹ . ? Bagshot sands: {	<i>Hampshire Basin.</i> Feet. 200. Upper freshwater formation ² . 20. Upper marine formation ² . 170. Lower freshwater formation ² .	<i>Paris Basin.</i> Feet. 40. Calcaire lacustre supérieure, 80. Sables marins supérieurs. 150. Calcaire lacustre inférieure. 50. Grès de Beauchamp ³ .
400. London clay: Highgate, Sheppey.	350. London clay: Barton, Brack- lesham and Bognor.	100. Calcaire grossier.
80. Plastic clays: pebble beds, fluviatile beds of Woolwich, and sands below them to the chalk.	1100. Sands and plastic clays ⁴ : variegated sands and clays, and lignites, forming the central and lower strata of Alum Bay, including the fossiliferous brown clay ⁵ (stratum "d" of Mr. Webster), and the red clays below it.	100. Lignites and Argile plastique.

¹ These numbers refer to a roughly approximate average thickness of the deposits.

² These three formations have of late generally been considered as one.

³ M. d'Archiac and others refer the Grès de Beauchamp to the thick stratum of sand immediately overlying the London clay at Alum Bay, and which they also consider the equivalents of the Bagshot sands.

⁴ Sometimes this distinction has not been admitted, and the series from the freshwater beds to the chalk has been considered as all belonging to the London clay series.

⁵ The presumed marine equivalents of the fluviatile beds of Woolwich.—*Sept.* 1847.

In that portion of the London tertiaries which lies to the west of London, one of the most characteristic features exhibited in the beds immediately overlying the chalk, is the frequent occurrence of a band of the *Ostrea bellovacina*, with a few sharks' teeth, imbedded usually in a clayey greensand, and generally separated from the chalk only by a bed, two or three feet thick, of greensand and clay, full of slightly-rolled green-coated flints. Sometimes, however, the *Ostrea* band descends to the chalk.

These strata, with their associated *mottled clays*, are well known from Dr. Buckland's description* of them at Katesgrove Pits, Reading, whence westward they may be traced to the extremity of the London tertiary district at almost all the points where these lowest strata are exhibited.

In the Hampshire basin this bed has not hitherto been known; but I had the satisfaction last summer of meeting with an excellent exhibition of it in a cutting of the Southampton and Salisbury railroad at Kembridge, about three and a half miles north of Romsey.

The agreement of this section with those exhibited in the neighbourhood of Newbury and Hungerford is striking, and is not confined to the layer of the *Ostrea bellovacina*, but extends to the associated beds of *mottled clays*. At the south end of the cutting at Kembridge the section is identical with that in immediate junction with the chalk at Alum Bay†, both in the arrangement of the strata and in the absence of fossils; but in proceeding northward, a band of oysters gradually appears, and at the further end of the cutting attains a thick-

Fig. 1.—Section on the Railway near Kembridge.

- a. Ochreous flint gravel.
- b. Red clays mottled with grey, dark plum-colour, and yellow at its base. No fossils. (Identical with the mottled clays No. 2 of Alum Bay and of Reading.)..... 15 feet.
- c. Clayey yellow and greenish sand, with the usual layer of slightly-rolled, large green-coated flints at the bottom; mixed also with a few small round flint-coated pebbles, and imbedded in an impure ochreous and argillaceous greensand. Above the flints, and partly intermingled with them, there is at the point "y" a layer about two feet thick of large *Ostrea bellovacina*. Towards the south end of the cutting it gradually thins out, and disappears altogether about midway in the section. The shells of these oysters are mostly very thick and large, and much corroded..... 4 feet.
- d. Chalk with flints. Its upper surface is rather uneven, and irregularly bored into from the greensand layer above, the substance of which now fills the tubular holes.

* Transactions of the Geological Society, 2nd series, vol. ii. part 1. p. 119.

† Excepting that the rolled flints on the chalk are at the latter place imbedded in a rather whiter and purer sand.

ness of two feet, forming a section agreeing perfectly with those of Newbury and Hungerford, where also the band of oysters is far from persistent. (See Plate XIV. Comp. Sec. figs. 5 & 7, points "e.")

The structure of the south end of the Kembridge cutting is that which commonly prevails throughout the Hampshire tertiary series south of this locality; whereas, as modified at the northern end, it represents that of a large portion of the London tertiary district. This section therefore affords, in conjunction with those of Alum and White-Cliff Bays, Southampton, &c., some stratigraphical and zoological evidence that this lowest division, both in Hampshire and west of London, commenced contemporaneously under very similar conditions, and in apparent connexion.

This point thus probably indicating the early co-relations of these two districts, affords a good base-line from which to measure their progressive development.

Overlying the sands with *Ostrea bellovacina*, or rather in further development of the same series, are the *mottled clays* with intercalated sands. These are seen in their greatest expansion, and in their most argillaceous condition, at Alum and White-Cliff Bays, and reappear, I infer, in lesser thickness and more sandy, but in similar superposition, throughout the western portion of the London tertiary district (see Plate XIV. Comp. Sec. fig. 2 to 11). It may be objected here, that the more variable beds of sands and *mottled clays* of the London district do not well represent the purer *mottled clays* of Hampshire; that the preponderance of sands mark them as a different group, referable rather to the great central mass of variegated sands and clays at Alum Bay, with which they have been hitherto grouped. Against this it can be shown that the *mottled clays* and associated sands are subject to great and rapid variations of thickness and structure, both from having been deposited on the inequalities of the chalk, and from their apparently irregular original drift. At Alum Bay they are 86 feet thick; at White-Cliff Bay, 140 feet; at Southampton, 100 feet; at Clarendon Hill, near Salisbury, apparently not more than 50 or 60 feet; at Pebble Hill, near Hungerford, 45 feet; whilst at Tilehurst, near Reading, they are said to be 150 feet thick.

The variation in the mineral character is of little importance. At Pebble Hill we see them subordinate to the beds of sand; at Newbury the sands and mottled clays are about of equal thickness, and form two beds only; at Reading we have five beds of mottled clays alternating with seven beds of sand; at Sonning Hill the sands have almost thinned out, and at Twyford we again have 40 or 50 feet of pure mottled clays, whilst near London they are frequently 80 to 100 feet thick. In fact, they present a remarkably uniform mineral type of beds of red mottled clay and of siliceous light-coloured sands, merely subject to variations of proportions.

They are also characterized throughout the Hampshire and London districts, whether they are formed of clay beds only, or consist of alternating beds of clays and sands, by the same remarkable absence of animal remains.

This therefore forms a well-marked and characteristic division, which will aid materially in taking the next and more debateable step.

London Clay.

Immediately overlying these *mottled clays*, or separated from them only by a thin subordinate bed of sand, there is found in the Hampshire district a thick and important mass of fossiliferous brown and grey clay, well-exhibited in the sections at Alum and White-Cliff Bays, and proved to exist in the same position in the well at Southampton (see Plate XIV. Gen. Sect. fig. 2 to 4). This deposit is well-marked and persistent in its lithological characters. At Alum Bay it is 200 feet thick, and at White-Cliff Bay and Southampton about 300 feet, apparently therefore thickening gradually in its range northward and eastward. Its local composition at the former two places I have described in my last paper: it is there termed "*the Bognor beds.*" I will therefore now confine myself to its more permanent and characteristic features.

In the first place it is almost uniformly preceded by a thin seam of sand, frequently green, and containing small rounded black flint pebbles, and occasionally also, when the underlying mottled clays have been sufficiently hard, rolled and water-worn pebbles of the *mottled red clay* itself, pointing to, as I have before observed, a sudden alteration of hydrographical conditions, and a change in the ancient seabottom. This fact is particularly noticeable in White-Cliff Bay.

Fig. 2.—Junction of the London Clay (1 to 5) and mottled clays at White-Cliff Bay*.

I dwell upon this fact, because it indicates a well-marked commencement of a different order of things from that which previously existed. (See also Plate XIV. Comp. Sec. 3 to 11, point "δ.")

The lowest beds of the London clay are generally more or less sandy, but the sand gradually disappears, passing into tough brown clay with layers of Septaria (and concretionary conglomerates at Southampton),

* This is best exhibited on the shore between high and low water level.

and a few subordinate sandy beds, the whole forming a total thickness of 300 feet. Sometimes the clays are of a dark grey, but brown is the predominating colour. As a mass the mineral character is almost entirely argillaceous, carbonate of lime though present being in comparatively very limited quantity, and the admixture of green and yellow sands occurring chiefly at the top and bottom of the deposit.

Another lithological character is the presence of two or three layers of round black flint pebbles, as well as their occasional dissemination, denoting an increased transporting power of water, but no change of condition. They are more numerous at Alum Bay than at White-Cliff Bay, and still more so at Southampton.

We will now pass over to the London district, and examine the strata there superimposed to the *mottled clays*. Commencing at Basingstoke and Odiham, we meet with in this position a thick and well-marked deposit of brown and bluish grey clays. To their lithological characters we will first confine ourselves, and ascertain whether these present any discrepancies with the Bognor beds of Hampshire. So far from this being the case, their agreement is remarkable,—far greater than could have been expected.

This great argillaceous deposit commences here, as in the Isle of Wight, with a mineral character different from that of the beds below it. At its base, a bed of sand with rolled flint pebbles almost invariably occurs, indicating therefore, along with other phenomena, that the London tertiary district probably underwent at this period a change of condition similar to that we have shown to have occurred in Hampshire.

Thus at Chinham near Basingstoke, we find the mottled clays and sands overlaid by a yellow clayey sand, with a few pebbles and patches of green sand, passing upwards into the mass of the London clay; at Itchingwell, near Kingsclere, by a thin band 9 inches thick of pebbles, over which is a brown sandy clay passing upwards into a tough brown clay, forming the lower part of the London clay; at Pebble Hill the same layer of pebbles, overlaid by dark sandy clays with London clay fossils. At Reading also the mottled clays are capped by brown clays and sand, with pebbles and patches of green sand, and again at Sonninghill: so also at various places along the southern edge of the London district, as at Guildford. A similar mechanical structure prevails at the base of the London clay at Hampstead, where however the sand and pebbles are cemented by carbonate of lime, a character of not unfrequent occurrence, forming in such instances large tabular masses, as at Hedgerly, Sonning, and various other places around London, and in Hampshire at Alderbury near Salisbury, and Southampton. In all these places this conglomerate band is usually very fossiliferous. (See Pl. XIV. Comp. Sec. 6, 7, 11. point δ.)

Further, the peculiar water-worn and irregular surface of the mottled clays and sand exhibited at their junction with the brown clay deposit in the Isle of Wight is also distinctly visible in the London district. This was very apparent in the long railway cutting at Sonning near Reading. The whole line of junction was there uneven and wavy, forming depressions and curves as much as 1 or 2 feet deep. This structure is also observable in a lesser degree at Chinham near Basingstoke, Pebble Hill, and Guildford.

At all these places in the London district where the superposition can be traced, these pebble beds are subordinate to sands chiefly yellow, but sometimes green and dark grey, laminated with brown clays, passing upwards into beds of the same colour and entirely argillaceous, with subordinate portions of a dark bluish grey colour, frequently very sandy. These strata constitute the great bulk of the *London clay*. Its upper beds are again generally brown, and near the top usually mixed with light-coloured sands in sufficient quantity to form a good brick clay without any further addition of sand.

Layers of Septaria occur irregularly throughout the *London clay*. At the western end of the district the clays frequently contain black flint pebbles, sometimes forming thin layers in the clay, at other times occurring, slightly dispersed, throughout considerable vertical masses. Nearer London these pebbles are of less frequent occurrence.

If, further, we compare the development and thickness of the *London clay* of London and the *Bognor beds* of Hampshire, we find the analogy continued; and as this is a point of some importance to the argument, we will confine ourselves to the few sections where we have positive and complete data.

We have already seen that at Southampton these clays are nearly 300 feet thick. The first measurement we can obtain in the London district is at Dogmersfield, near Odiham, where a well has shown these clays to be 320 feet thick,—a very close approximation to the Southampton section; and at both places they are equally well defined and limited by the *sands* above and the *mottled clays* below. Proceeding towards London the clays gradually become thicker; measuring 400 feet at Chobham, and at Highgate and Hampstead about 400 feet*; the same beds above and below, as at Odiham, serving as limits of vertical range. (See Plate XIV. Gen. Sec. fig. 1 to 11.)

We thus have, in mere physical conditions, a fair “*à-priori*” case for placing the *London clay* of the neighbourhood of London on a level with the *Bognor clay* in the Hampshire series. Their structure is analogous, their superposition alike, and their accumulation was apparently nearly coeval in time and equal in mass; while so far as these conditions are concerned, the presumed synchronism of the Barton clays and Bracklesham sands with the London clay would present great anomalies.

Organic Remains.

The foregoing hypothesis of structure, if correct, ought to be corroborated and proved by an examination of the organic remains.

We will commence with an estimate of the total number of species found in the Hampshire and in the London series, and then consider separately the numbers occurring respectively at Barton, Bracklesham, and London; examine their affinities, and see if any and how many species are peculiar to each of these groups of strata; and investigate the validity of the palæontological evidence upon which their correlation stands†.

* At some places around London they are occasionally thicker than this.

† In the determination of the species occurring in the several localities, the Catalogue of British Fossils of Mr. Morris was of the most essential assistance. I

Limited in the number of its Testacea as the whole of the marine tertiary series of London and Hampshire long appeared to be, as compared with the French series, there now appears a prospect, thanks to the zeal of Mr. Bowerbank, Mr. Wetherell, Mr. Edwards and others, of finding the English fauna far richer than was anticipated. The number of described species of Testacea already known in the London and Hampshire systems taken together amounts to nearly 400; and from information given me by Mr. F. C. Edwards of Hampstead, I am led to believe that, including undescribed species, we may estimate them at between 600 and 700. There is little doubt, I think, that they will shortly exceed even this number, especially as new lines of railway intersect the London clay, our research in which has been much limited by the extreme scarcity of permanent sections.

We will confine ourselves however to the 390 described species: of these 133 occur in the *London clay* of the neighbourhood of London, 193 in the strata at *Bracklesham Bay*, and 209 in the strata at *Barton Cliffs*. Out of the whole number only 35 species are common to all the three localities. Further, 8 are common to London and Bracklesham, 11 to London and Barton, and 55 to Bracklesham and Barton. (See list of species and table of distribution at the end.) It is possible that even the small number of species now given as common to these three groups of strata may yet be reduced as analogues are compared. It must also be borne in mind that some species, although common to all these groups, form, in each of them, distinct varieties. Granting however that the localities* of the described species have been correctly given, and that they have been sufficiently compared, the number of *London clay* shells (*i. e.* of the London district alone) occurring at *Barton* and *Bracklesham* only amounts to 55, out of the total number of 133, thus leaving 79 as peculiar to the London district. When to this fact we add the occurrence of the numerous distinct species of crustacea, fishes, reptiles and plants peculiar to the London district, have we not reason to doubt the contemporaneity of the clays of London with the strata of Barton and Bracklesham?—especially if we can show that the *London clay* has a much closer representative in the Hampshire system in strata distinctly below the Barton and Bracklesham series.

But if the clay of London be not synchronous with those of Barton and Bracklesham, in what relation does it stand to them?

The similarity of structure and physical conditions may indicate, as we have suggested, that the thick and extensive strata of *London clay* of the neighbourhood of London, and the lowest fossiliferous beds of

may here take the opportunity to state the great advantages which the valuable illustrated copy of this Catalogue, arranged by Mr. Morris, recently presented to the Geological Society by our President, Mr. Leonard Horner, will afford to the geologist. It will be a standard work of reference and authority, as the illustrations are mostly from the original works, many of which are of difficult access and very expensive.

* Some few palpable errors, where by mistake a fossil from the Barton clay has been quoted as found in the clays of the neighbourhood of London, or where distinct species from Hampshire and London have been considered as the same, are corrected.

clay immediately overlying the *mottled clays* of the Isle of Wight, have had a like and coeval origin, and that the *London clay* is consequently lower in the series than the *Bracklesham Bay beds*, and still more so than those of *Barton*. It is certainly possible that by greater rapidity of formation the London clay and the so-called Plastic clay of London might have expanded in the Hampshire district, so as to have had for their equivalents the whole of the strata from the chalk to the Freshwater series, including the Barton and Bracklesham beds. Here however the organic remains come to our assistance, and tend to strengthen our view, that the synchronism of the *London clay* extends only to the limits pointed out by similarity of structure.

Owing to the want of sections intermediate between the Isle of Wight and London, there has existed some little difficulty in establishing a satisfactory co-relation of the faunæ of this division in the neighbourhood of London with that which we take as its presumed equivalent in Hampshire, but some recent railway cuttings have materially facilitated the inquiry.

To render the palæontological evidence as clear and decisive as the subject will admit of, and to show that each portion of it is in unison with the whole, it will be desirable to study the organic remains in groups, as they are developed in different places in each system, so as to eliminate any modifications which they may undergo as they approximate in geographical distribution, and to ascertain to what extent the forms and species correspond.

Commencing with the Isle of Wight we have the following group :

Fossils of the Bognor beds of White-Cliff and Alum Bays.*

<i>Anomia lineata</i> , Sow.	<i>Pholadomya virgulosa</i> , Sow.
<i>Cassidaria carinata</i> , Lam.	<i>Pinna affinis</i> , Sow.
<i>Cardium Plumsteadense</i> ?, Sow.	— n. s.—a large one, same as at
<i>Corbula pisum</i> ?, Sow.	Bognor and Cuffell.
<i>Cyprina planata</i> , Sow.	<i>Psammobia compressa</i> ?, Sow.
<i>Cytherea obliqua</i> , Desh.	<i>Pyrula tricornata</i> , Desh.
<i>Ditrupea plana</i> , Sow.	— <i>Smithii</i> , Sow.
<i>Dentalium</i> .	<i>Pleurotoma</i> .
<i>Fusus tuberosus</i> , Sow.	— (small species resembling one from
— <i>angusticostatus</i> , Mell.	Southampton and Newnham).
<i>Infundibulum trochiforme</i> , Sow.	— four or five other n. sp.
<i>Nucula lunulata</i> ?, Nyst.	<i>Rostellaria Sowerbii</i> , Mant.
— <i>amygdaloides</i> , Lam.	— <i>lucida</i> , Sow.
<i>Natica glaucinoides</i> , Sow.	<i>Teredo antenauta</i> , Sow.
<i>Ostrea flabellula</i> , Lam.	<i>Turritella imbricata</i> , Desh.
<i>Panopæa intermedia</i> , Sow.	<i>Venericardia Suessonensis</i> , d'Archiac.
<i>Pectunculus brevisrostris</i> , Sow.	<i>Vermetus Bognoriensis</i> , Sow.
<i>Pholadomya margaritacea</i> , Sow.	

* Mr. Edwards, who has just returned from the Isle of Wight, informs me that he has, in addition to most of the specimens above mentioned, found the following ones in Stratum No. 4 of Alum Bay :—

<i>Acteon simulatus</i> , Sow.	<i>Modiola depressa</i> , Sow.
<i>Buccinum junceum</i> , Sow.	<i>Nucula minima</i> , Sow.
<i>Cassidaria striata</i> , Sow.	<i>Solarium patulum</i> , Sow.
<i>Cultellus affinis</i> , Sow.	<i>Typhis muticus</i> , Sow.
<i>Fusus Koninckii</i> , Nyst.	—
<i>Marginella</i> .	<i>Desmophyllum</i> .

All these are species which tend to confirm my views.—Oct. 1847.

Of these the *Cyprina planata*, *Ostrea flabellula*, *Panopæa intermedia*, *Pyrula tricostrata*, *Venericardia Suessonensis*, *Teredo antenauta* and *Ditrupe plana*, are common at White-Cliff, and comparatively scarce at Alum Bay, where however all the other species are far more abundant. From the latter place I have also several undescribed species of *Pleurotoma* and *Corbula*. Of other organic remains we have the *Cancer Leachii*, teeth of *Lamna*, and carbonized wood frequently pierced by the *Teredo*.

Our next point is the artesian well on Southampton Common; whence also the series is from beds as fully developed as those of the Isle of Wight.

The following is a list, chiefly from specimens in the collection of Mr. R. Keele of Southampton, who has had the kindness to give me the free use of all his Southampton fossils.

Fossils from the Bognor beds at the Artesian well, Southampton.*

<i>Anomia lineata</i> , Sow.	<i>Pectunculus decussatus</i> , Sow.
<i>Cancellaria læviuscula</i> , Sow.	— <i>brevirostris</i> , Sow.
<i>Cardium Plumsteadense</i> ?, Sow.	<i>Pholadomya margaritacea</i> , Sow.
<i>Cyprina planata</i> , Sow.	— <i>virgulosa</i> , Sow.
<i>Cytherea obliqua</i> , Desh.	<i>Pinna affinis</i> , Sow.
— <i>suberycinoides</i> , Desh. var.	<i>Pleurotoma rostrata</i> , Sow.
<i>Ditrupe plana</i> , Sow.	— two new species.
<i>Fusus bulbiformis</i> , Lam.	<i>Pyrula tricostrata</i> , Desh.
— <i>angusticostatus</i> , Mell.	<i>Rostellaria Sowerbii</i> , Mant.
— <i>complanatus</i> , Sow.	— (a small species resembling the
— <i>tuberosus</i> , Sow.	<i>Sowerbii</i> , and occurring also at Cla-
— <i>Koninckii</i> , Nyst.	rendon Hill and Cuffell).
— n. sp.: same as one found at High-	— <i>lucida</i> , Sow.
gate.	<i>Turritella imbricataria</i> , Lam.
<i>Infundibulum trochiforme</i> , Sow.	— <i>sulcifera</i> , Lam.
<i>Natica glaucinoides</i> , Sow.	<i>Typhis muticus</i> , Sow.
— <i>Hantoniensis</i> , Sow.	<i>Teredo antenauta</i> , Sow.
<i>Nautilus</i> (either <i>imperialis</i> or <i>Sowerbii</i>).	<i>Venericardia Suessonensis</i> , d'Archiac.
<i>Ostrea flabellula</i> , Lam.	<i>Vermetus Bognoriensis</i> , Sow.
<i>Panopæa intermedia</i> , Sow.	<i>Voluta elevata</i> , Sow.

The species of *Turritella*, *Panopæa*, *Pholadomya*, *Natica*, *Ostrea* and *Infundibulum* are very common. Carbonized wood occurs abundantly.

Proceeding northward, no opportunity offers of observing the organic remains of these beds until we reach the railway cutting at Clarendon Hill, three miles south of Salisbury, where however a depth of only about 40 feet of the lower beds of the Bognor clays are exposed. But in this limited extent we meet with precisely those fossils which are of the most typical species.

Fossils from the Bognor beds at Clarendon Hill.

<i>Anomia lineata</i> , Sow.	<i>Fusus tuberosus</i> , Sow.
<i>Cancellaria læviuscula</i> , Sow.	<i>Infundibulum trochiforme</i> , Sow.
<i>Cardium Plumsteadense</i> ?, Sow.	<i>Natica glaucinoides</i> , Sow.
<i>Corbula</i> .	— <i>Hantoniensis</i> , Sow.
<i>Cyprina Morrisii</i> , Sow.	<i>Nucula</i> .
<i>Cytherea obliqua</i> , Desh.	<i>Ostrea</i> (very large species, same as at
<i>Ditrupe plana</i> , Sow.	Old Basing).
<i>Fusus Koninckii</i> , Nyst.	— <i>flabellula</i> , Lam.

* See fig. 5. stratum c, *postea*, p. 388.

Panopæa intermedia, Sow.
Pectunculus brevirostris, Sow.
Pinna affinis, Sow.
Pholadomya margaritacea, Sow.
Pleurotoma (same species as at Newnham).
Psammobia compressa?, Sow.
Pyrula tricostrata, Desh.
 ——— Smithii, Sow.
Rostellaria (small species resembling the

Sowerbii; same as occurs at Southampton and Cuffell).
Rostellaria lucida, Sow.
Turritella imbricata, Lam.
Teredo antenauta, Sow.
Venericardia Suessionensis, d'Archiac.
Flustra.
Desmophyllum (same species as at Highgate).

The small undescribed *Rostellaria*, the *Natica glaucinoides*, *Panopæa intermedia*, *Pinna affinis*, *Pectunculus brevirostris* and *Venericardia Suessionensis* here occur in the greatest abundance. The *Panopæa* is beautifully exhibited in its normal position, as when living and boring downwards into the soft mud: its shell is preserved, but in a very friable state, as it also is at Southampton and in the Isle of Wight. The shells of the *Pinna* and *Pholadomya* are likewise very tender, and difficult to be obtained entire; they still however retain some of their lustre. The other shells are in a tolerably good state of preservation, especially the *Natica*, which usually exhibits a bright untarnished surface.

The thin conglomerate masses of rock before-mentioned as here occurring at the base of these clays are full of *Corbula*, *Cyprina Morristii*, *Ditrupea plana*, *Natica Hantoniensis*, *Nucula*, *Fusus tuberosus*, *Pectunculus brevirostris*, *Cytherea obliqua* and *Pleurotoma*. (Point δ in fig. 6. Comp. Sect. Plate XIV.)

On comparing the foregoing lists of fossils, we find that of the 37 known species which form a very typical and distinctive group in these beds in the Isle of Wight, 25 occur again among the 32 found at Southampton; and of the 23 species from Clarendon, 20 are of forms common at Southampton and the Isle of Wight.

We are warranted therefore, both by structure and organic remains, in regarding these strata of this portion of the Hampshire tertiary as synchronous. It is also evident that they possess a peculiar and distinct fauna, since, out of the 49 species which they contain, only 18 range upwards into the Bracklesham and Barton beds*.

If we now pass over to that portion of the London district nearest to the Hampshire tertiary district, we shall find a fauna perfectly ana-

* The limited supplies of specimens furnished by the well at Southampton, and the short examination hitherto made of these beds in the Isle of Wight, renders our knowledge of their fauna no doubt defective, and restricted probably to the most abundant species. A careful search in these beds at Alum Bay would doubtless produce a considerable addition to the number of organic remains now known: but even from our present knowledge of them it is apparent that they are, wherever exhibited in Hampshire, characterized by a peculiar group of fossils.

In addition to the species enumerated in the foregoing lists, there are a few others which occur at Bognor, and which, as we shall have to take them into account in our comparison of the Hampshire with the London series, are given below:

Conus.
Modiola elegans, Sow.
Nautilus Sowerbii, Sow.
Pholadomya Dixoni, Sow.

Pseudoliva semicostata, Desh.
Thracia oblata, Sow.
Venericardia Brongniarti, Mant.
Xiphidion quadratum, Sow.

logous to that just described, and only differing from it in proportion as it advances eastward, and the series of beds becomes more expanded.

At Pebble Hill, near Hungerford, which is distant about thirty-five miles north from Clarendon Hill, we find in some abundance in the clays over the mottled clays—

Panopæa intermedia, Sow.

? *Pinna affinis*, Sow.

Pectunculus brevirostris, Sow.

In the pebble bed in junction with the mottled clays, at various places in the neighbourhood of Newbury and Kingsclere, *Ditrupa plana* abounds. These are fossils characteristic of the lower beds of the *London clay*; but no opportunity offers for obtaining any considerable variety of organic remains until we reach the vicinity of Basingstoke. At Chinham, one mile north of that town, a cutting on the Reading railway shows the *mottled red clays* overlaid by laminated sands and brown clays mixed with green sand, and with patches of

Cytherea obliqua,

Natica glaucinoides,

Ditrupa plana,

Cardium Plumsteadense?, and

Pectunculus brevirostris,

Teeth of *Lamnæ*;

(point δ in fig. 8 of Comp. Sections, Plate XIV.). At a further distance of two miles on the same line, in a considerable clay cutting at Cuffell, we find a section very similar, both lithologically and zoologically, to that at Clarendon Hill*. In both localities there is the same remarkable abundance of the *Panopæa* imbedded in the clays, in a vertical position similar to that which the recent species assume in their living habitats at the present day, proving the quiescent deposition of these portions of the strata†. The *Pholadomya* and *Pinna*, the latter of which attains an unusually large size at Cuffell, exhibits also there the same peculiarity of position.

The fauna here becomes much more varied, comprehending nearly 60 species, in the determination of which I am much indebted to Mr. Morris. He has visited with me Cuffell and Newnham; and as this and most of the other lists have been revised by him and Mr. Edwards, I give them with much more confidence.

Fossils from the London Clay at Cuffell‡, three miles north of Basingstoke.

Arca impolita?, Sow.

Cardium nitens, Sow.

Bulla.

Cassidaria striata, Sow.

Cancellaria læviuscula, Sow.

Cerithium.

* The Cuffell cutting is however rather higher in the series than that at Clarendon Hill. Possibly between 100 and 200 feet above the *mottled clays*.

† Dr. Fitton has called my attention to the occurrence of the same interesting exhibition of present habits in past states, exhibited by the *Panopæa* and *Pinna* in the lowest beds of the *lower greensand*.

‡ Mr. Edward Cole, one of the under-engineers on that line of railway, has, on the several occasions that I have visited this section, afforded me every assistance. Having superintended this portion of the work, he has had a favourable opportunity, which he has not allowed to pass, of making a complete collection of the organic remains occurring at Cuffell. He has given me many specimens which I had not met with, and I am glad to say has recorded many good geological facts connected with the dip, thickness, &c. of the strata.

Corbula (small new species).	Pholadomya Dixoni?, Sow.
Cultellus affinis, Sow.	— virgulosa, Sow.
Cyprina planata, Sow.	Pinna affinis, Sow.
Cytherea obliqua, Desh.	— (n. s., a very large one).
Ditrupa plana, Sow.	Pleurotoma rostrata, Sow.
Dentalium nitens, Sow.	— elegans, Mell.
Fusus tuberosus, Sow.	— (four new species).
— angusticostatus?, Mell.	Pyramidella —?
— carinella, Sow.	Pyrula Smithii, Sow.
— trilineatus, Sow.	— tricostrata, Desh.
— (two new species).	Ringicula turgida, Sow.
Modiola depressa, Sow.	Rostellaria lucida, Sow.
— subcarinata, Sow.	— Sowerbii, Mant.
Murex cristatus, Sow.	— (small n. s., same as at Clarendon).
Natica Hantoniensis, Sow.	Solarium patulum, Sow.
— glaucinoides, Sow.	? Scalaria undosa, Sow.
Nautilus imperialis, Sow.	— (new species, large).
— Sowerbii, Sow.	Serpula trilineata?, Sow.
Nucula amygdaloides, Sow.	Teredo antenauta, Sow.
— lunulata?, Nyst.	Trivia (Cypræa, Sow.).
Ostrea (large species).	Turritella imbricata, Sow.
Pecten corneus, Sow.	— sulcifera, Lam.
Pectunculus brevirostris, Sow.	Typhis muticus, Sow.
Panopæa intermedia, Sow.	Venus (small species).
Pholadomya margaritacea, Sow.	

With these occur rarely, *Flustra*, *Pennatula*, apparently of the Highgate species, teeth of *Lamna elegans*, and defensive bones of *Myliobates*.

Four miles north of Cuffell, in the cutting at Clewett's Green, we have nearly the summit beds of the *London clay*. In parts they are very fossiliferous, containing numerous individuals of the following species:—

Anomia lineata, Sow.	Ostrea flabellula, Lam.
Cassidaria carinata, Lam.	Panopæa intermedia, Sow.
Corbula.	Pseudoliva obtusa, Sow.
Cyprina planata, Sow.	Pyrula tricostrata, Desh.
Cytherea obliqua, Desh.	Turritella imbricata, Lam.
— suberycinoides, Desh. var.	Teredo antenanta, Sow.
Fusus tuberosus, Sow.	Venericardia.
Lingula tenuis, Sow.	Voluta elevata.
Modiola elegans, Sow.	Palates of <i>Myliobates</i> .
Nautilus imperialis, Sow.	— <i>Ætobates</i> .
Natica glaucinoides, Sow.	Teeth of <i>Lamna elegans</i> .

On the line of the London railway at Old Basing, the *mottled clays* are immediately succeeded by a bed of dark brown clay with—

Ditrupa plana, Sow.	Pholadomya.
Cyprina.	Fusus tuberosus, Sow.
Astarte donacina, Sow.	Cytherea.
Turritella.	Pectunculus decussatus, Sow.
Nucula similis, Sow.	Vermetus Bognoriensis, Sow.

And at the Plantation one mile further eastward, in a tough brown clay, are found—

- Ostrea (same large sp. as at Clarendon Hill). Vermetus Bognoriensis.

On the same line, six miles from Basingstoke, at Newnham near Winchfield, a deep cutting in the *London clay* afforded me the following specimens:—

Fossils from the London Clay at Newnham, between the Winchfield and Basingstoke stations.

Anomia lineata.	Ostrea flabellula, <i>Lam.</i>
Acteon simulatus, <i>Sow.</i>	— Cymbula?, <i>Desh.</i>
Avicula media, <i>Sow.</i>	Panopæa intermedia, <i>Sow.</i>
Ancillaria (same sp. as at Highgate).	Pholadomya margaritacea, <i>Sow.</i>
Buccinum junceum.	Pinna affinis, <i>Sow.</i>
Cardium nitens, <i>Sow.</i>	Pleurotoma rostrata, <i>Sow.</i>
— Plumsteadense?, <i>Sow.</i>	— (two new species).
Cancellaria læviuscula, <i>Sow.</i>	Pseudoliva obtusa, <i>Sow.</i>
Cassidaria carinata, <i>Lam.</i>	Pyrula Smithii, <i>Sow.</i>
Cyprina planata, <i>Sow.</i>	— tricostrata, <i>Desh.</i>
Cytherea obliqua, <i>Desh.</i>	Rostellaria Sowerbii, <i>Mant.</i>
— suberycinoides, <i>Desh.</i> var.	— lucida, <i>Sow.</i>
Ditrupea plana, <i>Sow.</i>	Ringicula turgida, <i>Sow.</i>
Fusus bulbiformis, <i>Lam.</i>	Solen affinis, <i>Sow.</i> (<i>Cultellus</i>).
— errans, <i>Sow.</i>	Teredo antenauta, <i>Sow.</i>
— tuberosus, <i>Sow.</i>	Terebratula striatula, <i>Mont.</i>
Globulus depressus, <i>Sow.</i>	Turritella imbricataria, <i>Lam.</i>
Lingula tenuis, <i>Sow.</i>	— sulcifera?, <i>Lam.</i>
Modiola elegans, <i>Sow.</i>	Vermetus Bognoriensis, <i>Sow.</i>
— subcarinata, <i>Sow.</i>	Venericardia.
Nautilus imperialis, <i>Sow.</i>	Voluta elevata, <i>Sow.</i>
Natica glaucinoides, <i>Sow.</i>	Serpula extensa, <i>Brand.</i>
— Hantoniensis, <i>Sow.</i>	Teeth of Lamnæ.

These fossils are imbedded in a dark grey sandy clay, frequently containing numerous small round black flint pebbles. The shells are well-preserved, and most of them have attained a large size. The *Cyprina planata* especially are very large. Some of the *Septaria* are full of *Modiola* and *Cardium*. These three, together with the *Turritella imbricataria*, *Ostrea flabellula*, *Cytherea obliqua*, and the two species of *Natica*, are the common shells. Fossil wood pierced by the *Teredo* is plentiful.

In the small number of sections which have been exposed between Newnham and London, the fossils have been found to agree either with those of the above, or with others occurring at Hampstead or Highgate. But we need not, for our object, go further than Newnham, since from thence to Highgate the *London clay* ranges uninterruptedly. This point can therefore be taken as a fit term of comparison between the fauna of these beds in the neighbourhood of London* and those in Hampshire†.

* Mr. Wetherell has found at the base of the London clay at Hampstead a conglomerate bed similar to that of Clarendon, and analogous to the undurated layers at Chinham, and containing like them the *Rostellaria Sowerbii*, *Natica glaucinoides*, *Cytherea obliqua*, and *Pectunculus brevis* (Trans. Geol. Soc. 2nd Series, vol. v. p. 133). Mr. Warburton also gives an analogous group of fossils from a similar position at the base of the London clay at Holyport, near Maidenhead (Trans. Geol. Soc. 2nd Series, vol. i. p. 52). Mr. Rolfe has the same from Reading (Trans. Geol. Soc. 2nd Series, vol. v. p. 130). I have the same species from Sonning near Reading, and many other places; in all of them, as a group, there is a perfect identity.

† From Newnham to Old Basing the *London clay* can be followed, with little interruption, to the mottled clays over the chalk, and in the opposite direction it dips under the Bagshot sands at Winchfield. Newnham seems to occupy a place rather high in the middle of the series. From Old Basing, however, west-

Position of the London Clay in the Hampshire Tertiaries.

The question of the relative age of the *London clay* and the Hampshire series depends materially upon the evidence afforded at Newnham, Old Basing and Cuffell. If the London clay embraces in its synchronism the Bracklesham and Barton beds, then ought we to find some evidence of this expansion as it ranges westward and south-westward, in the gradual preponderance of forms peculiar to these latter beds. If, on the contrary, the equivalent of the London clay is, as I believe, restricted to the lower fossiliferous clays of the Hampshire system, then ought we to find at Newnham and Cuffell a fauna equally related to that of these lower clays and to that of Highgate, and distinct from that of the deposits of Bracklesham and Barton*.

Notwithstanding, however, the intermediate geographical position, and the favourable stratigraphical place, high in the series of the *London clay*, of the *Newnham* and *Cuffell beds*, the following table will show that the proportion of Bracklesham and Barton species is no greater there than in the *London clay* at Hampstead and Highgate (*ante*, p. 365). It will also appear that the strata at Cuffell and Newnham contain a fauna very closely allied to that of the *London clay* of the neighbourhood of London; whilst it is evident that the species which occur in the Bognor beds in Hampshire bear an equally near relation to those of Newnham and Cuffell as well as to those of Highgate and Hampstead, and exhibit no greater number than do the latter of Bracklesham and Barton forms. In fact, the relative proportion to the species of these latter two localities is maintained in each with much uniformity.

ward to Pebble Hill, the range of these clays cannot be so easily followed. The Reading line of railway gives some good sections; and at various points from thence to near Hungerford, the lower beds can be detected at intervals by their organic remains, leaving but little doubt that they are all members of the same series as at Newnham, as the fauna is the same throughout.

* At first sight this seemed to be more doubtful, some forms appearing which have hitherto been confined to Bracklesham and Barton, such as the *Globulus depressus*, *Fusus bulbiformis*, *Psammobia compressa*, and *Pseudoliva obtusa*. Two or three of these have however been found in the Bognor beds of Hampshire (see Lists). The Newnham group of fossils being also from beds rather high in the London clay, may possibly yield a larger proportion of fossils belonging to the overlying series than we find at Clarendon Hill, or even Cuffell, which occupy, I think, a lower position. In the list of fossils at the end of this paper it is the object to show that the three divisions of London, Bracklesham and Barton possess each, as groups, a distinct fauna, and therefore each group is taken as a whole, irrespective of subdivisions; and the distribution in the several divisions of the respective faunas, according to vertical range or to locality, is a question only casually touched upon. They are all however, the *London clay* especially, capable of zoological subdivisions. The *London clay* exhibits a typical group at the bottom of the series: in ascending several new species appear. Then again, many of the early species reappear in considerable numbers at the top of the series. But this is a wide field, on which I do not purpose here to enter, as it may form part of a fuller investigation into, and detail of, the Tertiary Geology of London. For our present object it suffices to consider the *London clay* as a whole.

Table showing the range of the Fossils given in the foregoing lists into other parts of the Eocene series of London and Hampshire.

Localities.	Number of identified and described species found at each locality.	Species common to Highgate or Hampstead.	Species common to Bognor*.	Species common to Bracklesham.	Species common to Barton.
Isle of Wight	37	29	19	14	13
Southampton	33	24	17	12	12
Clarendon Hill	23	16	14	11	11
Cuffell and Clewett's Green	51	39	24	18	16
Newnham and Old Basing...	43	30	21	19	19

From this examination it appears that the per-centage of species common in each locality to Highgate, Hampstead and Bognor is far greater than to Bracklesham and Barton†, and that the Highgate and Hampstead forms exist in nearly as large a proportion in these strata in Hampshire as they do in the western portion of the London district.

It is therefore fair to assume, both from strict analogy of structure and a near similarity of organic remains, that the *London clay* is represented in Hampshire by the lowest fossiliferous beds, which in my last paper I had termed the *Bognor beds*, and that consequently it is older than the *Bracklesham beds*, and still older than the *Barton beds*. I should also propose that the term *London clay* be applied and restricted to this its equivalent in Hampshire instead of the term of *Bognor beds*, as being the better-known designation, and the more important section of this formation (see table at end, and Plate XIV. Comp. Sect.).

I have previously stated‡ the probability that the *Bognor beds* are at or near the base of the *London clay*; but the same genera which at Bognor form a distinct and typical group, associated within narrow vertical limits, are found in the Isle of Wight in greater dispersion and isolation through a vertical range of 200 to 300 feet. (Strata 3 to 6 of Alum Bay, and 3 and 4 of White-Cliff Bay—see Plate XIV. Comp. Sections, figs. 2 and 3.) At Highgate, and elsewhere in the neighbourhood of London, we find the *Bognor group* of fossils chiefly congregated in great abundance at the base of the *London clay*. I

* The number of species found at Bognor amounts at present to about 32.

† I believe it likely that the proportion of species common to *London*, *Barton* and *Bracklesham* will be materially reduced as our knowledge of the Highgate, Hampstead and Sheppey forms extends. In the fine collection of Mr. Wetherell of Highgate, many of the numerous undescribed species from Highgate and the neighbourhood are of common and characteristic forms. If these were added to the list of *London clay* species, we should probably find, as at Newnham and in Hampshire, that the *London clay* of Highgate would exhibit a larger proportion of Testacea peculiar to it. The large work upon which Mr. Dixon of Worthing is engaged will also, I hope, shortly make known a more complete list of the organic remains from the productive locality of Bracklesham Bay, and also of those of Bognor.

‡ Journal of the Geol. Soc. for August 1846, page 236.

am however inclined to think that we need not restrict the synchronism of the *Bognor beds* of Hampshire to the lower part only of the *London clay*, but that we may consider that the conditions, which in the Isle of Wight were favourable to the prolonged existence of the characteristic Bognor fossils throughout the whole of the London clay, were altered as we approach the site of London by a greater depth of sea, whereby the shallow water and littoral fauna of Bognor had its character modified by the introduction of new forms, as the *Nautilus*, *Pentacrinites*, and other deep-sea animals which abound in the central beds of the *London clay* around London. The groups of organic remains in the intermediate localities bear corroborative evidence. At Alum Bay and Southampton we find a considerable number of Highgate forms, but still with a general prevalence of the Bognor group*. In the western portion of the London district we meet with a distribution of the fauna approximating closely to that of Hampshire, and showing a high range in the *London clay* of the Bognor group. At Newnham and Cuffell the fauna begins to exhibit the lower range of the Bognor group, and the introduction of a greater variety of Highgate forms; and in the neighbourhood of London we find the Bognor group, although largely preponderating in the lowest beds, but faintly represented in the greater bulk of the middle beds, whilst in the highest beds some species of the group reappear in the greatest abundance.

This is a phenomenon of considerable interest, inasmuch as it indicates that that prolonged and gradual subsidence of the sea-bottom, which I have before† endeavoured to show prevailed during the formation of the London clay (Bognor beds) in the Isle of Wight, extended in a nearly equal degree to the western portion of the London district. Over all this area the increasing depth caused by the subsidence appears to have been constantly neutralized by an accumulation of sediment, equal, or nearly so, to the amount of depression. By the joint and counteracting effects of these two causes, a nearly uniform and moderate depth was maintained throughout the seas then covering these districts, enabling the *Panopæa*, *Pholadomya*, *Pinna*, and other shallow-water genera, to exist all through this geological period, to the exclusion of the more varied fauna which greater changes of depth would have produced. But we have indications, as we proceed further eastward in the London district to Highgate and Sheppey, of a departure during part of this period from these uniform zoological conditions; for, as we have just mentioned, we here find various species of *Cephalopoda*, *Echinodermata*, some *Brachiopoda*, and of a generally deeper sea testacea, superadded in considerable abundance to the more limited fauna of the same age in the Isle of Wight. As the deeper sea forms here predominate, so do those of

* The typical species of this (if we may so term it) rudimentary group are, *Cytherea obliqua*, *Cardium Plumsteadense*, *Infundibulum trochiforme*, *Natica glaucinoides*, *Panopæa intermedia*, *Pectunculus brevirostris*, *Pholadomya margaritacea*, *P. virgulosa*, *Pinna affinis*, *Pyrula tricostrata*, *P. Smithii*, *Rostellaria Sowerbii*, *Turritella imbricatoria* (var.), *Teredo antenauta*, *Venericardia Suessonensis*, *Vermetes Bognoriensis*, and the *Ditrupa plana*.

† Journal of the Geol. Soc. for August 1846, page 237. The reasoning upon which this hypothesis is founded is there given, and need not therefore be repeated here.

the shallower waters gradually disappear. At the end of this period the latter again prevail to the near exclusion of the former.

From these more varied conditions, and from the operation of more numerous zones of depth, adapted to the existence of more numerous classes of Testacea, results probably the more diversified and abundant fauna of Hampstead, Highgate and Sheppey.

Comparison of the London Clay with the French Tertiaries.

In my paper on the Tertiary Geology of the Isle of Wight, I expressed an opinion that the *Bracklesham Bay beds* were of the age of the *lower Calcaire grossier* and the *Glaucanie grossière*. Since then I have had the opportunity of examining the large and valuable collection from Bracklesham of Mr. Edwards, and am confirmed in this view of their synchronism. The number of French species found at Bracklesham amounts to about 140 out of the total number of 193 described species. Of these 140 about 120 occur in the *lower Calcaire grossier* and the *Glaucanie grossière*; about 40 descend to the *Lits Coquilliers*; and still fewer are peculiar to the *upper Calcaire grossier* and bed above; thus showing a far more intimate connection with the first-named divisions than with any of the others*.

There are a few anomalies, but they are overbalanced by the stronger coincidences. Thus, among the few characteristic fossils of the *Lits Coquilliers* in France, we find foremost the *Bifrontia Laudunensis* and *Nummulites planulatus (elegans, Sow.)*. Both these species occur in considerable abundance at Bracklesham, but associated with them we have a large proportion of the characteristic species of the *lower Calcaire grossier* and *Glaucanie grossière*, including with many others,

Cerithium giganteum †, *Lam.*
Conus deperditus, *Brug.*
Fusus Noë, *Lam.*
Lucina gigantea, *Desh.*
— *concentrica*, *Lam.*
Melania costellata, *Lam.*

Pecten squamula, *Lam.*
Pleurotoma granulata, *Desh.*
Voluta spinosa, *Lam.*
— *cithara*, *Lam.*
Venericardia planicosta, *Lam.*
— *acuticosta*, *Desh.*

Of the 209 species of Testacea found at Barton, about 100 are identical with species occurring in France, of which 30 are found in the *Lits Coquilliers*, about 60 in the *Calcaire grossier* and *Glaucanie grossière* (more particularly the *lower Calcaire grossier*), and probably 20 in the overlying beds. The number of French analogues is here much less than in the Bracklesham series, and with a larger proportion of species of the *Lits Coquilliers*. This is peculiar, as from superposition there can, I think, be little doubt that the Barton series are higher than the Bracklesham Bay series. Before however

* At Chaumont, between Rouen and Beauvais, the *Glaucanie grossière* literally abounds with fine specimens of the *Venericardia planicosta*. It is the same species which constitutes so typical and common a form at Bracklesham, and in the beds of the same age at White-Cliff Bay and Southampton. From lithological character and superposition, it is more particularly with these beds that I should associate the Bracklesham sands and clays. I have not however visited Chaumont, nor have I been able to meet with any full account of its sections and fossils.

† A French author, in speaking of the *lower Calcaire grossier*, refers to it as "l'époque du *Cerithium giganteum*, cette coquille-reine qui est devenue une date géologique." This however may be doubtful.

we can reason upon this fact, we require a more extensive determination of the organic remains*.

We have before (*ante*, p. 358) shown that the *London clay*, so far from presenting the same large proportions of forms common to the *Calcaire grossier*, at present shows only about four per cent. of French analogues.

It is in the beds, therefore, of *Bracklesham* and *Barton*, and not in those of *Bognor* or *London*, that we have the approximate representatives in time of the *middle* and *lower Calcaire grossier*. The *London clay* itself is most probably, as I have before stated the *Bognor beds* to be, of the age of some of the subdivisions of the group of "*Sables inférieurs*" of M. d'Archiac,—possibly near the position of the *Lits Coquilliers*; but its exact parallel in this series cannot at present be clearly determined. At all events, the fossils of the *Lits Coquilliers* present a greater analogy to those of the *London clay* than do those of the *Calcaire grossier*. Still the number of species common to the two deposits is only about 33; or if we take the number of species found in the *Lits Coquilliers* and *Sables inférieurs* at 200, the proportion will be but sixteen and a half per cent. on that number. The following is a list of them†:—

<i>Anomia lineata</i> , Sow.	<i>Cardium semistriatum</i> ?, <i>Desh.</i>
<i>Cassidaria carinata</i> , Sow.	<i>Solarium canaliculatum</i> , <i>Lam.</i>
<i>Conus concinnus</i> , Sow.	<i>Nucula similis</i> , Sow.
(<i>bicoronatus</i> , <i>Mell.</i>)	(<i>margaritacea</i> , <i>Lam.</i>)
<i>Cytherea tenuistriata</i> , Sow.	? <i>Pectunculus pulvinatus</i> , <i>Lam.</i>
(<i>obliqua</i> , <i>Desh.</i>)	(? <i>P. brevirostris</i> , Sow.)
<i>Fusus porrectus</i> , Sow.	<i>Panopæa intermedia</i> , Sow.
(<i>unicarinatus</i> , <i>Desh.</i>)	(<i>Corbula dubia</i> , <i>Desh.</i>)
— <i>bulbiformis</i> .	<i>Pholadomya margaritacea</i> , Sow.
— <i>angusticostatus</i> , <i>Mell.</i>	<i>Pinna affinis</i> , Sow.
— <i>regularis</i> , Sow.	(<i>margaritacea</i> , <i>Lam.</i>)
<i>Globulus sigaretinus</i> , Sow.	<i>Pleurotoma colon</i> , Sow.
(<i>Natica sigaretina</i> , <i>Def.</i>)	— <i>elegans</i> , <i>Mell.</i>
<i>Infundibulum trochiforme</i> , Sow.	<i>Pseudoliva semicostata</i> , Sow.
(<i>Calyptrea trochiformis</i> , <i>Desh.</i>)	(<i>Buccinum semicostatum</i> , <i>Desh.</i>)
<i>Murex spinulosus</i> , <i>Desh.</i>	<i>Pyrula tricostrata</i> , <i>Desh.</i>
<i>Natica glaucinoides</i> , Sow.	<i>Ringicula turgida</i> , Sow.
(<i>labellata</i> , <i>Lam.</i>)	(<i>Auricula ringens</i> , <i>Lam.</i>)
<i>Nautilus zic-zac</i> , Sow.	<i>Sigaretus canaliculatus</i> , Sow.
<i>Corbula striata</i> , <i>Lam.</i>	<i>Teredo personata</i> , <i>Lam.</i>
<i>Rostellaria macroptera</i> , <i>Lam.</i>	<i>Turritella imbricataria</i> , <i>Lam.</i>
<i>Ostrea fiabellula</i> , <i>Lam.</i>	<i>Venericardia Suessonensis</i> , d'Archiac.

As in "*London clay*," *Foraminifera* and *Zoophytes* are comparatively scarce in the "*Lits Coquilliers*," whilst remains of *Reptiles* are not uncommon.

* The more exact relations of these two divisions will be discussed in the next paper.

† It is to be observed, however, that if we confine ourselves to a comparison of these fossils of the *Lits Coquilliers* with the fossils of the *London clay* at the intermediate geographical position of Hampshire, we shall find the analogy much stronger. Thus, out of the 42 Hampshire species, 26 are analogues of the *Lits Coquilliers*. But the difficulty is, that although this typical Hampshire fauna ranges on the one side into the Paris system, and on the other into the London system, yet it becomes respectively associated in each case with faunas in other respects dissimilar. At the same time we have good geological horizons both above and below, restricting to within tolerably narrow limits the superposition

It may however be observed that the *Lits Coquilliers* bear a much closer relation to the *Calcaire grossier* than the *London clay* does to the *Bracklesham sands* and *Barton clays*; since the proportion of species common to the two former is about 90 per cent., whereas in the latter it is only about 40 per cent.

We can thus for the present only approximate to the relative superposition of the *London clay*, and place it below the *Calcaire grossier*; for, notwithstanding we cannot assign it an exact equivalent, it is evident that it contains a rudimentary fauna (see lists, *ante*, p. 366-371), which may be considered, as a group, to indicate a synchronism with the lowest eocene division of M. d'Archiac (Groupe des Sables inférieurs).

We must not, however, at present draw too close a parallelism between the tertiary formations of the two countries. We appear in this country to have an important and larger development of strata of the age of the lower portion of the French series, and that to an extent which would constitute them the type of the period rather than a subordinate variation thereof.

A few of the more general conclusions derivable from the foregoing observations may here be mentioned.

It is probable that the tertiary sea at first extended uninterruptedly over the London, Hampshire and Paris tertiary areas;—that, at a period coeval with the change of conditions, both in structure and fauna, which is evident at the base of the *London* and *Bognor clays*, a separation took place between the Paris and Hampshire areas, leaving the latter one however still connected with that of London, during the deposition of the *London clay*;—that, after this period, the communication between the French and English tertiaries was restored, as evinced by the introduction in the Bracklesham beds of so many French species, and that this connexion was probably in part prolonged until the completion of the Isle of Wight series,—the London district in the meantime assuming a more isolated position, and emerging sooner from beneath the sea.

This leads to an inquiry into the age and structure of the *Bagshot Sands*, which will be found to be in perfect conformity with, and to corroborate, the hypothesis advanced in this paper. I hope shortly to have the honour of laying some remarks on this subject before the Society.

of these deposits. Possibly the *London clay* may have been formed during a period unrepresented, or only very partially so, in the French series. Perhaps the presence of the typical group of Bognor fossils in the *Lits Coquilliers* is the result of migration, at the conclusion of the London clay period, into more recently formed seas wherein the *Lits Coquilliers* were deposited. I am almost inclined to adopt this view, and to consider that the *London clay* period immediately preceded that of the *Lits Coquilliers*;—that it synchronises with some older portion of the *Sables inférieurs*.

The list of fossils, tables and sections accompanying this paper are placed at the end of the following one.