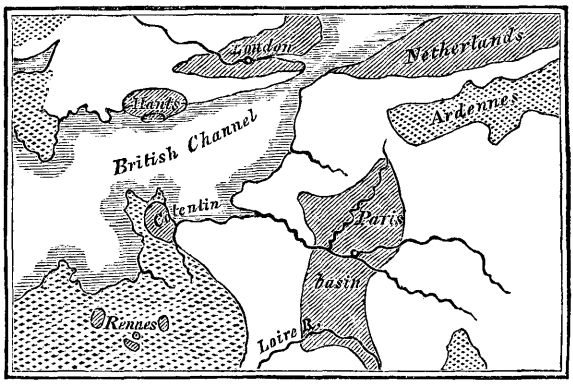
CHAPTER XX.

Eocene formations, *continued*—Basin of the Cotentin, or Valognes—Rennes—Basin of Belgium, or the Netherlands—Aix in Provence—Fossil insects—Tertiary strata of England—Basins of London and Hampshire—Different groups—Plastic clay and sand—London clay—Bagshot sand—Fresh-water strata of the Isle of Wight—Palæotherium and other fossil mammalia of Binstead—English Eocene strata conformable to chalk—Outliers on the elevated parts of the chalk—Inferences drawn from their occurrence—Sketch of a theory of the origin of the English tertiary strata.

HAVING in the last three chapters treated of the Eocene formations of different parts of France, we now propose to examine those which are found in the south-eastern division of England; but before we pass from the continent to our own island, we may briefly advert to several other spots where Eocene deposits have been observed. Their geographical position will be found delineated on the annexed map *.

MAP OF THE PRINCIPAL TERTIARY BASINS OF THE EOCENE PERIOD.

No. 62.



Primary rocks and strata older than the carboniferous series. Eocene formations.

N.B. The space left blank is occupied by secondary formations, from the old red sandstone to the chalk inclusive.

* This map is copied from one given by M. Desnoyers, Mem. de la Soc. d'Hist. Nat. de Paris, 1825, pl. 9; compiled partly from that author's observations, and partly from Mr. Webster's map, Geol. Trans., 1st series, vol. ii. plate 10.

Basin of the Cotentin, or Valognes.—The strata in the environs of Valognes, in the department of La Manche, consist chiefly of a coarse limestone resembling the calcaire grossier of Paris, of which M. Desnoyers has given an elaborate description. It is occasionally covered with a compact fresh-water limestone alternating with fresh-water marls. In these Eocene strata more than 300 species of fossil shells have been discovered, almost all identical with species of the Paris basin. (See Tables, Appendix I.) Superimposed upon the Eocene strata of this basin is a newer marine deposit, extending over a limited area, the fossils of which agree with those of the Faluns of the Loire*. Here, therefore, the geologist has an opportunity of observing the superposition of the Miocene deposits upon those of the age of the Paris basin.

Rennes.—Several small patches, also, of marine strata, have been found by M. Desnoyers, in the neighbourhood of Rennes, which are characterised by Eocene fossils and repose on ancient rocks, as will be seen in the map.

Basin of Belgium, or the Netherlands.—The greater part of the tertiary formations of the Low Countries consist of clay and sand, much resembling those of the basin of London, afterwards to be described. The fossil shells, also, are of the same species, 49 of which will be found referred to by M. Deshayes, in the tables, Appendix I.

Aix, in Provence.—The tertiary strata of Aix and Fuveau in Provence are of great thickness and extent, the lower members being remarkable for containing coal grit and beds of compact limestone, such as we only find in England in ancient secondary groups. Yet these strata are for the most part of fresh-water origin, and contain several species of Eocene shells, together with many which are peculiar to this basin. It would require a fuller comparison than has yet been made of the fossil remains of Aix and Fuveau, before we can determine with accuracy the relative age of that formation. Some of the plants seem to agree with those of the Paris basin, while many

* Desnoyers, Mem. de la Soc. d'Hist. Nat. de Paris, 1825.

of the insects have been supposed identical with species now living*. These insects have been almost exclusively procured from a thin bed of grey calcareous marl, which passes into an argillaceous limestone found in the quarries of gypsum near Aix. The rock in which they are imbedded is so thinly laminated that there are sometimes more than 70 layers in the thickness of an inch. The insects are for the most part in an extraordinary state of preservation, and an impression of their form is seen both on the upper and under laminæ, as in the case of the Monte Bolca fishes. M. Marcel de Serres enumerates 62 genera belonging chiefly to the orders Diptera, Hemiptera and Coleoptera. On reviewing a collection brought from Aix, Mr. Curtis observes that they are all of European forms and most of them referrible to existing genera†. With the single exception of an Hydrobius, none of the species are aquatic. The antennæ, tarsi, and trophi are generally very obscure, or distorted, yet in a few the claws are visible, and the sculpture, and even some degree of local colouring, are preserved. The nerves of the wings, in almost all the Diptera, are perfectly distinct, and even the pubescence on the head of one of them. Several of the beetles have the wings extended beyond the elytra, as if they had made an effort to escape by flying, or had fallen into the water while on the wing‡.

BASINS OF LONDON AND HAMPSHIRE.

The reader will see in the small map above given (No. 62, p. 275,) the position of the two districts usually called the basins of London and Hampshire, to which the Eocene formations of England are confined. These tracts are bounded by rising grounds composed of chalk, except where the sea intervenes. That the chalk passes beneath the tertiary strata, we can not only infer from geological data, but can prove by numerous artificial sections at points where wells have been sunk, or borings made through the overlying beds. The

* M. Marcel de Serres, Géog. des Ter. Tertiaires du Midi de la France.

† Murchison and Lyell. Ed. New Phil. Journ., Oct. 1829.

‡ Curtis, ibid., where figures of some of the insects are given.

Eocene deposits are chiefly marine, and have generally been divided into three groups: 1st, the Plastic clay and sand, which is the lowest group; 2dly, the London clay; and, 3rdly, the Bagshot sand. Of all these the mineral composition is very simple, for they consist almost entirely of clay, sand, and shingle, the great mass of clay being in the middle, and the upper and lower members of the series being more arenaceous.

Plastic clay and sand.—The lowest formation, which sometimes attains a thickness of from 400 to 500 feet, consists principally of an indefinite number of beds of sand, shingle, clay, and loam, irregularly alternating, some of the clay being used in potteries, in reference to which the name of Plastic clay has been given to the whole formation. The beds of shingle are composed of perfectly rolled chalk flints, with here and there small pebbles of quartz. Heaps of these materials appear sometimes to have remained for a long time covered by a tranquil sea. Dr. Buckland mentions that he observed a large pebble in part of this formation at Bromley, to which five full-grown oyster-shells were affixed, in such a manner as to show that they had commenced their first growth upon it, and remained attached through life *.

In some of the associated clays and sand, perfect marine shells are met with, which are of the same species as those of the London clay. The line of separation, indeed, between the superincumbent blue clay last alluded to, and the Plastic clay and sand, is quite arbitrary, as any geologist may be convinced who examines the celebrated section in Alum Bay, in the Isle of Wight †, where a distinct alternation of the two groups is observable, each marked with their most characteristic peculiarities. In the midst of the sands of the lower series a mass of clay occurs 200 feet thick, containing septaria, and replete with the usual fossils of the neighbourhood of London ‡.

* Geol. Trans., First Series, vol. iv. p. 300.

† See Mr. Webster's Memoir, Geol. Trans., vol. ii., First Series, and his Letters in Sir H. Englefield's Isle of Wight.

‡ See Mr. Webster's sections, plate 11. Geol. Trans., vol. ii., First Series.

The *arenaceous* beds are chiefly laid open on the confines of the basins of London and Hampshire, in following which we discover at many places great beds of perfectly rounded flints. Of this description, on the southern borders of the basin of London, are the hills of Comb Hurst and the Addington hills, which form a ridge stretching from Blackheath to Croydon. Here they have much the appearance of banks of sand and shingle formed near the shores of the tertiary sea; but whether they were really of littoral origin cannot be determined for want of a sufficient number of sections which might enable us to compare the tertiary strata at the edges with those in the central parts of each basin.

We have ample opportunities in the basin of Paris of examining steep cliffs of hard rock which bound many of the valleys, and innumerable excavations have been made for building-stone, limestone, and gypsum; but when we attempt to obtain a connected view of any considerable part of the tertiary series in the basin of London, we are almost entirely limited to a single line of coast-section; for in the interior the regular beds are much concealed by an alluvial covering of flint gravel spread alike over the summits and gentle slopes of the hills, and over the bottoms of the valleys.

Organic remains are extremely scarce in the Plastic clay; but when any shells occur they are of Eocene species. Vegetable impressions and fossil wood sometimes occur, and even beds of lignite, but none of the *species* of plants have, we believe, as yet been ascertained.

London clay.—This formation consists of a bluish or blackish clay, sometimes passing into a calcareous marl, rarely into a solid rock. Its thickness is very great, sometimes exceeding 500 feet *. It contains many layers of ovate or flattish masses of argillaceous limestone, which, in their interior, are generally traversed in various directions by cracks, partially or wholly filled by calcareous spar. These masses, called septaria, are sometimes continued through a thickness of 200 feet †.

* Con. and Phil. Outlines of Geol., p. 33. † Outlines of Geol., p. 27.

A great number of the marine shells of this clay have been identified with those of the Paris basin, and are mentioned by name in Appendix I. It is quite evident, therefore, that these two formations belong to the same epoch.

No remains of terrestrial mammalia have as yet been found in this clay, but the occurrence of bones and skeletons of crocodiles and turtles prove, as Mr. Conybeare justly remarks, the existence of neighbouring dry land. The shores, at least, of some islands were accessible, whither these creatures may have resorted to lay their eggs. In like manner, we may infer the contiguity of land from the immense number of ligneous seed-vessels of plants, some of them resembling the cocoa-nut, and other spices of tropical regions, which have been found fossil in great profusion in the Isle of Sheppey. Such is the abundance of these fruits, that they have been supposed to belong to several hundred distinct species of plants.

Bagshot sand.—The third and uppermost group, usually termed the Bagshot sand, rests conformably upon the London clay, and consists of siliceous sand and sandstone devoid of organic remains, with some thin deposits of marl associated. From these *marls* a few marine shells have been obtained which are in an imperfect state, but appear to belong to Eocene species common to the Paris basin *.

Fresh-water strata of the Hampshire basin.—In the northern part of the Isle of Wight, and part of the opposite coast of Hampshire, fresh-water strata occur resting on the London clay. They are composed chiefly of calcareous and argillaceous marls, interstratified with some thick beds of siliceous sand, and a few layers of limestone sometimes slightly siliceous. The marls are often green, and bear a considerable resemblance to the green marls of Auvergne and the Paris basin. The shells and gyrogonites also agree specifically with some of those most common in the French deposits. Mr. Webster, who first described the fresh-water formation of Hampshire, divided it into an upper and lower series separated by intervening beds of marine

* Warburton, Geol. Trans., vol. i. Second Series.

origin. There are undoubtedly certain intercalated strata, both in the Isle of Wight and coast of Hampshire, marked by a slight intermixture of marine and fresh-water shells, sufficient to imply a temporary return of the sea, before and after which the waters of a lake, or rather, perhaps, some large river, prevailed *. The united thickness of the fresh-water and intercalated upper marine beds, exposed in a vertical precipice in Headen Hill, in the Isle of Wight, is about 400 feet, the marine series appearing about half way up in the cliff.

Eocene mammiferous remains.—Very perfect remains of tortoises and the teeth of crocodiles have been procured from the fresh-water strata, but a still more interesting discovery has recently been made. The bones of mammalia corresponding to those of the celebrated gypsum of Paris, have been disinterred at Binstead, near Ryde, in the Isle of Wight. In the ancient quarries near this town a limestone, belonging to the lower fresh-water formation, is worked for building. Solid beds alternate with marls, wherein a tooth of an Anoplotherium, and two teeth of the genus Palæotherium, were found. These remains were accompanied not only by several other fragments of the bones of Pachydermata (chiefly in a rolled and injured state), but also by the jaw of a new species of Ruminantia, apparently closely allied to the genus Moschus †. Mr. T. Allan of Edinburgh had several years before found the tooth of an Anoplotherium at the same spot, and when we alluded to this in our first volume ‡, we threw out some doubts as to the authenticity of his specimen, stating at the same time, that in the Binstead beds, if anywhere in our island, we should expect such remains to be found. Although we carried our scepticism too far, it has been attended with good results, for it induced Mr. Pratt to visit Binstead, where he verified and extended the discovery of Mr. Allan.

* See Memoirs of Mr. Webster, Geol. Trans., vol. ii., First Series, vol. i. part i., Second Series, and Englefield's Isle of Wight.—Professor Sedgwick, Ann. of Phil., 1822, and Lyell, Geol. Trans., vol. ii. Second Series.

† Pratt, Proceedings of Geol. Soc., No. 18, p. 239.

‡ First Edition, p. 153.

These newer strata of the Isle of Wight bear a certain degree of resemblance to some of the green marls and limestones in the Paris basin, yet, as a whole, no formations can be more dissimilar in mineral character than the Eocene deposits of England and Paris. In our own island the tertiary strata are more exclusively marine, and it might be said that the Parisian series differs chiefly from that of London in the very points in which it agrees with the formations of Auvergne, Cantal, and Velay. The tertiary formations of England are, in fact, almost exclusively of mechanical origin, and their composition bespeaks the absence of those mineral and thermal waters to which we have attributed the origin of the compact and siliceous limestones, the gypsum, and beds of pure flint, common to the Paris basin and Central France.

English tertiary strata conformable to the chalk.—The British Eocene strata are nearly conformable to the chalk on which they rest, being horizontal where the strata of the chalk are horizontal, and vertical where they are vertical. On the other hand, there are evident signs that the surface of the chalk had, in many places, been furrowed by the action of the waves and currents, before the Plastic clay and its sands were superimposed. In the quarries near Rochester and Gravesend, for instance, fine examples are seen of deep indentations on the surface of the chalk, into which sand, together with rolled and angular pieces of chalk-flint, have been swept *. But these appearances may be referred to the action of water when the chalk began to emerge during the Eocene period, and they by no means warrant the conclusion, that the chalk had undergone any considerable change of position before the tertiary strata were superimposed.

In this respect there is a marked difference between the reciprocal relations of our secondary and tertiary rocks and those which exist between the same groups throughout the greater part of the continent, especially in the neighbourhood of mountain-chains. Near the base, for example, of the Alps,

* Con. and Phil., Outlines of Geol., p. 62.

Apennines, and Pyrenees, we find the newer formations reposing unconformably upon the truncated edges of the older beds, and it is clear that, in many cases, the latter had been subjected to a complicated series of movements before the more modern strata were formed. The latter rise only to a certain height on the flanks of the mountains which usually tower above them, and are recognized at once by the geologist as having been upraised into land when the tertiary formations were still forming in the sea. The ancient borders also of that sea can often be defined with certainty, and the outline of some of its bays and sea-cliffs traced.

In England, although undoubtedly the greater portion of the tertiary strata is confined to certain spaces, we find outlying patches here and there at great distances beyond the general limits, and at great heights upon the chalk which separates the basins of London and Hampshire*. I have seen masses of clay extending in this manner to near the edge of the western escarpment of the chalk in Wiltshire, and Mr. Mantell has pointed out the same to me in the South Downs. Near the escarpment at Lewes, for example, there is a fissure in the chalk filled with sand, and with a ferruginous breccia, such as usually marks the lower members of the Plastic clay formation. From the fact of these tertiary outliers Dr. Buckland inferred, 'that the basins of London and Hants were originally united together in one continuous deposit across the now intervening chalk of Salisbury Plain in Wilts, and the plains of Andover and Basingstoke in Hants, and that the greater integrity in which the tertiary strata are preserved within the basins has resulted from the protection which their comparatively low position has afforded them from the ravages of diluvial denudation †.'

We agree so far with this conclusion as to believe that the basins of London and Hampshire were not separated until part of the tertiary strata were deposited, but we do not think it probable that the tertiary beds ever extended continuously over

* Dr. Buckland, Geol. Trans., Second Series, vol. ii. p. 125. † Ibid., p. 126.

those spaces where the outliers above mentioned occur, nor that the comparative thinness of those deposits in the higher chalk countries should be attributed chiefly to the greater degree of denudation which they have there suffered.

Origin of the English tertiary strata.—In explanation of the phenomena above described, we shall endeavour, in the two next chapters, to lay before the reader a view of the series of events which may have produced the leading geological and geographical features of the south-east of England.

A preliminary outline of these views may be useful in this place. We conceive that the chalk, together with many subjacent rocks, may have remained undisturbed and in horizontal stratification until after the commencement of the Eocene period. When at length the chalk was upheaved and exposed to the action of the waves and currents, it was rent and shattered, so that the subjacent secondary strata were exposed at the same time to denudation. The waste of these rocks, composed chiefly of sandstone and clay, supplied materials for the tertiary sands and clays, while the chalk was the source of flinty shingle, and of the calcareous matter which we find intermixed with the Eocene clays. The tracts now separating the basins of London and Hampshire were those first elevated, and which contributed by their gradual decay to the production of the newer strata. These last were accumulated in deep submarine hollows, formed probably by the subsidence of certain parts of the chalk, which sank while the adjoining tracts were rising.