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THE GEOGRAPHICAL EVOLUTION OF THE ENGLISH CHANNEL.

ENGLAND is surrounded by shallow seas, and the shallowest of them is the English Channel. The shallowest part of the Channel lies between Hastings and Etaples, where the greatest depth is only 20 fathoms, or 120 feet, and though the water becomes deeper to the westward, yet a large part of the Channel floor would be converted into land by an upheaval of only 180 feet. If the Anglo-French region were upheaved to that extent England would be united to France and Belgium by a broad tract of land; and if it were raised till the coast-line coincided with the submarine contour of 40 fathoms (240 feet) the eastern half of the Channel would be converted into a fertile lowland, through which the rivers of Northern France and Southern England would prolong their courses, becoming the tributaries of a greater Seine that had its estuary in mid-Channel between the coasts of Dorset and the Cotentin.

That such was once the aspect of the area which is now covered by the waters of the English Channel was first pointed out by Mr. Godwin-Austen in 1850, and is a conclusion from which no geologist has ever dissented. But this aspect was only a late phase in the series of mutations which the Channel area has experienced, and behind it remain the questions: How long has such a valley existed, during what geological period or periods was it actually formed, and what was the condition of the district before its formation?

In the present essay I will endeavour to furnish answers to these questions, for the subject has of late been rather neglected on this side the Channel, though some of our French colleagues have, more or less successfully, attempted their solution.

We need not go very far back into geological time to find a period when the valley of the Channel, *la Manche*, as our neighbours call it,

was not in existence. There is not the slightest trace of it in the Cretaceous period: in the early part of that period the contours and slopes of the district were totally different from what they are now. Part of it was indeed covered by the sea, but this sea opened south-eastward across the north-east of France.

It is generally believed that at this time a large mass of land lay to the west of England and France, uniting Brittany to Cornwall and both to Ireland. From this land rivers ran eastward to the sea of the Vectian Sands, and no part of this sea seems to have extended further west than the 3rd degree of W. longitude, though the western extremity of a gulf or bay on the site of the English Channel may have reached to that limit and have received the waters of one or more rivers flowing from the west.

During the progress of the Cretaceous period extensive subsidence took place, and the area of this sea was immensely increased; but this subsidence seems to have been much greater on its eastern than on its western borders. The greater part of England, France, Belgium, and Holland were submerged beneath the sea in which the chalk was formed, but we do not yet know how far this sea encroached on the western land. It seems to have covered a large part of Devon, but there is no proof that it extended so far westward as to mingle its waters with those of the Atlantic; while in France there is evidence from which we may safely conclude that the land which stretched northward from Brittany through Cornwall was never submerged during any part of the Cretaceous period. The facts on which this conclusion is based may be expressed in three brief statements:

(1) The Lower Chalk passes westward into glauconitic sands.

(2) The Middle Chalk thins so rapidly from N.E. to S.W. that it must have thinned out before reaching Brittany.

(3) In the Cotentin glauconitic sandstone, representing the Lower Chalk, is covered directly by a sandy yellow limestone, which appears to belong to the very highest part of the chalk. In other words, the mass of the chalk is absent, and these beds seem to have been deposited in a little bay which indented the coast-line of the western land.

It would appear, therefore, that during the formation of the chalk there was no channel, strait, or inlet between Cornwall and Brittany, but continuous land, probably part of a large island, with a wide open bay, on its eastern shore.

Passing now to the Eocene period, we find that upheaval has taken place, and that the land areas in western Europe have once more been greatly increased at the expense of the seas. The lowermost Eocenes in the west of England and France are of fresh-water origin, and the Eocene sea lay at first to the east of England. The waters

of this sea, however, gradually extended themselves over the lowlands of the Anglo-Parisian basin, and the sea of the London Clay spread as far west as Dorsetshire, but thence its shore-line recurved to the south-east and cut the coast of France near the mouth of the Seine.

It was not till the epoch of the Calcaire Grossier (equivalent of our Bracklesham Beds) that the Eocene sea reached the borders of Brittany, and overlapped the Lower Eocenes so as to rest on the Cretaceous strata of the Cotentin. Here, then, we arrive at an epoch when the Channel area was occupied by a sea which may have opened westward into the Atlantic; let us see if there is any evidence that it actually did communicate with the ocean.

The geography of this period was such that there were three open seas or oceans with which the Parisian sea might have been connected: there was the Atlantic on the west, a larger Mediterranean on the south, and a North Sea to the north-east. Now the fauna of the Lower Bracklesham and Calcaire Grossier is essentially a southern fauna; it contains species of tropical and semi-tropical aspect, very different from those of the London Clay. These species cannot have been introduced from the northern sea, but must have come either from the south or from the south-west; that is to say, the existence of such forms so far north as Lat. 51 can only be explained by supposing that the sea in which they lived opened southward into the Mediterranean or westward into the Atlantic.

M. G. Dollfus, who has made a special study of the Tertiary strata of northern France, has recently examined the Eocene deposits along the southern border of the Paris basin, and is convinced that there was no opening in that direction; all the Eocene beds thin out and put on the aspect of shore deposits along that line of country. He concludes, therefore, that the opening which admitted the southern mollusca was westward along the site of the English Channel and through the Cotentin to the Atlantic. Professor Hébert was of the same opinion, and found confirmation of it in the identity of the fauna of the Cotentin Eocene with that of the contemporaneous deposits at the mouth of the Loire, such a close resemblance showing that both inlets must have been peopled from the same source, namely, the Atlantic Ocean.

We may, therefore, be sure that the solid barrier of land which had so long protected the Anglo-French seas from the waves of the western ocean had, at the close of the Cretaceous period, been reduced to narrow dimensions; the passes between its hill ranges had been widened and lowered, and its valleys had been cut down to a low base-level of erosion. The upheaval of early Eocene time had lifted the land to a higher level above the sea, but this only quickened the work of rain and rivers in deepening the passes and valleys.

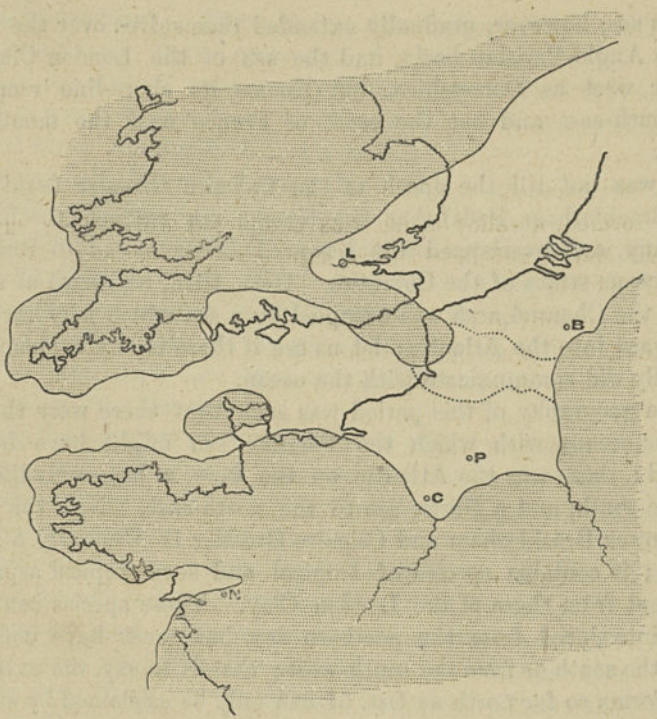

FIG. 1.—Sketch map of the positions of sea and land in the middle of the Eocene period.

When, therefore, a subsidence took place which affected the whole region (or, at any rate, all the southern part of it), both sea and land alike, the Atlantic waters advanced rapidly over the lower slopes and plains, and finally broke through the passes between the Breton and the Cornubian highlands, uniting themselves with the waters of the Anglo-Gallic sea, which had advanced from the eastern side through and north of the Cotentin.

The map, Fig. 1, will serve to illustrate the probable geography of this epoch, and shows the connections which the sea of the Calcaire Grossier had with the Atlantic on the west and the Belgian sea on the north.

The next change was an elevation of the Wealden-Ardennes ridge into an isthmus which separated the Belgian from the Anglo-Parisian sea, while throughout the Oligocene period so much sediment was carried by rivers into the latter sea that the whole of the Parisian and Hampshire basins were converted into huge swamps, with lagoons, which were sometimes filled with fresh water and sometimes with salt or brackish water.

Eventually, at the beginning of what is called Miocene time, the whole region was raised into land, and the Oligocene swamps were gradually drained by a system of streams which in all probability

united to form a river flowing westward through the gap between Cornwall and Brittany. Of this river no traces now remain; its work was mainly that of erosion, and any deposits which may have been formed in the lower part of its valley have been destroyed by subsequent inroads of the sea. There can be little doubt, however, that it was at this epoch that the actual "valley of the Channel" began to be formed, a valley which was completed during the succeeding Pliocene epoch, and has by final submergence been converted into an arm of the sea.

To resume our historical account of the area, the early part of the Pliocene epoch was one of partial submergence, during which the Atlantic waters entered the western end of the valley and spread over the lower parts of the country on either side, to a level of about 380 feet above the present level of the sea. Traces of this submergence remain at St. Erth, in Cornwall, and in the Cotentin. At the same time the Belgian sea advanced eastward and southward, till its shore line lay over the the central parts of the Weald country and the Boulonnais. The term *lay over* is used advisedly, because these areas were not, as now, depressions bordered by lines of escarpment, but were plains *dominated by still higher land on the south-west*. This conclusion followed as a natural and inevitable inference from Mr. C. Reid's determination of the Pliocene age of the Lenham Beds which occur on the summits of the North Downs.

Once more the unstable crust beneath the British region was lifted, and once more the sea was forced to retreat from the districts it had invaded during early Pliocene time; and the earth-throes which occurred during the later portion of that time resulted not only in a general elevation, but in the bulging or ridging up of the surface along certain lines. The lines or axes of these ridges cross the English Channel obliquely from north-west to south-east, and the portions of them which form English soil are known as (1) the axis of the Weald, (2) the axis of Portsdown, (3) the axis of Purbeck; corresponding to (1) the axis of Artois, (2) the axis of Bresle, and (3) the axis of Bray, in France.

The formation of these ridges was of course a gradual operation, and that of the Wealden area was the dominant one, for, as we have seen, its arch had been partly formed in the Eocene period, and it included two minor axes, that of Kingsclere and that of Winchester. This dominance of the Wealden uplift is a most important point, because it would seem that it not only acted as a local watershed, but that the streams flowing off it to the south-east into the Pliocene river were strong enough to maintain their channels through the minor ridges which slowly rose across their path. They cut their way through these ridges in the same way as the Green River of Colorado cut its way through the rising dome of the Uinta Mountains.

We may safely assume that one or more of these transverse streams trenched the Wealden ridge between Eastbourne and Etaples, just as the South Downs are now trenched by the valleys of the Ouse, the Adur, and the Arun. All these streams were tributaries of a river which traversed the central part of the Channel and was joined by another occupying the valley of the Solent before it cut through the ridge which then united the Isle of Wight to the Pays de Bray.

The rivers of southern England and northern France are, as it were, the dissevered and truncated relics of this Pliocene river system, and remnants of the deposits left by some of the inland tributaries of these Pliocene rivers have been found at Dewlish in Dorset, and at St. Prest, near Chartres, in France. These deposits are gravels containing remains of *Elephas meridionalis*, and are of about the same age as the Cromer Forest-bed, which is supposed to have been formed at the debouchure of the Pliocene Rhine into the North Sea; all the great rivers of Northern Europe having at this time more extended courses than they have now.

The history of the Channel area during the Glacial epoch is at present rather obscure, for geologists are not yet in agreement as to the extent of the submergence which took place in that epoch. Among the early Pleistocene deposits on the borders of the English Channel the raised beaches which occur at intervals along the south coast of England and the north coast of France are geographically the most important. Those of Devon and Cornwall contain a fauna which indicates a rather colder climate than that now prevailing in those counties; they are found at various levels up to a height of 60 or 70 feet above the sea, and they are often covered by the coarse stony loams which are locally known as "head."

Similar evidence of partial submergence during this period is found in Sussex, where a raised beach containing marine shells occupies a long tract of land between the South Downs and the sea, being traceable as far east as Brighton. This beach is generally covered by stony loam and brick-earth, comparable in many respects to the Cornish "head," and containing the bones of mammoth, rhinoceros, and other extinct animals, with the flint implements of Palæolithic man. Inland the beach is backed by a line of cliffs the foot of which is about 100 feet above the sea.

This Sussex beach contains stones and boulders which have apparently been derived from more western localities, and Mr. Clement Reid has recently succeeded in tracing these rock-fragments to a still older boulder-gravel, which seems to be the oldest Pleistocene deposit yet discovered on the south coast. This gravel occurs at Selsey, and contains large blocks and boulders, some of which bear the characteristic marks of ice-action, and have evidently been transported from their original homes by the agency of floating ice-

rafts. Some have come from Bognor, others from the Isle of Wight, and some are masses of granite and greenstone which are believed to have travelled from Cornwall and Brittany.

It would appear, therefore, that the Pliocene land-surface, which was described on the preceding page, underwent a gradual submergence in Pleistocene time. The sea crept up the valley of the great river which traversed the plain of "La Manche," and isolated first one and then another of the tributary rivers which drained the south of England and the north of France. When at last the land had sunk to a level of about 100 feet lower than that at which it now stands, it remained stationary for a time, while the sea carved out lines of cliffs and formed shingly beaches here and there beneath them.

The Channel Sea of this period occupied very nearly the same space as that of the present day, but the actual coast-line was not quite the same. Here, however, some interesting and important questions arise: How far did it extend to the eastward? Were the Straits of Dover formed at the time of this submergence? And did the sea work its way across the watershed between the drainage systems of the south and east of England so as to isolate Britain from the Continent?

On the English side of the Channel the eastward continuation of the old cliff and coast-line seems to have been destroyed by the inroads of the sea, which, even in the times of human history, have been continually cutting back the cliffs between Brighton and Eastbourne. Traces of the old shore-line occur along the north coast of France, as far east as the mouth of the Somme, but none have been found where that coast runs northward between Cayeux and Boulogne, so that if the sea had at this time cut through the continuation of the South Downs, it had certainly not made such a wide gap in them as that which now separates Beachy Head from the southern heights of the Boulonnais.

But as soon as the French coast turns again to the east, we find near Wissant a fragment of a raised beach, 16 feet above high-water mark; and a little further east, near Sangatte, the cliffs present a counterpart of the section at Brighton—an old pebbly beach with sea-shells, covered by an immense mass of yellowish stony loam and banked against a steep cliff of chalk. This stony loam is continuous with that which fringes the inland border of the plain of French Flanders, and this plain was clearly covered by the sea at the time when the Sangatte beach was formed.

It does not follow, however, that this shore-line was continuous with the southern coast of the Channel sea. It might have been the shore of an inlet which only opened eastward into the North Sea, while the Channel terminated at the foot of the South Downs, leaving a broad isthmus of land uniting the Boulonnais with the Wealden

area of England. It is true that some pebbles of red granite have been found in the old beach at Sangatte, but there is nothing like the large assortment of western stones which occur in the Sussex beach; moreover, Professor Prestwich has pointed out that fragments of red granite occur in the Lower Cretaceous sands of Kent, so that we have only to imagine a river traversing the continuation of these sands and opening into the suggested inlet or estuary, and we have a sufficient explanation of the granite pebbles at Sangatte. It is, in fact, very probable that before the formation of Romney Marsh the River Rother took this very course. Pebbles of granite, porphyry, and diorite have been dredged from the bottom of the Straits of Dover, and M. de Lapparent has explained their presence in the same way.

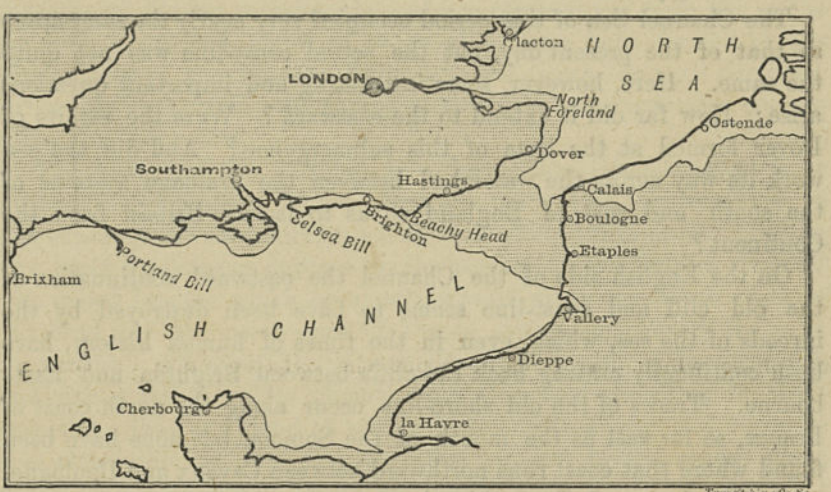

FIG. 2.—Supposed geography of the Channel area at the time the raised beaches were formed.

There is still another piece of evidence which bears upon the question: at Selsey, in Sussex, there is a deposit of marine mud containing an assemblage of mollusca which indicates a rather warmer climate than that of Sussex at the present day. Mr. Clement Reid has recently ascertained that this deposit is of intermediate age between the gravel with ice-borne erratics and the old beach previously mentioned, hence he regards it as evidence of a mild inter-glacial episode; but that the climate of an inter-glacial episode should be actually warmer than that of the present time seems rather unlikely, unless some additional local cause contributed to produce such a result. If we suppose that the Channel was then a gulf opening westward into the Atlantic, but having no connection with the cold waters of the North Sea, we have just the local conditions which would conduce to a higher mean temperature of its waters and a milder climate along its shores.

On the whole, therefore, and in the absence of any real proof to the contrary, the balance of evidence seems to be in favour of the conclusion that at this epoch the Channel was a gulf and that England was still united to France, although an inlet from the North Sea had commenced the formation of the gap which afterwards became the Straits of Dover.

The next episode certainly seems to have been one of upheaval, for in the opinion of most geologists the character and contents of the stony loams and "head" which overlie the raised beaches prove them to have been accumulated on a land surface. It is also generally supposed that they indicate a climate of semi-glacial severity, when the winters were long and the summers were short, when the soil was frozen to a great depth, and the snows, melted by the summer's heat, caused floods, which swept down large quantities of detritus into the valleys. Others, however, do not think that a more rigorous climate was necessary for the formation of these deposits, and only see the signs of a greater annual rainfall than that of the present day. However this may be it is highly probable that the land rose till the general elevation of the country was from 200 to 300 feet higher than it is now, and all the southern part of the North Sea became dry land, so that not only France, but Belgium and Holland, were then united to Britain.

We now arrive at the final phase of this long and varied history, the phase which has brought about the existing state of British geography. This was a general subsidence of all the countries around the southern part of the North Sea and the area of the English Channel, including also the greater part of England and Ireland. The submerged forests and beds of peat which are found at the mouths of many English valleys at depths of from 40 to 60 feet below high-water mark, show how much higher the general surface of the country was before this subsidence commenced. As it continued the tides flowed farther and farther up the valleys, and converted the river mouths into those estuaries and inlets which now form such excellent harbours along our southern coast.

At the same time the North Sea advanced southward over the low plains from which it had been displaced, eating its way up the estuaries of the Rhine and the Thames, and cutting back the land which lay between them, till it had regained all that it had lost and once more entered the gap between Folkestone and Sangatte.

If I have read the geological record aright, it was not till this epoch that England was completely severed from France, and the last link of land which bound the two countries together lay, not across the Straits of Dover, but along a line from Hastings to Boulogne. The waves of the North Sea worked their way westward across the northern part of the isthmus, covering the area of Romney Marsh and formed the

old coast-line which runs westward from Hythe to Lympre (the *Portus Lemanis* of the Romans). On the southern side of the isthmus the Chalk Downs were probably breached by a transverse valley similar to those of the Ouse, the Adur, and the Arun, and by this means the Channel sea would gain access to the low-lying central part of the isthmus. The low watershed of the Hastings sands would then be the only remaining barrier between the two seas, and when once the final breach was made it would rapidly be widened, for the soft sands and clays of the Wealden beds would offer but a feeble resistance to the inroads of the sea, aided by the slow but continual sinking of the ground.

Whatever may be the exact geological date of the final severance of England and France, the process was probably accomplished in the manner above described, the last neck of connecting land lying along the central watershed of the country, and not along the line of the North Downs. The hard chalk of Dover and Cape Blancnez does not yield so easily to the erosion of the sea as do the beds above and below it; hence it is on this account, and not because it was the last link of union to France, that the Straits of Dover are now the narrowest part of the "silver streak."

To describe the minor changes which have occurred since Britain became an island does not come within the scope of this essay; the task I have set myself being only to educe from the known geological facts an account of the long succession of changes which have led up to the existing state of geography, and thus to portray what appears to have been the geographical evolution of the English Channel.

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