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ORDINARY MEETING.*

CAPTAIN HEATH, R.N., IN THE CHAIR.

The Minutes of the last Meeting were read and confirmed, and the following paper was read by the Author :—

THE SUB-OCEANIC DEPRESSION KNOWN AS "LA FOSSE DE CAP BRETON," AND THE ADJACENT RIVER VALLEYS OF FRANCE AND SPAIN. By Professor J. LOGAN LOBLEY, F.G.S., F.R.G.S.

(Read Monday, January 1, 1900.)

THE sub-oceanic features off the western coasts of Europe have been prominently brought before the Members of the Victoria Institute by Professor Hull, in highly interesting and well illustrated papers, while the importance of the facts and the gravity of the conclusions that may be drawn from them have been recognized by the Royal Geographical Society and the British Association, before which bodies discussions of the subject have taken place. Communications on this important investigation have also been published in the *Geological Magazine*, from several geological authorities, including an important contribution to the discussion of the question in a paper on "The Eastern Margin of the North Atlantic Basin," by Mr. W. H. Hudleston, F.R.S., published in the *Geological Magazine* for March and April, 1899, which is accompanied by a bathygraphical map extending through fifty-five degrees of latitude.

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* Monday, January 1st, 1900.

The corresponding subject of the sub-oceanic features off the eastern coast of North America has been dealt with in considerable detail by Professor Spencer and Mr. Warren Upham, who have shown that these features of the sea bottom on the western side of the North Atlantic Ocean are quite analogous, if not quite similar, to those worked out by Professor Hull on its eastern side.

After the papers which have appeared in the *Journal of the Victoria Institute* by Professor Hull, it is not necessary for me to recapitulate the facts that have been ascertained or the general conclusions derived from them. Sufficient here will be a reminder that the Continental Platform underlying the sea on the western coasts of Europe has been found by isobathic soundings to be indented at places approximately opposite to present river-valleys by deep ravines or submarine valleys, the bottoms of which descend from the present littoral to the deep sea bottom outside the Continental Platform, cutting through what has been called the "Great Declivity," by Professor Hull, and the "Sub-Oceanic Slope" by Mr. Hudleston, while at the same time these depressions in the sea-bed widen out seawards in a manner similar to those of existing river-valleys.

It has therefore been concluded that these submarine depressions are none other than former extensions or prolongations of the river-valleys of the present land surface, formed by sub-aerial erosion when the continental area was elevated sufficiently, and this in late Geological or early Pleistocene times.

Although this explanation, which has been very clearly and strongly advocated by Professors Hull and Spencer, may appear to many obvious, and the only possible explanation of the remarkable phenomena in question, it has been objected (1) that the required change of relative level of land and sea is too great to accord with known geological facts; and (2) that the submarine depressions are not proportionate in all cases to the size and importance of the rivers to the mouths of which they are respectively opposite, and by which they are assumed to have been formed.

With the first of these objections I do not at present propose to deal, since I now wish to call attention to the second difficulty only, namely, the disproportion at present existing between some of the submarine depressions and the neighbouring rivers. I will therefore confine myself to the consideration of the question whether the elevation of land

surfaces to the extent required for the sub-aerial erosion of depressions cutting through the Continental Platform to its base would anywhere give such a change of position of greater and lesser erosive power as would sufficiently account for the admitted disproportion of some submarine depressions to the respective nearest rivers by the prolongation of which it is concluded they have been cut down to their present depth.

The examples most prominently brought forward of this disproportion are those of the small depressions opposite to the great rivers, the Loire and the Gironde, and the great depression called La Fosse de Cap Breton opposite to the smaller river, the Adour.

The Fosse de Cap Breton is in the bed of the great south-east angle of the Bay of Biscay, the Gulf of Gascony. It commences close to the shore-line adjacent to Cap Breton, about ten miles north of the present mouth of the River Adour, on the coast of the Landes, and extends westwards as a depression in the sea-bottom for a distance of about 100 miles. At a distance of six miles from the land it has a depth of 1,000 feet from the surface of the sea, and at ten miles from the shore-line a depth of 1,200 feet. At fifteen miles from the commencement of the depression another submarine valley from the mouth of the Adour opens into it on the south side, and then the Fosse rapidly deepens, assuming, in the words of Professor Hull, "the form and features of a grand cañon, bounded by steep, sometimes precipitous, walls of rock from 4,000 to 6,000 feet in height, and ultimately opening out on to the floor of the ocean at a depth of about 1,500 fathoms (or 9,000 feet)."

The sea bottom on the north side of the Fosse de Cap Breton is remarkably different from that on its south side. On the north the Continental Platform, commencing with a width of thirty miles, widens as it extends northwards, until it attains a breadth of about 150 miles off the coast of Brittany, while on the south side it is very narrow, at one place only six miles wide, and nowhere along the entire length of the Fosse of 100 miles is the platform more than twenty miles in breadth. Thus the Fosse de Cap Breton is approximately parallel with the north coast of Spain and at right angles with the southern part of the French shore of the Bay of Biscay, the coast of the Landes.

The adjacent coasts correspond in their physical features most strikingly with the sea floor on each side of the Fosse.

As is well known, the Landes is an extensive plain very little above the sea-level, spreading inland for a distance of 100 miles, and extending along the Bay of Biscay from the Adour to the Gironde, a distance of about 150 miles. The coast of Spain on the other hand is mountainous, the western extension of the Pyrenees, the Cantabrian mountains, fringing the shore-line, with their spurs forming head lands.

Corresponding, too, with the physical features of the two coasts is, as might be expected, their geological structure. The flat French coast area is formed of Quaternary accumulations overlying Miocene and Eocene strata, while the rocky, hilly, and mountainous Spanish coast lands are composed of strata of Secondary and Palæozoic Age.

Of the rivers flowing into the Gulf of Gascony, or south-east angle of the Bay of Biscay, the principal is the River Adour, which, although called by Dr. Blanford a comparatively trivial stream, is better, I think, described by Professor Hull as "a fine river." It has a breadth at the city of Bayonne of 800 feet, and from its source in the Pyrenees to its mouth measures at least 200 miles, and has several important tributaries, as the Nive, which joins it at Bayonne, the Oloron, the Gave de Pau, and on the north, the Midouze, which give the Adour a large drainage area extending for fully 120 miles along the northern side of the Pyrenees. About fifteen miles to the south of the mouth of the Adour, the River Nevelle flows into the sea at St. Jean de Luz. This at present is an unimportant river, but a little farther to the south and joining the sea at the very angle of the Bay of Biscay there is a river that deserves more attention than it generally receives. This is the River Bidassoa, the boundary river between France and Spain, and differs from the Adour and the Nevelle in draining the south side of the western part of the Pyrenees. It is even now a considerable stream, and the alluvial flats seen as Fuentarabia, at its mouth, is approached shows that in quite late Quaternary times it was a much greater river. These three rivers, the Adour, the Nevelle, and the Bidassoa, now pour their waters into the sea at the head of the Fosse de Cap Breton.

We may now inquire whether, under the conditions that must have obtained with an elevation of the contiguous lands to 9,000 feet above their present levels, the output of ice, and afterwards of water, together with the action of the sea at the bight of the Bay of Biscay, would not be of sufficient erosive power to produce the Fosse de Cap Breton,

while at the same time there was no such enormous erosive power possessed by either of the then existing rivers, the Loire or the Gironde.

With an added elevation of 9,000 or even of 7,000 feet not only the higher and mountainous districts of France and Spain, and especially the Pyrenean region, but the whole of the area so raised would be brought under glacial conditions. The Pic de Nethou in Maladetta, Mont Perdu, and a few other summits in the Pyrenees about 10,000 feet in elevation, have glaciers at the present time, and there would be many more glaciers on the Pyrenean mountains were it not for the fact that their summits are not favourably grouped for the accumulation of great glacier-producing masses of snow. Under the conditions supposed, the whole range of the Pyrenees, including all its spurs and offshoots, would reach far above the snow-line. This mountain region is of considerable breadth, for the main sierra of the Pyrenees is buttressed, as it were, on each side by mountains for a distance of from fifteen to twenty miles from the axis of the range, giving a breadth, therefore, of from thirty to forty miles of mountains extending in length from the Bay of Biscay to the Mediterranean Sea.

Although the summits of these mountains are not well adapted for the accumulation of snow and the formation of glaciers, this is not the case with those parts of the region now well below the snow-line, since there are innumerable valleys of great capacity amidst surrounding lofty hills and mountains, which if above the snow-line would retain snow and so accumulate sufficient material to produce very many and very large glaciers. Winds from the west and south-west, that is from the ocean, would prevail as now and bring with them enormous amounts of vapour and air charged with evaporated water from the warm surface waters of the equatorial seas and the scarcely less warm waters of the deflected equatorial current flowing north-eastward as now from the American continent, but, in consequence of the elevation of the West Indian, or the Antillean region, having a less northerly course. This vapour and water-gas would be rapidly condensed by the great cold of the mountains and plateaux, and the mountains being of great elevation, the atmosphere would be compelled to give up a very large proportion of its water. There would, consequently, be over the whole of the European south-west region an unusually great precipitation, and thus the material for the

production of vast glaciers and ice-sheets would here be furnished in profuse abundance.

It ought also to be borne in mind that with the elevation of the American or western continent also, or of its central portion, the Antillean region, there would be no so-called "Gulf Stream" as now to bring warmth-giving waters and consequent warmth-giving winds to the north of Europe. This deprivation would intensify the glacial conditions consequent upon elevation in the areas to the north, and the great cold so produced there would react on the temperature of mid and southern Europe. Thus an additional refrigerating influence must be taken into account. The result of the whole would be the covering of the Pyrenean region with an ice-cap or continuous glacier of great thickness through which only the more acute summits would penetrate. This vast body of ice, gradually descending to lower levels, as the Greenland ice-cap does at present, would form an ice-sheet covering all the lower levels. We are thus compelled to conclude that with an elevation of 9,000 feet, or even of 7,000 feet, the entire region of what is now southern France and northern Spain would have a climate of quite Arctic cold, and would be covered by a vast and continuous capping of ice.*

Glacial conditions, with the elevation postulated, must have extended over the whole of France, but they would be greatly intensified in the Pyrenean region and especially in its western half, from its elevation, and the much larger body of vapour-charged air that would be there intercepted and the consequent enormous amount of snow that would there be precipitated.

The great ice-sheet spreading to the north of the Pyrenean range would move in the direction of least resistance. When the surface features of southern France are considered it is at once seen that the direction of least resistance to an advancing ice-sheet from the northern side of the western half of the Pyrenees would be to the west, or in the direction of the sea, over the region now occupied by the drainage areas of the Adour and the Garonne, which includes the extensive low plain of the Landes, at present little above the level of the sea, to which it extends. The whole of

* On this subject see paper by Professor E. Hull on "Another possible cause of the Glacial Epoch." *Trans. Vict. Inst.*, vol. xxxi, with plate, p. 141 (1897–8).

this region, having little variation of elevation of surface, is one well defined physical area with higher lands on the north and east and the Pyrenees on the south, and open only to the sea on the west. This great area, consequently, under glacial conditions must have been covered by an ice-sheet, or vast glacier, moving constantly westwards, and as constantly giving off portions of itself to the sea where is now the Bay of Biscay.

The discharge of glacial ice from the southern part of the west coast of France would consequently be of vastly greater amount and erosive power than any discharge of land ice from the parts of the coast farther north, where neither the physical features of the interior land nor the climatal conditions would be nearly so favourable for the production of vast masses of moving ice descending to the sea along a restricted coast-line. As this constant discharge of glacial ice would powerfully erode and cut back the land, the sea cliffs would here be more rapidly cut back than farther north, and the coast-line would consequently recede and form a broad indentation. The great width of the submerged Continental Platform at the north of the Bay of Biscay, from 100 to 200 miles, and its comparative narrowness off the southern part of its eastern coast, corresponds in a remarkable manner with what might be expected to result from such localized intensity of erosive action.

Simultaneously with the great erosion by the glacial ice from the northern side of the Pyrenees there would be erosive action going on from the movement and discharge of the glacial ice produced on the southern side of the western end of the range. This would be by no means small. The district that now forms the north-western part of the Spanish province of Navarra and the whole of Guipuscoa consists of mountains rising to 3,000 or 4,000 feet above the sea-level, separated by deep valleys. These valleys when elevated above the snow-line would be eminently adapted to hold snow and form large glaciers. One of these, the valley of the River Bidassoa, runs far up into the mountains, and bifurcates and ramifies into deep and spacious subsidiary valleys that are quite ideal receptacles for the accumulation of vast masses of snow. This extensive valley, or rather system of valleys, opens out at its seaward termination in the very bight of the Bay of Biscay, and but little to the south of the Fosse de Cap Breton.

And along the whole of the south side of the Bay of

Biscay there are the long ranges of the Cantabrian mountains, which would also with the elevation supposed be the gathering grounds for, and the source of, innumerable glaciers. The erosive action consequent upon the continuous descent of glacial ice from these mountains would be very great also, and would consequently have a most destructive effect upon the northern coast of the Iberian peninsula, which would rapidly recede along its whole length, and in complete accordance with what would be the result of such action is the narrowness of the submerged Continental Platform along the north coast of Spain.

It will be obvious, from the considerations now briefly stated, that with the land of south-west Europe elevated above its present levels to a sufficient extent to place the bottom of the Fosse de Cap Breton above sea-level, enormous destructive action would be going on at the south part of the west coast of France and along the whole northern coast of Spain. In addition there would be the great glaciers from the south side of the western end of the Pyrenees cutting back the shore-line with very great erosive power at the angle formed by these two lines of coast.

Such powerful and simultaneous coast-destroying processes would have for their necessary result the formation of a great and deep bay in the very place where is now the more western and the deeper and wider part of the Fosse de Cap Breton. It must also be borne in mind that this bay-formative process would be going on throughout the whole of the vast period of the uprise, and only culminating in power at the time of the maximum elevation.

After the subsequent subsidence of the land areas had commenced and the lower levels had reached warmer zones of the atmosphere, the glacial ice would melt, at first on the land near the sea, and then farther and farther away from the coast, and with continued subsidence rivers would take the place of the former ice-sheet. These rivers would have great volume and great momentum, for they would be the only discharge for the vast accumulations of snow on the yet large areas above the snow-line as well as for the winter snows and the rains on the areas below the snow-line.

An examination of the hydrographical or drainage areas of the Garonne and the Adour shows that there is no marked physical division between them, the land between

the most western of the southern affluents of the Garonne and the most eastern of the southern affluents of the Adour having no greater elevation than the land between two affluents of either of these rivers. And between the main rivers themselves where they approach each other, between a few miles from Agen on the Garonne and Aire on the Adour, there is only a maximum elevation of 300 feet above the level of the sea. So that the entire area between the River Garonne and the Pyrenees may be considered to be physically but one hydrographical area, that with a greater volume of water, a greater fall, and consequently a much greater momentum of water-flow, would be drained by one river-system, since such conditions are calculated to give a straighter flow and a more direct discharge of drainage.

It is therefore highly probable that before the surface reached its present low level, and while the volume and momentum of the river-water was much greater than at present, the drainage of the whole of the great area between the Garonne and the Pyrenees, and now flowing in two river-systems, would be discharged into the sea from one river-mouth. This mouth, there is reason to think, was at the part of the coast where is now the deep water near the head of the Fosse de Cap Breton which bears the name of "Le Goul," and is opposite to Cap Breton.

A straight line joining Le Goul with the nearest point on the River Garonne, where it bends from a westerly to a northerly direction, near Port St. Marie, passes close to the River Adour at the point of the great bend in its direction from the north-west to the south-west between St. Sever and Dax and about ten miles from the latter town. This line is, moreover, nearly coincident with the valley of the chief northern affluent of the Adour, the River Midouze, for many miles.

And, indeed, even in recent times, and after continued subsidence had lowered the whole area to its present levels, it is known that the Adour entered the sea at Cap Breton, and then subsequently the mouth of this river was at a point on the coast still farther north that yet bears the name Vieux Boucan. Vieux Boucan is about twenty-five miles north of the present mouth, to which the river was finally diverted in the year 1579, and which outlet has to be maintained for the benefit of the city of Bayonne by costly engineering works. Thus the River Adour itself has had three different positions for its *embouchure*.

This considerable change of the course of a river in geologically recent times is an illustration of what great alteration may take place in river courses where the surface is approximately level and where Æolian deposits are accumulating. These deposits of blown sand are in the Landes very considerable and would in the past rapidly fill up any river channel from which the waterflow had been diverted.

It would thus appear that after this region had subsided to a very considerable extent from its previous maximum elevation, but before it had reached its present levels, a great river, taking to the sea all the waters from the glacial ice of the northern side of fully half of the entire range of the Pyrenees, and draining besides the lower area between these mountains and the higher lands of mid France, flowed directly towards the head of the deep bay previously formed by glacial action. This large and rapid river would be a sufficiently powerful eroding agent to cut down a great gorge at the head of the glacial bay. The River Bidassoa, coming from the elevated mountain valleys, would also pour into the same bay its abundant waters and add its crosive power, while the Rio Urema, the Rio Bilbao, and other rivers from the Cantabrian mountains would indent by smaller ravines the sides of the great embayment.

Besides the powerful erosive agents, glacial ice and rapid rivers, there must be added the waves of the sea, by which the sides of the great gorge in the coast-line would be cut back. By this action a widening process would contribute in giving the form and dimensions characterizing the Fosse de Cap Breton.

When by continued subsidence still lower levels had been reached, approximating to those now existing, and when the glacial ice of the Pyrenean region had ceased to lie on the mountain slopes and the inland waters had much diminished, with a corresponding great diminution of momentum of flow, a tendency to deviation from a short, straight, and direct course would, with accumulations of Quaternary deposits, favour a division of the main stream, and so bring about a separation of the old one great river-system into two river-systems. Some of the head waters, and these the more western, would unite into a main stream taking a more southerly course to the sea; and others, and these the more eastern and the greater in number and volume, would unite into a main stream taking a more northerly course. Thus

the separate rivers, the Adour and the Garonne, would be formed, and the latter, uniting with the Dordogne, would pour its waters into the Bay of Biscay by the wide channel of the River Gironde.

Then subsequently would be formed those minor depressions which are continuous with the present mouths of the Adour and the Gironde, the southern depression extending to the deep waters of Le Goul in the Fosse de Cap Breton, and the northern depression extending across the Continental Platform towards its edge to the north of the great Fosse.

If I have rightly interpreted the geological forces acting in the south-west European region during and after the Glacial Epoch, then the peculiarities of the sub-oceanic depressions of the Bay of Biscay have been accounted for by simple natural causes, and the origin of the Fosse de Cap Breton, which Reclus seemed to despair of elucidating, has been explained.

I venture to think, therefore, that the facts and considerations now adduced have removed one of the difficulties in the way of the general acceptance of the hypothesis of the sub-aerial erosion of those remarkable depressions in the sea-bottom that Professor Spencer and Professor Hull have so prominently brought before our notice in their highly interesting and important papers.

Discussion.

The Chairman.—I think we must all feel much obliged to Professor Logan Lobley for the very useful contribution that he has made to this subject, which has completed that which Professor Hull read before. Some of the points he touched on he did not explain to us so fully as Professor Logan Lobley has done to-day. He seems to have explained the peculiar construction of this deep water basin very clearly to us.

I hope those present will make remarks upon the subject.

Mr. David Howard.—The theory put forward by Professor Hull and supplemented by Professor Logan Lobley is exceedingly interesting. I cannot conceive such a localized action of water under the sea as to make a deep cut—unless under the most

extraordinary circumstances. This valley, shown by the contours, must have been cut while the land was above the sea; but it would be very interesting to work out this point. One cannot bear too strongly in mind the enormous power that speed in water has. Take the Thames Valley, where the water runs fast it cuts its way. The same volume and amount of water deposits the very mud it has cut from the upper level on the lower level, so that it is not quantity only but velocity. Therefore, if we once have a deep gulf cut and a quantity of water behind, we have a condition that constitutes an erosive action and nothing would determine it more than the Pyrenees. There you have one of the ranges of mountains that stops the entire moisture or current of air on the north side of those mountains. One knows how complete and intense is the dryness in the north of the Alps, with such excessive damp on the south, and that condition, with the warm Atlantic breezes cut off by the Pyrenees, would cause a constant and strong stream of water down the Adour just where it wanted to cut this deep gulf. Under those circumstances I must say I think about as strong a case is made out for that origin of these gulfs as it would be possible to have.

Professor LOGAN LOBLEY (in answer to a question by Mr. Baber) said: The configuration of the coast-line, at the time of the elevation, did not at all correspond with the present. It would more nearly correspond with the margin of the platform represented by the 200 fathom contour of the present day. So that you may take it that the coast-line at that time would be a long way distant from the present coast. These various indentations would be formed by subsequent erosive action occasioned by local circumstances, causing a greater amount of cutting back on one part of the coast than the other; but the general increase of denuding or erosive action, would be on the southern part of that coast-line, and the general effect of that would be to produce an embayment which would be afterwards continued by the action of the rivers.

The CHAIRMAN.—With reference to the action of water that Mr. Howard referred to, one can hardly realize, unless one sees it, the effect of configuration on mountains when brought into contact with the warm atmosphere of the tropical regions. I have seen, four feet high, close on the ground, a cloud rise in the horizon not much larger apparently than a man's hand. In half an hour,

or three-quarters of an hour, I have seen it as it approached the land, rapidly increase in size to about a square mile. One could hardly imagine that all that water could be deposited in such a small space. Of course if you get mountain ranges of 20,000 feet with a warm south-west wind blowing, you can imagine the enormous quantity of water that would be precipitated. Then as to the movement of sand, one can hardly imagine, unless one has seen it, the action of the wind on sand and the height of the sand wave. It is very much like the formation of a wave of the sea, and one sees how quickly the sand wave will move directly there is any wind of any strength. One sandhill I remember distinctly, about three-quarters of a mile long, and the edge of it was just as sharp as the back of a knife. Directly any wind blew the edge of sand fell down by its own gravity, a fresh edge being formed and its face always standing at a certain angle. So with a bay like that of Biscay you can understand any quantity of sand being thrown up.

I am sure we desire to convey our best thanks to Professor Logan Lobley for his very interesting paper, which I think has completed the whole question that was brought before us by Professor Hull on a previous occasion.

The meeting then adjourned.