

from Lower Gault to Chalk (*Echinoconus castanea*?), is hardly sufficient evidence to warrant the conclusion that a part of the rock-mass was of Upper Greensand age. There is nothing except the *Am. Selliquinus* that is specially characteristic of the Gault, and the question is this: What is the evidential value of the occurrence of *Echinocyphus difficilis*, and possibly also of *Echinoconus castanea* (?)? I think it may be answered in this way: it is more reasonable to suppose that these two species, or forms very closely allied to them, date really from Lower Cretaceous times, than it is to suppose the deposition of exactly the same kind of rock material should have continued at any one place from the time of the Lower Greensand to that of the Upper Greensand. In other words, I believe that the rock-mass from which the Moreset fossils have been derived was entirely a Lower Cretaceous rock, but high in that series, and corresponding approximately to the Aptien stage of France, and to the Lower Greensand or Vectian of the Isle of Wight.

#### VI.—ON THE CONTINENTAL ELEVATION OF THE GLACIAL PERIOD.

By Prof. J. W. SPENCER, M.A., Ph.D., B.Sc., F.G.S.

##### CONTENTS:

Introduction.—Character of the Submarine Antillean Valleys.—Gradients of Submarine Valleys.—Date of the Continental Elevation.—Migration of Mammals.—Submarine Channels off the Eastern Coast of America.—Submerged Plateau of the North Atlantic.—Continental Elevation a Cause for Glacial Climate.

##### Introduction.

BEFORE the last meeting of the British Association, held in Liverpool, Professor Edward Hull presented a paper upon "Another Possible Cause of the Glacial Epoch." In that paper, Professor Hull applied the writer's work on the "Reconstruction of the Antillean Continent,"<sup>1</sup> which brought together evidence of great continental elevation. This elevation and its effects upon the ocean-currents, in diverting them from the West Indian regions, with the consequent reduction of their temperature as they reach the northern latitudes in conjunction with the elevation of the land, were thought by Professor Hull to be sufficient causes for the production of the glacial climate over temperate regions in late geological times. The writer has hitherto never applied his observations on high continental elevation to climatic changes; but in this paper he proposes to extend briefly his researches from the Antillean region to the higher latitudes of America and the North Atlantic regions. Something has also been learned of the date of the great elevation; consequently inferences may be drawn as to climatic changes.

##### Character of the Submarine Antillean Valleys.

The feature of the paper on the "Reconstruction of the Antillean Continents," and subsequent observations of the region, show that

<sup>1</sup> J. W. Spencer, "Reconstruction of the Antillean Continent": Bull. Geol. Soc. Amer., vol. vi, pp. 103-140, 1894.

there are deep valleys, often of great length, extending from the mouths of the existing rivers, and crossing the American coastal plains, over deeply-buried channels. These are plainly recognizable in soundings upon the submarine coastal plateaux, and amongst the banks and islands of the neighbouring West Indian seas, to depths of 12,000 feet or more, before reaching the oceanic floors. The drowned valleys radiate from the continental margins and extend in a direction across that of the coast, and the mountain ranges to the back of it. Their courses do not usually coincide with those of the mountain folds. These submarine valleys are often recognizable for hundreds of miles in descending to the floors of the ocean-basins, as may be seen amongst the Bahamas. Frequently the divides between different systems are themselves submerged, as in the Straits of Florida. The submerged valleys are no broader than those of existing rivers, such as those of the Amazon and the St. Lawrence, nor indeed are they usually as wide. The Colorado cañon, from five to twelve miles across, between walls of 2,000 feet in height, is wider than some of the drowned valleys, which in part are cañon-like. Both the submarine plateaux and the floors of the valleys are like comparatively level plains or base-levels of erosion, which represent pauses when the streams and atmospheric agents could not further deepen their valleys, but only broaden them out into plains, until a subsequent elevation of the region permitted the streams once again to deepen their channels.

#### *Gradients of Submarine Valleys.*

The gradients of the submerged valleys (except along the reaches crossing extensive plains, now below sea-level) can only be compared with those of plateau regions, and not with the slopes of such a river as the Mississippi, which flows over great plains at low elevation. The manner in which the valleys descend from one platform to another is illustrated in the plateau region of Mexico and the West. An example of the declivity of such valleys may be seen along the Mexican Railway, back of Vera Cruz, and another above Monterey. The land valleys are made up of a series of steps with greater declivities between them than occur between those submerged. The various platforms represent the rise of the land during the excavation of the valleys. The gradients of the submerged plateaux are frequently as small as, or smaller than, those of such plains as the Mississippi, while the declivities at their margins are less abrupt than those of the land valleys descending from tablelands, as may be seen by comparing them with the Mexican valley sections. The gradient of the Colorado river, in its cañon 3,000 feet deep, is greater than that of the submerged platforms. Besides the greater valleys, descending from the high plateaux, there are many short tributaries, heading in amphitheatres, where the slopes may be from 200 to 600 feet per mile; the whole resembling gigantic "wash-outs." So also similar short drowned valleys occur on the edges of the submarine plateaux. The data concerning these comparative declivities were not obtained when the

original paper upon the submarine river-like valleys was prepared, but they now greatly strengthen the inferences that the drowned plateaux may be used as "yardsticks" for measuring the amount of late continental elevation.

In his paper referred to, Professor Hull endorses the correctness of the interpretation that the submerged valleys were formed by atmospheric agents. Such inferences being correct, the West Indies formed a high continental plateau, while the Gulf of Mexico and the Caribbean Sea were plains or inland lakes draining into the Pacific Ocean across what are now low passes of Mexico and Central America.

#### *Date of the Continental Elevation.*

Elsewhere the writer has shown<sup>1</sup> that the old Mio-Pliocene surfaces extended much beyond their present limits, and were subjected to long-continued reduction to base-levels of erosion. Upon the undulations of the country then produced, the Lafayette deposits of the continent form an extensive mantle, which has been provisionally considered as belonging to the late Pliocene epoch. The surfaces are enormously denuded. Following this formation northward, although there are but few exposures of contact, the writer has observed near Somerville, N.J., the Lafayette overlain by a few feet of glacial drift, which has been extensively denuded, as it is locally wanting. Resting upon the boulder drift, and where this has been removed, upon the underlying Lafayette loams and gravels, the Columbia formation may be seen. This feature shows that the epoch of glacial deposits occurred between the Lafayette and Columbia periods. Consequently, the epoch of great elevation, which favoured the excavation of the valleys, coincided with that of the glacial deposits of the early Pleistocene days.

#### *Migration of Mammals.*

The Antillean Continent formed a bridge connecting North and South America, over which only a few mammalian remains have been found, as the greater portion of it is now beneath the sea. At Port Kennedy, Pennsylvania, an extensive fauna has been discovered in fissures, and upon it Professor Edward D. Cope was engaged at the time of his recent death, but some results he had made known. Of 38 species of mammals, so far determined, a large percentage are extinct, and among these occur *Equus* and *Megalonix*. There is also an abundance of remains of an old form of South American bear, which are not known to have crossed the plains of the West. The occurrence of these types at Port Kennedy, Professor Cope regarded as strongly supporting the theory of the Antillean bridge in the early Pleistocene epoch. There is also a newer cave-fauna in Eastern North America, which belonged to a later period, separated from the first by a partial submergence, according to the conclusions of that distinguished author. *Elephas* has recently been found in Guadeloupe.

<sup>1</sup> "Reconstruction of the Antillean Continent," cited before.

*Submarine Channels off the Eastern Coast of America.*

The submerged valleys, which are best developed among the Bahamas and off the adjacent portions of the continent, provide the key for interpreting the submarine features of other regions. The broad subcoastal plain off the south-eastern States becomes narrowed to a few miles east of Cape Hatteras; but northward it broadens again, and eventually reaches a width of nearly 300 miles south-east of New England, and more than that across the submarine plateau which forms the Newfoundland banks. East of Labrador it has a considerable breadth, but the soundings there are too scanty for its delineation. In drawing the contours at a considerable distance apart, the same forms of indentation are repeated in the borders of the plateau as those observed farther south; but where the contours are drawn close together (even where the soundings are not as numerous as is desirable), the deep valleys are found to be continuations of existing rivers. Thus, Lindenkohl<sup>1</sup> traces the Hudson River channel to a depth of 2,832 feet, and the Great Egg Harbour channel to 2,334 feet, where the plateau is submerged only 600 feet. The Delaware and the Susquehanna valleys are also recognizable on the subcoastal plain to depths of about 3,000 feet.

In 1889, the writer showed how the Laurentian valley was submerged for a distance of 800 miles, beneath the waters of the Gulf of St. Lawrence, with the channel from 1,200 to 1,800 feet below the surface of the sea; but near the edge of the drowned plateau it descends abruptly to a depth of 3,666 feet.<sup>2</sup> The same is true of the valleys crossing the New England, Nova Scotia, and the Newfoundland banks. From the edge of the continental shelf, the Susquehanna valley descends precipitously to a depth of more than 9,000 feet, with its valley recognizable to 12,000 feet. The Delaware descends abruptly to 6,066 feet, and is plainly traceable to 11,256 feet, and to greater depths beyond. The same is true of the Hudson and its tributaries from Connecticut, being recognizable to depths of more than 12,000 feet. From the borders of Massachusetts, Nova Scotia, and the Newfoundland banks the valleys descend precipitously into amphitheatres 6,000 or 7,000 feet below the surface, and continue to depths of 12,000 feet, and in some cases to even 15,000 feet.

While to an unknown extent the drowned plateaux are covered with Tertiary formations, still the submerged valleys must, to a considerable extent, have been excavated out of hard Palæozoic and older strata, thus producing variations in the lengths of the deeper channels, and forming a contrast with some of those of the Antillean region.

From analogy with land valleys, the channels crossing the submarine coastal plains of a few hundred feet, afterwards of perhaps 3,000 feet, represent a long period of elevation. Then followed the

<sup>1</sup> American Journal of Science, vol. xli, p. 490, 1891.

<sup>2</sup> J. W. Spencer, "High Continental Elevation preceding the Pleistocene Period": Bull. Geol. Soc. Amer., vol. i, p. 63, 1889.

great elevation of perhaps two miles or more in height, continuing only long enough to allow the streams to dissect the margins of the tablelands, and form amphitheatres belonging to the new base-level of erosion. While the great depressions shown in the soundings may have in part been occasioned by an exaggerated oceanic subsidence along the line of the continental margin, yet amongst the West Indies it has been found that the actual depression has exceeded two miles. Although the deeper valleys of the north may be less than a hundred miles in length, their slopes are no greater than those of the valleys descending from the Mexican plateaux.

From the generalization of facts just given, the conclusion is, that the high continental elevation of the Antillean region extended northward in Eastern America, of which supporting data have been collected as far as Labrador.

#### *Submerged Plateau of the North Atlantic.*

If the analytical methods which have revealed the drowned valleys of the American coast be applied to the well-known North Atlantic plateau, similar valley-like phenomena will be discovered. While there are numerous soundings across the Atlantic, in the region of latitude  $52^{\circ}$ , the lines of soundings to the north are too far apart to everywhere afford detailed study of the submarine features; except that they show an extensive submerged plateau (from 7,000 to 9,000 feet) rising northward to the Iceland ridge, beyond which it again descends rapidly to depths of 12,000 feet, and west of Spitzbergen, 15,900 feet. The summit of the plateau, between Greenland and Norway, is submerged scarcely more than 1,200 feet. However, across the summit there are deeper channels, from the *cols* of which, valleys trend in opposite directions, like those amongst the West Indies or in the Straits of Florida. These *cols* are now submerged: that between Greenland and Iceland, to 1,974 feet; between Iceland and Faroe, 1,814 feet; between Faroe and Shetland, somewhat more than 3,000 feet; and between Shetland and Norway, about 1,000 feet. The southern margin of this plateau (in the region of latitude  $52^{\circ}$  N.) is indented by embayments and amphitheatres, similar to those of the border of the American plateau. From the comparatively numerous soundings upon the summit of the divide, and in the adjacent Arctic sea, the valleys from the *cols* just mentioned, and many others, can be traced to abyssmal depths. Thus, that between Greenland and Iceland descends rapidly from a depth of 2,000 feet to 6,642 feet, and may be followed to a depth of 9,000 feet. The valley in the opposite direction from the same *col*, extends northward, and receives the tributary from the Scoresby Sound (which is 1,800 feet deep far within the Greenland mass). In latitude  $74^{\circ}$ , there is a remarkable amphitheatre of 5,520 feet in depth; and just south-west of Spitzbergen, a similar amphitheatre of 8,100 feet in depth is found where the plateau is submerged only a few hundred feet. Spitzbergen and Norway are connected by a plateau which is generally depressed to less than 1,200 feet. From it valleys descend to the Greenland sea.

The Baltic valley hugs the coast of Norway, and beyond that it extends to the same sea. From the *col* of the channel between Faroe and Shetland, at a depth of somewhat more than 3,000 feet, a great valley extends southward. North-west of Ireland, this valley reaches a depth of 9,980 feet, upon the north-westward side of which the plateau is characterized by shallow banks; and it continues to a depth of 12,000 feet at the margin of the plateau. Tributary amphitheatres to this great valley may be seen westward of Ireland. One of these is 8,160 feet deep, where the platform has been depressed 5,040 feet; and two others have a depth of 10,500 feet, where the plateau is submerged only 4,000 feet. Further southward, extending from the oceanic basin, a large embayment indents and extends far into the platform south-west of Ireland, having still a depth of 10,500 feet, where the shelf is covered by only about 2,500 feet of water. The Bay of Biscay is a remarkable embayment of great depth, with tributary amphitheatres like those just mentioned. The amphitheatres mentioned have no extraordinary widths. Their land equivalents are characterized by inconsiderable streams descending precipitously over steps from plateaux of great altitude.

It is manifest, that Europe and Greenland form one continental mass, while the latter country is separated by a much deeper sea from the American continent. Accordingly, the search for these drowned valleys should be made by means of numerous soundings along lines parallel to the Iceland ridge, rather than off the coast of Ireland. From the fragmentary knowledge already acquired, it would be reasonable to expect the discovery of as complete systems of river-valleys as those found off the American coast and in the Antillean regions; indicating a late continental elevation of 12,000 feet or more.

#### *Continental Elevation a Cause for Glacial Climate.*

As has already been stated, the great continental elevation of Eastern America occurred during the early Pleistocene period, and was characterized by a stupendous amount of erosion, with the production of cañons and amphitheatres (at the heads of the valleys). Such an elevation of two miles or more, as measured by the depths of the valleys, must have produced a glacial climate in the more northern regions of America and of the North Atlantic. Thus we find a cause for the Glacial epoch; but many of the phenomena cannot be considered here. Whether the elevations of the North Atlantic and the American regions were absolutely simultaneous, or compensated each other with alternations, like the Antillean and Mexican undulations, is not known. Such alternations, with their diversions of the oceanic and atmospheric currents, together with the more recent partial submergence of the northern lands, would produce variations of the glacial phenomena, and would bring into close proximity those of high elevation and submergence, and of warmer and colder climates.

From as yet unpublished data, it appears that the late Pleistocene

depression of base-level in New England reached 2,700 feet at least. As there was a Mid-Pliocene (our separation of Pliocene and Pleistocene formations being largely arbitrary) elevation of undetermined amount, and as there have been several minor oscillations of level of land and sea, there is great latitude in the application of the phenomena to the Glacial epoch not yet determined—only that great elevation of measurable amount did obtain in Pleistocene days. With alternations of elevation between the North Atlantic and American plateaux, the changes of currents would further modify the climatic conditions of the period, so that this paper only suggests one phase of physical changes—tending to produce the phenomena of the Glacial period.

## NOTICES OF MEMOIRS.

### I.—THE AFFINITIES OF *HESPERORNIS*.<sup>1</sup> By O. C. MARSH.

IN the autumn of 1870, I discovered in the Cretaceous of Western Kansas the remains of a very large swimming bird, which in many respects is the most interesting member of the class hitherto found, living or extinct. During the following year, other specimens were obtained in the same region, and one of them, a nearly perfect skeleton, I named *Hesperornis regalis*.<sup>2</sup> In subsequent careful researches, extending over several years, I secured various other specimens in fine preservation, from the same horizon and the same general region, and thus was enabled to make a systematic investigation of the structure and affinities of the remarkable group of birds of which *Hesperornis* is the type. The results of this and other researches were brought together in 1880, in an illustrated monograph.<sup>3</sup>

In the concluding chapter on *Hesperornis*, I discussed the affinities of this genus, based upon a careful study of all the known remains. Especial attention was devoted to the skull and scapular arch, which showed struthious features, and these were duly weighed against the more apparent characters of the hind limbs, that strongly resembled those of modern diving birds, thus suggesting a near relationship to this group, of which *Colymbus* is a type. In summing up the case, I decided in favour of the ostrich features, and recorded this opinion as follows:—

“The struthious characters seen in *Hesperornis* should probably be regarded as evidence of real affinity, and in this case *Hesperornis* would be essentially a carnivorous, swimming ostrich.” (“*Odontornithes*,” p. 114.)

This conclusion, a result of nearly ten years’ exploration and study, based upon a large number of very perfect specimens and a comparison with many recent and extinct birds, did not meet with

<sup>1</sup> From the American Journal of Science, vol. iii, 1897.

<sup>2</sup> Silliman’s Journal, vol. iii, p. 56, January; and p. 360, May, 1872.

<sup>3</sup> “*Odontornithes*: a Monograph on the Extinct Toothed Birds of North America.” 4to, 34 plates; Washington, 1880.