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ORDINARY MEETING.*

THE VEN. ARCHDEACON ROBINSON THORNTON, D.D., V.P., IN THE CHAIR.

The Minutes of the last Meeting were read and confirmed, and the following Elections were announced:—

MEMBER:—Rev. E. Pitcairn Wright, London.

ASSOCIATE:—Rev. I. K. Hill, China.

CORRESPONDING MEMBER:—Pastor Georg Stosch, D.D., Berlin.

The following paper was read by the Author:—

ANOTHER POSSIBLE CAUSE OF THE GLACIAL EPOCH. By Professor EDWARD HULL, LL.D., F.R.S., F.G.S. (Plate.)

PART I.—INTRODUCTORY.

IT is known from soundings, carried out by the United States Navy, the British Admiralty and by private enterprise, that the eastern coast of America has for its margin a submerged terrace—known as "the Continental Shelf"—which stretches from the coast outwards to the hundred-fathom line, and terminates along an escarpment going down to about 450 to 500 fathoms, when another terrace is met with stretching for a greater or less distance under the Atlantic with an average depth of 2,700 to 3,000 feet, and in its turn bounded by a steep descent leading down into the abysmal depths of the ocean, which vary from 12,000 to 13,000 feet or more below the present surface. This second and deeper terrace, determined by Professor A. Agassiz, has been named by him "The Blake

* January 17th, 1898.

Plateau."* Off Cape Hatteras the breadth of the Continental Shelf is 15 miles, but it increases to 100 miles off the coast of New England, and to 200 miles off the coast of Maine.† The slope from 100 to 500 fathoms is often so steep, that the two contours approach very close together. The outer slope of the Blake Plateau is also remarkably steep in some places, so that the contours of 500 and 1,000 fathoms come almost into contact on the charts, as, for example, off Cape Hatteras. These two submarine terraces, with their marginal slopes, are continued around the West Indian Islands, the Gulf of Mexico, and the Caribbean Sea. In the Gulf of Mexico the Continental Shelf, shown by the 100-fathom line, stretches for long distances from the shore, especially from the Northern Coast and Yucatan, where it is distant 150 miles from the coast. Inside Florida the distance is about the same; and as the 100-fathom contour represents very closely the general continental margin, the *massifs* of the peninsulas of Florida and of Yucatan have more than twice their apparent breadth.‡

These two terraces, continuous as they are throughout such a great extent of coast-line, and with levels so generally uniform, naturally suggest formation during one or more periods of emergence and depression, interrupted by pauses; and this impression has been corroborated by the further determinations of Professor J. W. Spencer, drawn from a careful delineation of the physical features of these submarine terraces and their marginal slopes, resulting in a remarkable advance in our views of suboceanic geography.§ Briefly stated Professor Spencer shows that most of the river-valleys of the American continent opening into the Atlantic or the Gulf of Mexico are continued under the ocean, traversing first the Continental Shelf and then passing onwards through deep and wide "embayments" to the Blake Plateau, which they also traverse, until finally lost in the abyssal region,

* *Three Cruises of the "Blake"* (1888).

† Agassiz, *ibid.*, p. 95.

‡ *Ibid.*, p. 102. These terraces are represented by shading on the accompanying map (Plate).

§ "Reconstruction of the Antillæan Continent," *Bull. Geol. Soc., Amer.*, vol. vi (1895); also, "Terrestrial Submergence of the South-east of the American Continent," *Ibid.*, vol. v (1893). A copious review of Prof. Spencer's, Memoirs by Mr. A. J. Jukes-Browne, appeared in the *Geological Magazine*, April, 1895. Startling as are the deductions of Prof. Spencer, I am not aware that they are contested by any American geologist of eminence.

which they enter through channels so deep that, if elevated into land, they would resemble the great cañons of Western America. Some of the channels which cross the Blake Plateau are traceable for 200 to 300 miles, and reach depths of 10,000 feet before being lost in the suboceanic embayments. Similar features are presented by the deep channels which furrow the shelf of the Bahama Islands, and also by those of the Gulf of Mexico. But there is one remarkable feature which ought not to be omitted from notice here, viz., that the submerged channel between the peninsula of Florida and the Bahamas appears to have been a saddle or watershed, from which cañons descended eastwards towards the Atlantic, and westwards towards the Gulf of Mexico. Professor Spencer has named the latter the "Floridian" Valley. The Mississippi and all the great rivers which enter the northern shore of the Gulf of Mexico have their apparent prolongations in well-defined submerged river-valleys, to which Professor Spencer has given definite names. They have their final "embayments" at depths of about 9,000 to 10,000 feet. The same is also true of the rivers entering the Atlantic. The submarine cañons are in effect drowned river extensions opening out on the abyssal floor at depths of about 10,000 feet, under the surface of the Gulf Stream. Amongst the West India Islands the "Haitian" cañon passes on to the Atlantic floor between the Bahama Banks and the islands of Cuba and Saint Domingo; other examples might be cited, but enough has been said to give a general idea of the author's determinations. It is now time to state the conclusions at which he arrives. He maintains that the physical features determined by the soundings are such as can only be explained by supposing an uplift of the whole region bordering the Atlantic to the extent of the depth of these submerged river channels, namely, 10,000 to 12,000 feet as compared with the present sea-level, by which the coast of South America was connected with that of the Northern Continent by a plateau of continuous land now constituting the floors of the West India Islands, and converting them into the "Antillean Continent." This uprise gradually lessened westwards, and was counterbalanced by a depression of Central America, owing to which the Gulf of Mexico and Caribbean Sea were connected with the Pacific. From geological considerations this uprise took place at two epochs, viz., the Pliocene and Pleistocene, with an intervening epoch of depression; and the later uplift

was followed by several minor oscillations resulting in the present arrangement of land and sea. The distribution of the land fauna and flora seems also to be corroborative of Professor Spencer's views.

Such conclusions are sufficiently startling; but for myself, I do not see how they are to be controverted. The submerged terraces, and profound valleys by which they are traversed, are such as could only have been formed under sub-ærial conditions; it is impossible to conceive of their formation while under the waters of the ocean.*

The evidence of the former greater elevation of the American coast finds its counterpart in that of Greenland and the plateau on which stand the British Isles and Scandinavia defined by the 100-fathom line. That this plateau was a land surface drained by rivers continuous with the Rhine and others has been shown by Godwin-Austen, Professor T. Rupert Jones, and more recently by Mr. F. W. Harmer†; while as regards Greenland, Mr. T. C. Chamberlin, of America, has recently stated that "there is no ground to question the former elevation of Greenland."‡ It would therefore appear that the elevation which affected the eastern coast of the American Continent was continuous all round the northern and western shores of the North Atlantic. The views of Mr. Warren Upham tend to confirm this conclusion.§

As regards the period when these "stupendous changes of level" took place, Professor Spencer says that they reached their culminating point in the Post-Lafayette, or early Pleistocene epoch of Eastern America.‖ For the grounds of this conclusion the reader must be referred to Professor Spencer's memoir itself.

It has been suggested to me by more than one friendly critic that the submerged terraces and river-valleys have required a longer period for their formation than one special

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* Professor Spencer considers that the floors of the Gulf of Mexico and of the Caribbean Sea were converted into plains. This does not appear to be a well-founded conclusion; they may have been inland seas during the continental period as shown on the accompanying map.

† "The Pliocene deposits of Holland, etc.," *Quart. Journ. Geol. Soc.*, November, 1896, p. 748.

‡ "Recent Glacial Studies in Greenland," *Bull. Geol. Soc., America*, vol. vi, p. 219. (1895.)

§ "Causes of the Ice Age," *Journ. Vict. Inst.*, vol. xxix, p. 201.

‖ *Supra cit.*, p. 307.

epoch of the Pleistocene, in fact, that it may have begun in the Pliocene period, and that their present development is the ultimate outcome of erosive action continued through a very long lapse of time.* This is a view which commends itself to the judgment, and may be readily accepted. Possibly "the continental shelf" may be the result of Pliocene erosion; and the deeper shelf with its cross-cutting channels, that of the Pleistocene epoch. A Pliocene erosion extending down to 100 fathoms, or less, would not have been sufficient to cut off the arm of the Equatorial current from the Gulf of Mexico to the extent effected in the later Pleistocene epoch, but may have done so to some extent. We must not forget that the decrease of temperature due to the diversion of the Atlantic stream from its course into the Caribbean and Mexican Gulfs into the North Atlantic was a slow and gradual change commencing towards the close of the Pliocene and attaining its maximum effect in the succeeding epoch.

In concluding his memoir Dr. Spencer observes that "this study establishes the great mobility of the earth's crust, and opens out many new problems in dynamic geology." I propose to deal with one of the more evident problems arising from this inquiry; namely, the effect of the uprising of the Antillæan continent on the temperature of the Gulf Stream, and on the consequent climatic conditions of Western Europe and the adjoining regions.

Part II.—The Gulf Stream.

During the uprising of the Antillæan continent, that branch of the great equatorial current which now enters the Caribbean Sea and passes on into the Gulf of Mexico must have pursued a very different course from that of the present day. Its passage into the Gulf was debarred by the coast of high continental land, the direction of which must have caused the current to pass directly northwards into the North Atlantic as shown on the accompanying map (Plate). Such a change in direction would result in a difference of temperature, and we shall endeavour to ascertain, with some degree of accuracy, the amount of variation as compared with that of the present day.

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* This, indeed, may be inferred from the language of Professor Spencer himself, when he says that the changes reached "their *culminating point*" in the Pleistocene period.

It is known that the Gulf Stream receives a large accession of heat between the time that it enters the Caribbean Sea and leaves the Gulf of Mexico through the Straits of Florida. Off Cape S. Roque the surface temperature is 73° Fahr., and on issuing from the Gulf it has risen to 86° Fahr. having in its passage gained 13 degrees of heat. Increasing its latitude by ten degrees it loses but two degrees of heat, and with this temperature of 84° Fahr. it crosses the 40th parallel, and spreads itself out over thousands of square leagues—carrying its warmth into the Arctic regions, and giving an increase of twelve degrees of temperature to the climate of the British Isles above that due to latitude.*

Geographers have exhausted the powers of illustration in endeavouring to estimate the calorific effects of this great oceanic river. Croll states that each cubit foot of water carries from the tropics for distribution upwards of 1,158,000 foot pounds of heat.† The estimates of Maury and Herschell are still larger. According to the calculations of Meech the amount of heat transferred to the Arctic regions by the Gulf Stream is nearly half as much as that derived from the sun.‡ Lastly, Professor J. D. Forbes calculated that the quantity of heat thrown off in the Atlantic area by the Gulf Stream on a winter's day, would raise the temperature of the atmosphere which rests upon France and the British Isles from freezing point to summer heat.§ These statements will suffice to represent the effects of the Gulf Stream as it exists at the present day; we have now to inquire to what extent they would be modified under the view of the uprising of a barrier of land connecting North and South America along the line of the Antilles.

We have already seen that the Gulf Stream gains thirteen degrees of heat between C. San Roque and the Florida Straits. If we allow one degree for the increase between C. San Roque and the entrance to the Caribbean Sea, the gain between this point and the Narrows will be twelve degrees. If instead of entering the Caribbean Sea, the stream passed northwards along the coast of continental land, it would have been deprived of twelve degrees of heat, but it would have gained some heat while flowing for

* Croll calculates that on leaving the Gulf the *mean* temperature of the Stream is not under 65° Fahr.; *Climate and Time*, p. 25.

† *Ibid.*, p. 25.

‡ Meech, *Smithsonian Contributions to Knowledge*, vol. ix.

§ Forbes, *Travels in Norway*, p. 202.

1,000 miles under the rays of a tropical sun. If we allow two degrees for this, then the total loss of heat on passing the coast of Florida will have been ten degrees as compared with that of the present day; and instead of crossing the 40th parallel with a surface temperature of 84° Fahr. as stated above, the Gulf Stream of the period referred to would have only had a temperature of 74° Fahr., which would not be very much in excess of the summer temperature of the waters due to latitude at this parallel.*

We have now to inquire what would be the effect of so great a reduction of temperature upon the climate of the North Atlantic and adjoining regions. A diminution of ten degrees of heat as compared with that of the present day would undoubtedly exercise a very important influence on the climate of the regions bordering the North Atlantic and the coast and islands of the Arctic Ocean. Not only would the annual mean temperature be considerably reduced, but the increase of snow and ice over those tracts which are at present on the verge of perpetually glacial conditions would have the effect of lowering the temperature far beyond their own limits. As Lyell has truly observed, land in Arctic regions conduces to cold; and owing to the great extent of additional land in Europe and Asia which would be brought under the influence of an Arctic climate by the lowering of the temperature, the cold would be increased in the adjoining regions lying to the south.

There is one way, perhaps the only way, by which we may indicate diagrammatically the climatic conditions of which we are in search under the hypothesis of a North Atlantic current taking the place of the Gulf Stream, but with a temperature ten degrees lower than the latter. If we suppose that the annual mean temperature of all those regions influenced by the Gulf Stream as far south as (say) the parallel of 40° N. is reduced by about ten degrees below its present range, then we shall have the present isotherm of

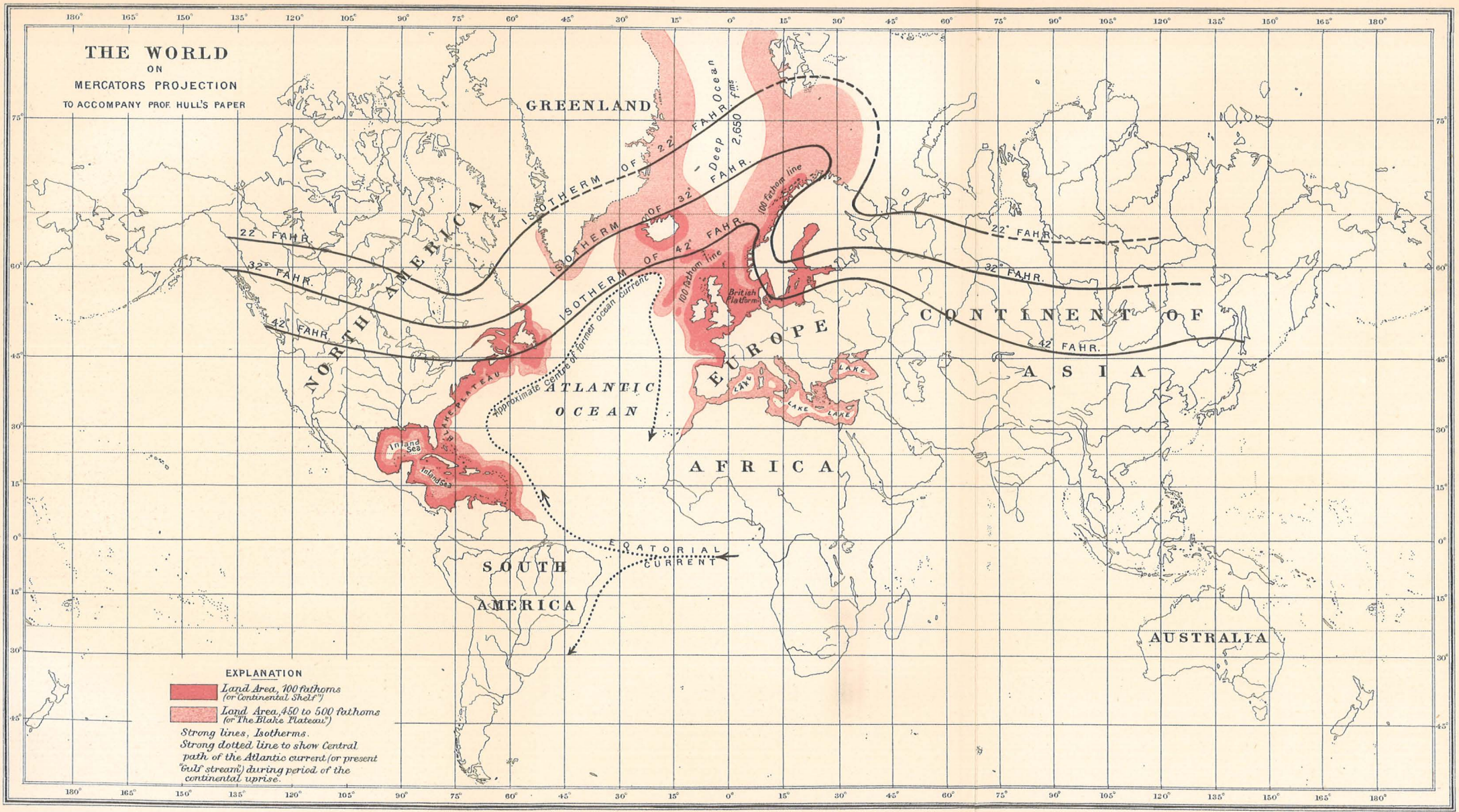
* Rennell has calculated that the waters of the Gulf Stream on leaving the Gulf of Mexico with a surface temperature of 86° Fahr. are 10° above that of the Atlantic in the same latitude; quot. by Lyell, *Principles*; 2nd edition, p. 244. A portion of the waters of the equatorial branch even now passes along the east coast of the West India Islands, ultimately joining the Gulf Stream. All this time however they are acquiring heat, but not to the extent which would be the case if they followed the main stream. The amount, however, is unimportant in its bearing on the question before us, as the conditions of this branch of the Equatorial current would have suffered no change.

(let us say) 32° Fahr. taking the position of that of 42° Fahr., and that of 42° taking the position of that of 52°; there will, in fact, be a general advance of cold southward. Then by observing the climatic conditions of the regions crossed by the present isotherms of 32° and 42° we shall be able to form an approximate idea of the climate, under the hypothetical conditions of temperature we are here considering. I am well aware that this mode of determination would not, in all cases, give strictly accurate results. Climates depend not only on temperature, but on relations of land and sea, on levels, prevalent winds and other conditions; but temperature is a main factor, and the mode of determination here suggested will probably afford fairly reliable results.

Isotherms.—Of all the isothermal lines representing annual mean temperature that may be drawn across the chart of the northern hemisphere, none is more important than that of 32° Fahr., the freezing point of water. This isotherm, according to Berghaus,* crosses America from lat. 58° N. on the west coast, to Cape Charles, lat. 52° 35′ N. on the east, skirts the southern coast of Greenland and crosses the Atlantic by the northern coast of Iceland, entering Europe near the North Cape; then trending southwards along the coast of Norway to the south of the Arctic circle, it crosses the Europe-Asian continent nearly along the 60th parallel to the coast of China. This isotherm is everywhere to the south of the Arctic circle except in that part of the Atlantic bordering the coast of Norway and lying to the south-east of Iceland, where it passes the circle along the arm of the Gulf Stream which, even in these high latitudes, gives evidence of its power to ameliorate the rigour of the climate.

The isotherm of 32° Fahr. may be regarded as a convenient line of demarcation between the permanently glacial regions and those which enjoy a temperate climate. To the north of this line are situated the frozen regions of Hudson's Bay, Labrador, Baffin's Bay and Davis Straits (regions only accessible during two or three months in the year), the continental-island of Greenland enshrouded in eternal snow and ice, the Greenland Sea blocked by ice-floes, the glacial isles of Spitzbergen and Franz Joseph Land, Novaia Zemlia and Liakov Isles (New Siberia) with the surrounding Arctic sea, whose surface of ice is only penetrable during three

* *Physikalischer Atlas* (Gotha, 1892). See map (Plate).



MAP TO ACCOMPANY PROF. HULL'S PAPER READ BEFORE THE VICTORIA INSTITUTE.

Stanford's Geog.l Estab.t London.

months in the year; lastly, the mountains of North Norway and Lapland and the frigid tracts of Siberia bordering the ocean, where the soil is permanently frozen a few inches below the surface; of all these regions it may be said, that if their temperature ever rises above freezing point of water, it is only to the extent of a very few degrees during the three summer months.*

Isotherm of 42° *Fahr.*—Very different is the climate enjoyed by those regions lying under the isothermal line of 42°. Leaving the western coast of America at Vancouver it crosses that continent by the Great Lakes to Nova Scotia in lat. 45° N.; then driven northwards by the Gulf Stream it crosses the 60th parallel half-way between Iceland and Scotland and reaches the coast of Norway a little north of Bergen, then curving round the southern shores of Scandinavia, passes into Russia south of St. Petersburg, and crosses Central Asia near the intersection of the parallel of 45° N. by the meridian of 90° E. This isotherm, except when it passes over the Atlantic, is characterized by extremes of heat and cold; but the heat predominates, and glacial conditions are impossible except at high altitudes such as are afforded by the mountains of Norway.

Effect of the conversion of the isotherm of 42° *into that of* 32°. —We are safe in supposing that if the isotherm of 32° once occupied the position of 42° of the present day, the climate along this line was very different from that which now prevails; let us endeavour to define its conditions in outline.

As regards America it may be inferred that the Great Lakes were in their northern portions permanently frozen over like the waters of Hudson Bay throughout eight months in the year, while Labrador and the lands lying along the western shore of Hudson Bay and extending to the shores of the Great Lakes were covered by snow which the sun of summer would be unable to melt. There would

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* The following are some of the temperature observations within the Polar regions:—

		Three Summer Months.	Three Winter Months.	An. mean temp.
Banks' Land	Lat. 74° N.	+ 35°	− 5°·7	+ 1°·8 Fahr.
Parry Island	„ 74° 25′	+ 37°	−10·6	+ 1°·4 „
Cornwallis Island	„ 74° 45	+ 36°	− 8·6	+ 2°·5 „
Northumberland Sound	„ 77° 0	+ 30°·8	− 11·8	− 1°·1 „

not be much change in the condition of Greenland or of the neighbouring seas except in the direction of increase of cold and greater accumulation of snow and ice. As regards Scandinavia we may safely infer that, owing to the increase of cold and the enormous precipitation of snow on the western slopes of the mountains, the snow line would descend far below its present limits, and glaciers would enter the sea north of the Arctic circle, where the ocean would resemble that of Davis Straits at the present day. That the highlands of the British Islands would be sufficiently cold to support perennial snow and glaciers may also be assumed. At the present day some of the highest parts of the Grampians are not much below the snow line, and snow often lies on Ben Nevis and Ben Mac Dhui all the year round. But we need not follow the subject further except to observe that the additional accumulations of snow on the higher regions would tend to intensify the cold throughout all the adjoining tracts of Western and Northern Europe and Asia.

Part III.—Effects of Elevation of Land.

But we must not forget that, as shown by Prof. Spencer, and more recently by Mr. Warren Upham, the submerged platforms and river-valleys occur along the American coast at least as far north as the Susquehanna in lat. 42° N., while other drowned "fjords" have been determined by Lindenkohl in connection with the Hudson—descending to 2,250 and 2,844 feet below the surface of the sea.* These features indicate elevation of the American continent—along the Atlantic coast—but, though not to the extent which was indicated in the case of the Antilles, still sufficient to have produced very marked effects on the climate of Eastern America. If this be so, then to the cold produced by the lowering of the temperature of the Gulf Stream must be added that due to increased elevation of the continental land itself. The combined effect of these two factors would, as it seems to me, suffice to call into existence a glacial climate of great severity over the region lying to the north of the St. Lawrence and the Great Lakes.

As regards the area of the British Isles and Western

* *Report U.S. Coast Survey for* 1884, pp. 435–81. J. D. Dana, *Am. Journ. Sci.* iii, vol. xl, pp. 425–437.

Europe a few words may be added to those in a previous page. It has been established as above stated, by the observations of Mr. Godwin-Austen,* Prestwich,† Delesse,‡ and Rupert Jones,§ that the platform upon which they are built was elevated to the extent of the 100-fathom line, owing to which Great Britain was united to Europe on the east and Ireland on the west. The distribution of the land fauna and flora requires such an hypothesis; as does the extension of the glaciers and sheets of ice over the area of the Irish Sea and the isles which border the western coasts of Ireland and Scotland from their centres of dispersion. At the time of this elevation, which, according to Mr. Godwin-Austen, was the close of the Pliocene period, Snowdon would have reached an elevation of 4,200 feet, Ben Nevis and Ben Mac Dhui about 5,000 feet each, and the Reeks, 4,014 feet. The whole region would have suffered a considerable decrease of temperature as compared with that of the present day; and, if in addition to this cause of increased cold, we add that arising from a reduction in the temperature of the Gulf Stream, we seem to be warranted in coming to the conclusion that such physical conditions would have brought about a glacial climate in this region.

Region of the Mediterranean, Southern Europe and Western Asia.—It may be objected that the hypothesis here advocated is insufficient to account for the colder conditions of climate which affected Southern Europe and the regions bordering the Mediterranean and extending eastward to the Himalayas. Throughout all these regions we have evidence that the climate was colder than at present during the Pleistocene period, resulting in the extension of the glaciers in the Alps, the Pyrenees, Caucasus and the Himalayas themselves; while, as Sir Joseph Hooker has shown, glaciers were formed

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* *Quart. Journ. Geol. Soc.*, vol. vi, p. 69.

† *Geology*, vol. i, p. 118, and vol. vii, p. 118.

‡ *Lithologie des mers de France* (1871).

§ "Antiquity of Man," *Rep. Croydon Micros. Club*, 1877, p. 2. This paper is accompanied by a map showing the land area produced by an uprise of 600 feet (100 fathoms) above the present sea-level. It is remarkable that this platform corresponds in position to the Continental Shelf of Eastern America above described. The descent from the 100-fathom plateau to that of 1,000 fathoms is remarkably steep along the western margin off the coasts of the British Isles, France and Spain; see Professor C. Wyville Thomson's *The Depths of the Sea*, Plate VII, p. 362 (1873).

amongst the mountains of the Lebanon from which they are now altogether absent.*

To this objection there may be offered two very forcible answers. *First.*—It may be confidently asserted that a general lowering of the temperature and change in the climate of Western Europe would necessarily produce some effect in the same direction on the regions lying beyond. If the climate of Scandinavia, of the British Isles, of France, Spain and Portugal became sensibly more rigorous, it is clear that owing to the circulation of the air currents, the climate of the adjoining regions to the eastward would also experience at least a proportionate change in the same direction owing to the greater accumulation of ice and snow in the higher altitudes. It is impossible to say to what distance this influence would extend, and did extend during the Pleistocene period; especially during the epoch of maximum cold. I think it may safely be assumed that none of the regions above enumerated were altogether unaffected by it; and for my own part I am inclined to believe that the entire northern hemisphere felt the loss of heat due to the diminution of temperature of the Gulf Stream.

Second.—But there remains a still more potent cause for the greater prevalence of glacial conditions than is the case at present in the regions referred to. It is well-known that towards the close of the Pliocene period the vast tract embracing the basin of the Mediterranean and adjoining regions extending eastward was undergoing gradual changes as regards the relations of land and sea. After a slight depression—during which sea-beaches were formed along the old coast lines in the lands bordering the Levant, there ensued a process of elevation ultimately resulting in the conversion of the Mediterranean basin into a chain of fresh-water lakes connected by rivers with the Black Sea and Caspian, and closed against the influx of the Atlantic waters by the uprise of the sea-bed at the Straits of Gibraltar. At this period Sicily was connected with Malta and Tunis, while the island was inhabited by elephants and hippopotami, as shown by Leith Adams and Spratt. The two lakes thus formed were connected by a river channel crossing the "Medina Bank," which is now submerged to a depth of 250 fathoms.†

* Hooker, *On the Cedars of Lebanon*, *Nat. Hist. Rev.*, 1862; also, Sir W. W. Smyth, Pres. Address Geol. Soc. (1868), *Quart. Journ.*, vol. xxiv, p. 58.

† Spratt, *Quart. Journ. Geol. Soc.*, vol. xxiii, p. 292.

Without going further into this very interesting subject, which I have dealt with in a former communication to this Institute,* it must here suffice to state that owing to the uprise of the whole region to the extent of 1,200 to 1,500 feet (200 to 250 fathoms) large tracts now under water were converted into land, and the adjoining land areas were upraised. This uprising of the land necessarily brought certain mountainous tracts within the limits of the snow line—as was the case in the Lebanon—where, as Sir J. D. Hooker has shown, glaciers were formed which have left their old moraines at a level of 4,000 feet above the present surface of the Mediterranean; mountainous regions such as the Caucasus, where perennial snow lies, were subjected to a more rigorous climate. That this general elevation of the Mediterranean and Syrian region extended much farther eastward I cannot doubt; how far it is impossible to say; but there does not appear to be any reason why its influence may not have been felt as far as the Himalayas, where, as we know from the observations of Sir J. D. Hooker, the glaciers once descended far below their present limits.† In all these considerations we must remember that the two possible causes—those of reduced temperature and of land elevation —were acting simultaneously; and it is to their combined influence that I venture to ascribe the general lowering of temperature, and prevalence of more Arctic climatic conditions of which we have evidence during the Pleistocene period.

PART IV.—CONCLUSION.

The causes which have been assigned for a glacial epoch may be arranged under two heads—the astronomical and the terrestrial. Under the former may be placed the theory of the late Dr. Croll, which has the support of Prof. James Geikie, and that of Sir Robert Ball more recently enunciated; under the latter is that of Lyell, who held that "in determining the climate of the globe geographical changes have exercised a preponderating influence."‡ Croll's hypothesis has been examined by Lyell, Prestwich,§ and others, who are unable to accept its conclusions, as well on astronomical as on physical grounds. Lyell in the last edition of

* *Trans. Vict. Inst.*, vol. xxix (1895).
† Hooker, *Himalayan Journals*, vols. i and ii (1855).
‡ *Principles*, vol. i, ch. 12. § *Geology*, vol. ii, p. 528.

his great work still adheres to his original views, which find support in the conclusions arrived at in the present paper. Few will deny that, but for the Gulf Stream, the British Islands and Northern Europe would now be subjected to glacial conditions; and with the aid of Professor Spencer's researches I have attempted to show how such conditions were brought about.

POSTSCRIPT.—Since the above was written, Mr. Warren Upham, of the United States Geological Survey, has dealt with this subject in an able paper communicated to the Institute in the Session of 1896–7,* and corroborates generally the views of Prof. Spencer, and other American geologists, including Dana and Le Conte, regarding the former great uprise of the continental lands at, or near the commencement of the Glacial epoch; arriving at similar conclusions with those of the author of this paper, but based mainly on the view of the lowering of temperature due to such elevation. In the paper here given to the Institute, I have endeavoured to show how, in addition to the lowering of temperature due to elevation of land in the Northern Hemisphere, the deflection of the Gulf Stream must have also materially influenced the climatic conditions. It need scarcely be stated that both papers were written altogether independently of each other; but their agreement in the conclusions will be regarded as confirmatory of the "epeirogenic" or "earth-movement" hypothesis.

The most able opponent of this hypothesis is Prof. James Geikie, and I have re-read his elaborate communication to this Institute,† dealing with this subject, in order to refresh my memory as regards his views and arguments; which have also been dealt with by Mr. Warren Upham; and as it seems to me, in the main, successfully.‡ I cannot see, for instance, upon what ground Prof. Geikie considers the American uplift to have been long antecedent to the Pleistocene epoch. Of course the uprise of the land around the shores of the North Atlantic was gradual, and the accumulation of snow and ice would also have been a very slow process; but both Spencer and Upham are agreed that this uprise commenced with the close of the Pliocene period; a

* Upham, "Causes of the Ice Age," *Journ. Vict. Inst.*, vol. xxix, p. 201 (1897).

† *Ibid.*, vol. xxvi.

‡ *Ibid.*, pp. 221 and 254, also vol. xxix, p. 237.

view which seems the more reasonable one.* At the same time I agree with Prof. Geikie in doubting that the oscillations of land of the Pleistocene period were to any great extent (if at all) due to the weight of accumulated snow (or its removal), as supposed by Dana. In the view of the occurrence of two cold epochs with an intervening warmer (or interglacial) stage, I have long been a believer, and maintain that it is borne out by the glacial phenomena of the British Isles, as I endeavoured to show many years ago,† but such movements were probably not dissimilar in their origin and cause to those of former geological periods to which the crust of the earth has been accustomed.

POSTSCRIPT.

Although it is some time ago since I received the following letter bearing upon the subject I have taken up in my paper, yet the author is so recognised an authority on Arctic matters that with his permission I quote it.

Col. H. W. FEILDEN, F.G.S., writes to me, December 13th, 1896:—

"I am inclined to think that there is much force in your view that the so-called Glacial epoch was due in a great measure to some deflection of the warm current from the Polar Basin.

"If Professor Spencer is correct the elimination of the Gulf of Mexico would deprive the northern Atlantic of its chief heating apparatus, and might induce glacial conditions over Scandinavia. If a system of glaciation sets in anywhere, where the precipitation exceeds the melting forces, there is no saying where it may end, given sufficient lapse of time.

"There is, however, another side of the proposition, about which I should like your opinion.

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* See on this point a more recent paper by Professor Spencer on "The Continental Elevation of the Glacial Period," *Geological Magazine*, January, 1898. In this paper the author extends his observations on the great continental uprise to the eastern and northern coasts of the Atlantic, suggesting changes regarding the European and British area far in excess of those referred to by myself for these regions.

† *Physical History of the British Isles*, ch. xiii, plates 13 and 14 (1882).

"Undoubtedly, the glaciation of the vast island-continent of Greenland, 1,200 miles in extent, north and south, is due to the refrigerating influences of the great Polar drift of cold water sweeping down its east side, swirling round Cape Farewell, and running up to Holstenborg on the west side. Whilst the icy current coming down Smith Sound plays a similar part on the west side.

"Now, if we could deflect this Polar current, so that it came down the Baltic, as it probably did, and along the west side of Norway, would not Scandinavia be as glaciated as Greenland, and England, Scotland, and Ireland, and the Faeroes, much as Spitsbergen is to-day?

"Again, is there any proof that the glaciation of North America was coincident with the Glacial epoch of Europe?

"Most travellers in those regions have pointed to the proofs of remarkable rapid elevation in recent times of the islands of the American Archipelago and of Grinnell Land, where recent shell-beds stand at an elevation of 1,000 feet.

"If we could again sink the American Archipelago 1,000 feet, the fender or buttress which keeps out the Palæocrystic ice would be removed, and that ice would pile up on the shore of the continent of America, much farther south than now, and probably glaciate it."

Here Colonel Feilden asks my opinion on the question, whether by the deflection of the north polar current down the Baltic and the west coast of Norway, Scandinavia would be as glaciated as Greenland? and he points out that this might take place by the submergence of the islands of the American Archipelago which have recently been upraised to the extent of 1,000 feet, as shown by beds of shells.

The passage of a polar current down the Baltic would require the submergence of Lapland to the extent of over 500 feet, a state of things which in all probability formerly existed, and the passage of a north current would doubtless have the effect described; but it is to be observed that the greater part of Greenland lies further north by 10° than that of Scandinavia, the effect of which would be to cause the climate of the former to be less rigorous under any circumstances; and this result would be accentuated by the prevalent wind-currents.

Colonel Feilden also inquires whether there is any proof that the glaciation of North America was coincident with the Glacial epoch of Europe?

My reply is, that although there may be no proof, the probabilities are in favour of the view, as the uplift of the land and ocean bed seem to correspond on both sides of the Atlantic, as I have endeavoured to show. But it is otherwise with the western side of the American continent, where reciprocal (not simultaneous) conditions appear to have prevailed, as Professor Spencer has recently shown, in his paper on the "Oceanic connection of the Gulf of Mexico with the Pacific" (*Bull. Geol. Soc., Amer.*, vol. ix, 1897).

The CHAIRMAN (the Ven. R. THORNTON, D.D., V.P., Archdeacon of Middlesex), having conveyed the thanks of the meeting to Professor Hull, a discussion on some technical points took place.

COMMUNICATIONS RECEIVED IN REGARD TO THE PRECEDING PAPER.

Professor T. RUPERT JONES,* F.R.S., writes:—

January 15th, 1898.

I have read Professor Hull's paper with much pleasure. He seems to establish the following facts and conclusions.

If we trace the 100-fathom line around the British Islands, as

* Professor Rupert Jones and Mr. Upham's communications were received in time to be read at the Meeting.

indicated on the Admiralty charts, we notice that opposite to the river-mouths opening out on the coasts there are corresponding indentations. So also off the North-east American and other coasts the deep-sea contour lines run parallel with the bays and river-mouths; and moreover the valleys of the land are continued by definite lines of relative depths (shown by soundings) down the great irregular slopes of the sea-bottom. These lines of valleys and gorges cross plateau after plateau on the ocean-floor, and notch their precipitous edges with successive gaps. These valleys are traced downwards and outwards for more than 200 miles, and even to a depth of two or more miles below the present surface of the water before they are lost on the abyssal floor of the ocean.

These successive submarine plains and plateaux were the result of littoral denudation at times when the continents high above water, were gradually sinking (like the smaller "Raised Beaches" during uprise of land), with such intervals of stability as allowed the destructive action of the air, water, and ice to make great horizontal notches along coasts and across river-channels. Consequently certain portions of the continents have been in former times at least two miles higher above the sea-level than they are now. With this elevation and wider extent of land the climate must have been much colder, even frigid enough for what has been termed a "Glacial Age."

Other points also are considered by the author. It was in late geological times that the coasts of the Northern Atlantic Ocean, both on the American and the European side, and across its northern region, had an elevation high enough for an arctic climate. The equatorial current could not then have had the heat it now obtains by its local confinement in the torrid Gulf of Mexico; and the vicinity of the snow-laden coasts of the North Atlantic would have reduced the equatorial warmth; so that it would have had little influence in ameliorating the climate of North-western Europe in the "Glacial Age."

He also intimates that, on account of the slow and unequal movements of the earth's surface, the coming and going of arctic conditions must have been different at times and places; and the glaciation of one region would not be quite synchronous with that of another. At all events a great part of North America, with North-western Europe, had a glacial climate in late Pliocene or early Pleistocene times.

The author carefully refers to the sources of information in the different parts of the subject of his paper.

Mr. WARREN UPHAM, A.M., F.G.S.A., writes :—

St. Paul, Minnesota.
January 3rd, 1898.

The explanation of the climatic changes and ice accumulations of the Glacial epoch presented in Professor Hull's paper, with its accompanying map, seems to me a most valuable addition to our understanding of this very exceptional and unique geological epoch. There can be no doubt that the epeirogenic uplifting of the lands on each side of the North Atlantic Ocean produced important changes of the Gulf Stream and of its influence on the climate of Europe. The lowering of the temperature of that great sea current may well have been a chief element in the causation of the Ice Age in the British Isles and Northern Europe, supplementing the effect due to the greatly increased altitude of the land, of which the fjords bear testimony.

In North America, however, where our storms and waves of varying barometric pressure and temperature sweep from west to east and north-east across the country, thence passing over the North Atlantic, we must, I think, ascribe the chief part in the production of the Glacial epoch to the high elevation of the land, probably 3,000 to 5,000 feet above its preglacial and its present height.

Professor Hull's map might indeed well be coloured farther into the present sea area between Europe and Greenland, to the submarine contour of 450 or 500 fathoms, as for the Blake plateau of America. If the preglacial uplift of the sea bed between the Atlantic and Arctic oceans was so great, which is very probable these oceans were completely separated by land, and the Gulf Stream and warm superficial oceanic drift from it were wholly excluded from contact with Scandinavia. That condition, in combination with the high land uplift, gives an ample explanation of the origin of the Ice Age in Europe, which seems to have been essentially contemporaneous with that of North America.

The Rev. R. ASHINGTON BULLEN, B.A., F.G.S., writes :—

There can be but one opinion about the interest and importance

of the theory set forth by Professor Hull. Huxley* leaves undecided the influence of the Gulf Stream in ameliorating the climate of Great Britain, and hints at the possibility of warm currents being due to the dominant south-westerly winds of the temperate part of the Atlantic. Under any circumstances, however, the lowering of the temperature of the Gulf Stream would have a marked effect on the temperature of the ocean and the air in the North Atlantic, and would affect the assumed currents due to the south-westerly winds.

To my mind the amelioration of our climate is mainly due to the Gulf Stream or to subsidiary currents proceeding from it. The existence of such fragile West Indian shells as *Spirula Perouii* on Portrush Beach, N. Ireland, and at Woolacombe, Devon, perfectly uninjured,† points to a branch of the Gulf Stream touching first the Irish and then the Devon coast. Mr. R. Welch, of Belfast, and friends, have collected eight to ten at a time, especially in September.‡ *Tellina radiata*, another West Indian shell, has occurred at Courtmacsherry Bay, S.W. Ireland and other places. Sir A. Geikie§ points to the occurrence of West Indian plants on the Irish coast as having been drifted across the Atlantic from west to east, or north-east.

In September, 1897, in the Allan liner *Parisian* from Liverpool to Montreal, the sea-water temperatures were logged approximately as follows :—

September	10th about	55° 20′	N. lat.	9°	0′	W.long.	58° F.
,,	12th ,,	56° 25′	,,	25°	31′	,,	55° F.
,,	13th ,,	56° 23′	,,	35°	23′	,,	55° F.
,,	14th ,,	55° 12′	,,	43°	6′	,,	48° F.
,,	15th ,,	53° 13′	,,	51°	50′	,,	35° F.
,,	16th, Gulf of St. Lawrence, Cape Norman E.S.E.						33° F.

The rapid fall from 48° to 33° F. was due to the Baffin's Bay cold current.

Now, assuming Professor Hull's statement of the lowering of the temperature due to the deflection of the Gulf Stream owing

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* *Physiography*, 2nd edit., p. 174.

† *Science Gossip*, 1897, p. 150. ‡ *Ibid.*

§ Geikie, *Physical Geography*, p. 139.

to the elevation of the Antillean continent, the temperature of the waters of Gulf of St. Lawrence even in so warm a month as September would be lowered from 33° to 23°. The St. Lawrence and adjacent seas would be ice-bound, and icebergs would be set adrift, to float even farther southward (probably 1,000 miles) than at present the Greenland bergs do, with a correspondingly lowering influence upon the temperature of sea and air. Judging from the influence of a large number of bergs adrift in the North Atlantic, in producing damp and cheerless summers in the British Isles, *e.g.*, 1877, 1878, 1879, &c., such conditions as Professor Hull supposes would make summer in these islands a thoroughly "glacial" one.

Judging from what I saw of geological phenomena in Connecticut in October last, the glacial conditions further south were even more rigorous than my estimate indicates.

Professor Newcombe and Rev. E. Hill are dissatisfied as astronomers with the astronomical explanation of the cause of the glacial epoch. Sir Joseph Prestwich* has fully discussed the question of recurring glaciations, which Croll's hypothesis renders necessary, rejecting these glaciations as facts either† (1) from want of evidence; or (2) because the geological evidence is all the other way. As this and various other astronomical theories are unable to bear the strain put upon them, we must, I think, conclude that some geographical explanation is the more probable, and that, as an uplift such as Professor Hull postulates would be attended by glacial conditions, his theory, or some modification of it, may be accepted as best satisfying all the conditions of the problem.

The Rev. G. CREWDSON, M.A., writes :—

January 18th, 1898.

May I be allowed to suggest a few considerations which seem to confirm the theory which Professor Hull has so ably expounded in his paper read yesterday on "Another Possible Cause of the Glacial Epoch."

In the present day it will be observed that owing to the Antarctic cold the stream of heated equatorial water is pressed northwards, a greater breadth of the stream being north of the

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* Prestwich, *Geology*, ii, p. 527, note.

† Prestwich, *Controverted Questions in Geology*, p. 23.

Equator than south of the line; consequently a larger proportion of water is diverted northwards at Cape S. Roque than would be the case if the stream were accurately equatorial.

If, however, Arctic conditions were to prevail in the North Atlantic, these conditions would be reversed, and a much larger amount of heated water would be diverted into the Brazilian current flowing southwards, than is at present the case, and the North Atlantic would receive less than its due share. This would not only lessen the amount of heat available for raising the temperature of the northern regions, but would also diminish the resistance that would be offered to cold currents from the Arctic Ocean; a point which receives increased importance from the consideration of possible changes in the Pacific area.

For there is another fact which can scarcely be said to be less than paradoxical in its character, that at the time when Northern Europe and Eastern North America were enduring a climate of exceptional rigour, Siberia and Western North America were enjoying a comparatively temperate climate. Somehow or other, therefore, warmth must have been able to find its way into the Arctic regions in that hemisphere at the same time that it was excluded from the European area. Now at the present day Behring Straits are narrow and shallow, and little or no water is able to enter from the Pacific equatorial current. But with the exception of the mountains to the south of Alaska, the land bordering the strait is, generally speaking, low and alluvial. If then this were depressed, a large free access would be opened to the Arctic Ocean on that side; and if this were the case I do not think it unreasonable to suppose that a stronger and more highly heated current would pass through than is found in the Gulf Stream, inasmuch as the Pacific is larger than the Atlantic, and the northward flowing stream would not have to contend with any counter-flowing current, all the water finding its exit by way of the Atlantic channel. It is obvious that by the time the water had reached the Scandinavian coast it would have lost all its heat, and would very largely contribute to further reduce the temperature in the North Atlantic area; and being comparatively unopposed in its southward course, and pressed forward by the floods from the Pacific, it would probably develope a force far exceeding that of the existing Greenland current; a force that would be sufficient in fact to produce those perplexing glacial markings in Scandinavia and elsewhere which Mr. Lindvall has ascribed with much prob-

ability to the action of drift-ice rather than that of a sheet of land-ice.

It is true that the tendency of the south flowing Arctic current would be to trend towards the Greenland side of the channel, owing to the effects of the revolution of the earth on its axis, but if Greenland shared, as it probably did, in the general elevation of the east coast of America, the current would be driven more towards the European shore, and the course of the Gulf Stream itself is an evidence that currents can be diverted by geographical or other causes into other than their natural channels.

This theory also meets another difficulty. Great cold does not necessarily mean abundant snow. A region of evaporation at no great distance is also necessary. A heated Siberian sea would afford just such an area as would be needed to produce a heavy snow-fall in North-West Europe and North-East America. We should thus have every condition for producing a Glacial epoch in these regions.

This seems to me to supply a simple explanation of this remarkable era, without calling in the help of a *Deus ex mâchina* such as the theory of cold and warm regions in space, or such slow working agencies as the varying eccentricity of the earth's orbit, a theory whose very supporters admit could only have produced the required effects if favoured by other exceptionally propitious circumstances.

Professor W. S. GRESLEY, F.G.S., of Erie, United States, writes:—

In response to your kind invitation to add to the discussion upon Dr. E. Hull's paper, proof of which I have read with much interest, I beg to say:—

1. It seems quite possible that the elevation referred to along the east of North America may have produced the clay-and-débris-filled fissures, known as "clay-veins," by which much of the coal-measures from Pennsylvania to Missouri, but especially in Pennsylvania and West Virginia, are more or less vertically intersected (see my paper, "Clay-Veins vertically intersecting Coal-Measures" in *Bull. Geol. Soc. of America*, vol. 9, pp. 35–58, copies of which I am sending to the Institute, and also to Dr. Hull). While all the evidence so far collected indicates that the origin of these fissures was long after the Carboniferous

period, and also post Appalachian uplift, no clue has as yet appeared giving the approximate age of them.

2. If so much *less* "Gulf Stream" heat went north during the period of elevation indicated upon Dr. Hull's map, the supposition is that, other conditions being the same, so much *more* of it flowed southward; and if so, we may postulate that in those days there was less Antarctic ice than now.

The Cavaliere W. P. JERVIS, F.G.S., Conservator of the Royal Italian Industrial Museum at Turin, writes:—

Few geological difficulties have constantly presented themselves to my mind of such a serious kind as the explanations advanced as to the causes of changes of climate on our globe in geological times, including the intense cold during the Glacial epoch, and the converse warmer temperature during the Miocene epoch. None of the theories elicited have convinced me. But the paper read before the Victoria Institute by Professor Hull, based, as the arguments are on the most forcible logical and palæontological data relatiug to the entire eastern and southern coast-lines of North America, has dissipated, as by enchantment, all my doubts, and the proofs he adduces of the former non-existence of the Gulf Stream appear to me to throw a bright light upon many obscure points of geological climatology.

Though Lyell laid great stress upon changes in the geographical configuration of our globe at successive periods of its existence, and showed the ever-changing elevation and depression of vast tracts of country, it would appear that enough attention has not been paid to these considerations, and hypothetical astronomical causes have found too much favour with not a few geologists—and in absence of proofs.

River-valleys have been plainly traced by Issel to great depths in the Mediterranean, in prolongation of what are now short valleys in Northern Italy, and doubtless elsewhere much progress will be obtained in our knowledge of the past, of the fauna and flora of geological epochs, and of the erstwhile distributions of land and water, by a more extensive study of soundings of the ocean.*

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* One of the most interesting series of six maps exhibited by Dr. Gerard de Geer in the Swedish section of the VIth International Congress, held in London in 1896, showed the glacial regions of Finland and

Professor Cooke describes the abundant fossil remains of elephants which he found in Malta, and draws from this fact, as also from the existence of like fossil bones in Sicily, the conclusion that these islands once formed part of the African continent, previous to a considerable submersion of land now constituting deep sea.

Professor Hull beautifully explains how we can find Arctic forms of marine mollusks in rocks not so far from London, and proves the possibility of there having once been extensive glaciers on loftier mountains in Scotland, and of which we still find the scratches.

Will the professor permit me to suggest that it would be a most important point, in order to corroborate his views regarding the assumption of a mean lower temperature of 10° F., previous to the formation of the Gulf Stream, to take accurately into account the longitudinal breadth of the Atlantic previous to the submergence of the Continental shelf and of the Blake plateau, *i.e.*, during the Pliocene and Pleistocene epochs, by ascertaining whether there are corresponding proofs of submergence of the South American continent, even of the African coast, for evidently *the length of time* the superficial ocean current was subject to the rays of a tropical sun would have an effect analogous to what takes place now in the Gulf of Mexico?

Professor Hull's able paper is calculated to open out a vast field of important geological investigations. The depression of the Atlantic coasts of North America and of North-Western

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Scandinavia at different periods; in the first map he endeavoured to prove the existence of a continuous ice barrier from Greenland to St. Petersburg, coming down as far south as Denmark and North Germany. The next map showed the retreat of the limit of eternal snow and ice, the line passing through central Sweden; while in another map the glaciers were confined to certain mountainous tracts of Norway; Sweden and Finland being out of the question. This is no mere conjecture. Professor Neovius, of Helsingfors University, in a prolonged conversation I had with him on this subject, declared that the deductions were founded on the geographical distribution of the granite ice-borne boulders abundantly found along more than 15° of longitude in consecutive order.

I found that glacial boulders of Finnish granite were well known to exist in the neighbourhood of Halle, while I was engaged at work at Eisleben, but in Finland and Sweden the boulders are more common along the edge of the former isotherm of 32°.

Europe has no parallel in many parts of Western Africa. But changes of climate in a reverse direction after the Miocene epoch can be accounted for by the still later upheaval which has left the vast deserts of Northern Africa, Arabia, and Central Asia, as clear proofs of the existence of former seas, permitting elephants to live in the long island of Morocco, Algeria, Tunisia, and Malta, and rendering the climate of Siberia milder than at present.

Geological and physical geography are twin sisters; their requirements are so intimately united that they cannot be too closely associated; the opening or closing of sea communication between two points, as likewise changes in the elevation of land, finally deviations of ocean currents, materially alter the climate of the globe, irrespective of all extra terrestrial agencies.

THE AUTHOR'S REPLY.

The general concurrence in my views, stated by Professor T. Rupert Jones, is a matter of much gratification. He has touched on one of the points referred to by Colonel Feilden above.

I gratefully appreciate the suggestions of Mr. Warren Upham in reference to the greater extension of the emergent land in the North Atlantic area than is shown on my map. I also concur with him that the greater elevation of the land of the American continent had more effect in bringing about glacial conditions in that region than the lower temperature of the Gulf Stream, which more directly affect the climate of Western Europe and the British Isles.

The views stated by the Rev. G. Crewdson seem to me well worthy of consideration, though the subject they open out is too extensive to be discussed here. The depression of the north-western American continent during the elevation of the north-eastern side of the same continent may be accepted as an all but proven fact, and the entrance of large masses of comparatively warm and moist Pacific waters by the enlarged Behring's Straits would doubtless have resulted in abundant snowfall on the Arctic land areas. On the general question regarding the reciprocal

movements of the land on alternate sides of the American continent the recent paper by Professor J. W. Spencer on "Great Changes of Level in Mexico and the Interoceanic Connections" (referred to above), have thrown much light.

The observations of Professor Gresley on the American "clay-veins" of the Pennsylvanian coal measures, an account of which I recollect reading some time ago, show how physical phenomena, apparently widely disconnected, may really have a bearing on each other. I have been much interested by the views of the Rev. R. A. Bullen, in which I fully concur, and am glad to have the support of an observer who has paid so much attention to the physical conditions of the North Atlantic.

The observations of Cav. W. P. Jervis are of much interest and very gratifying. I have had several letters of acknowledgment expressing interest in the subject of my paper from continental geologists, including Professor Dames, of Berlin, Dr. C. Barrois, of Lille, Professor Suess, of Vienna, and Professor Geinitz, of Dresden, and this of Cav. Jervis, of Turin, is a welcome addition to the list. The statement that Issel has traced old river courses to great depths in the Mediterranean in prolongation of valleys in North Italy is new to me, and is quite confirmatory of the results arrived at by the late Admiral Spratt, where he proved by soundings the existence of a river channel joining two of the lakes formed in the Mediterranean basin between Sicily and Africa during the period of upheaval and low water-level. (See *Quart. Jour. Geol. Soc., Lond.*, vol. xxiii, p. 292.) The existence of this channel shows the bed of the Mediterranean to have been upraised over 150 fathoms (900–1,000 feet) at this period.

As regards the points which the writer suggests in reference to the conditions of the Atlantic previous to the formation of the Gulf Stream, I hope to be able to give them attention.