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ORIGINAL ARTICLES.

I.—AMERICAN "SURFACE GEOLOGY," AND ITS RELATION TO BRITISH.
WITH SOME REMARKS ON THE GLACIAL CONDITIONS IN BRITAIN,
ESPECIALLY IN REFERENCE TO THE "GREAT ICE AGE" OF MR.
JAMES GEIKIE.

(PART I.)

By SEARLES V. WOOD, JUN., F.G.S.,
Illustrated by Two Maps and several Sections.¹

(PLATE XV.)

FROM no part of the world have we of late years derived more additions to the Geological Record than from North America. Besides important additions to the earliest pages of that record, the rich collections made by the United States Surveyors, both of fauna and flora, from the Cretaceous, Eocene, and Miocene deposits, have thrown much light upon the life history of the Earth; and it is even contended that they have bridged over the interval which, notwithstanding the Maestricht beds, the Pisolitic, and the Faoe Limestones, still remains sharply marked between the Cretaceous and Tertiary formations of Europe so far as they have yet been examined.

As regards those latest deposits, which, by adoption from the Frenchmen, as other fashions are from the Frenchwomen, it has become the fashion to call "Quaternary,"² and which have received of late years so large a share of attention from geologists, Americans have not been behind their European brethren in devoting to it abundant investigation. Memoirs and notices by Principal Dawson and others relative to the newer Geology of Canada have made us familiar with the general features of the Glacial and post-Glacial formations of the lower basin of the St. Lawrence, as have those of Professors Dana, Winchell, and others, with similar features in the United States, while recently³ there has appeared, in the Report of the Geological Survey of Ohio, a comprehensive memoir by Prof.

¹ The map of Yorkshire with sections will appear with Part III.

² Considering that the term "Primary" had long become obsolete, and that the term "Secondary" was fast becoming so, we might have been spared the absurdity of "Quaternary." However, as Crinoline has done so, I suppose, it will go out of fashion in time. The separation of Geology into "solid" and "superficial" officially made by the late Director of the Geological Survey of England, and on the basis of which the maps of the National Survey are to be delineated, is, to my mind, also an absurdity; but in deference to the leaders of fashion, I have adopted the term of "Surface Geology" in the title of this paper.

³ The Surface Geology of Ohio, by J. S. Newberry (Columbus, 1874).

J. S. Newberry, on the "Surface Deposits" of that State, and their connexion with the general features of Glacial and post-Glacial geology presented by the Central and Eastern parts of the North-American Continent; and from which the map of those regions that accompanies this paper is taken. A discussion of the views of American geologists occurs in the 35th chapter of the 2nd edition of Mr. Geikie's "Great Ice Age," and it seems to me that, in the present condition of our knowledge, the leading facts of this Memoir of Prof. Newberry may be usefully epitomized, and examined, in the way of analogy with those observed concerning our English Glacial and post-Glacial formations; and I propose here to make the attempt to do so.

Commencing with the oldest Glacial evidences in North America, Prof. Newberry describes the grooved and furrowed rock-surface, which is to be traced as far south as the 39th parallel of north latitude, and the extent and direction of which are indicated by the arrows on the map. This evidence of the occupation of the Eastern side of North America by glacier-ice is not confined to the basin of the St. Lawrence, but extends in the State of Ohio over the water-parting of the two great basins which receive the drainage of the central part of North America east of the Rocky Mountains; that is to say, it extends on to the northern edge of the basin of the Mississippi. These scratchings and groovings, though having a general north and south direction, nevertheless conform, according to Prof. Newberry, in a rude way to the present topography, and follow the directions of the great line of drainage. To the action of this ice when the continent stood several hundred feet higher than now, Prof. Newberry attributes the excavation of the basins of the great lakes, as will be further on described.

1. The oldest of the surface deposits is the Erie clay (No. 1), the origin of which Prof. Newberry attributes to the action of this sheet of glacier-ice during the period of its retirement before returning warmth, after the continent had become depressed 500 feet or more below its present level, and when the basin of the great lakes became, as this ice receded, occupied by an inland sea of freshwater.

He does not explain how, if the continent were depressed 500 feet below its present level, this basin could be occupied by freshwater, seeing that such a depression would bring all but the upper edges of the basin below the sea-level; nearly all the area of the basin of the St. Lawrence, as well as a large part of that of the Mississippi, inclusive of the water-parting of the two basins, being, according to the map which accompanies the Professor's Memoir and is reproduced here, below the 800-feet line. I presume, however, that he considers the sea to have been dammed out by a mass of the glacier-ice left remaining and filling the lower and narrow part of the St. Lawrence Valley, which lies several degrees of latitude further north than Ohio; but if so, there must have been an equal re-elevation of the continent before the growth of the forest surface (bed No. 2) over the Erie clay, because the warmth necessary for that growth must have thawed the dam and let in the sea, an event of

which there seems no evidence, the only fossil organisms which occur in the deposits of the lake-basin being those of land or fresh-water. So far as I can understand the case, however, there seems to me no necessity to infer any depression until after the formation of beds Nos. 1 and 2, as the phenomena indicated by these beds seem explicable by returning warmth alone, and by the draining off of the lake-waters after the deposit of No. 1; while the marine clays of the Lower St. Lawrence, which, so far as I have been able to gather the facts of American geology, alone afford evidence of any submergence of the St. Lawrence basin, seem to me, as subsequently explained, to belong to a later glaciation.

Prof. Newberry contends that the lower and unstratified portion of the Erie clay represents the material eroded by the glacier, which, as the ice-sheet retreated northward, it thrust out and left behind; and which now forms a nearly continuous sheet of Boulder-clay over the glaciated surface. He urges that this clay was not deposited beneath the glacier-ice, because it covers the glaciated surface in a sheet sometimes 100 feet thick, and that it must have accumulated at the margin of the glacier as it receded. This, if we substitute the sea in Britain for the lake in Ohio, is in chief measure, the mode of origin for which I have for many years past been contending in the case of the Glacial clay of England, as distinguished from Mr. James Geikie's view of its origin beneath the ice itself.

There is one feature, however, connected, according to my view, with the origin of the unstratified Glacial clay of England to which I find no parallel in Prof. Newberry's memoir, viz. the lifting of portions of this extruded mass, and its distribution over the bottom, partly from being dropped in small quantities, but principally in sheets or masses. This seems to me to have been clearly the mode of accumulation in the case of that part of the English clay which overlies the Middle Glacial sands, as well as of some portion of that part of the clay which has no Middle Glacial beneath it, but which, as at Dimlington and Bridlington in Yorkshire, contains within its mass beds of sand full of lamellibranchiate mollusca with valves in some cases united. When, however, the vast area of the American beds comes to be examined with the same minuteness as has been the case with the comparatively small area of the British, I do not doubt that parallel features will be found in them, unless the water under which the moraine was extruded was too deep to allow of this process.¹

¹ If, as some American geologists say, unstratified morainic clay has been found overlying the forest surface *in situ*, then these would seem to me to be instances of dropping from floating ice; for if the ice passed over the forest, it must have destroyed it. Some of our Norfolk geologists are now coming to the opinion that the long-known Forest-bed of Cromer is not *in situ*, but transported; and if they are right, the theories based upon the occurrence of peats and freshwater shells in the midst of Glacial clay will require much reconsideration. This, however, does not apply to the Pakefield and Kessingland root-indented bed, which is clearly *in situ*. If it should turn out that the Cromer Forest and freshwater deposits associated with it are not *in situ*, but stripped from some distant land-surface by ice, and transported, analogy for such a thing may be found in some peaty masses which I have observed imbedded in the midst of the marine-formed Contorted Drift in the Cromer cliff itself.

Mr. Geikie insists on the purely terrestrial origin of all this unstratified Glacial clay, and urges his views in the "Great Ice Age" with the amplitude for which a work specially devoted to the Glacial formation affords scope. It is impossible to meet his various contentions within the limits of a paper like this; but to insist, as he does, that rock-basins and great valleys of erosion have been excavated by the tremendous agency which is exerted by the combined vertical and horizontal force of glacier-ice thousands of feet thick moving over its bed, and at the same time to contend that this ice can have passed over finely-stratified sands, such as the Middle Glacial, pushing at the same time under it a thick moraine of clay brought from a distance, without disturbing the stratification in the slightest, does appear to me a most striking inconsistency. We are reminded by it of the steam-hammer which forges a 100-ton gun and cracks a nut without crushing the kernel; but glacier-ice is not kept under the delicate control that a steam-hammer is. Not only is the stratification undisturbed, but within very few feet of the junction of this undisturbed stratified sand with the morainic clay there occurs in several places, both in the East Suffolk cliff and in sections inland, a band of molluscan remains, mostly fragmentary, but containing intermixed with them an abundance of small papyraceous specimens of *Anomia ephippium*, and of the valves of *Balanus*, sharp and unworn, both of which have evidently fallen from objects floating in the sea. These small *Anomia* are so thin and tender that in the fossil state in which we find them they exfoliate, and may be blown into fragments by a strong breath; and in their living state they must have been very fragile. Are we to suppose that glacier-ice hundreds, nay, according to the extreme glacialists, thousands¹ of feet thick passed over these sands, rolling its moraine as it progressed, without either distorting the stratification of such sands or crushing the tender organisms within them which lie but very few feet from the line of junction?

This inconsistency becomes to my mind enhanced by Mr. Geikie's contention that the worn shells and shell fragments which occur in some of the morainic clays, as, for instance, in the purple clay of Holderness, the chalkless clay to the north of it, and in the Lancashire clays, are due to the ploughing out of anterior (inter-Glacial) sea-beds, and the intermingling of the ploughed-out shelly matter with the land-derived moraine material; for how, if such things occurred, could the sea-bed formed of the Middle Glacial sands to which I have referred have escaped destruction if the glacier

¹ In objecting in my paper, "On the Climate Controversy," in this *MAGAZINE* for September, 1876, to the extreme thickness assigned to the ice of Britain during the Glacial period, I spoke of the existing Antarctic ice being at least 5000 feet thick. In this I was led away by the instances of bergs of tabular form having been met with in Southern seas which rose more than 500 feet or 600 feet above the sea, given by Dr. Croll in his work on "Climate and Time." From the description of the Southern bergs, however, given by the *Challenger* Expedition, I do not see how the Antarctic ice can at its sea termination much exceed 2000 feet, even if it reaches that. It seems probable, however, so far as Greenland and Spitzbergen disclose the case, that land-ice is of less thickness at the glacier terminations than where it lies in greater masses further inland.

passed over it? The shells and shell-fragments, more or less worn, which occur in these morainic clays, owe their presence in my opinion to the alternate advance and recession (such as now in Greenland occurs from century to century) of the glacier-ice along the submarine valleys or fiörds, through which its escape to the sea took place; by means of which the sea-bottom of these fiörds was ploughed out and became mixed up with the moraine on the advance of the ice, and, thus intermixed, was deposited where it is.

To the same action, I conceive, was due all that part of the shell-bed contained in the upper layers of the Middle Glacial sands just referred to which consists of worn shells and shell-fragments; these having been carried away by the currents when the ice advanced on the submarine valleys, and been deposited in these sands in association with organisms fallen from floating objects. When the glacier-ice receded, this ploughing-out ceased, and the moraine accordingly ceased to be intermixed with shell-fragments, portions of it being carried away and dropped over these sands, while the bulk of it remained as extruded during recession on the bottom upon which the glacier had rested.

Different, however, to this must have been the conditions to which the sand thread full of perfect valves of *Nucula Cobboldiæ* which is present in the midst of the morainic clay near the foot of Dimlington Cliff owed its origin; for in that case the only explanation seems to be that the shells established themselves in a thin bed of sand deposited on the submarine moraine, and were afterwards killed and buried by the descent upon them of a sheet of the moraine lifted from some other place. This bed or thread of sand with shells was discovered by Prof. Hughes and Mr. Leonard Lyell, during a visit made by them to the Holderness coast, in company with Sir Charles Lyell; and in a memorandum sent to me with the shells by Sir Charles, the thread of sand was described as intercalated in the mass of the unstratified chalky clay, and *packed with perfect valves of Nucula Cobboldiæ and other shells*, some of them having the valves united. The position of this thread appears to have been below, but near to, the beds of sand occupying hollows in the chalky clay forming the lower part of Dimlington Cliff, and which were distinguished by Mr. Rome and myself in our sections¹ by the letter *b*, and which are overlain by the purple clay, also full of chalk debris in its lower part, but getting less and less upwards till such debris disappears altogether from the clay. These sand beds, *b*, are very irregular, and in some places they are intermixed with, and in others replaced by sheets of morainic clay, which present the distinct appearance of having been dropped successively. Mr. Geikie, in referring to the beds thus described by Mr. Rome and myself under the letter *b*, speaks as though we regarded them as marking an interval in which the chalky

¹ Quart. Journ. Geol. Soc. vol. xxiv. p. 148; and Palæontographical Society's volume for 1871; Introduction to Crag Mollusca, Supplement, p. xxv. They are also shown in the section which accompanies the sequel of the present paper under the letter *b*.

clay was converted into land and denuded, and then subsequently depressed beneath the sea; but this view was only offered by us as an hypothesis alternative to that which we regarded, and which I still regard, as the true one, viz. a change in the source of the morainic material due to the recession of the ice from the chalk country, which the gradual diminution upwards in the overlying clay of the chalk debris, and its eventual disappearance in the uppermost portion, seemed to us to indicate. In many subsequent references that I have made to the purple clay of Yorkshire, I have invariably regarded it as one continuous deposit with the chalky clay of East Anglia, and with the chalky clay which, underlying the purple, forms the base of the Glacial formation of South-Eastern Holderness, and seems identical with that of East Anglia. So far from being a separate deposit, this purple clay with lessening chalk debris, forms, in my view, about the middle portion of that one unbroken formation, the Upper Glacial, the deposit of which took place mainly in the horizontal form, and of which the chalky clay of East Anglia, and that forming the basement clay of South-East Holderness, constitutes the earliest and preceding part, and the chalkless clay of Holderness, into which the purple clay with chalk passes up, and the clay of the more northern counties, constitutes the succeeding parts.

Reverting to the case of morainic clay resting upon stratified sands with marine shells, I would call attention to the evidences which are available to show what kind of effect has actually resulted from the action of glacier-ice upon strata softer than rock when these formed the floor occupied by it. Thus in Norfolk we have evidence of glaciers having occupied the valleys which were cut out of the Lower Glacial and Crag beds down to the Chalk, and left their moraine upon that formation as they receded.¹ Where this has occurred, not only is the Chalk beneath the moraine matter altogether altered in character, having become a greasy marl, but the lines of flint which it contains are ruptured, and forced violently upwards, and crumpled together. This feature is most conspicuous nearest the surface where the grinding pressure of the glacier on its bed was most felt, and becomes less and less downwards until deep down (in some cases not until a depth of twenty feet in this solid, though altered, Chalk is reached) the lines of flint are found to regain their undisturbed state. A representation of this action of glacier-ice upon the Chalk at Litcham was given by me in 1866, in a paper in the *Quart. Journ. of the Geol. Soc.*;² and in a subsequent part of the present paper also I shall have occasion to describe the action of an ice plough on sands in the Yare Valley,

¹ See paper by myself and Mr. Harmer on the later Tertiary Geology of East Anglia, in *Quart. Journ. Geol. Soc.* vol. xxxiii. p. 74.

² vol. xxiii. p. 84. Instead of this action on the Litcham chalk having (as represented in the paper quoted) taken place during the formation of the Contorted Drift, I should now refer it to the time when, after the elevation of part of the Upper Glacial into land, the inland-ice pressed on the west of Norfolk, as explained in the sequel of the present paper: the bed *b* of the section in the paper quoted not being, apparently, the Contorted Drift.

which, where it did not sweep them out altogether, twisted them up in a violent manner with other sands on which they had reposed.

Can any one contend in the face of this that sands would be left undisturbed by glacier-ice moving over them with vast pressure?

In describing the morainic chalky clay, of which the Upper Glacial in East Anglia is formed, as having arisen in part from droppings, I have, until now, spoken of the dropping agent having been bergs, but it has since struck me that I have been to that extent in error. I was led to this view because, while it seemed to me clear that the morainic matter was dropped from floating ice, I was pressed by the impossibility of floe (or sea surface-formed) ice attaching itself to morainic material extruded in deep water.

In the case of this chalky clay, however, though the evidences of its having arisen in part by the droppings of the material from floating-ice are to my mind conclusive, yet we fail to find evidences in it of the action of grounding bergs, such as is so conspicuous in the case of the Contorted Drift. At the same time the general bearing of the facts connected with the accumulation of the chalky clay seems to me to indicate that during it the sea in East Anglia was too shallow to give rise to bergs, for these only break off where the water is deep enough to buoy up and break off the glacier termination. It is only some of the Greenland fiords where the water is very deep that thus give rise to bergs, for in others the glacier ending in shallow water melts in the sea, and fills up the fiord with its moraine.¹

We must, I now think, infer that the agent by which this dropping was accomplished was floe ice packed in winter around the glacier's termination which froze to the bank of morainic material at the glacier's foot, and so carried it away in sheets and masses during summer.

Resuming now our examination and enumeration of American Glacial phenomena, we find that the Erie clay, which in its lower part is unstratified like the Upper Glacial clay of East Anglia and of the North of England, and the Scottish Till, is similarly *full of rolled debris*; and it is described by Prof. Newberry as passing up in Ohio into laminated beds which he attributes to the deposit of the finer material ground up by the glacier-ice and suspended in the water of the basin. The interbedding of material ground up by glacier-ice in ordinary mud in the form of streaks of chalky silt, may be distinctly seen in the Contorted Drift of Cromer Cliff, as we follow it north-west from Cromer towards Weybourne, that is to say, towards the place where, during the formation of this Drift, the glacier discharged into the sea. In the chalky clay (or Upper Glacial) of East Anglia, owing, as it seems to me, to the shallowness to which at that stage of the Glacial period the sea had in that part of England become reduced, we do not encounter this feature;

¹ Brown, *Journal of the Geographical Soc.* for 1871, p. 351. Mr. J. W. Taylor, also, in the same journal for 1870, p. 228, says that numerous fiords in Greenland have been so filled up by the moraines extruded by the glaciers, that boats hardly find depth of water enough to ascend them, while one of the glaciers, that north of Frederikshaab, which is 15 miles wide, and ends, not in a fiord, but on the open coast, has formed a beach at its base with the moraine it extrudes.

but in Holderness, where the chalky clay passes up into the purple, and where, as explained in the sequel, the water was deeper, though not deep enough to form bergs, the morainic chalky clay does seem to pass up, through an intermediate stage formed by dropped sheets of morainic matter, into clay of the character which Prof. Newberry describes the upper portion of the Erie clay to be; for though it is not usually laminated, it is full of lenticular beds of sand, and to my eye presents the appearance of a clay formed by marine deposit from the ground-up material of a glacier carried away in suspension, and accompanied by copious droppings of rock debris from floating ice (see the clays *c* and *d*, with lenticular beds of sand and gravel, *c'* and *d'* therein, shown in the sheet of sections accompanying the sequel of this paper).

On the Canadian highlands, where the material acted on was harder, and where free drainage, as he calls it, washed away the finer portions, this clay, Prof. Newberry says, is largely replaced by gravel-sands and boulders. As the gravel-sands of these highlands could not, however, have been accumulated until the glacier-ice had receded from thence so as to give place for their deposit, we seem to have here a formation of Eskers and Kames, such as is discussed further on. If the gravels of these Canadian highlands occupy, as I imagine they do, elevations above the Erie clay, and also above that to which the submergence under which the Leda and Champlain clays accumulated reached, it seems to me that they must be Eskers or Kames formed by the melting of the glacier-ice when it ceased to discharge its moraine beneath the Atlantic, and beneath the lake waters, and had receded to these highlands. If, however, they be not thus referable to Kame and Esker origin, or if they contain marine organisms, they would, perhaps, answer to the Mountain (Moel Tryfaen) and high-level (Macclesfield) sands of England and Wales, which represent the latest portion of the Upper Glacial formation when the ice-sheet had wasted back to the mountain peaks, and North-west Britain had assumed the condition of an archipelago. Assuming them, however, not to be of marine origin, but Kames and Eskers (which, as presently explained, is the form assumed by the moraine when the recession of the ice takes place subaërially), it seems to me that they must be the product, and the latest product too, of the last glaciation to which the region they occupy has been subjected; for not only would the ice in its subaërial recession leave such beds, but it must, it seems to me, have ploughed out and destroyed the formations of any previous glaciation wherever it encountered them in its advance, and therefore up to wherever such subsequent ice reached.

Prof. Newberry observes that although the Erie clay occupies the same relation to the glaciated rock-surface as do the "Leda," "Champlain," and "Glacial" clays of the Atlantic coast, there is not sufficient evidence to connect them as exactly synchronous; but he considers that these Atlantic coast clays were formed in a similar way to that of the Erie clay; that is to say, during a subsidence of the Eastern coast of North America when the Atlantic

waters in following the retreating glacier covered, and in part stratified, the material ground up by it. In this view he (as do also several American geologists) differs from Principal Dawson, who has attributed the glaciation of the Atlantic coast to an Arctic current carrying icebergs, instead of to glacier-ice, either solely or in connexion with a following sea. It seems to me, however, as explained presently, that though formed in the way Prof. Newberry contends, they are more probably synchronous with the beds 3a, presently described, or even to some extent with the Lake terraces, or beds No. 4.

2. The formation which immediately succeeds the Erie clay in Ohio is, according to Prof. Newberry, that of a terrestrial surface indicated by forest-beds with logs and stumps, and sometimes upright trees, of which beds he gives many instances. This formation (No. 2), or the deposits associated with it, contains the bones of Elephant, Mastodon, and the giant Beaver, and it indicates, according to the Professor, a climate somewhat colder than that now prevailing in the same region, though some of the forest-remains of Ohio contain a large number of plants still growing there.

With reference to this terrestrial surface, Prof. Newberry observes that *no certain proof has yet been detected in America of the return of the glaciers to the area which they had before occupied and abandoned after the intervention of a milder climate, such as is found in Europe.* Now the preservation of so considerable an extent of forest-grown surface to the Erie clay, that is, between the deposits No. 1 and those presently to be described under the symbol 3a, seems repugnant to such an oscillation of climate; because this surface, and indeed the Erie clay itself, would, we must infer, have been ground out and destroyed by any re-occupation of its former site by glacier-ice,¹ and in such case the deposits which succeed it would all appear to belong to that period which, having followed the retreat of the confluent glacier-sheet in Britain and the elevation of this country from its general submergence, English geologists have hitherto been accustomed to call post-Glacial.

If, however, Prof. Newberry is right in regarding the glaciation which gave rise to the Erie clay as having taken place when Ohio stood 500 feet and more above its present level, and the beds which succeed the forest-surface as having been accumulated when the same area was depressed to as great or even greater depth below that level, this difference of altitude (1000 feet) may have so reduced the second glaciation as to prevent the re-occupation of the Erie clay area in Ohio by glacier-ice, notwithstanding the return over the earth

¹ This, as described further on in the present paper, has been the case with the Lower Glacial deposits in England. Mr. Geikie seems to see no difficulty in glacier-ice passing over forest-surfaces without destroying them, although to such ice is attributed the excavation of great valleys and rock-basins, but I do not believe in the possibility of such a thing, the two resulting actions appearing to me irreconcilable with each other. According to Prof. Dana the thickness of the ice which passed over the northern part of the United States was 6000 feet, exerting a pressure of 300,000 lbs. to the square inch, while it was double this on the watershed between Canada and Hudson's Bay. I am, however, very sceptical of these vast thicknesses of ice anywhere.

generally of conditions as frigid as those which prevailed during the first glaciation. On the other hand, if there never was anything more than such a limited depression of the St. Lawrence basin as sufficed to bring the Atlantic waters over those parts which are covered by the Leda, Champlain, and other marine clays of the coast districts (and I fail to see how there could have been more), we should not find this explanation of difference in level available as an explanation, but be driven to infer that the glaciation to which the beds overlying the forest-surface were due was a minor one; so that the ice did not reach to its former position, but damming up the lower valley of the St. Lawrence (which lies in several degrees higher latitude than Ohio), it filled the lake-basin with the waters produced by its dissolution, over which drifted the ice from whose droppings, and from the mud and gravel taken up by currents from the glacier discharge, these beds appear by Prof. Newberry's description to be made up—beds which possess very much the physical character of the Contorted Drift of Cromer, without its included marl masses, as well as of the purple clay of the district near Flamborough Head which is shown in the sections accompanying the sequel of this paper under the letter *d*.

3. The beds thus overlying the forest-surface in Ohio consist, according to the Professor, of clays, sands, and gravels of various kinds, sometimes containing boulders as well as having boulders extensively scattered over them. These beds, to which I have already referred under the symbol *3a*, he considers were deposited by the lake-waters while the Canadian highlands were occupied by glacier-ice, from which bergs breaking off drifted over the lake-basin and scattered blocks.

Looking at the general group of facts affecting the American region as described by Prof. Newberry, and at the general facts with which a long study of the English beds have made me familiar, I strongly incline to the belief that both in America and in Europe there have been two glaciations only; one, the greater, during which the beds that I term glacial were accumulated, and when Britain underwent its general submergence; and the other, the less, which was subsequent to the general emergence of this country, but occurred while the South of England was still partially submerged, and the North of England and South of Scotland had undergone partial resubmergence, and during which the older part of the beds that I term post-Glacial were accumulated. I think that if we take into consideration the greater height of the glacier generating land in Britain over that in Canada, this minor glaciation bears the same proportion to the major in both countries; for the Canadian highlands forming the northern lip of the St. Lawrence basin, and on which, according to Prof. Newberry, the ice terminated and sent off its bergs during the accumulation of the beds *3a*, lie between latitude 45° and 50° , which is at least 5° of latitude short of that to which the grooved rock-surface of Ohio shows the glacier-ice giving rise to the Erie clay had reached. In Britain there is not this difference in latitude between the limits of the major and minor

glaciations, and it seems to be still less in Switzerland, because both countries are more mountainous than Canada, and the conditions are therefore in this respect not parallel; but the similarity is to be discovered in the circumstance that the glaciers of the minor glaciation were in Britain nonconfluent (to any great degree at least), while in America the confluent sheet which they formed was arrested on the Canadian highlands instead of reaching to the centre of Ohio, as the confluent sheet of the major glaciation had done.

Inasmuch as during its greatest extension the ice in Britain did not reach much, if any, south of the 52nd parallel, while in Eastern North America it reached to the 39th, it seems clear that the marked difference in climate between the two regions which now exists, and is due to the influence of the Gulf Stream and the action of the prevalent winds, existed in a similar degree during the major glaciation; and we are assured by American geologists that in a similar way the existing preponderance of winter cold in Eastern North America over that in Western, which now obtains, obtained also during the Glacial period, as the evidences of glaciation have not on the Pacific coast been detected much if at all south of the 49th parallel. These appear to me to be very pregnant facts indicative equally of the cosmic origin of the Glacial period, and of the inapplicability of the Excentricity theory of Dr. Croll to its explanation; because, by the express statements of its author, the influence of excentricity would be inoperative on climate were it not for its effecting a complete diversion from Western Europe of the Gulf Stream, and its similar operation upon the great currents of the Pacific and other oceans, as well as the prevalent winds.

An identity of character between the vegetation which intervenes between the Erie clay surface and the beds 3a, and that now growing in the same region, would, if free from question, be of great importance, because so much uncertainty attaches to the evidence afforded by mammalian remains upon the question of climate; some geologists contending that we are entitled to infer from the presence of certain of these mammalia, especially the Hippopotamus, a period of warm or at least temperate climate; while others insist that mammalia adapt themselves so easily to all climates that they furnish no reliable evidence upon the question; and they endeavour to get over the difficulty of the Hippopotamus inhabiting a country whose rivers would have been thickly frozen over during winter, under conditions of climate much short of glacial, by attributing to this animal migratory habits like those of the Reindeer and Musk Ox, notwithstanding that in its living state it, and indeed, I believe, all Pachydermata, show, as far as known, no migratory disposition at all. In the case of a flora, however, to a great extent identical with one still growing on the same region, no such uncertainty could, I think, arise; and if, therefore, in the interval between the Erie clay and the beds 3a we got such a flora, we could hardly deny the intervention of a temperate climate; and were such an established fact in American geology, it would furnish a strong support to the case of a similar interlude between those two glaciations of major and minor

extent, of which I consider the English formations to afford evidence. Prof. Newberry, however, observes that most of the forest intervening between the Erie clay and the beds 3a was Coniferous, and that as it includes the Cedar and Cranberry, it may be regarded as indicating a climate somewhat colder than the present; for it is not clear that the forest-beds which yield so many of the plants which still grow in the same localities, and which could not have grown if the climate had been much colder, are of the same age as are those found intervening between the Erie clay and the beds 3a.¹

It should, however, be borne in mind that if the forest-beds thus intervening be *in situ*, a great amelioration must, it seems to me, have ensued; for unless the ice had completely thawed out of the lower valley of the St. Lawrence, which lies in several degrees higher latitude than Ohio, the lake-basin could not have been laid dry so as to support a forest growth; because an amelioration sufficient only to release the Ohio portion of the basin from the glacier-ice indicated by the Erie clay, and by the striated surface down to latitude 39°, would have only brought about those conditions which are described by Prof. Newberry as giving rise to the beds 3a, and which I have attributed to the return of a minor glaciation; viz. the filling of the Ohio lake-basin with freshwater instead of the formation of a land-surface. Moreover, how could the lake-basin have again become filled with freshwater after a land-surface, unless a return of glacial conditions took place, minor in degree, but sufficient to dam up the lower valley of the St. Lawrence with ice?

Whatever may prove to be the case, however, as to the nature of the terrestrial climate which preceded the minor glaciation, I think that we have in some parts of North-Western Europe evidences of a warmer marine climate during a very late geological period, than that which now exists in the same region as specified in the sequel.

Besides the beds 3a, Prof. Newberry describes certain gravels forming hills and mounds upon the water-parting which in Ohio divides the drainage flowing to the St. Lawrence from that flowing to the Mississippi. These gravels, which, in order not to dissever them from Prof. Newberry's sequence of deposits, we will call 3b, he regards as similar to Kames and Eskers as they are called in Scotland and Ireland; and they are attributed by him to the action of shore-waves among low islands and shallows, in which condition the highlands of Ohio were at the time when, during the formation of the clays with boulders (3a), North America underwent, he considers, a submergence so great that the sea overflowed the water-parting between the St. Lawrence and Mississippi basins.

I am unable, however, to understand why, if the sea overflowed

¹ It must not be, however, forgotten that the doubts which are being raised as to whether the Forest-bed of the Norfolk coast is *in situ* apply with greater reason to the forest-beds over the Erie clay which appear to have been only encountered in sinkings, and therefore not open to so rigorous an examination as the Norfolk forest; so that if the latter should turn out to be a land-surface ploughed off and removed by the agency of ice, it would be difficult to resist a similar explanation for the Ohio forest-bed; and in such case the beds 3a would probably prove to be only a continuation of the Erie clay formation itself.

this water-parting, and so invaded the lake-basin, some marine organisms do not occur in the deposits of that basin. Not only does Prof. Newberry make no mention of any such, but Mr. Hinde, in a paper in the Canadian Journal for April, 1877, insists that none but land and freshwater organisms have occurred in them. It seems to me, therefore, in the absence of better explanation, that the gravels thus occupying the Ohio water-parting are not of marine origin, but have come into existence in a different way altogether, viz.:

Not having seen the Kames and Eskers of Ohio, or even those of Ireland, I of course can only form my opinion by analogy; but those of Scotland I have seen throughout most of the Highlands of that part of Britain, and on both sides of them as far north as Inverness; and it appears to me that Mr. Jamieson's view of their origin, from the melting subaërially of ice which formed in the mountain districts of Scotland posterior to the emergence of our island from its great depression, is the correct one. Not only so, but nothing to my mind is more confirmatory of the view for which Prof. Newberry and I contend of Glacial clay, or Till, having had a submarine origin, than the contrast afforded by this Esker and Kame drift. When a glacier terminates in the sea, or a lake, the moraine material extruded and left behind by it in its recession is only washed out into gravel where it is subjected to current action. This action is exceptional, and may perhaps be induced by the outflow here and there of streams of freshwater from beneath the ice. In whatever way, however, the currents be caused, the formation of gravel during morainic extrusion with submergence seems to me to be partial, and the great bulk of the material to be accumulated in the unwashed form, because nearly all the glacier-ice is either carried away piecemeal from the termination of the glacier in the form of bergs, *to dissolve elsewhere*, which is the case where the water is deep enough; or else it wastes imperceptibly away into the sea that washes the glacier, which is the case where the glacier terminates in water too shallow to give rise to bergs. When, however, the glacier ends short of the sea, *i.e.* on land, these conditions are reversed; for all this ice dissolves in the glacier itself, and pouring from beneath it as water forms a torrential river, washing out the moraine material into gravel, which the glacier as it recedes leaves in heaps and ridges, while the muddy particles are carried off in suspension by the river. Thus, it appears to me that the unfossiliferous gravel which forms the principal part of the Drift of the Scottish Highland valleys arose from the melting back subaërially of the nonconfluent glaciers of the Hesse period. This period I contend was one of limited re-submergence which, reaching its maximum during the deposit of the Hesse clay, was confined to the northern parts of Britain. It is also the period, as it seems to me, during which the Glenroy roads were formed; and I observed that near the sea or the great lochs in the southern extremity of the Highlands, the moraine material consisted principally of gritty Boulder-earth, and at the northern extremity, as about Inverness, it passed downwards into similar earth; while in the higher valleys

of the Highlands the Drift was entirely of Kame character, *i.e.* gravel with boulders, though Boulder-earth covers the mountain sides up to great elevations. Assuming, therefore, that the north of Britain rose from its limited submergence during the Hesse period, and before the glaciers occupying the valleys of the mountain districts had wholly melted back, and then, after its elevation, that this melting back took place subaërially, we seem to me to get an explanation of much of the complex and seemingly conflicting phenomena of that region; for in the higher valleys which the limited post-Glacial submergence was insufficient to bring down to the sea-level, the valley drift would be all of this character, while in the lower valleys, especially towards their seaward terminations, the lower part of the Drift would be principally unwashed moraine, and the upper part of it washed Kame gravel.

Applying this now to the case of Ohio, and assuming, for the reasons given previously, that no depression of that part of the continent took place until after the growth of the forest-surface (2), which rests on the Erie clay, it appears to me that when the ice-sheet to which Prof. Newberry attributes the Erie clay reached to and rested on the water-parting between the St. Lawrence and Mississippi basins, where these Esker and Kame gravels are found, and where the grooved rock-surface attests the former presence of the glacier-sheet, its dissolution was all subaërial; and the water resulting from it escaped into the Mississippi valley, so that the resulting moraine was washed out into Kames and Eskers; but that so soon as it wasted back from the water-parting, and into the St. Lawrence basin, the melting of the ice began to form a lake, and this washing out of the moraine ceased. The moraine then extruded, being all left subaqueously, retained its original unwashed form of Glacial (Erie) clay, similar in character to the Upper Glacial clay of England, which was left beneath the sea by the retreat of the ice-sheet during the general submergence of Britain. If this view be sound, the age of the Ohio Kames and Eskers which, following the sequence assigned to them by Prof. Newberry, I have called 3*b*, would really be that of the oldest portion of the Ohio Glacial series, *viz.* coeval with the Erie clay (No. 1), of which they would constitute in the horizontal sequence of Glacial deposits the earliest portion.¹

The occupation of the Canadian highlands by an ice-sheet subsequently to the growth of the forest over the Erie clay seems to me to conspire with the evidence afforded by the recent character of the mollusca of the Leda, Champlain, and other marine clays of the lower basin of the St. Lawrence, and Atlantic coast, to show that

¹ Prof. Newberry observes that only patches of the Erie clay occur on the water-parting which is the region of these Kames, and in the details of sections that he gives, these Kame gravels do not rest on the Glacial deposits, but on the rock-surface. Mr. Geikie, in the second edition of his "Great Ice Age," similarly suggests that the Ohio Kames were due to the action of water flowing from the glacier-ice when it reached to the centre of Ohio, but he does not of course recognize such a distinction as I have endeavoured to draw between the deposit formed by the subaërial extrusion of the moraine and that formed by its subaqueous extrusion.

these marine clays belong to a later glaciation than that to which the Erie clay owes its origin; because I cannot, as I have already observed, conceive that with such vast erosive power as is attributed to glacier-ice any deposits of prior Glacial age could survive its destructive agency, so far as it extended. In the case of the older Glacial beds of East Anglia they remain undestroyed, it seems to me, only so far as the subsequent ice giving rise to the Middle and Upper Glacial formation did not extend. The depth of the water under which the Lower Glacial of East Anglia accumulated renders it difficult to conceive that this formation did not extend north and west of the limits to which it is now restricted; and it must have extended either in a marine or terrestrial form as far northwards as the ice to which it owed its origin wasted back or deflected; so that when we combine the absence of any formation representing it in the North of England with the Crag-like character of the mollusca of its basement sands, it seems but reasonable to regard this earlier part of the Glacial series as having been largely destroyed by the subsequent advance upon it of the ice.¹ Now there is an absence from the marine clays of the Lower St. Lawrence basin, and of the Atlantic coast, of any species of mollusca but such as still occur in a living state either in the Atlantic or in the Arctic sea immediately north of it,² while there are Crag forms in the English older Glacial beds, which are not known as living at all; and others, which, if living, are only represented by species known as such in the North Pacific; and two of these, as, e.g. *Nucula Cobboldiæ*, and *Tellina obliqua*, range in our Upper Glacial clay up to what I regard as about the middle place in its horizontal accumulation, viz. Dimlington Cliff base, and Bridlington. This leads me to think that the marine clays of the Lower St. Lawrence and of the Atlantic coast were deposited during the time of the later or minor ice-sheet which gave rise to the beds 3a of Ohio. Mr. Geikie also in his second edition refers these clays to the later part of the Glacial period as defined by him, which corresponds with what I call post-Glacial.

Besides the beds above described, and those yet to be mentioned under the number 4, there is the great Bluff formation or Loess of the Mississippi valley, described by Sir Charles Lyell in the successive editions of his well-known works, and in which at Natchez he mentions the occurrence of a human pelvis.

This formation Prof. Newberry regards as the silt brought down by the rivers which form the Mississippi drainage system when in flood, and spread out over the great valley as the sea by the elevation of the continent receded from it, the chief contributor being the Missouri with its affluents. There is, he says, evidence that the lower part of the valley near New Orleans was depressed nearly

¹ The line up to which this formation, and also the Middle Glacial and earliest part of the Upper, have been destroyed by the subsequent ice is defined in a note to the sequel of this paper.

² This, at least, is my impression, from the works to which I have had access. If the facts are otherwise, then my argument to that extent fails.

1000 feet below the sea-level; and as this must have brought the sea very high up the valley, its recession was a long affair, and the mud of the Bluff formation consequently represents the long period of this recession which its outspread accompanied, the portions at higher elevations being the oldest. He adds that this submergence brought the waters of the Gulf of Mexico up the valley of the Mississippi until the sea covered all the lower half of Ohio; and that it was during the maximum of this submergence, and during the accumulation of the beds 3a, that the action of the shore-waves formed the Kames and Eskers which occur on the watershed between the two basins; but, as I have before observed, if the sea had thus overflowed the water-parting, we are met with the difficulty that the waters of the lake-basin would have become salt, of which no evidence is offered. Neither does Prof. Newberry offer us any evidence of marine organisms to prove the occupation of the upper parts of the Mississippi valley by the sea. He describes certain clays with sands and gravels, which, occurring in Southern Ohio, belong to the deposits of the Mississippi basin; and these, he says, overlie a forest growth, which seems to be a continuation of that which, lying within the St. Lawrence basin, occurs over the Erie clay, and appear to be identical in age with the beds 3a. The relation which these clays, etc., bear to the Bluff formation of the Mississippi, he does not point out with sufficient clearness to enable me to apprehend precisely his view about them, but so far as I can gather from his memoir (p. 37), he regards them as the equivalent of that formation. If, however, the depression about New Orleans was coeval with that to which the marine clays of the Lower St. Lawrence and of the Atlantic coast are due, the Bluff formation would seem to have begun before this. Looking at the subject in the whole light afforded by the examination of the Glacial features of the St. Lawrence basin, as described by Prof. Newberry, it seems to me that the Bluff formation of the Mississippi valley must represent both the Glacial and the post-Glacial periods, and have commenced as far back at least as the Erie clay. Indeed, if the suggestion that the Kames and Eskers of the water-parting between the two basins in Ohio originated from the subaërial dissolution of the ice of the first sheet, when it rested there before shrinking back into the St. Lawrence basin, and forming a lake, be sound, the finer mud carried off by the water in forming such Eskers and Kames must have found its way into the Mississippi valley, and contributed to the material of the earlier part of the Bluff formation, whatever submergence the Mississippi valley underwent having been confined to its lower or Gulf extremity.¹

¹ In reference to this suggestion it would be interesting to learn to what extent rock-fragments have been found in the Mississippi valley which can be identified with rocks *in situ* in the St. Lawrence area. Prof. Newberry speaks of large quantities of gravel and boulders having been carried through the waste weirs, penetrating the water-parting, and deposited in lines leading towards the valley of the Ohio, so that I infer such rock-fragments of lake-basin origin do abound within the limits of the Mississippi valley, and up to the line of Northern drift limit shown in the map.

(To be continued in our next Number.)