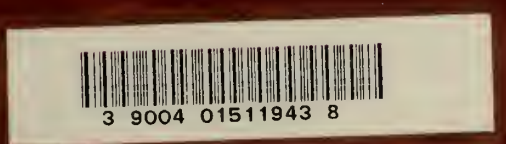

A REVIEW OF THE HISTORY OF THE GREAT LAKES.

BY

J. W. SPENCER, Ph. D., F. G. SS. (L. and A.).

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(Plate VIII.)

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1. Problems and Progress. "Problems settled in the rough and ready way by rude men, absorbed in action, demand renewed attention and show themselves to be still unread riddles; when men have time to think . . . . doubt . . . refuses to be cast out." In such a condition was our knowledge of the history of the Great Lakes, tributary to the St. Lawrence, when the writer commenced his fragmentary studies fifteen years ago. In these studies of the lakes some of the most interesting and important questions in dynamical, agricultural, and artistic geology are involved. Even if the Great Lakes had attracted the attention due them, their study would have been impracticable at an early date, at least until after numerous soundings had revealed their character; and until the railway surveys were made, for these furnish data for quantitative measurements. Many deep well-borings were needed to discover the buried valleys; and the surveys of the deserted shores have delimited the boundaries of the shrinking lakes, and made known the deformation of the earth's crust.

From intimate familiarity with the topographic features of the southern states, and by comparing them with those of the lake region, one can easily see that there would be very little difference between the features of the two areas, if the superficial drift at the north were removed and the country were then compared with that at the south where there is no such mantle. Accordingly the meteoric origin of the great St. Lawrence basin suggests itself; but the basin has been obstructed and several great lakes now occupy what were once broad rolling plains. Before men had time to study the lake history we were told that the lakes were valleys of erosion, but how they were made was hardly a question worthy of consideration. Later, it was an equally rough and ready method to tell us that the basins were excavated by glaciers. Their whole history is not yet written, but many chapters are now before us. Extracts of these will be given in their natural order (not in that of the discoveries), so that a short story of the lakes can be told.

2. Former High Continental Elevation. As will be shown in the next paragraph, the basins of the lakes are more or less like erosion valleys. The deepest sounding of lake Ontario is

491 feet below sea level; of lake Michigan, 262 feet: of lake Huron, 168 feet; and of lake Superior, more than 400 feet. Consequently, if these were erosion valleys, they must have been formed at such an altitude that the drainage of the region could have descended to the sea. As collateral evidence of the high elevation, we find that the lower St. Lawrence river and the Gulf are only a deeply submerged river valley, with tributary canyons, having a general depth increasing from 1,200 feet to 1,800 feet, but much deeper at the edge of the continental plateau. Hudson strait, the Gulf of Maine, New York harbor, and other points along the continental margin, reveal great submerged canyons that were once river valleys. Indeed, portions of the continent were once very much higher than now, especially in the south, where the coast and the Antillean region appear to have sunk from one and a half miles to two and a half miles during the Pleistocene period. These changes of level have been in undulations, with the greatest subsidence along the coastal regions, and more particularly in the south than in the north. But this forms a separate and partly written chapter, in which much progress has recently been made. It is sufficient to know that the lake region has stood at a high elevation during most of the time from the Carboniferous to the Pleistocene days, which were followed by changes of level resulting in the present altitude of the land.*

3. Character of the Lake Basins. The valley-like character of the lake basins appears to be challenged when the casual observer finds that some of the outlets are mostly obstructed by rocky barriers. This condition gives rise to the hypothesis of the glacial origin of the basins, for the theorist did not stop to compare the course of the basins and the escarpments with the direction of the glacial striæ. However one might doubt the correctness of the fluviatile hypothesis, the futility of the glacial origin could only be confirmed when the causes of the barriers closing the lakes were discovered, which will

*Previous papers on this subject by the present writer are: "High Continental Elevation preceding the Pleistocene period," Bulletin Geol. Soc. Am., vol. I, 1889, pp. 65-70; "Post-Pleistocene Subsidence versus Glacial Dams," Id., vol. II, 1890, pp. 465-476; "Terrestrial Subsidence southeast of the American Continent," Id., vol. V, 1893, pp. 19-22. Each of these papers is accompanied with a map.

be shown to have been the drift filling the old valleys and the warping of the earth's crust. But the basins are river-like and broad submerged valleys. Lake Ontario is 247 feet above the sea, but its greatest depth is 738 feet; and throughout a considerable portion of it, the southern side is bounded by high vertical but submerged walls, which for long ages formed bluffs along the ancient river.* Besides the longitudinal trough, another deep channel crosses the basin east of Toronto. Lake Erie is 573 feet above tide, but it is generally less than 100 feet deep, except over a small area where it is 210 feet; but beneath the waters of the shallow basin there are many buried channels, the deepest of which, at Cleveland, is 228 feet (Newberry). Lakes Michigan and Huron and Georgian bay, are at one altitude, 582 feet above the sea. Georgian bay is generally less than 200 feet deep, but at its southwestern side a channel reaches to a depth of 510 feet, in front of the foot of a very high escarpment, part of which is submerged. Another submerged escarpment crosses lake Huron. This has a descent of more than 400 feet. The deepest sounding is 750 feet. The two basins of lake Michigan (respectively 864 and 576 feet deep) have vertical submerged escarpments adjacent to them. Also there are some deep channels and fjords, one of which is 612 feet deep. Lake Superior has been studied less. More or less drift is known to occur between the lake basins, like that filling the submerged channels under lake Erie. The buried valleys will explain the connection between the lakes.

4. Glaciation of the Region. The striæ are nowhere parallel to the direction of the escarpments, whether these be submerged or above the level of the lakes, where they form bold topographic features. Nor are the vertical walls of the limestone escarpments polished by lateral glaciation. In short, the striæ are at considerable angles, even at right angles, to the rocky escarpments. Thus it appears that the valleys were not shaped by glacial action.

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*"Notes on the Origin and History of the Great Lakes," by the writer, Proc. Am. Assoc. Adv. Sci., vol. XXXVII, 1888, p. 197; "Origin of the Basins of the Great Lakes of America," by the writer, Quart. Jour. Geol. Soc., London, vol XLVI, p. 523 (also in AMERICAN GEOLOGIST, vol. VII, pp. 86-97, with map of the ancient Laurentian river system, Feb., 1891); and earlier papers.

5. Buried Laurentian Valley. Below the outlet of lake Ontario, the valley is covered to some extent with drift, but the greater part of the barrier closing the lake is rocky. Between Georgian bay and lake Ontario, the writer discovered a deep buried valley (by a series of borings, for there was no superficial evidence of it, although parallel to the Niagara escarpment), beneath the great drift ridges intervening between the two waters. The full depth has not been reached, although not less than 750 feet beneath the higher ridges, and it is probably very much deeper, as indicated by the fjords at both ends (in lake Ontario and in Georgian bay); so that here is the connecting valley between the submerged channels of the upper lakes and lake Ontario. The fjords of northern Michigan and the buried channels continue the evidence that from lake Michigan to the outlet of lake Ontario, the ancient Laurentian river flowed partly through the basins and partly across the country north of Toronto. The ancient river is thus named to distinguish it from the modern St. Lawrence river. The connection of the valley of Superior with the Laurentian river has not been determined; but judging from soundings in lake Michigan, we may suppose it to have been by way of the northern end of that valley.*

6. Buried Tributaries. A branch of the Laurentian river, now buried beneath 500 feet of drift, extended from the southern basin of lake Michigan across the Michigan peninsula and the southern end of the Huron basin. This large tributary, which has been named the Huronian river, is of the same age as the Laurentian river.

Through the Erie basin flowed the now buried and submerged Erigan river. Niagara river was not then in existence. But the Erigan passed from the Erie basin across the province of Ontario to the great canyon at the head of lake Ontario, thus descending to the lower basin.

Many branches and smaller tributaries are known to have joined these greater rivers, as revealed by the borings. In some cases there were no changes in the direction of the ancient and modern drainage. In other cases the streams have locally left the original waterways and again returned to the

*"Origin of the Basins of the Great Lakes," cited before; also "Discovery of the Preglacial Outlet of the Basin of Lake Erie into Lake Ontario," by the writer, Proc Am. Phil. Soc., Philadelphia, 1881.

old valleys. A characteristic of the former drainage is the filling of the ancient channels, above which the modern streams flow upon the accumulation of drift. The ancient valleys are relatively much shallower but broader than the modern, with sides more sloping and other marks of greater antiquity than the modern streams, where they have cut new channels in place of reopening the buried valleys.

7. Reversal of the Drainage of the Upper Ohio and other rivers. Among the earlier studies on buried valleys were those of Dr. J. S. Newberry, Dr. T. Sterry Hunt, and Mr. J. F. Carll. To Mr. Carll belongs the credit of first working out the reversal of the drainage of western Pennsylvania, where he discovered that the upper Allegheny and some other streams flowed into the Erie basin before the Pleistocene period. In 1881 the writer, following Carll, pointed out that there is evidence that the whole upper Ohio river, above the Beaver tributary, flowed to the Erie basin. This hypothesis was amplified by Dr. P. Max Foshay, and later the observations have been extended by Prof. T. C. Chamberlin and Mr. Frank Leverett, confirming the change in the direction of the drainage. The streams south of lake Erie generally drain a much smaller basin than formerly. So in New York, the upper waters of the Susquehanna, and of its tributaries, drained to the north into the Ontario basin, by way of the Finger lakes, which now occupy the old river courses, partially closed up by drift deposits and by terrestrial warping or deformation towards the north.

8. Closing of the Valleys into Lake Basins. The old Laurentian valley was more than a hundred miles wide, but it was interrupted by the deposition of drift in many places, most notably between Georgian bay and lake Ontario. To some extent the modern St. Lawrence river is flowing over a drift-filled valley. This obstruction has caused the modern drainage to be changed from the old directions and often to pass over rocky barriers. But in addition to the drift obstruction, we find that the recent terrestrial uplift has been greatest toward the northeast, producing barriers and forming basins. The warping has been measured and is found sufficient to account for all the rocky barrier below the outlet of lake Ontario. Moreover this northeastern elevation has caused all the

lakes to rise and flood their southern and western ends, since the modern lakes were established. The quantitative character of this change will be explained in the next paragraph, and the effects upon the modern drainage beyond.

9. Deserted Beaches in the Lake Region and their Deformation. The Laurentian lake region abounds with the remains of deserted beaches, terraces, sea-cliffs, and other evidences of former shore lines. The writer has made an extensive survey of these phenomena in Canada, across Michigan, in the Adirondacks, and in the Green and White mountains.* Mr. G. K. Gilbert did the first systematic work south of lakes Ontario and Erie.† Mr. F. B. Taylor has more recently extended the surveys north of lake Michigan and northeast of lake Huron;‡ and Dr. A. C. Lawson, north of lake Superior.§ There has been very little systematic work in the lake region upon these problems except by the named observers. Some of these old shore lines, after forming highways known as ridge roads, have been surveyed for hundreds of miles; others are broken or interrupted. Generally speaking, the northeastern extensions are unknown, owing to the want of surveys; to the changes in the topography, rendering their surveys difficult; to our ignorance of the phenomena; to our ignorance of suspected modern faults; and to our further ignorance as to how much the phenomena are ob-

*"Notes upon the Origin and History of the Great Lakes," cited before; "Deformation of the Iroquois Beach and Birth of Lake Ontario." Am. Jour. Sci., III, vol. XL, 1890, pp. 443-451; "Deformation of the Algonquin Beach and Birth of Lake Huron," id., vol. XLI, 1891, pp. 12-21; "High Level Shores in the Region of the Great Lakes and their Deformation," id., pp. 201-211; "Deformation of the Lundy Beach and Birth of Lake Erie," id., vol. XLVII, 1894, pp. 207-212; "The Iroquois Shore north of the Adirondacks," Bulletin, Geol. Soc. Am., vol. III, 1891, pp. 488-491. Each of these papers, excepting the one last cited, is accompanied with a map.

†"The History of Niagara River," Sixth Annual Report of the Commissioners of the State Reservation at Niagara, for the year 1889, pp. 61-84, with eight plates (also in the Smithsonian Annual Report for 1890); Proc. A. A. A. S., vol. XXXV, for 1886, pp. 222, 223.

‡"Reconnaissances of the Abandoned Shore Lines of Green Bay and of the South Coast of Lake Superior," AMERICAN GEOLOGIST, vol. XIII, pp. 316-327, and 365-383, May and June, 1894; "The Ancient Strait at Nipissing," Bulletin, Geol. Soc. Am., vol. V, pp. 620-626. Each of these papers has a map.

§"Sketch of the Coastal Topography of the North Side of Lake Superior, with special reference to the Abandoned Strands of Lake Warren," Twentieth Annual Report, Geol. Surv. Minnesota, for 1891, pp. 181-289, with map and profiles.

literated by iee aetion. This last question involves the problems of subsidence of the region and of the character of iee dams. The writer regards the beaches as substantially formed at sea-level (as some of the beaches unquestionably were), although the outlines may have been obstructed by glaciers, floe-bergs, or loeal ice aecumulations, or perhaps the northeastern eontinuity of the beaches is obliterated by reeent faults. These are unsettled questions. Much is still to be done in the survey of the aneient lakes, yet we have some interesting contributions to reeord eoncerning them, even without inquiry here as to the still unread history.

Fragments of beaches oecur in the peninsula between lakes Ontario, Erie and Huron, up to altitudes of about 1,700 feet; and terraees are found in the Genesee valley at a much greater hight, besides others at high levels elsewhere in the lake region. But when we deseend to an altitude of 778 feet, at the head of lake Erie, we are at a beaeh of great extent (to the northeast this rises several hundred feet); and one still more extensive is reached by deseending to 653 feet. All the higher shore developments are the remains of the first waters that eovered the drift at the close of the Pleistocene period, whether they were ice-bound arms of the sea, or held by glaeial dams, or by undiscovered land barriers sinee deformed by terrestrial movements. The beaches were water-levels, but now they rise toward the north and east in increasing ratio. At the head of lake Erie they are nearly level; at the eastern end of this lake the northeastern rise is between three and two feet per mile, aeeording as we take the uplift on the higher or lower beaches. East of Georgian bay the deformation is four feet; and near the outlet of lake Ontario it is from five to six feet per mile towards the northeast, but increases onward to seven and a half feet per mile. These rates of ascent are reeorded in shores not the highest; and there were many lower stages of the lakes.

10. Warren Water. The eontracting waters of the Great Lakes region, represented by the sueeession of beaches, the writer named the Warren water,—the aneestor of all these lakes; and its lowest strand is the Forest beach, whieh at the head of the Erie basin has an elevation of 653 feet above the sea. This lake, during part of its history, covered 200,000

square miles. But to the east it has not been defined, and its old margins have been very considerably tilted. With the continued rise of the land, the waters sunk to a lower level, dismembering Warren water and producing:—

11. Algonquin and Lundy Waters. When the level of the water fell about 150 feet below the level of the Forest beach, the upper three lakes were enclosed within the Algonquin beach, and Erie within the Lundy beach, which latter extended to the Ontario basin. At that time the waters of the lakes did not reach to their western and southern boundaries of today. Toward the northeast they connected by straits with the waters in the Ontario basin, but their eastern limit has not been surveyed.

12. Iroquois Water and Birth of the Modern Lakes. The waters gradually subsided to 300 feet below the planes of the Algonquin and Lundy beaches when the Iroquois shore commenced to be formed. This level has been proved to have been that of the sea, although it is now 363 feet above tide at the head of lake Ontario, 750 feet near the outlet of the lake, and nearly 1,500 feet at the northeastern extension of the Adirondacks. The old water plane is recognizable, by either continuous or interrupted portions of its shore line, all the way to the depression of lake Champlain, but it is not yet fully known, especially as to its location north of the Ottawa river. Lower beaches are also known in the Ontario basin.

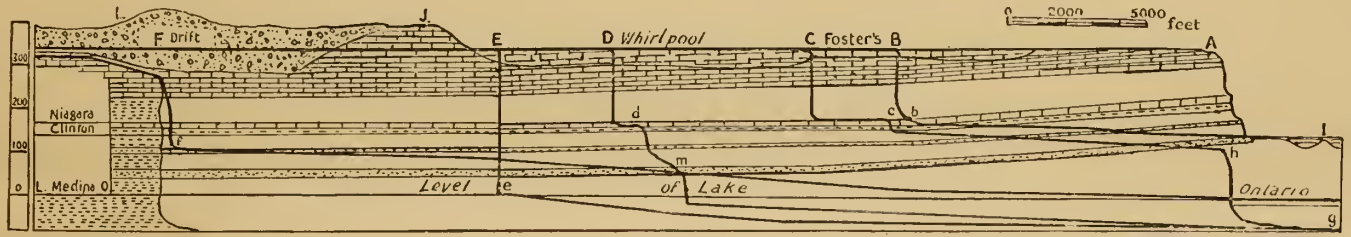
With the subsidence of the waters to the Iroquois level, the upper lakes shrunk within their narrow limits, and the Niagara river had its birth, at first draining only the Erie basin, whilst the three upper lakes outflowed by way of the Ottawa valley. Indeed, the Iroquois waters sunk more than 220 feet below the Iroquois beach, thus greatly reducing the area of that lake. The waters of the upper lakes also sunk so as to form sheets of very contracted proportions. By the continued rise of the land towards the northeast, the rims of the lakes were raised, backing the waters in the basins and extending the modern lakes as we see them. This rise was intermittent, but, for the average of the secular episodes of movement and repose, the warping in the Niagara district appears to have been a foot and a quarter in a century, and it was double that

amount at the outlet of lake Ontario, but almost zero at the head of lake Erie.

13. History of the Niagara River and Changes of the Outlets of the Lakes. From a recently written paper I make the following extracts, concerning the changes and recession of Niagara falls (Plate VIII). Upon the dismemberment of Lundy water, the Niagara river came into existence, and for a time (taken as 1,000 years) drained the infant lake Erie without cascading over a fall. The waters of the lower lake slowly sunk so that the total hight of the fall was 200 feet, with only the drainage of the Erie basin, or about $\frac{3}{11}$ of the modern volume of the water. The early falls are almost exactly reproduced in the magnitude of the American falls. The duration of the first episode is computed at about 17,200 years. Again the waters subsided in the Ontario basin (80 feet lower than now) so that the total descent was 420 feet. At that time the falls receded by three cascades (like the Genesee of to-day), at first with only the discharge of the Erie basin and afterwards with the drainage of all the upper lakes. This condition is computed to have lasted 10,000 years. Then succeeded one united fall of 420 feet, which lasted 800 years. Finally the northeastern part of the Ontario basin rose so that the descent of the river waters was reduced to 365 feet and afterwards to about 320 feet (the downfall from the head of the rapids above the falls to the lake below). This adds 3,000 years to the age of the falls. Thus, it can be seen that the age of the Niagara river is computed to be 32,000 years. It is now well established that the three upper lakes have discharged only a comparatively short time into the Erie basin, having formerly sent their waters to the Ottawa river. This change in the direction of the outlet is calculated at 8,000 years ago, when the northeastern terrestrial tilting turned the drainage into the Erie basin.

About fifteen hundred years ago, the differential uplift in the Niagara district and the recession of the falls through the Johnson ridge, a short distance below the present site of the falls, were competing for the mastery, and in the meanwhile the four upper lakes rose so high as to commence to send their waters to the Mississippi river. But the ridge was cut through and the waters were lowered to the exclusive Niagara drain-

LONGITUDINAL SECTION OF THE NIAGARA GORGE, SHOWING THE RETREAT OF THE FALLS AND THE GEOLOGICAL STRUCTURE.



EXPLANATION.

A. Brow of escarpment and original site of the fall.
I. Iroquois beach and level of that water.
B, b, I. Gorge or chasm at the end of the first episode.
C, c, h, g. Falls retreating in three cascades; but from *h* to *g* the slope was extended over a distance of twelve miles beyond the escarpment.
D, d, m, g. Cataract and gorge at the end of the second episode.
E, e, g. Development of the gorge at the end of the third episode.
F. Present site of the falls.
F, f, m, g. The present gorge from the falls to lake Ontario, by which its lower portion is partially submerged.
g. Level of the lowest lake stage during the Niagara river history (80 feet below the present lake level).
L. Lundy beach, capping the drift.
J. Johnson ridge.

Broken shading about the whirlpool shows the occurrence of drift on the west bank only, with the rock on the eastern; block shading represents limestone; dotted, sandstone; broken lines and unshaded portions, shales. The bottom of the river is about 80 feet below the present surface of lake Ontario, as shown in the figure.

age. If the terrestrial elevation of the land shall continue as for the last 1,500 years, the barrier across the outlet of lake Erie must rise so high as to turn the drainage of the lakes into the Mississippi, by way of Chicago; and it is computed that the end of the Niagara river and falls, under such conditions, will be about 5,000 years hence.

All these estimates are based upon the rate of recession of the falls and the amount of work done in each episode, as discovered in working out the history of the lakes. In 1842, Prof. James Hall made the first instrumental survey of the falls. The next was made in 1875 by the Coast Survey. In 1886, Prof. R. S. Woodward made the third; and in 1890 Mr. Aug. S. Kibbe made the last. From these four surveys, the mean rate of recession of the falls (that is, the mean elongation of the gorge) was found to be 4.17 feet a year. But the river in the region of the falls is now crossing a pre-Pleistocene valley, where the hard surface rocks have been removed for 80 or 90 feet in depth beneath the rocky ridge crossing the course of the canyon a short distance below the present site of the falls. Thus the amount of work now being done by the river is much less than the average demand upon the stream during the greater part of the life of the river. Before 1875 all statements as to the age of the river were pure conjectures, but that of Lyell was nearly correct. The estimates made upon the retreat of the falls alone have proved to be not even so accurate, although the method was better as far as it went; but it stopped short of the history of the falls. Again, speculations as to the ancient Niagara flowing down by the Whirlpool-St. David's valley have been disproved by the rock which crosses that course hundreds of feet above the lake level; instead, the Niagara here touches a little buried tributary of an ancient stream to the west.

In conclusion, the Niagara falls serve as a chronometer of geological time, as they give some idea of the epoch of the lakes. If the Ice age ended with the birth of Warren water, then we can roughly estimate it to date back some 50,000 or 60,000 years. At the birth of the Niagara river and falls, and long before, there was no ice barrier in the Niagara district. Lastly, if we regard the Iroquois water as at any time obstructed by ice, such conditions have not existed since the

close of the episode which ended 14,000 years ago. Whilst, however, the date of the decadence of the Ice age in this region is told, the falls do not necessarily record its termination in other and distant regions.

14. Recurrent Drainage of the Great Lakes into the Mississippi River by way of Chicago. Long ago, Dr. E. Andrews described the deserted beaches south of Chicago, and found that the highest reaches an elevation of 45 feet above the lake. For many miles around the head of the lake, the deserted shores are found far inland. There are other raised beaches near the lake. The different sets form an apparent succession, but in reality there is confusion between the old water-margins and the very recent beaches. The low plain at the head of the lake rises so gradually that at the divide between it and the Mississippi drainage southwest of Chicago it is only eight feet above the lake, with a rocky floor a foot or two lower (canal survey). In proceeding northward along the margin of the Michigan basin, beaches are found emerging from beneath the waters. From the measured deformation of the various sets of deserted shores, the depth to which the tilted beaches are depressed beneath the lake can be calculated.* These record the shrinking of the lake from the highest level south of Chicago to others even hundreds of feet beneath.

The Ridgeway beach extends from the Erie basin across southern Michigan, by way of Saginaw bay and the Grand river valley, and southeast of lake Michigan it descends and is lost in the sand dunes of that region; but, with the measured rate of deformation, it is computed to pass about 40 feet beneath the surface of the water. The Forest beach, the last strand of Warren water, is about 100 feet lower. The still lower Algonquin beach (the great shore line of the dismembered upper lakes) occurs well defined about the northern half of the lake (Andrews and Taylor); but if produced to the southern end of the basin, it would be submerged between 250 and 300 feet. There are other lower and less important deserted shores; but all these represent the subsiding of the lakes during the time of discharge of the waters of lake Huron

*"High Level Shores in the region of the Great Lakes and their Deformation," before cited.

by way of the Ottawa river, which is found to have drained the Huron, Michigan and Superior basins for about 24,000 years.

The highest of the beaches about the head of lake Michigan (at 45 feet) has been regarded as the equivalent of the Maumee beach, or not a lower strand, and therefore the oldest well defined beach of the region, although it is only a few feet above the present and recently deserted shores.

Owing to the terrestrial deformation, the Ottawa outlet of the Huron basin was closed by the rim being raised so high as to turn the overflow into the Erie basin. This northeastward uplift also affected the outlet of the Erie basin, and on account of the presence of the Johnson ridge, about a mile north of the present site of the falls of Niagara, caused an actual overflow of the drainage of all the upper lakes into the tributaries of the Mississippi. At that time the lacustrine silts upon the prairies at the head of lake Michigan were laid down. But the Niagara falls were receding at the rate of about four feet a year and completed the incision through the Johnson ridge about 1,500 years ago,* thus overcoming the terrestrial uplift of the Niagara district (which is about a foot and a quarter a century), and then the level of lake Erie was lowered to about 17 feet below the Chicago divide. The slightly raised beaches about the head of lake Michigan mark this late subsiding of the waters. The lowering of the waters by the recession of the falls has preserved the present outlet of the lakes for a further period, but if the late rate of terrestrial deformation shall continue in the future, the drainage of the upper lakes will be diverted from the Niagara into the Mississippi in perhaps 5,000 or 6,000 years, so that this result will be reached before the falls shall have receded to Buffalo.

*"Deformation of the Lundy Beach and Birth of Lake Erie," before cited.