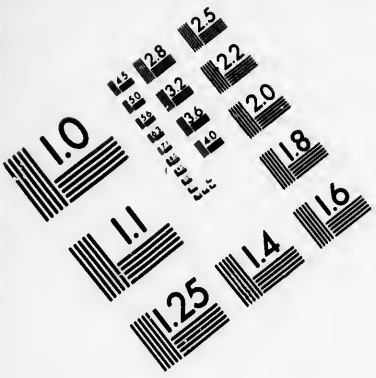

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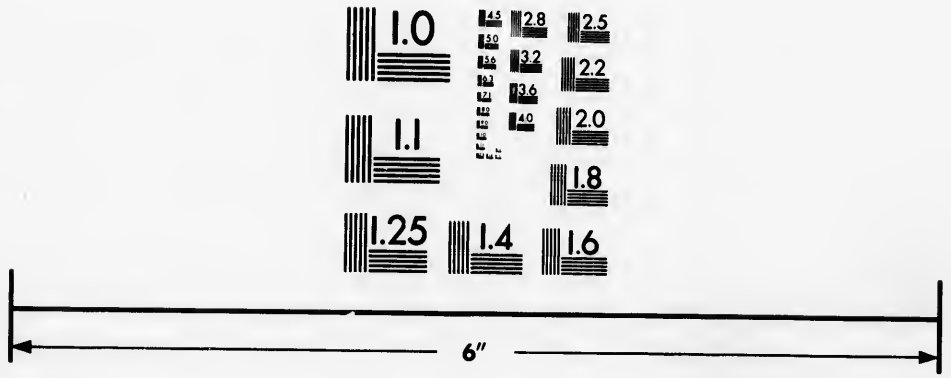

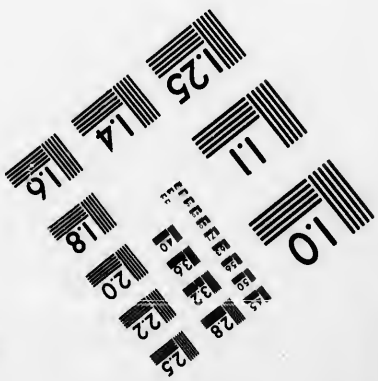

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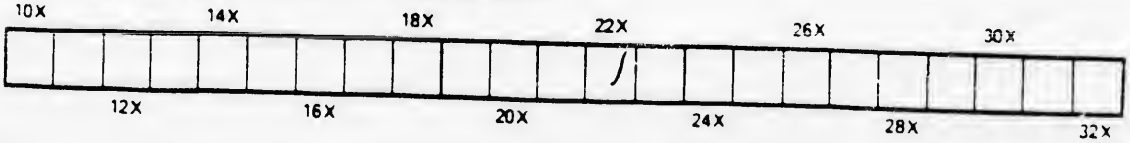

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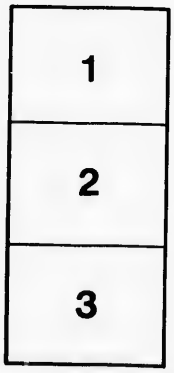

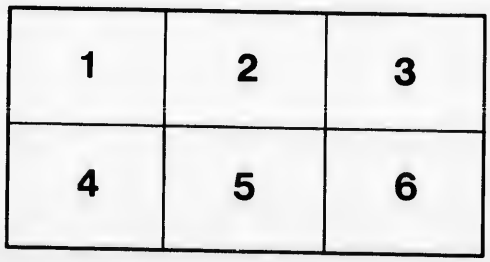

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H

AN ANCIENT RIVER.

Did Lake Erie Ever Discharge its Waters Through Dundas Valley?

PAPER READ BEFORE THE HAMILTON ASSOCIATION, DEC. 8, 1881.

A SHORT STUDY OF THE FEATURES OF THE REGION OF THE LOWER GREAT LAKES DURING THE GREAT RIVER AGE; OR NOTES ON THE ORIGIN OF THE GREAT LAKES OF NORTH AMERICA. BY PROF. J. W. SPENCER, B. A. SC., PH. D., F. G. S., KING'S COLLEGE, WINDSOR, N. S.

I propose to bring before this society a few notes on the physical features of the Great Lake region, which have a bearing on the origin of the lakes themselves, with a few deductions therefrom.

Although the bibliography of the subject is scanty, I will not detain the association with a notice of what has been written.

Whilst working out the origin of the Dundas valley, at the extreme western end of Lake Ontario, the discovery that the present great rock bound valley is only one of insignificance compared with the buried channels of preglacial date led to the broader study of the origin of the lake basins themselves, as the buried channel in the Dundas valley appeared to form a portion of the preglacial outlet of the basin of Lake Erie into that of Lake Ontario.

On this subject my first paper was read last March before the American Philosophical society, and was published in the last volume issued by it.

The same paper has been subsequently reprinted in volume 24 of the Reports of the Geological Survey of Pennsylvania. To this paper frequent reference will be made. During the present summer further details have been worked out, and observations have also been extended to the more important small lakes of Central New York.

But only some of the results of these observations can here be noticed.

THEORIES OF THE ORIGIN OF THE LAKES.

Of these there are three: 1. The basin of the lakes are geological valleys. 2 The basins were excavated wholly or partly by glacier action. 3. The basins were excavated wholly by atmospheric and fluviatile erosion, with their outlets closed by the drift of the ice age.

The relative values of these explanations will be seen in the succeeding pages.

FEATURES ALONG THE PREGLACIAL OUTLET OF THE ERIE BASIN INTO THE BASIN OF LAKE ONTARIO.

The Niagara escarpment encloses the western end of Lake Ontario by its hills, which face the lake just beyond its southern and western shores. Through this escarpment, at the entrance end of the lake, the Dundas valley is excavated. In the expanded valley the western portion of Burlington bay and the city of Hamilton are situated. Westward, however, of the latter place, the excavation through the escarpment closes to a width of

rather more than two miles. Of these hills the lower 250 feet are composed of Medina shales, and over these there are the thin intercalated beds of Clinton dolomites and shales, surmounted by a still greater development of compact Niagara dolomites. The general altitude of the rocky boundaries of the valley is rather more than 500 feet above Lake Ontario (516 feet north of Dundas, and 510 feet south of Ancaster.)

After the escarpment closes to form a valley of about two miles in width, just beyond the limits of the city of Hamilton, it extends westward for six miles, but at Copetown it becomes covered with drift, while on the southern side, at Ancaster, less than four miles distant, it abruptly ends. Westward of Copetown, on the northern side of the valley, the escarpment continues; but it is more or less covered with drift, through which there are occasional exposures of a rocky floor.

On the southern side of the valley, as just stated, the escarpment ends, and the country beyond consists of a large basin filled to an enormous depth with drift deposits, traversed by deep valleys.

The deeper portion of the valley, in which Dundas is situated is separated from the lake by Burlington heights, a ridge of stratified gravel that rises 108 feet above the lake, being an old beach composed of Hudson river pebbles. Behind this ridge is the extensive Dundas marsh, and further up the valley is the town itself.

As we ascend the Dundas valley we find that the channel between the rocky walls of the Niagara limestone becomes filled with drift which rises in places to the summit of the escarpment itself, but which is traversed by deep ravines.

At the upper end of the Dundas valley proper the character of the country differs from that in the valley. There is a large basin, which may be defined approximately by drawing a line from Ancaster village to the Grand river on the west, thence along the hills southward of the Grand river to near Brantford, thence northward to the main line of the Great Western railway, and thence eastward from near Harrisburg to Copetown and the north side of the Dundas valley. Much of this basin is from 50 to 100 feet lower than the country outside of it, which is underlaid by an almost horizontal limestone floor, 500 feet or more above Lake Ontario, and covered with only a moderate thickness of drift.

But in this basin the drift is developed to an enormous extent, seen not only in the ravines in the eastern portion which pass to Dundas valley, but also in the very deep wells. Even the drift divide between the ravines (almost dry) opening to the Dundas valley and the Grand river, is much lower than the level country outside of this drift filled basin.

The depth of the drift in the basin is said to be very great. The elevation between the two systems of drainage is almost 440 feet above Lake Ontario, or 113 above Lake Erie, whilst the ravines and deep wells which seldom reach the rock, indicate an absence of hard rock in many places, at least, to a level below the surface of the latter lake. In the Dundas valley proper, the depth of drift is very great, and cannot be much less than 1000 feet, half of which is below the level of Lake Ontario; for near the margin of the narrower portions of the valley produced to Hamilton, the drift was found in a well to reach a depth of 227 feet below the lake on a bed of Medina shales, and in the center of the valley, (two miles wide), to a calculated (in rocks of the Hudson river period) depth of not less than 400 feet, which would be deep enough to drain Lake Huron, and which would accord with the soundings in the western end of the partially filled lake. This being the case the depth of drift in channels in the basin west of Ancaster, not more than seven miles distant, in all probability reach a similar depth.

Into the western portion of this basin I have found at least two preglacial rivers emptied, namely: the Upper Grand river, then entering the basin near Harrisburg, and Nith's river, emptying northeast of Brantford. From the south eastern corner of the basin the broad depression of the Grand river valley extends to Lake Erie.

The Grand River valley is characterized by a broad depression two miles or more in width, which has a lateral elevation of about 440 feet above Lake Ontario or 113 feet above Lake Erie, and still further by boundaries more than 160 feet above the latter lake. The drift-filled bed of the river at Brantford is only 66 feet above Lake Erie, at Seneca 37 feet, and at Cayuga (more than 15 miles from the mouth), it is down to the lake level itself. The lower portion of the river is through a broad marshy country. At Dunnville, a few miles from the lake, piles had to be driven to a great depth to get a foundation for an embankment across the river. The margins of the valley are underlaid by limestone (Niagara on one side and corniferous on the other), though the ravine valley is excavated out of the softer rocks of the Onondaga group.

In its meanderings the river along portions of its course in several places crosses small spurs of Onondaga shaly limestones, but this character in no place precludes the

possibility of an adjacent buried channel. At most, all the waters that could come down the Grand River, even with any increased pitch of the country, and a larger precipitation of moisture, would scarcely be able to more than excavate the present bed. The country on either one side of the river or the other, is remarkably broken within the limits of the valley, but beyond it is equally remarkable for its level surface. The detailed features I cannot here enter into; but suffice it to say that my former conclusions, that the preglacial outlet of the basin of Lake Erie into that of Lake Ontario was along the buried portions of the Grand river and Dundas valleys, are sustained. This view is greatly strengthened when we study the hydrography of Lakes Ontario and Erie, and the ancient buried valleys connected with the latter lake.

THAT THE DUNDAS VALLEY IS NOT OF GLACIER ORIGIN

is almost too apparent for consideration. Not only have we found a river capable of excavating it, but the very nature of the valley, with more or less perpendicular walls, is not of such a character as to admit of its excavation by the erasion of glaciers. The direction of the axis of the valley is about N 70°. E. The summit edges of the walls on both sides are sharply angular and not rounded; nor is this angularity due to frost action to any extent, as shewn by the character of the lakes.

The surfaces of the rocky floor of the adjacent country are often covered with ice markings, but the striæ are not parallel to the axis of the valley.

There are also several preglacial tributary canyons or valleys, but all these have different directions to the glaciated surfaces.

Again, no glaciers in this region could have moved north-eastward, and equally impossible would it be for any ending streams from melting glaciers to move south westward up an inclination of several hundred feet. These remarks have an important bearing on the origin of Lake Ontario itself, for any force that could have excavated this valley in hard limestone along the true axis of the lake to a depth of nearly a thousand feet would be no important agent in the excavation of the lake itself, lying mostly in Medina and older shaly rocks.

BASIN OF LAKE ONTARIO.

Lake Ontario itself lies only in the lowest portion of a much larger basin, reaching on its southern and western margins to the base of the Helderberg and Niagara escarpments; on the northern to the gently rising lower Silurian and crystaline rocks; and on the eastern to the foot of the Adirondacks. The greater portion of the lake basin is excavated out of the shales of the Medina, Hudson river and Utica rocks, and in the north eastern shallow portion, out of the more calcareous rocks of the Trenton group.

In my former study of this lake, I have shown from the soundings that a narrow buried channel of 90 fathoms depth or more, extends for about 90 miles from near Oswego to the 78th meridian; and at a somewhat less depth 70 fathoms to near the meridian of the Niagara river. Westward of this limit the lake is more uniform in depth, being silted up. The deepest sounding, nearly north of Pultneyville, is 123 fathoms or 738 feet. This deep channel nowhere approaches to within twenty miles of the Canadian shore, although it is within six miles of the shores of New York. From the Canadian shore, the lake bottom slopes gently at an average depth of about 25 feet in a mile to the deep channel, but from the New York side, the slope for three or four miles is double that on the northern side, and then comes a plunge over the face of an escarpment, which in less than two miles is 330 feet, comparable with the Niagara escarpment, westward for some distance of the Niagara river. In one mile across the escarpment the descent is 210 feet.

The rocks of this submerged escarpment, are of Hudson river age, capped by a thin stratum of gently sloping Medina shales. The escarpment can be traced for nearly 100 miles, but in proceeding westward the lower portion becomes buried in the sediments deposited in the lake. Westward of Niagara river the escarpment is obscured by sediments, yet its existance is made known at the exit of the Dundas valley and elsewhere.

The Chemung above Elmira is much smaller than the portion below, which joins it at a considerable angle, but this portion of the river just above Elmira is more modern than the preglacial course of the Chemung, which, from Corning, passes directly to Seneca Valley at Horse Heads. One thing is certain, the Ontario basin, as it was emerging from the last subsidence of the Glacial Period flowed by the route indicated and lingered sufficiently long at the level of the upper part of the Seneca Valley to produce beaches, at the same level along various portions of margin of the basin. Until there was a great change of continental level, the route just described could not have been the preglacial outlet of the basin of Lake Ontario as a considerable portion of the Susquehanna for several miles below Towanda (738 feet above the sea) has a rocky bottom (Lisley) Cayuga Valley would not afford any better outlet, as its summit is 200 feet higher than

that of the Valley of Seneca Lake, and connects with the Susquehanna by diminished valleys. A pot hole at the mouth of Chesapeake Bay indicates an ancient depth of the Susquehanna River to at least 1,170 feet below the sea level. Many of the streams in Northern Pennsylvania now tributaries of the Susquehanna indicate an original northward flow to Seneca Lake. For the preglacial outlet of the Ontario basin to have been by the the Seneca and Susquehanna Valleys a very great level oscillation would have been necessary, but of this we have not the evidence.

BASIN OF LAKE ERIE.

The exceedingly shallow basin of Lake Erie has its bottom as near a level plain as any territorial tract can be. The mean depth for a great portion of the basin does not vary beyond the limits of from twelve to fourteen fathoms. A deeper portion of the lake, however, is found southward and eastward of Long Point, where, for about forty miles, the depth exceeds twenty fathoms—in some places reaching thirty five fathoms. This deeper portion turns around Long Point, and takes a course towards Haldimand county, in Canada, in the direction of the present mouth of the Grand river. The outlet of the lake towards the Niagara river, has a rocky bottom, (corniferous limestone.)

BASINS OF THE OTHER GREAT LAKES.

As I have pointed out elsewhere, Lakes Huron and Michigan partake of the character of subaerial valleys traversed by river systems. Dr. Newberry considers that these two lakes have been separated at a comparatively recent period.

With this view I am inclined to concur, and consequently have classified Huron with the lower great lakes. On a careful study, Lake Superior appears to be a valley of erosion rather than a geological valley, although its position may have been partly divided by geological depressions. Lake Michigan is even now almost deep enough to drain the greater lake whose probable outlet was along a route between the mouth of the Chocolate river, and the northern end of Lake Michigan across the country adjacent to Manistique lake and river. It has been frequently suggested that Lake Michigan had a preglacial outlet into the Illinois river. Since a small wet cutting was made near Chicago, some years since, waters from the lake now pass to the Mississippi drainage. However, the preglacial outlet has not yet been discovered, although it is probable that such a buried channel exists.

THE PREGLACIAL OUTLET OF LAKE HURON.

As the depression from Georgian bay to Lake Ontario is underlaid by a rocky floor more than 200 feet above the former water, there remain only two possible routes, one the Preglacial discharge. One of these routes by the Strait of Mackinac, where the deepest sounding is only 252 feet with the north eastern portion of Lake Michigan very shallow. The other and probable route is by a buried channel to Lake Erie. The southwestern counties of Ontario where borings have been made to a depth, through the drift of 200 and 152 feet respectively, beneath the surface of Lake Erie. These borings appear to indicate marginal depths of a great channel excavated out of an area of soft Devonian shales. Dr. Hunt has collected many of the records of the borings in this section of the province and from them we find that outside of the buried channel hard rocks rise to a considerable height above Lake Erie itself. I have shown elsewhere that this channel is in all probability a portion of the preglacial outlet of Lake Erie joined by buried channels along the route. An outlet by this route would perfectly account for the outline of the shore of Lake Erie, and the greater depths of the lake from the region of Port Stanley, around Long Point, towards the Grand River. Whether this route is sufficiently deep to drain the deepest place in Lake Huron (750 feet,) or not, has not been ascertained by actual observation, but certainly through the highest portion of the barrier in the Dundas Valley the buried channel is deep enough for all purposes. Many valleys now partly buried were once tributary to this great river system. In fact, the basin of Lake Erie abounds with them as if it were nothing more than a grand plain or prairie traversed by many streams cut into the soft rocks out of which most of the lake is excavated. Amongst the most important tributaries from the south were the Cayahoga (whose valley according to Dr. Newberry, is 228 feet beneath the lake surface) the Grand River, of Ohio; and the upper Alleghany, which Mr. F. J. Croll at the close of last year, demonstrated as flowing into Lake Erie near Dunkirk, as also some other rivers of Pennsylvania now sending their waters into the Ohio. The Grand River of Ohio is interesting as being the portion of a magnificent and remarkably straight river, now represented by portions of the valleys of the Monongahela, Upper Ohio, Beaver (reversed) Mahoning (reversed, this Mr. Croll shows to have been the case) and Grand. Ohio as recently pointed out to the American Philosophical Society. The

Upper Alleghany emptying near Dunkirk, would be directly opposite the outlet of the Erie basin, as before described.

EXCAVATIONS OF THE LAKE BASINS.

Having demonstrated that a great system of rivers extended through the various lakes it becomes apparent at once as the greater portion of all the great lakes, except Superior, are excavated mostly out of the more or less shaly rocks of the various regions, that the erosion of atmospheric agencies would tend to wear the country into gently undulating basins, for such only are the bottoms of the great lakes. In fact the lake bottoms have more uniform slopes than the adjacent surfaces of the country exposed to atmospheric influences. Whether geological valleys first determined the position of the lake basins, I do not venture to surmise, but one thing is certain that four of the great lakes, at least, are wholly produced by erosion in almost horizontal rocks. Also the small lakes of central New York have not had their position determined by geological faults as shown by Conrad forty years ago.

HYPOTHETICAL GLACIER ORIGIN OF LAKES.

The hypothesis that the lakes were excavated by glaciers will now be briefly examined. One cannot do better than give a summary of what Prof. Whitney (in climatic changes) says with regard to the erosive power of ice. "Ice per se has no erosive power. Glaciers are not frozen to their beds. Ice permeated with water acts as a flexible body and can flow accordingly. In neither the extinct glacier regions of California, nor in the shrunken glaciers of the Alps will it be found that ice scoops out channels with vertical sides as water does.

No change of form can be observed at the former line of ice.

It can now be seen that a great river extended from Lake Erie through the Dundas Valley, and through Lake Ontario, at the foot of a now submerged escarpment, receiving along the way the waters from great buried river channels, of which the Genesee river was one of the largest, as the Niagara was not yet in existence.

Before considering further the causes of the excavation of the lake, let us examine where there could have been an outlet for the waters of this great river system.

POSSIBILITIES OF AN OUTLET BY THE ST. LAWRENCE.

The northeastern portion of Lake Ontario is very shallow although the country surrounding it is low, yet it is underlaid by hard rocks, which are so frequently exposed through the moderate thickness of drift as to preclude the idea of a great buried channel existing adjacent to the St. Lawrence, which, a short distance below the outlet of the lake, flows over Laurentian rocks. However, in northern New York, but southward of the St Lawrence, there are some unimportant buried channels connected with the Ontario basin. The St. Lawrence river itself is modern from Lake Ontario to the junction of the Ottawa river, though the lowest portion of the river is conspicuously of ancient date, with pot holes indicating a depth of nearly 1,200 feet, without a considerable change of level, such as either that which would be produced by a level subsidence of northeastern Ontario and the Upper St. Lawrence, or a very great northern subsidence during a period of southern elevation. Any possibility of the preglacial outlet of the Ontario basin by the St. Lawrence seems impossible.

POSSIBILITIES OF AN OUTLET AT THE SOUTHEASTERN END OF THE LAKE.

Between the eastern shores of Lake Ontario and the foot of the Adirondacks, the broad plane appears to mark the former lake bottom before the lake contracted to within the present limits. This remark holds good for the great level between the southern margin of the lake and the escarpment to the south, although 150 feet above it.

The level country southeast of the lake is underlaid by almost horizontal Palæozoic rocks, which are exposed along many of the streams, and are covered generally with no great thickness of the drift." These rock exposures are seen as far south as a short distance north of Oneida lake. They are also seen along the Oswego river, and the lower portion of the Seneca. However, there is a deeply buried basin in the region of Onondaga lake. Oneida lake is only 60 feet deep and 127 feet above Lake Ontario, and is situated in a basin of drift. Onondaga lake is 119 feet above Lake Ontario, and is about 65 feet in the deepest sounding. It is a modern lake, situated in a great drift filled basin. The shallower portion of this basin is towards the northern end of this lake. It increases in depth on approaching Syracuse, but again becomes somewhat shallower on passing southward of this city. The drift filled basin reaches to a depth of about 290 feet below the surface of Lake Ontario. Southward of Syracuse the country rises to the escarpment forming the southern boundary of the Ontario Valley.

For many years, suggestions have been made that the Preglacial outlet of Lake Ontario was by the buried basin just described,

emptying its waters by the Mohawk and Hudson rivers into the Atlantic.

However, this outlet is not possible as shown by Mr. Croll, for the Mohawk river passes over metamorphic rocks at Little Falls, Herkimer county, at an elevation above Lake Ontario of about 125 feet, without the possibility of an adjacent buried channel through the ranging hills, through which the Mohawk Valley is cut. The origin of the Onondaga basin, then appears to have been by a river valley extending from the Adirondack Mountains westward and opening into the Ontario basin northward of Cayuga lake, having formed along the course of the basin now occupied by drift material and Onondaga lake, and perhaps that also of Oneida lake.

Most of the other lakes, especially those having a more or less meridianal direction, lie in great valleys, and are only closed up ancient river valleys.

All of these lakes, except Genesee and Cayuga, are at a considerable elevation. One of the deepest of these elevated lakes is Strauenteles, 613 feet above Lake Ontario and 320 feet deep. This lake as well as Owasco have northern modern outlets over rocky barriers. They lie in valleys several hundred feet deep (300 feet or more), and evidently emptied into the Susquehanna river in some former geological times. The valleys of these lakes, as well as several river valleys in the region, now having northern outlets, such as those of Onondaga and Butternut Creek, all radiate from adjacent or common points as they extend northward, evidently showing a former southern discharge. However, it is exceedingly difficult to determine how much of the valleys are of preglacial, and how much of interglacial or postglacial date, for there are evidently three periods of erosion— the valleys produced in the interglacial and modern epochs coinciding.

Thus far no apparent outlet of the great ancient Ontario basin has presented itself.

However one other route at first appeared possible:

BY THE SENECA LAKE, CHEMUNG AND SUSQUEHANNA RIVERS.

The features favoring this suggestion are: 1. The greatest depth of Lake Ontario north of Seneca lake. 2. The depth of Seneca lake, which is 612 feet or 423 feet below the level of Lake Ontario. 3. The direct continuity of Seneca Lake valley with that of the Chemung at Elmira, and of the latter valley with that of the Susquehanna at Sayre.

Aside from the morainic accumulations, there is nothing to prove the former existence of the glacier, except the smooth polished or rounded surfaces of the rocks, which have no more to do with the general outline of the cross section of the valley than the marks of the cabinet maker's sandpaper have to do with the shape and size of the article of furniture whose face he has gone over with that material.

The most important work of glaciers is the scratching and grooving of surfaces. This may, however, be done by dry rubbing, and therefore isolated scratched stones or patches are no evidence. The underlying rock surfaces may lose thier sharpeness, owing to contained detrital material beneath Alpine glaciers, and this is the result of water more than ice.

The only characteristics of ice action are striation and polishing. All floating ice shod with stones frozen in them will scratch surfaces over which they rub. The only glacial lakes which are formed are those where pre-existing valleys have been closed by morainic matter, but the water will soon reopen these dams by running over them.

Such are the deductions of the late Director of the Geological Survey of California, a man who has had opportunities for studying the action of glaciers better than probably most other geologists in America. So far, Prof. Whitney's investigations are applicable to our great lakes. Mr. George J. Hinde, F. G. S., one of the few geologists who has written from a Canadian stand point, is an uncompromising glacialist. Because he has seen scratches in the northeastern end of Lake Ontario, and also others in a similar direction at the western end of the lake, therefore he asserts that Lake Ontario was excavated by a glacier. Dr. Newberry accepts his statements as proof, but considers that a preglacial valley determined the direction of the continental glacier. Mr. Hinds also asserts his belief that the buried valley of the Niagara river (by way of St. Davids), as also those at Dundas, are of glacier origin. It has been proved uncontrovertibly that the Dundas Valley is a buried river channel. Also the Valley of Owen Sound and the St. David's Valley are both beds of preglacial or interglacial rivers. Let us analyze the direction of the ice scratches in the neighborhood of the western end of Lake Ontario. I have not seen any, out of very many sets, that is parallel with the axis of either the Dundas Valley, except possibly one polished surface in the valley, or the axis of the lakes, but always at considerable angles to it. In the region of Kingston, the prevailing scratches are S. 45° W, and some others S. 85° W., neither of which directions are parallel with

the axis of the lake. Granted that Mr. Hinde observed scratches which were parallel with the axis of the lakes, they of necessity would have been at angles with the submerged escarpment. If any glacier could have scooped out the basin of Lake Ontario, it left the summit edges of the Niagara escarpment as sharp as possible, and not planed off. Also if it excavated the deep trough of the lake it left a summit of soft Medina shales over the harder Hudson River rocks of the submerged escarpment, beneath which are Utica shales. From Dundas to the Georgian Bay the face of the escarpment (Niagara) is less abrupt, but even here, there has not been left more than fifty feet of drift at its foot, and this is mostly, if not altogether, stratified (excepting in channels now buried). The observations of Prof. H. Y. Hinde, on the coast of Labrador, are interesting. He has shown pan ice at the present time is polishing the sides of cliffs, and has been continuing its action whilst the coast has been rising several hundred feet. Even under the ledges of overhanging rocks the action is now going on—a phenomenon which, if in the lake region, would be attributed to glaciers. Also, he has seen boulder clay being formed at the present time by the action of pan ice (frozen sea water). This with a thickness of 8 or 10 feet gets piled up by the action of waves and wind, and consequently in the bays of the coast of Labrador, it polishes rock bottoms to a depth of fifteen feet or more below the surface of the water, and grinds off rough surfaces. I have frequently seen, myself, in northern regions, high boulders transported by the ice to which they were frozen in the margin of small lakes. From what has been written, it seems to me that the glacial origin of Lake Ontario does not rest on a single basis further than that ice scratchings, (producible by either glaciers or icebergs, neither of which need be great erosive agents), are seen at various places about Lake Ontario, both above and below the water-level. The remarks applied to Lake Ontario, hold good for the other lakes. Their topography strengthens the proof that their origin cannot be accounted for by glaciers, because we find the islands at the western end of Lake Erie, or northern end of Lake Huron, polished and striated. All the facts appear to point to one series of causes, namely, the lake basins are valleys of subaerial and fluviatile erosion although their outlets to the sea have not been demonstrated.

AGE OF THE RIVER VALLEYS.

The period of the river valleys just described dates far back in geological time. If the explanations brought forward be wholly correct, then the date of the commencement of the valleys should be placed after the close of the Palæozoic Time, as the valley of Susquehanna, and of some of the ancient rivers entering the lake basins are partly excavated out of carboniferous rocks, which had been previously elevated. This would agree with the older portions of the Mississippi river. However, the great river age did not culminate until Middle Silurian Times, as shown by the tributaries of the ancient Mississippi.

ORIGIN OF THE LAKES THEMSELVES.

In the ice ages the outlets of the valleys of the great lakes were closed by drift, apparently assisted by oscilations of the earth's crust, thus producing the lakes. Whether the fillings of the valleys were produced by glacier action by the agency of icebergs, or by that of floating pan ice, a natural explanation might be given, but as this depends upon unsettled glacial geology, I will not here delay to enter into the discussion. However, there appears to be every evidence of an interglacial epoch, when the greater portion of the present Dundas valley, the Niagara river by the old buried channel of St. David's, and many other valleys, everywhere in the lake region, were either re-excavated in the drift or originally opened, and that the second closing or filling of these valleys was not accomplished through any glacier action, but principally through the agency of pan ice and currents.

OSCILLATIONS OF THE CONTINENT IN THE LAKE REGION.

Until lately my investigations bearing on the origin of the great lakes have been mainly based on the hypothesis that the closing of the basins was not occasioned by the elevations of the lake margins by means of the local elevation of the earth's crust. This hypothesis then necessitates the existence of the buried valleys being outlets of the lake basins, which if their continued drifts were excavated, would rest on the preglacial drainage. My recent observations in New York and elsewhere have failed to obtain any proofs of the above supposition.

Outside the region of the lakes in the Red River Valley there are known at least two deep bore holes far apart, where the drift extends to a level below that of Lake Winnipeg and indicates that if the drift was removed from the Red Minnesota Valley that the drainage of some of the great lakes and rivers of the Canadian Northwest Territories would flow to the Mexican Gulf (as first pointed out by General Warren) without the necessity of a local change of level. This

fact extended to the lake regions strengthened my opinion as to the correctness of the above hypothesis. Whilst the fluviatic origin of Lake Ontario is apparent, yet the failure of demonstrating a drift filled outlet for the basin (which is 500 feet below the level of the sea), has forced me provisionally to accept the hypothesis that the basin was partly closed by oscillations of the region as strongly set forth in an able letter from Mr. G. K. Gilbert. As an evidence of local oscillation Mr. Gilbert has pointed out the Irondequot Bay near Rochester was excavated to the depth of more than 70 feet, and two miles wide, by streams of postglacial or interglacial date and subsequently submerged to the above depth. From this his conclusion is that at the time of excavation of this fiord-valley, the relative altitude of the locality and the rock sill over which Lake Ontario discharges differed from this present status by more than 70 feet. Corresponding perfectly with Irondequot Bay is Burlington Bay at Hamilton with a depth of 78 feet, with a closed beach across its mouth. From this and other local features, the surface geology of the Dundas Valley (of which a large amount of information has been collected, but not yet worked out) would indicate a greater elevation, to the extent of more than 78 feet at the head than at the present outlet of the lakes.

Let us consider for a moment the physical effect that would be produced upon the stratification by subsidence of the north-eastern portion of Lake Ontario and the upper St. Lawrence. The dip of the rocks at the western end of Lake Ontario is about 23 feet in a mile, westward or south.

At the eastern end of the lake, I believe, it is somewhat greater. The deeper portions of the lake are more than 40 miles from its present outlet. Any local depression gradually extending northeastward from the deepest surroundings of the lake to even the extent of 25 feet in the mile, would lower the outlet by the St. Lawrence to an extent far greater than would be sufficient to drain the lakes, provided this change took place at a time of high continental elevation, thus producing a broad depressed valley. We know that the valley of the lower St. Lawrence is submerged to the depth of at least nearly 1 200 feet.

The rocky boundaries of the region could scarcely more than indicate this change of level, as the dip of the rocks would pass from the condition of 25 feet in the mile or less to almost absolute horizontality, and we have no measure of comparison. If, however, the elevations took place to the northward to a greater extent than to the southward, such as might be occasioned by a change of the center of gravity of the earth, then the region to the southward of the lakes might be relatively sufficiently lowered as to permit the drainage to pass out by either the Mohawk or Seneca Lake valleys which, evidently, during some portions of the sea age, discharged waters from the expanded basin of the lake.

The local oscillations would also greatly aid in the explanation of the closing of the outlets of the Upper Lakes which would be the most satisfactory if we could establish the greater northern elevation of the lakes over the southern. With these remarks I will close.

The present paper is exceedingly unsatisfactory, owing to the fragmentary character of the facts that have been observed, and even only a portion of them have been worked out.

A word of tribute must be paid to those whose works have paved the way to the present study. General Warren, in his discovery of the former great changes of the drainage of the Winnipeg basin which concerns so large a portion of the continent, should fairly be placed as the father of Fluviatile Geology.

The records collected by and under the supervision of the Directors of the Geological Surveys of Ohio and Pennsylvania—Professors Newberry and Lesley, and those of Dr. Sterry Hunt have been of the greatest value in working out this subject.

To Mr. Croll belongs particular praise for working out the difficult problem of the Upper Alleghany into Lake Erie, and as his work, through the medium of the distinguished Director of the Pennsylvania survey led me to extend my studies beyond the western extremity of Lake Ontario and the Dundas Valley, so, I hope, that this fragmentary paper may assist in giving prominence to the difficult subject of Fluviatile Geology, and correct what errors of observation and deduction which occur in the pioneering work of a department of science now almost unrolled, and yet one more than any other, though modified by others, explains the surface features of the lake regions of the continent.