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INTO THAT OF LAKE ONTARIO;

WITH

Notes on the Origin of our Lower Great Lakes.

BY

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(*Read before the American Philosophical Society, March 18, 1881.*)

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Summary.

The object of this paper is to bring before the scientific world the following observations, bearing on the Preglacial Drainage and origin of our Great Lake Basins :

1. The Niagara escarpment, after skirting the southern shores of Lake Ontario, bends at nearly right angles in the neighborhood of Hamilton, at the western end of the lake ; thence the trend is northward to Lake Huron. At the extreme western end of the lake this escarpment (at a height of about 500 feet) encloses a valley gradually narrowing to four miles, at the meridian of the western part of the city of Hamilton, where it suddenly closes to a width of a little more than two miles, to form the eastern end of the Dundas valley (proper). This valley has its two sides nearly parallel, and is bounded by vertical escarpments, which are capped with a great thickness of Niagara limestone, but having the lower beds of the slopes composed of Medina shales. On its northern side the escarpment extends for six miles to Copetown ; but westward of this village it is covered with

drift, but it is not absent. On its southern side the steep slopes extend for less than four miles to Ancaster, where they abruptly end in a great deposit of drift, which there fills the valley to near its summit, but which is partly re-excavated by the modern streams, forming gorges from two to three hundred feet deep. To the north-eastward of Ancaster these gorges are cut down through the drift to nearly the present lake level.

Westward of Ancaster, a basin occupying a hundred square miles, where the drift is found tc a great depth, forms the western extension of the Dundas valley. With the north-western and western portions of this drift-filled area the upper portion of the Grand river and Neith's creek were formerly connected. The Grand river, from Brantford to Seneca, runs near the southern boundary of this basin, then it enters its old valley, which extends from Seneca to Cayuga, with a breadth of two miles, and a depth, in modern times, of seventy-five feet, having its bed but a few feet above the surface of Lake Erie. Near Cayuga, the deepest portion of the river-bed is below the level of Lake Erie.

2. The Dundas valley and the country westward form a portion of a great *river valley*, filled with drift. Along and near its present southern margin this drift has been penetrated to 227 feet below the surface of Lake Ontario, thus producing a *cañon* with a lateral depth of 743 feet, but with a computed depth, in the middle of its course, of about 1000 feet.

3. The Grand river, at four miles south of Galt, has, since the Ice Age, left its ancient bed, which formerly connected with that of the Dundas valley, as did also Neith's creek, at Paris.

4. Lake Erie emptied by a buried channel a few miles westward of the present mouth of the Grand river, and flowed for half a dozen miles to near Cayuga, where it entered the present valley, and continued this channel (reversed) to a place at a short distance westward of Seneca, whence it turned into the basin referred to above, receiving the upper waters of the Grand river and Neith's creek as tributaries, and then emptied into Lake Ontario by the Dundas valley. This channel was also deep enough to drain Lake Huron.

5. Throughout nearly the whole length of Lake Ontario, and at no great distance from its southern shore, there is a submerged escarpment (of the Hudson River Formation) which, in magnitude, is comparable with the Niagara escarpment itself, now skirting the lake shore. It was along the foot of this escarpment that the river from the Dundas valley flowed (giving it the present form) to eastward of or near to Oswego, receiving many streams along its course.

5. The western portion of the Lake Erie basin, the south-western counties of Ontario, and the southern portion of the basin of Lake Huron formed one Preglacial plane, which is now covered with drift or water (or with both) to a depth varying from fifty to one hundred feet, excepting in channels where the filling by drift is very great. A deep channel draining Lake Huron extended through this region, leaving the present lake near the Au Sable river, and entering the Erie basin between Port Stanley and

Vienna, at a depth near its known margin of 200 feet, but at a probable depth in the centre sufficiently great to drain Lake Huron.

6. The Preglacial valleys (now buried) of Ohio and Pennsylvania—for example ; the Cuyahoga, Mahoning (reversed), and Allegheny (deflected), formed tributaries to the great river flowing through the Erie basin and the Dundas valley.

7. The bays and inlets north of Lake Huron are true fiords in character, and are of aqueous origin.

8. The Great Lakes owe their existence to sub-aërial and fluviatile agencies, being old valleys of erosion of great age, but with their outlets closed by drift. Glaciers did not excavate the lakes and had no important action in bringing about the present topography of the basins.

9. The old outlet of the Niagara river, by the valley of St. David's, was probably an interglacial channel.

I. Introduction.

Whilst residing in Hamilton, Ontario (1877–80), a portion of my time was devoted to studying the geology of the neighborhood. At first it began in connection with Lieut. Col. Grant, H. P., Sixteenth Regiment, and some other gentlemen, in making collections of fossils ; as this locality is one of the best for obtaining Niagara Fossils (and also those of the Hudson River Formation from the drift pebbles in the beaches) in Canada. In 1874, the present writer published in the *Canadian Naturalist* a sketch of the local geology. In 1878, he laid the plan of collecting the information necessary for preparing an exhaustive paper on the Geology of the region about the Western End of Lake Ontario. When systematic work was commenced, the information gained required so much time for its study that it has long delayed the publication. A large number of new species of Niagara fossils (twenty-nine of the Graptolite family alone) were obtained. The present state of the work is, that a paper on the Palæozoic Geology, and another on the Palæontology, containing descriptions of many new fossil species, are ready for publication. A third portion, on the Surface Geology, is under way ; and the investigations on this subject have, step by step, carried the writer outside of his original field,—having assumed an importance never anticipated ; and have resulted in this advance notice of a few of the most striking facts concerning the origin of our great lakes. The completion of the work will be further delayed until opportunity will have been afforded to study some questionable points, especially such as relate to the drift deposits of the region, and others having a broader bearing on the physical geography of the lake regions in Preglacial times.

In the present paper, all discussion relating to the vexed glacial hypothesis is scrupulously avoided, except those questions bearing on a true explanation of the origin of our great lakes.

In the study of the surface geology, the first great question that presented itself was, "What is the origin of my native valley, Dundas?" The possibility of Lake Erie flowing down through the Dundas valley (though it suggested itself) did not seem probable, owing to the high lands between the two great lakes. However, in the *Canadian Naturalist*, 1874, I referred to it as having been produced by a "mighty river." This was like one of those gratuitous hypotheses that are common, now-a-days, for attributing to a continental ice sheet most of the causes of the present physical features of the continent, which do not readily explain themselves. Subsequently, Mr. George J. Hinde refers to it as having been scooped out by a glacier. This assertion will be found in the sequel to be a perfectly untenable hypothesis. Certainly, the origin of the valley was obscure, yet it showed that the excavation of a *cañon* of such magnitude required a proportionately great agent; and no present stream would account for even a small portion of the excavation. However, in this paper it will be seen that its existence was unquestionably occasioned by the action of a mighty river, as originally suggested. This outlet of Lake Erie also perfectly accords with, and accounts for the preglacial drainage of Pennsylvania, as made known at the close of last year by Mr. Carll, of the Geological Survey of that State.

II. Topography of the Region about the Western End of Lake Ontario.

The Niagara Escarpment.—This range of hills commences its course in Central New York, and extends westward, at no great distance south of Lake Ontario. It enters Canada at Queenston Heights, and thence its trend is to the western end of the lake, where, near Hamilton, it turns northward and extends to Cabot's head and Maintoulin island. Everywhere in Canada, south of Lake Ontario, it has an abrupt fall looking towards the northward; but at Thorold and other places to the eastward its bow is more broken than at Grimsby, and westward. At Hamilton, the brow of the escarpment varies from 388 to 396 feet above Lake Ontario.* About five miles east of Hamilton, the escarpment makes an abrupt bend enclosing a triangular valley, down which Rosseaux creek, and other streams now flow. This valley is about two miles wide at its mouth, and has a length of about the same distance.

About five miles westward of Hamilton, the Niagara escarpment becomes covered with the drift deposits of a broken country, or rather ends abruptly in the drift of the region. Above the range, the country gradually rises to the divide between Lake Ontario and the Grand river, or Lake Erie, without any conspicuous features. South-eastward of Hamilton, at a point about five miles from the brow of the escarpment, where the Ham-

* Prof. Dana places the mean level of Lake Ontario at 233.5 feet above ocean-level; the Canadian Geological Survey, at 232 feet; the New York Central Railroad, at 249.84; the Geological Survey of Pennsylvania, takes 573 feet as the mean of the results of determining the level of Lake Erie; the Welland canal levels show Lake Erie as being 326.75 feet higher than Lake Ontario; and the Hamilton and North Western Railway a difference of 328 feet, both of these last routes being short lines with direct courses. Therefore the height of Lake Ontario should be about 245 feet above the sea.

ilton and North Western Railway reaches the summit, the altitude above Lake Ontario is 493 feet. At Carpenter's quarry, two miles southward of the "mountain" brow, at the head of James street, the altitude reaches 485 feet; and near Ancaster the summit is 510 feet above Lake Ontario. From eastward of Grimsby (for twenty miles) to near Ancaster, the escarpment presents an abrupt face from 150 to 250 feet below the summit (having a moderate amount of *talus* at the base), thence it extends by a more or less steep series of slopes to the plane, which gradually inclines (sometimes by a succession of terraces), to the lake margin.

On the northern side of the town of Dundas, the abrupt face of the escarpment looks southward, and extends four or five miles westward, until the exposure becomes covered by the drift deposits near Copetown station, similar to the termination at Ancaster on the south side of the Dundas valley, but not by an abrupt ending as at the latter locality. About two miles east of the G. W. Railway station, at Dundas, the trend of the range bends more to the northward, and from this point there is a marked difference in the configuration of the country below the summit. The range, after extending beyond Waterdown, turns still more to the northward and passes near Milton, and Limehouse station (on the G. T. Railway), and thence extends to Georgian bay. The height of Copetown above the lake is 502 feet. On the west side of Glen Spencer it is 409 feet, and eastward of the same gorge the highest point is 520 feet (Niagara limestone coming within four feet of the surface). At Waterdown the altitude is over 500 feet (?) and at Limehouse the brow of the range (though only the lower beds of the Niagara limestones occur) is 810 feet. The features of the surface of the country above the highlands north of Dundas are much more varied than south of the Dundas valley. As the trend of the escarpment turns northward around the end of the lake, the face of the slope looks towards the eastward. But the country does not present the steep declivities as exhibited along the southern side of Lake Ontario; for the vertical face is usually less than 100 feet, and the country between it and the water has a more uniform pitch.

Basin of Lake Ontario. As is well known, Lake Ontario consists of a broad, shallow (considering its size) basin, excavated on the southern margin out of the Medina shales, and having its southern shores from one to several miles from the foot of the Niagara escarpment. The Medina shales form the western margin (where not covered with drift) to a point near Oakville. From this town to a point some distance eastward of Toronto, the hard rocks are made up of the different beds of Hudson River Epoch; while the soft Utica shales occupies the middle portion, and the Trenton limestones the portion of the Province towards the eastern end of the lake.

The country at the western end of the lake consists of slopes gently rising to the foot of the Niagara escarpment, noticed before. Sometimes this elevation is by terraces, and again by inclines so gentle, as between the foot of the escarpment at Limehouse (on the G. T. Railway) and the lake, where the difference of altitude above the water is more than 700 feet, without any very conspicuous features.

At the western end of the lake, the two shores converge at an acute angle. At about five miles from the apex of this angle is the low Burlington beach, thrown across the waters in a slightly curved line, which forms the western end of the open lake. Burlington lake, thus formed, is connected with the open lake by a canal of the same name, made where there was a former shallow opening between the waters within and without the beach. This beach is made up of sand and pebbles (mostly of Hudson River Age), and is more than four miles long, but nowhere is it half a mile wide.

No mean depth of Lake Ontario can be fairly stated. For geological purposes it has no mean depth, because it is simply a long channel with the adjacent low lands covered by back-water.

West of the meridian of the Niagara river the lake is evidently filled with more silt then eastward, as we find that the bottom slopes more gradually towards the centre, where the mean depth (increasing from the westward) of the channel may be fairly placed at 400 feet below the present surface of the waters. In this section of the lake, the average slope from both shores may be stated at 30 feet in a mile. At a short distance east of the 78th meridian, the character of the late bottom changes in a most conspicuous manner. Here we find a deeper channel which extends for more than ninety miles, having an average depth of about 90 fathoms or 540 feet, with, in some places, a trough of about 600 feet depth, generally near the southern margin of the 90-fathom channel. Here and there is a deeper sounding—the deepest being 123 fathoms or 738 feet. The long channel, surrounded by the 90-fathom contour line, is situated at a mean distance of not less than twenty miles from the Canadian shore, whilst its southern side approaches in some places to within six miles of the American shore, with which it is parallel. This 90-fathom channel varies from three to twelve miles in width. Its broadest and deepest portion is south of the Canadian peninsula of Prince Edwards' County.

The mean slope of the lake bottom, from the Canadian shore to this deep channel just pointed out, may be placed at less than twenty-five feet in a mile, with variations from twenty to thirty feet in that distance. The mean slope from the New York shore line to the 90-fathom channel may be placed at sixty feet in a mile, but varying generally from fifty to ninety feet. On examination we find that the greater portion of this slope belongs to a belt which descends much more rapidly than the off-shore depression.

That the southern side of Lake Ontario has a submerged series of escarpments or one moderately steep and of great dimensions, is manifest when we come to study the soundings. In fact, if the bed of Lake Ontario were lifted out of the water, this submerged escarpment would be more conspicuous than the greater portion of the present one, known by the name of the Niagara. In many places the descent from the table-land above the Niagara escarpment is no more precipitous than the slopes of the submerged Cambro-Silurian (Hudson River, in part, if not throughout the entire length) rocks, with its sloping summit, in part crowned by a gently sloping surface of Medina shales. Nearly north of the mouth of the Genesee river we find that within a single mile the soundings vary from forty-three to seventy-eight fathoms (between contour lines). This gives a sudden descent in one mile of 210 feet. As the soundings are not taken continuously to show to the contrary, most of the change of levels may be within a few hundred yards.

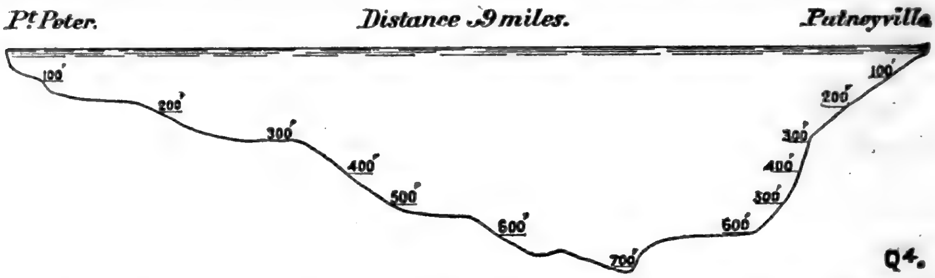
In the region of these soundings the deepest water outside of the 78-fathom line is 84 fathoms, while from the shore to the 43-fathom sounding the least distance is four and a half miles, thus giving the greatest mean slope of the lake bottom at sixty feet in a mile, before the escarpment is reached.

An excellent series of soundings can be studied in a line nearly northward from Pultneyville, N. Y.:

Distance from Pultneyville	Depth of Sounding.	Slope from previous Sounding.
0.5 miles.	42 feet.	
1.0 "	72 "	60 feet per mile.
1.75 "	126 "	72 " "
4.125 "	246 "	50 " "
5.0 " } Face of the escarpment.	{ 372 " }	144 " "
6.0 " }	{ 582 " }	210 " "
7.0 "	624 "	42 " "
10.0 "	642 "	6 " "
12.0 "	738 "	48 " "

Fig. 1.

Section of Lake Ontario from Point Peter Light, Ontario, to Pultneyville, N.Y.



Q4.

From this table it will be seen that in a distance of less than two miles the slope of the escarpment is the difference between 582 and 246 feet, or 336 feet as actually recorded. At Hamilton, the Niagara escarpment is only 388 feet above the lake, which is two miles distant, whilst the present slope at Thorold is spread over nearly twice that distance. That this escarpment is not local is easily seen. For a distance of over forty miles, from near Oswego westward, it plunges down 300 feet or more in a breadth varying from less than two to three miles. Eastward and westward of this portion of the lake this submerged escarpment can be traced for nearly one hundred miles, but with the portion deeper than the 70-fathom contour having more gradual soundings, as the base of the hills either originally had a more gradual slope, or the lake in its western extension has subsequently been filled with more silt.

Although we have not soundings made very close together, yet the admirable work of the United States Lake Survey is more than sufficient to prove the existing of a continuous escarpment that has an important bearing on the Preglacial geography of the region, and on the explanation of the origin of the Great Lakes themselves.

The soundings do not show a conspicuous escarpment after passing westward of the meridian of Niagara river, partly on account of the sediments filling this portion of the lake, and partly because the lake in all probability never had its channel excavated to so great a depth as farther eastward.

Attention must be called to the fact that the depth of the Niagara river is 12 fathoms near its mouth, but that the lake around the outlet of the river has not a depth exceeding four fathoms with a rocky bottom.

Another escarpment at the level of Lake Ontario, now buried, was discovered by the engineers of the enlargement of the Welland canal, according to Prof. Claypole (Can. Nat. Vol. ix, No. 4). When constructing, No. 1 lock, at Port Dalhousie, it was found that at its northern end, there was an absence of hard rock which formed the foundation of its southern end. Rods more than 40 feet long were pushed into the slimy earth without meeting any hard rock bottom. This discovery will be noticed in the sequel. *

Basin of Lake Erie. The exceedingly shallow basin of Lake Erie has its bottom as near a level plane as any terrestrial tract could be. Its mean depth, or even maxima and minima depths from its western end for more than 150 miles, scarcely varies from 12 or 13 fathoms for the greater portion of its width. The eastern 20 miles has also a bed no deeper than the western portion. Between these two portions of the lake, the hydrography shows an area with twice this depth (the deepest sounding being 35 fathoms). This deepest portion skirts Long Point (the extremity, a modern peninsula of lacustrine origin), and has a somewhat transverse course. An area of less than 40 miles long has a depth of more than 20 fathoms. The deeper channel seems to turn around Long Point, and take a course towards Haldemand county, in our Canadian Province, somewhere west of Maitland. The outlet of the lake, in the direction of the Niagara river, has a rocky bottom (Coniferous limestone).

The study of this lake at first appears less practicable than that of Ontario, but, when its former outlet and its tributary rivers are described, the writer trusts that he will have made some observations, that may help to clear the darkness that hangs about the history of our interesting lake region, before the advent of the Ice Age.

The Dundas Valley and adjacent Cañons. We may consider that the

* See Report of Chief Engineer of Canadian Canals, 1880.

Dundas valley begins at the "bluff" east of the Hamilton reservoir, and extends westward, including the location of the city of Hamilton and the Burlington bay, at least its western portion. With this definition, the width at the Burlington heights (an old lake terrace 108 feet above present level of the water) would be less than five miles. At a mile and half westward of the heights, the valley suddenly becomes narrowed (equally on both sides of its axis of direction, by the Niagara escarpment making two equal concave bends, on each side of the valley, whence the straight upper portion extends, the whole resembling the outline of a thistle and its stem), from which place it extends six miles westward to Copetown, on the northern side; and three and a half to Ancaster, on its southern side. The breadth between the limestone walls of this valley varies somewhat from two to two and a half miles. The summit angles of the limestone walls on both sides are decidedly sharp.

Dundas town is situated in this valley, its centre having a height of about 70 feet above Lake Ontario, but its sides rise in terraces or abrupt hills; and on ascending the valley, we find that between the escarpments are great ranges of parallel hills separated by deep gorges or glens, excavated in the drift by modern streams. This rugged character continues until the summit of the Post Pliocene ridges have a height equal to that of the escarpment. As the gorges ascend towards the westward, they become smaller, until at some distance south-west of Copetown and Ancaster, the divide of the present system of drainage is reached. Some of these streams have cut through the drift, so that they have only an altitude above the lake (which is seven miles distant) of 240 feet, while the tops of the ridges immediately in the neighborhood are not much less than 400 feet high, though they themselves have been removed to a depth of about another hundred feet, for the drift has filled the upper portion of the valley to the height of 500 feet above Lake Ontario. Even to the very sources of the streams, the country resembles the rivers of our great North Western Territories (or those of the Western States), cutting their way through a deep drift at high altitudes, which is not underlaid by harder rocks, showing deep valleys rapidly increasing in size and depth, as they are cleaning out the soft material, and hurrying down to lower levels—a strong contrast to the features in most other portions of our Province.

On the south side of the Dundas valley, a few unimportant streams, mostly dry in summer, have worn back the limestone escarpment, over which they flow, to distances varying from a few yards to a few hundred, making glens at whose head in spring time some picturesque cascades can be seen. At Mount Albion, six miles east of Hamilton, there are two of these larger gorges, whose waters, after passing over picturesque falls, 70 feet high, and through glens several hundred yards in length, empty into the triangular valley noticed before. On the north side of the Dundas valley, besides small gorges with their streams comparable to those on the south side, there are several of much larger dimensions; for example, that at Waterdown, six miles north of Hamilton. Still larger is Glen Spencer which has a *cañon* half a mile long, 300 feet deep and between 200 and 300 yards wide at its mouth. At the head of this is Spencer Falls, 135 feet high, and joining it laterally there is another *cañon*, with a considerable stream flowing from Webster's Falls, which, however, is of less height than the other. The waters feeding their streams come from northward of the escarpment, and belong to a system of drainage different from those streams which flow down through the drift of the Dundas valley, and are of much greater length. At the foot of Spencer Falls, the waters strike the upper portion of the Clinton shaly beds. The Falls now are two feet deeper than twenty years ago. Yet the stream is small, and makes a pond below in the soft shales. But this difference in height does not represent the rate of wearing or recession of the precipice. That the stream is much smaller than formerly is plainly to be seen, for at present it has cut a narrow channel, from ten to fifteen yards in width, above the falls, and from four to six feet deep, on one side of the more ancient valley, which is about 50 yards wide and 30 feet deep, excavated in the Niagara dolomites.

The surfaces of the escarpment in both sides of Glens Spencer and Webster present a peculiar aspect. That on the north-eastern side has a maximum height of 520 feet above the lake. On the same side, a section made longitudinally shows several broad shallow glens nearly a hundred feet deep crossing it and entering Glen Spencer. The surface of the rocks is glaciated, but not parallel with the direction of the channels. On the south-western side of the same *cañon*, we find that a portion of the thin beds of Upper Niagara limestone have been removed. This absence is not general, for it soon regains its average height of about 500 feet.

Dundas Marsh. The eastern end of the Dundas valley contains a large swamp, nearly three miles long, with a breadth of about three-fourths of a mile, known in the early settlement of the country by the name of Coote's Paradise.

This marsh was formerly connected by a small rivulet with Burlington bay, but this was subsequently closed by the G. W. Railway, when the cutting of Desjardin's canal through Burlington heights was completed. Into this marsh all the drainage of the Dundas valley is deposited, causing it to fill up at the rate of one-tenth of a foot per annum.

Burlington Heights. Across the eastern end of the Dundas swamp and some of its branches, are the Burlington Heights, varying from a few hundred yards to nearly a quarter of a mile in width, and over 100 feet in height, which have been an old beach, at a time when the lake level was at the same elevation, for we find that a lake beach extends along the flanks of the escarpment, both eastward and northward for a considerable distance at the same level. This is mentioned here as forming a most conspicuous terrace, and as changing the physical character of the western extremity of Burlington bay, and the outlet of the Dundas valley. Various terraces and beaches are found, both at lower levels, and also fragments at higher altitudes, or along the side of the "mountain," until some attain a height of 500 feet above Lake Ontario.

The Grand River Valley. The Grand river of Ontario rises in the County of Gray, not more than twenty-five miles from Georgian bay. Thence it flows southward, and at Elora the river assumes a conspicuous feature. Here it cuts through the Guelph Dolomites to a depth of about 80 feet and forms a *cañon* about 100 feet in width with vertical walls. At this place it is joined by a rivulet from the west, which has formed a tributary *cañon* similar to that of the Grand river itself.

The country in this region is so flat that it appears as a level plane. Farther southward the river winds over a broader bed, and at Galt the present river valley occupies a portion of a broad depression in a country indicating a former and much more extensive valley. In fact, the old river valley existed in Preglacial times, for the present stream has re-excavated only a part of its old bed at Galt, leaving on the flanks of one of its banks (both of which are) composed of Guelph Dolomites, a deposit of Post Tertiary drift, in the form of a bed of large rounded boulders mostly of Laurentian gneisses. The country for four miles south of Galt is of similar character, forming a broad valley, in which the present river flows. At this distance from Galt the river takes a turn to the south-westward; but at the same place, the old valley appears to pass in a nearly direct line with the course of the present bed (before the modern turn is made to the westward). As this portion of the valley now entered, has not to any extent been cleaned out by modern streams, it forms a broad shallow depression in the country extending for a few miles in width. Yet, it is often occupied with hills composed of stratified coarse gravel belonging to that belt, which extends from Owen Sound to the County of Brent, and called by the Canadian Geological Survey "Artemesia gravel."

It is through a portion of this valley that the Fairchild's creek flows. Many streams derive their supplies of water from the Beverly swamps, which also feed the Lindsay creek, that empties over Webster falls and flows down Glen Spencer through the Dundas valley to Lake Ontario.

The G. W. Railway, at four miles south of Galt, enters this valley and continues in it or its branches as far as Harrisburg, though the deeper depression is near St. George (a short distance west of Harrisburg). After leaving what I consider its more ancient bed, south of Galt (unless the country between the present bed and Fairchild's creek was an island), the Grand river flows southward to Paris and Brantford, having a deep, broad valley. At the latter place the valley may fairly be placed at a few miles in width, while further to the eastward the river winds in an old course, which had formerly a width of over four miles (see map). In the region of Brantford the valley is bounded by a somewhat elevated plateau. At Paris, Neith's creek enters the Grand river from the west, and has a valley almost comparable in size with that of the latter at this town. At Paris, the Grand river cuts through the plaster-bearing Onondaga formation. Similar rocks appear at various places along the river, at places where the river has cleaned out a portion of one side of its ancient valley.

At the Great Western Railway crossing, east of Paris, the bed of the river has an altitude of 495 feet above Lake Ontario, while at Brantford it is 410 feet (this elevation may not be perfectly accurate) above the same datum. From Brantford the river winds through a broad valley, with a general easterly direction, to Seneca, where the immediate bed is about quarter of a mile wide, flowing at the southern side of a valley, more than two miles wide, and 75 feet below its boundaries, which are 440 feet above Lake Ontario (see profile on subsequent page). At Seneca the bed of the present river-course is 365 feet above Lake Ontario, or only 37 feet above Lake Erie. (The H. & N. W. Railway levels give Lake Erie as 328 feet above Lake Ontario, whilst the Report of the Chief Engineer of the Welland Canal states that the difference of level is $326\frac{3}{4}$ feet. As these two levels agree so nearly, and as the other figures refer to the railway levels, I have followed them here.) Eastward from Seneca the river continues to have its broad valley as far as Cayuga. To near this town the waters of the Welland canal feeder reach, at a height of about 9 (?) feet above Lake Erie.

From Seneca to Cayuga the direction of the valley is nearly south, but at the latter place it abruptly turns nearly to the eastward, and in a short distance it passes to a flatter country and flows over Coniferous limestone. After a sluggish flow, it enters Lake Erie (passing through a marshy country) at Port Maitland, more than fifteen miles in a direct line from Cayuga. It must be remembered that, from Seneca to Cayuga, the valley is broad and conspicuous. At only a short distance south of the river, at Seneca, the summit of the country is occupied by a gravel ridge.*

Returning to the valley of Fairchild's creek, we find the stream principally flowing in the former bed of the Grand river, abandoned a few miles below Galt since the Ice Age. This creek crosses the Great Western Railway at a level of fifteen feet below the crossing of the Grand river, at a few miles to the westward. Again, the Fairchild's creek crosses the Brantford and Harrisburg railway at an altitude of 407 feet above Lake Ontario, or a little below that of the Grand river at Brantford, although it empties into it a few miles east of the city just named.

Fairchild's creek is now of moderate size meandering through the drift for a width of two miles. This drift is in part stratified clay. The Grand

* The General Manager and Chief Engineer of the air line of the G. W. Railway have recently kindly furnished me with a profile of the railway crossing over the Grand river. A similar favor has been kindly conceded by the Chief Engineer of the Canada Southern Railway. From both of these lines of levels (about a mile apart) we find that the hard rock appears in the drift at a few feet below the bed of the river. but at a level below that of the surface of Lake Erie. The stream, at these places, occupies the eastern portion of the valley about two miles from the ~~northern~~ or ~~north~~-western boundary of the valley, marked South by the contour line of 440 feet above Lake Ontario, noticed south of Seneca, but which also occurs westward of Cayuga, near the general bend in course of the river. On both of these profiles, at about half a mile to the westward of the present site of the river, a depression in the drift occurs to a depth but little inferior to that of the present river-bed. This appears to mark the place where the ancient channel leaves what is now the modern direction of the river for a nearly direct line to the Erie basin.

river from Brantford eastward, is generally excavated from the drift deposits, although occasionally one side of the valley shows rocks of Onondaga formation, exposed by the removal of the drift in modern times. It is also desirable to call attention to the fact that in the region of Brantford, much of the Onondaga Formation is shaly and forms the surface country rock, covering a broad belt, whilst from Seneca eastward, the surface of the country is more generally covered with Coniferous limestone.

Country between the Grand River and Dundas Valleys. The watershed between these two present drainage systems is at only a short distance south-west of Copetown, and the distance in a direction from the Fairchild's to the Dundas side of this divide is less than seven miles, with an average altitude of less than 480 feet (the same as that of the Fairchild's creek as it crosses the Great Western Railway). The highest point that I have leveled is 492 feet above Lake Ontario. On receding westward from the divide, the country gradually descends to the Fairchild's creek, which, as it crosses the Brantford and Harrisburg Railway, is 407 above the lake. It is considerably lower where it enters the Grand river. The region between the divide and the Grand river is traversed from north-west to south-east by a considerable number of streams, all with relatively large valleys, cut in the drift, since the present system of drainage was inaugurated in Post Glacial times.

The country from Jerseyville (about 465 feet above lake) slopes gradually to the Grand river, from six to eight miles distant to the southward.

On examination, it may be seen that the country is too high to permit the Fairchild's creek or Grand river, as they are at present situated, to flow over the height of land into the upper portion of the Dundas valley. As referred to before, the Niagara limestone forming the summit of the escarpment at Ancaster and eastward has a height of about 500 feet. These beds dip at only about 25 feet in a mile (to about 20 degrees west of south) and are not generally covered by a great thickness of drift, but in many places are exposed on or near the surface. Westward of Ancaster these limestones are nowhere to be found, but the country is only covered with drift. At a short distance west of this village, we find streams flowing north-easterly and easterly with very deep valleys in the drift, indicating the absence of the floor of limestone to a depth of over 250 feet below the surface of the escarpment. But on going westward we find that the streams have not cut to an equal depth, but still running deeply through drift. Eventually we reach the divide, after which we find that other systems of streams also cut deeply in the drift running in a south-easterly direction to join the Grand river; but the Niagara limestone is absent from a considerable extent of country.

On the northern side of the Dundas valley the escarpment after reaching Copetown is buried by the drift. Although the line of buried cliffs recedes somewhat to the northward of the Great Western Railway, yet there are occasional exposures, as at Troy and other places in Beverly and Flamboro, where the underlying limestones come to the surface. At

Harrisburg the limestones are known to be absent for a depth of more than 72 feet, as shown in a deep well in the drift.

In the town of Paris one well came upon hard rock at 10 feet below the surface, whilst another at 100 feet in depth, reached no further than boulder clay. This last well must have been in a buried channel of Neith's creek, as outcrops of gypsum-bearing beds of the Onondaga Formation frequently occur near the summit of the hills. From what has just been written, it is easily seen that the Niagara limestones are absent from a more or less horizontal floor (which is over 500 feet above the lake, on both the northern and southern sides of the Dundas valley) which continues from Dundas westward to near Harrisburg, where it meets a portion of the Grand River valley. But almost immediately west of Ancaster we find streams running northward at right angles to the escarpment, and cutting through drift to the depth of almost hundreds of feet. In fact, if we draw a line from Dundas to northward of Harrisburg (a mile or two), and another from Ancaster southward to the Grand river, we have two limits of a region where the limestone floor has been cut away from an otherwise generally level region. The southern side of this area is the southern margin of the Grand River valley, between Seneca and Brantford, and the western boundary is composed of Onondaga rocks east of Paris (which perhaps forms an island of rocks buried more or less in drift).

Additional proofs may be cited. About a mile south of Copetown a well was sunk to the depth of 100 feet before water was obtained. At two miles south east of the same village there is small pond only 240 feet above Lake Ontario, or more than 260 feet below the neighboring escarpment. This is in drift. Again, at a mile north of Jerseyville, the country has a height of 465 feet, with a well in the surface soil to a depth of 40 feet. A small rivulet flows in a valley a few hundred yards south of the last named well which has a bed 435 feet above the lake. At about a mile west of Jerseyville, the altitude is 468 feet with a well 52 feet deep. Again, at about two miles west of the same village, near the county line, the altitude is 460 feet, with a well 57 feet deep (the bottom being lower than the Fairchild's creek more than three miles to the westward). About a mile north of the last named station is a ravine 436 feet with the adjacent hills forty feet higher, and rising in a mile or two to about 500 feet. All these wells are in the drift. From exposures near Ancaster, it appears that the unstratified drift has not an altitude of much more than 400 feet. And as we know that some of these superficial beds are stratified clay, and over most of the country just described not a boulder is to be seen, neither on the surface nor in the material taken from the greater portions of the wells, it is probable that the water is only obtained on reaching the more porous boulder clay below. It has also been noticed that two wells, at least, are 100 feet deep before reaching water, therefore we may fairly place this as about the inferior limit of stratified superficial clays. By reference to the accompanying map, it will be seen that westward of the meridian of Ancaster there is an area of over 100 square miles, where the Niagara floor is known to be removed everywhere to a depth of 100 feet, and in its eastern portion to more than 260 feet, and still nearer Lake Ontario to a measured depth of more than 200 feet below its waters.

III. Topography and Hydrography of Lakes Superior, Michigan, Huron and St. Clair.

As the origin of all our great lakes is so closely related, it will not be out of place to describe briefly some of the features of the upper lakes that appear most striking. In the present paper it is only intended to call attention to some of the existing physical features of these great basins of water that appear to show a relation which existed in a more or less common origin of all our lakes. Though I have frequently visited many localities on these lakes, for this portion of the present paper I am particularly indebted to General Comstock, Superintendent of the U. S. Lake Survey, who kindly furnished me with the lake charts.

Lake Superior. This lake may be described as a large basin with a level or gently undulating bottom and steep margins. The mean depth may be placed at 800 feet below its present surface. Very few soundings exceed 900 feet. Of these, one near the centre of the basin is 954 feet, and another, not far from Duluth, is 1026 feet—the maximum depth of the lake, as shown by the hydrography.

The depth of the lake at three or four miles from the shore is generally as great as in its centre; in fact, it is often deeper near the shore on its north-western side. However, about the Apostle islands, between the Pictured rocks and St. Mary's river, and in some of the bays, the waters are shallower than in the open lake, with their floors more or less gradually sloping as they recede from the land. As is well known, the lake is generally surrounded by crystalline or metamorphic rocks, which rise from several hundred to even twelve or thirteen hundred feet above its surface. In short, the near shore hydrography simply shows that the present submerged margins of the lake are composed of the bases of the same rugged hills that surround it above the water. The margin of this mountain-bound basin forms a strong contrast with its floor, which, at most, is only a slightly undulating plane, extending for nearly its whole length and often for little less than its breadth, excepting in its south-eastern portion and some other places referred to above. In fact, the lake bottom is quite as level as most extensive planes which are now subjected to sub-aërial action.

That this great plane is not covered with any great depth of drift-deposit (excepting locally) appears evident on examining the character of the bottom of the lake in the soundings just off Keweenaw point, and those to the northward. In the various localities hard and rocky bottoms are alike found in both places, at the same depths, so frequently that they cannot be regarded as only rocky eminences protruding through the silt covered bottom which is generally observed.

The general direction of the deepest channel, for more than 200 miles along the north-western margin of the lake, appears to point to a river course in the region of its south-western extremity, and the few deeper holes to have been produced by some receding cascade from the adjacent shore to which there appears to be a transverse deep channel south of the mouth of Gooseberry river.

Again, Prof. N. H. Winchell calls attention to the depression in the low country between the Chocolate river (east of Marquette), and Train bay (near the Pictured rocks), as the only place where there could have been connection between the basins of Lakes Superior and Michigan. It may be remarked that some of the deeper soundings put in towards this portion of the coast, whilst, to the westward and eastward, the present lake bottom slopes more gradually. The soundings, however, that are near the shore, show a rocky bottom, excepting north of Laughing Fish point (Sable river), and along a narrow channel north of the mouth of Chocolate river. The lake is very shallow for some distance westward of the St. Mary's river.

Lake Michigan. This lake may be said to consist of a broad long plane, the northern half having a mean depth of about 600 feet, whilst the soundings in the southern half are not much more than half that measurement. The deepest sounding recorded is 870 feet, in the latitude of the southern end of Green bay. Throughout the whole length, the lake appears to be traversed by a deep channel, and in the northern end by more than one. Although the pitch of the bottom from the shore line is more or less gradual—generally less than 40 feet in a mile—yet, along the eastern side there is a precipitous escarpment extending for a considerable distance, which in one place suddenly descends, in a horizontal line of little over a mile, from 17 to 93 fathoms, or 456 feet, and increases 60 feet more in the distance of another mile.

The conspicuous channels in the submerged plane extend far northward to near the end of the lake. An interesting sounding east of the mouth of the Manistique river shows a depth of 448 feet, at a distance of two miles from the shore, whilst all the adjacent depths do not exceed 11 fathoms. This appears to be a continuation of the deep soundings, ten miles to the southward, but the surrounding lake bottom is covered with drift to a great depth, wherever the Niagara limestones have been removed. It is more than probable that this great depth is in a rock-bound channel of an ancient water course, which elsewhere has been filled with drift. It seems probable that it was a portion of a buried channel extending through the valley of the Manistique lakes to the depression in the country south of Lake Superior, alluded to above, and formed a Preglacial connection between the valleys of Lakes Superior and Michigan. Prof. Winchell regards the valley between the two lakes along the Chocolate and White Fish rivers (the latter emptying into Little Baie De Noc), as indicating the ancient connection. This route seems less favorable, as both Little Baie de Noc and Green bay are shallow compared with Lake Michigan, for the greatest depth, which is near an outlet through Portes des Mortes, is only 32 fathoms, whilst generally the bay does not exceed 100 feet.

Green bay is separated from Lake Michigan by a Niagara escarpment facing the westward, and rising two or three hundred feet above the waters. There appears not to have been any closer connections between these two basins at any previous time than at present, excepting when the waters were at a higher level. We are told that from Green bay for 400 miles to the Mississippi river, a broad, low depression occurs in the country and may have been a former outlet for Lake Superior. This valley is filled with drift even if it ever had a sufficient depth.*

Grand Traverse bay has a considerable depth in both of its branches, especially in the eastern. Here we find depths to 612 feet, whilst its northern mouth is now filled, so that it does not exceed 120 feet.

The north eastern portion of the basin of Lake Michigan has a general depth of less than 100 feet, but with deeper channels running through it. Many of the soundings about the Straits of Mackinac show a rocky bottom at no great depths. The channel between the 10-fathom contour margins is not much more than a mile and a half wide, and though generally shallower, contains a hole 252 feet deep. In proceeding outward, the deepest channel passes northward of Mackinac island, having a depth not exceeding 216 feet, and a width of less than a mile.

Again, a depression of the country extends from near Chicago, on Lake Michigan, towards the Mississippi river, which, in some places, is known to be filled with drift to a depth of more than 200 feet, according to Dr. Newberry. This is along the Illinois river, whose valley is from two to ten miles wide ; whose mouth is 200 feet lower than Lake Michigan ; and whose upper streams, near Chicago, are only a few feet higher than the neighboring lake.

Lakes Huron and St. Clair. Of these water basins we can make four divisions. The first section may be made to include the shallow basin south of a line drawn from Thunder bay, or Presqu' Ile, to Kincardine, in Canada, and Lake St. Clair. The second basin comprises the deep channels of Lake Huron, and extends northward to the Manitoulin islands and the Indian peninsula ; the third, the north channel between the Manitoulin islands and the Huronian hills, to the northward ; the fourth, Georgian bay proper.

The first of these divisions is represented by shallow water, seldom thirty-

* Since writing the above, I have fortunately been able to see General Warren's Report on the Transportation Route from the Mississippi river to Green bay (*via* the Wisconsin and Fox rivers). In this report we find that the bottom of the valley alluded to in the text has a maximum height of 208.8 feet above Green bay, and also that Lake Winnebago (on Fox river) is 169 feet above the same water. This small lake discharges by the Fox river, which flows over hard limestones down a series of rapids. Therefore Green bay never discharged its waters into the Mississippi river, and this depression in the country between the Great river and Lake Michigan (the Green bay portion) was not a former outlet of Lake Superior, since it was within about 200 feet of the present level. This fact strengthens the probable correctness of the suggestion that Lake Superior emptied into the northern end of Lake Michigan directly. Also, Green bay has evidently the character of a fiord. The outlet of Lake Michigan could only have been by the low country along the Illinois river.

five fathoms deep, but with a channel of about fifty fathoms depth running through it, towards the direction of the north angle of the Au Sable river, near Brewster's mills. Saginaw bay, belonging to this section, is like Green bay, shallow even at its mouth, where it is less than 100 feet deep.

Lake St. Clair is a flat plane, with its bed varying from 18 to 21 feet below its surface, and is altogether modern.

At Detroit the drift is 130 feet deep. The three south-western counties of Ontario are low and flat, and covered with drift varying generally from 50 to 100 feet in thickness below the level of Lake Erie. In places it is known to be absent to a depth of 200 feet below the same lake in portions of a buried channel to be noticed below. In fact, all the evidence appears to show that the southern end of Lake Huron and the western end of Lake Erie, with the intervening region, constituted one plane underlaid by a considerable depth of Erian shales, reposing on the thick development of Coniferous limestone, and traversed by deep channels running through it.

The section of Lake Huron under consideration is mostly excavated out of Upper Erian shales in a direction at right angles to the trend of the formations. The denuding action was lessened when the waters in the deeper northern part of the lake subsided to a level having a southern margin bounded by hard Coniferous limestone, covered to no very great depth with Upper Erian shales subjected to only sub-aërial action—the whole traversed with water courses in deep channels.

The second division into which, for convenience, I have made of Lake Huron, is that portion between the line drawn from Presqu' Ile to Kincardine, and the Manitoulin islands to the northward. This is the deepest portion of the lake and extends in a direction running from north-west to south-east. It consists of a broad plane traversed by several deep channels. The average depth of this plane below the surface of the lake does not exceed 75 fathoms, although there are channels much deeper, one of which is represented by a depth of 117 fathoms. There is also one isolated sounding, which reaches 125 fathoms or 750 feet, this being the deepest spot known.

The deeper channels appear to lead from the northern portions of the lake, and unite as they proceed southward, being separated by elevations indicating peninsulas or islands. Two of the principal channels appear to proceed from Mississagua strait (between Manitoulin and Cockburn islands), and from south of Manitoulin island, eastward of the Duck islands. However, the channels in the marginal portions of the lake are generally more obscured by drift or silt than towards the central waters. The channel, if such you can call it, proceeding from the Mackinaw straits is of inferior depth to those leading from the more northern end of the lake.

This portion of the lake is excavated out of the rocks of the various formations from the Niagara to the Coniferous limestones. But most largely out of the more or less soft rocks of the Onondaga group, along the strike of these formations, thus giving the eroding agencies the power of removing the softer basal rocks, and of producing an escarpment of the Coniferous limestone looking to the northward, until it was finally undermined, and worn back to its present position, submerged beneath the shallower waters of the southern portion of the lake, or buried in drift deposits.

On the northern side, the lake has not made so much encroachment, as it is bounded by the hard Niagara limestones of the Manitoulin islands, and the Indian peninsula of Canada, the strata dipping down beneath the lake. Yet it must be noticed that these rocky shores are indented by numerous deep bays transverse to their directions.

The North Channel. This is generally a shallow water, the greatest depth being only 204 feet. To the northward, we have the Huronian rocks forming the boundary. The islands, especially towards the eastward, and near the whole north shore, are generally composed of Trenton limestone. The southern margin of the channel, bounded by Manitoulin and the other islands, is often composed of Hudson river, more or less, shaly rocks, overlaid by the Niagara limestones (where not removed by denudation), constituting an escarpment facing the northward. In fact, the whole of the north channel is principally scooped out of the Hudson River Formation, which attains a considerable thickness in this region.

Dr. Robert Bell states that he has observed fifteen anticlinal folds traversing the group of the Manitoulin islands; and it is in these that we find the great indentations, and lakes in the islands, as well as the straits which separate them. Doubtless many of the southern ends of the Manitoulin lakes and channels are filled with drift. For example, the mouth of South bay is only 33 feet deep, whilst the upper portion is generally deep, one place giving a sounding of 156 feet.

In fact, the north channel may be considered as a broad continuation of the Spanish river westward. The Mississagua river points directly to Mississagua straits, which are 204 feet deep, as deep as any part of the channel itself. Thessalon river has a direction towards False Bay De Tour, which is 186 feet deep. Vermilion river flows amongst the islands west of Cloche mountains and probably had a connection to Lake Huron through some of the buried channels across Manitoulin islands, as between Manitouaning and South bays.

The narrow channel between the peninsula of Cloche mountains and Manitoulin island is less than 60 feet deep and appears to be a modern connection with Georgian bay.

Georgian Bay. The eastern and northern margins of this bay are composed of crystalline rocks; the south-eastern, of Trenton limestone; whilst the western is made up of the Hudson River shales capped with the Niagara limestone, on the Indian peninsula and Manitoulin island. This basin is principally excavated out of the Utica shale, and the somewhat harder rocks of the Hudson River Formation. It lies along the junction of the various formations, and thus on the removal of the lower soft layers of rock, an escarpment was produced which has subsequently and slowly continued to be undermined.

In the channels connecting this bay with Lake Huron, there are many small islands separated by shallow water. Yet in one place there are two deep soundings reaching 51 and 42 fathoms. The bay itself is much deeper than these passages, for there is an escarpment submerged to a depth of 498 feet immediately off the Indian peninsula, at Cabot's Head, which is itself 324 feet above the bay. This peninsula is deeply indented with bays or fiords.

There is a depression from the southern end of the bay, through the valley occupied by Simcoe, Balsom, Rice and other lakes, to the Trent river, emptying into the Bay of Quinté, an arm of Lake Ontario. This will be alluded to again.

IV. The Buried River Channel in the Dundas Valley and its Extensions.

That the Dundas valley is that of an ancient river valley now buried to a great depth with the *débris* produced in the Ice Age, becomes apparent on a careful study of the region. However, until a key was discovered the mystery of its origin was found to be very obscure. My own labors at studying this region may fairly be stated as the first systematic attempts at the solution of the present configuration of the western end of Lake Ontario and the adjacent valley. Assertions have been made that it was scooped out by a glacier, but this wild hypothesis was only a statement made without any regard to facts.

From the description of the topography, given in Section II, of this paper, it will be seen that the apparent length of the rock-bound valley is six miles, with a width of over two miles; then it widens suddenly to four miles (with concave curves on both sides), after which it gradually increases in width as it opens into Lake Ontario. The direction of the axis of the valley is about N. 70° E. The summit edges of the rock-walls on both sides are sharply angular and not rounded or truncated. This angularity is not due to frost action since the Ice Age, to any extent, as is shown by the character of the talus. The rocks of the summit are frequently covered with ice markings, but I am not aware of any locality where they have been observed as being parallel with the true direction of the valley, but on all sides one can observe them (sometimes at only small angles of less than 30 degrees) making conspicuous angles with its axis. One exception may be made to this statement. On a projecting ledge of Clinton limestone, at Russel's quarry, near Hamilton, at a height of 254 feet above the lake, and 134 feet below the summit of the "mountain," after the removal of some talus, I observed that the surface was polished, but with scratches so faint that they could scarcely be compared with those of fine sandpaper on wood; and the direction, if determinable, was parallel with the overhanging escarpment. There are many tributary *cañons*, which are evidently of greater antiquity than the Ice Age, which could not have excavated by the present streams, and are at all sorts of directions compared with the striated surface of the country.

The topography of the lower lake regions precludes the idea of a glacier flowing down the valley to the north-eastward. Again, as the direction of the ice was towards the south-west, the waters from the melting glaciers could scarcely flow up an escarpment many hundreds of feet in height. Even if the Niagara escarpment did not exist elsewhere, the non-parallelism of the striæ, and edges of the escarpment with their angular summits, is sufficient to prove the non-glacial origin of the valley in the hard limestone rocks. Moreover, at the eastern end of the narrower portion of the valley, there are two concave curves facing the lake, which of necessity would have been removed if such a gigantic grinding agent had been moving up the valley.

This glacier-origin of the valley being an absolutely untenable hypothesis, I sought for some fluviatile agent capable of effecting the present configuration of the region. At the time, no idea occurred that even the great valley of the present is only a miserable remnant of one of gigantic proportions obscured by hundreds of feet of drift. The question arose, could Lake Erie have ever emptied by this valley? This suggestion did not hold its ground for any length of time, because the present levels are all too high. Near Galt, the traces of the true origin first presented themselves. A branch of the Great Western Railway extends from Galt southward for about four miles in the valley of the Grand river, after which, without making any important ascent, it passes into the broad older valley, described above as that in which Fairchild's creek now flows. After a careful examination of the region, and of the railway levels, I came to the conclusion that this was an old buried valley. It then became apparent that if the Grand river had occupied the site of the Fairchild's creek, that the latter probably flowed down the Dundas valley, and that the Grand river, being one of the largest of the rivers of Ontario, might have been a sufficient cause for the great excavation at the western end of Lake Ontario. Having procured all the levels that bore on the subject which were available, it became necessary to connect several places myself by instrumental measurements, which work was accomplished last July, with the aid of Prof. Wilkins. As the whole floor of Niagara limestones is absent, as has previously been shown, the proof that the ancient Grand river flowed down the Dundas valley was completed, and of this discovery there was published a local notice last August. Significant and interesting as this fact was, relative to the change of systems in our Canadian drainage, a still more important issue was involved. When taking the levels between the Dundas valley (modern) and the Grand river, it was found that the whole calcareous floor was removed from a basin several miles in width, and that all the wells were sunk to a considerable depth in the drift before water could be obtained. On glancing at the map it will be seen that the Grand river from Brantford to Seneca meanders through a broad course, which in its ancient basin is several miles in width, but that from Seneca the valley is narrower, and the course of the stream more direct, as far as Cayuga. At Seneca the valley is two miles wide, and seventy-five feet deep. Also the bed of the Grand river at Seneca is in drift which is only 37 feet above the lake into which it now empties. As has been pointed out in the section on the topography, this broad valley continues to Cayuga within a few miles of the lake, whence its former probable course was by a nearly direct line to Lake Erie, now filled with drift, near the present bend in the river towards the eastward. At Cayuga, the rock beneath the drift-bed of the river is below the lake level, on the margin of its ancient valley. (See note, Section II.)

Having observed the connection between the Dundas valley, Grand river and Lake Erie, it dawned on me that I had established the knowledge of a channel having a very important bearing on the surface geology of the lake region. It now became apparent that Lake Erie had flowed by the Grand river reversed to a point west or north-west of Seneca, and thence by the Dundas valley into Lake Ontario; also that the upper waters of the Grand river, previously discovered as passing down the Dundas valley, were really tributary to the outlet of Lake Erie, and joined it somewhere south of Harrisburg; and that the basin between the Brantford (and the Grand river of to-day) and the Great Western Railway, at Copetown, formed an expanded lakelet along the course of the ancient outlet of Lake Erie, scooped out of the softer rocks of the Onondaga Formation before noticed. As the waters excavated a bed in a deeper channel, of course this lakelet would become an expanded and depressed valley, such as we often see amongst the hills of drift, at a short distance westward of Dundas. Possibly the Grand river divided and flowed around an island, the western side of which is occupied now by the town of Paris. At any rate, Neith's creek, at that town formed a large tributary to the river then flowing down to Lake Ontario.

Along the course from Cayuga to Lake Ontario all obstacles to the outlet of Lake Erie appear to be removed. But along the present course of the Grand river, eastward of Cayuga, the waters flow over Coniferous limestone. But this difficulty is removed on observing that the river, filled with drift, approaches Lake Erie to within a direct distance of about six miles, but that at this place it leaves its southward course and also its conspicuous valley and flows eastward, in the same manner as the Niagara river, above the Whirlpool, left its old choked-up outlet by the valley of St. David, and cleaned out a new channel for itself through several miles, in hard rock, from Queenston southward.

We have recently seen by a note in the second section of this paper, that the Grand River bed is near the eastern margin of its ancient valley at Cayuga. From northward of this town, at about half a mile to the westward of the river, a deep depression in the drift indicates the deeper portion of the ancient river as it left the modern channel direct for the Lake Erie basin. Also along this route the hard rock is known to be absent to a depth below the surface of Lake Erie.

In Ohio, the Geological Survey considers that Maumee river emptied into the Wabash. If the waters of Lake Erie ever passed by this route into the Mississippi river when they were at no higher level than at present, then there must be a channel buried to a depth reaching at least 170 feet above the lake, as that is the elevation of the divide between the upper waters of these two rivers.

The outlet of Lake Erie, indicated in this paper, is known at many places along its route to have no rock-bed for a distance below the surface of the higher lake, and to a probable depth shown below sufficiently great to empty Lake Huron.

Again, Mr. Carll has shown that the Allegheny drainage passed near Dunkirk into the Erie basin at a place just opposite to its outlet, as indicated by the present writer.

Much of the Dundas valley is underlaid by stratified Erie clay, which is known to extend to a depth of 60 feet below the surface of Lake Ontario, according to Dr. Robert Bell. In the upper part of the valley, streams have exposed some deposits of unstratified clay filled with angular shingle,

Fig. 2.

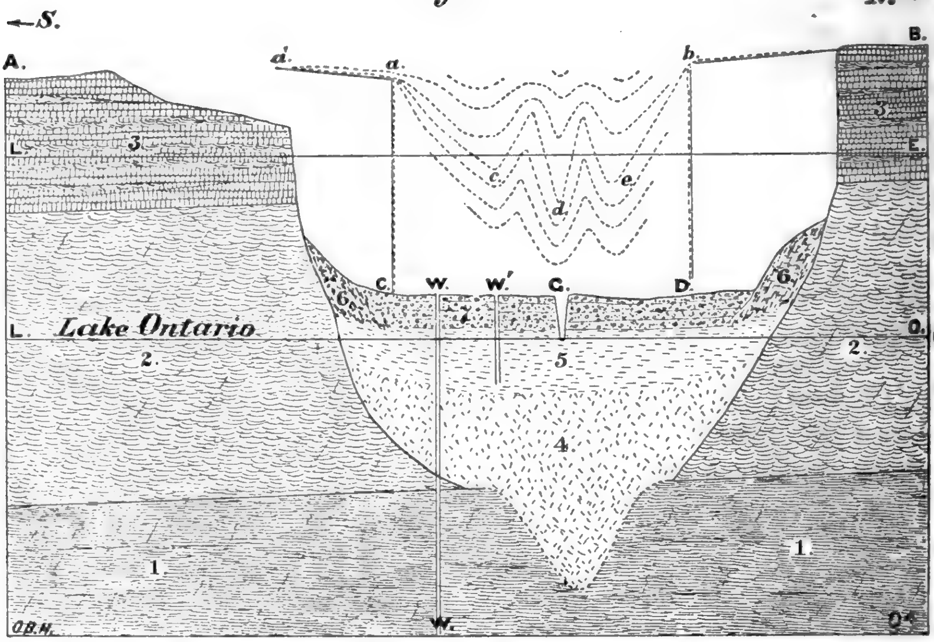


FIG. 2.—1. Hudson River Formation; 2. Medina shales; 3. Niagara and Clinton dolomites with some shales. A, C, D, B, modern valley at meridian of Burlington Heights; a, C, D, b, modern valley at meridian of Dundas; a, c, d, e, b, sections across, deeply excavated in beds of streams in western part of the Dundas valley; 4. Boulder clay filling ancient valley; 5. Erie clay; 6. Talus from sides of escarpment; 7. Old beach, 108 feet above lake at Burlington Heights. G. Desjardin's canal leading from Dundas marsh to Burlington bay; W, W, well at Royal Hotel, Hamilton; W′, another well at Dundas; L, O, level of Lake Ontario; L, E, level of Lake Erie. Horizontal scale, 2 miles to an inch; vertical scale, 400 feet to an inch.

derived from the thin beds of limestone forming the upper portion of the Niagara Formation. In the eastern portion of the valley, the Erie clay is overlaid unconformably by brown Saugeen clay or loam (stratified). In the upper portions of the valley the hills are capped by brown clays or sands. But along some of the hillsides excavated so deeply in the drift, we find old beaches resting unconformably on boulder clay.

Near the centre of the city of Hamilton, in the wider portion of the Dundas valley, a well was sunk to the depth of over 1000 feet. This well revealed a most interesting fact. Though known to me several years ago, I did not apply it until recently to its true bearing, since discovering the origin of the Dundas valley. Mr. J. M. Williams sunk this well, at the Royal Hotel, in Hamilton. He told me several years ago that he had to sink through 290 feet of boulders, before coming to hard rock, thus causing the outlay of a large sum of money in excess of his calculations. Unfortunately, this well-record has been lost by fire. At that time, the fact was so fresh in his memory (improved by the extraordinary cost of the well) that his statement could be relied on, being experienced in well-borings. The mouth of this well is 63 feet above Lake Ontario, and therefore the hard rocks are absent for a depth of 227 feet below the lake surface. See section, Fig. 2.

As the valley is five miles wide at this place, and as the well is only about one mile distant from its southern side, it becomes apparent that the valley in the centre must have been much deeper. Moreover, if we produce the southern side of that portion of the valley, which is over two miles wide, we find that the well is less than a quarter of a mile away from it. Now if we connect the top of the Medina shales (240 feet above Lake Ontario) with the base of the drift in the well, and produce it to the centre of the valley, it would indicate a central depth of over 500 feet. At the base of the drift there are nearly fifty feet of Medina shales, below which are the Hudson River rocks (more or less calcareous and arenaceous, mixed with the shales). This harder formation along the bed of a river would be less extensively removed by aqueous action than the overlying Medina shales, especially as the pitch of the waters would be much lessened. This graphic method of calculation seems as perfectly admissible here as it does in determining other constants of nature. However, I have placed the estimated depth in the section at about 70 fathoms below the lake surface, which depth is perfectly compatible with the soundings of the lake of no very great distance to the eastward. Even this depth gives only very gentle slopes from the sides of the river valley. It should be remarked that Burlington bay is excavated from stratified clays in places to a depth of 78 feet. But this water is silting up comparatively quickly.

Now we have seen that the deep excavation in the Dundas valley and westward is cut through more than 250 feet of Niagara and Clinton rocks, mostly of limestone, and to a depth in the Medina shales, so that the total known depth of the *cañon* is 743 feet, but with a calculated depth in the middle of the channel of about 1000 feet. This depth for a *cañon* is not extraordinary for Eastern America. In Tennessee there are river valleys excavated to a depth of 1600 feet, and in Pennsylvania Mr. Carll reports others to be equally deep.

Again, this Preglacial river explains the cause of the present topography of the western end of Lake Ontario. The drainage by this river swept past the foot of the submerged escarpment of Lake Ontario, described in preceding pages, until it passed the meridian of Oswego.

With such an outlet, and with the ancient Grand river valley buried to an equal depth, we have an easy solution to the problem of the drainage of Lake Erie. See section, Fig. 3.

Fig. 3.

Section of Grand River Valley at Seneca.

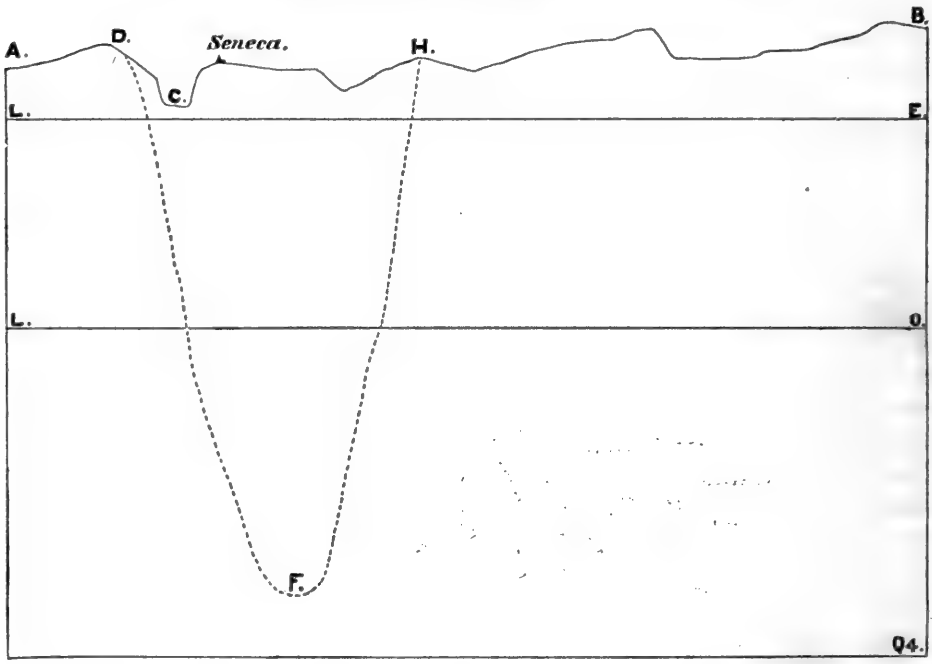


Fig. 3.—Section of Grand River valley at Seneca. A, D, C, H, B, is the profile of the H. & N. W. Railway; horizontal distance, 2 miles to an inch; vertical, 400 feet to an inch. C, represents position of Grand river; D, C, H, valley two miles wide and with maximum depth of 75 feet. L, E, level of Lake Erie; L, O, level of Lake Ontario; D, F, H, probable depth of buried valley.

Attention has been called in this paper to the deepest portion of Lake Erie being southward of Haldimand county, and about the end of Long point, and extending transversely towards the Pennsylvania shore.

So far, our remarks have applied to Canada. If we turn towards the American shore, we will see that the observations made there go very strongly in support of what has been written.

Several years since Dr. Newberry, Mr. Gilbert, and others, called attention to the deeply buried valleys of the Cuyahoga, Chagrin, Grand, Maumee and other rivers in Ohio, which emptied into Lake Erie much below their present levels. The Cuyahoga has its channel buried to a depth of 228 feet below the surface of Lake Erie of our time, whilst the deepest water in the neighboring portion of the lake is less than a hundred feet.

In Report III, of the Pennsylvania Geological Survey, issued in November, 1880, Mr. John F. Carll published excellent maps of the Preglacial drainage of that State and the neighboring portions of the adjoining States. This report on the Preglacial rivers is the result of five years' labors in the oil regions, and many of Mr. Carll's results have been derived from the facts made known by the borings for mineral oil.

Besides calling attention to the very deep valleys of erosion amongst the mountains, Mr. Carll has shown that in the oil regions the river valleys are frequently filled with drift to a depth of from 200 to 450 feet. In fact, nearly all the present rivers flow over beds deeply filled with drift. The map of the Preglacial drainage shows that the upper waters of the Allegheny emptied by the Cassadaga river, reversed, into Lake Erie, near Dunkirk, and had for tributaries many other streams now flowing southward; for example, the Conewango. These streams drained an area of 4000 miles, which now sends its surplus waters to the Ohio river. Again, the French and other rivers, now emptying southward from the Conneaut basin, emptied in Preglacial times into Lake Erie, westward of Erie city. Again, the Chenango, Connoquenessing, Mahoning and other tributaries of the Beaver river (itself now emptying into the Ohio) flowed northward, by the Mahoning river reversed, into the State of Ohio, to near the sources of the Grand and Cuyahoga rivers. Hence Mr. Carll did not continue its course, on the map, but from the study of the levels and character of the country, as described by the Geological Survey of Ohio, I have connected it with the Grand river of Ohio, as represented on my map. Thus we find three large areas now flowing southward formerly emptying into the Lake Erie basin.

The deepest portion of Lake Erie is between these ancient river mouths and the ancient *débouchement* of the Erie drainage by the Grand river of Ontario, as described in these pages.

Thus we have shown a consecutive system of drainage of the former waters of the buried channels into Lake Ontario, and thence running along the foot of the submerged escarpment of the latter lake to its eastern end, receiving the Genesee and other large rivers along its course. In a portion of the present notes, the writer will endeavor to make known still further the buried channels of Ontario, which exist between Lakes Huron and Erie when treating of the origin of these lakes.

The remaining portion of this paper will be devoted to the subject of the origin of our great lakes. The writer does not wish to enter here into the discussion of the drift deposits, and their origin at the present time, but to reserve it until the final report on the surface geology of the Western End of Lake Ontario. Yet the facts brought to light in this study have an important bearing on the great controversy of the Glacial Drift, and lead one to the conclusion that the Ultra-Glacial theorists stand on uncertain grounds.

V. Origin of our Lower Great Lakes.

On a former page of this paper attention has been called to Prof. Winchell's observations of an outlet from Lake Superior by way of Little Baie de Noc, and also my theoretical divergence slightly from this view. That an outlet did exist somewhere in the region between Lakes Superior and Michigan, seems certain, of course, we do not know to what depth, but from the evidence brought forward from the soundings in the northern end of Michigan lake to at least half the depth of our greatest lake, and probably to the whole depth.

There appears also to have been an outlet from Lake Michigan, near Chicago, emptying into the Mississippi river. These two lakes both lie outside of the study of the present paper, but before passing to the other lakes, let us note certain facts which present themselves to the view of the writer. Without taking up the bibliography of the subject, it may be stated that some have regarded the origin of the lakes as being due, to a greater or less extent, to the geological valley, formed at an earlier date. Of our five great lakes, certainly not more than one can possibly come into this category—that is Lake Superior. Not even the northern side of the north channel of Lake Huron, bordered by crystalline rocks, could be included. The writer even doubts that Lake Superior is essentially anything more than a valley of erosion, and if it be, it remains to be proven. Yet its position was probably determined to a greater or less extent by the orography of the region, and its excavation appears to have been principally by erosion. Although the lake is in the region of very ancient continental oscillations, there are no evidences of different elevations, and subsidences in different portions of the lake basins. Five years ago, I pointed out that Superior was eminently a region liable to atmospheric erosion, as the grèat volcanic seat situated about the Keeweenaw Point, in Presilurian times, would tend to weaken the strata. All who have made a study of the three miles in thickness of the copper-bearing rocks, pitched at various angles, whether on the northern or southern shores, and crossed by numerous faults, know that they are particularly liable to irregular atmospheric decay. As an example, we have remaining an excellent case in that in which Portage lake lies, now a valley transversely situated in the Keeweenaw hills, and excavated to a depth of six or eight hundred feet. In the narrow channel between Houghton and Hancock the waters are 60 feet deep and underlaid by a considerable depth of silt.

According to both Professors Dana and Whitney's explanation, fiords are valleys of erosion, when the land was at a higher level; but as a necessary condition, high hills or mountains should be near a shore, so as to give pitch to the descending waters; from this definition we can fairly consider most of the bays of Lake Superior, Lake Huron, and those about the Niagara escarpment in the region of the Green bay extension of Lake Michigan, as belonging to this category.

Lake Michigan is nearly deep enough to remove all the waters of Lake Superior. Such deep places as the 171-fathom hole north-east of Duluth could easily be produced by a cataract, the same as the water in the Niagara river is so much deeper than its rock-bound outlet into Lake Ontario. Moreover, the peculiar form of the south-western extension of Lake Superior can only be explained as having in part been produced by water, running in one direction or the other, as the St. Louis river now empties, at Duluth.

That the other lakes are not occasioned by a geological depression or elevation can be easily seen, as they are exclusively excavated from stratified rocks lying almost flat, perhaps dipping in no place at higher angles than 40 feet in a mile.

The North channel and Georgian bay of Lake Huron belong to a separate category from the rest of the lakes. I do not deny, as far as Lake Ontario and the north-eastern half of Lake Huron are concerned—both of which are excavated at the junction of hard and soft strata and parallel with their trend—that they might have had the direction of their first rivers determined by continental elevation. Yet, in no other respect are these lakes now occupying geological valleys.

Dr. Newberry is of the opinion that the valley of Lake Michigan was separated from that of Huron at the Straits of Mackinac, even at a comparatively recent period. I concur with this view entirely. Lake Michigan is 22 fathoms deeper than Lake Huron, and therefore could in no natural way have ever been entirely drained by the latter lake. There is no evidence of local subsidence, and the glacier theory is absolutely untenable, as will be seen further on. In the Beach Epoch of the Ice Age this separation seems to have existed, as it is stated that the highest beach north of Lake Michigan is 65 feet, whilst that on the island of Mackinac is more than 250 feet above these waters. We know that there are several correspondingly high beaches along the margins of the basin, including the three great lower lakes.

Thus we can cut off the two western waters of the great chain of American lakes from our subject and leave them for future inquiry.

Whether the above named outlets of Superior and Michigan are sufficiently deep to have drained their basins, at the time when we know that the Mississippi valley was several hundred feet higher than at present, remains to be shown.

The writer will now deal with those waters to the eastward, and see what difficulties have been removed and what still remain, for Lake Ontario is nearly a hundred feet deeper than the deepest sounding of any of our upper lakes.

Dr. Newberry prophesied that an outlet for Lake Erie into Lake Ontario would be discovered near the Welland canal. This outlet in an unexpected position I have discovered, and in a position which explains more perfectly the cause of the topography of Lake Ontario than any that could have been discovered forty miles to the eastward. Moreover, I have shown that its depth is not only sufficient to empty Dr. Newberry's deep Cuyahoga (228 feet below Lake Erie), or the ancient rivers, worked out by Mr. Carll (the most systematic study of fluviatile geology that has been done on this continent), but also sufficiently deep to empty the deepest waters of Lake Huron into Lake Ontario.

When was the advent of such a drainage system for this continent? Some of our American friends, who have advocated the sub-ærial and fluviatile origin of the lakes, have placed it back to the Devonian Age. About the commencement, we know nothing. It would be safer to place it after the Palæozoic time, for probably some portions of the Province of Ontario were covered with carboniferous deposits, as well as Michigan and Ohio, which have subsequently been removed by denudation.

Outlet of Lake Huron. The south-western countries of Ontario are dotted with borings for oil. From these well-records, one can draw only a single conclusion, that they are underlaid by drift (mostly stratified and perhaps wholly) to a depth of not more than 100 feet below the surface of Lake Erie, and that generally to not more than 50 feet. There are deeper borings in drift, it is true, but these may be fairly considered as in buried channels. For instance, at Detroit the drift is 130 feet deep. Again, at Port Stanley, it is 150 feet below the surface of the lake; at Vienna it is 200 feet below Lake Erie. If we draw a line from near the northern angle of the Au Sable river (of the south) to east of Vienna, we have a boundary to the deeply drift filled basin of south-western Ontario; for at Tilsonburg, St. Mary's and elsewhere (just east of this line) the hard limestones come to near the surface of the country much above the level of Lake Erie. Excepting a few shales, at Kettle Point, all the south-eastern shores of this lake are composed of sand dunes and other Post-Tertiary deposits. The upper portion of the Thames and Au Sable rivers are in conspicuously Preglacial beds filled with drift. The Au Sable after turning northward continues in a partly re-excavated valley to a point within a mile of Lake Huron, and then turns at an acute angle and runs for a dozen miles southward parallel, and very close, to the lake before emptying into it.

Now, if we look at the large geological map of Canada, it will be seen that the region underlaid by Upper Devonian shales extends south-eastward from Lake Huron, forming a narrow belt across the country to Lake Erie. Dr. Hunt has shown, that in places these shales are four or five hundred feet thick, beneath the drift. On a careful study, it will be seen that these south-western countries of Ontario simply formed a continuation of the valley of Lake Erie to Lake Huron, or *vice versa*. The depth of this valley, or plane, as we have seen, does not exceed 100 feet below the lake level (Erie), except in channels, and generally less than that depth; while the waters in adjacent portions of Lake Erie vary in depth from 30 feet, at the western end, to a maxium depth of 84 feet further eastward, where removed from the mass of modern sediments now being brought down by the western rivers. From these facts, but one conclusion can be drawn, and that is, the deepest western portion of Lake Erie is not silted up to a greater depth than the difference between its soundings and 100 feet; except in channels, such as the Cuyahoga.

From these figures it will be seen that the country including the greater portion of Lake Erie, the south-western counties of Ontario, and the southern portion of Lake Huron formed one nearly uniform plane, in shale-rocks, which, however, gradually sloped both to the northward and eastward towards the deepest portions of the lakes. From the borings, we see that there were channels, and I think that we are furnished with the data for pointing out where the outlet of Huron formerly flowed, even to a depth sufficiently great to drain the deepest portion of the lake, although filled with some sediment. That portion of the Au Sable flowing northward in an old buried valley, and then turning southward, indicates a portion of the ancient outlet. The channel having been dammed in the Ice Age, has caused the modern river to flow in the capricious manner indicated on the map. This portion of the river reversed, formed an ancient outlet for Lake Huron, and flowed to its south-western angle, then turning eastward, the direction (with gentle curves) was south of eastward across the country to Lake Erie, having Port Stanley on its right, and Vienna on its left bank. It is known that the channel at the former place was 150 feet, and at the latter 200 feet below Lake Erie, and with a sufficient distance between these places to have permitted of a valley four times that depth, even in the Hamilton shales, and underlying Coniferous limestones. At a distance of only a few miles eastward of this line, the Coniferous limestone comes to near the surface of the country, and is exposed by several modern streams. The upper portion of the Thames, the eastern branches of the Au Sable, and other streams belong to Preglacial times with buried channels, were tributaries to this old outlet.

Throughout the south-western counties generally there is a broad belt underlaid by several hundred feet of Devonian rocks (mostly of shale of the Hamilton group), beneath the drift deposits, which cover them to a depth of from 50 to 100 feet.

Two things along this route support the theory that this channel, known to be 200 feet deep (below Lake Erie) and able to drain half of the surface of Lake Huron, was of more gigantic proportions, is the nature of the drift near Port Stanley, and the configurations and soundings of Lake Erie. Near Port Stanley, the drift is piled up much deeper than it is usually found in this section of the country, reaching 150 feet above the lake. From whichever cause (glacier or iceberg), it is just what would be expected along the margin of a valley against which drift-bearing ice would be passing. The other indication is, that if we draw a line from a short distance north of Port Stanley to southward of Vienna (the direction of the valley), it forms a continuation of a nearly direct portion of the present shore, curving slightly to Long point, just off which the deepest portion of the lake is found, and around which the channel turns, to the Grand river of Canada. It cannot be justly said that the present configuration of the lake is independent of its Preglacial form. Nor can it be said that the lake is generally silted up to great depths, except in channels, for any such statement is unwarranted by facts, as I have shown from the analogy between the bottom of the western end of the lake, and the south-western counties, to be improbable.

Course of Preglacial Rivers. We are now able to construct an approximately true river map from Lake Huron to the eastern end of Lake Ontario.

The streams ran from the north and west of Lake Huron, south-eastward towards Goderich; thence southward, and entered the Au Sable near its northern angle; it turned eastward, near the southern angle of the same river, and with a gentle sweep, having Vienna on the left and Port Stanley on the right bank (receiving the upper-waters of the Au Sable and Thames as tributaries), it passed Long point, flowing near the present Canadian shore, and entering the Grand river (reversed) south of Cayuga; afterwards it passed down the Dundas valley towards north-east, into the basin of Ontario, and then along the foot of the buried Hudson River escarpment to near Oswego.

Along its course, it received, probably, a small stream from near Detroit, the Maumee, Sandusky, Chagrin, Cuyahoga, Grand (of Ohio, and its tributary, the Mahoning), Conneaut, Allegheny, and other rivers from the American States, and afterwards the Genesee and various other streams in its course through the basin of Ontario.

The rate at which this basin was excavated, of course depended on the wear of the limestone rocks after entering the Grand river. But as this was very slow, the softer shaly rocks would gradually be worn down, and the basin of these lakes, in the shaly rocks, across their beds, would be greatly widened, as we see it.

No great pitch in the rivers would be required to occasion a flow of the waters, a very few inches in the mile would suffice. If we observe the deepest portions of Lakes Huron and Ontario, we have a difference in altitude of 360 feet (both being below sea-level) in 400 miles along the route indicated, whilst probably there were lake-expansions along the course, thus causing the fall to be confined to a few places, especially through the Dundas Valley, in the form of a series of rapids after the capping limestones had been removed.

Excavation of Lake Basins. Having seen the course of the Preglacial drainage, let us ask how the broad lake troughs could be excavated. First let us look at Lake Ontario.

The river coming down the Dundas valley flowed originally at near the out-crop of the Niagara limestones, elevated by geological causes long ago. The direction of the stream was parallel to its trend. On the one side, were the soft Cambro-Silurian shales, geographically higher, geologically lower; on the other (southern) side, the Niagara limestones, beneath which were the soft Medina shales, until these were worn away in part. As the shaly rocks were removed the limestones would be undermined, and therefore we had the NIAGARA ESCARPMENT produced. How far these limestones have receded towards the present face and summit of the slope, is a question yet to be decided. As the waters sunk to a lower level a second escarpment was produced (the one noticed at Port Dalhousie, at the present lake level). Afterwards, the Hudson River shales (with some hard rocks) were pierced, whilst yet there were capping Medina shales, forming the surface of the country between the river and the limestone escarpment.

All this presupposes the continent at a higher level (at least between five and six hundred feet). Prof. Dana points out that the continent, during at least the Mesozoic, if not the Tertiary times, stood at an altitude equal to this measurement, as shown by the soundings at the mouth of the Hudson river, which extends 80 miles seaward ; and Prof. Hillgard has shown that the Mississippi also had nearly an equal elevation above that of the present day.

In the sketch of the topography of Lakes Erie and Huron, we have seen that the whole of the latter lake and the south-western half of the former are excavated mostly out of softer rock ; and the north-eastern half of Lake Huron is excavated along the junction of harder and softer rocks similar to Lake Ontario.

The rate at which these upper lakes were excavated would depend on the rate of the excavation of the Dundas valley and its extensions through the limestone, at first by a slow abrasion, and the solution of the carbonate of lime by the carbonic acid held in the water, and afterwards by the undermining of the hard rocks on the removal of the Medina shales.

As to Georgian bay and the North channel, these formed independent valleys. That the North channel is excavated out of the Cambro-Silurian shales, along the junction of Niagara limestones on one hand, and the metamorphic rocks on the other, is apparent at a glance ; as we see that the Spanish, Mississagua, Thessalon, and other rivers all point in that direction. It has been noticed that the North channel has the same depth as the deepest outlet ; and also that the deeper portions of the northern part of Lake Huron are in that direction. An appropriate coincidence is that the strait between Manitoulin and Cockburn islands should be called Mississagua, which was doubtless the ancient outlet of that river ; and False De Tour channel that of the Thessalon river.

Again, Georgian bay is scooped out of the soft rocks between the crystalline rocks on the east and the Niagara limestones on the west along the line of junction, similar to the North channel, or to Lake Ontario.

The Indian peninsula is a perfect counterpart to the Niagara escarpment, and the escarpment submerged beneath Lake Ontario. For here the Niagara limestones tower more than 300 feet above Georgian bay, whilst at the foot, but submerged, there is a precipitous descent of 500 feet below the surface of the lake. The deepest outlet into Lake Huron is only about 300 feet. Whether this is filled with drift deposit or not we cannot say. One thing is certain, that a broad depression in the topography of the country extends all the way from the southern end of Georgian bay, including Simcoe, Balsam, Rice, and a multitude of smaller lakes emptying into the bay of Quinté by the Trent river, to Lake Ontario. A great system of drainage did exist along this line. According to Sir William Logan, this trough is deeply filled with drift. Lake Simcoe is 130 feet above Georgian bay, however, and the height of land in the trough to the east of Lake Simcoe is more than 100 feet higher. It may be said that this trough is bounded by a ridge (known as Oak ridge) which is, according to the levels of the Toronto and Nippissing railway, 893 feet above Lake Ontario, and further westward to about the same height. The country gradually rises from Lake Ontario to this ridge, but on passing the summit, it descends nearly 300 feet. This ridge consists of drift to a considerable depth. I have several profiles across it. Yet there are no indications that the rivers, such as the Nottawasaga and others flowing northward into Georgian bay, formerly flowed in the opposite direction, emptying into Lake Ontario by the Humber.

The evidences are not quite clear whether the Georgian bay always emptied (except when the waters were at a much higher level), by the present outlet, or by that just indicated. But from the soundings I am inclined to favor the present route. It may be stated that the writer is assuming too frequently that the present soundings are some criterions of the original depths. This assumption I hope to prove in a subsequent paper, when treating of the drift-deposits, and feel confident that outside of confined channels of comparatively narrow width, or certain bays, that the evidence adduced, with regard to the western end of Lake Erie, holds still nearer to the truth when applied to the more northern waters. If Georgian bay were so filled with drift we ought not to find the deep escarpment situated so close to Indian peninsula.

One more remark is necessary with regard to Georgian bay and the North channel,—that is concerning the deep bays or fiords. All the conditions for the making of fiords as noticed under Lake Superior exist here. Owen sound, one of the largest of those fiords, is situated at the junction of the Niagara and Hudson River Formations, with a buried channel emptying into it, and now occupied by the small Sydenham river. At any rate the fluviatile origin of this rivulet is unquestionable (although Mr. George J. Hinde asserts that it was made by glacial action), after the study that we have made in the Dundas valley. The buried channel of the Sydenham river is more than half a mile wide at the town of the same name.

Some of the indentations in Manitoulin island were probably formed by rivers flowing across the island, but were closed by drift in portions of their course, thus producing the lakelets and bays. That most of these bays are fiords is apparent, as is also proven by the numerous islands north of Manitoulin islands, the whole being a perfect counterpart of Puget sound, or of the fiords of the Scandinavian peninsula.

Owing to the much greater depth, and other obstacles of the present time, it does not seem at all likely that Lake Huron ever emptied by Georgian bay, excepting possibly at the close of the great floods that made the whole region from Huron to Ontario one body of water, even then the present topography would not favor it.

The Outlet of Lake Ontario. The three great questions, involved in the sub-aërial and fluviatile origin of our three Great Lakes, are, where were the outlets of Lake Ontario, Lake Erie and Lake Huron, at sufficient depths to drain their basins. As shown, the outlet of Lake Erie through the Dundas valley is sufficiently deep to empty the two upper lakes. Also, the outlet described on previous pages points to every condition necessary to indicate its depth as being sufficiently great to empty Lake Huron, although the actual measurement (on the north-east side of the channel) has only reached to 200 feet below the surface of Lake Erie, with a bottom composed of soft shales. There now remains one other question to be answered, but certainly one of no greater moment than the ancient connection between Lakes Erie and Ontario—the outlet of Lake Ontario.

Dr. Newberry, at times a glacialist, finally appears to advocate the glacial excavation of the lakes after their courses had been determined by river action. Various writers for the last twenty years have referred to the deep buried channel near Lake Onondaga, more than 400 feet below its surface, as indicating the former outlet of Lake Ontario by this route, and down the Mohawk to the Hudson river. This course will not answer, as the Geological Survey of Pennsylvania has shown, for at Little Falls, Herkimer county, the Mohawk flows over metamorphic rock. Various fluvialists refer some buried route by the St. Lawrence. This seems scarcely possible, as that great river flows over hard rocks at various points for 200 miles eastward of Lake Ontario, unless the outlet existed somewhere between Kingston in Canada, and Oswego in New York, and continued in a buried course through crystalline rocks (in part) to eastward of Montreal. The north-eastern portion of Lake Ontario is very shallow, and the deepest channel points to the south-eastward extremity of the lake.

At the present time the writer knows nothing positively of the most probable outlet, as that by the Mohawk will not answer. Yet he will predict that its outlet will be found as certainly as the one between Lakes Erie and Ontario, of which there was no clue, or even suggestion until working up the origin of the Dundas valley. One other route presents itself, but as positive proof is not at hand, I will defer theorizing.

The Geological Survey of Pennsylvania has shown that many of the water courses, emptying southward at the present time, formerly emptied to the northward. In New York, we find most of the small lakes of narrow but long dimensions having their axis in a meridional direction. Also, these waters are generally along some stream flowing northward into Lake Ontario even at the present time. Though the bottoms of these lakes are frequently below the sea level, yet in no case, that I am aware of, are they nearly as deep as Lake Ontario. Doubtless these small lakes were former expansions of the rivers running into Lake Ontario in Preglacial times, and owe to ice, simply, the closing of their outlets by drift.

No local land oscillations apparent. I agree with Mr. Carll that there are no indications of local oscillations in the region of our lower great lakes, at least to account for any changes in the drainage systems. It has been a popular idea that the coast of New England, even at the present time, is sinking. If so, any changes must be very slow, for Mr. Henry Mitchell, of the United States Coast Survey, shows (in appendix 8 of report for 1877), that the whole north-eastern coast of the United States has undergone no change of level during the last hundred years.

Depths of the lakes cannot be accounted for by the relatively higher elevations of northern latitudes. In the first place, Lake Ontario has a bottom very much deeper (below the sea), than even the deepest sounding in Lake Superior, or 500 feet below sea-level.

If a sufficient elevation did occur, it would require to be local, or to extend far to the southward. That it was not local appears from the general dip of rocks in which it lies.

However, any continental elevation or subsidence occasioned by the change of the centre of gravity of the earth, such as that by the great accumulation of ice in the polar regions, would be equal to the elevation or subsidence at the pole multiplied by the sine of the latitude. From this we find that if the elevation at the poles were a thousand feet, the difference between the elevation or subsidence of the northern end of Lake Huron and the Dundas valley, would be equal to only about 40 feet. Even were the ice-cap uniform around the poles, it has never been calculated that it was sufficient to cause a polar difference of 3000 feet of level, which at most would effect the relative levels of the northern end of Lake Huron and the southern latitude of Ontario to no greater extent than 120 feet. Again, it is shown by Prof. Whitney, that no ice-cap occupied north-western America, and by the author of "Fire and Frost" (see Q. J. G. S.), that the ice-belt is only known to have surrounded the region of northern Atlantic. The greatest changes of level by the accumulation or removal of ice would thus be occasioned along the north-eastern margin of America in the region of the Appalachian and Laurentian mountains. If the continent continued high during the Ice Age, the coastal ranges would cut-off most of the moisture, and thus greatly lessen the thickness of any *ice sheet* over the region of the great lakes, if it ever did exist. This is exactly the state of the ice in Grinnell land (Lat. 81° N.). Messrs. Fielden and Rance, observed "the paucity of glaciers, and the non-existence of the ice cap," (Q. J. G. S., No. 135), and state that no glaciers descend to the level of the sea, as on the Greenland coast or Hall basin.

The idea of the lake basins being greatly effected by oscillations must be abandoned, except so far as the whole area was subject to a more or less uniform change acting proportionably on the eastern and central parts of the continent. Even then, the change was far too little to explain the depths of these waters. Another evidence against the irregular changes of the lake region is that, at the close of the Ice Age we have terraces in Canada a thousand feet or more above the sea, and at various levels all the way to the present surfaces of the waters. Terraces or ridges occur at similar heights in our country, Ohio, New York and elsewhere. In a subsequent paper the writer hopes to show the relation existing between these old beaches, terraces and kames, deposited when our three lakes formed one common body of water. That this water had numerous outlets, as the continent was rising, has been pointed out by the Geological Survey of Ohio, to say nothing of the outlets referred to by the Surveys of Pennsylvania and Canada. At only a comparatively few levels did the waters seem to linger, as the lower lake region was being desiccated, and therefore we do not find continuous shore lines between many of the beaches; Carll explains this by the waters being frequently lowered by *débâcles*, apparently an adequate reason.

Niagara River. That the Niagara river is Postglacial, at least from the Whirlpool to Queenston, is apparent. It is known that the Niagara river formerly left its present course near the Whirlpool and flowed down the valley of St. David, which is now filled with drift. This valley (through the limestone escarpment) is not so great as the present *cañon*. This buried valley of St. David could only have been produced after the closing of the Dundas valley outlet of the Erie basin, for until then the waters flowed at a very much lower level. Therefore, it seems necessary to regard this channel (not of very great magnitude) as an interglacial outlet for Lake Erie.

The geologists of the Western States point to the Forrest bed as a period of high elevation, preceded by the Erie clay (stratified) and succeeded by the yellow stratified clays or loam, corresponding to the Brown Sangeen clay of Canada, which is unconformable to the underlying Erie clays (or Boulder clay in the upper portion of the Dundas valley). So, for the present, we look upon the old course of the Niagara river as the channel excavated during this warm interglacial period.

Hypothetical Glacier Origin of the Lakes. The writer, having purposely left the hypothesis that the lakes were excavated by glaciers until now, will briefly examine what evidence is existing. 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. 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 a glacier 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 their sharpness, owing to contained detritus in the ice, and become rounded. The ground moraine is neither characteristic nor important. There is but little 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 that are formed are those where pre-existing valleys have been closed by morainic matter, but the waters will soon reöpen 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 most geologists in America. So far, Prof. Whitney's investigations are applicable to our great lakes, though I do not agree with him that some of them occupy geological valleys (unless possibly Lake Superior).

Mr. George. J. Hinde, F. G. S., one of the few geologists who has written from a Canadian standpoint, is an uncompromising glacialist. Because he has seen scratches in the north-eastern 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 statement as proof, but considers that a Preglacial valley determined the direction of the continental glacier.

Mr. Hinde also asserts his belief that the buried valley of the Niagara river (by way of St. David's) as also the valleys at Dundas and Owen sound, are of glacier origin. We have proved in this paper incontrovertibly that the Dundas valley is a buried river channel. Also it has been seen that 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 lake, but always at considerable angles. In the region of Kingston, the prevailing scratches are S. 45° W. (Bell) and some others at S. 85° W, neither of which directions are parallel with the axis of the lake. Granted that Mr. Hinde observed scratches that were parallel with the axis of the lake, they of necessity would have been at an angle with the submerged escarpment. If any glacier could have scooped out the basins 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 50 feet of drift at its foot, and this mostly, if not altogether, stratified (excepting in channels now buried).

The observations of Prof. Prof. H. Y. Hind, on the coast of Labrador, are here interesting. He has shown that *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 eight or ten 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 the writer 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. The description of their topography strengthens the proofs 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.

Before closing, permit me to thank those railway companies which have kindly furnished me with many levels. But in doing this, I may state that it is my purpose to make further requests and hope to do for Ontario, what the Pennsylvania Survey has done, in collecting all levels that bear on the topography of my native Province, in order to make a more complete study of the Preglacial drainage of the great lake region.

ERRATA.

Page	301	line	xxvii,	read	"contimued in this channel."
"	310	"	xxv	"	"Brant" for "Brent"
"	318	"	xxxi	"	"connection with Lake Huron'
"	319	"	xlii	"	"have been excavated"
"	323	"	xxxiii	"	"lake at no very great"
"	332	"	j	"	"westward it has about"
"	333	"	xvi	"	" refer to some buried"

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