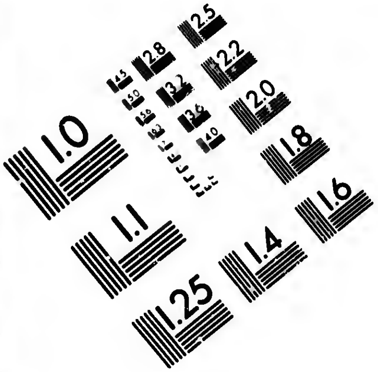
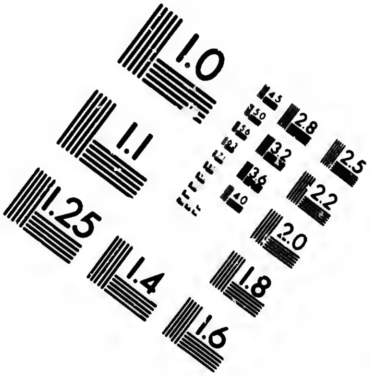

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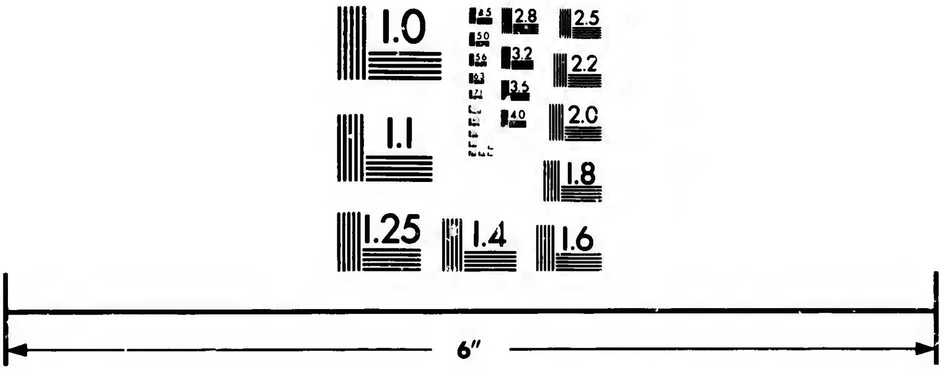

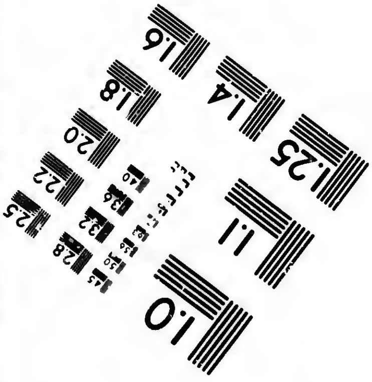
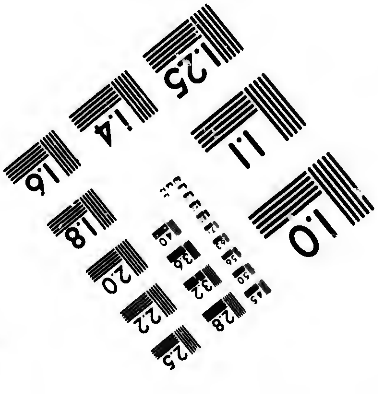

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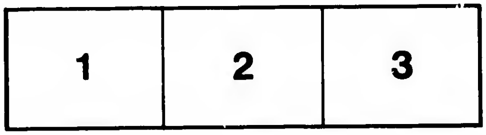
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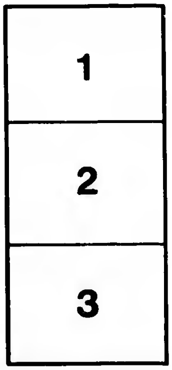
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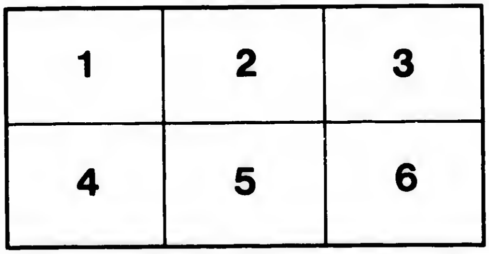
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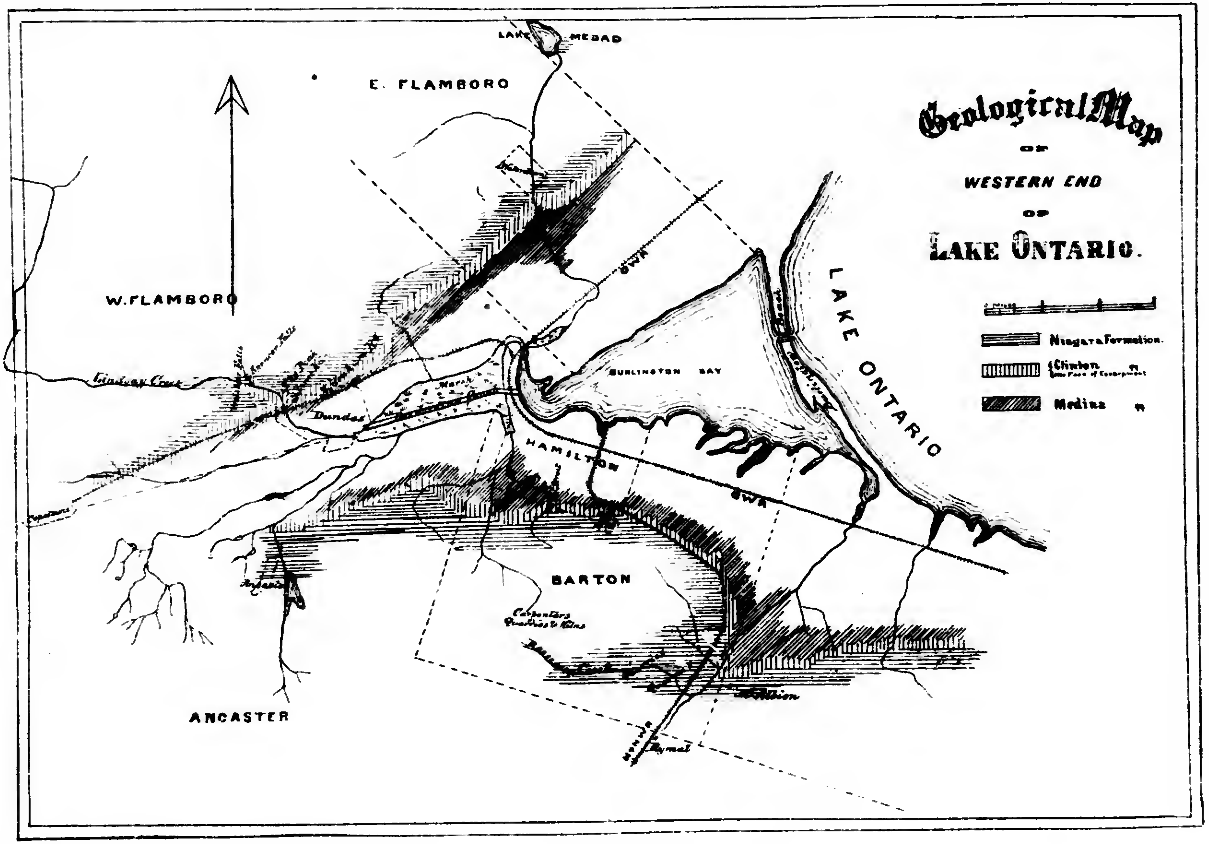

Geological Map
of
WESTERN END
of
LAKE ONTARIO.
Niagara Formation.
Clinton
Base Face of Escarpment
Medina
LAKE ONTARIO
BURLINGTON BAY
HAMILTON
BARTON
E. FLAMBORO
W. FLAMBORO
ANCASTER
LAKE MEDAD
Dundas
Marsh
Lindsay Creek
Carpenters Quarries & Kilns
Albion
Rymal
GWR

(From Canadian Naturalist, Vol. X., No. 3.)

PALÆOZOIC GEOLOGY

OF THE REGION ABOUT

THE WESTERN END OF LAKE ONTARIO

BY PROF. J. W. SPENCER, B.A.Sc., PH.D., F.G.S.,
Vice-President of King's College, Windsor, Nova Scotia.

PREFACE.—In 1874, I published, in this Journal, a short paper on the "Geology of the Neighbourhood of Hamilton." Subsequently (1877-80), I made an additional study of the region, and found an immense amount of geological information obtainable. This paper on the Palæozoic Geology was ready for print in the autumn of 1879, but its publication was delayed in order to complete the work; but as the completion seems some distance off, I present this paper on the first portion of the subject of the Geology about the Region of the Western End of Lake Ontario. A very large amount of new material in Palæontology has been collected and is now ready for press.

Although the principal facts of the Surface Geology have been collected, yet the study is not yet completed, it being very large, as more than local phenomena are involved.

I.—INTRODUCTION.

Skirting the Western End of Lake Ontario, in our Canadian Province of the same name, there are excellent exposures of the various portions of the Silurian formations (or Upper Silurian of the New York Geologists) overlying, to a depth of several hundred feet, the upper members of the Cambro-Silurian Age (of the Hudson River epoch) about the city of Hamilton, whilst between Oakville and Toronto, the rocks of the latter age appear at the surface of the country.

Those members of the Silurian formation which are exposed in the region under consideration belong to the Medina, Clinton, and Niagara epochs. The best localities for making geological examinations are at Thorold, Grimsby, Hamilton, Dundas, Limehouse Station (G.T.R.) and Rockwood. Nowhere in Eastern America are there better exposures of the various rocks of this age, though in some localities, especially in the Western States, the fossils are in a better state of preservation. However, in the above localities there is a very great difference in the preservation of the fossils found, and nearly 200 species of organisms can be procured from a limited number of localities. A considerable variation of texture is observed in the rocks in the different places, and although the number of species of animal remains is considerable, yet owing to the crystalline texture of the limestones, one is rewarded with meagre returns for his day's labor.

As we will see further on, the rocks under consideration are intermediate in character between those of the State of New York to the eastward, and those of Ohio to the westward, being more calcareous than their equivalents in the former State, and more argillaceous than those in the latter.

In the study of the various rocks of the Niagara group, I have examined the microscopical structure, and have made a number of chemical analyses. At the end of the present paper there will be found a catalogue of all the species of fossils in my own collection, with some few that have been obtained by others, but of which I have not been fortunate enough to obtain specimens. This will be found to be the fullest catalogue of Canadian fossils from the Niagara group yet published.

Again, a few minerals are procurable at various localities from cavities in the Niagara limestones, as well as mineral waters from several natural springs and artificial openings, all of which will be noticed in their proper places.

As no part of the Province affords a greater variety of interest to the student of geology than the region about the western end of Lake Ontario, I will endeavour to give a full but concise account of those features and objects of attraction that will assist the geological observer and student in the pursuit of this most attractive and useful study of Nature.

II.—TOPOGRAPHY AND DISTRIBUTION.

Extending along the southern shores of Lake Ontario, at distances varying from one to a few miles from its waters, there is a ridge of hills, or more properly an escarpment, known to geologists as the "Niagara Escarpment," extending from the State of New York into Canada, and entering our country near Queenston, whence the *cañon* of the Niagara Falls has worked backward for several miles. From the Niagara River this ridge extends westward to the town of Dundas, and thence the trend is a little west of north to Lake Huron and Manitoulin Islands.

This range everywhere forms a bold feature. Along the southern shore of Lake Ontario, the brow is 400 feet above the lake, while near the "Peak," north of Dundas, the height is 520 feet, from which place the ascent is gradual as it extends northward, until just west of Limehouse, the cliffs have a height of 847 feet, whence the plateau gradually rises to 936 feet at Rockwood (on the G. T. Railway), and northward, in Amaranth township, it has an elevation of 1400 feet above Lake Ontario. In its course, south of Lake Ontario, the slope is generally more abrupt than after the range assumes a northerly trend,—the upper portion often forming almost perpendicular cliffs from 100 to 250 feet above the rising slope at its base. The brow where the H. & N. W. Railway ascends the mountain (four miles east of Hamilton) is 395 feet, and at the head of James street, Hamilton, it is 388 feet above the lake, while the plateau above gradually rises to 493 feet, five and a half miles south of the former place, and to 485 feet, two miles south of the latter. This height of land forms the watershed between Lakes Ontario and Erie, and from it the country gradually slopes to the latter lake.

The rocks of this range belong to the various subdivisions of the Niagara Group of the Silurian Age. The Canadian Geological Survey, many years ago, separated the Niagara and Guelph groups from the overlying Lower Helderberg group, and called these Middle Silurian, whilst the New York geologists placed them all together, and called them Upper Silurian. We will adopt that nomenclature which recognises the rocks of the various groups from the Niagara to the Lower Helderberg (inclusive), as being members, not of the middle or upper, but of the one great Silurian Age, and consider the Lower Silurian formations (Trenton and Hudson River groups of America) of the New York Geological Survey, under the name Cambro-Silurian—a name given by one of the fathers of English Geology (Professor Sedgwick) before Sir R. Murchison included their Welsh equivalents as the lower portion of his "Silurian System," as the character of the organic remains is intermediate between *Sedgwick's Cambrian* and *Murchison's Original Silurian Systems.*

In the State of New York the Niagara group is divided in ascending order into the ONEIDA, MEDINA, CLINTON and NIAGARA EPOCHS, and overlies the Hudson River formation.

The Oneida of New York consists of a conglomerate, and is wanting in Canada, but all the other members of the series are present in the Province. At the head of Lake Ontario, the Medina is underlaid by the rocks of the Hudson River epoch; and the rocks of the Niagara period form the surface deposits adjacent to the lake region, while twenty miles to the westward, they are overlaid in the neighbourhood of the towns of Galt and Guelph by the deposits of the Guelph formation.

In the Niagara Peninsula, south of Hamilton, the Niagara formation is succeeded by some of the members of the Helderberg group, unless there be some thin concealed deposits of the Guelph group not exposed.

The general dip of the whole series is 25.5 feet in the mile in a direction of about twenty degrees west of south.

III.—GEOLOGICAL SECTIONS.

During the summer of 1879, the writer, with the assistance of the late George Beasley, Esq., C. E., made instrumental measurements of four Geological Sections—the most complete that could be obtained. Two of these sections were at Dundas, one at Hamilton, and one south-east of the city, from the watershed between Lake Ontario and Lake Erie, along the exposures of the Niagara Limestones in the bed of the Rosseaux Creek, to its falls at Mount Albion. These measurements required several days' levelling over many miles of ground. In addition to the principal sections, several smaller exposures were measured in order to compare the continuity of various strata.

The thickness and character of the lowest portions of the Medina formation were ascertained from the log of an Artesian well, sunk to a depth of 1600 feet, in the western part of Dundas.

Mr. Beasley and myself connected the thickness between the adjacent summit of the Medina group, which is 264 feet above the lake, by levelling (and allowing for dip) with the mouth of the well of which we had the record, and were thus enabled to calculate accurately the thickness of the formation.

Before advancing further we will give a tabular view of the four sections measured.

The first section is at the western end of Dundas, (near the place where the Artesian well was sunk.) The height of the mouth of the well was found to be 139 feet above Desjardin's Canal. Afterwards we levelled to the summit of the cliffs along the south-western side of the ravine, which is formed by the union of the two streams from Spencer's and Webster's Falls—the highest point of the exposed rocks being at the junction of the two glens, where the top beds are composed of the cherty bands of the same horizon as those which form the capping strata south of Hamilton. By means of this section and the Artesian well, we were able to ascertain the whole thickness of the Medina formation, the whole thickness of the Clinton formation, and the lower portion of the Niagara proper.

But the western side of the ravine is more than one hundred feet lower than the eastern side, although the rocks are nearly horizontal. This has been owing to the local denudation in the spur of rocks between two great valleys, which will be noticed in a future paper on the surface geology.

The ravine or *cañon* just referred to is more than 300 feet deep, if we calculate from its eastern (or rather north-eastern) side. Owing to the absence of the higher beds of the series, we levelled up the escarpment on the opposite side of the great glen, at the Limekilns, just east of the "Peak," where the highest rocks are 516 feet above the lake, although the soil rises a few feet higher a short distance to the northward.

By these measurements, and the necessary calculations in correlating the adjacent measurements, it was found that the whole thickness of the Niagara group is 800 feet at Dundas, of which the lowest 545 feet belong to the Medina series.

The second section is along the Sydenham road at Dundas. The third section is at Hamilton, between the head of James street and the Jolly Cut road. The fourth section, as we have seen, was taken along the Rosseaux Creek to Albion Falls.

SECTION I. (at Dundas).

In descending order: Beds 20-14 were measured above Limekiln. Beds 13-2, measured at the south-western side of Glen Spencer, are correlated with those above. Series of beds numbered 1 is at Artesian Well

Beds. No.	NIAGARA FORMATION.	*Thickness. Feet.*	
20	Fine grained gray arenaceous dolomite. Top bed glaciated. (Height above Lake Ontario 517 ft.)	10.6	
19	Dark dolomites (somewhat bituminous) containing concretionary masses of a brecciated appearance	9.7	
18	Measures concealed	10.2	
17	Gray and drab dolomites in thin beds—the upper portion forming brow of escarpment just east of "Peak."	28.3	
16	Earthy dolomites with conchoidal fracture	3.2	
15	Dolomitic shales covered with incrustations of epsomite	3.5	
14	Gray and variegated dolomites in thin beds with earthy partings	38.4	
		——	103.9
13	Cherty dolomites (?) concealed, by measurement 3.1 feet, but allowing for dip, 3.0 feet must be added, and this connects the section at the Limekiln with that measured at western side of Ravine from Webster's to Spencer's Falls	6.1	
12	Gray dolomites with numerous cherty nodules, this forms the brow of cliff at junction of Ravines from Spencer's and Webster's Falls	12.0	
11	Shaly dolomites, with shaly partings	2.0	
10	Compact dark gray dolomites, more or less argillo-arenaceous, in beds from two to two and a half feet thick	16.9	
9	Dolomitic blue shales, with shaly dolomites	13.1	
8	Compact light gray dolomite in one bed. This bed is constant for many miles, and it was from this that the dip was calculated, and checked in by other beds	5.3	
7	Niagara dolomites, covered here, but exposed elsewhere	10.0	
		——	65.4

	CLINTON FORMATION.		
6	Clinton bluish shales, with numerous thin beds of argillaceous dolomites, some of which are also very ferruginous, others are more arenaceous. Many contain fossils. Portions of the series are covered, but, being exposed in numerous places, show the character of the whole formation just described	77.5	
5	Argillo-arenaceous dolomites, which may be considered as beds of passage to the Medina beneath.	8.2	
		——	85.7

MEDINA FORMATION.

Beds. No.		Thickness. Feet.	
4	Bluish sandstones in two beds, splitting in slabs....	2.7	
3	Coarse sandstone—the GRAY BAND—varying much in thickness. This is separated from the beds above by shaly parting....	7.3	
2	Medina shales — green, red, or variegated — partly covered here, but various portions exposed in many places	141.0	
1	Red, green, and variegated shales (measured in Artesian Well)	394.0	
			545.0
	Total thickness		800.0

SECTION II. (at Dundas).

This section was measured partly along the Sydenham road, and partly in the glen just west of it. The measurements are in descending order, and the numbers of the beds refer to the equivalent beds in Section I.

NIAGARA FORMATION.

13 & 12	Cherty dolomites, forming brow of escarpment along Sydenham road. The upper portion in the section represented at the "Peak," by more than 100 feet, being removed by denudation for some distance back of the brow	19.0	
11	Dolomitic shales	0.8	
10	Compact gray dolomite, more or less argillo-arenaceous, in beds from 2 to 2.5 feet thick	14.0	
9 *b*	Shaly dolomites	4.5	
9 *a*	Dolomitic shales	6.0	
8	Compact gray dolomite in one bed, highly crystalline, with cavities filled with minerals	5.5	
7	Gray dolomite, more or less argillaceous	10.0	
			59.8

CLINTON FORMATION.

6 & 5	Clinton shales, with thin beds of areno-argillaceous dolomites, sometimes ferruginous, some of the beds are fossiliferous. About 20 feet from the top there is a bed of red ferruginous, calcareo-arenaceous sandstone, rich in casts of fossils	85.7	
			85.7

MEDINA FORMATION.

4	Bluish sandstone splitting into thin slabs	2.1	
	Shaly parting	0.8	
3	Coarse gray sandstone—the "Gray Band"—varying in thickness from 6.7 to 9 feet See below,	8.1	
2&1	Medina variegated shales (as calculated)	535.0	
			546.0
	Total thickness		691.5

Section III. (at Hamilton).

This section was measured along the brow of the escarpment at the city of Hamilton, between the ravine at the head of James street and the "Jolly Cut" road, about half a mile to the eastward. The section is in descending order. The numbering of the beds connects the section with the corresponding beds at Dundas. (See note in Appendix.)

Beds. No.		*Thickness. Feet.*	
	Niagara Formation.		
12	Thin gray dolomites, with an abundance of cherty nodules. This bed is known as the "Chert Bed," and forms the brow of the escarpment at Hamilton and eastward, being 388 feet above lake at head of James street. At head of Queen street this series is 19 feet thick	12.0	
11 & 10	Argillaceous dolomites, with shaly partings—upper portion known as the "Blue Building Beds." Beds 0.5–1 foot thick. (See analysis and fossils.)	15.5	
9	Dark hard dolomitic shales and dolomites weathering to gray—and lower beds most shaly. (See analysis.)	10.5	
8	Thick bed gray crystalline dolomite (nearly pure)...	4.5	
7	Argillo-arenaceous dolomite in beds from 1–1.5 feet thick. (See analysis)	8.8	
		——	51.3
	Clinton Formation.		
6*b*	Earthy dolomite, with shaly partings	8.0	
6*a*	Clinton shales, all dolomitic, with thin beds of harder rock, some of which are arenaceous, and others to a thickness of about 7 feet, are areno-ferruginous. The upper 9 feet may be considered as passage beds	76.9	
5	Passage beds of argillaceous dolomites. (Top projecting portion is glaciated, and is 254 feet above lake)	8.8	
		——	93.7
	Medina Formation.		
4 & 3	Coarse gray sandstone—"Gray Band." This bed varies in thickness..........	6.5	
2 & 1	Medina variegated red and green shales. Thickness from calculation of Dundas Artesian Well	538.5	
		——	545.0
	Total thickness		690.0

SECTION IV. (along Rosseaux Creek)

This section along Rosseaux Creek, extends from Albion Falls (in Barton Township) to Carpenter's Limekilns, on the Hamilton and Caledonia road. This line follows nearly the strike of the formation. The section is in descending order. The numbering of the beds refers to the corresponding strata at Hamilton and Dundas.

Only the Niagara Formation is represented.

Beds. No.		*Thickness. Feet.*	
	Dark gray bituminous dolomites at Carpenter's Limekiln, R. VI, lot 15, Barton. The top bed is two feet thick, with glaciated surface. This bed contains abundance of Stromatopora	11.5	
	Beds concealed	42.7	
	Grey bituminous dolomites (Range VII, lot 7, Barton) beds 0.25–1.0 foot thick, containing cavities filled with barite, calcite, selenite, fluorite, galenite, sphalerite, and other minerals in beautiful crystals, besides bituminuous matter	15.1	
	Covered beds	5.7	
	Earthy compact dolomite (Range VII, lot 5).	6.2	
	(The following is down the creek, R. VII, lots 4–1.)		
	Fine grained dark dolomite, in one bed, with glaciated surface	2.2	
	Areno-argillaceous dolomites, in thin beds with shaly partings, 0.2–0.4 foot thick	12.3	
	Dark brown flags, areno-argillaceous, with films of dolomite	1.3	
	Shaly dolomite (with abundance of *Streptelasma*)	2.5	
	Blue arenaceous shales, hardened with crystalline particles of dolomite	2.9	
	Argillaceous dolomites	3.2	
	Blue and red shaly rock	3.0	
	Dolomitic flags (Avicula bed), dark brown arenaceous	5.4	
	Covered beds	3.0	
	Earthy dolomites, forming bed of creek	7.5	
	Covered beds	3.7	
	Thin gray dolomites (areno-argillaceous), forming brow of escarpment, just west of Falls	4.0	
			132.2
11, 12 & 13	Cherty dolomites, at Albion Falls	18.4	
10	Argillaceous dolomites, in thin beds, with shaly partings	22.6	
9	Blue hard dolomitic shales, with beds of shaly dolomites	12.0	
8	Gray crystalline dolomite, in one bed	4.9	
7	Argillo-arenaceous dolomites, in thin beds	7.7	
			65.6
	Total thickness of Niagara beds		197.8

IV.--THE MEDINA FORMATION.

In referring to the Geological Reports of the State of New York, we learn that the Medina formation rests on what is known as "Oneida Conglomerate," which in Oneida County has only a thickness of 25 feet, though elsewhere it is as much as 100 feet thick, while in the State of Pennsylvania it is developed to the extent of 700 feet. There appears to have been a gradual passage from the band of gray sandstone, terminating the Hudson River formation in Oneida and Oswego counties, to the overlying conglomerate, both of which deposits, however, are wanting in the western part of the State, and are entirely absent from the series in Canada, as indicated at a short distance east of Oakville, on the north-western side of Lake Ontario, where the upper beds belonging to the close of the Cambro-Silurian Age are seen to rest beneath those at the commencement of Medina epoch.

In tracing the Medina formation from Oswego County, N.Y., it is found to increase in thickness until it attains a development of several hundred feet in the western part of the State, and at Dundas, at the head of Lake Ontario, it is 545 feet thick. Again the group gradually dies out to the westward, and is only represented in the State of Ohio by ten or twenty feet of red and blue mottled shales.

Almost the whole series is made up of more or less calcareous shales, some of which are also arenaceous (and almost resemble thin flags of unpure sandstone). In color the shales are red, green, or variegated. The series is capped by a course sand-stone, which is irregularly deposited and has a thickness in the region of Dundas and Hamilton, varying from seven to ten feet. It is known by the name of the "Gray Band," and is a characteristic stratum from the Niagara River to the Georgian Bay. Sometimes, however, it thins out to mere wedges, but the hollows occasioned by the sudden thinning process is filled up with earthy calcareous sandstones. This structure is well illustrated by a section in the glen just west of the Sydenham road, Dundas—the following section would not be represented longitudinally by more than thirty feet:

2.1 feet	Bluish sandstone......................	2.1 feet.
0.8 "	Shaly partings........	0.8 "
3.7 "	Thin shaly sandstones	6.7 "
4.0 "	Sandstone: The "Gray Band."	
1.3 "	Sandstone....	0.9 "

By this means it will be seen that the whole series does not materially alter in thickness, but that the undulations of the surface of the "Gray Band" resulted from unequal deposits of sand along the sea margins, and afterwards the inequalities were filled up by sediments of slightly different character. Sometimss the "Gray Band" shows ripple marks on its upper surface, while the more shaly partings have their surface characterised by wave action.

At Grimbsy, the lower portion of this band is of the usual gray color, but it passes into bright red sandstones irregularly deposited, and conspicuously mottled by large spots of a gray tint. At this locality the *Arthrophycus harlani* is very abundant, and though found in both the gray and red sandstones, it is more common in the former.

At Dundas the capping portion of the "Gray Band" consists of a bluish sandstone resembling quartzite, though this subdivision in the character of the beds is not noticeable at Hamilton.

All the thicker beds of Medina sandstone form excellent building material, though difficult to work on account of its compactness and toughness.

Along the *cañon* of the Niagara River more than 200 feet of the shales are exposed. So, also, there are excellent exposures in many of the gorges about the head of Lake Ontario. Perhaps the best section of the shales is to be obtained by following up the stream which flows into Burlington Bay after passing by the village of Waterdown. In the deep gorge of this stream the upper 250 feet of Medina shale is more or less exposed, though in some places covered by land-slides. The base of the Medina is exposed at a short distance east of Oakville.

At Dundas, an Artesian well was sunk a few years ago, and the following is the log of the boring, as published in the *Dundas Banner*:

Boulder Till	26	feet.
Blue Clay	48	"
Clay and Black Sand	5	"
Red Shales	341	"
Limestone and Grits	550	"
Total Depth	1600	"

The record of the character of the lower portions of the boring was not given. The "limestone and grits" represent rocks of the Hudson River formation. The record also stated that at 290 feet from the surface there was a thin bed of sandstone with a flow of gas and water; at 300 feet there was a flow of water rising eight feet above the surface; at 970 feet there was a heavy flow of gas. This imperfect record is unfortunately all that remains of much money that was expended in seeking for a supply of water for the town. The secretary of the Well Company has since died, and the complete record is lost. However, it serves a purpose, and by connecting the levels of the mouth of the well (which is 139 feet above Lake Ontario) with the adjacent Medina beds, we are enabled to calculate the thickness of the whole formation.

Other wells have been sunk to a considerable depth, years ago, but unfortunately their logs are not in existence. One, at an oil refinery, east of Hamilton, was sunk into the Medina shales, or perhaps just through them, when a sufficient supply of water was obtained, but which was strongly alkaline (see analysis below). At 40 feet from the surface (about 275 from top of the Medina series) a thin bed of sandstone was found. Another thin bed of sandstone comes to an out-crop at Burlington, on the northern side of the bay of the same name. The beds found at these two places are probably of the same horizon although their continuity is broken by the cause which originated Burlington Bay.

There was another important well sunk to a depth of 1009 feet, at the Royal Hotel, Hamilton, but though some water was procured by me and then analysed, the record of the boring was lost in a burning building. The eastern part of Hamilton is situated almost directly on Medina clays; but the surface of these is covered to a considerable thickness in the western part of the city by drift, which partly fills a Pliocene valley. (See a future paper on Surface Geology.)

The character of the Medina shales is shown by the following chemical analysis. The specimen chosen was typical of the green indurated shales which on weathering become red. It was obtained from a freshly broken surface at an artifical ditch in Ainsley's Hollow, west of Hamilton.

Silica	50·2
Alumina	12·0
Iron Protoxide	1·5
Lime	17·7
Magnesia	5·8
Carbon Dioxide	11·6
	98·8

A portion of the lime and magnesia was present as silicates, some of which was decomposed by acids. In various analysis of the Medina shale, made by Dr. Sterry Hunt, less than one per cent. of fixed alkalis was found to be present. Under the microscope, these rocks exhibit small crystalline dolomitic particles scattered through the mass, sometimes uniformly, and sometimes in thin layers.

From the geological evidence adduced by the Ohio Geological Survey (as will be noticed under the Clinton formation), the Hudson River formation was raised up into a shore line before the deposition of the members of the Niagara group. In the State of New York the Medina seas laved the shores of the Shawangunk Mountains, whence the pebbles for the conglomerate of the lower portion of the series were derived. The western margin of the sea was bounded by the "Cincinnati Arch," which has been an upland since the close of the Cambro-Silurian Age. The arenaceous material of the Medina series was obtained largely from the adjacent highlands to the eastward, although a portion of the sediments that form the "Gray band" was probably derived from the denudation of the more siliceous portions of the Hudson River formation of the Canadian shores.

The shaly beds of the Hudson River series, and particularly those of the Utica formation of the Canadian highlands, formed an abundant source whence denudations could derive an ample supply of clay to produce the wide-spread off-shore deposit of Medina shales in the northern portion of the sea. The period was generally one of subsidence until its close, when the "Gray band" was deposited, to be followed by the Clinton shallow seas, which were to be filled up with impure limestones, alternating with muddy sediments brought down from the adjacent shores.

Organic Remains.—One or two fragments of obscure seaweeds have been noticed by Col. Grant in the shales, otherwise they appear to be devoid of organisms.

The "Gray Band," however, contains a few poorly preserved casts of shells, besides several species of sea-weeds. The fossils are usually found crowded together on some portions of the surface of the sandstones, overlaid by more or less earthy partings, particularly at the junction with the overlying Clinton, or those beds that might perhaps be considered beds of passage.

The sea-weeds are the most common. *Arthrophycus harlani* is abundant at Grimsby. The branches of this organism is sometimes connected with lobed nodules, having the appearance of fruit pods; however, some palæontologists consider *Arthrophycus* as worm tracks, and, if this be the case, these lobed expansions are simply worm burrows at the end of the tracks.

A considerable number of undoubted worm tracks or Ichnites is also found. All the fossils consist of nothing more than casts in the sandstone.

The following meagre list of fossils has been obtained.

CATALOGUE OF MEDINA FOSSILS.

Genera and species	*Reference.*
Arthrophycus harlani	Hall, 1852, Pal. N. Y., Vol. II. *Locality*—Grimsby, Ont.
" " Fruit (?)	*Locality*—Grimsby.
Palæophycus sp.	*Locality*—Hamilton and Grimsby.
Zaphrentis bilateralis	Hall, 1852, Pal. N. Y., Vol. II *Locality*—Hamilton and Grimsby.
Atrypa oblata	Hall, 1852, Pal. N. Y., Vol. II. *Locality*—Hamilton and Grimsby.
Modiolopsis orthonota	Conrad, 1839, Ann. Rep. N. Y. *Locality*—Hamilton.
" sp	*Locality*—Dundas, Hamilton, and Grimsby.
Murchisonia subulata	Conrad, 1842, Jour Acad. Nat. Sc. *Locality*—Hamilton.
" *conoidea*	Hall, 1852, Pal. N. Y., Vol. II. *Locality*—Hamilton and Grimsby.
Pleurotomaria litorea	Hall, 1852, Pal. N. Y., Vol. II. *Locality*—Hamilton and Grimsby.
" *pervetusta*	Conrad, 1838, Ann. Rep. N. Y. *Locailty*—Hamilton and Grimsby.
Ichnites (several species)	*Locality*—Hamilton and Grimsby.

V.—CLINTON FORMATION.

In southern Herkimer County, N. Y., the Medina formation is wanting, and the Clinton rests on thin deposits of Oneida conglomerate, which itself dies out farther to the east. In the more eastern portions of the State of New York, where the Clinton series succeeds the Medina, it partakes of its lithological characteristics. However, as the Clinton extends westward its shales become intercalated with calcareous deposits that form a conspicuous feature. The calcareous beds increase in importance as the formation extends westward in the Province of Ontario, and at Hamilton they so nearly resemble those of the overlying Niagara, that the line of separation becomes almost arbitrary. The New York Geologists placed a hard layer of dolomite, containing remains of *Pentamerus*, and known as the "Pentamerus Band," as the upper bed of the Clinton of New York, while the Canadian Geological Survey considered it as the lowest bed of the Niagara series, which in our Province, it most nearly resembles. The latter division, between the Clinton and Niagara, I have adopted in this paper, if indeed, a division, except for convenience, should be made. In fact, the upper nine feet of the Clinton deposits at Hamilton might well be placed with the Niagara above. Nor are there any palæontological grounds of separation.

The Clinton group may be described as dolomitic shales, with numerous thin beds of argillo-arenaceous dolomites, some of which almost resemble impure sandstone. The indurated shales are generally of blue or dark gray, but in weathering they assume a red, brown or buff color. Many of the more calcareous bands are highly fossiliferous. About twenty feet from the top of the series there is a red or brown ferruginous calcareo-arenaceous rock, about eight feet thick, holding an abundance of casts of fossils, which are mostly of the genera *Modiolopsis* and *Lingula*.

It may be here remarked that none of the *Lamellibranchiate* shells retain any part of their original tests, while the *Lingulæ* have their shells well preserved, and often of a blue color.

This bed of red ferruginous rock is the representative of that peculiar bed of oolitic iron ore, called "Fossil Ore," forming a characteristic element of the Clinton group, extending from Wisconsin to New York, and thence along the Appalachian Chain to Tennessee and Alabama. In some places the "fossil ore" is only represented by ferruginous stains on the rock. This iron matter came probably from the denudation of the extensive iron ore deposits, Huronian Age, just north of the Clinton sea, in what is now Michigan.

The lower nine feet of the Clinton beds are composed of argillaceous dolomites with shaly partings, which are sometimes bituminous. Some of these layers are so granular and arenaceous as almost to resemble sandstones. From the few fossils obtained here, these rocks may be considered as beds of passage from the Medina. Including the beds that I have placed as beds of passage at the base and those at the summit of the Clinton formation, the whole thickness at Hamilton is 94 feet, and at Dundas 88 feet.

In New York, on the Genesee River, the Clinton group has a thickness of 80 feet, consisting of calcareous shales with thin beds of shaly dolomite, together with the characteristic *Oolitic iron ore* bed.

In Ohio this formation is represented by salmon-colored dolomitic limestones which vary in thickness from 15 to 40 feet.

As has been noticed, the Clinton deposits lithologically resemble those of the Medina, in eastern New York, while in the western part of the State, they approximate to the overlying Niagara. This resemblance is still greater in Canada, where much of the shaly matter is replaced by calcareous rocks, and in Ohio, according to the Geological Survey of that State, the argillaceous beds are wholly replaced by limestones. Again those differences in the fossils which characterise the respective Clinton and Niagara formations in eastern New York largely disappear in the more western deposits. In Canada the palæontological differences seem to be due to the state of preservation of organic remains in the shales and limestones respectively; for the forms which occur in the Clinton limestones are generally found in the calcareous rocks of the overlying Niagara, whilst the principal differences are in those fossils preserved in the Clinton shales, which are not represented above by similar rocks. In fact there is no more variation in the fossils found in the Clinton and Niagara formations at Hamilton than there is between those of the Niagara "Chert Bed" at Hamilton and of the upper layers at Barton, five miles distant.

Professor Orton found that the Clinton of Ohio contains pebbles of the "Cincinnati (Hudson River) limestones." In the south-western part of that State the deposits under consideration rest either on rocks of the Cincinnati group, or on the thin development of Medina shales (which are from ten to twenty feet thick). The conglomerates show that the underlying formations of the Cambro-Silurian Age had been hardened and uplifted into cliffs and shore lines before the commencement and deposition of the sediments in the seas of the Clinton epoch. At this time the Canadian Sea was one of shallow water. At Dundas, Hamilton and elsewhere, various thin hard beds from the base to the summit of the formation have their surfaces covered with ripple marks. As the muddy sediments, which filled up the northern and north-eastern portion of the Medina Sea, were principally derived from the *débris* of the Utica and Hudson River groups of the Canadian highlands, so also the Clinton shales appear to have been derived from the same source; but these muds gradually gave place to the organic limestone in the western portion of the Clinton seas.

Organic Remains in the Clinton Formation.—Recently an interesting group of small fossils was discovered by George J. Hinde, Esq., F.G.S., in Glen Spencer, Dundas. These organisms appear as black shining chitinous objects on the surface of the stone, usually about the twelfth of an inch in length or less, and were recognized by Mr. Hinde as the jaws of annelids or worms. They will be found described and figured in the August number of the "Quarterly Journal of the Geological Society of London," for 1879. Excepting the jaws, no portions of the heads of the animals were found. The following is a catalogue of Mr. Hinde's species:

FROM THE CLINTON BEDS.

Eunicites clintonensis.
Eunicites coronatus.
Eunicites chiromorphus.
Œnonites amplus.
Œnonites fragilis.
Arabellites elegans.
Lumbriconereites basilis.
Lumbriconereites triangularis.
Lumbriconereites armatus.
Glycerites calceolus.

Besides these, he describes three species from the Niagara formation; and as I have not the specimens in my collection, I will include them here with the Clinton species:

Œnonites? infrequens.
Arabellites similis.
Staurocephalites niagarensis.

The following is a catalogue of the Clinton fossils obtained at Hamilton and Dundas. This catalogue does not contain all the species that are included with the Niagara group proper, which Col. Grant and myself have found in the so-called Clinton beds, but only the more conspicuous species, or those not found higher up at Hamilton.

CATALOGUE OF CLINTON FOSSILS OCCURRING AT HAMILTON.

GENERA AND SPECIES	REFERENCE.
Buthotrephis gracilis	Hall. Palæont. N.Y., 1852.
" " var. *crassa*	" " "
" *palmata*	" " "
Roots of various *Algæ*	" " "
Stromatopora sp.	
Conophyllum niagarense	Hall. Palæont. N.Y., 1852.
Monticulipora lycoperdon	Say. " 1847.
Zaphrentis bilateralis	Hall. Palæont. N.Y., 1852.
Graptolithus clintonensis	" " "
Retiolites venosus	" " "
Palæaster granti	Spencer. Niag. Foss. 1882.
Eucalyptocrinus decorus	Phillips. Murch., Sil. Syst., 1839.
Helopora fragilis	Hall. Palæont. N.Y., 1852.
Clathropora frondosa	" " "
Fenestella prisca	Londsdale, Murch., Sil. Syst., 1839.
" *parvulipora*	Hall. 20th Rept. of Regents, N.Y., 1875
" *tenuis*	Hall. Palæont. N.Y., 1852.
" *lacunata*	Spencer, n. s. Niagara Fossils, 1882.
Polypora incepta	Hall, Palæont. N.Y., 1852.
Rhinopora venosa	Spencer. n. s. Niagara Fossils, 1882.
Retepora angulata	Hall. Palæont. N.Y., 1852.
Trematopora tuberculosa	" " "
Merista cylindrica (?)	" " "
Athyris (*Meristella*) *naviformis*	" " "
Strophomena rhomboidalis	Wahlenberg, Act. Soc. Sci. Upsal, 1821
Orthis elegantula	Dolman, 1837.
Lingula oblonga	Conrad, Ann. Rep., N.Y., 1839.
" *oblata*	Hall, Palæont, N.Y., 1852.
Posidonia (?) *alata*	" " "
Posidonomya (?) *rhomboidea*	" " "
Orthonota sp. (?)	
Modiolopsis, sev'l undetm'd spe's.	
Platyostoma niagarense	Hall, Palæont. N.Y., 1852.
" sp.	
Orthoceras clavatum	Hall, Palæont, N.Y., 1852.
Oncoceras subrectum	" " "
Conularia niagarensis	" " "
Tentaculites distans	" " "
Rusichnites bilobatus	
Ichnites, four undeterm'd spec's.	

VI.—NIAGARA FORMATION.

Topography and Distribution.—Overlying the Clinton formation, the most important member of the series—the Niagara (proper)—is much more widely developed than the lower portions of the group which are largely made up of mechanical deposits. Owing to the hard limestones of the Niagara epoch surmounting several hundred feet of soft Medina and Clinton shaly rocks, it forms a conspicuous feature in the country—the summit of the Niagara escarpment—as along its northern and north-eastern margins, the softer material forming the base of ridge has been removed by erosion, leaving abrupt cliffs.

The most eastern exposures of this formation in New York are near the town of Catskill, on the Hudson River. From this place it extends westward through the central and western parts of the State, forming the bold slopes, a few miles south of, and parallel to, Lake Ontario. Entering Canada at the Niagara River, its direction is westward, nearly parallel with its *strike*, as far as Dundas, at the extreme western end of Lake Ontario. Here the range of hills changes its course and extends to Cape Hurd, and thence through Manitoulin and Cockburn Islands. The range of hills south of the lake, as we have noticed, is about 400 feet high and generally has an abrupt face. However, from Dundas to Georgian Bay, although the country is of a higher altitude, the features are less broken on their eastern side, as they recede from Lake Ontario.

The southern portion of the basin of Lake Ontario is excavated in Medina shales, while its northern side is scooped out of the various rocks of the Hudson River, and the shales of the Utica formation, which once formed the margin of the old sea in the Niagara period.

From the northern end of Lake Huron the Niagara formation extends into Drummond Island, and thence along the whole northern and western shores of Lake Michigan. Again, the margin of the seas in this period abutted against the Appalachian chain as far south as Tennessee, as is shown by the remains of their old deposits. The large island of the "Cincinnati Arch" formed part of the barrier at the southern margin of the Mediterranean Sea, which extended over a region of thirteen degrees of longitude and eight of latitude, in the Niagara period, or, we may say, in the Silurian age.

In Canada many streams cut through the rocks of the region under consideration, and give fine exposures of their geological structure. The streams invariably excavate picturesque glens, at the head of which are usually cascades in magnitude from the Falls of Niagara to others forming a mere series of rapids.

Development—The best exposures of the Niagara formation in the State of New York are at Lockport, Rochester and Niagara River. It attains a thickness of 264 feet in that State. In Canada the upper portion of the series is so denuded in the neighbourhood of Lake Ontario, that it is impossible to get a complete section; and even many miles away where it passes into the overlying Guelph formation, as near Rockwood the line of junction is generally obscured by drift.

At Hamilton, by level measurements, a section of the lower 52 feet (being beds from 7 to 12 of Section III) was made by Mr. S. D. Mills and myself, between the exposure at the head of James street and the "Jolly Cut" road, a half mile to the east. Here the escarpment averages 390 feet in height above the lake. The cherty dolomites (No. 12 of Sections) form the capping stratum of the "Mountain." Along the Sydenham road (section II), the section, composed of the same beds, measured 60 feet (seven feet more of the "Chert bed" is exposed here than at Hamilton). Again, at the junction of Glen Spencer with Glen Webster, the same "Chert beds" form the capping stratum of the cliffs, and here the Niagara beds are a little thicker than elsewhere. However, on the eastern side of these ravines there is an additional exposure of 104 feet near the "Peak," which has not been removed by denudation, thus giving a maximum thickness of 169 feet at Dundas. However, by measuring the section at Albion Falls, and then levelling up Rosseaux Creek and along the strike of the formation to Carpenter's Limekilns, on Lot 15, and Range VI, Barton, two miles south of the brow of the "Mountain," at Hamilton, I succeeded in measuring a section of 198 feet from the base of the Niagara (proper). The height of the last station is 480 feet above the lake, and in addition the rocks are covered with five feet of soil, at the Church, on the same lot. Here the rocks have their surfaces grooved with ice action. It may be remarked that the capping bed in this place is almost wholly made up of the remains of *Stromatopora*.

This last section carries us to a higher horizon than any other measurable, yet the highest members of the series is still beyond our reach, being covered by the drift over the gently sloping country. However, if we follow the line of strike westward, and take the levels here, and at the nearest exposures of the Guelph formation, at Galt (which is a few miles north of the line of strike of the Barton Beds) and make allowance for dip, it would approximately be found that the unexposed upper beds of the Niagara formation reach to an additional 80 or 100 feet in thickness.

According to the reports of the Geological Survey of Ohio, the formation has a thickness of 275 feet in Highland county, and probably 350 feet in the northern part of the State. The Canadian Geological Survey estimated the whole thickness at 450 feet in the neighbourhood of Cape Hurd, if the dip were uniform

Thus we see that from the western part of New York to Ohio there is no great variation in the thickness of the Niagara deposits, where the surface is not removed by erosion, and we may fairly place the accumulations in the Canadian portion of the Niagara sea at 280 feet.

Not only is the deposition of the whole series literally uniform, but there are certain strata which are recognizable as constant over the region under consideration. Of these, the most conspicuous are the "Chert bed" (No. 12 of sections), and a thick compact bed of light gray dolomite (varying from four-and-a-half to five-and-a-half feet thick, and numbered 8 in the sections). It was from taking the levels of this last bed at Albion Falls, Hamilton and Dundas, that I estimated the dip at 25·5 feet in the mile, in direction, about twenty degrees west of south. Locally, however, I found the dip sometimes amounting to 37 feet. The distances of the sides of the triangle formed by the three stations above named, were taken from the large county map. The calculation agreed closely with that made from the approximate height of the base of the formation at Limehouse, and that known at Dundas, and taking the direction of the dip to be that found by the above mentioned triangle.

At Limehouse the surfaces of some of the strata are almost as irregular as those of the Medina at Dundas. On the north side of the Dundas Valley the rocks in some places are almost horizontal, but again they are found dipping a few feet in the mile to the northward. This being the case, generally, would make the Dundas Valley an anticlinal valley, with the slope in each side less than one degree.

Character of the Rocks.—In New York the lower part of the Niagara formation is represented by 80 feet of dark fossiliferous calcareo-argillaceous shales; at Thorold, Ontario, these are much thinner, and at Hamilton and Dundas they are not represented by more than from six to ten feet of muddy sediments (No. 9 of sections), whose upper portions graduate into more calcareous beds. The general character of the series at the western end of Lake Ontario may be represented by the following section in descending order;

(*a*) Thin beds of dark (often limestone and earthy) dolomites, with shaly partings. Some layers are fossiliferous..	132 feet.
(*b*) Thin beds of light-colored dolomitic rocks, containing an abundance of cherty nodules: fossiliferous..........	19 feet.
(*c*) Dark blue or gray shaly dolomites; fossiliferous.....	16 feet.
(*d*) Dolomitic compact shales..........................	10 feet.
(*e*) Light drab crystalline compact dolomite, in one bed.	5 feet.
(*f*) Dark gray compact dolomite, in moderately thick beds, the lowest of which contains *Pentamerus*.................	10 feet.

At Limehouse, only the lower beds are exposed near their junction with the underlying Clinton rocks. Here the deposits consist of light colored dolomites, of uniform texture in thick compact beds, holding only casts of fossils.

The representatives of this formation in Ohio consist of the Dayton limestone of five feet in thickness, succeeded by 60 feet of shales, over which there are 180 feet of limestones, and in Highland County the series is surmounted by 30 feet of sandstone. In referring to these western beds, we find included the Cedarville limestones, beds which are considered of the same horizon as the Guelph dolomites.

The color of the limestones becomes lighter on going westward, especially after turning a point at Dundas, which formed a right-angled prominent cape in the sea of the Niagara period. Even within a few miles, near Dundas, one can notice the lighter color of the purer calcareous deposits, and at Limehouse, to the north-west of the old cape, coloring matter and shale are almost wanting.

Composition and Chemical Analysis of the Limestones.—The Niagara limestones, in Canada, consist almost entirely of the double carbonates of lime and magnesia, with a varying percentage of clay, free sand and silicates of the alkaline earths. Sometimes, however, there is an excess of carbonate of lime over what is required for the production of the double carbonate. Under the microscope this excess of calcite is seen occupying the small spaces between the more uniformly crystalline particles of dolomite. The quantity of iron is generally small, and present in the state of protoxide, though in some of the beds it occurs as pyrites. Bituminous coloring matter is present in many of the strata, and in a number of beds it occasionally fills small cavities. There are but few beds east of Dundas which have not a considerable quantity of earthy matter present.

The shales in this region differ from limestones only in the larger quantity of clay and other silicates present in place of the calcareous matter, for they all contain a large percentage of carbonate. In fact many of the beds are of an intermediate character, that it is difficult to decide whether to call them earthy limestones or calcareous shales. Of several beds at Hamilton, I made the chemical analyses, together with a microscopic examination. A few of the results are here given.

Analysis I.—The sample was taken from near the base of the series (No. 7 of section) at the "Jolly Cut," Hamilton. Under the microscope only a mass of transparent particles of dolomite, separated by dark amorphous earthy matter, was visible.

Calcium carbonate	46·6
Magnesium carbonate	36·5
Ferrous carbonate	1·7
Calcium silicate	3·6
Magnesium silicate	
Alumina	4·4
Silica	6·7
Moisture	0·3
	99·8

Analysis II.—This analysis represents the composition of the thick bed of light grey dolomite (No. 8 of section) at the "Jolly Cut," Hamilton. The rock is highly crystalline, and shows crystalline plates of crinoids and shells, but seldom contains complete casts of fossils. Under the microscope it shows a mass of crystalline semi-transparent particles of dolomite, full of small cavities, which are often lined or filled with pure calcite, consequently the carbonate of lime is in excess. This bed contains many large cavities of several inches extent filled with foreign minerals, which will be noticed further on.

Calcium carbonate	59·7
Magnesium carbonate	38 2
Alumina and oxide of iron	1·5
Silica	0·4
	99·8

Analysis III.—The bed from which this sample was taken is about five feet above No. 8 of section, and is one of the harder and more compact layers (No. 9 of section) of that portion of the geological horizon which I have identified as the Niagara shales at the "Jolly Cut," Hamilton. It is said to produce hydraulic cement, but if so it would be of inferior quality.

Calcium carbonate	33·8
Magnesium carbonate	25·2
Calcium silicate	6·6
Magnesium silicate	2·7
Alumina	5·1
Ferrous carbonate	1·8
Ferric oxide	1 6
Ferrous disulphide (Pyrites)	1·9
Silica	20·0
	98·7

Analysis IV.—The sample for this analysis was obtained from the "Chert bed" (No. 12 of sections). The portion taken was free from cherty concretions, as these portions would be nearly made up of pure silica. Under the microscope there was only the usual crystalline structure of the dolomitic particles separated by dark earthy matter.

Calcium carbonate	46·6
Magnesium carbonate	38·9
Calcium silicate Magnesium silicate	2·3
Ferrous oxide	0·8
Alumina	2·4
Silica	9·3
	100·8

A large number of other specimens were examined under the microscope, but they were all of essentially the same structure, and more or less homogeneous, except some of the more flaggy beds where the crystalline calcareous matter was deposited in alternating layers with the more earthy matter.

As many of the dark beds are colored with bituminous matter some of the calcareous rocks burn to a white lime.

By way of comparing the Niagara rocks in Canada, with those in Ohio, I here quote several analyses of the limestones of this formation in that State, as made by Professor Wormley.

	I.	II.	III.	IV.	V.
Calcium carbonate........	85.50	54.45	50.90	55.50	54.20
Magnesium carbonate.....	11.16	42.23	39.77	43.28	44.80
Calcic & magnesic silicates.	——	——	7.07	——	——
Alumina and iron.........	2.00	0.40	1.19	0.30	0.10
Siliceous matter..........	2.20	2.00	.70	0.60	0.80
	100.86	99.08	99.63	99.68	99.90

Analysis of the Shales.—As noticed before, the Niagara shales are analogous to the limestones where the calcareous matter is partly replaced by argillaceous material.

Analysis V.—The sample here examined was from one of the most shaly layers (No 9 of the section) of the shaly portion of the formation at the "Jolly Cut," Hamilton. Under the microscope the earthy matter seemed to be held together by the crystalline particles of dolomite.

Calcium carbonate..................	29·4
Magnesium carbonate................	23·9
Calcium silicate ... Magnesium silicate ...	4·5
Ferrous oxide	0·9
Ferric oxide	1·6
Alumina	15·0
Silica	24·4
	99·7

The following analysis of the Niagara shale of Ohio was made by Professor Wormley:

Calcium carbonate	[illegible].60
Magnesium carbonate	30·87
Calcium silicate	8
Alumina and iron	8.40
Silica	12.21
Water (combined)...................	5.40
	99.56

Source of the Mechanical Deposits.—From the character of the rocks and their distribution in the Niagara period, as seen by glancing at a map of the Palæozoic Geography of America, we see that the mechanical sediments (shaly matter), of the northern and north-eastern margin of the old inland sea came principally from the Canadian highlands. The Hudson River group formed the shore line of most places, from the beginning of the Medina epoch, both in New York and Canada as well as along the "Cincinnati Arch." The eastern portion of the Province of Ontario was covered by the limestones of the *Trenton group;* the central portion, by the great accumulation of dark *Utica shales*, and these last by shales with intercalated limestones and sandstones of the *Hudson epoch*, extending along their western margin, and forming the north-eastern shores of the sea, as developed at the beginning of the Silurian Age (proper), in the region from what is now the western end of Lake Ontario to Georgian Bay.

It may be noticed that the limit of the Utica shales is not west of the meridian of the Niagara River. At the close of the Cambro-Silurian Age the deposits belonging to that period extended much farther southward than at present, probably to a latitude not far north of the southern shores of Lake Ontario —at least, in its eastern extension. It was in this soft material that the lake basin was subsequently excavated, the erosion having extended but a few miles into the Niagara limestones, and their underlying shales, and left the escarpment in bold relief.

Now, on examining the sediments south of the Canadian shores of those days, we find only thin beds of shale in the more eastern deposits, but these gradually thicken in extending westward, until, in the neighbourhood of Rochester, they amount to 80 feet (the place being south of the shores composed of Utica shale). Again, the shales begin to thin out at Thorold, Ontario, where they amount to fifty feet, while thirty miles westward, as at Dundas, they are only a few feet thick, and almost entirely disappear after turning the ancient Cape and passing west of the line from this town to Lake Huron, as the waters, there, were protected from the muddy eastern currents. The northern end of the sea was not subjected to the influx of mud to any extent, as in that direction the shores were adjacent to the old crystalline Huronian and other mountains. However, more shales make their appearance in the western area, having been derived from the somewhat shaly Hudson group of the "Cincinnati Arch," or, perhaps, from the margins of Medina shales that may have existed on the south-western island coast. Of course in the eastern portion of the old sea much shale came from the disintegrations of the other Appalachian highlands. During the Medina epoch, in this region, five hundred feet of shales were carried down into the eastern or north-eastern portion of the sea, while only twenty feet of sediments were deposited to the south-westward.

Again, the turbid waters in the Clinton epoch interrupted periodically the growth of impure organic calcareous beds, while the western portion of the old sea was nearly free from the influx of mud.

Character of the Marine Life and Origin of the Limestones.— We have observed that the greater portion of the upper beds of the Niagara epoch in New York, almost all in Ontario, and the greater portion in Ohio, together with a considerable portion of the Clinton epoch in Canada, and all of that horizon in the more south-western State, are made up of dolomitic limestones of a greater or less degree of purity. Let us examine into the condition of the seas and of the life that flourished at this time.

During the earlier days of the Mediterranean sea in the Niagara epoch, in the eastern and south-western areas, the waters were of a turbid character, though freer from earthy matter in its northern extension. Later, however, and during the greater period of its existence, only a small amount of shaly sediment was occasionally carried down, thus producing favorable conditions for the growth of marine life.

The limestones in Canada are of a highly crystalline texture, and consequently most of the traces of the organisms that contributed to their original formation are obliterated. Out of numerous specimens of rocks examined under the microscope, none show any organic structure, except some parts of those beds containing *sponges* or *stromatopora*, with here and there a place where a stray fossil has escaped obliteration, in the re-crystalization of the calcareous mud. In fact, as regards both shells and corals, there is seldom anything left more than their casts preserved in the stone. Even when, by chance, a portion of the original bed has escaped obliteration, it has become highly crystalline. Here and there is an exception to this statement, as in the case of the phosphatic shells, *Lingula* and *Discina*, in which frequently portions of the original tests remain. In the region under consideration nearly 200 species of fossils have been obtained from the beds of the Niagara group, yet the collector may spend days and obtain a mere handful of specimens to reward him for his trouble.

It may be noticed here that there is a bed near the top of the series at Dundas, several feet thick, that appears to be made up of breccia, the fragments being derived from older portions of the adjacent rocks.

During the long period required for the deposition of the limestones, the character of the organisms which inhabited the sea was subject to some important changes. One of these conspicuous periods has left its stamp in the "Chert beds," which are classed as No. 12 of the sections. The average thickness of this series of thin beds of limestone, filled with numerous concretions of cherty material, is eighteen or nineteen feet. The limestones are dolomites, as is shown by the previous analysis. By far the greater proportion of concretions show no organic structure, but yet, such large numbers when broken, show the internal sections of sponges, which mostly belong to the genera of *Astylospongia* and *Aulocopina*, that the origin of the siliceous nodules is at once apparent. On some portions of the brow of the escarpment, both at Hamilton and Dundas, these beds form the summit, and as the surface soil of the rocks weather, just beneath what is only a few inches of soil, the complete forms of the sponges become exposed by the action of the frost and of the plough. The sponge life was very considerable, that it could have afforded a sufficient source for so much soluble silica as to have produced the enormous amount of chert found in these beds. We know also that the variety of species was considerable. Nor was the sponge-life all that adorned the sea at that time. These beds are by far the richest in variety of species, from the lowest radiates to the higher types of life that are found in the Niagara series. It is also worthy of notice that it is in this small series that the greater portion of the rich *Graptolite fauna*, to be described in a succeeding paper, is found.

Just beneath these beds (No. 11 and 10) which are more shaly in character (of which the upper strata are known as "blue building beds"), we find our greatest number of *Trilobites* together with the high-type Crustacean, *Pterogotus canadensis* (Dawson), recently discovered by Col. Grant.

Another conspicuous epoch in the history of the ancient sea is marked by the great bed of dolomite (No. 8 of section). At no time was the sea so free from the influx of mechanical sediments. This bed with a thickness of about five feet forms an enduring monument for the myriads of crinoids whose remains most largely led to its formation, although subsequently it has absorbed magnesia. which in the re-crystallization of its molecules has obliterated all but the fragments of the original segments of their stems.

Another noticeable change in the rock-making organisms is found in a bed of dolomitic rock two and a half feet thick, almost literally filled with the remains of three or four species of *Stromatopora.* This stratum is near the surface bed at Carpenter's Limekilns. (Range VI, lot 15 of Barton) about three miles south of the centre of the city of Hamilton.

Besides the remains of life, as shown in these few more conspicuous beds, we find throughout the whole Niagara epoch that Bryozoons were numerous; Crinoids were abundant (in places, as at Grimsby, where some of the beds consist simply of masses of these stems). Corals were dominant in some localities, and Mollusks of every class were largely represented.

The Niagara limestones have been largely derived from broken shells, corals and other calcareous organisms, but subsequently the calcareous matter has combined with, or a portion of it has been replaced by, magnesia which had been precipitated amongst the comminuted organisms.

Henry C. Sorby, Esq., F.R.S., President of the Geological Society of London, (Q.J.G.S., May, 1879,) has shown that the condition in which calcareous matter is present in the structure of shells, or of allied forms of life, has much to do with the subsequent preservation of their remains in the rock, on the crystallization of their particles into solid limestones.

The principal condition in which lime is present in calcareous organisms is as the carbonate, either in the form of calcite or aragonite. However, there are some structures like the *Lingula*, where the lime occurs, as the phosphate, the same as in bones. The phosphate of lime is less apt to change its molecular condition than the carbonate, and, as a result, the shells of that material, or partially of it, are generally better preserved in the fossil condition than those of the carbonate. But these phosphatic shells have not contributed to any extent in the formation of the Niagara limestones.

The crystalline form of aragonite may be considered as an abnormal form of carbonate of lime, and Mr. Sorby shows that under various circumstances, it is easily resolved into the more stable form of calcite, whilst the carbonate, in the crystalline form of calcite, cannot be changed by any known process into that of aragonite. These two minerals form the principal constituents of the tests of shells—in some classes the aragonite being present, in others the calcite, and again in others the inner layer may be of aragonite and the outer of calcite, or *vice versa*.

Mr. Sorby gives the following classification of the mineral composition of the different orders of shells:

(*a*) *Crustacea.*—The mineral matter of crustaceans consists of calcite hardened on the surface with phosphate of lime.

(*b*) *Cephalopoda*—These shells are made up of aragonite together with a small amount of phosphate of lime.

(*c*) *Gasteropoda.*—In most of these genera the shell is wholly made up of aragonite, but in some the outer layer consists of calcite.

(*d*) *Lamellibranchiata.*—In many species of this group the tests are composed wholly of aragonite, in some entirely of calcite, whilst other shells have their inner layer of one material and the outer of the other.

(*e*) *Brachiopoda*, are composed wholly of calcite.

(*f*) *Echinodermata.*—Here the mineral matter is calcite.

(*g*) *Polyzoa* are composed of various mixtures of both minerals.

(*h*) *Hydroida and true corals* are made up of aragonite—the former class having a small quantity of phosphate of lime.

(*i*) *Foraminifera* are probably composed of calcite.

The removal of the organic matter holding the particles of the shell together disturbs the stability of the structure, and not only causes it to crumble by the disintegration along the lines between the different minute crystals, but also hastens a subsequent re-arrangement of the molecules into larger and less constrained crystals. Especially is this the case with fragments of aragonite which soon take the form of calcite, as is shown by the experiment of Mr. Sorby, where powdered coral (aragonite) kept for only a few weeks in water began to change into the condition of calcite. Moreover, this is not only an experimental test under favorable circumstances, but it is found that the modern limestones now forming about some of the West Indian Islands, have in places entirely lost or are losing the natural forms of the organic fragments of which they are composed. Again, the disintegrated fragments, which are assuming the more crystalline condition have their interspaces filled with carbonate of lime dissolved in the water, which was probably derived from the original material of the shells.

If the organic remains be included in a matrix of the same color, not only the form but also the certainty of its former presence in any position is apt to be lost. Especially is this the case with the corals and shells which are composed of aragonite. However, if the surfaces of the organisms were covered by thin layers of some foreign matter, as pyrites or mud, the former may still be preserved, but the place occupied by the structure will be found to have a more highly crystalline structure than the matrix itself, as the carbonate of lime of the shells, not having a great surface exposed by being broken into fragments, has more time for gradual re-arrangement of molecules, and, consequently, larger and more perfect crystalline forms are produced. This is found to be particularly the case with Lamellibranchiate shells (aragonite) in the rocks of the Niagara group at Hamilton, where only the remains of casts, procured in the manner just described are to be found, although some beds indicate that they were originally made up of a mass of these shells. The best preserved fragments of organic structure in our rocks are stems of crinoids, but these are generally re-crystallized, although they were even at first in the forms of small crystals of calcite.

The corals generally have become silicified but the forms are so far changed as to show that the original calcareous matter was re-crystallized before its replacement with silica was accomplished.

Some of the Graptolites are well preserved owing to the large amount of corneous matter that may have arrested molecular change. From obscure casts some of the beds of limestones appear to have been derived from Orthocerata. Brachiopods are the commonest fossils retaining any of their original appearance. Polyzoa are fairly preserved, especially in the "Chert bed," where also a few Gasteropoda retain their calcareous structure. In fact nearly all the fossils are better preserved in the "Chert bed" than elsewhere. This fact may in some way be accounted for owing to the presence of soluble silica derived from the sponges having cemented the calcareous plates together at the time when the animal matter of the structures was being gradually removed, for many of the fossils seem to be saturated with siliceous material.

The obliteration of the original calcareous organisms was completed by the physical changes which resulted in the combination of the calcareous matter, with the magnesian carbonate and the subsequent re-crystallization in the form of the double salt. According to the experiments of Mr. Sorby this was effected by the magnesia replacing a portion of the lime. But Dr. Sterry Hunt, many years ago, announced that, as indicated by his experiments, all magnesian limestones are derived from the precipitation of both carbonates simultaneously in an inland salt sea. At least as far as the Niagara dolomites are concerned, the calcareous organisms have played a most important part in furnishing calcareous matter, although the magnesian salt may have been exclusively derived from the evaporation of the waters in the immense inland Niagara waters, for at Grimbsy a bed of this dolomite shows its derivation almost exclusively from crinoids, and at Hamilton a similar bed in a more highly crystalline state, and filled with pores from the shrinkage, forms a marked feature of the series.

In the molecular change a condensation in volume would occur, thereby leaving the rock porous and permitting the carbonate of lime of the calcareous fossils to be washed out; as illustrated in the great bed of dolomite (No. 8 of sections) and some other beds, where the cavities have not been subsequently filled with argillaceous mud.

As a further illustration of the subsequent removal of the material of the shells by water, we need only go a little beyond the present region of study to the Guelph dolomites, where are numerous casts of shells in the porous stone, with the whole shell and its filling removed, thus leaving numerous cavities in the rock.

Dr. Hunt has conducted a series of experiments which throw light on the origin of dolomites. In lake basins where there is a considerable evaporation going on, the waters containing bicarbonate of soda cause the separation of all the lime as carbonate, and the formation of soluble bicarbonate of magnesia, which, subsequently on evaporation, separates in the hydrated form. The salts mingled together under deep pressure and heat will combine to form double carbonates. From the disintegration of feldspars and other rocks, an abundance of carbonates of soda, lime and magnesia, are constantly being brought down by streams and emptied into the sea basins. These chemical precipitates mixing with (and replacing according to Sorby) a portion of the calcareous sand derived from the organic remains in this region, have probably in a great degree given rise to our Niagara limestones, all of which are more or less of the character of true dolomites, but where some contain mechanical *detritus* as siliceous and argillaceous mud.

From this examination of the character of the limestones of the Niagara group, it is not surprising that there is such a paucity of fossils in this great development of rocks so largely composed of their remains. In very many strata I have found no fossils whatever, and even in those where they are most abundant, one is rewarded only after a long patient search. Yet, with all these difficulties, the geologist may collect in the region of our study a large number of species, of which there are catalogues under those parts of this paper on the Medina and Clinton epochs, and a still larger list at the end of this portion of the paper on the Niagara epoch proper.

VII.—MINERALS OCCURRING IN THE NIAGARA GROUP.

Excepting the beds of stone fit for building purposes and for burning to lime, there are no minerals about the western end of Lake Ontario of economic importance. However, many years ago some futile attempts were made south of the village of Beamsville to work a small "find" of galena The only sandstones fit for building purposes is the "Gray band" of the Medina formation. Blocks of this stone of any dimension that can be handled are obtainable. This stone has been extensively worked at Dundas, Hamilton, Grimsby and Beamsville. A great drawback in quarrying this material is that it can only be procured along the edge of the escarpment, and requires a vast amount of the shaly rocks of the Clinton formation to be removed, and even then the supply is of a limited quantity. The stone is very tough and hard on tools. I am informed that this rock was formerly manufactured into grindstones. The majority of the beds of limestone are too thin, or inferior, for anything more than the roughest building material. However, there is a sufficient number of layers to supply an abundance of building material of which the handsomest is obtained from the great dolomite (No. 8) and the subjacent beds. In fact all the beds belonging to the Niagara series, that will at all admit of use, are quarried at Hamilton, and the broken material of the "Chert band" and other layers is used for road metal, and only the more shaly limestones are rejected. The "Blue-Building beds," although somewhat earthy, form fair building material. At the old quarry along Rosseaux Creek, and elsewhere, in the higher portion of the series, good, fairly thick blocks of dolomite can be obtained

Though the limestones are generally rather dark, they burn to white lime, as the coloring is derived from organic matter. The principal limekilns are supplied from the highest beds of the Niagara series in the region of Hamilton and Dundas, while at Limehouse, on the Grand Trunk Railway, the lower beds are light colored, rather pure, and form excellent lime—Toronto and many other places being supplied with immense quantities of the product of these kilns. Some of the beds also burn to hydraulic cement.

However, there are interesting minerals in this region, other than those which can be turned to use in the arts. The first of these minerals that we will notice is *epsomite*. This mineral occurs on both sides of Glen Spencer. It is found as an efflorescence on the edges of the Niagara shales which are protected by overhanging thick beds of dolomite. This salt has arisen from the disintegration of the adjacent dolomitic beds and the action of decomposing pyrites. In various other protected places this efflorescence is seen, but it does not consist of pure *epsomite* being mixed with carbonate of lime, carbonate of iron, sand and clay.

In the five foot bed of dolomite (No. 8) fine cabinet specimens of *selenite* and crystalline *barite* can be obtained. Also massive *gypsum*, handsome crystals of *calcite* (variety of dog-tooth spar), *celestite* and *quartz* in small crystals, as well as *iron pyrites* are found. Many of the cavities when broken open are found to be filled with alkaline waters. In one of the Clinton beds, east of the "Jolly Cut" road, I have found fine red and green crystals of *barite*. However, the handsomest specimens were obtained in Carpenter's Quarry, on lot 7, Range VII, of Barton, not now worked. Fine specimens of crystallized *dolomite* (pearl spar), *calcite* (in large scalene dodecahedrons, and in other modifications of rhombohedrons), *blende*, *pyrites*, *galena*, purple, smoky and yellow *fluorite* in fine cubes, and several forms of *bituminous matter*, both liquid and solid (a variety of which was elastic) were found in considerable quantities filling the cavities of the rock, and often lining what were once crystallites. It was in beds of similar horizon at Beamsville that the galena was found and worked many years ago. The horizon of the beds is from 130 to 145 feet ~~above~~ the base of the Niagara in the neighbourhood of Hamilton.

In numerous places mineral waters are found. These are of two classes—alkaline and sulphuretted waters. Of the former class there are numerous springs along the sides of the escarpment. Similar waters have also been obtained in various wells that have been bored to a considerable depth. One of these wells was bored nearly, or perhaps, quite through the Medina shales at the Ontario Oil Refinery, east of Hamilton. The water of this place, I analysed in 1871.

Sodium chloride....	2·28
Magnesium chloride	0·60
Calcium Chloride..................	1·67
Potassium chloride...............	a trace
Calcium sulphate..................	0·20
Residue	·10
Water............................	94·90
	99·75

Another of these mineral waters was obtained at a depth of 1009 feet in Cambro-Silurian beds from the Artesian well at the Royal Hotel, Hamilton. The following analysis was made in 1870:

Sodium chloride	6·3711
Magnesium chloride	1·2723
Potassium chloride.............	traces
Calcium chloride	5·2723
Calcium Sulphate	·1167
Silica, iron, carbonic acid, ... iodine and bromine...........	traces
Water	86·9676
	100·0000

Unfortunately the record of this well was burned, although a little of the saline water still remains in my possession.

Of the second class—sulphuretted waters—we find a few springs, the principal being at Mount Albion, and at Sulphur Springs, Ancaster. One of the old springs near Mount Albion is now dried up. From others in this place the supply of gas has continued to be evolved for many years, and three jets of this gas, essentially sulphuretted hydrogen, are used to light Albion

Mills; the proprietor having built a reservoir of hydraulic cement over the spring. At "Sulphur Springs," Ancaster, the amount of gas is not so large, and the supply is scarcely more than enough to saturate the water, from which the sulphur is precipitated on exposure to the air. In both of these localities the gas arises from decomposing pyrites in the surrounding rocks.

VIII.—CATALOGUE OF NIAGARA FOSSILS FROM CANADIAN LOCALITIES.

In the following catalogue I have endeavoured to give a full list of all the fossils that have been discovered in the region under consideration. As no extensive Canadian catalogue has been published, I have been compelled to depend largely on my own collection, many species of which have been presented to me by Col. Grant. A few of the included species are not in my collection, having years before been sent away from the region by the collectors, of whom Col. Grant is the most indefatigable. The best collection of *Sponges* and *Stromatopora* is that of Mr. A. E. Walker. Of the former group several species have remained undescribed. Some of the species, including most of the *Graptolite family*, are the TYPE SPECIMENS, descriptions of which are about to be published. Had Col. Grant retained all his own collection, he would have been able, no doubt, to have considerably swelled my list.

The best localities at Hamilton for collecting fossils are at the "Jolly Cut," and in the adjacent openings in the quarries along the sides of the "Mountain," both east and west of this place. Also, in the gorges at the heads of James and Queen streets; at the "Bluff," near the city reservoir; along the Hamilton and North-Western Railway to the summit of the hills; in the ravines near Mount Albion; on lots 4 and 5, Range VII, of Barton, along the Rosseaux Creek; and on lot 15, Range VI, of the same township. At Dundas, the various glens form the best localities, as well as Sydenham road. At Grimbsy the richest fauna is found up the "Ravine," where the fossils are in a better state of preservation than at any other place in our Province. Other localities are at Thorold, Limehouse (on the G. T. Railway), and Rockwood.

CATALOGUE OF NIAGARA FOSSILS.

GENERA AND SPECIES.	AUTHORITY AND REFERENCE.
Stromatopora concentrica	Goldfuss, 1820, Germ. Petref.
Caunopora walkeri	Spencer, 1882, Niagara Fossils
" *mirabilis*	" "
Coenostoma constellatum	Hall, 1852, Pal. N. Y
" *botryoidea*	Spencer, 1882, Niagara Fossils.
Dictyostoma reticulata	" "
Astylospongia praemosa	Goldfuss, 1880, Petref. Germ.
" *sp.*	
Aulocopina granti	Billings, 1875, Can. Nat.

HYDROZOA.

GRAPTOLIDÆA.

GENERA AND SPECIES.	AUTHORITY AND REFERENCE.
Palæograptus (?) dubius	Spencer, 1882, Niagara Fossils.
Dendrograptus ramosus	" "
" *simplex*	" "
" *dawsoni*	" "
" *frondosus*	" "
" *praegracilis*	" "
" *spinosus*	" "
Callograptus niagarensis	" "
" *granti*	" "
" *(Dendrograptus) multicaulis.*	" "
" *minutus*	" "
Dictyonema retiforme	Hall, 1852, Pal. N Y.
" *gracilis*	" "
" *websteri*	Dawson, 1868, Acad Geol.
" *tenellum*	Spencer, 1878, Can. Nat.
Calyptograptus cyathiformis	" " "
" *subretiformis*	" " "
" *micronematodes*	" 1882, Niagara Fossils.
" *(?) radiatus.*	" " " "
Rhizograptus bulbosus	" 1878, Can Nat
Acanthograptus granti.	" " "
" *pulcher.*	" 1882, "
Inocaulis plumulosa	Hall, 1852, Pal. N. Y.
" *bella*	Hall & Whitfield, 1874, Pal. Ohio.
" *walkeri.*	Spencer, 1882, Niagara Fossils.
" *problematica.*	" 1878, Can. Nat.
" *diffusa.*	" 1882, Niagara Fossils.
" *ramulosa*	" " " "
" *cervicornis*	" " " "
" *phycoides*	" " " "
Thamnograptus bartonensis.	" " " "
" *(?) multiformis*	" " " "
Ptilograptus foliaceus	" 1878, Can. Nat.
Cyclograptus rotadentatus	" 1882, Niagara Fossils.

ACTINOZOA.

TABULATA.

Favosites niagarensis	Hall, 1852, Pal. N.Y., Vol II.
" *favosus*	Goldfuss, 1826, Germ. Petref.
Astrocerium (*Favosites*) *constrictum*	Hall, 1852, Pal. N.Y., Vol. II.
Syringolites huronensis	Hinde, 1879, Geol. Mag.
Cladopora multipora	Hall, 1852, Pal. N.Y., Vol. II.
Striatopora flexuosa	" " " "
Halysites catenulatus	Linnæus, 1767, Syst. Nat.
Syringopora verticillata (?)	Goldfuss, 1826, Germ. Petref.

RUGOSA.

Cyathophyllum radiculum	Rominger, 1876, Fos. Corals in Geol. Mich., Vol. III.
Omphyma stokesi	Milne-Edwards, 1876, Fos. Corals in Geol. Mich., Vol. III.
Petraia Streptelasma calycula.	Hall, 1852, Pal. N.Y., Vol. II.

ECHINODERMATA.

ASTEROIDEA.

Petaster bellulus	Billings, 1865, Pal Foss., Vol I.

CRINOIDEA AND CYSTOIDEA.

Lyriocrinus dactylus	Hall, 1852, Pal. N.Y., Vol. II.
Thysanocrinus liliiformis	" 1852, " "
Eucalyptocrinus decorus.	Phillips, 1829, Murch. Sil. Syst.
Stephanocrinus angulatus	Conrad, 1842, Jour. Acad. Nat. Sc.
Caryocrinus ornatus	Say, 1825, " "

POLYZOA.

Ceramopora foliacea	Hall, 1852, Pal. N.Y., Vol. II.
Clathropora (?) *gracilis*	Spencer, 1882, Niagara Fossils.
Fenestella elegans	Hall, 1852, Pal. N. Y., Vol. II.
Polypora (*Fenestella ?*) *albionensis*	Spencer, 1880, Niagara Fossils.
Lichenalia concentrica	Hall, 1852, Pal. N.Y., Vol. II.
Trematopora osteloata	" " " "

BRACHIOPODA.

SPIRIFERA.

Spirifera crispa	Hisinger, 1826, Act. Acad. Nat. Sc.
" *niagarensis*	Conrad, 1842, Jour. " "
" *radiata*	Hisinger, 1857, Petref. Suecica.
" *sulcata*	Sowerby, 1825, Min. Concl.
" *plicatella*, var *radiata*	Hall, 1867, 20th Regent's Report.
Atrypa reticularis	Linnæus, 1767, Syst. Nat.
Athyris (*Meristina*) *nitida*	Hall, 1852, Pal. N.Y., Vol. II.

RHYNCONELLIDAE.

Rynconella neglecta	Hall, 1852, Pal. N.Y., Vol. II.
" *obtusiplicata*	" " " "
" " var	" " " "
" *rugosa*	" " " "
Pentamerus oblongus.	Vanuxem, 1842, Geol. 3 Dist. N.Y.
Stricklandinia canadensis.	Billings, 1859, Can. Nat.

STROPHOMENIDAE.

Strophomena profunda	Hall, 1852, Pal. N.Y., Vol. II.
" *rhomboidalis*	Wallenberg, 1821, Act. Soc. Sci. Upsala.
Strophodonta semifasciata	Hall, 1863, Trans, Alb. Inst.
Streptorhyncus tenuis	" 1858, " "
Leptena transversalis	Dalman, 1827, Kongl. Vet. Acad. Hanal.
Orthis elegantula	Dalman, " " "
" *flabellelum*	Hall, 1843.
" *porcata*	McCoy, 1846, Sil. Foss. of Ireland.

CRANIADÆ.

Crania anna	Spencer, 1882, Niagara Fossils.

DISCINIDAE.

Discina tenuilamellata	Hall, 1852, Pal. N.Y., Vol. II
" *clara*	Spencer, 1882, Niagara Fossils.

LINGULIDEA.

Lingula oblonga	Conrad, 1839, Ann. Rep. N.Y.
" *lamellata*	Hall, 1852, Pal. N.Y., Vol. II.
" *ingens*	Spencer, 1880, Niagara Fossils.

LAMELLIBRANCHIATA.

Avicula emacerata	Conrad, 1842, Jour. Acad. Nat. So.
Pterinea brisa	Hall, 1867, 20th Regent's Rep. N.Y.
Posodonomya rhomboidea	" 1852, Pal. N.Y., Vol. II.
Modiolopsis subalata	" " " "
" sp.	" " " "

GASTEROPODA.

Platyostoma niagarensis	Hall, 1852, Pal. N.Y., Vol. II.
Lonoxema leda	" 1867, 20th Regents Rep., N.Y.
Pleurotomaria clipeiformis	Spencer, 1882, Niagara Fossils.

PTEROPODA.

Conularia niagarensis	Hall, 1852, Pal. N.Y., Vol. II.
" *magnifica*	Spencer, 1879, Can. Nat.
" *rugosa*	" 1882, Niagara Fossils.

CEPHALOPODA.

Orthoceras virgatum	Sowerby, 1839, Murch. Sil. Syst.
" *annulatum*	" 1818, Min. Concl.
" *simulator*	Hall, 1876, 28th Reg. Rep. N.Y.
" *crebescens* (?)	" 1867, 20th " "
" *bartonense*	Spencer, 1882, Niagara Fossils.
Cyrtoceras reversum	" " "
Lituites niagarensis	" " "

ANNELIDA

Cornulites flexuosus	Hall, 1852, Pal. N.Y., Vol. II.

CRUSTACEA.

TRILOBITA.

Illaenus barriensis	Murch. 1839, Sil. Syst.
Encrinurus ornatus	Hall, 1852, (vid Cybele punctata).
Sphaerexochus romingeri	“ 1867, 20th Reg. Rep. N.Y.
Calymene blumenbachii	Brongniart, 1822, Hist. Nat. Const. Foss.
Homalonotus delphinocephalus	Green, 1832.
Dalmanites limulurus	“ “
Lichas boltoni	Bigsby, 1825, Jour. Acad. Nat. Sc.,
Acidaspis halli	Spencer, 1880, Niagara Fossils.

EURYPTERIDÆ.

Pterygotus Canadensis	Dawson, 1879, Can. Nat.

APPENDIX.

Besides the previous catalogues of fossils found in the different formations of the Niagara Group in Canada, Messrs. Nicholson and Hinde have obtained the following species :

CLINTON.

Scolithus verticalis	at Dundas.
Arenocolites sparsus	“
Planolites vulgarus	“
Stromatopora lundii	at Owen Sound.
Zaphrentis stokesi (?)	“ “
Chaetetes fletcheri	at Dundas.
Phaenopora ensiformis	“
Ptilodictya crassa	“
“ (?) *raripora*	“
“ *punctata*	“
Leptocoelia planoconvexa	“
Orthis calligramma	“
Leptaena sericea	“
Tentaculites neglectus	“
Glyptocrinus plumosus	“

NIAGARA.

Stromatopora hindei	at Owen Sound.
Heliolites interstincta	“ “
Favosites venusta	“ “
“ (?) *multipora*	“ “
“ *dubia*	“ “
Cœnites (*Limaria*) *laminata*	“ “
“ *lunata*	“ “
Alveolites fischeri	“ “
“ *niagarensis*	at Richmond.

Astræophyllum gracile	at Owen Sound.
Caunopora annulata	" "
Syringopora retiformis	" "
Zaphrentis Roemeri	" "
Cystiphyllum vesiculosum	at Thorold.
Petraia pygmæa	"
Diphyphyllum cæspitosum	"
Clathopora fondosa	"
" *intermedia*	"
Retepora asperato-striata	"
Trematopora osteolaia	at Niagara River.
Fenestella tenuiceps	" "
Athyris intermedia	" "
Strophomena subplana	at Thorold.
Orthis biforata	"

In the catalogue above-named we find 34 species of Clinton and 49 of Niagara fossils, collected by Messrs. Nicholson and Hinde, of which the above 39 species have not been obtained by me, or in so poorly preserved condition as to be rejected from my cabinet. In the catalogue the names of fossils are not usually placed in two formations, but only in that where they more generally occur.

In the catalogue of the fossils of the Medina, Clinton and Niagara, given here, there will be found 121 species of Niagara and 53 of Clinton and Medina, of which only a few species are repeated in the lists. The principal omissions in my cabinet are in the poorly preserved specimens of the Clinton, at Dundas, and in the species found at Thorold and Owen Sound. Neither of the lists includes 13 species of annelid jaws, recently described by G. J. Hinde, Esq.

APPENDIX A.

Catalogue of Fossils of the Hudson River Formation, found in the Old Beaches at the western end of Lake Ontario.

The study of the occurrence of these fossils belongs, strictly speaking, to the Drift, which will be described in a subsequent paper. From the Palæontological point of view, they are more interesting in connection with this portion of the study of the Geology of the Region about the Western End of Lake Ontario than in that of the Surface Geology.

The following is a list of the fossils which I have obtained in considerable quantities from the fossiliferous pebbles of both the ancient and modern beaches in the region of Hamilton:

Stenopora fibrosa, Goldfuss.
Columnaria alveolata, Billings.
Athyris headi, Billings.
Strophomena alternata, Conrad.
Strophomena deltoidea, Conrad.
Leptæna sericea, Sowerby.
Orthis testudinaria, Dalman.
Orthis occidentalis, Hall.
Orthis lynx, Eichwald.
Obolella crassa, Hall.
Modiolopsis modiolaris, Conrad.
Modiolopsis ——— (several undermined species).
Cyrtodonta harrietta, Billings.
Orthonota ———
Ctenodonta ———
Lyrodesma poststriata, Emmons.
Ambonychia radiata, Hall.
Avicula demissa, Conrad.
Murchisonia gracilis, Hall.
Cyrtolites ornatus, Conrad.
Orthoceras lamellosum, Hall
Ormoceras crebiseptum, Hall.
Leperditia canadensis, Jones.

APPENDIX B.

Since writing the Report on the Palæozoic Geology of the Region about the Western End of Lake Ontario, I have observed that Dr. Hunt, in his Report on the Canadian Petroleum Regions of Canada (1863–66), gives the log of a well sunk on the eleventh lot of the seventh range of Barton, which is as follows:

Limestones with a little shale	250	feet
White sandstone	5	"
Red shales with bluish bands	595	"
Bluish and grayish shale	23	"
	873	"

The location of this well is about two and a half miles southward of the brow of the "Mountain" at Hamilton. The upper 250 feet include both the Niagara and Clinton formations, which measurement is almost precisely the same as the thickness of these strata ascertained by measurement at Dundas. Consequently, we may consider the summit beds in both places as nearly identical, whilst the beds at Carpenter's Limekilns, not much more than a mile distant from the Barton well, are geologically and geographically higher than at its mouth, but geographically lower than the inferior beds at Dundas, on account of the dip of the strata.

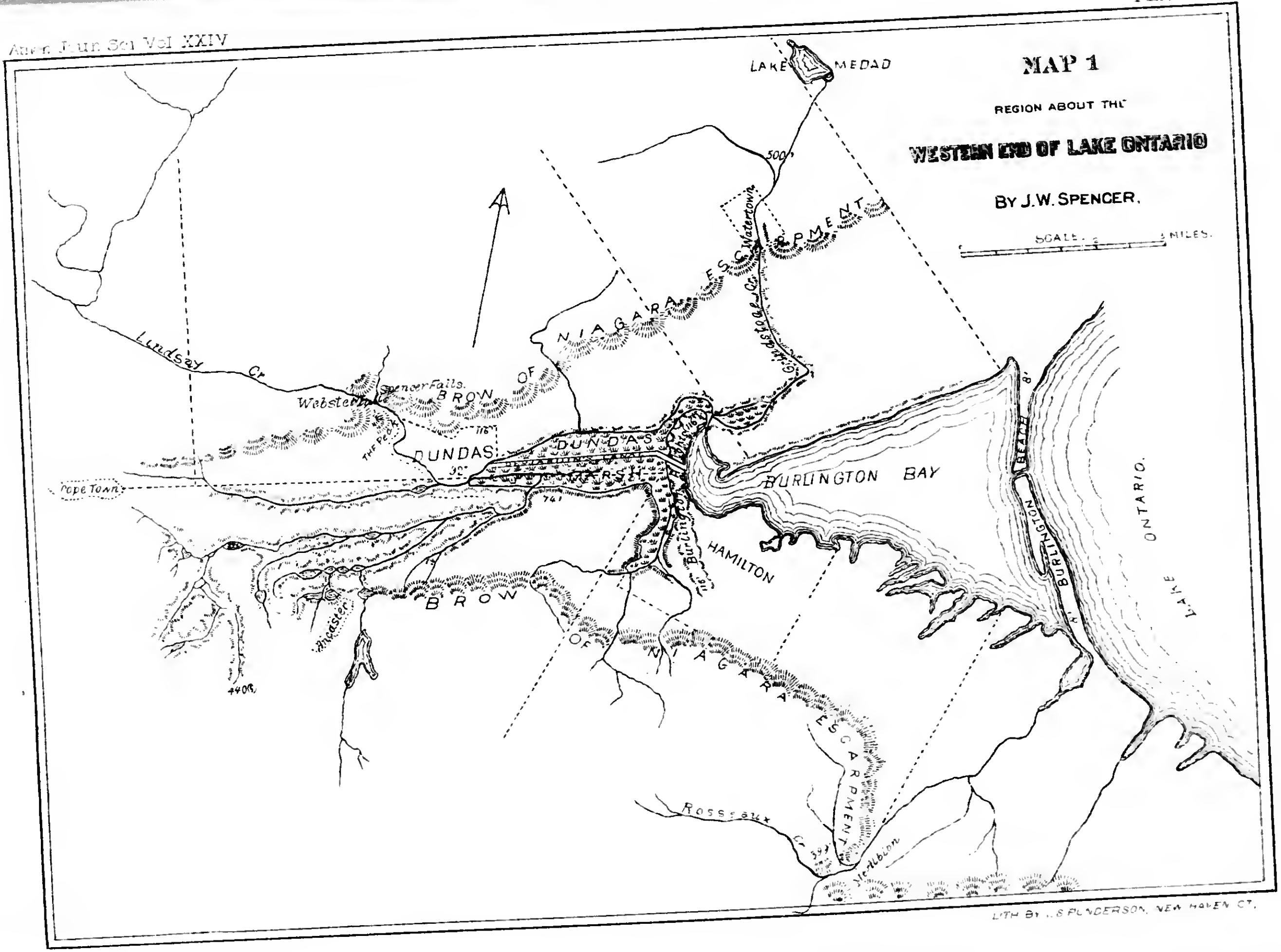
The five feet of sandstone constitute the prevailing "Gray Band" of the Medina formation.

The thickness of the Medina shales appears to be 595 feet. I have placed the thickness of the Medina shales at 535 feet; this being derived from the record of the well at Dundas, where they are underlaid by "limestones and grits," whilst in the Barton well the *red shales* are underlaid by "bluish and grayish shales," which probably belong to the Hudson River group.

It must be remarked that the Dundas well is not far beyond the turn in the bend of the Niagara escarpment, which I have designated by the name of ancient Cape Dundas. In the previous Report attention has been frequently called to the fact that all the shaly deposits decrease, and those which are calcareous increase the moment that we pass around the provisionally called Cape Dundas. In proceeding northward the Medina shales thin out and are last seen at Cabot's Head, and, according to Dr. Bell, are entirely absent from the series in the Manitoulin Island. Therefore this difference of about 60 feet is one of thickness and not of error. It was also noticed that in proceeding south-westward towards Ohio, that the Medina shales almost entirely disappear.

Had I known of the existence of the well in Barton at the time that I took the levels over the adjacent localities, it would have given an additional point for correcting the estimate of the dip. The altitude of the place, about a quarter of a mile north-east of the well, is 435 feet above Lake Ontario, while at a quarter of a mile to the eastward, it is 424 feet on a surface of rocks. Calculating from these data, the dip would be between 22 and 27 feet in a mile, but as the well is between these two points, we can retain our old estimate of 25.4 feet in a mile, having a direction of 20 degrees west of south.

PLATE VI.



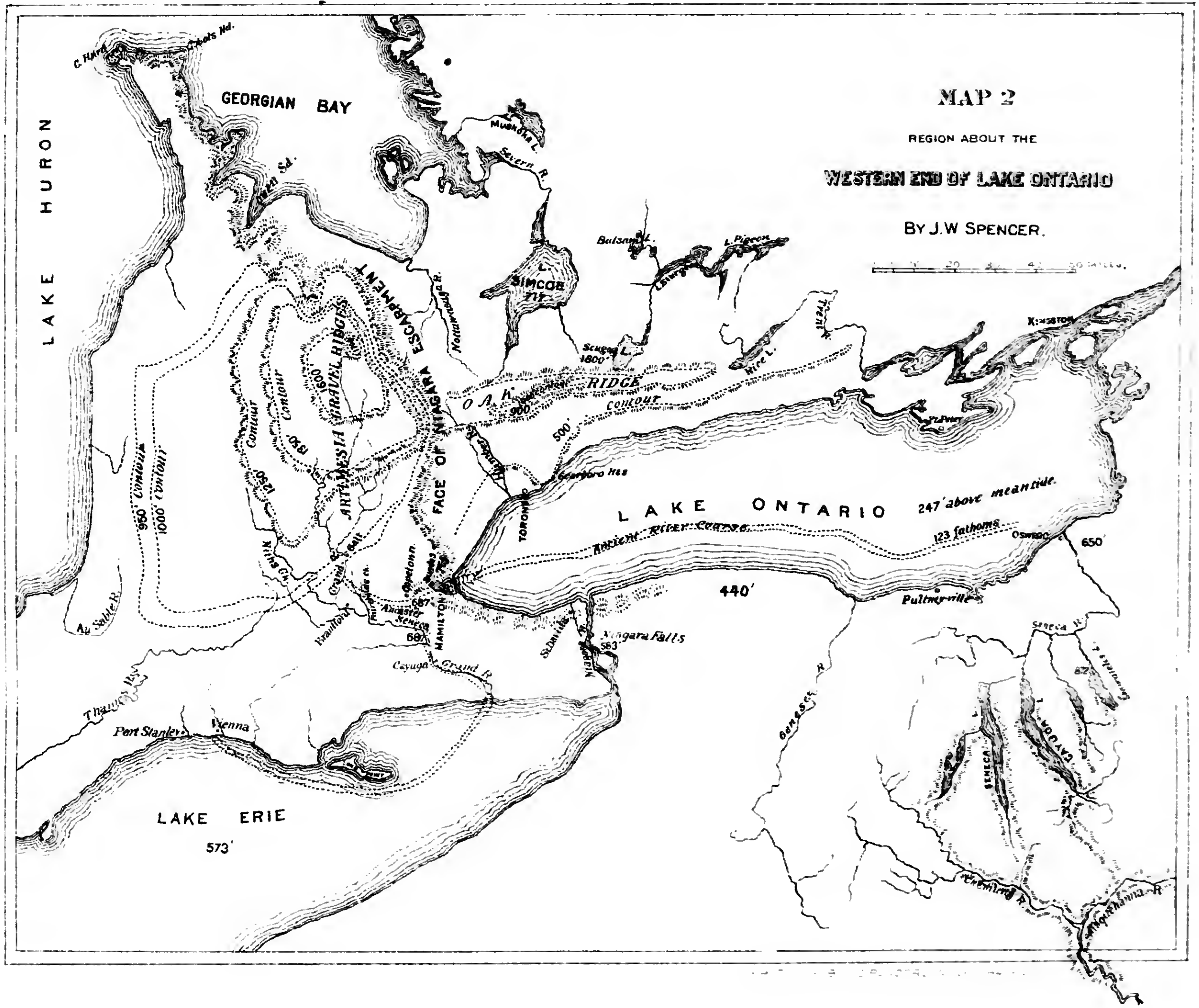
MAP 1

REGION ABOUT THE

WESTERN END OF LAKE ONTARIO

BY J. W. SPENCER.

LITH BY L.S. PUNDERSON, NEW HAVEN CT.



MAP 2

REGION ABOUT THE

WESTERN END OF LAKE ONTARIO

BY J.W SPENCER.

SURFACE GEOLOGY OF THE REGION ABOUT THE WESTERN END OF LAKE ONTARIO.

By J. W. Spencer, B.A.Sc., M.A., Ph.D., F.G.S.,
Vice-President of the University of King's College, Windsor, Nova Scotia.

(This Paper is Part II. of the "Geology of the Region About the Western End of Lake Ontario." For Part I., see this Journal. Vol X., No. 3.)

I.—INTRODUCTION.

We have seen in Part I. of the "Geology of the Region about the Western End of Lake Ontario" that a large and varied study may be made out of the exposures of the old rock-formations. In the present portion of the study, it will be found that the *Surface Geology* is not only of local interest, for, from it we are taught many things concerning the vexed subject of glacial geology;—about the origin of the Lower Great Lakes, the terraces and the transportation power of pan or floe ice, besides the physiography of the region before the advent of the Ice Age and especially the causes which combined to form this very picturesque region of Canada.

In Part I, on the Palæozoic Geology, a portion of the surface features were described with reference to the exposures of Palæozoic formations. The present descriptions of topography have reference only to the Surface Geology.

In order to more fully explain the causes which conspired to bring about the present features, it is necessary to wander somewhat beyond the Region about the Western End of Lake Ontario. The descriptions of the topography and a portion of the study of the origin of the Lower Great Lakes have already been published*

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* "Discovery of the Preglacial Outlet of the Basin of Lake Erie into that of Lake Ontario; with Notes on the Origin of our Lower Great Lakes." By J. W. Spencer, B.A.Sc., Ph.D., F.G.S., King's College, Windsor, N. S. Read before the American Philosophical Society, March 18, 1881, and published in the Proceedings of the Society. The same paper was re-published in Report Q., of the Pennsylvania Geological Survey, with Notes by Prof. J. P. Lesley, the Director. A portion of the paper on the Origin of the Lakes is copied from my Paper on the subject, read before A.A A.S., Cincinnati, Aug., 1881.

but will here be reprinted with some alterations without quotation marks.

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 Manitoulin 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 brow 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 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 Hamilton 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

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* The topography is partly represented on map accompanying Palæozoic Geology. Burlington Heights is the spur of land between the Marsh and Burlington Bay.

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 to 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. Farther to the northward the country rises until it reaches an altitude of 1462 feet above Lake Ontario, or 1709 feet above the sea, near Dundalk station, on the W. G. & B. Railway. The features of the surface of the country above the highlands north of Dundas are much more varied than south of 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.

*Basin of Lake Ontario.**—As is well known, Lake Ontario consists of a broad shallow (considering its size) basin, excavated

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* The various Canadian railways and canals, whose elevations are referred to sea level, take Lake St. Peter as the datum. This represents high tide in the St. Lawrence River. The elevation assigned to Lake Ontario is 235 feet (by the Grand Trunk Railway) and 232 feet, according to different Canadian authorities, (above Lake St. Peter). The U. S. Lake Survey places Lake Ontario at 246·91 feet, and Lake Erie at 573·60 feet above mean tide. The Welland Canal places Lake Ontario at 326·75 feet below Lake Erie (which is now generally acknowledged to be 573 feet above mean ocean level). Therefore in all future references to elevation above mean tide, I have taken Lake Ontario at 247 feet.

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 occupy the middle portion, and the Trenton limestone 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 Lake Ontario and the foot of the escarpment at Limehouse (on the G. T. Railway) 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 bay, thus formed, is connected with the open lake by a canal of the same name. 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 backwater.

West of the meridian of the Niagara river the lake is evidently filled with more silt than 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 lake 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 about 600 feet deep, 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 Edward's 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.

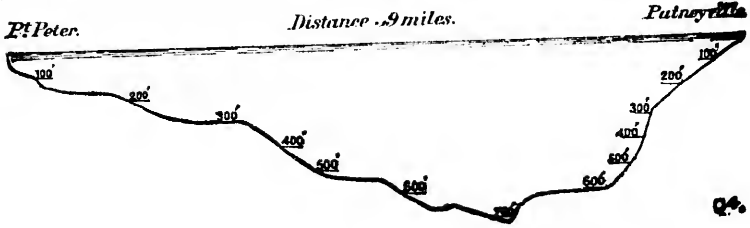
In the region of these soundings the deepest water outside of the 78-fathom line is 84 fathoms, whilst from the shore to the 43-fathom sounding the least distance is four and a half miles, thus giving the greatest mean slope of the lake bottom at sixty feet in a mile, before the escarpment is reached.

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

Distance from Putneyville.		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 Putneyville, N.Y.



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 existence of a continuous escarpment which 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 a depth not 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 can 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 Haldimand 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 (Corniferous limestone.)

The Dundas Valley and adjacent Cañons.—We may consider that the Dundas valley begins at the "bluff" east of the Hamilton reservoir, and extends westward, including the loca-

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

tion 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—many rounded and resembling *roches montounées*. 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 interglacial and 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 southern 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 northern 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 these 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 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, but only the removal of a little *débris* at the base. 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 surface of the escarpment on both sides of Glens Spencer and Webster presents 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 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 Grey, 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 plain. 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 Brant, 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, and feed the Lindsay creek. which 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 the Grand river 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 Paris, Nith'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, where the stream has cleaned out a portion of one side or other of its ancient valley.

Between the elevated plateau (of nearly 100 feet close to Lake Ontario) south of Brantford and that rolling country of equal height near Harrisburg, the alluvial-covered plain of from 400 to 460 feet above lake Ontario, more than ten miles wide, may be considered as a portion of an ancient enlargement of the great river basin.

At the Great Western Railway crossing east of Paris, the bed of the river has an altitude of 495 feet above Lake Ontario, whilst at Brantford it is 398 feet 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 a quarter of a mile wide, flowing near the southern side of a valley, more than two miles wide.

At Seneca the bed of the present river course is 365 feet above Lake Ontario, or only 37 feet above Lake Erie. Eastward of Seneca, the river continues to have its broad valley as far as Cayuga, where the hard bed of the river is below the surface of Lake Erie.

From Seneca to Cayuga the direction of the river 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 Corniferous 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.

The Grand river valley (75 feet deep) is more than two miles in width and bounded by lateral elevations of 440 feet above Lake Ontario, or 113 feet above Lake Erie; and farther by boundaries; on both sides, of 160 feet above the latter lake.

At Dunville, a few miles from the mouth of the river, piles were driven to a considerable depth without reaching hard rock. The margins of the valley are small, composed of either the more or less shaly Onondaga rocks, or Corniferous limestone. In the meanderings of the river from one side of the valley to the other, it occasionally crosses spurs of earthy Onondaga limestones, but the character is not such as to preclude the possibility of an adjacent buried river channel. At most, all the waters that could come down the Grand river, even with an increased pitch of the country, and a larger precipitation of moisture would scarcely be able to more than excavate its present bed. The country on either one side of the river or other is remarkably broken within the limits of the valley, but beyond it is equally remarkable for its level surface. This broad peculiar valley bears a strong contrast to that of the upper portion of its course (as at Elora) where the *cañon* could have easily been excavated by the present stream if sufficient time were given.

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 397 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 stratified clay.

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 highest point that I have levelled is 492 feet above Lake Ontario. On receding westward from the divide, the country gradually descends to the Fairchild's creek. 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 interglacial or modern 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 220 feet below the surface of the escarpment. On going westward we find that the streams have not cut to an equal depth, but are still running deeply through drift.

On reaching the divide west of Ancaster village, we find that the valleys, excavated out of the drift belonging to both the Dundas valley and Grand river drainage, inosculate at an elevation of about 460 feet above Lake Ontario, thus showing the former connection of the basins more than 100 feet below the rocky flows which surround them. Even in this depressed area wells are known to reach 60 feet in the drift without meeting with solid rock.

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 farthér than boulder clay. This last well must have been in a buried channel of Nith'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 a 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. 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 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 nearing 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. 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.—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 southwest, 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 Fairchilds'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 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 in August, 1880. 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.

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 beame apparent that Lake Erie had flowed through the Grand river valley 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,

Fig. 2.

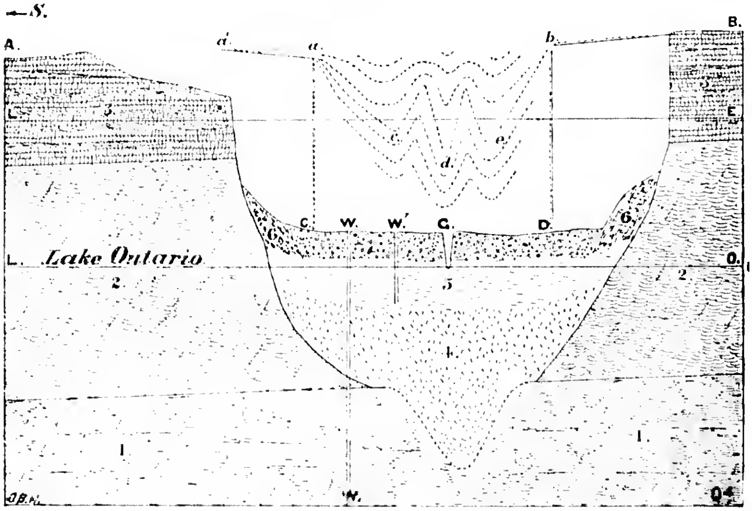

Fig. 2.—1. Hudson River formation: 2. Medina shales; 3. Niagara and Clinton dolomites with some shales. A, C, D, B, modern valley at meridian of Burlington heights; a, C, D. b, modern valley at meridian of Dundas; a, c, d, e, b, sections across, deeply excavated in beds of streams in western part of 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.

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.

From a careful study of the broad valley of the lower portion of the Grand river, it becomes apparent that it was a portion of the outlet of Lake Erie, which passing to the region of Seneca village, turned towards the Dundas valley, although the present river exposes shaly Onondaga rocks, occasionally as it approaches the margins of the old valley.

Again Mr. Carll has shown that the Alleghany 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, 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 at 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 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 reached the meridian of Oswego.

With such an outlet, and with the ancient Grand river valley buried by greater or less depth, we have an easy solution to the problem of the drainage of Lake Erie. Moreover the present barrier between the lakes may have quite probably been increased by local elevation of the land as we find the indications pointing to the Dundas valley being along the axis of an anticlinal of less than one degree of dip.

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 been 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 Guyahoga, 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 the 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 Alleghany 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. 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. In addition to this drainage I have pointed out the probability* that the Mahoning and upper Ohio, with the Beaver (reserved), Mahoning (reserved) and Grand (of Ohio) rivers formed a nearly straight valley, from the western side of the mountains of Virginia to Lake Erie.

Thus we find three large areas now flowing southward formerly emptying into 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 Genesse and other large rivers along its course.

Not only is the Dundas valley a deeply buried channel, but nearly all the streams that enter Lake Ontario are flowing over more or less deeply buried channels.

ORIGIN OF THE LOWER GREAT LAKES.

All of the chain of Great Lakes of North America are excavated principally out of the more or less shaly almost horizontal rocks of the various basins. They are all valleys of erosion (excepting perhaps, a portion of Lake Superior.) The erosive action of the atmospheric agencies would tend to wear the country into undulating basins,—for only such are the bottoms of the great Lakes. It is true that slight geological undulations may have determined the position of the lake-basins. The basins of Lakes Michigan, Huron and Ontario, especially, are traversed by long sub-lacustrine valleys resembling those of large rivers, and bounded by escarpments, which rise abruptly several hundred feet high. The description of the lake beds—the probable Preglacial outlets of Lakes Superior and Michigan (discharging their waters to the Mississippi valley ; the outlet of Lake Huron

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* See Proc. Am. Phil. Soc. XIX, 108.

(at least during a portion of its history) across the southwestern counties of the Province of Ontario, and entering the Erie basin somewhere between Vienna and Port Stanley; as well as a former outlet of Lake Erie into Lake Ontario, have been discussed somewhat fully in my paper published in the Transactions of the American Philosophical Society, already referred to. In order to keep nearer to the present subject of study, I will confine my remarks on the "Origin of the Lakes," to that of Lake Ontario, for the other lakes give corresponding testimony.

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.

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.

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

The river coming down the Dundas valley flowed originally 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 and the limestones were undermined, the NIAGARA ESCARPMENT was 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 600 feet). During some portion of the tertiary times, at least the eastern portion of the continent must have stood a thousand or twelve hundred feet higher than at present, as indicated by the soundings in the St. Lawrence river (near the mouth of the Saguenay), in the New York Harbour and off the mouth of the Chesapeake Bay.

The rate at which the upper lakes was excavated would depend partly upon 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.

At the time when the "Preglacial outlet of the Basin of Lake Erie, &c." was written (Feb. 1881) I felt confident that the Preglacial outlet of Lake Ontario would be more or less easily revealed, and therefore neglected to give due consideration to the erosion that would be effected by the action of the rain and rain-water. This may well be summed up by quoting from a criticism on my above mentioned paper, by Prof. J. P. Lesley, the Director of the Geological Survey of Pennsylvania[*] "For a number "of years I have been urging upon geologists, especially those "addicted to the glacial hypotheses of erosion, the strict analogy "existing between the submerged valleys of Lakes Michigan, "Huron and Erie, and the whole series of dry Appalachian "'Valleys of VIII,' stretching from the Hudson river to "Alabama; also of Green Bay, Lake Ontario and Lake Cham-"plain, with all the dry 'Valleys of II and III.' One single "law of topography governs the erosion of them all, without "exception, whether at present traversed by small streams or "great rivers or occupied by sheets of water; the only agency "or method of erosion common to them all being that of rain "water; not in the form of a great river, because many of them "neither are now nor ever have been great water-ways. As a "consequence of their absolute similarity of geological position, "general form and common genesis, their age must be one and "the same. The sea has had nothing to do with the production "for it has permanently invaded some of them, or even "temporarily others. Ice has had nothing to do with their

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[*] See Report Q4 of that Survey, 1881.

“ production, for those in the glacial regions differ in no respect
“ from those nearest the Gulf of Mexico. I also long ago urged
“ on theorists the necessity of taking into account as a prime
“ factor *the underground solution of limestone strata*, and the
“ subsequent aqueous removal of the fallen *débris* of overlying
“ strata, the roofings of caverns and the steeps of cliffs. . . .
“ A curious illustration is offered by the peninsula of Yucatan,
“ on the surface of which are no streams of water, the drainage
“ of the whole country being underground. It is useless to
“ repeat the oft-told demonstration; but it is well now that Dr.
“ Spencer has disembarrassed us of the chief difficulty of our
“ last pre-recent water-system of the north, to remind the
“ admirers of his great discovery that his new found ancient
“ Grand river did its work not only with the constant assistance
“ from the beginning to the end, of millions of smaller rivers,
“ creeks, runs, rills, but also in such subordination to them as a
“ general acknowledges to his troops, or a contractor to his army
“ of navvies. . . . Our Great Lake basins although traversed
“ by a great river, were not excavated by it, but by a universal
“ vertical descent of rain-water upon the areas, lowering their
“ surfaces gradually and nearly equally at all points while at the
“ same time mining it throughout the whole extent of its lime-
“ stone underfloor; the material being removed in the ordinary
“ way, by rills, rivulets, and the great rivers to the sea.”

On former pages an attempt has been made to give the physical configuration of the bed of Lake Ontario, and but little was said about the former outlet of the basin because little is absolutely known.

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

Possibilities of an outlet by the St. Lawrence. The north eastern portion of Lake Ontario is very shallow. Although the country surrounding it is low, yet it is underlaid by hard rocks which are so frequently exposed, through the moderate thickness of drift as to preclude the idea of a great buried channel existing adjacent to the St. Lawrence, which a short distance below the outlet of the Lake flows over Laurentian rocks. However, in northern New York, but southward of the St. Lawrence, there are some unimportant buried channels connected with the Ontario basin. The St. Lawrence river itself is modern from Lake Ontario to the junction of the Ottawa river, though the lowest portion of the river is conspicuously of ancient date, with pot-holes indicating a depth of nearly 1200 feet. Without a considerable change of level, such as either that which would be produced by a local subsidence of north-eastern Ontario and the upper St. Lawrence, or a very great northern subsidence during a period of southern elevation, any possibilities of the preglacial outlet of Ontario basin by the St. Lawrence seems impossible. However, the oscillation hypothesis seems to be more and more supported by observation.

Possibilities of an outlet at the south-eastern end of the lake. Between the eastern shores of Lake Ontario and the foot of the Adirondacks, the broad plane appears to mark the former lake bottom before the lake contracted to within the present limits.

This remark holds good for the "Great Level" between the southern margin of the lake and the escarpment to the south, although 150 feet above it. The level country south-east of the lake is underlaid by almost horizontal Palæozoic rocks, which are exposed along many of the streams, and are covered generally with no great thickness of drift. These rock exposures occur as far south as a short distance north of Oneida lake. They are also seen along the Oswego river, and the lower portion of the Seneca. However, there is a deeply buried basin in the region of Onondaga lake. Oneida lake is only 60 feet deep, and 127 feet above lake Ontario, and is situated in a basin of drift.

Onondaga lake is 119 feet above Lake Ontario, and is about 65 feet in the deepest sounding. It is a modern lake situated in a great drift-filled basin. The shallower portion of this basin is toward the northern end of the lake, it increases in depth on approaching Syracuse, but again becomes somewhat shallower on passing southward of this city. The drift-filled basin reaches to a depth of about 290 feet below the surface of Lake Ontario. Southward of Syracuse the country rises to the escarpment forming the southern boundary of the Ontario valley.

For many years, suggestions have been made that the Preglacial outlet of Lake Ontario was by the buried basin just described, emptying its waters by the Mohawk and Hudson rivers into the Atlantic. However, this suggested outlet is not possible, without considerrble local change of elevation, as shown by Mr. Carll, for the Mohawk river passes over metamorphic rocks at Little Falls, Herkimer County, at an elevation above Lake Ontario of about 125 feet, without the possibility of an adjacent buried channel through the range of hills, through which the Mohawk valley is cut. The Onondaga basin, then, appears to have been originated by a river extending from the Adirondack mountains westward, and emptying into the Ontario basin northward of the Cayuga lake, forming along the course the basin, now occupied by drift material and Onondaga lake, and perhaps that also of Oneida lake.

Most of the other lakes of central New York, especially those having a more or less meridional direction, lie in great valleys, and are only closed up ancient river valleys. All of these lakes, except two, Seneca and Cayuga, are at a considerable elevation. One of the deepest of these elevated lakes is Skeneateles (613 feet above Lake Ontario, and 320 feet deep). This lake, and Owasco lake, have northern modern outlets over rocky barriers. They lie in valleys several hundred feet deep (300 feet or more) and evidently emptied into the Susquehanna river in some former geological times. The valleys of these lakes as well as several river valleys in the region now having northern outlets (such as those of Onondaga, and Butternut creeks) all radiate from adjacent or common points as they extend northward, evidently shewing a former southern discharge. However, it is exceedingly difficult to determine how much of the valleys are of Preglacial, and how much of Interglacial or Postglacial date, for there are evidently three periods of erosion—the valleys produced in Interglacial and Modern epochs coinciding.

Thus far no apparent outlet of the great ancient Ontario basin has presented itself. One other route at first appeared possible —*by the Seneca Lake, Chemung and Susquehanna Rivers.* The features favoring this suggestion are: the greatest depth of Lake Ontario north of Seneca lake; the depth of Seneca lake, which is 612 feet (423 feet below the level of Lake Ontario): the direct continuity of Seneca lake valley with that of the Chemung, at Elmira, and of the latter valley with that of the Susquehanna, at Sayre. The valley of Chemung above Elmira is much smaller than the portion below, which joins it at a considerable angle, but this portion of the river just above Elmira is more modern than the Preglacial course of the Chemung, which from Corning passed directly to Seneca valley at Horse Heads. One thing is certain, the Ontario basin as it was emerging from the last subsidence of the ice age, flowed by the route indicated and lingered sufficiently long at the level of the upper part of Seneca valley, to produce beaches at the same level along various portions of the margin of the basin.

Unless there was a great relative change of continental level, the route just described could not have been the Preglacial outlet of the basin of Lake Ontario, as a considerable portion of the *cañon* of the Susquehanna for several miles below Towanda (738 feet above the sea) "has a rocky bottom." Cayuga valley would not afford any better outlet, as its summit is 200 feet higher than that of the valley of Seneca lake, and connects with the Susquehanna by diminished valleys.

A pot-hole at the mouth of Chesapeake Bay indicates an ancient depth of the Susquehanna River to at least 1170 feet below sea-level. Many of the streams in northern Pennsylvania, now tributaries of the Susquehanna, indicate an original northward flow to Seneca lake.

Oscillations of the Continent in the Lake region.—Until recently my investigations bearing on the origin of the great lakes have been mainly based on the hypothesis that the closing of the basins was not occasioned by the elevation of the lake margins, by means of the local elevation of the earth's crust. This hypothesis then necessitates the existence of buried channels being outlets of the lake basins, which, if their contained drift were excavated, would restore the Preglacial drainage. My recent observations in New York and elsewhere have failed to obtain any proofs of the existence of such channels.

Outside of the region of the lakes, in the Red river valley, there are known, at least, two deep bore-holes far apart where the drift extends to a level below that of Lake Winnipeg, and indicates that if the drift were removed from the Red-Minnesota valley the drainage of some of the great lakes and rivers of the Canadian North West territories would flow to the Mexican Gulf (as first pointed out by General Warren) without the necessity of a local change of level. This fact extended to the lake regions strengthened my opinions as to the correctness of the above hypothesis.

Whilst the fluviatile origin of Lake Ontario is apparent, yet the failure of demonstrating a drift-filled outlet for the basin (which is 500 feet below the level of the sea) has forced me provisionally to accept the hypothesis that the basin was partly closed by oscillations of the region, as strongly set forth in an able letter from Mr. G. K. Gilbert.

As an evidence of local oscillation, Mr. Gilbert has pointed out that the Irondequoit Bay, near Rochester, was excavated to the depth of more than 70 feet, and two miles wide, by streams of Post-glacial (or Inter-glacial) date, and subsequently submerged to the above depth. From this, his conclusion is that at the time of the excavation of this fiord-valley, the relative altitudes of the locality and the rock-sill over which Lake Ontario discharges differed from their present status by more than 70 feet. Corresponding perfectly with Irondequoit Bay is Burlington Bay at Hamilton, with a depth of 78 feet, with a closed beach across its mouth. From this and other local features, the surface geology of the Dundas valley would indicate a greater elevation, to the extent of more than 78 feet at the head than at the present outlet of the lake.

Let us consider for a moment the physical effect that would be produced upon the stratification by the subsidence of the north-eastern portion of Lake Ontario and the upper St. Lawrence. The dip of the rocks at the western end of Lake Ontario is about 25 feet in a mile, westward of south. At the eastern end of the lake, I believe, it is somewhat greater. The deeper portions of the lake are more than 40 miles from its present outlet. Any local depression gradually extending north-eastward from the deepest soundings of the lake, to even the extent of 25 feet in the mile, would lower the outlet by the St. Lawrence to an extent far greater than would be necessary to drain the lake, provided this change took place at a time of high continental elevation, thus producing a broad depressed valley. We know that the valley of the lower St. Lawrence is submerged to the depth of at least nearly 1200 feet. The rocky boundaries of the region could scarcely more than indicate this change of level as the dip of the rocks would pass from the condition of 25 feet in the mile or less to almost absolute horizontality, and we have no means of comparison. If, however, the elevations took place to the northward to a greater extent then the southward, such as might be occasioned by a change of the centre of gravity of the earth, then the region to the southward of the lakes might be relatively sufficiently lowered as to permit a portion of the drainage to pass out by either the Mohawk or Seneca Lake valleys, which evidently during some portion of the Ice Age discharged waters from the expanded basin of the lake. The local oscillations would also be necessary in the explanation of the complete closing of the outlets of the lake by these routes (as also those of the upper lakes). Prof. Lesley seems to favor the hypothesis of the former outlet of the Ontario basin by the Mohawk and Hudson rivers, but points out that the valley is underlaid by solid rocks at Little Falls (Herkimer County) at an elevation of 350 feet above tide. Therefore the deepest portion of the lake would be 850 feet below this barrier in the great valley. In closing the paragraph, the above named distinguished geologist says that if the above route be correct, then the country about Little Falls must have been elevated (query: by the Mohawk uplifts, as items of a more general Hudson river uplifts;) more than 900 feet. And this may possibly give us a rude geological date for the elevation of the Catskill "mountain plateau, sloping westward into Pennsylvania."

It is by no means necessary to assume that the local elevation which cut off any outlet to the sea, by either the St. Lawrence or Mohawk-Hudson rivers, took place during or at the close of the Ice Age for the period of the river-valleys just described dates far back in geological time. If the explanations brought forward be wholly correct, then the date of the commencement of the valleys should be placed after the close of the Palæozoic time, as the valley of the Susquehanna, and some of the ancient rivers entering the lake basins are partly excavated out of carboniferous rocks, which had been previously elevated. This would agree with the older portions of the Mississippi river. However, the Great River Age did not culminate until the middle Tertiary times, as shown by the tributaries of the ancient Mississippi.

In the Ice Age the outlets of the lakes were closed by drifts in addition to the agency of local oscillation. Whether the fillings of the valleys were produced by glacier-action, by the agency of icebergs, or by that of floating pan-ice, a rational explanation might be given; but as this depends upon unsettled glacial geology, I will not here delay by entering into discussion. However, there appears to be every evidence of an Inter-glacial epoch, when the greater portion of the present Dundas valley, the Niagara river, by the old buried channel of St. Davids, and many other valleys, everywhere in the lake region, were either re-ëxcavated in the drift, or originally opened; and that the second closing or filling of these valleys was not accomplished through any glacier action, but principally through the agency of pan-ice and currents.

Hypothetical Glacier Origin of the Lakes. The hypothesis that the lakes were excavated by glaciers will now be briefly examined. One cannot do better then 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 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 out line 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 the pre-existing valleys have been closed by morainic matter, but the waters will soon re-öpen 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.

Mr. George J. Hinde. F.G.S., one of the few geologists who has written from a Canadian standpoint is an uncompromising glacialist. On the uncertain evidence of ice scratches in the north eastern end of Lake Ontario. and also on those of others in a similar direction at the western end of the lake, he asserts that Lake Ontario was excavated by a glacier. Dr. Newberry accepts his statement, but considers that a Pre-glacial valley determined the direction of the continental glacier.

Mr. Hinde also asserts his belief that the buried valley of the Niagara river (by the way of St. David's) as also the valleys at Dundas and Owen Sound, are of glacier origin. We have proved incontrovertibly that Dundas valley is a buried river channel; also Owen Sound and the St. David's valley are both beds of Pre-glacial or Inter-glacial 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,) which 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 parellel 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

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 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 Professor H. Y. Hinde, on the coast of Labradore, 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.

One thing is certain, the valley of Lake Ontario is one of erosion —not of glacier-erosion—in operation, during much of the time that has elapsed since, at least, the close of the Palæozoic times, closed partly by drift, but also apparently by great geological uplifts, either along the Mowhawk-Hudson valley, or else the inconspicuous broad valley of the upper portion of the St. Lawrence river, formed a continuation of the Ontario plane, which in its north-eastern area became elevated, and now constitutes the shallow floor of the lake and the adjacent low uplands.

Age of Niagara River.—That the Niagara river is Post-glacial, 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 inter-glacial 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 Saugeen clay of Canada, which is unconformable to the underlying Erie clays (or Boulder clays in the upper portion of the Dunday valley). So, for the present, we look upon the old course of the Niagara river as the channel excavated during this warm interglacial period.

Age of the Niagara Escarpment.—This is manifestly of Preglacial date, and owes its origin to subaerial and fluviatible action before the advent of the Ice Age.

V.—GENERAL GLACIATION OF THE COUNTRY.

The glaciation of the eastern part of the Province of Ontario is generally south-eastward in the basin of the Ottawa river, but on the northern side of Lake Ontario it is generally south-westward until we pass the region of the Dundas valley.

The country north of Lakes Superior and Huron, as well as along the eastern portion of the latter lake, have the ice markings also in a general south-west direction. But from the height of land between the three great lakes (Huron, Ontario and Erie), the striations are more frequently towards the south-east. This direction continues to the Townships of Beverley and the northern portion of West Flamboro. It also continues along the Grand river valley, in the Niagara peninsula, as is shown at York (a short distance east of Seneca). But along the Niagara escarpment, on the northern side of Dundas (in the township of West Flamboro) we find several sets of striations, the prevailing direction being westward, or a few degrees south of west. On the escarpment south of Ancaster and Hamilton there are several sets of ice-grooves, but these vary generally from S 40° W to S 60° W,—being more to the southward than those on the north side of Dundas. The same remark applies to the country farther eastward, even to the Niagara river. In many places two or even four or five different sets of ice-markings are seen.

The following table represents some of the principal glacial markings, adjacent to the western end of Lake Ontario.

List of Ice Grooves.

No.	Locality.	Direction.	
	West Flamboro (Township :—		
	Near "Peak," at Dundas, prevailing grooves	W.	
	Near "Peak," at Dundas, other grooves	N. 73° W.	
	" " " "	N. 83° W.	Some are curved in same set.
	" " " "	S. 87° W.	
	" " " "	S. 80° W.	
	About 2 m. S. Strabane (Bell)	S. 49° E.	
	S. of Flamboro village (Bell)	S. 74 W. (with others S. 69° W.)	
	" " " "	S. 24° W.	
	Beverley :—		
	Near Sheffield (Bell)	S. 72° E.	
	" " 1 m. south-west (Bell)	S. 46° E.	
	" " 2 m. south (Bell)	S. 89° E.	
	Near Troy (Bell)	S. 76° E.	
	1 m. S. of Sheffield and 2.5 east (Bell)	S. 79° E.	
	Ancaster :—		
	At Ancaster village (Bell)	S. 59° W.	
	2 m. east of Ancaster village (Bell)	S. 71° W.	

Barton :—

At Rosseaux Quarry, lots 3 and 4. R. VII.	S. 40° W.
" Carpenter's " lot 7. R. VII.. ...	Older set S. 40° W.
" " "	Newer set, S. 57° W.
" " Limekiln. lot 15. R. VI...	S. 57° W. (deeply gr'ved polished and striated.)
Near Asylum, on mountain, at Hamilton.	S. 65° W. (deep grooves 0.5-2 in. wide.)
At Russel's Quarry, head of James St., Hamilton, on a ledge of Medina sandstone, on side of escarpment, 254 feet above lake and 134 feet below summit..............................	S. 80° W.
At York, on the Grand river (Bell)....	S. 68° E.
At Whirlpool. Niagara river (direction of river about S. 75 E. to N. 75 W.)..	S. 10° W.
At Niagara Falls (Bell)...............	S. 28° W.
At Rockwood (Bell)...................	S. 38° E.

In some cases the rocks presented a polished surface with numerous fine scratches, in others there are groovings a few inches broad, and perhaps one or two deep. In other places, again, there are deep troughs scooped out of the surface rock. One of the most interesting series of troughs is just north of the "Peak," at Dundas (at a height of 516 feet above Lake Ontario). Here the clayey earth has been removed, and the surface presents the appearance of a series of crests and troughs of waves, having a distance between the crests of about eight feet, with a depth varying from half to one foot—the direction of these is about S 65° W. Their surfaces are smoothed and polished and are again striated by several sets which cross them at small angles in a more western line. These ice-markings continue in straight lines, scratching both the troughs and crests (of the large grooves) equally. In some cases I have noticed acute bendings of the striations.

On the northern side of the Dundas valley the brow of the escarpment is abrupt, not having the angle at the summit planed off, except on the western side of Glen Spencer, where 100 feet or more have been removed, by causes to be explained below. The brow of the escarpment on the southern side of the Dundas valley and Hamilton is equally abrupt with that on the northern side of the town of Dundas, but the immediate brow is about 100 feet lower. Nowhere in the region about Hamilton and

Ancaster do we find the face of the escarpment with its angle planed off, although the top is in very many places ice-scratched to the very margin, in directions varying from 10 degrees or less. to 20 degrees, with its general trend.

The general axis of the Dundas valley may be placed at from N 70° E to S 70° W. Nowhere have I observed the striations parallel with its direction, except at about two miles east of Ancaster, and at another place at Hamilton; but this last, at Hamilton, requires further notice.

At Russel's quarry at the head of James Street, a large amount of clay and rubble, derived from the harder beds of the Clinton (and Niagara also) formation, was removed in order to quarry some of the upper beds of Medina sandstone. This sandstone is overlaid by a few feet of earthy dolomites of the Clinton divisions, these forming a ledge 254 feet above the lake and 134 below the summit of the mountain. Here I observed that the surface had been polished and scratched in the side of the escarpment at a depth of 134 feet, almost vertically below its brow. The direction was S. 80° W, or parallel with this margin of the Dundas valley, or the "Mountain." It is further worthy of remark that although the surface was polished, the striations were very faint.

VI.—POST PLIOCENE DEPOSITS.

Having noticed the general glaciated surfaces of the hard palæozoic rocks of the country, it becomes necessary to study the comparatively modern deposits which rest on them in order to understand the causes which produced the modern topography of the country.

The following table shows a classification of the geological epochs newer than the Pliocene Tertiary in America, represented in descending order:

IN WESTERN ONTARIO	IN EASTERN ONTARIO, QUEBEC, ETC.	EQUIVALENTS ELSEWHERE.
Recent Modern Era, represented by shell-marl, modern alluvium, etc.	Modern Era.	Modern Era (of Europe).
Older Modern Era, (excavations of valleys in terraces during a somewhat more elevated continent).		Reindeer, or Second Glacial Era of Europe.
Terraces and Beaches, (Artemisia gravel).	Terraces & Beaches.	Terraces and Beaches.
Algoma sand (?) Saugeen fresh-water clays, Forest bed (as of Ohio).	Saxicava sand.	Champlain Epoch (of Dana). Brick clay (with Arctic shells. Scotland).
Erie clay (with few boulders)	Leda clay.	Kames (Scotland Morainic debris, perched blocks, gravels, with animal remains, (Scotland).
Boulder clay (frequently absent).	Boulder clay.	Boulder clay, of Europe. Till, of Europe.
Striated rock	Striated rock.	Striated rock.

VII.—THE TILL, ERIE AND OTHER CLAYS.

General Distribution of the Erie and Saugeen Clays.—The greater portion of the surfaces of the striated rocks of Ontario is covered by *Erie clay*. This clay is always stratified, sometimes with sandy partings, and is more or less calcareous. It is blue when wet, but of an ash-color when dry, and the upper portion is of very fine texture. It frequently contains rounded boulders, and according to Dr. Robert Bell, the lower portion includes a greater or smaller number of fragments which are angular when composed of palæozoic rocks. It contains no shells of marine origin. Some of the immediately overlying and closely associated deposits are known to contain a considerable fauna of fresh water shells. The Erie clay has been seen at various heights above all the great lakes, and even reaching in the region of our Upper Great Lakes to a height of 1,000 feet above the sea, at Maganetawan river (Bell). It occurs along Lake Ontario at the mouth of Niagara river, at Thorold and westward. In the eastern part of the Dundas valley it has been pierced to the depth of 78 feet (60 of which are below the level of the lake.) I am not certain of its occurrence in the upper part of the Dundas valley. South of Brantford. Professor Bell estimates that it must have a thickness of 70 feet, but in Walpole, some miles east of Brantford, the corniferous limestone comes generally to within a few feet of the surface, whose soil is more or less of a clayey character, filled with fragments of corniferous limestone (richly fossiliferous), brought to the surface by frost. This clay also occurs largely about Lake Erie.

The Leda clay of the St. Lawrence valley was more or less denuded before the deposition of the Saxicava sand. So also the surface of the Érie clay was water worn or denuded by subaërial actions. It is then overlaid (often unconformably) by the *Saugeen clay*, which is brownish, in very thin beds (one inch, often separated by sand or gravel, or deposited with intercalated beds of sand. This clay forms a heavy soil. In the neighborhood of the Niagara river and elsewhere it contains fresh-water shells. In the region about the western end of Lake Ontario, much of the country is covered with this clay, or where it is removed by Erie clay. But in the localities immediately in the vicinity of the Niagara escarpment, and often in the Dundas valley, we have the soils formed from the more modern ruins of the Silurian rocks.

In noticing the occurrence of the general deposits in Canada, the boulder clay of the St. Lawrence appears to be wanting in the western portion of the Province of Ontario. The Erie clay, containing boulders, and also angular fragments in part has been provisionally assigned as the equivalent of both the Boulder and Leda clays of the St. Lawrence valley. The Boulder clay is unstratified (or there are only very few feeble indications of stratification), while the Erie clay is always stratified, showing different conditions of deposits. Yet the Erie clay generally rests on the striated Palæozic rocks in Western Ontario.

In the Dundas valley there is a deposit older than the terraces (for terraces and sea-beaches occur above it), and possibly older than the Erie clay, unless we consider this a higher portion of it, but which seems scarcely possible as it is thoroughly unstratified, filled with angular fragments of Niagara limestones and constituting a true

Till.—This forms a possible equivalent for the Boulder clay of the St. Lawrence valley. Principal Dawson remarks that the Boulder clay, as far as it is a marine deposit, is older on higher levels than on the lower. Now, we find that the western part of the Dundas valley is made up of great hills and valleys often in the form of *roches moutonnées*, formed largely by the modern denudation of the streams. Sometimes these hills are cut down to a depth of nearly 150 feet. Sections of several parallel ranges may be seen by crossing the country from Ancaster to the G. W. Railway, about two miles east of Copetown. The escarpments at these two places are about 500 feet above Lake Ontario, whilst the beds of some of the valleys (as, for example, near the "sulphur springs") is not more than 240 feet above the same water-level. In this Till, as exposed at the base of the hills, cut away in road-making, I saw only fragments of Niagara limestones, mostly of such thin slabs as the upper layers of the Silurian rocks at Dundas afford; and these stones make up a large percentage of the whole mass of the bases of the hills. Again, it is possible that these unstratified deposits extend down to the Palæozoic rocks beneath, which may be absent for a great depth below the level of Lake Ontario, as they are in the centre of the Dundas valley, more than two miles from the nearest portion of the escarpment. It is only after passing the flanks of these hills, farther eastward, that we find the Erie clay. Some of these hillocks near their summits have old beaches, others capped with clays. Their summits are mostly composed of clays of the Saugeen equivalent or of alluvium. The source of this Till is the ruins of the Niagara formation, and could have been derived from the upper beds of the rocks of that age, which occur on the summit of the escarpment both at Dundas and Ancaster.

Dr. Dawson has shown that the Boulder clays of Eastern Canada were deposited beneath water and contain remains (though not abundant) of Arctic animals. The marine deposit does not extend westward of the outlet of Lake Ontario, but beyond this meridian the Erie stratified clay, resting on glaciated rocks (generally), appears to occupy its place, and is often deposited at levels below the lake surface. However, there is (outside of the Dundas valley), at least one place where a few feet of Boulder clay may be seen—at the Garrison Commons, just west of Toronto, where the stiff clay contains angular fragments and slabs of shales and harder rocks of the Hudson river formation, together with well-rounded and scratched Laurentian boulders.

The Erie Clay in the Dundas Valley, is essentially of moderately deep-water origin, with only the upper portion of the deposit exposed, and rather free from pebbles. An interesting characteristic of this clay is that it burns to form buff-colored bricks (popularly white bricks), while the overlying clay burns to red bricks (Dr. Bell). It is finely stratified with frequently thin seams of sand. In the Dundas valley, the best exposures are on the sides of the branch of the Dundas marsh, which passes up to Beasley's hollow, west of Hamilton. It is especially well shown along the side of the marsh between the Protestant and Catholic cemeteries. There is here an exposure about 30 feet thick. A considerable portion of the terrace which extends from Dundas to Hamilton, at a height of about 70 feet above the lake, has its margin, bordering on the Dundas marsh, underlaid by Erie clay for about the lower 30 feet of exposure. The upper portion of the terrace is made up of a highly arenaceous clay of yellowish brown color, resting unconformably on the surface of the Erie clay, which had been denuded, and in places removed by streams before the deposition of the clay, which when wet resembles a bed of sand in strata from one to three inches thick. This latter clay is probably the representative of the *Saugeen clays*, and is best shown in section along the Hamilton and Dundas street railway. An unconformable junction is exposed just near the "basin" of the Desjardins canal at Dundas. This latter clay forms the loamy soil of one of the finest pieces of farming land in Canada. At the cutting of the Hamilton and Dundas railway, between the Half Way house and marsh, there is associated with the latter deposit a bed of very fine gravel where the pebbles are less than an inch in diameter. This may possibly be of more recent origin. In Beasley's hollow, near Ainsley wood, these clays rest on the Medina shale, and are represented by only a few feet exposed. According to Dr. Bell (as we have noticed before), the Erie clays extend to at least 60 feet below the surface of Lake Ontario, in the Dundas valley. To what depth it extends I cannot say, but it is underlaid by a Till to a depth of about 227 feet below the lake, near the margin of the ancient valley described in former pages. The "*Brown clays*" are also exposed on the northern side of the Dundas valley, on the terrace, at 90 feet above the water, on which the Dundas cemetery is situated.

Whilst the Erie clays extend to a considerable height above the lake on the borders of the marsh, they do not reach much higher than the water level at Burlington Heights. This fact has a bearing on the study of the Heights themselves.

Between the Dundas valley and the Grand river (that is, in the western part of the township of Ancaster and the adjacent portions of Brant), the country is generally overlaid by a brownish clay, often loamy, remarkably free from stones, and the equivalent (on the surface) of the Saugeen clays. Prof. Wilkins has observed this "brown clay" in stratified beds along the Fairchild's creek.

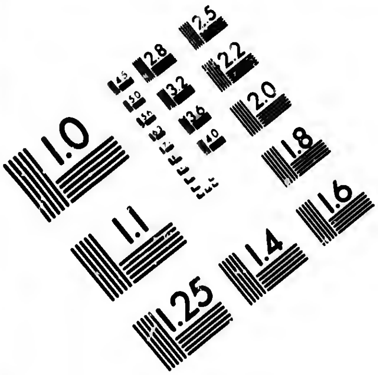
The Forest bed of Ohio, represented in Canada by logs and stumps, in the brown clays, at Toronto and elsewhere (Hind), marks the period of elevation of land during which the Erie and Leda clays were denuded before the deposition of the Saugeen arenaceous clays and Saxicava sand (of the St. Lawrence valley).

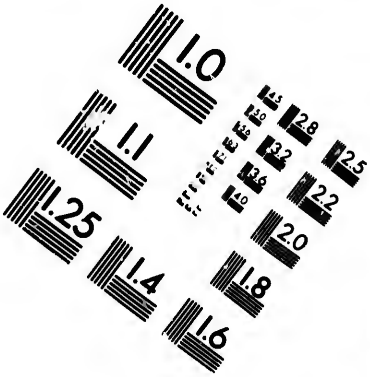
VIII.—STATEMENT OF THE GLACIAL AND ICEBERG THEORIES.

Before considering further the Post Pliocene deposits which occur in the "region about the western end of Lake Ontario," let us briefly examine the two theories that are given in explanation of their origin. It is not my purpose to enter details except those that bear on the explanation of the deposits in the region of study.

The Glacial Theory.—During the later Tertiary days the continent stood at least several hundred feet above its present altitude, probably at the time of the advent of the "great ice age." The two theories—the Glacial or Glacier, and the Iceberg or Floating Ice—differ essentially in the earlier part of the epoch. The former of these theories (or hypotheses) seeks to prove the continuing elevation of the continent after the close of the Pliocene epoch proper; that a great continental ice-sheet capped the northern portion of America, and reached in some instances as far of the 39th parallel of latitude; that the old rivers flowing southward had a greater pitch than at present, and the waters from the melting glaciers running down the elevated old river channels in a southerly direction (and also making new ones), scooped out most of the basins now buried to a depth often several hundred feet below their modern representatives, or the present surface of the land where the ancient valleys are entirely obscured. At the same time the erosive effects were obscured by the stones and *débris* deposited by the melting glacier, being transported by the waters rushing down the steep pitch of the river beds. With an increased elevation of the land, the continent would be more elevated to the northward, which would still further increase the velocity of the waters flowing southward, and retard or altogether stop those flowing northward. Other excavating effects would be produced by the glaciers shoving forward the decomposed rock beneath themselves. The existing valleys would to a greater or less degree determine the direction of the glacier itself. These glaciers, laden with stones and *débris*, moving over the land would naturally plane off the rocks below them, and the stones and sand contained in the ice would produce their striated and polished surfaces. The glaciers would transport the local material by the thrusts: and the rocks and other contained *débris* derived from the source of the glacier itself would be deposited as it melted, thus producing terminal (and also lateral) moraines. In order that the glacier could move southward it is not necessary that the surface of the land should have any slope, for if the ice were sufficiently deep, the weight to the northward or towards its source, would cause it to flow like a mass of apparently solid pitch, which when piled up is constantly seeking a lower level. Croll has calculated that the ice could flow if the surface stood at half of one degree above the ocean level. The terminal moraines produced would tend to dam the waters beneath the glaciers caused by their melting.

After the erosion by glaciers (and the striations of the surfaces of the rocks) was accomplished the continent began to be depressed, and the subsidence went on until the land was more than 500 feet below the present altitude. (But we will subsequently see that the depression continued till a submergence of 1800 feet at least, or perhaps several times that depression was attained). This subsidence and also the previous damming of lake and river basins produced immense inland lakes beneath the continental glaciers, or floating icebergs derived from them. As the glaciers melted, the transported *débris* contained in them was deposited in an unstratified manner on the land, or where it fell into water it was partly stratified. This period of the glacier constitutes the Diluvian era or Lower Champlain epoch. The preceding period of elevated continent forms the period of glacial drift. But the





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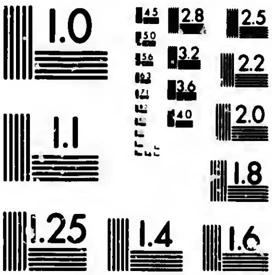

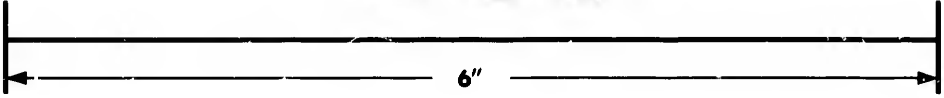

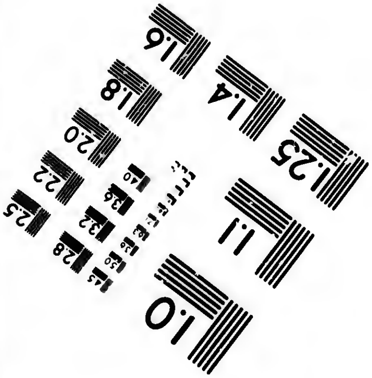

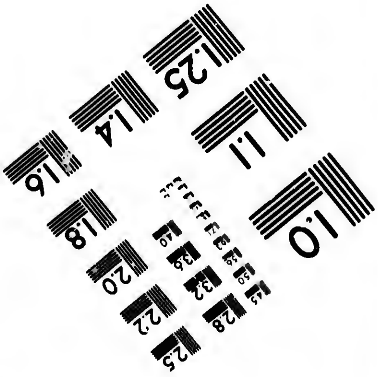

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greater part of the unstratified drift, as stated by Prof. Dana, was deposited in the Lower Champlain epoch.

The boulder clay of the St. Lawrence was deposited in both the Glacial Drift and Lower Champlain epochs (of Dana), and a portion of the Erie clay of the region of the great lakes in the latter epoch, if not in that of the Glacial Drift of the present classification. But as the Erie clay is stratified, it could not have been deposited in the epoch of the Glacial Drift according to the theory of an elevated continent. After the Diluvian or Lower Champlain epoch, the waters continued to be deep, but with much floating ice, bearing erratics. This constitutes Dana's Alluvian or "Upper Champlain era" of stratified clays and gravels.

At the same time the Leda clay (stratified by water and of marine origin) and the upper portion of the Erie clay (stratified and of fresh water origin) were deposited. Then the seas became shallow from the elevation of the continent; and, finally, in some places a forest growth appeared on the uplifted land Again, there was a subsidence on the production of a glacial lake, and there were then deposited the upper beds of Dana's "Alluvian era," corresponding to the Saxicava marine sands of the St. Lawrence, and the Saugeen clays of Ontario. There was still boulder-laden floating ice. As the continent was again rising, or the waters of the glacial lake subsiding, the elevated terraces or beaches were made at heights from 1700 feet to the sea level in the region of the lower lakes. These terraces will be described in succeeding pages. This elevating process continued until the continent stood at perhaps 200 feet above the present altitude, marking an epoch known in Europe as the Reindeer or Second Glacial period. Then came the subsidence which brought the continent to the present general level with the modern deposits.

The Iceberg Theory.—The Iceberg Theory differs essentially in the beginning and early days of the "Great Ice Age."

According to this theory the old channels now buried were produced in days before the advent of the Glacial period, by the erosive action of the atmosphere, and pre-existing rivers, when the continent was at a higher elevation, and date back to very ancient geological times. At the commencement of the Ice Age the continents were subsiding until depressed much below the present sea-level. At the same time glaciers were accumulating in the northern highlands, and even farther southward, where there were any elevated peaks or table lands. These highlands were constantly sending off icebergs which, breaking loose, were borne southward by the oceanic or lacustrine currents, and carrying with them their loads of stones and *débris* from the region of their foundation. The striations of the rock surfaces in continental areas, remote from glacial-producing mountains, (or hills perhaps) was accomplished by the stranding of the bergs in the comparatively shallow basins. This action is shown to-day on the coast of Labrador and Greenland. At the same time the melting bergs were depositing their loads as boulder clay. The iceberg theory accounts for the boulder clay of the St. Lawrence and the stratified Erie clay (with boulders) of the lake region, both dating back not only to Dana's Champlain epoch, but also to the epoch of his Glacial Drift.

There is no material difference in the explanations of the origin of the middle and later deposits of the Glacial period, as rendered by the more liberal view of the glacial and iceberg hypotheses, both recognizing the subaqueous origin of the Leda clay, the upper part of the Erie and other stratified clays, the Saxicava and other sands and beaches. However, according to the glacial theory, much of the stratification of the deposits took place in lakes and rivers dammed up by the glacier itself, without so great a subsidence of the continent as the extreme iceberg theorists would have.

Distribution of the Northern Drift.—Let us now examine what evidence, aiding the elucidation of the history of the Great Ice Age, can be derived from the study of the region of Lake Ontario. In doing this, however, it will be necessary to go somewhat out of the locality of our immediate study.

The so-called ice-cap of the northern hemisphere was confined principally to the region of the North Atlantic Ocean. In America, Professor Whitney states, as the result of extended observation, that there is no evidence of an ice age at low levels along the Pacific Coast, except along the sea, at such elevations as could be glaciated by floating ice during a slight subsidence along the coast of Vancouver's island, on an adjacent coast of the mainland. The southern limit of the northern drift on the eastern side of the Rocky Mountains may be approximately designated by a line drawn from the head waters of the Saskatchewan river to the mouth of the Missouri river, thence to the centre of Ohio, through Pennsylvania and New York, to northern New Jersey.

In Europe the northern drift descended from the Scandinavian mountains towards Central Russia. It did not cover Eastern Europe, nor any portion of Asia, but in the eastern hemisphere it was confined to the north Atlantic.

The greatest development of the deposits of the Ice Age is adjacent to where there would have been the greatest precipitation of moisture. We see to-day that much of Greenland is covered with glaciers, but Messrs. Fielden and Rance (of the Arctic Expedition of 1875-76) observed the paucity of glaciers in Northern Greenland, and that neither there nor in Grinneil's Land, north of about lat. 80° 20' were icebergs (derived from glaciers) met with, but all the ice was considered as floeberg ice. Capt. Nares explains the difference between the ordinary floe and Polar sea ice. The former is only a few feet thick, and meeting with obstacles, it sometimes gets piled up 40 feet or more in height, while the latter is 80 or 100 feet thick. and simply lifts any obstacle in its way. Now, our glacial friends, in referring to the "American Ice Caps" or sheet, can only refer to the region covered by northern drift before roughly outlined, which did not even cover Alaska. It must also be remembered that any such ice cap, as they require, would be lessening in thickness as it receded from the eastern margin of the continent. with its Laurentian and Appalachian Chains of mountains, to cut off the Atlantic moisture, as we have just seen with regard to the northern coast of Greenland. We are told that the drift is found in the White Mountains at an elevation of more than 6200 feet on the top of Mount Washington, with erratics (belonging to a lower topographical level) on the summit of the mountain, and that all this *débris* was pushed up by a glacier. Whilst there seems no doubt of the existence of glaciers in the White Mountain regions, it seems really too hypothetical to place a glacier in the White Mountains at the high elevation, that in moving would push up *débris* even 500 feet from the summit of the highest adjacent mountains.

Thickness of Ice Cap.—When Professor Agassiz announced his glacier hypotheses, requiring a continental glacier to overtop by 2,000 feet, the highest peaks of Mount Desert Island (which are in the same latitude as Mount Washington, with an elevation of more than 1500 feet) and project to Long Island Sound—Professor Leslie calculated "the height of the snow mass necessary for producing the supposed motion of this glacier at 20,000 feet, at the pole) and the abstraction of that amount of water from the sea would lower the sea-level over the whole globe about 600 feet. The snow cap necessary to lift drift material over Mount Washington would so much exceed this thickness as to increase the improbability. Nor does it seem possible that any local glacier in the White Mountains could, even if it had a sufficient thickness to produce its own flow, lift drift materials several hundred feet higher than the place whence they came, and not sheer off on the lower ice and pass around the high peaks—a constant requirement of the glacier hypothesis.

It is not my purpose here to attempt to discuss the ice cap in the White Mountain regions. Yet it is necessary to refer to this region on account of the great elevation of drift material, in looking out the causes of the drift in the region of Lake Ontario. The local evidence of moraine-formed dams does not seem sufficient to counteract the seeming impossibility above pointed out.

Transportation by Coast Ice.—The floating ice theory here answers much better than that of the glacier, for on the continent sinking the ruins of the hills of lower levels could be carried upward by the action of coast or pan ice of successive years, which along the Restigouche and St. Lawrence rivers has been known to move enormous blocks of rock to a considerable distance in a single season. The great precipitation of snow about the North Atlantic, along the ranges of American mountains bordering it, would tend to depress the north-eastern portions of the continent more than either those to the southward or westward. This depression was nearly 2,000 feet, at least in the later Terrace epoch of the Ice Age, beyond the Western End of Lake Ontario. In the mountain regions of the Pacific coast the evidence of a subsidence to more than 4,000 feet is apparent.

At the northern end of Skaneateles Lake in New York we find, at an elevation of 860 feet above the sea, Corniferous limestones, which belong to rock beds *in situ* at only lower levels to the northward. These apparently were lifted upward by floating ice during the subsidence of the region. Again, at the Western End of Lake Ontario, we find great quantities of water-worn pebbles, whose original rock lies thirty or forty miles away, but at only lower topographical levels, except a great distance away.

Terminal Moraine Hypothesis.—Another evidence strongly adduced by the glacialists, in support of the continental glacier, is the so-called terminal moraine, represented in Canadian North-West Territories and North-Western States by those ridges of drift hills, known as Coteau de Missouri. Coteau des Prairies, Kettle Moranies (of Wisconsin), the ridges about the southern end of Lake Michigan, across Ohio and Pennsylvania, the range of drift hills of New Jersey, and the drift hills of Long Island.

The whole of Long Island is composed of stratified drift (considered by Prof. Dana to have been deposited by the glacier ice water). Several, at least, of the so-called moraines of New York and Ohio, represented by the ridges south of Lakes Ontario and Erie, are evidently old water margins. The ridges south and west of Lake Michigan, constituing the so-called Kettle Moraines, are rudely stratified, according to Dr. E. Andrews, of Chicago. And the described structure of the North-western Coteau, containing so much gravel and boulders, even if the greater protion be not stratified, together with the flat country to the north and north-east (whence much drift material from the lower level of the valley of Lake Winnipeg was transported westward and southward to much higher altitudes) makes us look with doubt upon much that has been written about these regions, in support of the favorite Ice-Sheet theory.

With equal propriety could we call the Artemisia gravel and the Oak ridges (to be referred to under Terraces) as terminal moraines of the Province of Ontario; (at least the former of these ridges rises to an elevation little inferior to the Coteau des Prairies). These highest and most distant ridges, surrounding the great lake basins containing unstratified boulder clay would be just what one would expect to find where the laden ice, from northern highlands, after crossing this island sea, became stranded, and finally melted as the old hills were sinking to, or rising from the sea.

However, it is not my purpose to discuss the subject of the Glacial Geology of America, but only to describe some of the surface features in the "Region About the Western End of Lake Ontario," and see what lessons can be derived therefrom.

Agents of Glaciation.—Glaciation of rock surfaces can be produced by the action of the glaciers containing stones, or by that of floating ice shod with rocky matter. Ice of itself, unless frozen to its bed has no important erosive action. In fact, the principal erosion beneath a glacier is produced by the action of running water, hurling along the *débris* from the melting glacier. Again glaciers derive their principal loads of *débris* from overhanging rocks, which would seldom appear above a grand continental glacier. Ice with even little or no foreign material may polish surfaces (not scorify) when hurled by the action of waves and tide, as seen by Prof. H. Y. Hind, on the coast of Labrador, where the hard rocks have been polished for several hundred feet above tide, during the time that that portion of the continent has been rising.

From various Arctic expeditions, we learn about the enormous quantity of detritus which is annually removed by the floe or coast ice, though only half a dozen feet thick. This ice gets piled up, and by the action of wind and tide abrades the shore to an elevation of 30 feet or more.

Our American geologists of the glacial school seem unwilling to attribute the scorifying power to floating ice, which becomes temporarily stranded. Even the grinding of the contained stones in floating ice stranded at low tide, in the trough of waves of a rough sea, acting during long periods of time, would produce great effects. Fairly considering the question, the ice-marked surfaces of the region of our study tell us but little in favor of either the glacier or the iceberg hypothesis. Even the south-eastern striations in the highland counties of Ontario (characterized in part by the Artemesia gravel) at most could only have been produced by local glaciers discharging small bergs into the Ontario sea, whose general currents were drifting to the south-westward.

Any continental glacier passing over the region of our study must have filled the basin of the western end of Lake Ontario and the ancient Dundas valley (more than two miles wide, and from 750 to 1000 feet deep) else the Niagara escarpment of preglacial date facing the lake would have been planed off by the eroding force which struck it obliquely without having the direction of the force changed (except in the valley itself) for we find the summit angles sharp. Nor has this sharpness been subsequently produced by frost action as indicated by the talus at the base of the slopes. The ancient Dundas valley, as has been pointed out, brings additional proof, that the region was not excavated by glacial action. Even the removal of the upper hundred feet of the escarpment on the western side of Glen Spencer, which most nearly resembles glacial action, was not effected by ice-action but by subäerial agencies, which removed the upper surfaces of the narrow spur of rocks separating this glen and Glen Webster from the *cañon* of the Dundas valley.

It seems impossible that in the region of the lakes any great moving glacier did exist, which measured from a depth of what is now 500 feet below the sea to a height sufficiently great to push forward the *débris* from that depth to an elevation of from 1000 to 2000 feet or more over the highlands of New York, Pennsylvania and Ohio. The configuration of the region would not favor such a condition of ice—for the mountains of Labrador, of Quebec, and of New England, assisted by those of New York and Pennsylvania, together with the highlands of Ohio, would have necessarily cut off the moisture and prevented the precipitation on the interior of the continent, as we to-day see in Hall's basin and the Polar sea in the far north.

Origin of Boulder Clay.—Boulder clay may be produced by floating ice as well as by glaciers. Prof. H. Y. Hind has observed its formation at the present time on the coast of Labrador, by the action of pan ice. In Arctic regions the contortion of submarine mud by the jamming of stranding masses of the thick ice of the polar seas, has been observed to produce such effects as are often attributed to glaciers, and could quite as easily by pushing along the softened mud produce the so-called ground moraine, as a glacier.

Thickness of Drift.—Throughout the Province of Ontario, the average thickness of the Post Pliocene deposits is less than 50 feet, excepting in buried channels and along certain ridges. As exhibited in many sections exposed to the bed rock and in many bore holes, it seems that the drift is nearly everywhere stratified, and the unstratified drift is the exception outside of buried channels.

Glacial Lake (Hypothetical).—According to the glacial theory, after the recession of the glacier-ice which scooped out and filled the great lake basins, and moved over the hills (from 1500 to 2500 feet above their deepest beds) to the south, there was produced a great glacial lake by the closing of the outlets with ice, and in this lake the stratified drift was deposited. We have already shown that the lakes are not of glacier origin. If it had been possible for the ice to have been pushed up and over the great elevations referred to, yet it seems highly improbable, that a remnant of floating ice could have dammed up not only the lower outlets to the lacustrine sea, but also raised many of the lower ridges to the south by an ice barrier sufficient to prevent the overflow of its waters. As remarked by Prof. Dana, no moraines bear evidence of such a dam at 1000 feet above the sea. In the Province of Ontario the stratified drift in very many places is at a much higher level than long stretches of the barrier ranges to the south. Moreover, at the time when part of these stratified deposits were being produced the sea contained little or no floating ice wherewith to close the outlets, much less to increase heights of the barriers.

Consideration of Changes of Level and Deposit of Boulder and other Clays.—According to the glacial theory the continent stood at a much higher elevation in the ice age than at the present time, yet it does not demand any very great changes of level. So also in the above remarks, the subject of local oscillations has not been an element of consideration, yet great changes of level did take place. The marine boulder drift of the St. Lawrence valley, containing Arctic shells, reaches an elevation of over 500 feet, irrespective of higher and more modern terraces. Also the coast of Labrador has been known to have risen to great heights since the ice age. Prof. Dana remarks that the continent was more elevated to the northward than the southward.

During the great accumulation of ice along the mountains of Labrador, Quebec, New England, New York, etc., and in fact around the north Atlantic, there would have been a relative sinking of the continent arising from the change of the centre of gravity of the earth. The subsidence would begin along the Atlantic coast and extend westward. We know that the large deposits of Boulder clay in the St. Lawrence valley are marine and deposited beneath water. However, on moving up the St. Lawrence valley the evidences of the marine character gradually disappear as the Arctic shells cannot be traced to the western deposits. Nor do any of the marine Port Pliocene deposits pass westward of the east end of the valley of Lake Ontario (whose elevation is 247 feet above mean tide). The unimportance of the Boulder clay farther west in Ontario, or more frequently its entire absence, with Erie stratified clay containing a few boulders, especially near its base, resting on striated rocks, points to the fact that the ice age and the continental subsidence began earlier to the northeastward than it began in the valley of Lake Ontario and the region to the west of it. This being the case, we have an explanation for the change of character of the drift deposits from the marine "Boulder clay" of the St. Lawrence valley to that of the lower boulder-bearing (probably) fresh-water Erie stratified clays, for the conditions favorable to the deposition of the topographically lower Boulder clay would exist for a longer period than those of the Erie clay having been begun and partly completed before the formation of the latter clay. The increasing accumulation of ice about the barrier hills would close the St. Lawrence valley to marine currents, and cut off much of the precipitation of moisture from the interior basin, leaving it freer to the action of coast and berg ice from the adjacent mountains.

Higher than the Niagara escarpment, or 750 feet above the sea, the country beyond the western end of Lake Ontario affords very little Boulder clay except in old buried valleys.

The greater part of Erie clay appears to be contemporary with the later deposited portions of the Boulder clay and with the Leda clay of the St. Lawrence valley during a time of contracted ice sheets, when the sea was again making inroads on the continent. The Erie clay occurs at elevations of 1000 feet in the Province of Ontario.

The Unproven Character of the Glacial Hypothesis.—After careful study of the subject of the drift deposits in the lake region, and after reading an immense amount of literature on the subject of glacial geology of America, wherein one finds many intererestng discoveries, yet an enormous amount of dogmatism unworthy of scientific observers, there is but one conclusion that I can arrive at—namely, that the glacial theory is not applicable to the explanation of the physical features of the lake region, either of the moulding of the country, as considered under the origin of the lakes or of the glaciation, or of the drift deposits of the Ontario peninsula. It is true that a great theory cannot be considered either as proven or disproven by limited observation, and that is all which this paper purports be—not a consideration of the whole subject, even as far as America is concerned, much less Europe.

Events after the Close of the Epoch of Erie Clay.—After the period of the deposit of stratified Erie clay, there appears to have been an elevation of the land, for in Ohio and other States it is succeeded by a forest growth and denudation of the surface of the country.

During this time in Ontario the surface of the Erie clay was denuded, so that the succeeding Saugeen clays lie on it uniformly. The valley of the Dundas marsh and Burlington bay, besides such tributary streams as the Cold Spring creek were excavated in it. The Cold Spring creek excavated a channel in the Erie clay a few hundred feet wide (as seen along the Hamilton and Dundas street railway, which descends to the marsh along this creek), before the deposition of the arenaceous clay. In fact, a considerable portion of the Dundas valley was reëxcavated by the large streams of this time. It was during this period of denudation that the forest trees were flourishing which are found under the clays and sands about the city of Toronto and in the Scarboro Heights. Then came the subsidence with its deposit of Saugeen "brown clay" (described before), which covers so much of the surface of the Dundas valley and in fact a great portion of the Province of Ontario. During this deposit there appears to have been little or no floating ice in the region of study, as there is a remarkable absence of erratics. The erratics belong to later date.

The Scarboro Heights—East of Toronto. Mr. George Jennings Hinde has written an interesting paper.* Unfortunately the author is a member of the more advanced school of glacial thought. Over the stratified clays and sands there is a deposit of what Mr. Hinde calls Till. This fills a valley of a stream scooped out by a probably interglacial stream. However, the writer considers it (which he figures) as a glacial hollow (like our lakes) filled up. From the evidence as laid down, it is conspicuously an old water course, and there is no evidence given to show its glacial origin any more than there is evidence of the glacier excavation of the lakes. This so-called Till is composed of far drifted Trenton limestones and Utica slates. The most rational description of the presence of this "Till" is its derivation by coast ice from the Trenton and Utica rocks which formed the shores to the north and east.

Closing Remarks on the Glacial Theory.—In the Dundas valley there are a number of sheep backs or *roches montonniés*. The summits of these hills, at least, belong to the Terrace epoch, and may be easily explained by the denudation by streams, owing to the peculiar features of the country, which will again be noticed.

The Cause of the Arctic Winter is a question outside of this short descriptive study. However, the theory of the "secular

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* Canadian Journal. 1877.

changes of climate," arising primarily from the eccentricity of the earth's orbit, as proposed by Mr. James Croll and accepted by Mr. James Geikie in the two admirable works, "Climate and Time" and "Great Ice Age," seems the most feasible; and to those works I refer any enquiring readers. With regard to the *Ice Age of Scotland* and north of England Mr. Geike makes out a much better case than our American glacial friends. It must be remembered that Scotland is in the lattitude of from the middle to the northern part of Labrador, and were the Gulf Stream to change its course, and with a little increase in quantity of precipitation and fog, to-day, it would again become a glacial region. The drift which occurs in the lake regions of America resembles more nearly that of central Europe than that of Scotland and Scandinavia, where the evidences of glacial action are more apparent than on the continent. At the present time only glaciers in the far north discharge icebergs into the sea, yet these are driven farther southward than the extreme limit of southern drift in America. It must be remembered that these bergs come from a latitude not much farther north than the Scottish islands.

Therefore, the American reader must not be unintentionally led astray. On this continent there are but few writers who are unbiassed, and it is somewhat uncommon for a student to meet with a judicial production as geology has not yet produced the great mind who has been able to decipher all the valuable hierogliphics of surface geology on this continent. A portion of the partizan writings is unavoidable but very many more are unworthy productions of the servile obedience to the memory of the distinguished founders of the glacial theory, who never exacted the homage bestowed by some of their disciples, attributing to glaciers any sort of features whose origin is somewhat obscure.

IX.—TERRACES AND BEACHES.

Overlying the "Brown clays," or where these are absent, the blue Erie clays, there is a considerable number of terraces and beaches, whose remains are to be seen at the western end of Lake Ontario. Especially is this the case in the Dundas valley; but even here the majority have been more or less removed by subsequent denudation, so that at the higher levels there only remains an occasional hill capped with stratified sand or gravel, or small fragments of the isolated beaches skirting the Niagara escarpment.

High Beach near Waterdown.—Beginning with the beaches at the highest altitudes, about the immediate vicinity of Lake Ontario, there is an extensive deposit of sand and fine gravel near the village of Waterdown, on the top of the Niagara escarpment, at an elevation of 500 feet (estimated) above the lake.

High Beach near Ancaster.—On ascending the Dundas valley to the watersbed between it and the Grand river, about a mile west of Ancaster village, there are several deposits of stratified sand and fine gravel on the summits or sides of the hills at an elevation of 440 feet (estimated) above the lake. At one of the exposures of these deposits, there is an oblique bedding dipping 23 degrees to the south-eastward. False bedding is very common. These beaches are more or less composed of well water-worn pebbles of the Hudson river formation. At the same elevation but south of the Grand river, near Seneca village, there is another gravel deposit.

Highest Beach at Dundas.—Our next beach is the small remains of a terrace found at the height of 335 feet (levelled) above the lake, on both sides of the mouth of Glen Spencer. The elevation was levelled on the eastern side of the Glen. As only a very small fragment remains, fringing the older rocks, it is possible that it may have formerly extended somewhat higher. This is the *beach* in Dr. Bell's report to the Canadian Geological Survey, estimated at 318 feet. This deposit consists of rounded pebbles of the Niagara limestone, with which are associated pebbles of the Hudson river period and a few others of crystalline rocks. Much of this deposit has been artificially removed in making the railway embankment across Glen Spencer, near the Dundas station.

Another Beach at Ancaster is found on the sides of one of those so-called "sheep's back" northward from Ancaster. It is probably at the same elevation as the last terrace described at Dundas (335 to 360 feet above the lake). It is composed of very fine gravel and sand, derived more or less from both Hudson river and Niagara rocks, together with many angular beds of Niagara limestones and shales. The exposure of this deposit is on the south side of a spur or ridge which rises nearly 100 feet higher. As the ridge is covered with soil it is only at the pits where the gravel has been removed for road purposes that sections can be seen. Above the gravels there is a deposit of clay containing many angular slabs of Niagara limestones and shales.

More careful examination is necessary to determine whether this "boulder clay" is older or newer than the gravel which flanks the hill, for in some places it appears to overlie the gravel, but it may have been derived by land-slides from the higher level of the steep hills. In this region, north-west of Ancaster the hills, flanked with beaches, are separated by ravines, often 100 feet deep, with beds not more than 240 feet above Lake Ontario.

Terraces at the level of 261–224 *feet*—On the hills adjacent to the beaches described, near the outlet of Glen Spencer, there is a terrace with a rolling surface (on which is the Roman Catholic cemetery) of sandy material, having a height of 261 feet above the lake. The side of the same hill, at a height of 224 feet, shows stratified sand and fine gravel, which is exposed for fifty or sixty feet almost vertically. This is on the northern side of the town about three-fourths of a mile eastward of the railway station. The sand contains layers of fine gravel, much of which is evidently of the Hudson river formation.

Terrace at a Level of 180 *feet.*—One of the most perfect of the "sheep's back" occurs on the southern side of Dundas, within the corporation. This is situated behind "Gartshores dam" and has a height of 180 feet (levelled). A gravel pit has been opened on the upper portion and stratified gravel has been exposed for a depth of 30 feet. The lower portion of the hill near the dam is composed of blue clay, but a section of the whole hill has not been laid open. Most of the gravel is fine, but it contains a considerable number of stones eight or ten inches in diameter, with a few slabs as much as one and a half feet in diameter. These larger stones are mostly composed of Niagara dolomites and are semi-angular. I did not find Hudson river fossils in the pebbles, but am of the opinion that much of the gravel is composed of these rocks.

The Great Terrace at 116 *feet above Lake Ontario* is the most widely spread of all the ancient beaches. At the Dundas valley it occurs on the northern side of the town and includes the higher portions of the terrace on which the cemetery is situated. Here the surface is composed of brown clay, underlaid by a sort of quicksand, which is probably Saugeen clay.

The terraces and beaches at about this height are seen on the northern side of Burlington bay and farther eastward south of the lake. The Burlington heights (108 feet) belong to this system. Eastward from these heights it runs diagonally with a slight curve through the city of Hamilton until it abuts against the foot of the mountain, near the head of John street. Again, in the vicinity of the city reservoir (at the same height) it commences its course again and extends eastward. Occasionally where the older deposits are higher, or the escarpment sends out jutting ridges this terrace suddenly stops, but beyond, where the same contour line is met, the beach is found. A terrace northward of Toronto also occurs at a height of 108–114 feet above the lake, and near Burlington at 118 feet. This terrace formed an old beach, as is shown by the sorted and stratified sands and gravels everywhere in the localities mentioned except on the northern side of Dundas, or on the south-western side of the Burlington heights. The pebbles of this beach contain a few Laurentian rocks, but with this exception the whole of the mass is made up of ruins of the rock of the Hudson river epoch. These pebbles are well rounded and usually not more than six inches in diameter, although in some places there are large rounded slabs from one to two feet long. I have closely examined these deposits and have never seen any pebbles that appeared to be of the Niagara formation. Though all the stones are not fossiliferous (some arenaceous and some calcareous), yet a very large number show the characteristic Hudson river fossils. In this terrace, at Burlington heights, remains of the mammoth wapiti and beaver have been found.

Terrace at the Level of 70 feet.—Our next terrace is most apparent in the Dundas valley, although occurring on the northern side of the lake, and less conspicuously or more gently sloping in Hamilton and eastward. This terrace occupies most of the country beneath the escarpment from Beasley's hollow, at Hamilton, westward, to near Dundas. Its northern side slopes abruptly to the southern margin of the Dundas marsh. There is also a terrace on the northern side of the town of Dundas, at the same height (in the region of Victoria street and the driving park). The central portion of the city of Hamilton is on the same terrace which, however, more gradually slopes to the lake level than at Dundas. The height of this terrace is 70 feet. It is composed below (where exposed) of blue (Erie) stratified clay. Above, it is composed of a yellowish brown clay (the Saugeen equivalent) which is inconspicuously stratified, but in the cuttings of the Hamilton and Dundas railway, we have seen that the sand washes out and shows the stratification. Along the same railway cutting, near its northern margin. there is a bed of very fine gravel whose pebbles resemble those of Hudson river formation, but no fossil remains prove positively that origin. As the exposure of the limits of this gravel is not made, I cannot say certainly whether it is the same age or not, but am inclined to regard it as a marginal deposit on the side of the hill facing the Dundas marsh at a height of about 45 feet.

Beach at the Level of 15 *feet.*—Of our next beach only a small portion remains. It has a height of about 15 feet above the Dundas marsh on the side of Beasley's hollow, just below the Catholic cemetery, at Hamilton. It is composed of shell marl made up of masses of broken shells, whose components will be subsequently noticed, under modern deposits.

Present Lake Beach.—Our lowest and last beach is that of the present lake level, and extends a few feet above its present shores. The components of this beach from Toronto to Hamilton and eastward to Grimsby, Beamsville and Niagara river are of Hudson river pebbles with a few Laurentian stones. In the region of Hamilton the pebbles at the lake level in part have been derived from the older beach of the same material at the level of 116 feet. But the Burlington beach, separating the waters of the bay of the same name from Lake Ontario, could not have been derived from these deposits by any agency working at present. The Burlington beach is less than half a mile wide with a mean height of 8 feet and deposited in water about 80 feet deep. The present Burlington beach and the bed of the bay are exactly a counterpart of what was happening when the lower portion of the Dundas valley was submerged and formed a bay, cut off from the lake by what now forms the narrow ridge of Burlington Heights.

Other Beaches in Ontario.—In 1837, Mr. Thomas Roy measured the beaches between Toronto and Lake Simcoe, having the following elevations above Lake Ontario:—110, 210, 282, 310, 346, 402, 422, 592, 558, 526, 682, 734, 764 feet respectively.* Additional gravel beaches occur along the Northern railway at 600 feet, and on descending towards Georgian bay at 520, 388 and 354 feet above Lake Ontario. A still finer series of beaches

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* The elevations were copied from the Geology of Canada, where elevations were given above sea; the Geological Survey places Lake Ontario at 232 feet above high tide.

may be seen from Toronto westward along the Toronto, Grey and Bruce railway. The elevations and locations were kindly furnished me by Edmund Wragge, Esq., the chief engineer of the railway. These sand and gravel deposits occur at the following elevations above Lake Ontario:—160, 280, 370, 710, 990, 1340 feet respectively. After passing the summit of the road (1462 feet above Lake Ontario) and descending towards Lake Huron there are gravel beds at 1310 and 1000, and several beds with elevations down to 697 feet above Lake Ontaio. Along the western branch of the road there are also gravel deposits at 1299, 1130, 1050, 870, 850 and 830 feet above Lake Ontario.

Beaches Adjacent to Lakes Superior and Huron.—The "Geology of Canada" contains the following list of beaches adjacent to Lake Superior, near Petits Escrits, at 398, 408, 458, 502, 627, 635 and 699 feet above Lake Ontario. At Owen Sound there are beaches at 120, 150 and 200 feet above Lake Huron, or 466, 496 and 546 feet above Lake Ontario.

Beaches South of Lake Ontario.—Along the Great Western railway, adjacent to the valley of St. David's, (filling a portion of the *cañon* of the interglacial Niagara river) there is a beach at 386 (to about 250) feet above Lake Ontario.

I have not been able to obtain the list of any series of terraces and Ancient beaches in New York State. Prof. Hall places the highest "lake ridge" at 190 feet. I have observed the old beach adjacent to the Seneca lake and at the north end of Skaneatles lake, which reach to an elevation 860 feet above the sea, and have placed the top of this east beach about (613 + 12) 625 feet above Lake Ontario.

Gravel Ridges South-West of Lake Erie, have been observed by Messrs. G. K Gilbert and Winchell at 490, 386, 408, 350, 220, 195, 165, and 90—65 feet above Lake Erie.

Artemesia Gravel and Oak Ridge.—All the higher beds of stratified sand and gravel along the Toronto, Grey and Bruce railway are within the area of Dr. Bell's *Artemesia gravel*, which forms a slightly curved belt 100 miles long and about 23 miles broad, facing the Ontario valley. The belt extends from near Owen Sound, on Georgian bay, to near the city of Brantford.

Dr. Bell describes the Artemesia gravel as follows:—"This great belt of gravel has a general parallelism with the Niagara escarpment, and follows the highest ground of the peninsula. The materials composing it consist principally of the ruins of the

Guelph formation, on which the greater part of it lies except towards the southern extremity, where the Niagara formation is largely represented. Pebbles of Laurentian and Huronian rocks are everywhere mixed with the others and sometimes form a considerable proportion, while rounded fragments from the harder beds of the Hudson river formation occur locally in some abundance." (Note—These last rocks are obtained from lower levels.) "The gravel is all well rounded and generally coarse. It often constitutes what might properly be called cobble stones, being loose and free from any admixture of clay, and it is distinctly stratified. Well-worn boulders of Guelph, Laurentian and Huronian rocks are disseminated through the whole mass. At Brantford and Mount Forest (?) it overlies blue Erie clay."

TABLE OF ELEVATIONS OF TERRACES, BEACHES AND RIDGES.

The following elevations of terraces and beaches are here tabulated with reference to elevation above mean tide. This, however, can only be approximately done as none of the series is complete. Some of the elevations refer to the highest exposures and others to pits cut into the gravels:—

References of table on opposite page.

a On high lands of Michigan.
b Summit of land.
c Beach also of this elevation on Mackinac island.
d Adjacent to St. David's valley.
e Along W. G. and Bruce railway.
f Along Whitby branch of Midland railway.
g Along Midland railway.
h Along T. G. & B. railway.

TABLE OF ELEVATIONS.

At Western end of Lake Ontario. (Spencer.)	Between Toronto and Lake Simcoe. (Roy.)	Along Northern railway from summit to Georgian bay.	Along Toronto, Grey and Bruce railway. (Wragge.) *m* is on main line. *w* is on west branch.	Near Owen Sound. (Bell.)	Petits Ecrits, Lake Superior. (Geology of Canada.)	In New York State.	At western end of Lake Erie. (Geology of Ohio.)	Along the Lower St. Lawrence. (Dawson.)
			1,709 (*b*)		1,700 *a*			
			1,587 (m)					
			1,557 (m)					
			1,546 (w)					
			1,377 (w)					
			1,367 (m)					
			1,297 (w)					
			1,247 (m)					
			1.237 (m)					
		1.140	1,117 (w)					
			1,097 (w)					
			1.077 (w)					
							1,063 to	
1,011	1,001						959	
							981 to	
981							923	
			957 (m)					
929			944 (m)		946			900
					882			
	873				874	872		
		847	848 *c*		839 *c*		793	
	805						768	
		767		793			738	748
747	749	737						
687 (?)				745				
	669			713	705			
	649							
633 *d*		635			655		663 to	660
582	593	601	617					
	557				645	647	638	
	529					583(?)		
508			527					
to		498 *f*						
471								505
	457							479
								448
427						437 to		
	407		401			432		
						405		
								378
363								
		342 *g*						
327								325
255								
to								
247								

At a much lower level than the higher or medial portion of the Artemesia gravel ridge which runs nearly north and south; there is another ridge known as the "*Oak Ridge*," which leaves the Silurian escarpment near Palgrave (on the H. & N. W. railway) at a height of 722 feet above Lake Ontario. It extends eastward to near the "Great Bend" of the Trent river, the summit of the range being about twelve or fourteen miles north of the lake, after passing eastward of Toronto. The Northern railway crosses it at 754 feet, the Toronto and Nipissing at 893 feet, Whitby branch at 781 feet and the Midland railway at 665 feet above Lake Ontario. It is from 200 to 300 feet above the broad trough from Georgian bay to the Bay of Quinté, occupied by Simcoe, Balsam, Rice and other lakes drained by Trent river. The basin of this trough is underlaid by Palæozoic and older rocks. Several small lakes occur on this ridge without apparent outlets. A spur of this ridge runs to Lake Ontario near Scarboro, and forms the "heights," rising 300 feet above the lake. It consists principally of stratified fossiliferous clay and sand with two intercalated beds of boulder-bearing clay. Portions of the "Oak Ridge" eastward of the meridian of Toronto, consist of clay ridges—probably the exposed equivalents of the clay beds of "Scarboro Heights." The highest portion of Oak ridge is only 300 feet above the rocky floor of the trough, which forms the immediate northern margin. We are safe in concluding that the stratified character of the lower portion of the ridge continues downward to the rocky floor on which it lies, or with no important unstratified deposit beneath to constitute it a moraine.

In studying these ridges, especially the Artemesia ridge, we cannot fail to be struck with the similarity of those so-called Kettle Moraines of Wisconsin, Coteau des Pairies and Coteau de Missouri. There is a general parallelism between all these ranges. Even a portion of the Artemesia gravel is nearly as elevated as Coteau des Prairies.

Other high terraces and beaches occur along the St. Lawrence at 900 feet above the sea (Dawson); and in Labrador, at 1000 feet, besides erratics at much higher elevation (Hind).

In Ireland and Wales marine beaches are found at from 1200 to 1400 feet above the sea.

Origin of the Terraces.—As before pointed out, we have no evidence of any general morainic character of the "Oak ridge." On studying the levels of the country covered with Artemesia gravel, we see simply a high ridge of land with beach markings all the way down from the summit (over 1700 feet above the sea) to an altitude of about 950 feet, surrounded by one succession of old water-margins, indicating the gradual growth by elevation of a rocky or generally rocky island, for the "Artemesia gravel" reposes (as far as I have been able to learn) on hard rocks or stratified clays, except in the old buried channels of tributaries of the ancient Grand river (principally). Surrounding the old island we find in several places rude terraces of about the same altitude, at many miles apart. Yet the waters did not linger as long to form marked terraces as at lower levels. This general deposit in no way partakes of the character of a Scotch kame, even though we considered the "Oak ridge" of that character, as the latter much more nearly resembles one in outline, relative direction and composition than the Artemesia highlands. The whole series of beaches and terraces about Lake Ontario marks the slow elevation of the continent, causing lands at various elevations to be covered somewhat uniformly with the gravel and sand, and again somewhat intermittently, producing well marked terraces. Nor did this subsidence of the waters cease when the present lake level was obtained, as we have a comparatively modern ledge, carved out of the soft Medina rocks near the outlet of the Welland canal, below the surface of the lake and extending downwards for a known depth of more than forty feet. This fact would indicate local oscillation of the margin of the present lake basin.

I fail to comprehend how any glacial lake could have existed when it was producing terraces over all the great lake region at an elevation of what is now 1700 feet above the sea, for the surface of the waters was not covered with any great amount of ice —perhaps not much more than the ice fringes of the present day. Many portions of the southern highlands do not rise to any such altitude to be easily barricaded with the small amount of floating ice indicated by the transported material.

There seems a difficulty in explaining the absence of marine life in this area when it is found in the bed of the St. Lawrence valley, unless the whole period was one of comparatively short duration, and marine life did not get farther westward than the present outlet of Lake Ontario.

The Drainage of the Inland Sea.—This inland body of water, as the continent was gradually rising from beneath the sea level, evidently had a large number of outlets at different times by which it connected with the outside ocean. These old outlets are indicated by a number of river-like valleys crossing the highlands of Ohio and New York (not to refer to those extending from the valley of Lake Michigan and the present St. Lawrence valley). The following are the most conspicuous ancient waterways: Through the highlands of New York; 1, by the Mohawk river, at 434 feet above tide, 2, then by the valley of Tully lakes, at about 1200 feet; 3, by the valley of Skaneateles lake, at about 1200 feet; 4, by the valley of Owasco lake, at 1232 feet; 5, by the extension of the valley of Cayuga lake, at 1015 feet; 6, by the valley of the extension of Seneca lake, at 865 feet above mean tide; and several others at greater elevations. All these valleys are from 100 to 300 feet or more beneath the adjacent highlands. In Ohio, Dr. Newberry enumerates the following ancient channels:—1, by the valleys of the Grand and Mahoning rivers, at 936 feet above tide; 2, by the valleys of the Cuyahoga and Tuscarawas rivers, at 968 feet; 3, by the valleys of Black and Styx (a tributary of the Tuscarawas) rivers, at 909 feet; 4, by the valleys of Sandusky and Scioto rivers, at 910 feet; and 5, by the valleys of the Maumee and and Miami rivers, at 940 feet. The summits of all these valleys are more or less filled with stratified drift, and in some cases, as that of Seneca valley, the summit forms a long, nearly flat alluvial plane, free from boulders. All these valleys of New York, on the northward side of the divide are deeply underlaid by sediments, whilst to the southward, exposures of rocks along their beds are much more common. The remarkable connection between these old outlets and the beaches is very striking. Thus, there are at about the level of the lowest of these outlets, 434 feet, beaches on both the southern, western and northern boundaries of Lake Ontario at corresponding heights. Also, at the level of the next lowest enumerated outlet (by Seneca valley) at 865 feet, beaches were produced (only a few feet higher corresponding to the outlet through which water a few feet deep was passing), in New York (north end of Skeneatles lake), in Ontario (north of Toronto), and even in the region of Lake Superior.

Erratics and Origin of the Gravel of the Beaches.—Almost everywhere in the "region about the western end of Lake Ontario," well water-worn boulders of Laurentian and Huronian rocks are occasionally to be met with, and in some places they are abundant. They are abundant in such remnants of the boulder clay as exist, and in portions of the lower beds of stratified clay. At the western end of Lake Ontario they are not found in the Saugeen clay. However, in the later terraces they are found, though usually of small size. On the surface of the country above the Niagara escarpment they are met with much more frequently than below the escarpment (where they are very rare unless derived from one of the beaches). On the upper levels of the Dundas valley none are to be seen. The "Artemesia gravel" contains many. It also in places contains large quantities of the water-worn remains of Hudson river rocks, all derived from lower levels. Along Rosseau creek, in Barton township, there is a group of semi-rounded boulders two feet long, composed of Medina sandstones, whose outcrop is only two miles away, but at an elevation of two hundred feet lower, beneath the Niagara escarpment. The northern erratics are much more abundant and larger on the highlands of New York and Pennsylvania than at lower levels at the western end of Lake Ontario, and occur on top of the terrace deposits. Besides these deposits and the Devonian pebbles of New York, carried to higher levels, the materials of the beaches are derived more or less from the adjacent rocks. There seems, as far as Ontario is concerned, but one explanation for the lifting of these water-worn pebbles and boulders to higher levels, and that is their transportation and elevation by the slow agency of coast ice forming in many succeeding years during the time of continental subsidence, as we see to-day the large boulders in many of the north-western shallow lakes lifted from their beds, by the action of the thick winter ice, and drifted on some portion of the shore by the prevailing winds, there to be left on the dissolution of the ice, as reef several feet higher than the lake surfaces. Again, as the waters were receding many of the boulders along the coast would again be picked up by the annual ice, and transported to hills, and growing beaches which are now the highlands to the south, while the intermediate deeper beds received but few, rarely dropped by the passing ice. In regions less exposed to currents and shore deposits but little stony material was deposited, as is demonstrated in the upper portion of the Dundas valley and elsewhere. There does not appear to have been a large amount of floating ice, as indicated by the fine material over the beds of some of the old outlets noticed already.

The beaches at the higher levels are composed of much more local *débris* than those at 116 feet and at the present water level, about the western end of Lake Ontario now to be described.

Burlington Heights and Burlington Beach.—The lower part of the Dundas valley and the site of Burlington bay were excavated out of the Erie clay during the period of elevation of land that followed that epoch, and the interglacial Grand river flowed down this valley in the same way that the Niagara river flowed down the St. David's valley. These valleys became closed, however, during the deposits of the Saugeen clay and the terraces (the visible surface for a depth of 200 feet in the St. David's valley shows only stratified sand, and was not closed up by glacial action as has been suggested). Therefore the deposits of Burlington heights (and the 116 feet terrace) were not brought down the Dundas valley. Moreover, I have never seen a solitary Niagara pebble in this terrace, though sought for. Again, the Hudson river pebbles in the Dundas beaches at higher levels are all very small, whilst both the 116 feet terrace and the present lake beach contain some strata of cobble stones from four to six inches in diameter, with oval (water-worn) slabs from one to two feet long. The materials of these beaches have all been derived from the *débris* of Hudson river rocks and contain a small quantity of crystalline pebbles of moderately small size. The nearest exposures of Hudson river rocks is at Oakville (20 miles distant), but at a lower level. However, at Weston (30 miles distant) west of Toronto, the same rocks occur at 179 feet (and lower) above Lake Ontario. The shape of the pebbles is flattened oval, they were evidently derived from these northern exposures and transported around the whole western end of the lake to form the conspicuous terrace of 116 feet and the present beach. This transportation has been effected by the action of the waves and floating coast ice when the water was at the respective levels. The present beach may have been in part derived from the denudation of that 116 feet.

Burlington Heights forms the extreme western end of the bay of the same name and the Burlington beach, the end of Lake, Ontario. The Heights, varying from less than a quarter of a mile to a few hundred yards in width, separates the Dundas marsh (at the same level) from Burlington bay. The width of the marsh here is about half a mile. At the northern end, it was formerly connected with the bay by a ravine partly filled by a railway embankment after the heights were cut through for Desjardins canal. The elevation of the Heights is 108 feet above the lake, and is the connecting link between the terraces on both sides of the Dundas marsh, whose valley was excavated before their deposit. Burlington beach, from 300 to 500 yards wide, is about five miles long, and separates the bay from the lake in the same way as the Heights separate the bay from the marsh, the one being the counterpart of the other, when the lake stood at different levels. The bay inside of the beach is 78 feet deep. Neither of these beaches has been produced by sediments brought down by streams and thrown up in the form of sand bars, as in many modern harbors, because no important streams have flowed down the Dundas valley (since the epoch of high elevations at the close of the formation of the Erie clay) or do now flow. More particularly is this statement proven by the absence of all material belonging to the Dundas valley or region drained by its streams. In the Burlington Heights there is often flow and plunge bedding and slightly oblique stratification seen, which dip towards the lake. Lake Ontario never freezes more than a few miles from its margin, and even more than shore ice is uncommon. Winter storms often pile the ice and contained stones very high on the shores. Burlington bay always freezes over. It becomes apparent that both of these ridges (the latter rising only eight feet above the lake) were produced by the lake action from Hudson river pebbles and sand, transported by coast-ice and waves. Any *débris* of Hudson rocks found in the Dundas valley below 115 feet level is very small. The Laurentian pebbles are no more than the few deposited from the floating ice of the higher terrace epoch upon the region from which the detritus came.

The cause which determined the position of these ridges is easily explained. The extension of the lake into these narrow arms was frozen over during winter, not necessarily any colder than that of the present time. As the north-eastern winds were driving the coast-ice against the frozen barrier, it became broken up and deposited its burden of stones and sand in the same way that the present coast-ice with its contained stones continues to increase (though very slowly) the breadth of Burlington beach, aided with the action of the waves.

Hudson River Fossils in the last two Beaches.—Abundance of fossils occur in the pebbles of these beaches, at 116 feet above the lake and at the lake level. They are seldom found in the arenaceous pebbles, but most abundantly in the more flattened calcareous stone. I have obtained the following fossils:—*Stenopora fibrosa*, *Columnaria alveolata*, *Athyris headii*, *Strophomena alternata*, *S. deltoidea*, *Leptæna sericea*, *Orthis testudinaria*, *O. occidentalis*, *O. lynx*, *Obolella crassa*, *Modiolopsis modiolaris*, *Modiolopsis*, (numerous undetermined species), *Cyrtodonta harrietta*, *Orthonota sp.*, *Ctenodonta sp.*, *Lyrodesma poststriata*, *Ambonychia radiata*, *Avicula demissa*, *Murchisonia gracilis*, *Cyrtolites ornatus*, *Orthoceras lamellosum*, *Ormoceras crebiseptum*, *Leperditia Canadensis* and tails of *Calymene*.

Life Belonging to the Terrace Deposits.—Dr. Bell gives a list* of many places in Ontario where the stratified gravels and sands contain fresh-water shells. To his list other collectors have added localities. However, about the western end of Lake Ontario they are very rare, and I have seen only one or two localities where they are found although they occur near Niagara Falls.

The principal locality is not in the terraces, but will be described below.

However we have remains in Burlington Heights more interesting than shells. Many years ago in making the cutting through the heights of the Desjardins canal, at an elevation of 70 feet above the lake (about 38 feet below the summit), remains of the mammoth *Euelephas Jacksoni;* horns of a wappti, *Cervus Canadensis*, and the jaw of a beaver, *Castor fiber*, were found. In 1876, while making another excavation in the Heights the workmen found a tusk and one vertebra of a mammoth. At a depth of 30 or 40 feet from the top of the terrace there could have been no beach on which these animals might have wandered. Were the animals then unfortunate enough to be carried thither on the ice, were they drowned in attempting to cross from one side of the ancient valley to the other, or were their bones carried thither by the floating ice?

In several of the swamps north of Lake Erie teeth and bones of mastodons have been found, but these belong to more modern deposits.

XI.—MODERN DEPOSITS.

Most of the deposits of the present time consist of the soils carried down by the streams into the Dundas marsh and Lake Ontario.

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* Geol. of Canada, 1863.

One deposit now completed does not belong to this class. Just west of the Catholic cemetery at Hamilton and bordering on a branch of the Dundas marsh we find a bed of shell marl. This is almost entirely made up of broken shells, and contains also the following modern species in a state of preservation:—*Patula alternata*, *Triodopsis tridentata*, *Mesodon albolabri*, *Succinea*, *obliqua*, as recognized by Mr. Whiteaves. This deposit has a thickness of about 15 feet extending to that height above the marsh.

Some interesting facts with regard to the modern deposits in our lake and the Dundas marsh have recently come to light. The area of the Dundas marsh is rather more than two miles. It is generally shallow and filled with reeds. In the eastern portion there are some deeper places where the reeds do not grow, it is being rapidly filled by the accumulations of the sediments from the streams emptying into it. The deposits are now principally made during the increased flow of water of the spring freshets. A constant source of trouble has for many years been experienced by the silting up of the Desjardin canal, which passes through the marsh. As late as 1860 or 1865 the western end of the marsh was frequented for skating purposes; the same portion is now turned into fertile meadows. For nearly a score of years the proprietors have been trying to recover the land by making dykes. One dyke after another has been encroaching on the marsh until a considerable area is now drained. In making one of these dykes a trench was sunk to a depth of several feet, and at six and one-half feet from the surface Mr. James Chegwin came on a bed of saw-dust six inches in thickness. This was in the year 1876. On making inquiry, I learned that the first saw-mill in the region began operations about the year 1811. Thus we see that from the time that the saw-dust was brought down from Mr. Green's mill, in the Lindsay creek, a deposit of mud six and one-half feet thick accumulated in a period of about sixty-five years, or that the rate of deposit is about 1.2 ~~a tenth of an~~ inches per annum. It is probable that at the present time the accumulation is more rapid as the area of the deposit has been considerably lessened. The parts of the marsh outside and adjacent to the dykes are now entirely above water in the later portion of the summer. This silting up is continuing until the spring freshets can no longer overflow the low land, when all the sediments are carried into deeper water. Seasons of high water in the lake, of course, favor the thickening of the soil near the surface, when perhaps the succeeding season will be accompanied by low water, with the consequent distribution of the sediments in only the deeper portions of the area.

Lake Fluctuations.—In order to ascertain what proportion of the elevation of the bottom of the swamp was due to the sediments. I succeeded in getting some of the records of the fluctuations of the lake levels. In a Smithsonian contribution Col. Whittlesea has published a more or less complete register of the fluctuation of Lake Ontario at the port of Oswego between the years 1815 and 1857. The earliest of these records begins in 1815 and is continued for the next twelve years, during which time the annual fluctuation was very considerable, the extremes being as much as 4.5 feet. From 1840 to 1853 the maximum difference of levels was only two feet; while that from 1859 to 1873 (obtained from other records) was 2.8 feet.

The question arose whether the lands were rising (or water sinking) or not. At Oswego the mean height of the water between 1840 and 1853 was about nine-tenths of a foot higher than between 1815 and 1827. As the records obtained from 1859 to 1873 are not from same datum I cannot compare them with previous years. But if we take the heights from 1859 to 1866 inclusive, and those from 1867 to 1873 inclusive we find that during the later period, at Oswego, the waters were about nine-tenths of a foot lower. The table of fluctuations (obtained from Captain Fairgrieve, of Hamilton) for Toronto Harbor shows that the mean height of the water between 1874 and 1865 was one foot lower than that between 1864 and 1854 inclusive. In computing these heights the records for two years in each period are incomplete, therefore they have not been included in the calculations. The following are the mean heights of the lake at Toronto above a given datum mark for the years:—

1854	1 55	feet.	1865	1.00	feet.
1855	1.30	"	1866	—	
1856	1.46	"	1867	1.10	"
1857	—		1868	0.60	"
1858	2.25	"	1869	—	
1859	2.33	"	1870	2.50	"
1860	1.42	"	1871	0.83	"
1861	—		1872	— 0.40	"
1862	2.17	"	1873	0.40	"
1863	1.62	"	1874	1.00	"
1864	2.70	"			

The greatest fluctuation in the 21 years was 3.1 feet, at Toronto (omitting the four years '57, '61, '66, '69). From these fluctuations of the lake it can be seen that the position of the greatest deposition in the marsh will be somewhat changed in different years, as much of it is very near the water level. During a continuance of years of low water the sediments would be carried farther by the streams and consequently the higher grounds would not receive additions.

Filling up the Western End of Burlington Bay.—Grindstone creek empties into the western end of Burlington bay, and the currents principally pass close to the eastern side of Burlington Heights. As this stream brings down a large quantity of mud and, although emptying first into a swamp of its own), a considerable amount of sediment is carried into the bay and is deposited in the quieter waters near Carrol's point, at which place there is a long bar (submerged at high water) where these currents meet the waves of the open bay. This portion of the bay is fast becoming a swamp.

XII.—LAKE MEDAD.

About two miles northward of Waterdown, there is a small pond—Lake Medad—half a mile long. In the western part of Dundas valley there is a number of small ponds amongst the hills of drift material, but these are only small expansions of the various streams at heights from 510 feet to 210 feet above the level of Lake Ontario. On one side of Lake Medad there is a rugged shore of deeply weathered dolomites, extending more than 20 feet above its waters. The shore beneath is composed of a beach of pebbles. The opposite side of the lake is shallow, and is now occupied by a marsh. This lakelet is not an expansion of any modern rivulet. A number of insignificant streams empty into it, but not one of which could possibly have excavated the present basin. This lakelet is not on the uppermost portion of the Niagara escarpment, but in a somewhat broadly rugged country. The basin of Lake Medad is evidently a filled up portion of a larger water channel that became blocked by drift material, which it has been unable to clean out for itself in modern times. The whole lake could be drained by cutting through the drift deposits which occupy one of its extremities. I was informed by one of the inhabitants that he had discovered an underground outlet, so that a portion of the waters discharge by a stream directly into Lake

Ontario, while at present, the small visible outlet is by Grindstone creek, through Waterdown.

Comparing it with Lake Ontario, it has its Niagara escarpment on one side and on the other a gradually shallowing shore towards an area evidently filled to some depth with drift material analogous to the soft Cambro-Silurian rocks north of Ontario, whilst its outlet is blocked up, as the the greater lake is, in its south-eastern extremity.

Thus I will close a fragmentary work, which will, I hope, assist in the study of the surface geology of Ontario, and also give more prominence to the almost undeveloped subject of Fluviatile Geology.

(Having learned the value of accurate elevations, I have collected the levels of most of the railways in Ontario and some other lists of elevations which will follow the present paper.)

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