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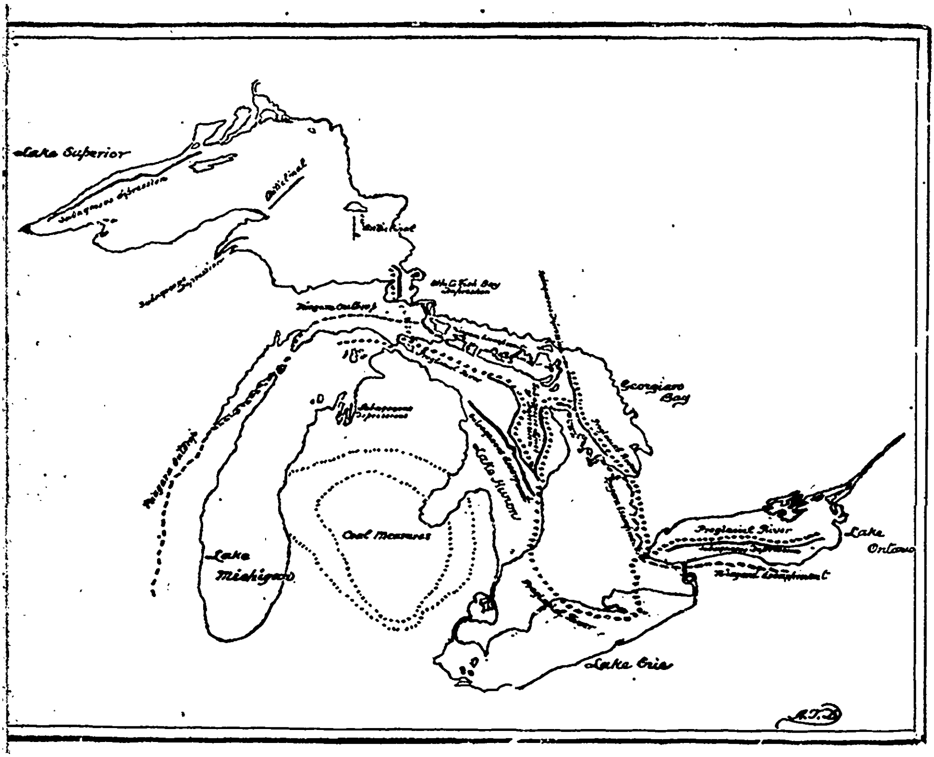
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The Great Lake Basins of The St. Lawrence.

By A. T. Drummond.

When recently considering the physical and geological relations of the Canadian flora, my attention was drawn to the many interesting questions connected with the formation of the St. Lawrence Great Lake Basins. What had been their history in past time? Were these lakes, as has been so long maintained, the outcome of the forces of the glacial age, or had they not in some cases an antecedent, and in others, or all, a subsequent history as well? What influences had they exercised on the climate, fauna and flora of the north-eastern part of the continent in the past? How far do their present contours and depths, the physical

Author's Note.—Since this paper was written, I have seen the very brief abstracts of articles on a similar subject by Prof. Spencer, which have been pnblished in the Record of Science for October, issued this month. I am glad to find that his views on one or two points referred to in this paper confirm the conclusions I had arrived at independently.

November, 1888.

and geological features of the surrounding country, the fauna of their depths, and the flora of their shores, furnish us with facts for the compilation of their history?

The object of the present paper is to suggest what has been the origin of the contours of the Great Lakes as they now present themselves. All writers on the subject are probably agreed that at a relatively recent quaternary period these lakes have been united consequent on a depression of the land, greatest at Lake Superior, and lessening towards the present St. Lawrence outlet. That in the previous glacial period this greater lake was a still larger inland sea extending farther southward, into which glaciers from the then more elevated Laurentian area, and rivers having their sources at the glaciers, flowed, and across whose surfaces floated icebergs and icefloes, carrying their burdens of boulders and débris in the direction in which the currents impelled them, has always appeared the most reasonable view to take. The depression would be a natural result of a rise of land to the north. It has not hitherto been sufficiently considered that whatever changes in level take place, the maintaining of an equilibrium in the earth's crust can in general terms be predicated. If there is a great subsidence in the land over any extended area, it may be assumed that there is a corresponding rise in the land over some other area. Thus, if over the Laurentian region there was an increase in height which gave some slope and consequently denuding power to the glaciers which flowed to the north and northeastward on the one side of the Laurentian axis, as shown by Drs. G. M. Dawson and Bell, and to the southwestward on the other, then we can accept the assumption that immediately to the southward or northward, or both, there might reasonably be an extensive depression of the land and an inflow of the sea. This inflow on the southward side also found its way, no doubt contemporaneously, as far west as the Rocky Mountains, as the enormous boulders and other features discovered by Dr. G. M. Dawson indicate. And there seems to be corroborative evidence of this inflow in the flora around the lakes and in the fauna of their depths, as will be shown hereafter. That in the St. Lawrence Basin this inland sea graduated by a general elevation of the land and by local warpings of the strata into the more circumscribed fresh-water lake before referred to as including the area of the present lakes, there seems no question. That, however, prior to this an interglacial period prevailed, to be followed by a second glacial period, there is not in Eastern Canada very satisfactory evidence, whatever credence we may give to the vegetal deposits relied on by some American geologists to prove more than one interglacial period, and to the peaty remains in the Canadian superficial deposits towards the Rocky Mountains.

The grave difficulties which on general physical grounds stand in the way of the larger conception of a continental ice-sheet, need not be repeated here. It may be well, however, to allude to one circumstance—the immense mass of the superficial deposits—which has been relied on as necessitating a glacial theory for its explanation, and which has a direct association with the history of the St. Lawrence Basin. It has been usual to ascribe largely to glacial action what must be the effects of ages of subæreal and sub-aqueous erosion and decay in this great lake basin since the Carboniferous age. Whilst most sections were above water for vast periods prior to the Carboniferous, the whole of the immense area drained by the Great Lakes has, subsequent to that period, and as far onwards as quaternary times, been dry land, excepting to the extent that these lakes, or any of them, may have themselves been in existence during the immense intermediate periods—periods measured not by centuries alone, but probably by countless centuries of centuries. All of the agencies ordinarily at work in producing growth, disintegration and decay were then in operation, and have been continuously since. Forests covered the land, and vegetation in its decay everywhere yearly contributed to the soil; torrents found their way to the rivers, and the rivers to the lakes and to the ocean, creating on their way boulders and gravel, and depositing clays and sands, not only on the river banks, but carrying them to these lakes and to the ocean in vast quantities; the ocean and lakes were themselves not only great factors in erosion on their coasts, but were the distributors of sands and clays over great areas of their floors; whilst added to these eroding powers were the ceaseless forces of the atmosphere in the heat of summer, in the frosts of winter, in the downpours of rain, and in the blasts of the storm—each contributing its measure of energy in the wearing down of mountain sides and cliffs, the carrying away of soil, and exposing of vegetation to decay—an energy not especially visible in its effects in a single year or in a decade of years, but productive of vast results in the course of centuries. And this growth, disintegration and decay going on ceaselessly from century to century, and from age to age, must have created immense deposits of boulders, gravel, sand and clays, in every part of the country, prior to the advent of the glacial period. If Croll's view were accepted, that since a previous glacial epoch, which he appears to suggest occurred during the Eocene age, a period of 2,500,000 years has elapsed, we can form some conception of what must have been the results of denudation during the enormous time previous to as well as since that age. These deposits were no doubt largely added to, and in many cases re-arranged, but the denuding effects of the glaciers, considerable as they may have been on the superficial features of the country, have been greatly exaggerated.

Again, some geologists have been too ready to accept existing levels as the basis on which to found conclusions regarding the levels of the country in its different sections in past times, without any reference to warpings of the strata which have since affected local or wide areas. These warpings are known to have cut through the channels of rivers, created new watersheds, opened up new river valleys, and reversed the currents of lakes. Spencer has recently drawn attention to such warpings in the Mississippi Valley and south of Lake Ontario.

Centres of Depression.

When examining attentively the general geological features of the country surrounding the Great Lakes, the careful student will not fail to observe that three great centres, as it were, of depression existed in its bygone history.

One occupies nearly the western half of Lake Superior, the floor of which here is overlaid by the Cambrian and upper division of the Keweenawan rocks. Beyond these, on the north-west and south-east sides of this part of the lake there occur, in successive descending order, the lower division of Keweenawan, the Animikie division of the Huronian, and what are supposed to be the Laurentian rocks.

Eastward of Lake Superior, it will be observed that, as far onward as the Carboniferous period, there were, near the present lakes, two other great centres, as it were, of depression, the one in Northern Pennsylvania, the other in Michigan. In passing southward from the Laurentian region lying between the Georgian Bay and the Upper Ottawa, the formations are met with in a regular, almost unbrok en, ascending order, from the Laurentian of Canada, through the Lower and Upper Silurian and Devonian, until the Carboniferous rocks of Northern Pennsylvania appear. The strata representing these formations occur in this regular succession, all within a distance from north to south of one hundred and seventy-five miles. The outcrops of several of these formations are, on the south side of Lake Ontario, more or less parallel to the length of the lake and to each other, whilst the outcrop of the Trenton and Black River limestones to the north of the lake runs in a line diagonally from the east end of Lake Ontario to the Georgian Bay.

That the area presently occupied by Lake Ontario was overlaid in part by Trenton limestones and Utica slates, but perhaps more by rocks of the Hudson River and Medina age, is apparent from the way in which these strata on the north-western side are again represented to the eastward and southward of the lake. Thus, the interesting questions to consider are: Do these strata presently form the floor of the lake, or have they within the lake area been removed by some vast erosive force acting at a recent period? In other words, is the lake the result of a synclinal depression or of erosion, or both? Again, is the apparent parallelism in the outcrops of the formations due to successive, gradual, permanent elevations of the land from the Laurentian period onward, each elevation stretching farther south than its predecessor, or is it due to a great erosive force which exposed in succession the upturned edges of the different strata, and as a farther result produced Lake Ontario?

In Michigan, again, the Carboniferous area which there at one time was the centre of depression, is even more conspicuous in its relations to both the surrounding geological features and the adjacent lakes. Here, on every side, there is a regular series of formations whose outcrops, after making every allowance for estimations, appear each in proper geological succession within the other, and in Michigan, form, as it were, irregularly concentric areas around the Carboniferous. Again, the contours of the shores of Lakes Michigan, Huron and St. Clair, and of Lake Erie at its western end, present the same idea of arrangement around the same central area. The interesting questions arising are: Were these formations originally laid down here with this more or less concentric arrangement which in Michigan they presently possess, or have they in recent or earlier times been the subject of some denuding force, which has given them this peculiar arrangement, and which probably has also aided in the creation or enlargement of the adjacent lakes? Again, as certain of these formations were evidently originally more or less continuous across the area now occupied by Lakes Huron and Michigan, has some vast erosive force created these lakes by removing the strata where they occupied the lake area, or do the strata underlie the waters of these lakes as a result of a depression, or, are there here the effects of both denudation and depressiou?

The central area of Michigan was, as far onward as the close of the era of the coal measures, generally under water, and unless Michigan has been the subject of extreme denudation, those portions of the State which surround the coal measures were dry land when these measures were deposited. Since that period the State has been entirely above water, if we except any depression during quaternary times. Whatever the oscillations have been at different periods, the fact remains that the State is now in considerable sections elevated between one thousand and two thousand feet above the sea, the areas between the central and northern portions of the State forming the highest levels. In the country on the immediate west side of Lake Michigan, the land has, with the same exception, been above water since about the period of the Niagara limestones and shales, and is now there, in many sections, also between one and two thousand feet above the sea. In the Ontario peninsula, on the east side of Lake Huron, there is an elevation reaching on the anticlinal at the Niagara escarpment as high as seventeen hundred feet. There is, however, good evidence, as will be shown farther on, that at some former time there have been certain marked disturbances in the general level of the Michigan, Erie, Huron and Ontario areas, operating probably simultaneously, and that these disturbances had much to do with the more general defining of the contours of these lakes.

In following the history of the Great Lakes, the physical features of the lake bottoms afford some interesting chapters. The soundings undertaken by Cols. Meade, Comstock, and other engineers of the United States War Department, and those of Capt. Bayfield and Commander Bolton of the Canadian Marine Service, enable us to form some important conclusions, especially when taken in connection with the physical and geological features of the coasts of the lakes. That the lakes have to even a moderate extent a glacial origin does not appear to be borne out by the facts which these soundings reveal, however much icebergs and glaciers have contributed their quota of results to the outlines of some portions of the coasts and to the character and disposition of the material upon these coasts and upon the lake bottoms.

Let us examine each lake in turn.

Lake Superior.

This lake is so distinct from the other lakes in its origin, that it must be separately considered.

The point of greatest depth is not in the centre, but forty miles north-east of Duluth, and about six miles off the west shore, where, in a small area, 1,026 feet is reached, or 426 feet below ocean level. The depression to this low level at this point is, as frequently occurs elsewhere, very sudden, the depths at the immediate sides being 690 and 816 feet. The line of deepest depression at this end of the lake does not lie along or near the central line of the lake, but follows somewhat irregularly the west shore from near Duluth until it reaches the entrance to Thunder Bay. Between this bay and Isle Royale the maximum depth is 990 feet. From that part of this line of deepest depression, lying south-west of Isle Royale, the lake bottom shallows, at first somewhat gradually, but finally more rapidly to the south shore east and west of the Apostle Islands.

Along the west shore of the lake the coast line is often high, being in frequent places from 900 to 1100 feet, and at Thunder Cape attaining over 1300 feet. Below the water-line, for nearly the whole distance between Thunder Bay and Duluth, there is at or within a mile of the shore a sudden descent to depths varying from 100 feet in some localities to over 600 feet in others, whilst in one instance alongside the islands, off the east side of Thunder Cape, the bottom is only reached at 780 feet. Two miles further away from this general coast line the depth becomes 500 to 1000 feet. Thus along this west coast shore, from the summit of the heights overlooking the lake to the deeper points in the line of the depression, which is generally about five miles distant, there is a total descent varying from 1600 to 1900 feet, except at Thunder Cape, where it is increased to 2140 feet. These soundings suggest that between Black Bay and the westerly end of the lake there are, running somewhat parallel with and close to the coast, great subaqueous cliffs, some probably like Thunder Cape, and of irregular outline and at different levels, and which give rise to the sudden increase in the depths of the lake here. There is, however, the possibility that a great downthrow, or dislocation, of the upper division of the Keewenaw Series, exists here, the hinge, as it were, of the depression being towards the south shore of the lake, and the rocks gradually sloping from this hinge to the line of deepest depression near the western shores. These cliffs lie in a general way parallel with the axis of the western end of the lake. Is it not suggestive that here we have the effects which gave rise in time to certainly the westerly half of this greatest of the inland seas? And may not the forces which resulted in these cliffs, or in this great dislocation, if such it be, have been simultaneous with some of those volcanic forces which at different periods produced the abrupt overflows, or great dikes, or interstrata, of the mainland in the Huronian or Keweenawan rocks, and gave direction to the heights which at its south-western end form there the rim, as it were, of Lake Superior. The Western sandstones of the south-west shore give further clue to their period of operation.

Parallel with these cliffs is another sub-aqueous escarpment in Keweenaw Bay, about twenty-five miles long, lying near the south-east shore and facing in the opposite direction. Here there is an abrupt descent from depths of 100 and 150 feet to depths varying from 300 feet to 552 feet. In the large outer bay the maximum depth is only 366 feet, and the average does not probably exceed 270 feet.

At the upper end of White Fish Bay the waters of Lake Superior converge, and flowing over the rocky rim of the lake here, result in the rapids of the Sault Ste. Marie, as they descend to the level of Lake Huron. The lake bottom in the bay has points of great interest. Running about due northward from near Pt. Iroquois, on the Michigan shore, past Parisian Island, on its western side, to opposite Pancake Point, on the Ontario side of the lake, a distance of about thirty-five miles, is a marked depression in the floor of the bay of from three to four miles in width, flanked on both sides by more or less abrupt, continuous cliffs of probably Potsdam age. From a depth varying on the top of the cliffs from 30 to 150 feet, the descent is quickly made to depths reaching a maximum of 612 feet, and averaging from 350 feet to 400 feet. Whilst the summits of these subaqueous cliffs form, on either side of the depression, a relatively level surface of about two to four miles in width for the whole thirty-five miles, beyond that width the lake bottom once more, but more gradually, slopes in the one case to the eastward, in the other to the westward, so as to form two other depressions parallel to that above described, but of much less depth. Beyond Pancake Point the middle depression leads to the general depths of the lake bottom outside of the bay, but with a somewhat decreased depth at the immediate outlet. In White Fish Bay the lake bottom is, like the coast near at hand on the southern side, composed chiefly of beds of sand, and it is clear that these depressions are now partially filled up with this material and with clay.

These subaqueous cliffs and depressions lie in a general direction parallel to the eastern coast line of the lake, and have probably their origin in the same cause, though subsequently more defined by river action. The conspicuous subaqueous ridge between Michipicoten Island and the higher division of rocks of Caribou Island has apparently also the same direction.

The forces which contributed to the formation of Lake Superior appear to have taken three principal directions: the first in a line from Michipicoten Island eastward and westward, parallel with the extreme northern and general line of the southern shores of the lake, and with the northern coast of Keweenaw Point, where profound depths almost skirt the shores; the second, already referred to, operating in the line of the western coasts, of the subaqueous depression near these coasts, and of the axes of Isle Royale and Keweenaw Point, and of the Keweenaw Bay depression; and the third, in a direction parallel with the eastern coast line, the White Fish Bay subaqueous cliffs and depression, and the apparent ridge between Caribou Island and Michipicoten Island. Other less important forces acted in other directions in forming Thunder Bay, Black Bay, with its deeply-channelled entrance, and the eastern and deeper side of Nepigon Bay. These forces *probably operated at different* times, each in its turn contributing to the further enlargement of the lake, which originally was no doubt of modest dimensions compared with the present area.

It is just probable that the operation of the second force in the order given above was more recent than that of the first, as a very marked subaqueous anticlinical in a line with and forming a continuation under the lake of the Keweenaw Peninsula, crosses to the centre of the lake, somewhat abruptly severing in two the deep, lake depression which runs from Michipicoten Island westward. There is a presumption that this anticlinal was formed subsequently to the depression, and, considering also the sandstones on the south-west coast, that the central part of the lake may thus be older than the south-western. Again, the Cariboo Island anticlinal apparently likewise crosses the deep, lake depression, and thus the central parts of the lake may also be older than the eastern. The White Fish Bay river channel being cut through the Potsdam sandstones, will also be more recent.

If we regard these earlier forces as having a common source with some of those which resulted in the eruptive rocks, forming so prominent a feature in, and so conspicuously interstratified with, the Huronian and Keweenawan Series, then we may date the origin of Lake Superior as far back as it may be Huronian and Keweenawan times. And this is by no means improbable. Foster and Whitney, and especially and more recently, R. D. Irving, have shown that the lake is, in both its eastern and western halves, a great synclinal trough or depression. This conclusion has been arrived at from—particularly in the western half—the generally constant dip of the Keweenawan rocks towards and under the lake; the frequent dip of the Huronian as well; the re-appearance of these strata on opposite sides in the western half of the lake; the regular order of succession of Keweenewan rocks, Huronian rocks and gneiss, granite and crystalline schists on all sides when proceeding inland from the coast, and the parallelism between the courses of the Keweenawan belts on the north and south shores, and of the coast line with these belts.

At the eastern end of the lake, Cambrian rocks overlie the Keweenawan and Huronian, and now form the rim over which the lake waters flow in their course to Lake Huron. It is conceivable that the submerged channel fractured through these rocks here was, for ages, the outlet of Lake Superior into the Trenton, Hudson River, and later seas, and that even in more recent times it joined the submerged river channel in Lake Huron, coursing its way across the sandstones, limestones, and shales of the north peninsula of Michigan by a connecting valley which subsequent elevation of the land has cut off.

Now, all these facts appear to effectually dispel the idea that Lake Superior has a glacial origin. It is undoubtedly the oldest of the Great Lakes, and has preserved its present general contour through vast periods and for countless ages before the glacial period. That glaciers prevailed on the mountains and hills on its coasts during the ice age, polishing and grooving the rocks and dotting the united inland sea with ice and icebergs at certain seasons is probable, but they merely added to the effect of previous ages in toning down the rough edges of these mountains and hills, and scattering the loose material thus produced over the broad surface of the bottom. Great areas of this lake's bottom around the Apostle Islands, the west side of the Keweenaw Peninsula, and within and on the west side of White Fish Bay, are surfaced with sand derived undoubtedly from the wear of the sandstones of these localities, whilst the general character of the bed of the lake, especially in its most profound depths, is clay.

Dr. Selwyn thinks that the geological features of the

Lake Nepigon country may be explained by that lake now occupying the crater of an ancient volcano, and he is inclined to take the same view of Lake Superior. Whatever may be said of Lake Nepigon, the features of the present floor of Lake Superior hardly bear out this conclusion, although there can be no question of the existence of enormous volcanic forces at different points.

Whilst the history of Lake Superior, during the vast ages which have elapsed between the Cambrian period and the close of the Tertiary, is in most respects a complete blank, yet, from the latter time, its history begins once more. Apart from the facts which the superficial deposits supply, some reference to which will hereafter arise in connection with the other lakes, the fauna of the lake itself and the flora now existing around its shores afford some interesting chapters.

On the jutting headlands of the lake, and along the shores of the bays of its northern coasts, there are both subarctic and boreal plants which appear to form a completely isolated group in these localities. Their original presence, there, it is difficult to disassociate from a migration before the close of the glacial era, when, with the somewhat colder climate, and under the influence of the low equable temperature of the great inland sea south of the glacier-clad Laurentian and Huronian mountains, subarctic and boreal plants found a natural highway along the coasts. With lofty mountains to the immediate northward, such plants, as well as perhaps arctic species, were doubtless not uncommon. As the waters receded and the climate became milder, these northern plants were driven to localities like the headlands of Lake Superior, where the low temperature and moist atmosphere were favorable to the continuance of some of them in a struggle for life, in which probably most became extinct.

The inland maritime plants of Canada, which occur along the coasts of all the Great Lakes, and on saline ground in New York State, and far westward, appear to be the remnants of a larger maritime flora which margined the coast probably before the close of glacial times, and certainly at a period when the great inland seas were saline, or in a state of transition from saline to fresh water, which the gradual change in the elevation of the land would have brought about. Their presence so far inland seems a direct argument for the saltness of this interior sea at these times, and under any circumstances proves, in connection with the subarctic and boreal plants of Lake Superior, that the climate, at the time of their migration, was not, along the shores of that lake more severe than on the coasts of the Lower St. Lawrence at the present day. These inland maritime plants are all now found there or on the coast of Nova Scotia. In further proof of this question of climate, does not the comparatively limited flora of the summits of the White Mountains, and other considerable heights in New England and New York, comprising chiefly four or five really arctic and a few subarctic and boreal plants, nearly all also found on the coasts of the Lower St. Lawrence, of the Gulf of St. Lawrence, or of the adjacent portions of Labrador, show that the true arctic flora had hardly, in glacial times, reached as far south as these mountains?

Profs. Verrill and S. J. Smith, in 1871, published in the *American Journal of Science* a list of the deep-water fauna dredged by them in Lake Superior. The list is interesting as shewing the existence in that lake as well as in Lake Michigan of the marine crustaceans *Mysis relicta*. Loven and *Pontoporeia affinis*, Lindst., previously detected in Lake Wetter in Sweden. Both species were discovered in the profound depths of the lake, as well as in the shallower waters. Species of *Gammarus*, which might possibly be marine, were also found. They are no doubt the survivors of a larger marine fauna which inhabited the St. Lawrence basin in glacial times, and would seem to afford proof of the saline character of the water of the great inland sea which occupied this basin when the subarctic, boreal and inland maritime plants migrated to the neighborhood of Lake Superior. The *Mysis* is a denizen of the Greenland seas, and suggests strongly that when the great inland sea prevailed the temperature of its water was maintained at a low point by cold inflowing streams, by currents, and by icebergs. These crustaceans thus aid in identifying the conditions under which the northern and maritime plants existed on the inland coasts.

Lake Huron.

This lake presents a totally different set of circumstances from those of Lake Superior. Its floor is laid in the Archaean Silurian and Devonian formations, whilst the Niagara escarpment, continued across the Ontario peninsula, gives shape to the two great divisions into which the lake surface is separated in its northern half.

In its profound depths the lake really forms three great basins—the Georgian Bay, the Central, and the Southern basins.

The continuation of the great Niagara escarpment in an irregular, subaqueous ridge connecting Cape Hurd, the Grand Manitoulin Island, and the various islands between them, gives the Georgian Bay a distinctive character. This ridge appears to present, under water, bold, precipitous cliffs facing the Georgian Bay, similar to the heights from Cabot's Head to Owen Sound, and with similar deep inlets, though penetrating the ridge in somewhat different directions. Whilst the cliffs on the islands form the real summit of the ridge, and its subaqueous portions rise to an average of within 30 to 40 feet of the lake surface, the depths on its immediate eastern sides often reach 250 feet. At Overhanging Point, between Cabot's Head and Cape Hurd, the depth at half a mile from the cliff reaches 540 feet, the deepest point of the Georgian Bay. Through this subaqueous ridge there does not appear to be any break permitting direct access from the deeper waters of the bay to those of the central parts of the lake beyond. Further, the dip of the strata forming the ridge appears by the soundings to fall gradually to the westward and south-westward, just as the same strata on the Bruce Peninsula slope to the westward, and those on the Manitoulin Islands in the curve which the outcrop of the Niagara limestones there takes, slope to the southward.

The Georgian Bay in this part appears to be subsiding, according to Bolton's survey. North-East Shingle, off Lonely Island, presently 2 to 5 feet below water, was in Bayfield's time, 3 to 4 feet above, whilst White Shingle, off Snake Island, now 1 foot below, was formerly 2 to 3 feet above. As Bayfield's survey was made in 1822, the maximum subsidence has been about one foot in each nine years. Commander Bolton, however, has personally suggested to me the possibility that floating ice may have been the cause.

On the eastern banks of the St. Clair River there are also evidences of subsidence, but these may be local.

It is possible that in some sections the Niagara escarpment, including under this term the whole strata exposed, may result partly from a fault. The country at the foot of and approaching the escarpment is in Canada, almost invariably either obscured by heavy superficial deposits, or covered by the waters of the lake, rendering exact observation difficult. It is quite possible that could the profound depths of the lake adjoining the east and north side of the Bruce Peninsula be studied, such a fault or faults might be discovered. Whilst the escarpment at Cabot's Head towers 324 feet above the water, the depths close at hand in the Georgian Bay reach about 498 feet, giving a total of 822 feet, and along the face of the escarpment lie the deepest parts of the Georgian Bay. From this line of depression the slope is upward towards the north-eastern shores of the bay, where the depths outside of the islands average about 60 feet, excepting in Parry Sound, where there is a maximum of 354 feet.

From Cabot's Head south-eastward, at every point and island, and sometimes also in the bays, Mr. Alex. Murray found a fringe of reefs close to the cliffs, all apparently composed of loose blocks, and probably all derived from the destruction of the cliffs by rapid currents, by the action of waves, as well as by the forces of the atmosphere. These reefs also extend a short distance eastward of Owen Sound. Two or three miles to the eastward of these cliffs Commander Bolton has found at least two abrupt elevations quite near to the surface and covered with loose rocks.

Whether, however, there has been any special subsidence in the strata on the eastern side of the escarpment or not, the escarpment itself has been the subject of elevation, greatest at the edge of the cliff and gradually lessening to the westward on the Bruce Peninsula, and to the southward on the Manitoulin Island, until all of the strata are lost under the waters of Lake Huron proper. The soundings along the whole eastern coast of the lake from Cape Hurd to Goderich, and southward, and off the southern coasts of the Manitoulin Islands, show that the strata continue to slope gradually towards the central parts of the lake.

Another somewhat parallel escarpment occurs on the west side of Matchedash Bay, and along islands at the extremity of the peninsula there. This is, however, in the area of the Trenton and Black River limestones, near or at their junction with the Laurentian rocks. The strata slope from Nottawasaga Bay upward to Matchedash Bay, where they present bold cliffs facing to the north-east. The depth of water adjacent to the cliffs on these islands is very considerable, reaching a maximum of 267 feet.

The central and southern deep-water basins of Lake Huron are readily distinguished. The former, which is the deeper of the two, lies in the Upper Silurian strata, and is separated from the latter, which rests on the Devonian rocks, by a well defined escarpment evidently of Corniferous limestone. This escarpment, starting from the Canadian side south of Kincardine, crosses Lake Huron in a north-westerly direction in, generally, a line with the Straits of Mackinac until near Presqu'isle Point, where it approaches the shallower waters of the Michigan coast. If 180 feet in depth of water were uniformly removed from Lake Huron, it would completely separate these two basins and leave the summit of this separating ridge in some cases 120 feet above water.

While thus this ridge approaches in some places within 60 feet of the present level of the lake, the profound depths on the immediate north-easterly side vary from 360 to 588 feet.

The deepest point in the lake is 750 feet, or 172 feet below ocean level, and is found in this central basin about thirty miles south-west of Cape Hurd. It is a sudden depression, as the depths a short distance on either side are 426 and 366 feet, and it does not occur in the general line of deepest depression. This line, starting from near the Canadian shore, takes a direction irregularly parallel with the Corniferous limestone escarpment to a point somewhat more than halfway across the lake, when its direction is diverted northward towards Grand Manitoulin Island. A branch of this line of deepest depression runs from off Kincardine almost due north in an irregular line towards Cape Hurd. Lake Huron is thus somewhat deeper in its Canadian half, and the central basin gradually shallows to about 180 feet near the Straits of Mackinac.

The southern basin comprises all that part of the lake south of the subaqueous Corniferous escarpment, and is much shallower than the central basin. The summit of the escarpment has an average breadth of about four miles, after which, on the south-western side, the slope becomes more distinctly to the south-west or west, and is somewhat gradual, though the greatest depth in this southern basin is reached at 330 feet in an abrupt depression at one point, at the beginning of this slope, about midway across the lake. The depth over the greater portion of this southern basin is very moderate, and about its centre is a large area, lying somewhat north-west and south-east, where, though almost surrounded by deeper water, the depth does not exceed 180 feet, and is generally less.

Whilst the bottom of the central basin is chiefly clay, with gravel in places, that of the southern basin is largely sand, especially in its lower third towards the outlet at the St. Clair River, and in Saginaw Bay.

Saginaw Bay appears to be a subaqueous continuation of the depression which crosses the State of Michigan along the Grand Valley and which, Rominger points out, seldom presents surfaces exceeding 100 feet above the lake. It does not average 30 feet in depth and it is suggestive whether it is not really a very shallow synclinal trough in the Carboniferous and Devonian rocks.

Now, all these facts, with others, have their bearing on the origin of Lake Huron. The abrupt, subaqueous Corniferous ridge diagonally crossing the lake; the different lines of direction of the Bruce Peninsula, its subaqueous extension and the Manitoulin Islands, and of their deep bays and inlets; the abrupt cliffs, both above and under water, showing rather the effects of undermining by waves and currents; the directions of the lines of deepest depression; and the varying and often sudden depths of the lake, showing that there has not been any general filling up of the hollows and depressions in the lake bottom, all militate against the idea that a great glacier from the north or north-east, gradually, in the course of ages, formed the depths and outlines of Lake Huron, nor do the directions of the ice grooves suggest what were evidently the travelling lines of the forces which gave rise to the above described and other physicial features of the lake. A reasonable conclusion, quite compatible with the existence of a fault, and with the elevation of the Niagara escarpment and of the land to the east of the Georgian Bay, would appear to be that the depression fronting this escarpment is in part the result of river excavation, and that through it flowed across Ontario, the drainage of the country to the northward and northwestward, until the waters joined the preglacial river which, as Spencer and Claypole point out, occupied the bed of Lake Ontario. This—supplemented by subsequent lake action—would account for much of the disintegration of the escarpment. The course of the river through Lake Huron was then, as shown by the line of depression, first to the south of eastward for some distance, then south towards the corniferous escarpment parallel to which it flowed, until, by a diversion to the north, it reached Cape Hurd and turning eastward, joined this river channel in a great fall over the subaqueous ridge now worn back to a line between Cape Hurd and Grand Manitoulin Island. Another stream from the north joined it at this point. These great preglacial rivers would continue their flow until the elevation of the anticlinal between the Georgian Bay and Lake Ontario blocked their course, and filling the Georgian Bay with water, created a new outlet, not by the St. Clair River, but to the southeastward of Lake Huron as hereafter referred to.

Though the eastern coasts, between the Bruce Peninsula and the County of Lambton, present bold clay cliffs of considerable height, the general dip of the strata from the Niagara escarpment which crosses Lake Ontario to the Georgian Bay, is towards and under the main body of Lake Huron. As already mentioned, this is also the case on the Manitoulin Islands, and south-eastward across the subaqueous escarpment to the Bruce Peninsula. Again, the strata on the Canadian side of Lake Huron proper appear on the Michigan side in the same relative positions. These facts tend to prove that the lake is in part now a synclinal trough which has been further depressed, in common with the surrounding country, at the time when the superficial deposits were formed, but which, in its rise to its present levels, has left behind the great clay cliffs now lining its eastern sides, which have been gradualy worn backwards by the action of waves and atmospheric causes.

The subject will be further referred to when discussing Lakes Michigan and Ontario, for the final shaping of the contour of these three lakes was in part due to one common cause.

Lake Michigan.

This lake rests, to a limited degree, on the Lower Carboniferous rocks, but chiefly on those of Upper Silurian and Devonian age. Its depth has been said to reach even 1,800 feet;[1] but the soundings made under the direction of the

[1] Encyclop. Britann. 9th ed. vol. 21, p. 178.

engineers of the United States War Department, do not indicate a greater depth than 870 feet, which is 292 feet below ocean level. This deepest point lies in the latitude of 44° 30' and rather nearer the Michigan than the Wisconsin shore. But a relatively limited portion of the lake has a depth exceeding 600 feet, and all of this portion is located in its northern half. The most northern parts of the lake are comparatively shallow, but there is clear evidence of a broad river channel cut through the rocky bed of the lake and running along the north side of the Beaver Island group to the Straits of Mackinac. Whilst the depth of the lake waters everywhere on either side is under 100 feet, this ancient river channel registers from 100 to 302 feet, the deepest points being in the narrowest parts of the Straits. From the Lake Huron side, another river channel entering the Strait, and with depths of from 154 feet to 210 feet, almost completes a circle around the Island of Mackinac, but is presently disconnected from the Michigan river channel by a narrow ridge or anticlinal, about two miles in width—the result of more recent warpings in the strata there—running from Point St. Ignace south-eastward, and over which there are now from 17 to 70 feet of water. These two subaqueous river channels were, without doubt, at one time connected, and at a previous period of these lakes' history, formed the outlet for the waters of Lakes Superior and Michigan. Both of these channels are flanked by the rocks of the Onondaga, Helderburg and probably Niagara groups, and have no doubt been enlarged by water action. It is at the same time a coincidence that in Lake Michigan the channel runs almost parallel with the northern coast of the lower peninsula of Michigan west of Mackinac and of the subaqueous ridge which connects the Helderberg rocks here with those of the Beaver Island group. Whilst this course is nearly due east and west, it will be noticed in this connection that the line of direction of the jutting headlands and islands immediately near them on the north shore, at and east of Mackinac Straits, is almost due south-east, and must be attributed to other causes.

The two peninsulas which defend the entrance to Green Bay are formed of the Niagara limestones which here curve to the south-west, and at Burnt Bluff and neighbouring points on the west side of the northern peninsula rise into an escarpment facing however to the north-west and west. Whilst at the base of this escarpment the water is, as a rule, comparatively shallow, the western side of the headland of the southern peninsula and of the adjacent islands carries deep water close to the shore, showing that the escarpment, continuing there, is in part, subaqueous, and faces also the north-west and west. It is important to observe these directions. Green Bay is however relatively shallow. The 100-foot line encloses a very limited area which, on the northern side, extends in a narrow, river-like prolongation, into Little Bay de Noquette, giving color, to that extent, to the possibility which Winchell has suggested, that in preglacial times there was a connection between the Lakes Superior aud Michigan basins by this bay and the Whitefish and Chocolate Rivers.

On the eastern side of the lake, Grand Traverse Bay in its upper half is divided by a long, narrow isthmus into two bays, each about twenty miles in length, and from one to two miles in width, with a general direction somewhat west of south. Though the outer bay which rests on the black shales has an average depth of 180 feet, these two inner bays are in reality narrow but abrupt and deep depressions varying in depth, in the one case, from 300 to 448 feet, and in the other from 300 to 612 feet. The lake bottom here is either clay, sand or rock. Lying almost parallel with these depressions are on the one side the long narrow lake known as Torch Light Lake, and on the other, the promontory which separates Grand Traverse Bay from the lake, and presents high bluffs on the western side. Originally these depressions were great fractures in the Devonian rocks, created by the elevation of the land here, just as the Niagara escarpment has been similarly fractured.

Between the Beaver Island group and the Manitou Islands is another extensive preglacial depression, in the rocky bed of the lake, and with deep inlets joining it from the north, north-east, north-east by east, south and south-west sides, and the whole connected towards the south-west end with the deeper parts of the lake beyond. The descent is generally so abrupt from the shallower parts of the lake on either side to the depths of this depression and its inlets as to convey the idea of escarpments or bold cliffs almost surrounding the depression. The Helderberg anticlinal separates it from the old subaqueous river channel. On the other hand, Little Traverse Bay—another fracture in the Michigan coast—which has 136 to 230 feet of water everywhere within half a mile of its shores, may be said to lie about due east and west. It is important to thus note the varying directions of the forces which have given rise to these different depressions or great fractures.

The southern half of Lake Michigan has a generally uniform appearance. Its coasts are not indented with deep bays, but preserve an outline somewhat straight at the sides and curved at the southern end; the waters, though shallower towards this southern end, have on the eastern and western sides a gradually increasing depth towards the central plateau of the lake; the lake floor, excepting the anticlinal or warp in the strata between Milwaukee and Grand Haven, is comparatively level and somewhat, but not altogether, free from abrupt depressions; and whilst the lake floor in the northern half of the lake is frequently rocky, it is in the southern half almost entirely overlaid with clay or sand. These deposits of sand are much more general along the whole western and southern than on the eastern coasts, indicating at the time of deposition stronger currents towards these sides. In fact, the southern end of the lake in its general contour and depths, and in the character of its floor, corroborates the view that whilst an outlet to the Mississippi valley from the united lakes existed here, it also for a considerable time was an outlet of the present lake before its waters had receded to their present limits.

The section of country to the south and west of the southern end of the lake is largely prairie, that part immediately surrounding the lake being but slightly elevated above its waters. At a very recent period these waters extended in shallows over the prairie country, giving it a marshy character. Parts of the land are still so low lying and wet as to be chiefly suited for grazing purposes. All of the level black-loam prairies of Northern Illinois and Indiana have at one time been of this marshy character, but by the annual growth and decay of the grasses, sedges and aquatic plants generally, the black loam soil has in the long lapse of time accumulated and the land has gradually appeared above the water. This extreme southern section of Lake Michigan has thus had its boundaries defined in their present outline within a period probably as recent as existing times.

Like Lake Huron the main portion of the lake is preglacial. The Wisconsin geologists, especially Winchell, Chamberlain and Salisbury, have strongly insisted not only on a continental ice-sheet covering Northeastern and Central North America in the glacial times, but on a great glacier having, during what they denominate the later glacial period, occupied among others, the Lake Michigan basin, whilst a separate smaller glacier overspread Green Bay and its surrounding country. Chamberlain thinks that Lake Michigan, in its regular outline and great depth and breadth, is due to glacial action, though it might have been deeply channelled by running waters in pre-glacial times. Like others of these geologists, he points to the so-called moraines running through Wisconsin, Illinois, Indiana and Michigan, some distance from but irregularly uniform with the coast line of the lake, as proof of the existence of the glacier. Now, it seems to me that the small extent of these moraines, if their, in general more or less, stratified appearance allows them to be called such, is ample evidence that if a glacier did occupy, for an immense period of time, the basin of the lake, its eroding power was small. If the great superficial area and depth of Lake Michigan had been excavated by the glacier, the accumulated debris forced to its edges would have been vastly greater than the moraines indicate, more especially when we consider the extensive areas crossed by the glacier between the lake and the moraines, and the vast Laurentian and Huronian country to the northward, then more or less glacier-clad and supplying debris, apart from the accumulated debris of ages previous to this time. Prof. Claypole has encountered the same difficulty in discussing the so-called moraines to the south of Lake Erie.

The character of the floor of the northern half of the lake also presents difficulties. The direction of the old river channels and of the depressions, varying from east and west to north and south, the frequent abruptness of the descent to them, the directions of the axes of the promontories and neighbouring islands, and the absence of any general filling up of the hollows and depressions of the lake bottom in its northern half, all indicate that the glacier, if it existed, did not contribute to the forming of many of the leading outlines of the coast, or to the stamping of the chief features upon the lake floor. The subject will, however, be further discussed when referring to Lake Ontario in connection with this lake and Lake Huron.

Lake Ontario.

An important fact which at once strikes the observer, when noting the soundings in this lake, is that the areas of greatest depth are all towards the southern side of the lake. The deepest point is 738 feet or 506 feet below the ocean level, and is located about fifteen miles off the New York State side, between Rochester and Oswego. The 600-foot line here encloses an area of about thirty-eight miles long and ten miles broad, lying about parallel to the coast, and within eight miles of it. To this deep depression there is a fall of about 300 feet in two and a-half miles on its immediate southern side. On the northern side the descent is more gradual. Another depression exceeding 600 feet, but very small in area, exists about the seventy-eighth meridian of longitude, but similarily towards the United States side. Again, the 300-foot line encloses an area about

150 miles long and 24 miles broad, and in outline very like that of the present lake, but approaching the southern side within three to seven miles for the whole distance. The line of deepest depression along the length of the lake is also located about two-thirds of the way across the lake towards the New York State side. South of Port Credit and Toronto it takes the centre of the lake, but after that swerves towards the southern side. Preserving a depth of 540 to 570 feet for over sixty miles, it reaches the 600-foot line area, and finally begins to shallow at about nine miles off Oswego, where the depth is 576 feet. The evidence afforded by the terraces on either side of Lake Ontario would appear to show that, on the elevation of the land to its present limit, the rise was greater towards the north of the lake than to the south. This would cause the strata on the north side to dip towards the south, and force the waters of the lake more towards the southern side.

The lake bottom within the 600-foot line is chiefly mud, whilst outside, within the 300-foot line, it is largely clay and mud, with sand in occasional places. Close to the southern and eastern shores, rock is met with for the whole distance, but, with one exception, not elsewhere. The only large connected stretches of sand occur off and to the north-east of Oswego, suggesting, though not necessarily, an old outlet there.

Between Stony Point, off Sackett's Harbor, and South Bay Point, on the Canadian side, there is a rise in the level of the lake floor, culminating in the Duck and Galloo Islands. Between this limiting line and the outlet of the lake at Kingston, not only is the depth shallower—not exceeding 120 feet except in what may be two river channels, on either side of Duck Island, running inwards for ten miles towards Kingston—but its bottom is in nearly all directions rocky, and the contour of its shores—unlike the rest of the lake—is irregular, with deep bays and channels, which with the islands lie in a general north-east and south-west direction. The absence of the mud or clay which overspreads the lake elsewhere, and the two river channels opening towards the lake, suggest that this section of the lake is more recent than the main basin beyond, and that the coast at one time may have been between South Bay and Stony Point. The conformation of the shores, the line of axis of the islands and the direction of the striæ at Kingston and of the limestone escarpment and striated Laurentian hills and gorge at Kingston Mills also suggest the action of a glacier from the north-east, whilst the whole would seem to show that at that time the lake outlet at Kingston did not exist. The absence of striæ on the surface of the limestones on the summit of the anticlinal at Fort Henry, near Kingston, though present in frequent places at the waterline, would indicate that the glacier here was not very thick. That the country around the present lake outlet has been in places subject to abrupt changes of level is shown by the heavily dipping limestones at Fort Henry and eastward, and the eruptions of granite through the syenitic gneiss and the limestone both here and farther down the river. There is some evidence to show that an eruption took place during the deposition of the Black River limestones, but the abrupt upheaval of these limestones at Fort Henry and Barriefield is conclusive that there were forces at work, operating in a somewhat westerly direction, subsequent to the Trenton and Black River, and possibly in recent, times.

That Lake Ontario has had a pre-glacial origin seems beyond question. Several causes have contributed to bring about its present outline and depth, and it may be that one or more of these causes operated after the glacial epoch. Towards the western and on the southern side the Medina sandstones and the Hudson River shales sink apparently north-westerly under the lake, at the eastern end the Trenton and Black River limestones dip to the east of south, and the general slope of these limestones between Kingston and Belleville is perceptibly towards the lake. There is thus some ground for the assumption that the Trenton limestones, Utica and Hudson River shales and Medina sandstones descend both ways under the lake waters, forming perhaps originally, in at least a part of the lake, a synclinal trough which was affected by after changes. The relative positions of these strata around the lake further suggest this.

Another feature, however, has played an important part in the formation of not only Lake Ontario but also of Lakes Huron and Michigan, and even had its strong influence on Lake Erie as well. The Niagara escarpment, which nearly fronts the southern side of Lake Ontario, passes around its immediate westerly end, and then, facing to the north-east, continues in a somewhat irregular north-westerly direction until it eventually forms the prominent features of the Bruce Peninsula between the Georgian Bay and Lake Huron. At Cabot's Head, at the end of this peninsula, there is a break, but this is only apparent as there is a subaqueous ridge here, commencing near Cape Hurd, with deep water on the Georgian Bay side. This ridge, through the neighbouring islands, connects the peninsula with the Manitoulin Islands. The same limestones re-appear, crossing these islands, in bold escarpments facing to the northward, and extend uninterruptedly to the State of Michigan, the height diminishing to the westward. Along the northern shores of Lake Michigan they continue until Green Bay is reached, where, facing to the westward, they once more in places rise into an escarpment. Here they form two horns of the bay, with islands and another subaqueous ridge connecting them. Thence these limestones are found in the country skirting the western shores of Lake Michigan and they probably form the floor of its southern end beneath the superficial deposits.

The dip of the strata is, from the escarpment north of Hamilton and on the Manitoulin Islands, to and under the waters of Lake Huron. From Dundalk station on the Toronto, Grey and Bruce Railway, on the summit of the escarpment, there is a fall of 1,119 feet to the level of Lake Huron at Kincardine, seventy miles distant. South of the valley of the River Thames, which lies on the Cincinnati anticlinal, and at Niagara Falls, the slope is towards Lake Erie. To the north of the cliffs, on the Grand Manitoulin Island, are parallel escarpments of Hudson River age, forming the bluffs on the northern side of the island, and with the strata dipping southward similarly to those of the Niagara age there. Again, the cliffs of Green Bay face to the westward, and the dip is easterly towards and under Lake Michigan.

This Niagara escarpment, in its course easterly from the western end of Lake Ontario, lies parallel to the axis of that lake, whilst in the other direction, it conforms in a general way to the course that more or less characterizes the outcrops of all the formations which, as it were concentrically, surround and underlie the coal measures of Michigan. The contours of Lakes Michigan and Huron and the Georgian Bay, and the subaqueous Corniferous escarpment crossing Lake Huron, also conform to this arrangement.

At the western end of Lake Ontario, the Niagara limestones in their outcrop suddenly change from an east and west course to one which is north-west and south-east. When these limestones were elevated into an escarpment, two separate lines of force appear to have operated—the one taking an easterly direction and causing the strata on the southerly side of the lake to dip in a southerly direction—the other taking a somewhat north-westerly course resulting in the strata thence to the Georgian Bay dipping more to the westward. These two forces appear to have, at the point of meeting, created a vast fracture in the escarpment near Hamilton, forming what ultimately became, chiefly through the eroding force of water, the Dundas valley. Again, between the Bruce Peninsula and the Manitoulin Islands, another change in the direction of the outcrop of both the limestones and underlying shales, caused, when the escarpment was elevated there, a series of great fractures which, by the action of the waves and currents and of atmospheric forces, and possibly of glaciers and icebergs as well, became, ultimately, the interrupted subaqueous ridge there. To similar fractures were no doubt originally due the narrow straits which divide the Manitoulin Islands from each other and the most westerly of them, Drummond Island, from the State of Michigan. Such fractures may perhaps be found on the upper peninsula of Michigan, but much less pronounced in character, as the strata there have not been elevated to the same extent. Finally, there are the fractures which afford the entrance to Green Bay, and those which constitute the various bays around the whole front of the escarpment.

Now, these different facts are not mere accidental occurrences, and their conformity to each other is not a mere coincidence. They show that the oscillations of the earth's crust in this particular area, covering the State of Michigan, the larger part of Lake Huron, and the immediate country to the east of Lake Huron, and to the west of Lake Michigan have, from the Trenton period and probably earlier, been of a peculiar nature. These oscillations were confined to this area, and the forces which gave rise to them appear to have operated in conformity, in a general way, with the curved outline of the area and towards its centre. It is impossible to ascribe to glacial forces the varying directions of the outcrops of the different formations within this area, from the Trenton to the Carboniferous, nor do the glacial striæ or the alleged directions taken by the glaciers suggest it. It is most reasonable to assume that this area, located as it is close to Lake Superior, where during Huronian and Keweenawan or probably later times were vast volcanic eruptions, has been subject to repeated oscillations in level around a central area. That these oscillations have continued to more recent periods is shown by the uplifting, west of the longitude of Hamilton, of the Niagara escarpment with its face always away from, whilst the dip is towards, the central area of the State of Michigan or of Lake Huron, as well as by the depression and re-elevation of this whole area when the present superficial clays were laid down.

That the Niagara rocks did not extend much farther north of their present position near the southern coasts of Lake Ontario, nor much farther eastward than the escarpment between Lake Ontario and the Georgian Bay, is shown by the present general position and direction of these and the underlying rocks to the immediate east, south and west of the lake, and the way in which they converge at the southern extremity of the Georgian Bay. A similar opinion may be ventured regarding the Medina sandstones. Prof. Bell, referring to Lake Ontario and certain other lakes, thinks that the glaciers descending from the higher grounds against the upturned edges of the softer rocks, tore them up rapidly, and carried away the debris, thus leaving the lake basins. The sharply defined edges of the escarpment, its generally bold face, and the comparatively short distance it has apparently receded, would, however, rather indicate in its case atmospheric effects, the wearing force of rivers, and the undermining action of waves upon an open lake or sea coast.

Sir William Logan, in the Geology of Canada, points out the resemblance of the Niagara escarpment, in places, to an ancient sea cliff. He also shows that it merely requires a depression of 442 feet to bring the ocean into Lake Ontario by way of the Hudson River and the Mohawk Valley, as well as by the St. Lawrence, and to inundate the whole of Central Ontario, although he did not then think that there was evidence that such an inroad had taken place. Such a depression would lead to the ocean penetrating as far west as the Niagara escarpment, and as far northward, in some places, as the Laurentian hills. The Georgian Bay would still be 140 feet above the ocean level, but if the thick deposits of sands, gravels and clays, between it and Lake Ontario, the positions of some of which are attributable to relatively very recent times, had not then existed, or were cut through at any point, the Georgian Bay would have been lowered to the ocean level, and have formed part of the same interior ocean as Lake Ontario. This would bring to the surface the presently submerged ridge between the Bruce peninsula and the Manitoulin Islands, owing to the lowering of Lakes Huron and Michigan to the level of the surface of the ridge. The outlet of these lakes would thereafter be over this ridge, and not by way of Lakes St. Clair and Erie. Now, the deep water cliffs on the eastern side of the subaqueous ridge, between the Georgian Bay and Lake Huron, and those which are immediately beneath the escarpment of the Bruce peninsula, would seem to indicate that the waters of this bay have been at much lower levels than now to admit of the denuding action of waves and atmosphere on these subaqueous cliffs, and further, as already mentioned, that these cliffs formed the western boundary of a large and rapidly flowing pre-glacial river which, before the upheaval of the ridge between the Georgian Bay and Lake Ontario, connected these two basins, the denuding of the escarpment being due largely to it.

Without further here discussing the question of a connection between this bay and Lake Ontario, this fact is clear that at a period comparatively recent, and yet so far distant that the mammoth (*Euclephas Jacksoni*) then living, has since become extinct, the Niagara escarpment formed the western and southern boundary of a large interior freshwater sea. The terraces and ridges around Lake Ontario show that this basin was considerably depressed or its outlet blocked, or that both causes intervened, raising the water to levels probably more than 400 feet higher than now. These terraces and ridges are found resting against the Niagara escarpment at Hamilton and Dundas, rising, Logan says, to a height of 318 feet, but they must in some cases be much higher there, as they nearly reach the summit of the escarpment along the line of the Grand Trunk railway; and whilst Bayfield mentions heights of 460 feet, Spencer gives the highest point on the summit near Hamilton as 516 feet. To the northward of Lake Ontario there are ridges of clay, sand or gravel, reaching varying heights. The summit on the Northern railway is attained at 755 feet above the lake, at twenty-six miles north from Toronto,[1] but the levels after falling nearly 300 feet, rise again at fifty-seven miles to 641 feet, passing first through a gravel ridge at fifty-three miles. Again, on the Toronto and Nipissing railway, the summit station is reached at 893 feet, at

[1] Spencer's Elevations in Canada.

twenty-seven miles back from the lake. Farther eastward on the Midland railway, in rear of Whitby, clay ridges are met with at twelve miles, attaining 649 feet, at fourteen miles 781 feet, and at thirty-three miles 674 feet. On the Port Hope section, further eastward, the heights are somewhat less. But let us not be led astray. Being so much higher than other ridges surrounding the lake, it is clear that the underlying Hudson River, Utica and Trenton strata, have been elevated during or since the deposition of these clays, sands and gravels, and in a direction roughly parallel with the lake. These superficial deposits obscure the strata, but this elevation, continued in a line towards Lake Huron, is noticeable on a greater scale at and beyond the townships, where it strikes the Niagara escarpment, whose summit near Dundalk station, on the Toronto, Grey and Bruce railway, has a height of 1,462 feet above Lake Ontario, and 1,127 feet above the Georgian Bay.

On the south side of Lake Ontario, where the subsequent elevation has been less than on the north side, an extended ridge of 188 feet has been thrown up. The American geologists have observed a gradual rise of 130 feet in this terrace, from the western end of Lake Ontario to Oneida Lake, and a rise of 170 feet more from Oneida Lake north to Jefferson County, beyond which it was not observed. This would imply a previous depression, increasing in depth with the south-easterly and easterly sides of Lake Ontario, and would show that its waters, now deeper towards the south-eastern end, were relatively more so in certain previous periods of the lake's history. The present levels have, as indicated, been largely influenced by the greater elevation on the northern than on the southern side, causing the waters to be thrown more towards the southern side.

At this period the outlet of the lake at the Thousand Islands was undoubtedly crossed by the Adirondack Mountains in a broad, rugged, irregular ridge, now partly depressed under the water to a maximum depth of about 250 feet. Some sand deposits occur towards Rockport, near Brockville, and in rear of Kingston, and may indicate the eastern and western sides of the ridge, but this is, presently, mere conjecture. The height of the marine terraces on Montreal Mountain and elsewhere, as compared with the level of Lake Ontario, the absence of the Leda clays with their marine shells and fish farther west than Packenham, and the direction of the ice grooves which have a trend to the west of south on the Lake Ontario side, and, generally speaking, to the east of north or of south, on the St. Lawrence and Ottawa River sides, all tend to suggest this former higher altitude of the Laurentian ridge at the Thousand Islands. In this connection it may be noted that whilst it is usual to refer to the direction of the ice grooves as being either to the east or west of south, it is quite in consonance with the direction of the St. Lawrence Valley that these grooves should sometimes be referred to as having a course to the east of north.

With the elevation of the Niagara escarpment came the first record we have in the history of Lakes Ontario, Huron and Michigan as independent basins with the contours of to-day. Previous to and after this elevation, the present basins of these lakes were the seat of a great river system, with probably lake expansions smaller and different in outline from those now existing. Profs. Spencer and Claypole suggest that Lakes Ontario and Erie in part formed the valleys of a great pre-glacial river which, Spencer thinks, crossed from Lake Huron through the counties of Lambton, Middlesex and Elgin, and swerving around Long Point to the deepest portion of Lake Erie, trended thence northward to the Dundas Valley. Through this valley it entered the present basin of Lake Ontario, the line of deepest depression in which it formed by cutting down into the Hudson River shales, along the escarpment of which it flowed. There is much in the features of the lake floors and of the superficial deposits to support some such view, if more recent local warpings in the strata are considered. The great fracture in the strata at Dundas would give the required direction to the river there, and would be greatly enlarged by its eroding action. The outlet of this river by way of the Mohawk

Valley, is considered by some to be debatable ground, but it is difficult to now predicate what the levels were in the land surrounding these ancient rivers and seas. There have since been general changes in elevation extending over large areas, and there have also been local warpings within restricted areas which have completely altered within these areas the former levels in their relations to each other.

Prof. Spencer's view of this ancient river was limited to a connection between the southern end of Lake Huron and the eastern end of Lake Ontario by way of Port Stanley, Long Point and the Dundas Valley. It seems most probable, however, that the subaqueous escarpment which diagonally crosses Lake Huron from opposite Kincardine in the direction of the Straits of Mackinac, and which parallels the deepest depression there, may have been the south-western boundary of an npper section or expansion of this pre-glacial river valley. The hard Corniferous rocks would form an effective protecting side for such a river valley. Allusion has already been made to the probably earlier northward direction of this river in the line of depression toward Cape Hurd and over the subaqueous ridge there. The subaqueous river channels, already referred to, on each side of the Straits of Mackinac and in Whitefish Bay, in Lake Superior, also indicate higher sections of this preglacial river, and if the view be accepted that Lake Superior had its outlet in these older times across the upper peninsula of Michigan, it is most in consonance with facts that the waters of this great and ancient inland sea found their course to the ocean at, at least, one period of its history, by way of these broad rivers of Tertiary and antecedent times, though the St. Croix valley has, probably, at another time, also formed an outlet.

At what time, however, was this Niagara escarpment elevated? This is a question difficult of answer. And yet the facts already given would indicate that it was prior in time to the deposit of the clays, sands and gravels against the escarpment in the Dundas Valley, at the Bruce Peninsula and elsewhere; prior to the deposit of the

Artemesia gravels, which for long distances crown the summit of the escarpment parallel to its face, and are largely derived from its debris; prior to the elevation of the ridge or anticlinal which lies between Lake Huron and the Trent Valley, and gives to the escarpment its highest elevations above the lakes; prior to the Niagara Falls; and prior to the erosion which widened the fractures in the escarpment at the Dundas Valley and at the points of meeting of the waters of the Georgian Bay with those of Lake Huron proper, as well as the waters of Green Bay with those of Lake Michigan. On the other hand, this period of elevation of the escarpment was contemporaneous with the appearance in their present outlines of Grand Manitoulin, Cockburn and Drummond Islands in Lake Huron, and viewing all the facts was undoubtedly pre-glacial. Whilst the elevation of the escarpment gave in general terms the outlines of the basin of the three lakes, it is not to be inferred that these basins were at once filled with water to present levels. The country surrounding the lakes must have been higher than now to enable the pre-glacial river to cut the deep channels in Lakes Ontario and Huron which now exist.

Lakes Erie and St. Clair.

These two lakes have undoubtedly been within a very recent period more intimately united than now, and are probably the most recent in origin of the St. Lawrence Great Lakes. They lie in a Devonian basin with the Silurian rocks forming the portion of the rim of Lake Erie between Sandusky and Toledo. This basin is, however, overlaid with superficial deposits to such an extent that both lakes really fill shallow depressions on the surface of these deposits, and appear rather to be overflows caused by the restricted passage now of the waters over the Niagara escarpment in the one case, and through the Detroit River in the other, than to be due to physical forces which operating in past ages excavated preparatory basins.

Lake St. Clair has an average depth of about 12 feet and a maximum depth of 22 feet. The floor, except some limited areas of mud and clay in the centre, is overlaid everywhere with sand. The coast lines are low and often marshy, and, along the Canadian side fronting the counties of Essex and Kent, the land is barely elevated above the lake surface. The whole country here has quite the characteristics of the modern prairie, and its formation is unundoubtedly due to similar causes which are still in operation. Centuries of growth and decay of tall grasses, rushes and sedges in the extensive shallow marshes bordering the lake gradually contributed a black loamy soil which even now is not much above the level of Lake St. Clair. And not only has there been a more intimate connection with Lake Erie, but that the lake has at one time been somewhat deeper and is gradually filling up, is shown by the character of the deposits on its floor and by the extensive, progressive delta of the St. Clair River. The heavier sediments in the waters coming from Lake Huron have been deposited in this lake, whilst the lighter silt appears to have been carried onwards towards and to Lake Erie.

The Detroit River, which now connects Lakes St. Clair and Erie, flows through a flat prairie-like country, but slightly elevated in most of its course above the water level. At the outlet of the river, on the Michigan side, extensive marshes prevail for some distance along the lake coast. The soil, however, is a fine yellow or drab-coloured silt containing minute grains of sand—the filterings no doubt from the coarser material deposited in Lake St. Clair.

For a lake of such wide area, Lake Erie is remarkably shallow. A line drawn from the City of Erie in Pennsylvania to Port Rowan, near Long Point, would have on its western side more than two-thirds of the lake area, and yet the maximum depth there does not exceed 84 feet. Again, a line from Pt. Pelée to Sandusky would form the eastern boundary of a large section, the greatest depth of which, except in one isolated spot, is only 48 feet, and the average is only about 30 feet. Whilst thus shallow, the main body of the lake east of Pt. Pelée is remarkably level. The general depth is between 60 and 84 feet to within four or five miles of the shore on each side.

The deepest point in the lake lies in its eastern third about ten miles south-east of Long Point, and registers 210 feet. Here, parallel with the axis of the lake, there is a depression about twenty-seven miles in length by a width of from five to six miles, the depth everywhere in which exceeds 180 feet. Surrounding this and about forty miles long by twenty-five miles wide is an irregular area which has a minimum depth of 120 feet. This wider depression approaches within six miles of the south shore and thirty-five miles of Buffalo, towards which city it gradually shoals to 24 feet at the entrance to the Niagara River. The level plateau on which the main body of the lake rests is generally clay, whilst for the ten miles adjoining the United States side, the lake bottom is sand or sand and clay, with, occasionally, gravel, and, near the shore, rock. In the deeper parts off Long Point, which evidently included a wider area in preglacial times, the bottom is clay or mud. This is frequently replaced by sand towards the Niagara River, whilst near the shore there on both sides the bottom is rock.

The currents of the lake have, in the past, played an important part in shaping the contour of the Canadian side. The American coast line has a uniformity which the Canadian has not. The direction of these currents is seen in the outlines of Point Pelée, Rondeau Harbour and Long Point and in the arched contour of the long coast line fronting the County of Elgin, whose high clay cliffs have been worn gradually backward through great distances to their present position by the eroding action of waves, frosts and rains, and have supplied material for shallowing the lake in front and building up Long Point. This process is still going on. Within the barriers created by Point Pelée, Rondeau Harbour and Long Point it is, however, being supplemented by the shallows becoming marshes which in time will fill up with mould arising from the annual growth and decay of the reeds, rushes and grasses which flourish in profusion there.

Leaving out of view the above subsequent changes in parts of its area, Lake Erie probably dates the outlining in a general way of its present limits back to the time when the Ontario Lake ridges were being formed, and when the clays and gravels were being piled up against the Niagara escarpment and had blocked the Dundas valley. The entire Ontario peninsula had been under water for a long period, and by the deposition of the clays over it, the courses of the pre-glacial rivers had been partly filled up. The united lakes, as their terraces show, had at first a high level, and their waters found here, as Newberry has shown, outlets to the southward through the gaps furnished by the river valleys in Ohio. On the elevation of the land, new drainage channels had to be cut by the water. It was then that the outflow from Lake Huron began by the St. Clair and Detroit Rivers and of Lake Erie by the Niagara River, the channels of the old glacial river having been blocked and the waters being kept back, not merely by the superficial deposits, but probably by warpings of the strata beneath as well. It may be that the lake level was at first retained at a higher point than now, the escarpment at Lewiston being 38 feet above Lake Erie. This would have prevented a separation then between that lake and Lake Huron. It is most probable, however, that the Niagara did not fall over the escarpment at Lewiston but found at this point, as at St. David's, a great fracture in the cliff, affording it a natural gorge down which its waters ran, and which they gradually further eroded. Other such fractures are found in the escarpment both south of Lake Ontario and between it and the Georgian Bay, some of them forming great ravines several miles in length, and presently, in some cases, the beds of streams. Such fractures were a necessary consequence of the elevation of the escarpment and of the directions which this elevation followed.

CONCLUSIONS.

In summing up the conclusions of this paper it may be said :

That glaciers, whilst contributing some results, had not much effect in eroding the lake basins proper, or in shaping the present general outlines.

That the superficial deposits are the accumulations of denudation during immense periods of time since the Carboniferous and earlier eras, and are not to be specially credited to the operation of glaciers.

That Lake Superior is the most ancient of the lakes, dating its origin as far back as Cambrian, Keweenawan and Huronian times; that it is, in part at least, a synclinal trough, that volcanic action has had most to do with its origin and the shaping of its coasts; that its early outlet was through the depression in Whitefish Bay and that its waters joined the great pre-glacial river system at or near the Straits of Mackinac.

That Lakes Michigan, Huron and Ontario were originally the bed of a pre-glacial river which first crossed the Ontario peninsula along the Niagara escarpment, and afterwards was diverted to a course by way of Long Point, on Lake Erie and the Dundas valley; that their basins were largely defined by the elevation of the Niagara and Hudson River escarpments, and in more recent times by warping of the strata and deposit of superficial sands and clays which blocked the old river channels and resulted in the lake basins retaining their water on the final elevation of the land to its present general levels.

That the pre-glacial river system expanded in time into smaller lakes in each of the present basins of Lakes Michigan, Huron, Erie and Ontario.

That Lakes Erie and St. Clair are the most recent of the lakes, and have at one time been more closely united, and that the formation of this united lake was due to the blocking of the old outlets both by superficial deposits and warping of the strata, and to the water being thus retained in the basin on the final elevation of the land to the levels of to-day.

That great fractures at or near the outcrops of the strata occasioned by the directions of the forces which elevated the strata, originated, in many instances, the deep bays and inlets which indent the Niagara and Hudson River escarpments and rocky coast lines of Lakes Michigan and Huron, these effects being afterwards supplemented by the action of waves, currents, atmospheric causes and probably local glaciers.

That since the elevation of the land to the levels of to-day, the action of waves and currents on the clay cliffs and sand deposits has, in many places, greatly rounded off the general outlines of the coast, and the material from this and other sources has been spread over the lakes, or has served to create new features in the coast line elsewhere.

NOTE ON BALANUS HAMERI IN THE PLEISTOCENE AT RIVIÈRE BEAUDETTE, AND ON THE OCCURRENCE OF PECULIAR VARIETIES OF MYA ARENARIA AND M. TRUNCATA IN THE MODERN SEA AND IN THE PLEISTOCENE.

BY SIR WILLIAM DAWSON, LL.D., F.R.S.

(1.) *Balanus Hamon.*

The fine species of Balanus above named, which is still living in somewhat deep water on our coasts, was first described as a Pleistocene fossil of Canada by Sir C. Lyell in his paper on "Fossils and Recent Shells collected by Capt. Bayfield."[1] Bayfield found it in the Pleistocene at Beauport, near Quebec. It was subsequently found by me in the Pleistocene at Rivière du Loup, St. Nicholas, and Montreal.[2] From the loose attachment of its radial plates, it is

[1] Philos. Trans. 1859.

[2] "Notes on Post Pliocene of Canada." Canad. Nat. 1872.

usually found in fragments, but entire specimens occur attached to stones and boulders at R. du Loup.

B. Hameri is at present extensively distributed as a living species in the North Atlantic and the Arctic Sea. I have specimens collected by Mr. A. Downes of Halifax, Nova Scotia, in a living state, near Halifax harbour. As a Pleistocene fossil, it occurs at Uddevalla in Sweden, and was named by Linnaeus *Balanus Uddevalensis.* The name *B. Hameri*, given by Ascanius in 1767, is that now recognized. It has also been found in Pleistocene clays in Greenland (Spengler), and in the Pleistocene of Russia (Murchison).

The specimens now under consideration are interesting, as being found farther west than previously; River Beaudette being on the line of the Grand Trunk Railway, 34 miles west of Montreal, and the locality being near its entrance into Lake St. Francis. They are also interesting from their remarkable perfection and the large masses which they form, some of which contain as many as a dozen individuals attached to each other. The specimens were collected by Mr. A. W. McNown, of Rivière Beaudette, and by Mr. Stanton, C.E., of Lancaster, and much credit is due to these gentlemen for their care in collecting and preserving these interesting fossils.

The animals seem to have been covered, when living, with an irruption of sand, for the opercular valves of many of them are still in place, and owing to a slight infiltration of calcareous matter, the radial plates and opercular valves have been cemented together, which accounts for their perfect preservation. It is to be observed, however, that the shells of Balani are composed of a remarkably dense and indestructible calcium carbonate, much less perishable than the shells of most mollusks.

The original attachments of the animals, so far as observed, have been on pebbles on the surface of clay, and as these afforded space only for one or two individuals, the young were obliged to attach themselves to the old in successive generations, forming most grotesque groups, which still remain entire.

In the same deposits were found shells of *Saxicava Arctica*. *Tellina* (*Macoma*) *Groenlandica* and *Mya arenaria* of a small variety. These shells would indicate cold and not very deep water; and although *B. Hameri* is at present a deep-water species, it is probable that in cold water it lives, like some other species, nearer the surface than in the warmer seas.

The specimens were found in an excavation near the railway, and so far as appears from the descriptions, in beds which belong to the top of the Leda clay and base of the Saxicava sand, a position which is usually the most productive part of our Pleistocene deposits in fossil shells.

From a note and sketch kindly furnished to me by Mr. Stanton, it appears that the shells occur about 27 feet below the surface, and about 11 feet above the level of Lake St. Francis. The containing beds are clay and sand, and above these are alternations of clay, sand and gravel, the top being gravel, with boulders immediately under the surface soil. The position of the shells would thus appear to be in what I have called the Upper Leda clay, or the base of the Saxicava sand, and under the newer gravel and boulder deposit which often caps the latter.

(2.) *Species of Mya, and Varietal Forms.*

In my Notes on the Post Pliocene of Canada,[1] I have remarked on the small size, peculiar forms and comparative rarity of *Mya arenaria* in the Pleistocene, as compared with the modern Gulf and River St. Lawrence, and on the abundance of *Mya truncata*, and especially of the short variety (*M. Uddevalensie*), while *Mya truncata* is comparatively rare in the modern waters of our coast, and the short variety especially so. I had last summer an opportunity at Little Metis to see both species and their different varieties living together in such a manner as to illustrate better the causes of the difference of the Pleistocene forms.

At the head of Little Metis Bay, where the water is shal-

[1] Canadian Naturalist, 1872.

low and warm, and the bottom is soft mud and sand, a large variety of *Mya arenaria* is very plentiful in the flats bare at low tide; so much so that the place is resorted to by fishermen from localities lower on the coast for bait. It sometimes attains the length of 4½ inches, and has a thick, dense shell, without perceptible epidermis, and often with radiating bands. So far as I am aware, neither *Mya truncata* nor the peculiar variety of *M. arenaria* referred to below, occurs on this part of the coast.

I have not infrequently dredged *Mya truncata*, usually the long variety, but sometimes the short Uddevalensis variety, in deep water outside the bay, but have not seen it above low-water mark, though it occurs not far from this line; and, on the opposite side of the River St. Lawrence, I have found it at Tadoussac, where the water is still colder, close to low-water mark. I was not aware that *Mya arenaria* occurred on the comparatively steep and stony shore outside the bay, and it is certainly not found there inside of the low-water limit.

Last summer, however, after a heavy easterly gale, great numbers of *Mya arenaria*, in a living state, and a few specimens of *M. truncata*, were thrown up on the beach, and must have been derived from the mud disturbed by the breakers at no great distance outside of low-water mark, or on a slight bank a little further seaward. These shells were all of small or moderate size, somewhat round and flat in form, much wrinkled and covered with a thick brown epidermis which extended a little way beyond the posterior end of the shell, which was, however, rounded and not truncated, and destitute of the corneous tube of *M. truncata*. Still, many of the specimens might, at first sight have been mistaken for *M. truncata*, with the tube partly broken off. This enabled me, *for the first time, to* understand the remark of Fabricius, that in Greenland the two species are so similar, that but for the hinge and the tube they might be confounded. With these were thrown up specimens of *M. truncata*, which must have lived with the others, the inner limit of *M. truncata* probably overlapping the outer limit of *M. arenaria.* The short or Uddevalensis variety of truncata was, however, very rare, only a few shells in a perfectly recent state having been found. and they probably lived in somewhat deeper and colder water than the others. The water, I may add, on this coast is so far affected by the Arctic current as to be quite cold, except near the shore and in shallow bays, and the species dredged in 10 to 15 fathoms are, in general, similar to those of the Labrador coast, belonging rather to the boreal than to the Acadian fauna. With the Myas were cast up shells of *Solen ensis,* var. *Americanus* of Carpenter, and of *Machaera Costata,* the latter sometimes of large size, though it is more abundant in the warmer water at the head of the bay, where *Purpura Lapillus,* a rare shell on this coast, also occurs on the reefs.

It is evident that though there is no passage from one species into the other, the long variety of *Mya truncata* represents the extreme limit of modification of that species for a shallow and warm-water habitat; while the small epidermis-clad variety of *M. arenaria* represents its extreme modification for deeper and colder water than usual; and along the coast at Metis these two varieties meet.

The coldness of the Pleistocene seas thus explains the occurrence, in the Upper Leda clay, of the peculiar small and epidermis-clad variety of *M. arenario* and of the short form of *Mya truncata.* The conditions in the colder parts of the River St. Lawrence approach in these respects to those of the Pleistocene, though they are no doubt more fully realized in the Arctic seas.

As I have remarked in my notes on the Post Pliocene, the brown wrinkled epidermis-clad variety of *M. arenaria* occurs plentifully along with *M. Uddevalensis* in the Upper Leda clay at Rivière du Loup.

From the accounts of Arctic collectors from Fabricius downwards, it would appear that in Greenland, as in Pleistocene Canada, *M. truncata* is very abundant, and occurs at low water in the sands, as *M. arenaria* does further south. It would seem also that it forms a large part of the food of the walrus and other animals, and is much used by the inhabitants. It also appears that a small variety of *M. arenaria*, with brown epidermis, is most common in Greenland, and occurs with *Mya truncata*, which is, however, more plentiful. The description given by Fabricius of *M. arenaria* obviously agrees with that of my small and brown variety from Metis.

It is interesting to note the companionship of these allied species in the North Atlantic throughout the Pleistocene and Modern periods, and their range of varietal forms applicable to each, according to the conditions to which they they have been exposed, along with their continued specific distinctness, and the preference of each for certain kinds of environment, so that in some places one, and in others the other, predominates, while this relative predominance, as well as the prevalence of certain varietal forms, might no doubt be reversed by change of climate or of depth.

On Modern Concretions from the St. Lawrence.

By Rev. Prof. Kavanagh, S. J.

With Remarks on Cylinders found in the Potsdam Sandstone.

The modern concretions referred to were collected on the the rush-covered shores of the St. Lawrence near Boucherville, and may be thus described :—

They resemble small radishes, like these, varying much in shape, are symmetrical, perforated axially, the more or less perfect bore or perforation often containing vegetable fibres.

Their production seems to be due to the action of the rush roots upon the soft, plastic clay, so indurating it that it can resist the wash of the waves; the receding of the water during the summer leaves these concretions standing out in relief, like fossils on a weathered surface.

The phenomenon seems to be analogous to that formation of nodules around organic nuclei within masses of soft material, which occurs in many geological formations.

These little bodies are evidently clay concretions formed around vegetable fibres, and hardened by a small percentage of calcium carbonate, since when treated with hydrochloric acid they effervesce feebly and become disintegrated. They probably originate in the molecular aggregation of the calcareous matter in the clay around any foreign body included in it. They are about half an inch in diameter, and the largest may have been two inches in length, with ronnded ends. When broken, they show a small central canal containing a little sand and strips of epidermal tissue, the remains of a root or stem. One shows three branches apparently proceeding in a verticillate manner from a central stem. In the centre, the light, reddish-brown colour of the clay has assumed a greenish hue, owing to deoxidation of the Peroxide of Iron by decay of the vegetable nucleus.

Remarks by the President on Certain Ancient Concretions, in Connection with the Above.

On a small scale these modern concretions are similar to those so often found to enclose vegetable remains in the carboniferous system; and in the Pleistocene at Green's Creek, on the Ottawa, vegetable stems are sometimes found enclosed in similar, but larger and harder concretions.

Concretions of this kind appear to throw light on those remarkable trunk-like cylinders which have been found in the Potsdam sandstone. These attracted the attention of Sir Wm. Logan many years ago; but as they showed no structure, external markings, or carbonaceous matter, they were not regarded by him as true fossils. More recently they have been studied by Dr. Selwyn in exposures on the bank of the Rideau canal, near Kingston. Dr. Selwyn has kindly sent photographs of these specimens, to be exhibited to the Society. Mr. A. Young, a student in applied science in McGill University, has also presented fine specimens to the

Peter Redpath Museum, one of which is on the table. In their entirely arenaceous character, their concentric lines of growth, as well as in traces of a central axis or canal of small dimensions, and, in one instance, in a regularly rounded end, they resemble concretions, but I have been unable to find any central organic matter. This may, however, have perished, leaving a mere cavity, as in the modern concretions above described, which would become filled with sand, like that of the enclosing cylinder. This at least appears to me at present the most probable explanation of these puzzling forms. It would be confirmed if any distinct vegetable or zophytic axis could be found in any of the specimens, or any carbonaceous matter representing such an axis. In the meantime, it may be regarded as a more or less probable conjecture as to their origin.

THE INFLUENCE OF THE NERVOUS SYSTEM ON CELL LIFE (METABOLISM).*

BY T. WESLEY MILLS, M.A., M.D., Professor of Physiology, McGill University, Montreal.

In a paper entitled "A Physiological Basis for an Improved Cardiac Pathology," read in abstract in August, 1887, before the Canada Medical Association, I endeavoured to show the relation of the cardiac nerves to the nutrition of the heart; but the subject grew as I proceeded with its study, so that I perceived that the theory I applied to the heart was equally true of the other organs and tissues. In that paper, which was published in the New York *Medical Record* of October 22nd, 1887, I advanced a large number of facts derived from common experience, physiological experiment, pathology, and clinical medicine, in favor of what I termed a theory of *constant neuro-trophic influence.*

* Read before the section in Physiology of the Congress of American Physicians and Surgeons, at its first annual meeting, September, 1888.

Briefly this theory was to the effect that in mammals, if not also in some lower groups of vertebrates, the nutritive processes are all under a *constant* regulative influence by the nervous system, in the sense that they are so dependent upon this influence, that they do not, and would not, go on without it. It was also pointed out that function was not a thing totally distinct and alone regulated by the nervous system, but that function was only one *phase* of a general metabolism, and was no more under the influence of the nervous centres than the other less recognized phases.

A year's additional study of the subject has convinced me more than ever of the necessity of widening our views of the relation of the various organic processes, so that instead of terming the theory, I would offer for your consideration one setting forth a constant neuro-trophic influence, I would replace it by the expression *constant neuro-metabolic influence,* as it implies a wider and truer conception of the subject, as I view it; and I am not sure but that it would be well to abandon the term "nutrition" altogether, or, if not, certainly to define it afresh.

The following, then, is a brief presentation of the subject in a form largely free from technicalities.

This subject is of the utmost importance, and has not received the attention hitherto in works on physiology to which we believe it is entitled. We may first mention a number facts on which to base conclusions :—

1. Section of the nerves of bones is said to be followed by a diminution of their constituents, indicating an alteration in their metabolism.
2. Section of the nerves supplying a cock's comb interferes with the growth of that appendage.
3. Section of the spermatic nerve is followed by degeneration of the testicle.
4. After injury to a nerve, or its centre in the brain or spinal cord, certain affections of the skin may appear in regions corresponding to the distribution of that nerve, thus, *herpes zoster* is an eruption that follows frequently the distribution of the intercostal nerve.

5. When the motor cells of the anterior horn of the spinal cord, or certain cells in the pons, medulla, or crus cerebri, are disordered, there is a form of muscular atrophy which has been termed "active," inasmuch as the muscle does not waste merely, but the dwindling is accompanied by proliferation of the muscle nuclei.
6. In *acute decubitus*, bed sores form within a few hours or days of the appearance of the cerebral or spinal lesion, and this with every precaution to prevent pressure, or the other conditions that favor the formation of such sores.
7. After section of both vagi, death results after a period varying in time, as do also the symptoms, with the animal.

In some animals pneumonia seems to account for death, since it is found that if this disease be prevented, life may at all events be greatly prolonged.

The pneumonia has been attributed to paralyses of the muscles of the larynx, together with loss of sensibility of the larynx, trachea, bronchi,and the lungs, so that the glottis is not closed during deglutition, and the food finding its way into the lungs has excited the disease by irritation. The possibility of vaso-motor changes is not to be overlooked. In birds, death may be subsequent to pneumonia or to inanition from paralysis of the œsophagus, food not being swallowed. It is noticed that in these creatures there is fatty (and sometimes other) degeneration of the *heart*, liver, stomach and muscles.

8. Section of the trigeminus nerve within the skull has led to disease of the corresponding eye. This operation renders the whole eye insensible, so that the presence of offending bodies is not recognized, and it has been both asserted and denied that protection of the eye from such irritation prevents the destructive inflammation.

With the loss of sensibility there is also vaso-motor paralysis; the intra-ocular tension is diminished, and the relations of the nutritive lymph to the ocular tissues is altered. But all disturbances of the eye, in which there are vasomotor alterations, are not followed by degenerative changes.

9. Degeneration of the salivary glands follows section of their nerves.
10. After suture of long-divided nerves, indolent ulcers have been known to heal with great rapidity.

This last fact, especially, calls for explanation. It will be observed, when one comes to examine nearly all such instances as those referred to above, that they are complex. Undoubtedly. in such a case as the trigeminus or the vagi, many factors contribute to the destructive issue, but the fact that many symptoms and lesions are concomitants does not of itself negative the view that there may be lesions directly dependent on the absence of the functional influence of nerve fibres over the metabolism.

We prefer, however, to discuss the subject on a broader basis, and to found opinions on a wider survey of the facts of physiology.

After a little time (a few hours), when the nerves of the submaxillary gland have been divided, a flow of saliva begins, and is continuous till the secreting cells become altered in a way visible by the microscope.

Now, we have learned that protoplasm can discharge all its functions in the lowest forms of animals and in plants, independently of nerves altogether.

What, then, is the explanation of this so-called "paralytic secretion" of saliva? The evidence that the various functions of the body, as a whole, are discharged as individual acts, or series of acts, correlated to other functions, has been abundantly shown; and looking at the matter closely, it must seem unreasonsble to suppose that this would be the the case if there was not a close supervision by the nervous system over even the details of the processes. We should ask that the contrary be proved rather than that the burthen of proof should rest on the other side. Let us assume that such is the case; that the entire behavior of every cell of the body is directly or indirectly controlled by the nervous system in the higher animals, especially mammals, and ask, What facts, if any, are opposed to such a view?

We must suppose that a secretory cell is one that has been, in the course of evolution, specialized for this end. Whatever may have been the case with protoplasm in its unspecialized form, it has been shown that gland cells can secrete independently of blood supply, when the nerves going to the gland are stimulated. Now, if these cells have learned, in the course of evolution, to secrete, then, in order that they shall remain natural—not degenerate—they must, of necessity, secrete, which means that they must be the subject of a series of metabolic processes, the final of which only is expulsion of formed products. Too much attention was at one time directed to the latter. It was forgotten, or rather, perhaps, unknown, that the so-called "secretion" was only the last of a long series of acts of the cell. True, when the cells are left to themselves, when no influences reach them from the stimulating nervous centres, their metabolism does not at once cease. As we view it, they *revert* to an original ancestral state when they performed their work, lived their peculiar individual life as less specialized forms, wholly or partially independent of a nervous system. But such divorced cells fail; they do not produce normal saliva; their molecular condition goes wrong at once, and this is soon followed by departures visible by means of the microscope. But just as secretion is usually accompanied by excess of blood, so most functional conditions, if not all, demand an unusual supply of pabulum. This is, however, no more a cause of the functional condition than food is a cause of a man's working. It may hamper if not digested and assimilated.

It becomes, then, apparent that the essential for metabolism is a vital connection with the dominant nervous system.

It has been objected that the nervous system has a metabolism of its own, independent of other regulative influence, but in this objection it seems to be forgotten that the nervous system is itself made up of parts which are related as higher and lower, or, at all events, which intercommunicate and energize one another.

We have learned that one muscle cell has power to rouse another to activity, when an impulse has reached it from a nervous centre.

Doubtless this phenomenon has many parallels in the body, and explains how remotely a nervous centre may exert its power. It enables one to understand, to some extent, many of those wonderful co-ordinations (obscure in detail) which are constantly taking place in the body.

We think the facts, as they accumulate, will more and more show, as has been already urged, that the influence of blood pressure on the matabolic (nutritive) processes has been much over-estimated. They are not essential, but concomitant in the highest animals.

Turning to the case of muscle, we find that when a skeletal muscle is tetanized, the essential chemical and electrical phenomena are to be regarded as changes differing in degree only from those of the so-called resting state.

There is more oxygen used, more carbonic anhydride excreted, etc. The change in form seems to be the least important from a physiological point of view. Now, while all this can go on in the absence of blood, or even of oxygen, it cannot take place without nerve influence or something simulating it.

Cut the nerve of a muscle, and it undergoes fatty degeneration and atrophy. True, this may be deferred, but not indefinitely, by the use of electricity, acting somewhat like a nerve itself, and inducing the approximately normal series of metabolic changes. If, then, the condition when not in contraction (rest) differs from the latter in all the essential metabolic changes in rate or degree only, and if the functional condition or accelerated metabolism is dependent on nerve influence, it seems reasonable to believe that in the resting condition the latter is not withheld.

Certain forms of paralysis (*e. g.*, hysterical) are not followed by atrophy. Why? Because in this form the metabolic nerve influence is still exerted.

The recent investigations on the heart make such views as we are urging clearer still. It is known that section of the vagi leads to degeneration of the cardiac structure. We now know that this nerve contains fibres which have a diverse action on the metabolism of the heart, and that according as the one or the other set is stimulated, so does the electrical condition vary; and everywhere, so far as known, a difference in electrical condition seems to be associated with a difference in metabolism, which may be one of degree only, perhaps, in many instances, still a difference. The facts, as brought to light by experimental stimulation, harmonize with the facts of degeneration by the cardiac tissue on section of the vagi; but this is only clear on the view we are now presenting that the action of the nervous system is not only universal, but that it is *constant*; that function is not an isolated and independent condition of an organ or tissue, but a part of a long series of metabolic changes. It is true that one or more of such changes may be arrested just as all of them may go on at a less rate, thus, actual outpouring of pancreatic secretion is not constant; but secretion is not summed up in discharge merely, and on the other hand it would seem that in some animals the granules of the digestive glands are being renewed while they are being used up in secreting cells. The processes may be simultaneous or successive. Nor do we wish to imply that the nervous system merely holds in check, or, in a very general sense, co-ordinates processes that go on unoriginated by it. We think the facts warrant the view that they are in the highest mammals, either directly (most) or indirectly originated by it; that they would not take place in the absence of this constant nervous influence.

The facts of common observation, as well as the facts of disease, point in the strongest way to such a conclusion.

Everyone has experienced the influence on, not one, but many, functions of the body, we might say the entire metabolism of depressing or exalting emotions. The failure of appetite, loss of flesh and mental power under the influence of grief or worry, tell a plain story. Such broad facts are of infinitely more value in settling such a question as that now discussed than any *single* experiment.

The best test of any theory is the extent to which it will explain the whole round of facts. Take another instance of the influence over metabolism of the nervous system.

Every athlete knows that he may overstrain, *i. e.*, he may use his muscles so much as to disturb the balance of his powers somewhere, very frequently his digestion, but often there seems to be a general break—the whole metabolism of the body seems to be out of gear. If we assume a constant nervous influence over the metabolic processes, this is comprehensible. The centres can produce so much only of what we may call nervous force, using the term in the sense of directive power, and if this be unduly diverted to the muscles, other parts must suffer. The same holds of excessive mental application.

On this view, also, the value of rest or change of occupation becomes clear. The nervous centres are not without some resemblance to a battery; at most the latter can generate only a definite quantity of electricity, and if a portion of this be diverted along one conductor, less must remain to pass by any other.

It is of practical importance to recognize that, under great excitement, unusual discharges from a nerve centre may lead to unwonted functional activity; thus, under the stimulus of the occasion, a man may in a boat-race originate muscular contractions he could not by the strongest efforts of his will cause under other circumstances. Such are always dangerous. We might speak of a reserve or residual nerve force, the expenditure of which results in serious disability. It also applies to mental and emotional effects, as well as muscular, and seems to us to throw light upon many of the failures and successes (so-called) of life.

It seems that our past views of secretion and nutrition have been partial rather than erroneous in themselves, and it is a question whether it would not be well to substitute some other terms for them, or, at least, to recognize them more clearly as phases of a universal metabolism. We appear to be warranted in making a wider generalization.

To regard processes concerned in building up a tissue, as apart from those that are recognized as constituting its function, seems to be illogical and unwise, with the knowledge we at present possess.

Whether, in the course of evolution, certain nerves, or, as seems more likely, certain nerve fibres in the body of nerve trunks have become the medium of impulses that are restricted to regulating certain phases of metabolism, as, *e. g.*. expulsion of formed products in gland cells, is not, from a general point of view, improbable, and is a fitting subject for further investigation. But it will be seen that we should regard all nerves as "trophic," in the wider sense. What is most needed, apparently, is a more just estimation of the relative parts played by blood and blood-pressure, and the direct influence of the nervous system on the life-work of the cell.

These views are greatly strengthened by the facts well known to every observer of disease in the human subject. The preponderating development of the cerebrum in man must be taken into account in the working of every organ. To have a normal stomach, liver, kidneys, etc., is not enough; for real health, all the parts of that great complex of organs we call the brain must not only work, but work in concert. We must regard the nervous centres as the source of ceaseless impulses that operate upon all parts originating and controlling the entire metabolism, of which what we term functions are but certain phases, parts of a whole, but essential for the health or normal condition of the tissues.

Against such a view we know no facts, either of the healthy or disordered organism.

On the Classification of the Cambrian Rocks in Acadia.

No. 2.

By G. F. Matthew, M.A., F.R.S.C.

1. *Comparison of Species with Description of a new Species of Obolus.*

When in Vol. III, No. 2, of this journal, the writer suggested a provisional arrangement of the members of the Cambrian System in Acadia, he did not anticipate that the doubt then resting upon the proper position of the Olenellus beds, (or Georgian Series), would so soon be removed.

Early in the past summer, he received from Dr. F. Schmidt, of St. Petersburg, his pamphlet "On a newly discovered Lower Cambrian fauna in Eastland," wherein is described, under the name of *Olenellus Mickwitzi*, a trilobite in all respects similar, in generic characters, to Mr. C. D. Walcott's *Mesonacis*. This trilobite is found in company with *Mickwitzia monilifera* (=*Lingula* (?) *monilifera*, Linrs.) a brachiopod of the Eophyton Sandstone. The Eophyton Sandstone is at the base of the Cambrian System in Sweden, below the Paradoxides bed, and this trilobite (*O. Mickwitzi*), therefore, is of greater antiquity than Paradoxides. This view of the comparative age of the Paradoxides beds is supported by the discovery (communicated to me by Mr. Walcott) of *Ollenelus* (?) *Kjerulfi* in the Cambrian beds of the State of New York. This species is well-known as being below the Paradoxides beds in Europe.

So there was, in the discovery of these two species in the situations designated, sufficient evidence to show that the Olenellus beds, or those containing the Georgian fauna, were below the Paradoxides, and not above, as I suggested in my former paper to be the more probable alternative.

Mr. Walcott has since made the position of these beds certain by visiting Newfoundland, and examining the district where, many years ago, Mr. A. Murray found the Georgian fauna in this relation: although it was not recognized by him as such, because, neither the assemblage of species collected by Mr. Murray, and determined by Mr. Billings, nor those of Georgia, Vt., had been sufficiently compared to show that they were of one fauna. Mr. Walcott states *that this fauna is unquestionably beneath the Paradoxides* beds in Newfoundland, at a depth of about 200 feet. There can be, therefore, no longer any doubt that the Olenellus-Doryphyge phase of the Olenellus fauna, which is the Olenellus fauna of Eastern North America, is older than the Paradoxides beds of the same region.

Though this fauna is found north, east, and west of New Brunswick, having been recognized in Quebec, Cape Breton, and Massachusetts, it has not been found in the first named Province, notwithstanding that there are there no less than 1,600 feet of Cambrian measures beneath the Paradoxides beds. *But, though this fauna has not been* found in New Brunswick, the writer proposes to point out where, from our present knowledge of the subject, it is likely to be found.

There is, in all the Cambrian basins of this Province, just beneath the oldest beds in which the Paradoxides are known to occur, a peculiar bed of shales, of considerable thickness, which, though apparently no coarser or harder than the beds below it, stands out in the sections with peculiar massiveness, and on examination is seen to be cut in all directions by the burrows of large marine worms. Here the brachiopods lie *at all angles in the shale, and in the worm-*burrows, as though the worms, in their search for food, had disturbed all the successive layers of the sea-bottom, and kneaded the mud into a continuous pasty mass.

This bed is at the top of Band *b.*, and marks the close of a period of disturbed physical conditions, that ushered in the tranquil time of the Paradoxides. In and below this bed, the remains of trilobites are rare; and except as regards the brachiopods, the known fauna differs entirely from that in the beds above. In the middle of Band *b.*, we have been able to recognize an *Agraulos,* and at the base an

Ellipsocephalus, both recalling forms which, in Europe, are associated with *Olenellus* (?) *Kjerulfi.*

In the most northerly basin of Cambrian Rocks, in the southern part of this Province, (New Brunswick), the writer, during the past summer, collected an *Obolus* near the base of Band *b.*, which may serve to link the fauna of this band with that of the Fucoid Sandstone, in Sweden. The shell in question is remarkable for the change in form which it underwent during growth, and for a peculiar radular ornamentation.

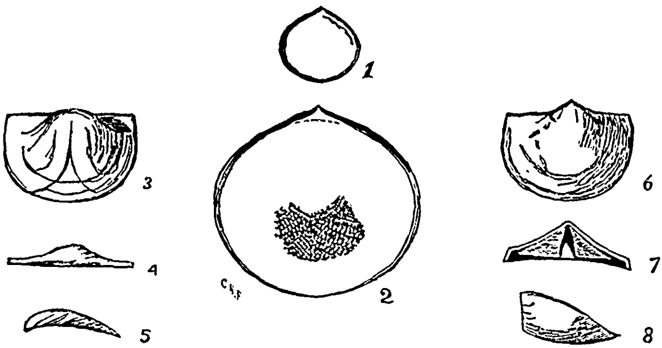
This variety of sculpture is not infrequent in the brachiopods, which are found in company with the Olenelloid trilobites. Such a form is known in the Fucoidal Sandstone, under the name of *Lingula* (?) *favosa* Linrs. Another similar one is *Lingulella cœlata,* Hall, and a third is *Kutorgina pannula,* White, of the Olenellus fauna of Nevada.

Dr. Hicks also figures and describes an organism from the Caerfai Group in Wales, as a doubtful Leperditia (*L.* ? *Cambrensis*) which may be a brachiopod with cancellated ornamentation, it is represented as of oval or semi-circular form, and is said to show a "reticulate ornamentation.[1] Possibly this, which is found in sandy beds with Ligulella, may alse be a brachiopod, with radular sculpture, but on the other hand it may be a fragment of a Olenelloid trilobite, as in this sub-family the surface has reticulate ornamentation.

Kutorgina pannula is a similar, but smaller form, in which the cancellation is raised as in some examples of our Obolus; and the possible outgrowths of the latter form may be seen by comparing its embryonic shell with *Kutorgina pannula.*

The following are the characters of the Obolus referred to above:—

[1] Quart. Jour. Geol. Soc., London, 1871, Vol. 27, p. 401.



OBOLUS PULCHER, n. sp.

Fig. 1. Ventral valve. Natural size.
" 2. Same, mag. 2½, to show the surface markings. The dotted line near the top of the figure indicates the outline of the dorsal valve at that part.
Fig. 3. Embryonic shell, Dorsal valve, mag. $\frac{15}{1}$.
" 4. Same, seen from behind.
" 5. Same, seen from the side.
" 6. Embryonic shell, Ventral valve, mag. $\frac{15}{1}$.
" 7. Same, seen from behind.[1]
" 8. Same, seen from the side.

General outline nearly orbicular; the valves gently, but rather flatly and evenly arched down from the centre all around, except that the dorsal is flatter at the back than elsewhere, and the ventral valve runs out into a short acuminate umbo.

Dorsal valve somewhat wider than long; more strongly arched towards the front than elsewhere; somewhat elevated at each end of the hinge line.

Ventral valve about as wide as long, sides and front evenly rounded; back produced into a short pointed beak, angle of incidence of the two sides, 110° to 120°.

Sculpture of the posterior half of the valves, consisting of minute tubercles, sloping forward, and arranged in rows, which arch forward across the mesian line from each late-

[1] The angle at each side is an error of the engraver.

ral margin, giving to the surface a cancellated appearance. In a few examples, the tubercles are connected, so as to give the surface a pitted appearance, like that of *Lingula*(?) *favosa* and *Kutorgina pannula.*

Sculpture of the anterior part on the front and sides in the adult consisting of concentric lines of growth, with faint, interrupted, radiating striæe.

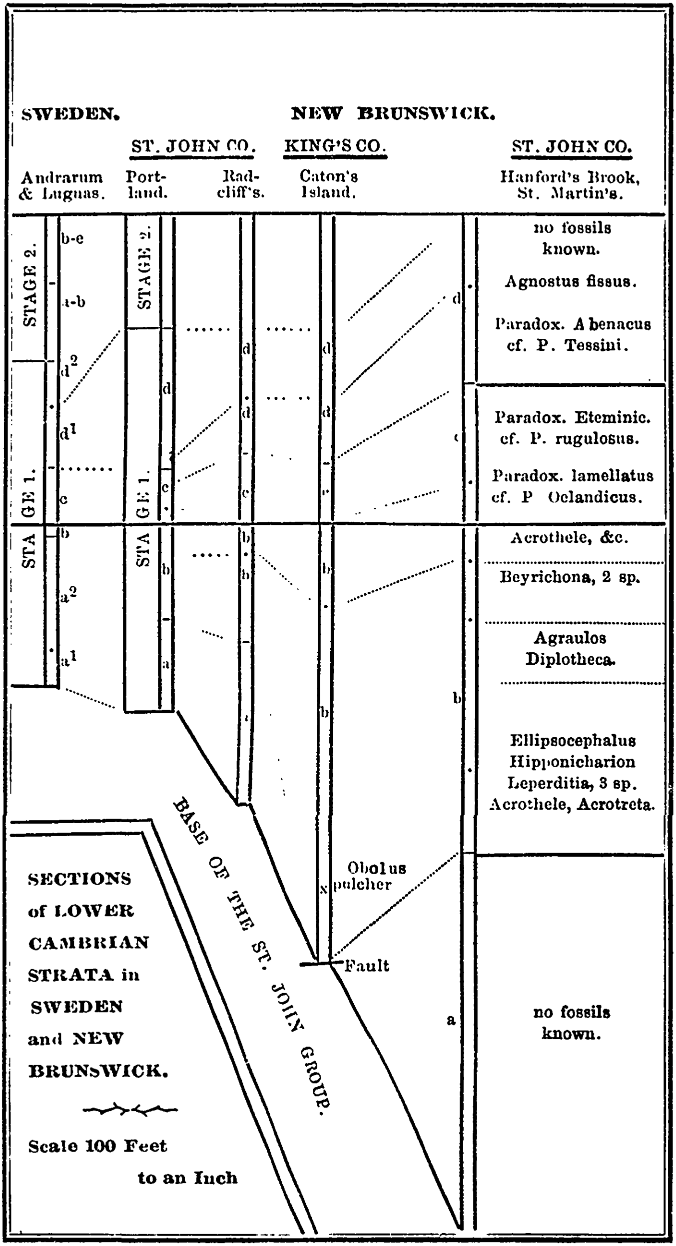
2. *Comparison of Sections in Sweden and New Brunswick.*

The relation of the Paradoxides beds to those beneath will be better understood by a comparison of the Acadian measures at several localities with the typical Cambrian series of Sweden. So nearly alike were the physical conditions, during this early period of Cambrian time, in those two countries, that the symbols originally used in New Brunswick, to designate the groups of beds, have served to distinguish nearly similar sub-divisions in Sweden and Norway.

In these sections the base of the Paradoxides beds has been taken as the datum-line, and the thickness of the beds above and below this horizon, indicated on a scale of 100 feet to an inch.

In Sweden, the beds which belong to the lower part of the column, and are marked *b.*, are the "Olenellus beds" of that country: those marked *a.* are the Fucoid and Eophyton Sandstones which, by the discovery of F. Schmidt, in Eastern Russia, are also to be counted as a part of the Olenellus beds, since, as already observed, the corresponding beds in Russia contain a Mesonacis. The brachiopod (*Lingula*(?) or) *Mickwitzia monilifera*, which is found with this trilobite, and is common to the Cambrian of Russia and Sweden, occurs in the latter country at the base of the Eophyton sandstone, and this sandstone appears to correspond in position to the white weathering sandstone, *a*, at the base of St. John Group in New Brunswick.

TABLE I.


SWEDEN.
NEW BRUNSWICK.
ST. JOHN CO.
KING'S CO.
ST. JOHN CO.
Andrarum & Lugnas.
Portland.
Radcliff's.
Caton's Island.
Hanford's Brook, St. Martin's.
STAGE 2.
STAGE 1.
b-e
a-b
d2
d1
c
b
a2
a1
no fossils known.
Agnostus fissus.
Paradox. Abenacus cf. P. Tessini.
Paradox. Eteminic. cf. P. rugulosus.
Paradox. lamellatus cf. P Oclandicus.
Acrothele, &c.
Beyrichona, 2 sp.
Agraulos Diplotheca.
Ellipsocephalus Hipponicharion Leperditia, 3 sp. Acrothele, Acrotreta.
Obolus pulcher
Fault
no fossils known.
BASE OF THE ST. JOHN GROUP.
SECTIONS of LOWER CAMBRIAN STRATA in SWEDEN and NEW BRUNSWICK.
Scale 100 Feet to an Inch

Of the sections of Cambrian Rocks in Acadia exhibited on the Table I, page 308, three are from theSt. John Basin, and the fourth from the northern basin in Kings Co., and they show clearly the varying thickness of the deposits of Division or Stage 1. in the different districts; this feature is much more noticeable in the lower bands (*a* and *b*) than in the upper *c* and *d*).

The most continuous and complete section found, is that on Hanford Brook, where the Cambrian measures are now separated from the rest of the St. John Basin by a low ridge of pre-Cambrian rocks; and from the differences that are observable in the details of the sections on the two sides of this ridge, it is probable that it existed in Cambrian times (compare the 3rd and 5th sections). Band *b* has its greatest thickness in the more distant basin in King's Co., (see fourth section), but does not show so much variety in the sedimentation as at the easterly exposures in the St. John Basin.

In this district at Hanford Brook, the fauna of 1 *b* presents itself in considerable variety. At the base, forty feet of the dark gray sandstone contains Ellipsocephalus and fragments of other trilobites; four entomostracans, viz., Hipponicharion and three species of Leperditia, which latter are remarkable for their thick tests, and pitted surfaces, and six species of brachiopods of the genera Acrothele, Acrotreta, Linnarssonia and Lingulella.

These sandstones are followed by fifty feet of comparatively barren, dark grey, sandy shales; and they by thirty feet of hard, purple-streaked sandstones, in which occurs an Agraulos of the form of *A.* (*Arionellus*) *primævus* of the bed *b* in Sweden, and the peculiar Hyalithoid shell *Diplotheca*, as well as numerous tracks of Psammichnites.

The olive grey shale, thirty feet thick, above this sandstone, is comparatively barren, but has yielded the two species of Beyrichona, a genus which has points of resemblance to Aristoze of Barrande.

The upper bed of *b*, twenty feet thick, is that already described as being cut up by worm burrows. In it the brachiopodous genera *Acrothele*, *Lingulella* and *Linnarssonia*, are not uncommon, and the species are the same as found in the Paradoxides beds above.

There is thus, in Band *b*, an entomostracan fauna of six species, as well as two trilobites which resemble those of the Olenellus beds in Sweden, but so far, no example of Olenellus itself or its kindred genera. Band *b* has a thickness of 170 feet, and Band *a* of 200 feet, so we may suppose these measures at the base of the St. John Group, are very near the horizon of Olenellus.

If we were to be guided by the indications given by the Scandinavian faunas, we would place the Olenellus beds as a stage only, below the Paradoxides beds, and would not consider them worthy to rank as a series: but if we regard the great development of the measures containing Olenellus on the Pacific slope of the continent, we cannot refuse to accord to them the latter grade. It is a series which appears to overlap that containing Paradoxides, but which in its commencement assuredly had a higher antiquity.

The author would, therefore, now arrange the Cambrian System, as it occurs in Acadia, as follows:—

	Localities.
D.—Upper Cambrian System (Potsdam series)...	Unknown.
C.—Middle and Lower Cambrian } Acadian Series,.........	St. John, &c.
B.—Lower Cambrian, Georgian Series,..........	C. Breton.
A.—Basal Cambrian, Etcheminian Series,.......	St. John, &c.

The relation of the two latter series has not been clearly shown, but the observations thus far made in New Brunswick, and Newfoundland, agree with the scheme above presented.

3. *On the relations of the Olenellus faunas of the Pacific Slope in North America.*

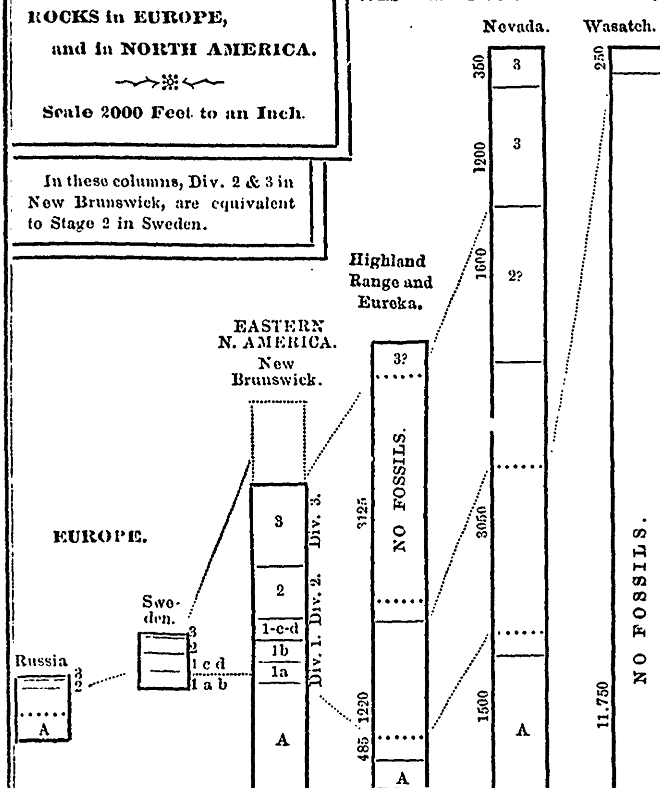
The Olenellus fauna which we have been considering is not the full development of this fauna as known in the West.

SECTIONS of CAMBRIAN ROCKS in EUROPE, and in NORTH AMERICA.

Scale 2000 Feet to an Inch.

In these columns, Div. 2 & 3 in New Brunswick, are equivalent to Stage 2 in Sweden.

WESTERN NORTH AMERICA.



CAMBRIAN IN RUSSIA.

3	Glauconite Sand	10 feet.	
2	Dictyonema Beds	10 "	=Divisions 2 and 3 in N.B.
	Ungulite Grit	60 "	
A	Blue Clay	300 "	=Series A. in N.B.
	Iron Sandstone	300 "	
		680	

CAMBRIAN IN SWEDEN.

3	Ceratopyge Beds	12 feet.	
2	Peltura Beds	34 "	=Div. 3 in N.B.
	Olenus Beds	40 "	=Div. 2 in N.B.
1	Paradoxides Beds	90 "	=Div. 1 in N.B.
	Fucoid Sandstone	60 "	
	Eophyton Sandstone	20 "	
		256	

A

In that region there are two phases of the Olenellus fauna found at different levels in the measures of the Cambrian System, which may be distinguished as the Olenellus-Dorypyge phase, and the Olenellus-Bathyuriscus (*cf.* Ogygia) phase: it is the former only which is known in Eastern North America.

According to Mr. Walcott's sections, of which an outline is given on Table II, page 311, these two phases are separated by about 1,200 feet of measures, and the older is found some 1,500 feet or more above the base of the Cambrian system.

I have attempted to trace, by dotted lines, the respective horizons marked by these two phases of the Olenellus fauna, and for comparison, the position also of the Upper Cambrian fauna in the same region.

The basal measures of the Cambrian System, which in these sections are indicated by the letter A, are found in Norway, Russia, Newfoundland, New Brunswick and Western America, and probably also in Wales. As for the Cambrian measures which are above these, when they can be indicated with sufficient certainty, the Lower Cambrian is marked by 1, the Middle Cambrian by 2, and the Upper Cambrian, by 3, to show the range of the faunas in the several sections.

Mr. Walcott takes the Nevada section as the typical one for the West. In this the Upper *Olenellus* fauna extends 3,050 feet above the lower; and beyond this, for 1,600 feet, its forms are mingled with those of the Upper Cambrian or Potsdam fauna,[1] which, from its position, may be considered equivalent to the Ceratopye beds of Sweden. If there is this mingling of the species of the Olenellus beds with those of the Upper Cambrian, no place remains in Western America for the great North Atlantic faunas of the Paradoxides beds, and of the Lower and Upper Olenus beds. The only inference we can draw from this is, that the Upper Olenellus fauna and the Passage beds above were cotemporary with the three North Atlantic faunas above named.

[1] See Bull. U. S. Geol. Survey, No. 30, p. 32.

It has been stated in the notice of the meetings of the Geological Congress in London (1888) that Mr. Walcott's fauna of Olenellus, of forty-two genera, and 113 species,[1] is of earlier date than the Paradoxides bed, but from Mr. Walcott's own observations in the West, it is evident that this fauna should be divided, as only the Olenellus-Dorypyge phase can with certainty be placed below the Paradoxides zone.

In order to show the characteristic species of the Olenellus Bathyuriscus or later fauna of Olenellus, the writer has selected the following species, which, according to Mr. Walcott, belong to this horizon.

The genera marked with an asterisk, are found in the Paradoxides beds.

*_Protospongia fenestra._
*_Eocystites_ (??) _longidactylus._
*_Lingulella Ella._
*_Kutorgina pannula._
*_Acrotreta gemma._
*_Acrothele subsidua._
*_Orthis Highlandensis._
*_Stenotheca elongata._
*_Hyolithes Billingsi._
*_Leperditia Argenta._
*_Agnostus intercinctus._
Olenellus Gilberti.
Olenoides lævis.
O. Nevadensis.
O. spinosus.
O. typicalis.
*_Ptychoparia Housensis._
*_P. Kingi_, (_Anomocare._)
*_P. prospectensis_ (")
*_P. quadrans_ (")
Crepicephalus Augusta.
C. Liliana.
Protypus senectus, (cf. Ellipsocephalus.)
Bathyriscus Howelli, (cf. Ogygia.)
B. producta, (").
Asaphiscus Wheeleri, (cf. Niobe.)

Among these species, *Acrotreta gemma* and *Acrothele subsidua* are similar to species of the Paradoxides beds. *Agnostus intercinctus* is a good example of the group of the Longifrontes, which has many species in the Upper Paradoxides beds, and some in the Lower. *Protospongia fenestrata* is a species of the Lower Paradoxides beds. Of the four species of Ptychoparia, three would by Swedish geologists be included in the same genus with *Anomocare micropthalmum*, also of the Paradoxides beds, and there are other

[1] See Bull. U. S. Geol. Survey, No. 30, p. 45.

Ptychopariæ which I do not make out clearly, from Mr. Walcott's notes, as of this horizon, but which probably belong here (*P. Piochensis*, and *P. coronata*) and these have a still closer resemblance to Anomocare. Olenellus and Olenoides may be considered as the representives of the Paradoxides family at this horizon, but the two last genera on the list find their representatives in Europe at a higher horizon than the Paradoxides zone, even as high as the summit of the Cambrian.

This remarkable grouping of genera, which it is stated gradually gave place to the Upper Cambrian fauna, would lead one to suppose that the introduction and removal of successive groups of marine forms in the West, during the Cambrian age, was governed by other conditions than those which prevailed in the better known regions around the North Atlantic Ocean.

In his former paper on the classification of the Acadian Cambrian Rocks, the writer considered the Olenellus fauna as a whole, but when the later phase of this fauna is removed, the evidence for the rest, *i.e.*, the Olenellus-Dorypyge phase, is in favour of its greater antiquity than the Paradoxides beds.

The great range of Olenellus in the west, as shown by Mr. Walcott's work, is unusual for a trilobite, but is parallelled by that of *Calymene Blumenbachii* in the Ordovician and Silurian and by other trilobites. [1] It is quite compatible with this feature, that the Olenellus-Dorypyge or older phase of the Olenellus fauna should also have a wide geographical range: accordingly, we find it spread all across the American continent, and although we do not know of the occurrence of Olenellus in Asia, its companion, Dorypyge, has been found in Northern China. Dr. F. Schmidt has described from a limestone on the Jenisei river, in Siberia, a trilobite which, by its form, agrees with the genus Dorypyge. Other Cambrian fossils are described in the same paper.

[1] *Protypus senectus* is also credited with a wide vertical range, but the examples figured are so defective that more than one genus may be included under the name.

In Europe, Olenelloid trilobites are again met with, but here, apparently, Dorypyge has not been found.

Taking this older phase of the Olenellus fauna as a basis, the two parellel series of trilobites may be represented in the following diagram:—

	North Pacific Basin.	North Atlantic Basin.	
3.	Upper Cambrian-Dikellocephalus-Ctenopyge fauna,		3.
2	Middle Cambrian. Passage beds to Upper Cambrian.	Peltura fauna........... Olenus fauna...........	2
1	OlenelleusBathyuriscus fauna. Lower Cambrian.......	Paradoxides fauna...... Olenellus–Dorypyge fauna......	1

This diagram is to be taken only as a suggestion of the possible relations of the Cambrian faunas on the two sides of the American continent, and is based upon our present knowledge. Paradoxides has been reported from Minnesota and from the Rocky Mountains on the line of the Canadian Pacific Railway; but imperfect examples of Olenellus and its allied genera so nearly resemble Paradoxides, that they are easily mistaken for it. They are distinguishable from Paradoxides by a decidedly reticulate ornamentation of raised lines on the surface of the crust, for in Paradoxides the lines are more or less parallel to each other.

NOTES ON THE FLORA OF MONTEBELLO, QUEBEC, ESTATE OF THE HON. MR. PAPINEAU.

By HENRY R. AMI, M.A., Cor. Mem. Torrey Botan. Club.

At the Annual Field-day, held under the auspices of the Natural History Society of Montreal, on the 16th day of June, 1888, at Montebello, the various members of that Society had an excellent opportunity offered them, of examining the more salient characteristics of the natural phenomena existing in that locality. In and around the spacious grounds and estates of the Hon. Mr. L. J. Papineau, kindly thrown open to the excursionists on that occasion, as also on a previous one (1881), the diversity of the soil and region, afforded quite a diversity of flora, as well as of fauna.

For example, *Cypripedium parviflorun, Habenaria dilatata? Arisæma triphyllum, Gaultheria procumbens, Linnæa borealis, Thuja occidentalis, Impatiens fulva, Oxcalis Acetosella, Goodyera pubescens, Pyrola elliptica, Thalictrum Cornuti* and other plants were noticed in the low-lying grounds, between the "manor" and the Canadian Pacific Railway track, whilst such species as *Comandra umbellata, Saxifraga Virginiensis, Prunus Pennsylvanica, Vaccinium vacillans, Asclepias Cornuti, Quercus rubra, Adiantum pedatum, Aquilegia Canadensis* and *Rubus odoratus* occupied the higher and dryer levels along the hill slopes and tops. It was a delight to meet with *Cypripedium acaule* in such numbers as were noted along the bluff of micaceous gneiss, close to the R. R. track, associated with *Chimaphila umbellata, Rubus villosus, Prunus Pennsylvanica* The beautiful little "blue-eyed grass"—*Sisyrhynchium mucronatum*, noted for the rapidity with which it ripens or produces its fruit—was also observed in large numbers; this species is found skirting the edge of the Laurentides from north of Montreal westward to Ottawa and farther west. Besides the above, *Polygala paucifolia, Lathyrus ochroleucus, Geum rivale, Dirca palustris, Lycopus Virginicus, Cypripedium parviflorum, Symphoricarpus racemosus, var. pauciflorus* are amongst those species which are of usual occurrence, and of general interest along the Ottawa valley.

A few plants have escaped cultivation and are spreading, viz.:—*Arabis hesperidoides, Allium Schœnoprasum* and *Convallaria majalis.*[1]

In order to ascertain in general, what the flora of the grounds surrounding the "manor" was—a list of the species was made on the spot, subsequently systematized, and hereto appended:—

[1] *Vide* Trans. Ottawa Field Naturalists' Club, No. 3, 1882, p. 23.

List of species found growing within the grounds of Mr. L. J. Papineau, and in the village of Montebello adjoining.

P. represents the Papineau Estates; M. Montebello, for locality.

Clematis Virginiana, L. P.
Anemone dichotoma, L. P.M.
Anemone Hepatica, L. P.
Thalictrum Cornuti, L. P.
Ranunculus abortivus, L. P.
" *acris, L.* P.M.
" *recurvatus, Poir.* P.
Coptis trifolia, Salisb. P.
Aquilegia Canadensis, L. P.
Actæa alba, Bigelow, P.
" *spicata, L. var. rubra, Ait.* P.
Chelidonium majus, L. P.
Cardamine pratensis, L. P.
Arabis hesperidoides, Gray. P.
Brassica alba, Gray. M.
" *Sinapistrum, Boiss.* M.
Capsella bursa-pastoris, Mœnch. M.P.
Thlaspi arvense, L. M.
Viola cucullata, Ait. P.
Cerastium vulgatum, L. M.P.
Tilia Americana, L. P.
Geranium Robertianum, L. P.
Impatiens fulva, Nutt. P.
Oxalis Acetosella, L. P.
" *corniculata, L. var stricta,* L. P.
Rhus Toxicodendron, L. P.
Rhus typhina, L. P.
Ampelopsis quinquefolia, Michx. P.
Acer Pennsylvanicum, L. P.
" *rubrum, L.* P.
" *saccharinum, L.* P.
" *spicatum, Lam.* P.
Polygala paucifolia, Willd. P.
Trifolium repens, L. P.M.
" *pratense, L.* P.M.
Medicago Lupulina, L. P.M.
Lathyrus ochroleucus, Hook. P.
Robinia viscosa, Vent. P.
Prunus Pennsylvanica, L. P.
" *Virginiana, L.* P.
Geum rivale, L. P.
Fragaria vesca, L. P.
" *Virginiana, Ehrh,* P.M.
Rubus odoratus, L. P.
" *strigosus, Michx.* P.M.
" *triflorus, Tich.* P.
" *villosus, Ait.* P.
Pyrus Americana, D.C. P.
Amelanchier Canadensis, v. oblongifolia, T. & G. P.
Ribes Cynosbati, L. P.
" *lacustris, Poir.* P.
Saxifraga Virginiensis, Michx. P.
Mitella diphylla, L. P.
" *nuda, L.* P.
Tiarella cordifolia, L. P.
Epilobium spicatum, L. P.
Sanicula Marilandica, L. P.
Osmorrhiza brevistylis, D.C. P.
Aralia nudicaulis, L. P.
Cornus Canadensis, L. P.
" *circinata, L'Her.* P.
" *stolonifera, Michx.* P.M.
Linnæa borealis, Gronov. P.
Symphoricarpus racemosus, Mix, var., pauciflorus, Robbins, M.
Lonicera ciliata, Muhl. P.
Diervilla trifida, Mœnch. P.
Sambucus Canadensis, L. P.
Viburnum acerifolium, L. P.
" *Opulus, L.* P.
Galium asprellum, Michx. P.
" *triflorum, L.* P.
Aster cordifolius, L. P.
Aster macrophyllus, L. P.
Erigeron Philadelphicum, L. P.
" *strigosum, L.* P.
Bidens frondosa, L. P.
Anthemis Cotula, L. M.
Achillæa millefolium, L. P.M.
Chrysanthemum Lecanthemum, L. M.
Artemisia vulgaris, L. M.
Antennaria plantaginifolia, R. Br. P
Cnicus arvensis, Scop. M.P.
Lappa officinalis, All. M.
Cichorium Intybus, L. M.
Nabalus sp. P.
Taraxacum officinale, Weber, M.P.
Vaccinium Pennsylvanicum, L. P.
Vaccinium vacillans Solander. P.
Gaultheria procumbens, L. P.
Pyrola elliptica, Nutt. P.
" *secunda, L.* P.
Chimaphila umbellata, Nutt. P.
Plantago major, L. P.M.

Plantago Rugellii, Decaisne. P.
Trientalis Americana, Pursh. P.
Veronica serpyllifolia, L. P.M.
Lycopus Virginicus, L. M.
Leonurus Cardiaca, L. M.
Cynoglossum, officinale, L. M.
" *Virginicum, L.* P.
Apocynun androsæmifolium, L. P.
Asclepias Cornuti, Decaisne. P.
Fraxinus pubescens, Lam. P.M.
Chenopodium album, L. P.M.
Atriplex patula, L. P.M.
Polygonum aviculare, L. M.
" *cilinode. Michx.* P.
" *hydropiper, L.* P. & M.
Rumex Acetosella, L. P.M.
" *verticillatus, L.* P.M.
Dirca palustris, L. P.M.
Comandra umbellata, Nutt
Ulmus Americana, L. P.M.
" *fulva, Michx;* M.
Juglans cinerea, L. P.
Quercus alba, L. M.
" *rubra, L.* P.
Fagus ferruginea, Ait. P.
Corylus rostrata, Ait. P.
Carpinus Americana, Michx. P.
Betula papyracea, Ait. P.
" *lena, L.* P.
Alnus incana, Willd. P.
Salix (several species). P. & M.
Populus balsamifera, L. P.
" *grandidentata, Michx.* P.
" *tremuloides, Michx.* P.
Pinus Strobus, L. P.M.
" *resinosa, Ait.* P.
Picea alba, Link. P.
Abies balsamea, L. P.
Pseudotsuga Canadensis, Michx: P.
Larix Americana, Michx. P.
Thuja occidentalis, L. P.
Juniperus communis, L.
Arisæma triphyllum, Torrey P.
Typha latifolia, L. P.
Alisma plantago, L. var. Americana, Gray. P.
Habenaria dilatata, Gray. P.
Goodyera pubescens, R. Br. P.
Cypripedium acaule, Ait. P.
" *parviflorum, Salisb.* P. (1881.)
Iris versicolor, L. P.
Sisyrhynchium mucronatum, Michx. L. P.M.
Smilax herbacea, L. P.M.
Trillium grandiflorum, Salisb. P.
Medeola Virginica, L. P.
Streptopus roseus, Michx. P.
Uvularia sessilifolia, L. P.
Clintonia borealis, Raf. P.
Smilacina racemosa, L. Desf. P.
Mianthemum Canadense, Desf. P.M.
Erythronium Americanum, Smith. P.
Allium Schœnoprasum, L. P.
Convallaria majalis, L. P.
Scirpus atrovirens, Muhl. P.
Carex intumescens, Rudge.
" *laxiflora, Lam.* P.
" *riparia, Curtis.* P.
" *stellulata, L.* P.
Agrostis vulgaris, With.
Calamagrostis Canadensis, Beauv. P.
Phleum pratense, L. P.M.
Equisetum hyemale, L. M.
" *sylvaticum, L.* P.
Pteris aquilina, L. P.M.
Adiantum pedatum, L. P.
Phegopteris Dryopteris, Feé. P.
Aspidium Thelypteris, Swz. P.
Onoclea sensibilis, L. P.
" *Struthiopteris, Hoffm.*
Botrychium Virginicum, Swz. P.
Lycopodium clavatum, L. P.
" *complanatum, L.* P.

OTTAWA, *June* 20*th*, 1888.

METEOROLOGICAL ABSTRACT FOR THE YEAR 1888.

Observations made at McGill College Observatory, Montreal, Canada. —Height above sea level 187 ft. Latitude N. 45° 30′ 17″. Longitude 4^h 54^m 18.55 W.

C. H. McLEOD, *Superintendent.*

MONTH.	THERMOMETER.					* BAROMETER.				Mean pressure of vapour. †	Mean relative humidity. ‡	Mean dew point.	WIND.		Sky clouded per cent.	Per cent. possible bright sunshine	Inches of rain.	Number of days on which rain fell.	Inches of snow.	Number of days on which snow fell.	Inches of rain and snow melted.	No. of days on which rain and snow fell.	No. of days on which rain or snow fell.	MONTH.
	Mean.	¶ Deviation from 14 year means.	Max.	Min.	Mean daily range.	Mean.	Max.	Min.	Mean daily range.				Resultant direction.	Mean velocity in miles per hour.										
January	3.66	− 7.24	40.0	− 20.5	15.09	30.1413	30.865	29.538	.333	.0446	78.8	−1.8	S. 77° W.	18.68	50.4	41.2	0.08	2	33.6	17	2.81	2	17	January
February	12.42	− 3.15	38.6	− 24.4	20.28	30.0971	30.617	29.514	.314	.0737	79.6	7.1	S. 44° W.	17.19	54.2	45.3	0.55	2	30.0	16	2.71	2	16	February
March	23.22	− 0.11	44.2	− 2.9	13.21	29.9866	30.563	29.173	.250	.1077	76.8	16.8	S. 64° W.	22.26	79.6	31.4	1.17	6	25.2	14	3.45	3	17	March
April	36.85	− 2.46	76.0	11.4	13.66	30.0719	30.507	29.544	.217	.1493	67.0	26.1	S. 81° W.	16.28	60.6	54.1	0.80	11	7.1	12	1.54	6	17	April
May	53.55	− 1.07	79.8	31.1	16.65	29.9576	30.306	29.555	.145	.2631	63.4	40.1	S. 46° W.	13.24	67.8	45.0	1.97	16	Inapp.	1	1.97	1	16	May
June	65.81	+ 1.24	88.1	46.5	18.06	29.8603	30.238	29.479	.161	.4319	67.0	53.7	S. 59° W.	13.47	59.6	58.9	3.12	19	..	..	3.12	..	19	June
July	67.93	− 1.17	87.1	47.4	20.04	29.9051	30.232	29.186	.161	.4190	62.2	53.7	S. 73° W.	13.31	52.1	69.2	1.32	13	..	..	1.32	..	13	July
August	64.18	− .07	85.8	47.6	14.28	29.8849	30.285	29.624	.138	.4562	75.5	55.5	S. 70° W.	12.54	65.4	43.4	7.89	19	.	..	7.89	.	19	August
September	55.43	− 3.03	74.0	33.2	13.56	30.0342	30.621	29.485	.157	.3556	78.9	48.5	S. 66° W.	11.46	60.8	48.2	3.69	16	.	..	3.69	.	16	September
October	39.51	− 5.84	58.0	28.5	11.31	29.9184	30.478	29.386	.215	.1913	77.9	32.8	W.	15.85	69.8	36.3	3.82	22	7.8	5	4.55	2	25	October
November	33.25	+ 1.33	68.0	1.0	12.09	30.0876	30.804	29.354	.291	.1761	80.5	27.7	N. 66° W.	17.65	74.0	33.2	5.10	16	11.0	10	6.40	4	22	November
December	22.39	+ 3.70	45.8	− 10.5	13.18	29.9220	30.558	29.283	.266	.1128	80.8	17.2	N. 81° W.	18.33	74.4	25.1	1.57	8	17.6	17	3.12	2	23	December
Sums for 1888	..	....	....	....	....		....	....	....	....		....		....	....	....	31.08	150	132.3	92	42.57	22	220	Sums for 1888
Means for 1888	39.83	− 1.74	....	....	15.12	29.9889	....	....	.223	.2318	74.0	31.4	S. 74° W.	15.85	64.1	44.3	....	....		....	3.55	..	18.3	Means for 1888
Means for 14 years ending Dec. 31, 1888.	41.58	....	...	....	...	29.9760	....	....	....	.2489	74.3	....	....	...	61.2	§ 46.4	27.20	132	125.8	85	39.66	15	202	Means for 14 years ending Dec. 31, 1888.

* Barometer readings reduced to 32° Fah., and to sea level. † Inches of mercury. ‡ Saturation, 100. § For 7 years only. ¶ "+" indicates that the temperature has been *higher;* "—" that it has been *lower* than the average for 14 years, inclusive of 1888. The monthly means are derived from readings taken every 4th hour, beginning with 3h. 0m, Eastern Standard time. The anemometer and wind vane are on the summit of Mount Royal, 57 feet above the ground, and 810 feet above sea level.

The greatest heat was 88.1 on June 22nd: greatest cold 24.4 below zero on February 10th; extreme range of temperature was therefore 112.5. Greatest range of the thermometer in one day was 50.1 on Jan. 13th; least range was 2.3 on Nov. 28th. The warmest day was June 22nd, when the mean temperature was 77.52. The coldest day was Feb. 10th, when the mean temperature was 15.90 below zero. The highest barometer reading was 30.865 on January 16th, the lowest was 29.173 on March 21st, giving a range of 1.692 for the year. The lowest relative humidity was 23 on May 26th. The greatest mileage of wind recorded in one hour was 62 on November 26th, and the greatest velocity in gusts was at the rate of 90 m. p. h. for 3 miles, and 110 m. p. h. for 1 mile, on March 13th. The total mileage of wind was 139,303. The resultant direction of the wind for the year is S. 74° W., and the resultant mileage 60,750. Auroras were observed on 21 nights. Fogs on 31 days. Hoar-frost on 15 days. Thunder storms on 20 days, and lightning without thunder on 8 days. Lunar halos on 9 nights. Lunar coronas on 7 nights. The sleighing of the winter closed, in the city, on April 7th. The first appreciable snowfall of the autumn was on October 3rd. The first sleighing of the winter was on December 18th.

The mean temperatures for January and December are the lowest on the records for the 14 years over which the present series of observations extends. The rainfall for August is the greatest recorded in 14 years. There was an earthquake rumble on July 1st.