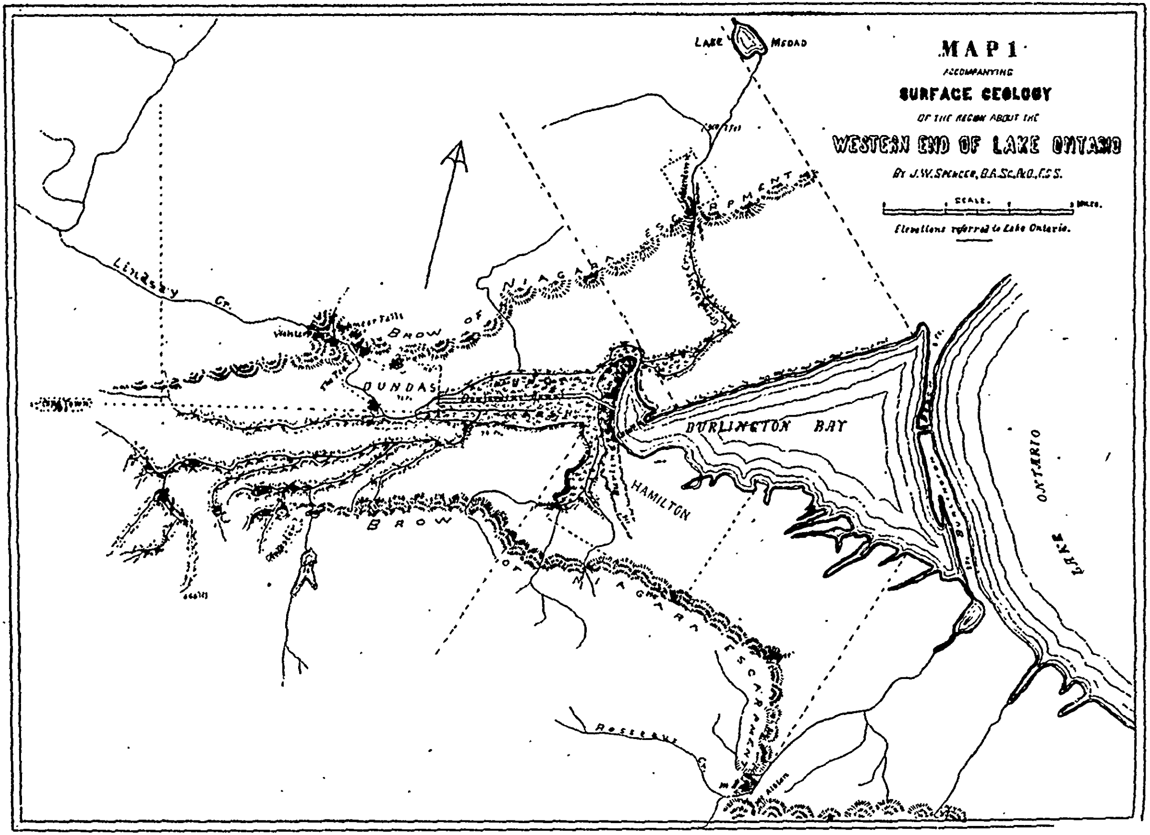
MAP 1
ACCOMPANYING
SURFACE GEOLOGY
OF THE REGION ABOUT THE
WESTERN END OF LAKE ONTARIO
BY J. W. SPENCER, B.A.SC.,PH.D.,F.G.S.
SCALE.
Elevations referred to Lake Ontario.
LAKE MEDAD
BURLINGTON BAY
LAKE ONTARIO
HAMILTON
DUNDAS
NIAGARA ESCARPMENT
BROW OF NIAGARA ESCARPMENT
BROW OF NIAGARA
Lindsay Cr.
Rosseaux Cr.

THE

CANADIAN NATURALIST

AND

Quarterly Journal of Science.

THE RELATIONS OF THE NATURAL SCIENCES.

By T. Sterry Hunt, LL.D., (Cantab.) F.R.S.

(The President's address before the Mathematical, Physical and Chemical Section of the Royal Society of Canada, at the first meeting of the Society, Ottawa, May 27, 1882.)

The occasion which brings us together is one which should mark a new departure in the intellectual history of Canada. Science and letters find but few votaries in a country like this, where the best energies of its thinkers are necessarily directed to devising the best means of subduing the wilderness, opening the ways of communication, improving agriculture, building up industries, and establishing upon a proper basis schools in which the youth of the country may be instructed in those arts and professions which are among the first needs of civilized society. The teachers under such conditions can do little more than interpret to their pupils so much of the wisdom of the past, and of contemporary science, as may suffice for the immediate wants of the country, and will have but scanty leisure for original investigation in the field of knowledge. There are however never wanting earnest and curious minds who feel an almost irresistible impulse to labor in this field, to enlarge the bounds of thought, and to grapple with the great problems of man and nature. To foster this spirit, to encourage its beginnings, and to extend the influence of its example, should be the aim of wise statemen and legislators who seek to elevate their kind and ennoble their nation: knowing that the brightest glories and the most enduring honors of a country are those which come from its thinkers and its scholars.

The world's intellectual workers are, from the very nature of their lives of thought and study, separated in some degree from the mass of mankind. They feel however not less than others the need of human sympathy and co-operation, and out of this need have grown academies and learned societies devoted to the cultivation of letters and of science. The records of these bodies in Florence, in Rome, in Paris, in London, and elsewhere, are the records of scientific progress for the last three centuries. Such bodies do not create thinkers and workers, but they give to them a scientific home, a centre of influence, and the means of making known to the world the results of their labors.

It was with a wise forethought that more than a century since Franklin and his friends founded at Philadelphia the American Philosophical Society. Its planting then seemed premature, but its vigorous growth during a century has served to show that the seed was not too early sown This, however, unlike many of the academies of the old world to which we have adverted, had no formal recognition from the state, and there came a period in the growth of the American Union when the need of an official scientific body was felt. Thus it was that nineteen years ago, in the midst of the great civil war, the American Congress authorized the erection of a National Academy of Sciences to which, as an American citizen, I have the honor to belong. The aim proposed in founding this Academy was to gather together what was best and highest in the scientific life of the nation, and moreover, to organize a body of councillors to which the executive authority could always look for advice and direction in scientific matters relating to the interests of the State. In that Academy—at first consisting of fifty, and now practically limited to one hundred members (a number which it has not yet attained)—the domain of letters is unrepresented; while the Royal Society of London is in like manner,—although scholars and statesmen seek the honors of its fellowship,—essentially an Academy of Sciences.

Our infant organization attempts a larger plan, and embraces with the mathematical and physical sciences, letters, philosophy, and history, imitating the Royal Irish Academy, which, like this, is divided into two classes; that of the Sciences, on the one hand, and that of Polite Literature and Antiquities on the other. The Institute of France, made up of five Academies, embraces the Fine Arts in its still wider scheme. The second class of our Society, with its two sections, aspires to cover the same ground as the Academy of Sciences of the Institute of France, the Science division of the Royal Irish Academy, the Royal Society of London, and the National Academy of Sciences of the United States.

The two sections into which our second class is now divided, namely III. including Mathematic, Physic and Chemistry, and IV. embracing Biology and Geology, are, in their aims and their objects, closely related to each other, and widely separated from sections I. and II. which are devoted respectively to French and English Literature and History Differences in language thus establish in the literary department of this society a natural division into two sections. In the department of the sciences, however, there is no natural basis for a similar division, and it will probably be found in the near future that subjects of common interest will draw more and more closely together our two sections until, as in the various societies which we have named, the distinction between mathematical, physical and chemical studies on the one hand, and geological and biological studies on the other, will be lost sight of. It seems to me therefore fitting that we should in this time and place consider the mutual relations of these two divisions, and inquire into the value of the distinctions upon which they have been based.

Apart from pure mathematic, which is based upon our intuitions of space, the sciences which now concern us have to do with material nature, and are properly called natural sciences. It is not their province to look behind or beyond the material world of nature, nor to grapple with the mystery of the Infinite with which, in the last analysis, the inquirer always finds himself face to face. Our various metaphysical systems are schemes which men have devised to solve this mighty problem, and to translate into intelligible language their efforts to comprehend it. What we call Nature is at once a mantle and a veil in which the spiritual both clothes and conceals itself. "I weave," Goethe makes the world-spirit say, "the living garment of the Deity." This phrase embodies a profound truth. All nature is living; it is, as the word *natura* itself, equally with its Greek equivalent, *physis*, implies, that which is growing, the perpetually-becoming or being born; and this sense, which underlies etymologically the words *natural* and *physical*, should never be lost sight of.

It is a common reproach in the mouths of certain cavillers at science that it does not explain the beginnings of life in matter.

That the plant and the animal are living, is evident to them, but they assume that the air, the water and the earth, the elements from which the plant grows and is fed, are dead; that life is a mysterious something which comes from without, and is extraneous to the organism. Perhaps we may trace the origin of this conception to the ancient legend; which appears in more than one form, of a human body fashioned out of dead matter and waiting for vivifying breath or fire. The student of inorganic nature, however, soon learns to recognize the fact that all matter is instinct with activities, and finds that a great number of those processes which were formerly regarded as functions of organized bodies are really common to these and to inorganic matter. The phenomena of gravitation, of light and of electricity, the diffusion and transpiration of gases and liquids, the crystallogenic process, and the peculiar relations of colloids, are all, when rightly understood, manifestations of energies and activities which forbid us to speak of matter as dead. To all of these dynamical (or as they are generally called, physical) activities of matter, supervene those processes which we name chemical, and which give rise to new and specifically distinct inorganic forms. The attaining of individuality by matter, which has always seemed to me the greatest step in the progress of nature, is first seen in the crystal, but therein the forces of matter are in a static condition, except so far as certain dynamical relations are concerned. It is not until solid matter rises from the crystalline to the higher condition of the colloid, that it becomes capable of absorption, diffusion and even of assimilation; that, in a word, it assumes relations to the external world which show that it possesses an individuality higher than the crystal, and is, in fact, endowed with many of the activities belonging to those masses of colloidal matter which biologists have agreed to call living.

In these phenomena we have the first developments of individuality and of organization, and I think that the careful student who endeavours with a strong mental grasp to seize the true relations of things will see that we have here to do, not with a new activity from without, but with a new and higher development of a force which is inherent in matter, and thus manifests itself at a certain stage in chemical development. He will then, in the words of a philosophic poet,

> "See through this air, this ocean and this earth,
> All matter quick, and bursting into birth."

The adjective, quick, is here to be understood in its primitive sense of living, as opposed to dead, and aptly defines the notion which I have endeavored to convey. All the energies seen in nature, are in this view, but manifestations of the essential life or quickness of matter, whether displayed in the domain of what are called dynamical or physical activities, in chemical processes, or in the phenomena of irritability, assimilation, growth and reproduction which we may comprehensively designate as biotical.

When we have attained to this conception of hylozoism, of a living material universe, the mystery of nature is solved. The Cosmos is not, as some would have it, a vast machine wound up and set in motion with the certainty that it will run down like a clock, and arrive at a period of stagnation and death. The modern theory of thermodynamic, though perhaps true within its limitations, has not yet grasped the problem of the universe. The force that originated and impelled, sustains, and is the Divine Spirit, which

> "Lives through all life, extends through all extent,
> Spreads undivided, operates unspent."

The law of birth, growth and decay, of endless change and perpetual renewal, is everywhere seen working throughout the Cosmos, in nebula, in world and in sun, as in rock, in herb and in man, all of which are but passing phases in the endless circulation of the universe, in that perpetual new birth which we call Nature. This, it will be said, is the poet's view of the external world, but it is at the same time the one which seems to me to be forced upon us as the highest generalization of modern science.

The study of Nature in its details presents itself to the mind in a two-fold aspect,—as historical and as philosophical. The first of these gives rise to a General Physiography or description of nature, which we commonly call Natural History as applied to each of the three great divisions designated as the mineral, vegetable and animal kingdoms. This physiographic method of study in the latter two gives us systematic and descriptive botany and zoology, with their classification and their terminology; while the physiography of the mineral kingdom includes not only systematic and descriptive mineralogy, as generally understood, but those branches of geology which we designate as petrography and geognosy, or the study of the constituents of the earth's crust, their aggregation and their distribution.

The second aspect of the study of nature, which we have designated as philosophical, regards the logic of nature, or what the older writers spoke of as General Physiology. This, is sometimes appropriately termed Natural Philosophy, a designation which is the correlative of Natural History. With this method of study in the organic kingdoms we are familiar under the names of physiological botany and physiological zoology, which concern themselves with anatomy, organography, and morphology, and with the processes of growth, nutrition and decay in organized existences. The natural philosophy of the inorganic world investigates the motions and the energies of the heavenly bodies, and then, coming down to our planet, considers all the phenomena which come under the head of dynamic or physic, as well as those of chemistry. These various activities together "constitute the secular life of our planet. They are the geogenic agencies which in the course of ages have moulded the mineral mass of the earth, and from primeval chaos have evolved its present order, formed its various rocks, filled the veins in its crust with metals, ores, gems and spars, and determined the composition of its waters and its atmosphere. They still regulate alike the terrestrial, the oceanic and the aërial circulation, and preside over the constant change and decay by which the surface of the earth is incessantly renewed, and the conditions necessary to organic life are maintained." * Thus the physiological study of the inorganic world, or in other words, its natural philosophy, includes in its scope at once theoretical astronomy and theoretical geology or geogeny.

The two-fold division which has been adopted in the scientific class of our new society does not correspond to that which we have just set forth; namely, of natural history on the one hand and natural philosophy on the other; nor yet, as might at first seem to be the case, to the more familiar distinction between inorganic and organic nature. Our section III. has been made to embrace, it is true, much both of the natural history and the natural philosophy of the inorganic world, including besides physic, and chemistry, both descriptive and theoretical astronomy, and mineralogy. This same section has also been made to include

* The Domain of Physiology, or Nature in Thought and Language, by T. Sterry Hunt; London, Edinburgh and Dublin Philosophical Magazine. ([V.] xii: 233–253,) for October, 1881.

mathematic, which in itself, does not belong to the domain of natural science, though in its applications it becomes an indispensable instrument in the study of nature, whether we investigate the phenomena of physic or of chemistry, or seek to comprehend the laws which regulate alike the order of the celestial spheres, the shapes of crystals, and the forms of vegetation.

Section IV, on the other hand, in its department of biology, includes alike the Natural History and the Natural Philosophy of the vegetable and the animal kingdoms. In this same section has, however, been included what we call geology, which is not a separate science, but the application alike of mathematic and of all the natural sciences to the elucidation of both the physiography and the physiology of our planet. So far as geology concerns itself with the history of past life on the earth, or what is called paleontology, it is biological, but in all its other aspects the relations of geology are with section III. The logical result of this complex character of geology should be either the separation of paleontology from the other branches of geological study, which find their appropriate place in our section III, or else the union of the two sections through this their common bond.

It will be noticed that in this brief survey of the field of natural knowledge I have not spoken of the technical applications of science, nor alluded to its important aspects in relation to the material wants of life. On this theme, did time permit, I might speak at length. There are two classes of motives which urge men to the pursuit of knowledge; on the one hand, those of worldly fame or profit, and on the other, the far nobler sentiment which has the finding-out of truth for its object. It would seem as if by a spiritual law, the great principles which are most fruitful in material results are not revealed to those who interrogate nature with these lower ends in view. Newton, Darwin, Faraday, Henry, and such as they, were not inspired by a desire for the praise of men, or for pecuniary reward, but pursued their life-long labors with higher motives, the love of truth for its own sake, the reverent desire to comprehend the hidden laws and operations of the universe. To such and to such alone does nature reveal herself. In the material as in the moral order, the promise of achievement is given to those who strive after knowledge and wisdom irrespective of the hope of temporal reward, and the history of science shows that it is such seekers as these who have attained to the discovery of those secrets which have been of the greatest benefit to humanity. The admonition is to all, that we are to seek first for truth and for justice, and with this comes the promise that to those who thus seek all other things shall be superadded.

It is good and praiseworthy to labor to extract the metal from the ore, and the healing essence from the plant, to subdue the powers of electricity and of steam to the service of man. To those who attain these ends the world gives its substantial rewards, but far higher honors are instinctively rendered to those who by their disinterested researches, undertaken without hope of recompense, have revealed to us the great laws which serve to guide the searchers in these fields of technical science; to those who have labored serenely, with the consciousness that whatever of truth is made known by their studies will be a lasting gain to humanity. "Thus," to repeat words used on another occasion,* "it ever happens, in accordance with the Divine order, that the worker must lose himself and his lower aims in his work, and in so doing find his highest reward; for the profit of his labor shall be, in the language of one of old, to the glory of the Creator and to the relief of man's estate."

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* The relations of Chemistry to Pharmacy and Therapeutics, an address before the Massachusetts College of Pharmacy, by T. Sterry Hunt; Boston, 1875.

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

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(For previous parts, see this Journal, Vol. X., Nos. 3 and 4.)

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

* See Report Q4 of that Survey, 1881.

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

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

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

Possibilities of an outlet by the St. Lawrence. The north-eastern portion of Lake Ontario is very shallow. Although the country surrounding it is low, yet it is underlaid by hard rocks which are so frequently exposed, through the moderate thickness of drift as to preclude the idea of a great buried channel existing adjacent to the St. Lawrence, which a short distance below the outlet of the Lake flows over Laurentian rocks. However, in northern New York, but southward of the St. Lawrence, there are some unimportant buried channels connected with the Ontario basin. The St. Lawrence river itself is modern from Lake

Ontario to the junction of the Ottawa river, though the lowest portion of the river is conspicuously of ancient date, with pot-holes indicating a depth of nearly 1200 feet. Without a considerable change of level, such as either that which would be produced by a local subsidence of north-eastern Ontario and the upper St. Lawrence, or a very great northern subsidence during a period of southern elevation, any possibilities of the preglacial outlet of Ontario basin by the St. Lawrence seems impossible. However, the oscillation hypothesis seems to be more and more supported by observation.

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

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

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

For many years, suggestions have been made that the Preglacial outlet of Lake Ontario was by the buried basin just described, emptying its waters by the Mohawk and Hudson rivers into the Atlantic. However, this suggested outlet is not possible, without considerrble local change of elevation, as shown by Mr. Carll, for the Mohawk river passes over metamorphic rocks at Little Falls, Herkimer County, at an elevation above

Lake Ontario of about 125 feet, without the possibility of an adjacent buried channel through the range of hills, through which the Mohawk valley is cut. The Onondaga basin, then, appears to have been originated by a river extending from the Adirondack mountains westward, and emptying into the Ontario basin northward of the Cayuga lake, forming along the course the basin, now occupied by drift material and Onondaga lake, and perhaps that also of Oneida lake.

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

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

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

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

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

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

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

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

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

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

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

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

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

The most important work of a glacier is the scratching and grooving of surfaces. This may however, be done by dry rubbing, and therefore isolated scratched stones or patches are no evidence. The underlying rock surfaces may lose their sharpness, owing to contained detritus in the ice, and become rounded. The ground moraine is neither characteristic nor important. There is but little detrital material beneath Alpine glaciers, and this is the result of water more than ice. The only characteristics of ice action are striation and polishing. All floating ice shod with stones frozen in them will scratch surfaces over which they rub. The only glacial lakes that are formed are those where the pre-existing valleys have been closed by morainic matter, but the waters will soon re-öpen these dams by running over them.

Such are the deductions of the late Director of the Geological Survey of California, a man who has had opportunities for studying the action of glaciers better than most geologists in America. So far Prof. Whitney's investigations are applicable to our great lakes.

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

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

Let us analyze the direction of the ice scratches in the neighborhood of the western end of Lake Ontario. I have not seen any (out of very many sets,) which parallel with the axis of either the Dundas valley (except *possibly* one polished surface in the valley), or the axis of the lake, but always at considerable angles. In the region of Kingston, the prevailing scratches are S. 45° W. (Bell) and some others at S. 85° W. neither of which directions are parellel with the axis of the lake. Granted that Mr. Hinde observed scratches that were parallel with the axis of the lake, they of necessity would have been at an angle with the submerged escarpment. If any glacier could have scooped out the basins of Lake Ontario, it left the summit edges of the Niagara escarpment as sharp as possible and not planed off. Also if it excavated the deep trough of the lake, it left a summit of soft Medina shales over the harder Hudson River rocks of the escarpment, beneath which are Utica shales. From Dundas to the Georgian bay the face of the escarpment (Niagara) is less abrupt, but even here, there has not been left more than 50 feet of drift at its foot, and this mostly, if not altogether, stratified (*excepting in channels now buried.*)

The observations of Professor H. Y. Hinde, on the coast of Labradore, are here interesting. He has shown that *pan-ice*, at the present time, is polishing the sides of cliffs, and has been continuing its action whilst the coast has been rising several hundred feet. Even under the ledges of overhanging rocks the action is now going on (a phenomenon which, if in the lake region, would be attributed to glaciers). Also, he has seen boulder-clay being formed at the present time by the action of *pan-ice* (frozen sea water). This, with a thickness of eight or ten feet gets piled up by the action of waves and wind, and consequently in the bays of the coast of Labrador it polishes rock bottoms to a depth of fifteen feet or more, below the surface of the water, and grinds off rough surfaces. I have frequently seen, myself, in northern regions, high boulders transported by the ice to which they were frozen in the margin of small lakes.

From what has been written, it seems to the writer that the glacial origin of Lake Ontario does not rest on a single basis further than that ice scratchings (producible by either glaciers or icebergs, neither of which need be great erosive agents) are seen at various places about Lake Ontario, both above and below the water level. The remarks applied to Lake Ontario hold good for the other lakes. The description of their topography strengthens the proofs that their origin cannot be accounted for by glaciers, because we find the islands at the western end of Lake Erie, or northern end of Lake Huron, polished and striated.

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

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

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

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

V.—General Glaciation of the Country.

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

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

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

List of Ice Grooves.

No.	Locality.	Direction.	
	West Flamboro (Township :—		
	Near "Peak," at Dundas, prevailing grooves	W.	
	Near "Peak," at Dundas, other grooves	N. 73° W.	
	" " " "	N. 83° W.	Some are curved in same set.
	" " " "	S. 87° W.	
	" " " "	S. 80° W.	
	About 2 m. S. Strabane (Bell)	S. 49° E.	
	S. of Flamboro village (Bell)	S. 74 W. (with others S. 69° W.)	
	" " " "	S. 24° W.	

Beverley :—

Near Sheffield (Bell)	S. 72° E.
" " 1 m. south-west (Bell)	S. 46° E.
" " 2 m. south (Bell)	S. 89° E.
Near Troy (Bell)	S. 76° E.
1 m. S. of Sheffield and 2.5 east (Bell)	S. 79° E.

Ancaster :—

At Ancaster village (Bell)	S. 59° W.
2 m. east of Ancaster village (Bell)	S. 71° W.

Barton :—

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

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

On the northern side of the Dundas valley the brow of the escarpment is abrupt, not having the angle at the summit planed off, except on the western side of Glen Spencer, where 100 feet or more have been removed, by causes to be explained below. The brow of the escarpment on the southern side of the Dundas valley and Hamilton is equally abrupt with that on the northern side of the town of Dundas, but the immediate brow is about 100 feet lower. Nowhere in the region about Hamilton and Ancaster do we find the face of the escarpment with its angle planed off, although the top is in very many places ice-scratched to the very margin, in directions varying from 10 degrees or less, to 20 degrees, with its general trend.

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

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

VI.—POST PLIOCENE DEPOSITS.

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

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

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

VII.—THE TILL, ERIE AND OTHER CLAYS.

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

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

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

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

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

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

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

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

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

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

VIII.—STATEMENT OF THE GLACIAL AND ICEBERG THEORIES.

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

* Canadian Journal. 1877.

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

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

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

IX.—TERRACES AND BEACHES.

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

TABLE OF ELEVATIONS OF TERRACES, BEACHES AND RIDGES.

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

References of table on opposite page.

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

TABLE OF ELEVATIONS.

At Western end of Lake Ontario. (Spencer.)	Between Toronto and Lake Simcoe. (Roy.)	Along Northern railway from summit to Georgian bay.	Along Toronto, Grey and Bruce railway. (Wragge.) m is on main line. w is on west branch.	Near Owen Sound. (Bell.)	Petits Ecrits, Lake Superior. (Geology of Canada.)	In New York State.	At western end of Lake Erie (Geology of Ohio.)	Along the Lower St. Lawrence. (Dawson.)
			1,709 (b)		1,700 a			
			1,587 (m)					
			1,557 (m)					
			1,546 (w)					
			1,377 (w)					
			1,367 (m)					
			1,297 (w)					
			1,247 (m)					
			1,237 (m)					
		1,140	1,117 (w)					
			1,097 (w)					
			1,077 (w)					
							1,063 to	
1,011	1,001						959	
							981 to	
981							923	
			957 (m)					
929			944 (m)		946			900
					882			
	873				874	872		
		847	848 c		839 c		793	
	805						768	
		767		793			738	748
747	749	737						
687 (?)				745				
	669			713	705			
	649							
633 d		635			655		663 to	660
582	593	601	617					
	557				645	647	638	
	529					583(?)		
508			527					
to		498 f						
471								505
	457							479
								448
						437 to		
427						432		
	407		401					
						405		
								378
363								
		342 g						
327								325
255								
to								
247								

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

XI.—MODERN DEPOSITS.

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

* Geol. of Canada, 1863.

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

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

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

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

1854	1.55 feet.	1865	1.00 feet.
1855	1.30 "	1866	—
1856	1.46 "	1867	1.10 "
1857	—	1868	0.60 "
1858	2.25 "	1869	—
1859	2.33 "	1870	2.50 "
1860	1.42 "	1871	0.83 "
1861	—	1872	— 0.40 "
1862	2.17 "	1873	0.40 "
1863	1.62 "	1874	1.00 "
1864	2.70 "		

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

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

XII.—LAKE MEDAD.

About two miles northward of Waterdown, there is a small pond—Lake Medad—half a mile long. In the western part of Dundas valley there is a number of small ponds amongst the hills of drift material, but these are only small expansions of the various streams at heights from 510 feet to 240 feet above the level of Lake Ontario. On one side of Lake Medad there is a rugged shore of deeply weathered dolomites, extending more than 20 feet above its waters. The shore beneath is composed of a beach of pebbles. The opposite side of the lake is shallow, and is now occupied by a marsh. This lakelet is not an expansion of any modern rivulet. A number of insignificant streams empty into it, but not one of which could possibly have excavated the present basin. This lakelet is not on the uppermost portion of the Niagara escarpment, but in a somewhat broadly rugged country. The basin of Lake Medad is evidently a filled up portion of a larger water channel that became blocked by drift material, which it has been unable to clean out for itself in modern times. The whole lake could be drained by cutting through the drift deposits which occupy one of its extremities. I was informed by one of the inhabitants that he had discovered an underground outlet, so that a portion of the waters discharge by a stream directly into Lake

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

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

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

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

PLAN OF FOREST PLANTING FOR THE GREAT PLAINS OF NORTH AMERICA.

By H. M. Thompson, Lake Preston, Dakota, U.S.A.

Read before the American Forestry Congress, Montreal, August. 1882.

In devising or advocating plans for forest planting, on the Great Plains which will prove to be generally beneficial in ameliorating climate, due consideration must be given to the physical features and to the meteorological conditions. These features and conditions may be briefly stated to be as follows:—

The Great Plains extend from the southern limit of the Staked Plains in Texas northwardly about 20 degrees of lattitude to the Saskatchewan river and Hudson's Bay, and from an irregular east line, commencing in Texas, running through the eastern part of the Indian Territory, Eastern Kansas and Nebraska, Western Iowa, the Bigwoods of Minnesota, and the Red river of the North; westwardly of this irregular eastern limit an average distance of about 10 degrees of longitude to the foot-hills of the Rocky Mountains, and containing an area of about 950,000 square miles. If all this region possessed a propitious climate, and all the soil were susceptible of culivation the area is sufficient to make 3,800,000 farms of 160 acres each, and which, by the aid of a proper forest economy, may be made capable of supporting an agricultural and pastoral population of fifty millions. This vast region, with the exception of the Black Hills, the Des Coteaux, and a few isolated mountains, may be said to be a level, or slightly undulating plateau, having an altitude of a few hundred feet in the eastern part. to several thousand in the western portion above tide water. The plateau is intersected by the Red river of the North flowing northwardly, and bisected by the Missouri, the Arkansas, the Red river of the South and their affluents, which with few exceptions, are of minor size "being raging torrents to-day and dry water courses to-morrow." The entire plateau is treeless, with the exception of narrow fringes of forests skirting the margin of the streams, the Des Coteaux, the Black Hills, the lakes and the few isolated mountains dotting the plains.

The soil of the eastern, and a portion of the southern district seems to contain most, if not all the mineral constituents needed for the successful growth of agricultural products, and for the native grasses and thus to possess an unlimited capacity for grazing flocks and herds. The soil of the central, the western and southwestern districts is more varied in its general characteristics, there being considerable areas of arable land capable of sustaining a vigorous vegetation, alternating with the sage brush plains.

The winter climate of the eastern part of the Great Plains is subject to sudden changes of heat and cold, with a dry atmosphere in the north more or less humid in the south. The snow drifts over an area hundreds of miles in extent. By such constant motion and atrition the flakes of snow become comminuted into minute particles. When in this condition accompanied by a low temperature and violent winds it fills the atmosphere so completely as to obstruct the vision. These terrific drifting snows are denominated blizzards, and often prove destructive to man and beast. The meteorological conditions prevailing in the summer are high temperature during the day, low temperature and heavy dews at night, constant winds varying from the moderate velocity of zephyr breezes to tornadoes and cyclones, slight rain falls or torrential floods and occasionally hailstorms, nearly all of the summer storms being accompanied with electrical disturbances unusual in forest regions. On the western portions of the Great Plains the aridity is so great that no certain reliance can be placed upon the productions of cereals and vegetables without irrigation. The constant winds of the Great Plains moving over the thousands of miles of space with no great chains of mountains or forests to impede their progress, and with nothing but the diminutive native weeds and grasses, to shield the earth's surface from the intense heat of the sun's rays, penetrating through an arid atmosphere, cause rapid evaporation of moisture from the soil. This moisture is wafted by the winds to where Nature's forest garb, by means of its cooling atmospheric influence lowers the temperature and enables Mother Earth to appropriate from the clouds formed in unforested climes, the moisture required for the sustenance of the vegetation clinging to her bosom for support.

The soil of the Great Plains containing all the constituents requisite for a varied vegetation, is capable of supporting an immense agricultural and pastoral population, to grow surplus products to meet the requirements of the commercial, mining and manufacturing population of other portions of the continent. In order to accomplish this, climatic conditions must be modified.

This result can be accomplished only by means of cultivated forests. The extent of the forests to be effective, must be commensurate with the vast area. The forests must be planted in such form as will generally shield the earth's surface from the sun's rays, and afford the greatest possible general resistance to surface winds, and harbor insectivorous birds; provide for the constant and equal distribution of electrical currents; provide for equalizing temperature and moisture; prevent the rapid flow of surface water; make provision for the retention of snow, and the prevention of the drifting of the soil of cultivated areas.

As yet no general system of planting has been put in operation to meet these requirements. In the group form of planting generally in vogue, for the purpose of growing timber for economic use, there may be a manifestation of some beneficial climatic results. It is apprehended, however, that such form of planting can but otherwise result in sudden changes in temperature, and in such disturbance of electrical and atmospherical currents as tend to increased occurrences of tornadoes and cyclones, as instanced in the destructive effects of storms in Kansas, Nebraska and Iowa, where they seem to increase in frequency and in destructive power in a ratio corresponding with the increase of the erection of habitations and other surface improvements and the increased area and growth of the cultivated forests planted in the group form.

It must be concluded, therefore, that the shelter-belt system is the best form of forest-planting for extensive plains. This form of planting has been advocated for many years in America. The principal, if not all the experiments in this direction, have been made by individual effort in isolated areas, and on a small scale, having usually been made to the extent of a few rows of trees around buildings, stock yards, gardens, and in some instances, around farms of considerable extent. These plantings have generally been made with the object of obtaining shelter only.

This system of planting on a more extensive scale, hovever, in which the shelter-belts are to be planted with all the trees needed for economic use, as well as for the purpose of shelter is, if we except the Des Coteaux, the Black Hills, and isolated mountains. applicable to the general topographical features and climatic requirements of the Great Plains.

These forest belts may be planted seven to ten rods wide around all sides of each 160 acre tract of land, or the shelter-belts may be of less width, and the 160 acre tract subdivided by substituting inside belts of such width that the land planted may equal ¼ or ⅕ of the whole area; or the plantings may be commenced two or three rods wide upon the north and west sides of the land, and further extended year by year as the means of the planter will permit until the maximum area is completed.

The first planting of trees may be profitably composed of such species as are indgenous to the locality, such as box, elder, cottonwood, soft maple, ashes, white and golden willow, European alder, catalpa, locust, butternut, black walnut, hickory, birches, larch, hardy evergreens and other species of trees as may be adapted to the soil and locality.

In after years, when the first planted trees become of sufficient size to afford shelter, other species considered of doubtful adaptation, or too tender to endure the climate without protection, may be planted inside of the shelter belts already established, and perhaps prove useful and remunerative to the planter.

If it be conceded that all things considered, the shelter-belt form will promote the increase of insectivorous birds; modify electrical conditions; lessen the evaporation of moisture from the soil; retard the velocity of surface winds; cool the earth and atmosphere in the summer; raise the winter temperature; increase the volume of atmospheric moisture; lessen blizzards in the north; lessen the liability to drifting soil and snow and mitigate the destructive effects of tornadoes and cyclones; make the soil more uniformly productive, and thus make the great plains the grazing ground of countless flocks and herds, and become the granary of the continent; our obligations to ourselves, to our country and to untold millions of the human race yet unknown, will be fulfilled only where large belts of forests are on these Plains.

The establishment of a general shelter-belt system of forest planting for the great plans cannot be inaugurated too soon. Individual effort in this direction, without the encouragement of wise legislation on the part of the respective Governments, will be isolated and the results too limited and too remote to be appreciably beneficial, hence the necessity of legislative action.

If history's teachings are true criteria, the wealth, power and prosperity of nations largely depend upon a successful agriculture; but a permanently successful agriculture cannot exist without the aid of a wise system of forest economy. A large part of the great plains is as yet public domain, and the respective Governments can by enactment embody a system of forest planting as a condition of grant or sale, and if need be, for the public good, may extend its requirements to lands owned by individuals and corporations. It then seems to be the part of wisdom for the respective Governments to inaugurate, at an early day, legislation providing for a general system of shelter-belt forest planting, applicable to the Great Plains, with discretionary powers vested in a special bureau of forest commissioners to make such modifications as might be required for the planting, on the margins of lakes, streams, hill-sides and mountain slopes. And in furtherance of this plan it would undoubtedly be wise to make suitable provision, in grants of land, to the territories when admitted as States by the Congress of the United States, and to the Provinces by the Dominion of Canada, for the purpose of establishing one or more experimental forest stations in each State and Province, under proper restrictions and conditions, with provisions requiring annual reports of experiments and observations to be made to the respective States and Provinces and to their respective general governments, which should also be distributed to other nations and all scientific associations of a national character, as an exchange for reports bearing on similar topics.

THE DENUDATION OF OUR FORESTS.

By G. L. Marler.

Read before the American Forestry Congress at Montreal, Aug. 22nd, 1882.

Having had twenty years' experience as a forest ranger on the south shore of the St. Lawrence I can speak on this subject from personal knowledge. The Province of Quebec is one of the principal territories from which mercantile lumber is drawn. When I speak of mercantile lumber I refer to that which is obtained from the following trees:—

Deciduous—Oak, elm, ash, birch, walnut, butternut, hickory, ironwood, maple, basswood, white birch, beech, poplar, cherry, balm of Gilead, plain tree, willow.

Evergreens—Pine, spruce, larch, cedar, balsam, hemlock.

There are two large belts of timber land in the Province of Quebec, one on the south side and the other and greater on the north of the St. Lawrence. The first extends from Gaspé to the head waters of the Connecticut river and from the banks of the St. Lawrence to the line separating the Province from New Brunswick and the United States. This belt contains about 30,000 square miles. The other extends from below the Saguenay to the Ottawa, and from the St. Lawrence northward 200 miles. It contains about 120,000 square miles.

Until a few years ago these great belts of timber land were reached only by the streams running through them, and could only be devastated by the lumbermen a few miles each side of these rivers, leaving large spaces untouched by the woodman's axe. But during the last twenty years this great belt has become the field of some dozen railroads, which have cut up the land like a checker board, and we must expect that in another ten years this belt will be entirely denuded of all merchantable timber.

The northern belt is now passing into the same phase as the southern. The rivers on the north shore are not so numerous as on the south side of the St. Lawrence, but they are of greater magnitude and extend further into the interior. Like the other belt, it is now being cut up by railways. If we open the Government statistics book we find that the gross returns of the forests for the year 1881 amount to the neat little sum of $24,-802,064, and as compared with the total exports of the Dominion of Canada, are equal to $\frac{1}{4}$ of the total amount, $92,000,826.

According to Government returns for 1871, the value of timber exported was $22,872,591.

Comparing the year 1881 with the year 1871 there is an increas of $2,000,000.

I have found that in 1871 the cut of timber as reported to Government was:—

White Pine	24,236,821	feet.
Red Pine	1,954,371	"
Oak	3,302,043	"
Tamarac	5,695'963	"
Birch	1,939,357	"
Elm	1,832,624	"
Walnut	117,589	"
Butternut	102,981	"
Hickory	197,827	"
Other kinds	26,290,264	"
Pine logs	12,416,408	"
Other logs	9,314,557	"
Masts	121,685	"
Staves	34,706	M.
Lath wood	25,706	Cords.
Tan bark	162,521	"
Firewood	8,713,083	"

Now reducing these several quantities to trees, we have an aggregate of 22,271,384 trees. If you say 50 trees to the acre, we have denuded in one year 545,428 acres, equal to three townships. There have expired since this return was made 10 years, which gives no less than 30 townships, equal to 3,240 square miles, or three whole counties, supposing each county to consist of ten townships. Having ascertained the total amount of exported timber, we must not forget the home consumption, which exceeds that exported.

Now what have we done in the way of preservation? Very little indeed.

The Quebec Legislature by an Act of 1882, chap. XIII., offers a bonus of $12 per acre to any one who will plant an acre of ground with trees, and keep it well preserved. It has passed an Act, 1882, chap. XI., to the effect that no person shall burn or set fire to any timber for the purpose of clearing land, from 1st July to 1st September.

The Government, in making their yearly estimates, generally amongst the items of revenue, state that they will get so much from forests. Now, when they make or prepare their estimates, they should carefully ponder on this item. It is not an annual revenue, it is absolutely taken from capital, which capital is being so rapidly reduced that ere many years the balance must be considered as *nil;* thoy are killing the goose that is laying the golden egg, in fact they have nearly reached the backbone. I have now to stop and consider our present position, and ask what must be done for the salvation of our trees—is there any means to replace the millions of tree that are cut down annually? I reply in the affirmative; every one has the power and capacity to aid in this great work. Does not every tree bear it own seed? And sowing or planting trees is no harder than sowing grain.

I have made a calculation that 200 acres (lots such as the present divisions of our townships) planted with a double row of trees, say maple, will give a belt of trees nearly three miles long and a plantation of sugar or other trees. Experience has shown that from 100 feet square of well prepared land sown with ash there can be transplanted enough to cover 100 acres. A return can be obtained after three years, as the smaller trees removed in thinning can be utilized for hop poles, etc. If the soil is well prepared a farm planted with trees will begin to give a return after three years at the rate of $10 per acre, increasing year by year to $40.

MISCELLANEOUS.

Worms and Crustacea* is the title of Vol. vii. of the "Guides for Science Teaching," issued by the Boston Society of Natural History. This excellent little work of 68 pages is specially intended for the use of teachers, but will also be found of great service to those who desire in private to obtain a general knowledge of the structure of the groups of animals of which it treats. The first sixteen pages are devoted to a description of the common earth-worm, and the Nereis or sea-centipede, which are taken as types of the classes to which they belong. The remaining portion of the book contains a very accurate description of the lobster, a crustacean easily obtained for study, and notes points in which other groups of crustaceans differ from that taken as the type. The book contains a large number of very good drawings, greatly enhancing its value. We can scarcely see how the publishers can give so much for so small a sum, the price of the book being only thirty cents.

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* "Worms and Crustacea," by Alpheus Hyatt, Boston Society of Natural History. (Ginn, Heath & Co., Boston).

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