THE GREAT ICE AGE AND SUBSEQUENT FORMATIONS AT OTTAWA, ONTARIO.

By H. M. Ami, M.A., F.G.S.

Among the most interesting and captivating subjects which attract the attention of even a casual observer in the realms of geological science, few are so full of interest and afford so much information as researches amongst the most recently deposited strata. Besides this interest, there is carried with it the fact of its practical importance, so that the economic aspects of the question have likewise to be taken into consideration.

There are numerous questions which press themselves one upon the other in examining the marls, sands, gravels, clays, boulders and kindred materials which constitute the Post-Tertiary deposits of a district. The following are some of the more important questions which we will attempt to consider with regard to our own locality:—

At what period in the Earth's History did the Glacial Epoch or the Great Ice Age make its appearance?

What were the causes which led to it, what phenomena characterized it, what was its duration and what traces did it leave behind? And again, specially, to what extent was this continent submerged, for how long, and what traces of animal life has that period left behind it; and, further, are there unquestionable proofs of a period of subsidence followed by another of elevation carrying us on to the present day, during which time numerous and varied lacustrine or alluvial deposits were laid down, and in the lapse of which man made his appearance.

Then, in which of the newer deposits are traces of the existence of certain tribes of the American Indians to be found? What are these traces? To what extent do they assist in forming an estimate of the degree of civilization to which these aborigines attained? What customs and modes of life are exemplified by the implements of various kinds found in what has been very appropriately termed the Human Period? At what time and for how long did these inhabitants occupy the land before the intrusion of the whites, and what was their history?

These are only a few of the more salient problems to which reference will be made.

It may not be thought amiss to note first what has already been done in the field of research with which we have to deal. In the "Geology of Canada," 1863, a report by Sir Wm. Logan and staff—there is a chapter on "superficial geology" in which a number of interesting notes are recorded from Ottawa and its environs, an examination of which had been entrusted to Dr. R. Bell. Then comes the work done in the Post-Pliocene geology of Ottawa by Sir J. A. Grant who produced a number of valuable papers, some of which were published in the United States and others here in Canada. At the mouth of and along Green's Creek, six miles distant from the city, and a favourite resort for students of Post-Tertiary geology, Sir J. A. Grant and Sir W. Dawson made important discoveries. The collections of the late Dr. E. Van Cortland show that he also devoted considerable attention to these interesting deposits, whilst the late Mr. E. Billings in his Canadian "Naturalist and Geologist" published notes on the same subject. The above mentioned work was prior to the organization of the Field-Naturalists' Club which has since vigorously pushed investigation in this direction. Nearly a score of members, have taken a more or less active part in these researches, whilst the abundance of work and material make it probable that greater attention will continue to be paid to the deposits in question. The work done already is considerable; but there remains a hundred-fold more to do. Mr. Surtees, the City Engineer, has been carrying on an extensive series of excavations in all parts of the city. These excavations or trenches are dug or blasted out to a depth ranging from eleven feet to eighteen feet six inches, so that deep and interesting sections have been exposed.

For the description of the Post-Tertiary or Post-Pliocene (Pleistocene) deposits it is first necessary to ascertain whence the material came which composes them, and in order to do this it is obviously necessary to examine the older rocks of the district, and to see of what their measures consist, and know the stratigraphical relations existing between the various members of these older underlying series.

Just as we have a great diversity of formations about Ottawa, so also have we a great diversity of substances in the materials which make up the rock of the Post-Tertiary deposits, (and let it be borne in mind, that in using the word "rock" it is used in its true geological sense, so that a handful of sand, a lump of clay, a mass of pebbles, cemented or not by finer detritus, are all as much "rock" as a pillar of freestone, a block of limestone or a column of granite). Most of the materials which are found in these newer deposits were derived from the older formations of the district, whilst erratic blocks, and the like, may have come from great distances. To go into details regarding all the kinds of rocks met with, would necessitate a protracted study of a great quantity of material which years of labour could not exhaust, and which would form the constituent elements of all the formations from the Laurentian to the Hudson River as they are developed in the "Ottawa Basin;" from the gneissoid, granitic and hornblendic rocks of the former, to the shaly magnesian and arenaceous measures of the latter. There would be the gneisses, pegmeties, crystalline limestones, serpentines, dolomites and diorites of the *Lower Laurentian*, occurring at Chelsea in the Laurentide Hills, there would also be included portions of the conglomerates and quartzites and calc-bearing sandrock materials peculiar to the unconformably overlying *Potsdam* and *Calciferous* formations, whilst the sandstones, shales and limestones of the *Chazy*, followed upwards without a break by the impure calcareous strata of the *Black River* and *Trenton* formations would all be mixed together with the likewise conformably overlying bituminous schists of the *Utica*.

The materials which compose the series of formations just mentioned and newer than the Laurentian were themselves derived from the Laurentian System, for this latter contains all the elements necessary for the formation of the sandstones, shales and limestones of the newer overlying Cambro-Silurian or Ordoviciau strata.

Having ascertained the series of strata whence the material was obtained which constitutes the various beds in the Post Tertiary deposits, let us consider the condition of affairs previous to and at the coming in of the Glacial Epoch.

This portion of the American Continent, which, during the earlier palæozoic period had alternately been submerged and elevated, remained in this latter state a long period of time, during which denuding agencies, such as atmospheric erosion, rain and other solvents carried away a great deal of material. This is a lapse of time, which, in other parts of Canada and elsewhere, is marked by a regular ascending series of newer formations deposited, for the most part, beneath the level of the then existing oceans, a period embracing within itself the whole of the Silurian and Devonian systems, together with the Carboniferous age or the coal measures. The Palæozoic Era thus ended Mesozoic times came in and the Triassic, Jurassic, and Cretaceous systems followed, overlying which all the Laramie and Tertiaries were laid, all of which are entirely absent in our district marking a great unconformity between the Glacial deposits and the Hudson River rocks about Ottawa.

The *Glacial Epoch* or the *Great Ice Age*, then, is the first of the series of Post Tertiary times, with which we have to deal, as it rests immediately upon, though with discordance of stratification (if that term may be employed here), and overlies the Cambro-Silurian and older formations in this district. Just previous to this period of glaciation, and whilst it lasted, there must have taken place a great elevation in this part of the North American continent, so that an extreme Alpine or Arctic climate was the natural result. Nor was this part of America the only one which enjoyed this particular state of affairs, but throughout the greater portion of North America as far west as the Great Missouri Coteau, in Europe, and in other continents, evidence of extreme cold, the result of great elevation, has been ascertained beyond doubt. Prof. Favre, of Geneva, whose admirable researches in Alpine geology have made him so famous the world over, in the "Résumé" of his "Geological Researches in Savoie and the neighbourhood of Mt. Blanc," points out clearly what was the origin of the glacial epoch in that part of Europe. "The amount of moisture or humidity," he says, "with which the atmosphere of Europe was filled on account of the elevation of land subsequent to the deposition of the tertiary deposits—the cooling effect of the neighbouring mountains, then more elevated than now-a-days—together with many other causes, led to a reduction in the temperature of the atmosphere resulting in an abundant

precipitation of snow on the leading peaks of the region." So in Canada, and in the Ottawa district, a great reduction in the temperature followed the great elevation, and immense quantities of snow, ice and water followed and glaciers were formed all over the district—a vast mer-de-glace covered this portion of Canada, whose height above the ocean level of that period was considerable. These glaciers, like modern ones, were characterized by many interesting particulars which a study of the latter can afford. The number, direction, movements, thickness, erosive or denuding power and the constituent parts of a glacier, or a system of glaciers, are questions full of interest. It has been ascertained that over four hundred glaciers can be seen in the central portion of the Alps, from Mont Blanc to the Tyrol, some of which are only three miles in length, whilst others exceed twenty miles from head to foot or from the point of origin to the snout. There is abundant evidence to show that the number of glaciers which must have existed here about Ottawa is very considerable. Perhaps the greater number, were subordinate or small ones and may, at length, have been absorbed in and formed part of "a great glacier." The direction in which they moved depended of course on the nature of the district, its physical or orographical character. The general trend of the great mer-de-glace in Canada during this epoch has been ascertained to be approximately N. E. and S. W. With regard to the direction of some of the glaciers, the striations or grooves on the rocks about Ottawa show that in some cases they travelled almost due east and west, as may be seen along Park Avenue, on Nicholas street and in other parts of the city, at other times they appear at a considerable angle to this direction, bearing almost due north and south, as at Buckingham on the Lièvre River. Regarding their movements and the speed with which glaciers travel, we consult Agassiz and find that he obtained the following results in 1841 and 1842 on some of the Aar glaciers :—

	ANNUAL MOTION.
I. FINSTER AAR—	
Stake near centre of glacier	269 feet.
" side "	160 "
II. LAUTER AAR—	
Stake nearest centre of glacier	245 "
" side "	124 "

whilst at *Chamonix* the ice near the shore of the *mer-de-glace* was found to move as follows, from June 29th to June 8th of the following year :

From	June	29	to Sept.	28	132 feet.
"	Sept.	28	" Dec.	28	70 "
"	Dec.	12	" Feb.	17	76 "
"	Feb.	17	" April	4	66 "
"	April	4	" June	8	88 "
			Total (in less than one year).....		432 feet

This would average over five hundred feet or about one-tenth of a mile in twelve months. The rapidity in the motion of a glacier, of course, depends upon the nature of the obstacles to be surmounted, as well as to a great extent upon the time or month of the year, different portions of the same glacier moving at different rates. A glacier which decends into a valley below, or discharges itself into a sea or arm of an ocean, does not necessarily lose any of its length, for whilst its snout is being melted and carried away to warmer portions, the head or initial point is ever receiving additional snow and ice to supply it constantly, and only a subsidence of the continent could produce a change in the climate of such an ice bound district.

We have no data existing here or traces left by means of which we can calculate the rate of motion of the glaciers about Ottawa during the great ice age, suffice it to say that as in the case of modern glaciers their rate of travelling varied at different times. Then as to the thickness of the great ice-mass which then invaded this district, that is a problem which to a great extent, has yet to be solved with us, nevertheless, let us examine the data at our disposal in reference to this interesting phenomenon. Taking the Ottawa Valley, in and around the city, as a typical example of a valley of erosion with subordinate branches, we see that facing the river and the north, there occurs a series of high " bluffs " or cliffs where the strata are clearly seen along their sides to be throughout nearly horizontal.*

That these beds could not have been deposited in such a position is beyond question, so that the prolongation of them northward must at one time have existed. What was it then, which removed all these and

*There are but few exceptions to this, due to dislocations, faults and folds in the strata, of purely local origin, but not of general significance in this problem.

to such a depth? This very question gives us a clue to one factor at least in the estimate of the powerful ice-mass which, coming from the West or W. N. W. struck down upon the shales and limestones of the formations here to be found. It also gives us data to estimate its thickness. The occurrence of striated rocks at the top of old Barrack Hill, where the Parliament Buildings now stand, shows that as that cliff is one hundred and eighty-seven feet above the level of the river, and over two hundred feet above the level of the bed of the river, the mass must have been much over two hundred feet. Further, in order that a mass of ice or a glacier carrying boulders and detritus—*moraine-profonde*—can groove and polish the rocks of a district to such an extent as was the case here, the superincumbent weight and attending pressures must have been enormous, and from what is known of present glaciers, whether in alpine or arctic regions, we know that its thickness must have been very great. A fair estimate, we believe, of the thickness of the glacier or mer-de-glace extending over our city and its environs during the glacial epoch must have been very little short of one thousand feet, if indeed that number is not too small. The erosive or denuding force of glaciers has as yet only casually been touched upon, for when we take into consideration the millions of tons of material which have been removed from even the small area about our city, it is marvellous to know where it all went. You can hardly find a loose rock or boulder in the fields without seeing written upon it indubitable marks of scratching and grooving, which, along with millions of others were held firm in a mixture of cementing clay and sand (to a small extent) carried forward upon the floor of the glacier and ground one against the other, at times, to such an extent that all angularities and rough points were removed and the boulders left smooth and polished. The striations, grooves and polished surfaces of rocks which up to this date attest clearly to the fact of the existence of those glaciers, besides the boulders themselves, may be seen not only in the places already mentioned, but at the corner of Sussex and Rideau streets, where there is an interesting exposure.

The effect of these glaciers upon the softer shaly strata of our neighbourhood is clearly shown in such a deposit of the Utica shales as is met with at Cumming's Bridge, on the Rideau River, or at the corner of

Maria and O'Connor streets, some 12 feet below the surface of the roadway. At these two places, whilst the shales of the Utica formation also occur *in situ* and undisturbed at a greater depth than is visible in either section, the uppermost measures of the section exposed and examined cannot certainly be said to be strictly *in situ*, as the beds are tilted at every conceivable angle, crushed and broken, and in the overlying glacial deposits are to be found some of the boulders themselves which assisted intilting and disturbing these once horizontal measures.

There occur a vast number of faults and dislocations in the measures of the Trenton and other formations about Ottawa, great breaks, which at times, run more or less parallel to each other and were the result of great pressure brought to bear upon the beds in question. Whether these faults and breaks are due to disturbances which took place about the close of the Silurian Age, or at the introduction of the Devonian, when Rigaud and Montreal mountains, and other similar volcanic or intrusive masses, were ejected amidst great perturbation ; or whether some of these faults were not in part due to the enormous pressure which the great ice-mass exerted upon the strata in later glacial times are questions which, though readily suggested to one's mind by the phenomena examined, do not find so ready a solution. Having now examined the number, direction, movements, thickness and the erosive power of the glaciers during this Great Ice Age, having very cursorily glanced at the results which were effected in giving to the country the general appearance which it possesses at the present day, there remains to find out what are the materials and under what conditions they were deposited.

The masses of boulders, also termed "boulder clay," "*moraine-profonde*," &c., unlike both the underlying older and overlying newer deposits are not stratified, *i. e.* they have no divisional planes of stratification or true bedding. Pebbles of various sizes and of every kind of rock in the district, usually rounded and smooth, held together or cemented by an argillaceous paste or clay with a certain admixture of arenaceous material derived from the more finely crushed *detritus* and *debris* at the bottom of the glacier, form the lowest division of our Post-Tertiary deposits. These "boulder clays," as they are appropriately termed, have a very large percentage of boulders in them, the

finer material being scanty and in a finely-divided or comminuted state. Such a deposit is one which "land ice" alone produces and one which resembles wonderfully the "moraine-profonde" of the ancient Rhône glacier as they may be seen near the Western extremity of Lake Geneva (a mile and a-half below) and in the adjoining districts. In further corroboration of these boulder clays being due to land ice is the fact that none of the organisms which would be expected to characterize marine clays are present therein. The total absence of organic remains (so far as ascertained) in these glacial clays, coupled with the fact of their occurrence in abundance in the Leda clays above, points clearly to a wide difference in the mode and condition of deposition of both, the one being laid at a great elevation above the sea level, the other below the level of an ocean or arm of a sea.

In examining the surface geology of Ottawa, one is struck with the diversity in the distribution and extent of this "boulder clay formation:" In some places, the only indexes present, which point to its existence at one time, are the striæ and grooves over the bare rocks, such as are exposed principally about Hull and Ottawa in the vicinity of the Grand River, whilst there are also numerous fields and tracts of country which exhibit that formation very clearly. In such post-glacial valleys and districts, from which the Leda clay, and Saxicava sand and overlying strata, have been removed by denudation, there occurs a large quantity of these boulders. Amongst these are no doubt included, at the present day, the erratics which were dropped by ice-bergs at a period subsequent to the Great Ice Age. The Rideau River Valley, of Post-Tertiary Age, and very recent, geologically speaking, presents numerous points of interest from its mouth at the falls in New Edinburgh to the Hog's Back. Nearly the whole of the Post-Tertiary formations were carried away by the once wide stream which flowed there, and even the glacial clays suffered not a little, as the materials cementing the pebbles are to a great extent entirely wanting. The Rideau Rifle Range extends, for the most part, over this formation, whilst the southern portion of the range, as well as its northern limit (at the 600 yard butte) are on the outskirts of the newer overlying marine clays. We have already spoken of *moraines*. These vary very much in extent and distribution just as the "boulder clay" or "till,"

as it is also sometime called, varies from next to nothing to twenty feet or more in thickness in different places. They are extensively developed about Ashburnham Hill, Gilmour's Mills, near the Hog's Back, etc., occupying their lower and regular position at the bottom of the Post-Tertiary series in Upper Town, Centre Town and Stewarton, cropping out in the rear of the City Hall, on the east side of the canal, and ever keeping in a normal position. This "till" is thence very generally distributed in beds of varying thickness, in the area included in a curve drawn from the New Militia Stores on the canal, along Sussex street up to St. Patrick street, then produced on to the bridges over the Rideau river, pretty nearly in a line with the curve which Sussex street there describes, and across to New Edinburgh through the Rideau Hall grounds, to a small extent, where these deposits thin out markedly, and continuing the line through Beechwood, in Gloucester, on in a south-easterly direction, we have a horse-shoe curve, in which are included vast accumulations of material left us by this Ice Period. But to come back to the *moraines*:—there are, besides these hard coherent masses of "boulder clay," large aggregations of more or less uniformly sized boulders held very loosely together, and form a prominent feature of the county. At Gilmour's Mills there is a good example of one of these whilst there has already been pointed out in the "Geology of Canada," 1863—already cited—that a number of zones or belts of boulders cross the Ottawa at different places near the city, one of which a few miles below Ottawa produces a shoal on account of which the navigability of the river at this point becomes dangerous and has obliged the Government to erect a lighthouse. These are what are termed "*morainic belts*," and are prominent features to consider.

There are a number of other particulars respecting which the detailed notes obtained from the excavations that have been carried on in our streets, though bearing immediately on this subject, cannot be included in the present exposition of the subject.

(To be Continued.)