Notes on the Post-Pliocene of Canada.

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Part I. Relative ages and mode of formation of the several members of the Post-Pliocene.

Marine Deposits.

The marine Post-Pliocene deposits of Lower Canada may be regarded as consisting of three distinct beds. These are—1st, the Superficial Sands and gravels, which I have elsewhere named the Saxicava Sand, 2dly, the underlying clay which I have named the Leda Clay, and which is known to the Geologists of the United States as the Champlain Clay*. 3dly the Boulder Clay. These beds, more or less interrupted by denudation or by the protrusion of older rocks, may be traced from Labrador to the Thousand Islands, and from the upper Ottawa to the Coast of Massachusetts — distances of about 600 miles in one direction and 300 miles in the other. They not only occupy the valley of the St Lawrence, but rise on its sides to an elevation of at least five hundred feet, and indicate a depression of the continent to the extent of at least Eight hundred feet: a depression which would reduce the land of Eastern America to clusters of rocky islands separated by deep and often wide channels.

* For detailed descriptions of these beds and lists of their fossils, I may refer to my papers in the Canadian Naturalist & Geologist, 1857 et seqr; and to the Report on the Geology of Canada by Sir William E. Logan, 1863; in which will also be found references to the papers on the same subject by Sir C. Lyell, Admiral Bayfield, Dr Bigsby & others.

The Saxicava Sand is a shallow-water deposit of yellowish sand and gravel, thrown down during the last emergence of the land. The shells which it contains are of the species still found on sandy and gravelly beaches and shallows on our coasts, and do not indicate any material change of temperature as compared with that of the Gulf of St Lawrence at present. Species of land and fresh-water shells occurring in the deposit in some places, point to the same conclusion in regard to temperature. The character and distribution of these sands and gravels indicate the action of tidal currents similar to those of the modern Gulf of St Lawrence ~~at present~~, but acting at a time when the land was at least five hundred feet lower than at present, and subsequently as it gradually rose to its present level. The Saxicava Sand consequently presents the appearance rather of a succession of beaches ~~and~~ bars and terraces than of a continuous stratum; and it has been much modified by both marine and subaerial denudation.

The Leda clay is a very fine, unctuous, clay of more or less chocolate coloured deposit, somewhat calcareous, and becoming red when burned, in consequence of the peroxidation of the compounds of iron which it contains. It is usually stratified, though rarely laminated; and in some cases it becomes a compact stony clay. Of the nature of boulder clay, into

which it passes in some localities both in ascending and descending order. A minute examination of the Leda clay shows that its materials have been derived principally from the waste of the gray and red shales of the "Quebec Group" of Sir William Logan. This formation, occupying a large area in the lower part of the St Lawrence Valley, has suffered enormous denudation during the subsidence and emergence of the land in the Post-Pliocene period, and the fine clay derived from its waste has been drifted by the currents from the North-east, which then as now prevailed along the American coast, to great distances to the South-westward, filling the lower parts of the St Lawrence and its tributaries with a fine muddy deposit sometimes 300 feet in thickness, but thinning toward the higher grounds. Through this clay the modern rivers of Canada have cut their beds, sweeping vast quantities back into the estuary and Gulf, from the excavation of which by the sea it was originally derived.

The Leda Clay was deposited in deep water. Its characteristic fossil which may be found ~~wherever the Clay~~ in every part of Canada where there has been this deposit, is the Leda Truncata, now an arctic shell and not occurring in the Gulf of St Lawrence, except in some of its deeper clay bottoms not yet ~~explored~~ explored by dredgers. In the Post-Pliocene period this shell must

have been one of the most common and widely dispersed in Eastern America. It abounded from Labrador to Massachusetts, and ascended as far as the Ottawa & Lake Champlain, and must have lived in ~~water~~ depths ranging from a few fathoms to one hundred fathoms or more. In its more shallow habitats it is associated with many species still living in the Gulf, as for instance Leda minuta, Nucula tenuis, Tellina fraterna and Saxicava rugosa, and also with the apparently extinct Astarte Laurentiana, which belongs more especially to the upper part of the Leda clay and the lower part of the Saxicava sand, and is replaced in some of the more modern parts of the formation near the present sea level, by its close ally A. compressa.

At the time when the Leda clay began to be deposited, the land must have attained to its utmost depression, and the greater part of the deposit belongs to the period of re-elevation. The Leda clay, as a marine deposit, is peculiar to that part of the St Lawrence valley below the Thousand Islands. The clays of similar character which occur in Upper Canada, around the great lakes, have as yet afforded no marine fossils. Still the height to which the Leda clay attains in Lower Canada would lead to the inference that at the

time of its deposition the sea must have extended at least to the base of the Niagara escarpment. It is possible that in Upper Canada the marine deposits have been modified & obscured by lacustrine action, and that marine fossils may yet be found.

Associated with the deposits above noticed throughout their whole extent, is the peculiar formation known as the "boulder clay" or "glacial drift", with its usual accompaniment of striated and polished rock surfaces. This deposit has usually been regarded as more ancient than the Leda clay, and is by some geologists even held to be a product of subaerial glacier action at a period preceding the great Post-pliocene subsidence. I believe however that in Canada the boulder clay is wholly a marine deposit, and that it is not a continuous sheet occupying a determinate place in the Post-pliocene formation, but rather a special kind of deposit indicating the local action of floating ice, and that its accumulation has been proceeding throughout the whole of the period of the Leda clay and Saxicava sand down to the present time.

As my own views on this subject have been somewhat modified by facts recently

obtained, and as it is a topic much discussed, I may give a few examples of what I conceive to be boulder deposits of different ages, from among the many which are afforded by the great extent of such deposits in Canada. I shall group them according to their relative dates.

1 Boulder drift anterior to the deposit of the Leda clay. At Montreal the Leda clay passes downward into a hard "till" filled with angular, sub-angular and rounded fragments of Silurian and Laurentian rocks, and with large boulders. The stones and boulders are not infrequently scratched and polished. This bed has hitherto afforded no fossils. The rock surfaces beneath it are polished and striated — the direction of the striae being S.W., which is the general course of the older striation in the St Lawrence Valley. The Island of Montreal is nearly in the centre of the St Lawrence Valley, at a considerable distance from the Laurentian hills bounding the valley on the north, and from which the greater part of the boulders have been derived. The direction of drift as indicated by the striation is nearly parallel to the course of the valley, and the European map of the Montreal mountain indicates by the distribution of the boulders around it, that the transport was to the S.W. & against the present slope of the valley. The north-east side of the

Mountain is steep and craggy, and its base is highly polished and striated. The South-East side on the other hand slopes downward into a very thick bed of boulder clay. Boulders from the Mountain itself also occur at great distances to the South-westward, and Laurentian boulders of great size occur nearly on the summit of the mountain at a height of about 600 feet. The same appearance of a crag to the north-east and a tail of boulders & boulder-clay to the South-west occurs in other detached hills of the plain of Lower Canada. Further, there appearances belong to the time of the formation of this older boulder clay, since the Leda clay rests equally on the higher and lower portions of the former. We thus learn that the older boulder drift was caused by a force acting against the slope of the St Lawrence valley from N.E. to S.W., extending its influence to a considerable height above the sea and carrying boulders to very great distances from their original sites. ~~against the prevailing slope.~~ These facts exclude the idea of the action of land glaciers, and point to a submergent condition of the land, and to powerful currents loaded with ice, flowing from the N.E. in the manner of the present arctic current on the American coast.

This conclusion is strengthened by minor indications in the clay itself. For example the iron which colours the clay, ~~in part,~~ ~~in fissures~~ where it has not been exposed to the air, does not occur in the state of peroxide, though it appears. This state is exposure. This is ordinarily ~~usually~~ an unfailing indication of subaqueous ~~deposits~~ and absence of marine deposition. Again the clay contains numerous rounded fragments of shaly limestone and other shale. These ~~not~~ immediately on exposure to air and frost, and could not have been rounded into pebbles except under water. Pebbles of pyritous limestone also, imbedded in the clay, have their iron pyrites quite bright and unstained at the surface.

It may be asked why, if this older boulder drift is marine, has it not like the Leda clay supplied fossils? Without insisting on the danger of resting on a merely negative argument I may say in reply:— ~~that~~ the conditions favourable to extensive drift-ice of coarse materials by ice are of necessity eminently unfavourable to animal life. Hence even those boulder deposits of a little later date which do contain fossils, usually hold very few. The conditions of deposit of the older boulder clay were probably a subsidence of the land with the removal of loose material from its surface on a large scale by shore and berg ice. In these circumstances marine animals could colonize the sub-

ding bottom only under great disadvantages, and we need not be surprised at the absence of fossils from the lower Boulder clay & their great rarity in the lower part of the Leda clay. Areas of subsidence may under ordinary circumstances be favourable to the existence of life and the preservation of fossils; but this is not the case when ~~they~~ are invaded by cold currents bearing floating ice. Hence all or nearly all our Post-Pliocene fossils belong to the period of Re-elevation.

2 Boulder drift Coeval with the Leda clay.— Though the Leda clay is usually very fine and regularly stratified, it occasionally contains large boulders, as if dropped on its surface by melting ice and subsequently buried, just as large boulders are now often dropped in Spring on the mud flats of the gulf of St Lawrence and the Bay of Fundy. Layers of small angular stones also occur in it, more especially Round its upper part and where it approaches rocky hills. In the district of Montreal and the Ottawa however, these indications are so insignificant as to show a great diminution of boulder clay &

as compared with the underlying boulder clay, and they do not exceed in amount the ice transport now in progress in the Gulf of St Lawrence. But when we trace the Leda Clay toward the mouth of the St Lawrence, we find that the Leda clay itself becomes a boulder-clay, or in other words that after the great deposit of boulders at Montreal had been succeeded by the Champlain precipitation of fine sediment, boulder clay was still being produced at somewhat lower levels nearer to the ocean. In illustration of this I may describe the appearances presented by the Post-Pliocene deposits in the vicinity of Rivière Du Loup and Cacouna, 230 miles north-eastward of Montreal.*

The rock formation at Cacouna and Rivière Du Loup is the Quebec Group, the softer shales of which have been eroded into valleys running N.E. and S.W. or parallel with the shore, while the harder shales and the sandstones and conglomerates project in abrupt ridges. The surface of the rocks is in places polished and striated, the striæ being nearly in the direction of the ridges, or in accordance with the prevailing S.W. direction already referred to. The valleys intervening between the ridges, and in some places the slopes and terraces fronting the coast, are

* See my paper on this locality, Can. Nat. Vol IX.

occupied with drift deposits, which are usually of somewhat irregular arrangement, owing to the interference of the numerous hard rocky ridges which project through them, and must have greatly modified the original deposit. Without dwelling on these local details, I may state the following as the order of superposition obtained from the study of a number of exposures at Riviere Du Loup, Cacouna, Isle Verte and intervening places. The order is ascending.

(1) Boulder clay – its paste a tough and usually light chocolate colored mud – filled with large Laurentian boulders, which can have been derived from no nearer locality than the opposite side of the River St Lawrence, here 20 miles distant. It is of variable thickness. In one place at Isle Verte I ascertained its thickness to be 50 feet & more. In its lower part fossils are rare. I found only a few broken valves of Leda truncata. In the upper part it holds in some places numerous deep water shells, especially Leda truncata L. pernula, Nucula tenuis and Tellina proxima.

(2) Upper Boulder Clay. The paste in this bed is of a dark gray color, more sandy and less tenacious than the former. It appears to be only a few feet in thickness, and is seen only in the lower levels of the Country. It has probably been removed by denudation from the more exposed localities.

This bed abounds in fossils, including most of those found at Leda and Nucula in the layers at the surface of the Leda clay and the base of the Saxicava sand. I collected in all 20 species, exclusive of Foraminifera, the most abundant species are Tellina proxima, Balanus Hameri (R. Rhyncomella pritteri) and Leda pernula. The stones and boulders in this bed are similar in character to those in the bed below but less pigment, and they are often covered on their upper side with magnificent specimens of Balanus Hameri four inches in height, and with Bryozoa, indicating that they were dropped in clear water, and quickly buried in sediment. The Rhyncomella and Leda are also found with their valves attached and perfectly uninjured: the whole affording an admirable example of the quiet deposit of boulder clay in water abounding in animal life. stratified clay.

(3) The bed last mentioned may in some places be observed to pass upward into a stratified sandy clay without boulders, and containing few fossils, principally Buccinum undatum and Tellina fabula. I did not observe this bed to attain a greater thickness than ten feet; but on the opposite side of the river, near Sadlepac, a bed of similar character attains to great thickness, almost to the exclusion of the boulder clay.

(4) Sand and gravel. On the flanks of

some of the rising grounds, there are beds of sand and water-worn pebbles with occasional large boulders. No fossils were observed in these; but in shingly and sandy matter constituting a low terrace near the margin of the St Lawrence, there are fragments of Saxicava, Mya and other common shells still living on the shore.

(5) Modern Deposits. — It is proper to mention that on some of the low terraces fronting the shore, there are considerable deposits of large valves of Mya arenaria. There are recent, and much old camping-grounds of the Indians. On the present shore also, there is in winter and spring much movement of boulders under the influence of the coast ice, about which will be noticed in the sequel.

That the formation above described is parallel in the arrangement of its parts with the older Boulder clay, the Leda clay, and Saxicava sand of Montreal, is obvious; and it implies in the main a similar series of physical conditions. Still I believe that it is not strictly contemporaneous. The difference of level renders it probable that the sea was still deep at Cacouna when it had become shallow at Montreal, and the assemblage of species at Cacouna is more modern in its character. In these respects, as well as on account of the occurrence of the same characteristic shell, I regard the Lower Boulder clay of Cacouna as not older than the Leda clay of

Montreal. It may even be somewhat newer. In any case it shows the formation of a true boulder clay in water tenanted by Leda truncata and other species, and thus probably during the re-elevation of the land, though it is possible that its deposition may have commenced while the land was subsiding.

3. Boulder drift of the period of the Saxicava Sand. — It is evident that if the Saxicava sand is a littoral bed formed during the emergence of the land, it must be of different ages according to the height at which it occurs. A sea beach like that above Cote des neiges on the Montreal Mountain, at a height of 470 feet above the sea, must be of greater antiquity than similar sea borders at the base of the hill and scarcely 100 feet above the sea level, while there are older than the beaches and sand flats only a few feet above the level of the high tide. The period of the Saxicava sand must therefore extend through the whole time of emergence; but in every locality it is on the whole more recent than the Leda clay of the same locality. It would appear that the change from the deposition of fine sediment to that of sand and gravel was, notwithstanding the greater shallowness, favorable to the transport of boulders, probably because the tidal currents were more powerful, or because extensive fields of ice grounded in the shallows and deposited their rocky burden upon them. It is certain that

and also perhaps in consequence of the denudation of portions of the older boulder clay during the emergence of the land.

near Montreal the Saxicava Sand, and
especially its more superficial portion, is more rich
in rounded Laurentian boulders than the Leda
clay. In other parts of the Country also
there are indications of the same character.
I shall give only one illustration, from the
drift deposits of the Ottawa Valley.
Near Green's Creek on the Ottawa, a place
where the Leda clay is well developed, and which
is celebrated as the locality of nodules con-
taining the fossil capelin, the river is crossed by
a band of calciferous Sandstone which rises to
some height on the north side, and plunges
beneath the Leda clay on the South side; and
what is rapidly connected with the unusual abundance
of fishes and of nodular concretions at this place.
When this ridge rises above the Leda clay it is
covered in part by sandy deposits which may
represent the Saxicava sand, and with large
Laurentian boulders not packed as is the
case with boulders carried by rivers
or lake ice, but loosely scattered, as if
dropped from floating ice which may have
grounded on the reef. A similar but more
extensive ridge of Chazy sandstone & limestone
occurs at the Grenville rapids, and is
covered with still larger Laurentian boulders,
well rounded and mixed with large
angular fragments of the underlying rocks
which seem to have been torn up by ice,
but without any indication of pushing by

a strong current or by lateral ice-pressure. The position of these boulders and their mineral character show that they must have been drifted down the Ottawa valley from the North or North-west; and it is to this later drift of the time of the Saxicava mud, when the re-elevation of the land had made some progress, and tidal currents had replaced the general arctic drift from the North-east, that I would attribute the peculiar local structure of the rocks of the Ottawa valley, which is from NW to SE. A similar explanation may be given in this manner (at right angles to that of the older drift) structure, as occurs in the Champlain valley and elsewhere.

A Recent Boulder drift. — Many years ago Sir Charles Lyell* quoted from Admiral Bayfield and Lieut. Bowen facts as to the drifting of boulders in the Gulf and River St Lawrence by the floating ice. Instances of this kind may be observed annually on any part of the coast. I have already mentioned the modern boulder-drift at Cacouna. On some parts of the shore the space between low water mark and half tide is occupied by a band of large boulders of Laurentian rocks, which are packed closely together and rest either on the fossiliferous Boulder-clay or on the bare rock. The arrangement of these boulders, though probably not their original transport from the opposite side of the

* Principles of Geology

river, is due to the floating ice which fills this part of the river in Spring, and drifts up and down under the influence of the flowing tide and of the winds. The actual movement of the boulders under this force, is proved by the fact that the tracks or roads made with great labour by the inhabitants, for the purpose of launching their boats and obtaining more ready access to their fish-weirs, are in a year or two obstructed or even quite filled with large boulders. Similar appearances may be seen in many other places on the banks of Lawrence, and it only requires a subsidence which would bring these bands of boulders under the influence of muddy deposits, to convert them into a sort of boulder clay.

Along the borders of Lakes and fresh water streams, similar accumulations occur, which must always be distinguished from the older boulder formation. On the margins of shallow lakes they appear as sloping belts of closely packed boulders or as ridges of gravel and stones; and they are still in process of formation, by ice apparently by the force of ice in Spring, though the expansion of the ice in winter has also been assigned as a cause. On rivers, as for instance on the Ottawa near L'Orignal, they appear as wide or less narrow bands of packed boulders stretching from the bank toward the middle of the river. In rapids, as at Jemille, they constitute flat pavements of boulders or more irregular

fields of angular slabs placed close together on edge, or leaning from the centre of the stream. ~~River and lake boulder drift is quite unlike in its effects the arrangements of boulders such the older boulder formations, and can readily be distinguished from them.~~

5 Supposed drift by Glaciers. — In the Report on the Geology of Canada, Sir William Logan refers to certain cases of striation on the north shore of Lake Huron and on the upper Ottawa and its tributaries, which he seems inclined to refer to the movement of land ice. Prof Hind also mentions similar cases in Labrador. I have not visited the localities referred to, and have not therefore seen any appearances which seemed to require such explanation. It is quite possible however, that during certain stages of partial submergence the mean temperature of Canada may have been so reduced by the diminution of its land surface and the influx of cold currents loaded with ice, as to permit the existence of glaciers in some of the hilly regions.

In the theory that Canada was at any time covered by a general or universal glacier, I must reject, for reasons some of which are stated in the above pages, and others will appear from the following statements, which I may be permitted to quote from an address delivered last Spring at the annual meeting of the Natural History Society of Montreal.

ly rejected this last doctrine; being convinced that insuperable physical and meteorological objections might be urged against it, and that it was not in accordance with the facts which I had myself observed in Nova Scotia and in Canada. The additional facts contained in the present Report enable me to assert with confidence, though with all humility, that glaciers could scarcely have been the agents in the striation of Canadan rocks, the transport of Canadian boulders, or the excavation of Canadian lake-basins. In making this statement I know that I differ in some degree from many of my geological friends, but I know that they will be rejoiced that I should freely and frankly state the reasons of my belief.

The facts to be accounted for are the striation and polishing of rock-surfaces, the deposit of a sheet of unstratified clay and stones, the transport of boulders from distant sites lying to the northward, and the deposit on the boulder-clay of beds of stratified clay and sand, containing marine shells. The rival theories in discussion are—*first*, that which supposes a gradual subsidence and re-elevation, with the action of the sea and its currents, bearing ice at certain seasons of the year; and, *secondly*, that which supposes the American land to have been covered with a sheet of glacier several thousands of feet thick.

The last of these theories, without attempting to undervalue its application to such regions as those of the Alps or of Spitzbergen or Greenland, has appeared to me inapplicable to the drift-deposits of eastern America, for the following among other reasons:

(1) It requires a series of suppositions unlikely in themselves and not warranted by facts. The most important of these is the coincidence of a wide-spread continent and a universal covering of ice in a temperate latitude. In the existing state of the world, it is well known that the ordinary conditions required by glaciers in temperate latitudes are elevated chains and peaks extending above the snow-line; and that cases in which, in such latitudes, glaciers extend nearly to the sea-level, occur only where the mean temperature is reduced by cold ocean-currents approaching to high land, as for instance in Terra del Fuego and the southern extremity of South America. But the temperate regions of North America could not be covered with a permanent mantle of ice under the existing conditions of solar radiation; for even if the whole were elevated into a table-land, its breadth would secure a suffi-

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The questions of Climate and of animal & vegetable life in Post-pliocene Canada, involved in the above extracts, I should prefer to treat in a future paper on the Fossils of the Post-pliocene beds. In the mean time I may state that the difference of climate does not appear to be greater than that which should result from the existing subsidence of land in the temperate regions of America, more especially if much arctic land encumbered with ice & still remained above the level of the sea. It is also true that the greatest cold and the most extensive ice-drift appear to have co-incided with the period of subsidence and of greatest depression, or that of the Older Boulder-Clay, and that the re-elevation of the land produced a gradual approximation to the present climatal conditions. But these points can be best illustrated by the fossils.

Prof Oliveira
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