SOME FEATURES OF CONTINENTAL GLACIATION

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Continental glaciation preserves in its deposits the record of its activity, and it buries beneath its own load the deposits made by earlier glaciers. Thus in Illinois and Iowa particularly it is possible to work out the history of repeated glaciations on the basis of deposits of different characters and ages separated from one another by the ancient soils, weathered zones, and sheets of gumbotil which are indisputable evidence that long times elapsed between the successive glaciations. In certain critical sections which have been exposed by running water or by human enterprise these indications of glacial history afford the opportunity for reliable interpretation. However, in the areas of glacial erosion the story is not so clear, for the glaciers which leave their telltale deposits in some places remove the evidences of their antecedents in areas of erosion. This paper has to deal with those regions which are almost barren of glacial till although severely glaciated.

The regions of glacial abrasion are largely to the north of the Great Lakes, and the areas of deposition are largely to the south. Roughly speaking the glaciers spread out from an area north of the lakes, pushing southward into an ever widening arc, until they were wasted by the warmer and drier climate of the south. The glacial deposits might be expected to be most abundant near the place of greatest wastage, which corresponds generally with the places of greatest advance of the ancient glaciers; on the other hand, it is evident that the area north of the Great Lakes has been scoured naked by glaciation to such an extent that glacial till is uncommon. The area of deposition is approximately twice as large as the area of erosion, and supposing the Pleistocene glacial deposits of all ages to be on an average forty feet thick, the amount eroded to provide these deposits appears to have been on an average about eighty feet deep. Unlike glacial deposition, glacial erosion is highly selective as to the bed rock, cutting much more deeply in some places than in others;

thus, with an apparent average depth of erosion about eighty feet, the maximum depth of erosion may well have been more than one-hundred feet.

It is proper to recall that there have been four episodes of Pleistocene glaciation aside from the Early and Late Wisconsin invasions, which were separated by very long intervals of time, and that a great deal of the deposits must have been removed by erosion before the following deposits were laid down. How great were the thicknesses of till which have been removed no person seems to have estimated, but it seems quite conservative to consider that it may have been as great as that which remains, for that which remains is after all merely fragmentary relics of the once extensive layers of pre-Wisconsin deposits. On the other hand, much of the material still preserved in the present terminal and ground moraines is of local origin like that previously eroded. Consequently it is apparent that no definite figure can be given as the amount which has been stripped from the crystalline masses north of the Great Lakes. At a maximum it may have been as much as one hundred feet on an average, and as a minimum it may have been as much as ten feet. Unluckily erosion removes the evidences of its work and definite proof is lacking. However, there are numerous lines of evidence which indicate that the depth of erosion was very considerable, and that maximum glacial erosion affected different places during different invasions. The places of great erosion were those peculiarly vulnerable to glacial erosion. Glacial erosion above all is highly selective in its attacks. Its selection depends, aside from the thickness, speed, coldness, and adequate load, upon the character of the bed rock, upon its jointing, and upon its stratigraphic attitude.

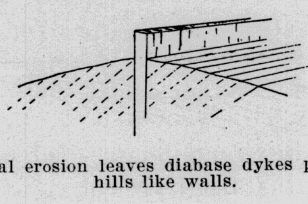

Fig. 1. Selective glacial erosion leaves diabase dykes protruding from quartzite hills like walls.

A massive igneous rock is more easily eroded than a hard rock-like quartzite, provided the quartzite is not jointed; in the case of a jointed rock, however, the quartzite is quarried by plucking and by being slipped out of its position along its planes of jointing, whereas the massive crystalline rock resists all glacial erosion except scour, which is nearly always relatively insignificant as compared with plucking and quarrying in blocks. On the north side of the Great Lakes there are numerous hills composed of well bedded quartzite with a ridge at the top composed of diabase which rises above the top of the quartzite hill like a wall. (Figure I.) Diabase is much more easily weathered than quartzite, it is not nearly so hard as quartz, and quartz veins stand out upon the glacially scarred surface of diabase, but when subjected to the erosion of continental glaciers the diabase rock is much stronger to resist quarrying than the hard, but well jointed quartzite. In several cases these diabase dykes have been found standing above the surrounding glaciated quartzite, like walls twenty feet high. Previous to glaciation these dykes were probably the location of valleys due to the easy erosion of the diabase; consequently their present attitude in relation to the quartzite indicates that not only was the quartzite eroded until it was level with the diabase but that it was carried away by glaciation so much faster than the diabase that the diabase relatively emerged from the quartzite. The difference in level of the top of the diabase and the surface of the quartzite indicates the difference in the amount of glacial erosion which the two have suffered, which must be small in comparison with the total erosion of both. Twenty feet in the difference of the erosion suffered by quartzite and diabase at the top of a hill seems to indicate that the total erosion was considerably more.

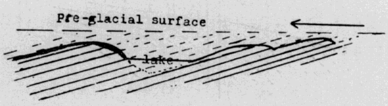

Fig. 2. Glacial erosion is notable where the formations dip in the direction of glacial advance.

But the erosion of the bed rock in the areas of crystalline rock is rather insignificant when compared with the enormous quantities which were stripped away from the sedimentary formations in the general region of the great lakes. The most important factor in their case, aside from the natural weakness of the rock as compared with that of the crystalline rocks, was the fact that the formations were dipping away from the direction of glacial advance. (Figure 2.) The ice shoved against and over the upturned edges of the rocks and broke pieces off, bearing them away in front and on top of the ice, rolling part of the load beneath it as it advanced over depressions or outliers of crystalline rock. The tremendous increase in the thickness of the glacial deposits south of the edge of the sedimentary rocks indicates very clearly the enormous load which they contributed. Illustrations of the effects of stratigraphic positions of the metamorphic rocks within the crystalline areas are numerous enough. The illustration (Plate I ———) shows part of the Serpent quartzite dipping southward, rendered still more susceptible to glacial erosion by the development of splendid bedding joints. However, it is the position of the formation, dipping about thirty degrees downward, which renders the joints valuable aids to the glacial erosion. This picture shows a stoss surface. It illustrates the sort of thing which may be seen in many places where the rocks dip southward: rocks which are in themselves relatively weak, like the Paleozoic sediments, are naturally more susceptible to this type of erosion than the strong Huronian quartzites.

When the rocks do not dip in a direction favorable to glacial erosion the plucking is notably important on the south side of the hills. This is just as true of the large hills as of the small ones. The illustration (Plate II ———) shows the southeastern end of LaCloche mountains. One can see easily enough that nearly all the hills are glacially quarried into precipitous slopes to the south, and that they have been abraded into more gradual slopes on the north side. The dip of the rocks in La Cloche mountains is nearly vertical.

Cliffs of other types abound. One of the most remarkable features of the country north of the Great

Lakes is the great number of cliffs to be seen. Inasmuch as the general relief is about three hundred feet over large areas, most of the cliffs are small. Many of them border lakes and rivers, many of them do not, some of them rise from the edges of swamps, the swamps being due to the physiographic control of the cliff rather than the cliff being a product of the lake which gives rise to the swamp. Most, if not all of these cliffs quite obviously antedate the last glaciation, and nearly all of them are the result of pre-Wisconsin glaciations and interglacial periods of erosion. Some of these cliffs border large rivers adequate with time to form great cliffs, but many of them are far from both lakes and streams, obviously owing their form to extinct conditions of erosion. Among other rivers the Nipigon river seems to follow pre-Wisconsin cliffs, for its valley is not uniform in character. Near the great cliff on the eastern side of the river shown in Plate III, the western banks are relatively low, and a portage which has been traveled by the Indians for centuries follows the top of an esker in a valley. The relations of these features show that the lowland preceded the last glacier. Obviously the great cliff is not the side of a V-shaped valley; consequently it must have been produced by the erosion of earlier times. Ordinarily cliffs which are not valley walls are made only by faulting, by the erosion of standing waters, and by glacial sapping. The abundance of cliffs north of the Great Lakes seems to indicate that glacial sapping and lake work have been prevalent in many places where today there are inadequate lakes and no glaciers. The cliffs themselves indicate the activity of pre-Wisconsin glaciation.

The antecedent character of these cliffs and their associated features probably indicate in themselves that there have been several times of glaciation in Pleistocene times, but it is very difficult to read their signs aright. One reason for this difficulty is of course because the country is covered with trees, which obscure observation. but the main reason is that all processes of erosion destroy the antecedent details of physiography, and were it not that glacial erosion is selective

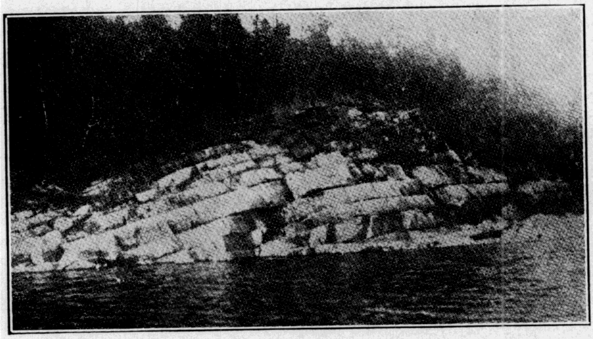

Plate I. The stoss side of a formation dipping in the direction of glacial advance. Rocks in this attitude are very vulnerable to glacial erosion. The Serpent quartzite (Huronian Series) on Lang Lake, Ontario.

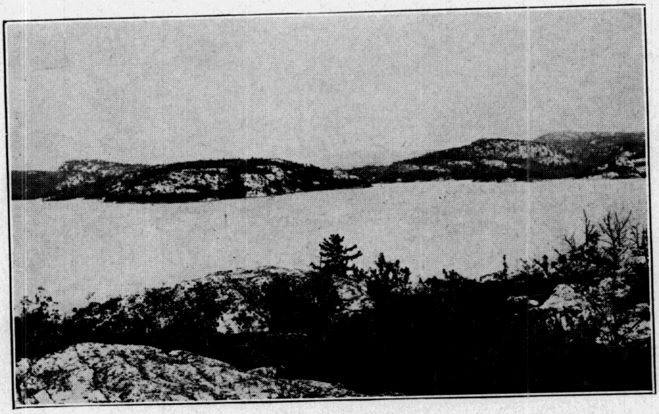

Plate II. LaCloche Mountains two miles northwest of Killarney, Ontario. Note the scarps on the southern faces of the hills produced by continental glacial plucking. Geological Survey of Canada.

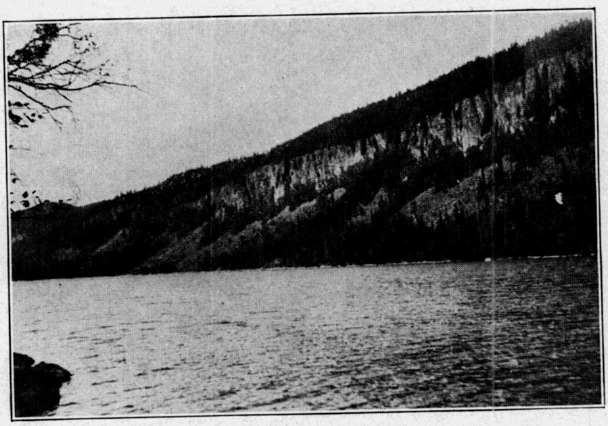

Plate III. A Pre-Wisconsin Cliff on the east side of the Nipigon River, Ontario. Most of the numerous cliffs of this type in Ontario appear to be of glacial or interglacial origin.

in its misses as well as in its hits there would probably be no indications left. However, in Bridgeland township,[1] east of Sault Ste. Marie, there is a hanging valley discharging into a swamp land above which it has built up a great alluvial cone. This valley runs east and west and is scoured on the north side and plucked into cliffs on the south side by the last glaciation. Consequently the valley is pre-Wisconsin. However, this is a hanging valley, and was a hanging valley at the time of its glaciation; consequently the cliff at which it ends is a pre-Wisconsin glacial valley. There are no geological processes in that region known to make hanging valleys except glaciation, and inasmuch as the hanging valley is over a hundred feet above the swamp at the foot of the cliff in such a place that the valley cannot be traced beyond the cliff, it appears that the hanging valley represents a stream which cut through glacial drift onto a buried diabase cliff. Apparently it was a superposed stream. The glaciation which made the

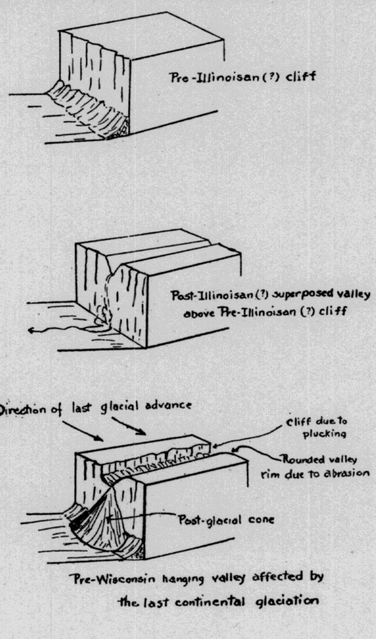

Fig. 3.

[1]Geol. Surv. Canada. Mem. No. 102, pp. 14-15.

drift through which the stream cut is not likely to have been the glacier which made the cliff, or if the cliff had been made by lake work, the lake may have owed its existence to earlier glaciation; consequently it appears that there are here three times of glaciation indicated. First, a glaciation which caused the cliff, second, a glaciation which buried the cliff with deposits through which a stream cut until it became superposed upon the top of the diabase hill, then erosion removed part or all of this glacial deposit, and third, the Wisconsin glaciation passed across this superposed valley. These relations are illustrated in Figure 3.

The case just discussed is believed to be the only one described in which there seems to be erosional evidence of three times of glaciation. However, if search were made for indications of this sort it might be that it would be possible to corroborate from the features of glacial erosion a considerable amount of the Pleistocene history which we know so well at present from the evidence provided in the areas of glacial deposition.