ART. VIII. THE PRODUCTION AND PRESERVATION OF LAKES BY ICE ACTION. BY THOMAS BELT.*

[*Read Feb.* 6, 1865.]

DURING a residence of two years in the Province of Nova Scotia, my attention was directed to the multitude of lakes, great and small, that are spread over the country, sometimes in connected chains, sometimes isolated on the tops and sides of hills, &c. These lakes form a common feature in the northern parts of America, and increase in number as we proceed northwards. The larger lakes are shown in maps of the Provinces, but it requires a visit to impress on the mind the number of small lakes and ponds that abound in every direction. Mr. Perley, speaking of Newfoundland, says :—

"The most remarkable feature of Newfoundland is the immense and scarcely to be credited abundance of lakes of all sizes. * * These are found universally over the whole country, not only in the valleys but on the highest lands, even on the hollows of the summits of the ridges and on the tops of the highest hills. These ponds vary in size from pools of fifty yards in diameter, to lakes of upwards of thirty miles long and four or five miles in width. The number of ponds which exceed a couple of miles in extent must on the whole amount to several hundreds; those of smaller size are absolutely countless."

My duties in connection with the management of some mineral properties in Nova Scotia, took me almost daily along the line of an important chain of lakes, which, stretching almost across the Province, had been taken advantage of by the Shubenacadie Canal Company to form a water communication from the Atlantic coast to Cobequid Bay, by connecting the different lakes with short canals. The works of the canal company exposed in many places the structure of the enclosing strata, and showed that most of the lakes were in true rock basins; and I had opportunities whilst mining operations were being carried on on the banks of one of the lakes, of studying the disposition of the heaps of boulder clay and gravel piled up on its sides.

The rocks in which the lake basins lie are chiefly extremely hard quartzites and metamorphosed schists, supposed to be of lower silurian age, although as yet no fossils have been discovered in them. They are irregularly covered with heaps of boulder clay, mostly unstratified. Wherever the surface of the rock is exposed, it is found to be scratched, grooved and polished; and other marks

* Read before the Geological Society, June 22, 1864.

of intense glaciation, such as the rounding of protuberant bosses of rock, and the transportation of huge boulders, are of frequent occurrence. The course of the main lines of scratchings varies from N.N.E. to N. N. W., and the lines of the major axes of the lakes and of the chains of lakes, have the same bearings. The Shubenacadie lakes commence at Dartmouth, near Halifax harbour, and stretch in an irregular northerly direction to the head of the Shubenacadie river, a distance of twenty-two miles, and with the river they occupy a great depression or valley, running from Cobequid Bay to Halifax harbour, a distance of fifty miles.

The largest of the chain, the Grand Lake, is eight miles long, and in its deepest part its bottom lies seventy-four feet below the mean level of the sea. The coast is indented with long, narrow, deep bays or fiords, running in the same direction as the chains of lakes. The glaciation of the rocks and the transportation of boulders point to the agency of ice, and the only question undecided is, whether we shall ascribe them to the action of glaciers or of icebergs. Icebergs, laden with rocks and clay, and ploughing up the bottom of the sea where they grounded, might be sufficient to account for the scratchings and for the transportation of boulders; but they do not furnish us with the power requisite to scoop out deep channels and gorges, often continuous for scores of miles, in hard rocks, which are as characteristic of a glaciated country as the minor scratchings and groovings. In Nova Scotia, the whole country has been hugely grooved and furrowed, and heaps, or rather hills of gravel, piled up on the sides and in the courses of the channels excavated. This configuration of the country is best explained, as it has been by Agassiz and others, by supposing that it was covered by a vast accumulation of continental ice, moving southward from the Arctic regions, which, when at its greatest development scooped out the larger vallies and deep fiords, and modelled the grander features of the country; and during its retrogression, when continental ice enveloping the hills had wasted into glaciers down the principal valleys, they, during their slow retreat, left terminal moraines in their courses, and heaps of gravel and angular blocks on their flanks.

It is readily admitted that such lakes as are formed by the damming up of channels with heaps of clay and gravel, may have been formed by glaciers leaving terminal moraines in their retreat, and the scooping out of long deep channels is easily understood; but the production of deep rock-basins is not so easily explained, and their glacial origin has been disputed by eminent geologists. We owe the theory of the production of rock basins by ice action to Professor Ramsay, who in 1859 showed that there was an intimate connection between mountain lakes and the evidences of glacial action, and argued that the rock basins had been ground or scooped out by ice, either in soft rocks surrounded by harder, or more generally, in places where a greater height of ice had accumulated and exerted a greater grinding pressure on the rocks beneath. In 1862 he extended his theory to account for the production of the great lakes of Switzerland, and even those of North America, contending that there is such a gradation of size from the least to the greatest that we cannot apply the theory to the one and not to the other.

The Lake of Geneva is 984 feet deep, the Lake of Zug 1279 feet, and the Lake of Brienz more than 2000 feet, and its bottom about 200 feet below the level of the sea. In Italy even these depths are exceeded, and we have the Lake of Como 1929 feet deep, and the Lake of Maggiore 2625 feet, and its bottom 1940 feet lower than the sea level. With regard to these great depths it has been urged by Sir Charles Lyell and others, that though the passage of prodigious masses of ice for ages over the surface would doubtless produce depressions where the hardness of the rocks beneath was not uniform, yet a depth would soon be reached where the movement of the ice in the basins would be arrested, and the discharge of the glaciers would be over and not through the ice-filled hollows. In a glacier as in a river, the lower strata move much more slowly than those at the surface, being impeded by the friction on the bed of what we may call the ice river—and as in the Lake of Maggiore the ice, on Professor Ramsay's theory, would have in its exit to ascend a slope of five degrees from its deepest part. It is contended that in such a case it would be simply dammed up, the glacier passing over it. It is true that in Australia there are deep hollows in the courses of the streams, in which water is stored up during the dry season, but this is a peculiarity of intermittent rivers and dependent upon the intermittent action. Again, in British North America, great holes are gradually worn during winter in the sleigh tracks, commencing at first with slight depressions in the hardened snow, and increased by the passage of every sleigh, until the holes become so deep as greatly to inconvenience travellers; but here again the action is very different from the steady continuous flow of glacier ice, the scooping out power depending on the sudden descent of the sleighs into the hollows, which, in the case of glaciers would be filled with ice.

Sir Charles Lyell considers that the great lake basins of Switzerland have not been scooped out, but that they are all due to unequal movements of upheaval and subsidence during the great oscillations of level since the commencement of the glacial period.* But whether or not this theory is sufficient to explain the formation of the great lakes of Switzerland and Italy, it does not apply to those of British North America, nor of northern Europe, where we have lakes of all sizes, increasing in number as we proceed northward, and found everywhere along with and evidently part of the glaciation of the land. It does not explain this palpable connection of rock basins with glacial action, and in seeking for another solution we naturally turn our attention, first of all, to that agent whose power has been so conspicuously displayed in the erosion of the deep valleys and fiords of glaciated countries.

These considerations have lead me to endeavour to solve the main difficulty in accepting Professor Ramsay's theory, viz.: the immense depths of some of the basins; and I think it may be shown that even if the ice were dammed up at moderate depths, it would still possess great grinding powers, which would be augmented instead of being diminished by increased depth. In the first place I must draw attention to a feature of all glaciers, the streams that issue from beneath them. In Switzerland, from the bottom of every glacier, rushes a torrent densely charged with mud. It is the same with the great glaciers of the Himalayas—the Ganges, the Pindur, the Kuphinee and the Thlonok, rise from beneath glaciers. The flow of water diminishes in winter, but never entirely ceases in glaciers of the first class. In Greenland, Dr. Rink says, that "in some places mighty springs are seen to come forth from under the outer edge of the ice, pouring out clayey water in continued quan-

* Antiquity of Man, p. 316.

tity throughout the winter." * Most of the water issuing from the bottom of glaciers proceeds from the melting of the ice at the upper surface of the glacier, finding its way to the bottom through crevices and channels in the ice; but a not inconsiderable portion is produced by the melting of the lower surface next the earth. Professor Forbes made some careful observations on this point, and found that in summer the glacier wasted away by melting at the surface 3.62 inches daily, and by subsidence or wasting at the bottom 1.63 inches daily. The water that issues from beneath the ice in Greenland throughout the long and severe winter, can only proceed from land springs and from the melting of the ice next the earth. The only example of glaciers that do not give off water during the winter that I have been able to find, are some of those small ones on the higher parts of the Alps that have been called "glaciers of the second class," on which, from their altitude, the effect of the earth's heat must be very small.

Let us apply these facts to the consideration of the question of a depression in the pathway of a glacier, which has reached such a depth that the ice is not bodily discharged from it, but simply fills it, the glacier passing over the choked up hollow. We have seen that at the bottom and sides of the hollow, the ice would be slowly melted by the earth's heat, increasing with the depth of the basin; as the ice at the *lower end* of the basin melted the whole mass would be pushed along by the thrust of the moving glacier above it. Into the crevice at the upper end would pour the water coming down the bottom of the glacier from above the basin, which would pass underneath and be forced out at the lower end, carrying with it the mud produced by the crushing down of the ice as it melted at the bottom, and by the grinding along its floor as it melted at the lower end of the basin. The water coming from above would assist in melting the ice, especially in summer, but its most important effect would be the scouring out of the bottom of the basin, so that an ever clean face of rock would be presented to the huge tool operating upon it. That such an action, or a somewhat similar one, would take place at the bottom of an ice filled basin, with a glacier passing over it, and that it would be effective in deepening it, I cannot doubt. It would in some measure resemble the action of a

* Jour. Geographical Soc. Vol. 23, p. 153.

hollow drill that has been proposed for boring holes in rock through which a current of water is forced to carry off the ground stone, and still more, the production of pot holes on our coasts and in the hard beds of many rivers, by the moving water turning a stone in a hollow and so gradually deepening it, until through time a cylindrical and deep cavity is formed. A lake basin is an immense pot hole, in which the mass of ice that filled it took the place of the moving stone, its grinding power vastly increased, and in great part due to the moving glacier above it. The eroding action would be slow, but it would be continuous, and the only limit in depth to its power would be when the hydrostatic pressure of the water equalled the weight of the superincumbent ice, a limit far beyond anything with which we have to deal. The rock basins of Nova Scotia are much shallower than those of Italy and Switzerland, because in the one case the rocks operated on have been hard metamorphosed schists and quartzites, in the other soft molasse, easily eroded; the work done being proportional to the hardness of the material.

Art. IX. On some Brine Springs of Nova Scotia. By Henry How, D. C. L., Professor of Chemistry and Nat. Hist., University of King's College, Windsor, N. S.

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In a former communication to the Institute,* and in another paper,† read before the Natural History Society of Montreal, I have given the composition of some of the mineral waters of the Province, known or reported to possess medicinal properties. Nearly all those analysed had for their leading ingredient sulphate of lime, or plaster, as it is called, the exceptions being a brine from the neighborhood of the Renfrew gold diggings, and that interesting water from Bras d'Or, of which the chief constituents were common salt and nearly as much chloride of calcium. In the discussion which followed the reading of my paper at the Institute, several springs were mentioned as locally famous, viz., those of Earltown, Shubenacadie, and a place a mile and a half east of Shelburne; but I believe no facts bearing on the composition of

*Trans. N. S. Inst., Vol. 1. † Canadian Naturalist, Oct. 1863.