

ART. VII.—*Observation upon the Glacial Phenomena of Newfoundland, Labrador and Southern Greenland*; by G. FREDERICK WRIGHT.

Dr. F. A. Cook's expedition to the Arctic regions in the summer of 1894 met with many reverses, ending in the loss of the Steamer *Miranda* and of the valuable collections which had been made by the naturalists on board. But the opportunities for glacial investigation were on the whole as good as could have been reasonably expected. The delays afforded nearly a week for observations in Newfoundland, and about the same length of time at three different points in Labrador, namely at Henley Harbor, St. Charles Harbor, and the Punch Bowl, while two weeks were at our disposal in Greenland in the vicinity of Sukkertoppen in latitude 65°25', where the inland ice sends a projection down to within fifteen miles of the open sea. Besides spending a week in camp at the edge of this portion of the inland ice, we made an excursion up Isortoki Fiord to a distance of twenty-five miles, having oppor-

\* Since the above was written I have received a letter from Mr. Putnam in which he informs me that he has since added two or three stations to the list as given above. He also makes the important suggestion that a similar line of gravity stations should be run across the southern part of the country. "We would then," he says, "get in another latitude a variety of conditions not found in the past season: a sea coast free from the mountains, along the Gulf Coasts an immense area of deposits, farther to the west a long, rising swell comparatively little disturbed with mountains, and beyond a great depression below sea level." It is earnestly hoped that he may be allowed to execute this interesting piece of work.

tunity to study the phenomena along each side to that point, and to get extensive views of the inland ice and of the country bordering it.

The glacial phenomena of Newfoundland have been very carefully studied by Mr. Alexander Murray and fully recorded in his paper before the Royal Society of Canada in 1882, published in the Proceedings and Transactions of that year, Sec. iv, pp. 55-76. I have little to add to what he has written, except to set the facts in their connection with those observed in Labrador and Southern Greenland, so as to assist in forming certain general conclusions.

The west coast of Newfoundland presents a nearly straight face to the sea, running about N.N.E. and S.S.W. The southwestern portion of the western coast rises in Cape Arguille to a height of 1800 feet. The rounded or sloping escarpments usually face to the westward, as if the ice-movement from that direction had covered the whole island.

The southeast and east coast is deeply indented with numerous large bays which for the most part trend in lines nearly parallel with the western face of the island. Grand Pond, whose surface is 116 feet above tide, has a depth of more than 1000 feet, its bottom being 988 feet below sea-level. The evidences of former occupation by glacial ice are universal in the island; glacial striae being found not only in the valleys opening out into the Atlantic, but upon the highest headlands. In the vicinity of St. John's the direction of the scratches varies, according to Murray, from N. 64 E. to S. 76 E. upon the higher lands, which are from 300 to 600 feet above the sea. On the summit of Signal Hill, which is about as high a point as there is upon the peninsula of Aviron, the direction of the scratches is S. 86 E. At Torbay, a few miles north, at 300 feet above tide, the scratches are S. 76 E. On the Great Belle Island in Conception Bay the direction is N. 38 E., or very nearly in line with the axis of the bay. At Topsail Head, however, which lies on the south side of the bay, just opposite the island, and 650 feet above tide, the scratches point, according to Murray, N. 43 W. It seems to me, however, a fair question, whether the direction of movement was not here S. 43 E., bringing it nearly in line with the scratches upon the rocks on the highlands between Topsail Head and St. John's.

So far as I could learn, the transported material in the vicinity of St. John's is local, the bowlders on Signal Hill being all traceable to outcrops a few miles west, where the land is very nearly upon a level with the summit of the headlands. Taken altogether, and in connection with the phenomena in Nova Scotia and Labrador, and with the soundings

of the surrounding sea, there seems every reason to accept the conclusion of Mr. Murray, that the glacial phenomena of Newfoundland belong to a general movement which filled the Gulf of St. Lawrence and extended some distance out upon the Atlantic plateau in this latitude. 1st. The glacial scratches which appear near the summits of the highlands are often at right angles to those appearing in the shallow valleys, indicating a movement, at the climax of the period, which was largely independent of local features. At St. John's there is a considerable accumulation of till upon the southeast side of the harbor up to about 200 feet; but there are very few indications of any vigorous movement of ice along the axis of the harbor. It was with difficulty that I found any indications of movement at all underneath this till. The whole appearance was that the harbor had been filled with nearly stagnant ice, having but a slight movement making very fine scratches in the direction of the axis of the upper part of the harbor, which was northeast, or about at right angles to the scratches upon Signal Hill, and to those near the summit of the hill upon the south side of the harbor.

2. The depth of Grand Pond (988 feet below sea-level) coincides with numerous other facts indicating a preglacial elevation. In Conception Bay the general depth of the water is from 100 to 140 fathoms; but the depth across the mouth is only 80 fathoms, indicating a bank which is most likely a terminal moraine. The mouth of Holyrood Bay is crossed by a similar bank, convex on the inside, and is covered by only thirteen fathoms of water, while it suddenly deepens on both sides to forty fathoms. As is well known, also (see especially a paper by Prof. J. W. Spencer, *Geol. Soc. of Am.*, vol. i, p. 68), the shallow water surrounding Newfoundland, and extending to Nova Scotia, is intersected by a deep channel extending from the Saguenay River down the St. Lawrence and through the Gulf, south of Anticosti Island, to the margin of the plateau which suddenly breaks off into the profounder depths of the Atlantic Ocean, about 200 miles from the present land margin. This channel is, throughout its entire length, more than 1200 feet in depth, reaching towards its mouth a depth of nearly 2000 feet. Throughout its entire length, also, it is pretty sharply bordered by a margin of shallow water less than 500 feet in depth.

3. Along the coast of Labrador the most instructive feature of the scenery is its subdued character, especially when contrasted with the west coast of Southern Greenland. From the Straits of Belle Isle to Hamilton Inlet the entire coast came within reach of our vision. Everywhere the land rises pretty rapidly to heights of from 1000 to 2000 feet. But though the rocks

are of Laurentian age, consisting of granite and gneiss, which would naturally weather into sharp peaks, the summits present everywhere a flowing outline. So far as we observed, there was not a single needle-shaped peak to interrupt the monotony of the scene. At St. Charles Harbor and at the Punch Bowl we spent several days in wandering over the hills near the shore, some of them rising to an elevation of nearly 1000 feet. But it was with the greatest difficulty that any glacial scratches were found upon the rocks, while the absence of till and of transported bowlders was equally remarkable. Similar absence of these characteristic glacial signs was noted by Prof. Carl Kenaston, who accompanied Mr. Bryant to the great falls on Grand River, nearly 200 miles inland. Still there can be no question that this whole region was enveloped in glacial ice. The absence of till probably accounts largely for the absence of scratches; for in that inclement climate disintegration of granitic rocks proceeds at a very rapid rate; so that we have few freshly exposed surfaces that have not suffered considerable disintegration. At Henley Harbor, which opens southward upon the Straits of Belle Isle, large granite bowlders were found upon the Devil's Dining Table, a remnant of an extensive basaltic eruption, which rises 250 feet above the sea-level. But around St. Charles Harbor and the Punch Bowl, it was very difficult to find any bowlders at all. The natural explanation would seem to be that we are here so near the center of a great glacial movement that all the sharp peaks were worn down, and the material carried away to points nearer the margin of the movement. It seems altogether likely that an ice-front stretched along near the border of the continental plateau as far as the banks of Newfoundland. But glacial conditions were, most likely, a concomitant of the elevation, so that the confluent glaciers spread out there upon the continent as they did in the interior portions of America.

Passing to Southern Greenland, one is deeply impressed by the great contrast in the scenery, though the geological formations are essentially the same. We had a view of the Greenland coast from the vicinity of Frederickshaab to the vicinity of Holstenborg, a distance of about 300 miles. While from Sukkertoppen, in lat.  $65^{\circ} 25'$ , we were able to make extensive tours into the interior up the fiords and along the channels and to make a minute study of a considerable section. The rocks are principally gneiss, with occasional veins of granite and trap. But instead of the flowing contour characteristic of the mountainous border of Labrador, the scenery of this part of Greenland as viewed from the ocean is extremely picturesque—needle-like peaks of Laurentian rocks running up at frequent intervals to heights of from 2000 to 4000 feet.

Nothing in the Alps or the Rocky Mountains is more characteristic of the forms assumed by such rocks under subaerial erosion than the numerous sharp peaks to be found all along this part of Southern Greenland. One has not far to go in the interior, however, to find the same subdued topography already noticed in Labrador. Upon penetrating Isortok Fiord 25 miles, the peak of Nukagpiak rises 4180 feet. From its flanks a projection of the inland ice-sheet can be seen 15 or 20 miles to the north. This ice-field is penetrated by two or three nunataks of about the same height with this mountain. But the elevated region intervening between this point and the eastern ice is characterized not by sharp peaks, but by truncated masses that have been rounded and smoothed by glacial, rather than by subaerial erosion.

On the contrary, the island of Sukkertoppen, which is about five miles in diameter, and still farther north the island of Sermeræut, which is about ten miles in diameter and rises to an elevation of 3300 feet, present on every side a continuous line of conical peaks which show every characteristic mark of having been sculptured mainly by water and subaerial agencies. As seen from the channels to the southeast, their outline, when thrown against the glowing sky of the north at midnight, is the most picturesque I have ever witnessed,—to be compared with that of the Teton Mountains when seen from the east or the west, and with the Aiguilles around the upper part of the Mer de Glace; while the view is scarcely less impressive when seen from some of the adjoining heights. They present none of the characteristics of a region which has been completely covered with glacial ice. If they have ever been so covered, an enormous time must have elapsed since the recession of the ice-sheet on that part of the coast.

But while it is not probable that the ice ever covered these marginal peaks, it is clear that at one time glaciers extended through all the fiords and filled all the channels to the very border of the sea. This is indicated both by glacial striæ and by transported boulders. In Isortok Fiord, which is now open back into the interior for 50 or 60 miles, and is bordered all the way by mountains 2000 or 3000 feet high containing local glaciers, glacial groovings are magnificently displayed near its mouth, where I had opportunity to observe them upon a scale scarcely inferior to that witnessed on Kelley Island, in the western end of Lake Erie, or in the vicinity of Victoria on the Island of Vancouver. (See illustrations in the *Ice Age of North America*, pp. 156, 237-245.) So powerful was the movement of ice at this point that it did not confine itself to the direct axis of the fiord, but pushed obliquely upwards toward a low promontory several hundred feet above sea-level,

while the flank of this promontory facing to the southeast was marked by two or three clearly defined moraines composed mostly of pretty well rounded boulders. Below the 200-foot level these had evidently been partially rearranged by wave action. But there was here a large amount, also, of till running down to the water's edge which had not been thus modified. This deposit of till was larger than any other which I saw in Greenland.

In the fiord at Ikamiut, about 20 miles north of Sukkertoppen, and directly east of the Island of Sermersut, the glacial phenomena were of the most significant kind. This fiord extends back from the open channel about eight miles, where it is met by the perpendicular ice-front of an extensive glacier which here projects from the inland ice. The height of this ice-front is from 100 to 200 feet, and the width of the fiord two and a half miles, but for about a third of its distance the ice terminates on gravel deposits that had been laid down in front of it. On the northern side of the glacier the ice is much broken, rendering it impossible for one to traverse it. The motion of the ice, however, is evidently very slow; for, though the front is perpendicular, the icebergs that break off from it are small and few, even when compared with those from the Muir Glacier in Alaska, and the water from the sub-glacial streams is only slightly colored by the glacial sediment.

We ascended this glacier along its southern edge for a distance of six miles, reaching an altitude of 1800 feet, where a very sharp and high *nunatak* divided the glacier which was here from six to eight miles wide.

Upon looking back over the space we had traversed we could see that at the head of Ikamiut fiord the glacier encountered a mountain rising 4000 feet which caused it to divide and put off two branches, one to the northwest and one to the southwest. The southern fiord leads directly down to Sukkertoppen, and is twice as long as that leading to Ikamiut.

From our point of view we could easily see that the southern fiord was much more encumbered by floating ice than the northern. From this point, also, the rugged and angular contour of the mountains along the coast were strikingly noticeable. Upon looking to the east the ice-cap, covered with freshly fallen snow, stretched away beyond the nunatak as far as the eye could see. We were looking out upon the same ice-field which we beheld two weeks before from Nukagpiak, at a right angle on the south side of Isortok fiord and twenty miles distant.

Among the most impressive phenomena upon this glacier were the majestic swells in the ice as it broke against the mountain barrier between the two fiords. In vast masses sepa-

rated by long fissures the ice turns to the right and to the left towards the head of the fiords, while opposite the mountain barrier it is pushed up in a smooth dome-shaped protuberance, so that when we were in the depression between the descent from the ice-field to the ascent towards the mountain, the appearance was almost exactly like that which often confronts one in a "sag" in a rolling prairie.

Above the height of 1500 feet the glacier was so covered with fresh snow that there was little opportunity for observation. Below this level there were numerous superglacial streams of large size, which eventually plunged into moulines several hundred feet deep. The surface of the ice from which the fresh snow had melted contained a large amount of fine dust corresponding, I suppose to Nordenskiöld's *kryokonite*. In shallow depressions this was occasionally an inch or two in depth. We estimated that, over considerable areas, the average thickness of the dust was a quarter of an inch. The height and bareness of the surrounding mountains favored such an accumulation, as the winds had free access to them. Unfortunately our specimens were lost, so that I have not been able to compare the dust found here with that described by Nordenskiöld and Holst; but the general appearance was similar to their specimens.

Numerous moraines, coming principally from the northern side of the glacier, joined to form two main lines before reaching the head of Ikamiut fiord. These stood considerably above the general level of the ice. One of the moraines was spread out over a width of fully a quarter of a mile,—that appearing to be the distance to which the stones had rolled transversely in the process of the lowering of the level of the ice in recent times by ablation. The number of perfectly rounded pebbles six inches or more in diameter interspersed a mile or more back from the front with this morainic debris upon the surface of the ice was such as to attract special attention.

Ikamiut fiord presents one of the best object lessons conceivable illustrating the process which went on everywhere in mountainous regions during the closing stages of the ice invasion. The fiord runs nearly east and west. The flanks of the mountain upon the north side of the fiord facing the sun, are entirely free from ice up to the border of the glacial front; but those upon the south side facing the north sustain a number of local glaciers fed by comparatively small neve-fields and extending varying distances towards the water's edge. The glacier nearest the mouth of the fiord comes down to within about 1000 feet of the sea-level, a second, farther up the fiord, reaches down to within about 500 feet of sea-level, a

third descends still nearer, while a fourth comes to the water's edge close to the ice-front of the main glacier. Still farther eastward, and higher up the mountain, a glacier is moving directly against the general ice movement. The face of the rocks upon the south side of the fiord are very plainly striated in the direction of the axis of the fiord up to a height of 1000 feet or more; while the present local glaciers are now producing scratches in numerous places at right angles to those produced when the fiord was full of ice, and a little above the head of the fiord the scratches produced are directly opposite to those which were made at the time of the maximum extension.

There is very little till to be found anywhere along this part of the Greenland coast, and when one considers the indications of the former extension of the ice down the fiords he is surprised at the small number of bowlders upon the surface. It is probable, however, that the bowlders have been largely dumped into the fiords. The moraine upon the main glacier, though very large, could easily disappear in the great depths of Ikamiut fiord after the ice had melted away. In the vicinity of Sukkertoppen there were a few bowlders of light colored granite so different from the gneiss of the vicinity as to furnish indubitable evidence of transportation by ice from a considerable distance in the interior.

I could find no indications of high terraces along this part of the Greenland coast. In a few protected places, however (at Sukkertoppen and Ikamiut and at the locality already referred to on the Isortok fiord), there was an arrangement of large numbers of rather small subangular bowlders which indicated a limited amount of water action up to a height of 200 or 300 feet. At Ikamiut shells were found in abundance in a terrace about 50 feet above tide-level. I saw no evidences of "englacial" till. The perpendicular face of the glacier seemed to be pure ice.

The most important inferences to be drawn from the foregoing facts are:

1st. That the ice-sheet of Southern Greenland formerly sent glaciers down through all the fiords, filling them to a height of about 2000 feet, and pushing even to the very margin of the continent. Greenland, therefore, like the rest of the world has had its ice age which has already partially passed away.

2d. During the maximum of the ice extension the mountains bordering the sea in Southern Greenland formed innumerable nunataks. The ice was not thick enough to cover them in solid mass, and there is no probability that the ice extended far out into Davis Straits.

3d. On the other hand, it is pretty evident that in Labrador and Newfoundland all the mountains were completely covered with glacial ice, which extended far out over the bordering continental plateau. But this was at that time probably elevated above the sea-level, so that it is doubtful if the ice ever extended far into the sea. The facts point to considerable preglacial elevations of land followed in Labrador, at least, by a period of extensive depression below the present level, and subsequent partial elevation.

4th. The freshness of the glacial striæ in exposed places and the small amount of modification which has taken place in the topography since the retreat of the ice sustains the abundant evidence elsewhere found of the recent date of the glacial period; while the indications of recent changes of level point to terrestrial rather than astronomical causes to account for the vicissitudes of the glacial period.