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EARLY DISCOVERERS

IV

ESMARK ON GLACIATION

The following is an extract from a paper by Professor Jens Esmark (1763–1839), *the Norwegian geologist and mineralogist*—"Remarks tending to explain the Geological History of the Earth." "*Edinburgh New Philosophical Journal*," *Oct.–Dec.* 1826, *p.* 107–21. *The original was published in Norwegian in "Nyt Magazin for Naturvidenskaberne,"* 1824. *Place names which were misspelt in the English translation have been restored to the spelling of the Norwegian original. They should all be recognizable even though the orthography of modern maps differs from that of* 1824.

After discussing evidence of glaciation in the Alps, on the north German plain and in Denmark, he gives his original observations from Norway, which must be quoted at length:

". . . But it is particularly in Norway I have found many proofs of the operation of immense masses of ice which have now disappeared.

1. As in other countries we find large, loose rocky masses lying spread over pretty level plains; for example, in travelling from Morstuen, on the Mjösen, to Leuten in Hedemarken. These must have been brought from a great distance, for there are in the neighbourhood no mountains of the same character as these masses.

2. In no other satisfactory way than by the operation of ice can we explain how those prodigiously large loose stones, sometimes with sharp corners, have been brought up to the ridges and tops of high mountains, which are found in such numbers in the province of Christiansand. The first time I met with such single loose blocks lying on the ridge of the high mountains in Nummedalen, I thought they must be the remains of strata, or of masses which had covered the mountain, and which had in after-times been decomposed and carried off by water, leaving those traces of their former existence. But, on examining them more closely, I found that this account

of the matter would not do, for I found that, in their internal structure, many of these stones neither corresponded with one another, nor with the mountain mass on which they rested. By the assistance of immense masses of ice, on the other hand, it is easy to conceive how they could have been brought from a great distance, and pushed high up on the mountains.

3. In travelling over our mountainous districts, especially in Österdalen, it will be frequently found that the slope of the mountain towards the valley is covered with large loose stones, mixed with a great quantity of loose sand and gravel, and that this covering extends to a considerable height over the bottom of the valley. If we consider attentively this mixture of large loose stones and gravel, we shall find that these could not have been produced and brought hither by any current of water descending through the valley, and depositing these larger and smaller remains of the ruins of the mountains; for the current which brought down the large masses, and deposited them there, could not possibly, at the same time, have deposited the finer sand and gravel, but must have carried it down to places where the influence of the current was less powerful. We may indeed suppose that two different currents at different times might produce this mixture; that the first and largest current deposited the large stones, and that a later and less powerful current deposited the gravel and sand. At first view this supposition seems not improbable; but, on a closer examination of this mixture, we shall find that it is not consistent with fact, for if a mighty current had brought down and deposited the large stones in the first instance, they must in that case rest upon one another, without any thing interposed between them, and the gravel, brought down and deposited by the succeeding current, could only have filled up the surrounding cavities; whereas, on the contrary, we find the large stones lying separated from one another, surrounded by sand and gravel, a circumstance which cannot be explained in another way than by supposing that the whole had formerly been filled up with ice, which had pushed the whole mixed mass up the slope of the mountain. The water of the ice, afterwards thawing, carried off by its rapid streams a part of the stones and gravel, which were then heaped together, deeper down in the valley: these heaps resemble entirely those which glaciers carry before them.

4. We come now to the fourth and the strongest proof, that immense masses of ice have formerly existed in Norway, in places where now no perennial ice is to be found. When I last summer (1823) undertook a journey to Stavanger, to examine the Union (Enigheds) Copper Works, which have been commenced and again given up, I made an excursion from the dwelling-house of Fossan, which Pontoppidan, in his map, calls Fosland, in Hölle Annex, in the parish of Strand, to examine a branch of the works at Vasbotten, about a quarter of a mile (more than one and a half English miles) north-east from Fossan. The road went first over some cultivated ground, ascending a little, but after between four and five thousand paces it went over a large level sandy plain. This plain was overspread with a multitude of tumuli that had been all opened. Urbur-Aasen, which reaches out to the sea, lay upon the right hand, and, on advancing farther on over the plain, you see the dwelling-house of Houkelie, at a little distance to the right, in a valley which stretches up into the hill. At the upper end this sandy plain was bounded by a glacier-dike or rampart, which extended across the whole valley. As this glacier dike is remarkable, and, so far as I know, the only one of its kind lying close to the level of the sea, in a district * where you find only a few heaps of perpetual snow in hollows of the mountains, where it slopes to the north-east, at the height of from two to three thousand Rhenish feet above the sea, I must be a little more particular in describing it. Its length across the valley, from mountain to mountain, is 2250 feet, its perpendicular height above the plain 100. At one of the ends where it approaches to the mountain, it is broken through, so that there the highest part of its brink is not above twelve feet higher than the plain. This opening or breach is not above 200 feet broad. The dike itself consists of coarse gravel and sand, mixed with a great number of immense blocks of gneiss, which is the prevailing kind of rock in the mountain. We find this gravel and sand not only heaped up across the valley, but

* By observations I made, Stavanger Church lies in Lat. 58° 57′ 56″.

pushed up in great quantity on the opposite side of the dike, to the length of 1400 feet towards the mountain.

The whole bottom of the valley is covered with a lake, which is called Houkelie-Vandet, of the same breadth as the length of the dike, and extending about ten thousand feet up the valley. The people in the neighbourhood say that it is one hundred fathoms deep. As the surface of the lake is only ten feet higher than the plain on the other side of the dike, and as this, therefore, where it is lowest, is two feet higher than the surface of the lake, there can be no run from it on this quarter. The water has its outgate at the other end, by a fall of a few feet, into a similar lake, and from this again, by a little fall at Vasbotten, it passes into a larger lake, called Eje-Vandet, from which it soon after runs into Lysefjorden. These three lakes lie in a semi-circle.

From this description it will be easy to see that this dike could have been formed only by masses of ice, which must have filled up the whole valley and by their spreading and pressure have hollowed out its bottom. In all probability the water of the melted ice, at a late period, burst through the dike and for a while had its issue through the opening, and its present outlet either did not then exist, or was filled up with ice and gravel. On the plain below we find not a trace of the gravel carried down from the dike, a thing of course not to be expected when we think of a torrent 200 feet in breadth rushing out with violence. Not only the dike itself, but the whole horizontal surface, exhibits proofs that there has been a glacier here, for the plain exactly resembles those which I found adjoining to the glaciers presently existing between Söndfjord and Lomb, in Gudbransdalen, where I had likewise occasion to travel last summer. The resemblance is so striking that every one who has an opportunity of making the comparison must form the same opinion. As a proof of this I may mention that Mr. O. Tank, a skilful young mineralogist who visited with me the dike of which I have given the description, and afterwards accompanied me to the glaciers I have just mentioned, on seeing the latter, without having heard a hint on the subject from me, he immediately exclaimed that the dike we had seen at Stavanger must be a glacier dike.*

As I think that what I have stated will be sufficient to prove that the Norwegian mountains have been covered with ice down to the level of the sea, and therefore that the sea itself must have been frozen, we may from this find the reason why the Norwegian mountains in general are so steep, I may say perpendicular, on the sides which hang over the valleys, not only in the valleys which are high above the level of the sea, but in those from the bottom of which the waters run into the Norwegian Fiords (Firths). Ice, or glaciers, by their immense expanding powers, must beyond doubt have produced this change in their original form, from this circumstance, that they were continually sliding downwards from the higher mountains to the lower districts and, by this progressive motion, carried with them the masses of stone which they had torn from the mountains. It is easy to explain why no trace of these masses thus separated is to be found immediately below the precipices thus formed.

As these mountain precipices are often from three, four, to five thousand feet high, and the valleys over which they hang are likewise several thousand feet in breadth, it must be a matter of astonishment to think of such valleys being filled with ice to the extent of several miles. This ice in lower districts must have stretched a long way out into the sea, and, on its thawing, large masses must have broke loose, and gone out to sea, as we find takes place now in the polar regions. I have no hesitation in affirming this, when I survey the effects of immense masses of ice, where there is no room to be mistaken.

I shall further mention the supposed effects of glacier ice in another part of Norway, at the level of the sea.

Last summer I went by sea from Bergen to Söndfjord and Nordfjord, on the outside of the

* The principal glacier in the valley of Boredhus (*sic* = Bondhus) descends from 3000 feet (914 m.) above the sea to 1400, with a moraine or dike of earth and stones in front from 600 to 800 feet broad.—Ed.

Scars (the rocks which lie along the shore), to examine the petrifactions which Pontoppidan talks of in his Natural History of Norway, as to be found in Steensund, in Sulen-Öerne, at the beginning of the 61° of north latitude. I went on shore at different places; and although I carefully examined every place around, I found not a trace of petrifaction.* On the contrary, I found that the part of the continent separated from it by the Sound, and the island of Indre- or Østre-Sulen, consisted of a solid conglomerate,† composed of boulders, from the size of a pea to that of a man's head. These boulders consisted chiefly of gneiss, quartz and clayslate, which were involved and bound together in a mass so solid that it was difficult to find out what the binding medium was, as the interstices between the large stones were completely filled up with small boulders. On closer examination, at particular spots, I found that this binding medium was chlorite and hard clay.

On this rock there seemed to me proofs of the powerful operation of ice. I found that the precipices on the side of the mountain next the Sound were several feet (*sic*) in height, and perfectly perpendicular; and though they were composed, as I have mentioned, of boulders cemented together, they were perfectly even and smooth. If these precipices had been the effect of rents, attended with successive masses tumbling down, then the boulders adjoining the rent must have been found adhering sometimes to the one and sometimes to the other of the separated masses (those which have fallen into the sea are no more to be seen); and, in that case, the boulder left in one mass must have left a mark of itself in the corresponding one. This, however, was by no means the case, as the rock which remained was perfectly smooth, and had the appearance as if these boulders had been cut across by a sharp knife. I can explain this phenomenon in no other way than by supposing that large masses of ice pressing through the Sound have cut these precipices lying parallel to the direction of the Sound.

I could give other proofs of the conclusion I have sought here to establish, but, to persons capable of judging of the matter, I consider these as sufficient."

* Professor Rathke, who had formerly been at the same place, and found none, recommended to me to make this examination.

† The translation is at fault here. It should read ". . . . I found that both the mainland and the island of Indre- or Østre-Sulen, which are separated by the Sound, consisted of . . ."—*Ed.*

(*Communicated by Professor Kaare Strøm, Oslo*)

THE INTERNATIONAL DEVELOPMENT OF SNOW SURVEYING

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SNOW surveying was initiated in north-western America forty years ago and has proved of the greatest value to farmers for estimating run-off for irrigation and to engineers for flood prevention. The methods of surveying have been gradually improved and many works have appeared dealing with this aspect of the matter. Snow survey systems have been extended from western North America westward to Australia and eastward to New England, Quebec, Newfoundland, Norway, Sweden, Switzerland, India and westward again to Argentina and Chile in South America. The systems in Australia, New England and Newfoundland have been quantitative. Nearly all the others are based on seasonal percentage or correlation. International snow surveys were first established in 1921 by the United States and Canada in the basins of the St. Mary and Milk Rivers in Montana, Alberta and Saskatchewan. Free access was granted across the national boundary and snow surveys and forecasts were shared.

In 1947 an international snow survey system was organized by India and Nepal in the Himalaya, particularly for the management of reservoirs under construction or planned on the Kosi and Tista