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THE JÖSTEDAL-BRÆ GLACIERS

IN

NORWAY,

WITH SOME GENERAL REMARKS,

And a Plate.

By C. M. DOUGHTY, B.A. Cantab.

LONDON:
EDWARD STANFORD, 6, CHARING CROSS.
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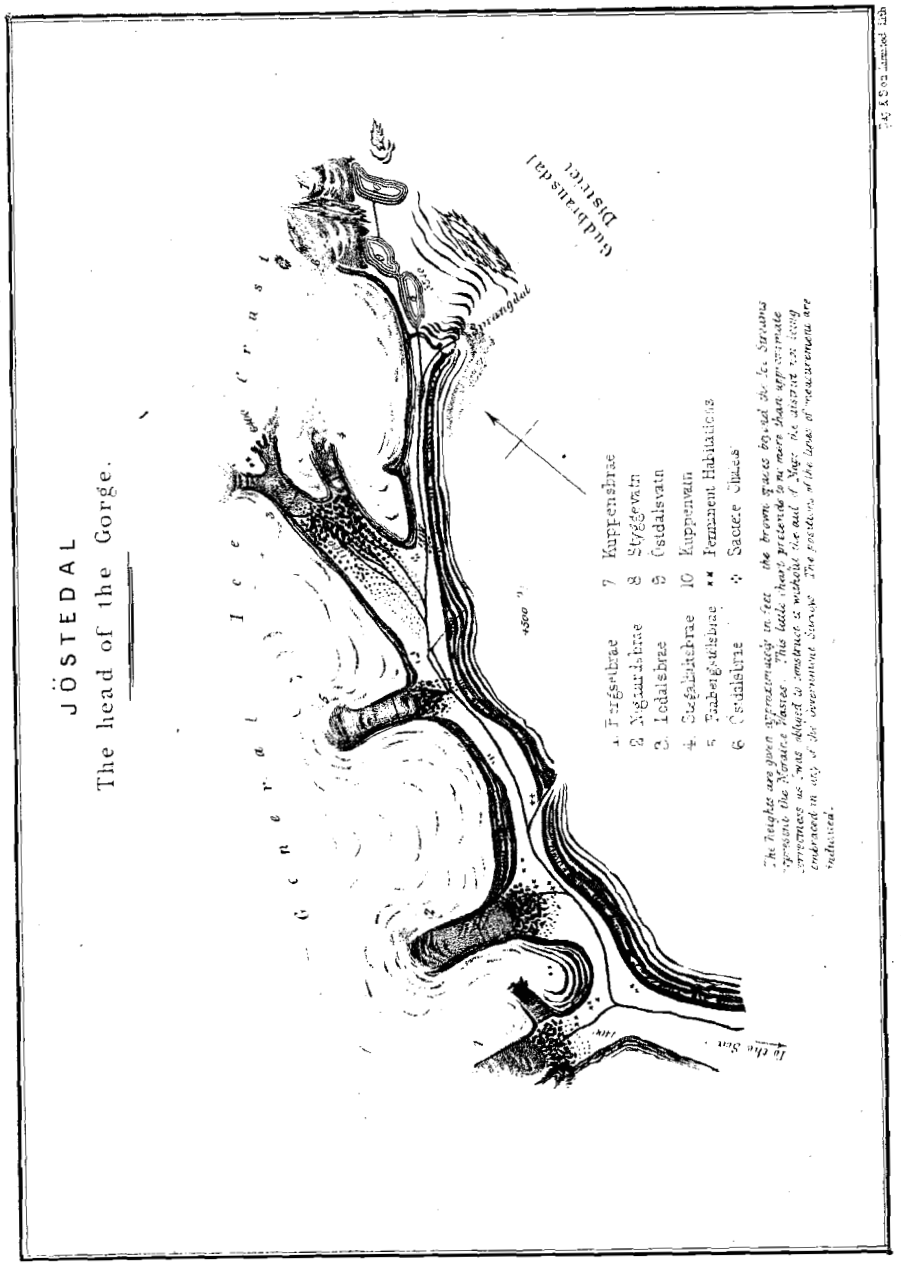

ON THE

JÖSTEDAL-BRÆ GLACIERS IN NORWAY.

THE Glaciers of the North of Europe are of very considerable interest, and have never been properly attended to. I propose in this place to describe the chief ice-streams which form the outlets of the Southern slope of the great Jöstedal-bræ.* The measurements which appear in the tables were made by me with a theodolite, in the months of July and August, 1864.

It is, perhaps, most convenient to divide glaciers into two kinds: one consisting of a stream and reservoir, like those common in the Alps, and the other forming, as it were, a crust to a large tract of land, and having several streams or outflows, like that at present covering Greenland. The Norwegian glaciers, for the most part, are certainly of this nature, from the peculiar character of the country—a great Alpine boss, as it were, cut up into immense plateaux by the intersecting valleys. On as many of these plateaux as reach the snow line, the snow, which is constantly accumulating, becomes trans-

* The Jöstedal-bræ lies between the parallels of 61° and 62°. It is a ridge of irregular shape, some sixty miles long and of inconsiderable breadth.

formed into a compact icy mass, traversed by crevasses, and by its weight and yielding constitution the entire mass gradually finds its way to lower levels, both squeezing out its surplus down the valleys as ordinary glacier-streams, and discharging from the cliffs in shoots of ice-blocks.

The southern slope of the Jöstedal-bræ is an excellent example. I will now proceed to the accounts of the several streams whose names are marked in the small chart appended.

The Bergœt Glacier.—I have no measurements of this stream; it plunges down into the valley very steeply in a great sheet, and two smaller streams, one on either side, flow down near it: all of them were formerly united and continuous as a single flow, of which many traces exist further down the valley now in cultivation.

The Ni-gaard Glacier—This is a beautiful ice-stream, which no traveller sees without admiring. One sees at the end of it an immense amphitheatre, down which it descends from the general ice-crust. It is about nine miles long and one broad, and seems to flow down in elegant curves; though, in reality, this is due to the tossing-up of the surface by some submerged knees of the mountains, and it passes through a nearly straight channel. No stones or earth soil its glistening surface, but ice-blocks are discharged upon it from the general ice-crust, which appears capping the cliffs, and creeping down in every depression, and pouring out its water in picturesque threads down the rocks. The cascade-water soon percolates down to that which is circulating already in the glacier, and forms about a sixth part of the white turbid stream which runs away at the foot of the glacier. There are neither "tables," nor "moulins," or "dirt-heaps" to speak of. The surface varies much, swelling into great diagonal, almost longitudinal, billows below, rugged and cut into seracs above. My guide and I, with a rope, the spikes of the country, and an iron-tipped stick, were able to traverse it for

about three miles. The veining of the ice can be seen almost everywhere, but it becomes rather contorted near the axis.

The following are the measurements made on this glacier, the motion calculated to twenty-four hours:

1. NIGAARD-BRÆ.

Intervals in Ells (Norwegian) by eye-estimation.	Number of Stake; Land w.	Character of Surface.	Diurnal Motion in Norwegian Inches.*	Remarks.
20	1	.. ..	1·1	Errors of plummet not recorded (very slight).
130	2	.. ..	6·1	
125	3	.. ..	8·4	
100	4	.. ..	9·9	Inclination of surface not ascertained — 16°?
120	5	Cut by profound and long crevasses into a series of longitudinal ridges.	8·5	
140	6		11·0	
115	7		11·1	Foot of the glacier above the sea 1060 feet (Vibe).
50	8		11·5	
110	9		12·4	
120	10	.. ..	11·2	
100	11	.. ..	11·7	
100	12	.. ..	11·5	
100	13	Tolerably uniform.	11·1	
100	14		10·2	
120	15	.. ..	9·8	
50	16	.. ..	9·7	
130	17	.. ..	9·0	
600	Land E.			
Total . 2330*				

* = 1550 yards = breadth of glacier. Average intervals, 100 ells (the irregularities occasioned by crevasses).

The Lodal's Glacier.—The wild Jöstedal gorge is barred to the north by this massive stream of ice, which is compounded of three streams and bears two moraines, one of which is afterwards lost in the general accumulation of debris on the left side, while the other, spreading out, covers over the greater part of the imposing glacier-front. The western of the three streams plunges steeply down from the mountains rugged in the extreme: at first its scars become healed when it unites with the main flow, but waves and dirtbands accompany it to the end.* The famous rock called

* The waves and bands are confined to this the western portion, which never apparentfy *fuses* with the rest of the stream, and has a system of veining distinct.

Lodal's Cloak separates the two eastern ice-streams, where they debouche from the general ice-crust. "Tables," of course, rills, water-shafts, and "dirt-heaps," are common; old lines of scars often determine the course of the rills. There are besides many ovoid patches in the ice, with a radial structure a few inches in diameter, and sometimes hollow and containing water in the middle. These, perhaps, are the last remains of old water-shafts nearly closed up by the yielding of the ice, or are extraneous blocks in which the structure has been produced by pressure. The sides of the glacier, as usual, are gigantic moutonnée precipices, and the beds of snow which lie heaped up to a great height in their shade, conceal the edges of the ice and much of the lateral debris. The water from this glacier issues from a very fine arched cavern, about seventy feet wide and thirty high, when we saw it.

We made two daily measurements on this glacier without moving the stakes, and the results will be found side by side in the table:—

2. LODAL-BRÆ.

Intervals in Ells (Norwegian) by eye-estimation and by pacing†.	Number of Stake: Land N.E.	Diurnal Motion in Norwegian Inches.	Ditto, Second Measurement.	Remarks.
150	1	·9	1·3	Error of plummet: 1st measurement, ·1 in. (circum.).
170	2	1·8	2·6	
165	3	2·4	3·5	2nd ditto, ·1 in. (circum.).
195	4	2·4	2·9	Inclination of axis at surface 6·5 (circum.).
135	5	2·6	3·2	
185	6	4·1	4·4	Length of the bræ (from the watershed) about 7 miles.
155	7	2·5	3·4	
195	8	2·8	2·9	
170	9	2·0	2·5	
170	10	9·1	1·3	Foot of the glacier above the sea 1710 feet (Vibe).
200	11†			
140	12			
150	Land S.W.			
Total . 2180*				

* = 1450 yards, true icebreadth . ·. prob. = 1190 yards circum. Average intervals, 150 ells.

† Stakes 11 and 12, which were not observed to alter their position, stood on the N.E. lateral snow-bed, probably over the (stationary) permanent accumulation.

The comparison shows an increase of motion on the second occasion, which is rather surprising; the warmth of the weather had gradually increased, which probably accounts for it. The glacier itself has a course of about seven miles from the watershed of its eastward tributaries, and about three-quarters of a mile broad at our line of measurement.

Retiring southwards we open upon the Gap of Trangedal, which contains *The Stegahalt Glacier*, a very wild and inaccessible mass of ice. It is reached, however, by a sharp climb through some Alpine thickets on the right, whence the dirtbands of the Lodal's Glacier are best seen. It is a very interesting glacier, not so wide as the others, but of greater length (some ten miles), and with an almost inappreciable inclination for most of the distance, but its back afterwards becomes broken quite across, and here its horrid gaping fissures plainly disclosed horizontal bedding, and other lines of a different character we saw distinctly cutting these at various angles, which must have been veins. Farther down, the great transverse slices at the surface are jammed together, healed and toned, and, gradually bulging out about the axis, soon gain the true appearance of waves. The ice then grows more crystalline, rapidly increases its inclination, and at last plunges into the valley almost precipitously with a fine fan of radial crevasses.

The table for this ice-stream is as follows:—

3. STEGAHALT-BRÆ.

Intervals in Ells (Norwegian) by eye-estimation.	Number of Stake; Land, S.E.	Diurnal Motion in Norwegian Inches.	Remarks.
30	1	2·6	Error of plummet, *nil*, nearly.
100	2	6·5	Inclination of axis at surface, 16° (circum.).
130	3	10·9	
125	4	13·2	Length of the bræ (from the watershed), about 10 miles.
120	5	13·7	
130	6	14·2	Foot of the glacier above the sea, 1,710 feet (Vibe).
120	7	14·7	
150	8	14·3	
70	9	12·7	
300	Land W.		
Total .. 1275*			

* = 850 yards = breadth of glacier. Average intervals, 160 ells.

The Faabergstol-bræ is the only glacier of any importance remaining. It, too, begins, as it were, in a tremendous amphitheatre. It is about seven miles long, following moderate gradients, a good deal broken below, and with incipient waves; at the present day it ends in a low shattered front, pouring out its water in several streams; but formerly it reached quite across the river, which then ran in an icy tunnel; and even more lately it possessed a cavern where all its waters issued.

Measuring as before:—

NAME OF ICE-STREAM—4. FAABERGSTOL-BRÆ.

Intervals in Ells (Norwegian) by eye-estimation.	Number of Stake; Land, S.E.	Diurnal Motion in Norwegian Inches.	Remarks.
15	1	5·1	Error of plummet, *nil*, nearly.
130	2	9·1	Inclination of axis at surface, 17°?
110	3	10·8	Length of the bræ (from the water-shed), about 9 miles.
100	4	10·6	
110	5	12·1	Foot of the glacier above the sea, 1,420 feet (Vibe).
100	6	10·3	
100	7	9·1	
100	8	9·3	
200	Land S.W.		
Total .. 965*			

* = 640 yards. Average intervals, 138 ells.

Although all the great ice-streams which pour into the Jöstedal gorge and its immediate branches have now been gone over, two immense icy streams remain, which, if they do not strictly belong to it, are yet a part of the same system of drainage, and deserve mention on other accounts as possessing some peculiarities, and as having never been visited by travellers. They appear in the chart on the extreme right, each of them projecting into a lake. The height of the surfaces of the lakes is about 3,500 feet above the sea, not very much below the snow line, and not more than 2,000 feet beneath the general water-shed. Here is an arctic climate and we found the lakes covered with ice in the middle of August, still thick enough to bear some wild reindeer, which we disturbed. We slept under a stone, while it froze outside, according to a minimum

thermometer. The general ice-crust of the plateau creeps over the rounded heights which rise up from the other side of the Stygge-vatn ("horrid-lake"), and loud peals are heard booming among the heights when some new ice-shoot takes place and seems to smoke in the distance. The glaciers "calve" into the lakes, the weather forbade our ascending them; their structure must be evidently less crystalline than the ice of the glaciers of the gorge. The Stygge-östdalvatne's lakes are perfect basins in the live rock; innumerable rounded hummocks of stone rise up from the water in all directions.

What has been said appears to show the perfect identity of these glacier-streams of Norway with the glaciers of the Alps. In pursuing the subject in Norway I was led into some reflections which I will now submit. It would seem that some idea of—

The Nature of the Channels of these Ice-streams may be formed by taking the valuation of such indications as these: the condition of the surface of the ice—the character of the walls of the channel—the fluctuations or mutations of the surface as the glacier recedes or advances—the aspect of the empty valley lower down, allowing for the nature of the rock—ascertaining the local climate, and comparing the valley with others most like it but no longer containing glaciers; and if the channel be supposed regular, and the motion of a single point be regarded, we have in climate, motion, and thickness, an equation with one unknown term wherewith to solve the problem. There are too a variety of—

Moraines.—Streams of all kinds may bear moraines and heap them up, and there is more than one kind even of glacial moraine. I observed in various

parts of Norway a number of very peculiar terminal moraines of small size, composed of boulders very regularly disposed. They were always opposite some depression in the rocks above, down which I imagine miniature glaciers in former times descended, leaving these memorials of their earlier limits when the old glacial climate had improved; but I was afterwards convinced by more extended observations, by seeing the process of accumulation actually going on, and by the assurances of the inhabitants that these were stones brought down by the avalanches which love these particular routes; although in some cases it is plain that avalanche moraines and glacier moraines have become mingled. The avalanches, which take a long time to melt, have usually traces of lateral moraines and dirt-heaps, and even "tables" may be seen on their surfaces.

Opposite "skars" likewise, there are often large and regular terminal moraines, but these are always recognizable.

As *Specimens of the Contemporaneous Fauna and Flora* are being entombed every day in glacial accumulations, and man occasionally among the rest, very early traces of the human race may some day be dug out from the deposits of the later glacial period, if man was then in existence and inhabited those parts of the globe

The Scandinavian Savants have well shown that a general crust of ice spread at one time over the entire peninsula, as is the case still in Greenland and other

countries; such peaks only as exceeded five thousand feet projecting out of the general glacial waste. The ice-crusts of the higher plateaux are the remains of this former condition, traces of which are left everywhere, and probably of mutations which occurred before the equilibrium of the present day was reached.

Glacial periods were more probably rather local than general.

Glaciation has evidently much diminished in the north polar regions, as an examination of the plates published in the various voyages make nearly certain. See especially the frontispiece to Vol. II. in Dr. Rink's large work on Greenland.

A great deal has been said of the *ploughing-out* powers of glaciers over loose materials. From what I saw in the Norwegian glaciers I should believe this action has been rather exaggerated; the snout of the glacier ploughs out a little and rises over the rest.

As regards the *traces of former glaciation*, those imprinted on the rocks aud stones are most important. If a glacial mass has moved over bare rock, it depends both upon the nature of the rock and the "arming" of the ice-mass, as well as its weight, what the effect on the surface of the stone shall be. It may be polished or scratched, or both or neither. The rocks in Jöstedal are everywhere *moutonnée* to the topmost heights, convexly and concavely too, with "Lee-" and "Shock- sides," though not always correctly, for the shock side depends at least as much upon the bedding of the stone as on the "shock,"

but scratches are by no means universal; indeed, it is sometimes very hard to find any, and on rock over which I was assured that ice in man's memory had moved, I have searched for them in vain. Nor when we searched for scratched stones in the moraines, and picked up hundreds of pebbles, could we find any; and neither my guide nor any other inhabitant had ever seen or heard of them. The rock seems tough, but is coarse-grained, and probably weathers freely. The smaller moraine pebbles are generally quite rounded, and seem to have been rolled about and sorted to some extent by the water—the wandering glacier streams. These streams are ever changing their courses, and working from side to side, as I saw myself in the course of my stay. In one place I discovered, with much surprise, a series of miniature longitudinal terraces which had been formed in this way, and every day's further observation brought additional evidence that this was everywhere going on; and I found myself at last, I believed, in a position to begin to account for a remarkable phenomenon which is such a prominent feature in Norway—the great terraces along all the valleys. I suppose that the combined cutting down and *erratic* energy of the streams have carved out these terraces out of the materials which lined them. This truth will, I suppose, be an important additional point of sight gained—a very important one of a combination of actions, which have produced these present appearances. (Elaborate examples may be seen in Dr. Hitchcock's 'Surface Geology,' or in Professor

Dana's 'Manual.') Probably, too, it will be found applicable in considering the erosion of estuaries, and even, in some cases, of terraces, in the solid rock.

Arctic marine shells are found in Norway up to 500 feet. It is maintained by the Norwegian geologists that there are *no grounds whatever* for the supposition that *any* part of the coast of their country is being elevated, but they believe Sweden to be rising on the south and east. They maintain that scores of Norwegian lakes have more than one outlet. None of the innumerable lakes have yet been properly examined with the lead, to ascertain the nature of these depressions.

The lowest night temperature on the surface of the ice during the month was 2° 2′ Cent. The freezing point is probably never reached in the few weeks of summer. The mid-day temperature ranged from 8° 2′ to 32° 3′ Cent.

About twelve feet of snow lie on the glaciers in the winter, my guide informed me. The torrents are then fast frozen over, and about one-eighth of their summer volume. The deepest crevasses and moulins plumbed did not exceed sixty-five feet.

The margins and fronts of the glaciers are sometimes of great height, 200 to 300 feet. The convexity of the streams about the axis is very noticeable. The ice is harder at the sides than nearer the axis. The structure of the ice at the end of the glaciers was an agglomeration of little blocks, bounded by moss-like cavities. The large torrent which rolls through

Jöstedal has filled up several small lakes or ponds along its course, and formed a delta; its bed is constantly shifting, and some conspicuous terraces occasionally line its sides: some fine pot-holes may be seen in some places. The gorge is thirty-five miles long; it is very wild; only twenty-eight miles are permanently settled; there is no better way than a rough bridle-path over the *roches moutonnées*; it is so narrow and deep that the sun is not often seen in winter. There is an immense moraine and some perfect terraces at the mouth. Professor Kjerulf and Professor Christie, of Christiania, gave me their kind assistance; and to my excellent guide, Rasmus Rasmusen, my ability to perform the measurements* is entirely due. The daily surface ablation of the glaciers appeared to be nine to twelve inches.

* The Norwegian measures are three per cent. greater than ours—a difference so slight that I allowed the tables to remain as they were. "Bræ" is the Norwegian for glacier.

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