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An Exploration in 1897 of Some of the Glaciers of Spitsbergen: Discussion

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are practically devoid of glaciers down their west coast, and have large glaciers in the east. The whole of the south-east of Edge island is occupied by a great glacier ending in the sea. Barents Land has several sharply pointed peaks, but the Edge island hills are mainly flat-topped, like those along the east coast of the main island.

Prince Charles Foreland now alone remains to be considered. It is very badly represented on the existing chart. At its southern extremity is an isolated hill. Then comes a very flat plain of about 50 square miles, raised but a few feet above sea-level. Next comes a mountain range consisting of fine, sharp snow-peaks. It is cut off on the north by a deep depression, running in a south-west direction from Seehonde bay, which, though marked south of St. John's bay on the chart, lies some miles north of it. North of Seehonde bay and valley the mountain range is continued, but the peaks, though fine in form, are not so high as those of the south group, but they send down eastward an almost uninterrupted series of glaciers into Foreland sound. Further north are yet lower snowy hills, which end in the bold headland called Bird's cape or Fair Foreland.

Before the reading of the paper, the CHAIRMAN (Sir Charles Wilson, Vice-President) said: I am sorry to say that our President is confined to his house by a bad cold, and he begged me to make his excuses for not being here this evening.

Sir Martin Conway is so well known to you all, that it is quite unnecessary for me to say any words of introduction, and I will ask him at once to commence his lecture on "An Exploration in 1897 of some of the Glaciers of Spitsbergen," which I am sure will be very interesting.

After the reading of the paper, the following discussion took place:—

The CHAIRMAN: There are several gentlemen here who I think we should like to hear this evening, and I will first of all call upon Mr. Garwood, who was with Sir Martin Conway in his last expedition.

Mr. E. J. GARWOOD: In deference to the request of our Chairman, I rise to say a few words, although I am afraid the time is getting late. I must ask you to make allowance for my feelings, labouring as I am under the novel sensation of possessing, for the first time in my life, some real territory of my own. Having been told before the meeting that you might like to hear a word or two about the geological features of the country which we explored this year, I have purloined one or two of my slides from Sir Martin's box with which to illustrate the subject.

The first point to which I should like to allude is the height of the snow-line in Spitsbergen. Many of you may be under the impression that in Spitsbergen the snow-line comes down to the sea-level. Before my visit two years ago, I imagined that the typical scenery so characteristic of our own climate was totally absent from the arctic regions; that is to say, that curious denudation curve, that logarithmic curve, so characteristic of a humid climate like our own, and so well seen in the valleys of Scotland and the lake district in Cumberland. I was surprised, however, to find that in the low valleys, where unoccupied by glaciers, this was not the case. We have there true denudation curves produced even up to a height of 1200 to 1500 feet on the western coast of Spitsbergen. This is well seen in photographs of the northern slope of the Trident, in the Sassendal, where the beautiful curve and the wonderfully symmetrical gullies are evidently the work of running water acting during the short summer months.

In our explorations in the more glaciated district further to the north last summer, about which Sir Martin has told you to-night, we found scenery of a markedly different type.

Rising as they do through the inland ice system, whose surface in the interior of King James Land stands at a height of upwards of 3000 feet, the mountain ridges stand out with sharp and cleanly cut contours. These nunataks show a marked absence of the denudation curve alluded to above, and their bold and precipitous outlines are evidently the work of frost alone. This is especially apparent in the range of peaks of which the Three Crowns form the most westerly outliers (Fig. 3).

Without entering into the detailed geology of the district, it is interesting to note the influence exerted by the geological structure on scenery sculptured by frost alone. This influence is much more marked here than it is in a humid climate, where the surface features have been carved by the action of water.

FIG. 3.—THE THREE CROWNS, KING'S GLACIER.

The terminal pyramids of the Three Crowns are composed of carboniferous dolomite, lying nearly horizontally, and traversed by well-marked vertical joints. It is along these planes that the action of frost is most marked, resulting in the production of perpendicular cliffs, frequently quite inaccessible. A sharp line can, however, be drawn at the base of this formation, where it rests on the purple Devonian (Silurian?) shales. In the latter formation, the absence of joints and the friable nature of the shales has resulted in the formation of gentle scree slopes, forming an angle of some 140° with the limestone cliff above. It is thus that we have produced the characteristic rock forms to which the name of the Three Crowns has been so aptly applied. The clean-cut diadems of golden dolomite cushioned on the purple folds of their Devonian pedestals stand like silent monuments of vanished empires.

It is always pleasant to meet old friends, and the fossils enclosed in the limestones recalled days spent on the slopes of Ingelbors', while the fish remains entombed in the Devonian shales had close affinities with the classical collections from the Old Red Sandstone of our own islands.

Here and there, as at the base of the Pretender, rise islets of an earlier age, lifting their heads through their icy covering, and I am proud to state that my patrimony to the East also dates from these Archæan times.

FIG. 4.—THE SUMMIT OF THE KING'S HIGHWAY.

FIG. 5.—HIGHWAY DOME, KING JAMES LAND.

The position of these carboniferous rocks to the north of Highway glacier requires a word of explanation. Their occurrence here appears to be due to a vast

dislocation or thrust running south-west from King's bay, which has brought up the older schists on the south side, and let down the whole of the carboniferous area

FIG. 6.—KING'S GLACIER AND BAY.

FIG. 7.—THE LAST CAMP NEAR MOUNT CHEIDENIUS.

on the north, for we find patches of carboniferous rocks let in against the schists on the south side of Highway pass. The disturbance curves somewhat on the south

shore of King's bay, causing the carboniferous beds to be tilted on end, and run as a broken ridge across the entrance of Ice fjord and Bell sound, in which latter bay the ridge forms the interesting little Axel island.

I would call your attention to some novel and somewhat interesting structures which we met with this year. They occurred both on the ice of Nordenskiöld glacier, and also on the King's glacier at the foot of the Pretender. They consisted of long arched tunnels running in parallel rows on the surface of the ice, and rising from 3 to 8 feet in height above the general level of the glacier. When we first saw these tunnels on Nordenskiöld glacier, we were inclined to attribute them to surface streams frozen in winter and arched by expansion into their present forms, but after a careful examination of those at the foot of the Pretender, I have come to the conclusion that they result from the snow bridges which here, as in Switzerland, span the crevassed portions of the ice, but which here, owing to the rapid melting and intense frosts, are converted into ice. On reaching smoother and more

FIG. 8.—NORDENSKIÖLD GLACIER CAMP.

level reaches of the valley, the walls of the crevasses close up, and the bridges are thus forced up into these arched tunnels by lateral compression.

An interesting result of river-action which we came across this year on the ice consisted of horizontal tunnels excavated, not on the surface of the glacier, but in the heart of the ice. One of these, which occurs on the left bank of Highway glacier, had a diameter of 12 to 15 feet, and was nearly circular in section. It was evidently produced by the discharge of a lake which formed between the ice and mountain range to the south, along the line of the thrust-plane described above. This lake would be dammed up every spring by the winter snow, but in summer it would empty itself almost instantaneously as soon as the barrier was broken through. In rushing through the ice-tunnel it carried with it innumerable fragments of rock, which it deposited all over the floor of its channel. This channel ran at right angles to the direction of Highway glacier, and we have here an instance of one possible origin of the gravelly ridges known in our own country as *kames*.

and *eskers*; for on the retreat of the ice now occupying Highway valley, this material will be deposited on the floor of the valley, forming a ridge of gravel containing glaciated and water-worn fragments running at right angles to the final drainage-line of the district.

If we examine photographs taken from Mount Nielson, and looking south-east across the island, it will be seen how little was known of the interior previous to our visit; for instead of the "High inland ice" which appears written across the chart at this place, we find, as shown by the photographs, ranges of mountains stretching across the island to North fiord (Figs. 4 and 5).

I cannot resume my seat without attempting to bring home to you something of the beauty and delicacy of the colouring, which is such a characteristic feature of midnight scenery on the coast (Figs. 6 and 7). The photograph (Fig. 6) was taken about 1 a.m., while cruising along the shore of King's bay, threading our way in the whale-boats through the countless icebergs broken off from the front of the King's glacier.

Prof. BONNEY: I am not going to say a word about Spitsbergen, because I am one of those most unfortunate people who have not seen it. I shall only venture a remark or two on a comparison which my friend Sir Martin Conway made between Spitsbergen and the Alps. I very much doubt whether it is possible to explain the general structure of the higher valleys in the Alps as he has done by reference to Spitsbergen. It seems to me that you cannot make any comparison between a district comparatively narrow in regard to its height with one like Spitsbergen, which is carved out of a kind of plateau. And, in addition to that, I may say that the present Alpine valleys seem to me to follow the ordinary lines of denudation, and resemble valleys that have been excavated by water in most parts of the world. But the fact is that so much sculpture work has been done on the Alps since the time they first began to rise that it is almost impossible to conjecture what their original structure was. I think that slight resemblance which he detects in one or two places to a plateau country, is the effect of the two disturbances the central Alps underwent while they were assuming their present form. In that district the great disturbances of the second elevation were concentrated on the northern side, and this no doubt had the effect of throwing that range rather abnormally high, giving a sort of trough between it and an outer range, which may at one time have been the actual crest of the ridge. But I do not think it possible that we can regard the lower Aletsch glacier as made by a small glacier eating back into the main upland valley which once, he presumed, drained towards the Rhone. Because of this—the structure of the Alpine valleys is certainly pre-glacial; that you can see in every part. You may notice it in the Pontresina district, and in the Val Bedretto. You can see in those very hard rocks that the glaciers have been down in that narrow V-shaped valley almost in the water's edge. Well, in addition to that, when you come to look at the cirques in the limestone districts, one cannot see how those can have been eaten back very appreciably if their beds were filled with *névé*, and further, it is evident from the way they are connected with the valleys, that if the valleys themselves were occupied down to their present beds by ice, so too the beds of the cirques must be occupied. But it may be said, perhaps, there were glaciers before the days of the great ice-age. No doubt, but still, were they glaciers of much importance? When the Alps were first upheaved, the temperature of Switzerland must have been at least 16° higher than it is at present. The effect of that would be to change the position of the snow-line, and, assuming the Alps to be at their present elevation, if the mean temperature were 16° higher than it is at present, you would practically have no glaciers at all, because the snow-line would be about 13,000 feet. With

that it would be impossible to talk of this cutting. No doubt the temperature fell steadily to the ice-age, but my point is that, putting the two things together, namely, the valleys having existed before the ice, and the improbability of there having been any great masses of ice, it is very improbable that material changes, such as the tapping of that upland valley by ice now forming the lower portion of the Aletsch glacier, ever would have occurred. I think, therefore, my friend Sir Martin Conway has really tried to stretch a truth to rather more than it will bear. He has, no doubt, spoken of what is a true cause in modifying the heads of glaciers, but I do think we cannot call it more than a secondary cause, and, at any rate, whatever may be its effect in Spitsbergen—and I cannot say anything about that, because I have not been there—I do not think it has produced any material effect in modifying the structure of the Alps.

MR. MARR: I have, in the first place, to thank the lecturer for his very able and interesting paper. Geologists are apt to state that geology is the geography of past times. Of course, you may at once retort that shows geologists are geographers not up to date. As it is rather late, I want to refer to one thing only, and that is that very charming diagram which Sir Martin Conway showed on the screen, the diagram where the glacier extended up the hillside, and was gradually robbing a larger glacier; the tear-drop extended until at last the whole of the hillside seemed to dissolve in tears. I would suggest, from a geological point of view, the robbery would have been better without the extension of the tears, for I believe that, although the glacier is largely responsible for draining off one valley system into another, the process is not due to the upper extension of the glacier, but to the action of the weather on the solid rock. The glacier is simply responsible for clearing away the *débris* which the weather has brought down, so that I fancy Sir Martin would make his case better if he did not put that upward extension in.

SIR ERASMUS OMMANNEY: As an old arctic navigator, I wish to express my admiration of what has been accomplished by this expedition. We are extremely indebted, I am sure, to Sir Martin Conway for striking out a new line of exploration in the arctic regions. Whatever we have done hitherto has been by coast navigation; he has had the courage to undertake the inland exploration, and to bring before us the physical features of the interior of Spitsbergen. Sir Martin Conway's experience as an alpine traveller has been able to provide us with the information he has brought us to-night. I believe that we have rarely had a traveller who has brought before us so vividly and so graphically all that he has seen. He has derived a vast amount of glacier information with such a very small party, from the highest elevations as yet attained in Spitsbergen.

DR. J. W. GREGORY: I have listened to the paper to-night with very great pleasure. It was my privilege two years ago to accompany Sir Martin Conway on the expedition to which the one just described was the sequel. Of the country which has been so graphically described by Sir Martin Conway, and which has been so beautifully illustrated by Mr. Garwood's lovely photographs, we caught occasional glimpses in 1896; in that year, as in 1897, the district appeared to be always bathed in sunshine, which was very tantalizing to us then, as we were nearly always wrapped in fogs. But last year Sir Martin Conway and Mr. Garwood had the benefit of the sunshine, and we have had the benefit of it to-night in the photographs which it enabled them to take. In regard to the geological theory in Sir Martin Conway's paper, I agree with the views expressed by Prof. Bonney, and I feel considerable doubt as to how far the agency invoked has been a valuable factor. No doubt it is a true cause, and must have some influence, but the question is whether it is the secondary or the primary cause of changes. The Alpine valley system in the main dates from pre-glacial times, and it is almost impossible

to ascertain how far the system has been modified by post-glacial changes. I heartily congratulate Sir Martin Conway and Mr. Garwood on their perseverance in returning to the country, and on the valuable results they have brought back.

Sir HENRY HOWORTH, M.P.: I have little to say except to emphasize what has been said so well already. I should like to add, however, that, being a member of Parliament, I have been delighted at the number of graceful adjectives these gentlemen have at command. In regard to the theoretical part of the issue raised by my friend Prof. Bonney and my friend Sir Martin Conway, there is this advantage—that what they have had to put forward is at all events consistent with the laws of physics and with the laws of ice-movement. Occasionally we have had to deal with some terrible theories which have been consistent with neither. The first paper I ever read in my life was when I was seventeen, when I read a paper before this Society on the areas of land that are rising round the two poles, which I mapped out and showed to be fairly continuous. One of the interesting points about Spitsbergen is this—that the evidence shows plainly that very recently the Spitsbergen archipelago has risen from the sea to a very considerable extent, and in that way its climate has been altered very much for the worse. Baron Nordenskiöld showed me some wonderful post-Tertiary shells he had found in Spitsbergen, and pointed out that those shells are not found in Spitsbergen now, but prevail in Southern Norway. This is another strong proof of the same fact. Just as the case of Greenland, where we have the same recent change in climate attested by the fact of the land having risen in the first place, and secondly by the occurrence of similar shells. Possibly the most arctic conditions that ever existed in these islands are not in periods that have gone by long ago, but in the current period; and that while we were suffering from tremendous glaciers in the old days, it would appear—and that is the view of more than one recent Danish explorer in Greenland—that the climate and the temperature were very much more moderate than they are at present in these high latitudes. I must, in conclusion, again repeat how delighted we have all been, both at the graceful discourse and the photographs, and I would say, that if ever I travel in these regions, there is no person other than my wife with whom I would rather travel than with one or other of these two graceful persons.

The CHAIRMAN: I think, at this late hour of the evening, it is almost time to close the meeting. I therefore ask you to allow me to return thanks to Sir Martin Conway for his eloquent lecture. We must all admire the way in which he attacked Spitsbergen, and he has brought the results of his journey before us in a very pleasant manner. I hope you will allow me to include in the vote of thanks Mr. Garwood, whose photographs have given us better pictures of the country than we have ever seen before; in fact, I think they are amongst the best photographs of arctic scenery that I have ever seen at the Society's lectures.

MR. FRAZER'S PAUSANIAS.*

By the Rev. H. F. TOZER.

A NEW edition of Pausanias' 'Description of Greece,' in which that work should be illustrated by the light which modern discovery has thrown on the subjects with which it deals, has long been a *desideratum* among

* Pausanias' 'Description of Greece.' Translated with a commentary, by J. G. Frazer. In six volumes. London: Macmillan & Co. 1898.