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JOURNEY ACROSS THE INLAND ICE OF GREENLAND FROM EAST TO WEST.

(Read at Meeting of Society, Edinburgh, 1st July, 1889.)

BY DR. FRIDTJOF NANSEN.

(With a Map.)

SINCE Greenland was discovered about nine hundred years ago, the interior of that continent has remained a mystery to Europeans as well as to the Eskimos, and many are the opinions and suggestions which have been put forward as to its real nature.

Our forefathers, the old Vikings, who first discovered Greenland, maintained that it was only the land near the coasts which was not ice- and snow-clad, whilst the interior was covered with a sheet of ice so thick that only in some few places could you see the ground underneath. This is, indeed, a fairly correct view, and until quite recently nobody knew more of it than this.

Many attempts have been made to penetrate into this mysterious interior. I shall here briefly mention only a few of them.

The first expedition known of was one undertaken in the middle of last century by a Dane, Paars, who was a major in the Danish army, and the first and last Governor of Greenland. He was sent by the Danish Government, with an escort of about twenty soldiers, with wives and children, twelve horses, guns, etc., and was ordered to cross Greenland on horseback from the west coast, and when he reached the east coast to build a fortress, found a colony, and take care of the old Norsemen who were thought still to survive. I need not tell you that this expedition only reached the inland ice and returned filled with horror. Major Paars wrote a very vivid description of all the dreadful dangers

that would be encountered on an expedition on the inland ice of Greenland. The impossibility of crossing Greenland was at once settled. Notwithstanding this there have been a great many attempts since that time.

Another Scandinavian, Dalager, who also lived last century, was more fortunate, and really walked over the ice several miles. Several Norwegians and Danes have also made the attempt this century, but did not succeed. In 1867 two well-known Englishmen, the famous alpinist, Whymper, and Dr. Robert Brown, also tried to penetrate into the interior, but were unfortunate; they met with very difficult ice, and were obliged to return some few miles from the coast.

More fortunate were the following expeditions:—that of Baron Nordenskiöld in 1870; the Danes, Captain Jensen, Kornerup, and Groth, 1878; Nordenskiöld again in 1883; and the American Peary with the Dane, Maigaard in 1886. These last reached about 100 miles from the coast, and a height of about 7500 feet.

All these attempts were made from the west coast, but from the little-known east coast nobody had tried, so far as is known.

How the plan of my expedition across Greenland was ripened in my youthful brain I shall not try to explain here. I got the idea one day in 1882, whilst on board a Norwegian sealing-ship we were ice-bound for twenty-four days near the still unknown part of the east coast of Greenland, and from that time I could not get it out of my mind.

My opinion was that if you fitted out an expedition in a proper way it was not at all an impossibility to cross Greenland, and the very men for such an expedition would be Norwegian "ski-runners." The Norwegian snow-shoes called "ski" are just the thing for traversing snow-fields, and that snow would be found in the interior of Greenland I never doubted. But there was another thing which also in my opinion was of the greatest importance, and that was the place from which to start. If we started from the west coast of Greenland I was quite sure we should not be able to cross, for then we should leave "the flesh-pots of Egypt" behind us, and in front of us would be the ice-desert and the east coast, which is not much better, and when we reached this coast we should have to cross to the west coast to be rescued. Even if one could keep up his own spirit to this, he might not be able to force his men forward when the food began to decrease.

I thought the only certain way was to penetrate the floe-ice and land on the desolate and ice-bound east coast between 65° and 66° N. latitude, and start from here for the inhabited west coast; in that way we would burn all bridges behind us, it would not be necessary to force the men forward, they would certainly have no temptation to return, whilst in front of us we would have the west coast inviting us with all the comforts of civilisation. They had no choice, only "forward." Our order was, Death or the west coast of Greenland. In this way was it accomplished.

When I first put forth my plan to cross Greenland most people said I was either mad or tired of my life. Neither was, however, the case; and, notwithstanding all warnings, more than forty men offered to accom-

pany me. I selected three Norwegians, viz. Captain Sverdrup, Lieut. Dietrichsen, and a peasant, Kristian Kristiansen Trana. From Lapland I got two Lapps, Samuel Balto and Ole Ravna, who, I hoped, would in various ways be of use to us, but I was rather disappointed; they were good and strong men, though Norwegians would have done just as well, and in dangerous positions they were easily frightened.

I must here acknowledge the liberality of Mr. Gamél, of Copenhagen, who contributed largely to the expenses of the expedition.

In the first days of May last year the expedition started from Christiania, and went *viâ* Scotland and the Faroe Islands to Iceland, where, on the 4th of June, we embarked on board the Norwegian sealing-ship *Jason* for the east coast of Greenland.

The coast of Greenland was not, however, as easily reached as expected, the floe-ice occurring in larger quantities than it generally does. For six weeks we had to wander about among the ice between Iceland and Greenland before we could approach the coast, so that I thought it convenient to leave the ship.

At last, on the 17th July, we left the ship in the ice near Cape Dan, outside the Sermilik fjord. A salute from the guns of the ship announced to the solemn and silent ice-world surrounding us that we were burning our last bridge leading back to civilisation and comfort. From this moment we had to take our own way. It was with strange feelings that we six men parted from our friends on board the ship and steered our two boats into this desolate ice-world, which now was going to be our home for a long time. We had, however, all of us the best hope of succeeding; that dangers and hardships were coming we knew, but we felt sure that we would overcome them.

The first thing we had to do, and a very important thing indeed, was to reach land. But before we could do this, we had to force our way through an ice-pack of about ten or twelve miles' breadth, and this was one of the most difficult parts of the whole journey. I had originally hoped to penetrate the ice in one or two days, but we met with a quite unexpected strong and dangerous current, which pressed the ice-floes against each other, and where we had to take great care that our boats should not be crushed; to make things more difficult we got for some time fog and heavy rain. In spite of all this we advanced, however, for about twenty hours rather rapidly, towards land. I could see the stones on the shore, and was already quite sure of reaching it within a short time, when we had the misfortune of getting one of our boats crushed during an ice-pressure; it could not float, and we were obliged to take it up on a floe to get it mended. This required several hours, and in the meantime we were swept southwards by the rapid current; the distance to land increased rapidly, and the speed with which we were swept along was so great that it was in vain to try to struggle against it. We had nothing left but to take leave of the beautiful mountains and the glaciers round the Sermilik fjord, and to look out for another landing-place, or perhaps destruction in the floe-ice, with its capricious currents, which at times carried us towards land, and at times again towards the open sea. To make the position still more awkward, we got heavy rain, which wet us

through to the skin. We could do nothing better than pitch our tent on the ice-floe and creep into our sleeping-bags to take a sleep, which, after twenty hours' constant hard work among the ice, was rather welcome.

I shall not tire you with a description of our drift along the east coast of Greenland: how we dragged our boats over the ice-floes, how we worked hard and tried to force our way towards land, how, in the nights, with those charming Arctic sunsets which call forth in your mind all your most tender feelings and dreams of your childhood, how we then could be seen throwing longing looks towards that wild and beautiful coast whither our only longing was, but from which we were parted only by some few miles of vexing ice.

I will not tire you with a description of how often we hoped to land, how often we were disappointed, and how often we were nearly wrecked amongst the ice; the worst of it was, that the precious summer-time was passing away, and we were not able to use it; the difficulty of carrying out our plans grew greater every day.

That you may get an idea of what risks one runs in such ice-currents, I shall here only tell you of a day and night we had there. It was one morning we observed that we were rapidly carried by a strong current towards the open sea, where a heavy sea was coming from the east down upon us; it was in vain to try to drag our boats over the floe-ice against this current; it was inevitable that we must come into the dangerous breakers at the margin of the ice, where it was impossible to stick to the ice. The ice-floes were smashed to pieces all around us; our own floe was broken into several pieces; we had nothing to do but select the strongest ice-floe we could find in the neighbourhood and to prepare for a struggle for life as hard as possible. We selected a strong floe, brought all our things and provisions into our two boats, which were standing on the ice-floe; only our tent and two sleeping-bags were still left for use on the ice. Towards night all was ready; we were then some thousand yards from the open sea; we could only too distinctly see how the ice-floes were washed by the heavy breakers, so that everything was swept away, how they were broken to pieces and then almost crushed into powder; within a few hours we would be at the outside margin, there would be nothing left but to try to get our boats through the breakers and enter the open sea; but, as it was best to face this struggle with as fresh energies as possible,—all men were ordered to sleep except one, who should keep watch and call us when it would no longer be possible for us to maintain our position. While Captain Sverdrup took the first turn, we crept into our sleeping-bags, and, as we were tired—all of us—we fell fast asleep within a few minutes. Even the Lapps slept well, though they had been dreadfully anxious all the day, and were quite sure they had seen the sun setting for the last time; one of them, who did not find the tent safe enough, slept in one of our boats, and did not even wake when the breakers very nearly had swept the boat away, so that Sverdrup was obliged to hold it.

After some time I was awakened by hearing the breakers roar just outside the tent; I expected to hear Sverdrup call, or to see the tent swept away, but Sverdrup did not call and the tent stood; I heard the

thunder of the breakers for some time, but then I did not remember anything more. I fell asleep, and did not wake again until next morning, when I was astonished to discover that we had again approached land, and were far distant from the open sea.

Sverdrup then told me that our position had been rather awkward for some hours in the night; we had had a large mass of ice by our side, which threatened to crush our floe every moment, and the breakers swept over our floe on all sides—only the spot where the tent was standing was spared. Once he came to the tent-door to call us. He unfastened one hook, but then thought he would yet look at the next breaker coming: this was worse than the former one. He returned to the tent, unfastened one hook more, but thought it best to wait and watch what the next breaker would be like. He did not unfasten any more hooks. Just at the critical moment the current turned, and we were again carried towards land, away from the dangerous breakers.

On the 29th of July we landed at Anoritok, which is, however, not very far from the south point of Greenland, and is situated in $61\frac{1}{2}^{\circ}$ N. lat., consequently about 250 miles south of the place where we intended to begin our journey across the continent. It was then very late in the season: the best time of the short Greenland summer had passed away, and there was but little left. It would have been very easy to reach the Danish settlements on the west coast near Cape Farewell; northwards the floe-ice was pressed tightly against the coast all the way. We had to choose here between certain rescue in the south and the accomplishment of our plans, or perhaps death in the north. If I had asked my two Lapps I was sure of the answer—it would have been southwards on any conditions; but if I had asked my brave Norwegians I was just as sure that the answer would be northwards—we should not at any risk give up our plans. None of them were, however, asked. Arrived inside the ice, the boats were steered northwards without any order: there were no thoughts of giving up our plans yet, there still was left time enough to cross Greenland if we used our time well. I will never forget the sensations which possessed us when we passed the last floe that parted us from land; it was as if we had escaped a long and dreary prison and saw life lying bright and gay before us.

And certainly life was bright, but I will not say we had much comfort, or rather much time to enjoy it; the order of the day was to sleep as little as possible, eat as little and as quickly as possible, and to work as much as possible. Our food was water, biscuits, and dried meat; for cooking we had no time, though there was game enough. The ice was very difficult, we often had to break our way through it by help of axe and poles. It often looked almost hopeless; it would take us hours to advance some few feet, but we advanced, and that is always better than to go backwards, and I had five brave companions who would not give it up. On the way we met with several encampments of heathen Eskimos living on this desolate coast. We hoped to get some help from them, but they could not advance through the ice so well with their skin boats as we could with our wooden ones, and we were obliged to leave them.

At last, on the 10th of August, we reached a place called Umivik, where I thought it convenient to begin our ice journey. After having examined the glaciers in the neighbourhood and found a good way, and after having made everything ready, we left our two boats on the coast and started on our journey across the unknown interior of Greenland. Our destination was the Danish settlement of Kristianshaab, at Disko Bay.

We had five sledges; the load on four of them was about 200 lbs. each, and on the fifth about double as much. The last was pulled by Captain Sverdrup and myself, who took the lead, the other four members of the expedition following, each pulling one sledge. Our food consisted principally of dried beef, pemmican, meat-biscuits, dried bread, butter, *pâté de foie gras* (not the Strasburg luxury), meat-chocolate, common chocolate, tea, etc. Besides provisions, we had on our sledges scientific instruments, guns, Norwegian snowshoes (called *ski*), Canadian snowshoes, Alpine axes and walking-sticks, Alpine ropes, one tent for all six, and two sleeping-bags of reindeer skin. As we slept three men in each bag, they were very warm; and we could stand the very low temperatures we had in sleeping on the snow.

Notwithstanding the very steep slopes we had to climb, and the many crevasses, etc., we advanced rather rapidly for two days; then we were stopped by a storm from the north, with heavy rain, and we had to stay in our tent lying down in our sleeping-bags for three days, while the ice melted rapidly under us, and the rain poured down above.

At first the snow was very uneven, but hard and good for sledge-pulling. There were plenty of dangerous crevasses, so that we had to be vigilant: no accidents happened, however. Occasionally some one fell up to the arms through the snow-bridges by which we had to pass over the large crevasses, but by help of the Alpine axes a deeper fall was prevented.

At some distance from the coast, however, the snow became very soft, and bad for pulling, and our difficulties went on increasing: the snow became looser, and the pulling was very hard work, even if we had not had a continuous snowstorm beating against us. I hoped that it would soon become better, but each day it became worse. It was only too clear that if it continued in this way we would not be able to reach Disko Bay till the middle of September, when the last ship left for Europe. We should thus have no hope of returning home the same year (1888) if we continued our way to Kristianshaab. We should probably have more hope of reaching a ship at Godthaab, situated further to the south, on the west coast of Greenland; and as I thought this direction to be of more scientific interest, I changed our route and turned towards Godthaab, though I expected to find more troublesome ice in this direction, and though it would be much more difficult to reach the Danish settlements for rescue after leaving the inland ice. That was on the 27th of August. We had then reached about $64^{\circ} 50' N.$, about 40 miles from the coast, and a height of about 7000 feet. By this change of direction the wind became so favourable that we could use sails on the sledges, and thus they became less heavy to pull. In this manner we advanced during three days; then the wind went down, and we were obliged to lower our sails.

In the beginning of September we reached a quite flat and extensive plateau, which resembled a frozen ocean. Its height was between 8000 and 9000 feet, though towards the north it seemed to be considerably higher. Over this plateau or high land we travelled more than two weeks. The cold was considerable. I am not, however, able to give an exact statement of the temperature, as our thermometers did not go low enough. I believe that on some nights it was between -45° and -50° Centigrade (between 80° and 90° below freezing-point, Fahrenheit). In the tent where we (six men) slept, and where we cooked our tea and chocolate, it was even less than -40° Centigrade (72° of frost, Fahrenheit). During one month we found no water. To get drinking water we were obliged to melt snow either in our cooking apparatus or by our own warmth in iron bottles, which were carried inside our clothes on our bosoms. The sunshine on these white snow-fields was bad for the eyes, but no case of snow-blindness occurred.

To give a description of the scenery during the day in this region is easy. We saw only three things: that was snow, sun, and ourselves. One day was quite like another. But still, even this part of the earth has its beauties, and I shall never forget the glorious sunsets and the nights on the snow- and ice-fields of Greenland, when the ever-changing northern lights were scintillating perhaps brighter than anywhere else. I shall never forget the strange impressions, as from another world, we derived in this solemn, silent nature, as we saw the lights spreading like a terrible fire over the whole sky, then gathering again in the zenith, as if swept together by a storm, always flitting, burning, and scintillating, and then at once disappearing, leaving the monotonous snow-fields in darkness as they were before.

Another more soothing and peaceful impression came upon us when the moon appeared and made its silvery way over the limitless snow-fields, over which the stars were sparkling with a brightness unknown in other latitudes. Indeed, I am certain that none of us will ever forget our night wanderings over the snow-fields of Greenland.

The landscape was not always, however, so peaceful as here described, sometimes we met snow-storms, and you often saw nothing but drifting snow. One day, the 8th of September, we were even obliged to remain in our tent, whilst it was nearly torn to pieces by the storm; the next day, when we wanted to continue our journey, we found that the tent was almost quite buried in the snow. We had to dig ourselves out through the snow, and we had to hunt for our sledges, which had quite disappeared; that, however, was very often the case in the mornings.

As to our daily life in these inhospitable surroundings, with a temperature of 70° to 90° of frost, Fahr., I shall not tire you with a particular description of that. I shall only say that we stood it pretty well.

The worst thing was to turn out in the morning. It sometimes happened that I found my head in the sleeping-bag surrounded by a crust of ice and rime caused by the freezing of my breath. To turn out an hour before the others to cook, and be obliged to touch iron articles and get spirits of wine on your fingers, was not very agreeable. I had

this pleasant work every morning, as the others, when they tried it, generally used too much fuel, and we had to be careful in that respect, as we could not get any water without fuel.

As to cleanliness, we could not afford to indulge much in that luxury. I am afraid you will consider me a thorough barbarian when I tell you that we did not wash ourselves from the time we left the ship *Jason* until we reached the west coast, that is, during two months and a half, and during that time we were never out of our clothes. That we did not wash had, however, its peculiar reasons: on the one hand we had no water; but, on the other hand, even when we had it, washing was strictly forbidden, as the washing of the face is very injurious on snow-fields, where the sun is constantly shining; the skin is easily blistered, and the sun can cause you dreadful pains.

Our cooking was not always of the tidiest character; we had no water to wash our cooking vessel, and when we had cooked pea-soup in the night, we had to cook tea or chocolate in the same vessel next morning, with the remains of the pea-soup in it. It was, however, rather good, as we could not afford to throw away anything in the nature of food, neither were we very particular about what we got to eat. I remember one night our cooking apparatus was upset, and all our precious pea-soup was poured out over the canvas floor of our tent; but we did not hesitate: we immediately took hold of each side of the floor, lifted it up, and sucked the pea-soup out of the middle. No drop was lost. We were compelled, in fact, to live like natives. Mashers, I fear, would not succeed in the interior of Greenland.

On the 19th September we got a favourable sailing wind, so that we could use sails on our sledges. We had only to stand on our *ski* and hold on to our sledges, while we rattled down the slope towards the west coast, sometimes with a speed quite astonishing. Certainly that was the most delightful ski race I ever had in my life.

Towards night, when it was getting dark, and as we were travelling at a good speed, I observed a dark spot in front of us. I did not understand what it was, but went straight ahead. At a distance of some few steps further, however, I discovered that it was a broad crevasse; the sledges were immediately turned just at the right moment; we were already on the margin of the crevasse; a second longer and the three of us leading with two sledges would have disappeared, and nothing would have been heard of us any more.

We had to be more vigilant after this. When the night came, we would use the favourable wind as long as possible, and as we got moonlight, we could sail on for a very long time. I went in front examining the ice, and the sledges came sailing afterwards. We had to pass many crevasses, but no accidents happened. Once, however, a snow-bridge over a very deep and broad crevasse fell down just when we had passed over, and very nearly took with it two men and two sledges. In the middle of the night we were at last stopped by ice so filled with crevasses that we could not advance any longer, and we had to pitch our tent and go to sleep. We were now very near the coast, but met with ice so difficult and uneven, and filled in all directions

with immense crevasses, that we could advance only very slowly. At last, on the 24th of September, we reached land at a small lake to the south of Kangersunek, a fjord where a large glacier issues.

On the 26th September we reached the sea at the inner end of the Ameralik fjord, in $64^{\circ} 12'$ N. lat. I shall never forget what pleasure and enjoyment it was to get water again, so that we could drink as we liked—no wine could have tasted better; and what a comfort it was to have any quantity of fuel, willow, and heather, so that we could make an open fire in the night and cook as much as we liked!

We had now reached our destination—the west coast of Greenland. The distance we had passed over the inland ice was about 260 miles. The interior of Greenland was explored, at all events in one direction, in spite of the general opinion that it was impossible to penetrate it. We had now only one thing left, and that was to get into communication with other human beings. This it was desirable to do as soon as possible, as we had not very much food left; we had plenty of dried beef, but we suffered from want of fat. But Godthaab, the nearest place where people lived, was still a distance of 50 miles away. As I saw that it would be no easy task to reach this place by land, the mountains being too difficult to pass, I thought it better to go by sea, and determined to make a boat. The next day three of us made a boat out of the canvas which formed the tent floor, of the bamboo rods used on the sledges, and willow boughs found near the shore. Towards night our boat was ready.

Next day, September 28th, Captain Syerdrup and I started with this boat for Godthaab. The first portion of the way we had to carry it, as the fjord is filled with glacier mud. This was rather a heavy task, as we often sank into the mud up to our knees. Next day we reached open water and got out of the Ameralik fjord. For some days we got contrary winds, and the boat was very heavy to pull against wind and sea, it being too broad as well as short. On the 3d of October we reached Godthaab, and were heartily welcomed by the population. Two boats were sent to bring the other four members of the expedition to Godthaab. Being stopped by a heavy storm, these boats were, however, obliged to wait for several days. At last, on the 12th of October, they arrived, and all of us were assembled in Godthaab. The expedition was finished, and Greenland was crossed for the first time.

My hope to find in Godthaab a ship for Europe was disappointed. I, however, learned that at Ivigtut, about 240 miles south of Godthaab, there was still a ship, the *Fox*, which in the middle of October was to leave for Denmark. I sent immediately a messenger (an Eskimo in his small skin-boat or kajak) to the *Fox* to ask the captain to come and take us home. As the season was very late, and as the captain of the *Fox* did not know how much ice there was towards Godthaab, he dared not come, and we were obliged to spend the winter in Greenland. Strange to say, this ship, the *Fox*, which brought the message to Europe that we were safely arrived at the west coast of Greenland, is the same ship which Sir Leopold M'Clintock commanded on his famous expedition in search of Franklin.

To spend a winter in Greenland was not very disagreeable to us. We had a pleasant time of it: there was plenty of shooting, sea-birds, ptarmigan, and reindeer; there was snow enough to enable us to use our *skis*. But the most fascinating of all was the life in the kajak—this small Eskimo skin-boat, only capable of holding one man, which certainly has not its equal, and is the best one-man vessel in the world. It is propelled by a paddle, and when you have learnt to manage it properly, you may go against the heaviest storm. If you are capsized by a sea, and can manage your oar, you can rise again and need not be afraid of anything. A skilled Eskimo can, in his kajak, go even 80 miles in one day.

For one who cannot manage his kajak easily it is rather a dangerous sport, and many Eskimos perish in the kajak every year; in Godthaab and neighbourhood six were thus drowned this winter,—but that is one of the reasons, perhaps, why kajak-sailing is so fascinating.

On the 15th of April this year the Danish steamship *Hvidbjørnen* came to bring us home, and we left Greenland, almost sorry to part from its happy people,—those children of nature, who have no experience of the miseries of civilisation, and who do not know real poverty. Sometimes they are in want, but generally they have plenty of food, and are always happy and content.

The voyage homewards was as pleasant as possible.

The scientific results of the expedition cannot at present be stated, the many observations not having been worked out by the specialists to whom they have been submitted. There are, however, some points which, especially in geological and meteorological respects, even at present are prominent; and though I am no geologist and no meteorologist, I shall mention some of those which to my mind are of much interest.

And first, I think the shape of the inland ice is of importance.

Many geologists have suggested that the interior of Greenland was ice- and snow-clad, but there have been others who were of the opinion that it was not snow-clad. Amongst the latter I will here especially mention the famous Nordenskiöld.

This prominent explorer of Arctic regions, who has seen more of ice- and snow-fields than most people, held the opinion that we are not entitled to conclude that the ice-covering extends throughout Greenland from coast to coast, notwithstanding that nobody had seen the boundaries of the “ice-desert.” He even believed “that it in most cases is a physical impossibility, that the interior of a large continent should be completely covered with ice under the climatic circumstances which occur on our planet south of 80° latitude.” As to the interior of Greenland, he says that it is even easy to prove that the conditions for the forming of glaciers cannot occur there if the surface of the land does not gradually and regularly rise from the east coast as well as from the west coast towards the centre. But, in Nordenskiöld’s opinion, no continent, the orography of which is known, has such a shape. Greenland he supposes to have an orographical embossment very much like Scandinavia; that is, it consists of mountain ranges and peaks separated by deep valleys and plains. As, in such a country, most of the rain and snow must fall in the neighbourhood of the coasts, whilst the interior is reached only

by dry and warm winds, there cannot be moisture enough to form a glacier there.

I will not here criticise Nordenskiöld's theories. The expedition from which I have just returned has, in my opinion, fully proved that they cannot be right as far as concerns Greenland. It is, I hope, proved that Greenland is not only ice- and snow-clad, but has a mighty shield-shaped covering of snow and ice, under which mountains as well as valleys have quite disappeared, and where you cannot even trace the configuration of the land and mountains. Whether this is also the case in the most northern parts of Greenland I dare not yet say; this must be decided by a new expedition, which would be of the highest interest.

At present we will only consider the southern parts of Greenland. The ice-covering has here, as already mentioned, the shape of a shield. Rather rapidly, but regularly, it rises from the east coast; reaches a height of 9000 to 10,000 feet; is rather flat and smooth in the middle; and falls again regularly towards the west coast. Considering this peculiar and uniform shape of the ice, the first questions that must force themselves upon us are, What has occasioned this uniform shape? what is the configuration of the land underneath?

I have heard geologists say that, judging from what has been observed by us, it is clear that Greenland is a tableland, the exterior parts of which are only excavated by the glaciers, so that fjords and valleys are formed, whilst the interior evidently has the shape of a high plateau, where no considerable valleys or mountains can be present, there being no glaciers to excavate the ground.

I think this conclusion is entirely false. I think that the shape of the surface of the inland ice is not at all caused by the configuration of the land underneath.

Nordenskiöld is certainly right when he says that the configuration of Greenland is very like that of Scandinavia, and especially that of Norway, and let us also say that of Scotland.

In the interior of Greenland, as well as near the coast; there must be mountains and valleys, just as well as here. That on the coasts there are formed deep fjords and lofty mountains very like those of western Norway we already know; they have just the same wild and prominent character in some places; they are perhaps even wilder than those I have seen in my own country.

If we entertain the opinion that these fjords are excavated by the ice, we must also conclude that the same ice has been able to excavate valleys and form mountains in the interior of the continent; to this subject I shall, however, return a little later. At present I will only state, that we have no right to attribute the reason of the shield-like shape of the ice to the configuration of the land underneath; the surface of the ice must have a shape of its own, which is given not by the land but by the meteorological conditions. Nobody can deny that the ice must in some places have quite an enormous thickness, as it fills the valleys and covers up all the mountains, and its thickness must evidently be regulated by the quantity of snow falling. This quantity must be largest

towards the coasts, gradually diminishing towards the interior. It is consequently very likely that the ice has not its greatest thickness just in the middle of the continent, but rather on both sides towards the coasts. We might thus already, *à priori*, have expected to find the shape of the ice just like that observed.

I have already mentioned that the surface of the snow-field in the interior is quite even and, as it were, polished. It has a striking resemblance to the undisturbed surface of a frozen ocean, the long but not high billows of which rolling from east to west are not easily distinguishable to the eye.

The principal agent which makes this surface so remarkably even is the wind. The levelling influence of the wind may easily be studied in our own mountains in the winter; there it may be seen how its prevailing effect is to remove every prominence: the snow is carried from the mountains into the valleys; it fills them and makes the mountains disappear.

This has of course also been the case in Greenland, only to a much larger extent, when its present glacial period commenced. The snow increased annually; gradually the valleys were filled up, the mountains disappeared, and the snow-field was produced which we now see. The work of the wind now is to level and polish the surface of this vast field, and make it as smooth as the surface of a lake in quiet weather, where you find no spot to fix the eye upon or where you can let it rest, where you have to use your compass just like you do at sea.

The surface of the snow-field in the interior consists of soft, loose and dry snow, which is easily moved by the wind. Even in mid-summer there is no snow-melting of importance in the interior. Even with the six-foot-long sticks we use for *ski*-running, I could not reach hard ice or snow underneath the soft layer. At intervals of six to ten inches quite thin ice-crusts occurred; between them there was, however, soft snow like that of the surface. These thin ice-crusts are evidently formed by the direct influence of the sun during midsummer. The sun in the middle of the day is then able to make the surface of the snow to melt a little; in the night, however, it freezes again. Whether these ice-crusts at certain intervals indicated annual layers of snow, or whether they only indicated heavy snowfalls during the summer, I am not able to decide; I am, however, inclined to hold the latter opinion, at all events to some extent.

I previously mentioned that we had snowfalls almost every day. When we compare this with the fact just stated that there is no real snow melting in the interior, it would seem as if we were obliged to conclude that the quantity of snow is still increasing in the interior of Greenland. This cannot, however, easily be the case, at all events not in any considerable degree, for if it were so, the quantity of ice and snow must also increase towards the coasts.

Judging from the observations and measurements which, during several years, have been made on the west coast of Greenland, it seems, however, as if the ice varies a little from one year to another, but that upon the whole its quantity keeps very nearly on the same level. We are not

thus entitled to assume that the quantity of snow is increasing in the interior.

But what is the reason why it does not increase?

As already mentioned, the snow-melting cannot be of any importance. The evaporation from the snow-surface cannot, in my opinion, be of much more importance, as it must be quite a trifle with such a low temperature of the air, and where most days a little snow falls. A factor of more importance is, I think, the snow-drifts occasioned by the wind, which very likely has a disposition to blow from the cold and high interior towards the lower and warmer coasts. In the middle of the continent the winds blow, however, in all possible directions, and thus even this factor is of no great importance. The principal factor in maintaining the level must, in my opinion, be the pressure which is produced within this immense layer of ice and snow. This pressure forces the ice downwards along the sloping sides of the mountains, through the valleys and towards the sea, into which it falls in form of ice-streams or glaciers, and is carried away in form of icebergs or is melted.

To a great many people it does not seem necessary that the ice must force its way to the coast in this manner, but I think that if we said that the interior of Greenland was filled or covered by an immense layer of pitch, nobody would doubt that this would find its way to the sea; yet, there is really in that respect no great difference between these two materials; by the immense pressure the ice is probably made even more viscid than melted pitch. But the pressure brings the ice to the sea not only in the form of ice, but also, and certainly in larger quantities, in the form of water. As is generally known, ice has the peculiarity that by pressure it can be transformed into water. At a certain depth we must therefore expect to see the ice thus transformed.

ON MARINE DEPOSITS IN THE INDIAN, SOUTHERN, AND ANTARCTIC OCEANS.

(With a Map).

BY JOHN MURRAY, LL.D., PH. D., etc.,
of the *Challenger* Expedition.

IN an article published in this Journal for November 1887 I gave some account of our knowledge of the deeper regions of the Indian Ocean, with special reference to the investigations carried on by Captain J. P. Maclear in H.M.S. *Flying Fish* during 1887.

Since that time extensive additions to our knowledge of the bathymetry and physical conditions of this ocean have been made by Captain Pelham Aldrich in H.M.S. *Egeria*, and by Captain A. Carpenter in H.M.S. *Investigator*. Through Captain Wharton, the Hydrographer of the Admiralty, I have received details of these investigations, and also the most excellent and valuable series of deposits collected with care by Captain Aldrich. These samples of the marine deposits have been submitted