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The North Polar Problem: Discussion

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Another thing with regard to the mode of investigation of the arctic regions which our expedition learned was perhaps this—that even with small means good results can be obtained. By acting on the hints given by the Eskimo, and pushing forward with “kayaks,” sledges, and dogs, one is enabled to penetrate into and cover considerable distances in regions which have hitherto been considered very difficult of access. In this way the drift-ice itself can be travelled over at a considerable distance from land—even where it is in motion; and I think this must be one of the ways in which it should be endeavoured to investigate the great unknown region between the North American arctic archipelago and the pole. Here, no doubt, many interesting problems are awaiting their solution. May a not far-distant future see those tracts traversed by human feet!

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### THE NORTH POLAR PROBLEM.\*

THE PRESIDENT: When Dr. Nansen was so good as to read us the interesting account of his expedition last month, owing to the peculiar circumstances of the occasion we were unable to take the usual discussion of the paper at that time. I therefore propose that we should take it this evening, and I shall read a short paper intended as a hook upon which the discussion may be hung.

It has taken centuries to obtain even a very general idea of the north polar region. Three centuries ago Mercator adopted the theory, which was derived from the mysterious Nicholas of Lynne, that four great rivers flowed down a chasm at the pole. Later there was Maury's theory of an open polar sea; and the most recent opinion that has prevailed was that the polar sea was shallow, with land, in the form of islands, extending north from Franz Josef Land.

Facts could not keep pace with theories, but they have gradually and painfully refuted them, and revealed to us the truth. It has long been known that a great stream of heavy ice flows down the east coast of Greenland. The archipelago of ice-capped islands, known as Spitsbergen, had its general outline made known by British seamen 270 years ago; and more recently it has been ascertained that the sea to the north of it is of great depth; while warm currents, proceeding from the Gulf Stream, flow up the Spitsbergen western coast, and eastward to Novaya Zemlya. The coast of Siberia was also known to be bordered

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\* Report of a discussion at the Royal Geographical Society, March 22, 1897. Map, p. 588.

by a sea of comparatively light ice, with frequent *polynias*, or pools and lanes of water, described by Wrangel, even in the winter.

The American side of the polar sea was gradually discovered to be of a very different character. Collinson found that very heavy ancient ice formed the pack from Bering strait to Franklin bay, only a narrow lane being kept open by the current of the Mackenzie and Colville rivers, between the land and the pack. M'Clure discovered that the same ancient ice extended along the whole western shore of Banks island. The surfaces of the floes resemble rolling hills, caused by the accumulated action of repeated thaws and the almost constant fall of snow on the upper surface, giving it a peculiar hill-and-dale appearance. Mecham found the same ancient ice along the western shore of Prince Patrick island. He described it as "tremendous," and he came to the conclusion that the sea on which it floats was of great extent. Parry met with this ancient ice when he attempted to go westward from Melville island, and it flows down McClintock channel south-east until it impinges on the coast of King William island. This stream was met with by Sherard Osborn and Vesey Hamilton on the western shore of Prince of Wales Land; and it stopped the progress of Sir John Franklin's ships to the American coast. Sir George Nares's expedition met with the same ancient ice extending for 300 miles along the northern coasts of Grant Land and Greenland. It was found to consist of small and rugged floes, separated by ranges of hummocks, from 30 to 50 feet high. The surfaces of the floes were studded over with rounded blue-topped ice-humps, the depressions between them being filled with snow, deeply scored into ridges by the prevailing wind. Every indication pointed to the conclusion that there was no land to the northward. But the sea was supposed to be shallow, because there were only 72 fathoms of water at a distance of 40 miles from the shore, and because the positions in which driftwood was found furnished an argument that there had been a general recent upheaval of the adjacent land. Huge masses of grounded ice, along the shore, were believed to have been broken off from large floes of ice, and were called "floe-bergs." The floes themselves are of enormous thickness, formed by continual accumulations from the annual snowfalls, which, by the increasing additions from above, are gradually converted into snow-ice. The process of formation of this ancient ice thus resembles that of glaciers, and the ice broken off from it has all the character of icebergs. It is deduced, from similarity of tides, direction of prevailing winds, and movements of the ice, that the line of ancient ice continues south-west to Prince Patrick island. The same reasons exist for the belief that Greenland does not extend far to the north, and this view is also confirmed by Prof. Houghton's study of the tides. The ice is subject to annual disruption during the summer months, and is in motion, driving backwards and forwards with the winds and currents, its main course being towards the east.

We thus find that this line of ancient ice extends from Bering strait to the north coast of Greenland, a distance of 1200 miles, for that it is continuous across the gap of 400 miles between Prince Patrick island and Aldrich's farthest is deduced from the coincidences of winds, tide, and drift. The fact that the heavy ice actually reaches the western part of the North American coast seems to indicate that there are no intervening lands, of any extent, to the westward of Prince Patrick island.

The discovery of Franz Josef Land brought to our knowledge a group of volcanic islands of the same geological period as Spitsbergen, approaching Spitsbergen closely at its western end, and on the same bank; in short, a continuation of the Spitsbergen group. Beyond this bank, the European polar sea was found to have a depth of 2000 fathoms south-east of Jan Mayen, 2650 fathoms between Spitsbergen and Greenland, and 1370 fathoms north of Spitsbergen. It was a correct deduction to assume that to the north of Franz Josef Land, which is but a part of the Spitsbergen group, there is the same deep polar sea.

There is an eastward drift of the ice on the coast of Grant Land; and it was assumed that there was a general drift of ice across the polar basin from the eastern to the western hemisphere, as well as a drift from left to right, due to the flow of warmer water into the polar area, which, as a cold current, seeks an outlet southward at every opening, owing to the polar area itself being surcharged, but only finds it for the ice it bears on its surface along the east coast of Greenland. The warmer water comes to the surface along the Siberian coast, and, aided by the outflow of the Siberian rivers and the prevailing winds, forms a current northwards across the polar area.

These were the conclusions which were derivable from the facts within our knowledge before the departure of Dr. Nansen. His return, with the rich fruits of his expedition, has thrown new light on the whole question, and, as I said on a former occasion, the north polar problem begins to take definite shape. Nansen's chief discovery is that there actually is a very deep sea north of the Franz Josef group, continuous with that which was known to exist north of Spitsbergen, and that this deep sea has a relatively warm temperature in its depths. He ascertained that the time occupied by the ice, in drifting across the polar basin on the parallels of the track of the *Fram*, is a little over three years, and that the ice-bearing ocean extends at least as far as the pole. For the *Fram's* track southwards to Spitsbergen leaves a great width thence to Greenland, down which a vast volume of ice drifts, which must necessarily come from a region north of the track of the *Fram*.

The question remains to be decided whether there is land of any extent in the vast unknown region between the Parry islands and the

New Siberian group. At one time I held the opinion that a chain of islands probably did exist, extending from the neighbourhood of Prince Patrick island towards Wrangel island. This opinion was solely based on considerations connected with the apparent line of Eskimo migration from Melville island to Greenland, as indicated by a continuous series of remains. But I now concur with Dr. Rink that these vestiges are due to visits from the American continent in times past. The presence of the ancient floes of heavy ice along the north shores of the American continent is evidence that no land of any size exists to the northward, on the meridians from Bering strait to Franklin bay. In fact, I am disposed to regard the whole line of heavy ancient ice which presses upon the shores of the American continent, of the Parry islands, and of the northern side of Greenland as evidence of a continuous drift from the eastern to the western hemisphere, across an ocean uninterrupted by land of any magnitude.

The presence of warmer water in the depths of Nansen's polar sea is an important discovery. It commences 100 fathoms below the surface, and extends down to 250 fathoms.\* If this warm current originates in that which flows up from the North Atlantic, Prof. Mohn has observed that its greater salinity, and consequent greater density, would keep it in the depths when it cools down, while the water from the great rivers would be much lighter, and continue on the surface. But there are, I believe, other opinions respecting the origin and eventual destination of this warmer undercurrent in the polar ocean, respecting the part it plays in the economy of that ocean, and respecting the causes of its long retention of some of the warmth derived from the equator.

The study of the currents, and still more of the meteorology of the polar ocean, as observed on board the *Fram*, will certainly throw further light on the polar question, for the observations are continuous during three years. Moreover, they cannot fail to have a practical bearing on atmospheric problems further south, and to increase our knowledge of the causes which influence meteorological changes. Much importance must also be attached to the magnetic observations taken by Lieut. Scott Hansen, after receiving instruments and instruction from Prof. Neumayer, of the "Seewarte" at Hamburg. Our knowledge of terrestrial magnetism is very incomplete, especially as regards the polar, and more particularly the south polar, region. Apart from the practical importance of the magnetic observations, it may well be that the curves of inclination, when plotted, may, with reference to points of greatest intensity, indicate the presence or absence of land over parts of the polar area.

The distribution and limits of animal and vegetable life is another help to a solution of the problems connected with the polar region.

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\* Surface,  $-1.6^{\circ}$  C. ( $31.70^{\circ}$  Fahr.); 100 fathoms,  $+0.8^{\circ}$  C. ( $33.44^{\circ}$  Fahr.).

Diatomaceæ and other minute organisms are reported to be abundant, but the larger forms of animal life appear scarcely to exist on the sea of ancient ice. Nansen's expedition only saw little auks which live in the lanes of water formed by the drifting ice, and a few dovekeys, and the only cetaceans were narwhals. Yet wherever there is land the land-arctic forms are met with, and the absence of flights of land-birds, such as Brent geese, to the northward, is an indication of the absence of land. The great polar sea is probably a sea without islands, and if so, it is a sea of solitude.

Looking back into past ages, we may discern the evidence of great changes in the polar area, as throughout the Earth's surface. The Spitsbergen archipelago, including Franz Josef Land, seems to be the broken fringe of a continent which, in the Jurassic age, was clothed with pine forests. At a still later period there was abundant arborescent vegetation in Grant Land, and it is probable that the conditions within the vast area of the polar ocean were then very different. From a geological point of view, there is much food for reflection, based on the knowledge we already possess respecting the north polar region; and much further research is needed, especially with regard to the upheaval of the land, which is reported from so many directions. A geological point of special moment is the extent to which the polar phenomena of an extensive land mass in the south, and a deep ocean in the north, are illustrative of and explicable by the theory of earth-folds.

In reviewing the whole polar question, it will be seen that great progress had been made towards its solution, in various directions, before the departure of Nansen's expedition, but only fragmentarily and by side lights, while even the collected facts were often misinterpreted and misunderstood. I consider that the light thrown upon it by Nansen has not only extended our knowledge positively, but has had the effect of piecing together what appeared before to be fragmentary, and of making the detached pieces fit into their proper places and form a consistent whole. There is much, no doubt, that needs discussion and a free interchange of opinions, both on the broad aspects relating to the physical geography, and to the special subjects of oceanography, meteorology, terrestrial magnetism, biology, and geology, on which I have touched very briefly.

There is, however, still much to learn. An expedition should be sent up Jones sound to connect the 400 miles between Prince Patrick island and Aldrich's farthest, and to examine the line of ancient ice in that unknown region. Another expedition should complete the examination of the northern side of Greenland. A third should be equipped on Nansen's plan, and sent to carry out Nansen's principle, by commencing the drift much further to the eastward, and passing over the pole itself. This would probably occupy four years, but it would bring back a further instalment of knowledge respecting the depths of the ocean

the currents and temperatures of the vast unknown area, and another series of magnetic observations. It should also decide the question of the existence of land between Prince Patrick and Wrangel islands.

It is true, therefore, that much remains to be done. Still, we already have a large mass of facts respecting the polar region, from which scientific deductions may be drawn, and this has been enriched and materially increased by the labours of Nansen and his gallant companions. On the various points of scientific interest which I have very briefly enumerated, I would now invite discussion; for such an interchange of impressions made on the minds of trained scientific men by the facts brought home by explorers, is of incalculable advantage in the prosecution of further research.

Dr. NANSEN: I must first express my great pleasure at being asked to speak on this occasion. I can assure you I feel highly honoured at being allowed to open the discussion on this most interesting paper by our distinguished Chairman.

It is very difficult in a few words to point out what may be of importance to discuss in a subject of such vast bearing. I shall, however, first only speak about these points which I think may be of most importance in connection with our expedition. I think that of specially great interest is what we have found as to the extension of sea in the north polar regions. We have seen that the whole sea to the north of Siberia is a very deep basin with comparatively warm water. We have seen that the sea-basin of the north polar region is only a continuation of the deep basin stretching northwards between Spitsbergen and Greenland, as our President has already pointed out. We knew before that for some distance north we had deep water. On the other hand, we knew that the depths to the north of Siberia and America were very small—80 fathoms at the greatest. Now we have seen that this deep sea-basin stretches eastwards as far as the New Siberian islands. All this part of the north polar sea is deep sea, averaging 2000 fathoms deep, and of course you cannot expect this sea-basin to stop here. We may expect it to stretch further eastward—as we see from the route of the *Jeannette* that the sea was getting deeper to the north very quickly; in a short distance it grew from 40 to 80 fathoms. Consequently, I believe we may consider the whole sea to the north of Siberia to be one extended deep sea-basin. I think we can with great certainty say that the pole itself must be situated in this sea-basin. If the *Fram* had not worked herself southwards out of the ice, it is quite certain she would have drifted further in a south-westerly direction along the coast of Greenland. But we could not expect to have got quite close to this coast, as, if the direction of the drift had continued, she would have come southward nearer to the outer margin of the current. Then there would have been a broad current of ice running out from the polar sea

between the probable route of the *Fram* and the east coast of Greenland. All this ice must come from some part of the polar sea north of the route of the *Fram*. It is, in a way, the same condition as we have with the great inland ice of Greenland, which has a great inner basin of heaped-up snow year after year, and all this must have some outlet somewhere. The inner ice of Greenland finds its outlet through the ice-fiords where the icebergs are produced. In the same way we may consider the polar ice in the polar basin; it must have an outlet somewhere, and the only one of importance is the one we have by Greenland; therefore most of the ice produced over this area is probably forced by wind and currents out this way. Some part of it is also pressed against the coast of America, and out through the sounds in the American archipelago. Now, it is evident, if the *Fram* had come down by the coast of Greenland, there would, as I have said, been a belt of ice between her and the coast; this ice must, however, represent an extended area to the north from which it originates, for the current runs at much greater speed in the south than in the north. It will consequently be much broader in the north, and probably will go beyond the pole. I think this one of the best evidences that the sea also has a great extension to the north. There were also others, *e.g.* the drift-ice always easily drifted northwards. The most difficult direction to drift in was constantly in a south-easterly direction; but it always went on easily in a north or north-westerly direction when the wind began to blow from the south or south-east. This proves there cannot be much land to the north, because if there were extensive land it must stop the drift of the ice in that direction. It also seems, according to the experiences and observations during Johansen's and my sledge journey, that the ice drifted with more speed in the north than in the south. It was more broken up, there was more motion between the floes, and in the water channel the current was often running pretty hard.

As the President has already mentioned, no land-birds were to be seen flying northwards. This also indicates the absence of land to the north, for if there were land there would probably be land-birds of some kind. We don't know any land yet where there are not birds.

I agree with the President that the polar ice seems to prove there cannot be much land to the north of the North American archipelago. I think it is probable we may find some islands; but land of great extent cannot easily exist between the islands we know and the New Siberian islands.

I should like to hear Admiral Sir George Nares's opinion about the great palæocrystic ice north of Greenland. I have some doubt whether that ice is really polar or sea ice; whether it is not glacial ice coming from some of the glaciers of Greenland or Grinnell land. The only difficulty would be if the ice Albert Markham met with during his journey is of the same description, because it would be difficult to make



the glacial ice drift far out to sea. The layers described by Dr. Moss makes it in my opinion probable, or at any rate possible, that it is glacial ice, because I believe it difficult for the real sea-ice to remain for such a long time as to obtain so many layers as seem to have been found. Sir George Nares would be able to give a better opinion on that ice than I could; however, if it is sea-ice, that may prove, I think, that there are islands in the north where the sea-ice can be closed up for some time in order to get these layers of snow heaped up annually on it. During the drift this stratified ice can hardly be formed, as I don't think the ice would take so long to drift across the polar region that many layers could be formed; the oldest ice we saw during our journey—and we saw some old ice—I should not think would be more than five or six years old, at all events.

The ice we saw was on an average, I should say, about 10 to 12 feet thick, and I don't believe that polar ice in the open sea will, as a rule, freeze much thicker. I paid much attention to the thickness of the ice at various seasons of the year. The ice formed in October and November, 1893, had next spring, in April, 1894, reached the thickness of  $7\frac{1}{2}$  feet, but it continued to increase steadily during the summer, and on June 9 it had reached the thickness of 8 feet 3 inches; and this in spite of the fact that the ice was now melted on the surface by the rays of the sun. On June 20 the thickness was still the same; the thaw on the surface was considerable, and there were large fresh-water pools in every direction, but the ice was being constantly formed on the under side in spite of this. The rest of June the ice continued about the same, until about July 10 it suddenly received a new layer underneath and became 9 feet thick. This increase I understood to be owing to the layer of fresh water which during the summer was swimming on the cold salt water underneath; at the depth where this fresh water touched the very cold salt water there was therefore formed a thick layer of fresh ice. This made the floe-ice considerably thicker. However, as the autumn approached the ice would decrease in thickness, but next winter it would continue to grow again slowly. On December 11 the thickness was 7 feet; on February 6, 1895, the thickness was 8 feet 4 inches. During the spring it went on growing, and on May 11, 1895, it had grown to 9 feet 10 inches, and it was about the same at the end of May. This was the thickness of the ice arrived at during more than one and a half year. We made some other measurements. The greatest thickness that we found the ice actually reached by freezing without being piled up was 13 feet 10 inches; this was in May, 1896, and probably after four years' drift in the sea. I think it may be that ice stopped by land and kept there for years might form thicker, but the warm water underneath would prevent the growing of ice to a certain extent. When it has reached a certain depth, it cannot form any thicker. There is sufficient heat

to prevent the formation of ice on the under side, but by the piling up of the ice much thicker floes will of course be formed.

I mentioned the water temperatures; I think they are also interesting, and will give you a few taken at various depths. Excepting the sea near the coast of Siberia, where of course the conditions are altered on account of the shallow water and the currents running along the coast, we find almost everywhere the conditions of the temperature pretty constant, almost the same month after month and year after year. Of course there were variations, but so small that they are not of sufficient importance to be mentioned here. I will take one series of temperatures obtained in August, 1894.\* Now, measuring by Centigrade thermometer, it would be on the surface 1·9 above, but at 2 metres' depth the temperature sank down to -1·3, very near the freezing-point of the salt water; at 20 metres it was the same as at 40 metres, -1·5, about the freezing-point of salt water with that salinity. The same temperature is found down to 100 metres, where it begins slowly to rise again, and is -1·4. Then it would rise slowly downwards; at 140 metres it was about -1 below freezing; at 200 metres it would be -0·03; then at 220 metres it rose above freezing-point, +0·19. Deeper the temperatures did not alter quite regularly, sometimes lower, sometimes higher again, showing that the currents must be running underneath. At 280 metres it was 0·4 above, and 300 metres 0·3, consequently lower again; at 350 metres it would again rise to 0·4, and then it would go on above freezing-point until 800 metres was reached, where 0·07 above freezing was registered. Then it gradually sank; at 1000 metres it was 0·1, and at 2000 metres it would be -0·6; at 3000 metres it would be -0·7. It sinks very slowly, but never reaches the freezing-point of salt water. When approaching the bottom it slowly rises again; at 3000 metres, 0·73; at 3400 metres it would be -0·69; at 3700 metres, 0·65; at 3800 metres, -0·64; the bottom was about 3850 metres deep. The main features found everywhere were, on the top a cold layer of water about 200 metres in thickness, or 100 fathoms; then the temperature of the water rose above freezing-point, and kept that down to 900 metres, or 500 fathoms; then it began to sink, and rose again when it touched the bottom. This same feature was repeated time after time, and the temperature in various months was so nearly the same, that it did not differ more than some few hundredths of a degree. This relatively warm water must be Atlantic water that runs into the polar sea as warm surface currents, branches of the Gulf Stream running northward along the west coast of Spitsbergen and eastwards to the north of Novaya Zembla. I believe that they run into the polar basin and fill the whole depth with this comparatively warm salt water, whilst the surface of the polar sea is formed by colder water with

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\* See table, p. 499.

less salinity, which is, of course, produced by the rivers that run into the polar basin, especially from Siberia.

I think these were, perhaps, the most important geographical and oceanographical results of the expedition. The drift of the ice, as you will have gathered from what I said in the Albert Hall, was mostly produced by the winds. The prevailing winds will produce a drift, or a current of ice if you will call it so. I dare not say yet whether there were other currents underneath. We have to work out the average directions and speed of the wind, and then work out the various observations as to the currents made by the help of constructions we sunk down into the water, before anything can be said with certainty on this subject.

The best period for our drift was winter and spring, and the worst period would be, as a rule, the summer and the beginning of the autumn. During that time we were stopped or drifted backwards; with the late autumn we drifted on again, and during the winter, as a rule, we had a fairly good drift, except during the last spring, when the *Fram* was stopped by southerly winds, until she at last got favourable winds and drifted on again. I quite agree with the President, that what now ought to be done in the arctic regions is especially the exploration of that part of the polar area to the north of the North American Archipelago and the north part of Greenland; but, as the President said, I think also that the same principle we made use of, to drift with the ice, ought to be tried once more. I think, if the expedition were as well prepared as we were, and went north through Bering straits, not so much to the west as the *Jeannette*, you would get another drift straight across the polar region, and that would probably last five years, and during these five years there would be excellent opportunities to take scientific observations of all kinds. I think what we really want is scientific observations from the arctic regions. Of course, in a shorter expedition with sledges some explorations can be done, and I do not think it is difficult to reach the pole in this way. If you care for it, you can easily do it with dogs; it is only a question of dogs. I am doubtful, however, whether it is worth while. You do not bring back sufficient observations to pay for the waste of time and labour; but we want scientific observations, and to get these, I can assure you there is not a better plan than that on which we worked—to go with the ship into the ice. It will give you the most excellent observatory you can wish for; you can have all kinds of laboratories on board, even much better arranged than they were on board the *Fram*, and if a man would spend five years over it, he would bring back observations that would pay him many times; he would then have rich material with which to form a clear and adequate idea of the physical conditions in the north polar region, and that is what we want.

The PRESIDENT: We have the great pleasure of welcoming Sir Joseph Hooker here this evening, and as he is a veteran who was studying

polar subjects and battling with polar ice thirty years before Dr. Nansen was born, I venture to request him to continue the discussion.

Sir JOSEPH HOOKER: It would give me very great pleasure if I could say anything that would throw any light upon this discussion. I certainly should have thought myself the last person to be called upon so early to speak on the subject. Of course my speciality is botany, and you would expect to hear from me something connected with the flora of these lands and countries, and how far the further exploration which your President supports is likely to throw any light on that branch of science. Now, I must confess I am in some difficulty, because the interest of botany in these regions is comparatively scanty; it is, however, threefold. In the first place, there is the existing flora, the flowering plants with which we are most familiar. Now, I don't think further exploration of the polar region will add much to our knowledge of that branch of botany. We pretty well know what the plants are, and don't expect any addition to our knowledge in that respect, nor their geographical distribution. It is further established that the arctic flora is divided under three groups—Asiatic, European, and American—that are slightly different from one another. These groups have been pointed out and pretty well limited in each direction. We don't expect the individual species to extend much further north than they have been found to do, and if they do, it can only be in respect of a very few species; and as we advance further into the polar area, we find ourselves in the position of the poor professor who had to lecture on the snakes of a certain island, and commenced his lecture by saying, "There are no snakes on this island." The two other divisions are of vast interest and great importance. One of these is the fossil flora. We know from repeated observations that, as your President pointed out, large floras are locked up in the geological formations of high northern regions. They occur in Skye, where fossil leaves are found in beds of trap. They are found in abundance in Greenland, and again in Spitsbergen. Now, that is a botanical subject of the greatest difficulty, because the plants occur only in a fragmentary condition, and it requires great skill and knowledge and a number of specimens to exactly ascertain what they are. What they have certainly proved is, that they are indications of a warm temperature having prevailed over these regions. Now, a further exploration may lead us to hope that more land will be found in the polar area in which these plants may be embedded, and which would therefore give us a vast extension of our knowledge of what the flora must have been in former days, and an increased number of specimens to certify the knowledge we have already.

The third point to which I have to draw your attention is the existence of that microscopic flora and microscopic fauna that swarm in the polar sea; of those plants especially which, being coated with silica, are absolutely indestructible, and, falling to the bottom of the sea,

form vast beds of what is practically Tripoli stone. Now, I am not aware of any beds of that description being found in the northern seas, but in the southern they extend along the shores of Victoria Land at a depth of 200 fathoms, as beds of silicious mud capable under pressure of forming Tripoli stone. Beyond this I don't think I have anything further to say, but may touch on one subject, which is a difficult one. I should like to know whether any observations were made during the expedition of the *Fram* on evaporation from the ice, and on the extent of loss by such evaporation. We have been told that where large masses of snow accumulate, they are carried off by floes in one case into warmer waters, and in the other in the form of glaciers. I have been led to doubt whether these sources account for the enormous waste of ice that goes on in the polar regions, and should be glad to know whether any observations of this subject were made by Professor Nansen.

The PRESIDENT : I don't know that any one can impress upon us the practical value of polar research better than Prof. Rücker, with regard to magnetic observations.

Prof. RÜCKER : I hardly expected to be called upon so early in the evening, because, although not wholly a laboratory worker, I have had no personal experience of expeditions which can be compared with that which has been described by Dr. Nansen ; but, at the same time, there can be no doubt that the interest of this expedition very largely centres about the magnetic work done, and I hope, when the various observations of Dr. Nansen and his friends have been worked out, something of interest may be added to our knowledge of magnetism. Perhaps it would be well to preface these remarks by a word or two on observations of this sort. There is no doubt that the whole subject is one of the most mysterious with which science has to deal, and we have at present very little knowledge as to the cause of the phenomena we observe. The time is now coming when the facts will be regarded from a wider point of view than that adopted a few years ago.

We now have sufficient knowledge of the magnetic state of the Earth to be able to draw fairly accurate magnetic maps, and, by the methods originally devised by the mathematician, Gauss, to get some idea of the magnetic state of the world as a whole. Instead of concentrating attention upon the more or less fictitious poles which the magneticians of the past were so fond of, an attempt is now being made to break up the forces into various groups, and to separate the great group of forces which represent the Earth's magnetism parallel to one axis, from others which may perhaps represent the disturbing influences. Then follows one of the most interesting questions which next century will solve. Is it possible that these groups of forces represent those portions of the magnetism of the Earth which are respectively at rest and stationary ? to picture the state of the Earth as partly due to permanent magnetism,

and partly to superimposed and moving magnetism which disturbs the simple results due to the first cause? If this were possible, if we could represent the Earth so, then a very great step would be made in the theory of terrestrial magnetism. It is to further observation that we must look for a solution of this problem, and, in order to solve it quickly, it is necessary that these observations should be well distributed over the Earth.

Dr. Nansen's expedition will, no doubt, have done a great deal in adding to our knowledge of the magnetic state of the north polar area, but one point has not been referred to which leads us to hope that the observations may be of a very high order of accuracy indeed. The land often produces a very great effect upon the needle, but Dr. Nansen's observations have been made, not only on non-magnetic ice, but on a vast depth of non-magnetic water, and therefore the disturbing causes which are so troublesome on land will be absent. Turning next to the meteorological conditions under which the observations were made, I can only say that I have myself made many magnetic observations under the comparatively small variations of temperature which we suffer from or enjoy, the heat of summer and the cold of winter. I know what the difficulties are, and I am overwhelmed with astonishment as to how such observations were made by polar explorers at all.

There is one point more to which I wish to refer. It is extremely desirable that the work done so well in the north should be carried out in the south. Some eighteen months or two years ago, a strong committee was appointed by the Royal Society, to wait upon the then Government, asking them to do something to help forward an antarctic expedition. The magnetical reasons for such an expedition were then fully explained, and I don't know that, in the comparatively small interval of time that has elapsed, there is much to add to them. I may, however, just refer to the main point. As every member of the Geographical Society knows, a vast portion of the southern hemisphere is covered with water. There are only two or three great projections of land running into it. At these points we know something of the magnetic state of the Earth, but of the intervening regions of the sea we know comparatively little, and it is essential, if we are to master the problem of the Earth's magnetism, that our knowledge should be increased. I therefore can only say, from the point of view of the science of magnetism, we want especially observations in the southern hemisphere, and I only hope the great impetus given by Dr. Nansen to polar exploration may, by some sort of resonant vibration, spread from the north to the south.

Prof. JUDD: It may appear at first sight that Dr. Nansen has brought back a message which will be very disappointing to geologists, when he tells us that in that great area there is practically no land, and that there is no hope for the geologists to learn anything new in their

particular domain. But I need not point out that there are many facts that may be obtained by polar, and even by north polar, exploration which will be of great interest to geologists, such as the nature of the bottom of the sea in that area; and we must all sympathize and rejoice with Dr. Nansen, that although no special provisions were made for deep-sea soundings, yet, with that wonderful ingenuity so largely the secret of his success, he managed to extemporize a line and obtain soundings that have been of such great value. Nevertheless, with proper appliances I doubt not we should obtain many samples of the bottom of this great ocean, and, more than that, it is possible that even dredging might be accomplished with proper appliances. But, taking the land which has been visited, it is far from devoid of interest. Sir Joseph Hooker has pointed out the wonderful character of the ancient flora found in the arctic regions, now carried to a much more northern point by these researches of Dr. Nansen; but I would remind you that those remarkable beds of Jurassic rocks, which contain the flora in question, are associated with volcanic rocks of great interest. Many geologists have had to regret the loss of specimens, but few have had to assign for their loss such a cause as that which deprives us of Dr. Nansen's specimens—their having been stolen by foxes. There is no doubt that the nature of these volcanic rocks is worth careful consideration. We are inclined to ascribe volcanic rocks to the same age as the stratified rocks with which they are associated; and, without denying that the whole of these volcanic rocks may be of Jurassic age, I would remind you that our own volcanic rocks, now known to be Tertiary, were long supposed to be Jurassic, because they were intruded into rocks containing Jurassic fossils. It is possible that part, if not the whole, of these rocks may really be of different age from the beds with which they happen to be associated. It may be that the basalts and other rocks found in the west of Scotland, and reaching away through Iceland to Greenland, may be found in the lands visited by Dr. Nansen, associated with an older series of volcanic rocks. There are many problems for a solution of which we must look to the new expedition we have almost had promised us to-night by Dr. Nansen, an expedition which, traversing the Arctic Ocean at a higher latitude, may bring us news of other new and interesting lands.

Dr. JOHN MURRAY: The President and Dr. Nansen referred to the depth of the polar basin and the temperature of the deep water as among the most interesting results of the expedition of the *Fram*. I cannot say that the results, so far as at present made known, are in any way unexpected, either with reference to the depth or the temperature of the deep water. The observations in this unknown region are of the very greatest importance, and we look forward to the publication of details with great interest; but, so far as we can at present judge, the results are precisely what oceanographers would have expected. In

the first deep-sea investigations, Thomson and Carpenter pointed out, to the north of Scotland, two areas at the bottom of the sea in which the temperature of the water at depths of half a mile differed as much as  $10^{\circ}$  or  $12^{\circ}$  C. These areas were not distant from each other more than 10 or 15 miles. The fauna in the two areas differed from each other as widely as the temperatures. It was believed that these waters of different temperatures existed at the bottom without any intervening barrier. After the return of the *Challenger* Expedition this area was again examined by the *Triton* and *Knight Errant* expeditions, and a ridge was found stretching between the north of Scotland and the Færoe islands, with an average depth on it of 250 fathoms, separating the cold from the warm water. On the north side of this ridge ice-cold water is found at a depth of 250 fathoms, and water of  $-1^{\circ}$  C. at a depth of 300 fathoms. But the Norwegian North Atlantic expedition has shown that these temperatures are found at a much greater depth along the western coasts of Norway. At the arctic circle the isotherm of  $0^{\circ}$  C. lies in the eastern part of the Norwegian sea at a depth of 400 fathoms, and the isotherm of  $-1^{\circ}$  C. at a depth of 900 fathoms. At the latitude of  $70^{\circ}$  the isotherm of  $0^{\circ}$  C. lies at a depth of 660 fathoms, and the isotherm of  $-1^{\circ}$  C. at a depth of 1100 fathoms. This is evidently due to the warm and salt water from the Atlantic sinking towards the bottom as it reaches higher latitudes. I should not expect a very cold temperature at the bottom in the region traversed by the *Fram*. At a latitude of  $80^{\circ}$  to the north of Spitsbergen, the highest temperature of the sea-water ( $3^{\circ}$  C.) occurs at a depth of 100 fathoms beneath the surface, and it is evidently this water which sinks in the polar area and gives the relatively warm water reported by the *Fram*. In the western parts of the Norwegian sea we find a condition of matters much the same as the *Challenger* found at the antarctic, viz. cold fresh water on the surface overlaying dense and warm water at a depth of 100 and 200 fathoms. From these considerations, those engaged in working out the *Challenger* observations have long been convinced that there was deep water towards the pole, and in my papers the depth of the polar basin has always been taken as not less than 1500 fathoms. It must be remembered that the range of temperature reported by the *Fram* rarely exceeds a degree and a half in the deep water. The observations of the *Fram* have confirmed the theoretical views of oceanographers, and cannot be said to have been in any way unexpected. It is, however, a very great thing to have made direct observations in this almost inaccessible region. Dr. Nansen has cut out of the unknown a great region, and has placed it well within the known.

Dr. BOWDLER SHARPE: I am sorry to say that, in the course of my studies of birds at the British Museum, and in the different volumes of the Catalogue I have had to write, it has not fallen to my lot to work out many of the birds of the arctic regions, and I am not perfectly



learned on that subject; still, I take it that the compliment paid me by the President, in calling on me to speak, means that perhaps the audience would like to know what ornithologists think of Dr. Nansen's voyage. We have heard, and every one confirms it, that in every branch of science his results have been of the greatest importance. So far the poor man has not had a moment to give us the results of his biological observations; but, from what we know of him, we are certain that what there was to be done was done, and that his discoveries will be placed before us in due time. Still, the interest of research in the arctic regions, as regards birds, always sums itself up into one or two directions to the explorer: "Be sure to find the egg of the Knot, or Curlew-Sandpiper, or find out Ross's Gull—tell us where it breeds." Dr. Nansen found Ross's Gull breeding, and that is all ornithologists can ask of an arctic explorer, that he solves one or two of these questions, and as Dr. Nansen has done that, I am sure his minor observations will also be of importance. Perhaps the audience may not know what Ross's Gull is. It is a very beautiful little Gull, with a hood and a wedge-shaped tail, and is called the wedge-tailed Gull. One of the specimens so called after the gallant commander occurred, or is said to have occurred, in Yorkshire, and two specimens in breeding plumage have been found off the coast of Greenland, and one of these was purchased by your late secretary, Henry Seebohm, and presented to the National Museum, where we have regarded it as one of our greatest treasures. There are not many specimens in museums, certainly not in breeding plumage. A number of specimens were got by the American expedition to Point Barrow; they were all young birds, and were seen only in September and October, travelling in flocks from south-west to north-east. But the breeding-place was entirely unknown, and therefore I should like to join my voice in congratulating Dr. Nansen on having solved one question of the few we set him to do when he went on his expedition.

Colonel FEILDEN: When our President advances the view that "the great polar sea is probably a sea without islands, and if so it is a sea of solitude," I would venture to point out certain facts which may throw a ray of light on this problem. The late Dr. Bessels of the *Polaris* expedition was the first to recognize and to record the number of foreign boulders scattered over North Greenland, in the vicinity of Thank God harbour, from the present shore-line to altitudes of 1000 feet. He remarked upon their absolute dissimilarity with the rock *in situ*, and, struck by a peculiar rock predominant amongst these erratic boulders, which he thought was precisely similar to a rock found *in situ* in South Greenland, came to the startling conclusion that when these erratics were deposited from their ice-rafts, the set of the current had been from the southward, up Smith sound, and into the polar basin. A more erroneous deduction could

not have been arrived at. Following in the footsteps of Bessels, and with the advantage of his experience—for he was a man of great scientific attainments—and fortunately having had much greater opportunities of geological investigation in that area, I satisfactorily determined that the present direction of the Smith sound current had not altered, certainly not for a long period of geological time.

The glacio-marine deposits so widely distributed over Grinnell Land and North Greenland testify to the fact that the currents and conditions under which these beds were laid down, from elevations of 1000 feet above the sea to the present-shore line, have been precisely similar. At every elevation we find the same coniferous wood from the great rivers of Siberia, the remains of the same fauna, and the same character of ice-borne erratic boulders. These erratics are of diverse lithological structure, but there is a widely distributed erratic amongst them, so marked in its composition, that I have little doubt it is the one that induced Bessels to formulate his theory of change in the present set of the currents in Smith sound. The rock I refer to is a peculiar gneissoid rock largely composed of garnet. Its structure is described in the *Geological Magazine* for 1895. This rock does not appear *in situ* on the American or Greenland shores that have been visited, from Capes Alexander and Isabella to Robeson's channel, and certainly not from Cape Union or Thank God harbour to Aldrich's Farthest on Grinnell Land, or to Lockwood's Farthest. From whence, then, are these erratics derived? Not from Siberia, I think; not from the New Siberian islands nor Bennet island. For it is noteworthy that of the many boulders examined in Grinnell Land, there was not one, I believe, identical in character with the known rocks *in situ* on the Asiatic side of the polar basin. Satisfied that the ice-transported erratics now resting on the shores of Grinnell Land and North Greenland facing the pole are not derived from the southward, and not from the continent of Asia nor the islands lying north of that continent, I think it not improbable that there may be some land or islands within the unknown area of the polar region from whence these erratics have been brought, and are still being stranded on the shores of Grinnell Land and North Greenland.

Sir LEOPOLD MCCLINTOCK: I beg to thank the President for his kindness in inviting me to speak. I have no doubt he expected me to say something interesting, but I am not going to say anything scientific; I will only remind you that I have had a great deal of experience of work in the arctic regions of the New World—something like ten years—and I have sledged over the ice-surface for 4000 miles; but I will only make one observation to you, which is to point out the strong dissimilarity of the ice north of the American continent from that which Dr. Nansen found on the Siberian shores. In all these long sledgings and years of experience

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and exploration, I never found any of these open lanes in the ice. We never found any cracks which we could not jump over : so utterly distinct was our ice from what Dr. Nansen experienced. We carried no boats ; we did not want them ; there was no current to set this polar pack in motion. There it remained outside the Parry islands, locked up by land, year after year until it attained enormous thickness. I think Lieut. Mecham, when sledging along the west coast of Prince Patrick island, in May, 1853, speaks of immense ranges of ice piled high up, from being forced in upon the shore, and showing a thickness of ice not less than 50 feet. It must have taken a long time for the floe to obtain such thickness as that. I only dwell upon these facts to show how different the two sides of the polar hemisphere can be, and that our experience in the Franklin search throws no light at all upon what Dr. Nansen has so clearly described to us to-night. I will not take up your time any longer, except to remark that the cause of this immense difference in the thickness of the ice encountered is worthy of investigation.

Sir GEORGE NARES : What we have learnt from Dr. Nansen's expedition is that there is evidently a dividing-line across the polar area, say somewhere from Bering strait across to Lockwood's Farthest north of Greenland, where you will find this heavy, or, as we called it in the *Alert* and *Discovery* Expedition, palæocrystic ice on the American side, and the lighter ice on the Asiatic coast. We knew before Nansen's expedition that along the Siberian coast there was young ice, *i.e.* one year's ice. We put it down to the warm water discharged from the enormous Siberian rivers, which so largely exceed the discharge from the American side ; but it is quite news to us now that this young ice two or three years old extends all the way to where we knew there was a current always running out of the polar seas. Nansen's voyage, in conjunction with the *Jeannette* drift from Bering strait to the Siberian islands, shows that all that drift is purely a wind drift. It was slow, but in a direction away from the land towards the northward and westward. Still it cannot be depended upon, and I think Dr. Nansen was very fortunate in his first year in getting away from that land, where we expected his difficulties would be. Once well away, we knew he would come across if his ship could keep up. As to this dividing-line, there is the question as to the thickness of the ice on the American side, and as to where it is derived from, and whether that line is straight from Bering strait or curved. There is no doubt that all along this coast the ice which we found north of Melville island and at Patrick's island is sea-ice. Now, Nansen tells us that in one year he measured 7 or 8 feet of ice, practically the same as our old measurements in other regions ; he gives us in two years 13 feet of ice that was solidly frozen ice without any rise of one floe over another. Very well ; now if you annually get floes of that kind nipped together, you will soon get ice of extreme thickness. Sir

Joseph Hooker put an important question about evaporation. Well, off the *Alert's* winter quarters the evaporation far exceeded the precipitation; but then, of course, you won't find the same balance all over the polar region; we were beyond the area of precipitation, and experienced very little snowfall. Further south it would be different, but at the border of the arctic sea evaporation far exceeds precipitation, therefore in the summer there is the constant melting down of the blocks on the top level of the floe, and consolidating into a regular massive piece of ice. Our measurements were over 100 feet thick, and there is no doubt, as Colonel Feilden says, there was no idea of this being formed anywhere except at sea. Of course, there is melted snow mixed with the salt-water formed ice, but there is no doubt that they were really floe-bergs. I won't enter into the question of land; I am rather inclined to go against Colonel Feilden and join with Nansen that there cannot be large lands. There may be some small islands, but certainly it has ceased to be now an important question to us. Nansen's journey over the ice of course enabled him to explore a much larger area than the friends he left on board the *Fram*. They were frozen up in their surroundings and drifted on, and it is a most remarkable thing to us—I join several arctics with me—the enormous quantity of ice all through this region of practically less than one year's growth. He comes across ice over and over again that has only been formed a few months. What I am aiming at is to put before you that his voyage is in no way an exceptional one. There is evidently this continuous drift through the polar region, and the enormous quantity of young ice met with proves that it can have been in no way an exceptional season. Now we are talking about another expedition, perhaps starting from the American side of Bering strait. I will only make one remark—that is, we must dwell upon the large number of American whalers that have been lost in the ice just in that spot north of Cape Barrow, and never been traced or heard of. There must be something different in the winds there, not blowing the ice off to get away from the land into the southerly current, totally different to that met with on the other side. As an interesting remark, talking about the palæocrystic ice, there is no doubt that there are few outlets through which it can come. We found it drifting through Robeson channel; it also is met with in the *cul-de-sac* south-eastward of McClintock channel, where it undoubtedly stopped Franklin from making the north-west passage.

As far as geographical questions go, I think I should like to have had this discussion a few months later. We have not had time to properly dwell on the large results of the Nansen Expedition; we have scarcely had time to read his interesting book; but the meteorological questions alone, in conjunction with those of the Jackson-Harmsworth Expedition for three years, will certainly enlighten us very greatly when

we can put them together. The question of the temperature of the sea was what I had a great deal to do with in the *Challenger*. We found very much the same tongues of cold and warm water in the antarctic region. But I should like to know by-and-by, when Dr. Nansen's results have been thoroughly worked out, how he explains finding warm water down at the bottom: it is most interesting, and found nowhere else in the world.

Dr. NANSEN: I will try to answer the various questions that have been put, and will do so as briefly as possible. Sir Joseph Hooker asked about diatoms in the north: I think in this respect the expedition has brought back some interesting results, as I discovered a whole new world of diatoms living on the surface of the polar ice in the fresh-water ponds found on the surface of the floes through the short summer in the north. I discovered some brown, yellow, or red-brown spots as soon as the ponds were formed. I thought it was mud, but by taking a little of this mud and placing it under a microscope, I discovered it was swarming with diatoms, and amongst them I found small animals feeding on them. As time went on I saw these small patches growing and forming holes in the ice, and thus a whole flora of diatoms was living on the ice, freezing up every winter and reviving again for the summer. I regret I cannot say anything about them to-day, because that is material which has to be worked out by a specialist, but I dare say there are many new and interesting forms amongst them. I also found a good many small infusoria. Unfortunately, I had not much literature with me to help me in these my investigations; but I brought material back, and I hope in this respect to get some results. On the whole we thus see that on the surface of the floe ice, constantly travelling across the polar region, there is a fauna and flora living every summer and freezing up in the ice every winter, and I dare say some of these diatoms may be the same as those found by the Nares Expedition in the ice north of Grinnell Land. In connection with this, I may also remind you that one of my evidences before I sailed, which I believed proved a current running across the polar region, was the mud I found on the drift-ice along the east coast of Greenland; in this mud diatoms were discovered which were only found once before in the whole world, and that was at a cape a little north-west of Bering strait. It may be that many of these diatoms found during this expedition will be the same species and of the same sort.

As to deposits of diatoms on the bottom, I believe our results are in the negative as far as my investigations go. In the samples of mud from the bottom of the polar sea I found but little organic life; the mud seems mostly to consist of mineral substances, and there was even very little chalk or anything of that kind to be discovered in it. Sir Joseph Hooker asked me one question as to the evaporation from the ice. I could not make any direct investigations on the subject, but from what

little I could make out, I got the impression that evaporation was considerably less than the precipitation. The whole winter there was a good deal of condensation of moisture going on on the surface; it was constantly covered with hoar-frost, and we made some attempts to determine the amount formed from day to day: it was considerable. I have not the material here to-night, so I cannot tell you more about it. I must say that my impression is that during the winter there is very little evaporation from the surface, but a good deal of condensation of moisture on the polar ice. Sir George Nares seemed to be of the opposite opinion. But there is one thing that struck me: if the palæocrystic ice is sea-ice, and the layers are consolidated by precipitation every year, then I believe this proves that the evaporation cannot exceed the precipitation; for if such was the case, I do not understand how the layers could be formed.

Prof. Rücker asked about our magnetic observations. I am sorry to say I cannot give much information about that here to-night, as that was not my line. Lieut. Scott Hansen had to take care of these observations, and as I had much to do with my own investigations, I had little time to spend over his, but I believe that they will throw some light on the problems mentioned by Prof. Rücker. I believe that the observations are exceedingly carefully done, and I can only say that, from what I saw of Scott Hansen's method of working, he was a constant object of my admiration. He carried on his observations with never-failing care at any temperature, even at  $60^{\circ}$  below zero, and came in with his nose or fingers frozen, and would not admit that it was cold outside. From what little I can gather from these observations, we found the inclination and declination pretty much what you would expect. Neumayer had already, before we went out, given us some data as he thought we should find them, and we actually found much the same as he had expected; but I believe the inclination, so far as I remember about  $87^{\circ}$  at the furthest north, was little more than was expected. There was one thing that made observations at times a little difficult: the disturbances of the needle were often very great, owing to the northern lights. I believe on one occasion we had disturbances about  $24^{\circ}$ , and that is, as far as I understand, unusually much.

Prof. Judd asked me a question about the geological results, and he spoke about the deposits in the arctic sea. I have already said something about it. I hope the samples will throw some light upon the deposits, though, of course, a new expedition, well equipped with deep-sea sounding apparatus, would bring back better samples. I believe these deposits will prove to be extremely devoid of organic matter, and will mostly consist of mineral substances. He said he thought it might be that the basalts of Franz Josef Land are Tertiary. I cannot deny it; only one thing makes me think they are Jurassic rocks, and

that is, that they rest on a bed of clay reaching from the level of the sea up to 500 feet above it. This is Jurassic (Russian Jura). Immediately on this clay rose the basalt, and on the top of the basalt I found in one place, with Jackson and Koetlitz, plants and fossils, which have been examined, and are found to be of late Jurassic age. The flora is mostly coniferous, and seems, as Prof. Nathorst says, to point to a not very warm climate, though naturally much more favourable than the climate in these regions to-day. This is one reason why I and Prof. Brögger, who have examined these basalts—although there has not been time for exact investigation—came to the conclusion that they were of Mesozoic origin. One circumstance that might also point in the same direction: the rocks are different from the basalts of Scotland, the Færoes, and Iceland; there is extraordinarily little olivine iron ore. They seem to resemble some basalts which are known from Spitsbergen, and Prof. Brögger believes that these belong to one area of eruption. I therefore believe that we must consider Franz Josef Land and Spitsbergen as belonging to the same group of islands; also that in the still unknown distance between them we will find a series of islands, mostly of volcanic nature.

I will only make a few more remarks as to Mr. Sharpe's question about the ornithological results. He asked where we found Ross's gull breeding, and I pointed to a place on the north-east side of Franz Josef Land. They were in the first islands we met with. I must, however, point out that I did not actually see birds breeding. I got the impression they must breed there because I saw old birds and young birds together the same year, and there were so many of them. I could not easily imagine they had come from a land far off, as I did not know of any such land. They were just in the neighbourhood of these islands, and as soon as we went away we did not see them any more. On the spot where we spent our last winter we did not see a single Ross's gull, while on these islands, not many miles to the north-east, it was a quite common bird—almost as common as the ivory gull and the kittiwake; that was the reason that led me to believe that the Ross's gull was actually breeding there. It may breed on the rocks on the beach, like the ivory gull, or perhaps on the ice; nobody knows. Of course it is not probable that they should breed on the ice; still, on these islands there were but few rocks. As the President remarked, we saw little auks in the north, but we saw more dovekies. As far north as we went in the *Fram*, we saw birds in the summer-time. It is extraordinary how far birds will fly away from land. In June and July, 1895, to the north of Franz Josef Land, we could see flocks of little auks and dovekies coming from the south, and then returning to the south again. We understood that these birds came from some land, and wished we could follow them; but we had to travel for weeks and weeks before we came to that land, which they probably reached in a few hours: and when

settled for the winter in Franz Josef Land, we saw in the spring the birds (little auks and dovekies) steer away out to sea; we could see no water, but they went straight out, and returned after twenty-four hours. The birds we saw on board the *Fram* were mostly ivory gulls and other gulls, dovekies, kittiwakes, Ross's gulls, mallemocks, scures, and a few little auks. These birds do not prove that there was any land in the neighbourhood, as I think they may be expected wherever there are water-lanes, because there they find plenty of food—small crustaceans; the birds we shot were always full of shrimps and small crustaceans. I believe these birds fly across the polar sea anywhere.

The circumstances to which Colonel Feilden drew attention in connection with my doubt about the palæocrystic ice, that there are diatoms in the layers of dust, is interesting, and, face to face with such a fact, I will give in and say I believe that the ice must be of oceanic origin. As to Colonel Feilden's belief in a land to the north on account of certain erratic blocks found on the shores of Grinnell Land and North Greenland, I will just put one question. Why could not these come from the interior of Greenland? May there not be far away under the glacier cover, rocks of the same description? and then I don't see any reason why blocks from them should not be carried to the coast by the glaciers. So long as we don't know the rocks in the interior of Greenland, I think the most natural explanation must be that these erratic blocks have come from that direction. I will just close with a few remarks on the interesting statement made by Sir George Nares about the palæocrystic ice. Now, in my opinion this ice is one of the most interesting problems in the polar region, a problem which I should like to see solved as soon as possible. I think we have here something quite different from the ice we have seen. If this palæocrystic ice really is oceanic, it must, of course, be very old, and I think it could only reach that thickness in the neighbourhood of land. My opinion is that this ice must be formed near the American side where the drift is stopped by the islands, where the pressure is tremendous, and the floes are piled up and frozen together, snow covered, and levelled up. I don't think ice of 50 feet thickness can easily be formed in the open sea, because I believe the loss of heat by radiation from the surface would not penetrate sufficiently quick to such a depth, and when the ice reaches a certain thickness, it cannot, therefore, easily grow much thicker by direct freezing. I believe this extraordinarily thick ice will only be found quite near the lands on the American side, and when we come a little further north we will find thinner ice more like the ice we found, and which has more motion than that across which Albert Markham travelled on his wonderful journey.

I said before I should like to see an expedition start from the sea north of the Bering strait, in the same way as we did. I know, as



Nares said, that many American whalers have been lost there, and have been drifted northwards and disappeared; but that is just one reason more why I should like to see an expedition start from that side. These whalers are not specially built to stand any pressure of ice; they are built to hold a big cargo, and they pay extraordinary little attention to the strength of the ship. If you build a ship like the *Fram*, and go north there, I think that is the best way of solving what is perhaps the most important problem left in the north polar region.

The PRESIDENT : It remains for me to propose to the meeting a vote of thanks to Dr. Nansen for the extremely interesting discourse he addressed to us at the commencement of this discussion, and for the great care he has taken in noting the remarks made by the various speakers, and in replying to the questions put by them.

The thanks of the meeting are also due to the distinguished scientific men and arctic officers who have joined in the discussion.

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## THE MESOPOTAMIAN PETROLEUM FIELD.\*

By Captain F. R. MAUNSELL, R.A.

THE existence of a petroleum-bearing belt of country on the north-east of the lower Tigris valley has been noticed by various travellers, the most recent being M. de Morgan in his 'Mission Scientifique en Perse,' who deals with the naphtha pits near Kasr-i-Shirin and Shuster, so far as came within the scope of his travels. He has gone very thoroughly into the geological formation of the country near these deposits, and infers† that the pits at Kasr-i-Shirin are part of a petroleum-bearing belt extending from Kirkuk to the north of the Pusht-i-Kuh; but if the notices of various other travellers be collated, it will be found that the prospective field of enterprise is of even greater size and commercial importance. Of the various sites of these springs, I have had opportunities myself of seeing those at Hammam Ali, El Fatha, Mendali, and Kifri, and have passed through most of the country near them. Bitumen from these pits has been utilized from the very earliest times, there being a legend that the coating of pitch used for the Ark was obtained from Hit, while from Al Hadhr came the Greek fire used with such effect against the siege implements of Severus.

Although known for so long a time, the deposits have never been satisfactorily explored, or their value tested by borings on modern

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\* Map, p. 588.

† 'Mission Scientifique en Perse,' vol. ii. p. 86.