AN UNPUBLISHED LETTER FROM NANSEN

by J. ROUCH

In 1898, Prince Albert of Monaco, who had devoted himself to oceanographic research during the previous fifteen years, decided to continue his activities in the direction of Spitsbergen. His new ship, the *Princesse Alice II*, had just been built, with a displacement tonnage of 1 400 tons, and possessed facilities for action lacking in his previous vessels, the *Hirondelle* and *Princesse Alice I.*

« My research since 1885 in the region of the Azores », he writes, « has yielded about everything I could expect from it. I am leaving for the polar regions in order to explore the depths of the ocean with the equipment I devised for my other explorations. I wish to investigate the depths which divide the deep parts of the North Atlantic from those reported by Nansen in the polar basin, the fjords of Spitsbergen influenced by the Gulf Stream, and the purely arctic regions where the pack will allow me to enter ».

According to his custom, Prince Albert prepared his cruise carefully, and did not hesitate to ask for advice and suggestions from oceanographers able to give such assistance. He hence wrote to Nansen, who had returned less than two years before from his brilliant voyage on the *Fram*. Fritdjof Nansen sent a long letter in reply, with diagrams drawn in his own hand, as follows :

Fridtjof Nansen Godthaab, Fysaker 2 July 1898

Albert I

Sovereign Prince of Monaco.

Dear Prince Albert,

Please accept my most hearty thanks for your honouring letter and extremely kind offer to help me in my work by making some special observations in the North Ocean. It was a great delight to me to learn that your Highness is going North on an Arctic cruise with the *Princesse Alice* this year, as I know that we will then get some highly important and much needed (results) observations from this part of the ocean, some of which I have specially been looking forward for as they are necessary to be able to explain some of the conditions found in the North Polar Basin during the drift of the *Fram*.

As I know that your time is precious I shall only draw your attention to some peculiarities in the temperatures of the sea in the various depths, which I think it would be of great importance to have carefully reexamined.

Your Highness will probably know that we found comparatively warm water under the cold layer of surface water of the Polar Basin. The section on the enclosed Pl. I will probably give an impression of the average distribution of the temperatures from the surface to the bottom as we found them in the Polar Basin. Between 200 m and 500 m the temperatures were from + 0.5° C to + 1.15° C. Under 500 m the temperature gradually and slowly sank with the depth. At 900 m it was 0.0° C. At 2 000 m about — 0.67° to 0.70° C. At 3 000 m between — 0.73° and — 0.82° C. At 3 800 m — 0.64° C. Such were with very small variations the temperatures in the various depths along the whole route of the *Fram*, and the differences between the series of temperatures taken in the sea to the North of the New Siberian Islands to the North of Franz Josef Land, and Spitsbergen are surprisingly small. The conditions thus seem to be extremely uniform in that part of the Polar Basin which we have examined.

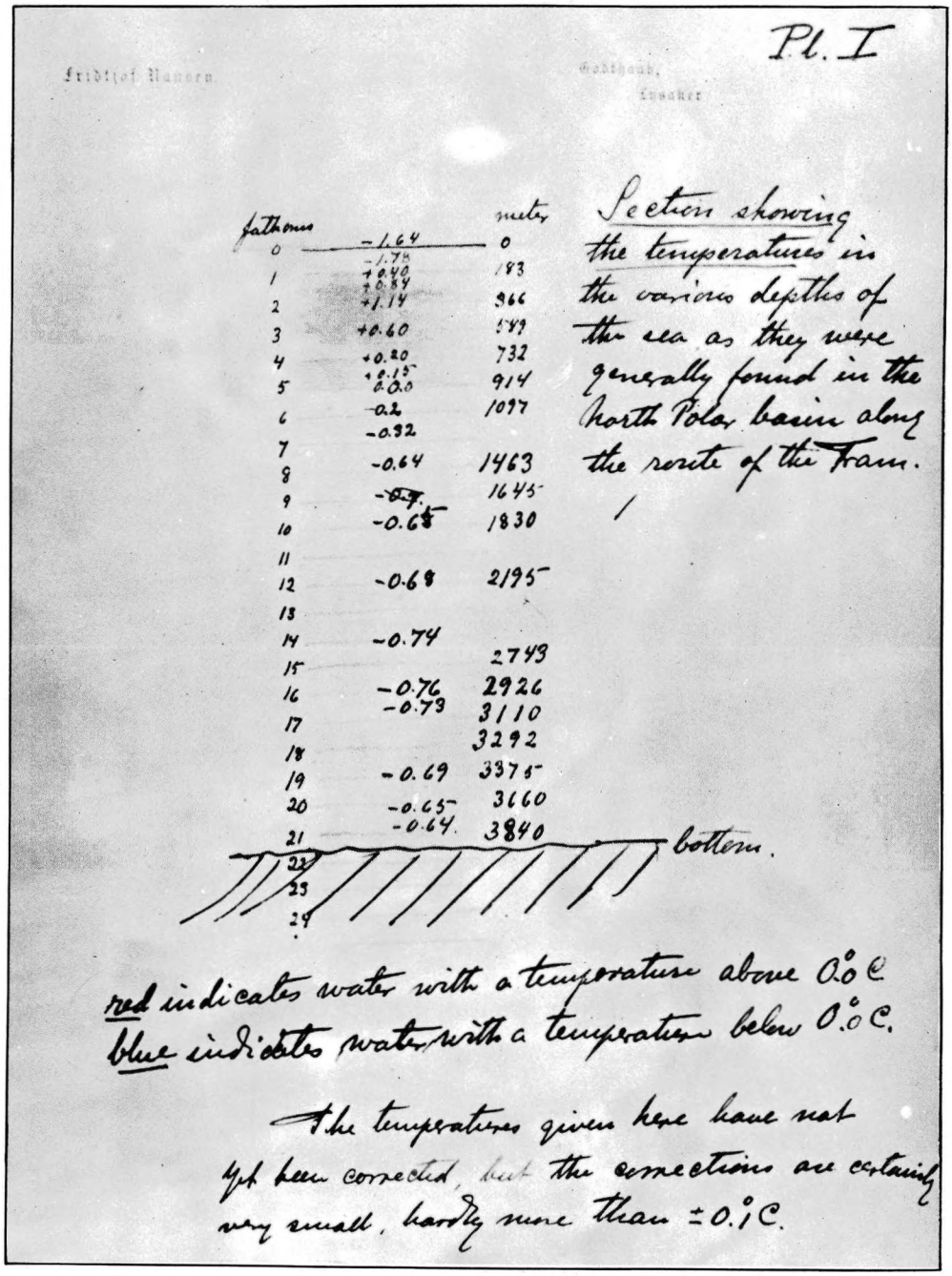
But if we compare these temperatures with what we know from previous expeditions (the Norwegian North Atlantic Expedition and other expeditions) about the temperatures of the North Ocean between Spitzbergen and Greenland there are some astonishing differences which seem to me very difficult if not impossible to explain at present, and it would certainly be of great interest to get the temperatures of this sea examined again with modern instruments and such a splendid outfit as there certainly is onboard the *Princesse Alice*.

Enclosed I send some transverse sections (Pl. II and III) showing the temperatures of the ocean west of Spitzbergen, which will explain more clearly what I mean. I have called the sections A, B, C, D. On the rough sketch map Pl. IV, it may be seen where the sections are taken. The blue colour indicates water colder than 0° C, and the red water warmer than 0° C. *

It will be seen that the bulk of warm water (warmer than 0° C) running northward along the west coast of Spitzbergen is supposed to grow smaller as it comes northward, in width as with as in depth. It must, however, be the continuation of this bulk of Gulf Stream water, which we found as warm water under the cold surface water along the whole drift-route of the *Fram*. It seems to me strange that such a comparatively small bulk of water should have such far-reaching effects and be able to travel such a long distance as from Spitzbergen to the New Siberian Islands, without losing more warmth, and I think it would be of great interest to get the limits (breadth as well as depth) of this warmer Gulf Stream water carefully examined. I take it as granted that at the same time the salinity of the water... also will be made the the subject of research, as in this repect these also seems to be very interesting conditions.

According to RYDER there should be a similar but much smaller bulk of warm water in a depth of about 100 fathoms along the East-Greenland-Coast (vide section A), while there is no such layer of warmer water *in the whole ocean* between this eastern branch and the branch of the Gulf Stream on the Spitzbergen side. This also seems strange to me, seeing that

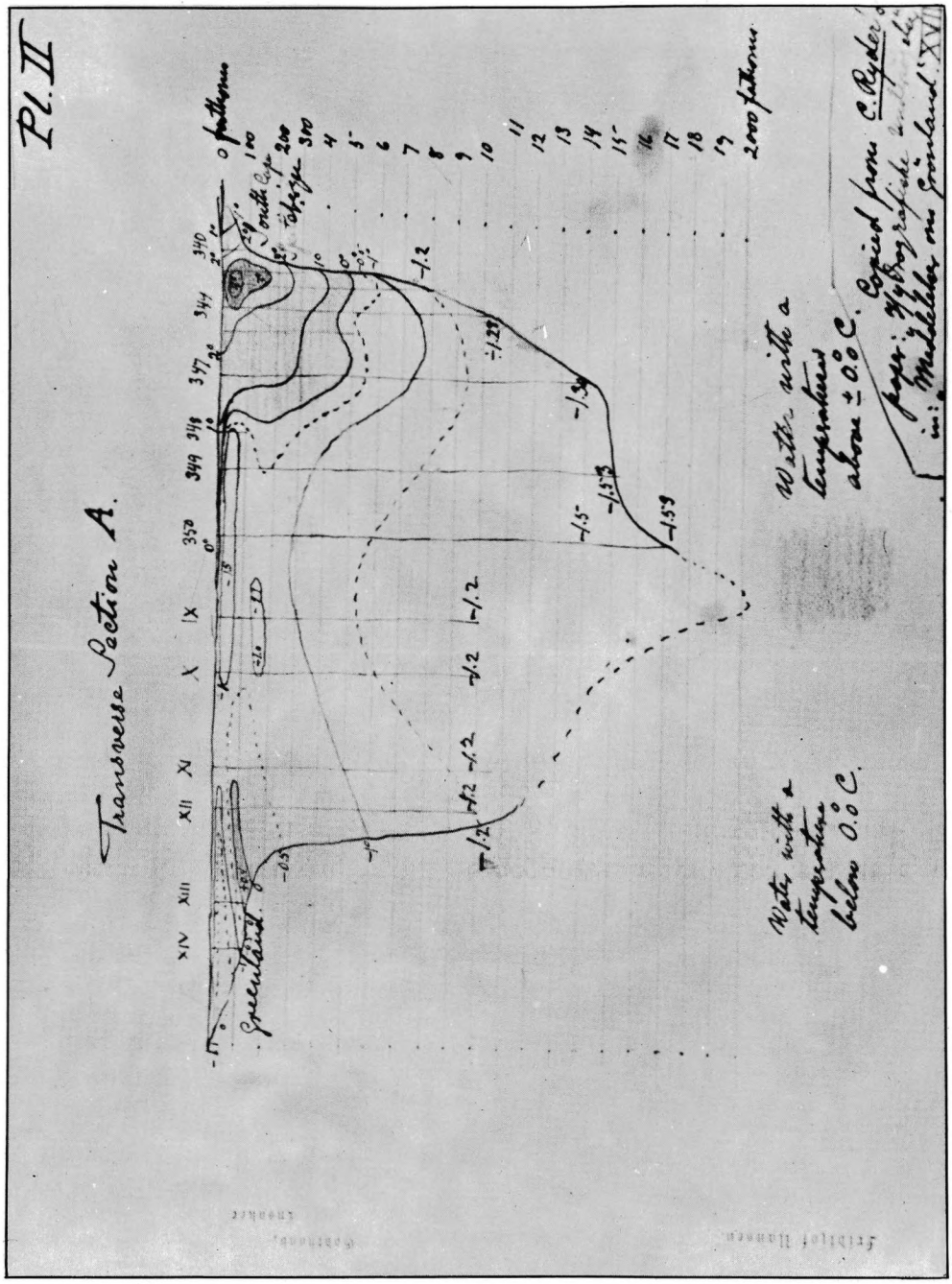
(*) The blue and red colours have not been reproduced in the figures.

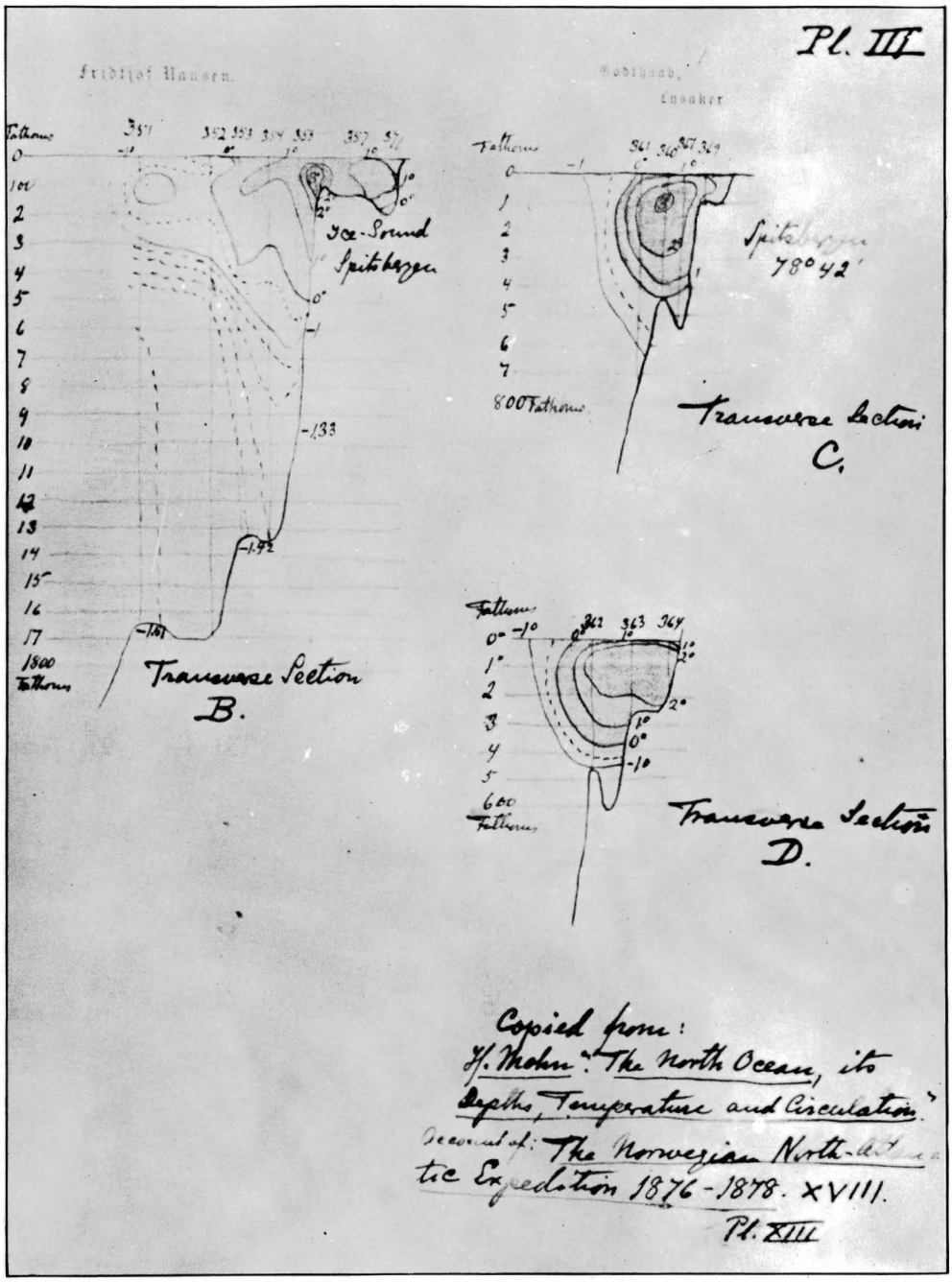


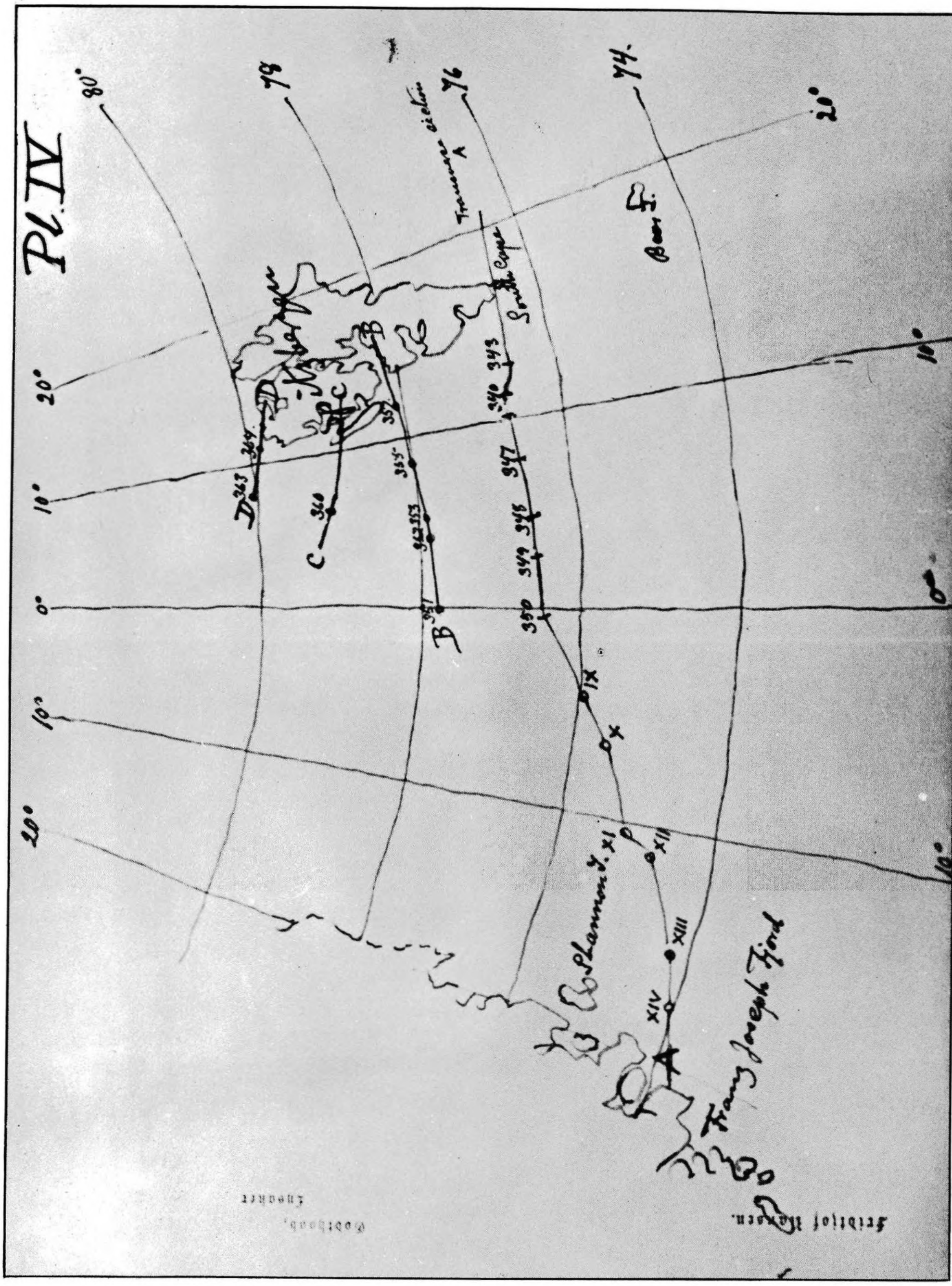
Section showing the temperatures in the various depths of the sea as they were generally found in the North Polar basin along the route of the Fram.

red indicates water with a temperature above 0.0° C.
blue indicates water with a temperature below 0.0° C.

The temperatures given here have not yet been corrected, but the corrections are certainly very small, hardly more than ±0.1° C.


Pl. II
Transverse Section A.
Greenland
Water with a temperature below 0.0° C.
Water with a temperature above ± 0.0° C.
0 fathoms
100
200
300
400
500
600
700
800
900
1000
1100
1200
1300
1400
1500
1600
1700
1800
1900
2000 fathoms


Pl. III
Fridtjof Nansen.
Godthaab,
Lusaker
Fathoms
Ice-Sound
Spitsbergen
Transverse Section
B.
Spitsbergen
78°42'
800 Fathoms
Transverse Section
C.
600 Fathoms
Transverse Section
D.
Copied from:
H. Mohn: "The North Ocean, its Depths, Temperature and Circulation."
Forming part of: The Norwegian North-Atlantic Expedition 1876-1878. XVIII.
Pl. XIII


Pl. IV
South Cape
Franz Joseph Fjord

we found warm water in the depth everywhere in the Polar Basin, from which all this cold water naturally should originate. It would certainly be important to get series of temperatures taken as far west and northwest from Spitzbergen as possible in order to get more information about this matter. Temperatures taken in the sea further south between Norway and Jaen Mayen could of course also be important.

I may also draw your attention to the strange fact that we never found the temperatures in the depth and at the bottom of the deep Polar Basin sink deeper than — 0.7° C and — 0.8° C, in a single case down to — 1.14, whilst according to previous observations the temperatures in the depths of the sea west of Spitzbergen or even west of Northern Norway are constantly below — 1.0° C when you come to greater depths than 1 700 m, and the temperature at the bottom is generally about — 1.5, which is nearly a whole degree colder than we found it in the north. I cannot easily explain why it should be warmer at the bottom near the Pole than farther south and I am afraid there may have been some faults with the instruments or with the observations; and it would therefore be a great thing to get new and careful observations with quite reliable instruments in these depths, as we have here to do with features of much importance for our knowledge about the circulation of the ocean.

Finally I should like to mention the rise of the temperature which I observed near the bottom of the Polar Basin, and which may be seen in the section Pl. I. At 2 900 m the temperature was — 0.76° C which was a minimum. From this depth the temperature was slowly rising towards the bottom where it was — 0.64° C (in 3 800 m). As far as I know, such rising temperature towards the bottom has not been observed before, but the reason may be that the instruments have not been sufficiently accurate, and I have a suspicion that similar conditions may also be found in other parts of the ocean, and it may be worth while to pay attention to it, may be we have here some features of great importance. It should certainly also be well to have these bottom layers examined with regard to their salinity.

I have now mentioned the features to which I specially wanted to draw your attention, and I hope your Highness will excuse me that I have expressed myself as fully, on a subject which it perhaps was quite unnecessary for me to mention, as such investigations probably would be made without my help. Still as the occasion was there I could not withstand the temptation to point out the controversies which seem to exist, and though I do not doubt that your Highness knows most of what I have said before, I thought it possible that you have not yet heard much about our hydrographic observations.

There is still one thing which I believe it would be of interest to know more about, in order to explain the circulation of the deep water in the Polar Basin, and that is the depth and length of that bottom *ridge* which seems to go in a northwesterly direction from the Northwest corner of Spitzbergen (about the direction of section DD in Pl. IV), but I am afraid the ice will prevent the *Princesse Alice* from coming very far from land in this direction. It is a strange coincidence that the depth of this ridge seems to be the same as the depth in which we found the isotherm for 0° C in the Polar Basin.

There are of course many other of your researches, the results of which I shall be eagerly looking forward for. I shall for instance take much

interest in your samples of the bottom sediments from the North. The mud from the bottom of the Polar Basin is remarkably devoid of lime and organic matter, whilst on the other hand we have found *mangan* in it. It is quite different from the *biloline clay* of the bottom of the North Atlantic, but to the North of Spitzbergen there is probably a transition stage to be found.

But I shall not take up your time by writing any further about all this. I am sorry to hear that my comrade Scott-Hansen is not going, he is a nice fellow, but I dare say there have been some difficulties with his military service which have prevented him. I hope, however, your Highness will get a good and reliable « ice man » from Tromsö who knows Spitzbergen well. I told Collett that if I could be of any service by finding one, it would of course give me much pleasure; but as I have heard no more from him I suppose it is now settled to your satisfaction. The only thing I now regret is that your route did not carry you in this direction as I was thus prevented from having the great privilege of making your personal acquaintance, which I have so long been looking forward to. But I hope that on some future occasion my fate may be more favorable. My very best wishes for a pleasant and successful voyage, may there be much open water or what the whalers call « an open season » which will allow you to get far North and West.

How I wish I could have been in Tromsö instead of this letter to see Your Highness and your magnificent ship.

Believe me, dear Prince Albert,

Very sincerely yours.

FRIDTJOF NANSEN.

This letter, written in July 1898, barely two years after the *Fram*'s return, indicates Nansen's initial general opinion of the oceanography of the polar basin. In the account he published several years later, in 1904, entitled : The Oceanography of the North Polar Basin (volume 3 of Scientific Results of the Norwegain North Polar Expedition 1893-1896) he described in minute detail the distinctive features of the various layers of water in the polar basin, which he divided into six distinct categories :

Surface polar layers 0 to 20-30 m	Cold water (— 0.9° to — 1.6°) with low salinity (21 to 31 or 32 parts per 1 000) moving west or northwest.
Cold polar layers 20 to 100 m	Very cold (— 1.6° to — 1.8°), average salinity (30 per 1 000 to 34 per 1 000). Coldest layers throughout basin at about 50 m.
Transitional layers 100 to 200 m	Transitional layers between polar and Atlantic waters. Temperature close to 0°. Salinity 34 per 1 000 to 35 per 1 000.
Relatively warm Atlantic layers 200 to 900 m	Temperature above 0° (0.5° to 0.6°), salty (35.2 per 1 000) originating from Gulf Stream. Particularly warm at 350 to 400 m.
Cooled Atlantic layers 900 to 3 000 m	Temperature under 0° (0° to — 0.8°). High salinity (35.3 per 1 000 to 35.4 per 1 000).
Layers warmed by heat of earth 3 000 m to bottom	Water warmed 1 or 2 tenths of a degree near bottom (— 0.76° to — 0.69°).

The polar basin contains two very different types of water. At the surface, between 0 and 200 m, the very cold water of low salt content constitutes the polar water proper, caused by the mixing of sea water with fresh water from the rivers of Siberia and North America. From 200 m to the bottom, extending over 3 000 m, salty and warmer water, which during several hundred metres between 200 m and 900 m has the peculiarity of showing temperatures above 0°, represents the water masses flowing into the polar basin from the Gulf Stream. These Atlantic waters cannot enter into the Sea of Barentz owing to the high submarine plateau between Norway and Spitsbergen. To penetrate into the polar basin, they must cross the relatively low sill between Spitsbergen and Greenland, which Nansen then estimated as having a depth of 700-800 m over a width of 150 km. In the polar basin, the warming influence of the Gulf Stream and of the water from the North Atlantic which flows in after it, is completely wasted insofar as the Arctic climate is concerned, since the warm and salty waters only exceptionally reach the sea surface.

Such are the general conclusions reached by Nansen after studying the observations of the *Fram*. The objection expressed in his letter to Prince Albert : « It seems to me strange that such a comparatively small bulk of water should have such far-reaching effects ... » no longer seems so important to him. However, he still has it in mind when he examines the irregular variations that may occur. He does not believe it likely that each year the Gulf Stream can discharge a sufficient quantity of water into the great polar basin, and this should only happen when the Gulf Stream is sufficiently well-developed west of Spitsbergen. But as in the basin's depths circulation must be very slow, frequent inflows are doubtless unnecessary to maintain the salinity at a very high rate.

In a paper dated 1928, entitled : « The Oceanographic Problems of the still unknown Arctic Regions », and published in *Problems of Polar Research* (American Geographical Society, 1928), Nansen takes up the same questions. He discusses recent observations, particularly his own survey, published in 1922, entitled « Spitsbergen Waters ». The deep waters of the polar basin have a uniform salinity of 34.93 parts per 1 000, and a uniform temperature of — 0.85°. This deep water cannot be formed in the polar basin itself, and probably originates from the Norwegian Sea, where the surface waters north-northeast of Jan Mayen show fairly similar characteristics in winter and early spring. These waters flow into the polar basin over the sill between Spitsbergen and Greenland, to which Nansen assigns a depth of 1 200-1 500 m.

Waters of similar origin moreover fill the depths of the Norwegian Sea, which does not show the wide temperature differences compared with the deep water in the polar basin as reported by Nansen in his letter to Prince Albert. The bottom water in the Norwegian Sea has a salinity between 34.70 $^0/_{00}$ and 34.94 $^0/_{00}$ and temperature varying from — 1.0° to — 1.2°.

The rise in the temperature of water near the bottom indicated in Nansen's letter has been observed in several oceans and is attributed to the adiabatic compression sustained by the water masses at such depths, rather than to transmission, by conductivity through the earth's crust, of heat within the globe. However, the increase in temperature depthwise in a sediment core has shown that transmission by conductivity through the

earth's crust of such heat is less negligible on the sea bottom than many oceanographers believe.

These hydrological features of the polar basin were adopted by oceanographers and published in treatises on physical oceanography up to about 1950. The Russians then divulged some of the results of the numerous expeditions they had undertaken in the Arctic Ocean, which included among other discoveries that of the Lomonosov ridge. On a line which perceptibly connects Smith Sound with the New Siberian Islands, this ridge shows average depths of 1 500 to 2 000 m, and in places does not exceed 1 000 m. It separates the Arctic Ocean into two large basins showing depths in excess of 3 000 m over large areas, and reaching 5 000 m in some places.

The Lomonosov ridge prevents any exchange of deep water between the two basins. In the basin located between the ridge, Canada and Alaska, the deep-sea temperatures are less cold than in the basin between the crest and Spitsbergen : — 0.4° instead of — 0.8°. The inflow of water from the Pacific through Bering Strait is much larger than at first supposed. In any case, the objection made by Nansen in his letter to Prince Albert has found a direct answer : the inflow of water from the Atlantic, although large on the surface down to about 1 000 m, and although extending over the greater part of the Arctic Ocean, is limited in deeper water by the Lomonosov ridge to an appreciably smaller volume. It should be noted that the *Fram*'s drift-route in the Arctic Ocean was all on one side of the Lomonosov ridge. The generalization of the *Fram*'s observations for the entire Arctic Ocean was not justified at depths greater than 2 000 m.