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04/ THE OCEANOGRAPHY OF DISRAELI FIORD NORTHERN ELLESMERE ISLAND.

by

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INTRODUCTION

In the spring of 1967, an oceanographic party led by H. Serson of the Defence Research Board, discovered a unique oceanographic situation in Disraeli Fiord on the north coast of Ellesmere Island (Latitude: 82° 54'N, Longitude: 73°45'W), (Hattersley-Smith and Serson, 1968). The upper part of the fiord, to a depth of about 44 meters, was filled with almost fresh water. Between 44 and 45 meters, the salinity increased from 5°/oo to 32°/oo while the temperature decreased from -0.6°C to -1.6°C.

The explanation for this remarkably rapid change in the properties of the water lies in the existence of the Ward Hunt Ice Shelf, a shelf of ice averaging about 44 meters in thickness which lies along the coast, blocking the mouth of Disraeli Fiord. This ice shelf apparently dams the upper 44 meters of the fiord while allowing free interchange with the Arctic Ocean at greater depths. This paper reports in part the analysis of the observations, but a complete analysis of all the data is under way and will be submitted for a more detailed paper.

OBSERVATIONS AND DISCUSSION

In May, June and July of 1967, an oceanographic program was carried out in Disraeli Fiord. The program was designed to determine the circulation pattern of the fiord, with particular emphasis on its response to the fresh water run-off during the melting season. It has been suggested by Crary (1958, 1960) and Hattersley-Smith and Serson (1967) that the outflowing water under the ice shelf might be low enough in salinity and temperature to refreeze onto the bottom of the shelf, thereby causing the shelf to gain thickness by accretion.

Fig. 1 locates Disraeli Fiord and the oceanographic stations which were occupied in 1967. The continuously manned station was close to the inner edge of the ice shelf. Twenty-five additional stations were taken within the fiord, 8 of which were full oceanographic stations. At the remaining 17 stations, salinity and temperature were taken to a depth of 60 meters with an "in situ" device of limited accuracy. Soundings and Bathythermograph readings were also obtained. Two additional stations were taken in the Arctic Ocean off the edge of the ice shelf near Ward Hunt Island.

Fig. 2 shows the bottom profile along the deepest part of the ice shelf. Below this, the bottom cross-sections are shown at the indicated positions. On the same diagram is shown the interface between the fresh and salt water (dotted line), and also a number of isotherms. It will be noted that all but the lower 0°C isotherm appear to show very little horizontal slope throughout the fiord, and that the interface between the fresh and salt water appears to be horizontal.

Fig. 3 shows temperature, salinity and sigma-t as functions of depth for the main station at Disraeli Fiord. Typical Arctic Ocean station conditions are included for comparison (Herlinveaux, 1961). The upper layer in Disraeli Fiord has an extremely high stability with respect to the lower, which inhibits mixing with the colder saline water lying below. It should also be noted that the density distribution indicates stability within the upper layer itself. The deeper water has characteristics similar to those at the station taken in the Canadian Basin of the Arctic Ocean (79°41'N, 111°08'W) with a slight difference in the temperature curve. These points are also shown in the T-S diagram in Fig. 4.

Fig. 5 shows two typical current profiles, one taken under late winter conditions (May) and the other during the peak of the run-off (July). Before the run-off from the glaciers into the fiord had started, there was a small current which had its maximum value at about 200 meters, when the thaw began; a somewhat stronger current appeared between 42-50 meters. Current measurements in the boundary layer were attempted, but failed due to freezing of the Ekman current meter. It is believed that maximum current occurs in the boundary layer, as indicated (dotted line) on Fig. 5. Before the melt period, a recording current meter was suspended at 200 meters. Later, when the current maximum appeared at a higher level, the recording meter was raised to 50 meters. So far the data from this current meter have not been analysed. The current measurements indicate the presence of a small tidal current in the lower layer. This was confirmed by tide gauge observations showing semidiurnal and diurnal periods with a total range of 10-15 cm. Serial observations of temperature and salinity showed no internal waves of tidal origin, but small fluctuations with a period of the order of minutes were observed in the boundary layer.

EVIDENCE FOR SUPERCOOLING

Two phenomena indicate that the water immediately above the halocline must be just at, or slightly below, its freezing point. On a number of occasions, when the oceanographic cable was raised after being left in the water for several hours, thin plates of ice up to 10 cm in diameter were found frozen to that part of the cable which had been above the halocline. It was suggested that this could have resulted from cooling of the cable by conduction down the cable to the very cold (-1.7°C) water at 60 to 90 meters. Although this seemed unlikely, an experiment was carried out to settle the question. An anchor was attached to the cable and separated from it by a 30 cm length of rope. The cable was then lowered so that the end of the metal cable was 43 meters below the surface. It was left for 48 hours then raised to the surface. The lower 5 meters had plates of ice frozen to it as before (Fig. 6). A few minutes after raising the wire, a number of large plates of ice floated to the surface, the plates were 30 to 50 cm in diameter, and less than a millimeter in thickness. A number of them had a keyhole-shaped aperture where the wire had apparently been torn out of them. Unfortunately, they were so fragile that it was not possible to remove them from the water to examine or photograph them.

Thirty-five temperature and salinity profiles were taken with an *in situ* salino-thermograph to a depth of 60 meters. More than half of these showed the characteristics seen in Fig. 7, where a small temperature inversion appears at a depth of 44 meters. The fact that it does not occur in all profiles is probably due to the fact that the increments of depth were such that the inversion is caused by ice forming at that depth and giving up its latent heat to the surrounding water. The ice would then float up to freeze to the bottom of the fiord ice. Since the salino-thermograph was of limited precision, it was not possible to use the values taken from it to calculate the freezing point of the water. However, by calibrating it against measurements made with the Knudsen bottles and reversing thermometers, a freezing point curve was obtained, with an accuracy of about 0.3°C. The difference between the observed temperature and the freezing point curve is plotted in Fig. 8. All that can be concluded from this is that the water is very close to its freezing point in the boundary layer. This is an indication that the outflowing "brackish" water in the boundary layer may refreeze onto the ice shelf, but at the present time no calculations of how much ice might be formed by this mechanism have been attempted.

TRITIUM MEASUREMENTS

A number of samples from the oceanographical stations were analysed for tritium content. Fig. 9 shows a tritium profile taken on July 5th in the melting season. The tritium content of the inflowing water sampled in one of the melt streams varied between 500-900 tritium units. Since the tritium content is inversely proportional to the age of the water, Fig. 9 indicates that the most recent water is located just above the boundary layer and the oldest water in the lower layer. This suggests that the melt water sinks to the interface where it flows directly out of the fiord, probably the same year. The tritium profile further shows that the minimum concentration occurred at 50 meters, with a slight increase with depth; at the present time, however, no explanation of this feature is offered.

COLD INTERMEDIATE LAYER OFF WARD HUNT ICE SHELF

An oceanographic station off the Ward Hunt Ice Shelf in the Arctic Ocean was also taken by H. Serson (Fig. 1). A comparison of the temperature distribution at this station with that of a typical temperature curve for the Arctic Ocean shows some interesting differences. The deeper layer of Disraeli Fiord and the Arctic Ocean, as may be seen in Fig. 3, gave approximately the same distribution, but at the station off the Ward Hunt Ice Shelf, the temperature curve shows a minimum at about 300 meters. From observations taken in the Nansen Sound system and Eureka Sound (CODC Report No. 4, 1967), one might speculate that the cold water moves through this region and then spreads out offshore along the coast of Northern Ellesmere Island. Ford and Hattersley-Smith (1965) however have not reported the cold intermediate water in the Nansen Sound system, which may indicate that this cold intermediate water occurs only at certain periods. Studies are under way to determine the source.

SUMMARY

The upper 43 meters in Disraeli Fiord is dammed from the Arctic Ocean by the Ward Hunt Ice Shelf. As a result, the upper 43 meters is filled with fresh water, resulting in an extremely high stability in the boundary layer. Small tidal currents are present in the lower layer. During the melt season, the maximum current was observed near the boundary layer, flowing out of the fiord. No internal waves of tidal origin were present. There is some indication of supercooling just above the interface. The spring melt from the land water appears to sink down to the interface and probably flows out of the fiord the same year. There is an indication that the outflowing "brackish" water may refreeze onto the bottom of the Ward Hunt Ice Shelf. A cold intermediate water layer at a depth of about 300 meters has tentatively been established off the Ward Hunt Ice Shelf.

ACKNOWLEDGEMENTS

Grateful thanks are due to Dr. G. Hattersley-Smith and H. Serson of the Geophysics Program, Defence Research Telecommunications Establishment, Defence Research Board, who arranged the logistics of this operation. The work was carried out in part on Defence Research Board contracts.

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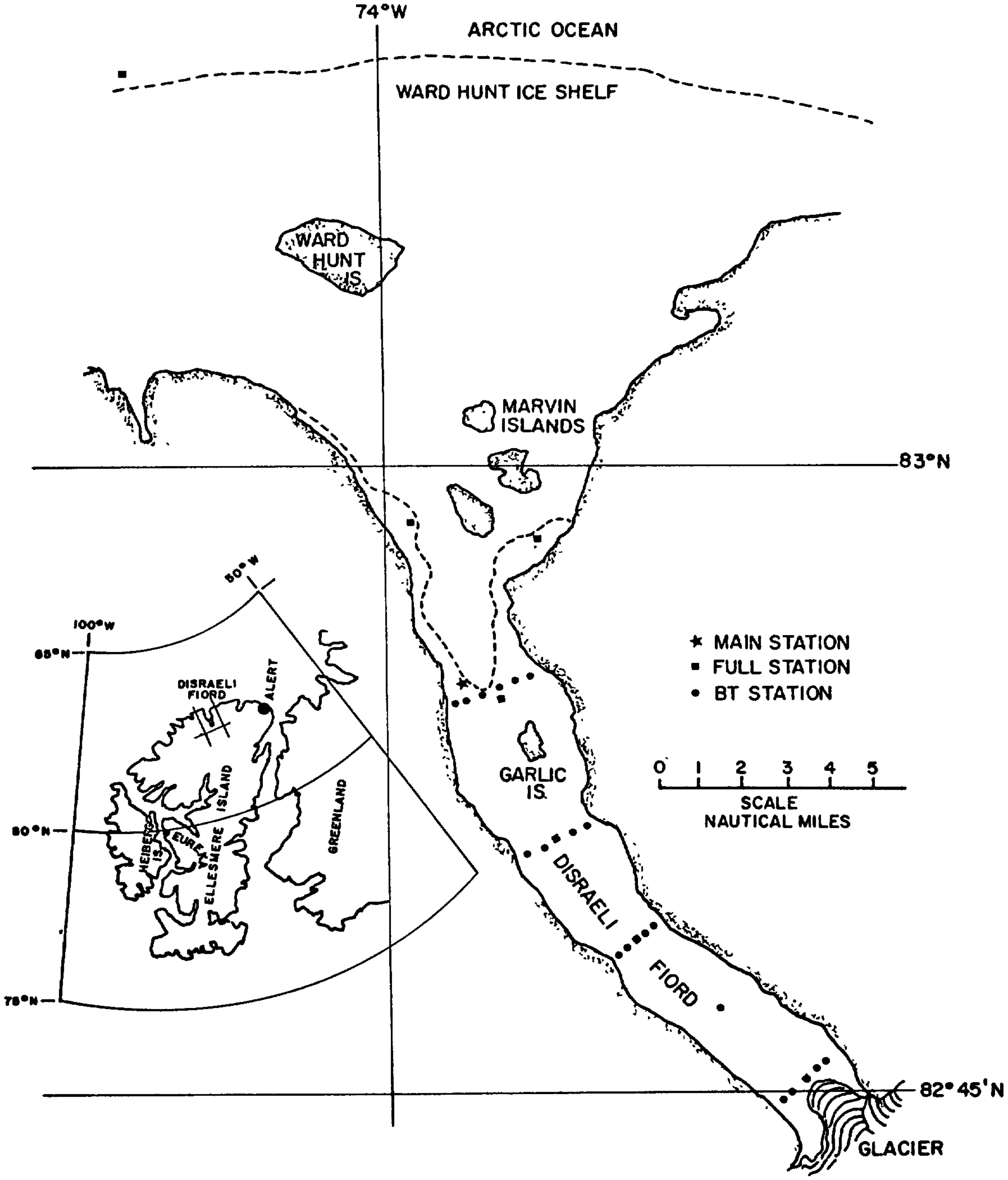

Fig. 1. Disraeli Fiord.

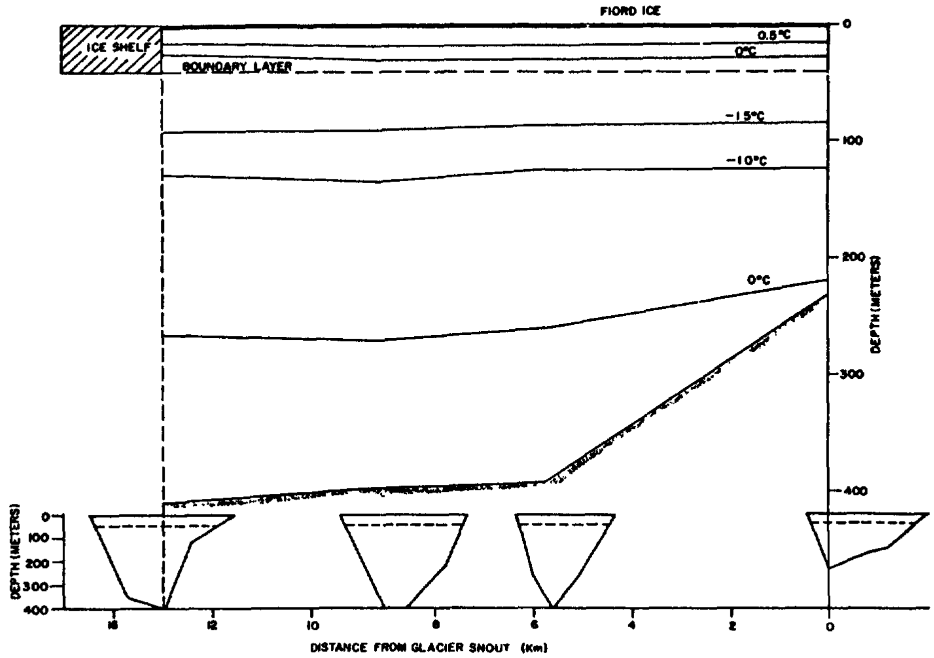

Fig. 2. Bathymetry of Disraeli Fiord.

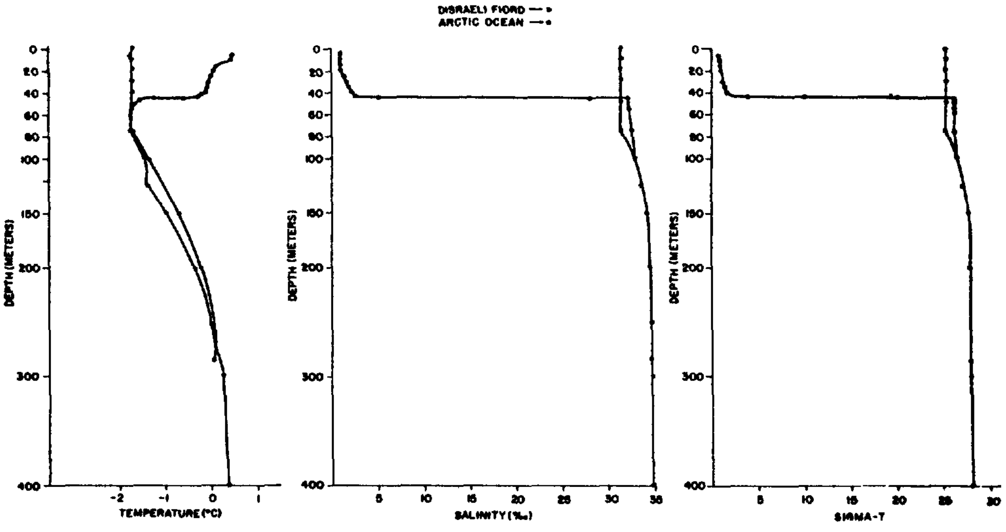

Fig. 3. Temperature, salinity and sigma-T profiles.

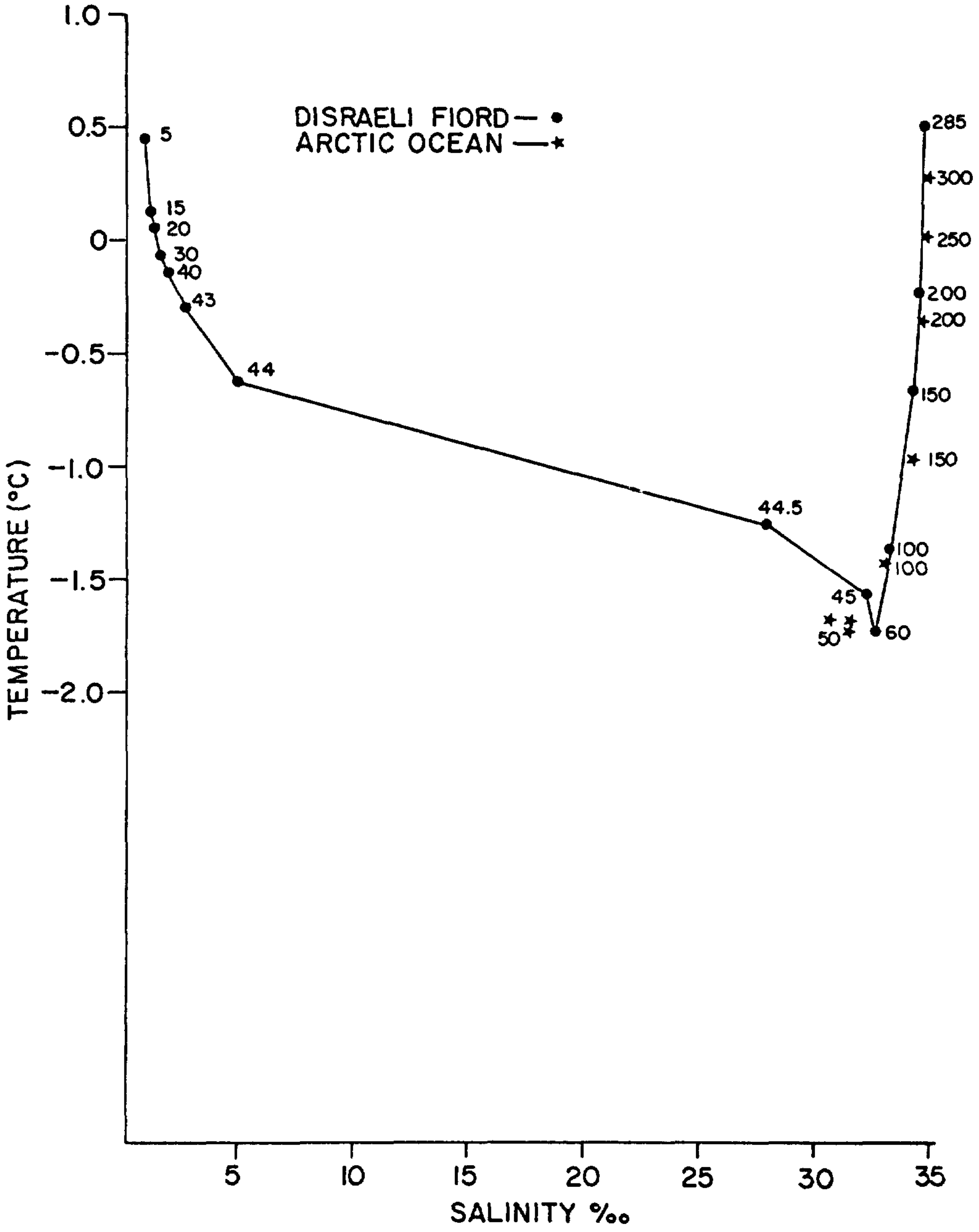

Fig. 4. Temperature--salinity diagram.

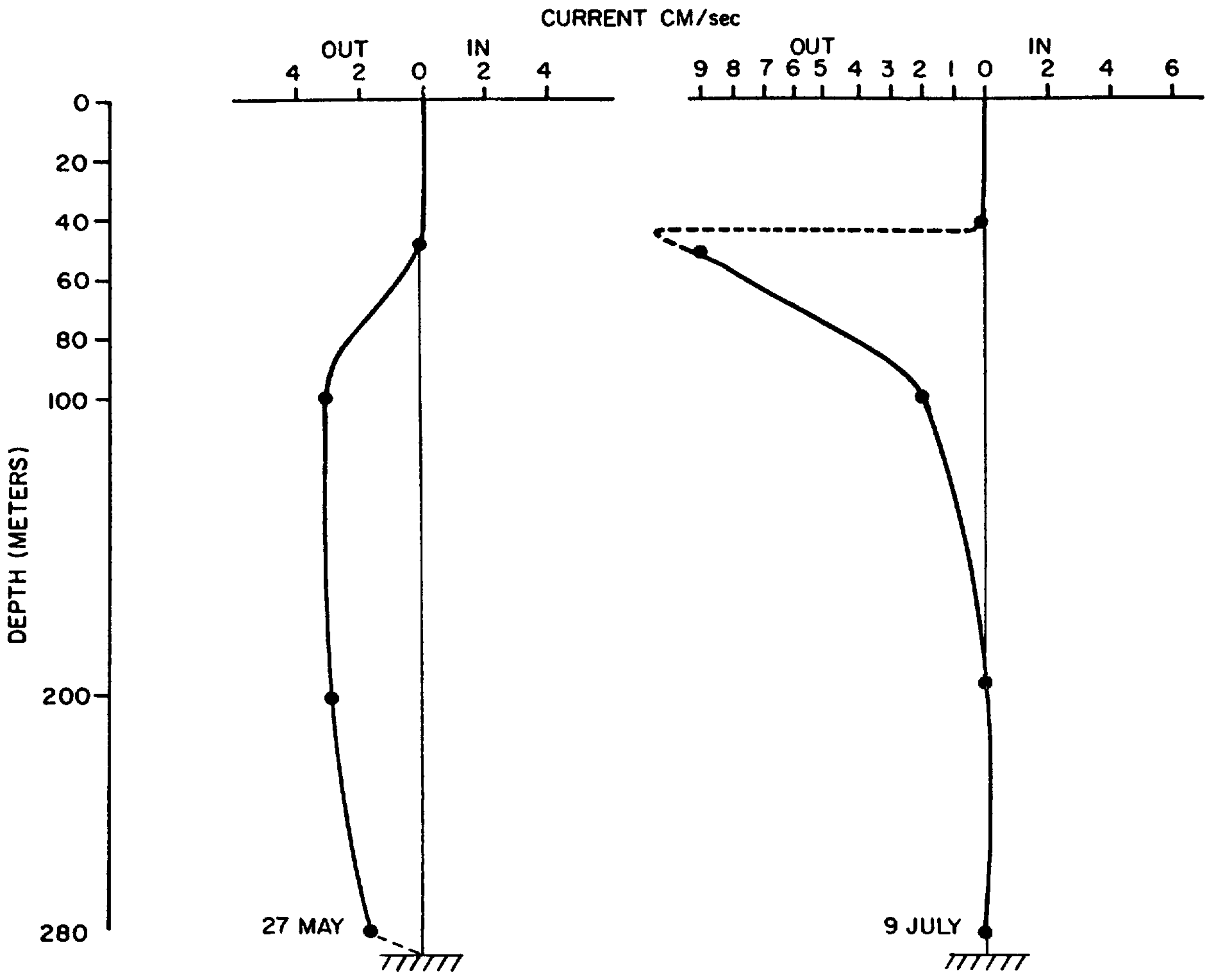

Fig. 5. Current profiles.

Fig. 6. Evidence for supercooling.

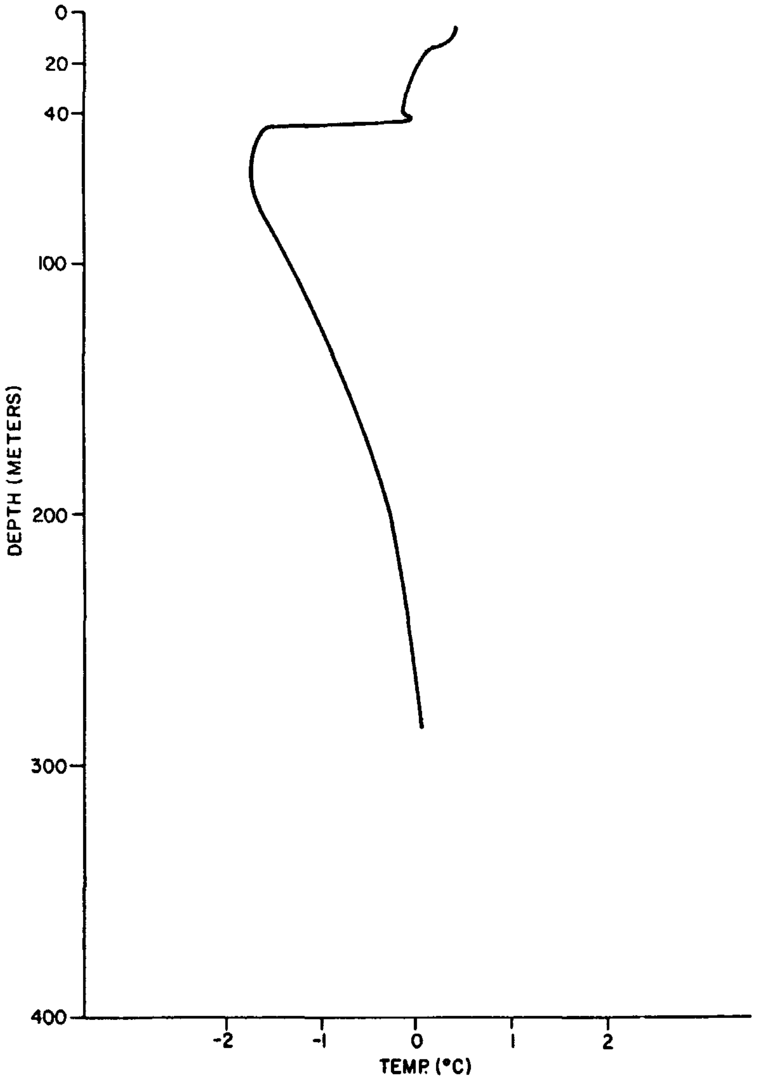

Fig. 7. Temperature profile.

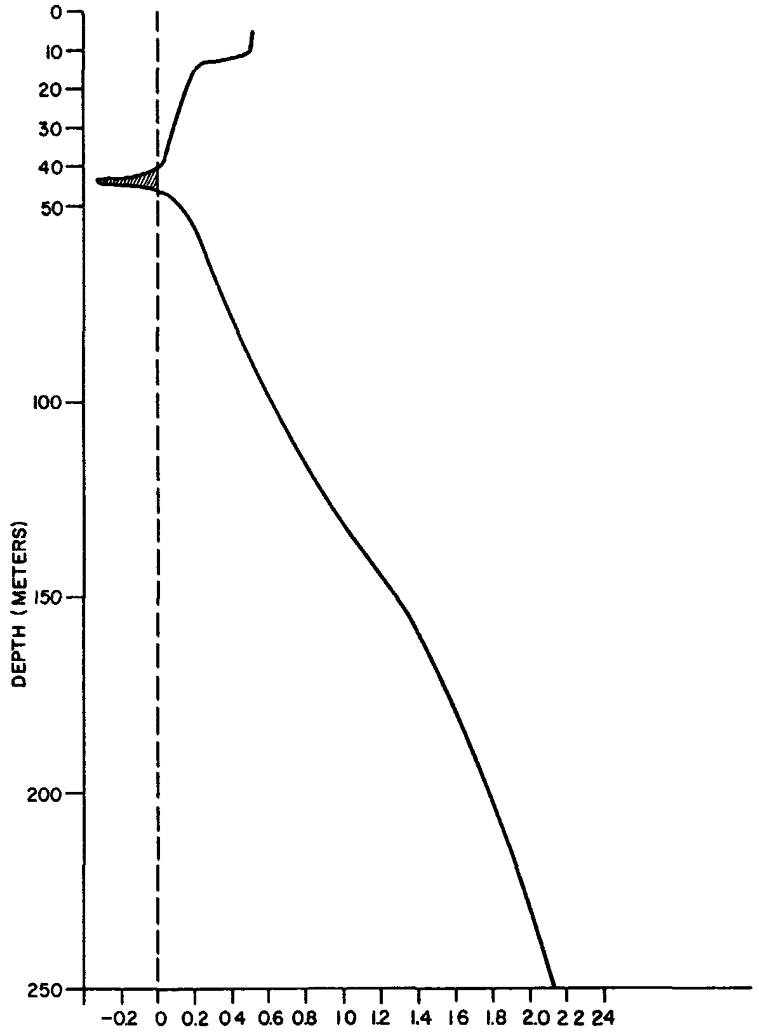

Fig. 8. Profile of temperature related to freezing point.

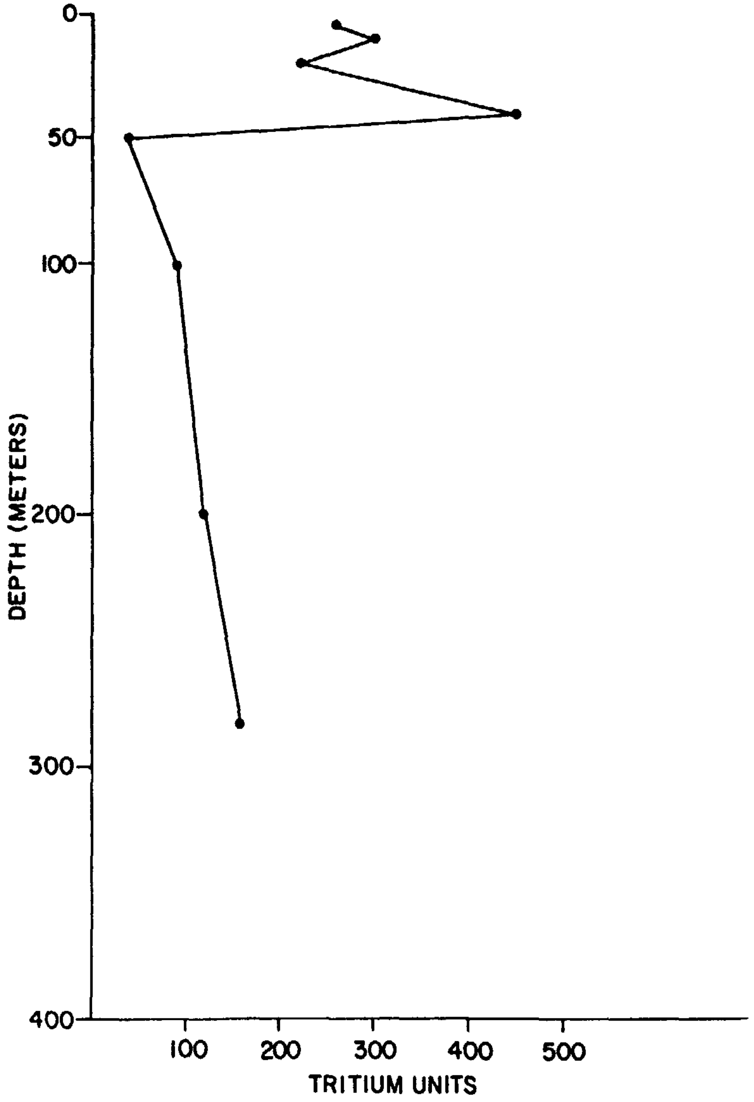

Fig. 9. Tritium profile.

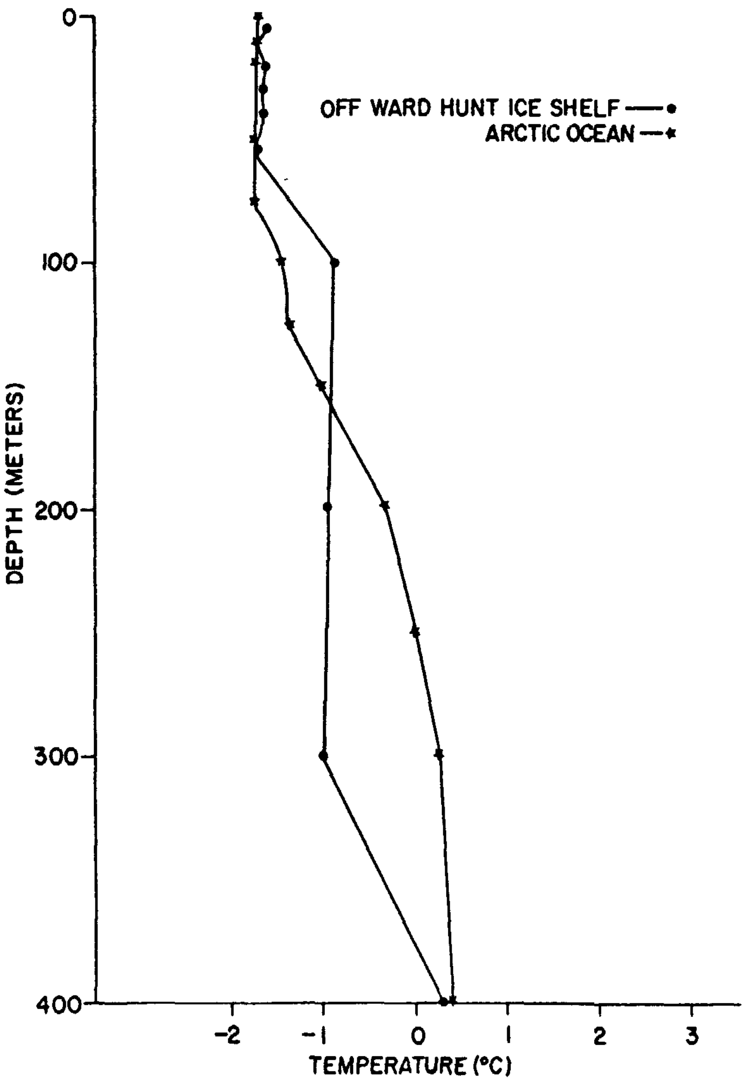

Fig. 10. Temperature profiles off Ward Hunt Island and at typical Arctic station.

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