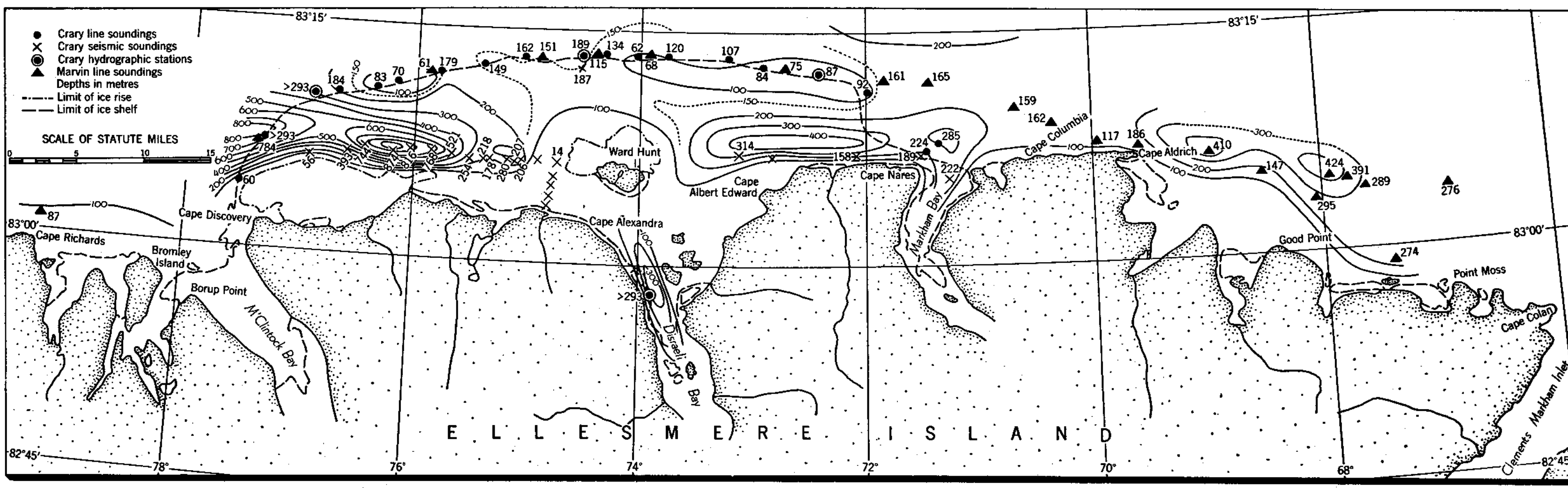

Fig. 1. Bathymetric chart along northern Ellesmere Island.

GEOPHYSICAL STUDIES ALONG NORTHERN ELLESMERE ISLAND

A. P. Crary*

Part I. Bathymetry

WATER depths in the general area of Ward Hunt Island off the north coast of Ellesmere Island, extending east to Point Moss and west to the mouth of M'Clintock Bay, were obtained from three general sources: line soundings made by Ross G. Marvin of the Peary Expedition of 1906; line soundings made by G. Hattersley-Smith and the author in 1954; and seismic observations made through the ice shelf by the author in the same summer.

In the summer of 1906, when Peary left on his memorable trip westward along the northern shore of Ellesmere Island, he instructed Marvin to take soundings in the polar sea north from Cape Hecla. Marvin, finding the open lead offshore a permanent fixture, was unable to carry out these instructions and proceeded instead along the edge of the smooth bay ice as far as Cape Richards, taking in all twenty soundings. Bushnell (1956) has located Marvin's report of his trip and presented it as it was given to Peary. Marvin's locations were fixed by horizontal angles to prominent capes and peaks, and also by a few sun shots. The latter, however, have not been located, but recent aerial mapping of the northern Ellesmere coast has made it possible to locate the positions from the horizontal angles.

In the last two weeks of June 1954 Hattersley-Smith (1955) and the author also journeyed along this same ice front between Markham and M'Clintock bays, making nineteen soundings, three hydrographic stations, and taking thirteen Phleger bottom core samples. Unfortunately, Marvin's account was not located in time to be of use in the planning or execution of the 1954 programme.

In the late summer of 1954 a total of twenty-five seismic soundings was attempted through the ice shelf, of which nineteen were successful. A portable Southwestern Industrial Electronics Company six-trace portable seismograph was used, with a seventy-five metre spread of geophones. Elastic impulses were produced either by a blow on a piton driven into the ice, or with a small TNT charge located in one of the small drainage ponds that were common on top of the ridges during this period.

Most of these seismic depths were taken along an east-west line extending from Ward Hunt Island west to the ice rise north of Cape Discovery. Five seismic stations were made early in September east of Ward Hunt Island, and

*Geophysics Research Directorate, Air Force Cambridge Research Center, Air Research and Development Command.

four more were made in a north-south line connecting the western side of the Ward Hunt ice rise to the Ellesmere mainland. Only two seismic stations were made in the vicinity of line soundings: one due north of Ward Hunt Island, where duplication was good; the other on the new part of the ice shelf north of Cape Nares where thirty-five metres difference in depth was found in about one kilometre. Unfortunately, the records from the north-south line from the Ward Hunt ice rise to the mainland were very poor and showed no definite reflections. By mid-September the air temperatures were dropping rapidly, causing almost constant cracking of the ice due to thermal stresses in the surface. Explosive charges and hammer impulses, both of which were used to some extent in this seismic work, seemed to augment or trigger these ice tremors. Though no definite depths were obtained here, there were no deep reflections noted such as were found along the western line. Additional evidence was obtained well inside Disraeli Bay, where a hydrographic station was made late in September. No bottom was reached here with the three hundred metres of hydrographic cable available.

Fig. 1 shows the bathymetric chart of this general area. It will be noted that a great deal of freedom has been taken in the drawing of the contours. The scarcity of data combined with the great variation in depth would allow other interpretations. This map has been contoured generally with the major deep and shoal features paralleling the coast line.

Hattersley-Smith (1955) has pointed out that extensive glaciation at one time enveloped much of this coast. Erratics were found on Ward Hunt Island at heights of more than 300 metres above sea level. Also, the raised beaches occurring at elevations of forty metres or more, both on Ward Hunt Island and on Ellesmere Island proper, testify to isostatic rise of the land, presumably following the retreat of heavy glaciation which at one time extended from the land into the coastal waters. The interpretation of the bathymetric map is that the shoals that lie 15 to 20 kilometres from the coast are moraines formed by these glaciers. Though the contouring shown would appear to limit these morainal banks to the north, there is no evidence for this.

Following the building up of these moraines, during a time of retreating glaciers, currents may have scoured out the deeps both to the east and west of Ward Hunt Island and to the north of Good Point. Deviation of these waters coastwise would have been caused by the moraines toward the north. Christie (in press) has mapped a late Palaeozoic unconformity in this area along which the deep scouring may have developed.

As seen on the map, there were two adjacent stations north of Cape Discovery, where bottom was not reached by the three-hundred-metre hydrographic line. A thankful acknowledgment must be made to the efforts of Marvin who, in a like situation, sledged back to a cache north of Ward Hunt Island to gather more sounding line and finally obtained a depth of 784 metres. This checks well with the 874 metres found by seismic means under the shelf area farther to the east.

From the seismic observations calculations of the depth of water, of the dip of the ocean bottom, and of the sub-bottom reflections can be made. Some

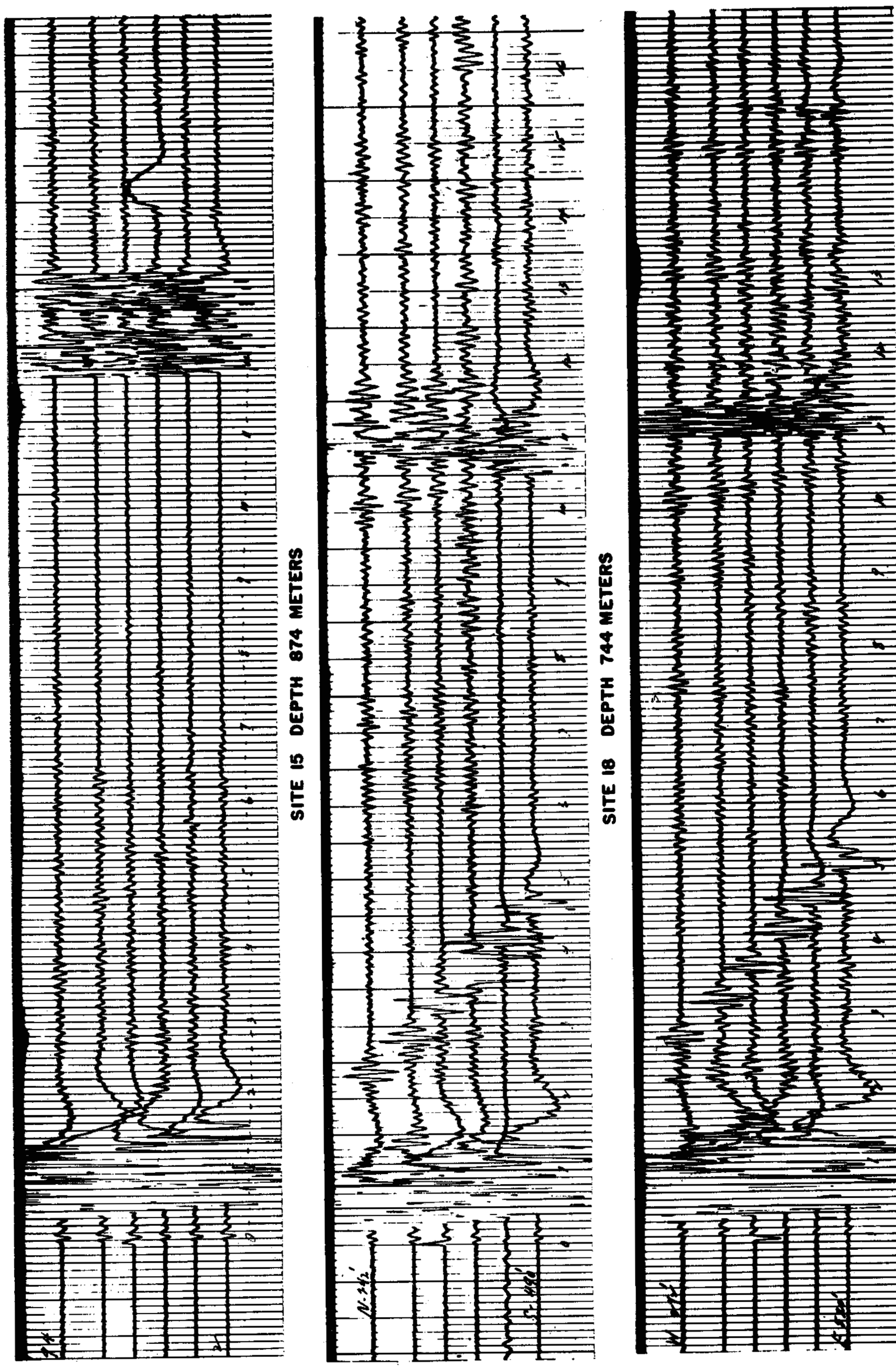

Fig. 2. Seismic records showing bottom and sub-bottom reflections.

general information on the thickness of the underlying sedimentary formations is derived from the depths, where abundant reflection energy is returned. Fig. 2 shows the best examples. These are records taken near the deepest water found under the western part of the shelf. Fig. 3 shows the section along this seismic line that, as can be seen from the map Fig. 1, lies almost parallel to the general strike of the beds. At seismic site 18, where the depth is 744 metres, strike and dip data were obtained that showed a dip of about 20° toward the north-northeast. This indicates that the deepest part of the trough lies somewhat north of the line and that this deepest part may not be continuous with the deep that Marvin located farther west. East of Ward Hunt Island dips in only the north-south direction were obtained. Nearest Ward Hunt Island at a depth of 314 metres the dip was 8.5° to the north; between Cape Albert Edward and Cape Nares at a depth of 158 metres the dip was 24° to the north. Obviously, this feature can not be accurately mapped without further data.

It is to be noted that the waters surrounding southern Ellesmere Island and Baffin Island show many similar off-shore deeps, such as those in Jones Sound, and those in Hudson Strait described by Dunbar (1951). The off-shore Ellesmere moraines have their counterparts also in the banks off western Greenland, although there no deeps lie between the banks and the coast. This may be due to the less rapid retreat of glaciers toward the central Greenland ice cap as compared with that in northern Ellesmere, or to the harder material.

There seems to be little doubt that the bays of northern Ellesmere are typical fiord types even though quantitative evidence is lacking. At the oceanographic station in Disraeli Bay bottom was not reached at 300 metres, although the station was 15 kilometres in from the mouth and less than one-fifth of the width from shore. The presence of islands southeast of Ward Hunt Island and the lack of deep reflections to the southwest of it would indicate a sill near the mouth of the bay.

No soundings were taken in Markham Bay. One seismic sounding and two line lowerings at the mouth of the bay indicated depths below 200 metres, though Marvin's values, a few kilometres north of this, were all less than 200 metres.

To the east, and depending entirely on Marvin's soundings, another deep has been indicated that extends from a point near Cape Aldrich east to a point north of Point Moss. The location of this deep is based on very limited data and its inferred structure is shown as of the same general character as those to the west.

Part II. Hydrographic Stations

The hydrographic stations belong to two periods: three were obtained prior to the summer melt at points north of Cape Discovery, north of Ward Hunt Island, and north-northwest of Markham Bay, whereas three others were obtained during the summer months. In Figs. 4 and 5 the pre-summer salinities and temperatures are shown, together with the values obtained at the ice island T-3 in April 1954, when it was about 300 kilometres northeast of Ward Hunt Island.

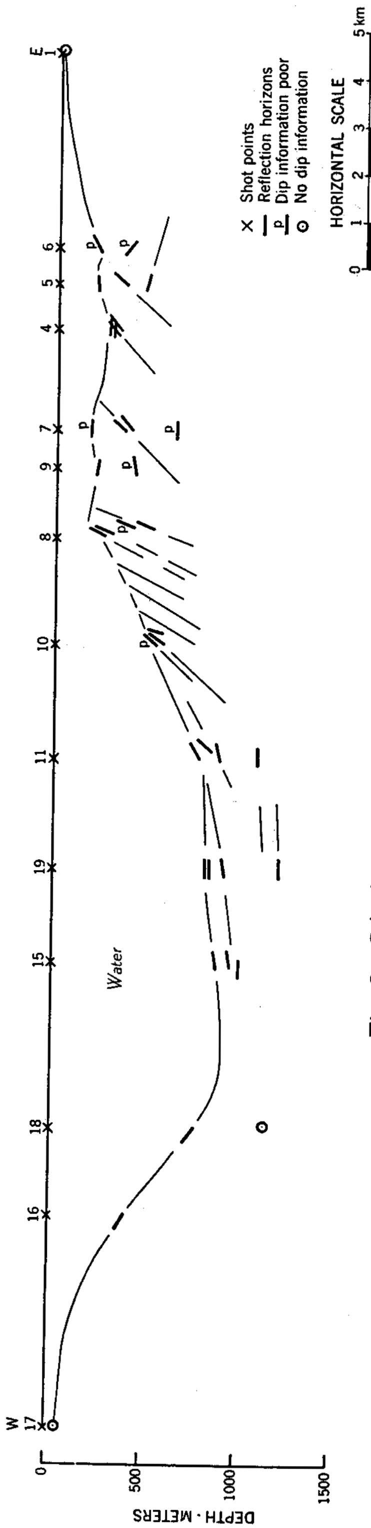

Fig. 3. Seismic profile west of Ward Hunt Island.

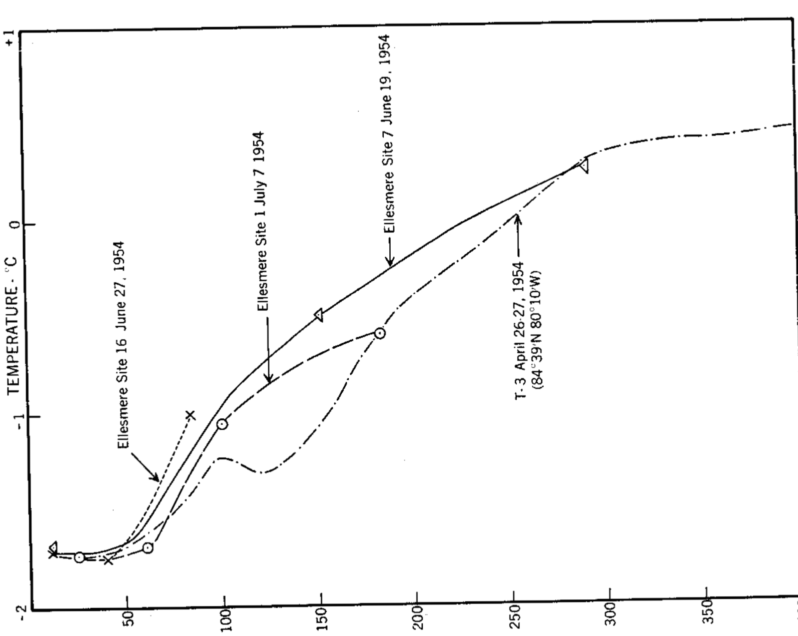

Fig. 4. Water temperatures before summer melt compared with those from T-3 in April 1954.

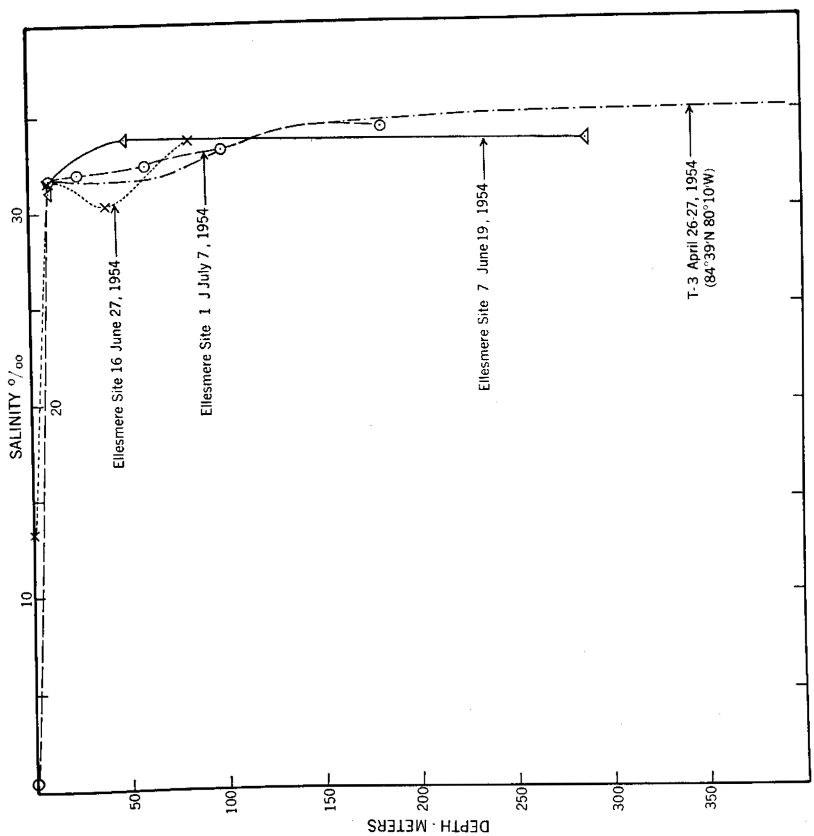

Fig. 5. Salinity measurements before summer melt compared with those from T-3 in April 1954.

It will be seen that the temperatures in the first fifty metres are nearly identical with those from T-3. Below fifty metres the temperatures are as much as 0.5°C higher, approaching the T-3 temperatures again at the greater depths. Temperatures taken at T-3 were also higher than those obtained elsewhere in the regions of the arctic basin. These Ellesmere waters are probably heated by fresh waters overlying them in bays and ice shelf areas.

Surface salinities are also high, 31.6 to 31.8‰, in the off-shore waters. High surface salinities, as pointed out by Worthington (1953), may be the result of proximity to the Atlantic water inflow, or, according to Nansen (1902), the result of distance from fresh water river outflows. Both factors undoubtedly affect different arctic areas in varying degrees. It is believed that the amount of open water in the winter season has most likely a large influence on the surface salinity. It is well known that in an area about 80 kilometres wide along the coasts of northern Ellesmere Island and Greenland continuous hummocking and forming of open leads take place that result during the winter months in a steady production of new ice. This process increases the salinity of the remaining waters. In contrast to the seas off northern Alaska and Siberia, the surface water is not freshened by extensive melting or by large river outflows in the summer.

Figures 6 and 7 show the variations of temperature and salinity of the waters during the summer season. These figures were all taken at the station north of Ward Hunt Island, with the exception of those obtained at the station inside Disraeli Bay on September 18. It will be seen that thaw waters are not evident even in early August. The significance of comparing the thaw water characteristics at the station north of Ward Hunt Island at the end of the summer season with waters at the same depths in mid-June is destroyed by the fact that large differences have been observed in the length of the summer season. On T-3 the summer was extremely short in 1953, lasting only from early July to the last week in July, as compared with the summer of 1954 on the Ellesmere ice shelf that extended from early July until early September.

The hydrographic station deep in Disraeli Bay is especially interesting in that it shows that little mixing of fresh and salt water has taken place. Since water at temperatures between 0°C and 4°C is heavier than water at 0°C, and since drainage waters from nearby areas of Ellesmere probably reach little more than 4°C before entering the bay, stratification such as is shown must be the case. The colder salt water will cool the warm bottom layers of fresh water, which then rise by convection until the whole fresh water column is at 0°C. Hence, we should expect minimum summer ablation from the bottom of the shelf, at least in the bays and in areas nearest the coast. Freezing may well take place at both top and bottom of the fresh water column, with the ice formed at the bottom floating upward to unite with that accreting at the under side of the ice shelf. It is extremely unfortunate that an attempt to penetrate Disraeli Bay in early May to establish a hydrographic station before the thaw began, met with failure due to the inability of the dog team to travel through the deep snow encountered inside the mouth of the bay.

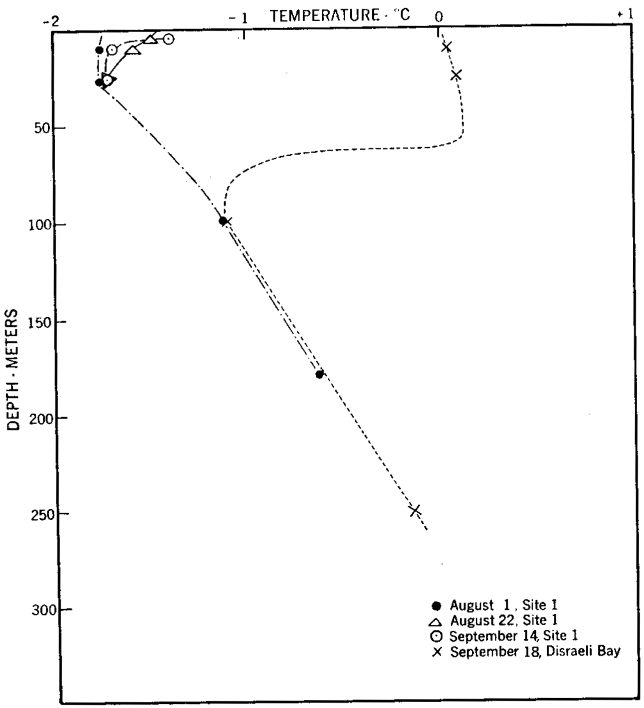

Fig. 6. Variation of water temperatures during the summer season.

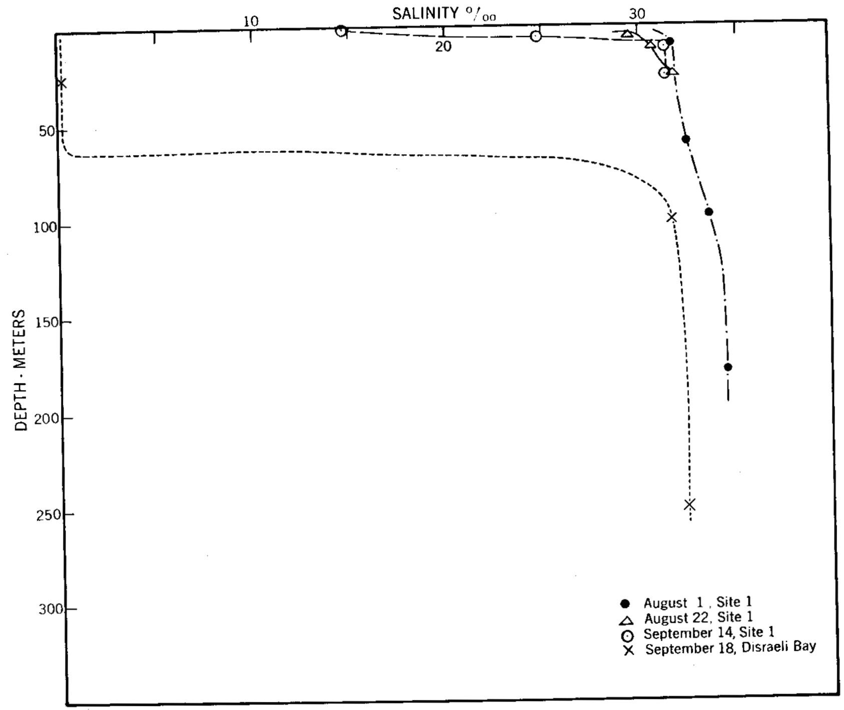

Fig. 7. Variation of salinity during the summer season.

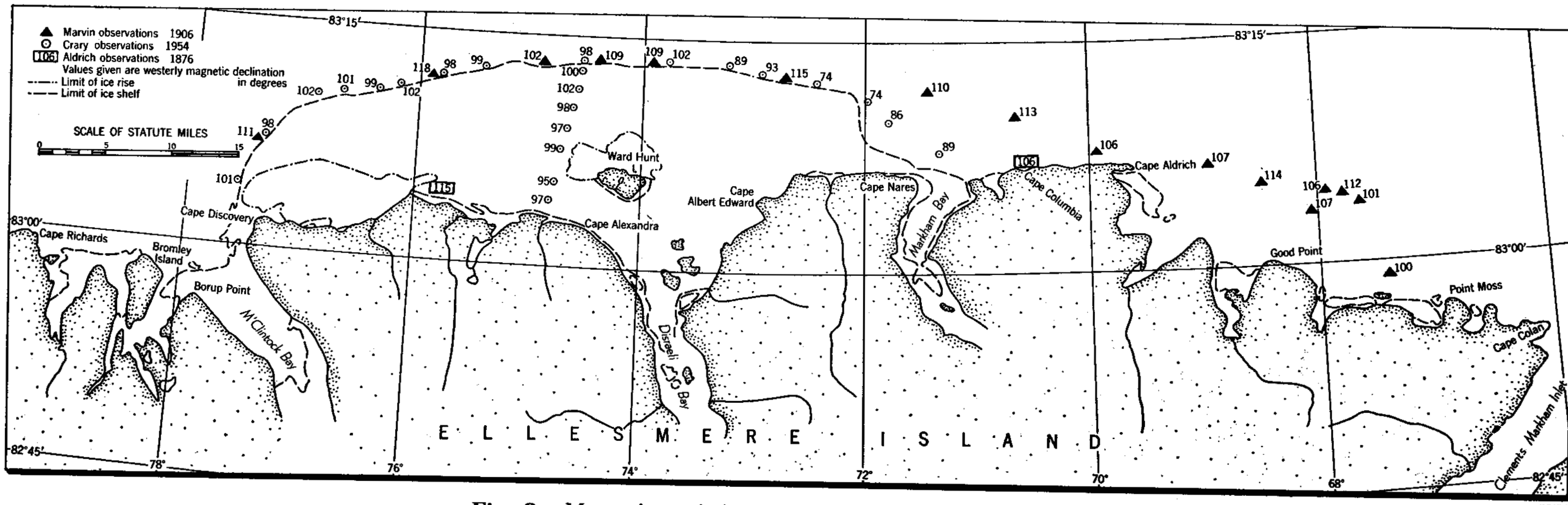

Fig. 8. Magnetic variations along northern Ellesmere Island.

Part III. Magnetic Declinations

Along the line of the transit survey across the width of the ice shelf and along the ice front during the oceanographic studies, magnetic bearings to the mountain peaks were regularly obtained. Marvin took similar magnetic bearings during his trip along the shelf. Reduction to magnetic declination or variation is possible when the locations of the sites of observations are known. The results of these reductions are shown in Fig. 8. It can be seen that in all cases the west declinations obtained from Marvin's data are greater than those obtained in 1954. Two values of declination obtained by Aldrich, who made a trip along the inside of the shelf in 1876, are also shown, but these are not located sufficiently close to later stations to allow direct comparison.

In Fig. 9 are plotted the observations obtained in 1906 and 1954 along the ice front that, as noted previously, had not changed significantly in position in this forty-eight year period. The average value of westerly declination obtained by Marvin is greater by 13° than that found in 1954. Madill (1948) has discussed the historical variations in the location of the North Magnetic Pole. Amundsen made a series of observations in 1904–5 showing the Magnetic Pole to be in the vicinity of 70°30′N and 95°30′W, whereas Madill's value in 1947 was 73°N and 100°W, corresponding to a shift toward the west as viewed from Ward Hunt Island of 9° that agrees quite well with the 13° cited above.

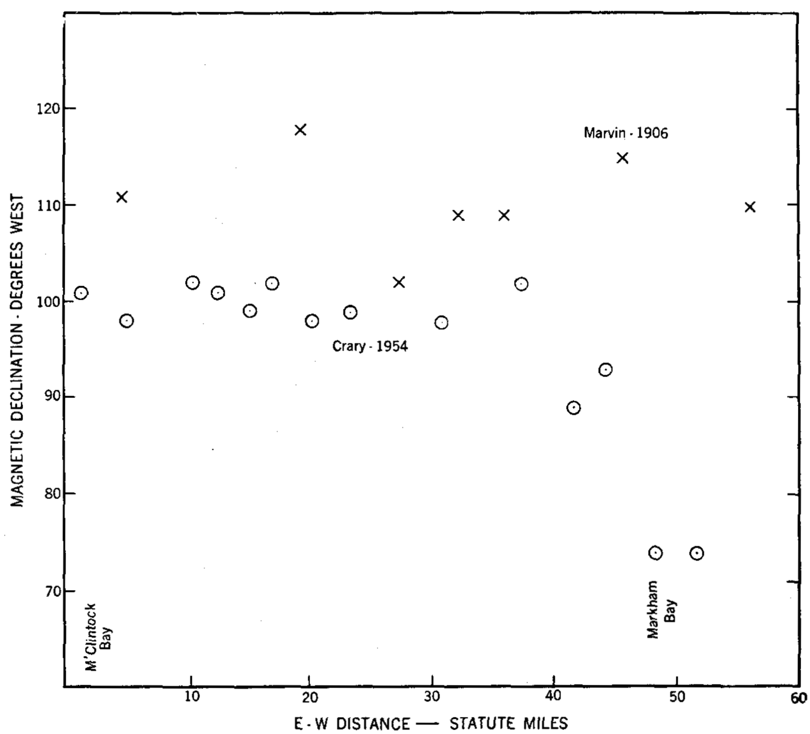

Fig. 9. Comparison of magnetic variations in 1906 and 1954.

Acknowledgments

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The oceanographic instruments were obtained from the Woods Hole Oceanographic Institution, to which grateful acknowledgments are given. The determinations of salinity and temperature from samples and field data were also made by this same institution. Information on the ocean temperatures and salinities at T-3 that had not been published previously, was furnished by L. V. Worthington of WHOI from field data obtained by Norman Goldstein and Charles Horvath.

Bottom cores obtained along the northern Ellesmere shore in 1954 will be discussed in a separate report by D. B. Ericson of Lamont Geological Observatory, Columbia University.

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