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Some Oceanographic Features of
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INTRODUCTION

Two oceanographic cruises were conducted in the Eastern Arctic by H.M.C.S. "Labrador" in 1955 and 1956 (Fig. 1, 2 and 4). Both cruises covered wide regions of the Arctic, but the principal areas of interest were Hudson Strait, northern Hudson Bay, Foxe Channel, and Foxe Basin. The exploratory nature of the work by "Labrador" was such that repeat or seasonal oceanographic observations could not be achieved in all areas in a single year, but within the two years, 1955 and 1956, oceanographic observations were made in northern Hudson Bay, in June, July, August, and October (Fig. 4).

The oceanographic program consisted of a number of studies, but in this particular area, the observations were limited to temperature, salinity, and oxygen measurements. From these data it is possible to indicate some of the water characteristics, seasonal changes, and currents for the periods of observation. A complete synoptic treatment of the data cannot be considered valid for all the present observations owing to time differences and different geographical areas of study. Therefore, each oceanographic section has been considered individually and related to other areas wherever possible.

Our understanding of the circulation in northern Hudson Bay and Foxe Channel is far from complete because there are too few observations in many areas, particularly the narrow channels where oceanographic observations are difficult to achieve. Other factors which must be studied are the seasonal aspects of the water characteristics and circulation. As yet even with the efforts of "Labrador" and other ships it is only possible to hint at whether some of these conditions are permanent, seasonal or sporadic.

PREVIOUS STUDIES

Many notable expeditions have been made to Hudson Bay but few have entered this region for the purpose of undertaking both oceanography and fisheries. It was not until 1930 when the Hudson Bay Fisheries Expedition was organized that both tasks were undertaken on a large scale in this area. A comprehensive field program was carried out to ascertain fisheries possibilities, and the biological, physical and chemical conditions of the waters of Hudson Bay and Hudson Strait (Hachey, 1931). Reference to the accomplishments of this Expedition are too numerous to list and the reader is advised to refer to Contributions to Canadian Biology, 1930, 1931, 1932 and 1933.

Since the 1930 Expedition only scattered oceanographic observations have been made in Hudson Bay by "Haida", "Calanus", and "Labrador" (Bailey and Hachey, 1951; Dunbar, 1958; and Campbell, MS 1958). Two recent expeditions have been completed by "Calanus" and "Labrador" in Hudson Bay, and their work may provide an additional contribution to our present knowledge of the region.

Oceanographic studies in Foxe Basin and Foxe Channel have been undertaken by a number of expeditions but in most cases the work has been restricted by heavy ice. It is only within the past few years with "Labrador" available that virtually all areas of Foxe Basin could be explored (Campbell, 1958). The circulation in Foxe Basin and Foxe Channel consists mainly of a strong southerly current along the western side of the basin and channel (Parry, 1824; Campbell and Collin, MS 1956).

In Hudson Bay the circulation is principally a counter-clockwise sweep of water around the bay with the strongest currents occurring along the eastern perimeter (Hachey, 1931a, and 1935; Dunbar, 1951). On the western half of the bay the currents are comparatively slow and distributed over a much wider region than on the eastern side.

The circulation in Hudson Strait consists of a dominant outflow along the southern side of the strait and a weaker inflow of Atlantic water along the northern side (Smith, Soule and Mosby, 1937; Campbell, MS 1958). Current continuations of the Atlantic inflow contribute in part to the outflowing waters on the southern side of the strait and to a west-moving current beyond Big Island. The latter current is believed to be made up of waters originating from the Atlantic intrusion, Hudson Bay, and Foxe Channel.

PHYSIOGRAPHY

The land masses and islands of northern Hudson Bay are made up chiefly of Precambrian and Palaeozoic regions (Fig. 3).

The Precambrian formations are found on Baffin, Mill, Salisbury and Nottingham Islands, northern Quebec, and the northeastern sides of Coats and Southampton Islands. The Palaeozoic areas cover most of Bell Peninsula and Coats Island and all of Mansel Island (Geological Map of Canada, 1955). The Precambrian rock formations are generally characterized by a rugged, uneven topography, and when viewed from the sea they appear abrupt and steep-sided. In contrast, the Palaeozoic land structures appear much more subdued in relief. All of these general relief characteristics are found in the bottom topography. Off Mill, Salisbury, Nottingham, and Digges Islands the bottom is uneven, and rugged, while off Bell Peninsula it is relatively smooth and unbroken (Fig. 3). Abrupt changes in the character of the bottom and depth appear only in Foxe Channel and the northern end of Hudson Bay. In these regions depths of the order of 300 metres are found (Fig. 3). However, the bottom in the northern end of Hudson Bay displays more of the subdued characteristics typical of Hudson Bay than Foxe Channel. Foxe Channel exhibits the same type of uneven features as Hudson Strait.

The bottom, north of Coats and Mansel Islands, deepens considerably towards Hudson Strait where depths of 300 - 400 metres are found off Digges Islands. However, towards Foxe Channel the bottom shallows to form a narrow ridge that extends from Bell Peninsula to Nottingham Island. The ridge is relatively shallow and flat immediately off Bell Peninsula, but offshore it gradually narrows and becomes uneven as the Palaeozoic bottom forms give way to Precambrian formations.

OBSERVATIONS AND RESULTS

Northern Hudson Bay

Temperature and salinity: The 1955 oceanographic program of "Labrador" commenced in Hudson Strait in early June and continued through Hudson Bay to Evans Strait (Fig. 4 and 5). All of this work was carried out at a time when heavy ice conditions prevailed in Hudson Strait and Hudson Bay. The timing of the survey in relation to the ice conditions was such that the temperature and salinity regimes may be considered as very nearly typical of late winter conditions. Under these conditions near extreme values of temperature and salinity were obtained at subsurface depths. Temperatures appeared to be almost at minimum values while the salinities were at maximum values. Many of the stations were occupied in "open pools" or "polynas" and hence surface and near surface salinities and temperatures vary over a wide range and are atypical of conditions in general.

Temperatures in Evans Strait were found to be low in general, with surface values ranging from -0.10 to -0.80° C (Fig. 5). At 20 metres temperatures dropped sharply to values of -1.50° C and less. Salinities were not unusual for the surface (31.5‰), but at 30 metres they were relatively high (33.0‰). Conditions near Hudson Strait were quite different with surface temperatures almost approaching 1.0°C. Cold water such as that found near the surface in Evans Strait was found only at depths of 75 metres and greater. A similar situation occurs for the distribution of salinity. Values of salinities confined within the upper 40 metres at Evans Strait are found distributed throughout the upper 150 metres of the water column at Hudson Strait (Fig. 5). The small temperature gradients found in Hudson Strait develop through the combined effects of the spring thaw and the northward transport of relatively warm water from southern Hudson Bay. The disappearance of ice in the southern part of Hudson Bay permits warming of the waters of the north-bound current. In addition, this current also carries large volumes of surface-freshened water, and as a result surface salinities off Digges Islands are low, 30.5‰ or less, compared with values of 31.5‰ or greater in Evans Strait.

A comparison of the temperatures below 50 metres reveals slightly wàrmer water off Digges Islands (-1.25 to -1.50°C) than in Evans Strait (-1.75 to 1.81°C) (Fig. 5). However, in the central area the temperature of the deep water remains relatively constant at approximately -1.50°C, but below 250 metres at stations 42 and 43 a large mass of water was found with a temperature of -1.26°C. This formation is believed to be a remnant patch of water that has remained over from the previous year. This is deduced from the close similarity of temperature and salinity conditions found in the area in the late autumn of 1956 (Fig. 6) and also in Hudson Strait in 1955 (Campbell, MS 1958). The occurrence in the spring of water with such temperatures is perhaps indicative of at least one of two other factors -- very little movement of deep water during winter, and a probable lower limit of winter cooling and mixing at approximately 250 metres.

The cold relatively high salinity water masses lying off Southampton Island in Evans Strait at depths of 50 metres or more are not found elsewhere in this section. They are found, however, in Foxe Channel. This relationship immediately raises the question of how the cold high salinity water is brought into Evans Strait and Hudson Bay. It could be introduced into these regions by a steady current or an intermittent spillover from Foxe Channel, or even form locally in the northwestern section of Hudson Bay. For the present there is too little dynamic evidence to base firm conclusions.

The distribution of temperature, salinity, and density indicates a change in characteristics of the water at Station 44 in Hudson Bay (Fig. 5). To the west of this station the water is colder and more saline than that to the east. The cold saline water west of station 44 appears to be a mixture of water from both Foxe Channel and Hudson Bay because off Southampton Island the waters mix and sink into the basin at the northern end of Hudson Bay. As a result of this phenomenon strong slopes of the isopycnal surfaces are created at depths below 50 metres. The reverse slopes east of station 44 appear to be related to a strong deep inflowing current that has been detected in Hudson Strait between Nottingham and Digges Islands (Campbell, MS 1958). An apparent surface extension of this current is really another phenomenon related to an eddy formation centred east of station 42.

The relatively warm low salinity water lying within the surface layer east of station 44 is Hudson Bay water that has been carried northwards by the coastal current along the eastern perimeter of the bay (Fig. 5).

A resurvey of these waters in October of the same year (Fig. 6) revealed major changes of water conditions compared with those found in the previous survey of June (Fig. 5). Surface temperatures off Digges Islands increased from less than 1.0°C in June to almost 5.0°C by October. The distribution of the above-zero temperatures in June was limited to a thin surface layer of 15 metres at stations 43 and 42 (Fig. 5), while the October above-zero temperatures extended almost across the section from Digges Islands to Coats Island and downwards to a depth of 60 metres at station 201 (Fig. 6). The cold deep water formations (less than -1.50°C) which were observed in June in the eastern part of Hudson Bay were either warmed through vertical mixing or replaced during the summer by waters with temperatures of -0.75 to -1.25°C.

A comparison of the two sections (Fig. 5 and 6) reveals a much more limited distribution of cold water in October than in June. The formation was still confined, however, to the same general locale as the coldest water in June. Subsurface temperatures of -1.00 to 1.25°C in the western section of Hudson Bay represent quite a change of temperature over that of June, 1955, when temperatures were -1.50 to -1.75°C (Fig. 5).

The marked changes which the temperature regimes have undergone by October are no less remarkable than the changes which have occurred to the salinity field during the summer months. Surface salinities were, on the average, 1 to 2 parts per mille lower in October than in June. Such changes can be expected in July and August when ice melts and river run-offs are greatest, but freshening of both surface and deep water as late as October indicates the retention of large volumes of fresh water in the bay. Mixing processes carry the fresh water to deep depths resulting in a depression of salinity. This is quite evident in the central and eastern parts of northern Hudson Bay where salinities have decreased over the summer throughout the upper 100 and 150 metres. Below these depths, salinities remained relatively undisturbed throughout the summer.

One other oceanographic section was occupied in Hudson Bay in 1955. A section across Evans Strait was first occupied in July and reoccupied in October, 1955 (Fig. 7 and 8). The July survey (Fig. 7) reveals another area comparable to that in Hudson Bay where temperatures were below -1.75°C. These temperatures are seen to cover a major portion of the strait below 30 metres. Salinities, however, were not unusual, ranging only from 31.0 to 33.0‰. The salinities compare favourably to those in June for the northwestern section of Hudson Bay (Fig. 5).

The possibility that the cold water originates in Foxe Channel has been mentioned, but the unexpected feature of the results from this section is the lack of any correlation with a flow of water from Foxe Channel. Formation or intrusions of water from the northwestern section of Hudson Bay are possible, but as yet no observations have been taken to indicate such a development (Dunbar, 1958). A resurvey of the Evans Strait section in October revealed a clearly defined westerly flow below 30 metres which presumably originated in Foxe Channel (Fig. 8). This evidence suggests the possibility that the westerly current is perhaps associated with summer conditions. On the other hand, the observations in July could be indicative of winter circulation patterns which are not known or understood at the present time.

The summer changes of temperature and salinity are significant for this section (Fig. 7 and 8). Minimum temperatures which were approximately -1.85°C in July were about -1.50°C in October. Changes of temperature within the surface layer over the same period of time were about one Centigrade degree. Surface salinities were higher in October than in July, indicative of the disappearance of brackish surface water. However, the dilution effects of melt water and river run-off were still apparent at the lower depths. Dilution of waters down to 80 metres or roughly to the 33.0‰ isohaline was evident in October, but in July only the surface waters showed any sign of dilution. At this time, the 33.0‰ isohaline was located at approximately 50 metres depth.

Currents: The coastal current along the eastern shore of Hudson Bay transports large quantities of warmed surface-freshened waters northwards (Hachey, 1931a). Consequently, low salinities and warm waters can be anticipated during the summer off the northeastern tip of Hudson Bay and along the south coast of Hudson Strait. Some effects of this current have been referred to previously but it is interesting to note several changes which occurr in the distribution of properties. In

October, for example, the 31.0 and 32.0‰ isohalines were located between the surface and 90 metres (Fig. 6), but in June the corresponding isohalines were located between the surface and 30 metres (Fig. 5). Similarly, subsurface temperatures (-1.0 and -1.25°C) in June were confined to depths less than 75 metres, but in October these temperatures extended to depths well below 250 metres. These changes can hardly be attributed to local heating but must evolve with the gradual warming of water in Hudson Bay and transport northward.

The mean slope of the isopycnal surfaces in October is such that a northerly flow of water extends almost across the whole breadth of Hudson Bay (Fig. 6). This movement of water is considered to be a summer phenomenon arising from the warming and freshening of Hudson Bay. The winter or spring counterpart is represented in the June survey and it can be seen that the northward movement is confined to the west central section of the bay (Fig. 5). Strong inflowing currents appear on the eastern side of the bay in June between 50 and 250 metres (Fig. 5) but in October such flows are restricted to a small region between 60 and 150 metres east of Mansel Island (Fig. 6). The inflowing currents are made up of water from Hudson Strait and contain mixtures of Atlantic and Foxe Channel waters (Campbell, MS 1958). From all the data the writer has studied for this area it appears that this current is strongest in the winter and weakest in the summer.

Dunbar has reported a small southerly surface current east of Coats Island for August, 1953 (Dunbar, 1958). The results of the 1955 cruise for October suggest a similarly directed flow but at depths below 50 metres. At this time the surface movement appears to have been northward (Fig. 6). It seems unlikely that these currents are permanent features of the circulation in Hudson Bay, but rather an outcome of the relative strengths of the currents in Fisher and Evans Straits and Foxe Channel.

The two sections across the entrance of Hudson Bay (Fig. 5 and 6) indicate shallow inflows of water west of Digges Islands down to depths of 30 and 50 metres. These results are surprising because strong outflowing currents have been reported in this region (Sailing Directions for Northern Canada, 1951). These currents could perhaps be associated with large eddies or an inshore branch of a return circulation. There is, however, a strong outflow down to depths of 150 metres through Digges Sound and around Digges Islands.

Evans Strait is a region where significant variations have occurred with oceanographic observations. The observations taken in July indicate a weak easterly movement of water in the centre of the strait (Fig. 7). However, in October of the same year two currents appeared to be present on the northern side of the strait, one an easterly directed current essentially confined to an upper 30 metre layer and the other a westerly current limited to deep water. The westbound current extended across the strait and upwards to the surface off Coats Island. The current on this side of the strait appears to be much weaker than on the Southampton Island side (Fig. 8). The July survey of 1955 (Fig. 7) bears out Dunbar's contention that a northeasterly flow is experienced in Fisher Strait (Dunbar, 1958). The conflicting results which we now have at hand point to the fact that the currents in this region are far from being positively identified. The possibility of seasonal variations of the current flows for summer and winter months appears very likely.

Southern Foxe Channel

Temperature and Salinity: Following the July observations in Evans Strait the oceanographic work was concentrated in Foxe Basin and the northern half of Foxe Channel. The ship returned to the southern limits of Foxe Channel in August and three sections were occupied, from Bell Peninsula, via Lloyd Point and Mill Island to Leyson Point, Southampton Island (Fig. 4, 9, 10 and 11).

In two of the sections across Foxe Channel deep water was found with temperatures below -1.75°C (Fig. 9 and 10). Salinities were carefully checked at all depths where these unusual temperatures were found and values exceeded 33.75‰. Both conditions are markedly different from those observed in Hudson Bay (Fig. 5 and 6). Bottom temperatures and salinities were appreciably lower and higher respectively in Foxe Channel than in Hudson Bay (Fig. 5, 9 and 10) despite the fact that the surveys in Foxe Channel were two months later than the first survey in Hudson Bay. The different characteristics of the water are attributed in part to the source of the water, and also to the fact that the ridge between the two bodies of water (Foxe Channel and Hudson Bay) prevents a free exchange of bottom waters.

The overlying surface waters of Foxe Channel showed some variations in temperature. Surface values of 0.0 to 2.0°C occurred along the southeastern tip of Southampton Island while across the channel surface temperatures were of the order of -0.5 to -0.75°C (Fig. 9 and 10). Beneath the surface layer particularly in the central and western regions, there is a sharp transition within 20 to 40 metres, to cold water with temperatures ranging from -1.25 to -1.50°C.

The surface-freshened waters on the western side of Foxe Channel are associated with the warmest water, while across the channel almost isothermal and isohaline conditions accur together (Fig. 9).

At stations 103 and 104 in Foxe Channel (Fig. 9) some of the isotherms and isohalines curve upwards into the surface layer while others curve downwards into deep water. This unusual characteristic seems to be typical of the area since it has been observed at a number of other sections, always immediately off Foxe Peninsula (Campbell and Collin, MS 1956). In this region the water conditions can be typed by a small variation of temperature and salinity throughout the water column. Between stations 103 and 104 the salinity and temperature variations are only 1.0 part per mille and 0.75 Centigrade degrees respectively, between 10 and 130 metres (Fig. 9). At station 104 the salinity range in the upper 150 metres is even less, of the order of only 0.3 parts per mille. Station 107 (Fig. 10) is outside this peculiar region of uniform conditions and the distribution of temperature and salinity conforms more nearly to the distribution on the western side of the channel. The above described phenomena are believed to be associated with the intense turbulence that develops with flood and ebb tides. Evidence of the turbulence can be observed on the sea surface, where countless surface eddies form; these are visible for miles. If ice is present the floes are set into circular motion presenting an eerie scene to the observer.

The cold deep waters are characterized by unusually high salinities. Bottom salinities in the southernmost section of Foxe Channel (Fig. 10) are 33.50 to 33.75‰, considerably higher than those values found in Hudson Bay (Fig. 5 and 6). However, these values are not maxima for Foxe Channel as bottom salinities continue to increase northward through Foxe Channel. Values found in the section, Terror Pt. to Lloyd Pt. (Fig. 9) were 33.50‰ at 200 metres and 33.80‰ near the bottom. Further north, in Foxe Basin, salinities were found of the order of 33.95‰ at several stations. In all cases where these extreme salinity values were obtained temperatures were exceptionally low.

The distribution of the cold high salinity water is confined to the central and western regions of Foxe Channel. Subsurface salinities and temperatures on the eastern side of Foxe Channel tend to be less extreme than those in other areas of the Channel. Differences are particularly noticeable for the sections Mill Island to Leyson Pt. (Fig. 10) and Lloyd Pt. to Mill Island (Fig. 11). The lowest temperature found between Lloyd Pt. and Mill Island was only -1.50°C, while the highest salinity was just over 33.0‰. This section (Fig. 11) reveals temperature, salinity, and density distributions that are alike and very nearly uniform from top to bottom. The horizontal gradients are well-developed and not unlike the conditions mentioned earlier for the turbulent waters off Foxe Peninsula. The cause of these peculiar distributions of property appear to be a combination of turbulence and currents.

This area of Foxe Channel was resurveyed the following year in August with the network of stations expanded to Nottingham Island and Seahorse Pt., Southampton Island (Fig. 4, 12, 13 and 14).

The observations of the 1956 survey indicated almost a complete absence of the cold bottom water that was so prominent the year before. A few observations of temperature as low as -1.75°C were recorded in Foxe Channel in the same general area and depths as previously, but neither these temperatures nor the salinities indicated any appreciable volumes of cold high salinity water (Fig. 9, 10, 12 and 13).

Apart from the characteristics of the deep water the distributions of temperature, salinity, and density in Foxe Channel are similar for both years. Low temperatures were still featured in 1956 at all depths below 75 metres. However, cold water cells of -1.50°C were located between 50 and 100 metres in the two sections, Bell Peninsula to Foxe Peninsula and Foxe Peninsula to Nottingham Island (Fig. 12 and 13). It was possible that these sections intersected a core of cold water that extended at least throughout the southern part of Foxe Channel. The core of cold water is located in a region that would be expected to be the least affected by the currents, judging from the slopes of the density surfaces. It is conceivable, then, to expect these formations to remain relatively unaffected by water movement in the channel.

The surface coastal waters off Southampton Island were again warm, but not to the same extent as the year before. Coastal warming of the water is possible and the most likely area where inshore warming could take place is East Bay. However, extensive ice fields lying along the Southampton Island coast in 1958 probably inhibited any possibility of coastal warming. The cell of warm water, located at a depth of 20 metres between Nottingham Island and Seahorse Pt. (Fig. 14), is unusual and possibly is related to similar conditions in Hudson Bay and Hudson Strait near Digges Islands (Fig. 6).

Salinity conditions in Foxe Channel (Fig. 9 and 12) do not show any noteworthy departures for the two surveys except in the deep water, where salinities were much greater in 1955 than 1956. By and large it can be expected that lower surface and subsurface salinities will appear on the Southampton Island side of Foxe Channel than off Foxe Peninsula, since on the eastern side turbulence carries high salinity water from deep levels to the surface.

Currents: The exchange of waters between Foxe Channel, Hudson Strait, and Hudson Bay is complicated by the number of narrow channels and the bottom configurations. However, it is relatively easy to establish that there is a strong southeasterly flow in Foxe Channel along Southampton Island (Fig. 9 and 12) (Parry, 1824; Campbell and Collin, MS 1956).

This current extends to considerable depths being quite broad and extensive in the uppermost layers of the channel. For the main part it parallels the Southampton Island coast until it intersects the ridge between Bell Peninsula and Nottingham Island. In this region the deep portion of the current is deflected towards Hudson Strait. The upper current strata may also be similarly directed with a branch of the current possibly sweeping into Hudson Bay and Evans Strait.

In the central and eastern part of the oceanographic sections in Foxe Channel (Fig. 9, 12, and 13) the isopleths slope sharply downwards toward the eastern side of the channel, indicative of a northward movement of water. The geographical limits of the current are well-defined in Foxe Channel, but towards Hudson Strait it is difficult to precisely establish the exact boundaries of the current because the turbulence of the waters makes it virtually impossible to give a simple interpretation of the data.

The region lying between Foxe Channel and Hudson Strait is the least known area because the oceanographic picture is complicated by tidal currents and turbulence created over the uneven bottom. Turbulence and vertical mixing are considered to be extremely important because the mixing of the water intensifies and partly maintains the strong slopes of the isobaric surfaces. The inflow of water from Hudson Strait to Foxe Channel appears on both sides of Mill Island (Fig. 10 and 11). It is a deep current and is confined to depths below 50 metres. Outflowing currents from Foxe Channel directed towards

Hudson Strait occur below 50 metres on the northern side of Nottingham Island and above 50 metres on the southern and northern sides of Mill Island and down to depths of at least 50 - 75 metres close inshore along Foxe Peninsula (Fig. 11 and 13).

Characteristics of the Cold High Salinity Water

The unusual temperatures and salinities found in Foxe Channel and Foxe Basin are intriguing aspects of the oceanography of the area. Several questions can immediately be raised about the origin and formation of the water in view of the fact that this type of water was not found in either Hudson Bay or Hudson Strait.

Distribution: For the most part the extreme values of temperature and salinity were confined to depths of 200 metres or more in Foxe Channel. The distribution of the temperature and salinity at 200 metres depth is shown in Figures 15 and 16 for the channel, Hudson Bay, and Hudson Strait. The shaded portions of the Figures represent regions of depths less than 200 metres.

The differences of water temperatures at 200 metres in Foxe Channel, Hudson Bay, and Hudson Strait range from -1.73 to -1.85°C in Foxe Channel to -1.50 and -1.69°C in Hudson Bay and -1.45 to -1.51°C in Hudson Strait (Fig. 15). Salinities differ as well, they are significantly higher in Foxe Channel than either Hudson Bay or Hudson Strait (Fig. 16). Salinities varied from 33.30 to 33.87‰ in Foxe Channel compared with 33.10 and 33.26‰ for Hudson Bay and 33.20 to 33.35‰ for the western end of Hudson Strait.

Differences of temperature and salinity at depths below 200 metres are even greater than those described. In Foxe Channel, for instance, temperatures dropped to values of -1.86 and lower (-1.96°C) while salinities varied from 33.85 to 33.95 ‰ and at one station to a value of 34.04‰. In contrast, temperature and salinity conditions in Hudson Bay and Hudson Strait remained relatively unchanged from 200 metres to the bottom. The only significant increase of salinity occurred in the western end of Hudson Strait where salinities of 33.35 and 33.40 ‰ were found.

Temperatures and salinities in Foxe Basin varied considerably within normal limits, but abnormal temperatures and salinities were found as in Foxe Channel. At one station in Foxe Basin a bottom sample of water was taken with a temperature and salinity of -1.98°C and 34.07 ‰, respectively. Similar water characteristics were found elsewhere in Foxe Basin, but only within the southern areas of the basin. Depths of these stations were less than 100 metres in contrast to the depths of observations in Foxe Channel. From these results it would appear that there is an obvious continuity of water conditions in Foxe Basin and Foxe Channel, but not in Hudson Bay or Hudson Strait. The explanation for the lack of continutiy of these water conditions in Hudson Bay is based on the existence of the ridge between Southampton and Nottingham Islands. This ridge apparently prevents a free exchange of deep water between Foxe Channel and Hudson Bay. Nevertheless, there is evidence revealing an occasional spillover of cold high salinity water into Hudson

Bay and Evans Strait (Fig. 5 and 7). Reference to this phenomenon has been made earlier in respect to the correlation of the temperature and salinity data for Evans Strait and Foxe Channel.

The exchange of waters between Foxe Channel and Hudson Strait takes place freely and one might logically look for evidence of the cold high salinity water in Hudson Strait. Salinities greater than 34.00‰ have been found only off Ungava Bay and at the eastern end of Hudson Strait (Campbell, MS 1958). Temperatures, however, were comparatively high (-0.75 to 1.00°C).

The absence of any appreciable amount of cold saline water in Hudson Strait can be explained if the water originates in Foxe Channel. Turbulence in the narrow channels between Foxe Channel and Hudson Strait is of such intensity that the characteristics of a water column are changed. The resultant water conditions are not unlike those described for the waters off Foxe Peninsula (Fig. 11).

The distribution of the water is limited to Foxe Channel and Foxe Basin, and either region is a likely source of the water. Hudson Bay and Hudson Strait cannot be completely excluded, but it has been shown that both areas contain waters of relatively low salinities, and high temperatures. The circulation in these regions could conceivably carry cold high salinity water into Foxe Channel, but it is highly unlikely that one could account for the higher salinities and colder water in Foxe Basin than in Foxe Channel. Concluding from these facts that an invasion of cold high salinity water is improbable for Hudson Bay or Hudson Strait, there is still the possibility of an intrusion of this type of water from the Gulf of Boothia. Oceanographic data are not available for this area in 1955, but in 1956 extensive surveys were carried out by "Labrador" in the Gulf of Boothia and Prince Regent Inlet. No observations of comparable temperature and salinity relationships for either the Gulf of Boothia or Prince Regent Inlet approached the values referred to in this report for Foxe Basin and Foxe Channel (Collin, MS 1958). Further, it has been found that the temperatures and salinities in northern Foxe Basin are not unusual (Campbell and Collin, MS 1956). These conditions, therefore, leave an area within Foxe Basin and Foxe Channel where such water is found.

The validity of the temperature observations is admittedly open to question and Dunbar (1958) has pointed out the possibility of thermometer malfunction. A restudy of the results was undertaken and it was found that the low temperatures were observed at 52 oceanographic stations. All the thermometers used were new and the observations under question were recorded on six thermometers. Moreover, at a number of stations essentially the same low temperature observations were made on two and three thermometers. It can be said that such thermometers are in error, but the occurrence of the unusually high salinities at the same depths and stations forces one to consider not only the validity of the temperature observations but also of the salinity observations. It is felt that both are intimately related and are true measures of the temperature and salinity of the waters in Foxe Basin and Foxe Channel.

Origin: In order to satisfy the geographical limits of the distribution of the cold high salinity water and the temperature-salinity correlations it is felt that there must be some mechanism or mechanisms of water formation peculiar only to Foxe Basin or Foxe Channel. Cooling and freezing processes can lower the temperature and increase the salinity but a lower limit is established by the formation of ice. This mechanism, in order to be self-generating, requires open water where either turbulence or wind constantly remove the ice that is formed when freezing takes place. These processes undoubtedly occur in the Arctic, but it is unlikely such a system can remain self-generating over the winter or on a large enough scale to produce the quantity of cold saline bottom water discovered in Foxe Basin and Foxe Channel. Super cooling of water is possible, but again it is unlikely such a phenomenon can remain self-generating on the scale required.

Geographical factors peculiar to Foxe Basin lend themselves to a hypothesis that the cold saline water might be formed by the freezing of water on the tide flats. Foxe Basin contains about 6,000 sq. miles of tidal flats which represents almost one temth of the basin area. In some regions such as Bowman Bay the width of the tidal flats is of the order of 6 miles.

Under the appropriate meteorological conditions cooling and freezing of water could take place on the tide flat bottoms. The rise and fall of the tide will alternately expose the tide flats to cold atmospheric conditions and marine conditions regardless of how much ice is formed. It is seen that there are two independent processes taking place. The replacement of sea water on the tide flats by tidal action, and the chilling of water by ice and tide flats after exposure to severe meteorological conditions at low tide. The freezing out of fresh water will naturally increase the salinity and depress the freezing point. These processes continually repeated over the tide flats effectively remove and store fresh water in the form of ice.

Winter air temperatures for Foxe Basin are very much lower than the freezing point of fresh water. The mean January daily temperatures, for example, are approximately -22.0°F (Thomas, 1953). Mean daily air temperatures for December, January, and February are slightly higher than this value but still sufficiently low to maintain freezing conditions.

As long as low air temperatures occur during periods of low tide there will be freezing surfaces available for incoming flood waters. The growth of ice will be accompanied by the formation of brine cells and brine pools of higher concentrations of salt than the original sea water. The escapement of the "brine concentrate" to the sea is achieved either by seepage or recovery on flood tide. The "brine concentrate" will, of course, be high in salt content and well-below normal sea temperatures. Offshore mixing processes will tend to reduce the extreme conditions of temperature and salinity found over the tide flats.

The dense waters resulting from the processes of formation are found throughout most of the water column in Foxe Basin. The vertical distribution of the water appears to depend on mixing and the quantity of the cold high salinity water produced in the basin. In Foxe Channel, however, the water appears to sink directly to the bottom depths.

In 1956 when the same areas were surveyed again the cold salinity water was almost completely absent except for traces revealed in one section in Foxe Channel (Fig. 12). In that year bottom temperatures varied from -1.69 to -1.83°C while the salinities ranged from 33.35 to 33.60‰. Even these values do not compare with those of the year before, but they are more extreme than the conditions found in Hudson Bay (Fig. 6).

The explanation for the absence of the cold saline water in 1956 appears to be related to the relatively mild winter of 1955-56. Bates (1958) has pointed out that air temperatures in Foxe Basin and Hudson Strait were considerably above their normal values for the winter of 1955 - 56. The difference from normal conditions was approximately 600 to 800 degree days. In terms of ice growth this difference amounts to about 7 - 10 inches of ice growth.

The occurrence of the cold saline waters in other years is not known, but Hachey (1931 and 1954) has reported unusually low temperatures in Hudson Bay. He has questioned the observations, but in view of the findings in 1955, the occurrence of such low temperatures in 1930 cannot be entirely dismissed. The winter conditions for 1929 - 1930 and 1954 - 1955 are recorded as amongst the most severe in the Eastern Arctic (Monthly Record of Meteorological Observations, 1929, 1930, 1954 and 1955). Perhaps the severity of the winter period, 1929 - 1930 had some effect on the water conditions of Hudson Bay as first reported by Hachey (Hachey, 1931 and 1954).

SUMMARY

1. Two oceanographic surveys were carried out in northern Hudson Bay, Foxe Channel, and Hudson Strait, in June, July, August and October of 1955, and August of 1956.

2. The June surveys in Hudson Bay reveal what is considered to be winter conditions below the surface layer. Remnant water masses from the previous year are believed to exist at deep levels. The surface layer exhibits temperature and salinity characteristics of Foxe Channel waters off Coats Island, but off Digges Islands the surface waters show some of the effects of warming and dilution in southern Hudson Bay.

3. The autumn survey results typify the summer water conditions of Hudson Bay. Water temperatures are higher in June particularly on the eastern side of the bay. Salinities show a slight decrease from those of June owing to the release of fresh water from rivers and ice.

4. The two surveys carried out in Foxe Channel reveal almost identical distributions of property, temperature and salinity, although in 1955 bottom salinities and temperatures were much higher and lower respectively than in 1956.

5. Current patterns in Hudson Bay differ for each survey, and it is thought that seasonal changes may be the cause. The general movement of water, however, is northwards, but on both the western and eastern sides of the section (Coats Island to Quebec) there are inflowing currents from Foxe Channel or Evans Strait and Hudson Strait respectively.

6. The circulation in Foxe Channel is dominated by a

southeasterly flow along Southampton Island. The main body of this current is deflected into Hudson Strait by the ridge which separates Foxe Channel from Hudson Bay. The surface layer may be similarly directed, but some water appears to escape into Hudson Bay, it is not know definitely whether this escapement would constitute a permanent current or not. There is some evidence indicating that a summer current sweeps out of Foxe Channel into Evans Strait and that it weakens and perhaps disappears in the winter.

7. The distribution of cold high salinity water in Foxe Basin and Foxe Channel is discussed with reference to conditions in Hudson Bay, Hudson Strait, northern Foxe Basin and the Gulf of Boothia. The local distribution of the water points to the possibility that it might be formed in Foxe Basin. It is suggested that the water originates through a process of freezing on the tide flats in Foxe Basin. Tides, currents, and mixing ultimately bring the water into Foxe Channel.

ACKNOWLEDGEMENT

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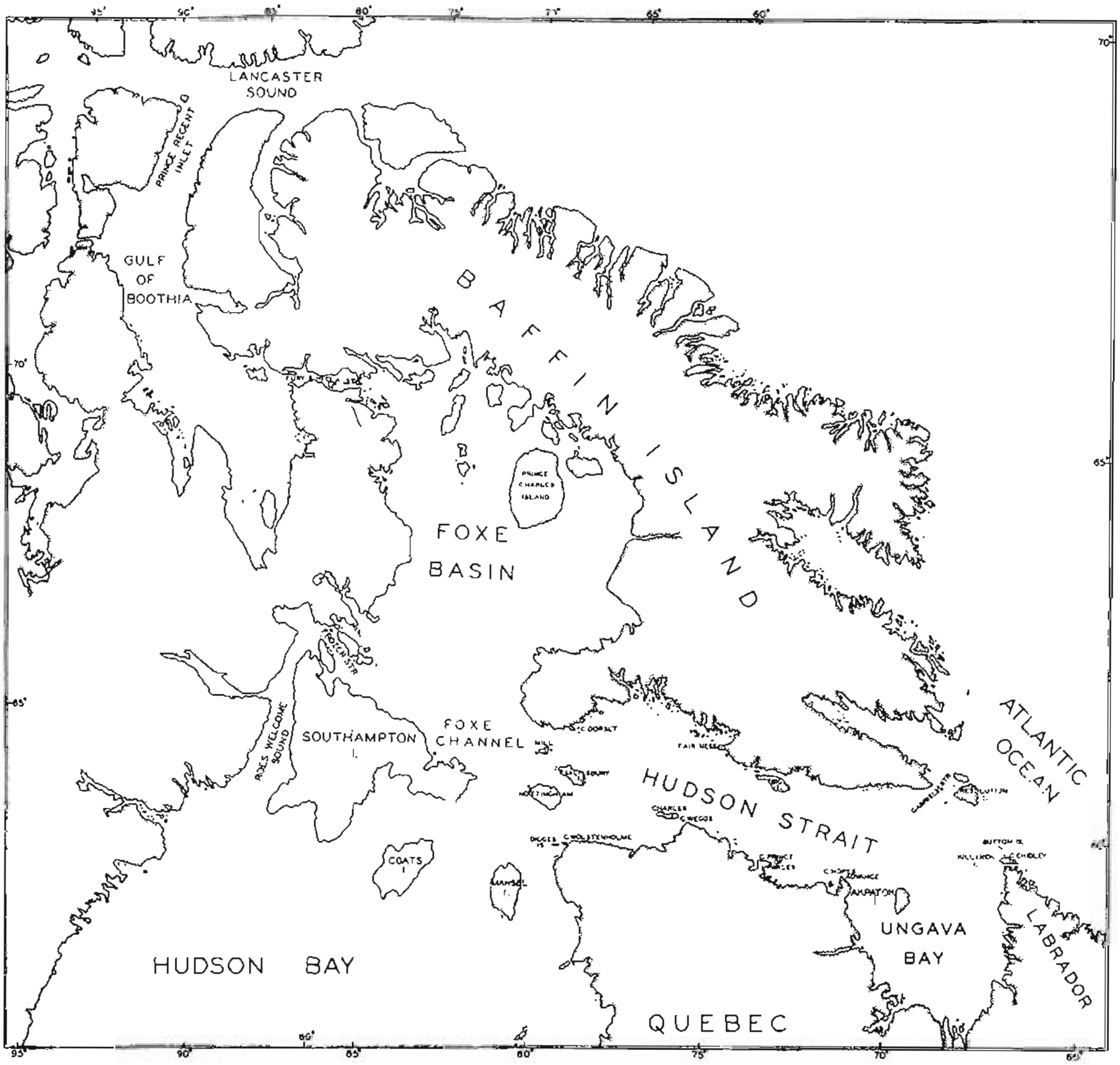

Fig. 1. Hudson Strait, Foxe Basin and Hudson Bay.

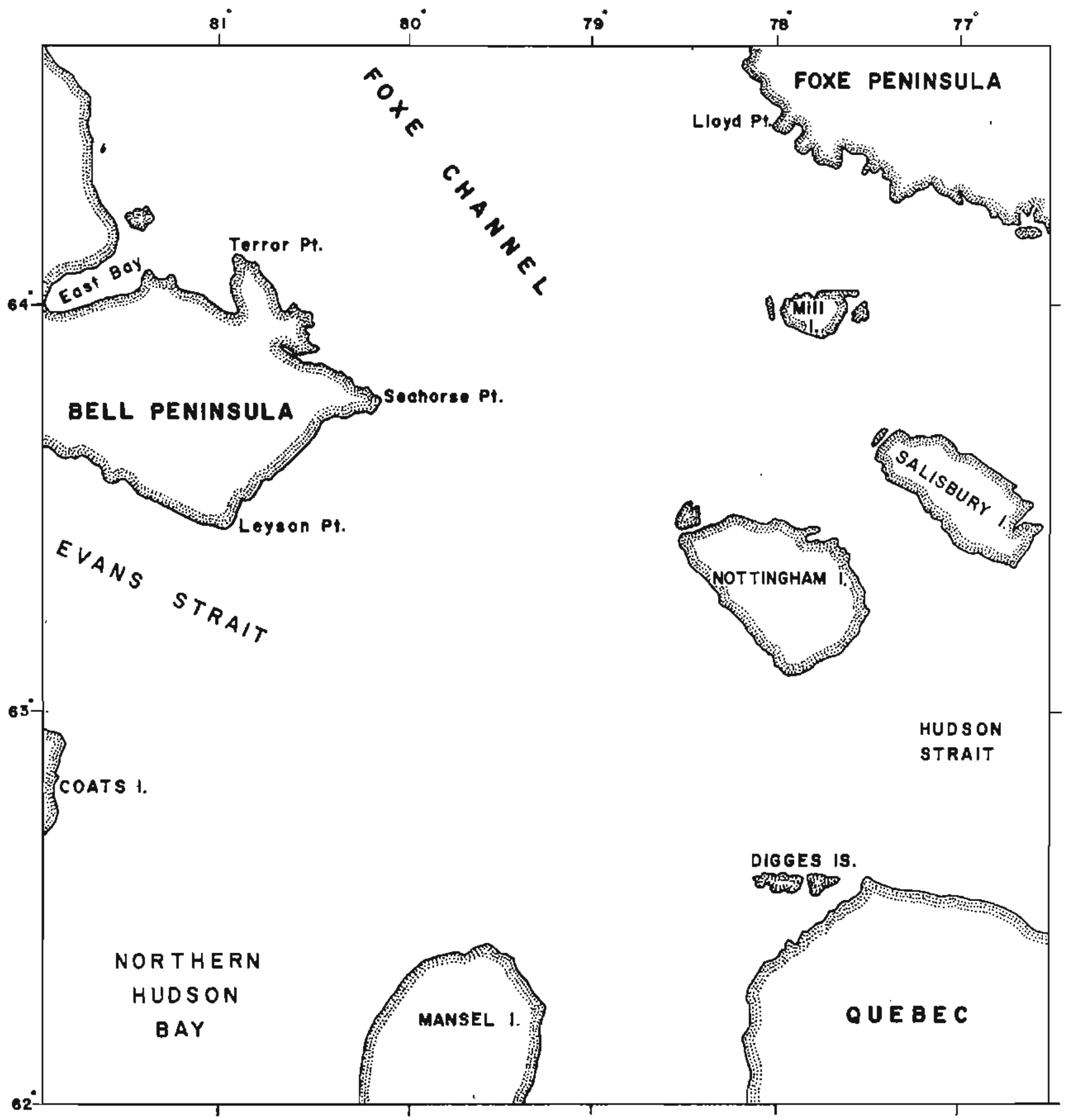

Fig. 2. Northern Hudson Bay, Foxe Channel and Hudson Strait.

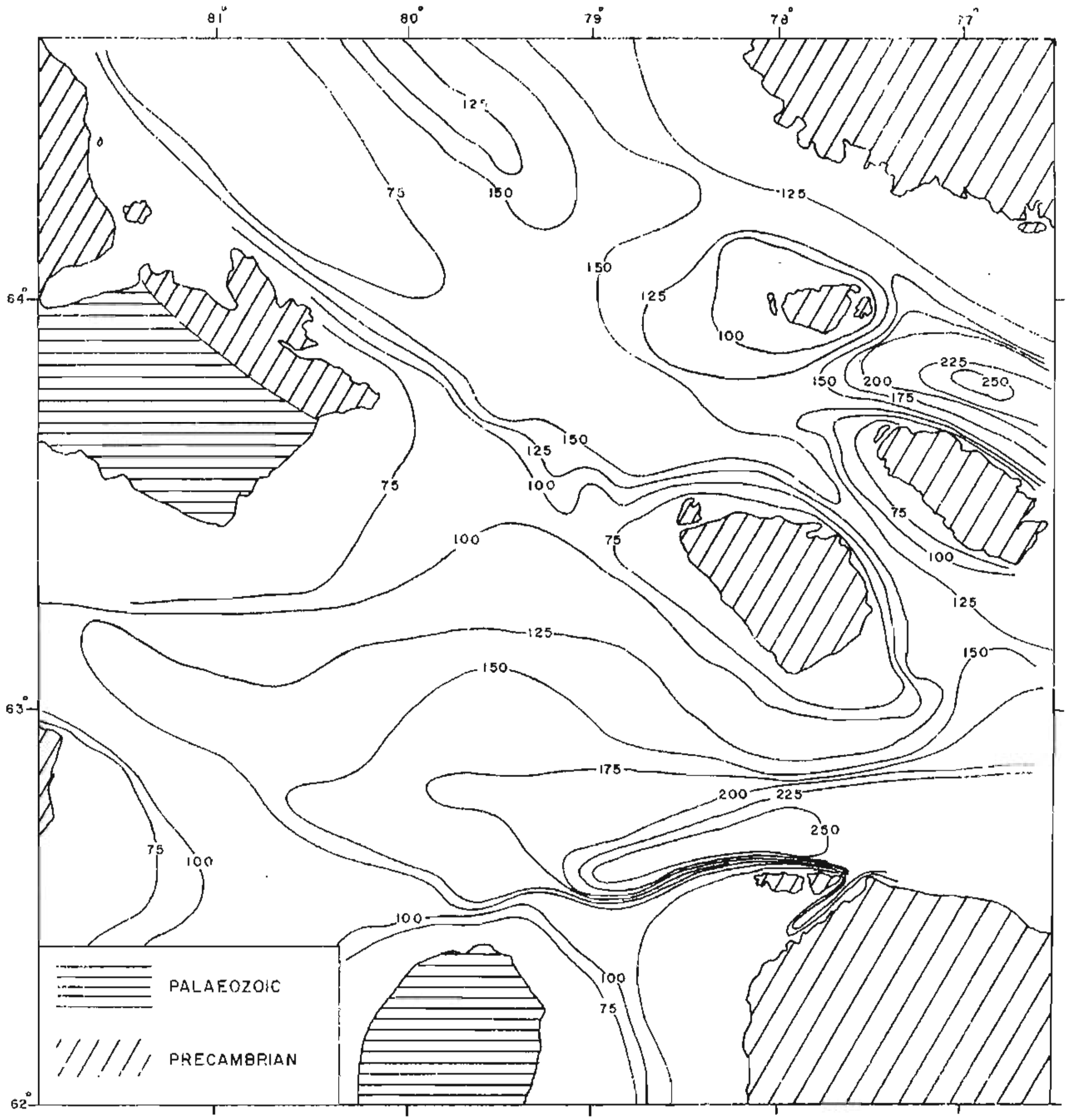

Fig. **3.** Geology and submarine topography of northern Hudson Bay (depths in fathoms).

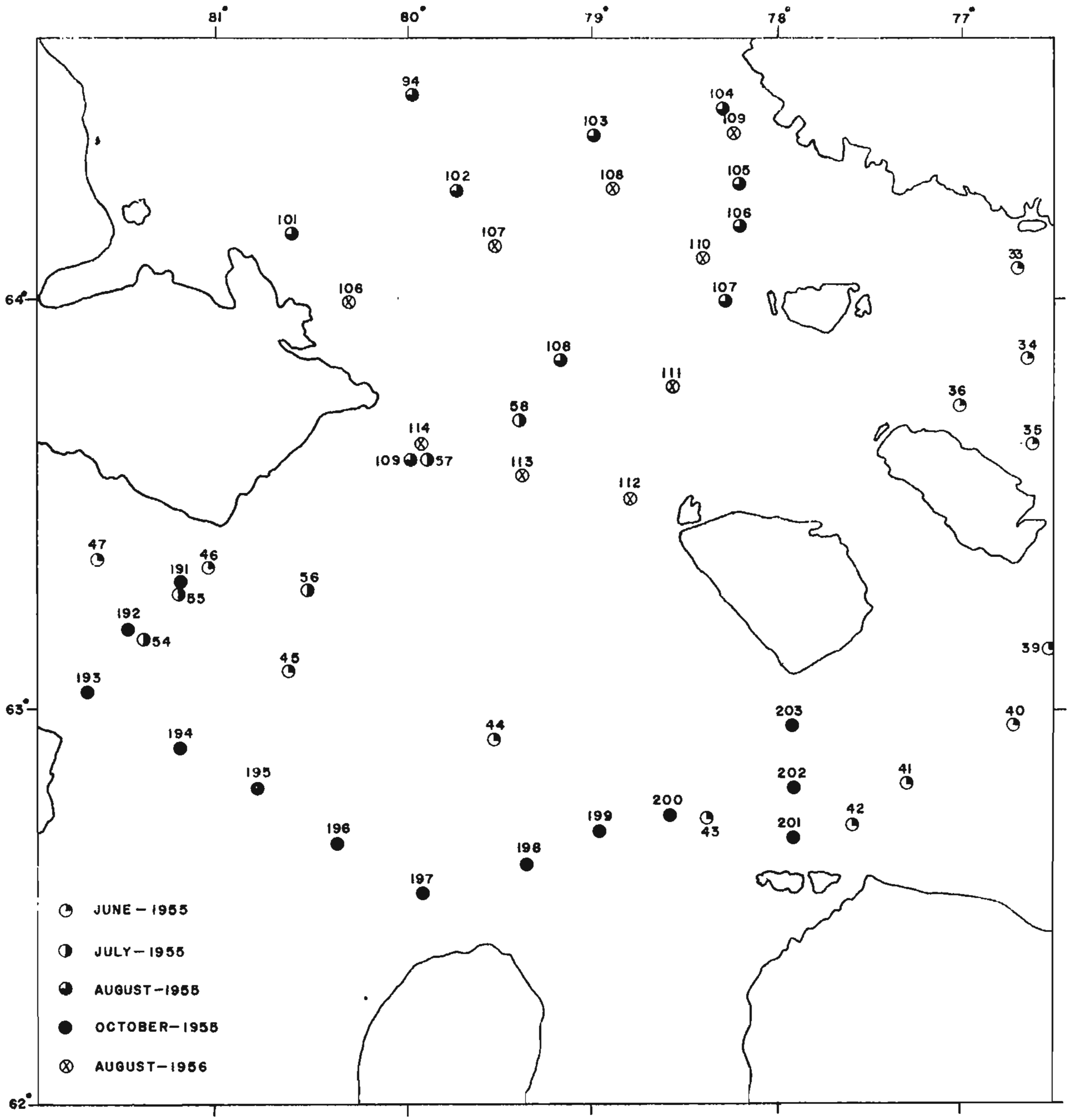

Fig. 4. Oceanographic stations northern Hudson Bay, Foxe Channel, and Hudson Strait, 1955 and 1956

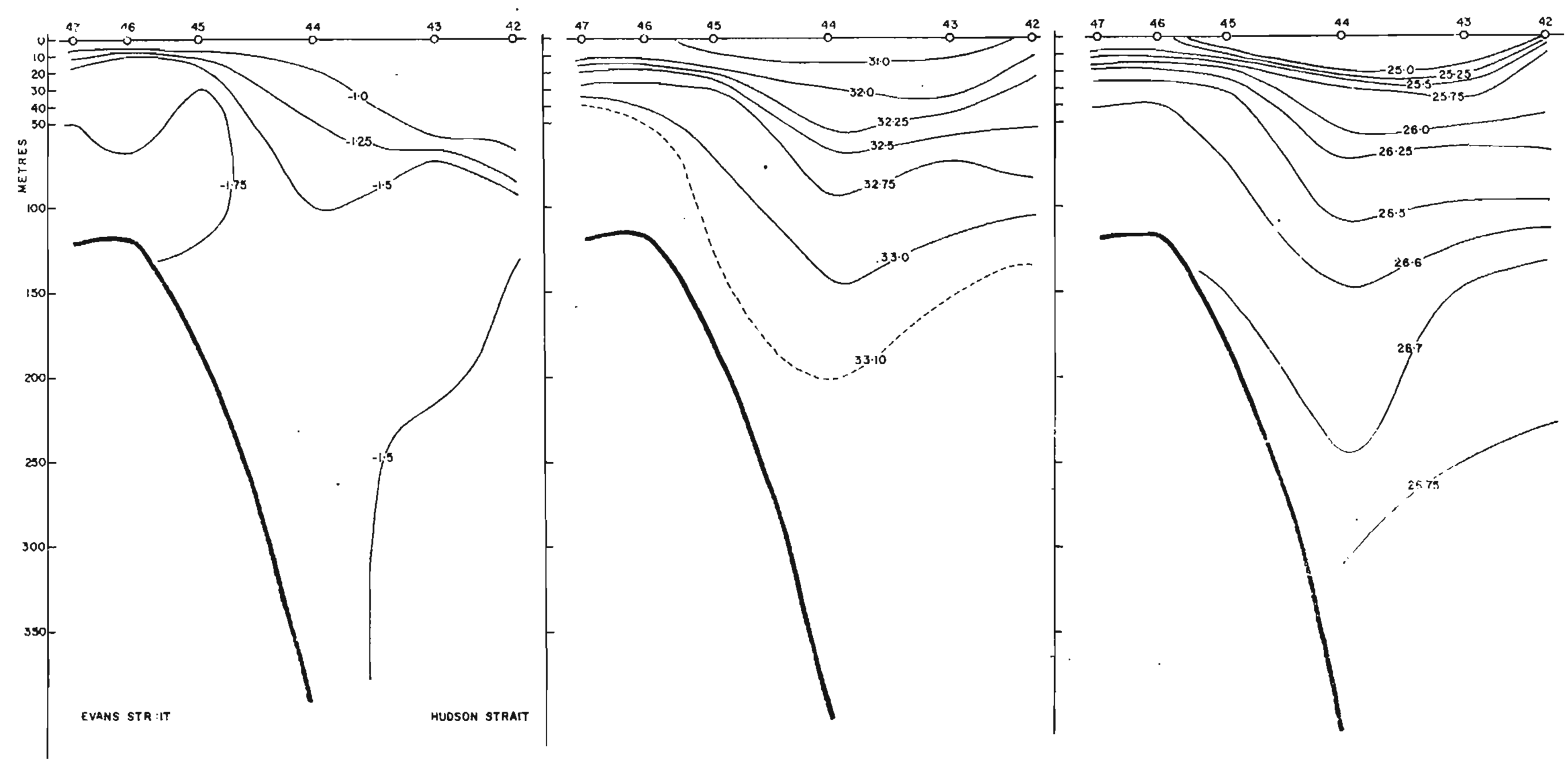

Fig. 5. Temperature, salinity and density profiles Hudson Bay, Hudson Strait to Evans Strait, June 1955.

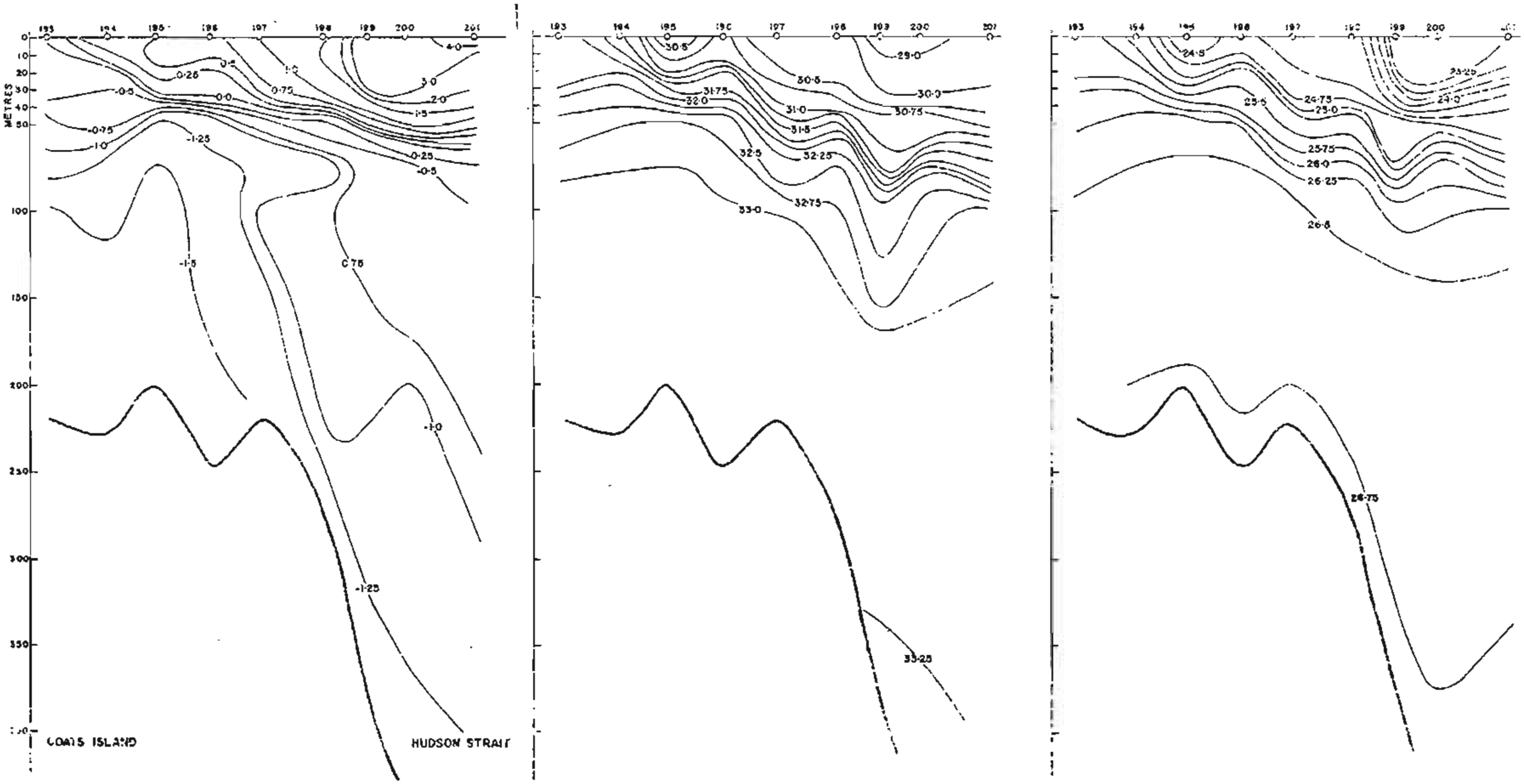

Fig. 6. Temperature, salinity and density profiles Hudson Bay, Coats Island to Hudson Strait, October 1955.

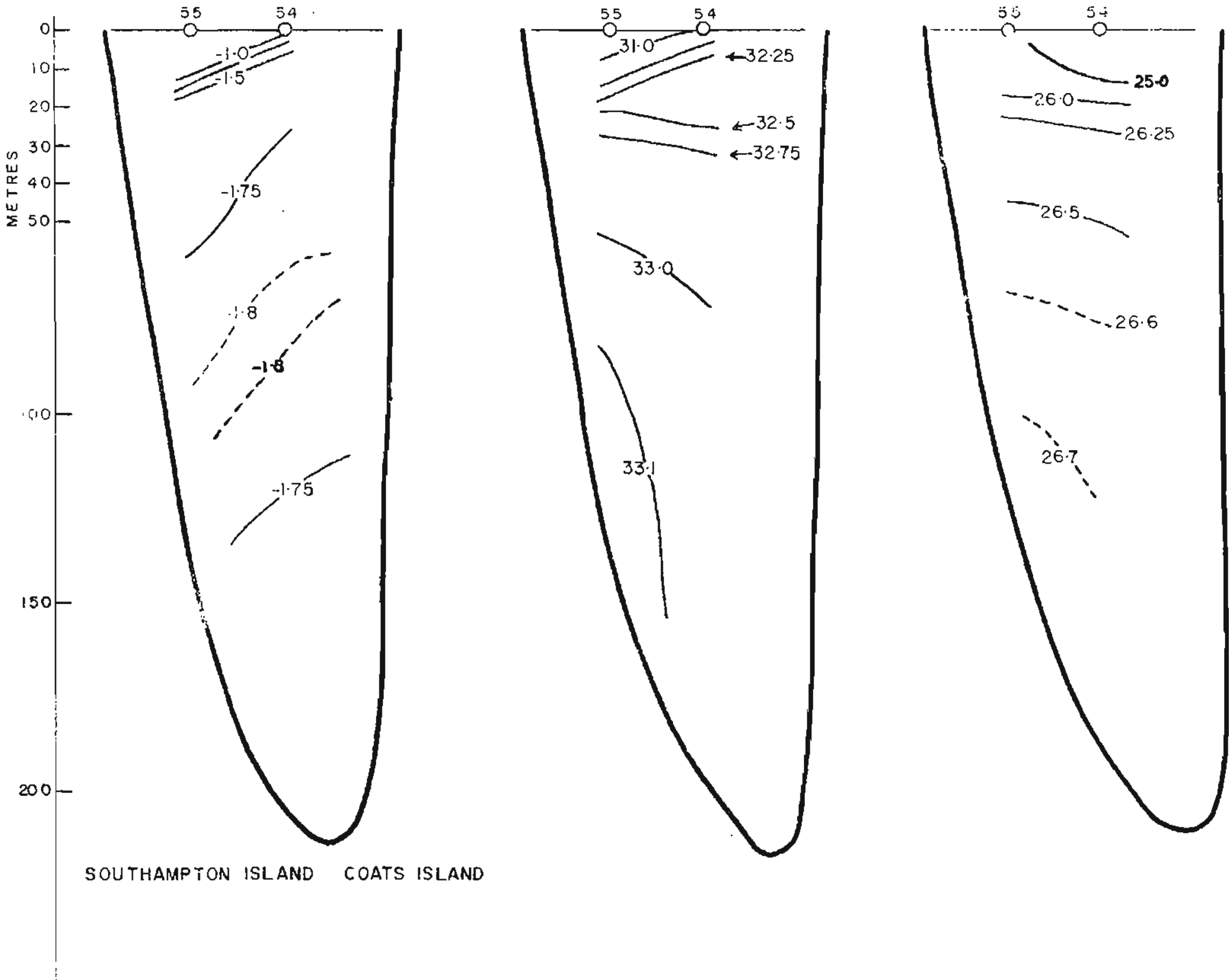

Fig. **7.** Temperature, salinity and density profiles Evans Strait, Hudson Bay, July 1955.

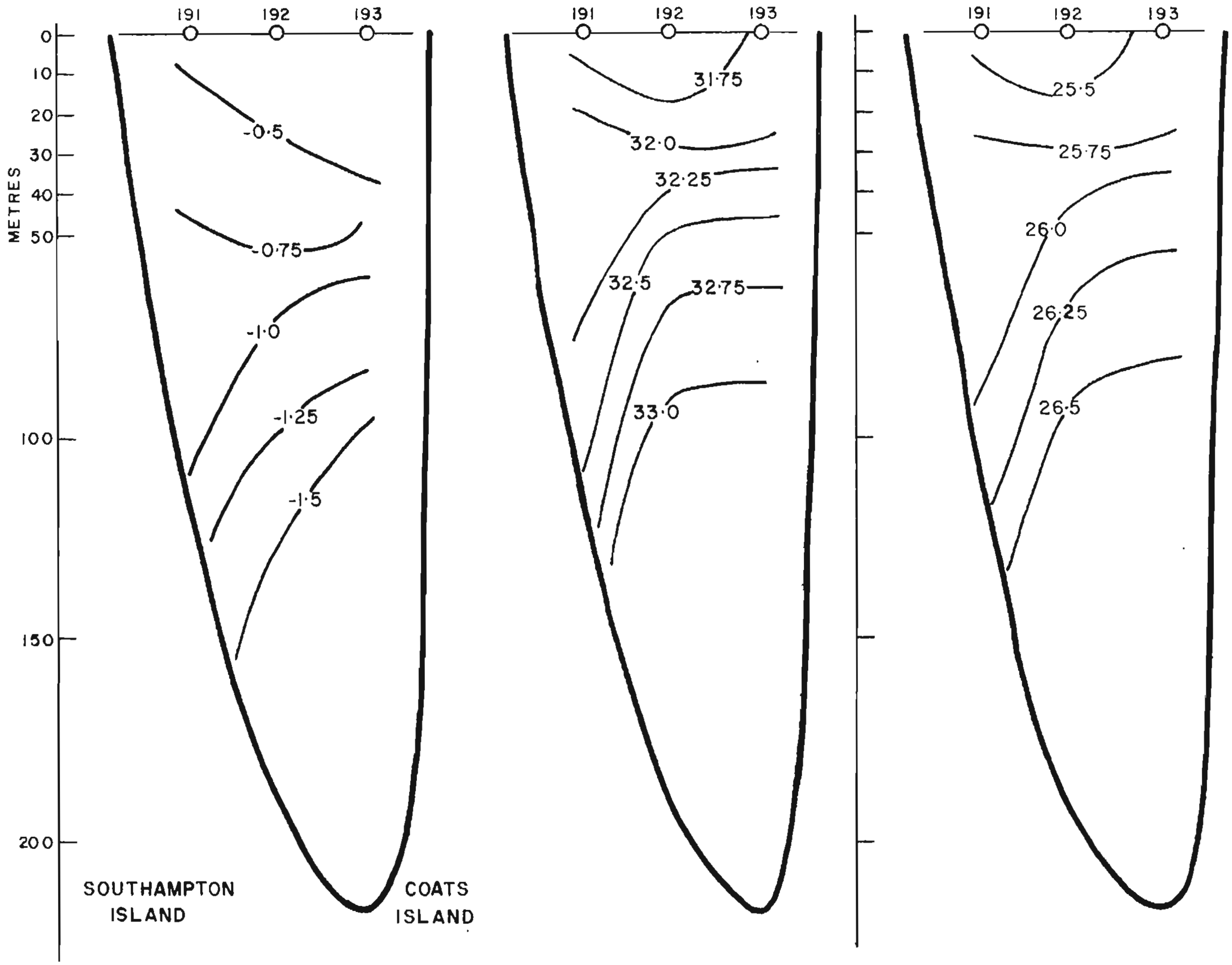

Fig. 8. Temperature, salinity and density profiles Evans Strait, Hudson Bay, October 1955.

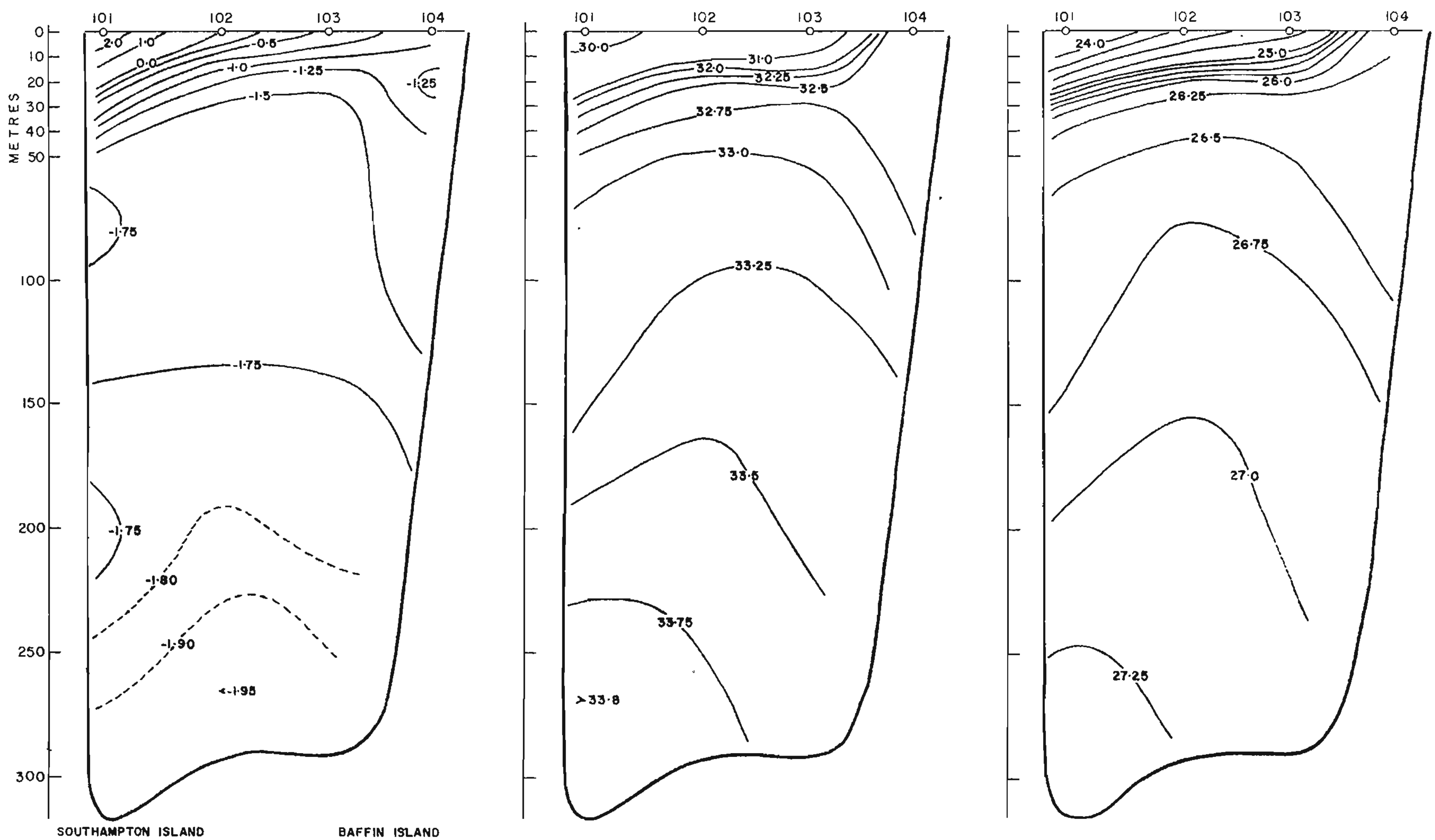

Fig. **9.** Temperature, salinity and density profiles Foxe Channel, Terror Pt., Southampton Island to Lloyd Pt. Baffin Island, August 1955.

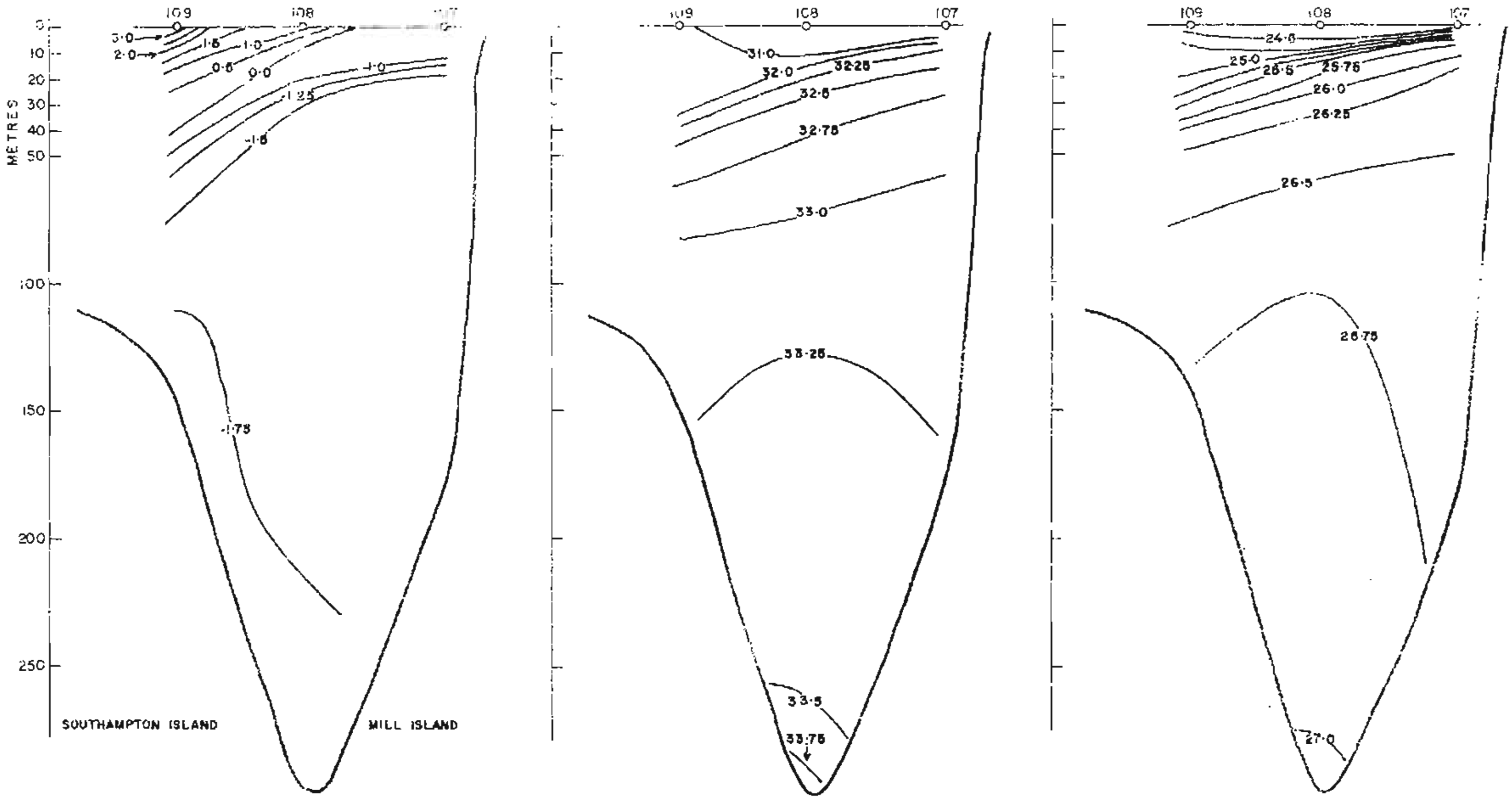

Fig 10. Temperature, salinity and density profiles Foxe Channel, Mill Island to Leyson Pt., Southampton Island, August 1955.

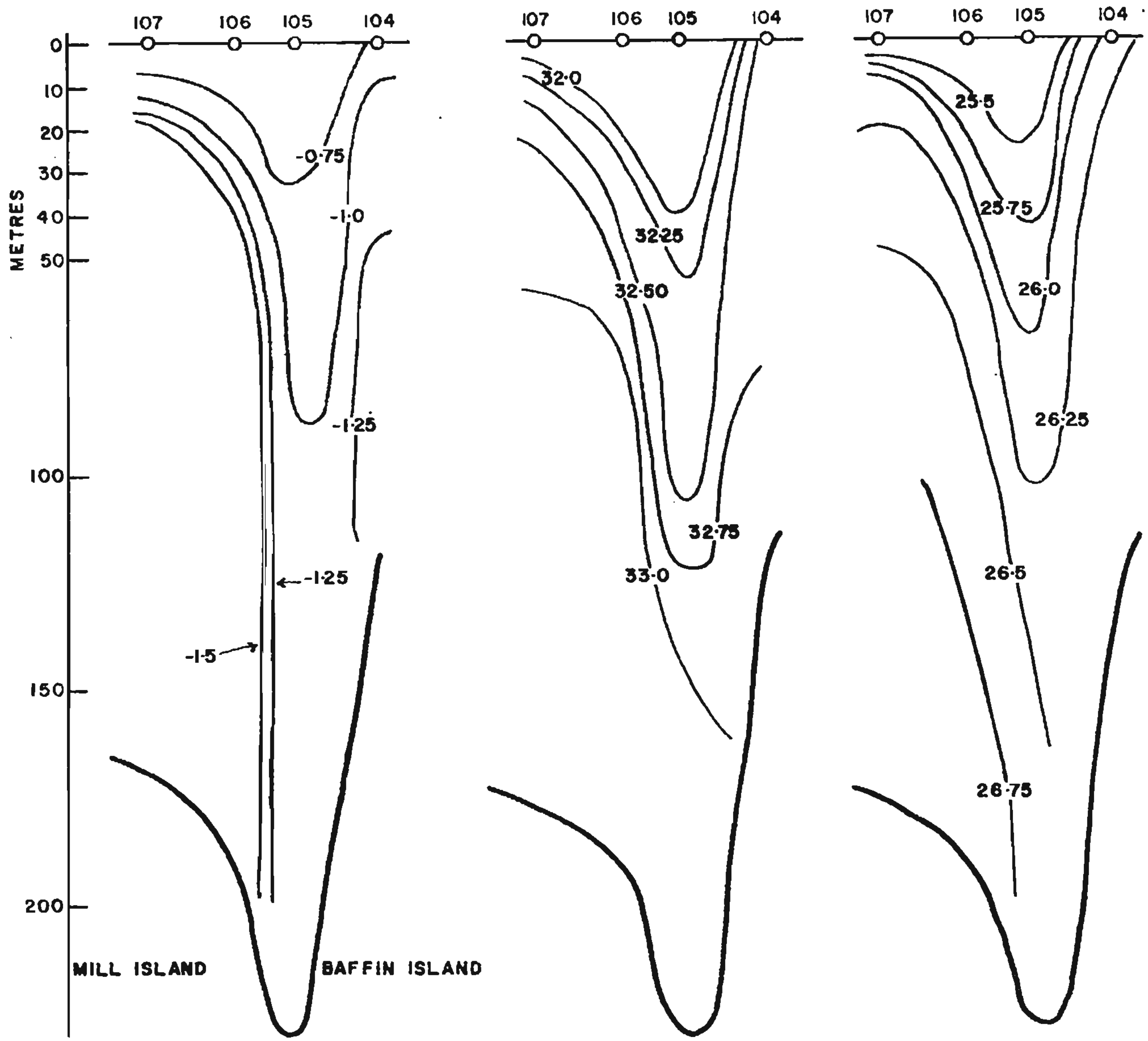

Fig. 11. Temperature, salinity and density profiles Foxe Channel-Hudson Strait, Lloyd Pt., Baffin Island to Mill Island, August 1955.

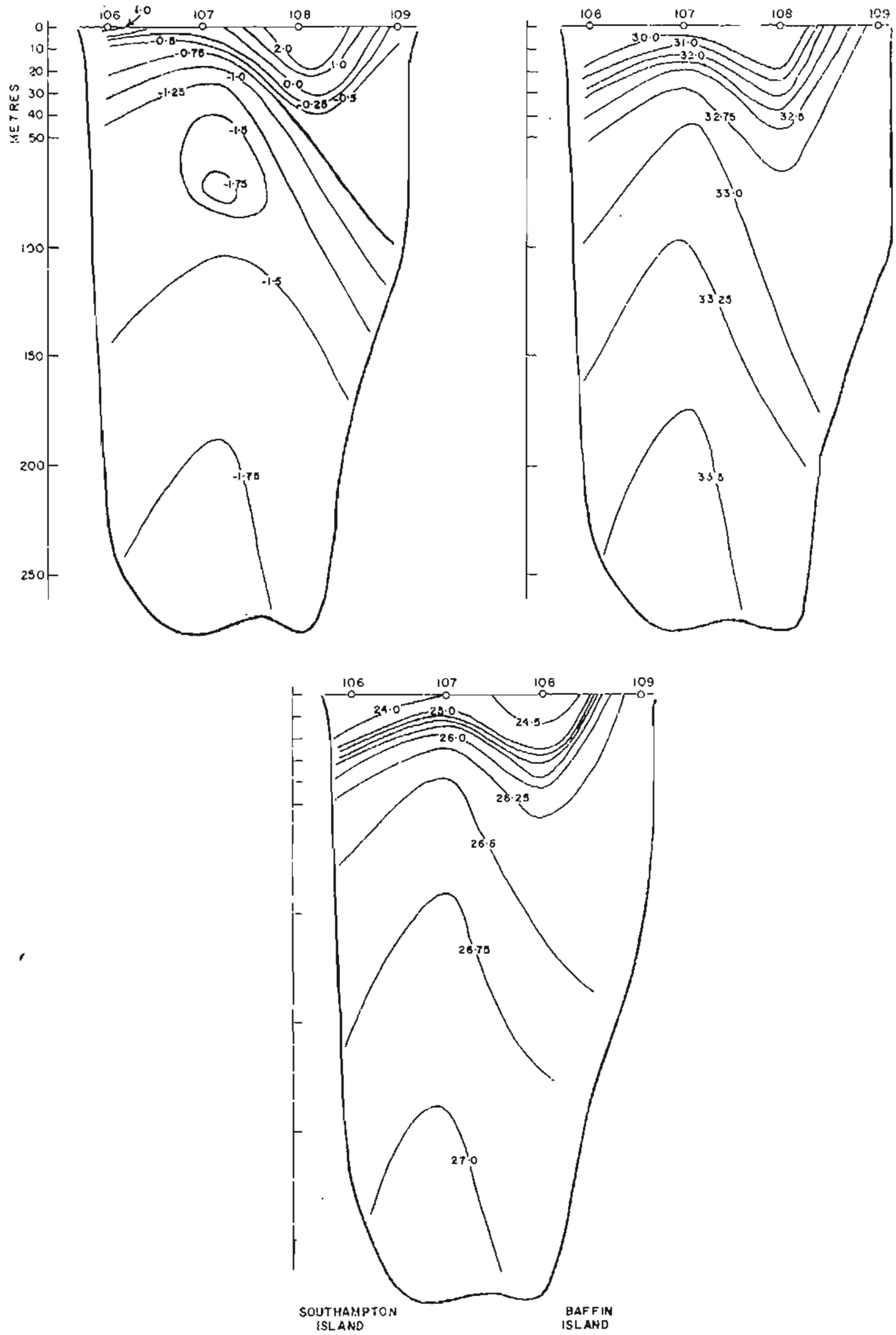

Fig. **12.** Temperature, salinity and density profiles Foxe Channel, Bell Peninsula, Southampton Island to Lloyd Pt., Baffin Island, August 1956.

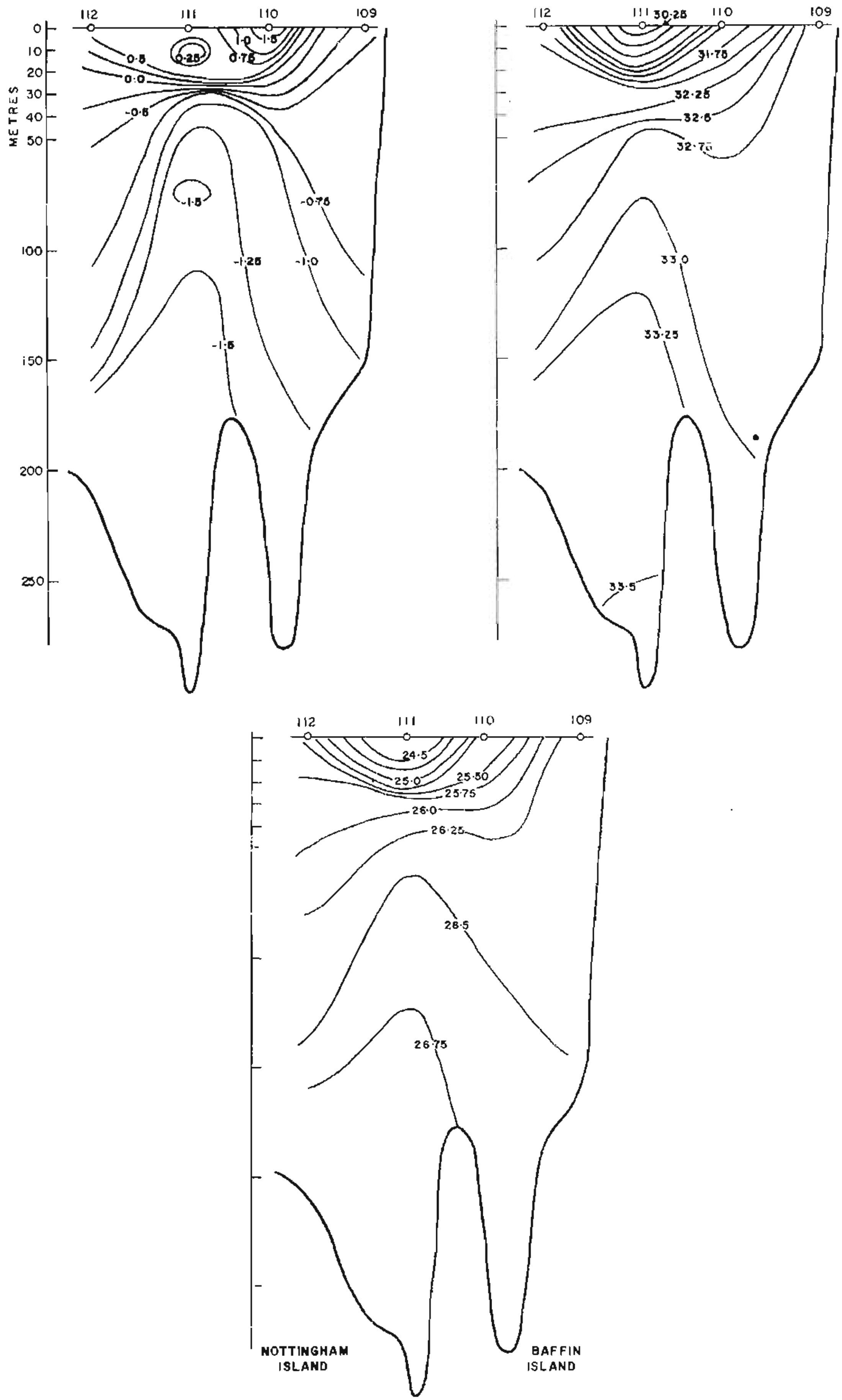

Fig. 13. Temperature, salinity and density profiles Foxe Channel-Hudson Strait, Lloyd Pt., Baffin Island to Nottingham Island, August 1956.

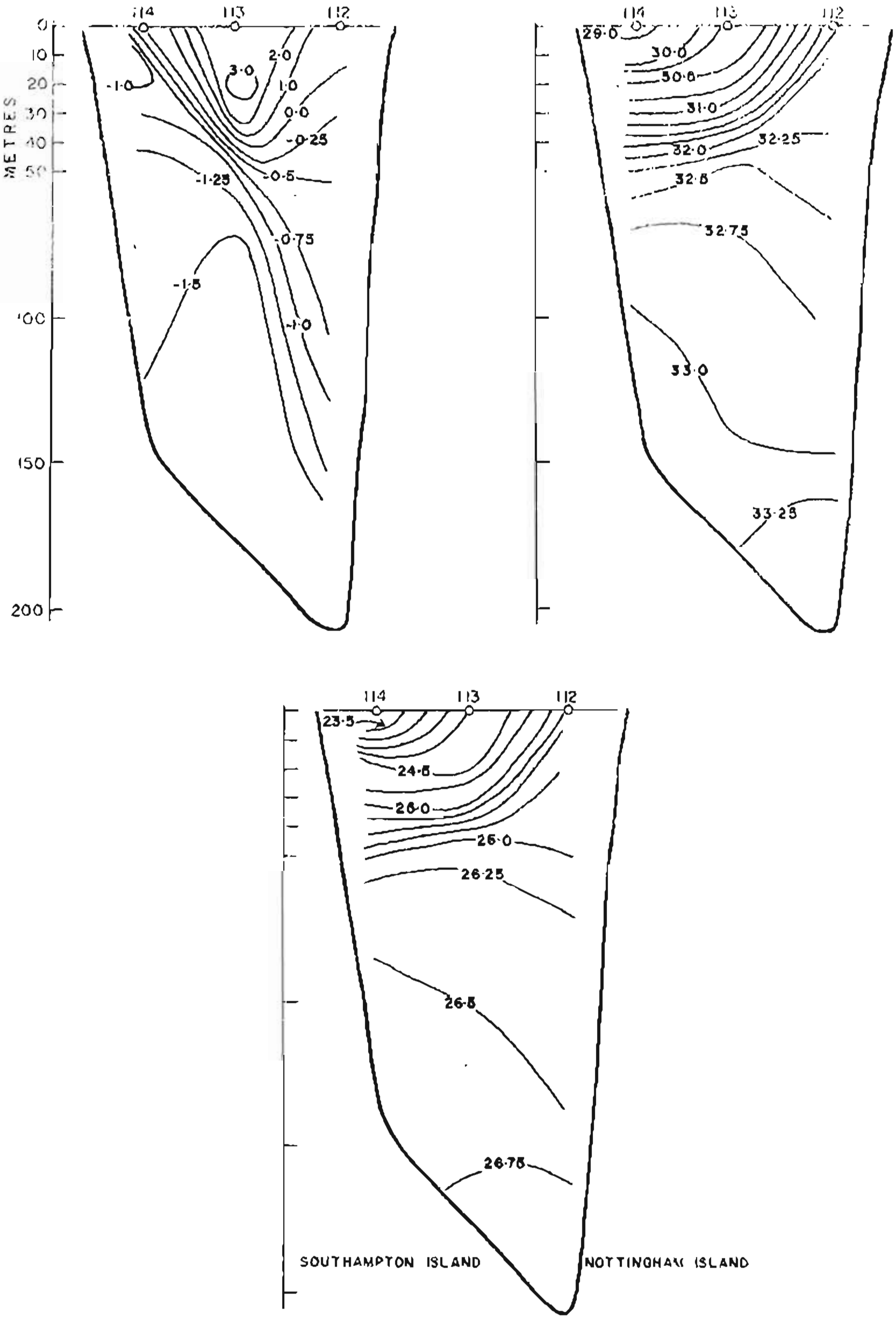

Fig. 14. Temperature, salinity and density profiles Foxe Channel-Hudson Bay, Nottingham Island to Seahorse Pt., Southampton Island, August 1956.

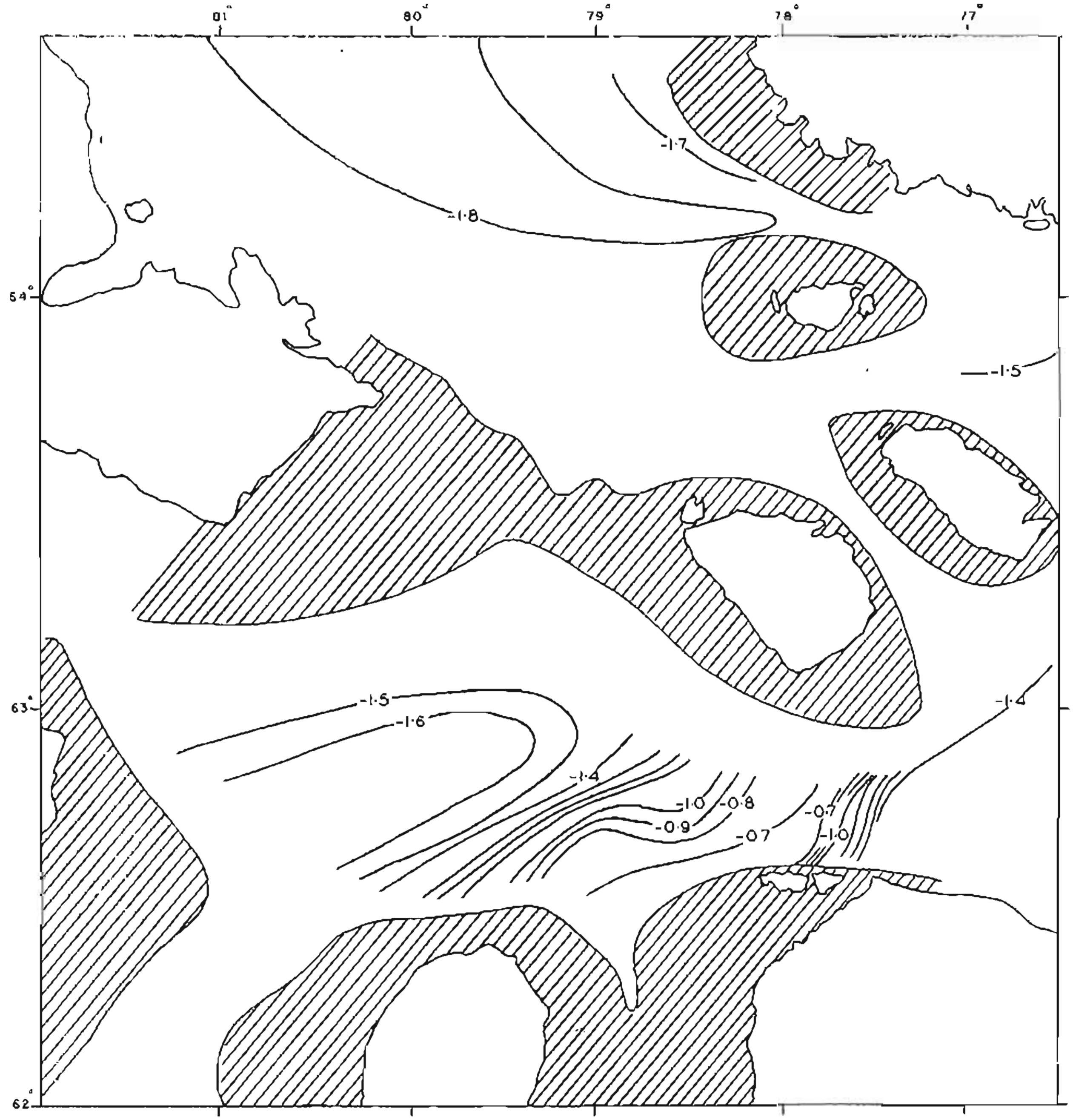

Fig. 15. Distribution of temperature, 200 metres, Foxe Channel, Hudson Bay and Hudson Strait, 1955.

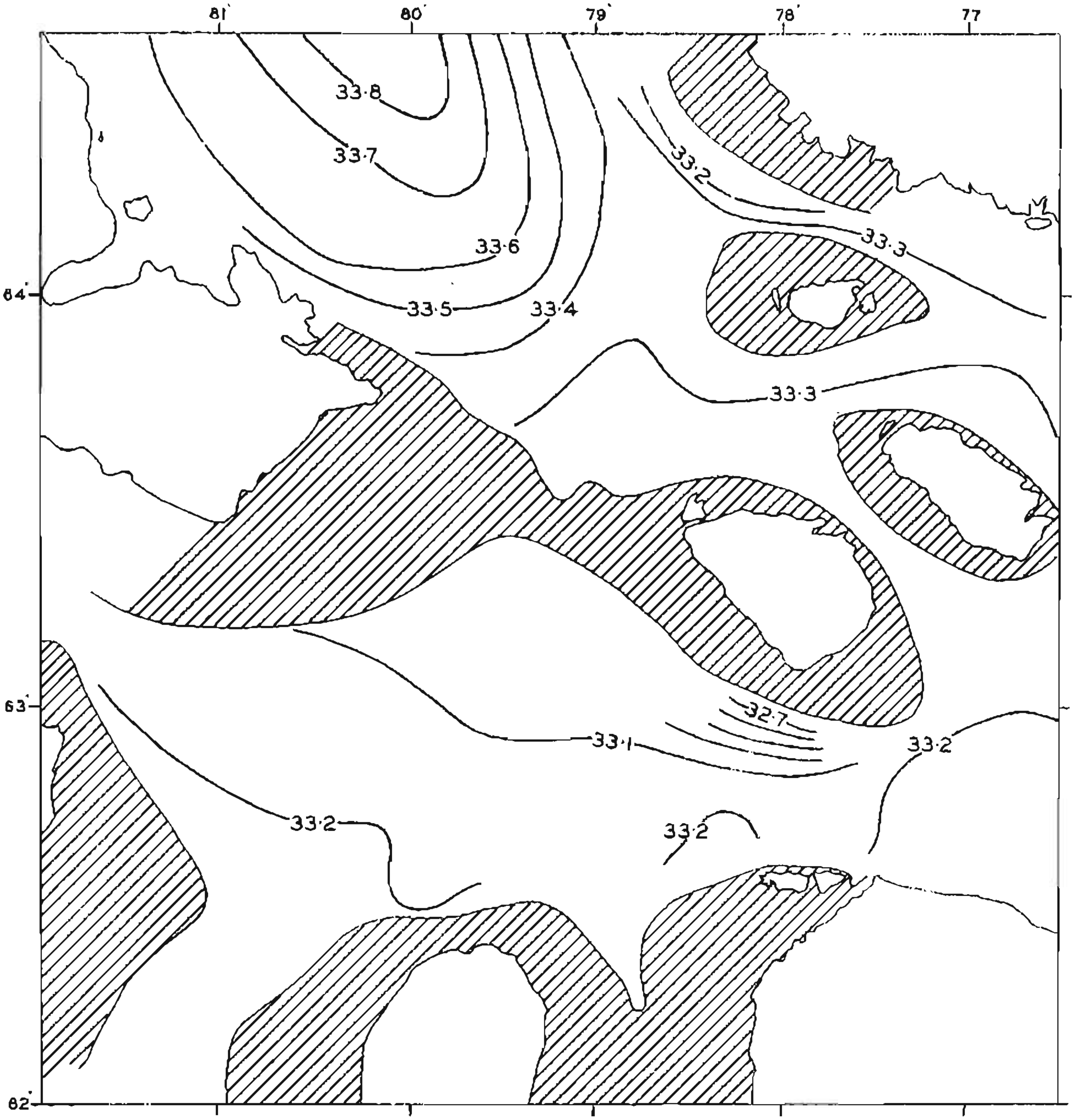

Fig. 16. Distribution of salinity, 200 metres, Foxe Channel, Hudson Bay and Hudson Strait, 1955.

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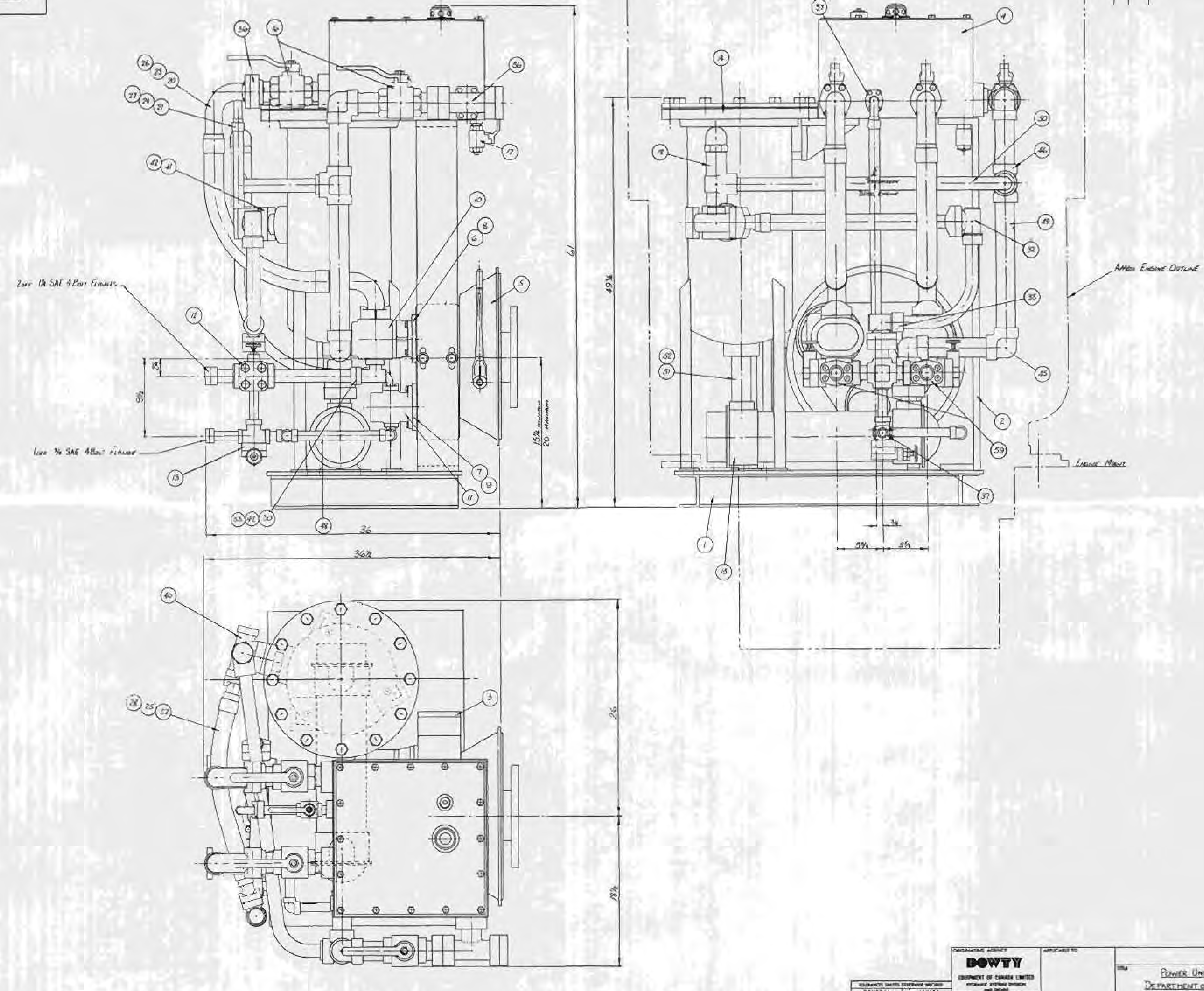

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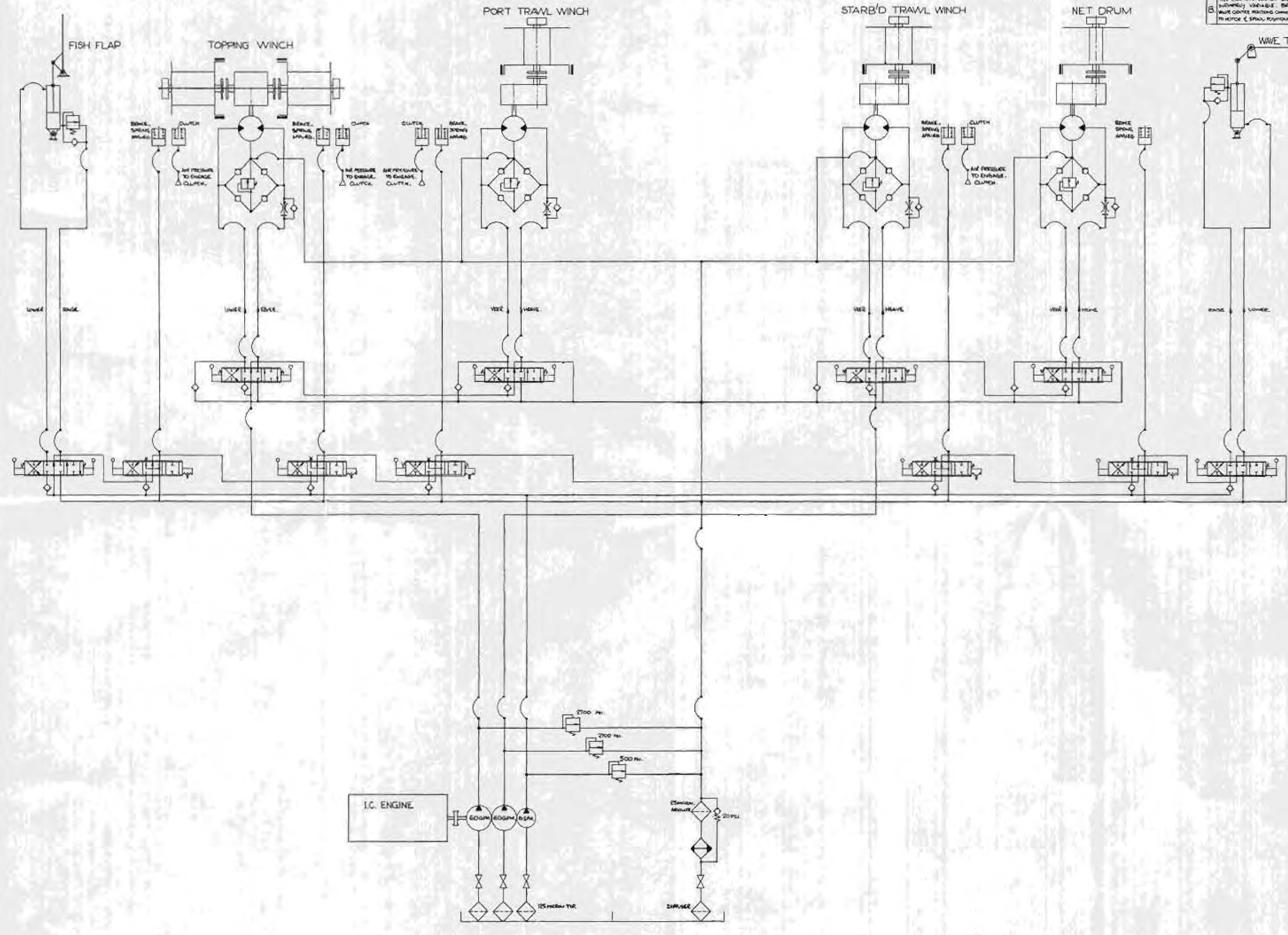

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