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OCEANOGRAPHIC OBSERVATIONS IN NARES STRAIT ARCTIC CANADA, SEPTEMBER 1963

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LIST OF ILLUSTRATIONS

The strait between northeast Greenland and Ellesmere Island includes Smith Sound, Kane Basin, Hall Basin and Robeson Channel. This waterway, recently named Nares Strait, is one of the channels through which there is an exchange of water between the Arctic Ocean and the north Atlantic. An estimated 16% of the total net discharge of water out of the Arctic Ocean takes place through this passage.

A number of research expeditions have recorded oceanographic observations in northern Baffin Bay. The Danish GODTHAAB Expedition succeeded in taking 11 stations in the southern end of Smith Sound in 1928, and in 1954, 4 stations across Smith Sound were recorded aboard HMCS LABRADOR. Seven additional stations were taken in 1961 and 1962 by LABRADOR in northern Baffin Bay.

Canadian and American research surveys in 1963 added important new observations on the oceanography of the strait and the geological structure of the depression which forms Smith Sound. Oceanographic observations in Smith Sound and Kane Basin, which included a 3 day series of current measurements in the narrows of the passage, were made from the USCGC EVERGREEN between July 27 and August 4, 1963. Later, during the period September 15 to 23 a series of oceanographic stations through northern Baffin Bay and Nares Strait to 81°21′ north, was carried out aboard the Canadian icebreaker LABRADOR.

Ice conditions in Nares Strait are extremely variable and there are few reports on which to base an account. The concentration of ice in the strait depends largely on the prevailing winds such that northerly winds tend to move large masses of polar ice into the passage and persistent southerly winds are associated with weakening ice concentrations. In general, summer ice concentration of 4 to 10 tenths throughout the length of the passage presents considerable difficulty to icebreakers operating in these waters.

Exceptional ice conditions prevailed during the summer of 1963 owing to the presence of a large section of shelf ice which was aground in the strait until late in July. While in Kennedy Channel this massive floe formed an effective obstruction to the southward movement of sea ice through the passage resulting in unprecedented ice free conditions in Kane Basin and Smith Sound. The sea ice distribution at the time of the survey and the position of the LABRADOR stations are shown in Fig. 1.

The bathymetry of the strait is irregular. The depth decreases from over 700 metres in Hall Basin to a limiting depth of 250 metres in Kane Basin and 460 metres in Smith Sound. Apparently the minimum depth through the system is 250 metres at 79°50' north, in Kane Basin. In effect the strait forms a barrier between the Arctic Ocean and Baffin Bay at depths greater than 250 metres and limits the exchange of water to the upper layers.

The vertical distribution of properties in Baffin Bay is remarkably similar to that of the Arctic Ocean. A three layered system, defined on the basis of temperature, is characteristic of both regions. In each case the vertical profile is identified by a surface layer at near freezing temperature and low salinity, a warmer intermediate layer with a temperature maximum at 500 metres and a deep layer through which temperatures decrease with depth and salinity is almost constant. In these extremely cold waters (0°C) the temperature has little influence on the density thus the gross features of the mass distribution may be represented by the salinity pattern.

In the Arctic Ocean the upper layer, to a depth of about 200 metres, is characterized by temperatures near the freezing point and maximum salinity of 34.5‰. At the surface, sharp variations of temperature and salinity occur, the result of changing ice conditions and seasonal fresh water runoff. In the Canadian Basin a weak temperature maximum at 75-100 metres has been associated with the influx of Pacific water through the Bering Strait.

The intermediate depth layer is identified by temperatures greater than $0^{\circ}C$ and a well defined temperature maximum of $0.4^{\circ}C$ at 400-500 metres. This water is of Atlantic origin and forms a continuous layer between 250 and 1000 metres throughout the entire Arctic Ocean. Salinity increases with depth to almost uniform values of 34.90‰ at the temperature maximum. At depths greater than 500 metres temperature decreases to $-0.5^{\circ}C$ at 2500 metres and salinity increases gradually to a bottom maximum of 34.96‰.

In Baffin Bay the vertical profile shows a marked increase in the range of temperature, and maximum salinity values at depth are 0.5‰ less than those recorded in the Arctic Ocean.

The surface layer is identified by temperature in the range -1.7° to $8.0^{\circ}C$ and salinity less than 33.8‰. This layer extends to a depth of 150 metres at which level a weak temperature minimum normally occurs. The intermediate layer in Baffin Bay is recognized by temperatures greater than $-0.5^{\circ}C$ and salinity 34.2 to 34.5‰ within the depth interval 200 to 1000 metres. The temperature maximum of $1.2^{\circ}C$ occurs between the depths of 400-600 metres whilst at greater depths temperature decreases to $-0.4^{\circ}C$ and salinity is practically constant at 34.5‰.

The 1963 oceanographic observations in Nares Strait were recorded during the period September 15 to 23. The effect of the tidal oscillation on the distribution of properties through the strait is unknown but it has been established that a tidal reversal of the surface currents may occur in Smith Sound. Current observations recorded in 1962 show that in the centre of the passage there is a southwesterly set of 0.5 to 2.0 knots during the falling tide and an equally strong northeasterly current with a flood tide (Pilote, 1963).

Figure 2 shows the vertical distribution of temperature and salinity through Nares Strait. It is apparent that within the upper 200 metres the pattern is uniform through the length of the passage with the exception of patches of low temperature and salinity water at the surface. These surface variations are characteristic of northern waters and are the result of local ice distribution and the admixture of relatively fresh melt-water off the ice.

At depths greater than 200 metres there is an obvious contrast between the slightly warmer, higher salinity water to the north and the cold water of lower salinity in Smith Sound. This condition is clearly shown by the configuration of the isolines for 34.6‰ salinity and zero temperature through Kane Basin. Figure 3 a cross section of salinity over the Kane Basin rise also shows the distribution of the deep, 34.5‰ salinity water in the western part of the channel.

The 1963 LABRADOR observations indicate that the deepest water to pass southward over the Kane Basin rise has a characteristic temperature of $-0.5^{\circ}C$ and salinity of 34.50‰. However, there is insufficient data to define the southward distribution of this water into northern Baffin Bay. The maximum salinity measured in Smith

Sound is 34.49‰ at 641 metres and the associated temperature is -0.3°C. The resultant density distribution indicates that the influx of high salinity Kane Basin bottom water through Smith Sound may not be a continuous process but is likely limited to a sporadic, thin bottom layer.

The distribution of bottom salinity superimposed on a rough outline of the bathymetry of the passage relates the southward decrease in bottom salinity to the topography of the sea floor and shows the extent of the 34.5‰ salinity water, Fig. 4.

Contours of dynamic height anomalies in Smith Sound for September 20-23, 1963, have been calculated from a grid of 16 stations based on an assumed reference level of 250 decibars, Fig. 5. There is no evidence to indicate a reference level at any intermediate depth through the strait since the distribution of properties is characteristically uniform with depth. The 250 metre reference level was accepted solely on the evidence that 250 metres appears to be the limiting depth in Kane Basin, thus there may be some justification in the selection of this depth as a level of no motion through the system. The dynamic topography shows a predominantly southwesterly movement at the surface increasing in intensity to a maximum of 80 cm/sec near the centre of the strait. The most pronounced current appears to cross the passage from east to west and to continue southward along the Ellesmere coast. At this stage of the flow, a weak, northerly counter current is developed in the southern section.

Current velocity profiles were compiled for two sections established across the southern end of the strait on September 22, 1963, Fig. 6. Mean velocities between successive pairs of stations were calculated for all standard depths from the surface to 500 metres and the velocity profiles constructed in the manner described by Smith, Soule and Mosby (1937). The data are presented in Table I.

An estimate of the consistency of the calculated velocities based on a single set of data may be derived from the fact that the dynamic height anomalies are computed to the nearest millimeter and the location of the station is assumed to be within 500 metres of the true position. It is estimated, that for this survey where the distance between stations is rarely more than 13 kilometers, the error in "L", the distance between stations, may be as much as 1 kilometer or 7%.

At the mean latitude of the survey, the possible variation in the dynamic height of 2 millimeters produces a difference in the calculated velocity of less than 2 cm/sec between stations 10 kilometers apart. Such a difference may be considered quite insignificant. If one assumes the maximum difference in the dynamic height measured between adjacent stations, the possible error in the distance may result in a variation in the calculated velocity of 6 cm/sec. This variation will tend to cancel out over a section of several stations, thus volume transport determinations based on the velocity profile will not be subject to significant variations resulting from normal discrepancies in position. However, variations in the transport calculations resulting from different interpretations of the contour pattern of the velocity profile may be as high as 25% when the pattern is drawn from such few data as are available in this investigation. This limitation makes the calculation of the

TABLE I Calculated velocities at selected depths in Smith Sound, September 22, 1963.

Stations Depth, m	37-36 cm/sec	36-35 cm/sec	35-34 cm/sec	34-33 cm/sec	29-30 cm/sec	30-31 cm/sec	31-32 cm/sec
0	33.0	26.5	-12.6	2.1	83.4	-27.5	-3.9
20	29.4	15.5	-10.2	2.1	63.8	-24.3	-6.2
50	18.6	3.5	-10.2	2.8	39.2	-21.2	-2.7
100	6.0	3.0	-8.4	00	20.1	-19.6	2.3
150	1.8	4.0	-6.6	-2.8	11.7	-18.0	1.1
200		5.0	-4.2	-2.8	9.5	-16.4	00
240		3.5	-2.4	00	10.6	-15.9	
300		2.5	-1.8	-1.0	12.3	-15.9	
400		1.0	00		14.0	-13.2	
500			1.0		00	00	

The negative sign (-) indicates northward movement.

volume transport based on a graphical integration of the velocity profile a most unreliable procedure in this instance.

The net volume transport through Smith Sound has been calculated for four sections using the formula

$$V = c \int_0^d (\Delta D_A - \Delta D_B)\, dz$$

developed by Jakelln (1936), based on an assumed reference level at 500 metres. The advantage of this method lies in the fact that it is independent of the distance between stations and relies entirely on the computed dynamic heights. The disadvantage is that the accuracy of the results is dependent on the selection of a theoretical level of no motion and only net flow may be derived from the calculations. The velocity profile must be drawn if the opposing components of the flow are to be examined. The transport data for sections 33-37, 29-32 and 22-24, 1963 and 1-3, 1962 are presented in Table II.

TABLE II Calculated volume transport through Smith Sound. (Millions cubic metres per second)

Date	Section	Volume Transport
Sept. 22, 1963	33-37	0.28 southward
Sept. 22, 1963	29-32	0.21 southward
Sept. 20, 1963	22-24	0.13 northward
Sept. 26, 1962	1-3	0.16 southward

The volume transport was also computed graphically from the velocity profile of section 33-37, Fig. 6. This method produced a result of 0.34 x $10^6 m^3$/sec in a southerly direction. Further attempts to calculate the volume transport through the strait using a graphic method based on the velocity profiles met with little success due to ambiguities in the velocity contour pattern which cannot be overcome when the distribution is plotted from such limited data.

There have been two previous attempts to describe the exchange through Smith Sound based on actual measurements. Kiilerich (1939) estimated that the southward flow on August 10, 1928, was 0.42 x $10^6 m^3$/sec. This figure was accepted on the evidence of the calculated transport through one incomplete section across the strait and accompanying calculations of the discharge through Davis Strait which revealed that such an influx through Smith Sound was required to balance the transport budget.

Bailey (1957) found the volume transport through Smith Sound to be 0.42 x $10^6 m^3$/sec. to the northward, as determined from the results of four oceanographic stations recorded on August 12, 1954.

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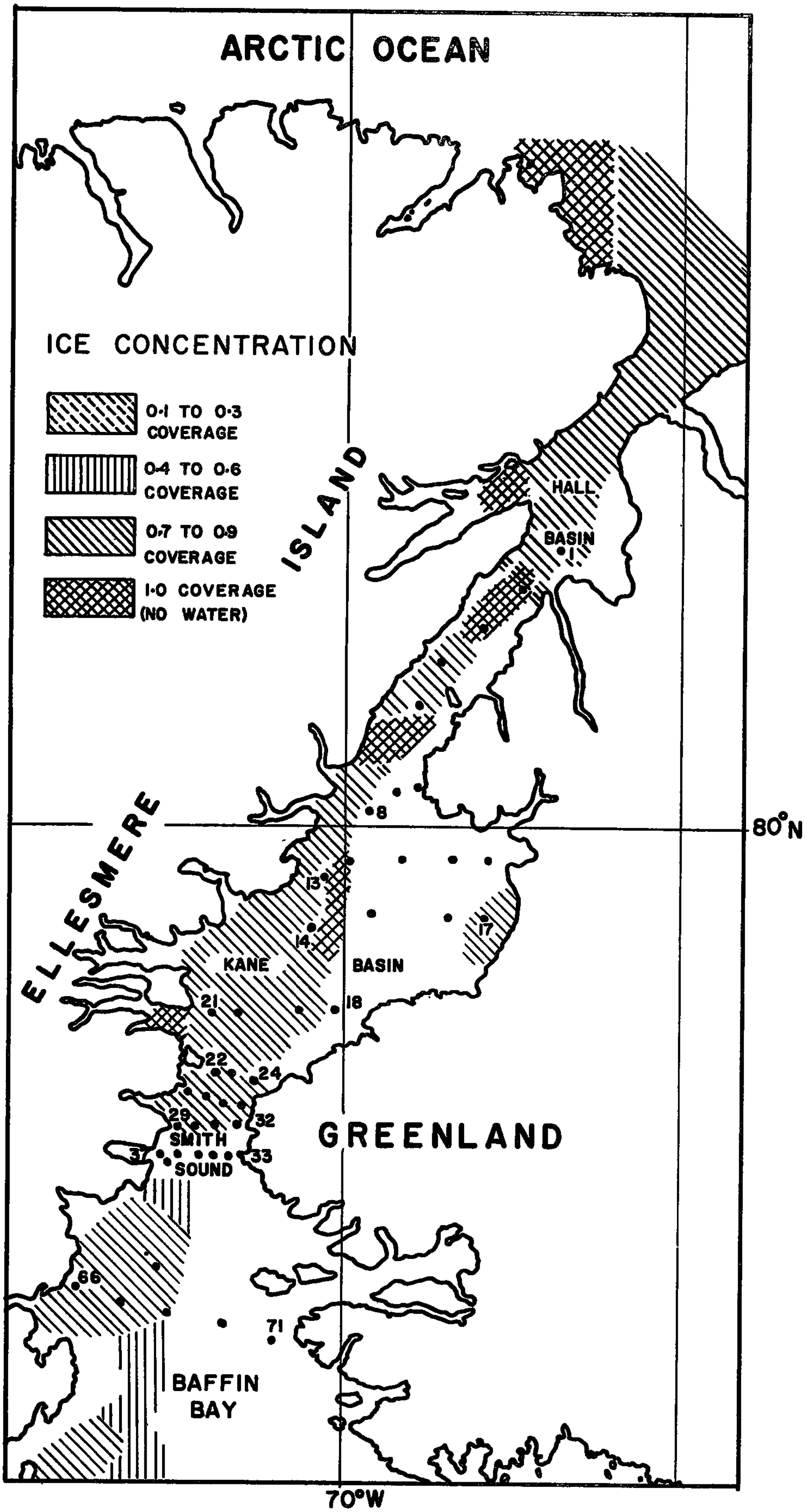

Figure 1 Positions of oceanographic stations and sea ice distribution, September 15-23, 1963.

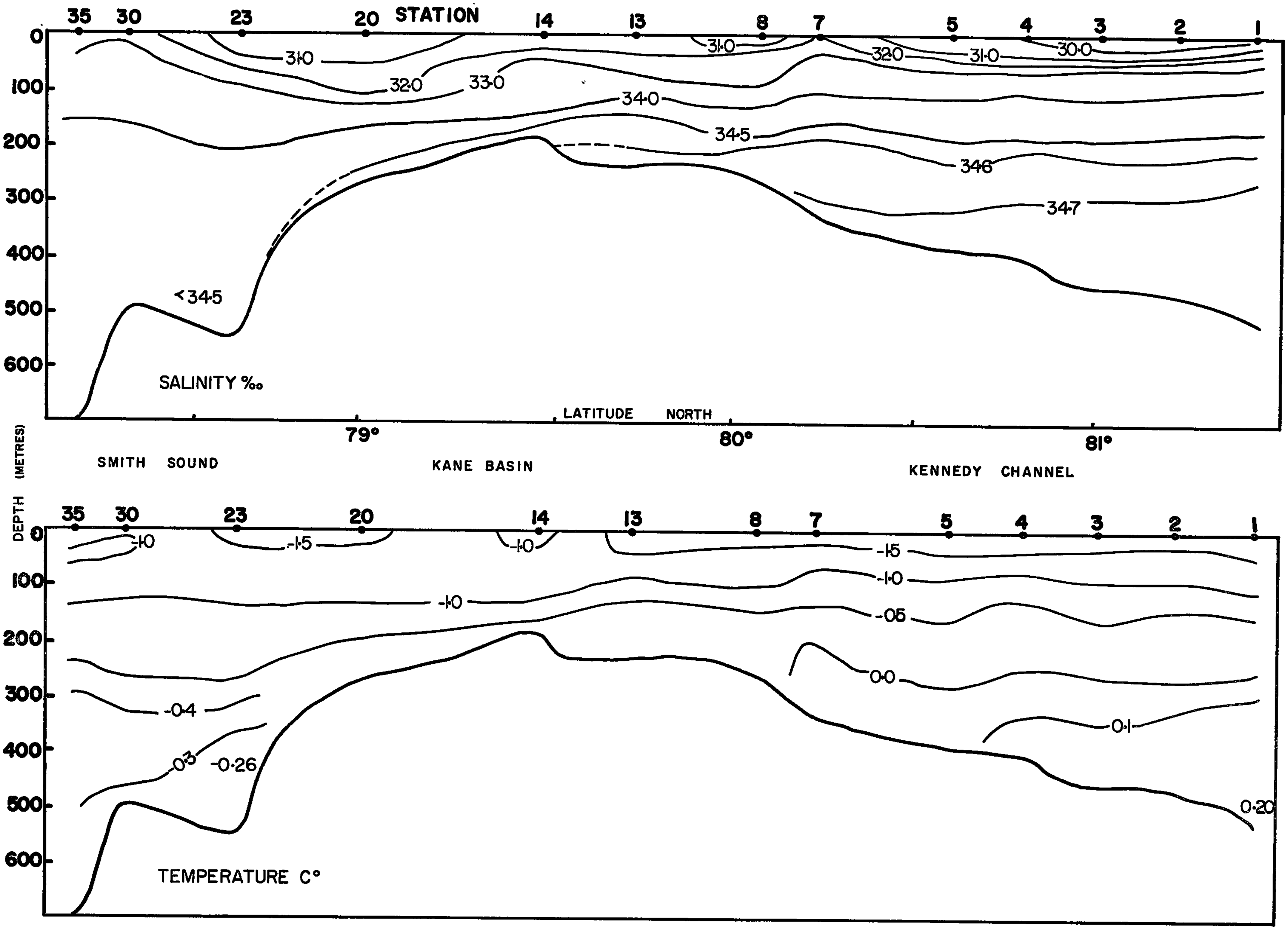

Figure 2 Profiles of temperature and salinity, Nares Strait, September 15-22, 1963.

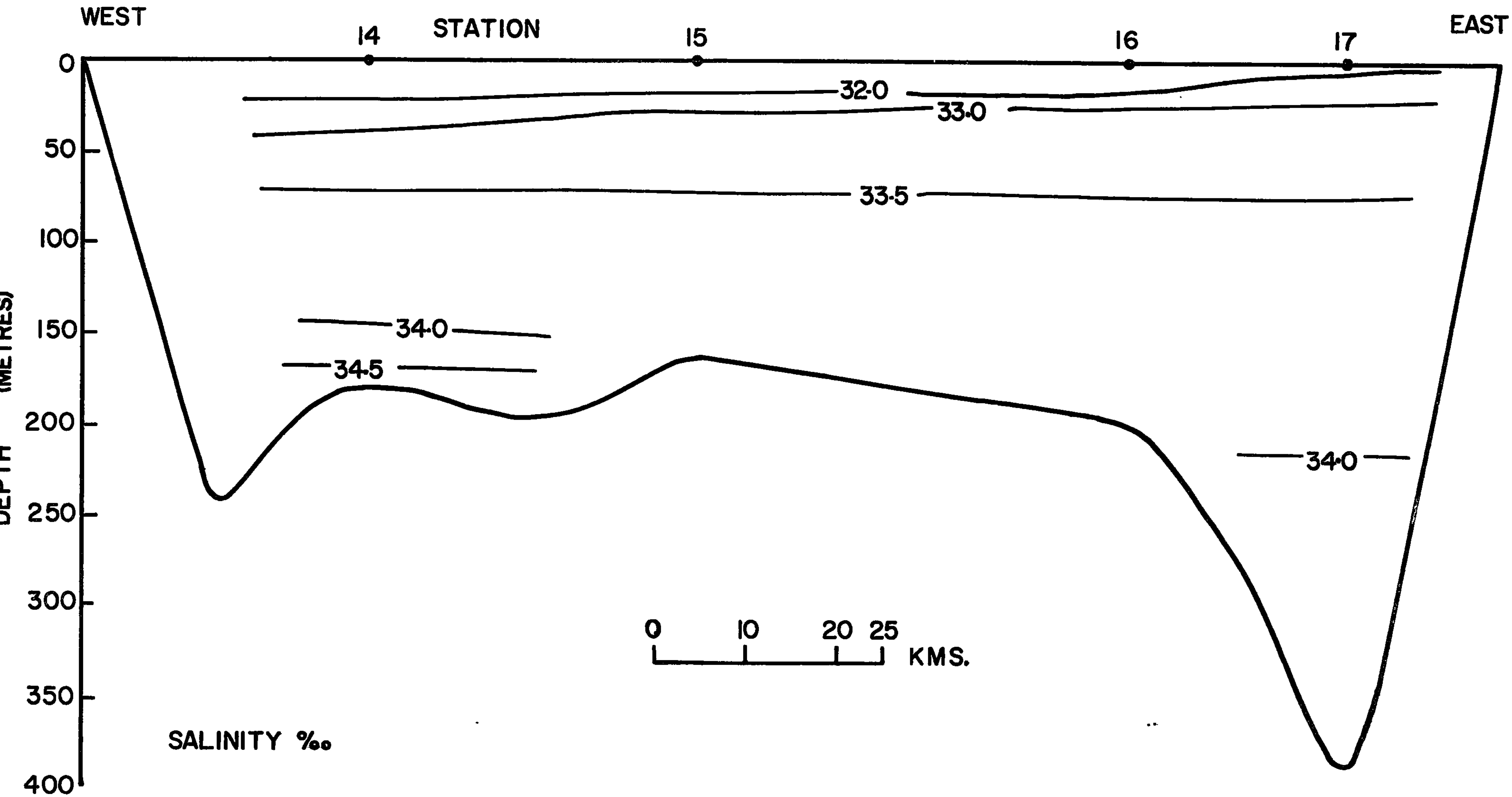

Figure 3 East-west salinity profile, Kane Basin, September 19, 1963.

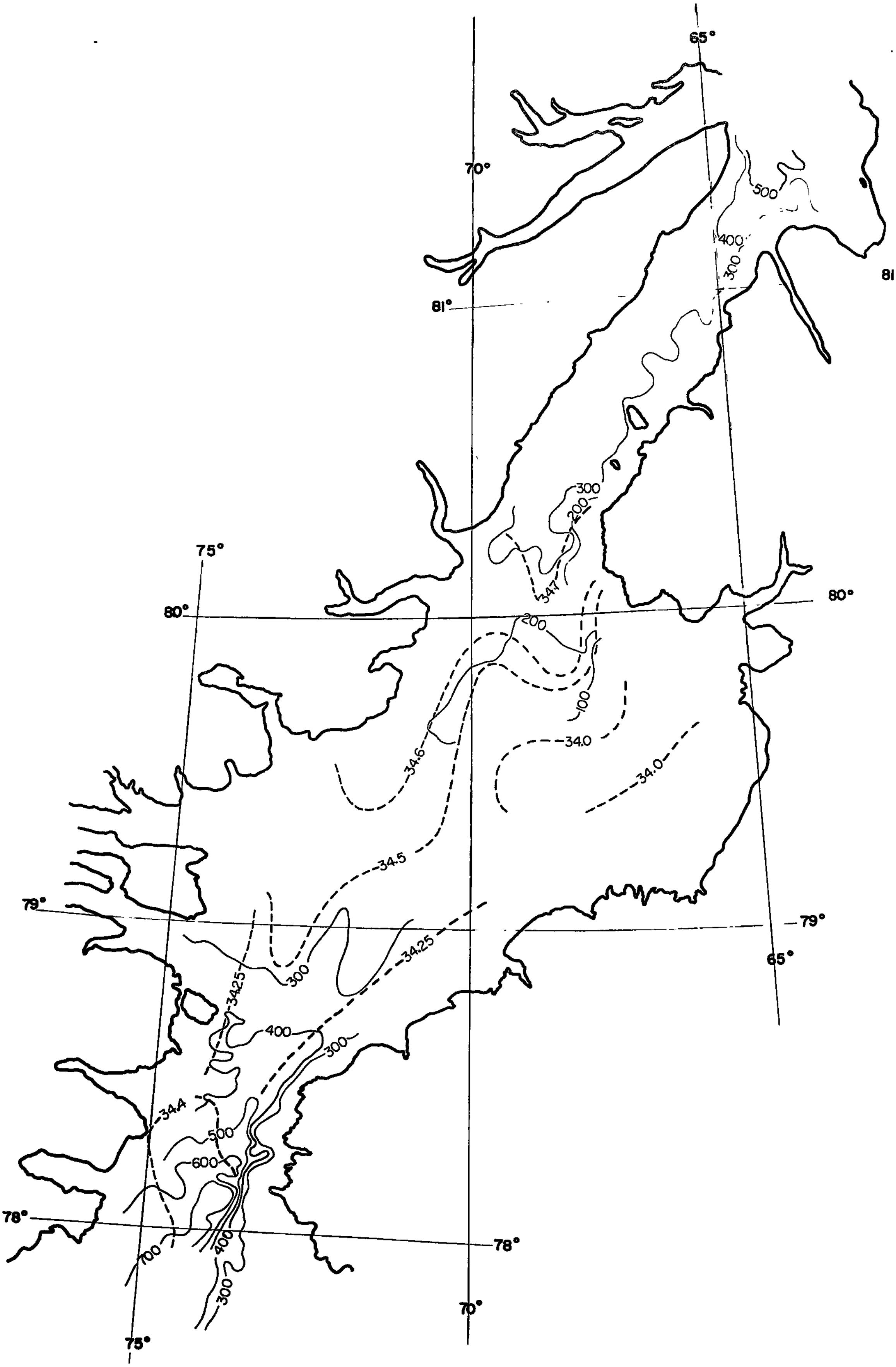

Figure 4 Distribution of salinity near bottom and bathymetry, (contour interval 100 metres), Nares Strait.

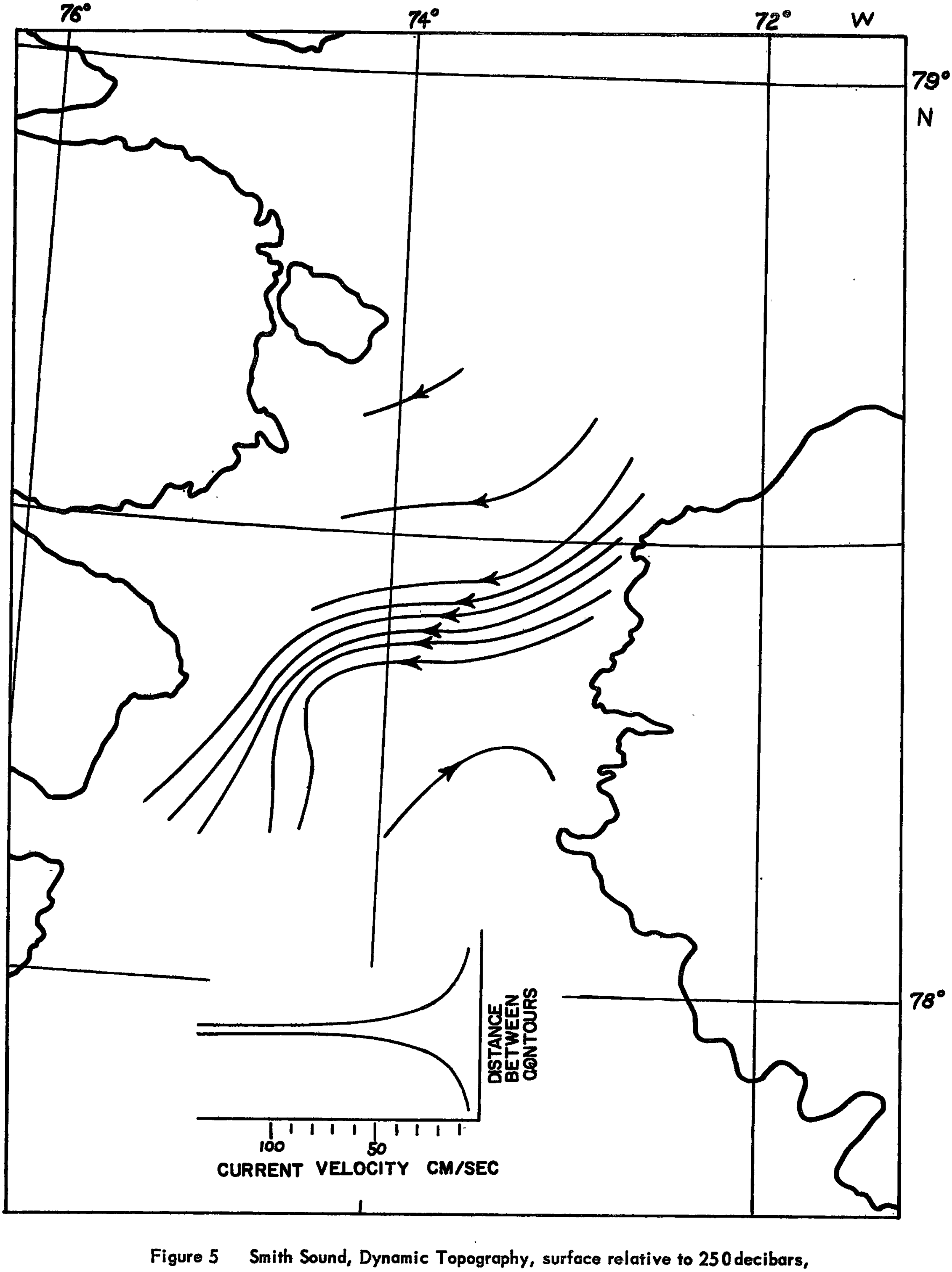

Figure 5 Smith Sound, Dynamic Topography, surface relative to 250 decibars, contour interval 2 dynamic centimetres, September 20-23, 1963.

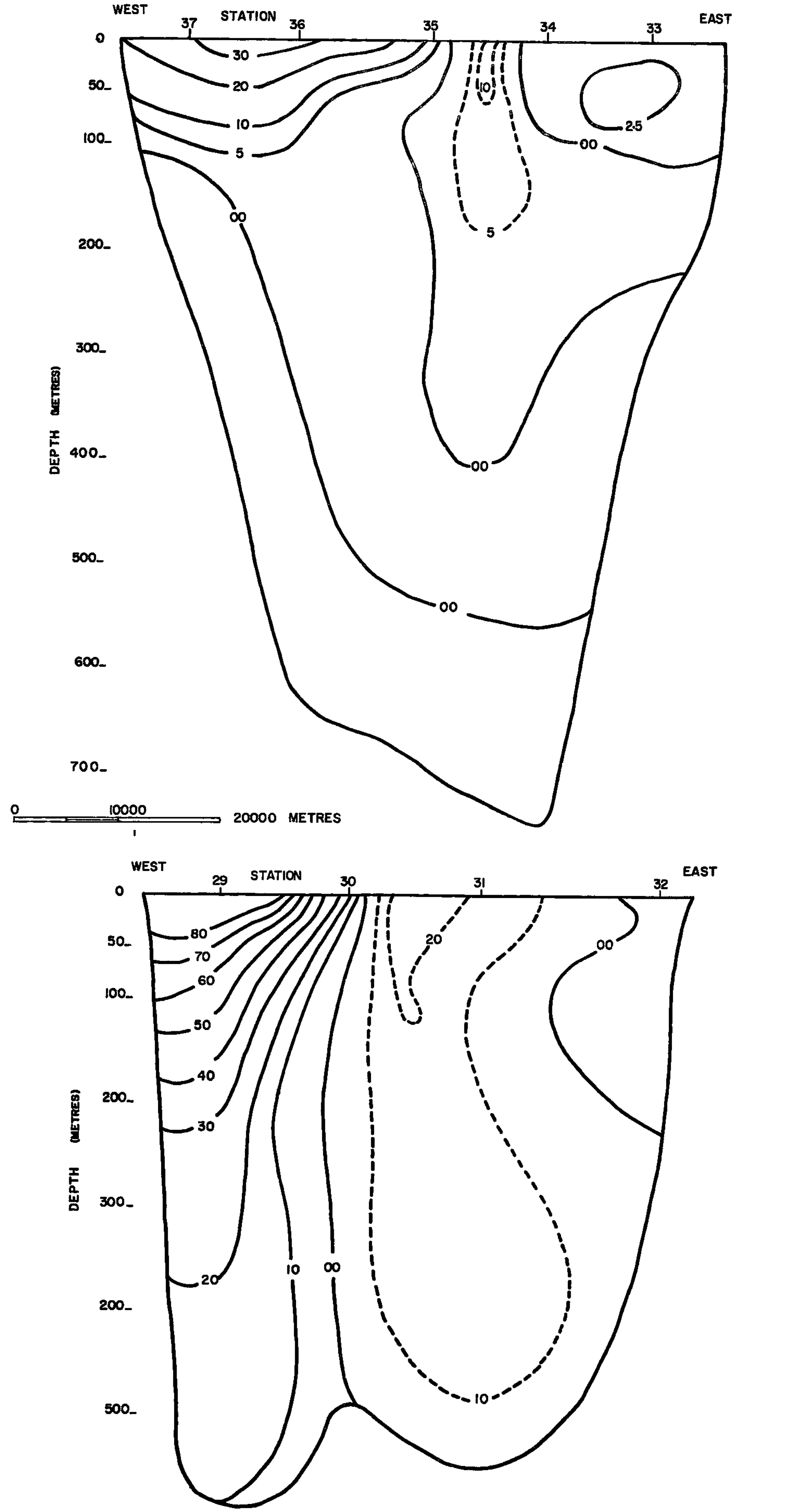

Figure 6 Relative Current, cm/sec, reference level 500 decibars, September 22, 1963. The solid lines indicate a current in a southerly direction and the dashed lines, a northerly direction.