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# A Review of the Oceanographic Conditions in Subareas 0 and 1 in the Decade 1970-79

by

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## 1. Introduction

In the decade 1970-1979 the investigations of the oceanographic environment in Subareas 0 and 1 have had the same status of second priority as previously as compared to biological investigations although the amount of data collected seems to have increased quite a bit. Still, however, the majority of observations consists of temperature and salinity measurements chiefly from the warm season of the year. Knowledge of the circulation in the area is based mainly on the study of dynamic topography charts, but in the period 1975-1978 current measurements were carried out during an environmental survey program in connection with oil explorations off West Greenland, see Chapter 3.

The aim of this paper is to give a review of the results of the oceanographical observations carried out in the two subareas during the decade. Surveys were performed mainly by research vessels from Denmark, the Fed. Rep. of Germany, and the U.S.S.R. The majority of the data available to the author is concerned with Subarea 1. Therefore this area will attach the greatest importance in the paper.

In order to give a discussion of the year-to-year as well as the seasonal variations of the hydrographical conditions (Chapter 2), the Fylla Bank section has been chosen as a representative for Subarea 1, primarily because it is geographically situated almost in the middle of the area, and secondly because temperature and salinity observations, for most of the years, are performed regularly throughout the year.

## 2. Hydrography

The hydrographical conditions along the west coast of Greenland can change a lot from year to year, resulting in changes of the conditions for biological production. The yearly change of the physical environment may be illustrated by the mean temperature of the upper 40 m at the Fylla Bank in the middle of June. The variations over the last 100 years are illustrated in Fig. 1. The line at 1.8$^{o}$C indicates the lower limit for high survival of cod larvae.

The decade 1960-1969 fased out with a considerable drop in the mean temperature, and the nineteenseventies can roughly be characterized as a restoring periode, but it is seen that only in three years the temperature conditions have been favourable for the survival of the cod larvae.

An impression of the temperature variations during the decade as well as during individual years can be obtained from Fig. 2 a-c, which summarizes all the temperature observations made by Grønlands Fiskeriundersøgelser at Station 4 of the Fylla Bank section situated just west of the bank itself.

A general trend in these observations is the relatively high temperatures below 100 m during the winter (October-April), often with temperatures above 5$^{o}$C in the whole water column below about 200 m. This may be taken as a clear sign of the dominance of the Irminger water at this time of the year, which confirms the results of Soule *et al.*(1963) who at Kap Farvel found the mass transport of the East Greenland component to the West Greenland current to approach zero in August-September while the Irminger component more than doubled its mass transport in the same period.

For most of the years a shallow summer thermocline develops, with a maximum temperature of 3-5$^{o}$C, and a thickness of about 40 m.

During the winter the surface layer naturally cools reaching temperatures below 0$^{o}$C, very often below -1$^{o}$C, too. The cooling of the water causes an increase in the density of the water resulting in a deepening of the cold upper layer due to the process of vertical convection. This phenomenon is clearly illustrated for instance by the observations from February-March 1975 in Fig. 2 b or by the measurements of Svetlov (1975), from March 1974, Fig. 3.

Beside these general characteristics some years have their own features of which a few will be mentioned.

i) In 1970, the year with the lowest June mean temperature at the Fylla Bank, the upper 100 m had temperatures below $0^{\circ}C$ up until June, part of this layer even had temperatures below $-1^{\circ}C$, and in September a layer between 30-110 m had temperatures below zero. Also during the summers of 1975 and 1976, a layer relatively thin with minus temperatures was observed.

ii) Generally the water between 300-500 m has a temperature between $3^{\circ}C$ and $4^{\circ}C$ in the spring, but in 1973 this layer was characterized by temperatures above $4^{\circ}C$, possibly owing to, for that part of the year, a relatively high inflow of Irminger water.

In contrast to 1973 the water below 300 m was cold in May 1976 with temperatures below $3^{\circ}C$, which was accompanied by a decrease in the salinity of the layer, see Fig. 5, a phenomenon probably due to mixing with water from the Baffin Land current.

iii) In December 1976 and 1978 a pronounced decrease in the temperatures of the deep layers is observed, i. e. the cooling of the lower 400 m, which normally takes place during January and February, was accelerated these winters for some reason.

An impression of the temperature distribution along the coast of West Greenland can be obtained from Fig. 4 showing vertical temperature sections from Frederikshåb in the south to the Hare Island in the north in July 1971, except for the Frederikshåb section which is from the middle of August.

Although 1971 was a cold year and July falls in the season just before the intensification of the Irminger current clear signs of the presence of water from this current are found right up to the Hare Island.

The depth at which the Irminger water is found is increasing towards the north, and mixing with other and colder watermasses on its northward passage is seen by the disappearance of the $4.5^{\circ}C$ isoterm between Sukkertoppen and Holsteinsborg, and the $4^{\circ}C$ isoterm between Egedesminde and the Hare Island.

The presence of arctic water from the Baffin Land current is seen at the outer stations of the northern sections with temperatures below $0^{\circ}C$, in the core at 50-100 m even below $-1^{\circ}C$.

Regarding the salinity Fig. 5 shows the salinity at 3 depths: 0 m, 200 m, and 600 m at the Fylla Bank St. 4 for the whole decade.

As expected the variation declines with depth. The surface salinity varies within 2 o/oo, the 200 m salinity within 0.8 o/oo, and the 600 m salinity within 0.2 o/oo.

It seems a general trend that the surface salinity decreases in October-November, probably due to outflow of fjord water from the great Godthåb Fjord system, which will not reach St. 4 in the section until late in the year because of the strong northgoing currents. The hypothesis of the less saline water being of fjord origin is confirmed by Fig. 6 taken from Kudlo and Borovkov (1975).

Another explanation might be that meandering in the West Greenland current takes place, but it seems unlikely that such a meandering will occur so regularly each year.

No specific trend in the salinity at 200 m is found because traditionally it is an area where mixing between watermasses of different origin takes place.

The most pronounced variation of the salinity at 600 m is the decrease in the middle of 1976 which is discussed above.

## 3. Circulation

### 3.1. General

Knowledge of the circulation in the Davis Strait, including the West Greenland current is mainly obtained by analysing hydrographic observations, i. e. construction of dynamic topography charts.

Kudlo *et al.* (1979) have, based on PINRO observations in the Strait from 1962-1978, drawn up a probable mean scheme of the geostrophic circulation in the surface layer of the Davis Strait for the warm period of the year, i. e. April-October (Fig. 7). The advantage of such a mean circulation chart is restricted to give an impression of how the water masses move in the area of interest, while it suffers from a number of disadvantages:

i) It is a mean picture of a season in which, as seen in Chapter 2, great hydrographic changes take place.

ii) As the hydrography changes from year to year, naturally also the circulation undergoes yearly variations, see Aleksiev *et al.* (1972).

iii) In their paper Kudlo *et al.* underline that the method of construction is subjective.

Regarding the decade of interest in this connection Kudlo in cooperation with various authors has given two dynamic topography charts, Kudlo *et al.* (1975, 1976).

Fig. 8 shows the geostrophic circulation in the Davis Strait in September-November 1973. It is seen to differ in several respects from the mean circulation chart given in Fig. 7. The current along the west coast of Greenland is rather intense, while the transport in the Baffin Land current is about normal due to local vorticites in the current. Another peculiarity is the anticyclonic water cycle centered at 65°N which brings water at the central part of the Strait to the Store Hellefiske Bank, which is confirmed by the low temperatures in the surface layer in the Holsteinsborg section in November 1973 shown in Fig. 9.

The circulation in November 1974 (Fig. 10) is not as intense as in 1973, the West Greenland current is broader and the westward deflection begins more southerly in 1974 than in 1973. Also the usual meandering of the West Greenland - and Baffin Land - currents takes place in the area of the Greenland-Canadian ridge.

### 3.2. Currents

In contrast to previous decades current measurements at various positions along the west coast of Greenland were carried out in the seventies. These current measurements were made during the summer period in the years 1975-1978 as a part of an investigation of the environmental conditions offshore West Greenland carried out in connection with the oil exploration program which took place in that period. A detailed report of the measurements is compiled by the Danish Hydraulic Institute (DHI) (1979).

The measurements were performed by using Aanderaa RCM4 selfrecording current meters with a measuring interval of 10 minutes.

The currents along the west coast of Greenland are, naturally, composed of a number of tidal components causing no net drift of the water particles and a residual current component generated chiefly by pressure gradients.

In order to evaluate the net drift of the water masses the tidal components of the current have been eliminated by taking a 24 hour running mean of the current observations.

The DHI has, based on the observations of the four year period, worked out a mean picture of the 24-hour mean current distribution in the investigated area representative for July and August for three depth intervals: 20-59 m, 60-240 m, and 250-410 m, in the form of current roses, Fig. 11-14. Additionally, the mean net drift velocity vector is calculated for the same depth intervals, Fig. 15-17.

The maximum 24-hour mean current reached a value of approximately 30 cm/s. while the maximum mean net drift velocity was about 20 cm/s. The highest velocities were generally found to the south of and on the banks, and the velocities had a tendency of decreasing with increasing depths.

The directions of the currents were mainly northerly with local modifications owing to the general features of the bottom topography, see for instance the currents around the area of the Holsteinsborg deep separating the Lille Hellefiske and the Store Hellefiske Banks. In the southern part of the deep the current is practically always directed towards north-east parallel to the depth contour, while just north of the deep at Station F9 the dominating direction is west-north-west and west, with great velocities, above 24 cm/s more than 25% of the time. The reason for this big variation in the current direction within a relatively small distance probably is that the north-eastward flow in the deep cannot escape northward over the shallow bank and therefore has to turn west following the southern part of the bank.

Also at the northern edge of the Store Hellefiske Bank the currents clearly follow the bottom topography flowing into the Disko Bay. The excess of water in the Bay flows out south and north of the Disko Bank once more following the depth contours.

3.3. Tides

A general description of the tidal conditions in the Davis Strait was given by Godin (1966), who found the cotidal charts for the principal semi-diurnal ($M_2$) and diurnal ($K_1$) tidal components given in Fig. 18 and 19.

The $M_2$-component has a amphidromic point at about 70$^{O}$N almost in the middle of the strait. At the west coast of Greenland it has its highest amplitude of 120 cm in the area of Godthåb reducing to about 60 cm in the Disko Bay area. At the coast of Baffin Island the amplitude lies between 15-40 cm.

The amplitude of the $K_1$-component is relatively small, 10 cm near Godthåb increasing to 30 cm in the Disko Bay and Baffin Island area.

During the environmental investigations in 1975-1978 pressure gauges installed offshore near the seabed, and water level recorders onshore along the coast were used in order to improve the understanding of the tidal conditions and to determine the tidal range in the area of interest.

The results of the data analysis are shown in Fig. 20 and 21. They are seen to be in good agreement with the results of Godin (1966).

Based on the current observations discussed in Section 3.2 an analysis of the tidal currents were carried out. Only the semi-diurnal components $M_2$ and $S_2$, and the diurnal components $K_1$ and $O_1$ were found to give rise to currents of importance.

The geographical distribution of the tidal conditions in the three depth intervals used previously, i. e. 20-57 m, 60-240 m, and 260-410 m are given in Fig. 22 and 23 in forms of tidal hodographs for the greatest semi-diurnal and diurnal components, $M_2$ and $K_1$, respectively.

The big variations in the size and the orientation of the hodographs due to topography and depth are worth noticing.

Generally the tidal current velocities increase from the south where velocities below 10 cm/s are found, towards the north with maximum values of 25-35 cm/s in the area between $67^{\circ}$-$68^{\circ}$N. To the north of $68^{\circ}$N the velocities decrease again to a value about 15-20 cm/s.

Finally, it appears to be a general trend that the tidal currents decrease with depth.

## 4. Summary and conclusion

During the seventies the temperature conditions along the west coast of Greenland, exemplified by the mean temperature of the upper 40 m at the Fylla Bank, have returned to the level they had before the strong cooling period at the end of the sixties.

The variation in salinity at Station 4 at the Fylla Bank Section has been investigated, and a periodic decrease in the surface salinity in October-November is revealed.

Current observations carried out in the last half part of the decade mainly confirm the general trends of the circulation in the area known from the construction of dynamic topography charts. Additionally, information of the deviations due to the wind, the meteorological pressure distribution is obtained.

Knowledge of the tides has been achieved partly by the current measurements yielding the tidal currents, and partly by water level measurements revealing cotidal lines and amplitudes. The latter appeared to be in good accordance with the results of Godin (1966).

## Acknowledgements

The author wishes to express his gratitude to the staff at Grønlands Fiskeriundersøgelser for their kind hospitality during the preparation of this paper. Special thanks are given to the Director, Sv. Aa. Horsted, for assistance with a literature review and valuable comments, Mrs. Elin Vilner for typing the manuscript, and Miss Susanne Frischauf for assistance with the illustrations.

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Soule *et al.*, 1963. Physical oceanography of the Grand Banks region, the Labrador Sea and the Davis Strait in 1962. Bull. U. S. Cst. Guard, No. 48.

Svetlov, I. I., 1975. Some peculiarities of the temperature conditions of waters of the West Greenland and Baffin Land Currents in 1974. Int. Comm. Northw. Atl. Fish., Res. Doc. 75/77, Ser. no. 3504.

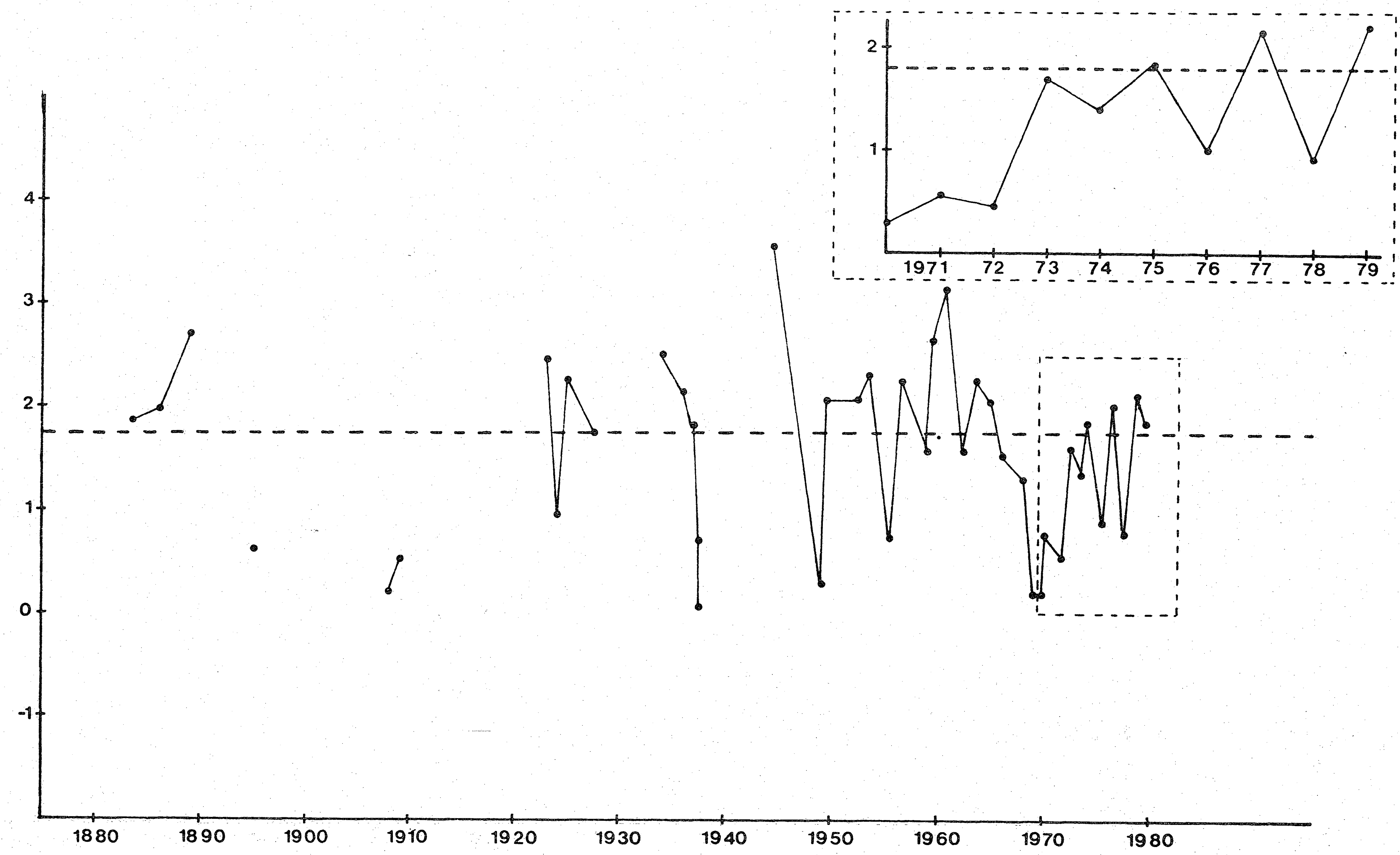



Figure 1. Mean temperature of the upper 40 m medio June at the Fylla Bank.

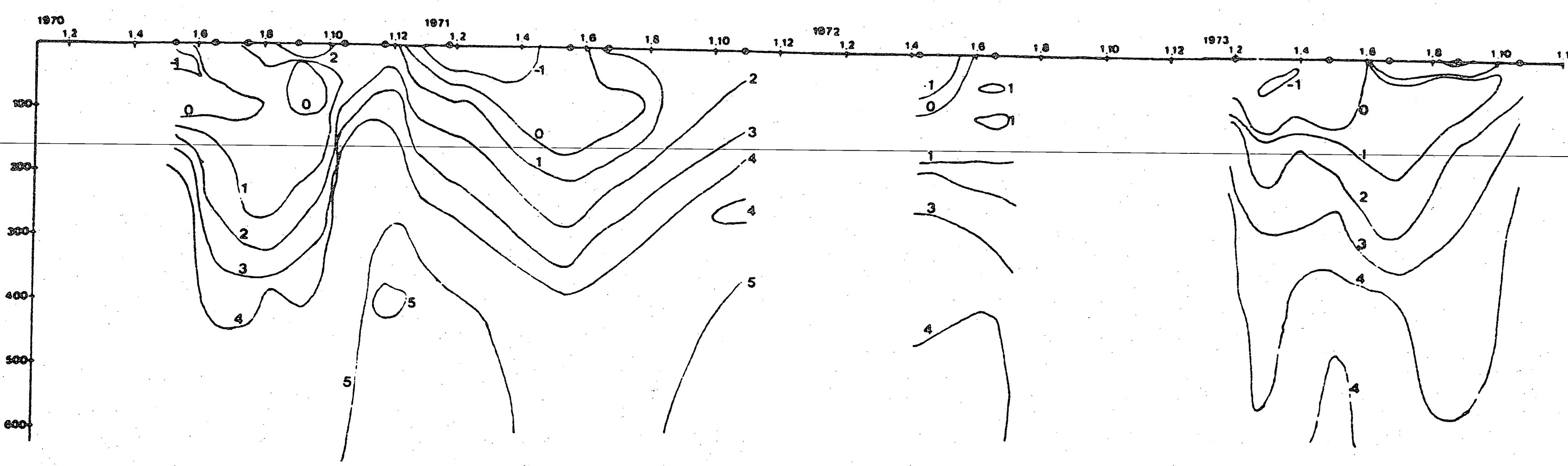



Figure 2a

Figure 2 a-c. Temperature distribution at the Fylla Bank section, St.4 during the decade ( ● indicates dates of observation).

Fig.2a

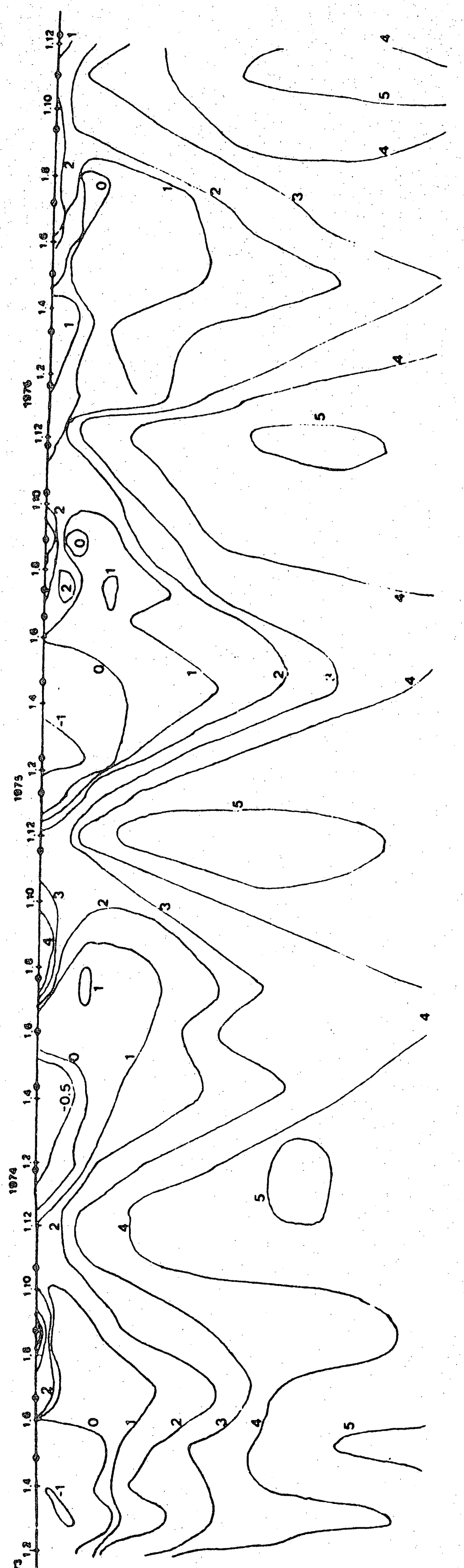



Figure 2b. Text see Figure 2a

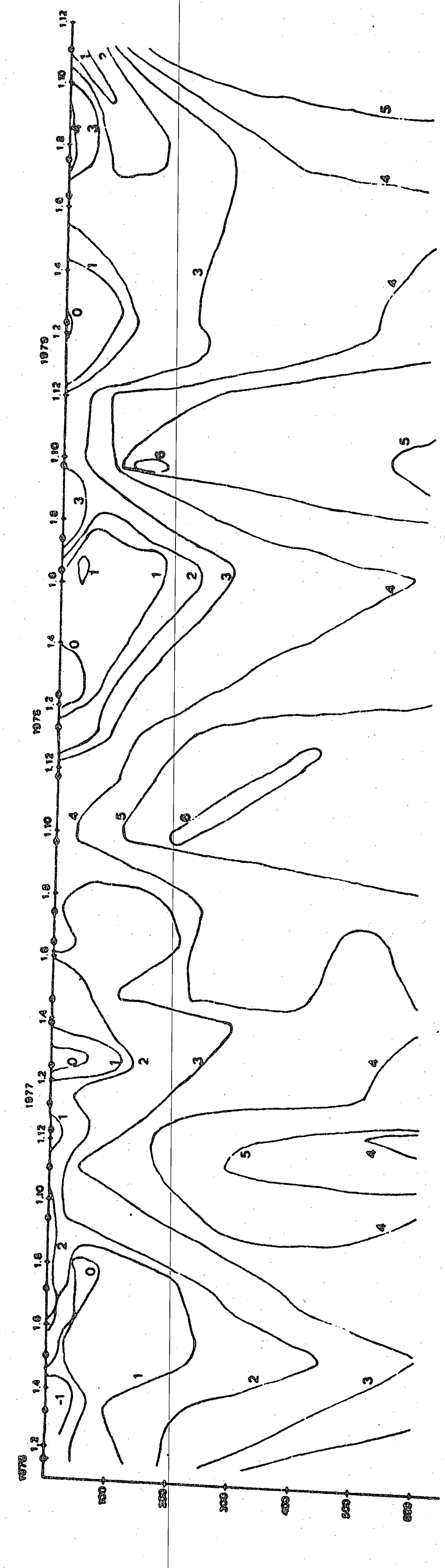



Figure 2c. Text see Figure 2a

Fig.2c

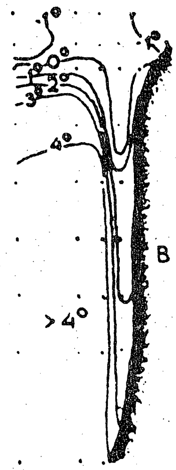
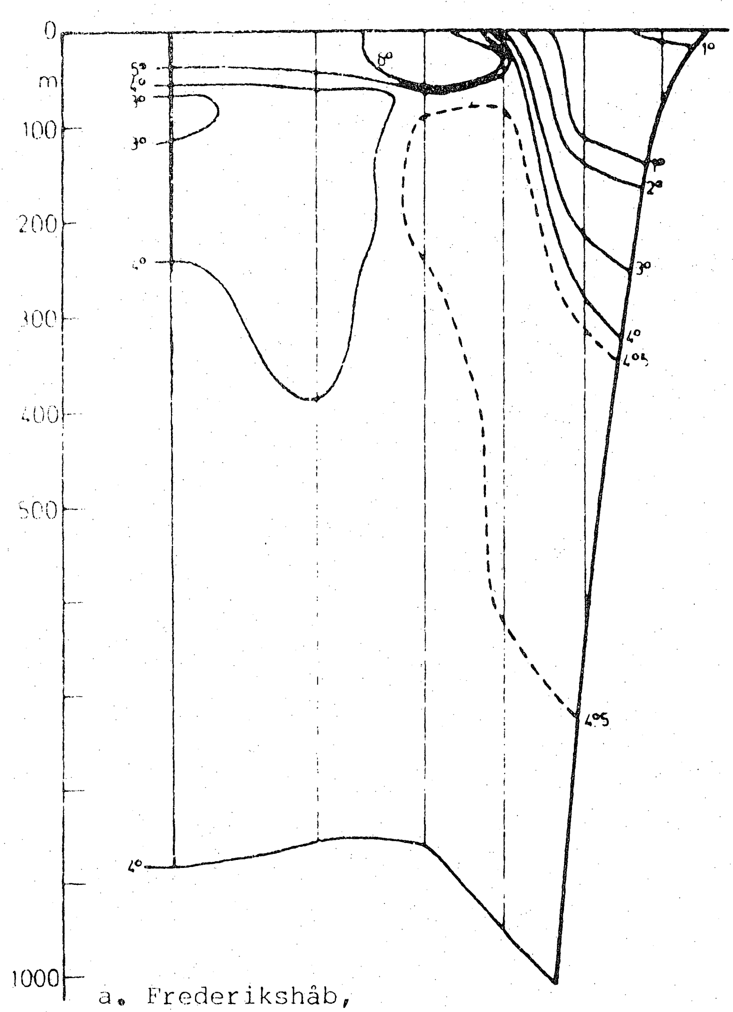
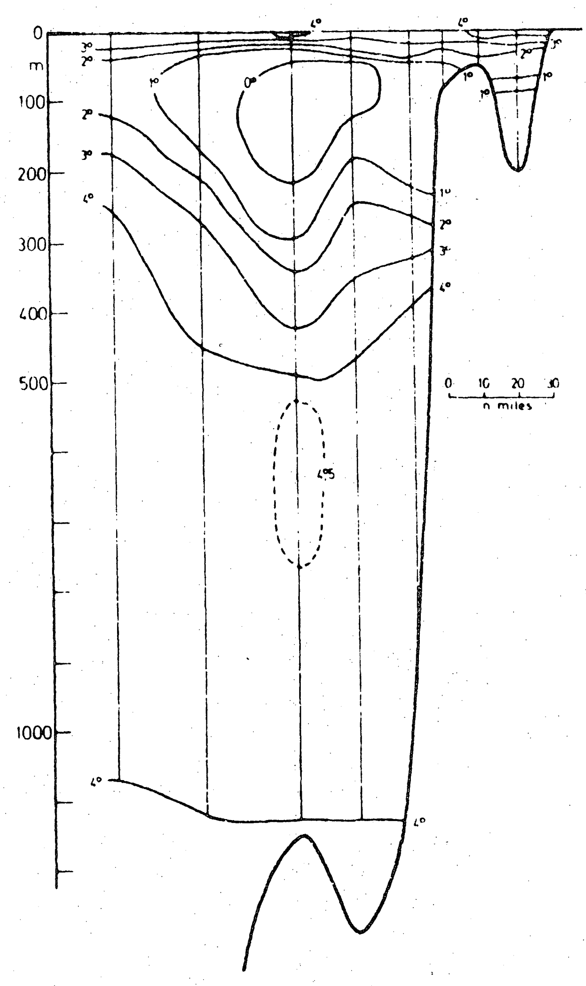



Figure 3. Water temperatures on the Fylla Bank Section in March 1974. Svetlov 1975.




a. Frederikshåb, 16-17 Aug. 1971

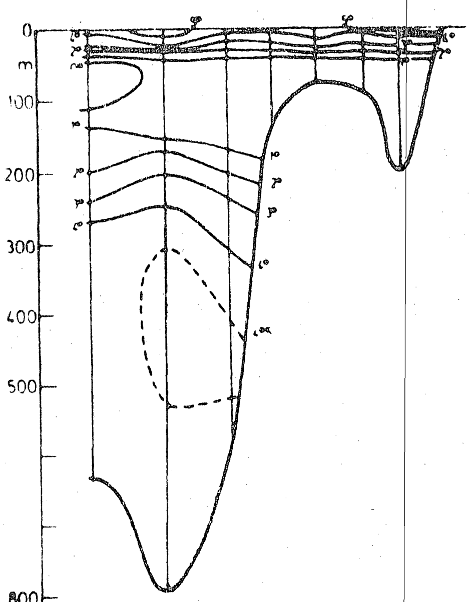



b. Fylla Bank, 18-19 Jul. 1971

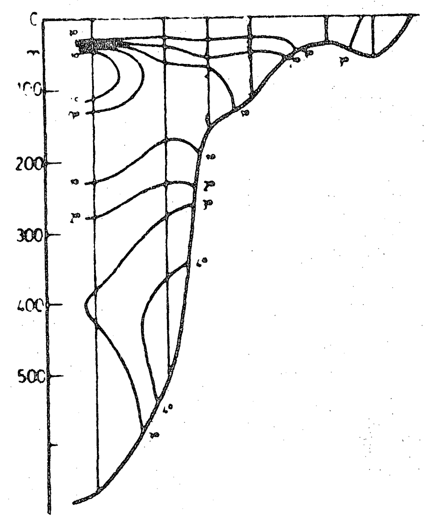
Figure 4, a-f. Vertical temperature distribution along the coast of West Greenland.

cont. .....

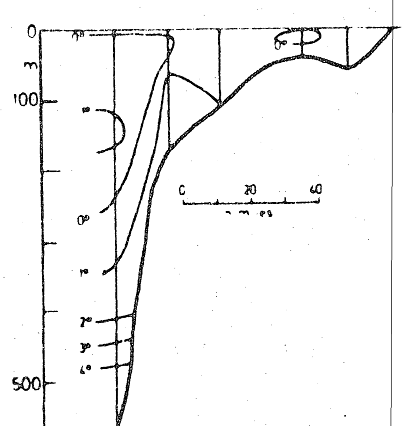
Figure 4 cont.



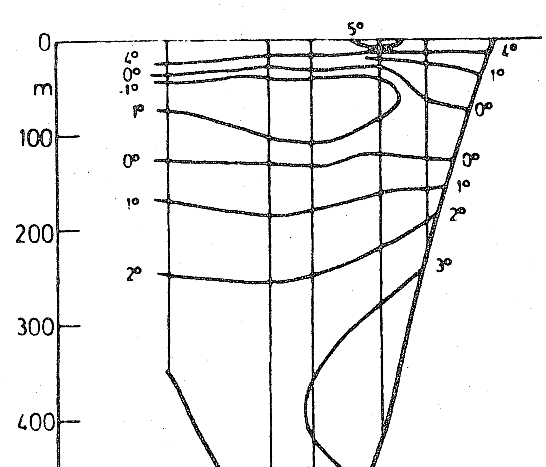

c. Sukkertoppen,
20 Jul. 1971




d. Holsteinsborg,
21-22 Jul. 1971




e. Egedesminde,
12 Nov. 1971




f. Hareø,
27-28 Jul. 1971

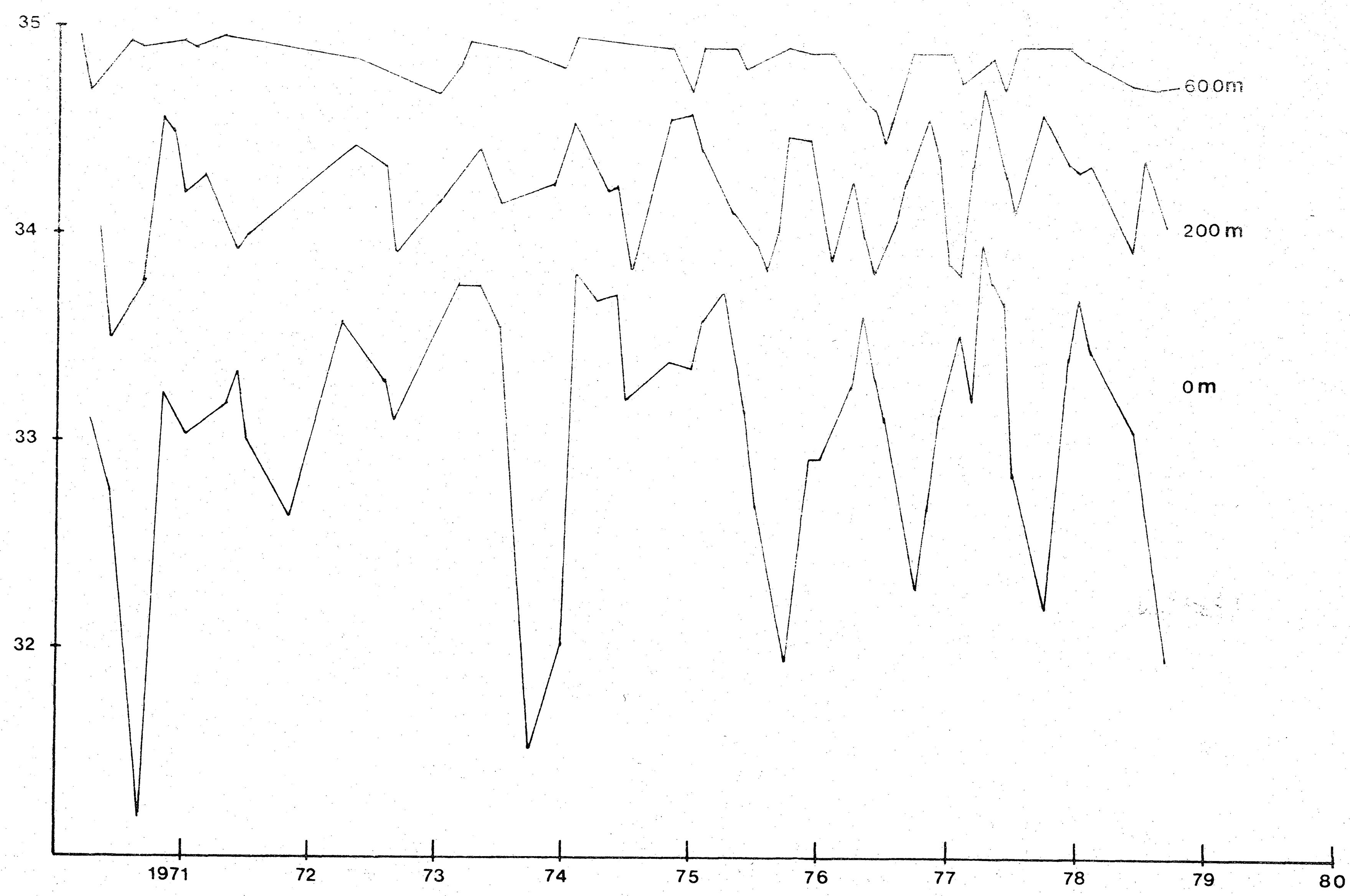



Figure 5. Salinity at three depths at the Fylla Bank Section, Station 4 during the decade 1970-79.

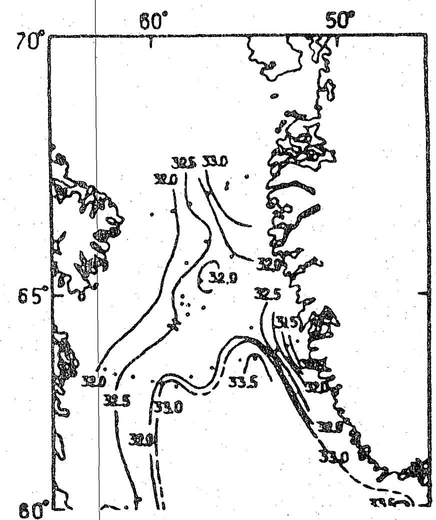



Figure 6. Surface salinity in the Davis Strait, November 1973 (Kudlo & Borokov, 1975).

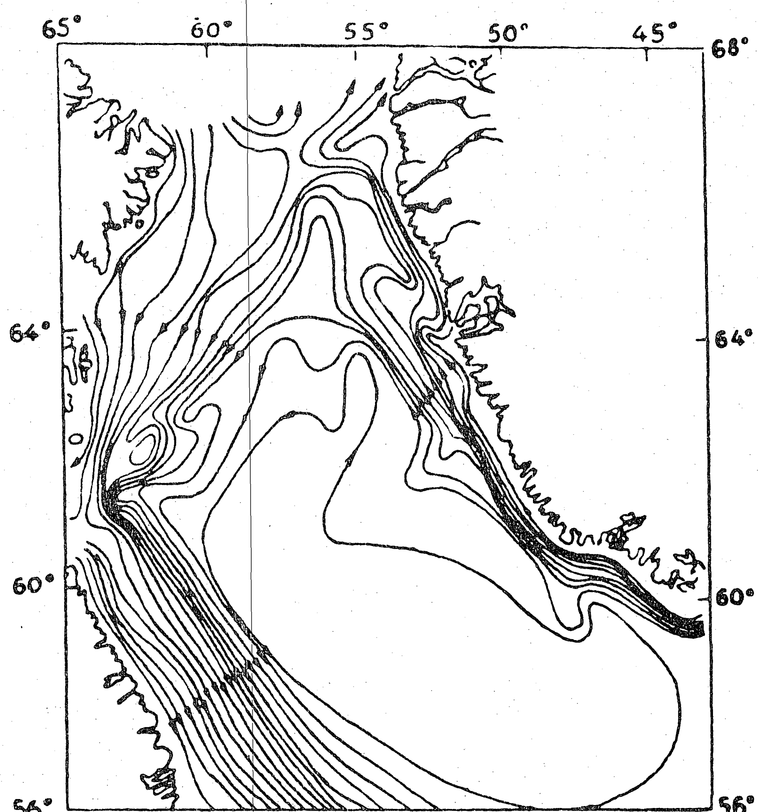
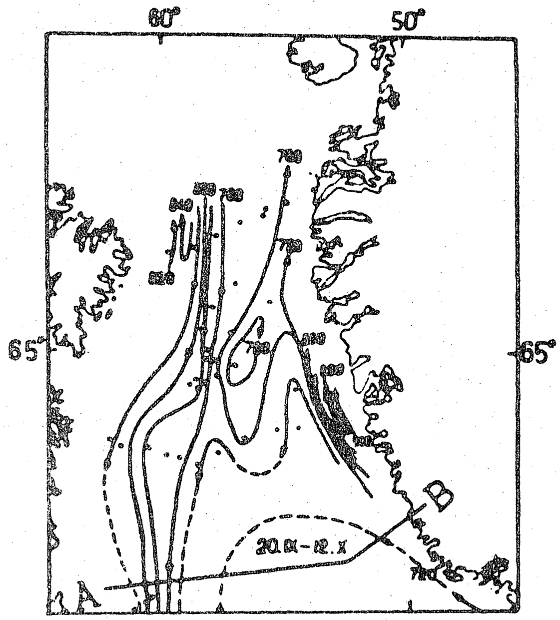



Figure 7. The probable scheme of mean geostrophic water circulation in the surface layer of the Northwest Atlantic for the warm period of a year (Kudlo et al. 1979).



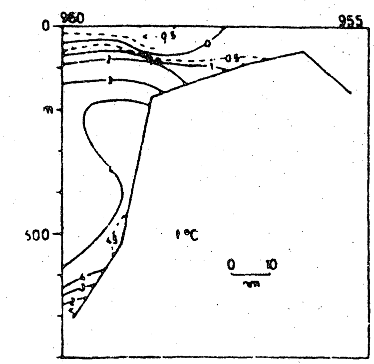




Figure 8. Geostrophic circulation in the Davis Strait areas in September-November 1973, 0-200 db (Kudlo et al., 1975).

Figure 9. Temperature at the Holsteinsborg section, November 1973.

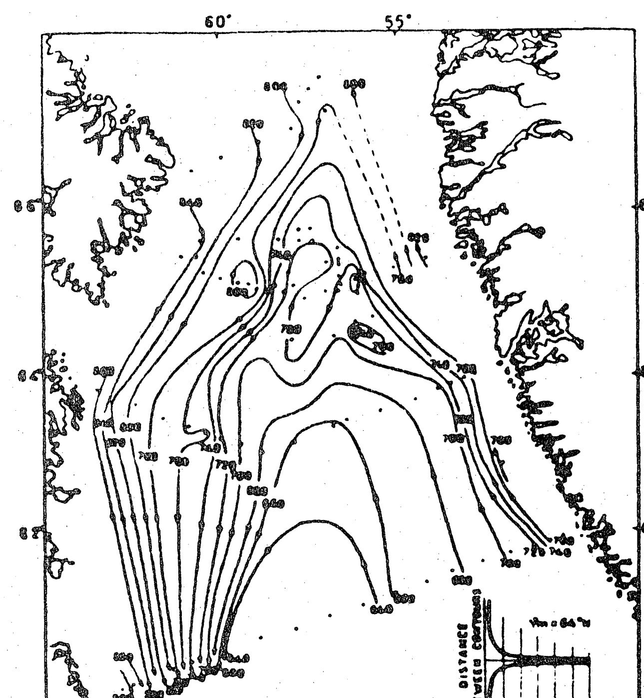



Figure 10. Geostrophic circulation in the Davis Strait area in the 0-200 dbar, 6 November - 12 December, 1974 (kudlo et al. 1976).

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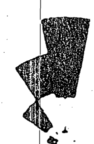

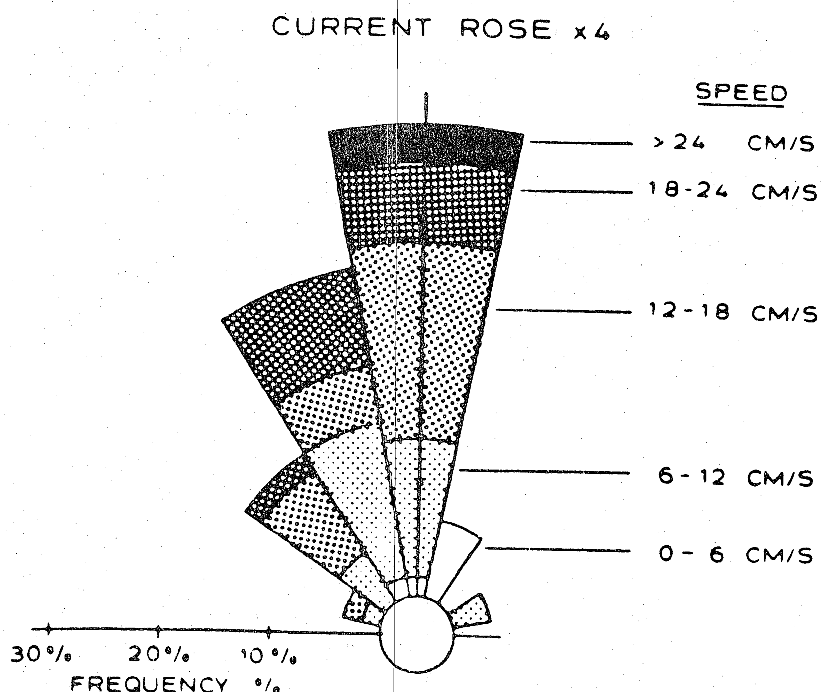


Figure 11. Legend to the current roses shown in Figures 12-14.

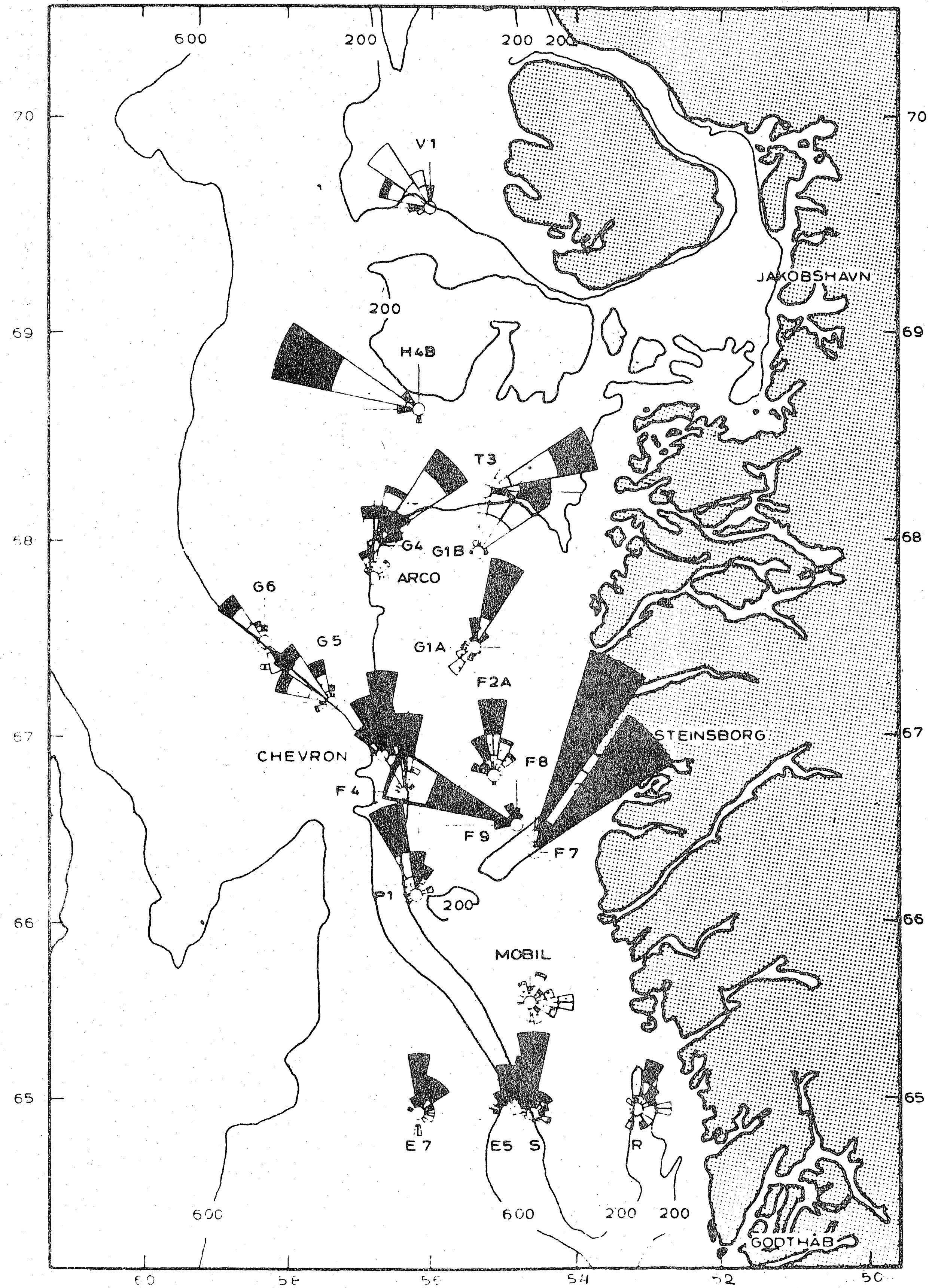


Figure 12. Current roses for the depth interval 20-57 m.

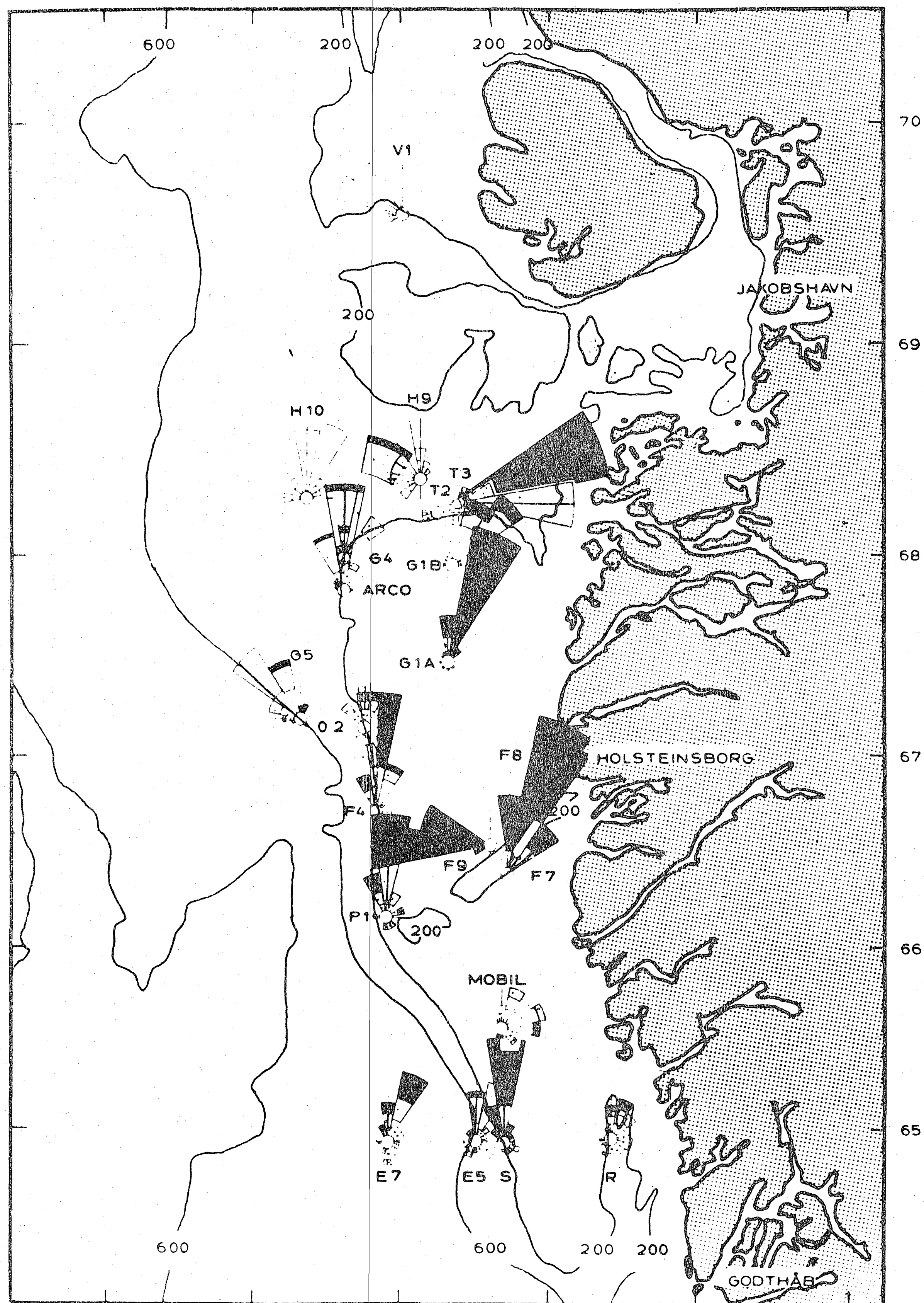


Figure 13. Current roses for the depth interval 60-240 m.

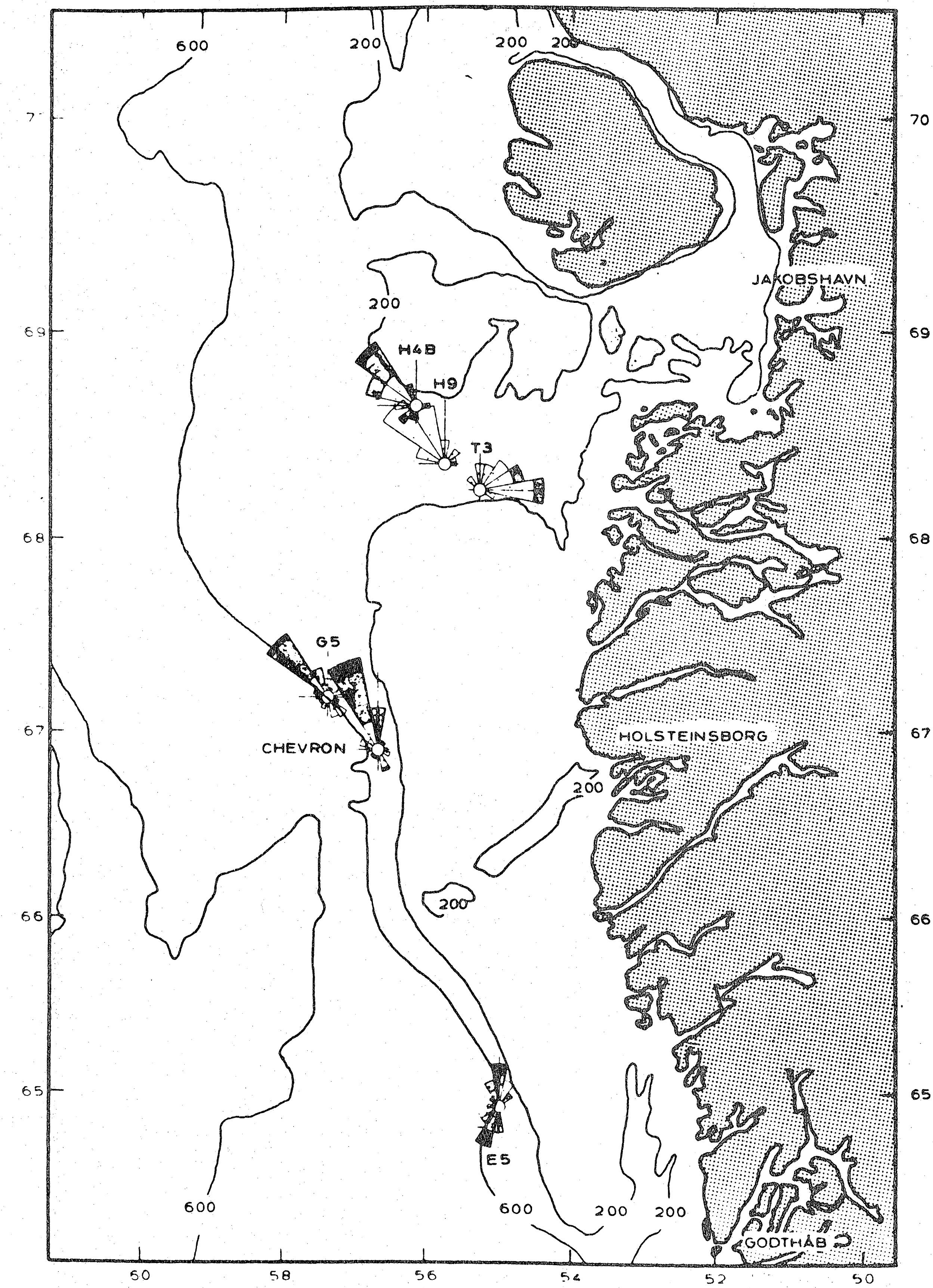


Figure 14. Current roses for the depth interval 260-410 m.

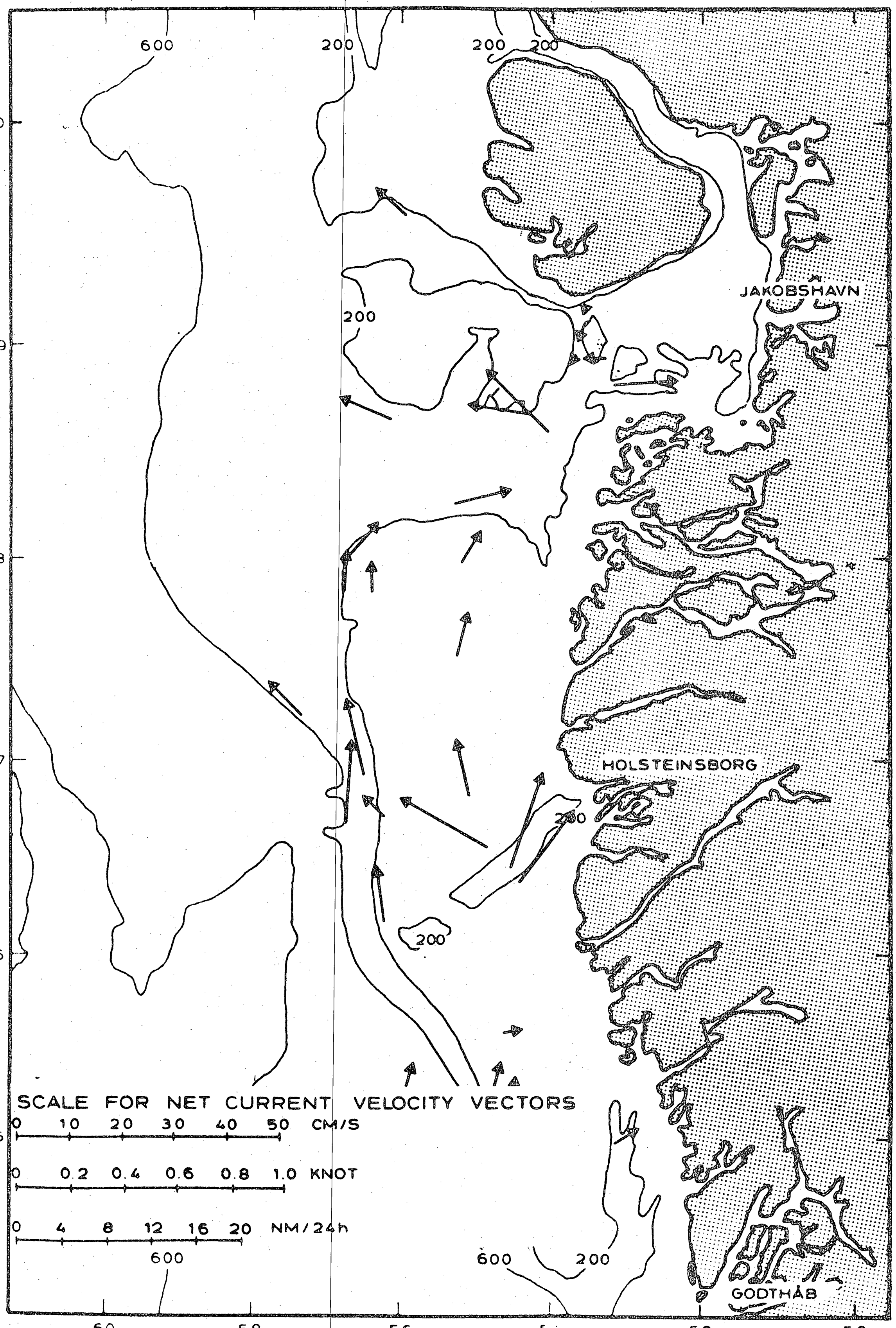


Figure 15. Net current velocity vectors for the depth interval 20-57 m.

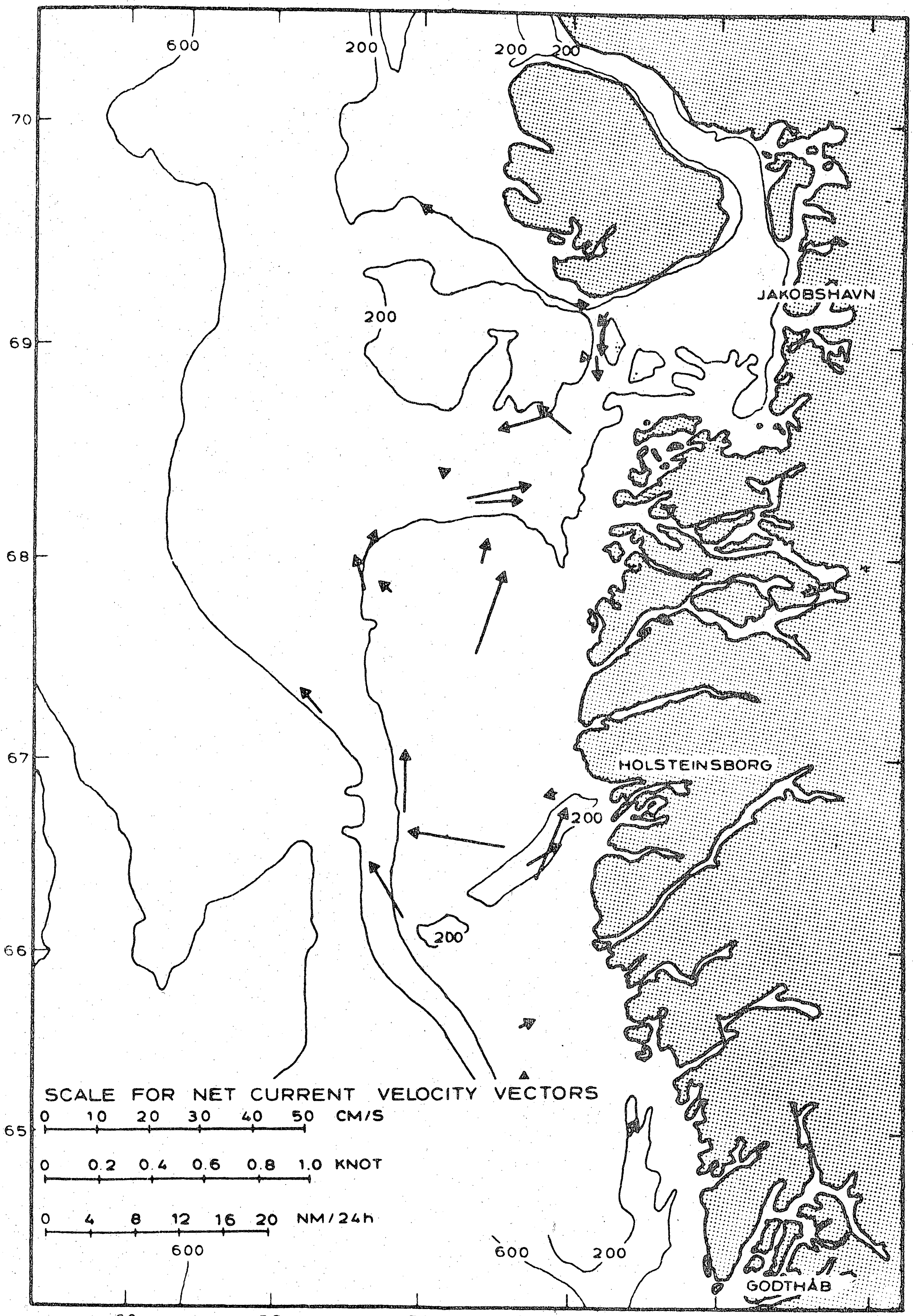


Figure 16. Net current velocity vectors for the depth interval 60-240 m.

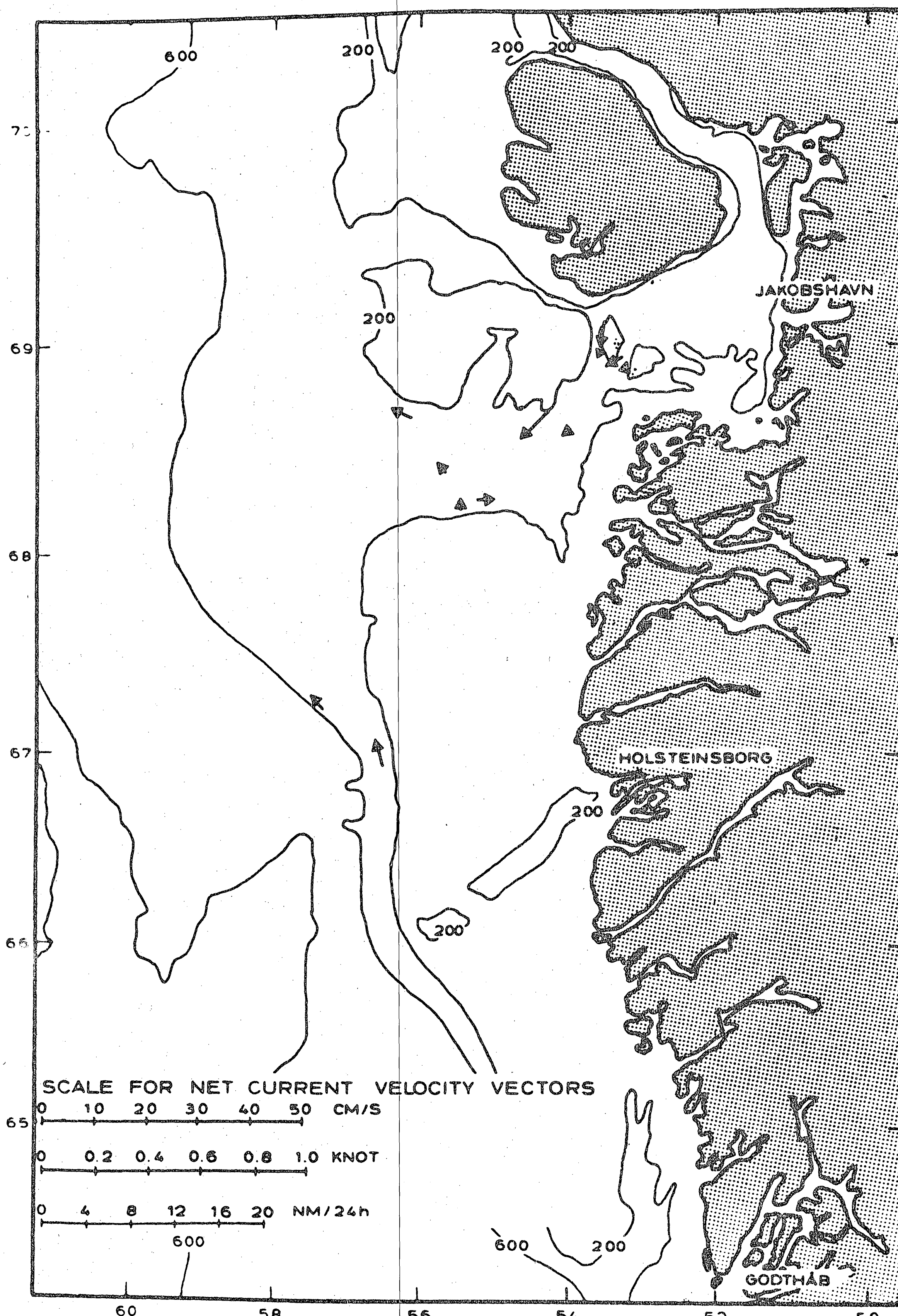


Figure 17. Net current velocity vectors for the depth interval 260-410 m.

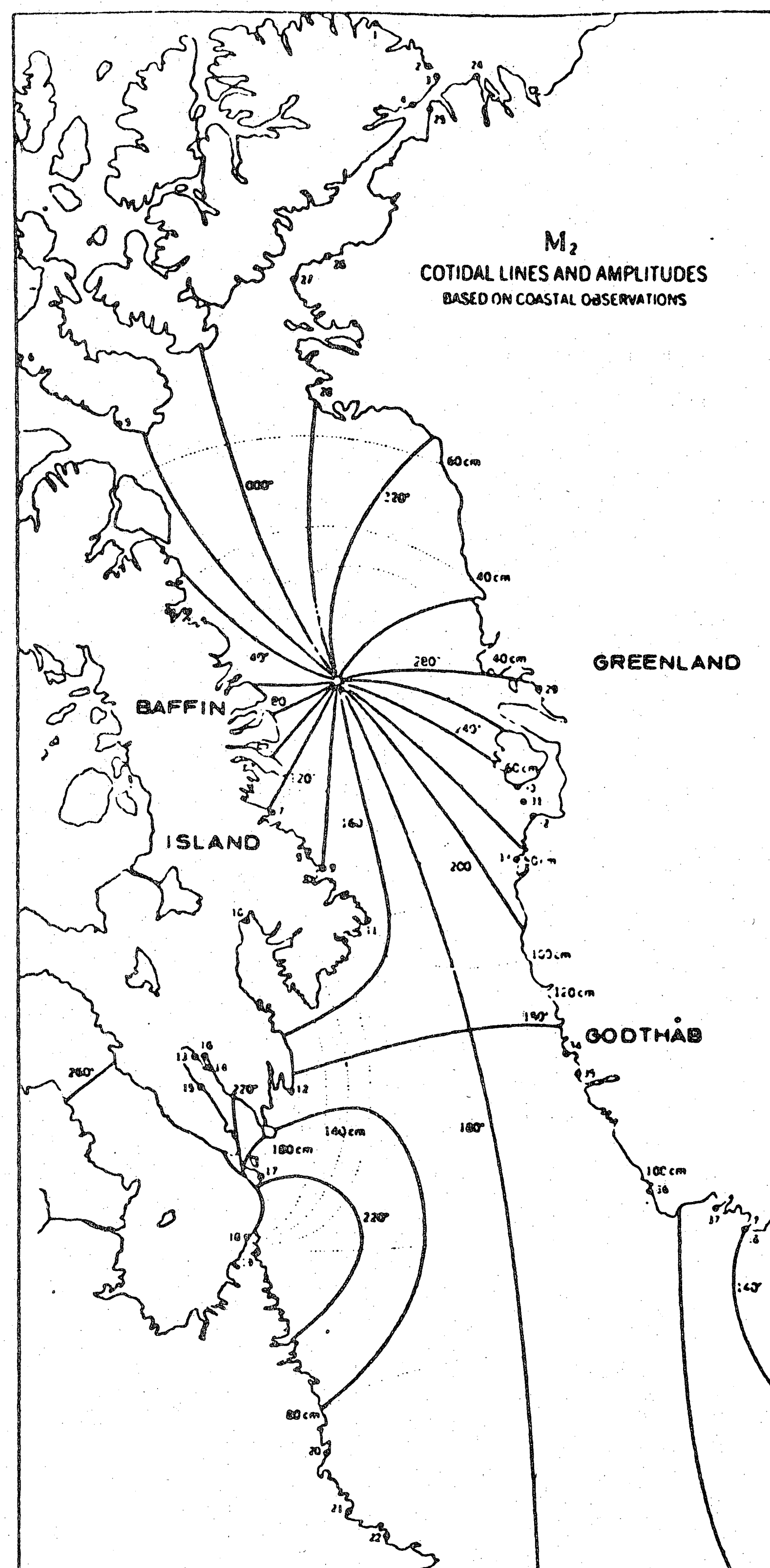


Figure 18. $M_2$ cotidal lines and amplitudes, based on coastal observations. Phase relative to GMT -4 hours.

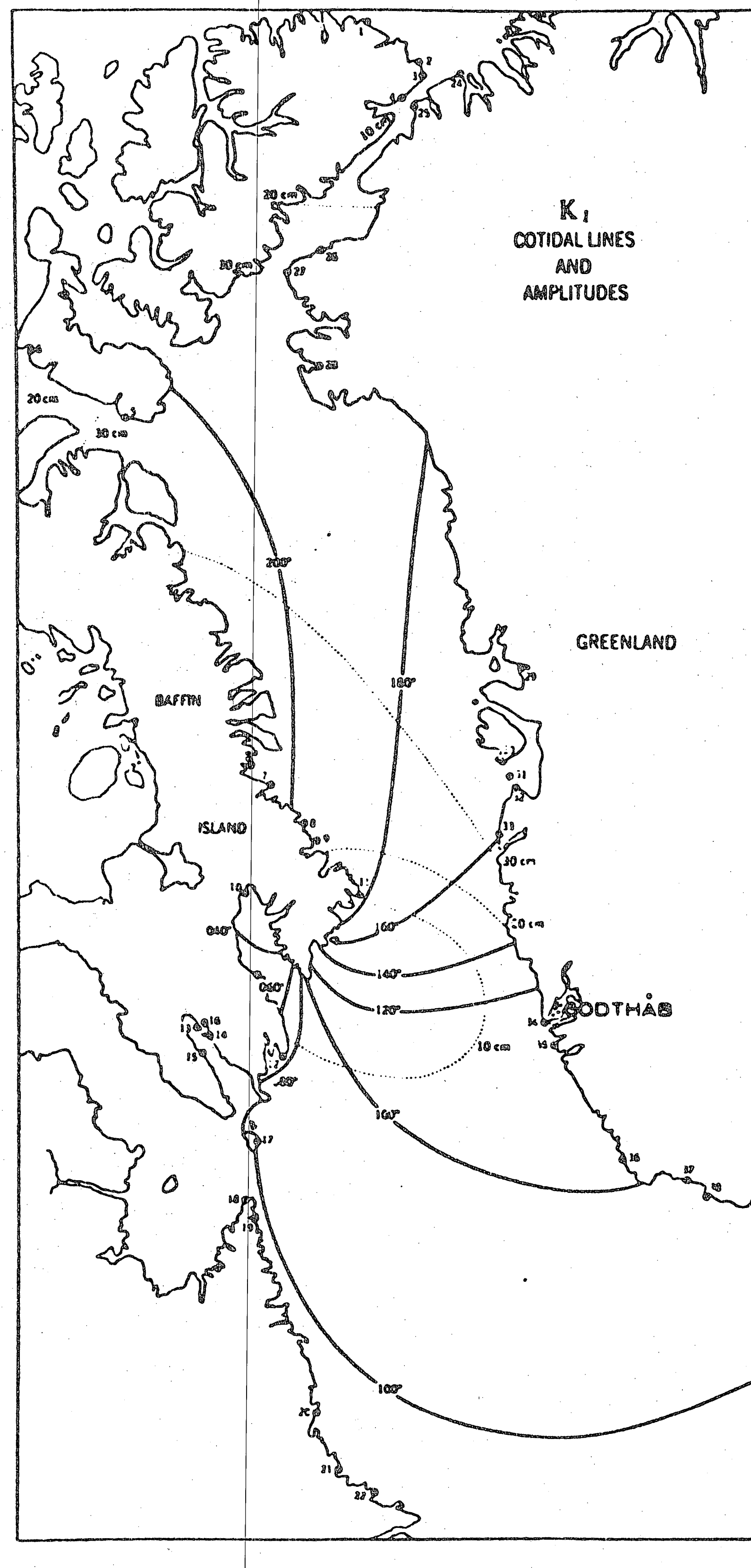


Figure 19. $K_1$ cotidal lines and amplitudes, based on coastal observations. Phase relative to GMT -4 hours.

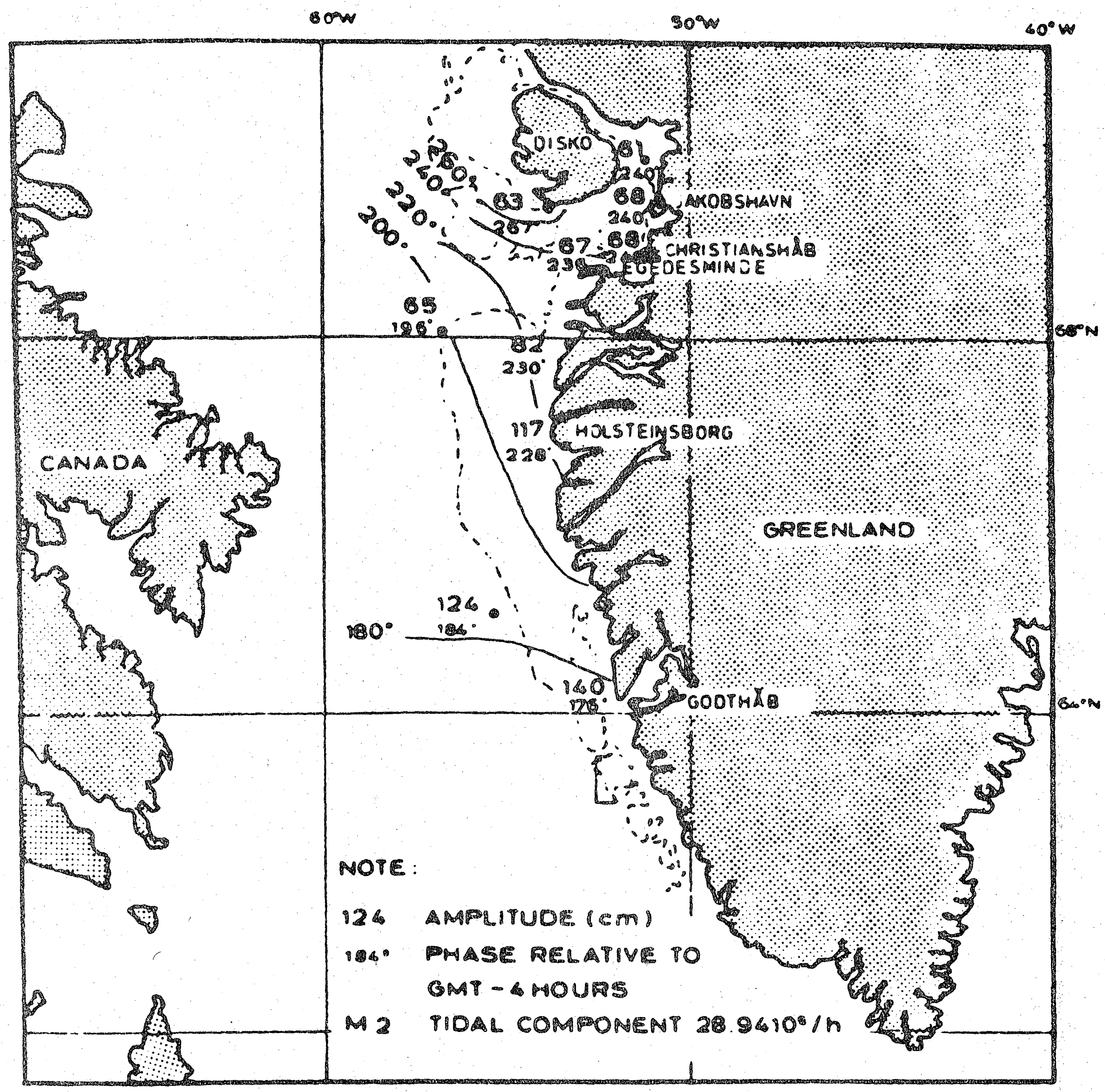


Figure 20. $M_2$ cotidal lines and amplitudes based on water level measurements during 1975-78.

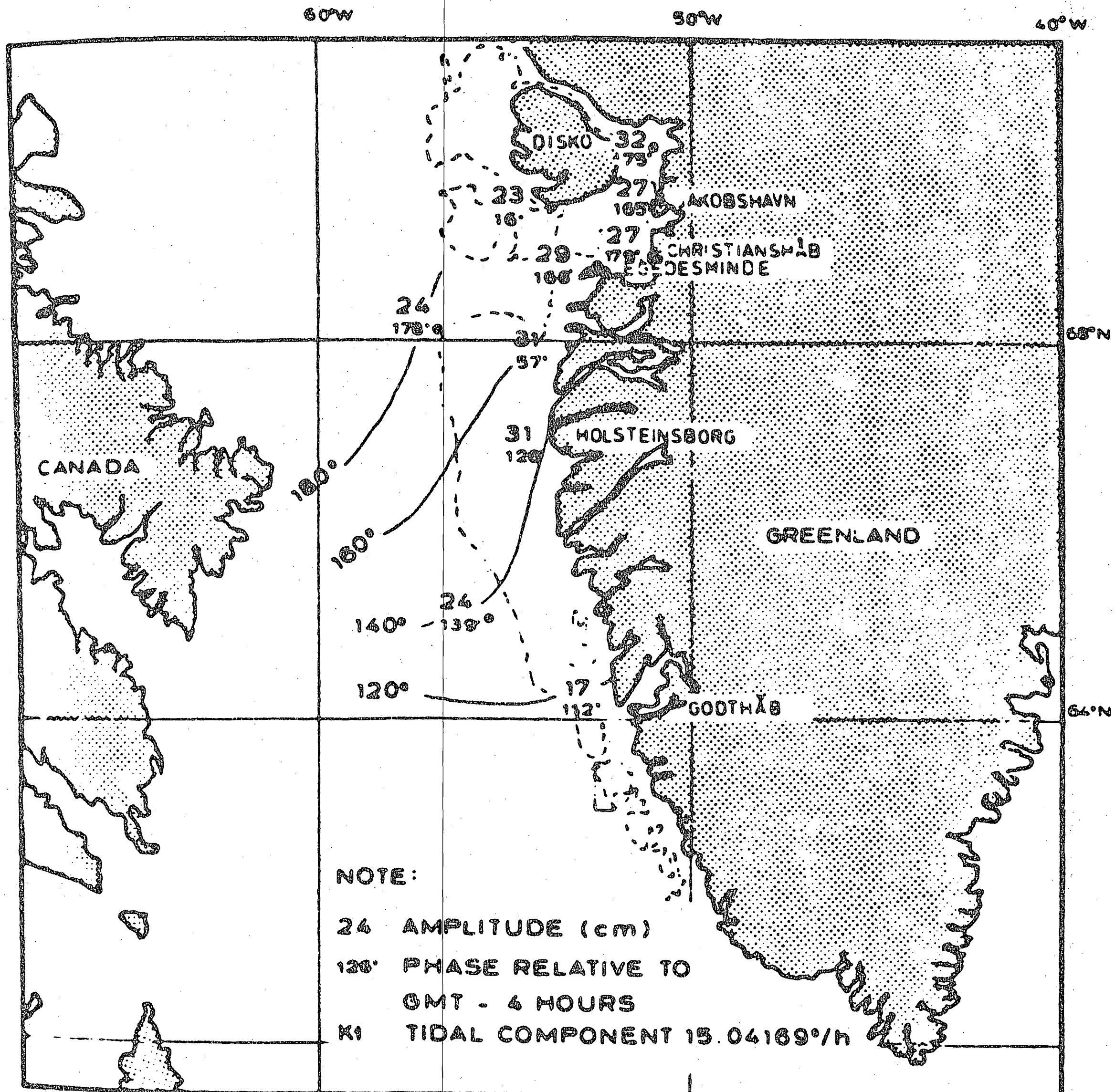


Figure 21. $K_1$ cotidal lines and amplitudes based on water level measurements during 1975-78.

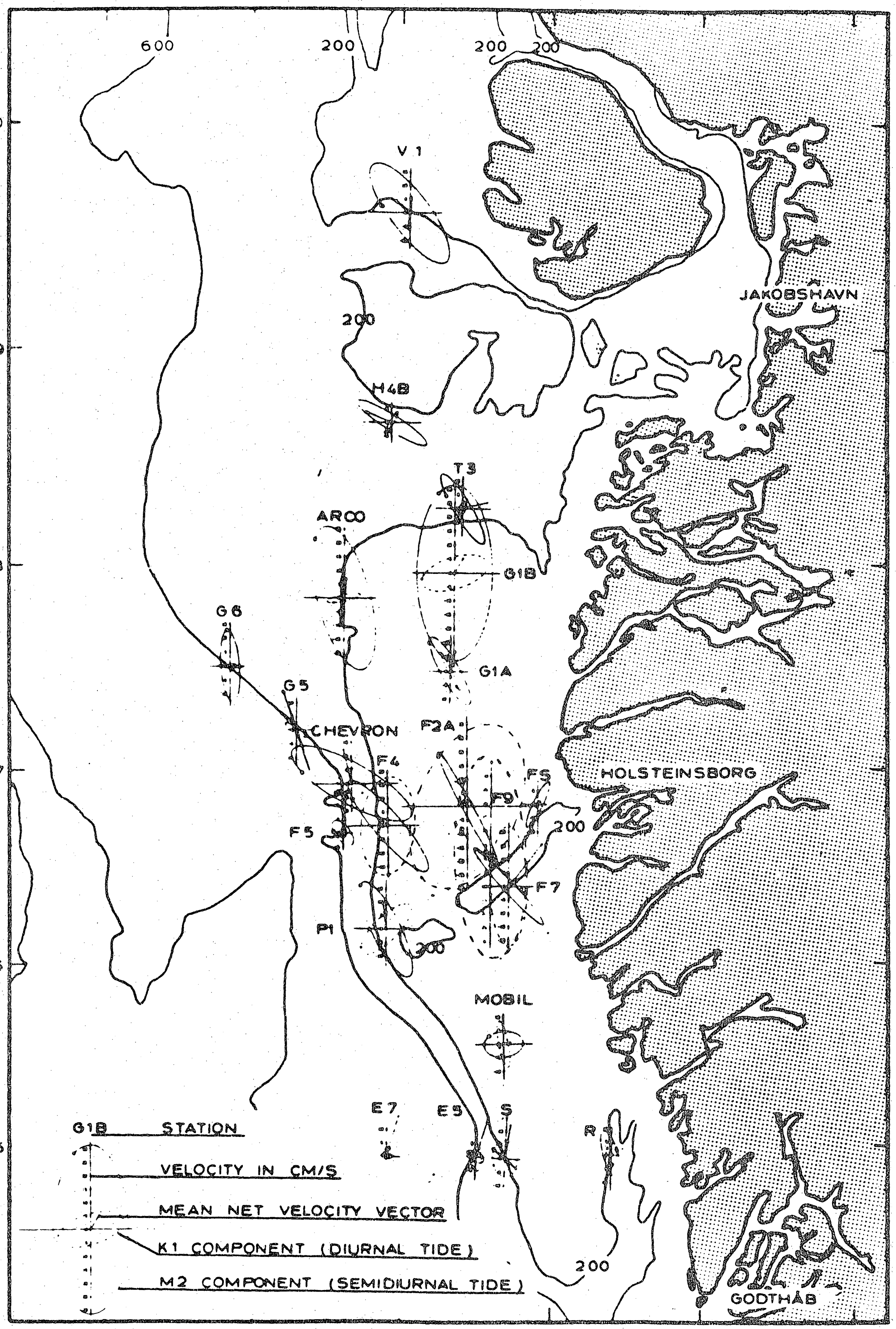


Figure 22. Tidal hodographs for $K_1$ and $M_2$ components for the depth interval 20-57 m.

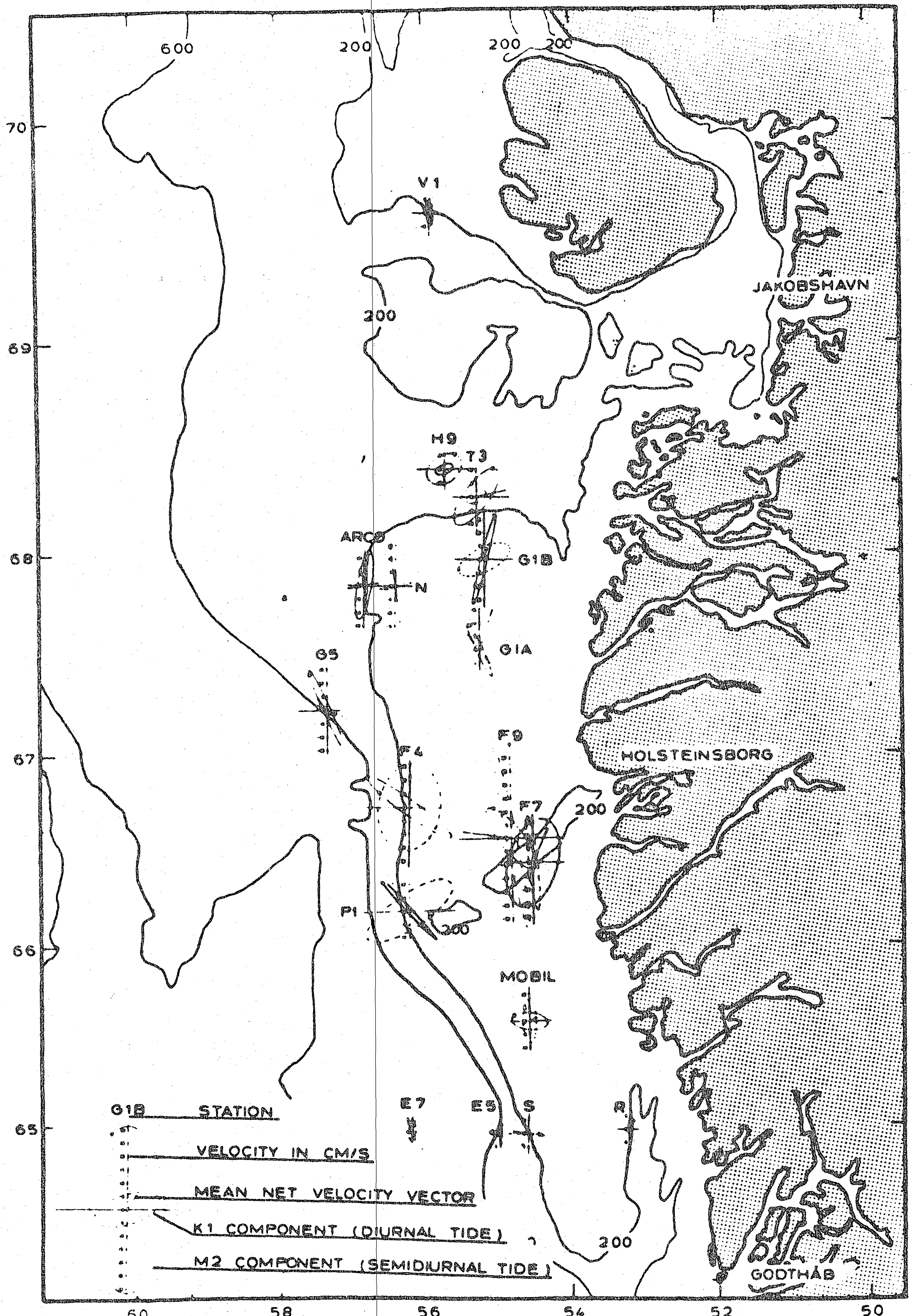


Figure 23. Tidal hodographs for $K_1$ and $M_2$ components for the depth interval 60-240 m.

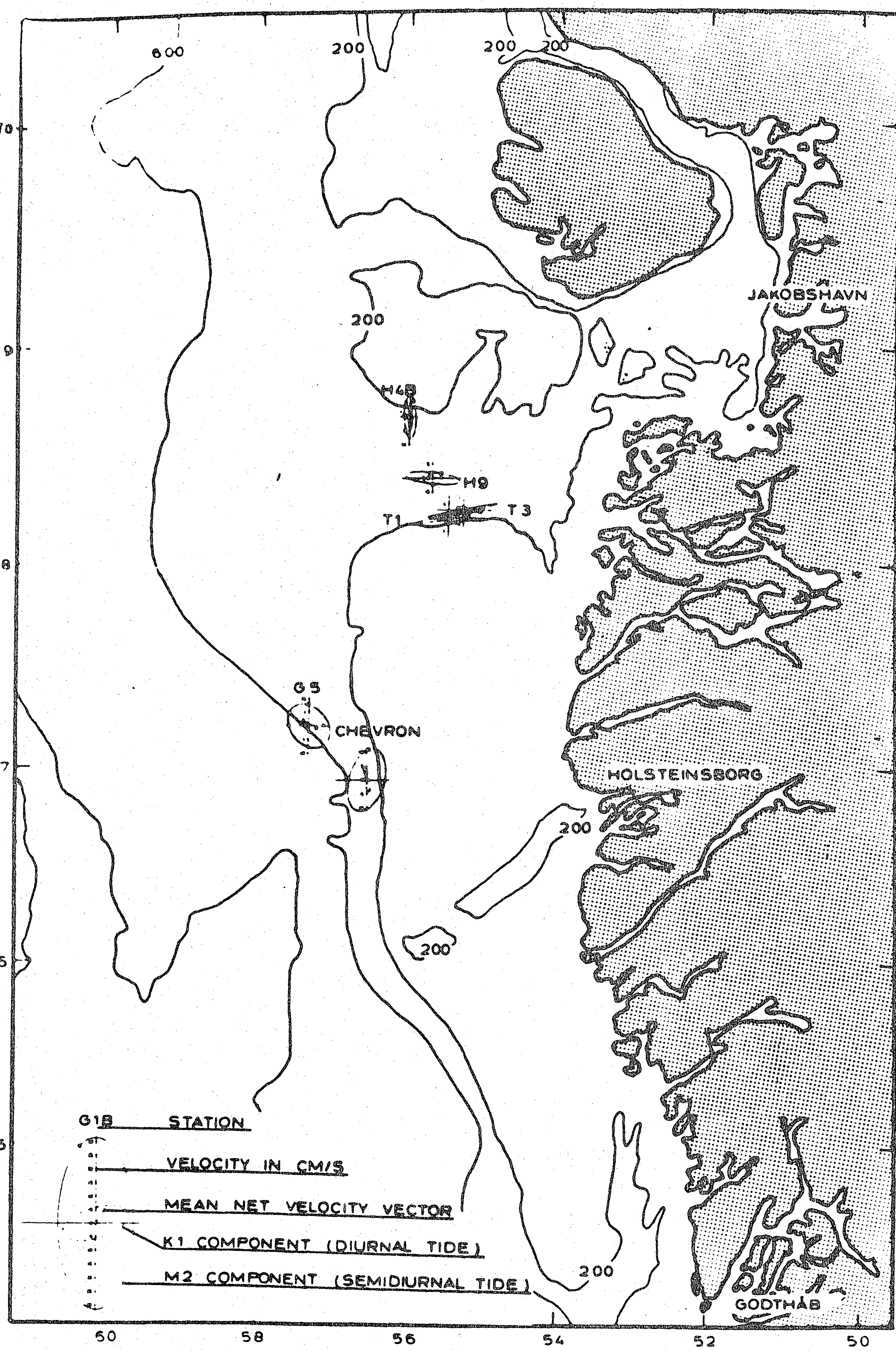


Figure 24. Tidal hodographs for $K_1$ and $M_2$ components for the depth interval 260-410 m.