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Characteristics of low salinity intermediate waters around the Faroes

by
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Introduction

Low salinity waters at intermediate levels are a significant hydrographic feature of the region east of Iceland and north and east of the Faroes (MARTIN 1976, MEINCKE 1972). In his monograph on North Icelandic waters, STEFANSSON (1962) shows that waters with salinities below 34.92°/oo and temperatures in the range from 0°C to 3°C are composed of Arctic and Atlantic waters which are mixed during winter convection in the area south of Jan Mayen and on the wide shelf north of Iceland. Away from the area of generation these low salinity waters are found at depths between 200 and 500 m, lying between saline and warm Atlantic water in the surface layer and medium saline, low temperature Norwegian Sea deep water. With respect to water mass exchange between the southern Norwegian Sea and the northeastern North Atlantic, the depth of the low salinity water falls into the sill-depth range of the Iceland-Faroe ridge. Therefore a study of overflow-processes can benefit from the existence of the characteristic low salinity water by using it as a natural tracer for water movements at intermediate levels. An example for this is given by describing the distribution of intermediate waters as observed during a 10-day hydrographic survey of R.V. "Poseidon" in Faroe waters from June 24 to July 4, 1977 (see Fig. 1).

Data and analysis

The data were obtained using a Howaldt-CTD (Bathysonde) in combination with a computer (NOVA). Salinities were computed according to ROHDE (1972), no spikes were removed. For regions with moderate vertical temperature gradients the accuracies yielded are $\pm$1dbar, $\pm0.01^{\circ}$C and $\pm0.03^{\circ}$/ooS as compared to salinities obtained from simultaneous bottle samples. The TS-relation for each station was then analysed for the following water-mass composition:

Water mass	Abbrev.	$T^{\circ}C$	S°/oo
Modified North Atlantic water	MNA	$\geq$ 8.0	$\geq$35.20
Norwegian Sea deep water	NS	$\leq$-0.5	$\approx$34.92
North Icelandic Winter water/ Arctic Intermediate water	NI/AI	$\geq$ 3.0	$\geq$34.78
East Icelandic water	EIW	$\leq$ 1.5	$\leq$34.63

The characteristic TS-values of the water masses were chosen as follows: MNA and NS correspond to the classical notion (e.g. MARTIN, 1976). NI/AI comprises both water types formed during winter convection in the Iceland Sea and over the North Icelandic shelf. They cannot be distinguished in Faroe waters, therefore MARTIN (1976) names it IFR (Iceland-Faroe ridge) water. Traditionally its salinity is 34.88°/oo, but in 1977 it had to be taken as 34.78°/oo on the basis of the observations (see Fig. 8). EIW was an unexpected water mass, but the very low salinity lead the author to speculate on the influence of Icelandic coastal waters.

For this study two characteristic parameters for each water mass are available. Therefore the linear mixing-relationship does only allow a definite solution for TS-values obtained by mixing of three water masses (HERMANN, 1967). For most stations MNA, NS and NI/AI were indeed sufficient to describe the TS-distribution. In cases, where EIW was present as a fourth water mass, it was found to be not interacting with MNA. Thus it was possible to analyse the station two times, the first run giving the composition in terms of MNA, NS and NI/AI and the second run resulting in the composition from EIW, NS and NI/AI. Figure 8 readily demonstrates how the observed TS-profiles fall into the two mixing triangles. The error in the percentage of a water mass contributing to a particular TS-value was estimated to be ±10%.

Presentation of results

A selection of the "Poseidon"-data set is presented in this paper as sections of temperature, salinity, portions of NS, NI/AI and EIW where observed. The sections present conditions found over the northeastern flank of the Iceland-Faroe ridge (Figs 2 and 4), at the northeastern edge of the Faroe-plateau (Fig. 5), in the Faroe-Shetland channel (Fig 6 and 7), in the Faroe-Bank channel (Fig 3) and over the southwestern flank of the Iceland-Faroe ridge (Fig 2). The same clockwise arrangement around the southeastern tail of the Iceland-Faroe ridge was used in Figure 8 which presents summary TS-plots of selected stations along each of the sections shown in Figures 2-7. The full data set from the cruise was used to construct Figures 9a-d. They show the spatial distribution of the depth and the salinity of an observed intermediate salinity-minimum and the depth and the percentage of the NI/AI-maximum.

Discussion

The purpose of the hydrographic investigation was to describe the distribution of low salinity intermediate waters around the Faroes. The situation found can be discussed as follows:

1. An intermediate salinity minimum was found over the northeastern flank of the Iceland-Faroe ridge and in the Faroe-Shetland channel (Fig 9a,b). In the northwestern part of the investigated area, the salinity minimum was strictly linked to the polar front (Figs 2 and 4). The front was strongly inclined and details

of the TS-distributions, like the one presented in Fig 4f indicate vigorous advective processes at scales of 10-30 km in the horizontal and 50-100 m in the vertical direction. Over the northern Faroe-slope, where the sections were located well south of the polar front, the salinity minimum was more smoothly distributed. It basically takes a tongue-like shape, indicating advection parallel to the bathymetric contours into southeasterly direction. When it gets into the region where the isobaths turn into the Faroe-Shetland channel, the tongue-like structure is lost and the intermediate minimum becomes a broad feature throughout the channel. There was no salinity minimum observed in the Faroe-Bank channel and over the southwestern slope of the Iceland-Faroe ridge (see Figs 9a,b).

2. To explain the salinity minimum, two water masses are involved (Figs 2-6): NI/AI and EIW. Fig 2 shows that near the polar front NI/AI lies above EIW, that they are both sharp layers inclined with the polar front and that the distribution of concentration indicates a spreading from surface into deeper layers. Comparing Fig 4, 5 and 6 with Fig 2, it is obvious that EIW rapidly disappears in southeasterly direction and that the salinity minimum corresponds to the NI/AI maximum. In the Faroe-Bank channel and on the southwestern flank of the Iceland-Faroe ridge, where the salinity has no intermediate minimum, the portions of NI/AI are generally small (see Figs 9c,d).

3. The discussion of the salinity minimum and its contributing water masses can be complemented by summarizing the sections and maps into a spatial TS-series, arranged clockwise around the tail of the Iceland-Faroe ridge (see Fig 8). Generalizing the structure of the water column, we can clearly separate the region north and east of the Faroes from the Faroe-Bank channel and the southwestern slope of the ridge. Whereas in the first one there is a core of low salinity water (mainly NI/AI) mixing with the surface and the deep waters, the intermediate waters in the second region have basically been formed by direct mixing of surface and deep waters. The exception in the TS-plot of

stations35-45 is only an apparent one since stations 35-37 belong to the hydrographic regime of the southwestern flank.

4. Attention is drawn on a detail of the TS-diagrams in Fig 8. The TS-points between NS and NI/AI for the first four sections do not fall onto a smooth line as should be expected for stationary mixing. This feature is an indication of advective changes, i.e. intrusions of EIW for stations 46-56 and 35-45 and intrusion of "new" NI/AI for stations 114-124 and 136-145. This is consistent with the observed tongue-like structure of the salinity minimum.

5. The observation discussed before can be used to comment on two important kinematic features in the Faroe area. (a) During the time of the cruise there is evidence that only a small amount of NI/AI entering the Faroe-Shetland channel from northwest leaves through the Faroe-Bank channel. Since there has never been any NI/AI observed over the Wyville-Thomson ridge, it can be concluded that either the inflow-outflow of NI/AI is strongly intermittent or that most of the NI/AI leaves the channel in northeasterly direction back into the Norwegian Sea. From former data sets (Overflow '60, Overflow '73) and from MARTIN (1976) the latter possibility seems to be more realistic. (b) During the time of the cruise there was no strong overflow across the Iceland-Faroe ridge. As mentioned under 3, the hydrographic regime north and south of the ridge were different with respect to intermediate waters, although NI/AI was observed close to the bottom north of the crest line (Figs 2 and 4). Moreover there is no evidence for a continuous layer of NS above 50% across the sill, even on the section through a notch (stations 55-60). Taking the information from KOLTERMANN et al (1976), that the fairly strong current (20-30 cm/sec) above the southwestern flank is directed towards Iceland under the control of local topography, Fig 8 leads to conclude that during the time of the cruise the hydrographic structure of the southwestern flank of the Iceland-Faroe ridge was controlled by the Faroe-Bank outflow.

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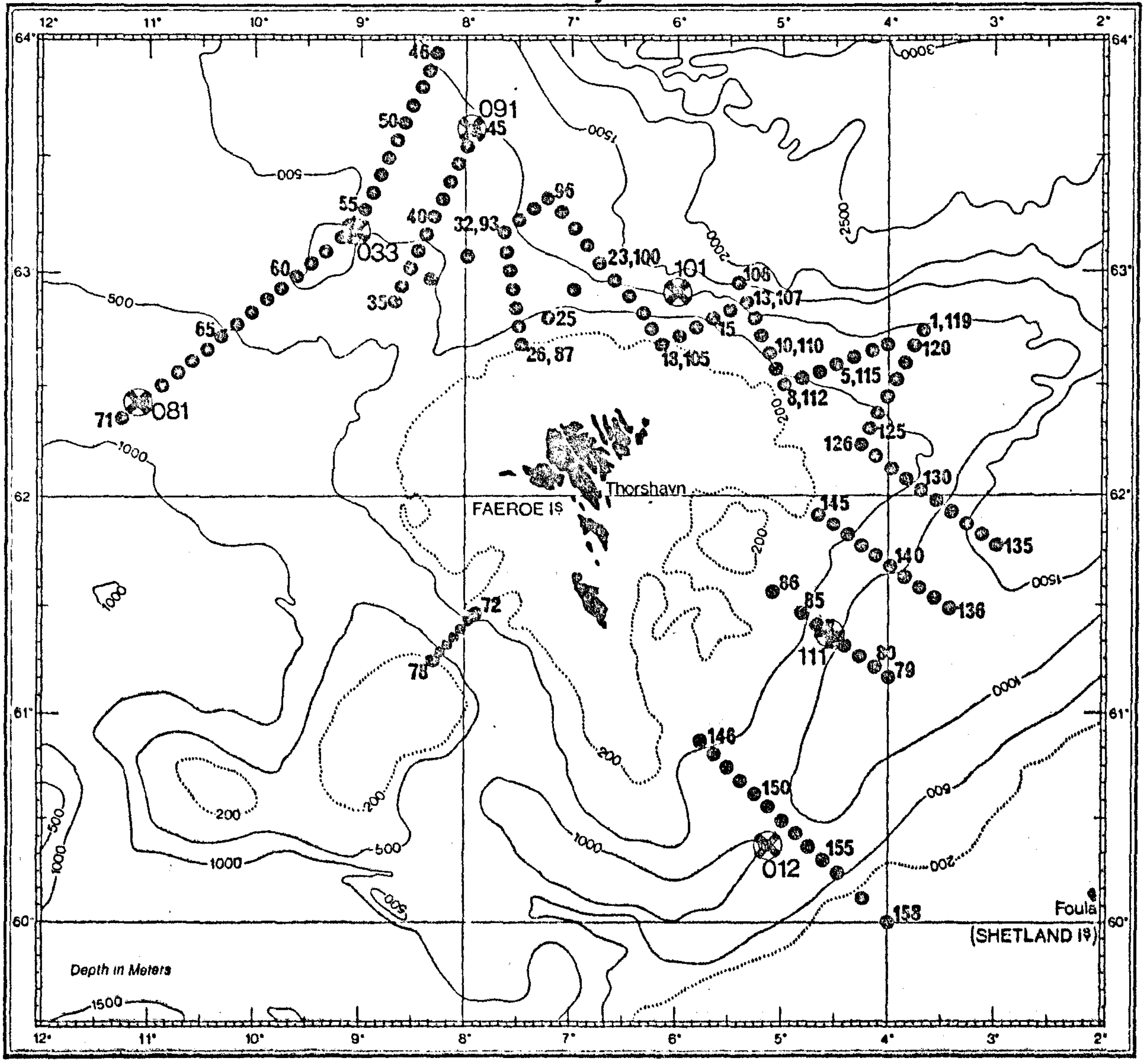
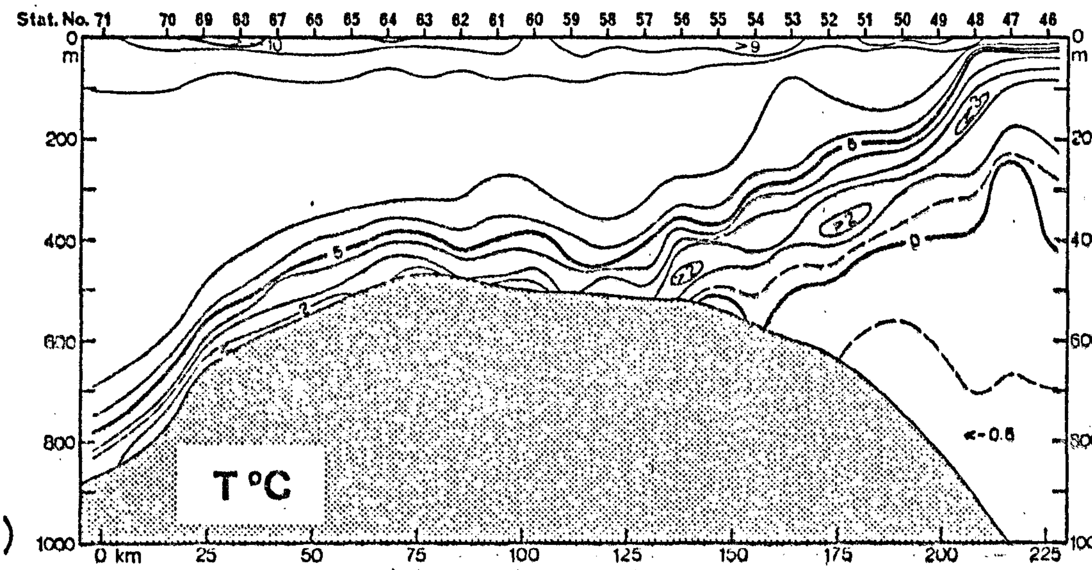


● CTD-Station ⊗ CM-Mooring

Fig. 1

Fig. 2a)

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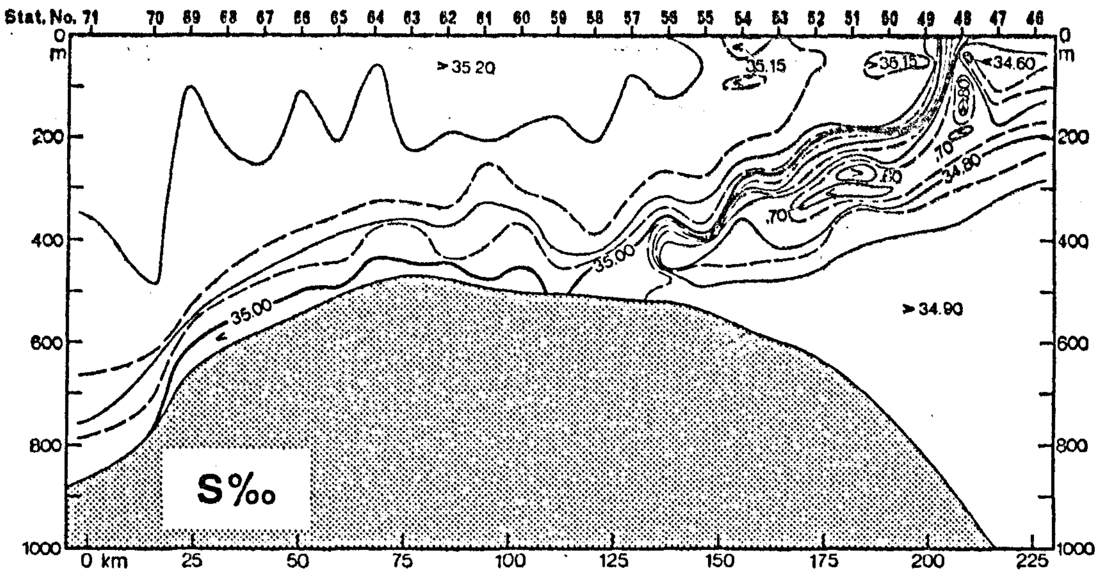
0 m
200
400
600
800
1000
0 km 25 50 75 100 125 150 175 200 225
10
>9
5
2
6
3
>2
0
<-0.6
T °C

b)

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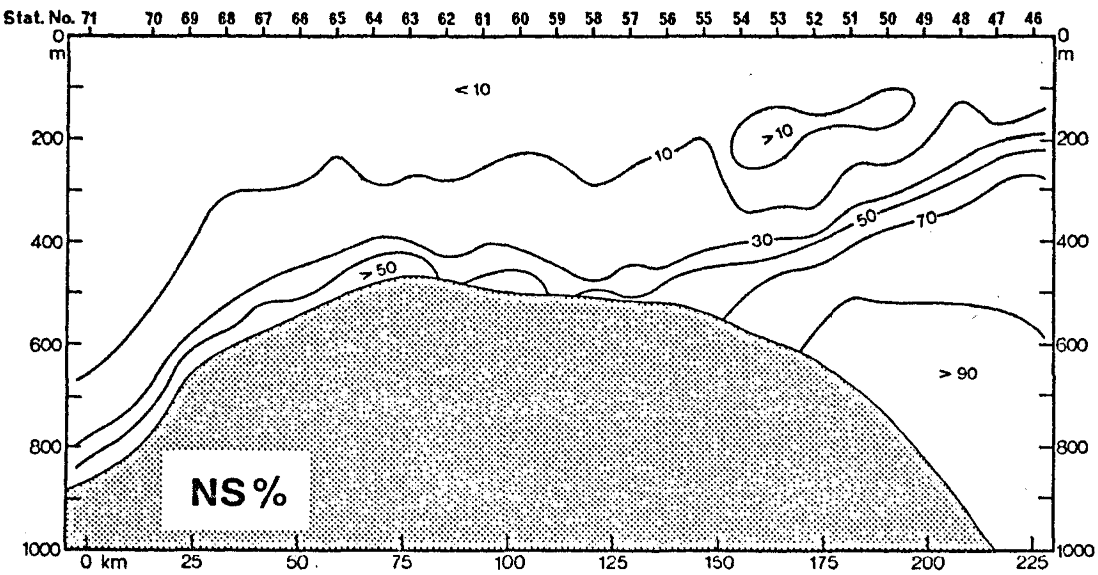
0 m
200
400
600
800
1000
0 km 25 50 75 100 125 150 175 200 225
>35.20
35.15
>35.15
<34.60
.70
34.80
35.00
>34.90
S‰

c)

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0 m
200
400
600
800
1000
0 km 25 50 75 100 125 150 175 200 225
<10
>10
10
30
50
70
>50
>90
NS%

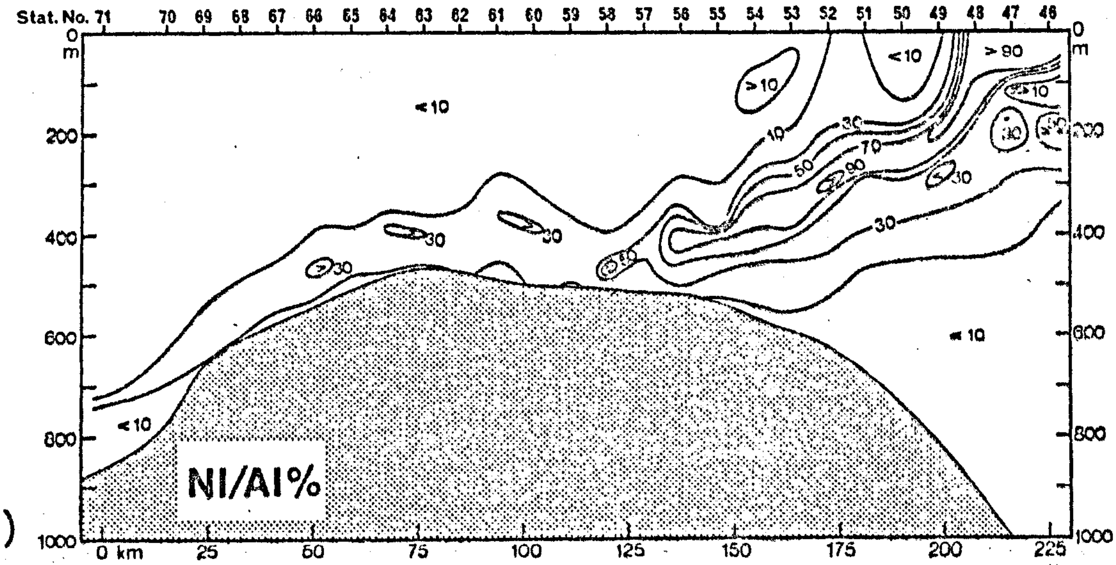
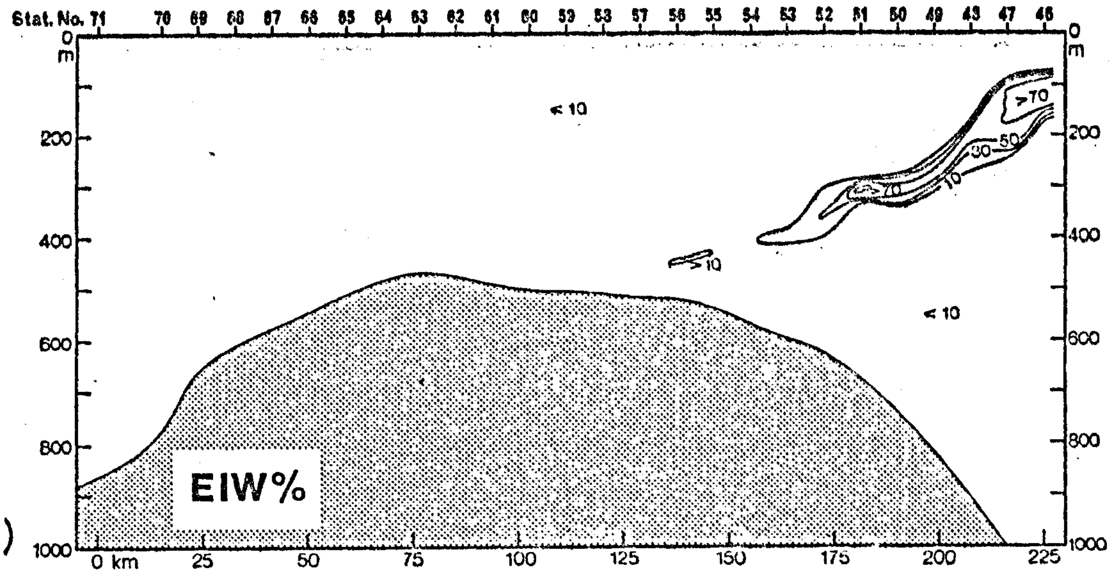

Stat. No. 71 70 69 68 67 66 65 64 63 62 61 60 59 58 57 56 55 54 53 52 51 50 49 48 47 46
m
NI/AI%
< 10
> 10
> 90
0 km 25 50 75 100 125 150 175 200 225

Fig. 2d)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m
EIW%
< 10
> 70
0 km 25 50 75 100 125 150 175 200 225

e)

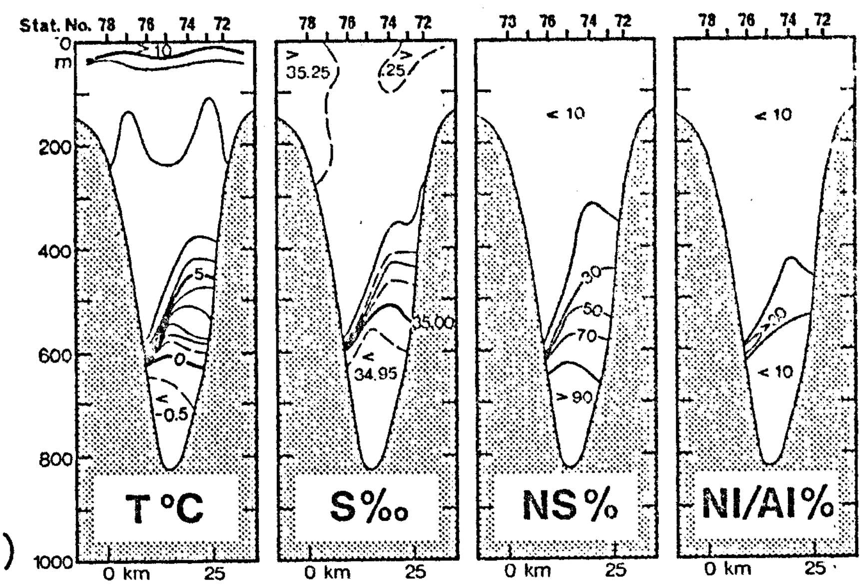

Stat. No. 78 76 74 72
m
T °C
S‰
NS%
NI/AI%
35.25
34.95
35.00
< 10
> 90
0 km 25

Fig. 3)

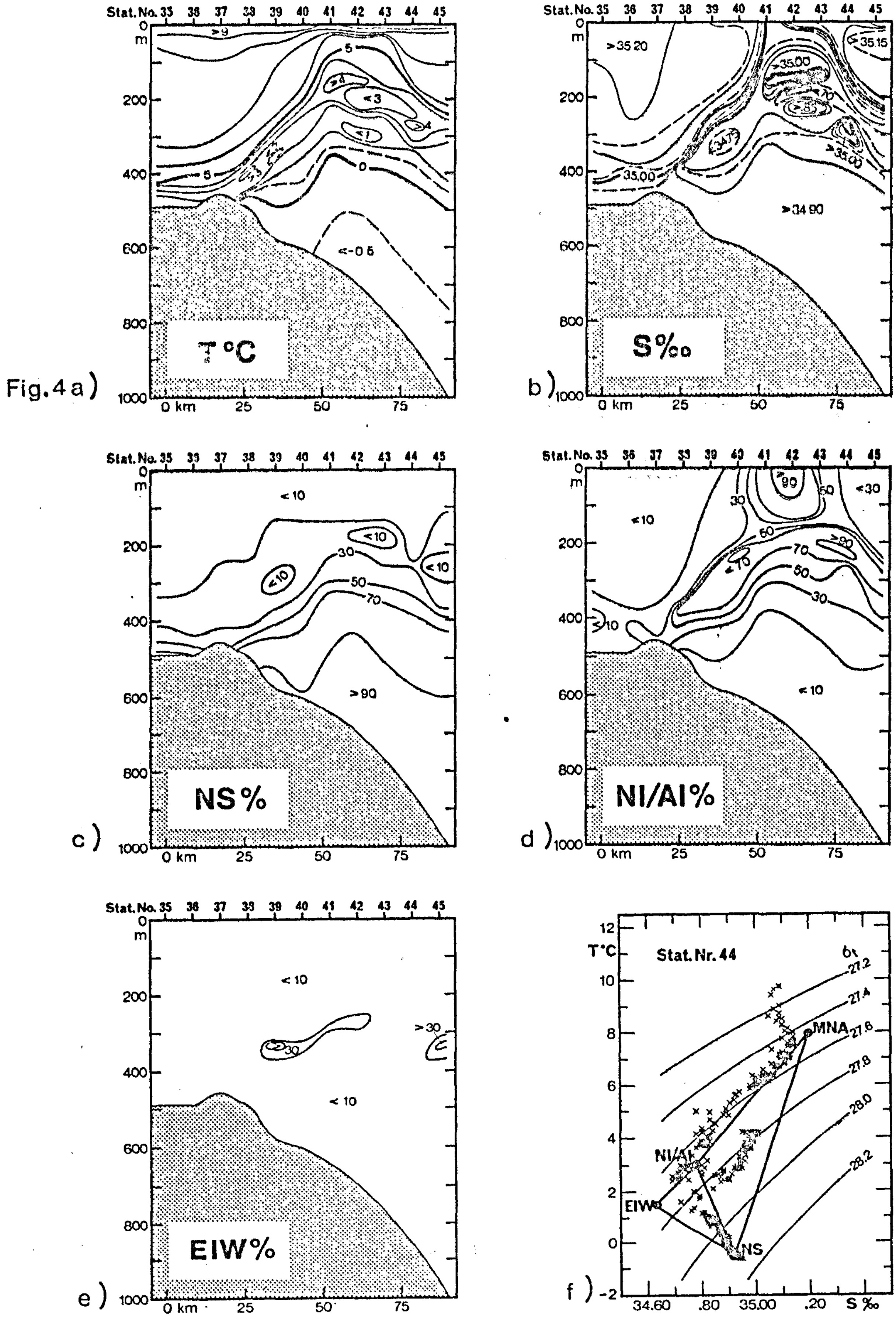


Fig. 4 a)
Stat. No. 35 36 37 38 39 40 41 42 43 44 45
T °C
b)
S ‰
c)
NS %
d)
NI/AI %
e)
EIW %
f)
Stat. Nr. 44
T °C
S ‰
NI/AI
EIW
NS
MNA
27.2
27.4
27.6
27.8
28.0
28.2
0 km 25 50 75

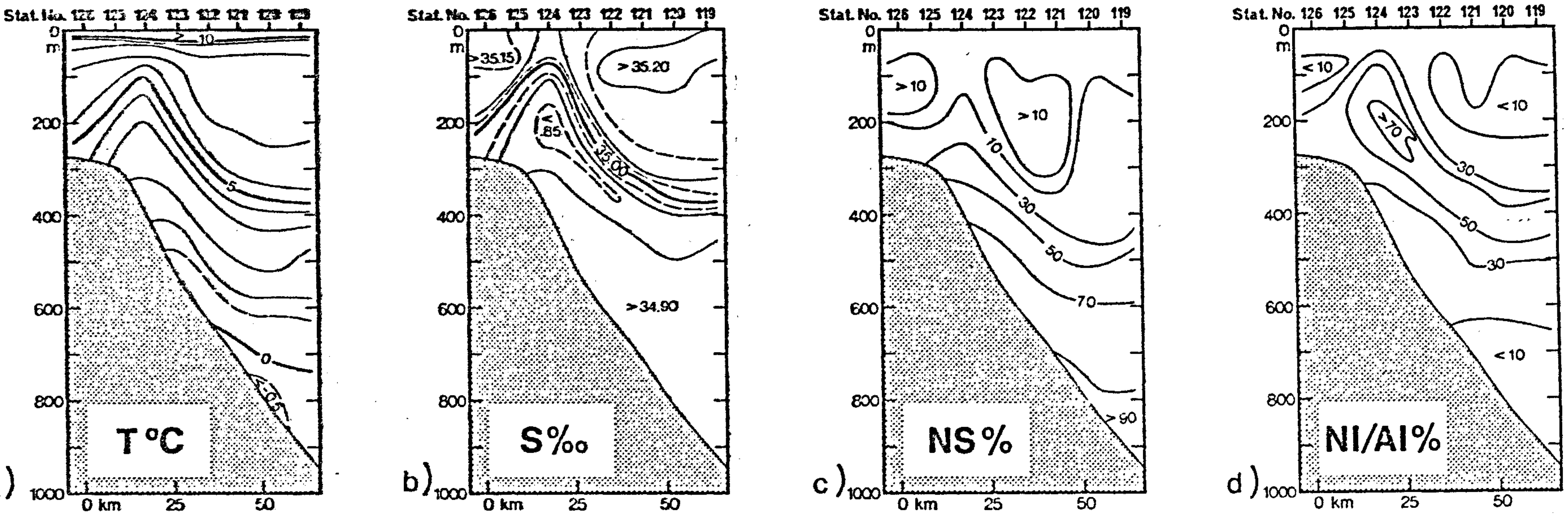


Fig. 5a) b) c) d)

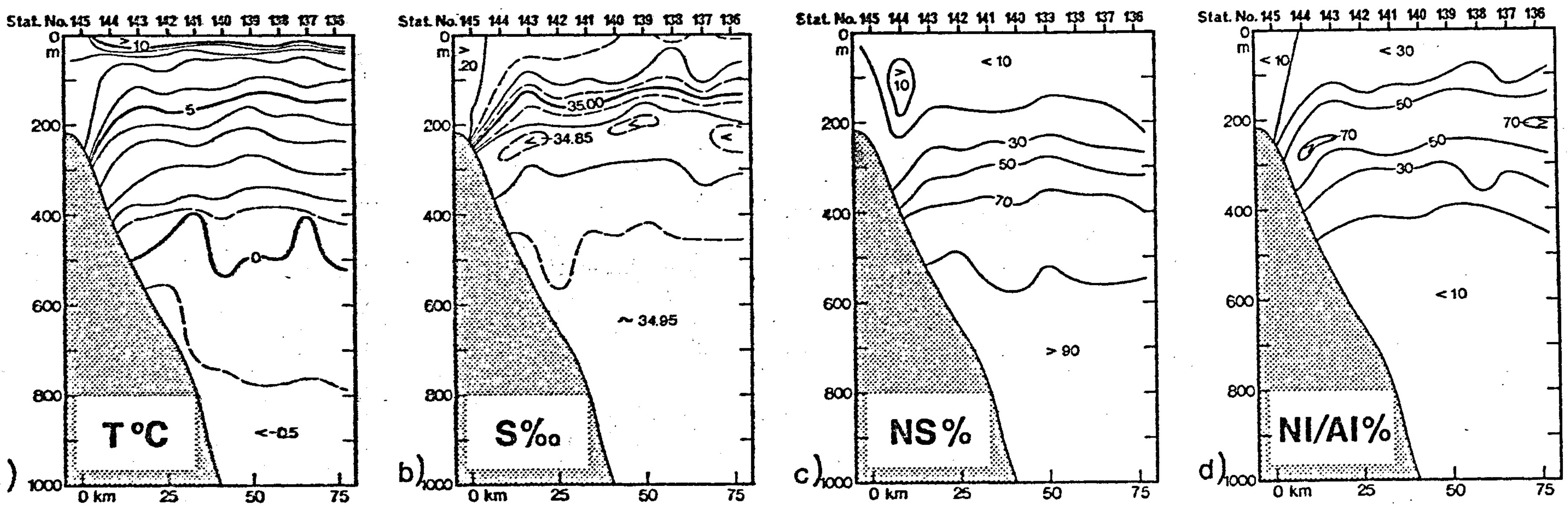


Fig. 6a) b) c) d)

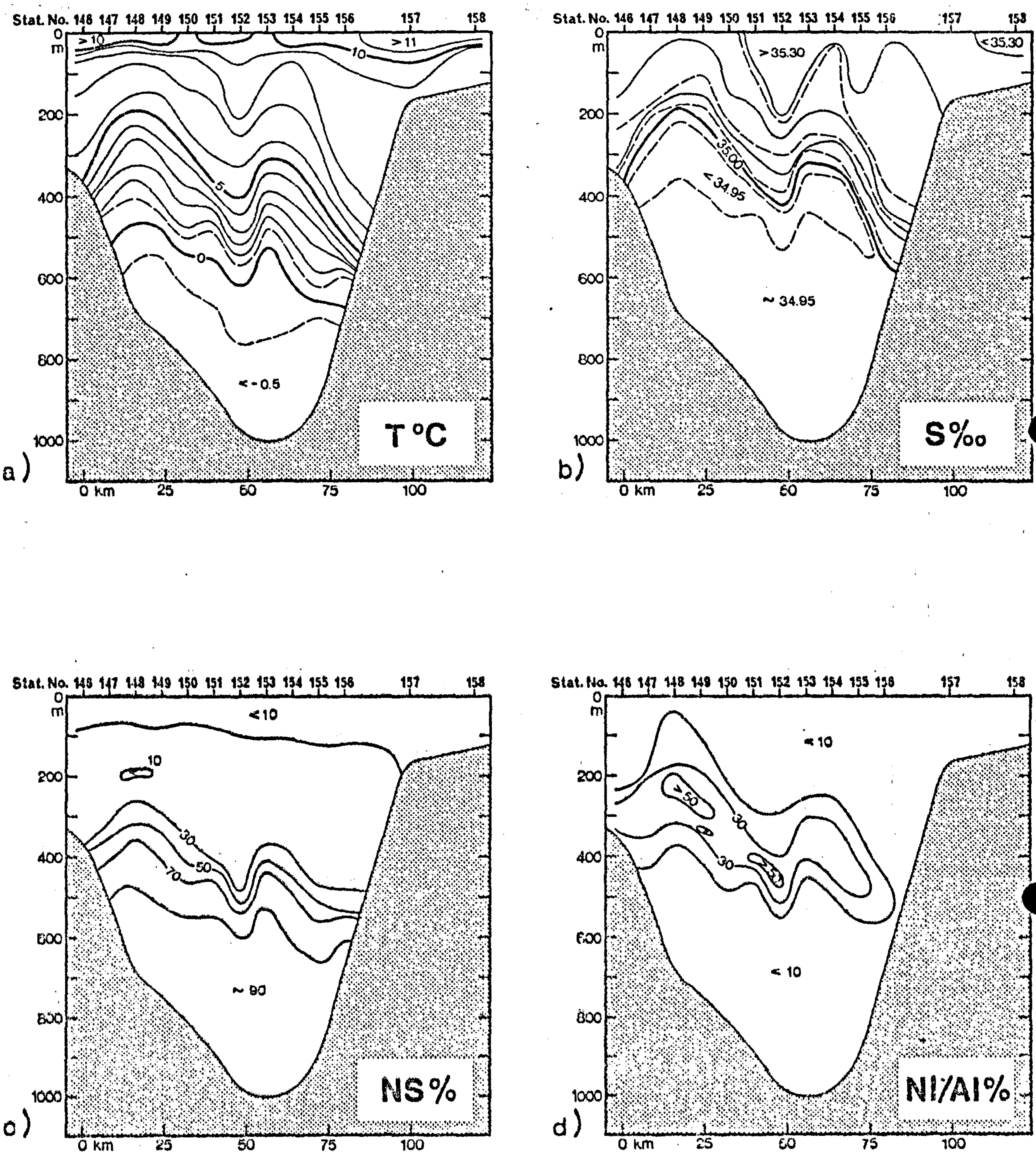

Stat. No. 146 147 148 149 150 151 152 153 154 155 156 157 158
0 m
200
400
600
800
1000
0 km 25 50 75 100
>10
10
>11
5
0
<-0.5
T °C
>35.30
<35.30
35.00
<34.95
~34.95
S‰
<10
10
30
50
70
~90
NS%
<10
>50
30
<10
NI/AI%

Fig. 7 a) b) c) d)

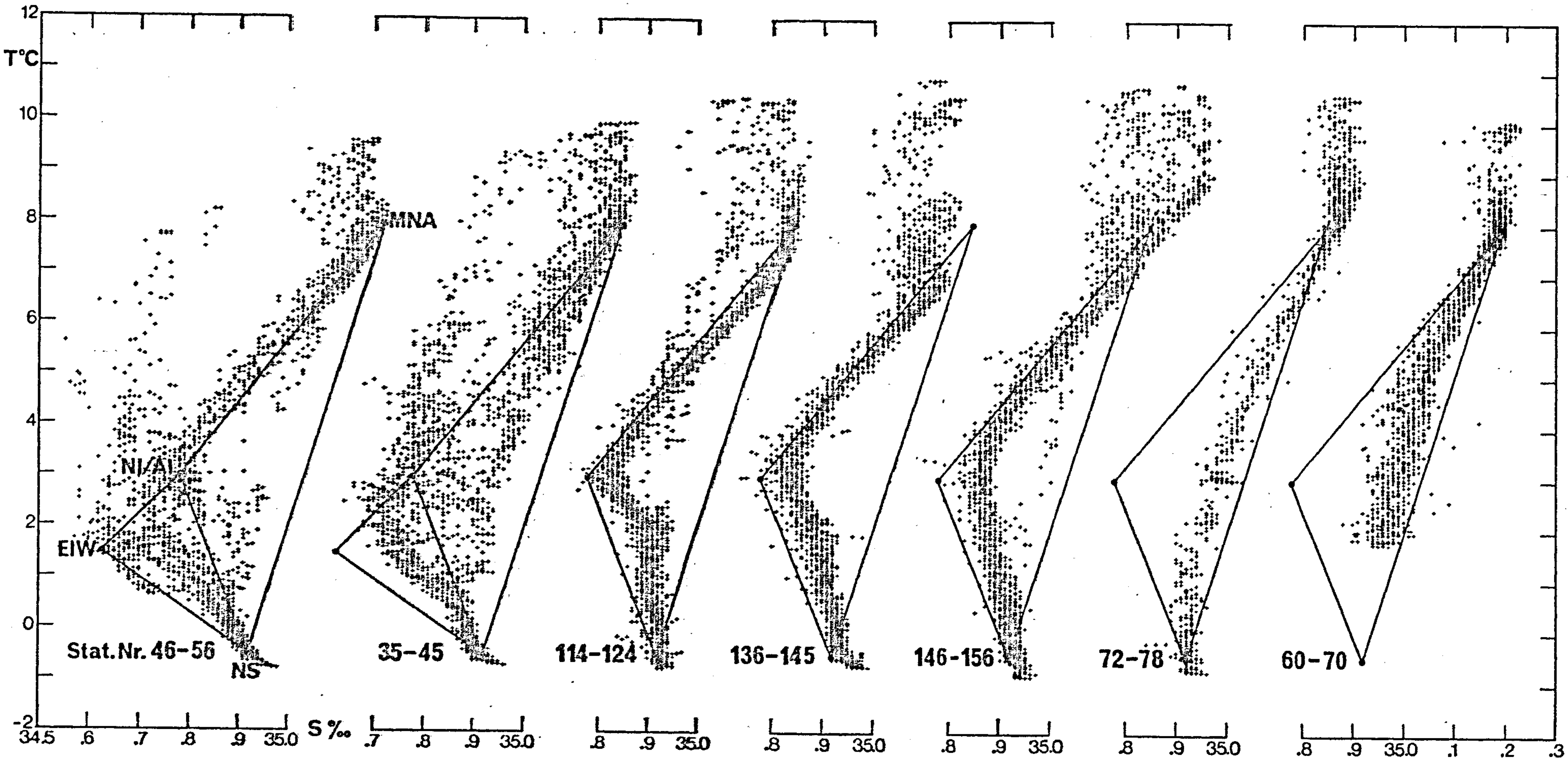

12
T°C
10
8
6
4
2
0
-2
MNA
NI/AI
EIW
NS
Stat. Nr. 46-56
35-45
114-124
136-145
146-156
72-78
60-70
S ‰
34.5
.6
.7
.8
.9
35.0
.1
.2
.3

Fig. 8

z(Smin) m

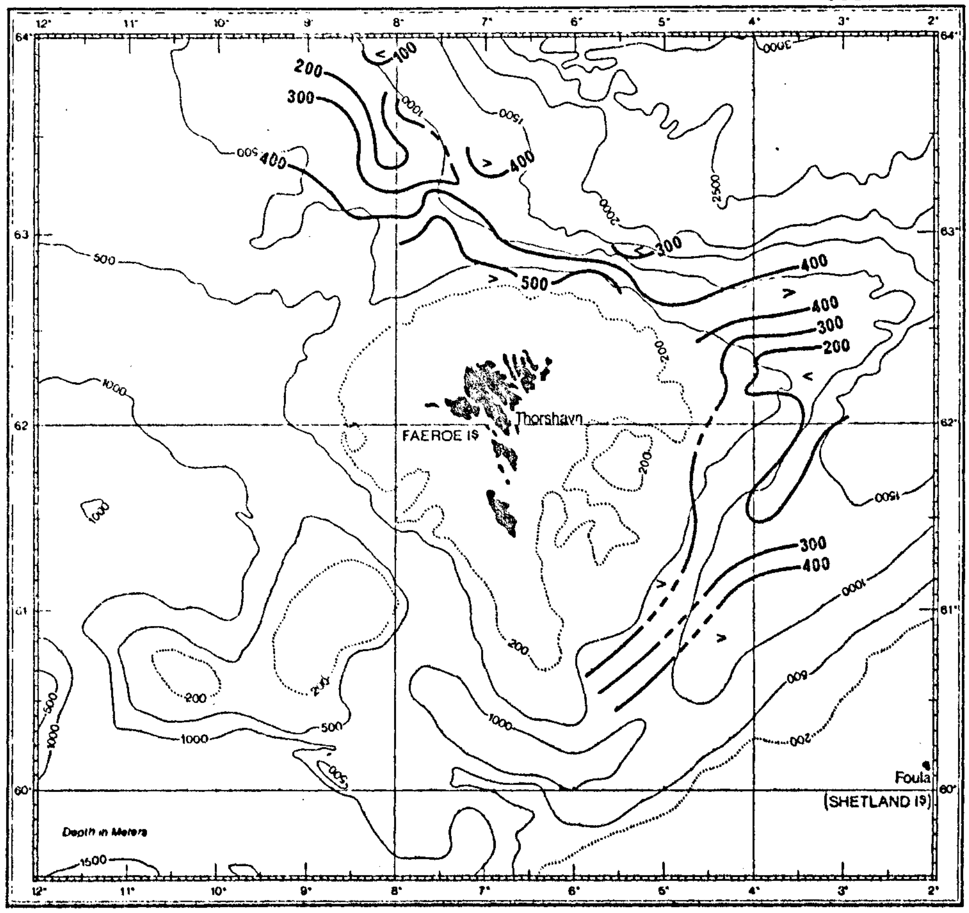
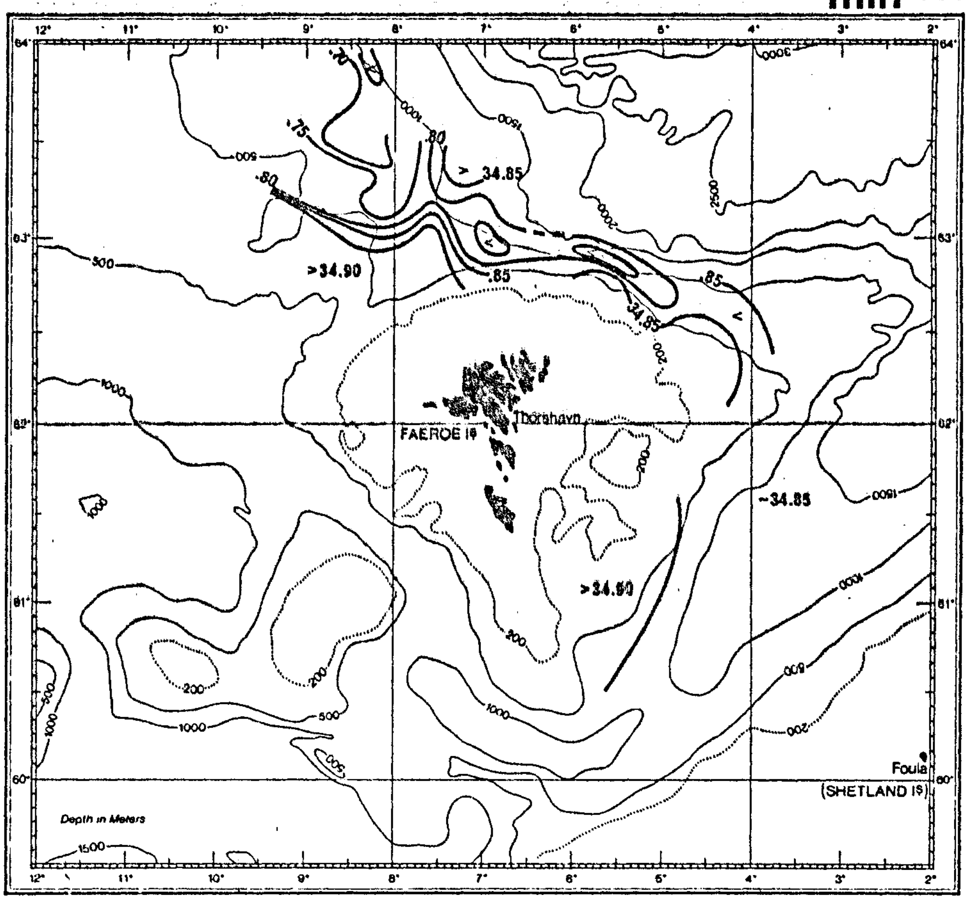


Fig. 9a)

Smin ‰



b)

z (NI/Al max) m

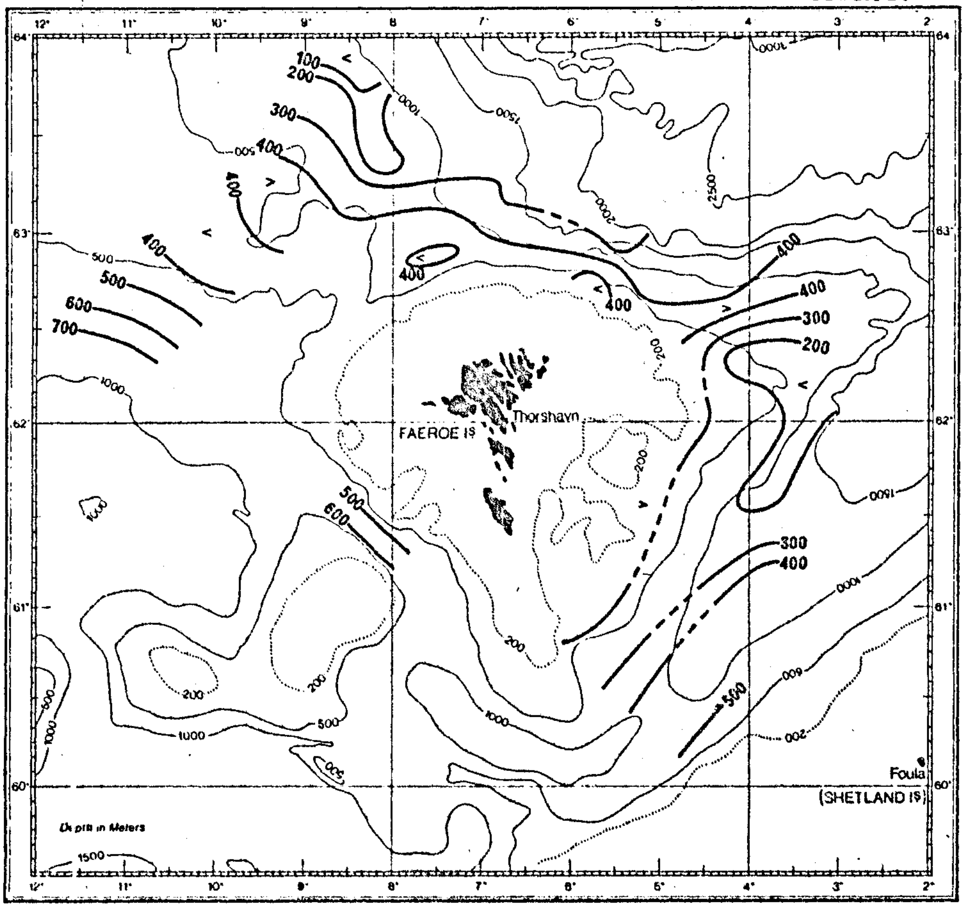
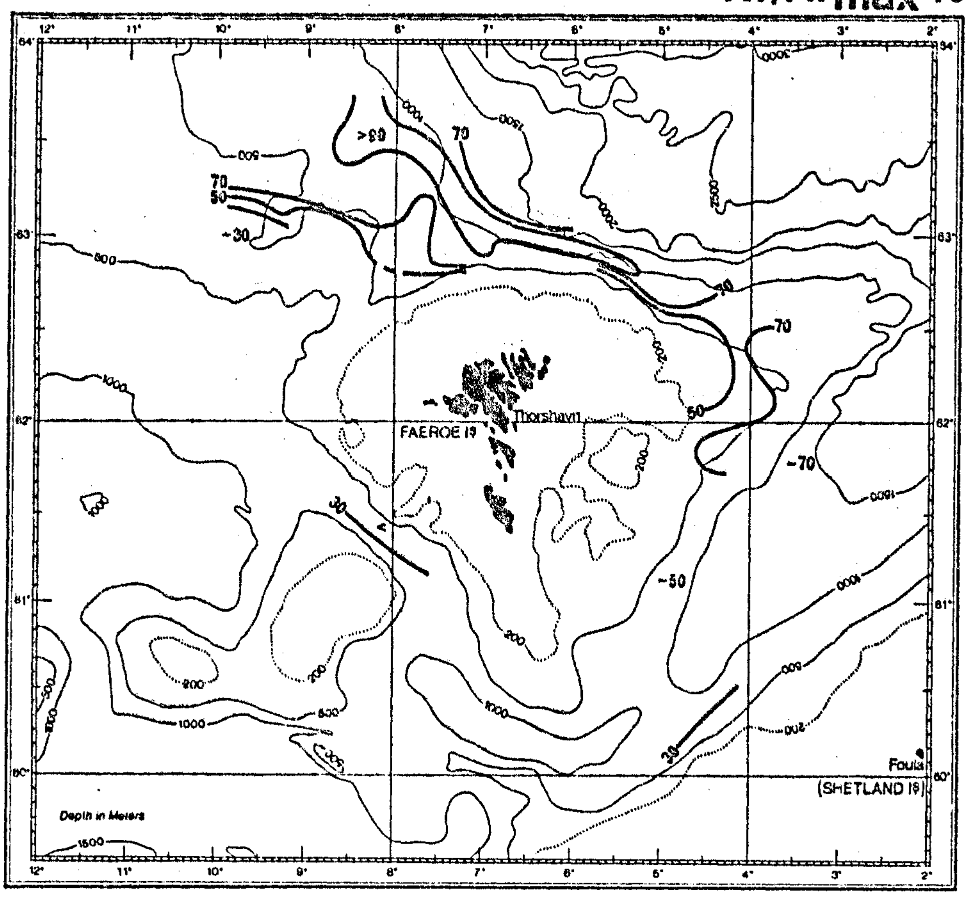


Fig. 9c)

NI/Al max %



d)