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## Hydrography of the region between the King George and Elephant Islands (BIOMASS III, October — November 1986)

**ABSTRACT:** Hydrological conditions in the region between the King George and Elephant Islands were defined on the basis of 24 STD measurements and 20 XBT profiles made in the time period from 26 October to 16 November 1986. In the entire investigated region the surface water temperature was below zero, often close to freezing point. The presence of summer modification of surface water with its characteristic thermal minimum was not found. Between the Scotia Front and the relatively well pronounced stream of geostrophic currents the anticyclonic meander was observed above the edge of the shelf at the depth of 100 m. Its spread was about 10 nM and within this meander the downwelling of surface water was noticed. As a compensating water movement, the upwelling of warmer waters was observed in the Drake Passage at 400 m.

Key words: Antarctic, physical oceanography, BIOMASS III.

### 1. Introduction

The investigated region during the BIOMASS III expedition covered a part of northern boundary of WSC (Weddell–Scotia Confluence) which is also called by some authors the Scotia Front (Gordon 1967; Patterson and Sievers 1980). The hydrological and hydroacoustic measurements were performed in order to investigate, on a coarse scale, the structure of the water column.

### 2. Material and methods

The measurements were performed with STD Bissett-Berman sound (model 9040) at 24 hydrological stations situated in the region of Elephant Island. These measurements were supplemented with additional 20 XBT

profiles made at positions situated in the distance of over 2 nM from the hydrological stations. The temperature measurements were made with this XBT instrument down to 850 m. The instrument as well as XBT probes were provided by a Spanish group of scientists who cooperated during the expedition.

Whenever it was possible (not too long a distance between STD and XBT stations) the salinity from STD was combined with the temperature from XBT in order to achieve better understanding of the existing phenomena.

From the grid of oceanographic stations 6 sections were separated (Fig. 1).

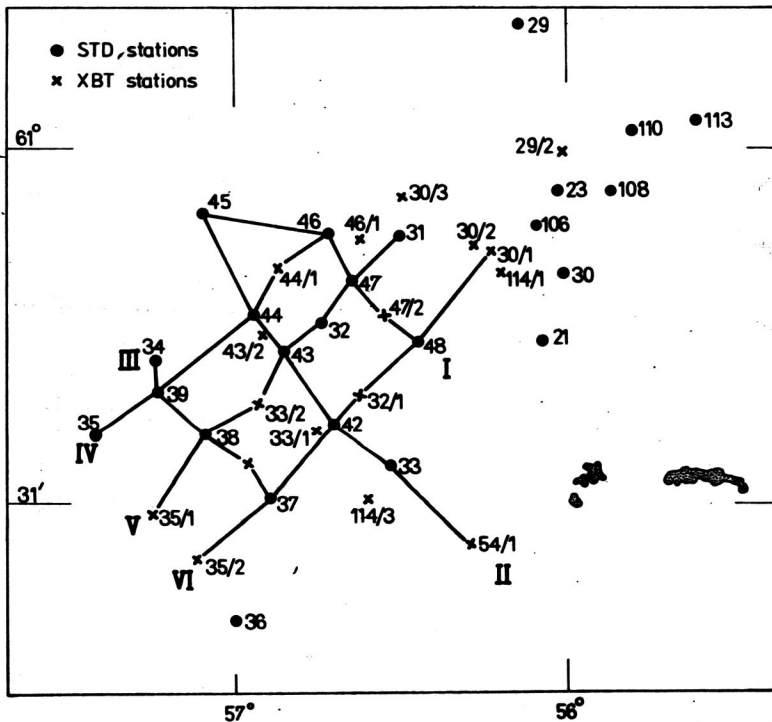


Fig. 1. Map showing STD and XBT stations and selected sections made during BIOMASS III expedition

R/V "Profesor Siedlecki", October — November 1986

The nomenclature used in this paper is the same as in Tolstikov (1969) and in Deacon's pioneer paper of 1933.

For better positioning of forms of dynamic topography reflecting the geostrophic currents the situation found at 100/500 hPa was considered. The level of 100 hPa was under a relatively small influence of local short-lasting anomalies resulting from ice melting or solar radiation. Considering the variety of morphological forms, the maximal extent of XBT measure-

ments, the vertical distribution of water masses existing at shallow stations, the acceptance of reference level of 500 hPa made it possible to unify the picture of geostrophic currents in the south-western part of the investigated region.

### 3. Results and discussion

#### 3.1. Temperature

In the entire investigated region the temperature of water at the surface was very low, often close to freezing point, and remained in the range from  $-1.8$  to  $-0.9^{\circ}\text{C}$ . For the salinity values varying from  $33.97$  to  $34.20 \times 10^{-3}$  the freezing point was from  $-1.87$  to  $-1.88^{\circ}\text{C}$  (Fujino, Lewis and Parkin 1974). The surface distribution of isotherms (Fig. 2) did not reflect any hydrological front. It is worthy of notice that the lowest temperature was observed in the northern part of the region.

At 100 m depth (Fig. 2) the low temperatures, in the range from  $-1.7$  to  $-1.0^{\circ}\text{C}$ , predominated and only two local areas with temperatures being above  $-0.3^{\circ}\text{C}$  were found. One of the regions, represented by station 46, was situated close to the continental slope and the second one — represented by station 106, investigated at the end of expedition, was situated on the shelf.

The temperature of surface water, remaining in the range from  $-1.8$  to  $-0.9^{\circ}\text{C}$ , as well as the absence of the minimum in the thermal vertical structure of surface waters (Gordon 1967) testifies to the fact that during the expedition the summer modification of surface water was not found.

The highest horizontal gradients of temperature were observed above the continental slope at the distance of about 10 nM from the edge of the shelf and these were noticed in the layer 200–300 m (Fig. 2). At the depth of 200 m and above the shelf the temperature was within the range from  $-1.3$  to  $-0.8^{\circ}\text{C}$  while at station 45, situated farthest north, the temperature at the same depth was  $1.6^{\circ}\text{C}$ . At the depth of 300 m the temperature above the shelf changed from  $-0.6$  to  $0.0^{\circ}\text{C}$  and at the station 45 it was  $1.9^{\circ}\text{C}$ . In the western part of the region the temperature above the shelf varied from  $-1.2$  to  $-0.8^{\circ}\text{C}$ .

In the sections I, II and III (Figs. 3, 4, 5) the inflow of warm waters from Drake Passage as well as the situation of the thermal front and the thermal structure above the shelf, are clearly visible. The distribution of isotherms at these stations confirms the existence of the thermal front above the slope at the distance of about 10 nM from the edge of the shelf. In station 47 of the section I (Fig. 3) the 300 m deep bend of isotherms: 0,  $-0.5$  and  $-1.0^{\circ}\text{C}$  was noticed. This bend was V-shaped, and this phenomenon suggests the existence of an anticyclonic eddy. Similar but less pronounced

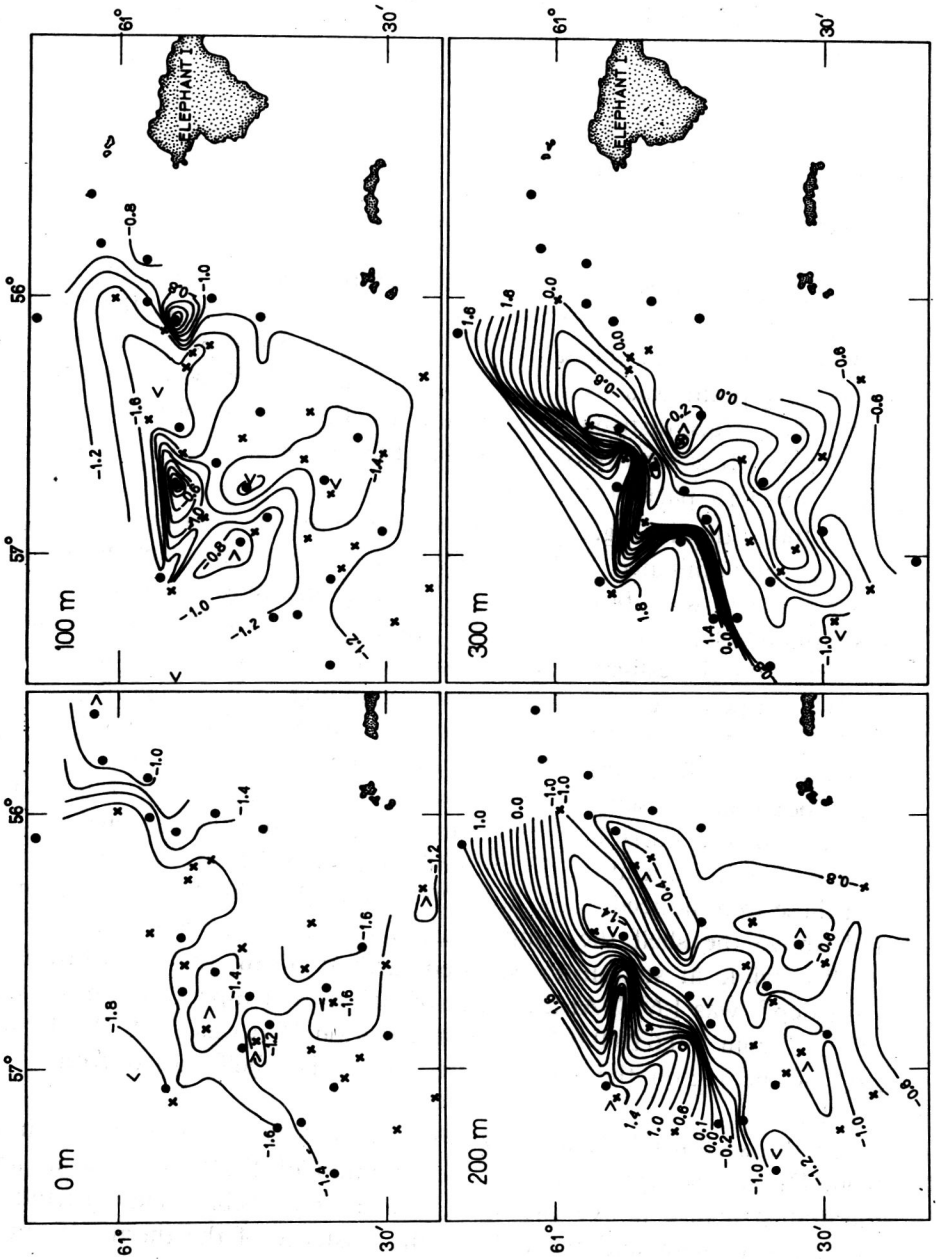


Fig. 2. Horizontal distribution of temperature ( $^{\circ}$ C) at 0, 100, 200, 300 m. October/November 1986

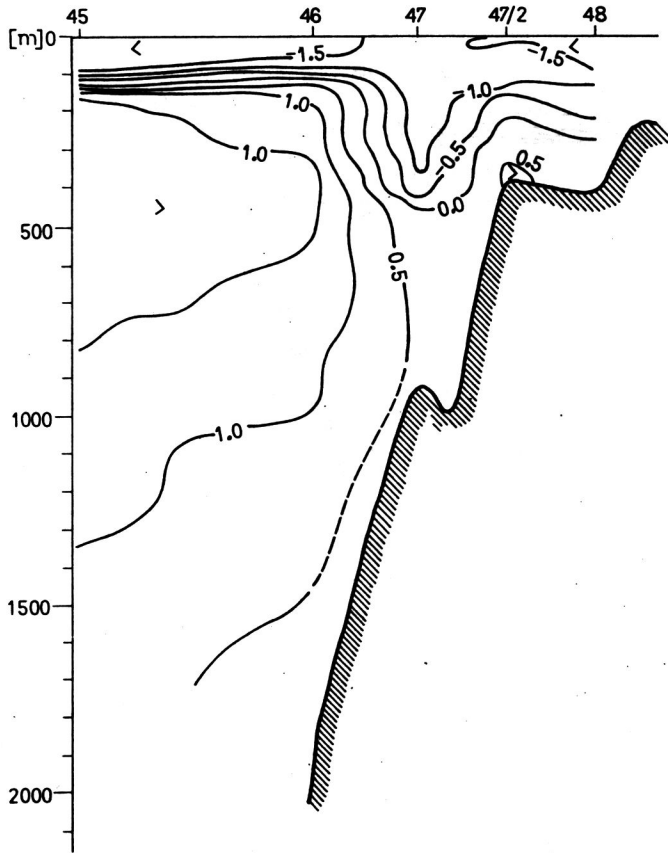


Fig. 3. Vertical distribution of temperature at section I. October/November 1986

phenomena were found at station 43 of section III and station 39 of section III (Figs. 4, 5).

The analysis of sections situated parallel to the continental slope and especially of section IV (the farthest north-eastern one) (Fig. 6) gave additional information on the spatial distribution of the temperature. In the western part of the region the lowering of the position of thermocline, and especially the lowering of isotherm  $0.5^{\circ}\text{C}$ , were seen. The position of this isotherm was at 200 m in station 44 while at 650 m in station 35. At the same time, the thickness of the warm water layer, limited by isotherms  $0.5^{\circ}\text{C}$  and  $1.0^{\circ}\text{C}$ , decreased.

The XBT profile made at the station 44/1 showed a vertical distribution of temperature unique for this time of the year. This distribution showed several overlappings of cold and warm waters which suggested the occurrence of the anticyclonic whirl. It is worth of notice that a similar phenomenon was observed at the described station 47 situated not far from station 44/1.

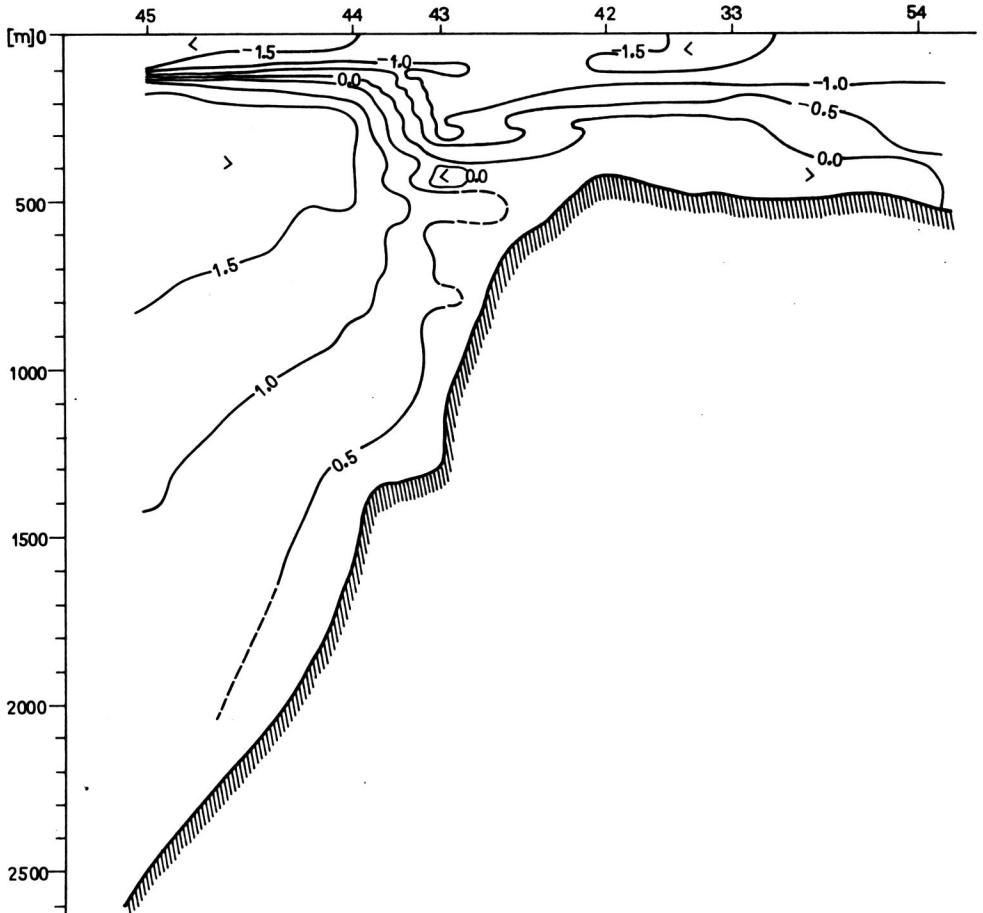


Fig. 4. Vertical distribution of temperature at section II. October/November 1986

The water columns in stations 44/1 and 47 were separated from each other by the water column (station 46) with a thermal structure typical for the occurrence of Warm Deep Water in Drake Passage (Gordon 1967).

In section V (Fig. 7) several elliptically closed isotherms, showing negative values at depths above 300 m and positive ones below 400 m, can be seen. This profile represents a picture of intrusions from the shelf region and from Drake Passage. The encounter took place beyond the thermal front and was noticed between sections IV and V.

Above the shelf (section VI) the stratified distribution of temperature, with its positive values below 300–350 m and reaching 0.3°C near the bottom, was observed (Fig. 7).

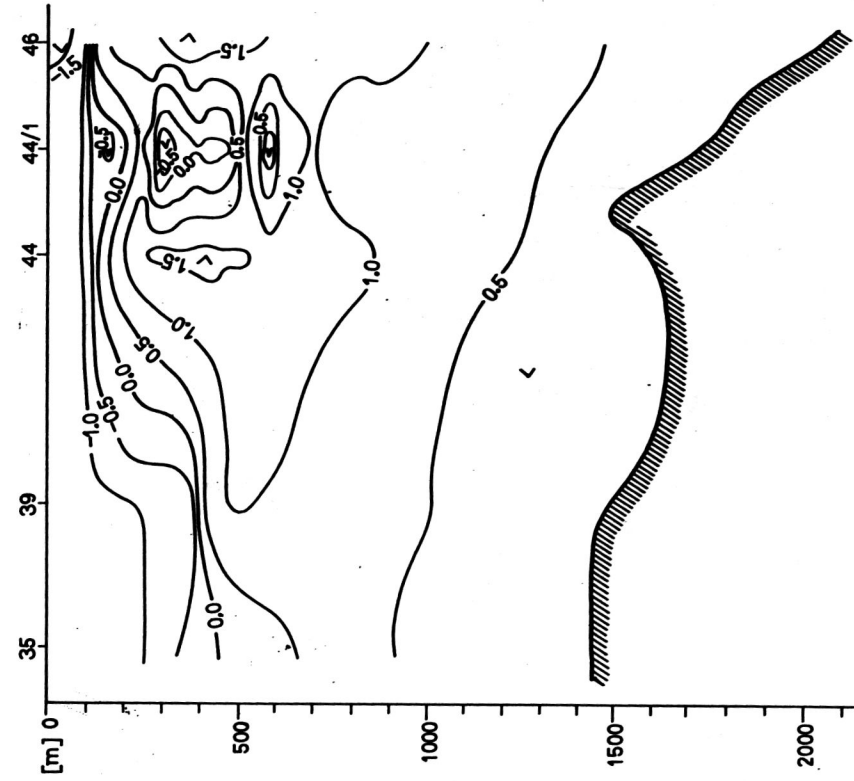


Fig. 6. Vertical distribution of temperature at section IV. October/November 1986

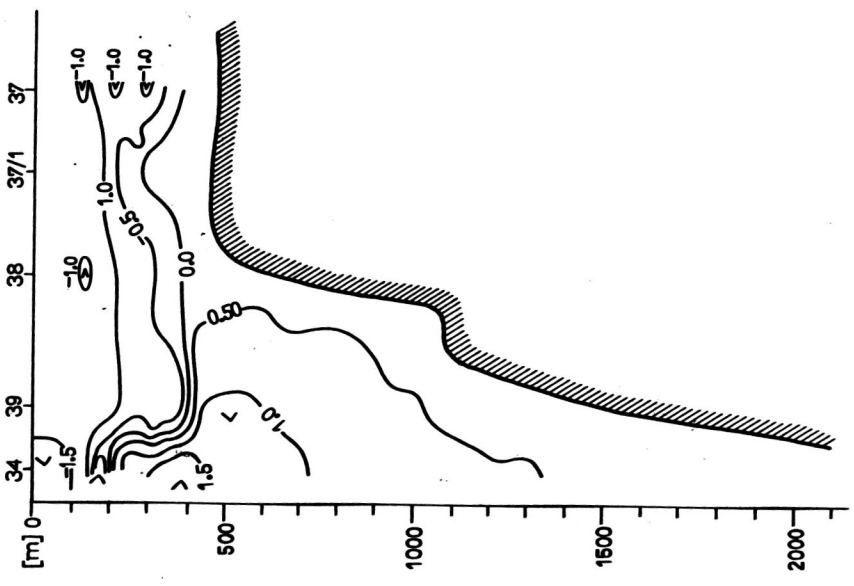


Fig. 5. Vertical distribution of temperature at section III. October/November 1986

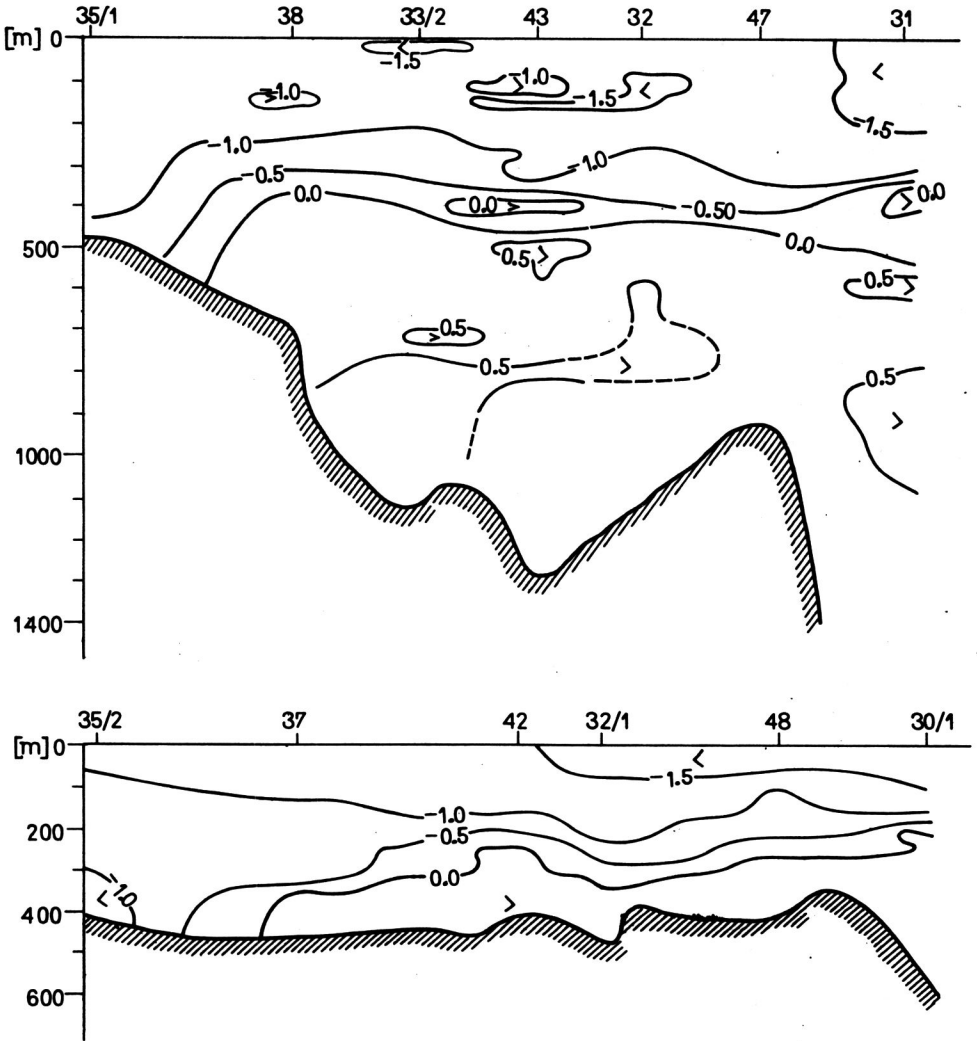


Fig. 7. Vertical distribution of temperature at sections V and VI. October/November 1986

### 3.2. Salinity

The surface distribution of isohalines (Fig. 8) followed the shape of the shelf edge and the salinity gradient was low ( $0.015 \times 10^{-3}/\text{nM}$ ). The minimal salinity ( $33.97 \times 10^{-3}$ ) was measured at station 45 situated in the north-western part of the region while the highest values, being above  $34.20 \times 10^{-3}$ , were found above the shelf, between the King George and Elephant Islands (stations 36–113).



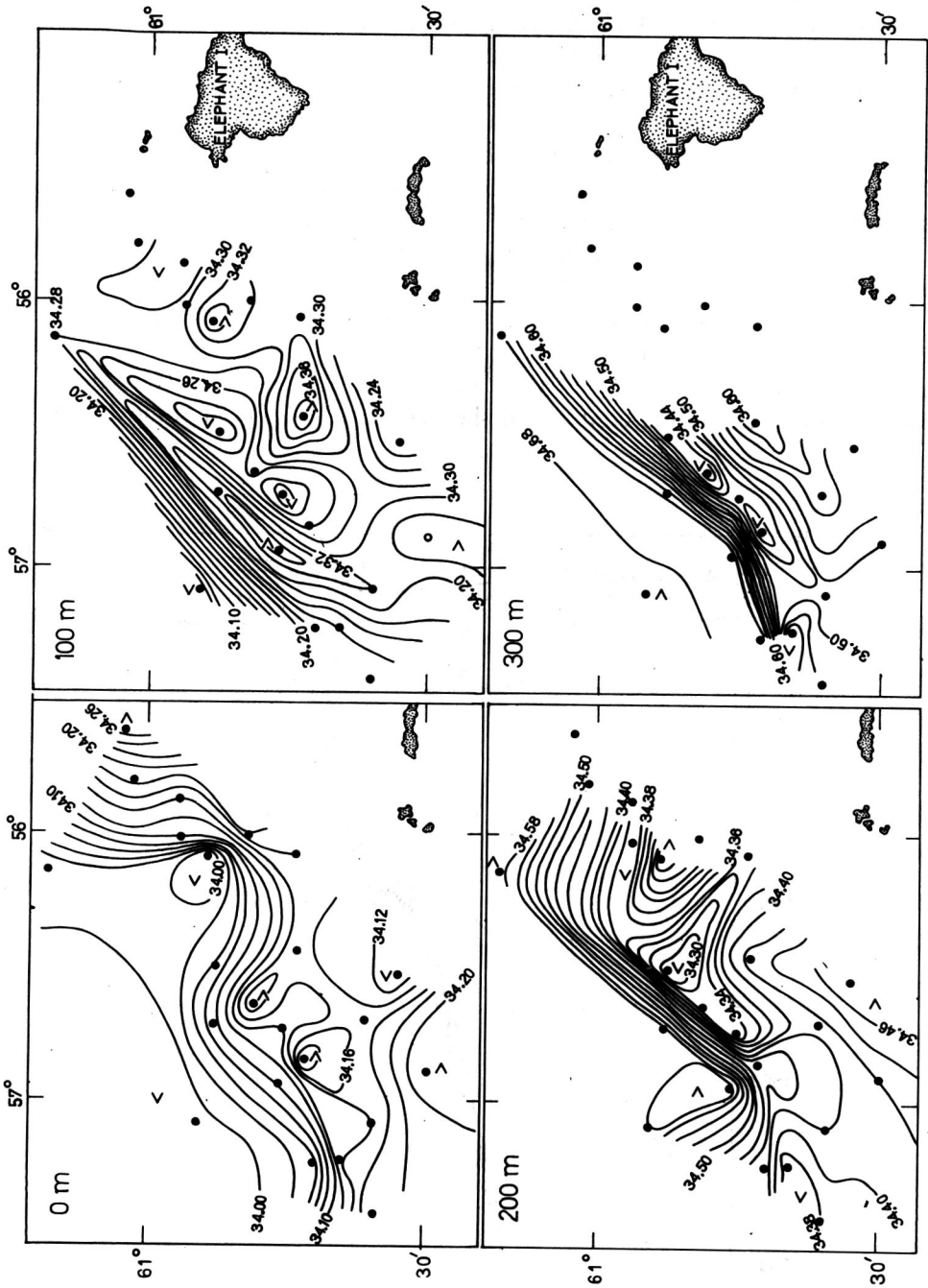


Fig. 8. Horizontal distribution of salinity ( $S \times 10^{-3}$ ) at 0, 100, 200, 300 m. October/November 1986

The same decreasing tendency of salinity values towards the north-west observed at the depth of 100 m (Fig. 8). The part of the region above the shelf and its slope was characterized by a number of areas with closed isolines representing higher or lower salinity values.

At the depth of 200 m (Fig. 8) the distribution of salinity increase was different. The salinity front with a relatively high salinity gradient ( $0.06 \times 10^{-3} / \text{nM}$ ) ran parallel to the shelf edge. The maximal values of salinity ( $34.50 - 34.59 \times 10^{-3}$ ) were observed on the western side of the front while the lowest ones ( $34.30 - 34.40 \times 10^{-3}$ ) were measured in close proximity to the front, but from the shelf side. At the same depth level but on the shelf the salinity was increasing, reaching values  $34.36 - 34.48 \times 10^{-3}$ .

The distribution of salinity at the depth of 300 m was similar to that at 200 m. The zone of minimal values of salinity ( $34.44 - 34.46 \times 10^{-3}$ ) was more clearly pronounced on the eastern side of the front. The salinity front, spreading above the continental shelf (Figs. 9, 10, 11) at some 10 nM

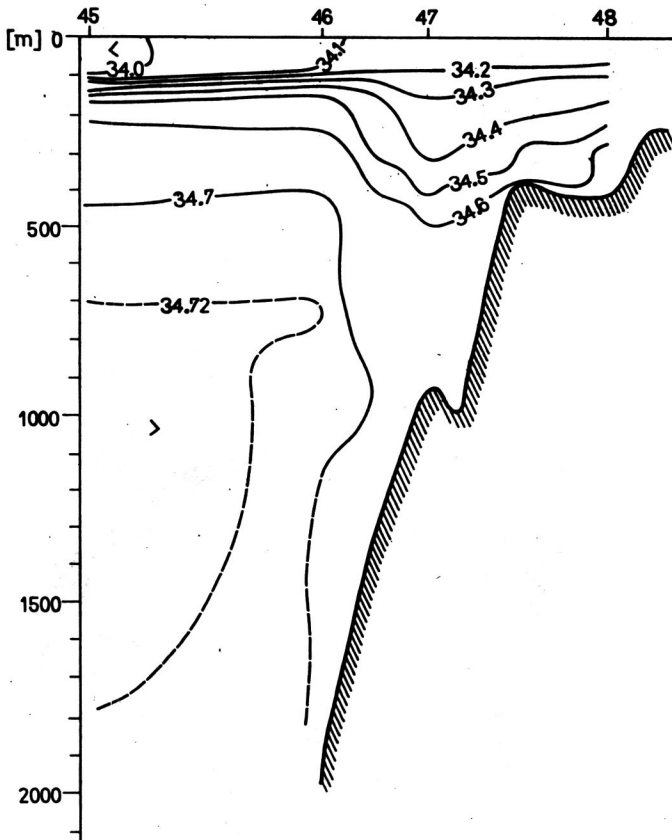


Fig. 9. Vertical distribution of salinity ( $S \cdot 10^{-3}$ ) at section I. October-November 1986

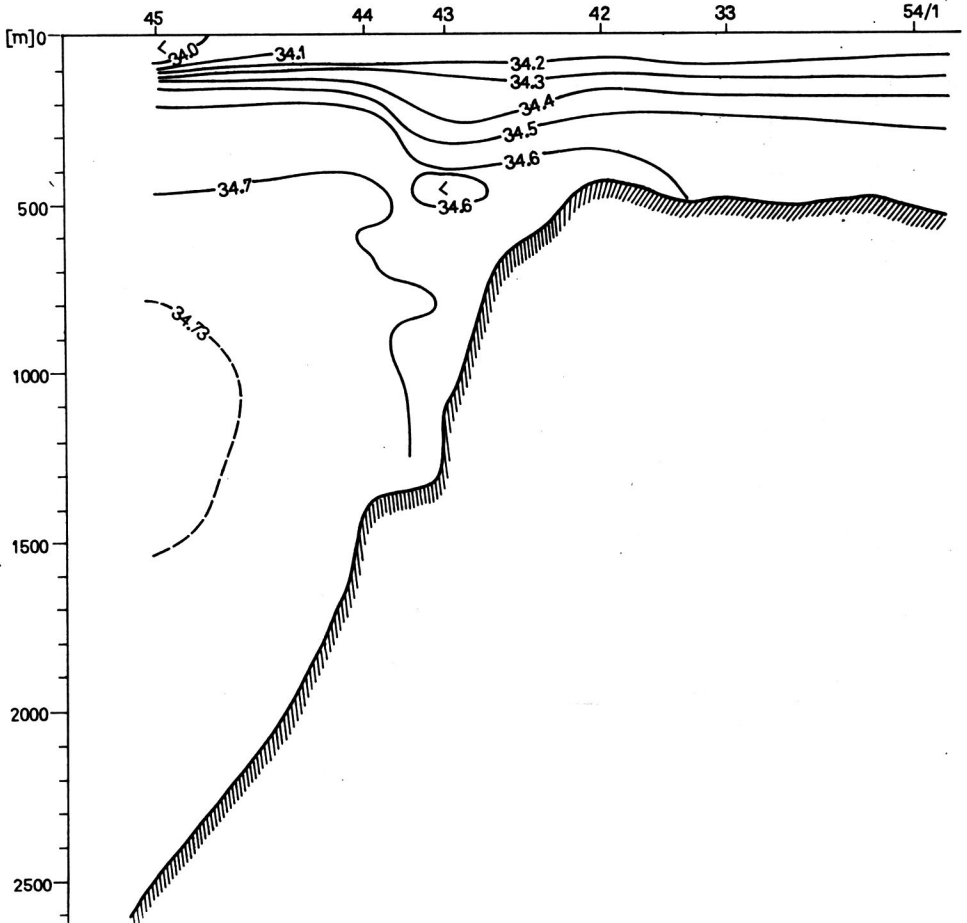


Fig. 10. Vertical distribution of salinity ( $S \times 10^{-3}$ ) at section II October/November 1986

from the edge of the shelf, occurred most clearly in the layer 200–500 m. In stations situated beyond the shelf (sections I–IV; Figs. 9, 10, 11, 12) in the layer between 500–700 m and 500–800 m there was maximum salinity and its values were changing from  $34.72$  to  $34.73 \times 10^{-3}$ . Sections which were parallel to the shelf edge (IV, V, VI; Figs. 12, 13) allowed to observe the sharpness of the outline of the halocline. The weakest halocline was observed in areas where a horizontal salinity front occurred.

On the basis of the analysis of temperature and salinity it can be ascertained that in the investigated region, below the surface layer reaching 50 m depth, there occurred two main water masses: Warm Deep Water in Drake Passage and a cold mass of waters present above the shelf within Weddell-

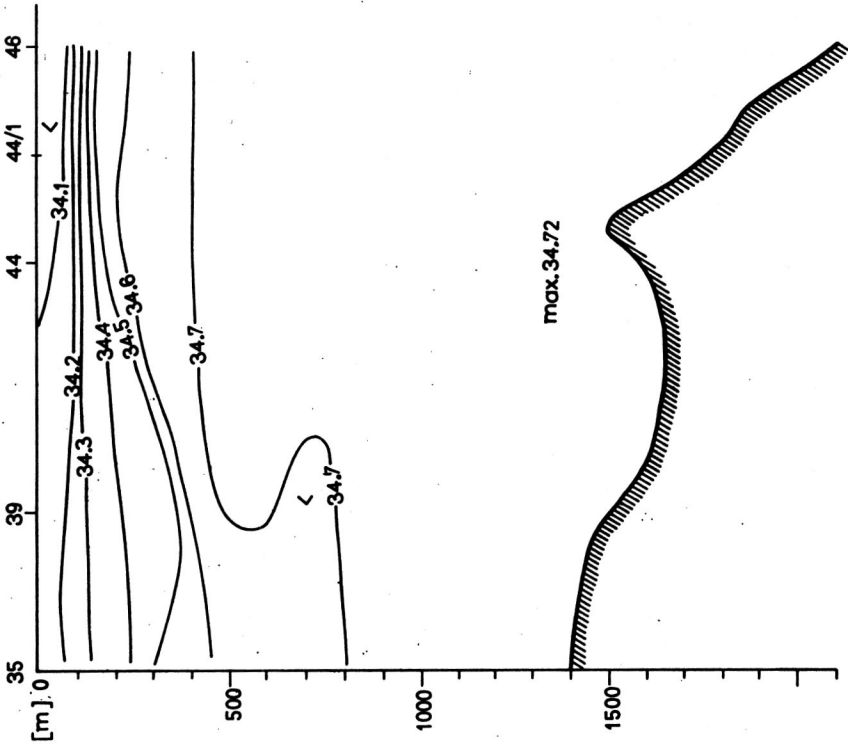


Fig. 12. Vertical distribution of salinity ( $S \times 10^{-3}$ ) at section IV. October/November 1986

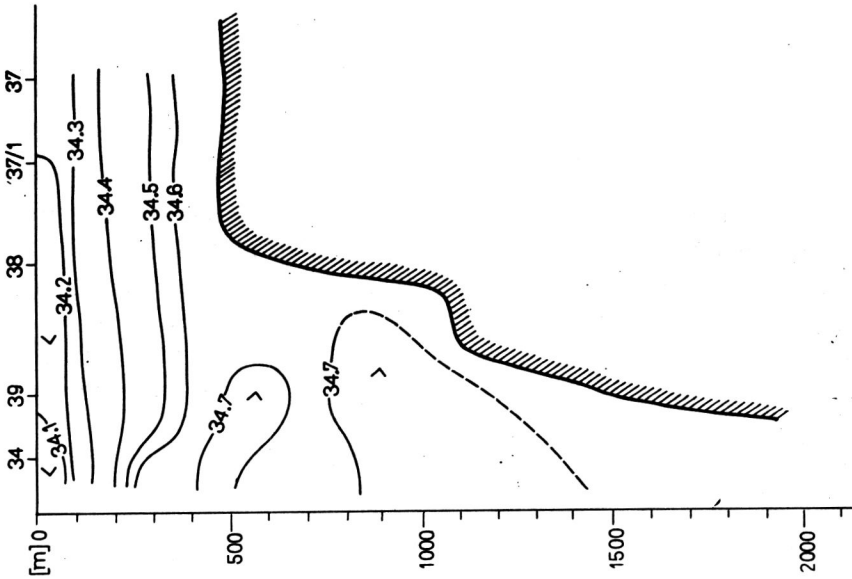


Fig. 11. Vertical distribution of salinity ( $S \times 10^{-3}$ ) at section III. October/November 1986

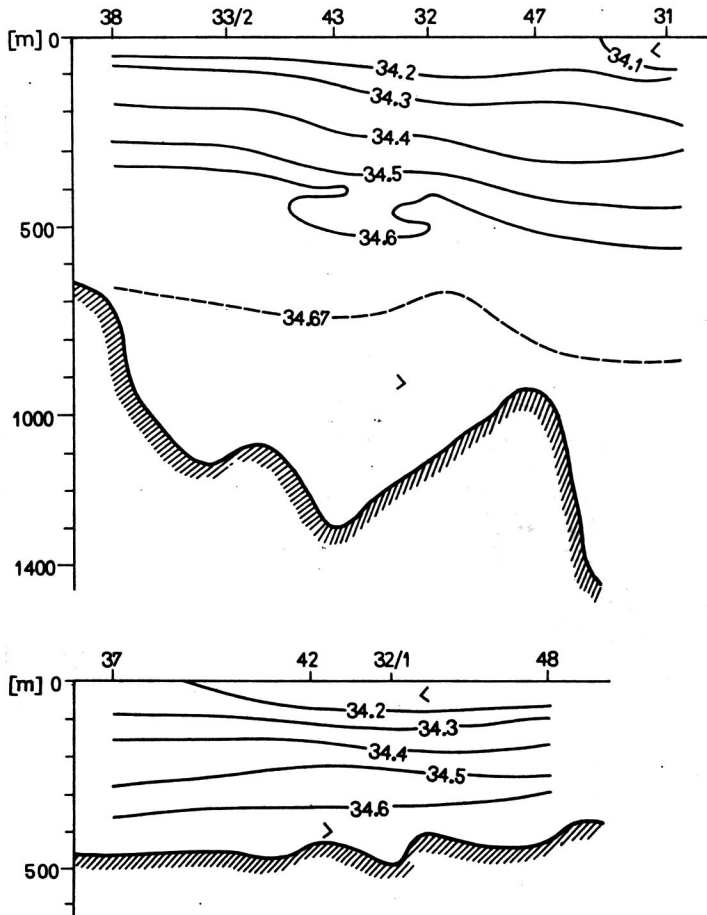


Fig. 13. Vertical distributions of salinity ( $S \times 10^{-3}$ ) at sections V and VI. October/November 1986

-Scotia Confluence (Patterson and Sievers 1980). The Warm Deep Water had its characteristic T-S curve with a maximum temperature of  $1.9^{\circ}\text{C}$  at about 400 m and distinct maximum salinity of  $34.72 \times 10^{-3}$  in the layer 700–1200 m. These results are in agreement with those given by Gordon (1967).

In the western part of the region there was observed a certain form of discontinuity in advection of Warm Deep Water onto the shelf.

Distribution of isotherms and isohalines and especially the position of isotherm  $1^{\circ}\text{C}$  at the section V (Figs. 6, 12) was a testimony of this discontinuity. It is possible that it could have resulted from the shape of the shelf edge in that region.

### 3.3. Geostrophic currents

The dynamic relief indicates the occurrence of the main flow of geostrophic currents along the continental shelf and towards the north-west (Fig. 14).

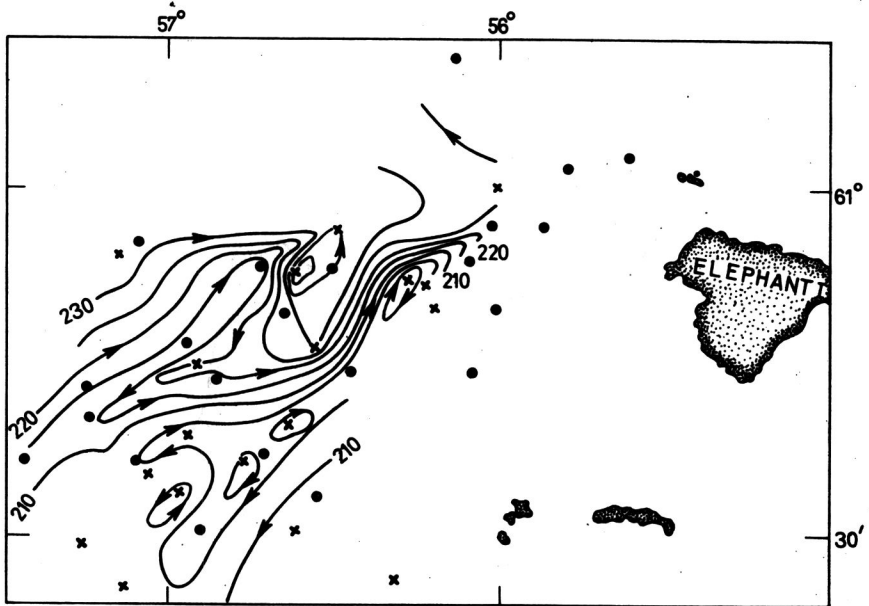


Fig. 14. Dynamic relief at the surface of 100 hPa computed in relation to the 500 hPa reference surface. October/November 1986

In the eastern part of the region, there occurred an anticyclonic whirl which produced an effect of anticyclonic meander along section IV. Due to that whirl acting near the Scotia Front the main stream of the flow was shifted towards the shelf edge. The width of the main stream at that point was 11 nM, and at the same time the stream lost its energy in the more shallow parts of the shelf, to the west of Elephant Island.

The undulating character of isotherm perpendicular to the shelf sections (I, II, III; Figs. 3, 4, 5) was well pronounced in the upper part of the front, in layer 100–400 m, from the side of the shelf. This character, according to Stern (1967) may testify to a prevailing inflow of cold waters from above the shelf. Besides this fact there were observed several thermal intrusions taking place in the layer of 100–400 m. Between the Scotia Front existing above the continental slope and the stream of geostrophic currents visible above the shelf edge the anticyclonic meander occurred. In this meander a downwelling was observed and this was most clearly seen at stations 47, 43 and 39.

Below the depth of 400 m there was an upwelling of warm waters onto the shelf. The biggest extent of warmer waters with temperature above 0.0 C was found along the section II and reached the XBT station 54/1 (Fig. 4).

The results of vertical temperature distribution obtained for the XBT station 44/1 testify to the existence of smaller dynamic forms within the described pattern of geostrophic currents. The vertical distribution of temperature in this station as opposed to surrounding thermal structures, suggests the sinking of colder waters into warmer ones. This unique thermal structure at station 44/1, resulting from the local dynamics, made it impossible to combine the temperature results from this station with the results of salinity from neighbouring stations (st. 44, 46). Thus, the density calculations could not have been made for the station 44/1.

The above shelf waters of the south-western part of the region were characterized by low gradients of dynamic heights which testifies to weak currents.

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## 5. Streszczenie

Warunki hydrologiczne rejonu poligonu określono na podstawie 24 stacji STD i 20 pomiarów XBT wykonanych w okresie od 26.X do 16.XI.1986 r. Pomiarzy XBT przede wszystkim uzupełniły określenie rozkładu temperatury oraz — tam, gdzie to było możliwe, dzięki przypisaniu zasolenia umożliwiły dokładniejszy opis przepływów prądów geostroficznych.

Z uzyskanej siatki stacji hydrologicznych wydzielono 6 profili w celu zobrazowania rozkładów pionowych temperatury i zasolenia.

Na całym obszarze badań woda powierzchniowa miała temperaturę poniżej zera, często bliską wartości temperatury zamarzania. Rozkład temperatury i zasolenia w warstwie od 0 do 50 m, a często i 100 m, nie odzwierciedlał zjawisk hydrologicznych na niższych głębokościach. W okresie badań nie zaobserwowano wody powierzchniowej letniej modyfikacji z charakterystycznym minimum temperatury. Poniżej warstwy powierzchniowej wystąpiły dwie zasadnicze masy wodne: ciepła woda głębinowa w Cieśninie Drake'a oraz zimna masa wód nad szelfem. powstała między innymi w wyniku konwekcyjnego mieszania w okresie zimy na obszarze strefy konfluencji Mórz Weddella i Scotia.

Pomiędzy wyspami King George i Elephant, wzdłuż krawędzi szelfu prądy geostroficzne przemieszczały występujące tam masy wodne w kierunku północno-wschodnim. W ramach tego zasadniczego kierunku pomiędzy Frontem Scotia nad stokiem kontynentalnym, a wyraźniejszą strugą nad krawędzią szelfu pojawił się antycyklonalny meander o szerokości ok. 10 Mm. W obrębie tego meandru wystąpiło zstępowanie wód powierzchniowych napływających znad szelfu. Jako zjawisko kompensacyjne w wodach poniżej 400 m wystąpiło wynoszenie cieplejszych wód z Cieśniny Drake'a na szelf.