

Hydrography of the Bransfield Strait during 1984 Southern Summer. SIBEX - Phase I

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ABSTRACT

The SIBEX (Phase I) expedition was realized in the Bransfield Strait and adjacent zones between January 27th and February 10th, 1984, on board the R/V Capitán Luis Alcázar.

Forty seven (47) oceanographic stations were performed, down to a maximum depth of 700 m. The variables measured were temperature, salinity and dissolved oxygen. To study its distributions, graphs of vertical and horizontal sections were prepared.

Water masses and types were studied by means of T-S diagrams; geopotential anomaly of the sea surface relative to the pressure levels of 1 MPa and 2 MPa and stability of the surface layer were also analyzed.

The results showed some differences with the ones obtained during FIBEX. Sea surface temperature and salinity were in general higher in all the studied area.

The water masses and types identified coincided with the ones described for FIBEX, with differences in the surface layer which was warmer.

The geopotential topography showed a main flow to the NE in the center and northern part of the strait. The southern part showed a flow to the SW generated in the Antarctic Sound which runs up to Trinity island and then it joins the main flow.

RESUMEN

La expedición SIBEX (Fase I) se desarrolló entre el 27 de enero y el 10 de febrero de 1984, a bordo de la M/N Capitán Luis Alcázar, cubriendo el estrecho Bransfield y zonas adyacentes.

Se realizaron 47 estaciones oceanográficas hasta una profundidad máxima de 700 metros, obteniéndose datos de temperatura, salinidad y oxígeno disuelto. Para analizar la distribución de propiedades se prepararon gráficos de secciones horizontales a 0, 25, 50, 100 y 200 metros; de 10 secciones verticales correspondientes a los cortes transversales efectuados durante el crucero; y una sección vertical longitudinal siguiendo el eje del estrecho Bransfield. Además, se estudiaron masas y tipos de agua mediante diagramas T—S, anomalía geopotencial de la superficie referida a los niveles de presión de 1 MPa y 2 MPa y estabilidad del estrato superior de la columna de agua.

Los resultados mostraron algunas diferencias con los obtenidos durante FIBEX, encontrándose en general temperaturas más altas en aproximadamente 1°C y mayores salinidades superficiales en gran parte del área de estudio. Las masas y tipos de agua encontrados coinciden con los descritos en los Talleres de Trabajo de FIBEX, apreciándose que las aguas del interior del estrecho Bransfield son mezcla

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de tres tipos principales, agua del mar de Weddell, del mar de Bellingshausen y aguas interiores del estrecho de Gerlache. También tiene gran relevancia el agua fría y salina que se forma en la zona adyacente a la península Antártica.

El flujo de agua determinado por el estudio de la anomalía geopotencial reafirma, en general, el sentido de mezcla inferido de los diagramas T—S; mostrando una dirección general, en el centro y norte del estrecho, hacia el NE y un flujo hacia el SW pegado a la península Antártica que alcanza hasta isla Trinidad.

INTRODUCTION

The Bransfield Strait, which separates the Antarctic Peninsula from the South Shetland Islands, has not been in general well studied, although its northern location makes it easily accesible during the southern summer. Its axis has a NE - SW direction and it is bounded by Piloto Pardo Islands to the NE and by Hoseason, Low and Smith Islands to the SW. Its bathymetry is characterized by a wide continental shelf bordering the Antarctic Peninsula and by three deep basins located along the Strait near the South Shetland Islands. These basins are separated between them and with the adjacent seas by depths near or less than 1,000 meters, making difficult the interchange of properties below this depth.

One of the first and more detailed studies of the Bransfield Strait Hydrography, is the one from Clowes (1934), which is based upon data collected by the "William Scoresby" and "Discovery" expeditions during 1927, 1929 and 1930. Clowes suggested the formation of the deep water of the basins in the same strait by thermohaline processes during winter near the Antarctic Peninsula. The same author also concludes that the relatively warm and low salinity waters found during summer in the western and northern portions of the Bransfield Strait and the subsurface temperature and salinity maximums are a consequence of the advection of Bellingshausen Sea waters into the Strait. The southeastern sector of the Bransfield Strait is influenced by the colder and saline waters of the Weddell Sea, which penetrates over the wide continental shelf near D'Urville and Joinville Islands.

A later study by Gordon and Nowlin (1978) made under the "International Southern Ocean Studies" programme, confirms what was suggested by Clowes as formation mechanism of the bottom waters of the strait. These authors conclude also that temperature and salinity inversions observed in the central and eastern portion of the Bransfield Strait are a consequence of advection from Bellingshausen Sea waters into the strait.

In the summer of 1981, as part of the investigations of the "First International Biomass Experiment" (FIBEX), the Instituto Antártico Chileno organized a biological-oceanographic cruise which was executed in the Bransfield Strait during February of that year.

The main results, related with the physical and chemical characteristics of the Bransfield Strait waters, were published by Sievers (1982) and by Salamanca and Acuña (1982), who confirmed many of the findings of previous authors and suggested a classification of the water masses and types of the Strait.

During 1983 a new expedition to the area was planned under the "Second International Biomass Experiment-Phase I" (SIBEX-Phase I). Its objectives were oriented mainly to study the Strait oceanography, with the purpose of obtaining a more detailed view of its physical and chemical characteristics.

In this context, the Instituto de Fomento Pesquero (IFOP) proposed and executed this project whose general objective was "to get a better knowledge and characterize the physical oceanographic conditions of the Bransfield Strait during 1984 southern summer".

MATERIALS AND METHODS

SIBEX-Phase I expedition was carried on between January 27th and February 10th of 1984 on the R.V. "Capitán Luis Alcázar". The surveyed area included the Bransfield Strait and adjacent waters between longitudes 54°W and 66°W (Fig. 1).

A total of 47 oceanographic stations were performed down to a maximum depth of 700 meters. Water samples were obtained with NISKIN bottles equipped with two protected and one non-protected inversion thermometers. The variables measured were temperature, salinity and dissolved oxygen.

Salinity was determined with an Autolab Mod. 601 salinometer and the dissolved oxygen content by means of the Carpenter modification for the Winkler method (1965).

The information processing was performed with an IBM S-34 computer at IFOP. To analyze the information, charts of the vertical and horizontal distribution of temperature, salinity and dissolved oxygen were prepared.

For the surface circulation analysis, its geopotential difference with the 1 MPa and 2 MPa pressure levels was graphed. In those stations with less than 200 meters of depth, values were calculated following Reid and Mantyla (1976).

Stability was calculated by means of the approximate equation:

$$E = \frac{\Delta \sigma_t}{\Delta z} \times 10^5; \text{ with units } [10^{-8} \text{ m}^{-1}]$$

The stability value obtained with this equation for 200 meters depth, differs in about 1% with the value calculated including the compressibility terms (Lynn *et al.*, 1982). With the values obtained graphs were made of the stability between 0 and 150 meters and of the depth at which the stability is negative.

To characterize water masses and types of the surveyed area, T-S diagrams prepared by the "Centro Nacional de Datos Oceanográficos" (CENDOC) with the data obtained during the cruise were used. A classification was done based on comparisons with previous studies results, specially with those of the international workshops of FIBEX.

Based on the T-S diagrams, graphic information is presented about the probable orientation of the mixing processes, in order to reinforce the information obtained from the geopotential differences.

RESULTS

1. *Temperature*

The surface temperature distribution (Figure 2), shows the lowest values in the Bransfield Strait near the Antarctic Peninsula and between Astrolabe Island and the southeastern sector adjacent to the Strait. The highest values are located near the South Shetland Islands and in the Gerlache Strait.

The isotherms run approximately parallel to the axis of the Bransfield Strait, south of Nelson Island a high temperature ($> 2.0^{\circ}\text{C}$) cell is located. In the western sector of the Strait (Sections 7 to 9) temperature characteristics are very homogeneous with values over 1°C . At the surface, values fluctuated between -0.36°C and 2.53°C .

At 25 meters (Figure 3) and 50 meter (Figure 4) depth, a slight decrement in temperature values is observed and the overall distribution is similar to the one at the surface. The high temperature cell south of Nelson Island is present in these two levels and disappears at 100 meters depth (Figure 5), depth at which a significant cooling is noted relative to the upper levels.

At 200 meters (Figure 6) the temperature distribution in the Bransfield Strait is similar to previous levels with values in general below zero. To the west of Deception Island an increasing temperature gradient is found as nearing the Bellingshausen Sea. In this area values are higher in relation to previous levels.

The vertical distribution (Figures 7 to 17) shows for the surface layer an increasing temperature from south to north in all sections, excepting N^o 6 and 7, which are located near the entrance to Gerlache Strait. Temperature decrease with depth in sections 2 to 6 and in the southern portion of section 7.

Section 1 shows a marked minimum which deepens from south to north between 100 and 300 meters with values below -1°C . The three first sections present temperature inversions in the upper 75 meters of the water column. In the southern portion of section 2 temperatures below -0.5°C are found under 80 meters depth; to the north the isotherms sink following the bottom configuration. Further north in this same section an important mixed layer in the upper 50 meters is appreciated.

In sections 3 and 0 the lowest temperature values ($< -1^{\circ}\text{C}$) are located below 400 meters, and in sections 4 and 5 under 500 meters. The four sections show important temperature gradients in the first 100 meters, with the isotherms sinking towards the South Shetland Islands, being this feature particularly strong in section 4.

Section 6 presents a strong gradient in the upper 75 meters. Below this depth

isotherms sink following bottom topography and the lowest values (-0.5°C) appear under 300 meters.

In the central and southern portion of section 7 a weak gradient is found at the surface layer, with temperatures over 1°C . In the northern part of this section and in the ones which follows, higher temperature and a different distribution of them at the surface can be observed. Centered at 150 meters depth an important relative minimum is found, this is also observed at the northern portions of sections 8 and 9. In section 8 the relative minimum is quite strong between 50 and 200 meters. At greatest depths temperature becomes higher, reading values over 2°C near 400 meters.

2. Salinity

At the surface, salinity increase towards the Antarctic Peninsula and Clarence Island (Figure 2). Two strong salinity gradients are present, the first one at the northeast entrance of the Gerlache Strait and the other one to the northeast of the Antarctic Peninsula. Towards the Bellingshausen Sea values are low and homogeneous.

The lowest salinities (< 33.6) are found in the Gerlache Strait and in station 1-2 in the Weddell Sea. On the other hand, the highest values (> 34.4) can be observed in the Bransfield Strait, to the northeast of the Antarctic Peninsula and to the south of Elephant Island.

At 25 meters depth (Figure 3) the Gerlache Strait gradient is considerably weaker, not occurring so with the one observed near the Antarctic Peninsula. The overall salinity distribution at this depth is similar to the surface one, excepting that in the western sector of the Bransfield Strait salinities are higher. To the south of Deception Island an important gradient is formed and the isohalines configuration suggests the presence of a meander.

At 50 meters depth (Figure 4), a general increment of the salinity values is observed and a moderate gradient appears to the south of Livingston Island. The gradient observed near the Antarctic Peninsula at previous levels is considerably weaker.

At 100 meters (Figure 5) and 200 meters depth (Figure 6) salinity values are higher reaching figures over 34.6 in the Bellingshausen Sea. The general distribution is homogeneous and no important gradients are present.

In the vertical sense, all sections (Figure 7 to 17) show a salinity gradient in the surface layer, between 0 and 200 meters, being this feature intensified in sections 1 and 7, where low salinity values (< 33.6) are found at the surface.

In general, salinity increases with depth and below 300 meters conditions are homogeneous. Under 400 meters salinities are higher in the eastern part of the studied area.

In sections 1,0 and 5 relative salinity maximums (> 34.7) are present around 100

meters producing inversions. Weaker inversions are present in the surface layer of many stations, and in sections 3 and 4 inversions are present below 300 meters.

In section 10 (Figure 17) the 34.6 isohaline sinks between sections 6 and 0, and the 34.3 and 34.4 isohalines climb to the surface at the eastern portion of the section; many important inversions can be appreciated in the surface layer.

3. *Dissolved oxygen*

At the surface (Figure 2) the dissolved oxygen content increases from the Antarctic Peninsula towards the South Shetland Islands, excepting a sector adjacent to Livingston Island, and to the east of the Bransfield Strait where characteristics are very homogeneous with values over $8 \text{ cm}^3/\text{dm}^3$.

From the east margin of the Bransfield Strait to the Bellingshausen Sea, oxygen concentrations decrease with the lowest values located in the southwest portion of the studied area. At this level dissolved oxygen values fluctuated between 5.37 and $8.47 \text{ cm}^3/\text{dm}^3$.

At 25 meters depth (Figure 3) oxygen values are lower than at the surface but the distribution is similar. South of Livingston Island values are still low and to the Bellingshausen Sea values decrease, excepting an area north of Palmer Archipelago where values over $7 \text{ cm}^3/\text{dm}^3$ are present.

At 50 meters depth (Figure 4) the distribution of dissolved oxygen is still similar to previous levels with values slightly lower. The area with values over $7 \text{ cm}^3/\text{dm}^3$ to the north of Palmer Archipelago has diminished its extension but maintains its presence down to 100 meters.

At 200 meters depth (Figure 6) concentrations of dissolved oxygen decrease to values under $6 \text{ cm}^3/\text{dm}^3$, with the exception of an area surrounding Deception Island. Characteristics are very homogeneous with the lowest values located in the western sector of the studied area.

In all the vertical sections (Figures 7 to 17) the dissolved oxygen content gradually diminishes with depth.

Sections 1 and 2 present values over $8 \text{ cm}^3/\text{dm}^3$ in the surface layer and under $5 \text{ cm}^3/\text{dm}^3$ below 300 meters.

Sections 4 and 6 shows a relative maximum with values over $7 \text{ cm}^3/\text{dm}^3$ located at 100 meters depth. On the other hand, in section 5 a relative minimum is present at 50 meters depth, with values under $6 \text{ cm}^3/\text{dm}^3$.

In the northern sector of section 7 at 150 meters depth a relative maximum with values over $6 \text{ cm}^3/\text{dm}^3$ is observed; below 400 meters the isoline of $4 \text{ cm}^3/\text{dm}^3$ appears.

In section 9 a relative maximum similar to the afore mentioned appears at 200 meters depth.

Section 10 (Figure 17) shows a gradual decrease of oxygen values towards the Bellingshausen Sea, both at the surface and at depth.

In general it can be stated that the distribution of dissolved oxygen is homogeneous in all the studied area with weak gradients and values ranging from 4 to 8 cm³/dm³.

DISCUSSION

1. *Properties distribution*

In general sea surface temperatures show a similar distribution to the ones described by Clowes (1934) and Sievers (1982), with values near the ones reported by Clowes (*op. cit.*) and approximately 1°C higher of the ones informed by Sievers (*op. cit.*) for the Bransfield Strait.

It is worth to note that the data obtained by Clowes (*op. cit.*) as the obtained in this work were taken during years of strong thermal alterations in the equatorial and subtropical zones of the Pacific Ocean, which were identified as intense El Niño events (Quinn *et al.*, 1978; Quinn and Zopf, 1984). Nevertheless, it has not been reported that this kind of alterations affects this zone of the Southern Ocean.

With depth an increase in temperature towards the SW is appreciated, this is caused by the presence of the cold water characteristic of the Weddell Sea in the eastern edge of the study area and by warmer circumpolar water in the area near the Bellingshausen Sea.

In section 10 (Figure 17) near 61°W and below 200 meters a sharp sinking of the isotherms originates a thermal front, due probably to the convergence of warm deep water from the Bellingshausen Sea with the cold deep water of the Bransfield Strait. This feature was reported also by Gordon and Nowlin (1978) and it can be noted on figure 16 of Sievers (1982).

In the transversal sections a similar situation occurs, specially significant in stations 4-3, 4-4, 3-3 and 3-4 (Figures 11 and 9), probably caused by the advection of warmer and less dense waters from the Bellingshausen Sea towards the NE by the southern side of the South Shetland Islands, feature also reported by Clowes (1934) in the same area.

Surface salinity in the studied area is higher than the ones reported in previous studies (Clowes, Sievers, Gordon and Nowlin, *op. cit.*), with the exception of the southeast portion where less saline waters—probably caused by the melting of great volumes of ice in northern Weddell Sea—originates a strong gradient. Situation similar to the one reported by Sievers (1982) and Clowes (1934). Clowes attributes, as this work does, the modification of the normally cold and saline waters of the Weddell Sea to ice melting processes, although he found the low salinity core more to the NW.

Another strong gradient area is found in the northern entrance of the Gerlache

Strait, where low salinity waters from the strait converge with high salinity waters advected from the Weddell Sea through the Antarctic Sound. The same situation is reported by Sievers (1982), who suggests the existence of a frontal zone in the same area.

In the Bellingshausen Sea sector covered by this study, salinity was notoriously higher than the one reported by previous studies.

With depth, temperature and salinity values were in general higher than the ones reported in studies made during FIBEX and DISCOVERY expeditions. Isohalines also present, as in temperature, sharp sinkings.

Temperature and salinity inversions are found in a great number of stations at different depths, being more important the latter ones since they produce instability in the water column.

Figure 20a shows the stability of the water column between 0 and 150 meters, the negative stability sector forms a tongue-like intrusion to the SW by the meridional portion of the Bransfield Strait. It is interesting to note that this configuration is similar to the one described for the surface distribution of chlorophyll "a" by Uribe (1985) on this same cruise.

Figure 20b shows the depths at which stability is negative; it is worthy of notice that the greatest depths of these instabilities coincides with the central portion of the Bransfield Strait. This can be attributed to the strong winter convection processes, which help to the formation of the deep waters of the Bransfield Strait.

In some sections, relative minimums of salinity can be appreciated near 100 meters depth, these all also attributable to winter mixing processes. In the surface layer inversions also occur (Figures 8 and 9), due probably to the presence at the surface of waters influenced by recent melting of sea ice.

Dissolved oxygen distribution has similar characteristics to the ones found during FIBEX expedition, with slightly lower values, effect attributable to differences in temperature. Likewise, with depth values of dissolved oxygen are lower than the ones reported by Sievers (1982) down to 250 meters, limit of his sampling.

2. T-S Diagrams

The same classification proposed by Biomass Report Series 30 (1982) has been used to denominate T-S pairs in the studied area.

Figure 18 shows that in general the inner waters of the Bransfield are a mixture of three main water types (W, B y S) and of the water formed in situ on the continental shelf of the Antarctic Peninsula.

The water named W originates in the Weddell Sea; it has low temperatures (< 1°C) and salinities which vary between 33.8 and 34.7. The lower values at the surface are probably due to melting processes in the vicinity of the Antarctic Peninsula. With increasing depth salinity acquires the characteristic higher values of this water type.

Water type named B, originates in the Bellingshausen Sea and it is characterized by the presence of Antarctic Surface Water, with its temperature minimum located in this occasion around 40 meters depth, and of Deep Circumpolar Water which induces an increase in temperature and salinity with depth, reaching at 200 meters values over 2°C and 34.6 correspondingly.

The type named S corresponds to inner waters of the Gerlache Strait with high temperatures ($> 2^{\circ}\text{C}$) and low salinities (< 33.6) at the surface, effect attributable to solar radiation and ice melting. These characteristics change with depth, with a decrease in temperature and an increment of salinity. The surface layer temperatures for this type of water were significantly higher than during FIBEX, when temperatures did not reach values over 0°C.

Other water type which is specially important on the continental shelf of the Antarctic Peninsula is the one named W_1 ($t = -0.5^{\circ}\text{C}$; $S = 34.5$). This water which is formed near the Antarctic Peninsula (Biomass Report Series N° 31, 1983), extends its influence to all the meridional sector of the Bransfield Strait, showing a southwestward mixing direction (Brw).

Water of the Bellingshausen Sea (B and B_1) mixes with waters of the Bransfield Strait near the South Shetland Islands, originating T-S pairs of the type Brs, on which it is possible to identify three main water masses; the Antarctic Surface Water with its characteristic temperature minimum a bit deeper around 100 meters, the Circumpolar Deep Water and the Bransfield Strait Bottom Water. This T-S pair extends itself to the NE up to Nelson Strait and appears again in the open waters between King George and Elephant Islands (Bw), probably due to advection which takes place by the north of the South Shetland Islands.

The general mixing sense, inferred from the T-S pairs, is in accordance with the situation described by Clowes (1934), Gordon and Nowlin (1978), Sievers (1982) and by FIBEX workshops (Biomass Report Series 30 and 31). The greatest differences with the mentioned studies are in the surface layer where, as it has been discussed, temperatures were higher in all the studied zone.

3. *Geopotential difference*

Figure 19 shows the geopotential difference from the surface to the pressure levels of 1 and 2 MPa; this method has been used to infer circulation considering the difficulty of defining a level of no-motion, as was reported by Biomass Report Series 30 and 31.

In the mentioned figure it can be observed that in the Bransfield Strait the flow lines have a general NE direction. Nearby the Antarctic Peninsula a flow to the SW is suggested and in the northeastern part of the study zone, the flow is to the North. These situations confirm the mixing directions described from the T-S pairs analysis.

The meander mentioned by Clowes (1934), Stein and Rakusa-Suszczewski (1983) and described also on Biomass Report Series N° 30 and 31 for the area south of Deception Island, is not clearly evident this time. Although a hint of it is present on the flow lines referred to 2 MPa, specially on the $0.08 \text{ m}^2/\text{s}^2$ one.

The SW flow in the area of the Antarctic Peninsula continental shelf which seems to generate from the Antarctic Sound reaches approximately to Trinity Island, and the return flow to the NE appears in the vicinity of the eastern entrance of the Gerlache Strait.

In the southeast sector of the Bransfield Strait where the largest salinity gradients were found, an anticyclonic gire insinuates in the flow lines referred to both levels.

Finally, the sharp deviation to the north of the flow lines south of Piloto Pardo Islands could be evidence of the presence of the Weddell Scotia Confluence in this sector of the studied area.

CONCLUSIONS

The studied area showed temperatures and salinities higher than the ones found during FIBEX by Sievers (1982) and similar to the description of Clowes (1934) for February 1929.

The Bransfield Strait water present mixing of three main types: Weddell Sea Water, Bellingshausen Sea Water and Gerlache Strait Water. An important role is played by water formed near the Antarctic Peninsula which predominates in the meridional part of the Bransfield Strait.

The mixing sense inferred from the T-S diagrams coincides with the situation described for previous years by Clowes (1934), Gordon and Nowlin (1978), Sievers (1982) and by FIBEX workshops (Biomass Report Series 30 and 31).

The inferred surface circulation of the Bransfield Strait showed a general NE direction, with the exception of the zone adjacent to the Antarctic Peninsula where a flow to the SW from waters coming from the Antarctic Sound reach Trinity Island and then returns to the NE with the main flow.

The flow lines insinuated the formation of a weak meander south of Deception Island and an anticyclonic gire in the southeast sector of the Bransfield Strait.

RECOMMENDATIONS

From this work and from the analysis of previous studies it is evidently difficult to describe the circulation of the Bransfield Strait, since its characteristics generate serious doubts of the validity of using the geostrophic method on it. This statement supports the necessity of future direct current studies using proper instruments and for a long period of time.

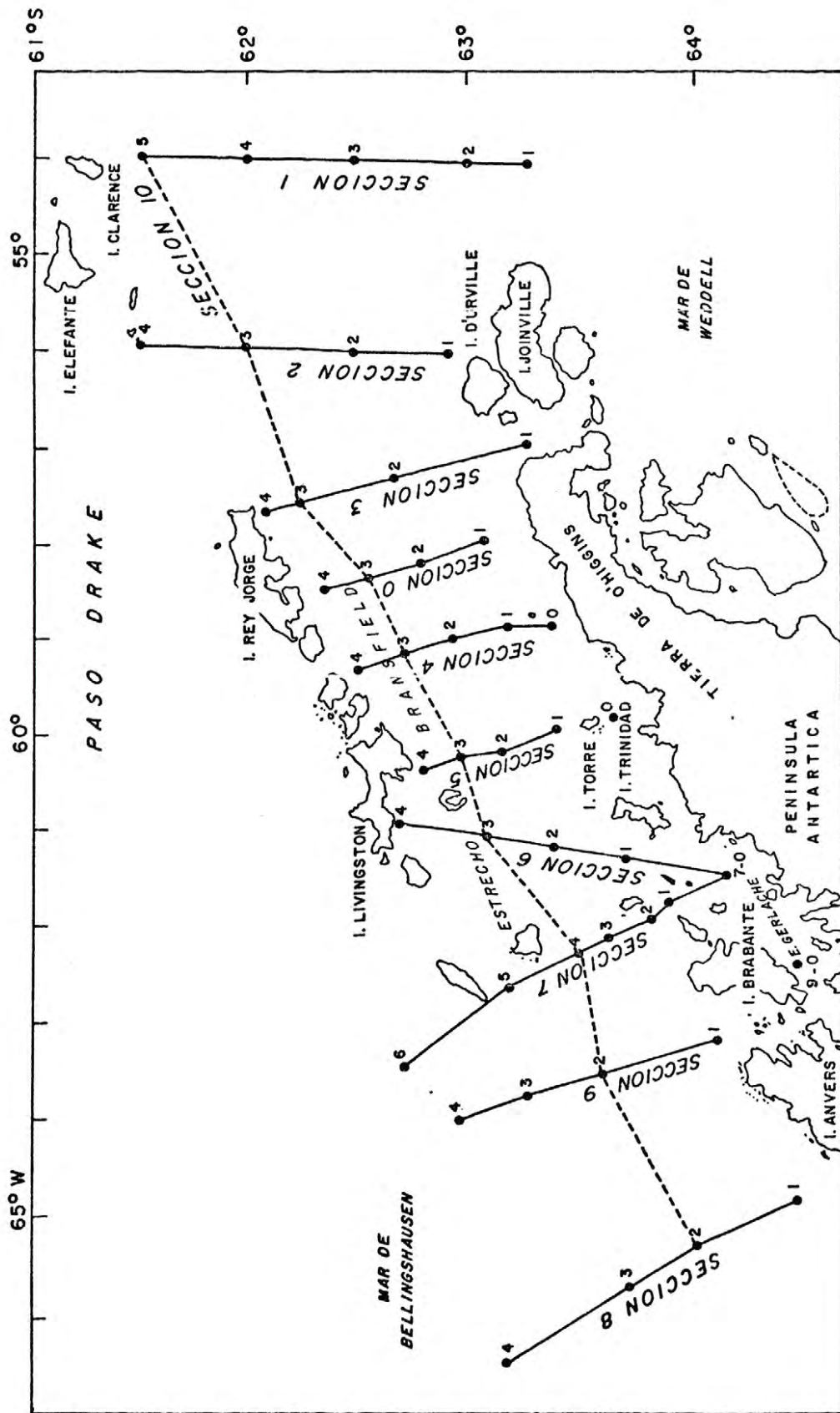


Figure 1: Geographic position of the oceanographic stations and sections.

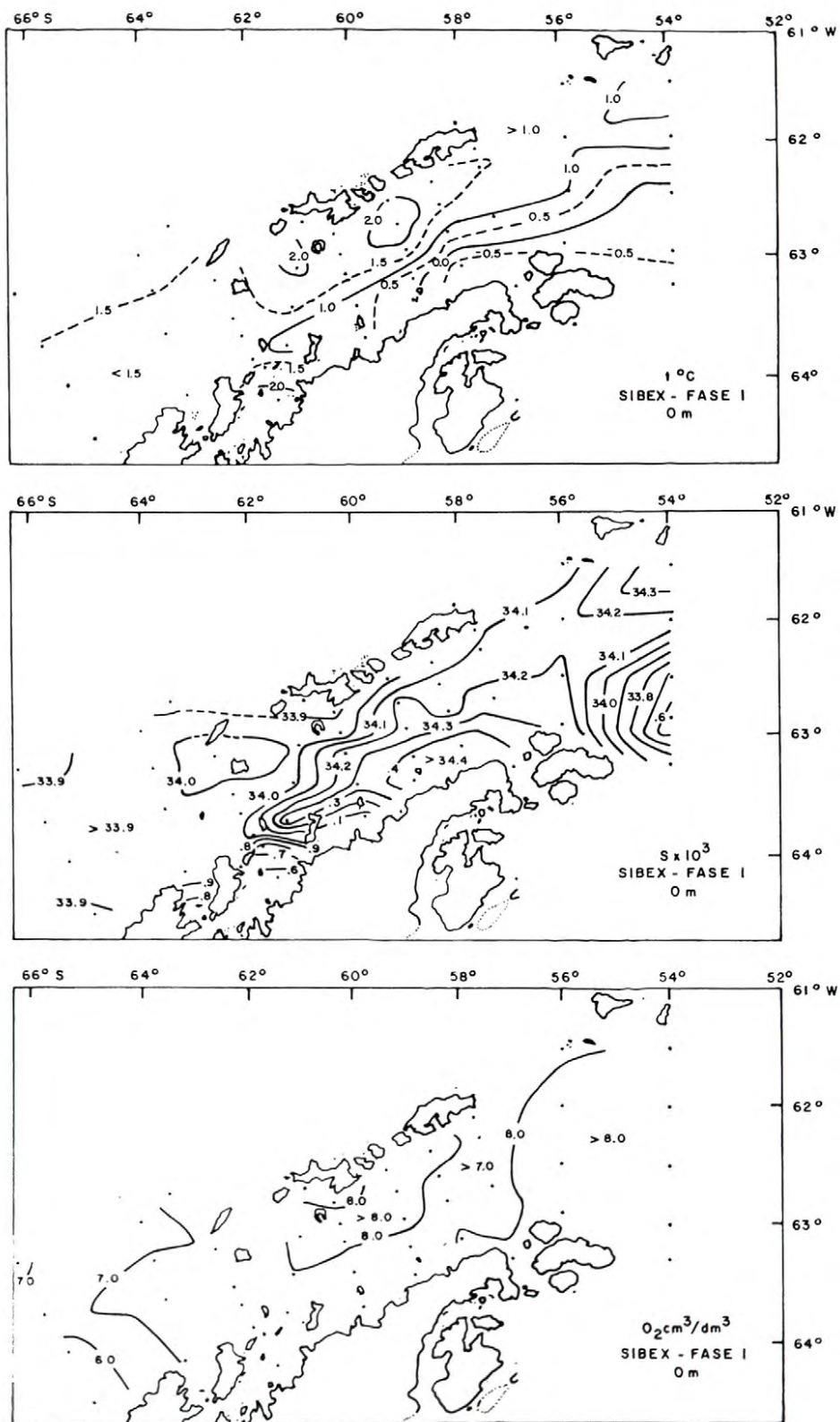


Figure 2 Surface horizontal distribution of temperature, salinity and dissolved oxygen.

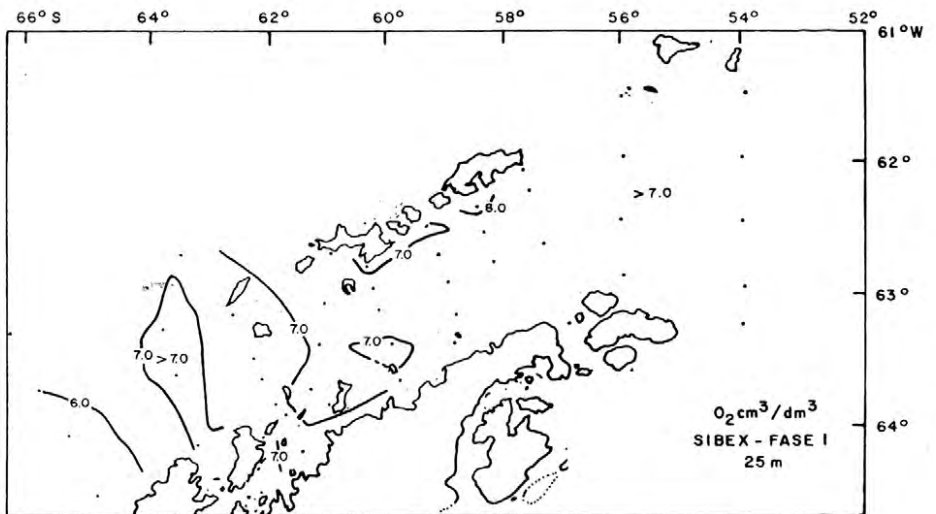
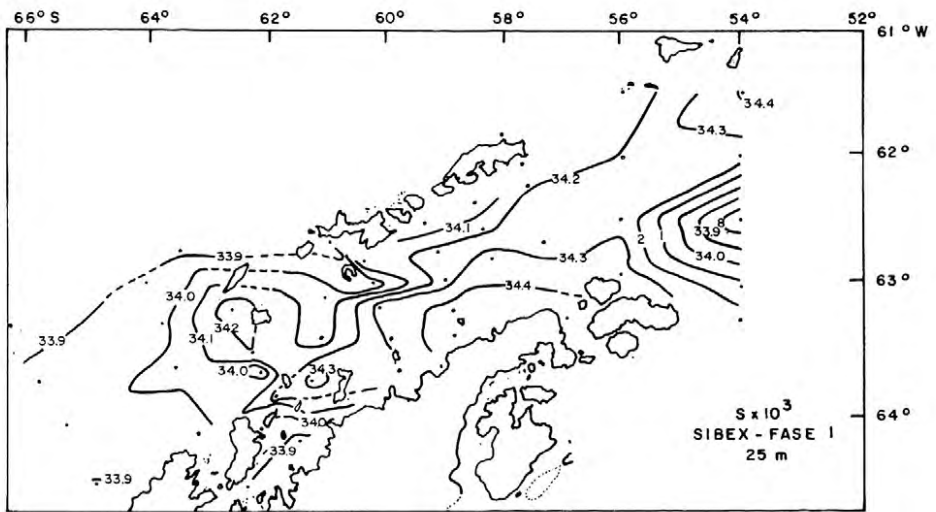
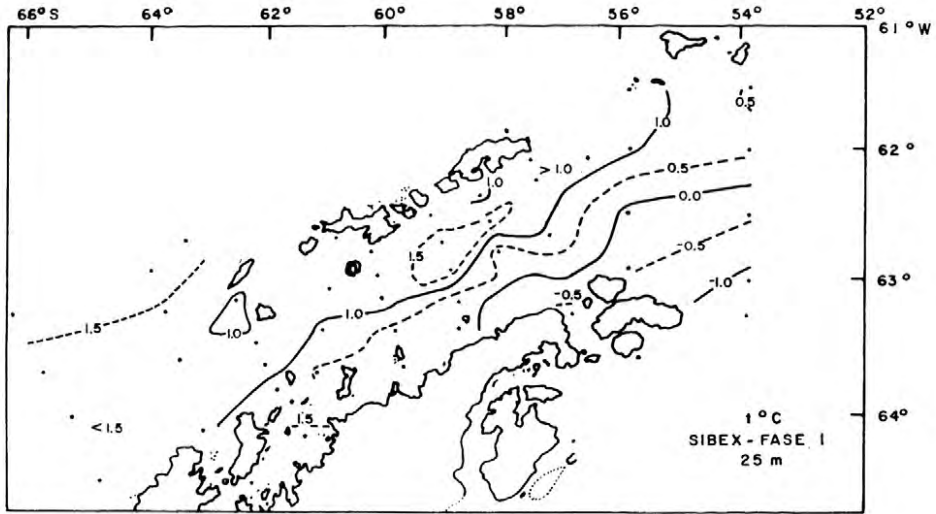


Figure 3: Horizontal distribution of temperature, salinity and dissolved oxygen at 25 meters.

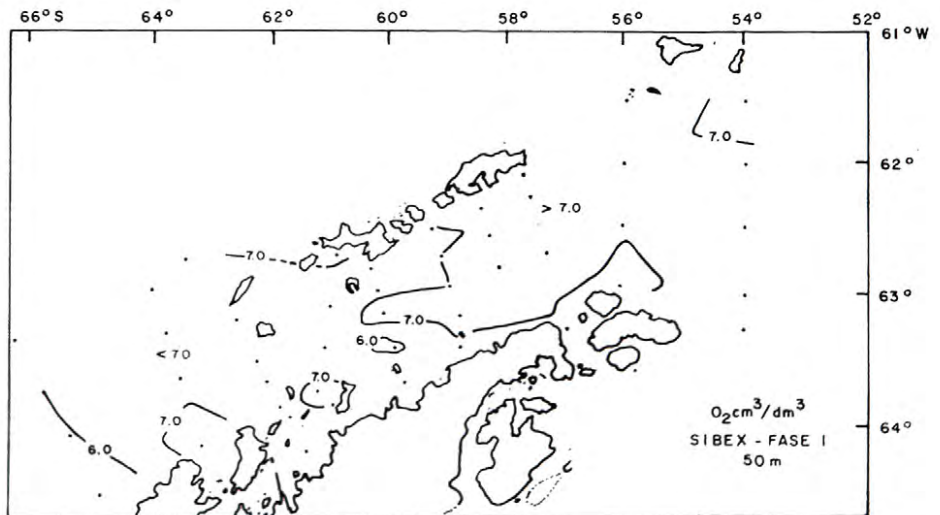
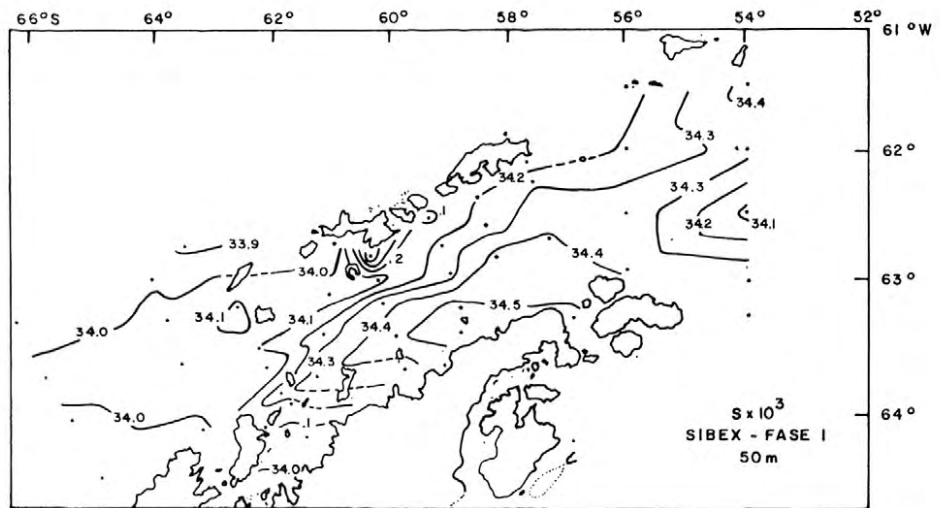
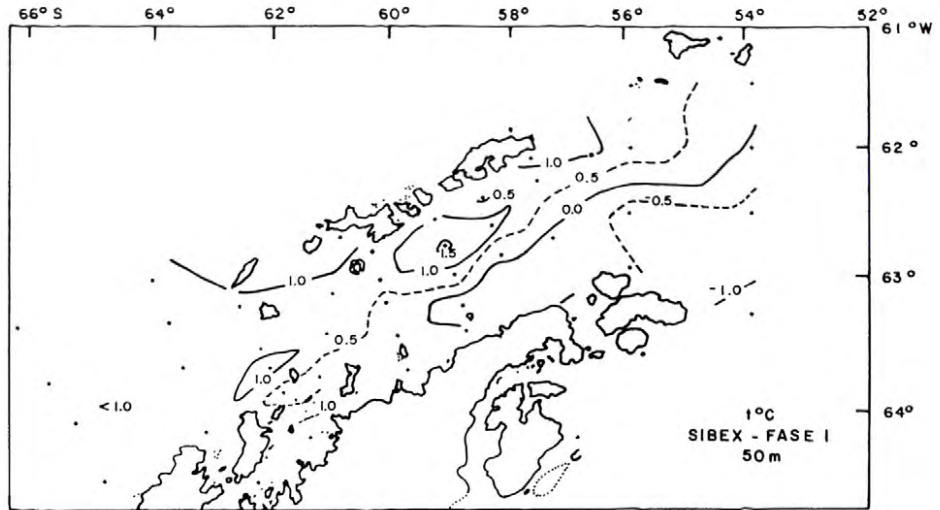


Figure 4: Horizontal distribution of temperature, salinity and dissolved oxygen at 50 meters.

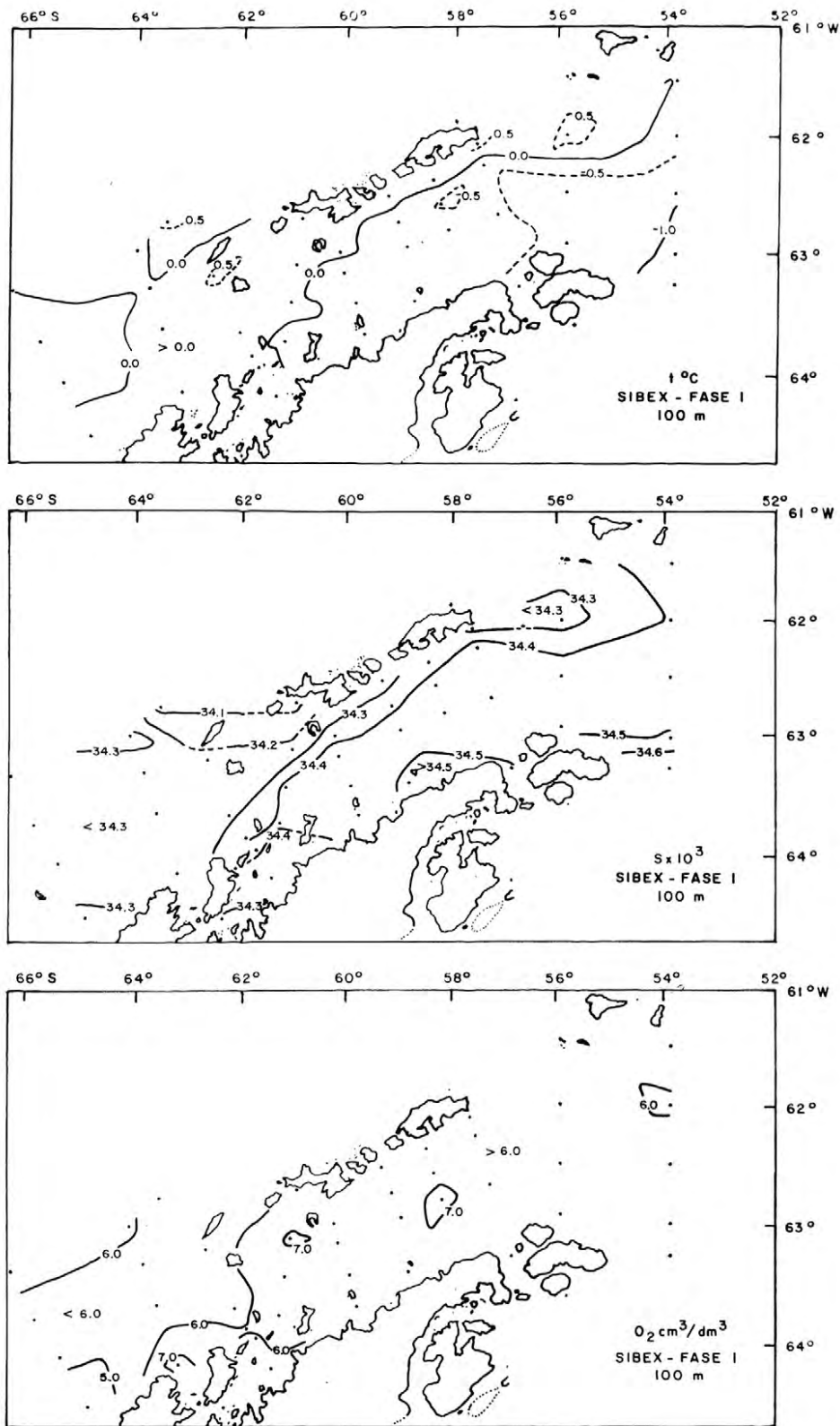


Figure 5: Horizontal distribution of temperature, salinity and dissolved oxygen at 100 meters.

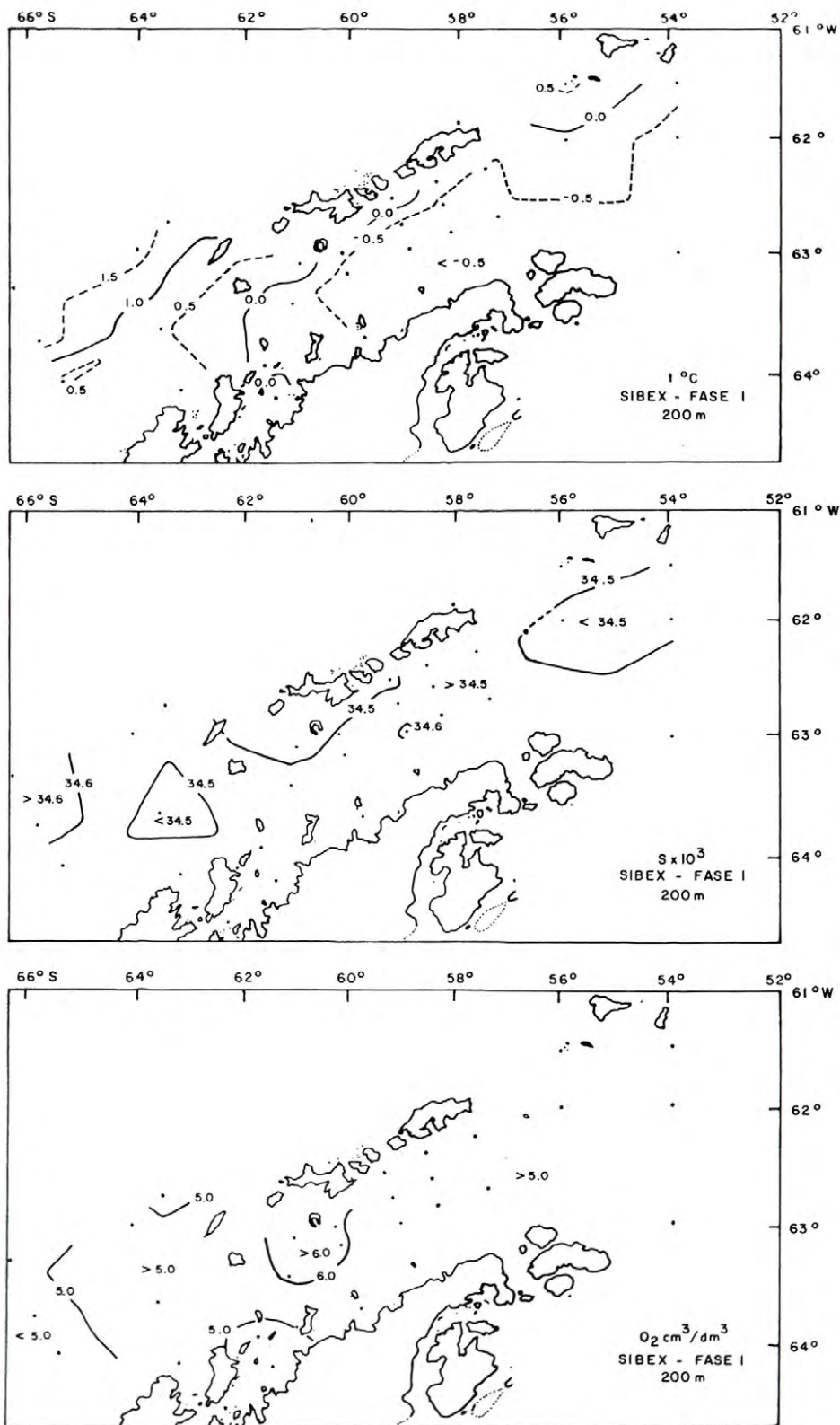


Figure 6: Horizontal distribution of temperature, salinity and dissolved oxygen at 200 meters.

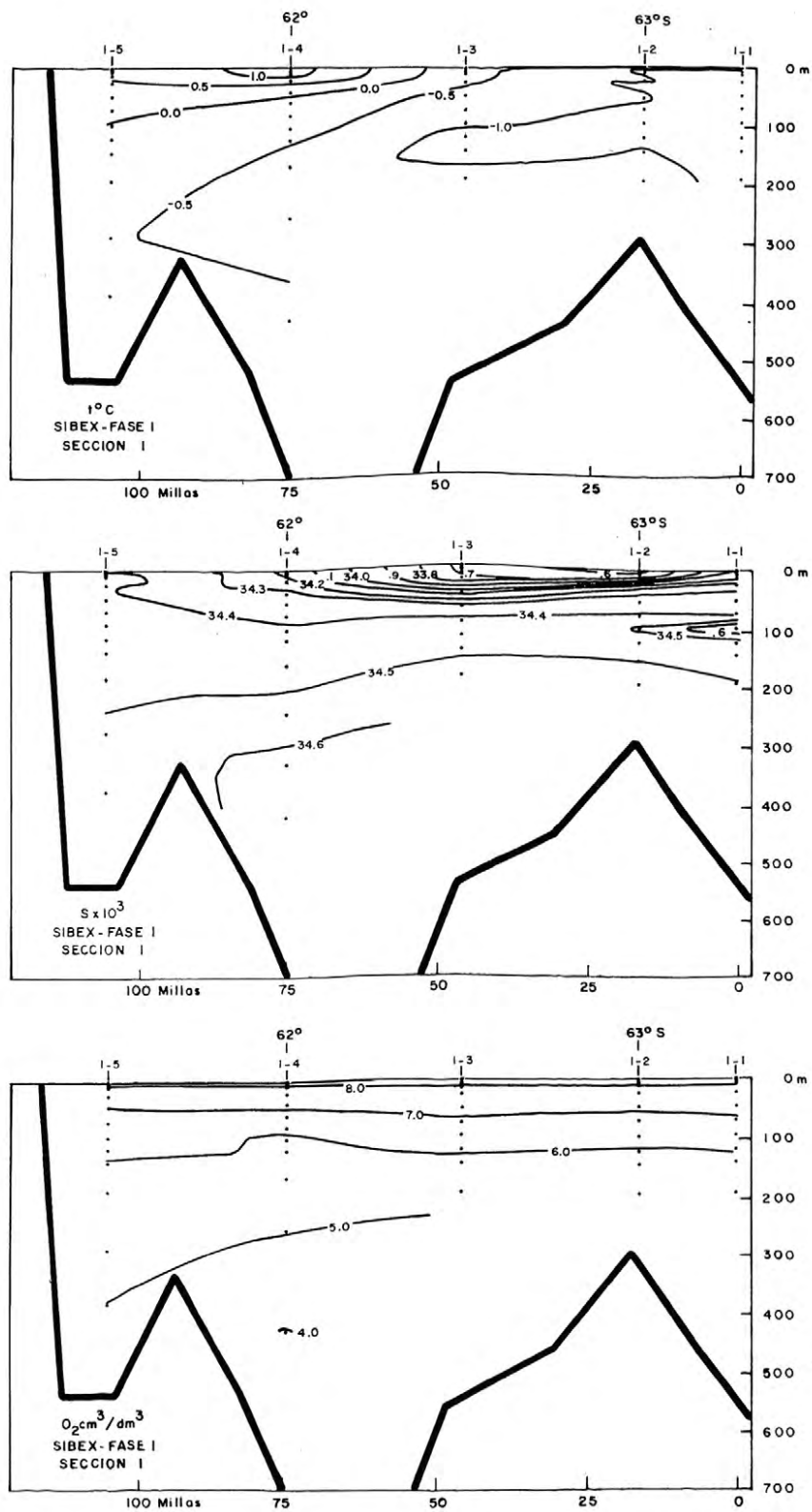


Figure 7: Vertical distribution of temperature, salinity and dissolved oxygen in Section 1.

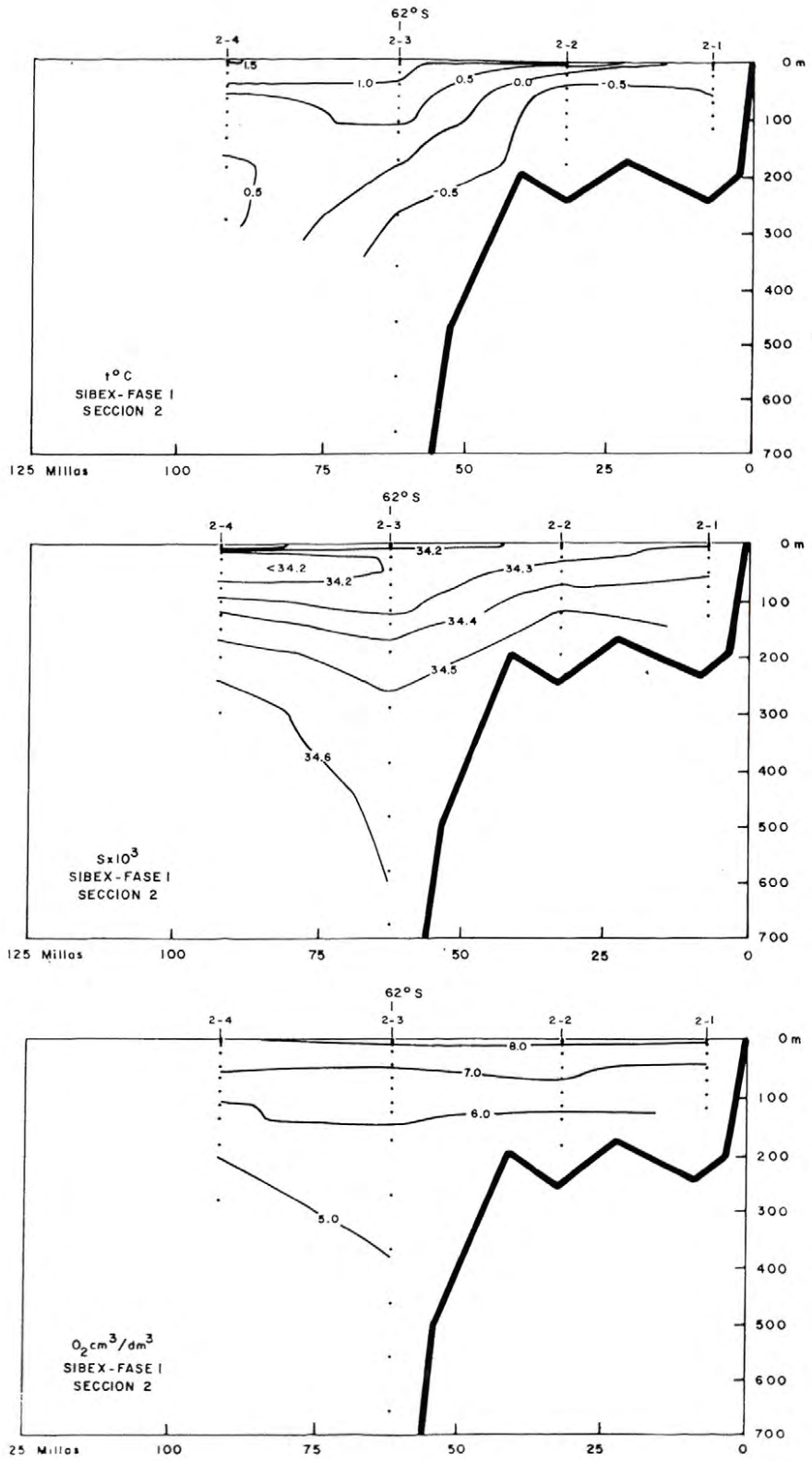


Figure 8: Vertical distribution of temperature, salinity and dissolved oxygen in Section 2.

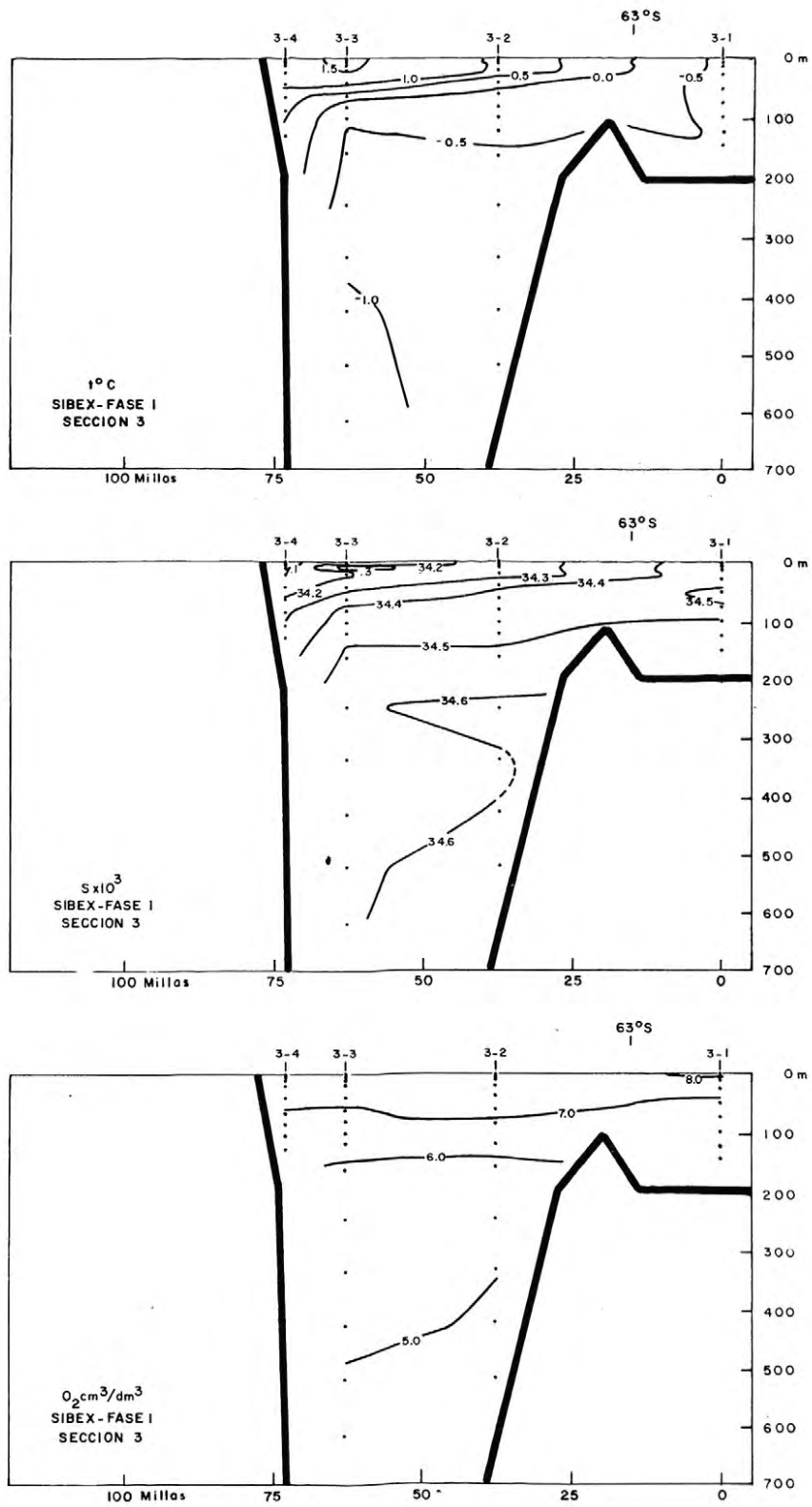


Figure 9: Vertical distribution of temperature, salinity and dissolved oxygen in Section 3.

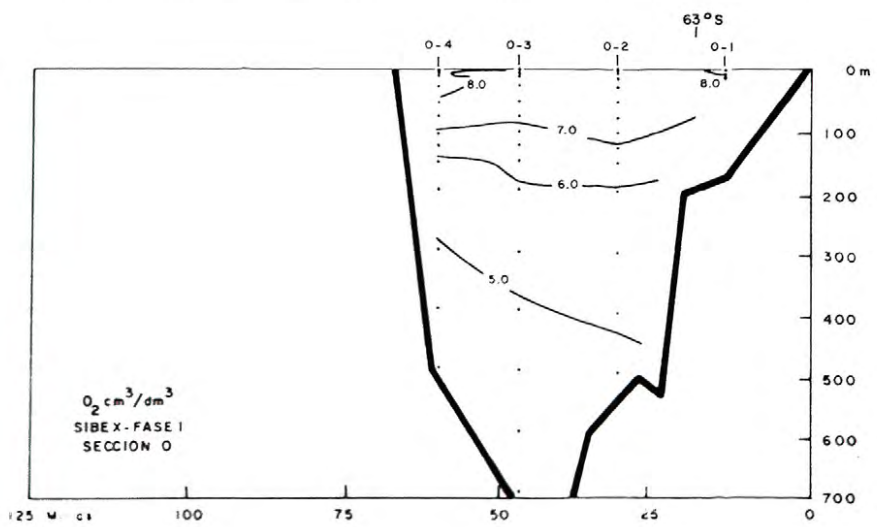
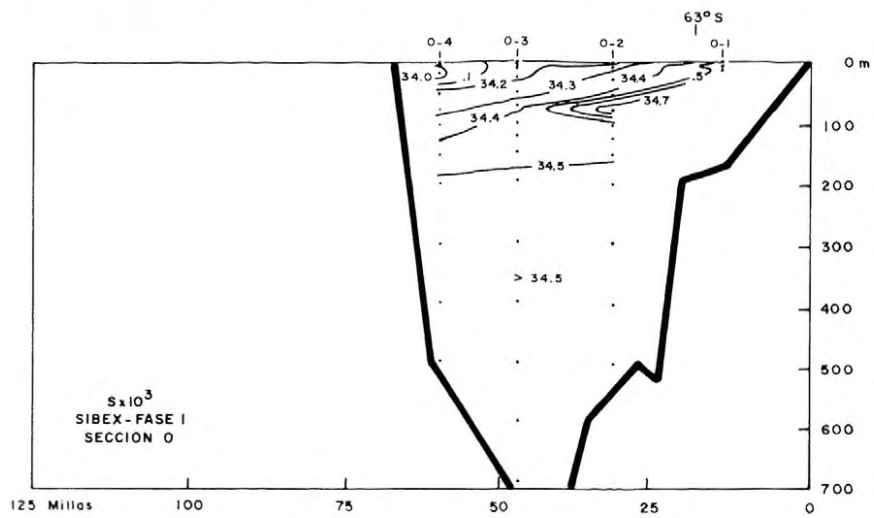
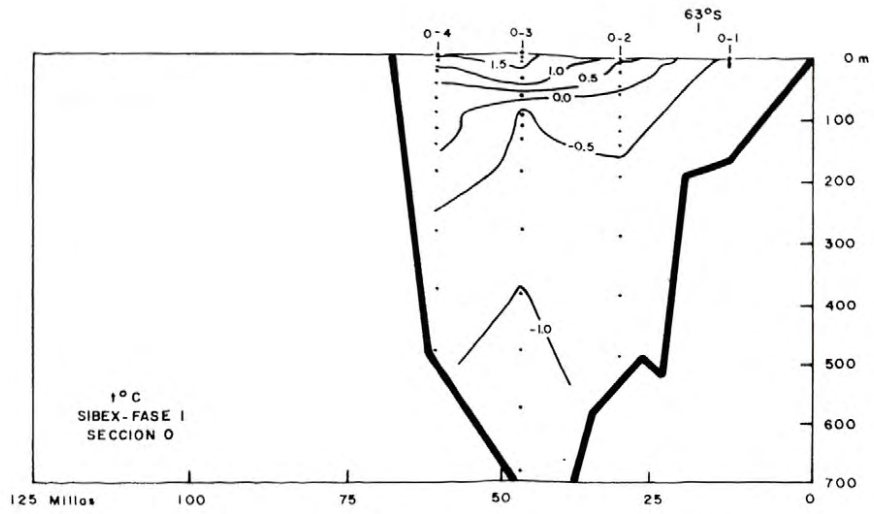


Figure 10: Vertical distribution of temperature, salinity and dissolved oxygen in Section 0.

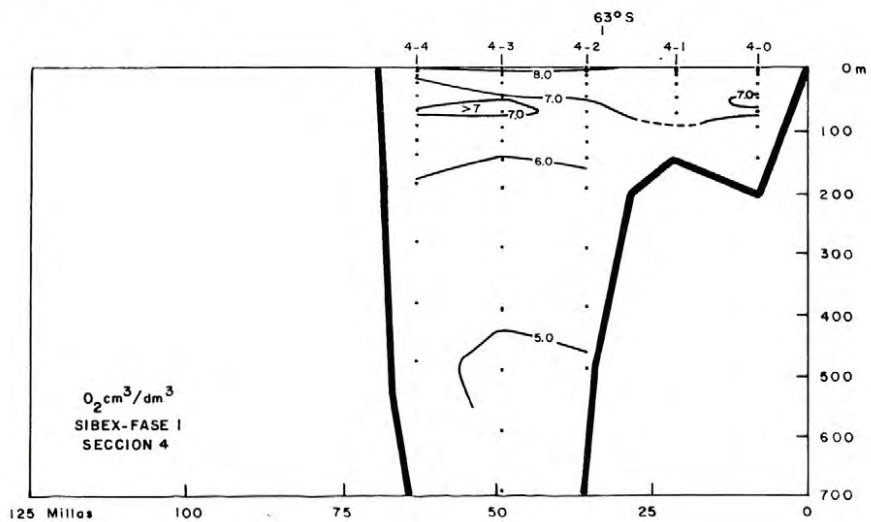
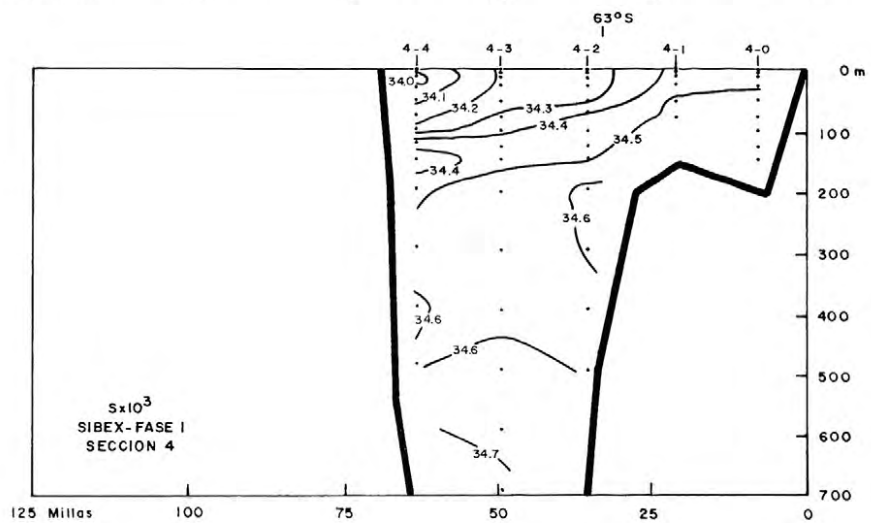
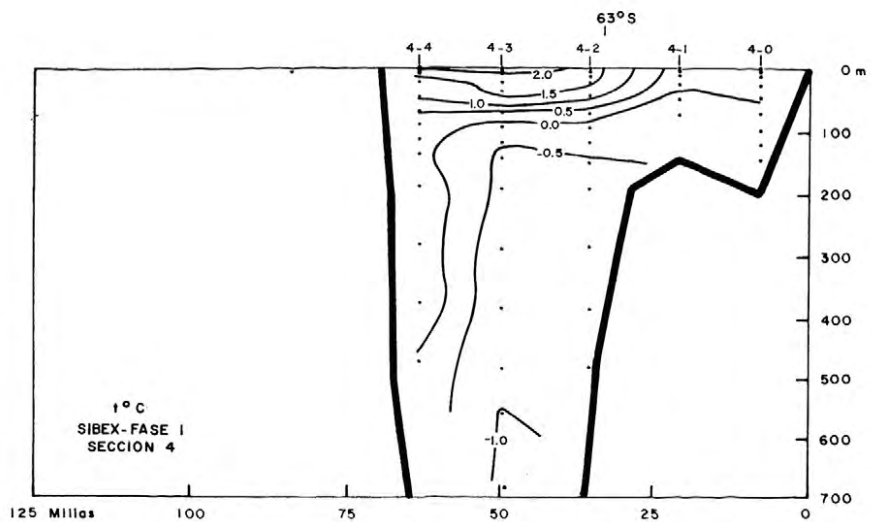


Figure 11: Vertical distribution of temperature, salinity and dissolved oxygen in Section 4.

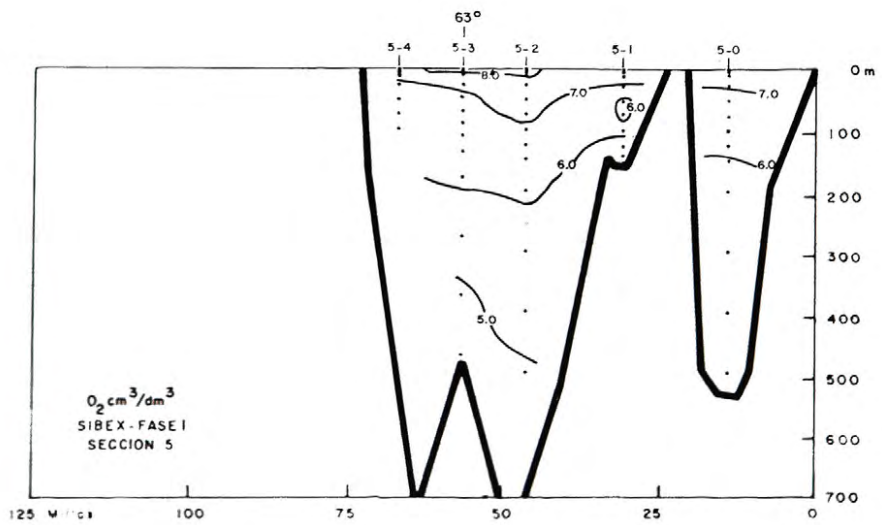
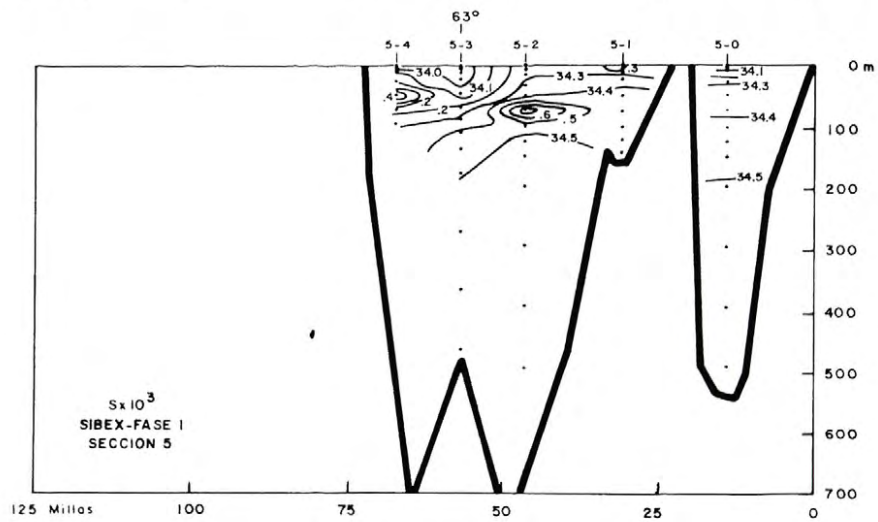
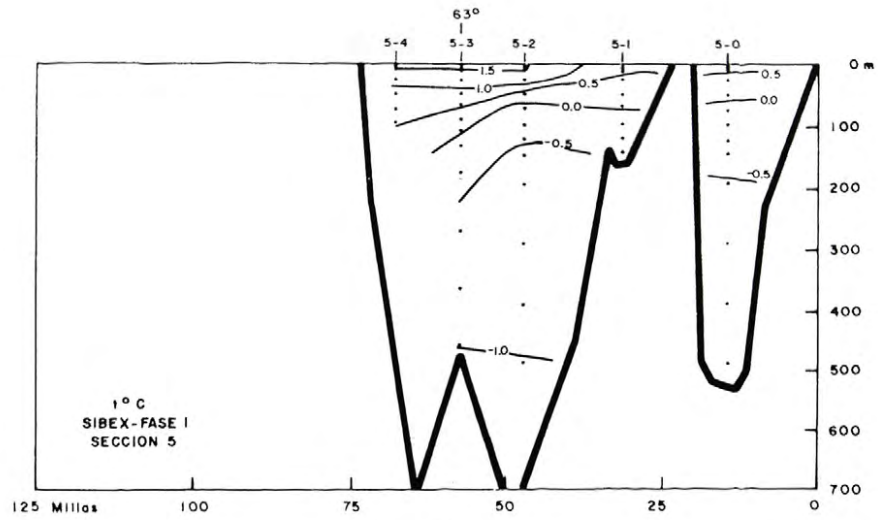


Figure 12: Vertical distribution of temperature, salinity and dissolved oxygen in Section 5.

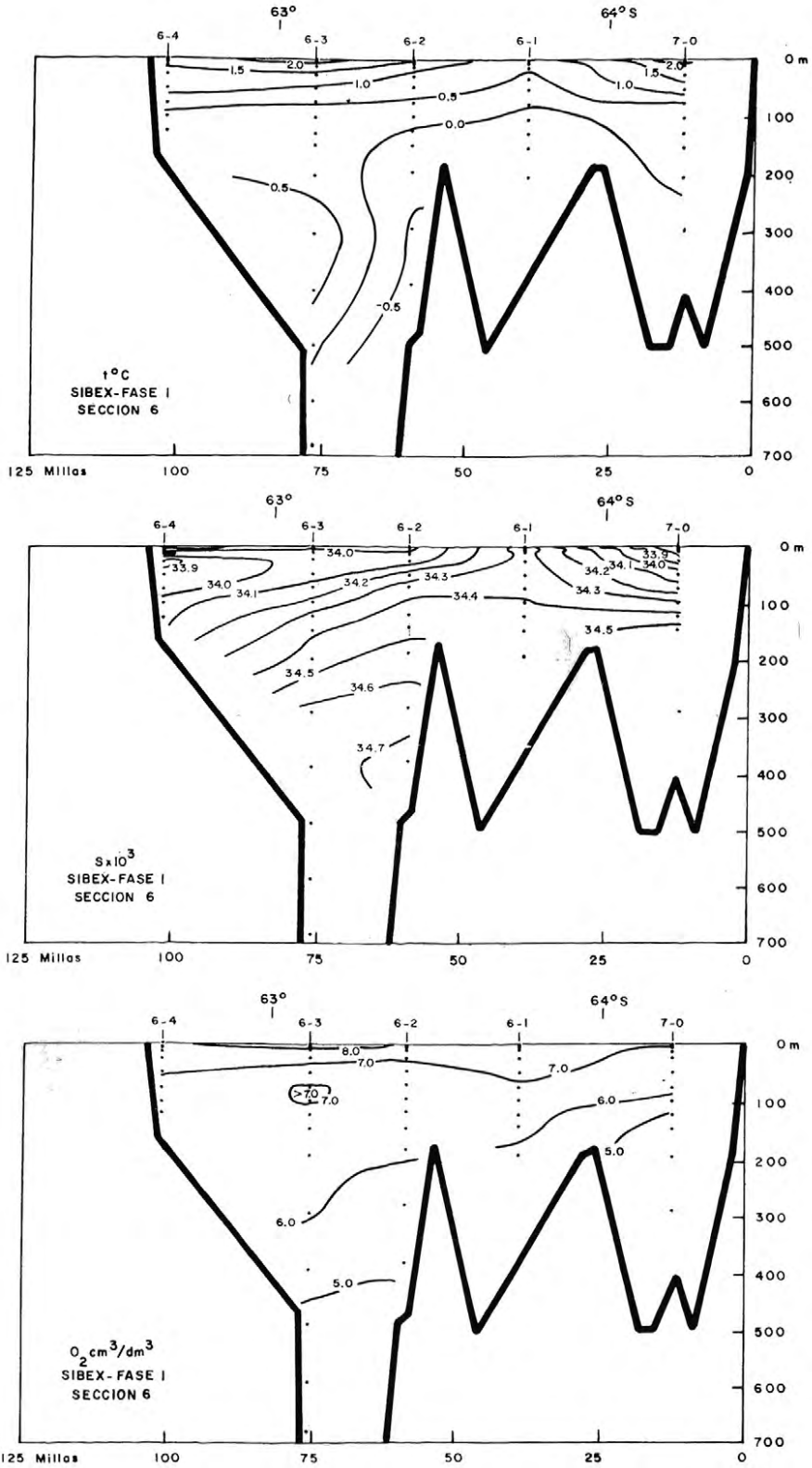


Figure 13: Vertical distribution of temperature, salinity and dissolved oxygen in Section 6.

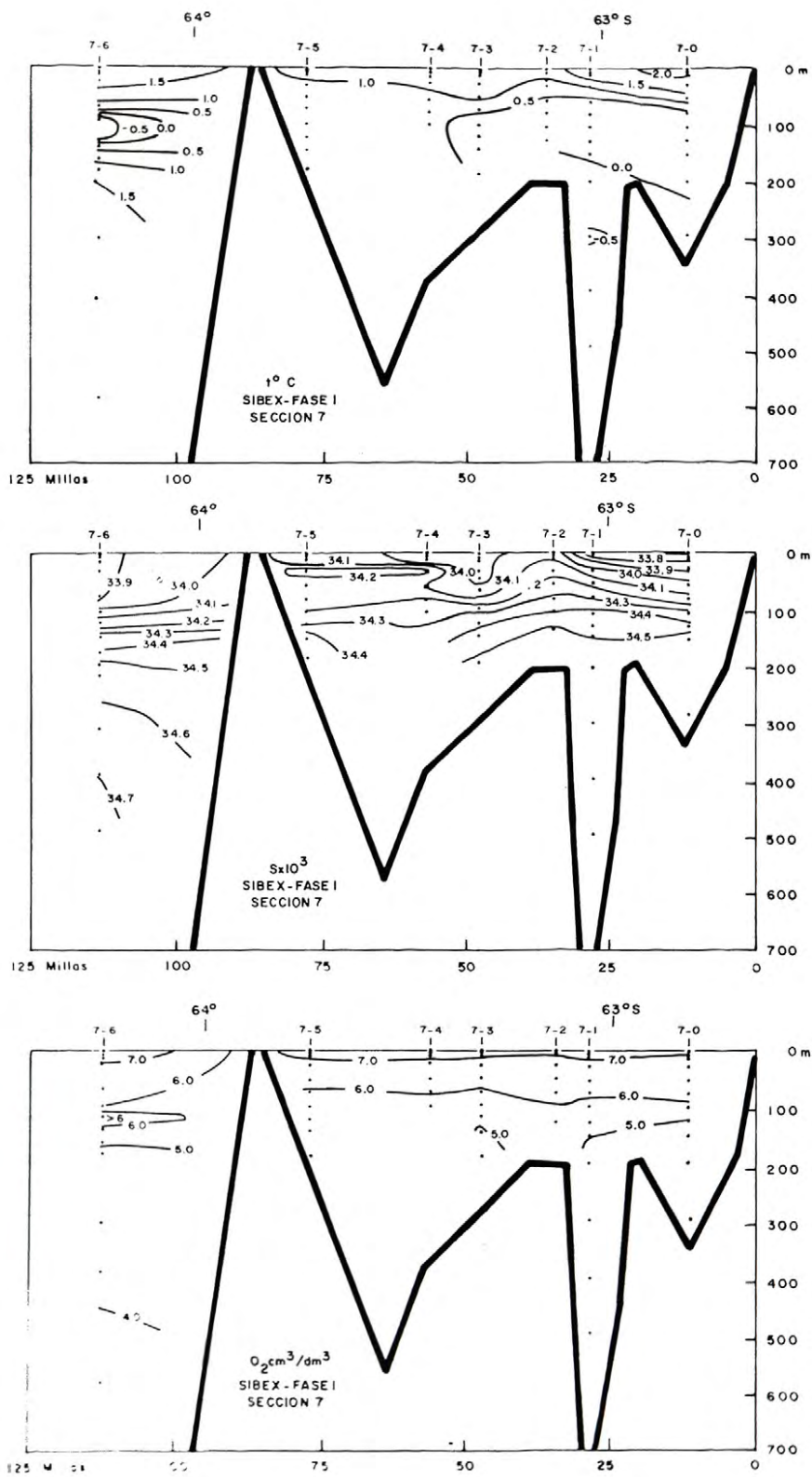


Figure 14: Vertical distribution of temperature, salinity and dissolved oxygen in Section 7.

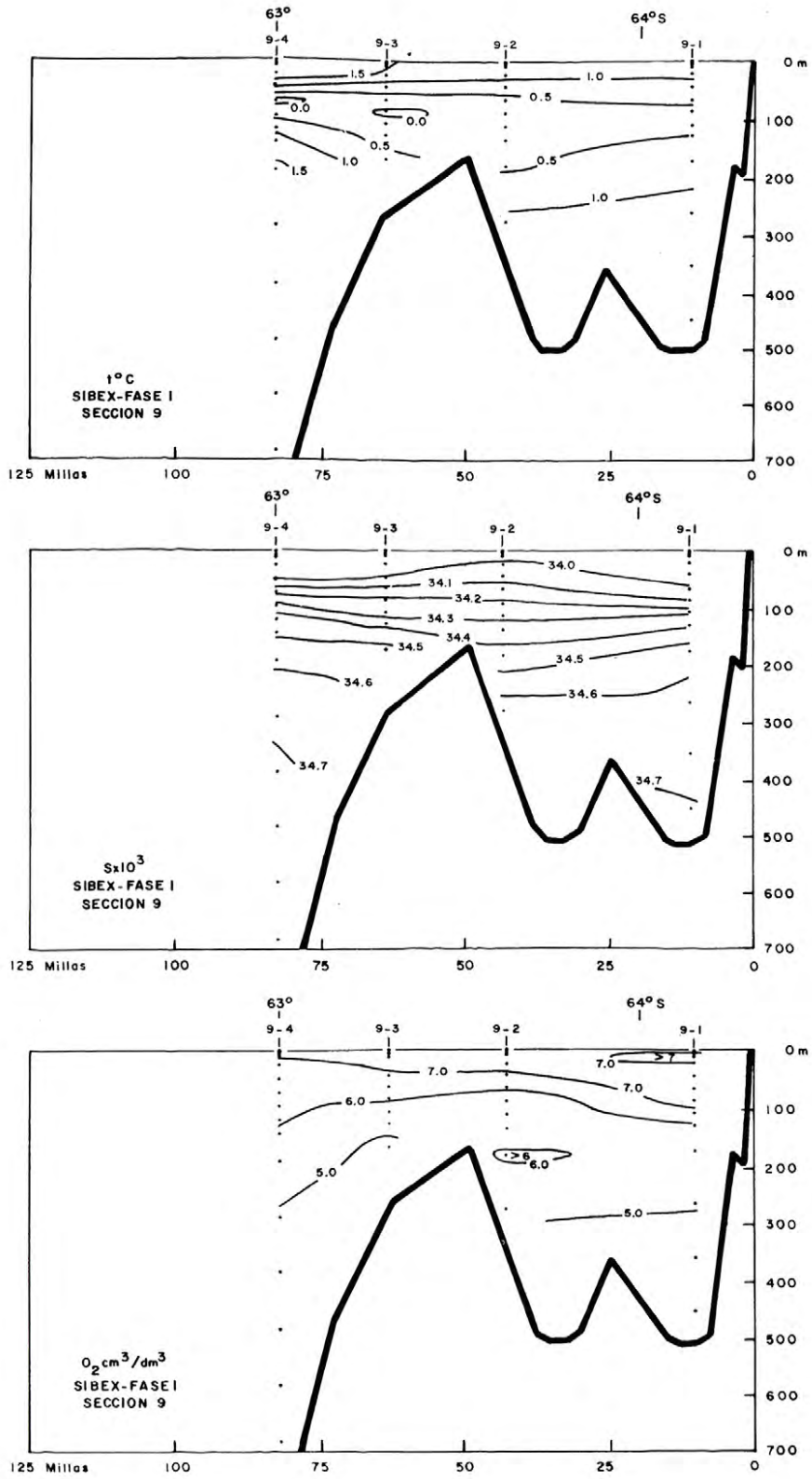


Figure 15: Vertical distribution of temperature, salinity and dissolved oxygen in Section 9.

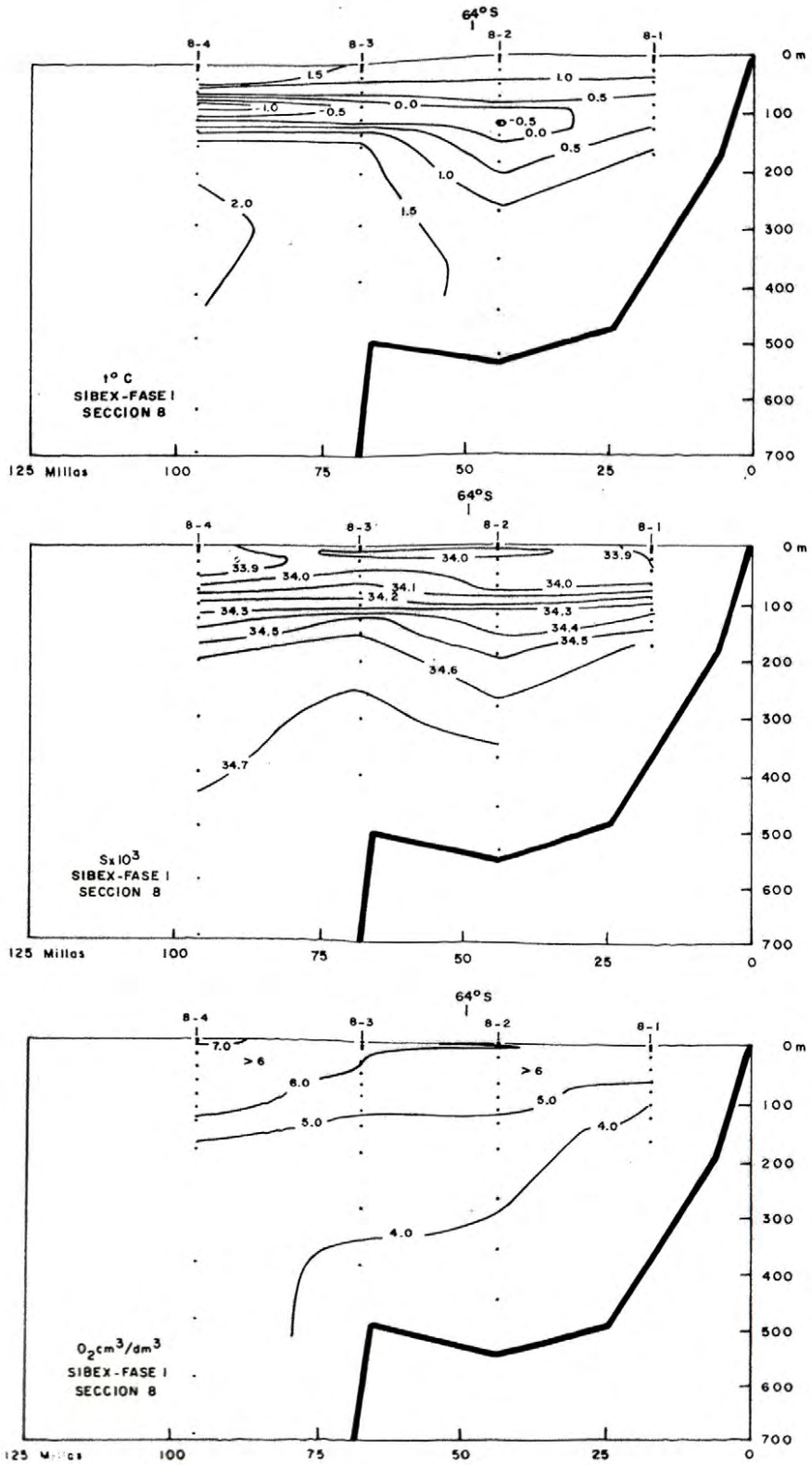


Figure 16: Vertical distribution of temperature, salinity and dissolved oxygen in Section 8.

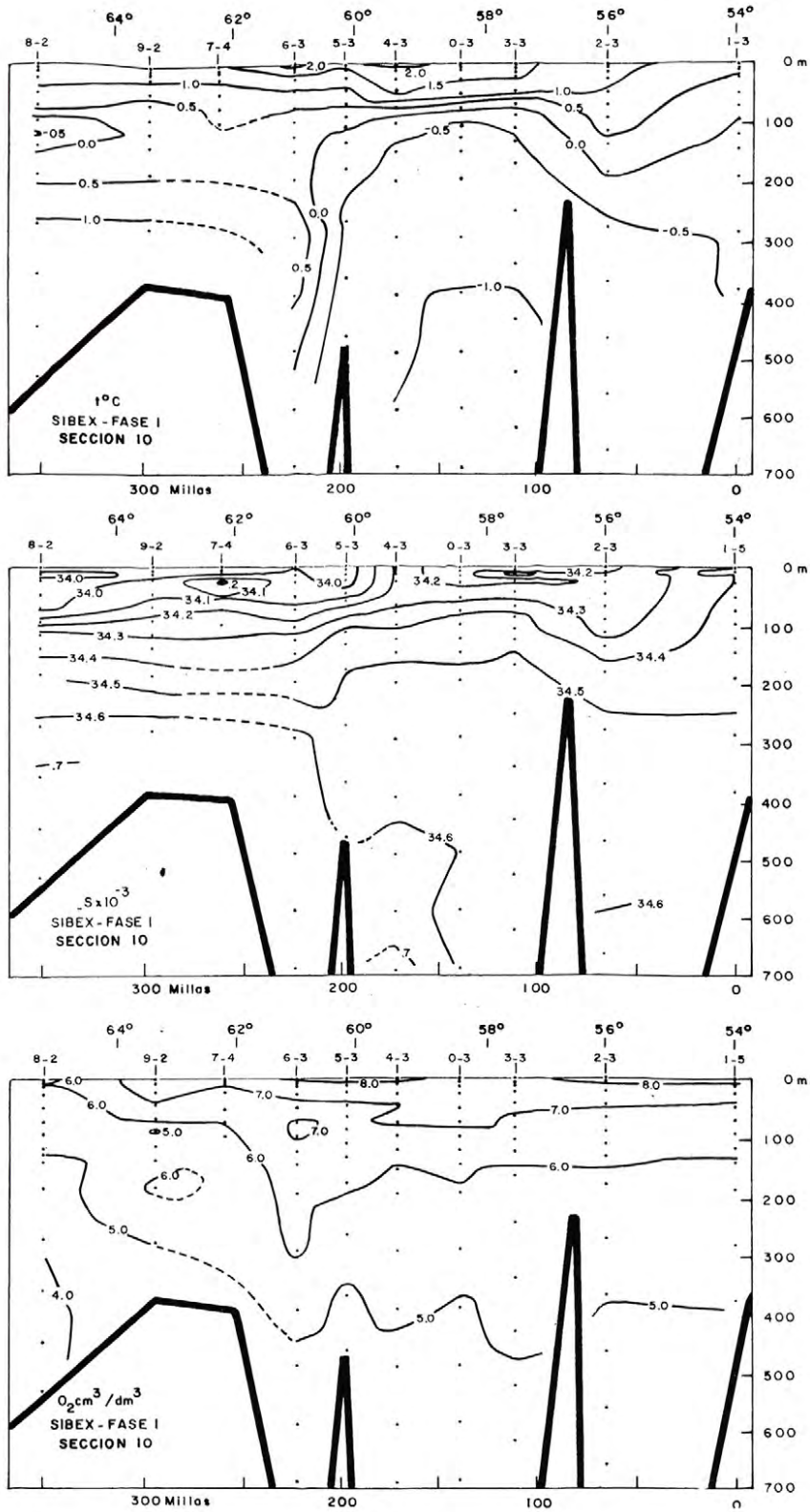


Figure 17: Vertical distribution of temperature, salinity and dissolved oxygen in Section 10.

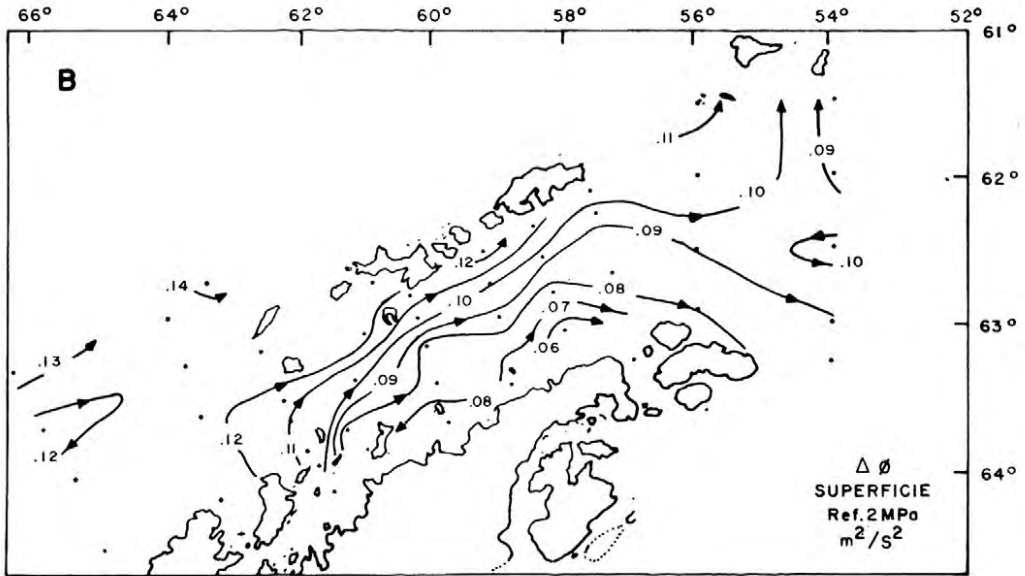
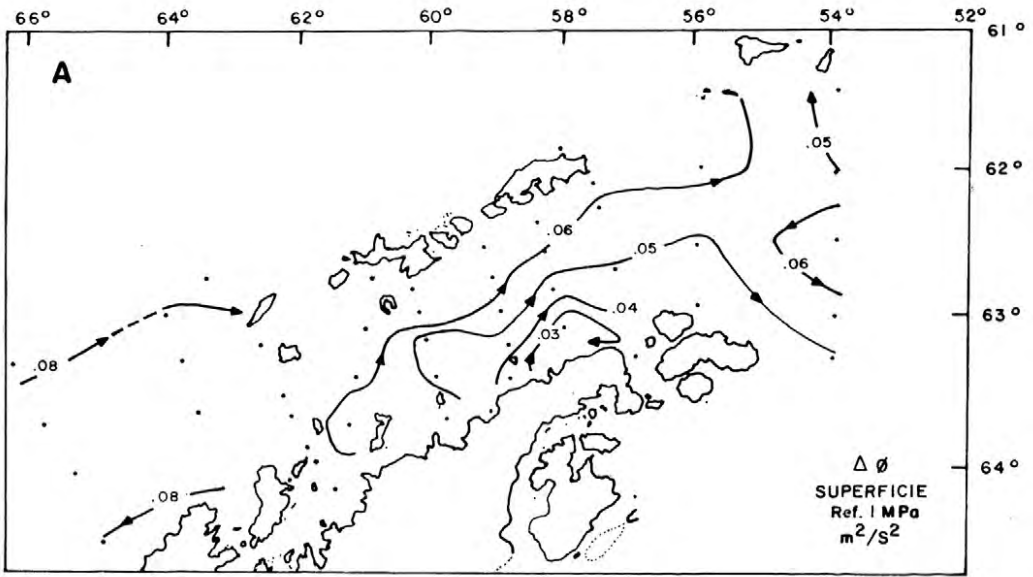


Figure 19: Geopotential difference: A) Referred to 1 MPa. B) Referred to 2 MPa.

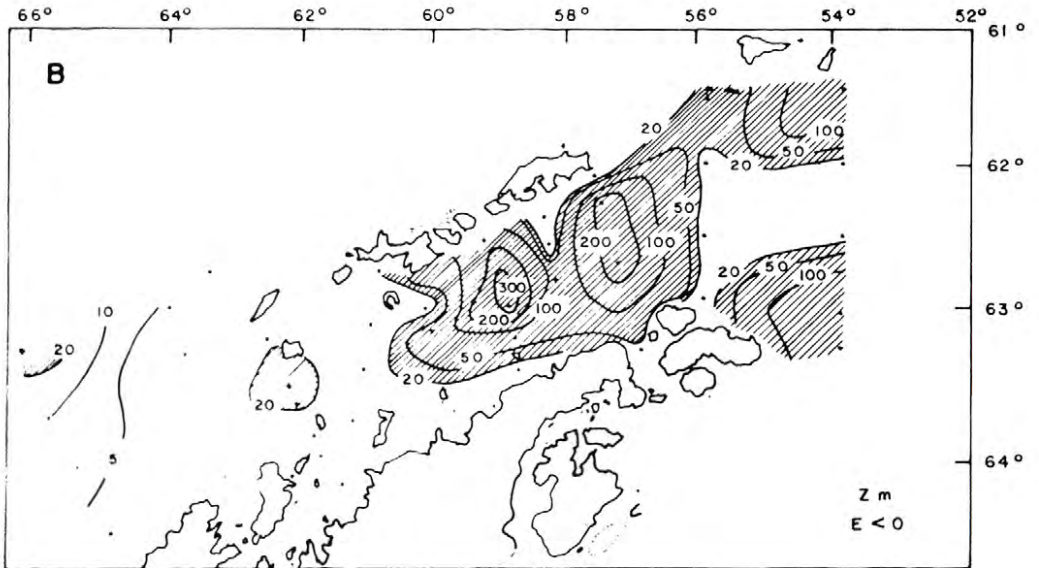
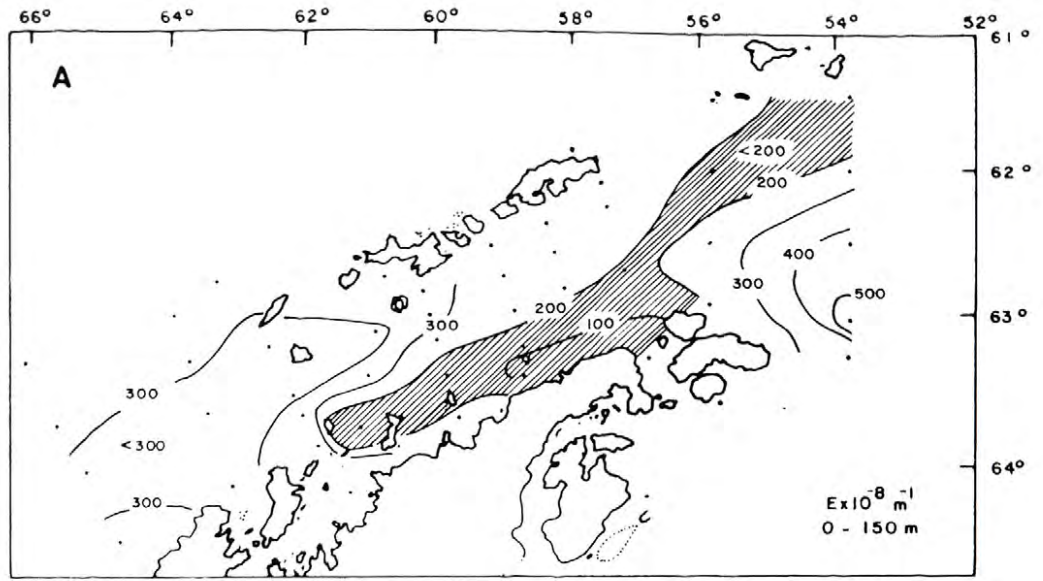


Figure 20: A) Stability of the water column between 0 and 150 meters depth; B) Depth of negative stability.

REFERENCES

- BIOMASS SCAR/SCOR/IABO/ACMRR. 1982. First Post-FIBEX Hydrographic Data Interpretation Workshop. Hamburg, F.R.G. 20-26 Sept. 1982. Biomass Report Series 30.
- BIOMASS SCAR/SCOR/IABO/ACMRR. 1983. Second Post-FIBEX Data Interpretation Workshop. Hamburg, F.R.G., 16-20 May 1983. Biomass Report Series 31.
- CARPENTER, J.H. 1965. The Chesapeake Bay Institute Technique for the Winkler dissolved oxygen method. *Limnol. and Oceanogr.* 10:141-143.
- CLOWES, A.I.J. 1934. Hydrology of the Bransfield Strait. *Discovery Rep.* 9:1-64.
- GORDON, A.I. and W.D. Nowlin, Jr. 1978. The basin waters of the Bransfield Strait. *J. Phys. Oceanogr.*, 10:1584-1610.
- LYNN, R.J., BLISS K.A. and L.E. ELBER. 1982. Vertical and horizontal distributions of seasonal mean temperature, salinity sigma-t, stability, dynamic height, oxygen and oxygen saturation in the California Current, 1950-1978. *CalCOFI, Atlas N° 30.*
- QUINN, W. ZOPF, D. SHORT K. and R. KUO YANG. 1978. Historical trends and statistics of the southern oscillation, El Niño, and Indonesian droughts. *Fishery Bull.* 76(3):663-678.
- QUINN, W. and D. ZOPF. 1984. The unusual intensity of the 1982-1983 ENSO event. *Tropical Ocean-atmosphere Newsletter.* 26:7-8.
- REID, J.L. and A.W. MANTYLA. 1976. The effect of the geostrophic flow upon coastal sea elevations in the northern north Pacific Ocean. *J. Geophys. Res.* 81(18):3100-3110.
- SALAMANCA, M. and A. ACUÑA. 1982. Estudio sobre oceanografía química en las masas de agua en que habita el krill. *Ser. Cient. INACH* 28:137-161.
- SIEVERS, H. 1982. Descripción de las condiciones oceanográficas físicas, como apoyo al estudio de la distribución y comportamiento del krill. *Ser. Cient.* 28:87-136.
- STEIN, M. and S. RAKUSA-SUSZCZEWSKI. 1983. Geostrophic currents in the South Shetland Island area during FIBEX. *Memoirs of National Institute of Polar Research. Proceedings of the Biomass Colloquium in 1982. Special Issue* 27:24-34.
- URIBE, E. 1985. Distribución y abundancia de clorofila "a" durante SIBEX (FASE 1). *Ser. Cient. INACH,* 33:121-158.