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14. Abstract/Notes

INPE scientists participated in the CABO FRIO VI cruise, sponsored by the Brazilian Hydrographic and Navigation Office (DHN). During the cruise hydrographic data were collected along 8 meridional sections to the east, south and west of Cabo Frio. A precision radiation thermometer also obtained continuos surface temperature data from the underway ship. Preliminare analyses of the 8 hydrographic sections showed the coolest surface water (19.4ºC) to be located south of Cabo Frio at the most inshore station. A surface thermal gradient (0.33ºC/km) was found between the second and third most inshore along the same section. The continuous record of the radiometer, however, showed the coolest water (17.4ºC) to be between the most inshore stations and to be accompanied by an even stronger surface thermal gradient (3.25ºC/km) on the seaward side of the coldest water. Surface charts of temperature, salinity and density (sigma-t) were also analyzed and showed relatively low salinity to correspond to a cool surface plume and to extend south and west of Cabo Frio. Further to the south warm water of high salinity was present from the Brazil Current. Vertical profiles from the 8 sections, subsurface horizontal charts and shipboard winds are also discussed. The presence of a layer of cool, relatively low salinity water residing at 100-150 m on the continental shelf and a core of warm, saline Brasil Current water at the shelf are discussed in terms of the local geostrophic circulation and upwelling conditions.

15. Remarks

This paper was presented at the International Symposium on Utilization of Coastal Ecosystems: Planing, Pollution and Productivity, hold at Rio Grande - RS, November 22-27, 1982.

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WATER CHARACTERISTICS AND CIRCULATION IN THE CABO FRIO UPWELLING AREA DURING CABO FRIO VI CRUISE, NOVEMBER 3-14, 1981.

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ABSTRACT

INPE scientists participated in the CABO FRIO VI cruise, sponsored by the Brazilian Hydrographic and Navigation Office (DHN). During the cruise hydrographic data were collected along 8 meridional sections to the east, south and west of Cabo Frio. A precision radiation thermometer also obtained continuous surface temperature data from the underway ship. Preliminary analyses of the 8 hydrographic sections showed the coolest surface water (19.4^{o}C) to be located south of Cabo Frio at the most inshore station. A surface thermal gradient (0.33^{o}C/km) was found between the second and third most inshore stations along the same section. The continuous record of the radiometer, however, showed the coolest water (17.4^{o}C) to be between the most inshore stations and to be accompanied by an even stronger surface thermal gradient (3.25^{o}C/km) on the seaward side of the coldest water. Surface charts of temperature, salinity and density (sigma-t) were also analyzed and showed relatively low salinity to correspond to a cool surface plume and to extend south and west of Cabo Frio. Further to the south warm water of high salinity was present from the Brazil Current. Vertical profiles from the 8 sections, subsurface horizontal charts and shipboard winds are also discussed. The presence of a layer of cool, relatively low salinity water residing at 100-150 m on the continental shelf and a core of warm, saline Brazil Current water at the shelf are discussed in terms of the local geostrophic circulation and upwelling conditions.

Introduction

Coastal upwelling can be generally described as the result of one or more physical processes that give rise to an offshore movement of water on the continental shelf or above the slope, resulting in a replacement of this water from depths usually greater than that advected offshore. Because the water in the surface layer is replaced by water from greater depth, the area in which upwelling occurs exhibits lower temperature in the surface layer than in the surrounding water. Coastal upwelling has been found to occur in many coastal zones of the world, although the driving forces and resulting circulations are frequently different as noted by Smith (1981) for 3 different geographic locations. Interest in studying coastal upwelling has been strong, persistent and widespread. During its committment to the multiyear Coastal Upwelling Ecosystems Analysis (CUEA) Project for instance the United States invested more than 20 million dollars (Wooster 1981).

The occurrence of coastal upwelling off the Brazilian coast at Cabo Frio was first reported by Emilsson (1956). Various and descriptive numerical studies of the Cabo Frio region were subsequently made and the vertical velocity of upwelling for the Cabo Frio area was estimated to be up to about 10^{-2} cm sec^{-1} (Inostroza et al 1976; Jeng 1977; Tanaka and Almeida 1978, etc.) Other researchers have noted an eastward flowing bottom current from current meter observations made on the continental shelf near Cabo Frio (Rodrigues, 1977; Fahrbach and Meincke 1979). Cool water with a salinity of about 35.2-35.5‰ has also been observed south of Cabo Frio and to the west along the botton of the continental shelf and has been associated with an eastward subsurface flow (Mascarenhas Jr. et al, 1971). A recent study by Miranda (1982) provides a fairly detailed analysis of water masses on the continental shelf between Cabo de São Tomé and Ilha de São Sebastião. The literature suggests that Cabo Frio upwelling is generally more limited in scale when compared to upwelling centers located along eastern margins of the world's oceans.

For Brazil the Cabo Frio area is generally considered to be the site of the strongest center of upwelling on the Brazilian coast. Studies describing various aspects of the Cabo Frio upwelling center have been made and they are in the literature (Almeida et al, 1971; Rodrigues, 1973; Tanaka, 1977). The present study considers spatial variations of physical properties and parameters such as temperature, salinity, sigma-t, geostrophic circulation and also remotely sensed temperature data from the hydrographic vessel.

This report is based on data from the CABO FRIO VI cruise made during 3-14 November 1981 using the Brazilian hydrographic vessel Almirante Saldanha under the sponsorship of the Diretoria de Hidrografia e Navegação located in Rio de Janeiro. The area of the study is seen in "Figure 1". During the cruise 49 hydrographic stations were occupied along 8 meridional transects extending across the continental shelf "Figure 2". Among the data collected during the cruise were: temperature, salinity, dissolved oxygen, shipboart meteorological observations, chlorophyll, nitrate, silicate, phosphate, Secchi disk insitu photometer, net tows and some geological grab samples. Information in the Material and Methods Section is limited to that used in this report. A report discussing results from a comparison of chlorophyll with temperature and the chemical nutrient data is given by Maluf and Stevenson (1982) in a separate report.

Material and Methods

Temperature measurements were used from two sources: Nansen bottles containing precision reversing thermometers and radiometer temperatures from a Precision Radiation Thermometer (Barnes Model PRT-5). Subsurface temperatures were available only from the Nansen casts. Nansen temperatures were processed in the conventional manner and are considered accurate to within 0.02°C. The PRT-5 instrument was calibrated together with its stripchart recorder prior to the cruise and the data are considered known to within 0.1°C.

Following the cruise, the analog record of the radiometric brightness temperatures were routinely digitized by hand at 1 cm intervals, plus any thermal gradient features, maxima, minima, etc. Even after normal calibration radiometers may not give the same temperatures as bulk temperatures (Saunders, 1970). To determine the extent of departure of the PRT-5 readings from the

Nansen temperatures, paired temperatures at each hydrostation were used to determine at least squares fit. For Transect III and IV this effort yielded:

$$T_{nan} = 5,65\ T_{prt} - 5.78$$ (Transect III) and

$$T_{nan} = 5.71\ T_{prt} - 6.67$$ (Transect IV), both significant at > 99% level. The regression equations were then used with the radiometric temperatures to obtain an estimate of error about the regression line-that is to obtain and estimate of the Root Mean Square Error (RMSE) for the PRT-5 instrument of ±0.17^{o}C for Transect III and ±0.30^{o}C for Transect IV data.

Salinity samples were collected from Nansen bottles for each hydrocast and the salinity values were determined from inductive salinometers. Salinity data are considered known to within about 0.02^{o}/oo.

Sigma-t was determined from paired temperature and salinity data and calculated from equations of state given in Lafond (1951) using a microcomputer. Questionable values of temperature, salinity or sigma-t were resolved by comparing T-S diagrams for the station in question with adjacent stations.

Horizontal charts of temperature, salinity and sigma-t were prepared for 0,50 and 75 m depth using the corrected hydrographic data in the usual manner. Vertical hydrographic sections for T, S and sigma-t were also constructed from 0 to 300 m depth. Horizontal profiles temperature from PRT-5 data were constructed using the digitized record data.

Maps of geostrophic circulation for the surface and 50 m depth were next constructed. To obtain geopotential anomaly data for the individual stations a program was written for a microcomputer starting with specific volume anomaly values. A decision was made to reference the geopotential field to the 300 decibar surface (approzimately 300 m depth). The more southerly stations shown in "Figure 2" were sufficiently deep, but the inshore went stations only to intermediate depths. To allow for a common reference level the dynamic height increments of the adjacent deeper stations were used for those depths of the shallower stations that were below the maximum cast depth. In this manner it was possible to numericaly integrate the data from the shallow stations to obtain a reference level of 300 db for all of the stations. It is important to note that such an extrapolation technique does not provide new data at depth since the extrapolated data in the column is homogenous to the adjacent stations. Instead, only the upper part of the water column (for which data are available) varies, depending upon the data of the individual stations. The technique is not new and has been noted a number of times in the literature. Interpretation of the circulation around the shallow water stations must be considered more qualitative than quantitative. Additional information regarding the hydrographic station data and the cruise may be obtained from the report Ministério da Marinha, IPqM (1982).

Results

The wind data during the cruise period suggested that conditions favorable to upwelling (wind blowing from the northeast quarter) were only present during november 6 and 7, when the ship was traversing Transect II and a part of III. During the rest of the cruise, the winds were either intermittent or blowing from the southern quarter. For this reason it is considered that the cool upwelled water observed on Transects III and IV presented a weak upwelling state followed by a relaxation of the fluid system.

PRT-5 Temperature Profiles

The two mos interesting profiles of radiometric temperature, that is the profiles that indicate both the recently upwelled water and a warm core eddy, are shown in "Figure 3" (A,B). The Nansen temperatures are shown by dotted lines while the continuous radiometric temperatures are given by solid line. The strongest gradient from the Nansen temperatures is found between station 5927 and 5928 where the gradient is 0.33^{o}C/km.

The coolest water was found by the radiometer Transect III where 17.4^{o}C was observed just inshore of station 5927. The most interesting feature of "Figure 3" is the presence of two strong fronts associated with the cold water. The inshore front had a gradient of 3.3°C/km, while the offshore front had a gradient of 0.76°C/km. The temperature difference, however, was 4.9°C and 3.0°C respectively, for the offshore front and inshore front. In addition a number of secondary frontal features were present further offshore, where the temperature differences across the front approached 1°C.

Transect IV also contained cool upwelled water although about 2°C warmer than that observed on Transect III. Some thermal gradients are present on Transect IV but they are weaker also than those observed South of Cabo Frio.

Surface Temperature, Salinity and Sigma-t

Variations in the surface distribution of temperature, salinity and sigma-t are seen in "Figure 4" (A,B,C,). The coolest surface water (< 20°C) is present just south of Cabo Frio along Transect III and extends westward to Transect IV and corresponds to the area most often observed to have cool surface water. A thermal front is present along the southern limit of the cool upwelled water where it comes into contact with water of the Brazil Current. The 35.25-35.50°/oo isohalines curve toward and around the same area indicated by the cool isotherms but the salinity field does not as clearly indicate the effect of upwelling due to runoff and discharge from rivers and coastal embayments. The 25.25-25.50 σ_t values are more clearly related to temperature than salinity. A second cool patch of water is evident along Transect VIII and corresponds to a salinity of 35.25-35.50^{o}/oo and a σ_t of 24.50-25.00. This density is less than for the upwelling center off Cabo Frio but although the isohalines extend from the Cabo Frio area to the westerly patch of cool water. The third feature of note is the warm (> 23^{o}C) water with 36.25-36.50^{o}/oo salinity. The temperature and salinity values are those commonly associated with water from the Brazil Current. Because the effect of the warm temperature with high salinity are compensatory, the σ_t of the saline patch is intermediate to that of the coastal water and upwelled water.

Temperature, Salinity and Sigma-t at 50 m Depth

Temperature is coolest again on Transect III just south of Cabo Frio although 13-14^{o}C water is also present alongshore between Transects III and VIII "Figure 5" (A,B,C). There is a decrease of about 7^{o}C from the surface to water at 50 m depth. The salinity associated with the cool water is 35.25^{o}/oo which gives rise to a σ_t of 26.5. The difference in surface density and density at 50 m is due to the temperature change between the two depths.

The warm water found near 23^{o} 45'S, 42^{o} 15'W is only 1^{o}C cooler than the surface water. Due to the closed pattern at the surface and the circular pattern at 50 m, the warm water has the appearance of a warm core eddy. The salinity in this eddy is $\geq$ 36.50^{o}/oo and has a σ_t of 25.50.

The cool water feature located along Transect VIII has become a part of the cool water on the shelf and has a salinity of about 35.50^{o}/oo and a σ_t of about 26.50, the same density observed for the upwelling center south of Cabo Frio.

Temperature, Salinity and Sigma-t at 75 m Depth

The cool patch of water off Cabo Frio and the warm core eddy are still present at 75 m depth "Figure 6" (A,B,C). The cool water has the same temperature and salinity as that at 50 m and indicates that the water has undergone little or no mixing from 75 m to 50 m. Both the 13^{o}C isotherm and the 35.25^{o}/oo isohaline follow the bathymetry of the shelf and suggest that the cool water observed at the cool sea surface naer Cabo Frio does not upwell just from the south but that water of the same characteristics is found along the continental shelf to the west. The 26.5 isopycnal follows both the 13^{o}C and 35.25^{o}/oo isolines.

The warm core eddy contains water only 2^{o}C cooler than that found at the surface. A salinity of 36.5^{o}/oo and a σ_t 25.50 also suggest that the warm core eddy is only slightly modified in the upper 75 m of the water.

Vertical Sections

Vertical sections of temperature, salinity and sigma-t are shown for Transect III in "Figure 7" (A,B,C,) and for

Transect IV in "Figure 8" (A,B,C). Along Transect III warm ($22-23^{o}C$), saline ($36.2^{o}/oo$) water of the Brazil Current was found over the continental slope and extended onto the shelf as far as station 5928. The core of the Brazil Current water lies at 50 m depth where the salinity is $36.4-36.6^{o}/oo$ and the water temperature is $22-23^{o}C$. This values are consistent with those of the Oceanographic Atlas for the month of November (Inostroza and Maluf, 1978). The sigma-t associated with this core is 25.4. Inshore of station 5928 the strong thermal and haline fronts separate the Brazil Current from the cool, less saline upwelled water. At 100-125 m depth, $12^{o}C$ water with a salinity of $35.2^{o}/oo$ and σ_t of 26.6 is found lying on the continental shelf. The upwarping of the isotherms and isopycnals on the slope and over the shelf suggest that the cold water normally found at a depth of 200 m was advected up and onto the shelf during the upwelling process. A comparison of "Figures 3A and 7A" shows that the $17.40^{o}C$ water observed by the radiometer was present at 10-20 m at station 5927. Upwelling was sufficiently strong apparently to bring this water from a depth of 125 m over the slope to within 10-20 m at station 5927 and to the surface just inshore of this station.

Vertical sections of temperature, salinity and sigma-t for Transect IV are seen in "Figure 8" (A,B,C). Warm water in the upper 50 m indicates that the Brazil Current is present on the continental shelf in this hydrographic section; and the core of the Current is evident in 8B as a salinity maximum at 30 m depth. The inshore boundary of the Current, however, does not have the strong frontal interfaces seen in the Cabo Frio transect. The 17^{o}C water seen on or near the surface south of Cabo Frio is found at 20-30 m in this section. This water is present at 125 m depth over the slope. Water lying on the bottom of the shelf "Figure 8A" is also about 1^{o}C warmer than the cold core noted in Transect III. The salinity and density of this cold core, none the less is 35.2^{o}/oo and 26.6 σ_t respectively, and indicate that the core is the same for both transects. The difference between Transects III and IV is that the features seen in Transect IV are generally weaker than those same features observed on the Cabo Frio Transect.

Geostrophic Circulation

Geostrophic circulation was determined from the geopotential anomaly (ΔD) field for the sea surface and for 50 m depth, both referenced to the 300 decibar (db) surface. It is to be remembered that the circulation indicated for the inshore stations is based on extrapolation to 300 m depth and must therefore be considered very qualitative.

Surface circulation is shown in "Figure 9A". The circulation is dominated by the Brazil Current which enters the area from the north-east. After flowing around and to the south of Cabo Frio, the Current meanders as it continues to the west and south. The warm core eddy previously noted is readily seen in the circulation as a counterclockwise feature. With this sense of rotation, the surface water tends to flow inward toward the center of the eddy and the warm, saline characteristics of the eddy are preserved. The eddy in "Figure 9A" can be expected to contain low levels of nutrients since no nutrient rich water is expected to ender through the bottom of the eddy (Maluf and Stevenson, 1982).

To the south of Cabo Frio, water appears to leave from the coast and flows out to sea. It is recalled that geostrophic circulation only accounts for the horizontal circulation that would normally flow parallel to the coast when in proximity to the coast. In this instance the vertical component of motion (the upwelling velocity) provides the needed mass implied by the anomalous observed pattern. The circulation recurves back toward the coast and suggests why some cool water is present along Transect IV, but not the strong upwelling fronts observed along Transect III.

Circulation at 50 m is shown in "Figure 9B". The warm core eddy is also present and is seen by its counterclockwise rotation, along the edge of the Brazil Current. The circulation tongue extending from the Cabo Frio area is still present and suggests that there may be appreciable upwelling present at this depth. There appears to be good qualitative agreement between the isotherm distribution of "Figure 5A" and the streamlines of "Figure 9B".

Conclusions

Observations from the Cabo Frio VI cruise were used in making several conclusions. During the period of the cruise the wind conditions were only favorable for upwelling during november 6 and 7 and thereafter were either intermittant or unfavorable. During november 3-14, 1981, the Brazil Current (evidenced by 22-23^{o}C, 36.2-36.60/oo and 25.0-25.4 σ_t water) was present over the outer part of the continental shelf of the area of study. Upon approaching and flowing around Cabo Frio, the Current began a series of meanders. Along the northern edge of the Current a warm core eddy was present and possessed counter clockwise rotation. The eddy extended to a depth of at least 75 m with little change in its composition.

South of Cabo Frio, water of 17.4^{o}C was found at the surface by the infrared radiometer onboard the ship. On either side of this cold water thermal fronts were present. The stronger gradient was located on the inshore side of the cold water where the gradient was 3.3^{o}C/km. The temperature difference across the two fronts, however, showed the offshore temperature difference to be 4.9^{o}C and the inshore difference to be 3.0^{o}C. Temperature, salinity and sigma-t information from 50 m and 75 m depths suggests that upwelling was present off Cabo Frio at these depths. The coolest water, found at a depth of about 125 m on the slope, ascended onto the shelf and finally into the surface layer off Cabo Frio. Cold (12^{o}C) water with a salinity of 35.2^{o}/oo and a sigma-t of 26.6 appear to be closely associated with the upwelling center observed off Cabo Frio. This water was also found on the continental shelf to the west of Cabo over a distance of about 125 km. It is proposed that this water is a part of an equatorward undercurrent that may flow along the slope and at times on the continental shelf. When conditions are favorable for upwelling, the undercurrent is not only present in the vicinity of Cabo Frio but ascends into the surface layer forming the patch of cold surface water observed there.

The infrared radiometer used during the cruise provided very useful data for the delineation of surface conditions around the upwelling center and the thermal fronts associated with the center. In addition to being used for airborne studies, the instrument seems well suited for use onboard a research ship.

Acknowledgments

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References

ALMEIDA, E. G.; MASCARENHAS, JR., A. S.; IKEDA, Y. Preliminary results and analysis of the Mission SEREMAR II. São José dos Campos, INPE. Dec. 1971 (Report 14/ONU/INPE).

EMILSSON,I. Relatório e resultados físico-químicos de três cruzeiros oceanográficos em 1956. Contrções. Instituto Oceanográfico Universidade São Paulo, série Oceanogr. fís., (1): 1-70, 1956.

FAHRBACH, E.; MEINCKE, J. Some observations on the variability of the Cabo Frio Upwelling. CUEA Newsl., 8 (3): 13-18, 1979.

INSTITUTO DE PESQUISAS DA MARINHA (IPqM). Projeto Cabo Frio, COMISSÃO OCEANOGRÁFICA CABO FRIO VI, Edição Provisória, maio 1982

INOSTROZA VILAGRA, H. M.; ALMEIDA, E. G.; MASCARENHAS JR., A. S. Expedição Oceanográfica SEREMAR IV. São José dos Campos, INPE, 1976. (INPE-825-NTL/049).

INOSTROZA VILAGRA, H. M.; MALUF, S. Atlas de estruturas oceanográficas da carta Sudeste do Brasil para estudos de sensoriamento remoto. São José dos Campos, INPE, jan. 1978. V. 2. (INPE-1179/NTE/108).

JENG, T. J. Contribuição ao estudo do Fenômeno de Ressurgência Costeira na Região de Cabo Frio (RJ) (long. 42°W - 43°W). São Paulo, Instituto Oceanográfico Universidade de São Paulo, 1977.

LAFOND, E. C. Processing oceanographic data. Washington, DC, U. S. Navy Hydrographic Office, 1951. 114 p. (Pub. 614).

MALUF, S.; STEVENSON, M. R. Comparison of Chlorophyll a measurements with selected physical and chemical parameters in the Cabo Frio upwelling region during nov. 3-14, 1981, International Symposium on the Utilization of Coastal Ecosystems; Planning, Pollution and Productivity. Rio Grande do Sul, 22-27 nov. 1982.

MASCARENHAS JR., A. S.; MIRANDA, L. B.; ROCK, N. J. A study of the Oceanographic Conditions in the Region of Cabo Frio, Costlow, J. D. In: COSTLOW, J. D., ed. Fertility of the sea, Beaufort, Duke University Marine Laboratory, 1971. V. 1, p. 285-308.

MIRANDA, L. B. Análise de massas de água da plataforma continental e da região oceânica adjacente; Cabo de São Tomé (RJ) a Ilha de São Sebastião (SP). Tese de Livre Docente, São Paulo, Instituto Oceanográfico da Universidade de São Paulo, 1982.

RODRIGUES, R. F. Upwelling in Cabo Frio. Thesis MASTER of Science in Oceanography. Monterey, CA, Naval Postgraduate School, 1973.

RODRIGUES, R. F. Evolução da Massa D'água durante a Ressurgência em Cabo Frio. Rio de Janeiro, Instituto de Pesquisas da Marinha, Ministério da Marinha, 1977.

SAUNDERS, P. M. Corrections for airbone radiation thermometers. Journal Geophysical Research, 75 (36): 7596-7601, 1970.

SMITH, R. L. A Comparison of the Structure and Variability of the Flow Field in Three Coastal Upwelling Regions: Oregon, Northwest Africa, and Peru. In: RICHARDS, F. A., ed. Coastal upwelling, coastal and estuarine sciences 1. Washington, DC, American Geophysical Union, 1981. p. 107-118.

TANAKA, K.; ALMEIDA, E. G. Aplicação das imagens de Satélite LANDSAT e dados oceanográficos na verificação de um modelo matemático de ressurgência. São José dos Campos, INPE, ago. 1978. (INPE-1349-NTE/131).

TANAKA, K. Simulação da ressurgência comparada com dados oceanográficos e de sensores remotos em Cabo Frio. São José dos Campos, INPE, 1977. (INPE-1085-TPT/061).

WOSTER, W. S. An Upwelling Mythology. In: RICHARDS, F. A., ed. Coastal upwelling, coastal and estuarine sciences 1. Washington, DC, American Geophysical Union, 1981. p. 1-3.

Figure Legends

1 - Area of study off Southeast Brazil, showing local bathymetry.

2 - Station positions located along the 8 meridional transects.

3 - Radiometric temperature profile for Transect III (A) and Transect IV (B).

4 - Surface maps of Temperature (A), Salinity (B) and Sigma-t (C).

5 - Maps at 50 m depth of Temperature (A), Salinity (B) and Sigma-t (C).

6 - Maps at 75 m depth of Temperature (A), Salinity (B) and Sigma-t (C).

7 - Vertical sections for Transect III, showing Temperature (A), Salinity (B) and Sigma-t (C).

8 - Vertical sections for Transect IV, showing Temperature (A), Salinity (B) and Sigma-t (C).

9 - Geostrophic circulation for the sea surface (A) and 50 m depth (B), referenced to 300 decibar surface.

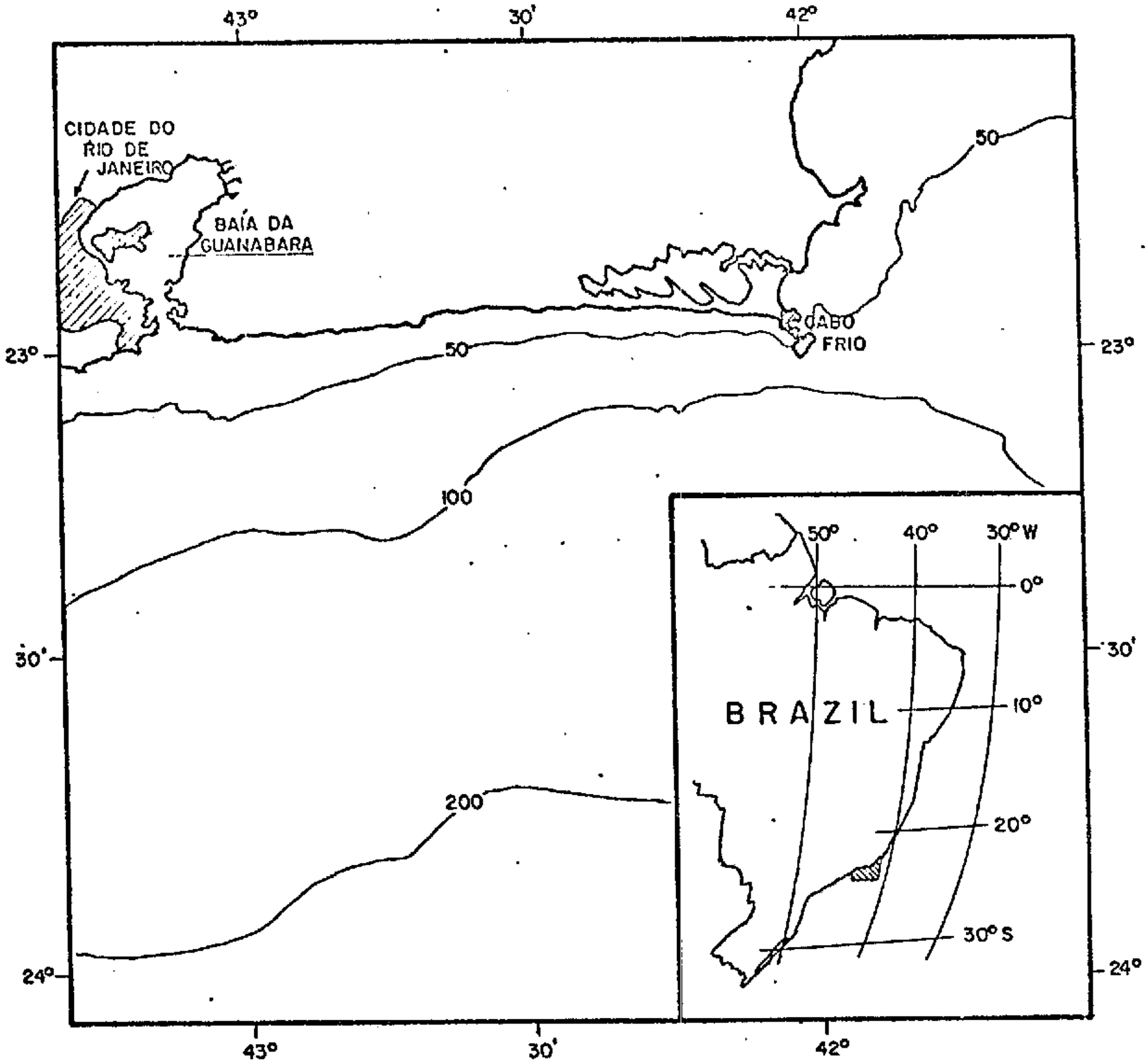

Fig. 1 - Area of study off Southeast Brazil, showing local bathymetry.

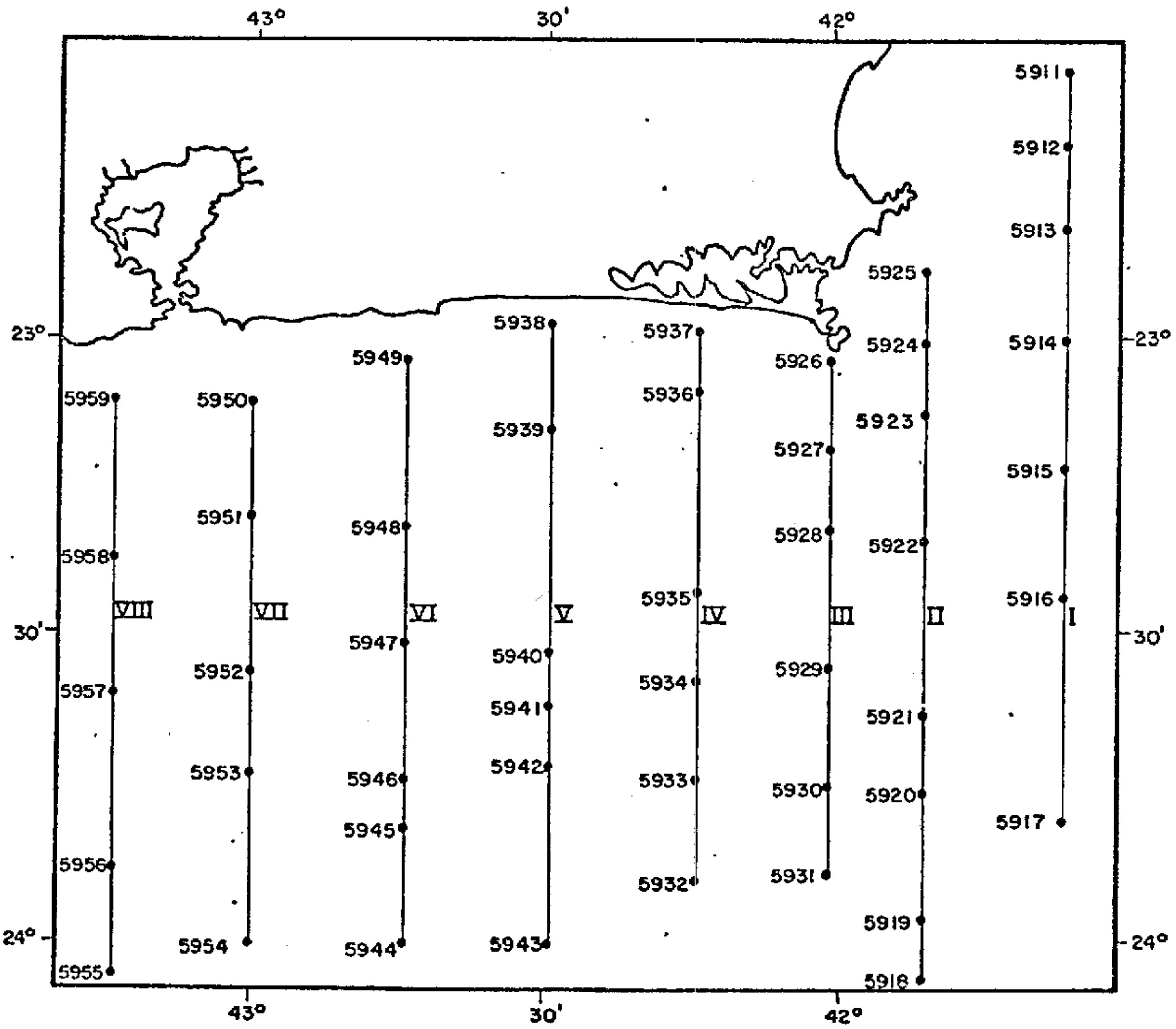

Fig. 2 - Station positions located. along the 8 meridional transects.

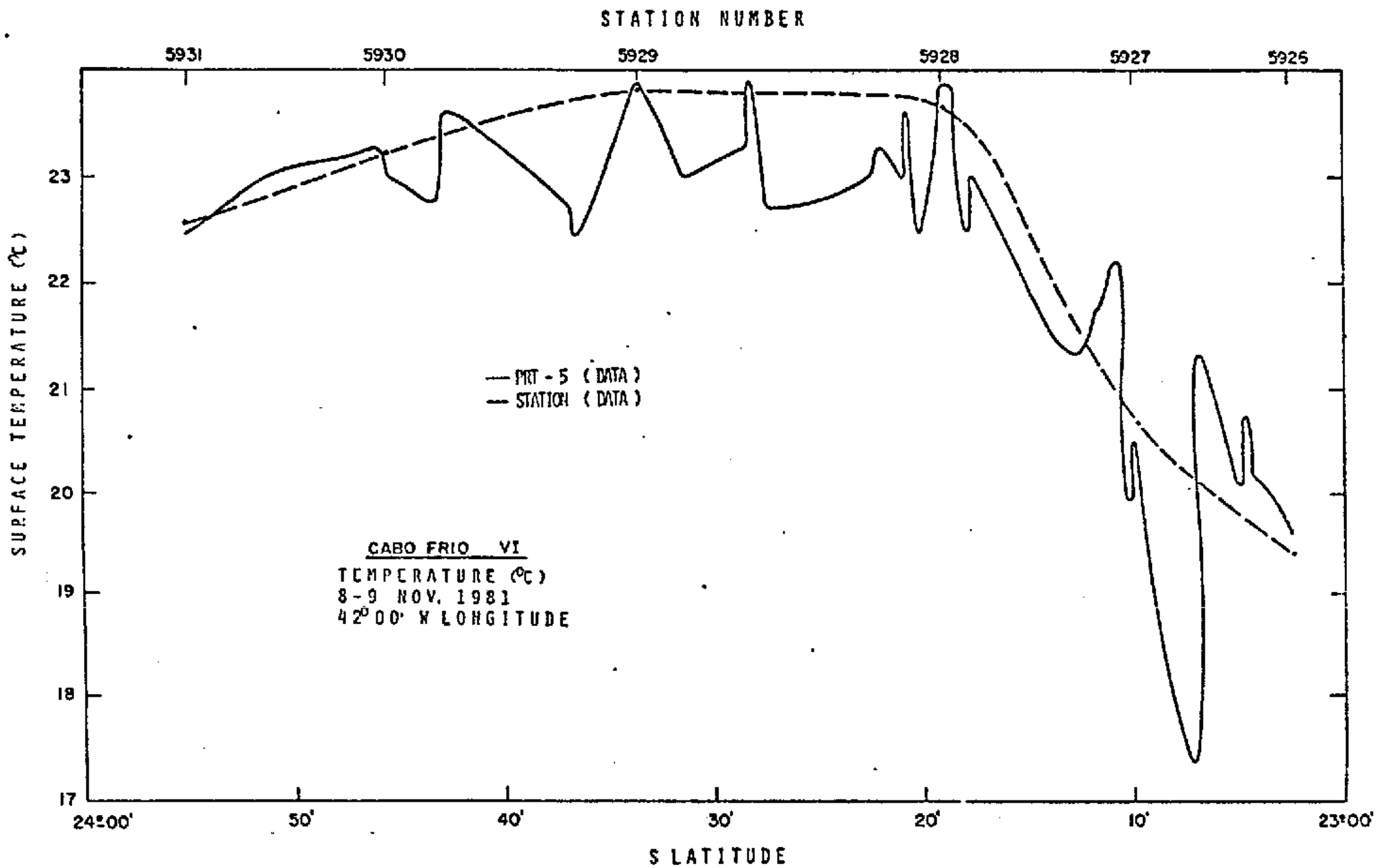

Fig. 3A - Radiometric temperature profile for Transect III.

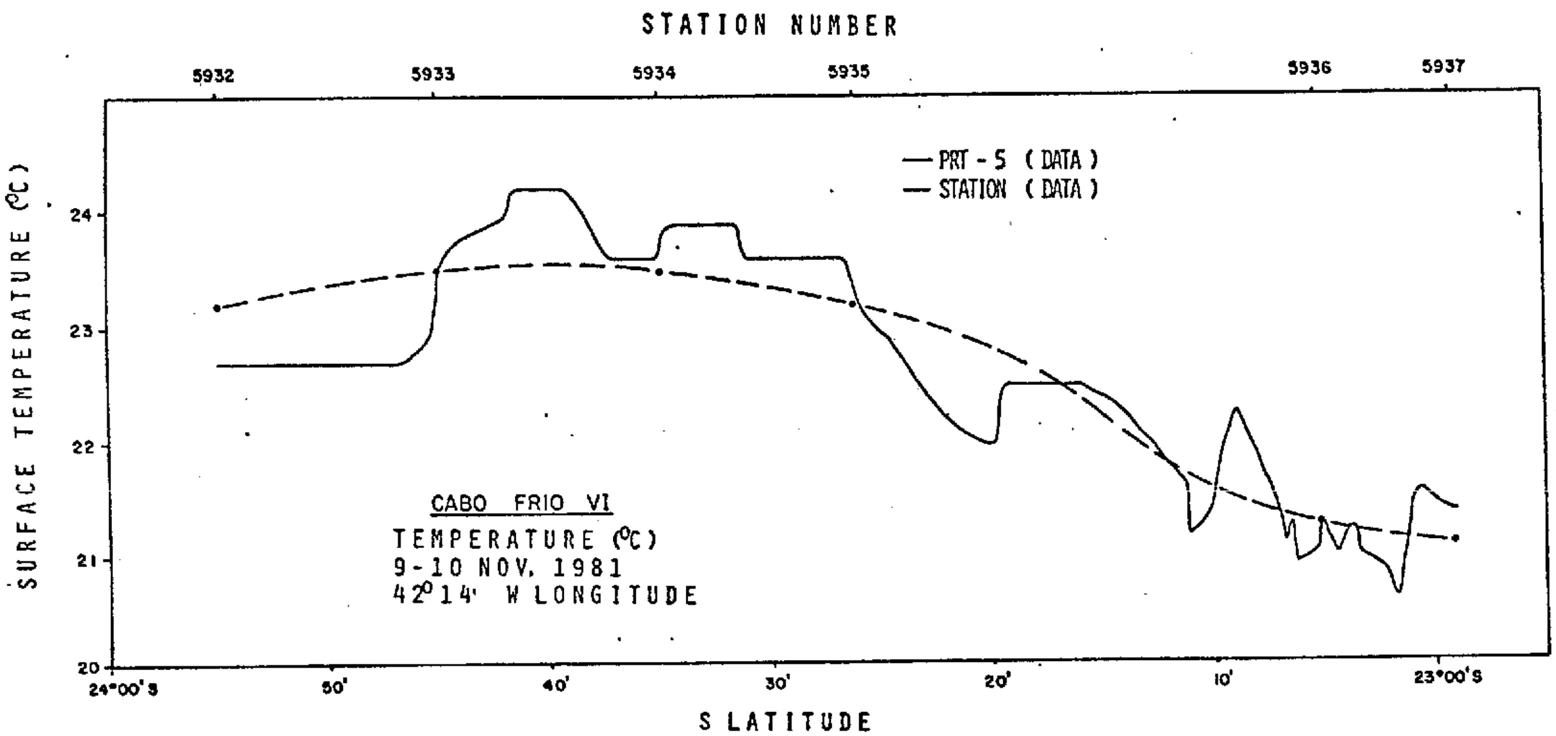

Fig. 3B - Radiometric temperature profile for Transect IV.

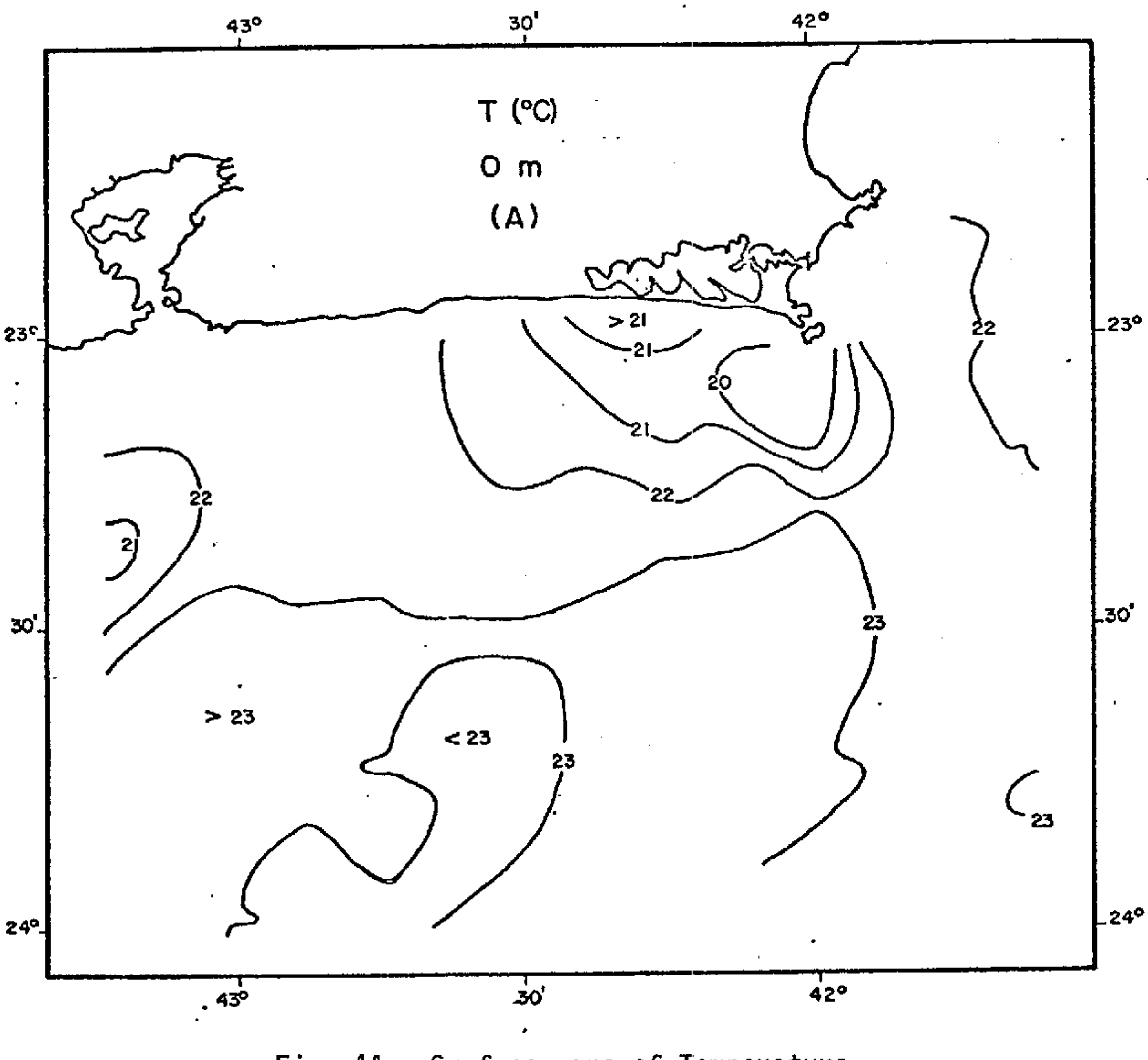

Fig. 4A - Surface maps of Temperature.

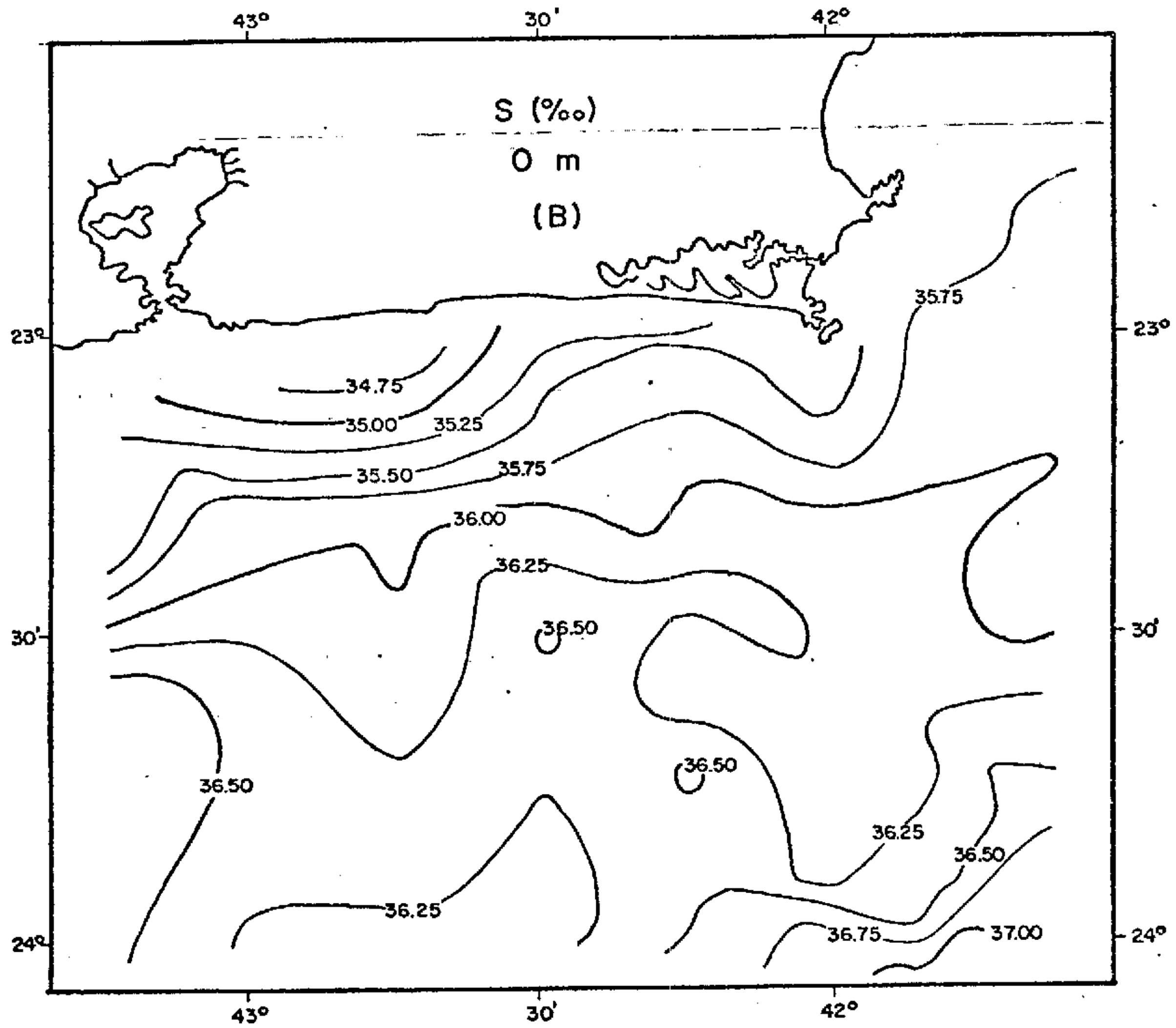

Fig. 4B - Surface maps of Salinity.

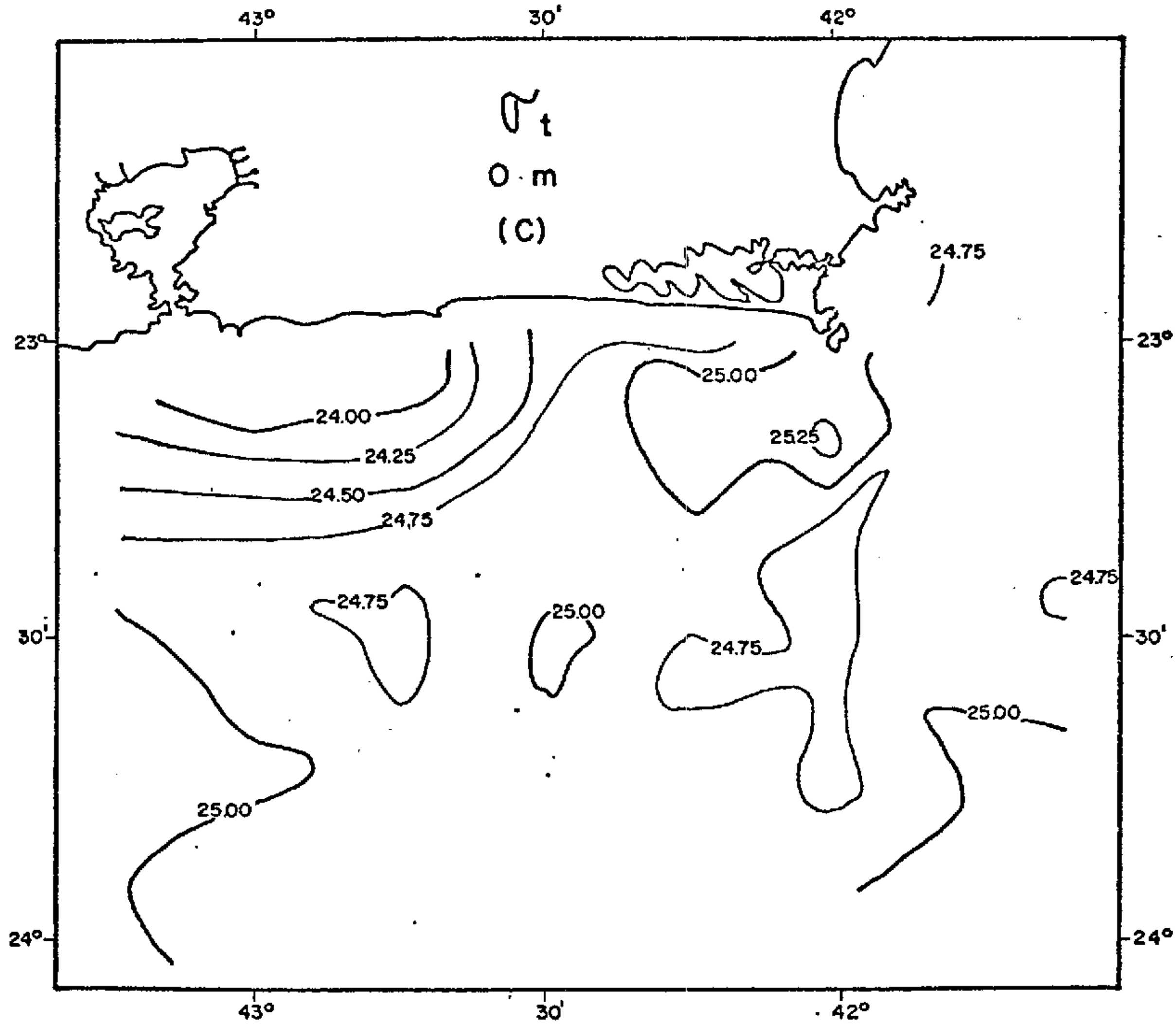

Fig. 4C - Surface maps of Sigma-t.

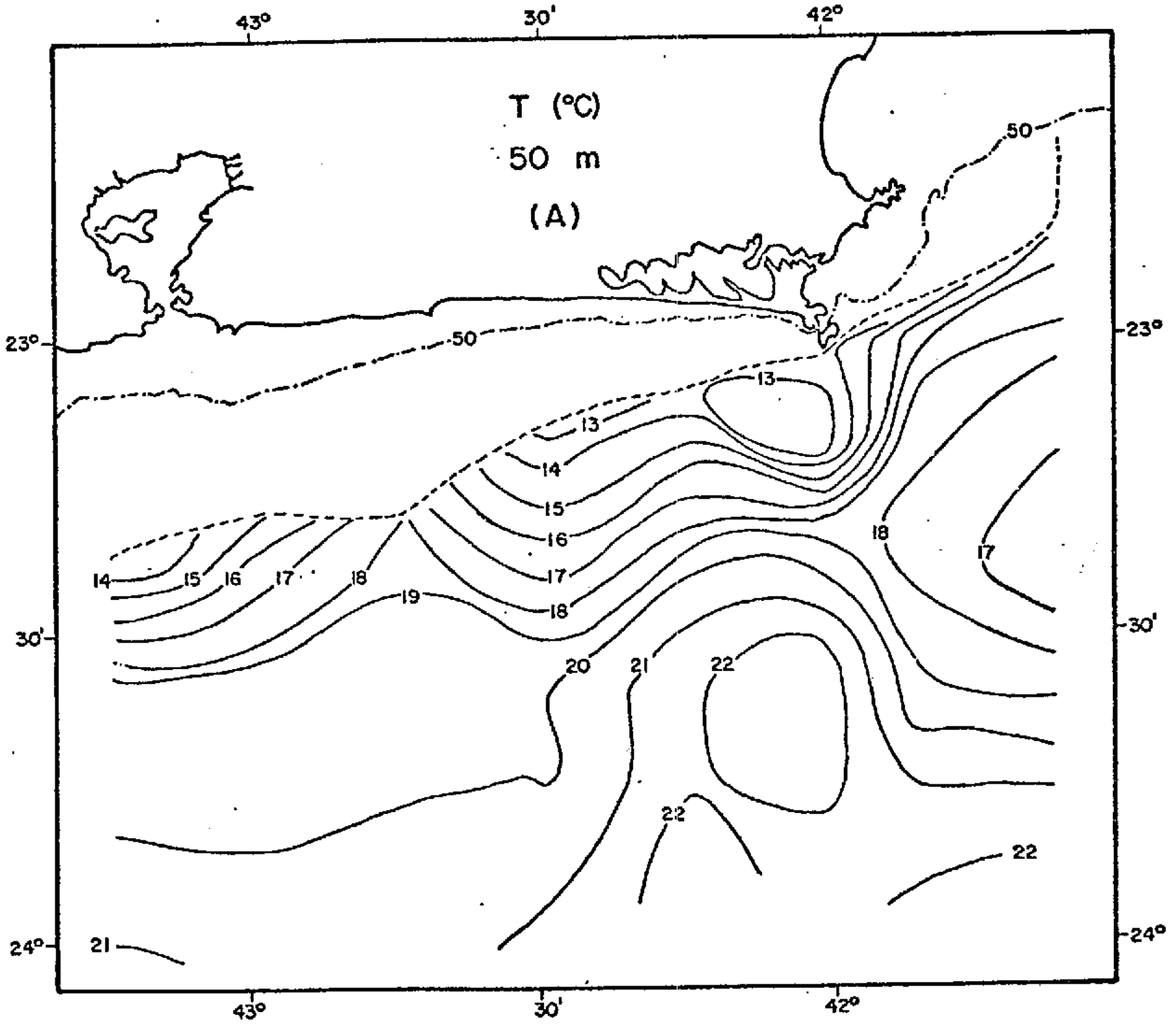

Fig. 5A - Maps at 50 m depth of Temperature.

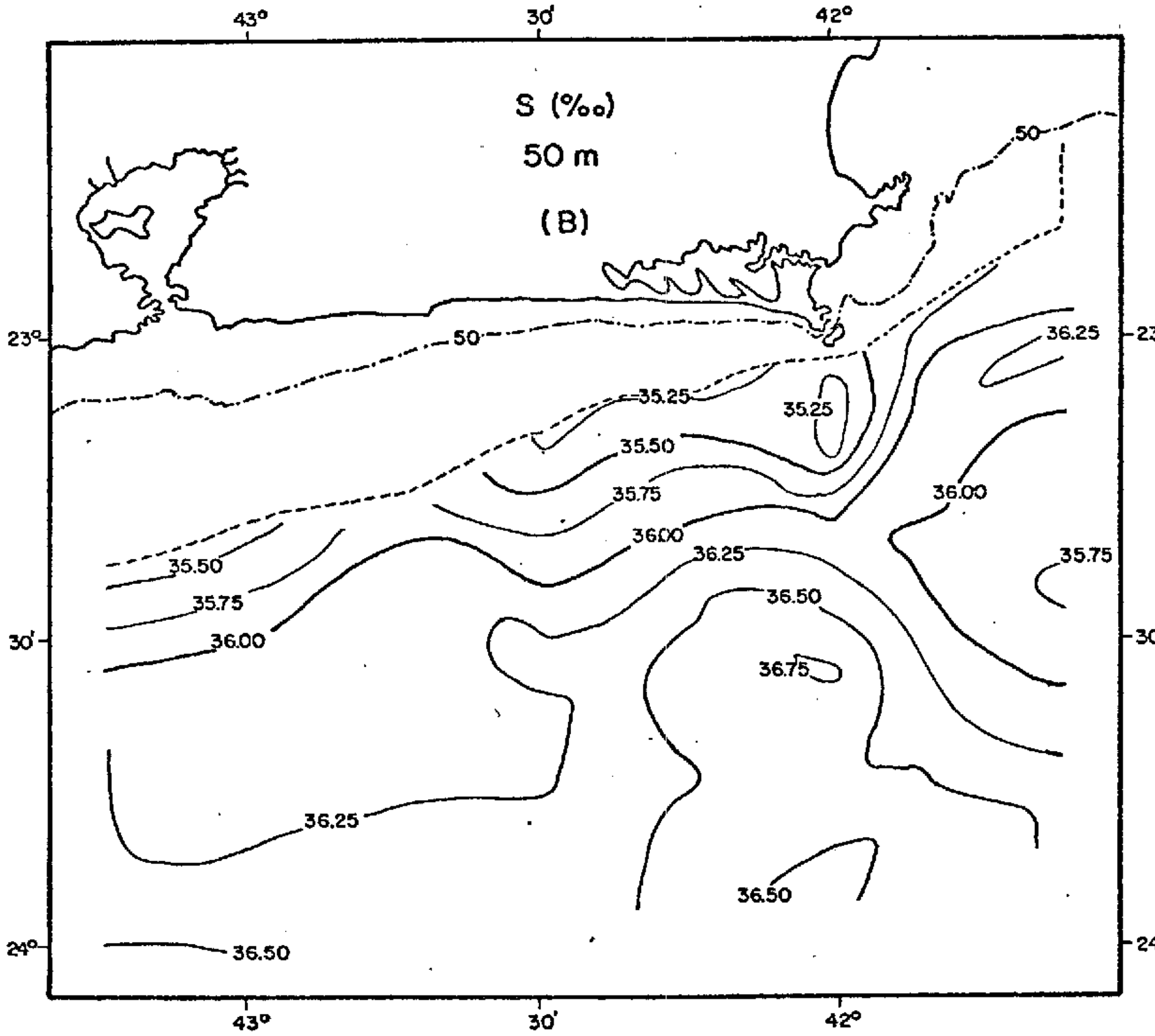

Fig. 5B - Maps at 50 m depth of Salinity.

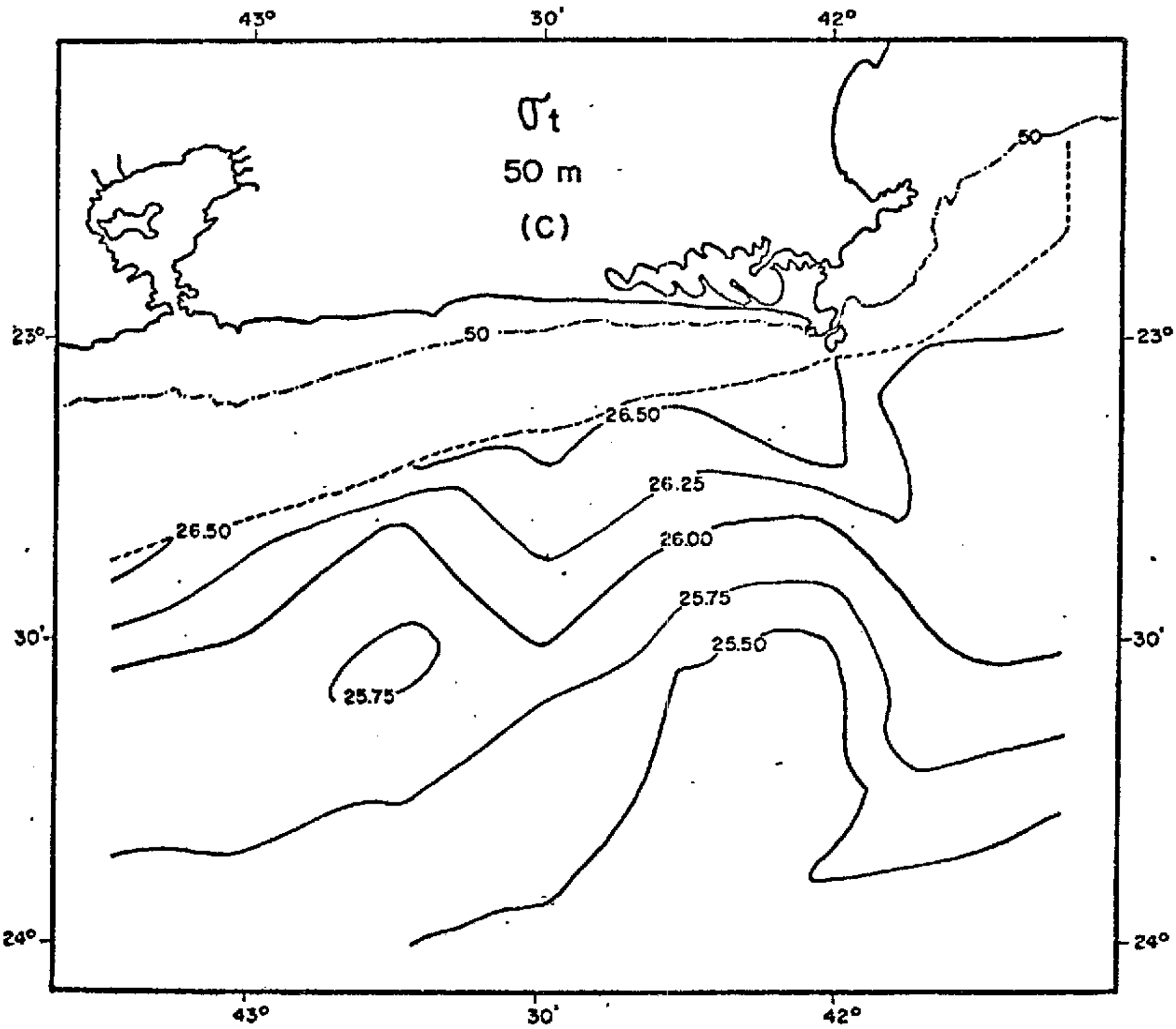

Fig. 5C - Maps at 50 m depth of Sigma-t.

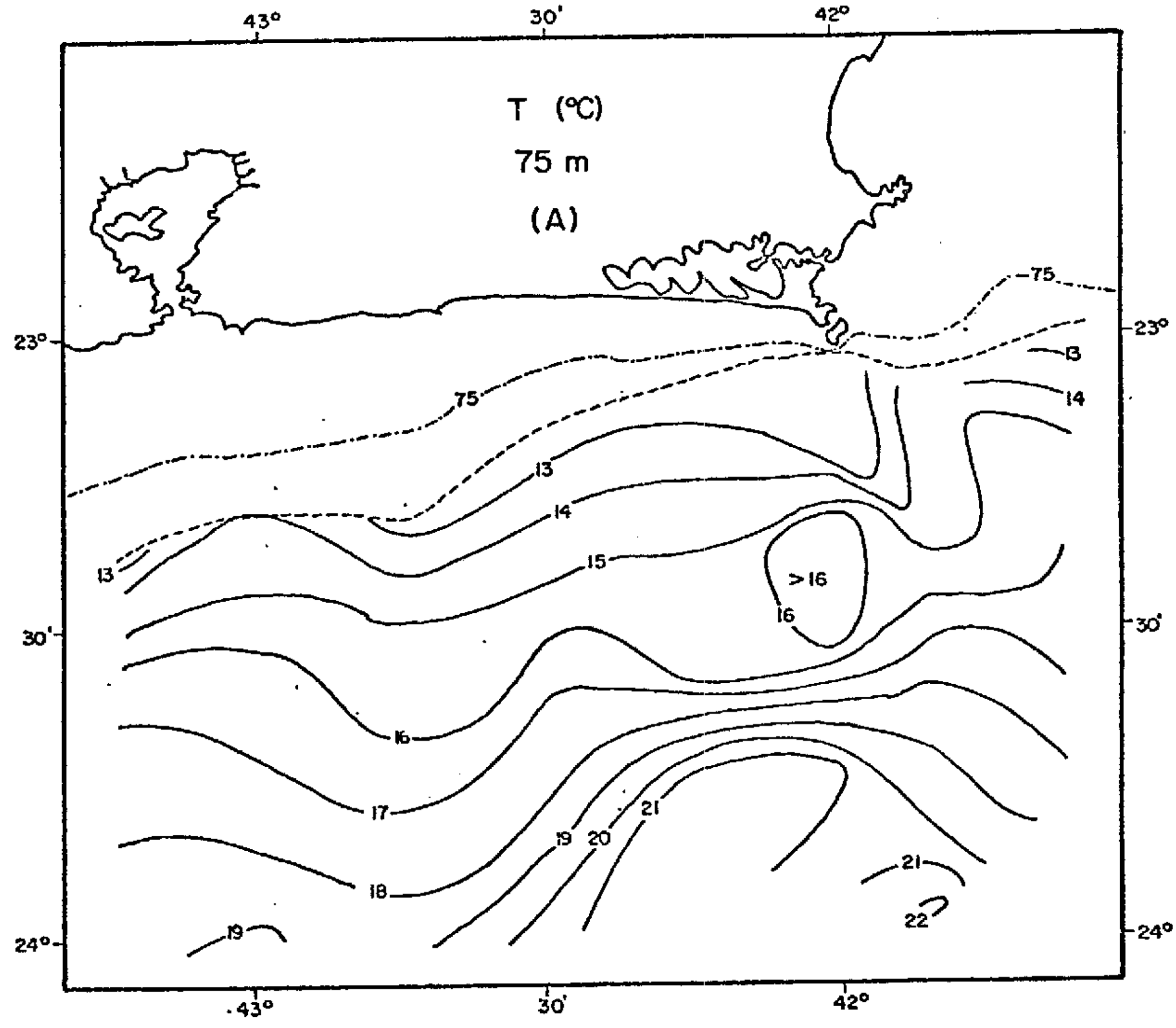

Fig. 6A - Maps at 75 m depth of Temperature.

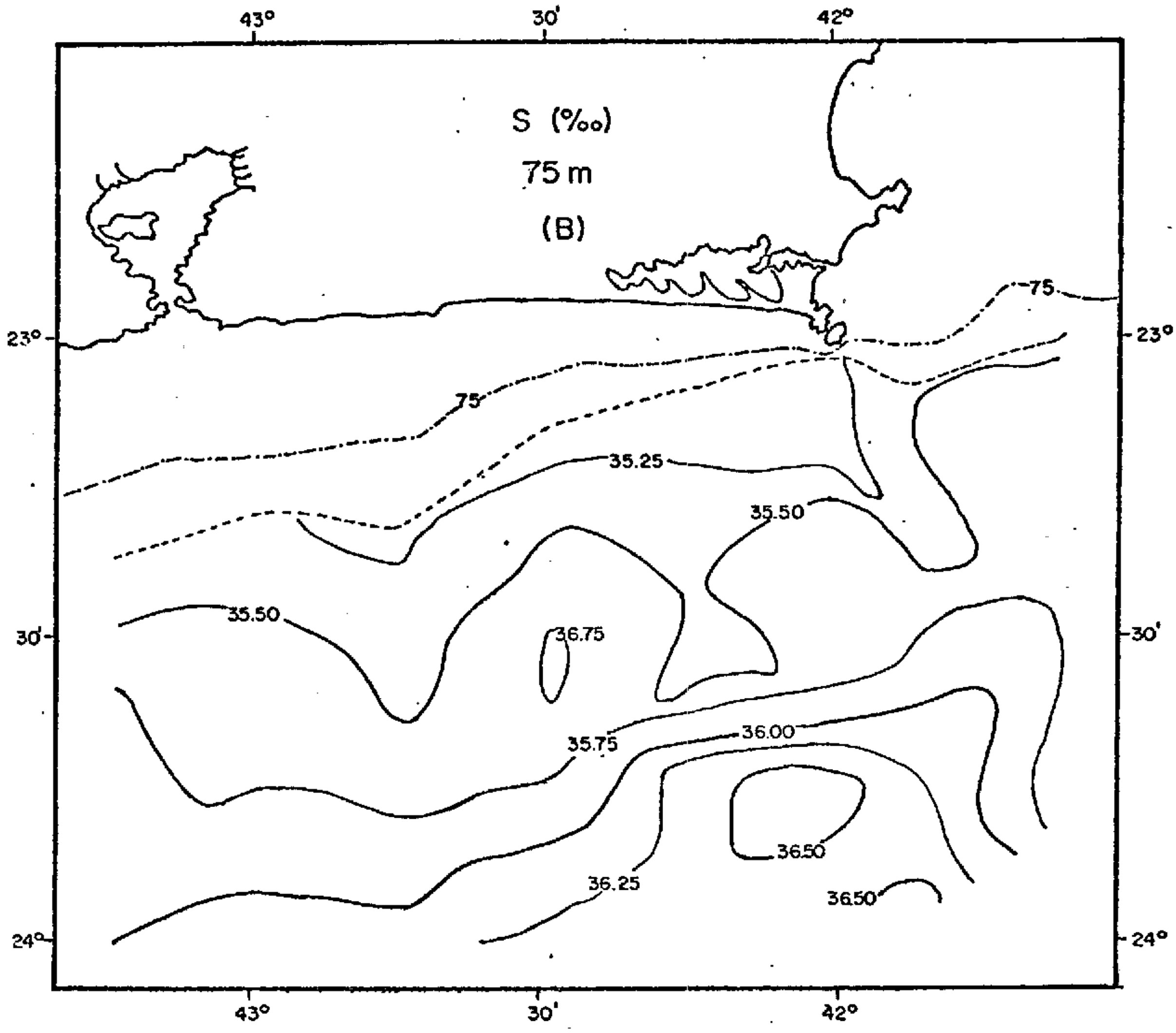

Fig. 6B - Maps at 75 m depth of Salinity.

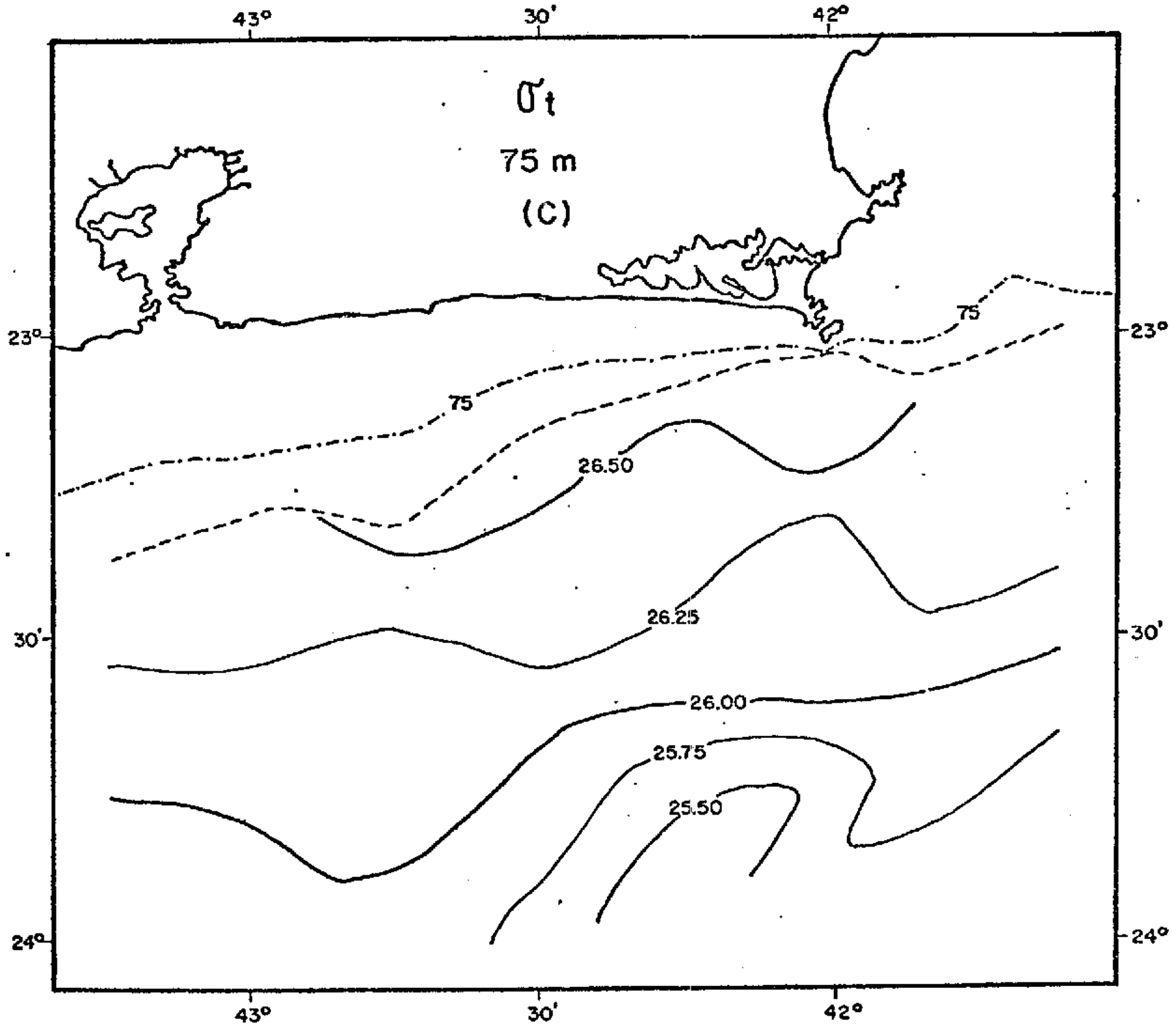

Fig. 6C - Maps at 75 m depth of Sigma-t.

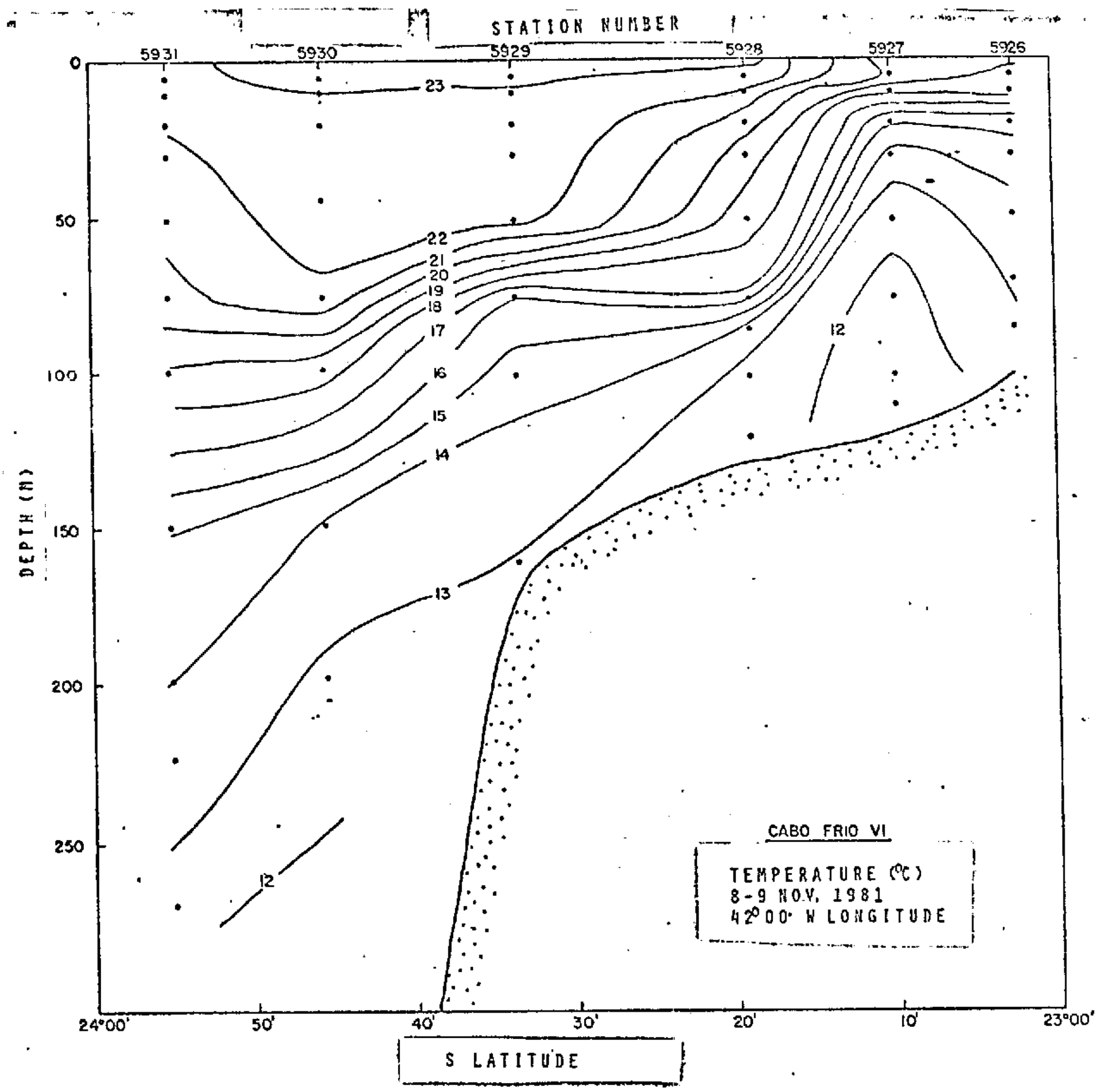

Fig. 7A - Vertical sections for Transect III, showing Temperature.

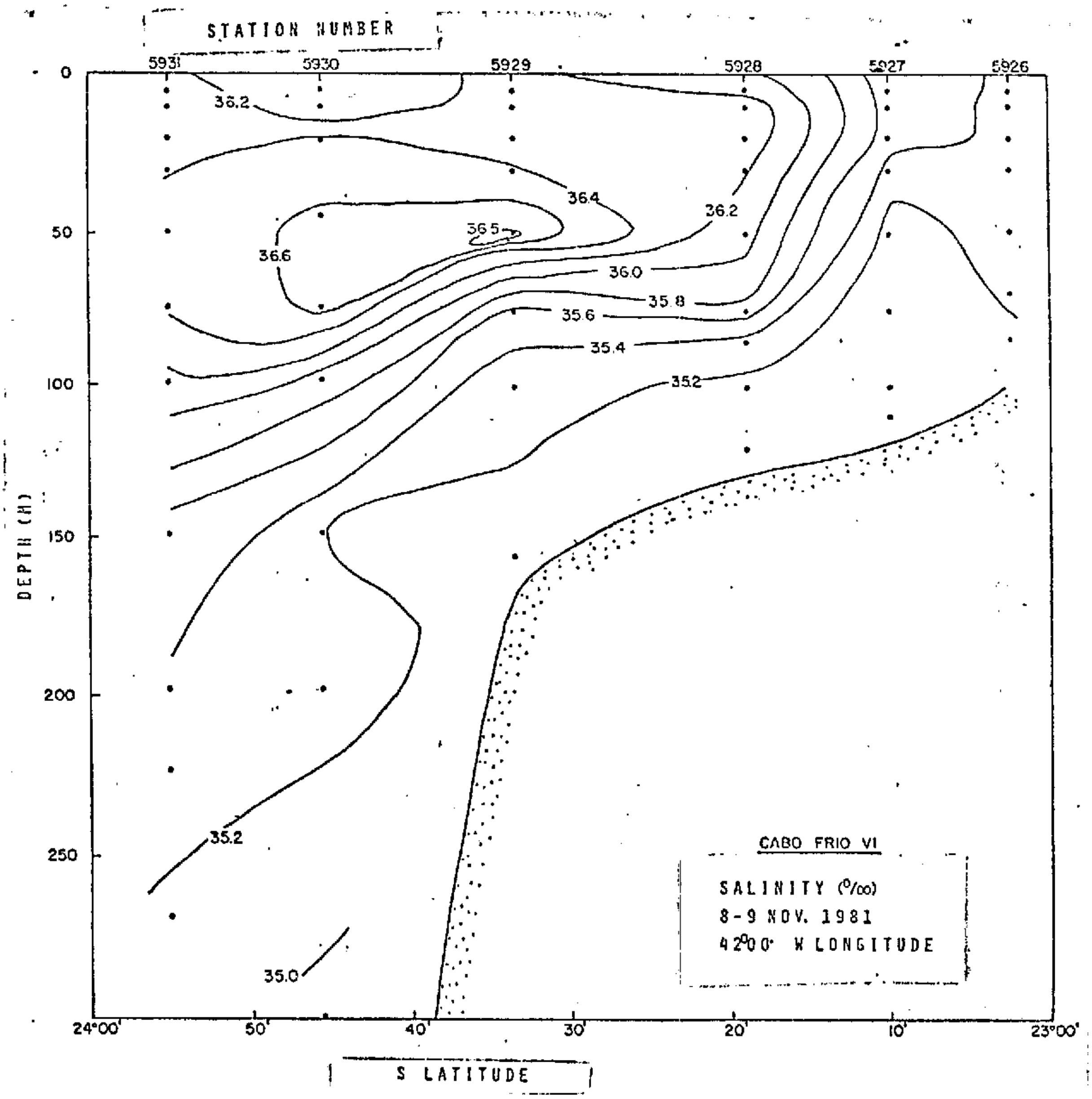

Fig. 7B - Vertical sections for Transect III, shoving Salinity.

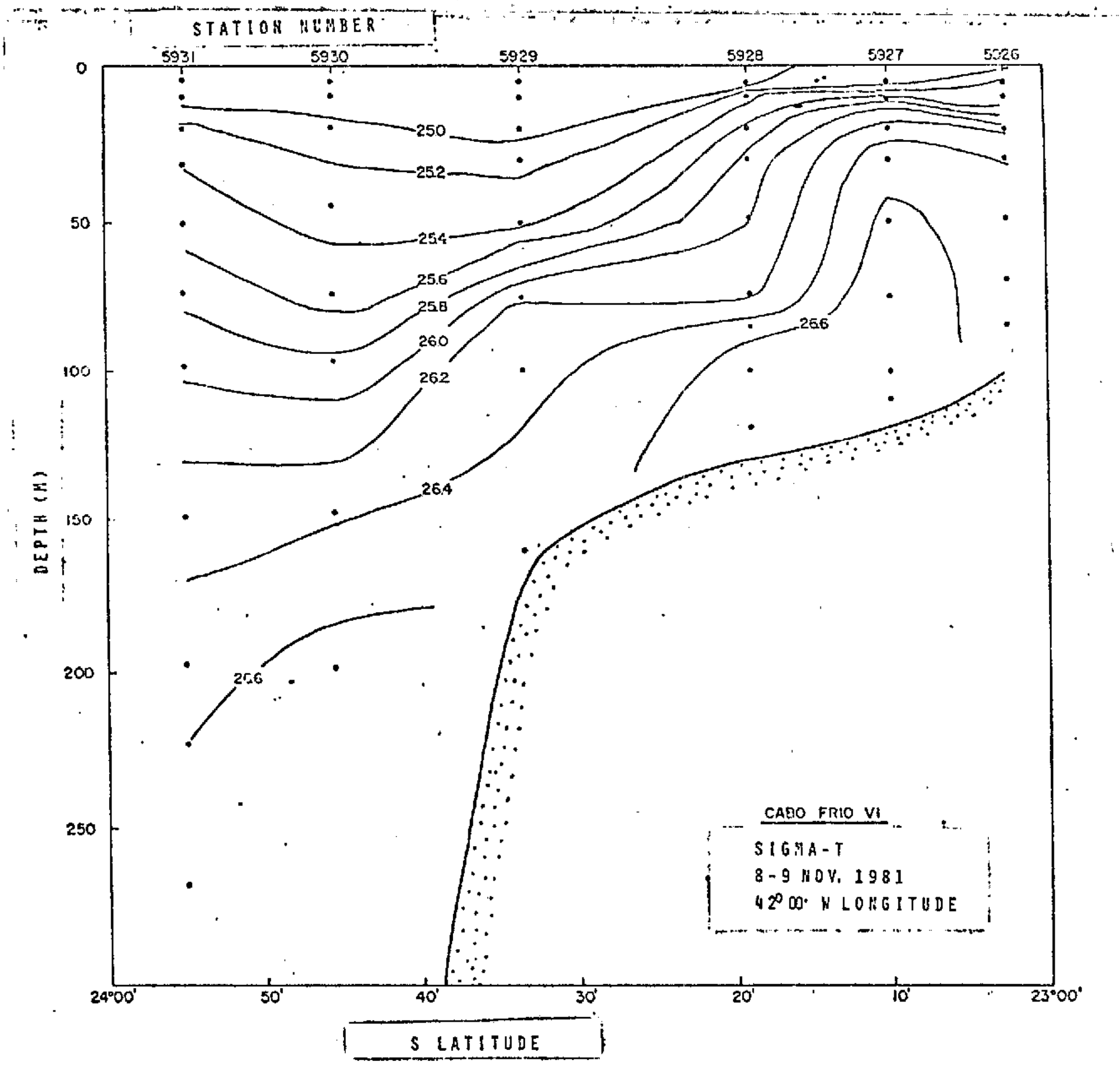

Fig. 7C - Vertical sections for Transect III, showing Sigma-t.

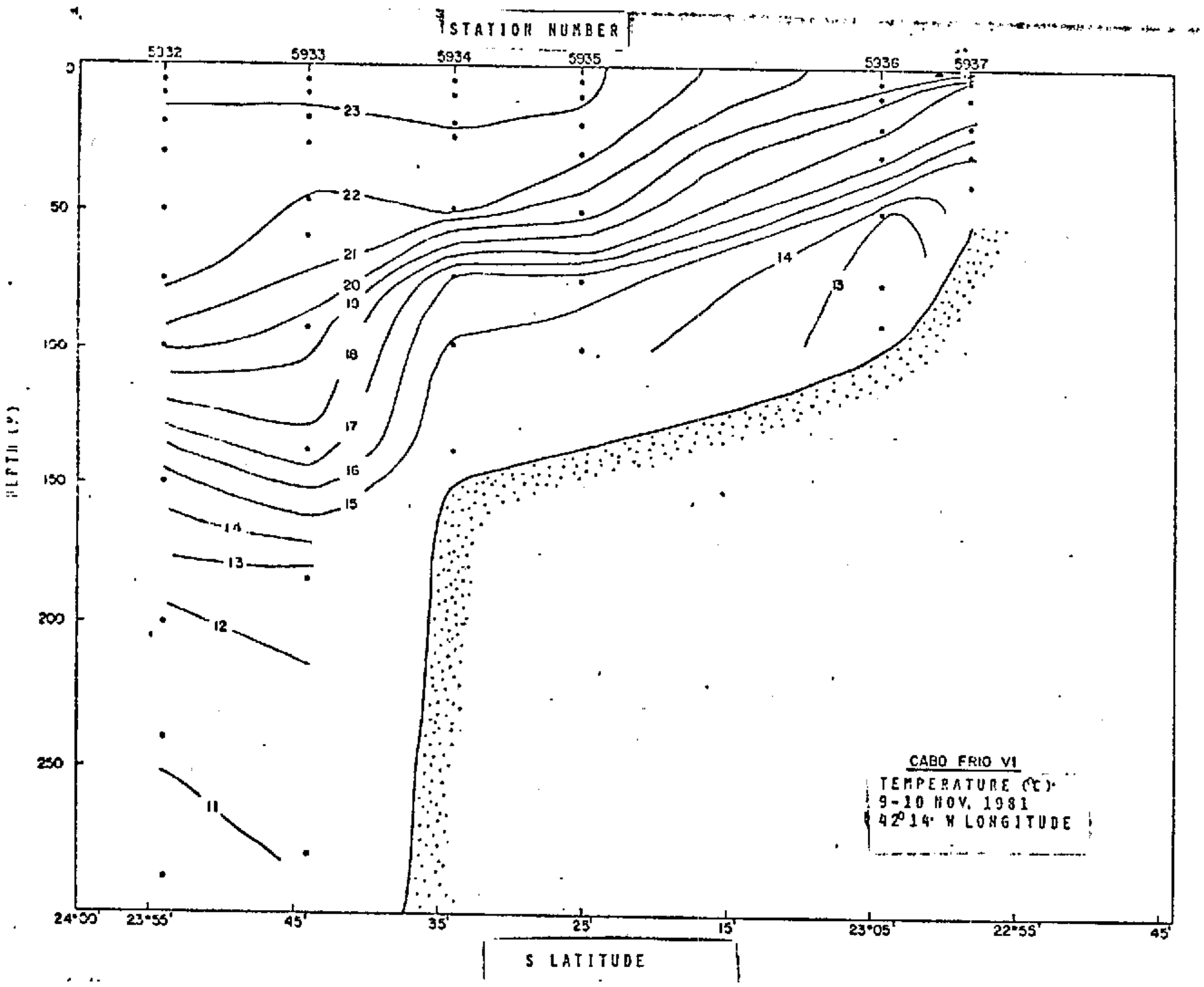

Fig. 8A - Vertical sections for Transect IV, showing Temperature.

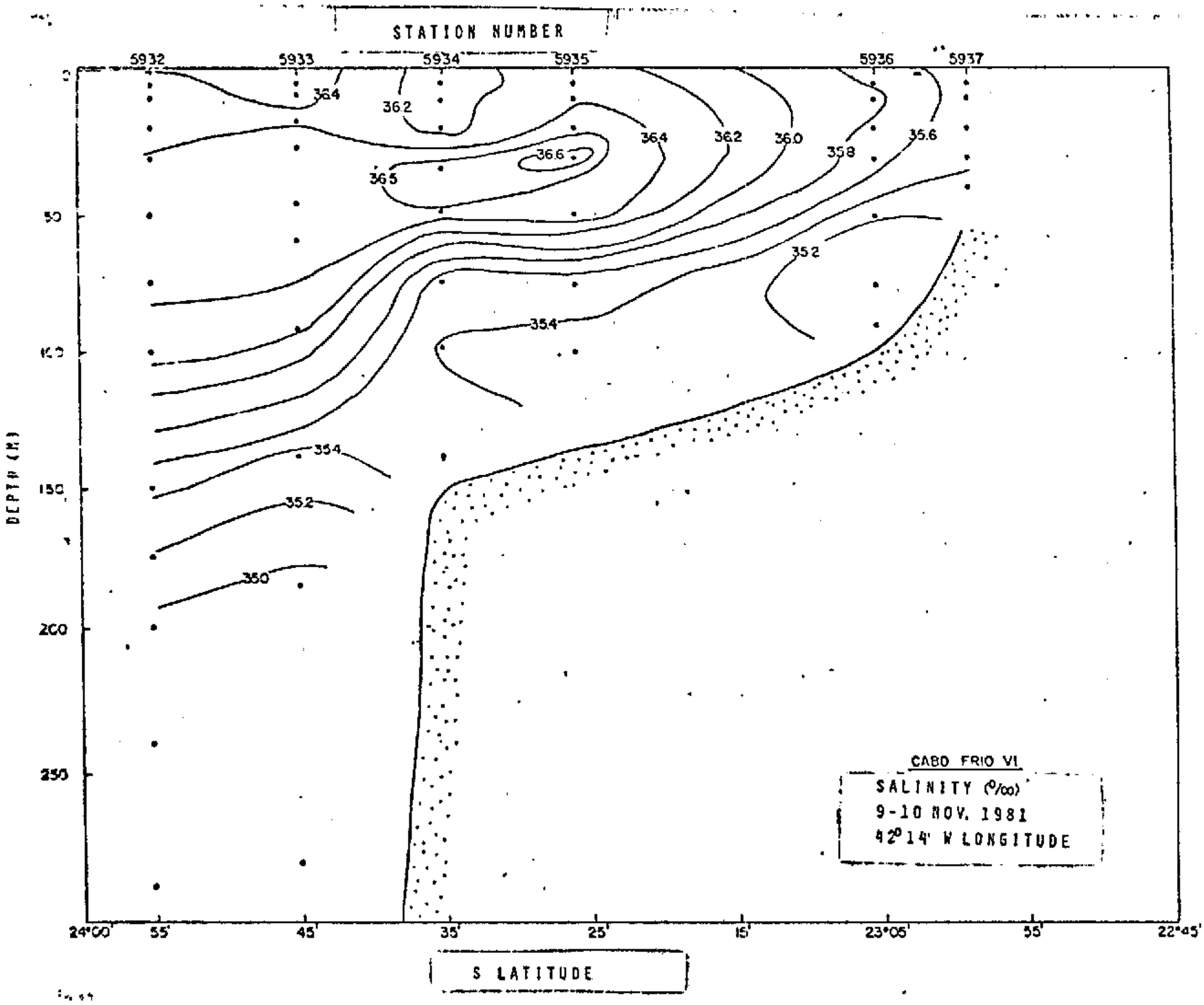

Fig. 8B - Vertical sections for Transect IV, showing Salinity.

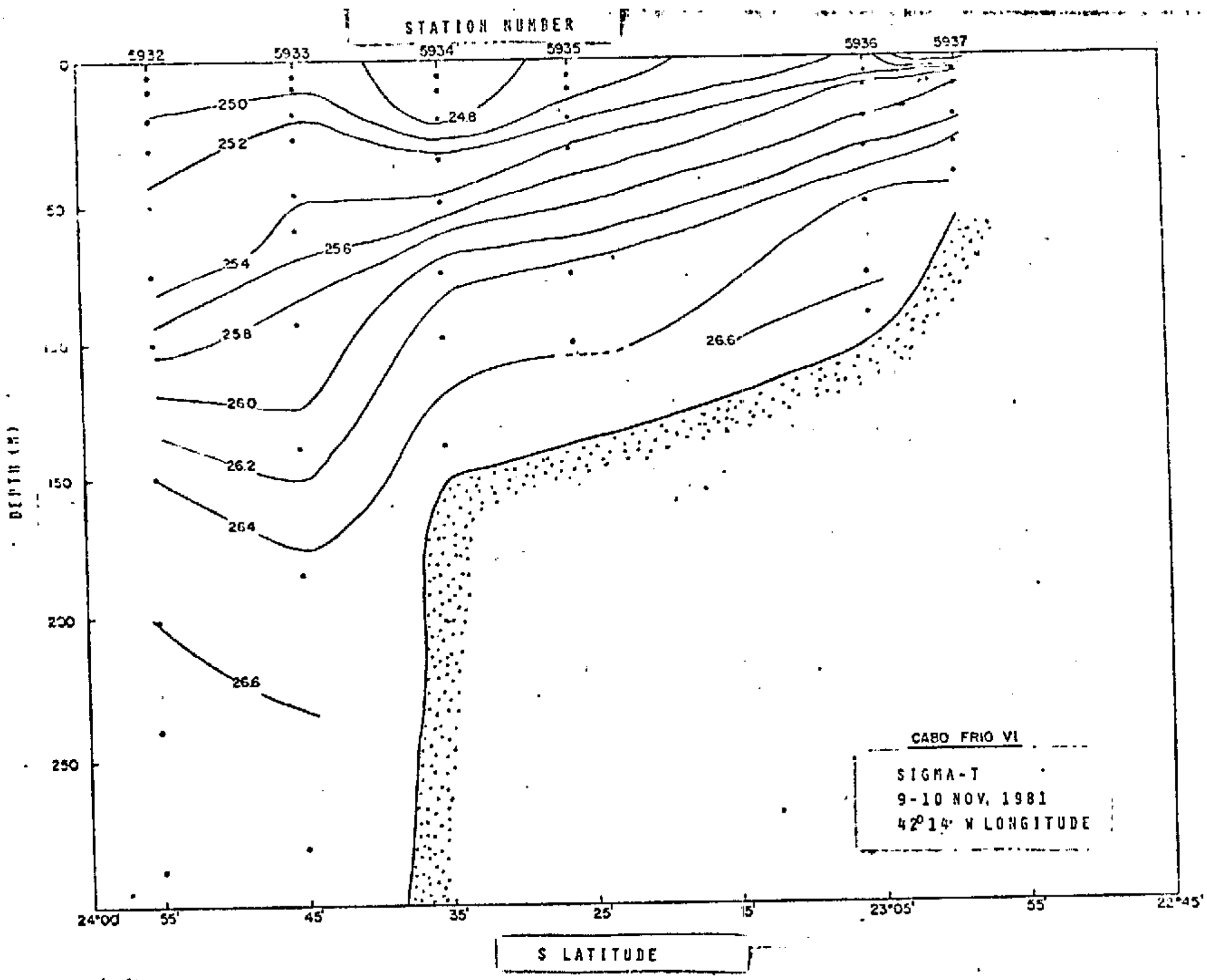

Fig. 8C - Vertical sections for Transect IV, showing Sigma-t.

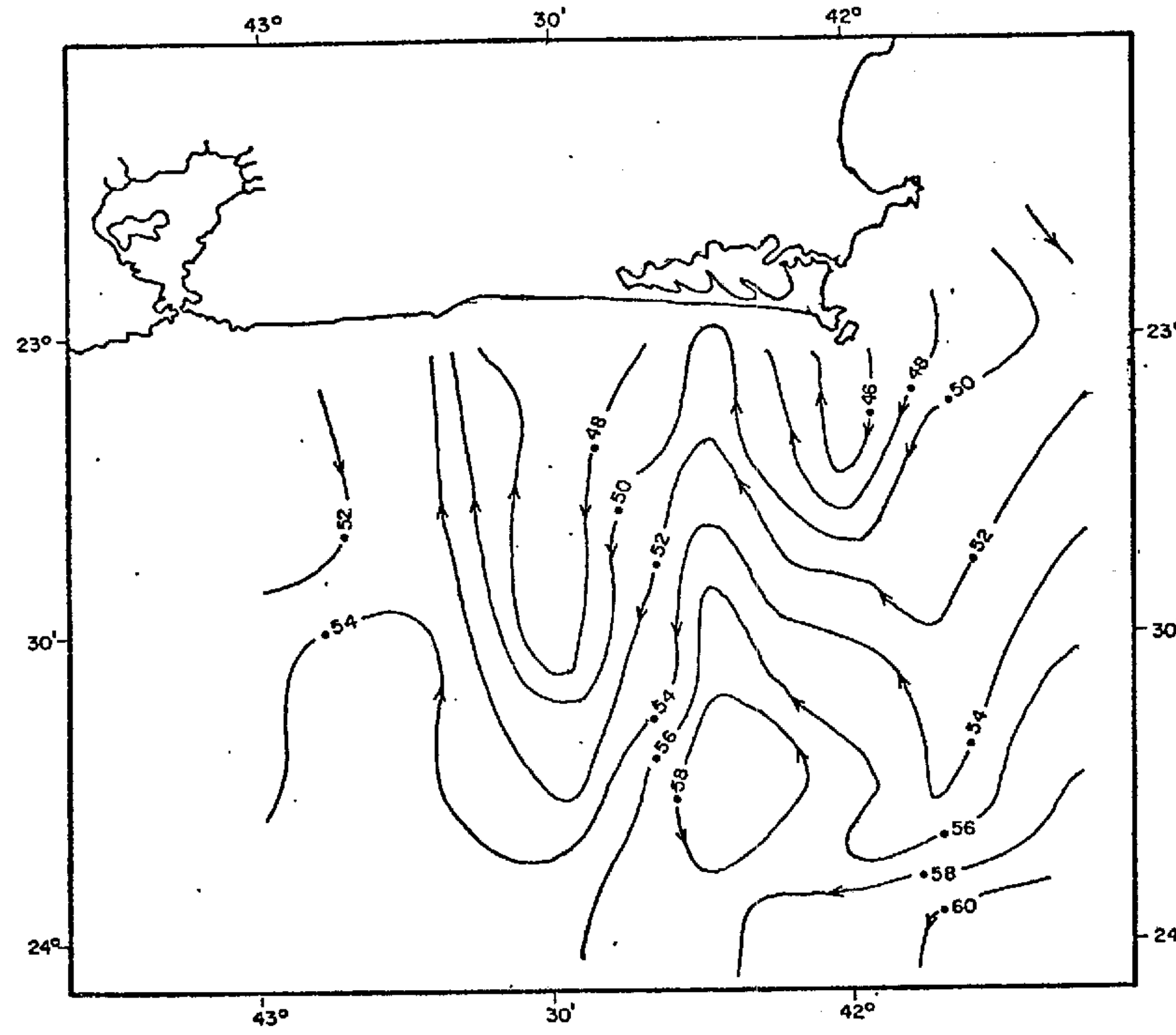

Fig. 9A - Geostrophic circulation for the sea surface.

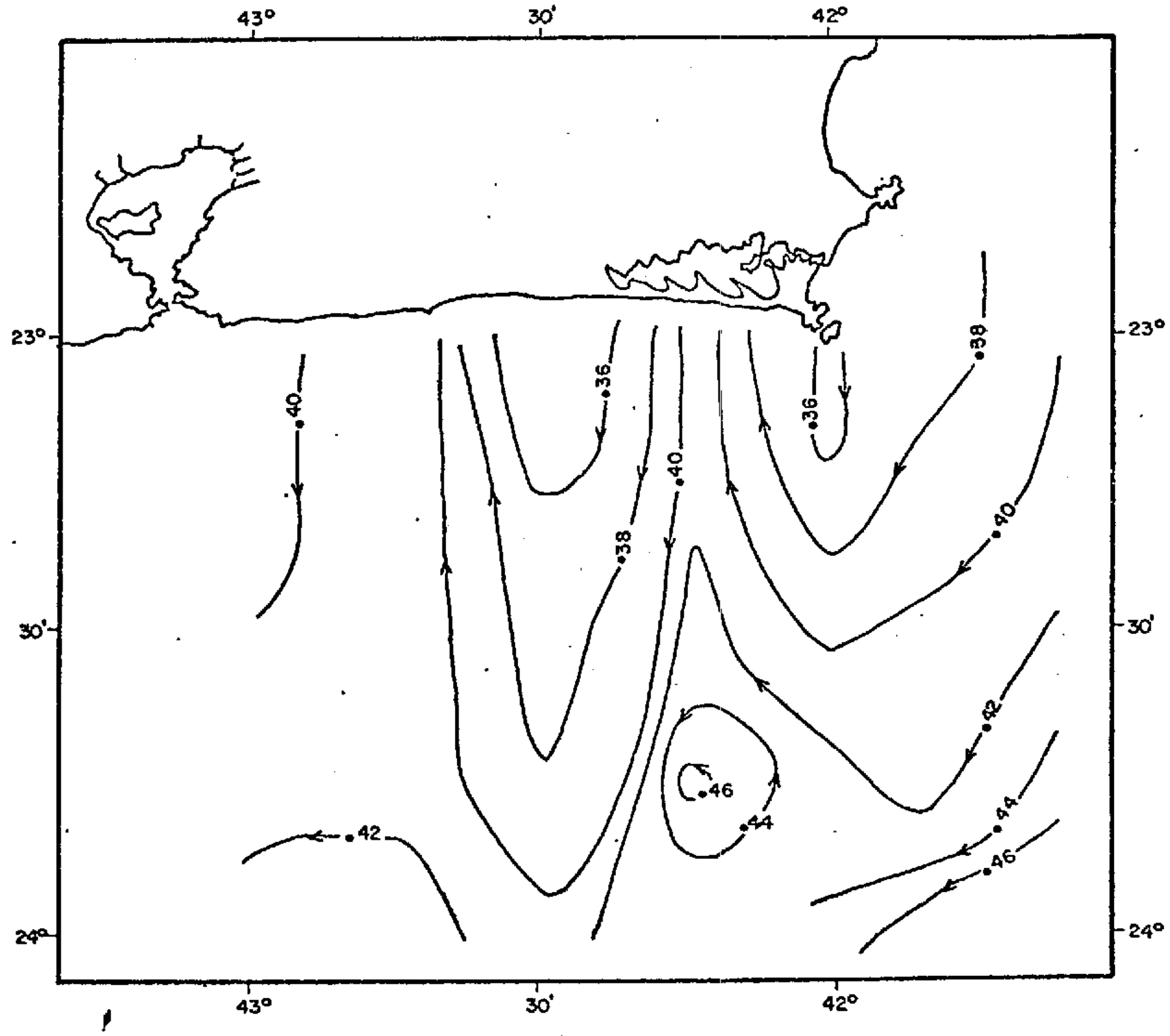

Fig. 9B - 50 m depth, referenced to 300 decibar surface.