REPORT ON THE OCEANOGRAPHIC INVESTIGATIONS CARRIED OUT AT THE SOFALA BANK BY THE SOVIET TRAWLER "SEVASTOPOLSKY RYBAK" IN SEPTEMBER-DECEMBER 1982

by

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INTRODUCTION

In September-December 1982 a fisheries research cruise was carried out at the Sofala Bank (figure 1) by the SRTM "Sevastopolsky Rybak". Oceanographic investigations have been conducted in association with the fisheries research.

Three coverages were made of the Sofala Bank each lasting for slightly less than three weeks. This will allow for three descriptions of the oceanographic conditions in the area, with some reference being made to variability. This paper is just a preliminary report of those investigations.

METHODS

The survey grids are shown in Figures 2-4. No attempt was made to indicate which observations were carried out at each station, as this would make the figures unnecessarily complicated. Instead, the positions of the stations used for the different horizontal distributions are indicated by dots in Figures 5-12.

Nansen casts for temperature and salinity determinations were performed at virtually all stations during the first and the third coverages. Water bottles were placed at 0-2-3-5-10-20-30-50-75-100 m. Additionally, bathythermograph soundings were carried out to the bottom at all stations during the three coverages. Secchi depth and water colour (Forel Scale) were determined at all stations performed during daytime in the first coverage.

For sake of simplicity water colours were grouped in four categories:

1 - deep blue
2,3 - greenish blue
4,5,6,7 - bluish green and green
8,9 - yellowish green

Temperature and salinity profiles are shown in Figures 13-28. The sections were numbered from south to north using the third coverage as a basis. Each figure refers to one section and contains the three profiles corresponding to the three coverages (e.g. Figure 16). In cases where one or two profiles were missing the corresponding spaces were left blank (e.g. Figures 13, 14 and 21). Surplus sections from the first coverage were not considered.

RESULTS

During the approximately two months period separating the first from the third coverage a temperature rise of about $2^{o}C$ has occurred. In each coverage the temperature tended to be some $2.5^{o}C$ higher at the north than at the south (Figures 7,9 and 11). No similar trend was found in what concerns salinity, although important changes were observed from one coverage to another (Figures 8, 10 and 12). It is quite remarkable the correspondance between the salinity distribution of Figure 8 and the distributions of optical properties of Figures 5 and 6. This suggests that water of river origin can successfully be traced by means of colour sensors.

Important differences in the surface characteristics allow us to distinguish three main areas in the Sofala Bank:

A - north of Pebane (latitude 17^{o} 20'S)

B - between Pebane and roughly latitude 20^{o}S
C - south of latitude 20^{o}S

Area A was always characterised by the presence of salinities between 35.1 and 35.3, values that are not typical of shelf water. During the first coverage values above 35.2 were only observed north of latitude 17^{o}S (Figure 8) while, during the third coverage, they were found over the whole shelf near Pebane (Figure 12). During the second coverage those salinity values were instead found at the inner part of the shelf extending to area B (Figure 10). Changes in the surface salinities from the first to the third coverages were accompanied by the disappearence of an inshore pocket of low temperature and its replacement by warmer water (Figures 7, 9 and 11).

Area B can be considered as characterised by a strong interaction of Low Salinity Shelf Water (LSSW), mainly of Zambezi origin, with Oceanic Water transported by the Mozambique Current. Strong horizontal salinity gradients were therefore found in this area. Great variability was also one of its characteristics.

During the first coverage the lowest salinities were found to the north of the Zambezi delta associated with a low temperature tongue extending northwards (Figures 7 and 8). Salinities higher than 35.0 were only found at the outer part of the shelf.

During the second coverage (Figures 9 and 10) only some remains of the LSSW could be detected to the north of the Zambezi, near Quelimane. Surface salinities higher than 35.0 were present over the whole shelf north of the delta, while the lowest salinities were found to the south of it. The salinity range and gradient were similar to those found during the first coverage (Figure 8). Similar temperatures were detected at the inner and outer parts of the shelf north of the delta, as well as over the whole shelf due south of the Zambezi (Figure 9). An area of lower temperature was present at the mid part of the shelf north of the delta.

During the third coverage salinities greater than 35.1, characteristic of Oceanic Water, were present over the whole shelf north of Quelimane (Figure 12). To the north of the Zambezi the temperature was fairly constant around 28^{o}C (Figure 11). The lowest salinities were found near the Zambezi mouth. Comparatively to the second coverage (Figure 10), LSSW was apparently starting to propagate northwards (Figure 12). South of the Zambezi the salinity distribution was similar to those of the two previous coverages, except for an inshore pocket of higher salinity near Beira. To the south of Quelimane the isohalines tended to be roughly parallel to the isobaths at the outer part of the shelf. The temperature distribution (Figure 11) shows a high temperature tongue extending southwards at the inner and mid parts of the shelf and a low temperature tongue extending northwards at the outer shelf.

Area C was characterised by the presence of high salinity water that is known to be of shelf origin (BRINCA et al. 1981 a, 1981 b, 1983 a, 1983 b). This area is separated from Area B by a salinity front running more or less zonally (Figures 8 and 12). A positive onshore salinity gradient was observed during the first coverage (Figure 8), while Figure 12 reveals some kind of an eddy situation. A less intense meridional front separated the High Salinity Shelf Water (HSSW) from the LSSW coming from north.

Sections I-III (Figures 13-15) reveal that the HSSW was nearly homogeneous from surface to bottom. Some unstability was, however, detected at the surface during the third coverage (Figure 14-C). The LSSW coming from north can also be traced in Figures 14 and 15. Apparently, its influence in area D was greater during the first coverage than during the third one.

During the third coverage the HSSW propagated northwards reaching the area of Section V (Figures 16-C and 17-C). Traces of this water were in fact found in stations 197, 201 and 204. At station 201 (Figure 17-C) it was confined to the upper 3 m giving rise to an unstable situation. At station 208 (Figure 18-C) it was still possible to trace the influence of HSSW.

Contrasting with the nearly homogeneous vertical structure observed in sections I-III, the other sections show vertical gradients over the shelf. The temperature profiles reveal that water lifting occured at the outer part of the shelf, which was probably a manifestation of a similar movement over the non-investigated slope area. Water lifting was quite clear in sections VIII and XII during the first coverage (Figures 20-A and

24-A), sections VIII, XI, XII, XIII and XVI during the second coverage (Figures 20-B, 23-B to 25-B and 28-B), and sections IV-IX, XI, XV and XVI during the third coverage (Figures 16-C to 21-C, 23-C, 27-C and 28-C). Particularly evident cases are those shown in Figures 19-C and 23-B to 25-B.

Salinity values greater than 35.3 can be seen in Figure 22-C at dephts of 30-40 m. These values can only be due to lifting of Subtropical Water from about 150 m, where the core of the subsurface salinity maximum is usually found offshore (SAETRE and JORGE DA SILVA, 1982). Figure 24-C shows a similar situation where this water was lifted to the surface. In none of these figures can one find any indications of water lifting in the temperature profiles. This suggests that this process occured before the area was surveyed.

Salt wedges due to the influence of LSSW, particularly connected to the Zambezi runoff, were observed mainly to the north of the delta. They were quite clear during the first coverage in sections X and XII (Figures 22-A and 24-A), changing into a distinct two-layer structure in section XIII (Figure 25-A), and to an offshore lens of low salinity further north in section XIV (Figure 26-A). During the third coverage salt wedges were found in sections VIII-X (Figures 20-C to 22-C). Figure 19-A shows the only case of a salt wedge found to the south of the Zambezi.

DISCUSSION

The results of the three coverages made during the present cruise may reflect three different, successive stages of a variable dynamic process. Each stage can be characterised by a certain degree of interaction of the relatively warm and saline Oceanic Water, transported by the southgoing Mozambique Current, and the slightly cooler Low Salinity Shelf Water (LSSW), mainly of Zambezi origin.

Lateral displacements of the core of the Mozambique Current may have determined the routes of propagation of LSSW. During the first coverage only the shelf area north of Pebane seemed to be directly influenced by Oceanic Water, while the LSSW flew northwards and turned offshore between Quelimane and Pebane (Figures 7 and 8; see also Figures 24-A to 26-A).

During the second coverage the direct influence of Oceanic Water was apparently exerted over the whole shelf area north of the Zambezi mouth, and drastically reduced the northward propagation of LSSW (Figure 10). This is seen to flow mainly southwards associated with temperatures similar to those of the Oceanic Water (Figure 9). This association may be regarded as an indication of the important role played by the Mozambique Current in the transport of Zambezi water. Figures 23-B to 25-B provide some evidence that the lower temperatures found over the mid part of the shelf north of the Zambezi (Figure 9) were due to lifting of water at the outer part of the shelf.

During the third coverage, while the whole shelf area to the north of Quelimane showed surface values typical of Oceanic Water (Figures 11 and 12), low salinities were found to the north of the Zambezi apparently associated with a tongue of low temperature that extended northwards. The shape of the isotherms in Figure 11 suggests that such tongue was probably the result of an intrusion of oceanic water onto the shelf area to the south of the Zambezi. This might have forced part of the shelf water northwards, while another part was forced southwards, as suggested by the lower salinity tongue surrounding the area of HSSW. However, at the inner part of the shelf south of the Zambezi the water was apparently moving southwards, as suggested by the shape of the isotherms and the low surface salinity values.

The present results show that the southward transport of Zambezi water is apparently a permanent feature. On the other hand, its northward flow, although associated with lower salinities, seems to depend largely on the direct influence of Oceanic Water over the shelf area.

RECOMMENDATIONS FOR FUTURE RESEARCH

Having in mind all the results from the investigations carried out in the Sofala Bank area (BRINCA et al., 1981 a, 1981 b, 1983 a, 1983 b), attention should be payed to the following points in future research:

i) Cruises covering the whole area should always be conducted in the same direction (preferably north- south), particularly when surveys are made in sequence, as in the present case;

ii) Water colour and Secchi depth should always be determined aiming, inter allia, to obtain ground truth for satellite data;

iii) Selected sections should be extended beyond the slope and carried out in all research cruises (four sections are probably enough, approximately along the directions of sections II, VI, X and XVI);

iv) Short-term variability studies should be started, at least along two of those selected sections;

v) Direct current measurements should be conducted over the shelf in selected points along the sections where time variability studies are carried out.

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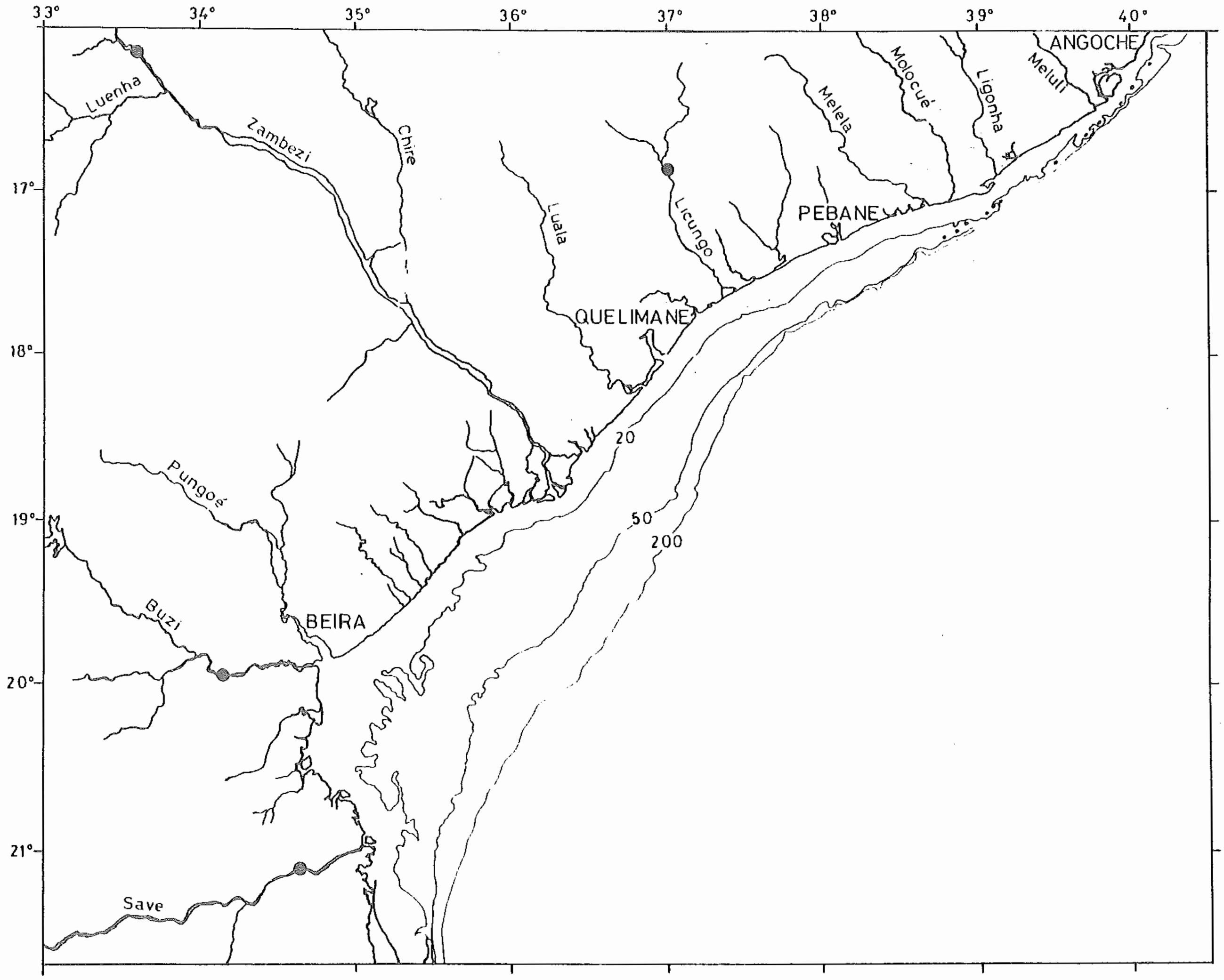


Figure 1. Sofala Bank - bathymetry (m) and main rivers.
●) - Gauge station

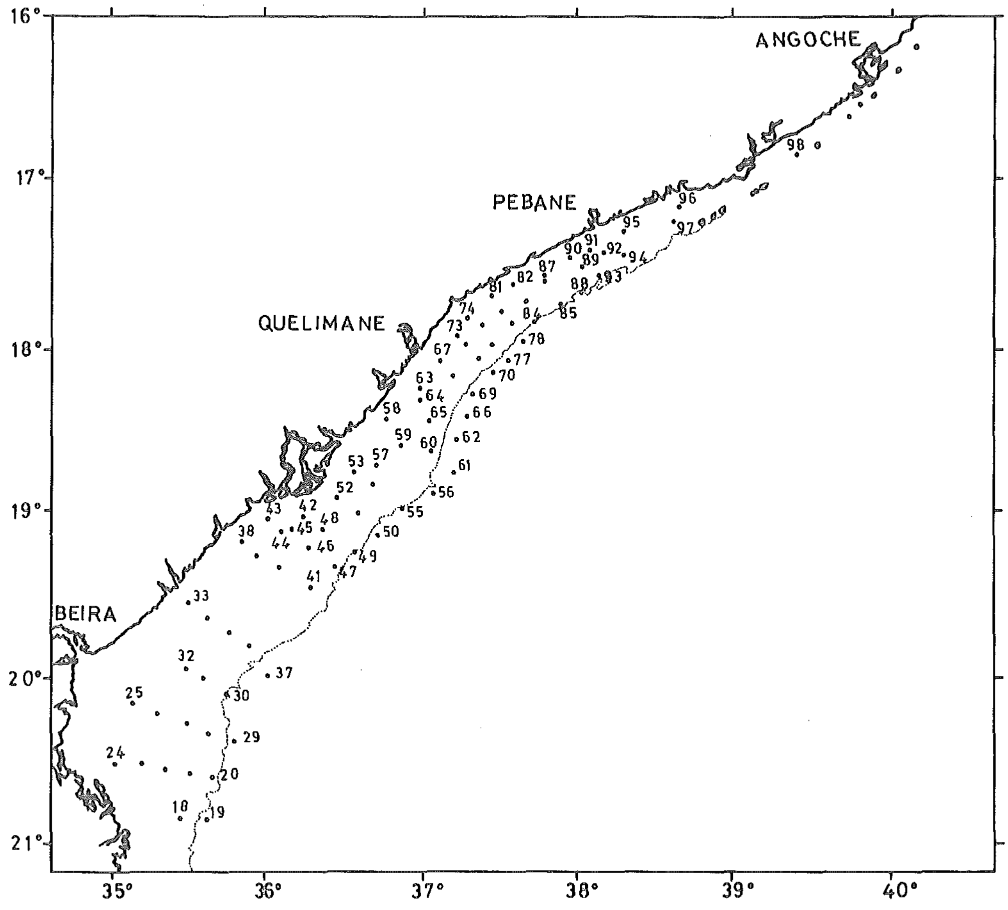


Figure 2. Station grid, 22 Sep-8 Oct 1982

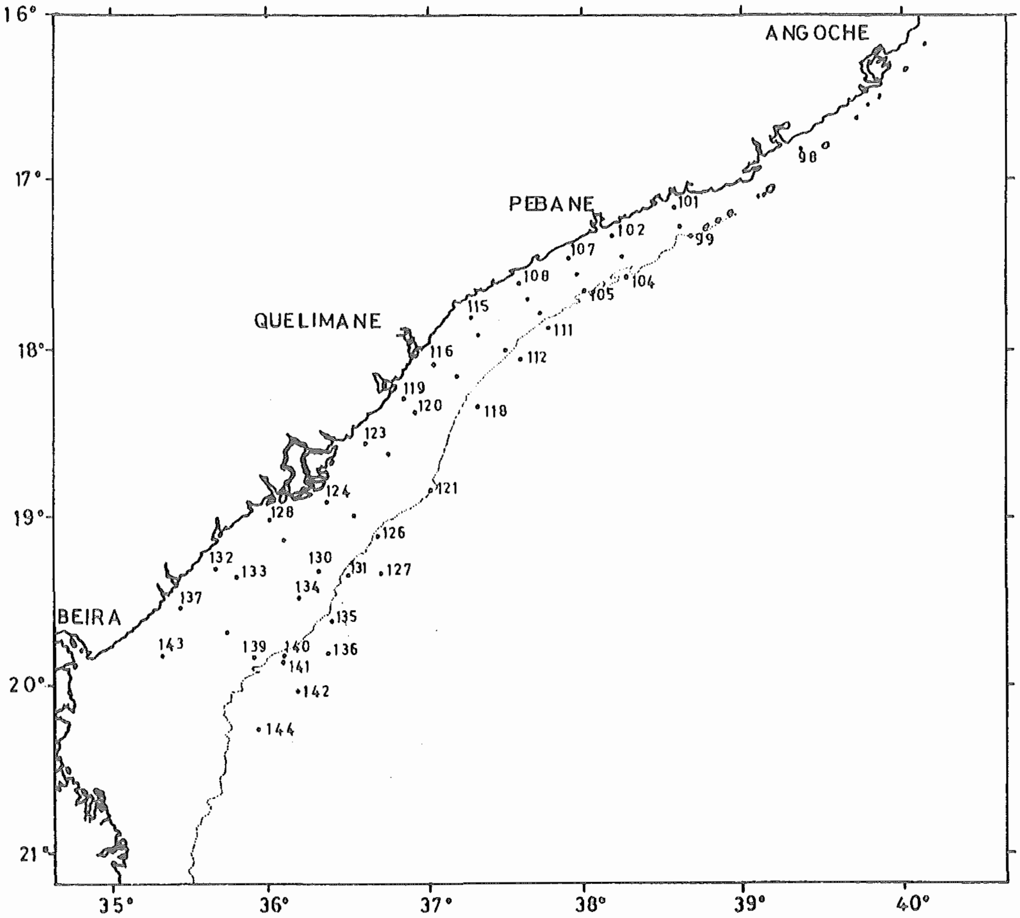


Figure 3. Station grid, 8-25 Oct 1982

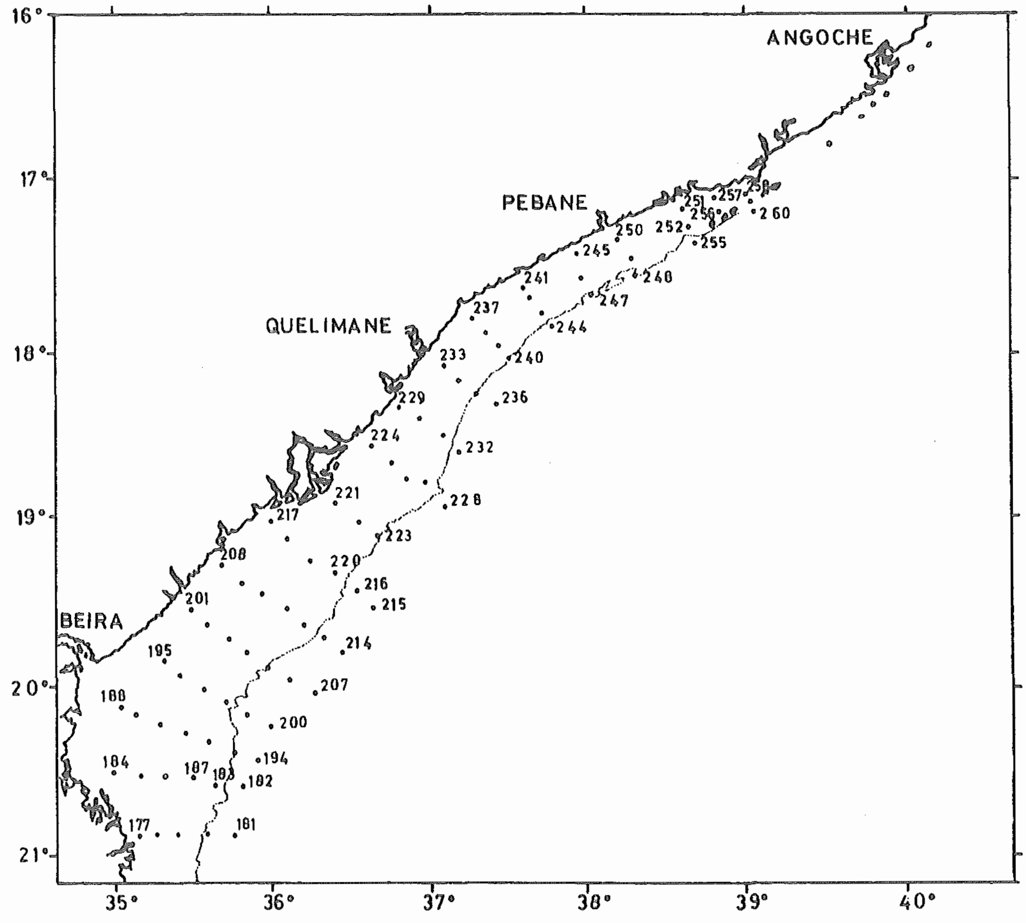


Figure 4. Station grid, 18 Nov-4 Dec 1982

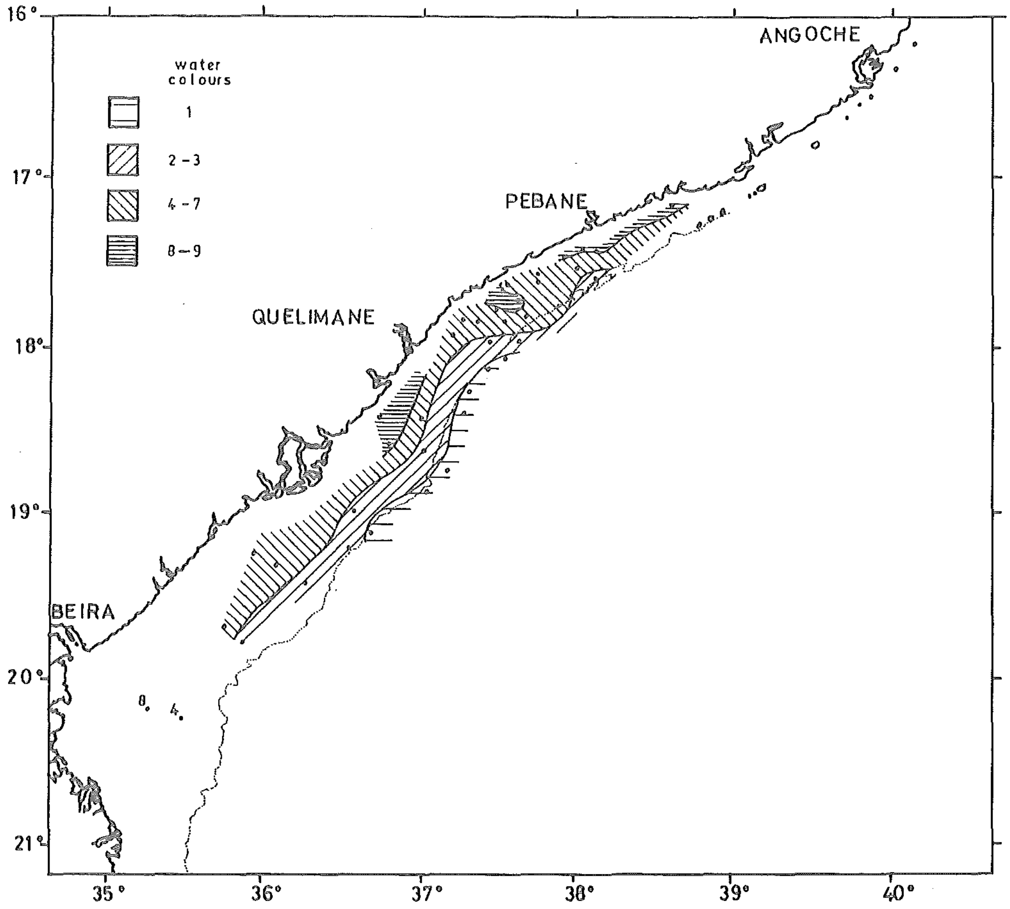


Figure 5. Water colour (Forel), 22 Sep - 8 Oct 1982

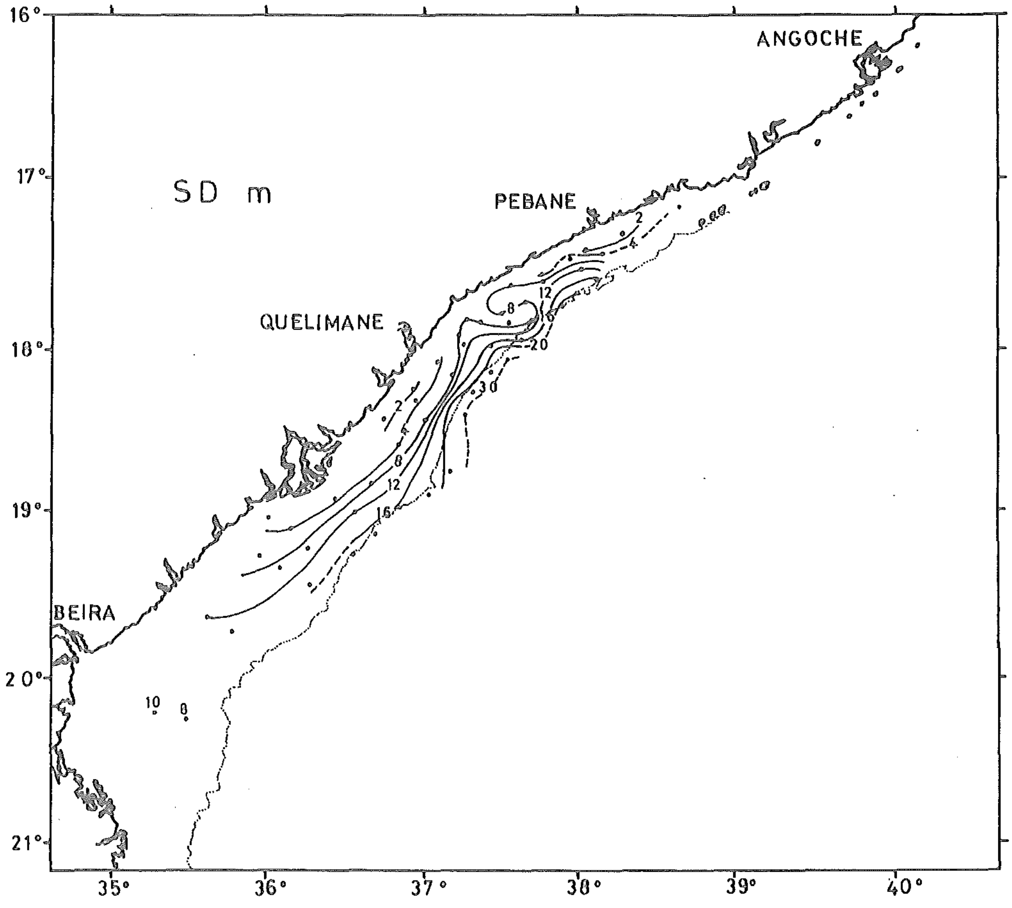


Figure 6. Secchi depth, 22 Sep-8 Oct 1982

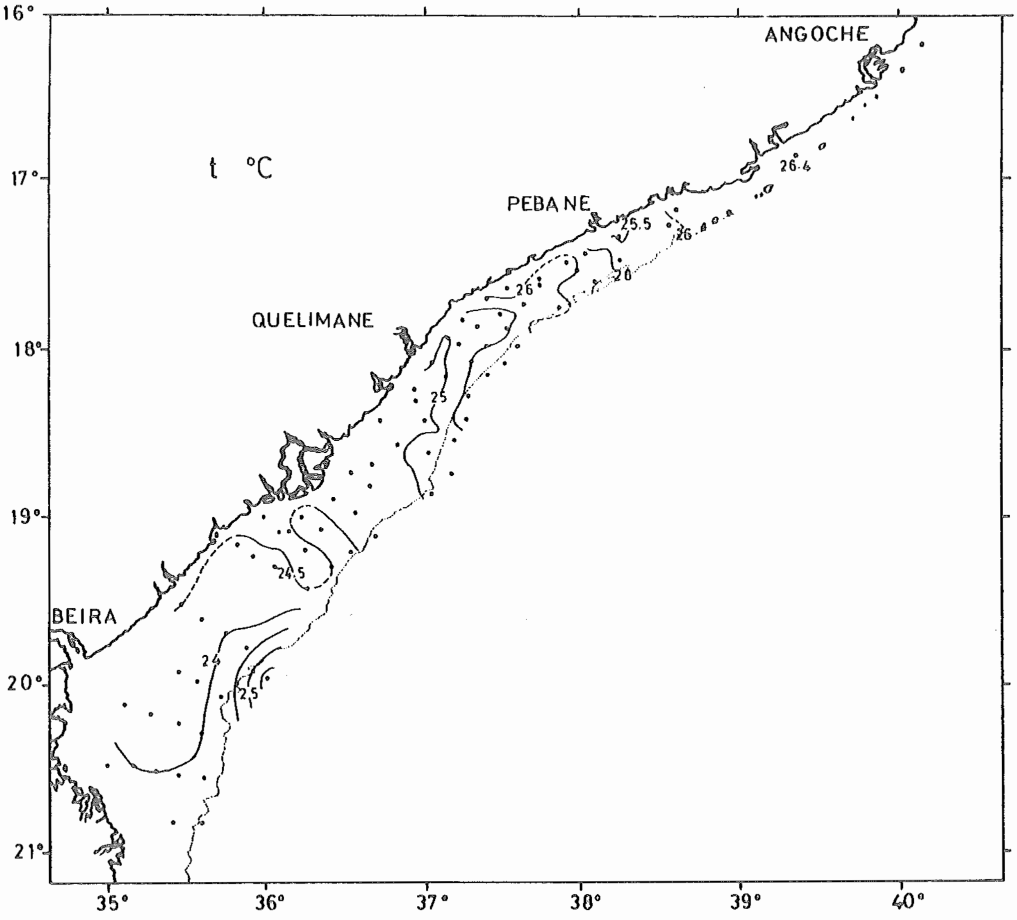


Figure 7. Surface temperature, 22 Sep-8 Oct 1982

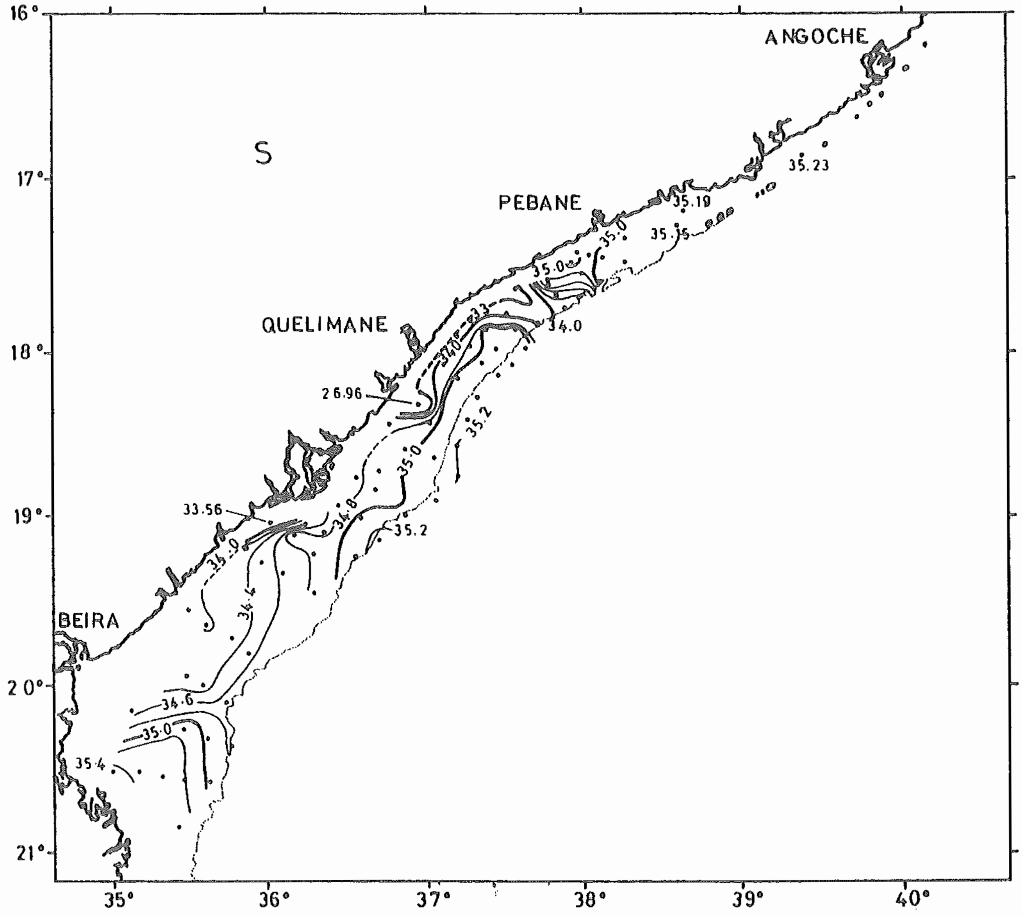


Figure 8. Surface salinity, 22 Sep-8 Oct 1982

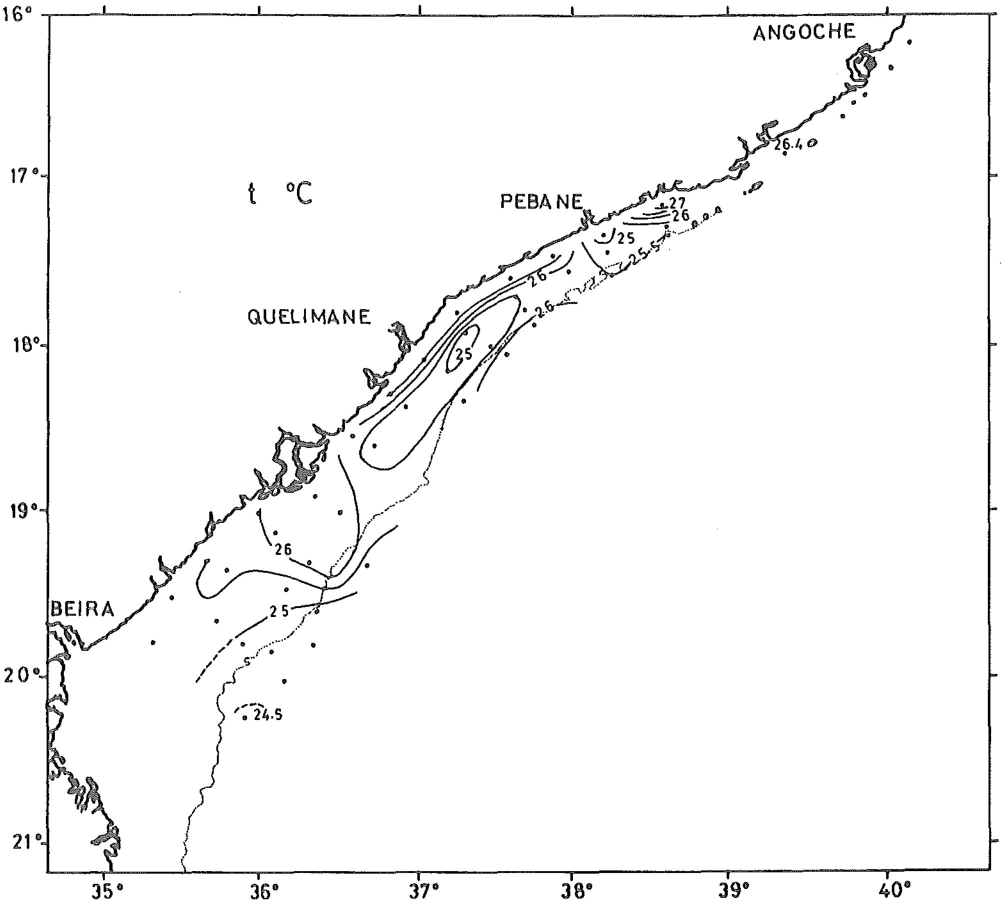


Figure 9. Surface temperature, 8-25 Oct 1982

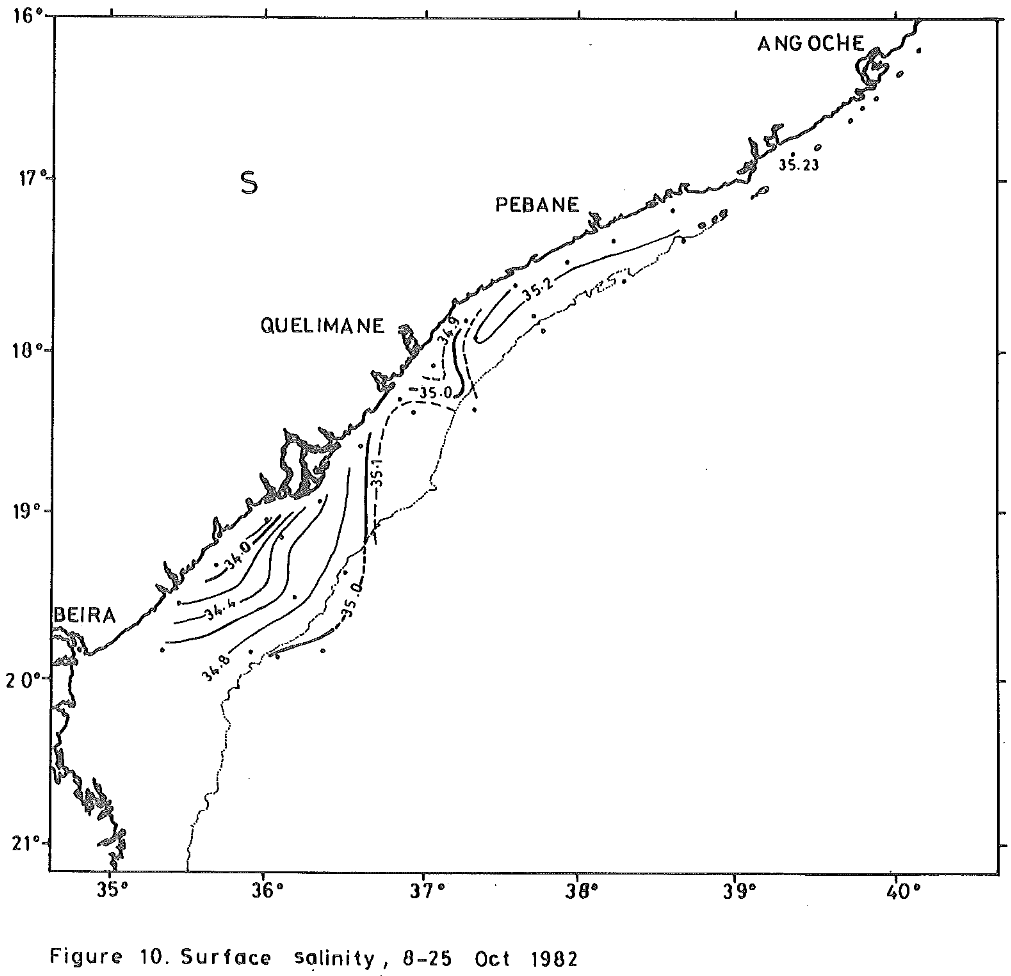


Figure 10. Surface salinity, 8-25 Oct 1982

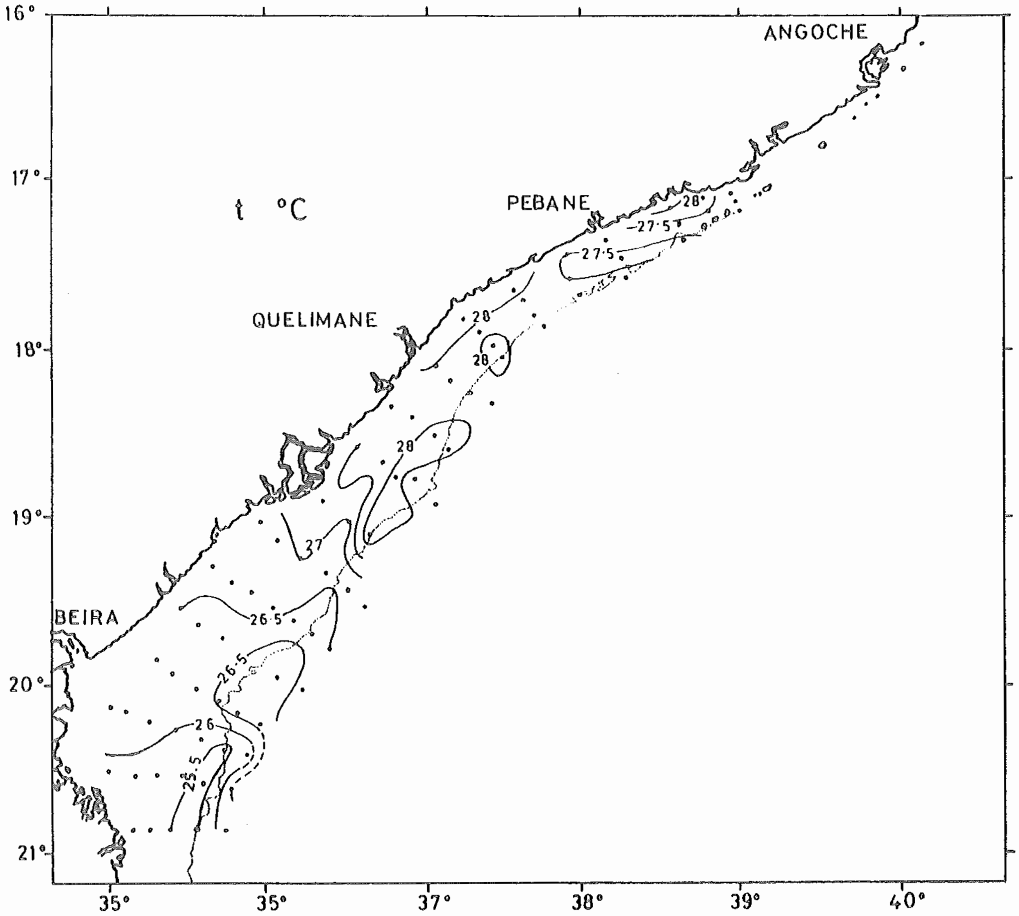


Figure 11. Surface temperature, 18 Nov- 4 Dec 1982

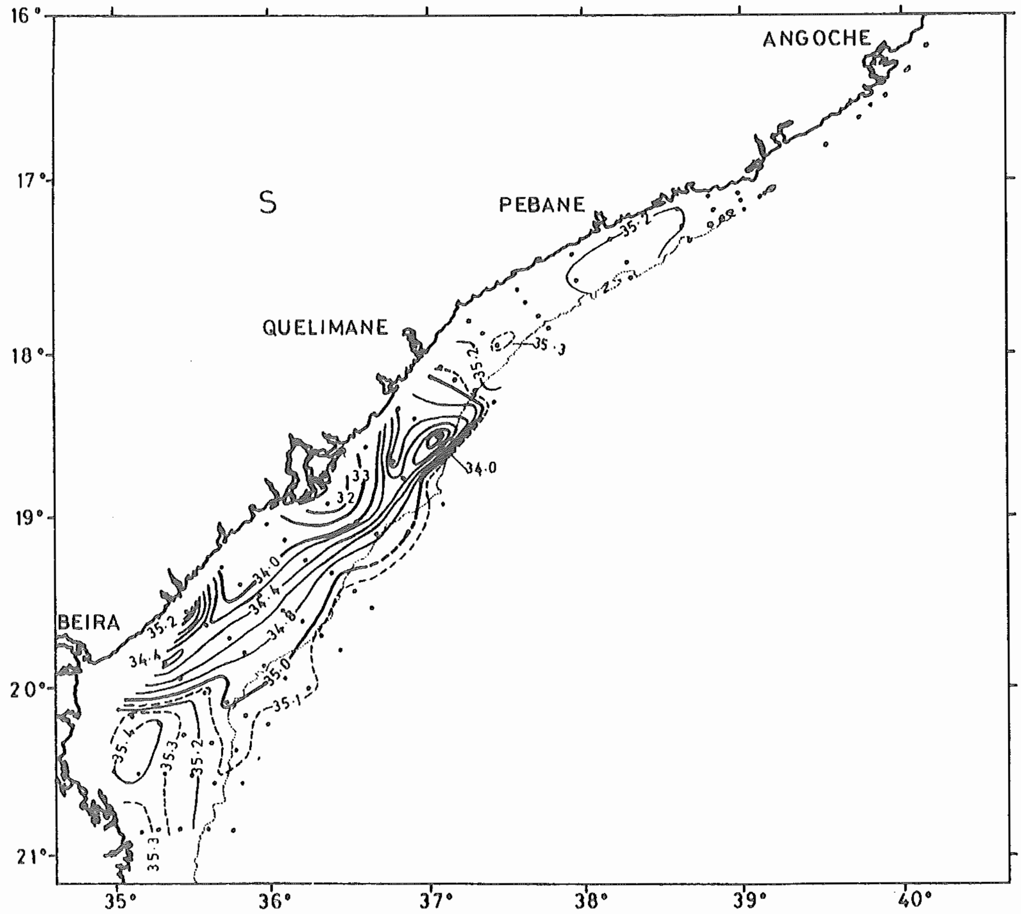
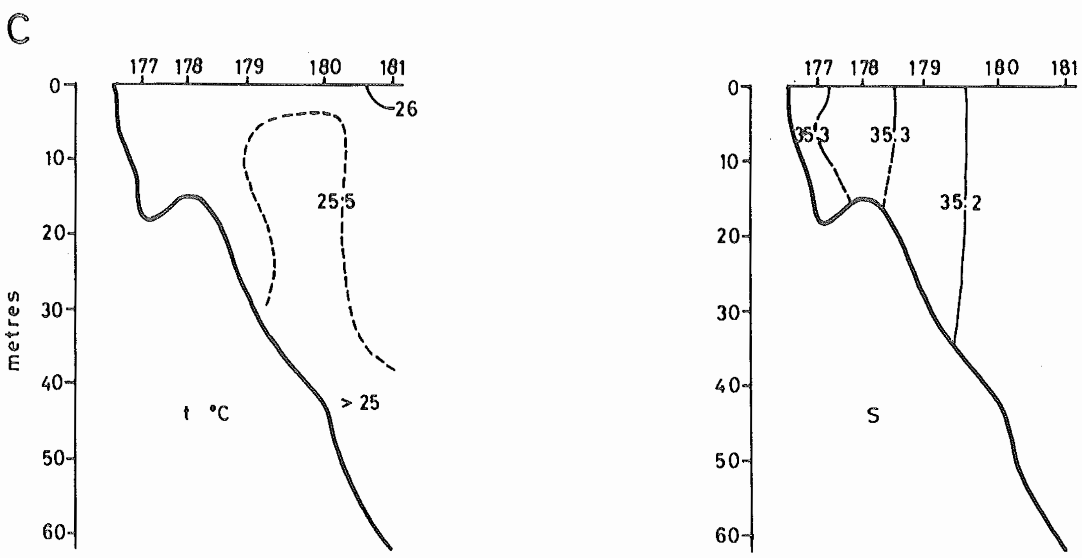


Figure 12. Surface salinity, 18 Nov-4 Dec 1982

Figure 13

Temperature and salinity profiles
at Section I

C - 18 NOV 1982



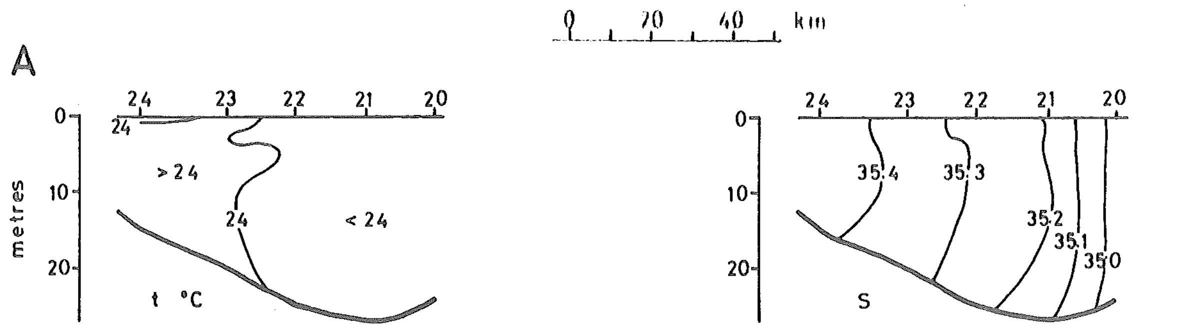
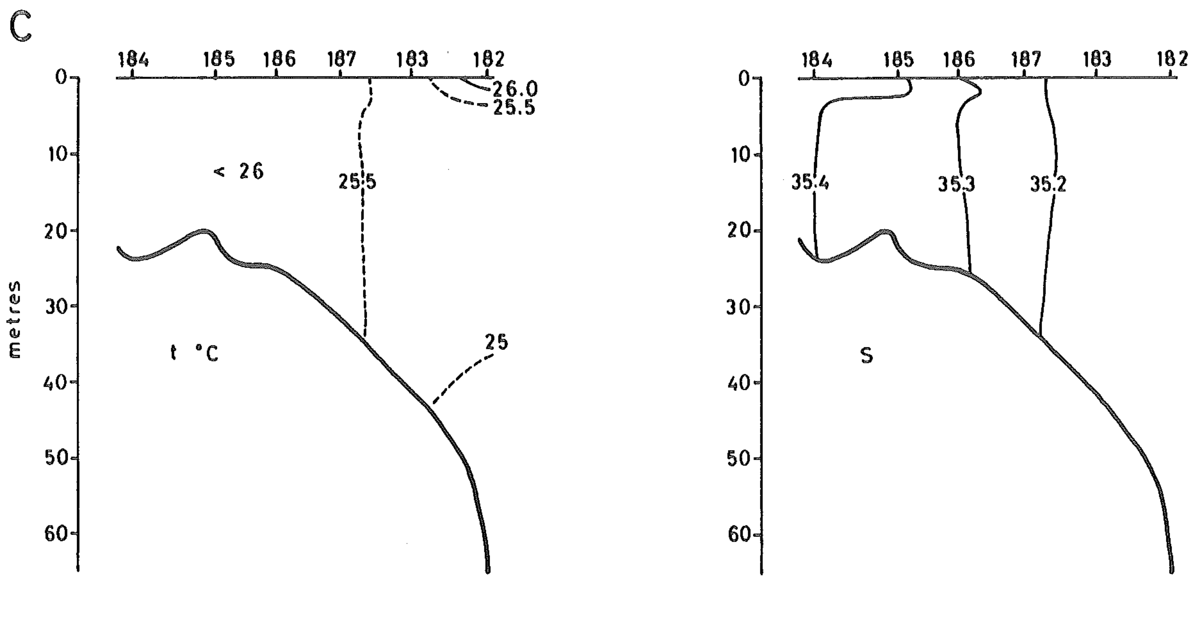


Figure 14

Temperature and salinity profiles
at Section II

A – 23 SEP 1982

C – 18–19 NOV 1982



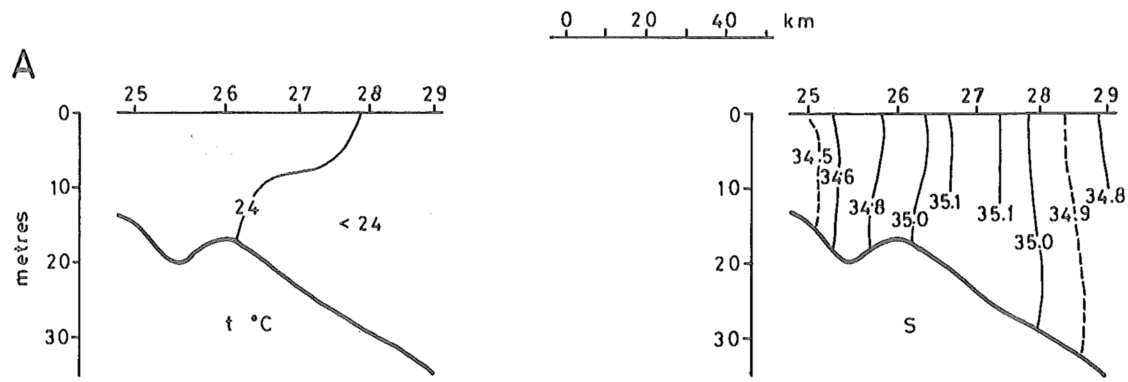


Figure 15

Temperature and salinity profiles at Section III

A – 23 SEP 1982

C – 19-20 NOV 1982

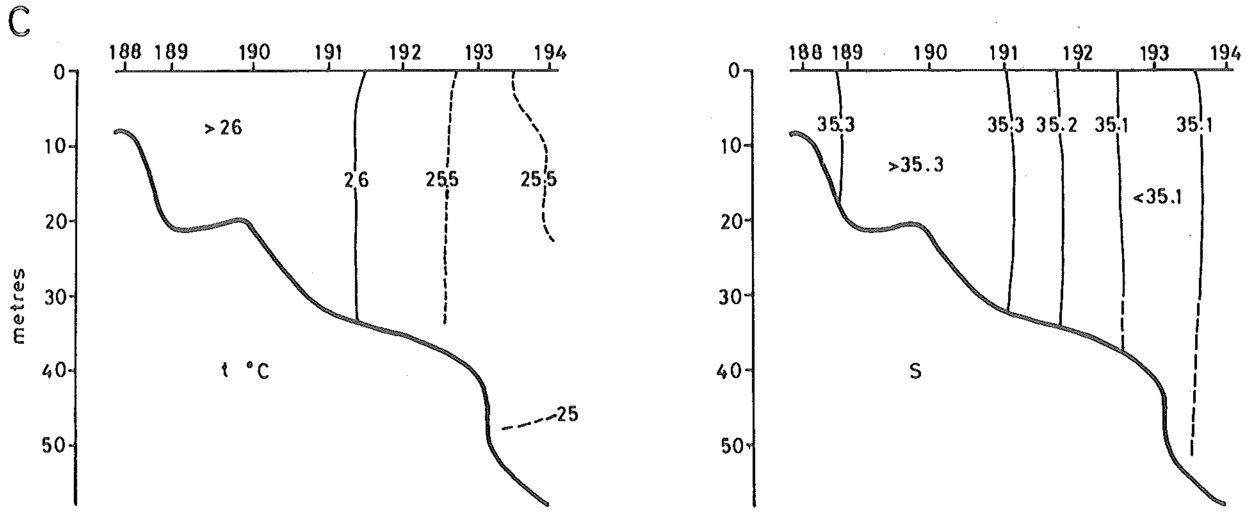
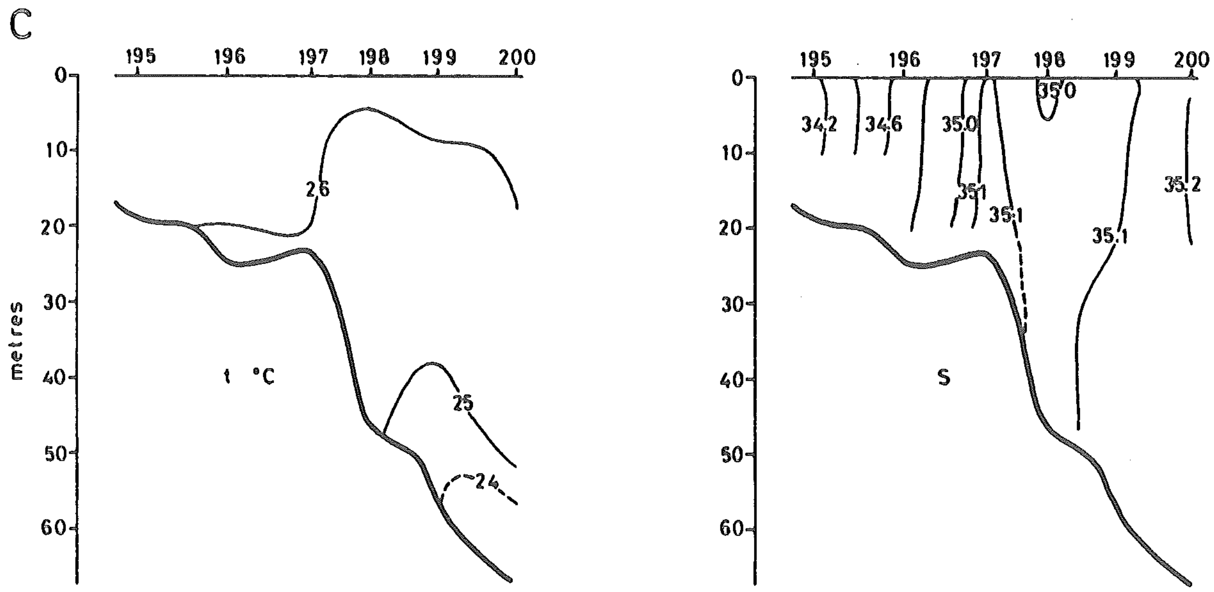
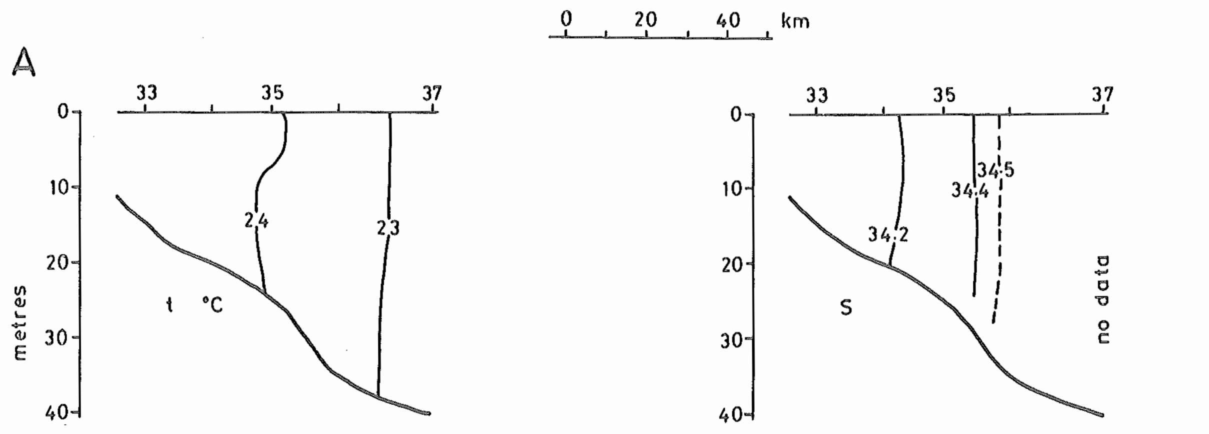


Figure 16

Temperature and salinity profiles at Section IV

C - 20 NOV 1982





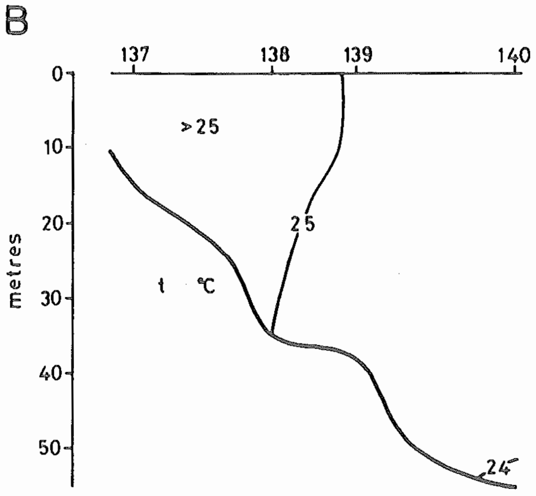


Figure 17

Temperature and salinity profiles at Section V

A - 24 SEP 1982

B - 24 OCT 1982

C - 21 NOV 1982

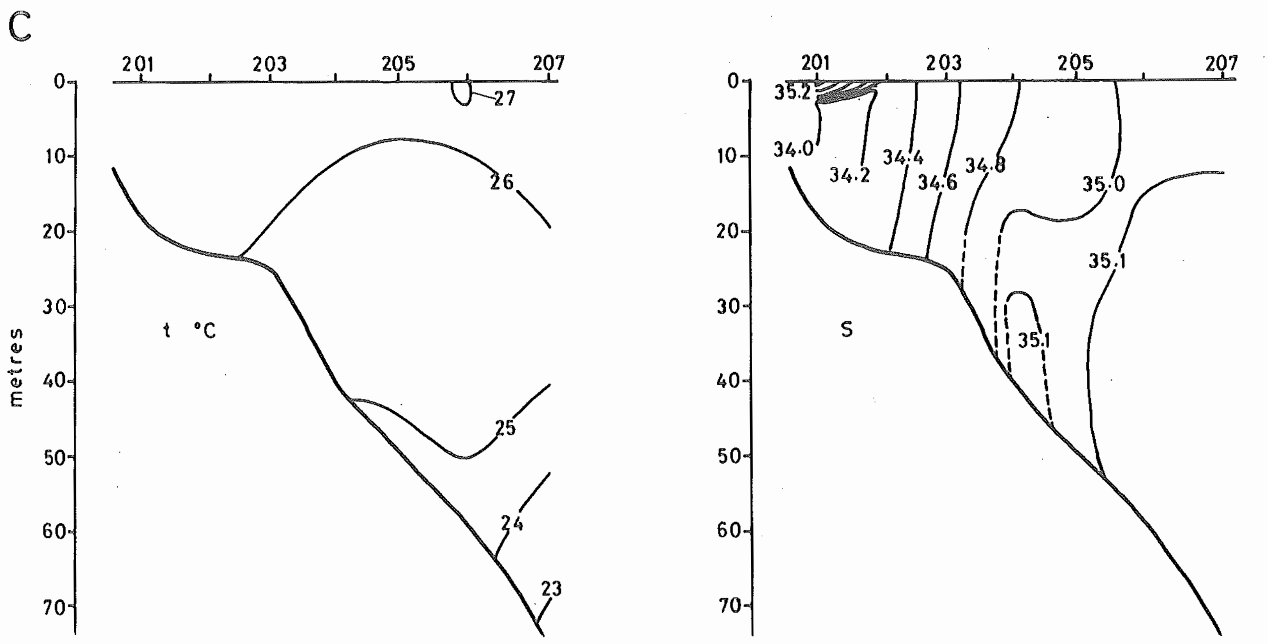
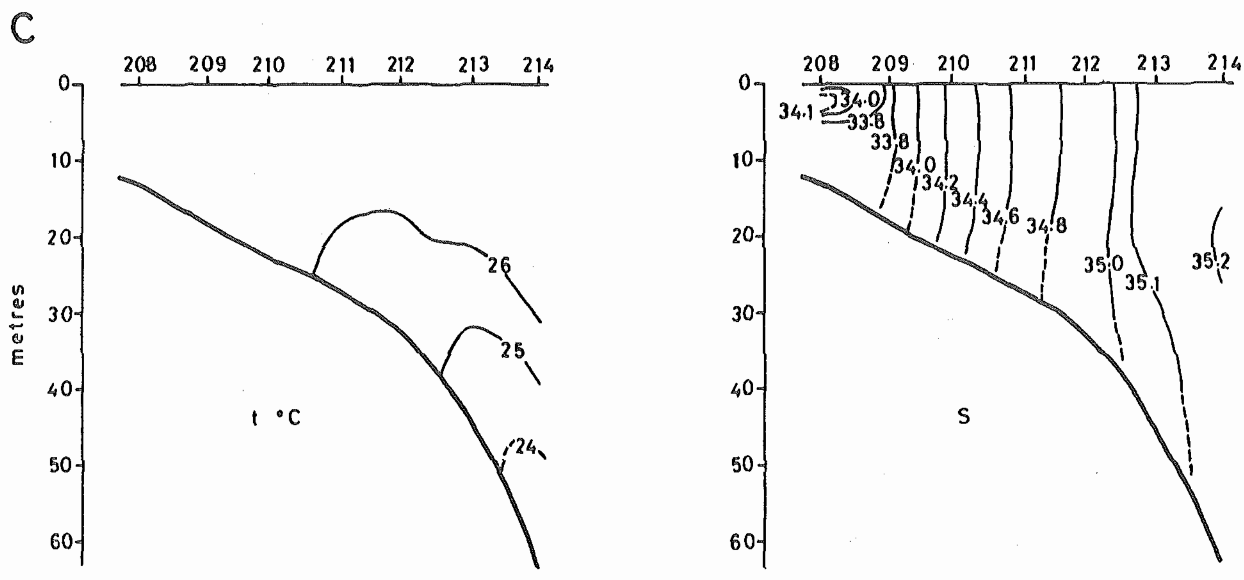
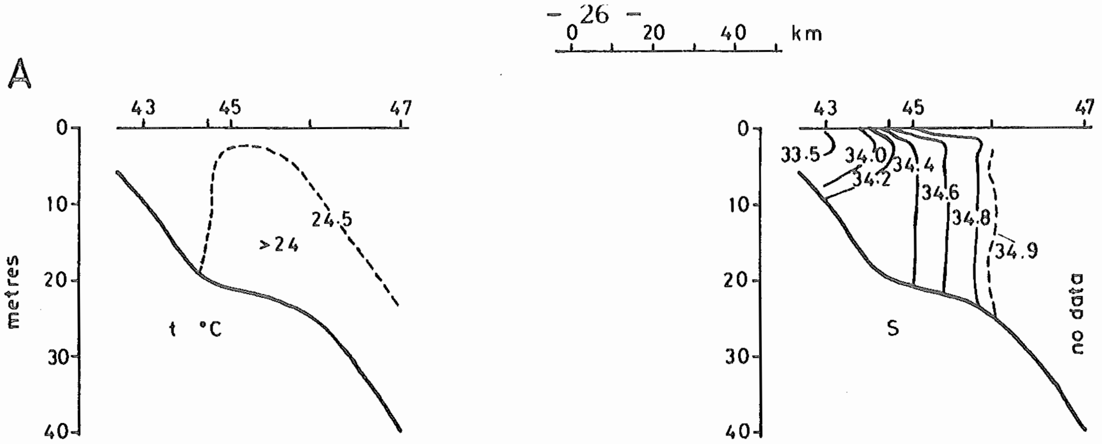


Figure 18

Temperature and salinity profiles
at Section VI

C - 22-23 NOV 1982





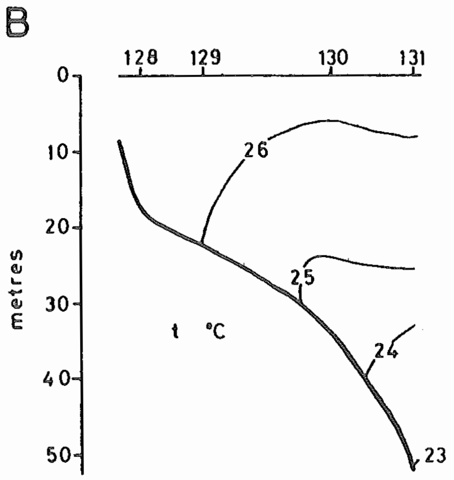


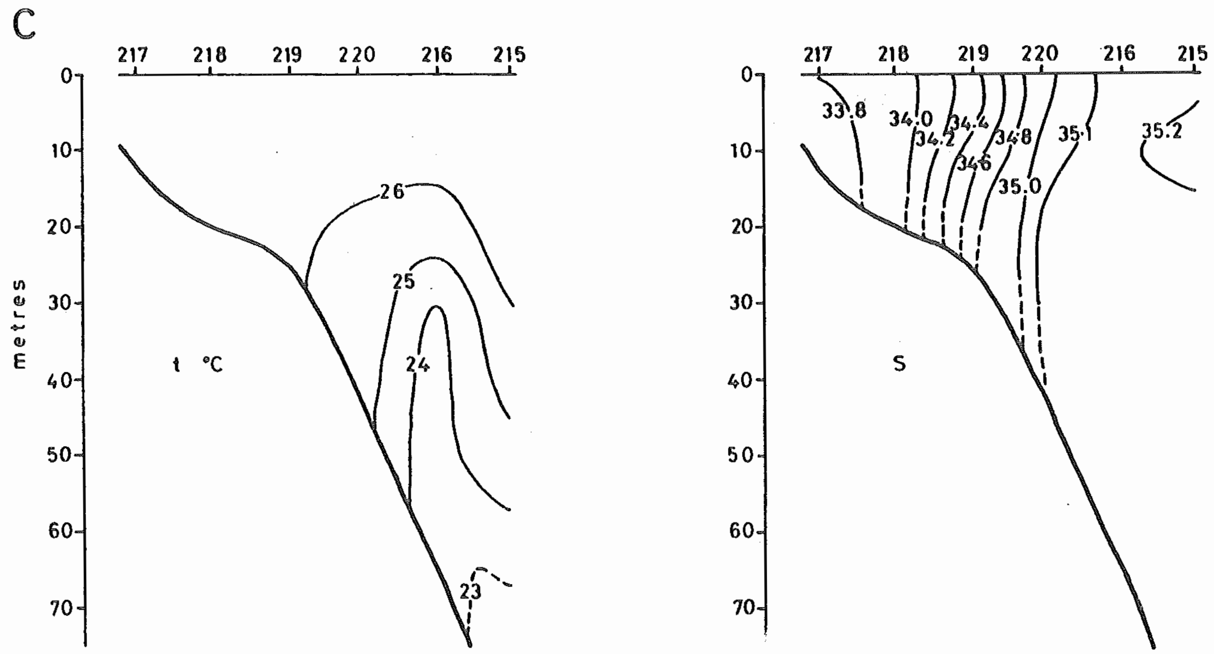
Figure 19

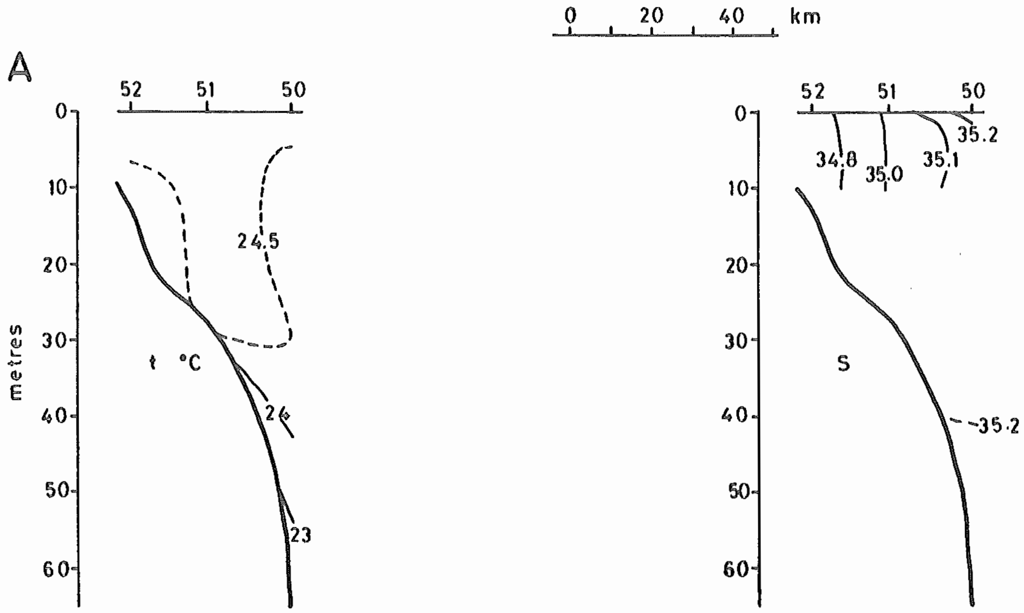
Temperature and salinity profiles at Section VII

A – 27 SEP 1982

B – 20 OCT 1982

C – 23-24 NOV 1982





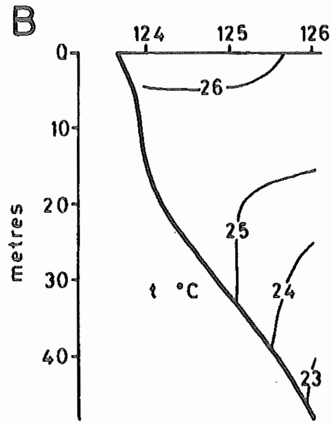


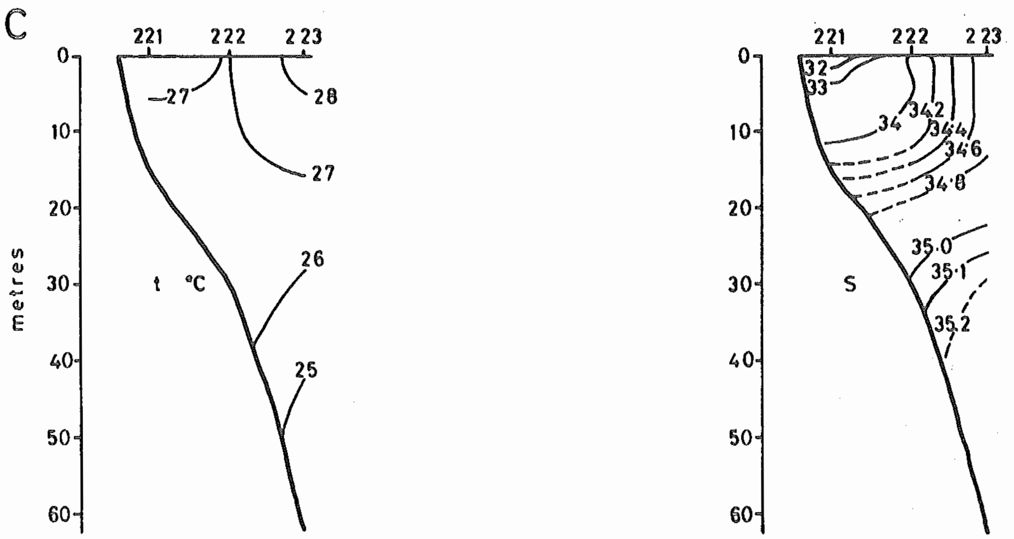
Figure 20

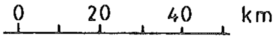
Temperature and salinity profiles a Section VIII

A - 28 SEP 1982

B - 19 OCT 1982

C - 25 NOV 1982





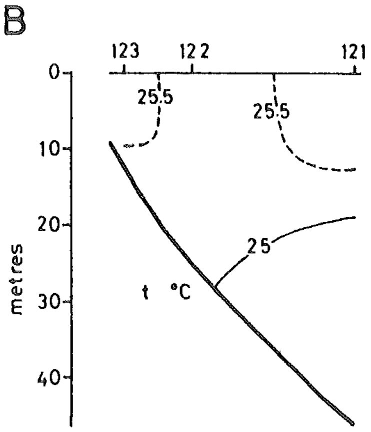
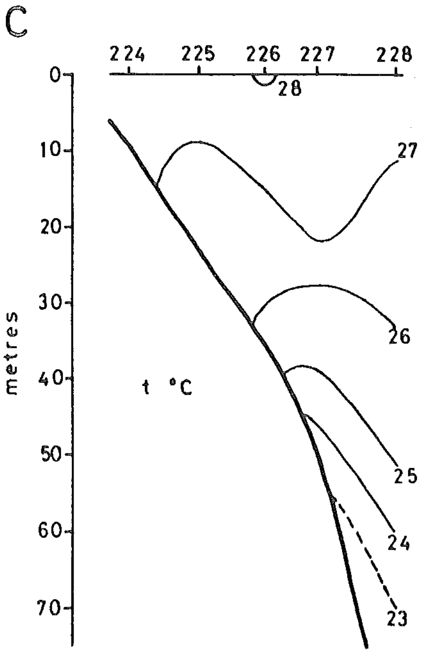
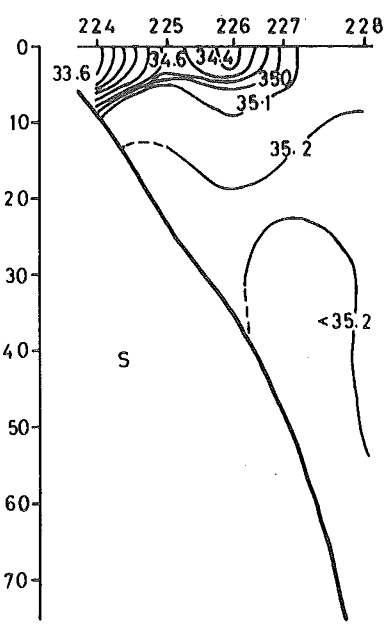


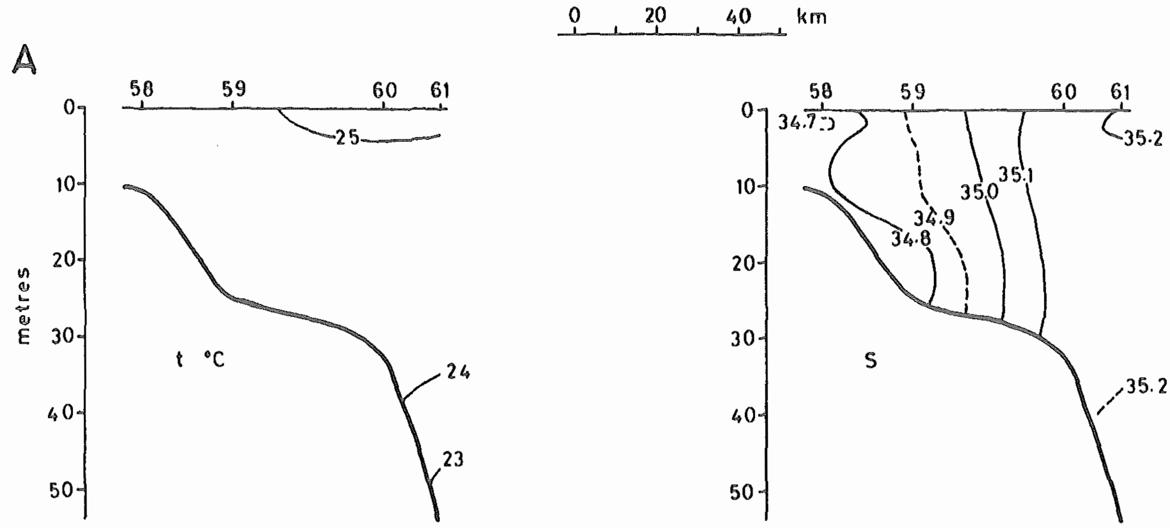
Figure 21

Temperature and salinity profiles
at Section IX

B - 18-19 OCT 1982
C - 26 NOV 1982







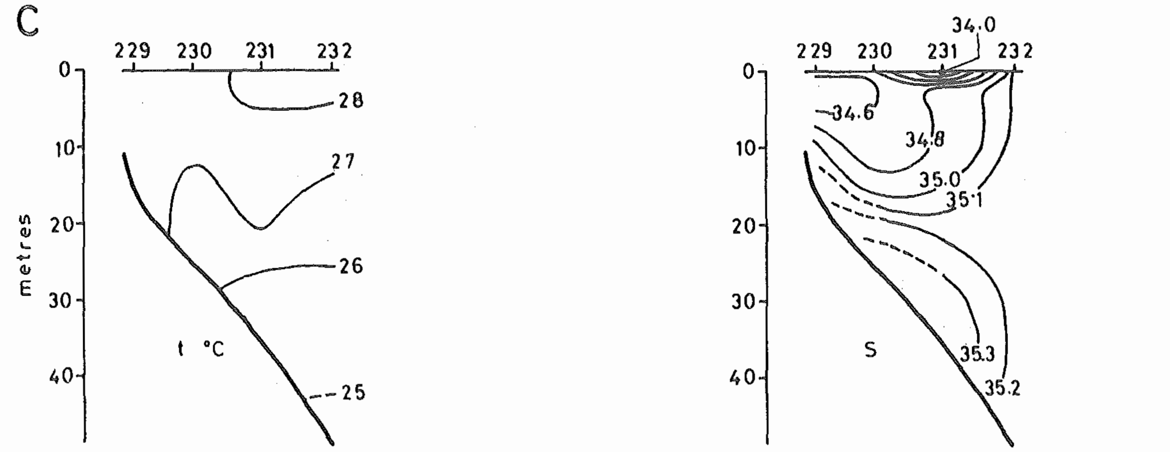
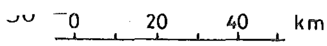


Figure 22

Temperature and salinity profiles at Section X

A – 29-30 SEP 1982

C – 27 NOV 1982



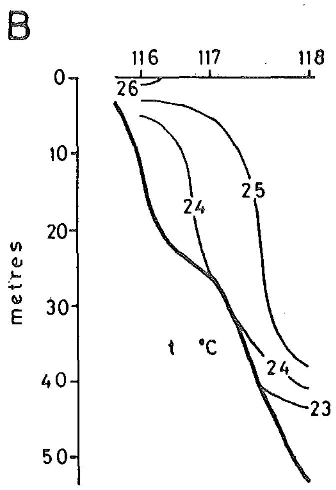
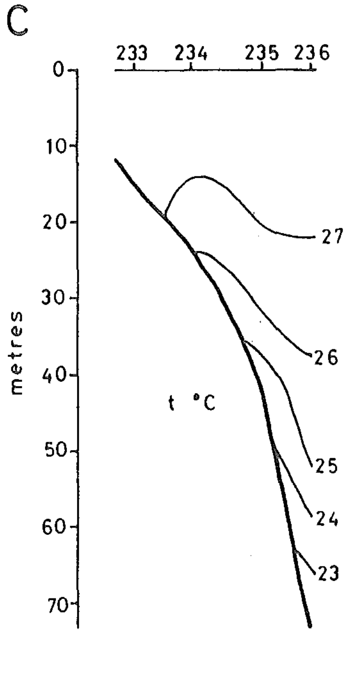
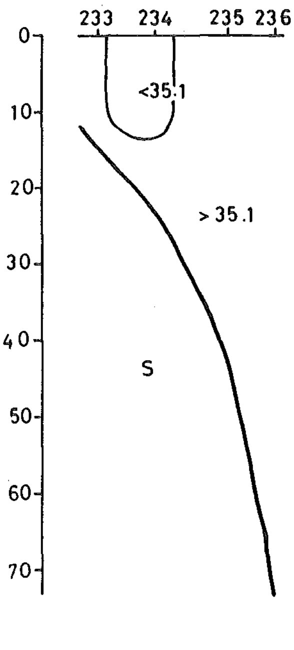


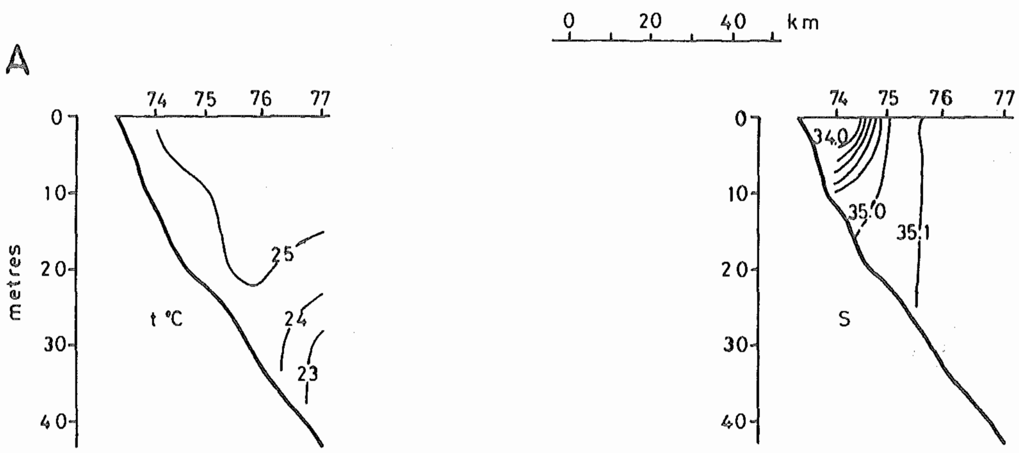
Figure 23

Temperature and salinity profiles
at Section XI

B - 16-17 OCT 1982
C - 28 NOV 1982







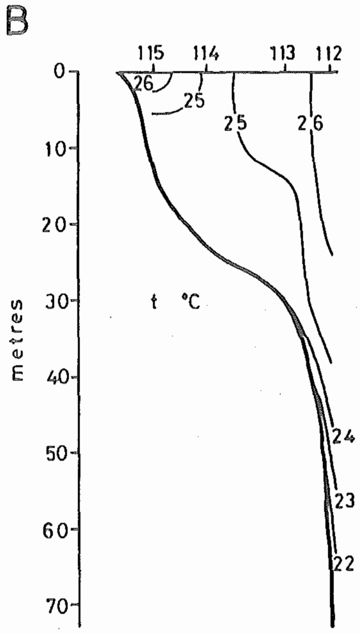
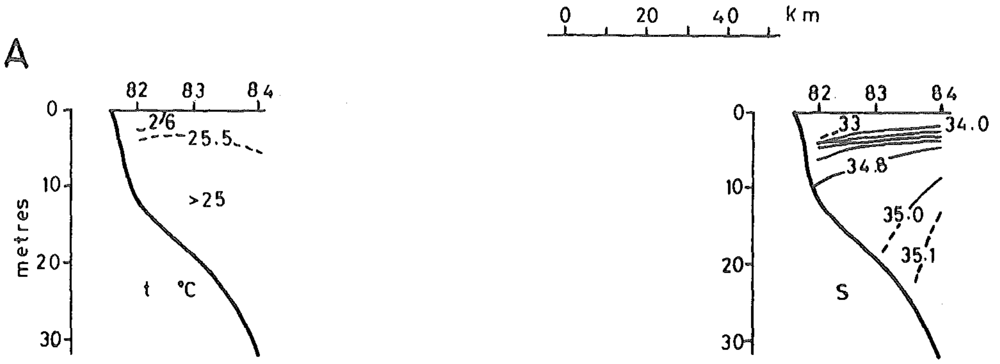


Figure 24

Temperature and salinity profiles
at Section XII

A - 3 OCT 1982
B - 15-16 OCT 1982
C - 29 NOV 1982



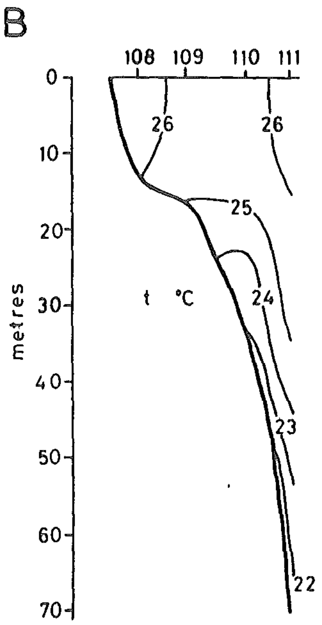


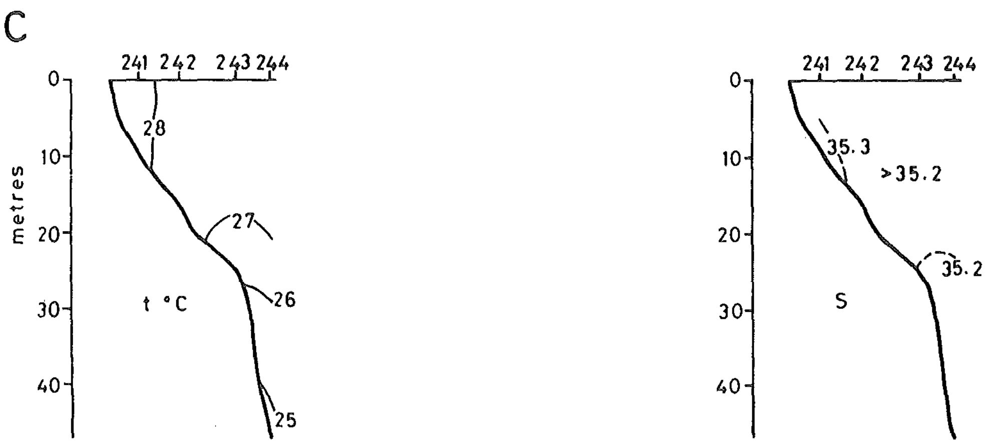
Figure 25

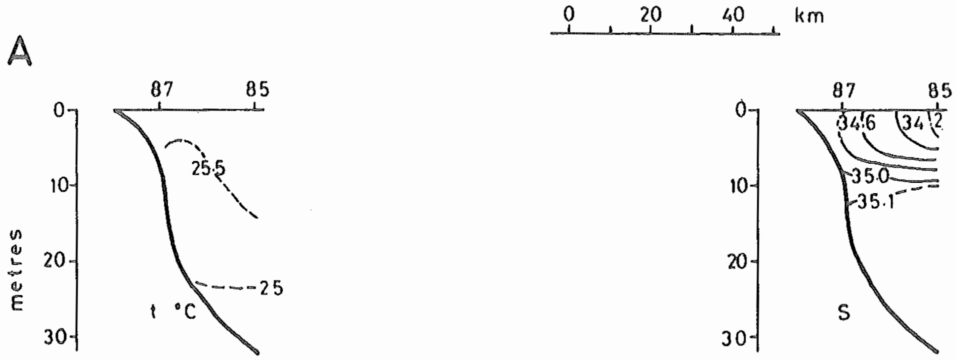
Temperature and salinity profiles at Section XIII

A - 4 - 5 OCT 1982

B - 14 - 15 OCT 1982

C - 30 NOV 1982





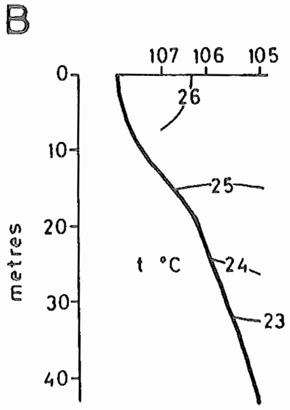


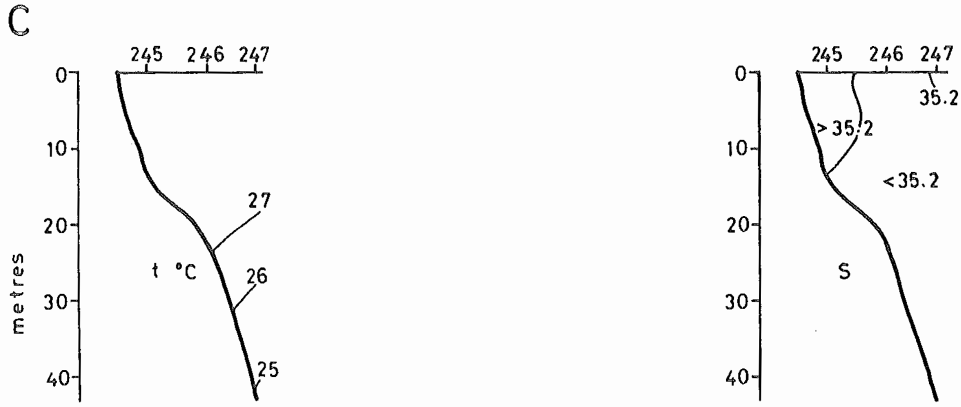
Figure 26

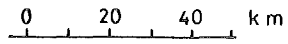
Temperature and salinity profiles at Section XIV

A - 5- 6 OCT 1982

B - 14 OCT 1982

C - 1 DEC 1982





B

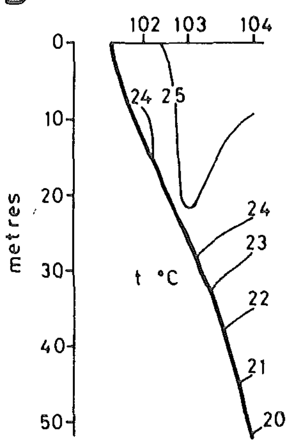
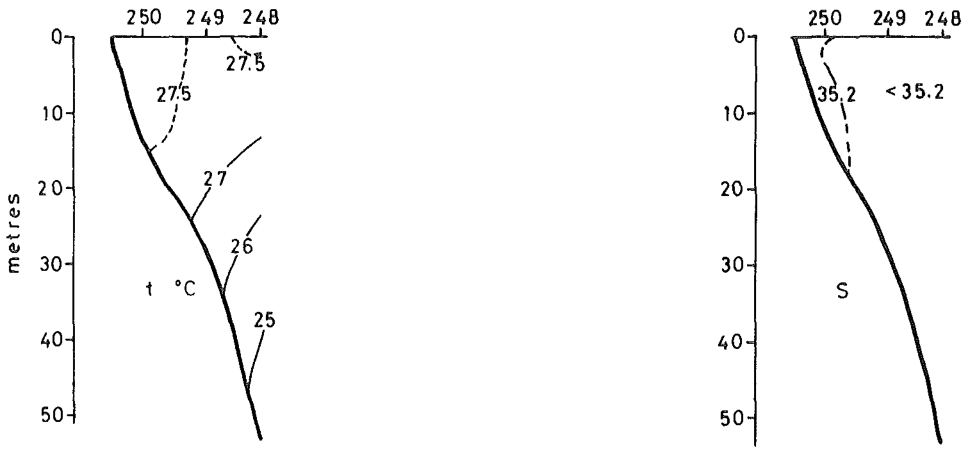


Figure 27

Temperature and salinity profiles
at Section XV

B - 13-14 OCT 1982
C - 1- 2 DEC 1982

C



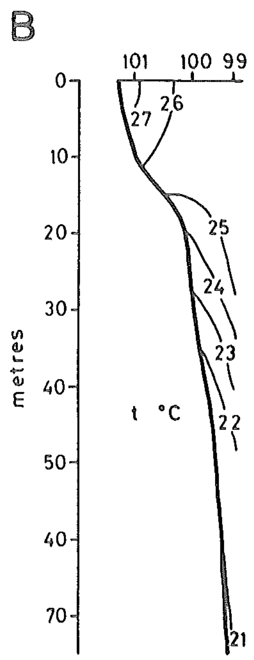


Figure 28

Temperature and salinity profiles
at Section XVI

B – 13 OCT 1982
C – 2 DEC 1982