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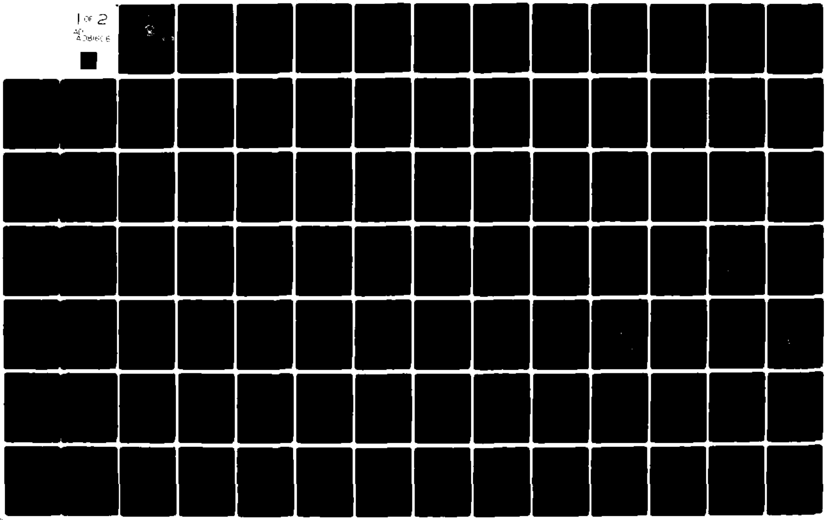

NAVAL POSTGRADUATE SCHOOL

Monterey, California

THESIS

MEASUREMENT OF THE
CALIFORNIA COUNTERCURRENT

by

Keith Coddington

June 1979

Thesis Advisors: J. B. Wickham
S. P. Tucker

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SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

REPORT DOCUMENTATION PAGE		READ INSTRUCTIONS BEFORE COMPLETING FORM
1. REPORT NUMBER	2. GOVT ACCESSION NO.	3. RECIPIENT'S CATALOG NUMBER
4. TITLE (and Subtitle) Measurement of the California Countercurrent		5. TYPE OF REPORT & PERIOD COVERED Master's Thesis; ~~June 1979~~
		6. PERFORMING ORG. REPORT NUMBER
7. AUTHOR(s) Keith Coddington		8. CONTRACT OR GRANT NUMBER(s)
9. PERFORMING ORGANIZATION NAME AND ADDRESS Naval Postgraduate School Monterey, California 93940		10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS
11. CONTROLLING OFFICE NAME AND ADDRESS Naval Postgraduate School Monterey, California 93940		12. REPORT DATE Jun[redacted]79
		13. NUMBER OF PAGES 135
14. MONITORING AGENCY NAME & ADDRESS(if different from Controlling Office) 12) 136		15. SECURITY CLASS. (of this report) Unclassified
		15a. DECLASSIFICATION/DOWNGRADING SCHEDULE

16. DISTRIBUTION STATEMENT (of this Report)

Approved for public release; distribution unlimited.

17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)

18. SUPPLEMENTARY NOTES

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

California Countercurrent
California Undercurrent
Davidson Current
California Current

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

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During that same period vertical temperature and salinity profiles were made at 23 stations on four separate cruises in the study area south of Monterey, California. These arrays of

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The California Countercurrent was found to be present in the region of study during the entire observation period. Its offshore position and extent, its intensity and its vertical location and extent varied in a way largely consistent with its reported behavior in other locations along the U.S. West Coast.

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Measurement of the California Countercurrent

by

Keith Coddington
Lieutenant, United States Coast Guard
B.S., United States Coast Guard Academy, 1973

Submitted in partial fulfillment of the requirements for the degree of

MASTER OF SCIENCE IN OCEANOGRAPHY

from the

NAVAL POSTGRADUATE SCHOOL
June 1979

Author: Keith Coddington

Approved by: Steven P. Tucker, Thesis Co-Advisor

Jacob B. Wickham, Thesis Co-Advisor

Dale F. Leipper, Chairman, Department of Oceanography

William M. Tolles, Dean of Science and Engineering

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Direct measurements by moored current meters and indirect measurements from geostrophy are compared and discussed for a region over the continental slope off central California during the Davidson Current period.

During that same period vertical temperature and salinity profiles were made at 23 stations on four separate cruises in the study area south of Monterey, California. These arrays of moored current meters simultaneously recorded the flow of the current at specified levels.

The California Countercurrent was found to be present in the region of study during the entire observation period. Its offshore position and extent, its intensity and its vertical location and extent varied in a way largely consistent with its reported behavior in other locations along the U.S. West Coast.

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ACKNOWLEDGMENT

The author would like to express his sincere appreciation to his thesis advisors, Professor S.P. Tucker and Professor J.B. Wickham. Their knowledge and expertise in this project was only surpassed by their willingness to freely devote their time.

Special appreciation is extended to the Captain, W.W. Reynolds, and crew of the R/V ACANIA. Their highly skilled seamanship provided for smooth array installation and retrieval. Appreciation is also extended to Mr. Tim Stanton for his assistance in translating the current meter tapes.

Finally, a devoted thanks to my wife, Michelle, for her patience and understanding during this time.

I. INTRODUCTION

A. THE CALIFORNIA CURRENT SYSTEM

In the past decade eastern boundary currents and coastal upwelling have come under considerable scrutiny. This is due in part to their influence on the fishing industry and various other economic enterprises. Examples of eastern boundary current systems are the California, the Peru, the Benguela and the Canary Current Systems.

One eastern boundary current system, the California Current system is made up of an equatorward surface flow which extends along the entire west coast of the United States and Baja California and a counterflow, poleward, sometimes beneath this, at others on the surface shoreward of it. The equatorward surface flow is fed by the North Pacific Current, i.e. the northern limb of the North Pacific Gyre, and is known as the California Current. The poleward flow may be submerged, when it is then termed the California Undercurrent, or, at certain times of the year it may appear at the surface, when it is called the Davidson Current.

Reid, Roden and Wyllie (1958) apply the term California Current to all southward flow in the North Pacific Gyre. It is common to define the boundary of the California Current at a distance 1000 kilometers from shore (Hickey, 1978). High velocities are generally not encountered in this cold water mass.

The California Undercurrent is a poleward flow of water, the temperature and salinity of which is slightly higher than that of the surrounding water and which is usually found shoreward of the southward flowing California Current. It is much narrower and has a maximum of northward flow at intermediate depth. It is uncertain whether the Davidson Current is superimposed on the California Undercurrent, suppressing the core to great depths, or whether the Davidson Current is actually the expression of the undercurrent at the surface (Hickey, 1978).

The California Undercurrent is present year round and, with the onset of north-northwest winds and upwelling along California, it is found predominately below 200 meters. It is characterized by relatively high temperature, salinity and phosphate and low dissolved oxygen concentrations because of its southern origin. The undercurrent has been intensely studied off Oregon, Washington, and Southern California, but direct current measurements are lacking for the Central California region.

B. PREVIOUS STUDIES OF THE CALIFORNIA UNDERCURRENT

The California Undercurrent was first discussed by Sverdrup and Fleming (1941). During their cruises in 1937, they defined "northern water" on a T-S curve which showed an increase in salinity with decreasing temperature (Figure 1, curve C131). The T-S curve for "southern water" showed salinity relatively constant as temperature decreased (Figure 1, curves 5.3 and B III, 31). They constructed a chart, defining percentage of southern water for given T-S pairs (Figure 2). Using these parameters they traced southern water as far north as Cape Mendocino. They also found that the southern water was close to the coast and was concentrated in the northward flowing current. They also showed the existence of the northward flowing undercurrent by means of dynamic heights.

Reid, Roden, and Wyllie (1958) expanded on Sverdrup and Fleming (1941) and Sverdrup, et al. (1942). They concluded the evidence for the undercurrent was of two sorts: (1) The warm or more saline subsurface water of low oxygen content suggested southern origin; and (2) geostrophic flow at the 200 decibar surface with respect to both the 500 and 1000 decibar surfaces indicated a northward flowing current, 30-60 miles in width near the coast north of 30°N and somewhat wider to the south.

Direct measurements of the undercurrent was made by Reid (1962, 1963) and Reid and Schwartzlose (1962) using drogues. Their results indicated the existence of a northward flowing current at 200 meters depth off Monterey, California, and Baja California. During the winter they found that a northward flow existed at the surface.

As a part of a California Cooperative Oceanic Fisheries Investigation (CALCOFI) study Wyllie (1966) showed the existence of a northward flowing undercurrent on the basis of dynamic topography. Wyllie's charts of mean monthly dynamic topography on the 200 decibar surface relative to 500 decibars provide the best description of the flow of the undercurrent in January south of Cape Mendocine (Figures 3 and 4).

From Point Conception northward stronger subsurface flow was observed in winter than in summer. The weakest flow occured from March to May. Pavlova (1966) found that during the spring, when the undercurrent appears to be absent at the usual depth of about 200 meters, it may be present at depths exceeding 500 meters. Pavlova also concluded that the undercurrent actually reaches the surface during late fall and winter, when it is known as the Davidson Current. Wyllie's data supported these conclusions.

Wooster and Jones (1970) found that a characteristic of the undercurrent was a relatively high salinity bulge centered at sigma-t equal 26.54 (150 cl/t) on the T-S diagram (Figure 5). They also gave some evidence for an interannual variation in the northward extent of a given isohaline. They pointed out that a coastal deepening of isotherms and isopycnals and rising of isohalines are characteristics of the poleward undercurrent.

In the last ten years the study of the undercurrent has been concentrated north of Cape Mendocino and to some extent in the vicinity of Monterey, California. Mooers, Collins and Smith (1976) in their study of upwelling off the Oregon coast found a northward flow along the continental slope between 300 and 1000 meters. They suggested that it may exist at greater depths and may extend from the continental slope to perhaps 500 kilometers from shore. Their primary observations were conducted during the same year and season as those of Wooster and Jones (1970). Mooers, et al, (1976) found that during July 1975, the near surface flow was predominately southward, and the near bottom flow alternated between northward and southward. In August and September 1965 and 1966 the near bottom flow was predominately northward.

Huyer and Smith (1976) and Halpern, Smith and Reed (1978) used direct measurements of current on the slope and shelf to describe the seasonal developments of the undercurrent off the coast of Oregon. Huyer and Smith's (1976) data suggest that the northward flow is present at depths greater than 400 meters in the spring but increases in speed and vertical extent as the season progresses. That the undercurrent was found at the shelf edge by summer is consistent with Pavlova's (1966) findings for northern California. Halpern, Smith, and Reed's (1978) current meter results support those of Huyer and Smith (1976). The data of both these studies suggest that the shelf and slope undercurrents were portions of the same flow.

Eddies are frequently observed off the coast of Vancouver Island, B.C. Mysak (1977) in conjunction with his study of the undercurrent suggests that the eddies are produced by baroclinic instability of the California Undercurrent. For the undercurrent he found a northward flow along the continental slope but a southward flow farther offshore. Thus, off Vancouver Island the northward flowing California Undercurrent is essentially confined to the continental slope. The main core of the current at that latitude occurs around 300 meters.

Off Monterey, California, the undercurrent has been studied by Molnar (1972), Hughes (1975), Greer (1975), and Wickham (1975). Wickham (1975) used drogues and a continuous measuring salinity-temperature-depth profiler (STD). For August three main results were found in conjunction with the undercurrent: (1) At both 50 meters and 200 meters geostrophy and drogues both indicate that there is a narrow band of poleward flowing water near the shelf edge; (2) both drogues and geostrophy also indicate that there is a complex flow father west which seems to split the poleward flow into two branches; and (3) there is a broader poleward flow still farther west which is centered at 40-50 kilometers from the shelf edge.

An analytical model by McCreary (1977) indicated that, due to local wind forcing, the pycnocline tilts alongshore to balance the meridional component of the wind and results in an alongshore flow. This disturbance is not confined to the coast but propagates offshore and northward as a Kelvin-Rossby wave carrying along with it both the pycnocline deformation and the alongshore flow.

Hickey (1978) has examined most of the data to date. She found that the northward subsurface flow is generally found off the west coast of North America over the continental slope. The flow on the 200 decibar surface is most continuous alongshore and strongest (south of Point Conception only) in summer and early fall. It is weakest and least continuous in the spring. North of Point Conception, the flow on the 200 decibar surface is stronger during winter than during summer and fall. She found that the depth of the high-speed core varied seasonally and that the flow appeared to have a jet-like structure, both vertically and horizontally and appeared to extend to the bottom over the slope. This is in agreement with McCreary (1977) who called this jet-like flow, quasi-geostrophic. In support of Wooster and Jones (1970), Hickey (1978) found that the salinity and temperature at the core of the undercurrent generally decreased from about 34.6‰ and 9.5°C off Baja California to about 33.9‰ and 7°C off Vancouver Island.

The flow from the surface to a depth of about 500 meters is confined to the continental slope, but the overall width of the region of northward flow has not been firmly established. The relationship between the undercurrent jet that occurs over the upper slope and the slower broader flow that occurs deeper in the water column farther offshore is uncertain.

C. STATEMENT OF THE PROBLEM

The presence of southern water can be inferred from isohalines, isotherms, and isopleths of sound speed; and the geostrophic current can be inferred from isopycnals. The current can also be found through direct measurements by means of current meters. Wickham (1975) noted that a comparison of geostrophic observations with direct measurements of current would test the utility of geostrophy to describe flow in areas of complexity, such as off Monterey, California.

The initial objective of this study was to collect data by both means. This involved setting up stations where salinity, temperature and depth measurements could be taken and moored current meter arrays could be maintained. The thesis addresses the problems associated with the assembly and maintenance of the moored current arrays, the collection of salinity, temperature and depth data, and the analysis and interpretation of the direct and indirect current observations.

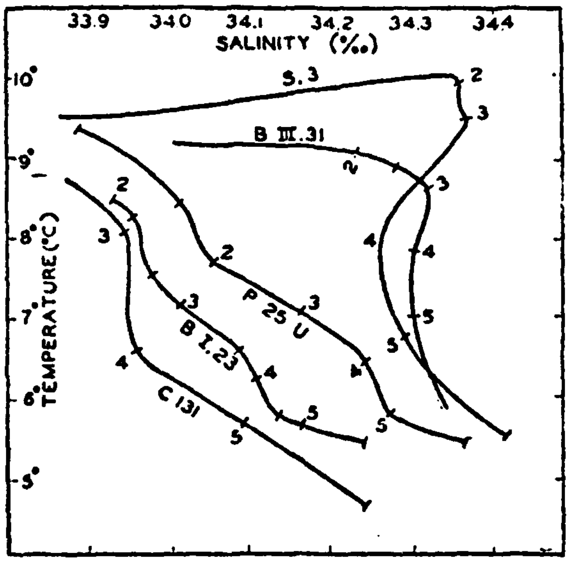

Figure 1. Temperature-salinity curves selected stations (Sverdrup and Johnson, 1941).

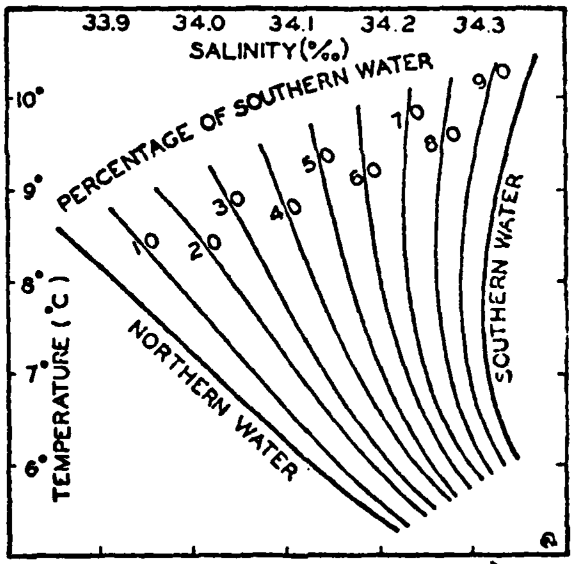

Figure 2. Diagram showing T-S curves defining percentage southern water (Sverdrup and Johnson, 1941.

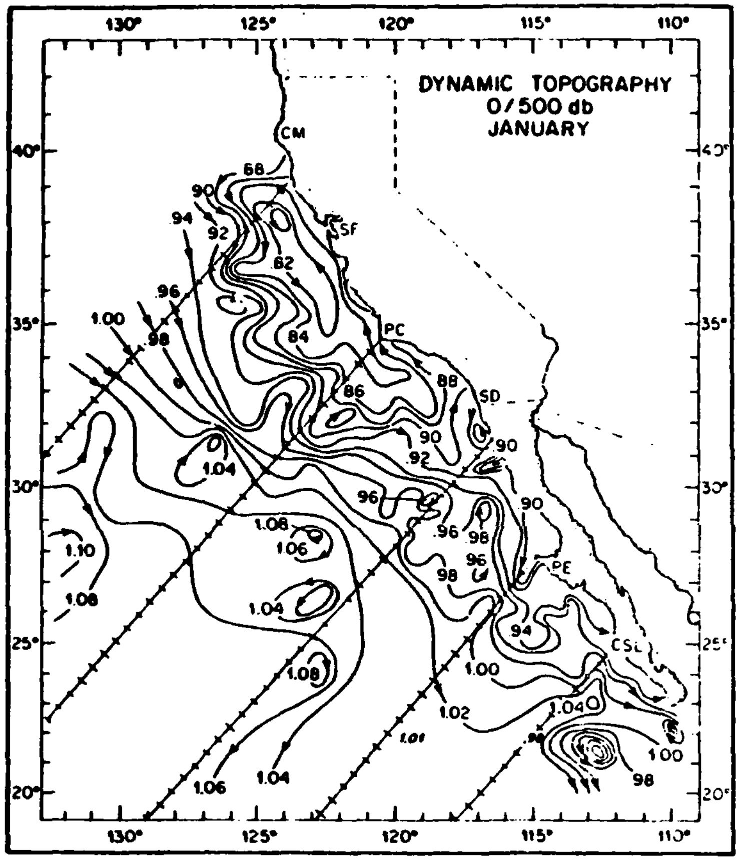

Figure 3. Mean dynamic topography of the sea surface off California and Baja California relative to 500 db during January, contoured from data given by Wyllie (1966). Contour interval is 0.02 dynamic meters (Hickey, 1978).

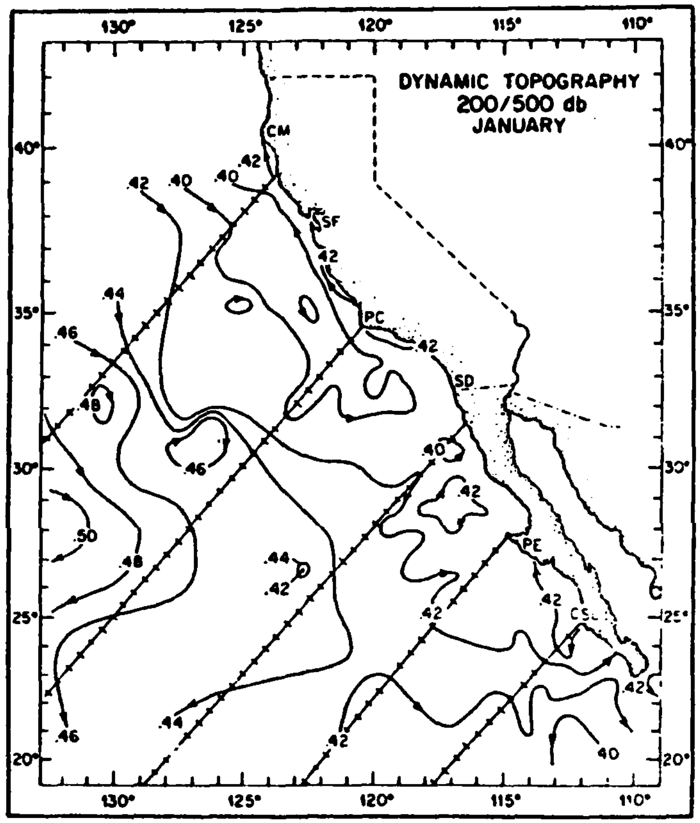

Figure 4. Mean dynamic topography of the 200 db surface relative to 500 db off California and Baja California during January, contoured from data given by Wyllie (1966). Contour interval is 0.02 dynamic meters (Hickey, 1978).

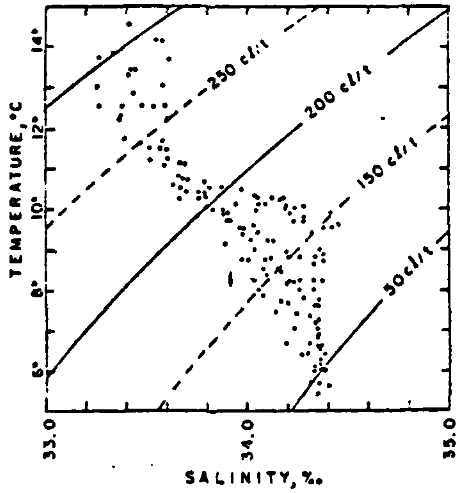

Figure 5. Temperature-salinity relationships for selected stations in California undercurrent (Wooster and Jones, 1970).

II. AREA OF INVESTIGATION

The area of investigation is south of Monterey, California, as shown in Figure 6. Two lines of stations were established. The station locations and water depths are listed in Table I.

One of the reasons for positioning the stations on this part of the California coast is the relative simplicity of the bathymetric features. The depth contours run approximately parallel to the coast, and the shelf break is close to the coast. Another, but crucial, reason for using this part of the California coast is that it is less heavily fished than the areas immediately to the north and to the south. The current meter arrays are entirely subsurface with no surface markers. The presence of fishing activity increases the possibility of array damage or loss which we have tried to minimize through our selection of the study area.

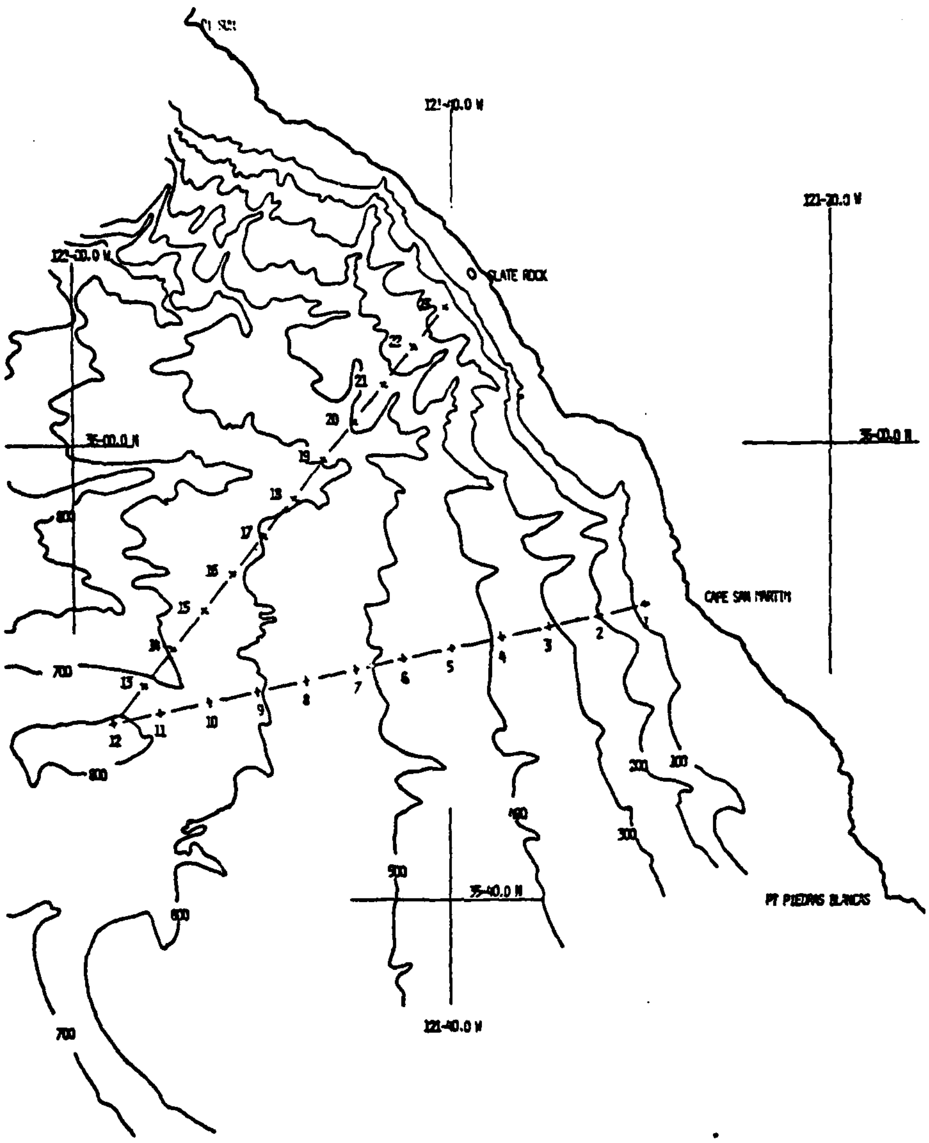

Figure 6. Chart indicating area of investigation and stations. Depth contours in fathoms.

TABLE I

STATION	LATITUDE	LONGITUDE	DEPTH (METERS)
1	35-53.0	121-29.8	100
2	35-52.5	121-32.3	357
3	35-52.1	121-34.7	520
4	35-51.6	121-37.4	668
5	35-51.1	121-39.9	759
6	35-50.7	121-42.4	833
7	35-50.2	121-45.0	915
8	35-49.7	121-47.6	988
9	35-49.2	121-50.1	1061
10	35-48.7	121-52.7	1150
11	35-48.3	121-55.4	1182
12	35-47.8	121-57.7	1044
13	35-49.5	121-56.1	1274
14	35-51.1	121-54.6	1183
15	35-52.7	121-53.0	1146
16	35-54.3	121-51.3	1089
17	35-55.9	121-49.9	1080
18	35-57.6	121-48.3	1098
19	35-59.3	121-47.8	997
20	36-00.9	121-45.2	842
21	36-02.5	121-43.5	732
22	36-04.3	121-42.0	560
23	36-05.9	121-40.2	350

III. SALINITY-TEMPERATURE-DEPTH OBSERVATIONS

A. INSTRUMENTATION AND DATA COLLECTION

Watermass data was collected on four separate cruises of the R/V ACANIA, the oceanographic vessel of the Naval Postgraduate School. The cruises were on 27-28 November 1978, 8-9 January 1979, 22-23 January 1979, and 21-22 February 1979. During each cruise all 23 stations were occupied. Sampling of watermass properties was done where possible to 500 meters, the reference level used by CALCOFI (Wyllie, 1966).

For each cruise the primary instrument, a Bisset Berman Model 9006 STD , was used for delineating the vertical distributions of temperature and salinity. Nansen bottles and reversing thermometers provided independent measurements to check the calibration of the STD. Expendible bathythermograph (XBT) drops and surface temperature observations were made also at each station.

The analog recorder usually used with the Model 9006 STD was replaced on these cruises. The three separated signal frequencies were sent through a Hewlett-Packard Model 57307A VHF Switch with a 20 milisecond settling time to a Hewlett-Packard Model 5328A Universal Counter. The resulting binary coded decimal output was then read into the random access memory of a Hewlett-Packard 9831A desktop computer. After each complete profile the data was transferred to magnetic tape. Profiles were recorded for both the descent and ascent of the STD.

Spikes in the salinity trace are known to be caused by a poorly matched time constant between the conductivity sensor and the platinum resistance thermometer used in the STD to correct the conductivity measurements to salinity. Salinity spikes were eliminated by comparison of descent and ascent profiles and XBT profiles. This was done by hand during examination of the profiles.

B. RESULTS

The results for each cruise are shown as vertical sections for both the Cape San Martin line and the Slate Rock line. Vertical sections are drawn for: salinity, temperature, sigma-t, sound speed, geostrophic currents, and sigma-t and salinity together. The dynamic topography of the 100 db, 200 db, and 300 db surfaces relative to 500 decibars is also given for the four separate cruises.

Salinity and temperature sections were contoured using data stored on the magnetic tapes from the HP 9831A computer after the salinity spikes had been removed. Sigma-t, geostrophic shear, and dynamic heights were calculated using the library computer program HYDRO, available at the Naval Postgraduate School for the IBM 360 computer. Sound speed was calculated using Wilson's equations (Wilson, 1960), available in the same program.

From the calculation of geostrophic shear mean values for four station intervals were found. This was done to reduce the non-geostrophic contributions to the calculations which are inversely proportional to the distance over which geostrophic shear is averaged. Thus, resolution is diminished in order to give a more accurate picture of the larger scale circulation features.

Dynamic heights were smoothed in a similar manner. Values were averaged over three station heights. For station 12 the mean value was found using stations 11, 12, and 13. For the coastal stations 1 and 23 only two stations were used in the averaging, i.e., stations 1 and 2 and stations 22 and 23. For the coastal stations with less than 500 meters of water the stations were treated as if the depth were 500 meters and dynamic topographies were extrapolated from the first station seaward with such depth.

There are no results for stations 21, 22, and 23 during the cruise of 21-22 February 1979, as these stations were lost due to failure of the data recording equipment. On the same cruise there were four stations at five nautical mile intervals added to the west of station 12. This allowed computation of geostrophic shear out to station 12.

C. DISCUSSION OF WATERMASS PROPERTIES AND GEOSTROPHY

The presence of souther water is indicated by the distributions in two cross-sections of salinity, temperature, sigma-t, and sound speed on the series of four cruises. The current structure for the same series is deduced from geostrophic current sections and from dynamic topography at three different levels, both currents and topographies being referred to 500 decibars. Direct current measurements are discussed later in Section IV.

Water with relatively high southern watermass properties is present below the pycnocline on the first cruise on 27-28 November 1978. This is particularly evident on the salinity sections, Figures 7 and 8. Both show a bulge of high salinity water below 200 meters, on Figure 7 for example between stations 3 and 10. The associated temperature and sound speed sections (Appendix B) also indicate the presence of southern water in this region. On this cruise the southern water characteristics appear below 200 meters and from about 4 kilometers to 38 kilometers offshore over the continental slope.

Geostrophy, Figures 27 and 28, indicates northward flow in the upper layers with a surface maximum of 25 to 30 cm/sec. The current appears to have two branches with weaker southward flow between them. Wickham (1975) found similar indications of branched flow farther offshore for his August data in the latitude of Monterey, and these were confirmed by drogue drifts. This branched northward flow is further shown at each of the three levels of contoured dynamic topography (100, 200, and 300 decibars, Figures 15, 16, and 17). Some southward flow appears at all three levels from stations 15 to 18. This is a small-scale feature and might not be real since small scales are not well resolved by geostrophy.

Comparison will be made in Section V between geostrophic and direct current measurements.

The cruise of 8-9 January 1979 also showed southern water; but, as Figures 9 and 10 show, the bulge of high salinity occurs farther west. The associated temperature and sound speed sections (Appendix B) also show this westward displacement of the southern water. Below 200 meters this southern water is found 15 kilometers farther offshore than on the last cruise. Although Pavlova (1966) and Hickey (1978) indicated the countercurrent moves offshore in the spring, our observations were made during the winter season. McCreary's (1977) view of the current's variations as manifestations of baroclinic Kelvin-like waves is consistent with this offshore movement.

Geostrophy in the cross-sections for 8-9 January 1979 (Figures 29 and 30) also shows the northward flow farther offshore. There is still a maximum at the surface, but with an increase in velocity to 70 cm/sec normal to the Cape San Martin line and 35 cm/sec normal to the Slate Rock line. There is an indication that this may be the shoreward branch of the northward flow found during the first cruise, as southward flow appears on the offshore edge of both sections. Dynamic topography (Figures 18, 19, and 20) shows this same pattern. At the 100 db level (Figure 18) the flow is intense and northward between stations 3 and 9. To the west of station 9 the flow intensity drops off sharply and southward flow appears between stations 13 and 15. To the east of station 3 the dynamic topography is generally flat with northward flow indicated. At the 200 db level (Figure 19) the flow is weaker but is still northward between stations 3 and 9. Southward flow is now more evident between stations 13 and 15. At the 300 db level (Figure 20) the flow is southward with only a trace of northward flow between stations 15 and 17.

The cruise on 22-23 January 1979 shows reductions in southern water characteristics. All indicators, i.e., isopleths of salinity, temperature, sigma-t, and sound speed, are nearly parallel with only small horizontal gradients. Note that the 34.20 ‰ isohaline which in November lay in places higher in the water column than 200 meters is now at a depth of 300 meters, except within a few kilometers of the slope. This may indicate that southern water has moved seaward or deeper beyond the range of observations.

Geostrophy shows slight westward propagation of the northward flow (Figures 31 and 32, also, 21, 22, and 23). The flow appears slower, 20 cm/sec, and more diffuse. At the 200 db level (Figure 22) southward flow now exists shoreward of station 4. At the 300 db level (Figure 23) the flow has become more diffuse and the southern flow is now shoreward of stations 5 and 20.

The observations for the cruise of 21-22 February 1979 indicate an increase in salinity below 200 meters (Figures 13 and 14), the 34.20 ‰ isohaline having risen to a depth of 250 meters over most of both sections. The dynamic topography

(Figures 24, 25, and 26) now indicates a northward flow at stations 2 and 3 at the 200 db and 300 db levels. The geostrophic sections do not show this since the station averaging interval used in their construction does not permit calculations shoreward of station 4. This flow at the eastern stations and below 200 meters may be the start of the undercurrent.

An immediate observation must be made: The regions with indications of southern water and the regions where northward flow is indicated by geostrophy do not exactly coincide. For all the cruises considered, geostrophy shows a northward surface flow, in some instances with flow as great as 70 cm/sec, even though the watermass characteristics in some regions are not southern. This is not too surprising, since near the boundaries between watermasses, eddies and entrainment of anomalous water is common. The observed variations in salinity and velocity may also have alternative explanations. Passing eddies or meanders in the countercurrent might give results similar to those just discussed.

In the following section the currents inferred from geostrophy are compared to those measured directly by moored current meter arrays along the Cape San Martin line.

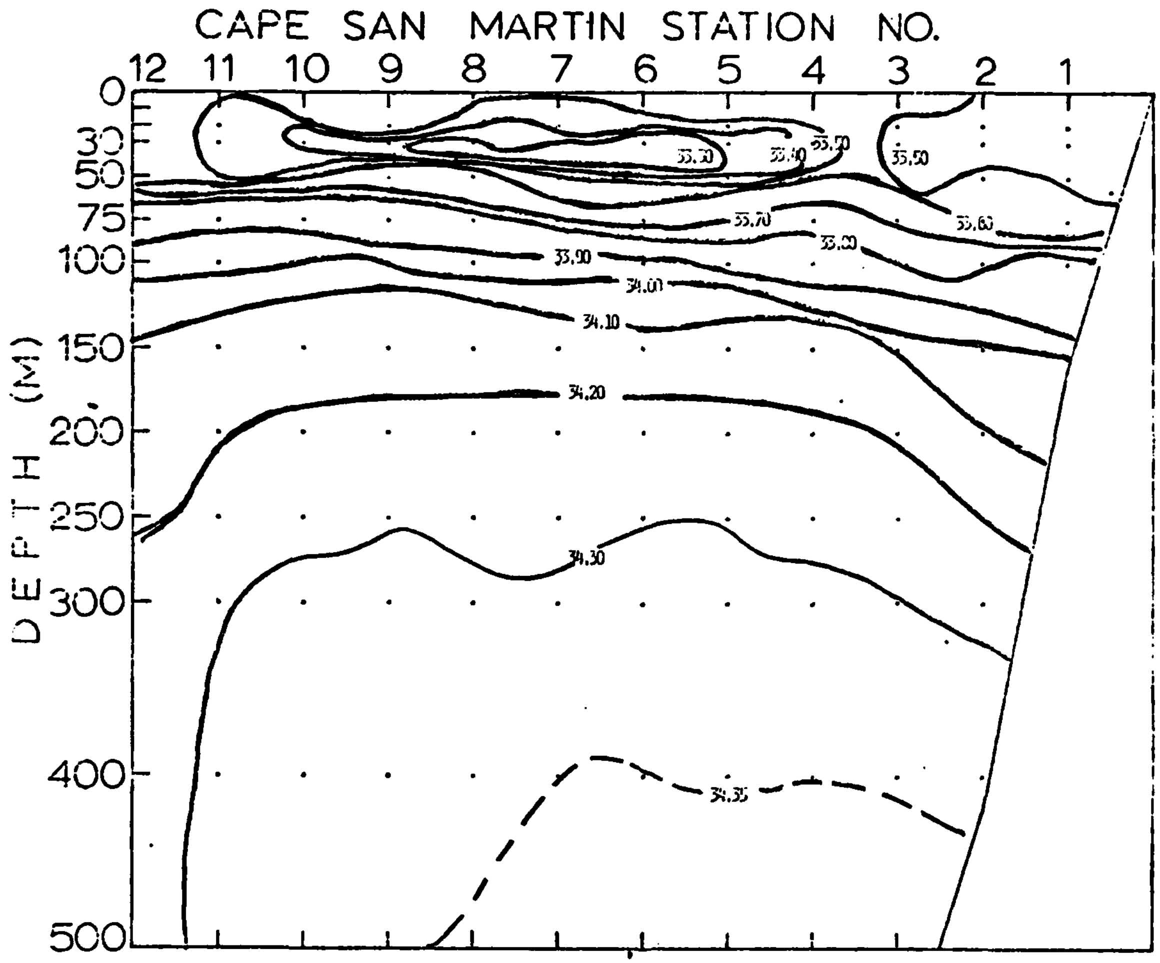

Figure 7. Salinity (‰) on a vertical section for the Cape San Martin line on 27-28 November 1978.

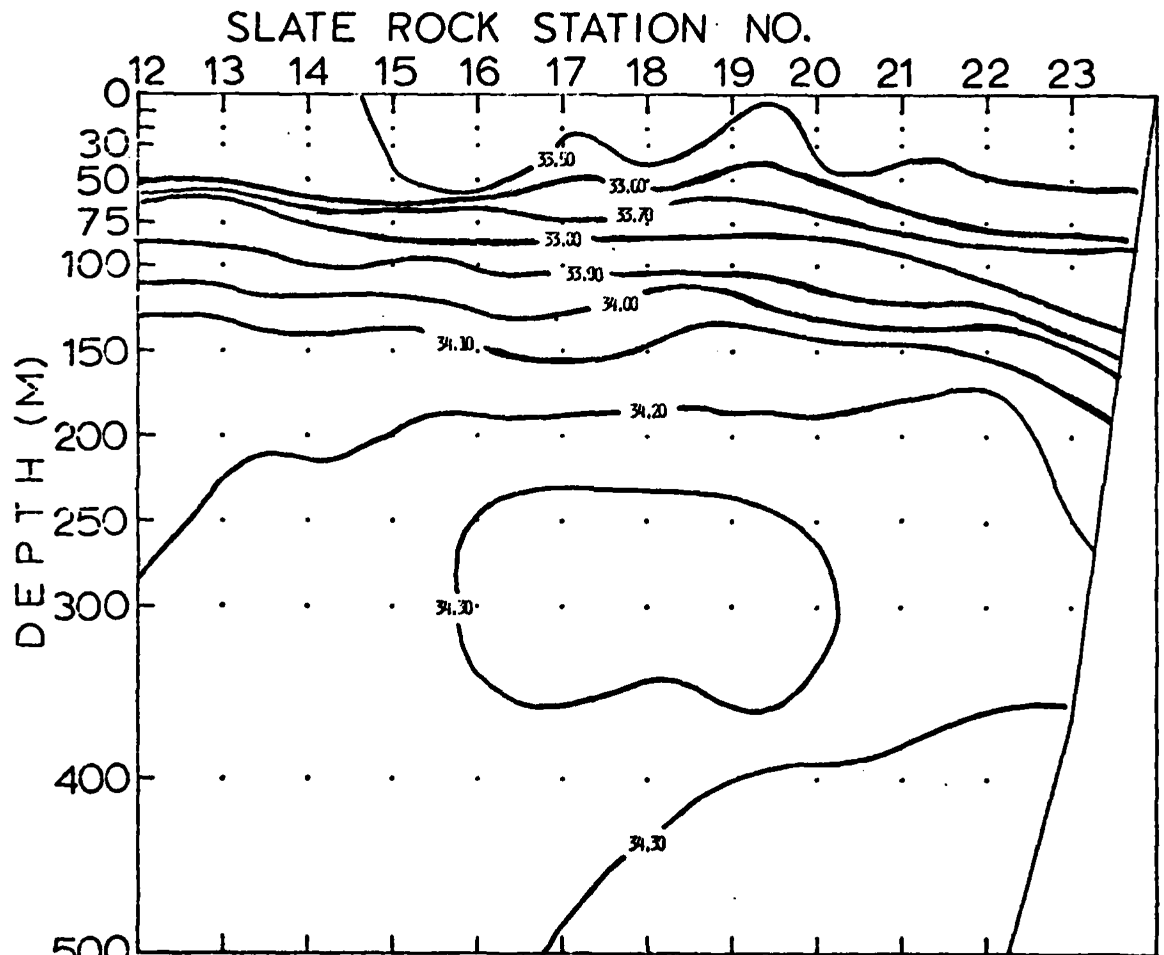

Figure 8. Salinity (‰) on a vertical section for the Slate Rock line on 27-28 November 1978.

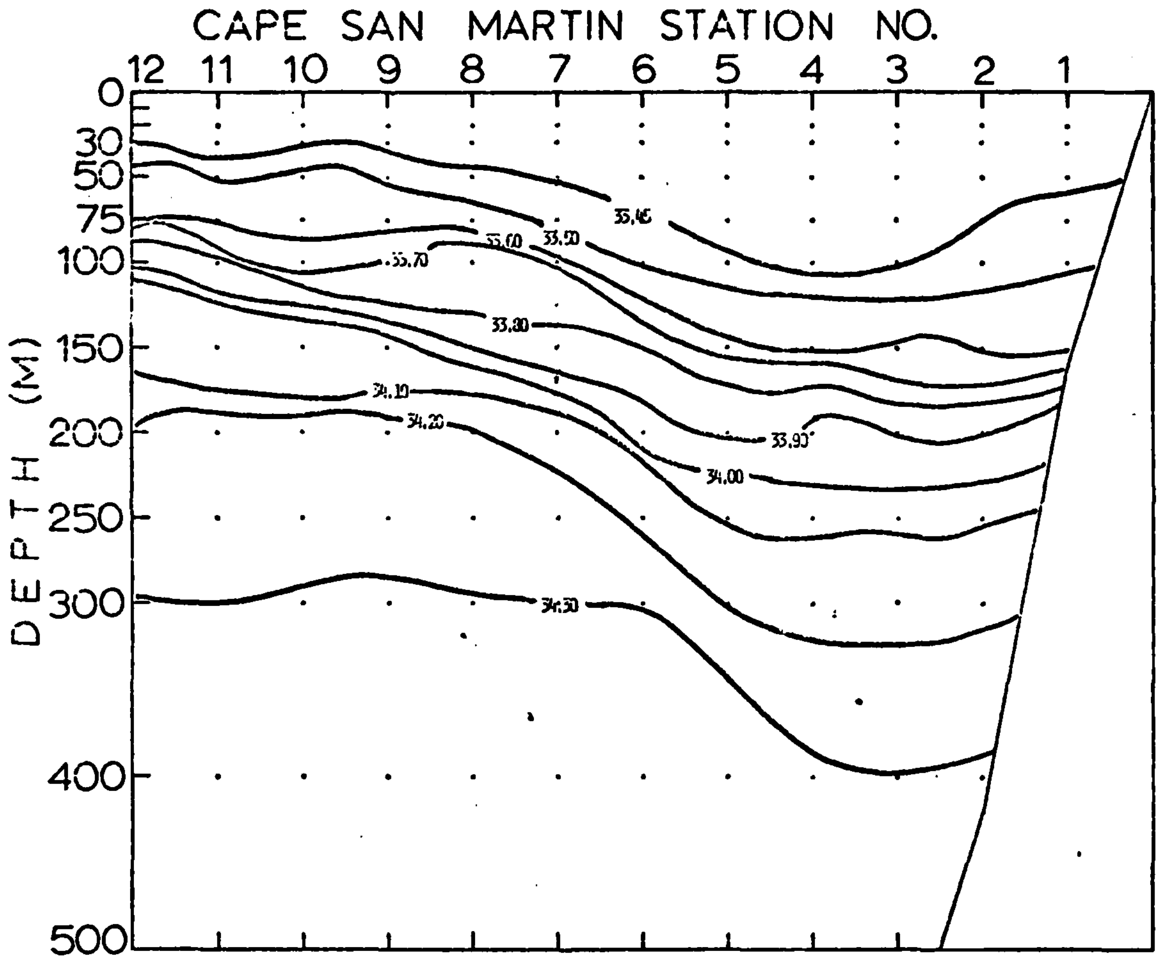

Figure 9. Salinity (‰) on a vertical section for the Cape San Martin line on 8-9 January 1979.

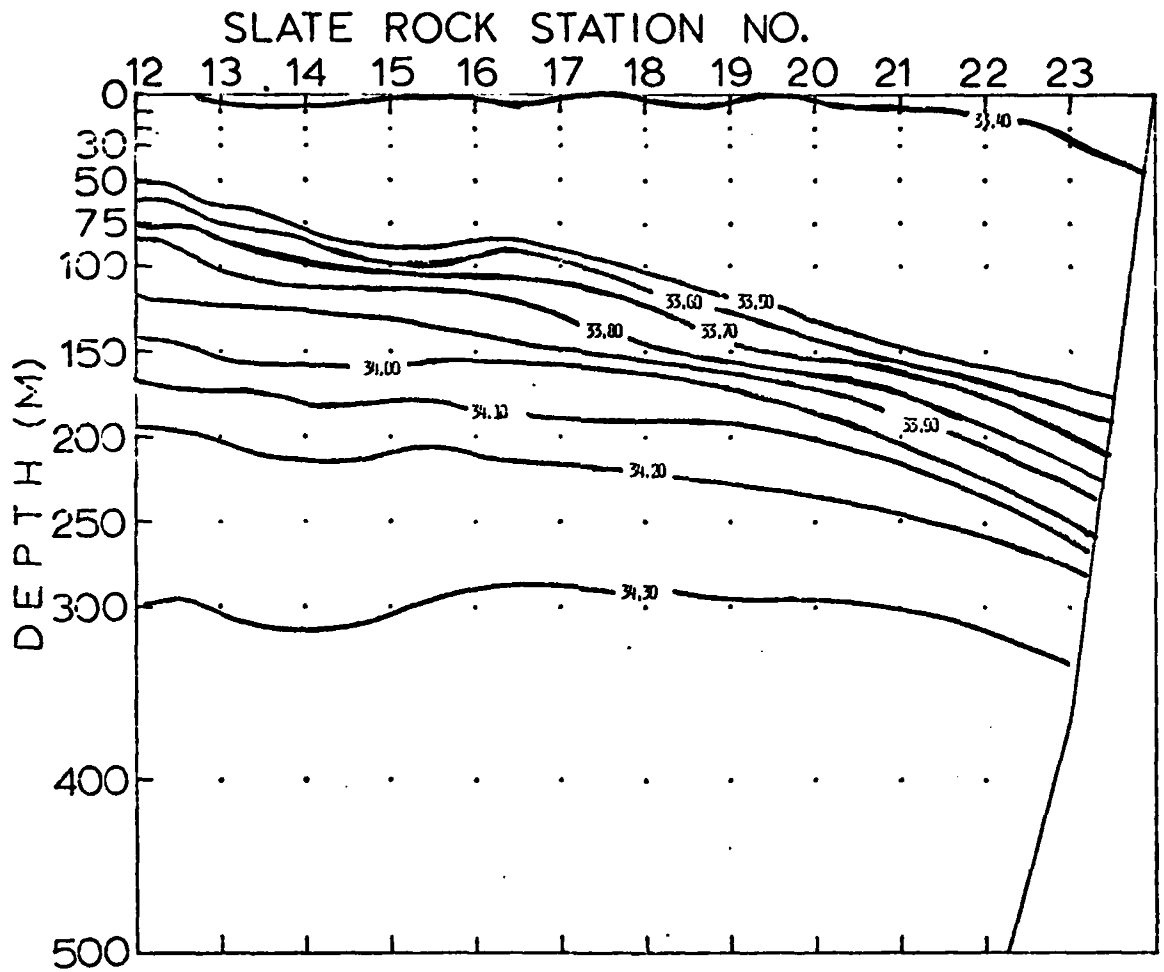

Figure 10. Salinity (‰) on a vertical section for the Slate Rock line on 8-9 January 1979.

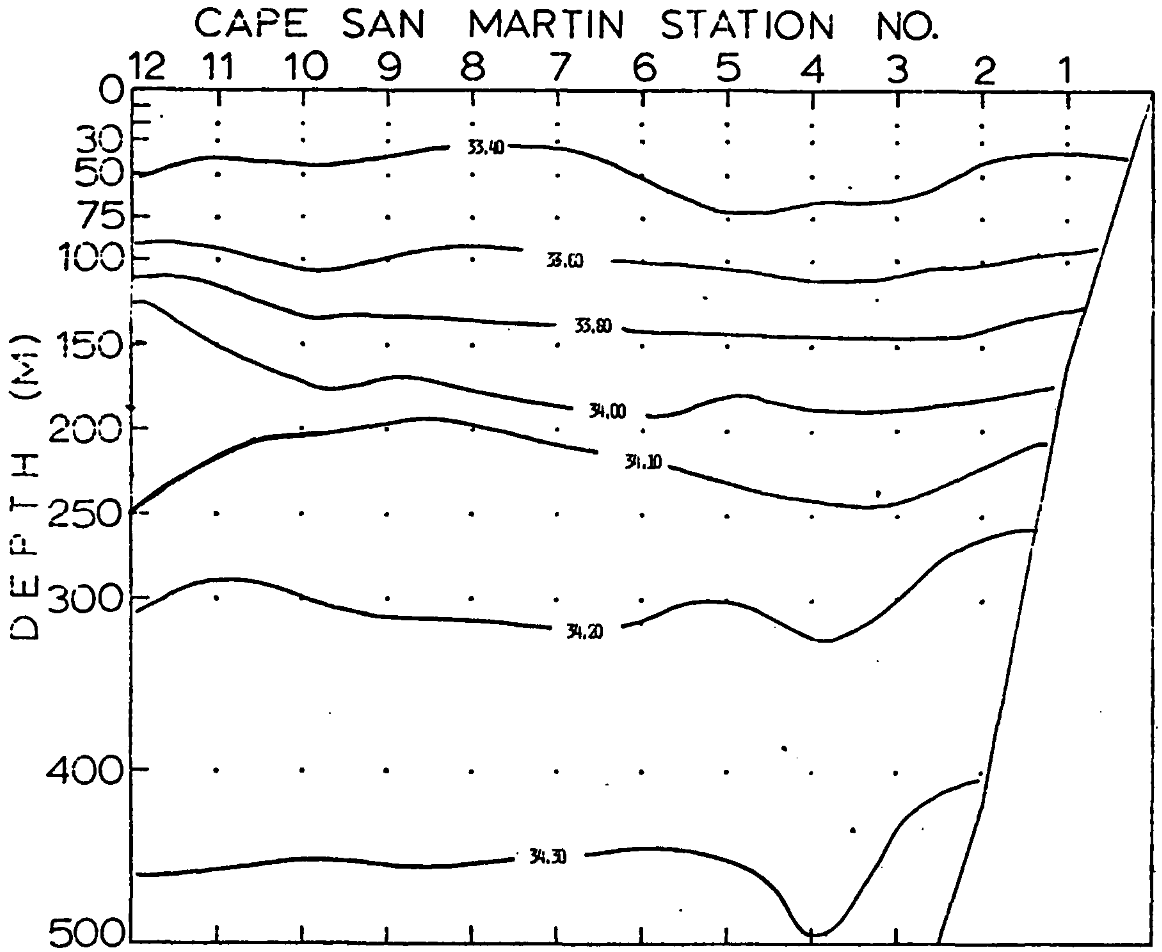

Figure 11. Salinity (‰) on a vertical section for the Cape San Martin line on 22-23 January 1979.

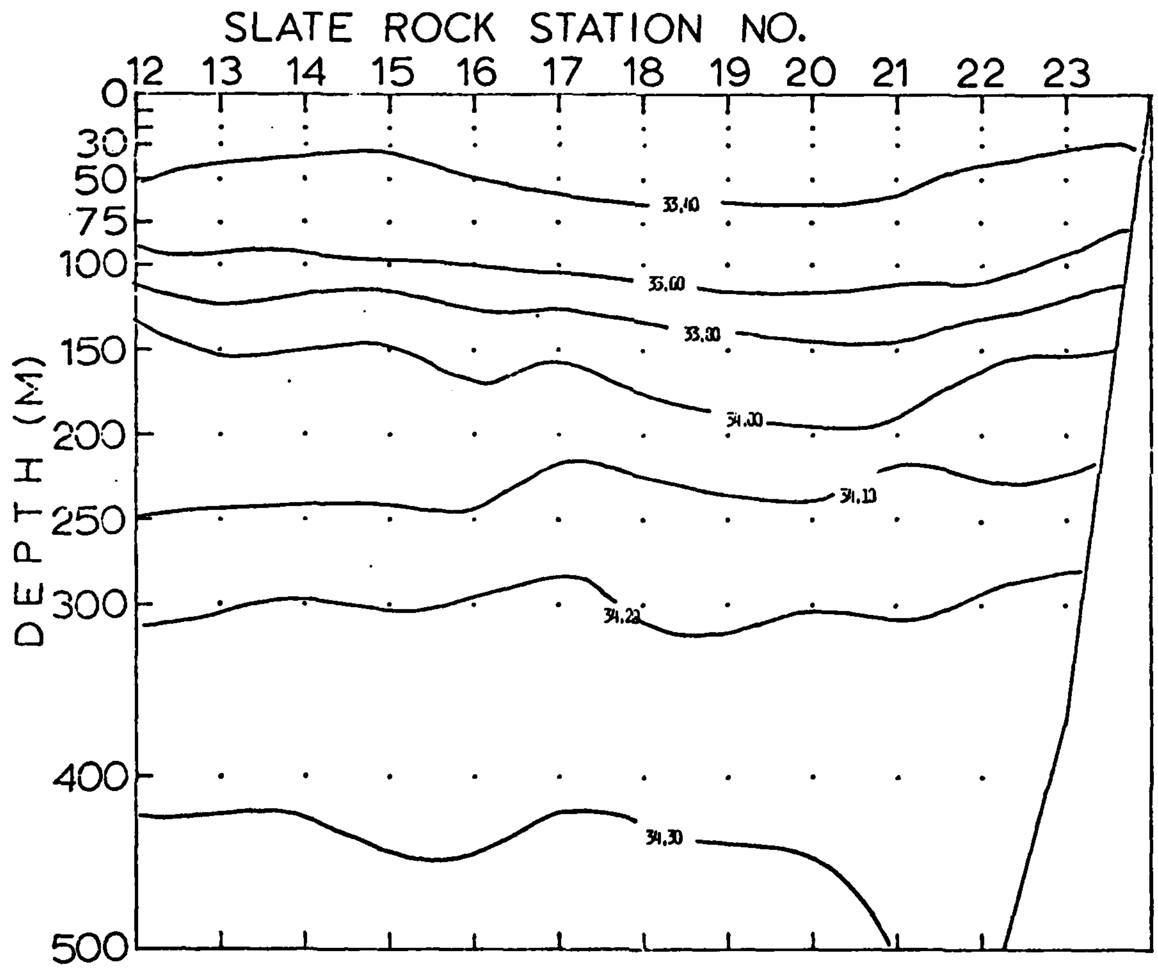

Figure 12. Salinity (‰) on a vertical section for the Slate Rock line on 22-23 January 1979.

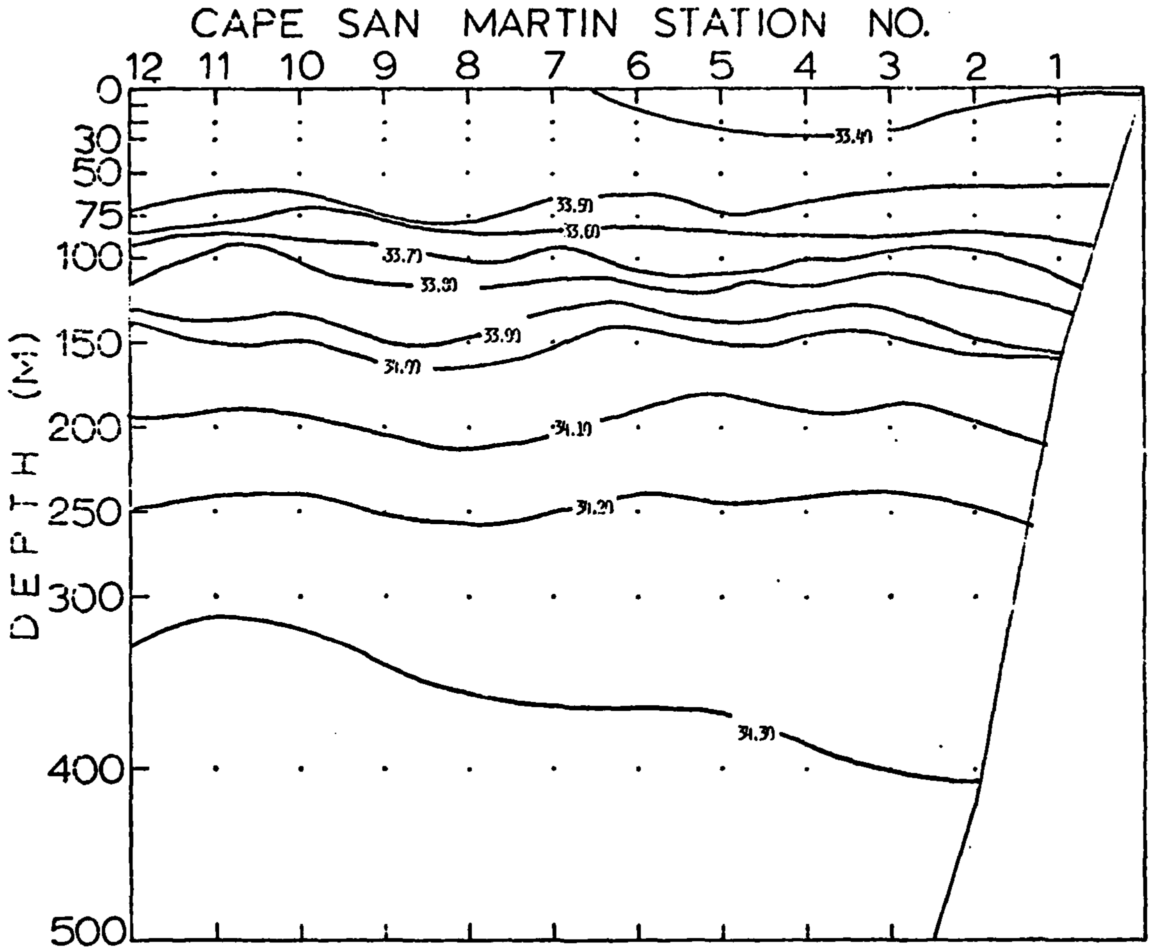

Figure 13. Salinity (‰) on a vertical section for the Cape San Martin line on 21-22 February 1979.

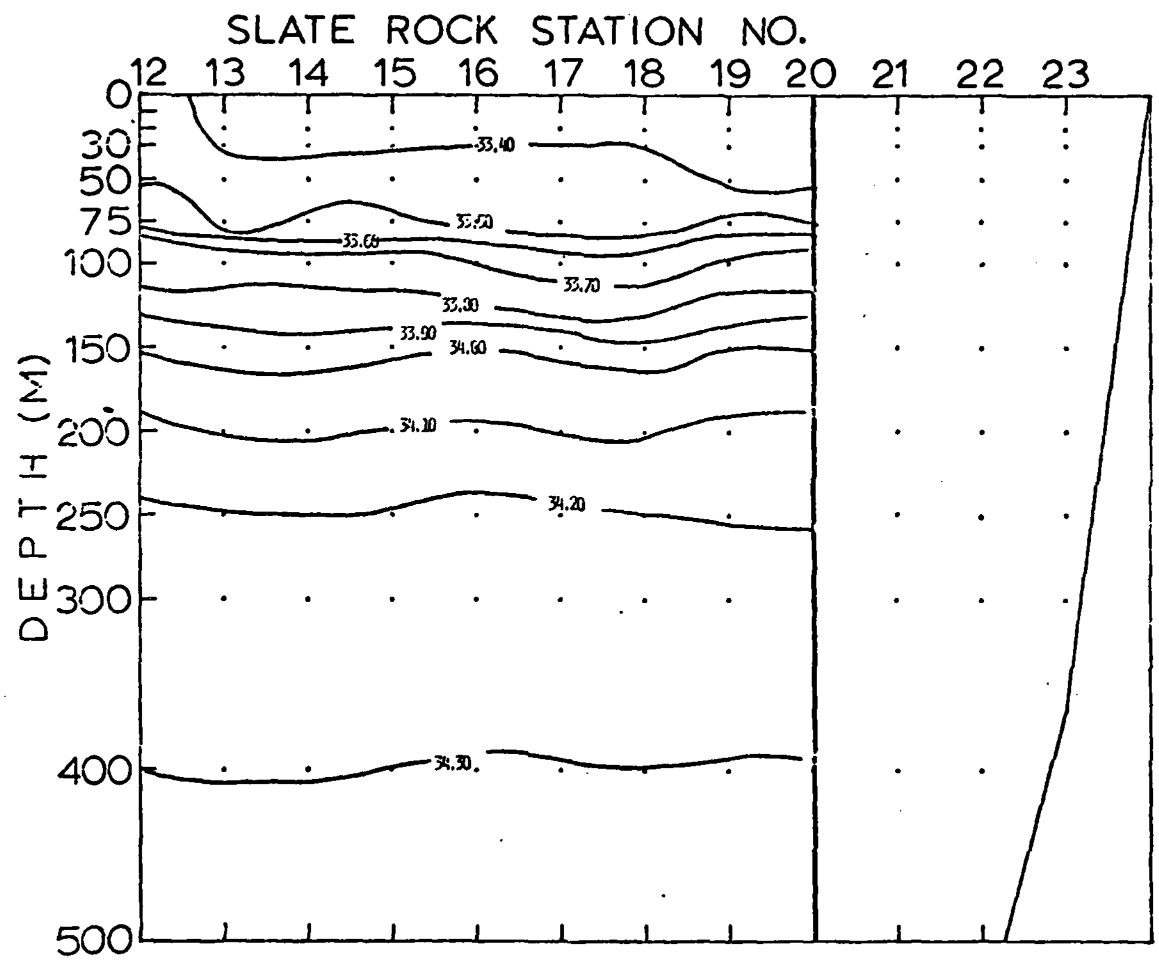

Figure 14. Salinity (‰) on a vertical section for the Slate Rock line on 21-22 February 1979.

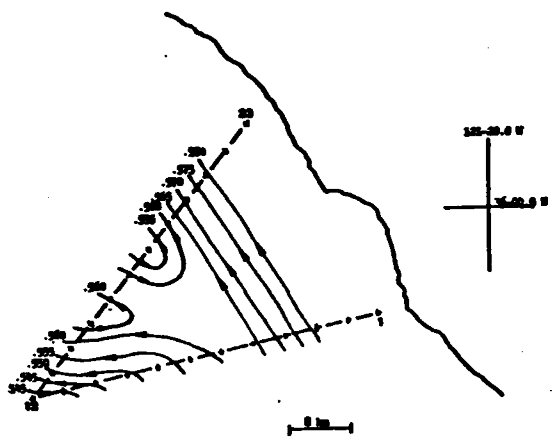

Figure 15. Dynamic topography of the 100/500 decibar surface on 27-28 November 1978. Units are in dynamic meters

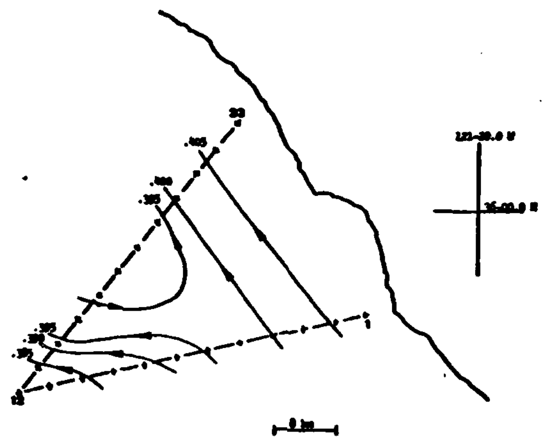

Figure 16. Dynamic topography of the 200/500 decibar surface on 27-28 November 1978. Units are in dyanmic meters

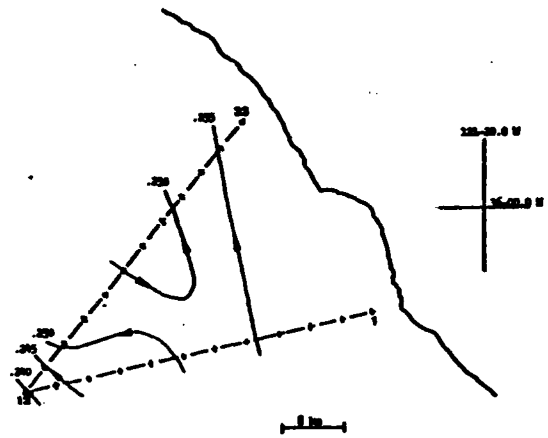

Figure 17. Dynamic topography of the 300/500 decibar surface on 27-28 November 1978. Units are in dynamic meters

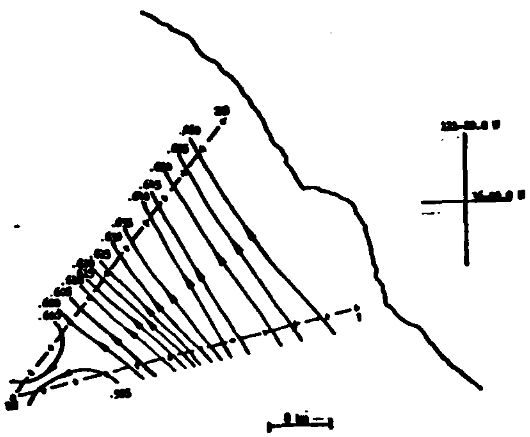

Figure 18. Dynamic topography of the 100/500 decibar surface on 8-9 January 1979. Units are in dynamic meters.

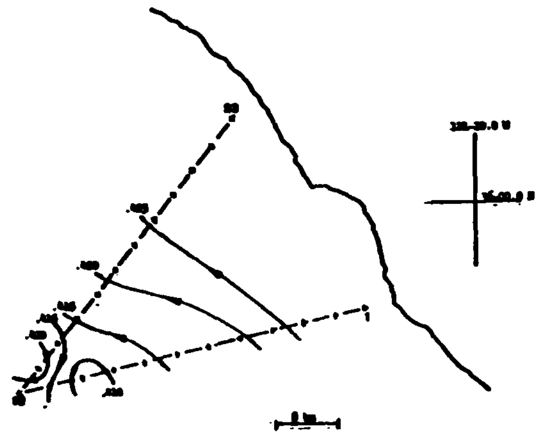

Figure 19. Dynamic topography of the 200/500 decibar surface on 8-9 January 1979. Units are in dynamic meters.

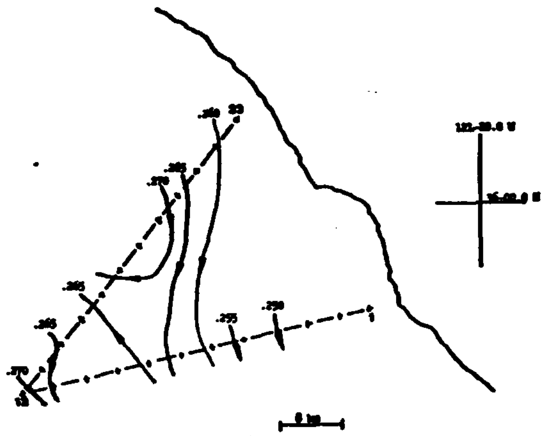

Figure 20. Dynamic topography of the 300/500 decibar surface on 8-9 January 1979. Units are in dynamic meters.

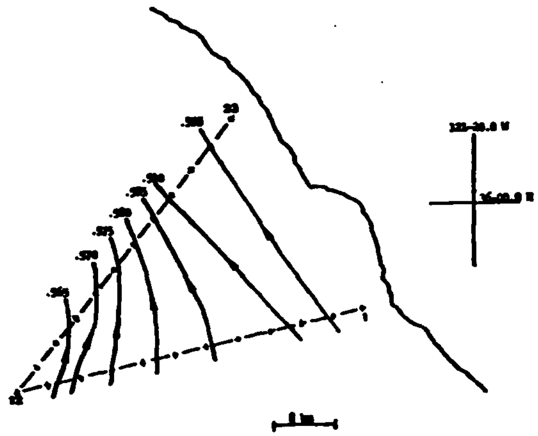

Figure 21. Dynamic topography of the 100/500 decibar surface on 22-23 January 1979. Units are in dynamic meters.

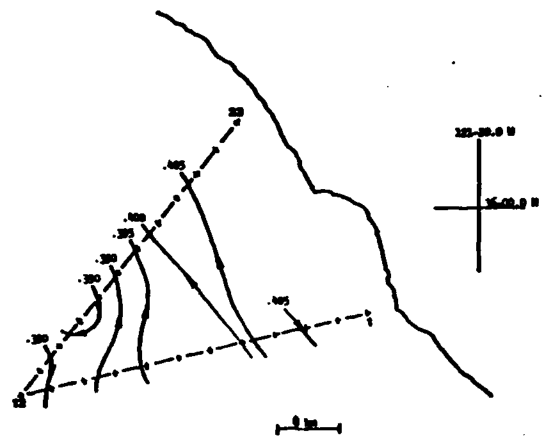

Figure 22. Dynamic topography of the 200/500 decibar surface on 22-23 January 1979. Units are in dynamic meters.

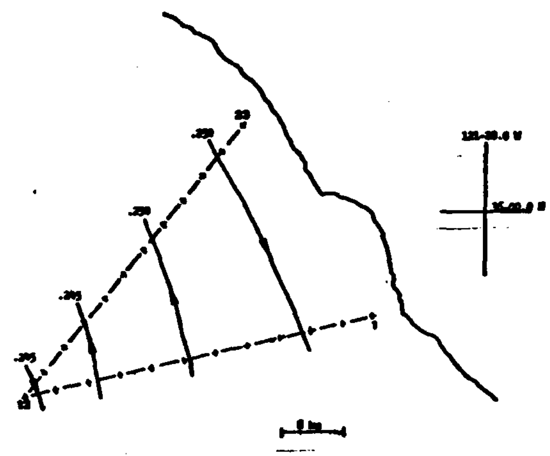

Figure 23. Dynamic topography of the 300/500 decibar surface on 22-23 January 1979. Units are in dynamic meters.

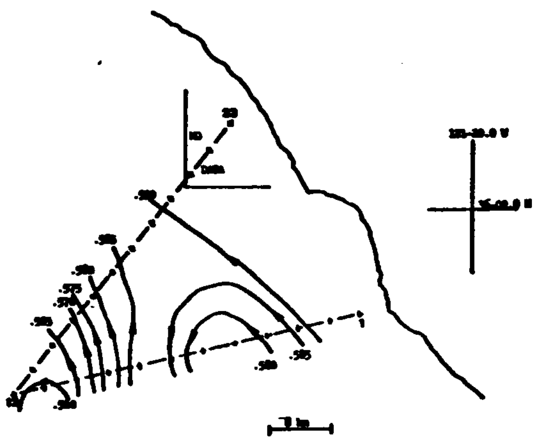

Figure 24. Dynamic topography of the 100/500 decibar surface on 21-22 February 1979. Units are in dynamic meters.

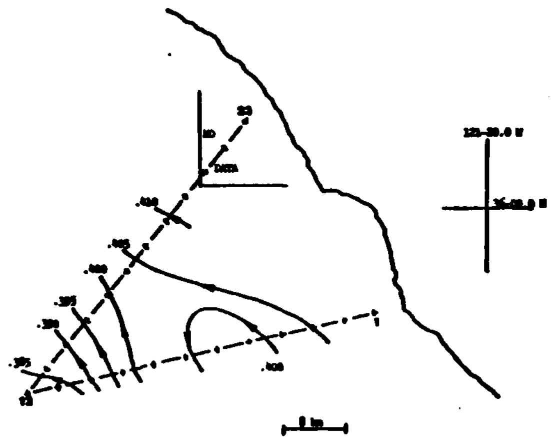

Figure 25. Dynamic topography of the 20C/500 decibar surface on 21-22 February 1979. Units are in dynamic meters.

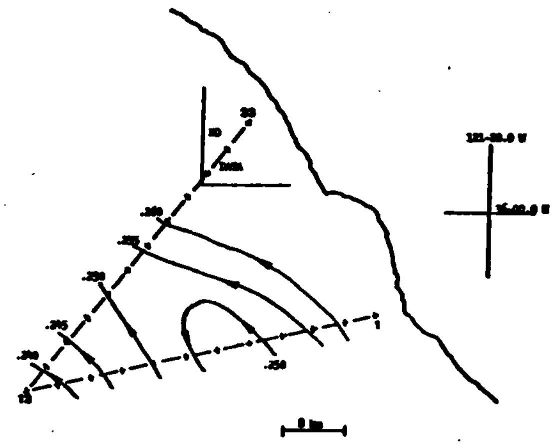

Figure 26. Dynamic topography of the 300/500 decibar surface on 21-22 February 1979. Units are in dynamic meters.

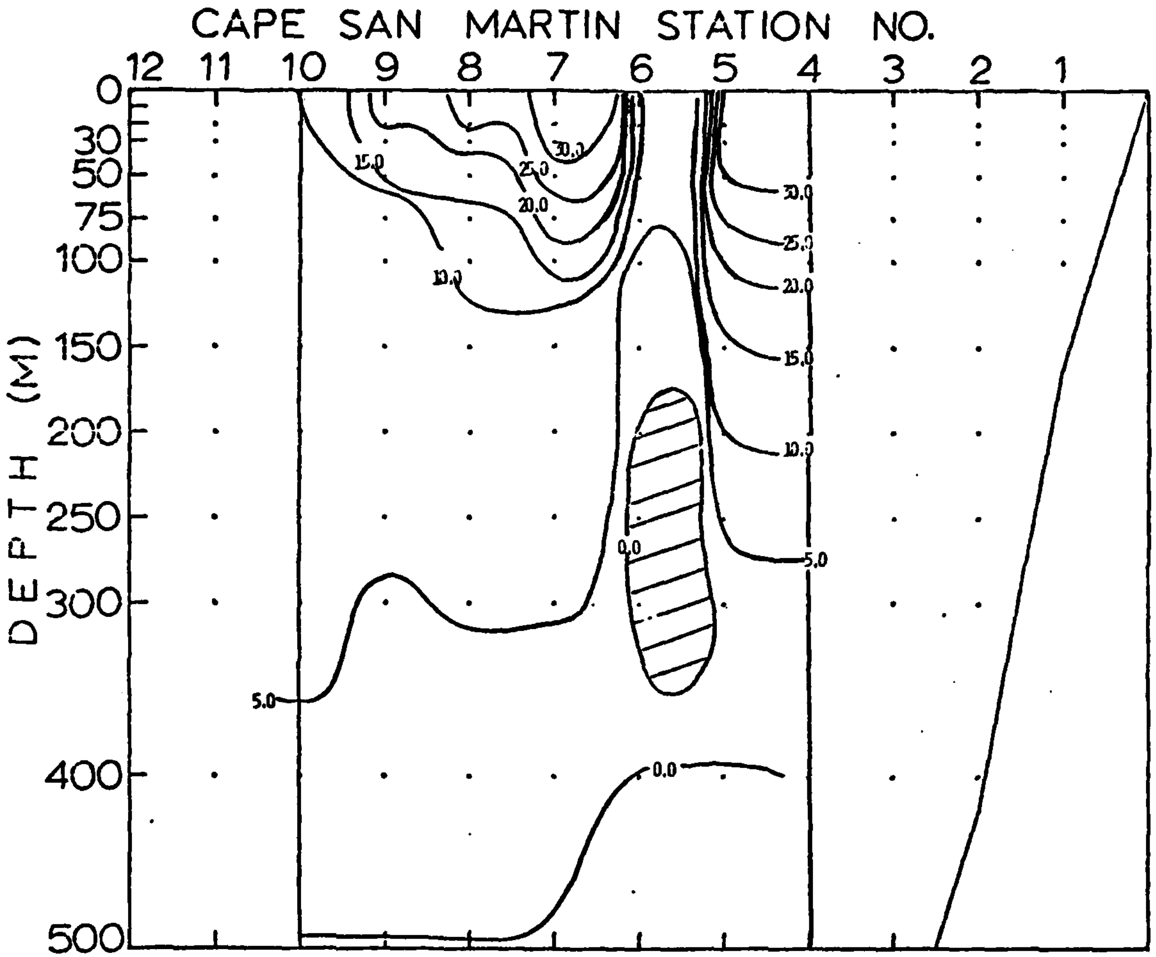

Figure 27. Vertical section of the normal component of geostrophic velocity in cm/sec for the Cape San Martin line on 27-28 November 1978. Southward flow indicated by cross hatched area.

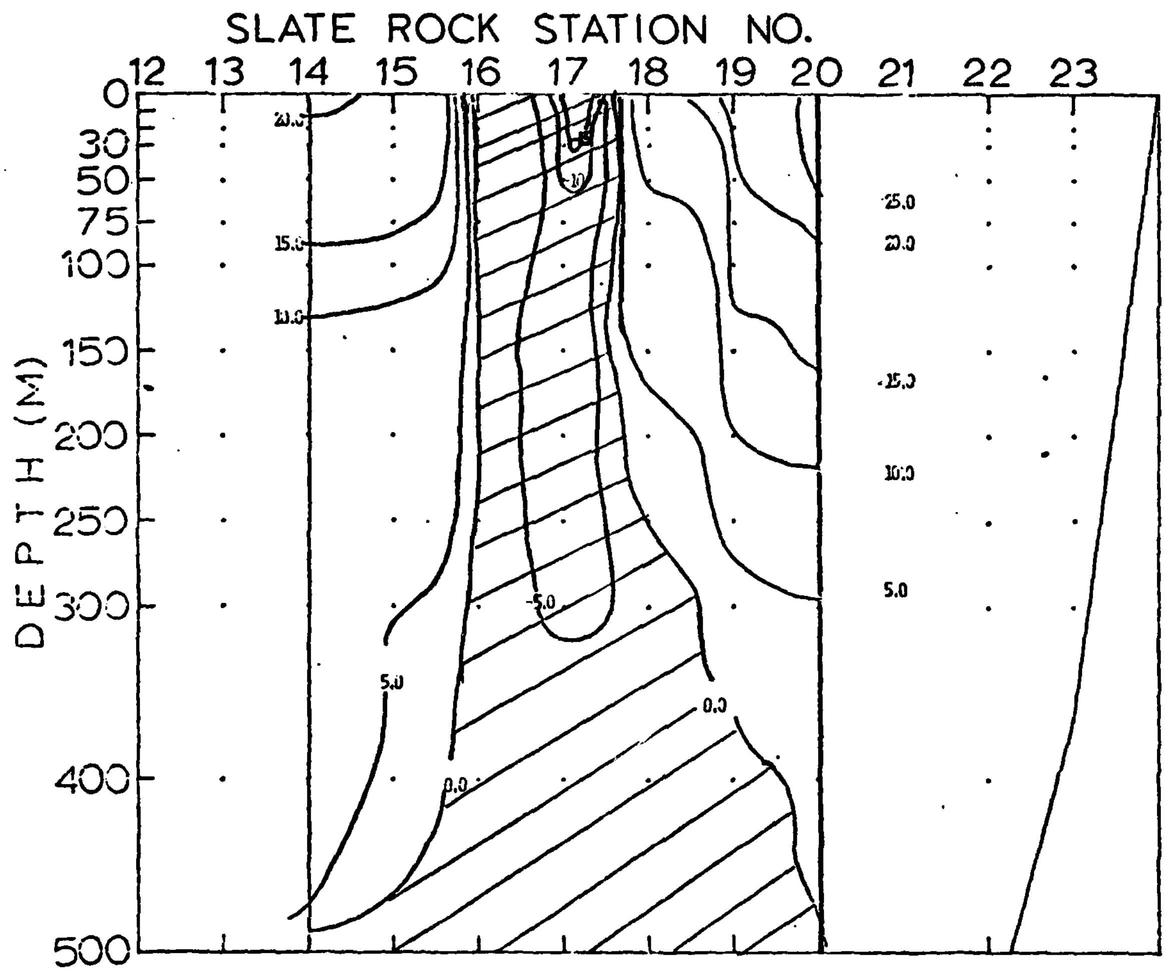

Figure 28. Vertical section of the normal component of geostrophic velocity in cm/sec for the Slate Rock line on 27-28 November 1978. Southward flow indicated by cross hatched area.

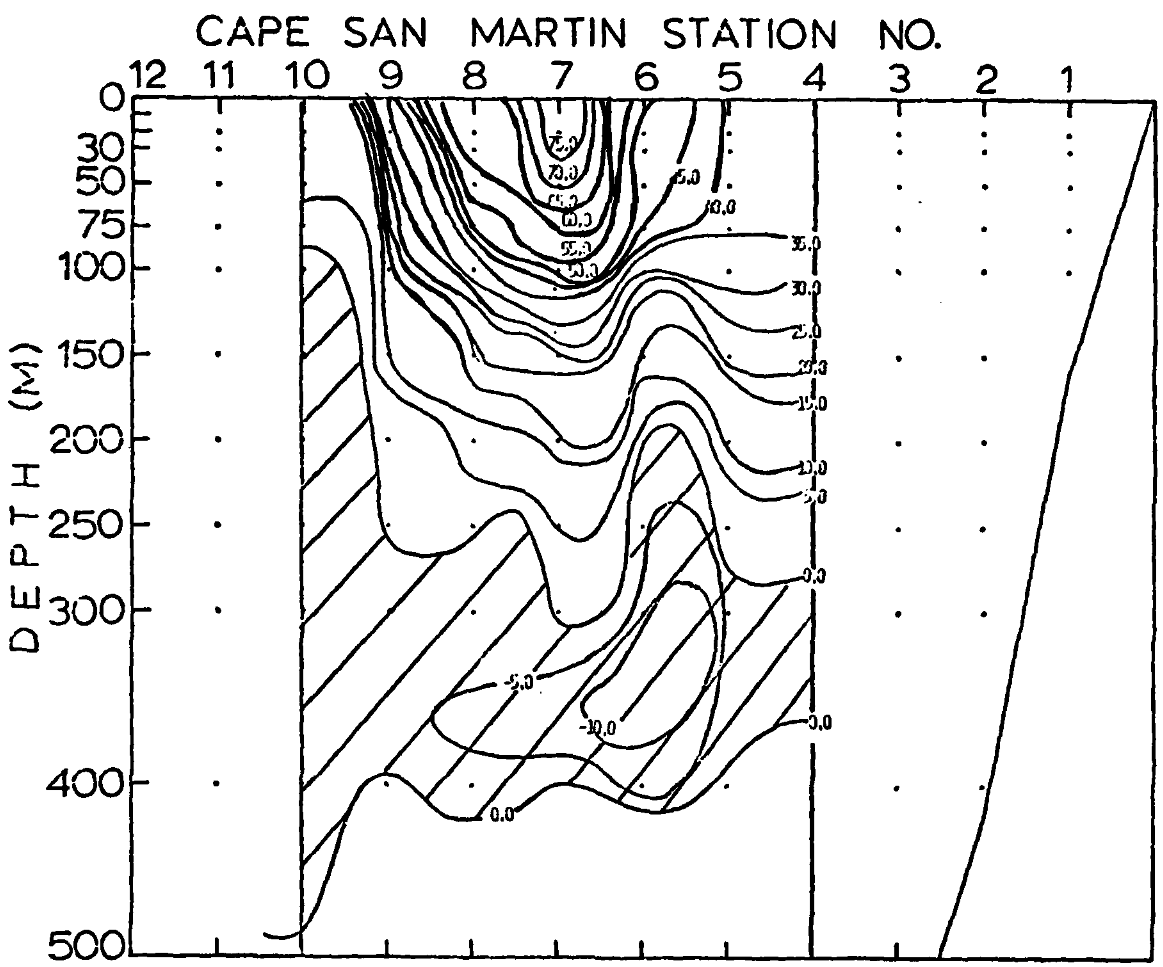

Figure 29. Vertical section of the normal component of geostrophic velocity in cm/sec for the Cape San Martin line on 8-9 January 1979. Southward flow indicated by cross hatched area.

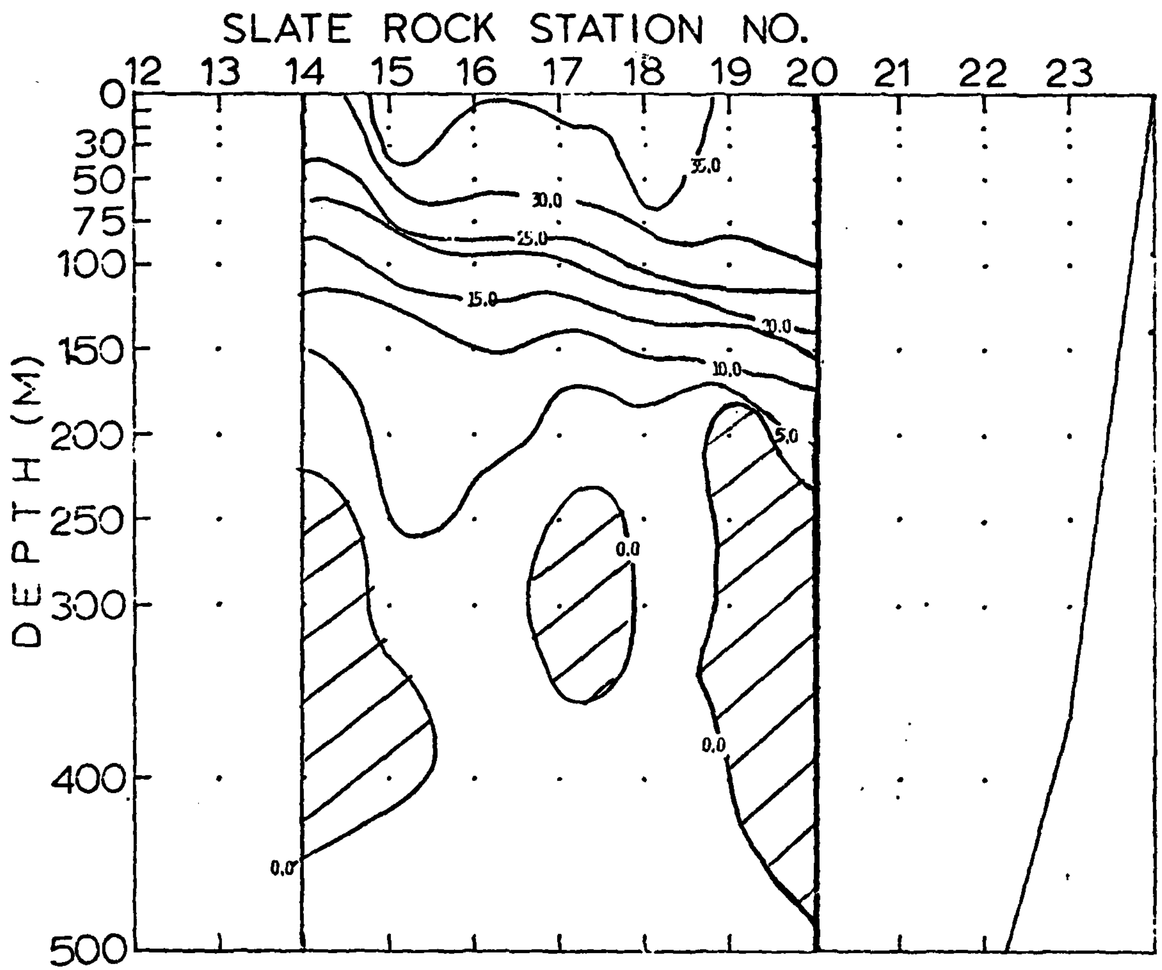

Figure 30. Vertical section of the normal component of geostrophic velocity in cm/sec for the Slate Rock line on 8-9 January 1979. Southward flow indicated by cross hatched area.

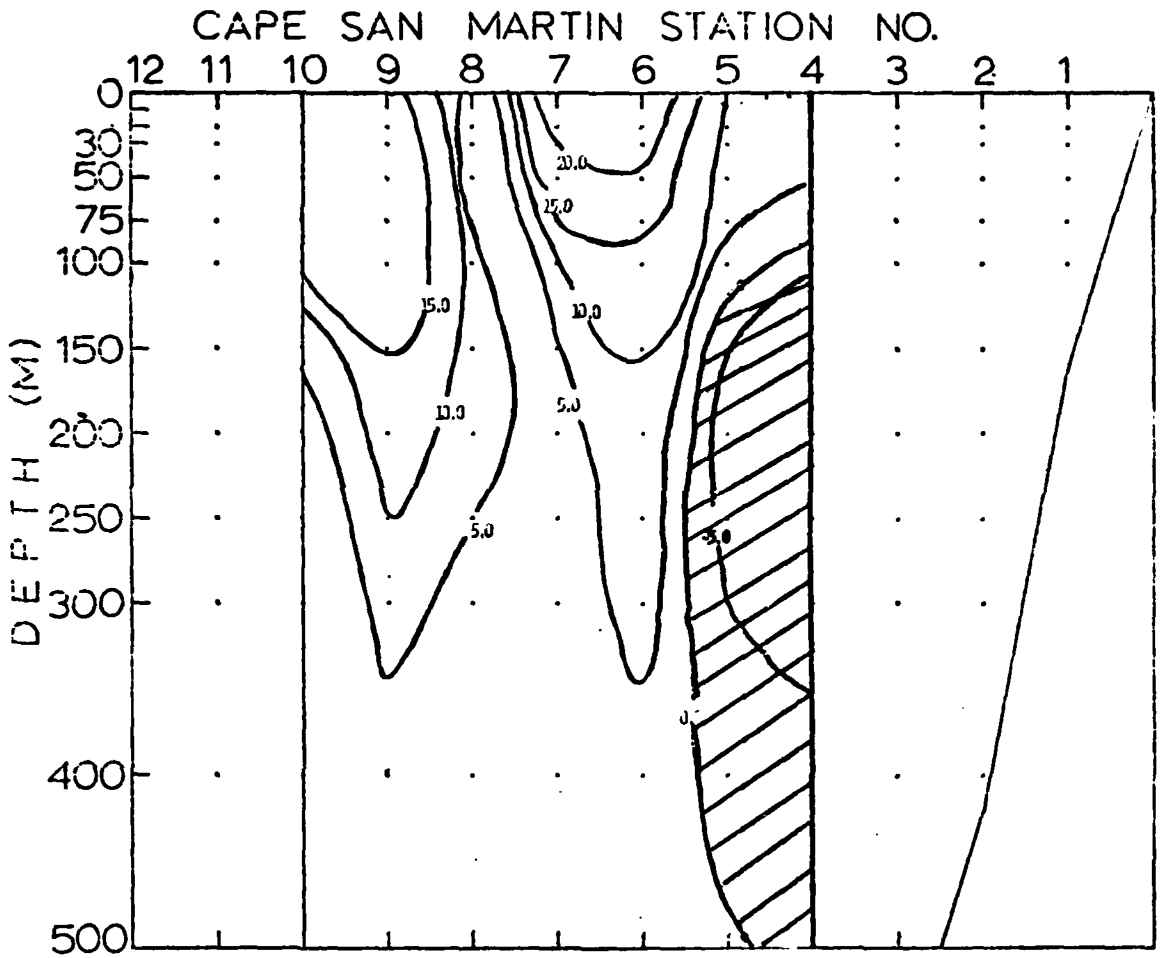

Figure 31. Vertical section of the normal component of geostrophic velocity in cm/sec for the Cape San Martin line on 22-23 January 1979. Southward flow indicated by cross hatched area.

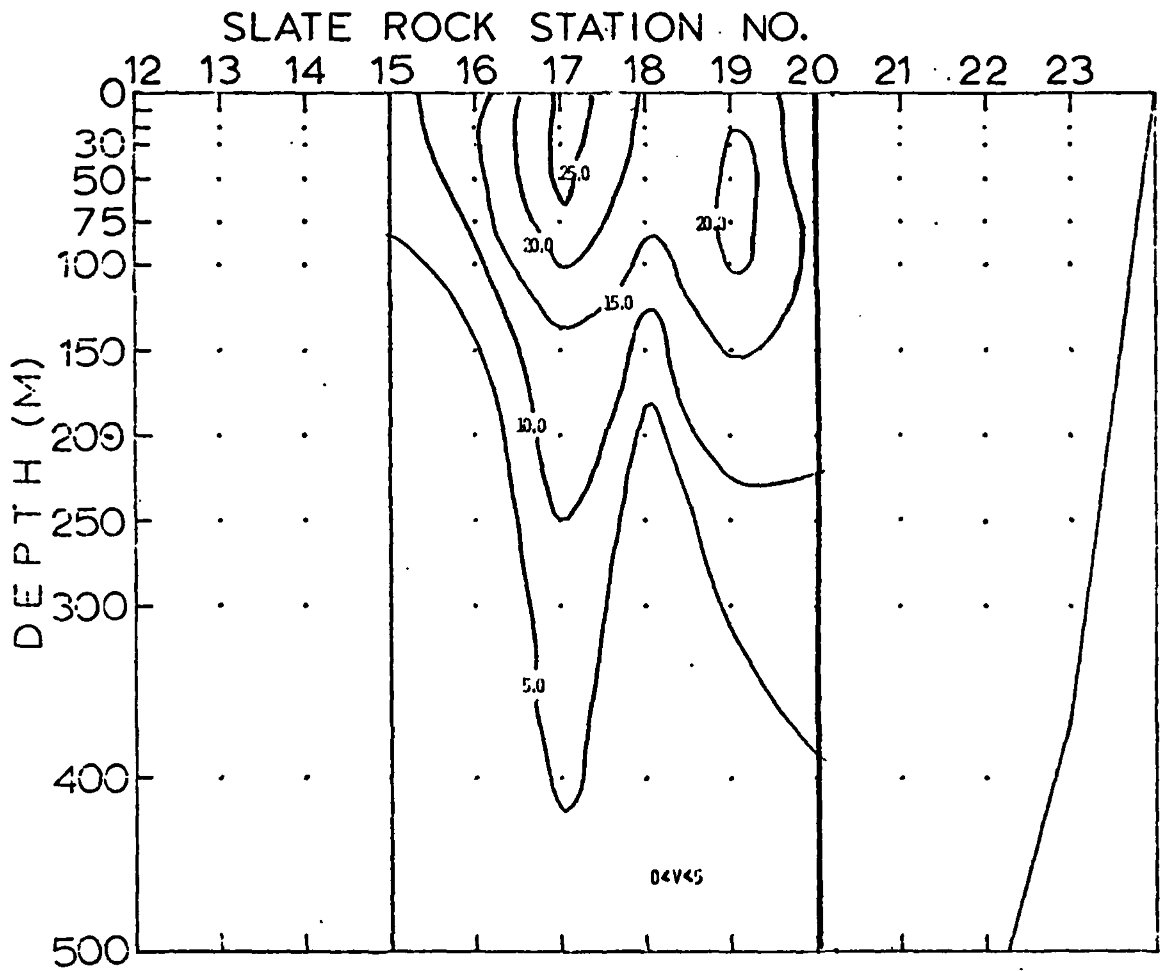

Figure 32. Vertical section of the normal component of geostrophic velocity in cm/sec for the Slate Rock line on 22-23 January 1979. Southward flow indicated by cross hatched area.

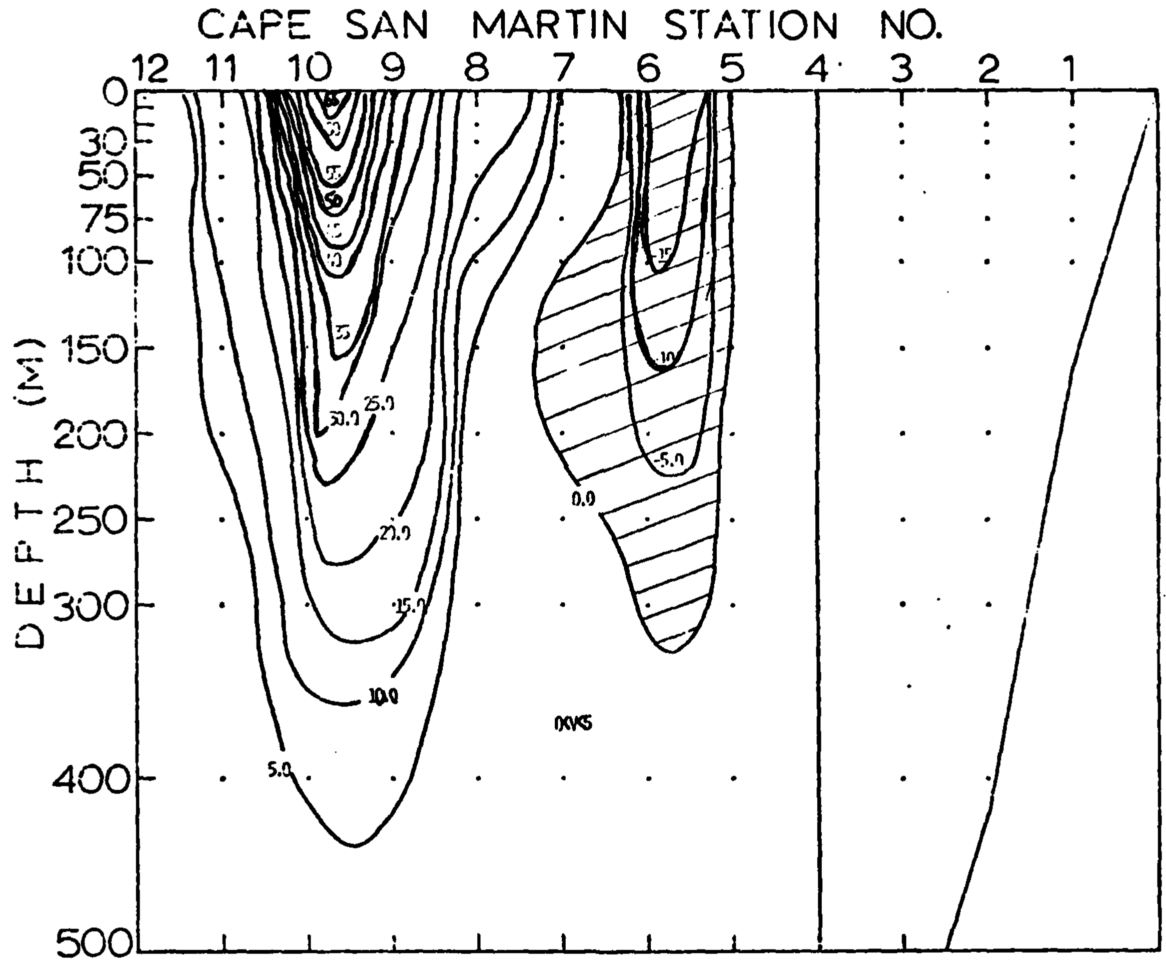

Figure 33. Vertical section of the normal component of geostrophic velocity in cm/sec for the Cape San Martin line on 21-22 February 1979. Southward flow indicated by cross hatched area.

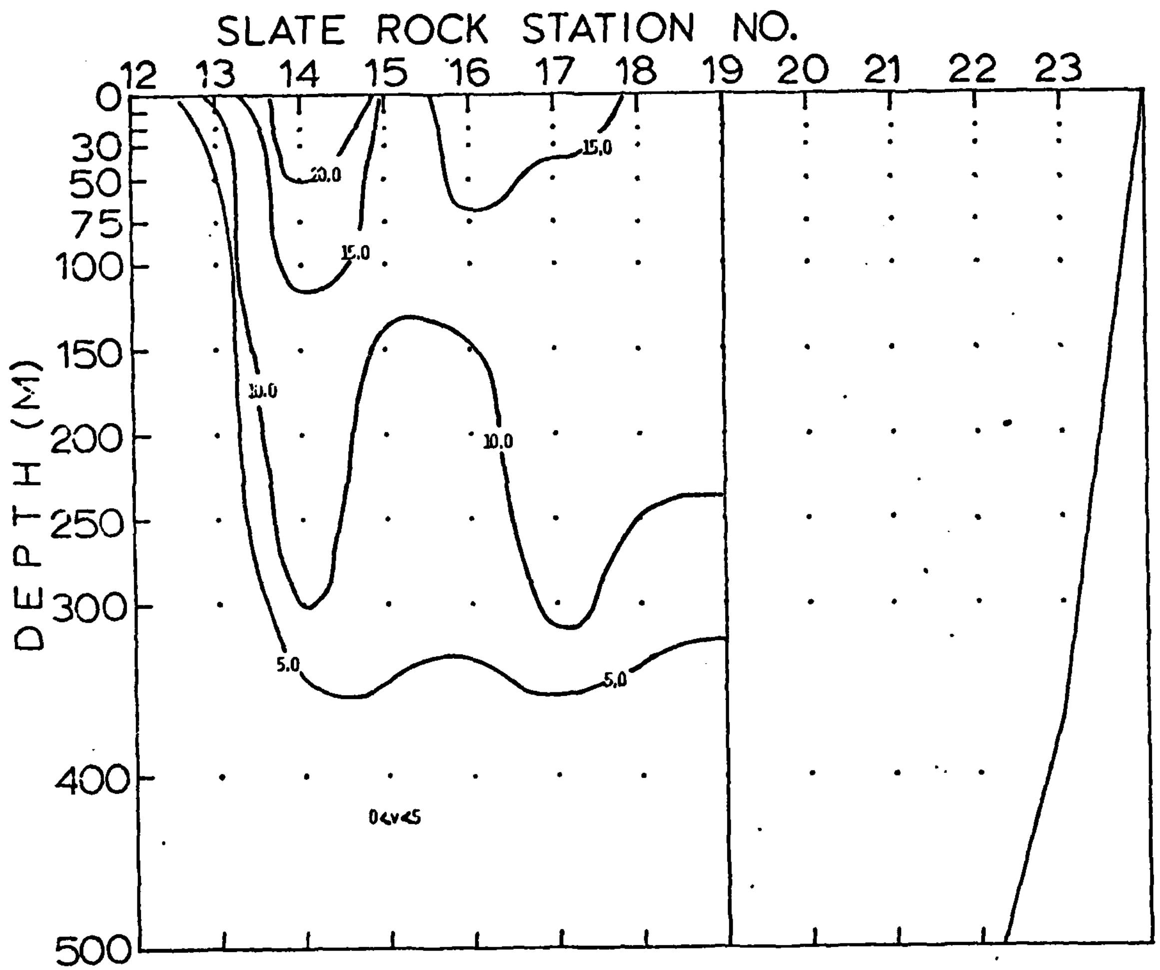

Figure 34. Vertical section of the normal component of geostrophic velocity in cm/sec for the Slate Rock line on 21-22 February 1979. Southward flow indicated by cross hatched area.

IV. DIRECT CURRENT OBSERVATIONS

A. INSTRUMENTATION AND DATA COLLECTION

Data collection was begun with the first array installed on 25 July 1978. This array contained one meter. The array was placed in 371 meters of water at approximately the position of station 2 (Figure 6) and remained in the water for one month. The second array was also placed near station 2 in 354 meters of water on 20 September 1978. The array contained one meter and remained in the water for two months. The meters from both the first and second array were placed at approximately 200 meters depth. Two larger arrays were installed on 27 November 1978. They contained three meters each and were installed in water of 353 meters depth near station 2 and 777 meters depth near station 5. The meters were situated at depths of 100, 175, and 300 meters. Both arrays remained in place until 22 January 1979.

Organization of each array was done by means of the NOYFB computer program. The original program was written by Donald Moller of the Woods Hole Oceanographic Institution in Fortran II for the Hewlett-Packard 2100 series. The program has been rewritten in Fortran IV for compatibility with the IBM 360 computer and is given in Appendix A. Through the use of on line terminals the program gives the operator a description of the mooring and its performance from an operational point of view. Given environmental data and mooring components, the program presents the operator with mooring behavior information for evaluation of collected data as well as array design modifications. Step by step instructions for program operation are displayed to the user with the sequence determined by his selection of options. Standard mooring component characteristics (buoyancy, cross-sectional areas, elastic properties, etc.) are written into the program. These components are those used by Woods Hole Oceanographic Institution. Components which are non-standard with respect to the program are added during initialization or may be changed by an option.

The current meter used in these arrays is the Aanderaa Recording Current Meter Model 4 (RCM4). It is a self-contained instrument for recording speed, direction, and temperature of ocean currents with conductivity and pressure options. The RCM4 has a depth capability of 2000 meters. The RCM4 uses a rotor type current speed sensor, a magnetic compass, and a thermistor. An electro-mechanical encoder (analog to digital converter) samples and converts the measurements to binary digital signals which are then recorded on 1/4-inch magnetic tape. A sampling interval of 10 minutes was chosen for our meters. Input parameters for the RCM4 into the NOYFB program are: W(I) = -64.66 (buoyancy per meter length) and A(I) = +0.065 (area of component in square meters per meter length).

The array is arranged as in Figure 35 with no surface markers in order to keep all array elements out of the region of strong surface wave action. An acoustic release is used for retrieval of the arrays. It is an AMF Acoustic Release/Pinger Model 242, which is activated acoustically and also has a reply pinger used for interrogation and, if necessary, as a locating beacon.

Buoyancy for the array is provided by Benthos glass spheres. The glass spheres are 17-inches in diameter, housed in plastic hard hats and are capable to a depth of 6700 meters. They provide 55 pounds of buoyancy each and are connected together in pairs with 3/8-inch galvanized chain.

The wire finally used was 5/32-inch, 7x7 stainless steel wire, breaking strength about 2400 pounds, and stainless Nicopress fillings around plastic thimbles. Although the initial arrays used 1/4-inch galvanized wire with copper Nicopress fittings for terminations. Zinc anodes were attached to all Nicopress fittings, following a technique developed at Oregon State University (OSU). After one month of immersion the zincs on some of the wire fittings had almost totally disappeared. It was feared that a longer use would have led to corrosion of the copper Nicopress fittings and possibly to the loss of the array. It was then decided to use stainless steel wire. Again, following the technique developed at OSU, plastic 1/2-inch thimbles are used at all eye terminations. Galvanized anchor shackles with stainless steel cotterpins were used as connectors for

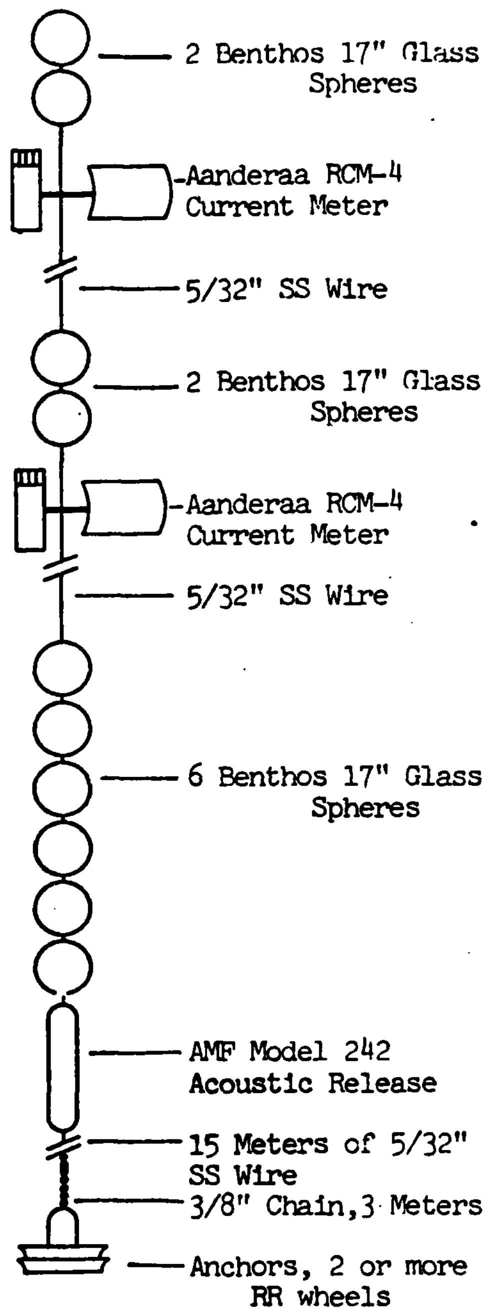

Figure 35. Array configuration.

the various components. Zincs are maintained on the meters and release as a protection against their corrosion. Input parameters for the wire into the NOYFB program are: W(I) = -0.1225 (weight of component in pounds per meter length), A(I) = +0.00397 (diameter in meters), RBS(I) = +2400.0 (rated breaking strength in pounds), and AW(I) = +0.065 (cross sectional metal area of wire in square inches).

Below each release is a 15-meter section of wire, 3-meter section of 3/8 inch chain and the weights. Weight is provided by scrap railroad wheels which have a weight of about 600 pounds per wheel in water. Two wheels are used for the shallow arrays and three for the deeper arrays.

Placement of arrays was done from the R/V ACANIA by the method of stringing the array out behind the ship, upper-most components first, and dropping the anchor last. As an added precaution a 7-foot cargo parachute was attached to the anchors to slow their rate of descent.

B. DISCUSSION OF DIRECT CURRENT MEASUREMENTS

All data obtained with the current meters was converted to speed and direction using Aanderaa calibration constants and consolidated on a single IBM compatible tape.

Current speed and direction were used to construct progressive vector diagrams. Vertical and horizontal scales are equal in these diagrams. The vertical axis is zero degrees, magnetic north. The coast in the study area is aligned approximately in a 305° magnetic direction.

The current at station 2 during the period 25 July to 28 August 1978 is depicted by the progressive vector diagram shown in Figure 36. This meter was at 220 meters depth. During its operation the average overall current was 336° magnetic at 7.6 cm/sec. With respect to the alignment of the coast this shows a slight onshore component.

The semidiurnal components in the currents are visible upon close examination (the crosses on the diagram appear at two-day intervals). Two reversals of current which last four-days each can be seen at the top of the figure.

The second meter was installed in September (Figure 37) at the same location, station 2, but at a depth of 190 meters. It was in operation from 20 September to 27 November 1978. For this period the progressive vector diagram is shown in Figure 37, and the crosses are located at three-day intervals. The mean flow was 318° magnetic at 2.9 cm/sec. During the middle of the observation period numerous reversals of flow appear. These oscillations suggest that the meter was near a frontal zone and that its position alternated between sides of that zone, perhaps as a meander or eddy in the countercurrent moved through the station's position. The mean flow over the seventy days is dominated by the countercurrent flowing nearly parallel to the coast.

Figures 38 through 42 are progressive vector diagrams for the arrays in operation from 27 November 1978 to 22 January 1979 on moorings at stations 2 and 5. The crosses in all these figures are at three-day intervals. Semi-diurnal components are again visible.

Figures 38, 39, and 40 are for the array at station 2. The upper meter was at 100 meters depth (Figure 38). The mean flow at this level was toward 337° magnetic at 12.8 cm/sec, a moderately strong onshore and northward flow. On the 8th of January the flow changes from northward to southward for three days. The next meter was at 175 meters depth (Figure 39). The mean flow was toward 321° magnetic at 3.2 cm/sec. This small mean value is deceiving; it results from a period of mainly southward flow during the first nine days and oscillations during the last part of the period. The speed during the middle of the period was at a maximum of 25 cm/sec during a three-day period. Thus, although the oscillations result in a small value for the local time-averaged flow, weakening of the countercurrent is not necessarily implied. The oscillations may simply imply a spatially fluctuating front in the region.

The bottom meter on this array was at 300 meters (Figure 40). The mean flow at this level was towards 151° magnetic at 1.8 cm/sec. During most of the period the flow appears weak and fluctuating. The oscillations are mainly in two directions, northward and southward parallel to the coast. The meter appears to be astride the front separating the countercurrent and the southward flow. As the countercurrent meanders the meter moves from one flow to the other. In summary the current is moderately strong and northward at the surface and weak at mid-depth with the exception of the strong northward flow during the middle of the period. The oscillations during the first and last days and at the lower meter indicate a moving shear zone between the countercurrent and the southward flow.

Figures 41 and 42 are for the array installed at station 5 and operating in the interval 27 November 1978 through 22 January 1979. The upper meter was at 140 meters depth (Figure 41). The mean flow was toward 319° magnetic at 12.3 cm/sec. As can be seen, the flow is almost exclusively northward, parallel to the coast, during the entire period. The exception is a three-day interval at the start with southward flow.

At 215 meters (Figure 42) the mean flow was toward 308° magnetic at 6.3 cm/sec. This reduction of the mean from the upper meter is largely due to the southward flows during the first nine days and an eight-day period beginning about 1 January. During these reversals the flow maintains its new direction and intensity without multiple oscillations. The sharp, clear change in flow indicates reversal from countercurrent to southward flow with no lingering of the front in the region of the meter. This pattern is similar to that at station 2 with a weakening of flow with depth and the appearance of southward flow at the deeper meters.

In summary the mean flow at the surface during the period of 27 November 1978 through 22 January 1979 is northward with an onshore component and a surface maximum of speed. At mid-depth the current has maintained its direction with reduced speed. At the deeper meters the flow is variable in direction and speed, indications of a frontal region separating northward and southward flow.

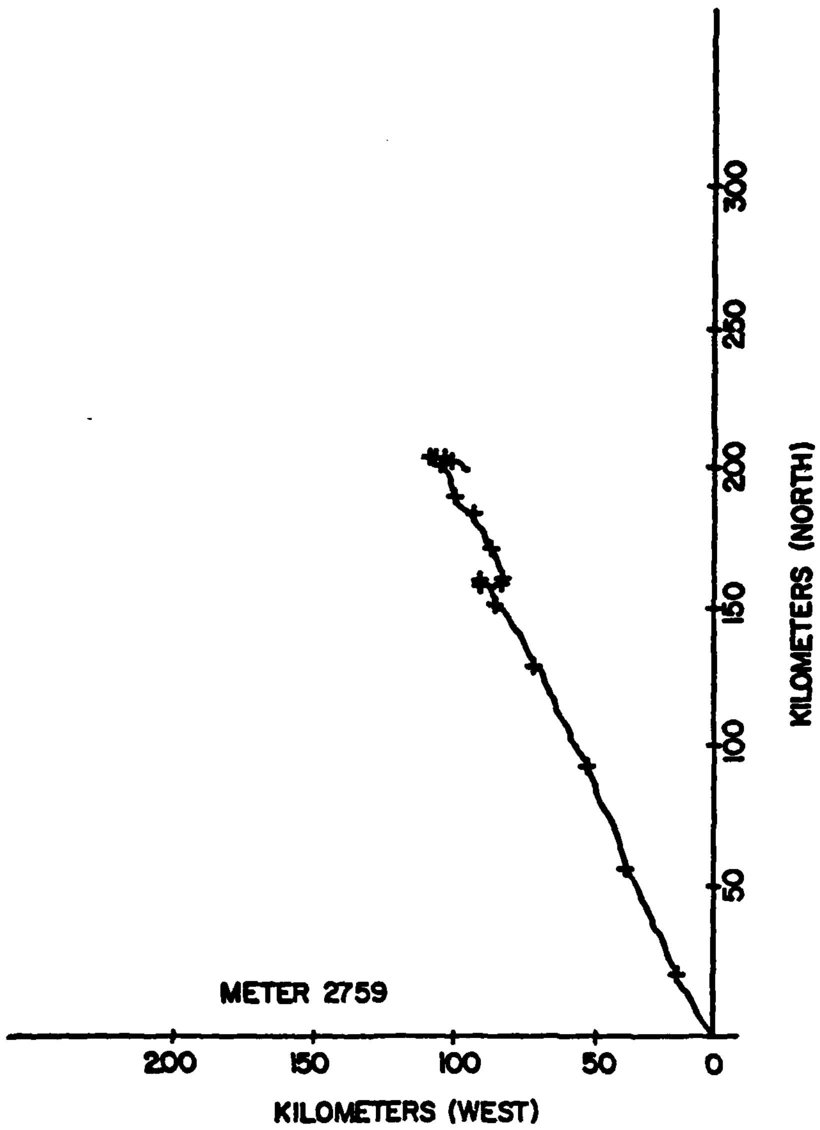

Figure 36. Progressive vector diagram for the current meter at 220 meters depth at station 2 from 25 July 1978 to 28 August 1978. Crosses are positioned at 2 day intervals. Vertical axis indicates Magnetic North.

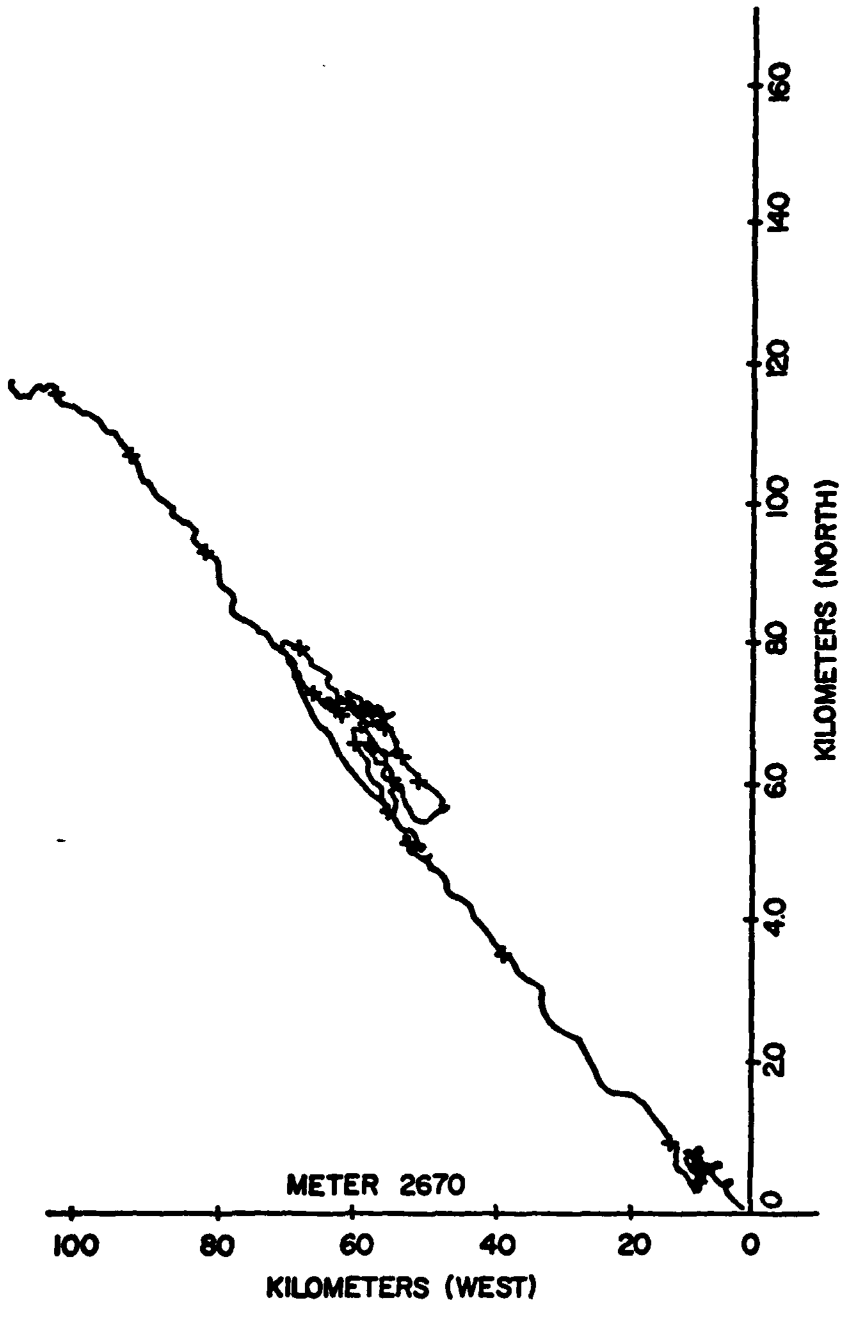

Figure 37. Progressive vector diagram for the current meter at 190 meters depth at station 2 from 20 September 1978 to 27 November 1978. Crosses are positioned at 3 day intervals. Vertical axis indicates Magnetic North.

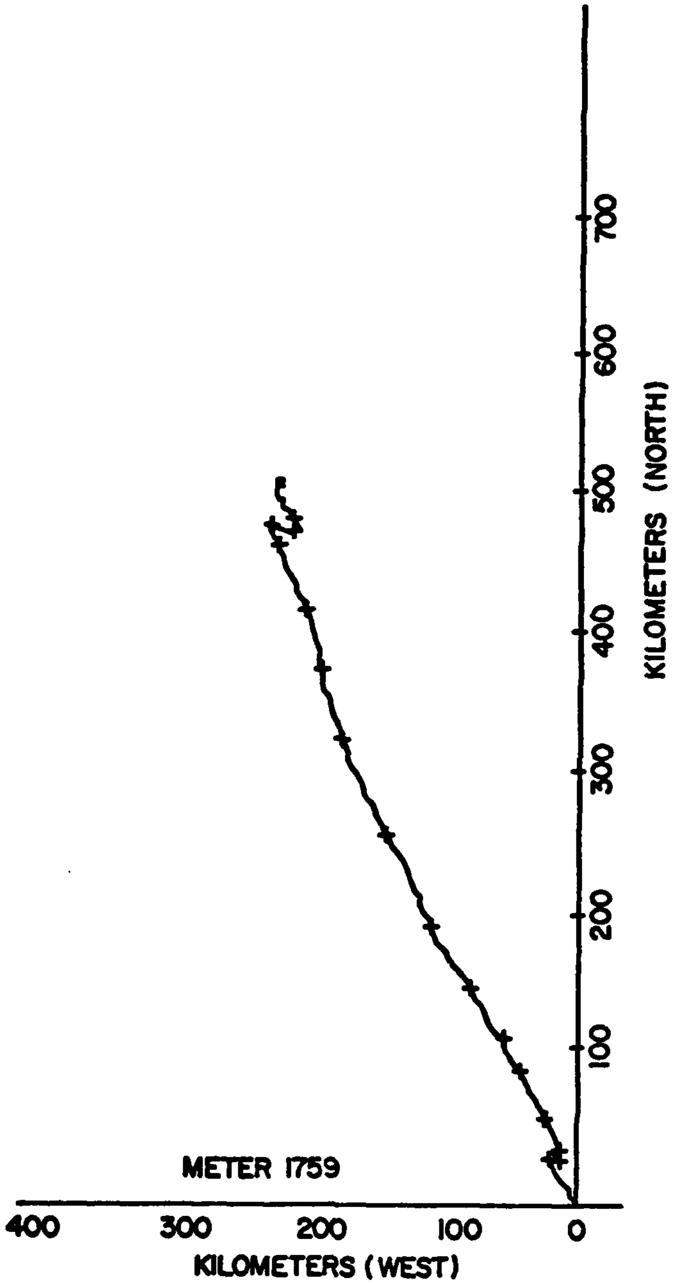

Figure 38. Progressive vector diagram for the current meter at 100 meters depth at station 2 from 27 November 1978 to 22 January 1979. Crosses are positioned at 3 day intervals. Vertical axis indicates Magnetic North.

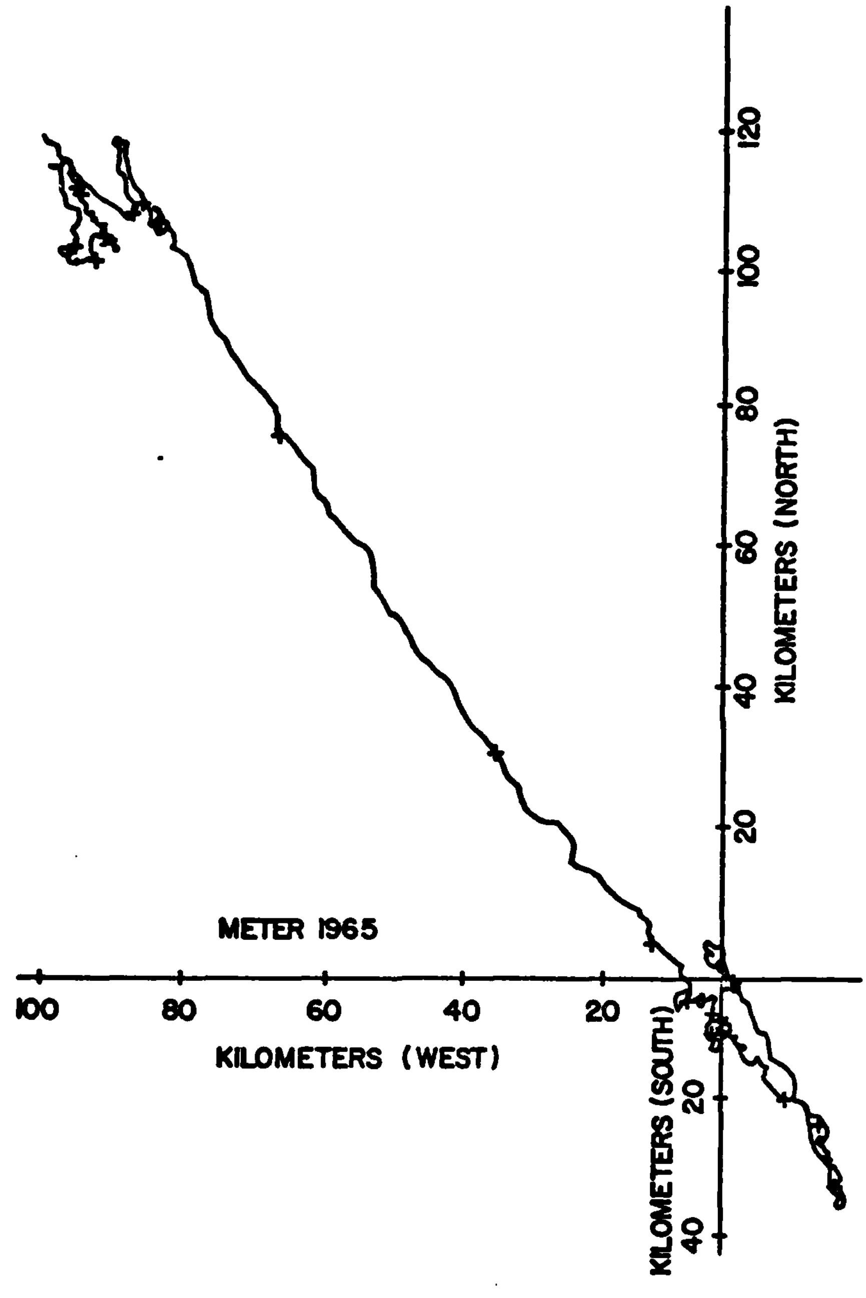

Figure 39. Progressive vector diagram for the current meter at 175 meters depth at station 2 from 27 November 1978 to 22 January 1979. Crosses are positioned at 3 day intervals. Vertical axis indicates Magnetic North.

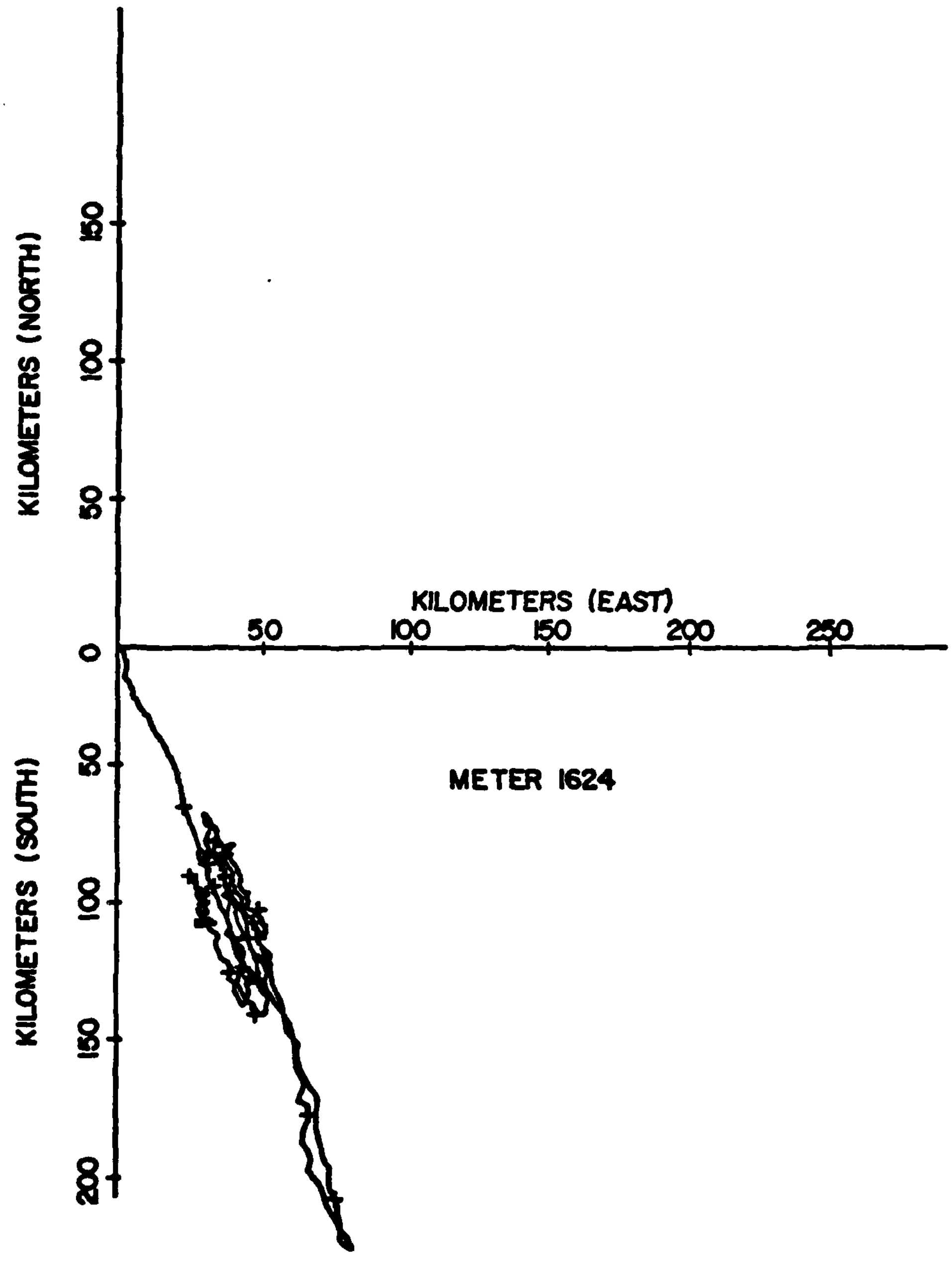

Figure 40. Progressive vector diagram for the current meter at 300 meters depth at station 2 from 27 November 1978 to 22 January 1979. Crosses are positioned at 3 day intervals. Vertical axis indicates Magnetic North.

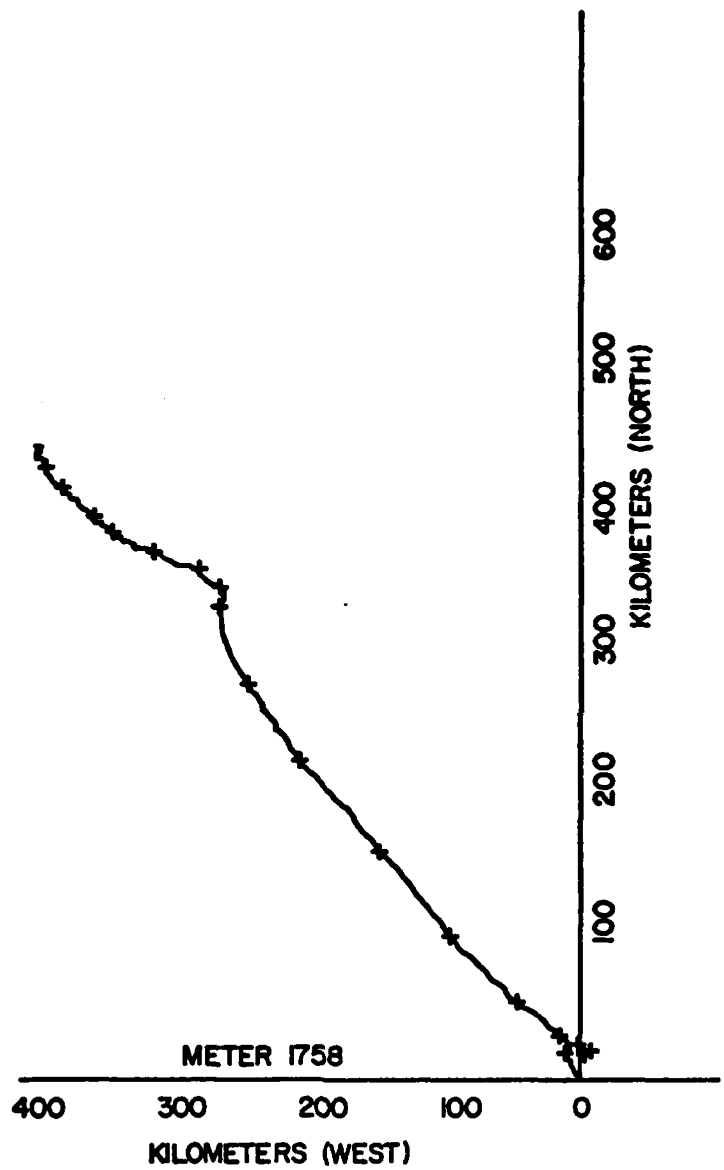

Figure 41. Progressive vector diagram for the current meter at 140 meters depth at station 5 from 27 November 1978 to 22 January 1979. Crosses are positioned at 3 day intervals. Vertical axis indicates Magnetic North.

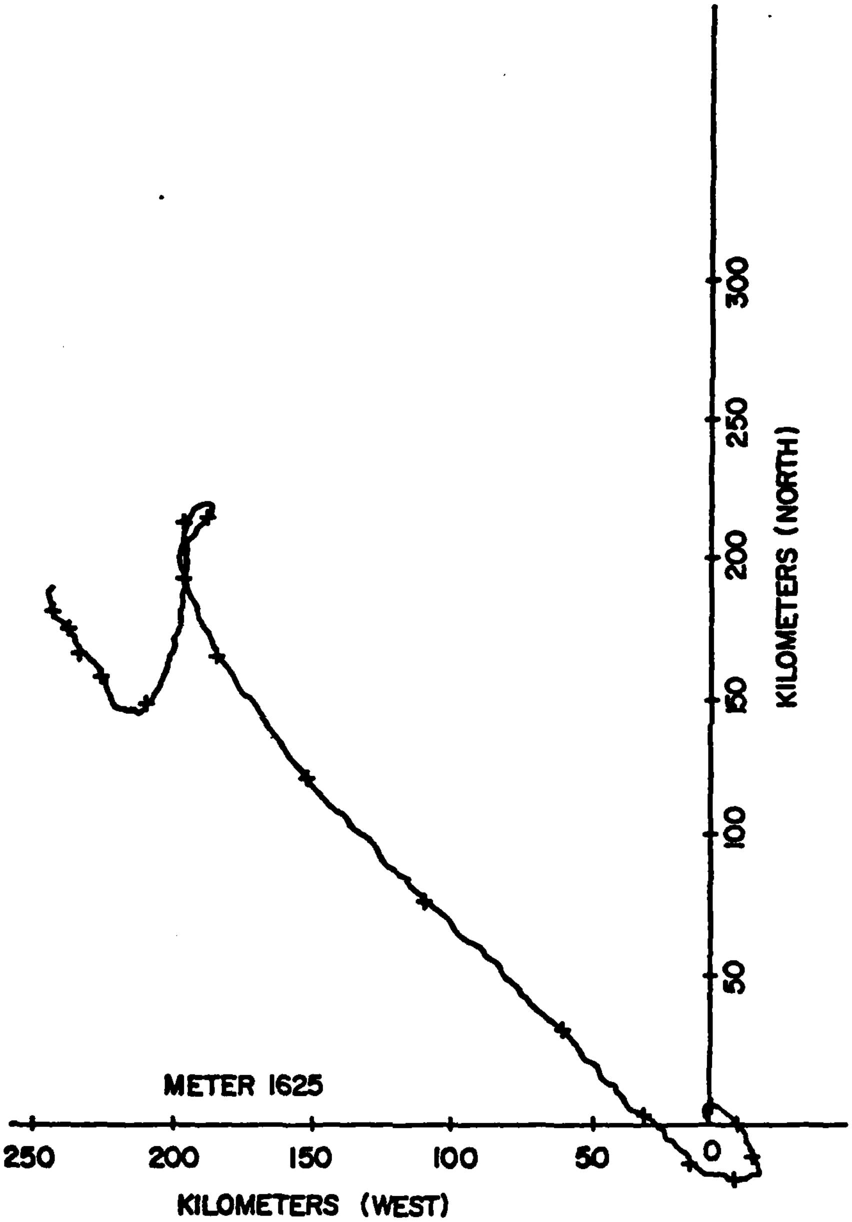

Figure 42. Progressive vector diagram for the current meter at 215 meters depth at station 5 from 27 November 1978 to 22 January 1979. Crosses are positioned at 3 day intervals. Vertical axis indicates Magnetic North.

V. COMPARISON OF GEOSTROPHY WITH DIRECT CURRENT MEASUREMENTS

The two methods of inferring currents, indirect (geostrophy) and direct (current metering) coincided on 27 November 1978 and 8 January 1979. There were vertical profiling for watermass properties on the Cape San Martin line and simultaneous direct measurements at stations 2 and 5 of that line.

The mean velocity from the current meters was found for a 24-hour period bracketing the time during which watermass properties were sampled. This was accomplished by computing: $\vec{V}(t) = \frac{\vec{R}(t+12) - \vec{R}(t-12)}{24}$ where $\vec{R}$ is the position vector at the given time taken from a list of the values used to produce the progressive vector diagram. This 24-hour averaging was done so as to smooth the high frequency non-geostrophic contributions to the flow while retaining larger scales. It must be expected that this averaging process does not smooth out all non-geostrophic components. Those which remain contribute to differences between the direct (current meter) and indirect (geostrophic) velocity measurements.

The mean metered velocities at stations 2 and 5 on both 27 November 1978 and 8 January 1979 are compared to those velocities found by geostrophy in Table II.

As seen in Table II, on 27 November 1978 at station 2, there is general agreement on the direct and indirect measurement of velocities at 100 and 175 meters. At 300 meters the methods of measurement indicate opposite flow directions. Dynamic topography indicates the region to be fairly flat with adjacent northward flow. The current meter shows a moderate southward flow of 10 cm/sec. This bottom meter is the meter which showed obvious non-geostrophic components, frequent oscillations between northward and southward flow. On the same data at station 5, the table shows strong agreement between the two methods of measurement. Geostrophy indicates a slightly stronger flow and the current meters show more of an onshore flow.

On 8 January 1979 at station 2, there is poor correlation of the current from the two measurement methods. Geostrophy indicates the region, at mid and lower depths, to be fairly flat with weak flow. Direction can only be inferred from that at station 4 (Figures 19 and 20). At the 100 meter level the current meter shows an onshore southward flow while geostrophy indicates northward flow parallel to the coast. At station 5 one can see reasonable agreement between the two methods of measurement (Table II). Current meters show uniform speed with depth and geostrophy indicates weakening of the flow with depth.

In summary there is general agreement between the two methods of measurement. It must be remembered that geostrophic calculations for station 2 were based on extrapolations and to that extent are uncertain. Further, the averaging of the current over 24 hours does not remove all non-geostrophic components, especially in the periods of strong fluctuations. The geostrophic current, as expected, is a more useful estimate of the flow in this variable regime during the relatively quiet (i.e., steady) flow periods.

VI. CONCLUSIONS

In summarizing the current and watermass variations, the time interval between cruises is used for an initial breakdown. Currents are described by geostrophy at the time of each cruise and by current meter measurements during the intervals. Watermass properties are known only at cruise times.

From 27 November 1978 to 8 January 1979, near the level of 100 meters, there is an increased halocline slope downward toward the coast and an intense northward flow spreading westward. This spreading flow also occurs at 200 and 300 meters. Below 300 meters, southward flow develops. A salinity maximum at 300 meters occurs near the center of the station lines in November and at the western edge in early January.

From 8 January 1979 to 22 January 1979 the halocline levels off and becomes less intense. At 100 meters the northward flow has weakened and at 200 meters remains unchanged. From 300 to 500 meters there is a reduction in salinity due to horizontal advection, vice vertical, of low salinity water. There is also reduced southward flow below 300 meters during this interval.

These results by indirect measurements are consistent with direct (current meters) methods. At 100 meters northward flow spreads westward from 27 November 1978 to 22

January 1979. At about 1 January this flow shows an increased westward component, i.e. it crosses contours into deeper water. Vertical extent of the northward flow also increases during this period. Southward flow is present at mid-depth until 6 December when it turns northward at both stations 2 and 5. At 300 meters, a frontal region separating northward and southward flow, the flow is southward until early December when much oscillating dominates the rest of the period.

Indications are that the flow is branched and northward at the surface, consistent with Wickham's (1975) findings farther north. Presence of a surface maximum, Davidson Current, during the winter is almost universally consistent with the observations of other investigators. Westward propagation of the flow tends to support McCreary's (1977) model.

From 22 January 1979 to 21 February 1979 there is an increase in salinity at all levels. The northward jet shows further westward movement.

Measurement of the currents is still in progress. A 3-meter array was installed farther west at station 7 and in April 1979 was increased to a 4-meter array. Arrays are also being maintained at stations 2 and 5. Along with current meter measurements, simultaneous measurements of watermass properties are made at regular intervals.

TABLE II

COMPARISON OF CURRENT METER AND GEOSTROPHIC CURRENT VELOCITIES ON 27 NOVEMBER 1978 AND 8 JANUARY 1979

Date	Station	Depth (meters)	Current Meters θ(1) direction (ref. Mag N)	Current Meters V(1) (cm/sec)	Geostrophy θ(2) direction (ref. Mag N)	Geostrophy V(3) (cm/sec)
27 November	2	100	331°	16.2	310°	strong
		175	352°	2.9	305°	moderate
		300	112°	10.0	335°	weak
27 November	5	140	337°	9.5	310°	15.1
		215	339°	4.7	305°	9.1
8 January	2	100	076°	4.8	310°	strong
		175	249°	6.8	variable	weak
		300	332°	38.3	variable	weak
8 January	5	140	300°	16.6	310°	25.1
		215	240°	16.9	285°	weak

NOTES

(1) θ and V (current Meters) found using $\frac{\vec{R}(t+12) - \vec{R}(t-12)}{24}$ where $\vec{R}$ is the position vector at the given time taken from a list of values used to produce the progressive vector diagram.

(2) θ (geostrophy) found from dynamic topographies.

(3) V (geostrophy) $V = \frac{V_n}{\cos\theta}$ where V_n is the normal component of velocity from geostrophic cross sections and θ is the angle from the normal.

```
C     PROGRAM NOYFB
C
C     PROGRAM NYOFB, REVISED VERSION OF:
C     REVISION 9.1, MARCH 1975
C     REVISED OCTOBER 1978 BY K. CODDINGTON
C     FOR USE WITH IBM 360 COMPUTER
C     WRITTEN IN FORTRAN IV LANGUANGE
C     REQUIRES SUBROUTINES CALC,CONST,TRANS,PTIO
C     REQUIRES FUNCTION JCD
C
C     DETERMINES THE STATIC CONFIGURATION OF SUB-SURFACE
C     MOORINGS WHEN ACTED UPON BY NON-COPLANAR CURRENT PROFILES
C
C
C     MAIN PROGRAM CONTROLS I/O AND OPTION SELECTION
C     SENSE SWITCH OPTIONS ARE INDICATED BY ISSW(I) WHERE 1=ON AND 2=OFF
C     S.S. - 1 - ON - LIST INPUT PARAMETERS
C      '   - 2 - ON - OUTPUT SEGMENT STATS
C      '   - 3 - ON - OUTPUT SUPPLEMENTAL STATS
C      '   - 4 - ON - OUTPUT SUMMARY MOORING STATISTICS
C      '   - 5 - ON - OUTPUT COMPONENT CHARACTERISTICS
C      '   -10 - ON - OUTPUT TO SOFT COPY DEVICE
C      '   -10 - OFF- OUTPUT TO HARD COPY DEVICE
C      '   -14 - ON - ABORT RUN - GO TO 'PAUSE'
C
      COMMON W(42),A(42),RBS(24),AW(5),E(16)
      COMMON IT(65),XL(65),TW(66),CDN(5),CDT(5)
      COMMON DCP(20),CP(20),RCP(20),IHDG(36)
      COMMON T1(65),T2(65),T3(65),T4(65),T5(65),T6(65),T7(65)
      COMMON IDA(10),IDM(10),DB(10)
      COMMON DPT,QN200,D200,FPM,LI1,LC,LC3,NEW,TERMW,TERML
      COMMON RD,PI,TL,IC,IV,FUDG,RC,SEG,DONE
      COMMON TCLIN,TTENS,TROTN,QBKUP,TVELO,ANCR,ANCRA
      COMMON ISSW(14)
      ISSW(1)=1
      ISSW(2)=1
      ISSW(3)=1
      ISSW(4)=1
      ISSW(5)=1
      ISSW(6)=1
      ISSW(7)=1
      ISSW(8)=1
      ISSW(9)=1
      ISSW(10)=1
      ISSW(11)=0
      ISSW(12)=0
      ISSW(13)=0
      ISSW(14)=0
```

```
      DATA IBLANK/'    '/
      LL = 0
      IC = 0
      NEW = 15
      ISLEW = IBLANK
C
C     SET STANDARD WHOI COMPONENT CONSTANTS
C
      CALL CONST
C
C     ENTER I/O UNIT REFERENCE NUMBERS
C     STANDARD U.R.N. FOR WHOI/BUOY COMPUTER ARE LISTED
C
      WRITE (6,1)
1     FORMAT ('0ENTER FIVE I/O DEVICES',/,' SOFT COPY,HARD COPY,PAPER PU
     1NCH,KEYBOARD,PAPER READER',/,' STANDARD URN ARE: 6,8,2,5,2')
      READ (5,600) LO1, LO2, LO3, LI, LI1
600   FORMAT (5I1)
      WRITE (LO1,46)
   46 FORMAT ('0INITIAL RUN FROM P.T.?: 1-YES, 0-NO')
      READ (LI, 601) I
601   FORMAT (I2)
      IF (I-1) 59,55,55
C
C     INPUT MOORING COMPONENTS AND CONSTANTS FROM PAPER
C     TAPE OR OTHER SOURCE
C
   55 CALL PTIO
      WRITE (LO1,51) DPT
   51 FORMAT (F6.1)
      LL = 0
      GO TO 105
C
C     THE FOLLOWING SECTION PERMITS INPUT OF VARIABLE
C     PARAMETERS FOR THE INITIAL AND SUBSEQUENT RUNS
C     FORMAT STATEMENTS DESCRIBE THE OPERATIONS
C
   59 CONTINUE
   60 WRITE (LO1,2)
    2 FORMAT ('0CHANGE COMP. CONSTANTS?: 1-YES,0-NO')
      READ (LI, 602) I
602   FORMAT (I2)
      IF (I-1) 75,61,61
   61 WRITE (LO1,3)
62    READ (LI, 603) I,J,X
3     FORMAT ('0ENTER CODING:1-W(I),2-A(I),3-RBS(I),4-AW(I)',/,' THEN TY
     1PE COMPONENT CODE NO. AND NEW VALUE')
603   FORMAT (I2, 1X, I2, F10.5)
```

```
   63 GO TO (65,66,67,68,70), I                                          NY000970
   65 W(J) = X                                                           NY000980
      GO TO 69                                                           NY000990
   66 A(J) = X                                                           NY001000
      GO TO 69                                                           NY001010
   67 RBS(J) = X                                                         NY001020
      GO TO 69                                                           NY001030
   68 AW(J) = X                                                          NY001040
   69 WRITE (LO1,700)                                                    NY001050
  700 FORMAT ('ONEXT OR 05')                                             NY001060
    4 FORMAT ('ONEXT OR 99')                                             NY001070
      GO TO 62                                                           NY001080
   70 IF (LL-1) 75,340,340                                               NY001090
   75 WRITE (LO1,5)                                                      NY001100
    5 FORMAT ('OCHANGE STRETCH CHARACTERISTICS?: 1-YES, 0-NO')           NY001110
      READ (LI, 604) I                                                   NY001120
  604 FORMAT (I2)                                                        NY001130
      IF (I-1) 151,76,76                                                 NY001140
   76 WRITE (LO1,6)                                                      NY001150
    6 FORMAT ('OENTER: 1-WIRE, 2-DACRON, 3-NYLON, 4-UNSPEC.')            NY001160
   77 READ (LI, 605) I                                                   NY001170
  605 FORMAT (I2)                                                        NY001180
      IF (I-99) 78,80,80                                                 NY001190
   78 WRITE (LO1,7)                                                      NY001200
    7 FORMAT ('ONOW ENTER THE 4 CONSTANTS')                              NY001210
      I = I*4-3                                                          NY001220
      READ (LI, 606) E(I), E(I+1), E(I+2), E(I+3)                        NY001230
  606 FORMAT (4E12.5)                                                    NY001240
      WRITE (LO1,4)                                                      NY001250
      GO TO 77                                                           NY001260
   80 IF (LL-1) 151,340,340                                              NY001270
C                                                                        NY001280
C     'I2' IS THE COUNTER FOR INSERT AND DELETE                          NY001290
C                                                                        NY001300
  150 WRITE (LO1,8)                                                      NY001310
    8 FORMAT ('OTYPE 1-CHANGE, 2-INSERT, 3-DELETION THEN')               NY001320
  151 WRITE (LO1,9)                                                      NY001330
    9 FORMAT ('OMOORING COMP. NO., TYPE, LENGTH OR NO. OF BALLS')        NY001340
      I2 = 0                                                             NY001350
  153 IF (LL-1) 158,155,155                                              NY001360
  155 READ (LI, 607) N,I,J,X                                             NY001370
  607 FORMAT (I2,1X,I2,1X,I2,1X,F10.5)                                   NY001380
      GO TO (850,180,190,340),N                                          NY001390
  158 READ (LI,608) I,J,X                                                NY001400
  608 FORMAT (I2,1X,I2,1X,F10.5)                                         NY001410
      IF (I-99) 160,92,92                                                NY001420
  160 IC = I                                                             NY001430
  175 I1 = I+I2                                                          NY001440
```

```
      IT(I1) = J
      XL(I1) = X
      GO TO 195
C
C     CHANGE COMPONENT
C
850   I1=I+I2
      IT(I1)=J
      XL(I1)=X
      GO TO 810
C
C     INSERT COMPONENT
C
  180 I1 = IC
  182 IF (I1-(I+I2)) 186,186,184
  184 XL(I1+1) = XL(I1)
      IT(I1+1) = IT(I1)
      I1 = I1-1
      GO TO 182
  186 XL(I1+1) = X
      IT(I1+1) = J
      IC = IC+1
      I2 = I2+1
      GO TO 810
C
C     DELETE COMPONENT
C
  190 I3 = I+I2
      I4 = IC-1
      DO 192 I1 = I3,I4
      XL(I1) = XL(I1+1)
      IT(I1) = IT(I1+1)
  192 CONTINUE
      IC = IC-1
      I2 = I2-1
810   WRITE (LO1,811)
811   FORMAT ('ONEXT OR 04')
      GO TO 153
  195 WRITE (LO1,4)
      GO TO 153
197   IF (LL-1) 92,340,340
   92 WRITE (LO1,10)
   10 FORMAT ('OLINE MEASURED AT 200(D)SQR?: 1-YES, 0-NO')
      READ (LI,609) I
609   FORMAT (I2)
      IF (I-1) 95,94,94
   94 ON200 = 1.0
      D200 = 1.0
```

```
      GO TO 96
   95 QN200 = 1.042
      D200 = 1.032
   96 IF (LL-1) 98,340,340
   98 WRITE (LO1,11)
   11 FORMAT ('0ENTER ANCHOR WT.(+LBS), AREA((M)SQR)')
      READ (LI,610) ANCR, ANCRA
  610 FORMAT (F7.2, F5.2)
      IF (LL-1) 215,340,340
  215 WRITE (LO1,19)
   19 FORMAT ('0ENTER COMMENTS - 1 LINE MAX.')
C
C     SET 'COMMENT' ARRAY TO BLANKS
C
      DO 217 K = 1,36
      IHDG(K)= IBLANK
  217 CONTINUE
      READ (LI,35) (IHDG(K),K = 1,36)
   35 FORMAT (36(A2))
      IF (LL-1) 100,340,340
  100 WRITE (LO1,41)
   41 FORMAT ('0ENTER: DEPTH OF WATER (METERS)')
      READ (LI,611) DPT
  611 FORMAT (F6.1)
  105 CONTINUE
  110 IV = 1
      WRITE (LO1,12)
   12 FORMAT ('0INPUT CURRENT PROFILE--DEPTH(METERS),SPEED(CM/SEC),DIREC
     1TION(DEGR)')
  112 READ (LI,612) DCP(IV), CP(IV), RCP(IV)
  612 FORMAT (F6.1,1X,F4.1,1X,F5.1)
      IV = IV +1
      IF (DCP(IV-1)-DPT) 112,115,115
  115 IV = IV-1
      IF (LL-1) 120,340,340
  120 WRITE (LO1,13)
   13 FORMAT ('0CHANGE STANDARD CD?: 1-YES, 0-NO')
      READ (LI,613) I
  613 FORMAT (I2)
      IF (I-1) 130,122,122
  122 WRITE (LO1,14)
   14 FORMAT ('0ENTER: 1-WIRE,2-LINE,3-INSTR,4-BALLS,5-UNSPEC.  THEN CD(
     1N),CD(T)')
  123 READ (LI,614) I,X,Y
  614 FORMAT (I2,1X,F3.1,1X,F6.3)
      IF ( I-99) 124,127,127
  124 CDN(I) = X
      CDT(I) = Y
```

```
      IF (I-4) 126,125,126
C
C     Y/PI FOR CDT OF SPHERES ALLOWS USE OF THE
C     EQUATION FOR THE TANGENTIAL DRAG OF CYLINDERS
C
  125 CDT(I) = Y/PI
  126 WRITE (LO1,4)
      GO TO 123
  127 IF (LL-1) 130,340,340
  130 WRITE (LO1,15)
   15 FORMAT ('0SEGMENT LENGTH(METERS)?')
      READ (LI,615) SEG
615   FORMAT (F7.2)
      IF (LL-1) 200,340,340
  200 WRITE (LO1,16)
   16 FORMAT ('0AUTO LENGTH ADJUST?:-0 TO 10 COMPCNENTS')
      READ (LI,616) IDZ
616   FORMAT (I2)
      IF (IDZ.EQ.0) GO TO 206
  202 WRITE (LO1,17)
   17 FORMAT ('0ENTER: CRITICAL COMP., CESIRED DEPTH, ADJUST. COMP.')
      DO 204 I = 1,IDZ
      READ (LI,617) IDA(I), DB(I), IDM(I)
617   FORMAT (I2,1X,F6.1,1X,I2)
  204 CONTINUE
  206 IF (LL-1) 210,340,340
  210 WRITE (LO1,18)
   18 FORMAT ('0ENTER MAGNITUDE, INCLINATION,AZIMUTH OF P.F.')
      READ (LI,618) TTENS,TCLIN,TROTN
618   FORMAT (3F5.1)
      IF (LL-1) 211,340,340
  211 WRITE (LO1,42)
   42 FORMAT ('0CHANGE IN TERMINATION CONSTANTS?: 1-YES, 0-NO')
      READ (LI,619) I
619   FORMAT (I2)
      IF (I-1) 213,212,212
  212 WRITE (LO1,43)
   43 FORMAT ('0ENTER TERM. LENGTH(METER),WT.(LBS)')
      READ (LI,620) TERML,TERMW
620   FORMAT (F6.3,1X,F6.3)
C     SET LL=2: INDICATES INITIALIZATION COMPLETE
213   LL=1
      GO TO 340
C
C     START NEW COMPUTATION
C     RESET CRITICAL VARIABLES TO 0.0
C
  220 CONTINUE
```

```
      TW(1) = 0.0
      TL = 0.0
      BKUP = 0.0
      DONE = 0.0
C
C     CALCULATE LAUNCH TRANSIENTS
C
      CALL TRANS
      RC = DPT-TL
      FUDG = 0.0
C
C     SET HARD / SOFT COPY DEVICE FOR OUTPUT
C
  244 IF (DONE-1.0) 255,245,245
  245 LO = LO1
      IF (ISSW(10)) 247,246,247
  246 LO = LO2
C
C     WRITE INPUT PARAMETERS
C     WRITE HEADING
C     'ISLEW' ADVANCES PAGE TO NEW SHEET
C
  247 IF (ISSW(1)) 248,253,248
  248 WRITE (LO,20) ISLEW
20    FORMAT (1H1)
      WRITE (LO,35) (IHDG(K),K = 1,36)
      WRITE (LO,21) (CDN(I),I = 1,5),(CDT(J),J = 1,5)
   21 FORMAT (/20X,17H INPUT PARAMETERS//16X,18H DRAG COEFFICIENTS
     1/10X,43H WIRE       LINE      CYLIND     SPHERE    UNSPEC.
     2/6H CD(N),5(4X,F5.3),/6H CD(T),5(4X,F5.3))
      WRITE (LO,22) DPT,ANCR,TTENS,ANCRA,TCLIN,TVELO,
     1TROTN,SEG,TERMW,TERML
22    FORMAT ('OWATER DEPTH',6X,F6.1,9X,'ANCHOR WT. (LBS)', 7X,F7.1,/, '
     1OP.F.MAGNITUDE',4X,F7.2,8X,'ANCHOR AREA',15X,F5.2,/,'OP.F.INCLINAT
     2ION ',1X,F7.2,8X,'TERM.VELO.(M/MIN)',8X,F5.1,/,'OP.F.AZIMUTH',6X,
     3F7.2,8X,'SEGMENT LENGTH',10X,F6.1,/,'OTERM.WT',11X,F7.3,7X,'TERM.L
     4ENGTH',15X,F5.3)
      WRITE (LO,23)
   23 FORMAT (//6X,16H CURRENT PROFILE/
     132H  DEPTH         SPEED        DIRECTION)
      DO 250 I = 1,IV
      WRITE  (LO,24) DCP(I),CP(I),RCP(I)
   24 FORMAT (1X,F6.1,2X,F5.1,7H CM-SEC,2X,F5.1,4H DEG)
  250 CONTINUE
C
C     WRITE HEADING FOR SEGMENT STATS. IF SS-2 IS ON
C     AND REENTER SJB. CALC
C
```

```
  253 IF (ISSW(I)) 254,269,254
  254 WRITE (LO,20) ISLEW
      WRITE (LO,35) (IHDG(K),K = 1,36)
      WRITE (LO,33)
   33 FORMAT (//28X,18HSEGMENT STATISTICS )
      WRITE (LO,34)
34    FORMAT (//' COMP TYPE LENGTH INCL XEXC. YEXC. C.SPD C.DIR M.AZI UD
     1RAG VDRAG TDRAG')
C
C      SUBROUTINE CALC PERFORMS ALL BASIC CALCULATIONS
C
  255 CALL CALC
      IF (ISSW(14)) 320,257,320
C
C      CHECK DIFFERENCE BETWEEN ASSUMED DEPTH(RC) AND THE
C      CALCULATED DEPTH OF THE TOP COMPONENT. LESS THAN 2.0 M.?
C      IF YES - CHECK AUTO ADJUST STATUS,
C      IF NO  - CALC NEW FUDG, SET NEW RC.
C      (X-RC)*0.7 TO HASTEN CONVERGENCE IN LARGE CURRENT SHEER
C
  257 IF (DONE-1.0) 258,269,269
  258 X = DPT-T4(IC)
      IF (ABS(RC-X)-2.0) 260,259,259
  259 FUDG = FUDG+(X-RC)*0.7
      RC = (DPT-TL)+FUDG
      GO TO 255
C
C      AUTO ADJUST EVALUATION - CHECK SPECIFIED INSTRUMENT
C      DEPTHS,  IF AT DESIRED DEPTHS - SET (DONE=2.0) AND
C      GO TO OUTPUT,  IF DEPTHS ARE INCORRECT - ADJUST
C      LENGTH OF (IDM) AND GO TO (220)
C
  260 IF (IDZ-1) 266,261,261
261   DO 264 K = 1,IDZ
C
C      CHECK AND ADJUST LOWEST ELEMENTS FIRST
C
      J = (IDZ-K)+1
      I = IDA(J)
      Z = ((DPT-T4(IC))+T4(I))-DB(J)
      IF (ABS(Z)-1.0) 264,262,262
  262 I = IDM(J)
C
C      99% OF Z TO PARTIALLY ALLOW FOR STRETCH
C
      XL(I) = XL(I)+Z*0.99
      GO TO 220
  264 CONTINUE
```

```
  266 DONE = -.0
      GO TO 245
C
C     IF SS-4 ON OUTPUT SUMMARY OF MOOR. STATS.
C
  265 IF (ISSW(4)) 271,281,271
  271 WRITE (LO,20) ISLEW
      WRITE (LO,35) (IHDG(K),K = 1,36)
  272 WRITE (LO,25)
   25 FORMAT (22X,28HMOORING STATISTICS - SUMMARY
     1//' COMP TYPE LENGTH  WEIGHT  DEPTH  INCLIN TENSION  EXCUR  DRAG B
     2ACK-UP')
      IBKUP = 0
      BKUP = QBKUP
      DO 280 K = 1,IC
      I1 = IT(K)
      IF (IBKUP) 274,274,273
  273 BKUP = 0.0
      GO TO 276
  274 BKUP = BKUP-(XL(K)*W(I1)+TERMW)
      IF (IT(K)-35) 276,275,276
  275 IBKUP = 2
  276 QW = XL(K)*W(I1)
      QX = (DPT-T4(IC))+T4(K)
      QY = SQRT((T5(IC)-T5(K))**2+(T6(IC)-T6(K))**2)
      WRITE (LO,26) K,IT(K),XL(K),QW,QX,T2(K),
     1T3(K),QY,T1(K),BKUP
   26 FORMAT (I4,3X,I2,2X,F6.1,1X,F7.1,2X,F6.1,1X,
     1F5.1,3X,F6.1,1X,F6.1,1X,F5.1,1X,F7.1)
      IF (ISSW(14)) 320,280,320
  280 CONTINUE
C
C     IF SS-3 ON OUTPUT SUPPLEMENTAL STATISTICS
C
  281 IF (ISSW(3)) 282,291,282
  282 WRITE (LO,20) ISLEW
      WRITE (LO,35) (IHDG(K),K = 1,36)
      WRITE (LO,27)
   27 FORMAT (/24X,23HSUPPLEMENTAL STATISTICS
     1//39H COMP TYPE CD(N)  AREA  STR.LT PERC.STR
     232H  S.F. XEXCUR YEXCUR LAUNCH TENS )
      DO 290 K = 1, IC
      I1 = IT(K)
      J1 = JCD(I1)
      IF (IT(K)-25) 283,284,284
  283 QR = RBS(I1)/T3(K-1)
      GO TO 285
  284 QR = 0.0
```

```
 285 QA = XL(K)*A(I1)
     QS = (T7(K)/XL(K))*100.0
     QSL = T7(K)+XL(K)
     QX = T5(IC)-T5(K)
     QY = T6(IC)-T6(K)
     WRITE (LO,28) K, IT(K),CDN(J1),QA,QSL,QS,QR,
    1QX,QY,TW(K)
  28 FORMAT (I4,3X,I2,3X,F3.1,1X,F6.3,2X,F6.1,3X,F5.2,3X,
    1F5.1,F7.1,F7.1,3X,F6.1)
 290 CONTINUE
C
C     IF SS-5 ON OUTPUT COMPONENT CHARACTERISTICS
C
 291 IF (ISSW(5)) 292,320,292
 292 WRITE (LO,20) ISLEW
     WRITE (LO,35) (IHDG(K),K = 1,36)
     WRITE (LO,47)
  47 FORMAT (/16X,26H COMPONENT CHARACTERISTICS
    2//' COMP TYPE LENGTH      A(I)     W(I)    RBS(I)    AW(I)')
     DO 300 K = 1,IC
     I1 = IT(K)
     X = 0.0
     Y = 0.0
     IF (IT(K)-6) 293,294,294
 293 X = AW(I1)
 294 IF (IT(K)-25) 295,296,296
 295 Y = RBS(I1)
 296 WRITE (LO,48) K, IT(K),XL(K),A(I1),W(I1),Y,X
  48 FORMAT (I4,3X,I2,2X,F6.1,1X,F9.7,1X,F9.5,1X,F7.1,1X,F8.6)
     IF (ISSW(14)) 320,300,320
 300 CONTINUE
     WRITE (LO,49) (E(I),I = 1,16)
  49 FORMAT (//19X,18H STRETCH CONSTANTS
    1/2X,6H COMP.,8X,3H(1),10X,3H(2),10X,3H(3),10X,3H(4),
    2/,' ( 1 -   5)',4(E13.5),/,' ( 6 - 10)',4(E13.5),/,' (11 - 15)',4(E
    313.5),/,' (16 - 20)',4(E13.5))
C
C     END OF RUN
C     'PAUSE' TO THINK, IF SO INCLINED
C     WRITE OPTIONS FOR POSSIBLE CHANGES
C
 320 CONTINUE
     WRITE (LO1,29)
29   FORMAT ('OPAUSE, RUN=22, END=99')
     READ (LI,229) IDUMMY
229  FORMAT (I2)
     IF (IDUMMY.EQ.99) GO TO 345
 321 IDZ = 0
```

```
      WRITE (LO1,44)
44    FORMAT ('OCHANGE OPTIONS',/,'0 1 COMP.CHAR.',/,'  2 STRETCH CHAR.'
     1,/,'  3 MOOR.CONFIGURATION',/,'  4 200(D)SOR MEASURE',/,'  5 ANCHO
     2R WT.',/,'  6 WATER DEPTH',/,'  7 CURRENT PROFILE',/,'  8 DRAG COE
     3FF',/,'  9 SEGMENT LENGTH',/,' 10 AUTO ADJUST STATUS',/,' 11 P.F.
     4AT TOP',/,' 12 TERM.CONST.',/,' 13 COMMENTS',/,' 14 CONTINUE W/O R
     5ECALC',/,' 15 INPUT MOOR.FROM PTR',/,' 16 OUTPUT MOOR.TO PP')
323   READ (LI,621) NEW
621   FORMAT (I2)
C
C     OPTION  1  2  3   4  5  6   7   8   9   10  11  12
      GO TO (61,76,150,92,98,100,110,122,130,20C,210,212,
     1215,245,55,336,220), NEW
C       13  14  15  16  99
C
C
C     OUTPUT EXISTING MOORING AND CONSTANTS TO PAPER TAPE
C
  336 CALL PTIO
  340 WRITE (LO1,31)
   31 FORMAT ('0GO? - (17) OR OPTION? - (1 TO 16)')
      GO TO 323
  345 CONTINUE
      STOP
      END
      SUBROUTINE CALC
C
C     SUBROUTINE CALC - USE WITH PROG. NOYFB, REV. 9.1
C     CALCULATION TO DETERMINE ALL MOORING STATISTICS
C
      COMMON W(42),A(42),RBS(24),AW(5),E(16)
      COMMON IT(65),XL(65),TW(66),CDN(5),CDT(5)
      COMMON DCP(20),CP(20),RCP(20),IHDG(36)
      COMMON T1(65),T2(65),T3(65),T4(65),T5(65),T6(65),T7(65)
      COMMON IDA(10),IDM(10),DB(10)
      COMMON DPT,QN200,D200,FPM,LI1,LC,LC3,NEW,TERMW,TERML
      COMMON RD,PI,TL,IC,IV,FUDG,RC,SEG,DONE
      COMMON TCLIN,TTENS,TROTN,QBKUP,TVELO,ANCR,ANCRA
      COMMON ISSW(14)
C
C     RESET VARIABLES TO INITIALIZE
C
      TLD = DPT-TL
      DRAG = 0.0
      JC = 2
      TSTR = 0.0
      TVHT = 0.0
      CLIN = TCLIN*RD
```

```
      PCLIN = CLIN
      TENS = TTENS
      ROTN = TROTN*RD
      TXEX = 0.0
      TYEX = 0.0
      CPK = 1.076391E-01
C
C     PRIMARY LOOP
C
      DO 570 I = 1,IC
      I1 = IT(I)
C
C     DETERMINE DRAG COEFF. SUBSCRIPT (FUNCTION JCD)
C
      J1 = JCD(I1)
C
C     DETERMINE NO. OF SEGMENTS IN COMPONENT (I)
C
  500 L = 1+IFIX(XL(I)/SEG)
C
C     SECONDARY LOOP FOR SEGMENT CALC.
C
  505 DC 562 K = 1,L
C
C     SET SEGMENT LENGTH (CLI) AND BUOYANCY (WT)
C     CALC. CURRENT:- MEAN DEPTH (DN), SPEED(VN),
C     DIRECTION(ROT), FOR EACH SEGMENT
C
      IF (K-L) 509,507,507
  507 CLI = (XL(I)-SEG*FLOAT(K-1))+TERML
      WT = W(I1)*(CLI-TERML)+TERMW
      GO TO 510
  509 CLI = SEG
      WT = W(I1)*SEG
  510 DN = TLD+(CLI/2.0)+FUDG*((DPT-(TLD+CLI/2.0))/TL)
C
C     ASSIGN DEEPEST CURRENT VALUES IF DN EXCEEDS DPT
C
      IF (DN-DPT) 514,512,512
  512 VN = CP(IV)*CPK
      ROT = RCP(IV)*RD
      GO TO 519
  514 IF (DN-DCP(JC)) 518,516,516
  516 JC = JC+1
      GO TO 514
  518 VN = (CP(JC-1)+(((DN-DCP(JC-1))/(DCP(JC)-DCP(JC-1)))
     1*(CP(JC)-CP(JC-1))))*CPK
      ROT = (RCP(JC-1)+(((DN-DCP(JC-1))/(DCP(JC)-DCP(JC-1)))
```

```
      1*(RCP(JC)-RCP(JC-1))))*RD
C
C       SET ROTN=ROT WHEN TENSION = 0
C
  519 IF (TENS) 522,522,524
  522 ROTN = ROT
C
C       CALC. DRAG FORCES,TENSION,INCLINATION AND AZIMUTH OF SEG.
C       ITERATE UNTIL CHANGE LESS THAN 0.1 DEGREES FOR
C       INCLINATION - LOOP 526 TO 530
C       MOORING AZIMUTH - LOOP 526 TO 527
C
  524 X = ROTN
      Y = ROTN
      Z = TENS*SIN(CLIN)
  526 QCLIN = PCLIN
      ANINC = QCLIN-CLIN
      UTVN = VN*COS(ROT-ROTN)
      VTVN = VN*SIN(ROT-ROTN)
      DRGT = A(I1)*PI*CLI*CDT(J1)*(SIN(QCLIN)*UTVN)*
     1(ABS(SIN(QCLIN)*UTVN))
      UDRGN = A(I1)*CLI*CDN(J1)*(COS(QCLIN)*UTVN)*
     1(ABS(COS(QCLIN)*UTVN))
      VDRGN = A(I1)*CLI*CDN(J1)*VTVN*ABS(VTVN)
      WTT = WT*COS(QCLIN)
      WTN = WT*SIN(QCLIN)
      QTENS = TENS*COS(ANINC)+WTT+DRGT
C
C       (-WTN) CHANGE SIGN OF WTN FOR CORRECT SENSE
C
      PCLIN = ATAN ((UDRGN-WTN-TENS*SIN(ANINC))/QTENS)+QCLIN
C
C       AVOID /0.0 IN STATEMENT 523
C
      IF (QTENS*SIN(PCLIN)) 523,529,523
  523 ROTN = ATAN((VDRGN-Z*SIN(X-Y))/(QTENS*SIN(PCLIN)))+X
  529 IF (ISSW(14)) 570,525,570
C
C       ASSURE +PCLIN
C
  525 IF (PCLIN) 531,530,527
C
C       RATE OF CHANGE IN AZIMUTH < 0.1 DEGREE?
C
527   IF (ABS(ABS(X)-ABS(ROTN))-(0.1*RD)) 530,528,528
  528 X = ROTN
      GO TO 526
C
```

```
C     RATE OF CHANGE IN INCLINATION < 0.1 DEGREE?
C
530   IF (ABS(QCLIN-PCLIN)-(0.1*RD)) 532,526,526
C
C     HANDLES 180 DEG. ROTATION OF AZIMUTH WHEN VDRGN = 0.0
C
  531 FCLIN = -PCLIN
      ROTN = ROTN+PI
      GO TO 524
  532 TENS = COS(PCLIN-CLIN)*TENS+WT*COS(PCLIN)+DRGT
      CLIN = PCLIN
C
C     STRETCH CALC.: - J2 = 1 FOR WIRE (538)
C                           2 FOR DACRON (544)
C                           3 FOR NYLON (544)
C                           4 FOR UNSPECIFIED (544)
C
      STRL = CLI
      ELT = 0.0
534   IF (I1-21) 536,554,554
  536 J2 = ((I1-1)/5)+1
      IF (J2-2) 538,540,540
  538 ELT = ((TENS/RBS(I1))*E(1))+(TENS/(E(2)*AW(I1)))
      GC TO 546
C
C     INTERPOLATION BETWEEN TW(I)&TW(I-1) FOR LAUNCH TRANSIENTS
C     FOR PERMANENT ELONGATION CALC.
C     ELT = PERMANENT ELONGATION + ELASTIC ELONGATION
C
  540 X = TW(I-1)+(((TW(I)-TW(I-1))/XL(I))*(SEG*FLOAT(K-1)+CLI))
      IF (X-TENS) 542,544,544
  542 X = TENS
  544 N =(J2-1)*4+1
      ELT = (((X/(E(N)*A(I1)**2))**E(N+1))+((TENS/
     1(E(N+2)*A(I1)**2))**E(N+3)))/100.0
C
C     CALC. SEGMENT STRETCHED LENGTH(STRL)
C     LENGTH * PERCENT STRETCH * 200(D)SCR MEAS. K
C
  546 GC TO (548,550,552,548), J2
  548 STRL = CLI*(1.0+ELT)
      GO TO 554
  550 STRL = CLI*(1.0+ELT)*D200
      GO TO 554
  552 STRL = CLI*(1.0+ELT)*QN200
C
C     CALC. HORIZ. EXCUR. (XEX&YEX) AND VERT. HEIGHT(VHT) OF SEG.
C
```

```
  554 XEX = ( STRL*SIN(CLIN))*COS(ROTN)
      YEX = (STRL*SIN(CLIN))*SIN(ROTN)
      VHT = STRL*COS(CLIN)
C
C     OUTPUT SEGMENT STATISTICS
C
      Z = CLIN/RD
  557 IF (DONE-1.0) 560,558,558
  558 X = ROT/RD
      Y = ROTN/RD
      VN = VN/CPK
      WRITE (LO,32) I,I1,CLI,Z,XEX,YEX,VN,X,Y,UCRGN,VDRGN,DRGT
   32 FORMAT (I3,3X,I2,3X,F5.1,1X,F4.1,2(1X,F5.1),1X,
     13(1X,F5.1),2(1X,F5.2),1X,F8.5)
C
C     SUM SEGMENT STATS. WITH COMPONENT TOTAL
C
  560 DRAG =DRAG+UDRGN
      TVHT = TVHT+VHT
      TXEX = TXEX+XEX
      TYEX = TYEX+YEX
      TSTR = TSTR+(STRL-CLI)
      TLD = TLD+CLI
  562 CONTINUE
C
C     TRANSFER COMPONENT STATS. INTO T ARRAYS
C
      T1(I) = DRAG
      T2(I) = Z
      T3(I) = TENS
      T4(I) = TVHT
      T5(I) = TXEX
      T6(I) = TYEX
      T7(I) = TSTR
      TSTR = 0.0
  570 CONTINUE
      RETURN
      END
      SUBROUTINE CONST
C     SUBROUTINE CONST - FOR USE WITH PROG. NOYFB, REV. 9.1
C     INPUT STANDARD WHOI BUOY COMPONENT CHARACTERISTICS
C     AND STRETCH CHARACTERISTICS AND DRAG COEFFICIENTS
C
      COMMON W(42),A(42),RBS(24),AW(5),E(16)
      COMMON IT(65),XL(65),TW(66),CDN(5),CDT(5)
      COMMON DCP(20),CP(20),RCP(20),IHDG(36)
      COMMON T1(65),T2(65),T3(65),T4(65),T5(65),T6(65),T7(65)
      COMMON IDA(10),IDM(10),MDB(10)
```

```
      COMMON DPT,CN200,D200,FPM,L11,LO,LO3,NEW,TERMW,TERML
      COMMON RD,PI,TL,IC,IV,FUDG,RC,SEG,DONE
      COMMON TCLIN,TTENS,TROTN,QBKUP,TVELO,ANCR,ANCRA
C
C
      TERMW = -2.19
      TERML = 0.203
      RD = 0.017453293
      PI = 3.141592654
      FPM = 3.28084
C
C     A(I) - AREA OF COMP. IN SQR.METER PER METER LENGTH
C           (LINE,WIRE,CHAIN = DIAMETER IN METERS)
C     W(I) - WEIGHT OF COMP. IN POUNDS PER METER LENGTH
C           (+= POSITIVE BUOYANCY, -= NEGATIVE BUOYANCY)
C     RBS(I) - RATED BREAKING STRENGTH IN POUNDS
C     AW(I) - CROSS SECTIONAL METAL AREA OF WIRE IN SQR.INCHES
C
C
C     WIRE CONSTANTS: (1)-3/16',(2)-1/4',(3)-5/16',(4)-3/8',(5)-?
C     U.S.S.,TORQUE BALANCED JACKETED 3X19 WIRE
C
      A(1) = 6.5786E-03
      W(1) = -0.154
      RBS(1) = 4000.0
      AW(1) = 0.01611
      A(2) = 8.3566E-03
      W(2) = -0.266
      RBS(2) = 6750.0
      AW(2) = 0.02738
      A(3) = 9.9568E-03
      W(3) = -0.41
      RBS(3) = 10300.0
      AW(3) = 0.04206
      A(4) = 1.15824E-02
      W(4) = -0.594
      RBS(4) = 14800.0
      AW(4) = 0.06015
      A(5) = 0.0
      W(5) = 0.0
      RBS(5) = 1.0
      AW(5) = 1.0
C
C     SAMPSON, SINGLE BRAID DACRON, WHOI SPECS
C     DACRON LINE CONSTANTS: (6)-3/8',(7)-7/16',(8)-1/2',
C     (9)-9/16',(10)-5/8'
C     DIAMETER IS 93.5% OF NOMINAL SIZE
C
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```
      A(6) = 8.90588E-03                                              NY007690
      W(6) = -0.0375                                                  NY007700
      RBS(6) = 5700.0                                                 NY007710
      A(7) = 1.03902E-02                                              NY007720
      W(7) = -0.0516                                                  NY007730
      RBS(7) = 7000.0                                                 NY007740
      A(8) = 1.18745E-02                                              NY007750
      W(8) = -0.0667                                                  NY007760
      RBS(8) = 9000.0                                                 NY007770
      A(9) = 1.33588E-02                                              NY007780
      W(9) = -0.0851                                                  NY007790
      RBS(9) = 11200.0                                                NY007800
      A(10) = 1.48431E-02                                             NY007810
      W(10) = -0.1082                                                 NY007820
      RBS(10) = 14000.0                                               NY007830
C                                                                     NY007840
C     COLUMBIA, SINGLE BRAID PLAITED NYLON, WHOI SPECS                NY007850
C     NYLON LINE CONSTANTS: (11)-3/8',(12)-1/2',(13)-9/16'            NY007860
C     (14)-5/8',(15)-3/4'                                             NY007870
C     DIAMETER IS 93.5% OF NOMINAL SIZE                               NY007880
C                                                                     NY007890
      A(11) = 8.90588E-03                                             NY007900
      W(11) = -0.011                                                  NY007910
      RBS(11) = 3700.0                                                NY007920
      A(12) = 1.18745E-02                                             NY007930
      W(12) = -0.0204                                                 NY007940
      RBS(12) = 6400.0                                                NY007950
      A(13) = 1.33588E-02                                             NY007960
      W(13) = -0.0261                                                 NY007970
      RBS(13) = 8200.0                                                NY007980
      A(14) = 1.48431E-02                                             NY007990
      W(14) = -0.033                                                  NY008000
      RBS(14) = 10400.0                                               NY008010
      A(15) = 1.78118E-02                                             NY008020
      W(15) = -0.0457                                                 NY008030
      RBS(15) = 14200.0                                               NY008040
C                                                                     NY008050
C     UNSPECIFIED SYNTHETIC LINE : (16)-? THROUGH (20)-?              NY008060
C                                                                     NY008070
      A(16) = 0.0                                                     NY008080
      W(16) = 0.0                                                     NY008090
      RBS(16) = 1.0                                                   NY008100
      A(17) = 0.0                                                     NY008110
      W(17) = 0.0                                                     NY008120
      RBS(17) = 1.0                                                   NY008130
      A(18) = 0.0                                                     NY008140
      W(18) = 0.0                                                     NY008150
      RBS(18) = 1.0                                                   NY008160
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      A(19) = 0.0                                                       NY008170
      W(19) = 0.0                                                       NY008180
      RBS(19) = 1.0                                                     NY008190
      A(20) = 0.0                                                       NY008200
      W(20) = 0.0                                                       NY008210
      RBS(20) = 1.0                                                     NY008220
C                                                                       NY008230
C     CHAIN: (21)-1/4',(22)-3/8',(23)-1/2',(24)-3/4'                    NY008240
C                                                                       NY008250
      A(21) = 2.74E-02                                                  NY008260
      W(21) = -2.33                                                     NY008270
      RBS(21) = 5400.0                                                  NY008280
      A(22) = 3.7E-02                                                   NY008290
      W(22) = -5.12                                                     NY008300
      RBS(22) = 12150.0                                                 NY008310
      A(23) = 4.8E-02                                                   NY008320
      W(23) = -9.02                                                     NY008330
      RBS(23) = 21600.0                                                 NY008340
      A(24) = 6.85E-02                                                  NY008350
      W(24) = -19.52                                                    NY008360
      RBS(24) = 48.6E+03                                                NY008370
C                                                                       NY008380
C     CYLINDRICAL INSTRUMENTS:                                          NY008390
C     DIVISOR IS THE LENGTH OF THE INSTRUMENT (METERS)                  NY008400
C     (25)-VACM,(26)-850(LT),(27)-850(HEAVY),                           NY008410
C     (28)-ENG.CM,,(29)-INCLINOMETER,(30)-DEPTH REC.,                   NY008420
C     (31)-TENSION REC.,(32)-TENSAC                                     NY008430
C     (33)-?,(34)-?,(35)-RELEASE,AMF TRANSPONDING                       NY008440
C                                                                       NY008450
      A(25) = 0.1579                                                    NY008460
      W(25) = -75.0/1.9                                                 NY008470
      A(26) = 0.17917                                                   NY008480
      W(26) = -40.0/1.8                                                 NY008490
      A(27) = 0.17917                                                   NY008500
      W(27) = -50.0/1.8                                                 NY008510
      A(28) = 0.16043                                                   NY008520
      W(28) = -40.0/0.8                                                 NY008530
      A(29) = 0.16043                                                   NY008540
      W(29) = -40.0/0.8                                                 NY008550
      A(30) = 0.16043                                                   NY008560
      W(30) = -40.0/0.8                                                 NY008570
      A(31) = 0.16043                                                   NY008580
      W(31) = -40.0/0.8                                                 NY008590
      A(32) = 0.16875                                                   NY008600
      W(32) = -70.0/1.6                                                 NY008610
      A(33) = 0.0                                                       NY008620
      W(33) = 0.0                                                       NY008630
      A(34) = 0.0                                                       NY008640
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      W(34) = 0.0                                                       NY008650
      A(35) = 0.1499                                                    NY008660
      W(35) = -80.0/1.8                                                 NY008670
C                                                                       NY008680
C     SPHERICAL INSTRUMENTS:                                            NY008690
C     DIVISOR IS THE LENGTH OF THE INSTRUMENT (METERS)                  NY008700
C     (36)-?, (37)-MIT P/T, (38)-RADIC FLOAT                            NY008710
C                                                                       NY008720
      A(36) = 0.0                                                       NY008730
      W(36) = 0.0                                                       NY008740
      A(37) = 0.207                                                     NY008750
      W(37) = -18.0/0.4                                                 NY008760
      A(38) = 0.26                                                      NY008770
      W(38) = 41.0/1.0                                                  NY008780
C                                                                       NY008790
C     SPHERES MOUNTED ON 3/8' CHAIN, 1 METER COMPONENT LENGTH           NY008800
C     (39)-16' SPHERE - 17.5' O.D., (40)-17' SPHERE-18.5' O.D.          NY008810
C                                                                       NY008820
C                                                                       NY008830
      A(39) = 0.25138                                                   NY008840
      W(39) = 43.5                                                      NY008850
      A(40) = 0.26962                                                   NY008860
      W(40) = 53.0                                                      NY008870
C                                                                       NY008880
C     UNDEFINED COMPONENTS W/UNIQUE DRAG COEFF.                         NY008890
C     (41)-?, (42)-?                                                    NY008900
C                                                                       NY008910
      A(41) = 0.0                                                       NY008920
      W(41) = 0.0                                                       NY008930
      A(42) = 0.0                                                       NY008940
      W(42) = 0.0                                                       NY008950
C                                                                       NY008960
C     DRAG COEFFICIENTS - CDN-NORMAL, CDT - TANGENTIAL                  NY008970
C     (1)-WIRE,(2)-LINE & CHAIN,(3)-INSTRUMENTS,                        NY008980
C     (4)-SPHERES, (5)-UNSPECIFIED                                      NY008990
C                                                                       NY009000
      CDN(1) = 1.3                                                      NY009010
      CDT(1) = 0.007                                                    NY009020
      CDN(2) = 1.3                                                      NY009030
      CDT(2) = 0.007                                                    NY009040
      CDN(3) = 1.2                                                      NY009050
      CDT(3) = 0.9                                                      NY009060
      CDN(4) = 0.5                                                      NY009070
      CDT(4) = 0.5/PI                                                   NY009080
      CDN(5) = 0.0                                                      NY009090
      CDT(5) = 0.0                                                      NY009100
C                                                                       NY009110
C     STRETCH CHARACTERISTICS                                           NY009120
```

```
C      (1-4)-WIRE,(5-8)-DACRON,(9-12)-NYLON,(13-16)-UNSPECIFIED
C
       E(1) = 1.428571E-03
       E(2) = 20.5E+06
       E(3) = 0.0
       E(4) = 0.0
       E(5) = 2.81E+06
       E(6) = 0.607
       E(7) = 3.83E+06
       E(8) = 0.74
       E(9) = 1.56E+05
       E(10) = 0.516
       E(11) = 1.3262E+05
       E(12) = 0.535
       E(13) = 0.0
       E(14) = 0.0
       E(15) = 0.0
       E(16) = 0.0
       CONTINUE
       RETURN
       END
       SUBROUTINE TRANS
C
C      SUBROUTINE TRANS - FOR USE WITH PROG. NOYFB, REV. 9.1
C      CALCULATE AND STORE IN ARRAY (TW), PEAK TENSION ON EACH
C      COMPONENT EXPERIENCED DURING ANCHOR LAST LAUNCH
C      INITIATES EACH RUN BY DETERMINING TOTAL RELAXED LENGTH (TL)
C      AND RESERVE BUOYANCY AT COMPONENT NO.1 (QBKUP)
C      CALC. TERMINAL VELOCITY OF FREE FALL ANCHOR (TVELO)
C
       COMMON W(42),A(42),RBS(24),AW(5),E(16)
       COMMON IT(65),XL(65),TW(66),CDN(5),CDT(5)
       COMMON DCP(20),CP(20),RCP(20),IHDG(36)
       COMMON T1(65),T2(65),T3(65),T4(65),T5(65),T6(65),T7(65)
       COMMON IDA(10),IDM(10),DB(10)
       COMMON DPT,QN200,D200,FPM,LI1,LO,LO3,NEW,TERMW,TERML
       COMMON RD,PI,TL,IC,IV,FUDG,RC,SEG,DONE
       COMMON TCLIN,TTENS,TROTN,QBKUP,TVELO,ANCR,ANCRA
       X = 0.0
       J = 0
       DO 420 I = 1, IC
   401 I1 = IT(I)
C
C      SUM INPUT LENGTHS (TL) AND COMP. BUOYANCIES (T1(I))
C      T1(I) IS USED FOR TEMPORARY STORAGE
C
       TL = TL + XL(I) + TERML
       X = X+TERMW+W(I1)*XL(I)
```

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```
      T1(I) = X
C
C     RESERVE BUOYANCY (QBKUP) AT TOP COMP. = SUM OF WEIGHTS
C     OF RELEASE (35) AND ALL COMPONENTS ABOVE IT
C
      IF(J-1) 402,405,405
  402 QBKUP = X
      IF(I1-35) 405,403,405
  403 J = 2
C
C     DETERMINE DRAG COEFF. SUBSCRIPT (J1), FUNCT. JCD
C
  405 J1 = JCD(I1)
C
C     CALC. TOTAL AREA*CD FOR EACH COMPONENT AND SUM
C     GO TO 410 - WIRE, LINE AND CHAIN
C           412 - INSTRUMENTS(CYLINDERS)
C           410 - SPHERES
C           412 - UNSPECIFIED
C     Y = CDT*SURFACE AREA
C
      Y = CDT(J1)*PI*A(I1)*XL(I)*FPM**2
      GO TO  (410,410,412,410,412), J1
410   TW(I+1) = TW(I)+Y
      GO TO 420
412   TW(I+1) = TW(I)+(CDN(J1)*(PI/4.0)*A(I1)**2
     1*FPM**2)+Y
  420 CONTINUE
C
C     CALC. VEL.**2(VSQ), CD*AREA OF ANCHOR APPLIED
C     THEN CALC. TERMINAL VELOCITY AND TRANSIENT PEAK LOAD
C
      VSQ = (ANCR-T1(IC))/(TW(IC+1)+ANCRA*FPM**2*1.15)
      DO 425 I = 1,IC
  416 TW(I) = T1(I)+TW(I+1)*VSQ
  425 CONTINUE
      TVELO = (SQRT(VSQ)/FPM)*60.0
      RETURN
      END
      SUBROUTINE PTIO
C
C     SUBROUTINE PTIO - FOR USE WITH PRCG. NOYFB, REV. 9.1
C     INPUT/JUTPUT SUBROUTINE FOR PERMANENT RECORD OF MOORING
C     SPECIFICALLY FOR USE WITH A PAPER TAPE READER AND PAPER TAPE
C     PUNCH BUT USEABLE WITH OTHER I/O CEVICES
C     READS/WRITES NUMBER,TYPE AND LENGTH OF MOORING COMPONENTS
C     READS/WRITES CONSTANTS AND VARIABLES USED FOR MOORING CONFIG
C     READS/WRITES OPERATOR COMMENTS
```

```
C
      COMMON W(42),A(42),RBS(24),AW(5),E(16)
      COMMON IT(65),XL(65),TW(66),CDN(5),CDT(5)
      CCMMON DCP(20),CP(20),RCP(20),IHDG(36)
      COMMON T1(65),T2(65),T3(65),T4(65),T5(65),T6(65),T7(65)
      CCMMON IDA(10),IDM(10),DB(10)
      COMMON DPT,QN200,D200,FPM,LI1,LC,LC3,NEW,TERMW,TERML
      COMMON RD,PI,TL,IC,IV,FUDG,RC,SEG,DONE
      CCMMON TCLIN,TTENS,TROTN,QBKUP,TVELO,ANCR,ANCRA
   36 FORMAT (4F13.7)
   37 FORMAT (I2,F13.7)
   38 FORMAT (36(A2))
   39 FORMAT (7F8.3,I2)
      IF (NEW-15) 1010,1006,1000
 1000 WRITE (LO3,39) DPT,QN200,D200,ANCR,ANCRA,TERMW,TERML,IC
      WRITE (LO3,36) (W(I),A(I),I = 1,42),(RBS(I),I = 1,24),
     1(AW(I),I = 1,5),(E(I),I = 1,16),(CDN(I),CDT(I),I = 1,5)
      DO 1002 I = 1,IC
      WRITE (LO3,37) IT(I),XL(I)
 1002 CCNTINUE
      WRITE (LO3,38) (IHDG(I),I = 1,36)
      GO TO 1010
 1006 READ (LI1,39) DPT,QN200,D200,ANCR,ANCRA,TERMW,TERML,IC
      READ (LI1,36) (W(I),A(I),I = 1,42),(RBS(I),I = 1,24),
     1(AW(I),I = 1,5),(E(I),I = 1,16),(CDN(I),CDT(I),I = 1,5)
      DO 1008 I = 1,IC
      READ (LI1,37) IT(I),XL(I)
 1008 CONTINUE
      READ (LI1,38) (IHDG(I),I = 1,36)
 1010 CONTINUE
      RETURN
      END
      FUNCTION JCD(I1)
C
C     FUNCTION JCD - USE WITH PROG. NOYFB, REV 9.1
C     SET SUBSCRIPT FOR COMPONENT DRAG COEFFICIENTS (J1)
C     (5) -      '      41 AND 42
C     (4) -      '      36 THRU 40
C     (3) -      '      25   '  35
C     (2) -      '       6   '  24
C     (1) -      '       1   '   5
C
      JCD = 5
      IF (I1-41) 483,487,487
  483 JCD = 4
      IF (I1-36) 484,487,487
  484 JCD = 3
      IF (I1-25) 485,487,487
```

```
485 JCD = 2                                                        NY010570
    IF (I1-6) 486,487,487                                          NY010580
486 JCD = 1                                                        NY01C590
487 CONTINUE                                                       NY010600
    RETURN                                                         NY010610
    END                                                            NY010620
```

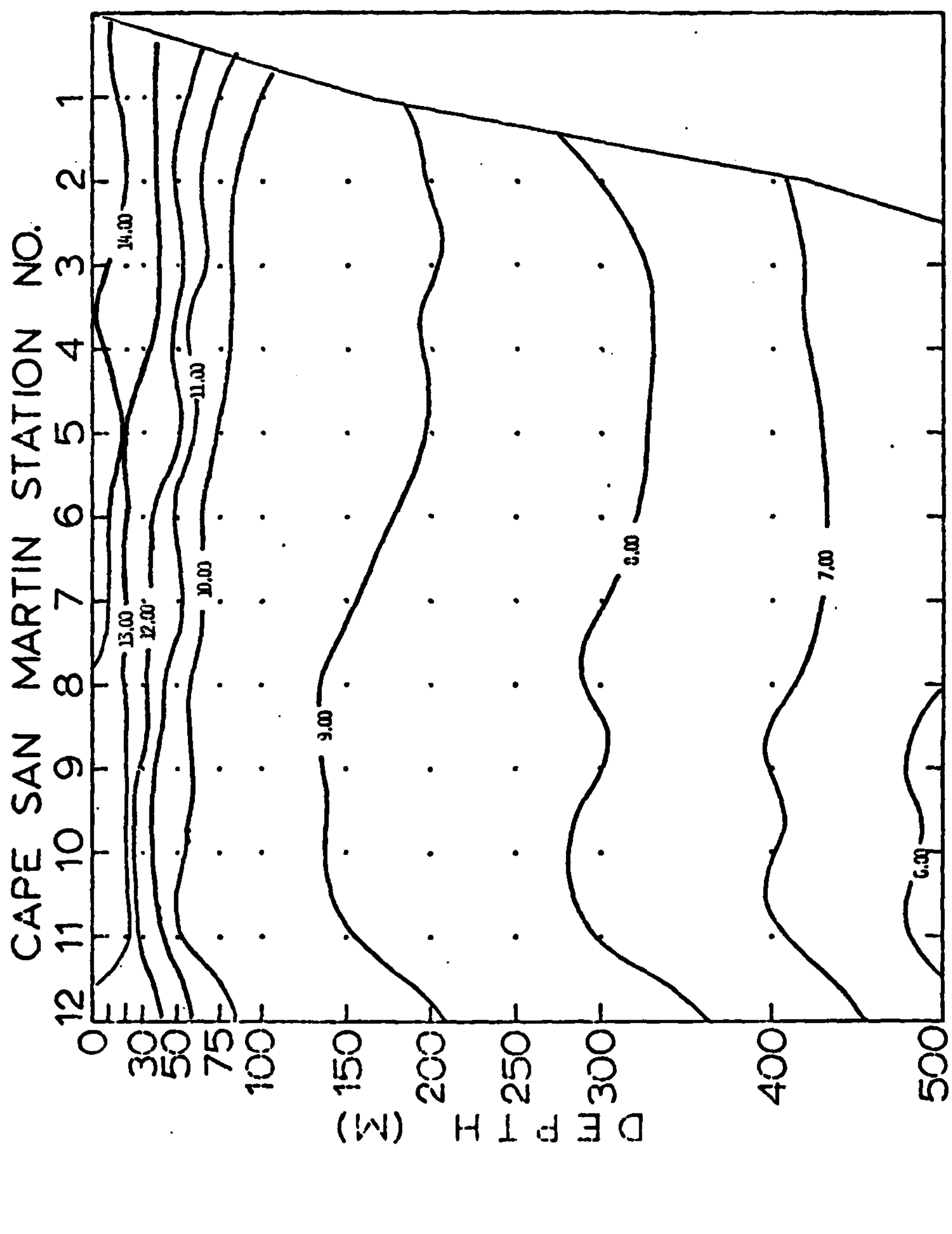

Figure 43. Temperature (°C) on a vertical section for the Cape San Martin line on 27-28 November 1978.

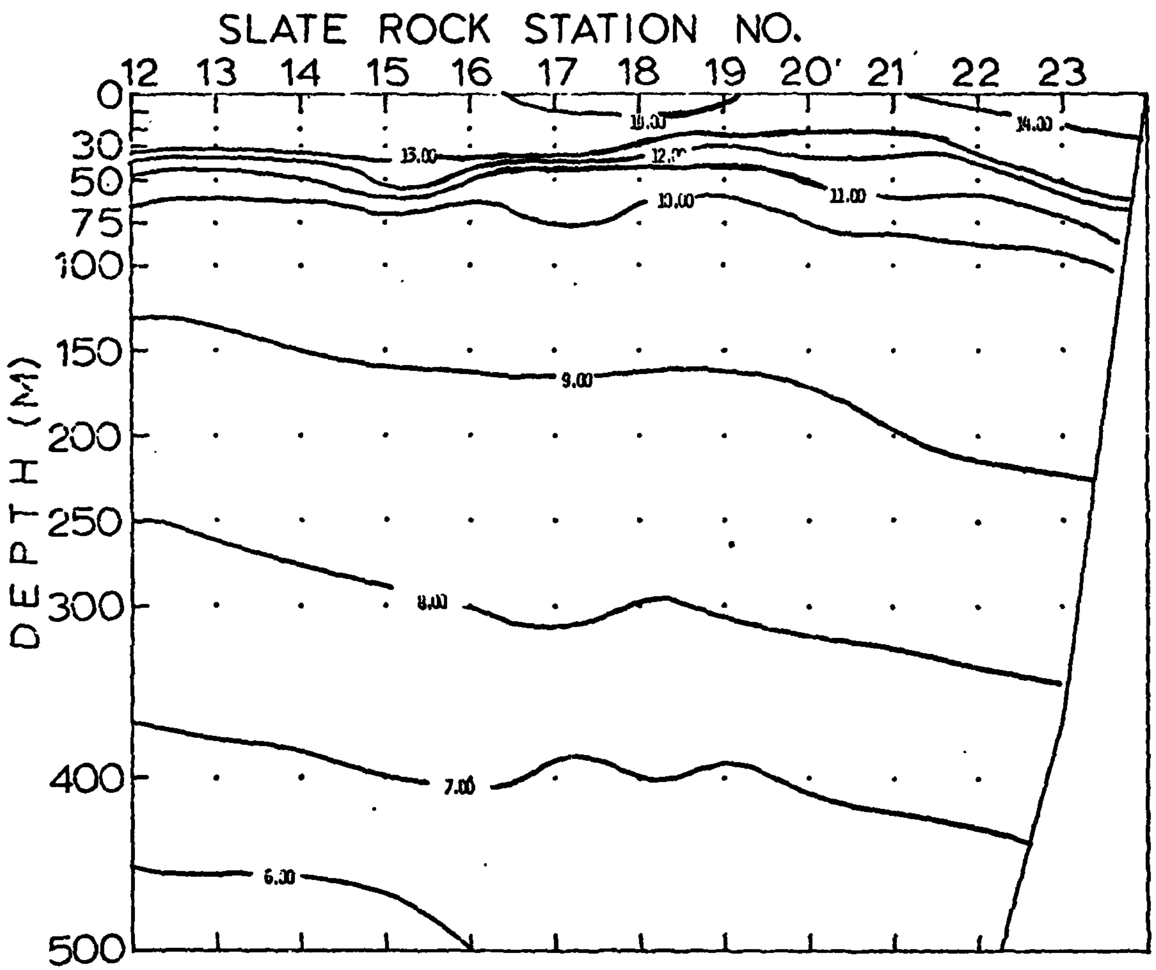

Figure 44. Temperature (°C) on a vertical section for the Slate Rock line on 27-28 November 1978.

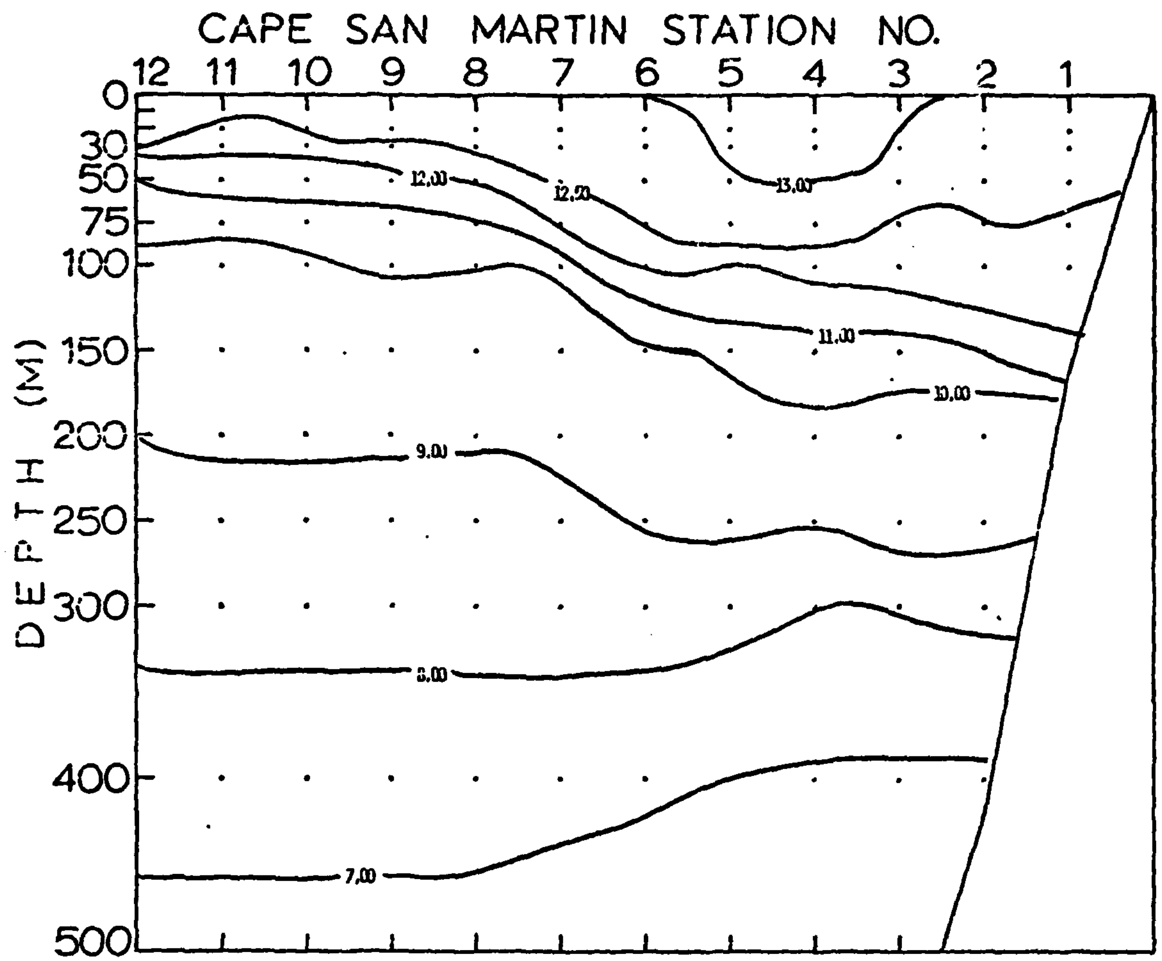

Figure 45. Temperature (°C) on a vertical section for the Cape San Martin line on 8-9 January 1979.

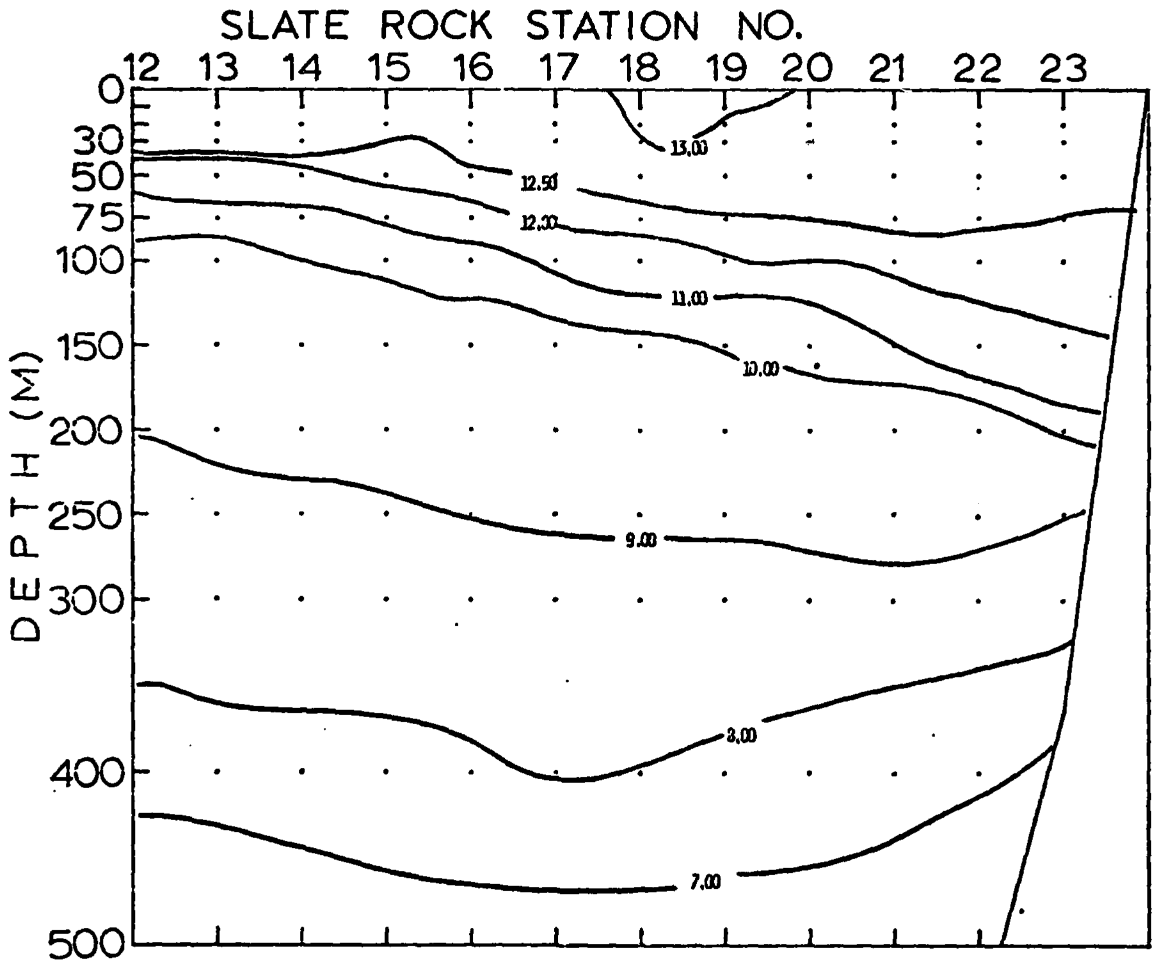

Figure 46. Temperature (°C) on a vertical section for the Slate Rock line on 8-9 January 1979.

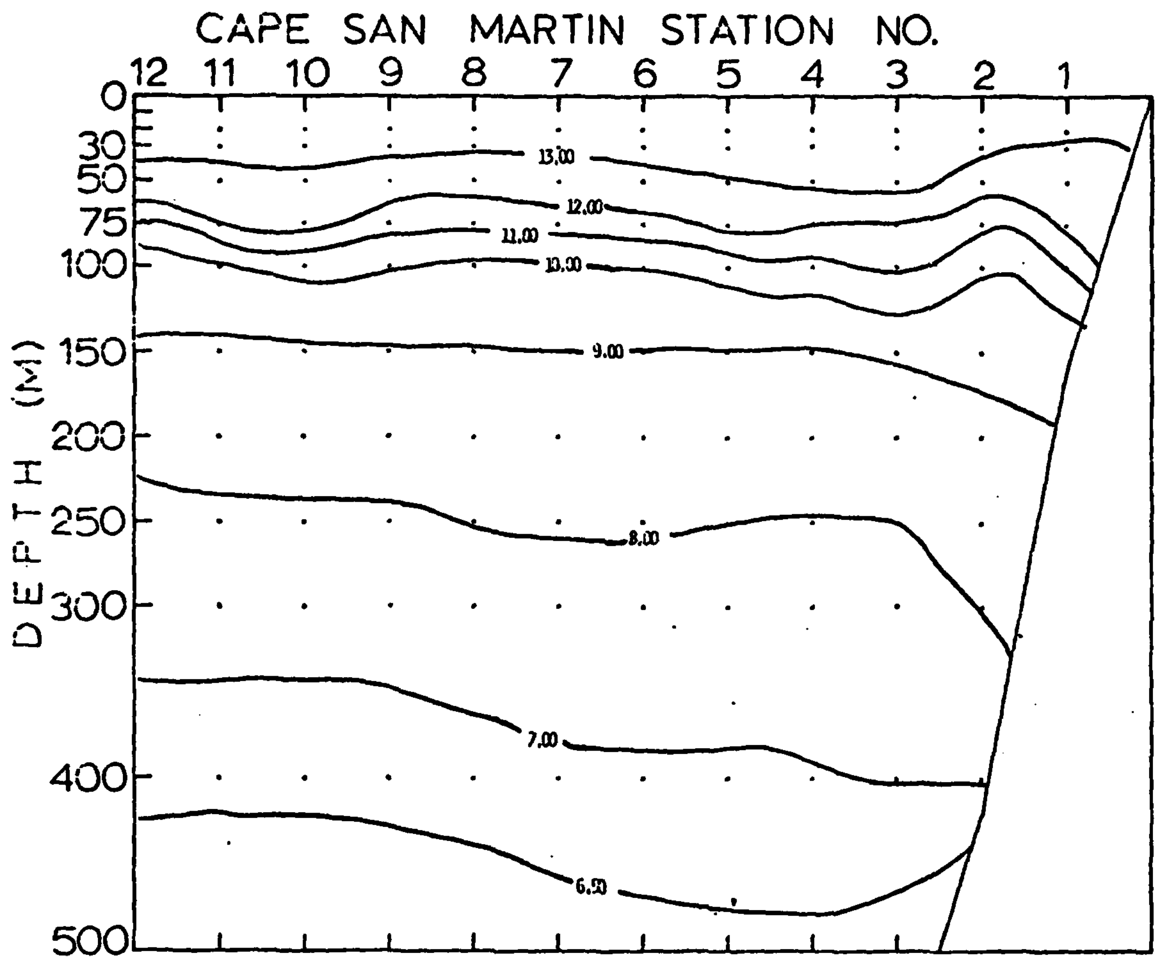

Figure 47. Temperature (°C) on a vertical section for the Cape San Martin line on 22-23 January 1979.

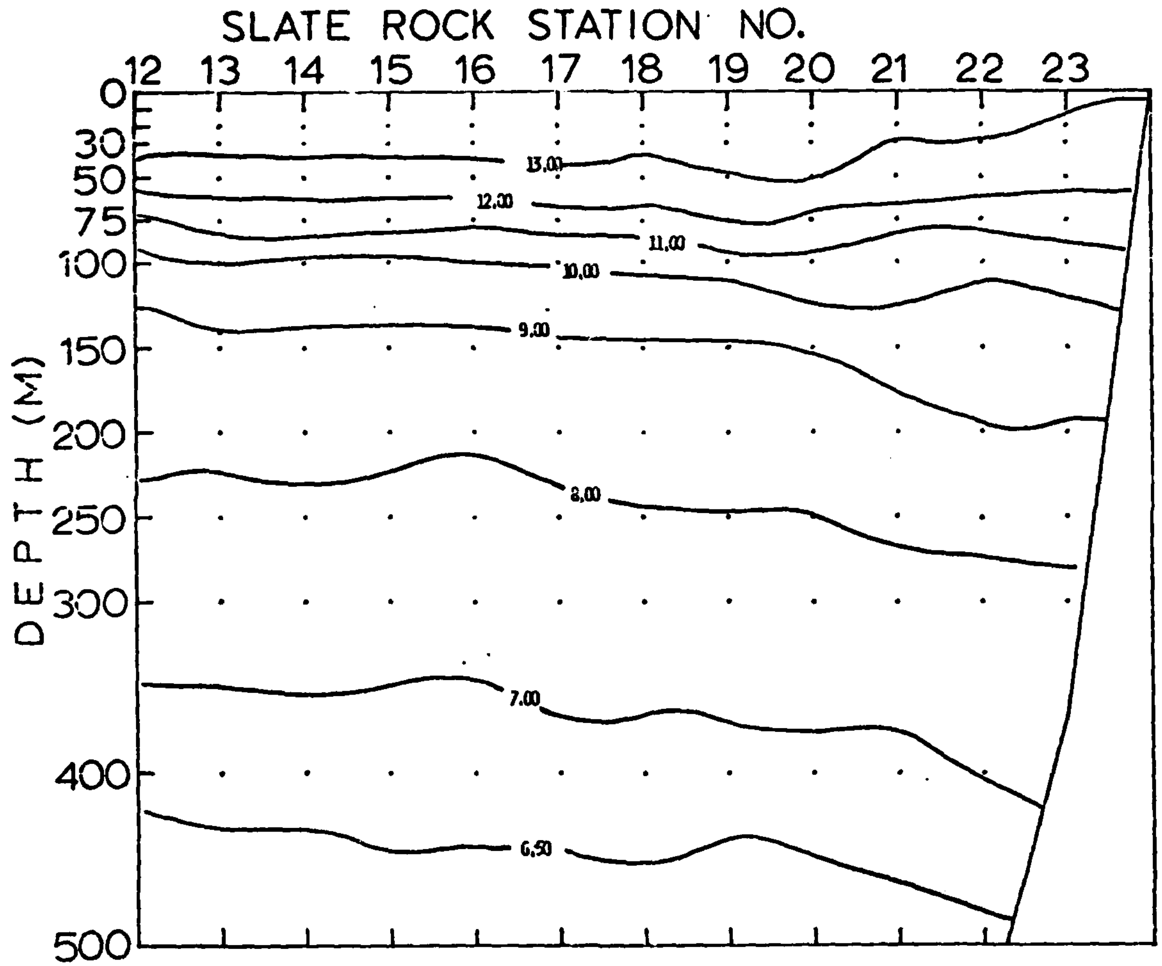

Figure 48. Temperature (°C) on a vertical section for the Slate Rock line on 22-23 January 1979.

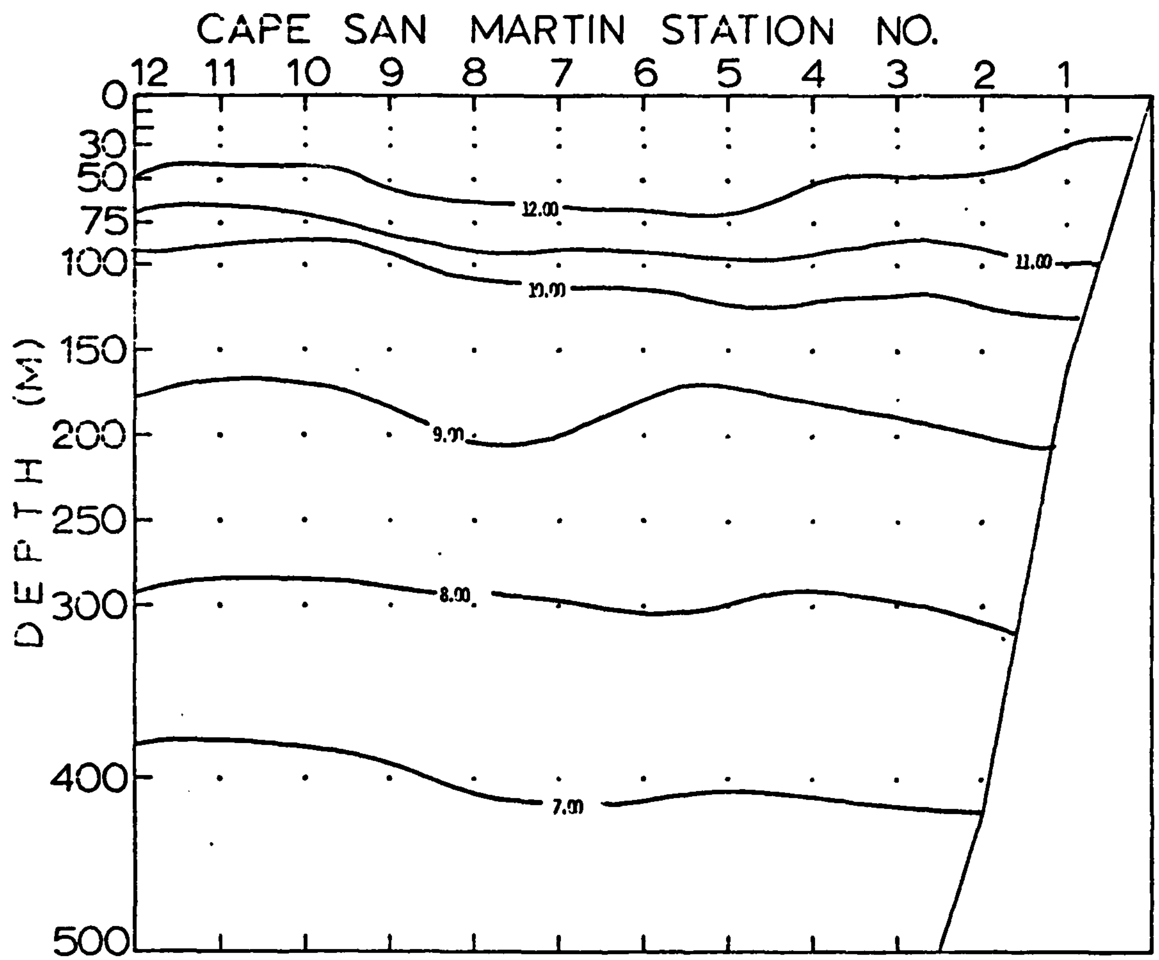

Figure 49. Temperature (°C) on a vertical section for the Cape San Martin line on 21-22 February 1979.

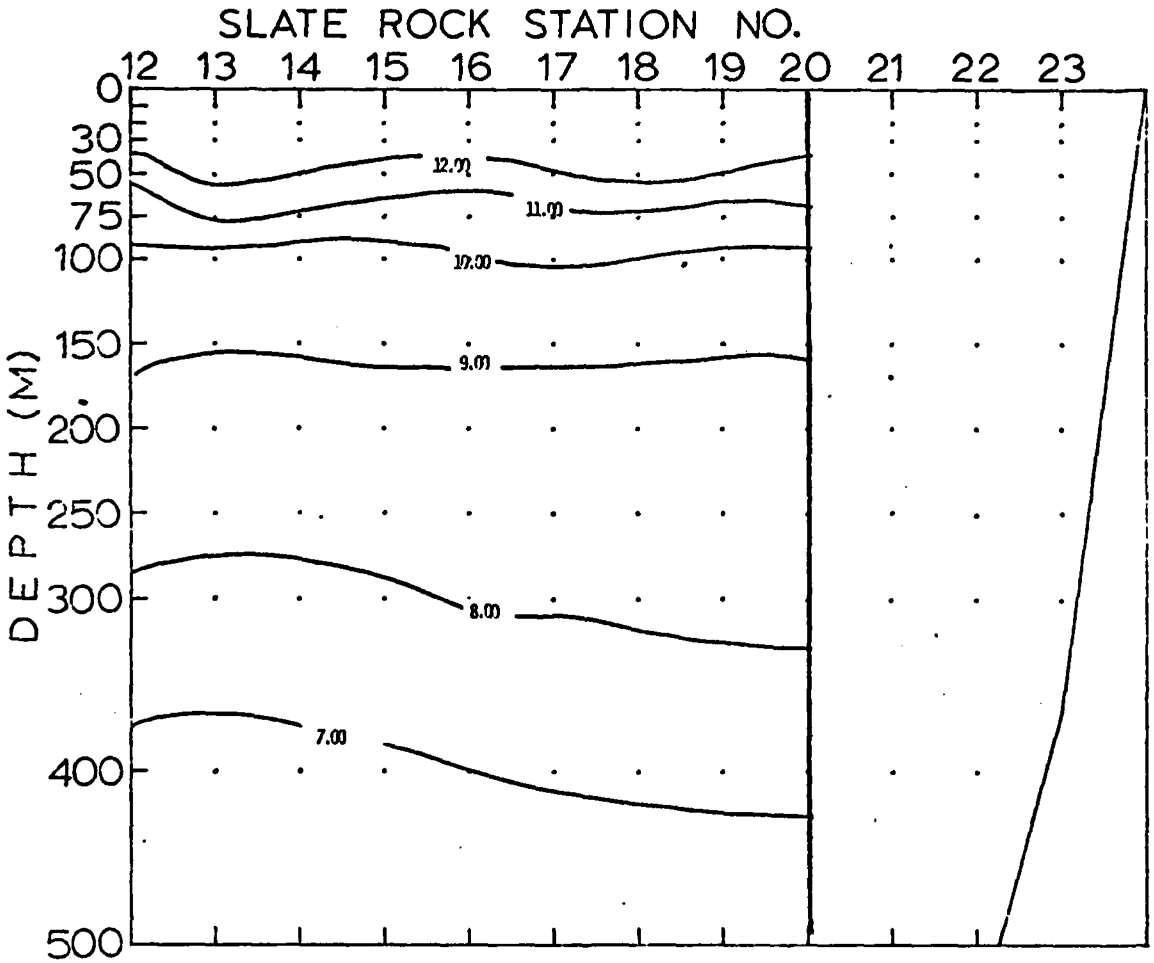

Figure 50. Temperature (°C) on a vertical section for the Slate Rock line on 21-22 February 1979.

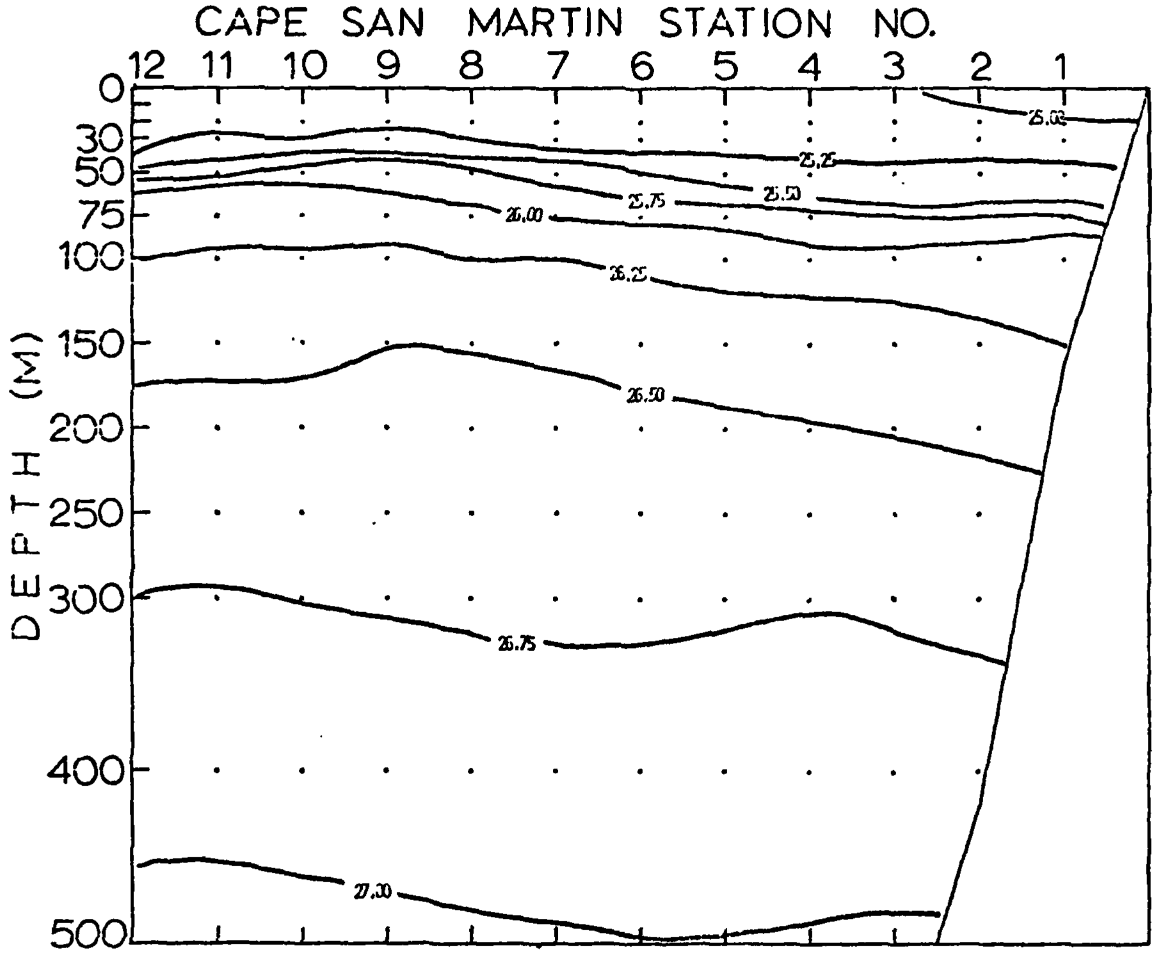

Figure 51. Sigma-t on a vertical section for the Cape San Martin line on 27-28 November 1978.

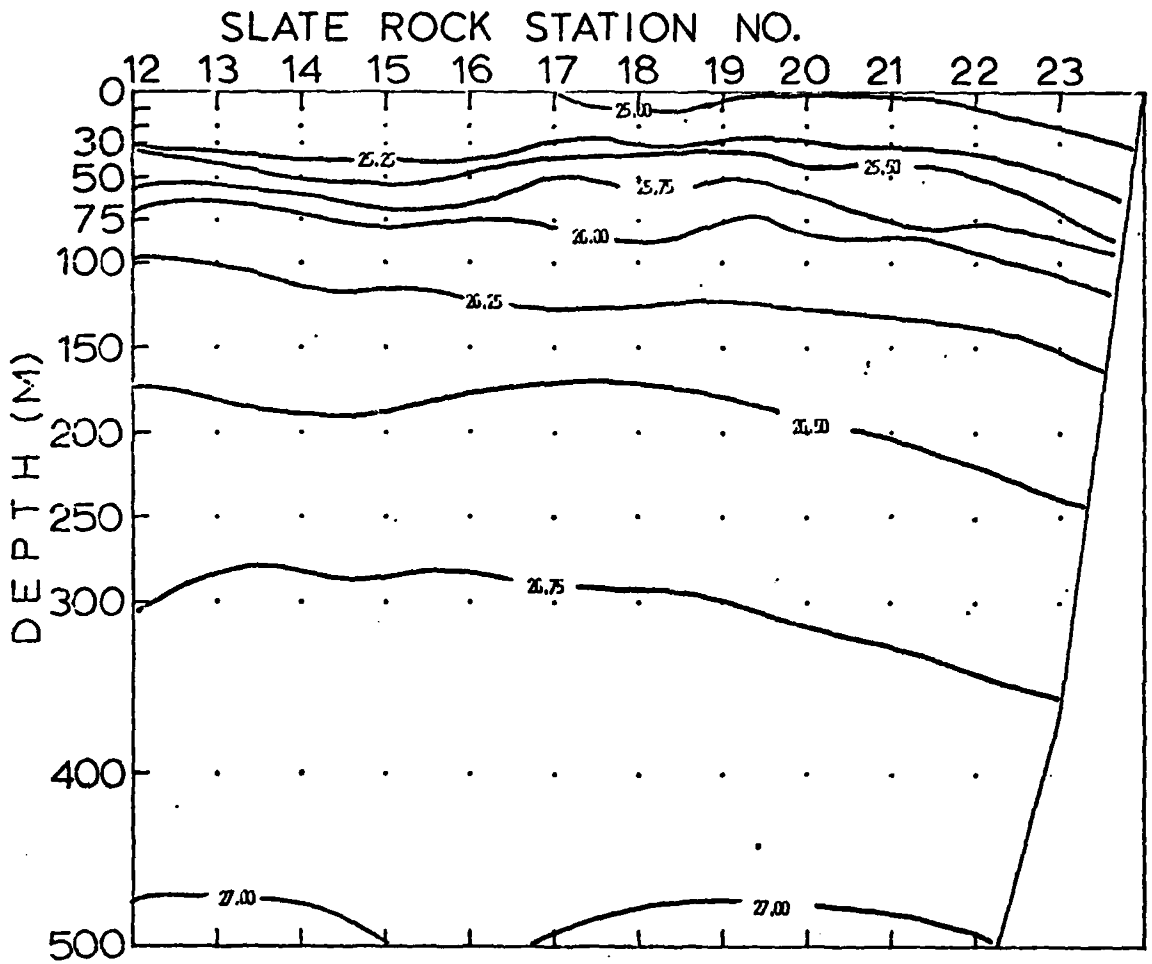

Figure 52, Sigma-t on a vertical section for the Slate Rock line on 27-28 November 1979.

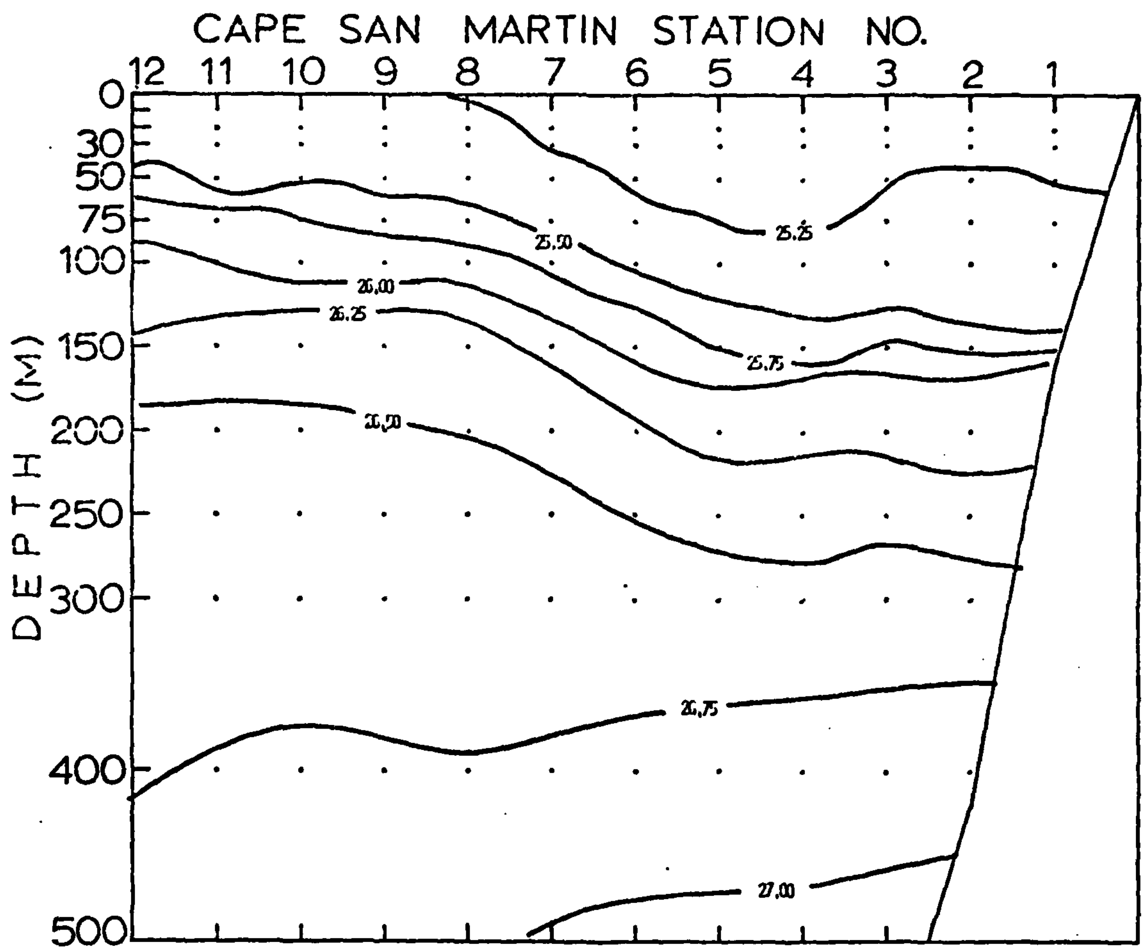

Figure 53. Sigma-t on a vertical section for the Cape San Martin line on 8-9 January 1979.

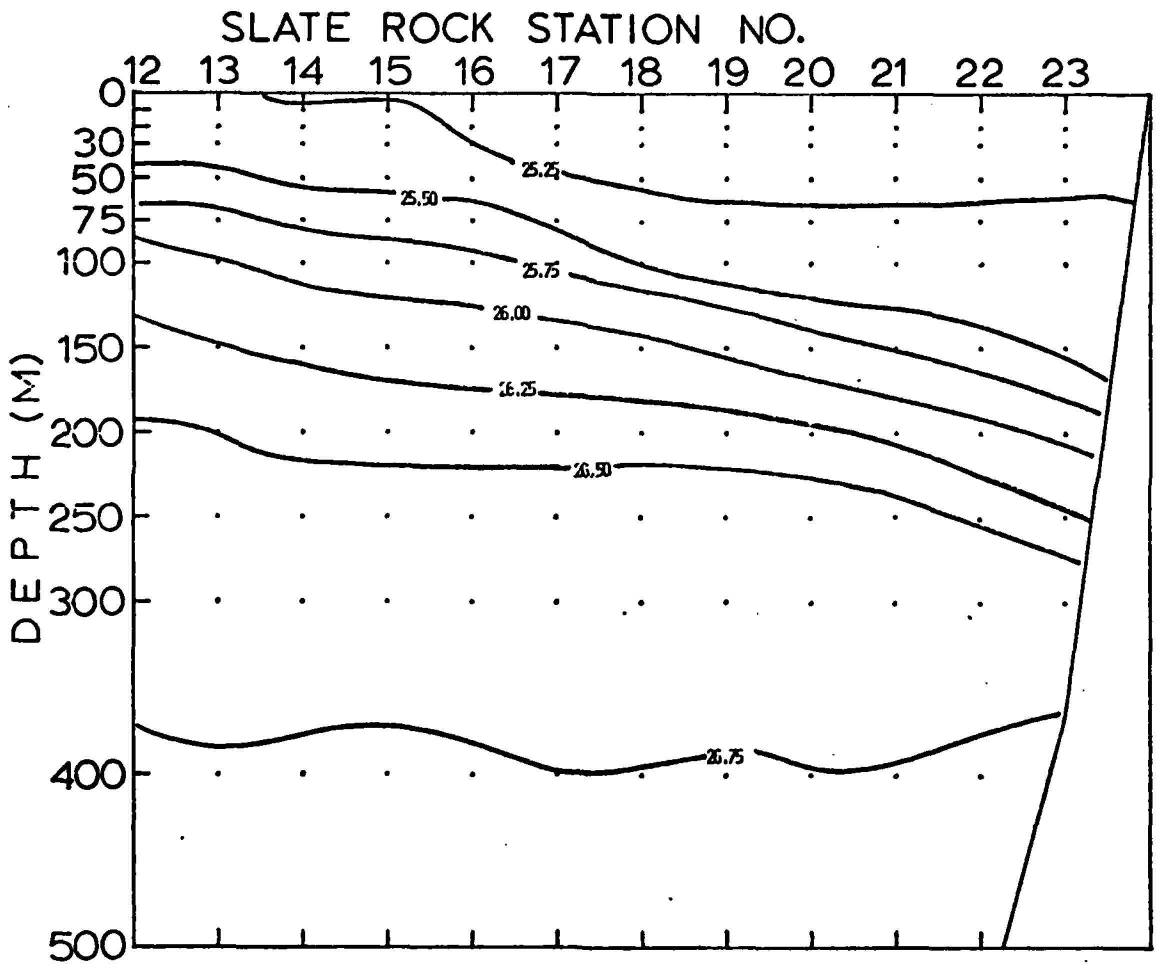

Figure 54. Sigma-t on a vertical section for the Slate Rock line on 8-9 January 1979.

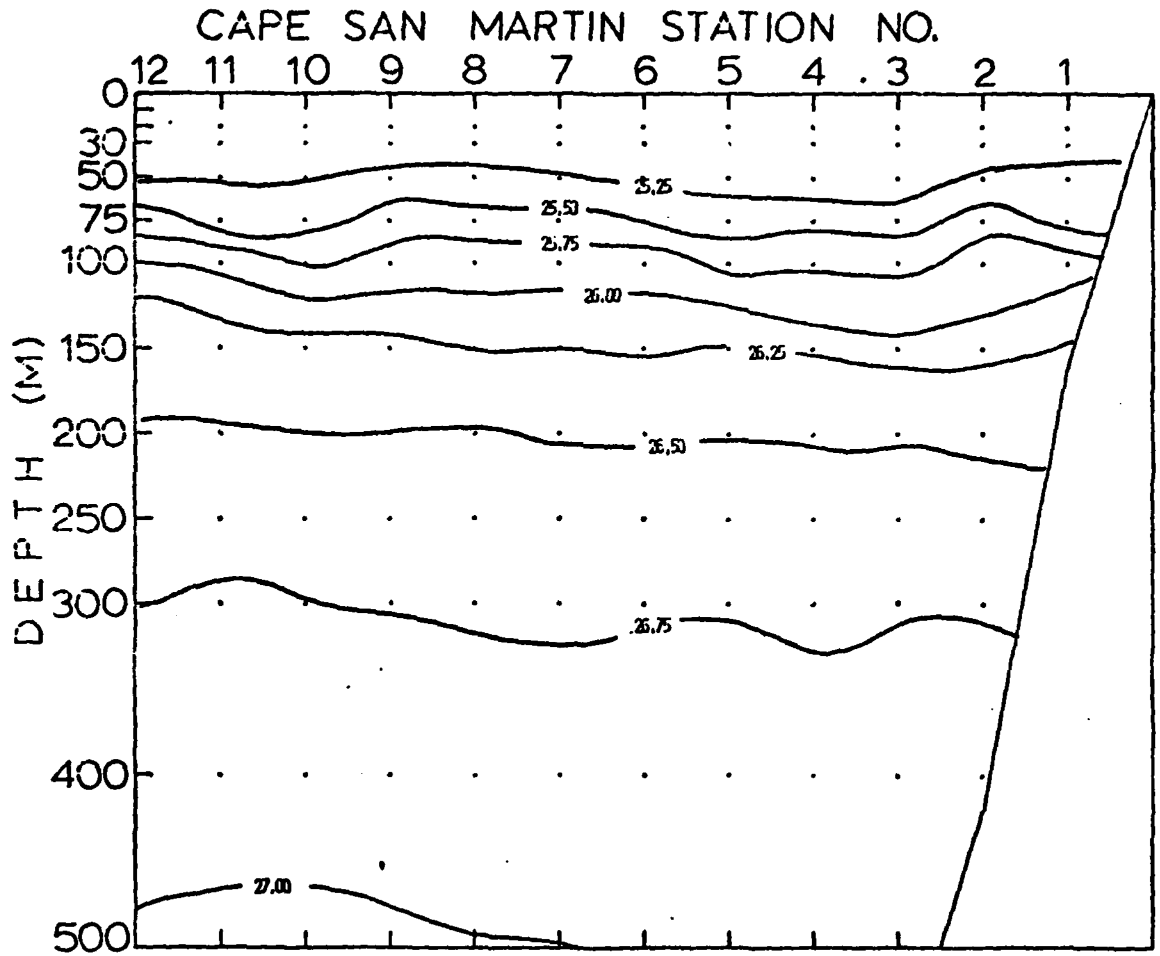

Figure 55. Sigma-t on a vertical section for the Cape San Martin line on 22-23 January 1979.

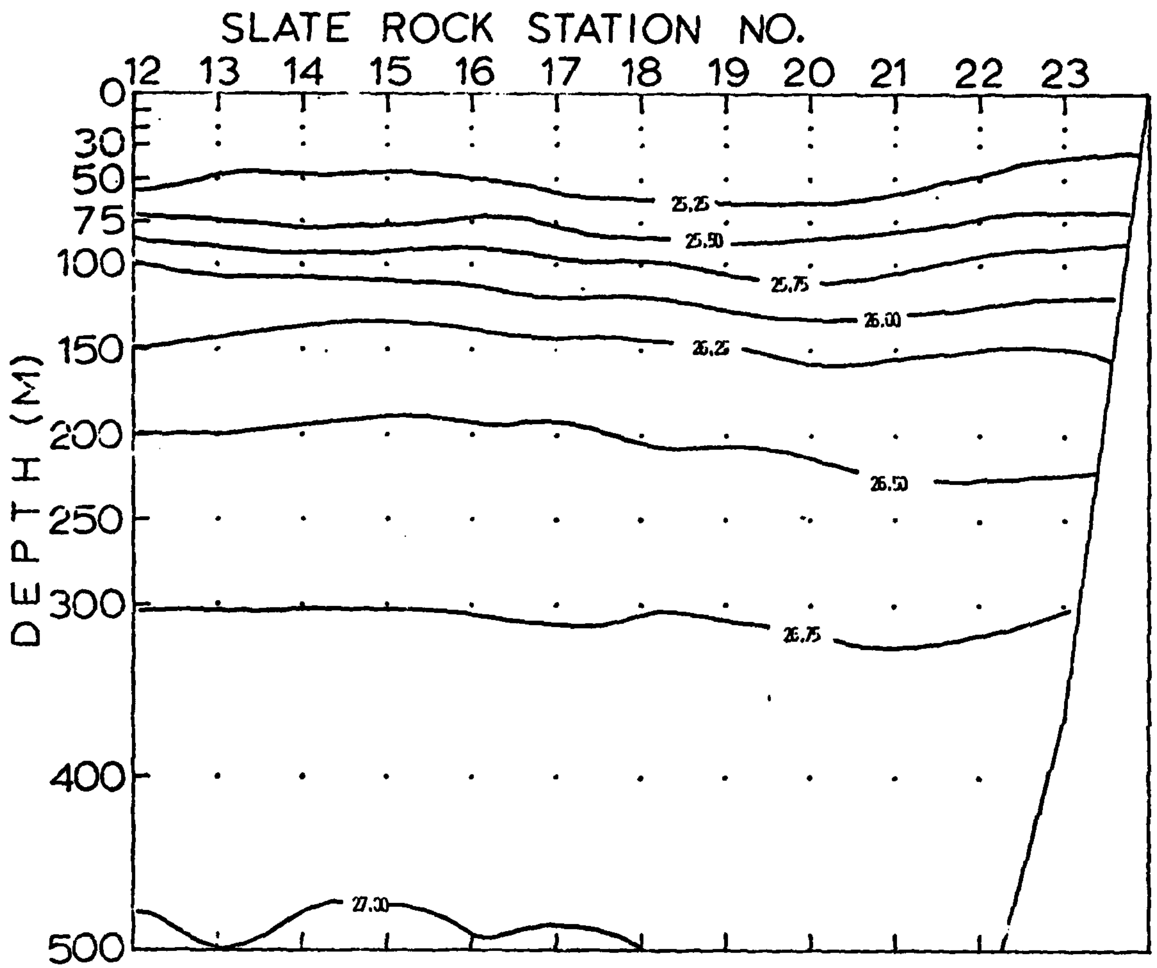

Figure 56. Sigma-t on a vertical section for the Slate Rock line on 22-23 January 1979.

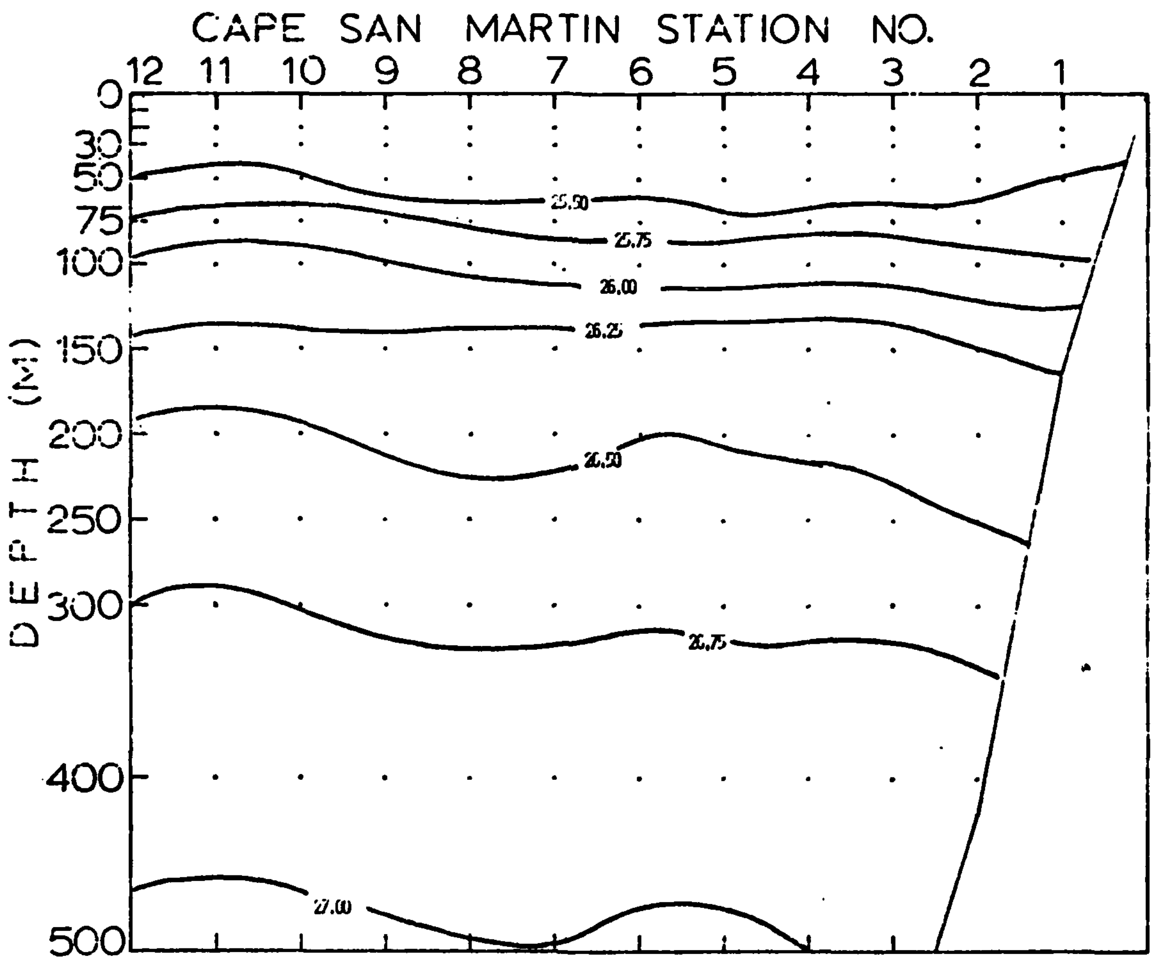

Figure 57. Sigma-t on a vertical section for the Cape San Martin line on 21-22 February 1979.

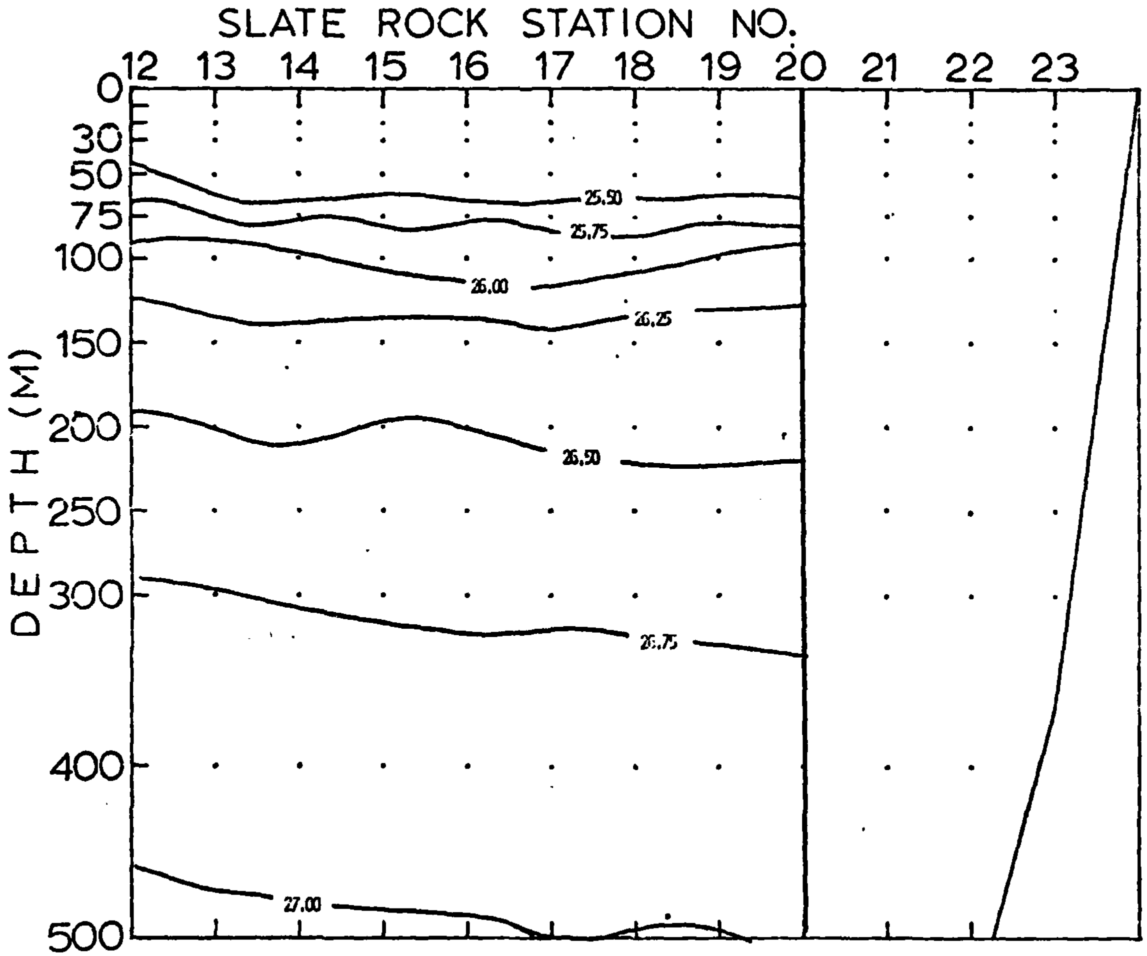

Figure 58. Sigma-t on a vertical section for the Slate Rock line on 21-22 February 1979.

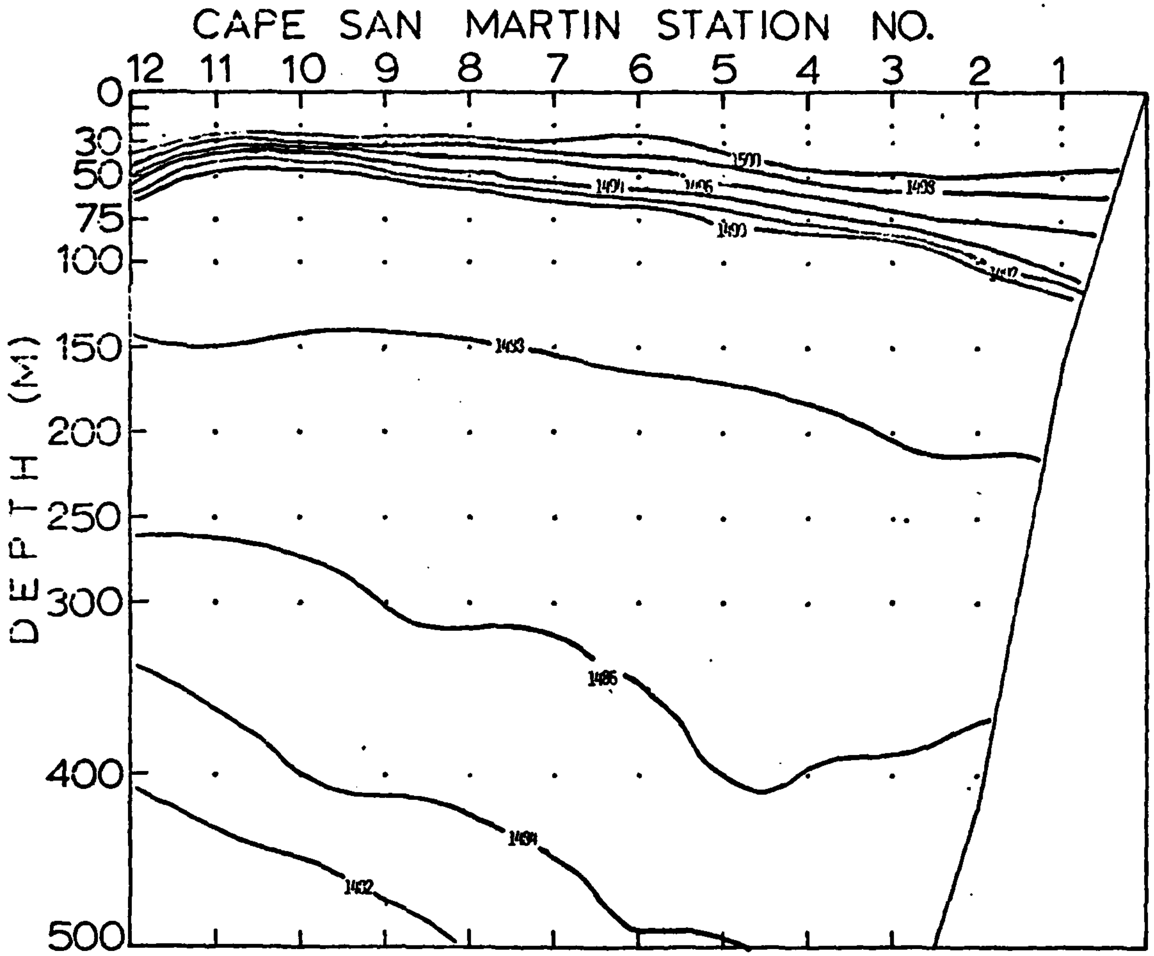

Figure 59. Sound speed (m/sec) on a vertical section for the Cape San Martin line on 27-28 November 1978.

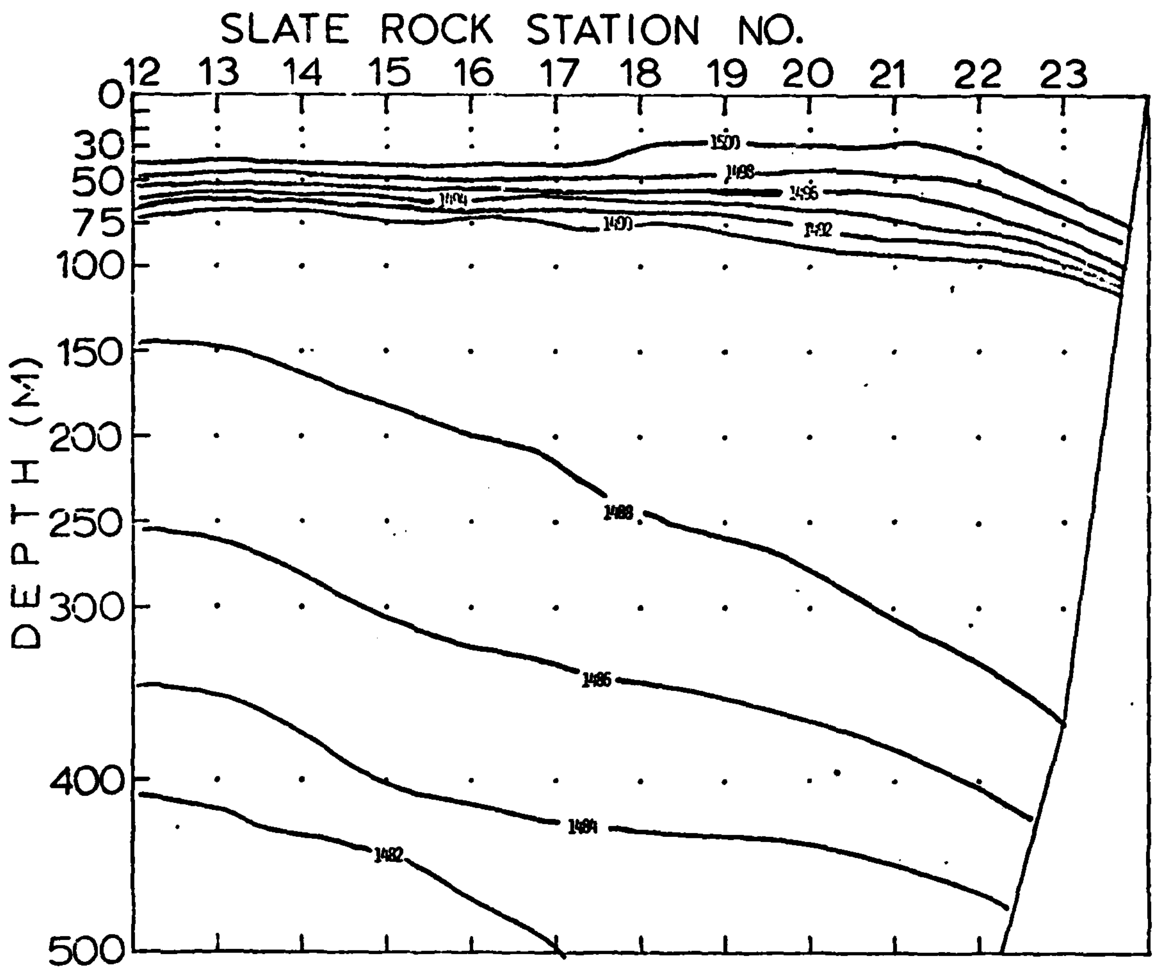

Figure 60. Sound speed (m/sec) on a vertical section for the Slate Rock line on 27-28 November 1978.

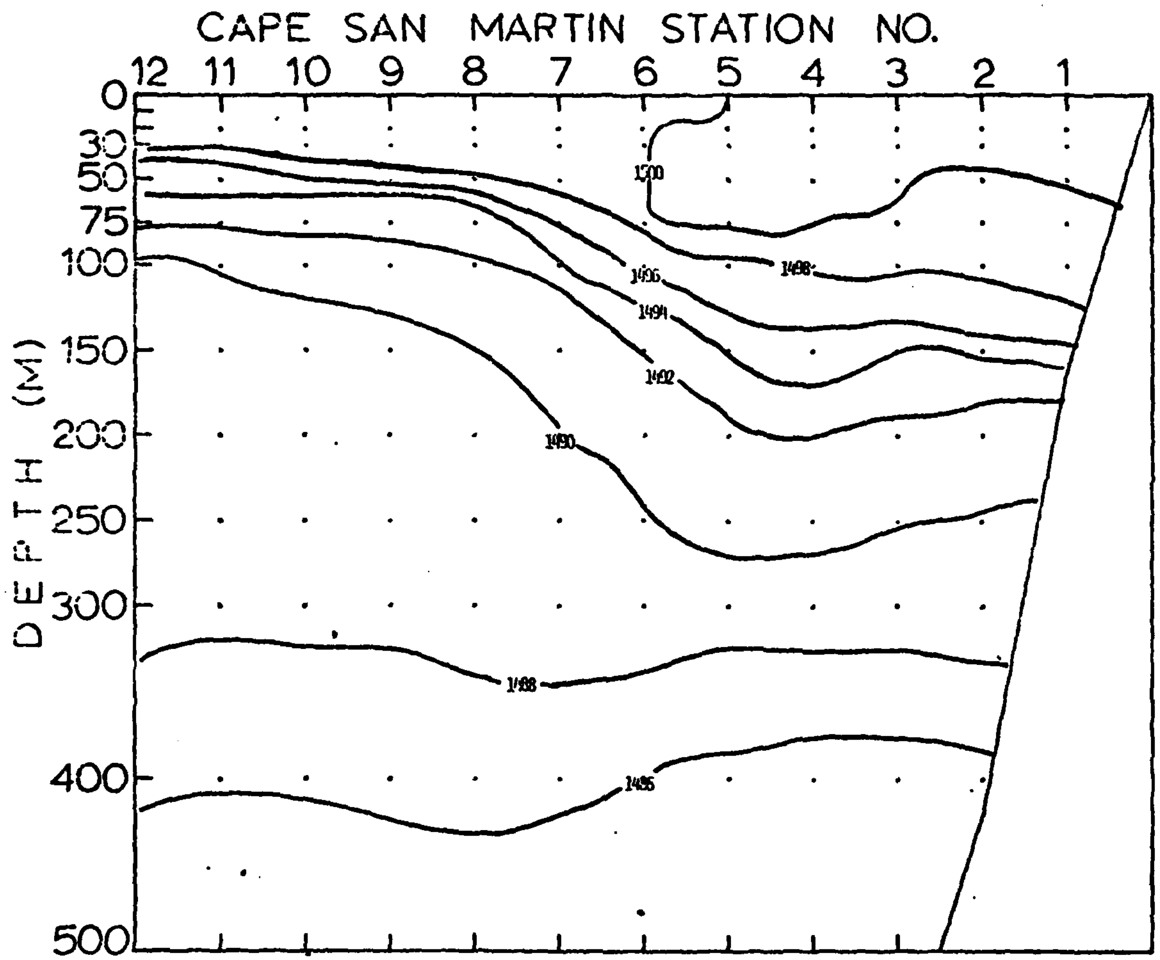

Figure 61. Sound speed (m/sec) on a vertical section for the Cape San Martin line on 8-9 January 1979.

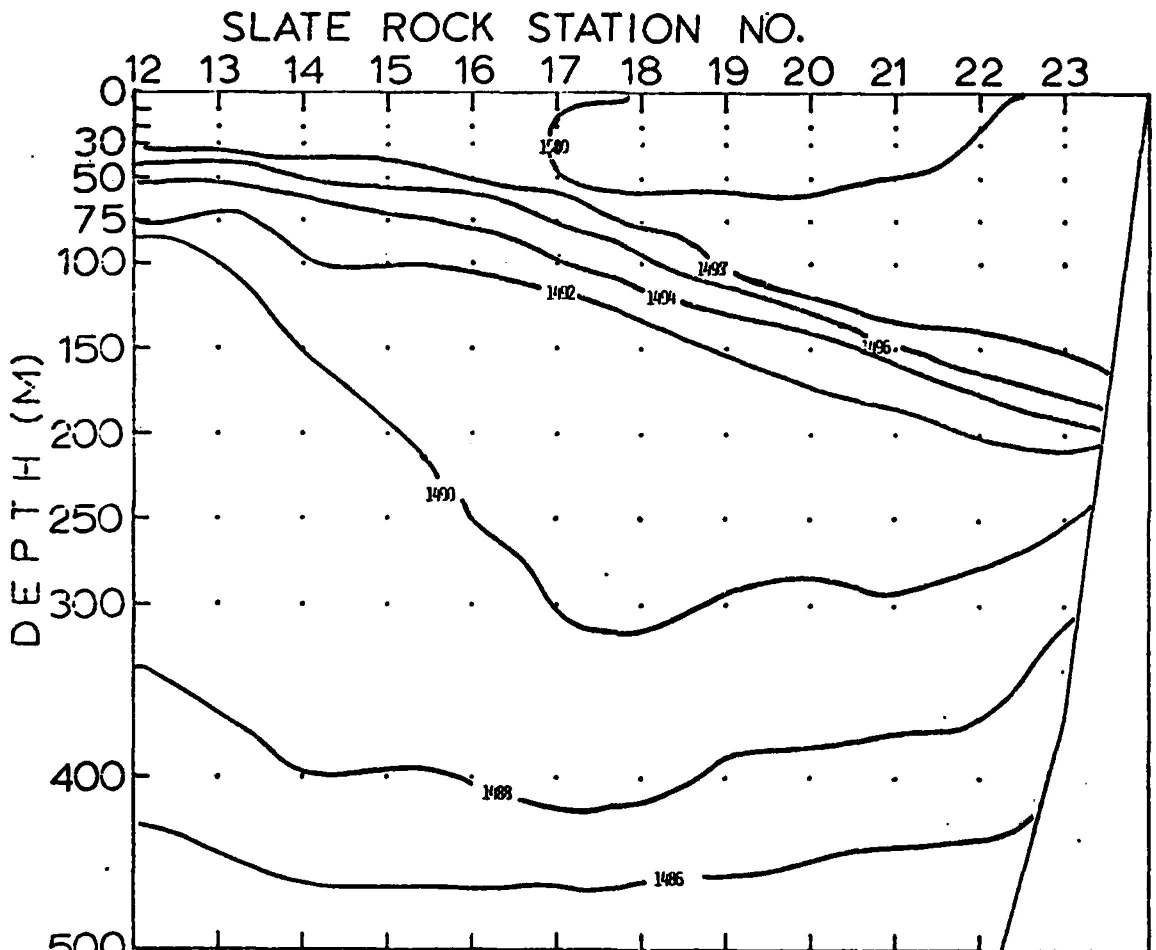

Figure 62. Sound speed (m/sec) on a vertical section for the Slate Rock line on 8-9 January 1979.

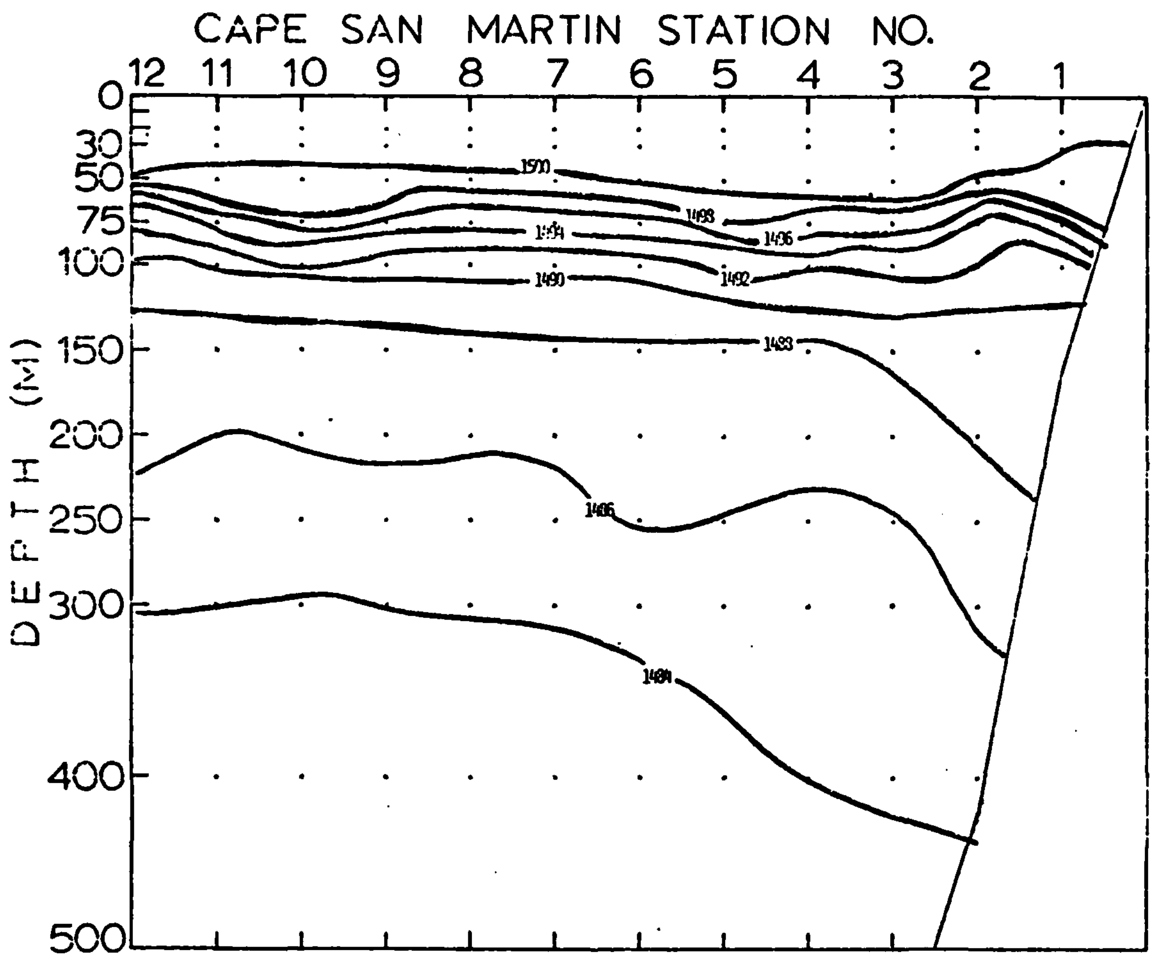

Figure 63. Sound speed (m/sec) on a vertical section for the Cape San Martin line on 22-23 January 1979.

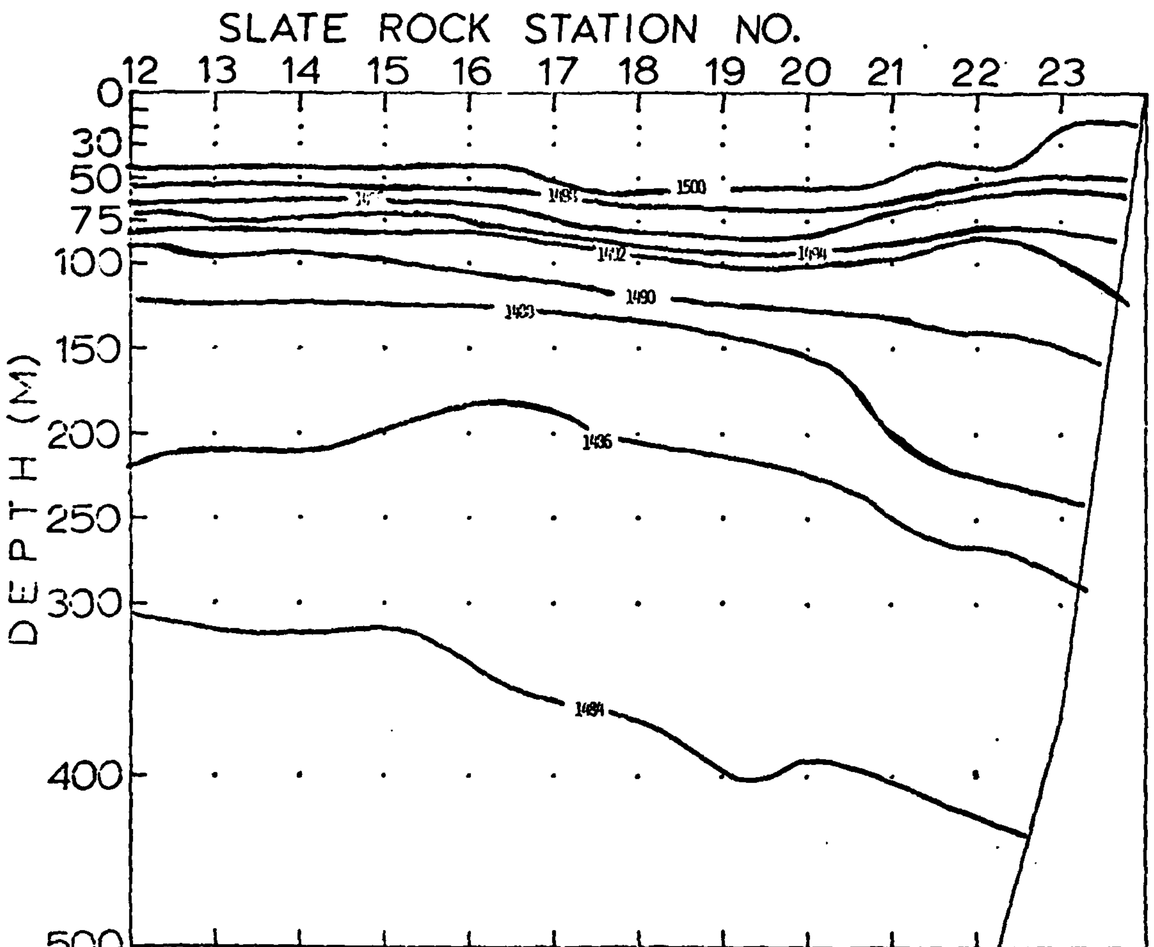

Figure 64. Sound speed (m/sec) on a vertical section for the Slate Rock line on 22-23 January 1979.

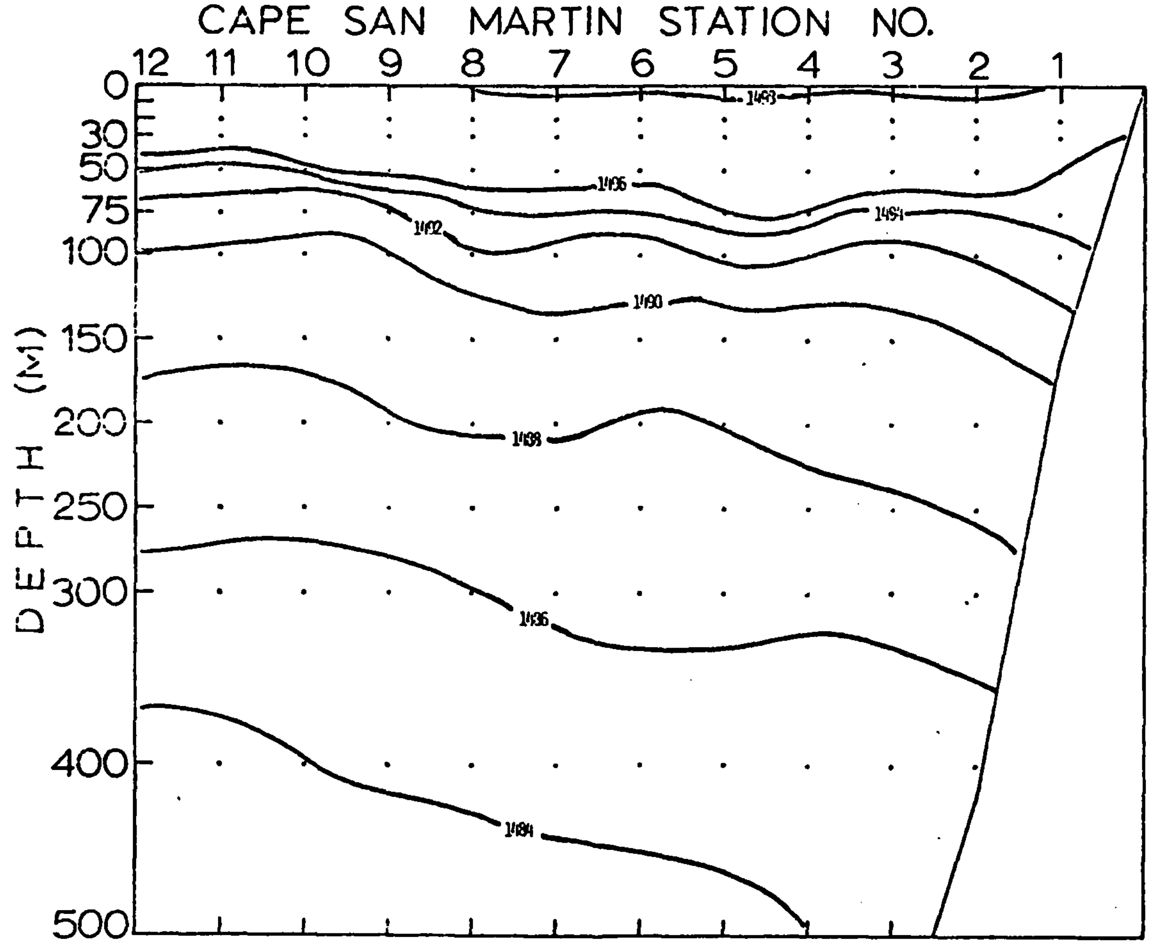

Figure 65. Sound speed (m/sec) on a vertical section for the Cape San Martin line on 21-22 February 1979.

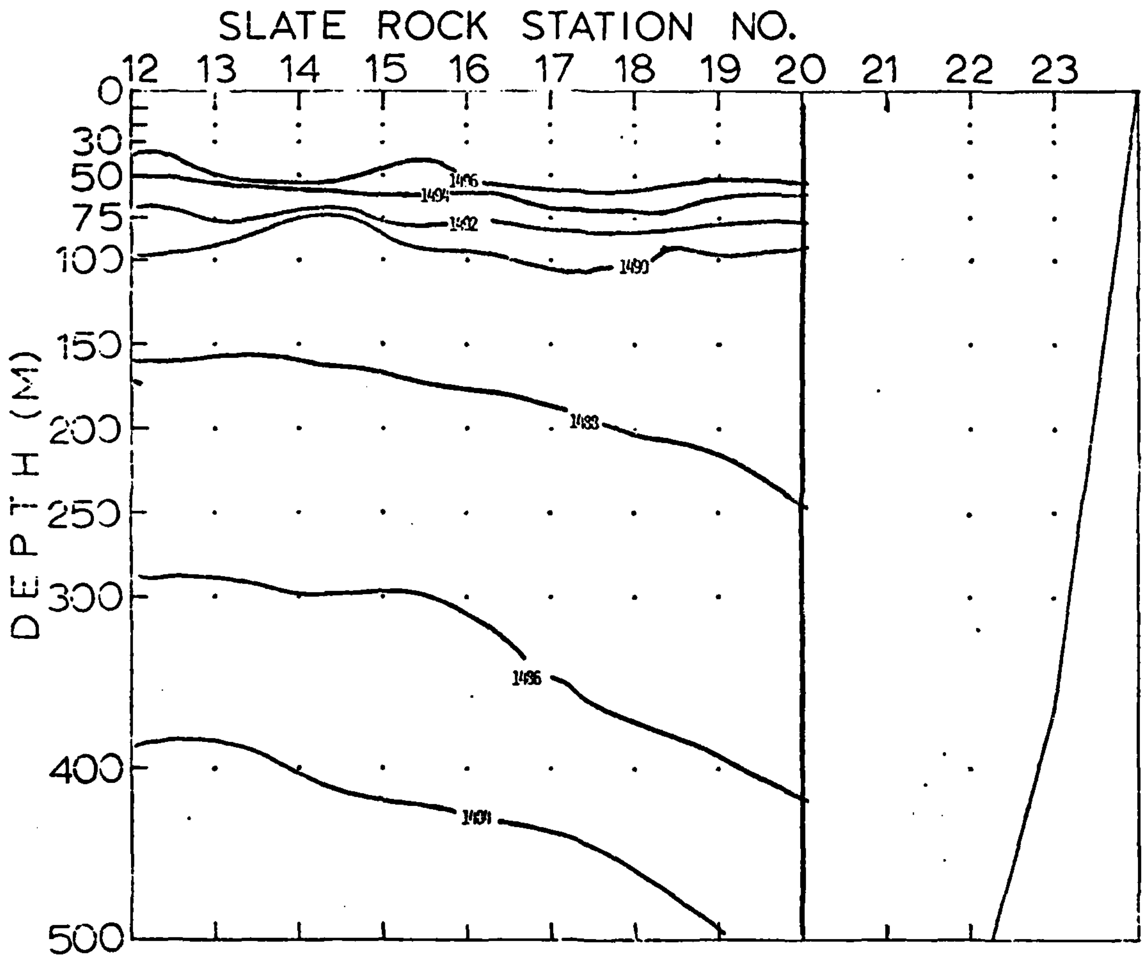

Figure 66. Sound speed (m/sec) on a vertical section for the Slate Rock line on 21-22 February 1979.

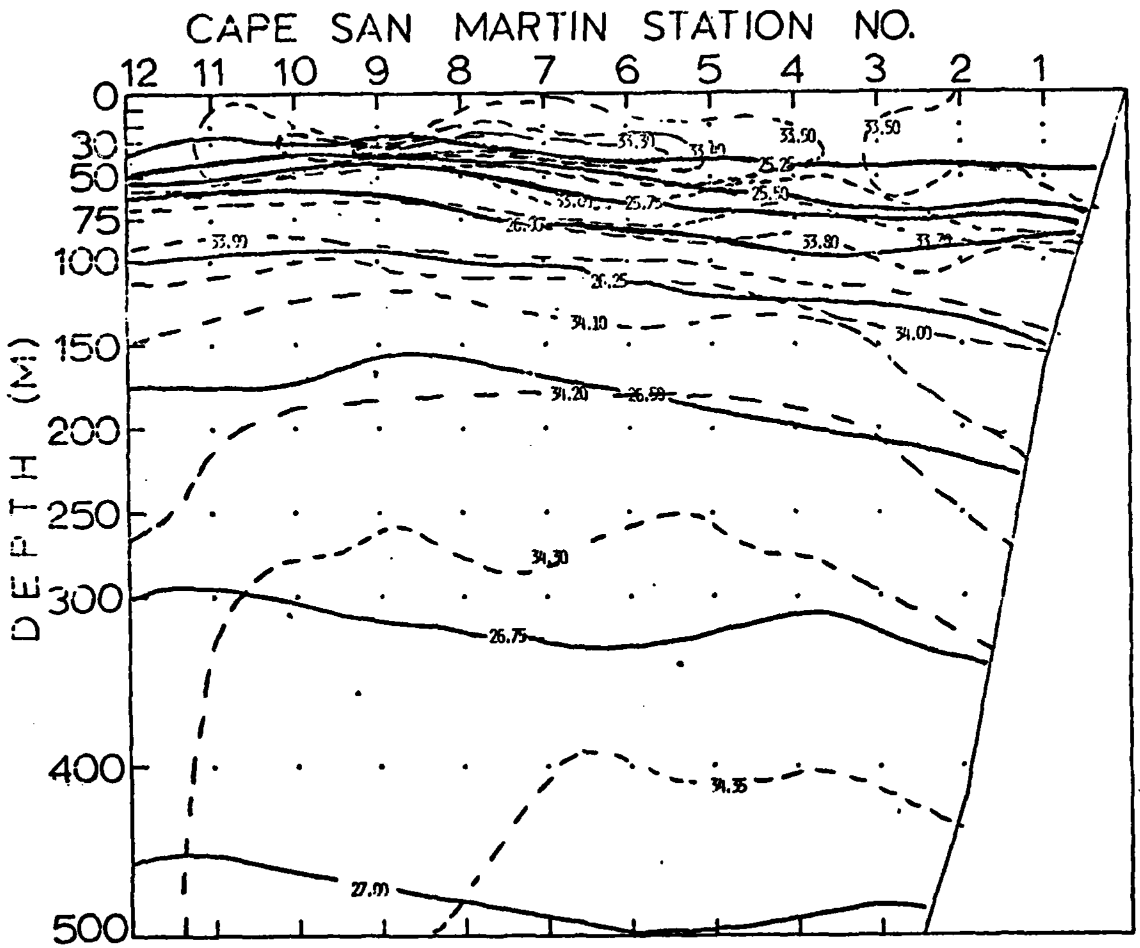

Figure 67. Sigma-t, solid line, and Salinity (‰), dashed line, superimposed on a vertical section for the Cape San Martin line on 27-28 November 1978.

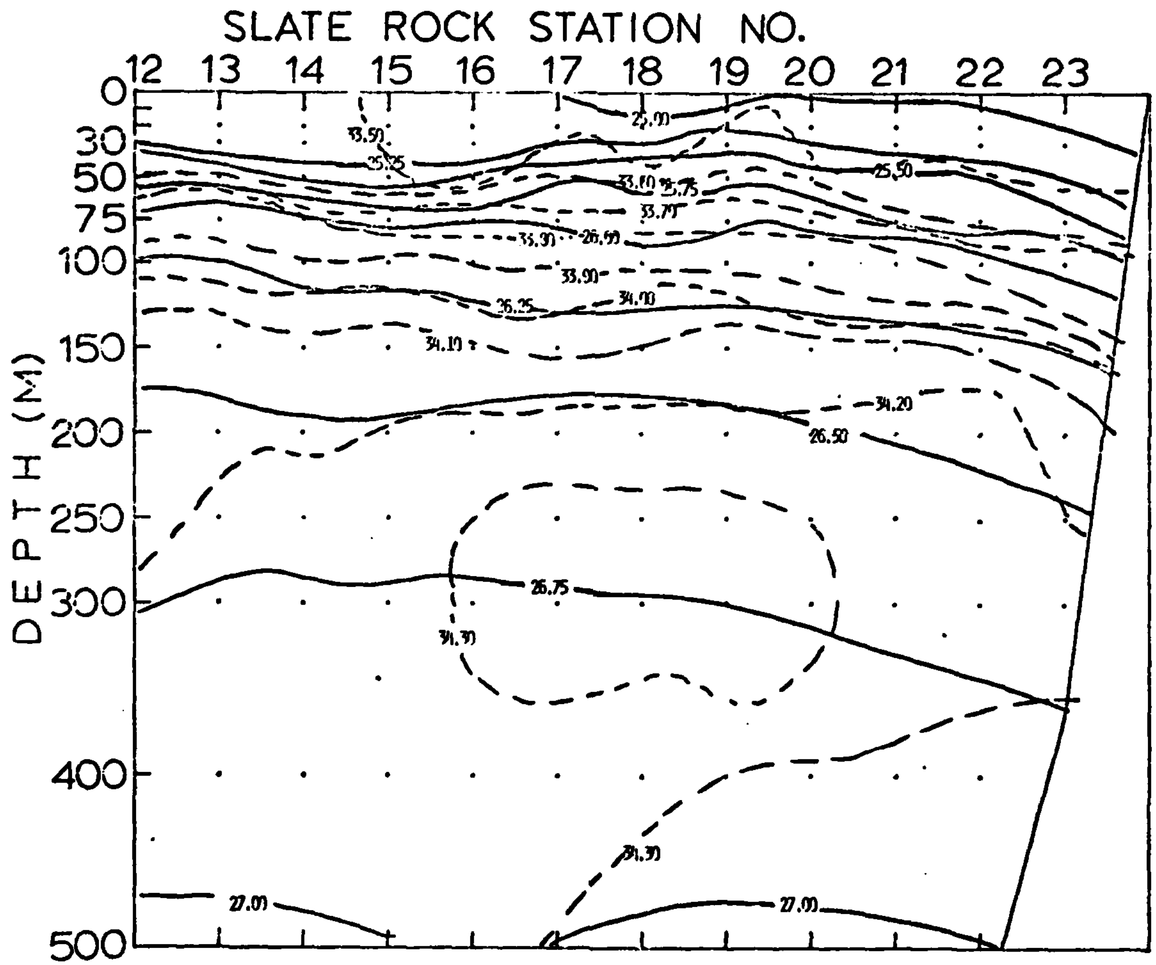

Figure 68. Sigma-t, solid line, and Salinity (‰), dashed line, superimposed on a vertical section for the Slate Rock line on 27-28 November 1978.

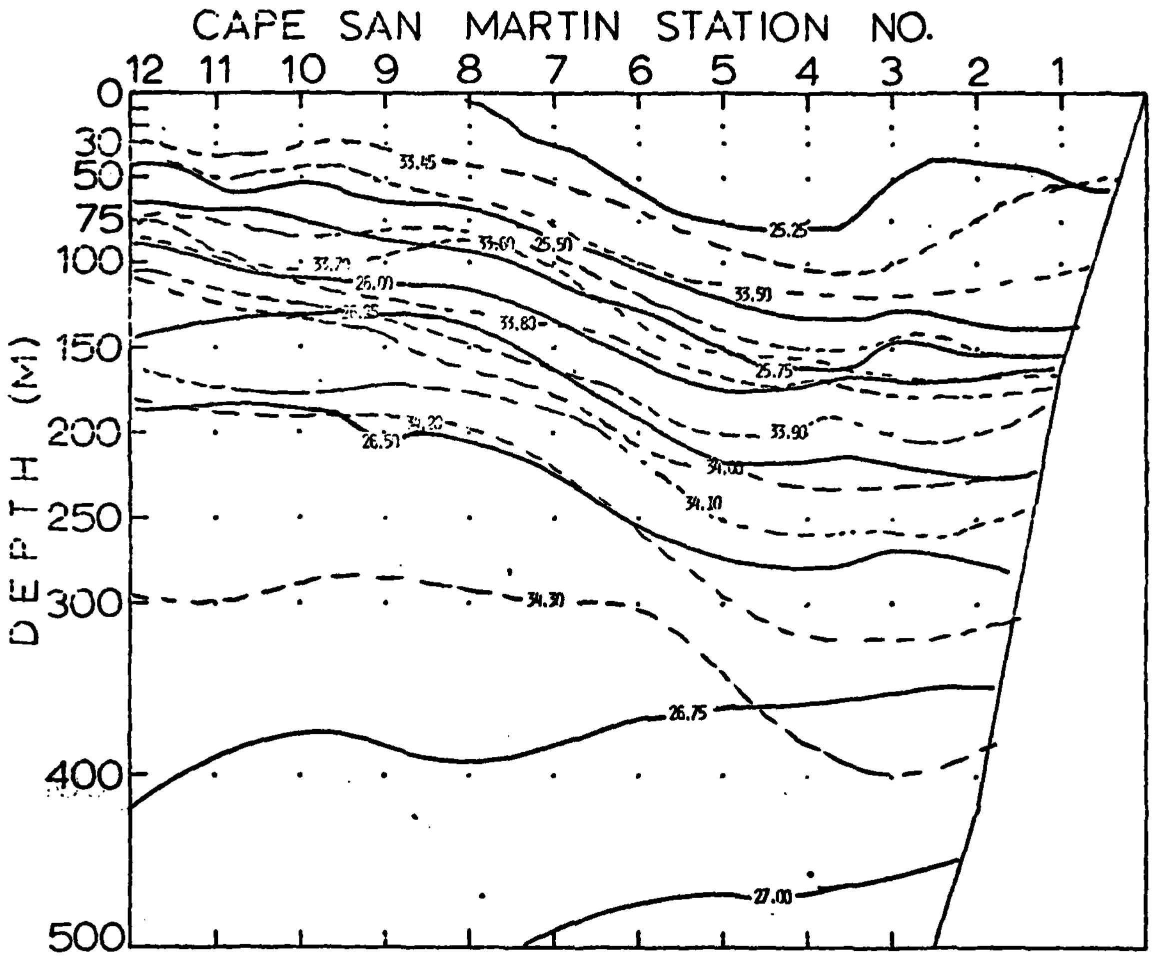

Figure 69. Sigma-t, solid line, and Salinity (‰), dashed line, superimposed on a vertical section for the Cape San Martin line on 8-9 January 1979.

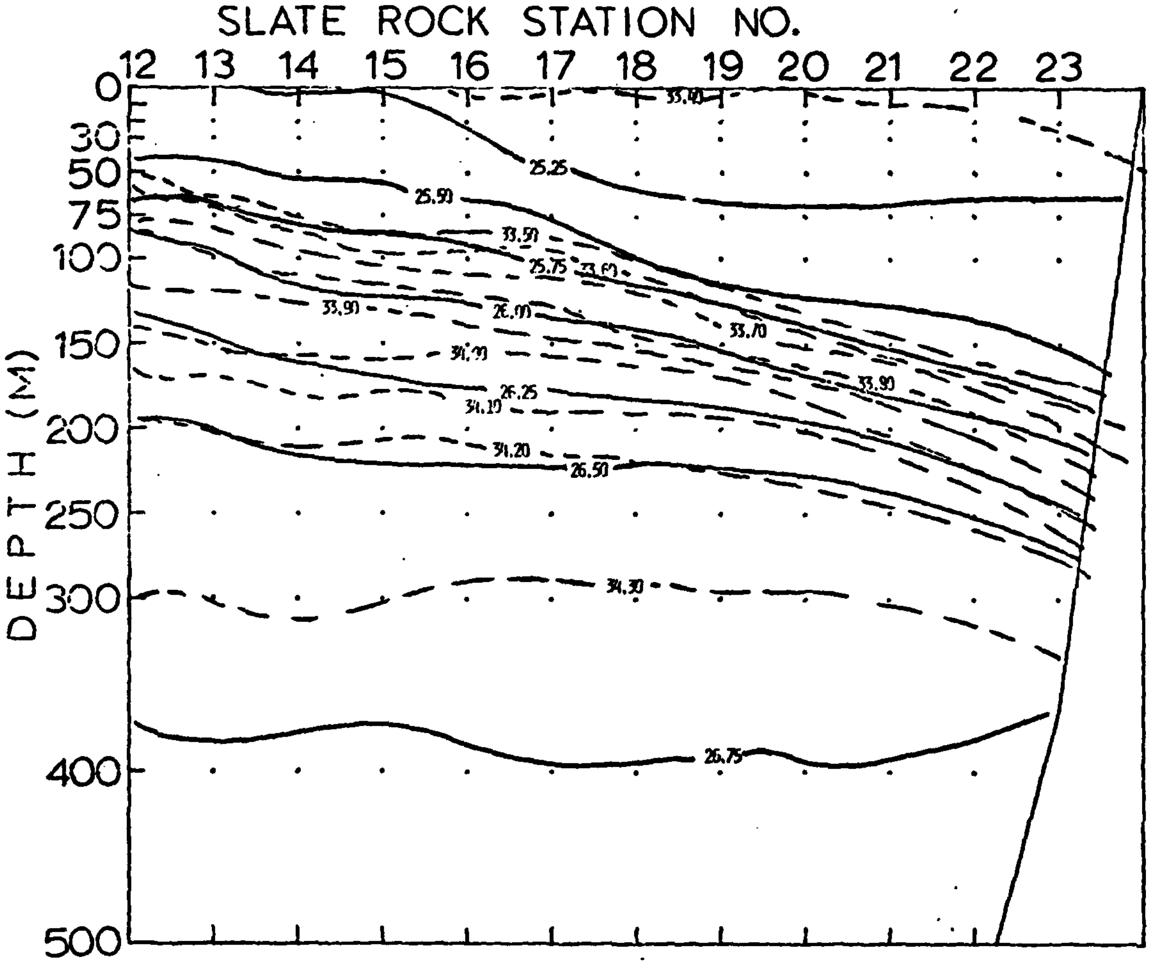

Figure 70. Sigma-t, solid line, and Salinity (‰), dashed line, superimposed on a vertical section for the Slate Rock line on 8-9 January 1979.

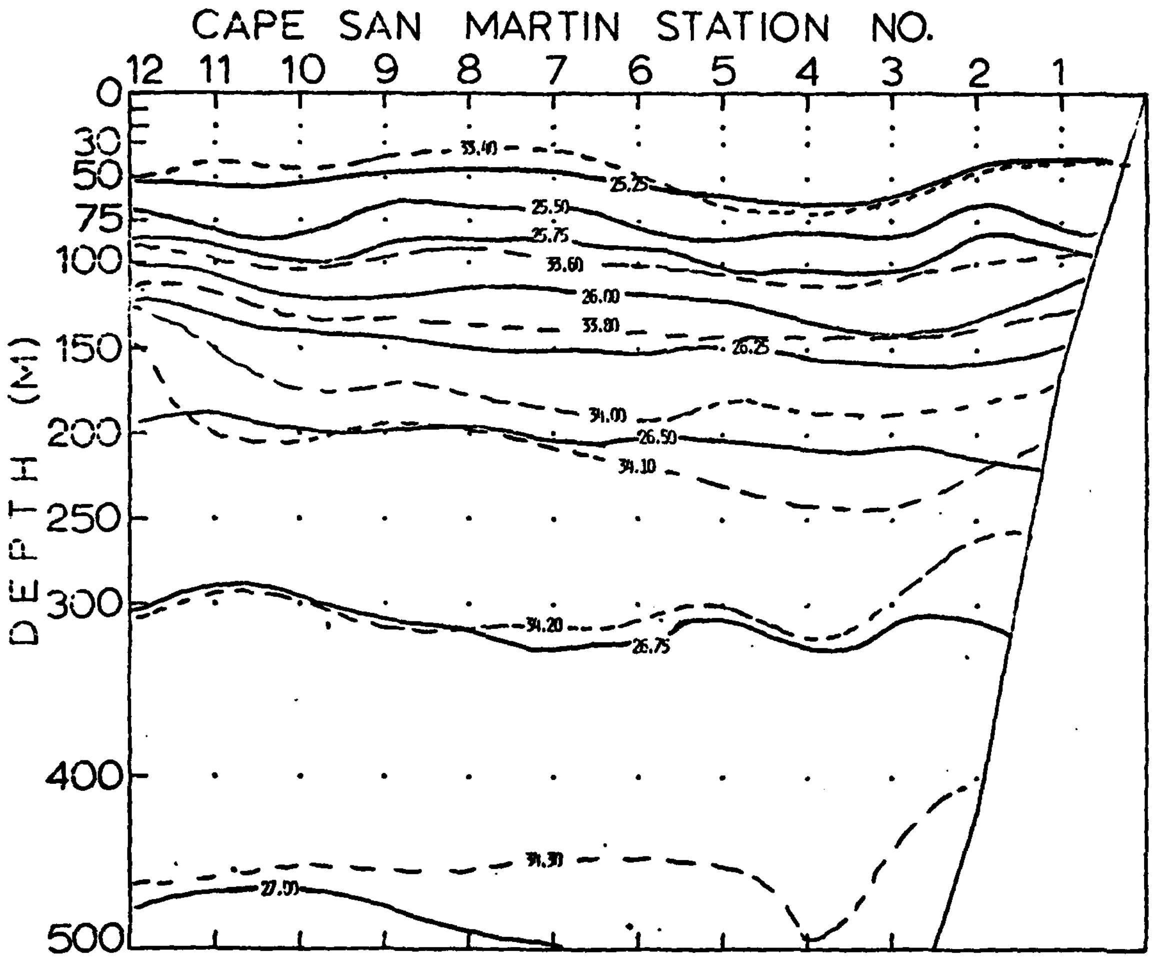

Figure 71. Sigma-t, solid line, and Salinity (‰), dashed line, superimposed on a vertical section for the Cape San Martin line on 22-23 January 1979.

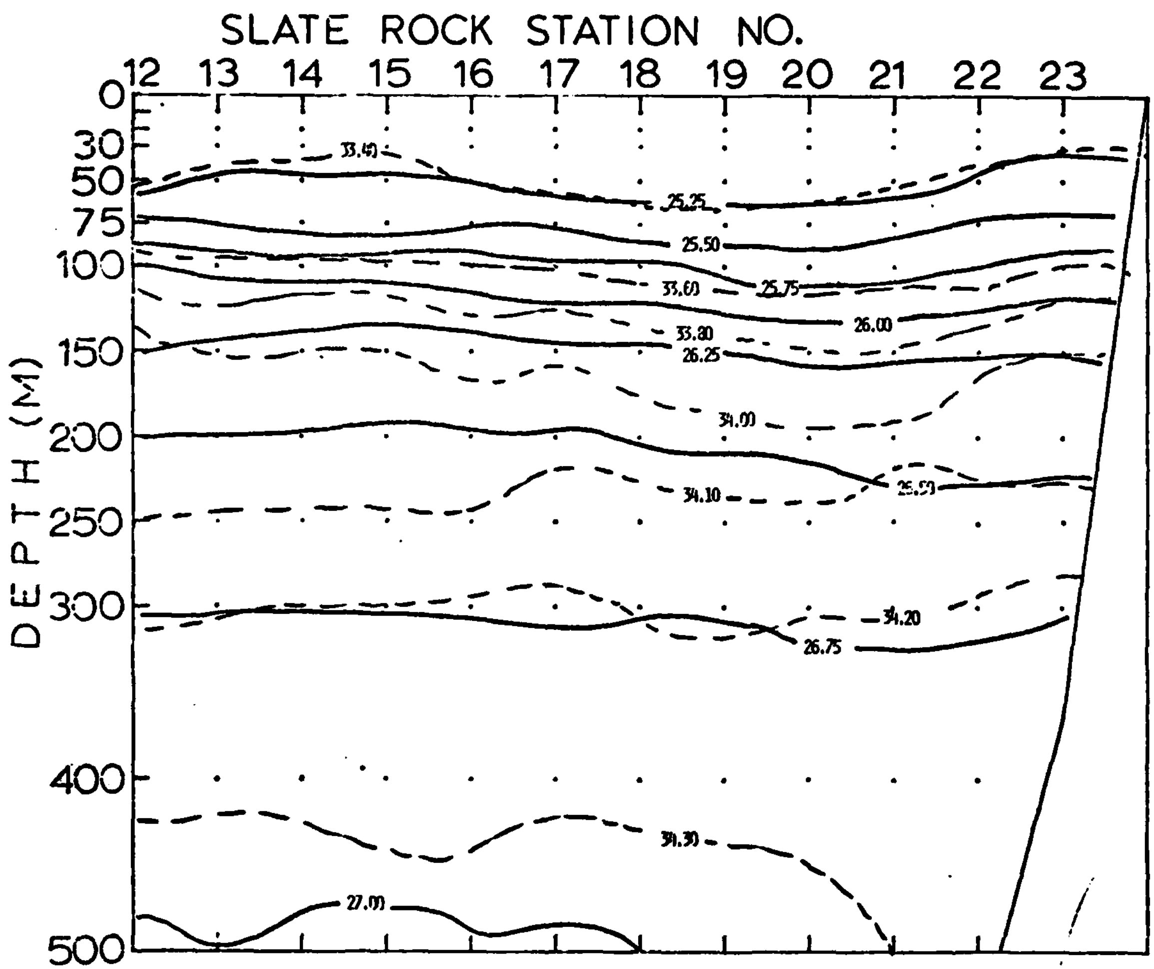

Figure 72. Sigma-t, solid line, and Salinity (‰), dashed line, superimposed on a vertical section for the Slate Rock line on 22-23 January 1979.

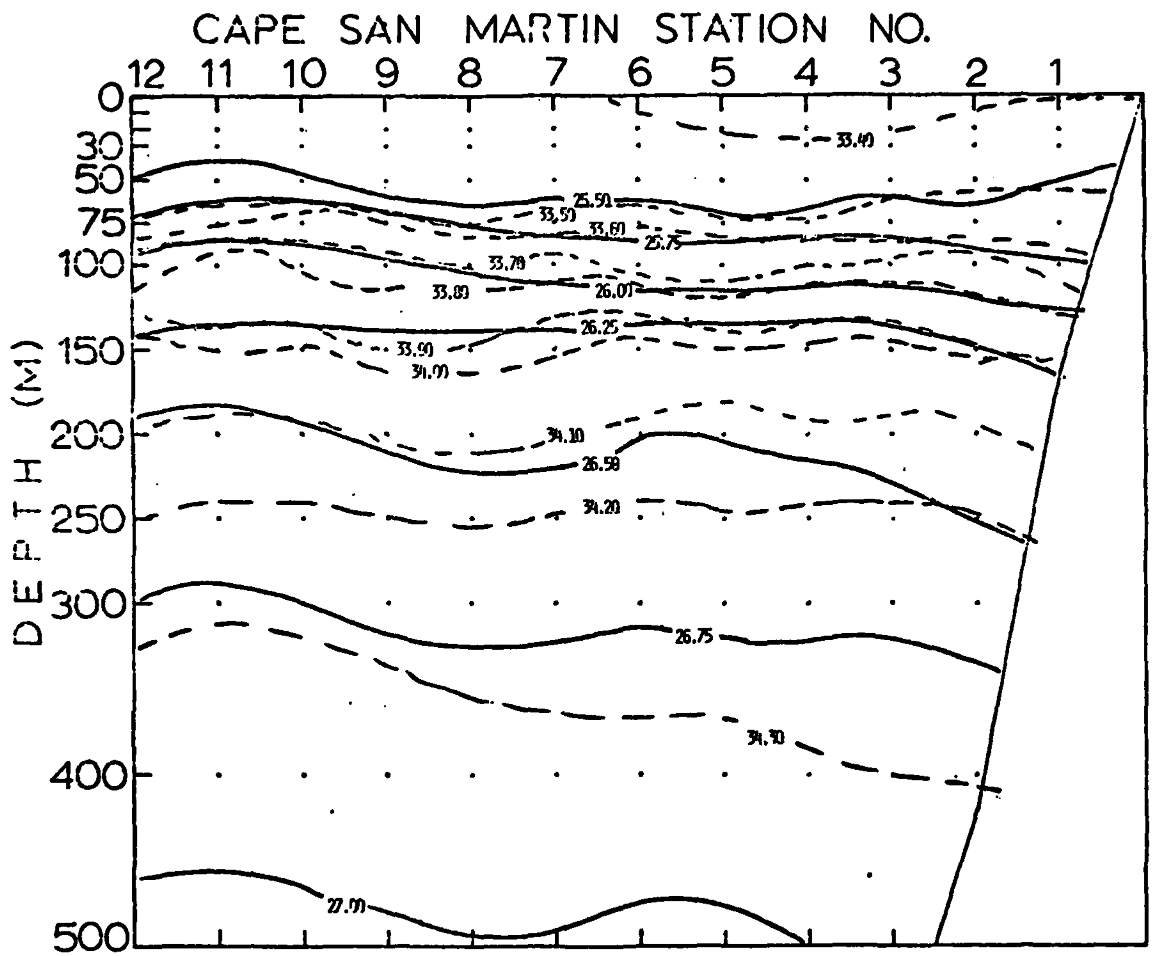

Figure 73. Sigma-t, solid line, and Salinity (‰), dashed line, superimposed on a vertical section for the Cape San Martin line on 21-22 February 1979.

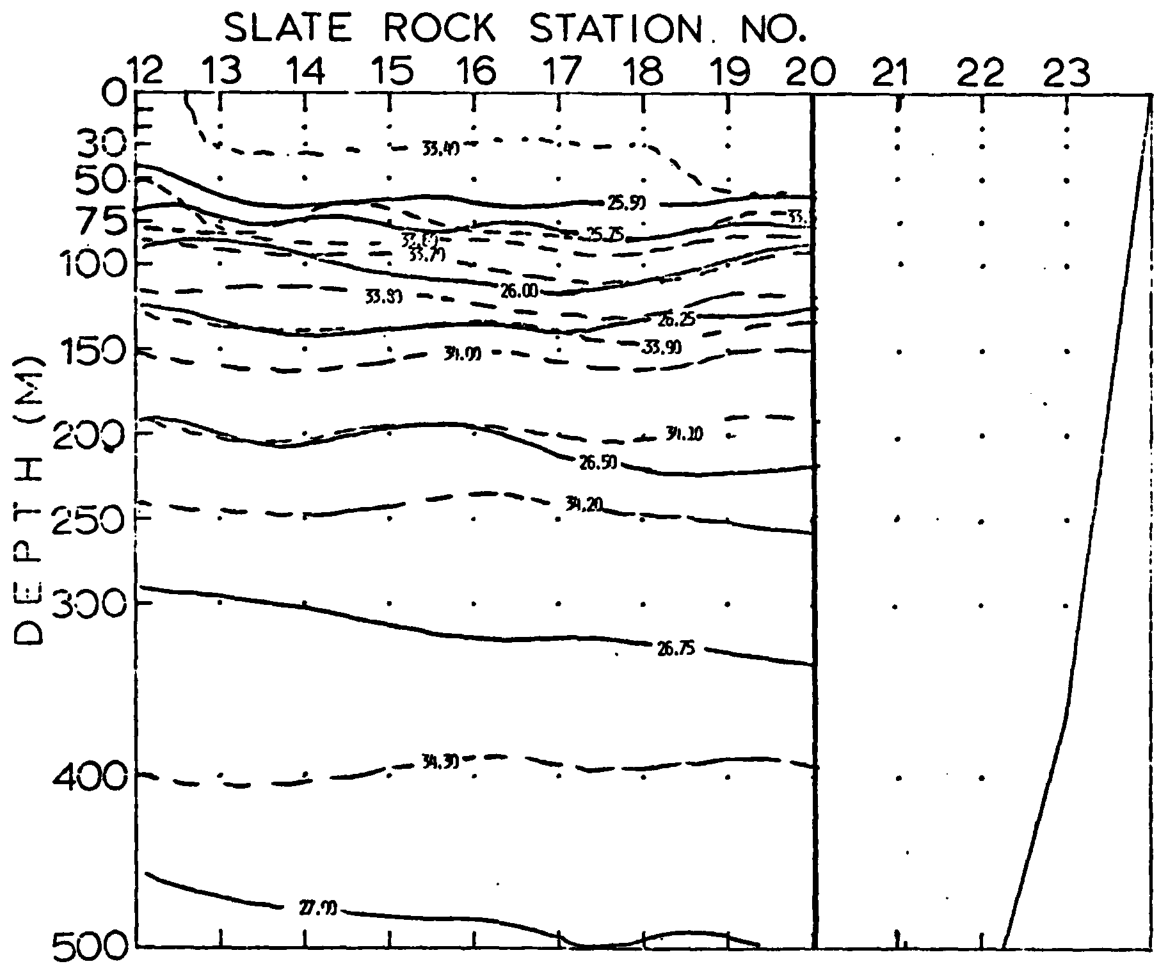

Figure 74. Sigma-t, solid line, and Salinity (‰), dashed line, superimposed on a vertical section for the Slate Rock line on 21-22 February 1979.

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