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Water Column Thermal Structure Across the Shelf and Slope Southeast of Sandy Hook, New Jersey in 1979

by

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Transect Analysis

During 1979 twenty-eight expendable bathythermograph (XBT) transects were collected across the continental shelf and slope from the entrance of New York Harbor out to the 106 Dumpsite (Fig. 1). Transects were obtained in all months except February when bad weather prevented the collection of data. Table 1 shows a summary of the transects collected, the parameters monitored, and the major oceanic features sampled within the Middle Atlantic Bight. The timing and duration of warm core eddy passages through the transect were determined from the analysis of Fitzgerald and Chamberlin (this volume).

January: Early and late January sections, "Delaware II" 79-01 and "Tamaroa" 79-01 (Figs. 2 and 3), respectively, depicted vertically isothermal water. Cold, homogeneous shelf water such as this is normal for the New York Bight at this time of year.

Compared to transect analyses from 1976-1978 (Cook 1979a, 1979b, Cook and Hughes 1980 in press) the range of January temperatures on the shelf and the upper slope appeared normal, ranging from 5°C nearshore to 10°C at the shelf break (Figs. 2 and 3). Both sections exhibited similar surface temperatures at comparable distances offshore.

Between stations 18 and 25 on 6-7 January (Fig. 2) 9°-10°C water appeared at 40 m depth. This parcel might have extended to the surface since satellite analysis at that time showed sea-surface temperatures (SST's) of 11°C over the shelf. Since 9°-10°C water did not occur over the shelf in the late

January section (Fig. 3), it was apparent that atmospheric conditions had cooled shelf water during the month.

February: Data for February were not available. However, satellite imagery indicated a continued decrease in SST's during the month.

March: Two transects were made in March. "Delaware II" 79-03 data (Fig. 4) was collected in early March and the "Mormac Argo" 79-03 (Fig. 5) in late March.

Shelf water remained vertically homogeneous through March (Fig. 4, stations 17-20). At the end of March a slight warming was observed over the continental shelf (Fig. 5). This was attributed to warmer than usual air temperatures and a decrease of winds over the New York Bight during late March.

In early March (Fig. 4) the coldest SST's of the year were observed across the shelf. Temperatures ranged from 2° to 7°C, while by the end of March (Fig. 5) temperatures of 3° to 9°C were recorded. The coldest bottom temperature of the year, 2.2°C (Fig. 4, station 16), was recorded in early March at ≈30 m. Compared with March 1976-78 transect analyses, the shelf SST range was normal. The Shelf/Slope Front, indicated on each figure by an arrow at the surface, was visible between stations 37 and 38 (Fig. 5) and intersected bottom at 140 m. An offshore advection of shelf water, characterized by colder 9°-11°C temperatures and <34.5 o/oo salinity, was observed at stations 32-35 (Fig. 5).

April: In April the "Delaware II" 79-04 (Fig. 6) and the "Advance II" 79-01 (Fig. 7) transects were collected. Early April SST's ranged from 5° to 7°C (Fig. 6), while by the end of April they had warmed to 9°C (Fig. 7). Vertical isotherms still appeared through early April (Fig. 6), attesting that vernal warming had not yet occurred; while just one week later (Fig. 7) stratification had begun to show in the water column over the shelf. Warmer water underlying the isothermal surface water indicated a slope water intrusion at the bottom (Figs. 6 and 7).

Surface warming effectively sealed off the bottom waters from surface exchange by thermal stratification in mid-April. Thermal stratification resulted in development of the cold cell, the insulated winter-cooled bottom

water. A weighted average cold cell temperature was determined for each subsequent transect where it appeared. This value was calculated by 1) determining the first isotherm below the thermocline that bounded the outer edge of the cold cell; 2) counting the area on grid paper defined by each isotherm; 3) multiplying each area by the isothermal temperature to obtain a weighted temperature; 4) totaling the individual areas and the weighted temperatures, and 5) dividing the sum of the weighted temperatures by the sum of the individual areas to obtain a weighted average cold cell temperature (see Table 1). The average cold cell temperature in April was 6.8°C.

The early April transect (Fig. 6) terminated ≈37 km seaward of the shelf break without crossing the Shelf/Slope Front, suggesting that offshore forces were causing a seaward migration of the front. Early April satellite imagery confirmed a Shelf/Slope Front seaward displacement. By late April the Shelf/Slope Front had migrated to ≈74 km seaward of the break at the surface (station 13-14). The front moved offshore at the bottom from 80 m to 110 m during the month.

May: The "Mormac Rigel" 79-02 (Fig. 8) and the "Whiting" 79-01 (Fig. 9) cruises occurred 5 and 8 May, respectively. The "Mormac Argo" 79-04 (Fig. 10) transect was taken on 28-29 May. Sea surface temperatures increased from 11°C in early May (Figs. 8 and 9) to 13°C by the end of the month (Fig. 10). In the beginning of May a temperature range of 7°-11°C occurred in the surface 20 m (Fig. 8, stations 1-9 and Fig. 9, stations 1-8). By the end of May (Fig. 10) the temperature gradient in the thermocline increased to 1°C/meter ranging from 6°-13°C (stations 2-9). The May SST's were similar to those recorded for May 1976 and 1977, but 2°-3°C warmer than those of May 1978. The May sections (Figs. 8, 9 and 10) showed a mixed layer depth of ≈10 m. The thermocline occurred in the next 10 m, with the well-mixed cold cell below this and extending to the bottom. The average cold cell temperature decreased from 6.1°C in early May (Fig. 8) to 5.5°C (Fig. 10) at the end of May.

Throughout the month the Shelf/Slope Front remained within 37 km seaward of the shelf break. Warm core Gulf Stream Eddy 79-A appeared to impact on the Shelf/Slope Front (Fig. 8, stations 10-12 and Fig. 10, stations 11-13) and was characterized by warm temperatures (18°C) and high salinities (36 o/oo). The shape of the front changed as Eddy 79-A progressed farther

into the area. The cold cell was drawn offshore of the shelf break, possibly because of eddy entrainment of shelf water (Fig. 9, stations 8-9 and Fig. 10, stations 10-11).

June: Two "Mormac Rigel" cruises, 79-03 and 79-04, provided XBT data for June (Figs. 11 and 12). The SST range was 15°-17°C in early June (Fig. 11) and rose to 16°-18°C by mid-June (Fig. 12). Surface temperatures for early June were 1°-2°C warmer than 1978 (Cook 1979a, 1979b, Cook and Hughes 1980).

As warming progressed, the thermocline temperature gradient intensified through depths of 6-30 m (Fig. 11, stations 19-24; Fig. 12, stations 1-10), increasing to 2°C/meter as compared to 1°C/meter in May. A shallow mixed surface layer was evident in mid-June, at times only 6 m deep compared to 10 m in May.

Remnant 4°C water was recorded on the bottom in early June (Fig. 11). The average cold cell temperature rose during the month from 5.3°C to 5.9°C. The Shelf/Slope Front continued to intersect bottom near the 80 m isobath. Gulf Stream Eddy 79-A is evident in both June sections as a deepening of the 14°C isotherm to about 150 m.

July: Transects were made on 7, 18-19, 22 and 28 July. The ships providing data were the "Albatross IV", the "Tamaroa", the "Mormac Rigel" and the "Mormac Argo", respectively (Figs. 13-16). Over the month SST's rose from 19°-20°C (Fig. 13, stations 17-23) to 24°-26°C (Fig. 16, stations 1-10).

The thermocline became shallower and the gradient intensified in July. Early July showed the surface mixed layer to a maximum depth of 12 m (Fig. 13, stations 17-23). Lack of storm activity resulted in stratification reaching to within 4-6 m of the surface in late July (Fig. 16). A temperature increase of 12°-14°C occurred within the thermocline and a gradient of 2°-3°C/meter was observed.

The average cold cell temperature dropped to 5.1°C in early July (Fig. 13), perhaps because of cold water advected from the north. It warmed to 6.2°C by 28 July (Fig. 16). Temperatures less than 5°C persisted within the cold cell until the end of July (Figs. 13, 14 and 15) when the minimum increased to nearly 6°C (Fig. 16). The minimum temperatures were

similar to those recorded in July 1978, but July 1976 and 1977 showed cold cell temperatures 3°-4°C warmer (Cook 1979a, 1979b, and Cook and Hughes 1980).

An apparent "calving-off" of 9°-10°C water occurred in mid-month (Fig. 14, stations 9-10) and subsequently established the Shelf/Slope Front over the shelf at the surface (Fig. 15, stations 18-19; Fig. 16, stations 8-9). An offshore parcel of shelf water is evidenced (Fig. 16, stations 9-17) by an anomalously low surface salinity. These changes in frontal shape may be related to the movement of Eddy 79-B into the New York Bight at the end of the month (Fig. 16, stations 11-12).

August: The "Albatross IV" 79-08, "Belogorsk" 79-01 and "Tamaroa" 79-05 transects occurred 1 and 5-6, 18-19 and 23 August, respectively (Fig. 17-19). Early August SST's over the shelf rose to 25°C (Fig. 17) and were the highest temperatures for the year.

Thermocline temperatures ranged from 7°-25°C at the beginning of August (Fig. 17), with a gradient of 3°C/meter and a shallow mixed layer (4-6 m). Strong storms occurred during the second week of August, deepening the mixed layer to 20 m (Fig. 18) and lessening the thermocline temperature range to 8°-19°C. The SST's rose again to 20°-21°C by 23 August (Fig. 19, stations 1-8).

The average cold cell temperature increased from 7.1°C to 8.7°C. A seaward migration of the cold cell was apparent. The 10°C isotherm was at 80 m in mid-August (Fig. 18, stations 18-19), but had deepened to 100 m by 23 August (Fig. 19, station 8).

September: Transects were made by the "Kelez" 79-01 (Fig. 20) and the "Mormac Rigel" 79-06 (Fig. 21) cruises. As the month progressed, SST's cooled from 21°C to 19°C (Fig. 20, stations 1-9, and Fig. 21, stations 14-25).

Continued surface cooling and mixing deepened the thermocline from 20 to 28 m. The range of the thermocline temperature became less than in August. A temperature gradient of 2°C/meter occurred within the thermocline which ranged from 10°-19°C.

During the month the average cold cell temperature increased 1.2°C to almost 10°C. Cold cell temperatures ranged from 8°-11°C at mid-month (Fig. 20) to 9°-11°C by the end of the month (Fig. 21). An apparent

division of the cold cell occurred (Fig. 21), probably as an artifact of the Hudson Canyon influence on the contouring.

Although Eddy 79-B had moved southwest of these transects, the remnants of its influence appeared in both sections. Warm 14°C water was recorded to >100 m depth (Fig. 20, stations 12-13, 20), then receded to 80 m (Fig. 21, stations 9-11). Parcels of cold 11°-12°C shelf water occurred offshore as a result of entrainment around the passing eddy (Fig. 20, stations 18, 14, 17). The Shelf/Slope Front moved 28-37 km offshore at the surface.

A third warm core eddy, 78-I, appeared in the "Rigel" 79-06 section (Fig. 21, stations 2-8). It was located off the New York Bight according to satellite imagery. Temperatures greater than 14°C were recorded at 180 m depth and 35-36 °/oo salinities appeared at the surface.

October: Three transects were taken in October. The "Mormac Rigel" 79-07 occurred 4-5 October (Fig. 22), the "Vigorous" 79-01 on 5 October (Fig. 23) and the "Mormac Argo" 79-07 on 26 October (Fig. 24). Sea surface temperatures over the shelf cooled from 19°C (Figs. 22 and 23) to 15°C (Fig. 24).

Mixing at the surface caused fluctuations in the thermocline depth between 10-40 m (Fig. 22, stations 1-10). By the end of October (Fig. 24, stations 15-23) the thermocline had stabilized and deepened to below 30 m. At the beginning of October the temperature gradient within the thermocline was 2°-3°C/meter (Fig. 22) and the temperature range was 11°-18°C. By 26 October the gradient was 1°-2°C/meter while the range was reduced to 11°-15°C (Fig. 24).

The Shelf /Slope Front remained slightly offshore of its normal position at depths of approximately 100 m (Figs. 22 and 23). As the month progressed the average cold cell temperature rose from 10.6°C to 11.9°C.

Intrusion of 14°C water to depths of 215 m (Fig. 22, station 15) and 180 m (Fig. 23, station 12) reflected the presence of Eddy 78-I. The "Mormac Rigel" 79-07 (Fig. 22, stations 12-18) transected the eddy while the "Vigorous" 79-01 section passed southwest of the eddy (Fig. 23, stations 9-14). High salinity slope water (34.5 - 35.7 °/oo) intruded shoreward at the surface due to the influence of Eddy 78-I (Fig. 22, stations 9, 12-13). Satellite imagery indicated entrained shelf water along the

trailing edge of the eddy. A mixture of shelf and slope water (34.5 - 34.8 °/oo) appeared entrained at the northeastern edge of the eddy (Fig. 22, stations 19-20).

November: The November sections were made from XBT traces taken from the "Mormac Argo", 3 November (Fig. 25) and the "Mormac Rigel", 15-16 November (Fig. 26). The SST's for early November (Fig. 25, stations 1-12) ranged from 13°-15°C, while mid-month temperatures had cooled to 12°-14°C (Fig. 26, stations 14-25).

Evidence of a weakened thermocline was apparent in early November (Fig. 25). The thermocline persisted at 40 m depth but the temperature range was reduced to 13°-15°C with a gradient of 1°C/meter. Above the thermocline the water was well mixed. Fall overturn occurred during mid-November (Fig. 26, stations 15-25), about two weeks later than in 1978 (Cook and Hughes 1980). Annual maximum bottom temperatures, ≈13°C, were recorded on the shelf following fall overturn (Fig. 26). A remnant of the cold cell remained through mid-November with an average temperature of 11.7°C. It extended down the slope to 110 m at the beginning of the month (Fig. 25, stations 1-11), but by mid-month the seaward edge had receded to 90 m depth (Fig. 26).

Both sections were influenced by passage of Eddy 79-E. The eddy effects were more pronounced at mid-month as the eddy drew closer, but in both cases 14°C water appeared at 160 m depth (Fig. 25, stations 17-21; Fig. 26, stations 4-7). Surface waters in the eddy cooled from 20°C to 18°C, but high salinities (35.5 °/oo) persisted.

December: Three cruises were used to characterize the Mid-Atlantic Bight in December. "Mormac Rigel" 79-09 occurred on 1 December (Fig. 27), while the "Mormac Argo" 79-09 and 79-10 cruises occurred on 5 and 14 December, respectively (Figs. 28 and 29). At the beginning of December SST's ranged from 11°-13°C, but had dropped to 10°-12°C by mid-December.

Isothermal conditions existed over the shelf to ≈70 m depth, while from 70-120 m depth warm 13°C slope water rested on the bottom at and beyond the shelf break. Warm SST's (Fig. 27, stations 14-16; Fig. 28, stations 4-6; Fig. 29, stations 12-14) and intrusions of 14°C water to depths of 120-140 m reflected the passage of Eddy 79-E to the southwest of the transect.

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Cook, S. K. 1979b. Water column thermal structure across the shelf and slope southeast of Sandy Hook, New Jersey, USA, in 1977. Annal. Biol. Copenh. 34:14-21.

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Table 1. Water Column Thermal Structure in 1979.

Vessel	Cruise no.	Date	Cold cell area-weighted avg. temp. (°C)	Depth range of cold cell minimum/ maximum denth offshore (m)	Average cold cell depth in meters	Position of Shelf/slope front shoreward (-) or seaward (+) of 100 fm mark/km	Eddies present along transect
"Delaware II"	79·01	6-7 Jan	Isothermal (<5-10°C)	-	-	-	No
"Tamaroa"	79·01	30 Jan	Isothermal (7-10°C)	-	-	-17	No
"Delaware II"	79·03	3 Mar	Isothermal (2-8°C)	-	-	-	No
"Mormac Argo"	79·03	23 Mar	Isothermal (<4-9°C)	-	-	+ 9	No
"Delaware II"	79·04	5-14 Apr	Isothermal (<5-11°C)	-	-	>+ 7	No
"Advance II"	79·01	20-21 Apr	6.8	<27-66	≈47	+33	No
"Mormac Rigel"	79·02	5 May	6.1	18-84	51	+ 3	Yes 79·A
"Whiting"	79·01	8 May	6.0	<30-77	≈54	- 6	Yes 79·A
"Mormac Argo"	79·04	28-29 May	5.5	30-80	55	+ 6	Yes 79·A
"Mormac Rigel"	79·03	7 Jun	5.3	<38-48	≈43	+ 6	Yes 79·A
"Mormac Rigel"	79·04	16 Jun	5.9	30-77	53	+20	No
"Albatross IV"	79·06	5 Jul	5.1	32-76	54	-	No
"Tamaroa"	79·04	18-19 Jul	5.8	30-72	51	+70	Yes 79·B
"Mormac Rigel"	79·05	22 Jul	6.0	38-78	58	-35	Yes 79·B
"Mormac Argo"	79·05	28 Jul	6.2	48-77	62	+ 7	Yes 79·B
"Albatross IV"	79·08	1,5-6 Aug	7.1	36-70	53	-	Yes 79·B
"Belogorsk"	79·01	18-19 Aug	8.1	40-84	62	-	Yes 79·B
"Tamaroa"	79·05	23 Aug	8.7	44-98	71	+ 7	Yes 79·B
"Kelez"	79·01	17-18 Sep	9.5	34-78	56	+22	Yes 78·I
"Mormac Rigel"	79·06	23 Sep	10.0	38-68	53	+26	Yes 78·I
"Mormac Rigel"	79·07	4-5 Oct	10.6	46-92	69	+ 4	Yes 78·I
"Vigorous"	79·01	5 Oct	10.8	50-108	79	- 9	Yes 78·I
"Mormac Argo"	79·07	26 Oct	11.9	37-88	62	+94	No
"Mormac Argo"	79·08	3 Nov	11.5	32-112	72	+70	Yes 79·E
"Mormac Rigel"	79·08	15-16 Nov	11.7	46-90	68	-13	Yes 79·E
"Mormac Rigel"	79·09	1 Dec	Isothermal (<12->13°C)	-	-	+11	Yes 79·E
"Mormac Argo"	79·09	5 Dec	Isothermal (12- 14°C)	-	-	0	Yes 79·E
"Mormac Argo"	79·10	14 Dec	Isothermal (<10- 14°C)	-	-	+22	Yes 79·E

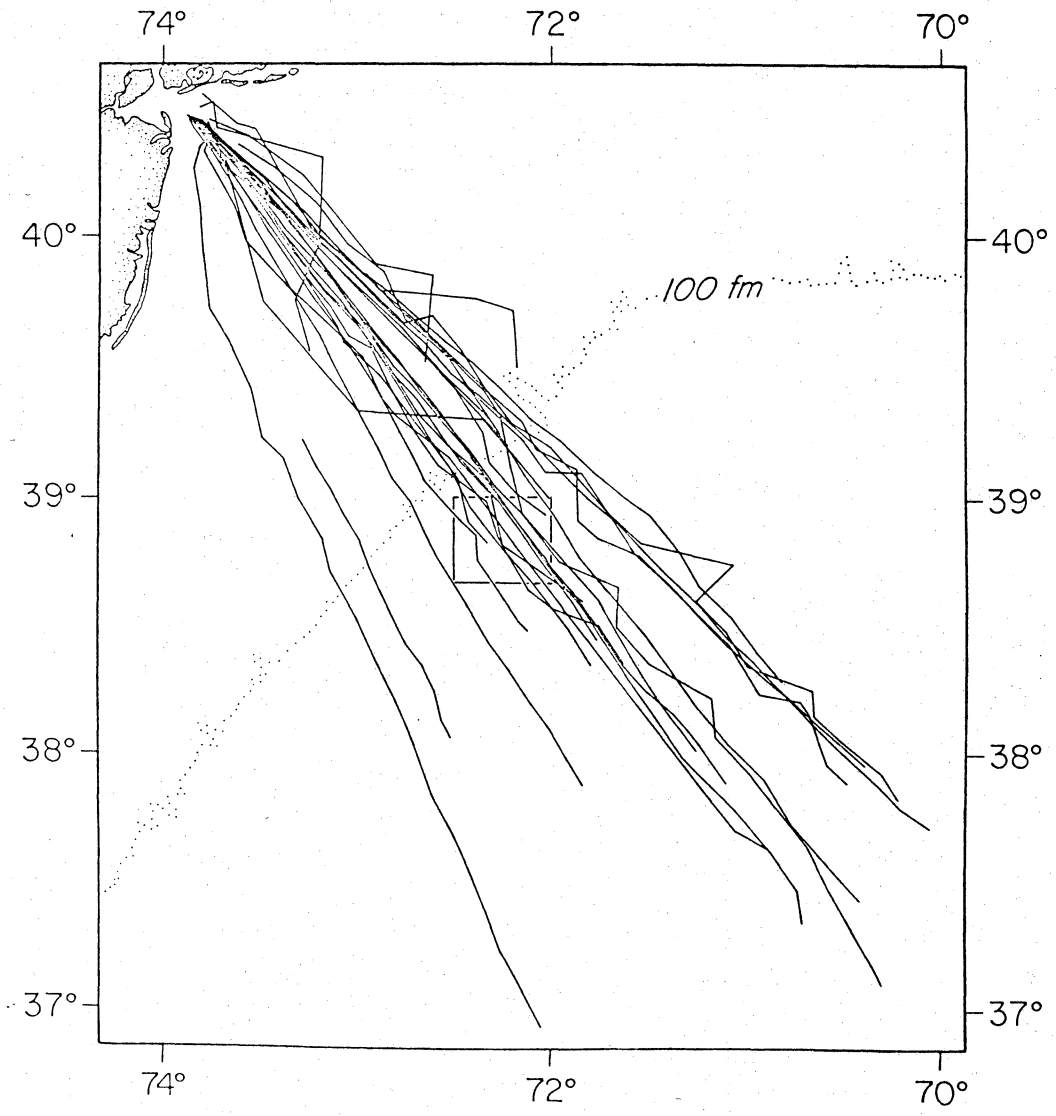

Figure 1. Location of 28 XBT transects collected during 1979.

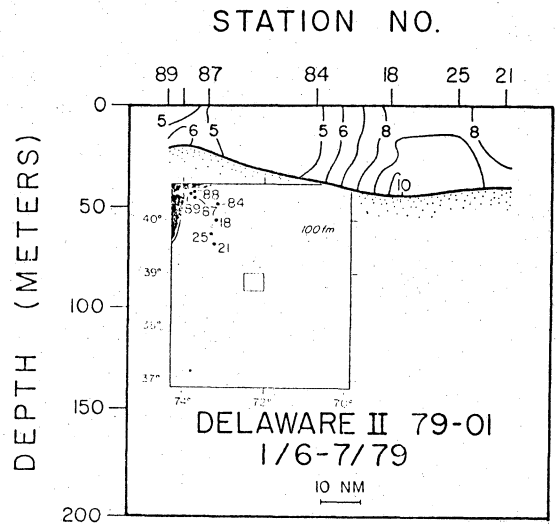

Figure 2. January temperature (°C) transect collected by RV "Delaware II", 6-7 January 1979.

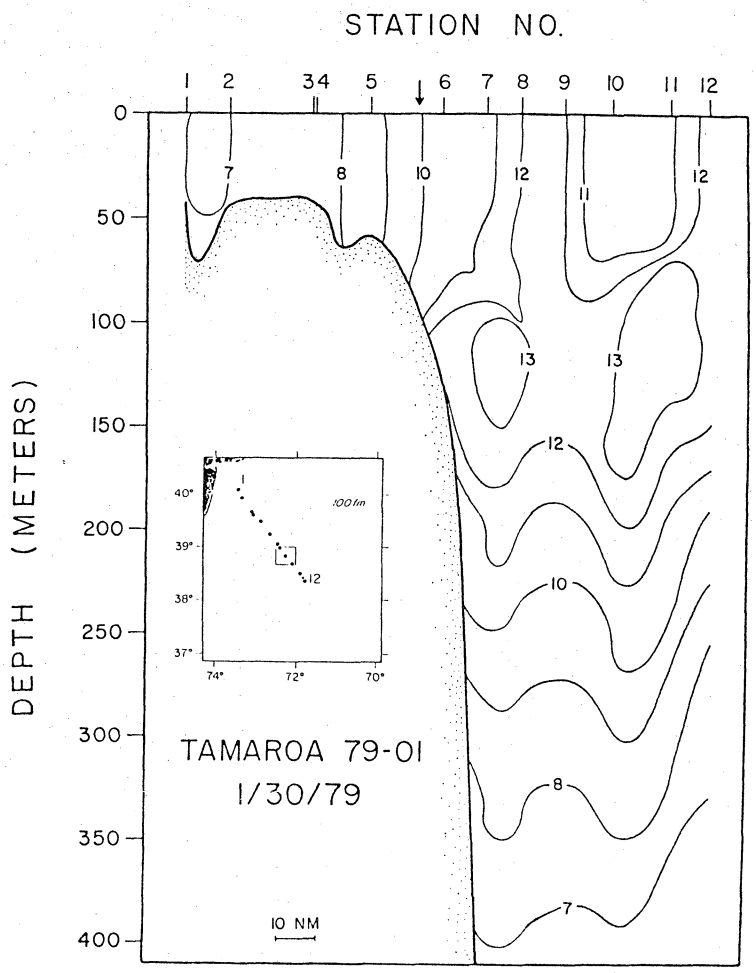

Figure 3. Second January temperature (°C) transect collected by USCGC "Tamaroa", 30-31 January 1979.

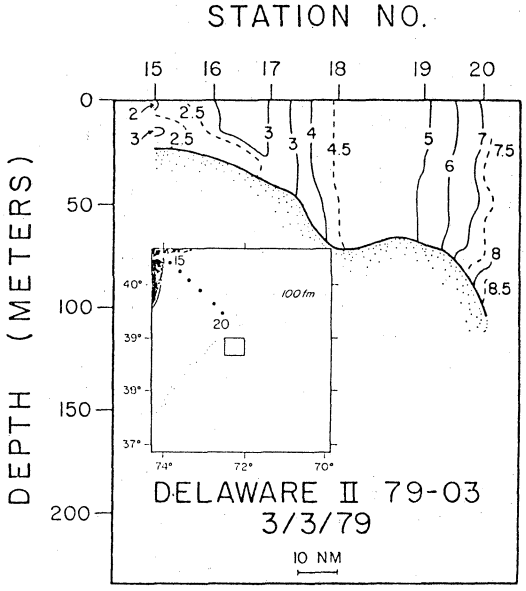

Figure 4. March temperature (°C) transect collected by RV "Delaware II", 3 March 1979.

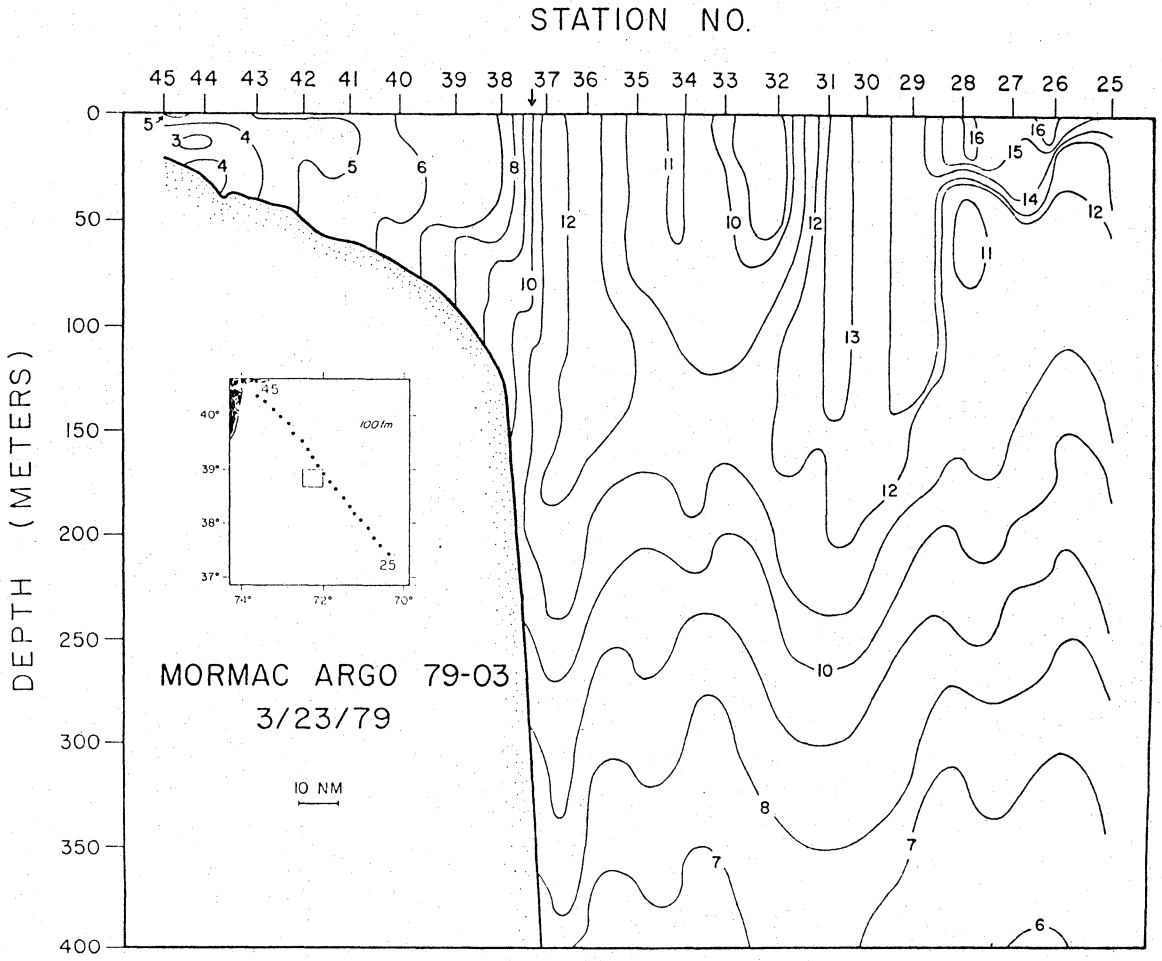

Figure 5. Second temperature (°C) transect collected by "Mormac Argo", 23 March 1979.

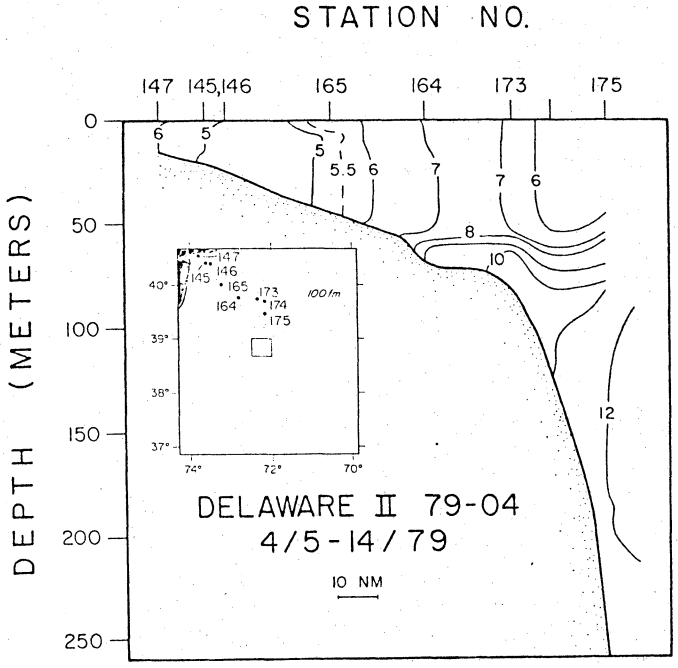

Figure 6. April temperature (°C) transect collected by RV "Delaware II", 5-14 April 1979.

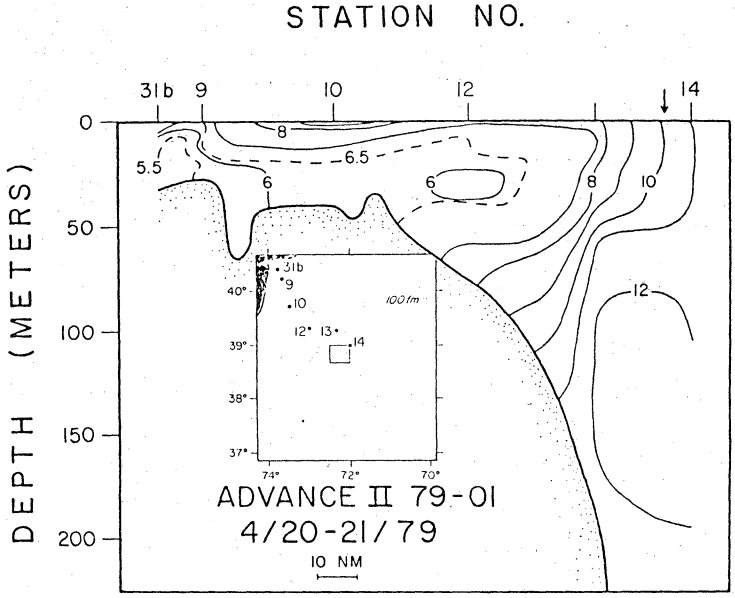

Figure 7. Second April temperature (°C) transect collected by RV "Advance II", 20-21 April 1979.

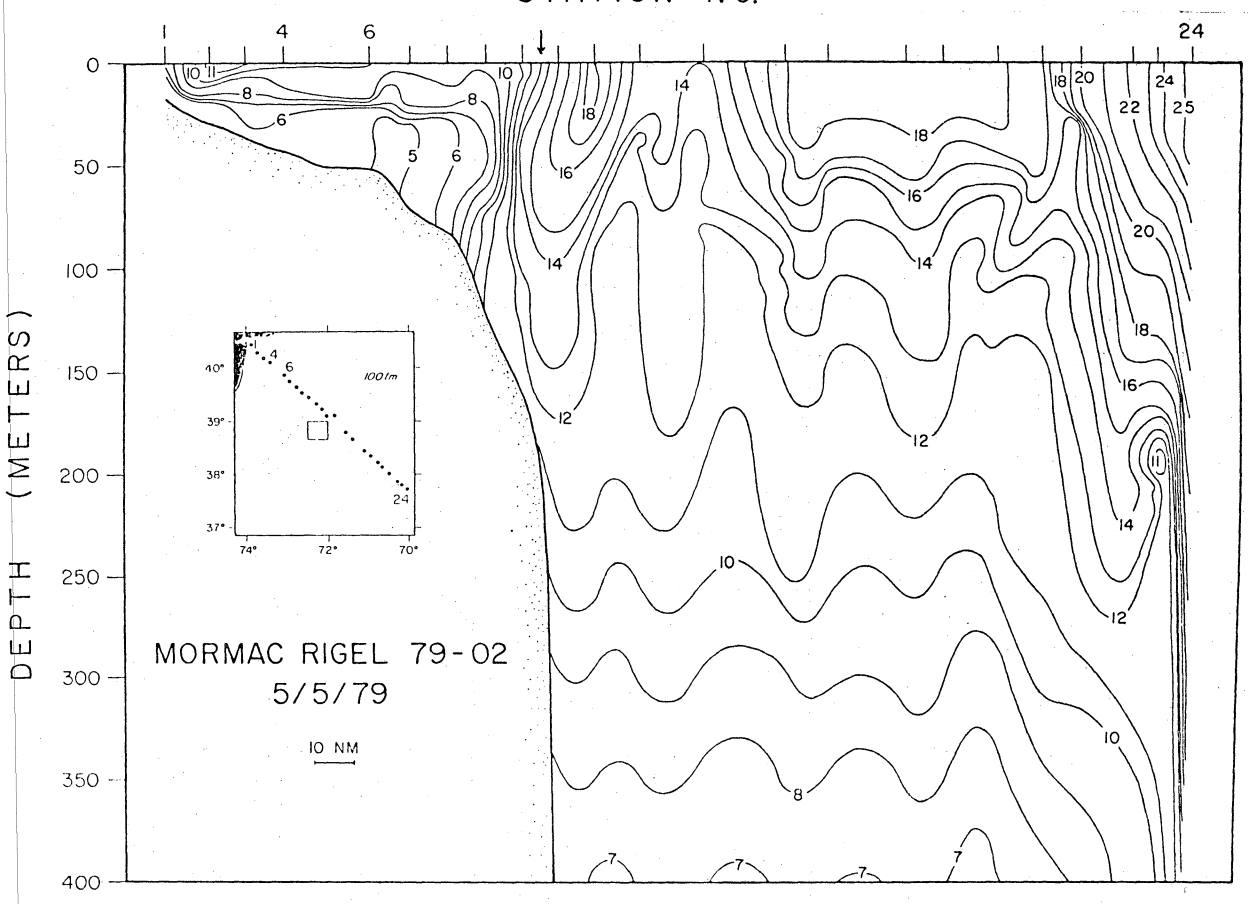

Figure 8. May temperature (°C) transect collected by "Mormac Rigel", 5 May 1979.

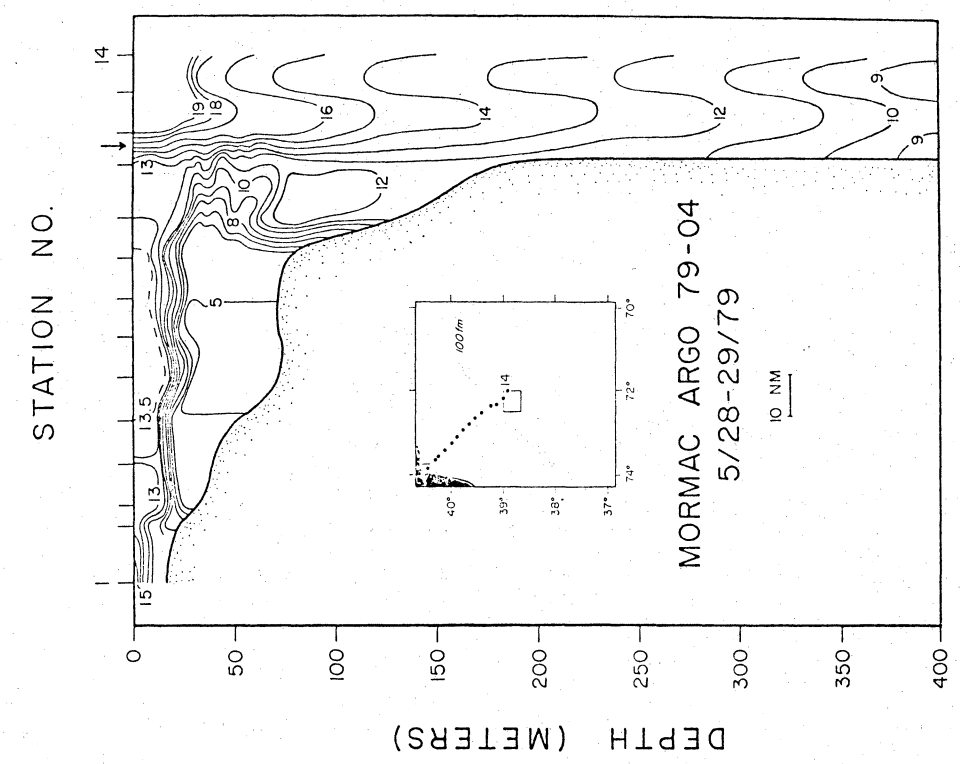

Figure 10. Third May temperature (°C) transect collected by "Mormac Argo", 28-29 May 1979.

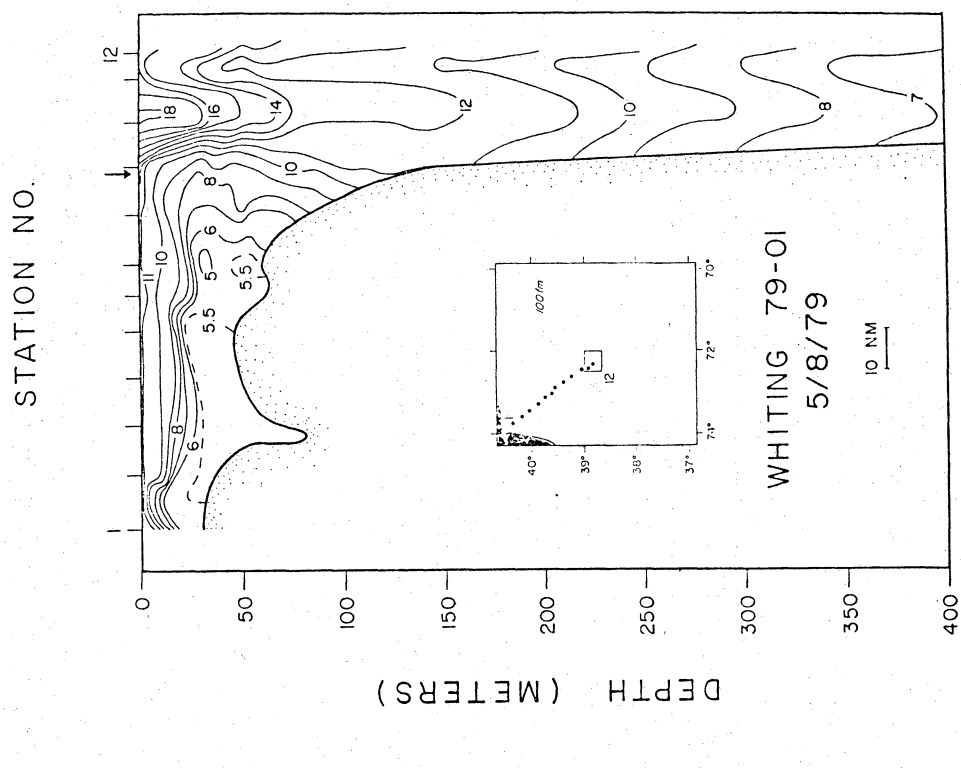

Figure 9. Second May temperature (°C) transect collected by "Whiting", 8 May 1979.

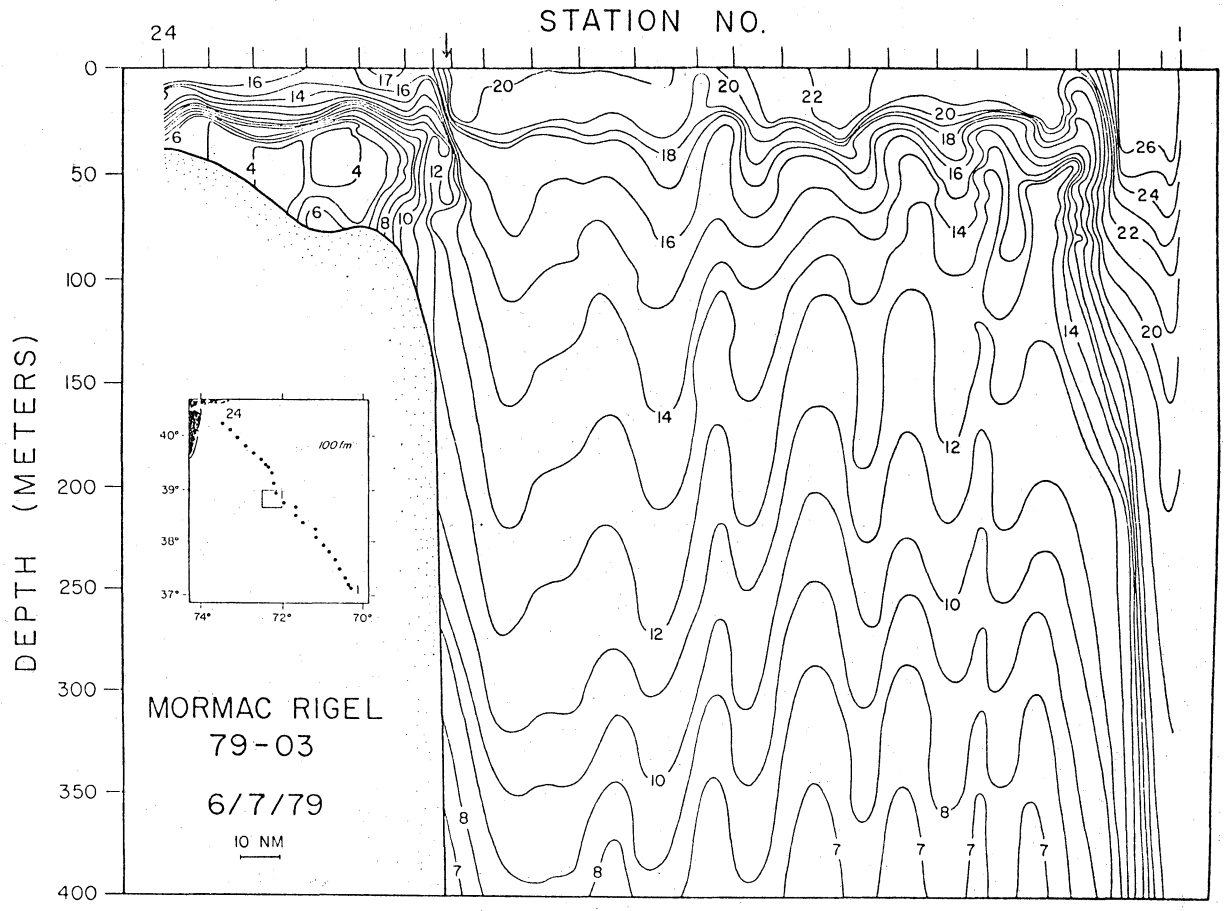

Figure 11. June temperature (°C) transect collected by "Mormac Rigel", 7 June 1979.

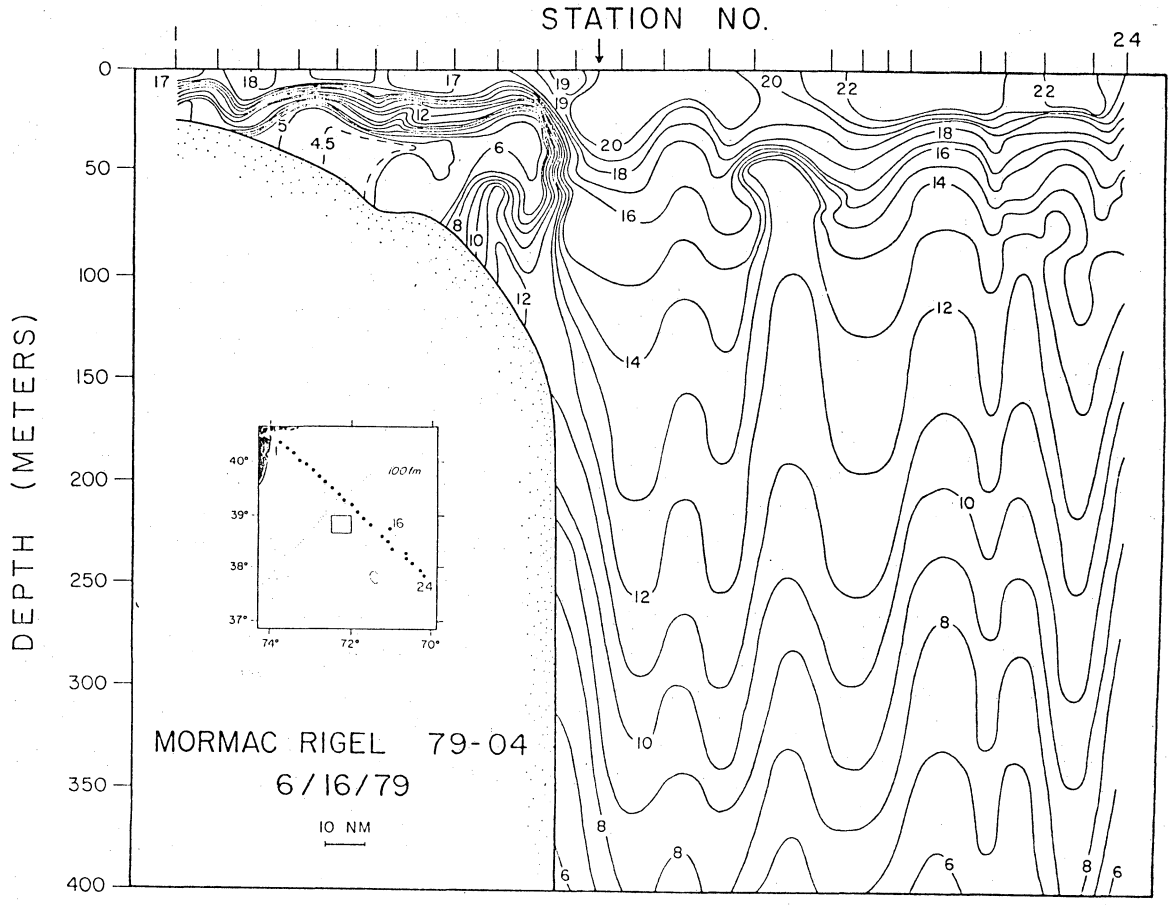

Figure 12. Second June temperature (°C) transect collected by "Mormac Rigel", 16 June 1979.

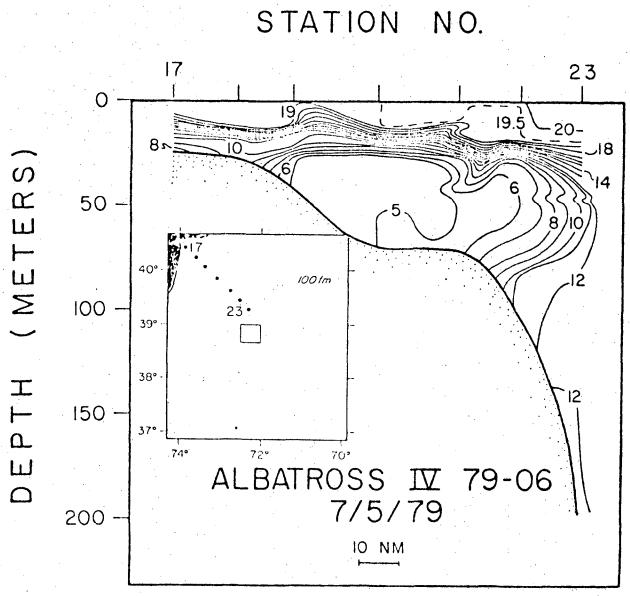

Figure 13. July temperature (°C) transect collected by RV "Albatross IV", 5 July 1979.

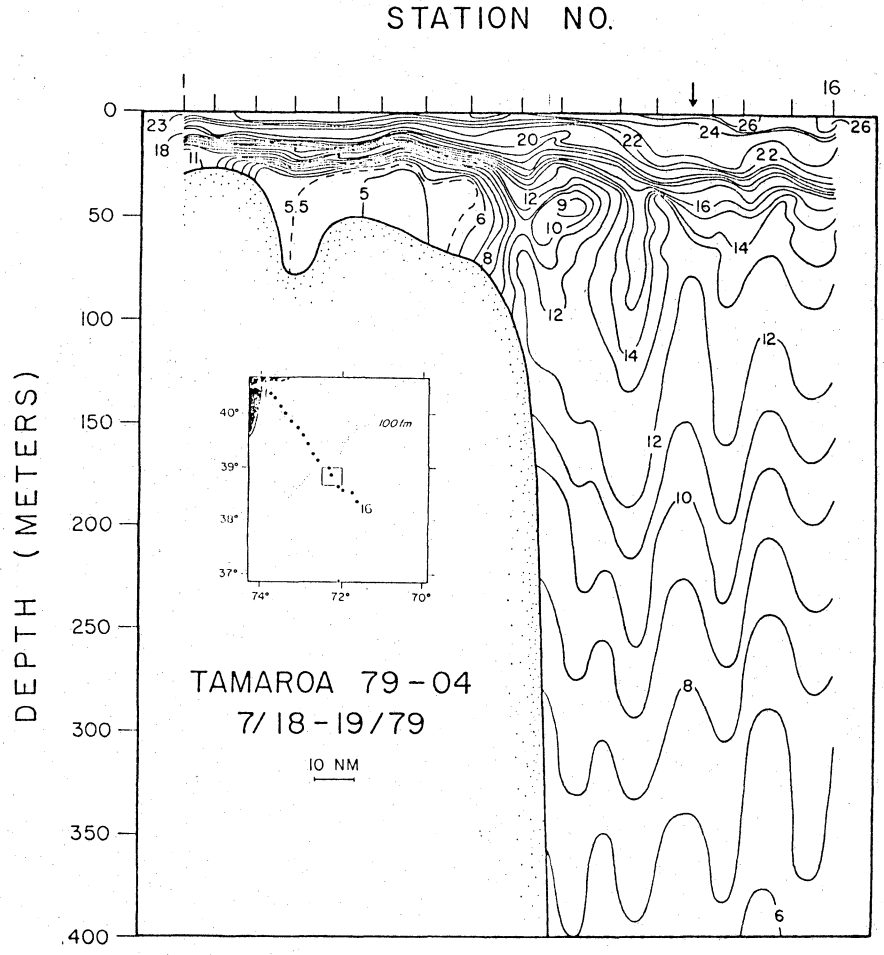

Figure 14. Second July temperature (°C) transect collected by USCGC "Tamaroa", 18-19 July 1949.

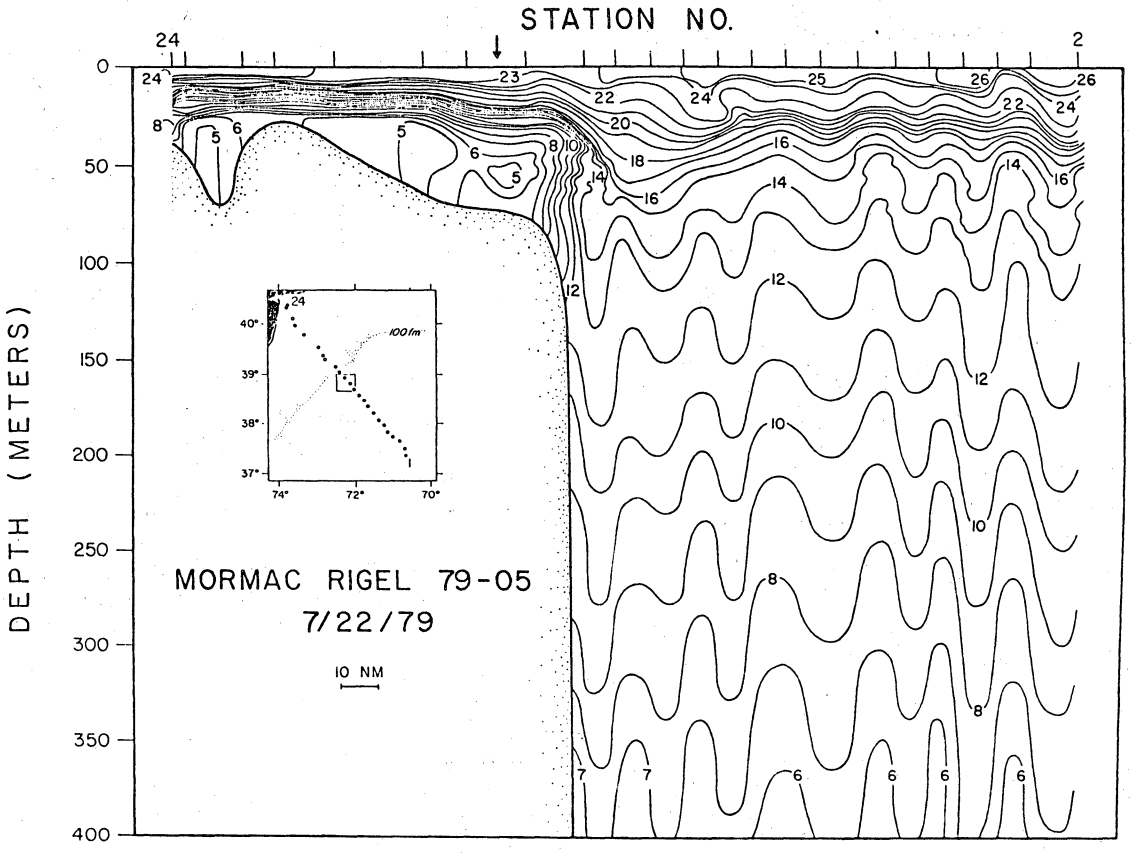

Figure 15. Third July temperature (°C) transect collected by "Mormac Rigel", 22 July 1979.

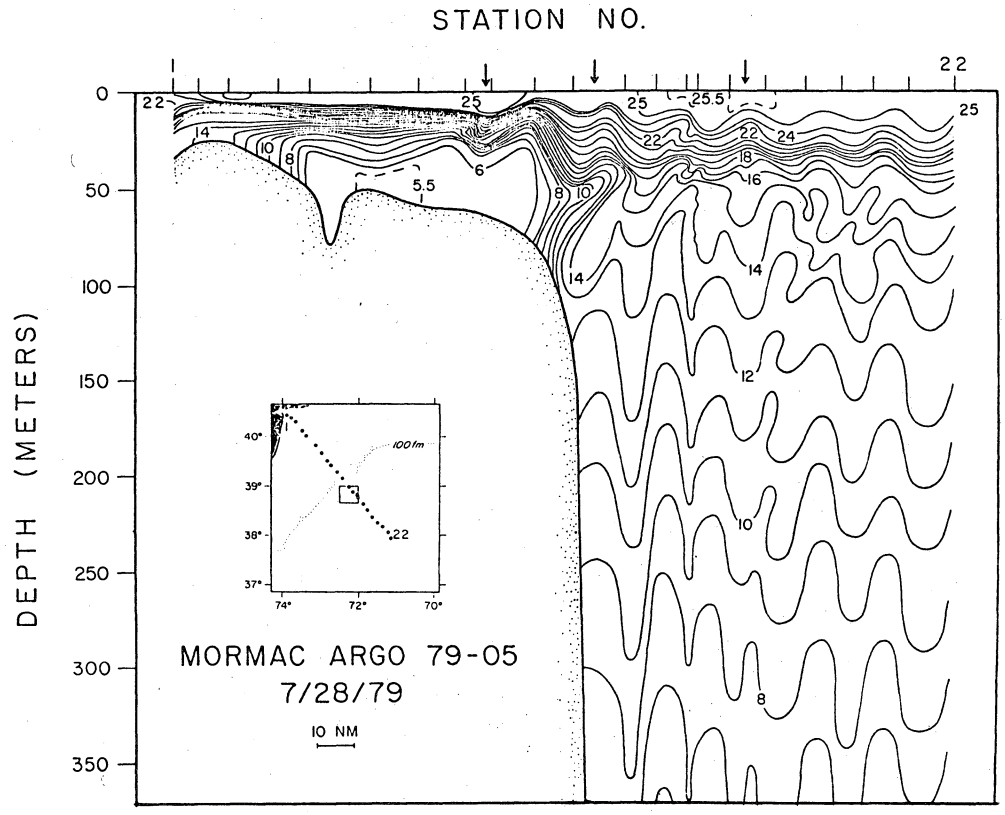

Figure 16. Fourth July temperature (°C) transect collected by "Mormac Argo", 28 July 1979.

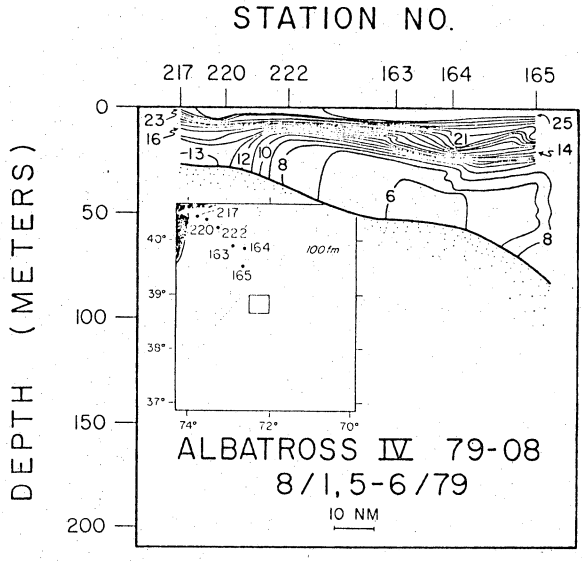

Figure 17. August temperature (°C) transect collected by RV "Albatross IV", 1, 5-6 August 1979.

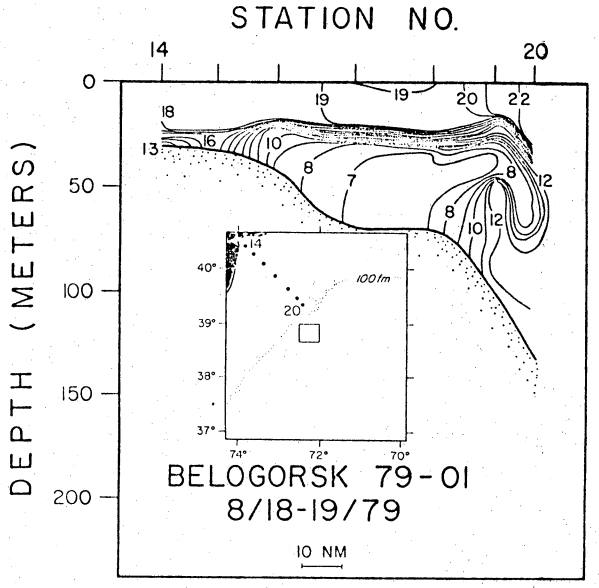

Figure 18. Second August temperature (°C) transect collected by "Belogorsk", 18-19 August 1979.

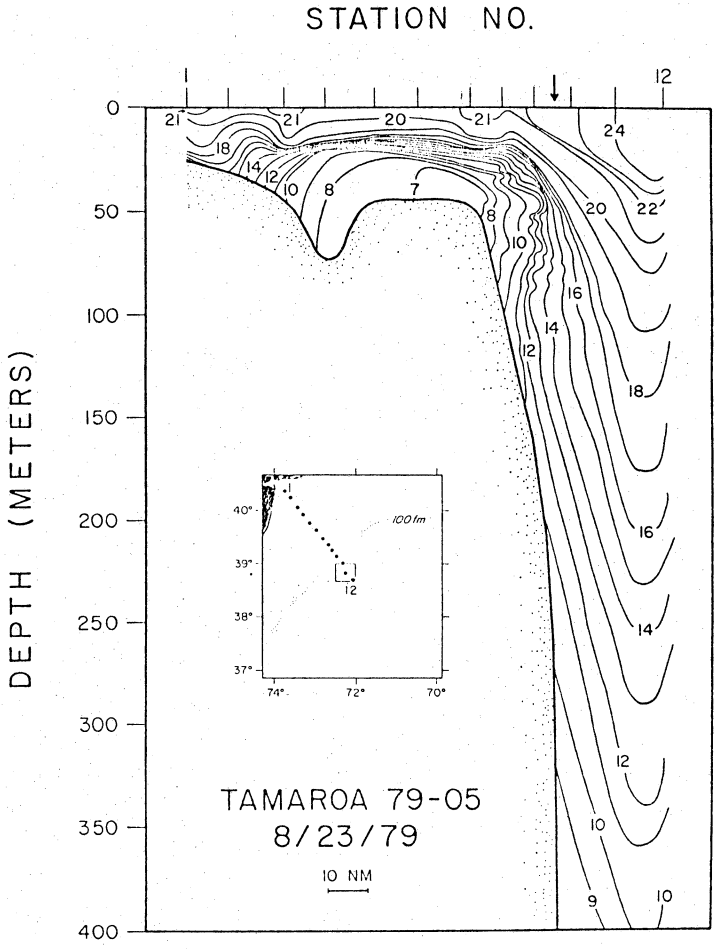

Figure 19. Third August temperature (°C) transect collected by USCGC "Tamaroa", 23 August 1979.

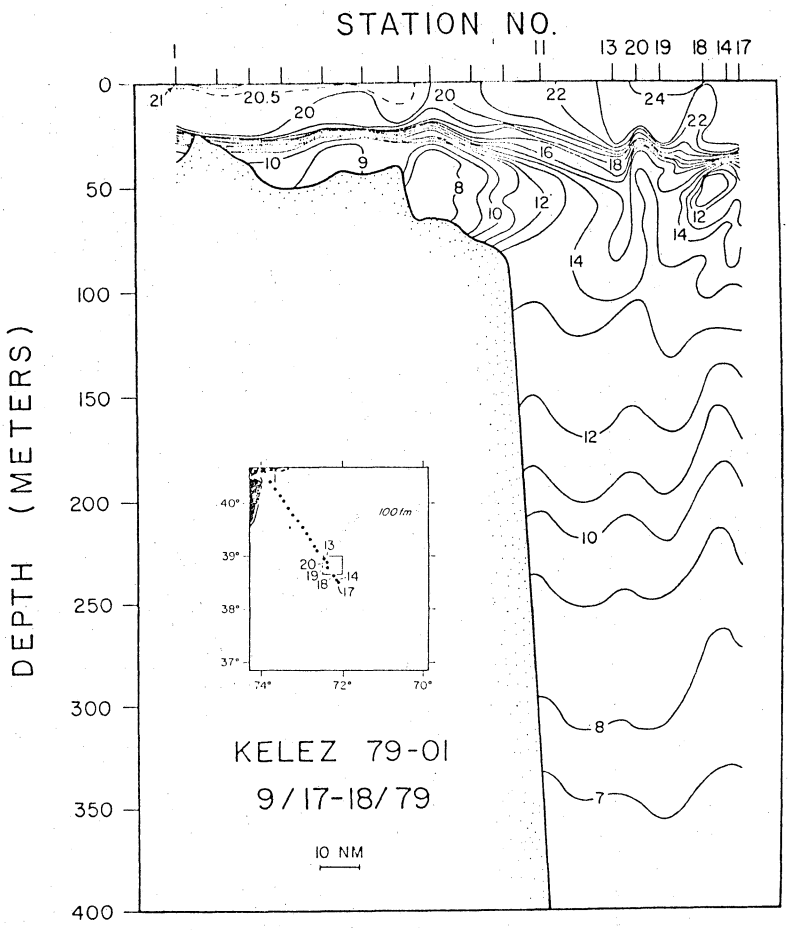

Figure 20. September temperature (°C) transect collected by RV "Kelez", 17-18 September 1979.

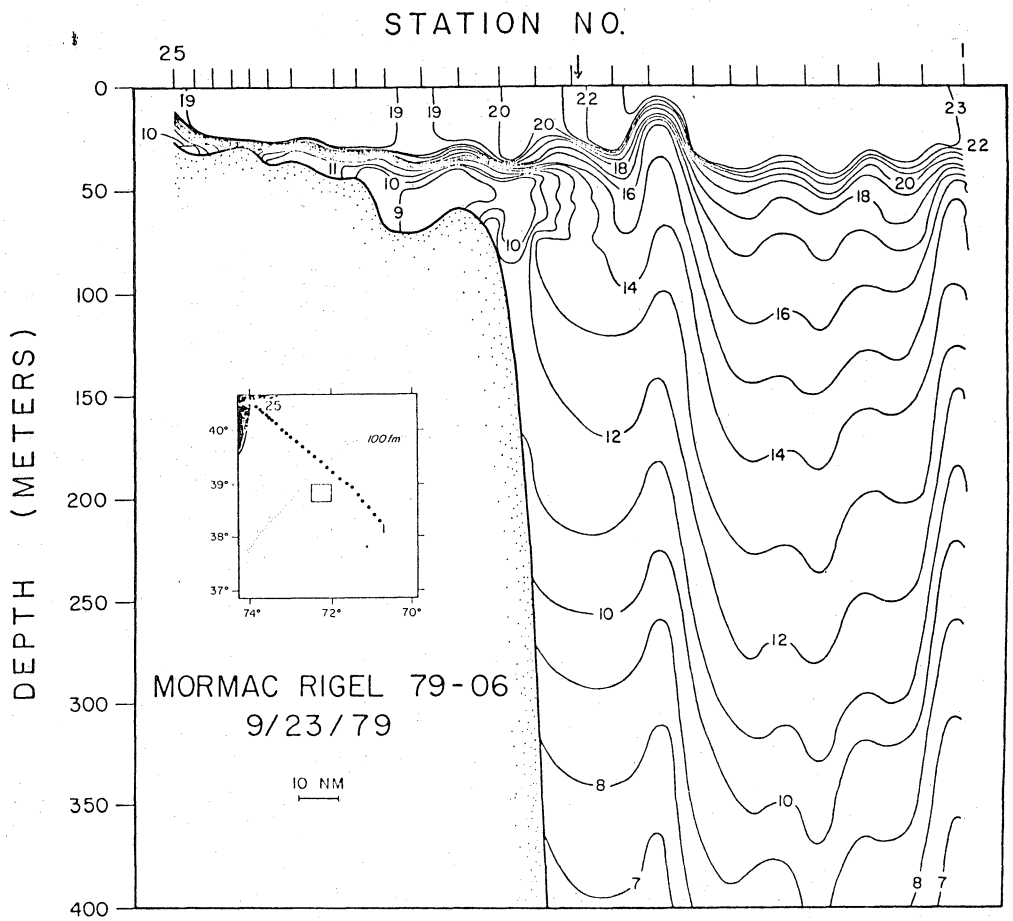

Figure 21. Second September temperature (°C) transect collected by "Mormac Rigel", 23 September 1979.

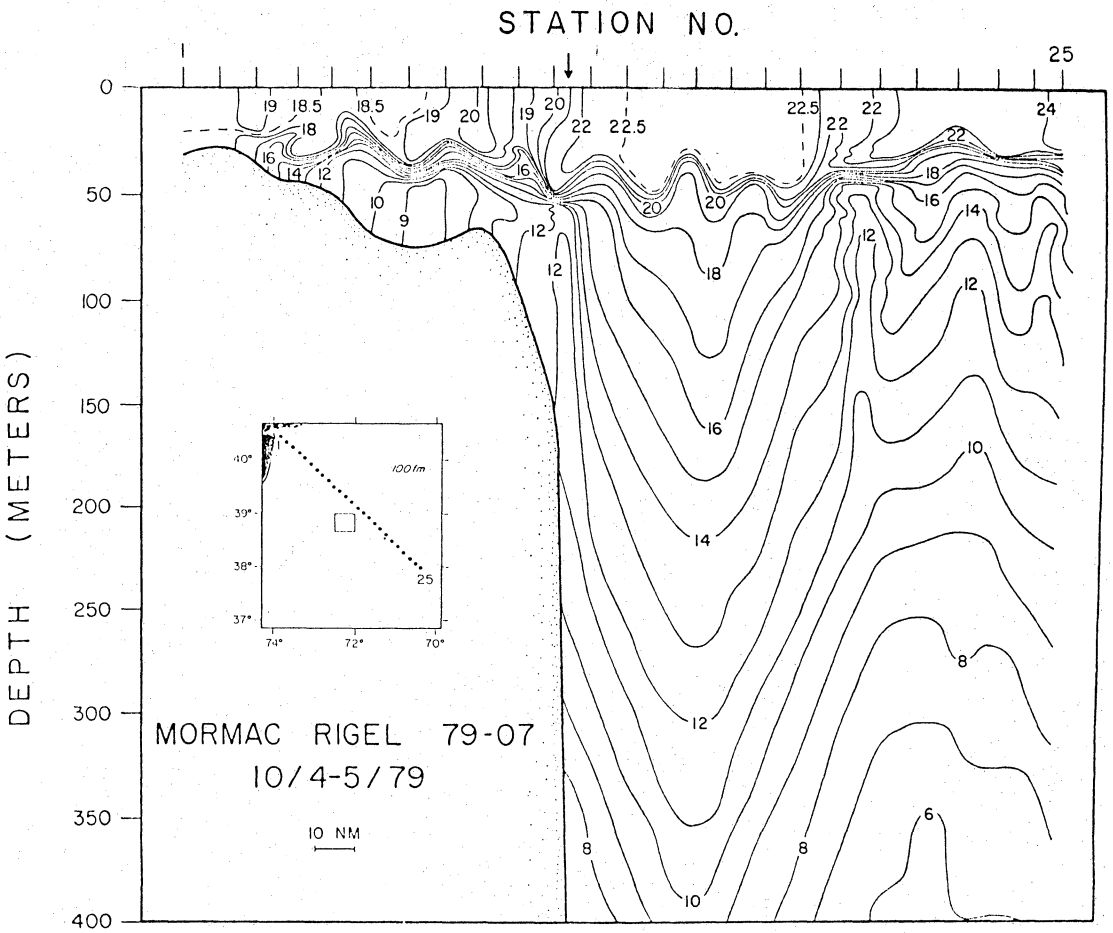

Figure 22. October temperature (°C) transect collected by "Mormac Rigel", 4-5 October 1979.

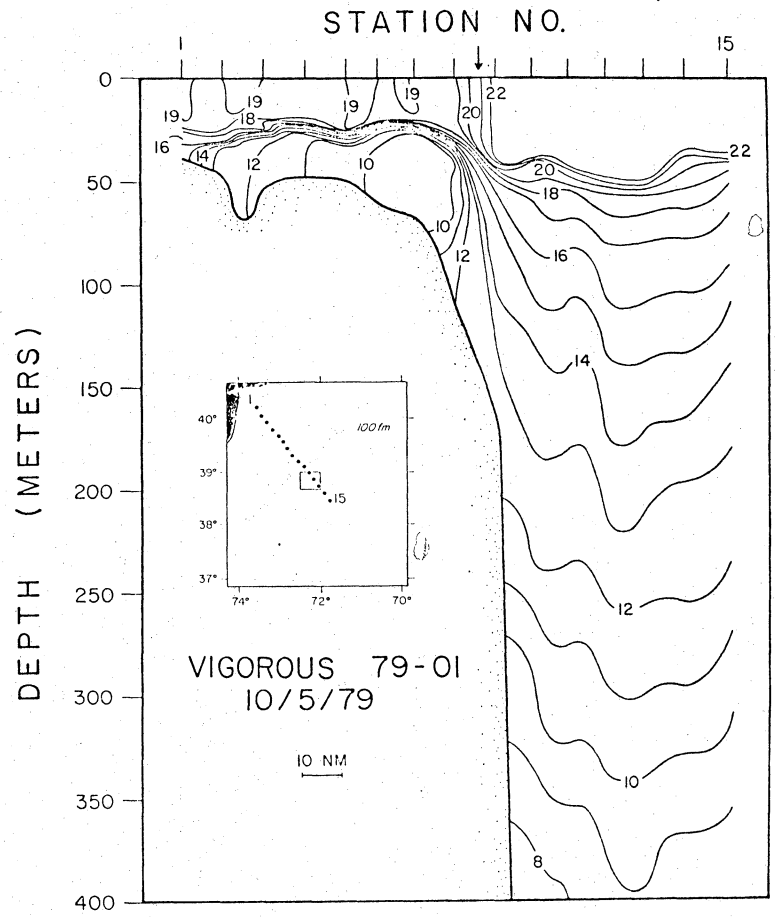

Figure 23. Second October temperature (°C) transect collected by "Vigorous", 5 October 1979.

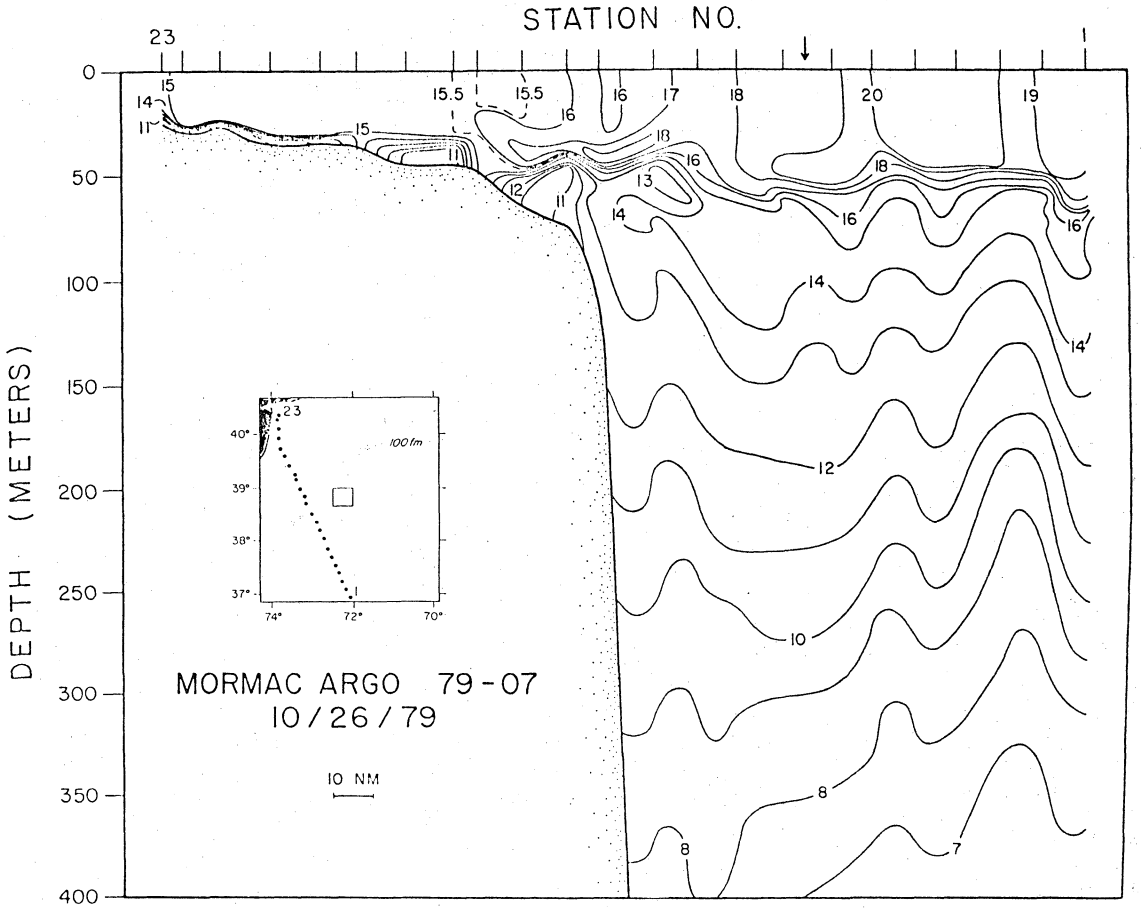

Figure 24. Third October temperature (°C) transect collected by "Mormac Argo", 26 October 1979.

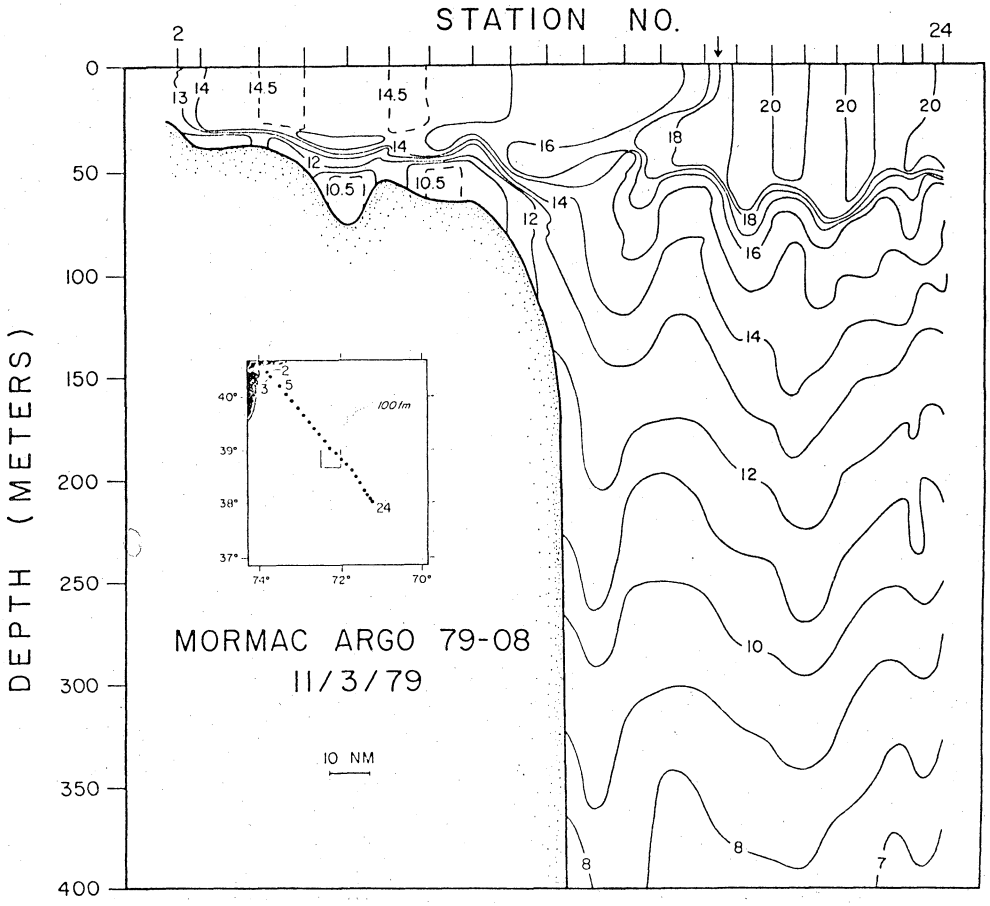

Figure 25. November temperature (°C) transect collected by "Mormac Argo", 3 November 1979.

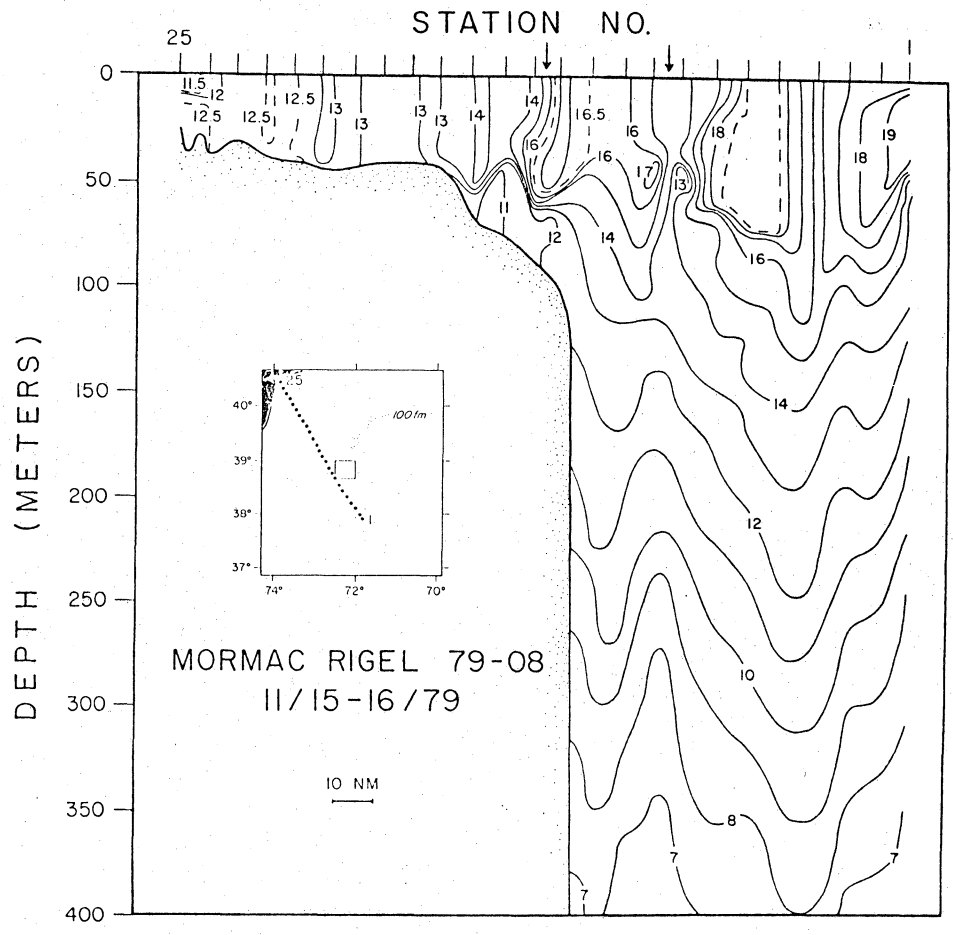

Figure 26. Second November temperature (°C) transect collected by "Mormac Rigel", 15-16 November 1979.

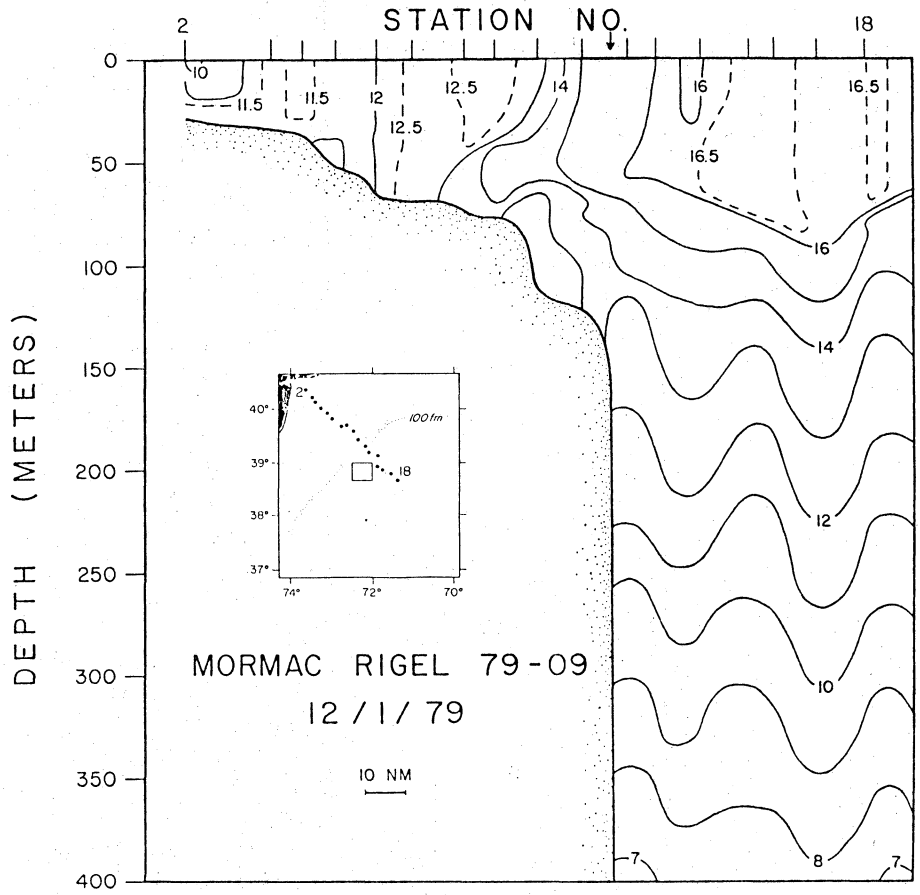

Figure 27. December temperature (°C) transect collected by "Mormac Rigel", 1 December 1979.

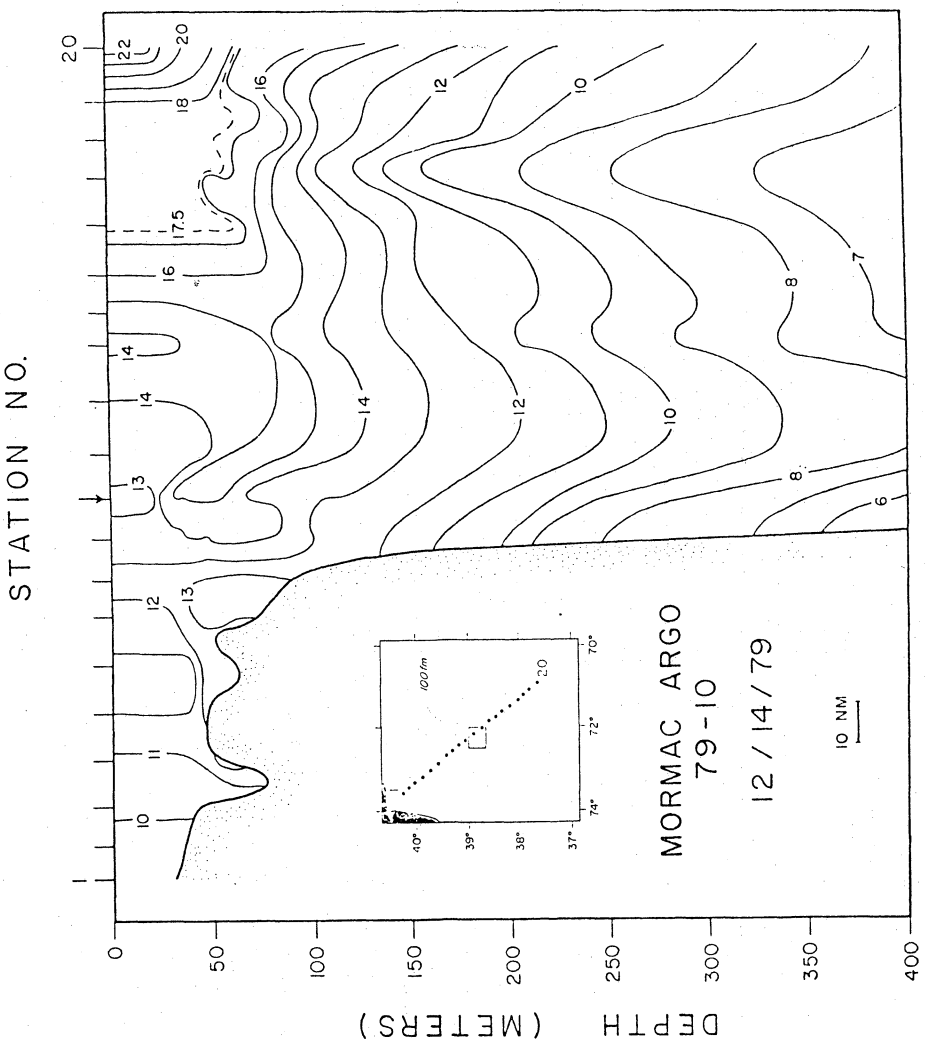

Figure 29. Third December temperature (°C) transect collected by "Mormac "Argo", 14 December 1979.

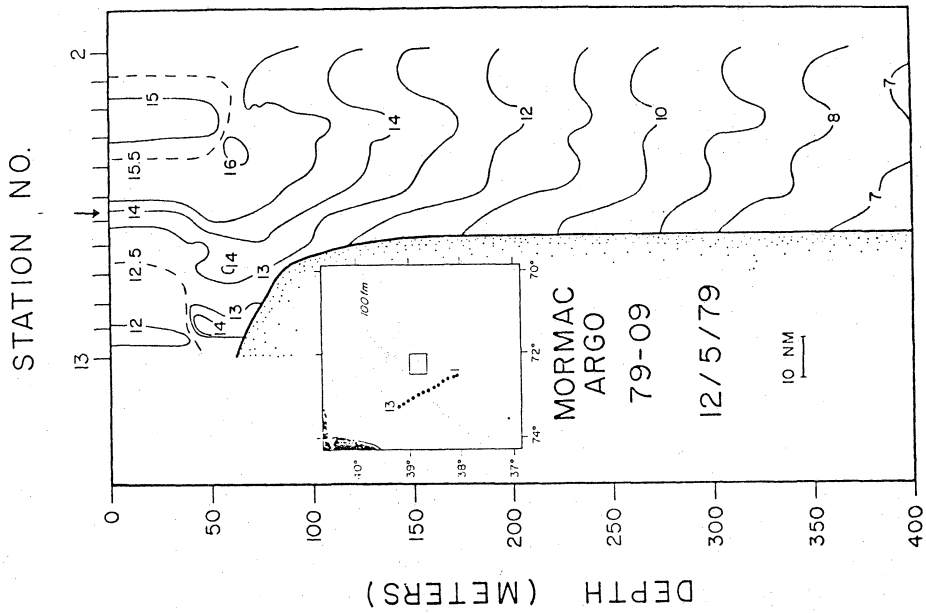

Figure 28. Second December temperature (°C) transect collected by "Mormac Argo", 5 December 1979.