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HYDROGRAPHIC STUDY OF THE SHELF AND SLOPE WATERS OF NEW YORK BIGHT

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ABSTRACT

This report presents results obtained from three oceanographic cruises made by the Marine Sciences Research Center during 1970 and 1971 to investigate the physical characteristics of the shelf and slope waters of New York Bight.

The existence of a sharp temperature-salinity front over the continental slope was confirmed during the months of June 1970 and April 1971. Associated with this front is a subsurface warm tongue delineated by a temperature maximum which intersects the edge of the shelf at a depth of about 150 meters.

Data obtained in August 1971 showed no evidence of any temperature front over the slope but suggested the existence of an irregular salinity gradient in this region.

Three factors appear to be important in the dynamics of the formation and dispersion of the subsurface warm tongue over the continental slope. These are the existence of the temperature-salinity front and the associated convergence zone, the meanderings of the Gulf Stream and the creation of warm eddies, and the intrusion of Labrador water into the Bight.

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INTRODUCTION

This technical report represents the results of three research cruises undertaken by the Marine Sciences Research Center to study the waters of the continental shelf and slope of New York Bight. The first cruise, 7010, June 1-6, 1970, was aboard the R/V MANNING, a 65-foot T-boat belonging to the Columbia University School of Mines. The second cruise, 7101, April 2-16, 1971, was made on the R/V UNDAUNTED, a 140-foot converted ocean-going tug operated by the Cape Fear Technical Institute, Wilmington, North Carolina. The third cruise, 7102, August 5-21, 1971, was also on the R/V UNDAUNTED.

This report is concerned only with the hydrographic survey in New York Bight. Useful information pertaining to nutrient distributions in the near coastal regions of Long Island Sound, New York Harbor and vicinity, and the New Jersey shoreline was gathered under the direction of M. G. Gross and C. D. Hardy on the cruises and will be reported elsewhere.

Patterns for the three cruises are displayed in Figure 1. The numbers refer to the stations detailed later. Some stations have been omitted from the chart either because they were located too far from the sections or because no relevant data were taken. Of particular interest on each cruise was the oceanic front near the edge of the continental shelf. This boundary between the shelf and slope waters, not to be confused with the north wall of the Gulf Stream, is extremely variable in space and time. Its characteristics vary considerably between summer and winter, and one aim of the cruises was to gather pertinent data at different seasons of the year.

OBSERVATIONAL METHODS

Observational equipment aboard the R/V MANNING consisted of a submersible pump which could be lowered to a maximum of 50 meters for delivery of a continuous flow of water of up to 0.6 liter sec^{-1} (10 gal. min^{-1}). A thermistor fastened to the pump assembly provided *in situ* temperature measurements which were traced on a strip chart recorder. Included in the onboard instrument package were a conductivity bridge salinometer (Bissett-Berman Model 6230), an oxygen meter (Yellow Springs Instrument Co. Model 54), and a thermometer for measuring the water sample temperature as it passed through the laboratory equipment.

Facilities aboard the R/V UNDAUNTED made it possible to upgrade the instrumentation to include measurements of chlorophyll by fluorescence, or alternatively, turbidity by optical absorbance. The water fed into the instruments could be derived either from the submersible pumping system while on station or from a continuous source of near surface water (3.5 meters) from the ship's sea water intake. The latter arrangement allowed continual sampling of the sea surface properties between stations.

The submersible pump was improved by the attachment of a simple depth sounder to the pump assembly. In this manner the distance between the pump and the sea floor could be accurately monitored. This made it possible to sample very close to the bottom, yet insured that the pump was not made inoperative by sucking in sediments.

The surface water data was supplemented by the use of a Salinity, Temperature, Depth (STD) recorder with a depth range of 350 meters (Bissett-Berman Model #9060), loaned by the Cape Fear Technical Institute. Unfortunately a faulty sealing caused flooding of the electronics during the cruise; however, much useful information was obtained before the mishap.

The measuring apparatus for the August cruise was basically the same as for the April one; the STD was unavailable but a continuous-flow salinometer (Bissett-Berman Model #6600T) was added. This allowed continuous measurement of both surface temperature and salinity and provided data on step-like horizontal salinity gradients across the summer oceanic front.

An attempt was made to offset the loss of the STD recorder for deep sampling with the addition of an experimental on-deck jet pump lifting water through 212 meters of 1.9 cm I.C. plastic hosing. One station was made with this apparatus but friction in the hose reduced the flow to less than .06 liter sec^{-1} (1 gal. min^{-1}), which represented a flushing time of around ten minutes. Difficulty in retrieving the hose was encountered and it was decided to postpone use of the system pending further development.

CRUISE 7010 STATION OBSERVATIONS

Leg 1

Stations 1 through 9, shown in Figure 1, were made by working continuously for a 26-hour period to obtain a detailed temperature-salinity section across the shelf off New Jersey. Properties were measured approximately every 5 meters down to a depth of 50 meters. A single station (10) was also made near the center of the continental shelf (see Figs.1 and 5).

On a bearing of 126° from Atlantic City, New Jersey, the surface salinity increased gradually until a sharp increase between stations 7 and 8 indicated a front between shelf and slope water. This was investigated by continuing to station 9, only to find that the temperature and salinity decreased. Unfortunately low fuel reserves necessitated a return to port. Station 8 may have represented an anomolous bolus of slope water or a meander of the front.

Figures 2, 3, and 4 display the temperature, salinity, and sigma-T sections for the cruise.The surface sigma-T of stations 7, 8, and 9, 24.11, 24.08, and 24.00 respectively, showed little variation. Figure 5 is a temperature-salinity plot of all the data obtained.

It appeared that the deeper waters (20-50 meters) fell into two categories. On the shelf, the bottom waters had a salinity near 32.2 o/oo with a temperature between 5° and 8° C. Off the shelf the waters between 25 and 50 meters ranged in salinity between 33.2 and 34.0 o/oo with a temperature range between 10° and 11° C. Station 6 represented a transition between the bottom shelf water and the slope water.

The results confirm the existence of cold water on the continental shelf in June. The transition to slope water between 25 and 50 meters is very rapid (only station 6 is in the transition zone). A very steep increase in temperature and salinity was encountered between stations 7 and 8; however, the decrease to station 9 indicates that the main oceanic front was not crossed.

The temperature versus depth profiles have been supplemented by data obtained from the U.S. Naval Oceanographic Office which dropped expendable bathythermographs (XBTs) from the Cunard liner HMS FRANCONIA on the New York-Bermuda crossing every few days, and thus provided valuable spatial-temporal data on a straight line across the oceanic front and the Gulf Stream (Fig. 6).

Figure 7 shows temperature contours obtained on FRANCONIA cruise 118-70, May 29-30, 1970, two days before MSRC cruise 7010 and some distance to the north (compare Figs. 1 and 6). Figure 7 confirms the spillout of cold shelf water to the southeast and the presence of the warm bolus near station 54. The north wall of the Gulf Stream can be clearly observed intersecting the surface between stations 48 and 49. A disruption of the steep temperature gradient of the north wall occurs between depths of 75-100 meters and may represent a source of the warm water tongue (labeled temp. max.). The temperature maximum which defines the core of the tongue intersects the shelf at a depth of approximately 150 meters. The warm Gulf Stream core with a maximum temperature in excess of 28° C is centered at a depth of 50 meters at station 36.

Figure 8 displays the temperature structure (isotherms) found one week later on FRANCONIA cruise 119-70. The intersection of the north wall of the Gulf Stream with the surface was crossed 53 kilometers farther southeast than during cruise 118-70. The presence of the temperature maximum and the spillover of cold shelf water can clearly be seen.

CRUISE 7101 STATION OBSERVATIONS

Temperature and salinity data were obtained in April by two transects of the continental slope, the first from Montauk Point, N.Y. on a heading 155° (leg 2, stations 38-51), and the second to New York Harbor on a heading of 305° (leg 3, stations 51-85). Measurements showed the existence of a sharp slope (oceanic) front, and confirmed the presence of downwelling of warm saline water associated with this convergence zone. This tongue then appeared to slide under the colder, yet less dense slope water until it intersected the continental slope at approximately 200 meters.

Leg 2

Figures 9, 10, and 11 display the effect of the downwelling obtained from the data of leg 2.

The temperature profile in Figure 9 appears to have a fairly uniform structure with no disruption of the contours on the slope. This contrasts with results obtained from summer data, when the occurrence of a strong thermocline coupled with the underlying layer of cold (7°C) shelf water led to a complicated mixing structure near the top of the slope (see section on cruise 7102).

The high salinity tongue displayed in Figure 10 corresponds in position to the temperature maximum but has a slightly more complex structure with a low salinity patch of water (less than 35.3 o/oo) entrapped within itself. Note the patch of high salinity water (35.5 o/oo) at 110 meters found at station 44.

The sigma-T plot of Figure 11 illustrates the monotonic increase in density downwards which implies stability relative to vertical mixing process. It is difficult to assess whether this downwelling is a slowly varying phenomenon, since the motions may be drastically altered by large-scale advective processes and meanders of the front. The density of surface shelf water decreases near stations 38-40. This is due to the runoff of cold, fresh water from the continent, especially that carried by the Hudson River.

The T-S plot of Figure 12 illustrates the mixing processes. The open circles show the simple mixing of brackish and slope water to produce shelf water. The straight line represents the mixing line at 5 meters depth across the shelf and the slope front. The T-S coordinates for stations 41 through 46 all lie within the dotted circle. The points are shown this way to avoid cluttering. The line through the open square is the T-S trend for North American Basin water, and was obtained from a vertical temperature-salinity profile outside the oceanic front at station 51 (38°33.8'N, 70°22.0'W). The third phenomenon of interest is the distribution of temperature and salinity along the temperature maximum. All these points lie within the dotted circle shown in the figure. The cooling vector is calculated by computing the change in salinity by evaporation associated with a change in temperature for surface waters overlain by saturated air. Water cooled by exchange of heat and water vapor at the surface will fall along this line. Thus the water of the maximum, if formed by this process, originally had a surface temperature of 13.6°C and salinity of 35.4 o/oo.

Leg 3

Figure 13 displays the isotherms along the section of leg 3 (stations 51-85). The area with no data resulted from the failure of the STD recorder, discussed earlier. Again the temperature maximum is evident and rises to the surface between stations 51 and 52. Note the cold patch at station 58. The slope front intersects the surface near station 52.

The complex salinity structure on the slope is evidenced in Figure 14. Here the complementary salinity maximum appears to have broken up into a series of patches of salinity extrema. Figure 15 shows the sigma-T variations along the leg. It appears that the horizontal isopycnals may be folded around station 60 due to meandering of the water mass. Typical New York Harbor sigma-T values of 15.0 are seen in the vicinity of stations 84 and 85.

The mixing line across the shelf on leg 3 is displayed superimposed on Figure 12, showing that the characteristics are very similar to leg 2. The appropriate FRANCONIA data for this period are shown in Figure 16 and illustrate a strong temperature maximum with a core temperature reaching 14°C and intersecting the shelf at 160 meters. Figure 17 shows the isotherms observed six days later slightly north and parallel to those shown in Figure 16. The core of the temperature maximum reaches 13.5°C as it intersects the surface at station 31.

CRUISE 7102 STATION OBSERVATIONS

Four transects were made across the shelf during this cruise (legs 4 through 7). In addition a detailed survey was made of the entrance to New York Harbor.

Leg 4

Figure 18 illustrates vertical isotherms taken starting from the Battery (off the end of lower Manhattan) out to station 88. For clarity some of the station numbers have been left off the master cruise plan (Figure 1). The main features of Figure 18 are a sloping thermocline near shore caused by warming of shallow coastal waters, a strong thermocline farther from shore, and an anomalous patch of colder water between stations 74 and 78.

This latter feature shows up in the vertical isohalines of Figure 19 as a patch with salinity less than 29 o/oo. Note the strong salinity gradient near shore and the absence of a strong halocline offshore. Figure 20 graphs the isopycnals and demonstrates that the pycnocline is dominated by the thermocline right across the section. The horizontal isopycnals between stations 74 and 78 rule out the possibility of continuing upwelling leading to the cold patch shown in Figure 18. The inherent stability in the water column is described in more detail in Figure 21. Stations 66, 78, and 80 represent three stations which were placed inshore, in the middle of, and seaward of the patch. The diagram shows the surface gradient in temperature and salinity going seaward (sigma-T = 20 to 21) and the common bottom shelf water at the intersection of the three mixing lines with sigma-T $>$ 25.0.

Figure 22 shows the patch in more detail from surface isotherms. (The station positions are indicated in Figure 24).

A year-long survey of the area shown in Figure 22 has been made by the Sandy Hook Marine Laboratory (Walford, 1970). They found that the patch exists at the head of the Hudson Channel and is present throughout the year.

The patch has the interesting property of being cooler than the surrounding water during summer, and warmer than its surroundings through the winter. It appears that there are seasonal currents along the Hudson Channel which exhibit themselves at its landward end in these anomalous patches. It would be fruitful to investigate these currents in more detail at a future date,especially since large amounts of sewage sludge are dumped in this region.

It is interesting to note a periodicity in the surface temperature shown in Figure 22. Near the northern tip of Staten Island the temperature reaches 23°C but drops to 21°C about 8 miles down harbor. The temperature increases again to 23°C between Sandy Hook and Rockaway Point. Southeast of the cold patch the water warms again to 23°C. The wavelength of this periodicity is consistent with the interpretation that this structure is formed by the advection of Hudson River water of temperature 21°C onto the shelf by tidal oscillations in New York Harbor.

A T-S diagram at a depth of 3.5 meters for New York Harbor is presented in Figure 23. For this purpose the area has been divided up into five regions illustrated in Figure 24. The points were selected from local maxima and minima taken at regular intervals from the continuous surface record of the salinograph.

The contribution of the five regions is clearly shown in Figure 23 which indicates the transition from Harbor to shelf water. The two mixing lines intersect in the center of the cold patch. Regions IV and V are essentially isopycnal.

Figure 25, 26 and 27 display the water characteristics along leg 4 from stations 87 to 95. Spillover of shelf bottom water can be noticed in Figure 25 and a temperature maximum underlies the thermocline at about 75 meters. The absence of a sharp temperature front should be noted.

A gradual increase in surface salinity is accompanied by a transition from a horizontal to a vertical salinity gradient between stations 88 and 90. A weak salinity maximum (core salinity 35.5 o/oo) coincides in position with the temperature maximum. Excepting the area labelled "no data" the values were obtained by Nansen bottle casts below 50 meters. (Bathythermograph drops were taken for stations 88 and 89 illustrated in Fig. 25.)

Figure 27 illustrates the transition from shelf to ocean water as evidenced by the rising to the surface of the sigma-T = 21, 22 isopycnals.

Continuous surface (3.5 meters) temperature and salinity measurements taken along leg 4 (Fig. 28) show the absence of any significant temperature gradients but the slow increase in salinity, punctuated with numerous inversions in traversing the shelf and slope. Note the decrease in salinity after stations 93-94.

Leg 5

Data were obtained to depths of only 55 meters on leg 5. The isotherms in Figure 29 are similar in character to those plotted in Figure 25 for leg 4, suggesting the spillover of shelf water onto the slope, and the strong thermocline between 10 and 25 meters. Likewise the salinity plot of Figure 30 is very similar to that of Figure 26 in the common regions. Figure 31 illustrates sigma-T contours for the leg.

The continuous surface (3.5 meters) temperature and salinity of leg 5 shown in Figure 32 exhibit more complex behavior, with the surface temperature dipping to 22° C at station 100. The salinity shows a general increase seaward with a series of sharp local extrema evident especially near stations 98 and 99. Again the salinity decreases near the seaward end of the record. Figure 33 is a T-S diagram which illustrates mixing of surface shelf and slope waters on legs 4 and 5. The mixing of the surface shelf water is shown by lines at the top of the diagram (closed and open circles). A vertical profile (triangles) taken at station 95 shows the transition from surface to North American Basin water (Wright and Worthington, 1970). The spillover of bottom shelf water (closed squares) contributes to the shape of the vertical profile at station 95 as shown by the mixing line between sigma-T = 25 and 26. The data do not indicate the source of the salinity maxima observed at 25 meters.

Leg 6

Figure 34 taken from bathythermograph studies on leg 6 again shows the spillover of cold shelf water and the disruption of the strong shelf thermocline near station 122. No salinity data were gathered on this leg. The continuous surface (3.5 meters) temperature and salinity graph of Figure 35 confirms the absence of any thermal front but exhibits again the gradual increase in salinity seawards. Note the step-like nature of the transition due to alternating regions of low and high horizontal salinity gradients.

Leg 7

No station data were gathered on this leg. Figure 36 again shows the absence of any significant temperature gradients, but a very steep salinity front can be detected followed by a region of small gradient inshore, except for a patch of relatively saline water near the end of the leg (position A).

Two FRANCONIA temperature sections are available for August 1971 (the period covered by cruise 7102). Figure 37 exhibits all of the features previously discussed. A well developed ocean thermocline overlies the spillover of bottom shelf water and the region of subsurface warm water centered at 125 meters. Regions of local temperature maxima are numerous and make it difficult to trace the source of this water. A cold eddy with core temperature less than 10° C can be seen centered at a depth of about 60 meters at station 63.

An even more complex structure was found 8 and 9 days later (Fig. 38). The upper face of the warm water mass interacted with the strong thermocline to produce the contours displayed. A cold intrusion of 11° C water pinched off the seaward end of the warm water mass and again makes difficult any interpretation of the source of this water mass. No evidence exists in either Figure 37 or 38 of any horizontal surface temperature gradients.

DISCUSSION

It is of historical interest to note that the existence of the subsurface warm water mass has been known for almost 100 years. Various temperature measurements of the slope waters of New York Bight have been documented by Bigelow (1915).

In 1882 Verrill found the bottom shelf water to be decidedly colder than the previous year and no trace was found of the warm belt between 150-200 meters. Associated with the disappearance of the belt was the extraordinary mortality, by the millions, of the tilefish (Lopholatilus chamaeleonticeps) which inhabits this warm subsurface water. Reduced almost to extinction by this tragic kill, tilefish gradually increased in numbers until in 1917 about 11.5 million pounds were taken commercially (Bigelow and Schroeder, 1953; McHugh, 1972).

The seasonal variations of temperature and salinity have been extensively described by Bigelow (1933) and Bigelow and Sears (1935) respectively. Their reports covered the area from Cape Cod to Chesapeake Bay and clearly show the persistence of the temperature and salinity maxima in New York Bight. Ketchum and Corwin (1964) studied the continental shelf waters south of Montauk Point, Long Island and found the bottom shelf waters to remain cold throughout the year. They were able to correlate average shelf salinities with the runoff from the Connecticut River.

Measurements obtained by Volkman and Moore (1972) at Site D ($39^{\circ}10'$N, $70^{\circ}00'$W, see Fig. 6), which is a fixed hydrographic station at the outer edge of the continental slope, have shown the occasional intrusion of cold meanders from the Labrador current. These intrusions could account for a periodic disappearance of the warm belt.

Further useful sources of information pertaining to the hydrography of New York Bight are listed as supplementary references at the end of this report.

CONCLUSIONS

The cruises have provided some insight into the dynamic processes involving the seasonal movement of the waters of the continental shelf, especially with regard to the spillover of shelf waters onto the slope and the mixing of fresh, shelf, slope, and North American Basin waters.

The results of the three cruises discussed in this report have confirmed the existence of a temperature-salinity front over the continental slope during April and June. The position and intensity of the front is extremely variable as can be confirmed by comparison with those surface isotherms published by the U.S. Coast Guard Oceanographic Unit which extend far enough out to sea. The August cruise results show the absence of a significant temperature front but the existence of a gradual irregular salinity gradient across the continental slope.

Three mechanisms appear to be important in the dynamics of the subsurface temperature maximum underlying the slope waters. The first is the temperature-salinity front and the associated convergence zone and downwelling of slope waters. The second phenomenon is the meanderings of the north wall of the Gulf Stream and creation of warm eddies which drift southwestward along the continental slope through New York Bight (U.S. Naval Oceanographic Office, 1970). A third factor is the possible intrusion of Labrador water into the region and the resultant dispersal of the warm belt.

It is clear that much more data will be needed to gain full insight into the detailed hydrography of this complex region of the coastal Atlantic Ocean.

ACKNOWLEDGEMENTS

The authors wish to extend their thanks to the Columbia University School of Mines for the use of the R/V MANNING, and to the Cape Fear Technical Institute, North Carolina, for use of the R/V UNDAUNTED and the STD recorder. The operation of the UNDAUNTED was funded by the Office of Sea Grant, National Oceanographic and Atmospheric Administration, U.S. Department of Commerce.

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The FRANCONIA data were kindly supplied by Mitchell K. Shank, Jr. of the U.S. Naval Oceanographic Office, Washington, D.C.

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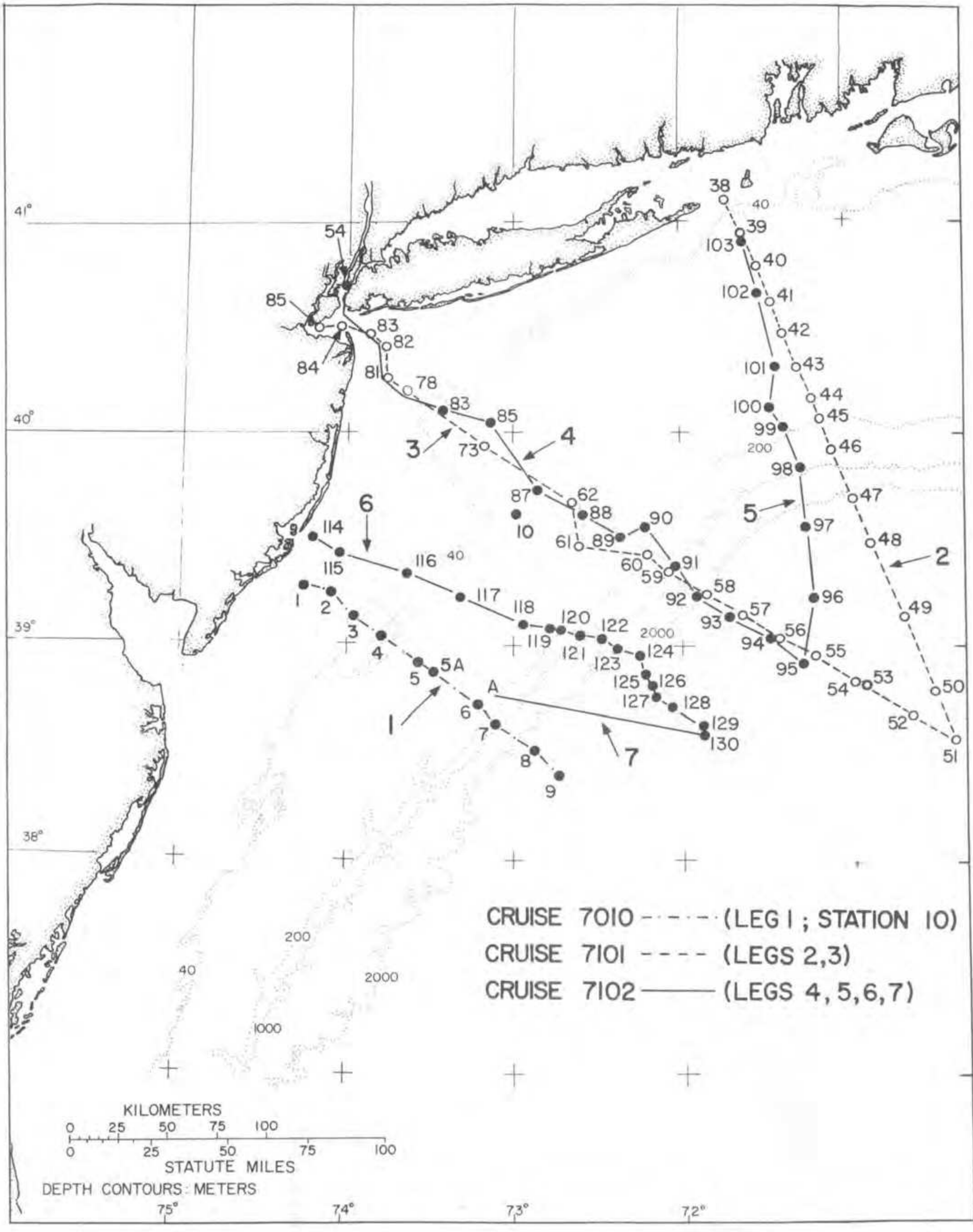
CRUISE 7010 (LEG 1 ; STATION 10)
CRUISE 7101 (LEGS 2,3)
CRUISE 7102 (LEGS 4, 5,6,7)
KILOMETERS
0 25 50 75 100
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STATUTE MILES
DEPTH CONTOURS: METERS
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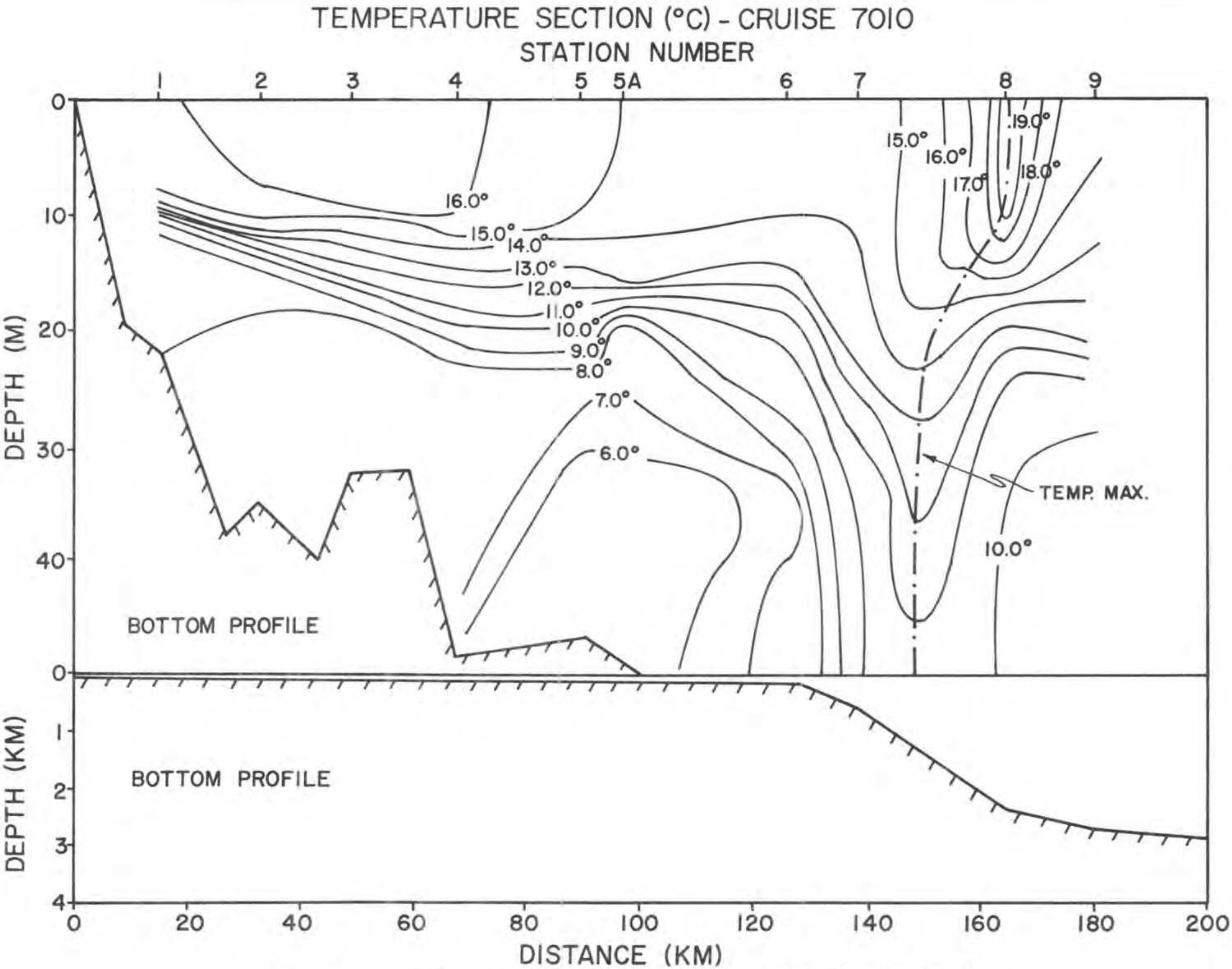


Fig. 2. Temperature section, Leg 1, June 4-5, Cruise 7010.

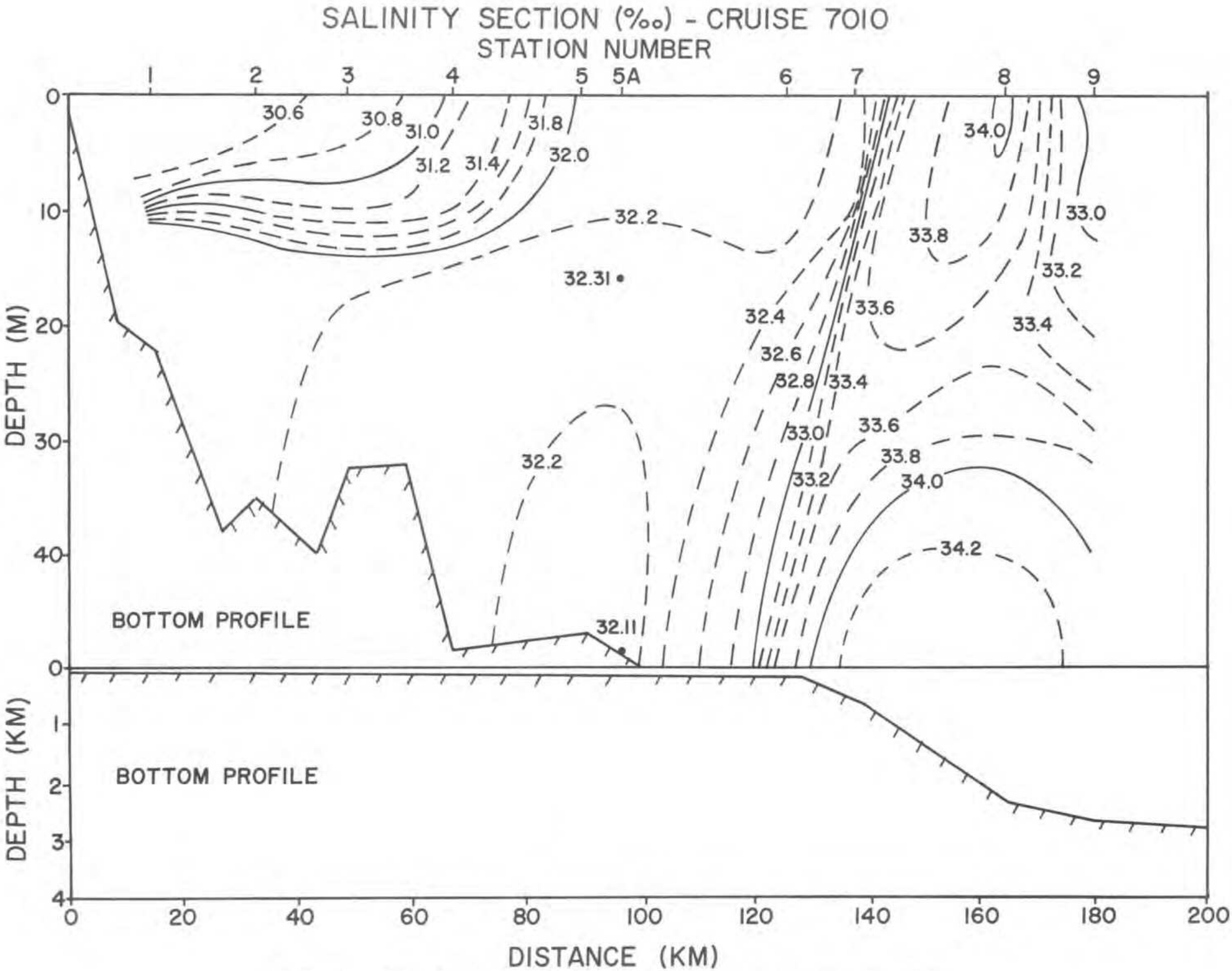


Fig. 3. Salinity section, Leg 1, June 4-5, Cruise 7010.

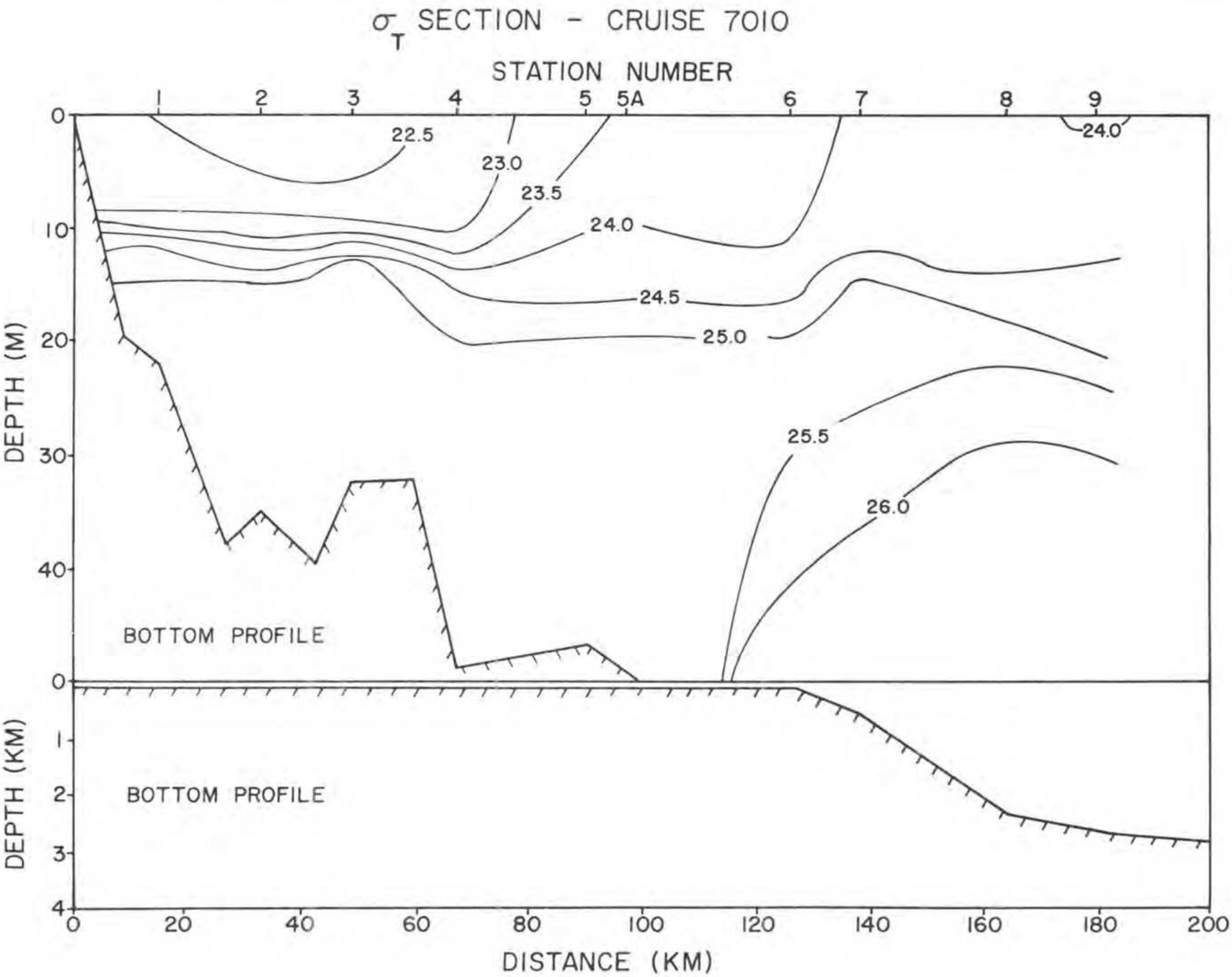


Fig. 4. Sigma-T section, Leg 1, June 4-5, Cruise 7010.

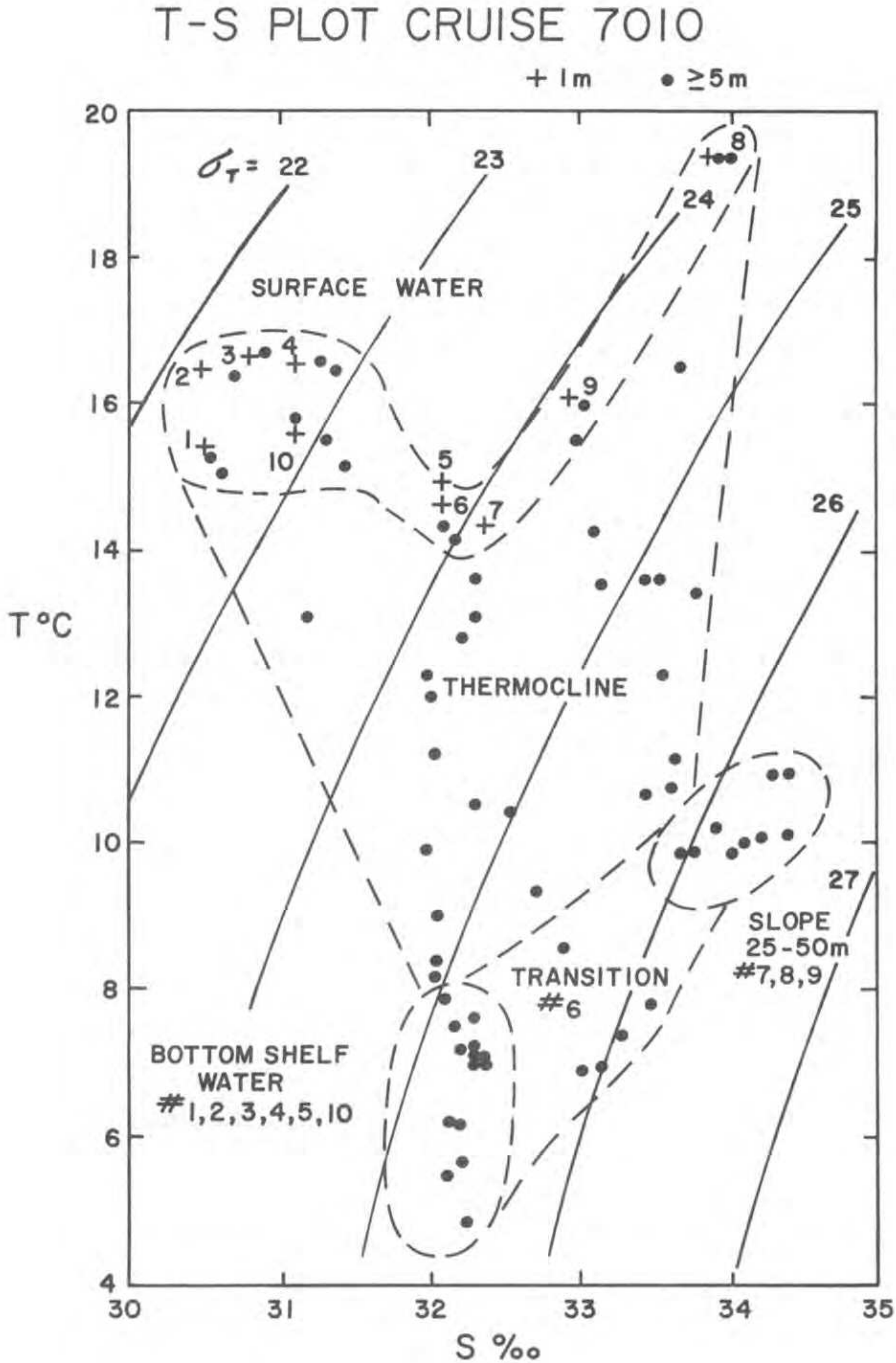


Fig. 5. Temperature-salinity plot, June 4-5, Cruise 7010.

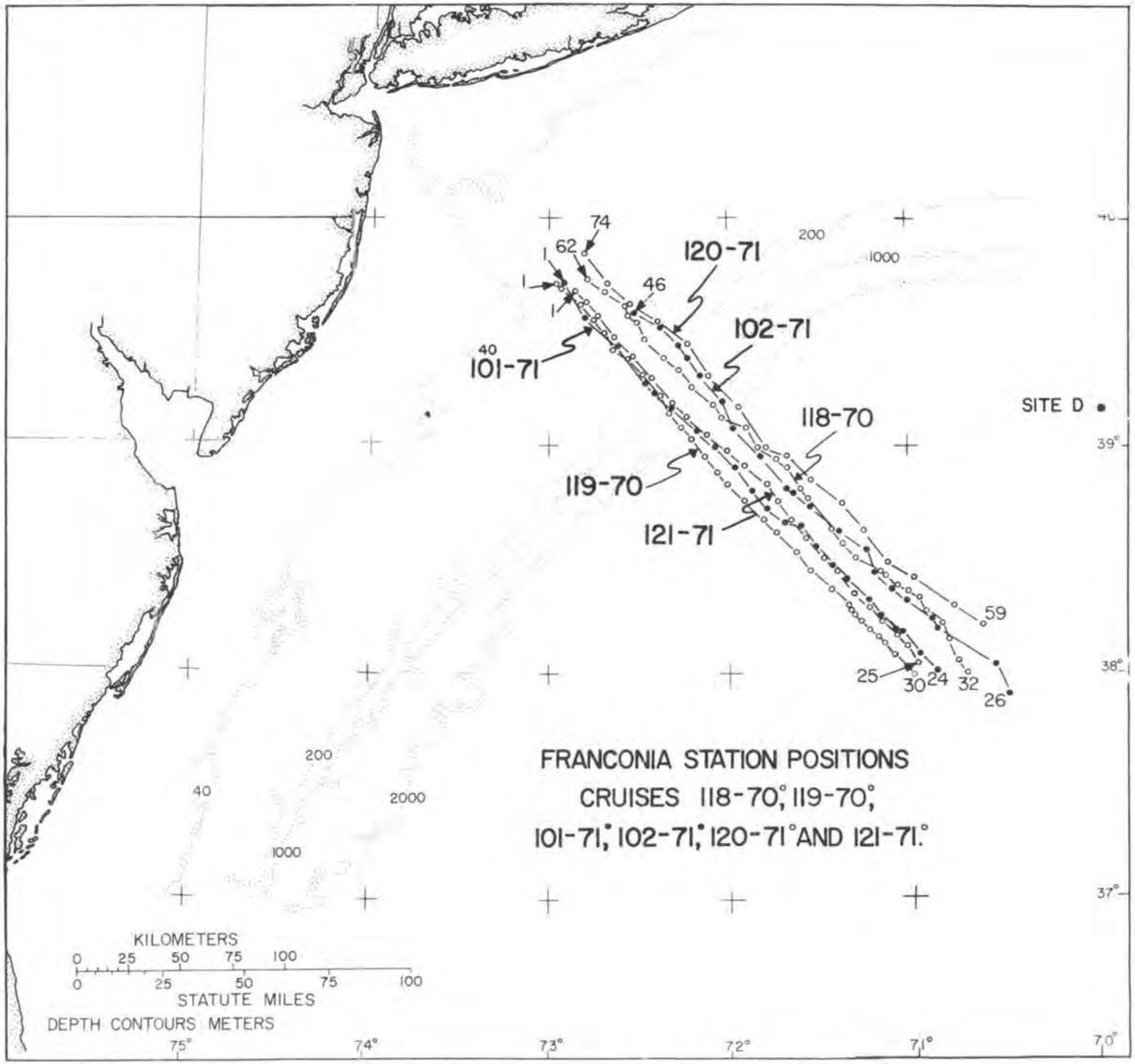


Fig. 6. Franconia station positions.

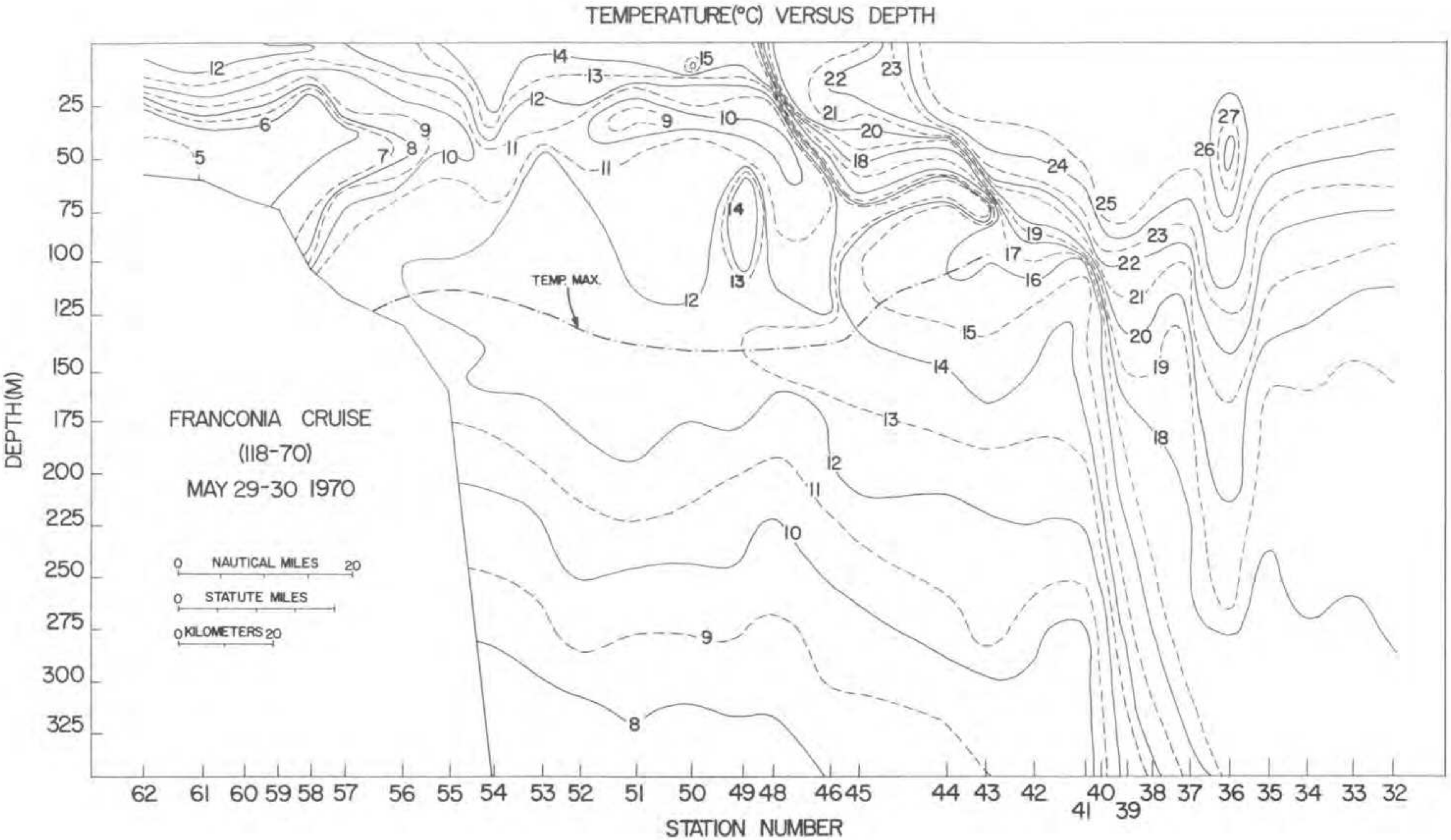


Fig. 7. Temperature versus depth, Franconia cruise 118-70.

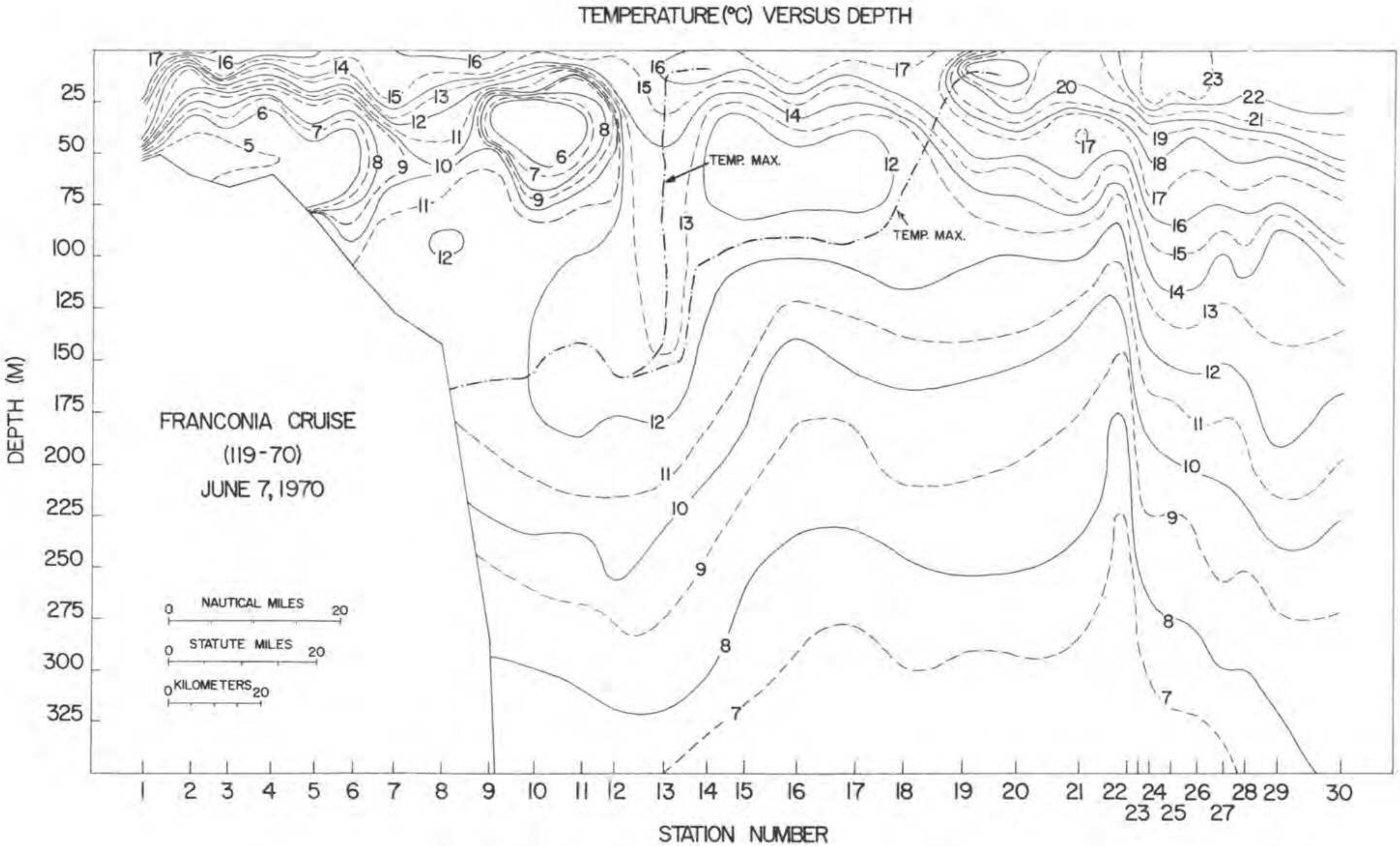


Fig. 8. Temperature versus depth, Franconia cruise 119-70.

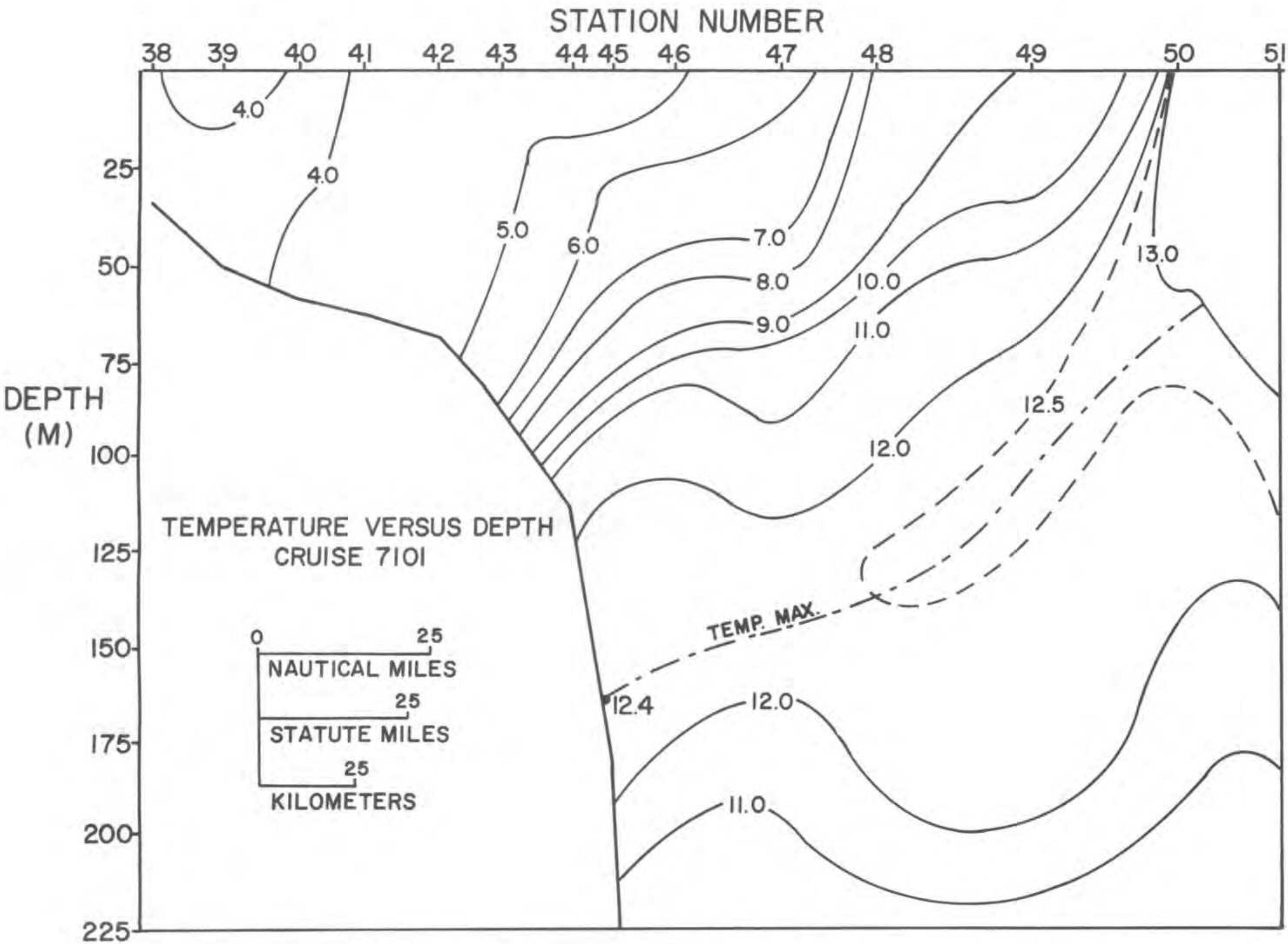


Fig. 9. Temperature versus depth, Leg 2, April 12-13, Cruise 7101.

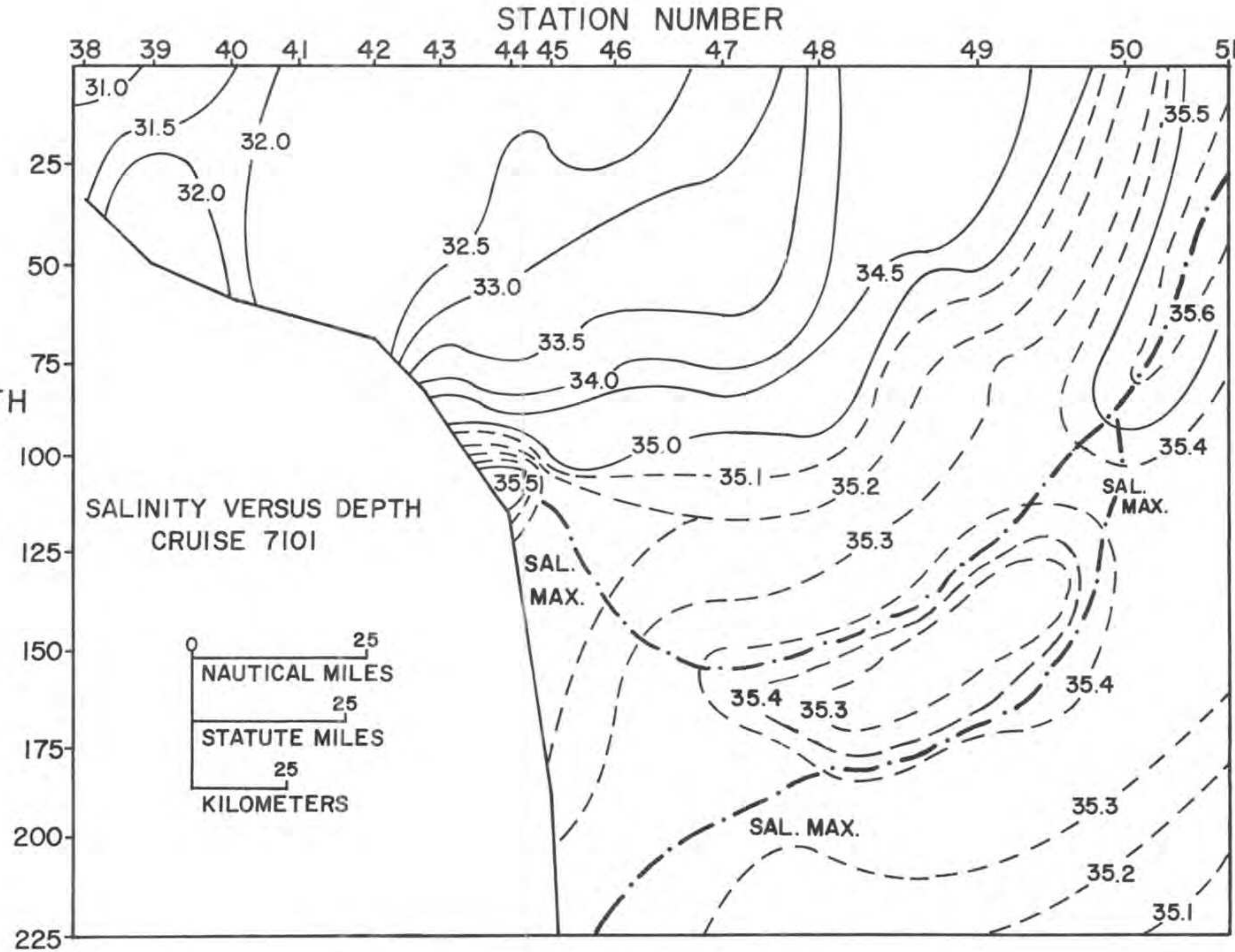


Fig. 10. Salinity versus depth, Leg 2, April 12-13, Cruise 7101.

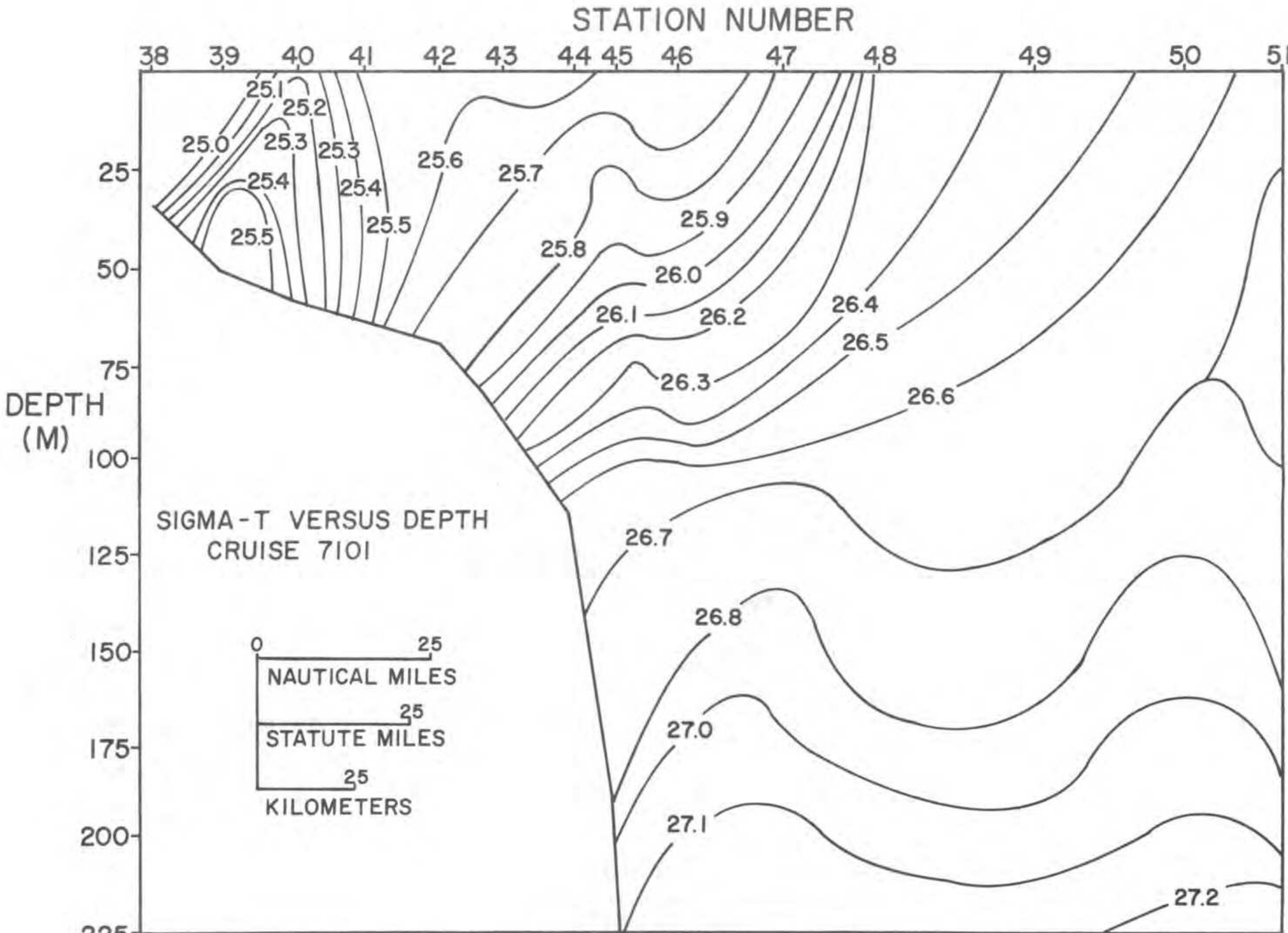


Fig. 11. Sigma-T versus depth, Leg 2, April 12-13, Cruise 7101.

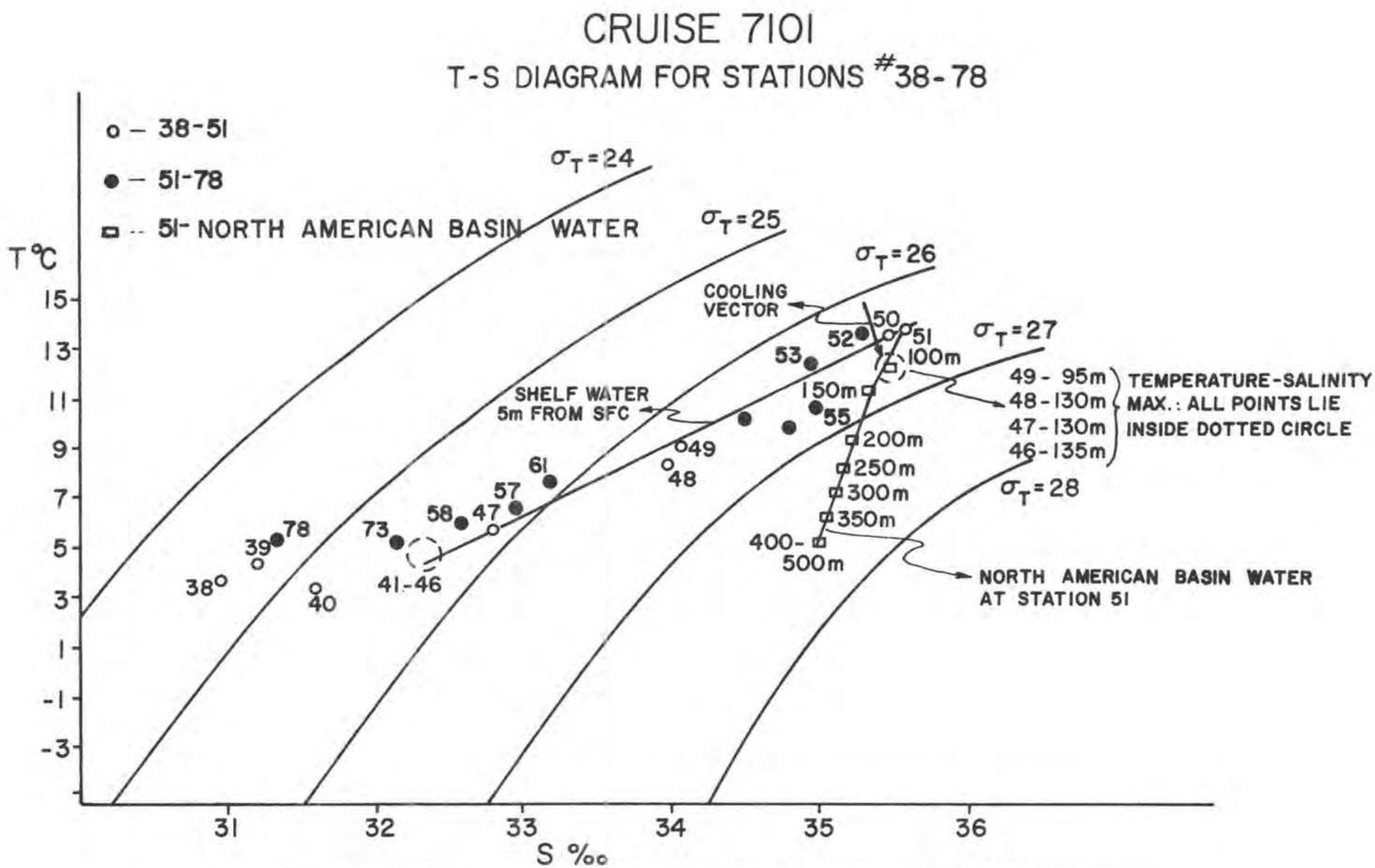


Fig. 12. T-S diagram for stations 38-78, Legs 2-3, April 12-15, Cruise 7101.

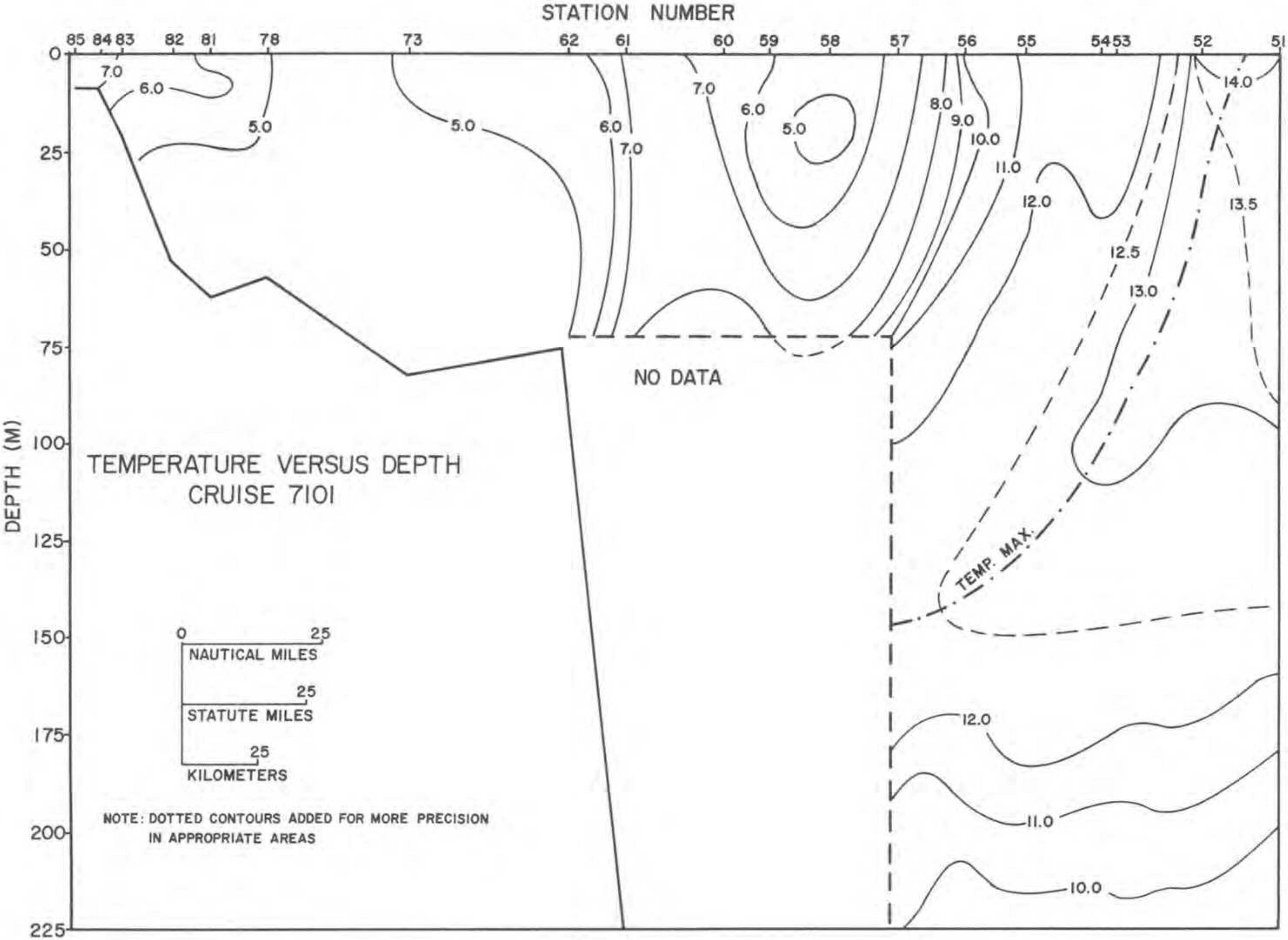


Fig. 13. Temperature versus depth, Leg 3, April 13-15, Cruise 7101.

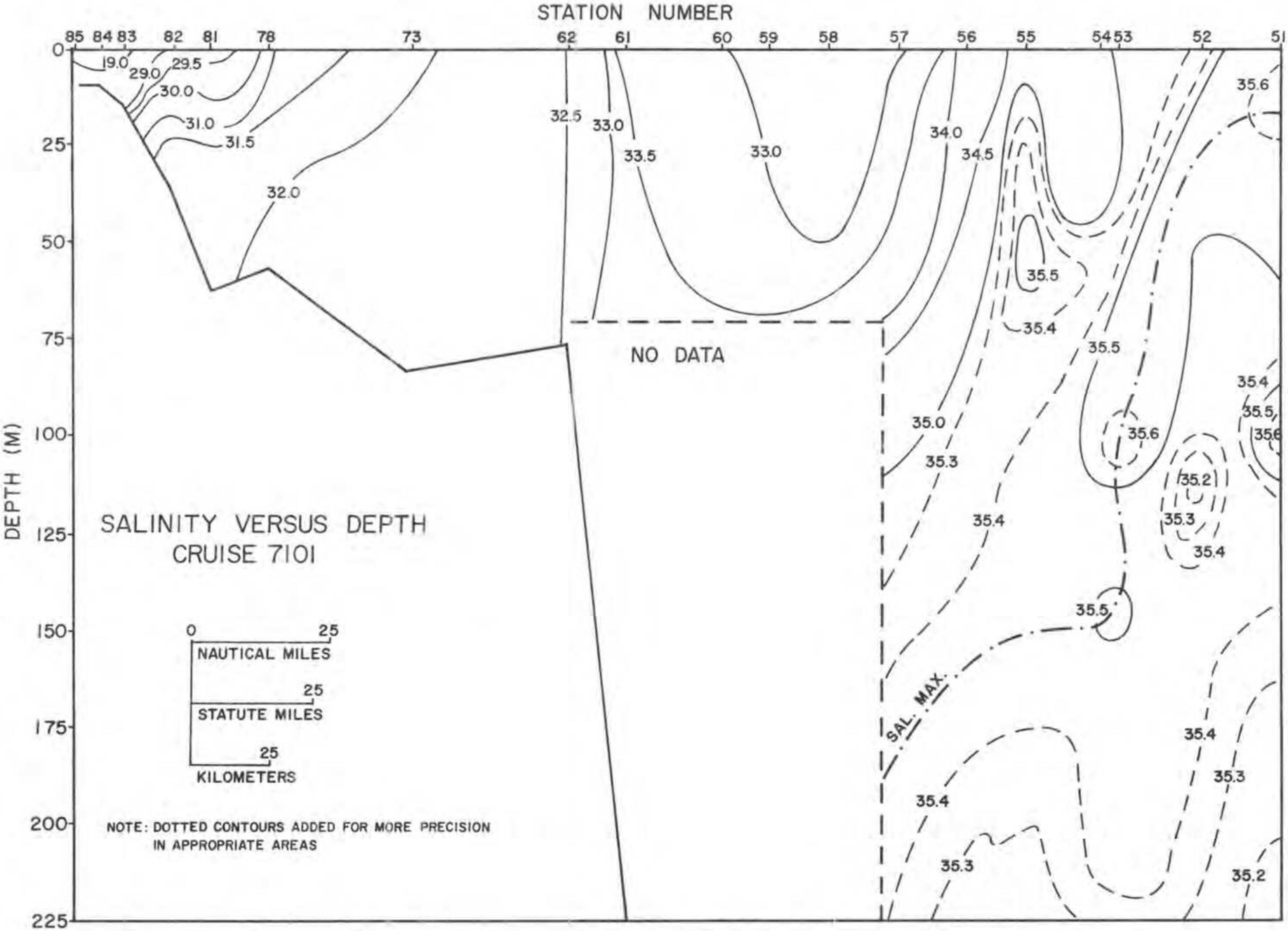


Fig. 14. Salinity versus depth, Leg 3, April 13-15, Cruise 7101.

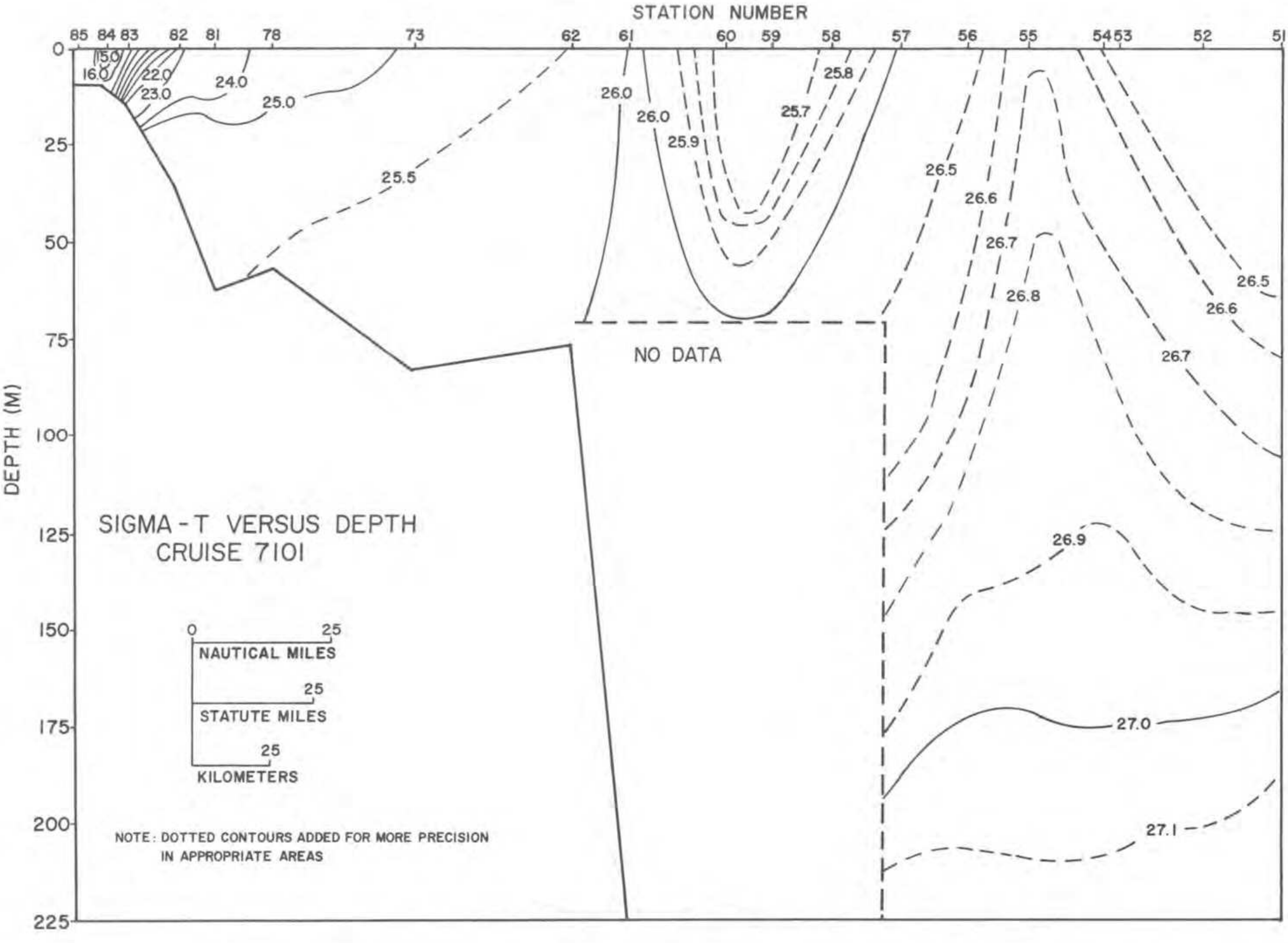


Fig. 15. Sigma-T versus depth, Leg 3, April 13-15, Cruise 7101.

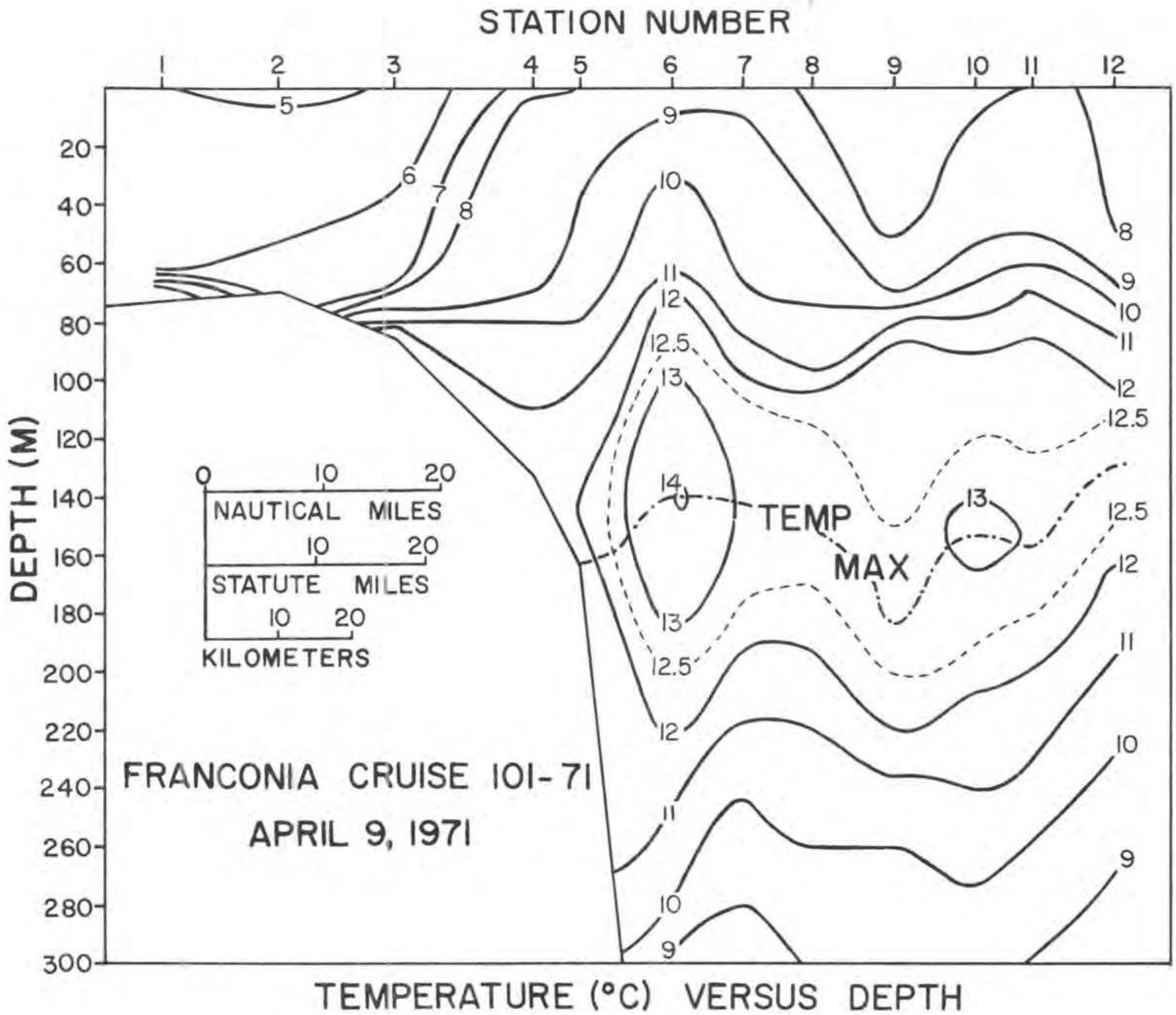


Fig. 16. Temperature versus depth, Franconia cruise 101-71.

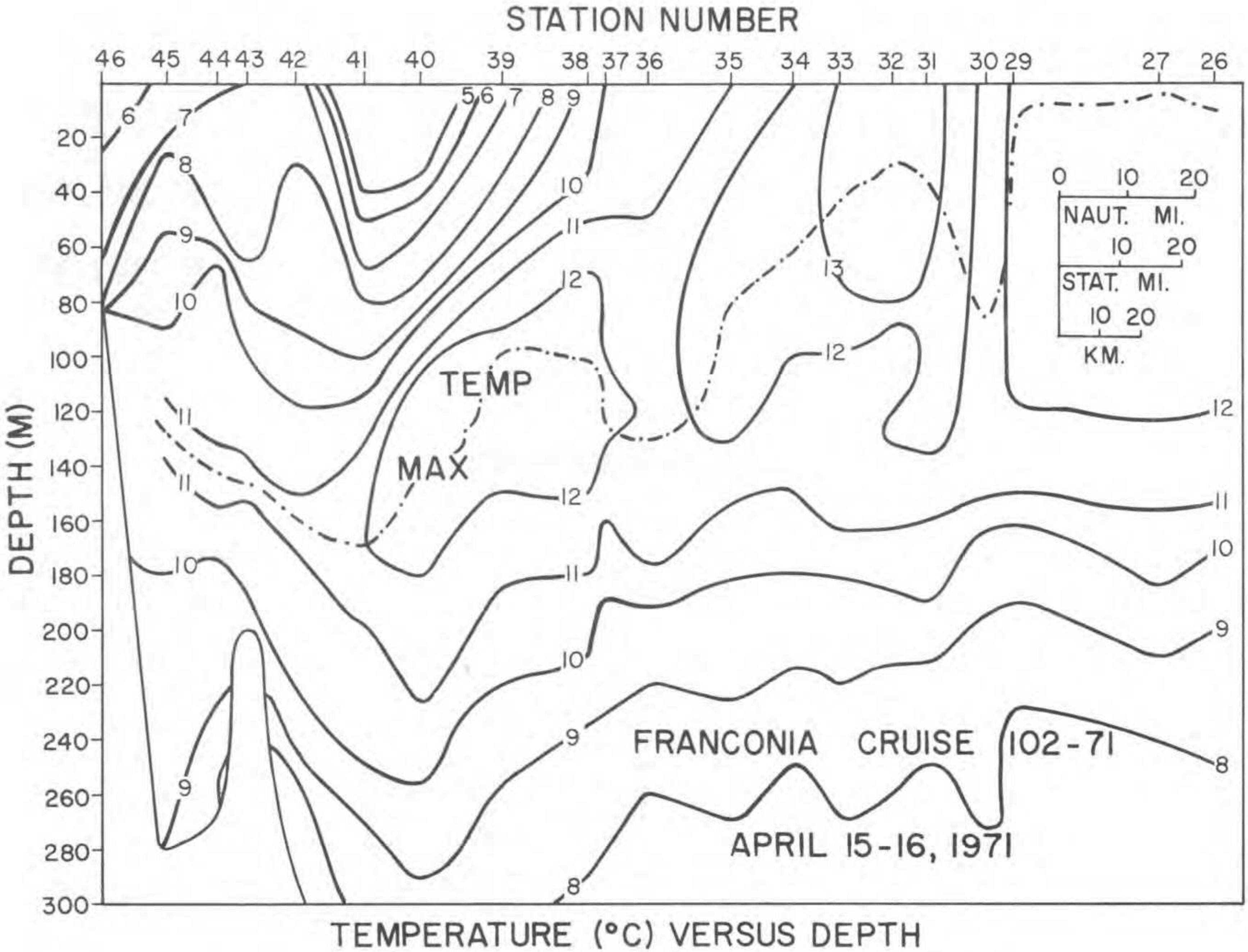


Fig. 17. Temperature versus depth, Franconia cruise 102-71.

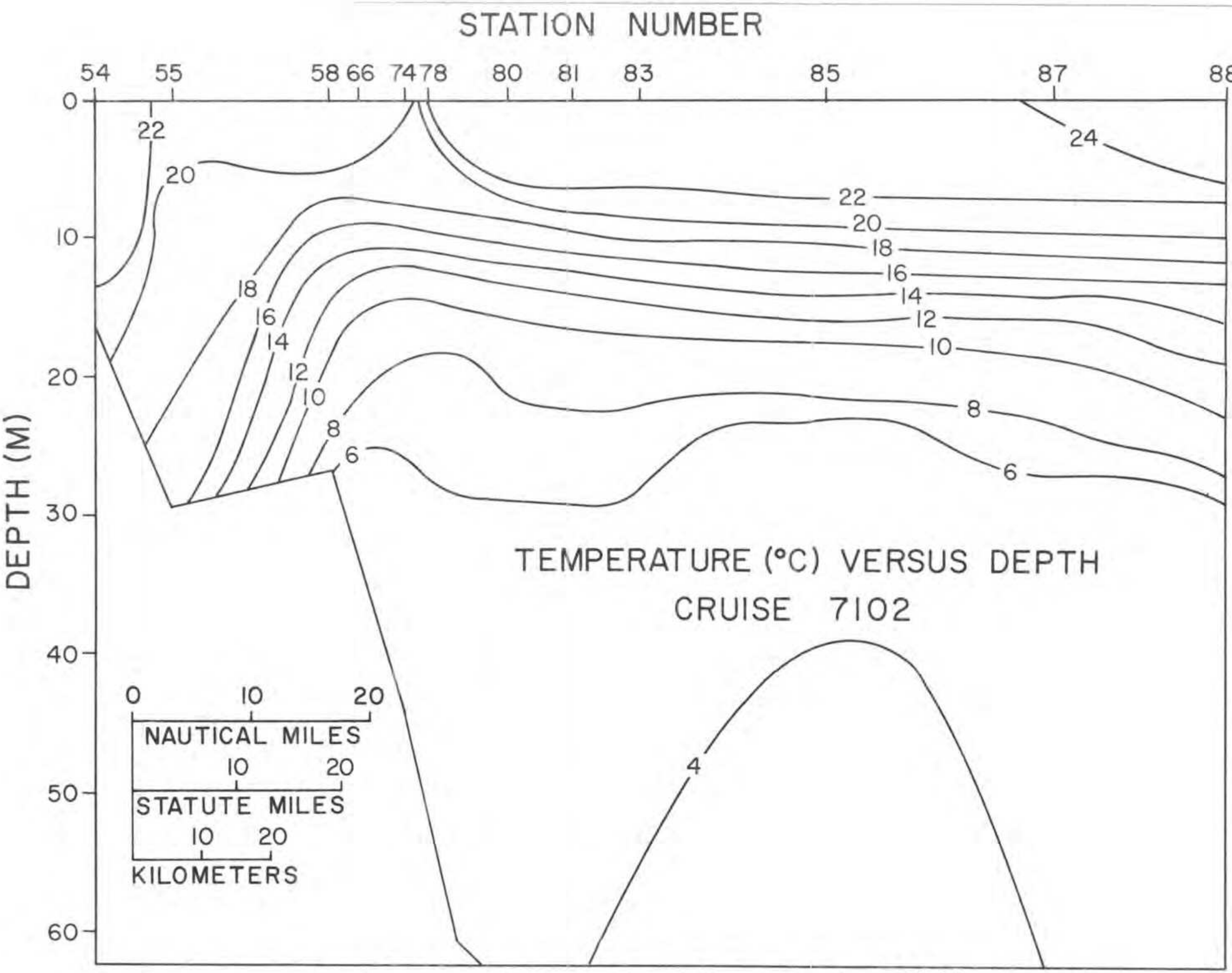


Fig. 18. Temperature versus depth, Leg 4, Aug. 14-15, Cruise 7102.

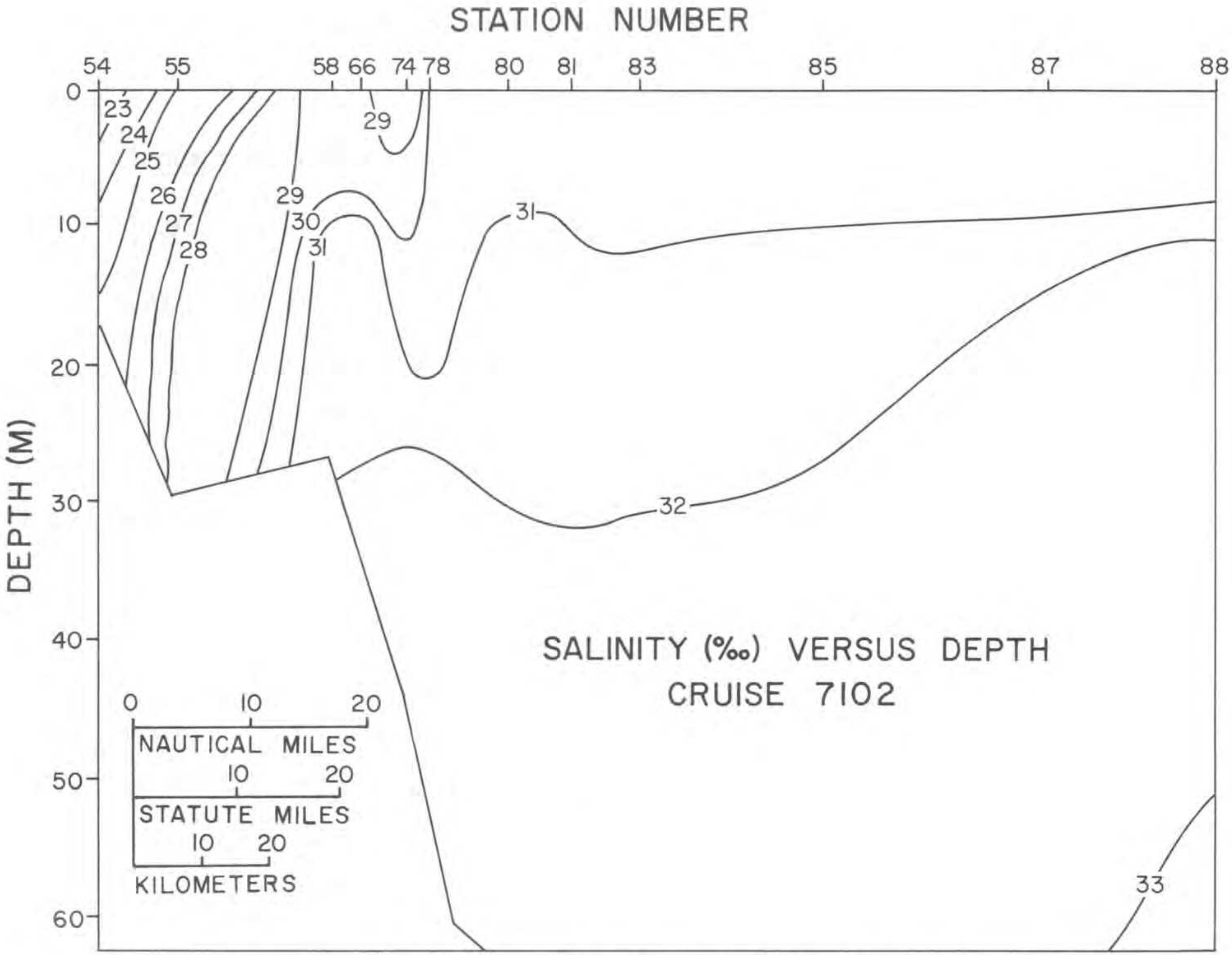


Fig. 19. Salinity versus depth, Leg 4, Aug. 14-15, Cruise 7102.

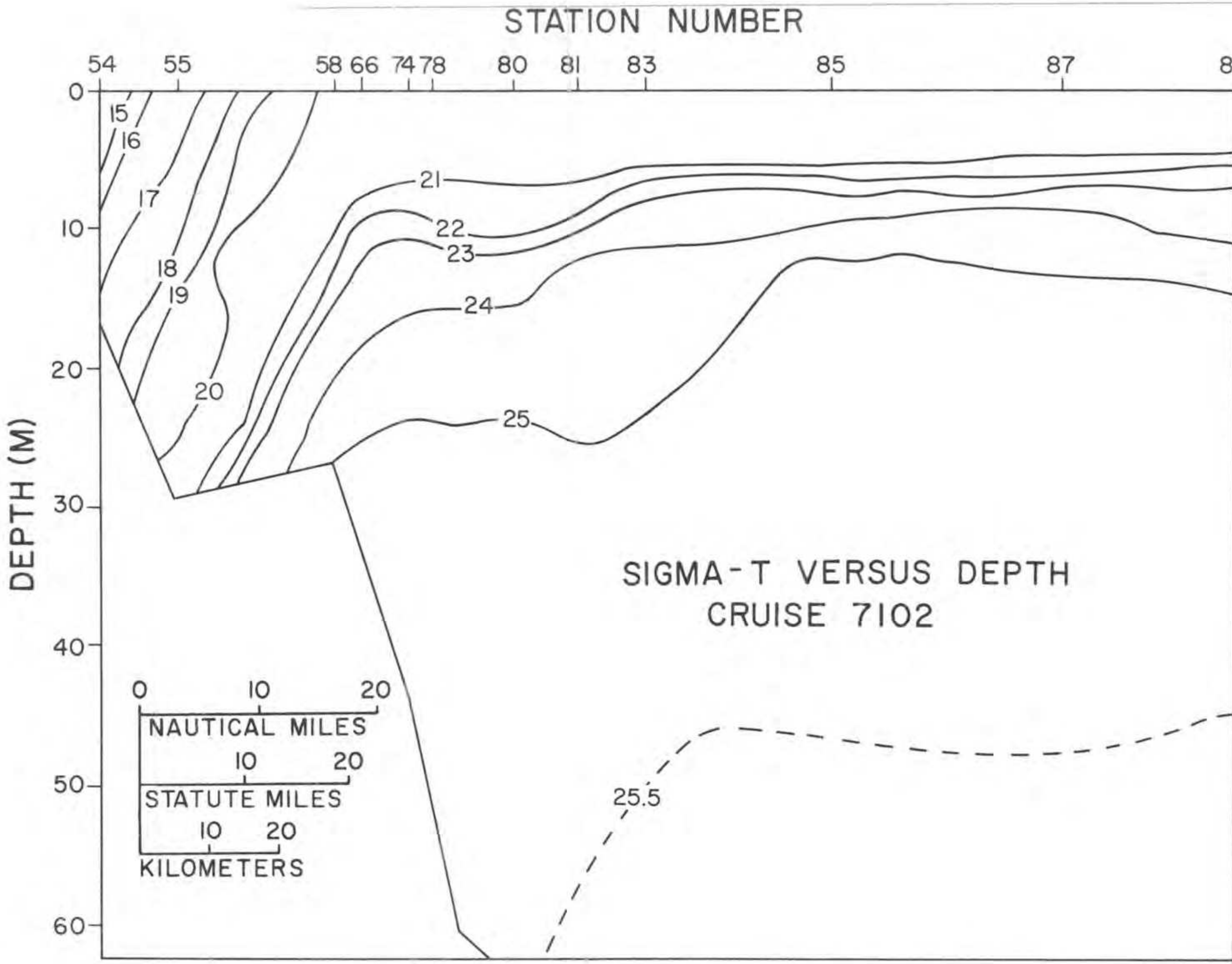


Fig. 20. Sigma-T versus depth, Leg 4, Aug. 14-15, Cruise 7102.

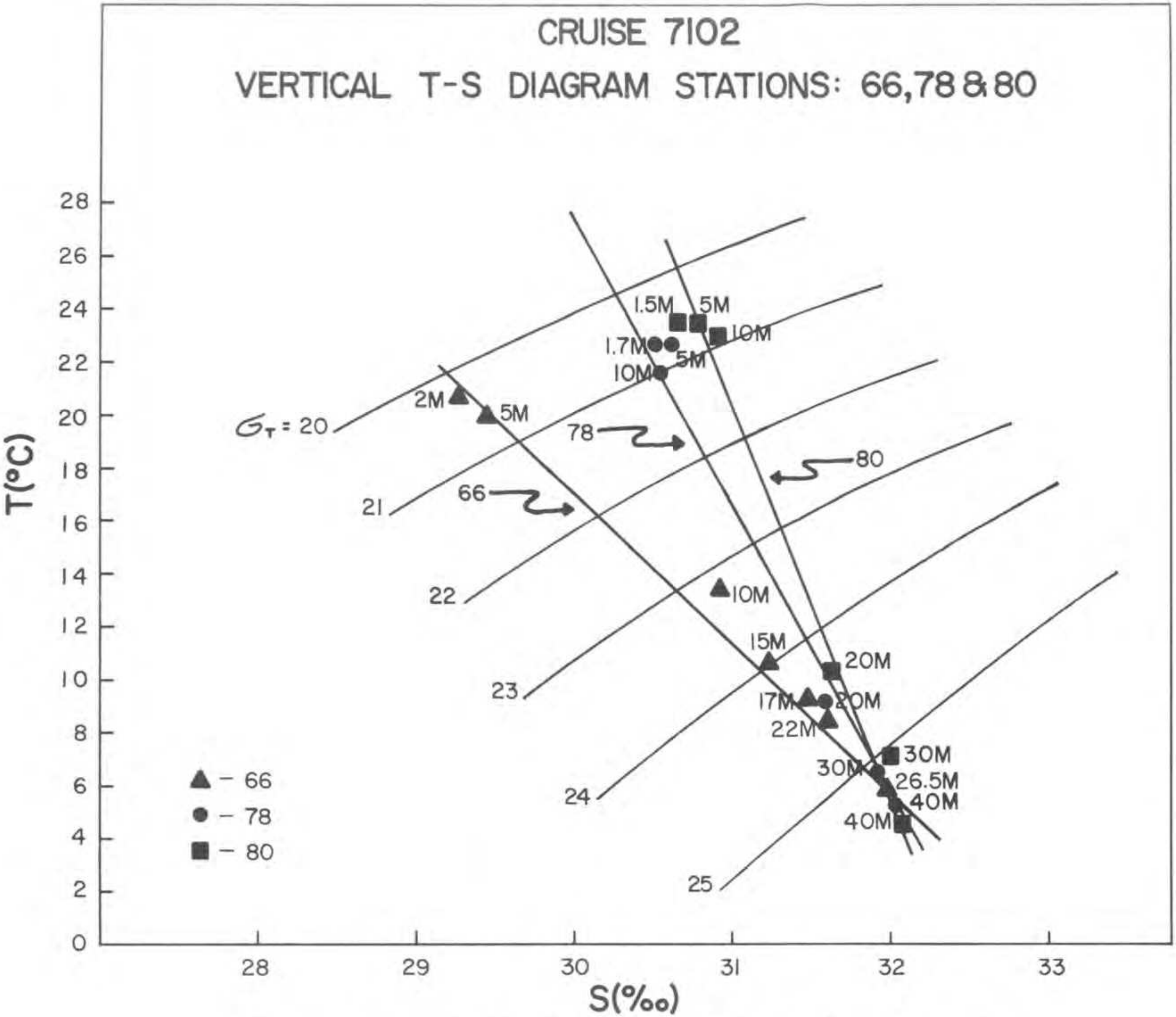
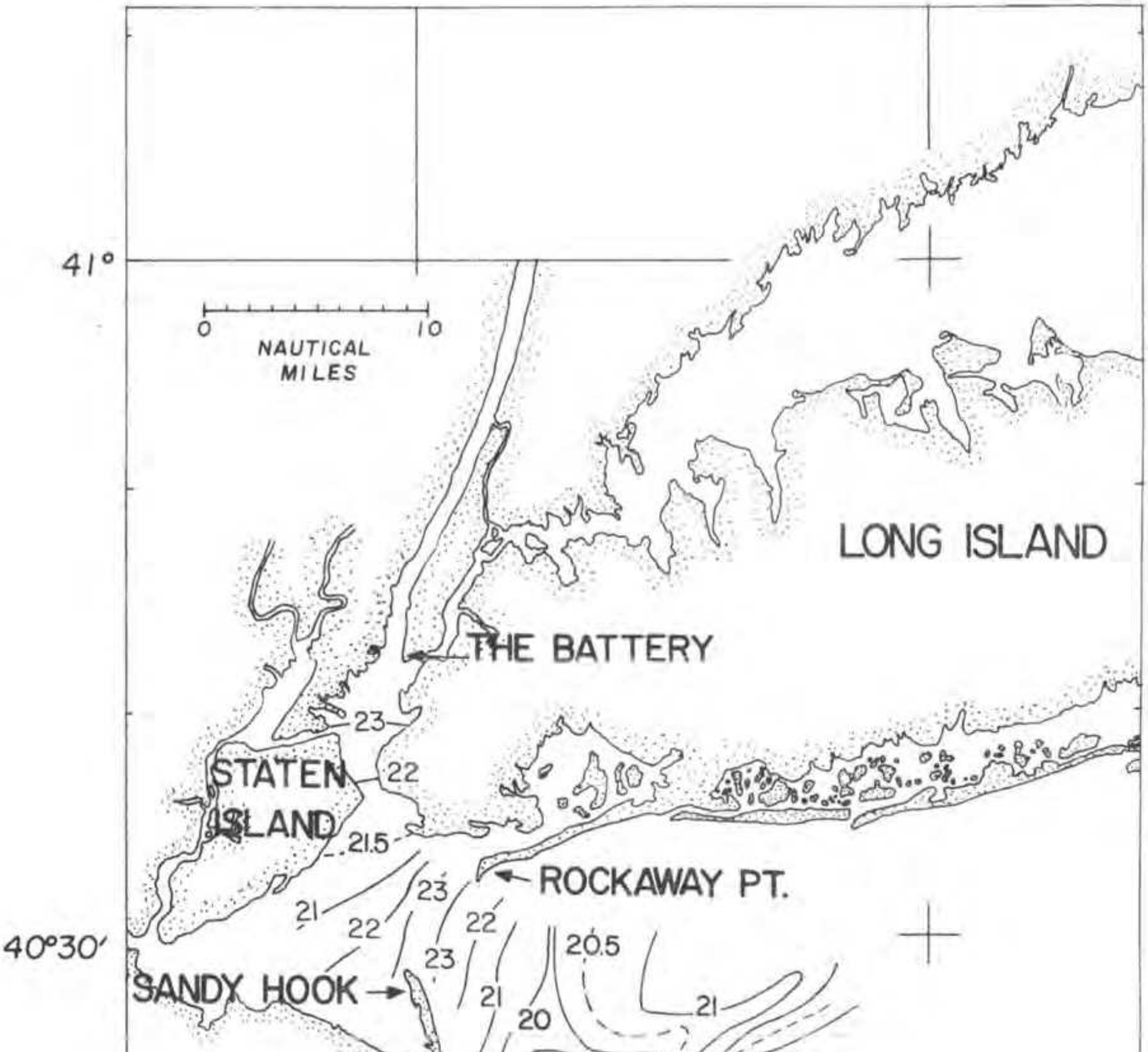


Fig. 21. Vertical T-S diagram, stations 66, 78, & 80, Leg 4, Aug. 14-15, Cruise 7102.



CRUISE 7102

SURFACE (3.5M) TEMPERATURE (°C) CONTOURS

N.Y. HARBOR ENTRANCE

Fig. 22. Surface temperature contours, N.Y. Harbor entrance, Aug. 14-15, Cruise 7102.

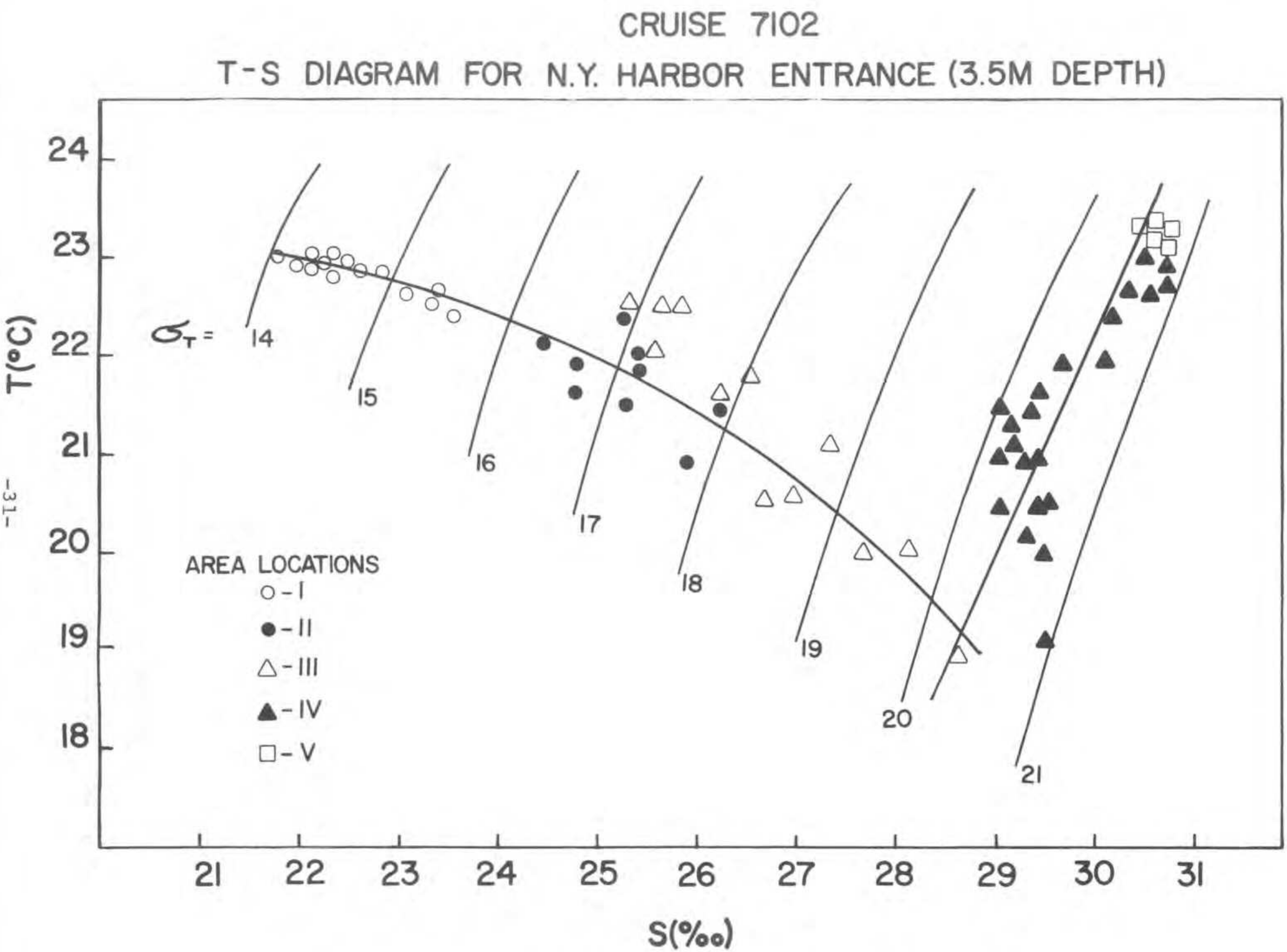
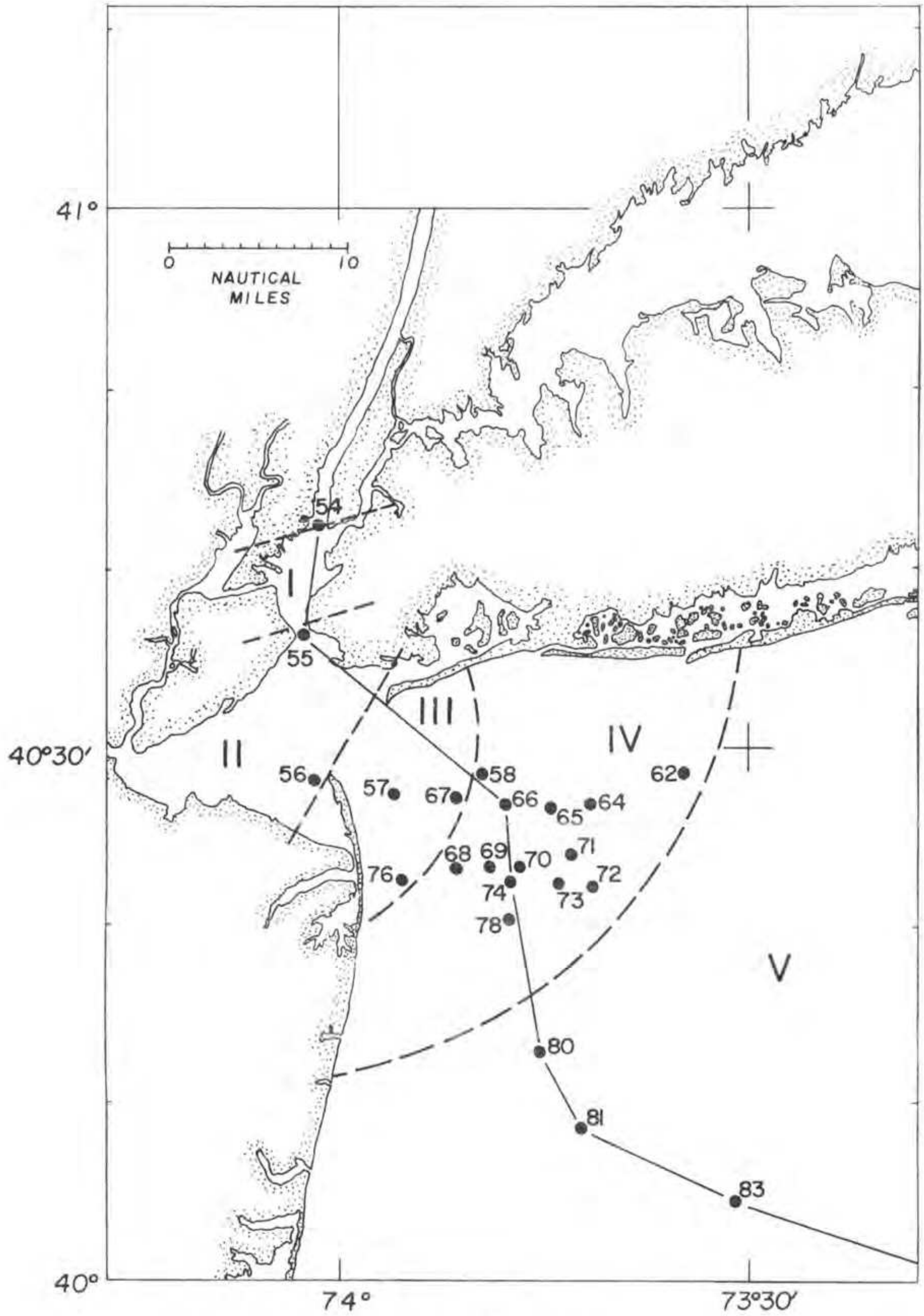


Fig. 23. T-S diagram for N.Y. Harbor entrance, Aug. 14-15, Cruise 7102.



CRUISE 7102
CRUISE PLAN FOR N.Y. HARBOR ENTRANCE

Fig. 24. Cruise plan for N.Y. Harbor entrance, Aug. 14-15, Cruise 7102.

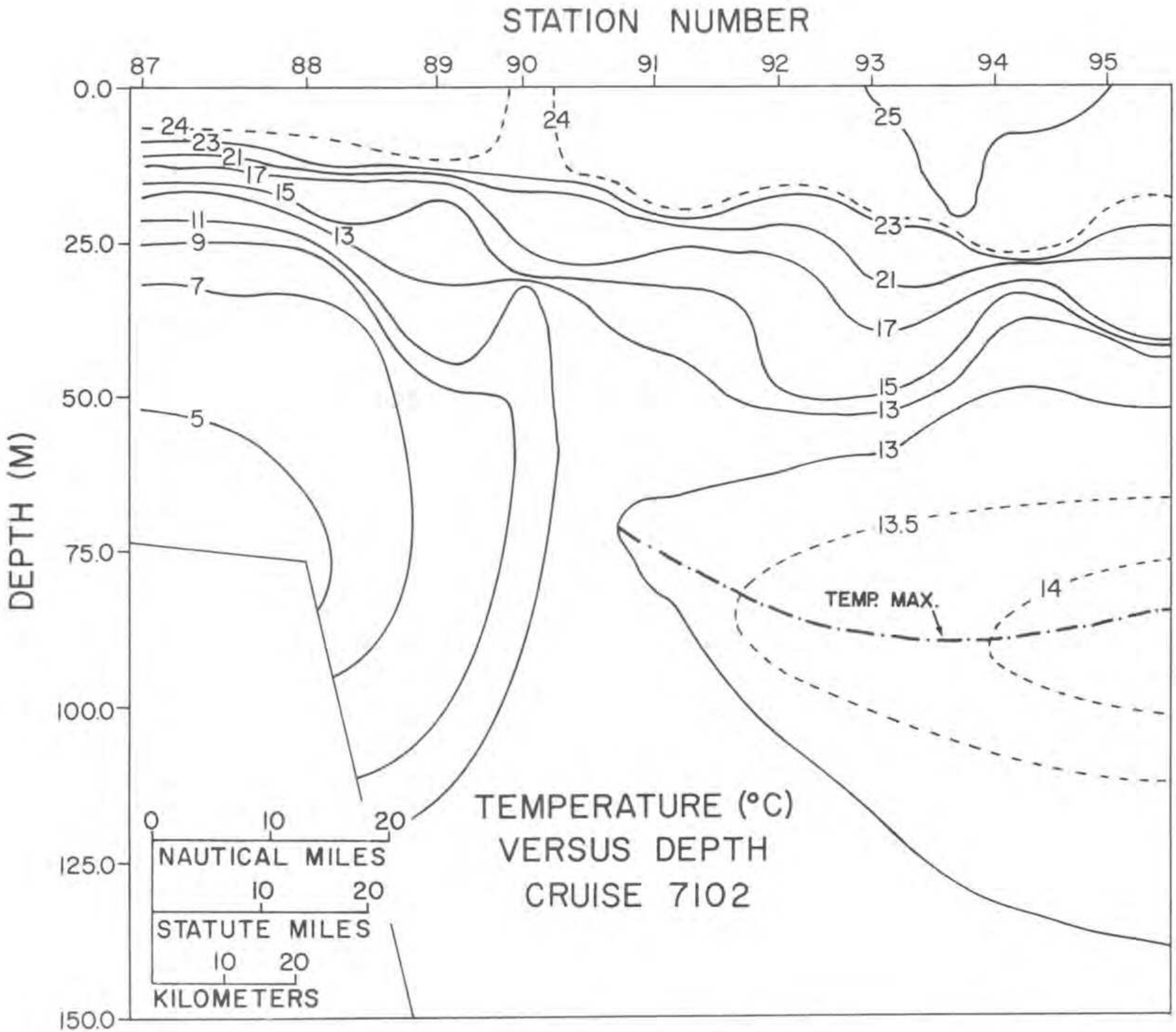


Fig. 25. Temperature versus depth, Leg 4, Aug. 15-16, Cruise 7102.

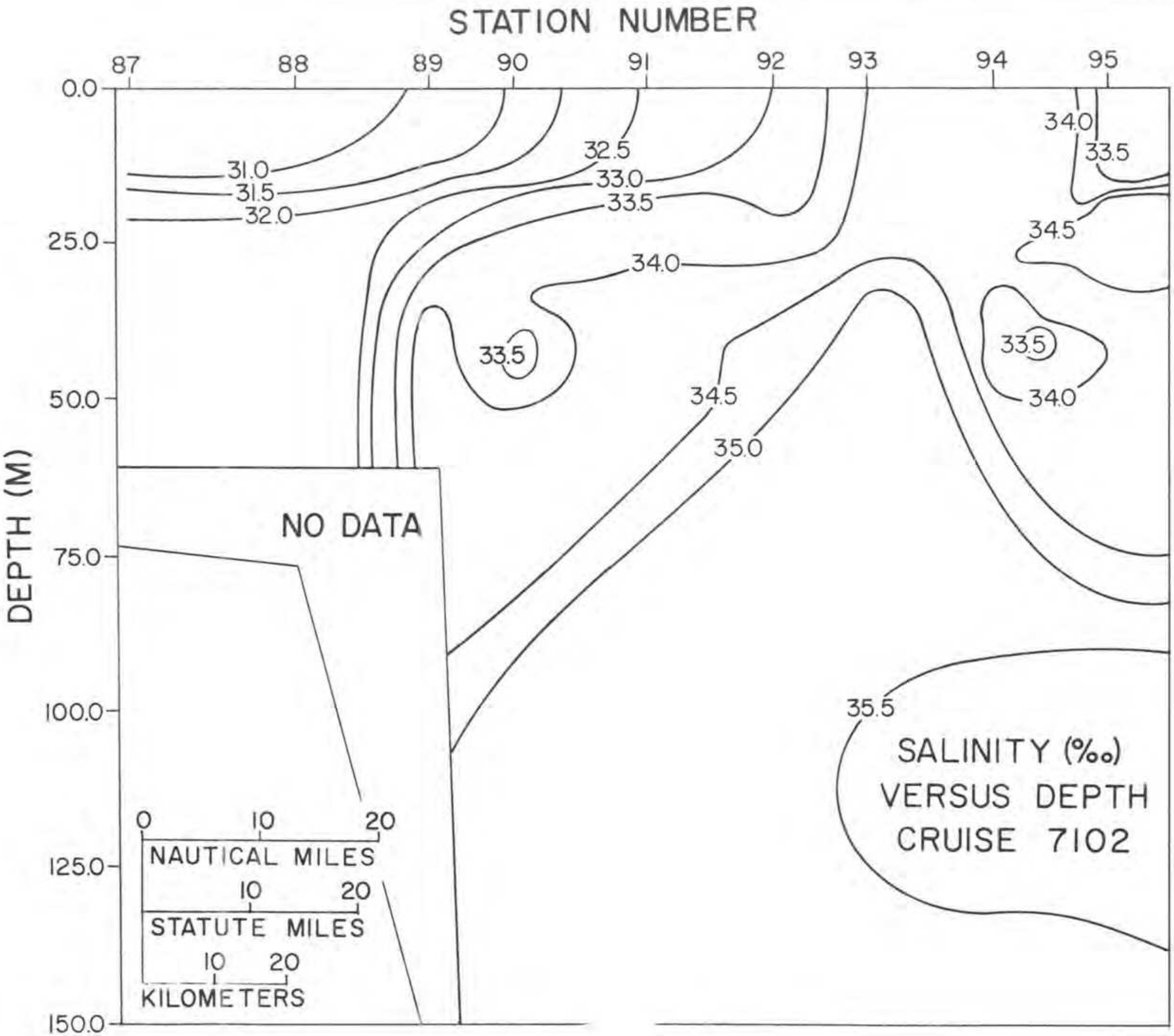


Fig. 26. Salinity versus depth, Leg 4, Aug. 15-16, Cruise 7102.

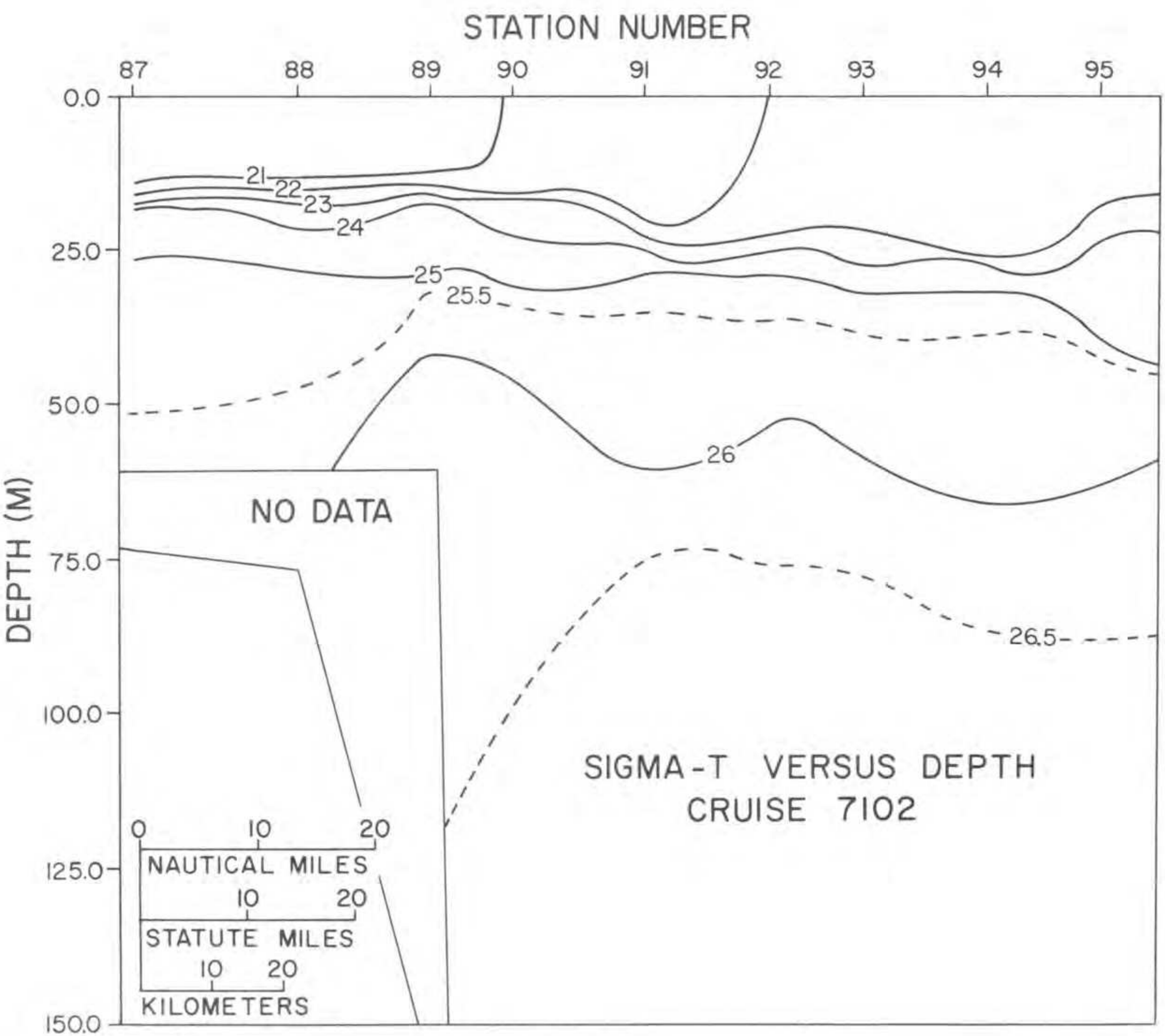


Fig. 27. Sigma-T versus depth, Leg 4, Aug. 15-16, Cruise 7102.

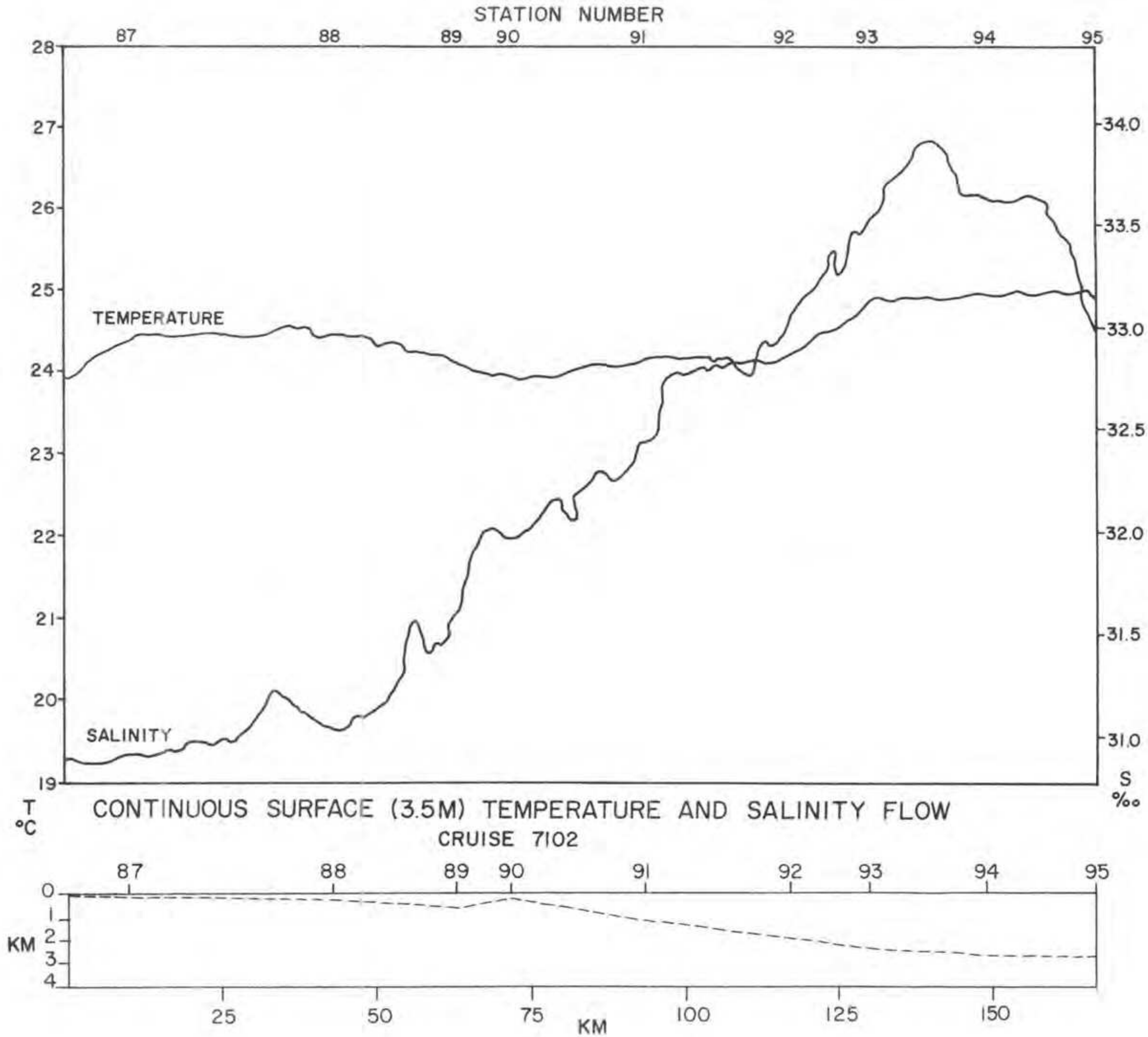


Fig. 28. Continuous surface temperature and salinity flow, Leg 4, Aug. 15-16, Cruise 7102.

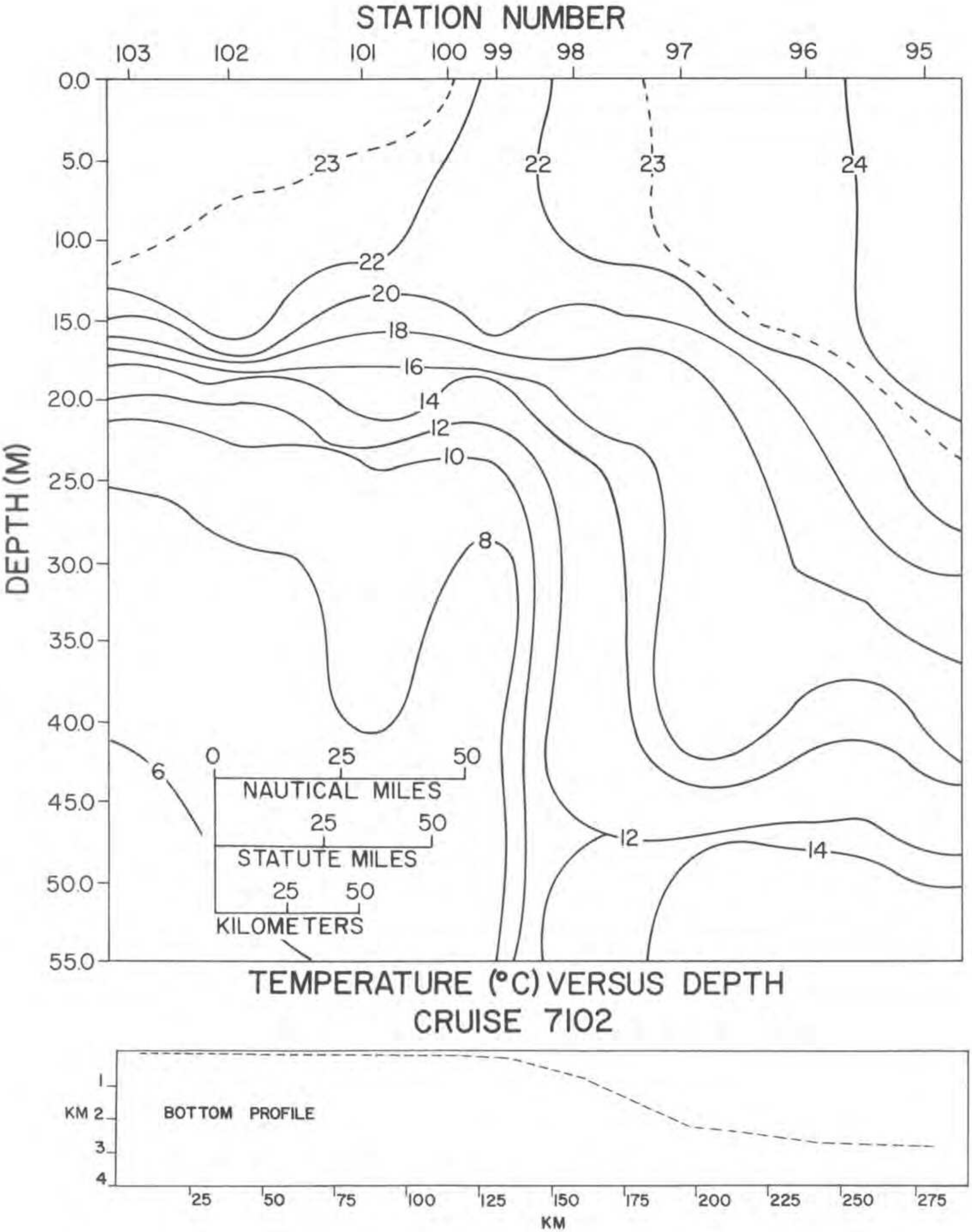


Fig. 29. Temperature versus depth, Leg 5, Aug. 16-17, Cruise 7102.

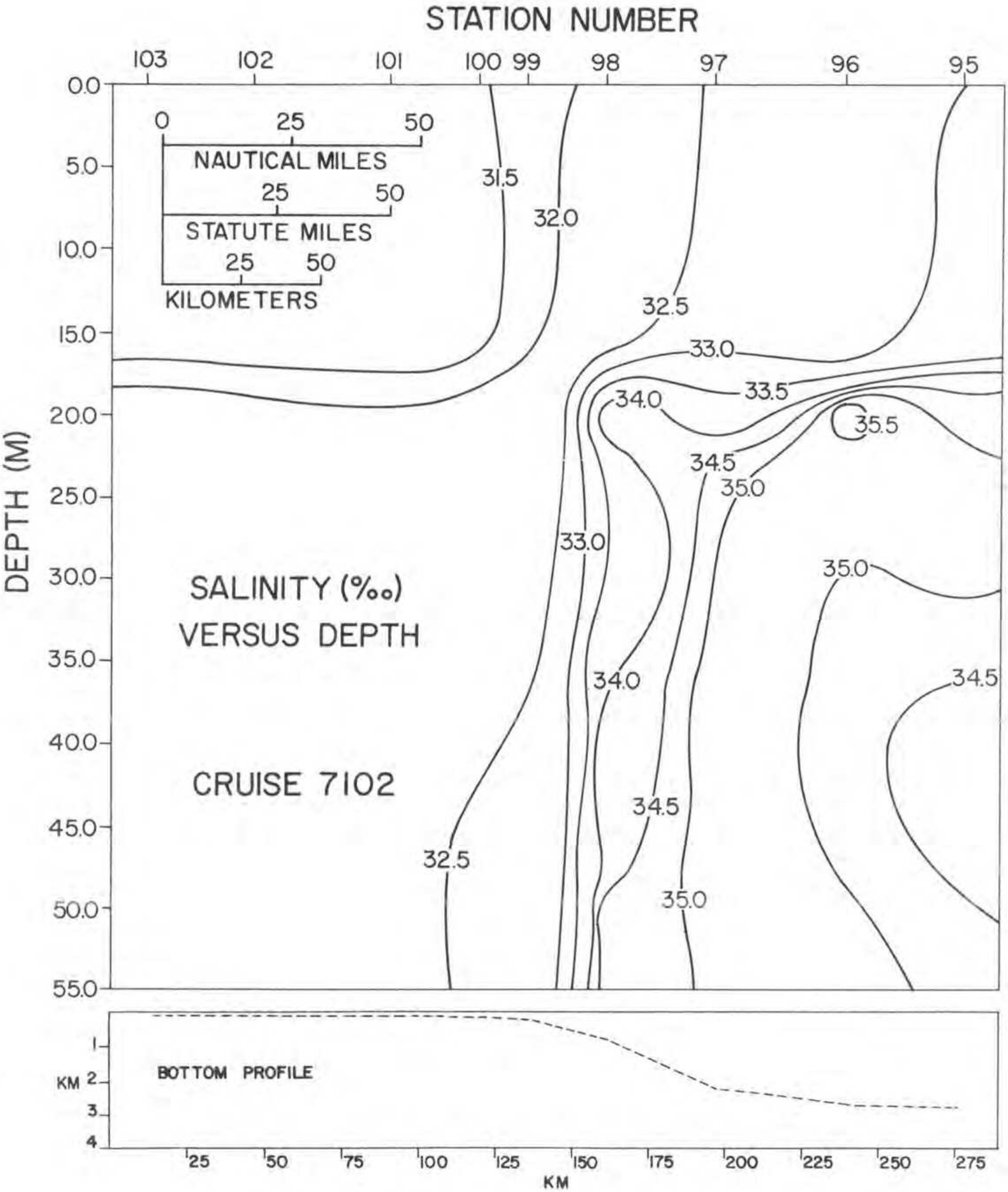


Fig. 30. Salinity versus depth, Leg 5, Aug. 16-17, Cruise 7102.

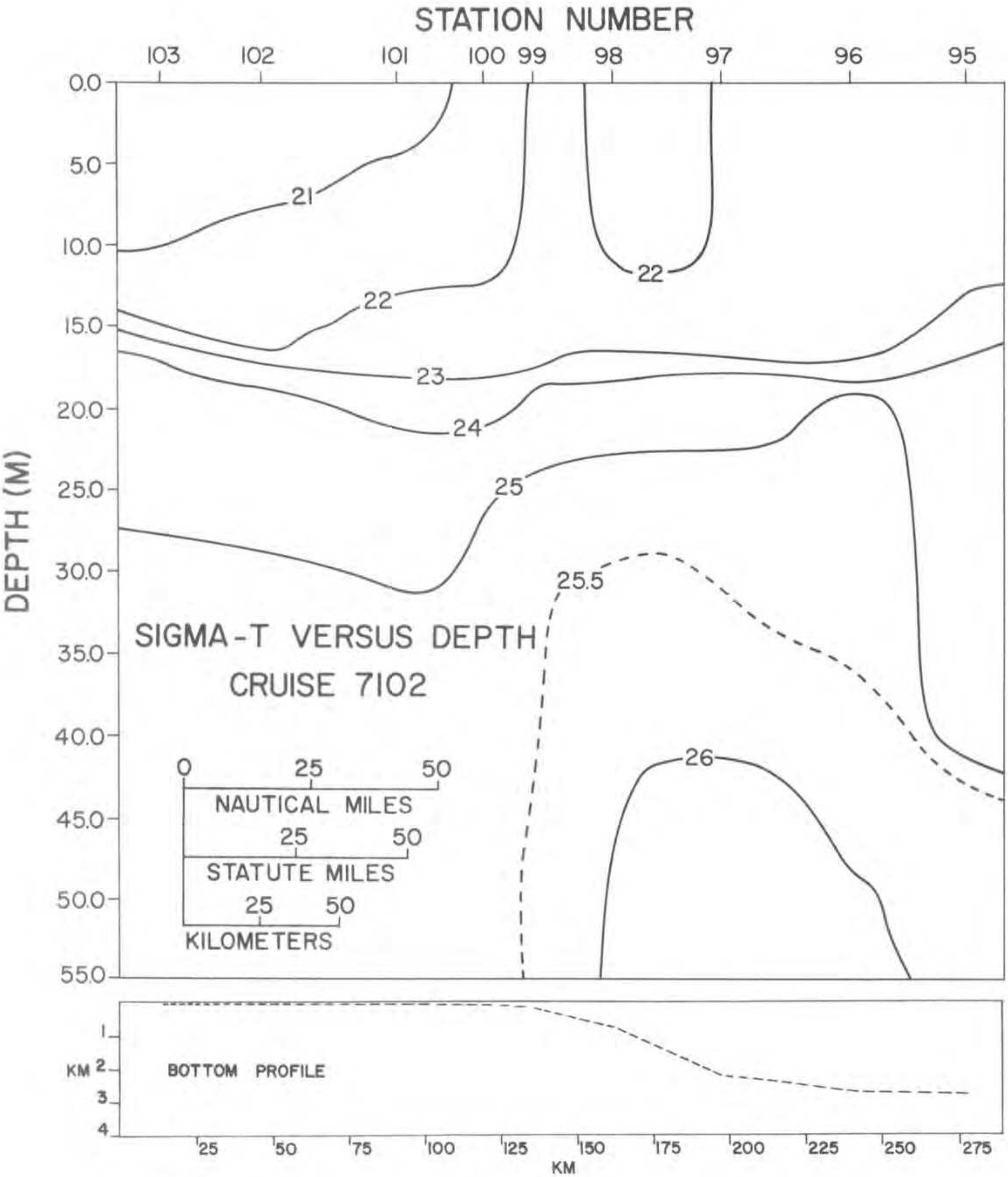


Fig. 31. Sigma-T versus depth, Leg 5, Aug. 16-17, Cruise 7102.

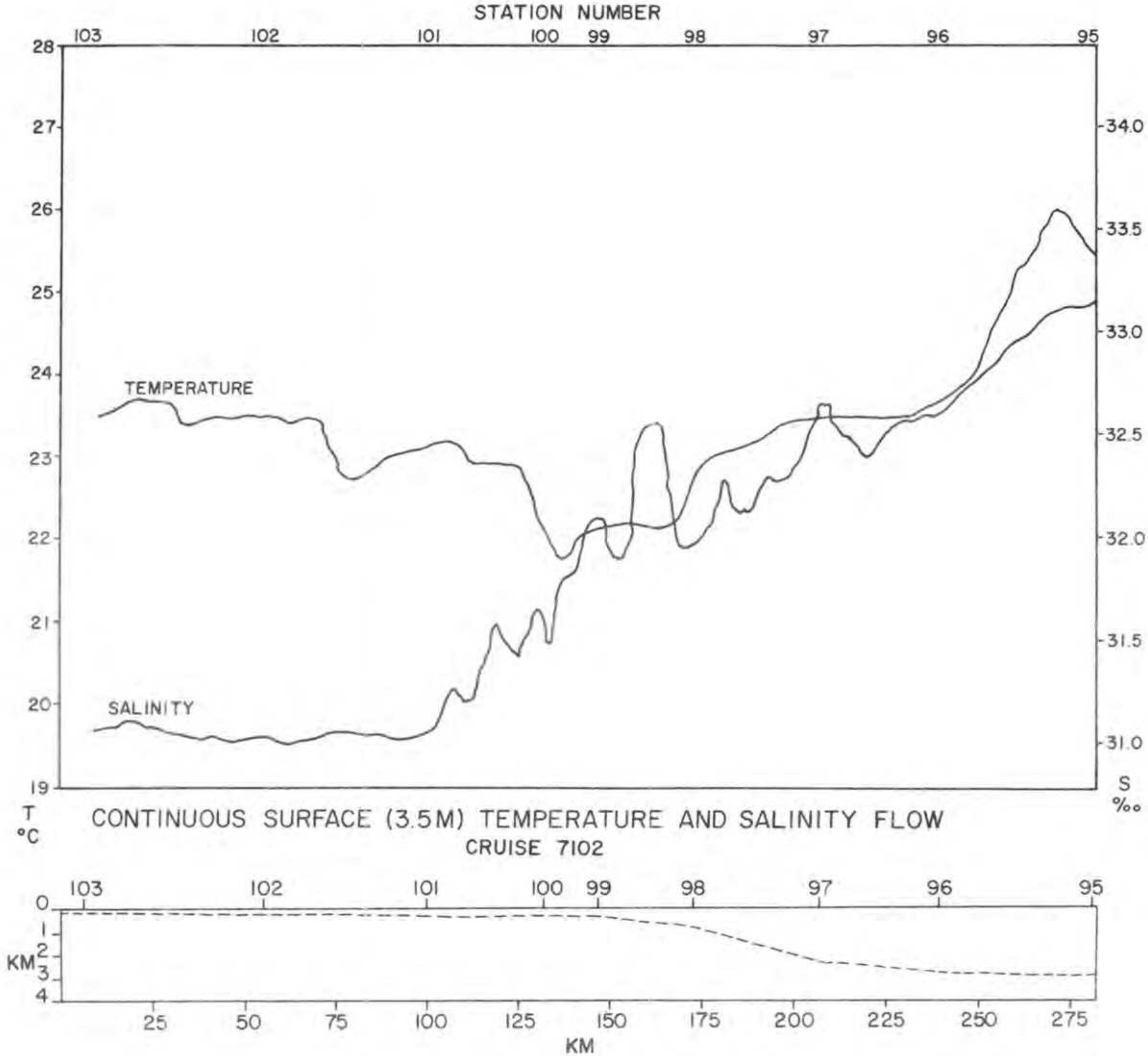


Fig. 32. Continuous surface temperature and salinity, Leg 5, Aug. 16-17, Cruise 7102.

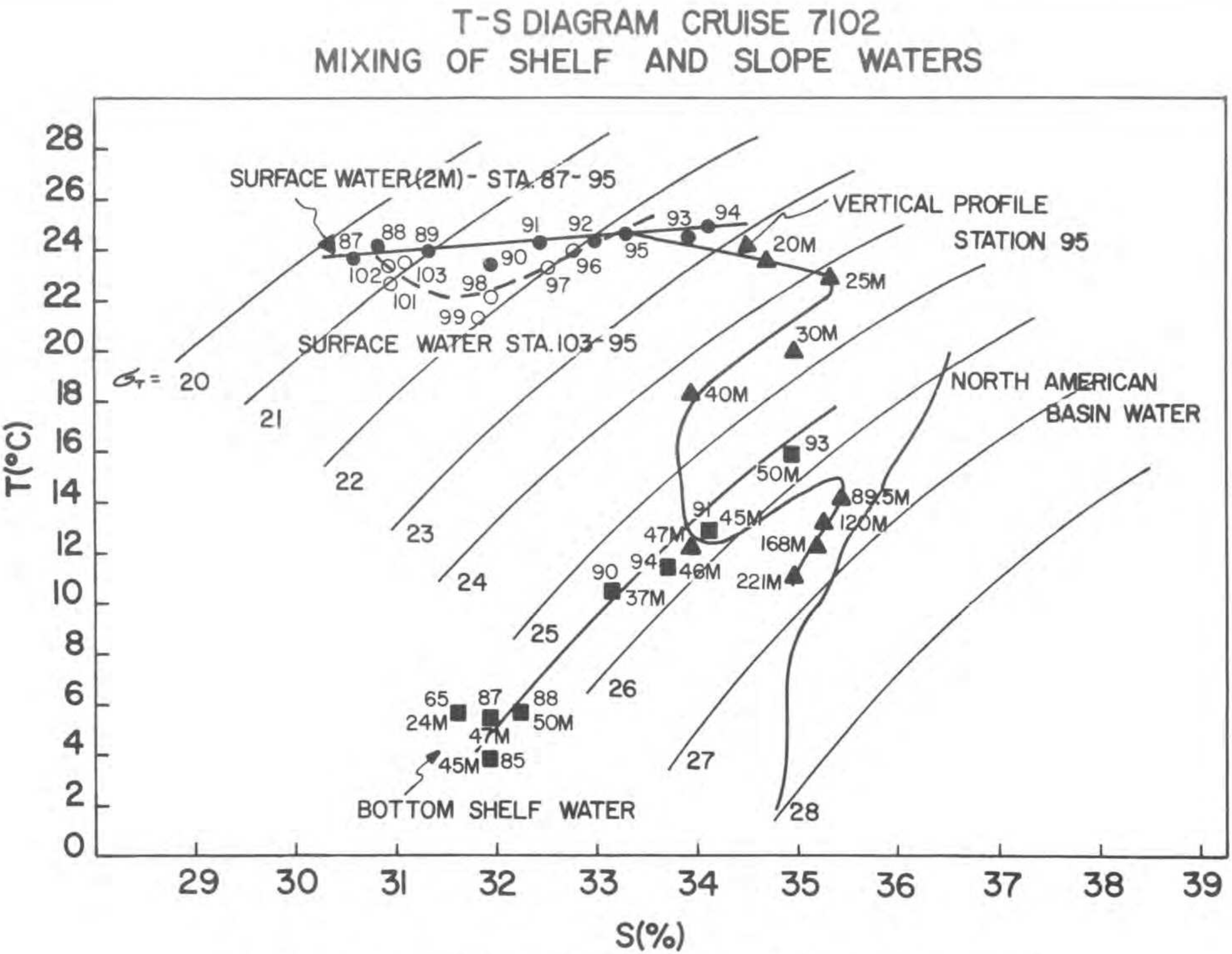


Fig. 33. T-S diagram Aug. 15-17, Mixing of shelf and slope waters, Cruise 7102.

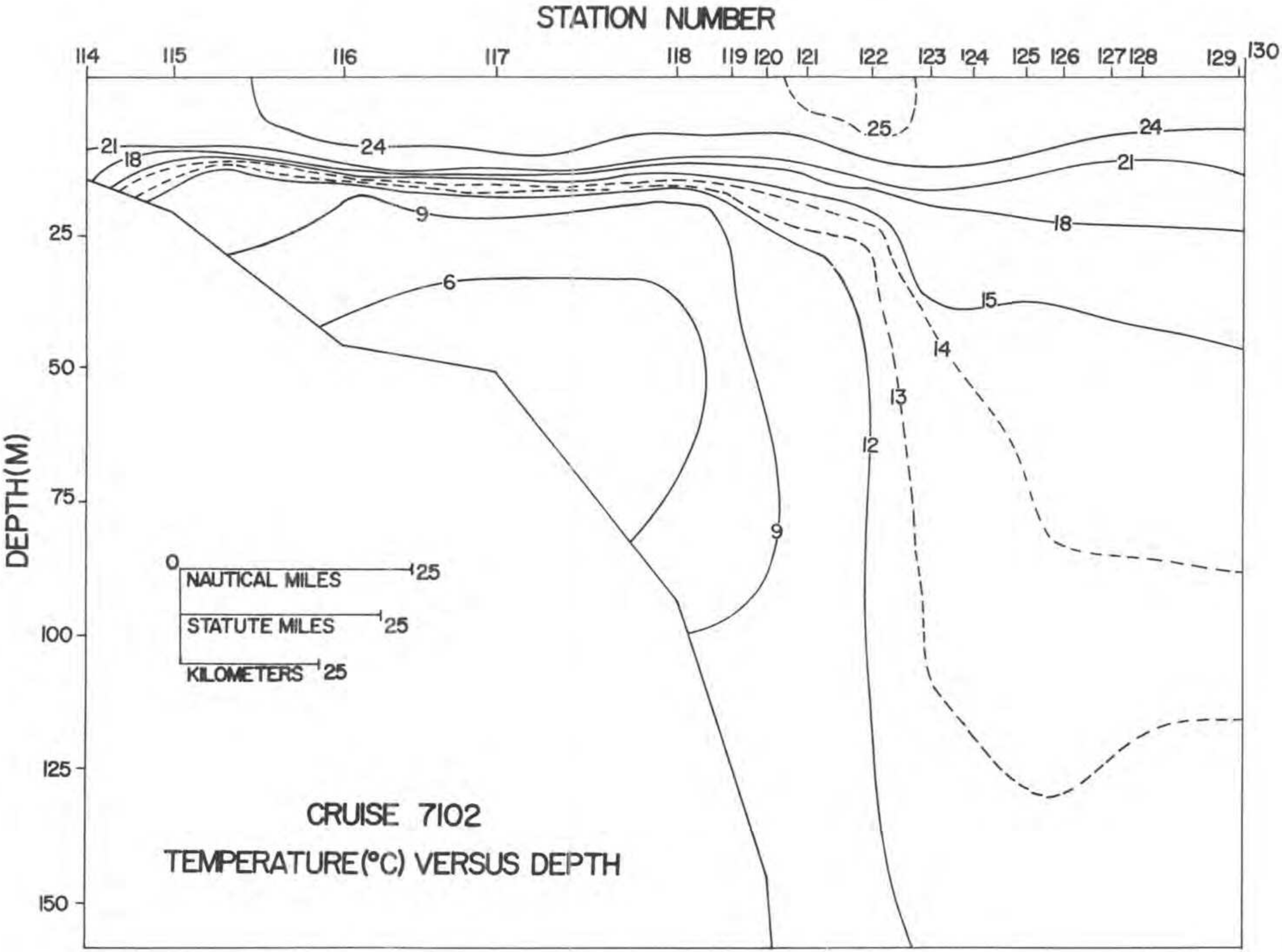


Fig. 34. Temperature versus depth, Leg 6, Aug. 19-20, Cruise 7102.

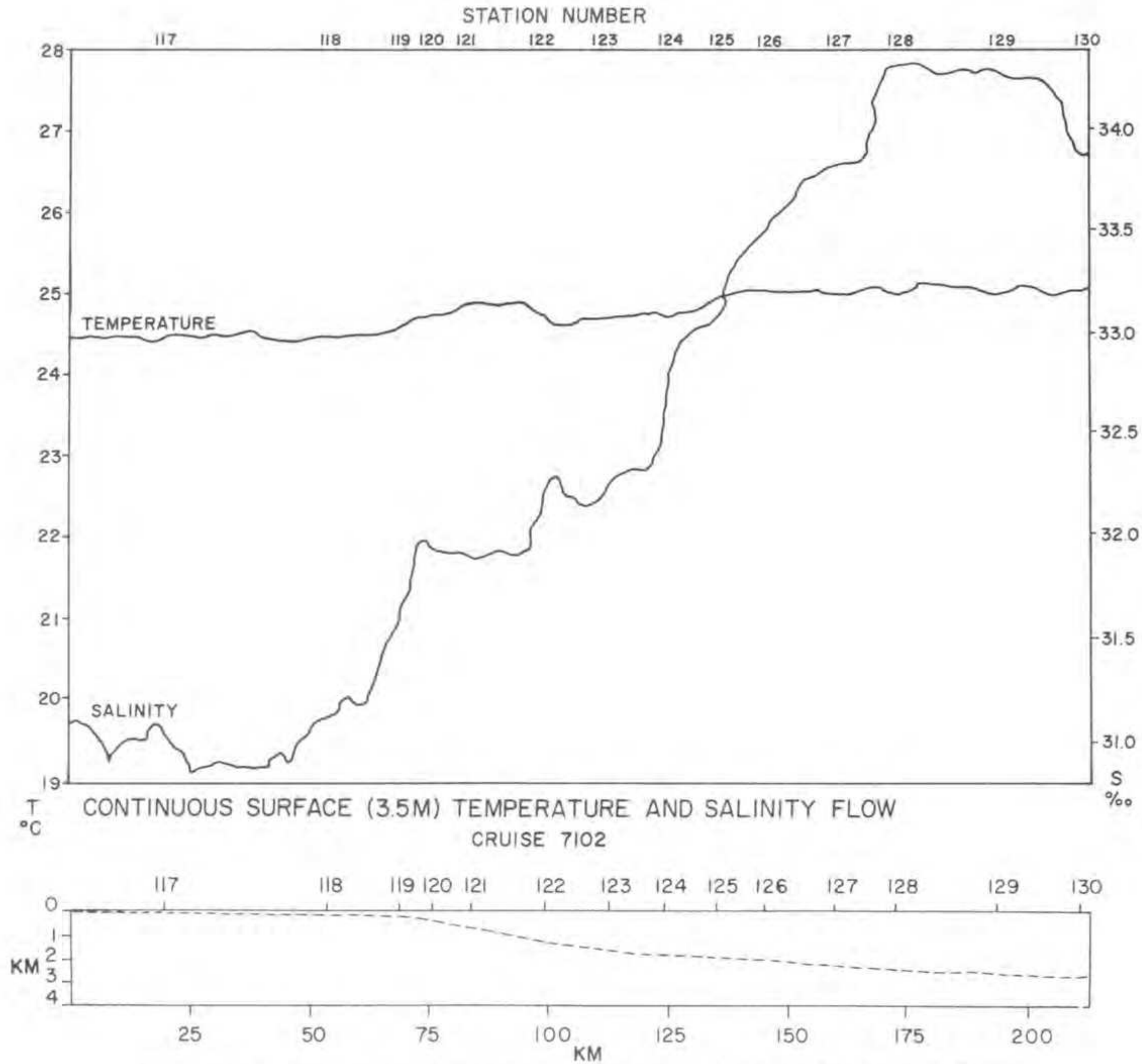


Fig. 35. Continuous surface temperature and salinity flow, Leg 6, Aug. 20, Cruise 7102.

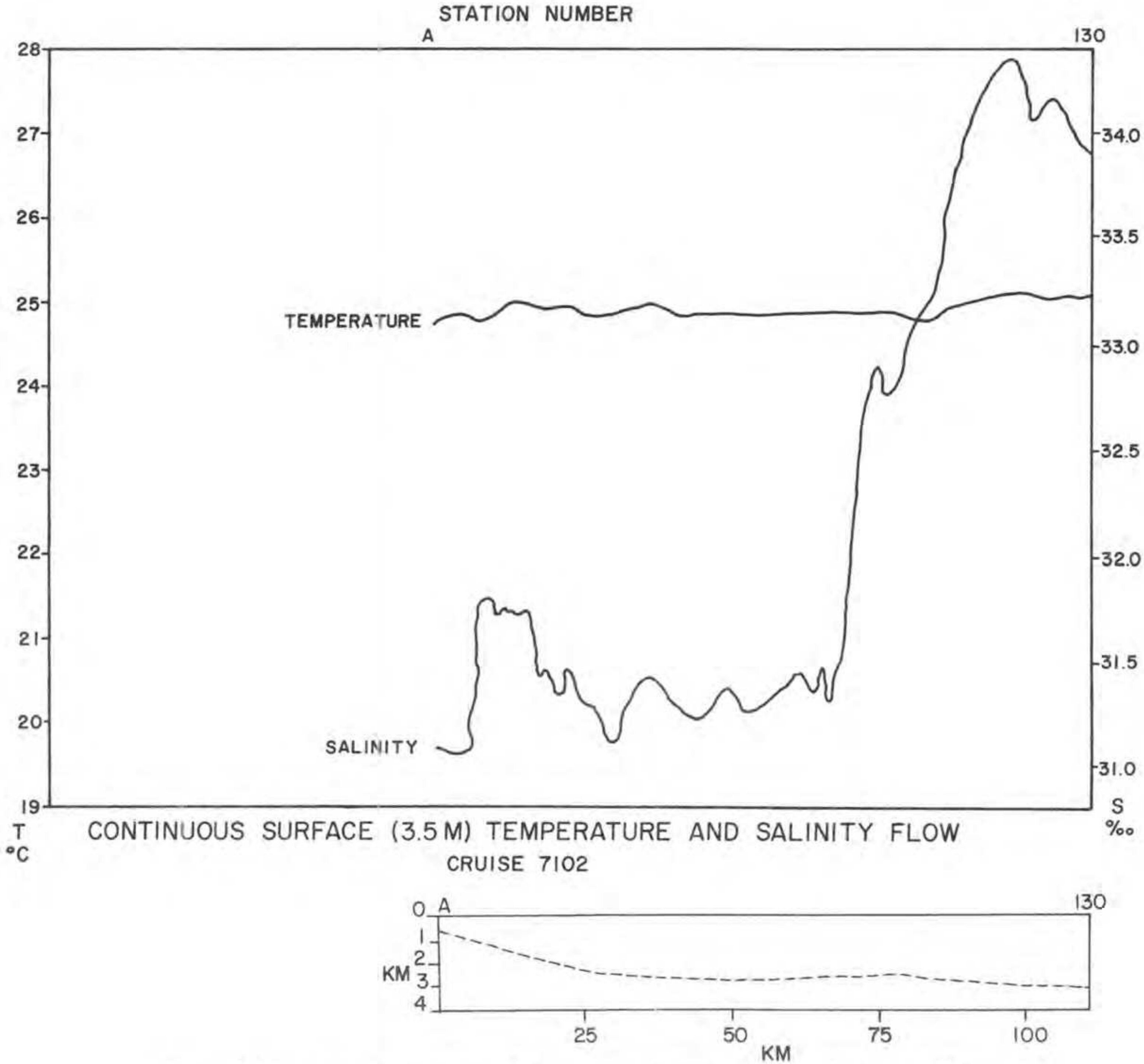


Fig. 36. Continuous surface temperature and salinity flow, Leg 7, Aug. 20-21, Cruise 7102.

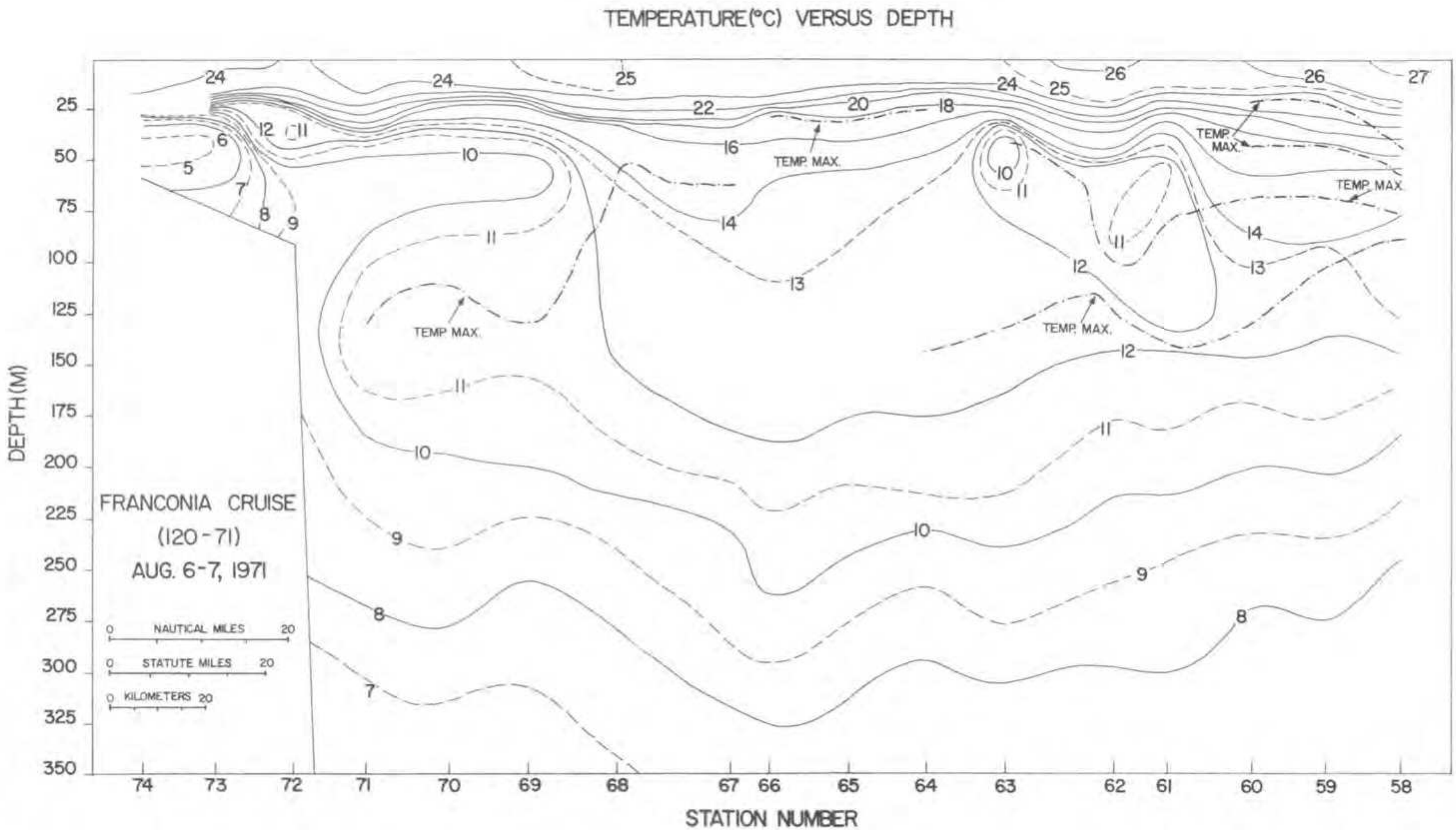


Fig. 37. Temperature versus depth, Franconia Cruise 120-71.

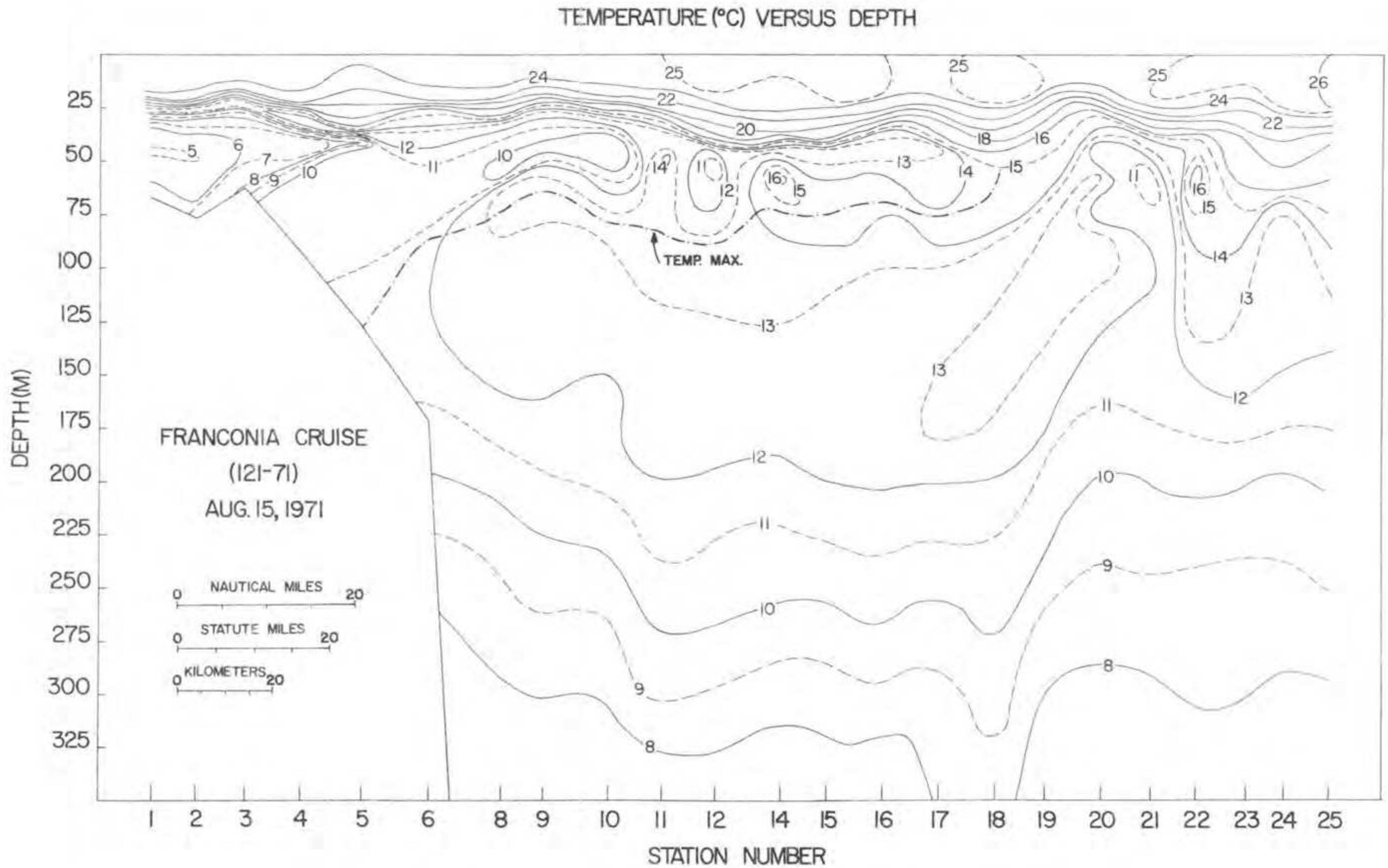


Fig. 38. Temperature versus depth, Franconia cruise 121-71.