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Seasonal Meteorological and Hydrographic Conditions in the Northern Half of the Middle Atlantic Bight: 1975-76

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IN THE NORTHERN HALF OF THE MIDDLE
ATLANTIC BIGHT: 1975-76

Evon P. Ruzecki
Chris S. Welch
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Special Report in Applied Marine Science
and Ocean Engineering No. 172
of the
Virginia Institute of Marine Science
Gloucester Point, Virginia 23062

This report was extracted from "Middle Atlantic Outer Continental Shelf Environmental Studies: Volume II. Chemical and Biological Benchmark Studies", the final report to the Bureau of Land Management, U. S. Department of Interior, prepared by the Virginia Institute of Marine Science under Contract No. 08550-CT-5-42. References to other chapters and appendices of the complete report have been left intact in this extract.

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CHAPTER 3

PHYSICAL OCEANOGRAPHY AND CLIMATOLOGY

E. P. Ruzecki
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INTRODUCTION

The physical oceanographic portion of this study was designed to achieve, as its primary purposes, identification of water masses in the study area during the sampling period and characterization of hydrographic and meteorological conditions at sampling locations when biological and chemical samples were taken. To aid in water mass identification, samples of near surface and near bottom water taken at each station were analyzed for dissolved micro-nutrient concentrations.

Two secondary tasks were assigned to the physical oceanography group: obtaining and field processing water samples for dissolved and particulate organic carbon content and measuring optical characteristics of the water column. The former was done in conjunction with the water column cruises while the latter was accomplished during the benthic sampling cruises. All samples and field data from these secondary tasks were transferred to other investigators for further processing and analysis.

METHODS AND MATERIALS

Nomenclature

This section is included to define abbreviations used in this chapter.

<u>Abbreviation</u>	<u>Definition</u>
BCD	Binary Coded Decimal
CTD/DO	Conductivity, temperature, and depth instrument fitted with an in situ dissolved oxygen sensor. This nomenclature pertains to the instrument manufactured by Neil Brown Instruments, Inc.
CTD-P	Conductivity, temperature, and depth instrument manufactured by Plessy Instruments. The instrument does not have a dissolved oxygen sensor.
DO	Dissolved oxygen
GMT	Greenwich Mean Time

Micronutrients	Unless otherwise specified, micronutrients refer to nitrates, nitrites, and dissolved organic phosphates-arsenates.
POC-DOC	Particulate organic carbon and dissolved organic carbon.
XBT	Expendable bathythermograph used to obtain a temperature vs. depth trace.
PDR, PFR	Precision depth recorder
KH ₂	Kilohertz (thousand cycles per second).

Field Sampling

Meteorological Parameters

Measurements. Meteorological parameters measured consisted of wind speed and direction, atmospheric pressure (sea level), wet and dry bulb air temperature, sea surface temperature, and direction, period, and height of wind waves and swell. Additionally, estimates of visibility, cloud cover and type, and concurrent weather conditions (fog, precipitation, formation or dissipation of clouds, etc.) were made and recorded. All meteorological data were entered on VIMS Form 200 (see Appendix I) and, with the exception of wind speed, converted to metric units. (Wind speed was recorded in knots.) Time of meteorological observations was entered as local time and converted to GMT (hours and tenths). Those parameters which required a judgment by the observer (visibility, present weather, cloud cover, and type) were coded according to the World Meteorological Organization guidelines (Anonymous 1972). Specific codes for each of these observations are listed on the VIMS Form 200 at the location where the data are recorded.

Frequency. Measurements were made at three hour intervals while sampling was conducted on the water column cruises and once per station on the benthic cruises. The latter were occasionally augmented by ship's weather records from the bridge log. Continuous records of sea level pressure were obtained with a barograph; however, these records suffered from contamination resulting from ship motion and opening and closing of doors.

Instrumentation. Values of atmospheric pressure and wind speed and direction were obtained from the ship's aneroid barometer and anemometer respectively. The latter values were corrected for ship's speed and heading prior to entry on the data sheet. Wet and dry bulb air temperatures were measured with a ventilated psychrometer (Bendix Model 566). Barographs used were manufactured by Weather Measure (Model 8201), and sea surface temperature was measured with a thermistor type thermometer manufactured by Hydrolab of Austin, Texas (ARA Model ET 100).

Oceanographic Parameters

Measurements. Measured oceanographic parameters were: water temperature, conductivity, pressure, electrical current generated as a result of dissolved

oxygen permeation through a membrane, temperature of a dissolved oxygen probe, light transmission, and light scattering. In addition to these in situ measurements, water samples were obtained from various levels in the water column [near surface (upper 5 m) and near bottom levels (within 5 m of bottom) were always sampled, with as many as ten additional samples taken at various intermediate levels]. Water samples were processed, as described below, for independent laboratory analyses of concentration of salinity, dissolved oxygen (DO), nitrites, nitrates, total dissolved organic phosphates (micronutrients), particulate and dissolved organic carbon (POC-DOC), and suspended sediments.

Measurements of water temperature as a function of depth were made at positions halfway between water column and benthic sampling stations as they were occupied.

Frequency. Sampling frequencies varied between water column and benthic stations as well as within each type of station for various types of water samples taken.

I. Water Column Stations. During the first two cruises (BLM01W and BLM02W) in situ measurements and water samples were taken once at each station. On subsequent cruises (BLM03W and BLM04W) four sets of in situ measurements were made at each station (at approximately six-hour intervals). Each set of in situ measurements was augmented with near surface and near bottom water sampling for salinity and DO determinations. Additionally, water samples for determination of micronutrients as well as POC-DOC concentrations were obtained near surface and near bottom once at each station.

II. Benthic Stations. In situ measurements and near surface and near bottom water samples were taken at all benthic stations. Water samples were field-processed (as described below) for laboratory determinations of concentrations of salinity, DO, and micronutrients. Water samples for determination of suspended sediment load were obtained at near surface and near bottom depths at one station from each cluster of four stations. This was usually the first numbered station from each lettered group (i.e. stations A1, B1, C1, etc.). Suspended sediment samples were obtained from all stations in the G, K, and L groups because they were arranged as transects rather than clusters. When a thermocline was evident at a station scheduled for suspended sediment sampling, an additional sample was taken in the vicinity of the thermocline.

Instrumentation. Three instrument groups were used to obtain the in situ measurements and water samples which resulted in the physical oceanography data. Water samples and in situ measurement of conductivity, temperature, pressure, and DO were obtained with a CTD/DO-Rosette Sampler combination. Optical properties of the water column (only measured during the benthic sampling cruises) were obtained with a nephelometer-transmissometer. During the first benthic cruise, this instrument was attached below the supporting structure of the CTD/DO-Rosette unit. On subsequent benthic cruises, it was used as a separate unit. An expendable bathythermograph (XBT) system was used to obtain depth-dependent temperatures between benthic and water column stations.

I. CTD/DO-Rosette System. This system consists of two independent instrument configurations, each containing an underwater portion (sometimes referred to as a "fish") and a deck control-readout portion. The underwater portions are interfaced through electrical cable connections as are the deck units. Underwater and deck units are connected by an electro-mechanical cable. The CTD/DO portion of the system measures conductivity, temperature, pressure, and two parameters used to calculate dissolved oxygen. The rosette portion is essentially a triggering system to close water sampling bottles at desired depths. Three configurations of the CTD/DO-Rosette system were used during the study. They are schematically represented in Figure 3-1a to 3-1c. Each configuration contained an underwater pinger (Benthos Model 2216) which was used to determine the distance of the sensing package from the bottom.

During the first two water column cruises, the configuration of the underwater portion of the system was as shown in Figure 3-1a with the CTD/DO "fish" and the pinger occupying sampling bottle positions on the rosette sampler. Figure 3-1b shows the configuration used during the final two water column cruises. During these cruises, the CTD/DO "fish" was placed horizontally below the Rosette sampler, and the pinger was mounted vertically below the Rosette sampler. This was also the configuration used during the first two benthic cruises with the following exceptions: the pinger was mounted on the electromechanical cable above the CTD/DO-Rosette package, and, during the first benthic cruise, the nephelometer was mounted beside the horizontal CTD/DO "fish". A third configuration was used for the third and fourth benthic cruises. This is shown in Figure 3-1c, where the CTD/DO "fish" was mounted vertically below the Rosette unit, and the pinger was attached to the electromechanical cable above the sampling unit.

A. CTD/DO Sensing Instrumentation. The CTD/DO instrumentation used during all cruises except the first water column cruise was a Neil Brown Mark III CTD interfaced with a Beckman Minos Dissolved Oxygen sensor. Interfacing was accomplished by the CTD manufacturer. The CTD system is described in detail by Brown (1974), and the DO sensor is described by Greene et al. (1970). Previously enumerated measurements were sensed with the underwater unit. Temperature, conductivity, and pressure were measured 32 times a second. While the DO parameters were allowed to change once a second, 32 measurements were made each second. Measurements were digitized in the underwater unit, and data are transmitted up the electromechanical sea cable to the deck unit which also served as a power supply. Digitized data were processed in the deck unit with output options for a digital panel display, recording as digital information on an analog tape recorder, recording as digital information on a digital tape recorder, and recording on graphic recorders as XY, XYY or time dependent plots. Options used during this study were the digital panel display and analog tape and XYY graphic recorders. At sea, data on both the downcast and the upcast of the CTD/DO sensing package were recorded on magnetic tape, while plots of temperature and conductivity as functions of pressure were made only on the downcast to indicate the location of a thermocline or halocline. Resulting plots were used to assist in determining depths at which water samples were to be taken.

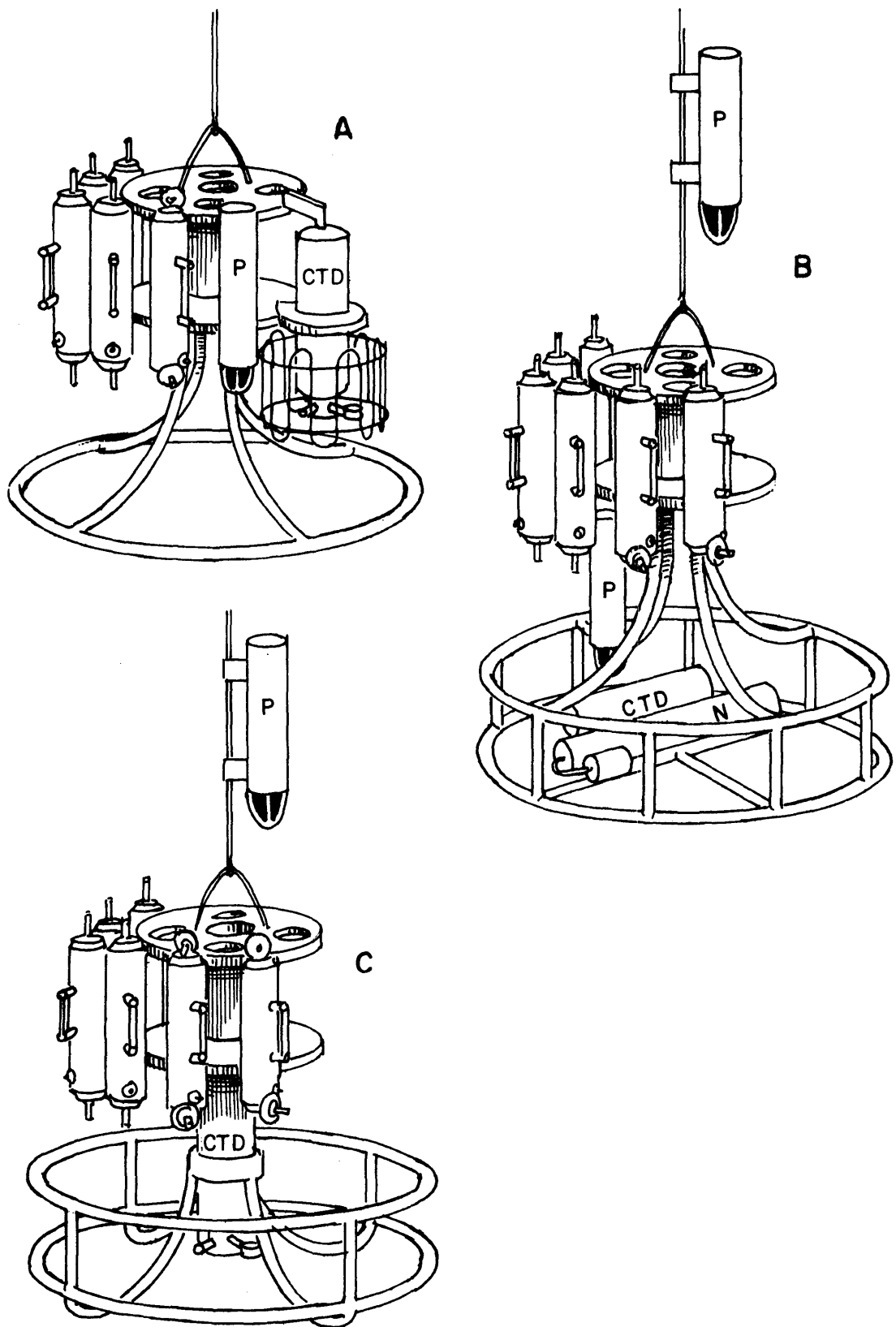


Figure 3-1. Various configurations of CTD/DO and Rosette sampler and underwater units with pinger used. (A) CTD/DO unit and pinger each occupy a bottle position; (B) CTD horizontally below Rosette; (C) CTD vertically below Rosette.

During the first water column cruise, a Plessey 9040 Model STD (CTD-P) was used in lieu of the Brown CTD/DO system. This was done because fabrication and testing of a second Brown instrument had not been completed prior to sailing time. The CTD-P is described in publications by Plessey Environmental Systems (undated). This instrument had recently been modified to a CTD configuration and calibrated by the NOAA instrument facility in San Diego, California. Data from this unit were obtained by recording ten second averages of frequencies resulting from measurement of pressure, conductivity, and temperature at frequent depths throughout the water column at each station. Water samples for laboratory analysis of salinity and DO were obtained at these depths as described below.

B. Rosette Sampling Unit. The rosette sampler is a two part system composed of an underwater ("fish") portion and a deck command portion. Both portions were interfaced to the "fish" and deck portions of the CTD/DO system. The sampler, described by Niskin (1968), is essentially a pulse signal generator connected, via the sea cable, to a stepping switch. When the trigger button on the deck unit is depressed, power from the CTD/DO deck unit "fish" is turned off, and a capacitor to the "fish" is charged in the rosette. When a specified charge is reached in the capacitor, it is discharged into a stepping motor. The stepping motor in the "fish" is isolated from the CTD/DO "fish". The stepping motor releases a triggering device in the rosette "fish" which in turn releases haliards which had been holding the end caps on a Niskin bottle open. A water sample is thus captured at a desired depth. Completion of the operation is signalled on the deck unit by movement of a counting switch and illumination of a "ready" light. The entire process takes eight to fifteen seconds to complete. Once the process is completed, power is returned to the CTD/DO system. The rosette unit used during this study was designed to obtain twelve five-liter water samples.

C. Expendable Bathythermograph (XBT) systems. A Sippican XBT system was used during this study. It consisted of a MK2A recorder and a hand held launcher. To operate the system, an XBT, with its cannister, is placed in the hand-held launcher and a locking mechanism in the launcher closed. This closure completes an electrical circuit between the XBT probe and the recorder via the launcher. When the circuit is complete, the recorder advances its chart paper approximately one quarter inch (to where the recorder stylis is at the zero depth mark on the chart paper), and a "launch" light is illuminated. To launch the XBT, a retention pin is removed from the cannister allowing the probe to fall into the water. On striking the water, a second circuit is completed which supplies power to the thermistor in the probe and begins the advance of the recorder chart paper. As the probe falls through the water column, temperature changes are sensed by the thermistor and relayed through a seawater ground and a pair of thin connecting wires to the recorder. The chart advance on the recorder is at a constant rate, and the chart paper is scaled to coincide with the slightly nonlinear fall rate of the probe. As temperature changes are sensed by the probe on its descent, the stylis in the recorder moves across the temperature scale. The result is a recording of depth-dependent

temperature at the launch site. Two spools of thin wire, one in the probe and the other in the cannister, allow the operator to launch an XBT while the ship is underway. As the probe descends, wire is payed off the spool in the probe, and, as the ship moves away from the launch site, wire is payed off the spool in the cannister. When the recorder has advanced through a predetermined number of cycles, the system is turned off, and a reload light is illuminated indicating the system is ready for launching another probe.

D. Nephelometer-Transmissometer. The Nephelometer-Transmissometer used to measure optical properties of the water column on the optical properties of the water column on the benthic cruise was supplied by the U. S. Geological Survey and used according to their instructions. For information about this instrument, its use, and resulting data, the reader is referred to the report on this study which has been prepared by USGS.

Shipboard Protocol

Sequential Activities. Responsibility for obtaining the in situ measurements and water samples which constituted the field program for physical oceanography rested with two individuals on each cruise: an hydrographer trained in physical oceanography and an electronics engineer or electronics technician trained in instrument operation and maintenance. Assistance in placing gear over the side and retrieving gear was obtained from other members of the field scientific party and ship's crew. Because of his background and training, the electronics-oriented member of this team was frequently called upon to repair various items of scientific or shipboard equipment not specifically related to physical oceanography or meteorology but essential to proper execution of the cruise. These items included depth measuring equipment (PDR, PFR or Fathometer), positioning equipment (Loran C) and, on several occasions, the underwater camera and strobe used to obtain bottom photographs.

The following sequence of events occurred at each station occupied on either water column or benthic cruises with two exceptions. Meteorological data were recorded every three hours during water column cruises, and the nephelometer-suspended sediment activities were confined to the benthic cruises.

(1) On notification of the chief scientist or watch captain of arrival on station within five minutes, the CTD/DO and nephelometer units were turned on for warm up. Prior to warm up, the optics of the nephelometer were cleaned with distilled water. During the first benthic cruise (BLM01B) turning the nephelometer on or off required opening the instrument case. This constituted a hazard to the instrument electronics because the activity had to be accomplished on deck and allowed for possible saltwater contamination of the internal portion of the instrument. As a consequence of this hazard, great care was taken to prevent salt spray or splash from reaching the "naked" instrument. Turn on times were recorded.

(2) When the desired geographical location was reached (as determined by the combination of Loran C and depth readings) a printout of the Loran C position was obtained. This printout consisted of at least ten pairs of Loran coordinates and was attached to a page in a Loran C Log Book. Information pertaining to date, time, cruise number, station

number, and type of activity (grab, CTD/DO cast, neuston tow, XBT cast, etc.) was entered on the same page. Loran pages were consecutively numbered and field data sheets contained provisions for entering the Loran C log page number.

(3) With the exception of the first benthic cruise (BLM01B) the first instrument cast made was the nephelometer cast to measure optical characteristics of the water column prior to contamination by sediment plumes resulting from grab operations. During cruise BLM01B, the nephelometer was lowered in conjunction with the CTD/DO instrument suite. At the conclusion of each nephelometer cast, the instrument was turned off and time was recorded.

(4) After the nephelometer cast the CTD/DO "fish" was placed in the water and allowed to soak until the temperature of the DO sensor equilibrated to ambient water temperature. This usually took five to ten minutes. On the benthic cruise this equilibration period was used to record meteorological data. Once the DO sensor temperature equilibrated, the CTD/DO cast was taken and water samples captured with the Rosette sampler. The "fish" was brought on deck, and water samples were removed from the Rosette mounted Niskin bottles for field processing as described below.

CTD/DO Cast. During the pre-cast CTD/DO warmup period the data recording analog tape recorder was turned on, and the tape was allowed to run for approximately 30 seconds (or until the tape counter advanced through ten units). This was done to allow a definite break between recordings of successive casts on any one tape. The recorder was then switched to the "record" mode and a voice recording made which gave information on cruise, station, date, and time. The recorder was then switched to the "pause" mode which stopped the tape transport. The recording convention followed throughout all cruises was to connect the CTD/DO output into the right channel of the audio tape and make verbal comments on the left channel. After the warmup period, the recorder was switched off "pause", and the recorder input was switched to the "tape" mode. At the same time, the CTD/DO deck unit was switched from the "CTD Direct" to the "replay" mode. With this arrangement of selectable switching the data stream came from the "fish", through the sea cable, and was recorded directly on tape by the recording head. The tape deck playback head then played back the previously recorded data (after about a 1 second delay) into the CTD/DO deck unit where the recorded signals were processed, displayed on the deck readout, and were used to drive the plotter. This somewhat involved procedure assured us of having recordings of usable data. Any malfunction of the CTD/DO system or the recording system could then be immediately detected. A simpler arrangement would have been to read the data from the "fish" on the deck unit and then record it. This, however, would not assure us of having usable data on the tape.

The bottom finding pinger was turned on, the DO sensor cap removed and the "fish" was then placed in the water for DO sensor equilibration. Prior to the "fish" entering the water, the pressure sensor offset (if any) was noted verbally on tape. Time of entry into water and tape count of entry time were recorded on the field data sheet (VIMS Form 200). The "fish" was allowed to soak at a depth where all Niskin bottles remained below the surface (sensor depth of three to five meters depending on sea conditions) until the

desired equilibration temperature (a difference of $\pm 0.5^{\circ}\text{C}$ between ambient and DO sensor temperature) had been reached.

Once equilibration had been reached, the downcast was started with verbal notation on tape. This notation also indicated station depth as discerned from the PDR. At stations over 50 meters deep and at shallow stations when a wire angle was evident due to station keeping maneuvers of the ship, the descent of the "fish" was watched on the PDR by switching this instrument to a "listen" mode. In this mode, two trace lines were recorded on the PDR chart, one resulting directly from the sonic emission of the bottom finding pinger and the other from the reflection of this sound off the bottom. As the "fish" approached the bottom the two lines came together. The downcast was stopped by announcing "stop!" to the winch operator when all available depth indicating sources (PDR, meter wheel, and CTD/DO pressure reading) indicated the "fish" was within three to five meters of the bottom. At this time the CTD/DO deck unit display was switched to the "hold" position, the announcement of a pending Rosette sample was made into the tape recorder, the plotter was switched to the standby position, and a Rosette sample taken. While the Rosette sample was being taken, the time and reading from the tape counter were recorded on the field data sheet as were the readings of pressure, conductivity, temperature, DO current, and DO sensor temperature. During the water column cruises, three additional samples of 30 liters each were taken at the end of the downcast. This water was obtained for other investigators for chemical analysis. Once the bottom water samples were taken, the graphic recorder was switched to the "record" mode, the pens were lifted, and the CTD/DO deck unit was taken off the "hold" position. Values of DO current were observed and, when they approached the just previously recorded values, the upcast was started. This delay for the DO sensor usually took one minute and was necessary because, as previously stated, during a Rosette sample cast, power to the CTD/DO "fish" is turned off. When the power is turned back on, the output from the DO sensor oscillates greatly and takes approximately one minute to "settle down." The upcast was then started by telling the winch operator the next depth to be sampled. These instructions were also recorded to assist in tape translation. When the next depth was reached, the sampling procedure was repeated. The final sample was taken at three to five meters below the surface (depending on sea conditions). During periods of extremely calm weather, the near surface sample was taken at a bottle depth of one meter.

Once the CTD/DO cast was completed, all instrumentation was turned off, and water samples were removed from the Niskin bottles for various types of processing.

Water Sample Processing. Water samples captured with the Rosette sampling system were contained in Niskin bottles. Figure 3-2 schematically shows opened (cocked) and closed (tripped) Niskin bottles mounted on a Rosette sampler. Water samples were removed from the Niskin bottles in the following order for specific ship-board processing: DO, salinity, micronutrients, and POC-DOC or suspended sediment. Each sample bottle and cap used was thoroughly rinsed with 100 to 200 ml of sample water prior to being filled.

I. DO Samples. DO samples were processed according to the Azide modification of the Winkler method (Standard Methods 1976). Samples were removed by first placing a six-inch length of rubber hose over the Niskin bottle spigot and inserting the free end into a rinsed 4 oz. sample bottle.

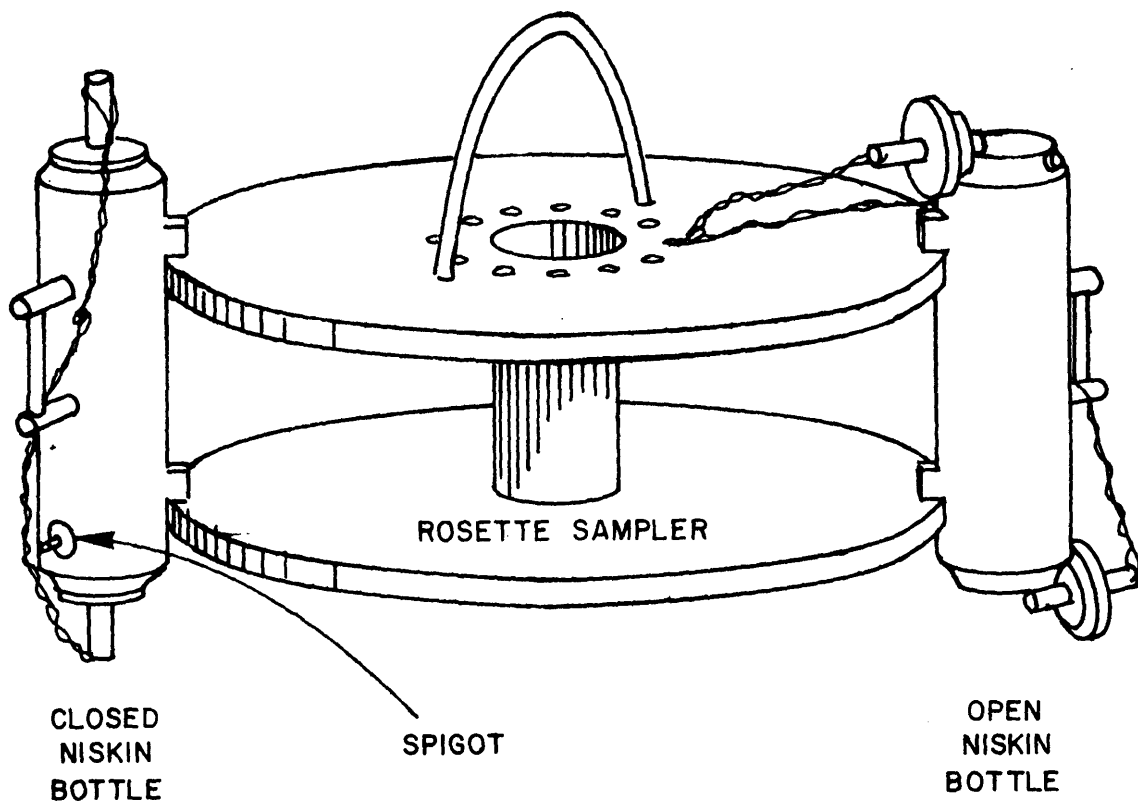


Figure 3-2. Schematic representation of a Rosette sampler with two Niskin bottles (one open and one closed) attached.

Water was allowed to drain into the sample bottle taking care that the rubber hose remained at the bottom of the bottle and was free of air bubbles. The bottle was filled and allowed to flush at least twice before the hose was removed. The hose was removed, again taking care that no air bubbles entered the bottle, and a screw cap was secured to the bottle. (Screw caps had conical polyethylene inserts which forced a portion of the sample out of the bottle as the cap was attached.) The sample bottle was then inverted to check for air bubbles. If bubbles were evident, the bottle was emptied and the process repeated. Sample bottle numbers were recorded on the VIMS Form 200.

Shipboard processing of DO samples consisted of carefully adding 1 ml of manganese sulfate solution then 1 ml of alkali-iodide-azide reagent sodium iodide, recapping the bottles and shaking vigorously until the sample was thoroughly mixed and a white floc precipitate appeared. The samples were allowed to stand until the precipitate settled to the lower two-thirds of the bottle then were shaken again and allowed to settle a second time. Once the precipitate had settled a second time, 1 ml of sulfuric acid was carefully added, the bottles capped and shaken again. Samples were then placed in a covered container and stored for titration ashore.

II. Salinity Samples. Once DO samples had been obtained from the Niskin bottles, salinity samples were removed. These were placed in sample-rinsed 4 oz. bottles allowing an air space for sample expansion. Bottle numbers were recorded on the VIMS Form 200 and samples stored for onshore analysis.

III. Micronutrients. Field processing of micronutrient samples consisted of filtering and freezing the samples. Samples were drained from the Niskin bottles into rinsed polyethylene transfer bottles. Prior to each cruise, the transfer bottles and all glassware used in the filtering process were acid washed and rinsed in glass distilled water. Samples were filtered through 0.45 micron millipore filters. Approximately 200 ml of sample was filtered through a new filter and the filtrate used to rinse the filter flask. This filtrate was discarded and a second 200 ml aliquot of the sample was filtered through the same apparatus. This second sample was used to rinse an acid washed, pre-numbered polyethylene sample bottle (4 oz. size). The numbered sample bottle was then filled two-thirds full of sample, capped, and frozen. Bottle numbers were recorded on VIMS Form 200, and samples were kept frozen until analyzed ashore.

IV. Suspended Sediment Samples. Samples for suspended sediment analysis were obtained at one station from each group of clustered stations and from each station on a transect (the G, K, and L stations) during the benthic cruises. Samples were obtained from near surface, near bottom, and the vicinity of the thermocline when one existed. Shipboard processing was in accordance with written and verbal instructions from the U. S. Geological Survey. Attempts were made to filter four liters of sample through a pre-weighed 0.45 micron millipore or nuclepore filter (depending on which was furnished by USGS or available from the VIMS Geology Department). Water was drained from the Niskin

bottles into a pre-rinsed, four liter polyethylene bottle with 0.1 liter calibration marks on the side. The starting volume was recorded, and the sample was filtered until all four liters had passed through the filter or the filter clogged. In the latter case, the volume of unfiltered water was also recorded. Filters and filter holders were washed with 100 ml or more of filtered distilled water, upper portions of filter holders were removed, and the filter was again washed with 10 to 20 ml of filtered distilled water to remove salt water from the filter edge. Filters with their suspended sediment loads were then placed in their original numbered plastic petri dishes, labelled according to station, cruise, depth (and, occasionally volume of water filtered), and frozen until transferred to USGS. Suspended sediment samples furnished USGS were accompanied by lists containing identification of filters (by number), cruise, station, depth, and volume of water filtered.

The only variation in this procedure was with respect to source and type of filter and type of filter holder. These variations are explained below.

A. Cruise BLM01B. No filters or filtering apparatus was supplied by USGS. Filters were obtained from Dr. M. Nichols of VIMS. They were numbered, washed, dried, and weighed 0.45 micron millipore filters. A list of filter numbers and successive weights for each filter was sent to USGS with the previously mentioned cruise and station data. During this cruise, filters were placed in millipore filter funnel arrangements as shown in Figure 3-3a. Samples were poured from the transfer bottles into the funnels.

B. Cruises BLM02B and 03B. USGS furnished pre-weighed nuclepore filters. Each filter was in a numbered petri dish and every tenth dish contained three filters, two nuclepore filters separated by a millipore filter. The filtering apparatus used was the same as during the previous cruise except that samples were siphoned from the transfer bottle to the filter funnel.

C. Cruise BLM04B. In addition to pre-weighed filters, USGS furnished filter holders, valving, and various lengths of vacuum tubing from which the apparatus pictured in Figure 3-3b was assembled. This arrangement was a vast improvement over previous set-ups in that it did not need constant attention.

A large (5-gallon) bottle was evacuated to serve as a vacuum chamber and overflow reservoir. The in-line filter holders were attached to this bottle in parallel with valves for each filter holder. Sample water was drawn into the top of the in-line filter holder as shown, passed through the filter, and into the reservoir.

V. Dissolved and Particulate Organic Carbon (DOC and POC). A 1-liter graduated cylinder was rinsed with about 50-100 ml of sample. The rinse water was discarded, and the graduated cylinder was filled to the 300 ml level. The foil wrapping (used on all DOC and POC apparatus to prevent dust, diesel smoke, and other material from contaminating the samples) was removed from a clean filter and holder assembly and placed

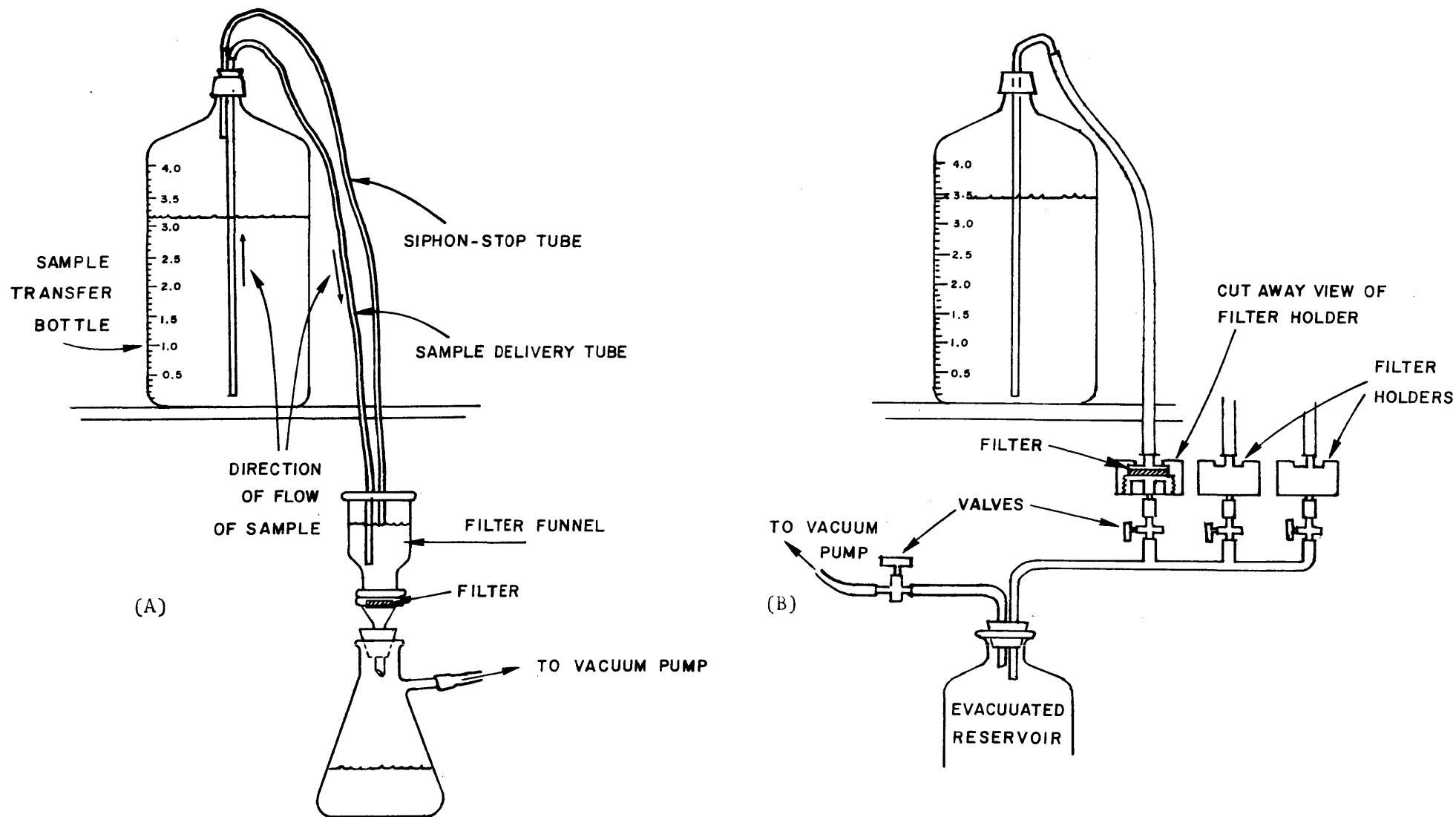


Figure 3-3. (A) Filter-siphon arrangement used for suspended sediment filtering for cruises BLM02B and 03B. Similar arrangement was used for BLM01B except that sample was poured into filter funnel, siphon was not used (clamp not shown on filter funnel). (B) Filtering arrangement used in suspended sediment filtering for cruise 04B showing filter holders, reservoir, and valving arrangement.

in line (position B in Figure 3-4). The foil wrap and cap from a sample bottle were removed and placed in line next to the filter holder (position C, Figure 3-4) taking care to keep the bottle cap clean by re-wrapping it in foil. The overflow reservoir was carefully placed in line between the sample bottle and vacuum pump (position D, Figure 3-4). Next, the foil wrap was removed from the suction tube (position A, Figure 3-4), and 300 ml of sample was siphoned through the filter into the sample bottles. The excess filtrate was drawn into the overflow reservoir. When all the sample had passed through the filter, the vacuum was turned off and the filter assembly removed and wrapped in foil. This was replaced with a new filter holder assembly, and the graduated cylinder was refilled to the 300 ml level with more sample which was filtered through the sample bottle as before. The process was repeated a third time; then the foil wrap was replaced on the siphon tube, and the filter and holder were removed from line and wrapped in foil. The sample bottle was removed from line and enough filtrate was discarded to bring the level down to the shoulder of the bottle. The cap and foil wrap were replaced on the bottle, and both filters and bottle were labelled with cruise number, station number, sample depth, and date and time the sample was taken. The filters and sample bottles were placed upright in a freezer for transport to shore. Once a sample had been processed, glassware and connecting tubing were rinsed by siphoning 100 ml of 0.3 normal HCl through the system followed by 100 ml of glass distilled water. Foil wrappings were then replaced.

Laboratory Processing

Shore-based activities applied to records of in situ readings and water samples secured and treated at sea are grouped into three broad categories: analyses of samples to determine concentrations of various constituents, posting of these results to field data sheets and editing of the data sheets, and conversion of tape readings of in situ measurements to (nominal) half meter average of temperature, salinity, and dissolved oxygen.

Sample Analysis

Salinity. Water samples secured at sea for salinity analysis were allowed to thermally equilibrate in the laboratory for a minimum of 24 hours. Temperature and conductivity ratio (relative to Copenhagen standard sea water) of the samples were measured with a laboratory salinometer (Beckman model R57-B) and the latter recorded on laboratory work sheets along with bottle number cruise and date of collection. Conductivity ratios were converted to salinity (in parts per thousand) using a computer program based on salinity vs. conductivity ratio tables furnished by the manufacturer. The laboratory salinometer has a rated accuracy of ± 0.003 parts per thousand, however this is only applicable to salinities in the vicinity of 35 parts per thousand. Salinities higher and lower than this are measured to less accuracy with a maximum error of ± 0.01 part per thousand (A. Cline, pers. communication). For this reason, salinities determined with this instrument are reported to the nearest 0.01 part per thousand. The laboratory salinometer was calibrated, at the beginning of each day's use, with Copenhagen standard sea water.

Salinity values thus obtained were posted to field data sheets (VIMS Form 200) beside the appropriate bottle number.

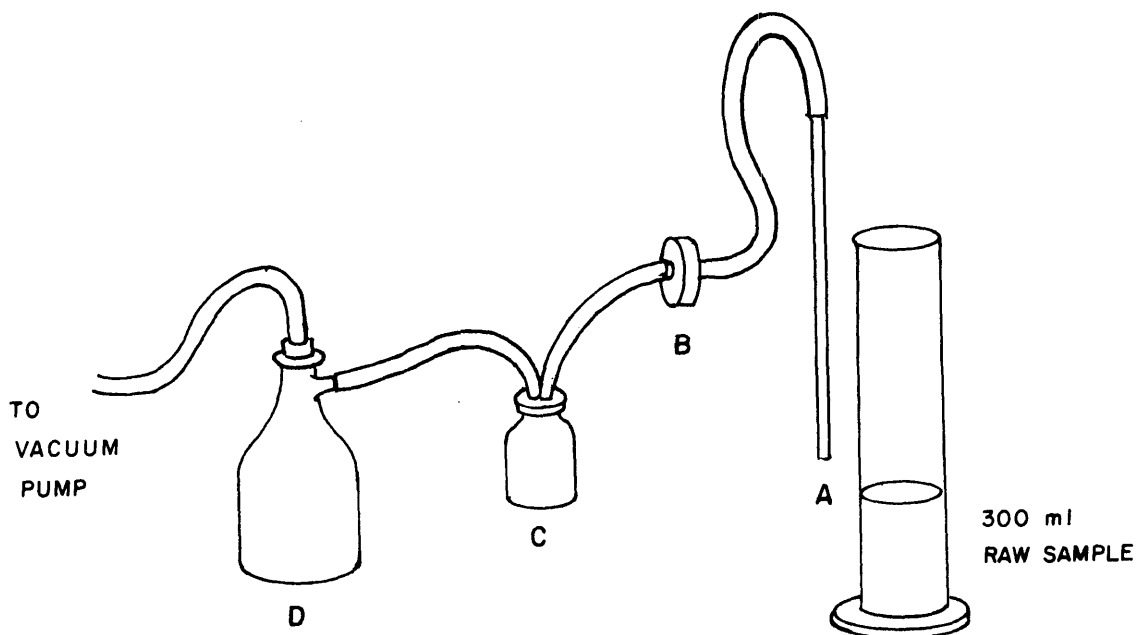


Figure 3-4. Arrangement of equipment for field processing of POC-DOC samples. A, suction tube; B, pre-combusted POC glass filter in holder; C, DOC sample bottle; and D, overflow reservoir.

Dissolved Oxygen. Water samples which had been field processed for DO analysis were titrated in the laboratory with sodium thiosulfate solution (using starch as an indicator) according to procedures outlined in Standard Methods (1976). Thiosulfate was standardized each morning, after every fiftieth sample, and when a new solution was made. Quantity of titer used was recorded on laboratory sheets along with bottle number, date of analysis, cruise number, and date as well as thiosulfate standardization information. Values of DO in mg/liter were determined from this information and posted in appropriate locations on field data sheets.

Micronutrients. Frozen field samples were stored in a freezer until they could be processed. Samples were removed from the freezer (in quantities up to fifty) and placed in a refrigerator to thaw overnight. Thawed samples were analyzed on a Technicon Auto Analyzer (model AAI). Analyses for nitrite and nitrate were run in accordance with Technicon Industrial method 158-71W AAI while those for orthophosphate + arsenate were run in accordance with Technicon Industrial method 155-71W AAI with modifications of the EPA methodology for the AAI applicable to saline waters (Standard Methods 1976).

I. Preparation of Standard Solutions for Micronutrient Analyses.

A. Nitrate and Nitrite. The following procedure was used: 0.0691 g of sodium nitrite (NaNO_2) was dissolved in one liter of deionized distilled water. This concentration was 1000 $\mu\text{gat N/l}$ and was called stock standard A for nitrite.

0.101 g of potassium nitrate (KNO_3) was dissolved in one liter of deionized, distilled water. This concentration was 1000 $\mu\text{gat N/l}$ and was called stock standard A for nitrate.

Stock standard B for both parameters was prepared by pipetting 10 ml of stock standard A into separate 200 ml volumetric flasks and adding deionized distilled water to the 200 ml mark. Concentrations of each were 50 $\mu\text{gat N/l}$.

There were three working standards prepared daily in concentrations of 5.0, 2.5, and 1.0 $\mu\text{gat N/l}$. 20 ml of stock standard B was pipetted into a 200 ml volumetric flask for 5.0 $\mu\text{gat N/l}$ concentration; 10 ml of stock standard B was pipetted into a 200 ml volumetric flask for 2.5 $\mu\text{gat N/l}$ concentration; and 5 ml of stock standard B was pipetted into a 250 ml volumetric flask for 1.0 $\mu\text{gat N/l}$ concentration.

Working standards were then run on an autoanalyzer with the instrument set at 5.0 $\mu\text{gat N/l}$ giving peak height of 100 concentrations of 2.5 and 1.0 $\mu\text{gat N/l}$ reached peak heights of 50 and 20 respectively.

B. O-Phosphate. 0.136 g of anhydrous potassium dihydrogen phosphate (KH_2PO_4) was dissolved in one liter of deionized distilled water. This concentration was 1000 $\mu\text{gat P/l}$ and was called stock standard A for phosphate. Stock standard B was 10 ml of stock standard A pipetted into a 200 ml volumetric flask and diluted to 200 ml. This concentration was 50 $\mu\text{gat P/l}$.

There were the three working standards prepared daily in concentrations of 4.0, 2.0, and 1.0 μg at P/1. 200 ml of stock standard B was pipetted into a 250 ml volumetric flask and diluted to 250 ml for 4.0 μg at P/1 concentration; 10 ml of stock standard B was pipetted into a 250 ml volumetric flask and diluted for 2.0 μg at P/1 concentration; and 40 ml of stock standard B was pipetted into a 200 ml volumetric flask and diluted for 1 μg at P/1 concentration. Working standards were run on an autoanalyzer with the instrument set at 4.0 μg at P/1 giving peak height of 100 and 2.0 and 1.0 μg at P/1 reaching peak heights of 50 and 20 respectively.

Particulate and Dissolved Organic Carbon. Frozen filters and water samples were allowed to thaw at room temperature. The filters were air dried with a water aspirator. Glass ampules (10 ml, Owens-Illinois) were prepared for use by being tapped upside down on a clean surface (to remove any particles of foreign material) and the top of the neck of each ampule wrapped with a piece of lightweight (one-inch square) aluminum foil twisted to form a cover for the ampule. Ampules were precombusted at 550°C for four hours. Six ampules were used for each sample giving triplicate analysis for each POC and DOC. To each ampule, 0.2 gm of potassium persulfate and 0.25 ml of 6% phosphoric acid were added.

For POC analysis, a filter was placed in an ampule and 5 ml of distilled water added. For DOC analysis, a 5 ml aliquot of thawed filtrate was added. Both POC and DOC were done in triplicate. Ampules thus filled were purged of inorganic carbon constituents for four to six minutes with purified oxygen (400°C) flowing at a rate of 60 ml/min., and then sealed in an apparatus especially designed to prevent CO₂ contamination from the sealing flame. Sealed ampules were heated at 125°C in an autoclave for four hours to oxidize the organic carbon to CO₂.

CO₂ content of each ampule was then analyzed in an ampule breaking apparatus (manufactured by Oceanography International Corp., College Station, Texas) which allowed the CO₂ to be flushed through an infrared analyzer (Model 524, Oceanography International Carbon Analyzer).

The carbon dioxide content of each ampule was determined by flushing the gas content of the ampule with nitrogen into the gas stream of a non-dispersive infrared analyzer sensitized to carbon dioxide. The detector output of the analyzer was recorded as a peak on a Hewlett-Packard (Model 724A) potentiometric strip chart recorder equipped with an integrator.

Standard carbon dioxide conversion graphs were made by plotting the integrated area versus carbon for standardized sodium carbonate solutions. These values were made by injecting a known volume of the sodium carbonate standard through a rubber septum in a special vial containing 25% phosphoric acid solution.

The organic carbon concentration of each ampule was determined by comparing the integrated area to the standard carbon dioxide conversion graph.

The deviation for triplicate DOC determination on the same water sample was generally 5% or lower, with POC usually 10% or lower. A reagent blank

value was determined with each set of water samples sealed. The DOC reagent blank value usually varied from 0.003 mg carbon to 0.004 mg carbon. The POC reagent blank usually varied from 0.003 mg carbon to 0.006 mg carbon. Triplicate values of POC and DOC were averaged and reported in mg/liter concentrations.

Conversion, Posting, and Editing of Data

Entries of in situ measurements on field data sheets (VIMS Form 200) were coupled, in the laboratory, with Latitude-Longitude information derived from Loran "C" readings and results of water sample analysis. Data sheets were then checked for completeness and correctness and sent to the VIMS Data Processing Center for keypunching. Printouts of keypunched data were obtained from data processing along with the original data sheets and the two compared. Errors were noted and appropriate corrections made. XBT traces were digitized by determining depth-temperature combinations for local maxima, minima, and inflection points as well as surface and bottom temperatures. These values were entered on VIMS XBT data sheets (VIMS Form 201) along with bucket temperature, surface salinity, and other appropriate information (date, time, location, station designation, etc.). When isothermal conditions were indicated, data entries were made at frequent intervals. Completed XBT data sheets were checked and sent to Data Processing for keypunching and printouts. These results were checked against the original data sheets and corrections made when necessary.

Computation of Parameters from Values on CTD/DO Tapes

Reported values of temperature, salinity, depth, DO, and σ_t were computed from measurements recorded at sea on audio tape from CTD/DO casts. Signals on the audio tape were actually (bit-serial binary) values of pressure, temperature, conductivity, and two DO associated measurements.

The digital data stream originates in the Neil Brown CTD underwater probe. For cruises BLM01 through BLM03, the basic sample consists of ten, eight-bit binary words. For subsequent cruises, the sample consists of eleven words, due to a modification to the CTD system increasing the digitization of O₂ probe current from 8 to 12 bits. These words are sent from the CTD probe to the deck terminal unit in bit-serial, teletype format with one start bit preceding and two stop bits following each eight bit word. The transmission is by frequency coding each bit so that it can be stored on a stereo tape deck (AKAI Model GX-630D). Two frequencies are used: 5kHz and 10kHz with one cycle of 5kHz representing a zero and two 10kHz cycles representing a one. The data is played back off the tape, about one second after it is recorded, and fed to the Neil Brown deck terminal.

The terminal decodes the data and provides four outputs: visual displays of CTD sensor variables in engineering units; folding scale analog voltages proportional to pressure, conductivity and temperature; bit-serial teletype and clock digital signals; and TTL logic compatible bit-parallel outputs, with separate strobe signals, one for each eight bit word in the sample. There are also a number of test points and front-panel jacks for observing various signals in the deck terminal.

The sample is also called a frame. It is generated and transmitted by the CTD probe at the rate of 31.25 frames per second. The bits are transmitted at the rate of 5000 per second. The first word in the frame is the "frame sync" and alternates between 00001111 and 11110000 binary from one frame to the next. The next six words are the 16-bit digitizations of pressure, temperature, and conductivity. These and the remaining words in the frame are transmitted least significant bit first (Table 3-1). The eighth word contains the sign bits (+ or -) for pressure, temperature, and oxygen probe temperature in the lowest three bits. The highest five are wired to identify the different CTD units (done after cruises BLM02). The ninth word is the eight bit digitization of the O₂ probe current. The tenth is the eight bit digitization of O₂ probe temperature. In all cruises starting with BLM04, the ninth and tenth words contain the twelve bit digitization of O₂ probe current, and the eleventh is the eight bit O₂ temperature word (Table 3-2).

The Neil Brown deck terminal provides each eight bit word, one at a time, with a clock pulse indicating when the word is present for output. Baker, of VIMS, designed and built an interface which transfers each word to a Digi-Data Model 1300/800-PPB-400 nine track digital tape recorder. This interface provides counting and trigger circuits to set tape record lengths at any size up to the 400 word recorder input buffer limit. Each record is started with a frame sync word and set to be an integral number of frames in length. Record lengths for BLM01-03 cruise tapes have been 250 or 320 words. Front panel switches on the interface select single-record or continuous recording. When the recording is stopped, the record in progress is allowed to complete its cycle. The resulting digital tape is IBM-compatible with a density of 800 characters per inch.

The audio tapes of the CTD casts are brought in from the field and transcribed on 9-track tape in the lab using the same audio recorder and CTD deck terminal (recorders and terminals are interchangeable among themselves). The transcription procedure is to record, at the beginning of a cast, a single record of data made when the CTD was still in the air, but turned on long enough for the electronics and sensors to stabilize. The rest of the records in a downcast are recorded continuously. They start when the CTD probe has been in the water long enough for the water and O₂ probe temperature readings to close within 0.5°C. The downcast terminates with one End of File (EOF) mark on the digital tape just before or after the first rosette bottle sample.

Rosette samples interrupt the data and cause long lasting transients in the O₂ probe current. They are only taken on the upcast. The upcast data is recorded continuously on the digital tape, starting before the first rosette sample. The upcast ends after the CTD probe has been removed from the water and is terminated with two EOF marks on the digital tape. Aborted casts are terminated with two EOF marks. The last upcast is terminated with three EOF marks to mark the end of the tape. The digital tape is then rewound and labeled for filing. About three 90-minute audio tapes can be transcribed onto one 1200 ft. digital tape.

The transcribed digital tapes are labeled CTD 001 through CTD 999 and then processed on the VIMS IBM 370/115 computer. The processing must be done in two passes. The first program CTDRAV, generates oceanographic variables of depth (m), pressure (dbar), temperature (°C), conductivity (mmho/cm) O₂ probe current (µA), O₂ probe temp. (°C), salinity (ppt), time (sec), O₂ partial pressure (atm), O₂ dissolved concentration (ml/l), and the number of samples per output.

Table 3-1. CTD Frame Format (Cruises BLM001 through BLM003).

Word	Sensor	Bits
1	(Frame sync)	0001111 or 11110000
2	Pressure (dbar)	least significant eight bits binary
3	Pressure	most significant eight bits binary
4	Temperature (°C)	l.s. bits
5	Temperature	m.s. bits
6	Conductivity (mmho/cm)	l.s. bits
7	Conductivity	m.s. bits
8	(Signs)	l _{sb} , pressure, 1 for - l _{sb} +1, temperature 0 for + l _{sb} +2, O ₂ temp.
8	(Unit No.)	five most significant bits, 0 for CTD S/N 1295, 1 for CTD S/N 1495
9	O ₂ current (μA)	eight bits binary
10	O ₂ temp. (°C)	eight bits binary

Table 3-2. Changes to CTD Frame Format (Cruises BLM004 and subsequent).

Word	Sensor	Bits
9	O ₂ current (μA)	least significant eight bits binary
10	O ₂ current	0000XXXX, lowest four bits of words are most significant four bits of O ₂ current digitization
11	O ₂ temp. (°C)	eight bits binary

Conductivity is corrected for pressure and temperature effects. Time is generated from the sampling rate. Depth, salinity, O_2 partial pressure, and dissolved oxygen are calculated from the measurements and the most recent calibrations. All the variables are ordered by 0.5 meter depth slots into which the samples (frames) are averaged with equal weight.

The second pass involves correcting the calculated salinity and oxygen variables to depth and bottle sample measurements. This was done only for sufficiently accurate bottle samples; otherwise correlations were performed.

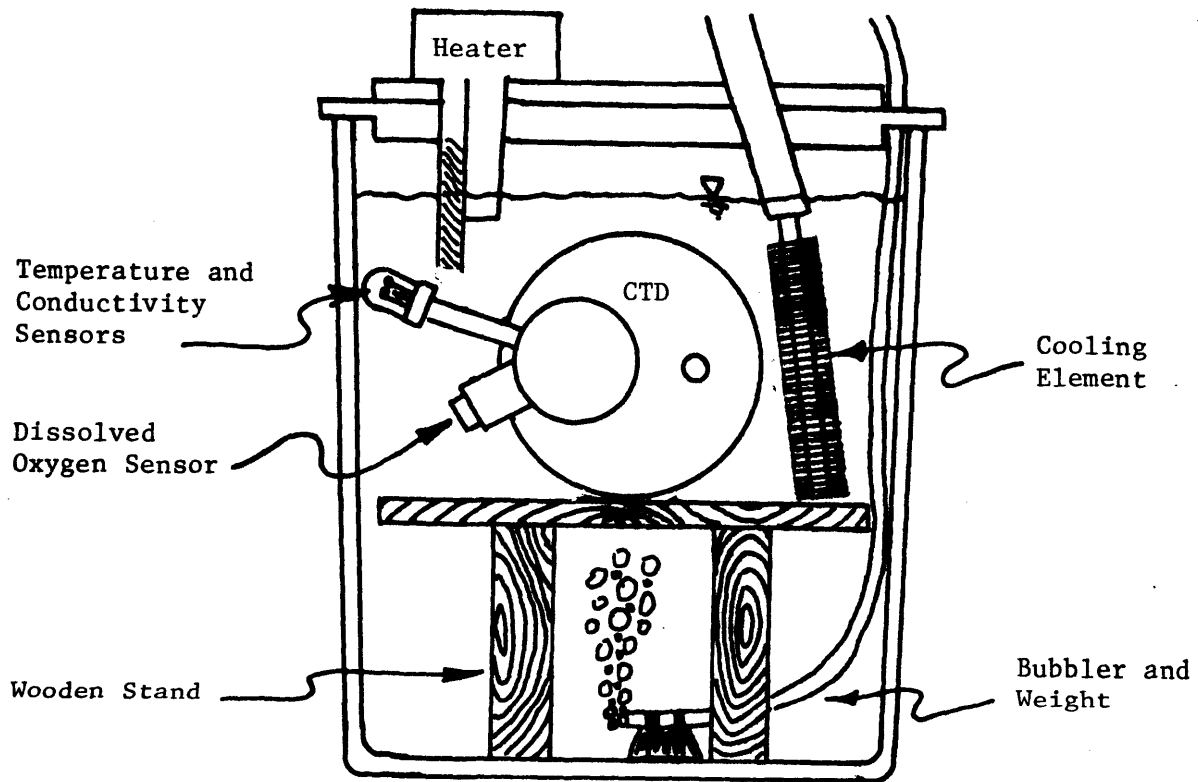
The data processing programs discussed here were developed with the help of three primary sources: the GEOSECS Operations Group of Scripps Oceanographic Institution, the Woods Hole Oceanographic Institution, and Neil Brown Instrument Systems, Inc. In particular, Dr. Arnold Bainbridge of Scripps provided information and program examples for processing and calibrating data from the Beckman pressure-compensated polarigraphic dissolved oxygen sensor. He also provided some early processing of VIMS data and general guidance on CTD cast and data processing procedures. Also of great help in the processing and calibration of oxygen data were Beckman technical memoranda provided by Mr. J. C. Burgess of Beckman's Advanced Technology Operations, Anaheim, California, and consultations with Dr. Rudolph Bieri of the VIMS Environmental Chemistry Department.

Mr. Douglas Moore of Woods Hole provided copies of WHOI CTD editing and processing programs for the Neil Brown CTD and also a copy of Publication WHOI-74-89, "WHOI/Brown CTD Microprofiler: Methods of Calibration and Data Handling". The Woods Hole publications were particularly helpful in setting up cast and calibration procedures. Help and manuals provided by Neil Brown Instrument systems were instrumental in data calibration and data translation from audio to digital tapes.

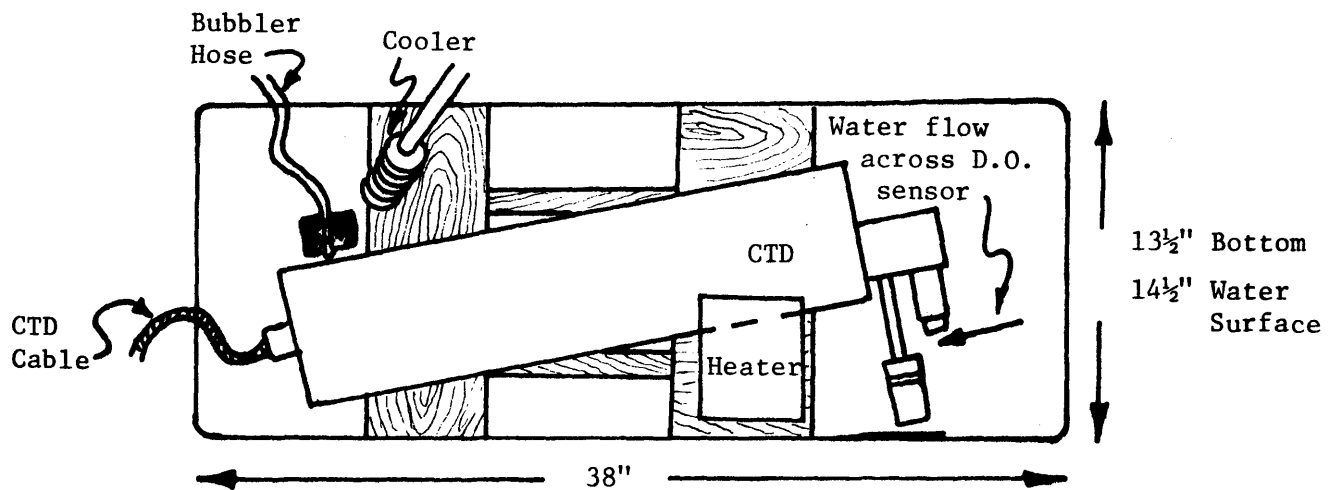
Instrument Calibration and First Pass Calculations. Oxygen calibration curves were taken from Neil Brown CTD's S/N 1495 and S/N 1295. The data were recorded verbally and directly from the CTD on audio tapes BLM034 and BLM035 and on VIMS Form 200's.

The physical set-up (Figures 3-5a and 3-5b) consisted of placing the CTD on a wooden stand inside a "giant" Igloo chest full of slightly saline (2.3-3.0 ppt) tap water. The water was supplied with a steady stream of bubbles from a $\frac{1}{4}$ in. tygon tube connected to a Gelman Inst. Co. Model 13154 air pump giving about 1.3 CFM. Heating was accomplished with Techne model TU-12 temperature controlled immersion heater. Cooling was accomplished with a Techne model RU-8 dip cooler. Circulation for the oxygen probe was done with a Jabasco model 12560 "Water Puppy" 12VDC bilge pump, rated at 5 GPM. Flow over the oxygen probe was channeled with a suction head (Figure 3-6) made of PVC and galvanized plumbing parts. The suction head was placed over the oxygen probe and connected to the inlet of the bilge pump with $\frac{5}{8}$ in. diameter garden hose; the water was returned to the opposite end of the igloo chest. The flow was sufficient to attain at least 94% of the full probe output current according to information provided by Beckman Instruments.

The procedure followed was similar to that used on regular CTD casts such that time, display readings, and audio tape counter number were recorded on the voice channel of the tape and on VIMS Form 200's. A water sample for



a) End view of probe in Igloo Chest.



b) Top view of Igloo Chest.

Figure 3-5. Physical arrangement for calibration of DO sensor on CTD/DO probe.

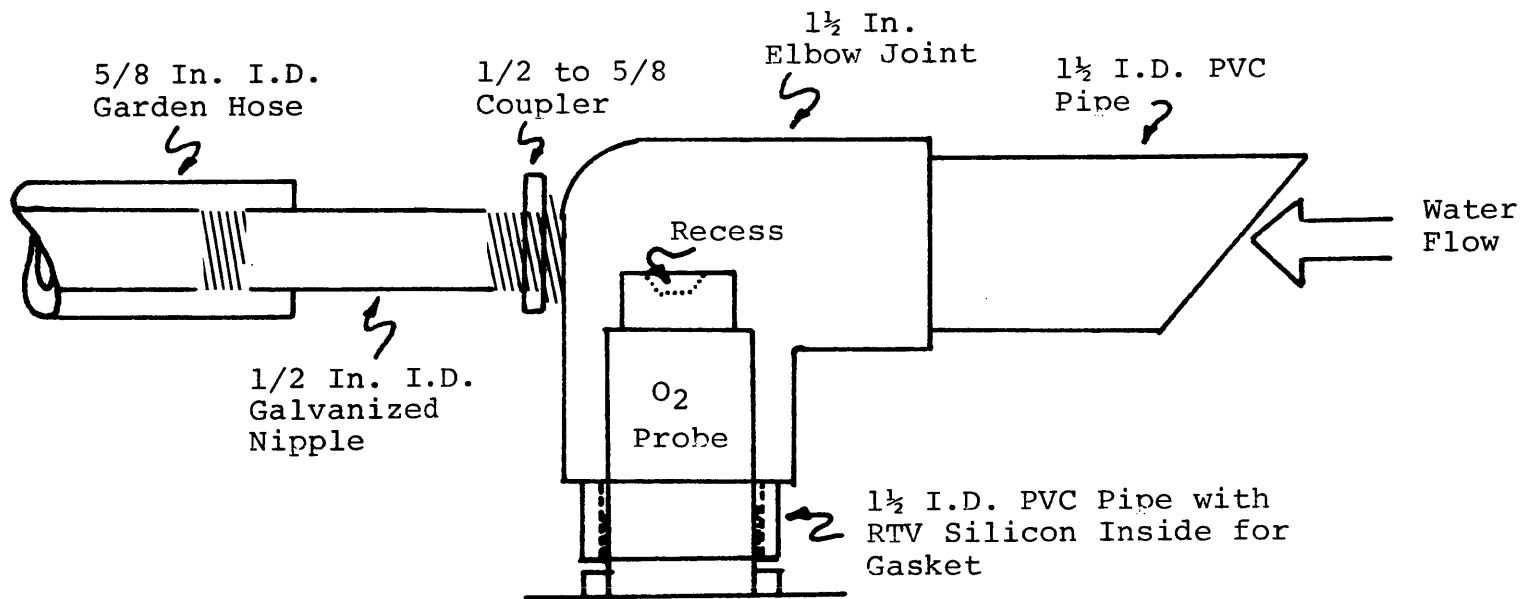


Figure 3-6. O₂ sensor suction head used in calibrating DO section of CTD/DO underwater unit.

dissolved oxygen (Winkler analysis) was taken immediately after the recorded information for each point of temperature and was fixed within 5 minutes. At various points salinity bottle samples and barometric pressure readings were taken.

The first reading for one sitting was usually near room temperature. The water was then heated or cooled to the next data point temperature. Data was then taken and the water temperature lowered. The highest temperature was about 30.5°C and the lowest about 4.5°C. In cooling, the bath temperature was lowered to the next point or a little below and the dip cooler turned off. When the oxygen sensor temperature was within 0.3°C of ambient, data was taken. Occasionally the bath was reheated a few tenths of a degree to match the oxygen sensor temperature. The CTD deck unit display was then held constant five times for verbal and written readings and bottle samples taken. It was observed that the oxygen sensor display temperature was consistently lower than the displayed water temperature at the lower temperatures and did not exhibit the time lag seen at higher temperatures.

The time response of the oxygen sensor current was observed to be about 15 seconds to full output in the CTD S/N 1295 sensor. This was measured by leaving the bilge pump off for a sufficiently long period and then timing the rise in current after the pump was turned back on. The stagnant water in the suction head tended to cause the probe current to drop to 50 or 60% over a period of several minutes after shutoff of the pump. The probe in CTD S/N 1495 was not so tested, but is believed to be about as fast.

CTD S/N 1495 was calibrated first. The results are the averages of the five displayed values for each variable at each point shown in Table 3-3. The pertinent values for O₂ calibration with the results of the bottle sample measurements are shown in Table 3-4. Values in parentheses are estimates of data not taken. Similar tabulations are made for CTD S/N 1295 in Tables 3-5 and 3-6.

The curves for I_{O₂} are much smoother than earlier attempts, and the curves for ΔT, (where ΔT = T_{O₂} - T) show the increasing negative offset of the probe temperature, T_{O₂}, with decreasing water temperature. Calibration results are given in Figures 3-7 and 3-8.

According to Beckman Technical Memorandum ATO-1019A, "Beckman Dissolved Oxygen Monitor Polarigraphic Oxygen Sensor", the current through the sensor is defined by:

$$I_{O_2} (\mu A) = K p_m p_{O_2}, \quad (1)$$

where K = sensitivity factor,

p_m = membrane permeability, a function of water pressure and temperature, and

p_{O₂} = partial pressure of oxygen (atm), a function of the dissolved oxygen, Bunsen's coefficient, and water pressure.

Table 3-3. 5 point averages of display readings, S/N 1495 CTD
 O_2 calibration, 5-7 July 1976.

P(d bar)	C(mmho)	T($^{\circ}$ C)	I_{O_2} (μ A)	T_{O_2} ($^{\circ}$ C)	Barometer (m bar)
+0.12	4.3326	26.1148	0.692	26.20	
+0.06	4.6882	30.0494	0.738	30.02	
0.52	4.6054	29.0390	0.712	29.16	
0.40	4.5240	28.0948	0.700	28.14	
0.52	4.4276	26.9618	0.688	26.98	1017
0.40	4.3420	25.9624	0.676	26.08	
0.42	4.1686	23.9420	0.648	23.90	
0.20	4.0154	22.2004	0.620	22.36	1016
0.30	3.8304	19.9334	0.582	19.78	1016
0.30	3.6736	17.9820	0.552	17.60	1015.5
0.00	3.5180	15.9722	0.530	15.72	1015
0.12	3.3600	13.7506	0.496	13.52	1015
0.00	3.2358	12.2112	0.472	11.90	1015
-0.24	2.9718	8.8968	0.430	8.52	1015
-0.20	2.8008	6.7626	0.414	6.28	1014
-0.22	2.7526	6.0454	0.402	5.72	
-0.32	2.6772	4.9062	0.404	4.38	1013.5
-0.36	2.6586	4.5850	0.400	4.06	1013

Table 3-4. S/N 1495 CTD O_2 Calibration.

I_{O_2} (μ A)	T($^{\circ}$ C)	T_{O_2} -T	Barometer (m bar)	Bottle Salin. (ppt)	Titrated Bottle O_2 (mg/l)
0.692	26.1148	.0852	1017		7.024
0.738	30.0494	-.0294	1017		6.829
0.712	29.0390	.1210	1017		6.302
0.700	28.0948	.0452	1017	2.322	6.673
0.688	26.9618	.0182	1017		6.829
0.676	25.9624	.1176	1016.5		7.141
0.648	23.9420	-.0420	1016		7.551
0.620	22.2004	.1596	1016	2.319	7.610
0.582	19.9334	-.1534	1016		7.688
0.552	17.9820	-.3820	1015.5	2.319	8.293
0.530	15.9722	-.2522	1015	2.359	8.488
0.496	13.7506	-.2306	1015		9.112
0.472	12.2112	-.3112	1015	2.350	9.639
0.430	8.8968	-.3768	1015		10.049
0.414	6.7626	-.4826	1014	2.350	10.517
0.402	6.0454	-.3254	1014		10.693
0.404	4.9062	-.5262	1013.5	2.368	10.966
0.400	4.5850	-.5250	1013	2.395	11.024

Table 3-5 . 5 point averages of display readings, S/N 1295 CTD O₂ Calibration, 9-10 July 1976.

P (d bar)	C (mmho)	T (°C)	I _{O₂} (μA)	T _{O₂} (°C)	Barometer (m bar)
+0.28	5.3022	23.6816	0.676	23.88	-
0.22	5.9390	30.0820	0.792	30.28	-
0.22	5.7143	27.8290	0.738	28.02	1013
0.32	5.5025	25.8904	0.702	26.14	1013
0.32	5.2898	23.8722	0.668	23.96	1013
0.24	4.8038	18.5464	0.576	18.36	1016
0.18	5.0420	22.0722	0.640	22.10	-
0.40	4.8232	19.9580	0.598	19.90	1016
0.38	4.6174	18.0032	0.564	17.90	1016
0.40	4.4228	16.1074	0.536	15.88	-
0.38	4.2320	14.2466	0.492	13.78	1015.5
0.50	3.9890	11.8206	0.474	11.40	1015
0.50	3.8020	9.9028	0.448	9.72	1014.5
0.54	3.6080	7.8885	0.416	7.64	1014
0.40	3.6956	8.8592	0.424	8.34	1014
0.56	3.4876	6.6260	0.392	6.06	1014
0.60	3.3344	5.0274	0.368	4.38	1014
0.60	3.2844	4.4922	0.364	3.78	1014

Table 3-6. S/N 1295 CTD O₂ Calibration.

I _{O₂} (μA)	T (°C)	T _{O₂} -T	Barometer (m bar)	Bottle Salin. (ppt)	Titrated Bottle O ₂ (mg/l)
0.676	23.6816	.1984	1013	3.028	8.355
0.792	30.0820	.1980	1013	2.960	7.366
0.738	27.8290	.1910	1013	2.982	7.568
0.702	25.8904	.2496	1013	2.982	7.588
0.668	23.8722	.0878	1013	2.969	7.972
0.576	18.5464	-.1864	1016	3.021	8.880
0.640	22.0722	.0278	1016	2.936	8.174
0.598	19.9580	-.0058	1016	-	8.779
0.564	18.0032	-.1032	1016	2.933	9.586
0.536	16.1074	-.2274	1016	2.930	9.869
0.492	14.2466	-.4666	1015.5	2.926	9.707
0.474	11.8206	-.4206	1015	2.920	10.554
0.448	9.9028	-.1828	1014.5	2.917	10.494
0.416	7.8885	-.2485	1014	2.939	11.302
0.424	8.8592	-.5192	1014	2.945	12.916
0.392	6.6260	-.566	1014	2.945	11.604
0.368	5.0274	-.6474	1014	2.954	11.726
0.364	4.4922	-.7122	1014	2.942	11.504

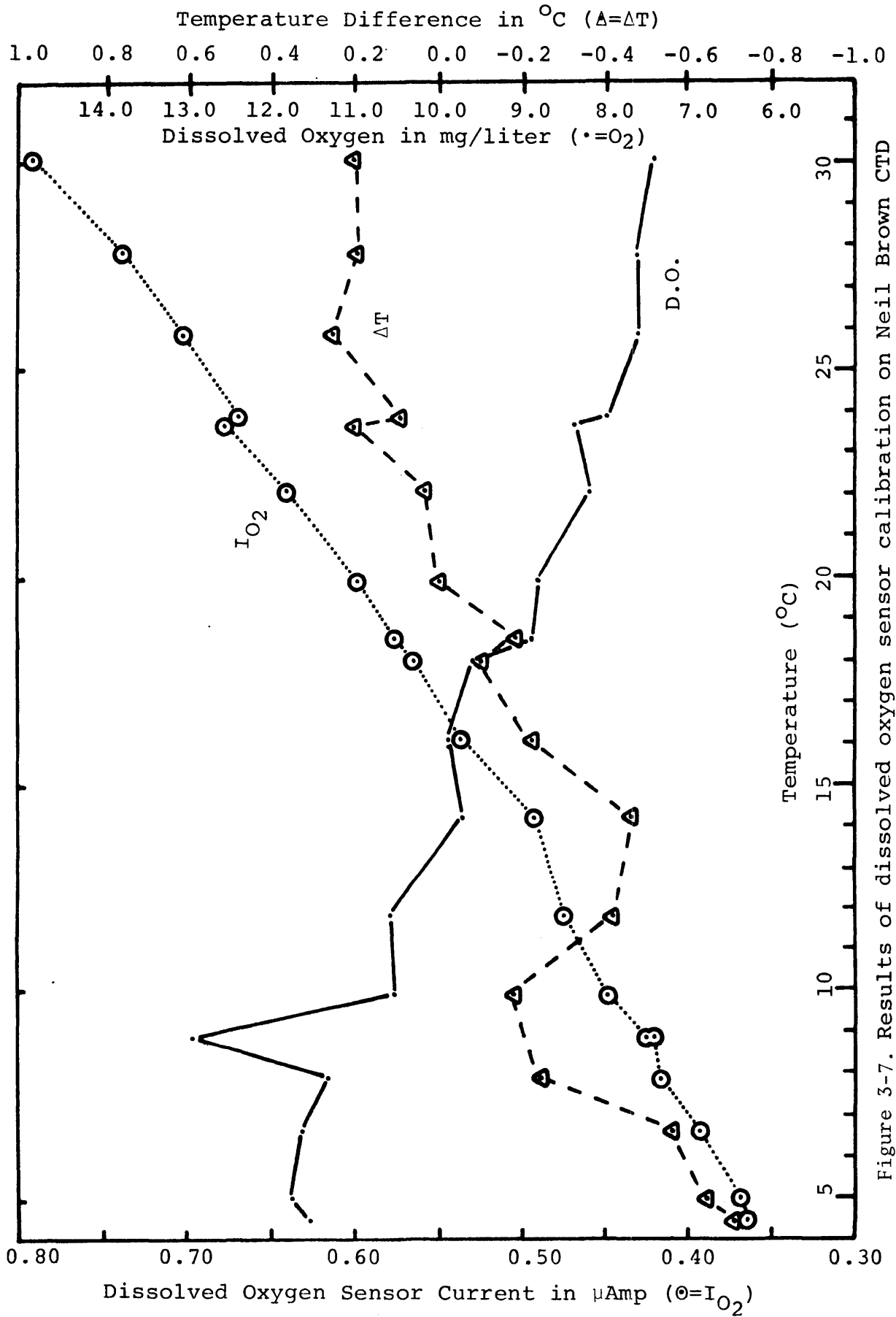


Figure 3-7. Results of dissolved oxygen sensor calibration on Neil Brown CTD #1295.

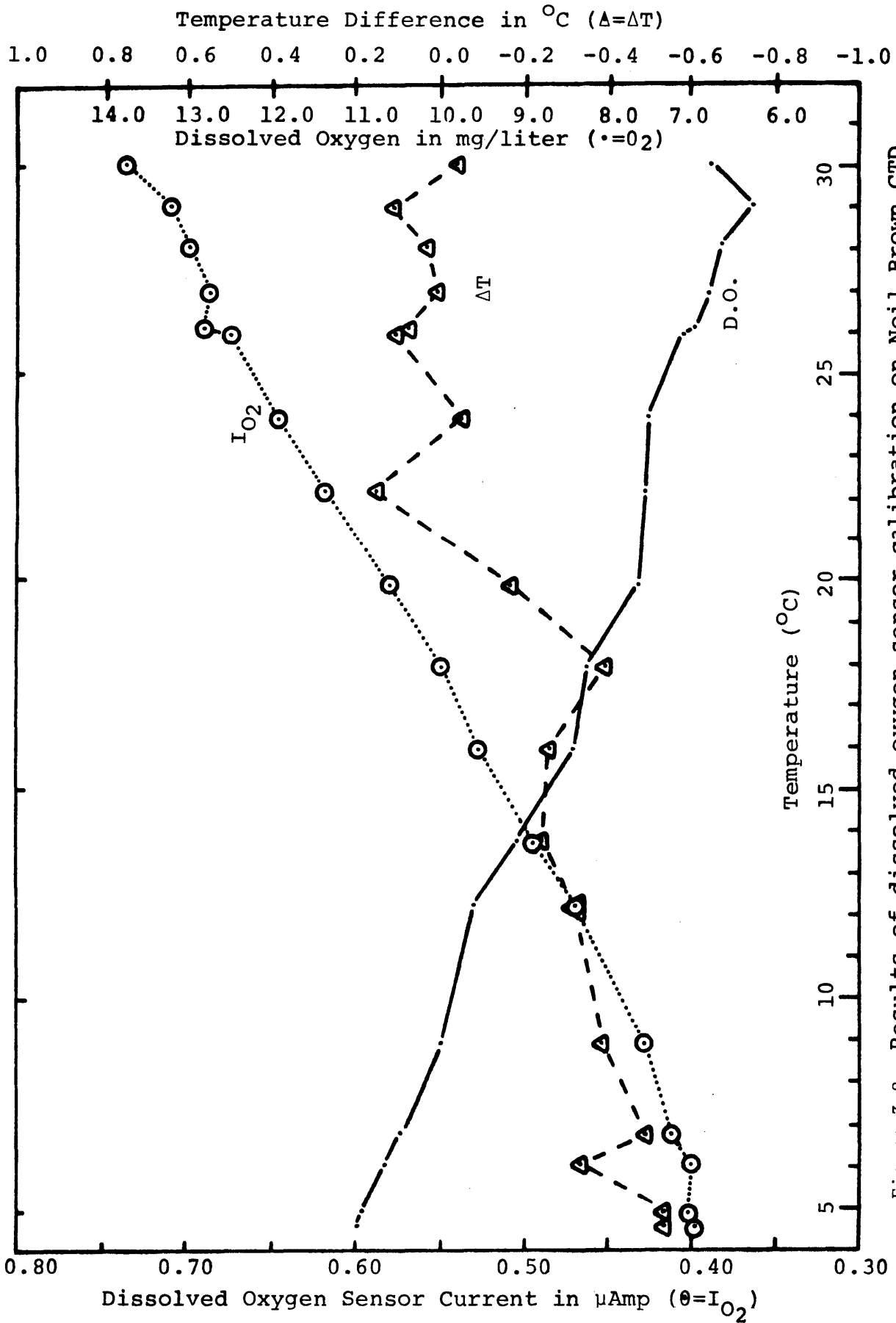


Figure 3-8. Results of dissolved oxygen sensor calibration on Neil Brown CTD #1495.

Bunsen's coefficient is a function of salinity and temperature. It is not mentioned in the Beckman ATO-1019A, but was given to us in the PROB2 Fortran subroutine by Dr. Arnold Bainbridge (Scripps GEOSECS Operations Group) in one consultation with him.

By separating the pressure and temperature effects, and approximating the temperature effects by an inverse polynomial, the O_2 probe current equation is:

$$I_{O_2} = \frac{e\gamma P p_{O_2}}{F(T)}, \quad (2)$$

where: p_{O_2} = partial pressure of oxygen (atm),
 p = sea water pressure (dbar),
 $F(T)$ = polynomial function of temperature in $^{\circ}C$, and
 γ = exponential coefficient of pressure effects.

The dissolved oxygen is found by applying Bunsen's coefficient to the partial pressure:

$$D_{O_2} = B P_{O_2} \quad (3)$$

where: D_{O_2} = dissolved oxygen (ml/l),
 B = Bunsen's coef., a function of salinity and temperature, and

$$1 \text{ ml/l } O_2 = 1.42953 \text{ mg/l } O_2 \quad (4)$$

Bunsen's coefficient is defined by Bainbridge in PROB2 as:

$$B = 1000. e^x, \quad (5)$$

where: $x = -58.3877 + 8580.79/u + 23.8439 \ln(v) + S(-0.034892 + v(0.015568 - 1.9387(10^{-3})v))$,

S = salinity of the water (ppt)

u = absolute temperature of the water ($^{\circ}K$), and

v = $u/100$.

Note that for temperature, $T(^{\circ}C)$,

$$u = T + 273.16 \quad (6)$$

It is assumed that the entire oxygen probe is at temperature T in the above calculations.

If the entire probe is at temperature T and the pressure can be assumed to be zero (compared to the accuracy of the pressure measurement and the pressures encountered in actual operation), the partial pressure can be found from the oxygen current by the sensitivity function:

$$P_{O_2} = I_{O_2} F(T) \quad (7)$$

If the entire probe is not at temperature T, the sensitivity function can be approximated by the average of the sensitivity at the water temperature, T, and the sensitivity of the backend probe temperature, T_{O_2} :

$$\bar{F} = \frac{F(T) + F(T_{O_2})}{2}, \quad (8)$$

according to the method of PROB2. Equation 7 is rewritten:

$$P_{O_2} = I_{O_2} \bar{F} \quad (9)$$

The temperature T_{O_2} is measured by a thermistor in the screw contact socket of the oxygen probe (not in the probe itself), it is taken that the temperature varies in such a way from the membrane, water temperature, T, to the temperature at the other end of the probe, T_{O_2} , that Equations (8) and (9) hold true. The back-end probe temperature, T_{O_2} , is highly dependent on the CTD case and internal temperature. The thermal masses and conductivities involved are such that T_{O_2} lags T by about 15 minutes with the CTD in well-stirred water.

The Scripps subroutine, PROB2, also makes predictive calculations on the partial pressure to correct for the oxygen probe time constant, which is on the order of six to fifteen seconds at room temperature and is also a function of temperature. No data was taken in this regard in the O_2 calibrations. Therefore, no calculations are made in our present subroutines to correct for time lag.

Equations (3) through (9) are used as a basis for calculating dissolved oxygen concentration and oxygen partial pressure in CTDRV. The calculations are also based on which CTD was used. For each CTD, the sensitivity function, F(T), and a corrected probe temperature, T_{O_2} , are calculated based on the calibration data.

For each probe, a first-order least squares fit of T_{O_2} to T was made using a Hewlett Packard 9810A calculator. The calculated value of T by the linear fit was taken to be the corrected probe temperature, T_{O_2} . For CTD S/N 1295, the correction is:

$$T_{O_2}C = 0.7443 + 0.9656T_{O_2} \quad (10)$$

For CTD S/N 1495, the correction is:

$$T_{O_2}C = 0.5859 + 0.9768 T_{O_2} \quad (11)$$

All data points were used for each fit. The program used to make the fit came from the Hewlett Packard library.

In order to get a function of F(T) for each CTD, two programs were used. The first was written in BASIC on the NOVA 1220 minicomputer. The inputs are the oxygen probe current, and temperature, water temperature, bottle sample salinity, and bottle sample dissolved oxygen from the O₂ calibration data. The oxygen probe temperature is corrected and then averaged with the water temperature:

$$\bar{T} = \frac{T + T_{O_2}}{2} \quad (12)$$

The averaged temperature and the bottle salinity are used to calculate Bunsen's coefficient for that sample point (by Equations (5) & (6)). The bottle sample dissolved oxygen is divided by the calculated Bunsen's coefficient (Equation (3)) to get the partial pressure of oxygen at that point.

The sensitivity at that point is calculated by dividing the calculated partial pressure by the measured oxygen probe current:

$$F(\bar{T}) = p_{O_2} / I_{O_2} \quad (13)$$

By printing out the appropriate variables, a tabulation of probe current, averaged temperature, sensitivity function, Bunsen's coefficient, and partial pressure of oxygen can be made for each CTD.

A least-squares polynomial fit of sensitivity function to temperature was made using the IBM FORTRAN Scientific Subroutine Program library on the VIMS IBM 370 computer. The sample main program POLRG with the subroutines GDATA, ORDER, MINV, and MULTR was used, omitting subroutine PLOT and changing the polynomial coefficient output to E15.6 format. One data point at I_{O₂} = 0.424μA in the CTD S/N 1295 data was omitted because of a titrated DO value that was too high. The best fit for CTD S/N 1295 was a second-order polynomial:

$$F(T) = 0.596878 - 0.015579T + 0.000130268T^2 \quad (14)$$

The best fit for CTD S/N 1495 was a third-order polynomial, but the second-order polynomial was chosen to maintain consistency:

$$F(T) = 0.509933 - 0.0112861T + 0.0000715741T^2 \quad (15)$$

The pressure effects lumped together as an exponential in Equation (12) may be calculated from the fitting of pressure-sorted CTD cast data to the titrated DO bottle samples from the same cast:

$$\frac{D_{O_2 \text{ CTD}}}{D_{O_2 \text{ Bottle}}} = \beta e^{YP} \quad (16)$$

Plots of F(T) vs. T for both CTD units are given in Figure 3-9.

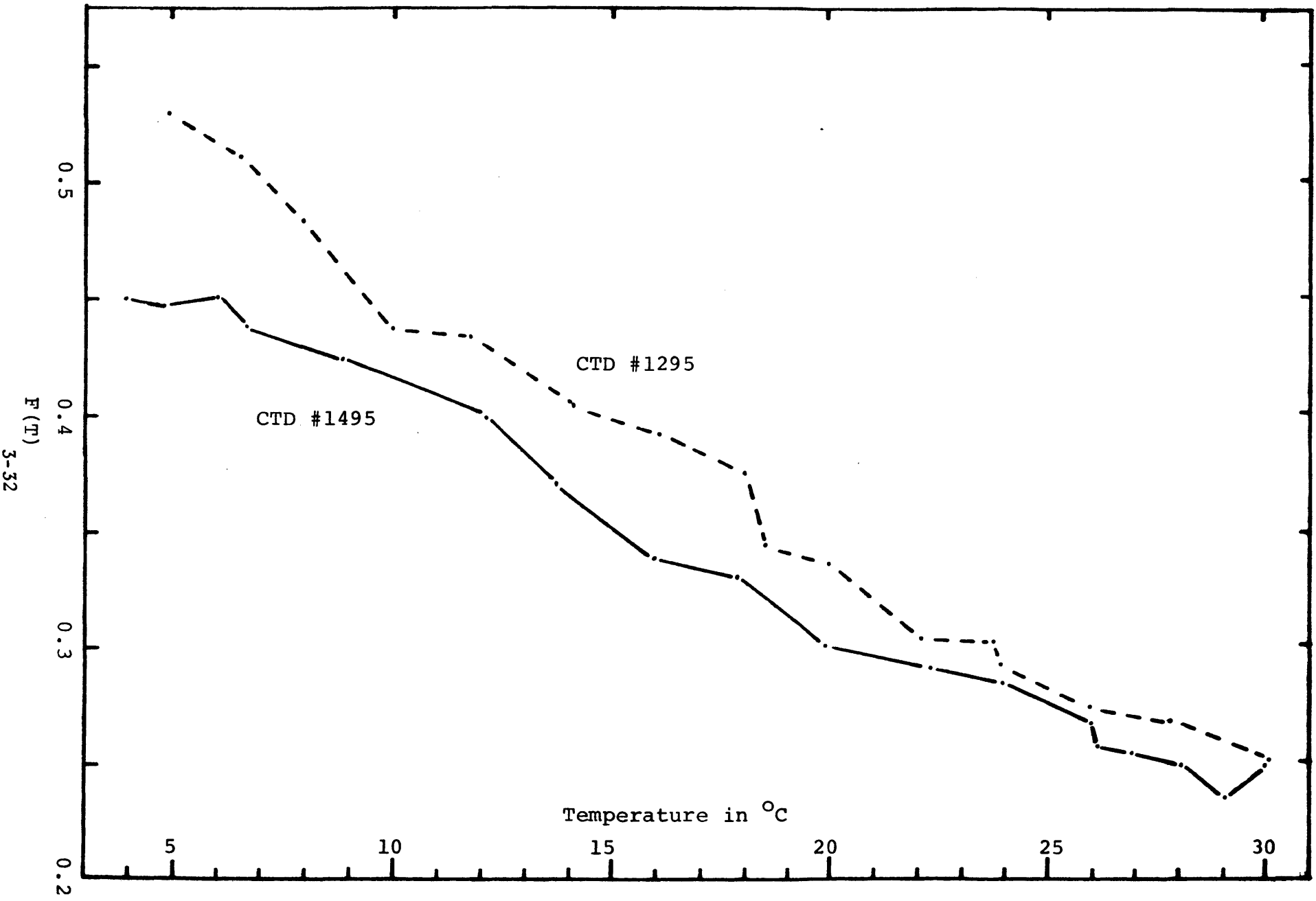


Figure 3-9. F(T) vs. temperature.

First Pass Calculations. The first pass program in present use is called CTDRAV, written by Baker. In brief, CTDRAV reads a record at a time from the binary digital tape and generates FORTRAN floating point variables containing the frame sync, unit number, and measured sensor values. In each record, the consecutive frames are checked for proper length and consistent frame syncs. Data that does not check out is dropped. Rate limits are applied from frame to frame on each measurement to eliminate noise spikes. Frames with more than one rate limit exception in pressure, temperature, and conductivity are dropped. Because the remaining probe values are digitized in the CTD every 32 frames or 1.024 seconds, a separate set of similar averages is kept and used to generate partial pressure and dissolved concentration of oxygen for every 1.024 seconds of raw data.

As the records are averaged, their values are sorted into 0.5 meter wide depth slots.¹ The records are weighted according to the number of frames per record. At appropriate times, when the program sorting storage is full, each slot is adjusted to give each frame an equal weight in a slot average, and the storage is printed out and dumped onto an output tape in FORTRAN-compatible format. At the end of each downcast and upcast, the sorting storage is dumped, and the minima and maxima of the frame values used for output are written at the printer and on the output tape. There is also an indicator for cast direction and CTD unit number. The output tape is given an End of File (EOF) mark, rewound, and printed out.

A copy of CTDRAV with flowcharts is included as Appendix 3-A.

Program CTDCR1. The final pass of the data in the CTD processing cycle consists of program CTDCR1.² This program operates in a user-chosen way on the pressure averaged data coming from CTDRAV to produce corrected tapes of the parameters calculated from CTDRAV. It also computes the potential temperature and σ_t of the data in each pressure-averaged record and places them on the output tape. It accepts up to six user-defined constants for each station for use in the correction. CTDCR1 concatenates a header card with each input tape station record on the output tape. The printout from CTDCR1 acts both as a record of the concatenation and as a listing, in an easily readable form, of a selected subset of values of oceanographic (as opposed to engineering) interest.

The mechanism for correcting the record is implemented in a subroutine CORR, which transfers the input record to the output buffer. This subroutine has access to the input data and an array of up to six constants which are entered in a card for each station. An entry to CORR, designated as CORPRT, allows the writer of a version of CORR to document the action of the subroutine on the output printout using appropriate write statements and Hollerith format. As this operation is programmed, it can use as many lines of free format as required.

¹ The high data rate requires the employment of an averaging process unless microstructure is being investigated. Had these averaging procedures not been employed, a CTD/DO cast lasting one hour would result in 112,500 frames of data. This data, printed one frame per line, would generate a 1562.5 ft (or approx. $\frac{1}{4}$ mile) computer printout.

² Written by C. Welch.

Thus, CTDCR1 was used to correct values of temperature, salinity, or DO calculated by CTDRV. The method used to correct DO values was to determine a line of best fit between bottle DO and CTD/DO values (as calculated in CTDRV) for each station sampled and apply the equation for this line to the CTDRV output.

The output of CTDCR1 is contained on a "final digital" tape, which is used to generate plots and as entry to the NODC transmission process.

RESULTS

Two methods of presenting meteorological and hydrographic data have been employed: digital magnetic tape and graphic. Digital tapes were used to generate data listings and plots of temperature, salinity, and DO versus depth as well as T-S and DO-S diagrams. Data listings were, in turn, used to develop various contour plots. A listing of all meteorological and hydrographic data is not included with this report because of its size. (A complete listing of all data would result in an eighteen inch thick printout.) Magnetic tapes containing all data have been furnished to NODC for inclusion in their data file.

Graphics

Meteorological and hydrographic data (to include results of micro-nutrient analysis) have been presented in several ways to meet contract requirements and assist possible users. Graphics are combined on a cruise basis with individual station data ordered numerically by station identification within any given cruise.

Meteorological Parameters

Time histories of atmospheric pressure, wind speed and direction, wet and dry bulb air temperature, and cloud cover are plotted on a per-cruise basis. They are presented as the first figure(s) in the series for each cruise. All parameters were plotted on the same figure to give a complete picture of meteorological conditions during each cruise. Wind data for cruise BLM02B is missing after 21 March 1976 because the anemometer was blown away by winds greater than 60 knots.

Hydrographic and Micronutrient Results

Hydrographic and micronutrient data are presented in groups by cruises. Each group contains the following plots:

- 1) Surface and bottom distribution of temperature, salinity, DO, NO_2 , NO_3 , and O-PO_4 .
- 2) Contour plots of temperature, salinity, DO, and density (σ_t) as functions of distance and depth along sections I through V as shown in Figure 3-10.
- 3) Plots of the variation of temperature, salinity, DO, NO_2 , NO_3 , and O-PO_4 at near surface, mid-depth, and near bottom along sections I through V (Figure 3-10).
- 4) Plots of temperature, salinity, DO, and density (σ_t) as functions of depth for numerically ordered stations on each cruise.
- 5) Plots of temperature vs. salinity and DO vs. salinity for numerically ordered stations on each cruise.
- 6) Results of XBT casts taken on each cruise.

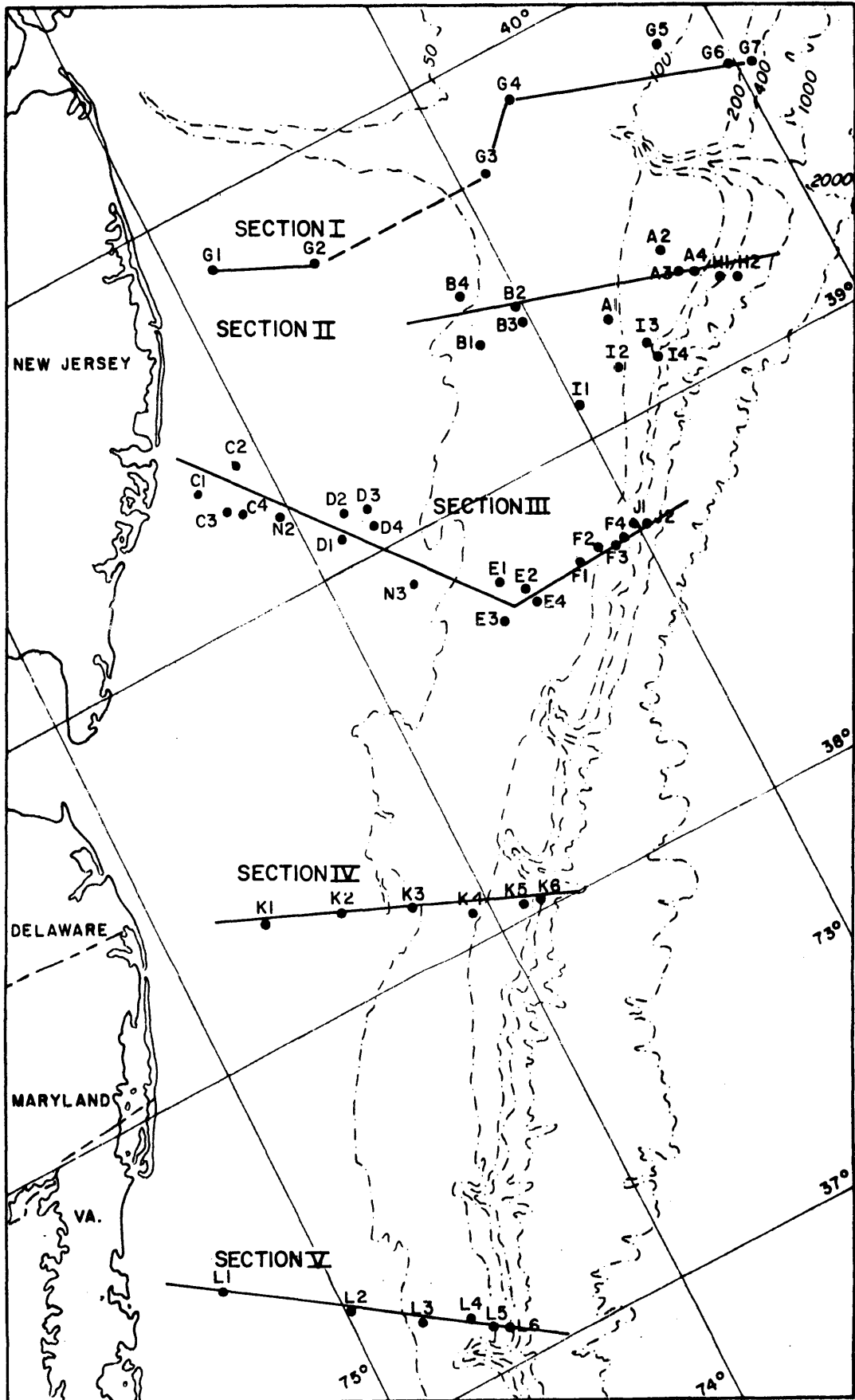


Figure 3-10. Chart of Baltimore Canyon trough study area showing Sections (I through IV) along which isopleths and surface, mid-depth, and bottom values of temperature, salinity, DO, and σ_t were plotted.

Surface and bottom distributions as well as sectional contours (1 and 2 above) should be treated with caution. These "summary" type displays of data suffer greatly from discontinuous sampling experienced during the longer (winter and summer) benthic cruises. Several instances arose where a temporal "gap" of from three to fifteen days existed between adjacent stations on a transect. These "gaps" resulted from either weather conditions which made safe sampling impossible or adjacent stations being occupied on separate legs of the Benthic Cruise. The greatest disparity resulting from these conditions is evident in surface distributions of parameters measured during BLM02B. In these plots, definite discontinuities in isopleths were left at appropriate locations. (Similar treatment was not given to the bottom distributions for this cruise because it was felt that bottom conditions would change at a slower pace than surface conditions. This, however, is indeed a moot decision.) Similarly, discontinuities in isopleths are incorporated in sectional plots (2 above) when sampling of adjacent stations occurred at intervals greater than five days. In these cases, sampling periods are indicated at the top of the figure.

All contouring was done by hand and assumed linear horizontal gradients at all depths. Vertical gradients were determined from half meter averages of CTD/DO data. Plots of individual parameters as functions of depth and T-S, DO-S figures were generated by computer using results of CTD/DO casts. XBT plots were also computer generated and used recorded data points obtained from XBT traces as previously described.

All plots of individual parameters at each station and XBT's are not included in the main body of this report because their number exceeds 1000. They are, however, available on microfiche. These plots are arranged by station in the following sequence: temperature, salinity, DO, and σ_t vs. depth; temperature vs. salinity; and DO vs. salinity. Depth dependent plots were plotted from zero to 160 meters. When a given station was greater than 160 meters deep, additional depth dependent plots were made which went from zero to 800 meters. Similar treatment was given to XBT plots.

Sequential Presentation of Results

As previously indicated, graphic results are ordered according to the alphameric coding of cruises (BLM01B, 01W, 02B, 02W, etc.). Subgroupings within each order are arranged in the following sequence;

- 1) Meteorological data
- 2) Surface distributions (arranged by temperature, salinity, DO, NO₂, NO₃, and O-PO₄)
- 3) Bottom distributions (following the above arrangement)
- 4) Sectional plots (in sequence and arranged by temperature, salinity, DO and σ_t for each section)
- 5) Variations of temperature, salinity, and DO at near surface, mid-depth and near bottom as well as variations of NO₂, NO₃, and O-PO₄ at near surface and near bottom (grouped by section)

Lateral variations of temperature, salinity, and DO are plotted by parameter with each plot representing near surface, mid-depth, and near bottom values of one parameter along a section. Similar data for micronutrients are arranged as plots of near surface values of NO₂, NO₃, and O-PO₄; near bottom plots of the same constituents; and an additional plot giving near bottom variations of NO₃ along each section. This latter plot was included because near bottom values of NO₃ ranged from 0.00 to nearly 30 μgm atoms per liter while NO₂ and O-PO₄ only varied between 0.00 and less than 5 μgm atoms per liter.

Cruise BLM01B

Fall 1975

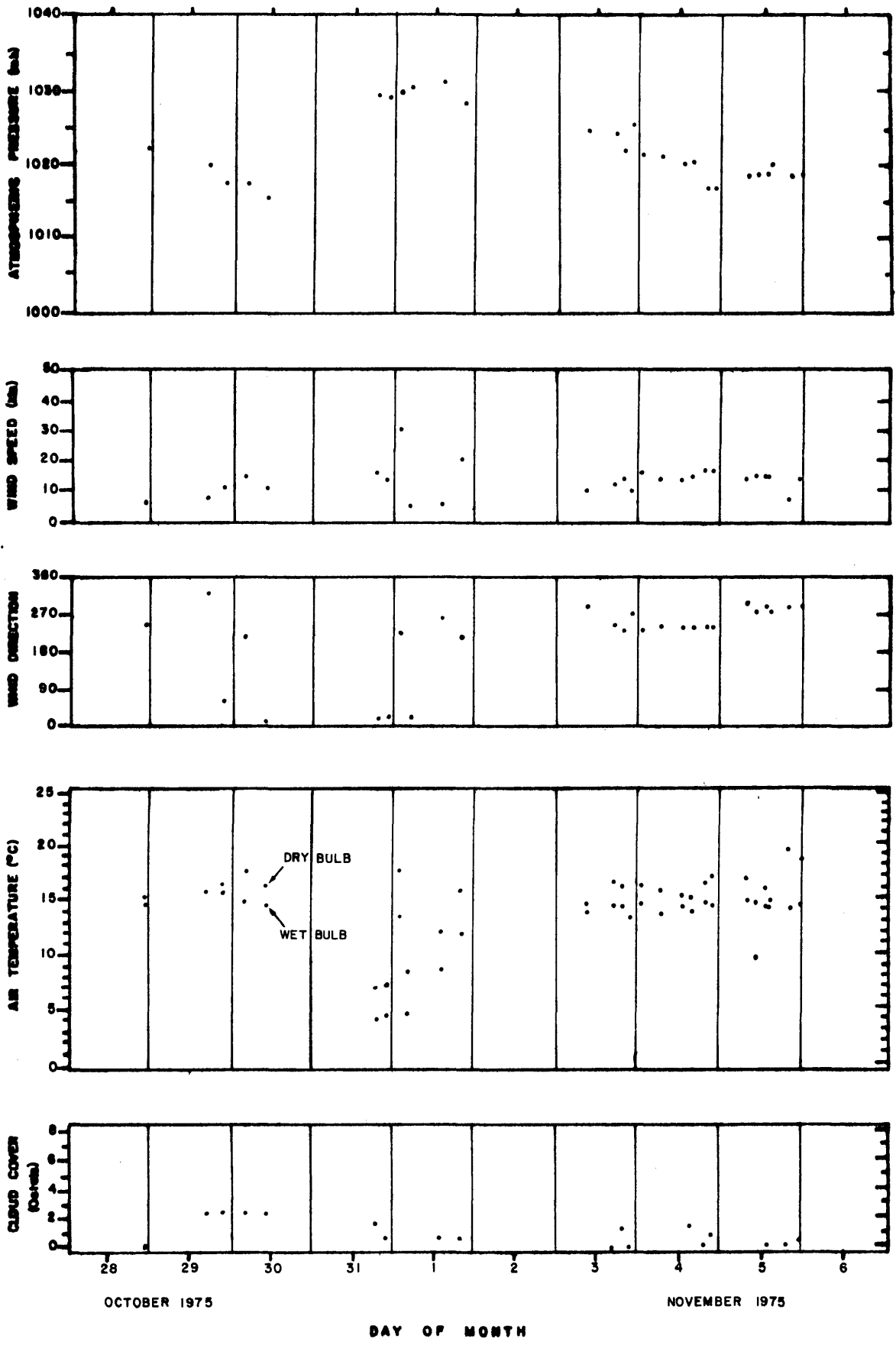


Figure 3-11. Meteorological data collected during cruise BLM 01B 28 October to 5 November 1975.

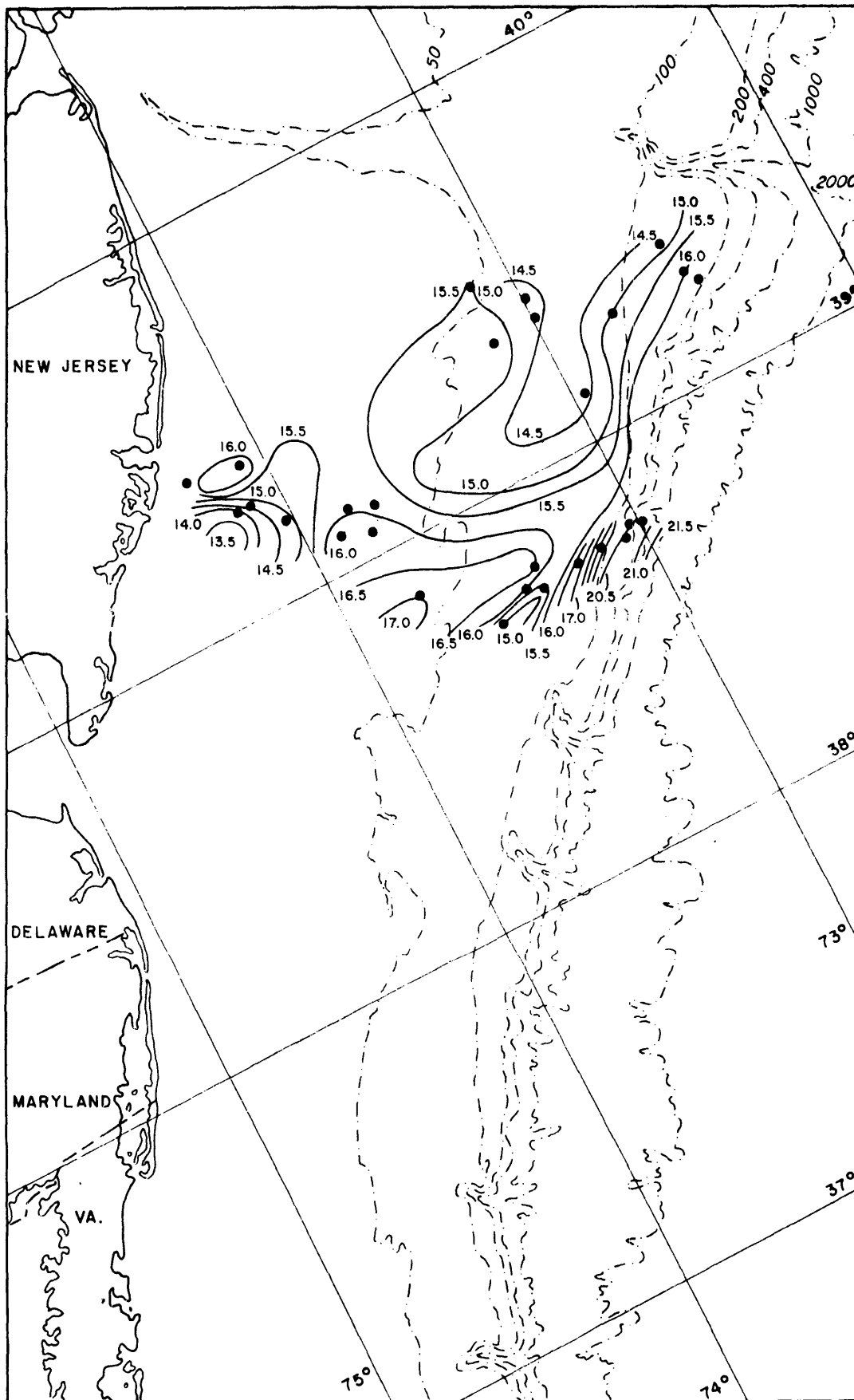


Figure 3-12. Surface temperature ($^{\circ}\text{C}$) distribution in the northern portions of the Middle Atlantic Bight during the period 27 October to 6 November 1975 (Cruise BLM01B)

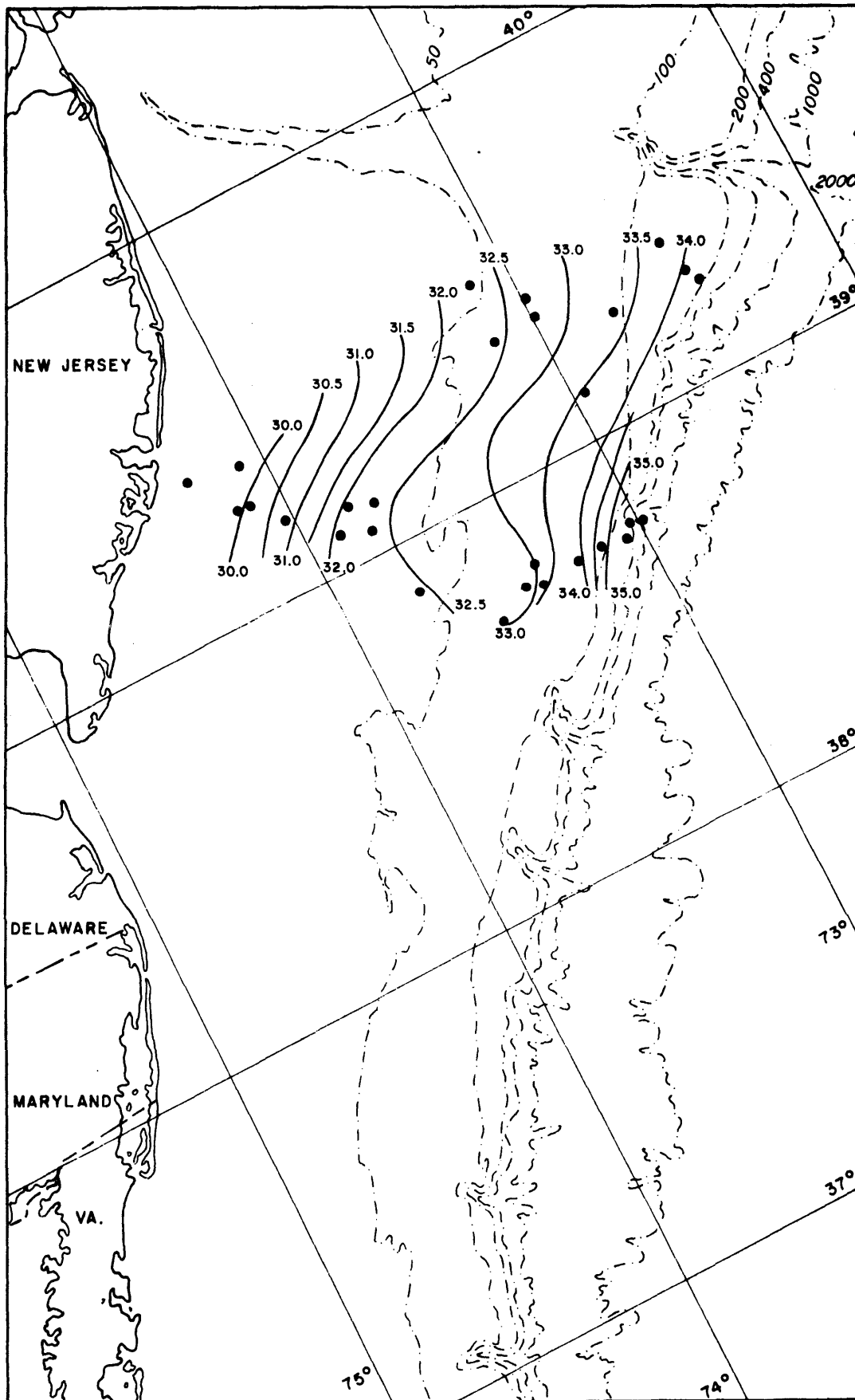


Figure 3-13. Surface salinity (ppt) distribution in the northern portions of the Middle Atlantic Bight during the period 27 October to 6 November 1975 (Cruise BLM01B)

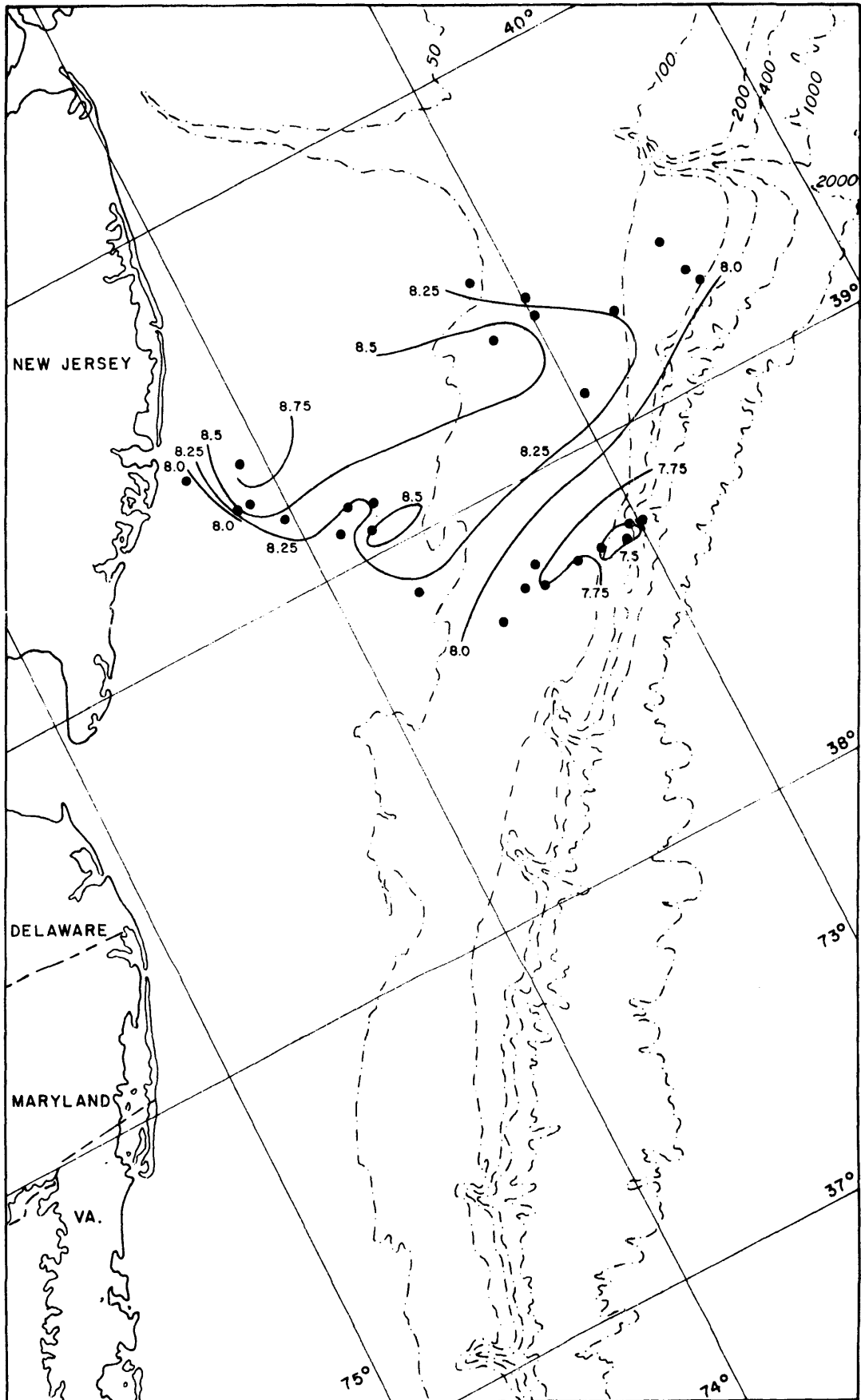


Figure 3-14. Surface dissolved oxygen (mg/l) distribution in the northern portions of the Middle Atlantic Bight during the period 27 October to 6 November 1975 (Cruise BLM01B)

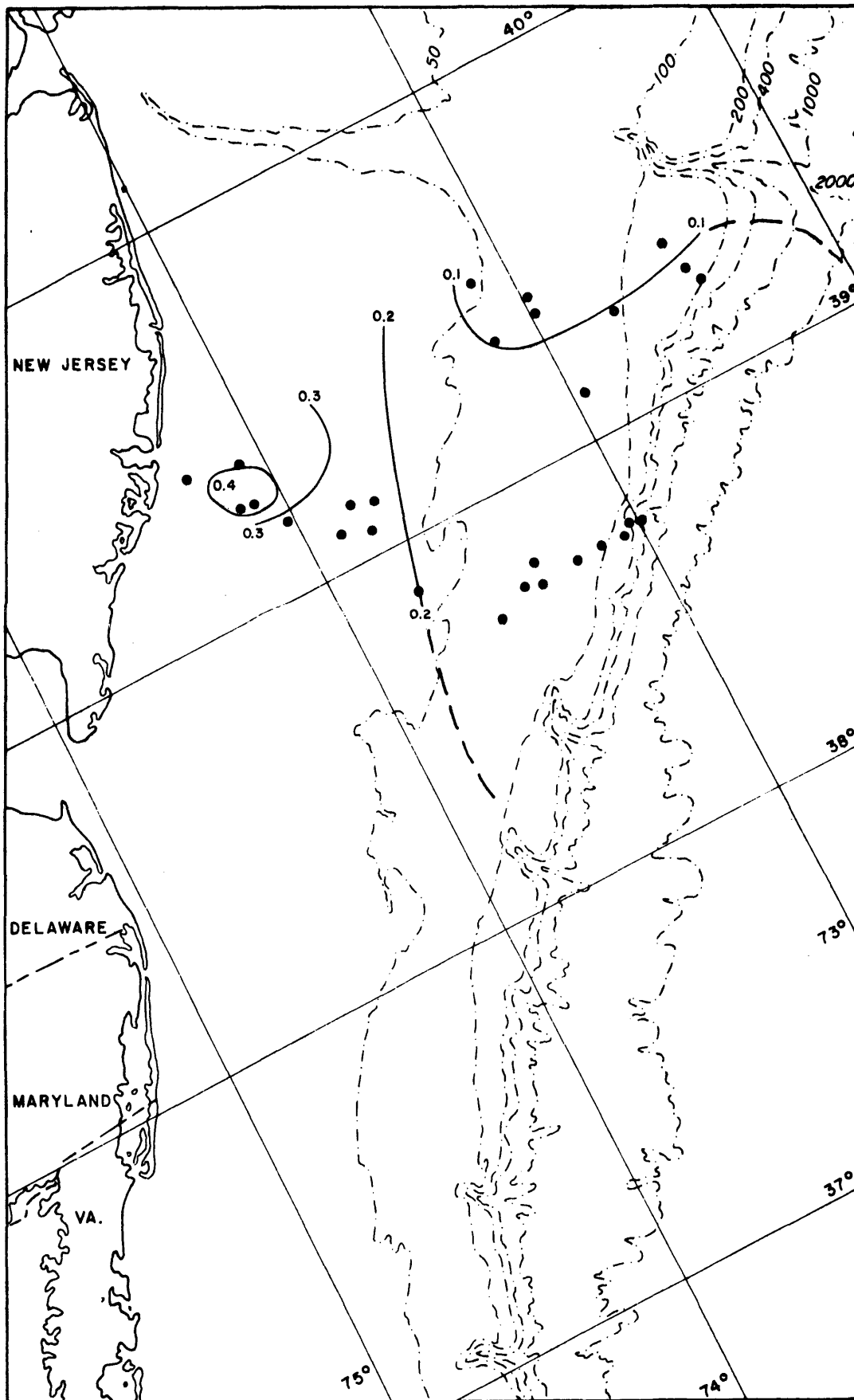


Figure 3-15 Surface NO_2 ($\mu\text{g atoms/l}$) distribution in the northern portions of the Middle Atlantic Bight during the period 27 October to 6 November 1975 (Cruise BLM01B)
3-42

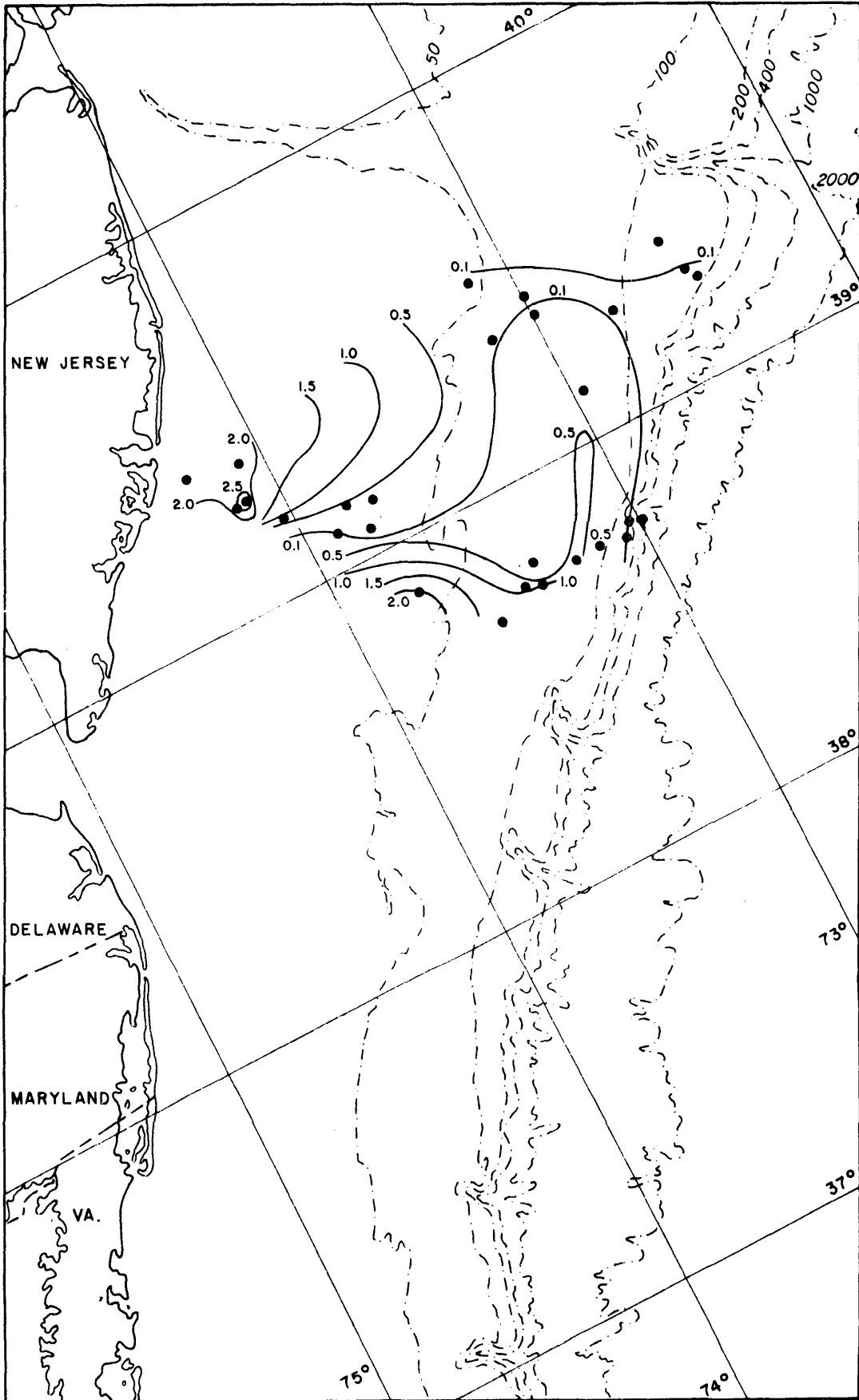


Figure 3-16. Surface NO_3 ($\mu\text{m atoms/l}$) distribution in the northern portions of the Middle Atlantic Bight during the period 27 October to 6 November 1975 (Cruise BLMØ1B)

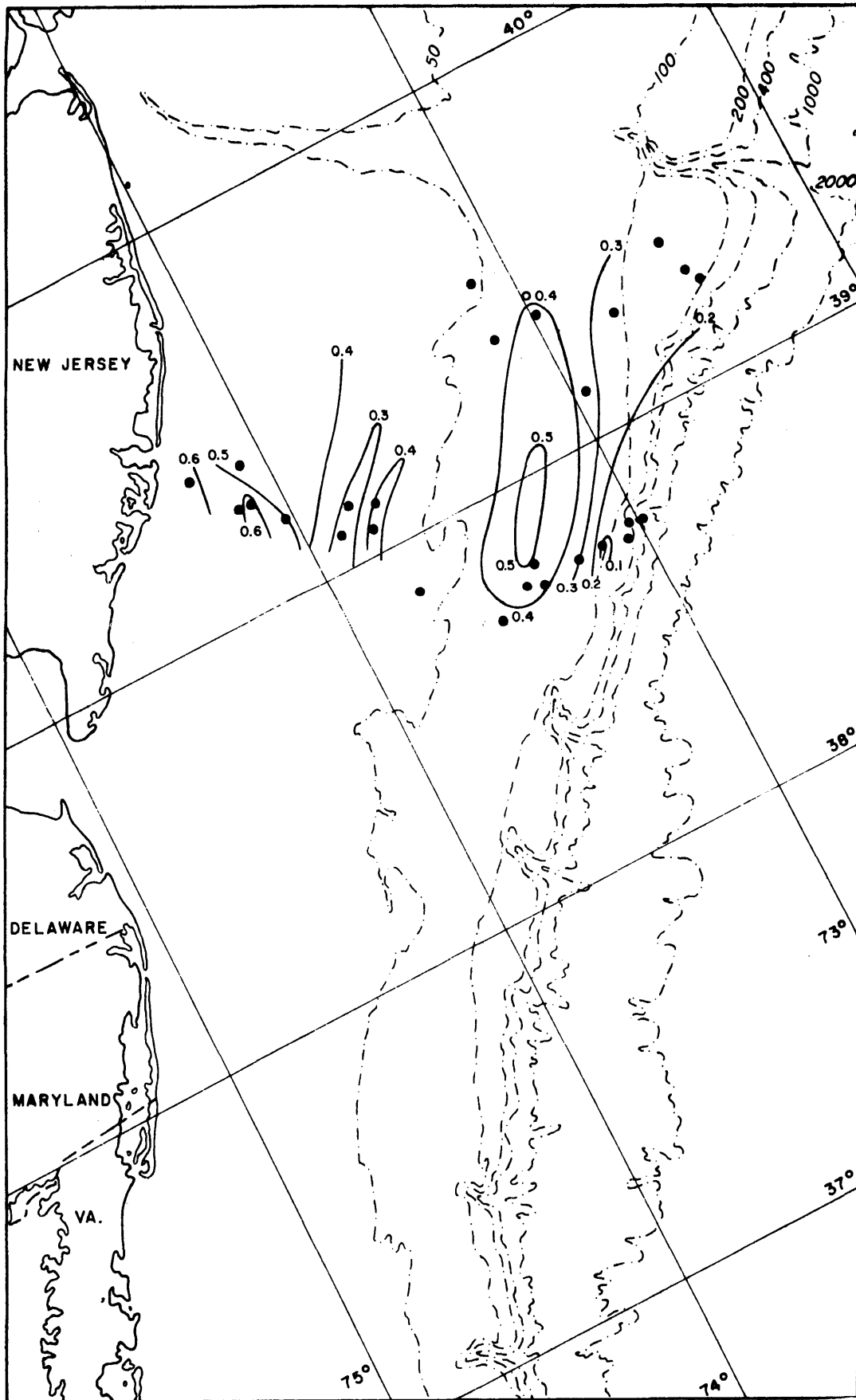


Figure 3-17. Surface $O-PO_4$ ($\mu\text{gm atoms/l}$) distribution in the northern portions of the Middle Atlantic Bight during the period 27 October to 6 November 1975 (Cruise BLMØ1B)

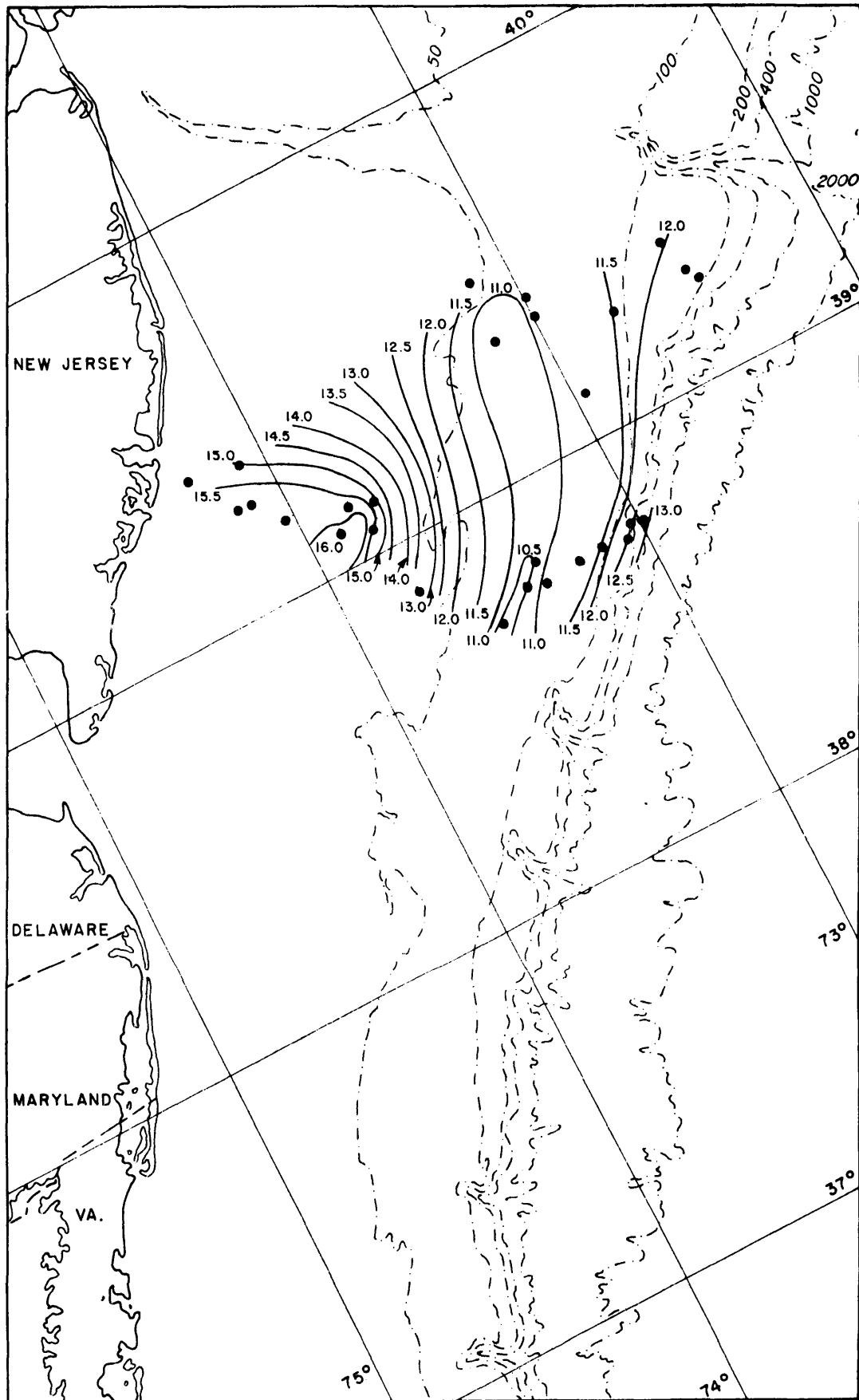


Figure 3-18. Bottom temperature ($^{\circ}\text{C}$) distribution in the northern portions of the Middle Atlantic Bight during the period 27 October to 6 November 1975 (Cruise BLM01B)

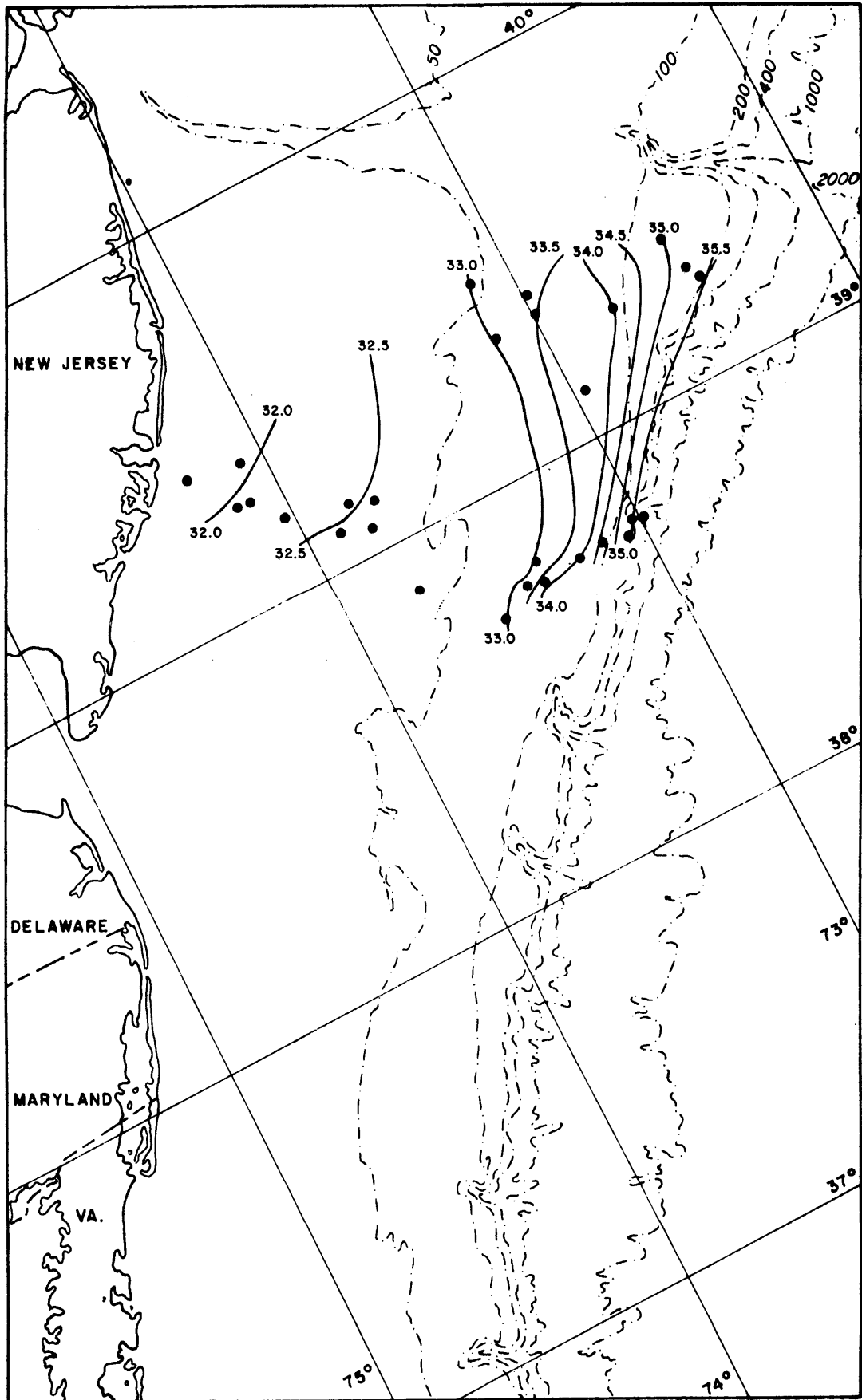


Figure 3-19. Bottom salinity (ppt) distribution in the northern portions of the Middle Atlantic Bight during the period 27 October to 6 November 1975 (Cruise BLM01B)

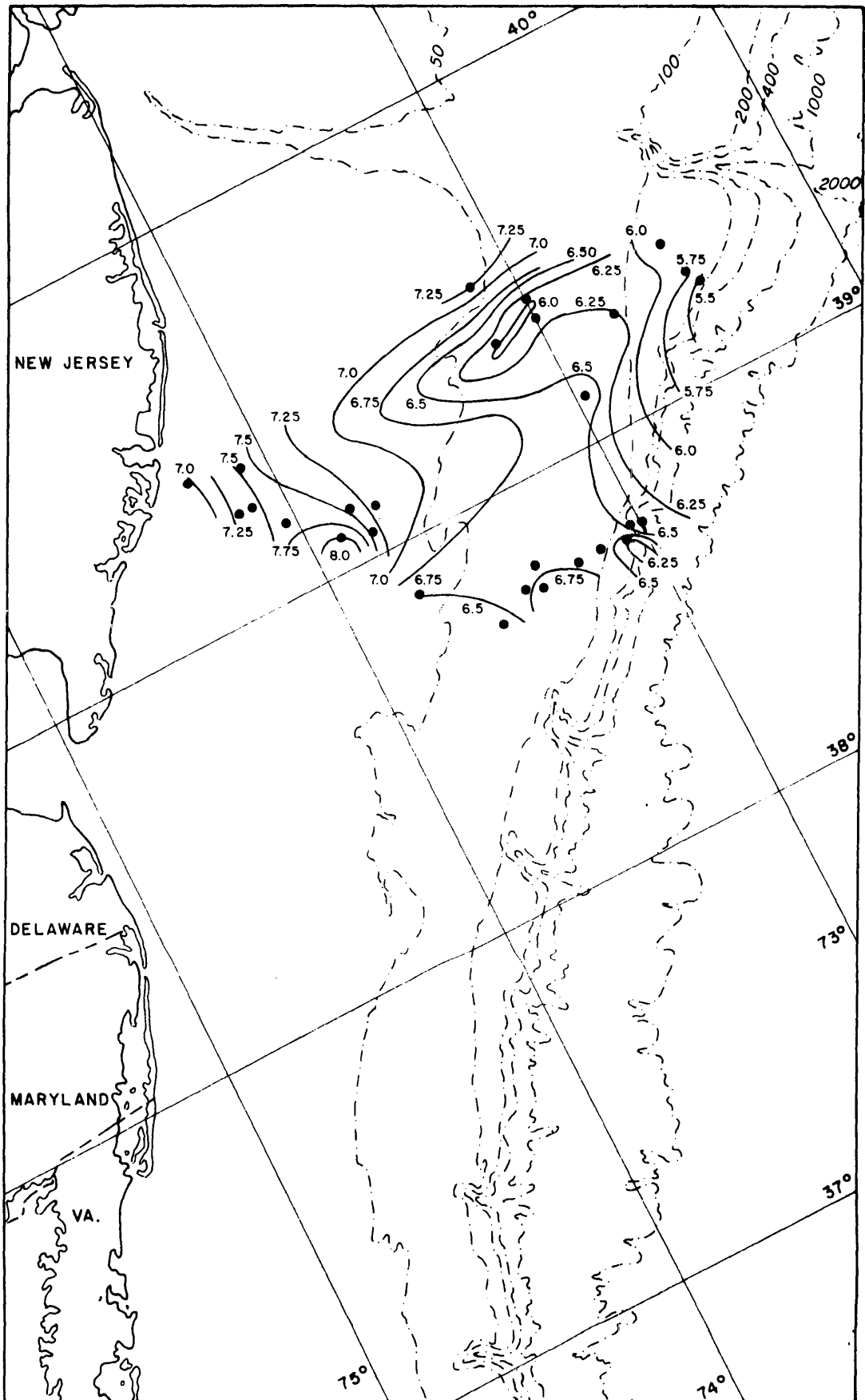


Figure 3-20. Bottom dissolved oxygen (mg/l) distribution in the northern portions of the Middle Atlantic Bight during the period 27 October to 6 November 1975 (Cruise BLM01B)

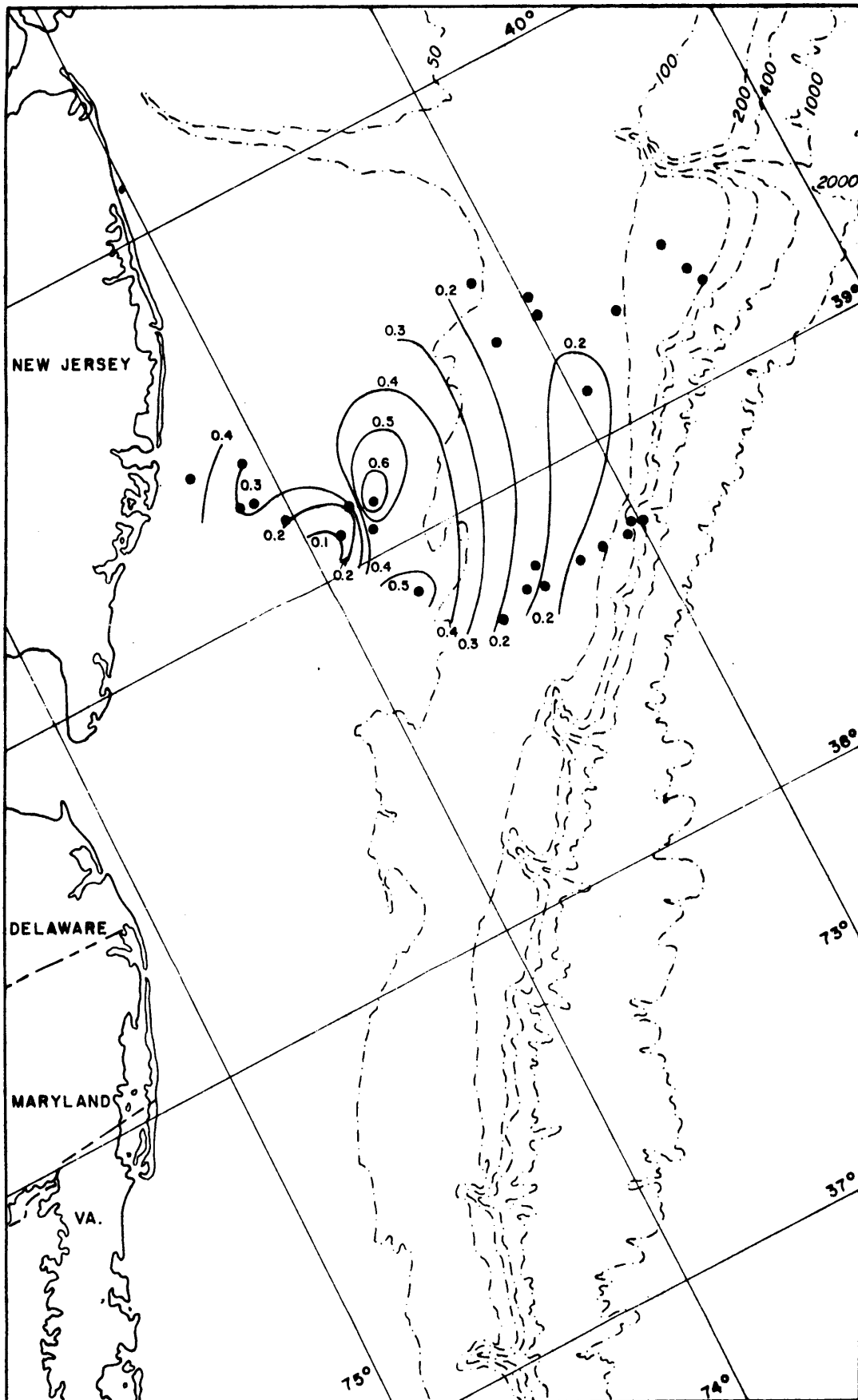


Figure 3-21. Bottom NO₂ ($\mu\text{gm atoms/l}$) distribution in the northern portions of the Middle Atlantic Bight during the period 27 October to 6 November 1975 (Cruise BLMØ1B)

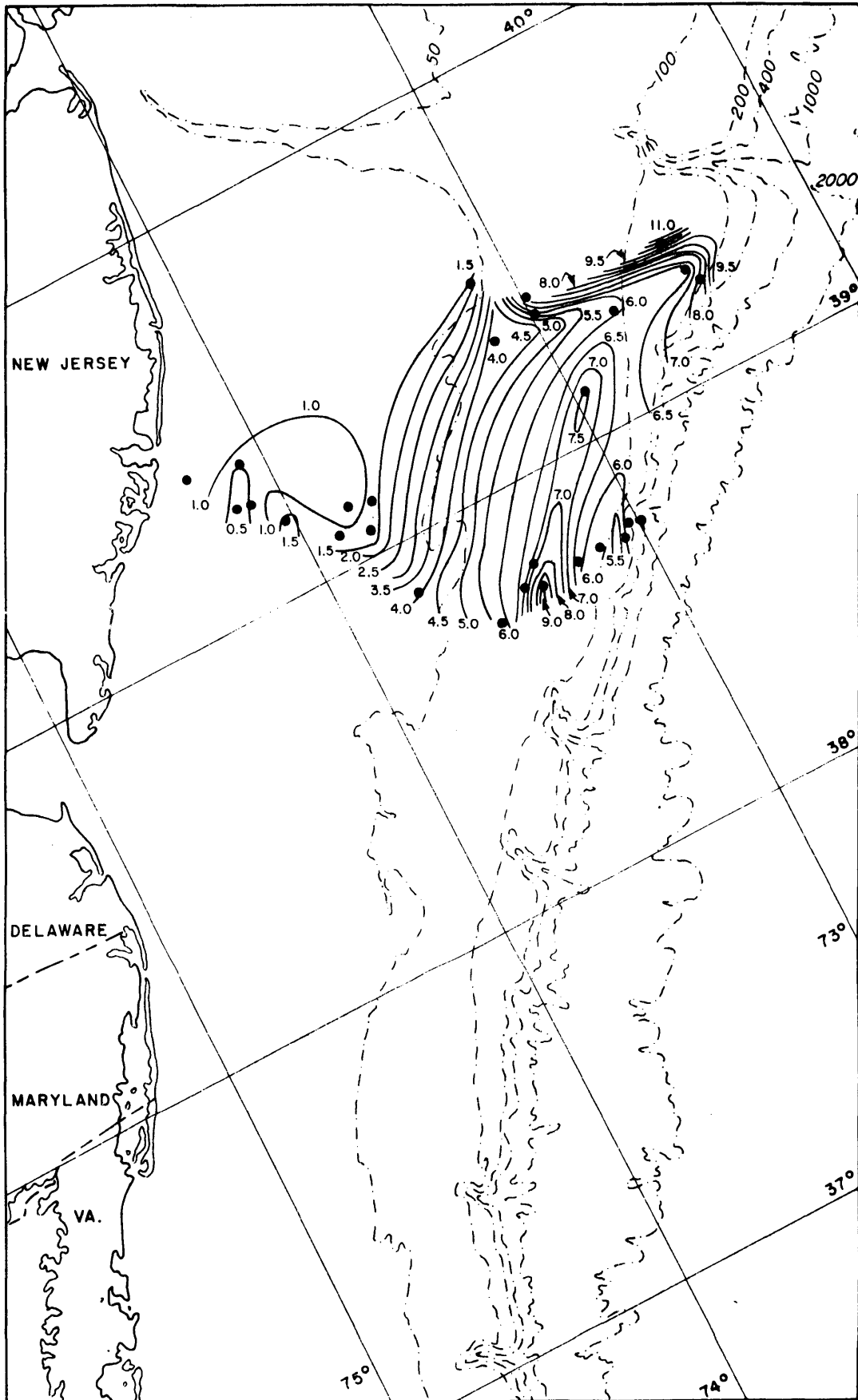


Figure 3-22. Bottom NO_3 ($\mu\text{g atoms/l}$) distribution in the northern portions of the Middle Atlantic Bight during the period 27 October to 6 November 1975 (Cruise BLM01B)

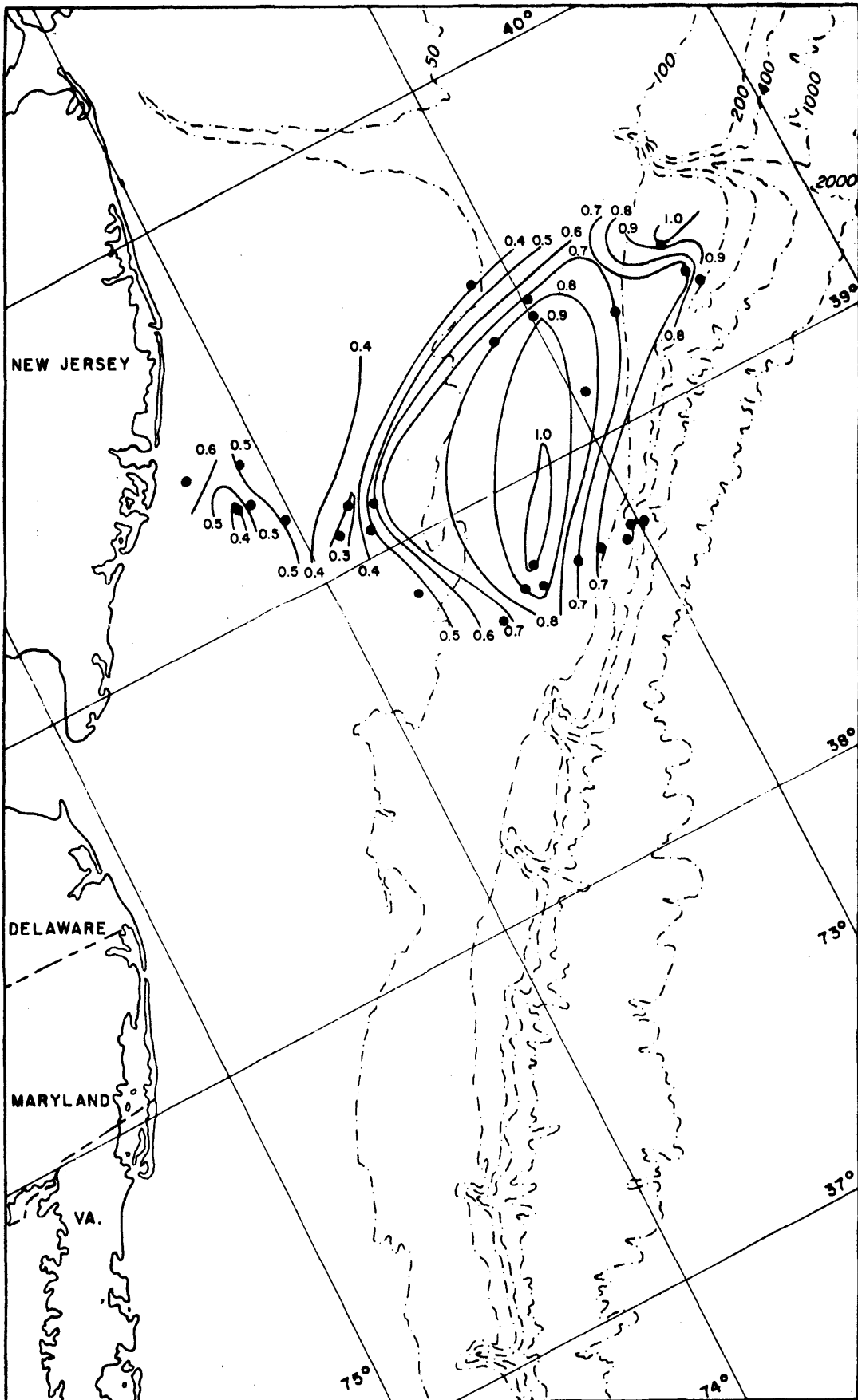


Figure 3-23. Bottom 0-PO₄ (µgm atoms/l) distribution in the northern portions of the Middle Atlantic Bight during the period 27 October to 6 November 1975 (Cruise BLM01B)

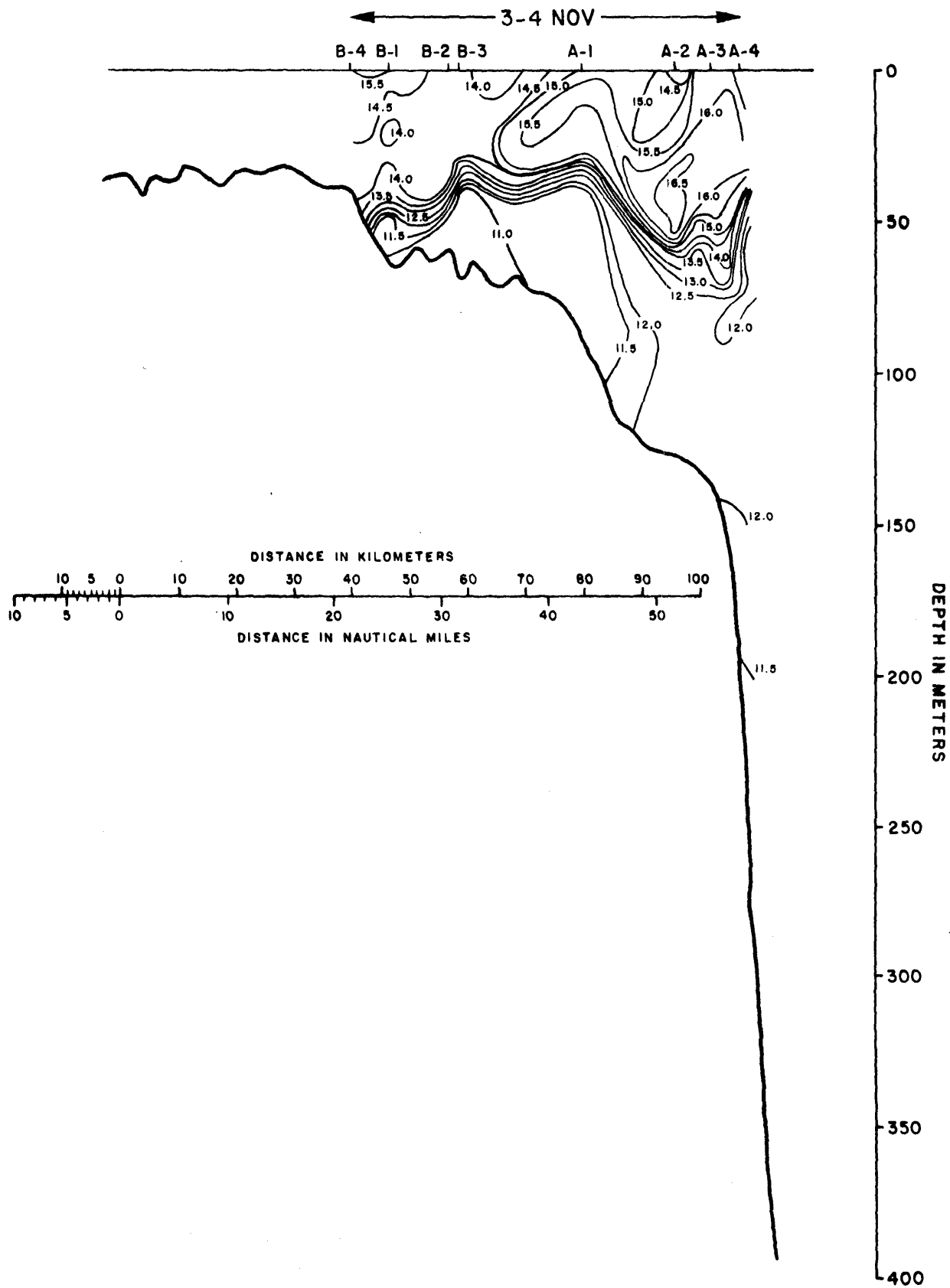


Figure 3-24. Temperature ($^{\circ}\text{C}$) along Section II (Stations B4 to A4, 3-4 November 1975) during cruise BLM01B. Section location is shown in Figure 3-10.

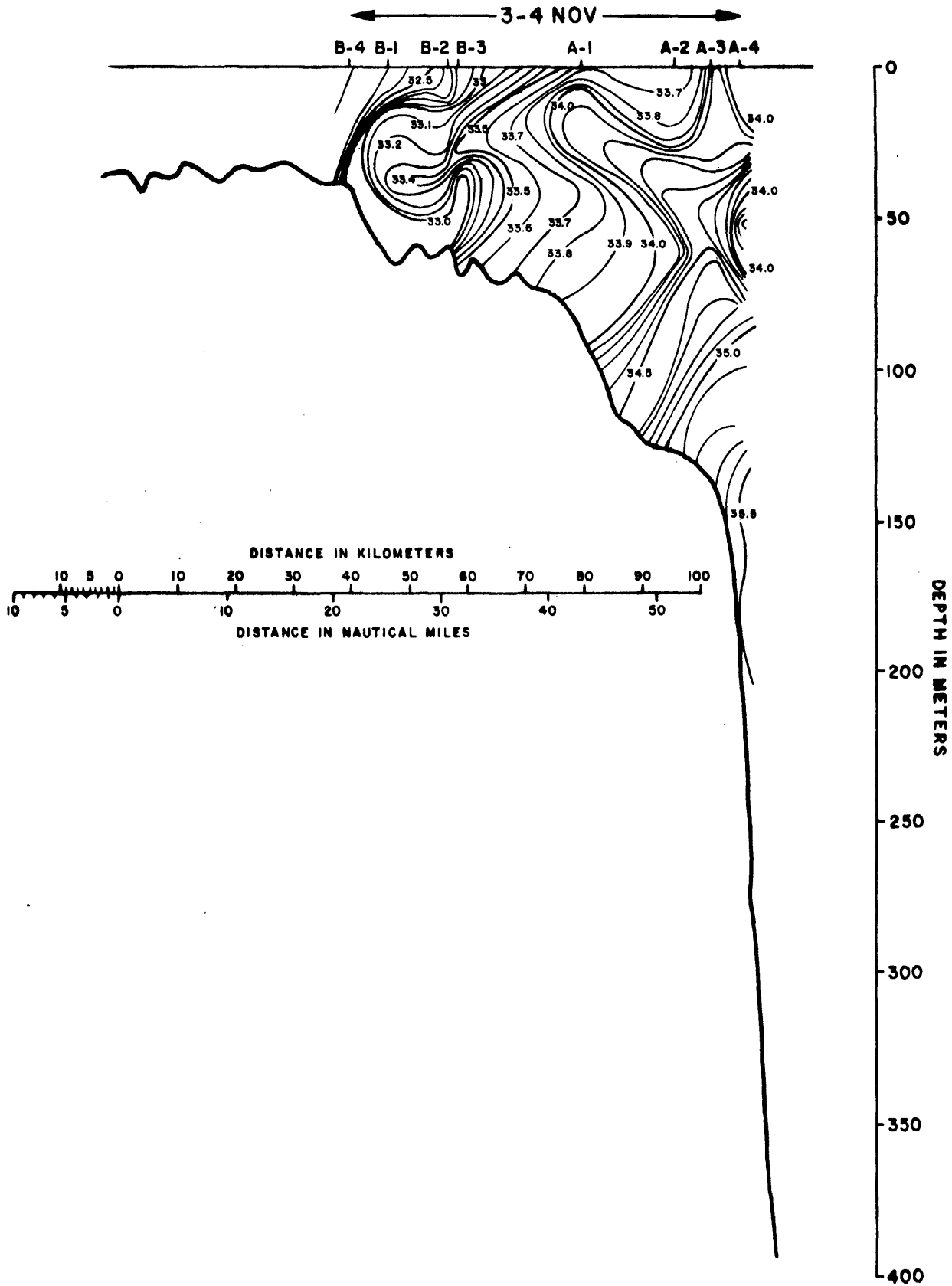


Figure 3-25. Salinity (ppt) along Section II (Stations B4 to A4, 3-4 November 1975) during cruise BLM01B. Section location is shown in Figure 3-10.

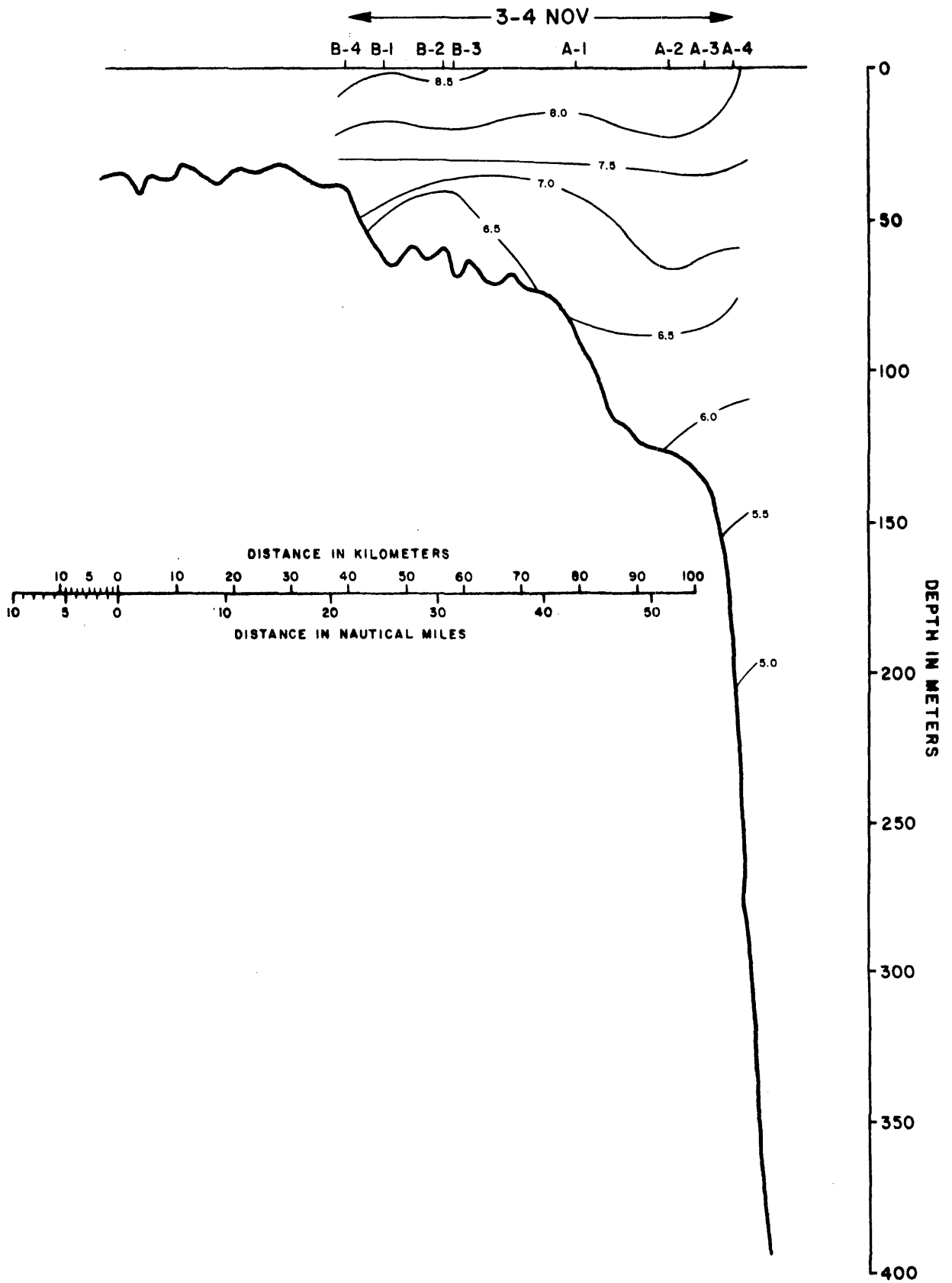


Figure 3-26. Dissolved oxygen (mg/l) along Section II (Stations B4 to A4, 3-4 November 1975) during cruise BLM01B. Section location is shown in Figure 3-10.

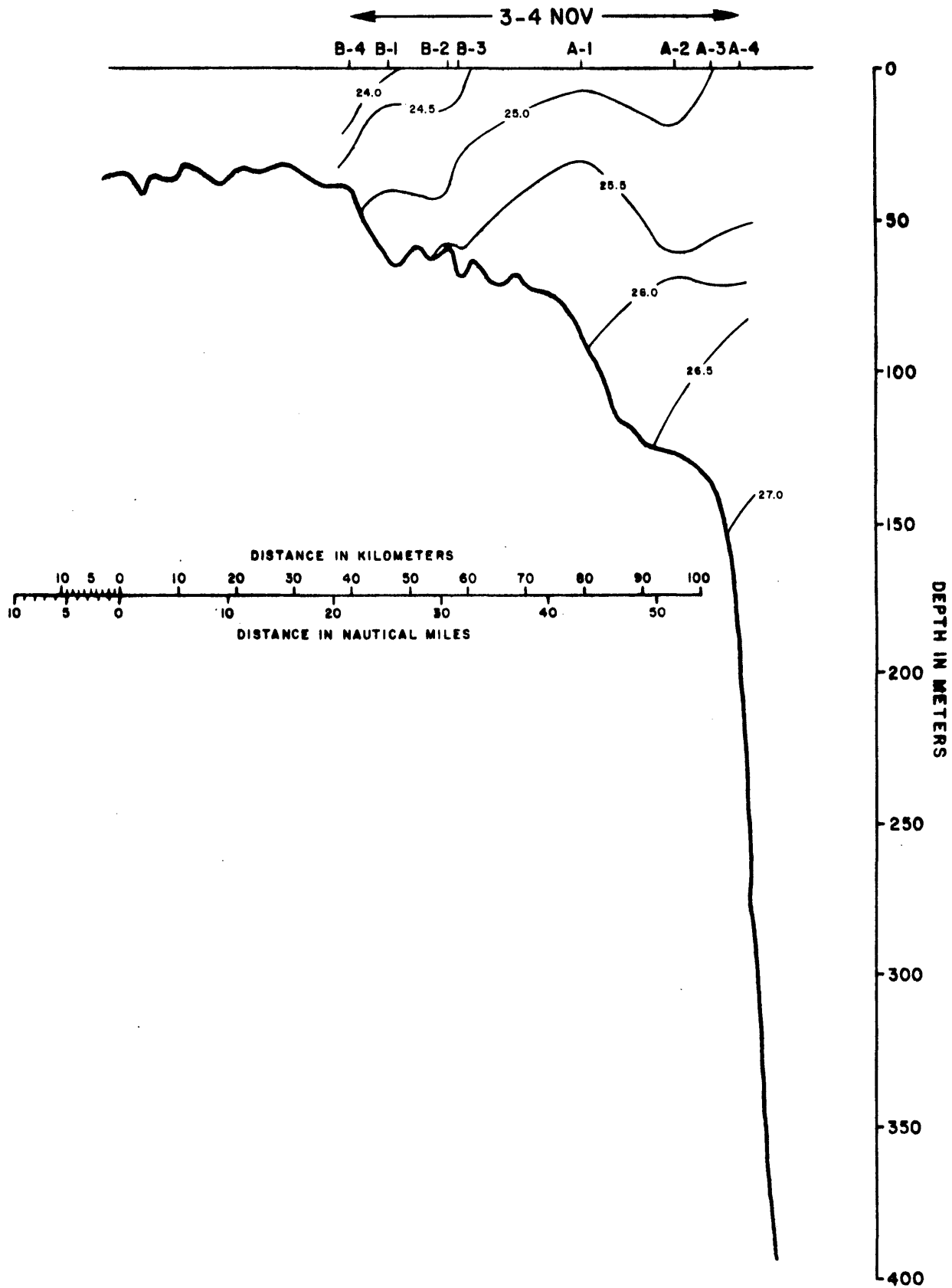


Figure 3-27. Density (σ_t units) along Section II (Stations B4 to A4, 3-4 November 1975) during cruise BLM01B. Section location is shown in Figure 3-10.

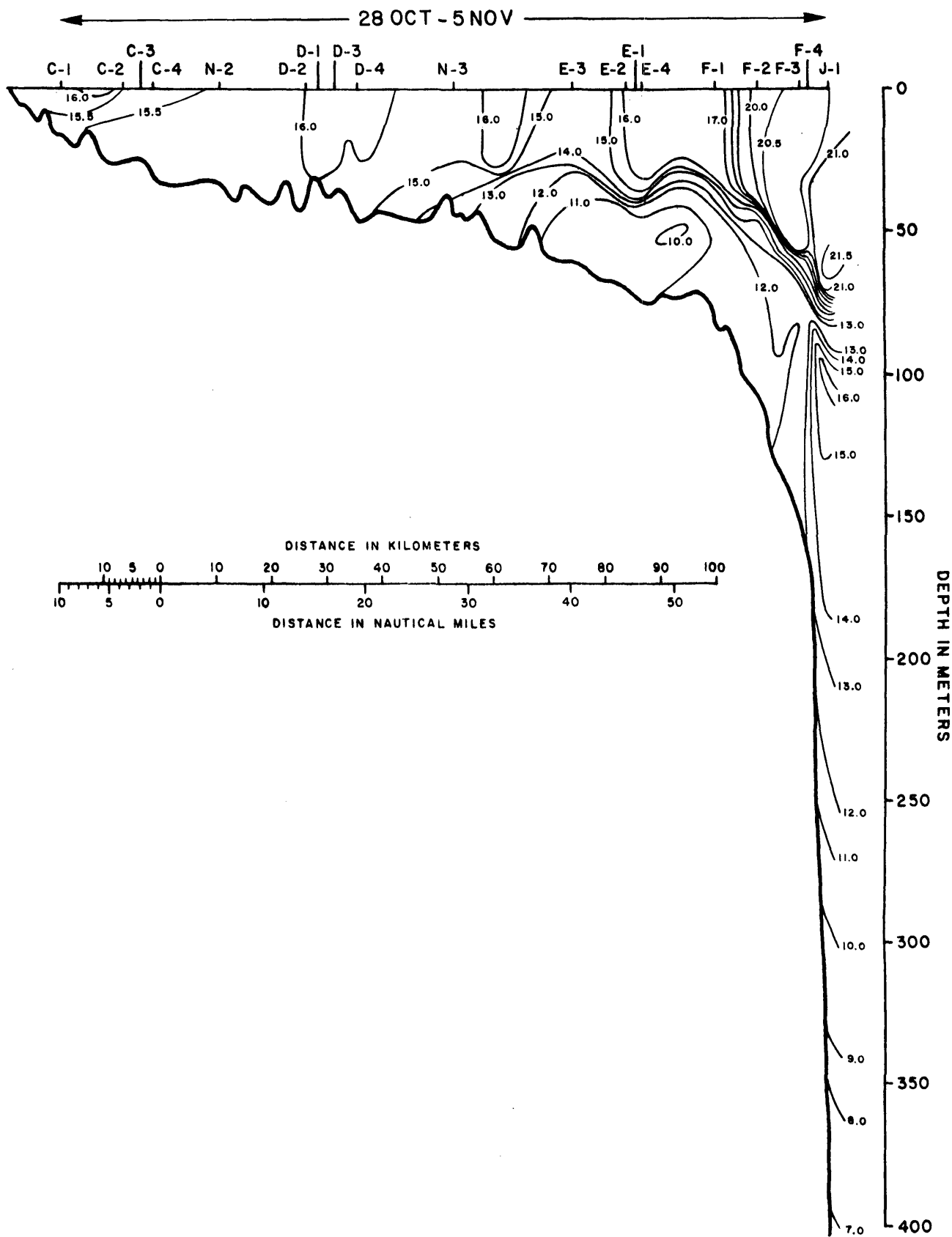


Figure 3-28. Temperature ($^{\circ}\text{C}$) along Section III (Stations C1 to J1, 28 October - 5 November 1975) during cruise BLM01B. Section location is shown in Figure 3-10.

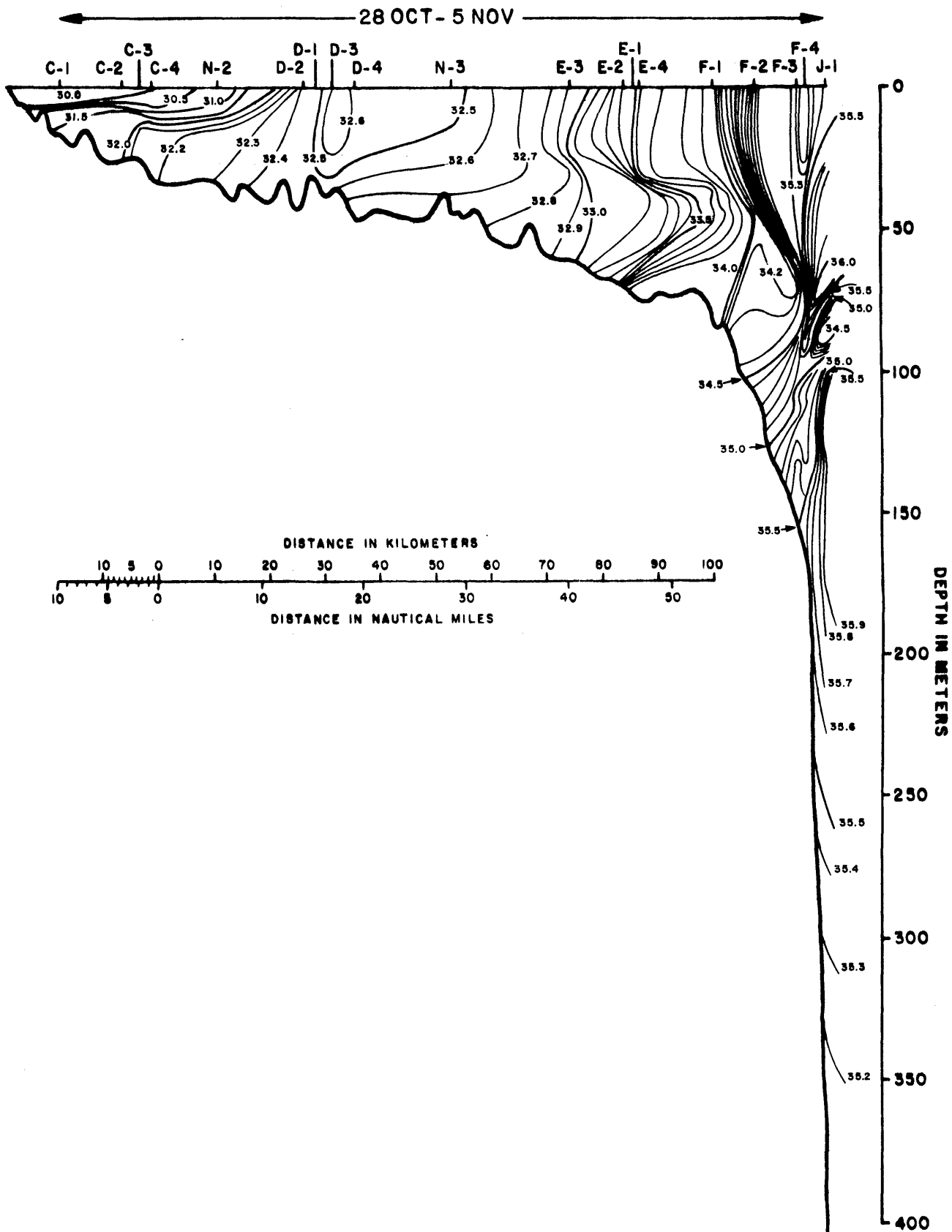


Figure 3-29. Salinity (ppt) along Section III (Stations C1 to J1, 28 October - 5 November 1975) during cruise BLM01B. Section location is shown in Figure 3-10.

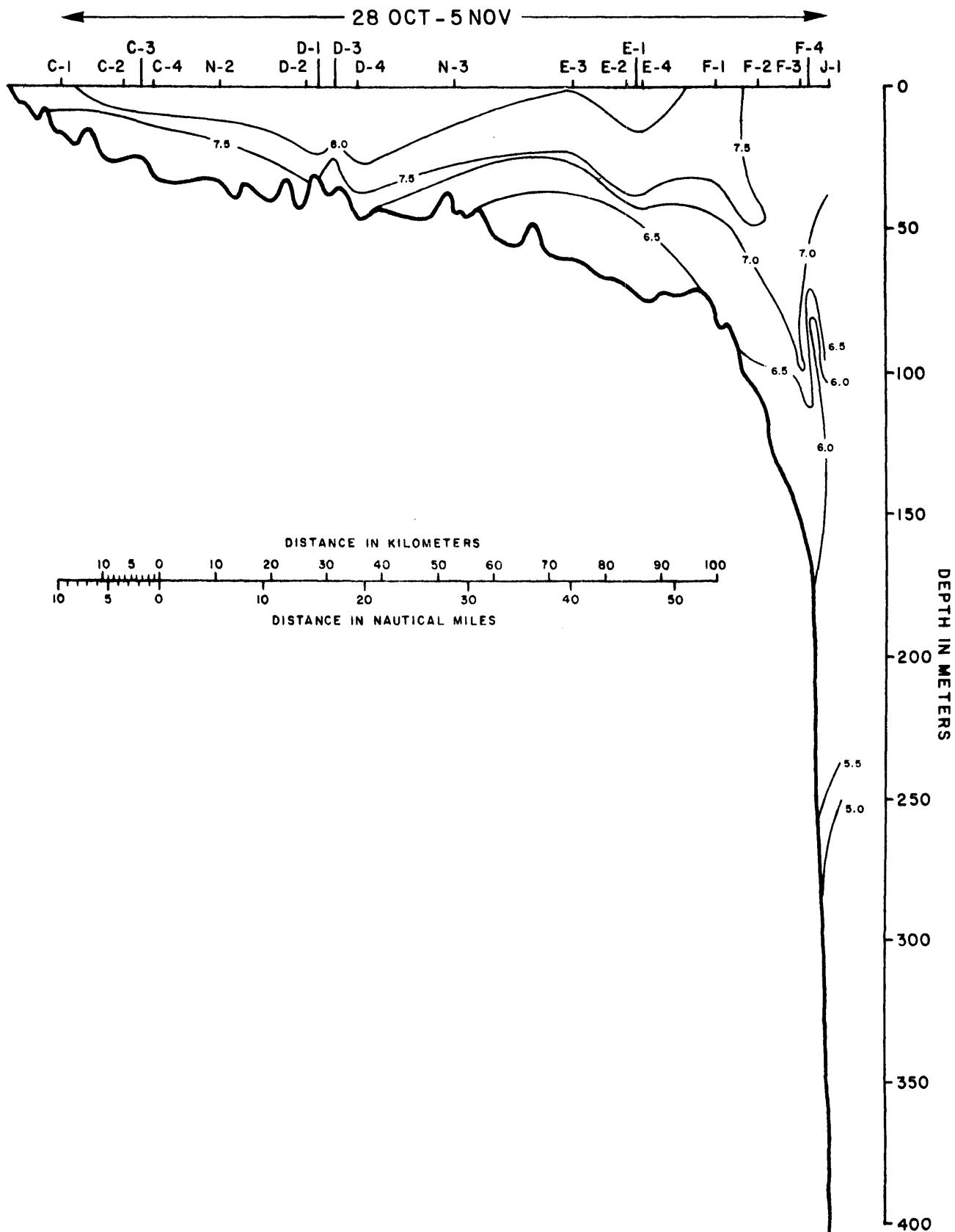


Figure 3-30. Dissolved oxygen (mg/l) along Section III (Stations C1 to J1, 28 October - 5 November 1975) during cruise BLM01B. Section location is shown in Figure 3-10.

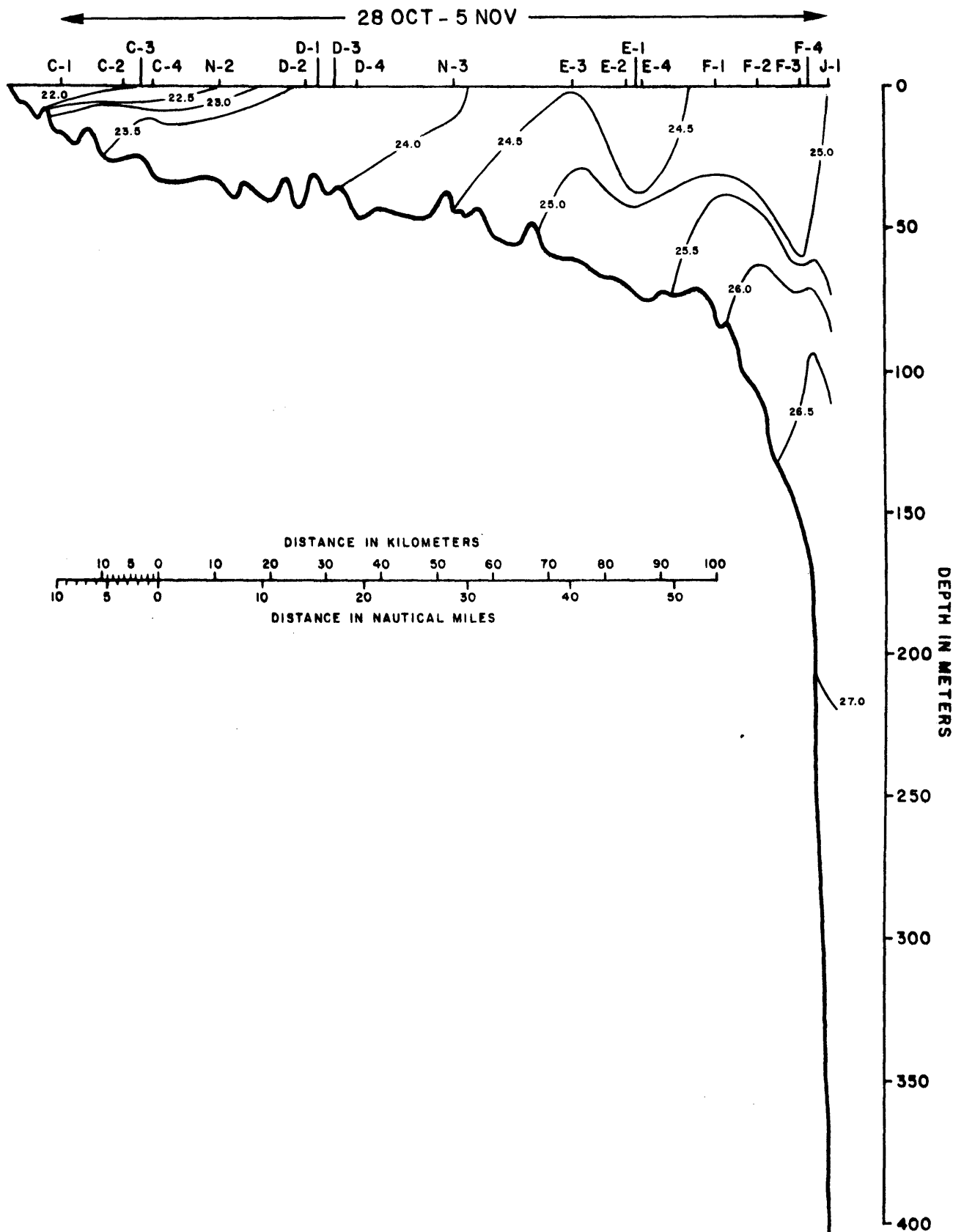


Figure 3-31. Density (σ_t units) along Section III (Stations C1 to J1, 28 October - 5 November 1975) during cruise BLM01B. Section location is shown in Figure 3-10.

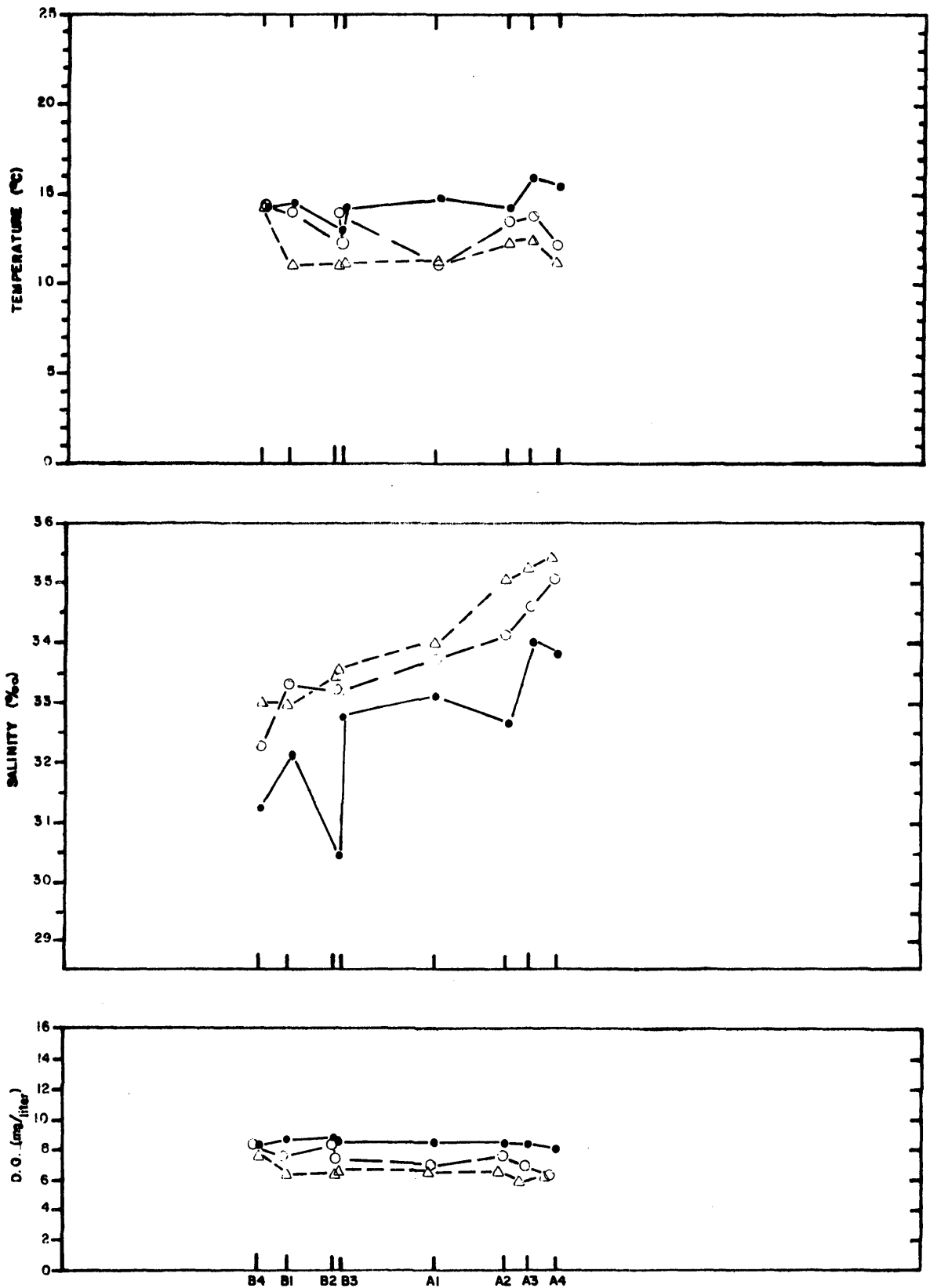


Figure 3-32. Surface (•), mid-depth (○) and bottom (△) values of temperature, salinity and DO measured along Section II on cruise BLM 01B.

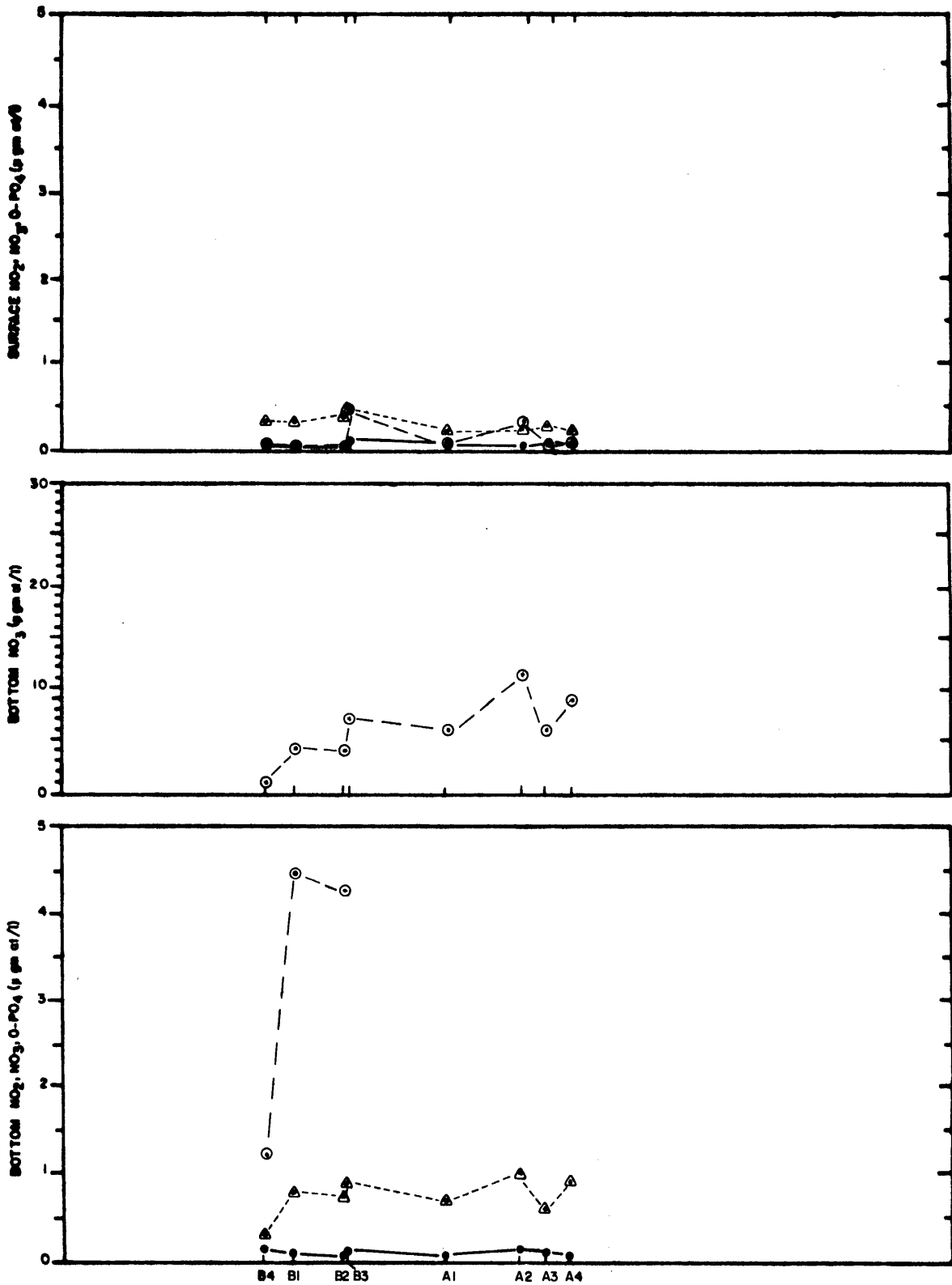


Figure 3-33 . Concentrations of dissolved NO₂ (•), NO₃ (◊), and O-PO₄ (Δ) in near surface and near bottom waters along Section II during Cruise BLM 01B. Bottom concentrations of dissolved NO₃ were substantially greater than those of other micronutrients hence the center plot.

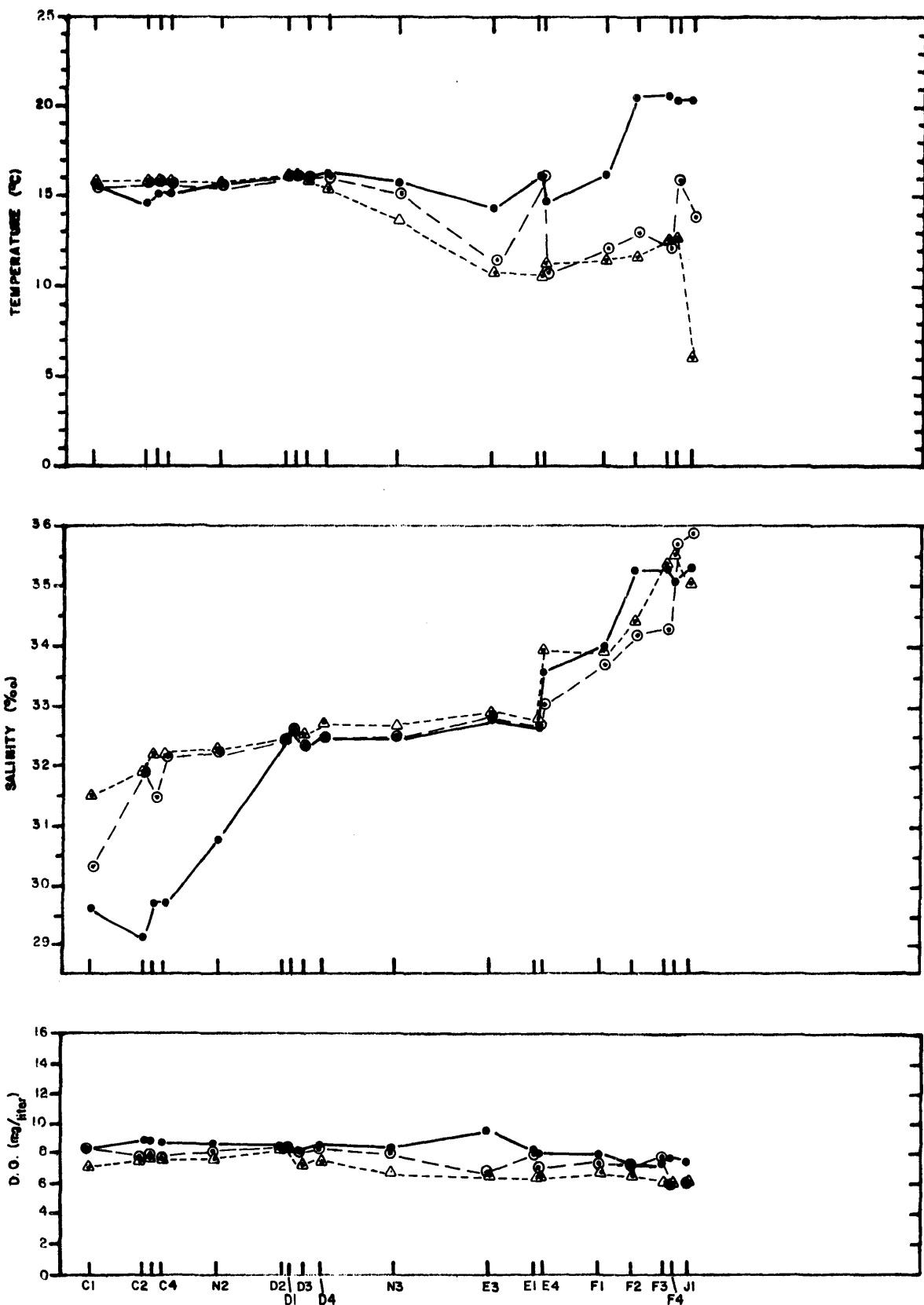


Figure 3-34. Surface (•), mid-depth (◊) and bottom (Δ) values of temperature, salinity and DO measured along Section III on cruise BLM 01B.

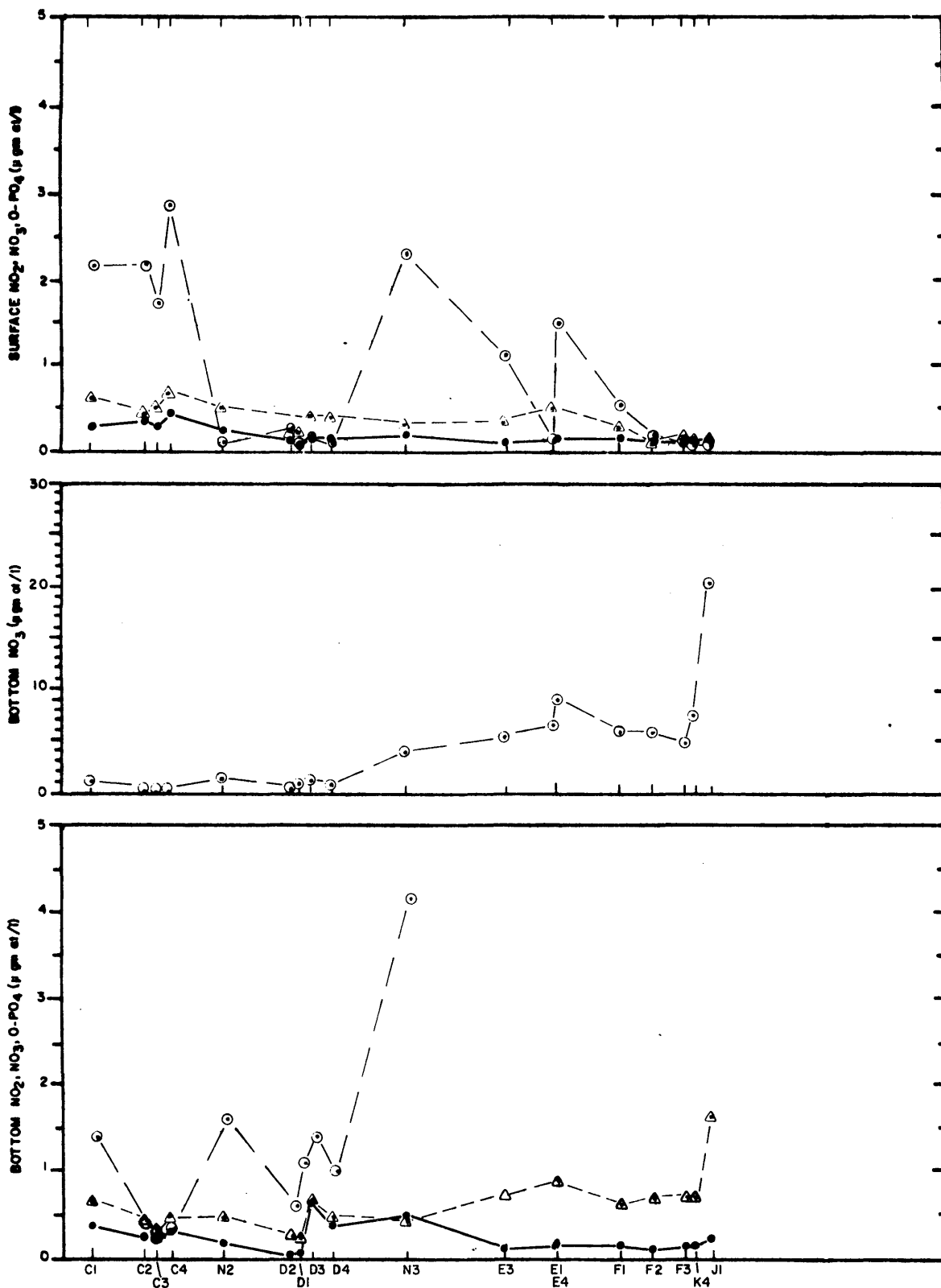


Figure 3-35 . Concentrations of dissolved NO_2 (*), NO_3 (θ), and O-PO_4 (Δ) in near surface and near bottom waters along Section III during Cruise BLM 01B. Bottom concentrations of dissolved NO_3 were substantially greater than those of other micronutrients hence the center plot.

Cruise BLM01W

Fall 1975

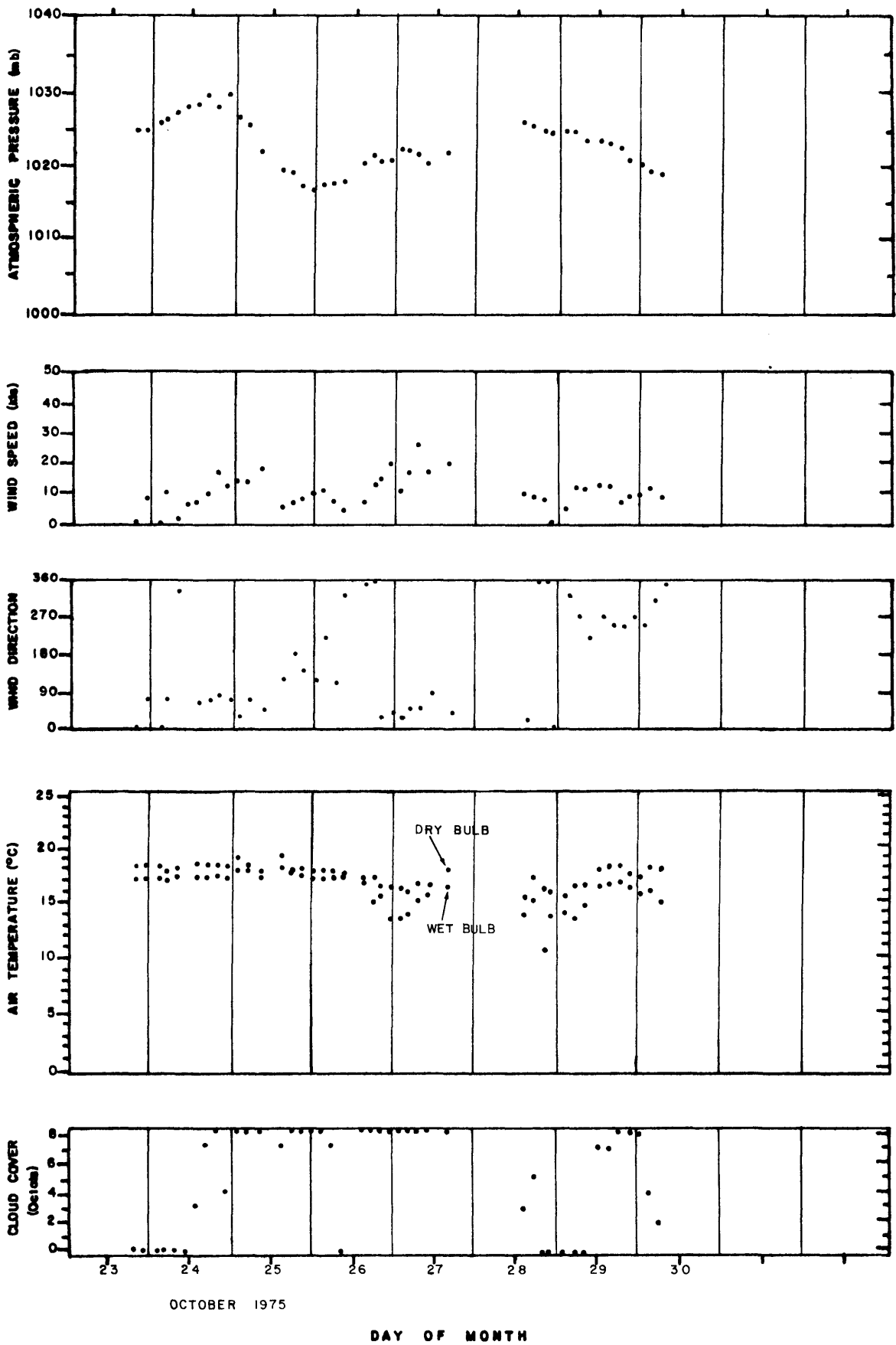


Figure 3-36. Meteorological data collected during cruise BLM 01W 23-30 October 1975.

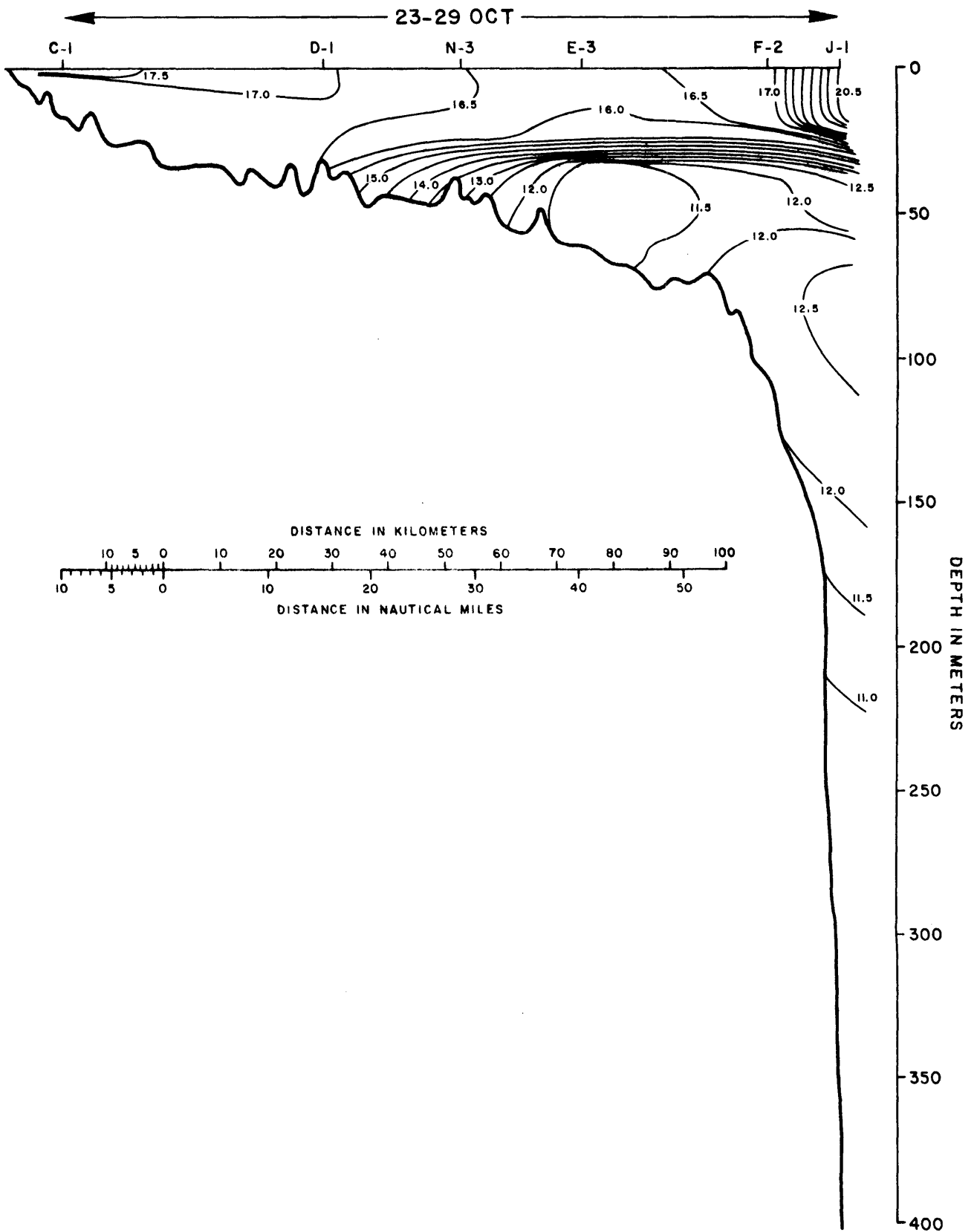


Figure 3-37. Temperature ($^{\circ}\text{C}$) along Section III (Stations C1 to J1, 23-29 October 1975) during cruise BLM01W. Section location is shown in Figure 3-10.

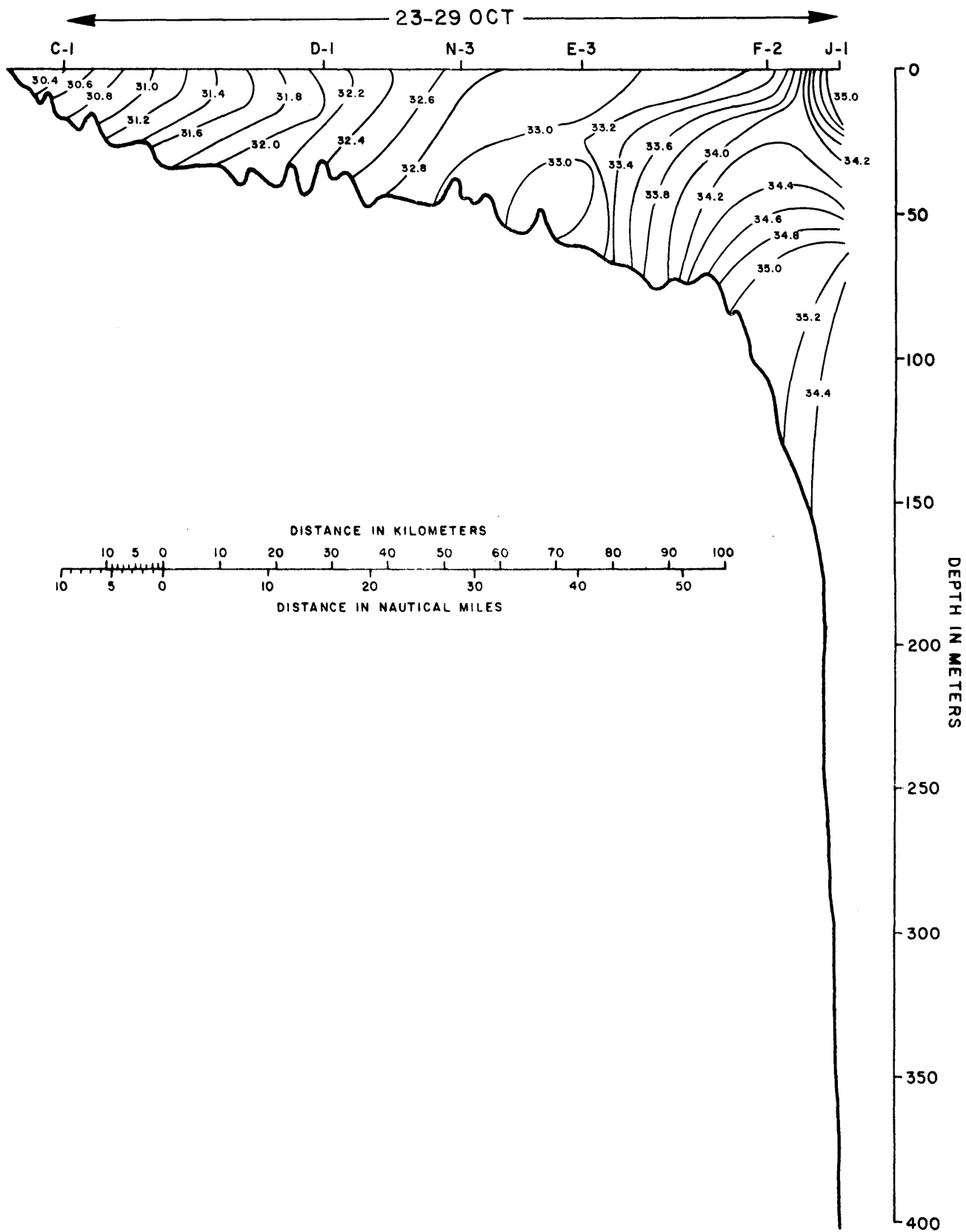


Figure 3-38. Salinity (ppt) along Section III (Stations C1 to J1, 23-29 October 1975) during cruise BLM01W. Section location is shown in Figure 3-10.

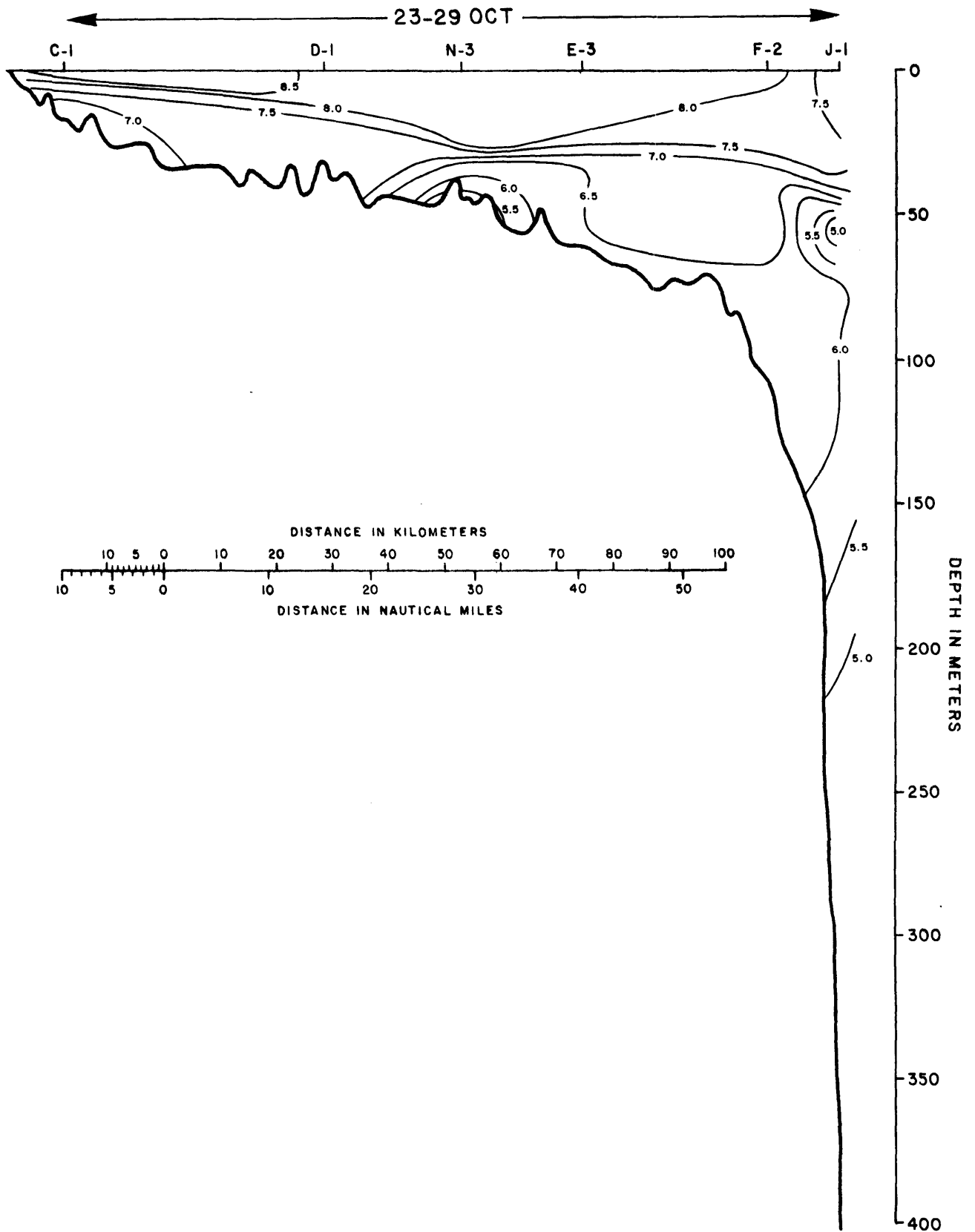


Figure 3-39. Dissolved oxygen (mg/l) along Section III (Stations C1 to J1, 23-29 October 1975) during cruise BLM01W. Section location is shown in Figure 3-10.

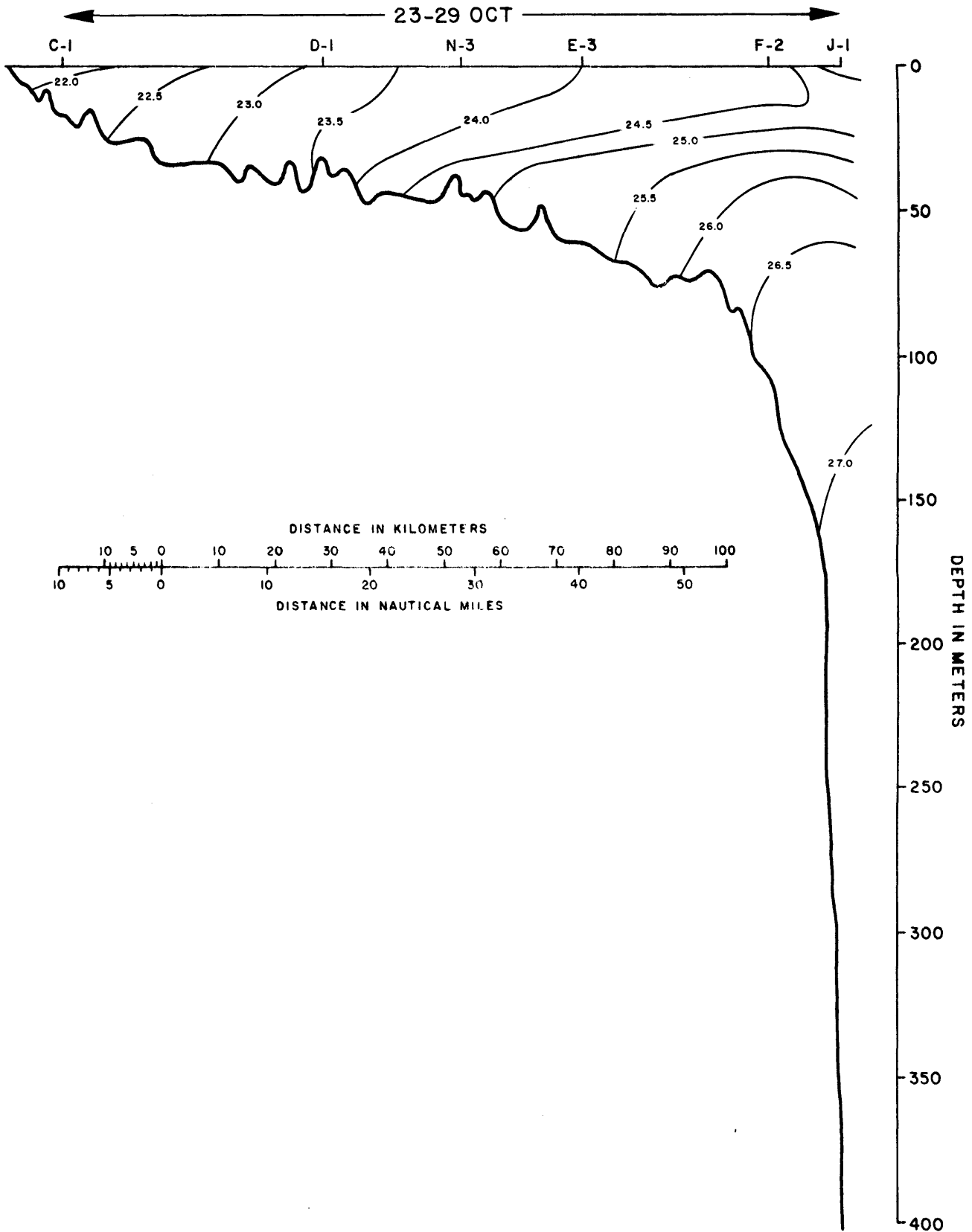


Figure 3-40. Density (σ_t units) along Section III (Stations C1 to J1, 23-29 October 1975) during cruise BLM01W. Section location is shown in Figure 3-10.

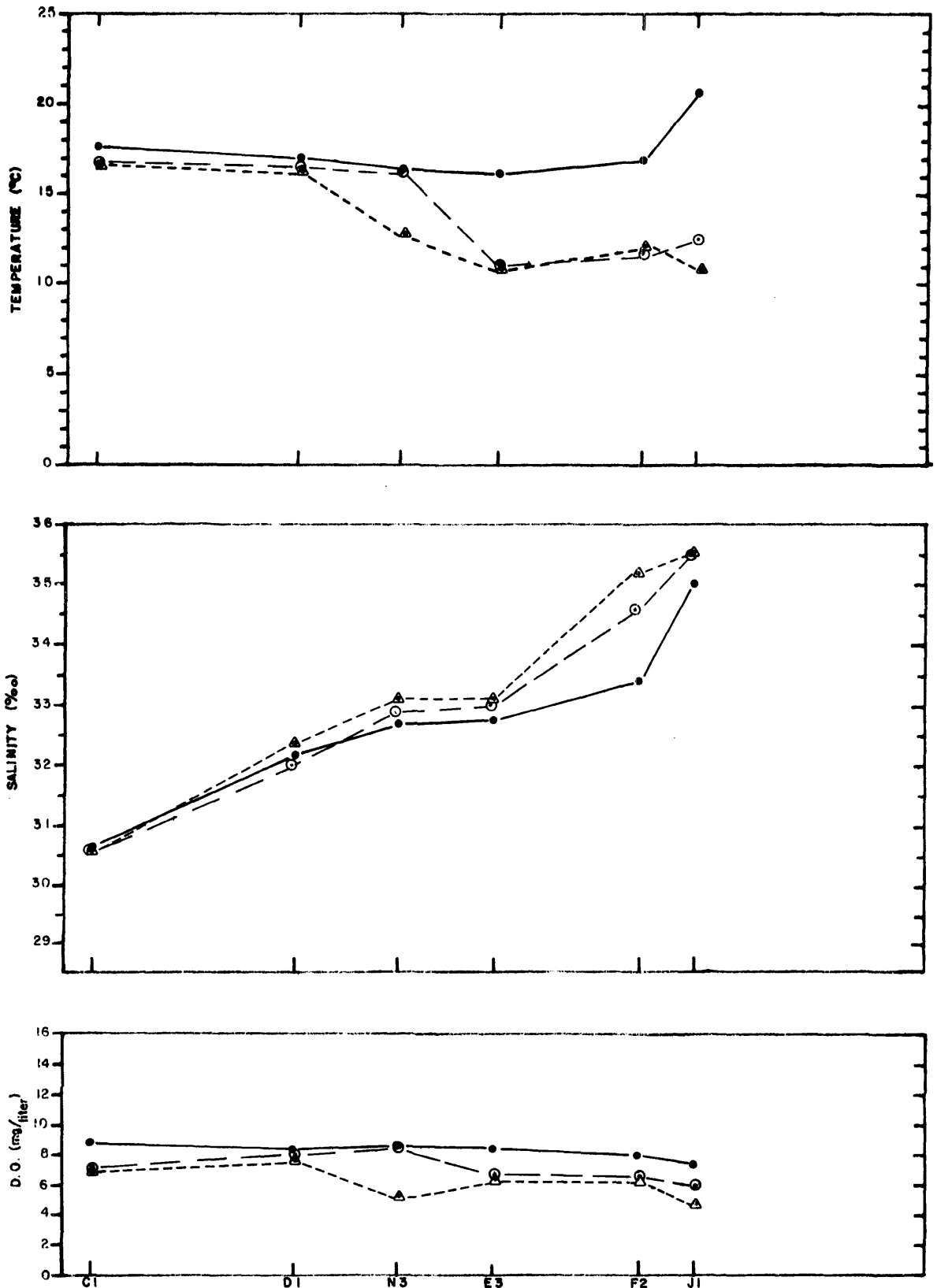


Figure 3-41. Surface (\bullet), mid-depth (θ) and bottom (Δ) values of temperature, salinity and DO measured along Section III during cruise BLM 01W.

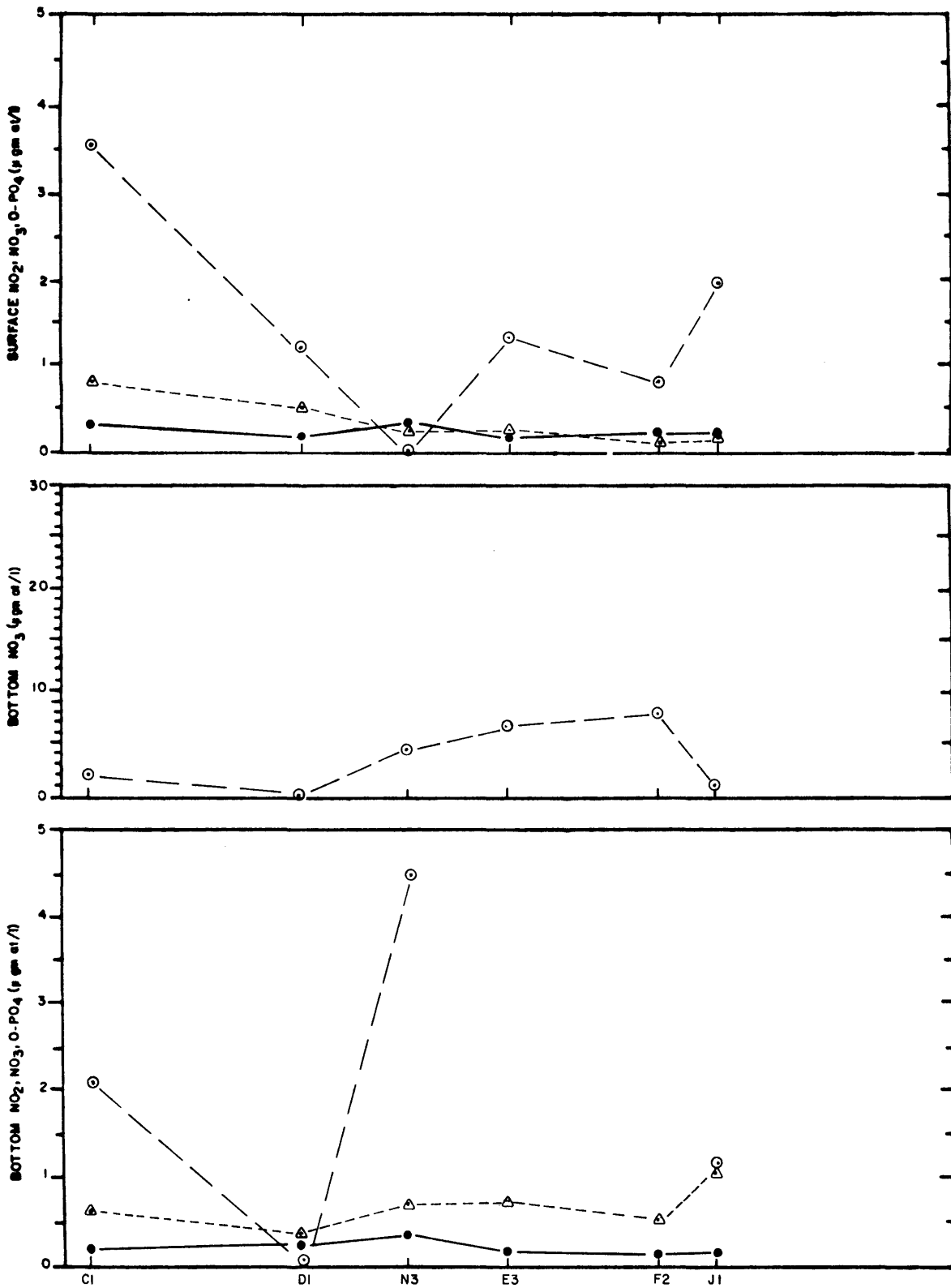


Figure 3-42 . Concentrations of dissolved NO₂ (•), NO₃ (θ), and O-PO₄ (Δ) in near surface and near bottom waters along Section III during Cruise BLM 01W. Bottom concentrations of dissolved NO₃ were substantially greater than those of other micronutrients hence the center plot.

Cruise BLM02B

Winter 1976

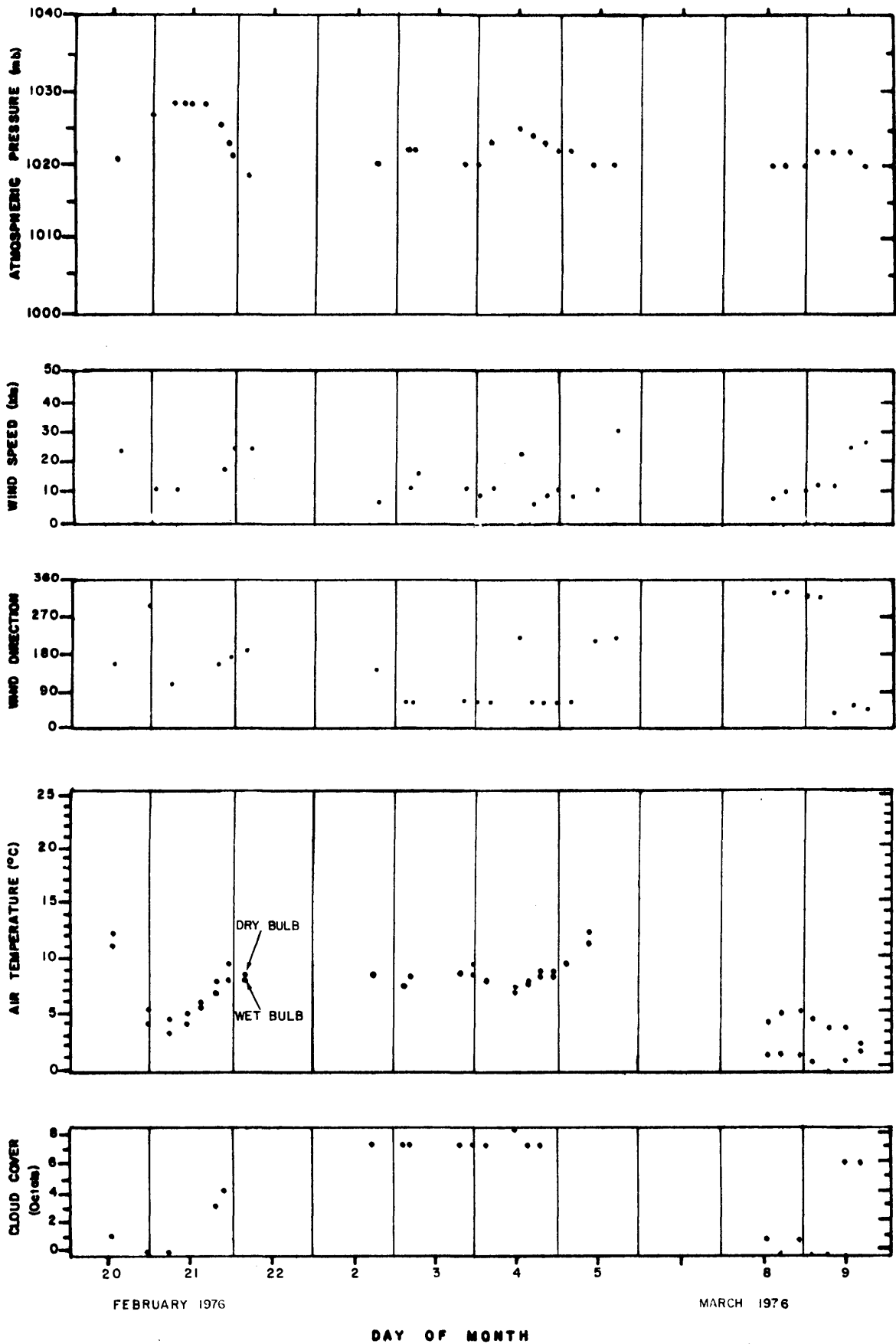


Figure 3-43. Meteorological data collected during cruise 02B for the period 20 February to 9 March 1976. Note omissions of 23 February to 1 March and 6, 7 March.

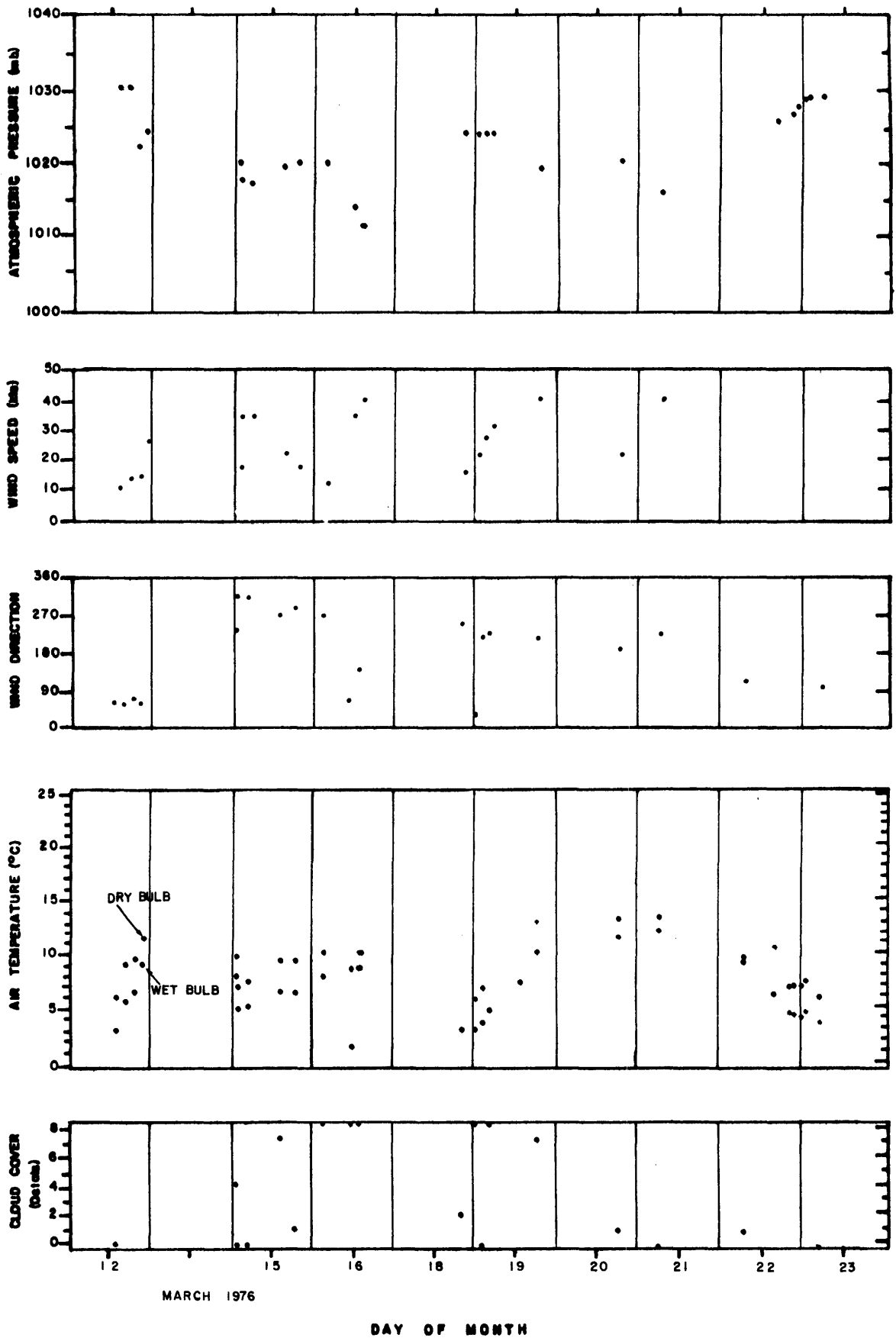


Figure 3-43. (continued) Meteorological data collected during cruise BLM 02B for the period 12-23 March 1976. Note omission of 13, 14 and 17 March. Anemometer lost on 21 March.

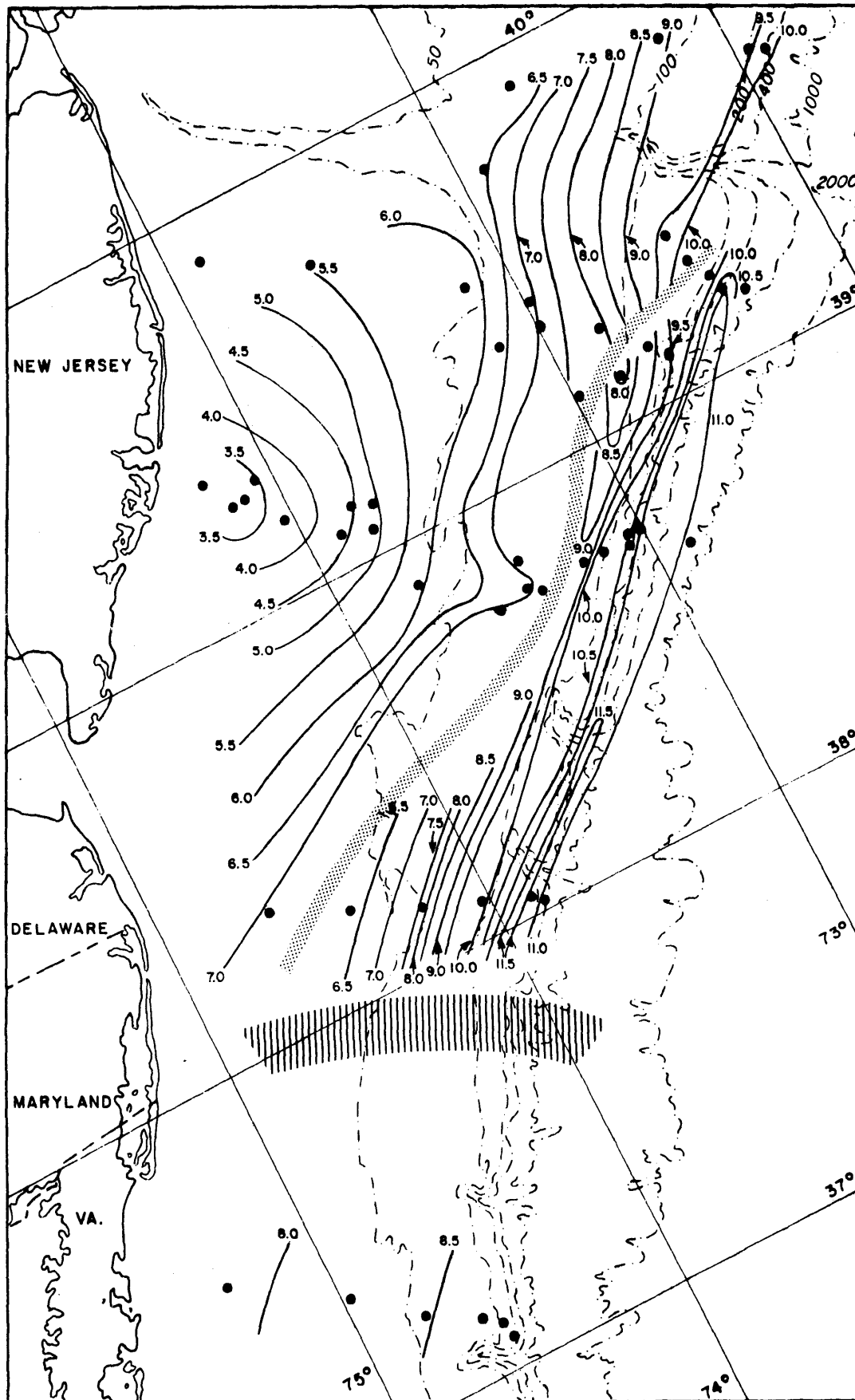


Figure 3-44. Surface temperature ($^{\circ}\text{C}$) distribution in the northern portions of the Middle Atlantic Bight during the period 19 February to 23 March 1976 (Cruise BLM02B). Shaded and hatched areas indicate discontinuity in data caused by 1) break in sampling between 10 and 15 March 1976, and 2) wind event (southwest winds in excess of 60 knots), respectively.

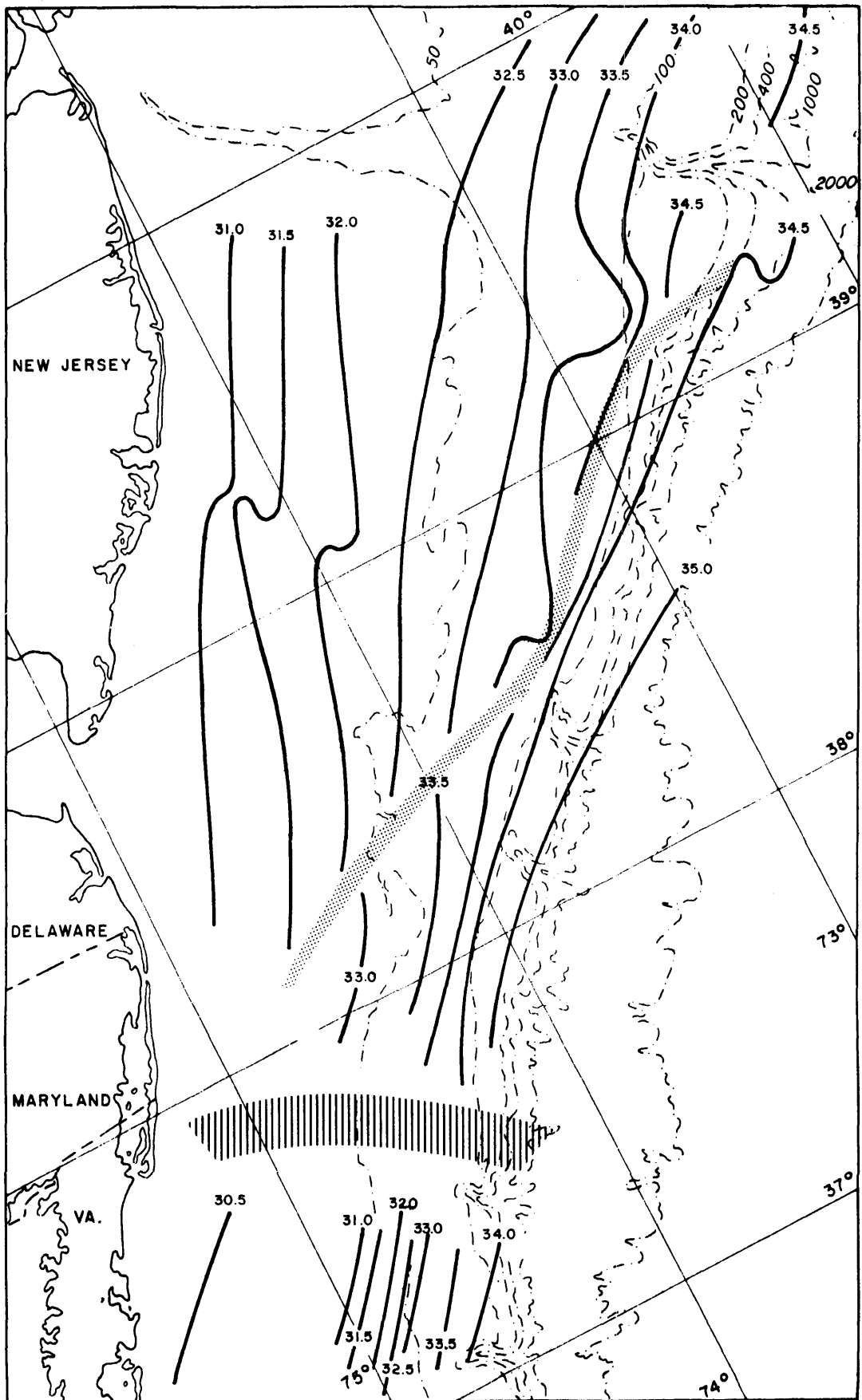


Figure 3-45. Surface salinity (ppt) distribution in the northern portions of the Middle Atlantic Bight during the period 19 February to 23 March 1976 (Cruise BLM02B). Shaded and hatched areas indicate discontinuity in data caused by 1) break in sampling between 10 and 15 March 1976, and 2) wind event (southwest winds in excess of 60 knots), respectively.

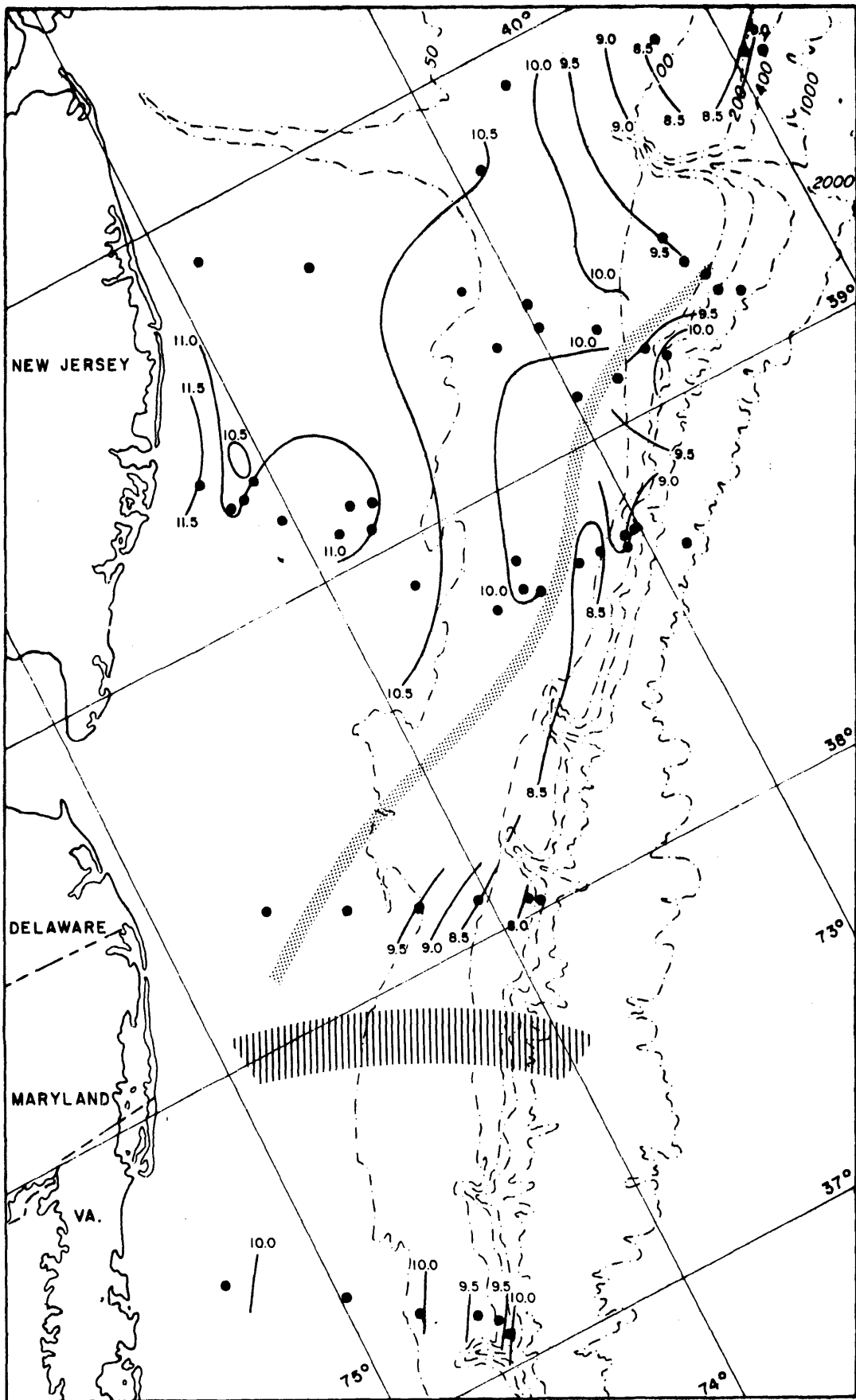


Figure 3-46. Surface dissolved oxygen (mg/l) distribution in the northern portions of the Middle Atlantic Bight during the period 19 February to 23 March 1976 (Cruise BLMØ2B). Shaded and hatched areas indicate discontinuity in data caused by 1) break in sampling between 10 and 15 March 1976, and 2) wind event (southwest winds in excess of 60 knots), respectively.

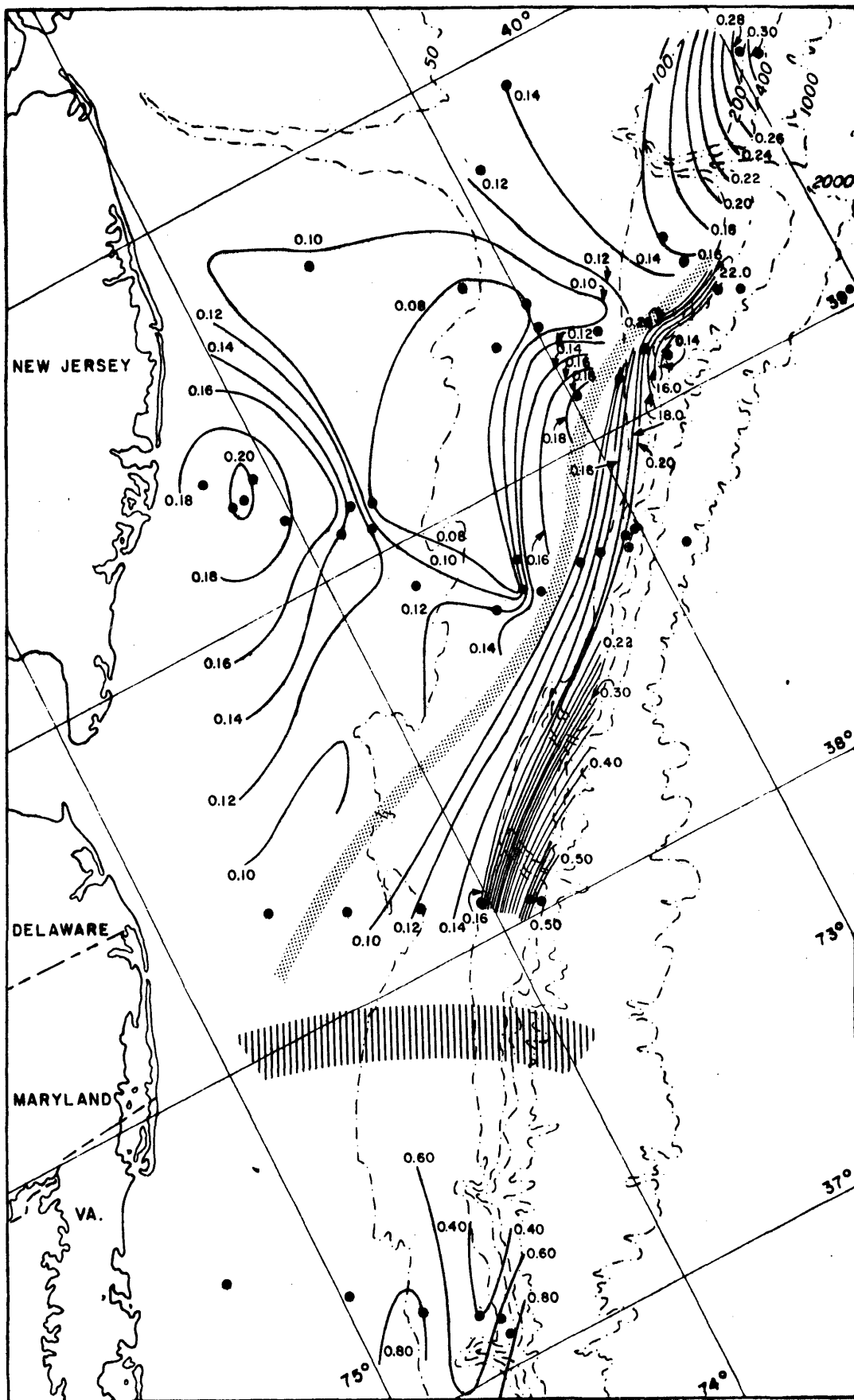


Figure 3-47. Surface NO₂ ($\mu\text{gm atoms/l}$) distribution in the northern portions of the Middle Atlantic Bight during the period 19 February to 23 March 1976 (Cruise BLM02B). Shaded and hatched areas indicate discontinuity in data caused by 1) break in sampling between 10 and 15 March 1976, and 2) wind event (southwest winds in excess of 60 knots), respectively.

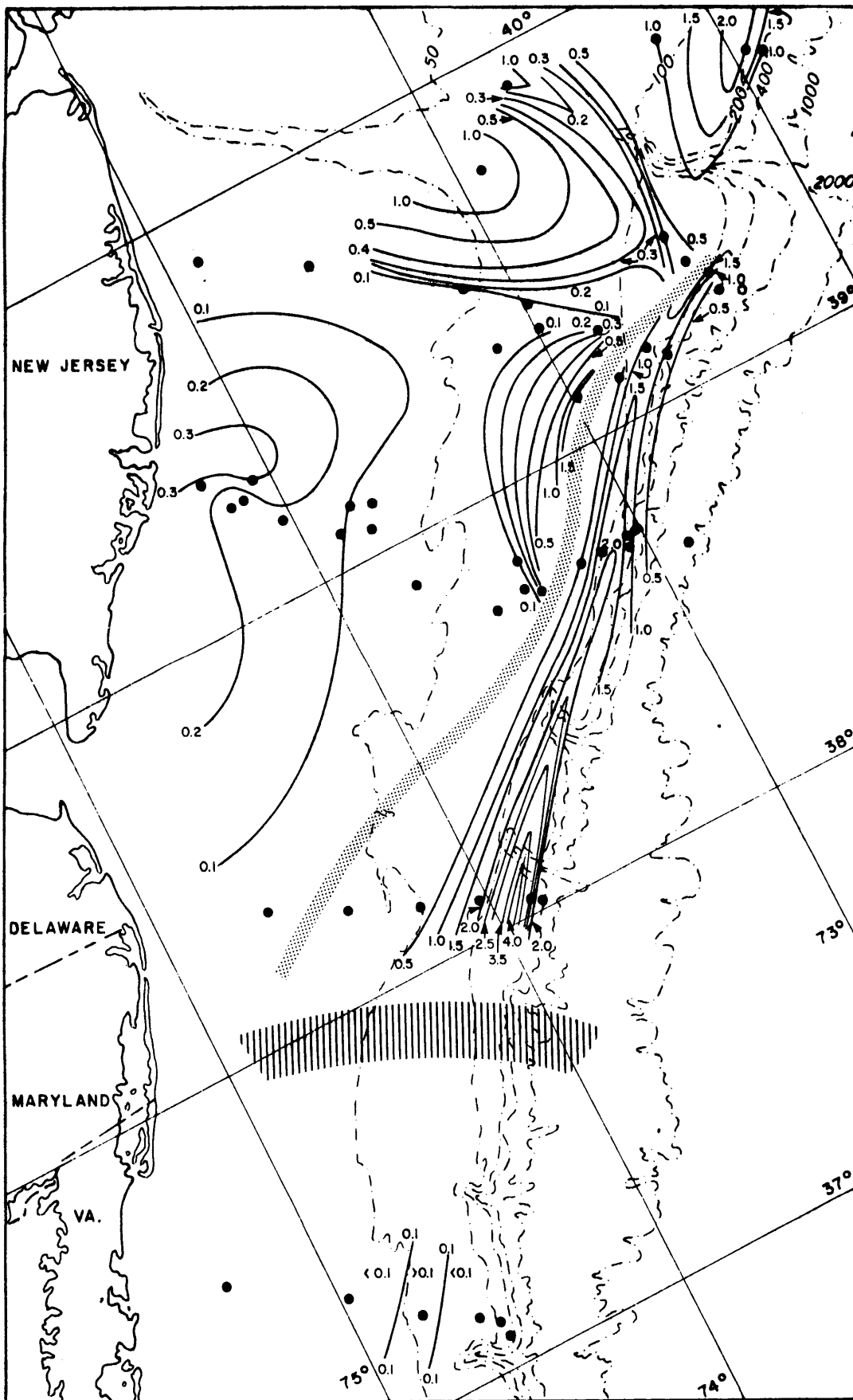


Figure 3-48. Surface NO_3 ($\mu\text{g atoms/l}$) distribution in the northern portions of the Middle Atlantic Bight during the period 19 February to 23 March 1976 (Cruise BLM02B). Shaded and hatched areas indicate discontinuity in data caused by 1) break in sampling between 10 and 15 March 1976, and 2) wind event (southwest winds in excess of 60 knots), respectively.

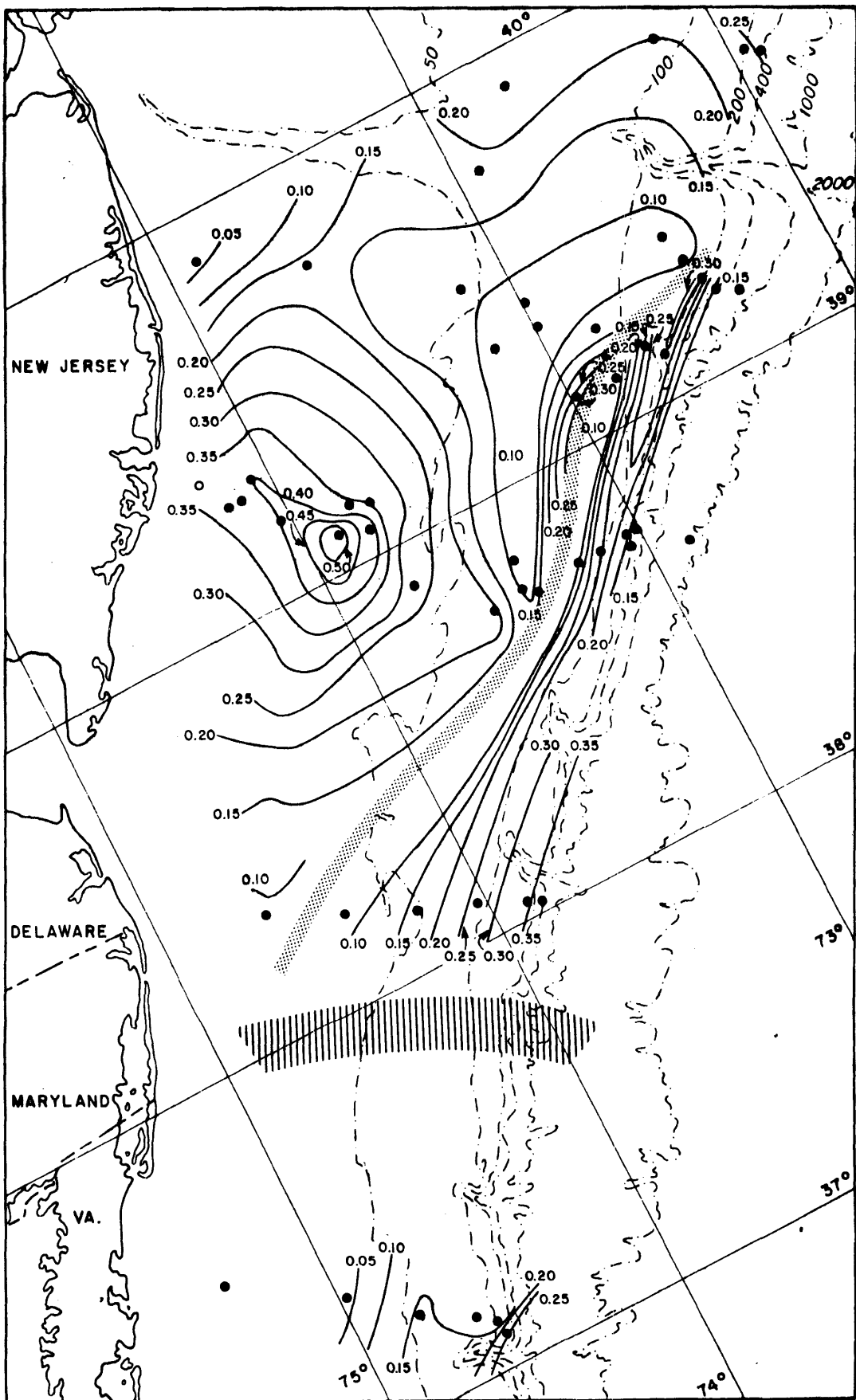


Figure 3-49. Surface O-PO₄ (μg atoms/l) distribution in the northern portions of the Middle Atlantic Bight during the period 19 February to 23 March 1976 (Cruise BLM02B). Shaded and hatched areas indicate discontinuity in data caused by 1) break in sampling between 10 and 15 March 1976, and 2) wind event (southwest winds in excess of 60 knots), respectively.

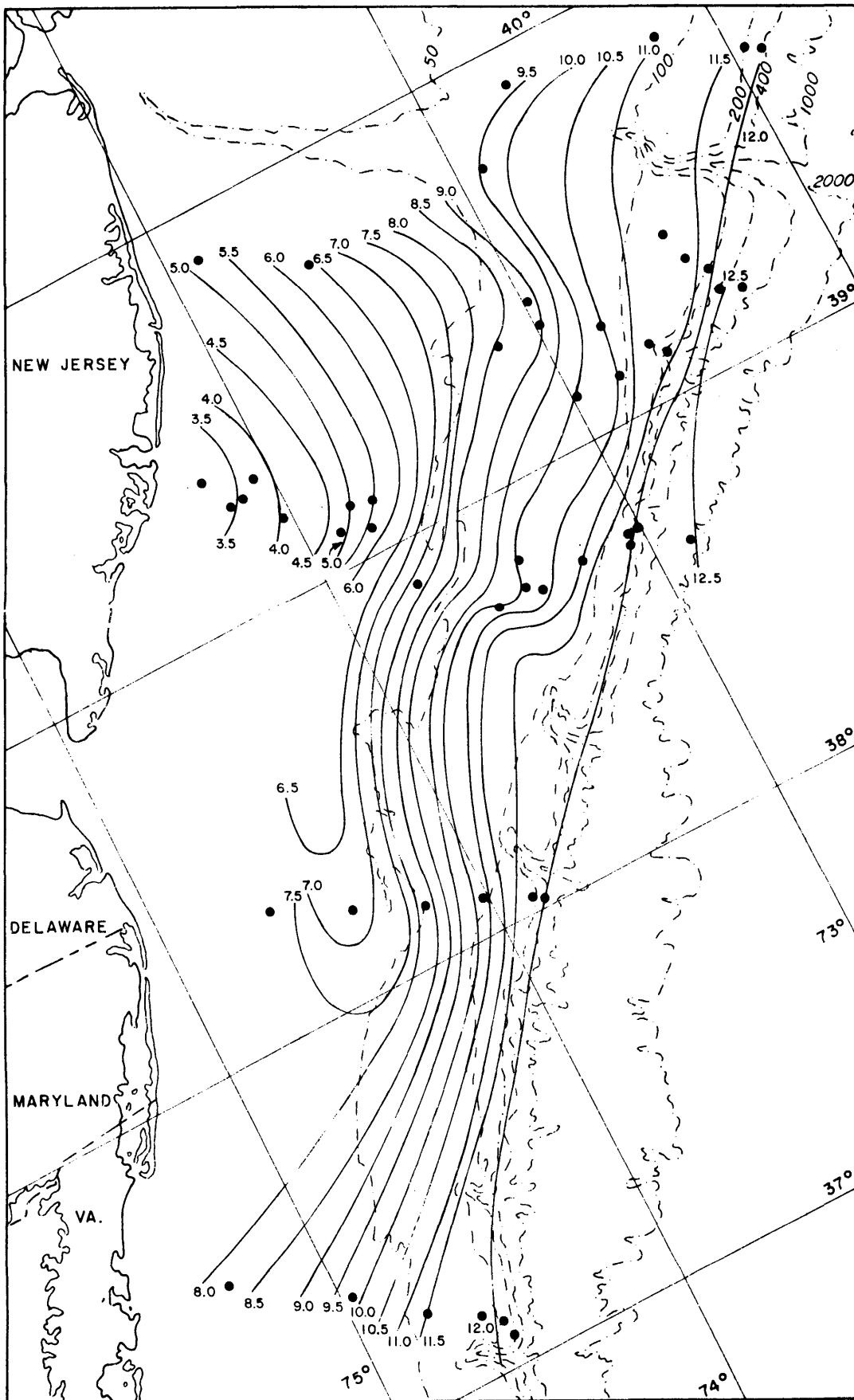


Figure 3-50 Bottom temperature ($^{\circ}\text{C}$) distribution in the northern portions of the Middle Atlantic Bight during the period 19 February to 23 March 1976 (Cruise BLM02B)

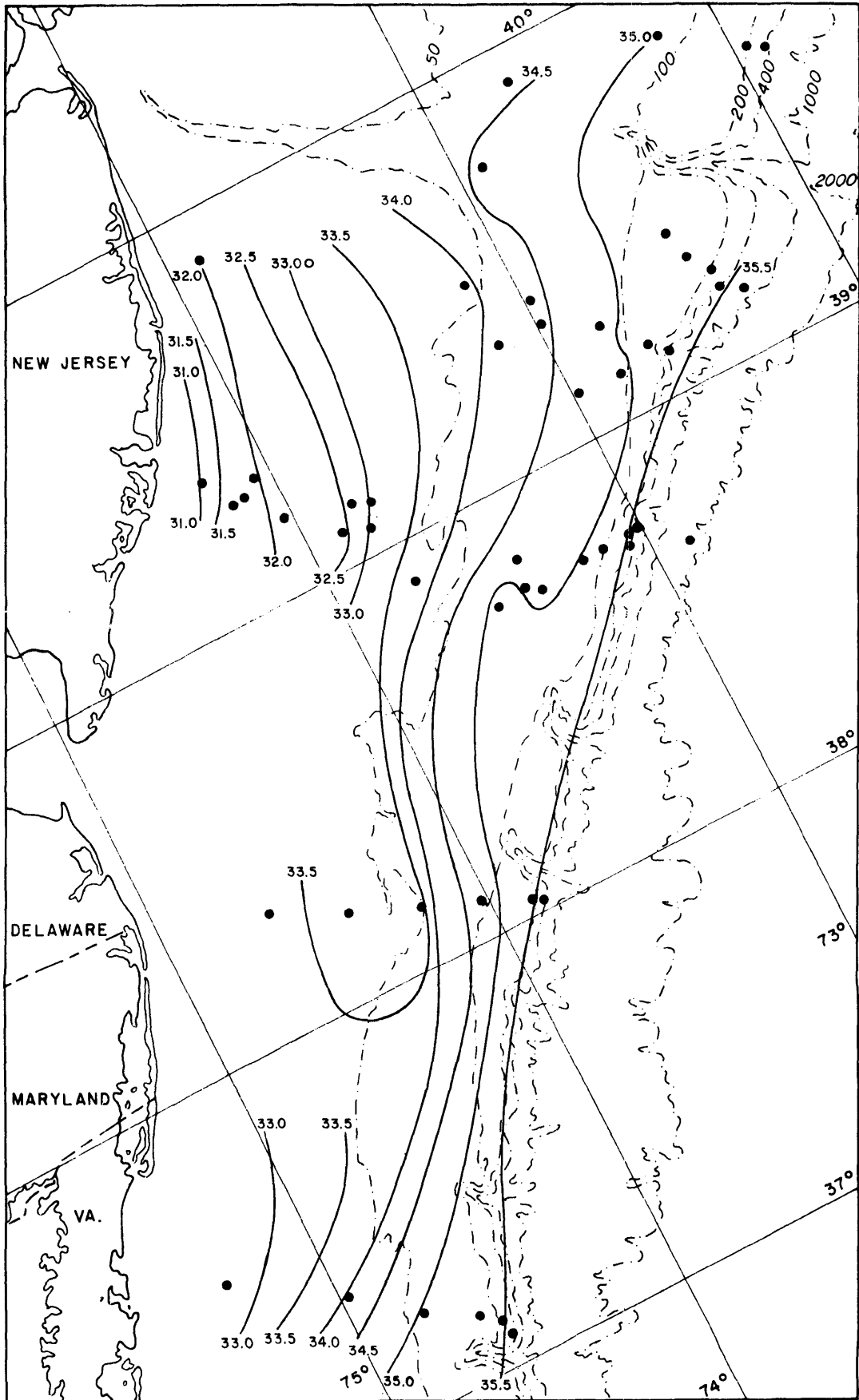


Figure 3-51. Bottom salinity (ppt) distribution in the northern portions of the Middle Atlantic Bight during the period 19 February to 23 March 1976 (Cruise BLM02B)
3-81

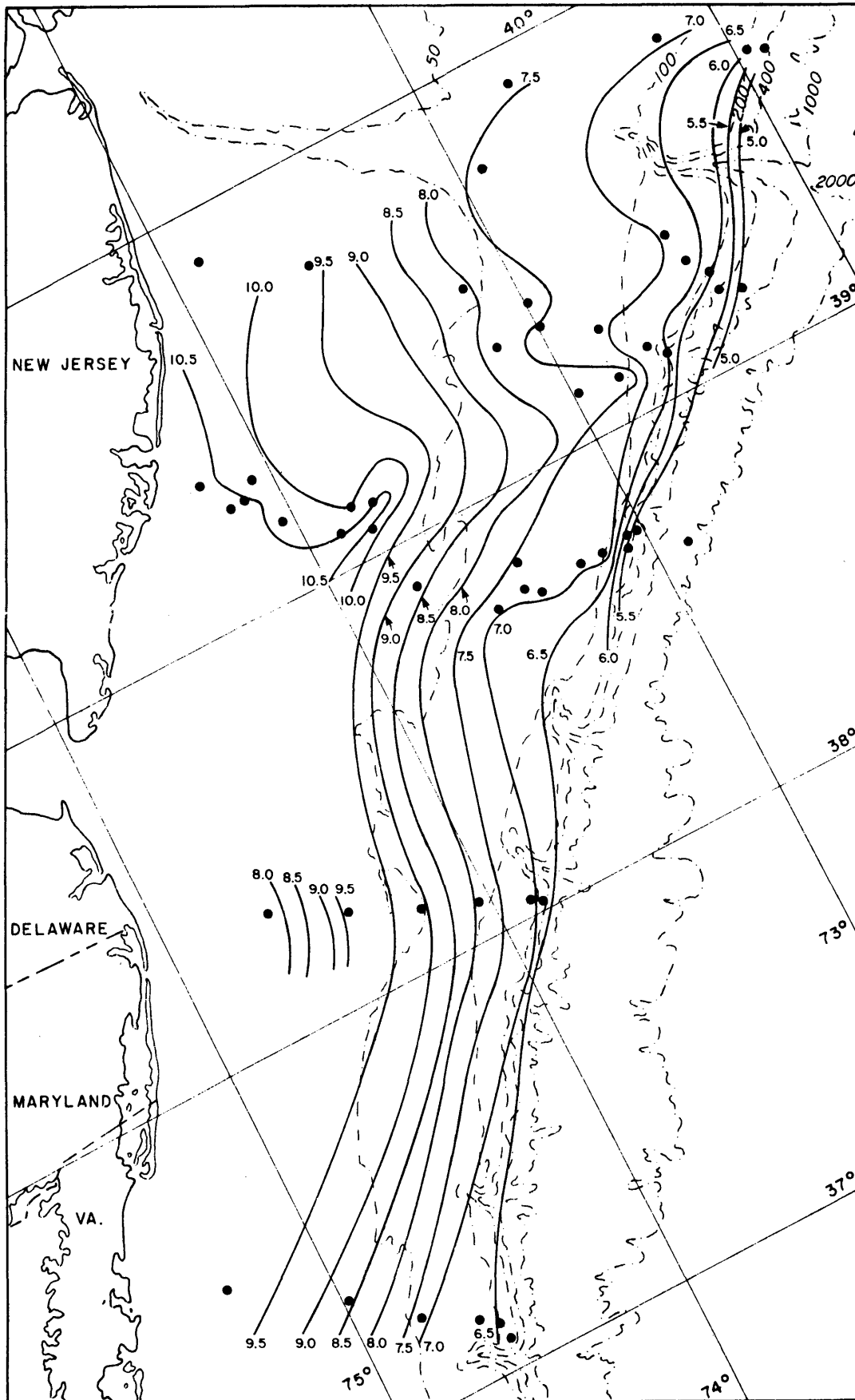


Figure 3-52. Bottom dissolved oxygen (mg/l) distribution in the northern portions of the Middle Atlantic Bight during the period 19 February to 23 March 1976 (Cruise BLMØ2B)

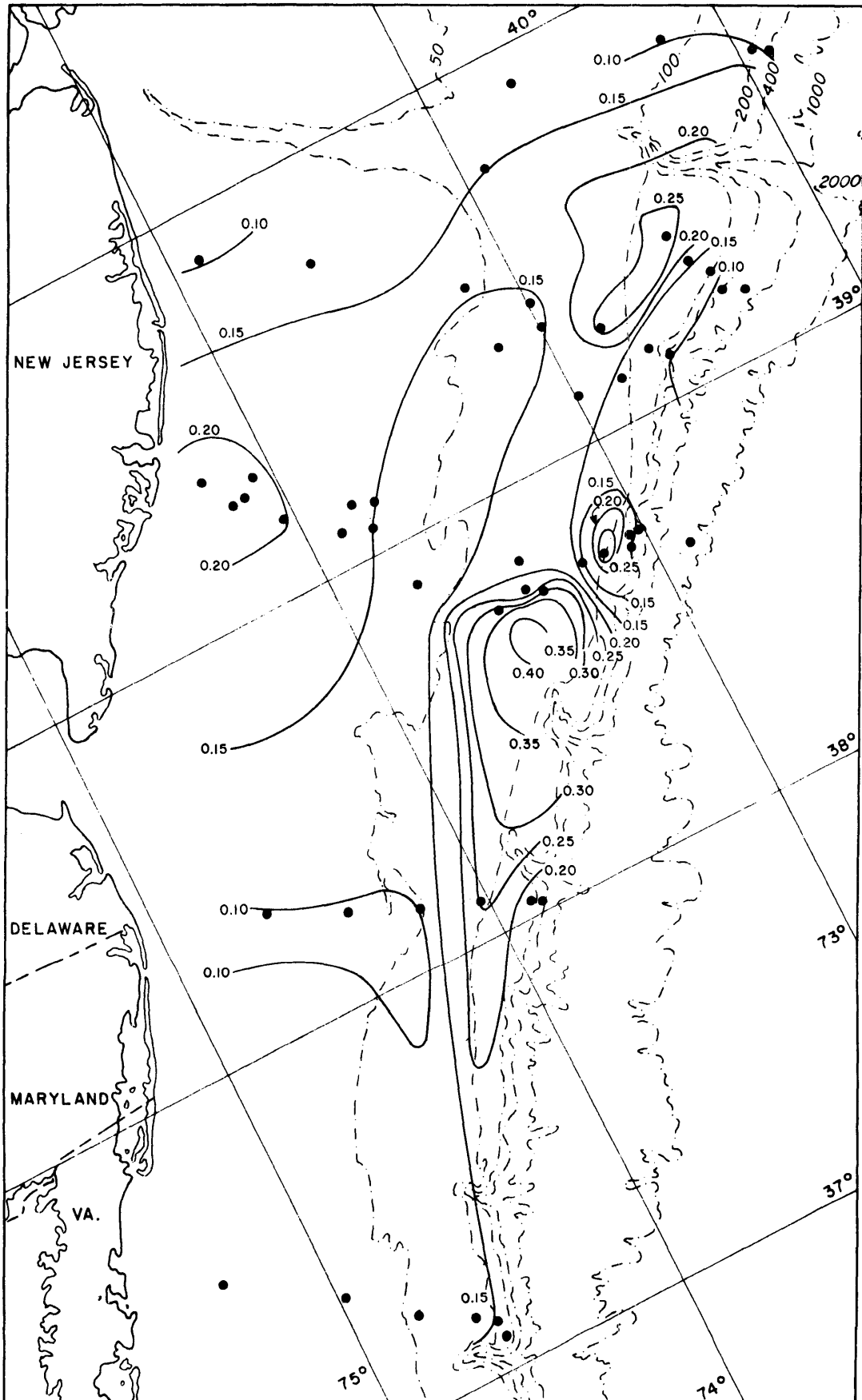


Figure 3-53. Bottom NO₂ (μgm atoms/l) distribution in the northern portions of the Middle Atlantic Bight during the period 19 February to 23 March 1976 (Cruise BLM02B)

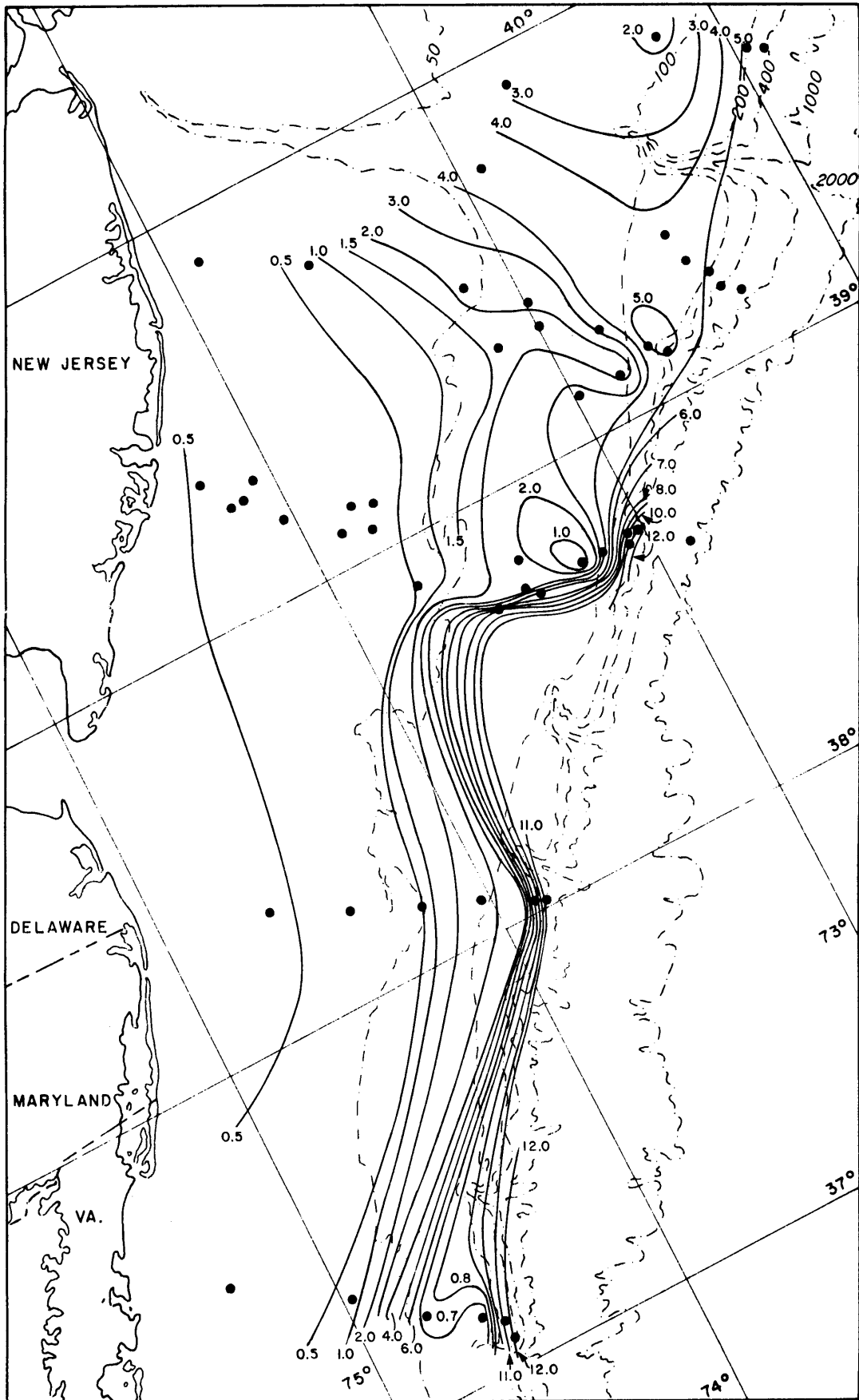


Figure 3-54. Bottom NO_3 ($\mu\text{g m atoms/l}$) distribution in the northern portions of the Middle Atlantic Bight during the period 19 February to 23 March 1976 (Cruise BLM02B)

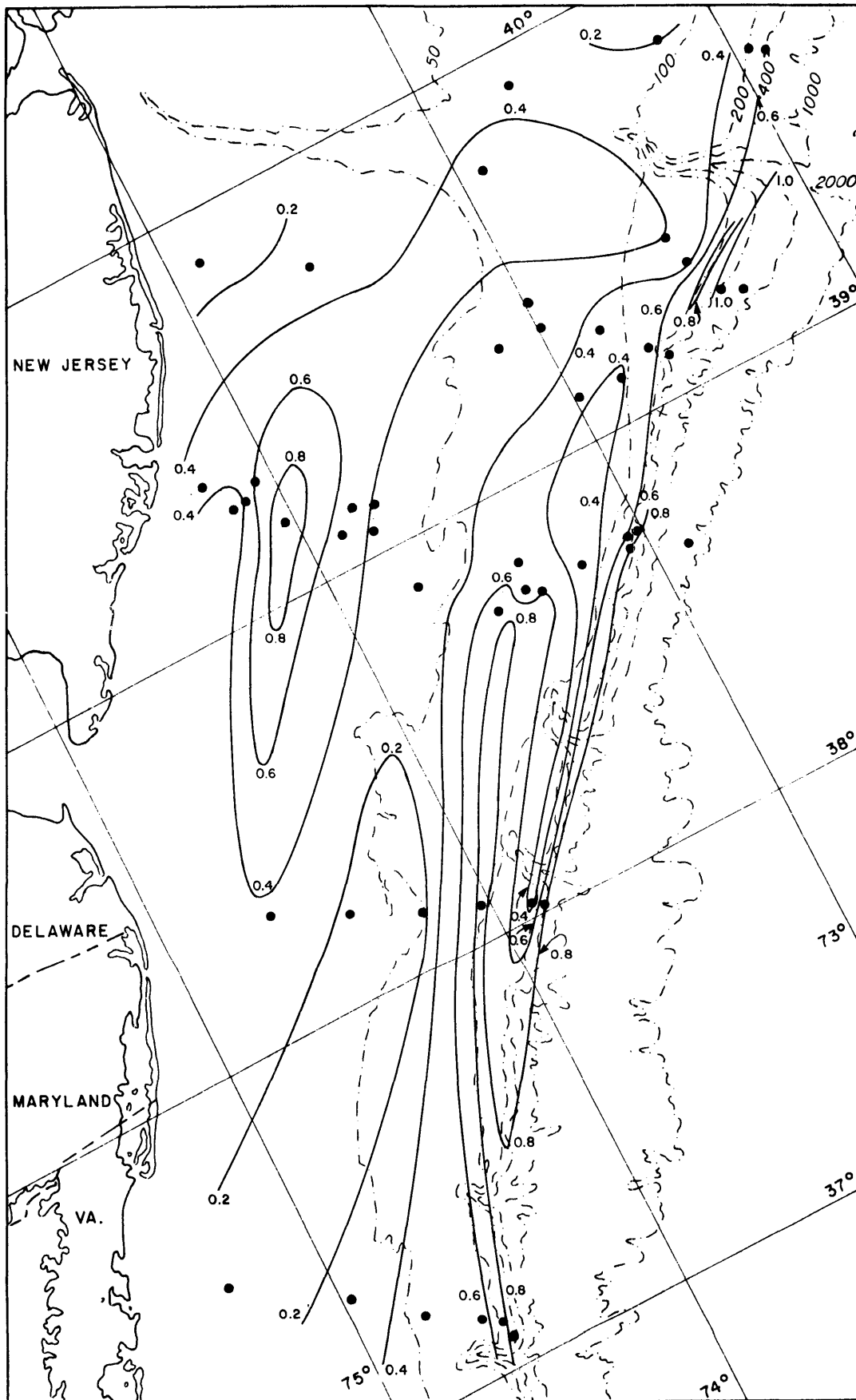


Figure 3-55. Bottom O-PO₄ (μgm atoms/l) distribution in the northern portions of the Middle Atlantic Bight during the period 19 February to 23 March 1976 (Cruise BLM02B)

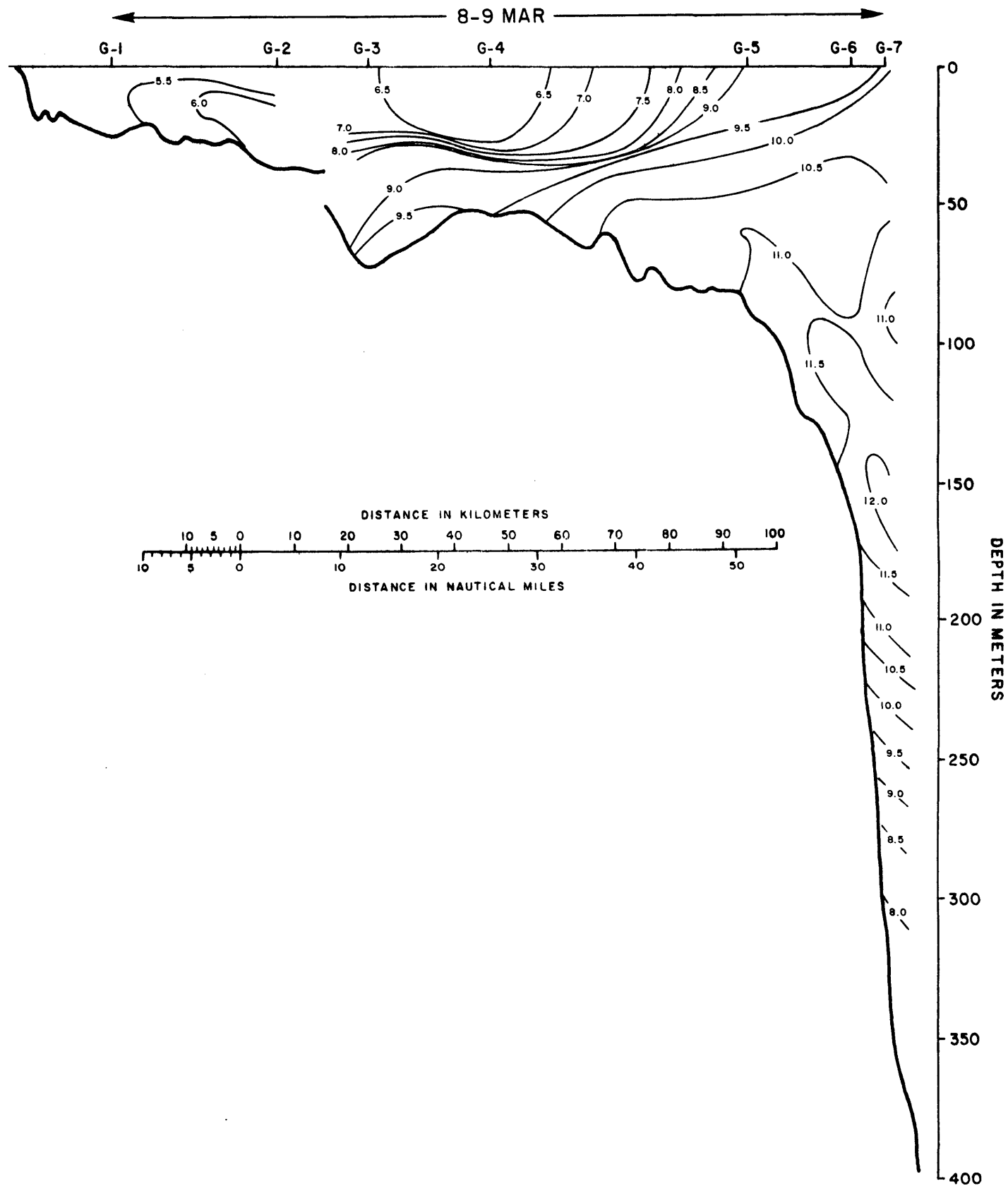


Figure 3-56. Temperature ($^{\circ}\text{C}$) along Section I (Stations G1 to G7, 8-9 March 1976) during cruise BLM02B. Section location is shown in Figure 3-10. Breaks in isopleths signify spatial breaks in sampling continuity.

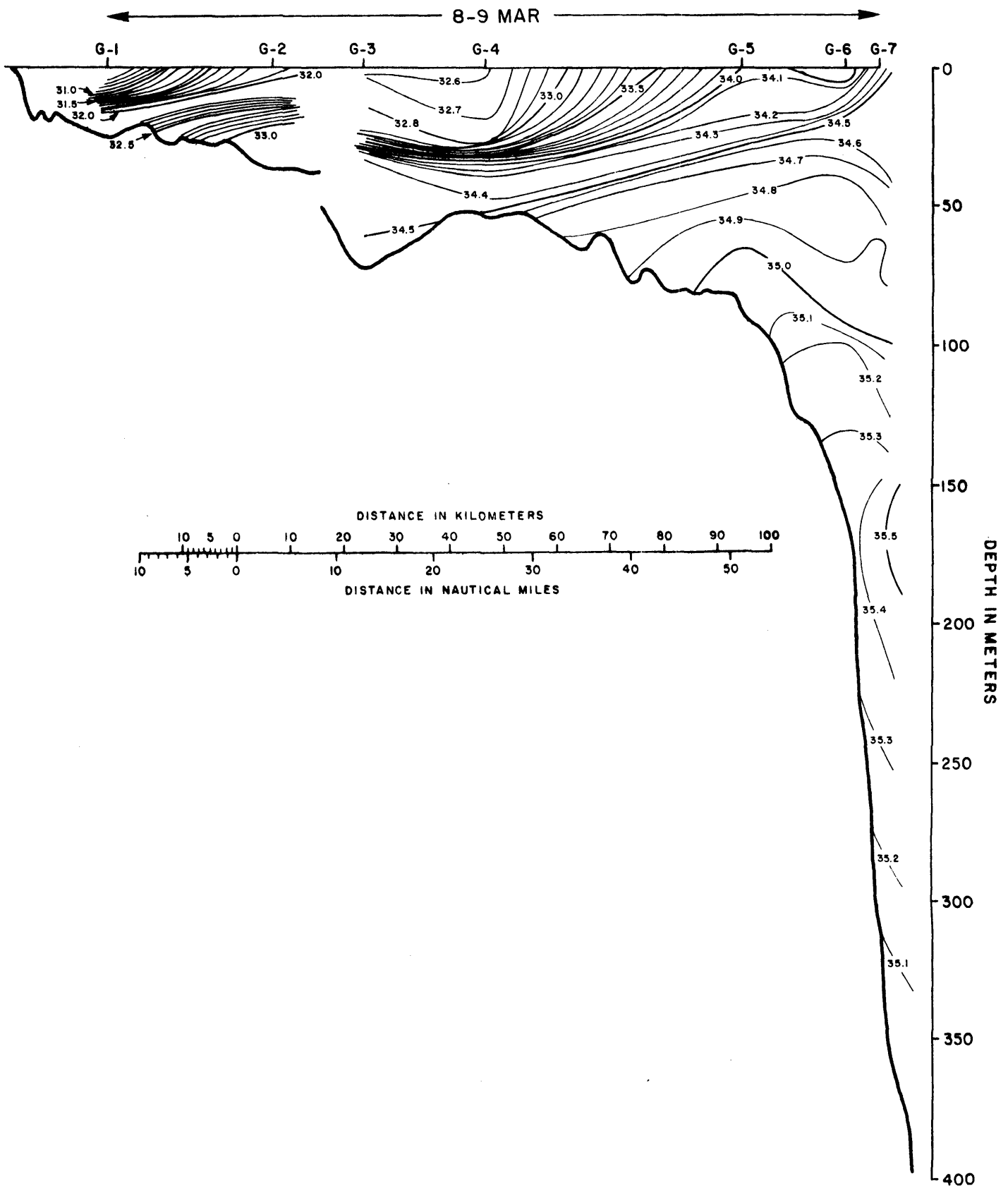


Figure 3-57. Salinity (ppt) along Section I (Stations G1 to G7, 8-9 March 1976) during cruise BLM02B. Section location is shown in Figure 3-10. Breaks in isopleths signify spatial breaks in sampling continuity.

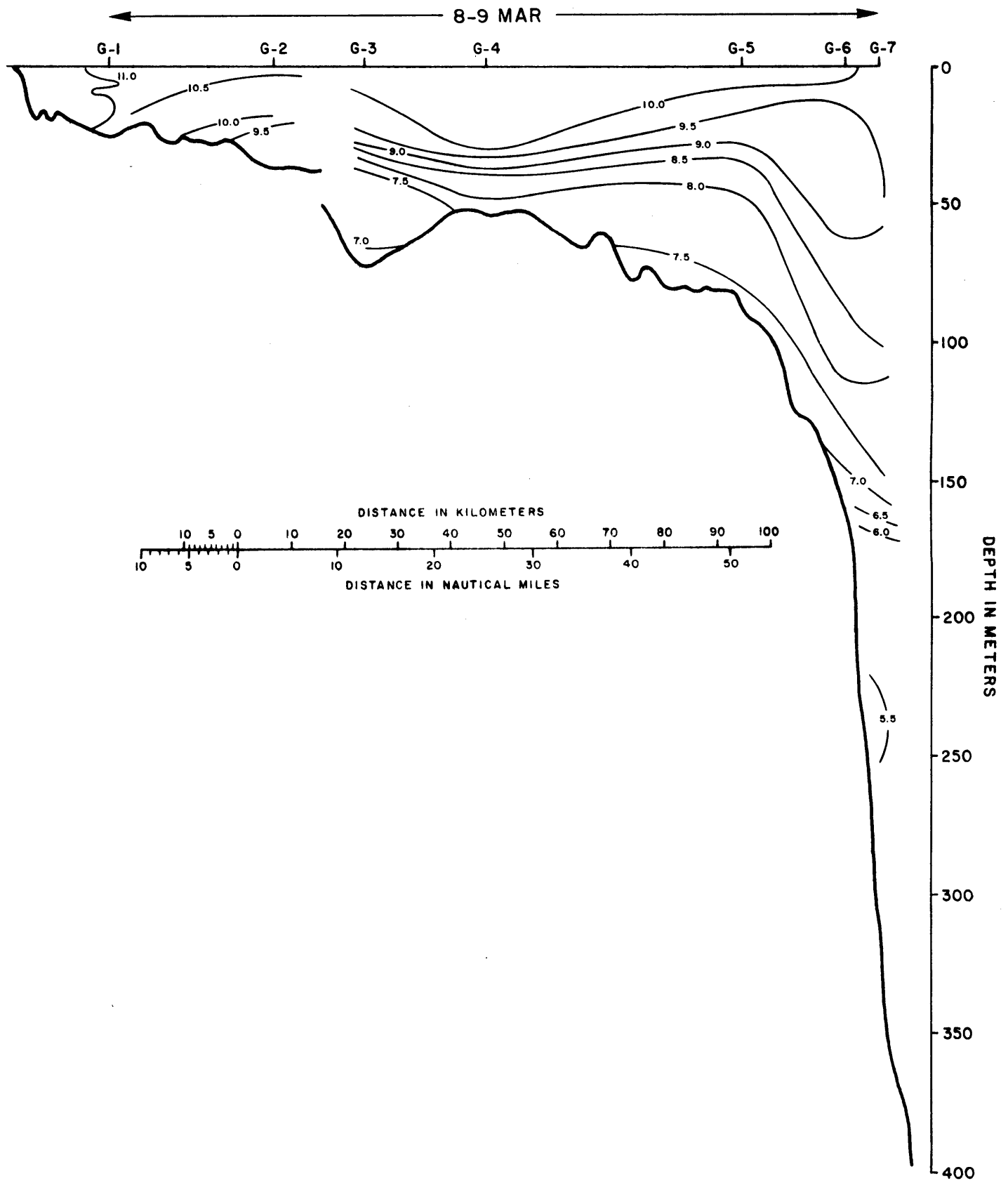


Figure 3-58. Dissolved oxygen (mg/l) along Section I (Stations G1 to G7, 8-9 March 1976) during cruise BLM02B. Section location is shown in Figure 3-10. Breaks in isopleths signify spatial breaks in sampling continuity.

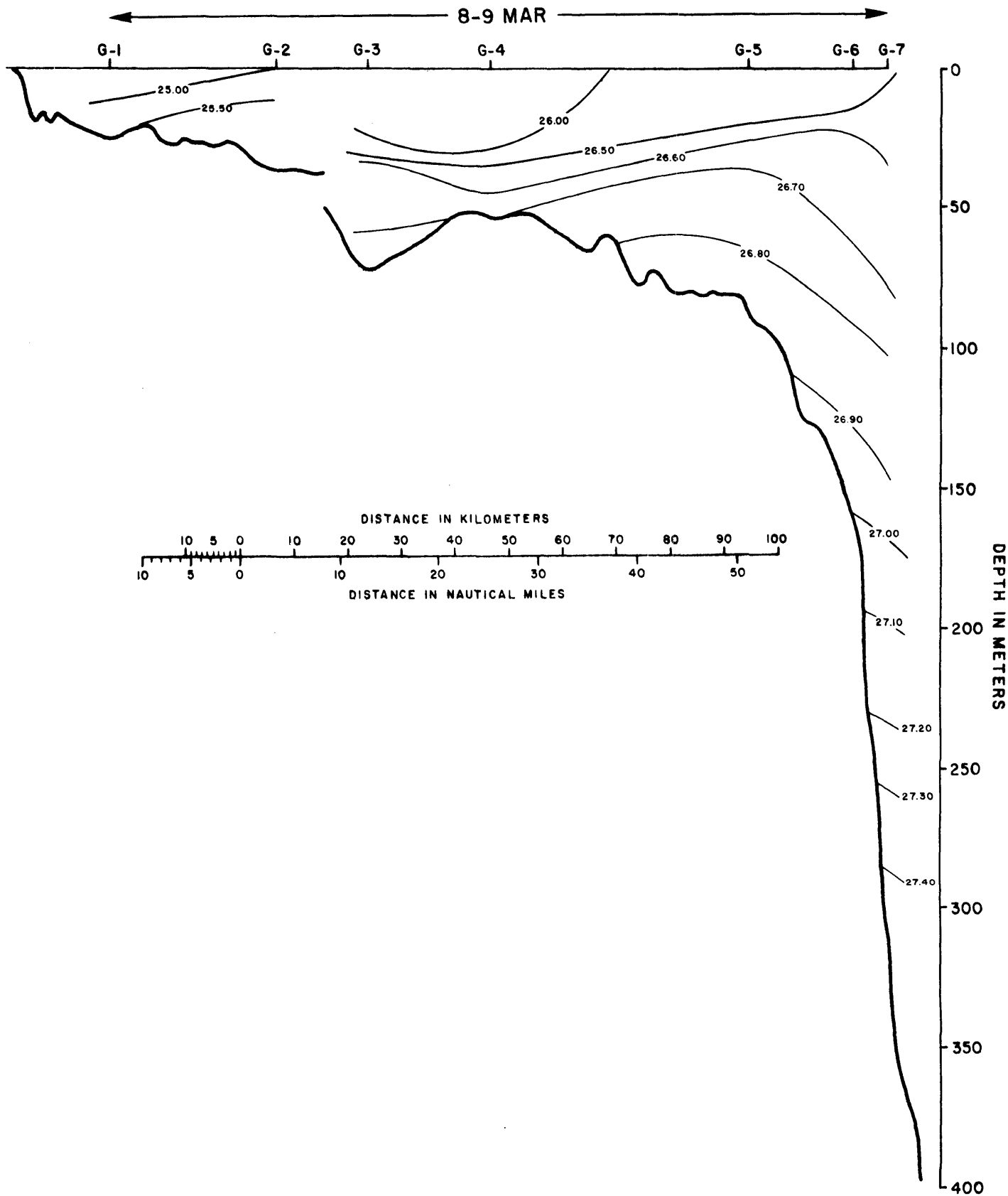


Figure 3-59 . Density (σ_t units) along Section I (Stations G1 to G7, 8-9 March 1976) during cruise BLM02B. Section location is shown in Figure 3-10. Breaks in isopleths signify spatial breaks in sampling continuity.

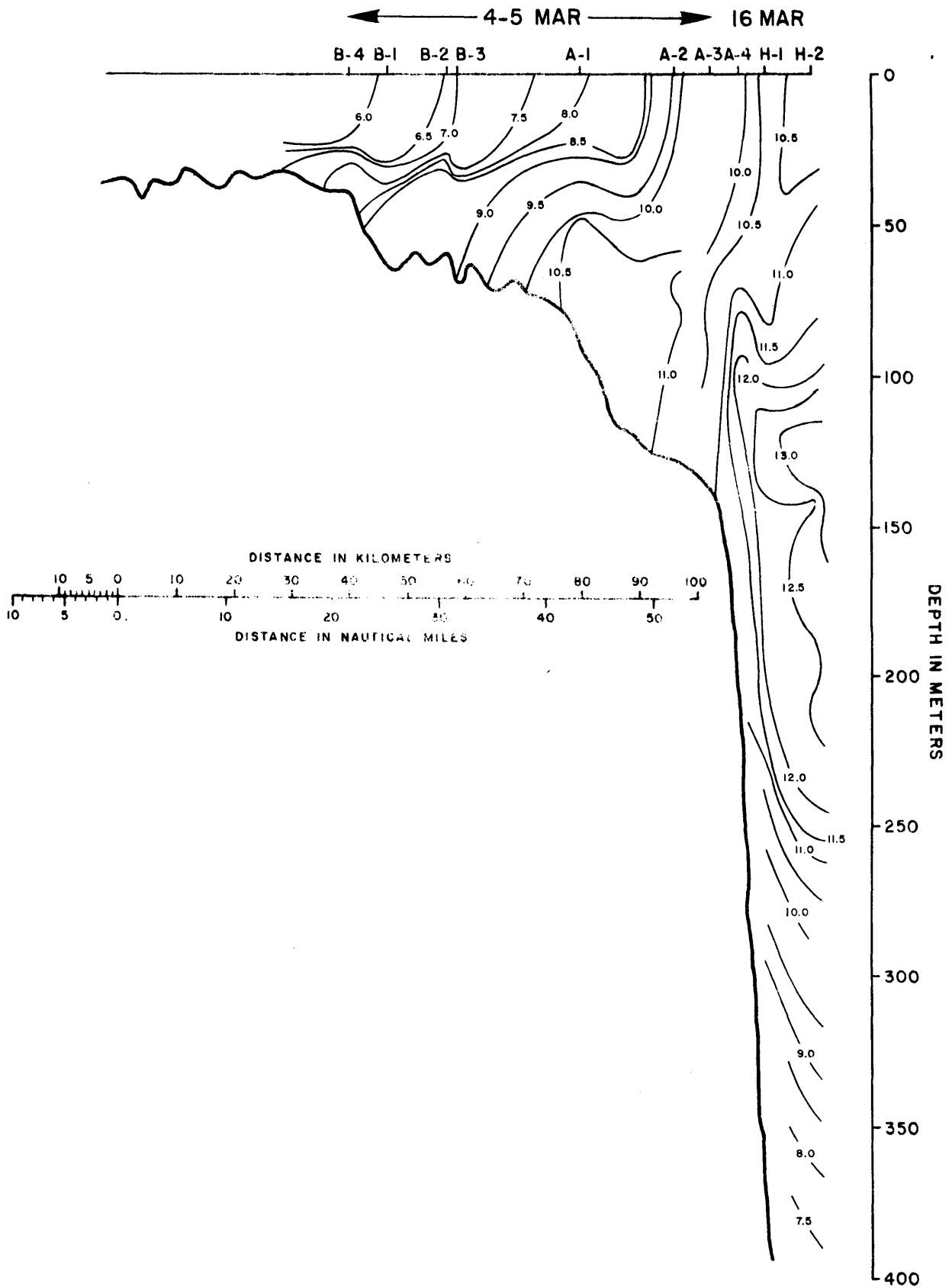


Figure 3-60 . Temperature ($^{\circ}\text{C}$) along Section II (Stations B4 to H2, 4-16 March 1976) during cruise BLM02B. Section location is shown in Figure 3-10.

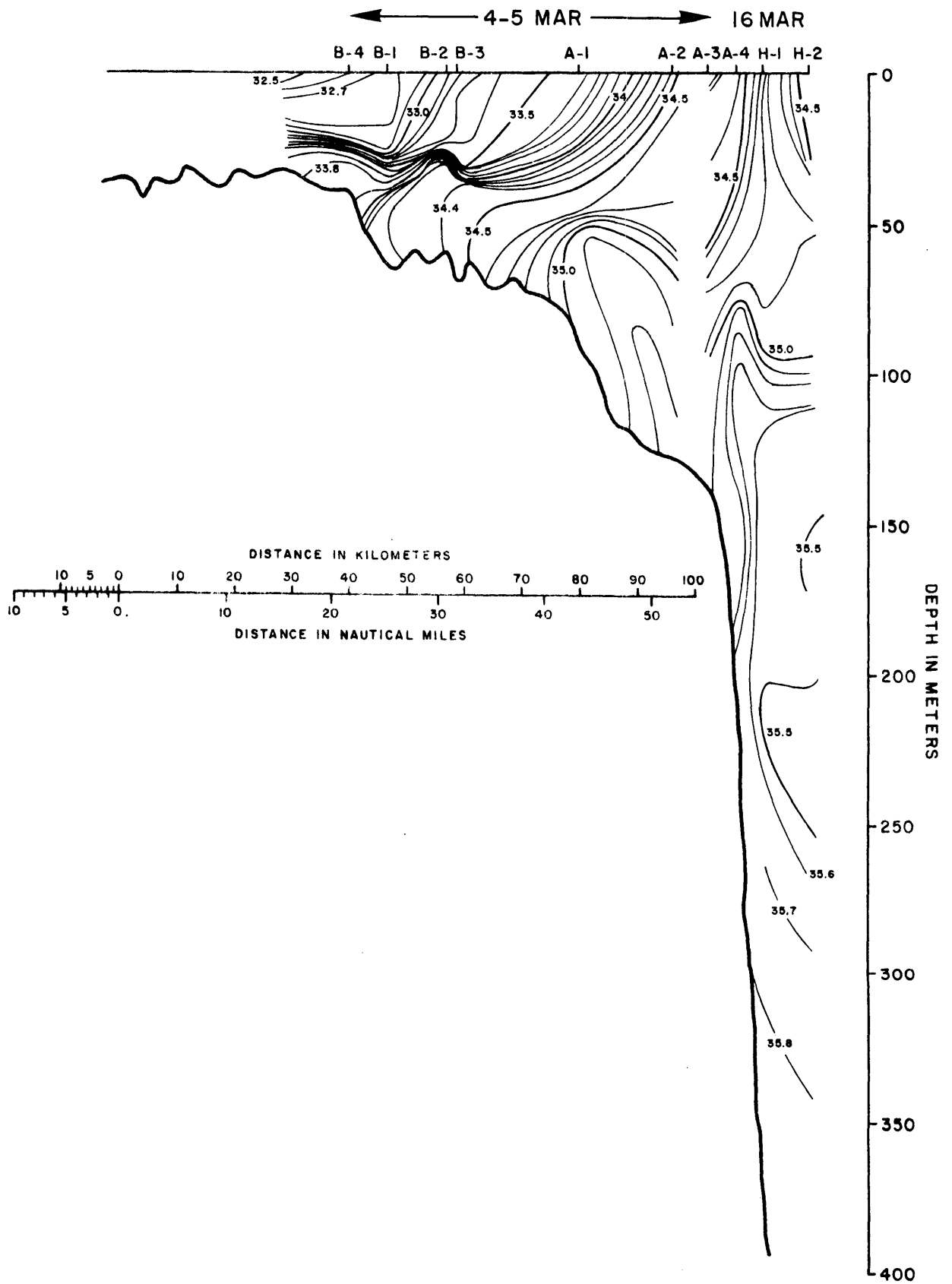


Figure 3-61 . Salinity (ppt) along Section II (Stations B4 to H2, 4-16 March 1976) during cruise BLMØ2B. Section location is shown in Figure 3-10.

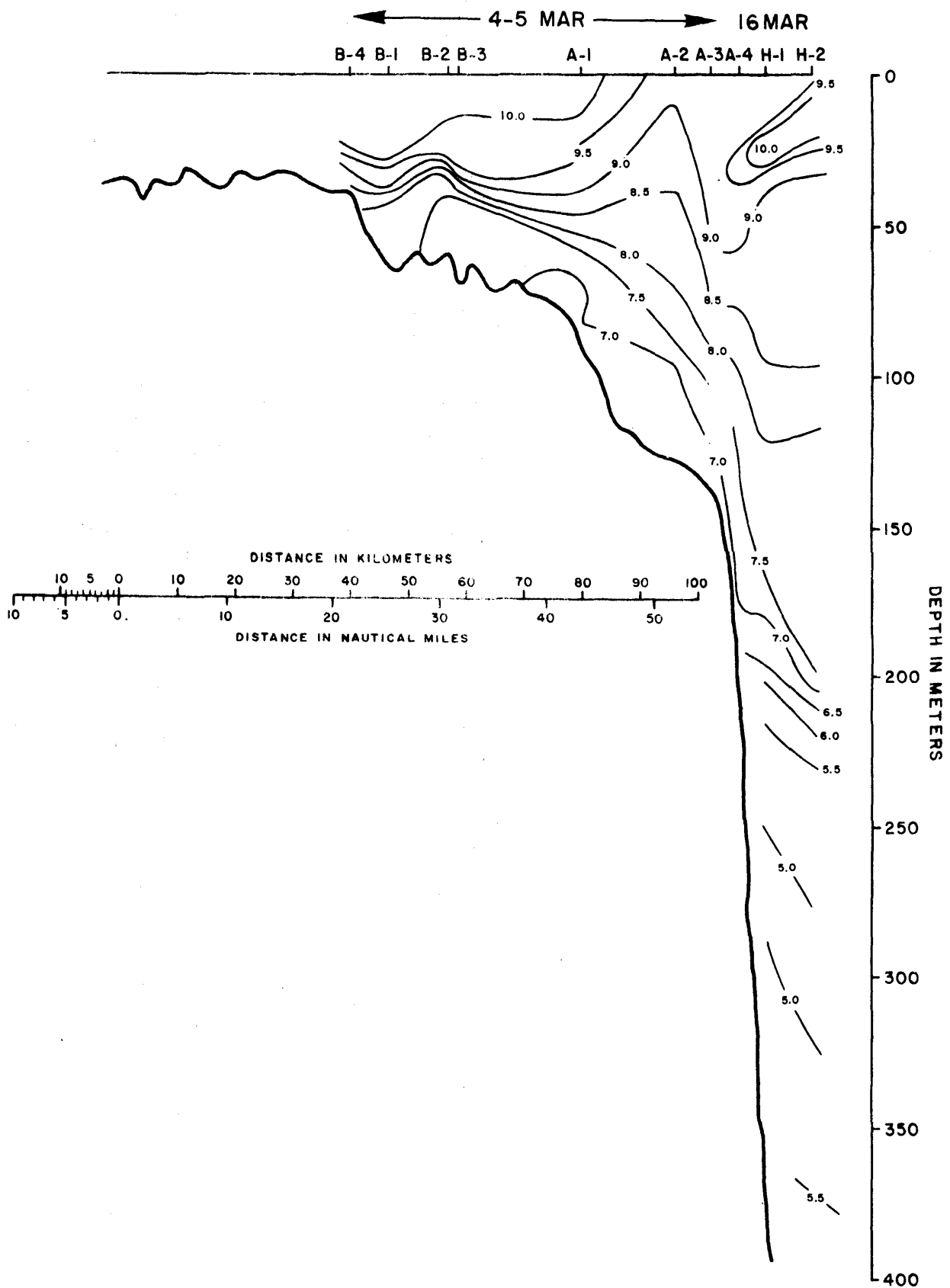


Figure 3-62 . Dissolved oxygen (mg/l) along Section II (Stations B4 to H2, 4-16 March 1976) during cruise BLM02B. Section location is shown in Figure 3-10.

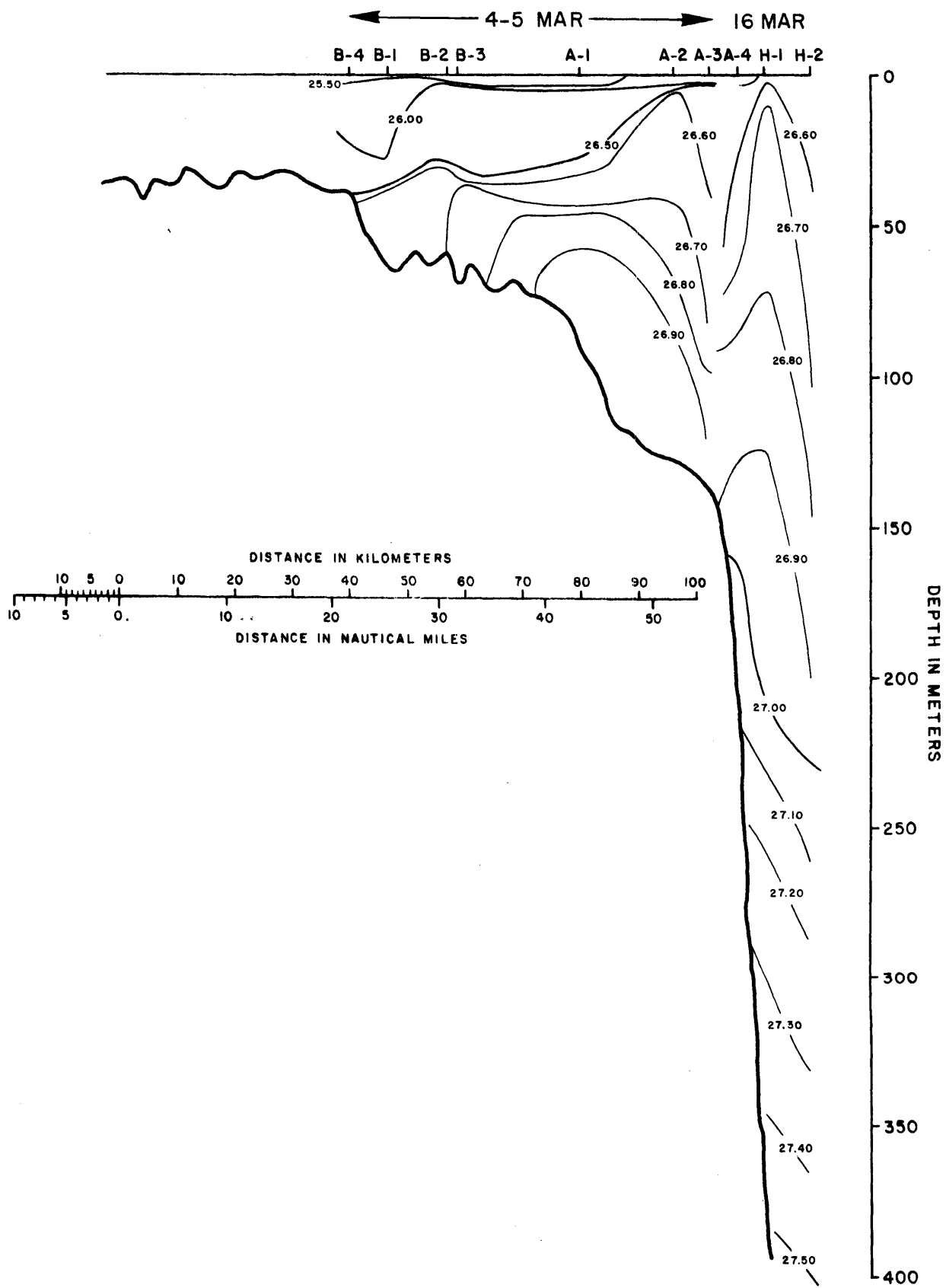


Figure 3-63 . Density (σ_t units) along Section II (Stations B4 to H2, 4-16 March 1976) during cruise BLM02B. Section location is shown in Figure 3-10.

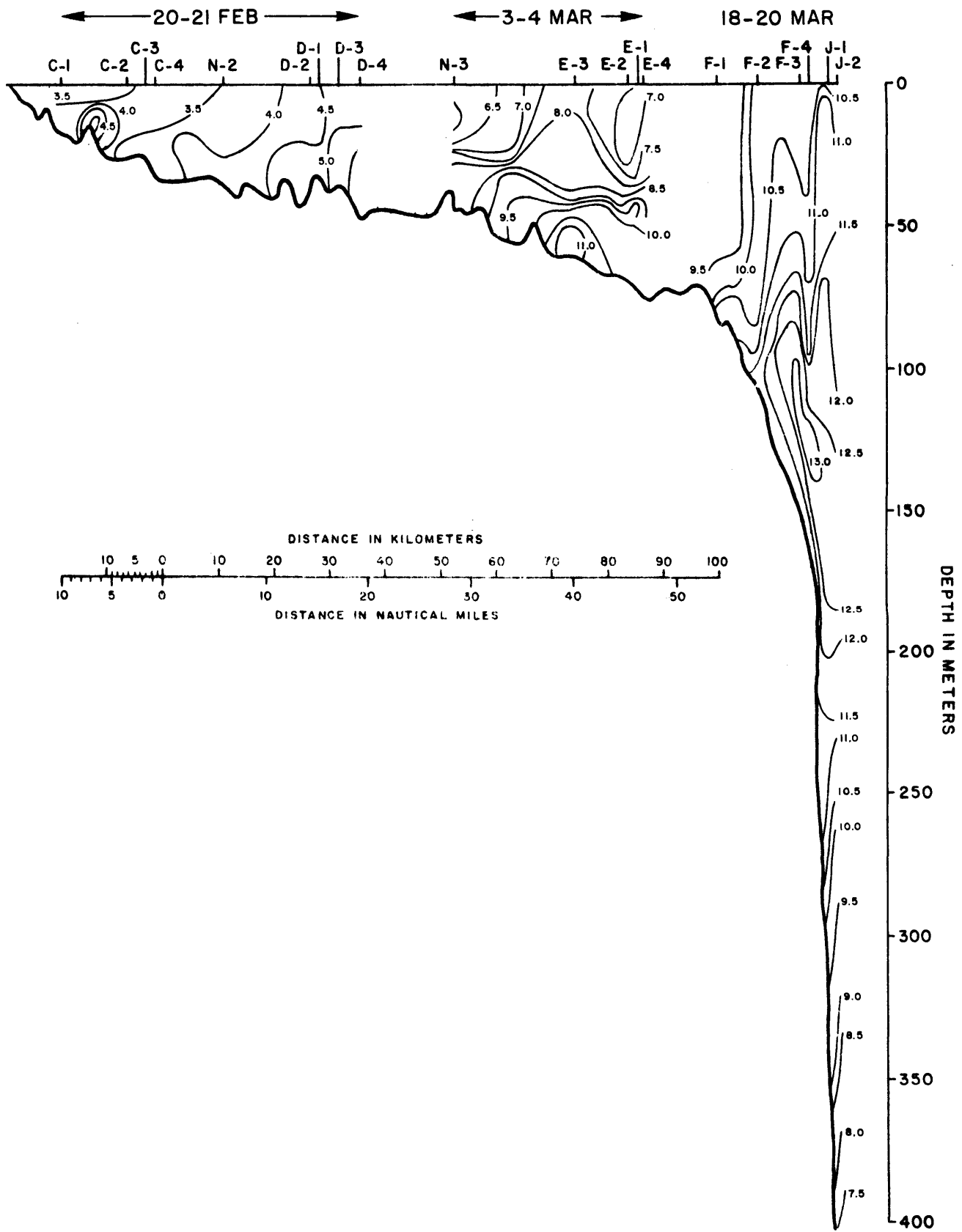


Figure 3-64 . Temperature ($^{\circ}\text{C}$) along Section III (Stations C1 to J2, 20 February - 20 March 1976) during cruise BLMØ2B. Section location is shown in Figure 3-10. Breaks in isopleths signify temporal breaks in sampling continuity.

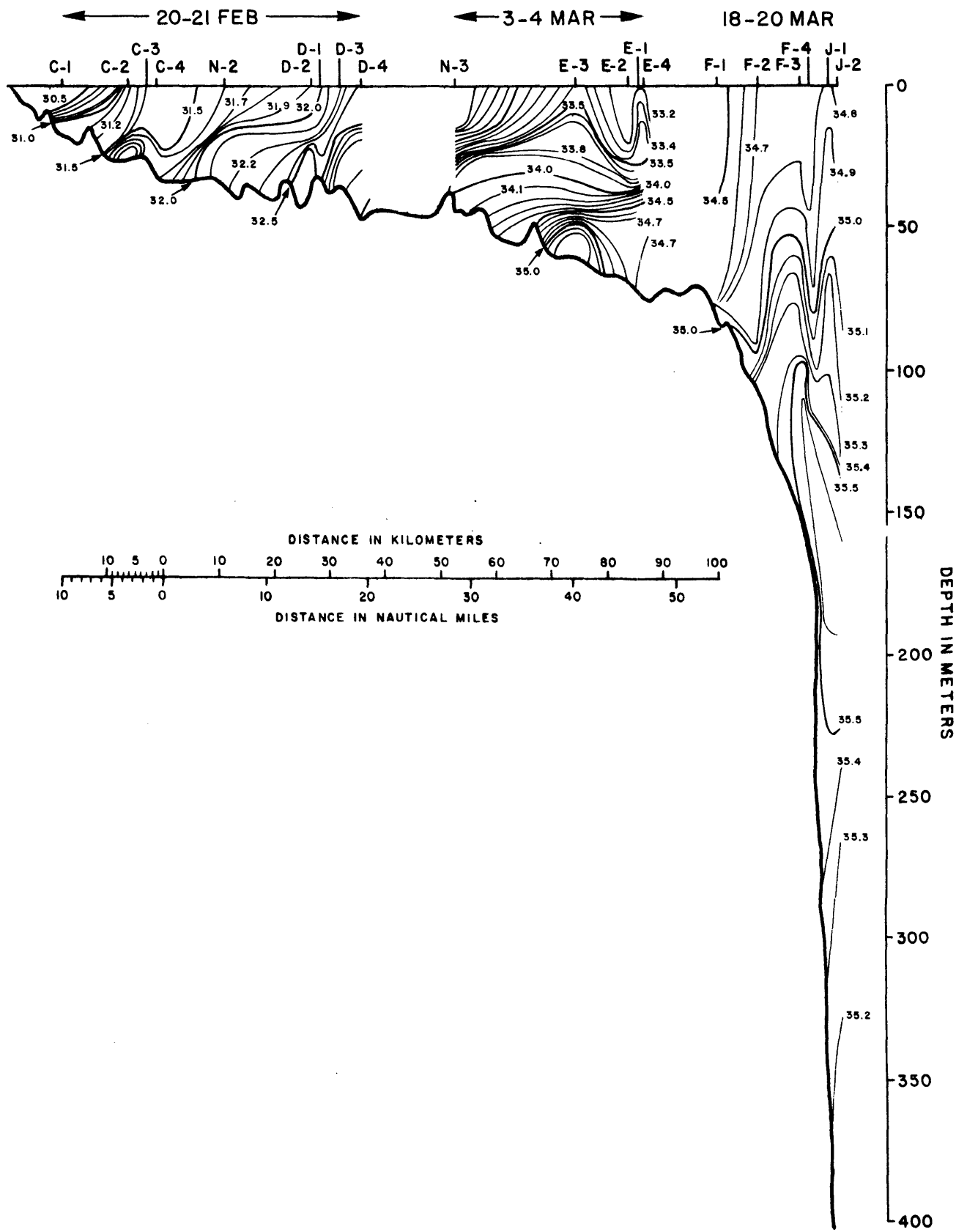


Figure 3-65. Salinity (ppt) along Section III (Stations C1 to J2, 20 February - 20 March 1976) during cruise BLM02B. Section location is shown in Figure 3-10. Breaks in isopleths signify temporal breaks in sampling continuity.

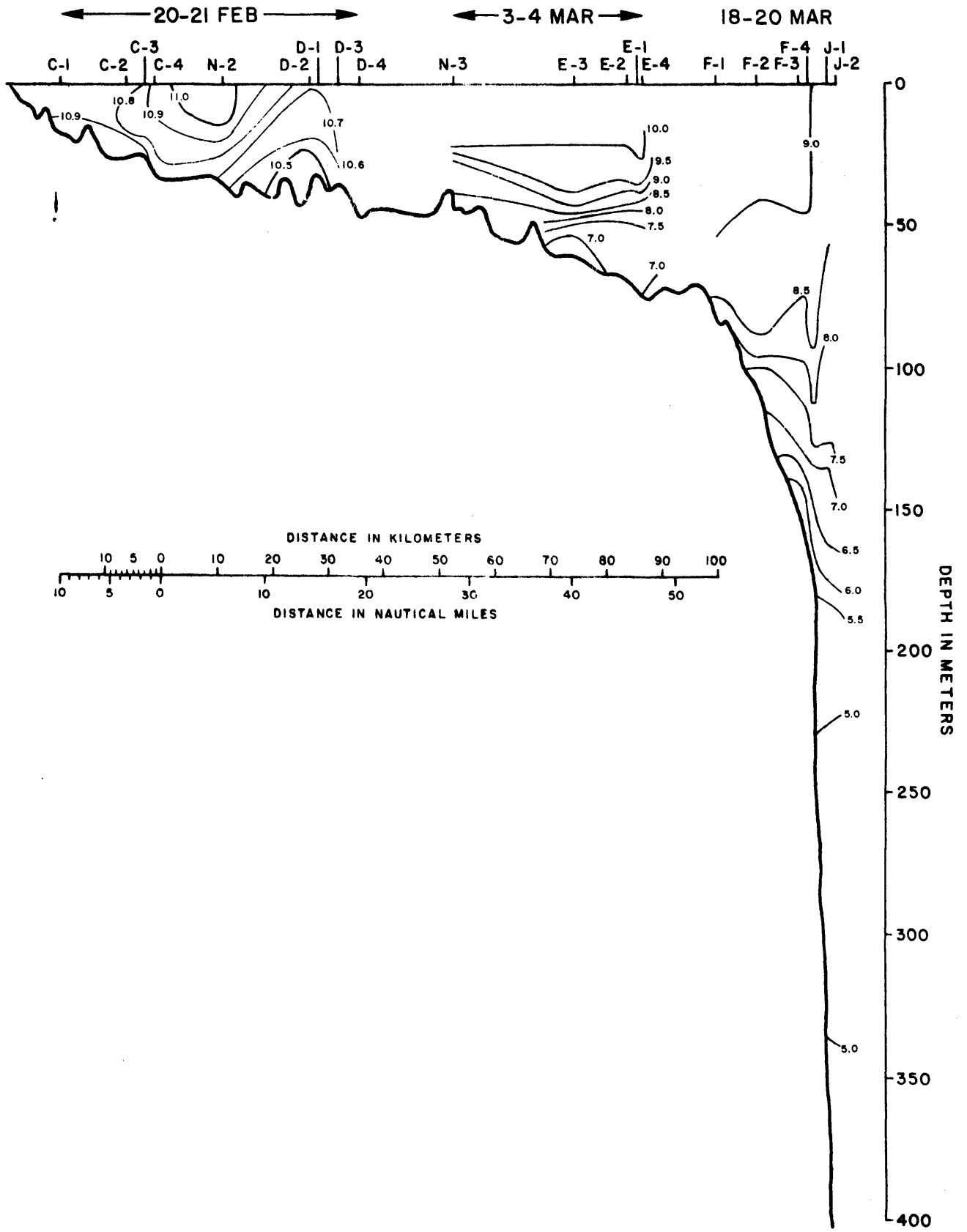


Figure 3-66. Dissolved oxygen (mg/l) along Section III (Stations C1 to J2, 20 February - 20 March 1976) during cruise BLM02B. Section location is shown in Figure 3-10. Breaks in isopleths signify temporal breaks in sampling continuity.

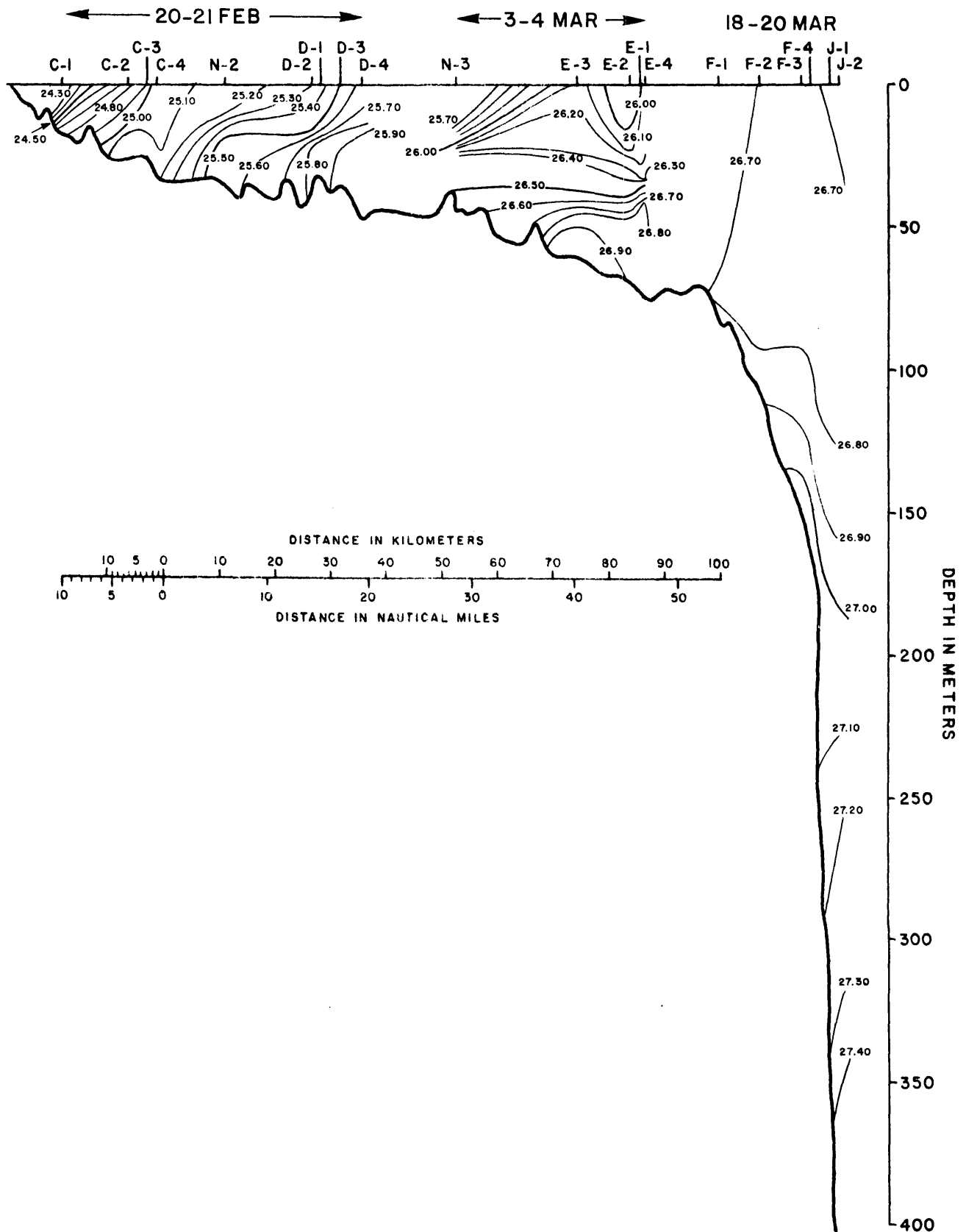


Figure 3-67. Density (σ_t units) along Section III (Stations C1 to J2, 20 February - 20 March 1976) during cruise BLMØ2B. Section location is shown in Figure 3-10. Breaks in isopleths signify temporal breaks in sampling continuity.

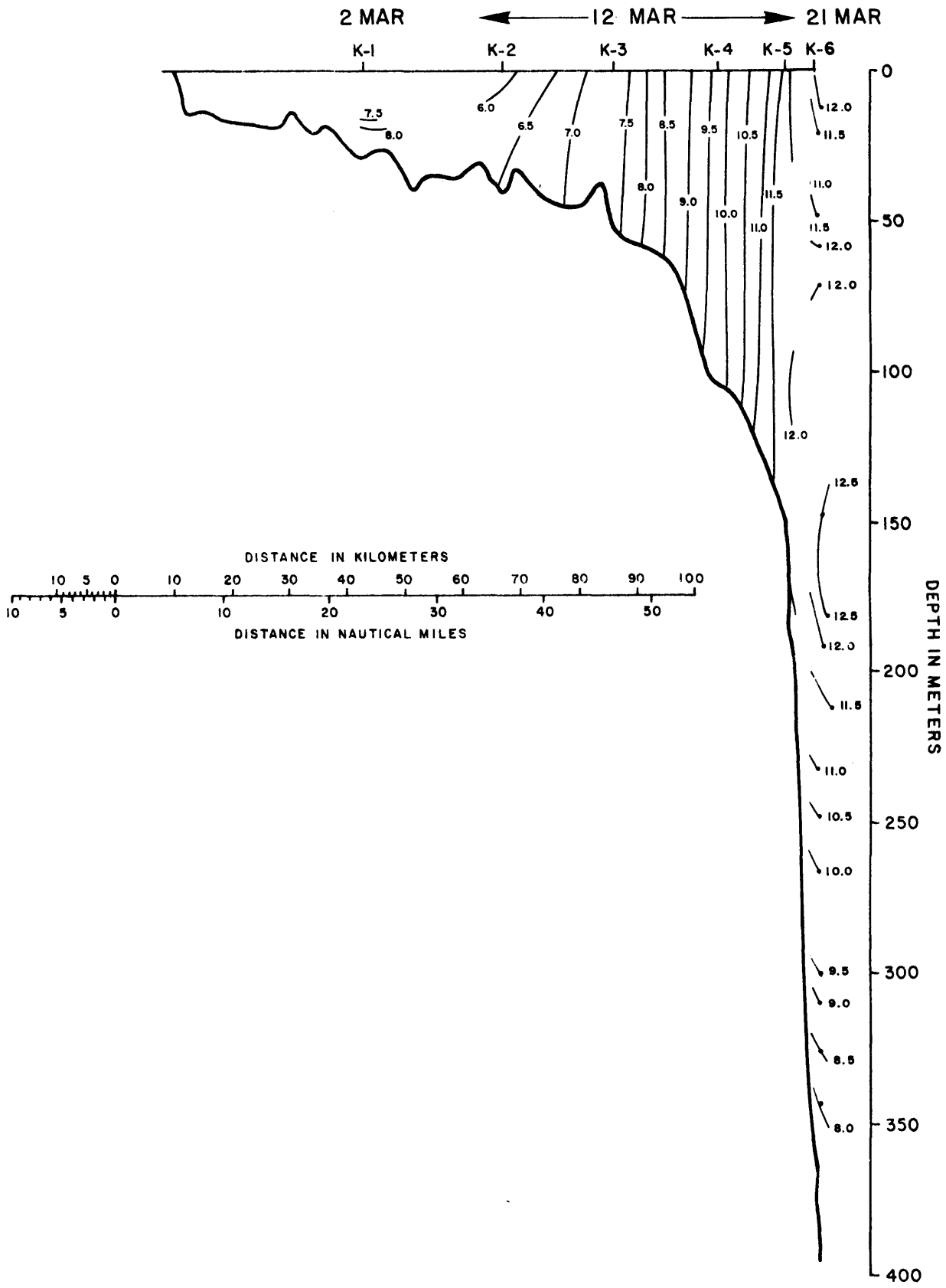


Figure 3-68. Temperature ($^{\circ}\text{C}$) along Section IV (Stations K1 to K6, 2-21 March 1976) during cruise BLM02B. Section location is shown in Figure 3-10. Breaks in isopleths signify temporal breaks in sampling continuity.

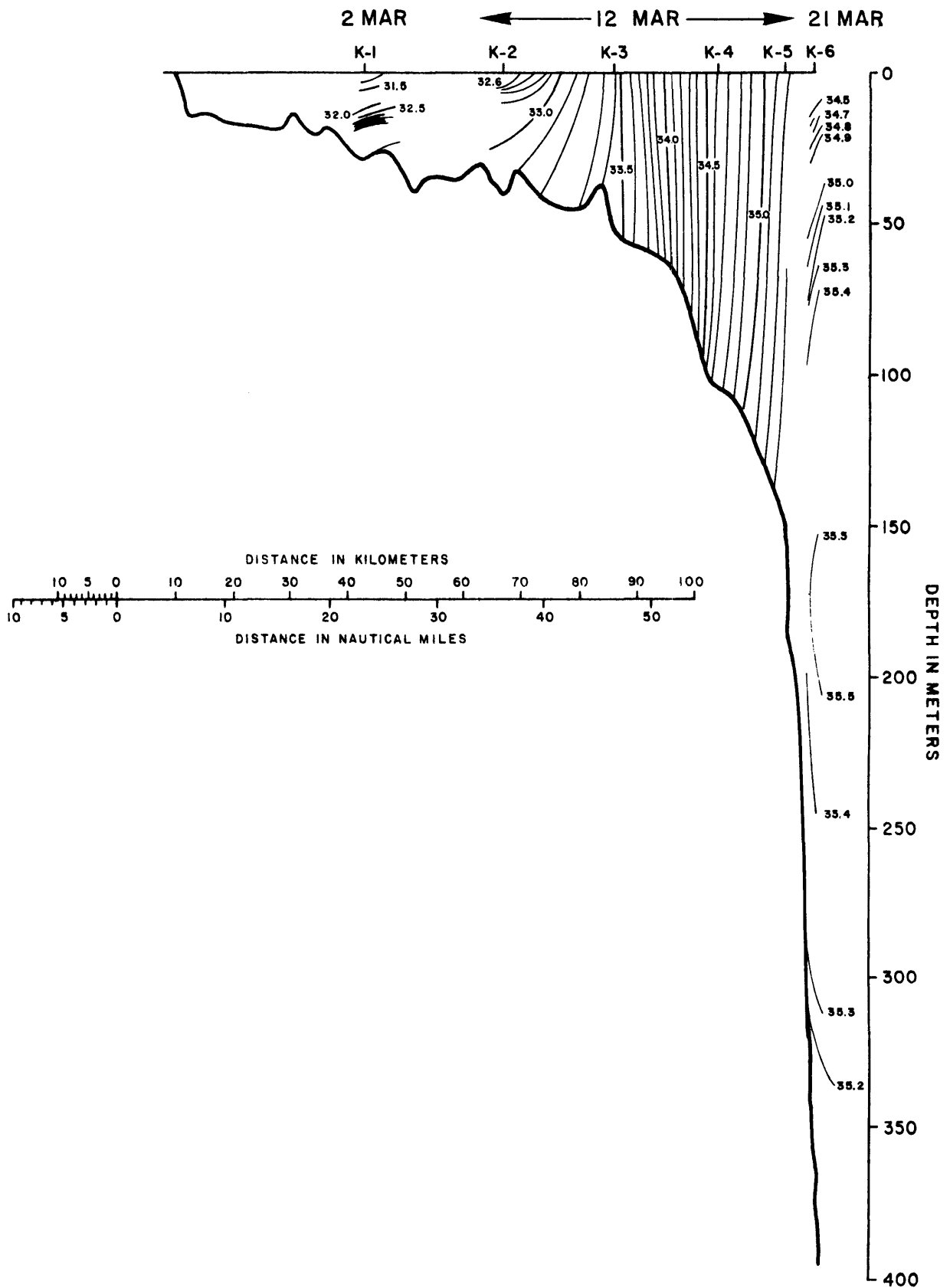


Figure 3-69. Salinity (ppt) along Section IV (Stations K1 to K6, 2-21 March 1976) during cruise BLMØ2B. Section location is shown in Figure 3-10. Breaks in isopleths signify temporal breaks in sampling continuity.

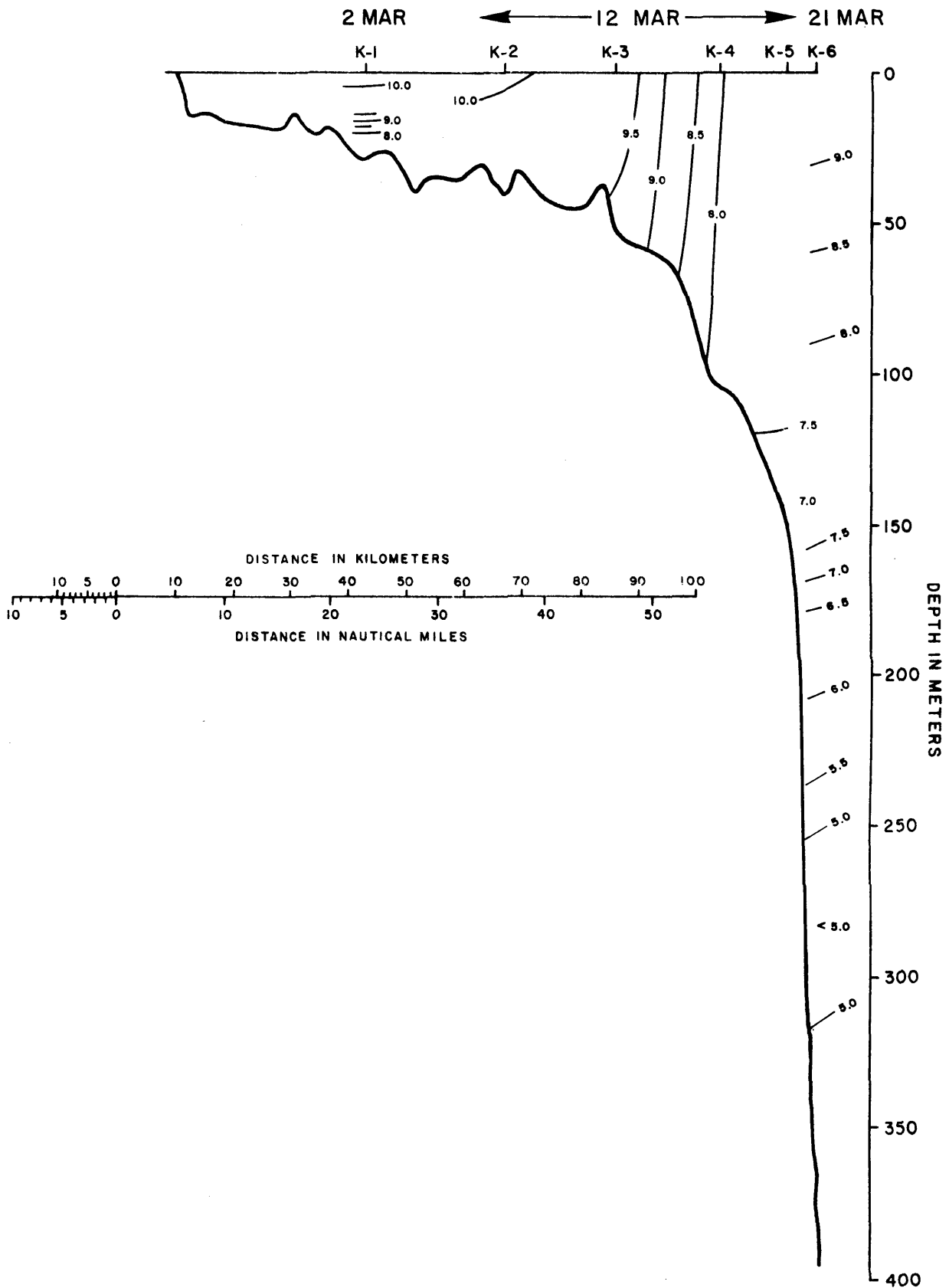


Figure 3-70. Dissolved oxygen (mg/l) along Section IV (Stations K1 to K6, 2-21 March 1976) during cruise BLM02B. Section location is shown in Figure 3-10. Breaks in isopleths signify temporal breaks in sampling continuity.

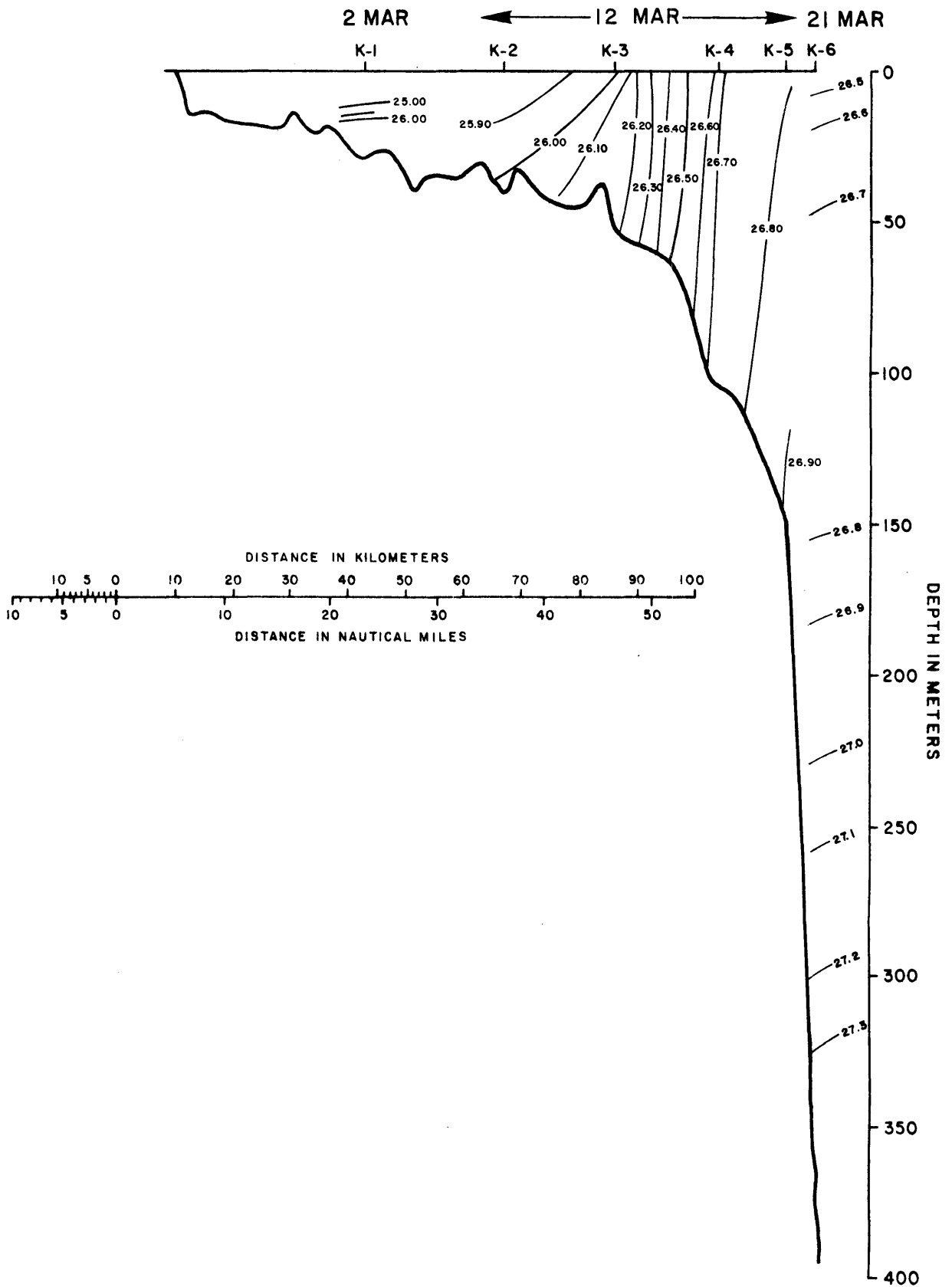


Figure 3-71. Density (σ_t units) along Section IV (Stations K1 to K6, 2-21 March 1976) during cruise BLM02B. Breaks in isopleths signify temporal breaks in sampling continuity.

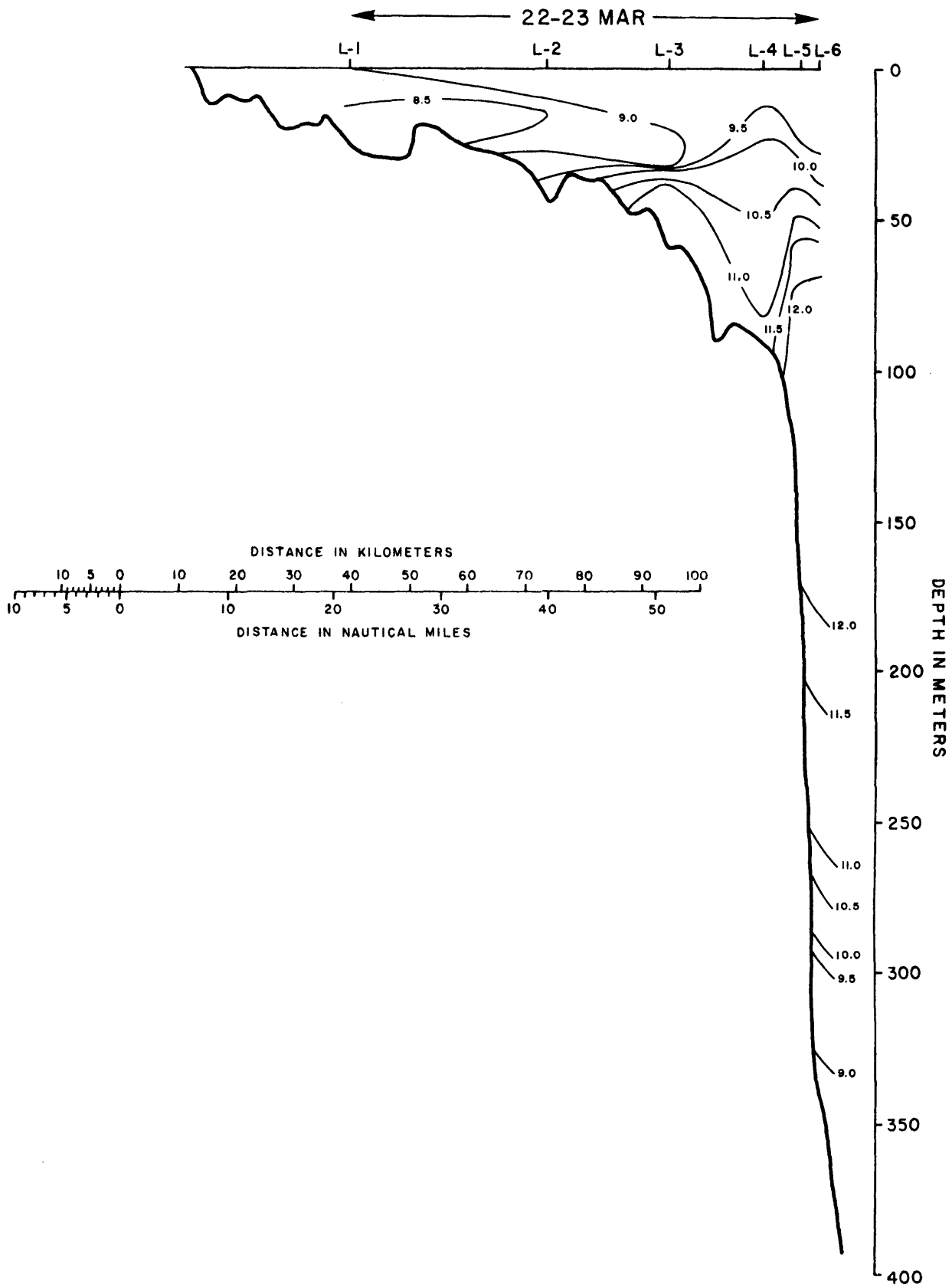


Figure 3-72. Temperature ($^{\circ}\text{C}$) along Section V (Stations L1 to L6, 22-23 March 1976) during cruise BLM02B. Section location is shown in Figure 3-10.

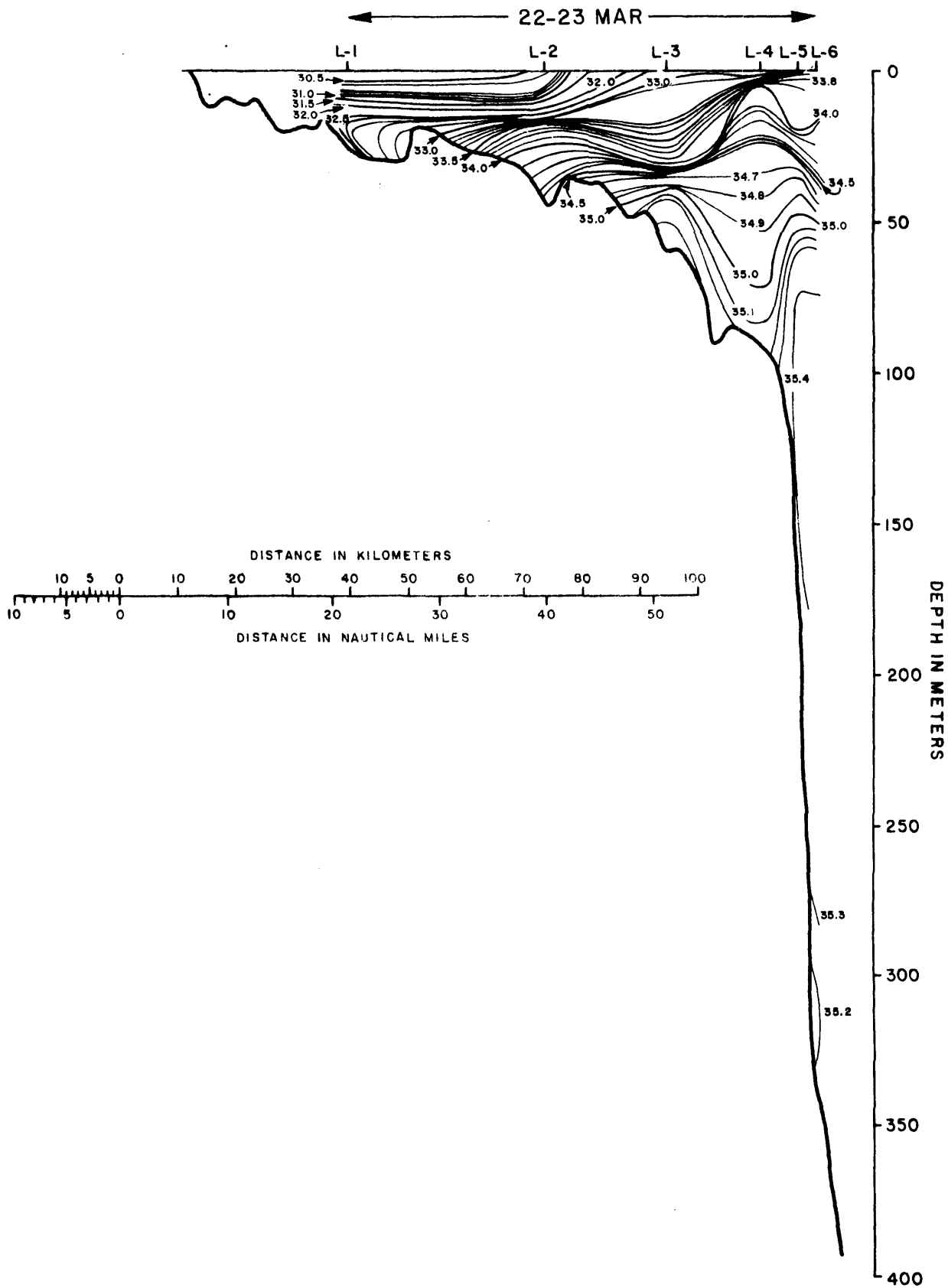


Figure 3-73 Salinity (ppt) along Section V (Stations L1 to L6, 22-23 March 1976) during cruise BLM02B. Section location is shown in Figure 3-10.

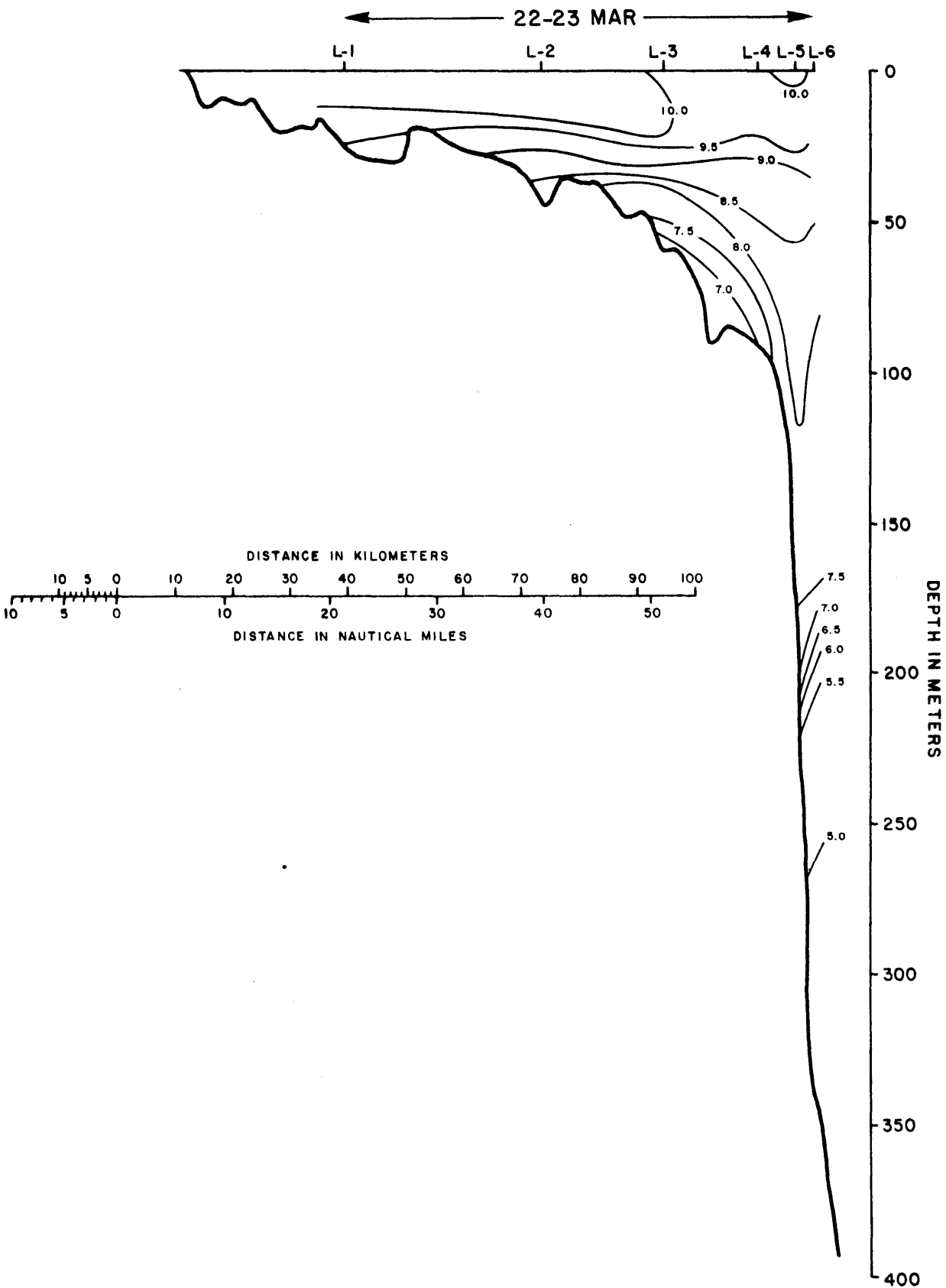


Figure 3-74. Dissolved oxygen (mg/l) along Section V (Stations L1 to L6, 22-23 March 1976) during cruise BLM 2B. Section location is shown in Figure 3-10.

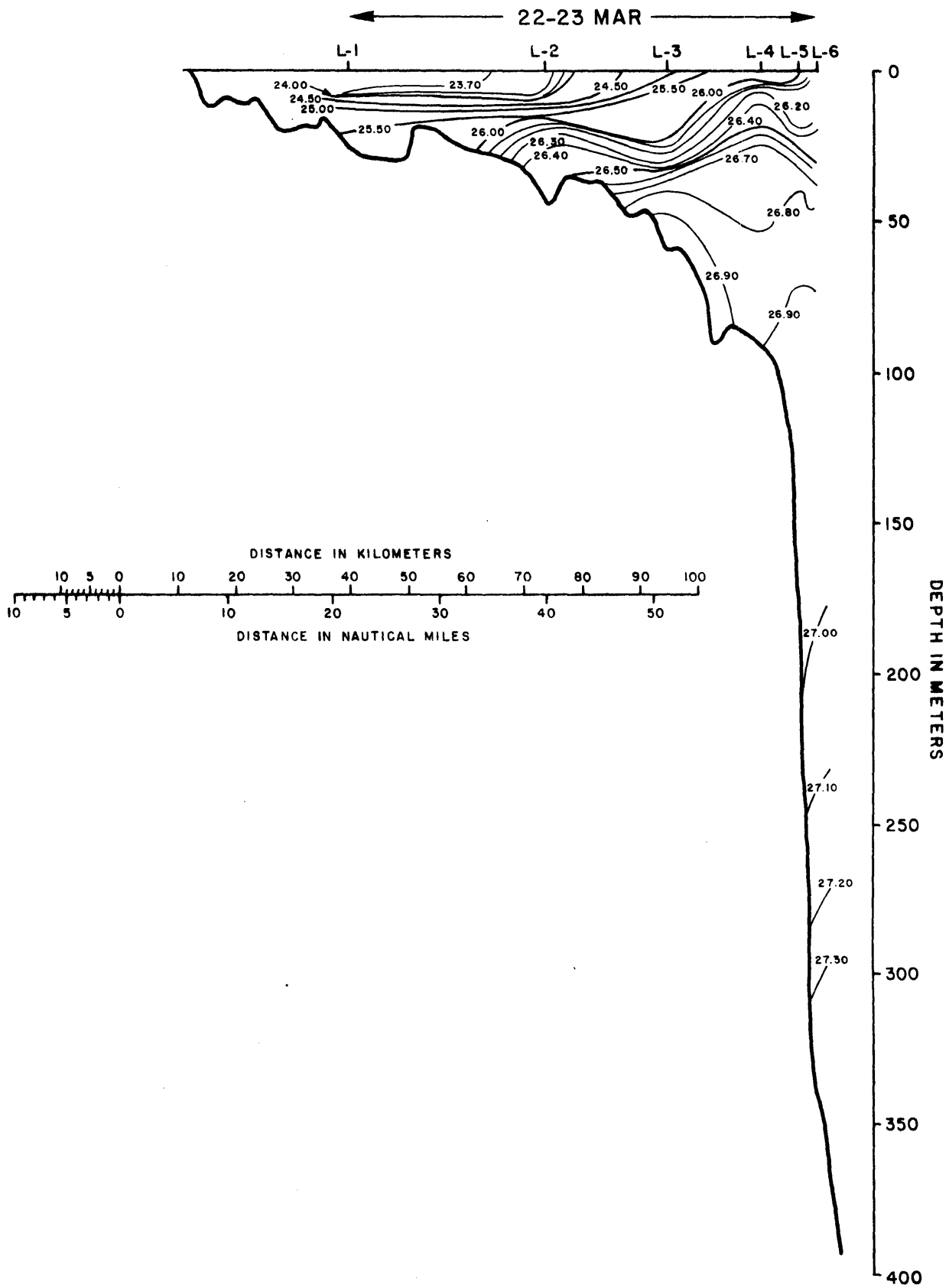


Figure 3-75. Density (σ_t units) along Section V (Stations L1 to L6, 22-23 March 1976) during cruise BLM02B. Section location is shown in Figure 3-10.

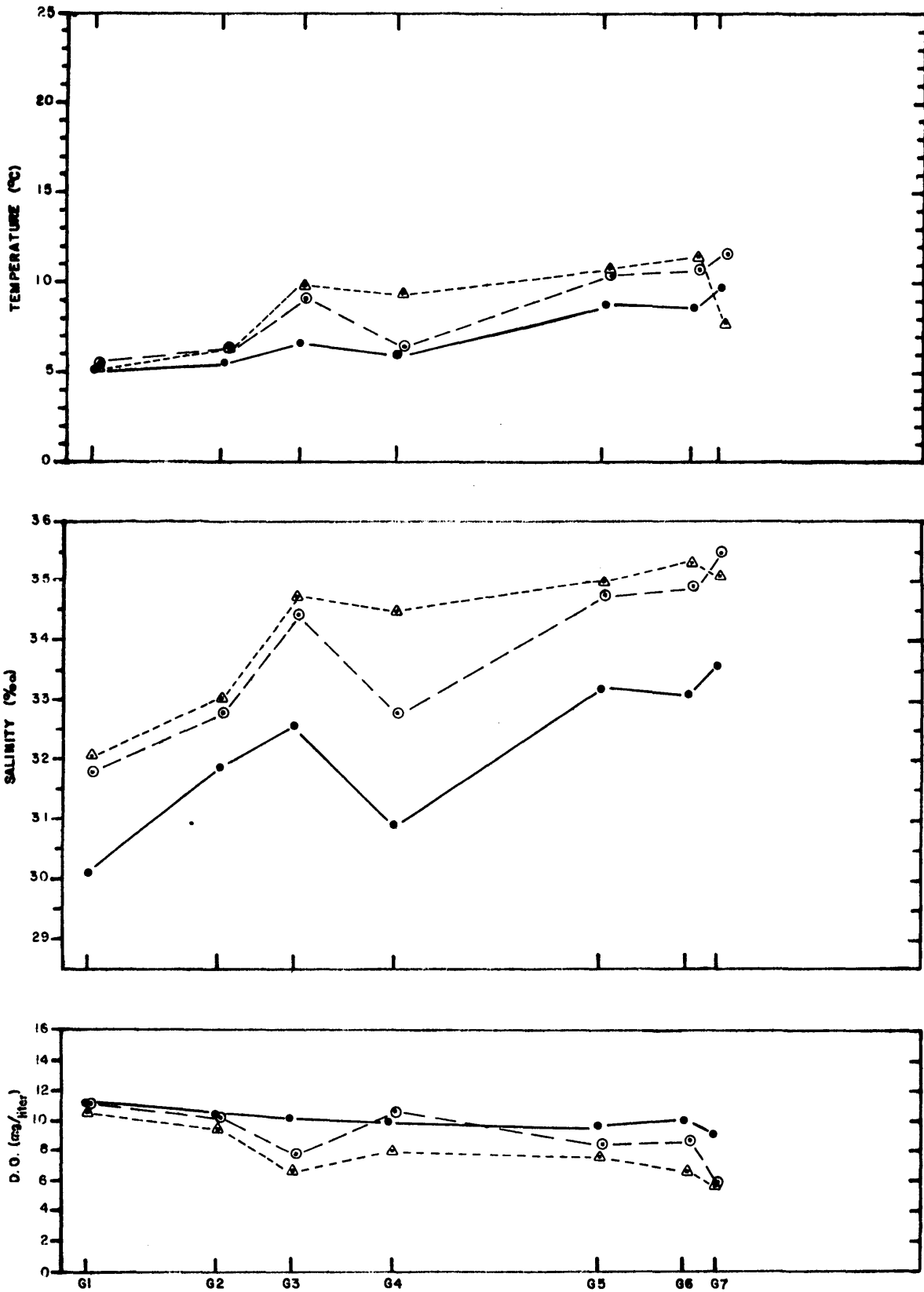


Figure 3-76. Surface (•), mid-depth (◊) and bottom (Δ) values of temperature, salinity and DO measured along Section I on cruise BLM 02B.

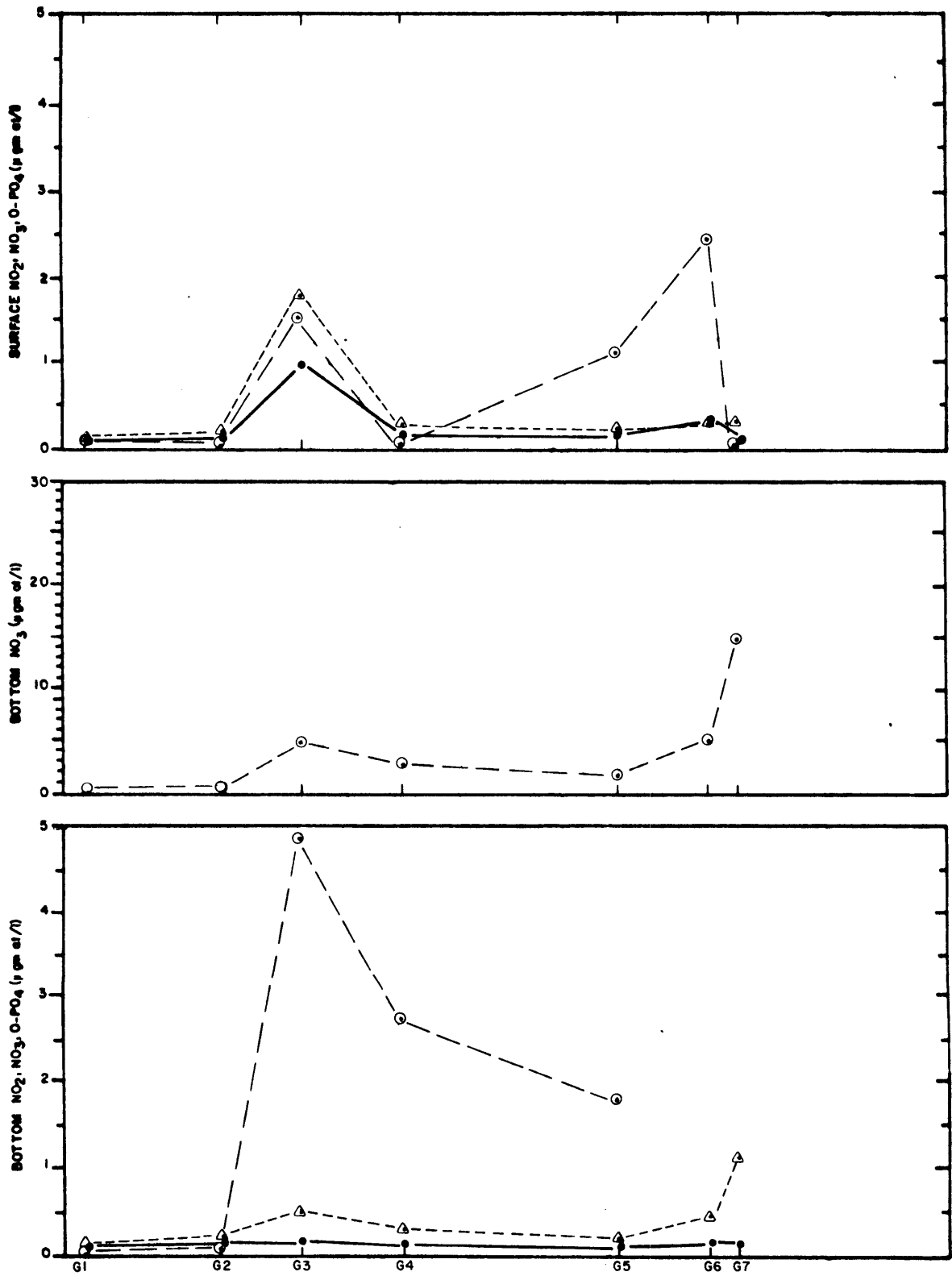


Figure 3-77 . Concentrations of dissolved NO₂ (•), NO₃ (⊙), and O-PO₄ (Δ) in near surface and near bottom waters along Section I during Cruise BLM 02B. Bottom concentrations of dissolved NO₃ were substantially greater than those of other micronutrients hence the center plot.

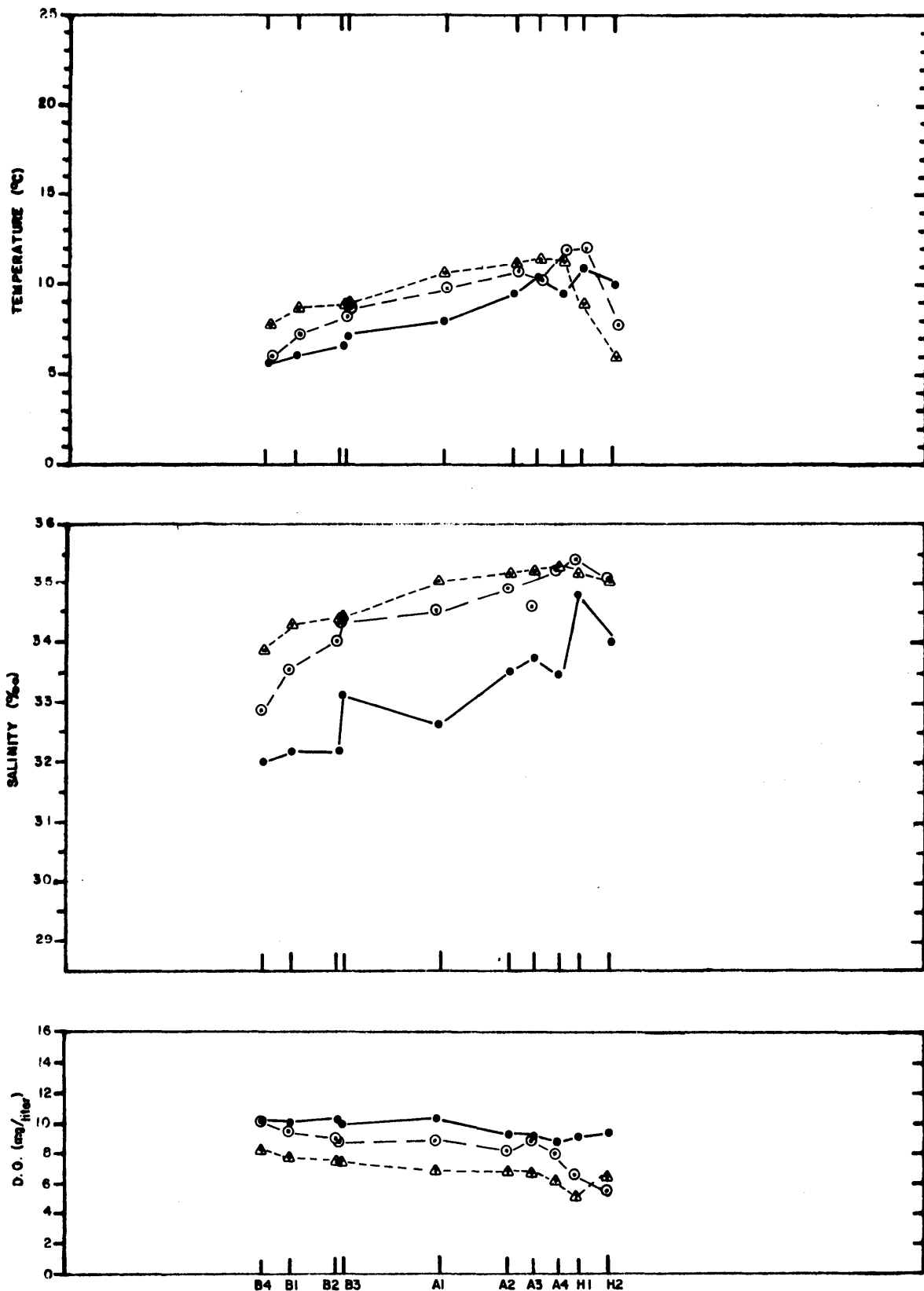


Figure 3-78. Surface (\bullet), mid-depth (\circ) and bottom (Δ) values of temperature, salinity and DO measured along Section II on cruise BLM 02B.

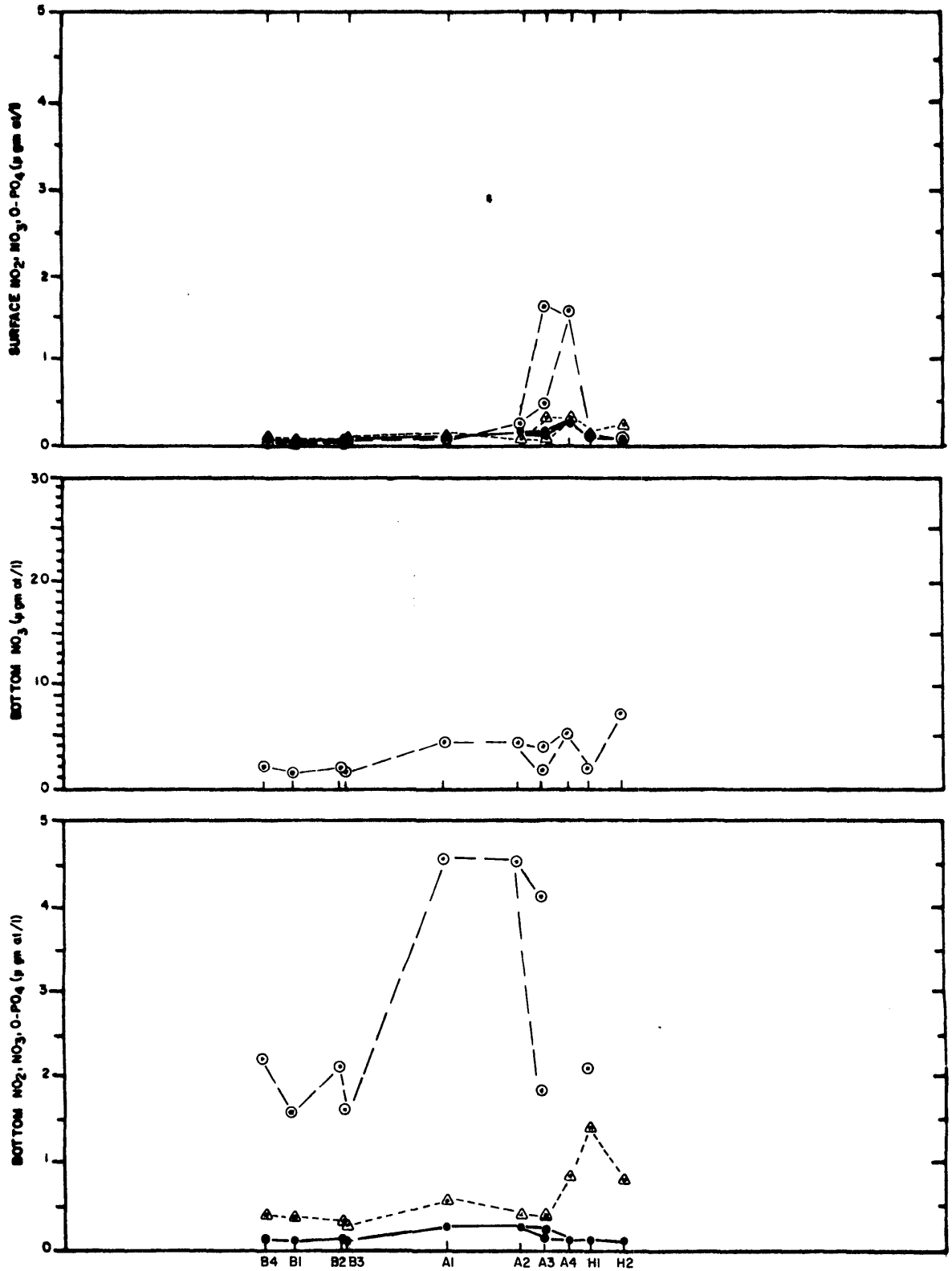


Figure 3-79 . Concentrations of dissolved NO_2 (\bullet), NO_3 (\circ), and O-PO_4 (Δ) in near surface and near bottom waters along Section II during Cruise BLM 02B. Bottom concentrations of dissolved NO_3 were substantially greater than those of other micronutrients hence the center plot.

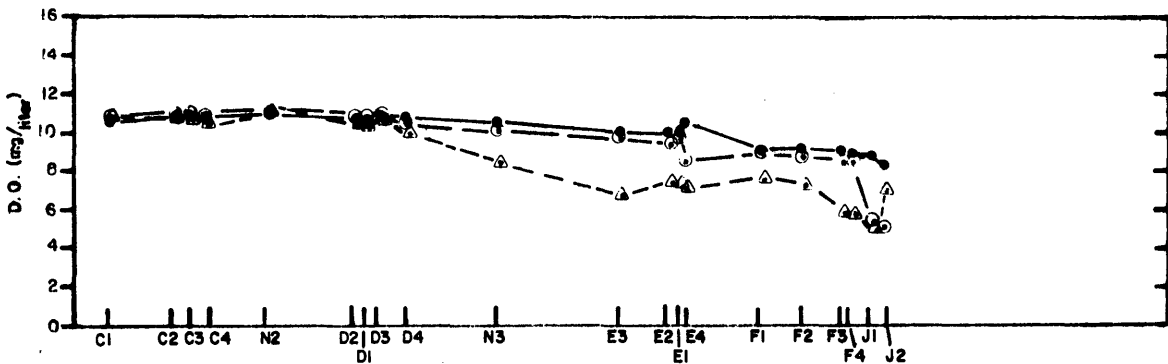
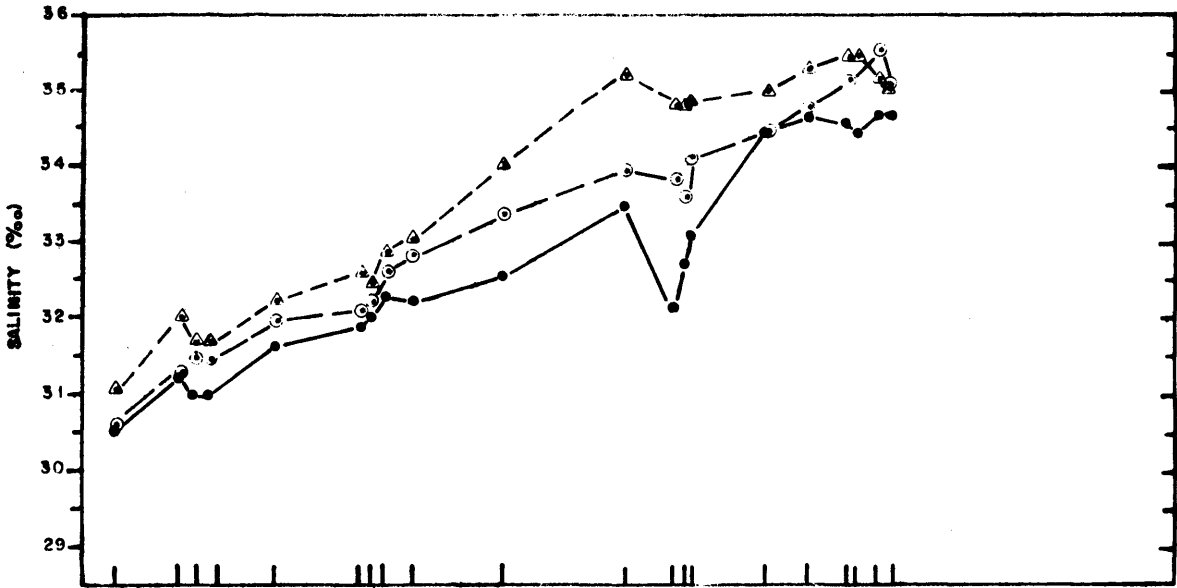
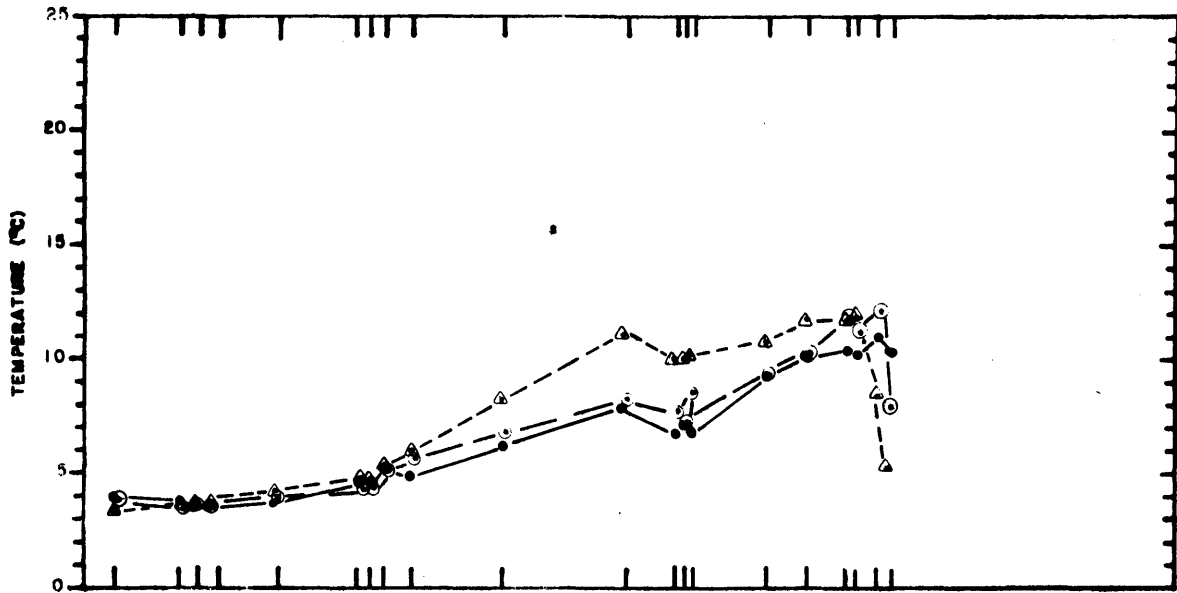


Figure 3-80. Surface (•), mid-depth (◊) and bottom (Δ) values of temperature, salinity and DO measured along Section III on cruise BLM 02B.

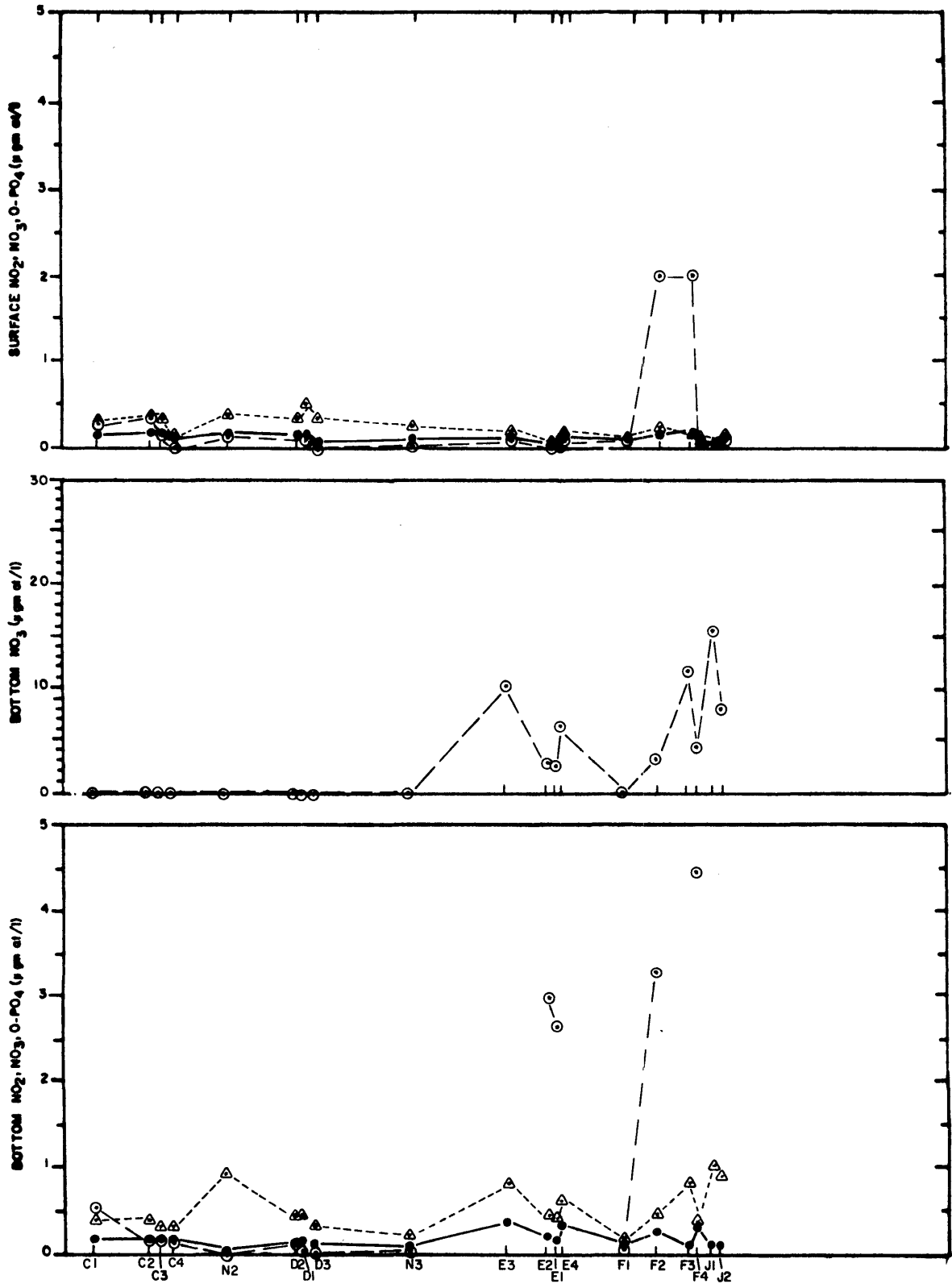


Figure 3-81 . Concentrations of dissolved NO₂ (•), NO₃ (○), and O-PO₄ (Δ) in near surface and near bottom waters along Section III during Cruise BLM 02B. Bottom concentrations of dissolved NO₃ were substantially greater than those of other micronutrients hence the center plot.

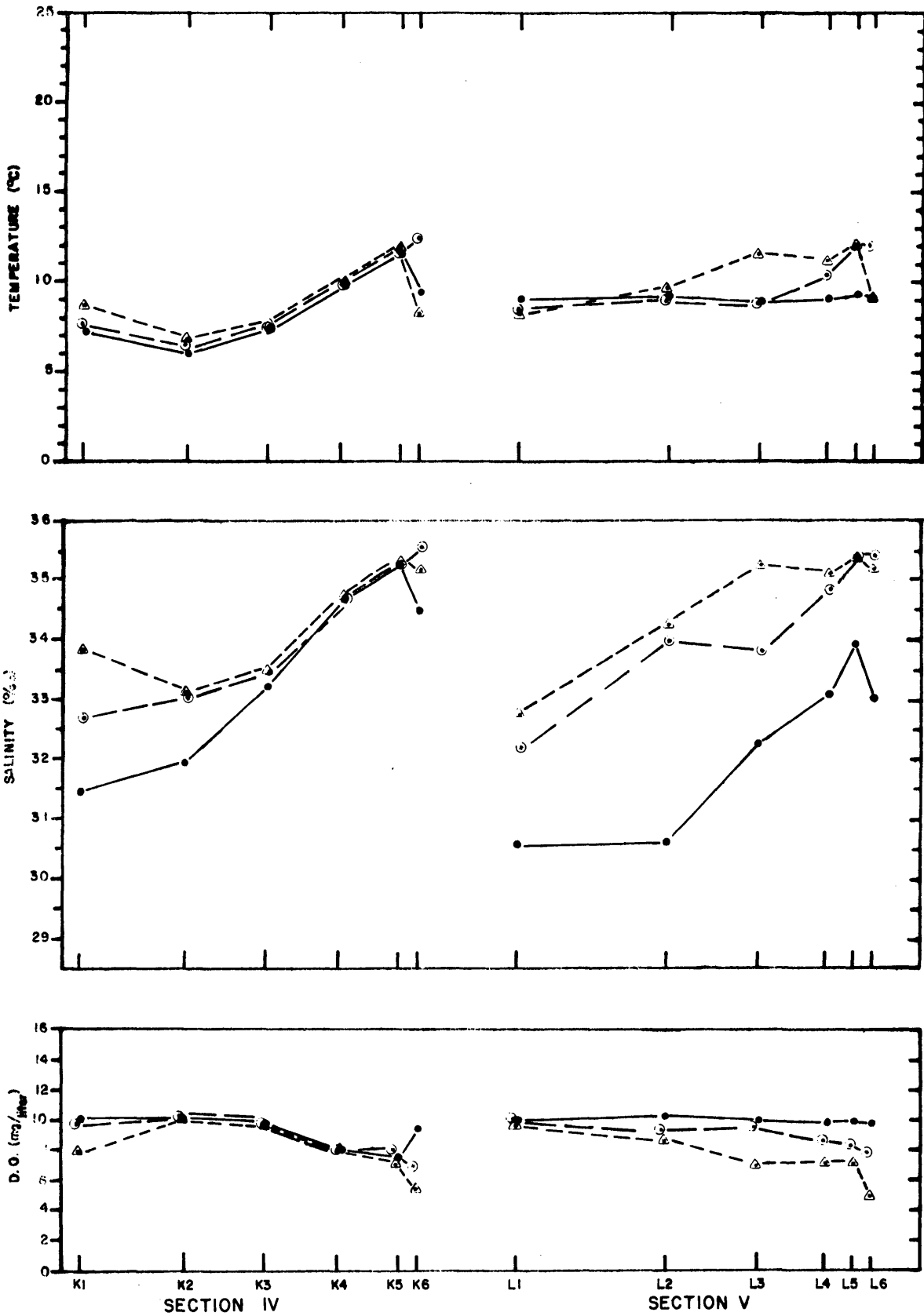


Figure 3-82. Surface (•), mid-depth (◊) and bottom (Δ) values of temperature, salinity and DO measured along Sections IV and V on cruise BLM 02B.

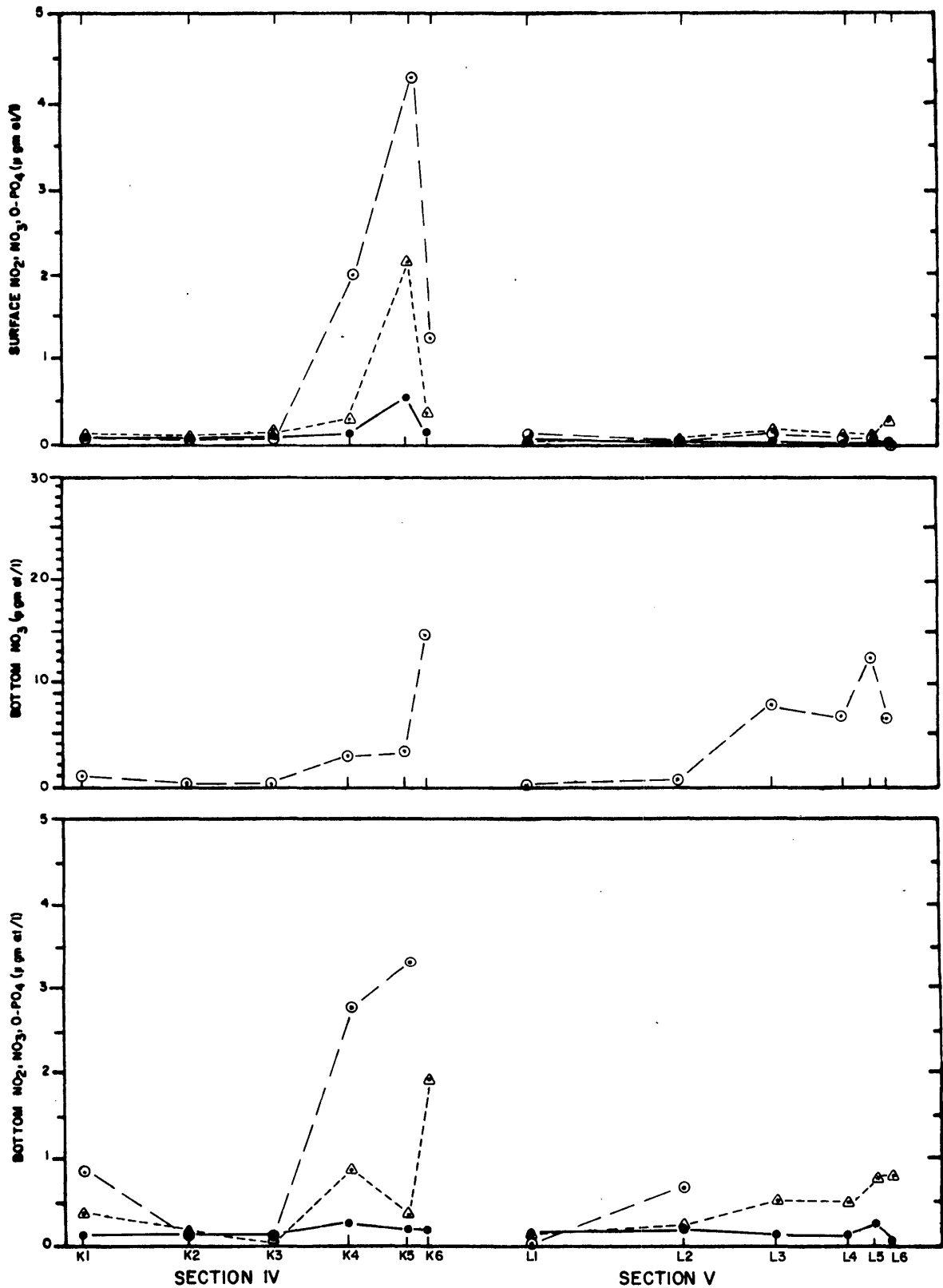


Figure 3-83 . Concentrations of dissolved NO₂ (•), NO₃ (⊙), and O-PO₄ (Δ) in near surface and near bottom waters along Sections IV & V during Cruise BLM 02B. Bottom concentrations of dissolved NO₃ were substantially greater than those of other micronutrients hence the center plot.

Cruise BLMØ2W

Winter 1976

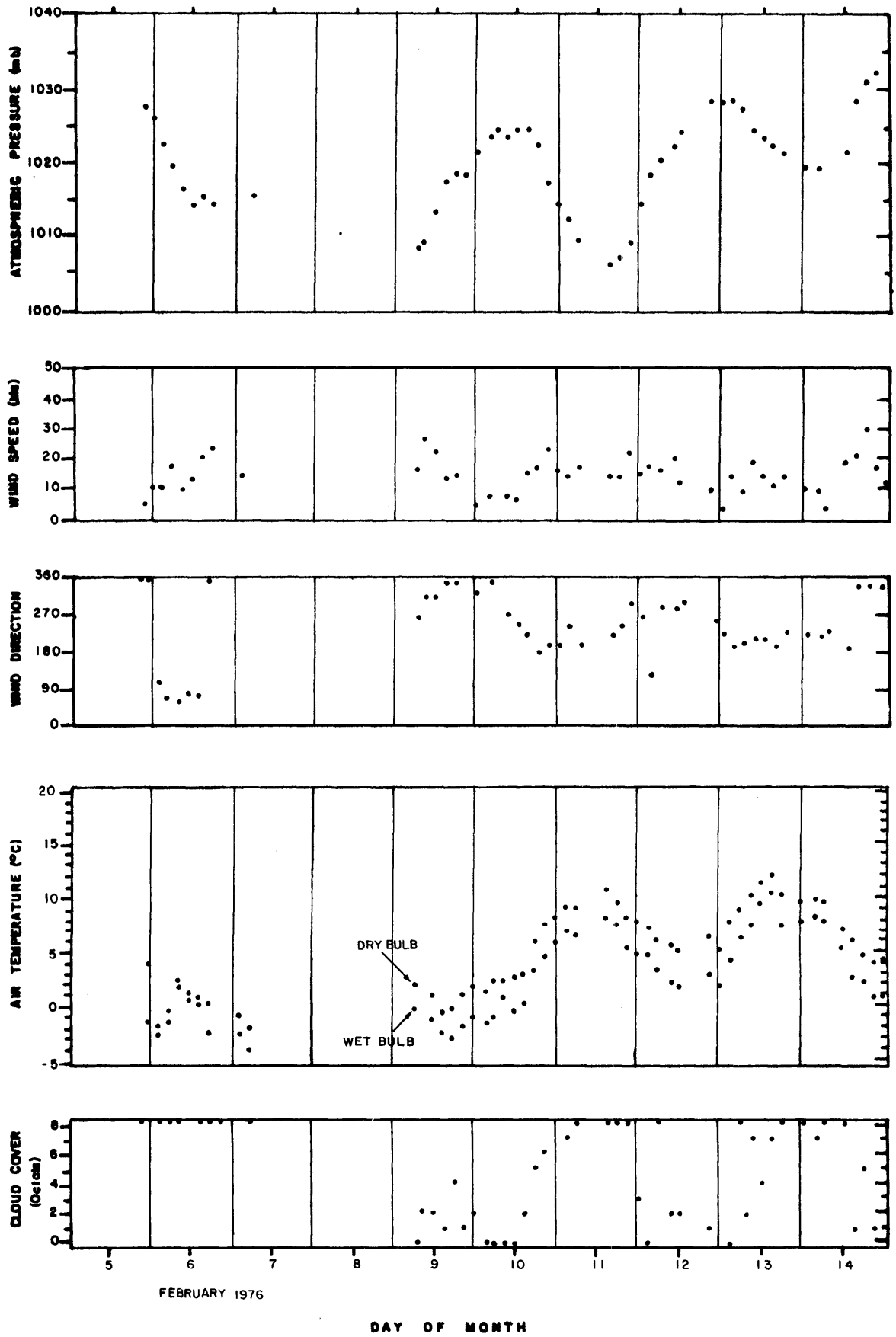


Figure 3-84. Meteorological data collected during cruise BLM 02W 5-14 February 1976.

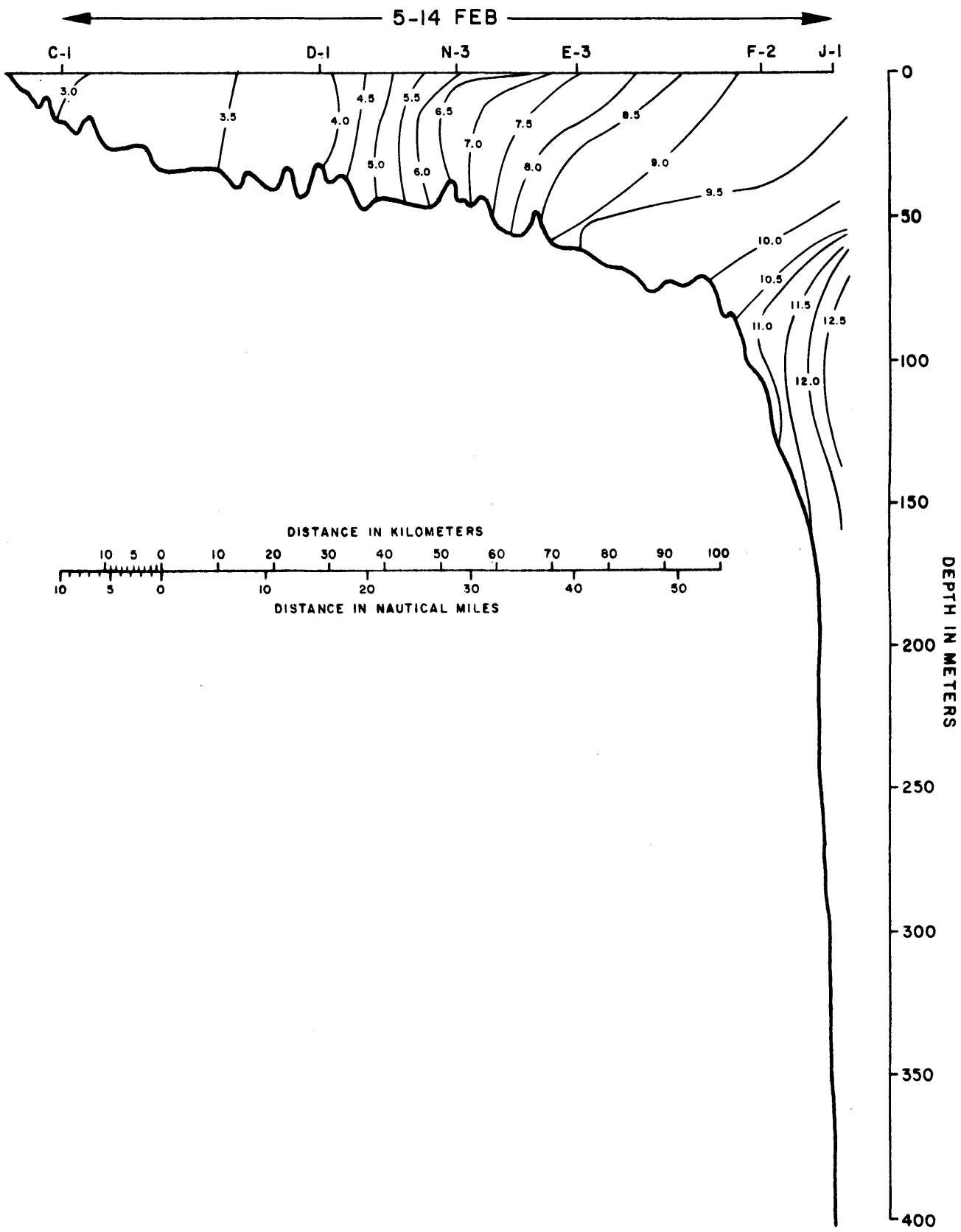


Figure 3-85. Temperature ($^{\circ}\text{C}$) along Section III (Stations C1 to J1, 5-14 February 1976) during cruise BLM02W. Section location is shown in Figure 3-10.

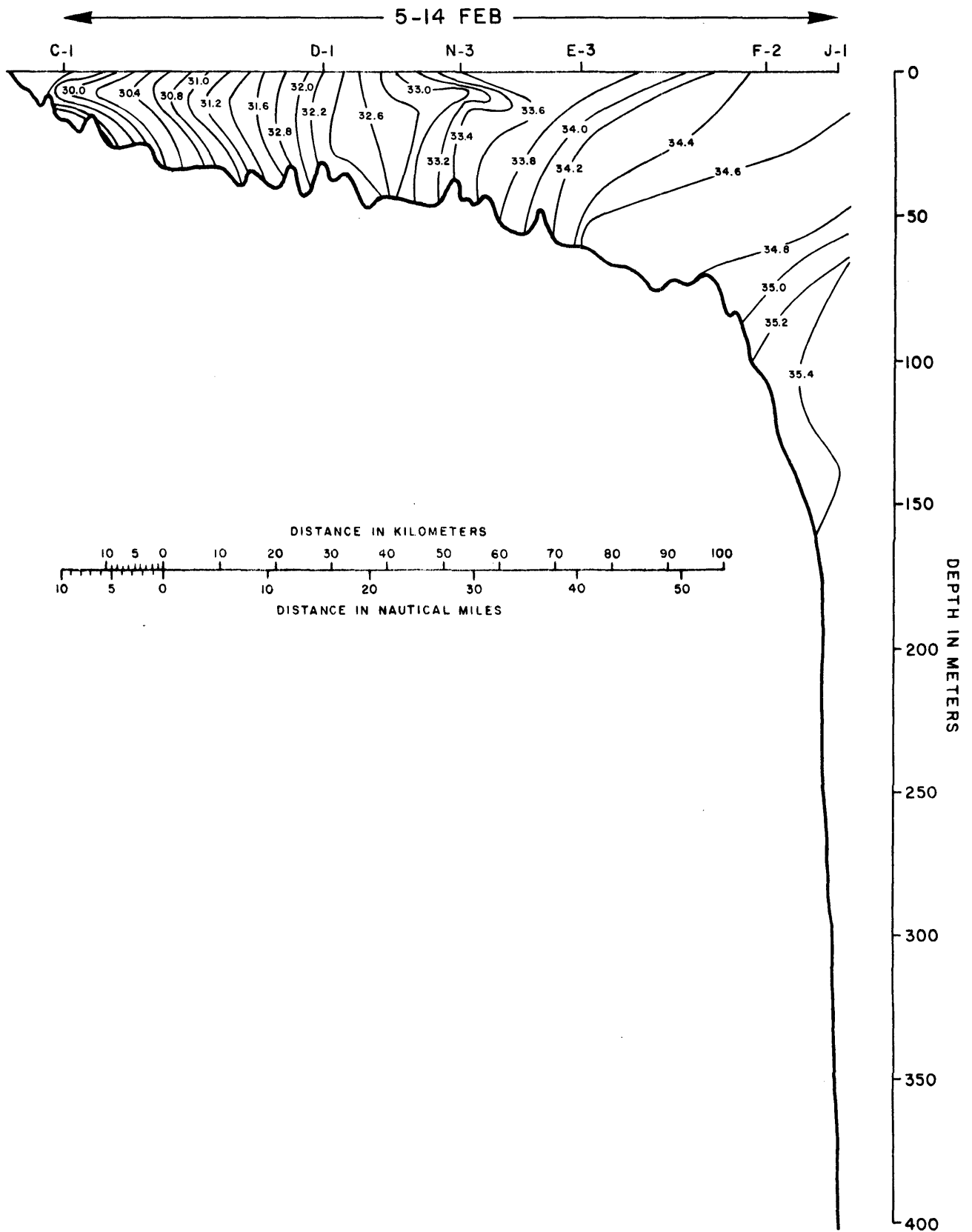


Figure 3-86. Salinity (ppt) along Section III (Stations C1 to J1, 5-14 February 1976) during cruise BLM02W. Section location is shown in Figure 3-10.

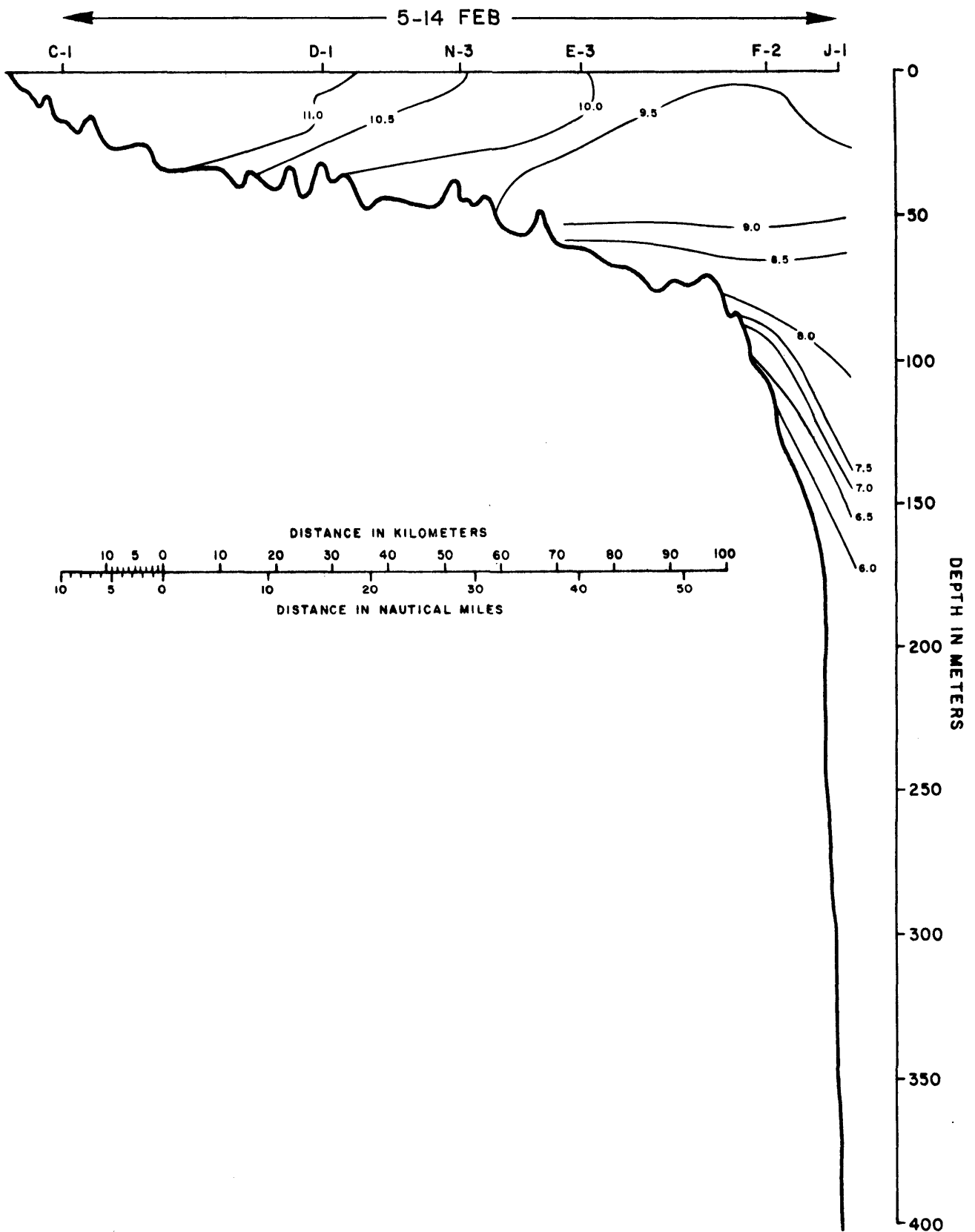


Figure 3-87. Dissolved oxygen (mg/l) along Section III (Stations C1 to J1, 5-14 February 1976) during cruise BLM02W. Section location is shown in Figure 3-10.

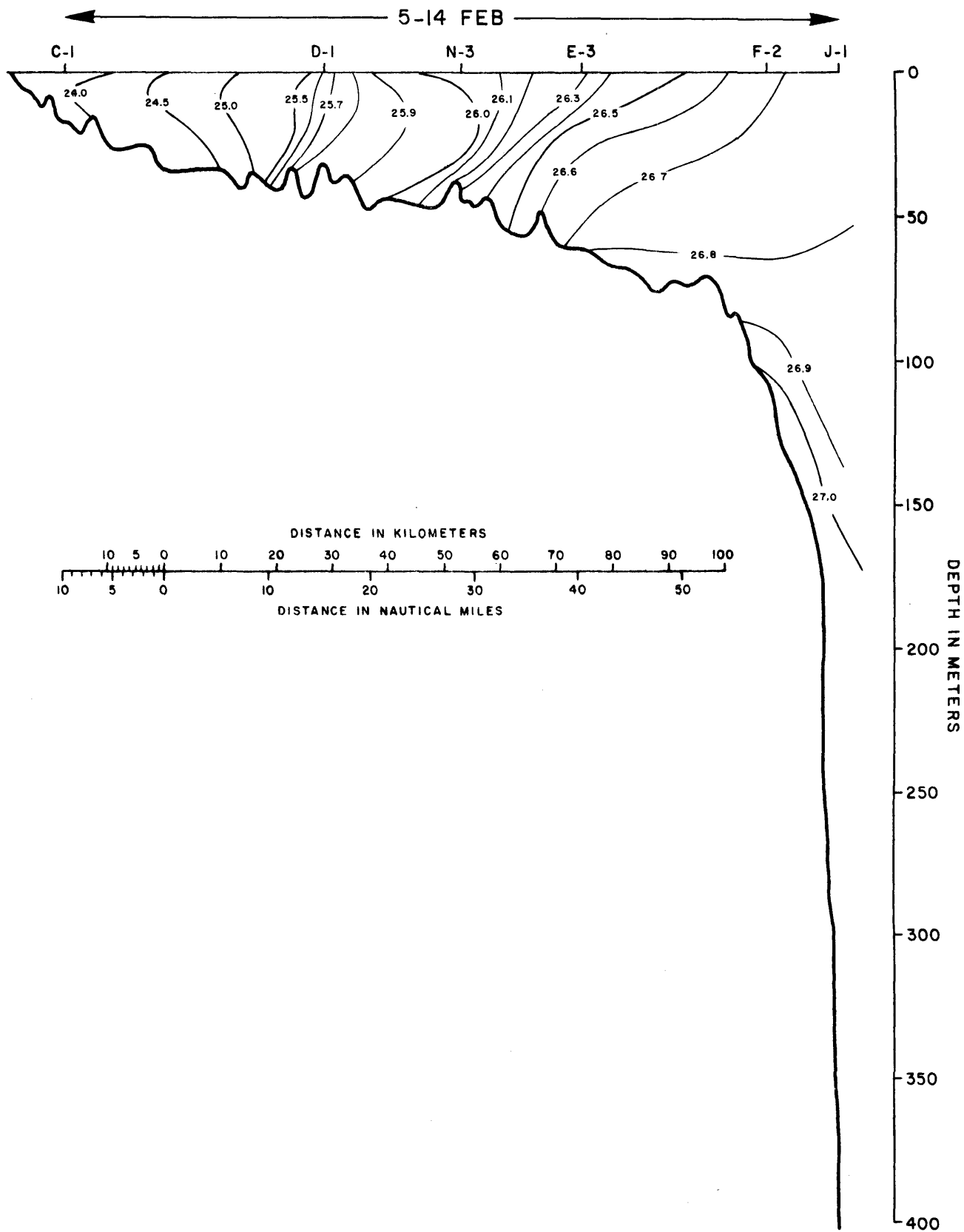


Figure 3-88. Density (σ_t units) along Section III (Stations C1 to J1, 5-14 February 1976) during cruise BLM02W. Section location is shown in Figure 3-10.

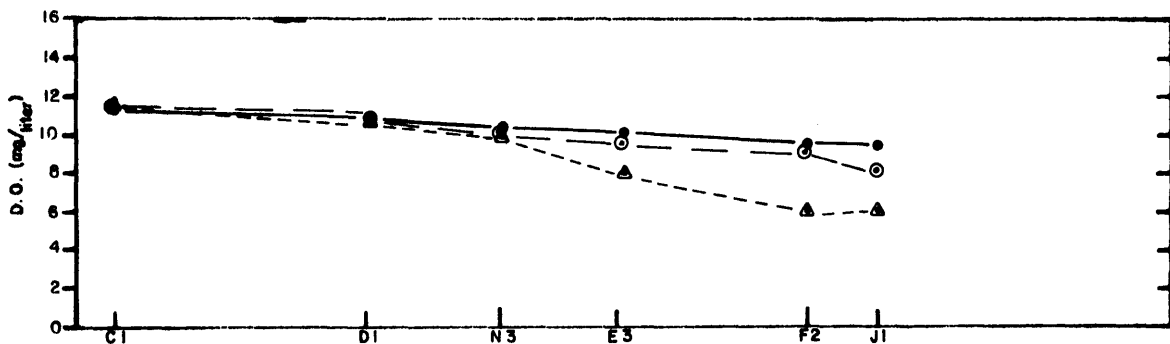
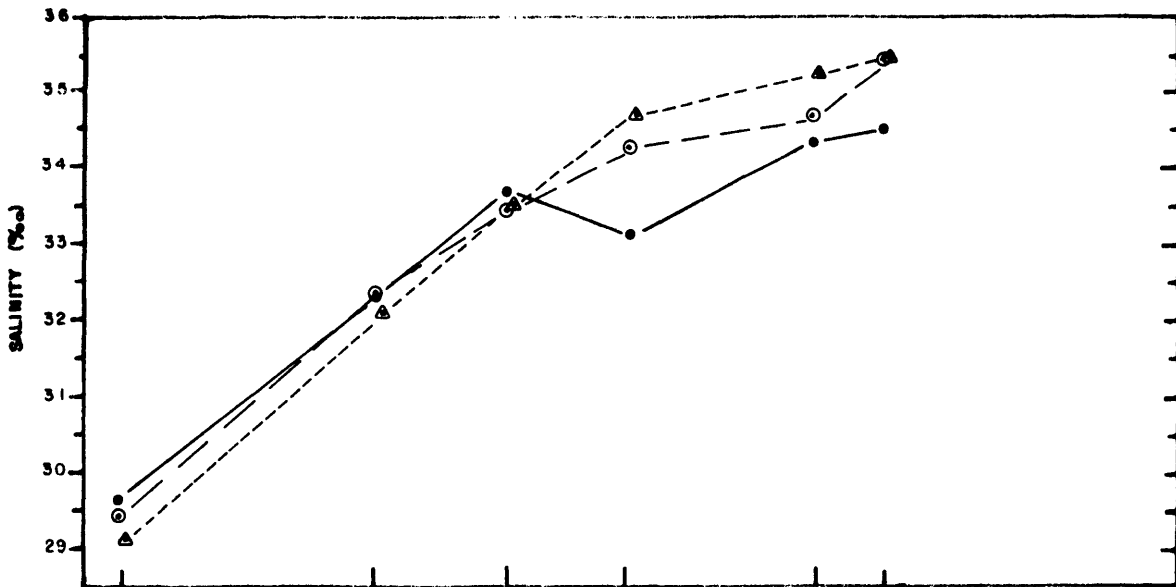
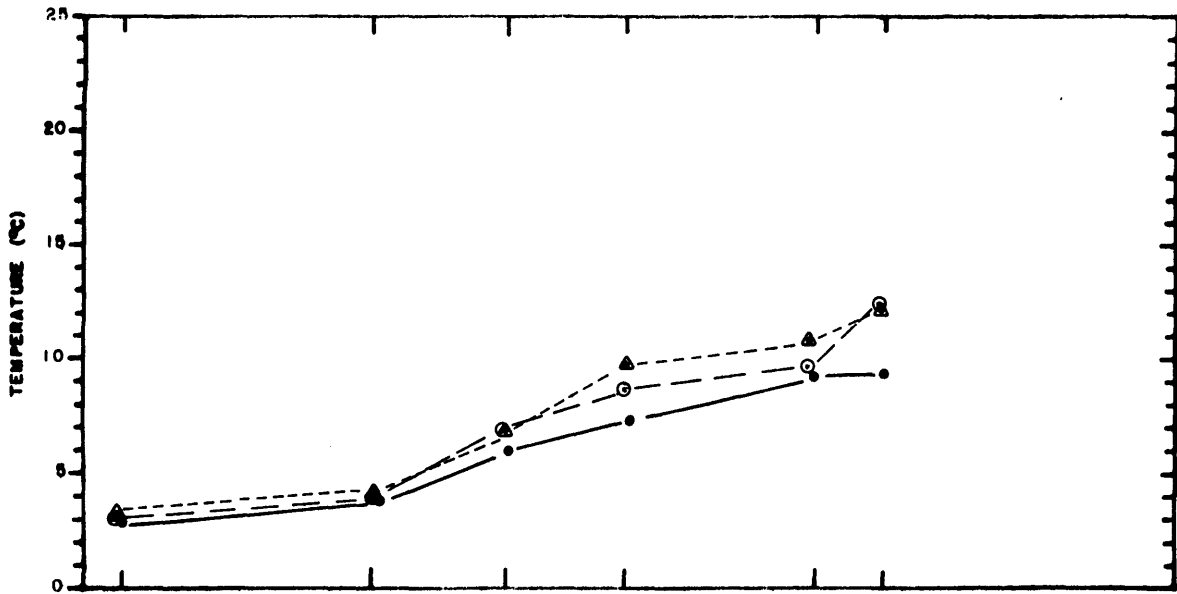


Figure 3-89. Surface (•), mid-depth (⊙) and bottom (Δ) values of temperature, salinity and DO measured along Section III on cruise BLM 02W.

Cruise BLMØ3B

Spring 1976

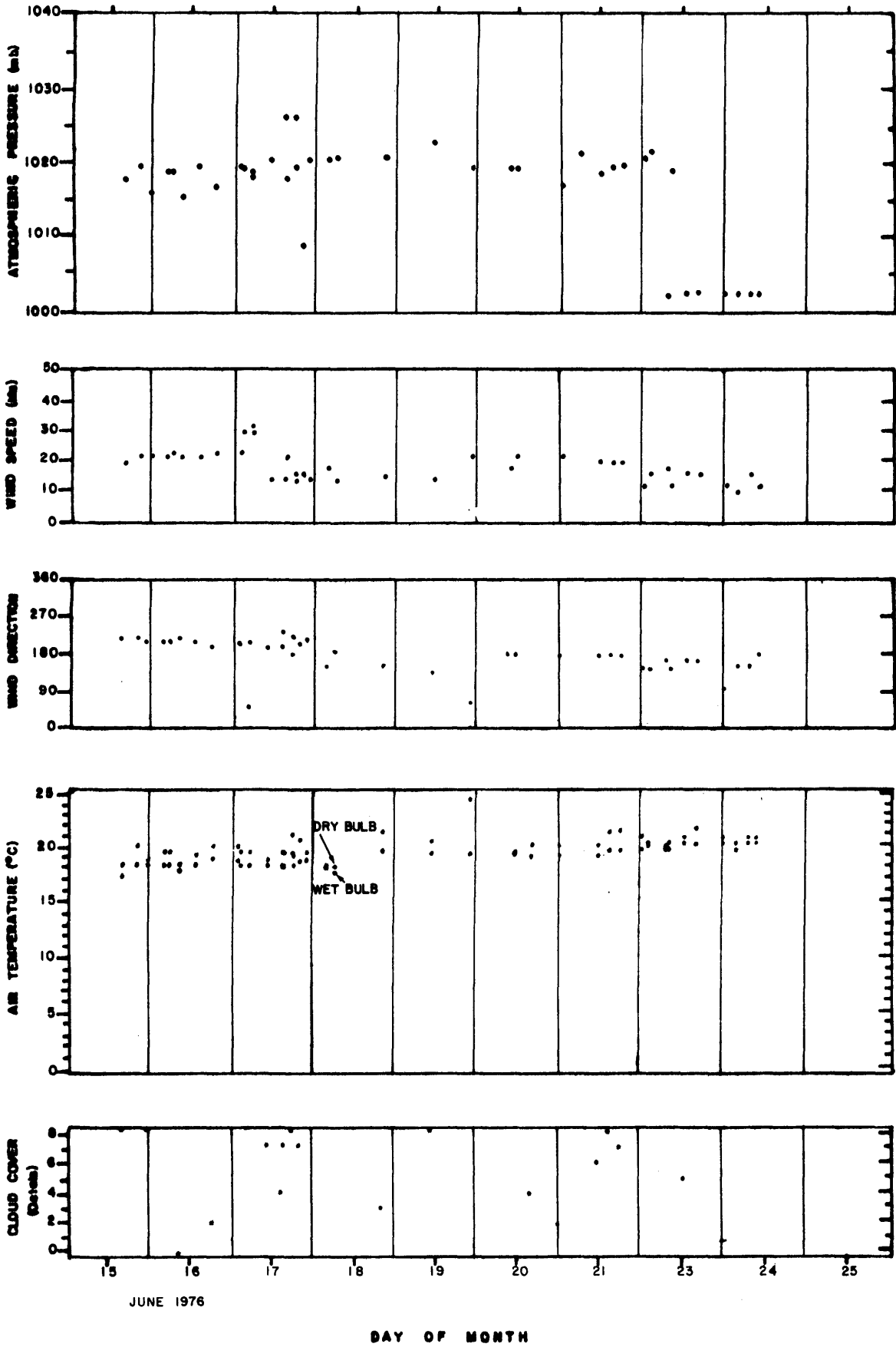


Figure 3-90. Meteorological data collected during cruise BLM 03B 15 to 25 June 1976.

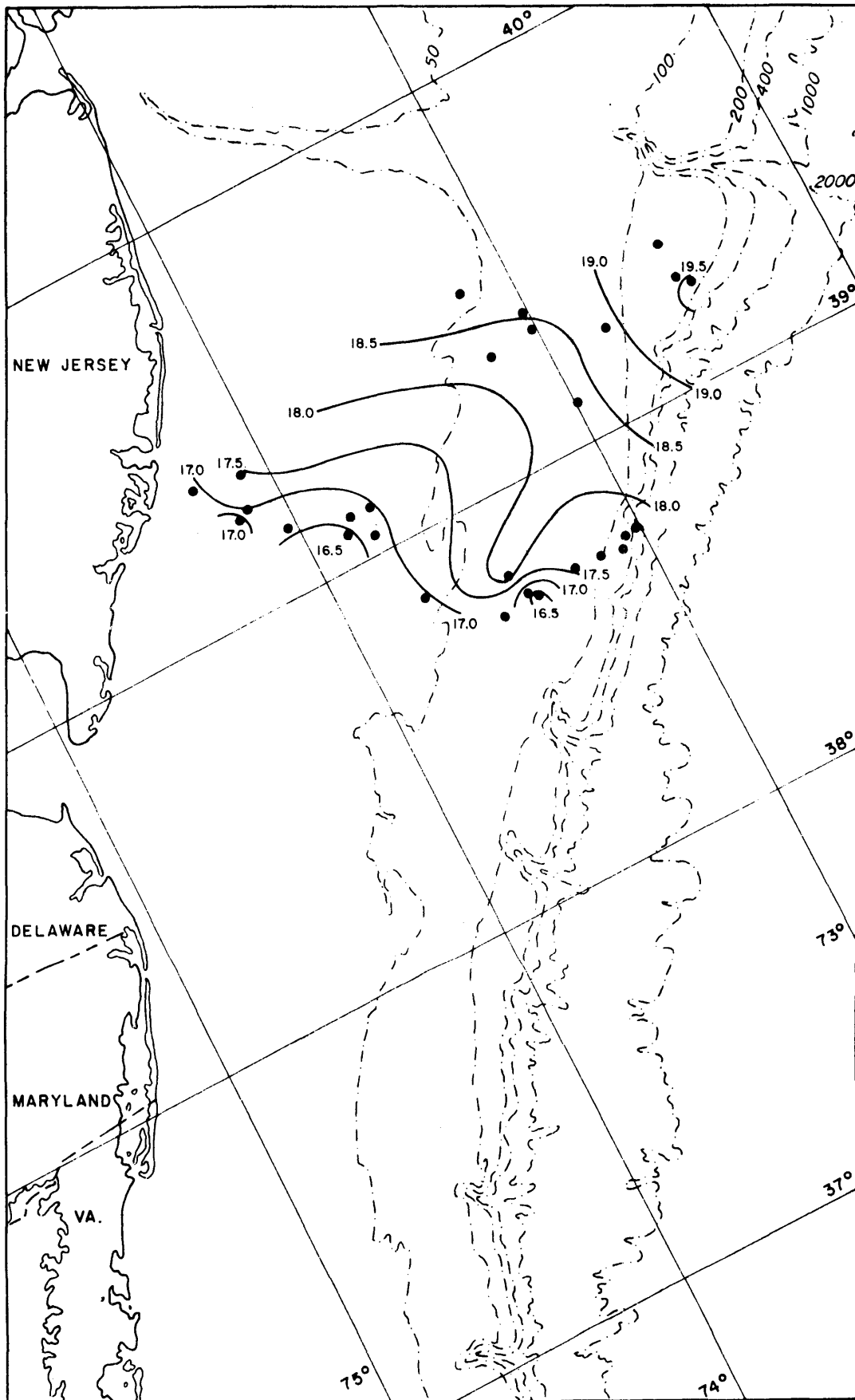


Figure 3-91. Surface temperature ($^{\circ}\text{C}$) distribution in the northern portions of the Middle Atlantic Bight during the period 15 to 23 June 1976 (Cruise BLM03B)

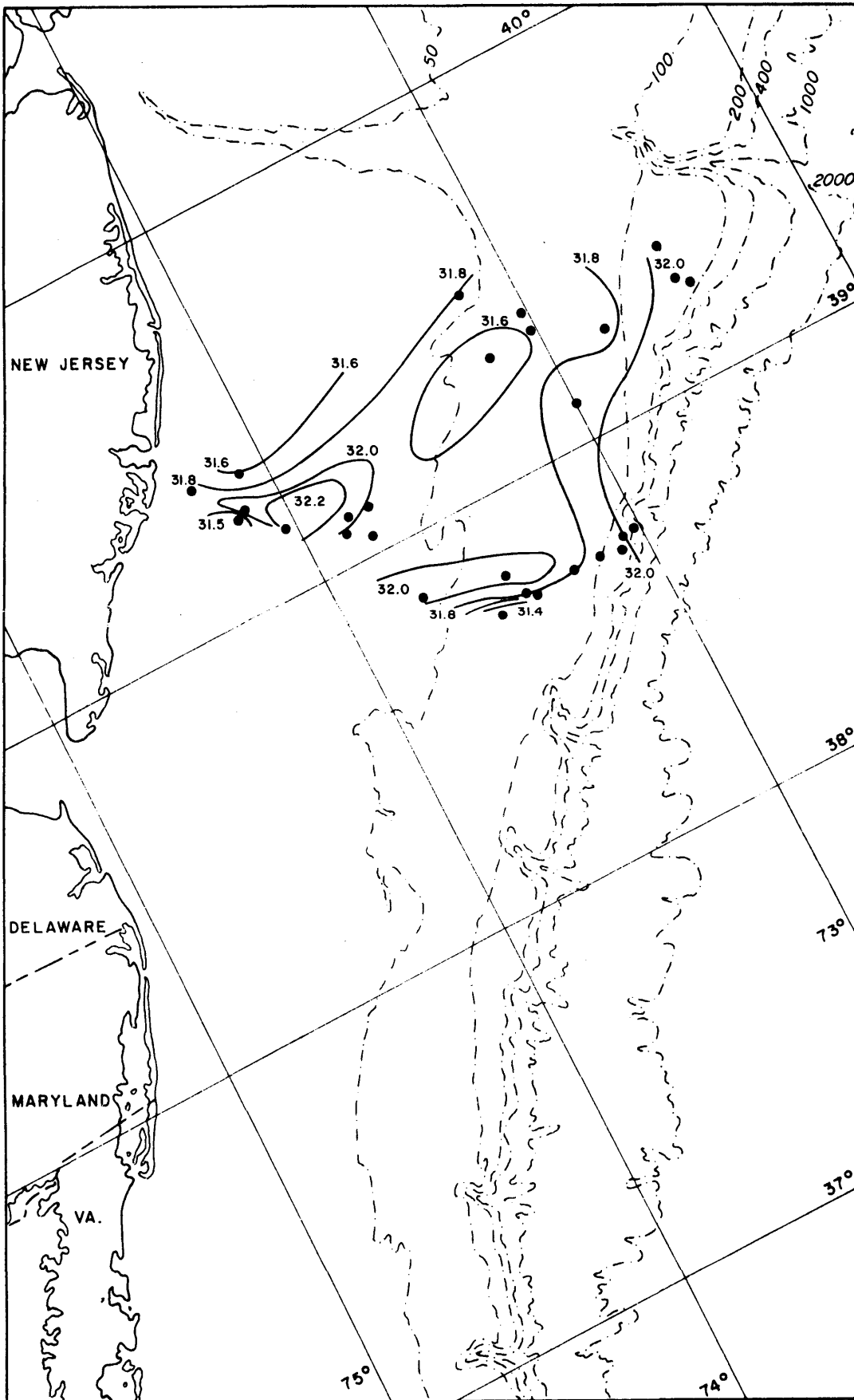


Figure 3-92. Surface salinity (ppt) distribution in the northern portions of the Middle Atlantic Bight during the period 15 to 23 June 1976 (Cruise BLM03B)

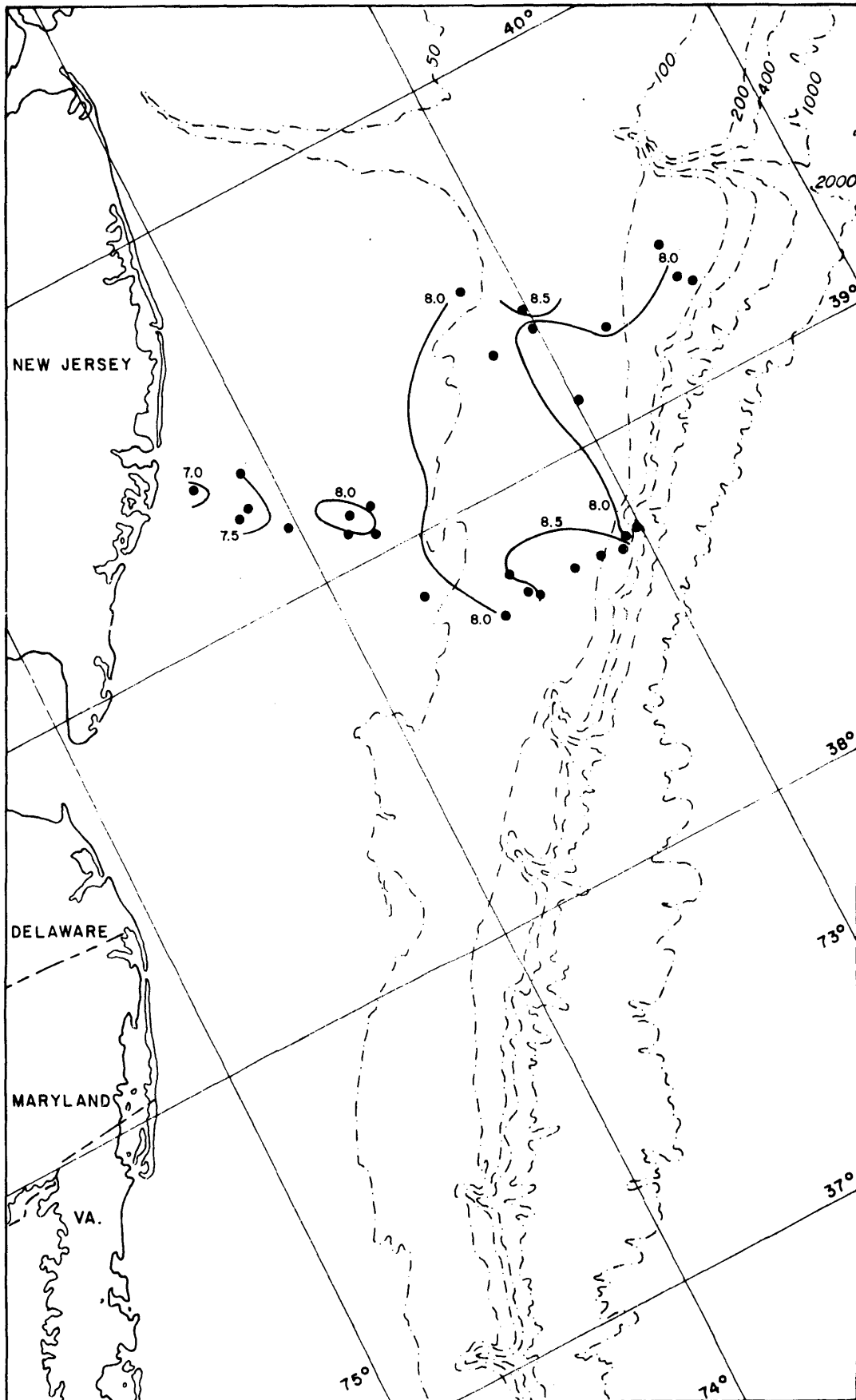


Figure 3-93. Surface dissolved oxygen (mg/l) distribution in the northern portions of the Middle Atlantic Bight during the period 15 to 23 June 1976 (Cruise BLM03B)

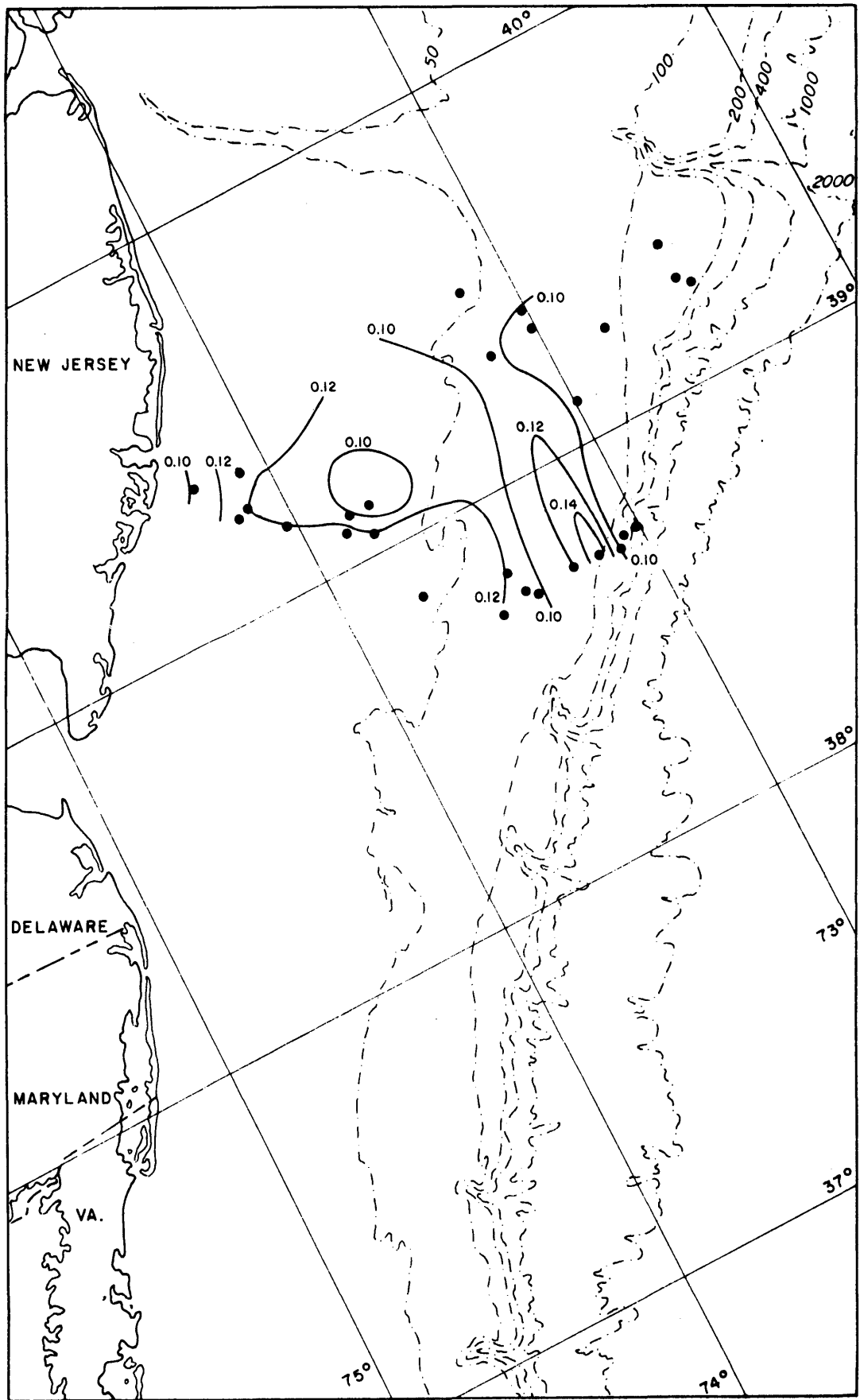


Figure 3-94. Surface NO₂ (μg atoms/l) distribution in the northern portions of the Middle Atlantic Bight during the period 15 to 23 June 1976 (Cruise BLM03B)

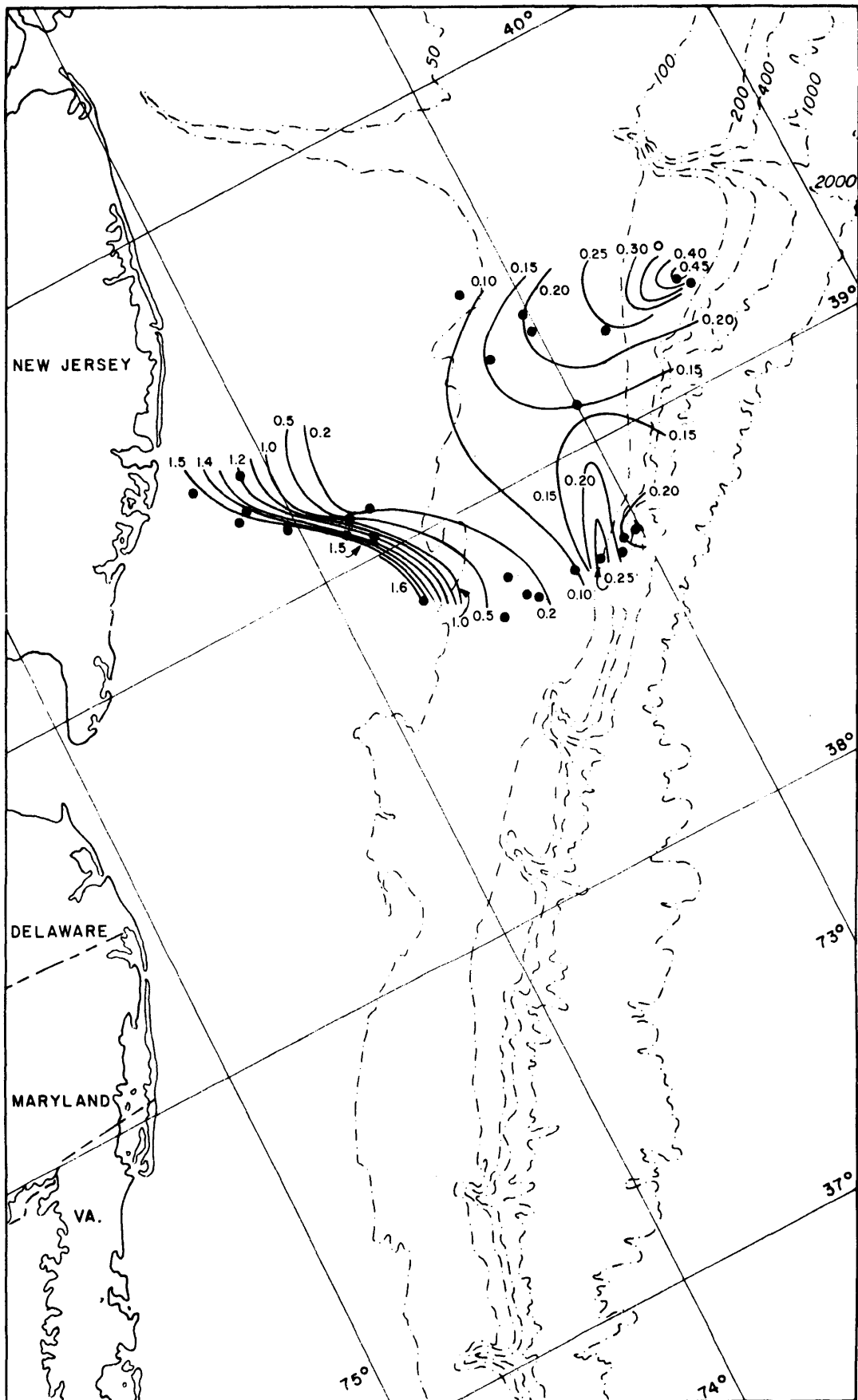


Figure 3-95. Surface NO_3 ($\mu\text{gm atoms/l}$) distribution in the northern portions of the Middle Atlantic Bight during the period 15 to 23 June 1976 (Cruise BLM03B)

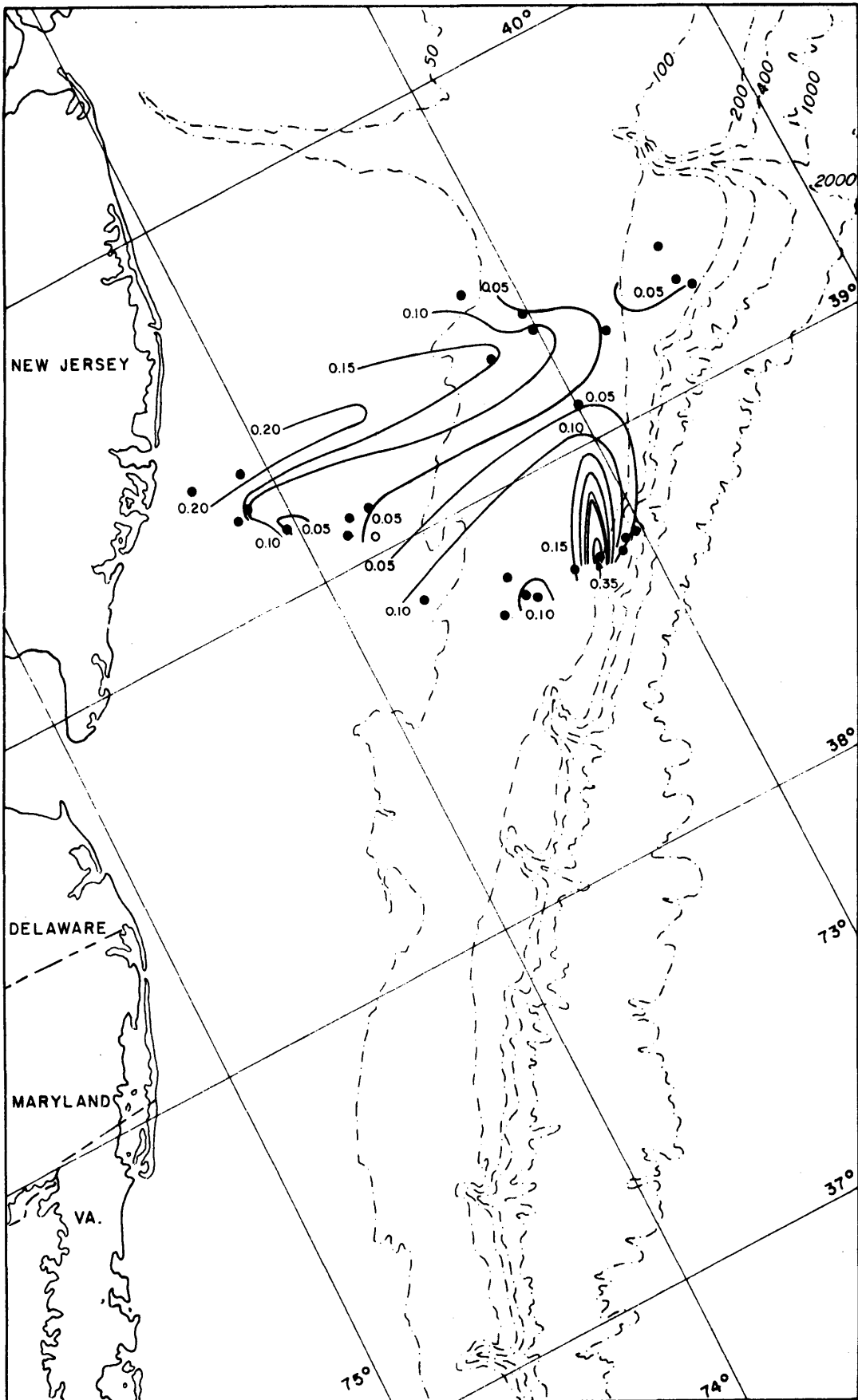


Figure 3-96. Surface O-PO₄ (μg atoms/l) distribution in the northern portions of the Middle Atlantic Bight during the period 15 to 23 June 1976 (Cruise BLM03B)

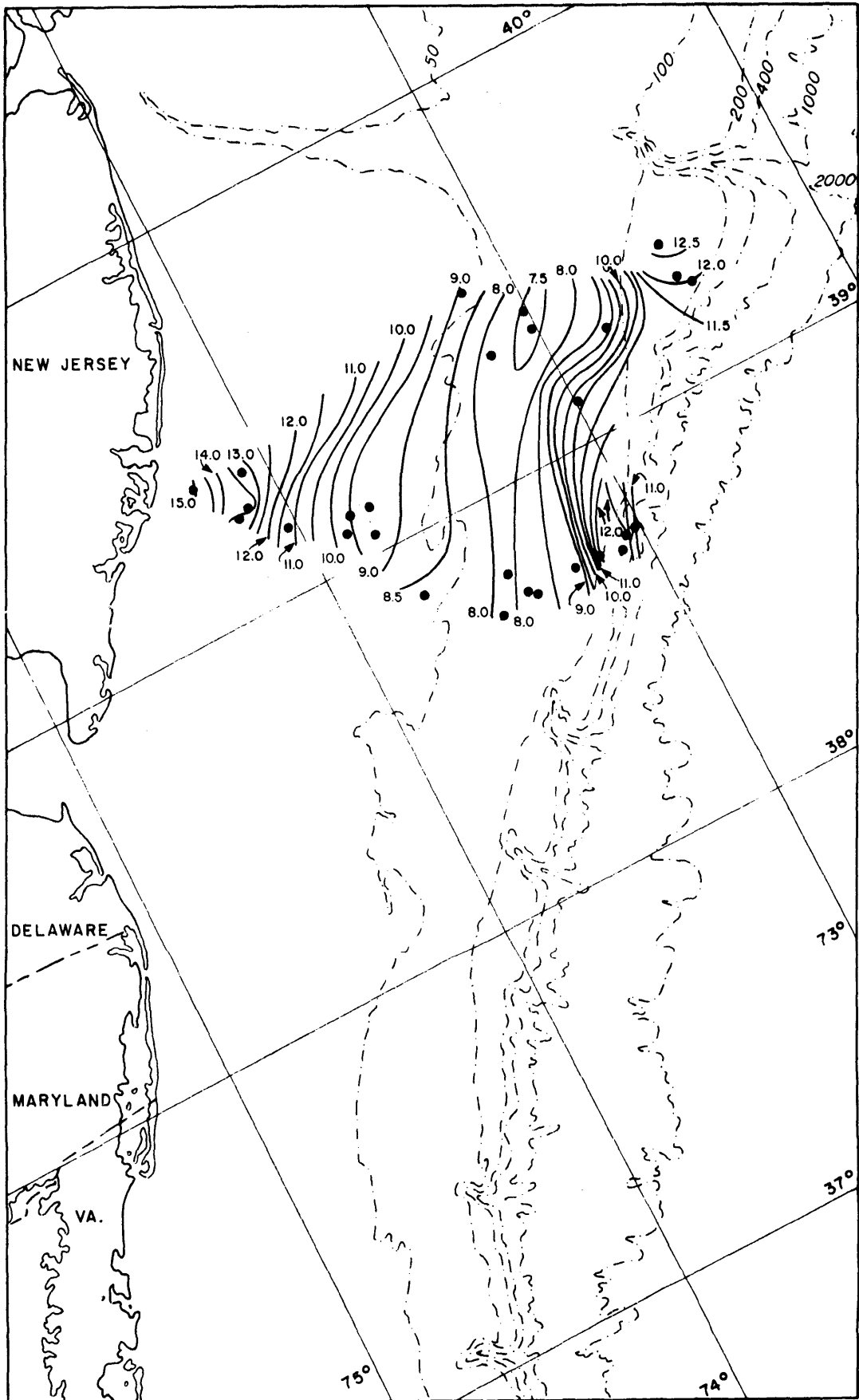


Figure 3-97. Bottom temperature ($^{\circ}\text{C}$) distribution in the northern portions of the Middle Atlantic Bight during the period 15 to 23 June 1976 (Cruise BLM03B)

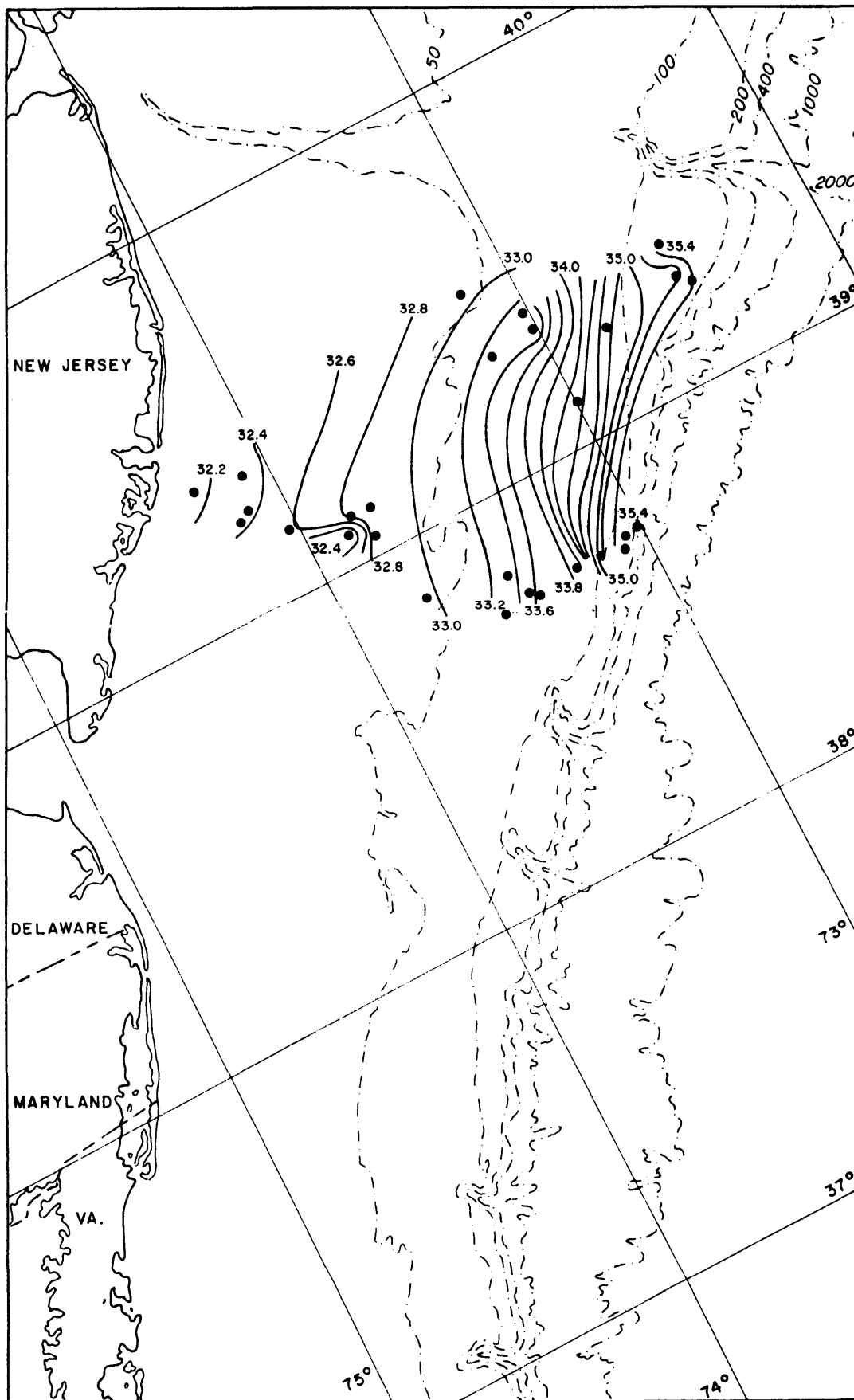


Figure 3-98 Bottom salinity (ppt) distribution in the northern portions of the Middle Atlantic Bight during the period 15 to 23 June 1976 (Cruise BLM03B)

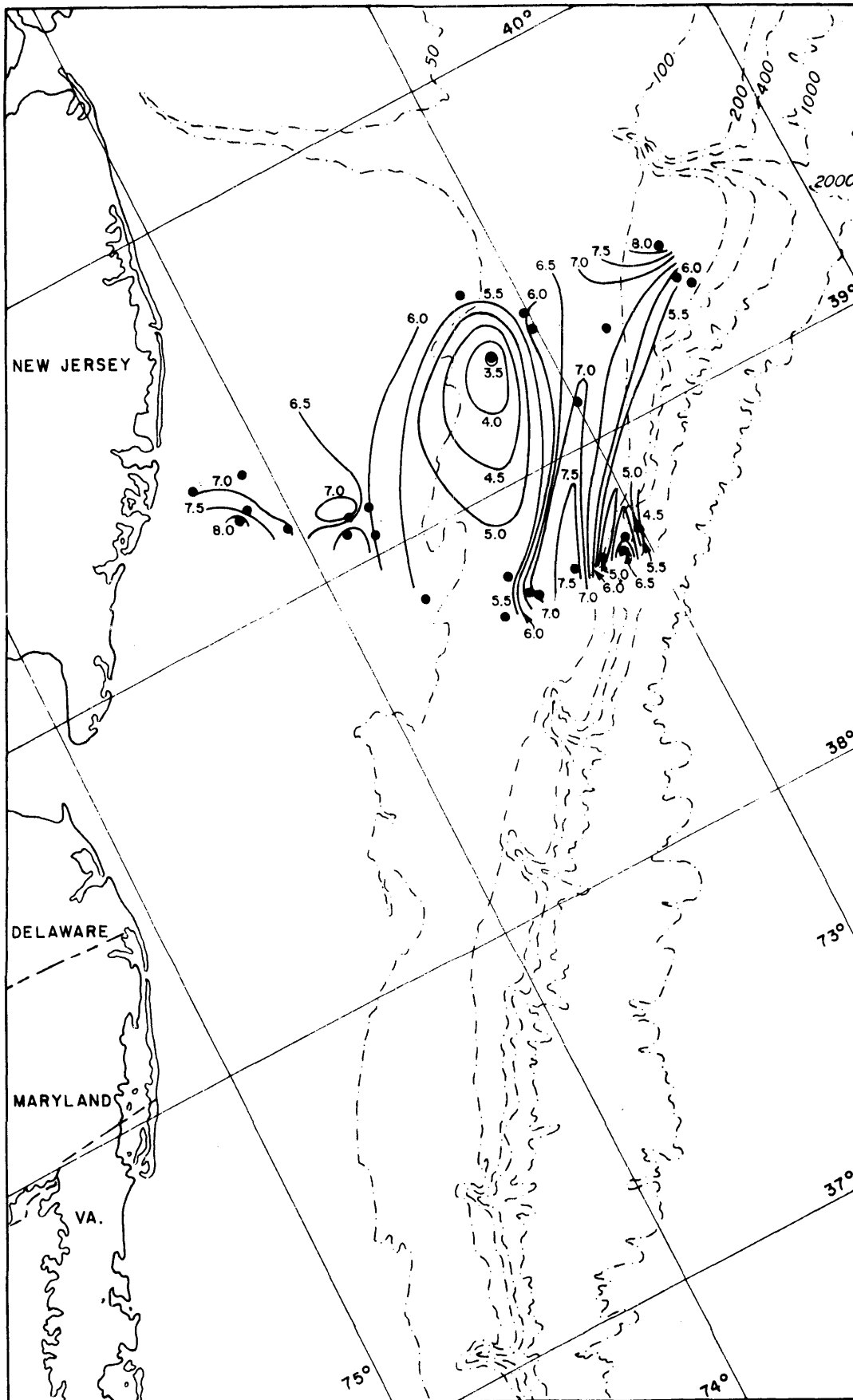


Figure 3-99 Bottom dissolved oxygen (mg/l) distribution in the northern portions of the Middle Atlantic Bight during the period 15 to 23 June 1976 (Cruise BLM03B)

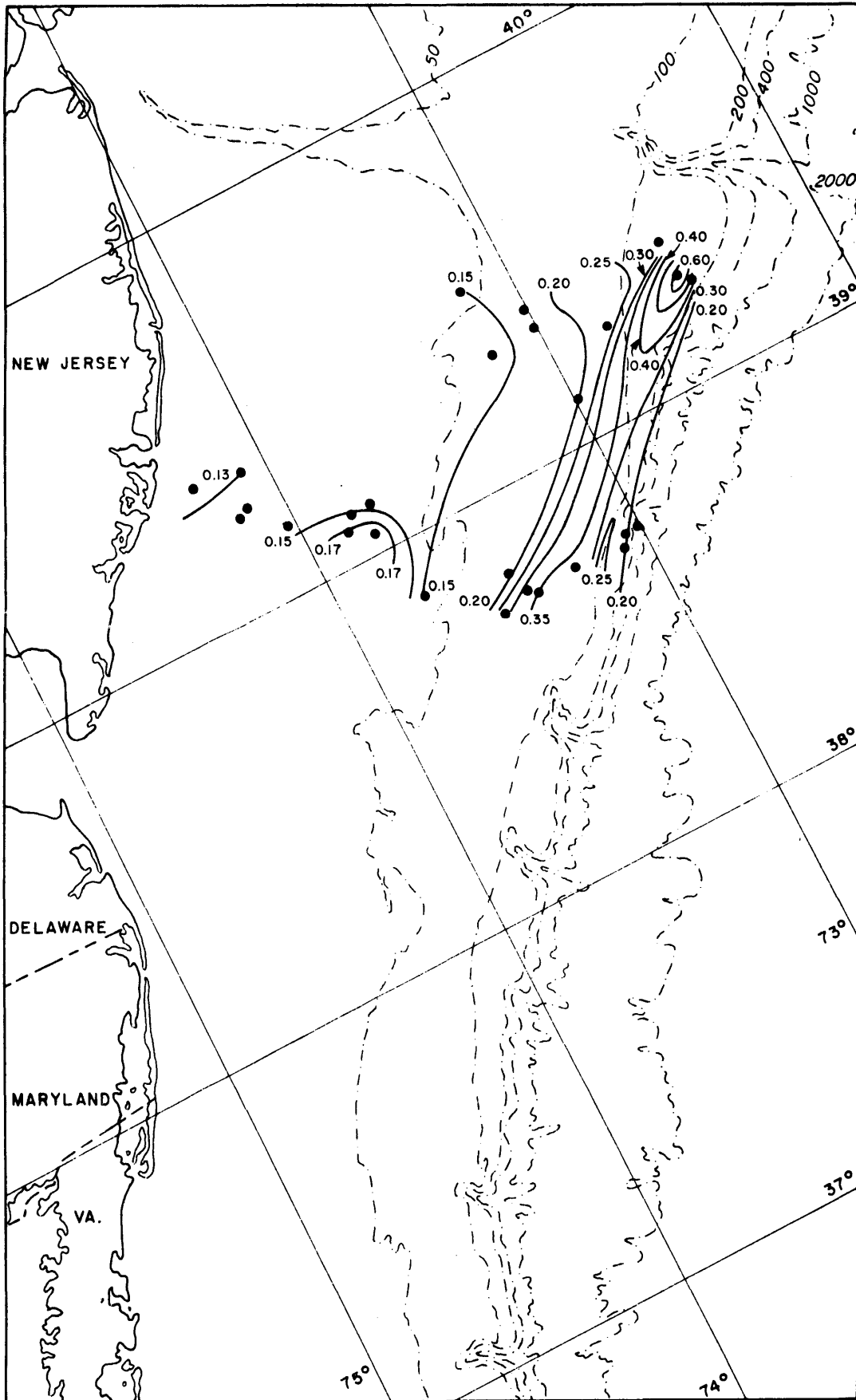


Figure 3-100. Bottom NO₂ (µgm atoms/l) distribution in the northern portions of the Middle Atlantic Bight during the period 15 to 23 June 1976 (Cruise BLM03B)

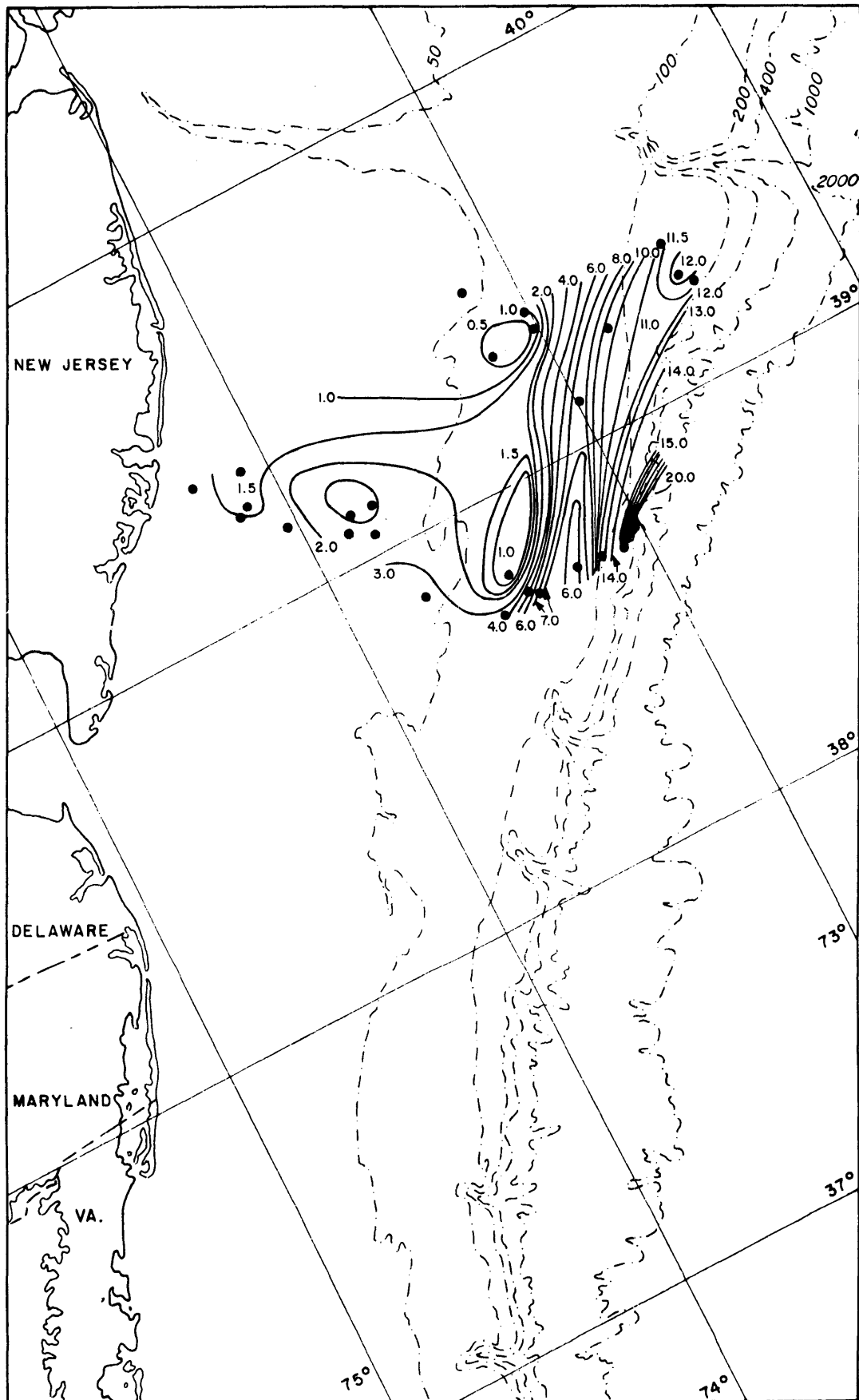


Figure 3-101. Bottom NO_3 ($\mu\text{gm atoms/l}$) distribution in the northern portions of the Middle Atlantic Bight during the period 15 to 23 June 1976 (Cruise BLM03B)

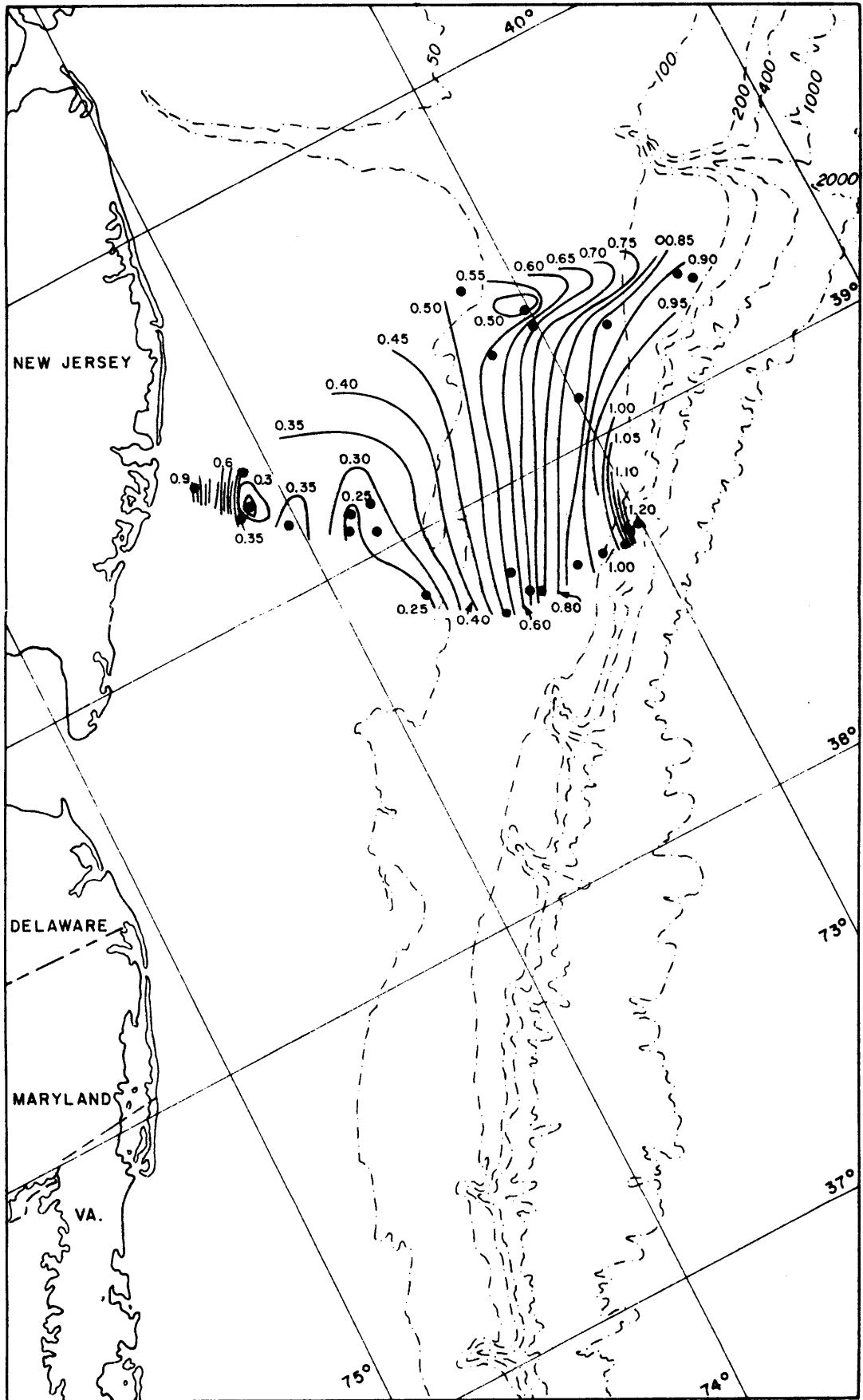


Figure 3-102. Bottom O-PO₄ ($\mu\text{gm atoms/l}$) distribution in the northern portions of the Middle Atlantic Bight during the period 15 to 23 June 1976 (Cruise BLM03B)

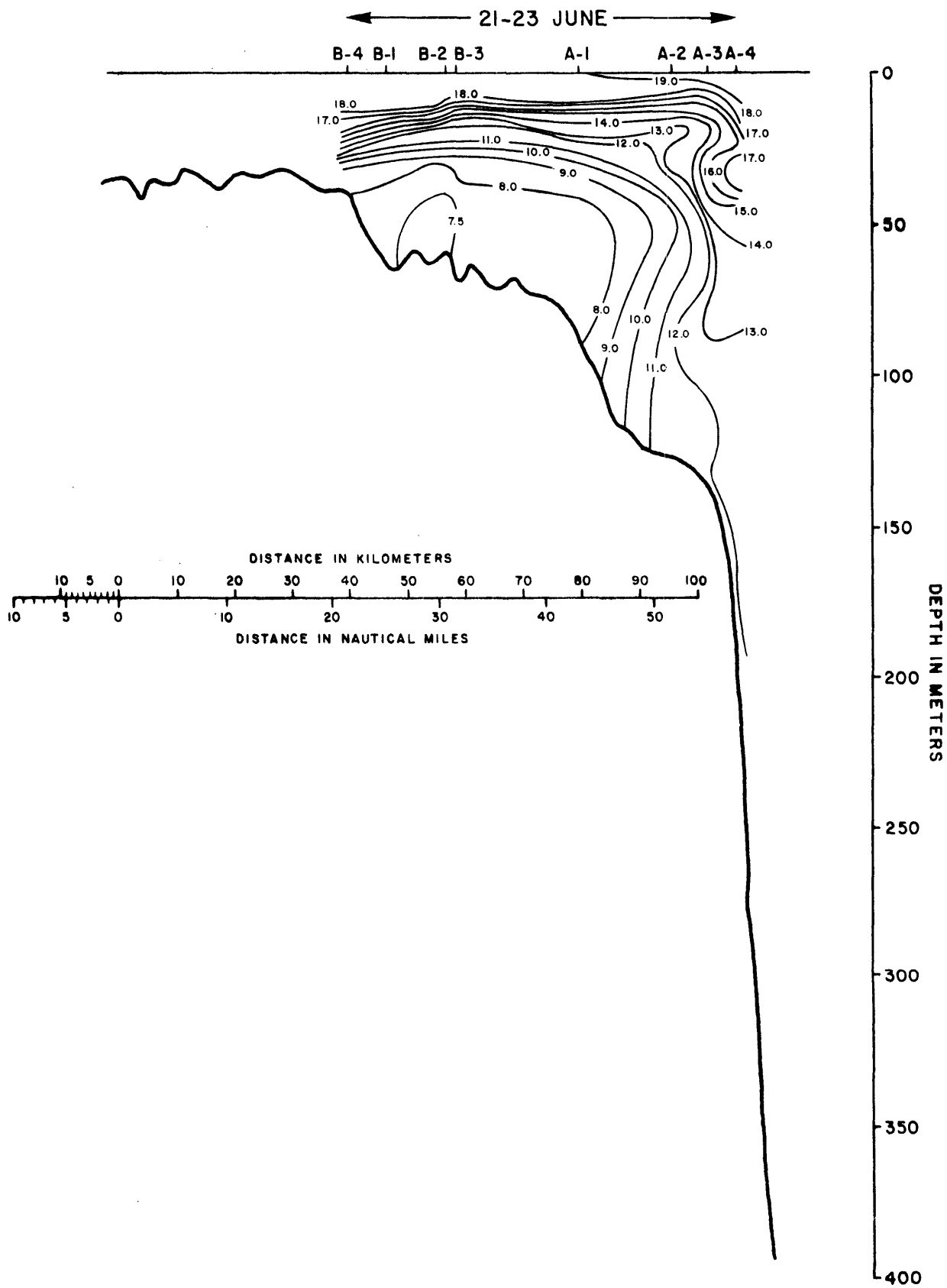


Figure 3-103. Temperature ($^{\circ}\text{C}$) along Section II (Stations B4 to A4, 21-23 June 1976) during cruise BLM03B. Section location is shown in Figure 3-10.

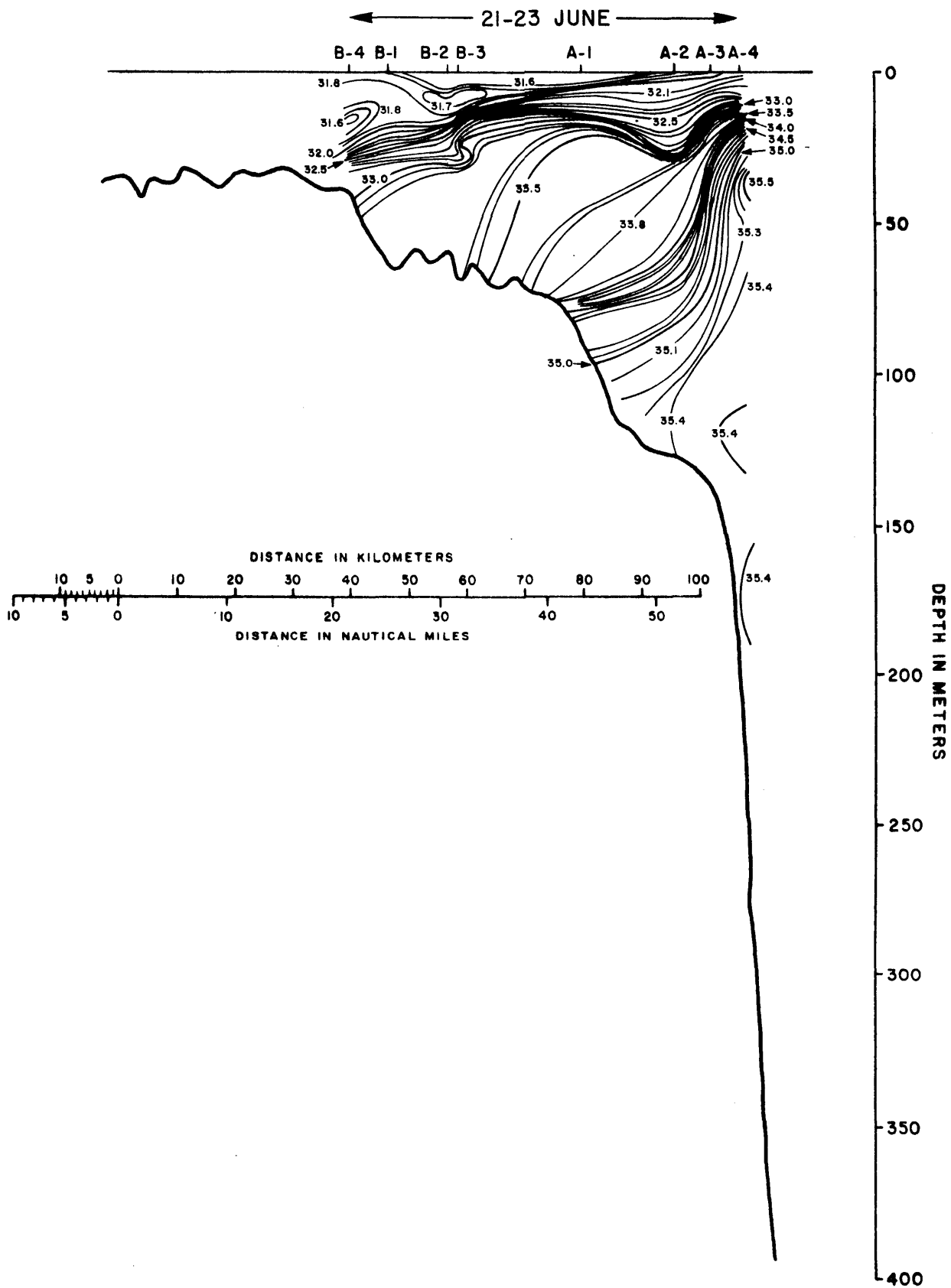


Figure 3-104. Salinity (ppt) along Section II (Stations B4 to A4, 21-23 June 1976) during cruise BLM03B. Section location is shown in Figure 3-10.

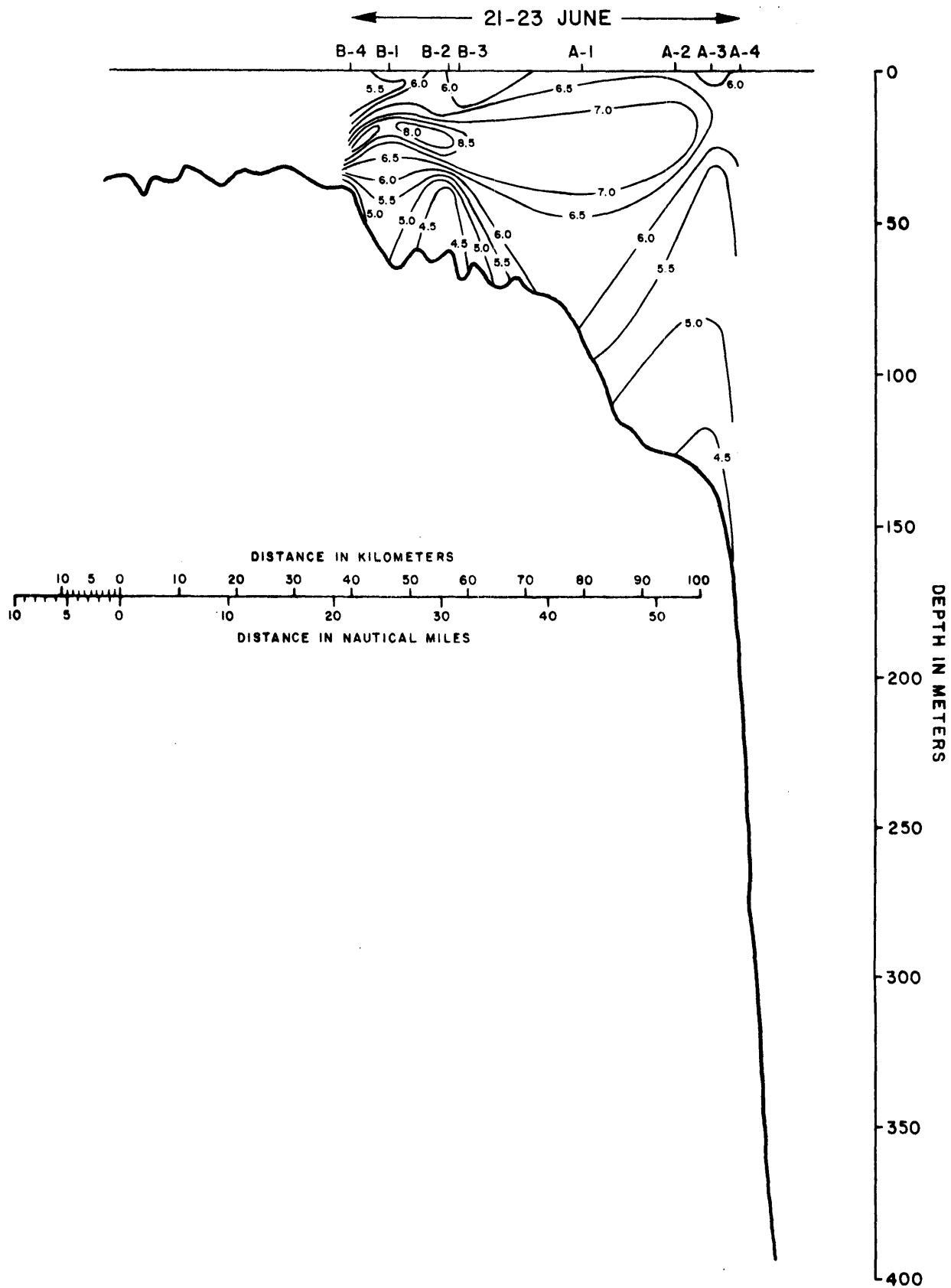


Figure 3-105. Dissolved oxygen (mg/l) along Section II (Stations B4 to A4, 21-23 June 1976) during cruise BLM03B. Section location is shown in Figure 3-10.

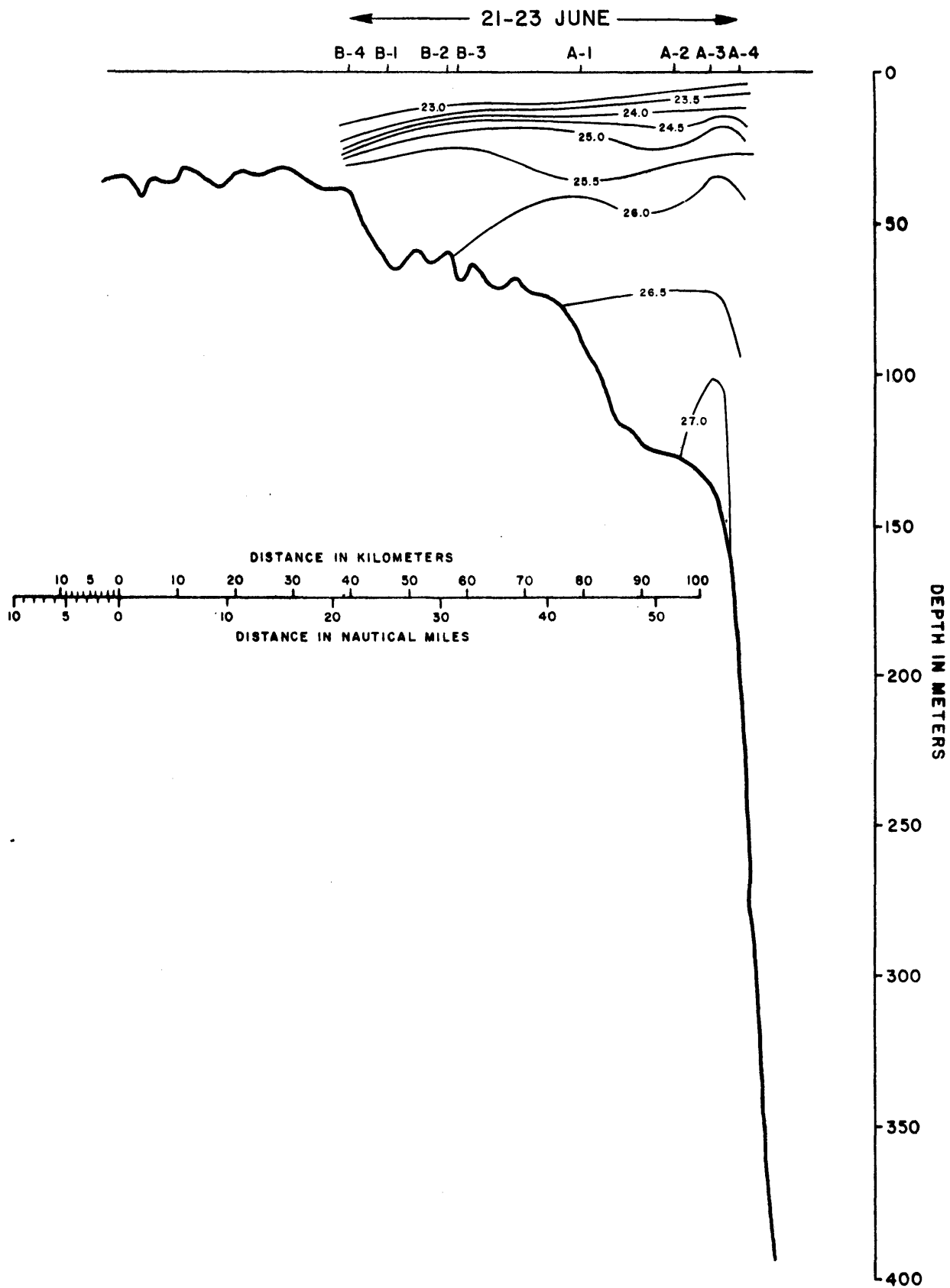


Figure 3-106. Density (σ_t units) along Section II (Stations B4 to A4, 21-23 June 1976) during cruise BLM03B. Section location is shown in Figure 3-10.

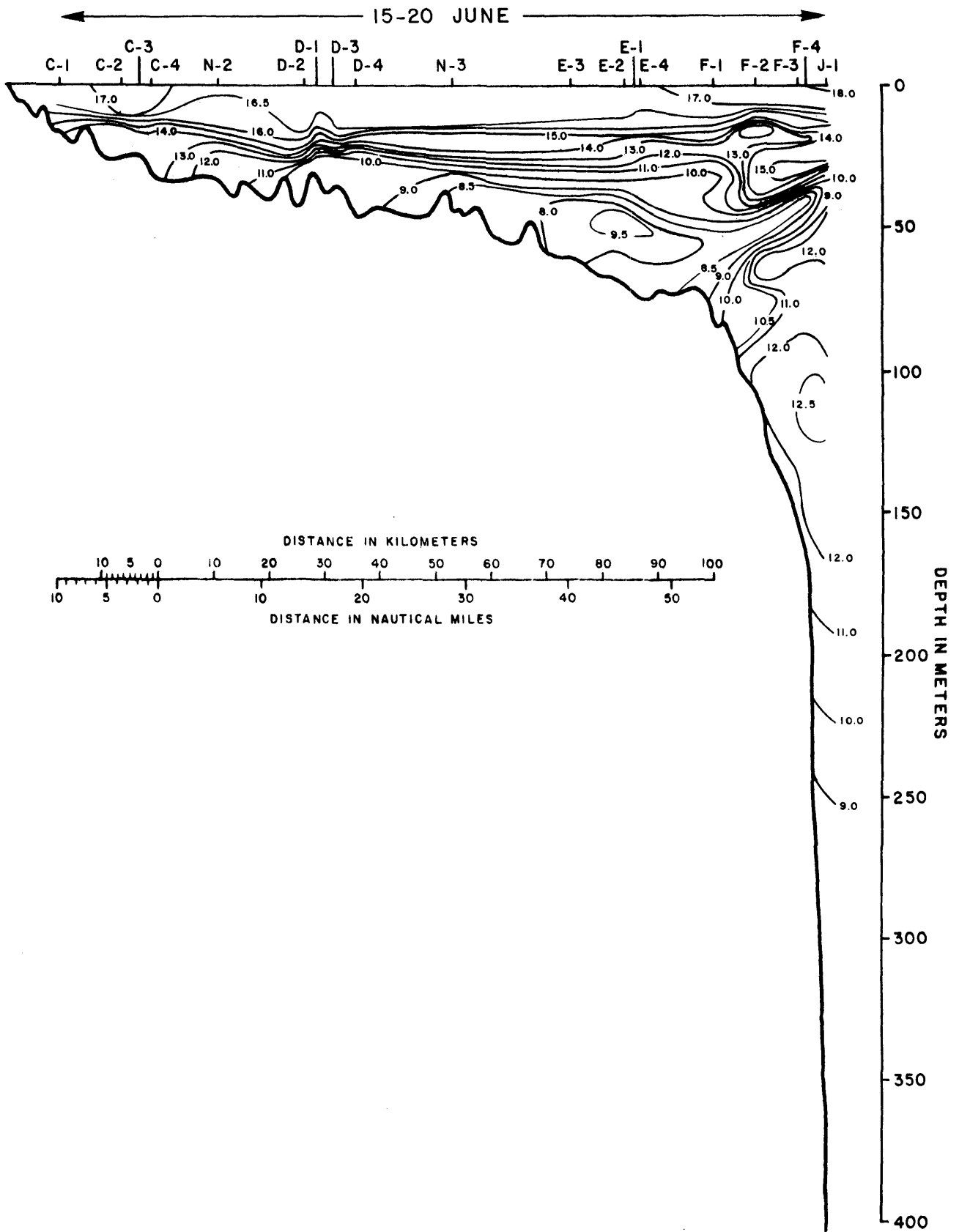


Figure 3-107. Temperature ($^{\circ}\text{C}$) along Section III (Stations C1 to J1, 15-20 June 1976) during cruise BLM03B. Section location is shown in Figure 3-10.

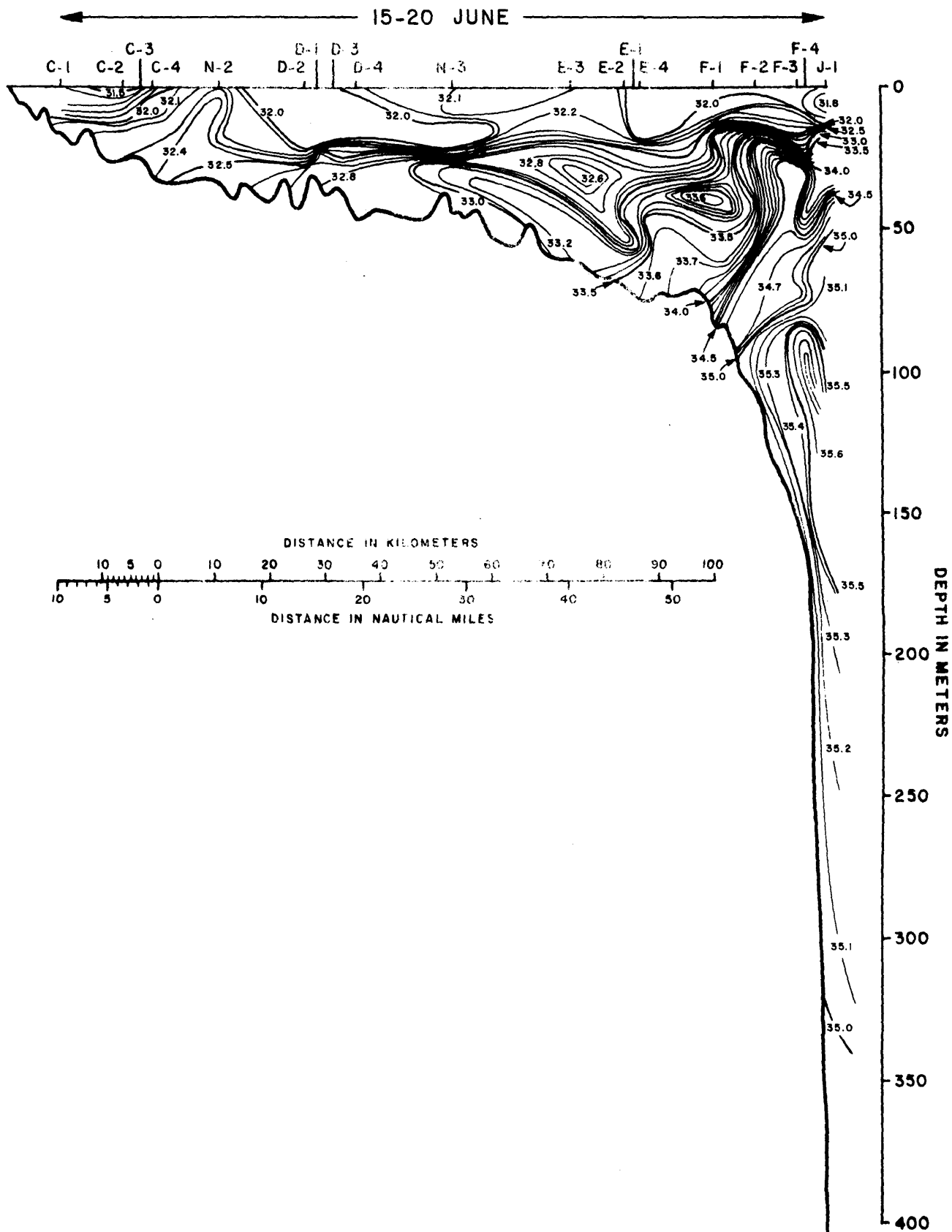


Figure 3-108. Salinity (ppt) along Section III (Stations C1 to J1, 15- 20 June 1976) during cruise BLM03B. Section location is shown in Figure 3-10.

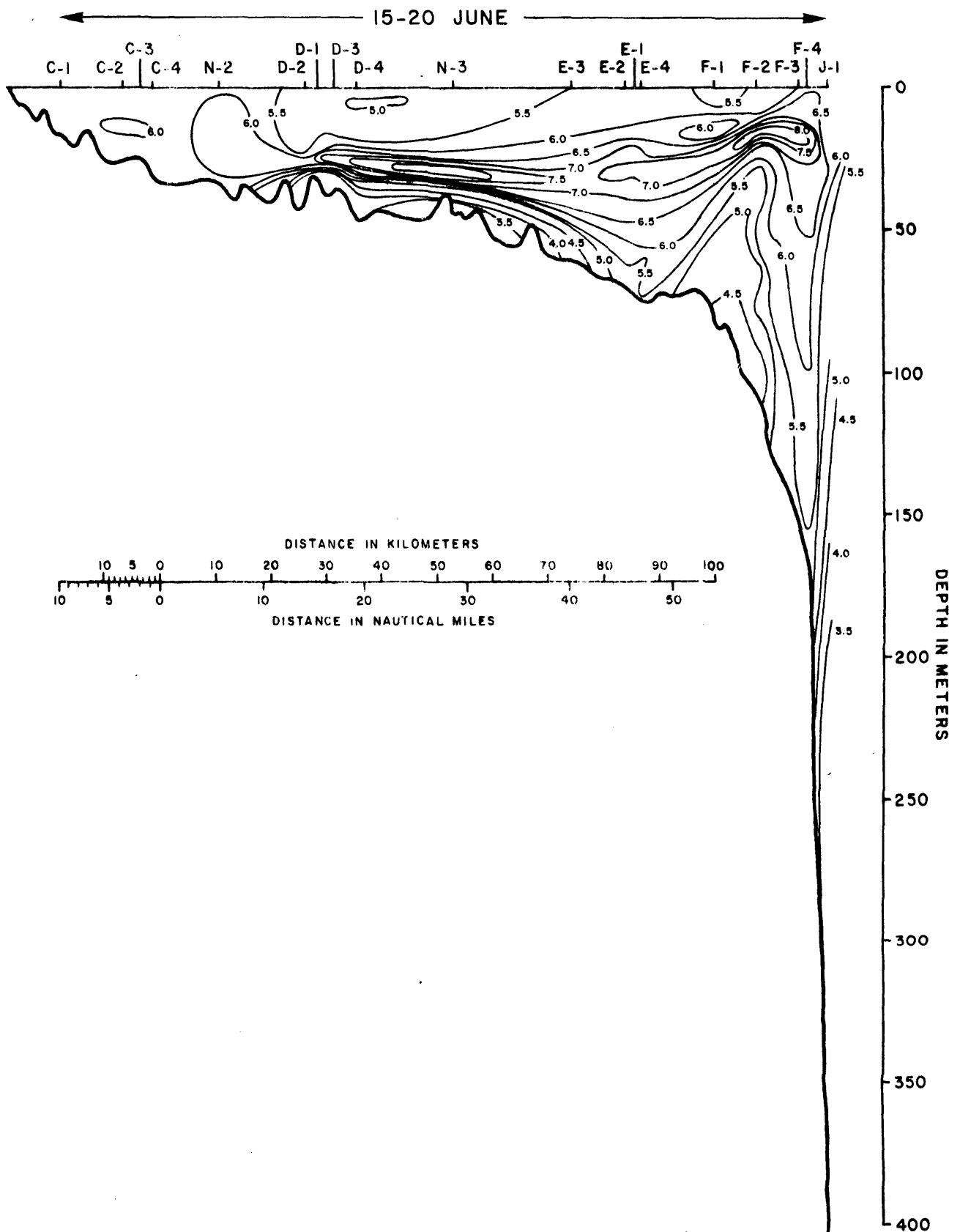


Figure 3-109. Dissolved oxygen (mg/l) along Section III (Stations C1 to J1, 15-20 June 1976) during cruise BLM03B. Section location is shown in Figure 3-10.

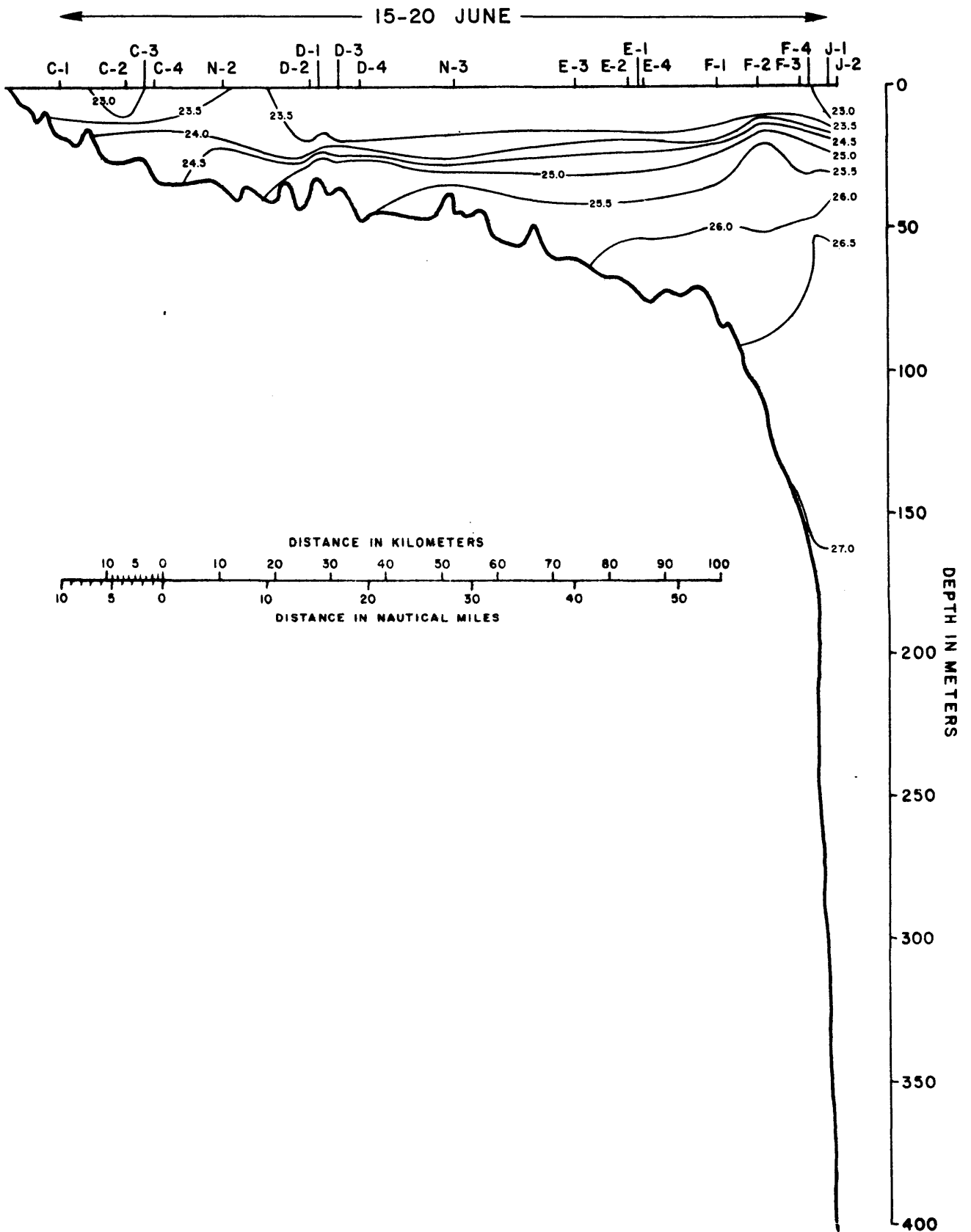


Figure 3-110. Density (σ_t units) along Section III (Stations C1 to J1, 15-20 June 1976) during cruise BLM03B. Section location is shown in Figure 3-10.

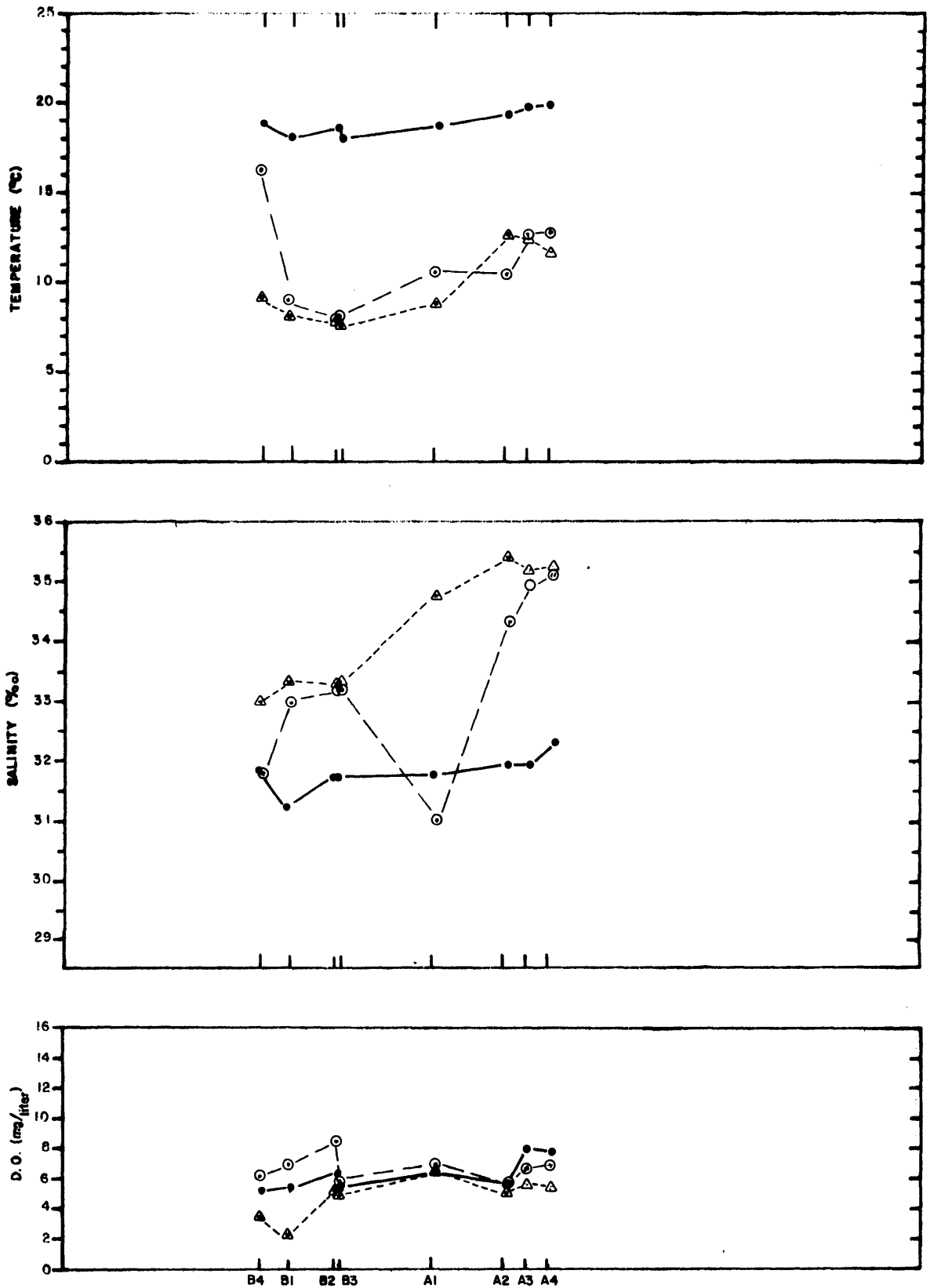


Figure 3-111. Surface (•), mid-depth (◊) and bottom (Δ) values of temperature, salinity and DO measured along Section II on cruise BLM 03B.

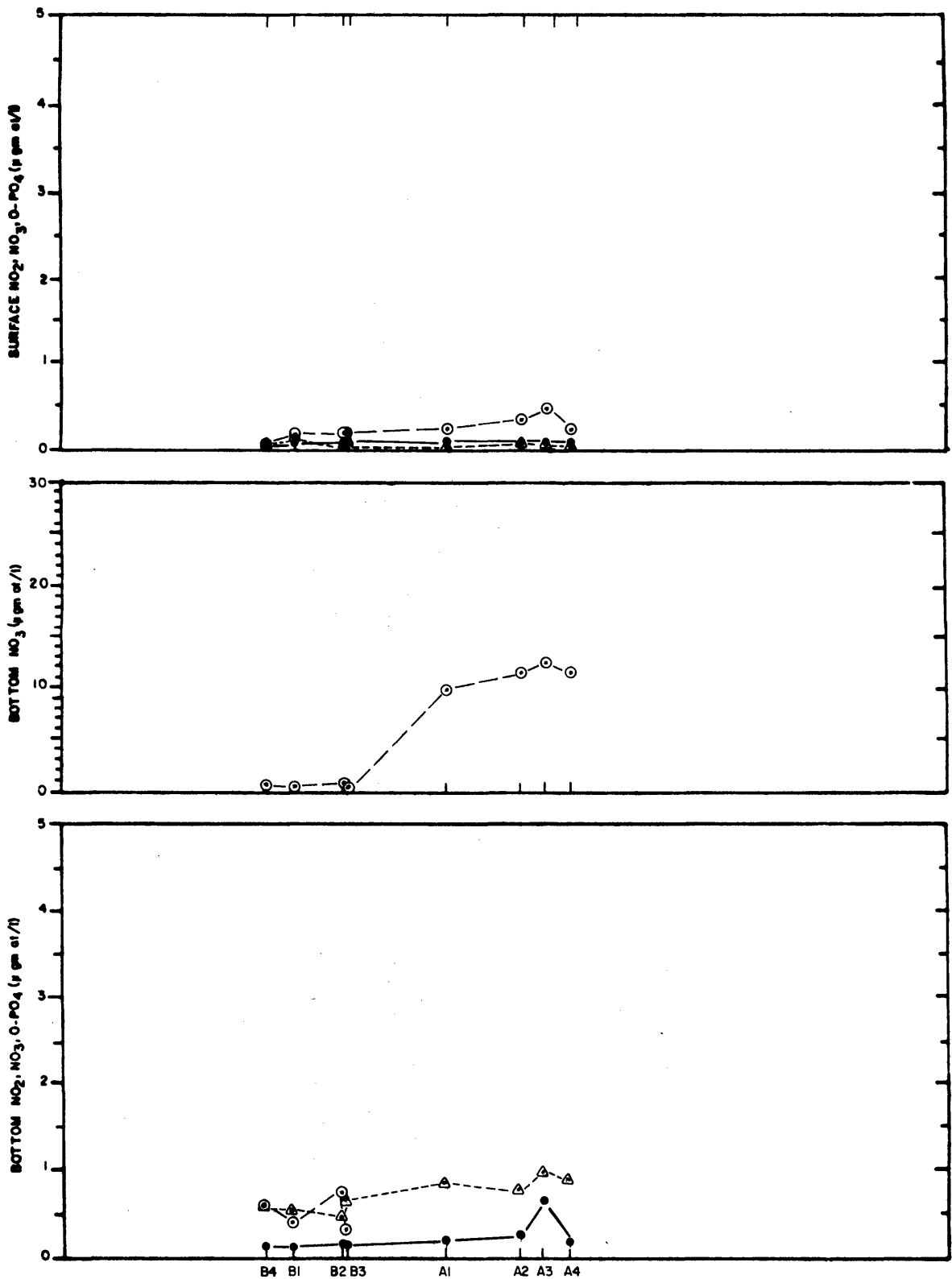


Figure 3-112. Concentrations of dissolved NO₂ (•), NO₃ (○), and O-PO₄ (Δ) in near surface and near bottom waters along Section II during Cruise BLM 03B. Bottom concentrations of dissolved NO₃ were substantially greater than those of other micronutrients hence the center plot.

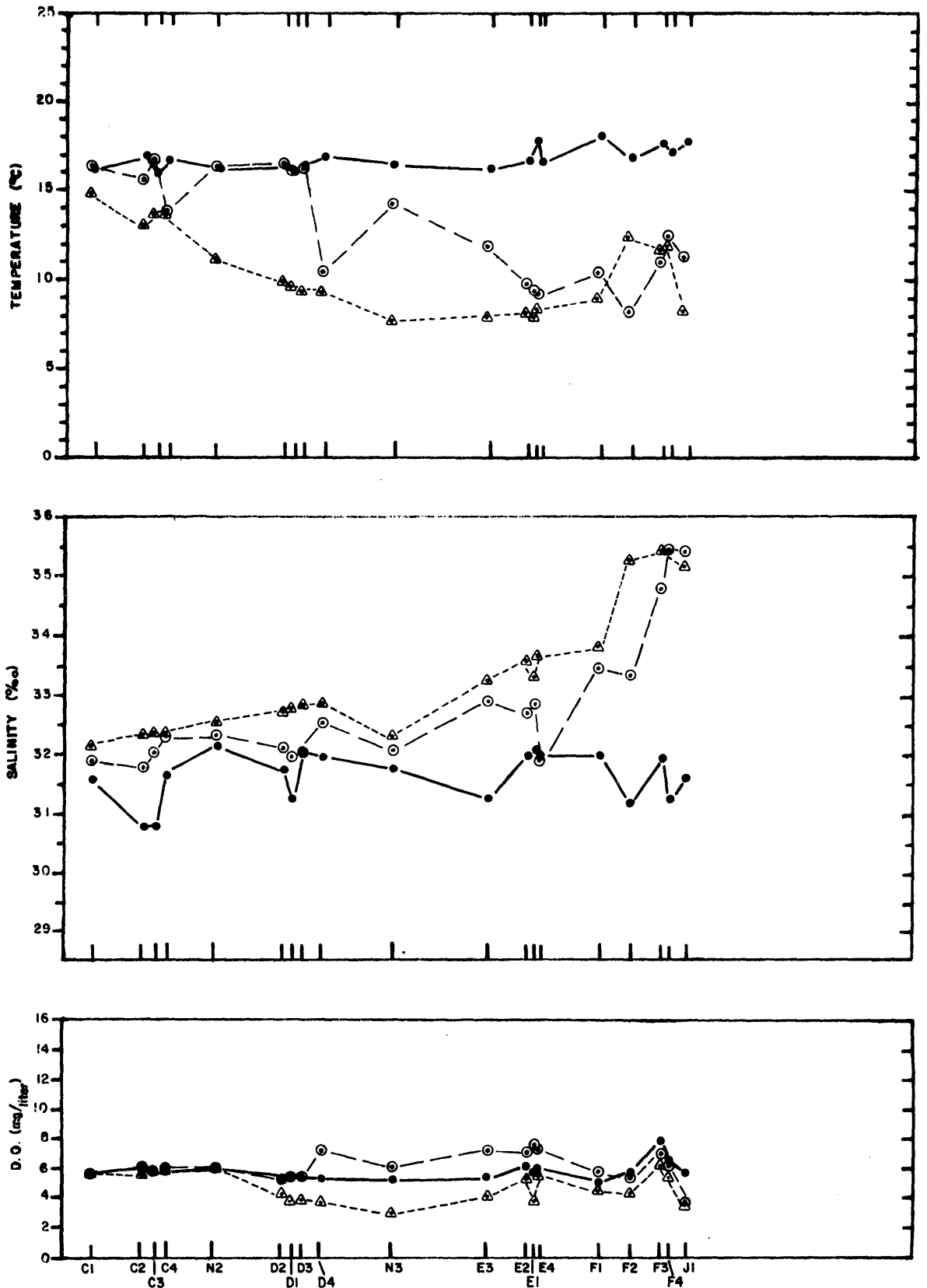


Figure 3-113 Surface (•), mid-depth (◊) and bottom (Δ) values of temperature, salinity and DO measured along Section III on cruise BLM 03B.

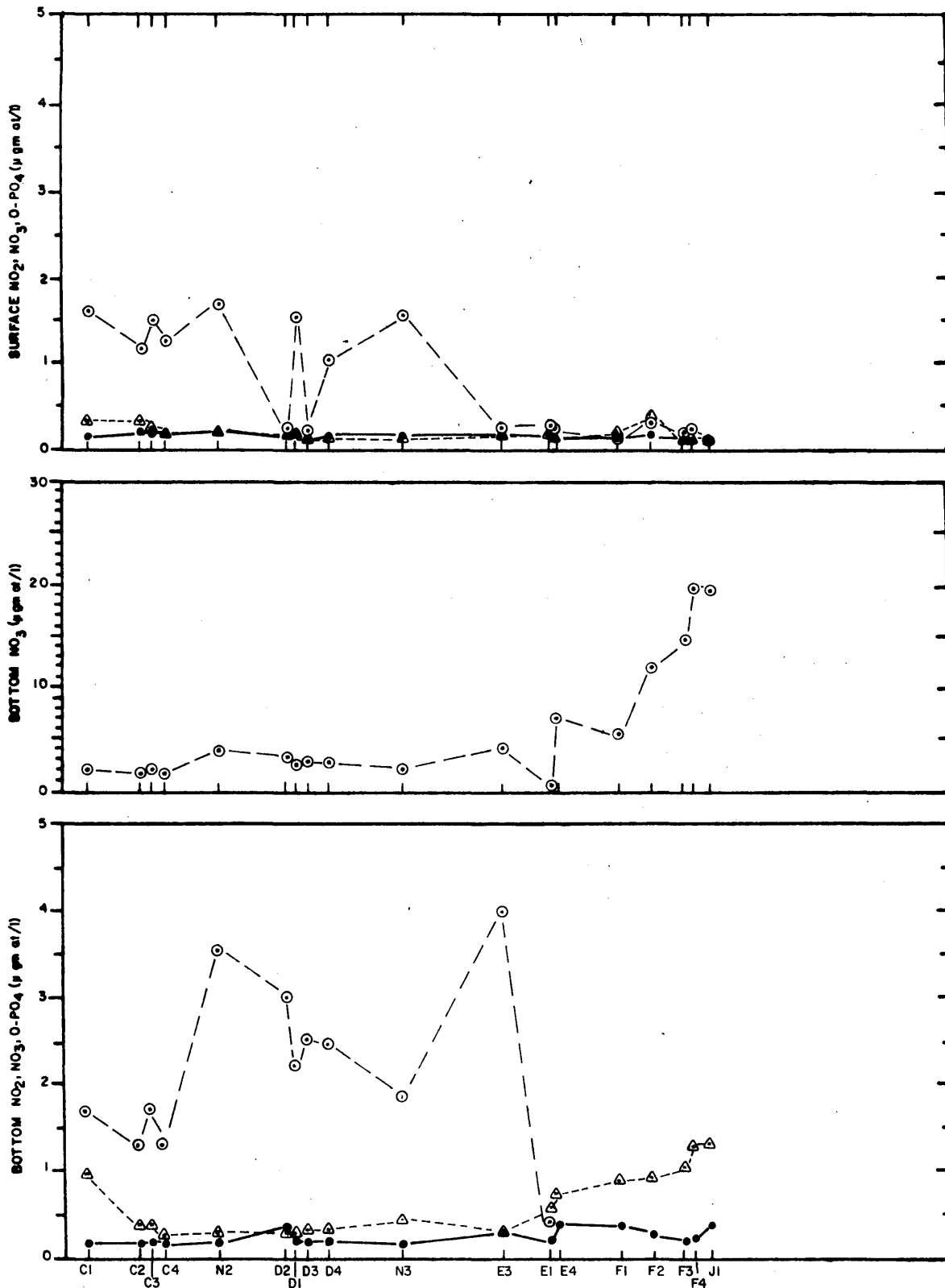


Figure 3-114. Concentrations of dissolved NO₂ (•), NO₃ (θ), and O-PO₄ (Δ) in near surface and near bottom waters along Section III during Cruise BLM 03B. Bottom concentrations of dissolved NO₃ were substantially greater than those of other micronutrients hence the center plot.

Cruise BLM03W

Spring 1976

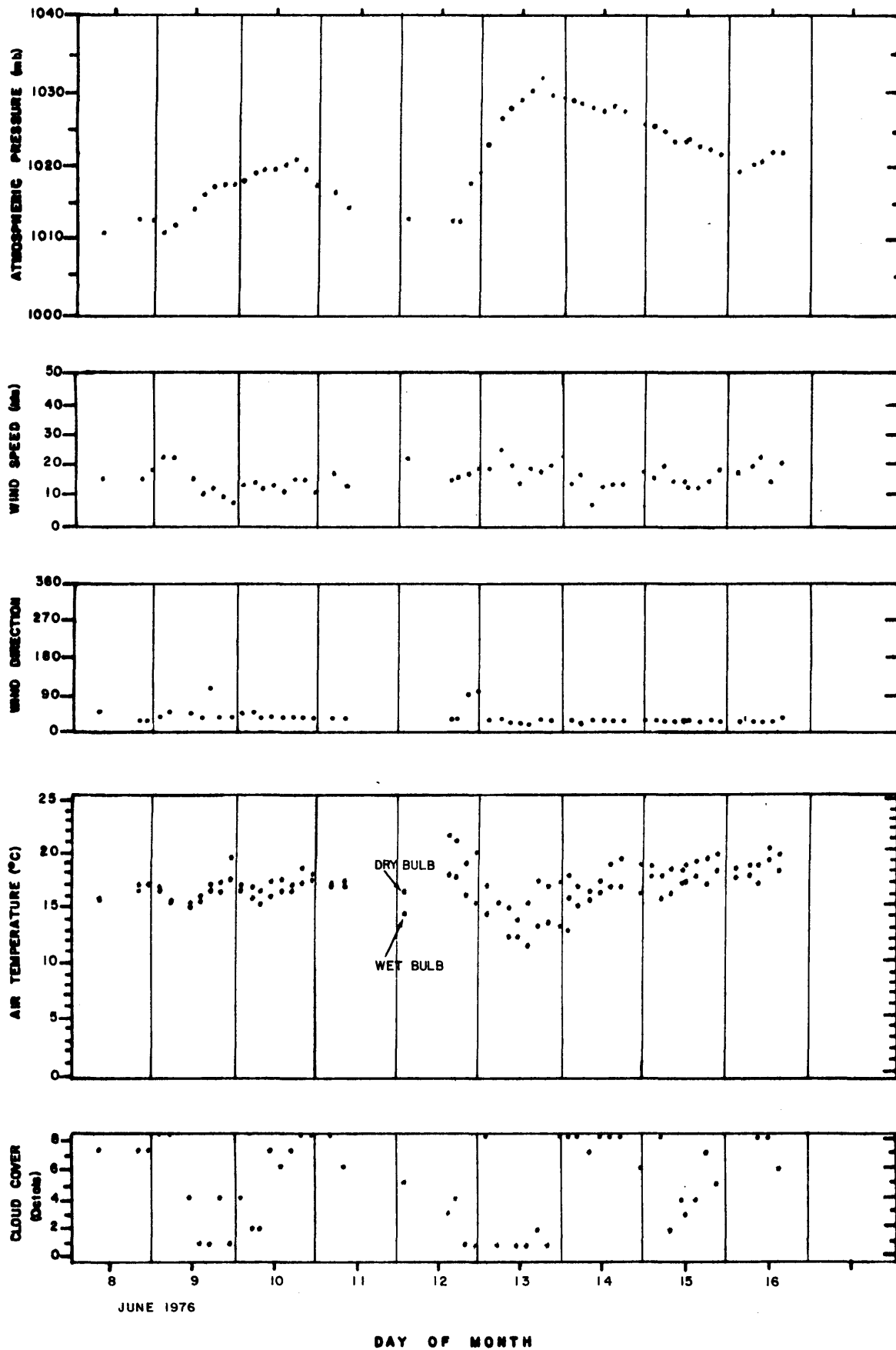


Figure 3-115. Meteorological data collected during cruise BLM 03W 8 to 16 June 1976.

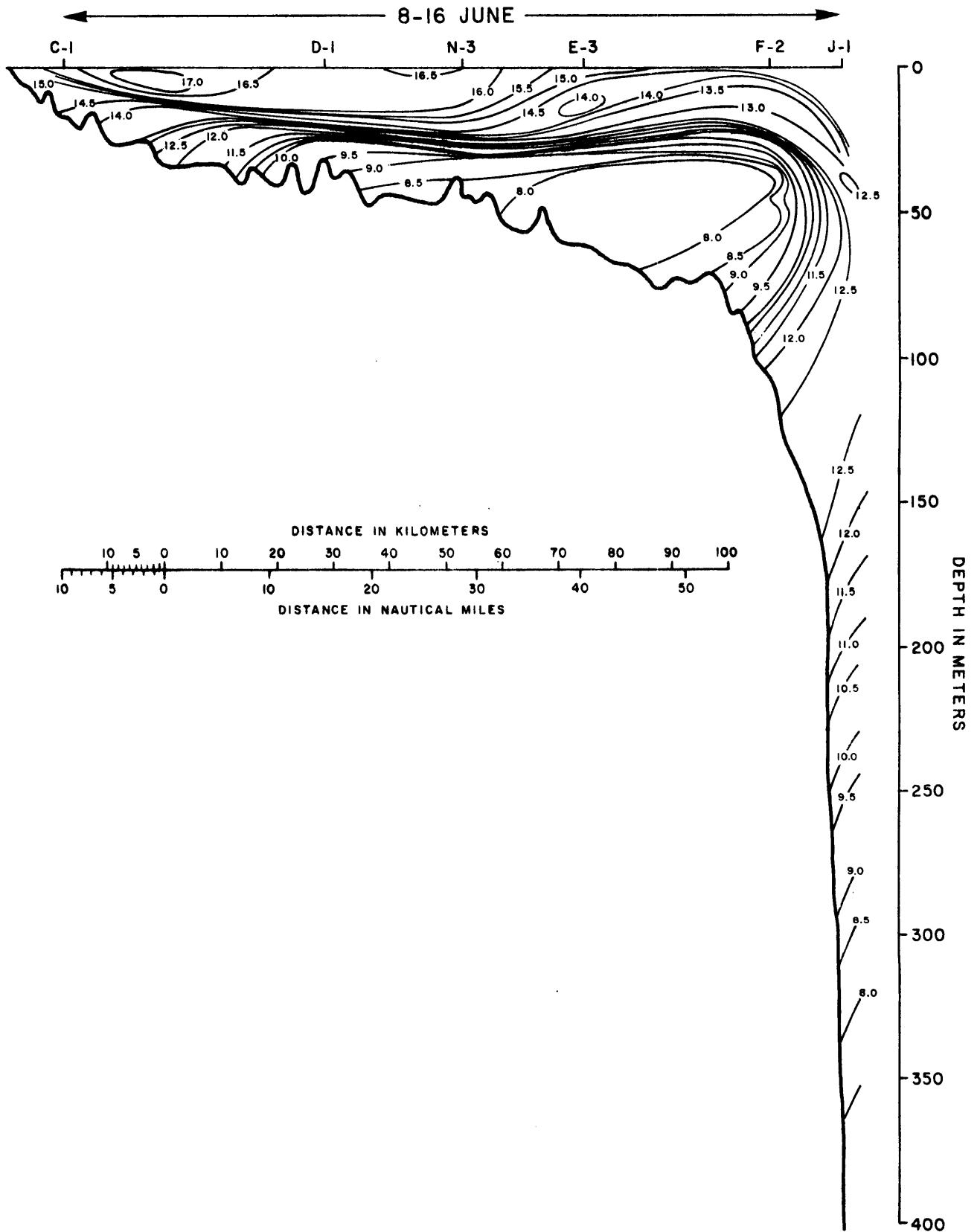


Figure 3-116 Temperature ($^{\circ}\text{C}$) along Section III (Stations C1 to J1, 8-16 June 1976) during cruise BLM03W. Section location is shown in Figure 3-10.

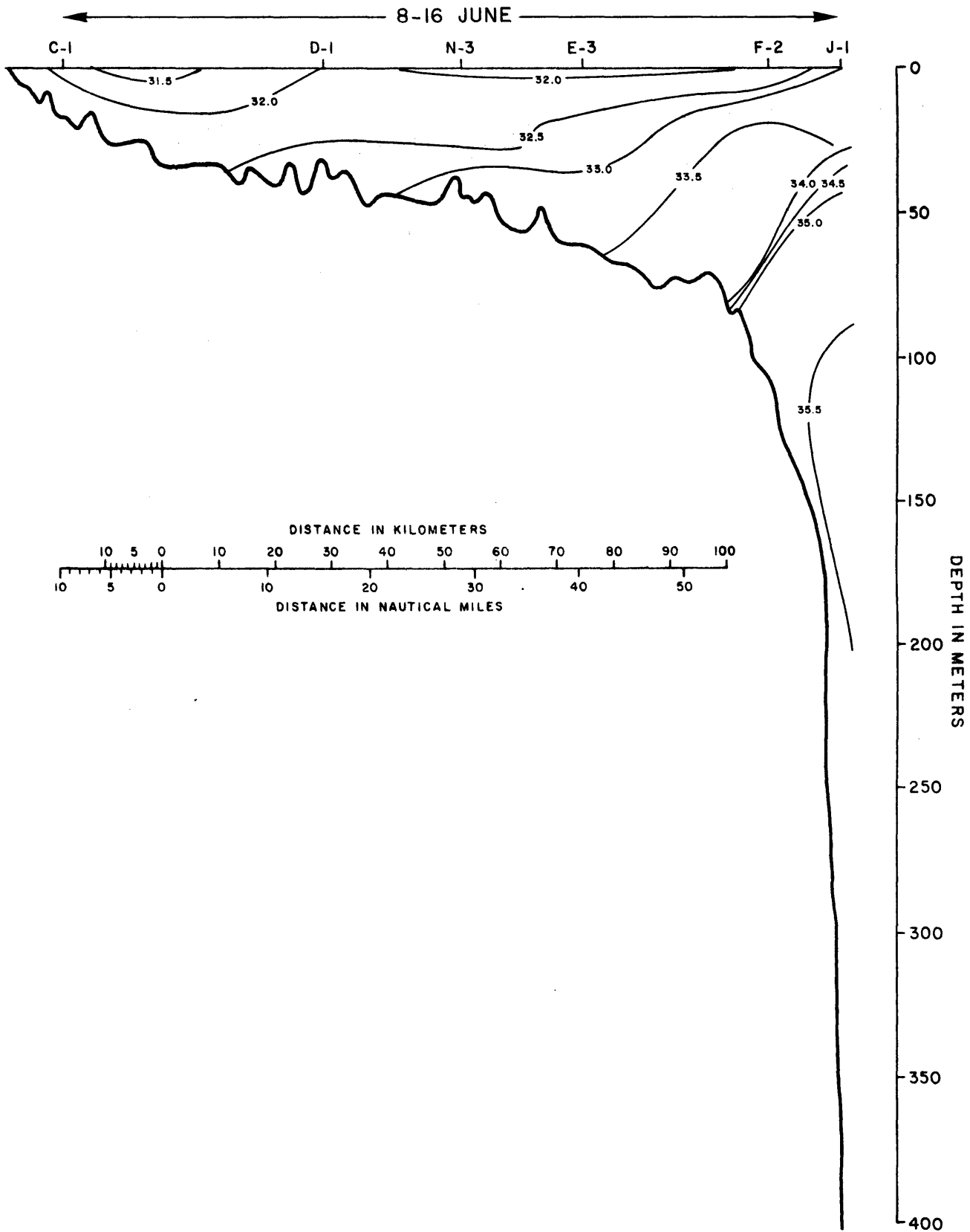


Figure 3-117. Salinity (ppt) along Section III (Stations C1 to J1, 8-16 June 1976) during cruise BLM03W. Section location is shown in Figure 3-10.

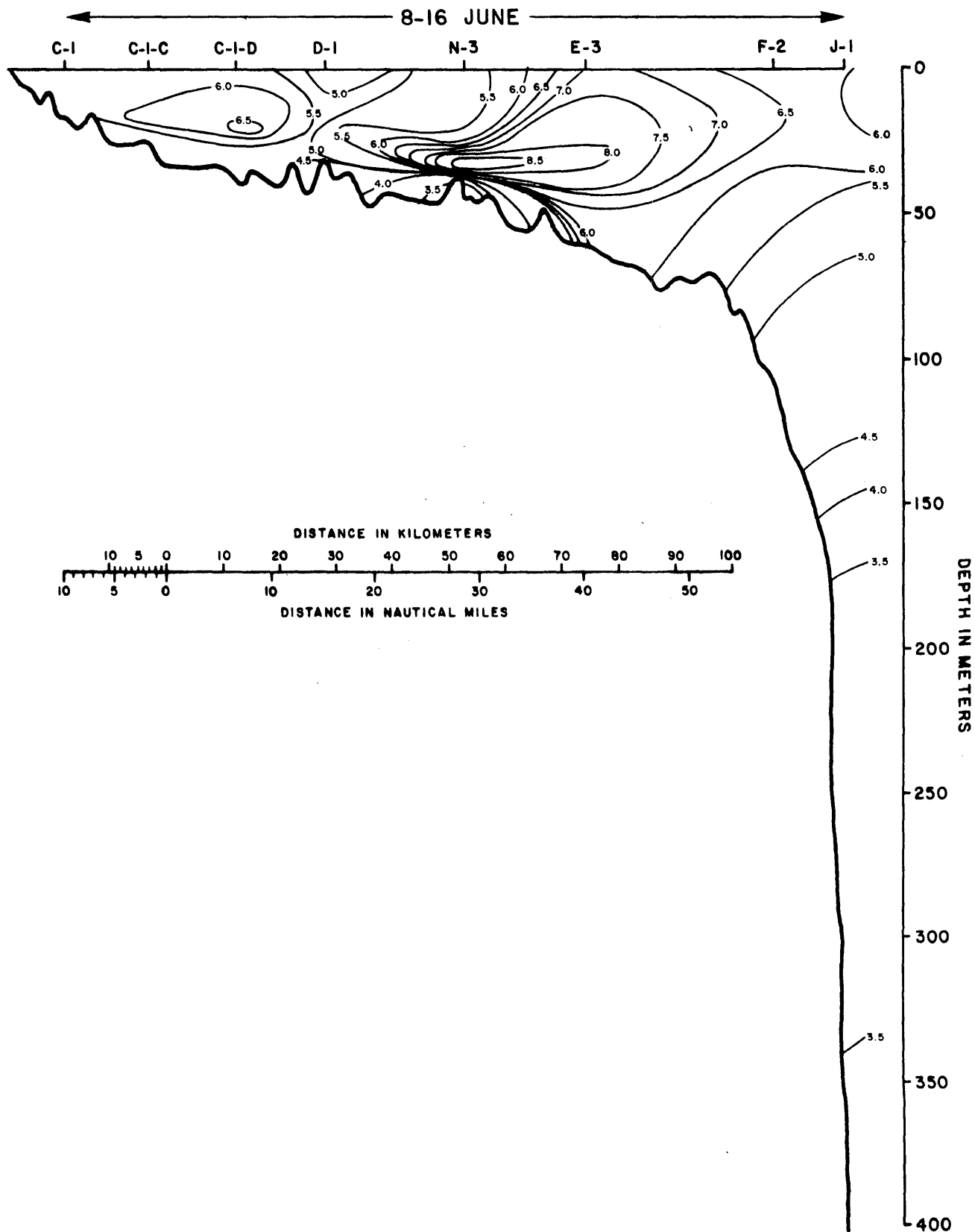


Figure 3-118. Dissolved oxygen (mg/l) along Section III (Stations C1 to J1, 8-16 June 1976) during cruise BLM03W. Section location is shown in Figure 3-10.

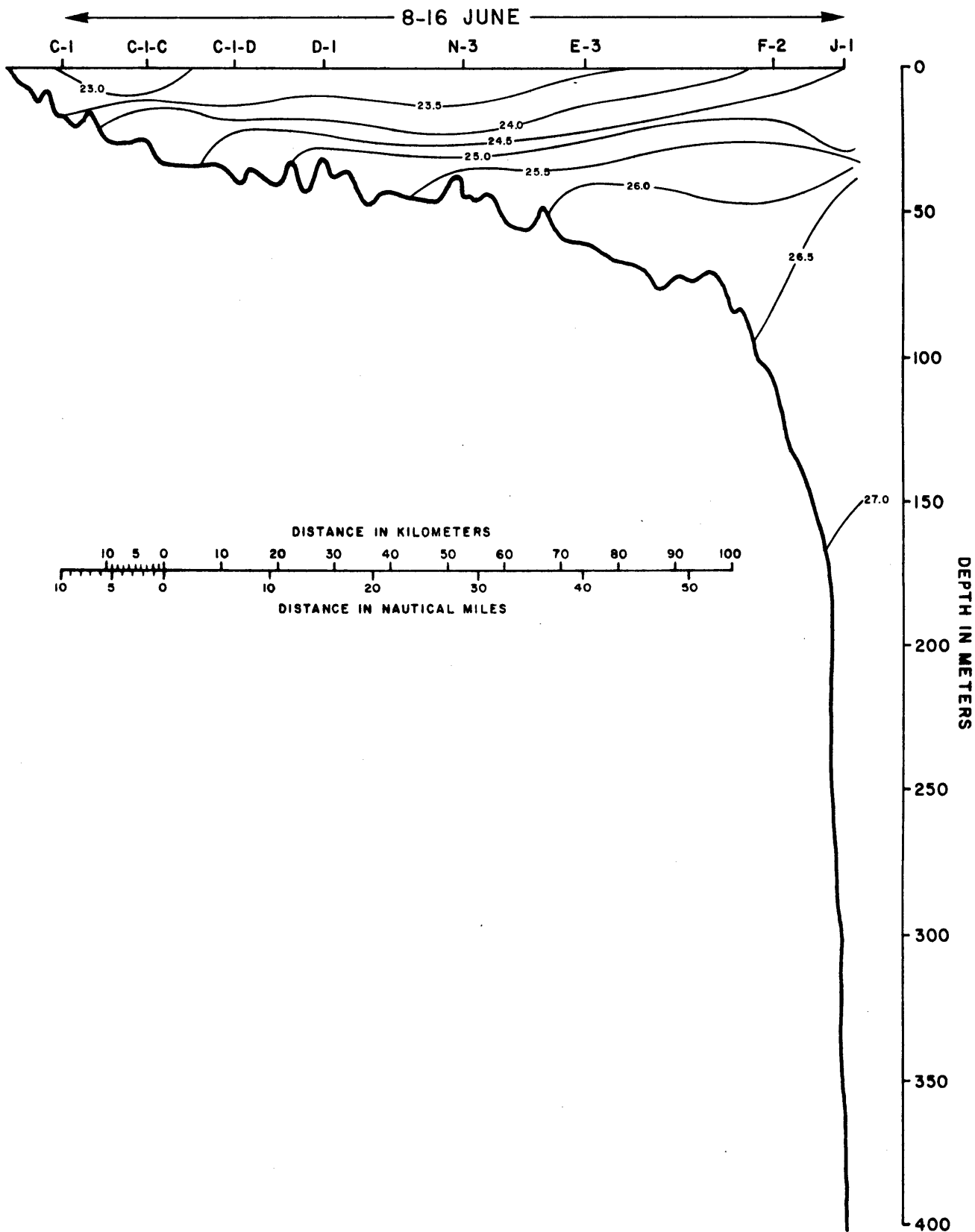


Figure 3-119. Density (σ_t units) along Section III (Stations C1 to J1, 8-16 June 1976) during cruise BLM03W. Section location is shown in Figure 3-10.

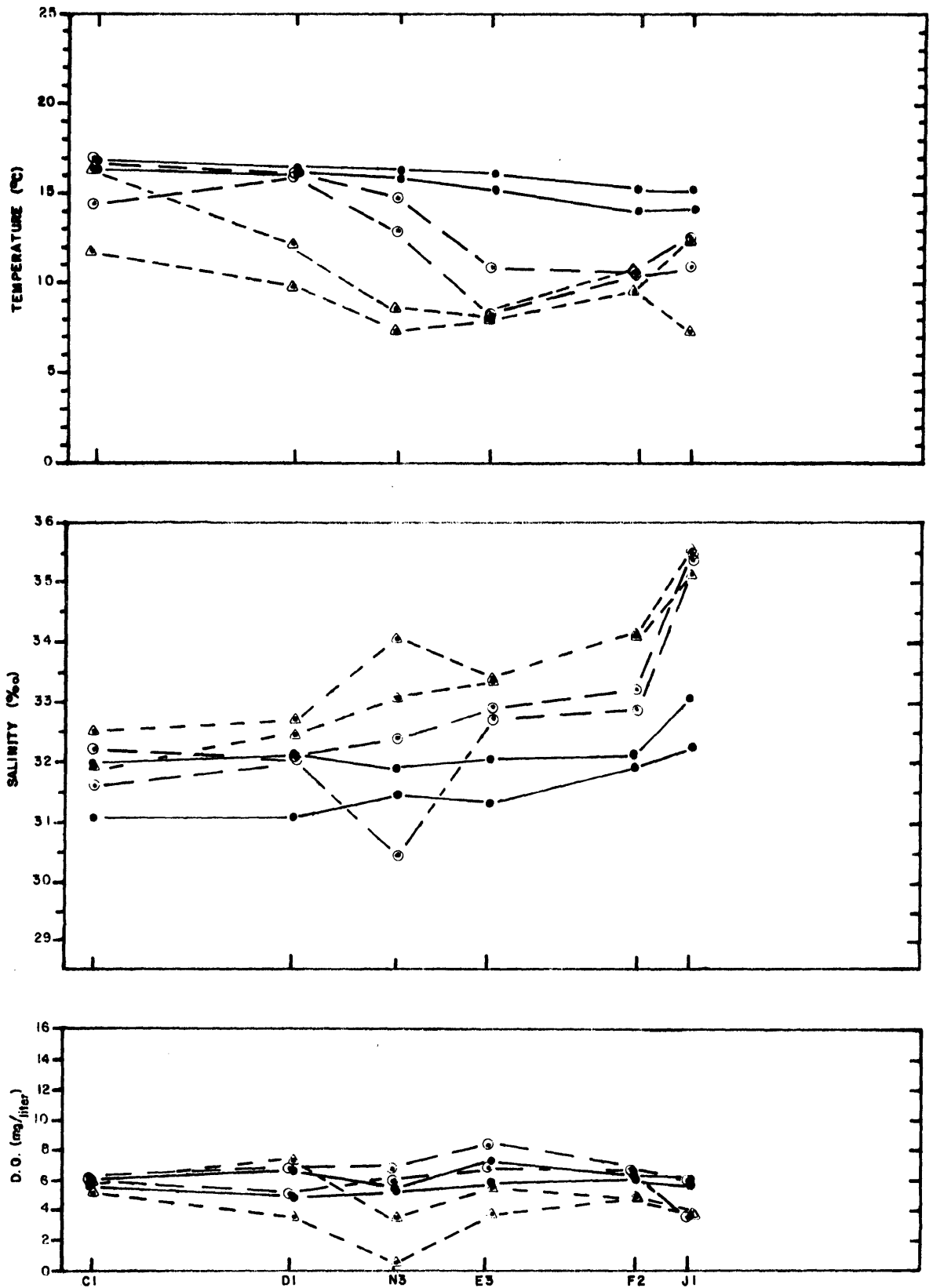


Figure 3-120 Surface (\bullet), mid-depth (\circ) and bottom (Δ) values of temperature, salinity and DO measured along Section III during cruise BLM 03W. Maximum and minimum values measured from four casts are shown at each station.

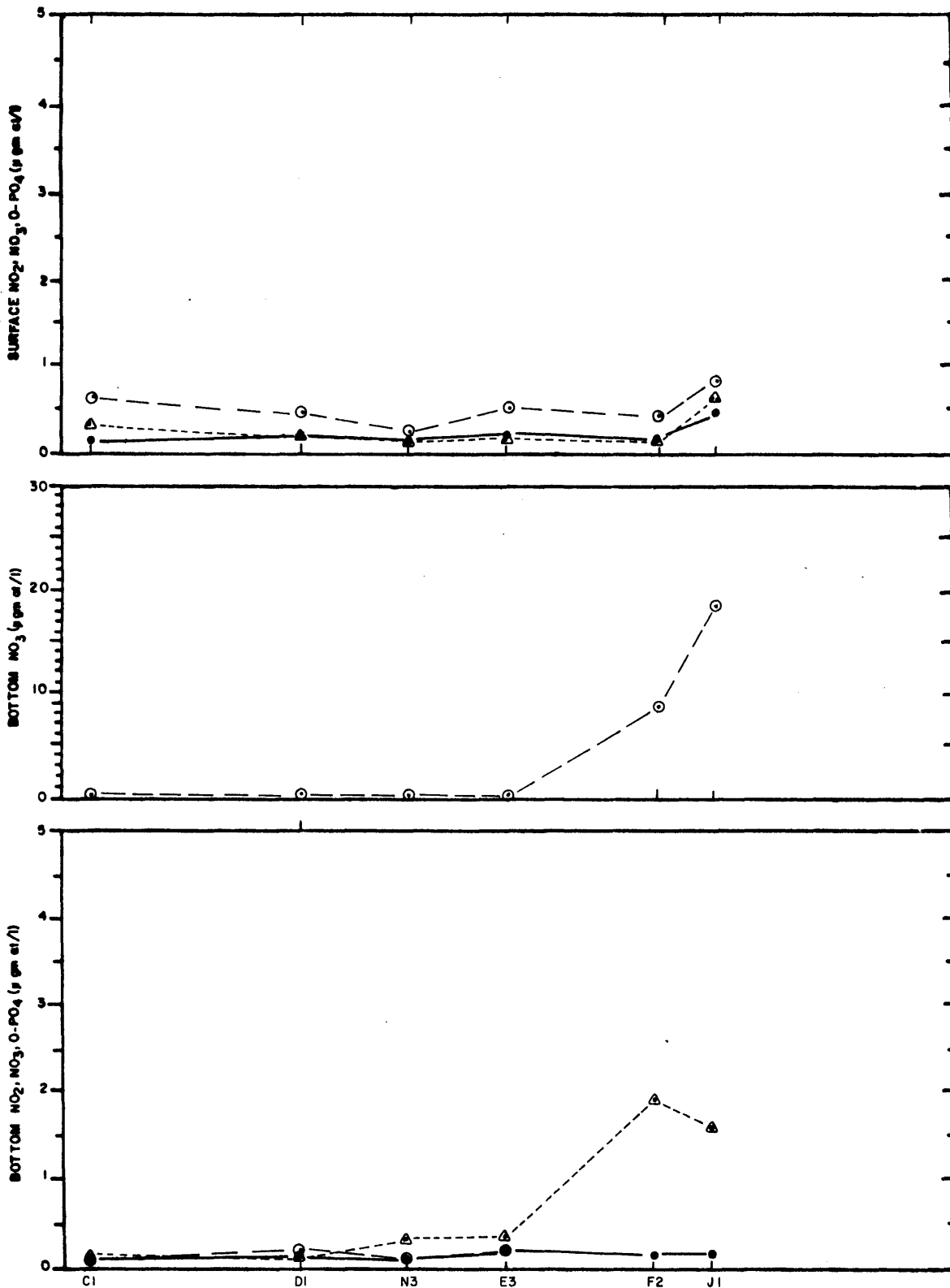


Figure 3-121. Concentrations of dissolved NO₂ (•), NO₃ (◊), and O-PO₄ (Δ) in near surface and near bottom waters along Section III during Cruise BLM 03W. Bottom concentrations of dissolved NO₃ were substantially greater than those of other micronutrients hence the center plot.

Cruise BLM~~0~~4B

Summer 1976

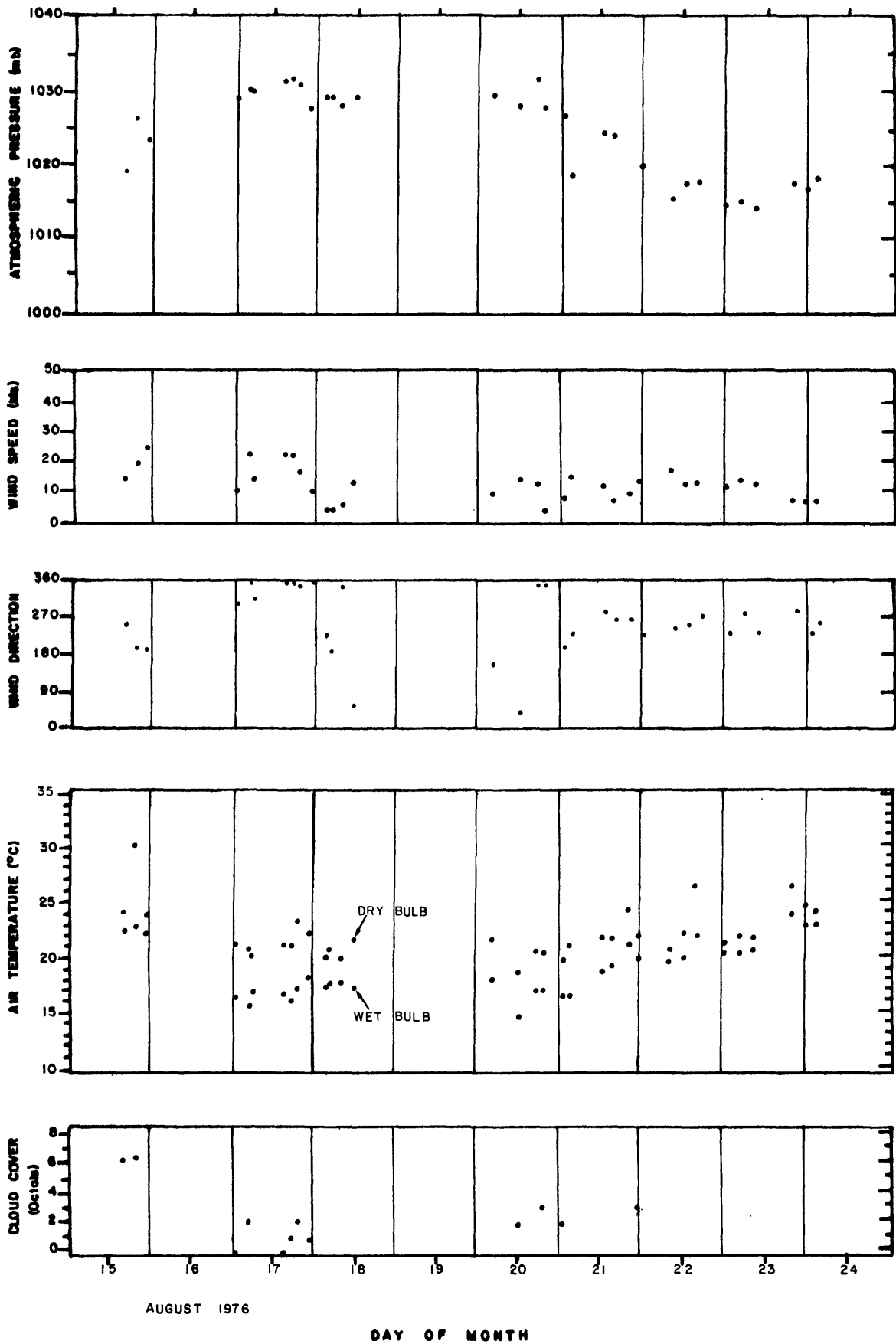


Figure 3-122 Meteorological data collected during cruise BLM 04B 15 to 24 August 1976.

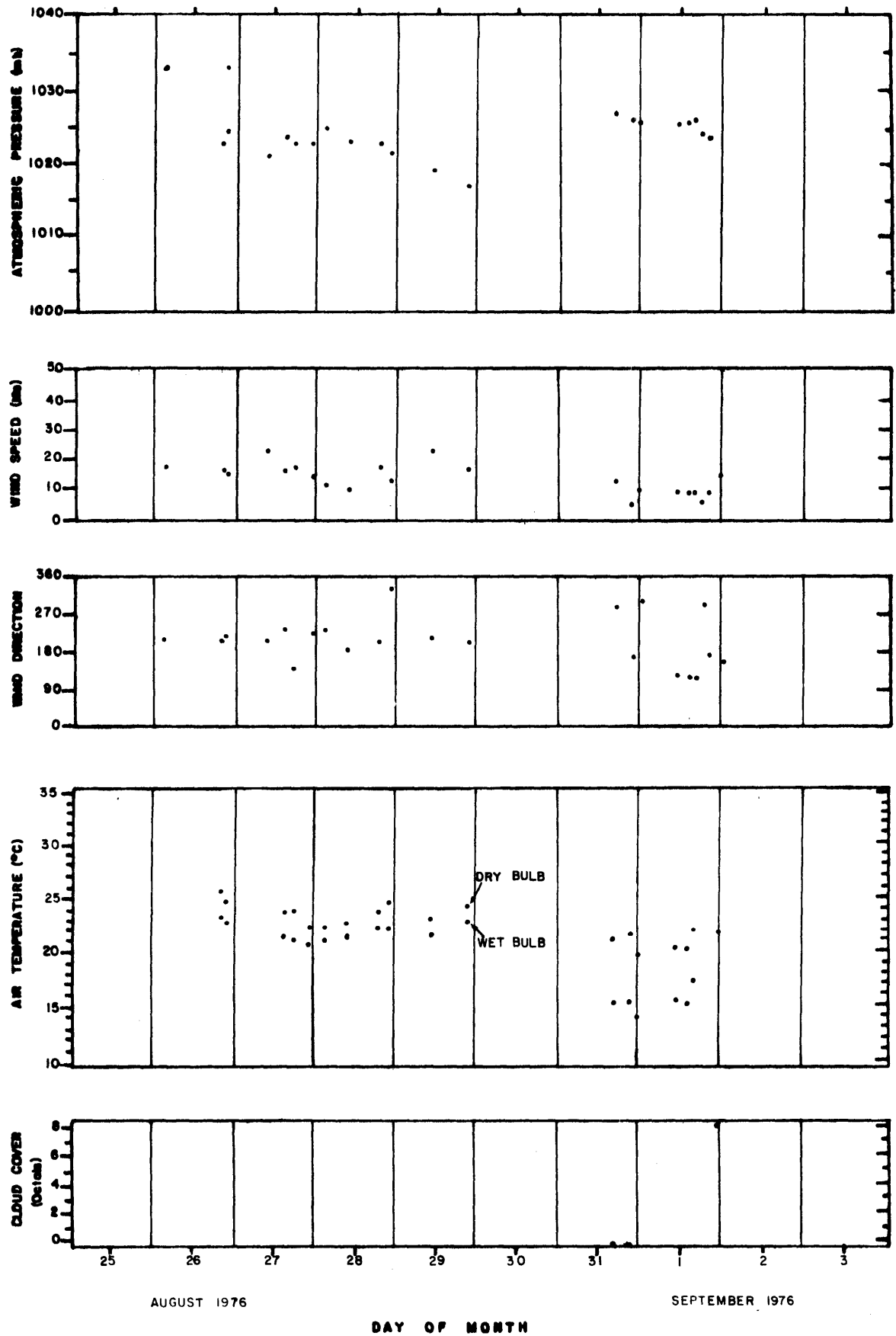


Figure 3-122. (continued) Meteorological data collected during cruise BLM 04B 25 August to 1 September 1976.

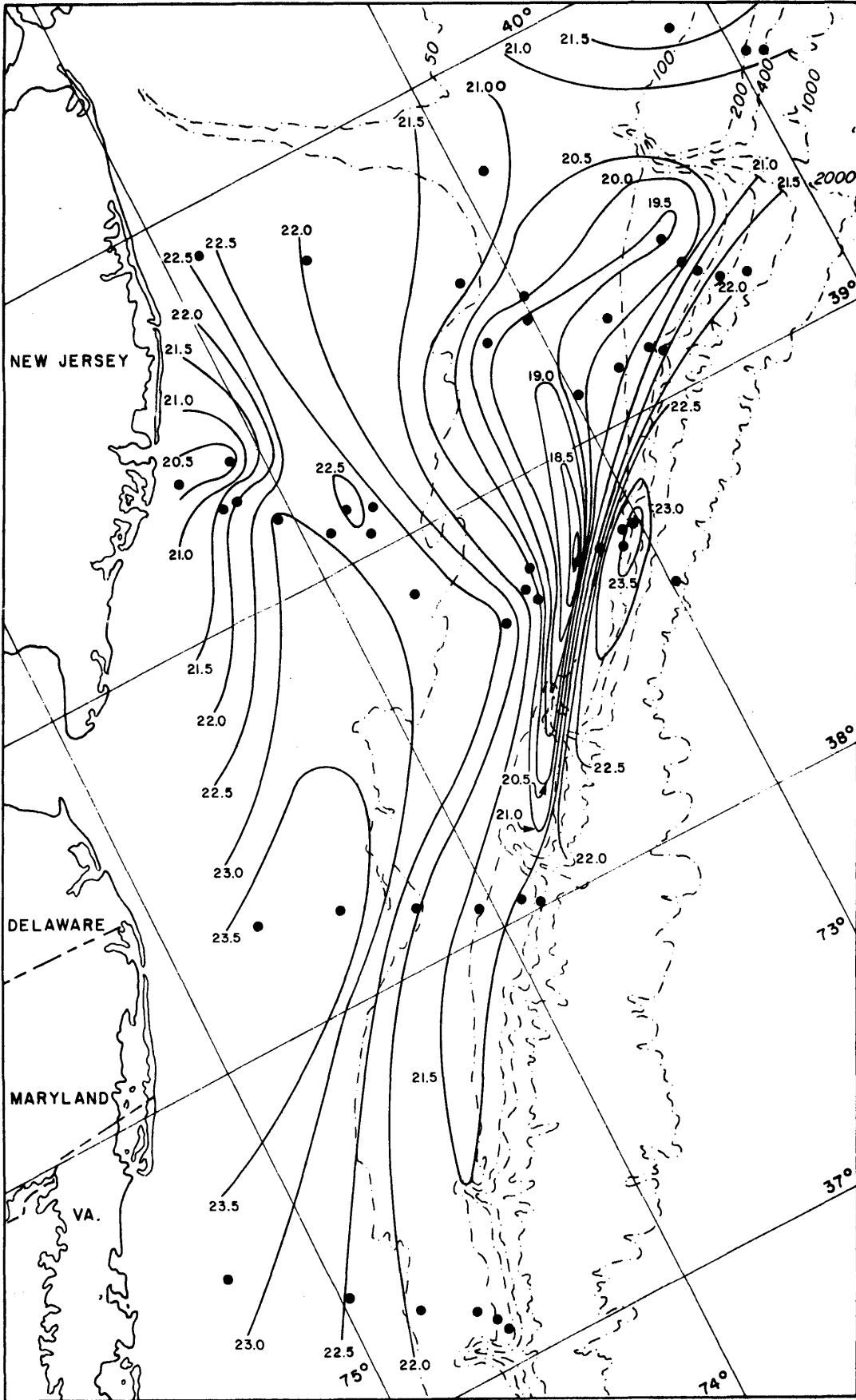


Figure 3-123. Surface temperature ($^{\circ}\text{C}$) distribution in the northern portions of the Middle Atlantic Bight during the period 15 August to 1 September 1976 (Cruise BLM04B)

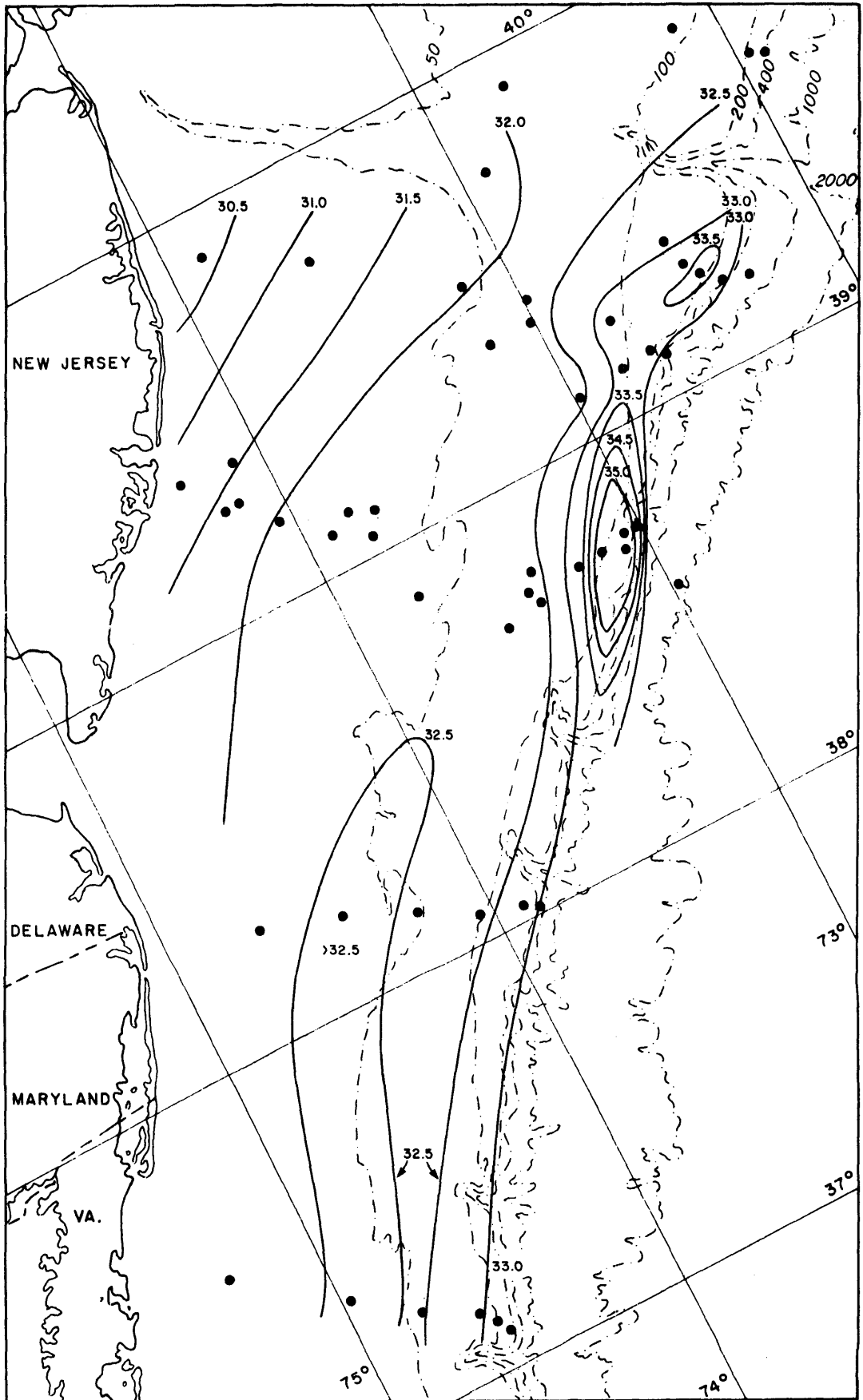


Figure 3-124. Surface salinity (ppt) distribution in the northern portions of the Middle Atlantic Bight during the period 15 August to 1 September 1976 (Cruise BLM04B)

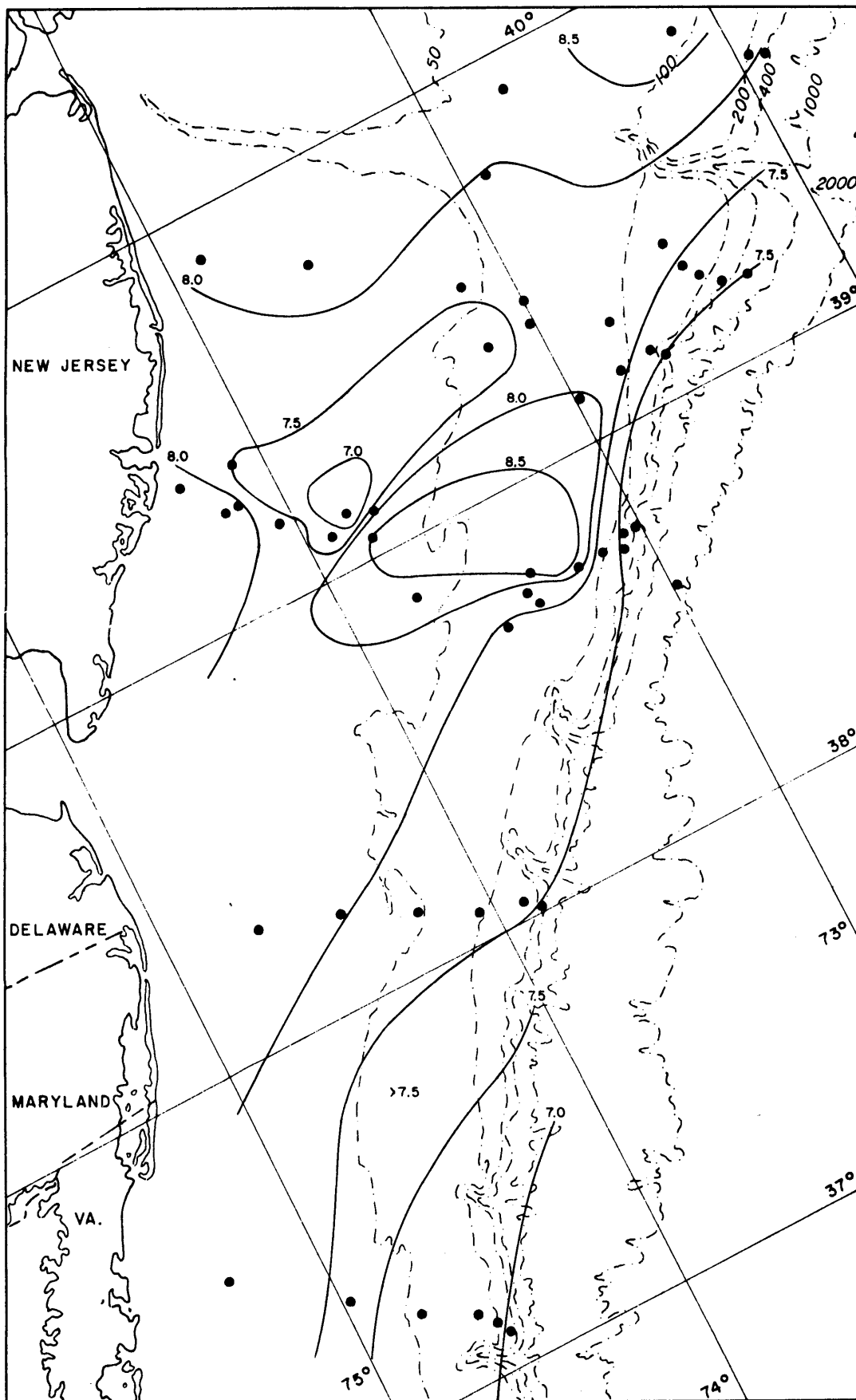


Figure 3-125. Surface dissolved oxygen (mg/l) distribution in the northern portions of the Middle Atlantic Bight during the period 15 August to 1 September 1976 (Cruise BLM04B)

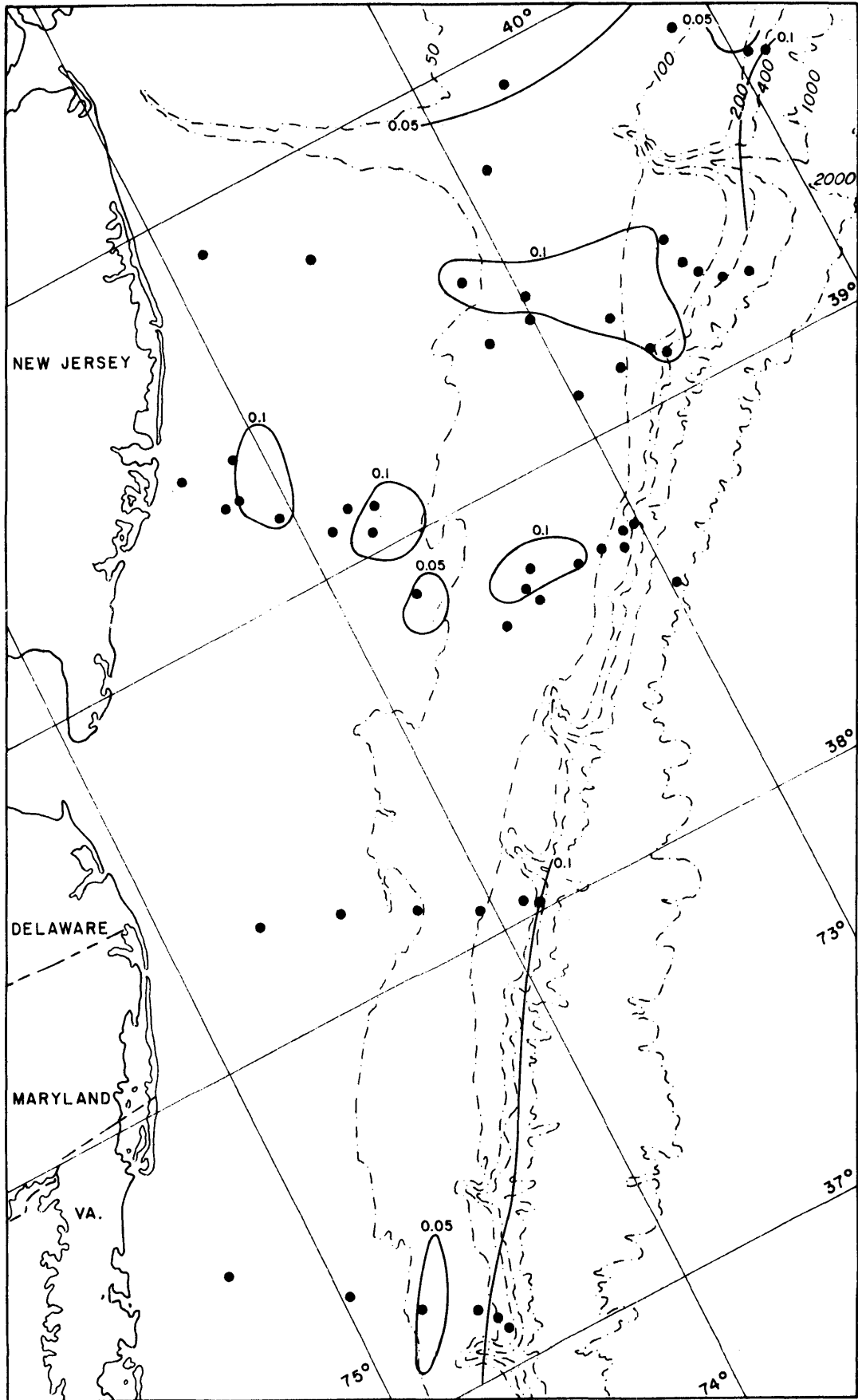


Figure 3-126. Surface NO_2 ($\mu\text{gm atoms/l}$) distribution in the northern portions of the Middle Atlantic Bight during the period 15 August to 1 September 1976 (Cruise BLM04B)

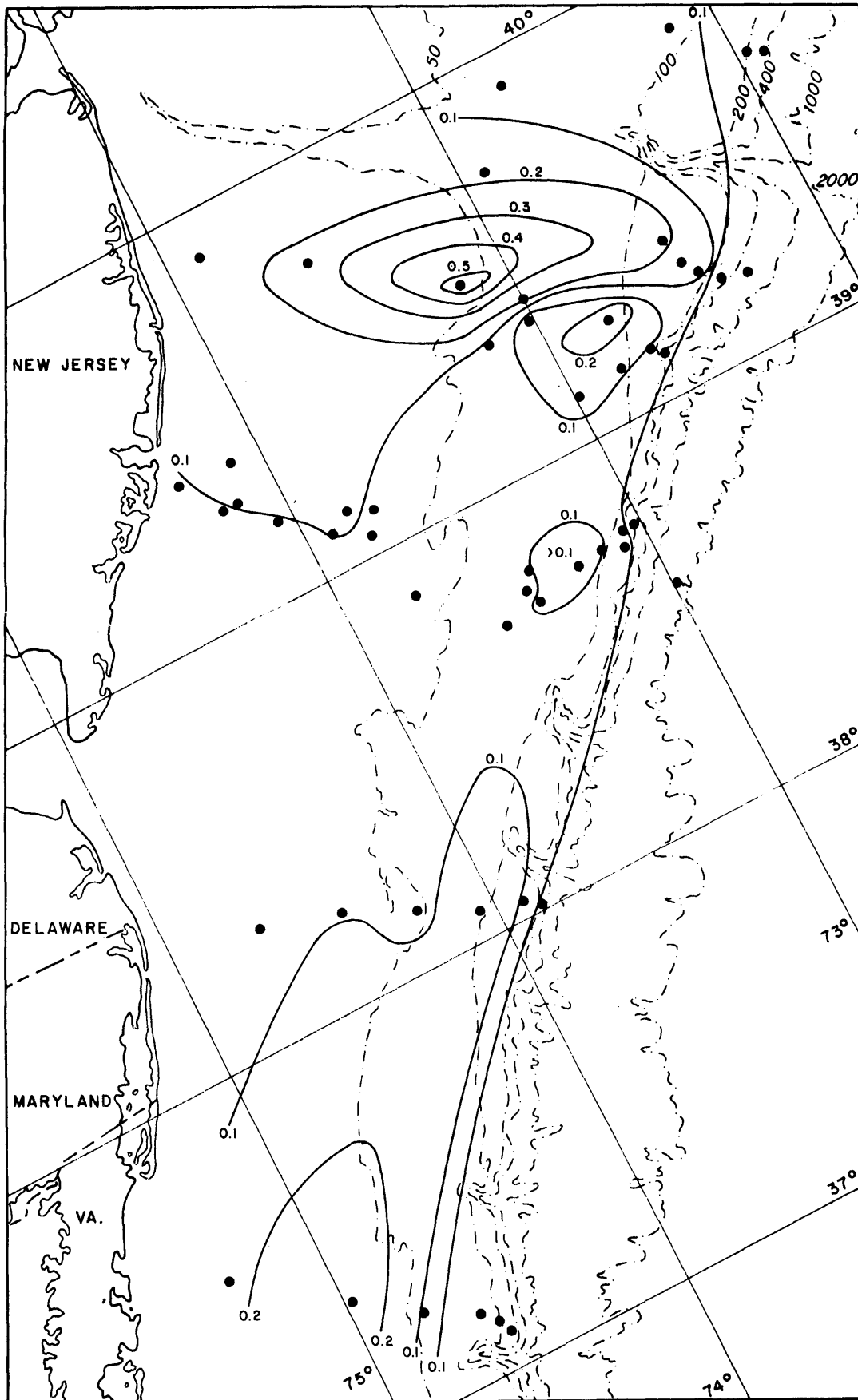


Figure 3-127. Surface NO_3 ($\mu\text{g atoms/l}$) distribution in the northern portions of the Middle Atlantic Bight during the period 15 August to 1 September 1976 (Cruise BLM04B)

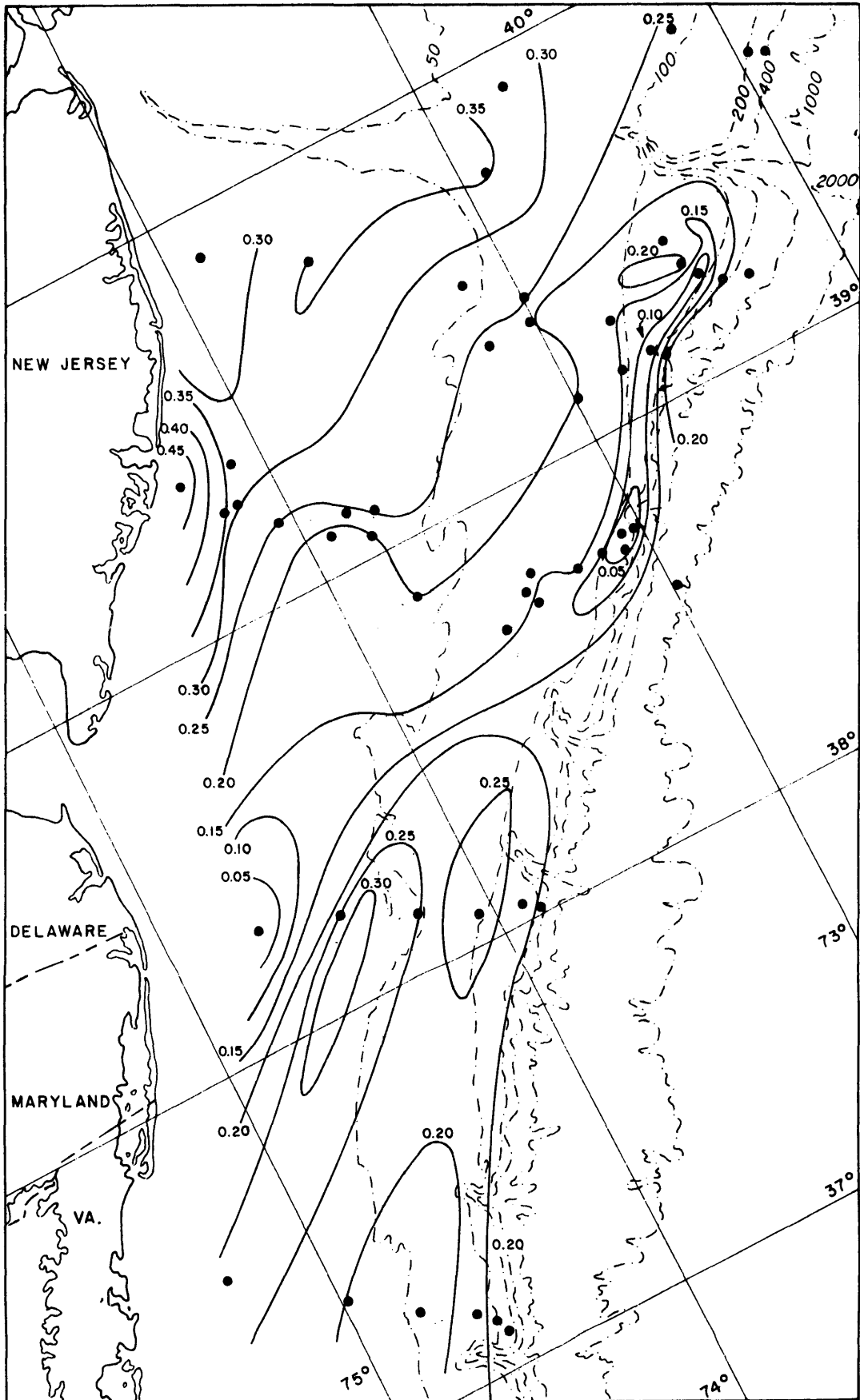


Figure 3-128. Surface $O-PO_4$ ($\mu\text{g atoms/l}$) distribution in the northern portions of the Middle Atlantic Bight during the period 15 August to 1 September 1976 (Cruise BLM04B)

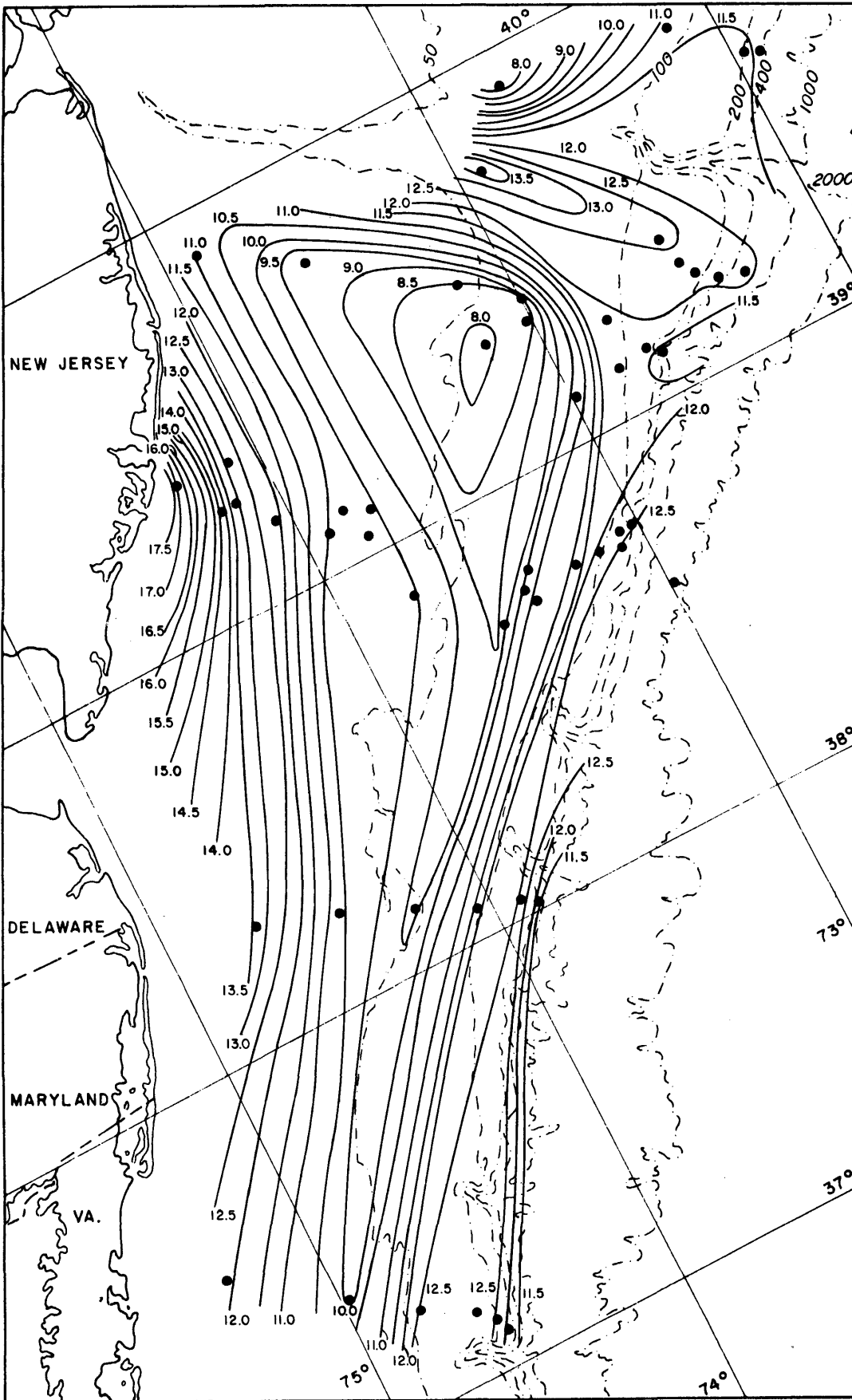


Figure 3-129. Bottom temperature ($^{\circ}\text{C}$) distribution in the northern portions of the Middle Atlantic Bight during the period 15 August to 1 September 1976 (Cruise BLM04B)

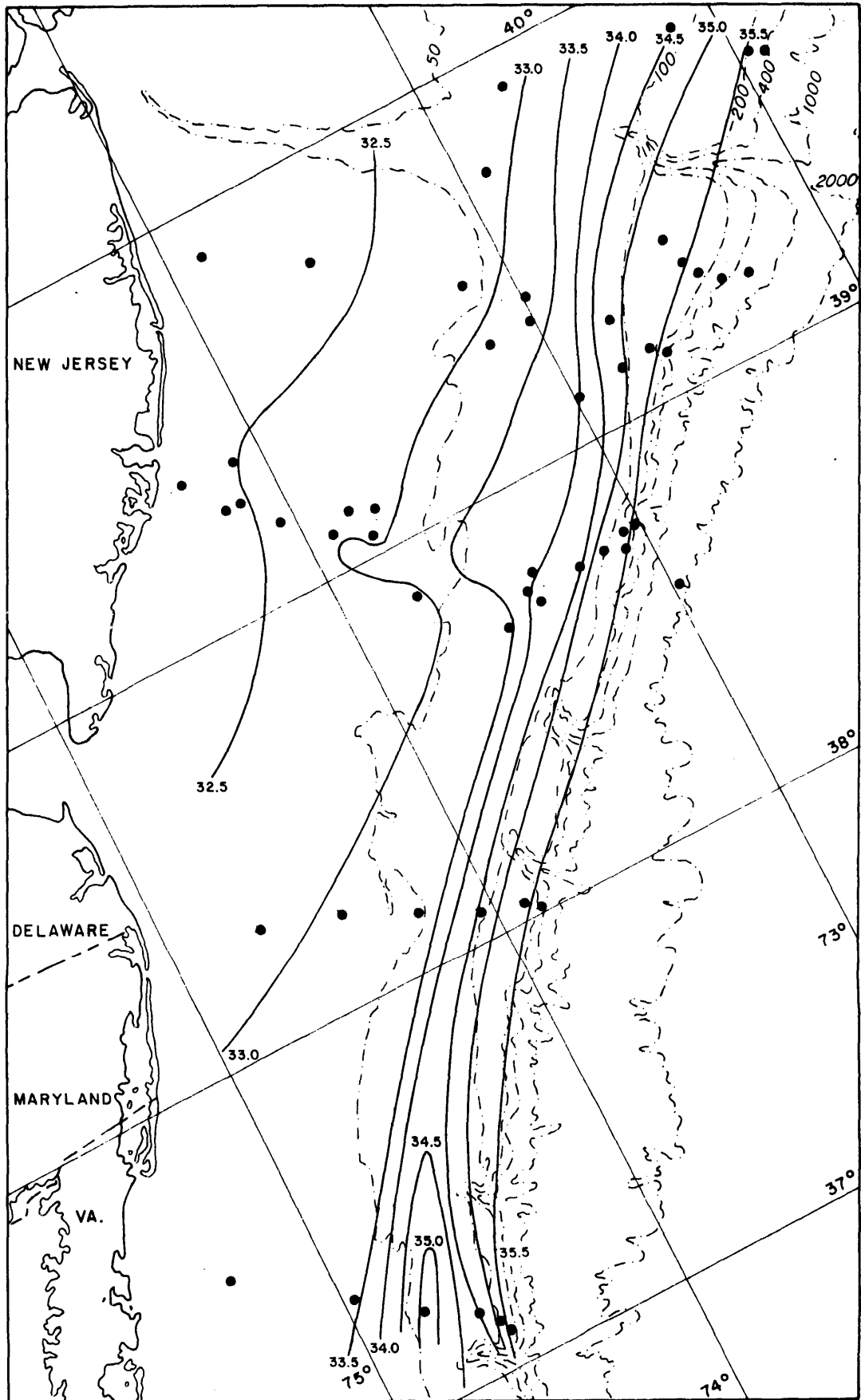


Figure 3-130. Bottom salinity (ppt) distribution in the northern portions of the Middle Atlantic Bight during the period 15 August to 1 September 1976 (Cruise BLM04B)

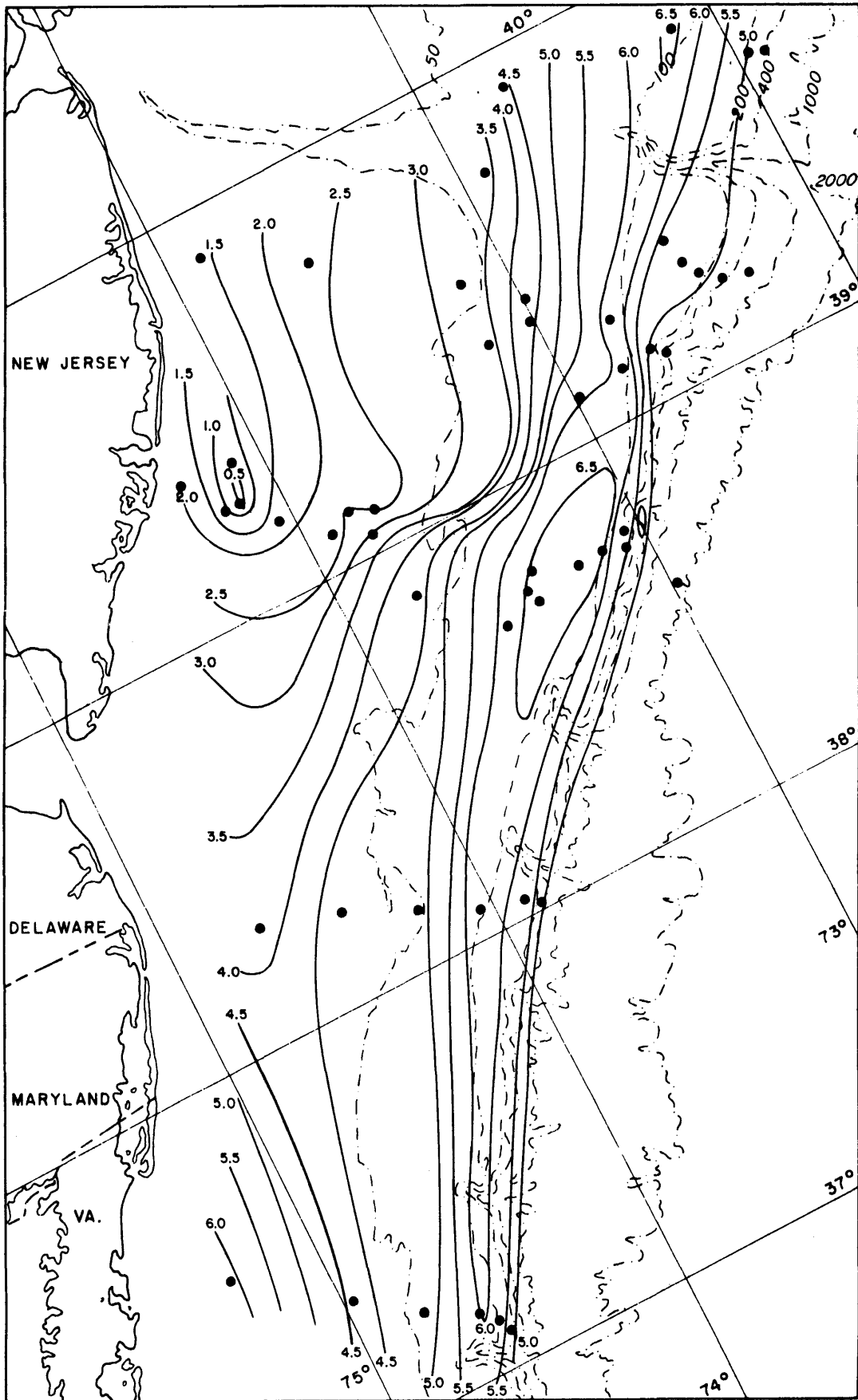


Figure 3-131. Bottom dissolved oxygen (mg/l) distribution in the northern portions of the Middle Atlantic Bight during the period 15 August to 1 September 1976 (Cruise BLM04B)

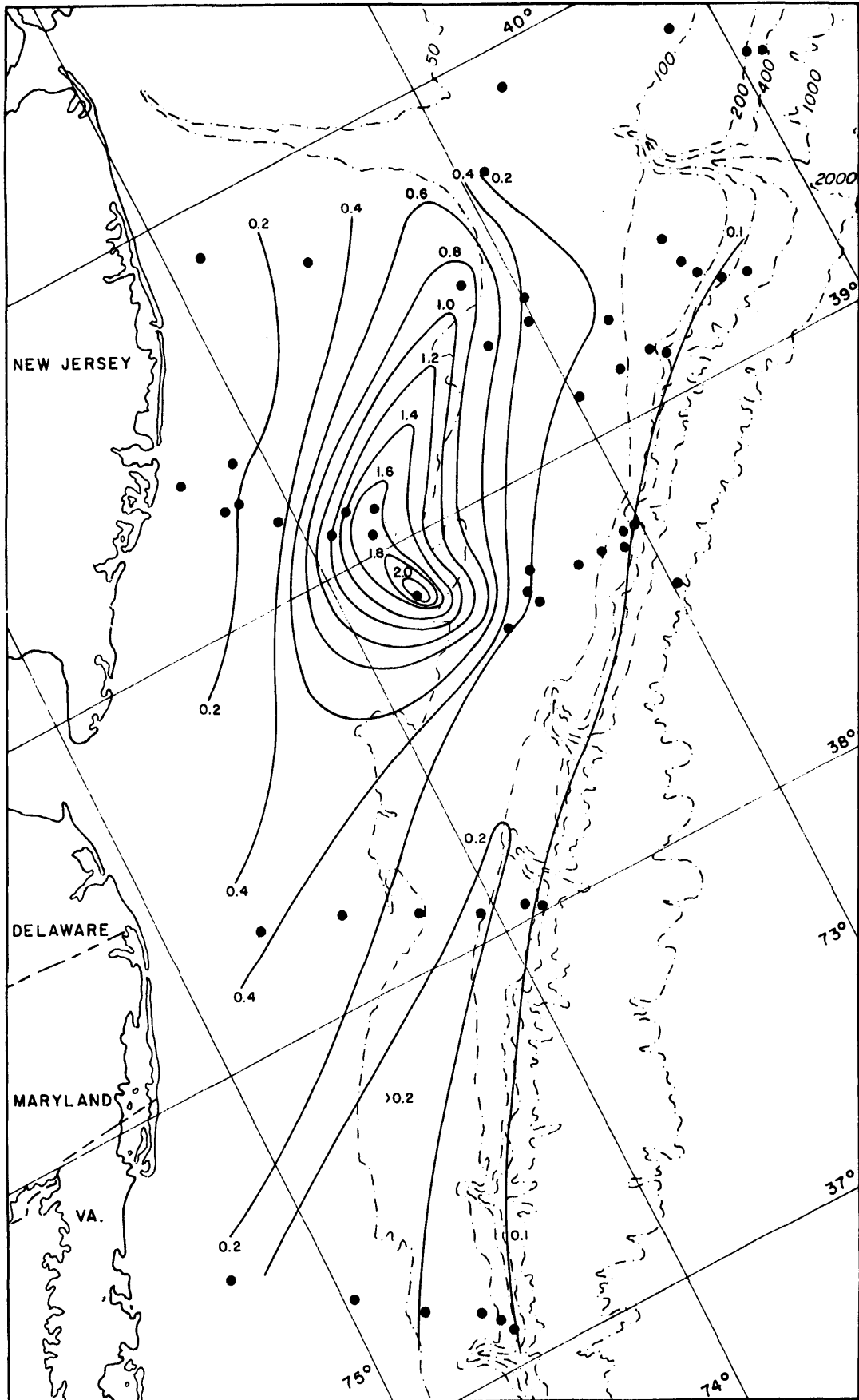


Figure 3-132. Bottom NO₂ ($\mu\text{gm atoms/l}$) distribution in the northern portions of the Middle Atlantic Bight during the period 15 August to 1 September 1976 (Cruise BLM04B)

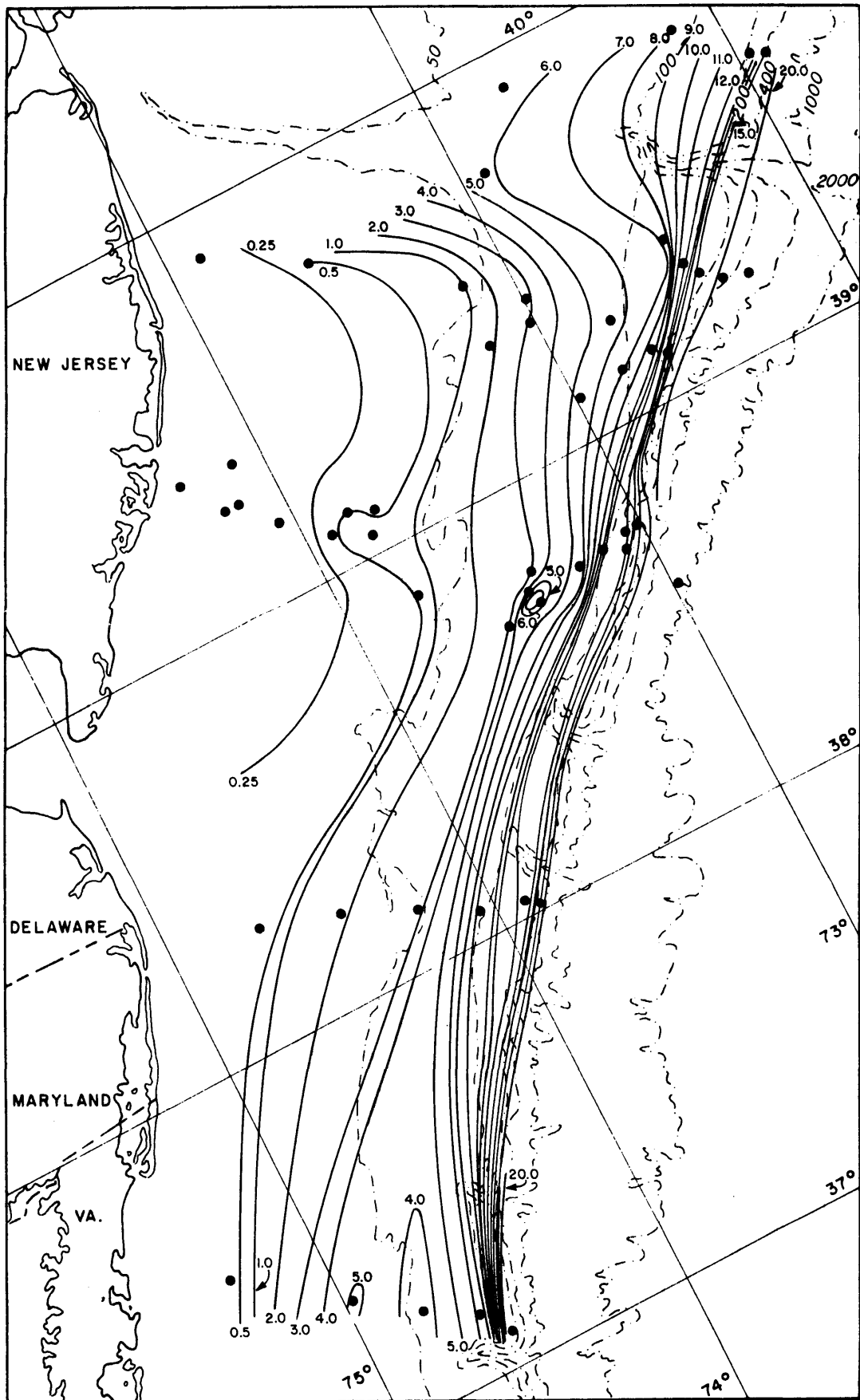


Figure 3-133. Bottom NO_3 ($\mu\text{g atoms/l}$) distribution in the northern portions of the Middle Atlantic Bight during the period 15 August to 1 September 1976 (Cruise BLM04B)

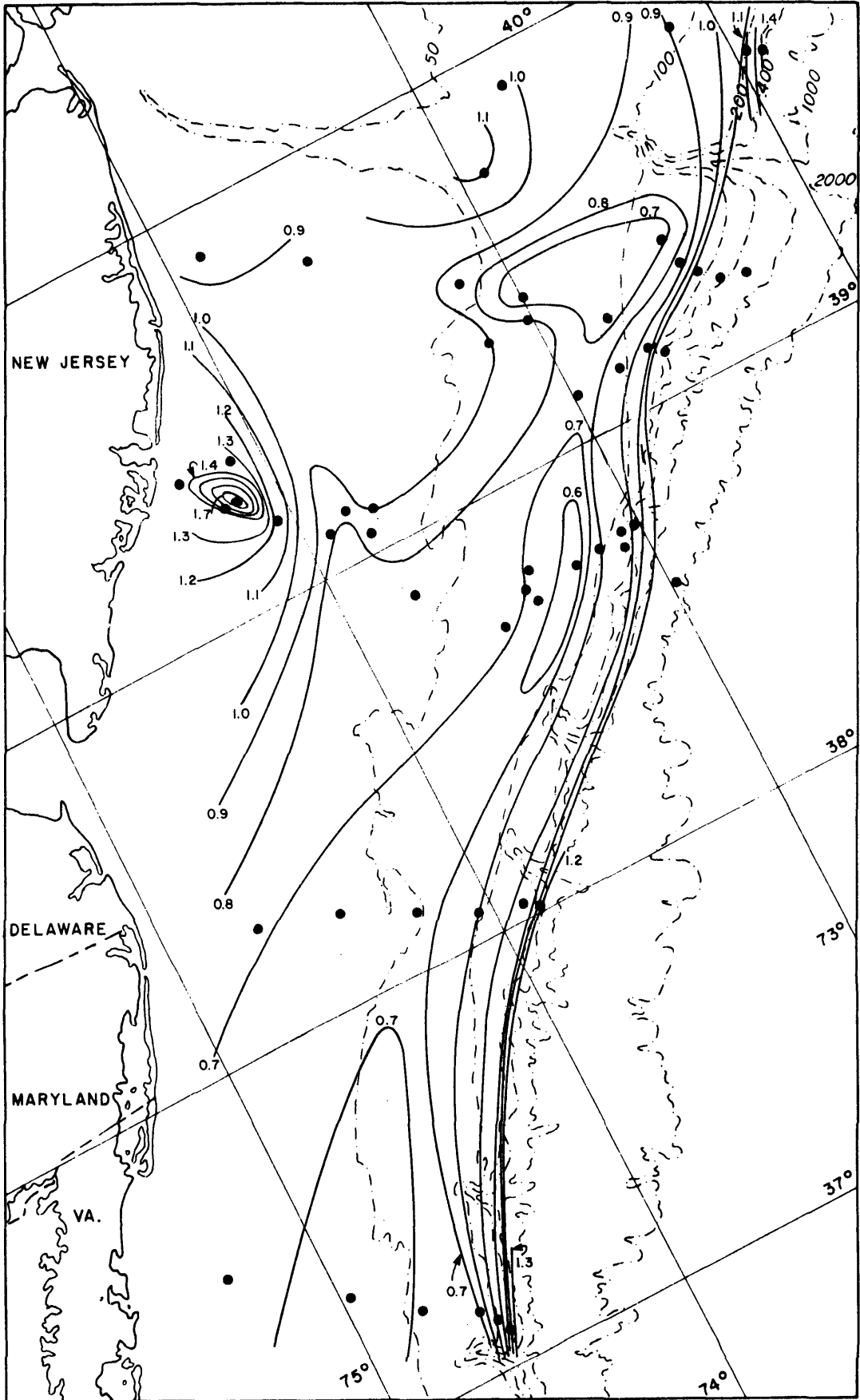


Figure 3-134. Bottom O-PO₄ (μgm atoms/l) distribution in the northern portions of the Middle Atlantic Bight during the period 15 August to 1 September 1976 (Cruise BLM04B)

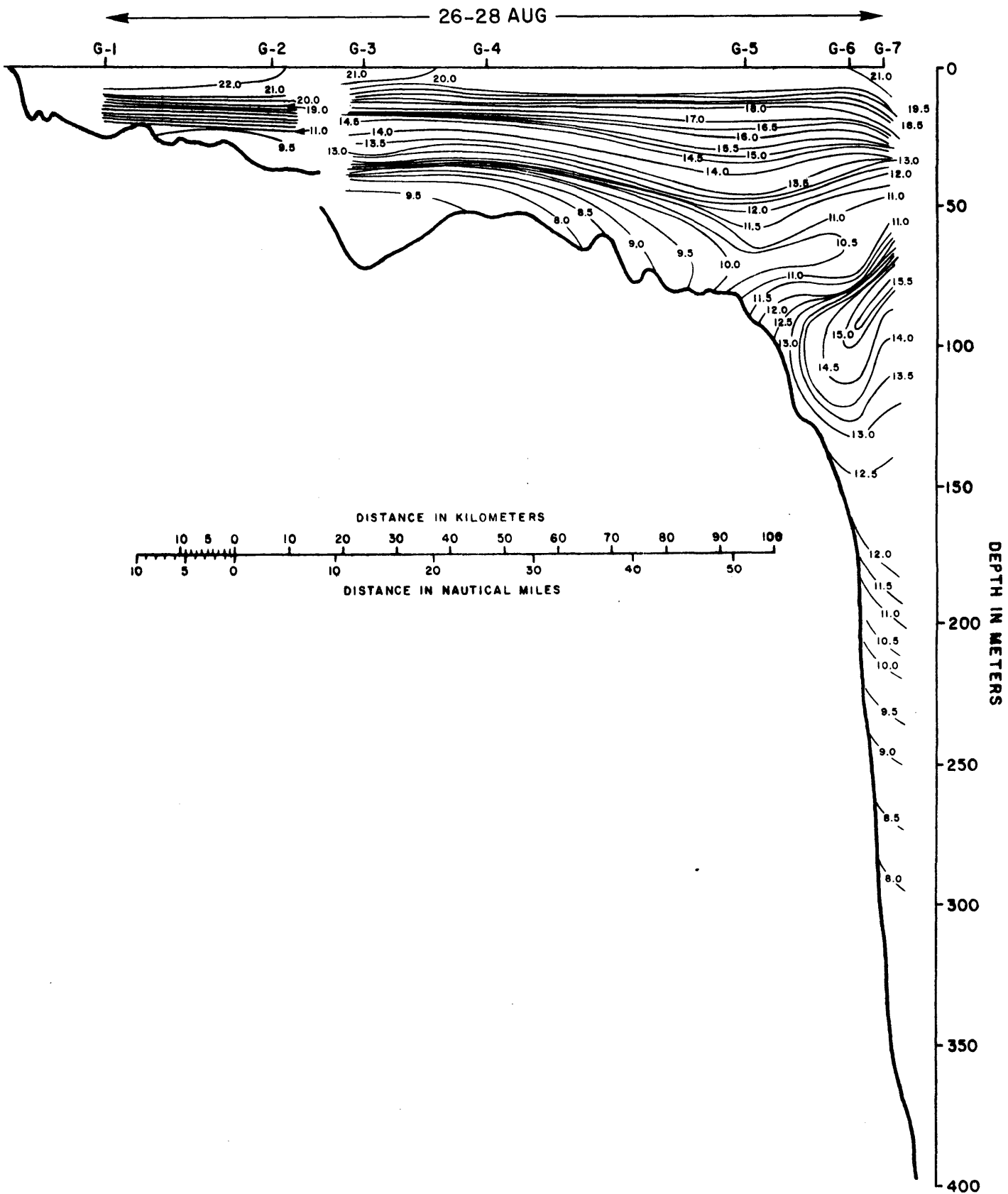


Figure 3-135. Temperature ($^{\circ}\text{C}$) along Section I (Stations G1 to G7, 26-28 August 1976) during cruise BLM04B. Section location is shown in Figure 3-10. Breaks in isopleths signify spatial breaks in sampling continuity.

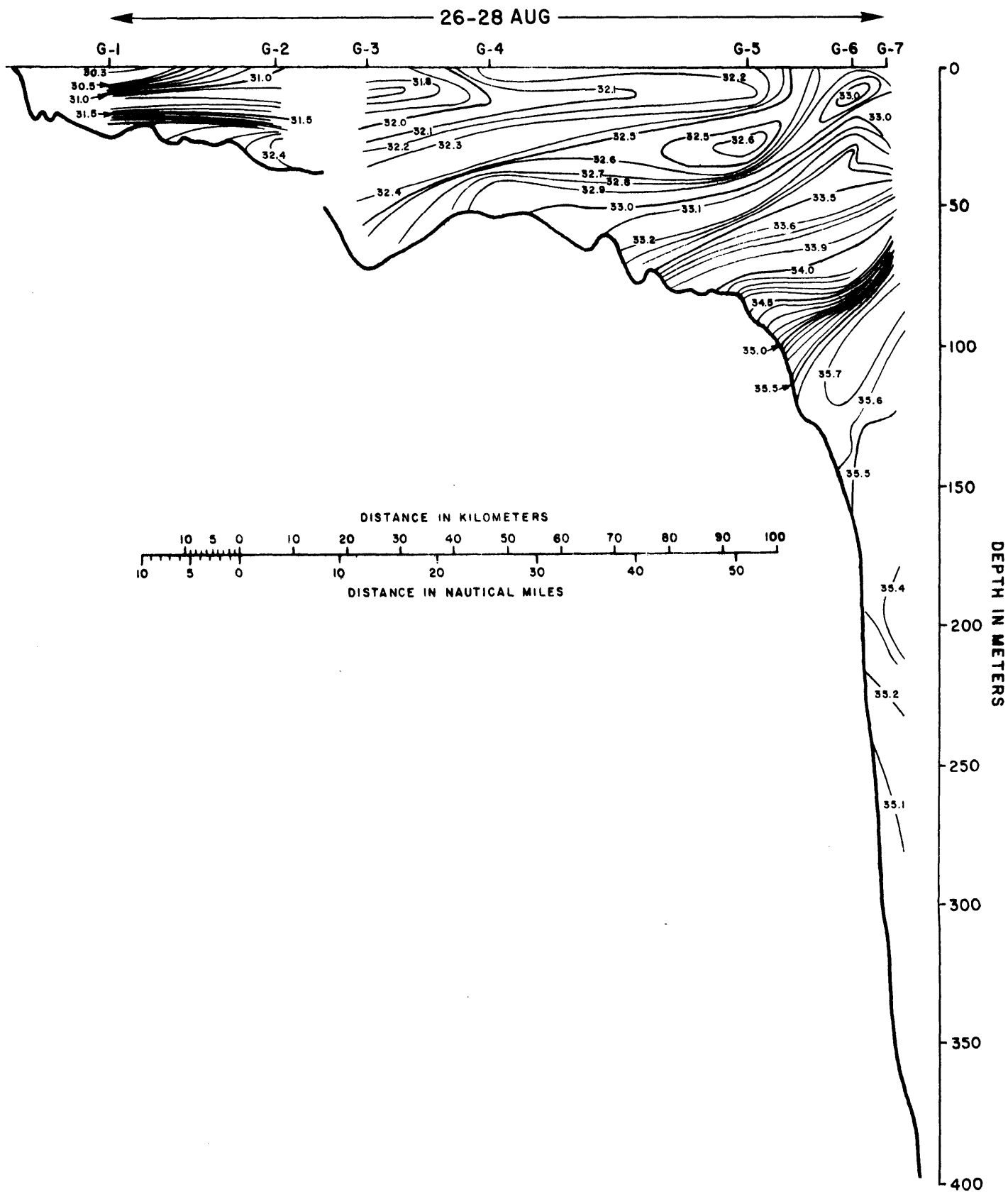


Figure 3-136. Salinity (ppt) along Section I (Stations G1 to G7, 26-28 August 1976) during cruise BLM04B. Section location is shown in Figure 3-10. Breaks in isopleths signify spatial breaks in sampling continuity.

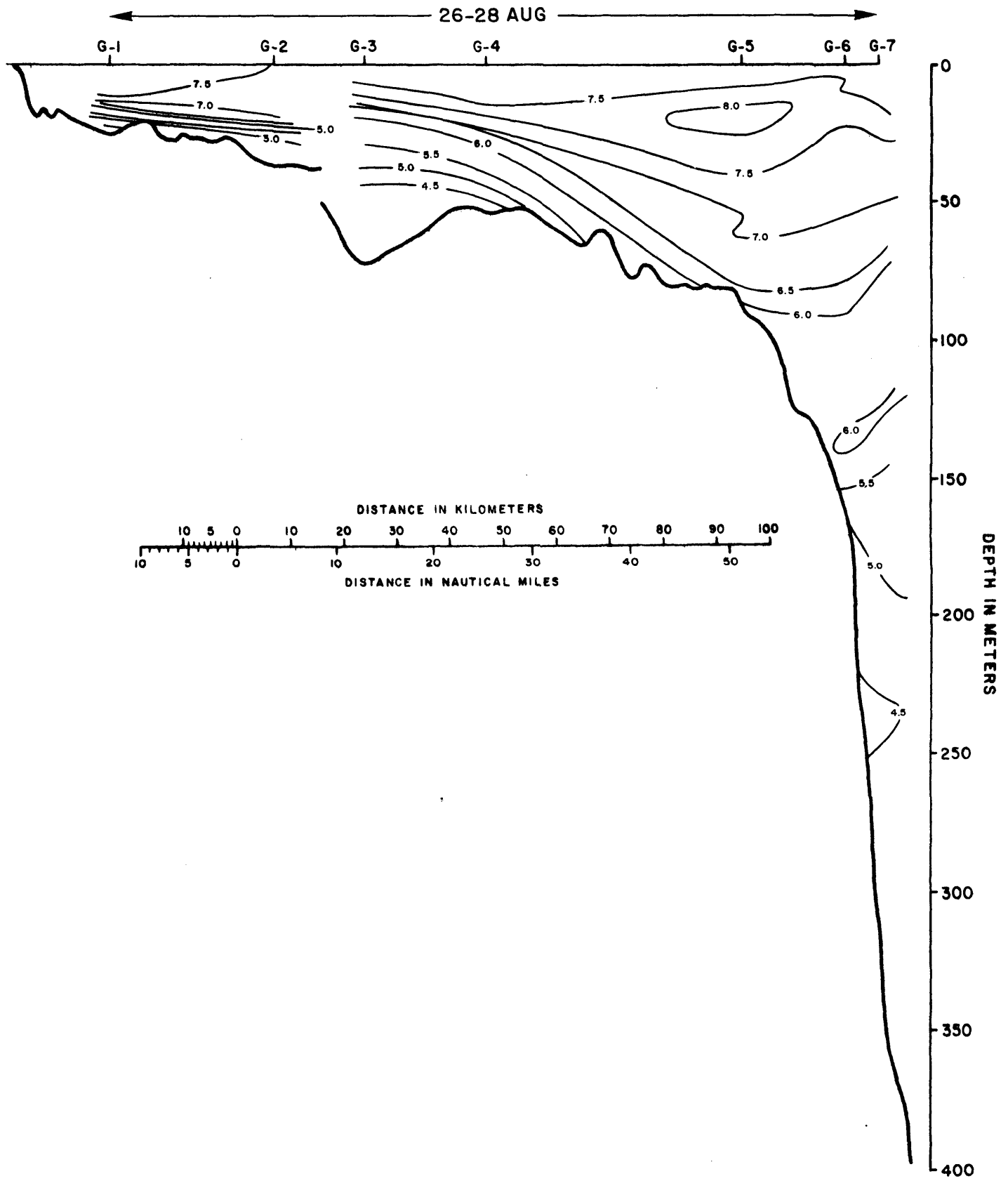


Figure 3-137. Dissolved oxygen (mg/l) along Section I (Stations G1 to G7, 26-28 August 1976) during cruise BLM 4B. Section location is shown in Figure 3-10. Breaks in isopleths signify spatial breaks in sampling continuity.

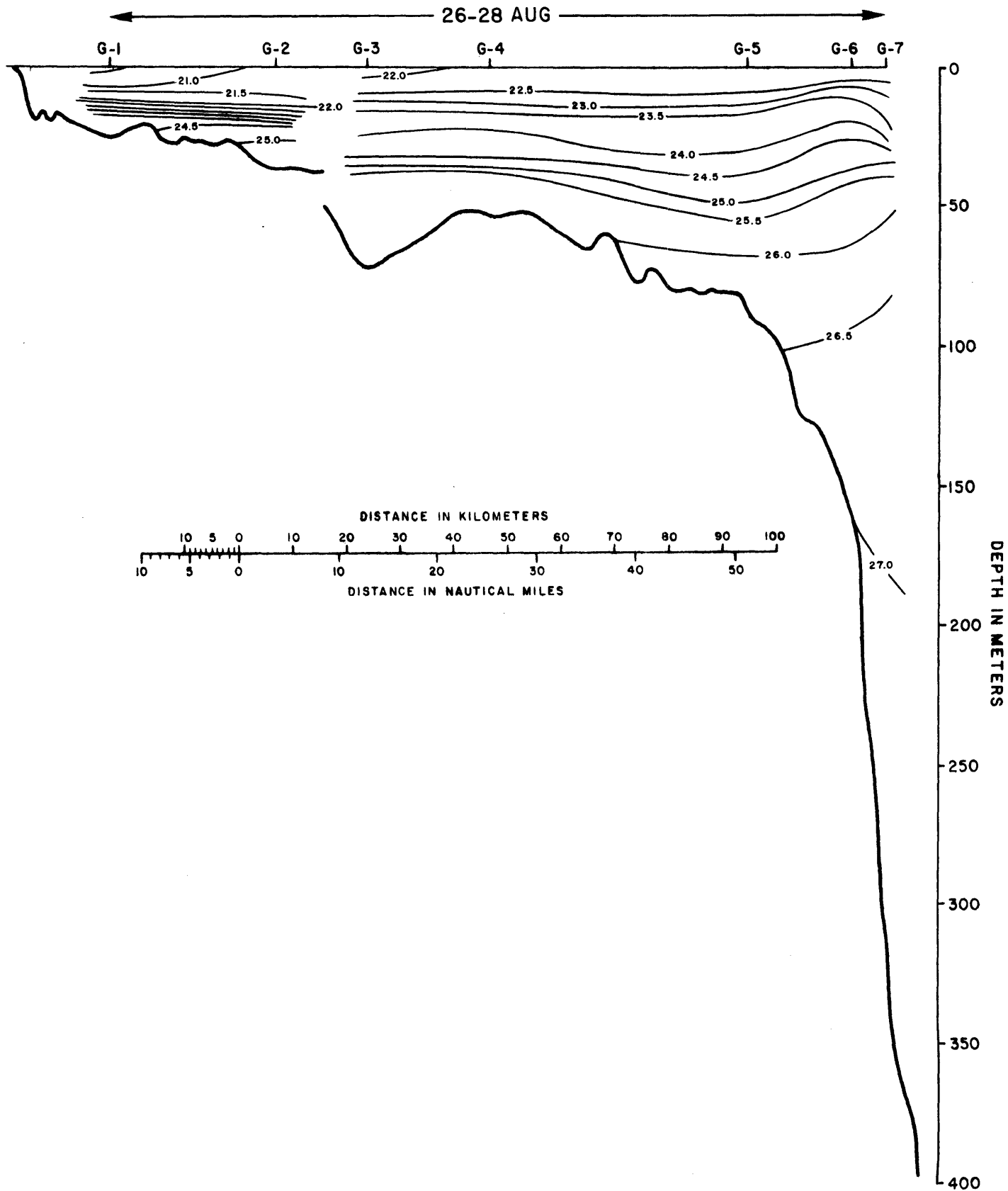


Figure 3-138. Density (σ_t units) along Section I (Stations G1 to G7, 26-28 August 1976) during cruise BLM04B. Section location is shown in Figure 3-10. Breaks in isopleths signify spatial breaks in sampling continuity.

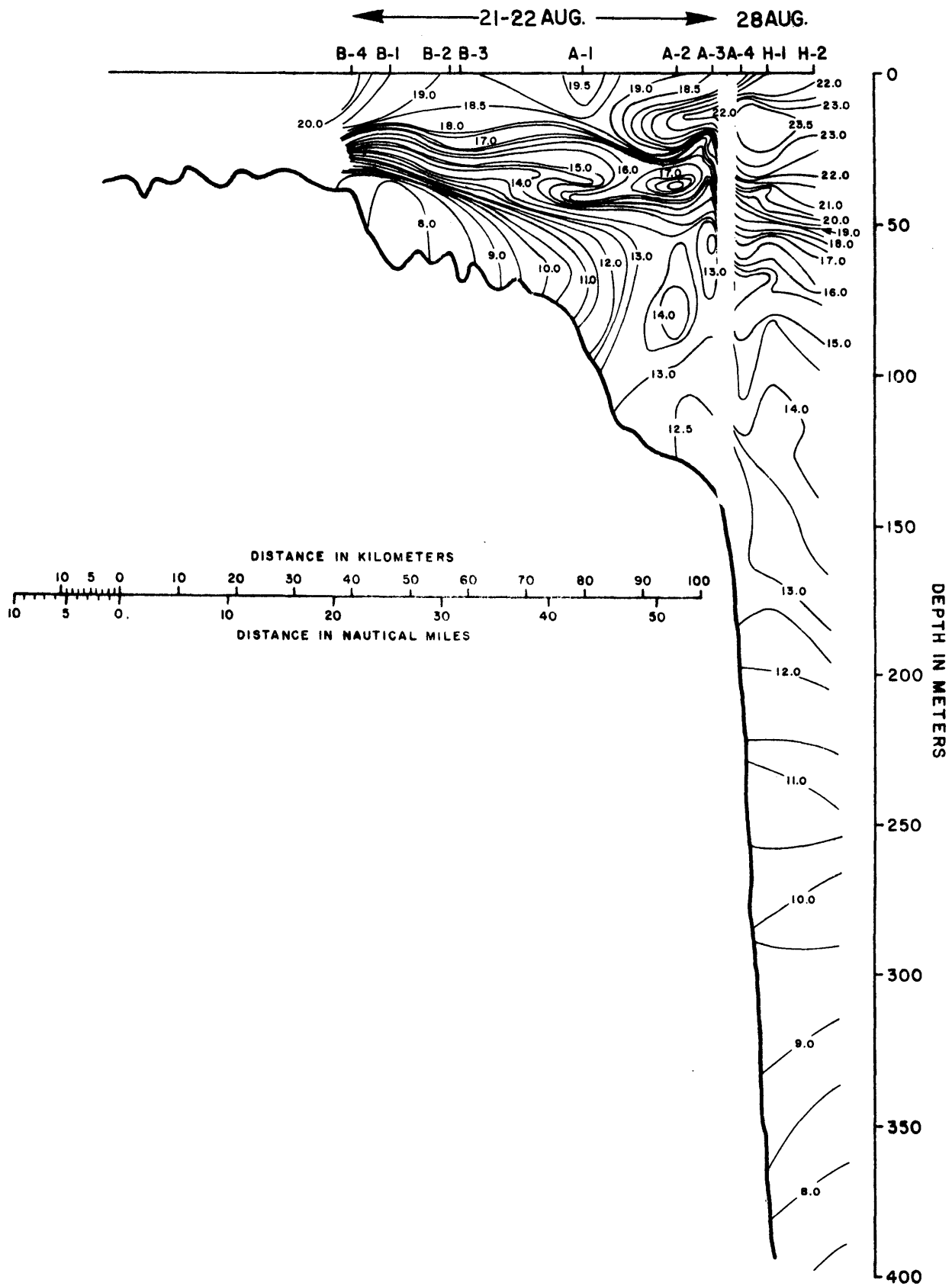


Figure 3-139. Temperature ($^{\circ}\text{C}$) along Section II (Stations B4 to H2, 21-28 August 1976) during cruise BLM04B. Section location is shown in Figure 3-10.

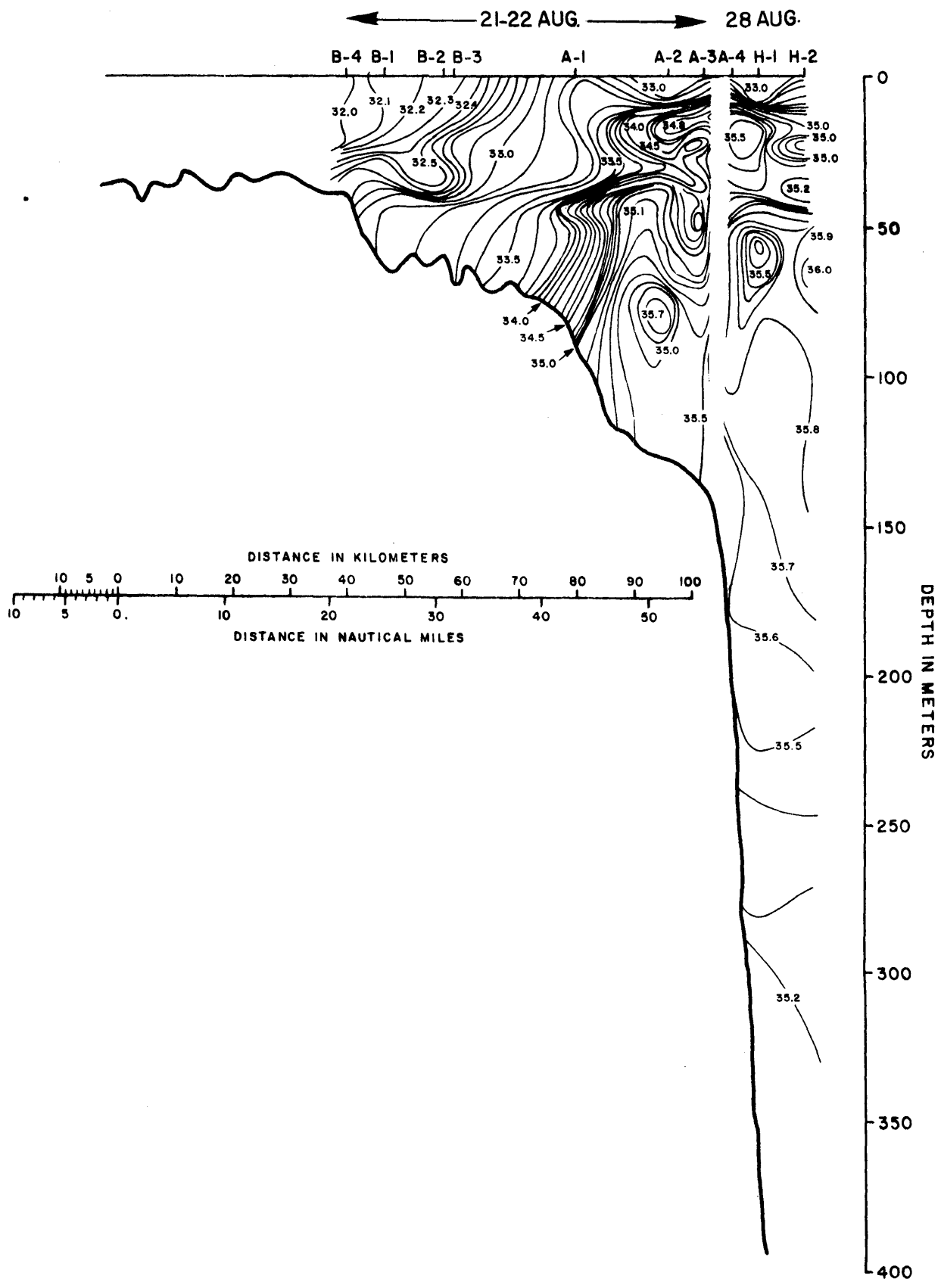


Figure 3-140. Salinity (ppt) along Section II (Stations B4 to H2, 21-28 August 1976) during cruise BLM04B. Section location is shown in Figure 3-10.

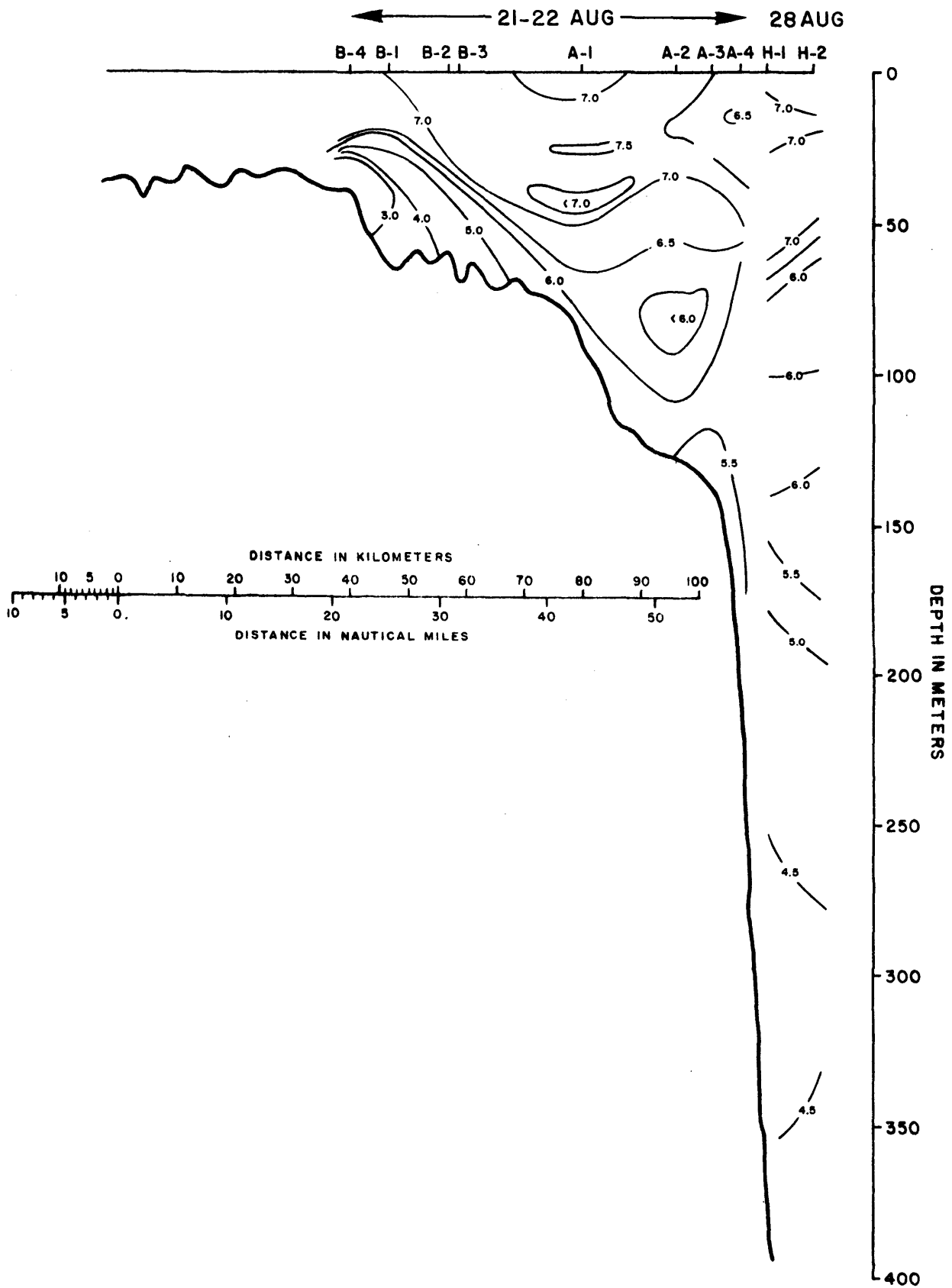


Figure 3-141. Dissolved oxygen (mg/l) along Section II (Stations B4 to H2, 21-28 August 1976) during cruise BLM04B. Section location is shown in Figure 3-10.

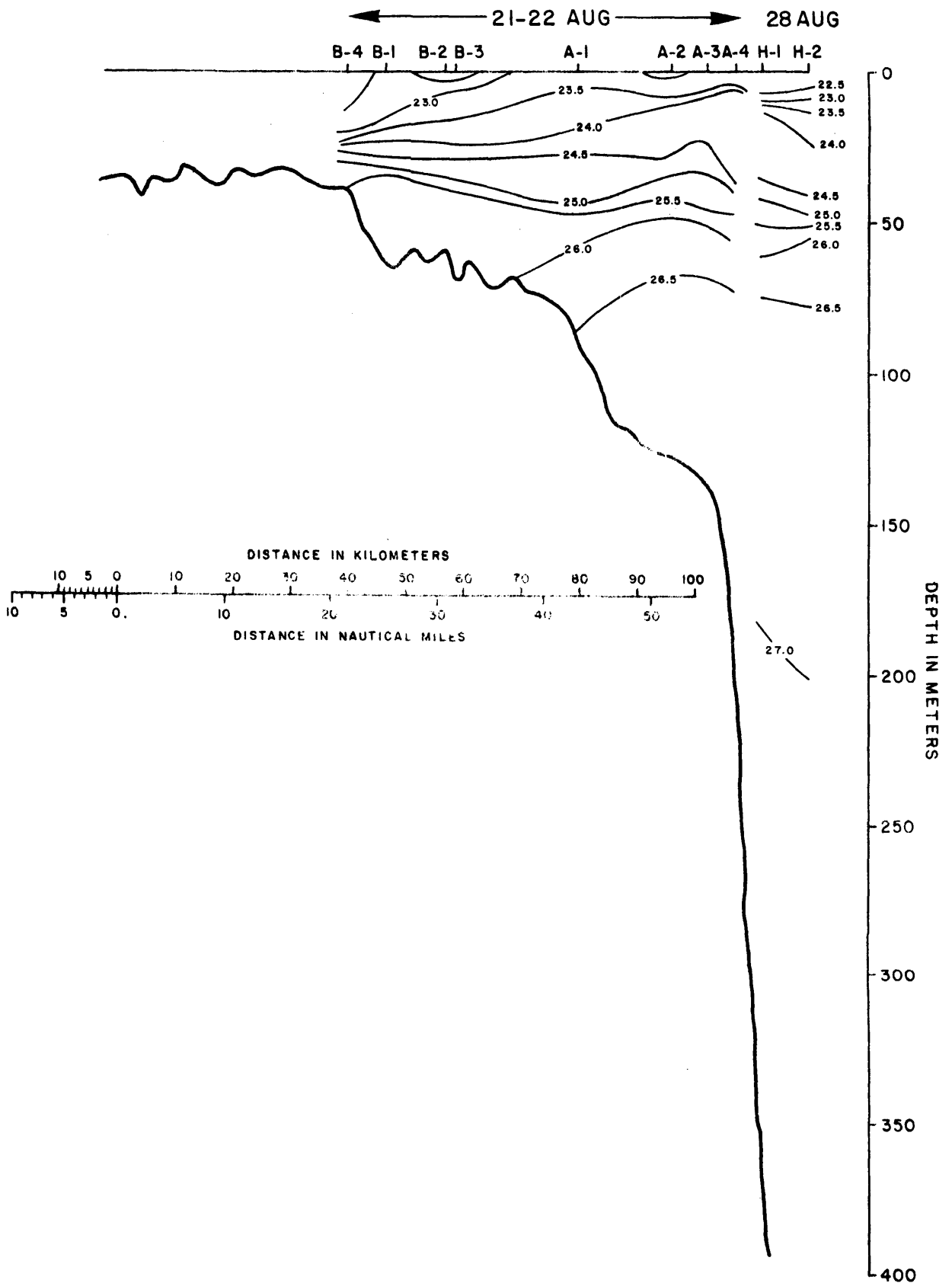


Figure 3-142. Density (σ_t units) along Section II (Stations B4 to H2, 21-28 August 1976) during cruise BLM04B. Section location is shown in Figure 3-10.

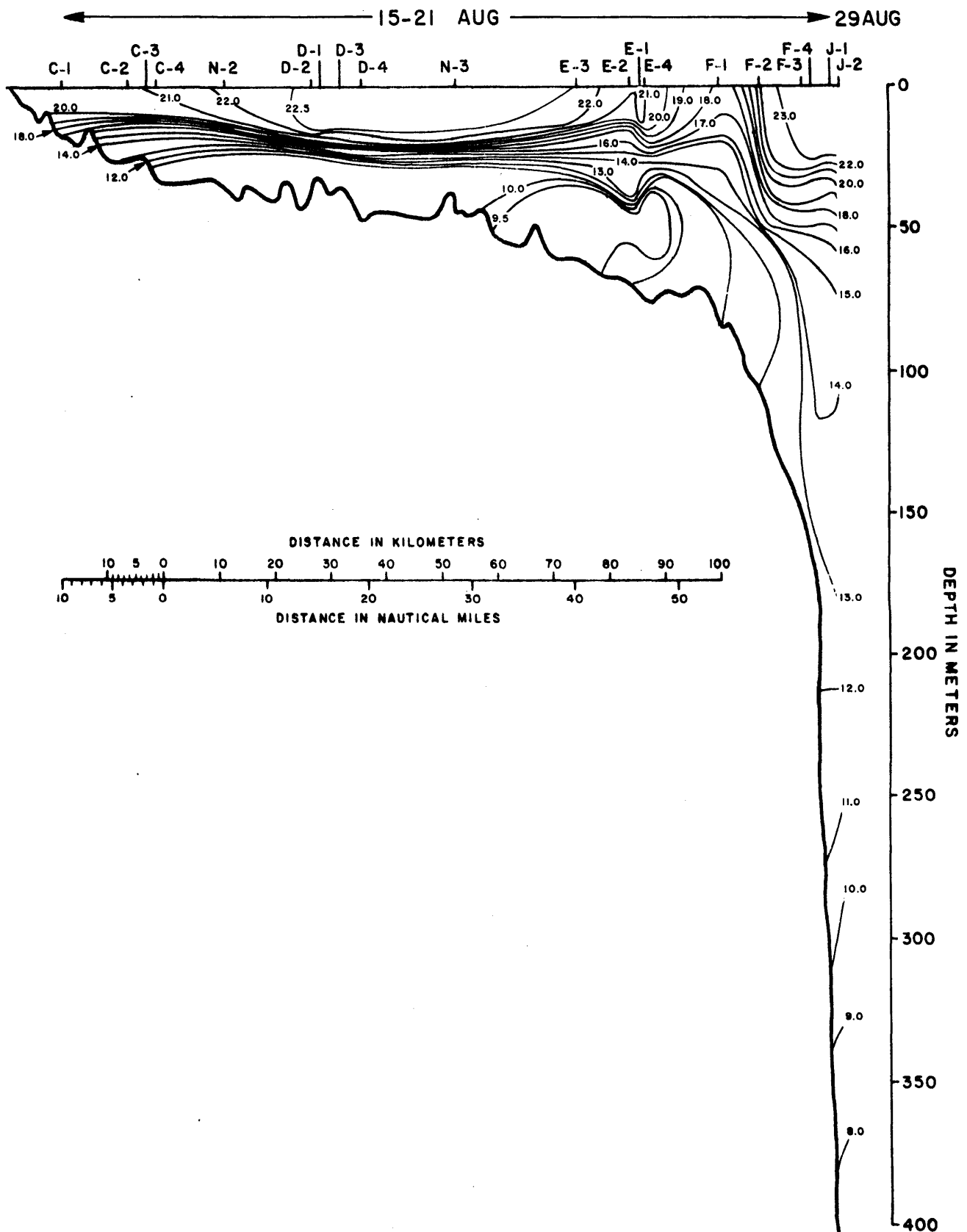


Figure 3-143. Temperature ($^{\circ}\text{C}$) along Section III (Stations C1 to J2, 15-29 August 1976) during cruise BLM04B. Section location is shown in Figure 3-10.

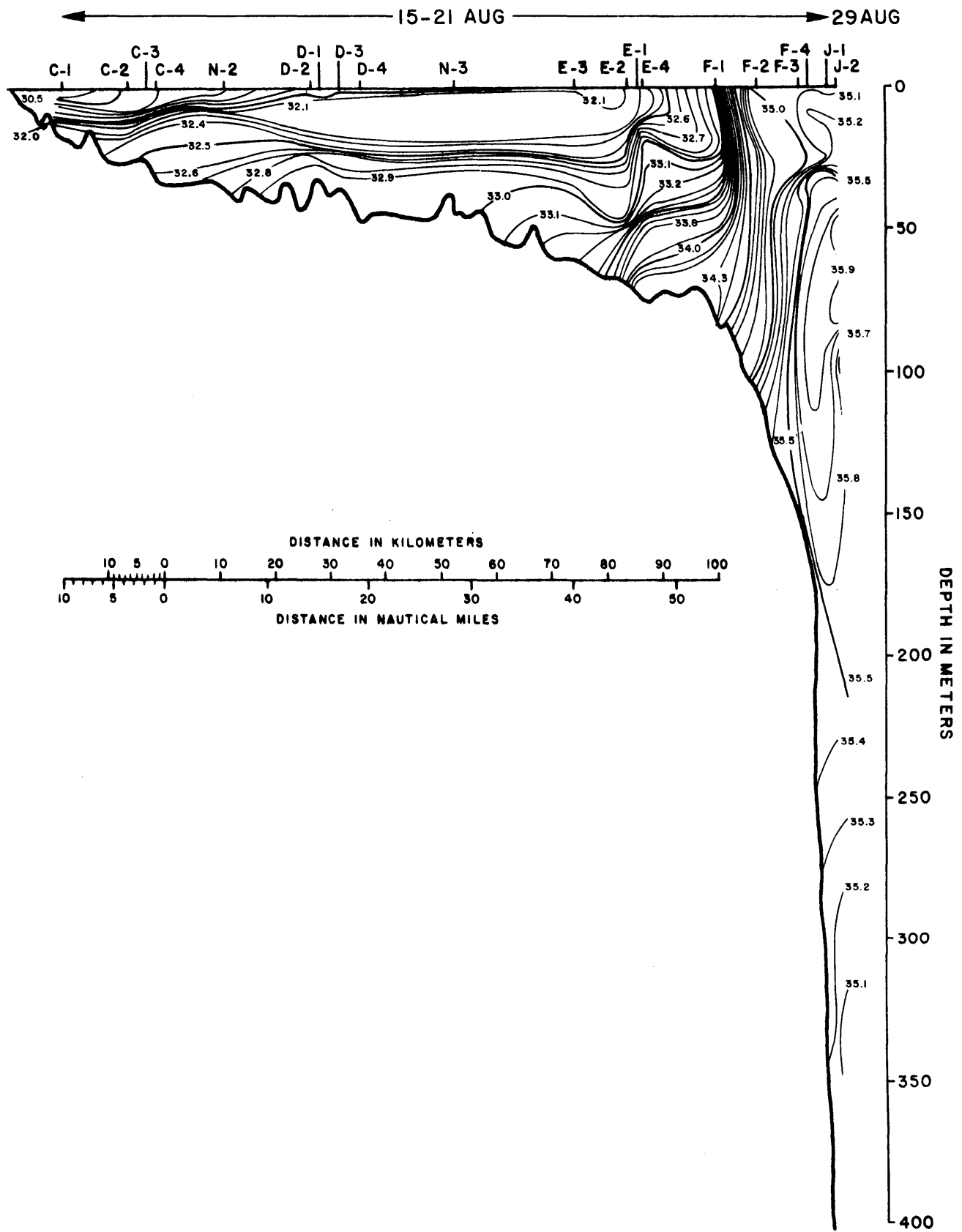


Figure 3-144. Salinity (ppt) along Section III (Stations C1 to J2, 15-29 August 1976) during cruise BLM04B. Section location is shown in Figure 3-10.

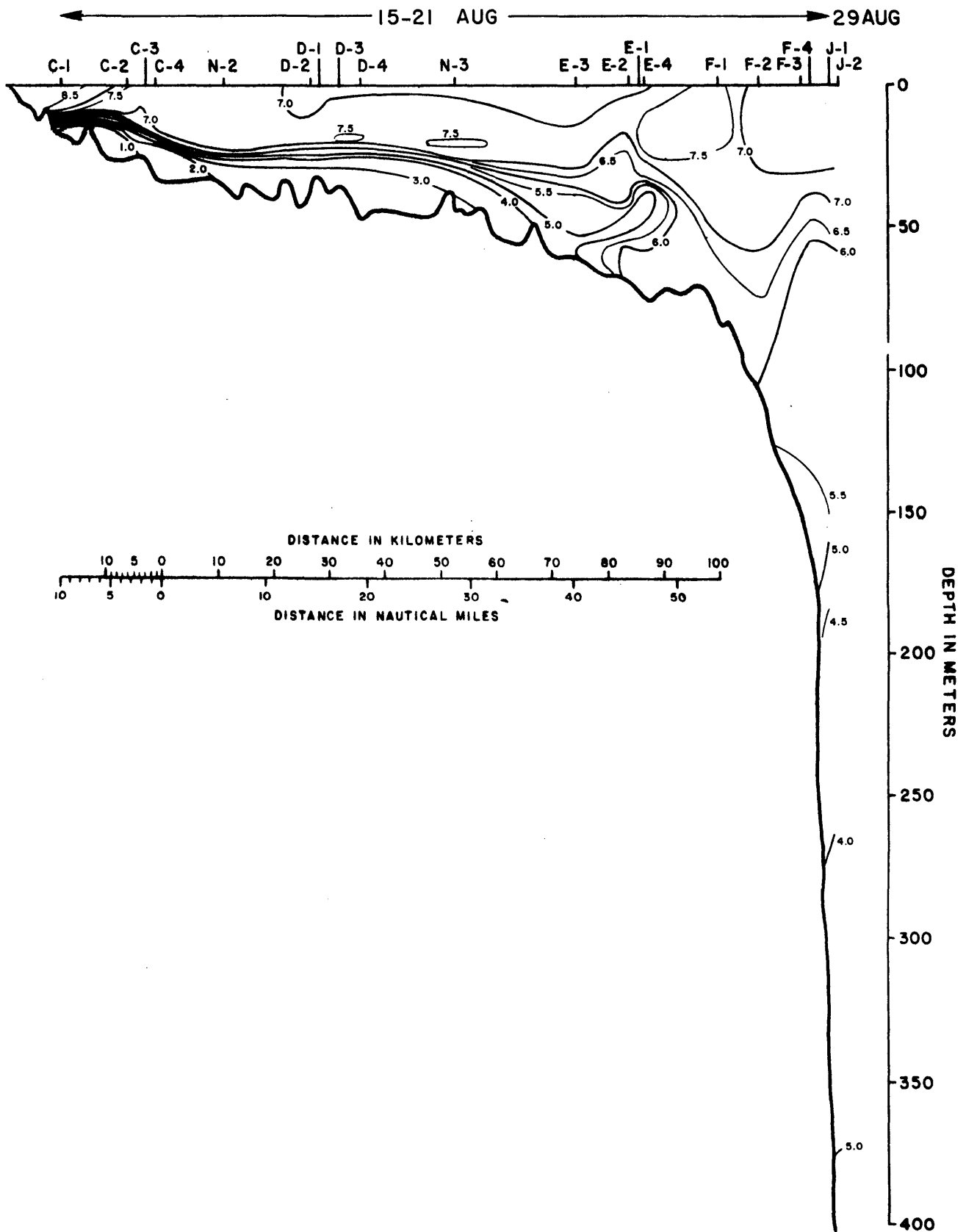


Figure 3-145. Dissolved oxygen (mg/l) along Section III (Stations C1 to J2, 15-29 August 1976) during cruise BLM04B. Section location is shown in Figure 3-10.

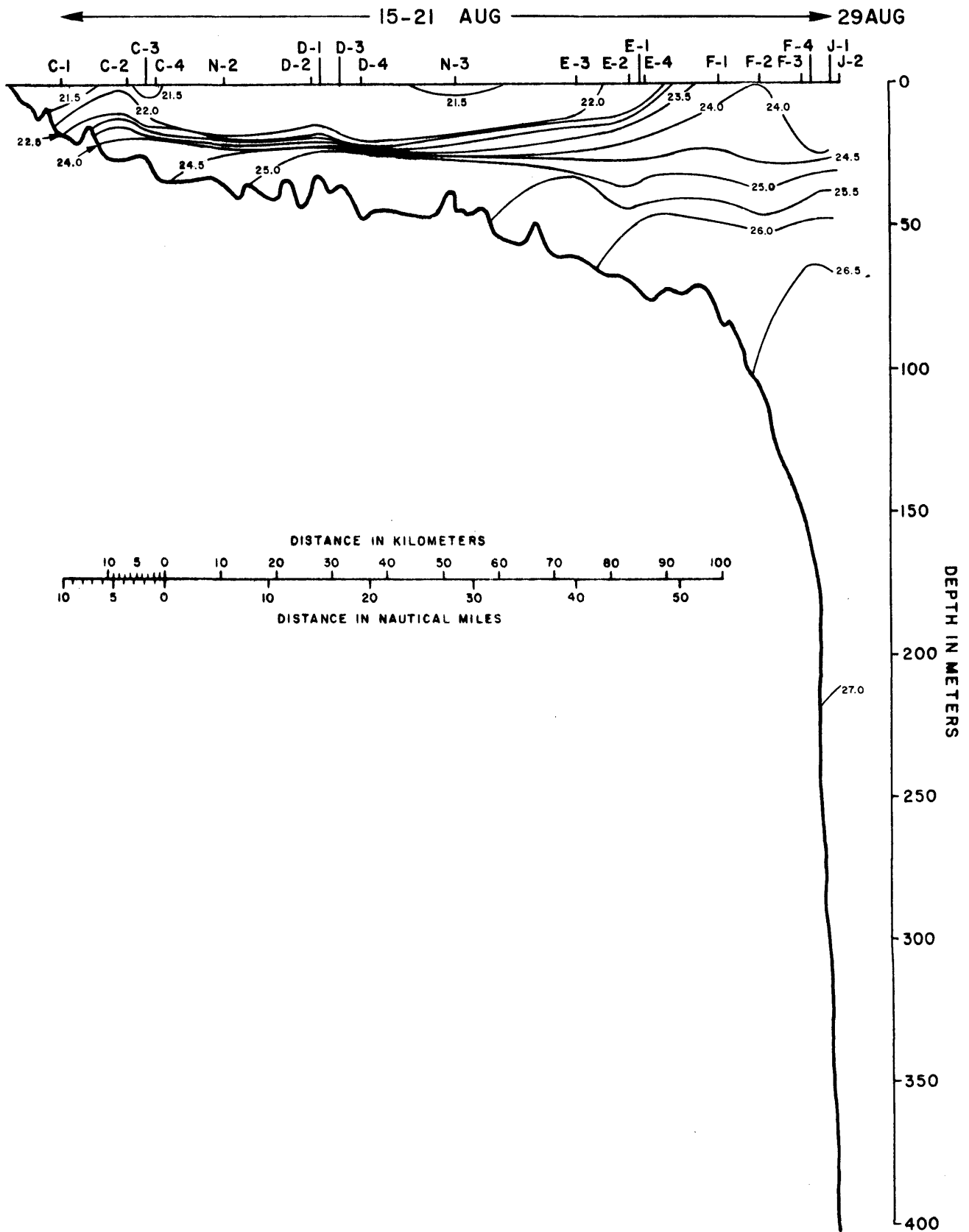


Figure 3-146. Density (σ_t units) along Section III (Stations C1 to J2, 15-29 August 1976) during cruise BLM04B. Section location is shown in Figure 3-10.

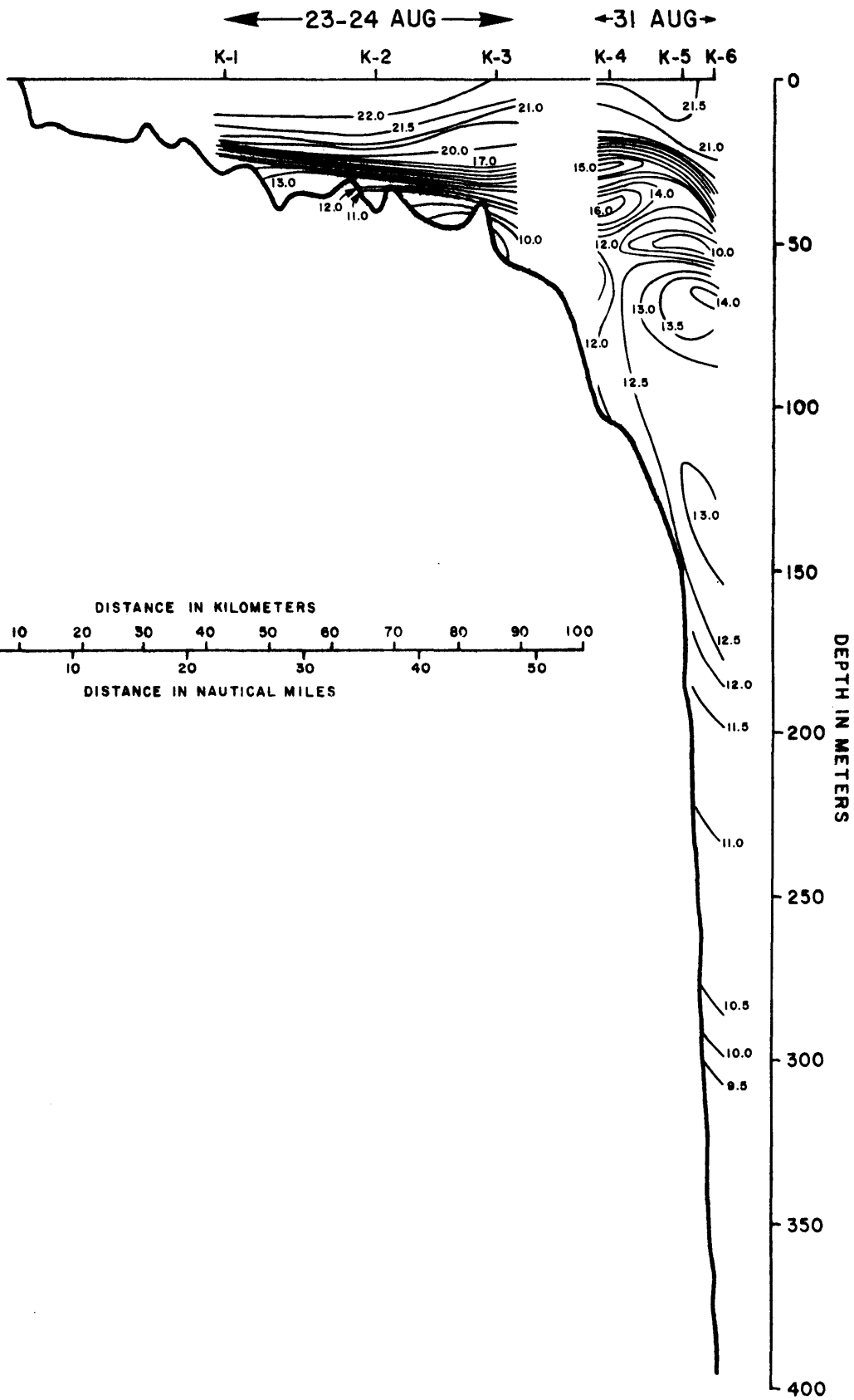


Figure 3-147. Temperature ($^{\circ}\text{C}$) along Section IV (Stations K1 to K6, 23-31 August 1976) during cruise BLM04B. Section location is shown in Figure 3-10.

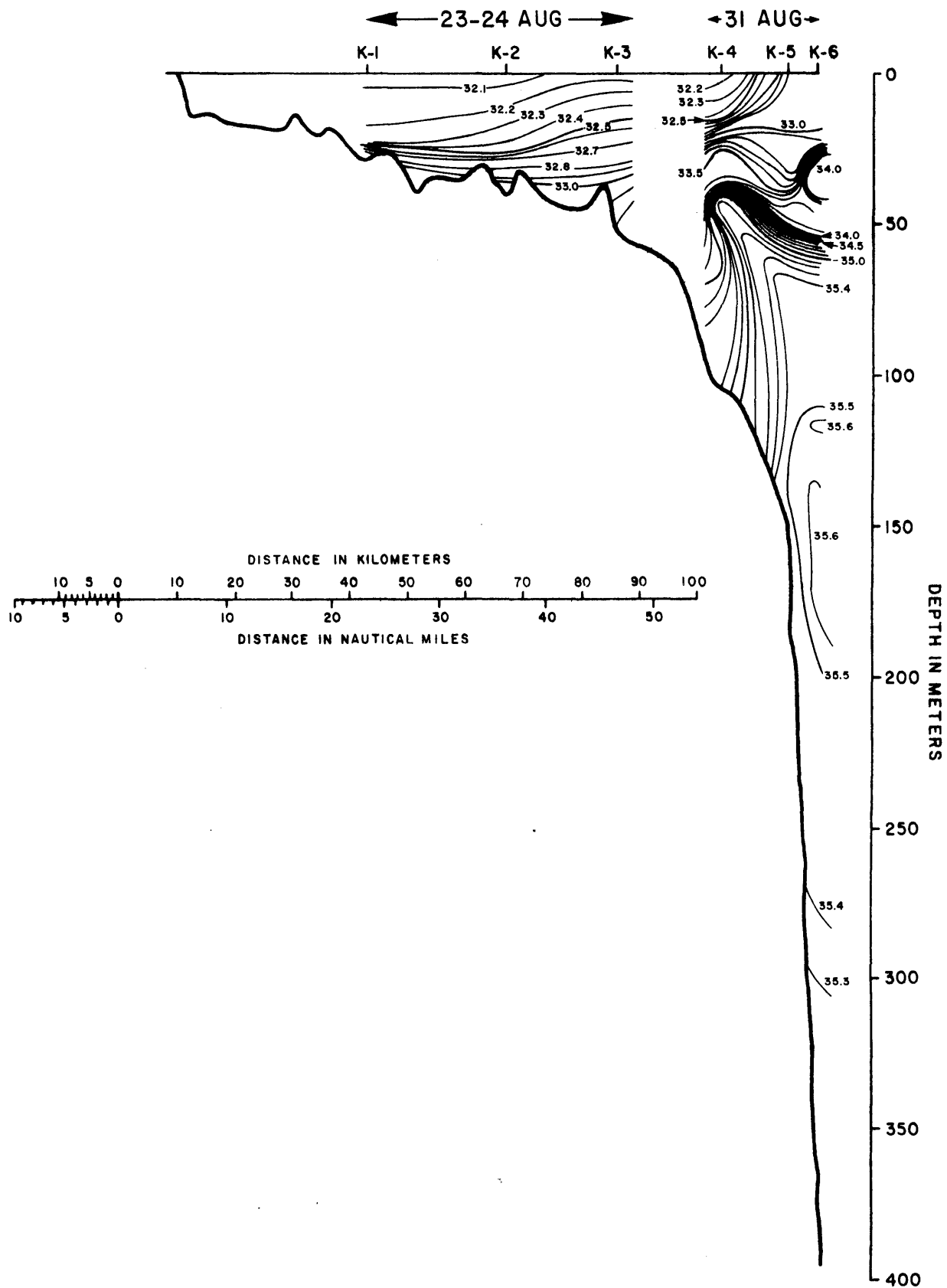


Figure 3-148. Salinity (ppt) along Section IV (Stations K1 to K6, 23-31 August 1976) during cruise BLM04B. Section location is shown in Figure 3-10.

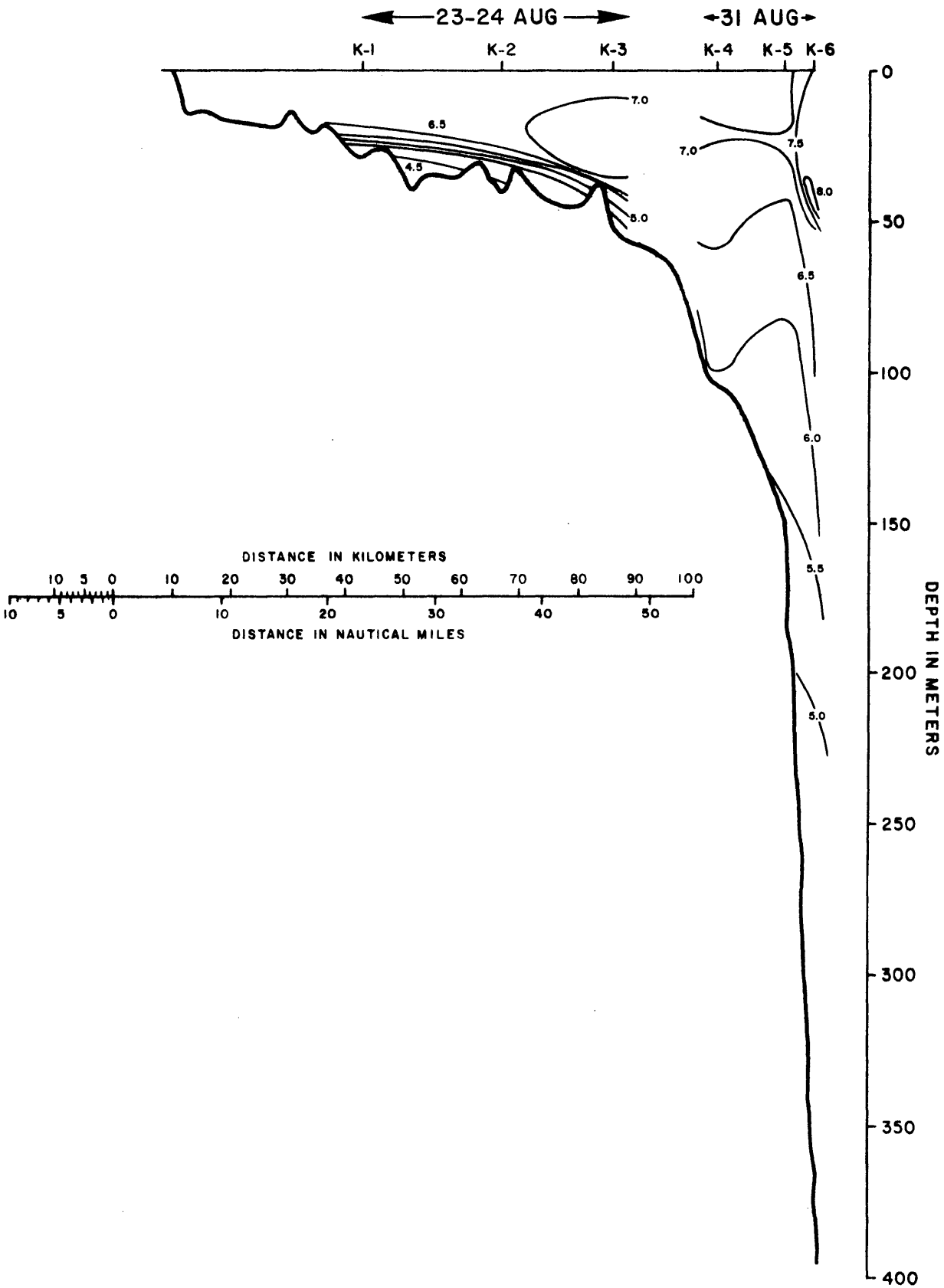


Figure 3-149. Dissolved oxygen (mg/l) along Section IV (Stations K1 to K6, 23-31 August 1976) during cruise BLM04B. Section location is shown in Figure 3-10.

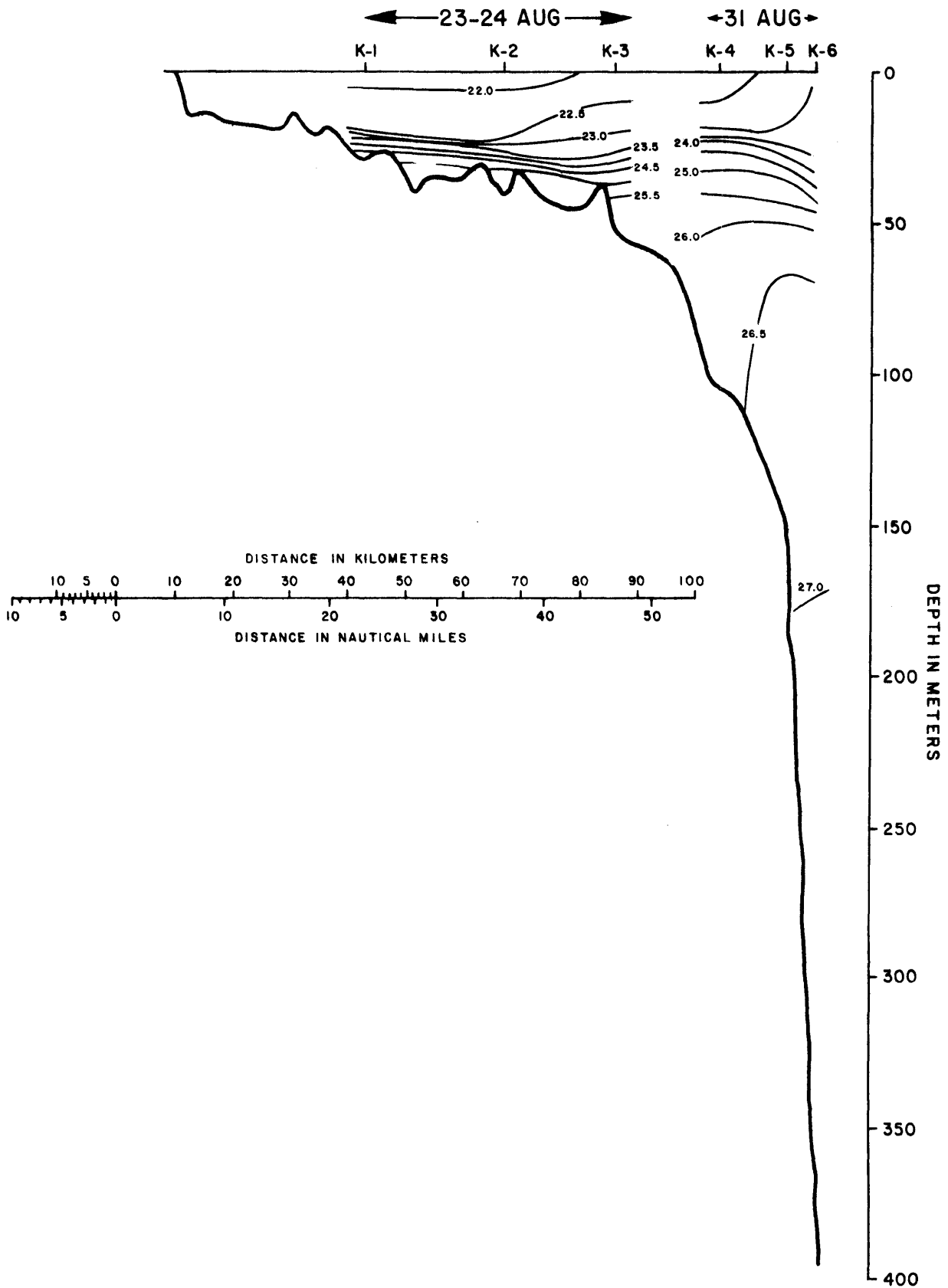


Figure 3-150. Density (σ_t units) along Section IV (Stations K1 to K6, 23-31 August 1976) during cruise BLM04B. Section location is shown in Figure 3-10.

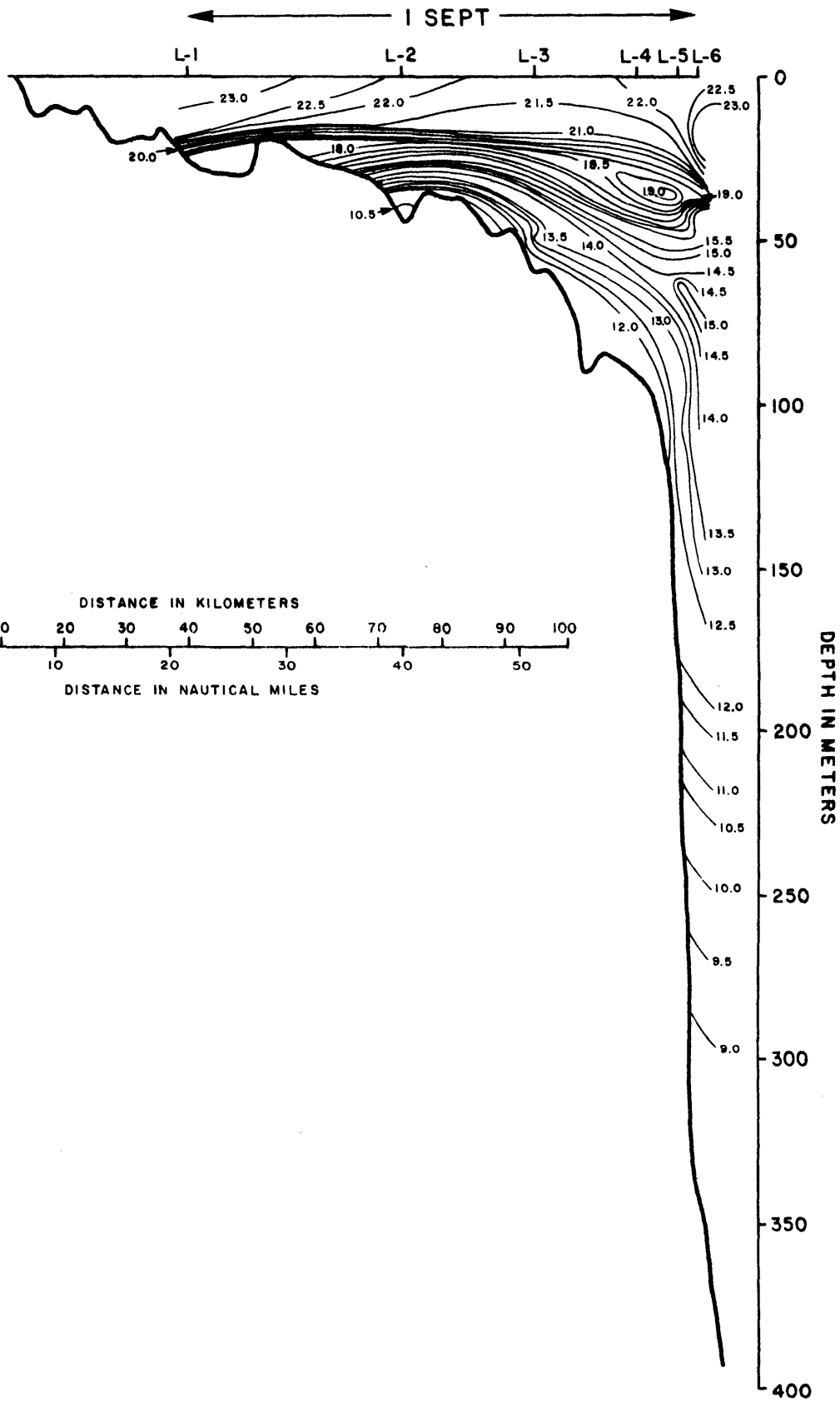


Figure 3-151. Temperature ($^{\circ}\text{C}$) along Section V (Stations L1 to L6, 1 September 1976) during cruise BLM04B. Section location is shown in Figure 3-10.

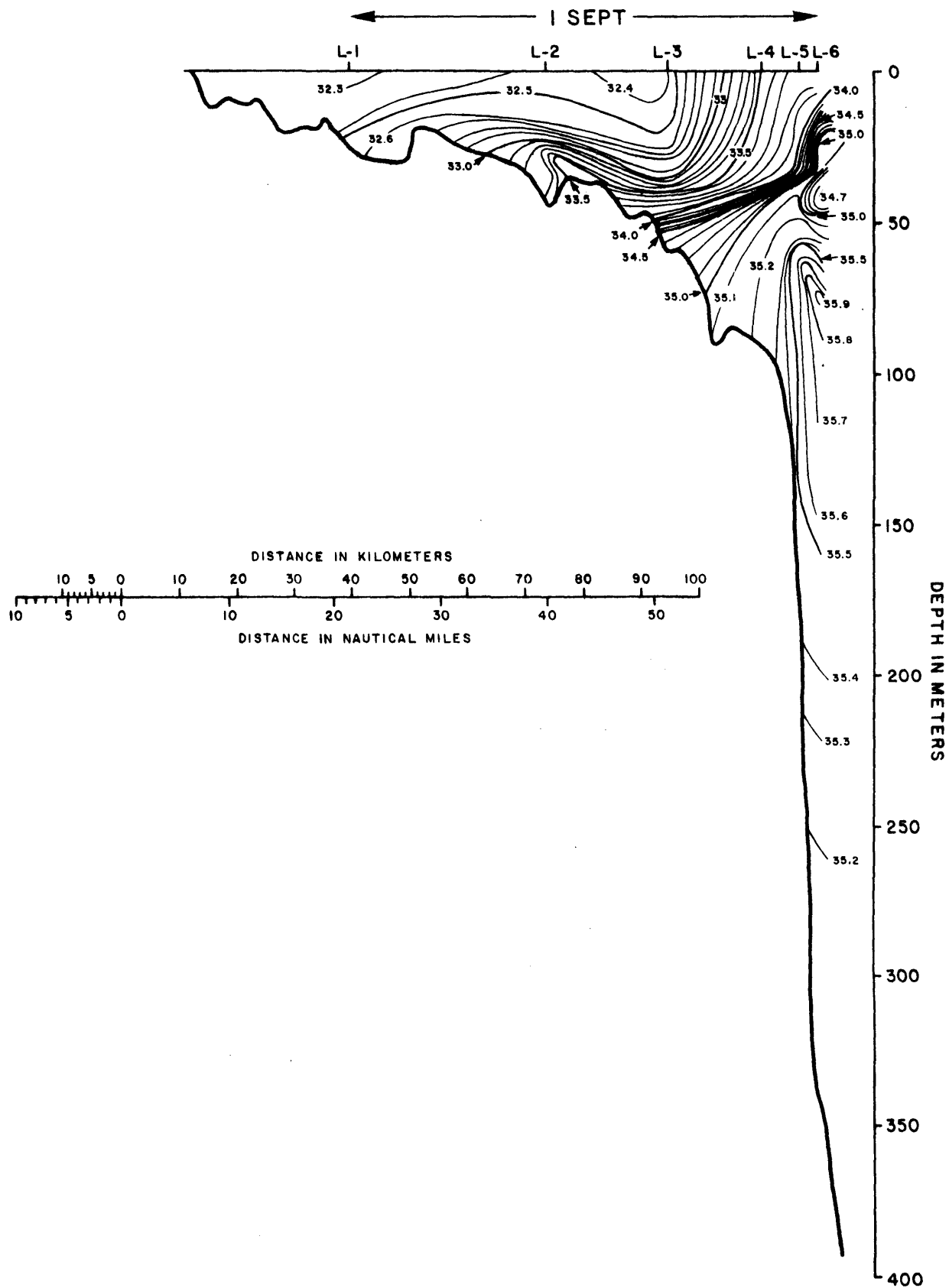


Figure 3-152. Salinity (ppt) along Section V (Stations L1 to L6, 1 September 1976) during cruise BLM04B. Section location is shown in Figure 3-10.

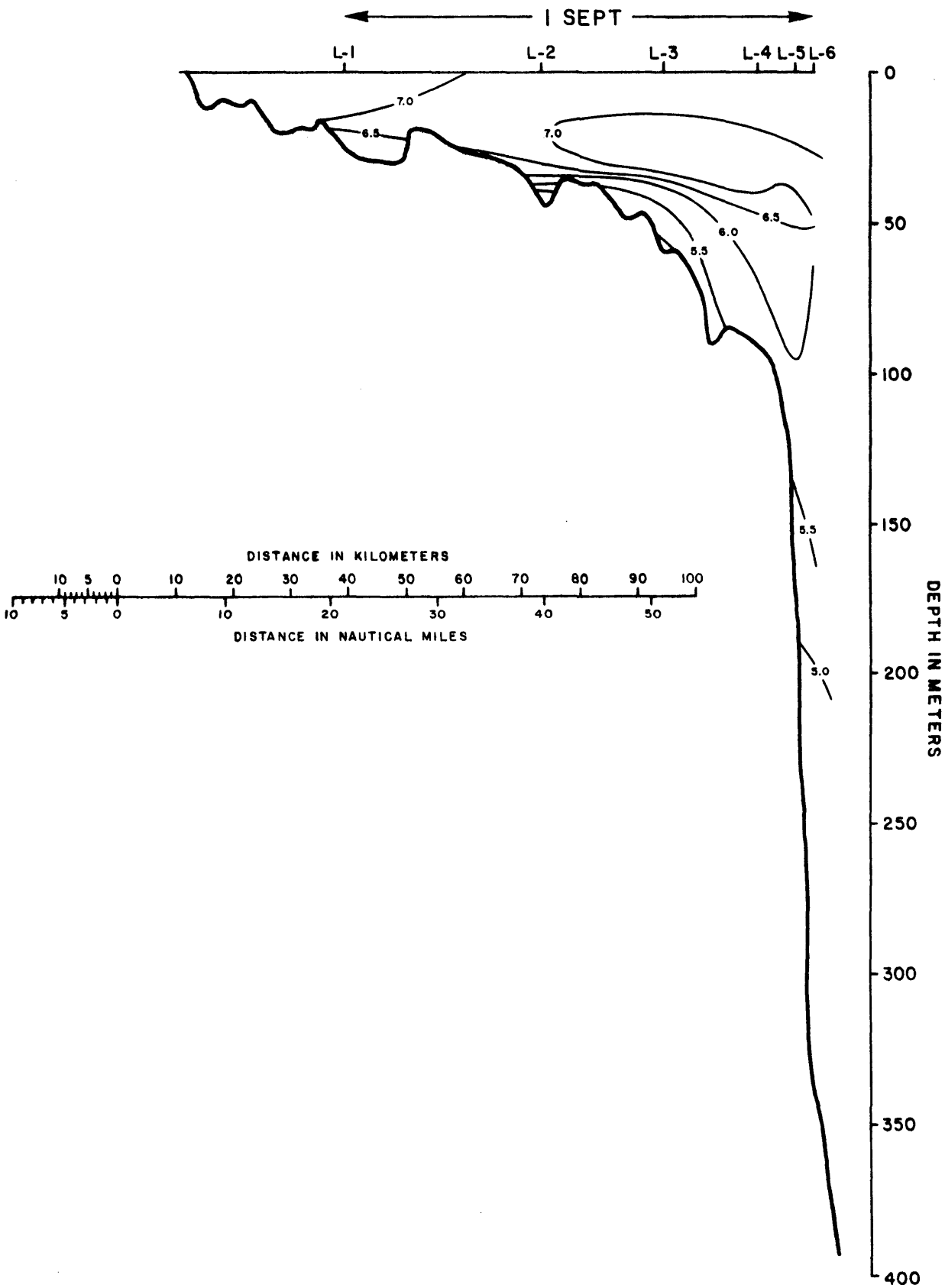


Figure 3-153. Dissolved oxygen (mg/l) along Section V (Stations L1 to L6, 1 September 1976) during cruise BLM 4B. Section location is shown in Figure 3-10.

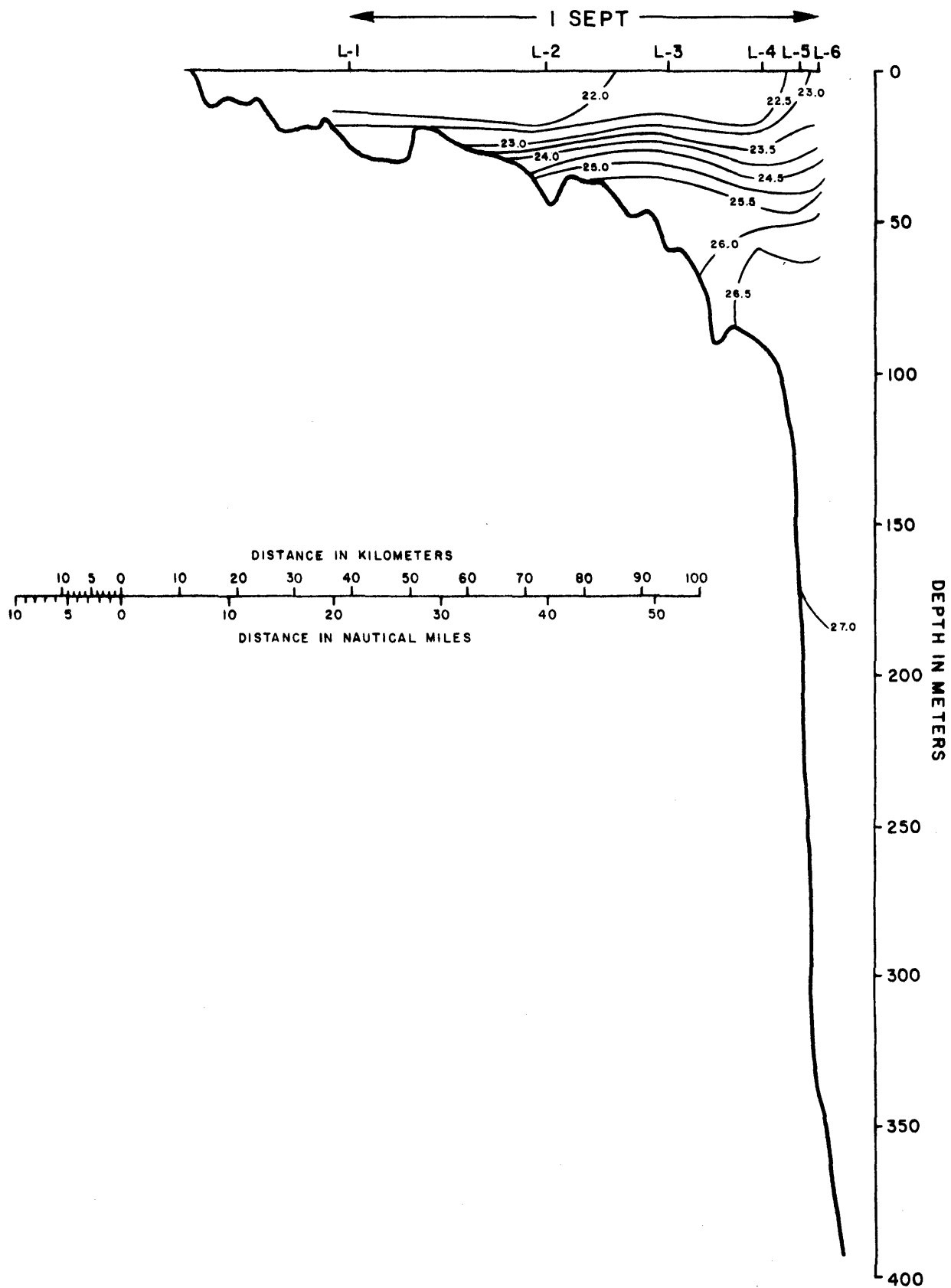


Figure 3-154 . Density (σ_t units) along Section V (Stations L1 to L6, 1 September 1976) during cruise BLM04B. Section location is shown in Figure 3-10.

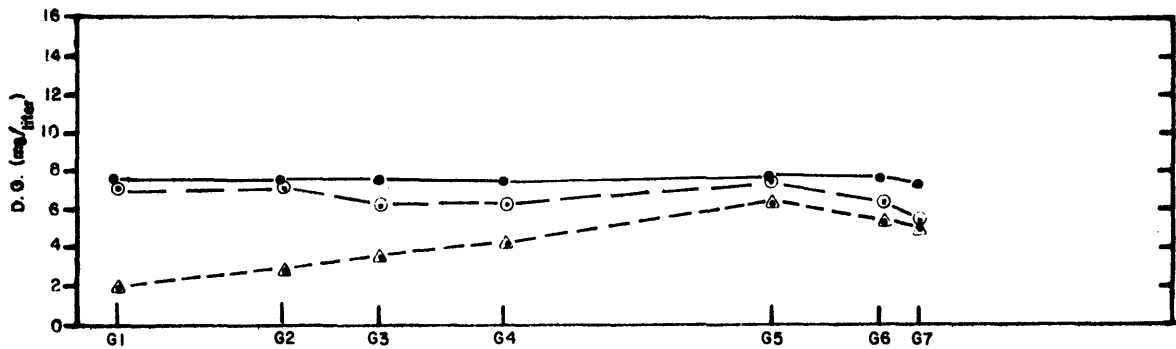
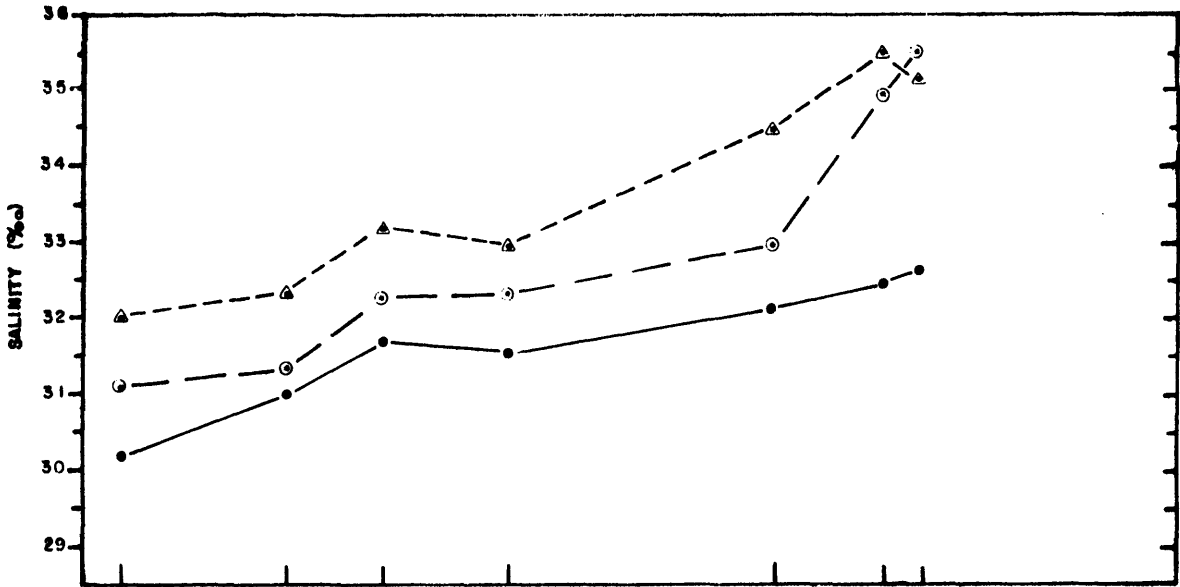
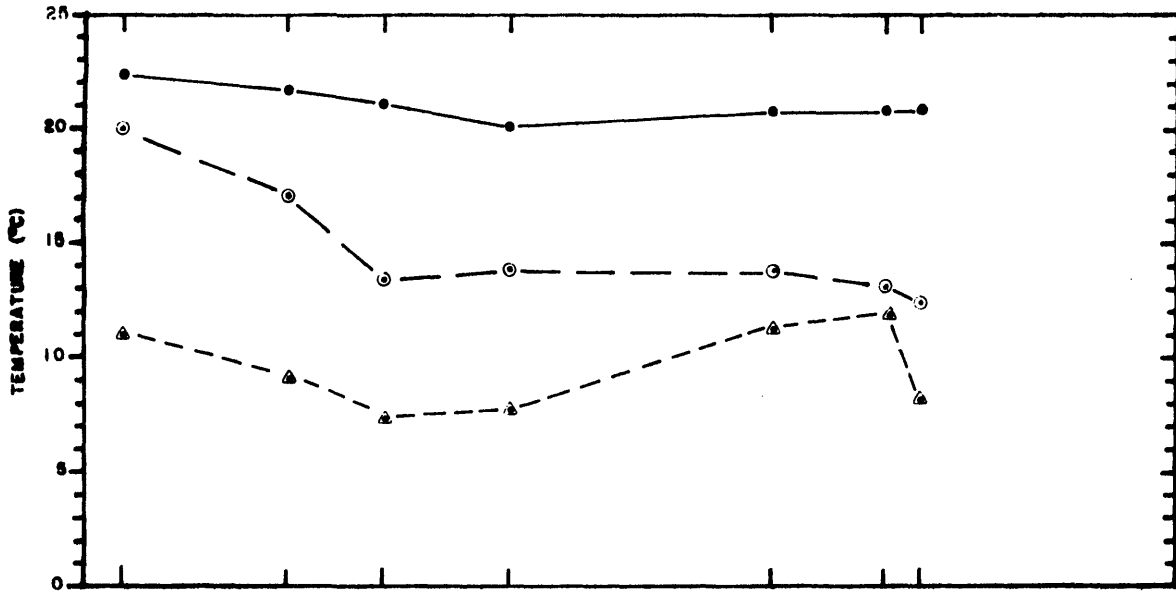


Figure 3-155. Surface (•), mid-depth (◊) and bottom (Δ) values of temperature, salinity and DO measured along Section I on cruise BLM 04B.

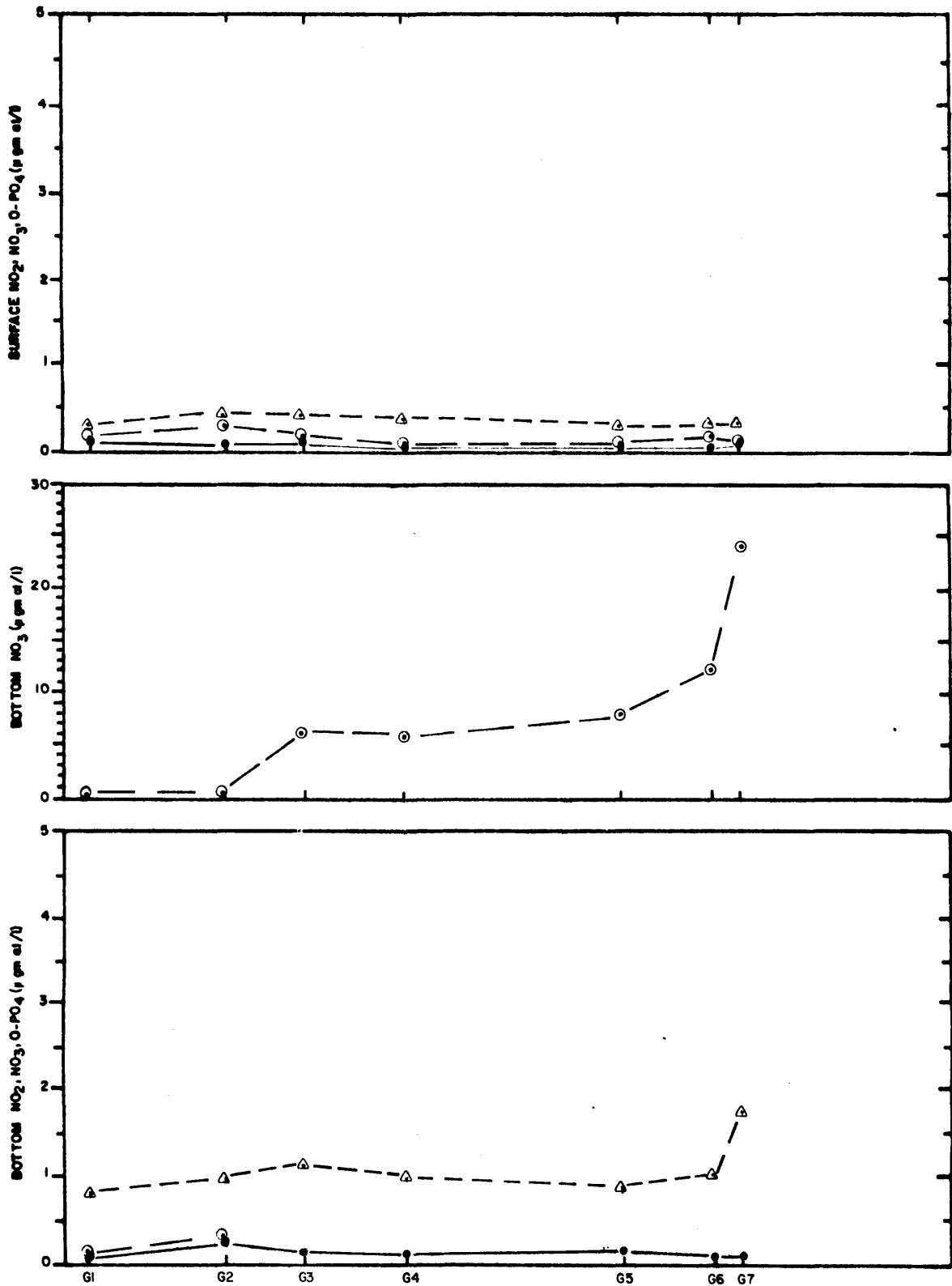


Figure 3-156. Concentrations of dissolved NO_2 (+), NO_3 (θ), and O-PO_4 (Δ) in near surface and near bottom waters along Section I during Cruise BLM 04B. Bottom concentrations of dissolved NO_3 were substantially greater than those of other micronutrients hence the center plot.

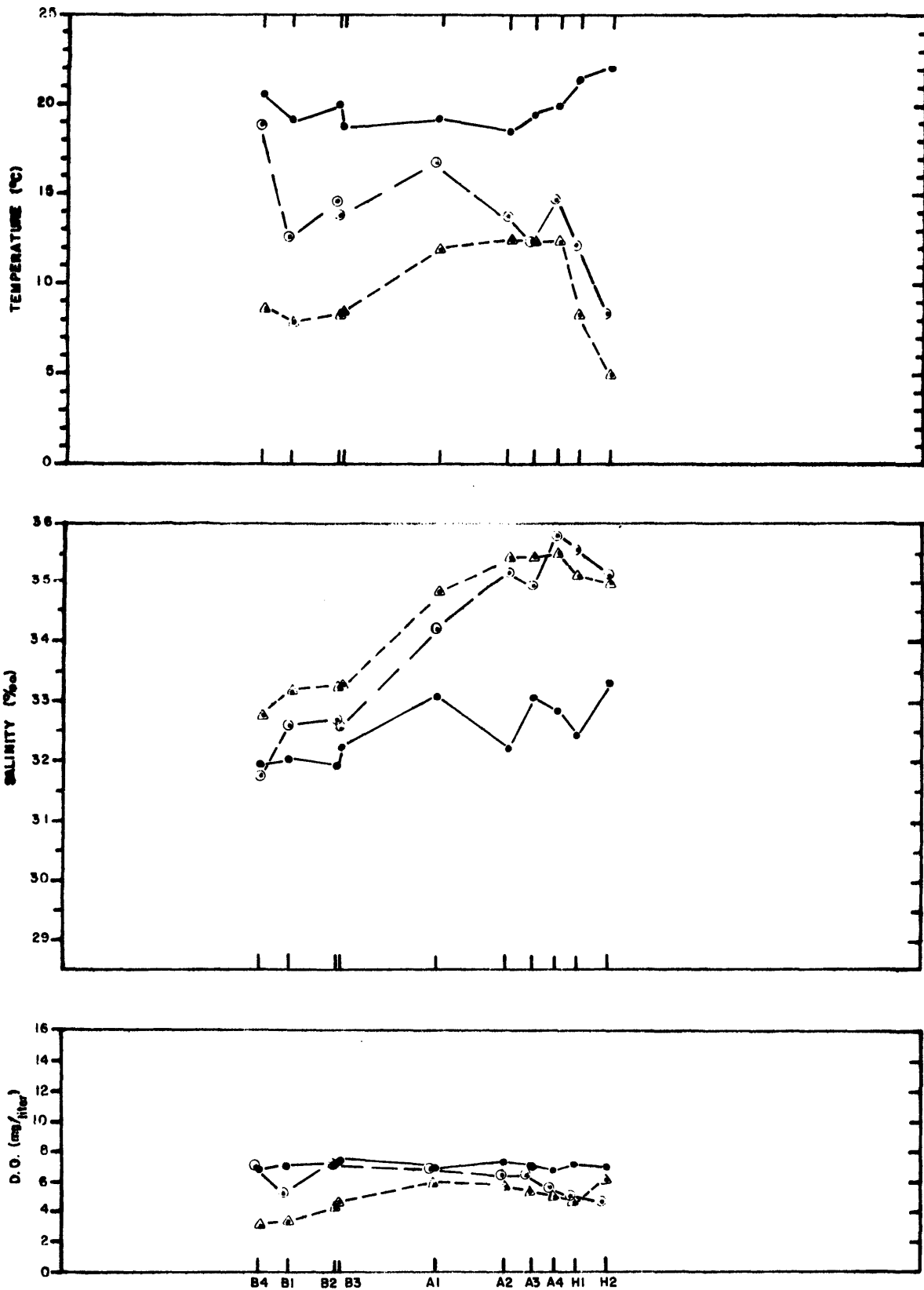


Figure 3-157. Surface (•), mid-depth (◊) and bottom (▲) values of temperature, salinity and DO measured along Section II on cruise BLM 04B.

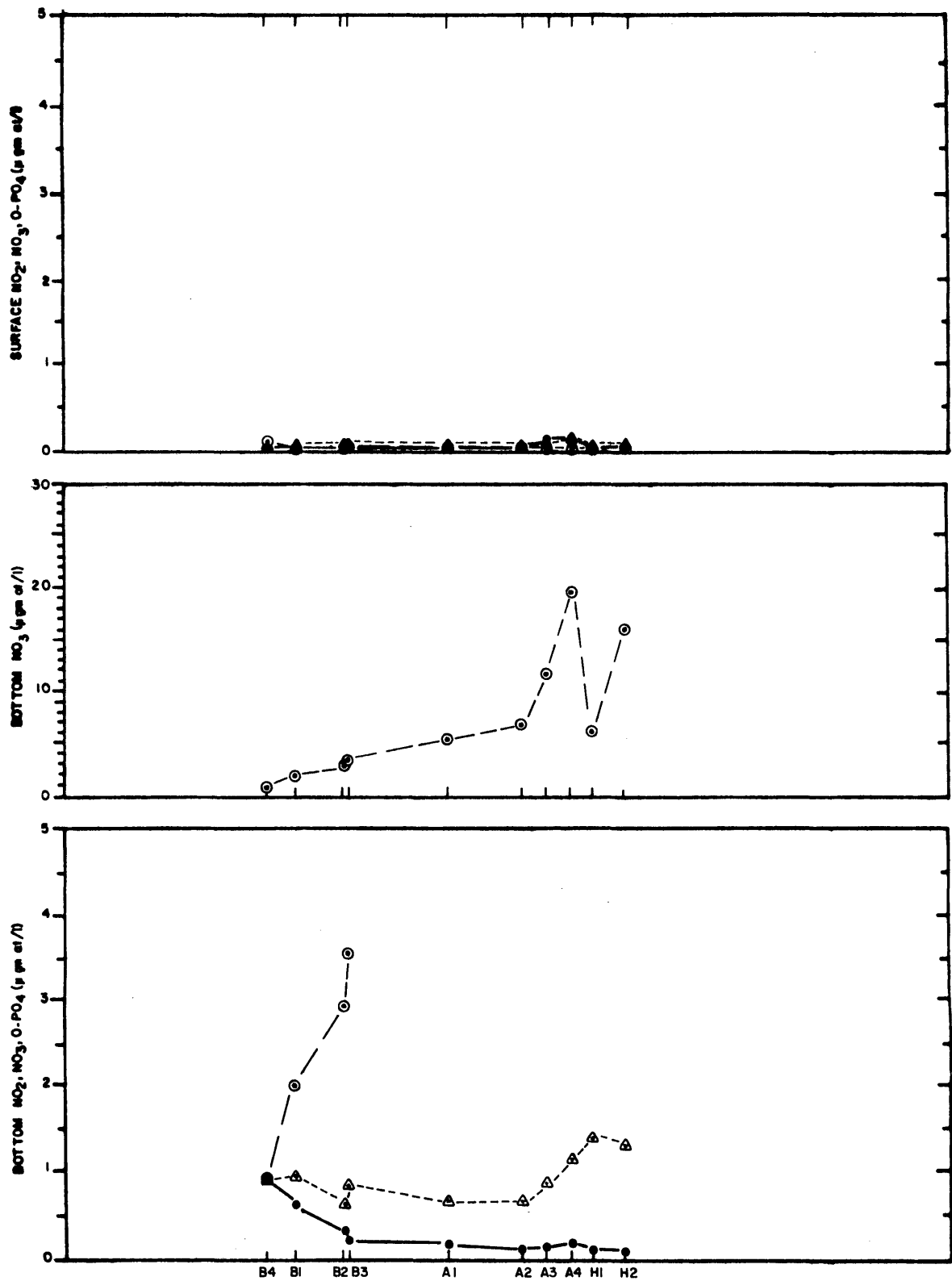


Figure 3-158. Concentrations of dissolved NO_2 (*), NO_3 (θ), and O- PO_4 (Δ) in near surface and near bottom waters along Section II during Cruise BLM 04B. Bottom concentrations of dissolved NO_3 were substantially greater than those of other micronutrients hence the center plot.

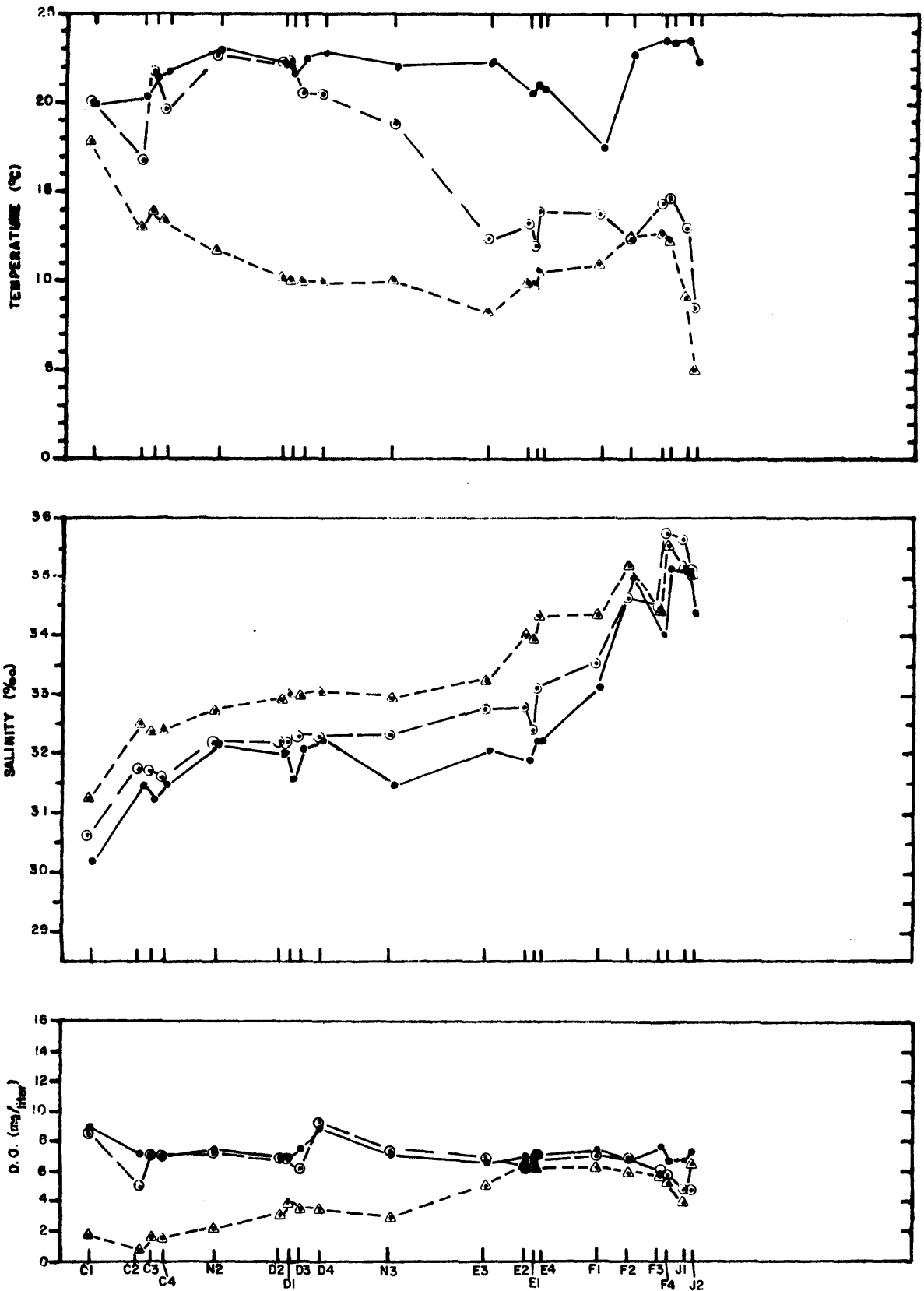


Figure 3-159 Surface (•), mid-depth (◊) and bottom (Δ) values of temperature, salinity and DO measured along Section III on cruise BLM 04B.

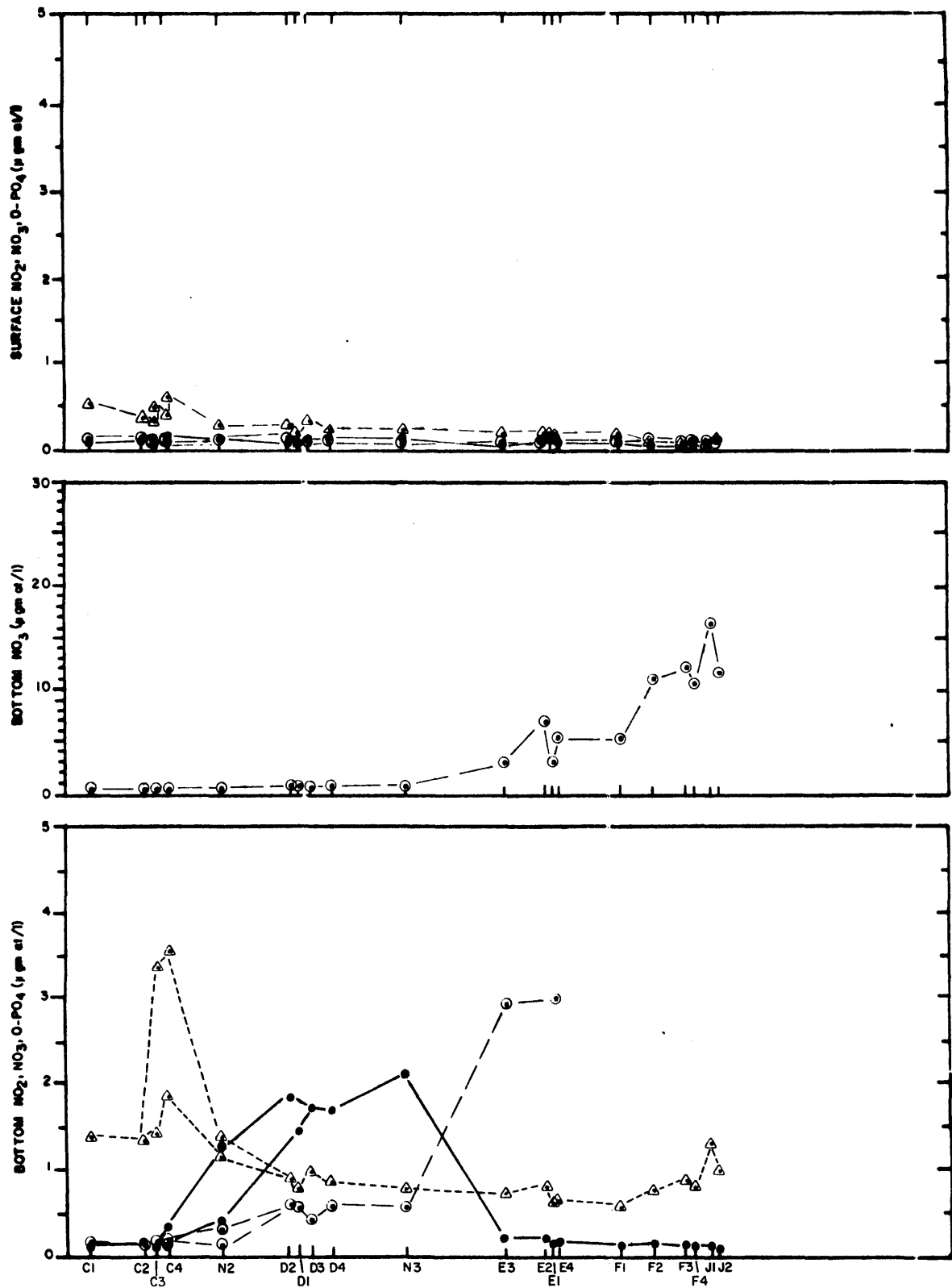


Figure 3-160. Concentrations of dissolved NO₂ (•), NO₃ (○), and O-PO₄ (Δ) in near surface and near bottom waters along Section III during Cruise BLM 04B. Bottom concentrations of dissolved NO₃ were substantially greater than those of other micronutrients hence the center plot.

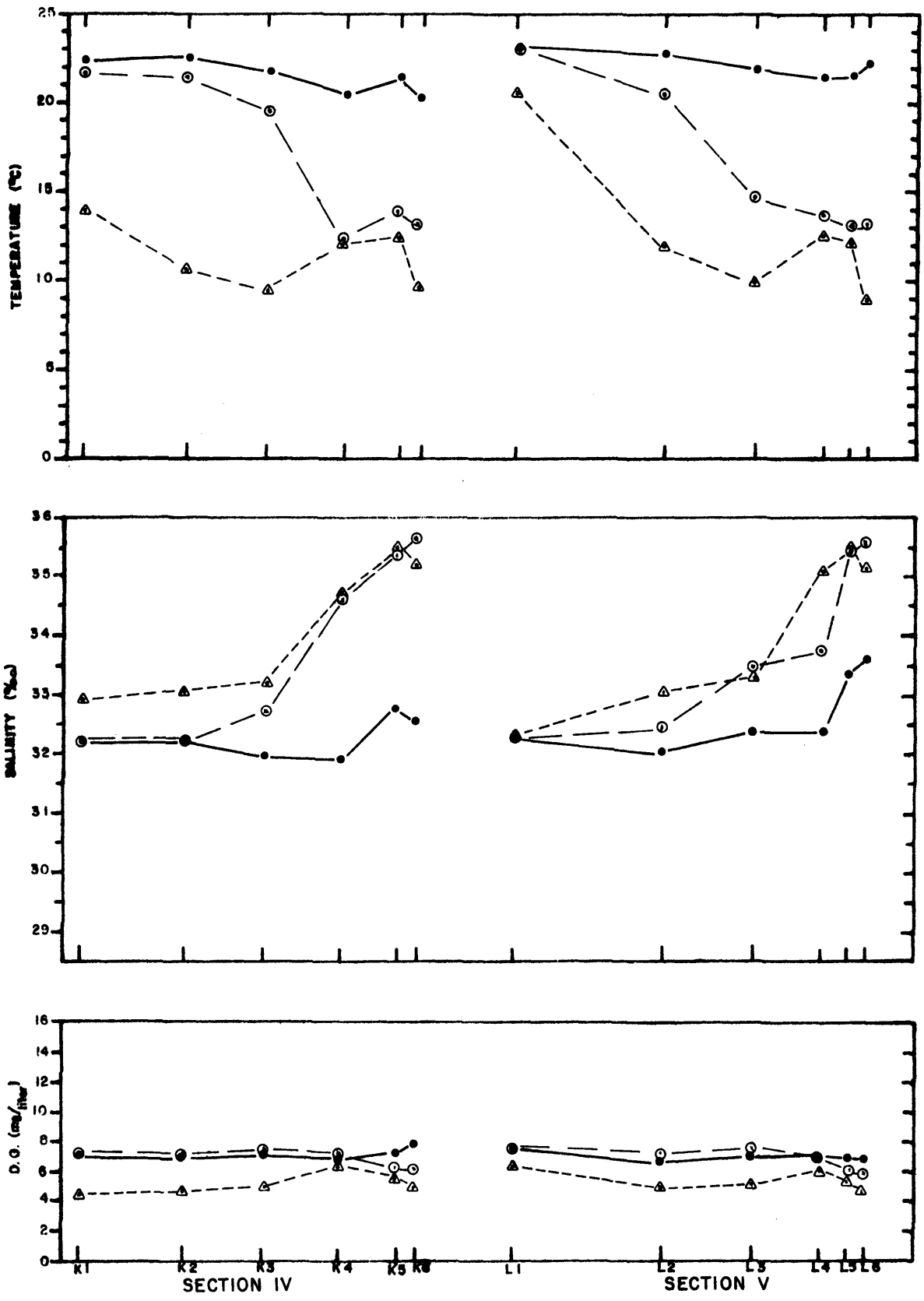


Figure 3-161. Surface (•), mid-depth (◊) and bottom (Δ) values of temperature, salinity and DO measured along Sections IV and V during cruise BLM 04B.

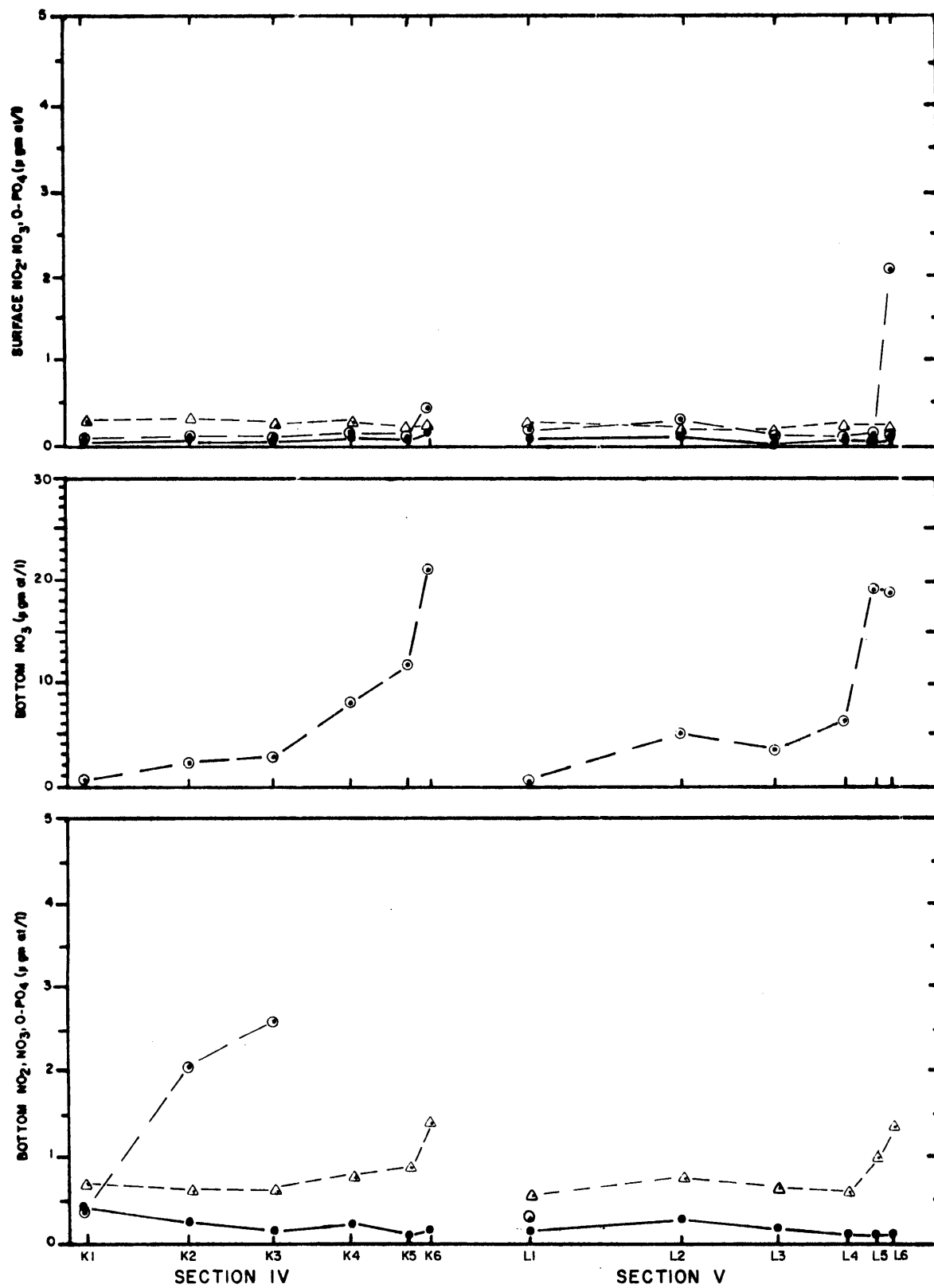


Figure 3-162. Concentrations of dissolved NO_2 (\bullet), NO_3 (\circ), and O- PO_4 (Δ) in near surface and near bottom waters along Sections IV & V during Cruise BLM 04B. Bottom concentrations of dissolved NO_3 were substantially greater than those of other micronutrients hence the center plot.

Cruise BLM~~0~~4W

Summer 1976

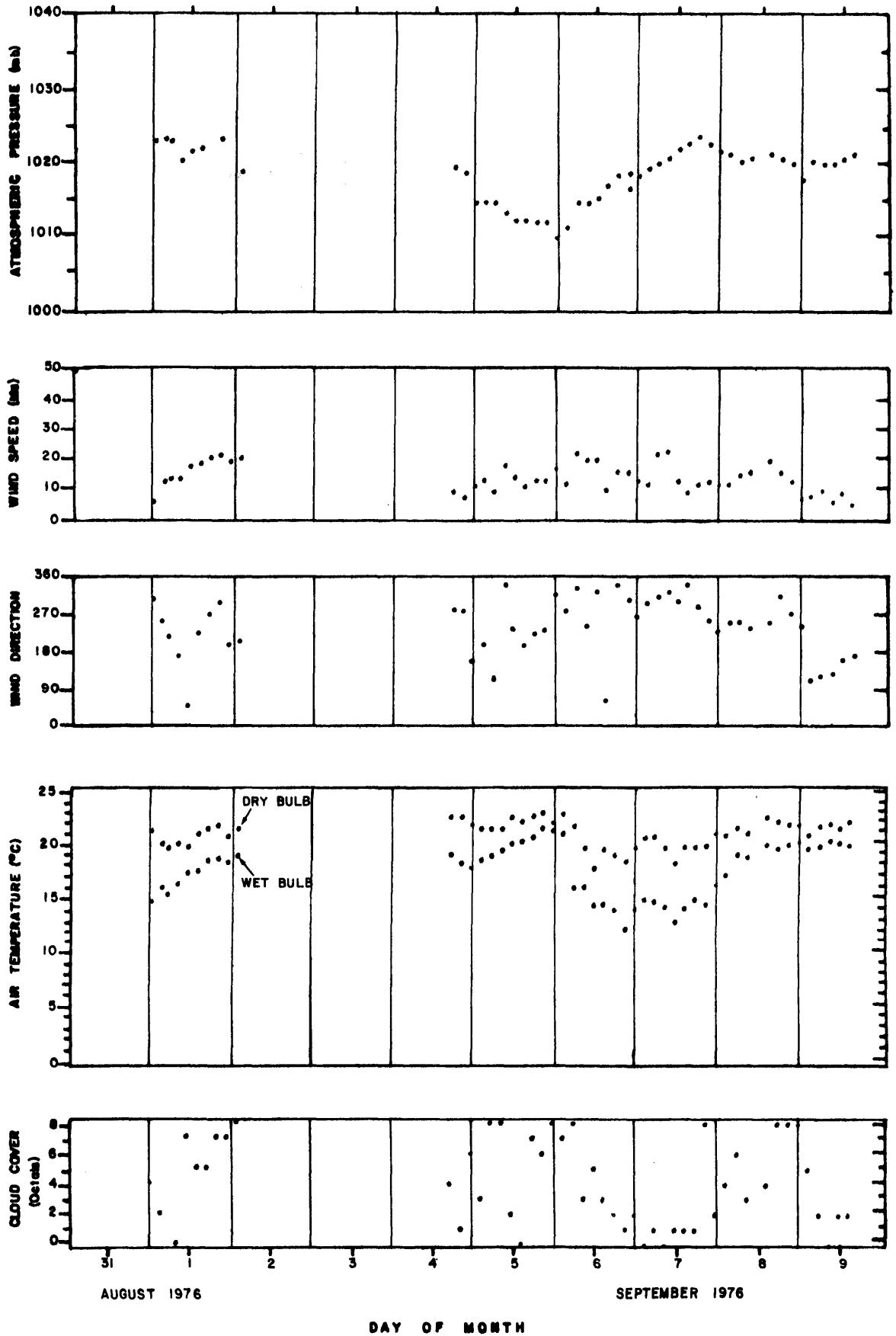


Figure 3-163. Meteorological data collected during cruise BLM 04W 31 August to 9 September 1976.

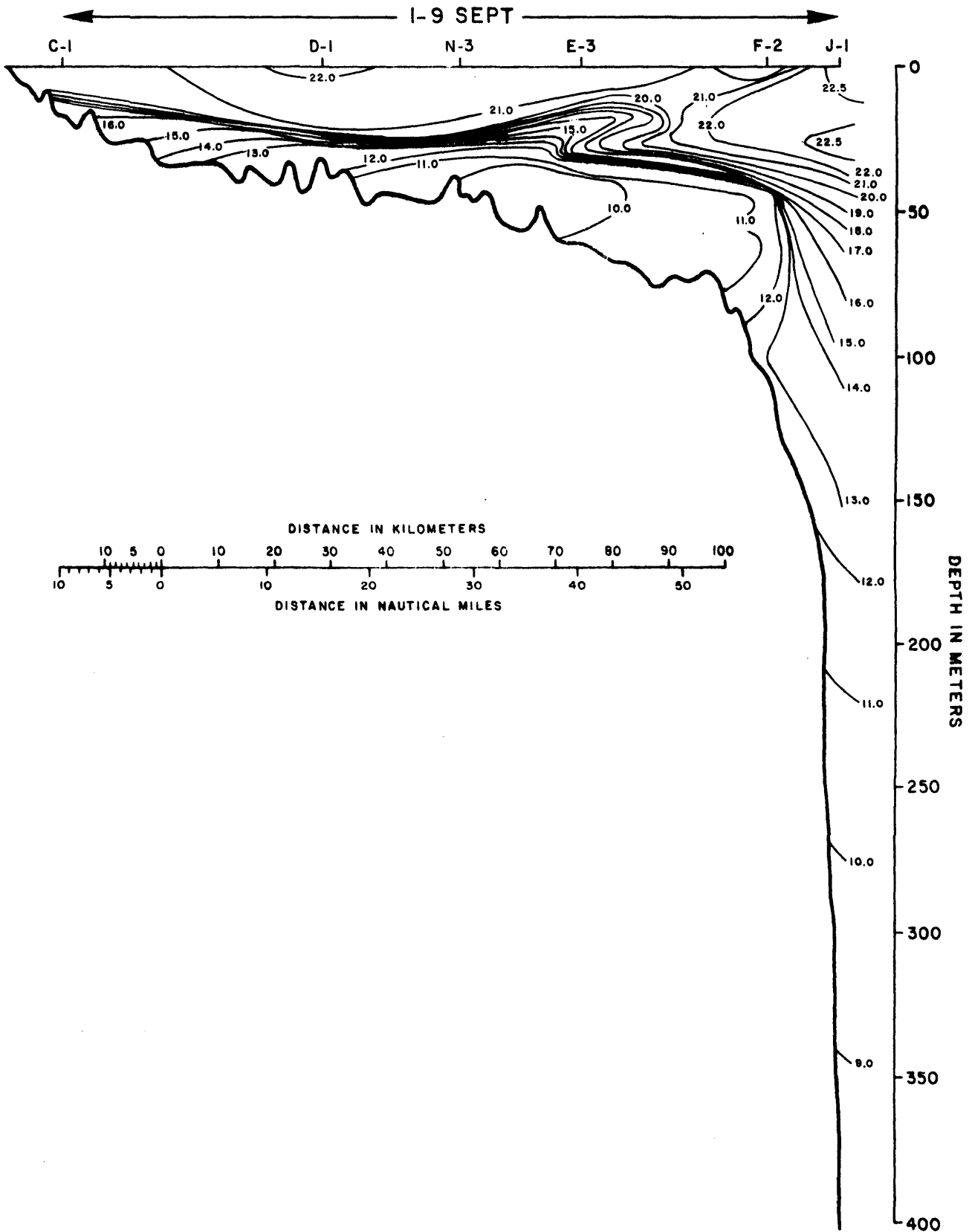


Figure 3-164. Temperature ($^{\circ}\text{C}$) along Section III (Stations C1 to J1, 1-9 September 1976) during cruise BLM04W. Section location is shown in Figure 3-10.

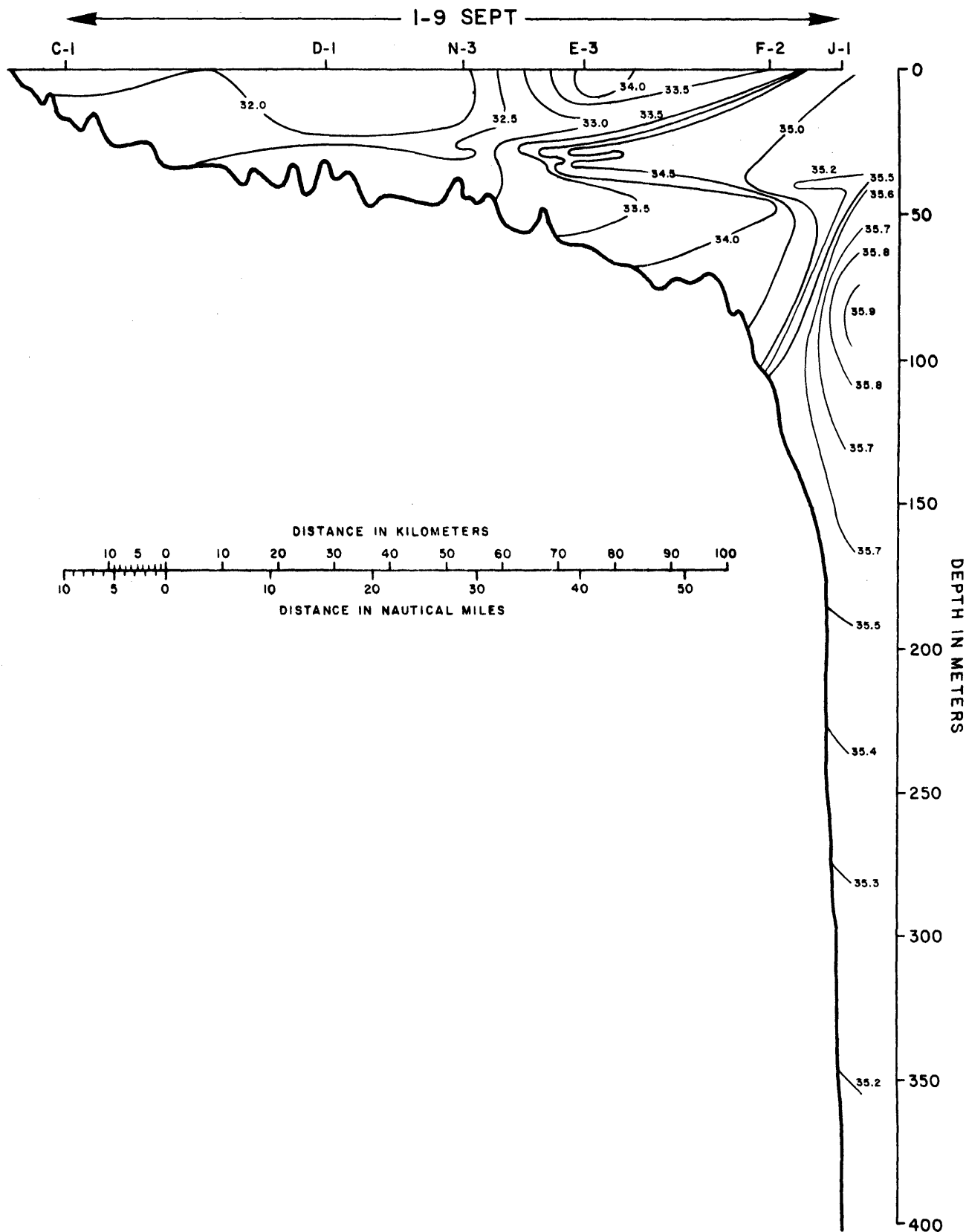


Figure 3-165. Salinity (ppt) along Section III (Stations C1 to J1, 1-9 September 1976) during cruise BLM04W. Section location is shown in Figure 3-10.

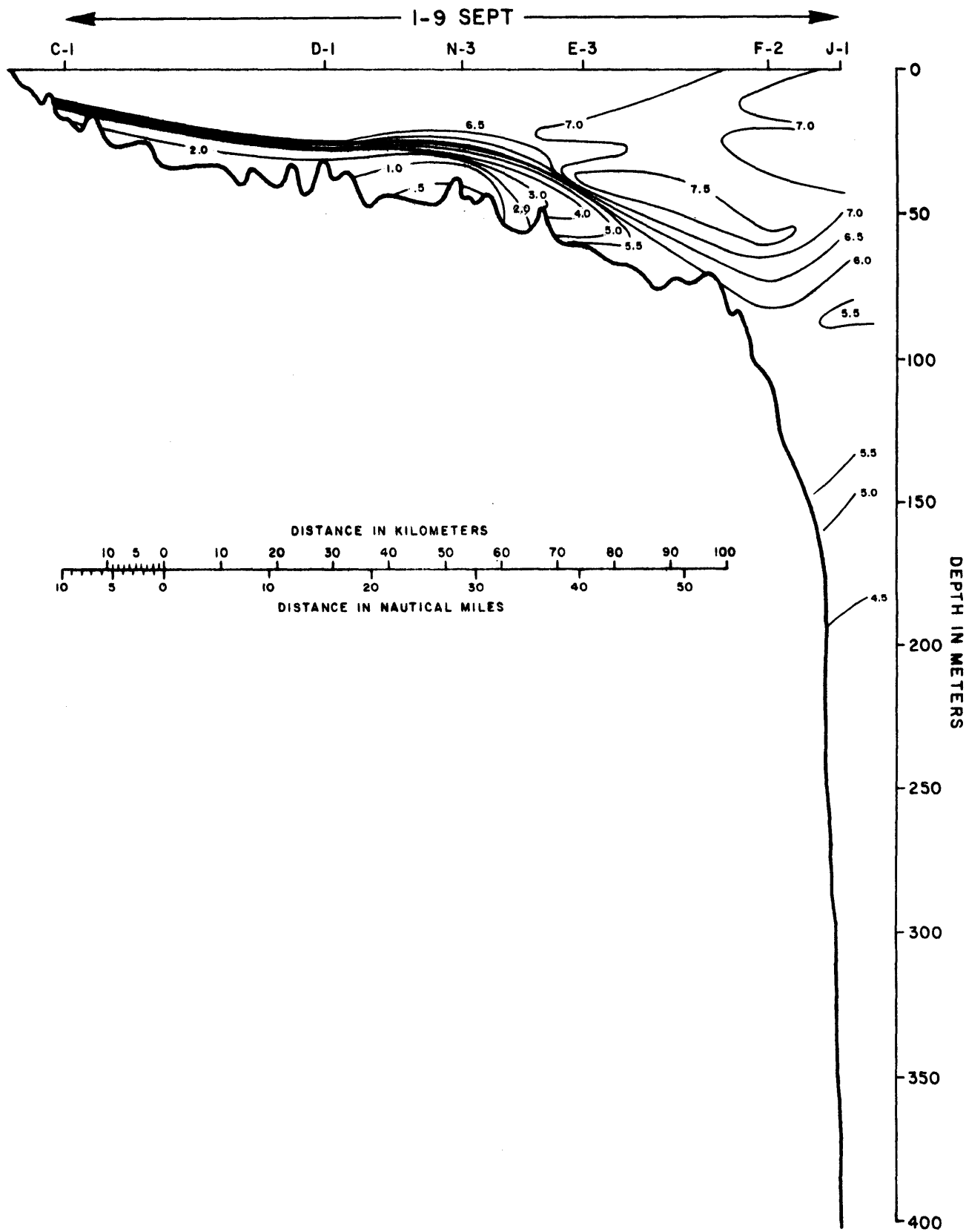


Figure 3-166. Dissolved oxygen (mg/l) along Section III (Stations C1 to J1, 1-9 September 1976) during cruise BLM04W. Section location is shown in Figure 3-10.

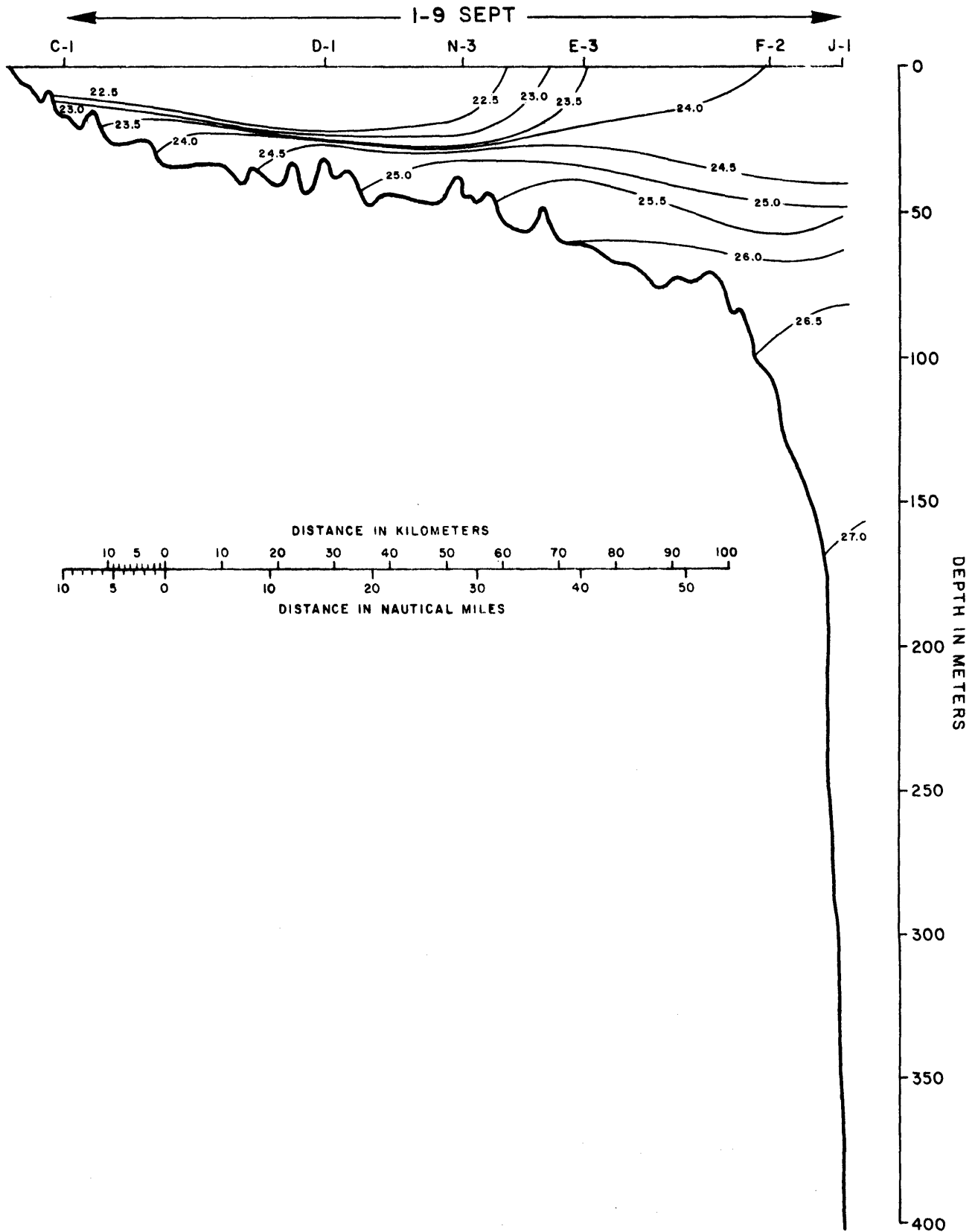


Figure 3-167. Density (σ_t units) along Section III (Stations C1 to J1, 1-9 September 1976) during cruise BLM04W. Section location is shown in Figure 3-10.

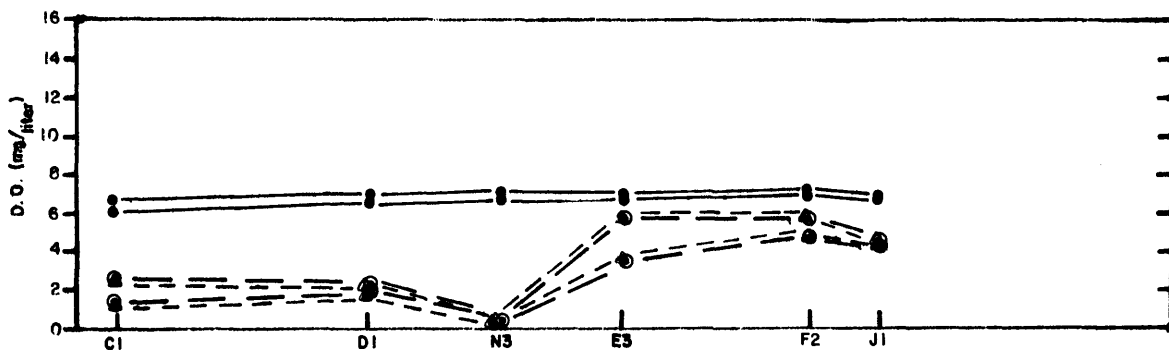
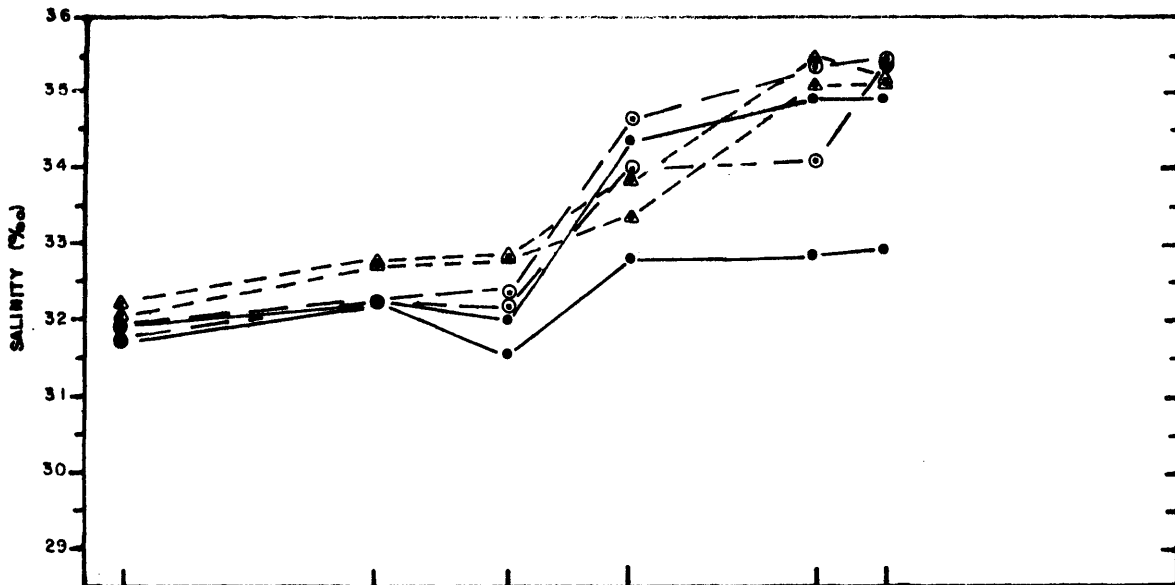
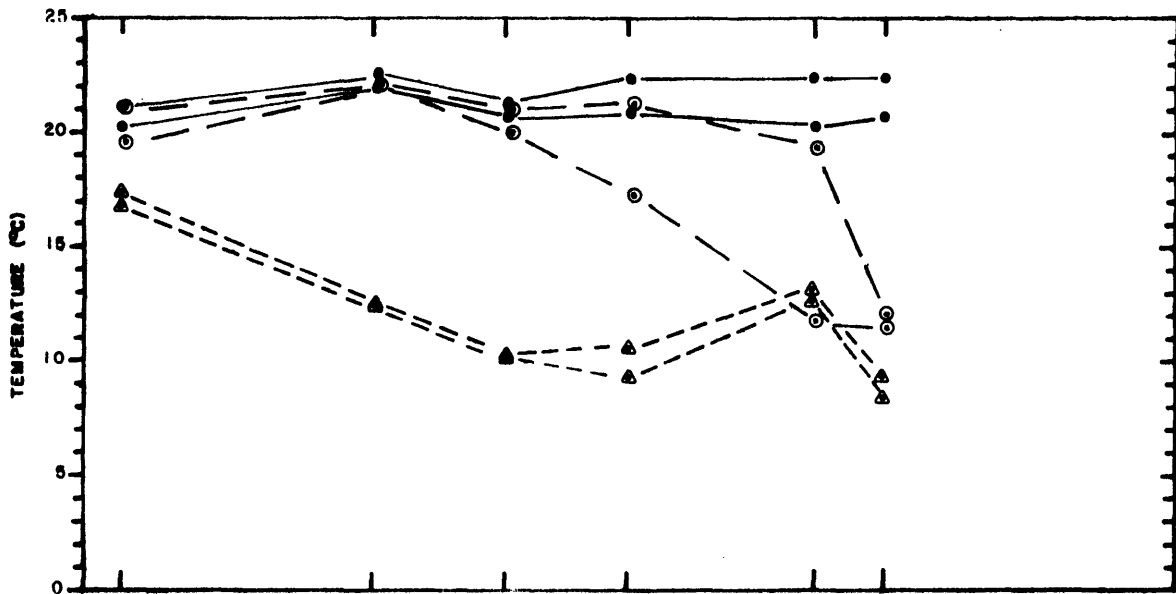


Figure 3-168. Surface (•), mid-depth (⊙) and bottom (Δ) values of temperature, salinity and DO measured along Section III during cruise BLM 04W. Maximum and minimum values measured from four casts are shown at each station.

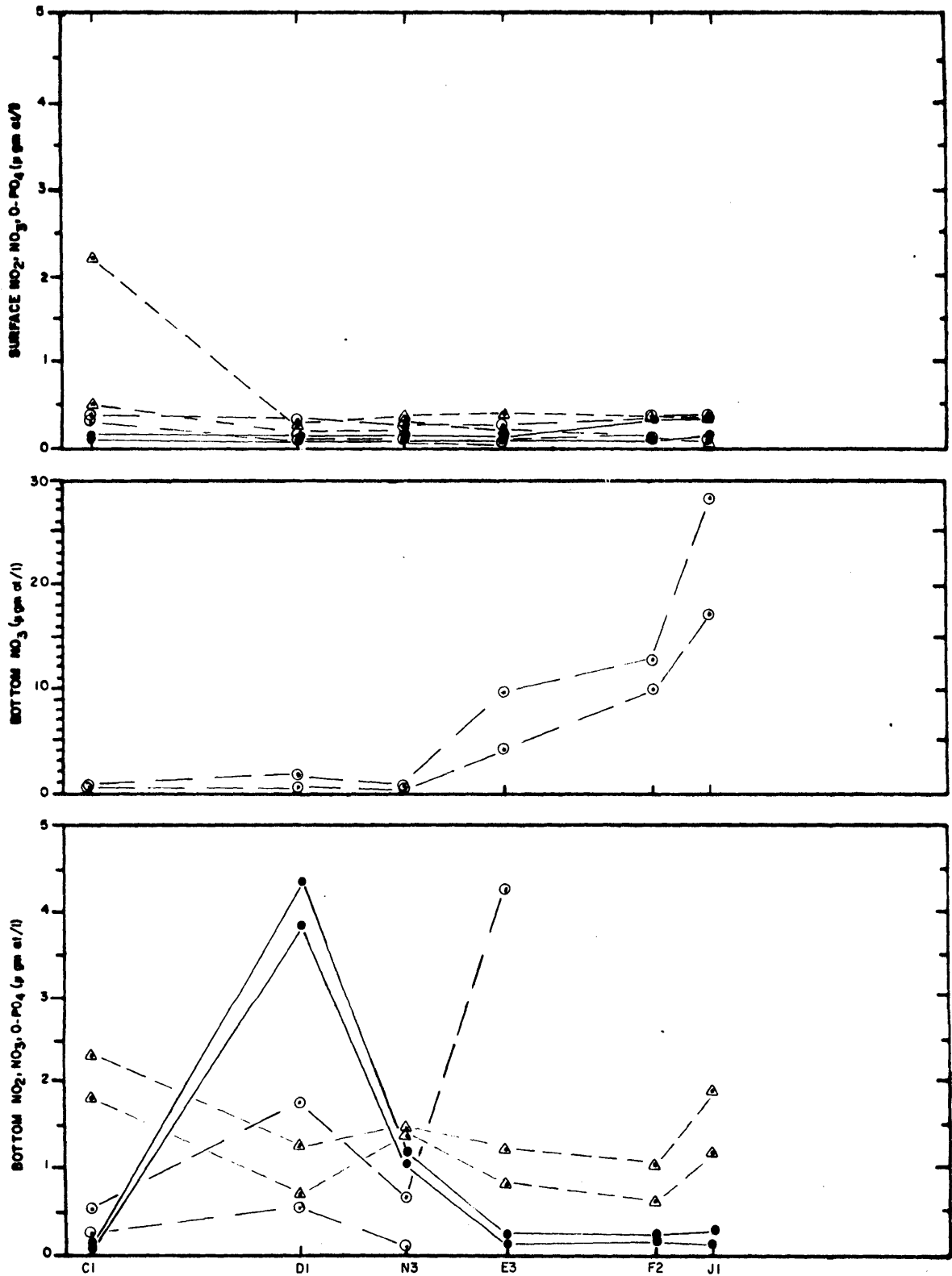


Figure 3-169. Concentrations of dissolved NO₂ (◐), NO₃ (●), and O-PO₄ (Δ) in near surface and near bottom waters along Section III during Cruise BLM 04W. Bottom concentrations of dissolved NO₃ were substantially greater than those of other micronutrients hence the center plot.

Cruise BLM04T

Summer 1976

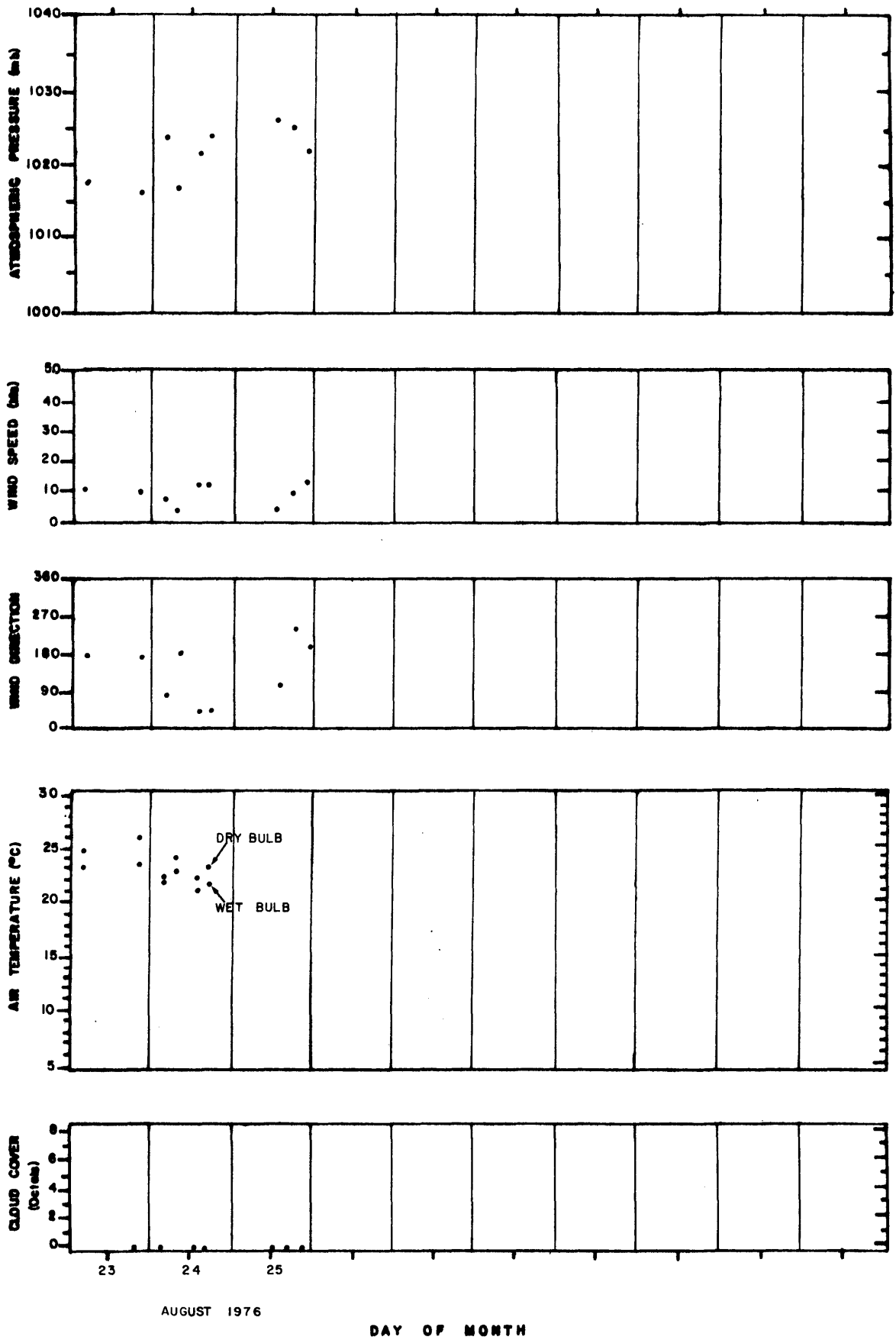


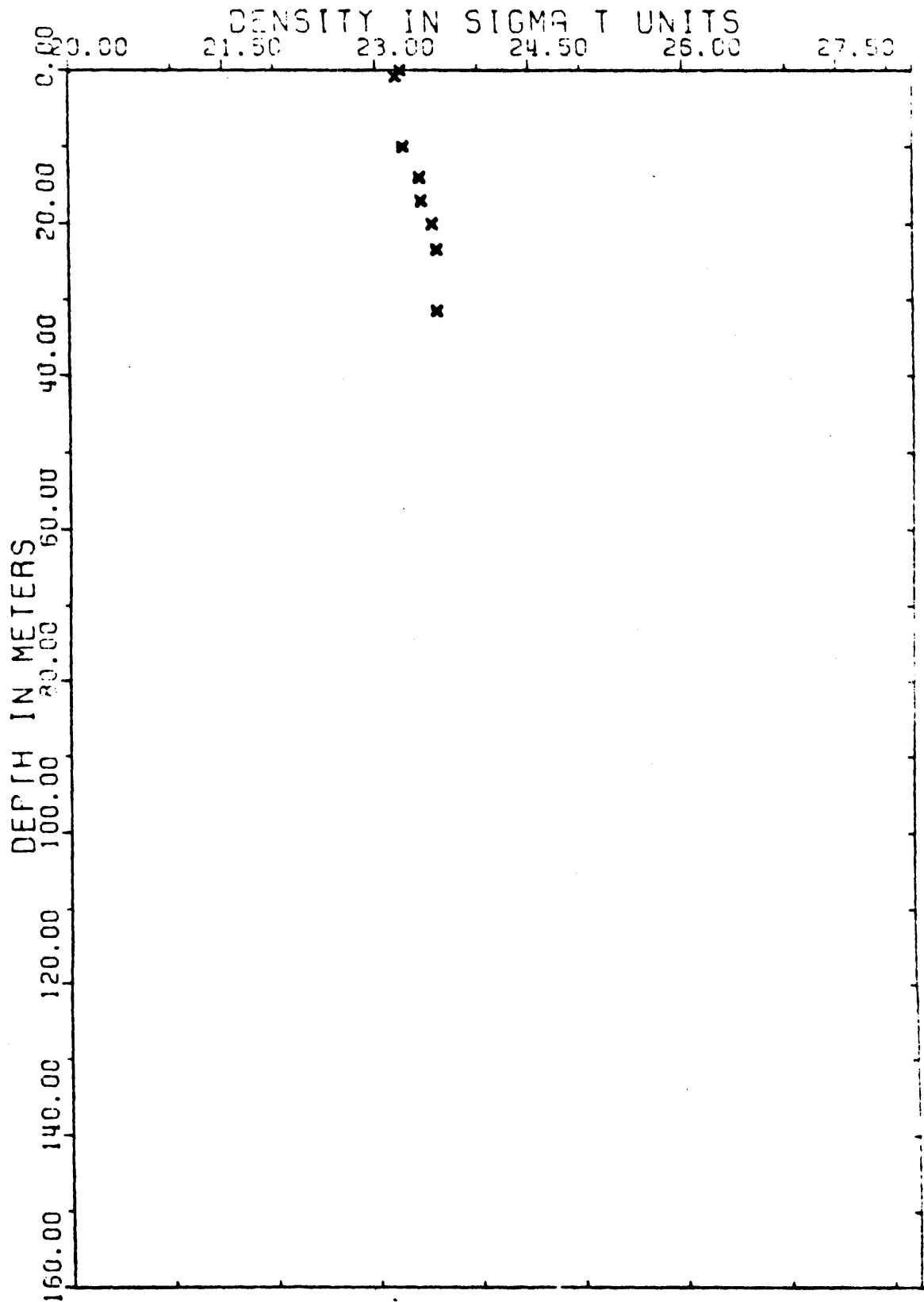
Figure 3-170. Meteorological data collected during cruise BLM 04T 23-25 August 1976.

DISCUSSION

Autumn Conditions (October - November 1975)

Temperature, Salinity, and Density

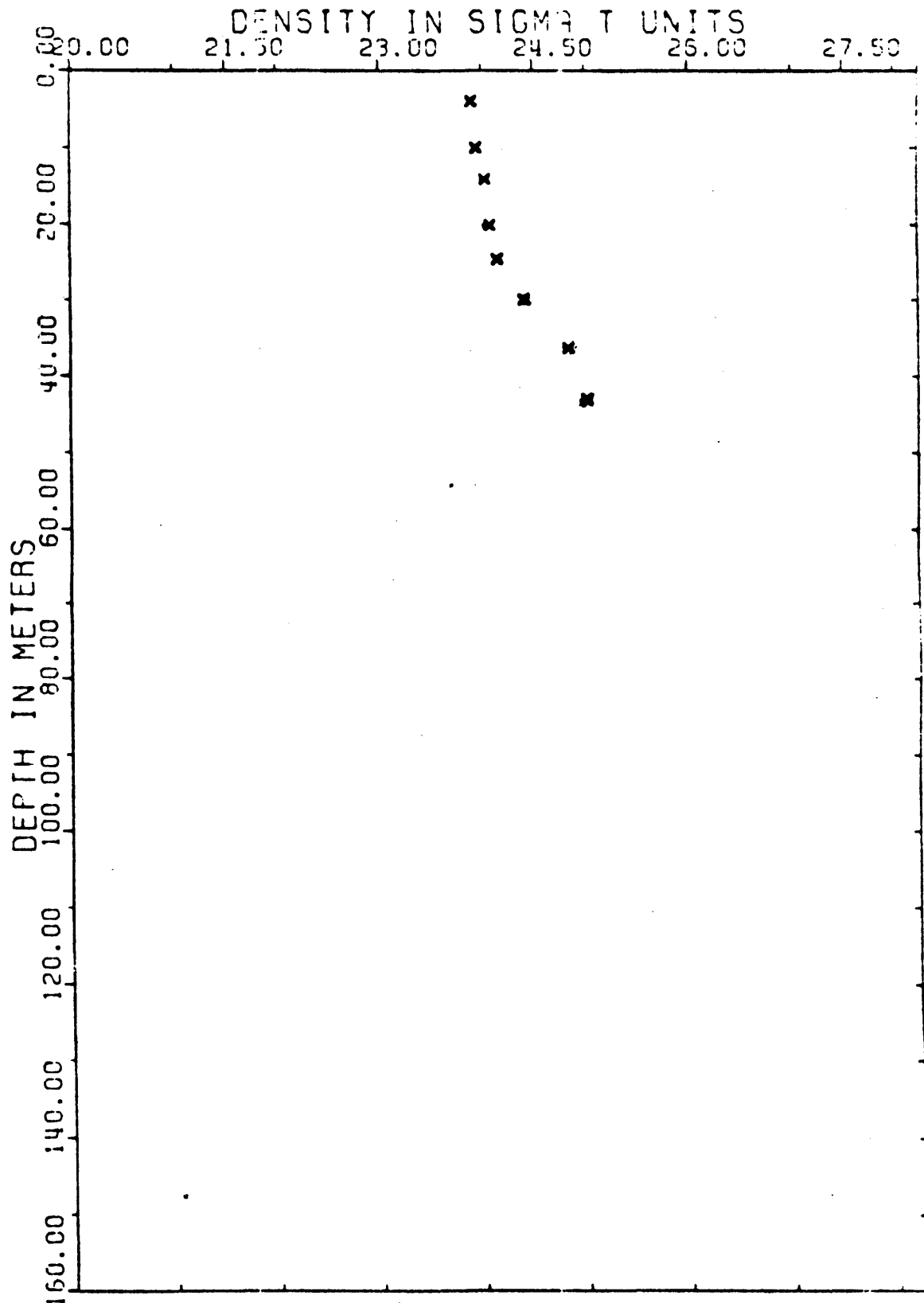
Vertical mixing of the water column was proceeding from inshore to off-shore while cruises BLM 01B and BLM 01W were in progress. Cruise BLM 01W was confined to the region represented by Section III in Figure 3-10 and took place between 23 and 29 October. Figures 3-37, 3-38, and 3-40 show substantial vertical mixing out to station D1 with high thermal stratification between 25 and 30 meters seaward of station E3. Salinity stratification for this cruise changed from horizontal to vertical between stations N3 and E3 (Figure 3-38) was reflected in the more horizontal arrangement of isopycnals beginning in the same region (Figure 3-40). The seaward progression of this stratification was most evident when σ_t vs. depth plots for stations D1, N3, and E3 are compared. They are presented here as Figures 3-171, 3-172, and 3-173. A thermal front was encountered between stations F2 and J1 and appeared as a near surface (down to 20 meters) intrusion of relatively warm ($>20^\circ\text{C}$), salty (>34.5 ppt) water. This is illustrated in plots of temperature and salinity vs. depth at Station J1 (Figures 3-174 and 3-175). A pool of cold, relatively fresher water (11.5°C , 33 ppt) was evident at the bottom between stations N3 and E3. This same region was sampled one week later during cruise BLM01B with results shown in Figures 3-28, 3-29, and 3-31 for temperature, salinity, and σ_t , respectively. During this one week period, vertical mixing extended some 15 km further seaward with horizontal stratification redeveloping near shore in the vicinity of the C stations. The "cold pool" retained a thermal signature (Figure 3-38) and was evident as a seaward bulge of the 33.5 ppt isohaline centered around 50 meters (Figure 3-29). The thermal front was evident between stations F1 and F2 and descended from a depth of 40 meters at Station F2 (Figure 3-176) to 72 meters at J1 (Figure 3-177). Isohalines (Figure 3-29) and isopycnals (Figure 3-31) indicated a shoreward intrusion of slope water along the bottom. The "cold pool" was also evident along Section II in the vicinity of the B stations (Figures 3-24 and 3-25). Extensive interleaving of shelf and slope water was evident in the vicinity of the A stations with an indication of "calving" (Cresswell 1959) of shelf water into the slope regions. However, sampling did not extend sufficiently seaward to verify this. The "cold pool" was also evident in horizontal distributions of temperature and salinity (Figures 3-18 and 3-19) for this season and seemed to be (thermally) most intense in the vicinity of the E stations.



CRS BLM01W STA. D1

21.1 HR. 24 OCT. 1975

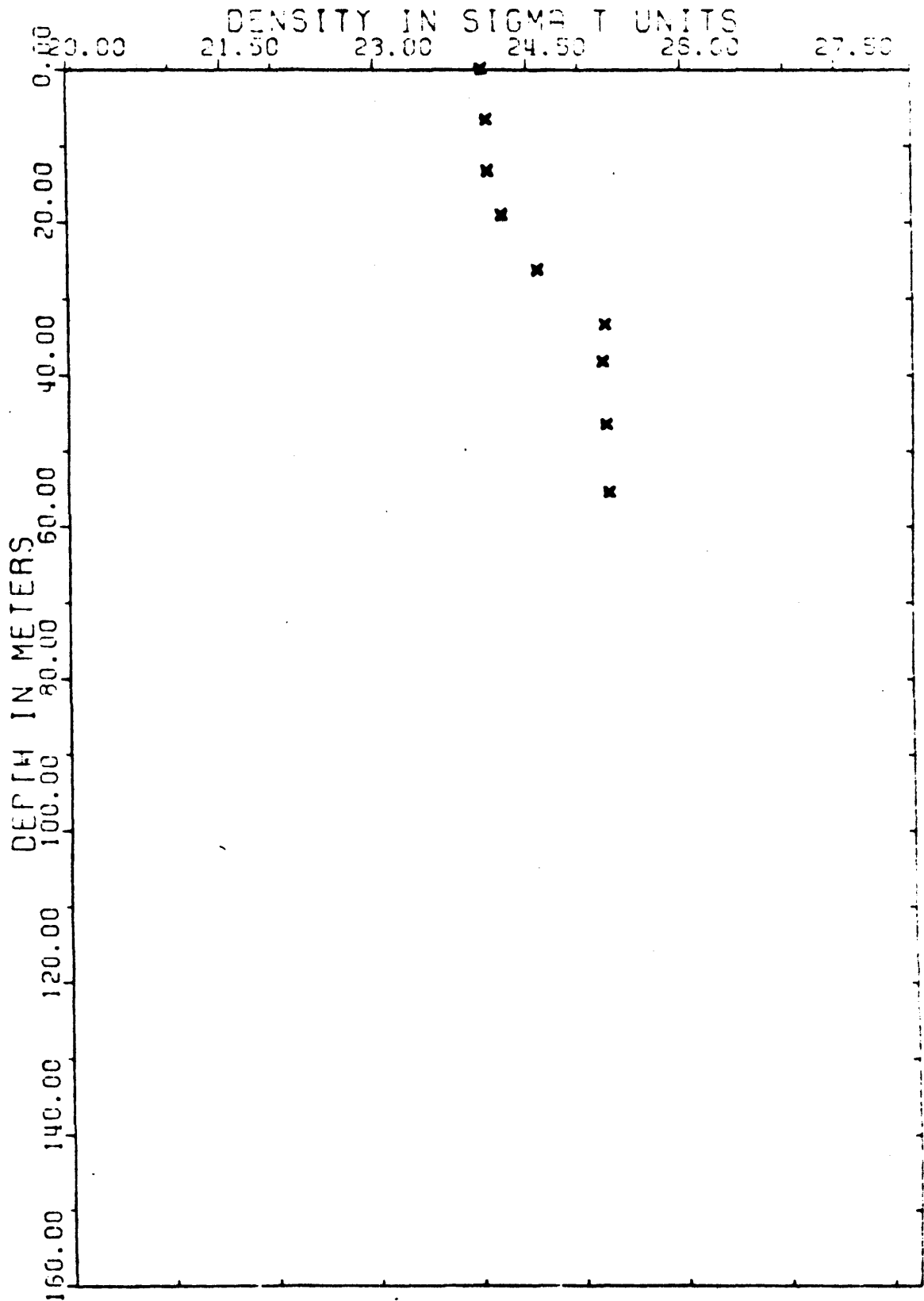
Figure 3-171. Density as a function of depth at Station D1 during cruise BLM 01W.



CRS BLMU1W STA. N3

23.0 Hrs. 25 Oct. 1975

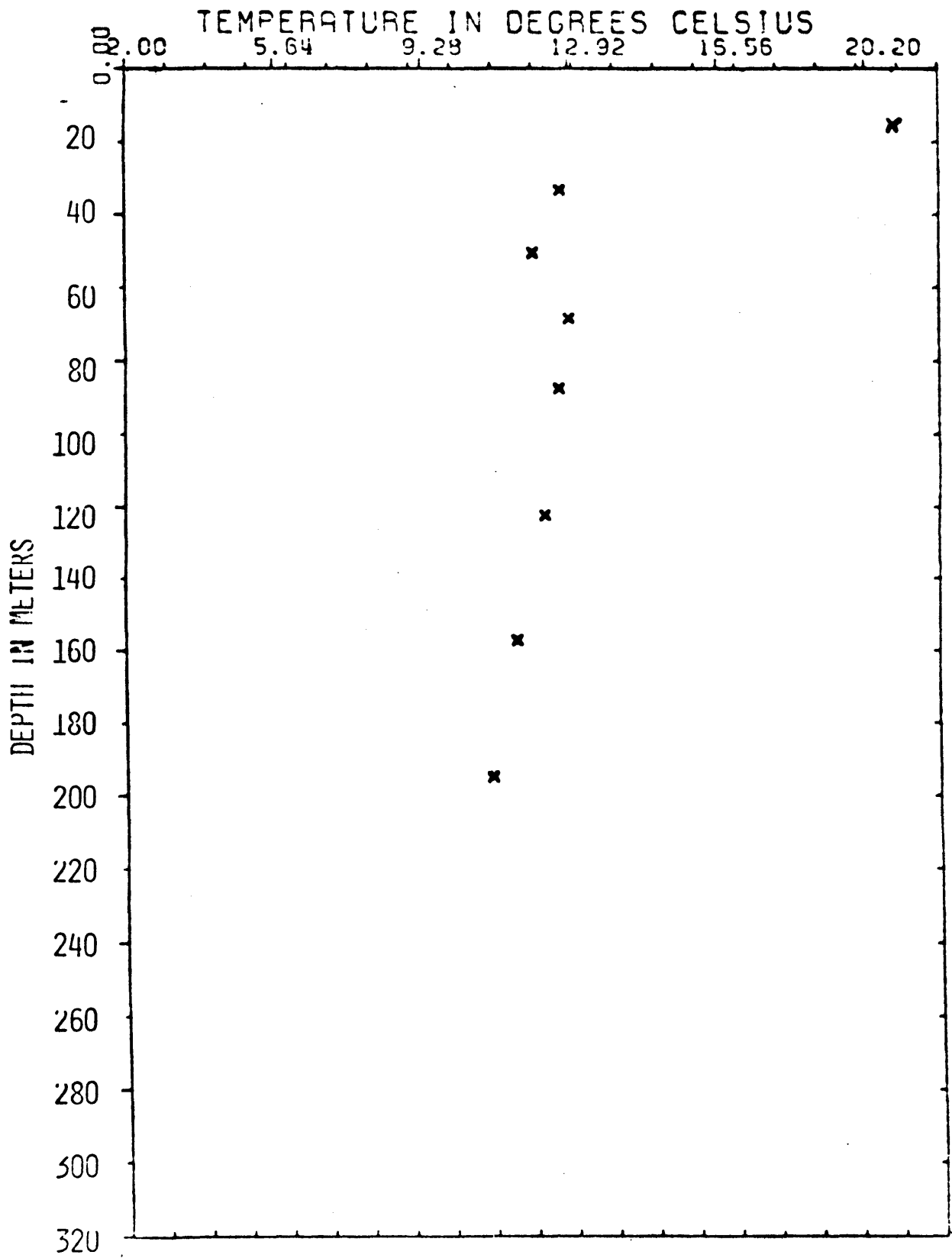
Figure 3-172. Density as a function of depth at Station N3 during cruise BLM 01W.



CRS BLM01W STA. E3

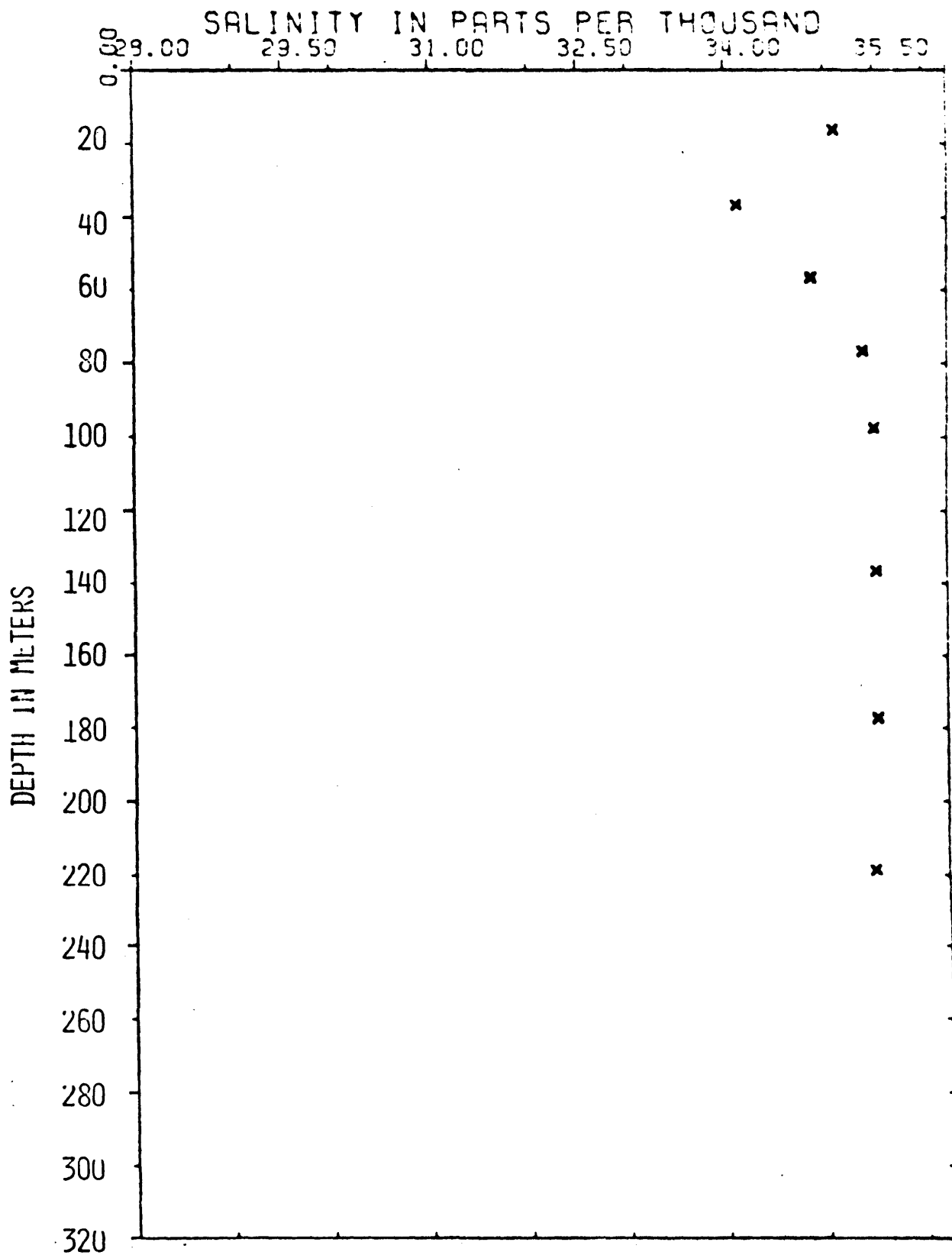
21.5 HR. 26 OCT. 1975

Figure 3-173. Density as a function of depth at Station E3 during cruise BLM 01W.



CRS BLM01W STA. J1 18.2 HR. 29 OCT. 1975

Figure 3-174. Temperature as a function of depth at Station J1 during cruise BLM 01W.



CRS BLM01W STA. J1

18.2 HR. 29 OCT. 1975

Figure 3-175. Salinity as a function of depth at Station J1 during cruise BLM 01W.

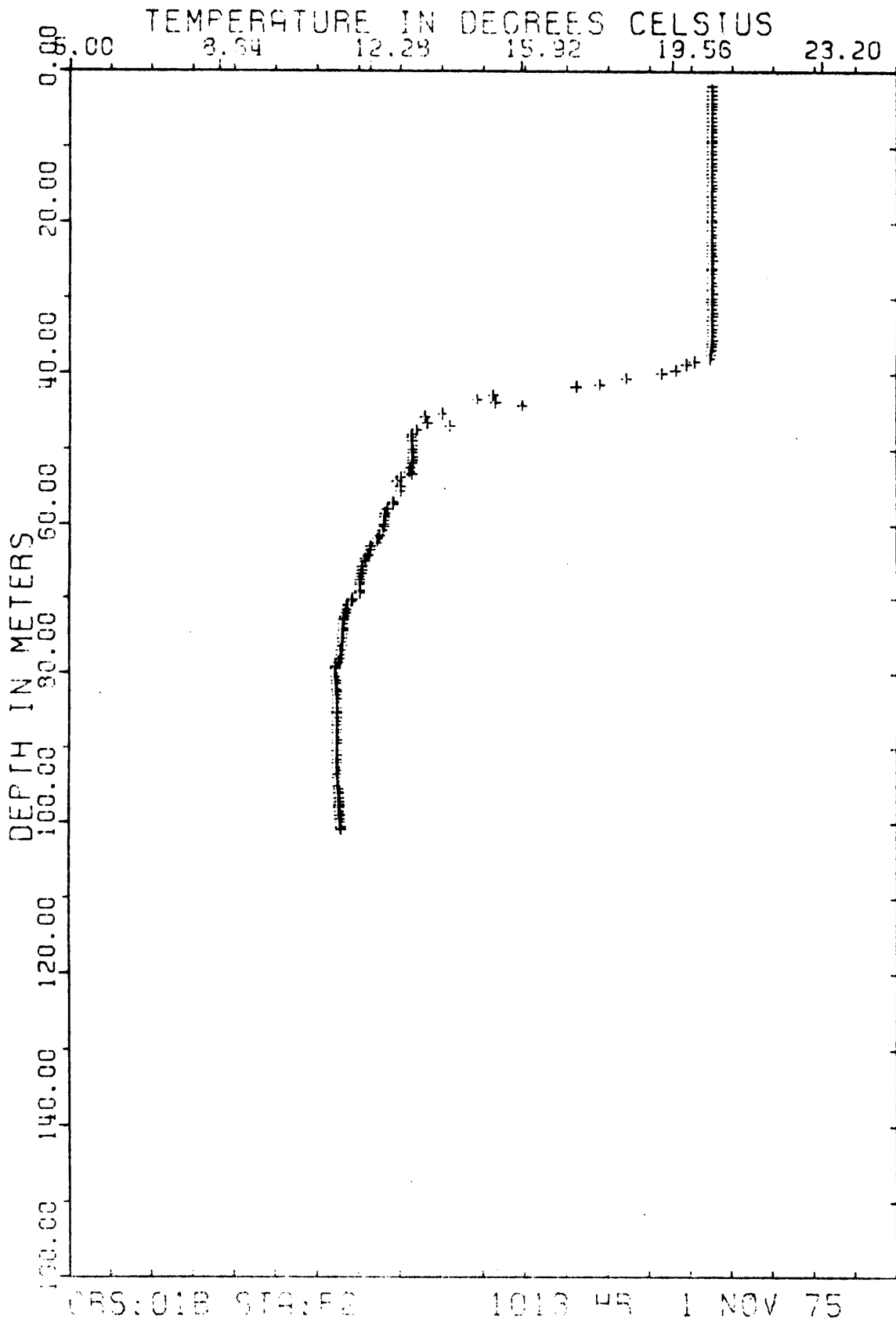


Figure 3-176. Temperature as a function of depth at Station F2 during cruise BLM 01B.

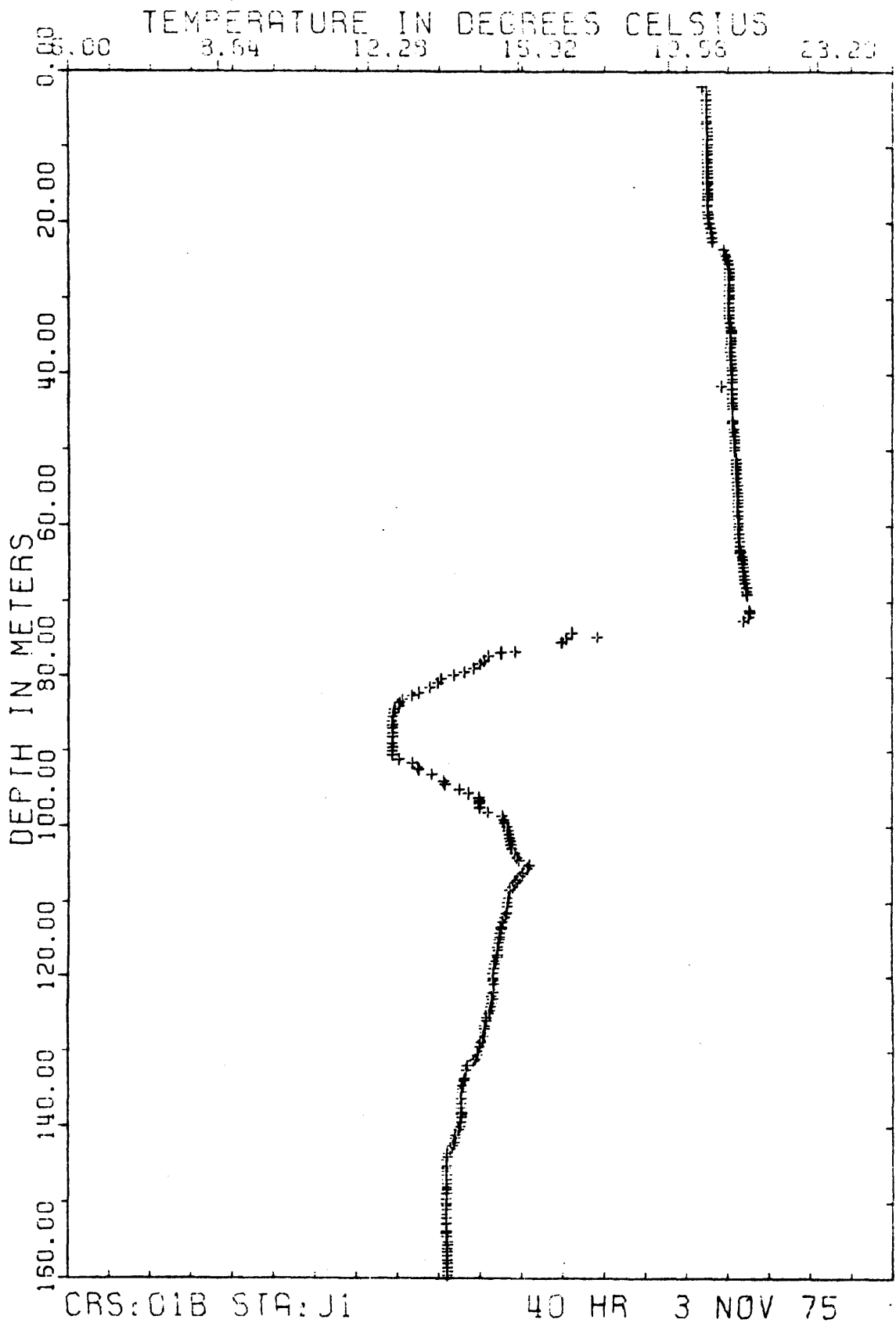


Figure 3-177. Temperature as a function of depth at Station J1 during cruise BLM 01B.

Dissolved Oxygen and Micronutrients

Dissolved oxygen values ranged from 5.5 to 10 mg/liter throughout the area during this season. Two exceptions were stations N3 and J1 during cruise BLM 01W where bottom DO values were in the 5 mg/liter range (Figures 3-32, 3-34, and 3-41).

Of the dissolved micronutrients analyzed, NO_2 and O-PO_4 quantities were less than 1 $\mu\text{gm atm}$ per liter in both near surface and near bottom waters (Figures 3-15, 3-17, 3-21, and 3-23). Highest values of O-PO_4 were found near the bottom on the outer shelf at depths between 100 and 150 meters. Nitrates were highest at the bottom (in many cases, an order of magnitude higher than nitrites) (Figures 3-33, 3-35, and 3-42), with highest values found to the south of Hudson Canyon (Figure 3-22).

Winter Conditions (February - March 1976)

Temperature, Salinity, and Density

Normal wintertime inverted thermal conditions were found at all except the outermost stations as shown in Figures 3-76, 3-78, 3-80, and 3-89. Significant changes in hydrographic conditions were evident, however, when results of cruise BLM 02W were compared with those of BLM 02B. The former cruise occupied stations along Section III between 5 and 14 February, while the latter cruise covered the same region in three sections: the inner portion (C to D stations) on 20 and 21 February; the central portion (N3 to E4 stations) on 3 and 4 March; and the outer portion (F1 to J2 stations) from 18 to 20 March. During the water column cruise general vertical homogeneity persisted out to Station D1. Seaward of this station, thermal and salt stratification developed with cooler freshened water overlying warmer saltier water. This structure persisted along with general conditions of warming and increased salt content in the seaward direction. These conditions are illustrated in Figures 3-85 and 3-86 as well as temperature-depth, salinity-depth, and T-S plots for stations D1 (Figures 3-178 to 3-180), E3 (Figures 3-181 to 3-183) and J1 (Figures 3-184 to 3-186). During the temporally segmented sampling of this section on the benthic cruise (BLM 02B), conditions at Station D1 remained essentially the same twelve days later while those at Station E3 (sampled over twenty days later) showed an increase in both temperature and salt content of bottom waters (Figures 3-187 and 3-188) indicating an intrusion of slope water. Comparison of Figures 3-85 and 3-86 with Figures 3-64 and 3-65 further illustrates how conditions along this section changed during the winter sampling period.

The seaward portion of Section IV appears to be anomalous in the winter benthic sampling sequence. Vertical homogeneity persists for temperature, salinity, DO, and density in this region as illustrated in Figures 3-68 to 3-71. All other sections show colder, relatively fresh water overlying warmer ($>10.5^\circ\text{C}$) saltier (>34.5 ppt) water intruding from the slope region up onto the shelf to depths of less than 75 meters (Figures 3-56, 3-57, 3-60, 3-61, 3-64, 3-65, 3-72, and 3-73). These sections (I, II, III, and V) also illustrate a horizontal density stratification that is weak but persistent with no well developed pycnocline.

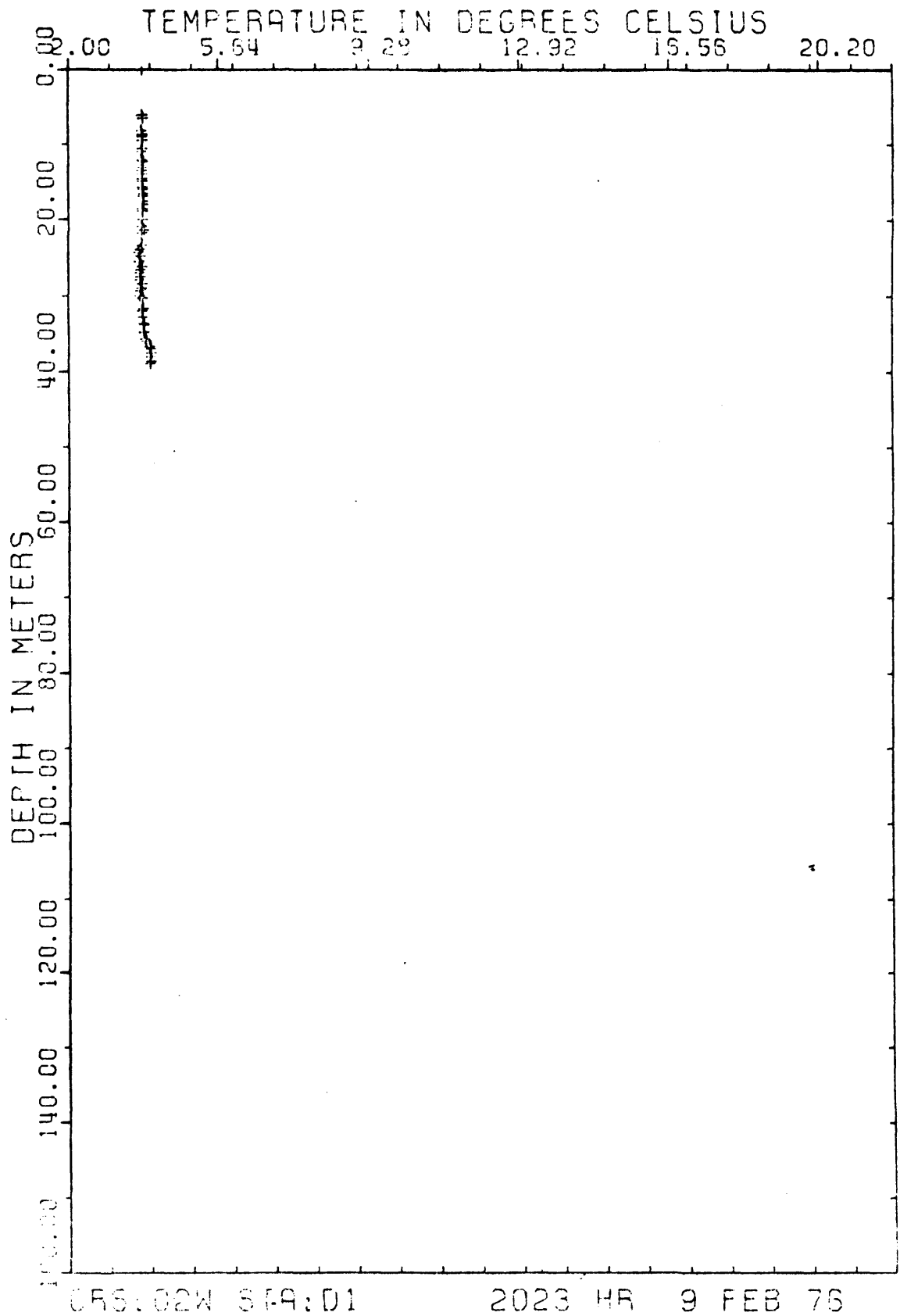
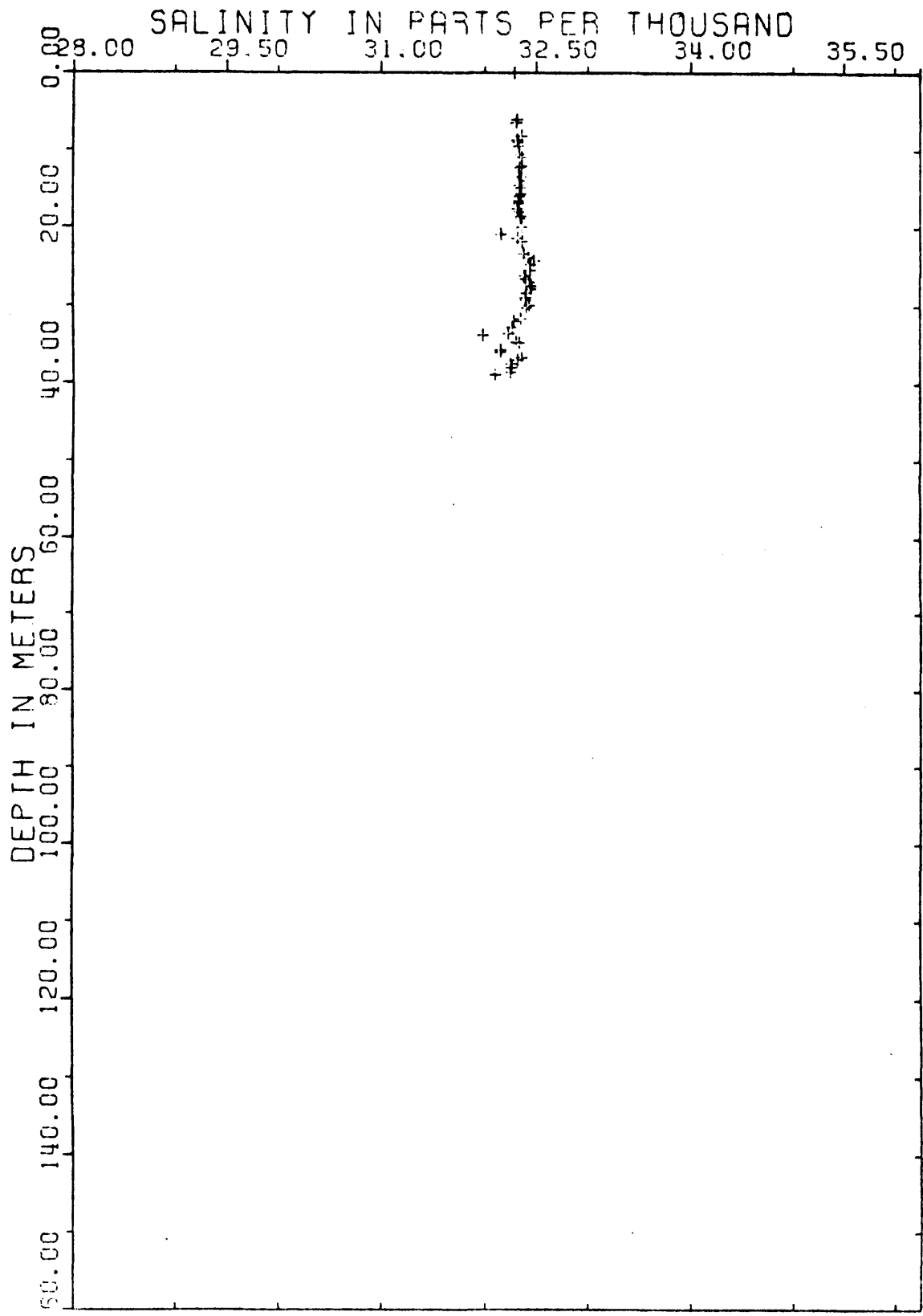


Figure 3-178. Temperature as a function of depth at Station D1 during cruise BLM 02W.



CRS:02W STA:D1 2023 HR 9 FEB 76

Figure 3-179. Salinity as a function of depth at Station D1 during cruise BLM 02W.

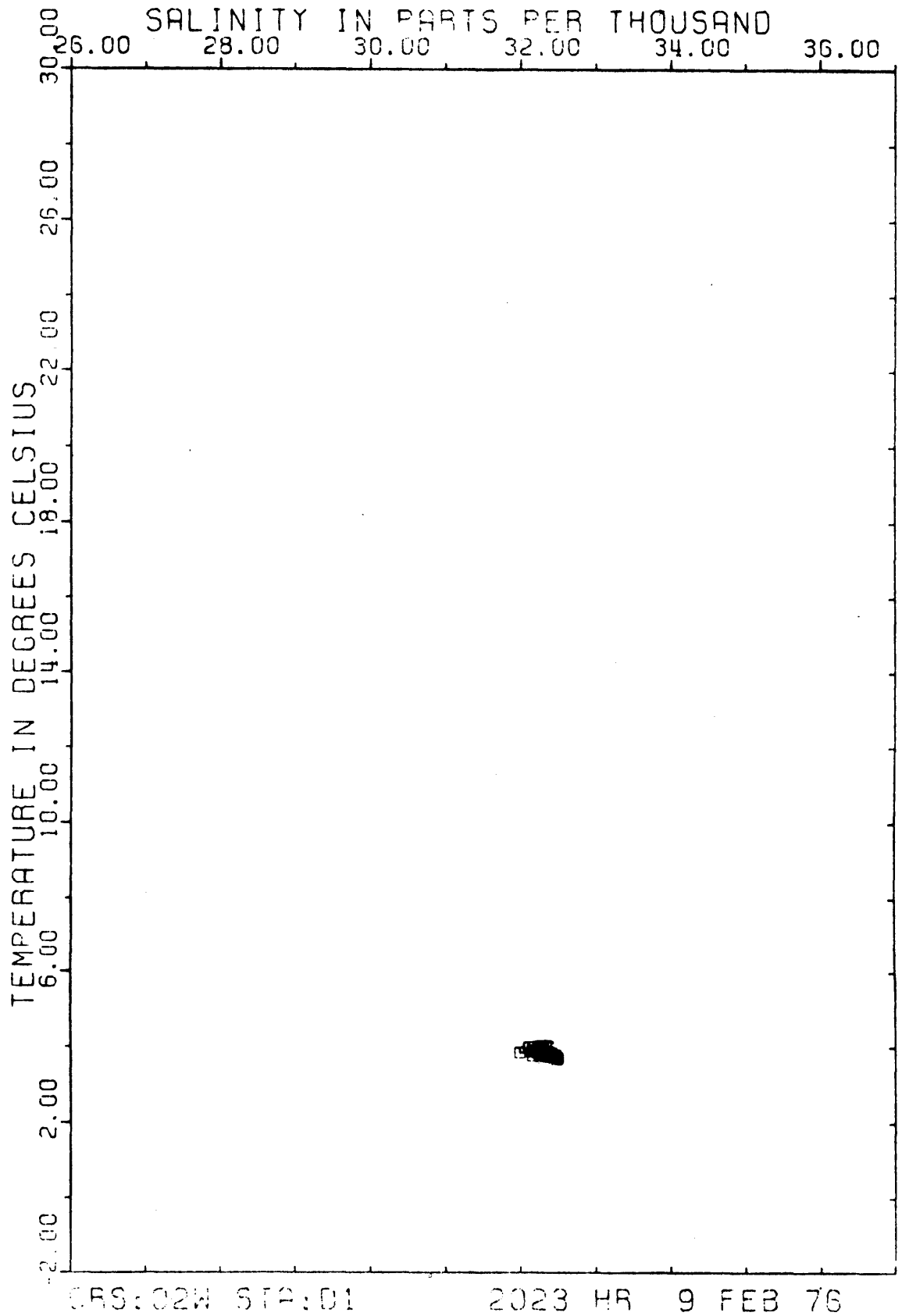


Figure 3-180. T-S diagram for Station D1 during cruise BLM 02W.

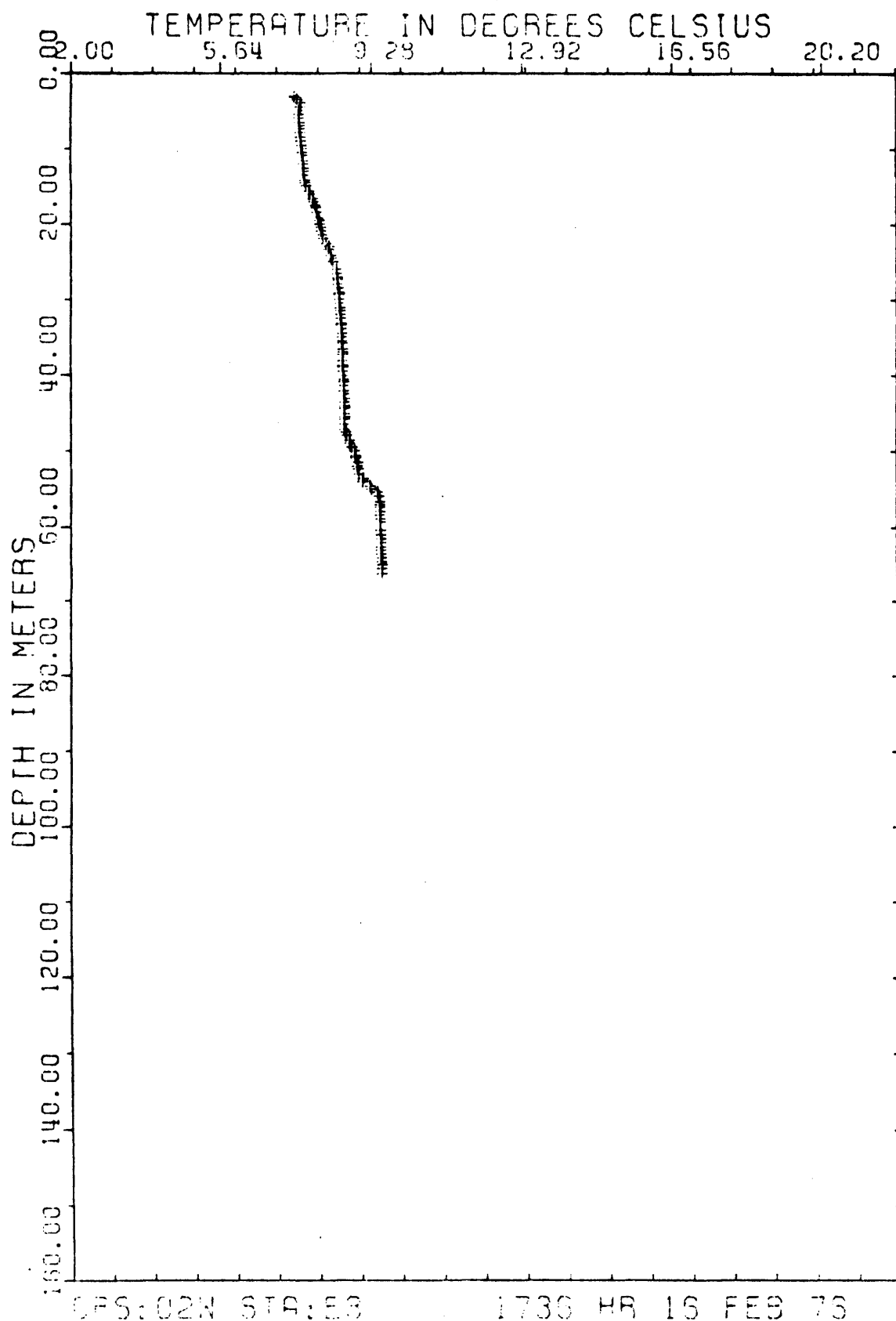


Figure 3-181. Temperature as a function of depth at Station E3 during cruise BLM 02W.

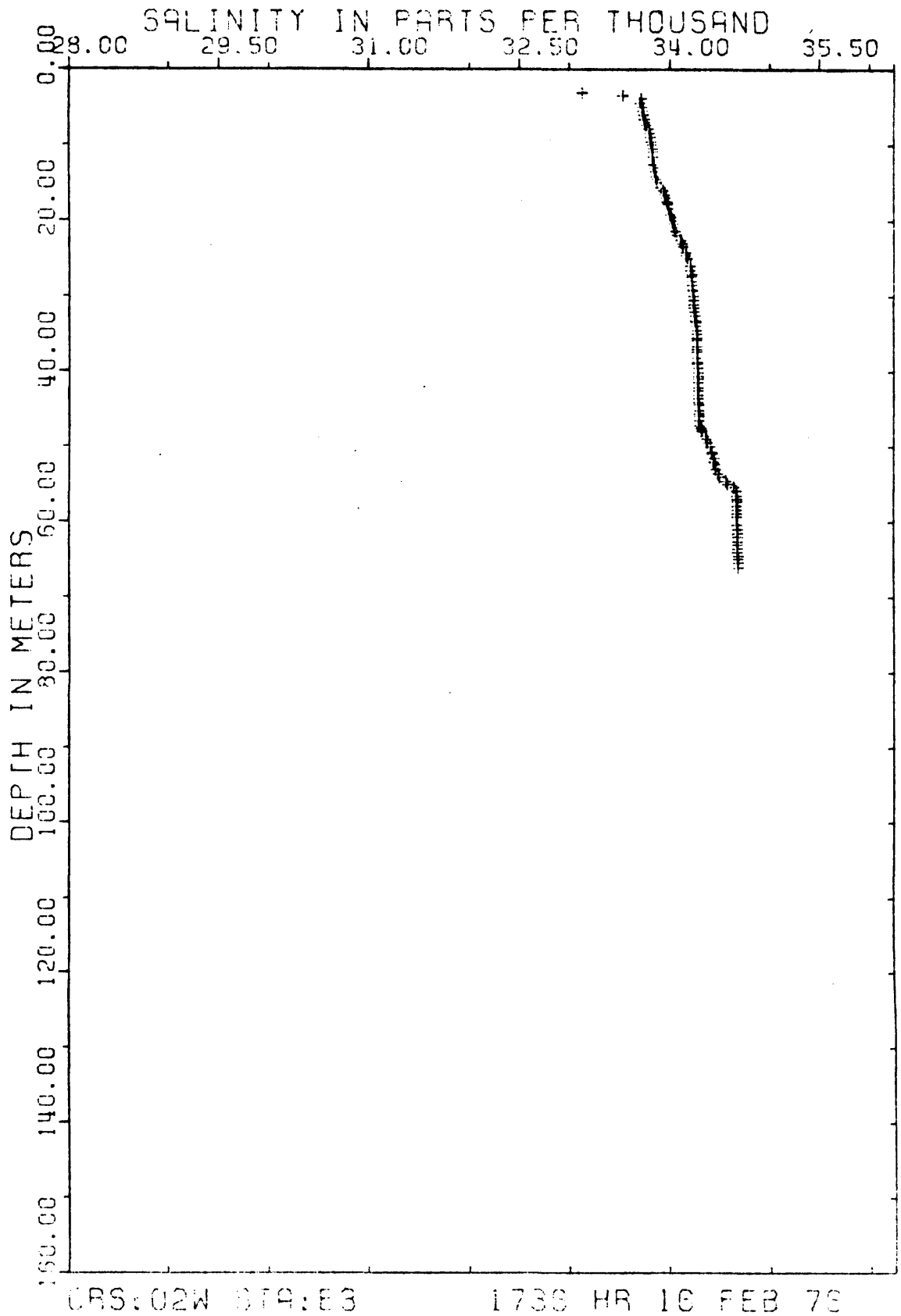


Figure 3-182. Salinity as a function of depth at Station E3 during cruise BLM 02W.

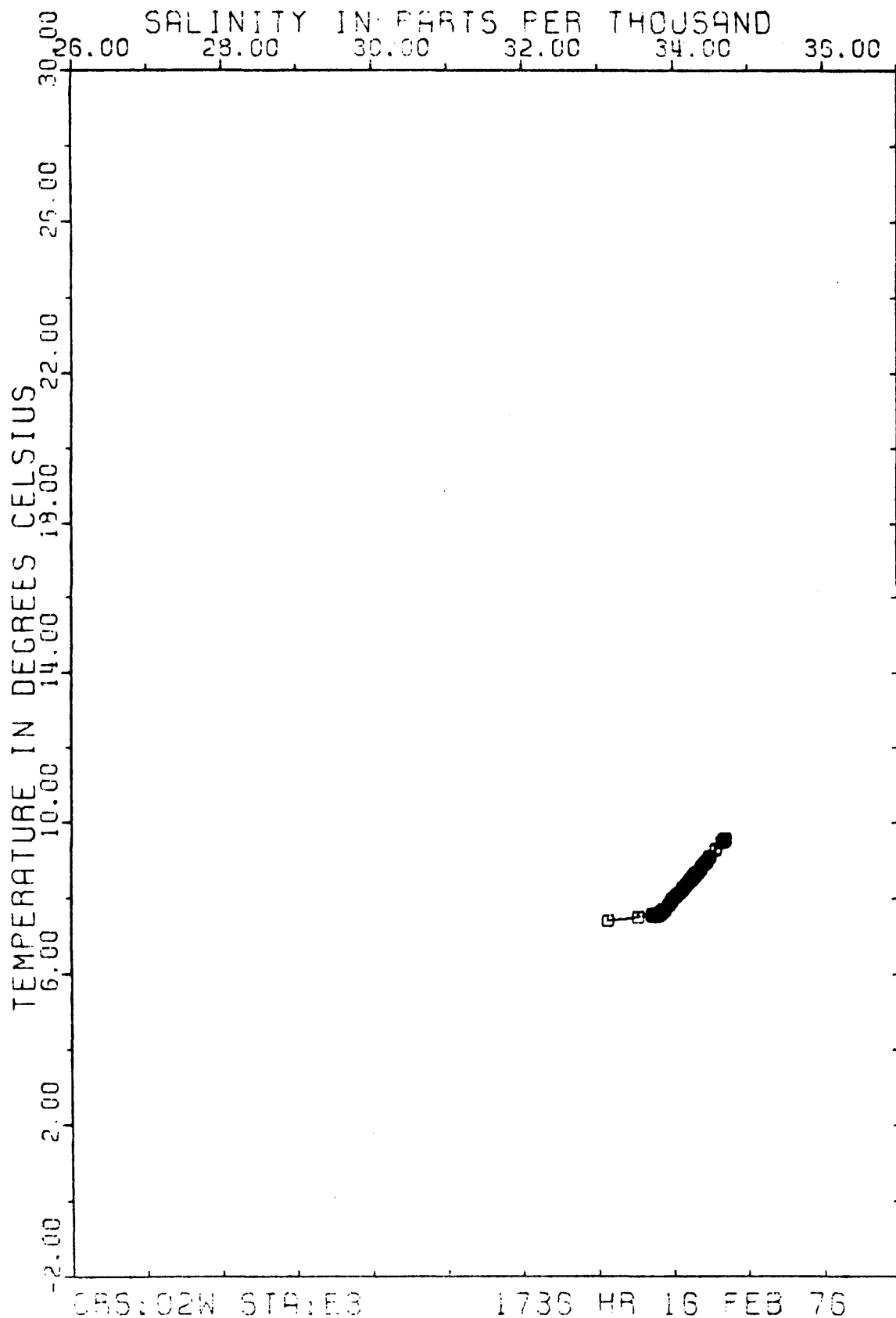
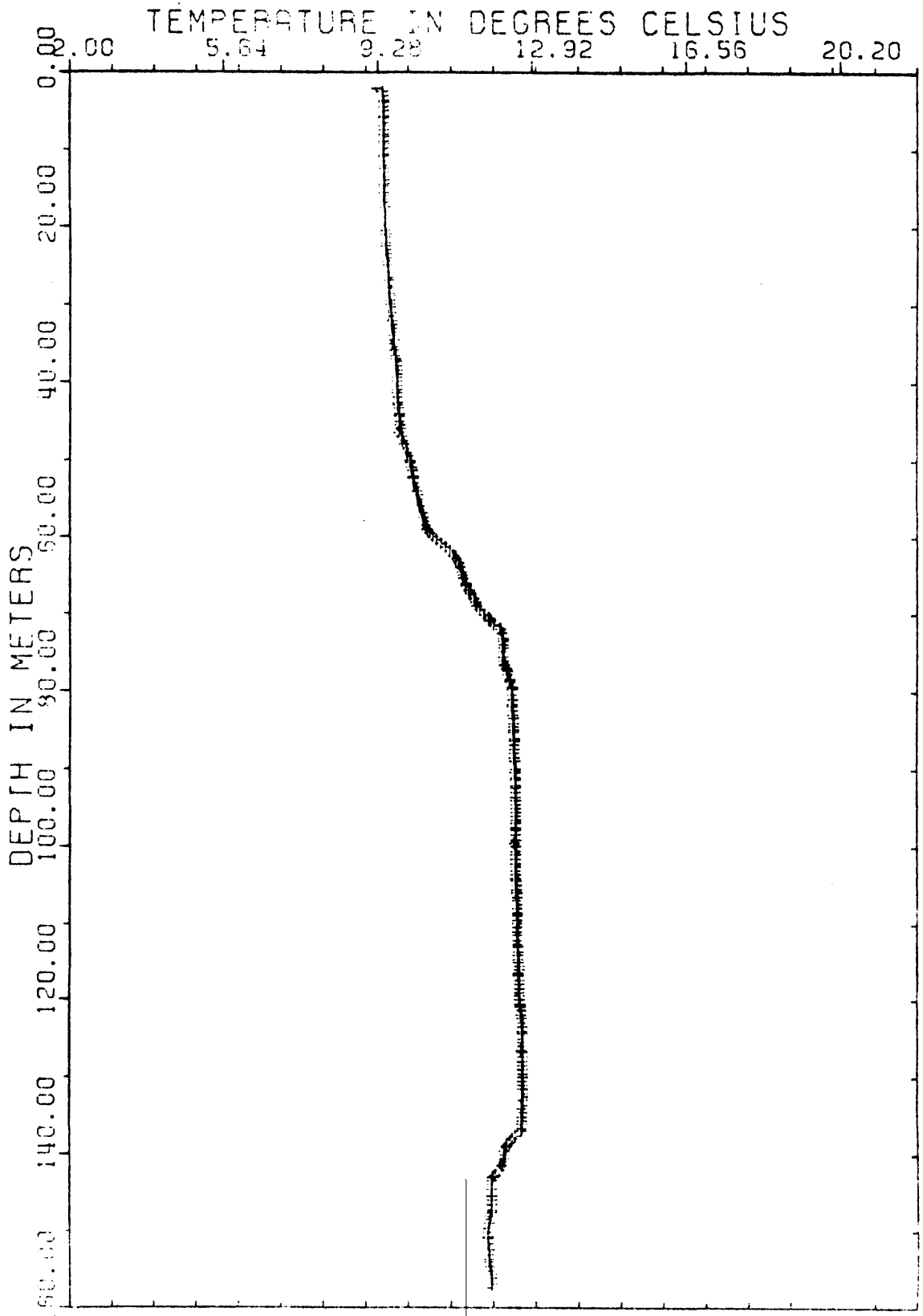


Figure 3-183. T-S diagram for station E3 during cruise BLM 02W.



CRS:02W STA: J1

600 HR 14 FEB 76

Figure 3-184. Temperature as a function of depth at Station J1 during cruise BLM 02W.

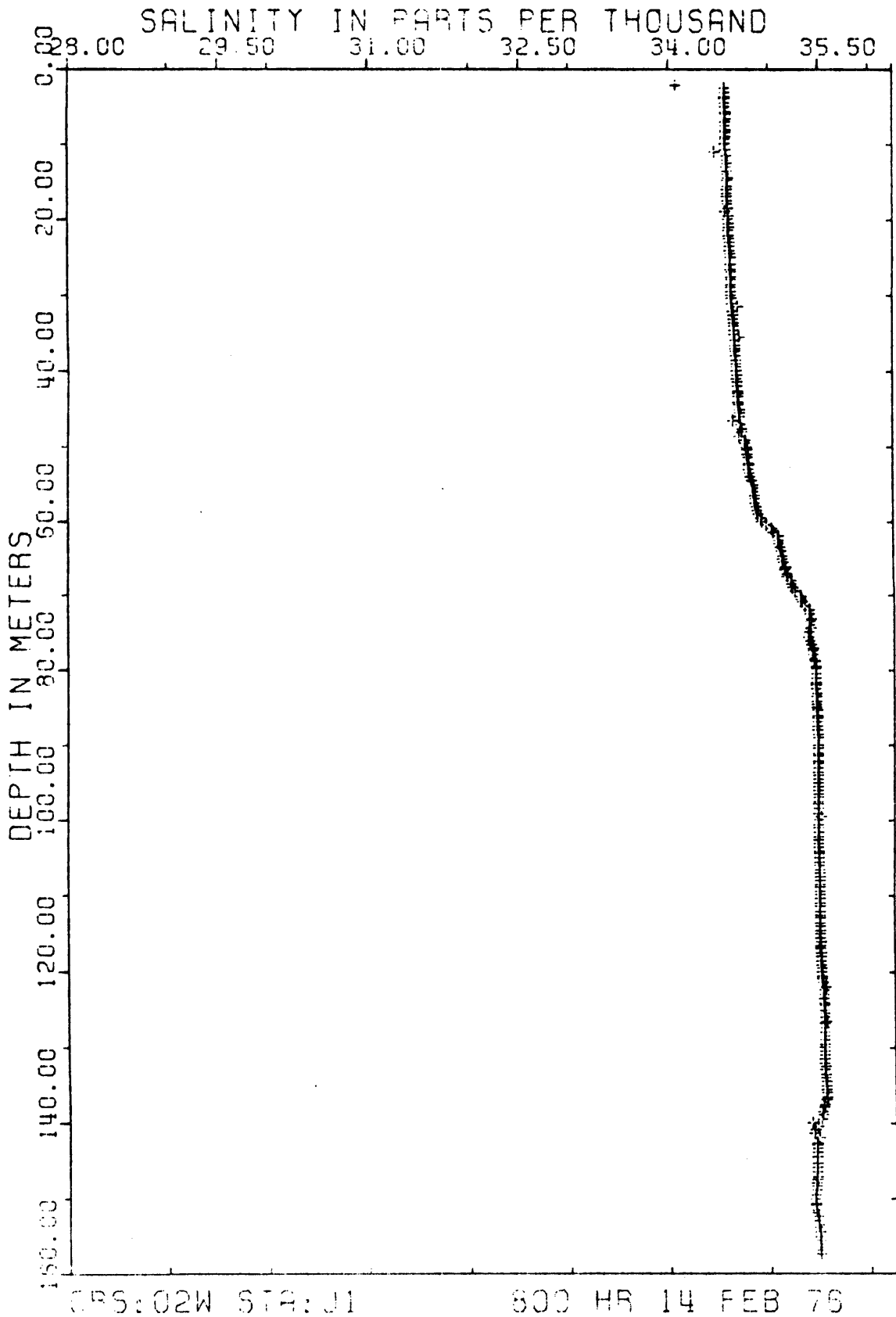


Figure 3-185. Salinity as a function of depth at Station J1 during cruise BLM 02W.

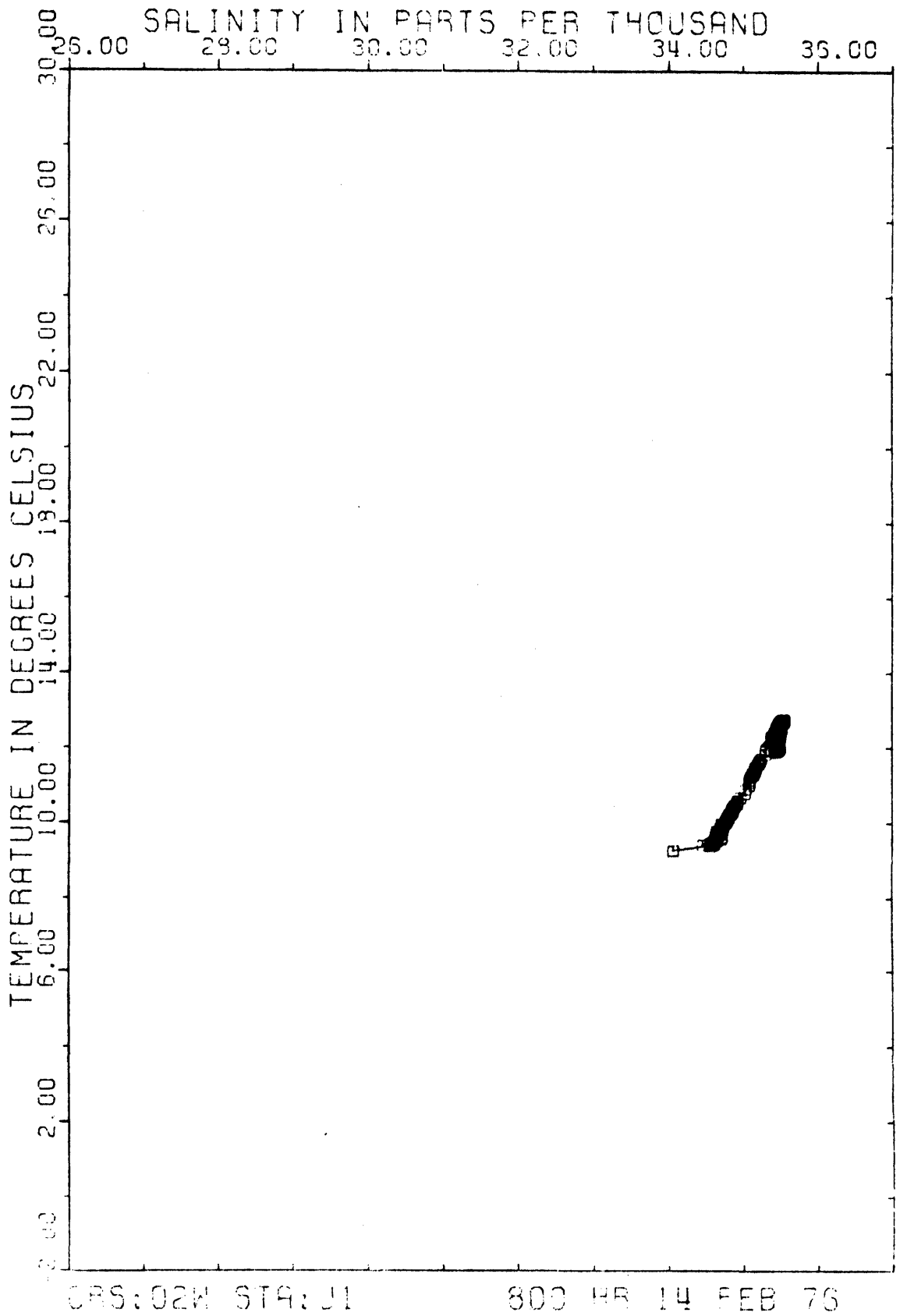


Figure 3-186. T-S diagram for Station J1 during cruise BLM 02W.

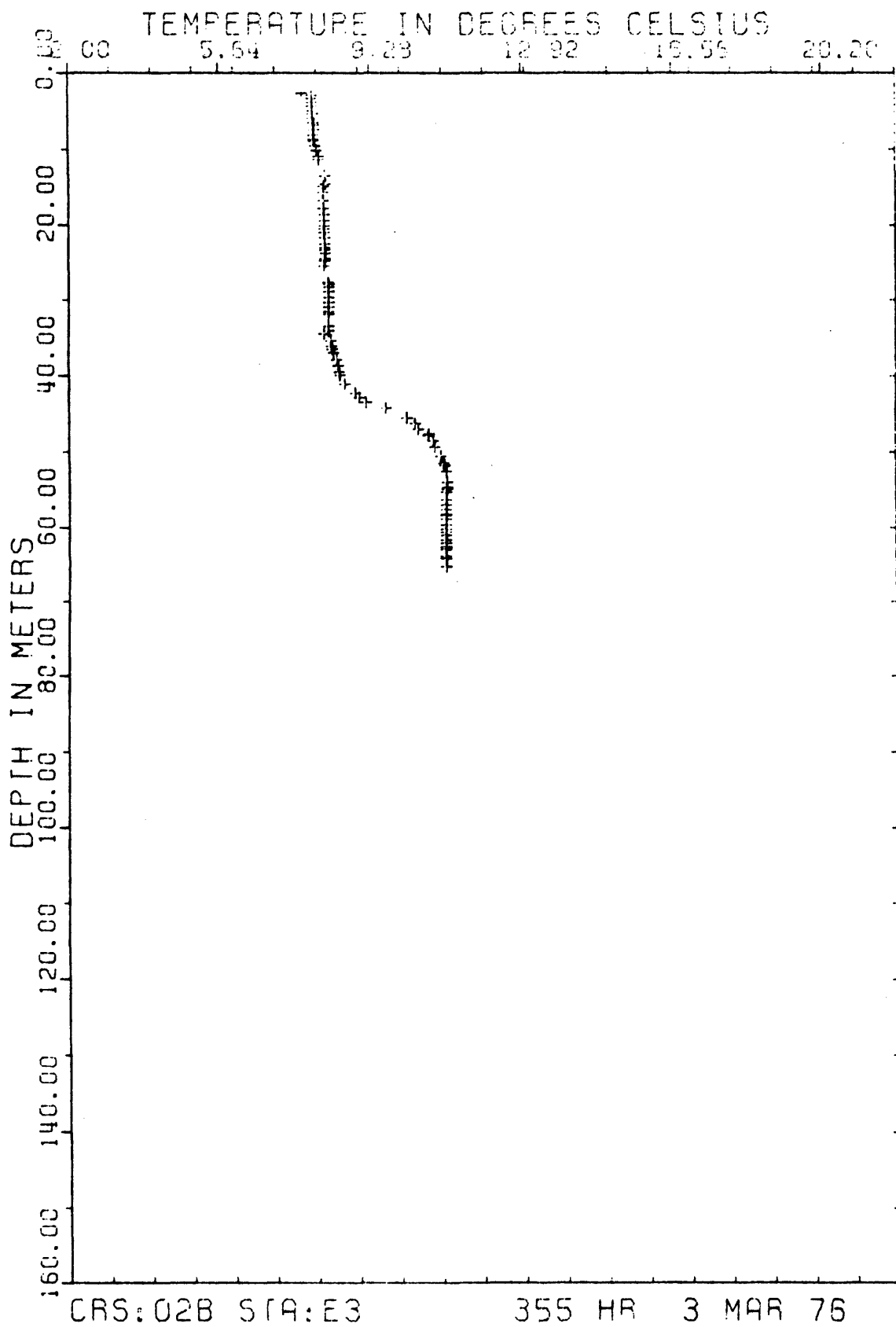


Figure 3-187. Temperature as a function of depth at Station E3 during cruise BLM 02W.

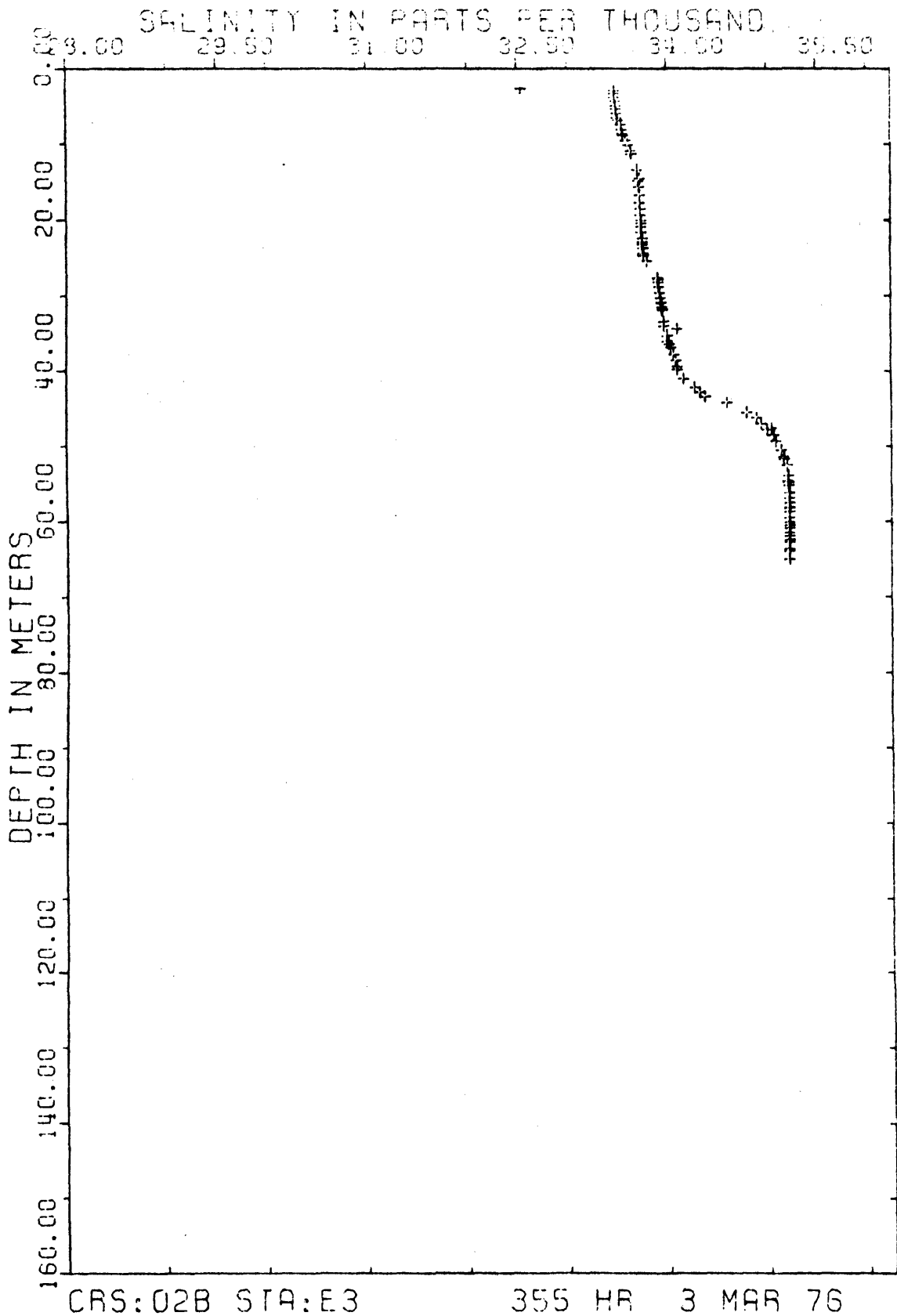


Figure 3-188. Salinity as a function of depth at station E3 during cruise BLM 02B.

Dissolved Oxygen and Micronutrients

Dissolved oxygen content of shelf waters during the winter sampling period ranged from 6 to 10 mg/liter for all regions except mid depths and bottom at deeper stations.

Dissolved micronutrient distributions were similar to those of the previous season in that, with the exception of NO_3 at the bottom on the outer shelf, concentrations were generally less than 1 $\mu\text{gm atm per liter}$.

Spring Conditions (June 1976)

Temperature, Salinity, and Density

Conditions encountered during the spring cruise indicated substantial freshening in the lower layers. Figures 3-104, 3-108, and 3-117 show the preponderance of shelf waters to have salinities less than 33.5 ppt. The strong intrusion of 34.5 ppt slope water along the bottom, which was encountered during the previous winter, was absent. Vernal warming extended to a depth of 18 to 20 meters across the shelf and produced a thin mixed layer. The thermocline region thickened in the offshore direction and covered depths ranging from 3 meters thick near shore to 27 meters thick near the shelf break. These conditions are most evident in Figures 3-189 to 3-192 which are plots of temperature as a function of depth for stations C1, D1, N3, and E2 respectively. Salinities in this mixed layer were in the 32 ppt region and increased to 33.5 ppt at the bottom at Station E2. The resulting pycnocline was strong, generally coincident with the thermocline, and progressed through 2.5 σ_t units at Station E2.

Persistence of the "cold pool" was evident with strongest signatures in the vicinity of the B and E stations as evidenced from Figures 3-97, 3-103, 3-107, and 3-116. Seaward of the E stations, intrusions of slope waters were evident at depths below 25 meters.

Dissolved Oxygen and Micronutrients

Bottom dissolved oxygen values were lowest in the vicinity of the 50 to 75 meter isobaths as evidenced in Figures 3-99, 3-105, 3-109, and 3-118. These low DO's went down to less than 3.5 mg/liter and were invariably overlain with highly oxygenated water which was found in the vicinity of the thermocline-pycnocline. This condition is most dramatically illustrated in Figures 3-193 to 3-195 for stations B1, N3A, and D4. Low bottom DO values were undoubtedly due to consumption and lack of deep mixing during the period between the winter and spring cruises. High DO values in the vicinity of the thermocline-pycnocline are most likely due to phytoplankton activity in this region (Jerlov 1970).

Micronutrients again show low values (<1 $\mu\text{gm atm per liter}$) except for NO_3 which appeared in substantially higher concentrations in near surface as well as bottom waters (Figures 3-112, 3-114, and 3-121).

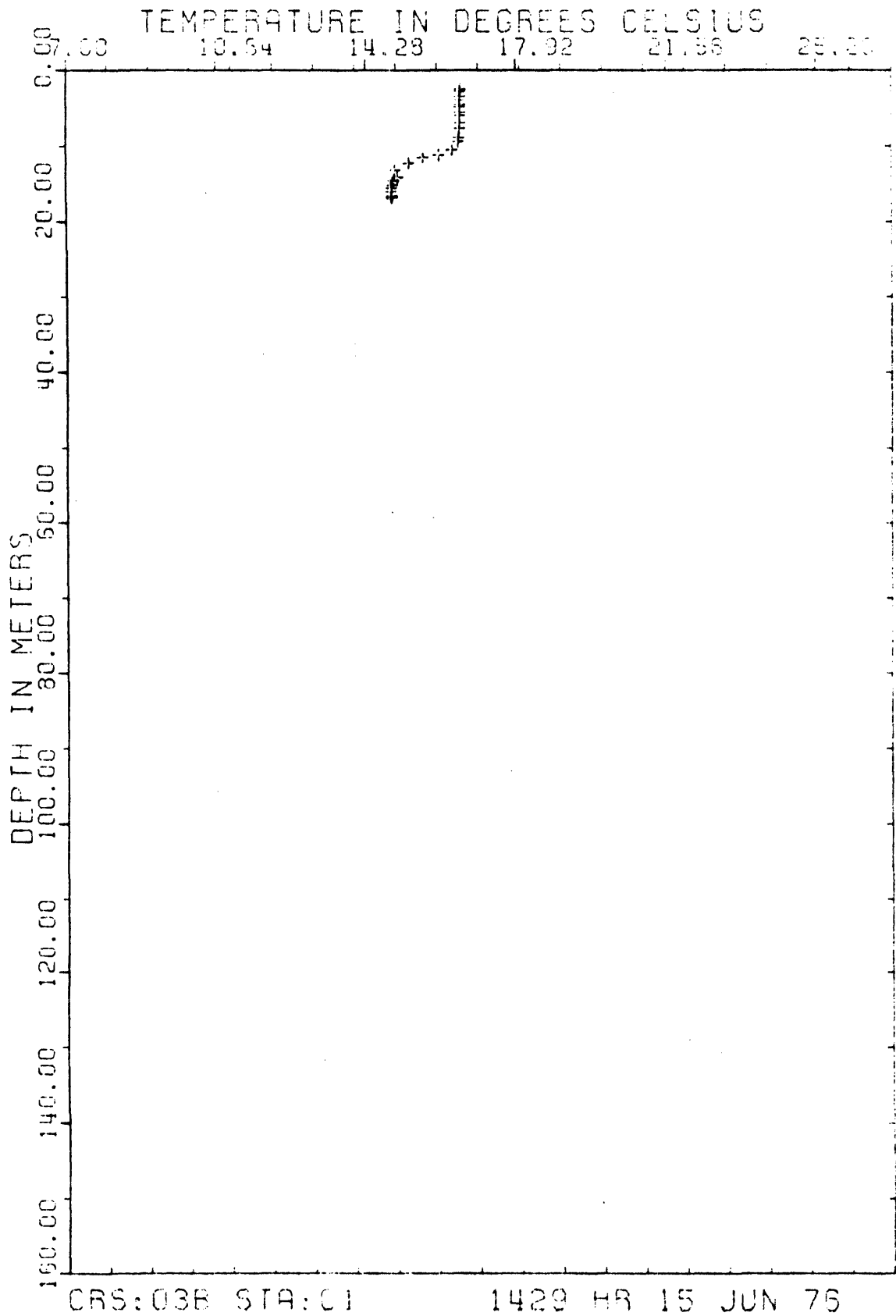


Figure 3-189. Temperature as a function of depth at Station C1 during cruise BLM 03B.

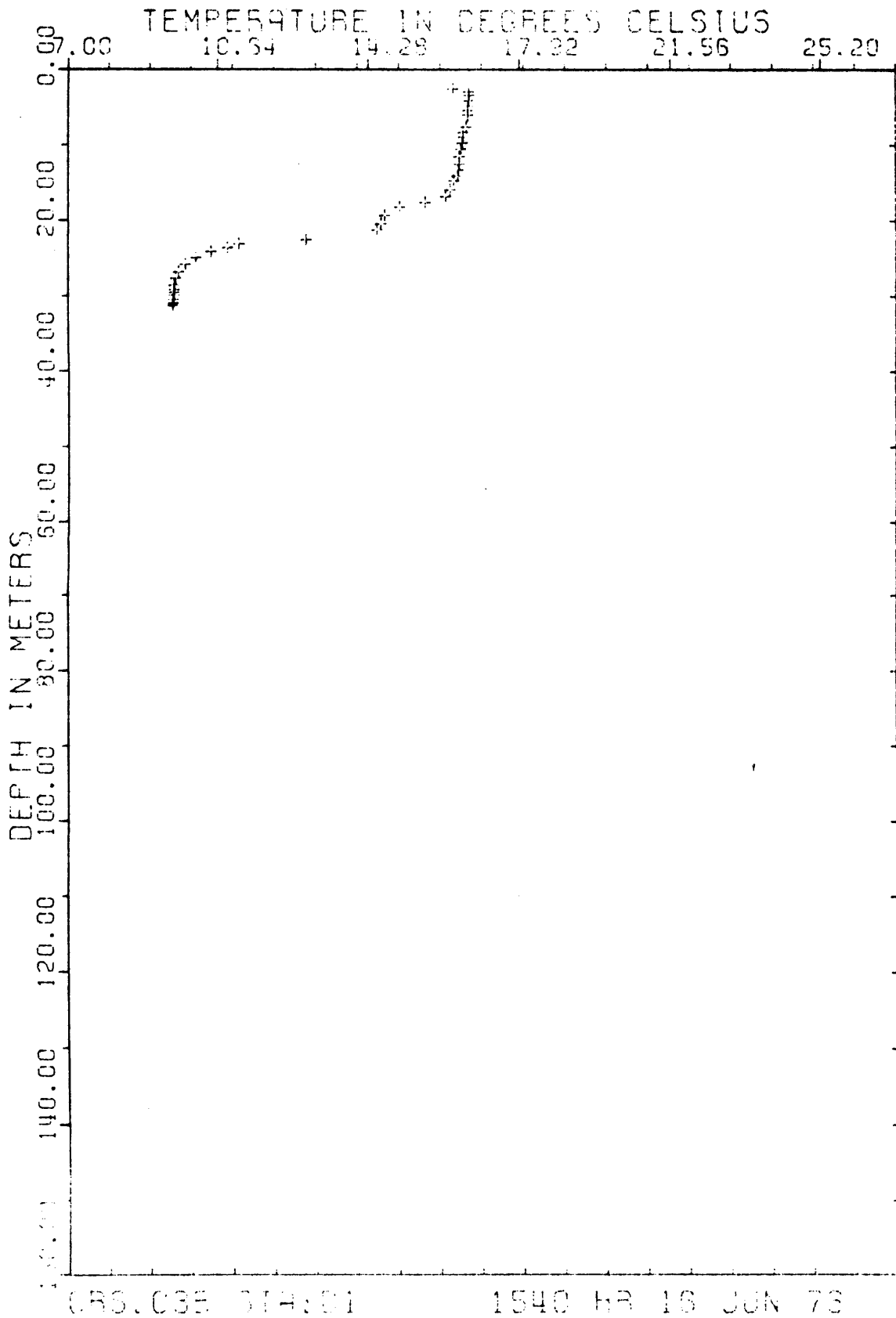


Figure 3-190. Temperature as a function of depth at Station D1 during cruise BLM 03B.

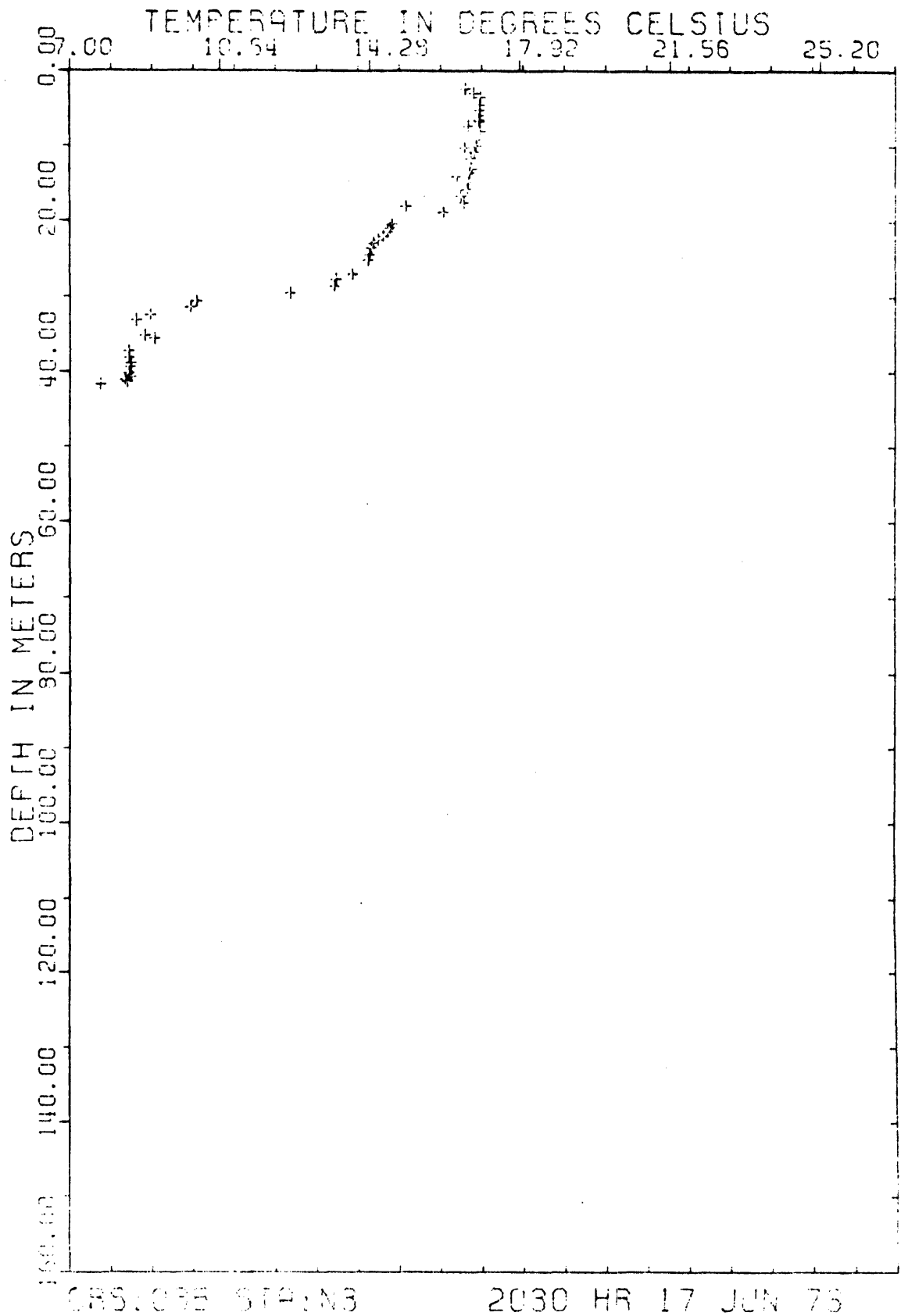


Figure 3-191. Temperature as a function of depth at Station N3 during cruise BLM 03B.

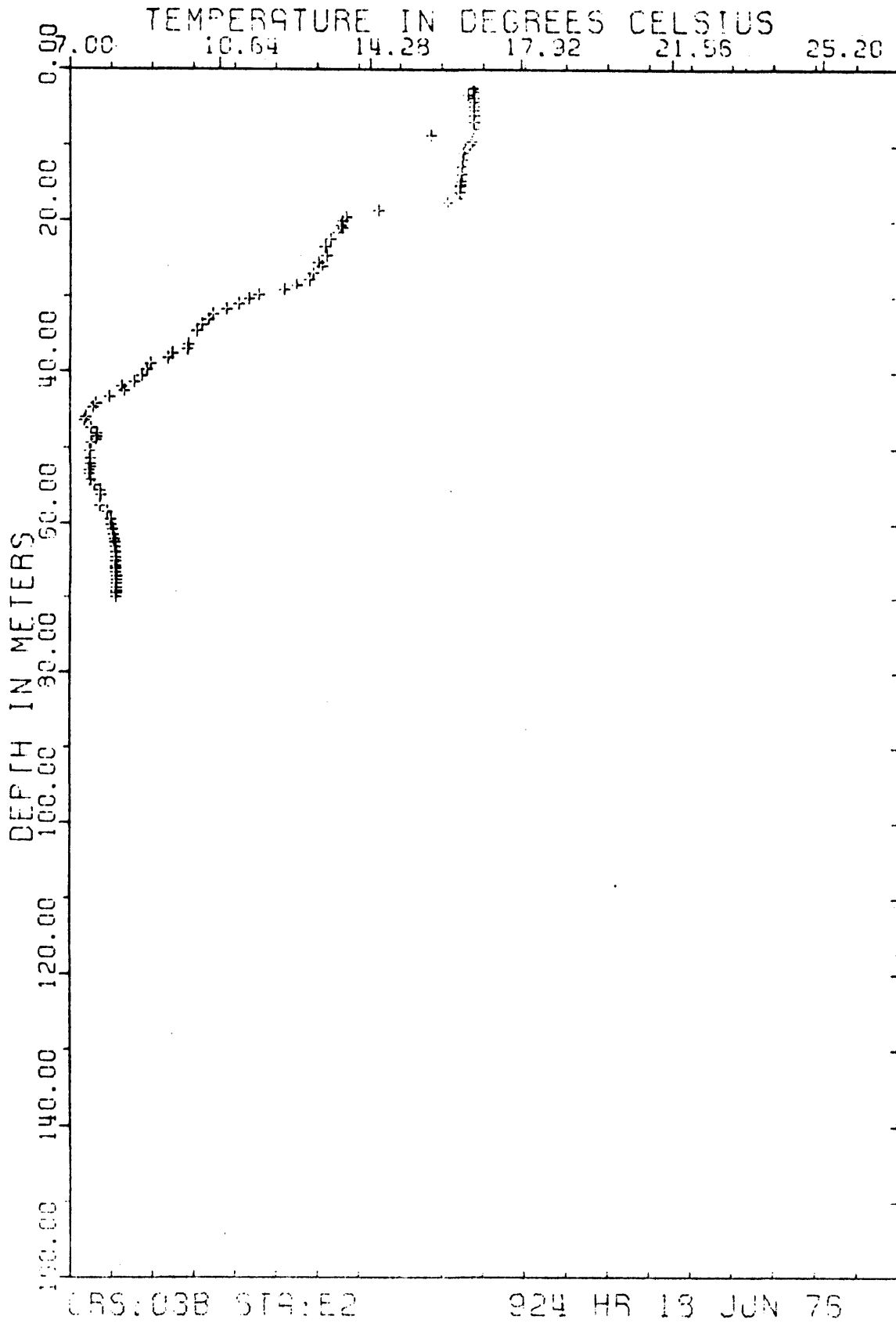


Figure 3-192. Temperature as a function of depth at Station E2 during cruise BLM 03B.

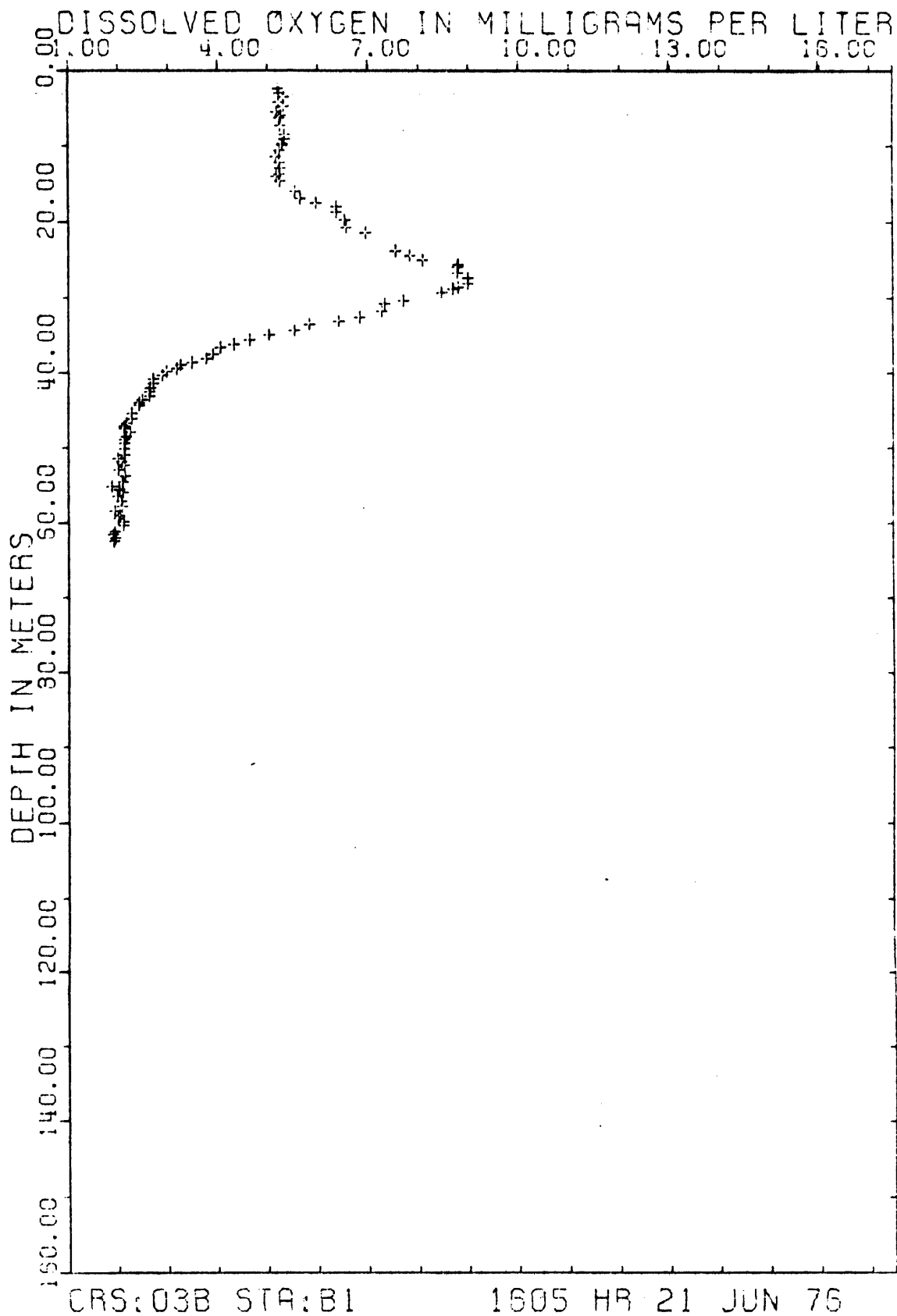
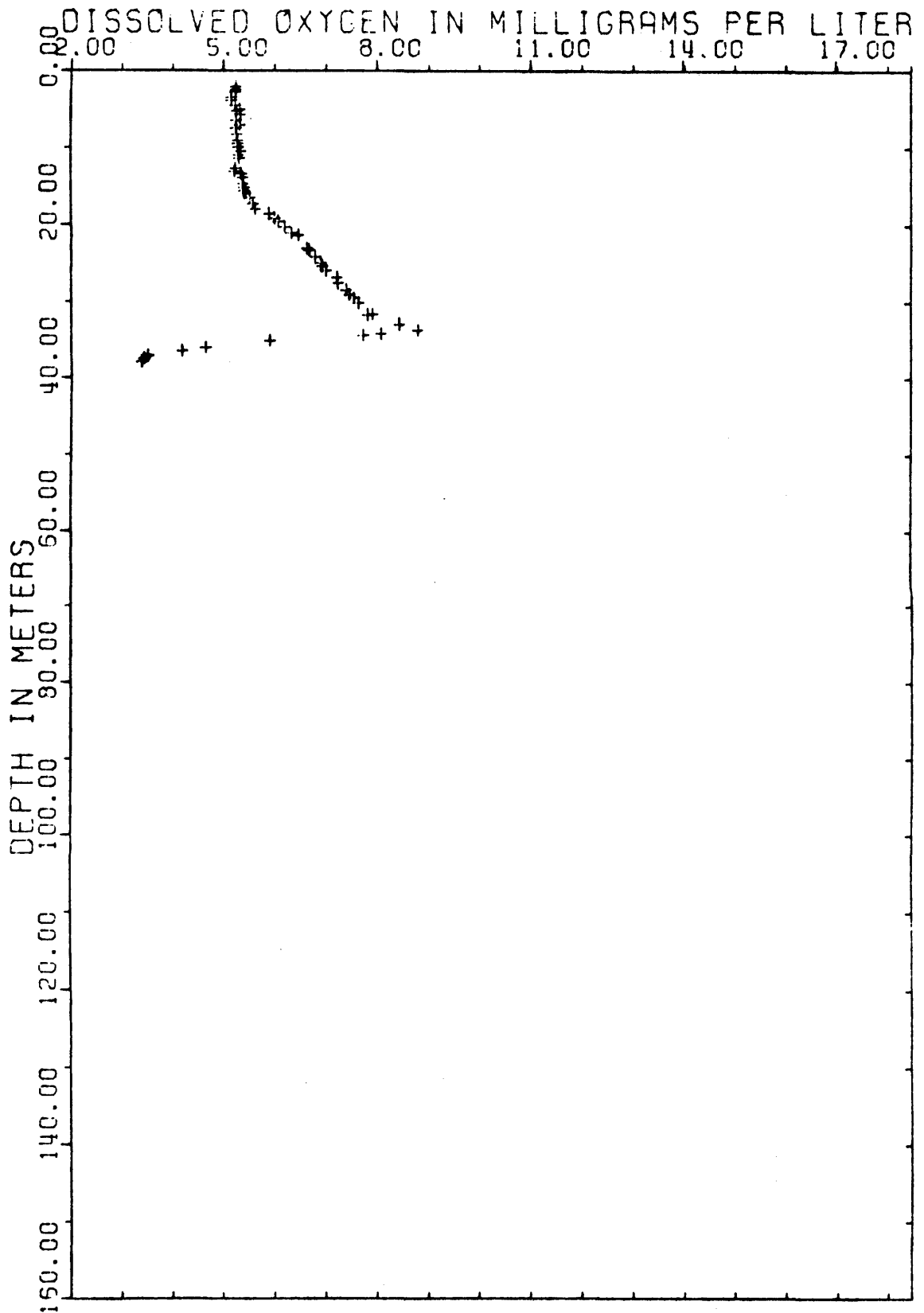


Figure 3-193. Dissolved oxygen as a function of depth at Station B1 during cruise BLM 03B.



CRS:03W STA:N3A 2220 HR 14 JUN 76

Figure 3-194. Dissolved oxygen as a function of depth at Station N3A during cruise BLM 03W.

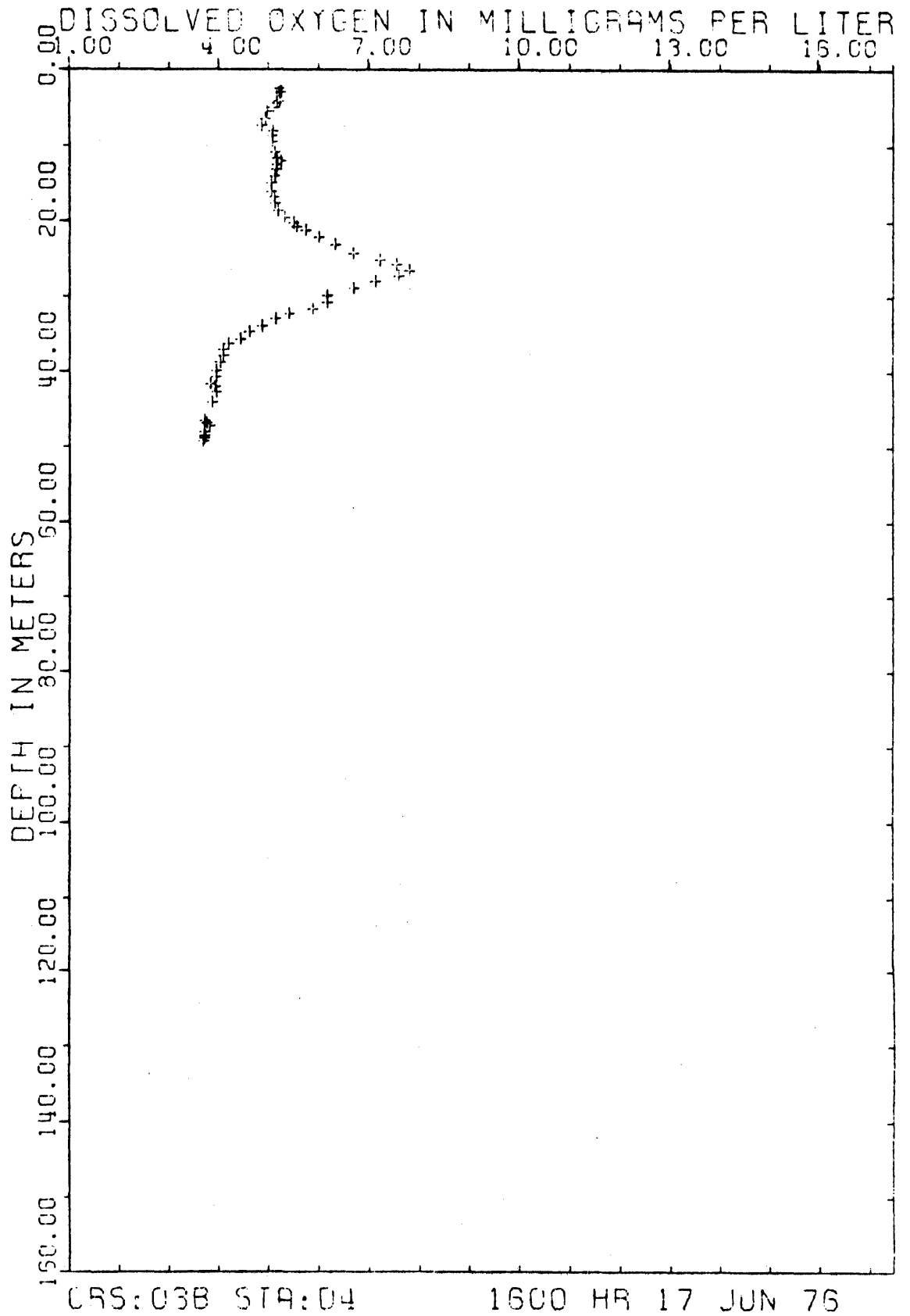


Figure 3-195. Dissolved oxygen as a function of depth at Station D4 during cruise BLM 03B.

Summer Conditions (August - September 1976)

Temperature, Salinity, and Density

The thermohaline structure of shelf waters found during the summer cruises showed strong vertical stratifications with nearly horizontal isopycnals extending offshore to where water depths were between 75 and 100 m. In the outer shelf region, mixing with slope water was evident with strong intrusions of slope water along the bottom as indicated by the positions of the 34.5 ppt isohaline in Figures 3-140, 3-144, 3-148, and 3-152. The mixed layer gradually thickened from 15 to 20 meters in its offshore extension as evidenced by temperature vs. depth trace for stations C1, D1, N3, and E2. (Figures 3-196, 3-197, 3-198, and 3-199). Persistence of the "cold pool" is evident along Sections II and III where water depths are between 50 and 75 meters. Figures 3-139 and 3-200 show this pool to be approximately 20 meters thick along Section II while along Section III it appears to be 25 meters thick and 0.5°C warmer (Figures 3-143 and 3-201). In both cases, salinity of the pool water is 33.1 to 33.2 ppt. The general shape and extent of this "cold pool" can be seen in Figure 3-129.

A region of apparent upwelling was encountered in the vicinity of Station F1 on Section III. Isotherms show a definite bend toward the surface (Figure 3-143); however, there is no similar bending of the isohalines (Figure 3-144). In fact, a salinity frontal system appears in this region. Upward bending of isopycnals does occur, except that this feature is found seaward of the regions of "thermal" upwelling (Figure 3-146).

Dissolved Oxygen and Micronutrients

The summer cruise occurred during the time anoxic water plagued the inner shelf regions near the New Jersey coast. Figure 3-131 shows the extent of bottom anoxic conditions encountered. Further seaward, bottom DO values increased but an oxygen minimum layer became detached from the bottom and extended seaward over intruding slope waters as seen by comparing Figures 3-144 and 3-145. This oxygen minimum layer is further illustrated in Figures 3-202 and 3-203 which show DO as a function of depth at stations E2 and E1 respectively.

Two significant changes in the surface and bottom distributions of micronutrients were encountered when compared to previous seasons. Bottom values of nitrites were elevated immediately seaward of regions of strong anoxia (Figures 3-158, 3-160, and 3-132), and the region of thermal upwelling showed a depletion of surface $O-PO_4$ (Figure 3-128).

Water Mass and Type Analysis

The water type progression observed during the first full year of cruises (BLM 01 to BLM 04) is, in many general respects, similar to that described by Beardsley and Flagg (1975) and Voorhis, Webb, and Millard (1976) over the shelf and slope south of New England. Some of the differences that are evident are due to the more onshore and southern extent of the present study when compared to those cited above. In all of these cases, the use of a profiling CTD unit allowed interpretations to be made with data which, had only discrete bottle samples been used, would remain obscure.

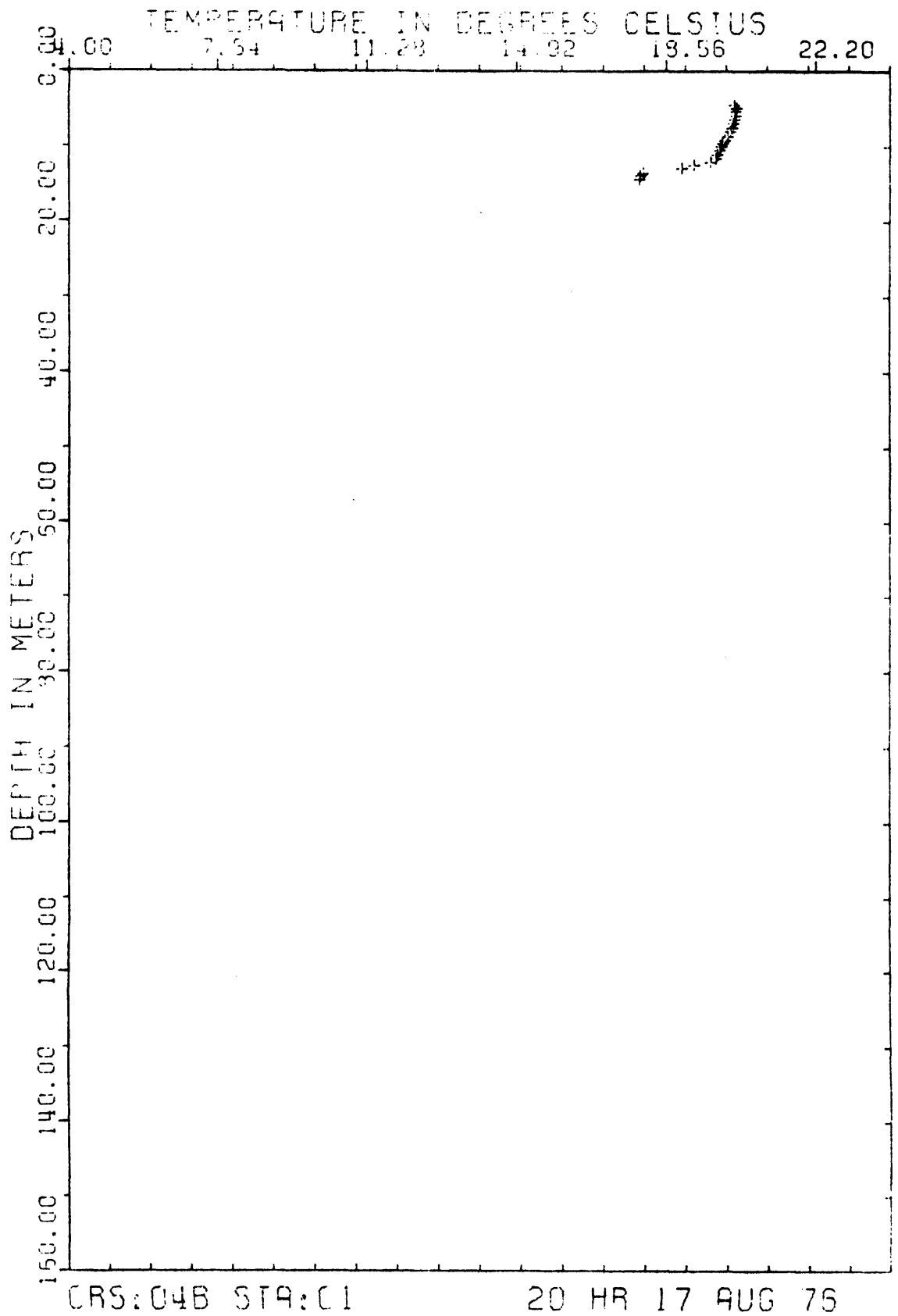


Figure 3-196. Temperature as a function of depth at Station C1 during cruise BLM 04B.

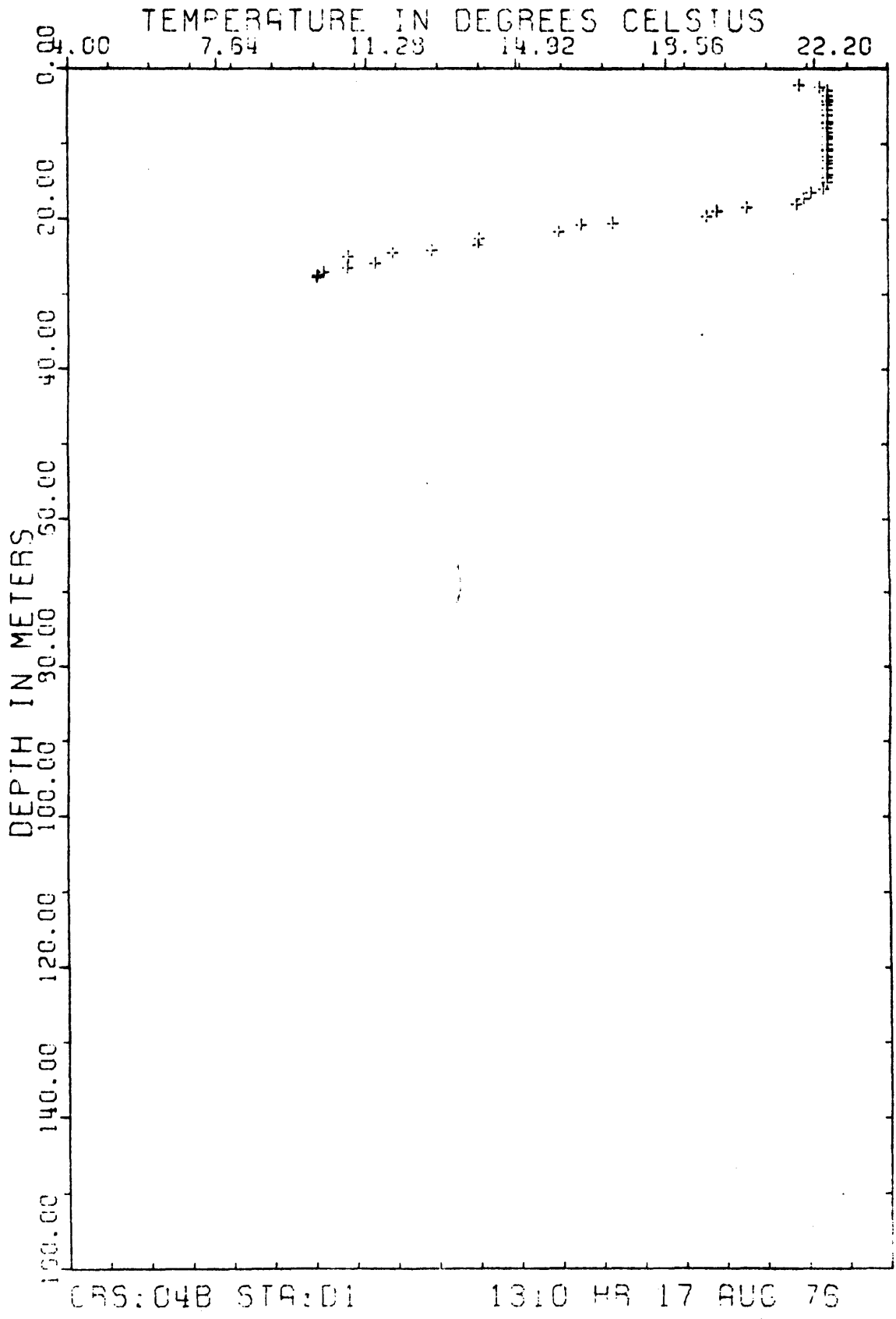


Figure 3-197. Temperature as a function of depth at Station D1 during cruise BLM 04B.

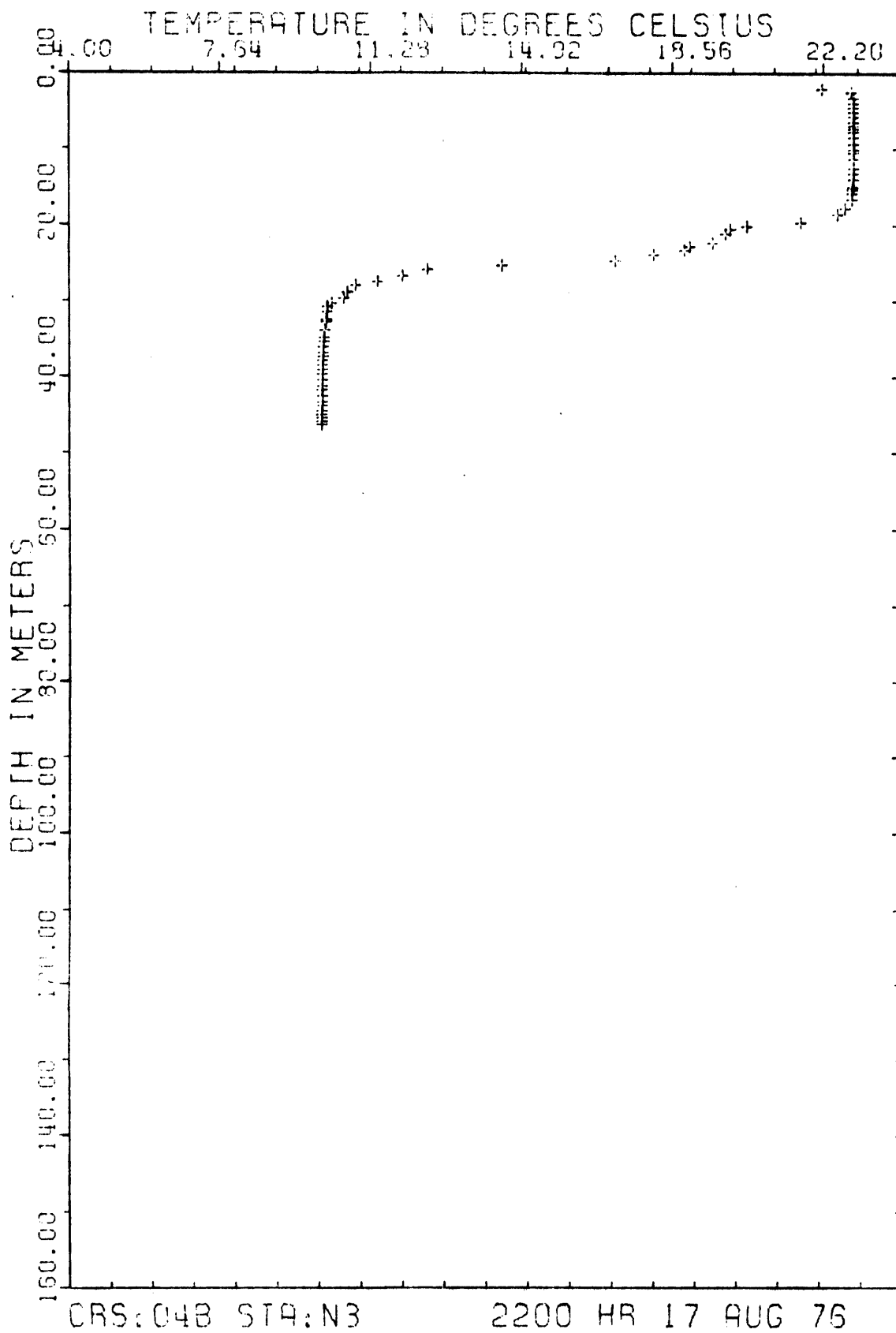


Figure 3-198. Temperature as a function of depth at Station N3 during cruise BLM 04B.

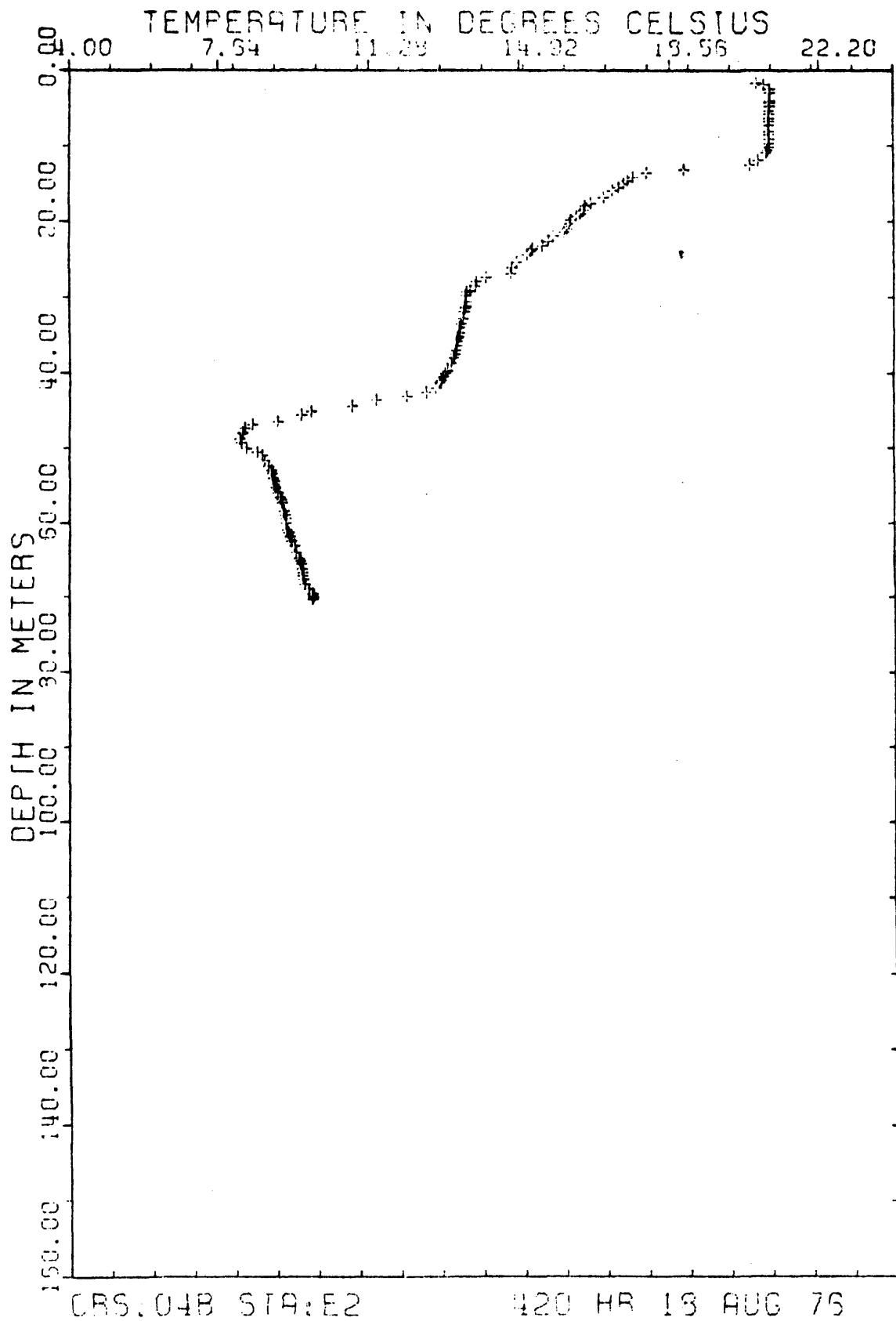


Figure 3-199. Temperature as a function of depth at Station E2 during cruise BLM 04B.

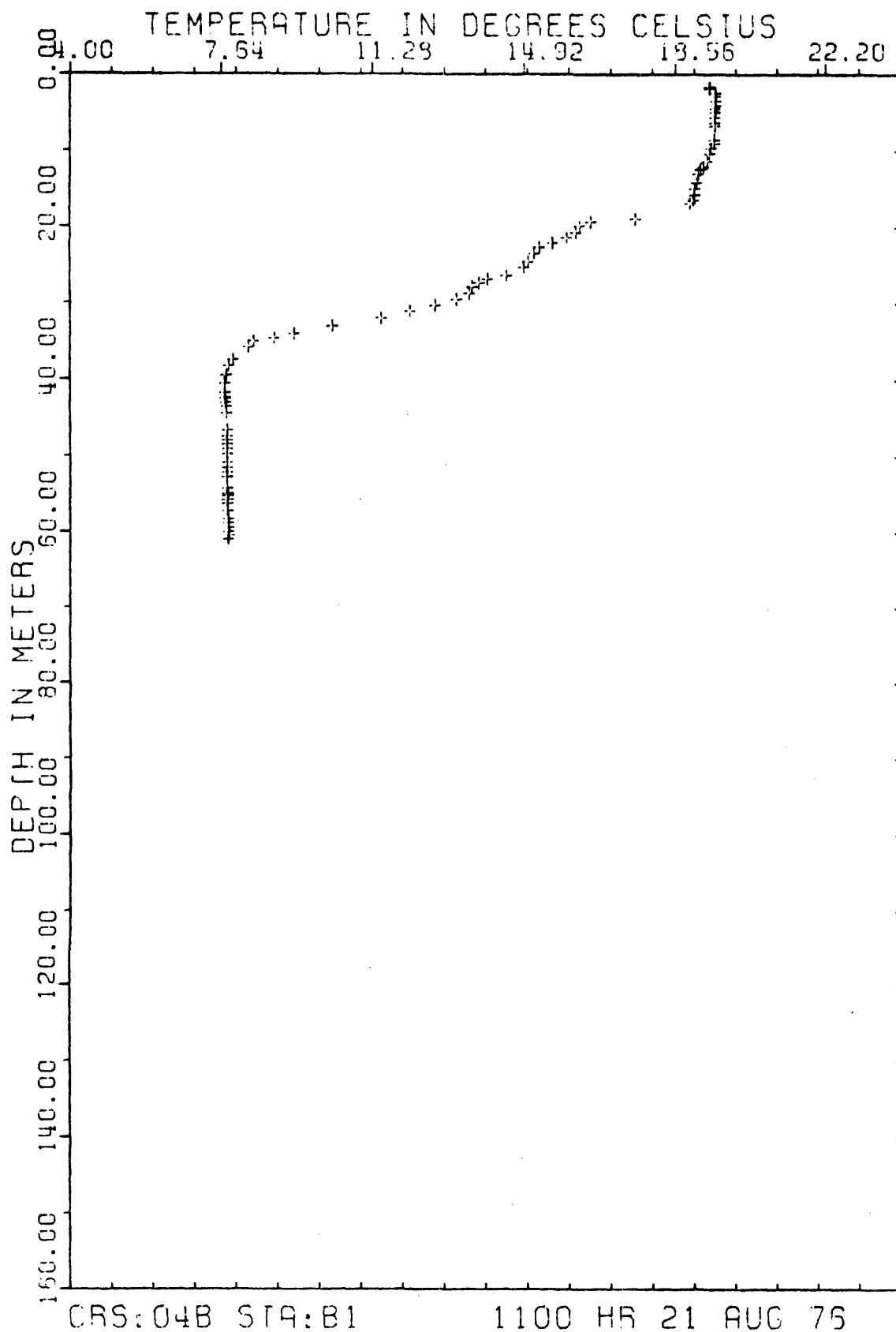


Figure 3-200. Temperature as a function of depth at Station B1 during cruise BLM 04B.

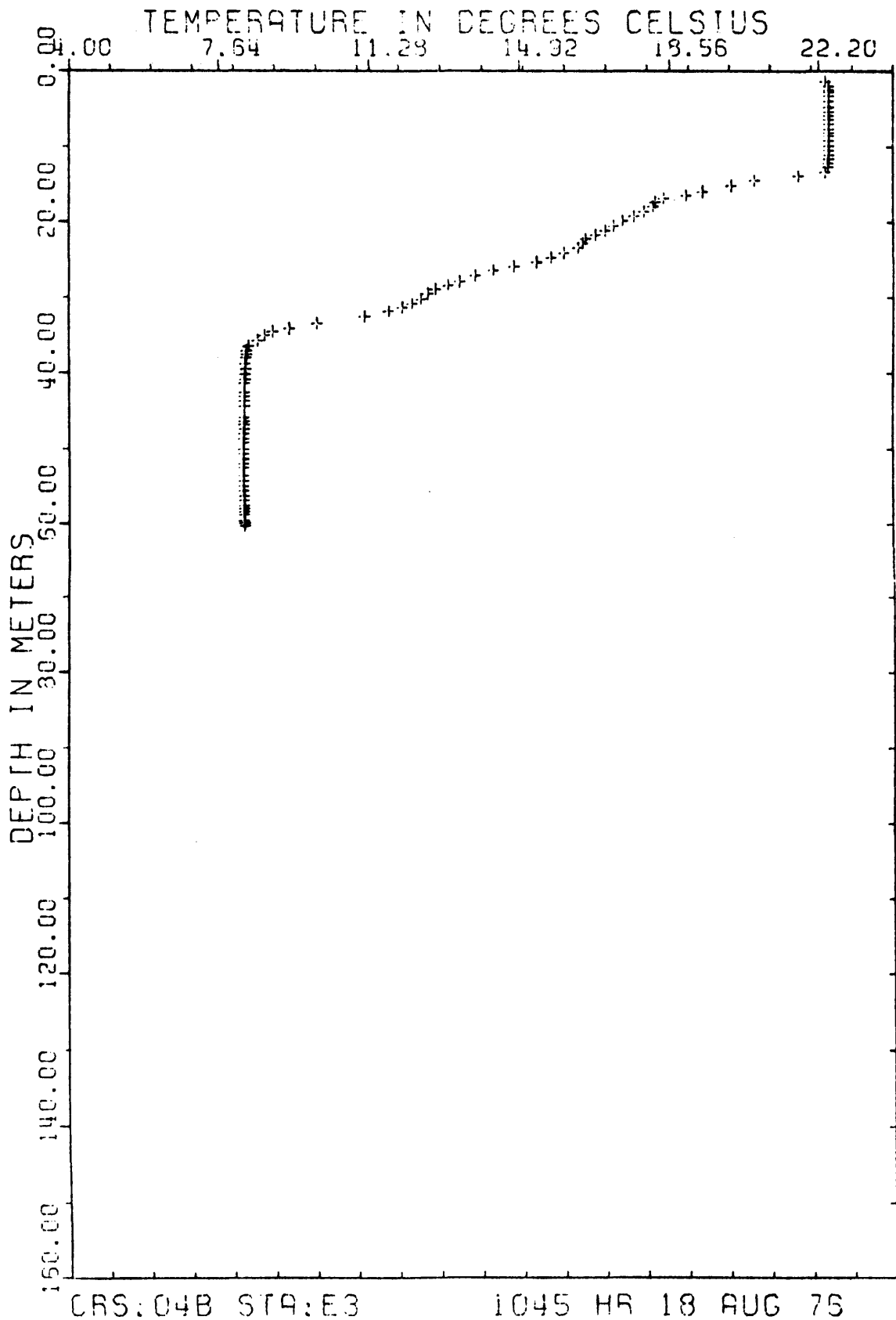


Figure 3-201. Temperature as a function of depth at Station E3 during cruise BLM 04B.

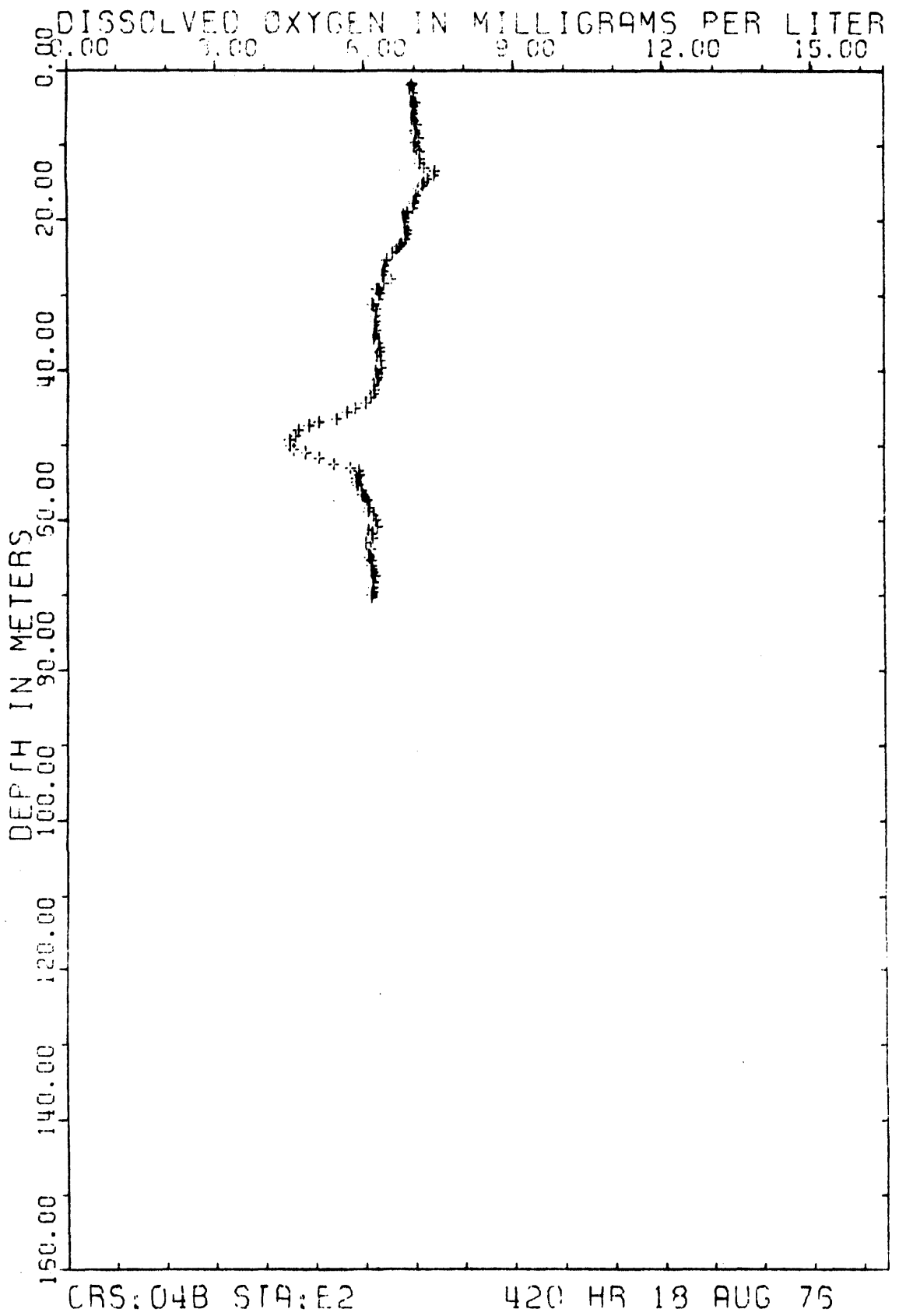


Figure 3-202. Dissolved oxygen as a function of depth at Station E2 during cruise BLM 04B.

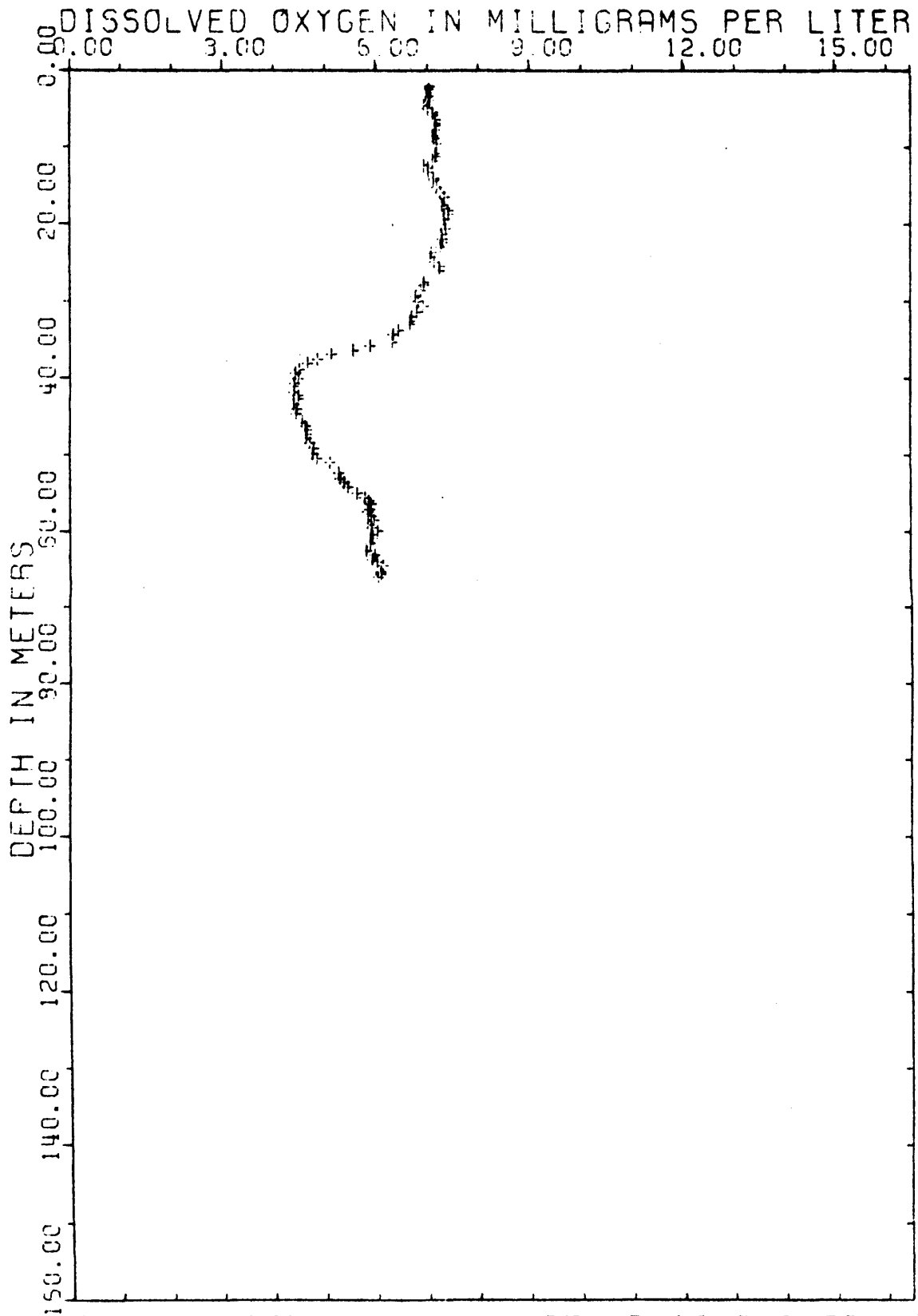


Figure 3-203. Dissolved oxygen as a function of depth at Station E1 during cruise BLM 04B.

Before examining these results in some detail, some features of the individual cast Temperature vs. Salinity curves will be noted. In the simplest case, for example Station D2 on cruise BLM 01B (Figure 3-204a-c), the intensity of the fall mixing creates a truly homogeneous water column which appears in the T-S correlation as a single point. In the example, a 27 meter long water column has been stirred to the point that it has a single value of temperature and salinity. In this case, the water is a 16.2°C and 32.4 ppt. Although the entire column is represented by a single water type, it is not likely to be a stable one, as it is certainly in the midst of being cooled, and hence "migrating" vertically down the T-S plane, as it is being observed. The next simplest case is well represented by Station B3 on cruise BLM 02B (Figure 3-205a-c), 4 March 1976. This case is that of some mixing between two well defined water types. In this instance, the interpretation is slightly complicated by the freshening of the water adjacent to the free surface. Such a freshening is consistent with about 3 cm of recent precipitation. The slight asymmetry in the population of water types in the narrow mixing region indicates that the turbulent mixing intensity is greater in the lower water type than in the upper one. A feature of this T-S curve which will be important in later analysis is that an agglomeration of points marks the two primary water types. As a slight contrast to this case, that of Station B1 in the same cruise (Figure 3-206a-c) shows nearly the same T-S correlation line, but an agglomeration region is evident nearly midway between the two end points on the mixing curve. In this case, there are three water types evident in the water column, which again shows freshening in the uppermost region. Such a correlation is consistent with a series of events which includes strong wind mixing, perhaps nearshore, of two water types resulting in the formation of a "daughter" water type which, under the cessation of the mixing driving, intrudes between the "parent" water types. A more general case of mixing in pairs between three water types is shown by Station E4 of cruise BLM 01B (Figure 3-207a-c). This curve exhibits an "L" shape, with agglomerations at the two ends and the corner of the "L". In this case, the intermediate water type bears no apparent relation to the types between which it is found. A still more complex signature is found on the outer part of the shelf, particularly during the summer. This pattern, represented well by Station I1 of cruise BLM 03B (Figure 3-208a-c) is found when the shelf-slope front breaks down into interleaving layers or intrusions. As the thin layers erode between the thicker layers, they lose their characteristic temperature and salinity, and the sharp points of their "L"s become rounded off. The remaining well defined water types are associated with the sharp corners remaining on the correlation curve. The resulting pattern is reminiscent of a telegraph wire strung between poles, so it is suggested that a "telegraph wire signature" be assigned as a name to this particular signature. A similar example is given by Voohris et al. (1976) in their Figure 13. The final illustrative example is given by Station J1 of cruise BLM 01B (Figure 3-209a-c), November 1975. The lower right part of this correlation diagram consists of what appears to be an entire agglomerated line. This line represents the slope water, and it is a stable feature found during all seasons of the year in the deep (greater than 200 meter) stations. Its T-S characteristic is within the range of North Atlantic Central Water. The slope water represents a true water mass, as distinct from the water types discussed above.

A great variety of T-S correlation signatures was observed during the year's survey of the continental shelf, in contrast to the apparent stability

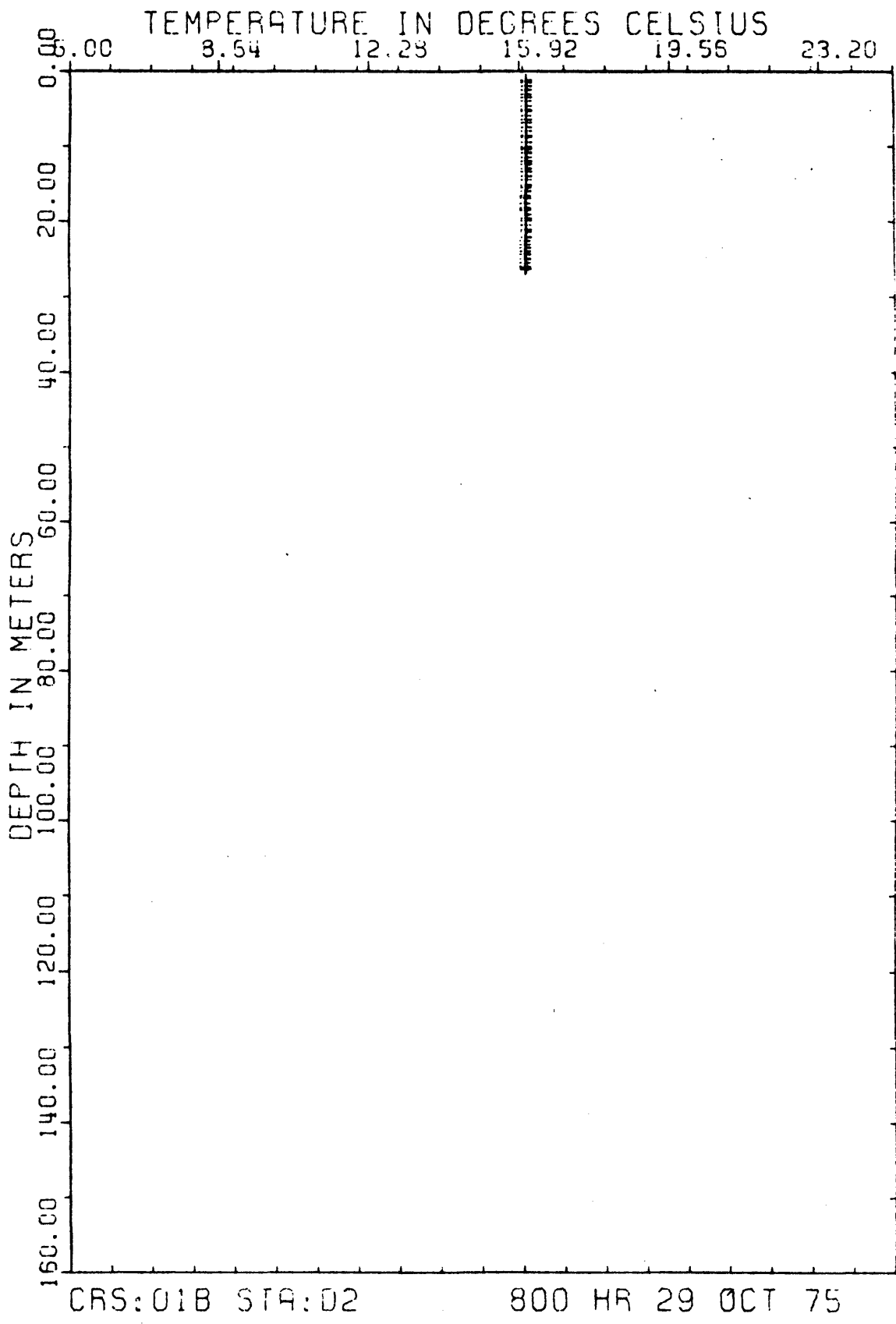


Figure 3-204a. Temperature as a function of depth at Station D2 during cruise BLM 01B.

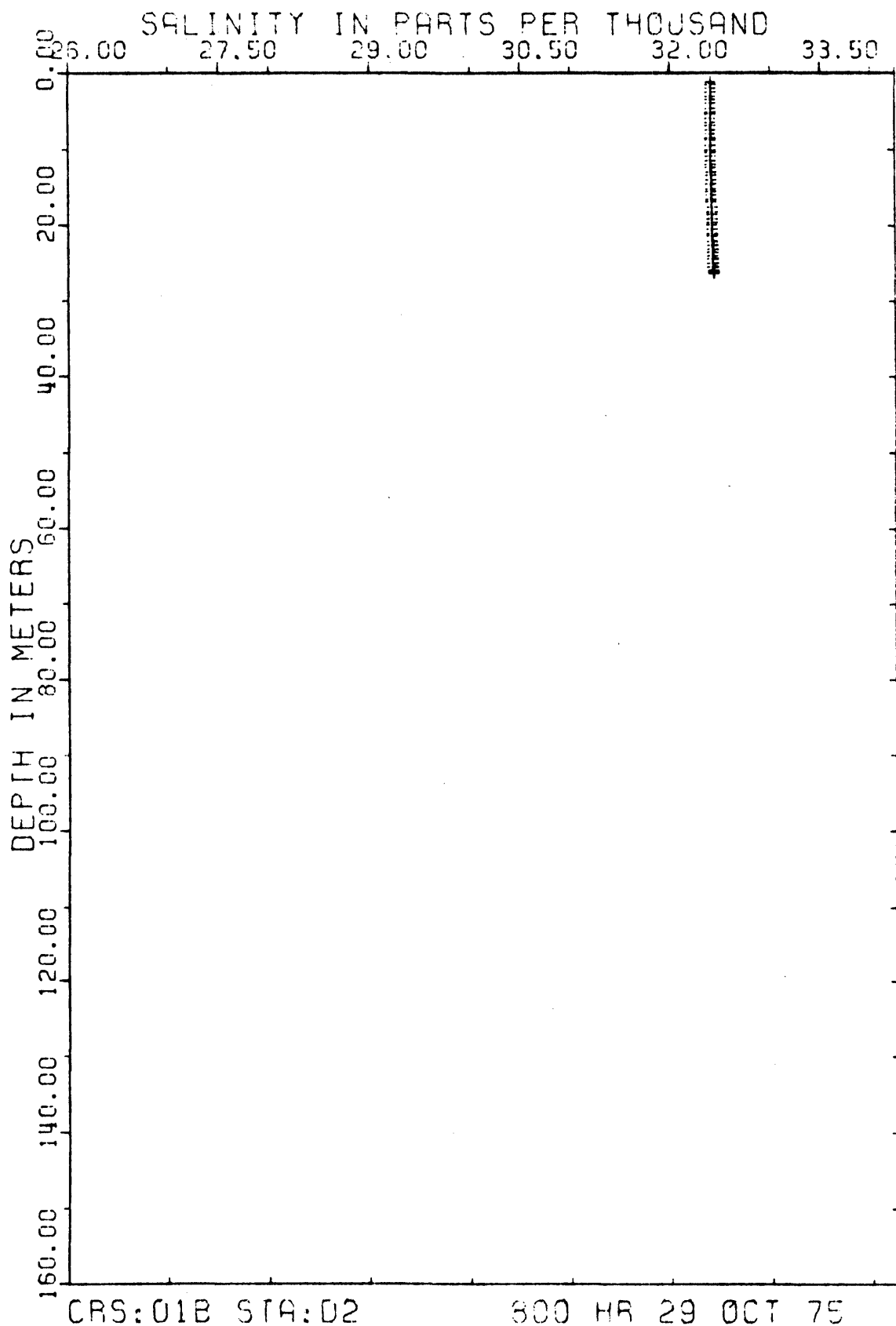


Figure 3-204b. Salinity as a function of depth at Station D2 during cruise BLM 01B.

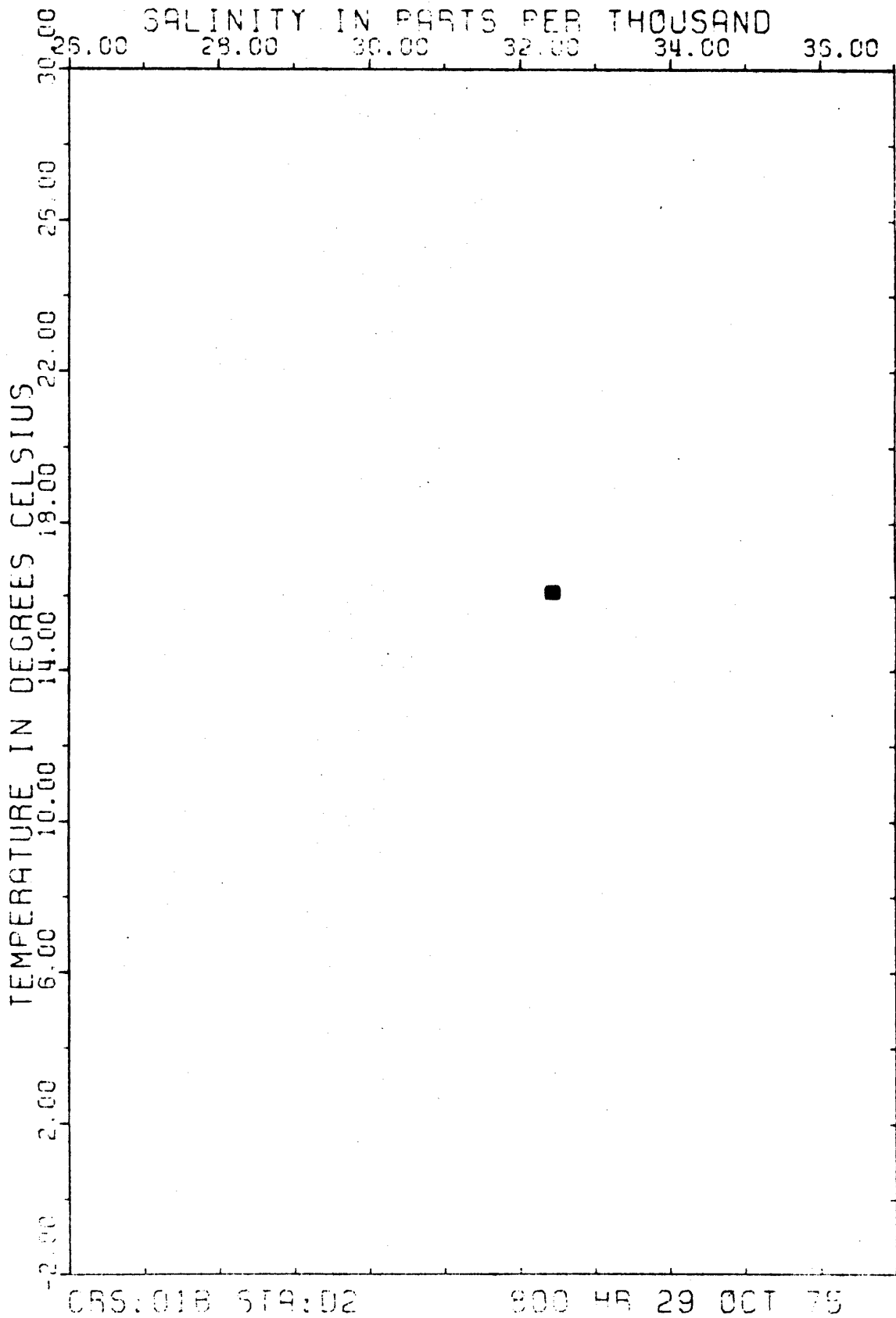


Figure 3-204c. T-S diagram for Station D2 on cruise BLM 01B.

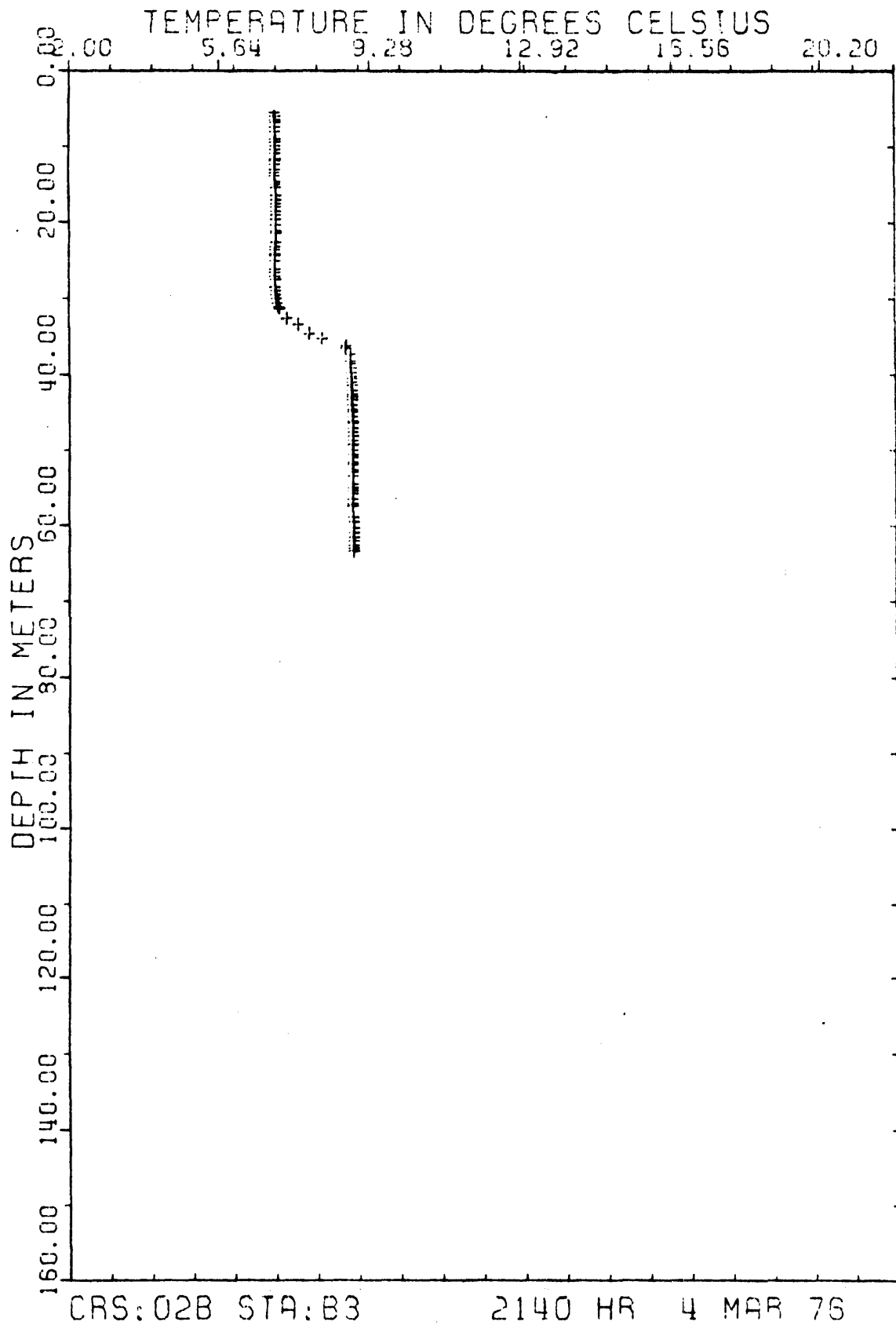


Figure 3-205a. Temperature as a function of depth at Station B3 during cruise BLM 02B.

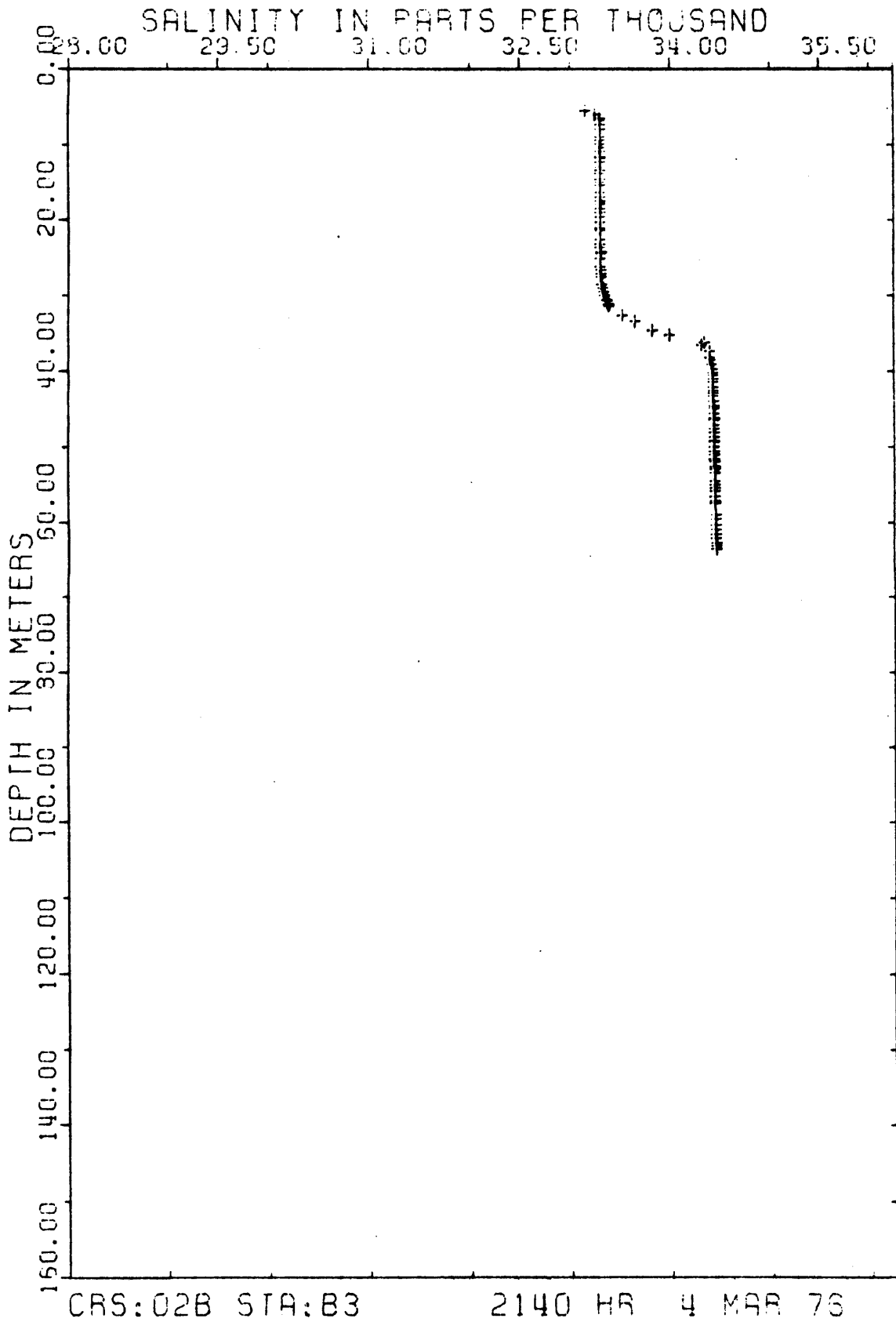


Figure 3-205b. Salinity as a function of depth at Station B3 during cruise BLM 02B.

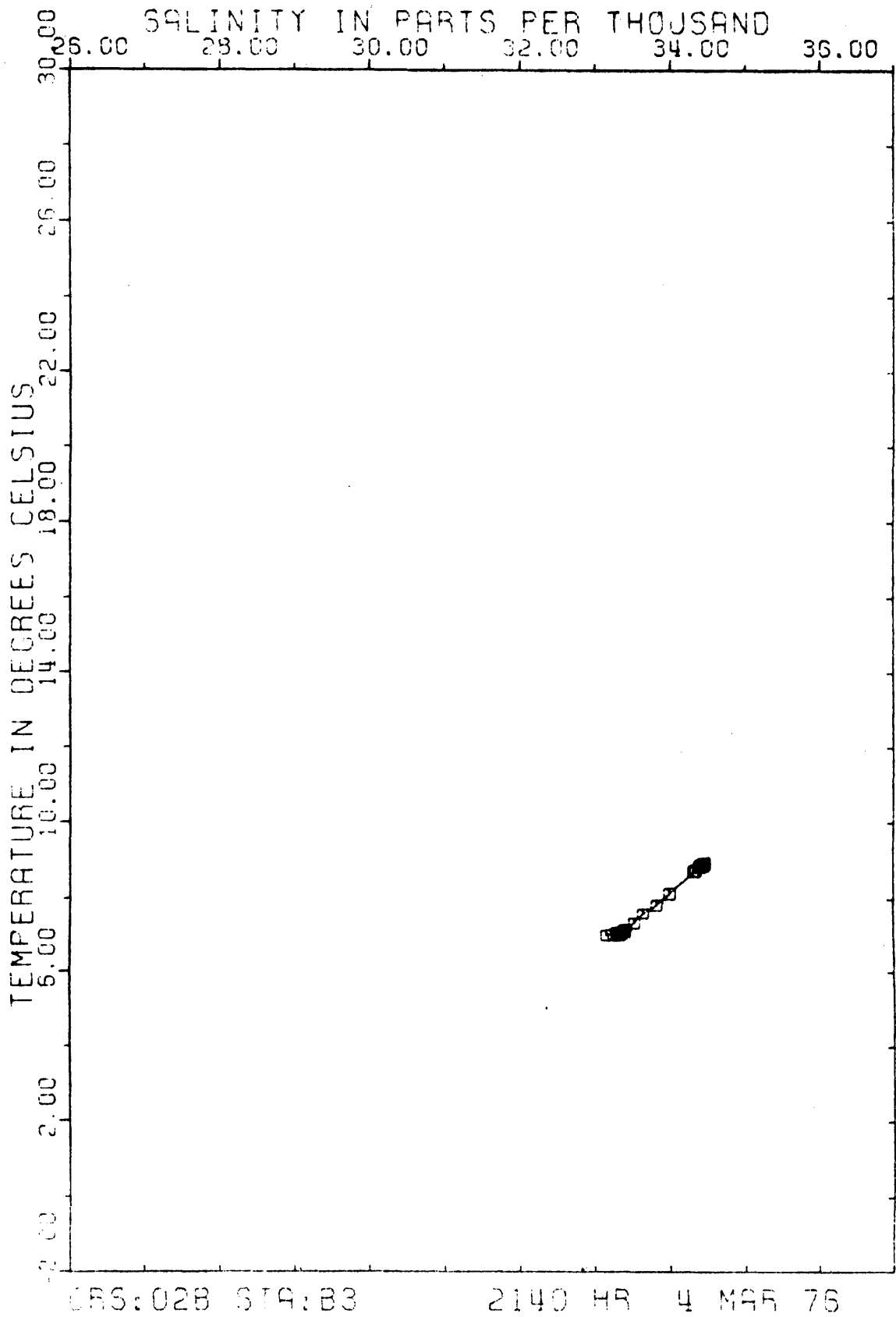


Figure 3-205c. T-S diagram for Station B3 on cruise BLM 02B.

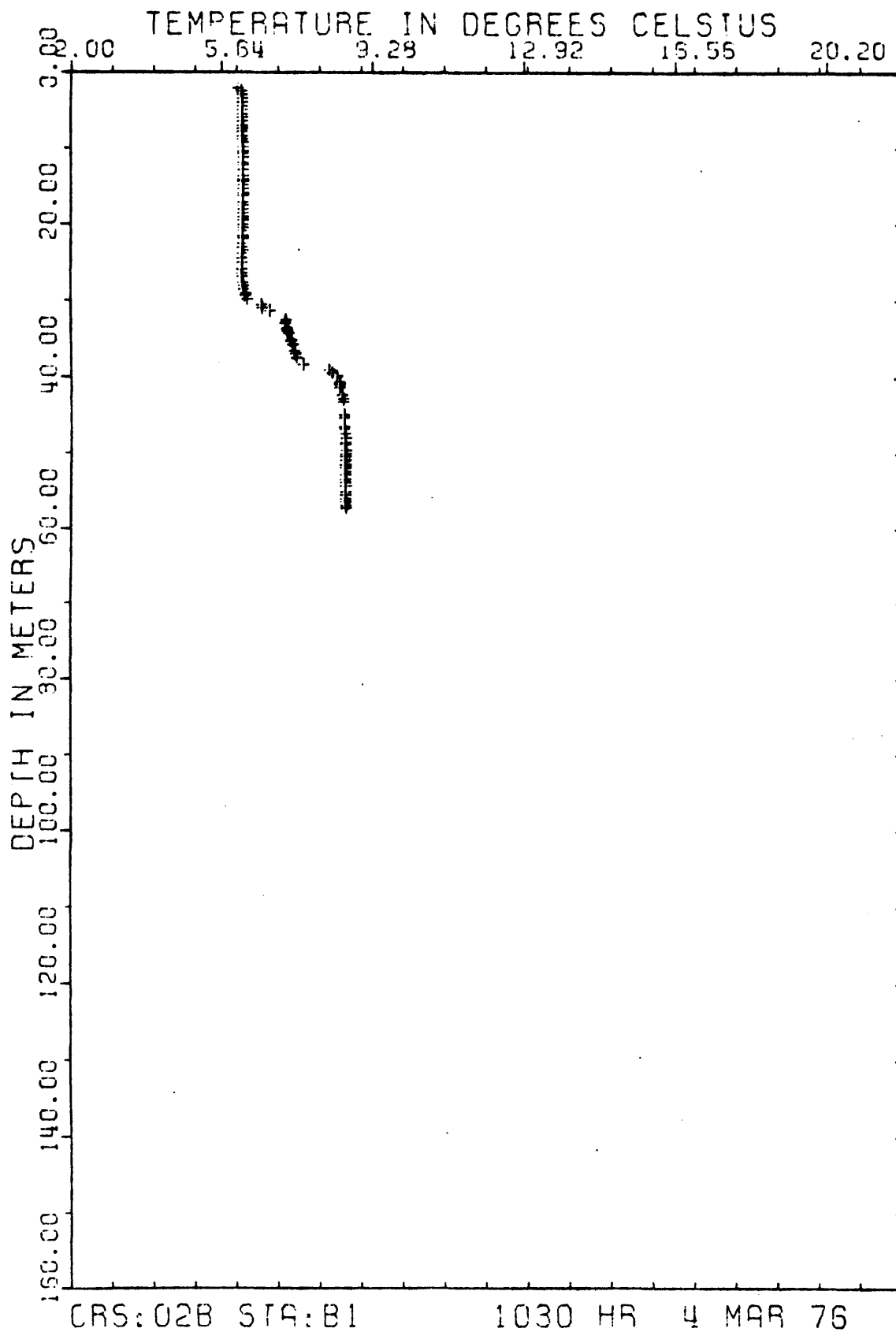


Figure 3-206a. Temperature as a function of depth at Station B1 during cruise BLM 02B.

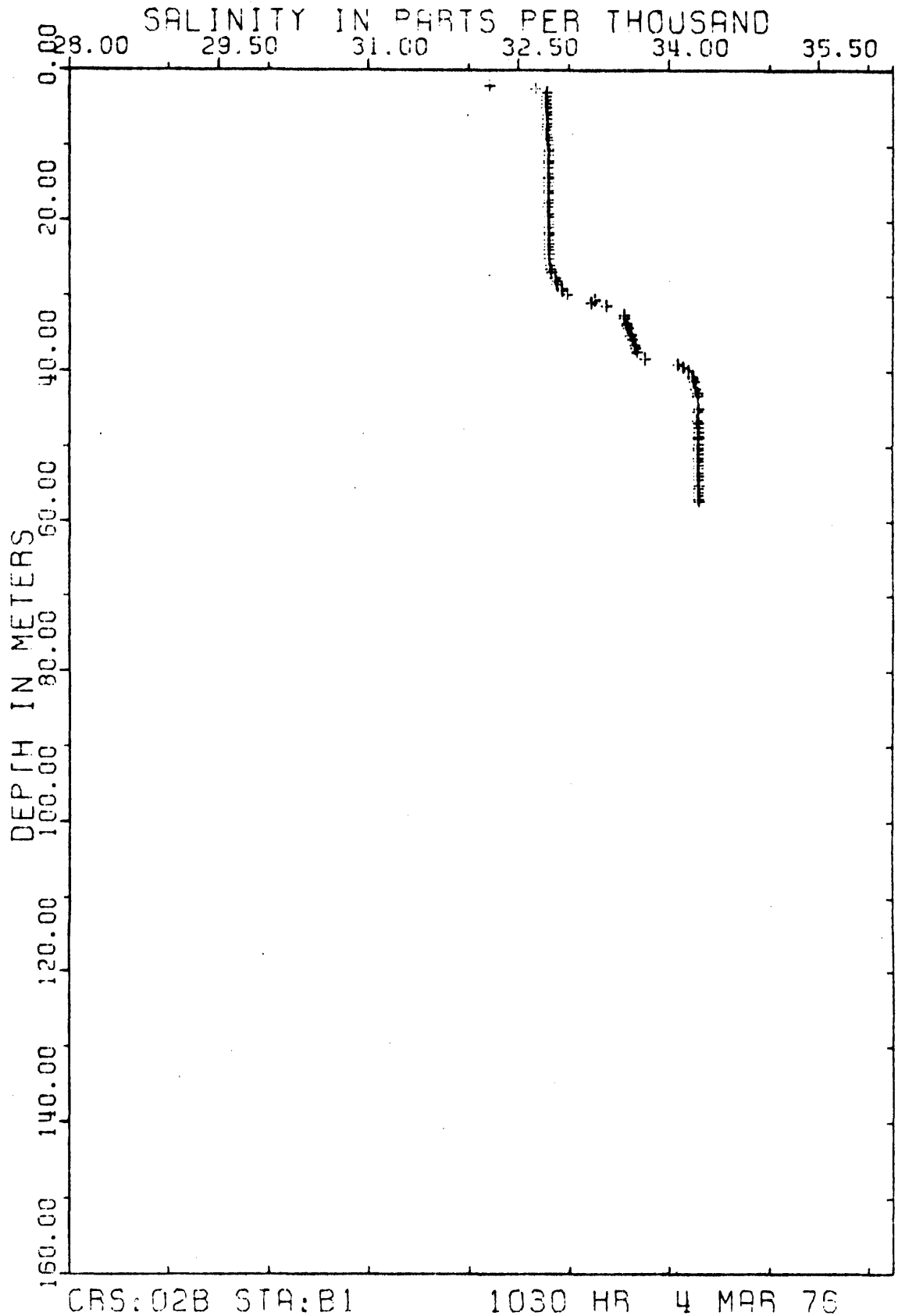


Figure 3-206b. Salinity as a function of depth at Station B1 during cruise BLM 02B.

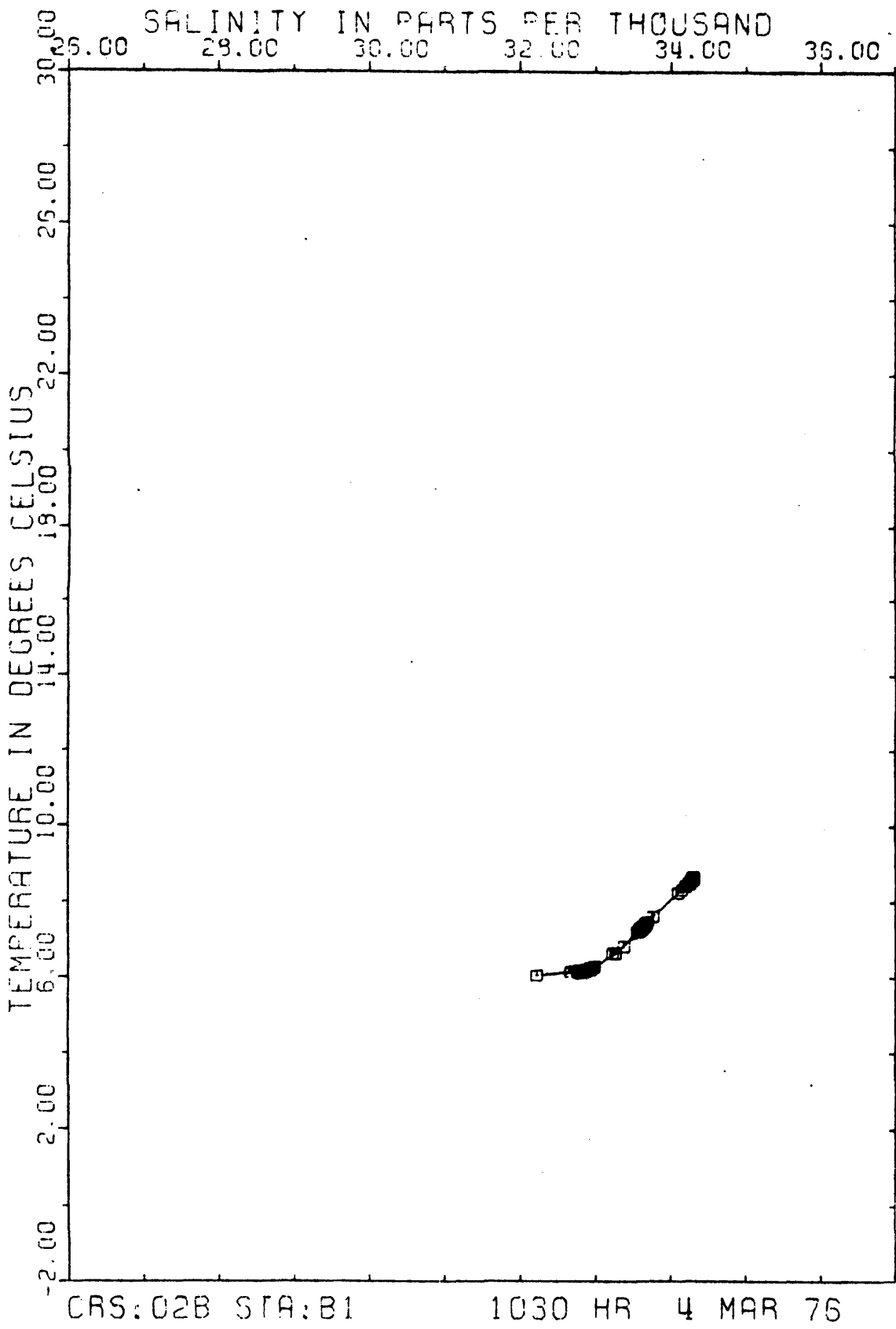


Figure 3-206c. T-S diagram for Station B1 on cruise BLM 02B.

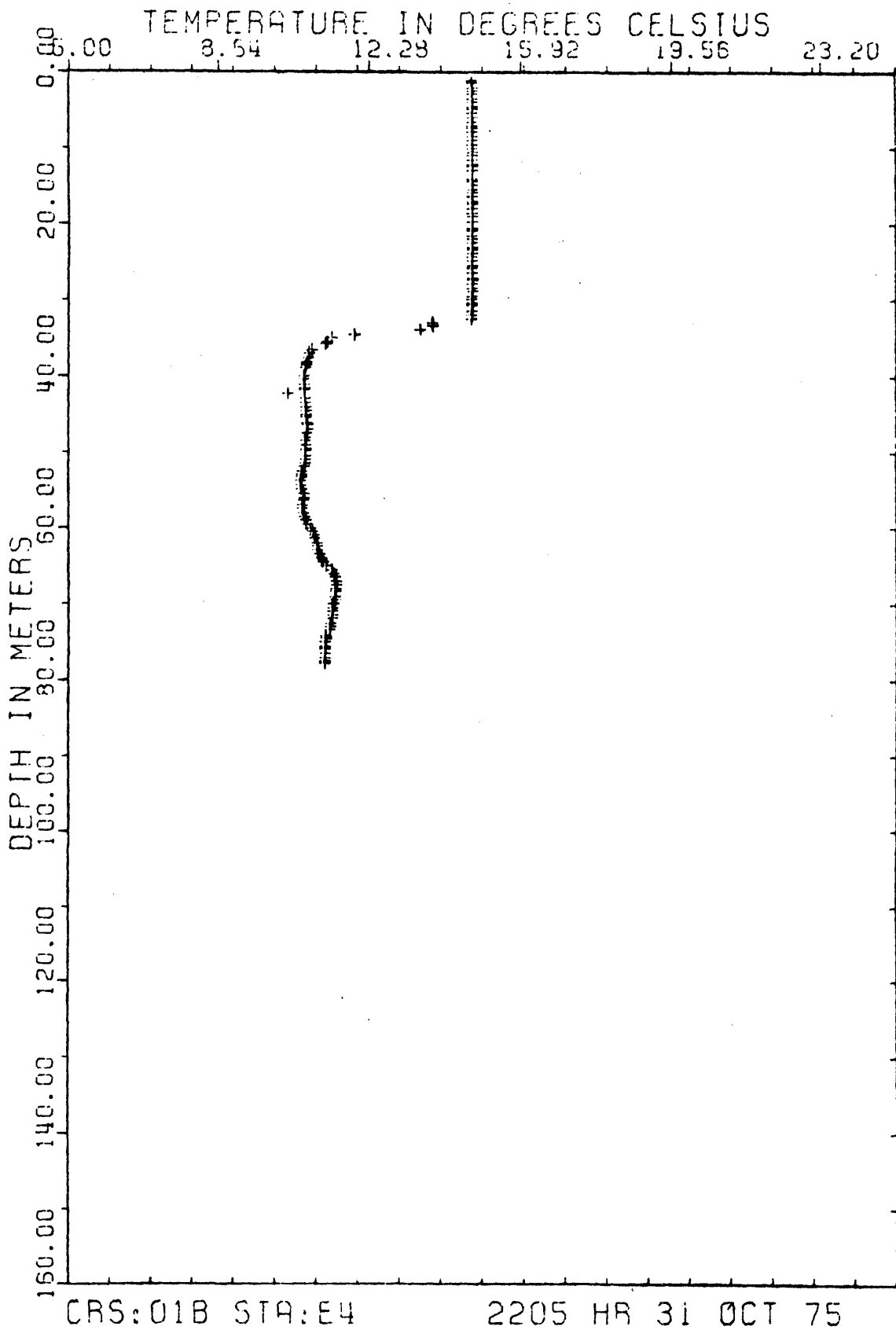


Figure 3-207a. Temperature as a function of depth at Station E4 during cruise BLM 01B.

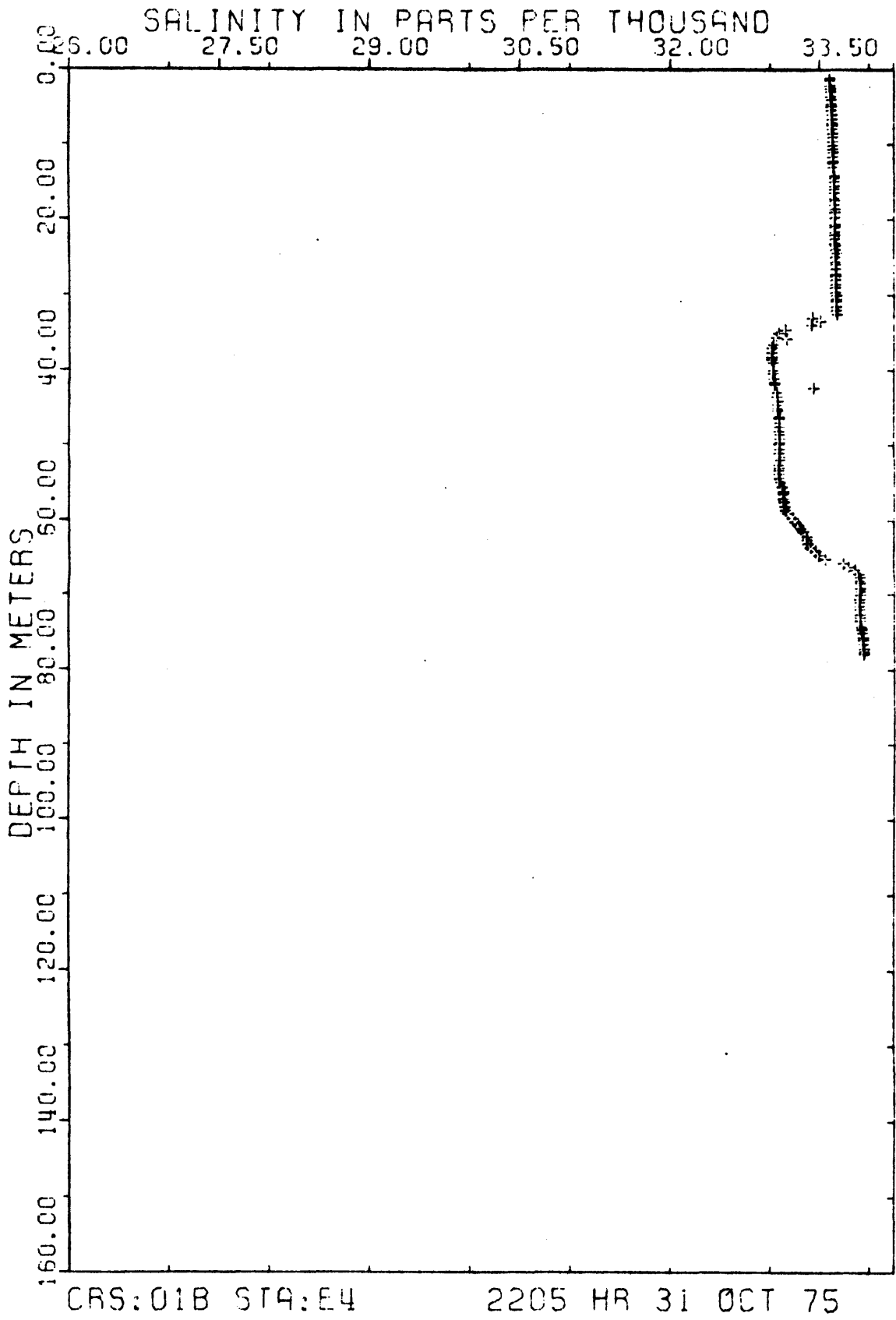


Figure 3-207b. Salinity as a function of depth at Station E4 during cruise BLM 01B.

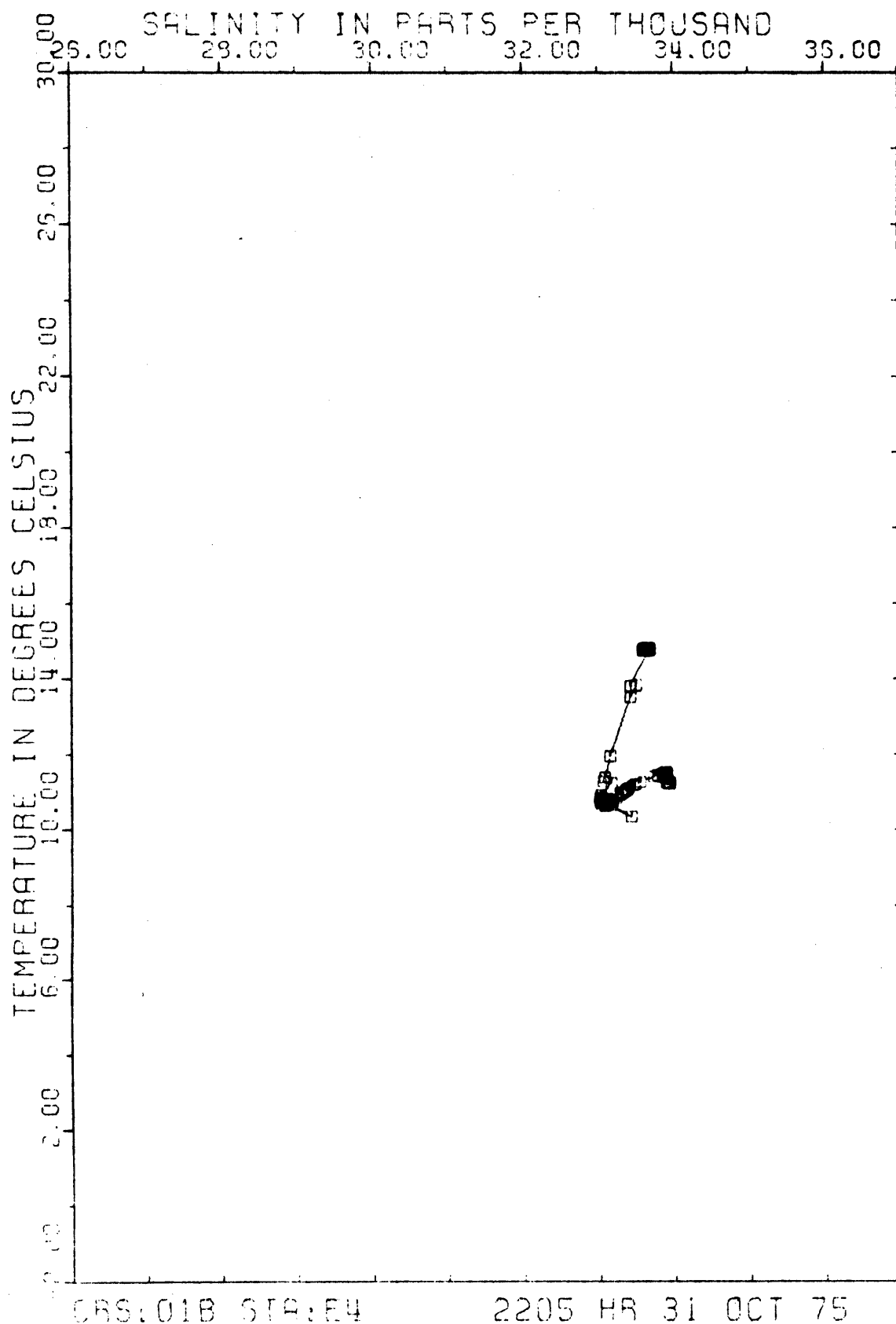


Figure 3-207c. T-S diagram for Station E4 on cruise BLM 01B.

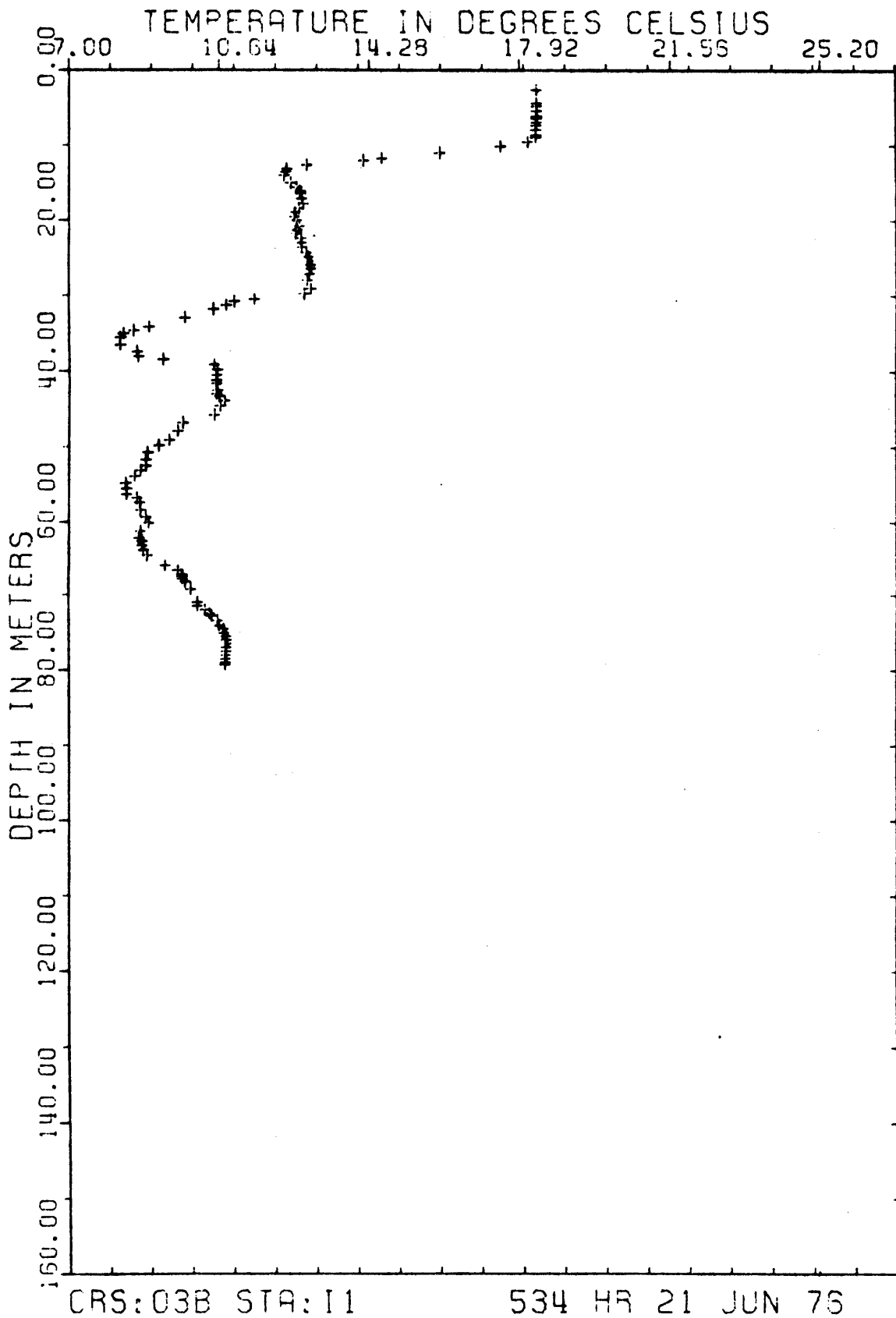
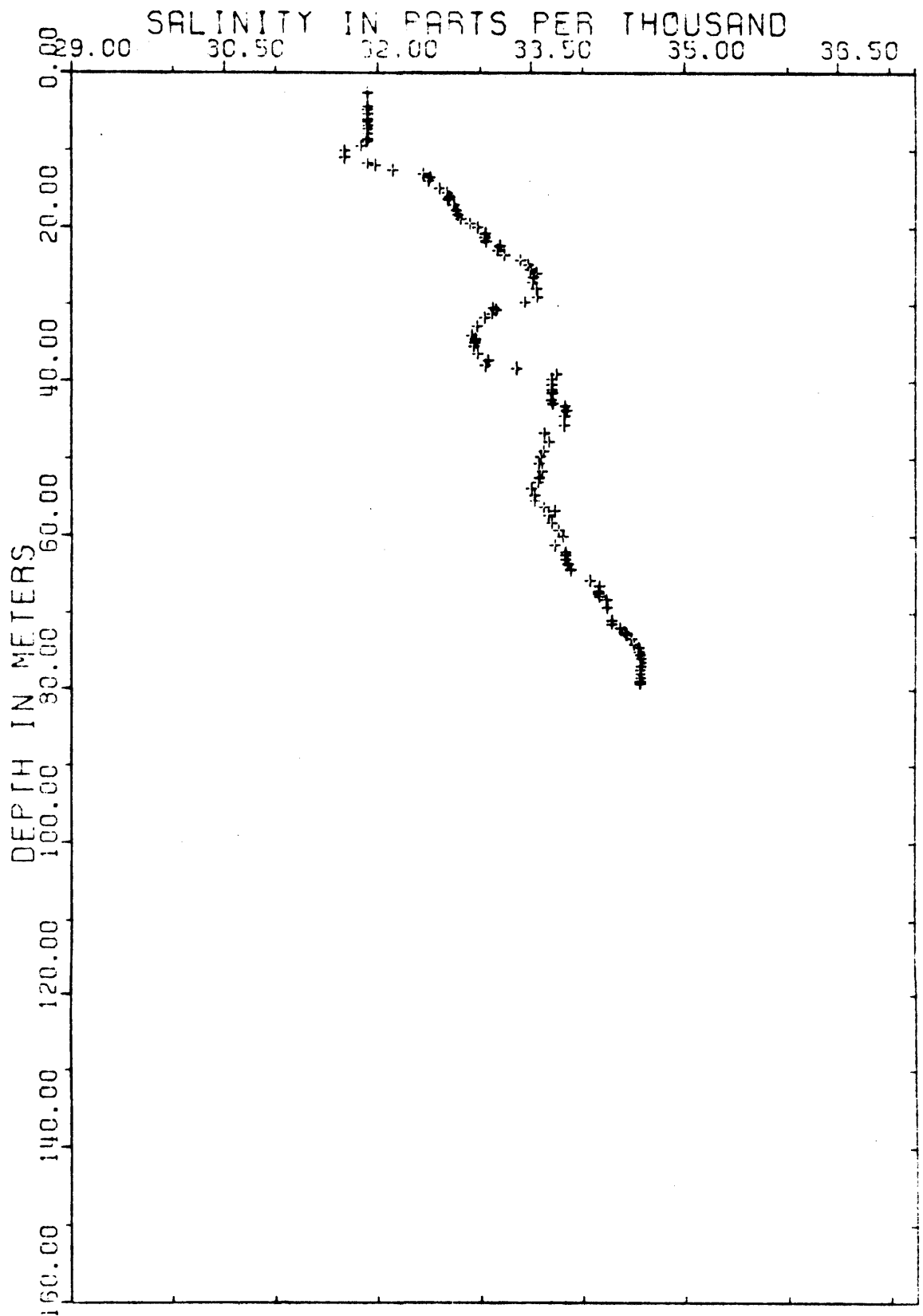
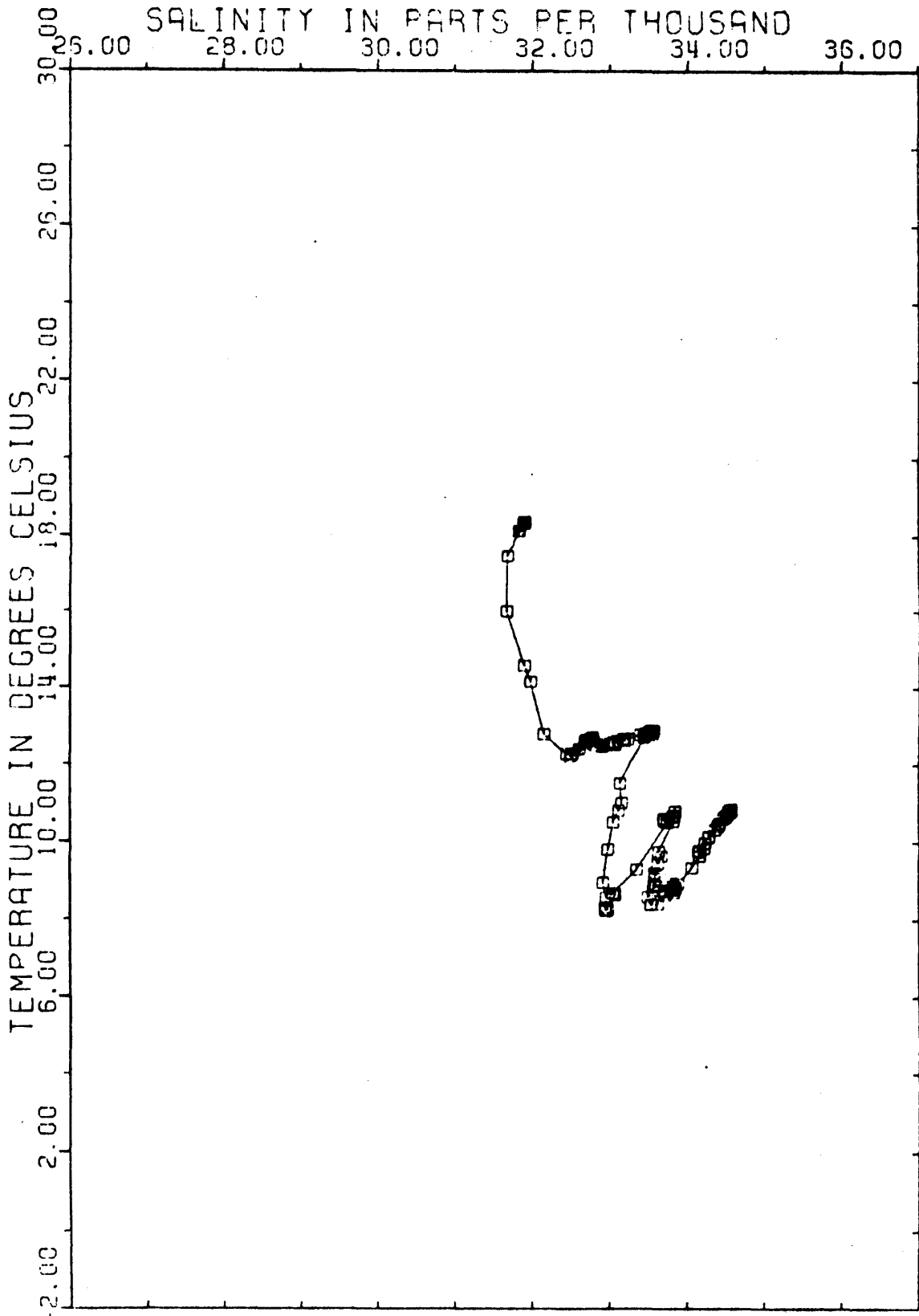


Figure 3-208a. Temperature as a function of depth at Station 11 during cruise BLM 03B.



CRS:03B STA:11 534 HR 21 JUN 76

Figure 3-208b. Salinity as a function of depth at Station 11 during cruise BLM 03B.



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Figure 3-208c. T-S diagram for Station 11 on cruise BLM 03B.

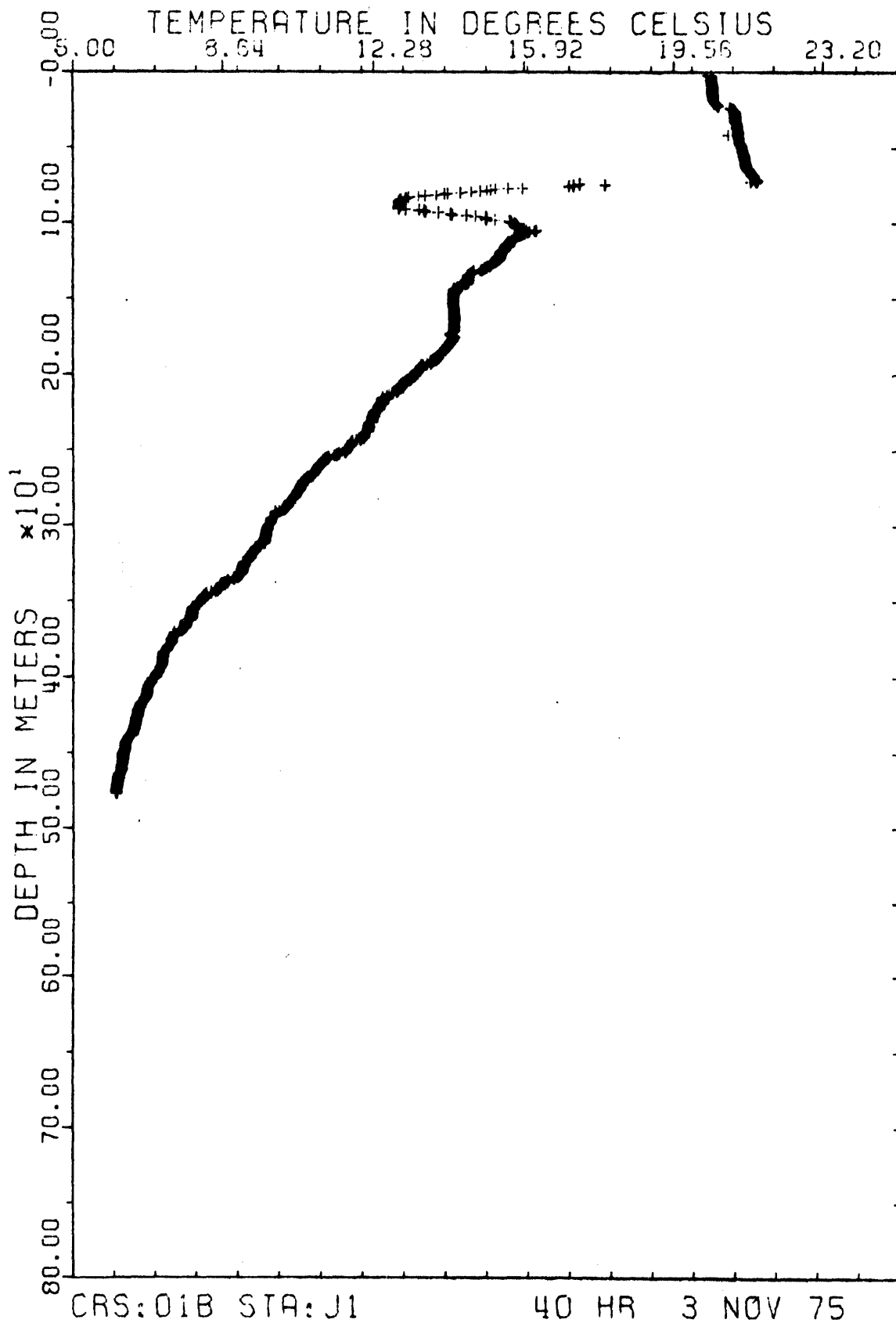


Figure 3-209a. Temperature as a function of depth at Station J1 during cruise BLM 01B.

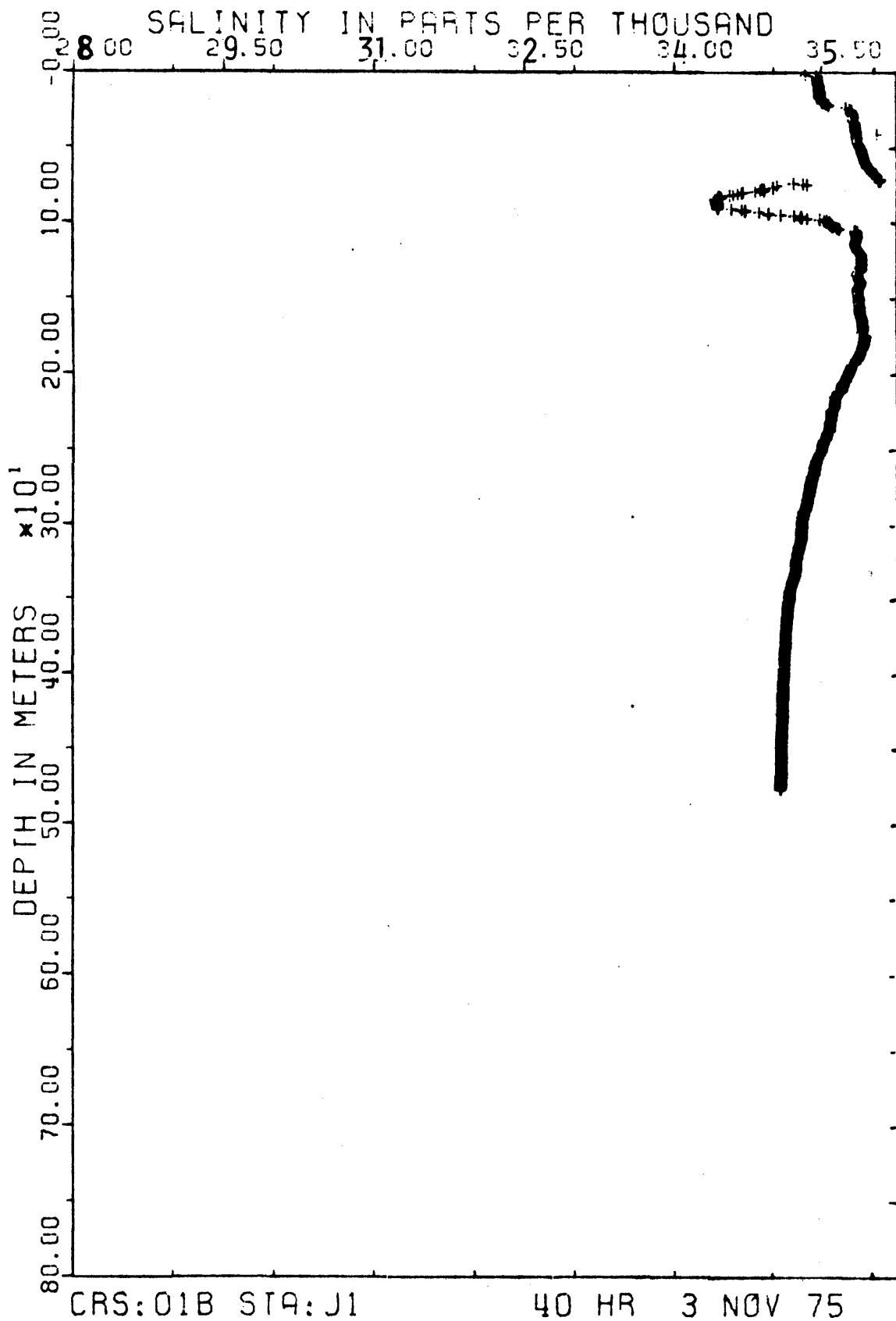
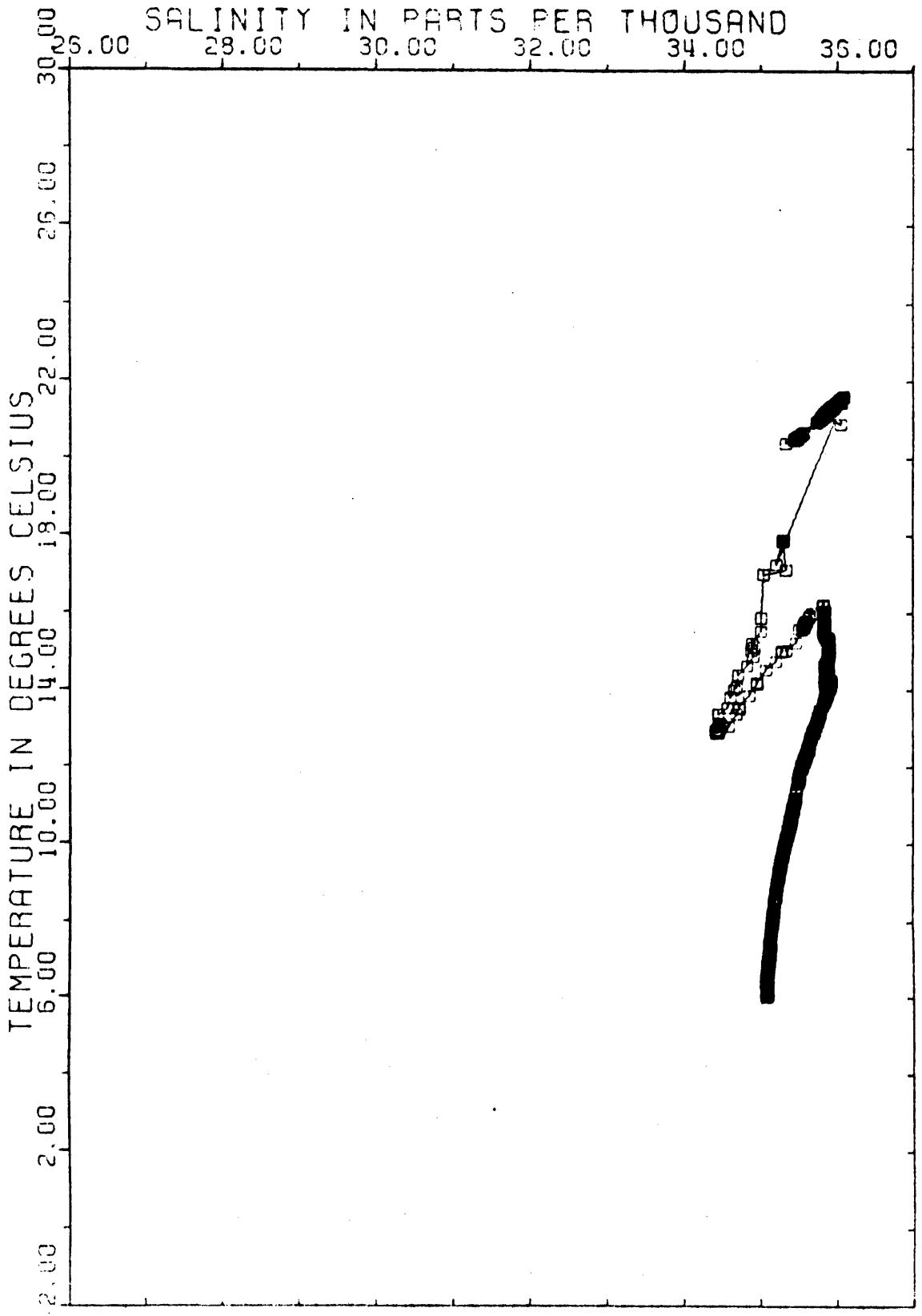


Figure 3-209b. Salinity as a function of depth at Station J1 during cruise BLM 01B.



CRS:01B STA:J1 40 HR 3 NOV 75

Figure 3-209c. T-S diagram for Station J1 on cruise BLM 01B.

of the T-S correlation of the slope water. This contrast is the reason that, from an oceanic point of view, shelf hydrography seems confusing, complex, and highly variable. However, with the aid of a modern, high resolution CTD system, we arrive at the same impression as did Beardsley and Flagg (1975) when they state,

"...Our data indicates that, contrary to the historical conception, the shelf exhibits a well defined temperature-salinity correlation and moreover this correlation remained approximately constant over the duration of the one-month experiment which occurred during the period of the seasonal extreme....."

The longer temporal and greater spatial extent of our sampling grid has allowed us to amplify somewhat on this impression and construct a series of diagrams which illustrate the progression of water types in the area of study during the first field year. As the T-S correlations for the year 1976 are qualitatively similar to those reported for other years (Beardsley and Flagg 1976; Voorhis et al. 1976) there is some basis for the interpretation that the described seasonal cycle is representative of the seasonal cycle in general, even though some features of the study year (for instance, the oxygen depletion event during the summer) were unusual.

In order to examine the progression of water types over the shelf from T-S correlation data, without undue emphasis being placed on transition zones which actually represent a very small volume of the water, an analysis was performed by identifying the agglomeration points from each of the individual cast correlations and displaying them on a single T-S plot for an entire cruise. Since the data for the water column cruises is similar to that of the benthic cruises, only the analyses for the benthic cruises are presented here as Figures 3-210a-d.

The seasonal pattern of summer is destroyed during the early and middle autumn, leaving a certain amount of confusion in the correlation plots. Recall that the example for the single point T-S correlation curve is taken from the autumn cruise and that the water type so defined is not stable, but is "migrating" towards lower temperatures under the influence of autumnal cooling. During this time, the slope water signature, shown in Figure 3-210a, extends to its lowest value of σ_t encountered during the year. As the winter progresses, the cooling and migration of the points on the T-S correlation curve reaches a winter pattern consisting of the slope water signature for σ_t less than 27 (Figure 3-210b). The curve extends nearly straight to the inshore stations, where σ_t is equal to 25 for this year. The straightness of this line indicates that winter mixing is controlled, over the shelf region and seasonal cycle, by some turbulent exchange process triggered in part by deviations of density from this line of reorganization. Voorhis et al. (1976) show a similar curve in their Figure 5. They term the water mass defined by this line "winter transition water" south of New England. The present study, extending to the shore, carries the description of this water mass all the way to the shore and σ_t 's of 25, while the Voorhis et al. description, focused on the shelf break, only defines this line to σ_t of 26. If the repetition of the line from one year to another is an indication of general case, we may speculate that the turbulent exchange process controlling winter mixing can draw on slope water as a reservoir of

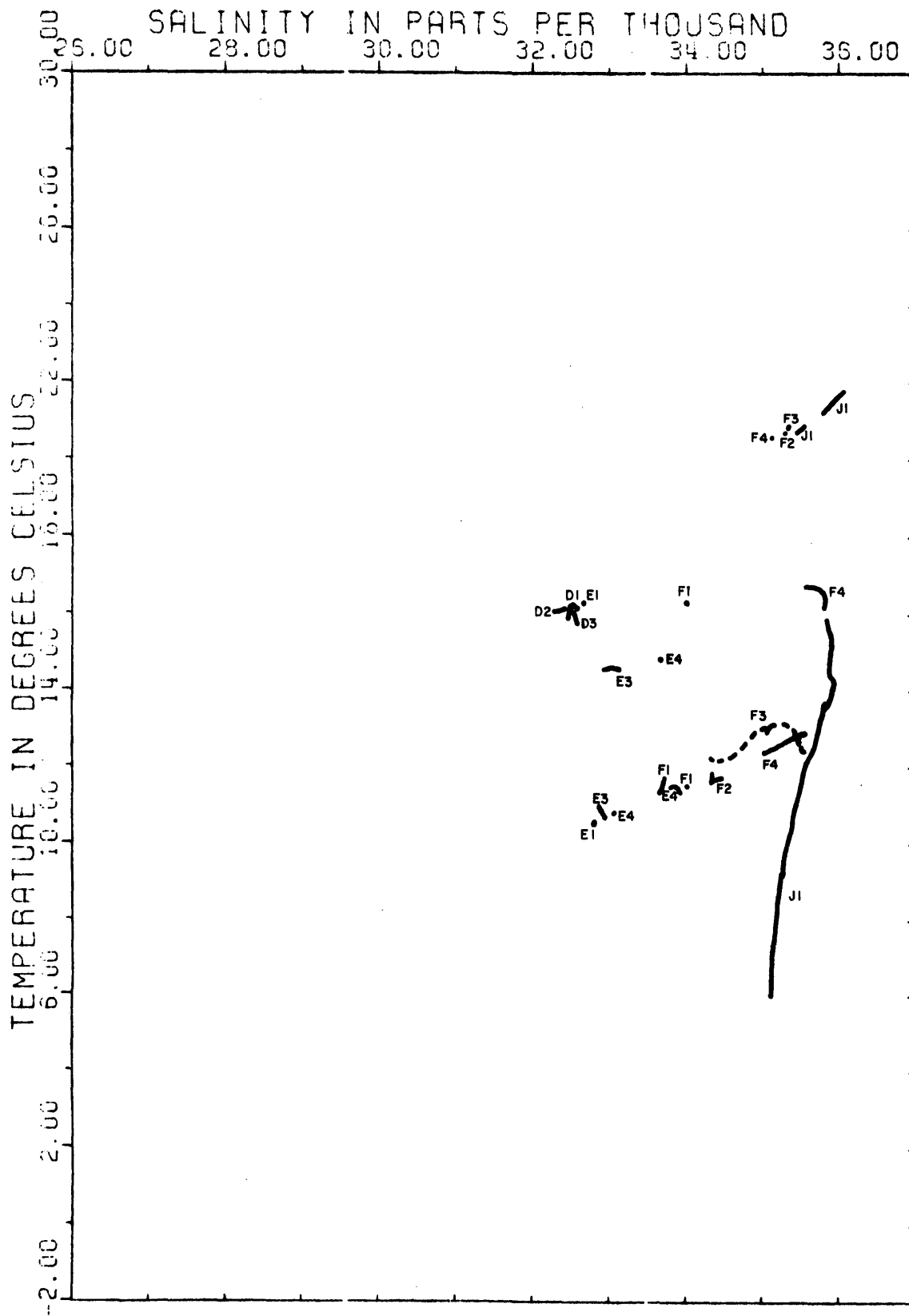


Figure 3-210a. Agglomeration diagram showing water types present at stations during cruise BLM 01B. Early winter conditions are shown.

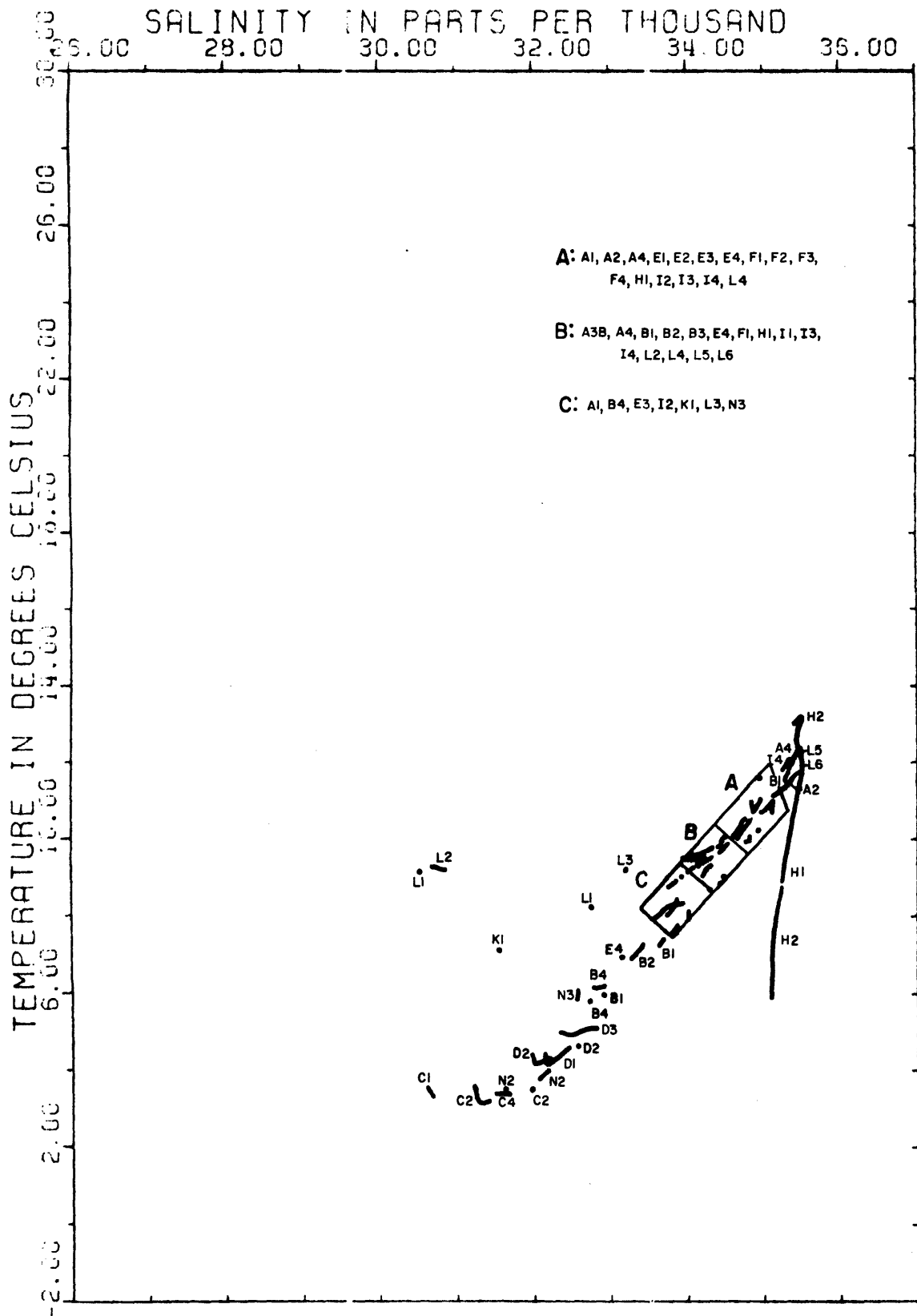


Figure 3-210b. Agglomeration diagram showing water types present at stations during cruise BLM 02B. Populous clusters of water types are enclosed in labelled boxes, with the appropriate stations for each box listed above.

cooling which occurs during the winter. In the data for this study, some anomalous points are recorded which deviate markedly from the otherwise well established straight line. These are located primarily at the L stations along Section V. As noted in the analysis of surface patterns elsewhere in this report, Section V was occupied subsequent to a wind event which included winds of more than 60 knots from the southwest, an unusual event for the winter season. The anomalous water types are all associated with water near the surface. A source of fresh water consistent with these observations is the outflow from Chesapeake Bay, which normally flows towards the south, but may have been driven to the northeast by the strong southwest winds. The lower parts of stations along Section V are well within the grouping of points associated with the "winter transition water" line of reorganization. As spring warming starts, the winter transition water mass is truncated at the σ_t 26 level, and a new water mass, termed "spring-warmed shelf water" is formed over the inner and middle shelf, extending later out to the outer shelf. The spring warming is accompanied by the yearly maximum of runoff from the tributaries, so the newly forming water mass tends to extend towards smaller values of salinity as it reaches higher temperatures. This signature is illustrated by Figure 3-210c from the present study. The new corner of the correlation curve is associated with the "cold pool" which is such a characteristic feature of the regional shelf summer hydrography. The majority of the winter transition water disappears from the T-S correlation at this time, and the shelf water and slope water appear juxtaposed with a frontal structure between them. This front, as noted by Bumpus (1974), has been an observed feature of the shelf for many years. It is frequently broken down into an interleaving structure which results in the "calving" of "bubbles" of water of markedly different temperature and salinity but nearly the same density as the water in which they are embedded. The stations which have water types between the shelf and slope types are all near the edge of the shelf in Figure 3-210c. This calving process near the shelf-slope front is the major process of cross shelf mixing during the summer months. Its action erodes the "cold pool" during the summer as well as the general shelf water mass. A later stage in this process is shown in Figure 3-210d, where a spreading out of the T-S correlation of the shelf water indicates that the shelf is acting more as a series of independent systems and less as an entity during the summer. Additional warming is also evident in this figure. The freshening of the inshore stations during the late summer is evidence that the cross-shelf mixing is greatly reduced in the summer. The T-S correlation is, at this time, fully developed and ready for the reorganization imposed by the autumnal cooling.

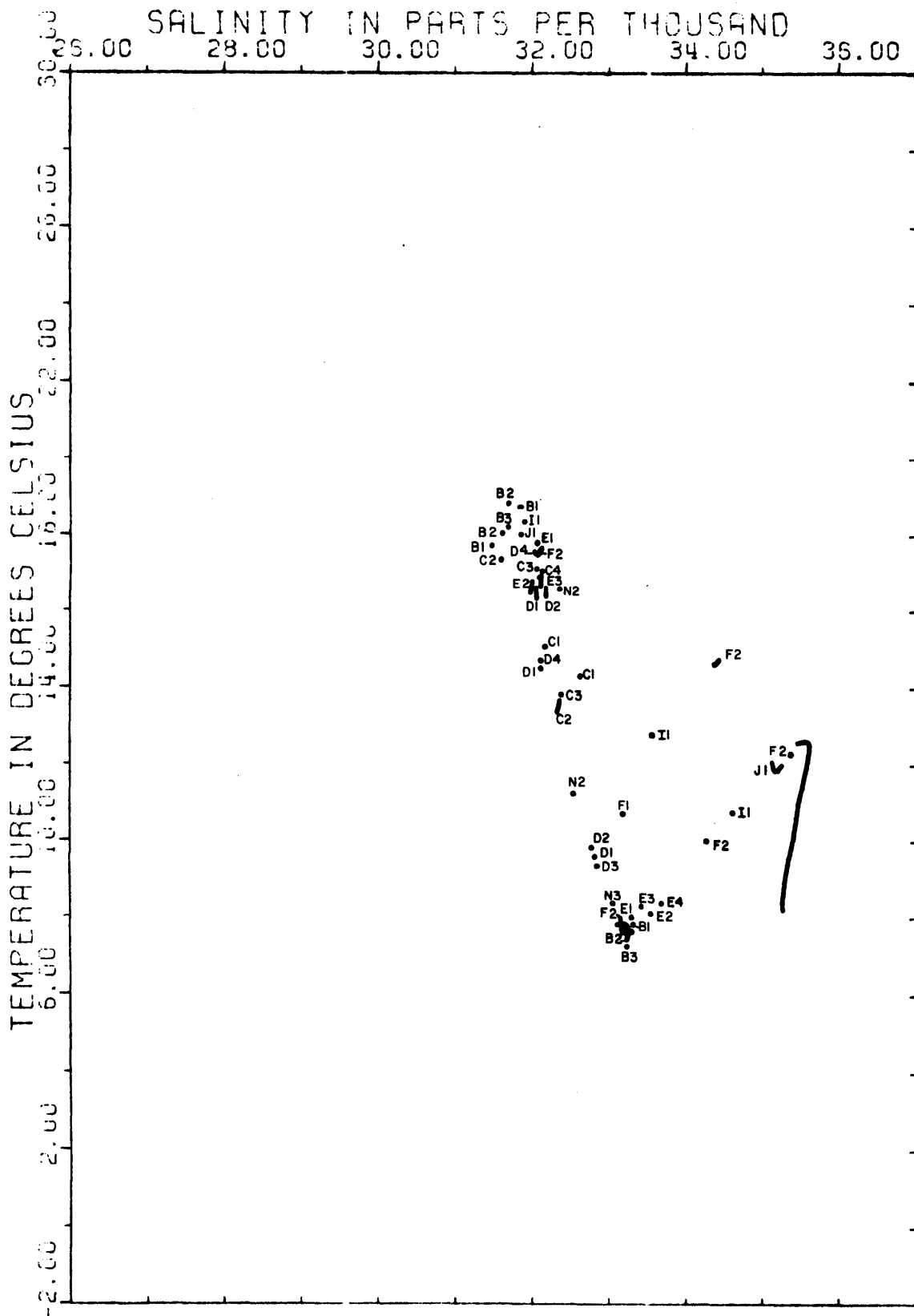


Figure 3-210c. Agglomeration diagram showing water types present at stations during cruise BLM 03B. Spring conditions are shown particularly to the left of the curve.

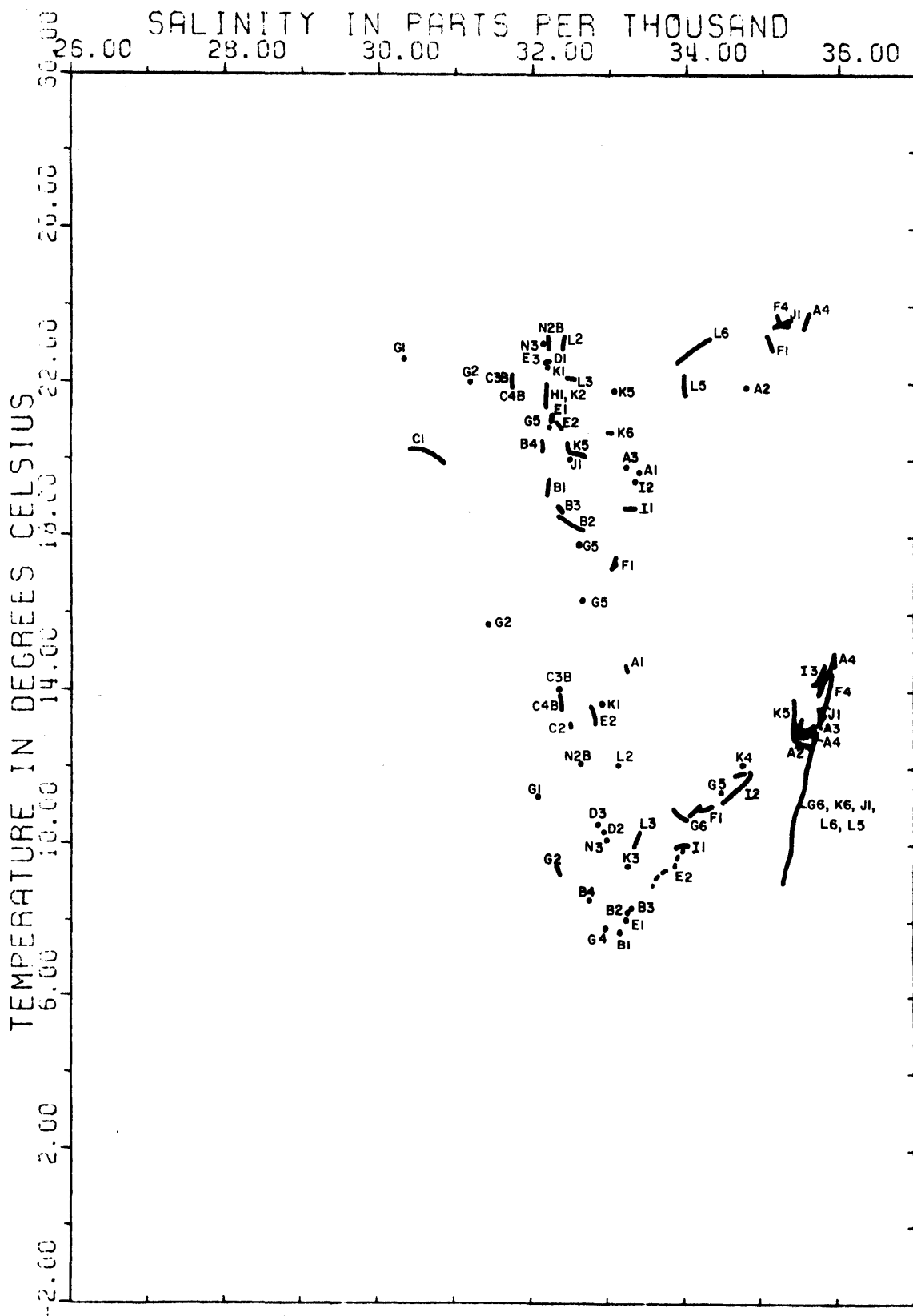


Figure 3-210d. Agglomeration diagram showing water types present at stations during cruise BLM 04B. Late summer conditions are indicated.

Summary of Significant Findings

1. The major effort of this portion of the study was to obtain values of several parameters over a year's time. The parameters measured or calculated include: temperature, salinity, dissolved oxygen, density, nitrite, nitrate, and ortho-phosphate. These are presented as surface and bottom charts as well as sections. The figures are found between pages 3-34 and 3-207. This set of analyses is the single most significant result of the first year's physical study for it presents a set of observations which can be used as a baseline for future work and comparisons. Several features of shelf hydrography during the year invite further comment.
2. The winter period is generally presumed to be well mixed resulting in nearly vertical isopycnals. This is illustrated in Figure 3-71 between stations K3 and K5 which were sampled on 12 March 1976. In contrast to this is the vertical stratification found a week earlier, approximately 170 km to the north between stations B2 and A3 (Figure 3-63). The earlier situation (stations B2 to Z3) follows a period of unusual southerly and easterly winds while the later sampling follows a winter storm (see Figure 3-43). Southerly winds will result in offshore Ekman transport with compensatory onshore flow at depth. This is illustrated by the isohaline configuration in Figure 3-61. Thus, the concept that stratification on the shelf is a dynamic response of hydrographic structure to applied stresses rather than a thermally induced stratification due to local warming is supported.
3. During the early summer of 1976, anoxic conditions developed in bottom waters near the New Jersey coast. The general extent of these conditions during the latter half of August can be seen in Figure 3-131 which shows bottom DO values for the period 15 August to 1 September. Comparison of the results of the summer benthic cruise with those of the summer water column cruise along section III (Figures 3-145 and 3-166) shows that the center of anoxic water moved from a region approximately 10 km off shore during the last two weeks in August to approximately 78 km off shore during the first week of September. Examination of temperature and salinity sections for the same region and period (Figures 3-143, 3-144 and 3-164, 3-165) shows that the anoxic condition moved off shore with no zonal motion of the water (T-S structure of bottom water changed little at stations C1 and N3). The lowest value of oxygen is seen to have moved from close to shore to about 65 km out to sea during this period of time.
4. In addition to these event descriptions, several processes are evident in the data. a. A mid-level dissolved oxygen maximum is indicated in Figures 3-193 to 3-195. These maxima are common summer features and are indicative of biological oxygen production. b. The existence of agglomeration points in T-S correlation curves as shown in Figure 3-207c and plotted in Figures 3-210a-d indicate that much of the mixing on the shelf is caused by events which homogenize a certain amount of water in a short time. c. The "cold pool", a commonly observed feature, is evident in Figure 3-116, which shows temperature along section III during mid-June. d. The shelf edge front is usually observed in salinity sections such as Figure 3-144. This feature frequently has a compensating temperature distribution, with a resulting smoother pattern of density (Figure 3-146) implying some adjustment process having taken place.

ACKNOWLEDGEMENTS

Many people assisted in various phases of this project. We thank them all. Specific thanks are due to our field assistants: Scott Fenstermacher, Jim Cumbee, Ken Worrell, Benji Hahn and Steve Snyder; the technical staff who assisted in preparing drafts of many of the figures: Ms. Shirley Crossley, Ms. Terrell Markle and Ms. Trish Smith; and the data processing staff, Ms. Ginny Shaw, Ms. Shirley Robbins and Ms. Glenda Owens who spent many hours processing CTD tapes and preparing computer graphics.

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APPENDIX 3-A

PROGRAM DESCRIPTION OF CTDRAW

Name: CTDRAW

Type: Main Program

Language: FORTRAN F on VIMS IBM 370/115

Purpose: To generate a 9-track, 800 bpi FORTRAN magnetic tape of depth-sorted oceanographic measured and derived variables, from a binary input tape of raw Neil Brown CTD/DO data.

Description:

Generates averages of measured variables in engineering units for each record of raw binary data. From those averages, salinity and depth are calculated. Separate averages for 1.024 second data periods are kept to generate partial pressure and dissolved concentration of oxygen. Time averaged values of depth, pressure, temperature, conductivity, oxygen probe current, oxygen probe temperature, salinity, elapsed time by data rate, partial O₂ pressure, and dissolved O₂ concentration are sorted and averaged into 0.5 meter depth slots. The depth averages give equal weights to individual samples. They are written on an EBCDIC output tape with indicators for cast direction, CTD unit number, output variable minima and maxima, and number of samples per slot. When the binary input tape is finished, the output file is marked with an End-Of-File (EOF), rewound, and listed.

Input Terminals: Card reader
9-track tape unit, SYS016

Output Terminals: 9-track tape unit, SYS011, FORTRAN unit number 14
Line printer

Usage:

1. Job Control Language:
*b\$\$bJOBbJNM=CTDRAW,USER=(no.)/(name), CLASS=N
//bJOBbCTDRAWb(no.)/(name)
//bLOG
//bOPTIONbLINK
//bEXECbFFORTRAN
//bFTCbLINECNT=55
Fortran main program (if not binary deck)
Fortran BLOCK DATA
Fortran subprograms and functions
/*
bbbINCLUDE
Binary (main program +) subprograms

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/*
//bEXECbLNKEDT
//bPAUSE,bPLEASEbMOUNTbCTDXXXbONb281,bREADbONLY
//bASSGNbSYS016,X'281',X'C8'
//bPAUSE,bMOUNTbVCMXXXbONb280,bREAD/WRITE
//bASSGN SYS011,X'280',X'C8'
//bTLBLbIJSYS11
//bEXEC
    data cards
/*
/¢
*b$$bEOJ

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2. Input Tapes, CTD001 through CTD999:

Raw binary CTD data on 800 bpi, 9-track magnetic tape. Records of less than 500 words in integral multiples of frame lengths. Downcasts are terminated by a single EOF mark, upcasts by two EOF marks, and the end of the tape by three EOF marks. The first record of every downcast is data taken before the CTD enters the water and after a 15-minute turn-on and warm-up period. The rest of the downcast starts with the CTD in the water, after the oxygen probe temperature is within 1°C of the water temperature. The downcast finishes just before or just after the bottom rosette sample. The upcast starts before the bottom rosetts sample and ends after the CTD leaves the water.

3. Output Tapes, VIMS labeled:

EBCDIC, 800 bpi, 9-track magnetic tape in 12F10.4 format. The twelve output variables are as follows:

Code word - negative for downcast, positive for upcase,
 + 10.0 for pressure sorted data, + 20.0
 for minima and maxima, + 0.N added for
 CTD unit no. N.

Pressure (d bar)
 Temperature (°C)
 Conductivity (mmho/cm)
 O₂ probe current (µA)
 O₂ probe temperature (°C)
 Salinity (ppt)
 Time, from cast start by data rate (sec)
 Partial pressure O₂ (atm)
 Dissolved concentration O₂ (ml/l)
 Number of samples/code word - number of samples (frames)
 per depth sort, repeated code word for minima or maxima.

Each downcast or upcast is recorded with the pressure sorted data in order, followed by one record of the minima of the middle ten output variables and one record of the maxima of the same variables. The ten minima and maxima are each bracketed by code words.

4. Input Cards:
 For each station cast (downcast and upcast) an input card in
 FORMAT(3A2,2I3,I4,I2)
 gives the following header information:
 NAME(1),NAME(2),NAME(3)=six letter alphanumeric station code
 LATD=degrees of latitude
 LATM=minutes of latitude
 SERIAL=serial number of CTD used, 1295 or 1495
 SKP=file number of first cast to be used on the input tape
5. Line Printer:
 The first two averaged records in each down- or upcast are
 printed out in the following manner:
 KTIME in FORMAT(1H0,11H**RECORDb=b,I3)
 KTIME,KL,KLO,KDO,FS,UN,FTO in FORMAT(1H0,4I5,3F10.4)
 (AV(I),I=1,11) in FORMAT(1Hb,11F10.4)
 At every range limit exception of input oxygen probe current,
 the printout is:
 KTIME,KUIO,D,P in
 FORMAT(1H0,31H**POSSIBLEbBOTTLEbTRIPbKTIMEb=b,I6,9HbbKUIOb=b,
 I3,2F10.4)
 When the sorting storage has been filled and when the sorting
 routine is commanded to finish, the next line is a comment in:
 FORMAT(16H0**SORTEDbOUTPUT)
 followed by the same data written on the output tape in:
 FORMAT(1Hb,12F10.4)
 At the end of a downcast, the minima of the sample values of
 the output variables, excluding samples in the first two
 records, are written out as:
 (XM(I,1),I=1,10) in
 FORMAT(10H0MINIMA:bb,10F10.4)
 followed by the maxima:
 (XM(I,2),I=1,10) in
 FORMAT(10H0MAXIMA:bb,10F10.4)
 The last comment before the output of the next cast is:
 FORMAT(1H0,17H**ENDbOFbDOWNCAST)
 The end of an upcast includes the same type of information and
 comment as the downcast, followed by:
 FORMAT(1H0,17(1HX),15HbbENDbOFbUPCAST)
 The end of the tape output includes the above followed by:
 FORMAT(1H0,32(1HX),13HbbENDbOFbTAPE)
 After this the output tape is unwound and listed, beginning
 each down- and upcast sorted output with a new page.

Variable List:

1. COMMON/BLK1/
 IOB=(not used)
 KEOF=number of consecutive EOF marks read from input tape
 KETM=KEOF+1 if KEOF>0 (not used)
 FT=time of data sample from start of cast, based on data rate
 FIV=integer array for storing equivalent values of 8-bit
 binary data from an input record
 EU=(not used)
 IFIV=current beginning of sample frame in FIV

JFIV=current end of sample frame in FIV
 IEU=(not used)
 IFL=length of input binary sample frame (8-bit words)
 IRL=length of input binary record (8-bit words)
 FR=frame rate (31.25/sec)
 DU=array of engineering unit oceanographic variables,
 converted from a sample frame in FIV:
 DU(1)=frame syn (15 or 240)
 DU(2)=pressure (d bar)
 DU(3)=temperature (°C)
 DU(4)=conductivity (mmho/cm)
 DU(5)=O₂ probe current (µA)
 DU(6)=O₂ probe temperature (°C)
 DU(7)=CTD unit number
 DU(8)=frame time from start of cast (sec)
 KUIO=number of O₂ probe current boundary limit exceptions
 per input record
 UIO=upper limit allowed for O₂ probe current (µA)
 KDO=counter flag to force completion and reinitialization
 of the oxygen variable calculations with the present
 input record
 KUN=CTD unit number by data card input
 KTIME=Number of input records, from the start of the cast,
 accepted for processing and output
 UN=CTD unit number by sample frame
 XM=minima and maxima oceanographic variables (by frame for
 measured variables and by record for calculated variables)
 for each upcast or downcast, excluding the first two
 records. The variables (XM(I,1),I=1,10) are the minima
 and (XM(I,2),I=1,10) are the maxima.
 The variable designations for the I indices correspond
 to those of the DU array except for:
 XM(1,J)=depth (m)
 XM(7,J)=salinity (ppt)
 XM(9,J)=calculated O₂ partial pressure (atm)
 XM(10,J)=calculated O₂ dissolved concentration (ml/l)

2. COMMON/BLK2/

AV=present record average array. Variables correspond to
 those in the XM array except for:
 AV(11)=number of frames used in this record
 NAV=number of frames used in present record
 KL=number of rate limit exceptions for pressure, temperature,
 and conductivity in present record
 AVL=last record average array
 KLO=number of rate limit exceptions for O₂ probe current
 and temperature in present record

3. COMMON/LIM1/
 - DPM=maximum allowed rate for pressure (d bar/sec)
 - DTM=maximum allowed rate for temperature (°C/sec)
 - DCM=maximum allowed rate for conductivity (mmho/cm/sec)
 - DIOM=rate limit for O₂ probe current (µA/sec)
 - DTOM=rate limit for O₂ probe temperature (°C/sec)

4. COMMON/OXY1/
 - FTO=average frame time of current oxygen calculation variable
 - OX=period average array for oxygen calculations. (Corresponds to AV array in COMMON/BLK2/.)
 - NO=number of samples in current oxygen calculation

5. COMMON/SORT1/
 - YO=sorting and output array. Second index is by depth step, DY. First indices are:
 - YO(1,J) through YO(10,J)=depth sorted variables corresponding to AV array in COMMON/BLK2/, weighting each sample equally
 - YO(11,J)=number of input samples averaged into the Jth depth slot
 - YO(12,J)=number of input records averaged into the Jth depth slot
 - BS=starting point of downcast depth sorting (m)
 - BC=current starting point of YO array (m)
 - DY=slot size of depth sorting (m)
 - MX=1, AV array index for depth
 - NY=number of depth slots in YO not empty

6. COMMON/HDR/LATD,LATM,NAME,SERIAL,SKIP
 - See part 4 of Usage

7. OTHER VARIABLES
 - KIOL=value of KUIO for last record
 - SL=value of salinity for last record
 - CAST=indicator for downcast, upcast, and unit number status
 - DO=dissolved O₂ concentration (ml/l)
 - PO=partial O₂ pressure (atm)
 - D=depth (m)
 - KM=flag to force initialization of XM array

Restrictions: Determined by subroutines.

Subprograms Required:

SUBROUTINE PSORT (X,I)
 SUBROUTINE RECAV
 FUNCTION SGN(X)

SUBROUTINE SALIN (P,T,C,S,SL)
SUBROUTINE MINMAX (X,XM,KM)

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