

A Description of Oceanographic Conditions off the Southeastern United States During 1974

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Introduction

The Marine Resources Research Institute under a contract from the National Marine Fisheries Service (NMFS) has conducted a series of oceanographic cruises along the continental shelf of the southeastern United States since 1972. As a part of the NMFS Marine Resources Monitoring, Assessment, and Prediction (MARMAP) Program, these cruises were designed to obtain, process, analyze, and distribute data pertinent to living marine resources of waters contiguous to the United States. The results from 1973 were reported previously (Mathews and Pashuk, 1977), with this report covering 1974 cruise data.

Methods

All hydrographic data, except temperature, were obtained from water samples collected aboard the R/V *Dolphin* during 1974. Temperature was determined using reversing thermometers (placed on Niskin bottles) and bathythermographs, both mechanical and expendable. Unprotected thermometers were used at deep stations to determine the depths of reversal.

Dissolved oxygen was measured at sea with an oxygen meter immediately after collection. Nutrient and salinity samples were stored in polyethylene bottles and analyzed ashore. Nutrient samples were analyzed using colorimetric methods (Strickland and Parson, 1972) on samples frozen upon collection and not thawed until analysis. Salinities were determined conductometrically with an induction salinometer.

All samples were collected during 1974 as shown in Table 1.

Results

Dotted lines signify missing data and, hence, inferred orientations of isopleths. These lines were drawn only

to indicate a reasonable trend supported by other data in the same geographical area.

Horizontal Distributions

Density (σ_t). Surface densities ranged from about 20.0 to 27.0 with maximum values occasionally at midshelf locations (Figs. 6-10). With the exception of cruise DP7403 during August 1974, nearshore surface densities were frequently higher than or equal to outer shelf (Gulf Stream) surface densities.

Fifty meter density distributions were similar to those at the surface, but their range was somewhat smaller, i.e. < 24.5 to > 26.0 (Figs. 11-13).

One hundred meter density distributions had some of the features of the shallower sections, but there were overall differences in shapes of the isopycnals (Figs. 6, 8, 14, and 16). The isopycnals follow the shelf edge to a great extent in Figure 16.

Bottom density distributions resembled 100 m sections and mainly followed the shelf edge and coastline (Figs. 17-19). Only the most general features were evident in both the surface and bottom sections and these were primarily nearshore as opposed to outer shelf (Figs. 7 and 18).

Temperature. Surface temperature ranged from < 12° > to 29°C, with the least variation in temperature occurring on the outer shelf near the Gulf Stream (Figs. 20-24). Zones of lower temperature water were evident at the coast, usually near river mouths, (Figs. 21, 24). The zone of lower temperature water was present at the shelf edge east of Charleston, where water < 20°C was at the surface, possibly due to upwelling (Fig. 21). Horizontal surface temperature gradients were highest during winter months (Fig. 20) and lowest during summer (Fig. 22).

TABLE 1. Cruise Data.

<u>Cruise Number</u>	<u>Date</u>	<u>Purpose</u>
DP7401	January 8-13, 1974	investigation of menhaden eggs
DP7402	April 1-May 9, 1974	groundfish cruise
DP7403	August 13-September 1, 1974 September 15-18, 1974	groundfish cruise driftbottle cruise (see Barans and Roumillat, 1976)
DP7404	November 7-14, 1974	driftbottle cruise

Fifty meter isotherms retained many of the surface features, although actual temperatures were, of course, generally lower. Temperatures ranged from $< 18^{\circ}$ to $> 27^{\circ}\text{C}$ (Figs. 25-29). The temperature differential between surface and 50 m was slight on the shelf, in some cases being virtually non-existent (Figs. 20, 21, 24, 25, 26, and 29). The greatest differentials (up to 8° or 9°C) were measured in the summer and fall, during which time the 50 m isotherms varied in shape distinctly from the surface isotherms (Figs. 22, 23, 27, and 28).

One hundred meter isotherms were generally similar in shape to those at 50 m, but some distinct differences were evident (Figs. 25-32). The 50 to 100 m temperature differential was slight along the shelf, with some areas having no difference and others being about 1°C . Beyond the shelf edge the differential was 5° to 6°C in most cases. The overall temperature range was from $< 15^{\circ}$ to $> 24^{\circ}\text{C}$ (Figs. 30-32).

Bottom temperatures were much lower at the shelf edge and beyond than on the shelf (Figs. 33-37). Temperatures ranged from $< 7^{\circ}$ to $> 27^{\circ}\text{C}$ in depths ranging from 500 to < 50 m. Temperature increased from the coast across the shelf at the surface, e.g. see Figs. 20 and 25, and generally decreased on the bottom, e.g. see Figs. 35-36. Isotherms at the shelf edge were highly compressed in several locations (Figs. 34 and 36).

Salinity. Salinities were high at most stations and depths during the 1974 cruise series, with few salinities $< 33.0^{\circ}/\text{oo}$ (Figs. 38-42). Lower salinities ($< 34.0^{\circ}/\text{oo}$) were generally found near the coast, reflecting the effects of runoff. One zone of relatively low salinity water ($34.5^{\circ}/\text{oo}$) was located at the shelf edge east of Savannah (Fig. 40).

With only a few exceptions the 50 m and deeper water was usually about $36^{\circ}/\text{oo}$ or higher (Figs. 43-51). These exceptions were for the most part lower salinity bottom water nearshore (Figs. 49-51). One other area of reduced salinity ($< 35.5^{\circ}/\text{oo}$) was detected at the shelf edge at 30°N latitude at 100 m (Fig. 48).

Dissolved Oxygen. Dissolved oxygen (DO) was generally high, with concentrations > 5.5 ml/l occurring at some locations and 4.0 to 5.0 ml/l being common at most stations (Figs. 52-63). The lowest DO concentrations (< 3.0 ml/l) were recorded at or beyond the shelf edge at 100 m (Figs. 59-60) and at the bottom (Figs. 62-63). The somewhat lower concentrations observed during August 1974 at the surface (< 3.5 to > 4.5 ml/l) probably resulted from typical summer conditions of high water temperature and low wind mixing (Fig. 54).

Orthophosphate. Orthophosphate concentrations ranged from < 0.25 $\mu\text{g-at}/\text{l}$ at the surface to 2.5 $\mu\text{g-at}/\text{l}$ at the bottom (Figs. 64-75). The higher concentration (> 1.5 $\mu\text{g-at}/\text{l}$) at the surface (Fig. 65) may be the result of the intrusion or upwelling of deep, nutrient-rich waters. Concentrations increased with distance from the coast in general, although some exceptions were evident (Fig. 74).

Vertical Distributions

Density (σ_t). Density vertical sections are shown in Figs. 76-79. During the winter cruise (January 1974) dense water ($\sigma_t \geq 26.5$) was evident at the coast in contrast to the relatively light water ($\sigma_t < 25.5$) at the outer shelf and in the vicinity of the Gulf Stream (Figs. 76).

Temperature. The shapes of the isotherms in most of our transects are similar to those of the isopycnals at the same locations (Figs. 80-86). The intrusion of warmer Gulf Stream water onto the shelf can be seen during the winter and spring cruises in some vertical sections (Figs. 80-82).

Salinity. Salinity was high ($\geq 36.0^{\circ}/\text{oo}$) at most stations except for those near the coast (Figs. 87-91). Maximum salinities occurred at depths < 100 m in most transects, with some maxima being recorded on the shelf at depths < 50 m (Figs. 89-91). Two maxima were observed at $32^{\circ}30'\text{N}$ latitude during the spring cruise with one at 50-100 m depth and the other near the surface. Generally the lowest salinities were found at the coast in very shallow water, but in the $31^{\circ}30'\text{N}$ latitude transect during summer 1974 the lowest salinity water was beyond the shelf edge (Fig. 91).

Dissolved Oxygen. Oxygen concentrations in the upper 50 m were generally ≥ 4.0 ml/l, while oxygen minima occurred at depths > 100 m at most transects (Figs. 92-96). Oxygen minima were found at intermediate depths at two locations as opposed to being at the bottom (Figs. 92-96). Oxygen maxima were always located at the surface and usually near the coast (Figs. 92-96).

Orthophosphate. Orthophosphate concentrations were rather variable, ranging from < 0.2 to > 2.0 $\mu\text{g-at}/\text{l}$ (Figs. 97-101). Nutrient-rich water intruded onto the shelf or upwelled at several stations where orthophosphate concentrations were ≥ 1.5 $\mu\text{g-at}/\text{l}$ (Figs. 99).

Discussion

The influence of climate on nearshore

waters can at times be important, whether from the standpoint of affecting water temperatures or salinity.

During the 1973 cruises the effects of increased runoff were clearly seen through reduced nearshore salinities and temperatures during winter and spring (Mathews and Pashuk, 1977). Since our winter 1974 cruise did not sample off South Carolina during the period of maximum runoff for South Carolina rivers (Fig. 102), we were not able to detect a lowering of temperature and salinity similar to that of 1973. However the spring water temperatures near the coast were lower in 1974 than in 1973 ($< 18^{\circ}\text{C}$ vs. 21°C), which is somewhat paradoxical based on air temperatures, i.e. from January to May air temperatures were consistently higher in 1974 than 1973 (U.S. Department of Commerce, NOAA, 1976). Cooper River runoff was relatively high in April and about average in May 1974 (Fig. 102), but the salinities near Charleston were high (about $34^{\circ}/\text{oo}$), indicating low runoff. Atkinson (1978) recorded similar salinities and temperatures in late April off Charleston also.

Our data indicated the many interactions taking place on the continental shelf with respect to mixing, upwelling, and Gulf Stream intrusions. Surface circulation, as derived from density distribution, illustrates the complexity of these interactions (Figs. 103-107). Agreement was good between the drift bottle returns of Barans and Roumillat (1976) and our circulation patterns below Cape Fear with southerly to southwesterly currents being predominant during September, 1974. Spring circulation was quite complicated with southwesterly currents flowing near the coast, suggestions of eddies off Florida and Georgia, and offshore deflection of the Gulf Stream east of Charleston (Fig. 104).

Much has been written about the deflection of the Gulf Stream off Charleston due to bottom topography, i.e. the "Charleston bump" or "the Charleston rise" (Brooks and Bane, 1978, Pietrafesa *et al.*, 1978, Rooney *et al.*, 1978, and Legeckis, 1979). Mathews and Pashuk (1977) observed this deflection in 1973 during winter and spring cruises with indications of upwelling or intrusions. This same deflection was observed during spring and summer cruises in 1974 in horizontal displays of density (Figs. 7-8) and temperature (Figs. 21-22). Due to the limited geographical range of the other cruises, little or no information is available for winter and fall deflections at the Charleston rise.

Intrusions of Gulf Stream water apparently occur along the continental shelf edge at many locations by several modes. Atkinson (1977) suggested that these intrusions may override, interlayer,

or move along the bottom due to easterly movements of the Stream. Blanton *et al.* (1981) relate intrusions to topographic features such as capes and areas of diverging bathymetry, e.g. Capes Canaveral, Fear, and Lookout. Prevailing winds can also induce upwelling along the shelf edge. Our data illustrate intrusions at several geographic locations, due perhaps to several modes or driving forces. Overriding, bottom intrusions, or some combination thereof is evident in our density and temperature data, as illustrated in Figures 76-83. Entrapment of upwelled water or some similar process may explain the small pockets of high density water observed off Florida at 29° and 31°N latitude (Figs. 7, and 77). These two zones, however, are somewhat different in that the surface water at 31°N is high in orthophosphate ($\geq 1.5 \mu\text{g-at}/\ell$), while surface water at 29°N is considerably lower ($< 0.5 \mu\text{g-at}/\ell$) (Fig. 64). This may be a reflection of biological activity in the area near 29°N or the source water itself.

Conclusions

While many complex interactions between shelf and Gulf Stream waters exist, some general phenomena occur often enough to be predictable. Large horizontal temperature gradients exist during winter as compared with warmer seasons. The upwelling or intrusion of cold, nutrient rich waters is evident at many points along the shelf edge. Deflection of the Gulf Stream off Charleston and concomitant upwelling occur on a semi-permanent basis.

The intrusion of nutrient-rich waters is undoubtedly important on a localized basis, directly or indirectly contributing to increased primary production and the effect thereof on the food chain. By carefully studying upwelling and intrusions, it may be possible to enhance coastal fisheries with a predictive capability.

Acknowledgements

Funds for this study were provided by the National Marine Fisheries Service, Marine Resources Monitoring, Assessment, and Prediction Program. Grateful appreciation is extended to the many individuals who made this investigation possible, ranging from the crew of the R/V *Dolphin* to laboratory personnel. Special thanks are given to Karen Swanson and Bryan Stone for art work, Virginia Young and Kathy Austin for salinity and nutrient analyses, Drs. W.F. Kinard and V.G. Burrell, Jr., for their critical review, and Beverly J. Ashby for typing the manuscript.

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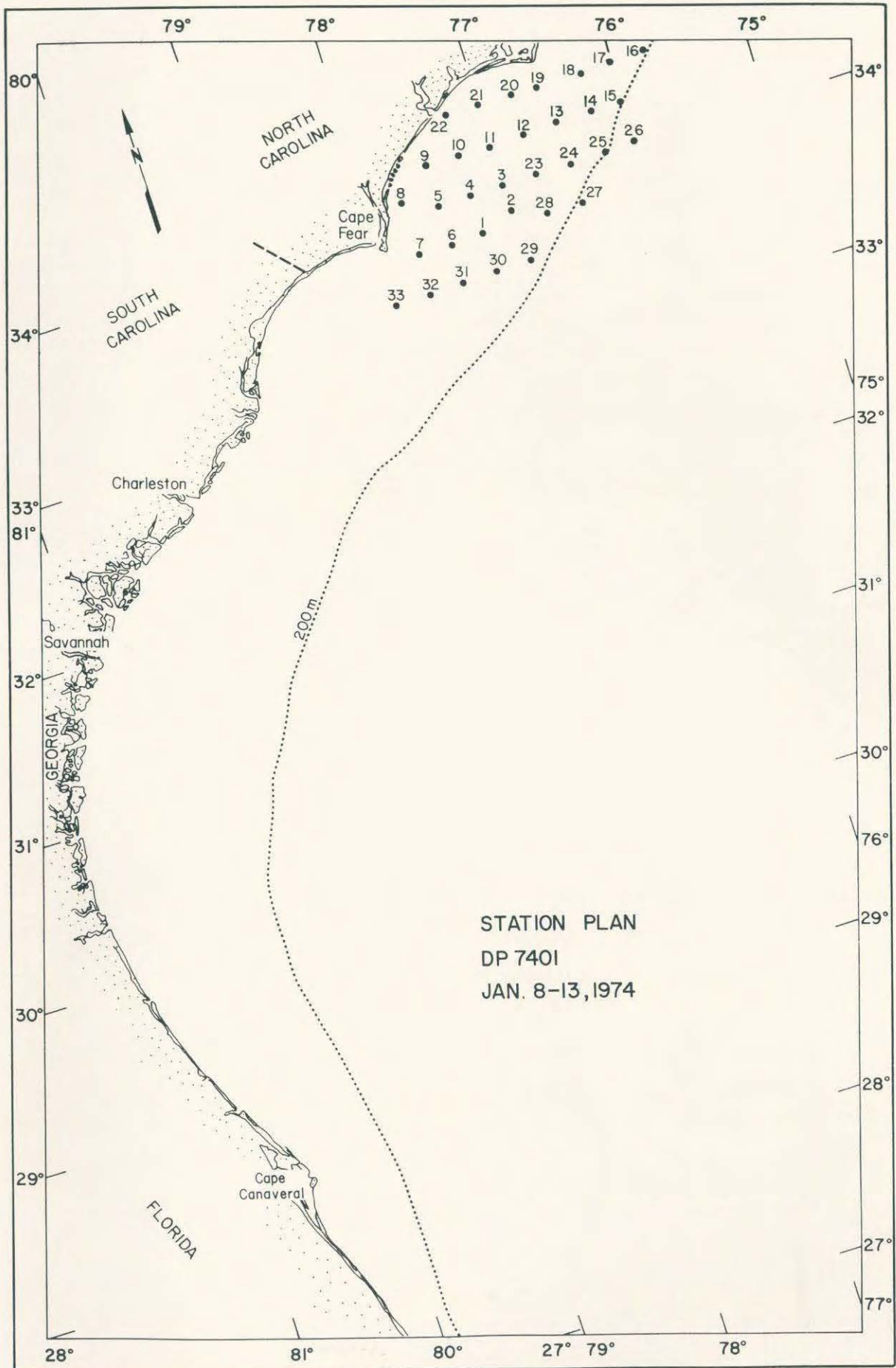


FIGURE 1.

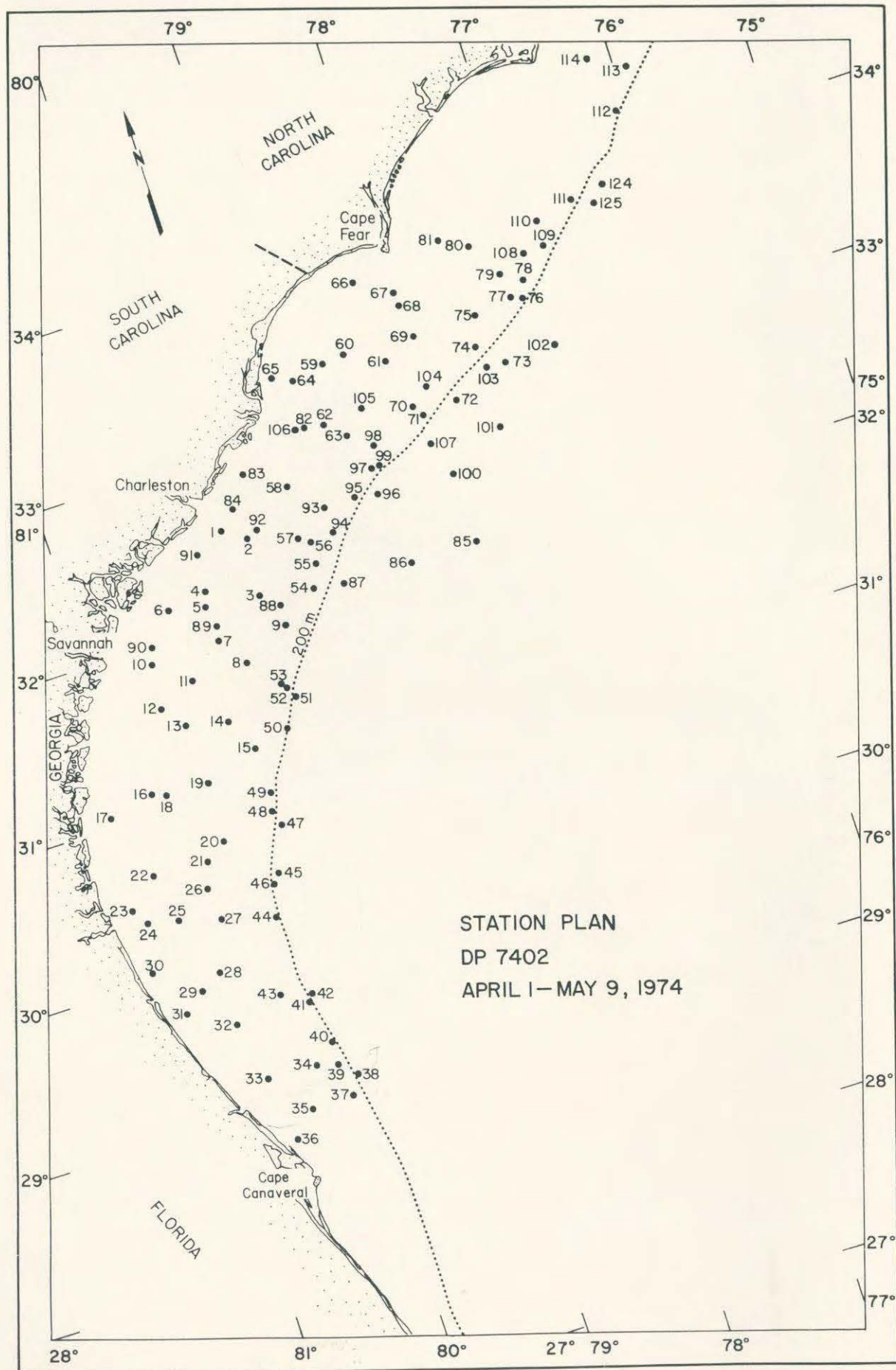


FIGURE 2.

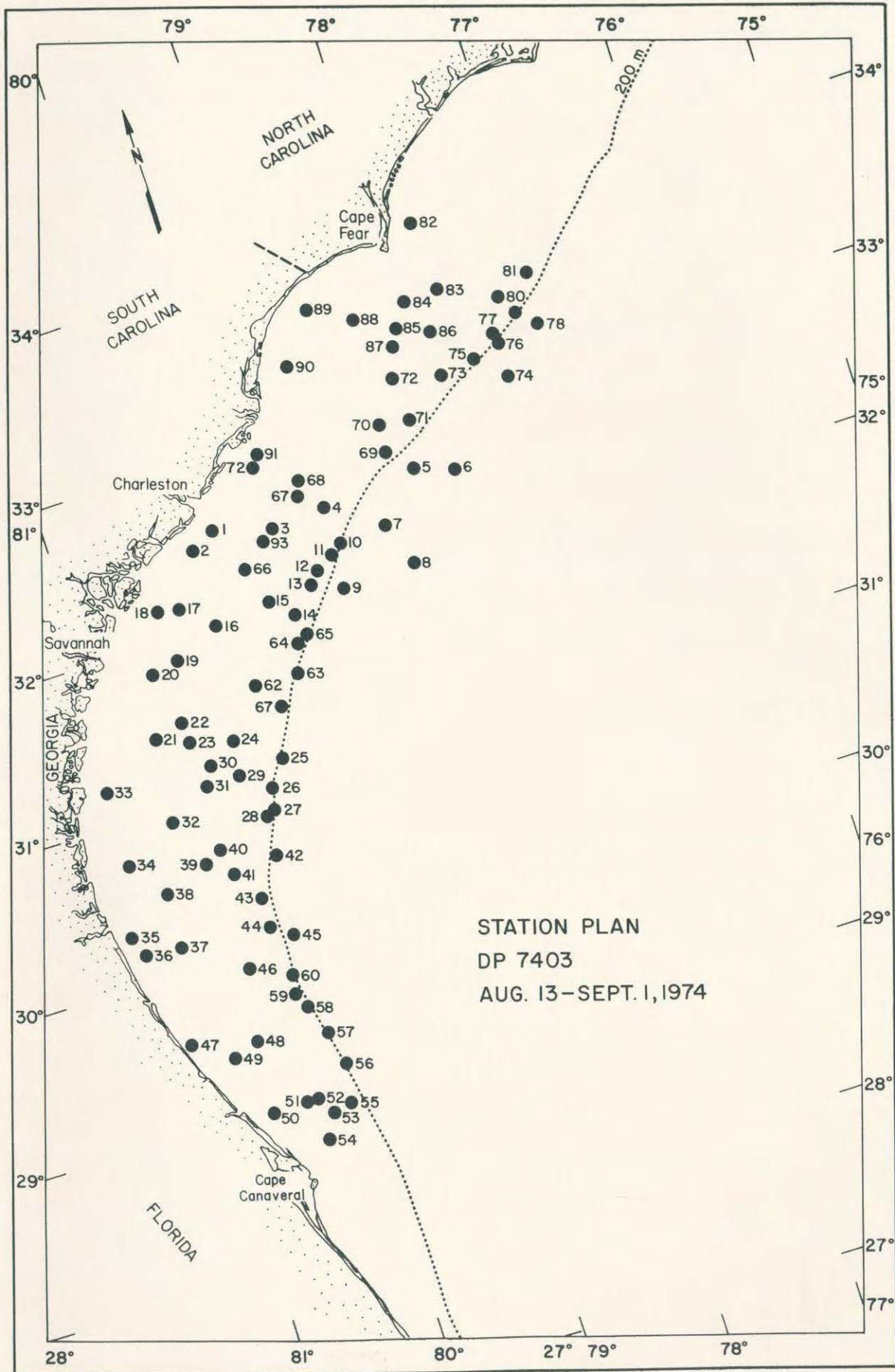


FIGURE 3.

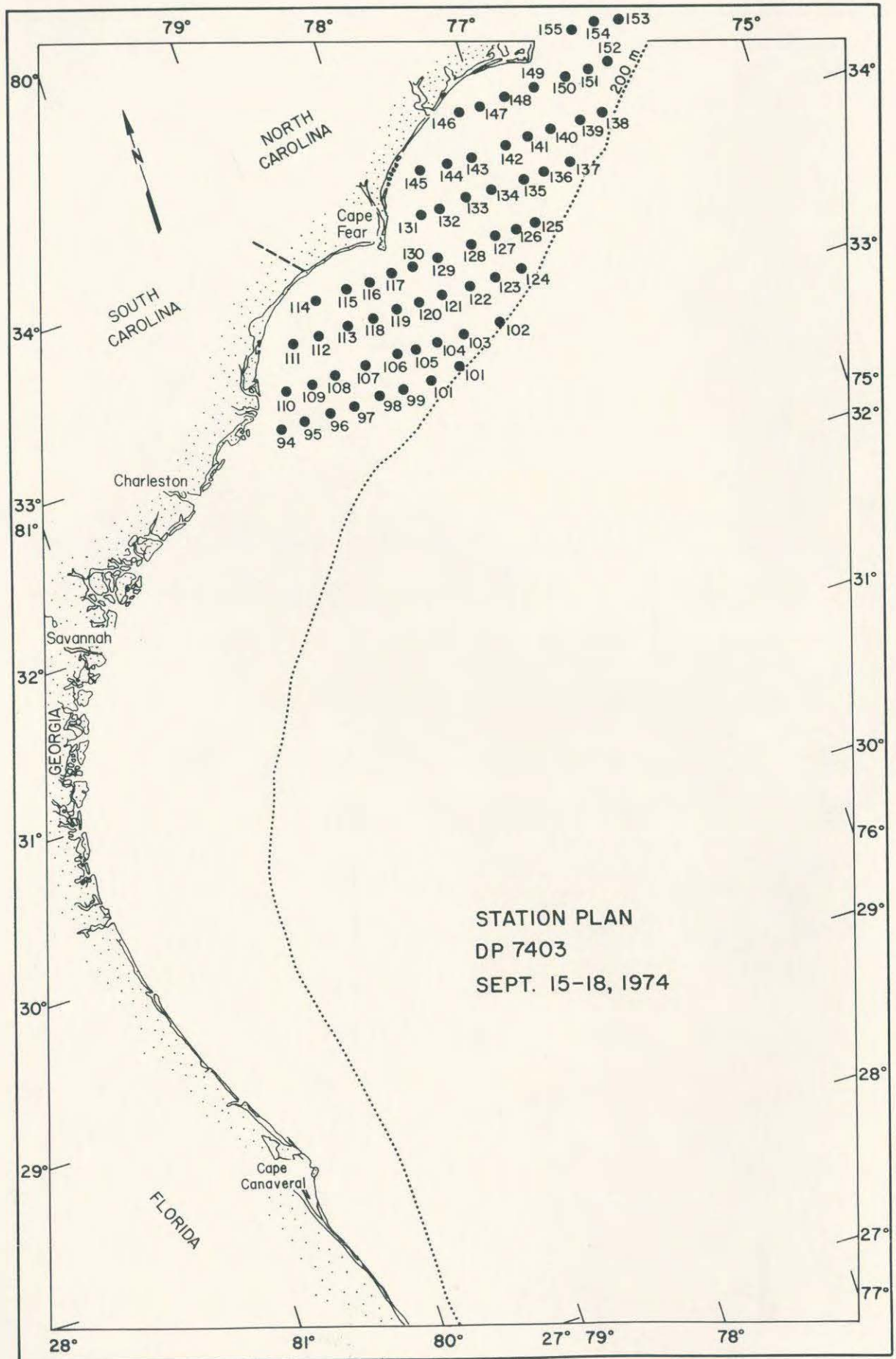


FIGURE 4.

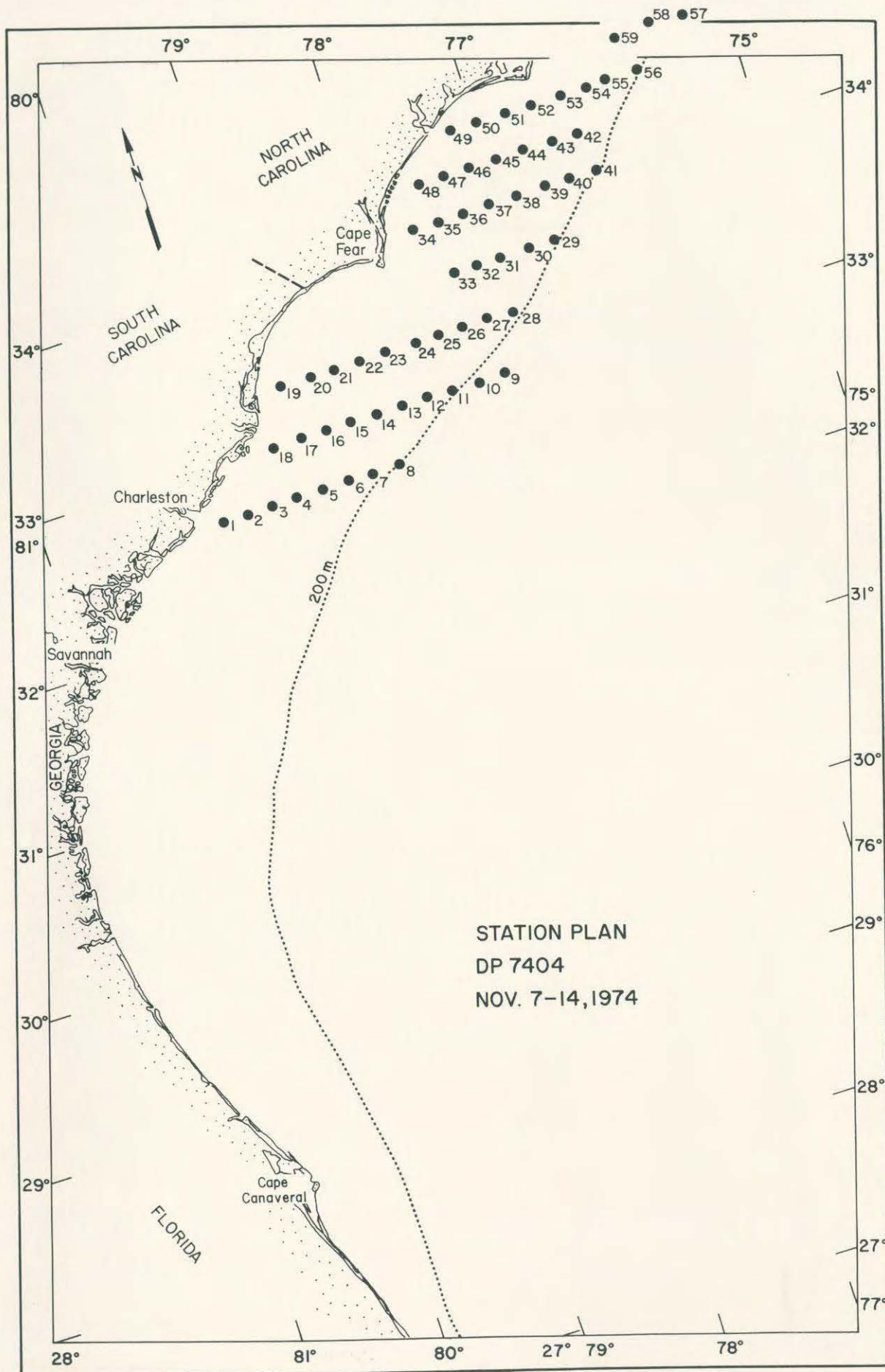


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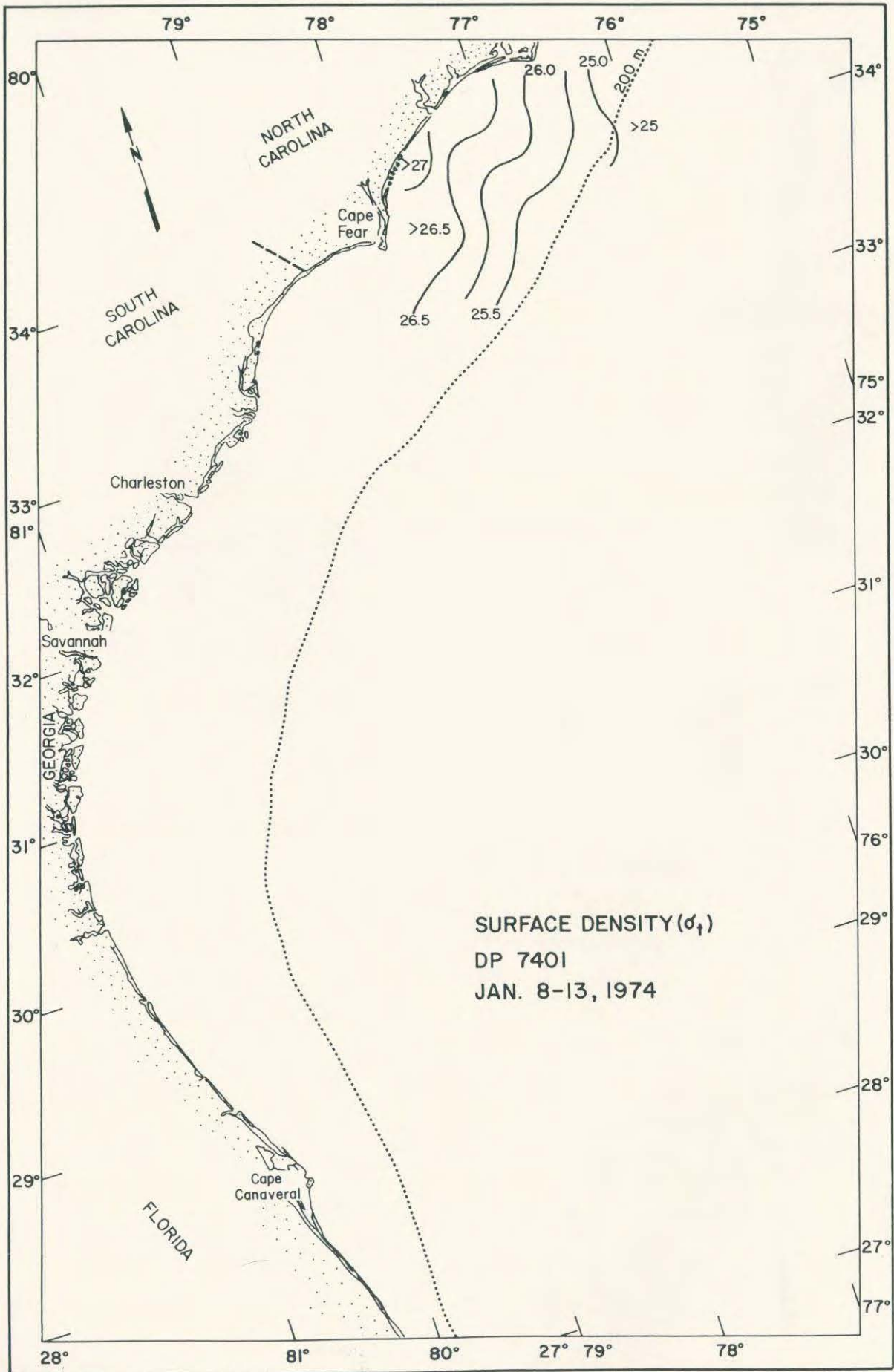


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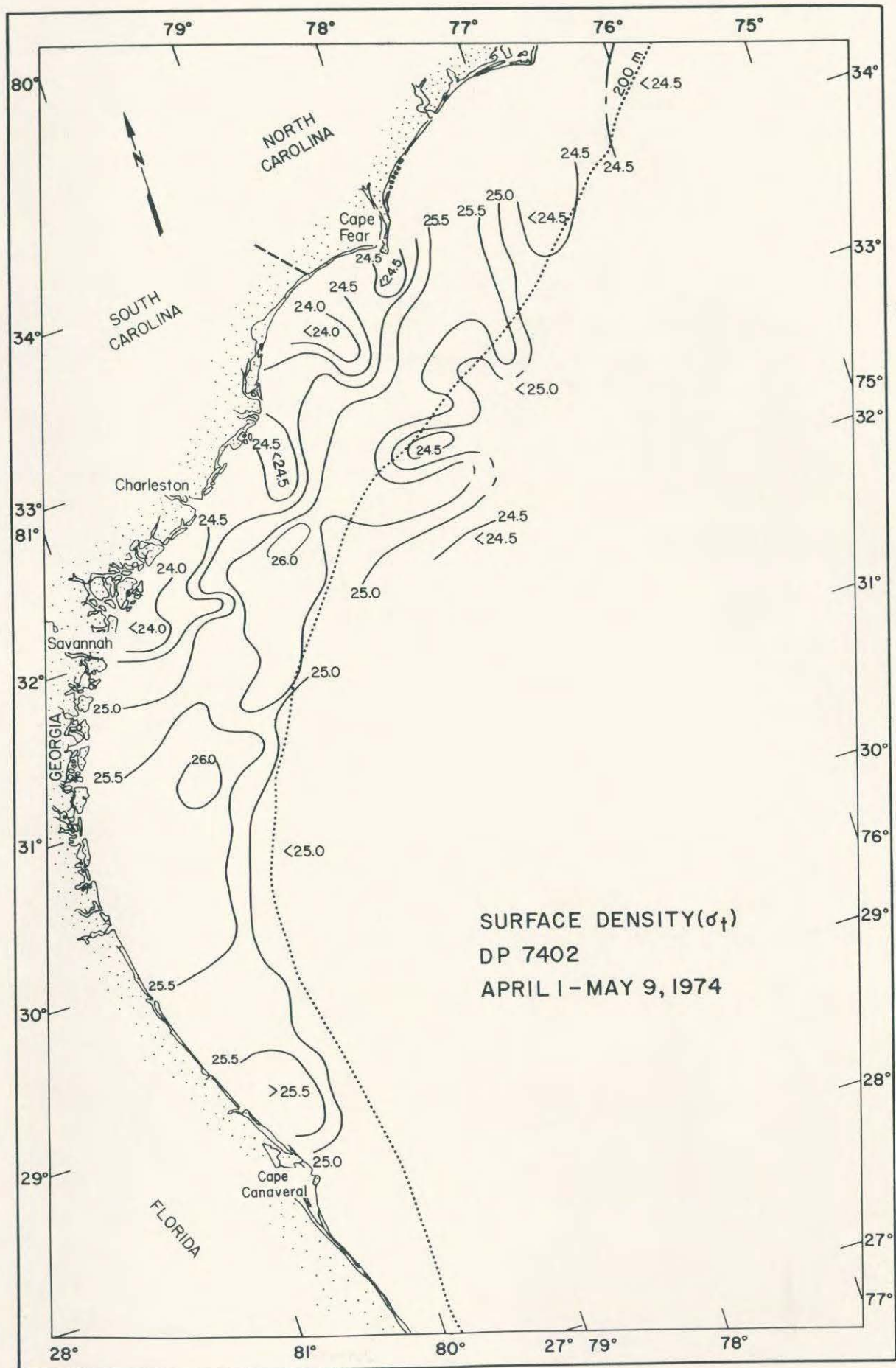


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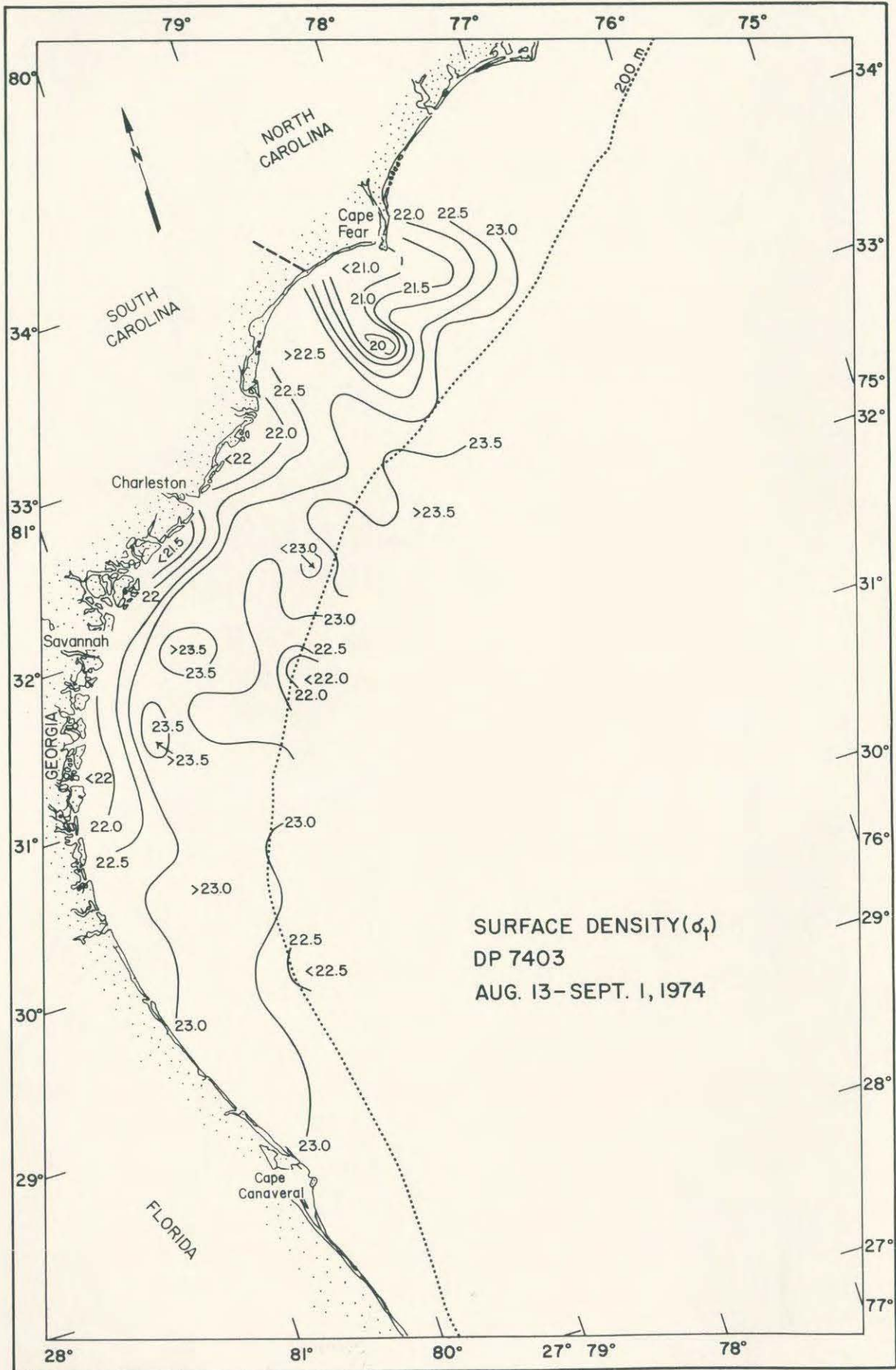


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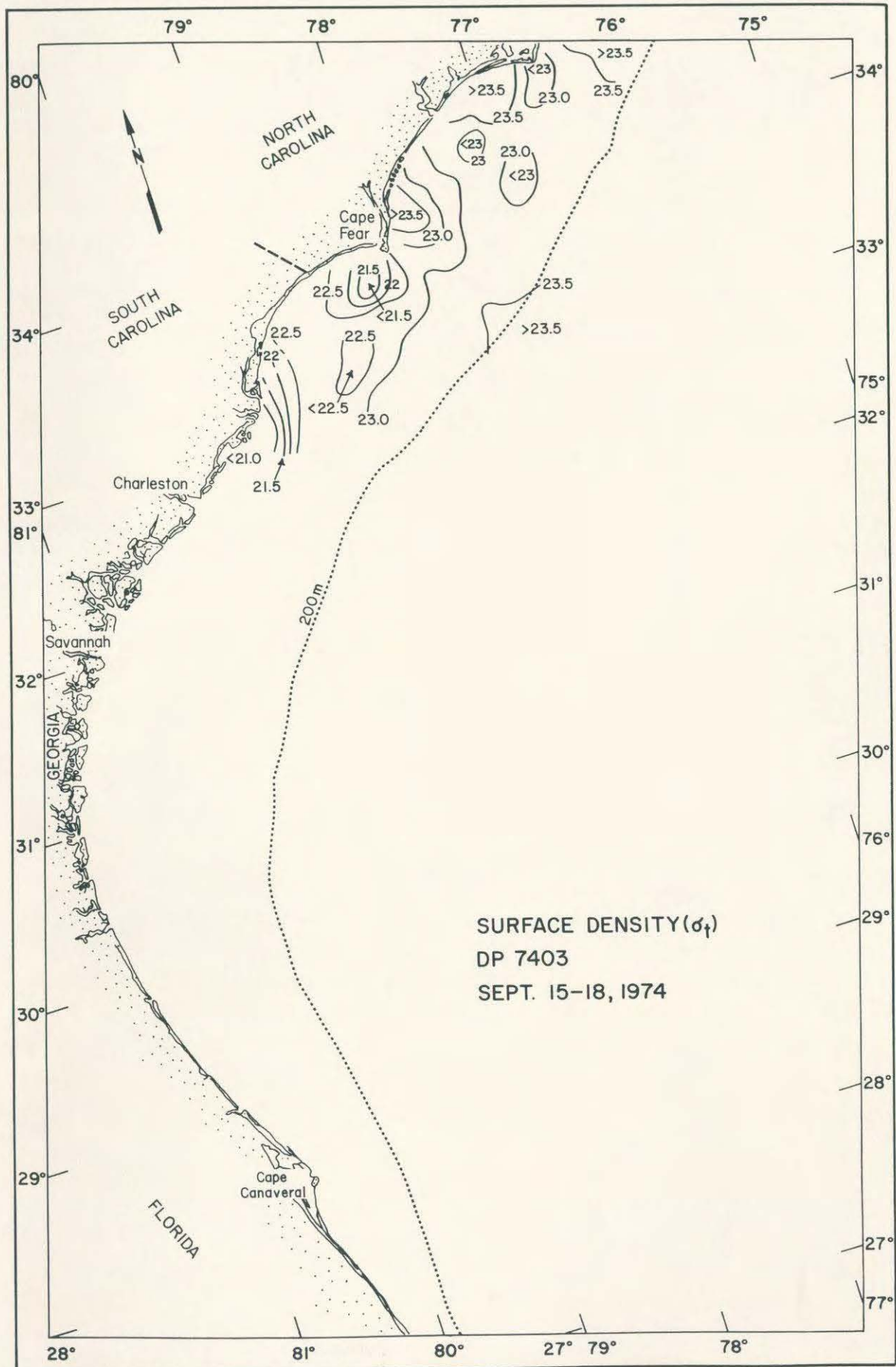


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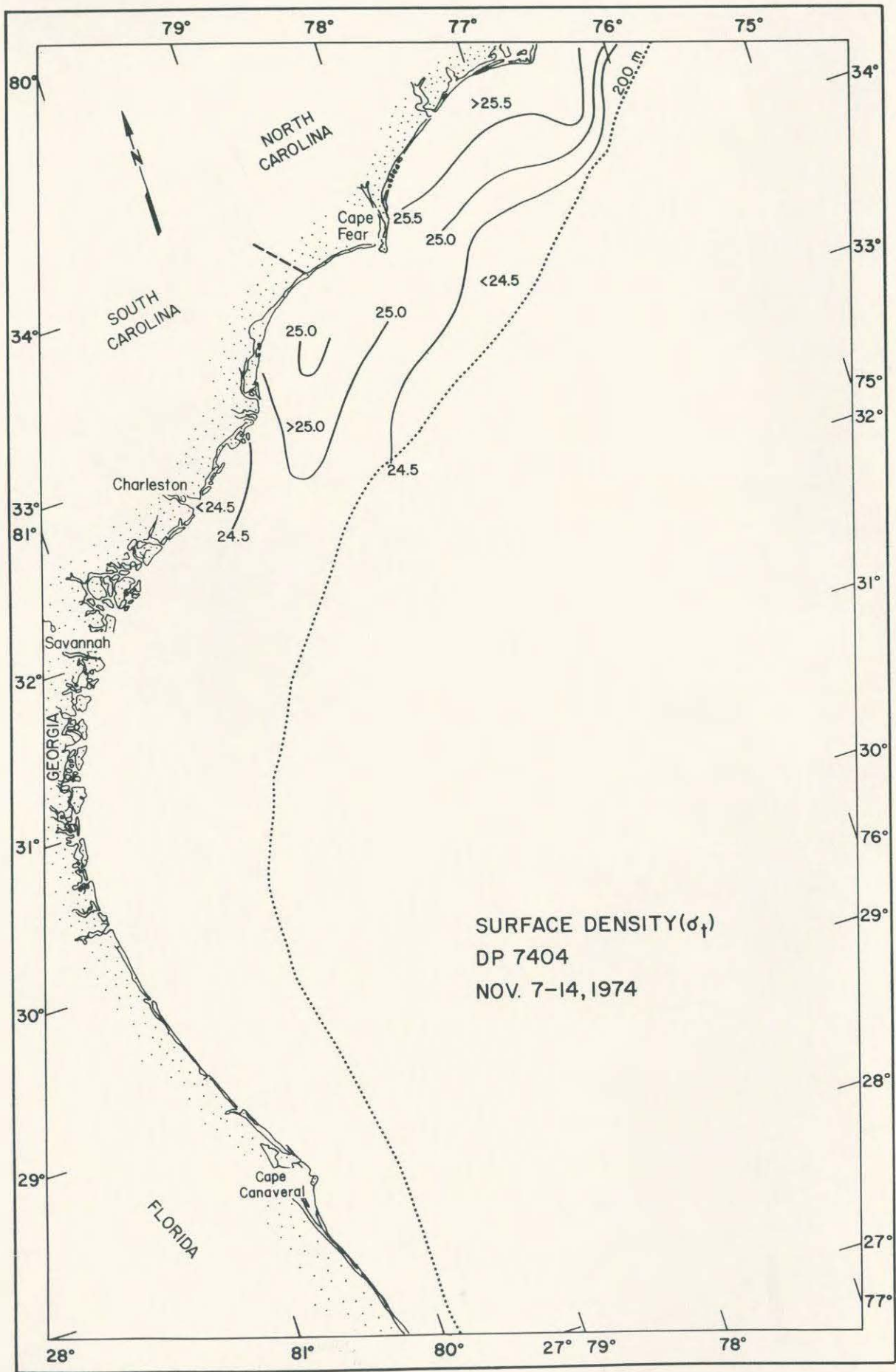


FIGURE 10.

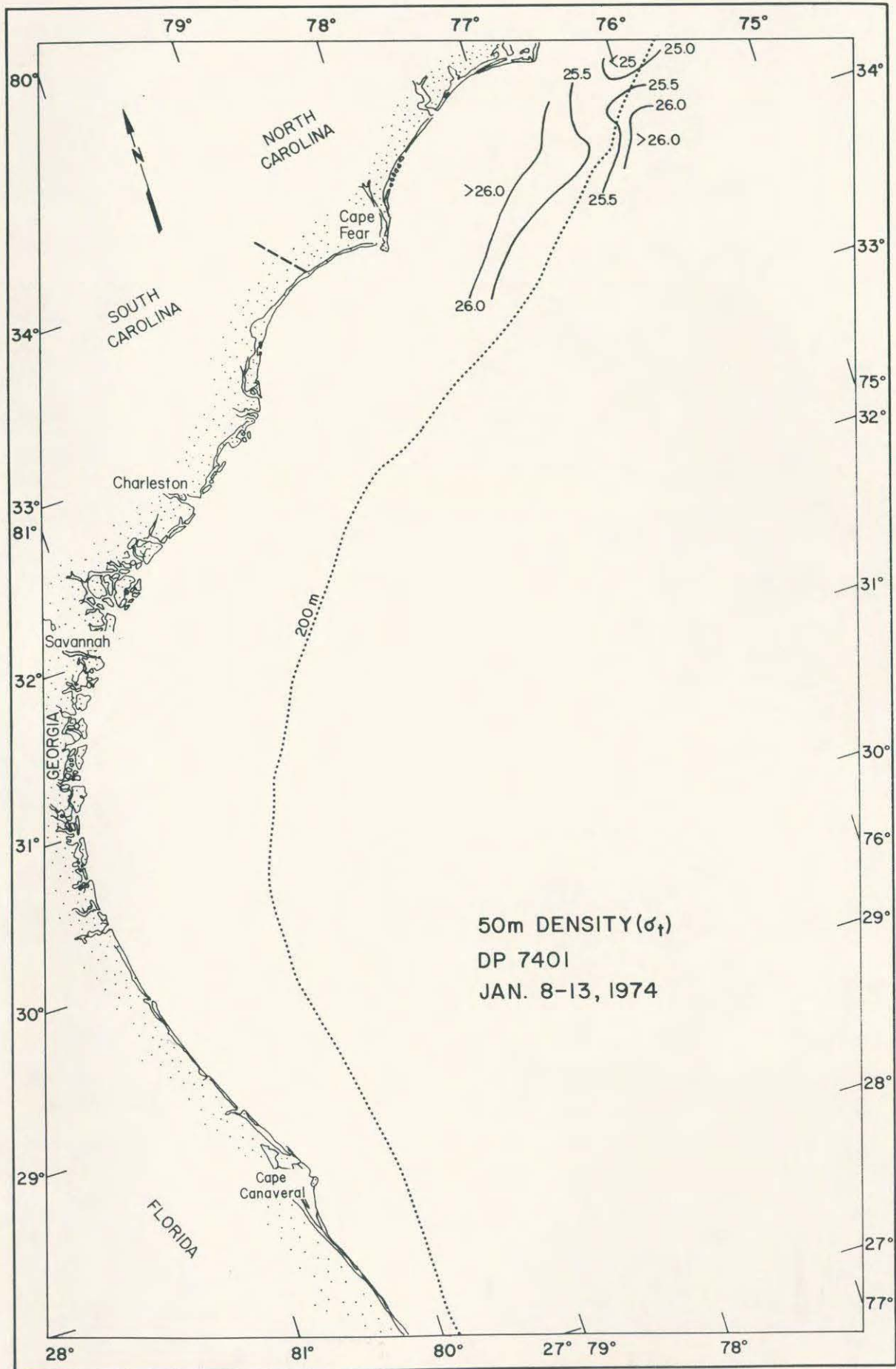


FIGURE 11.

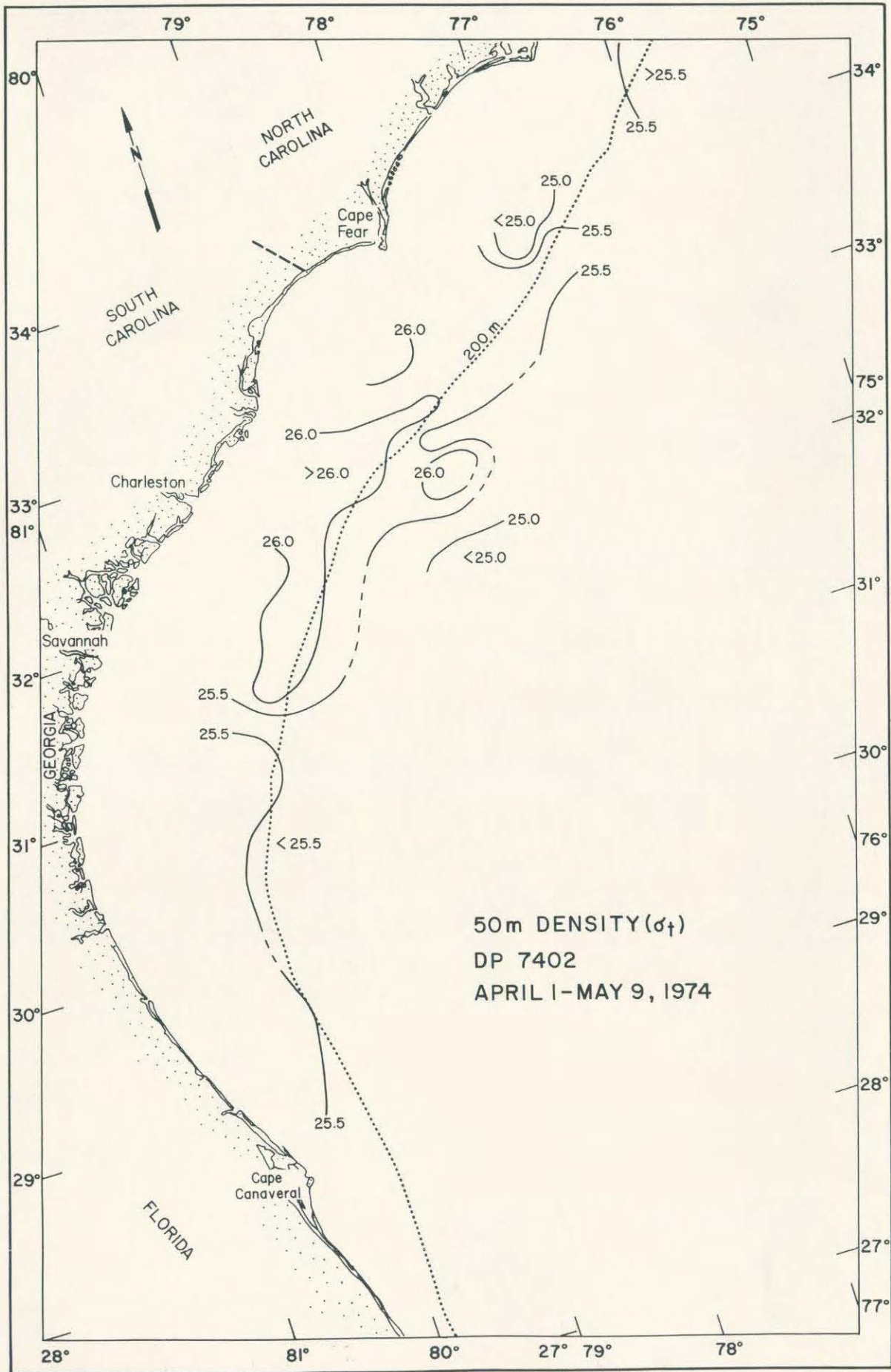


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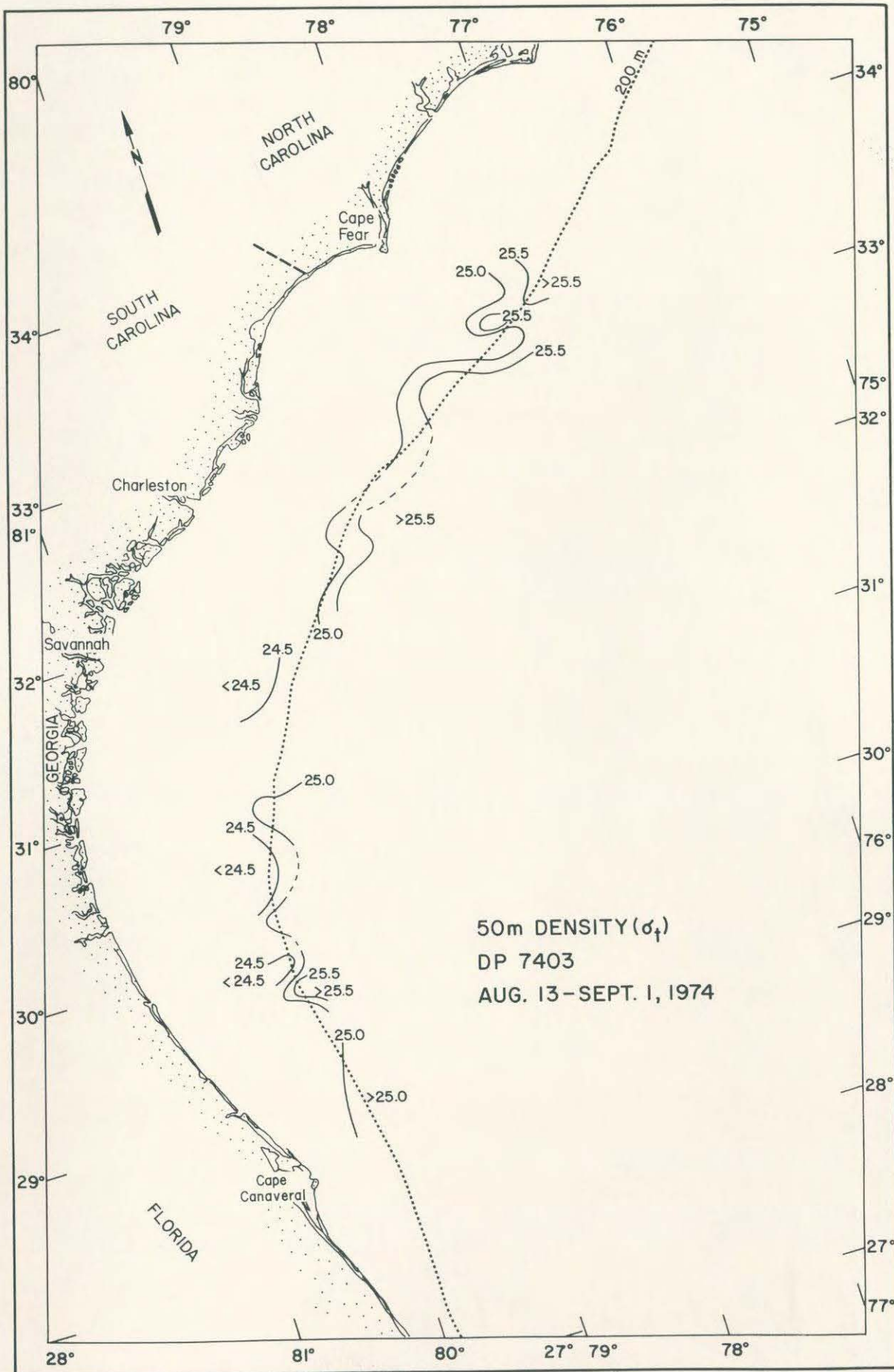


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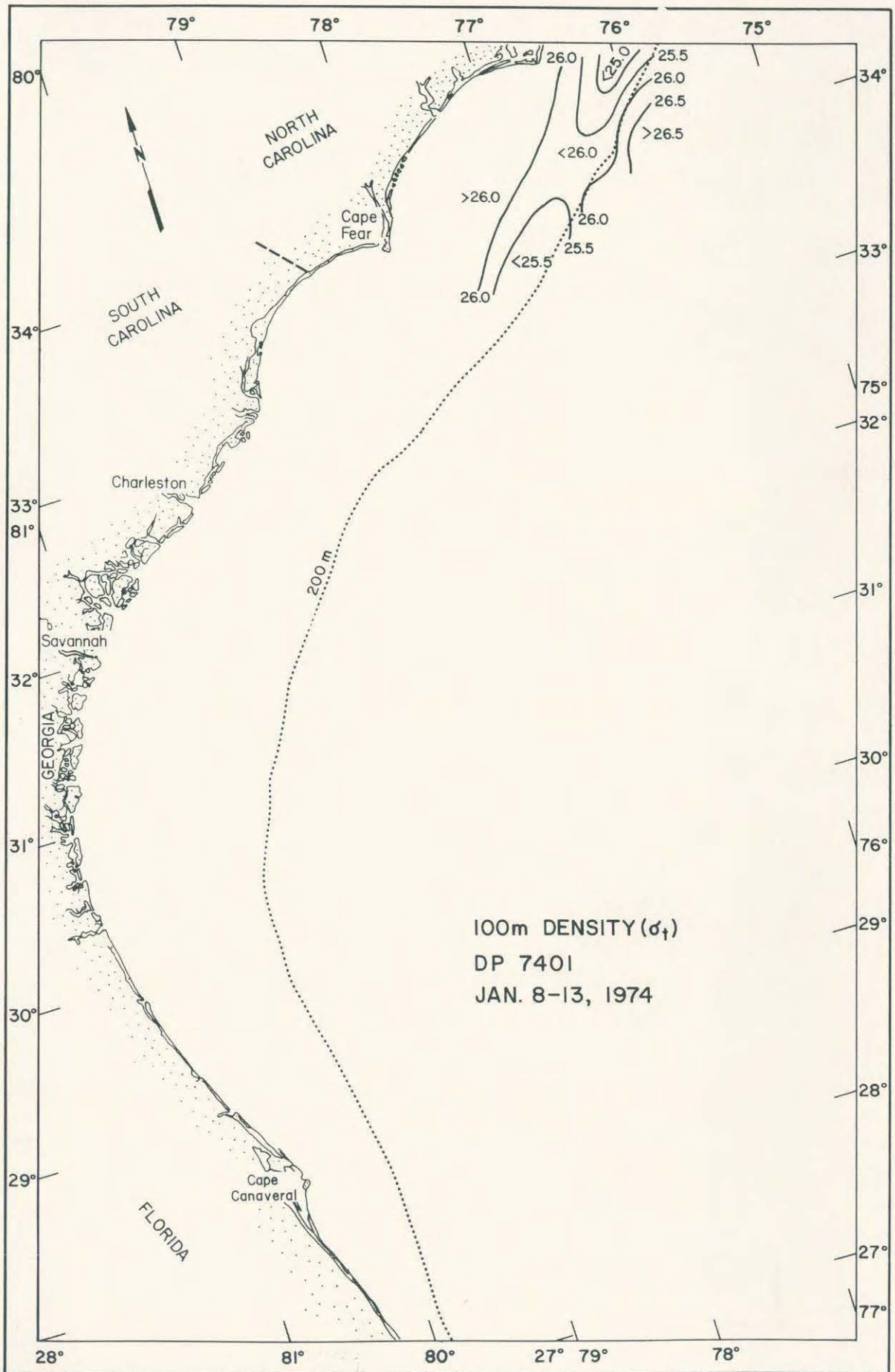


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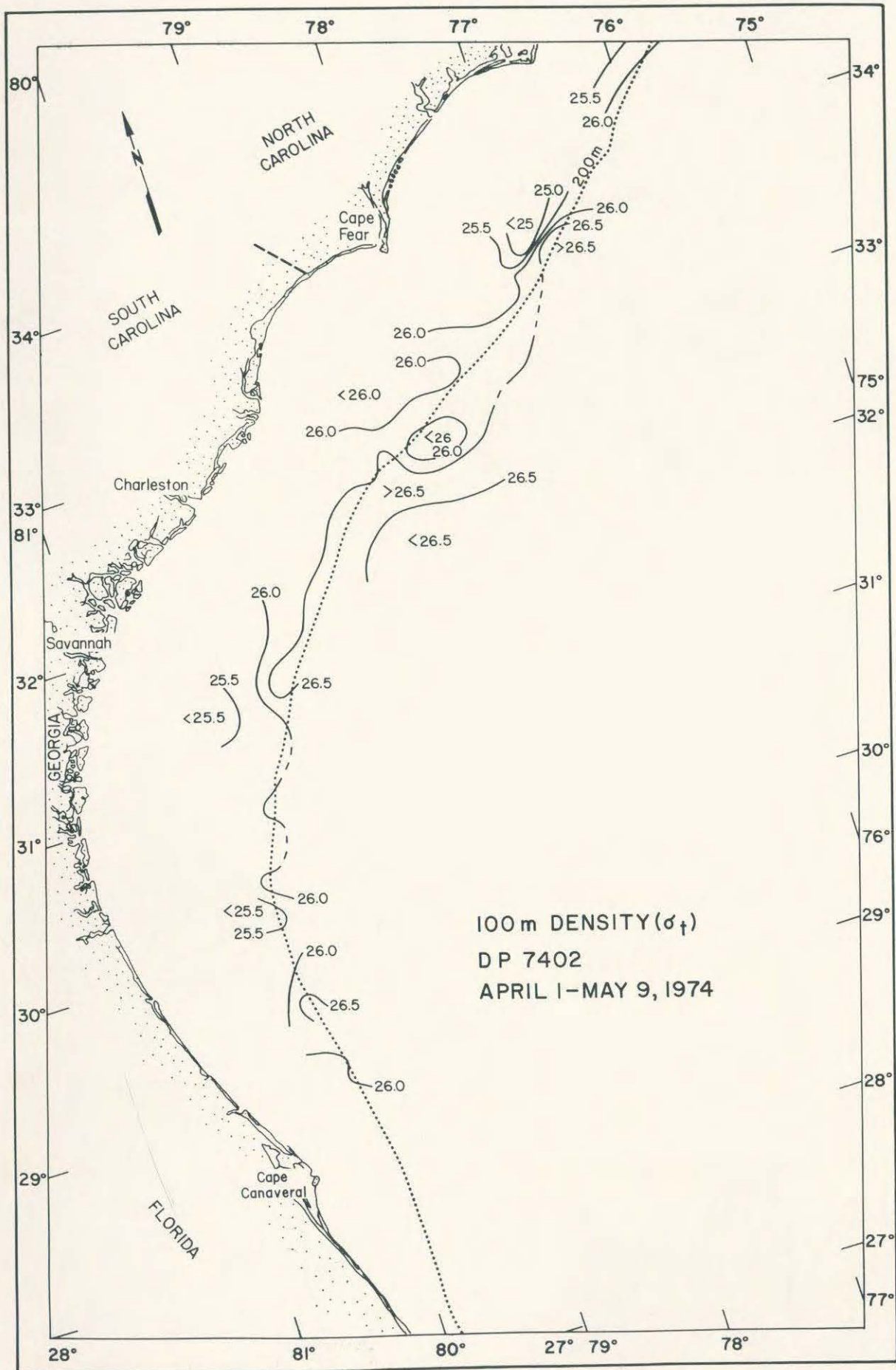


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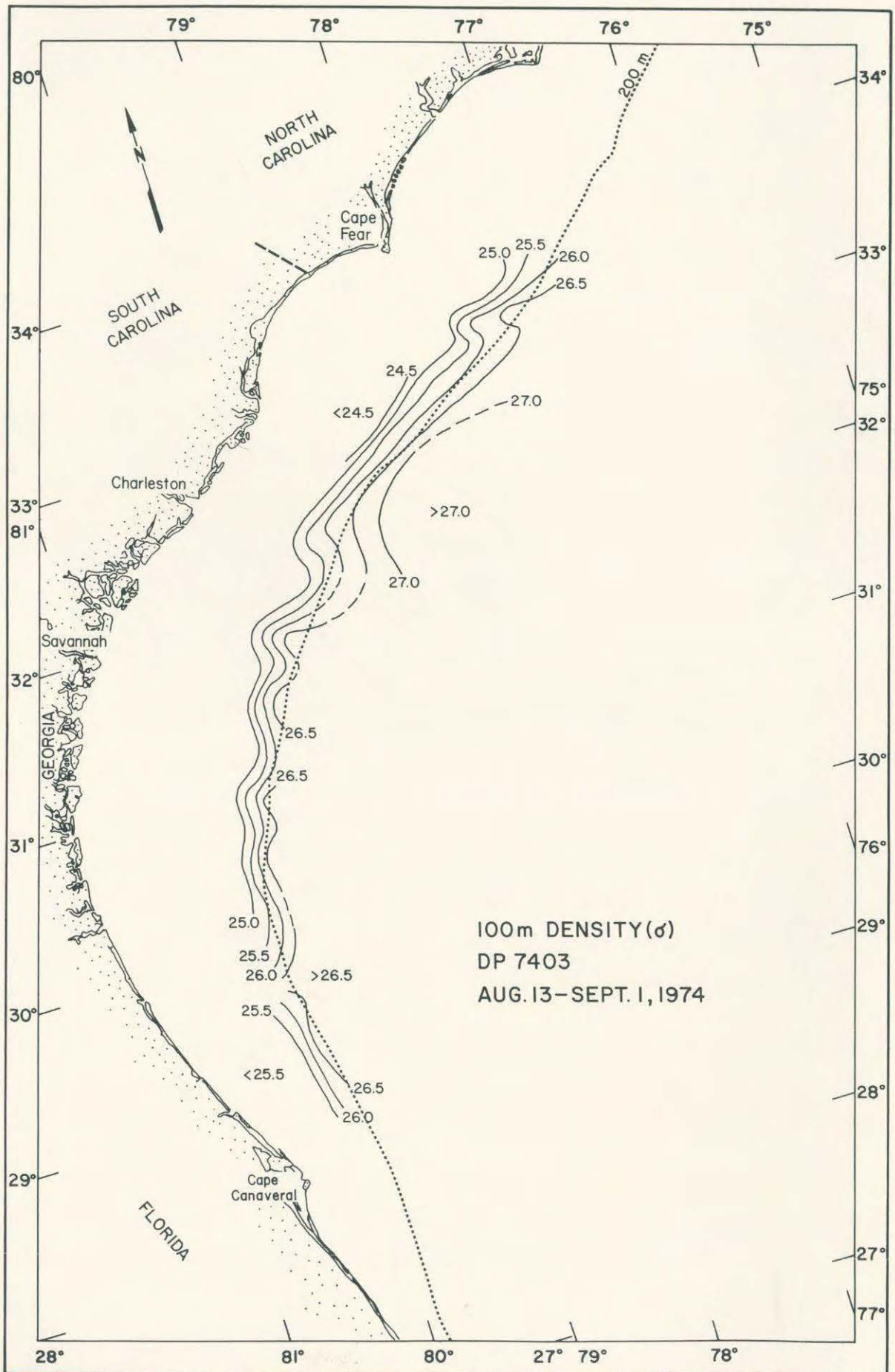


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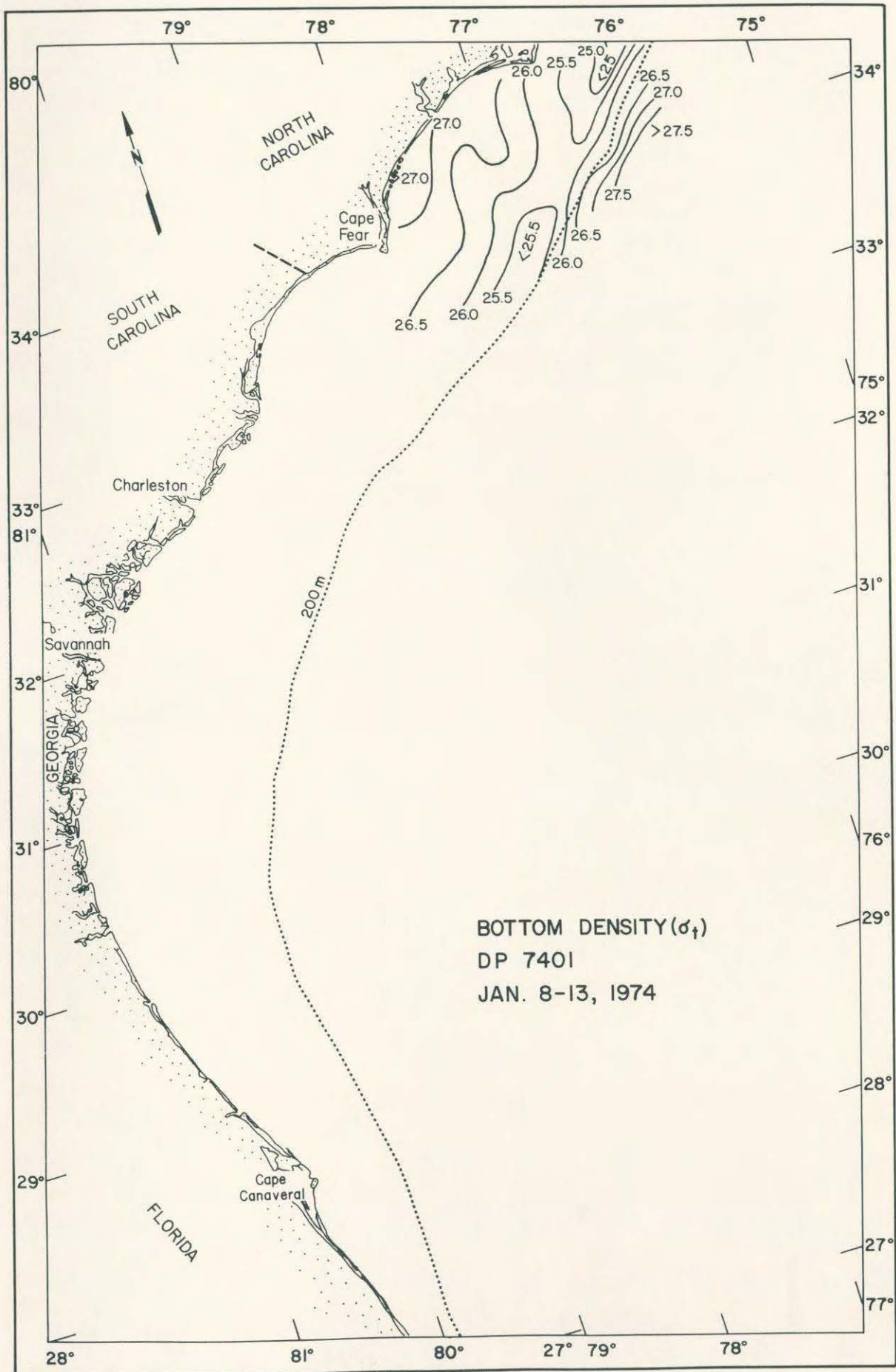


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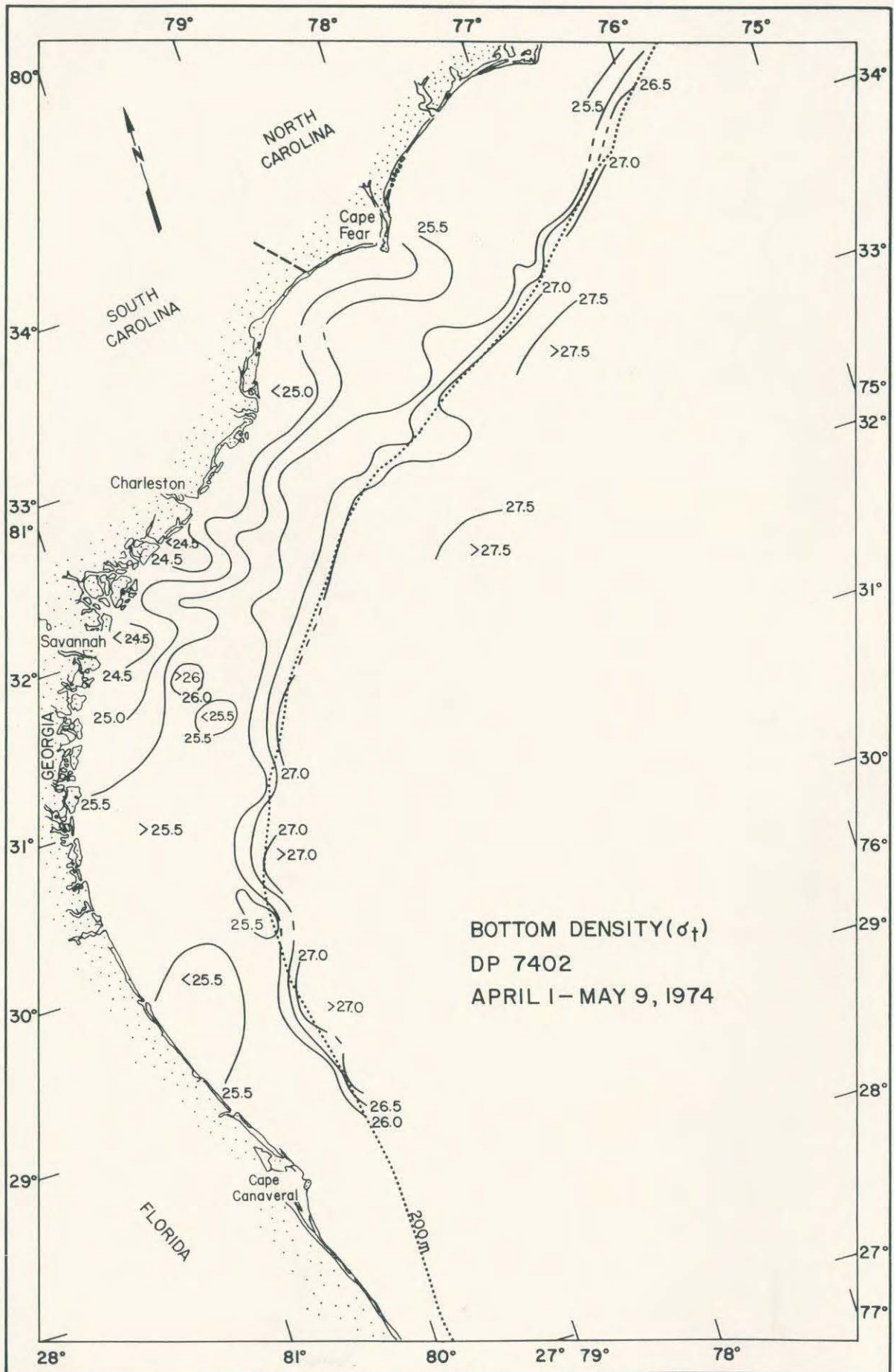


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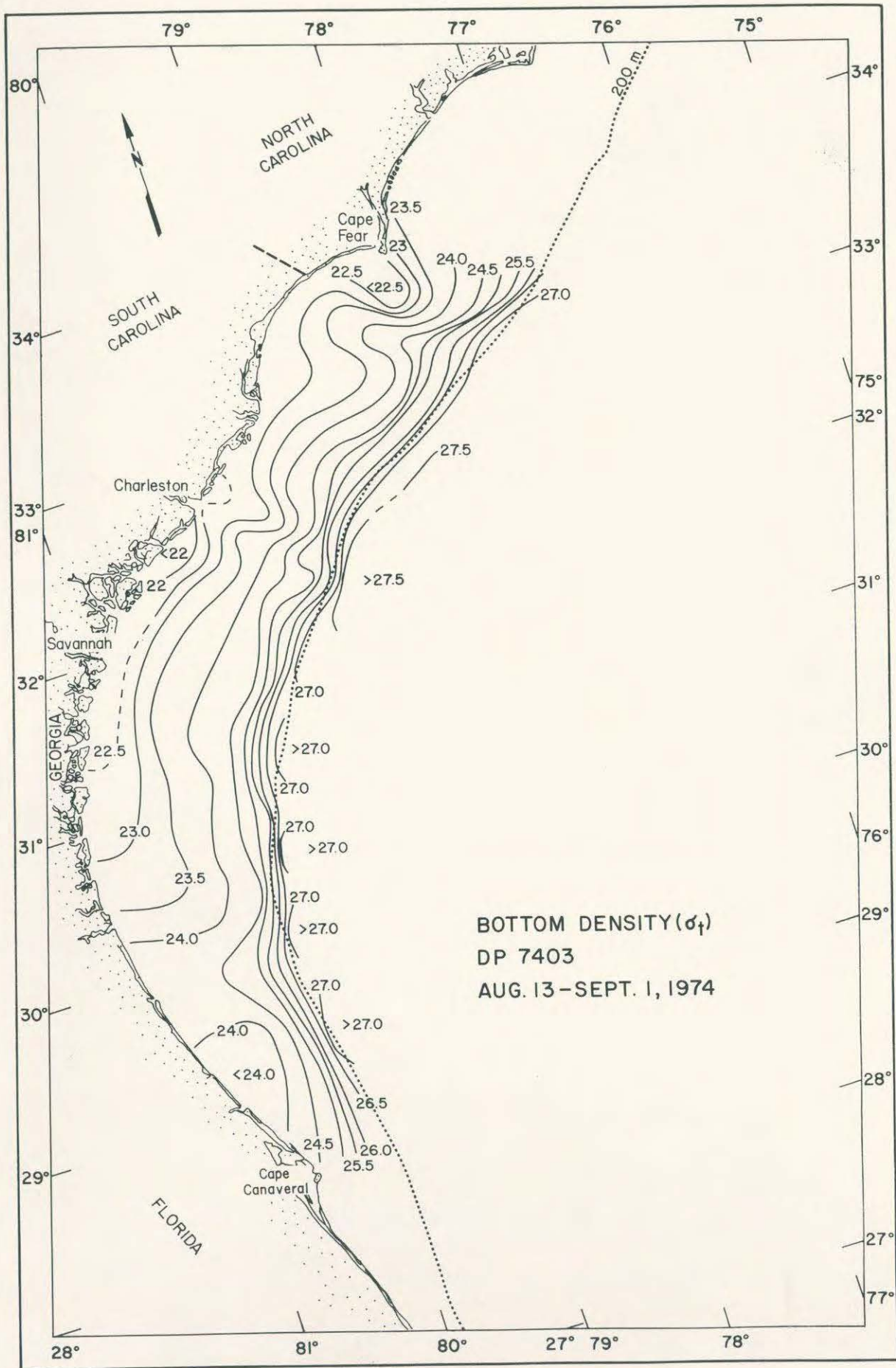


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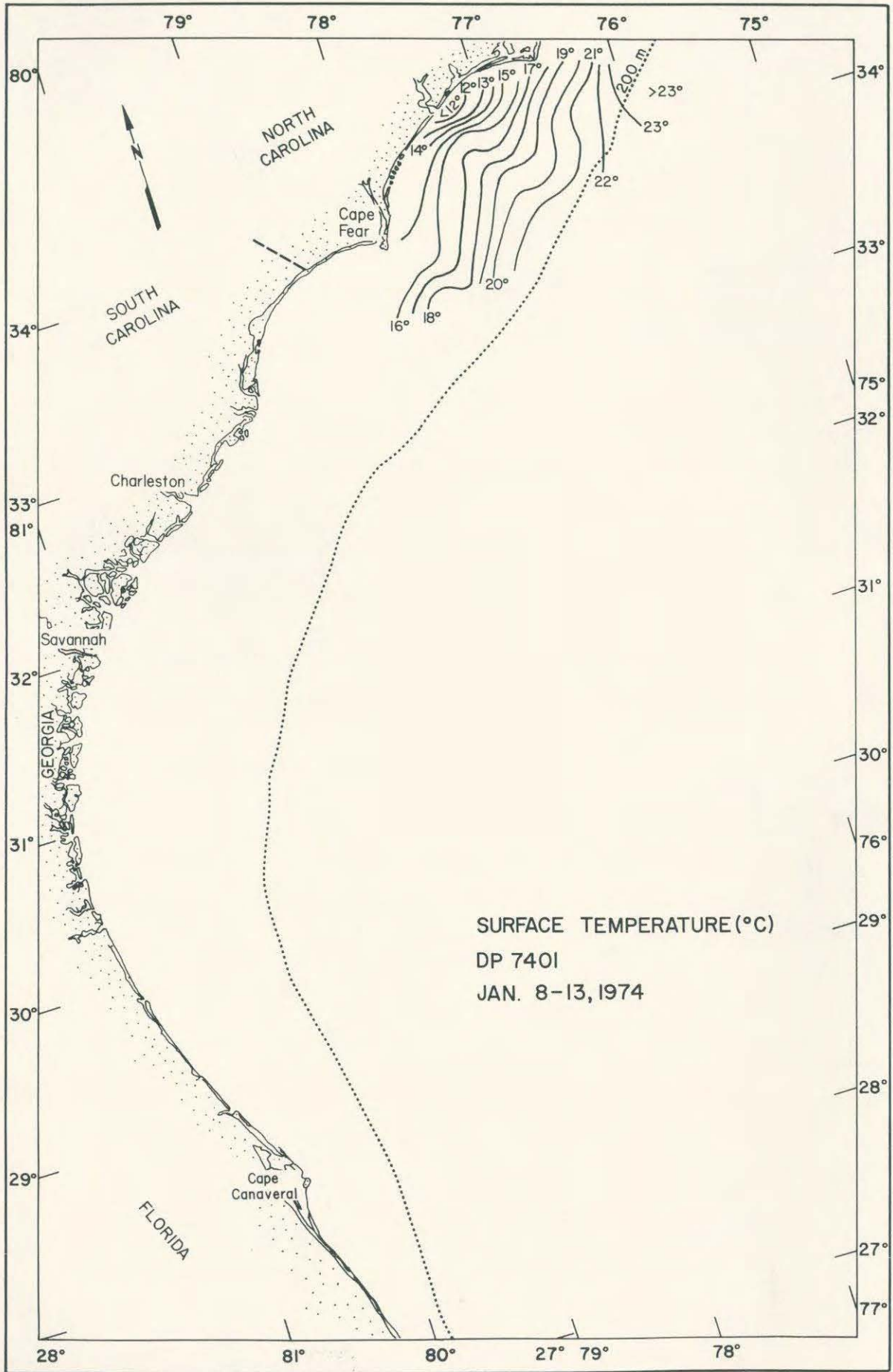


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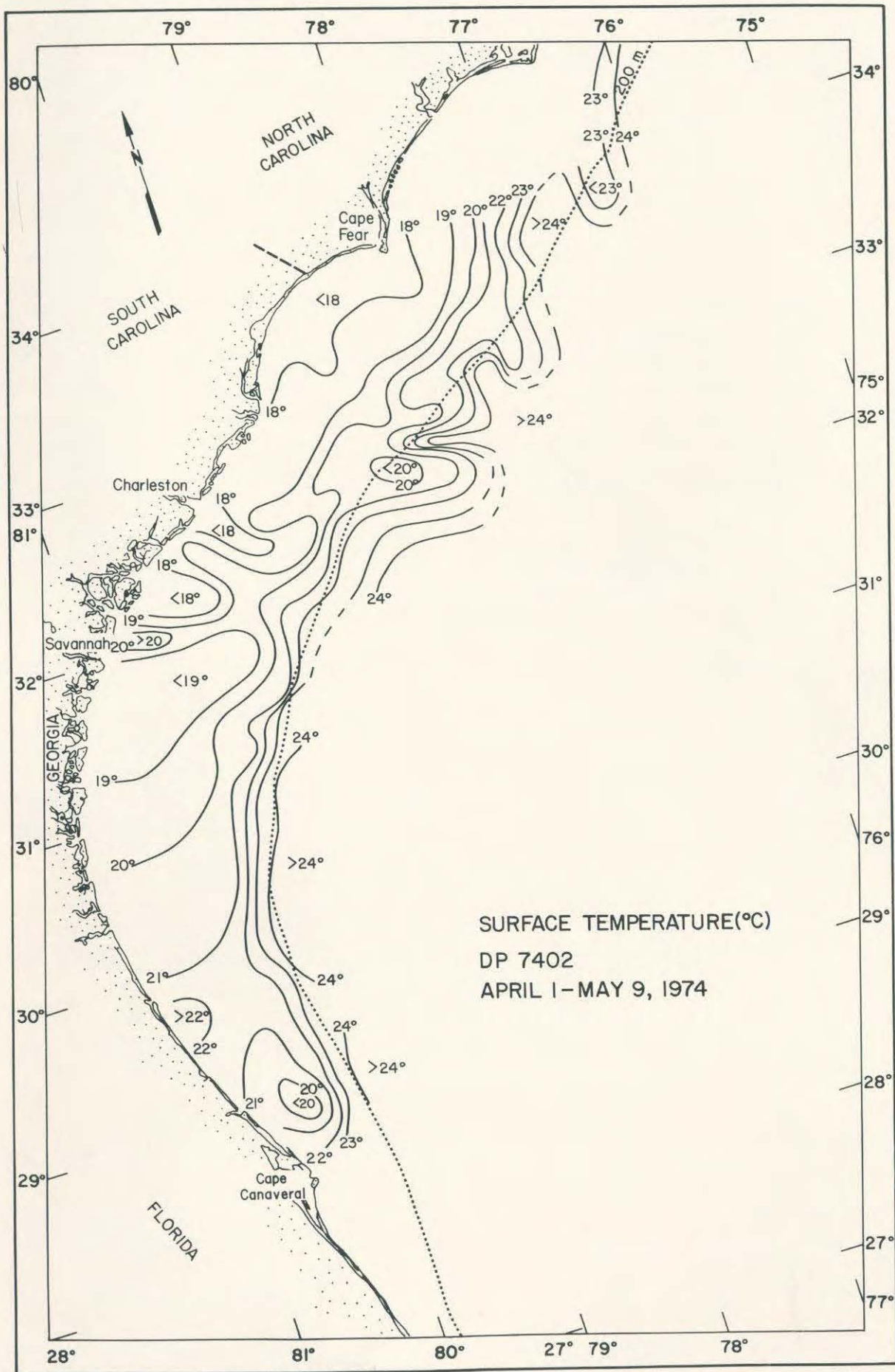


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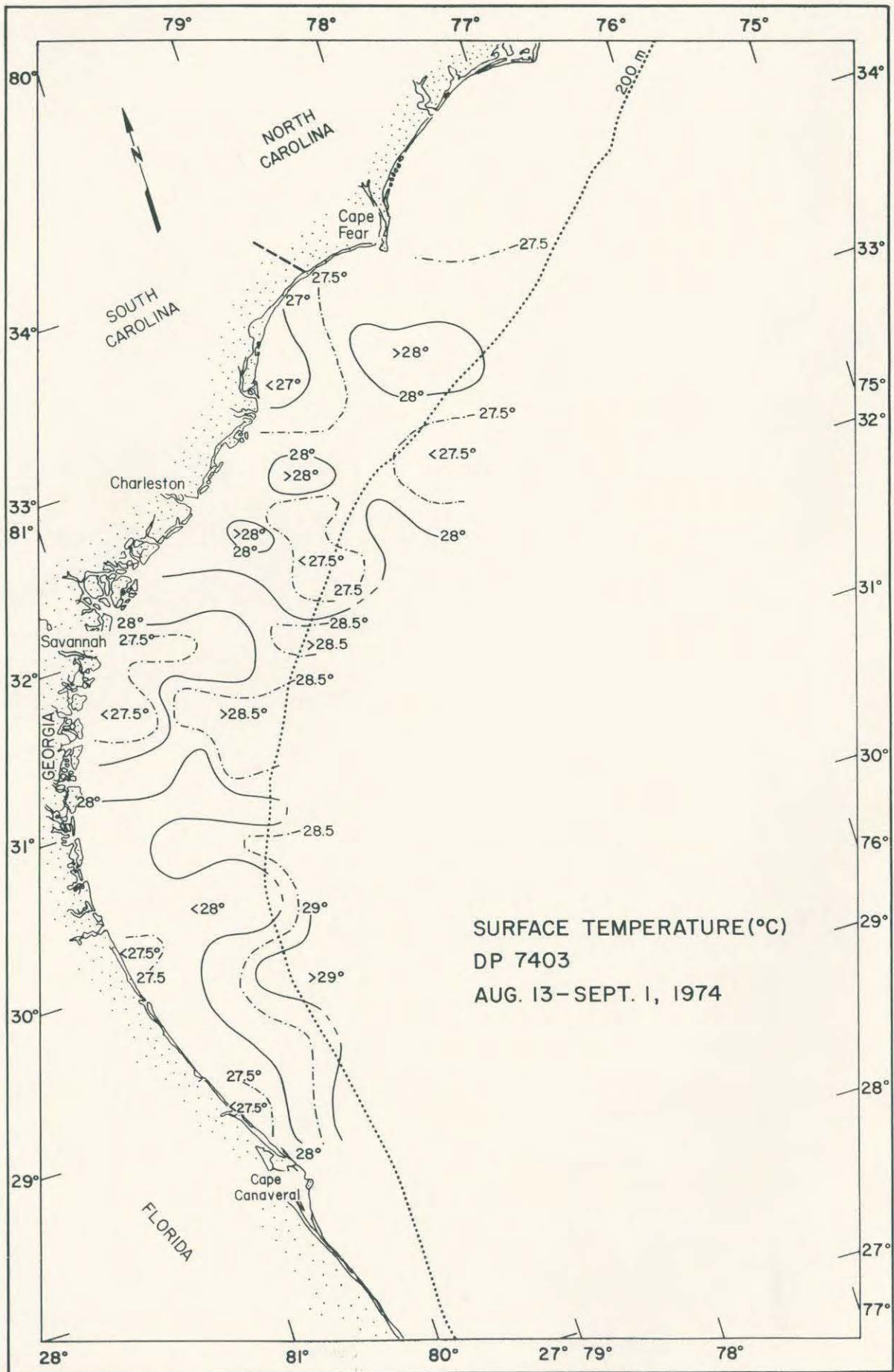


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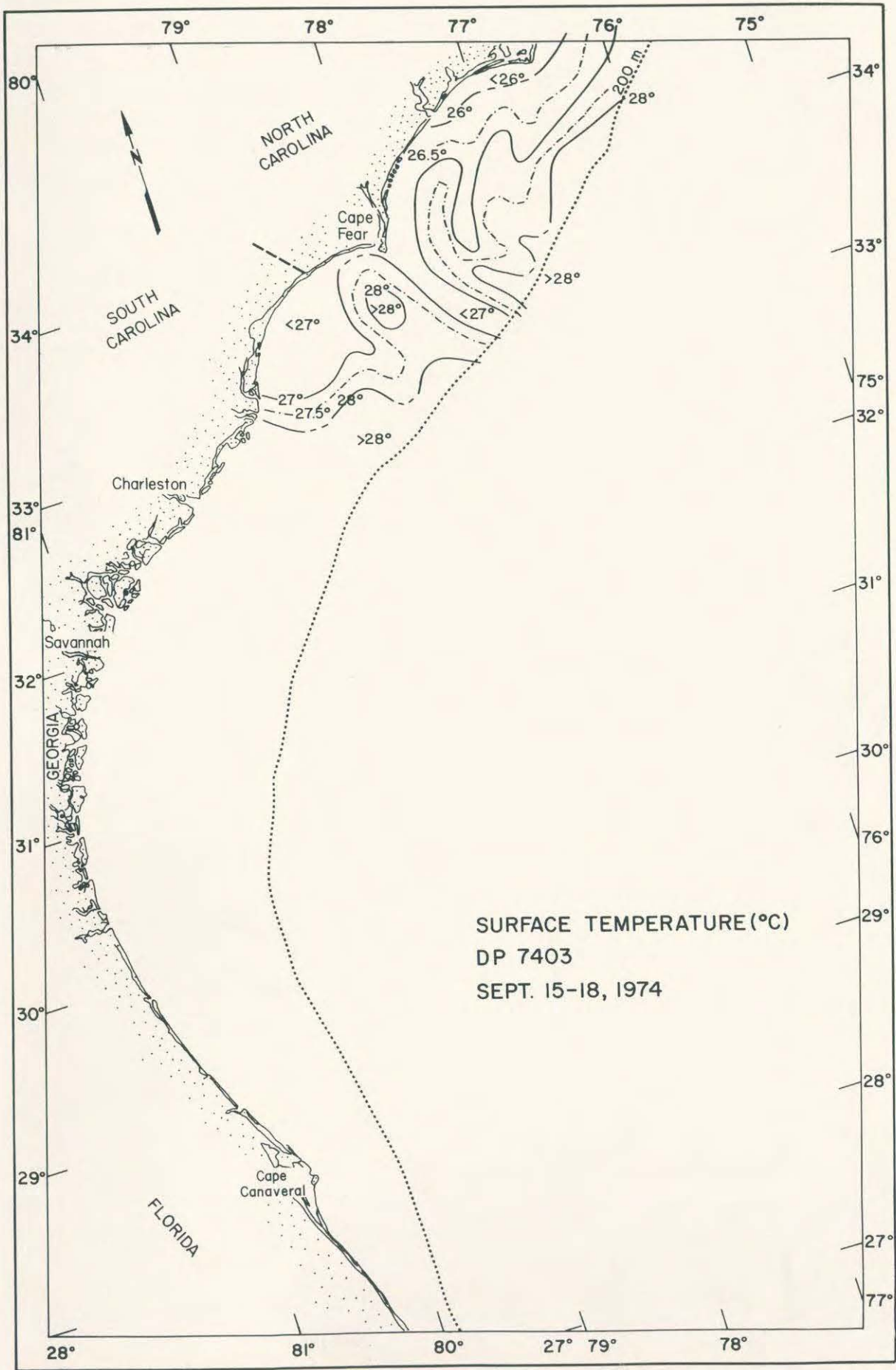


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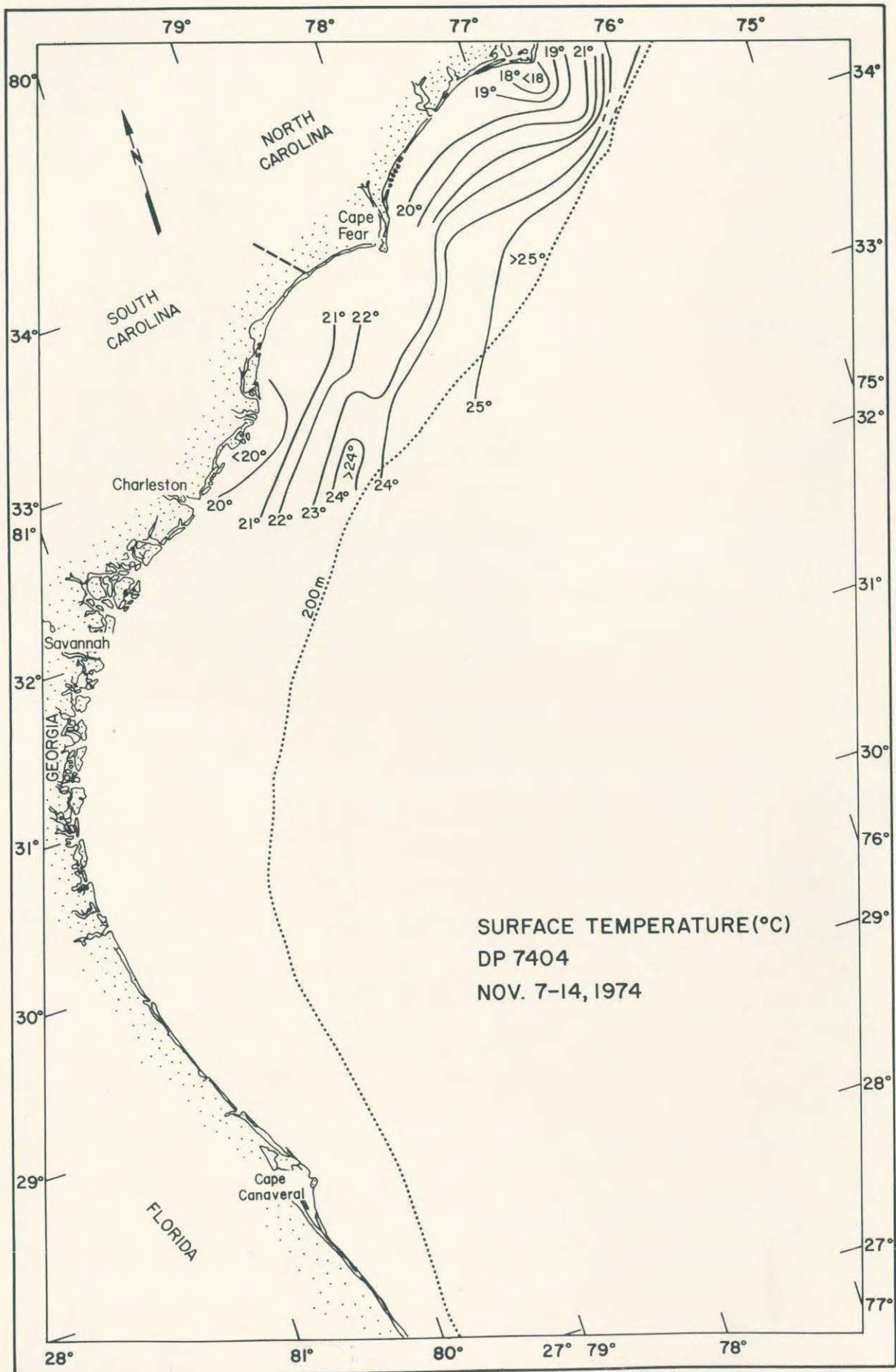


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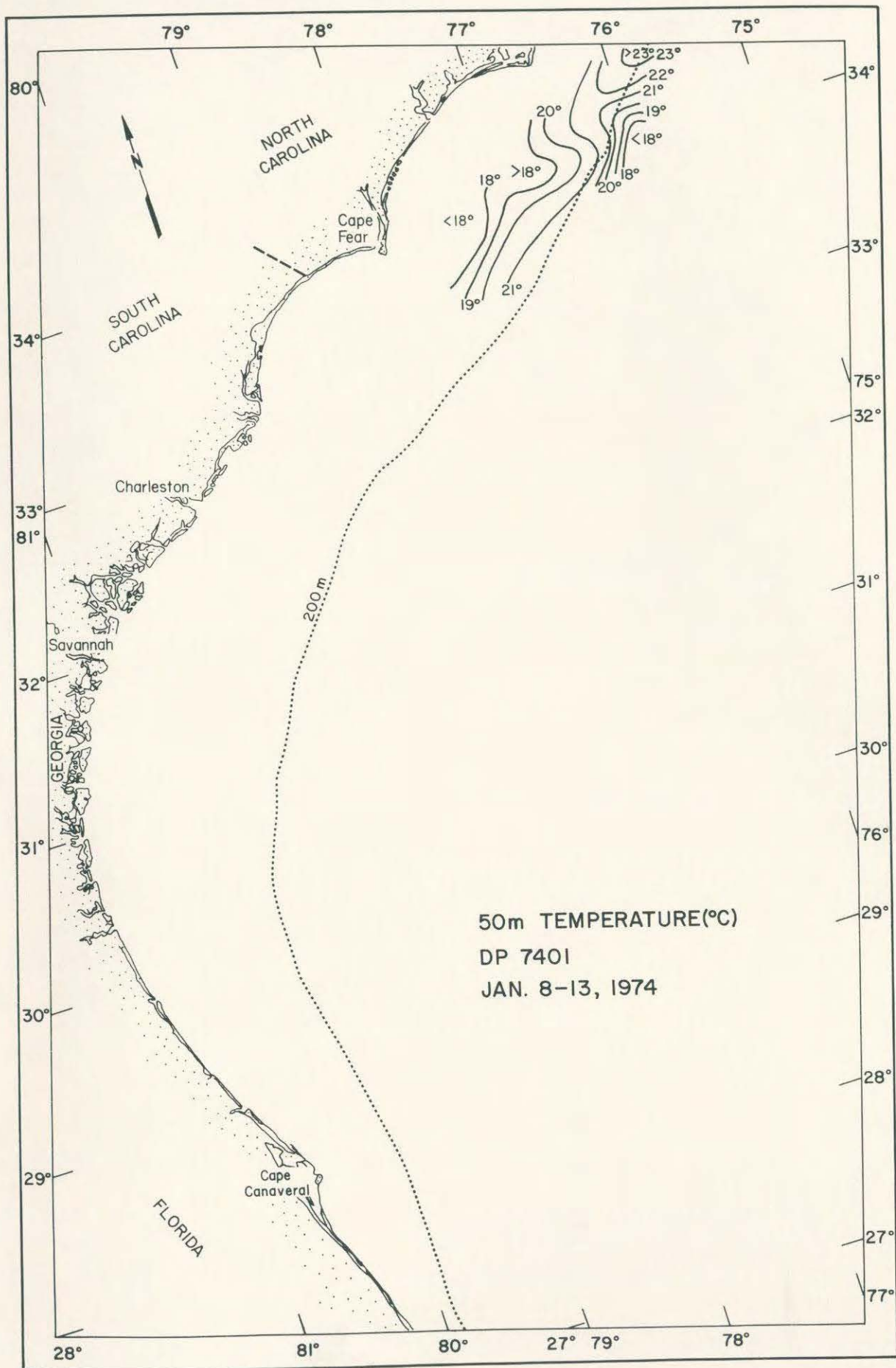


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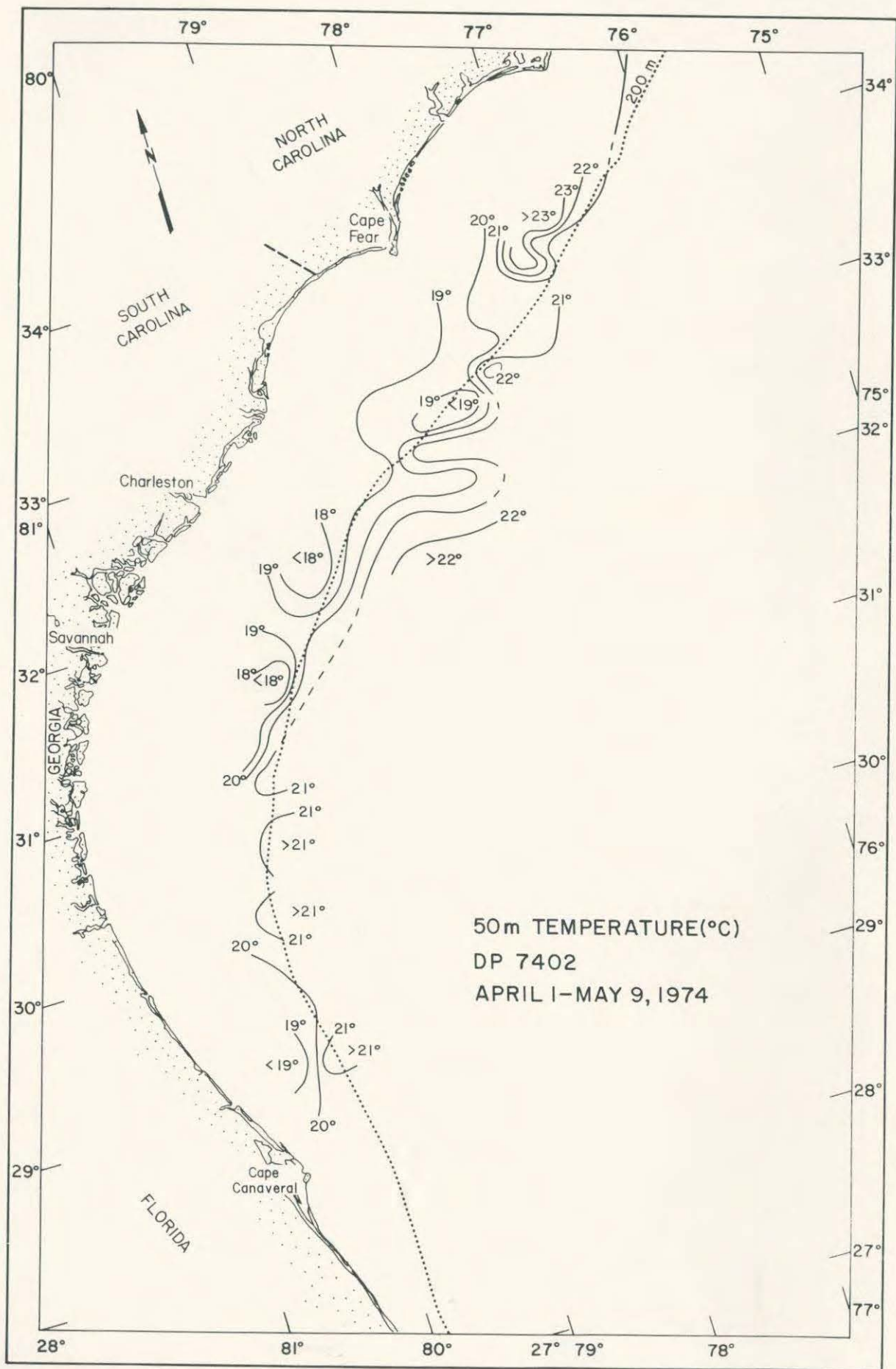


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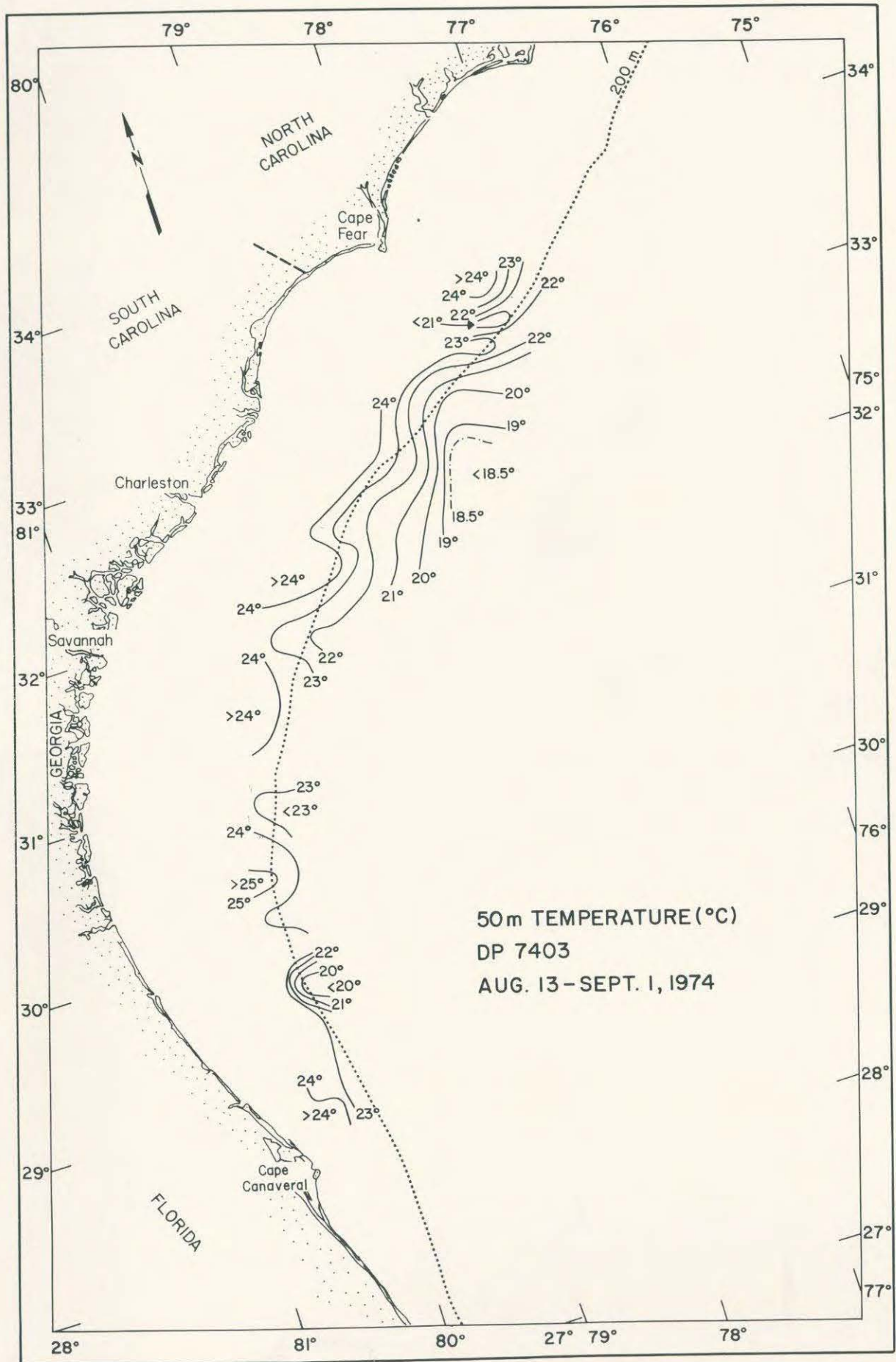


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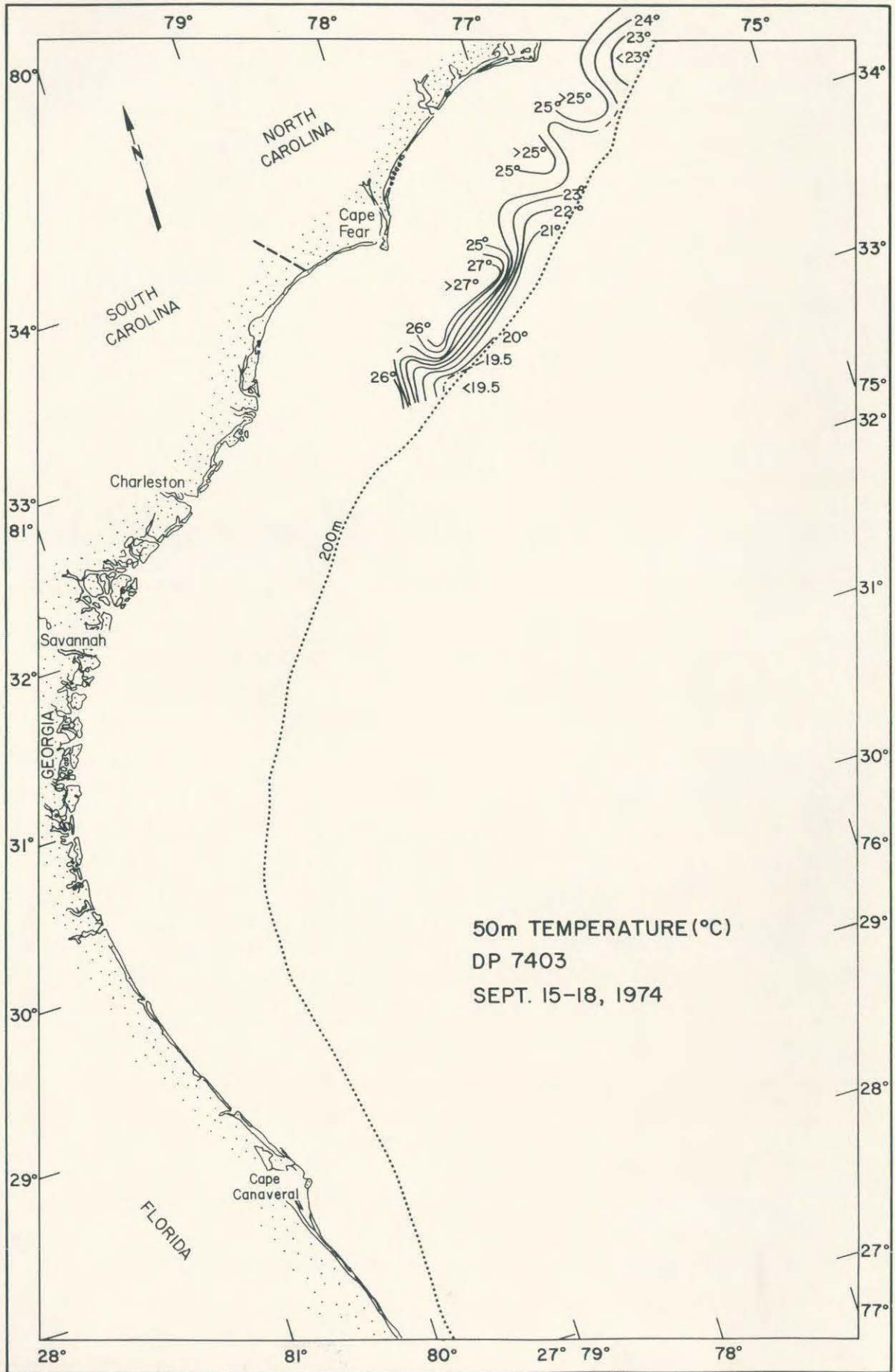


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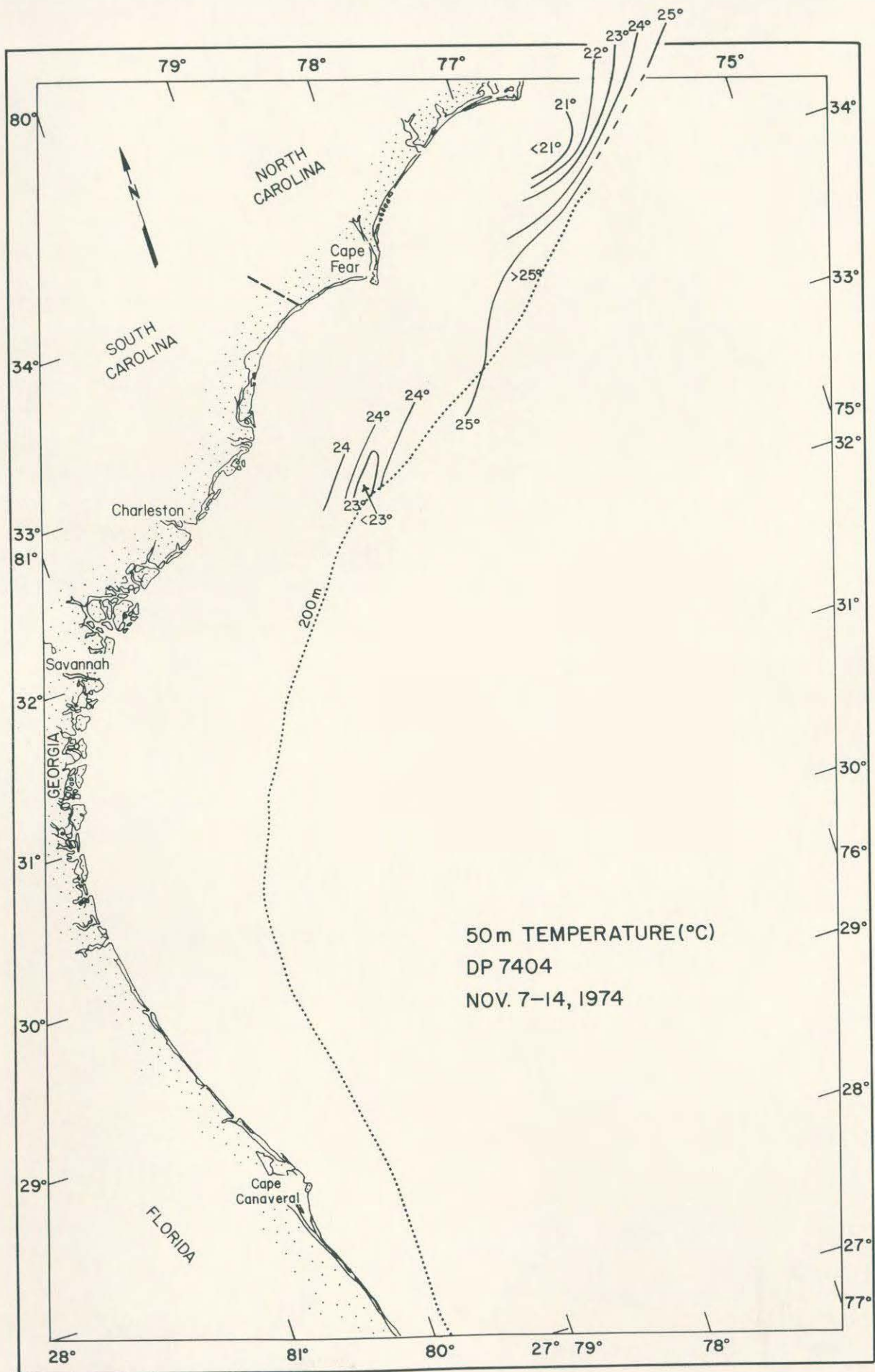


FIGURE 29.

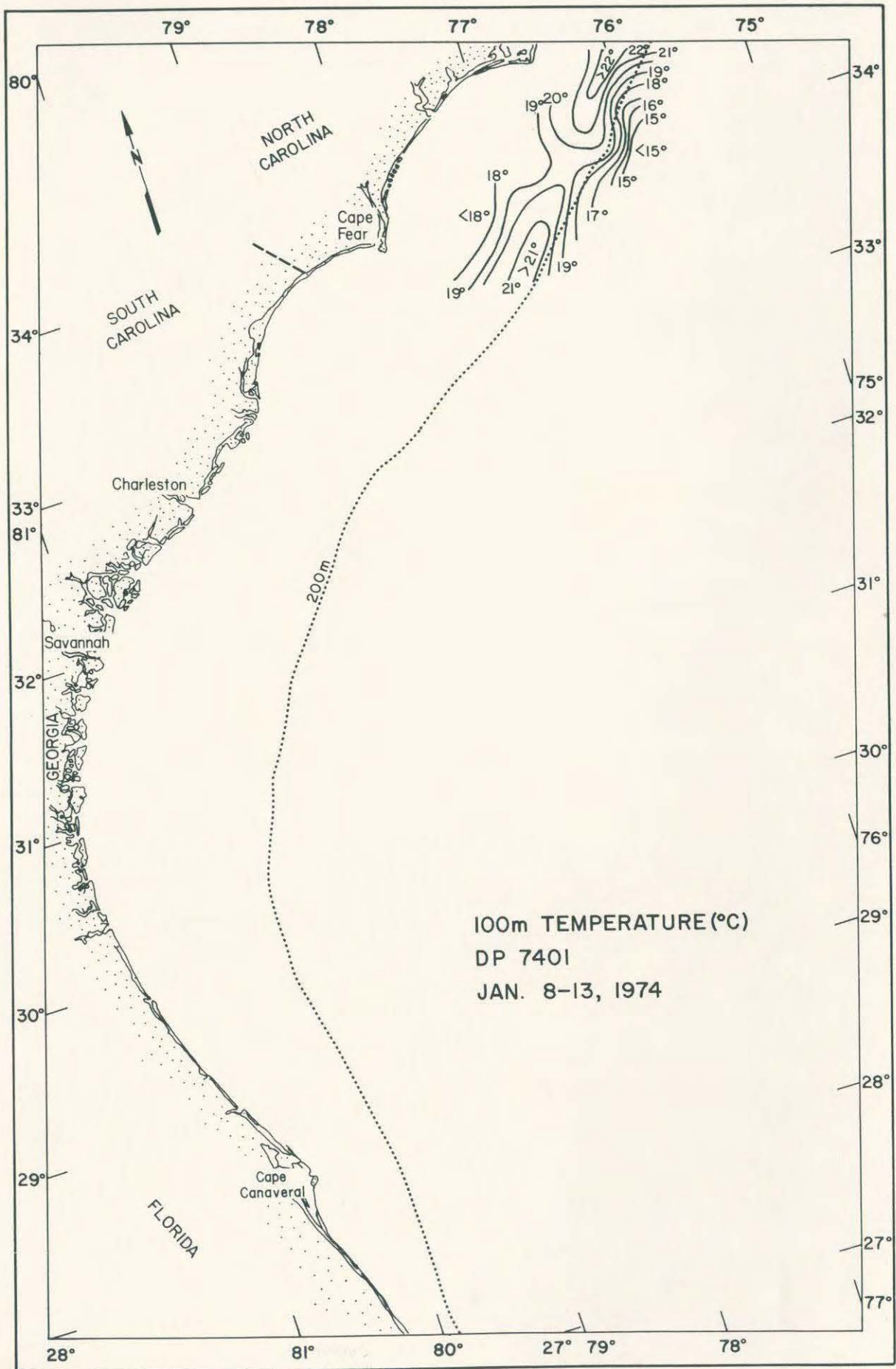


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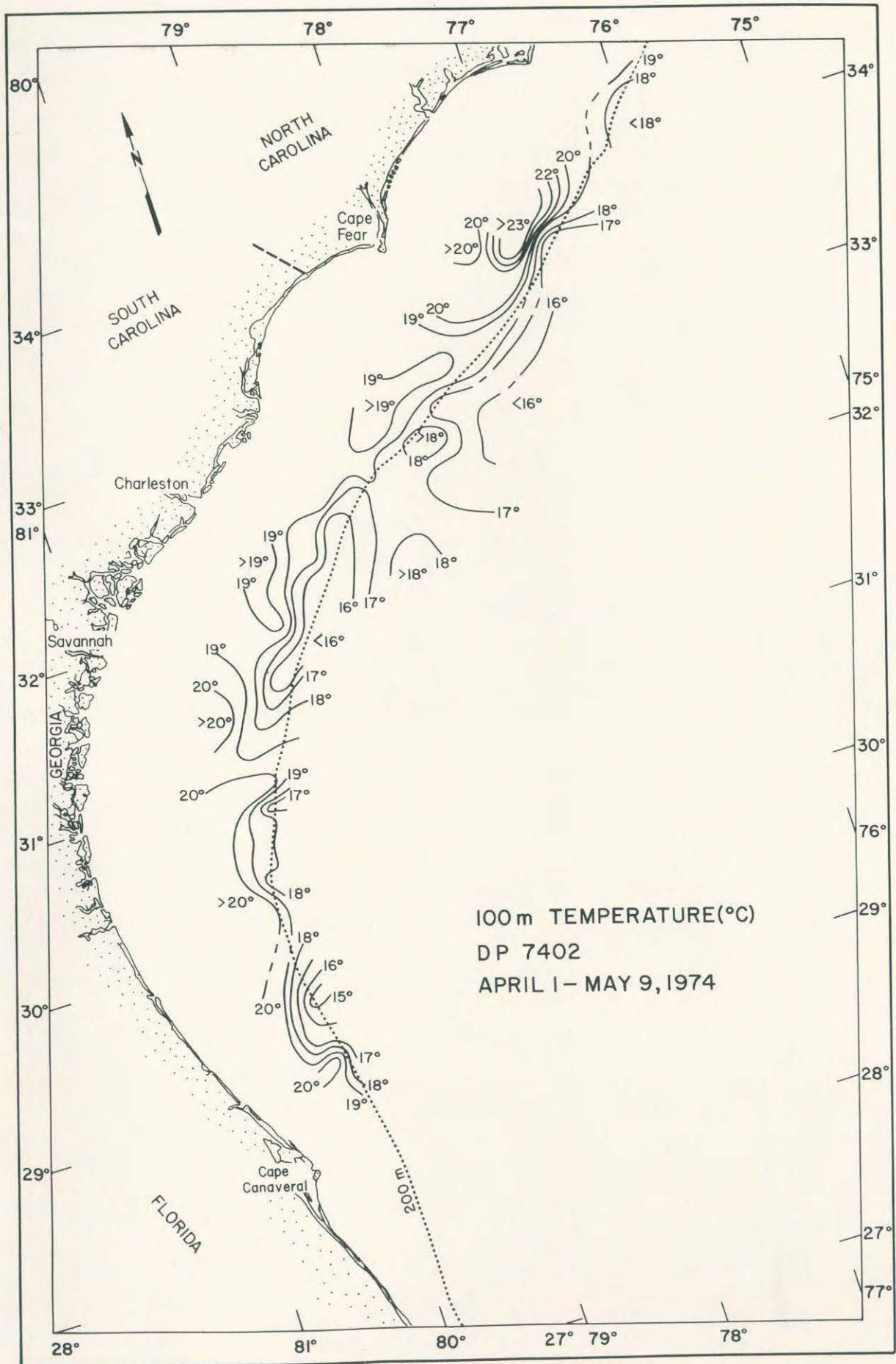


FIGURE 31.

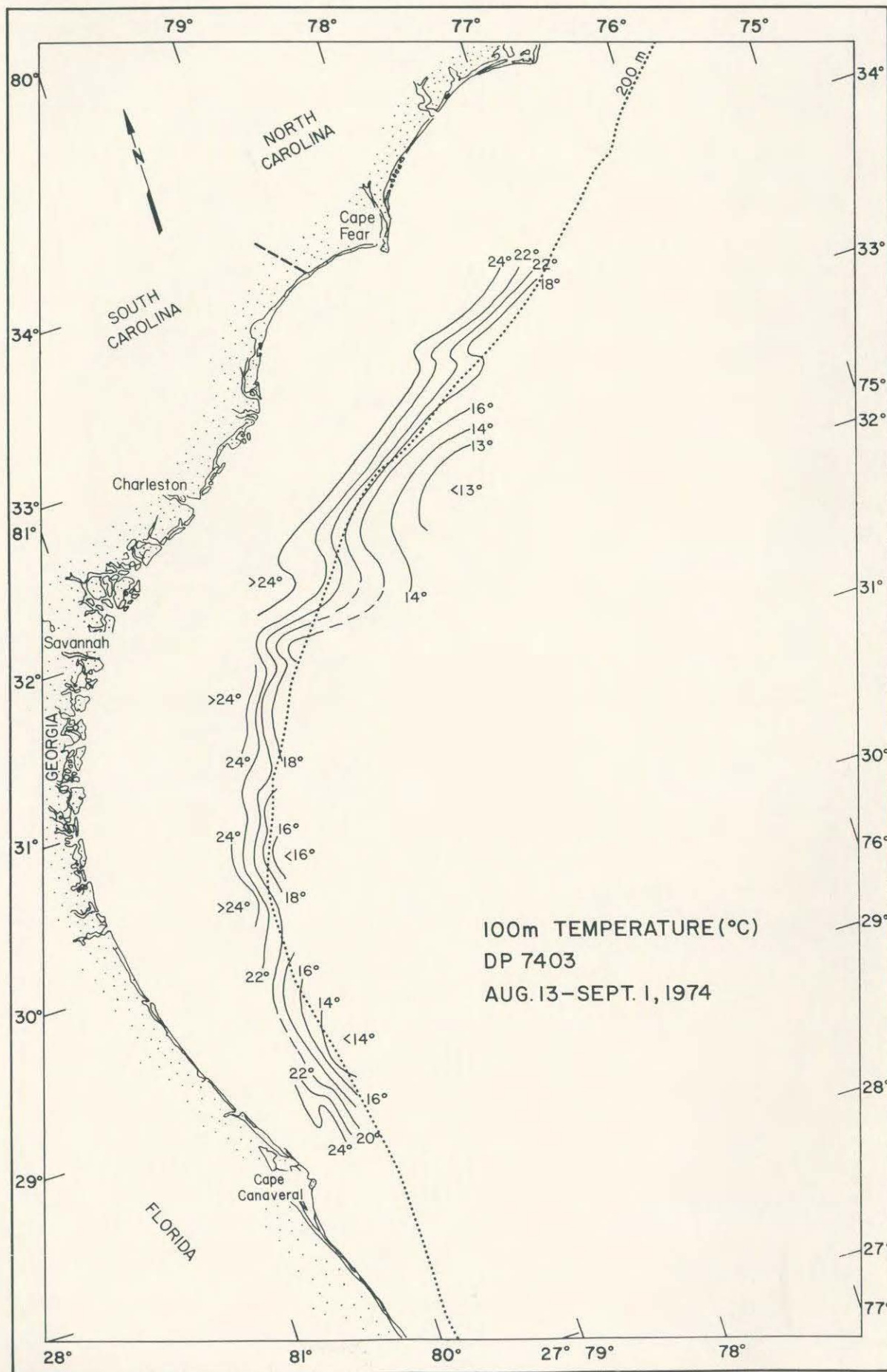


FIGURE 32.

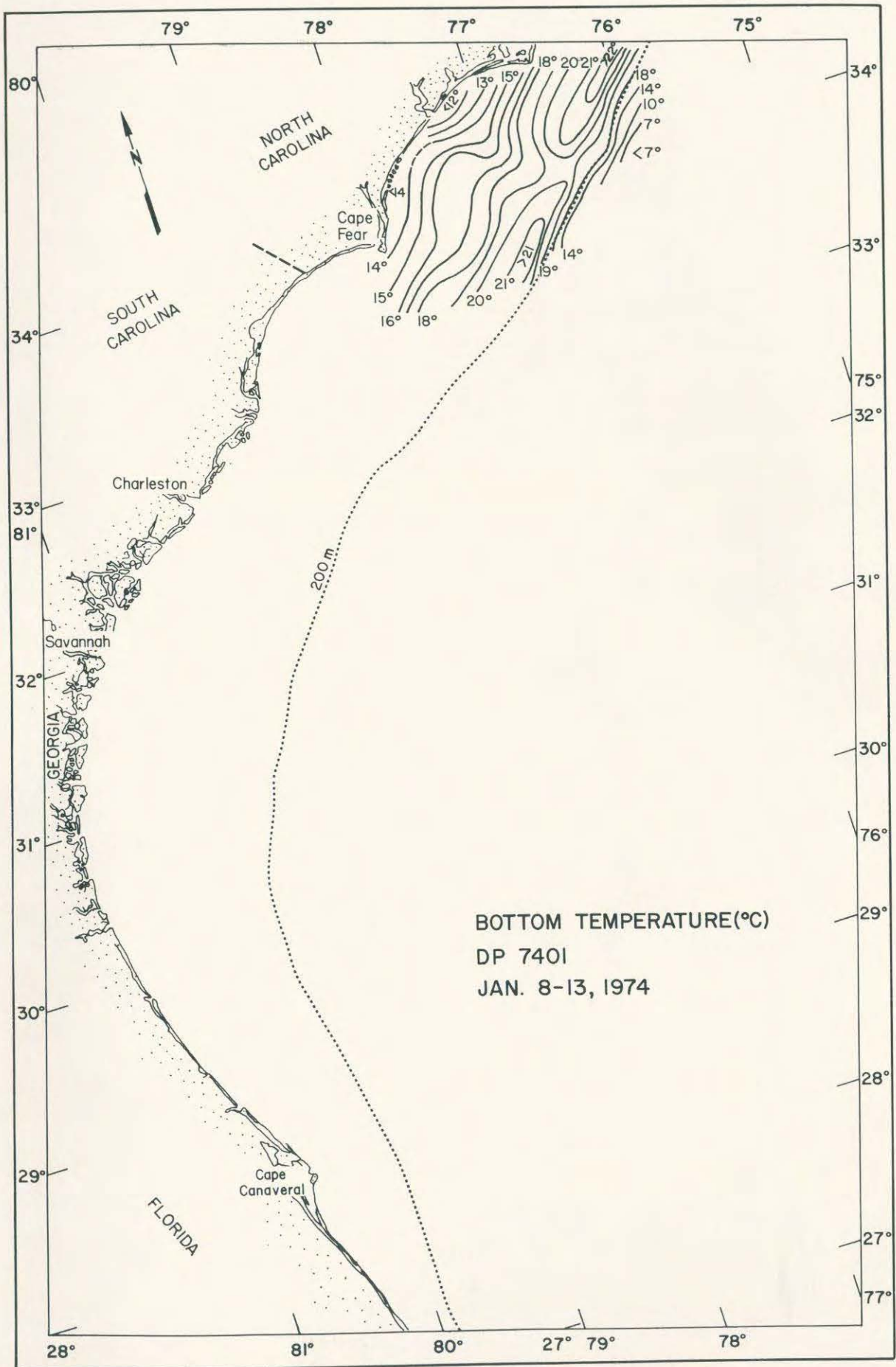


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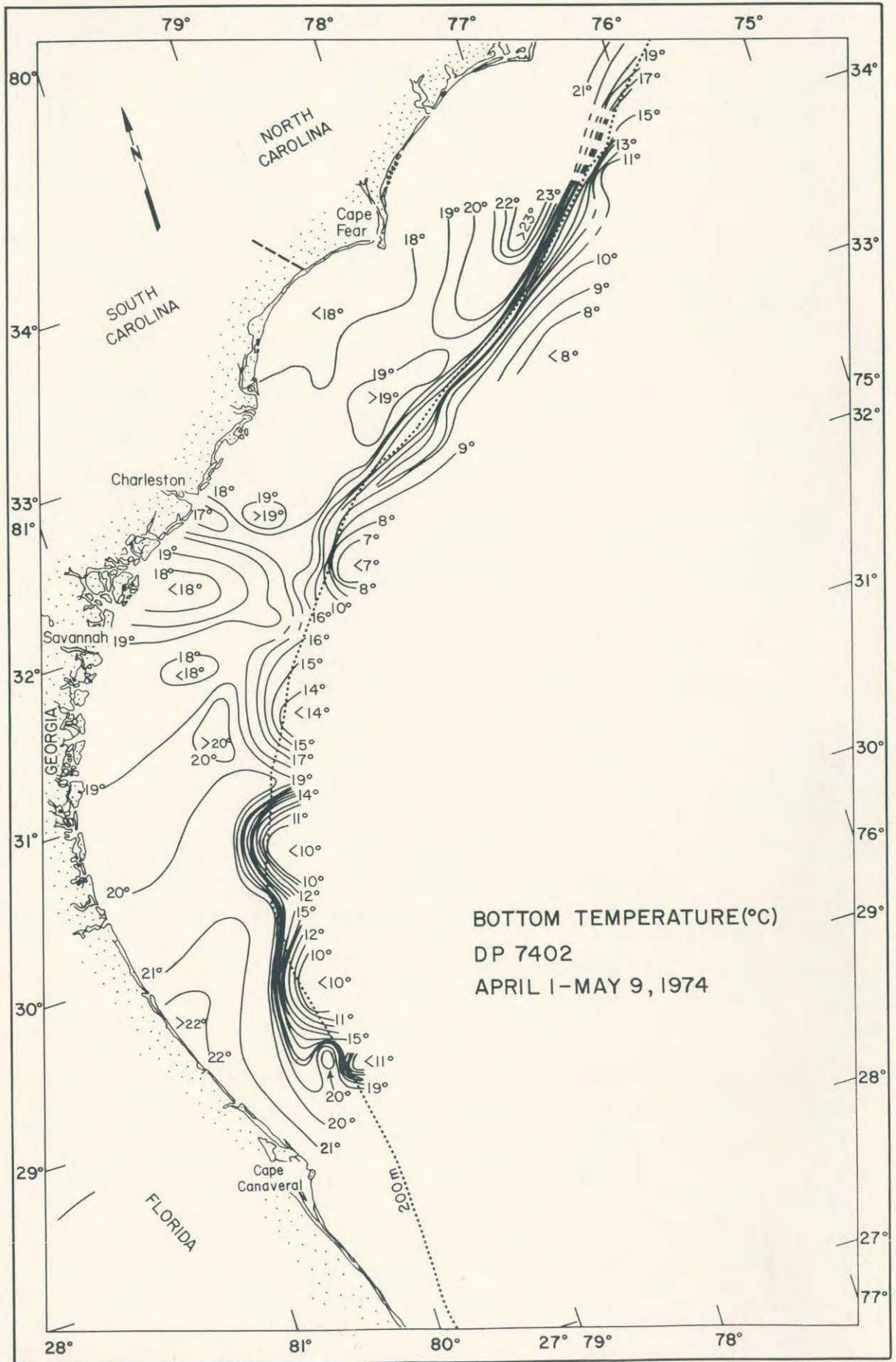


FIGURE 34.

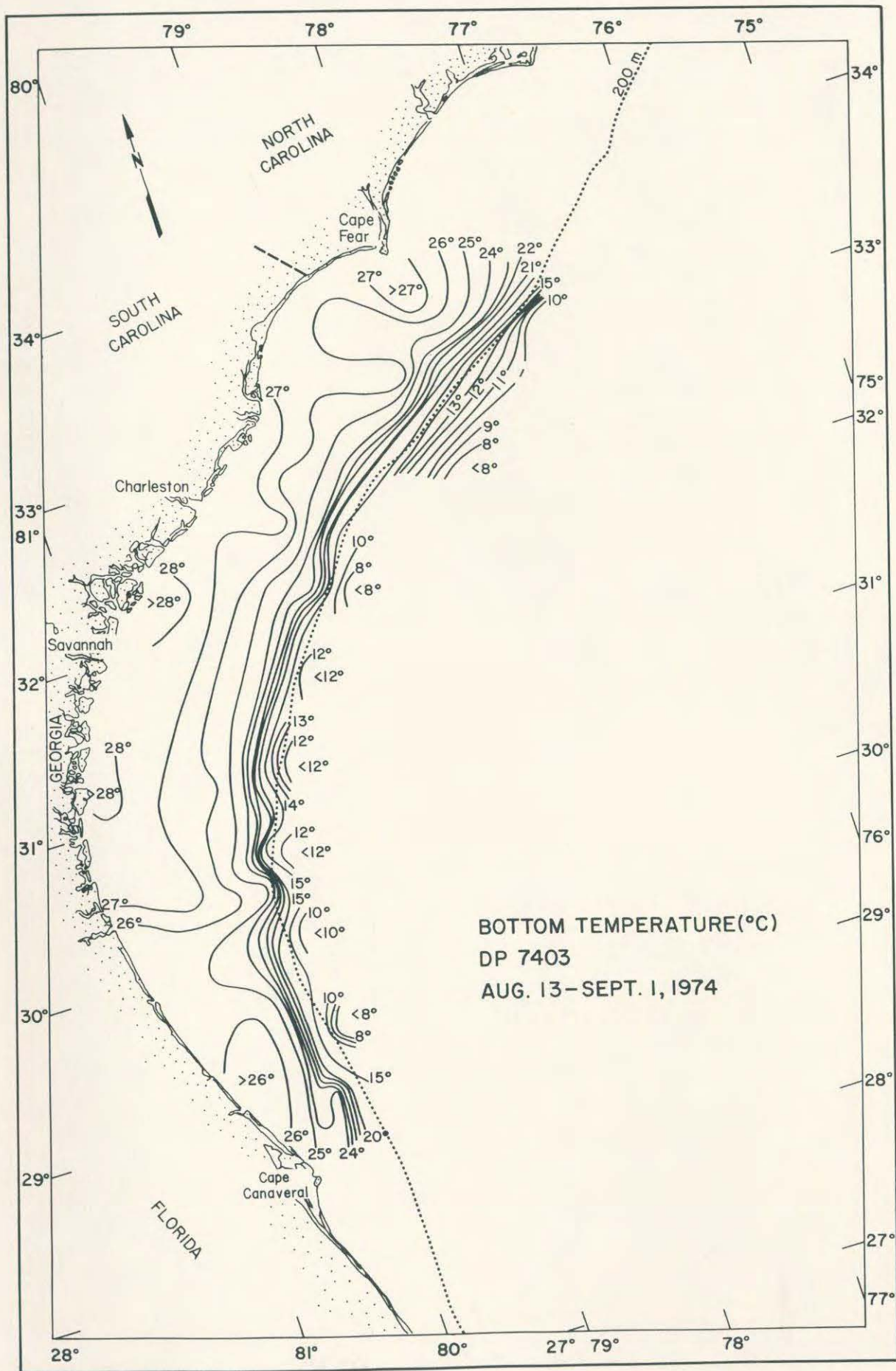


FIGURE 35.

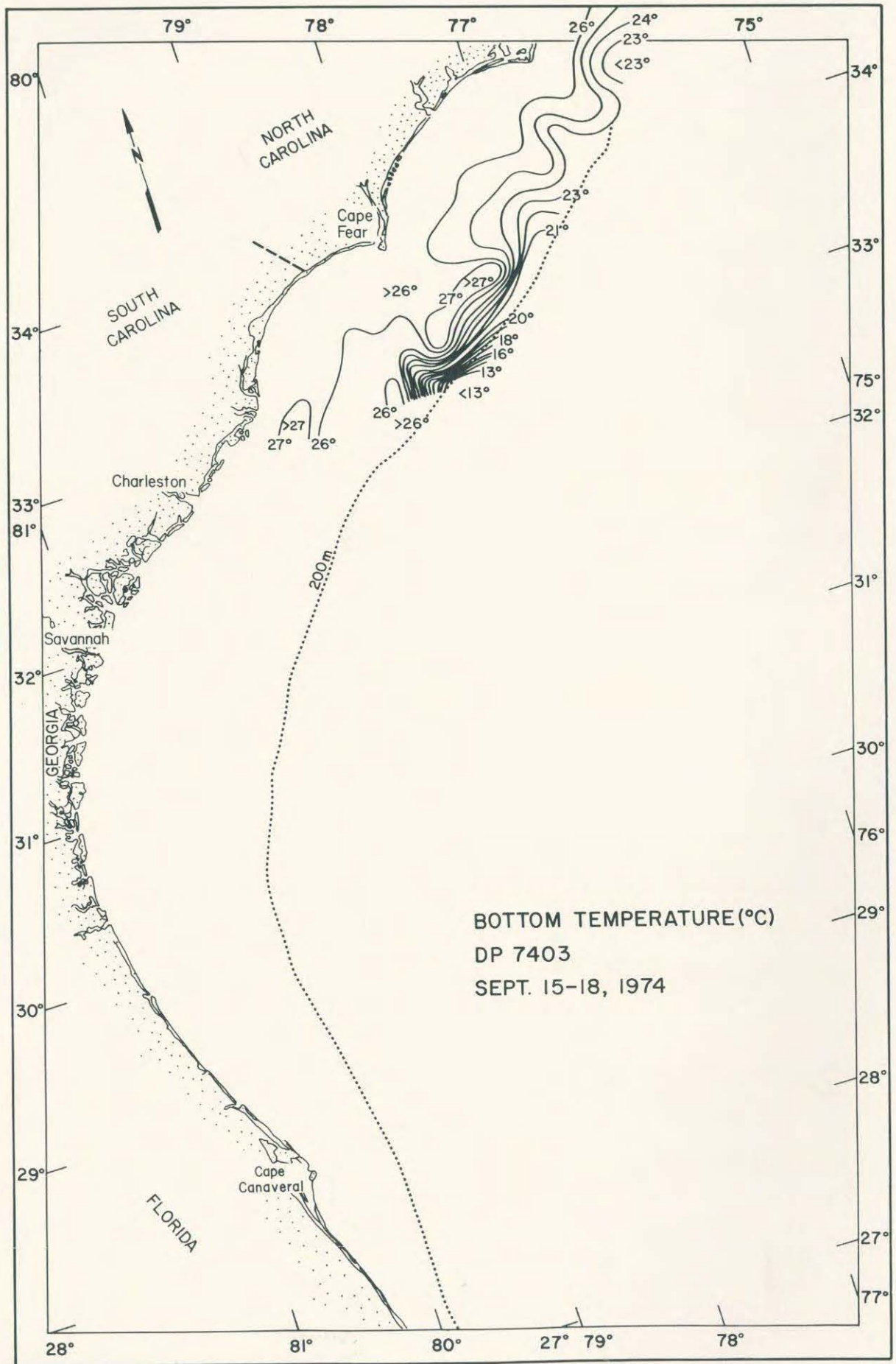


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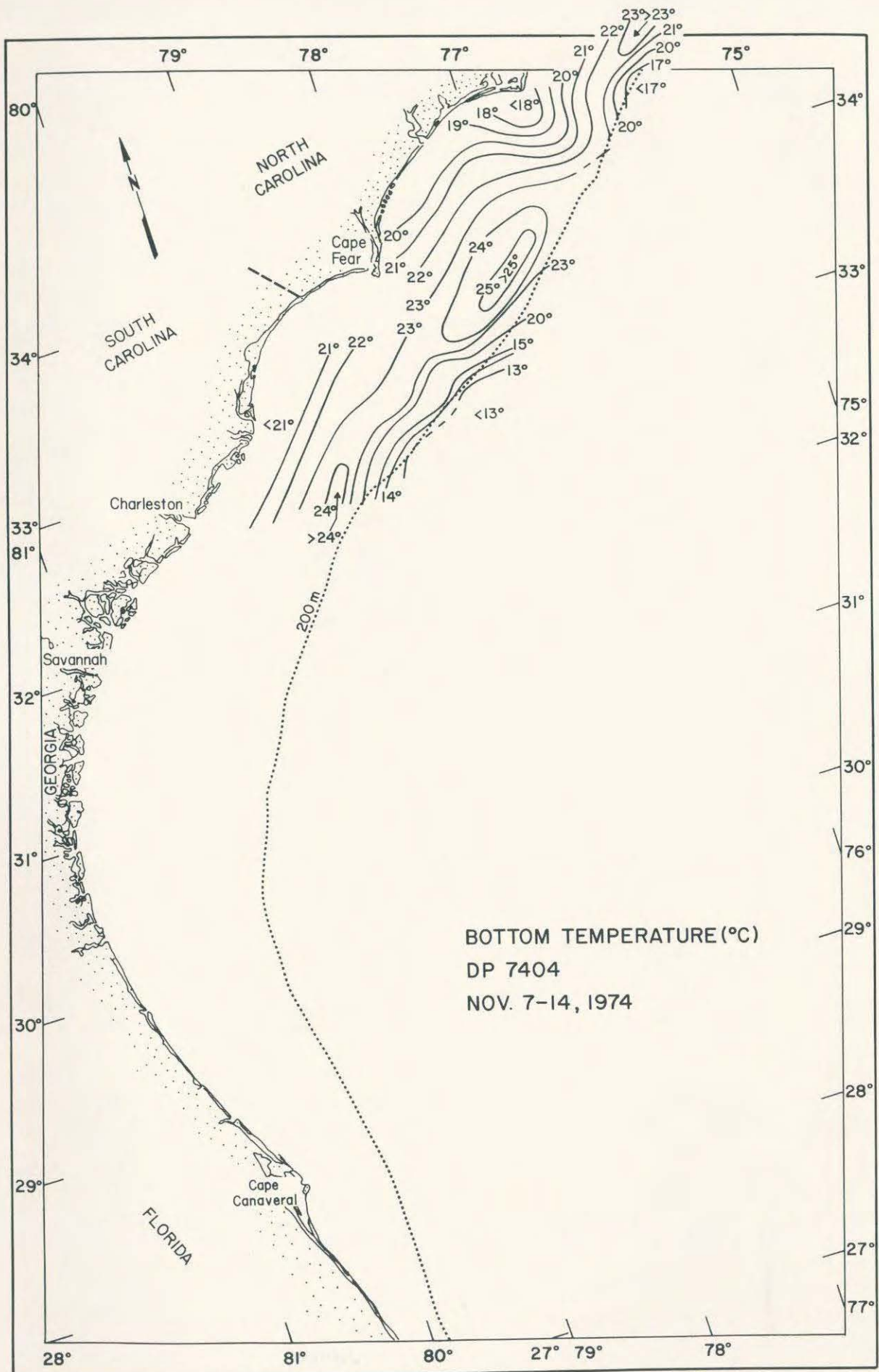


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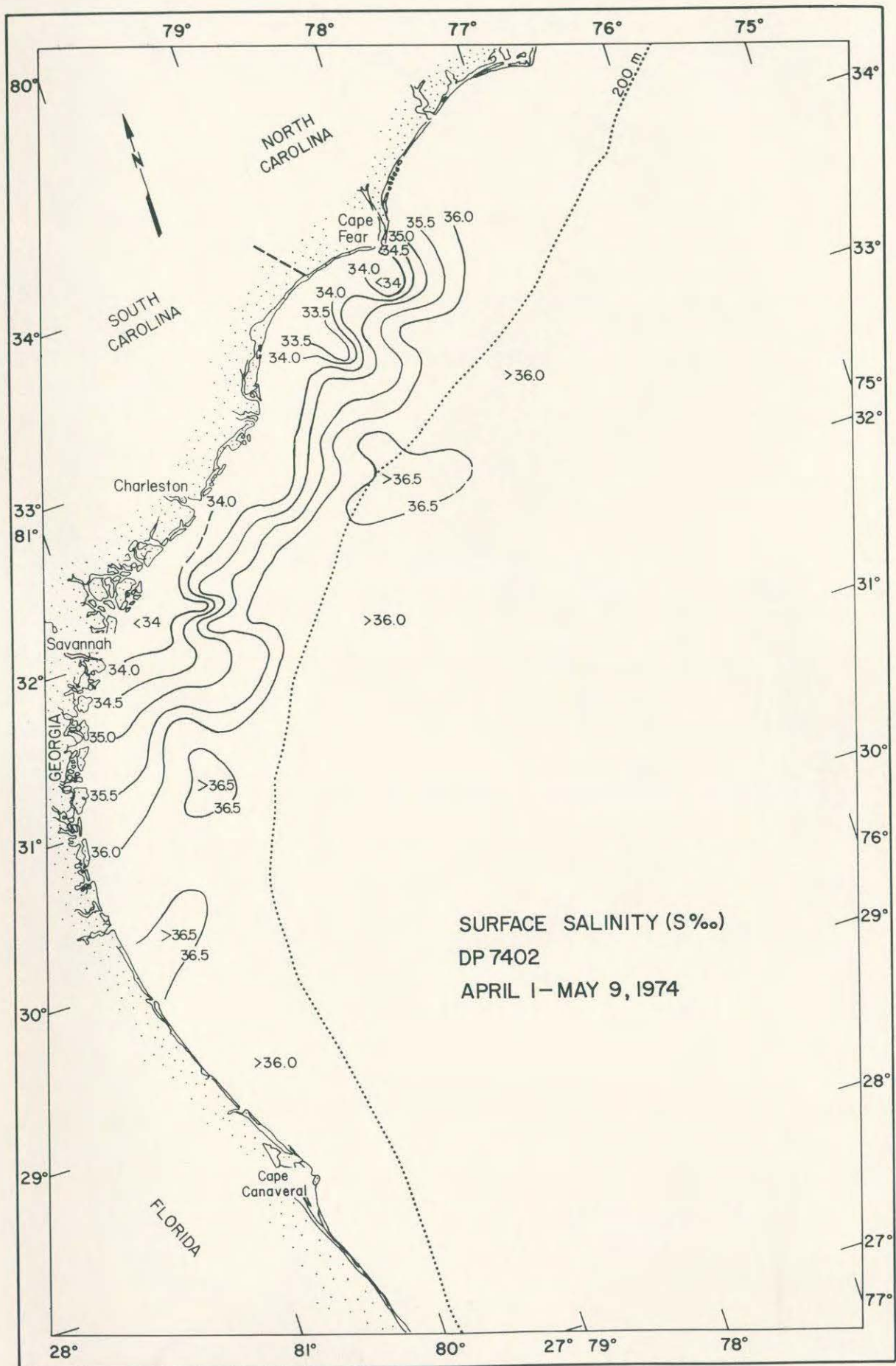


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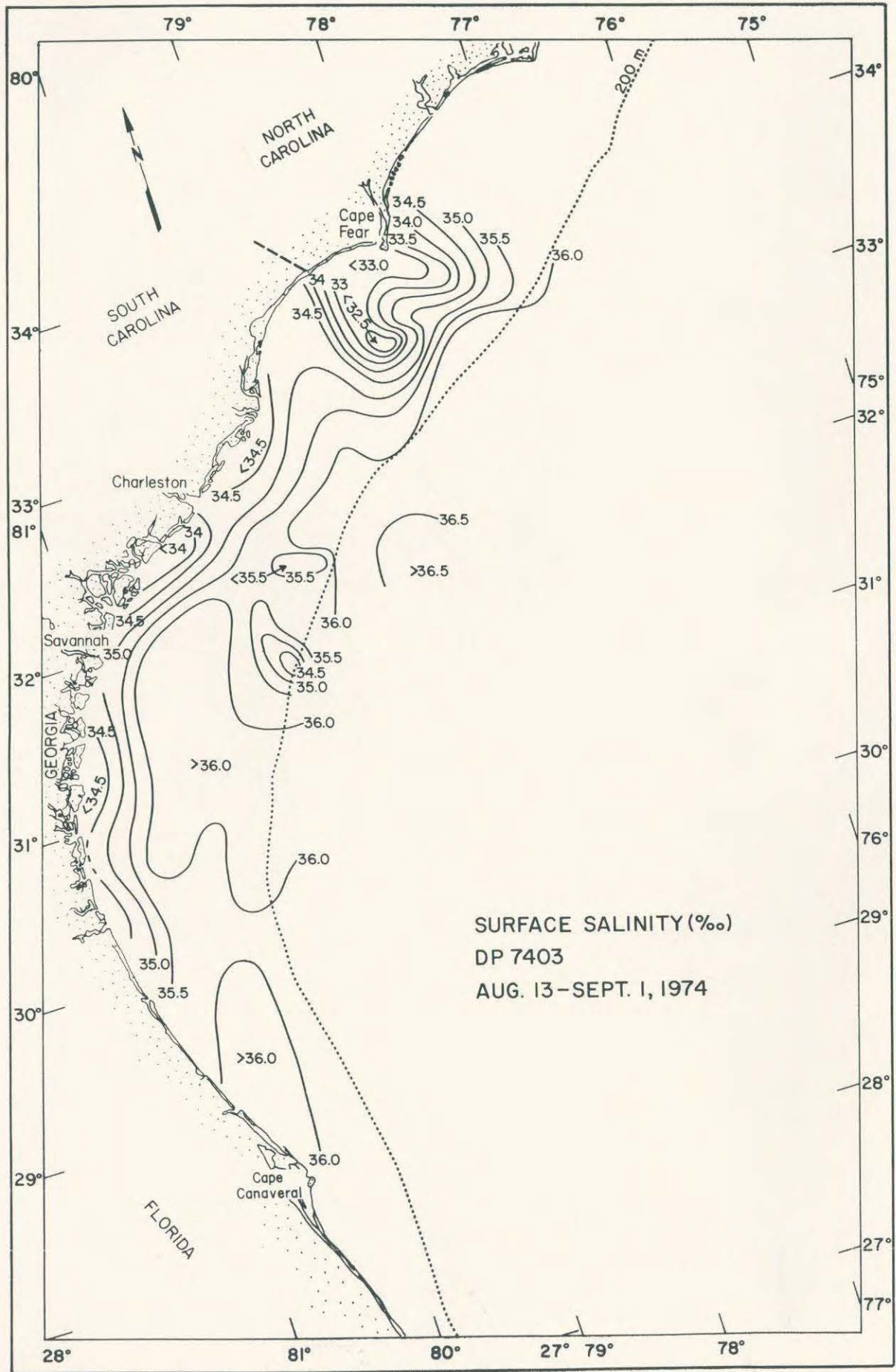


FIGURE 40.

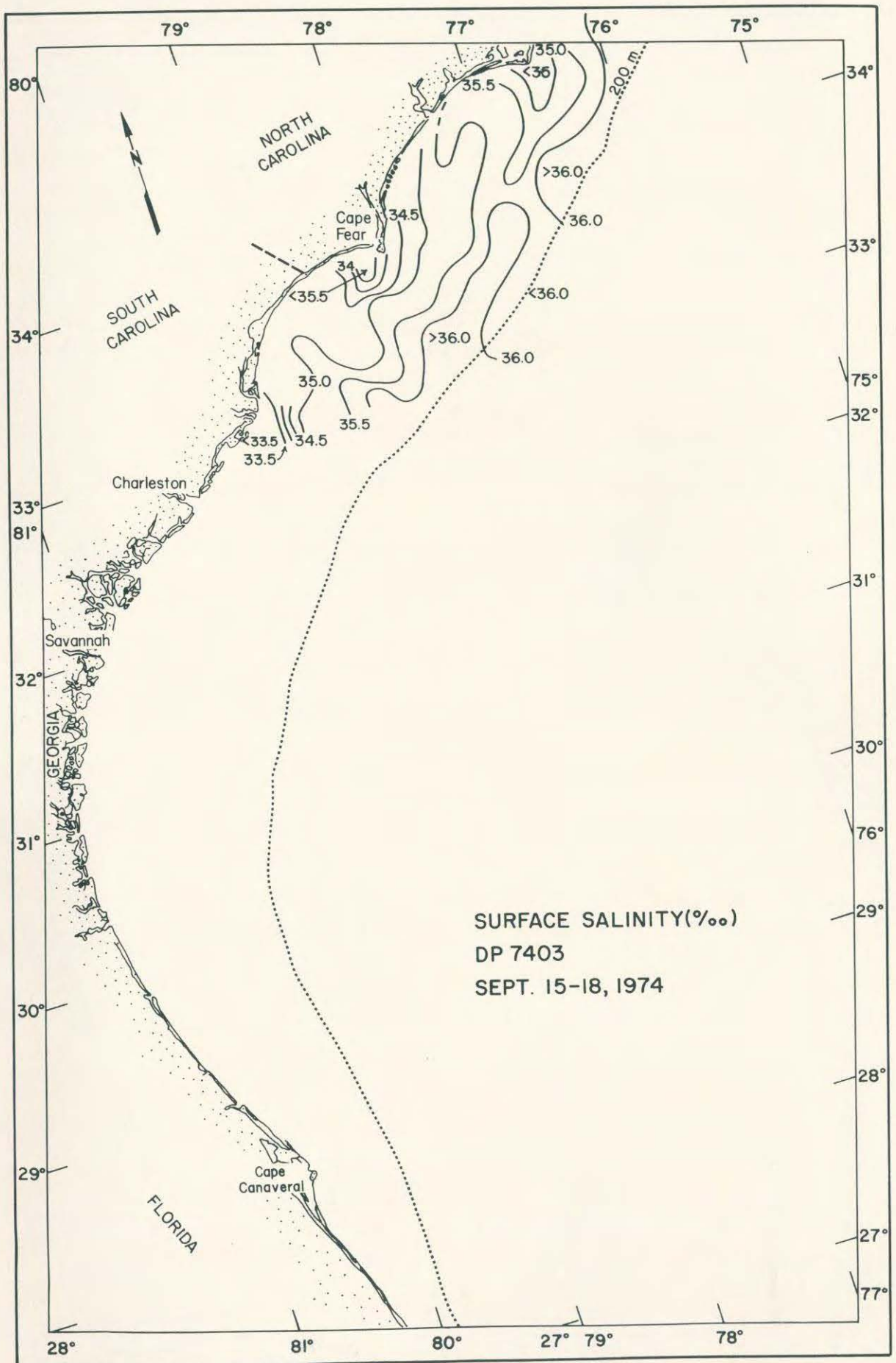


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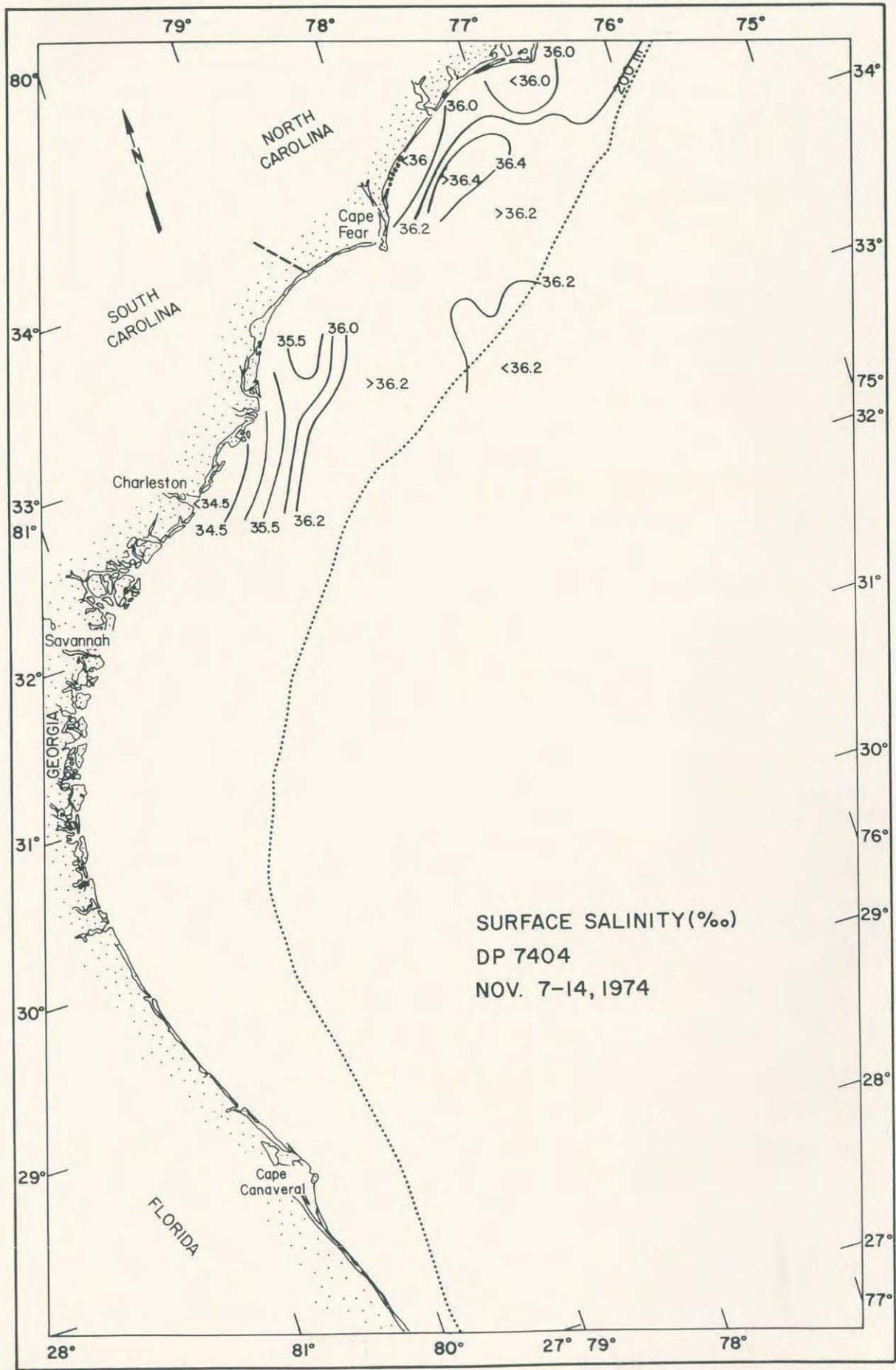


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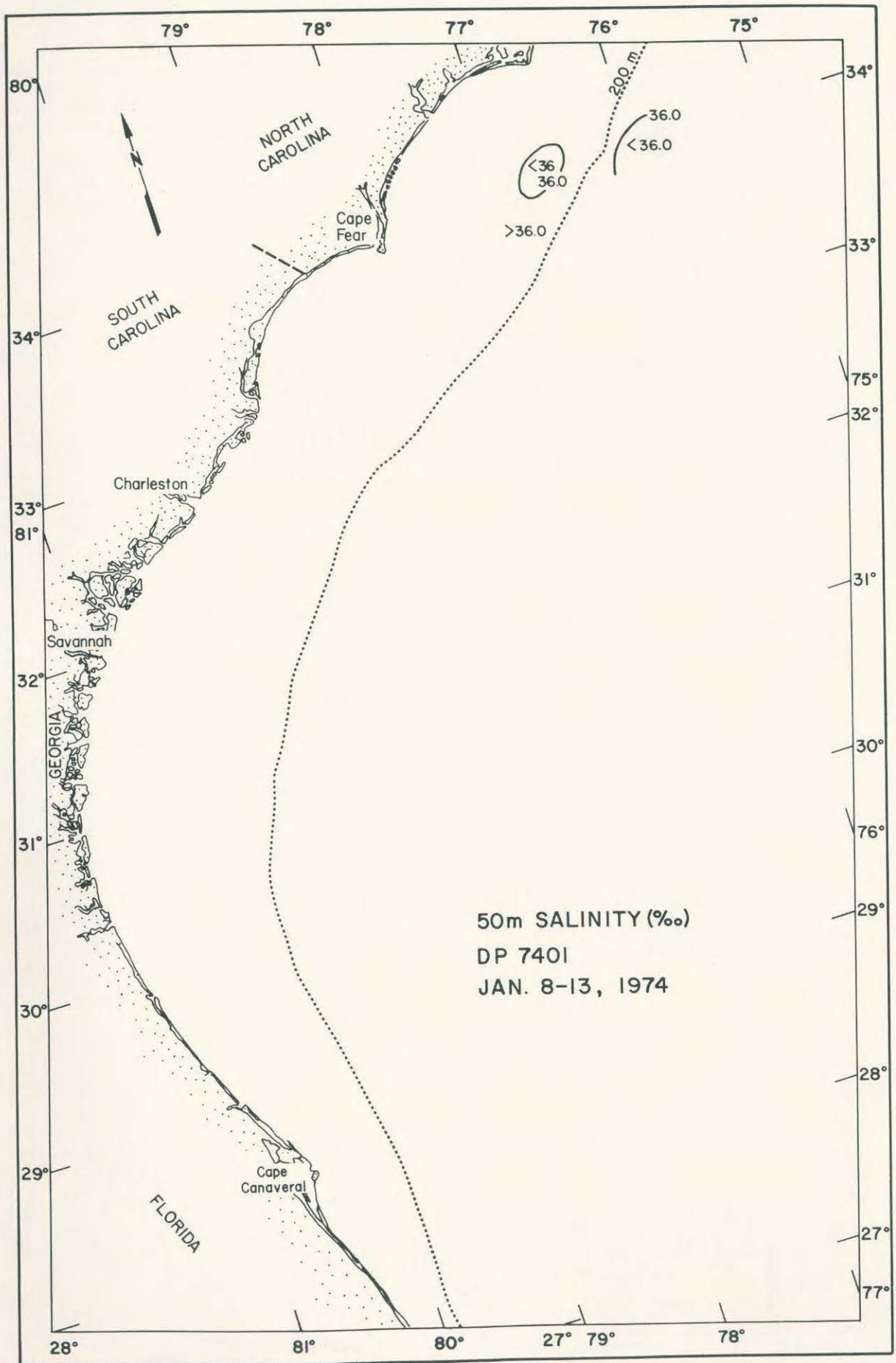


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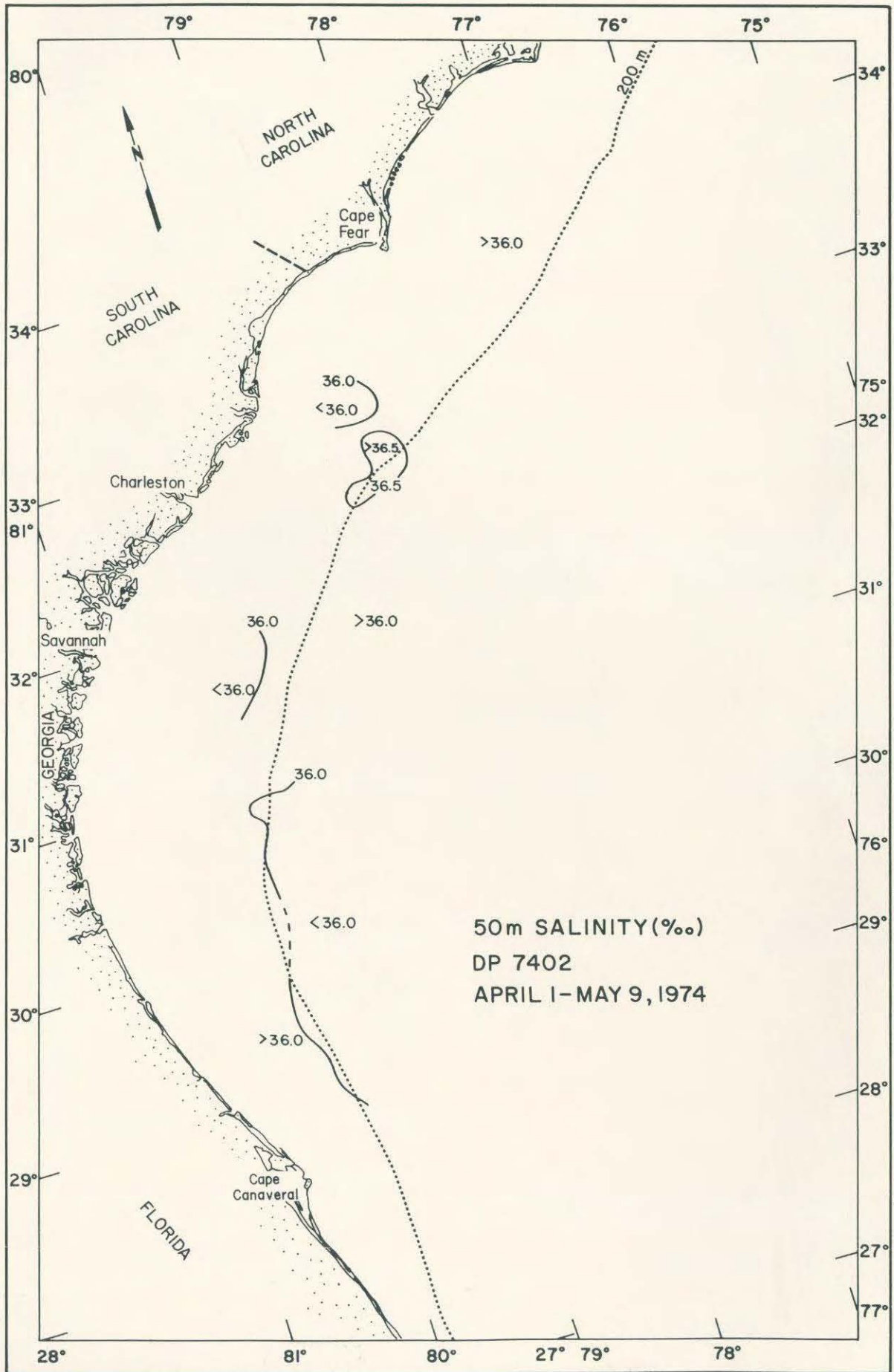


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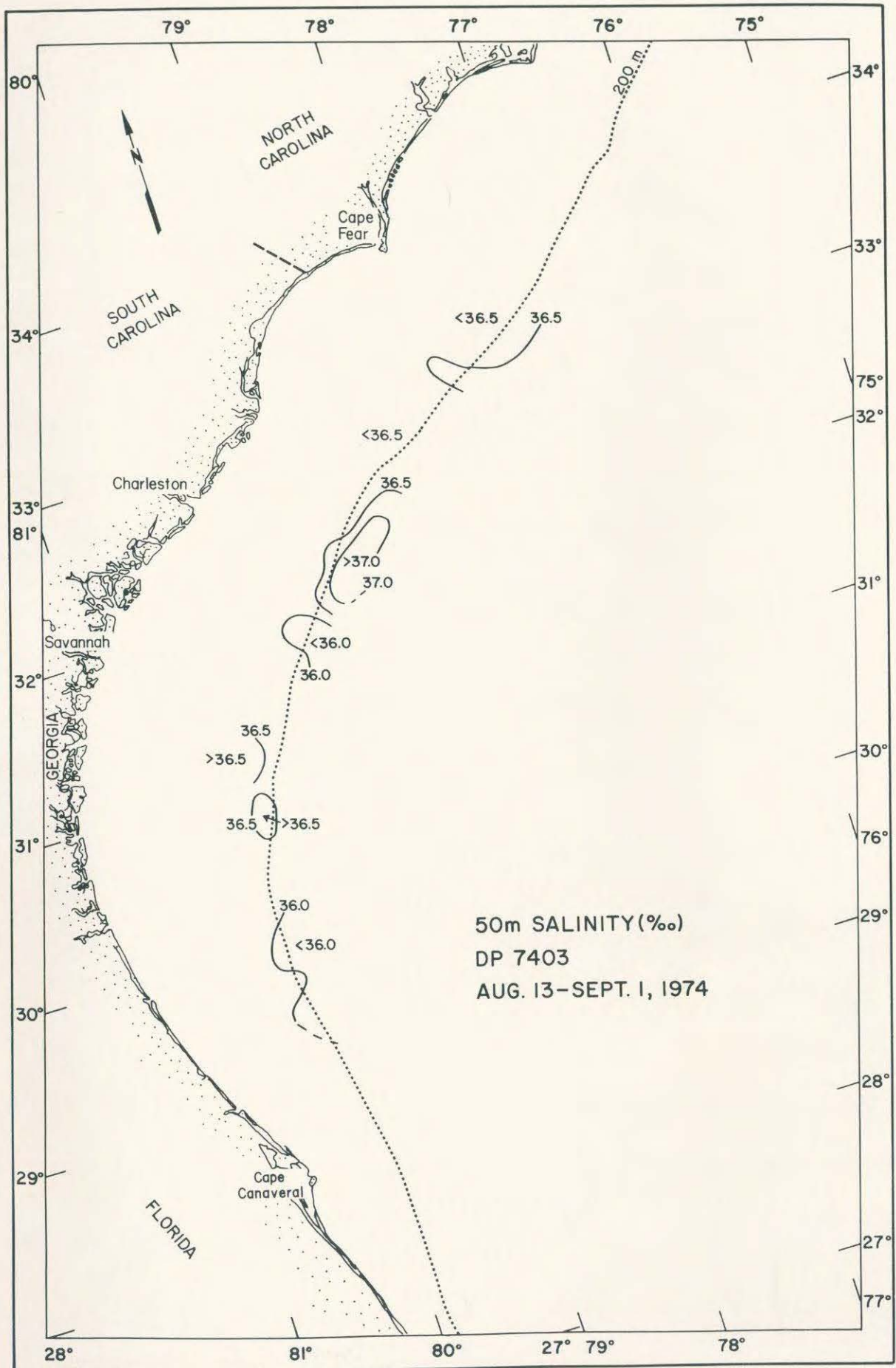


FIGURE 45.

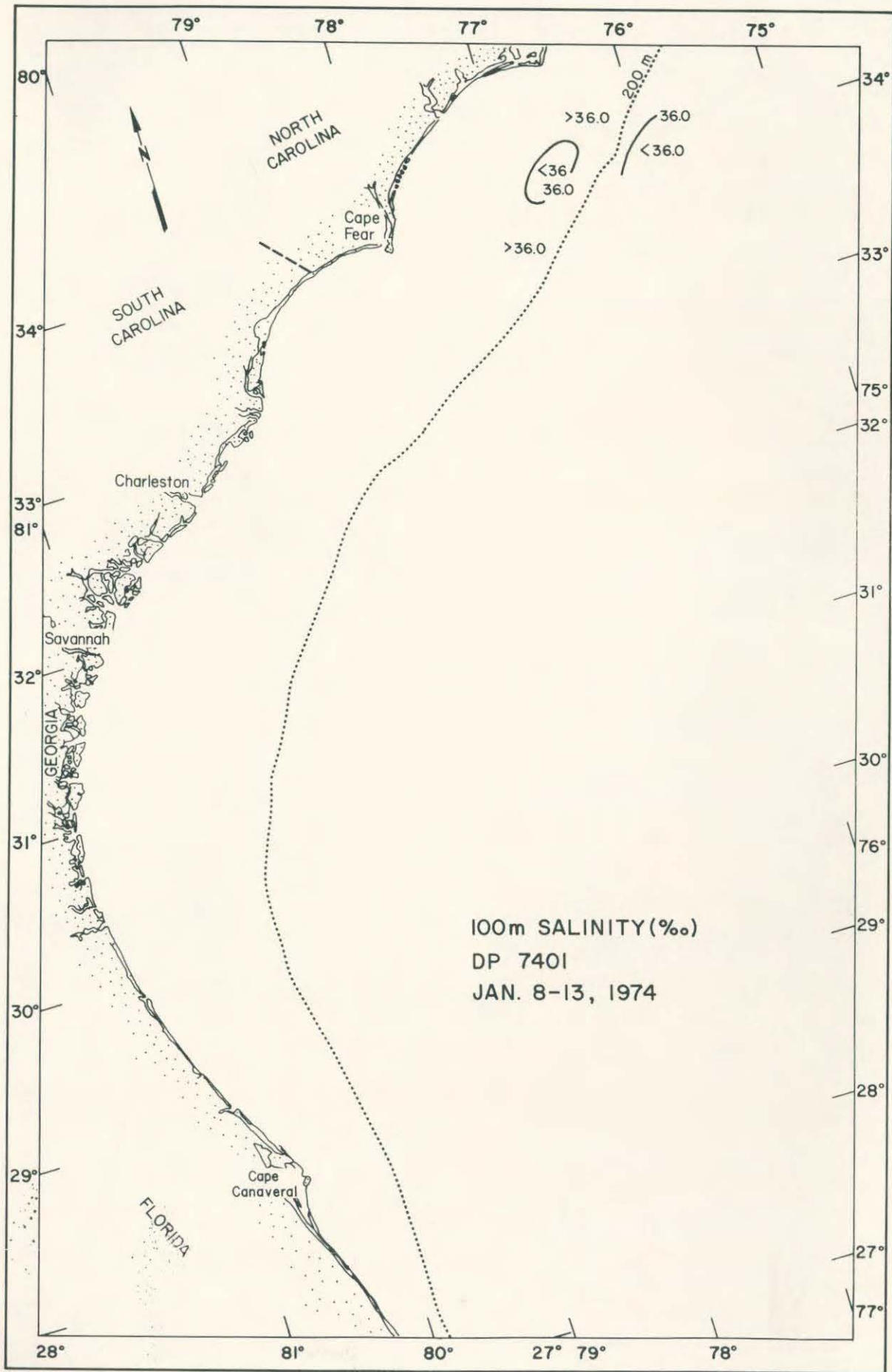


FIGURE 46.

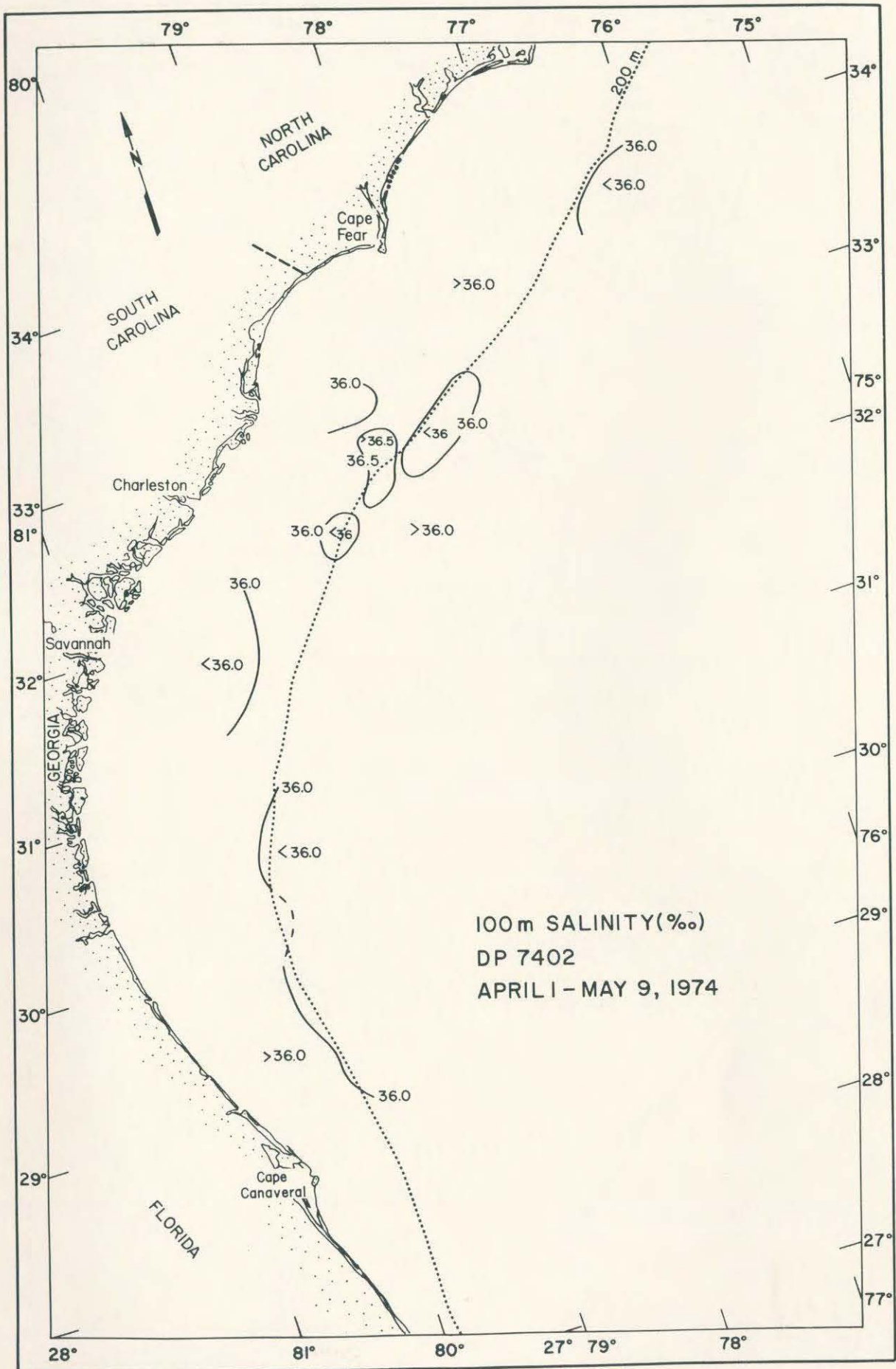


FIGURE 47.

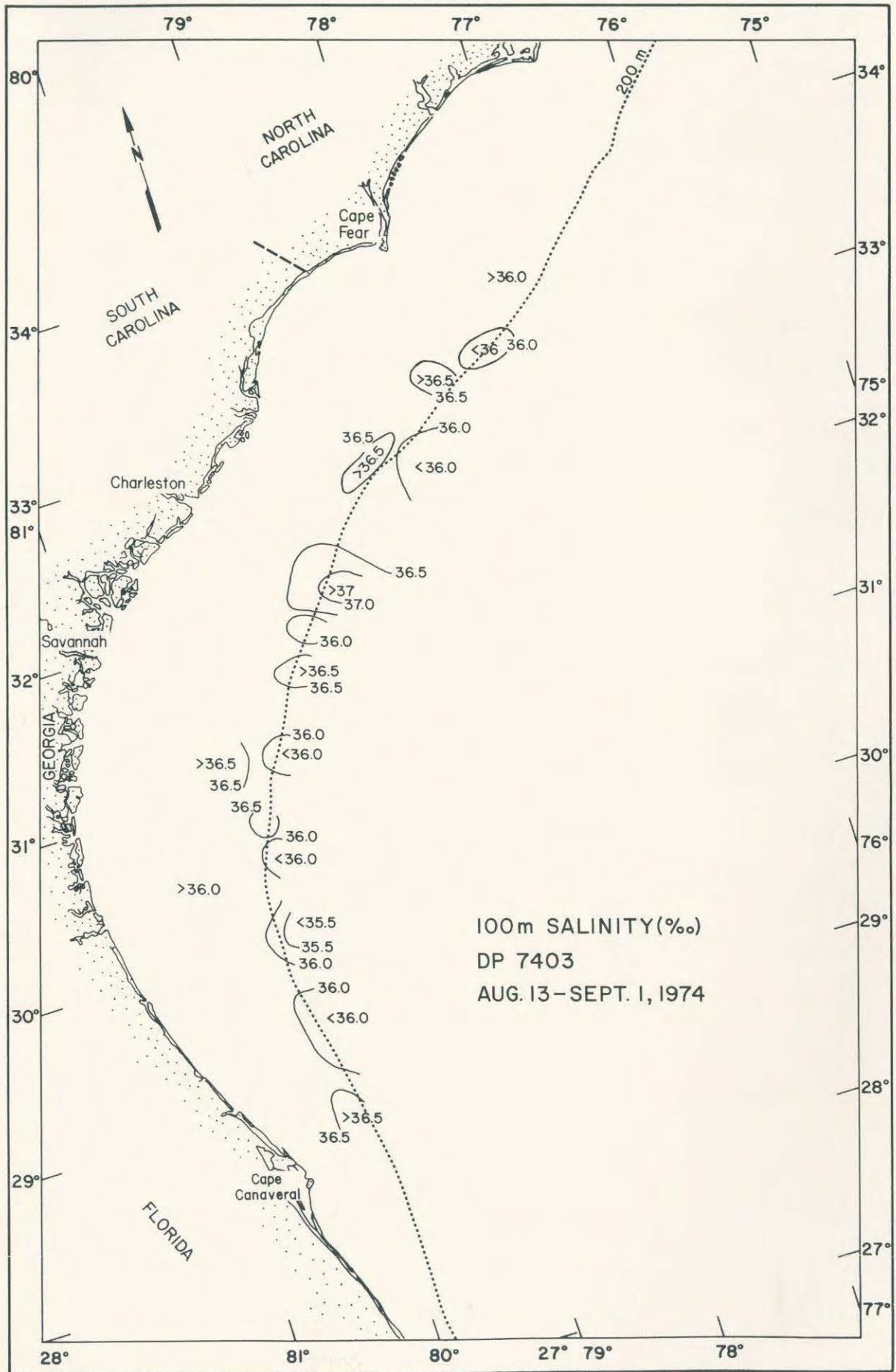


FIGURE 48.

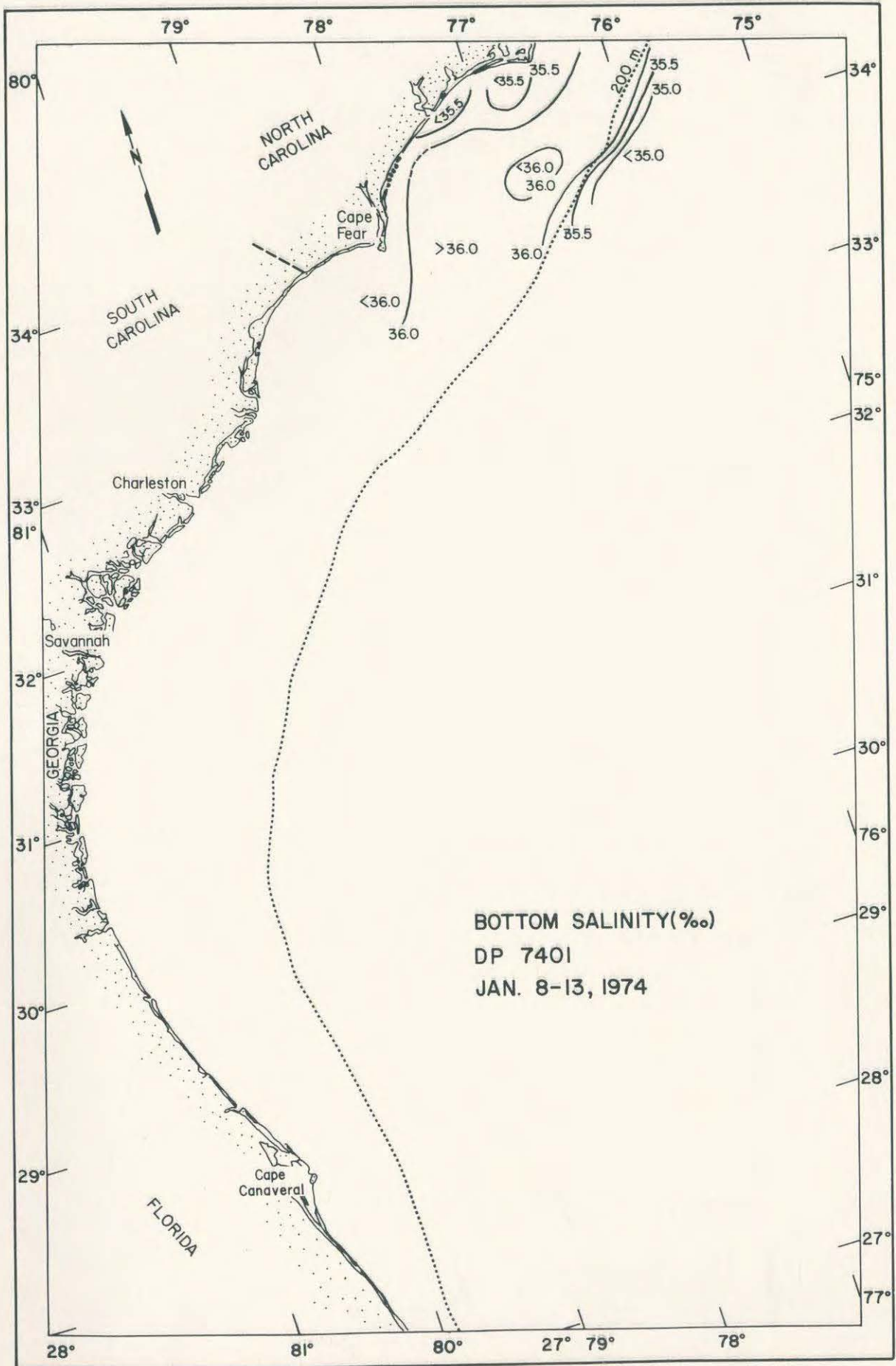


FIGURE 49.

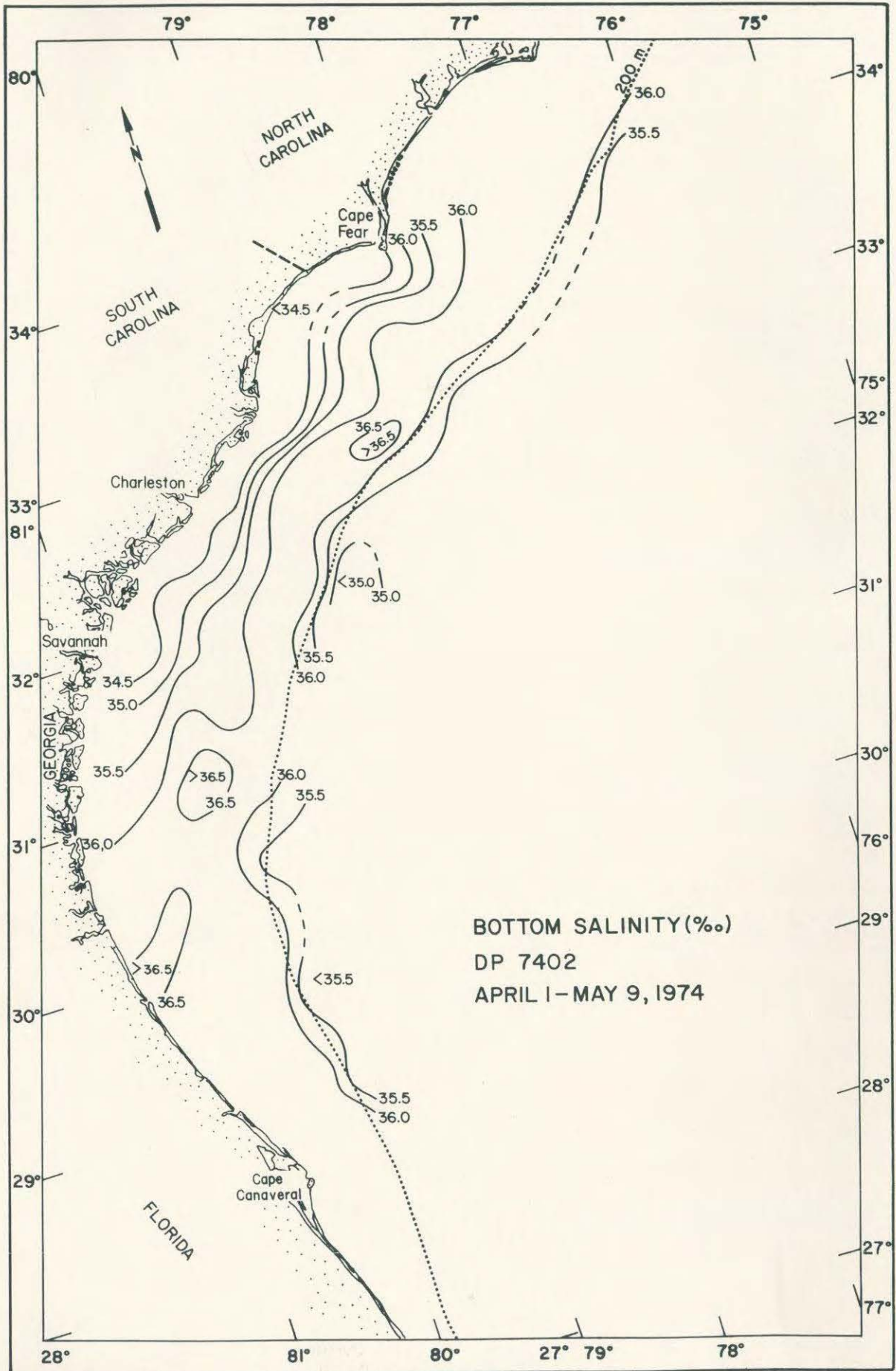


FIGURE 90.

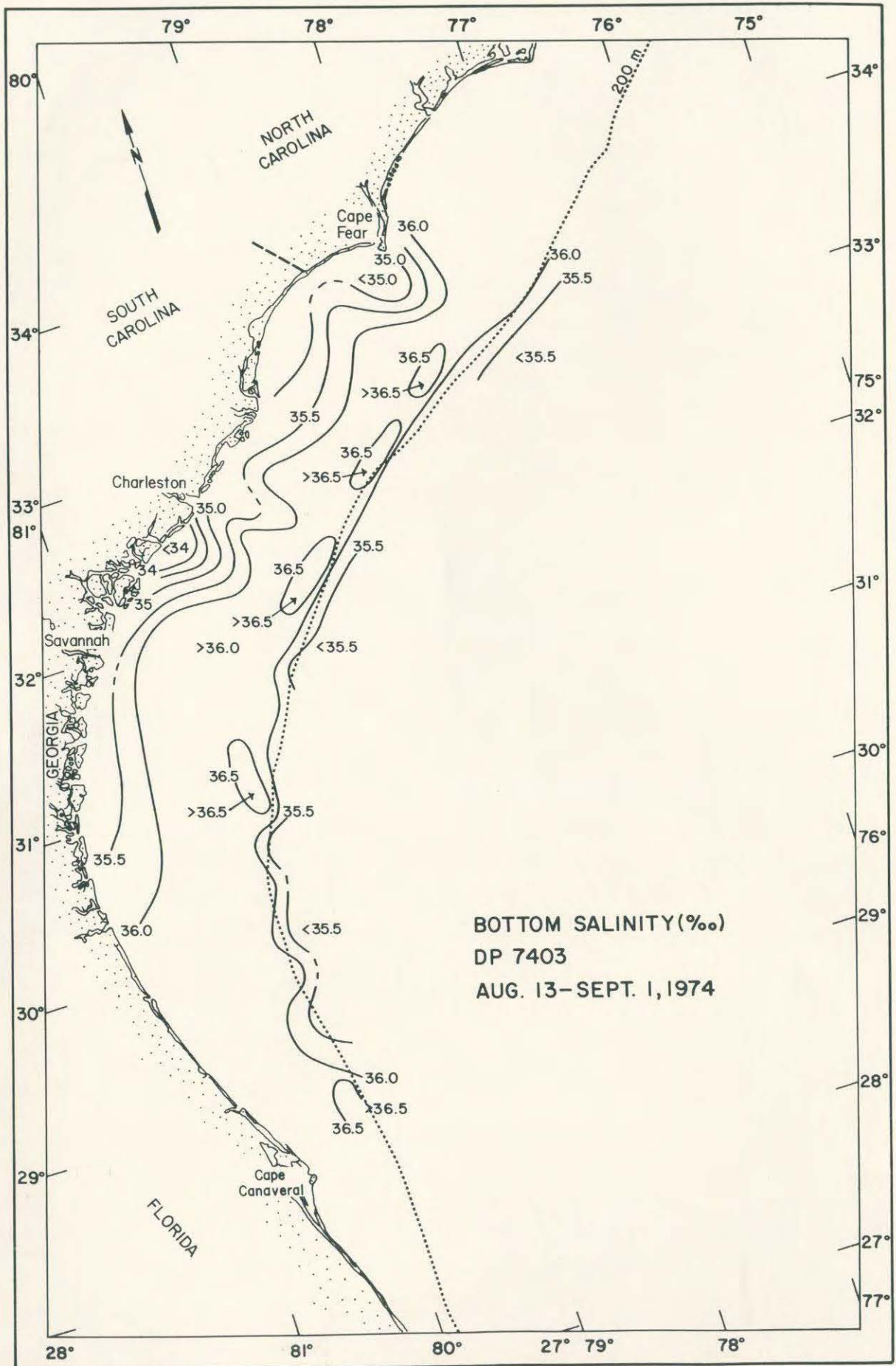


FIGURE 51.

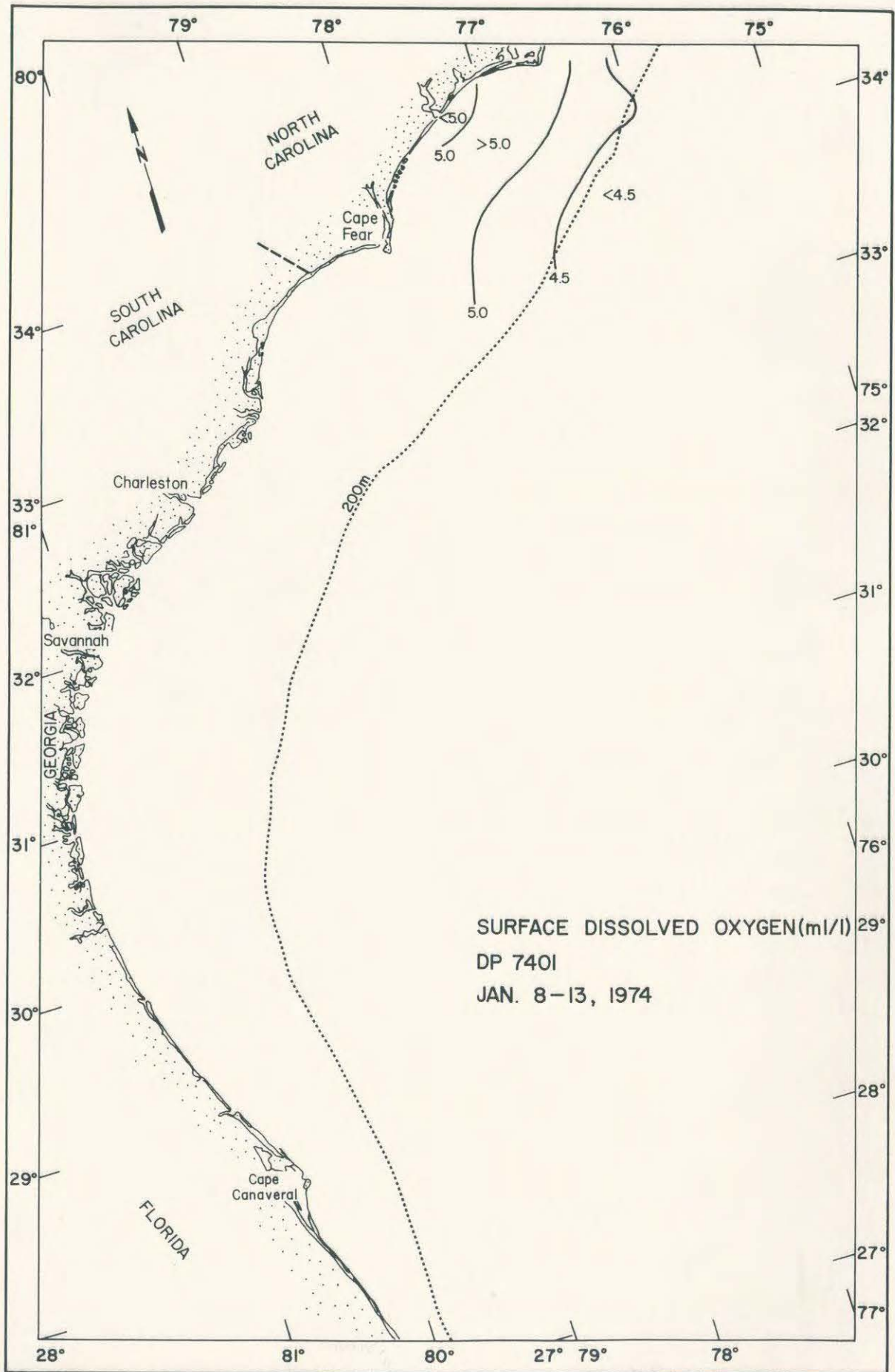


FIGURE 52.

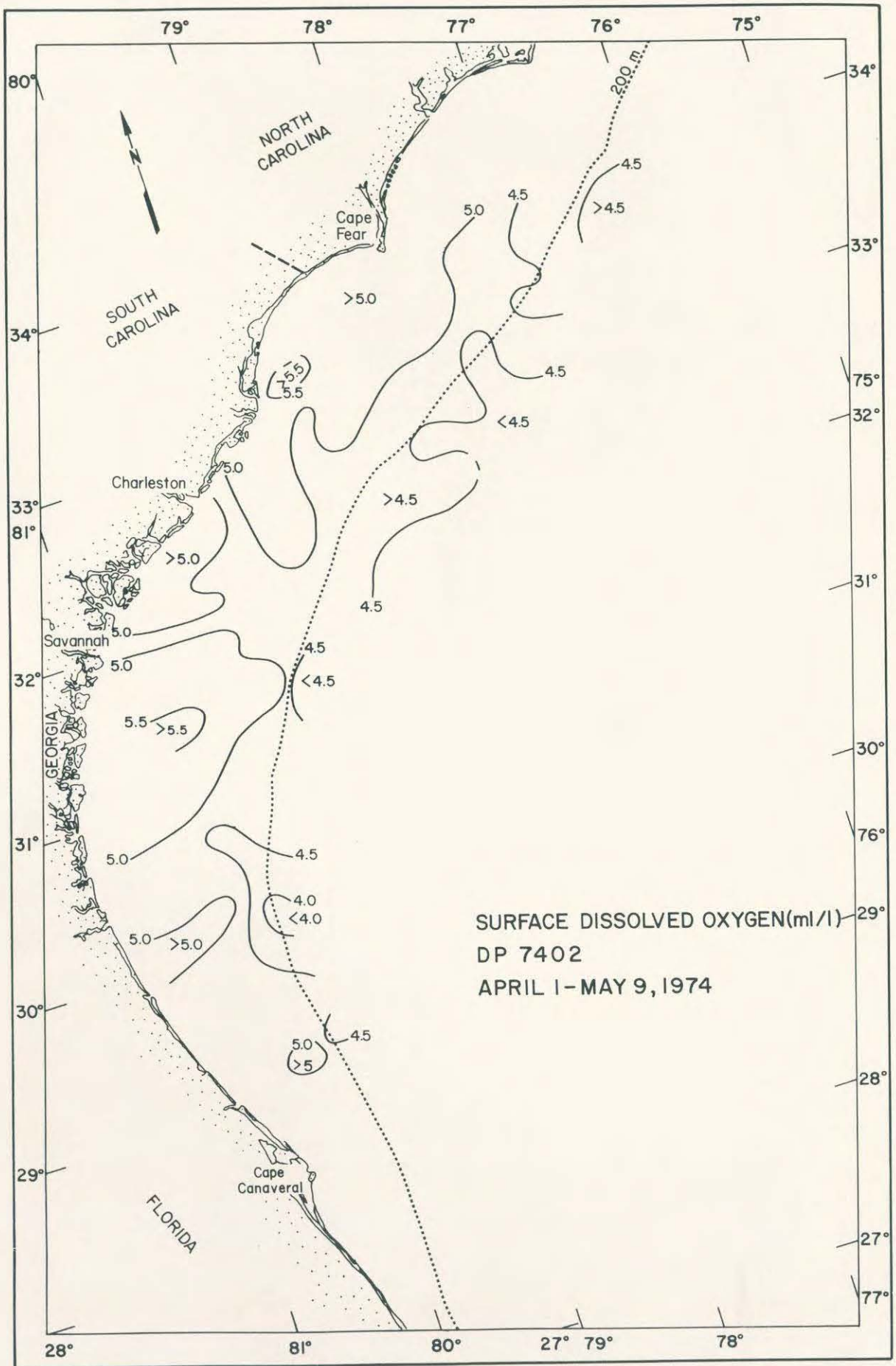


FIGURE 53.

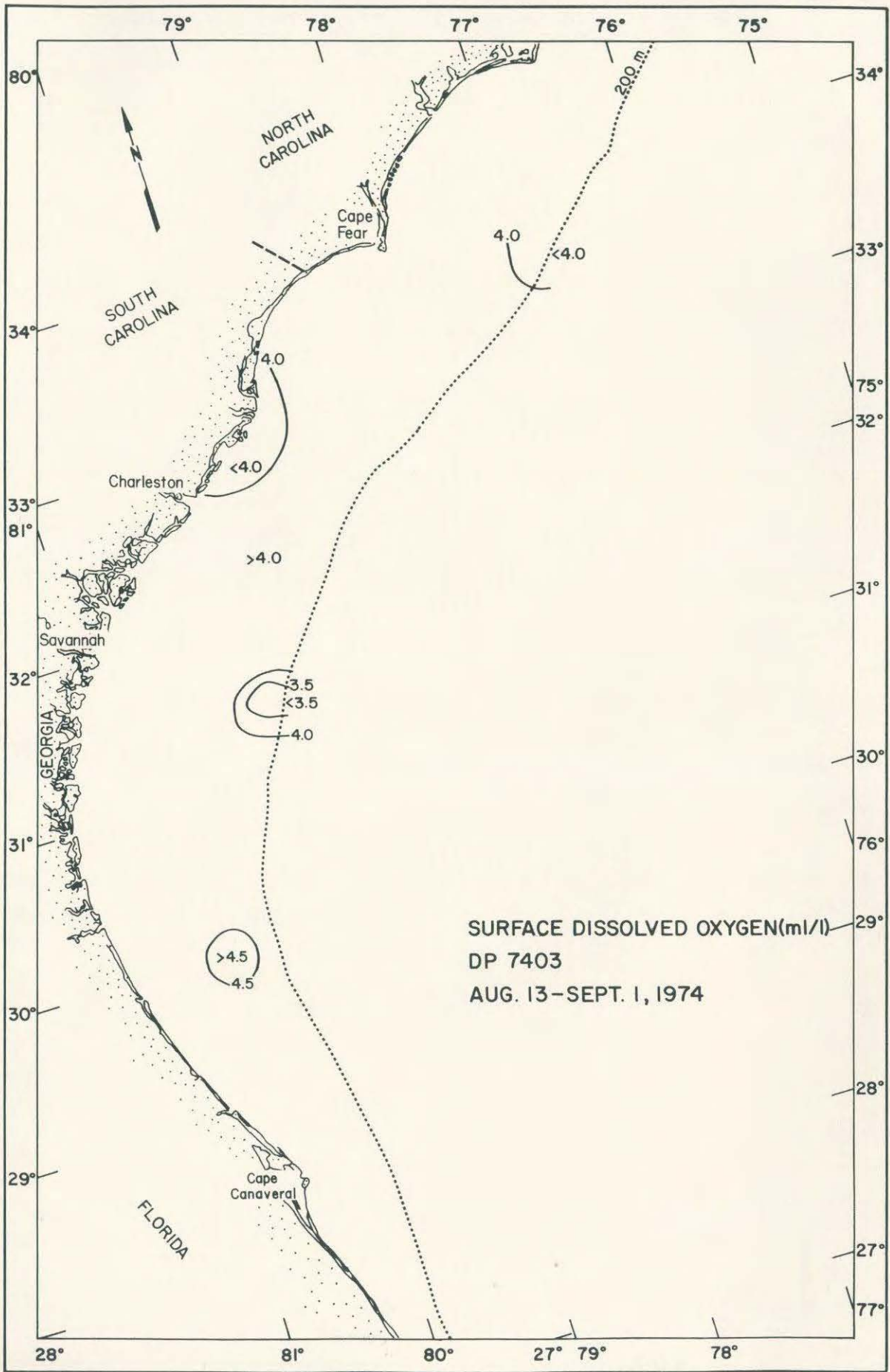


FIGURE 54.

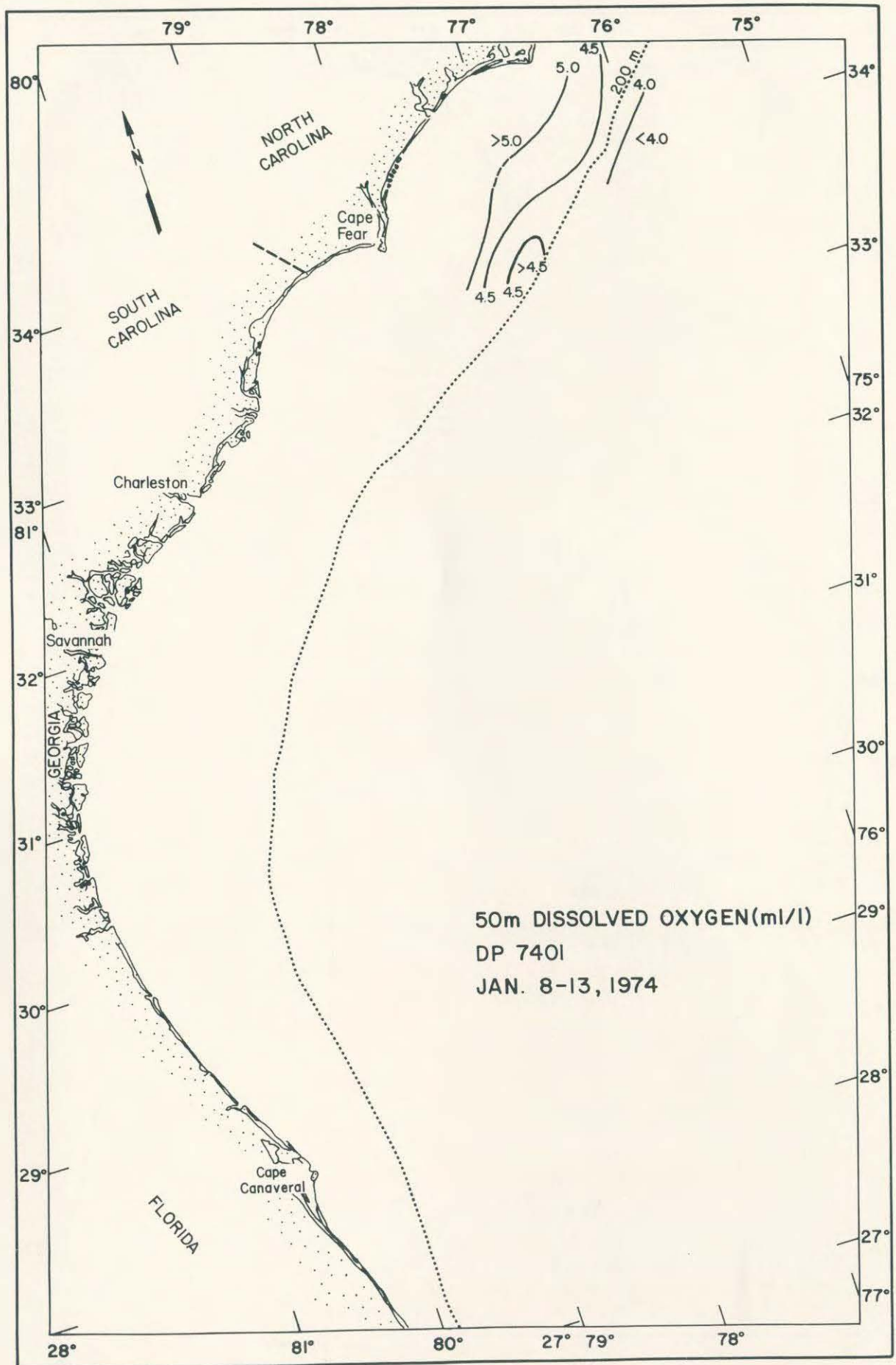


FIGURE 55.

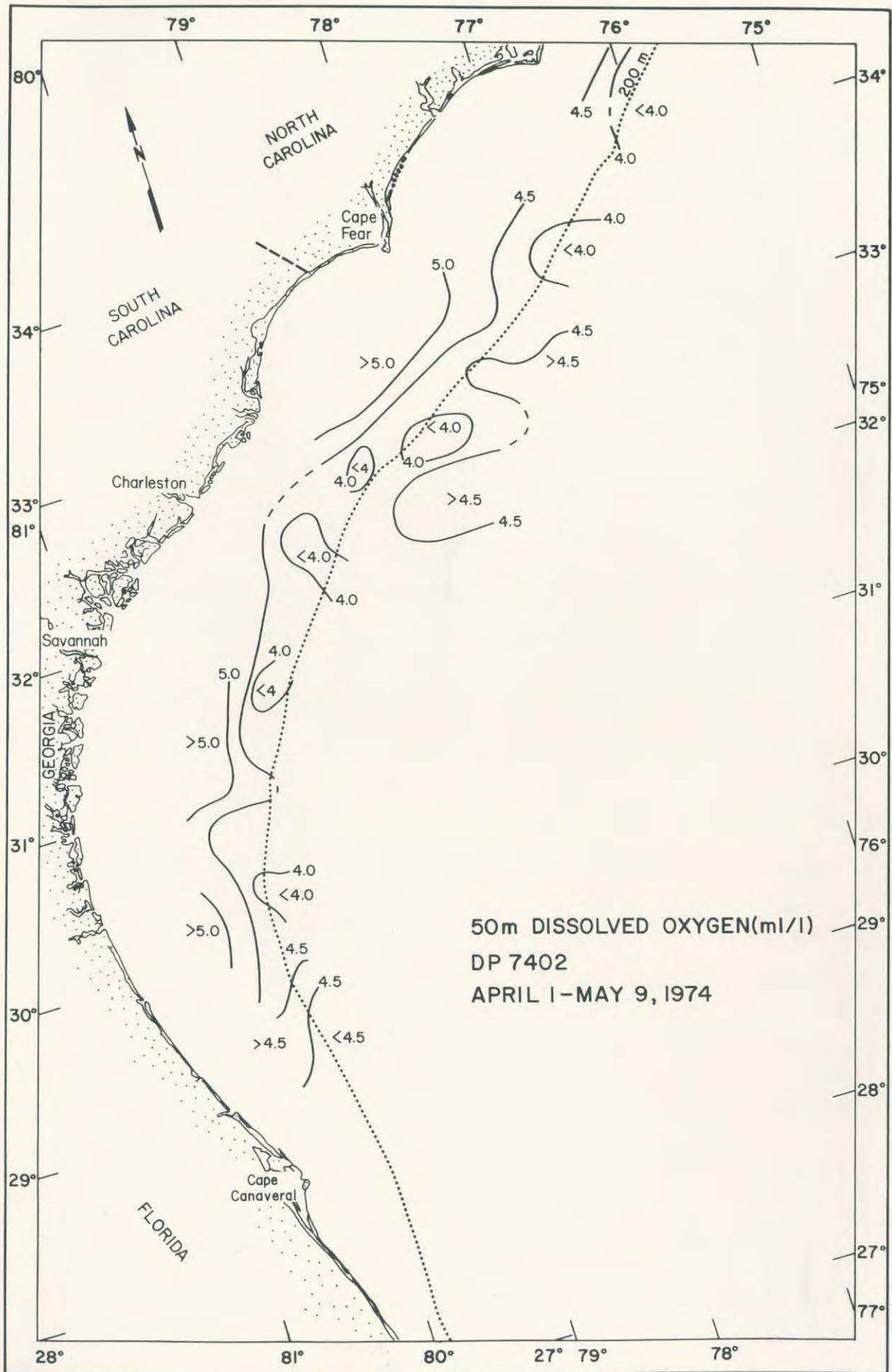


FIGURE 56.

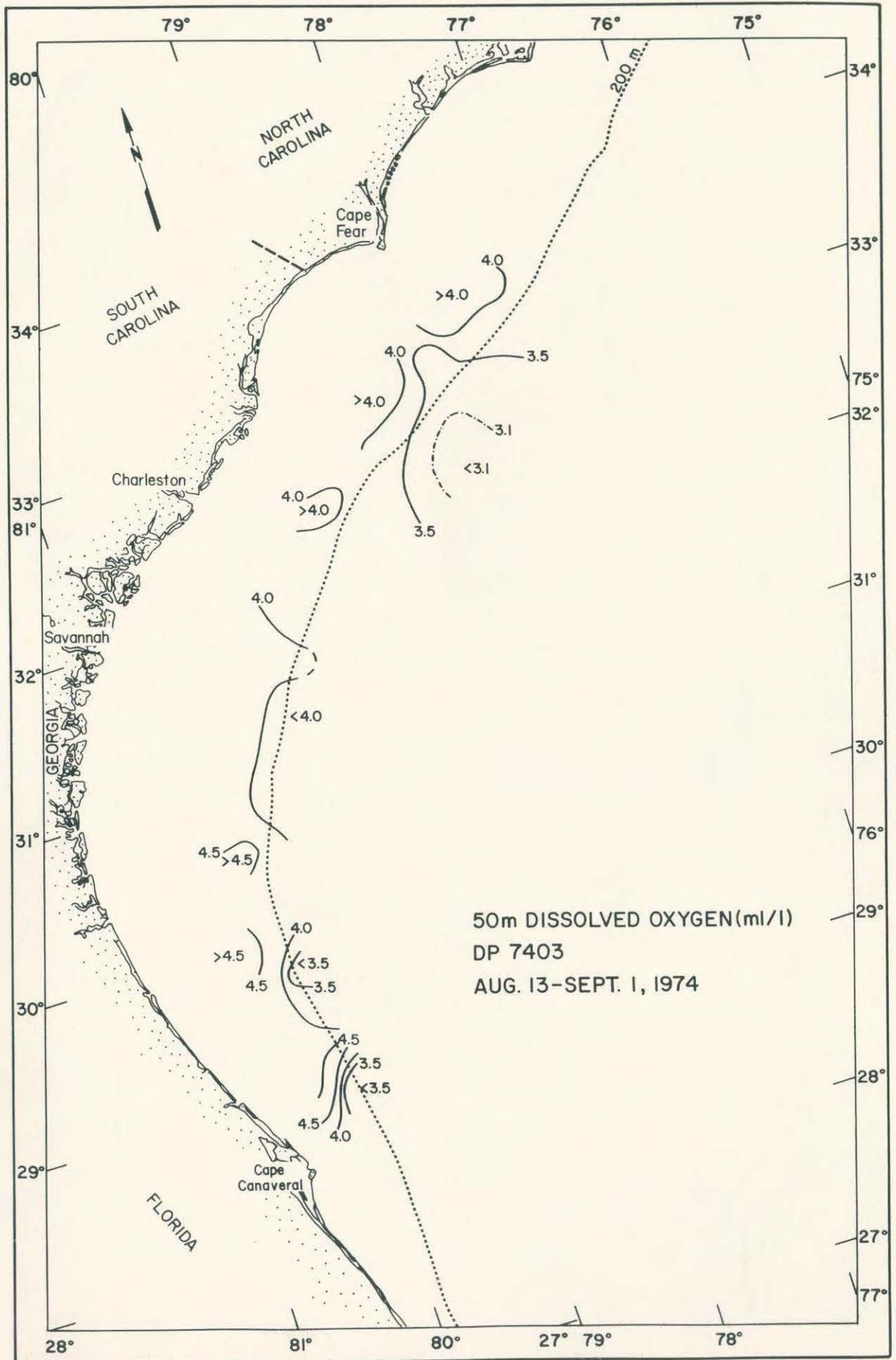


FIGURE 57.

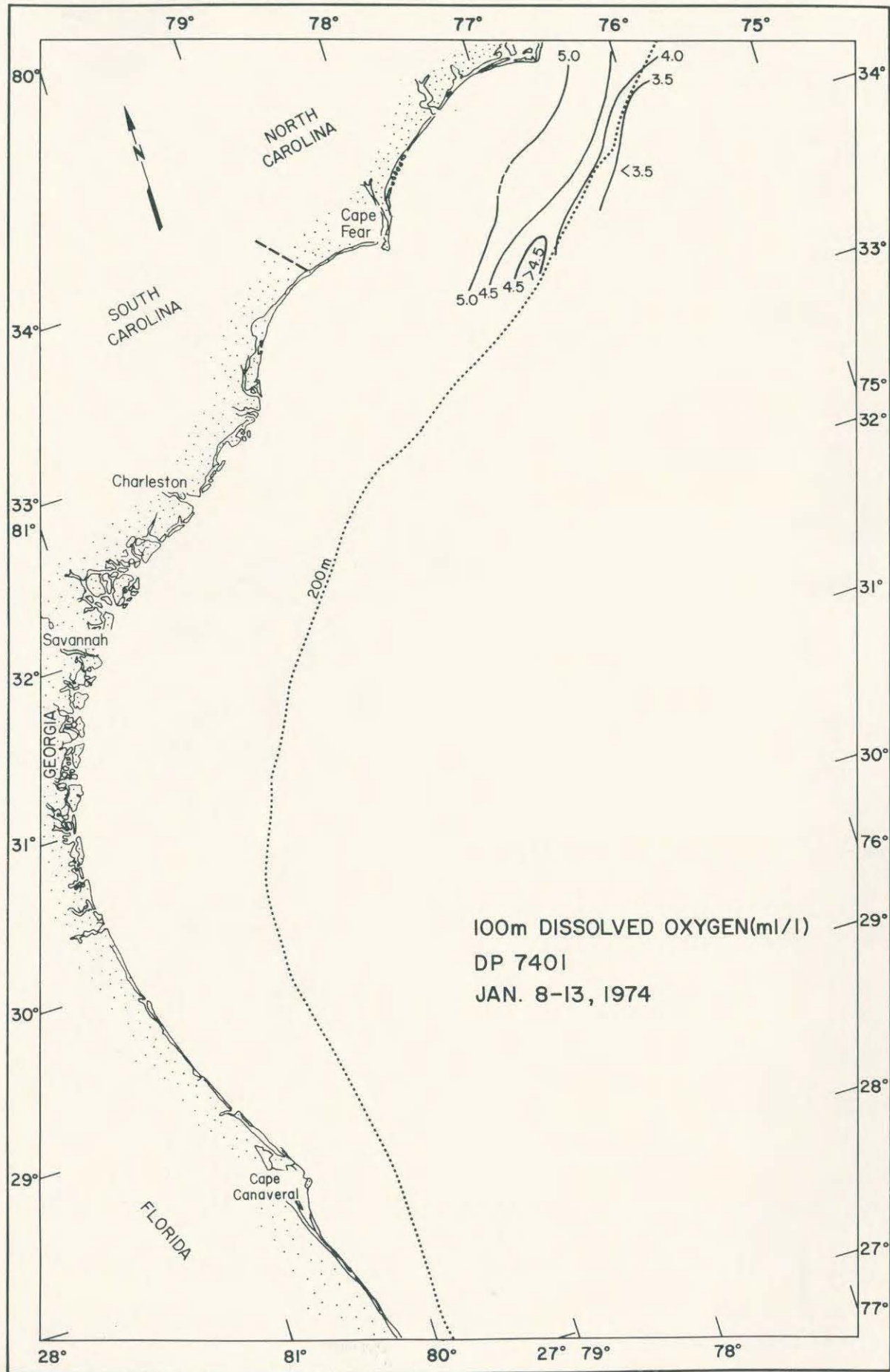


FIGURE 58.

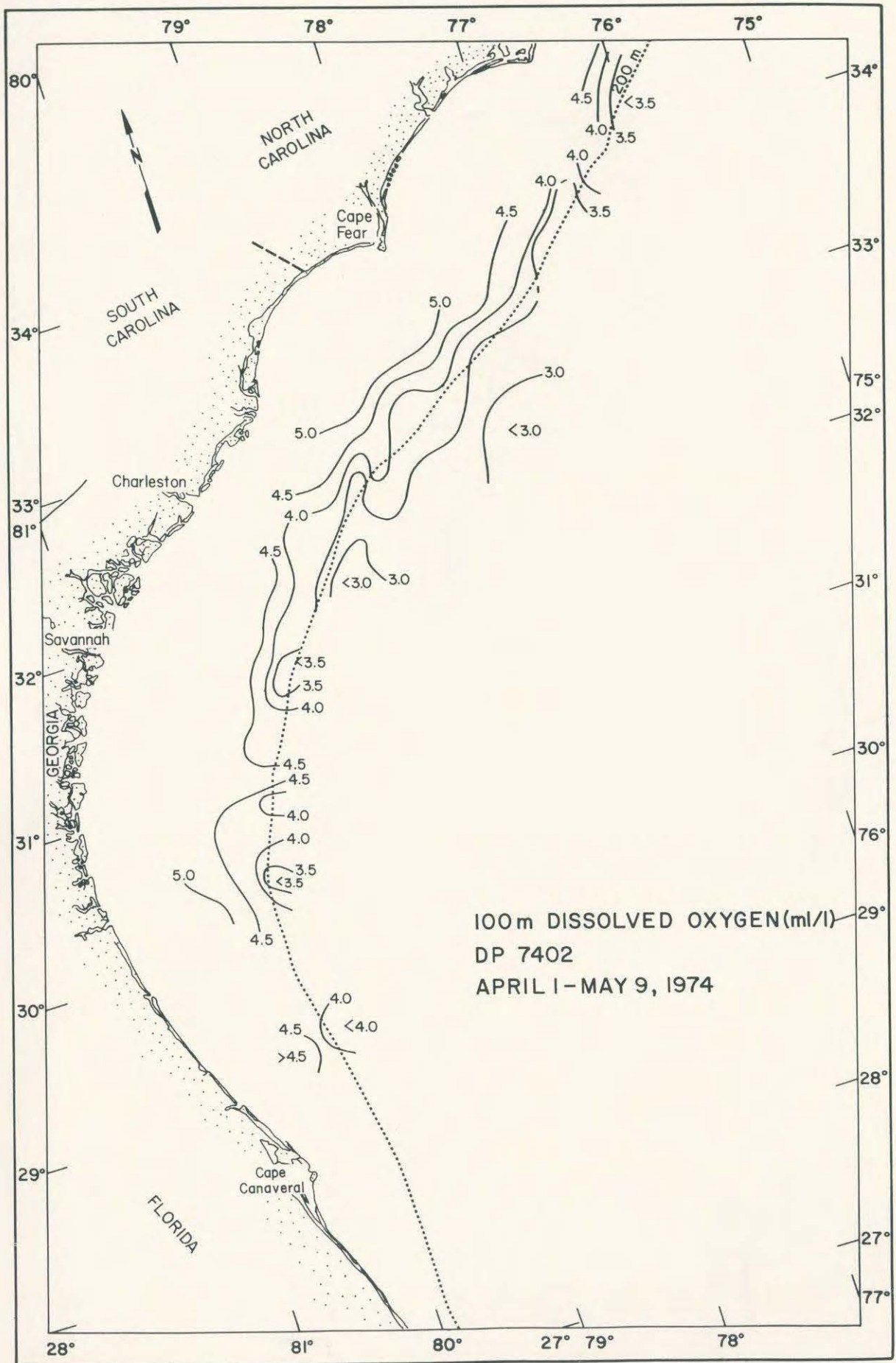


FIGURE 59.

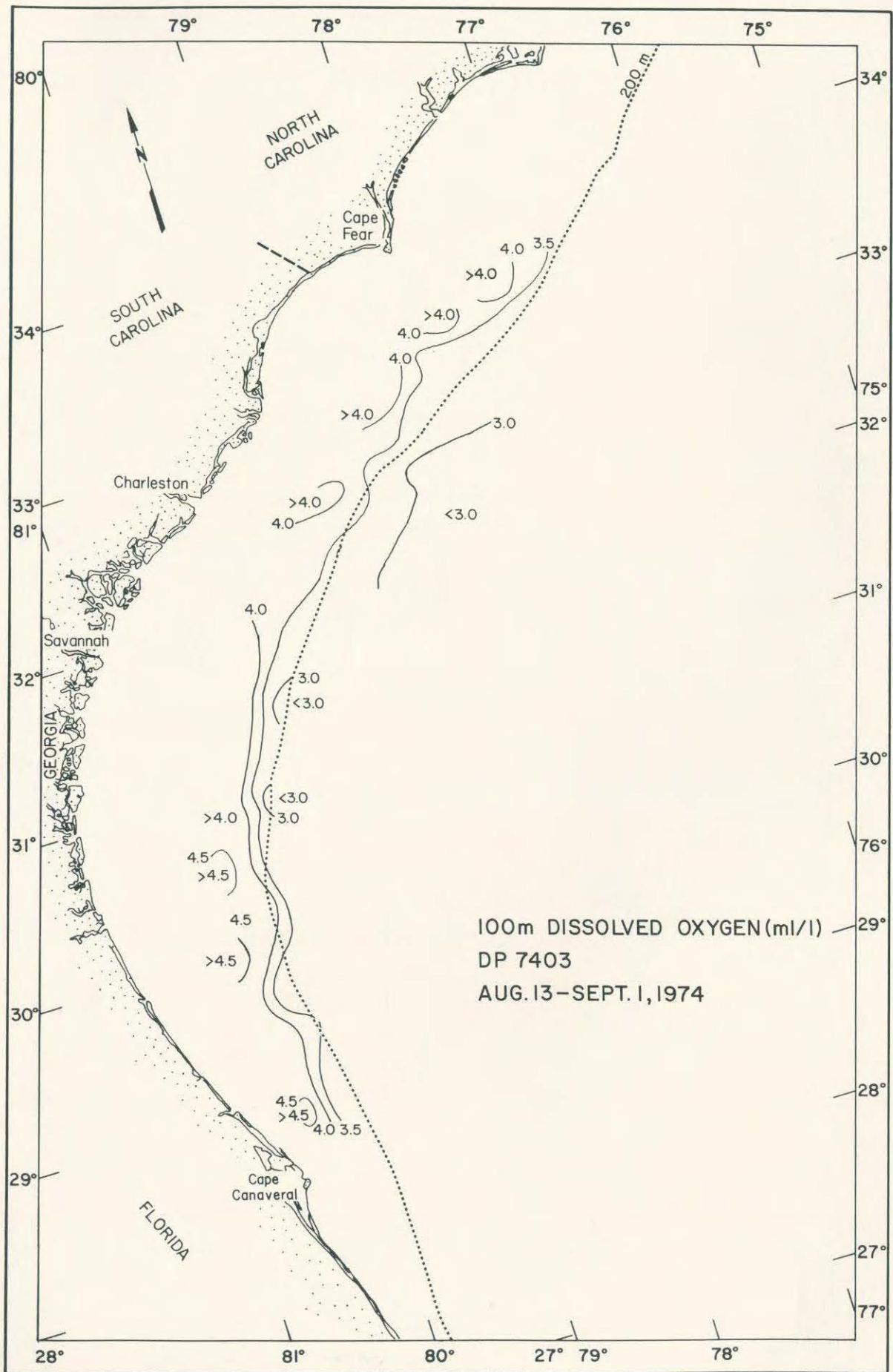


FIGURE 60.

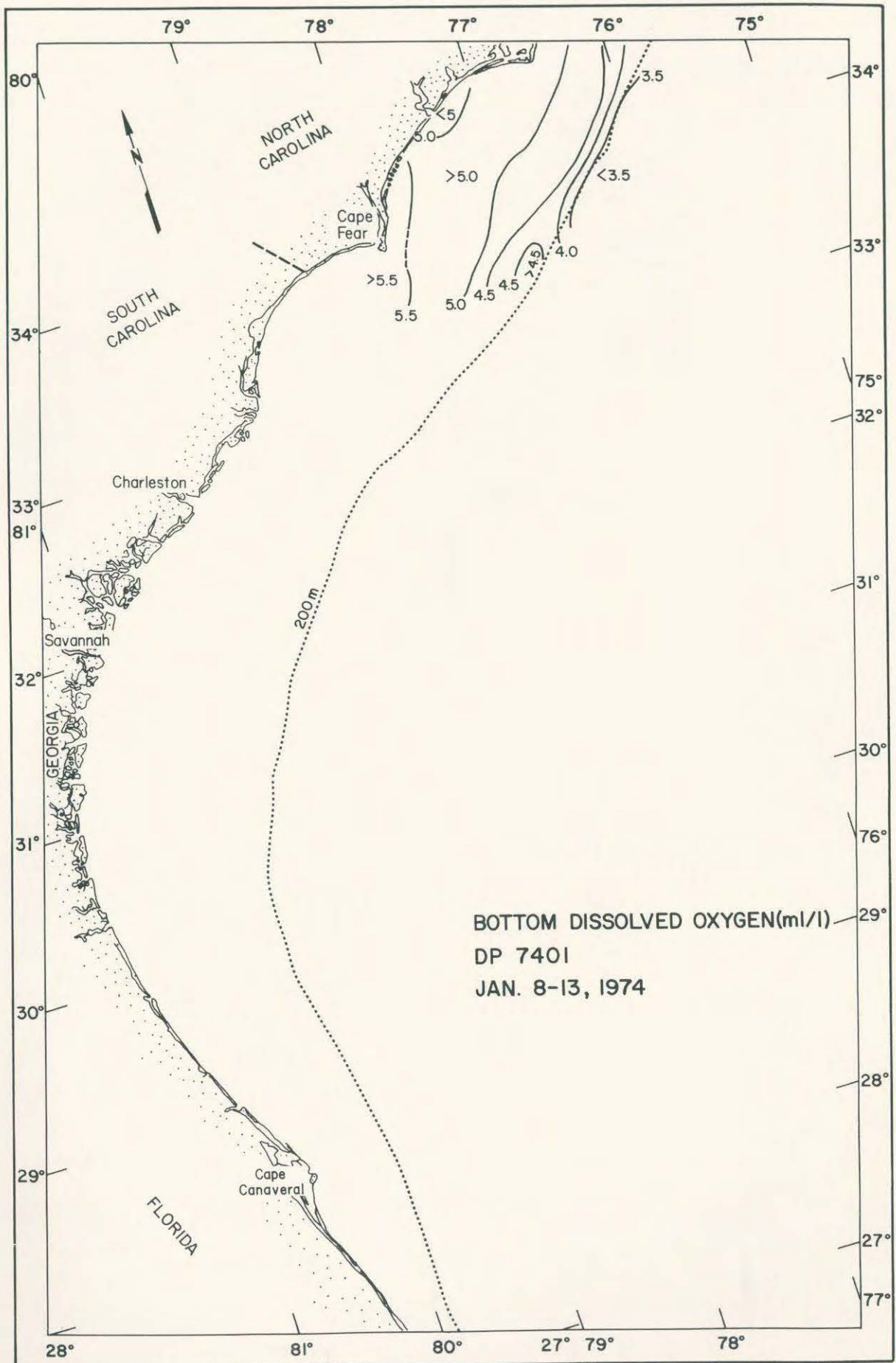


FIGURE 61.

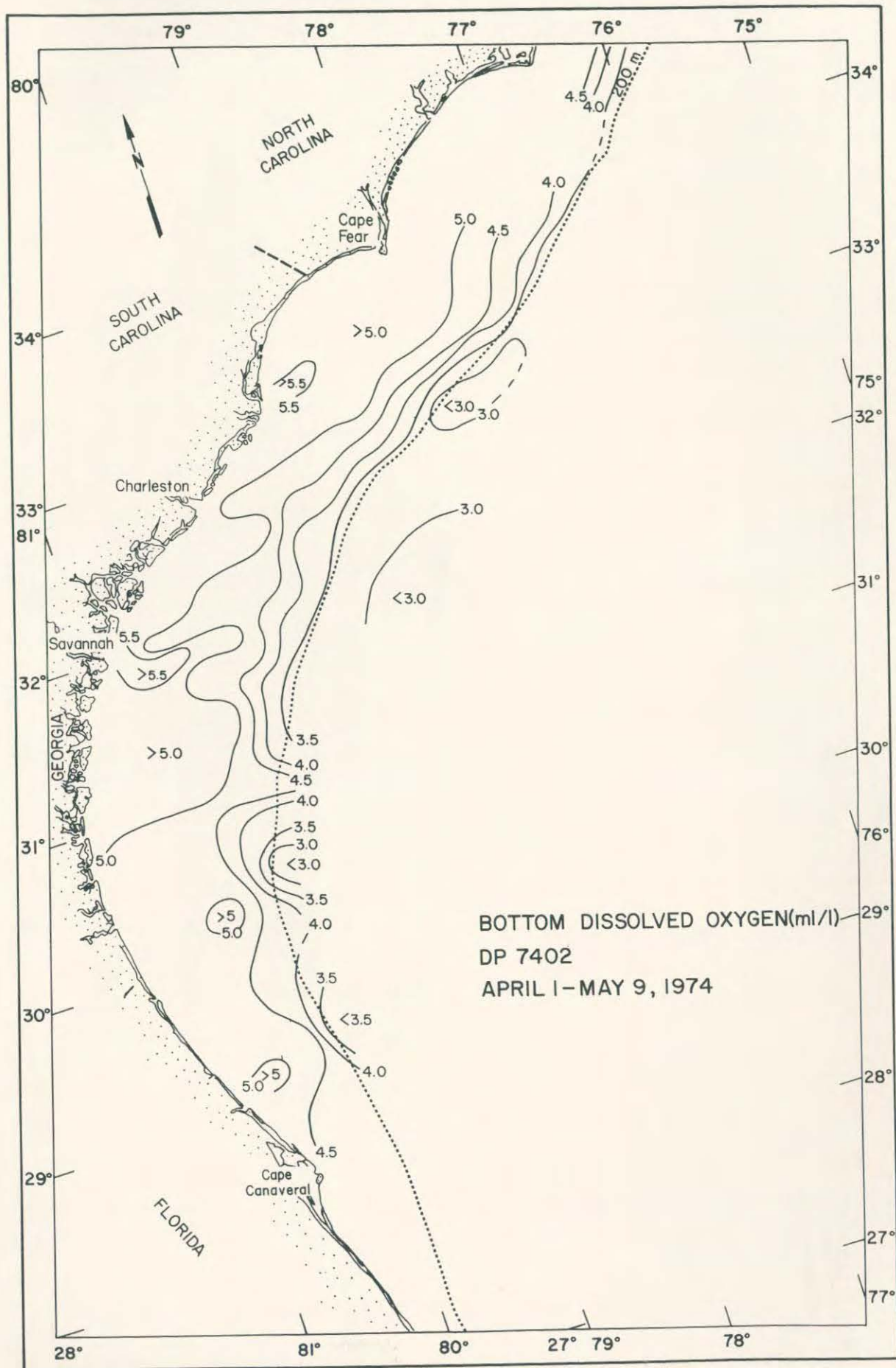


FIGURE 62.

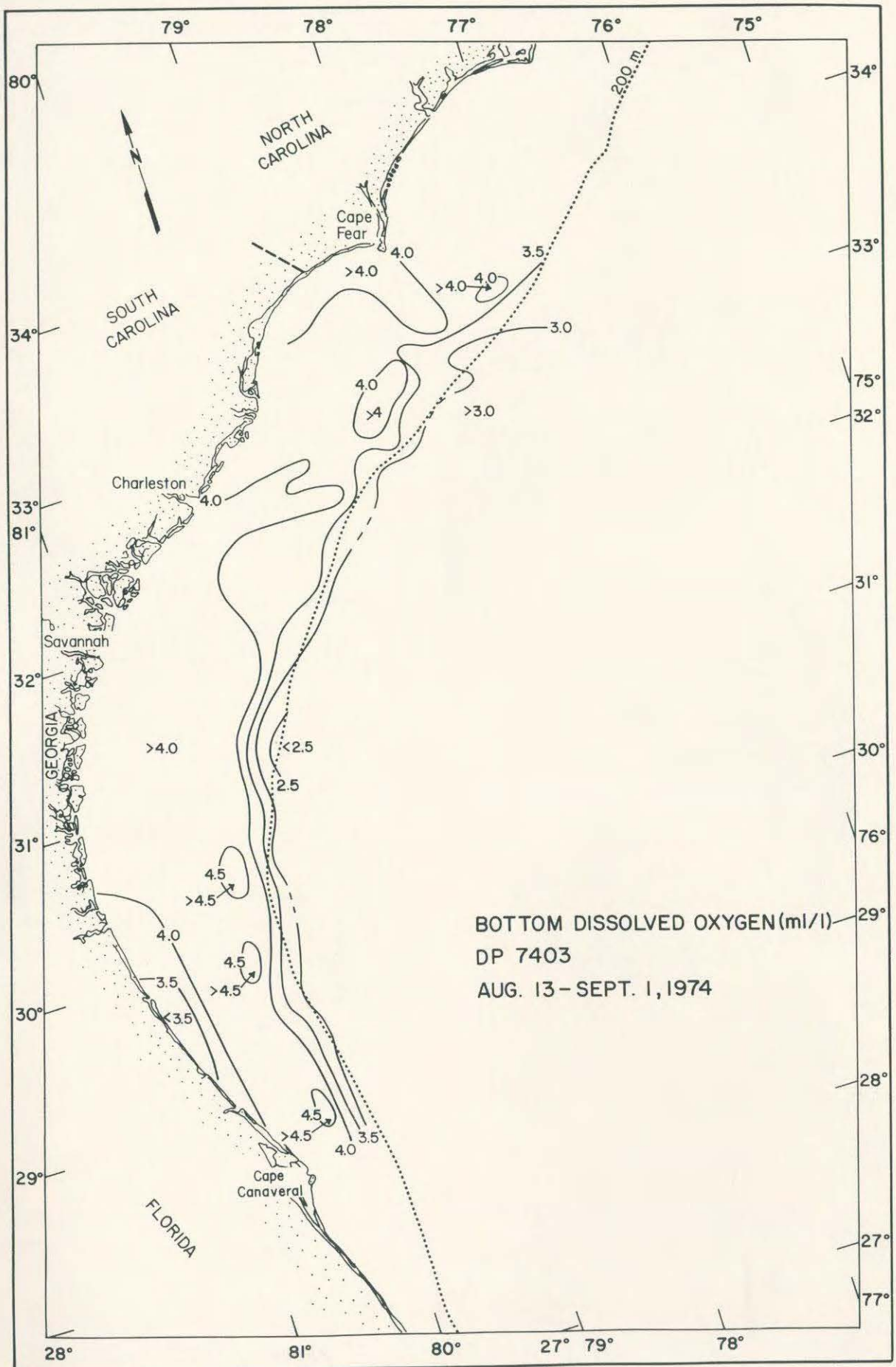


FIGURE 63.

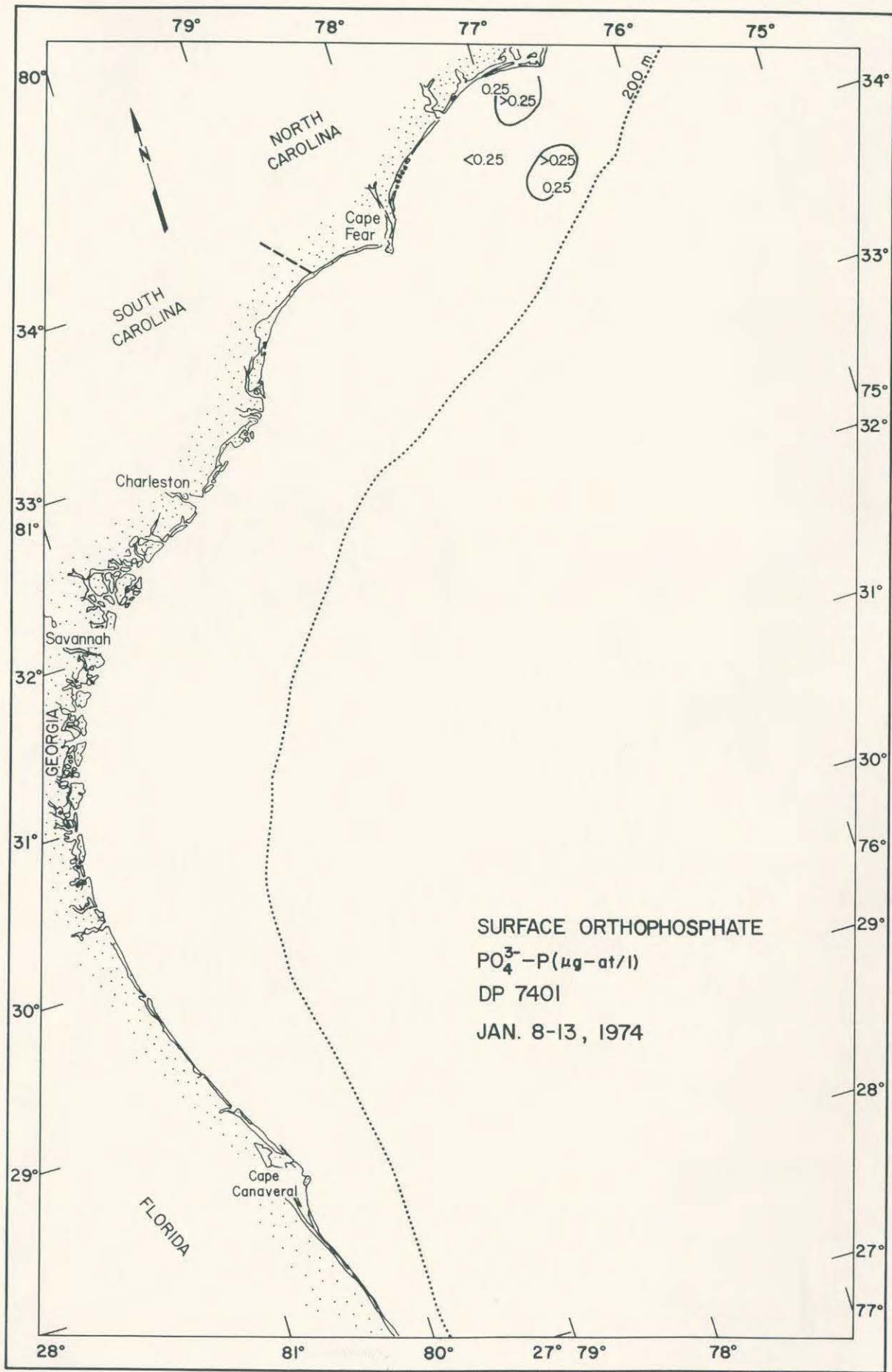


FIGURE 64.

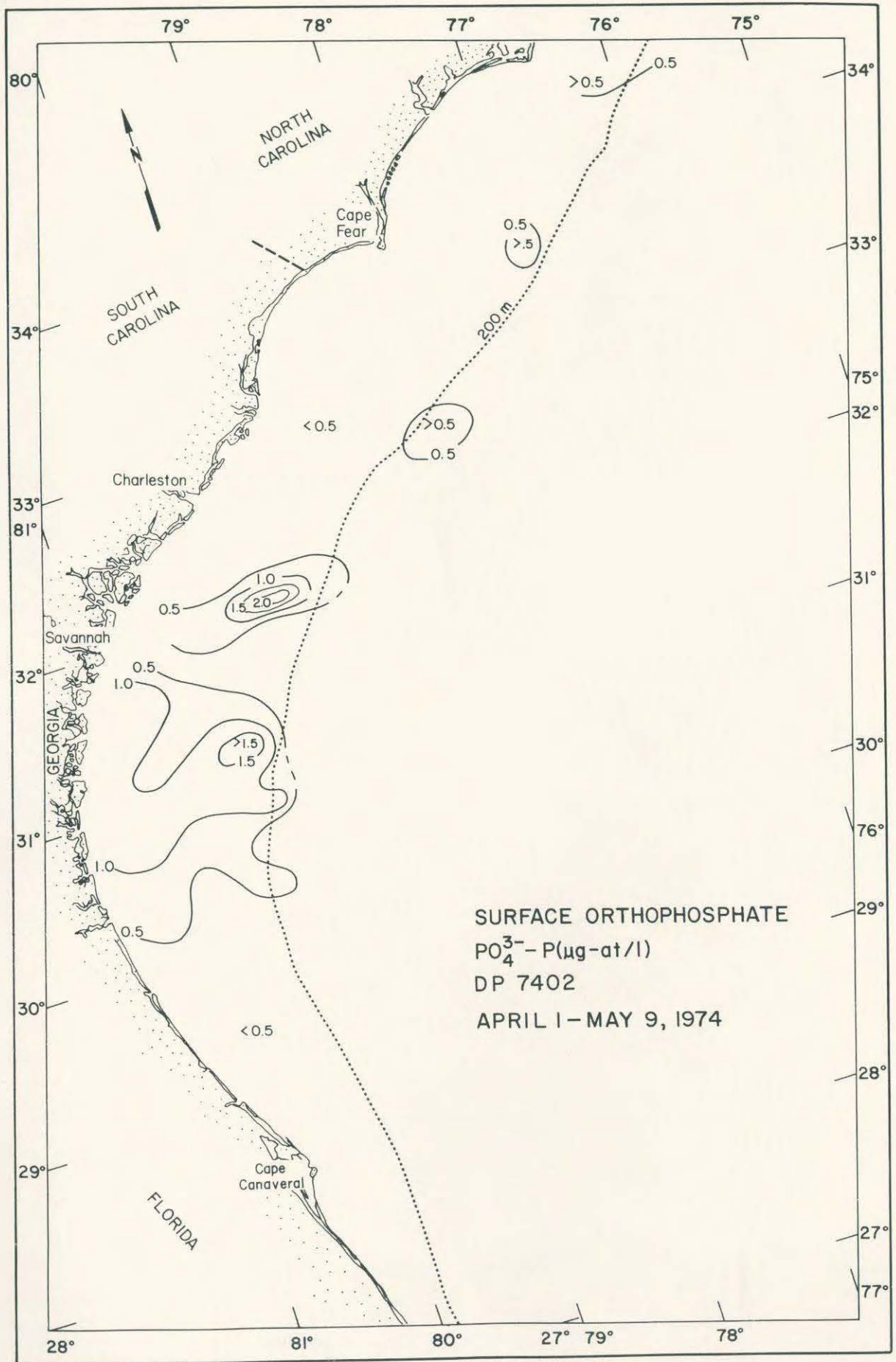


FIGURE 65.

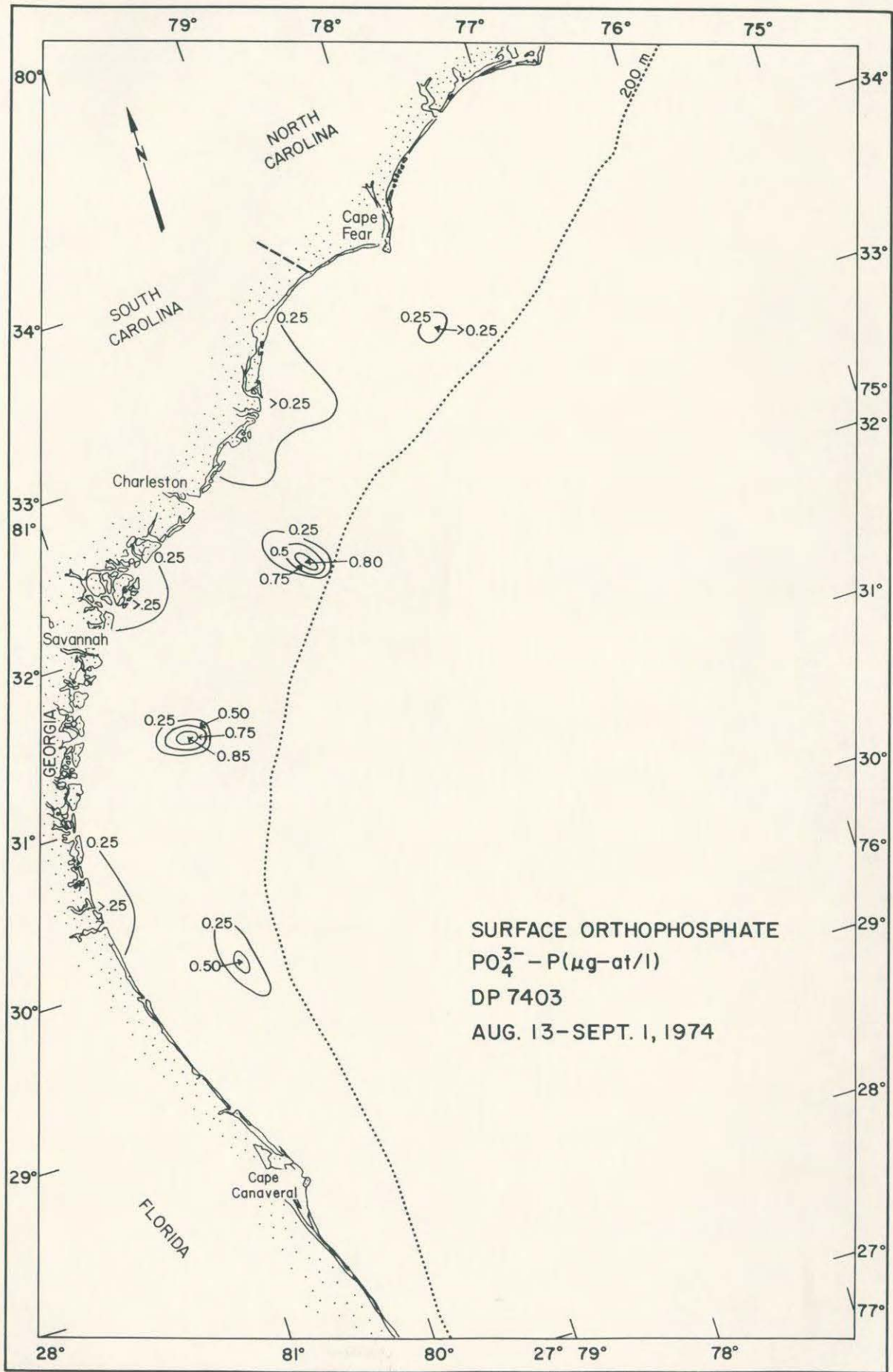


FIGURE 66.

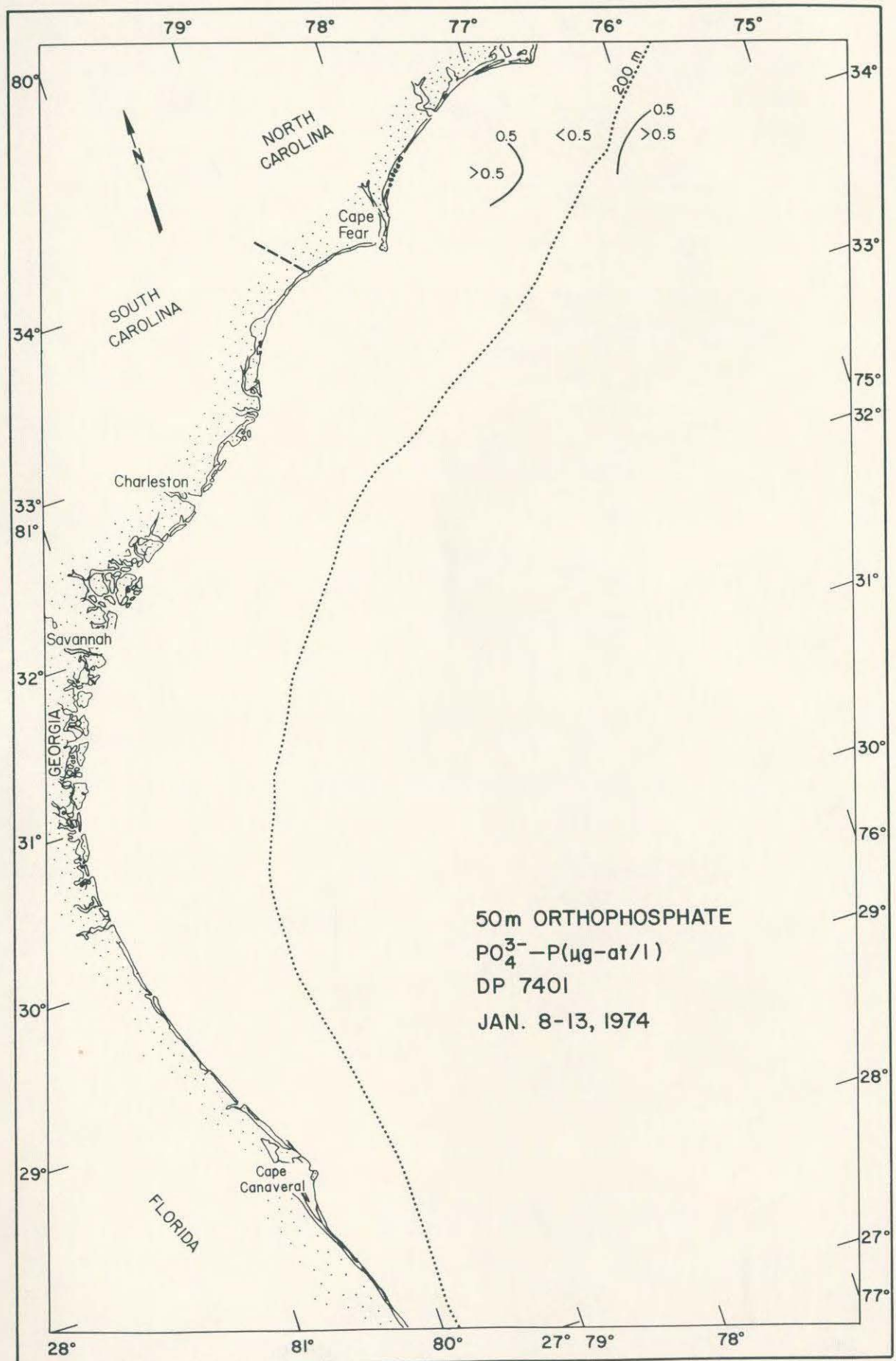


FIGURE 67.

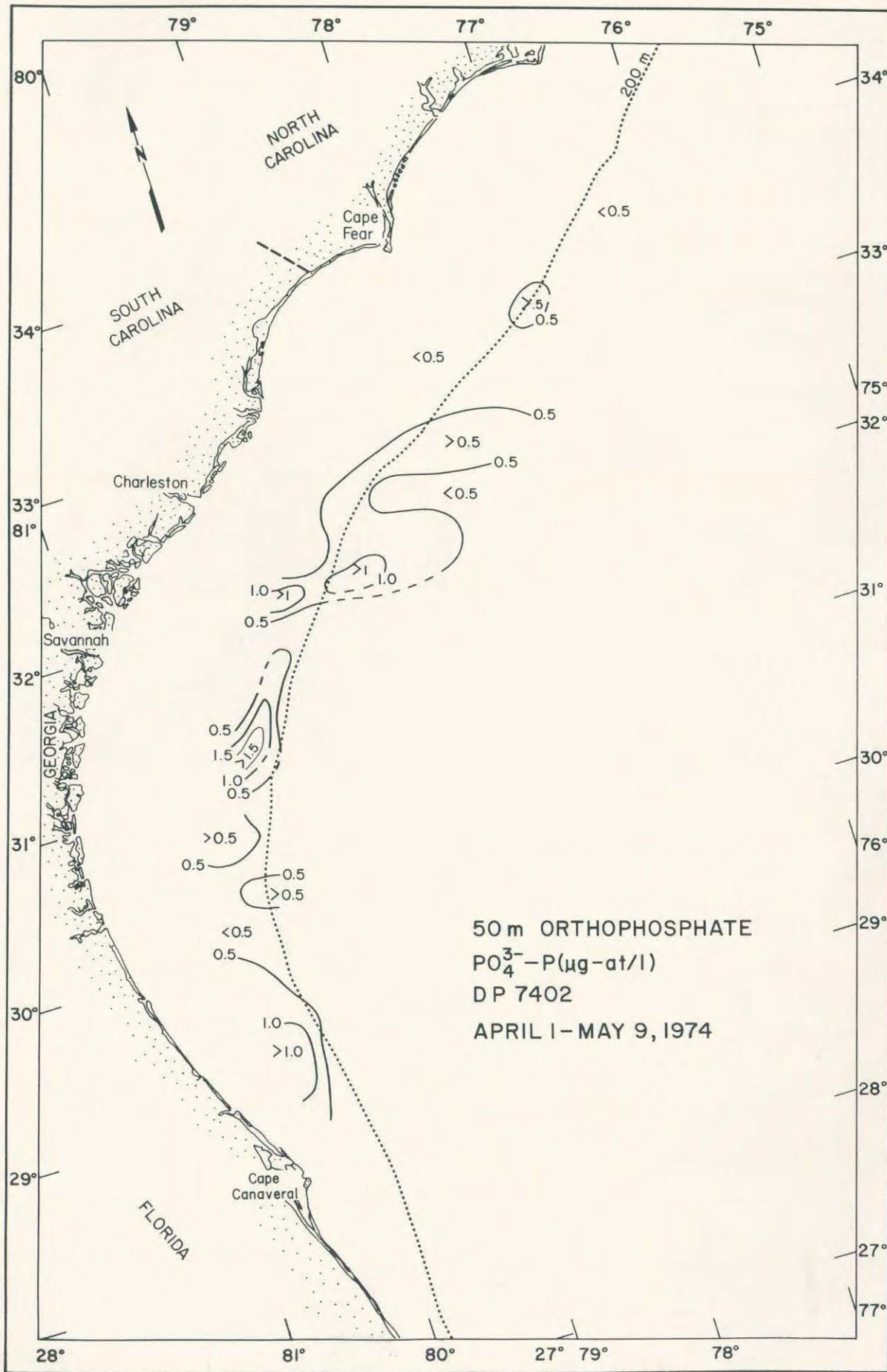


FIGURE 68.

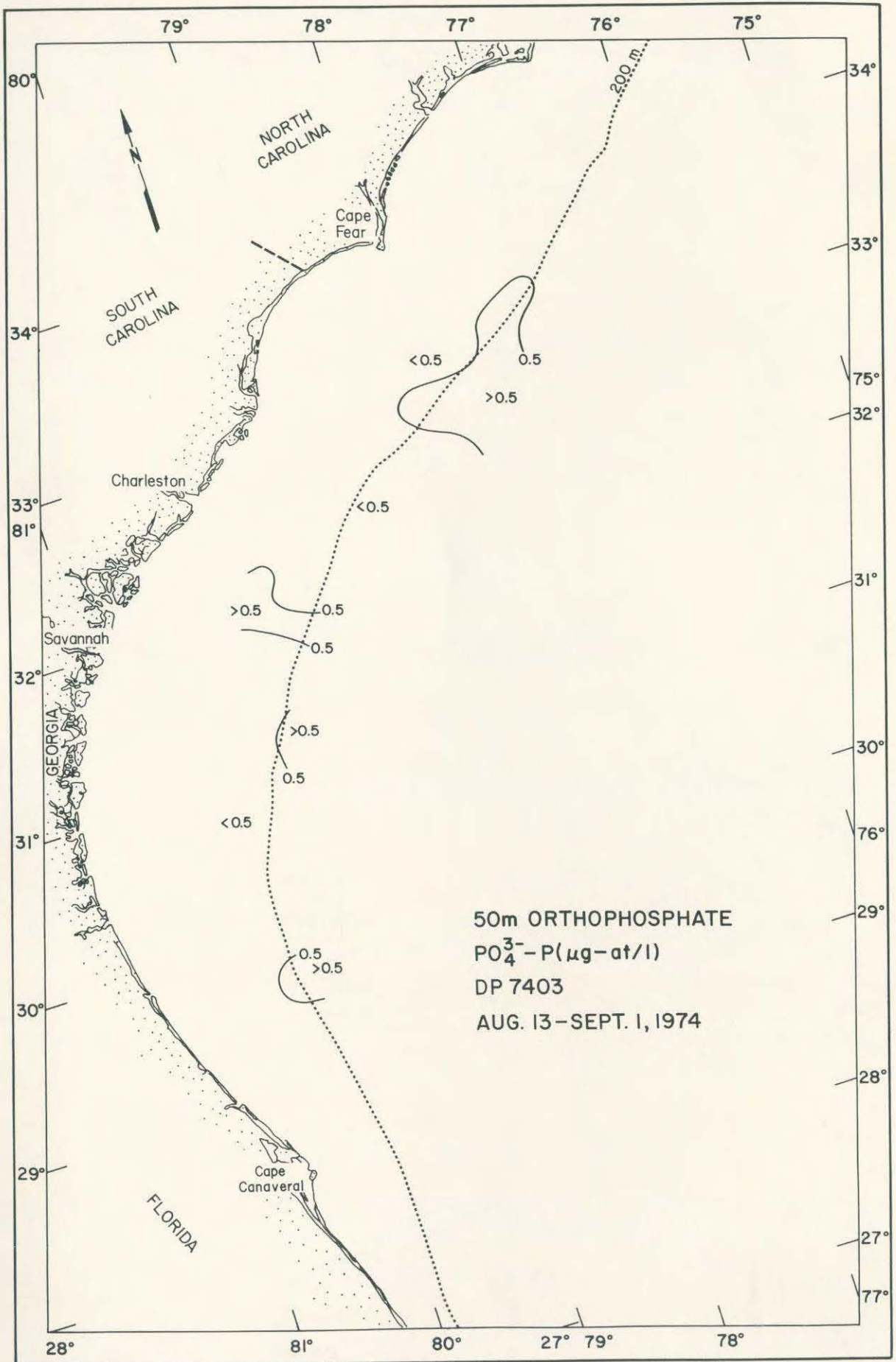


FIGURE 69.

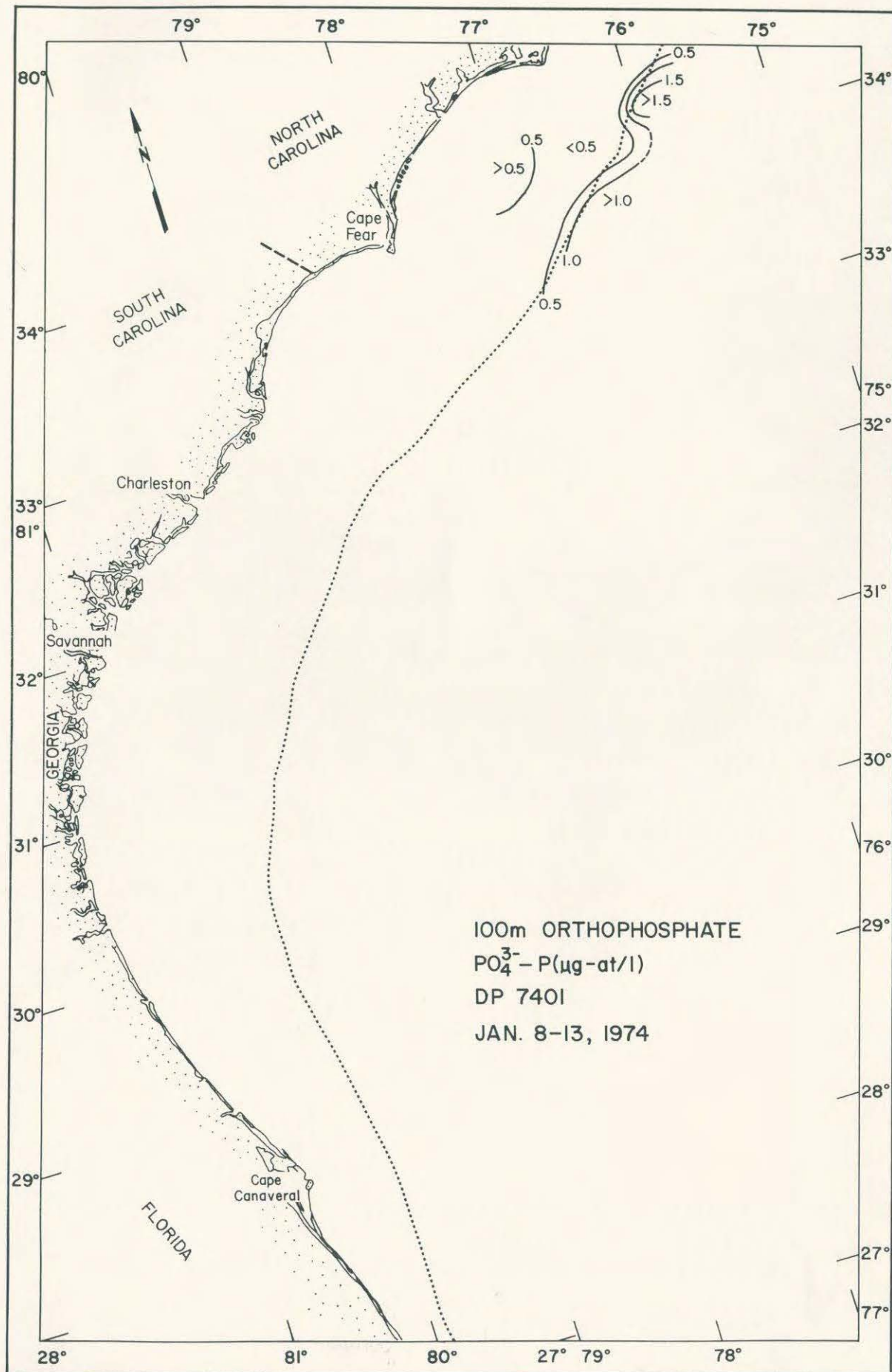


FIGURE 70.

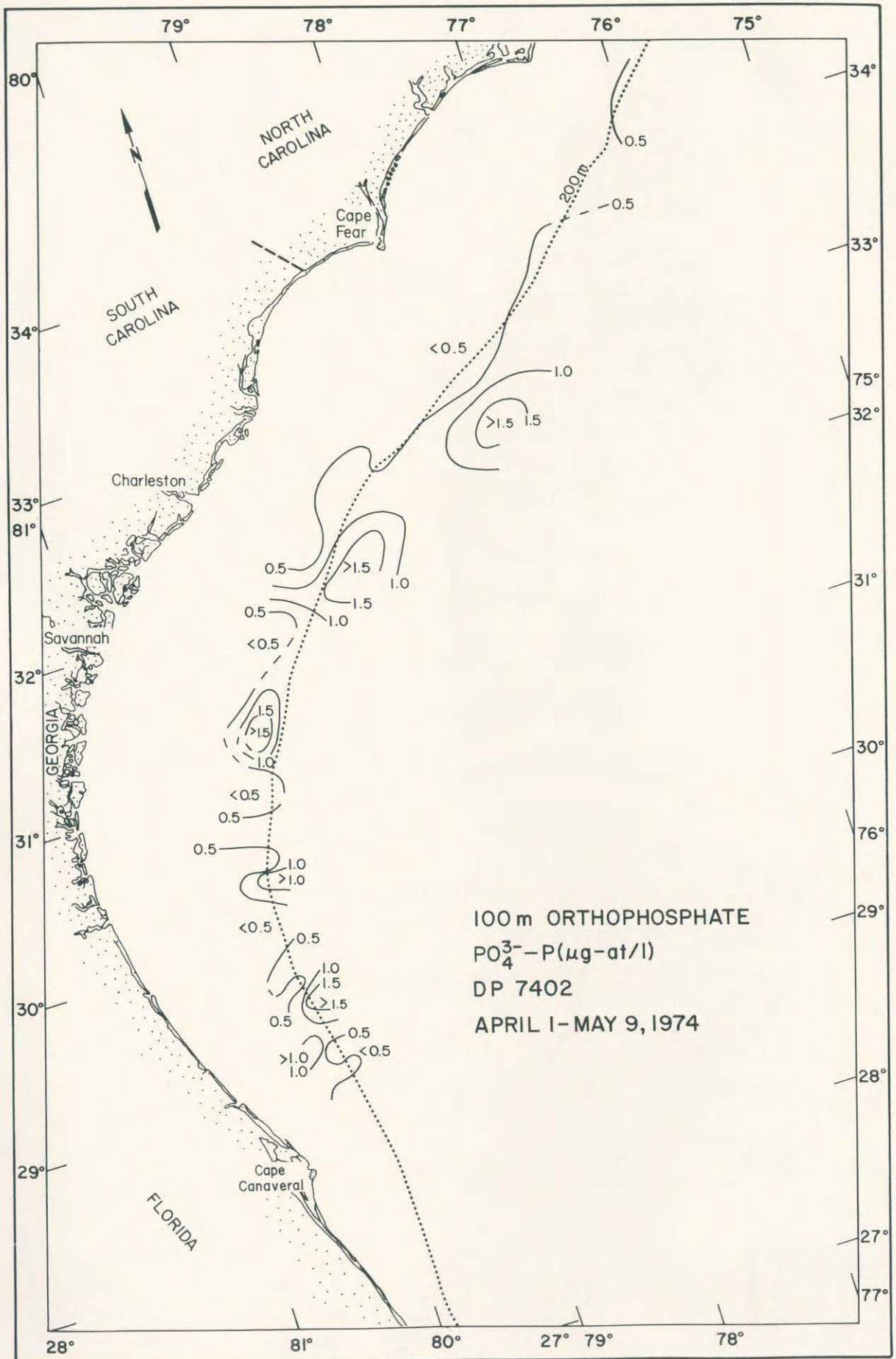


FIGURE 71.

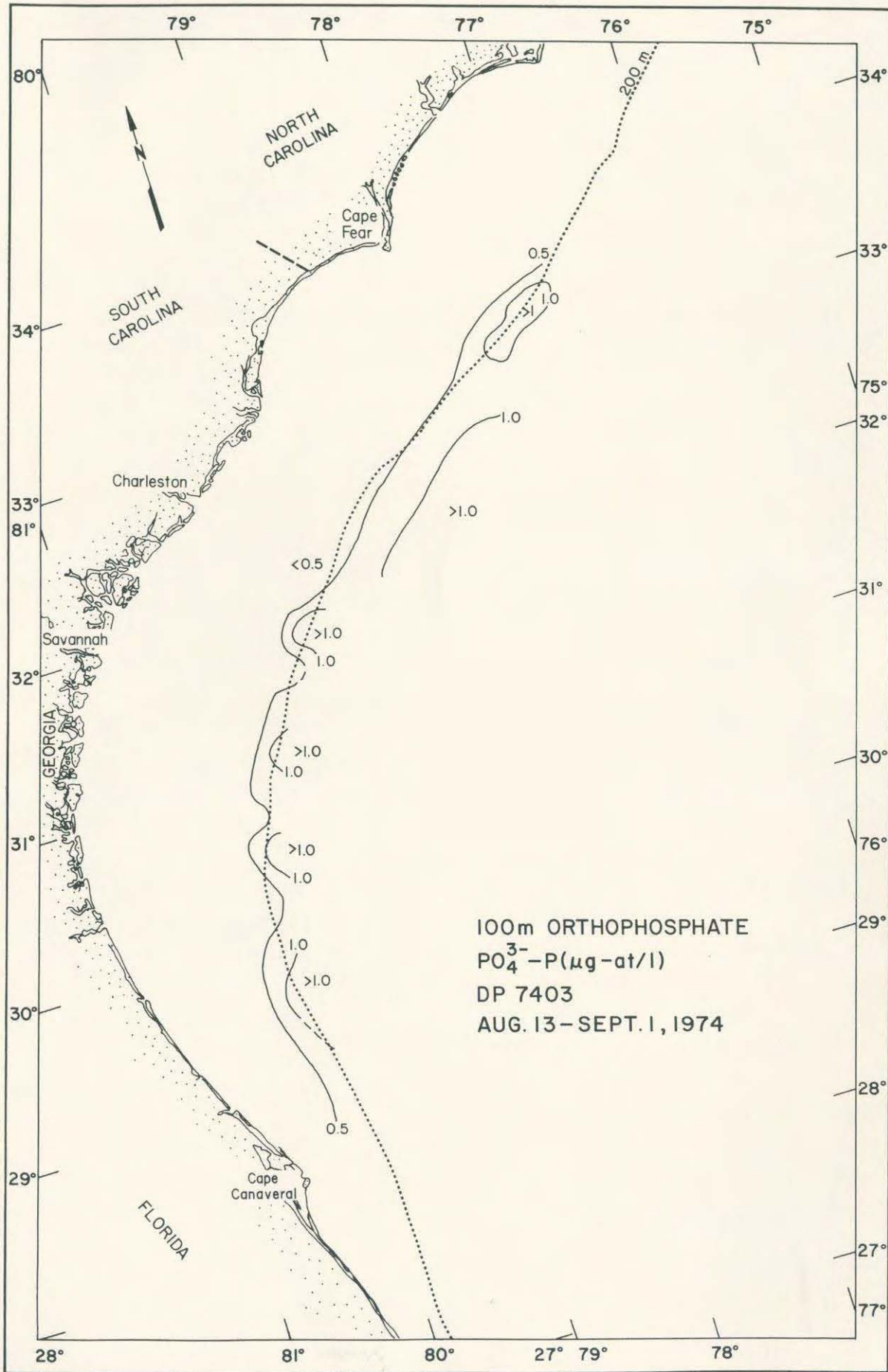


FIGURE 72.

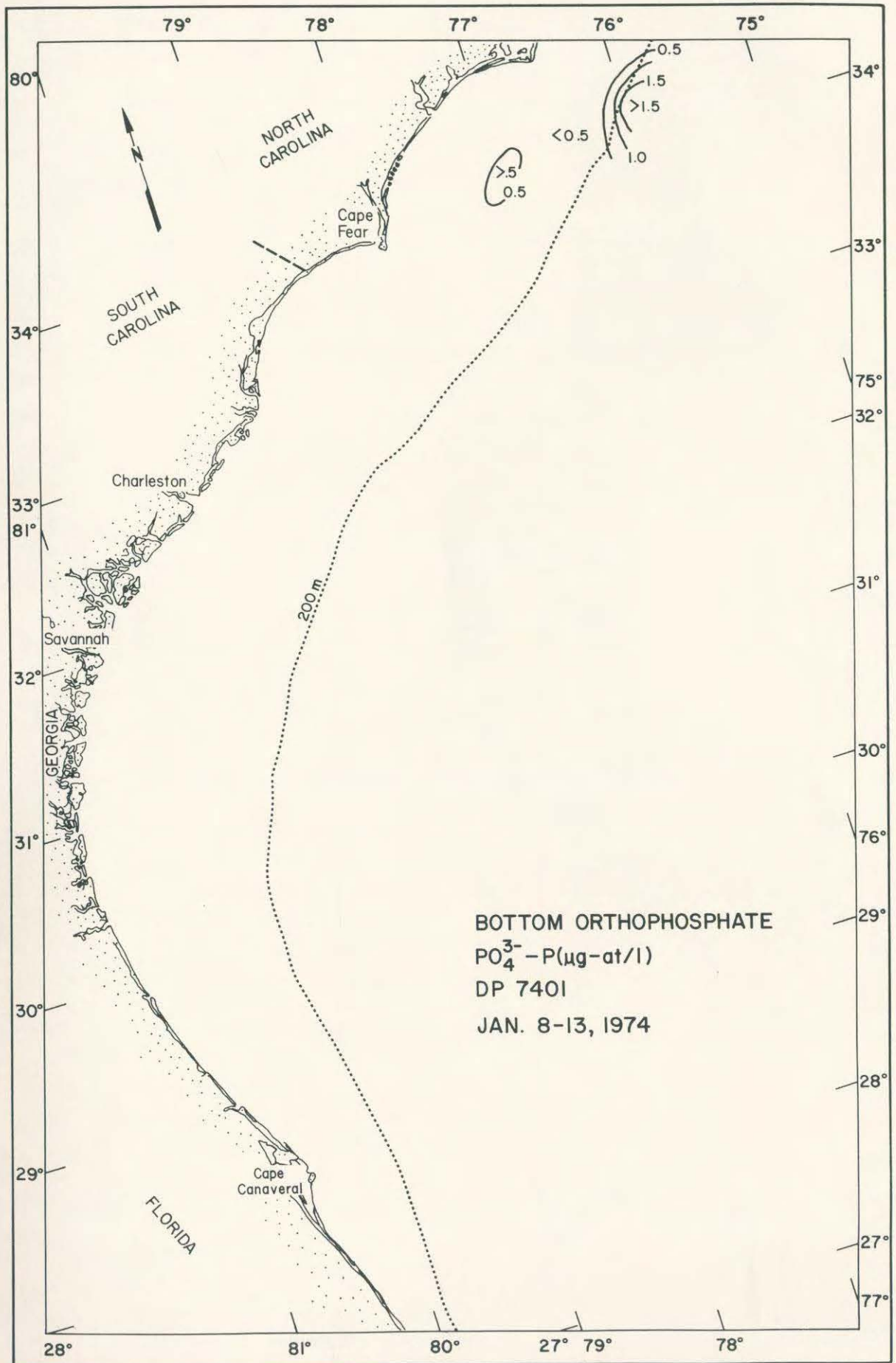


FIGURE 73.

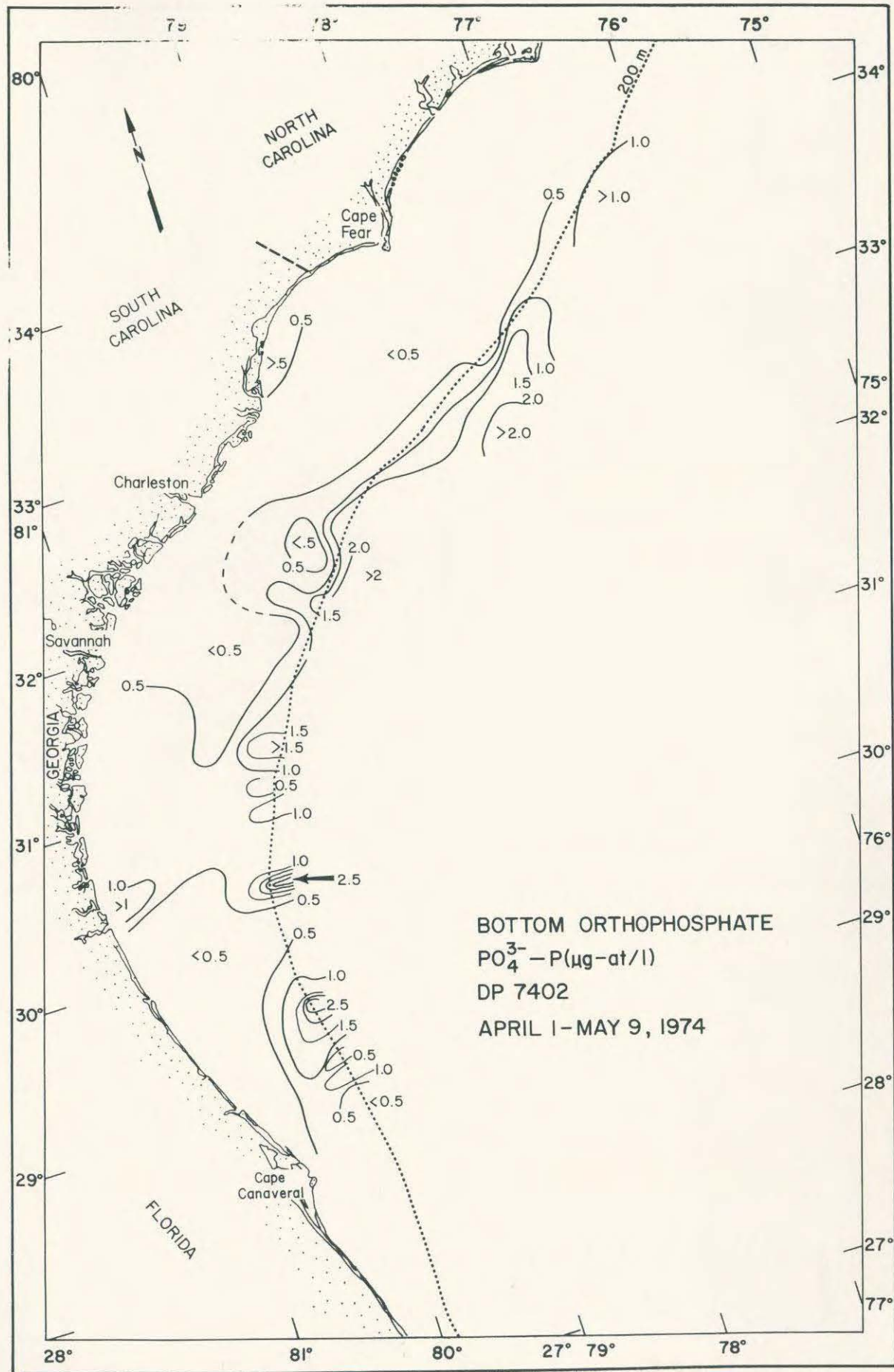


FIGURE 74.

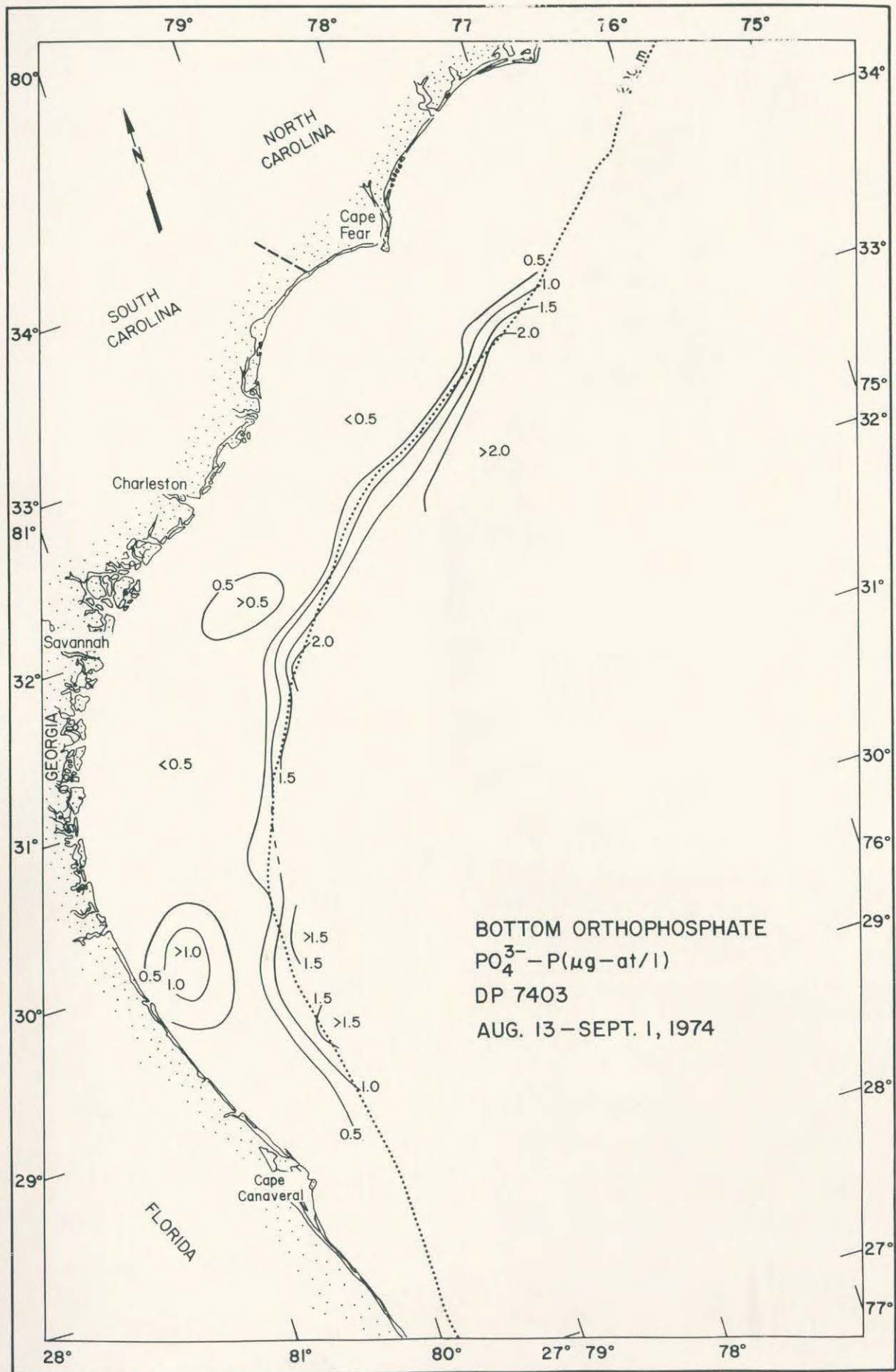


FIGURE 75.

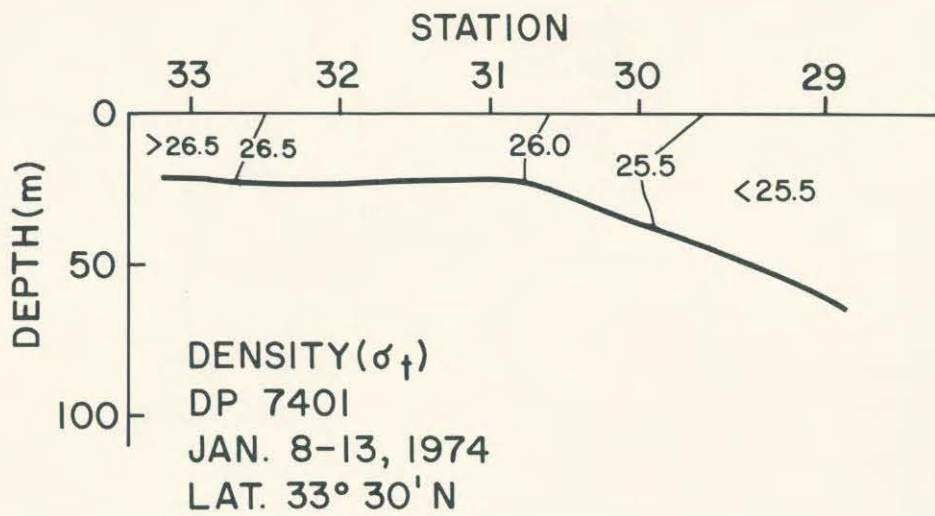
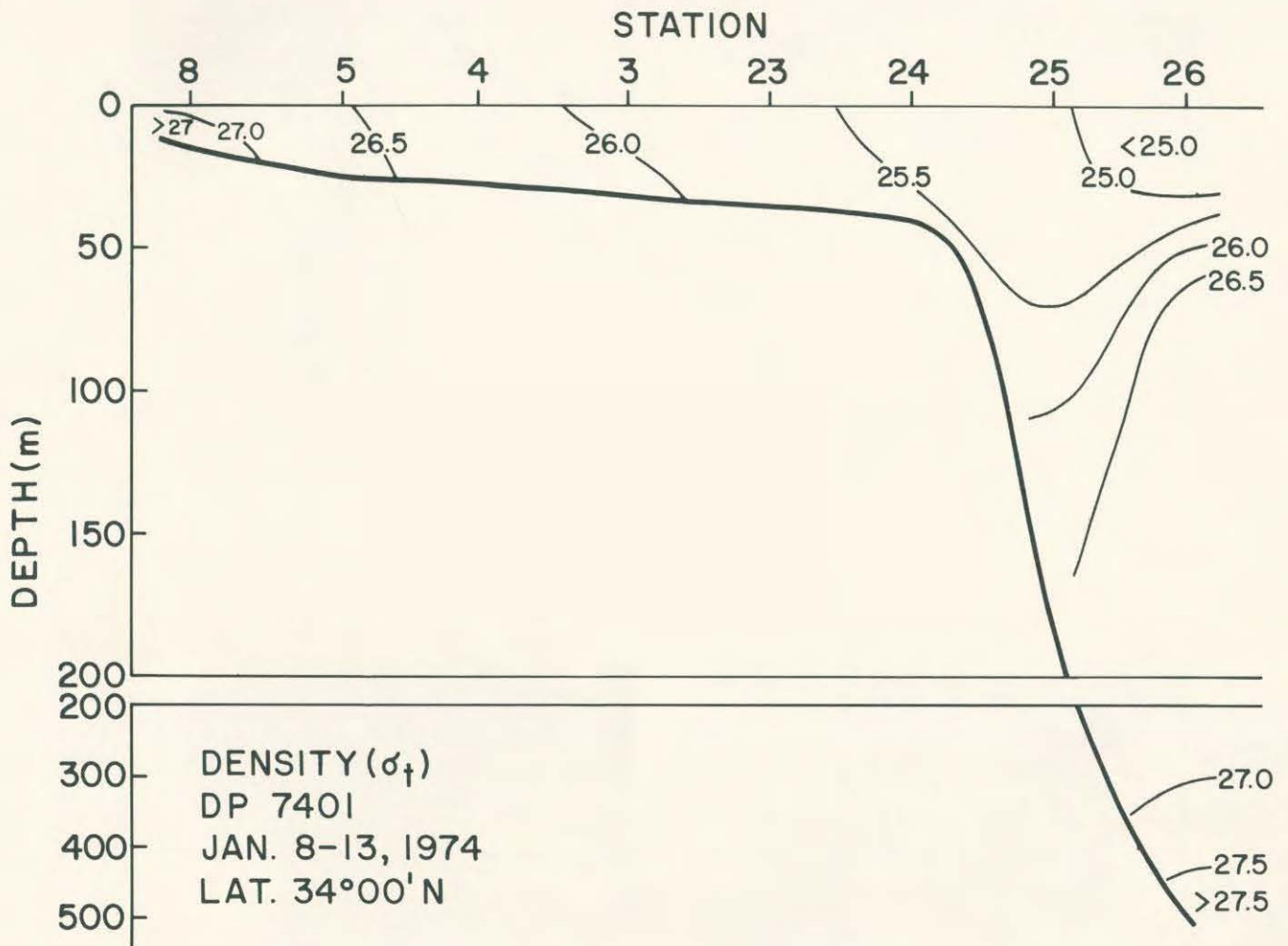


FIGURE 76.

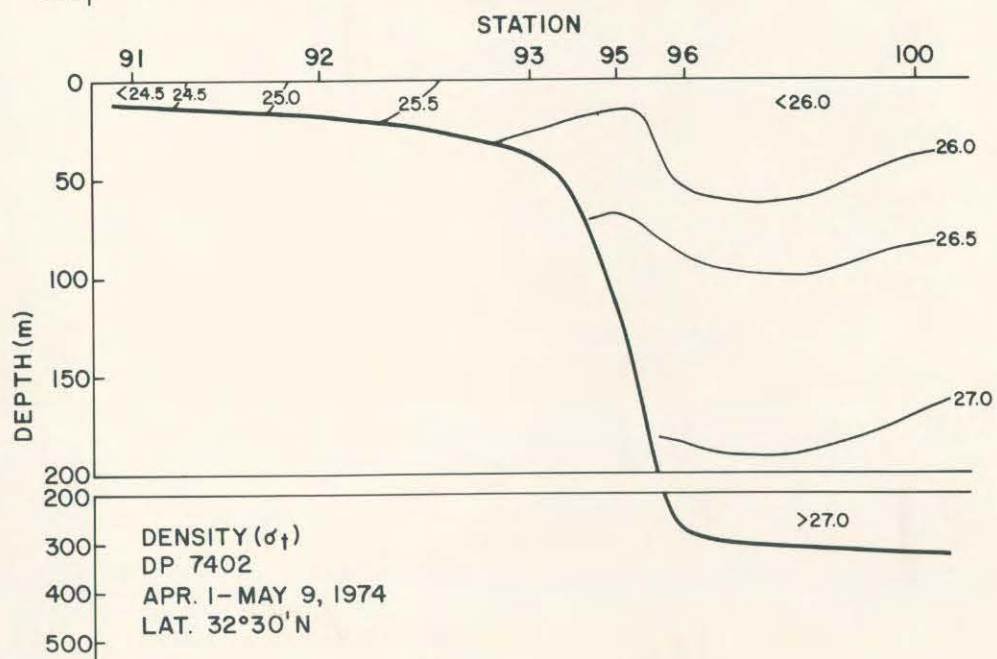
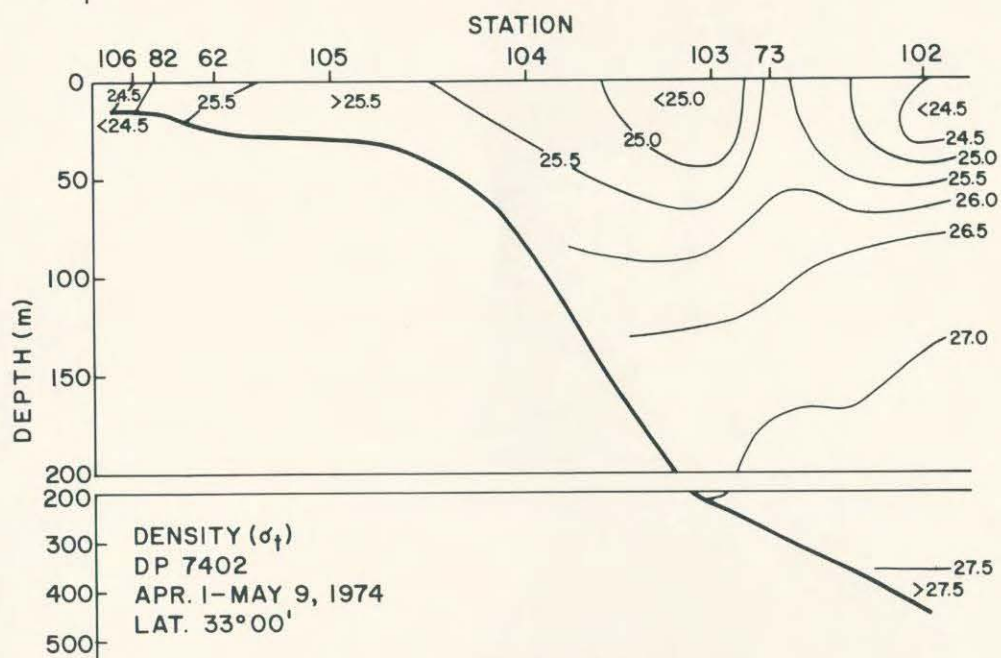
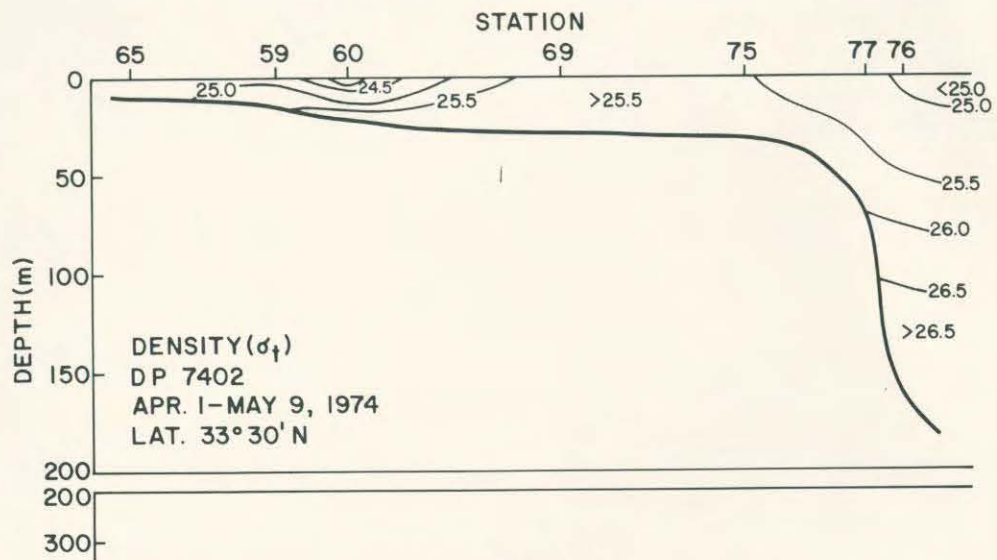


FIGURE 77.

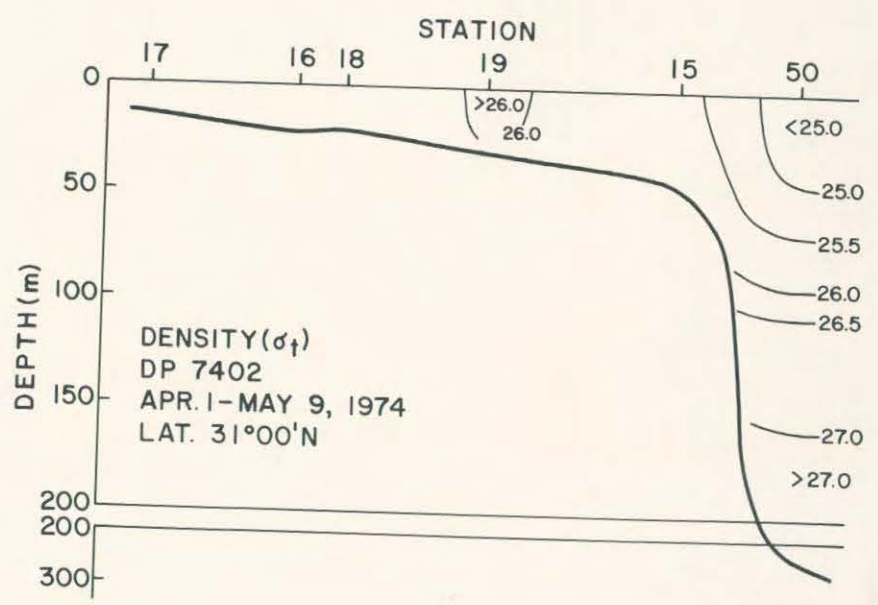
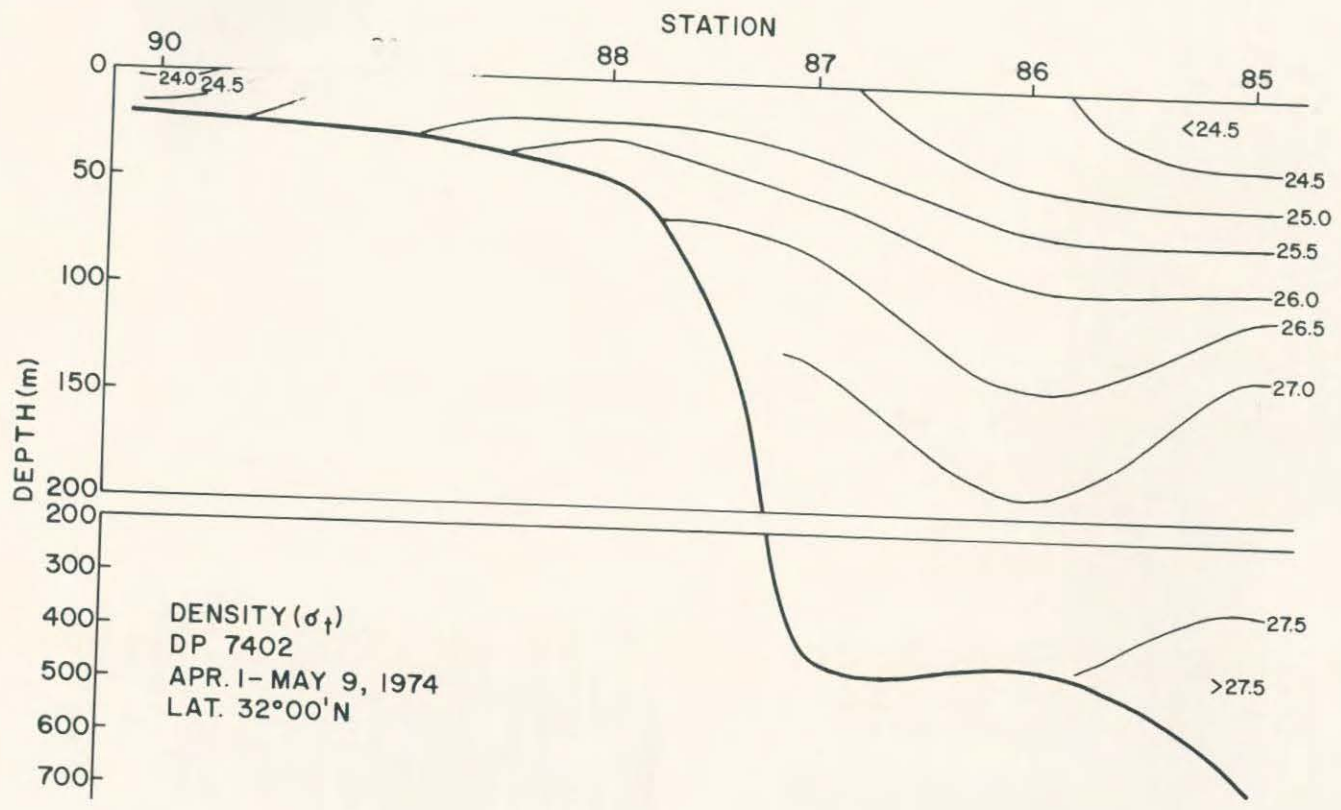


FIGURE 78.

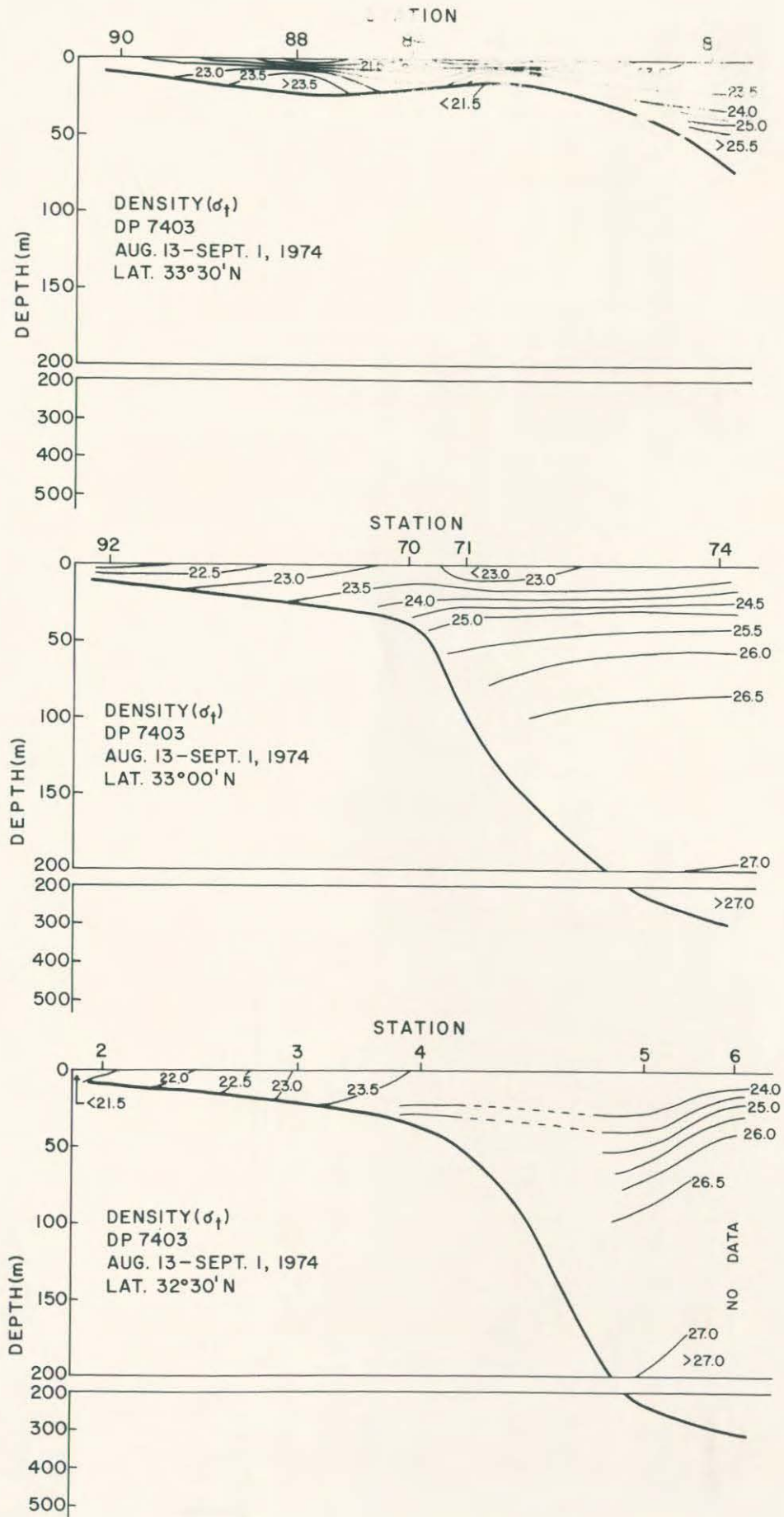


FIGURE 79.

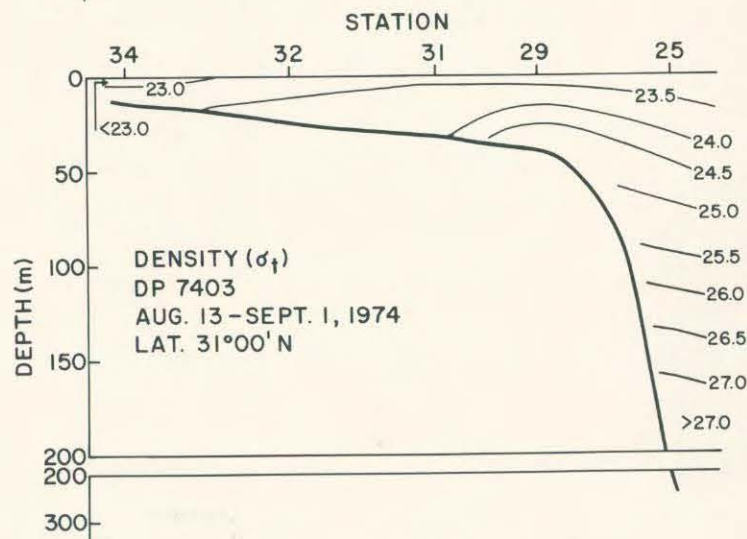
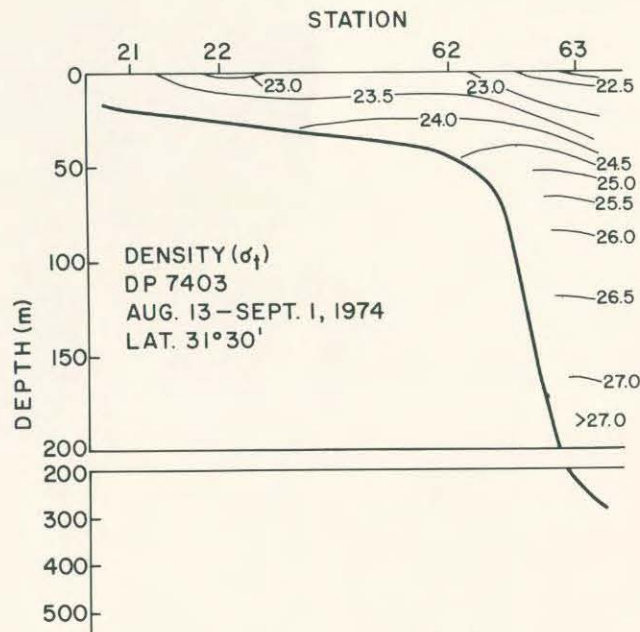
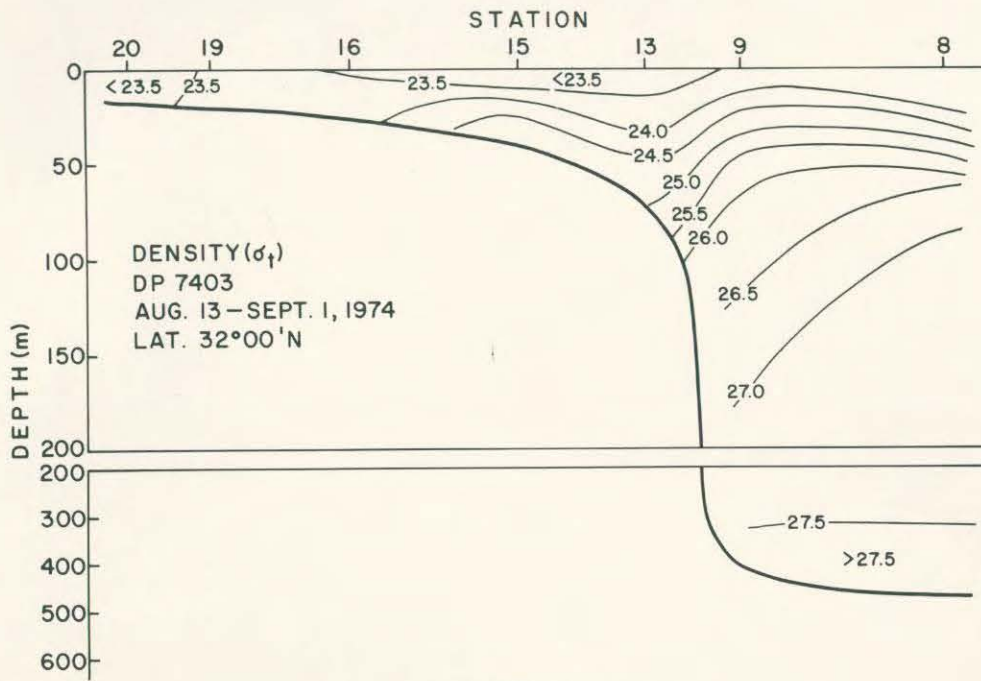


FIGURE 80.

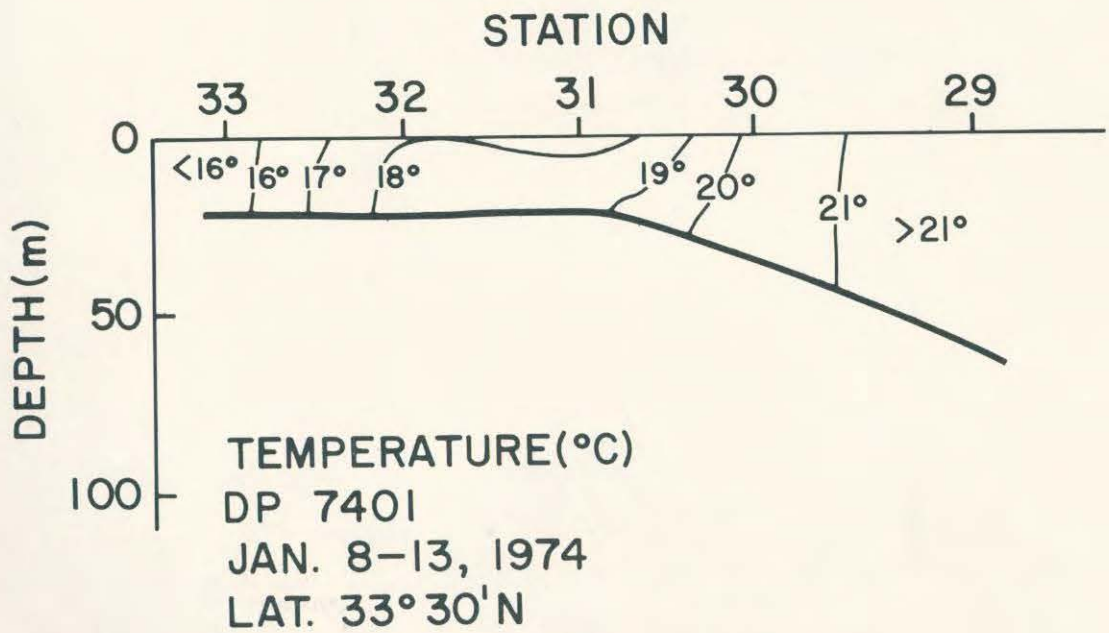
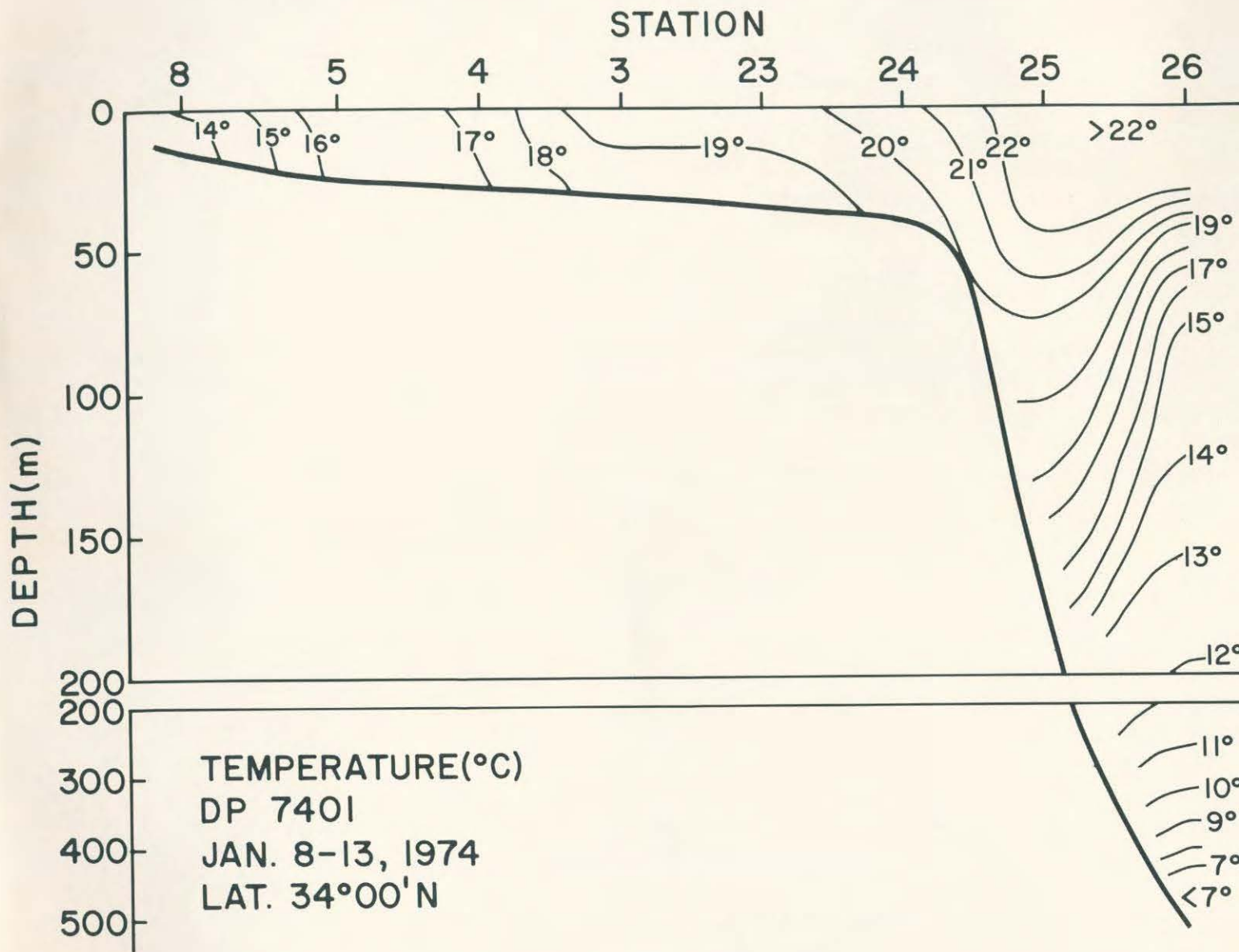


FIGURE 81.

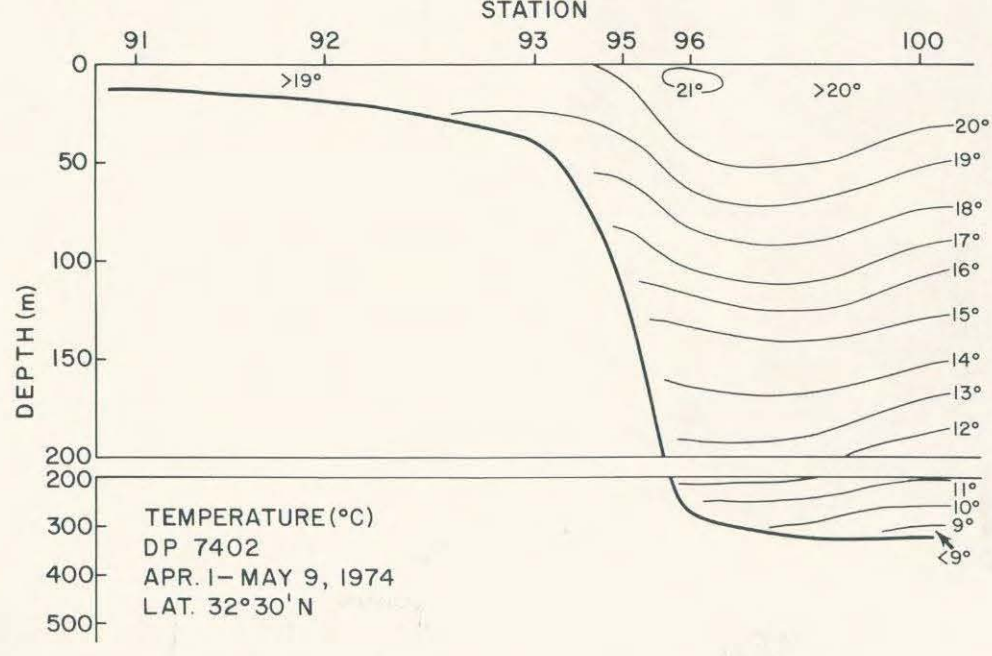
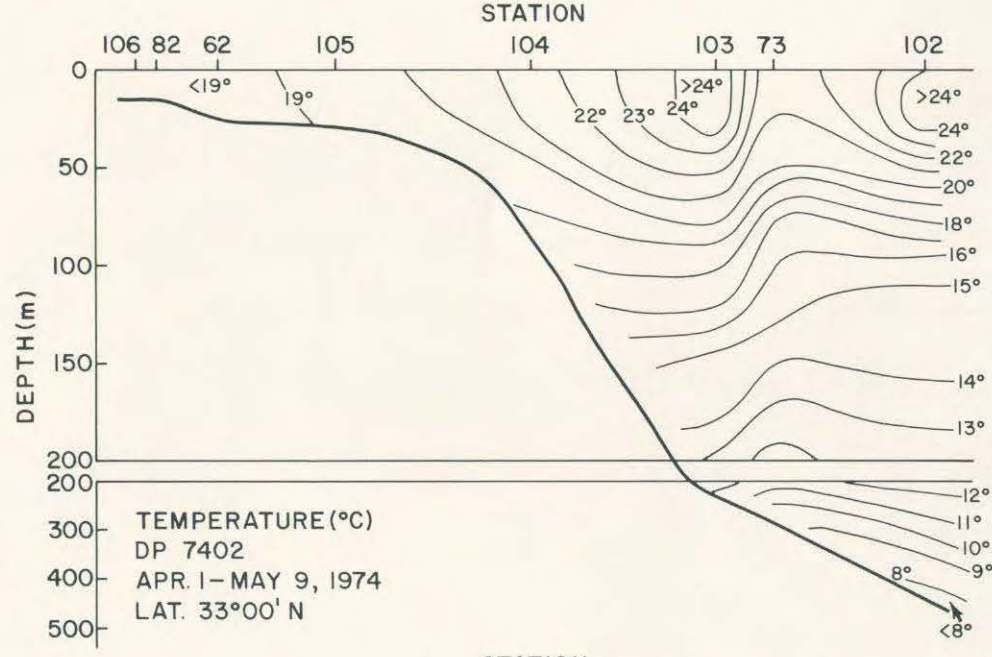
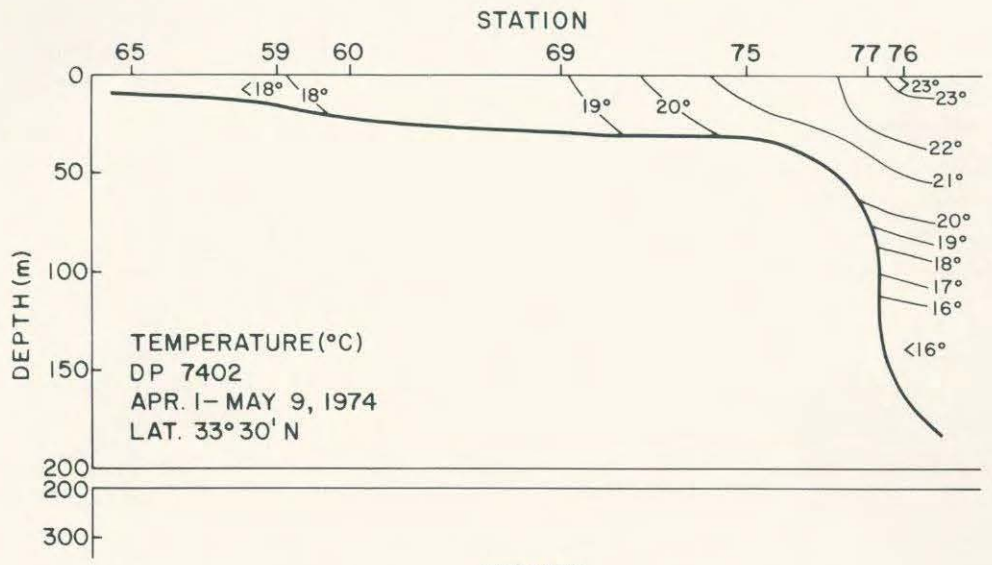


FIGURE 82.

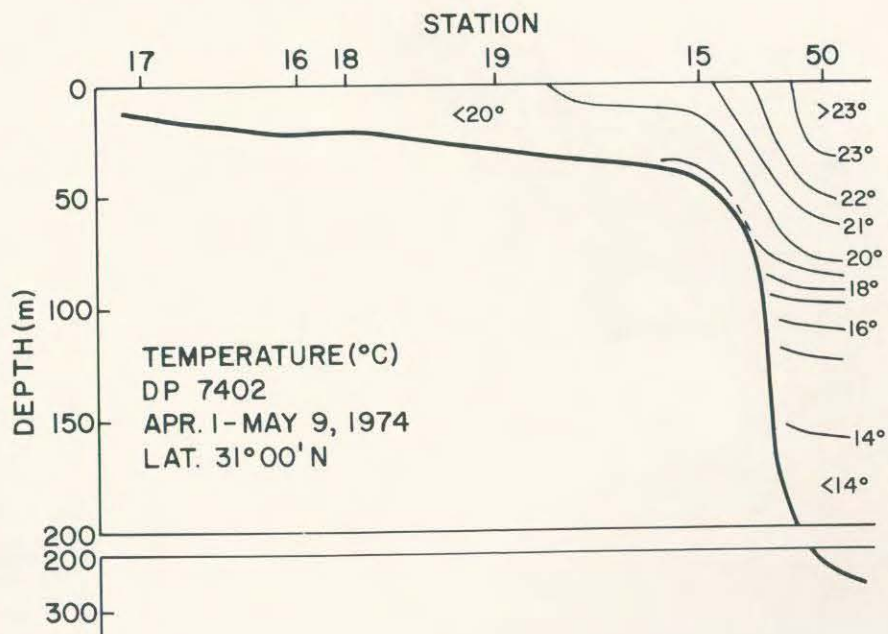
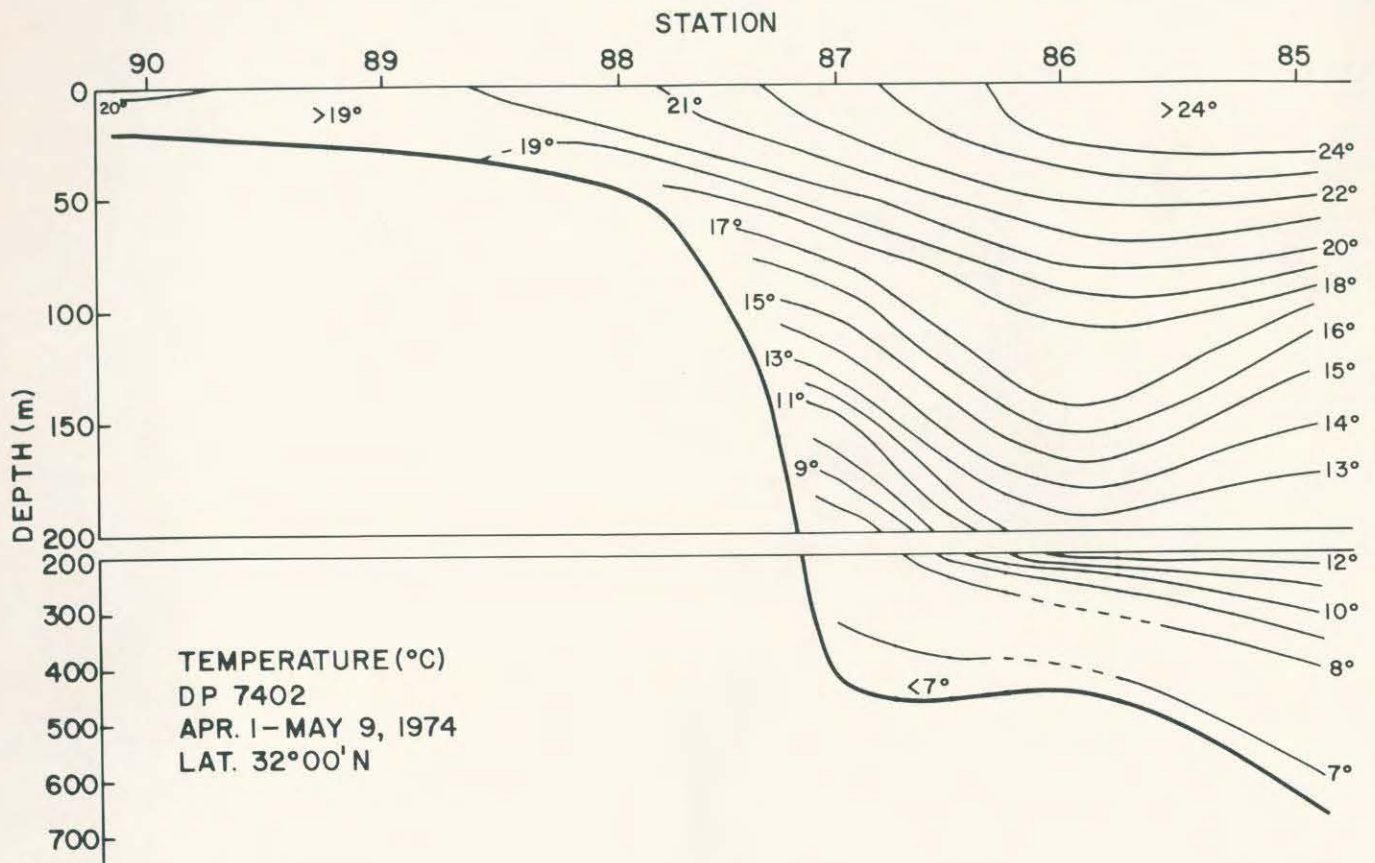


FIGURE 83.

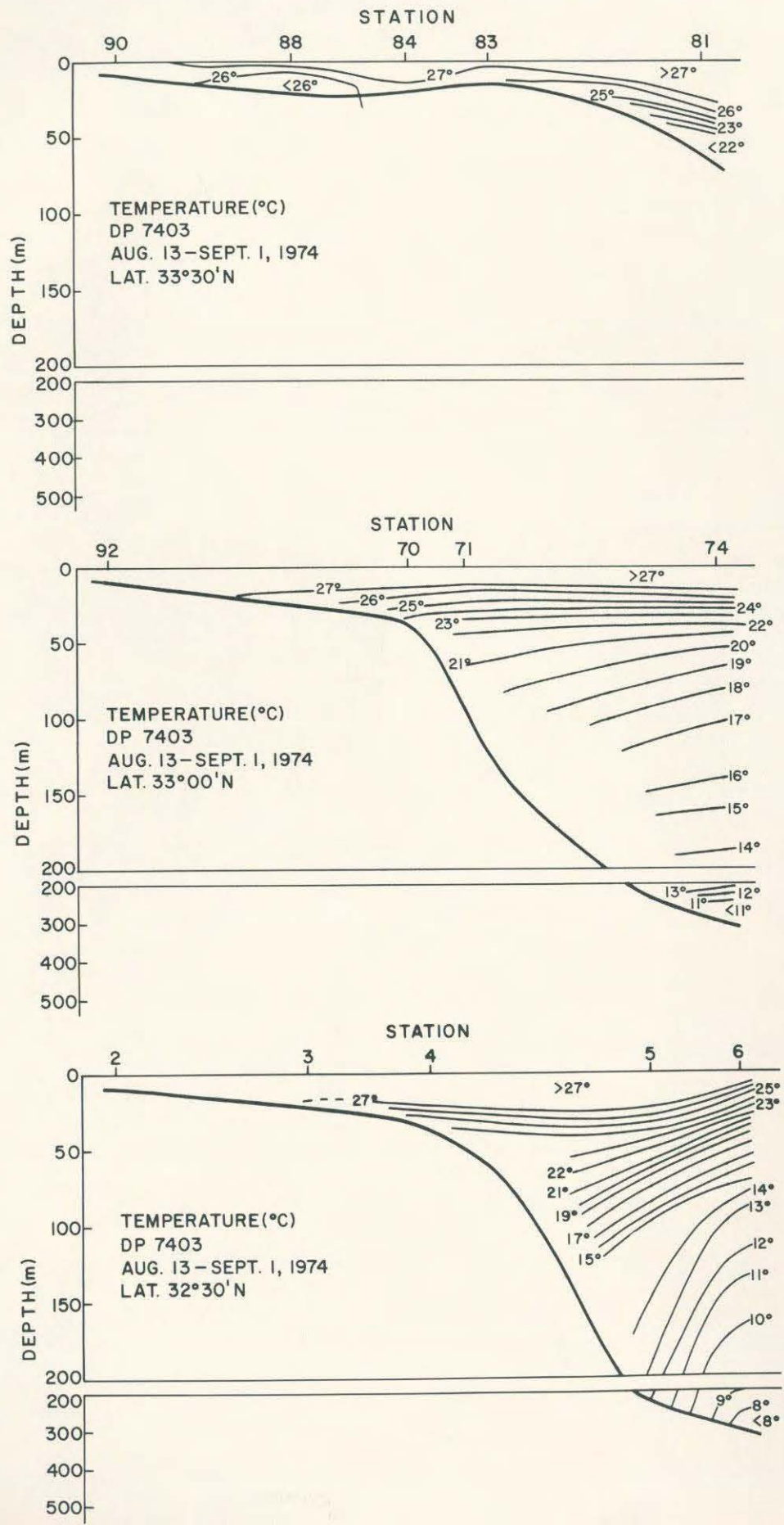


FIGURE 84.

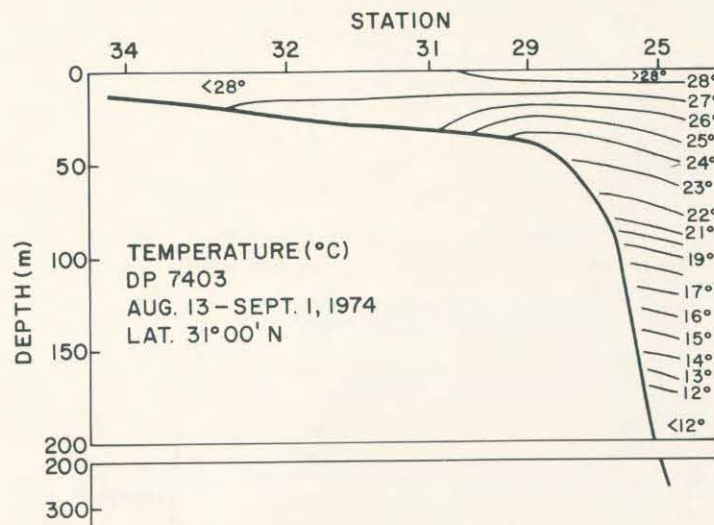
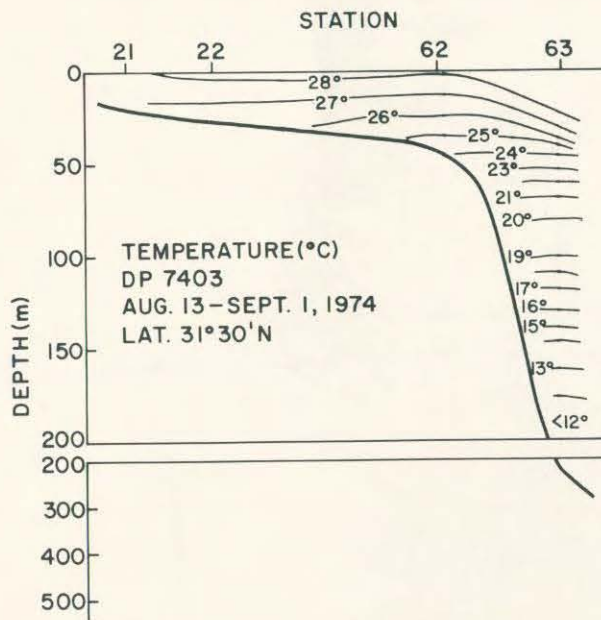
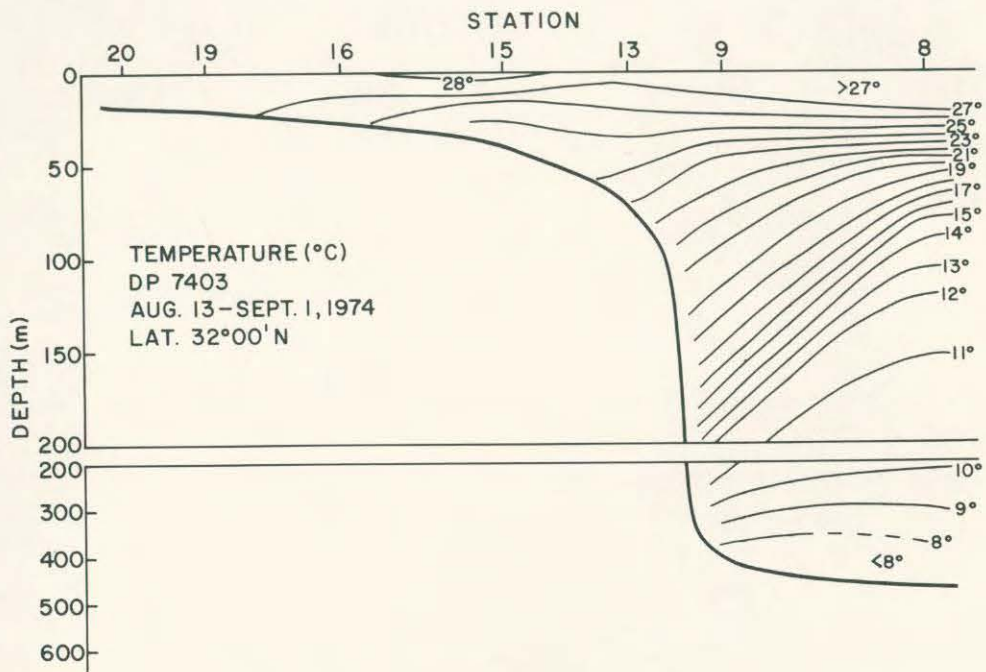


FIGURE 85.

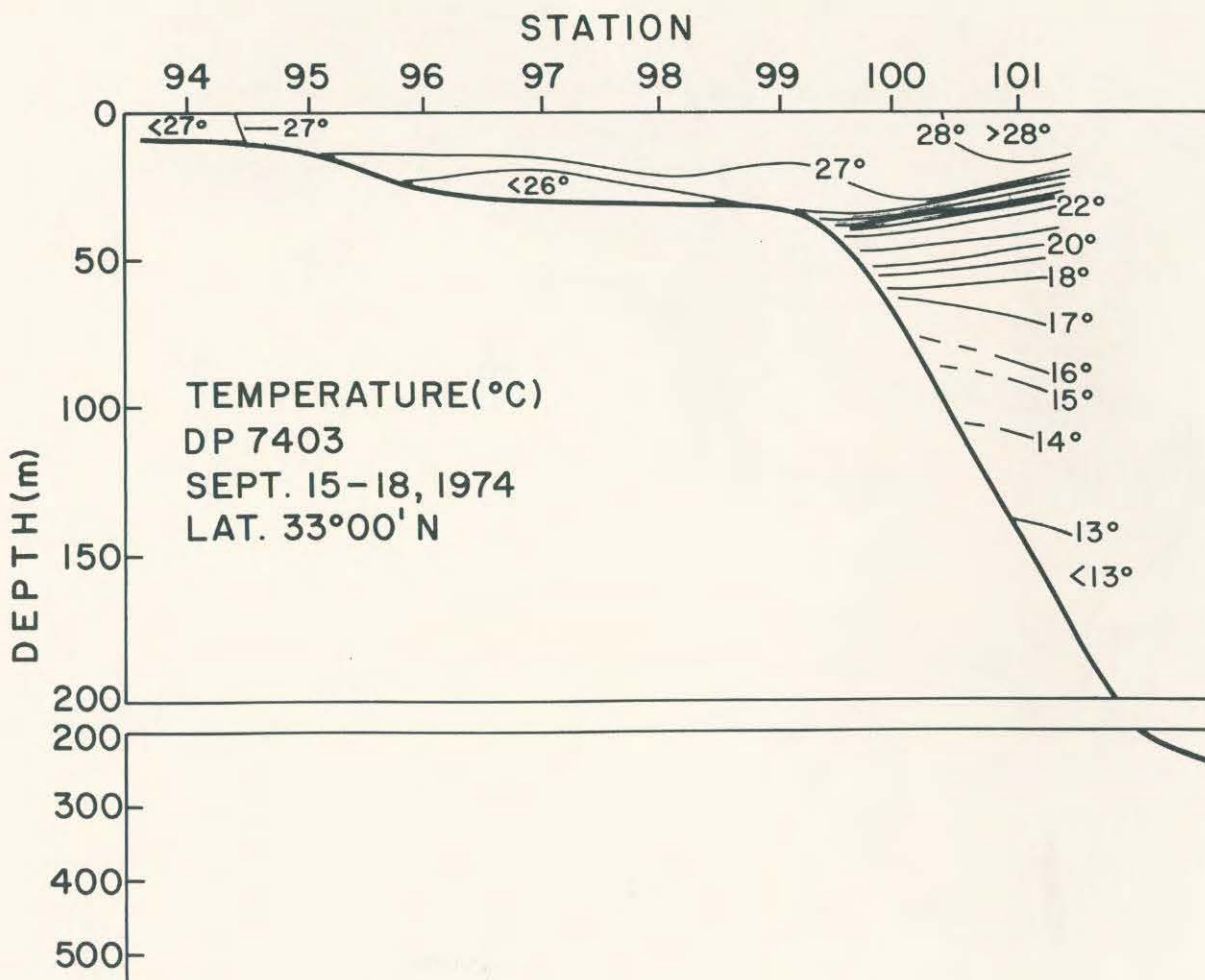
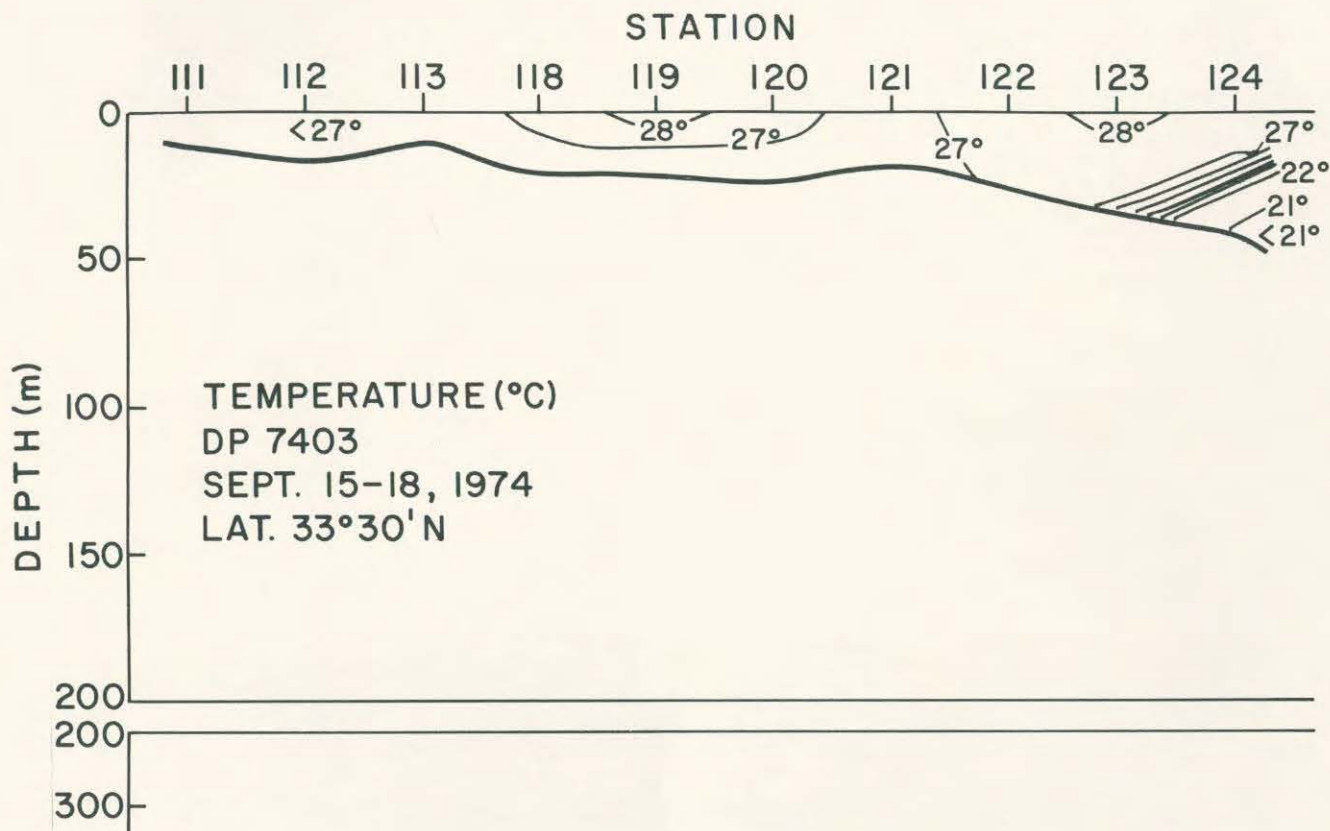


FIGURE 86.

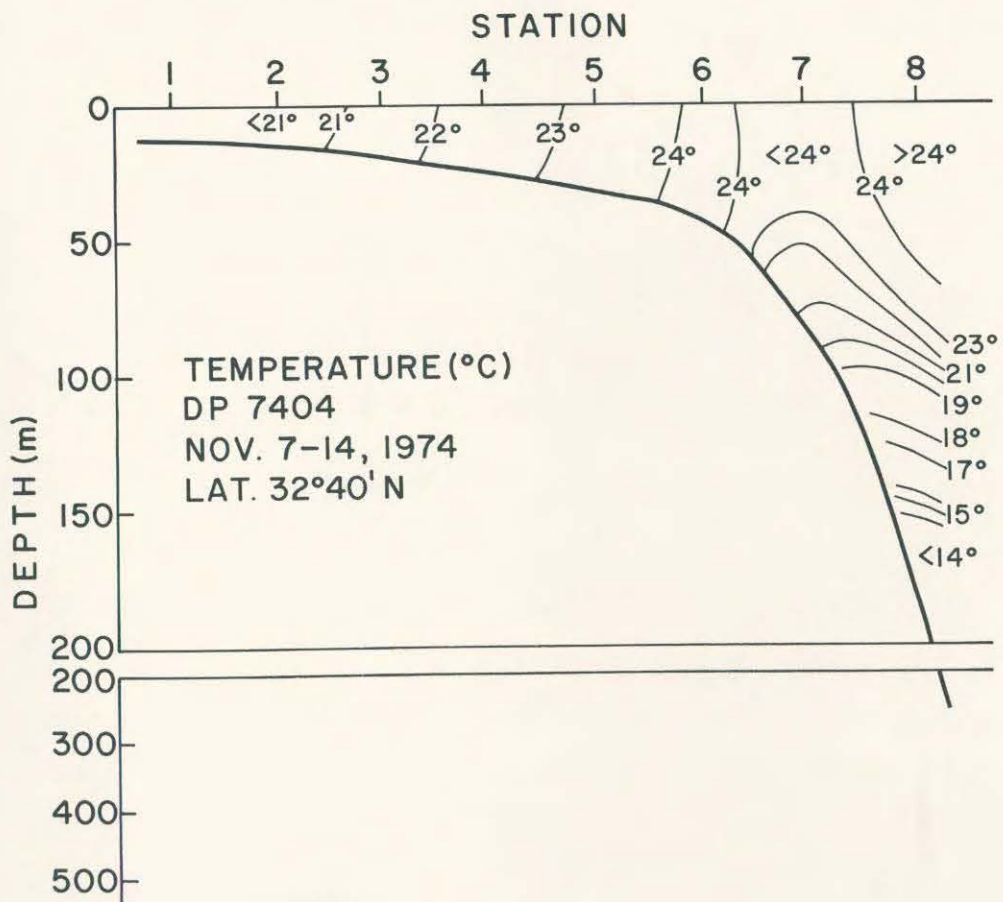
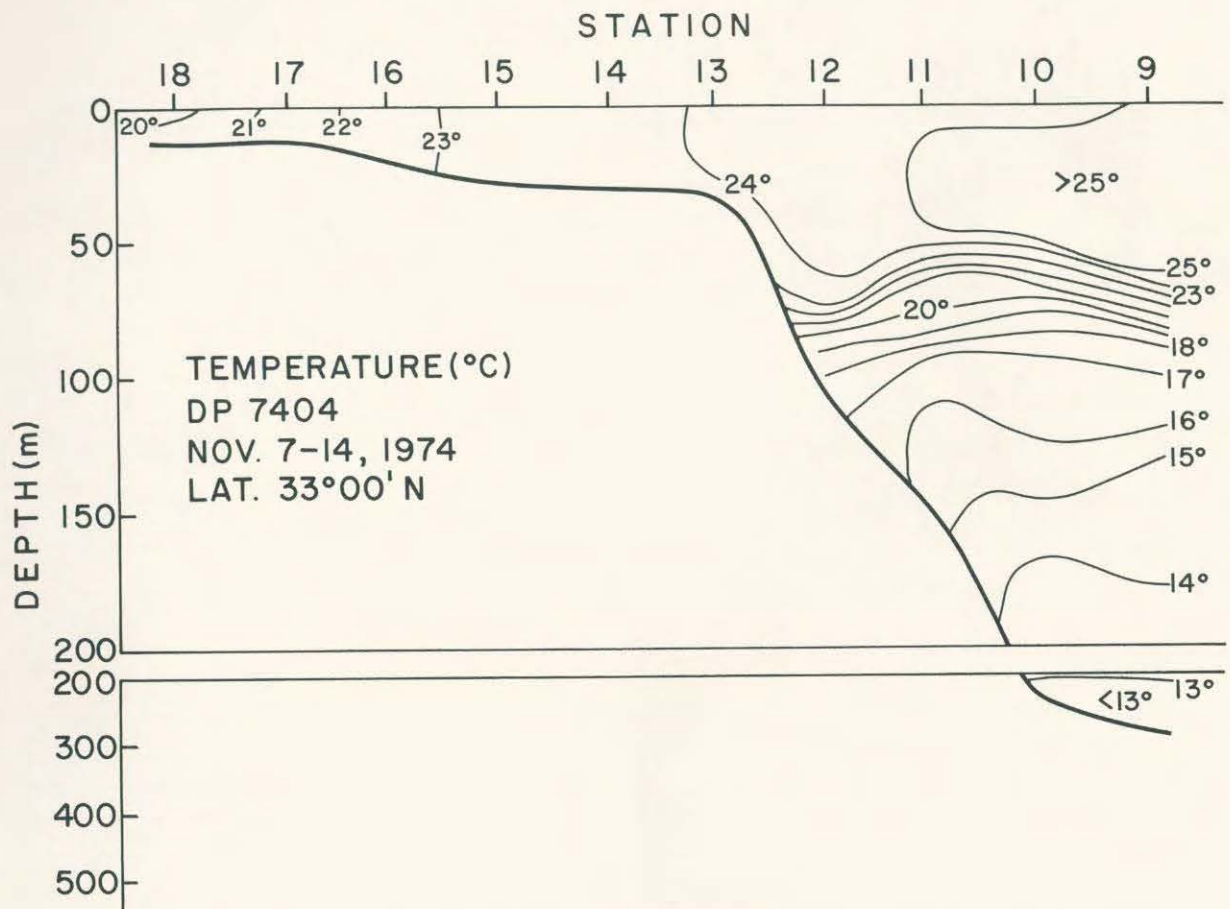


FIGURE 87.

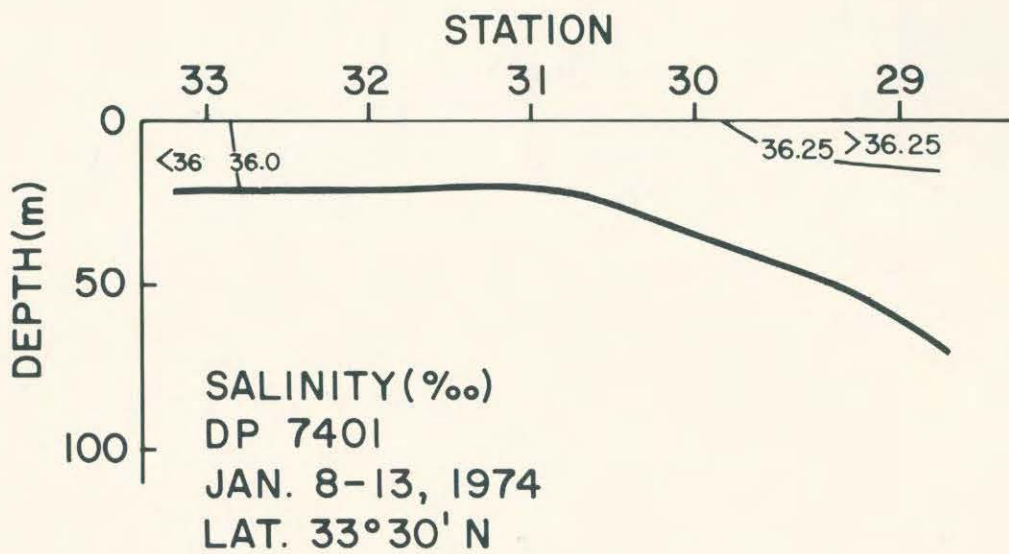
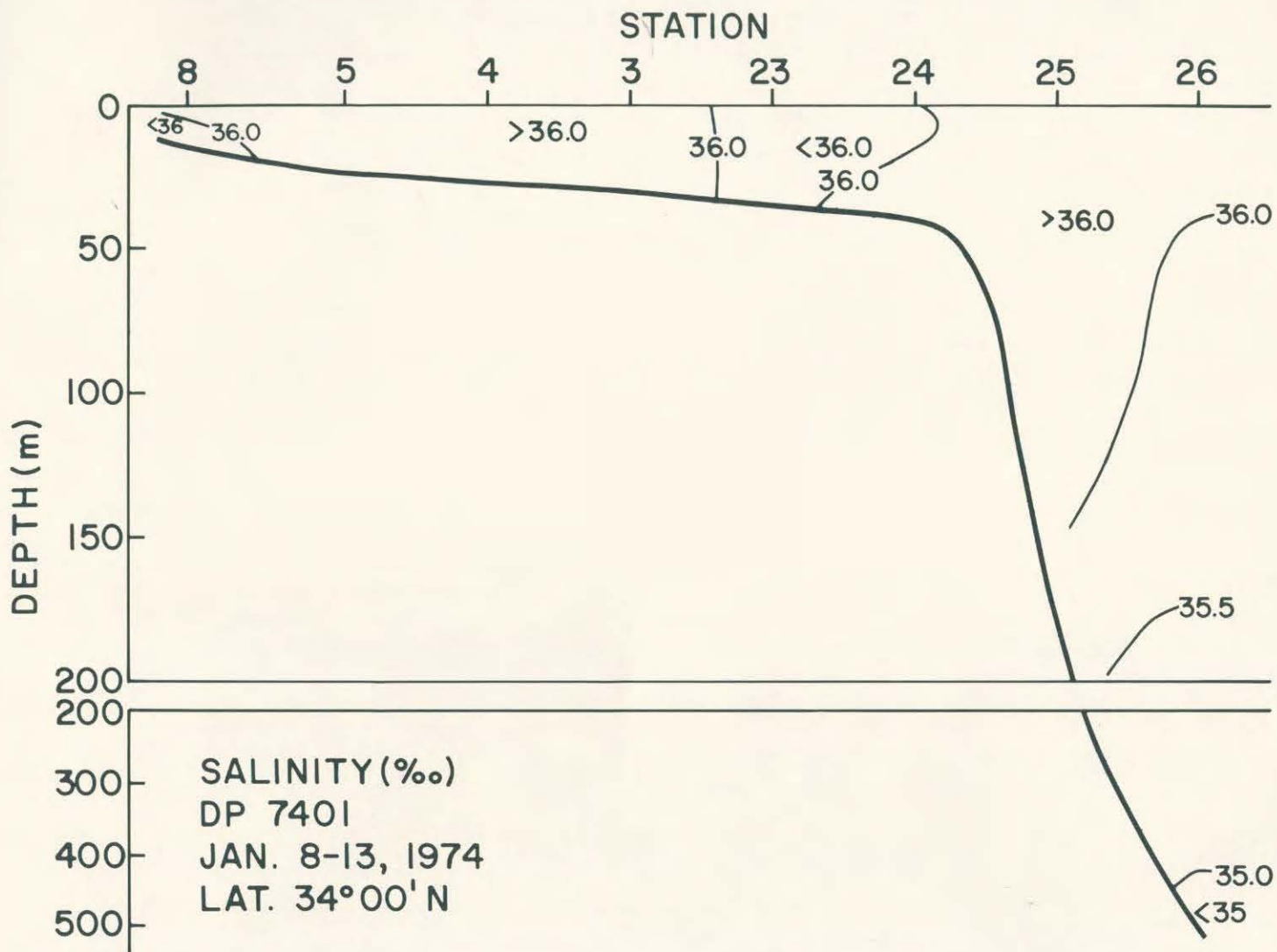


FIGURE 88.

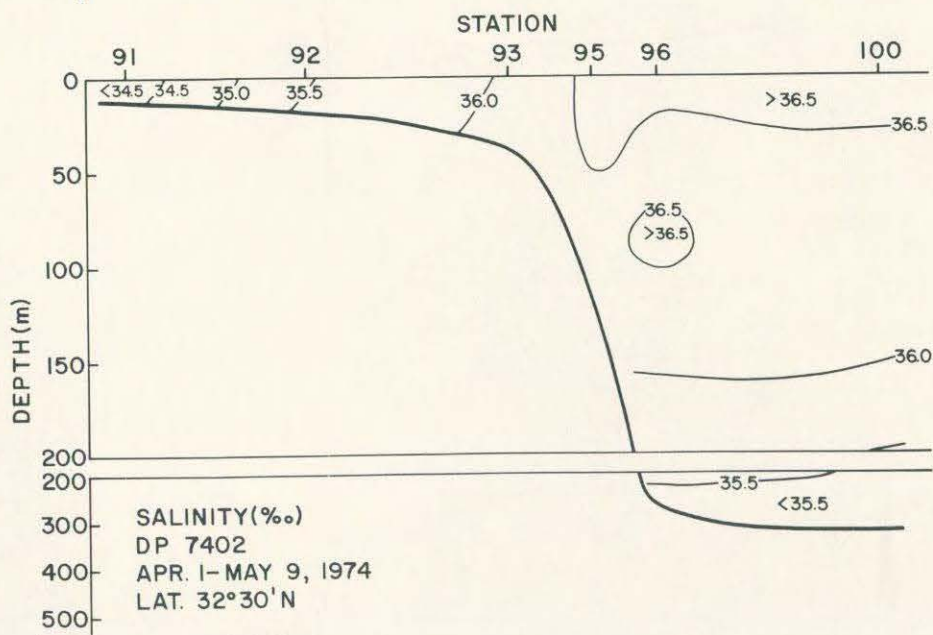
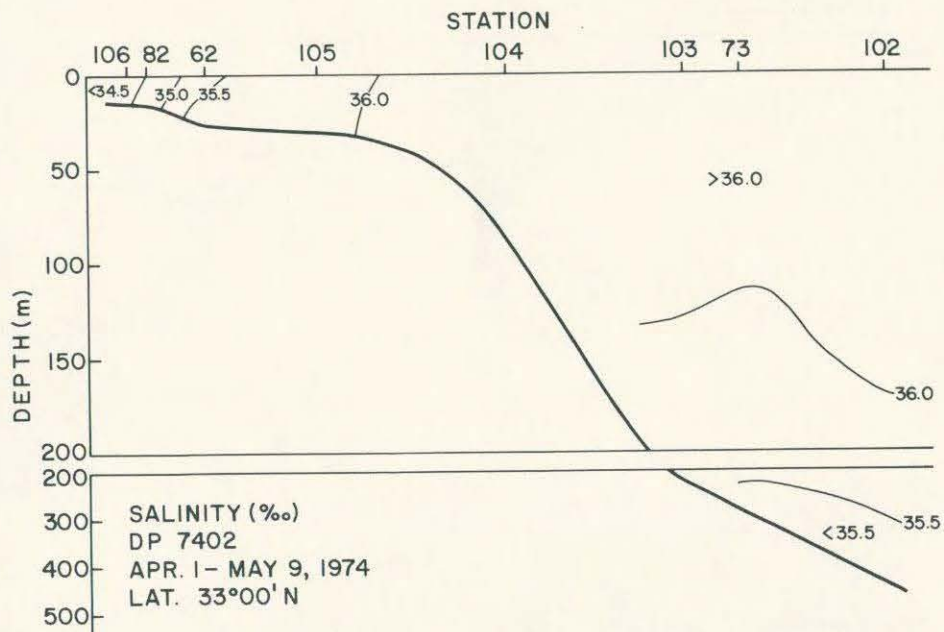
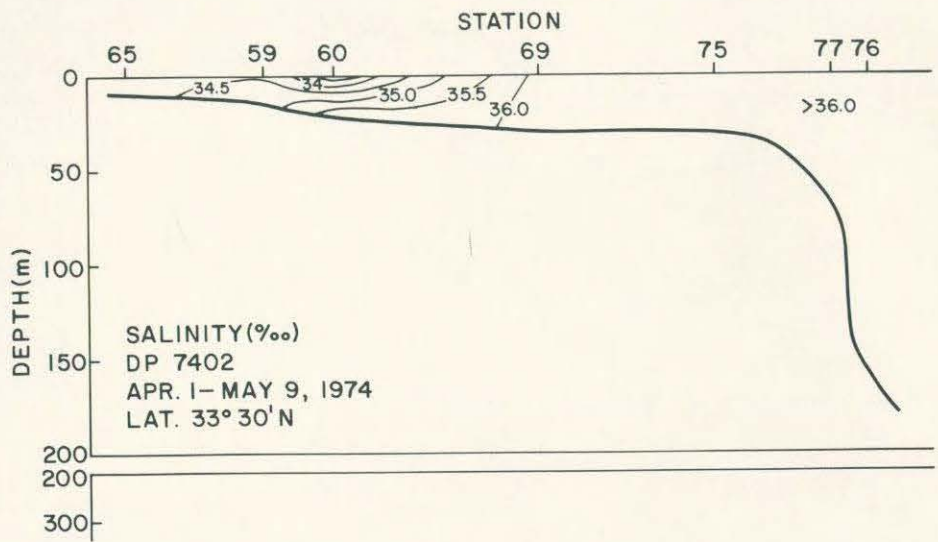


FIGURE 89.

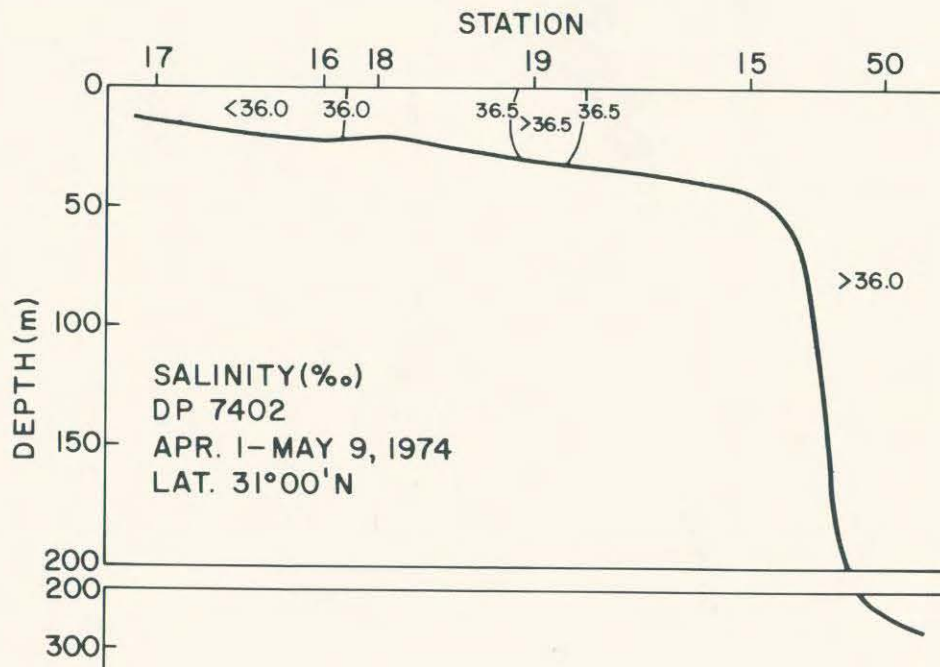
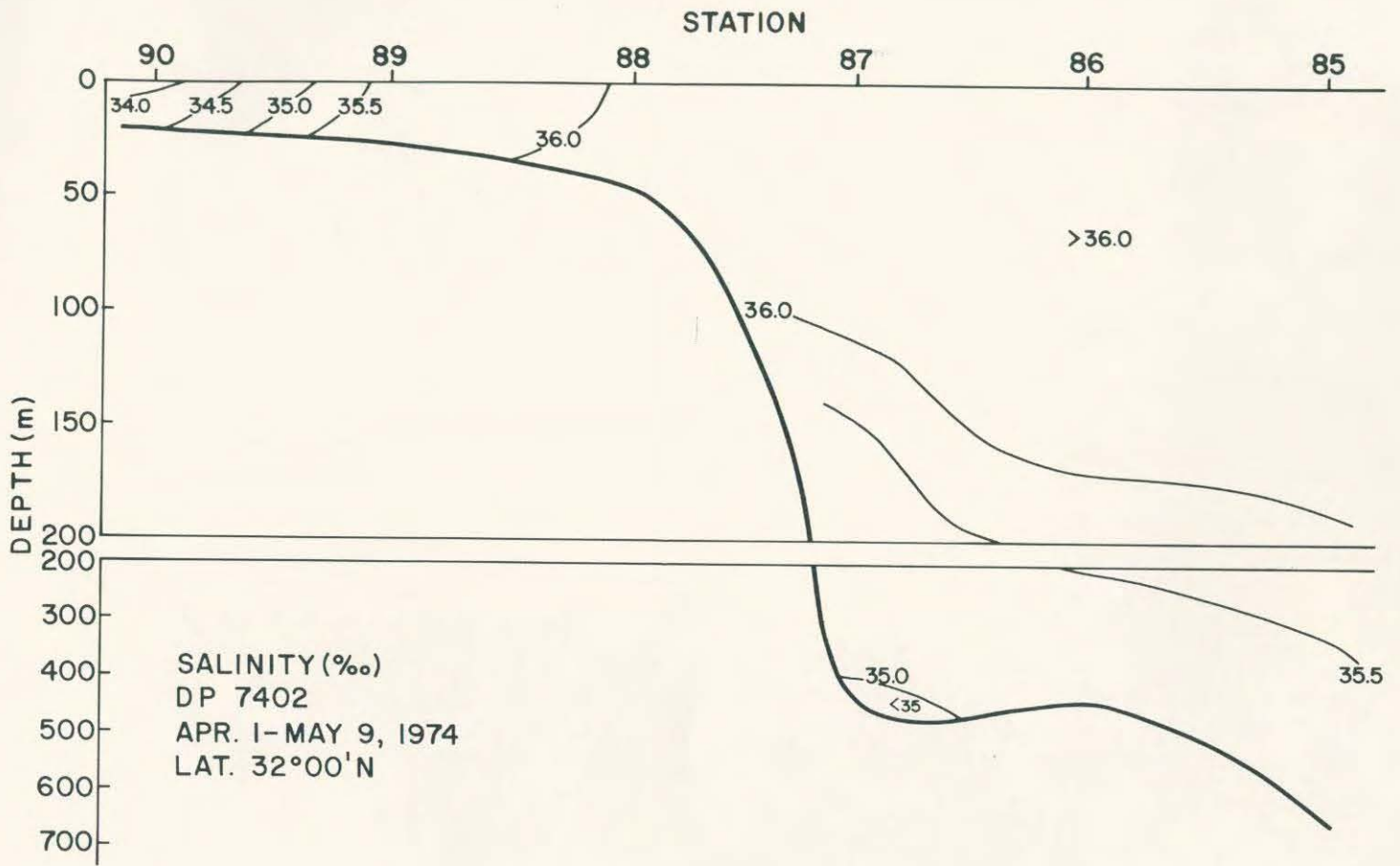


FIGURE 90.

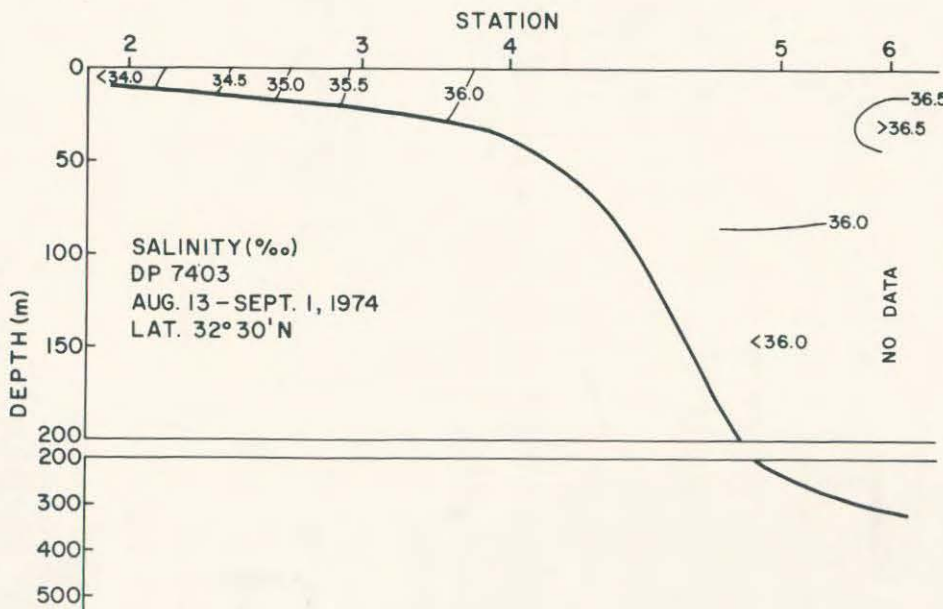
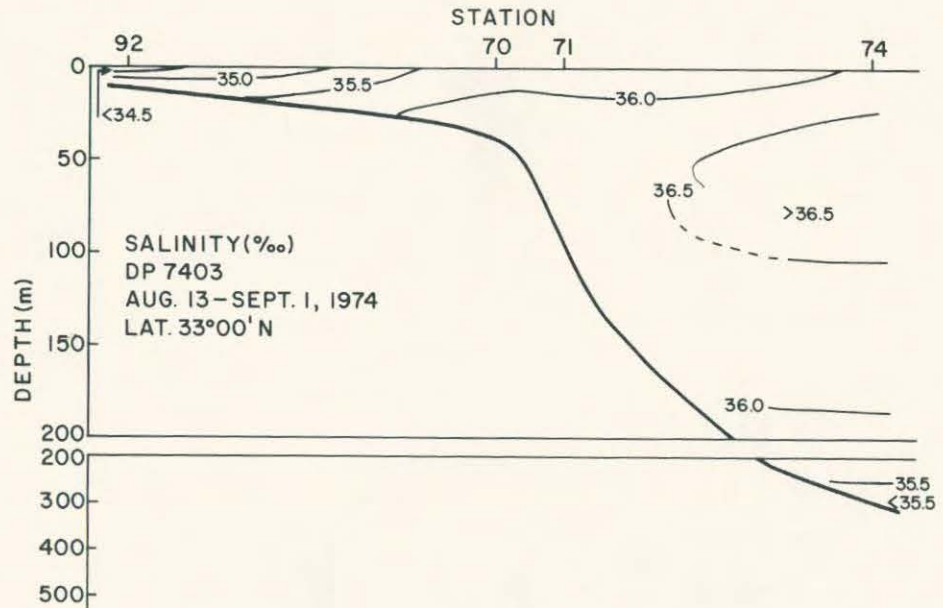
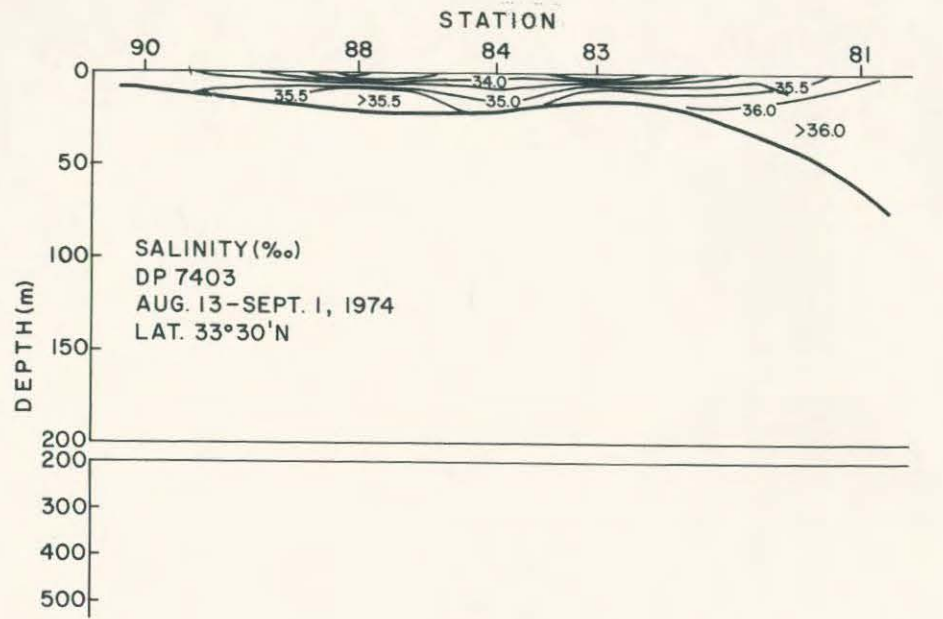


FIGURE 91.

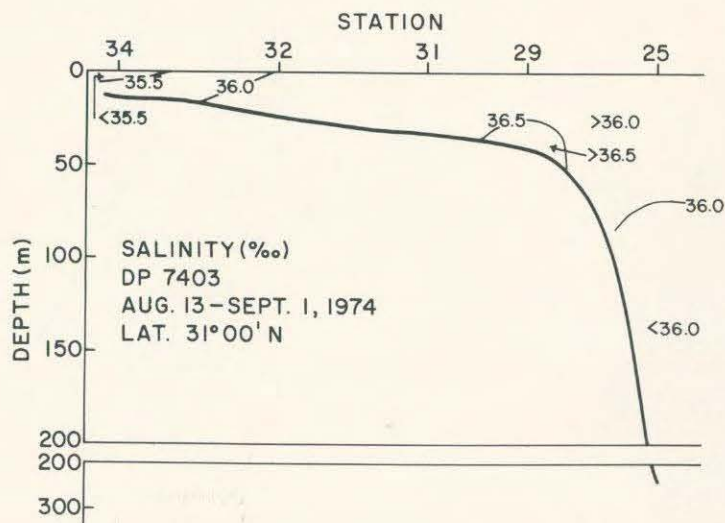
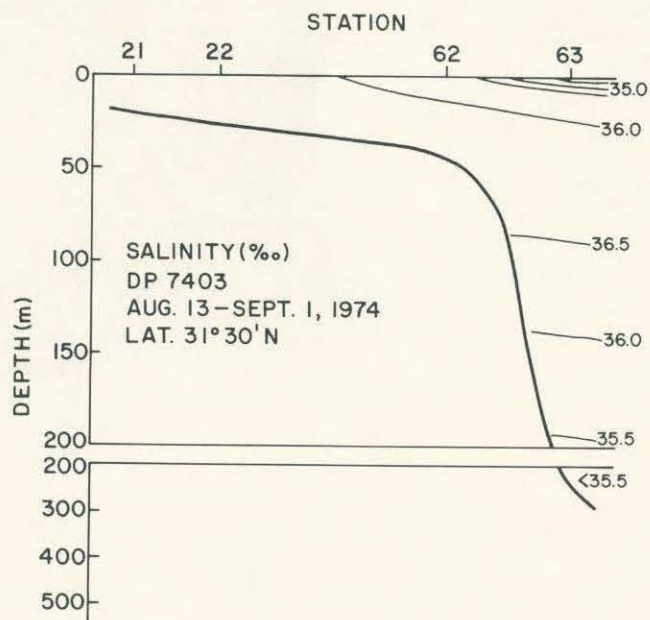
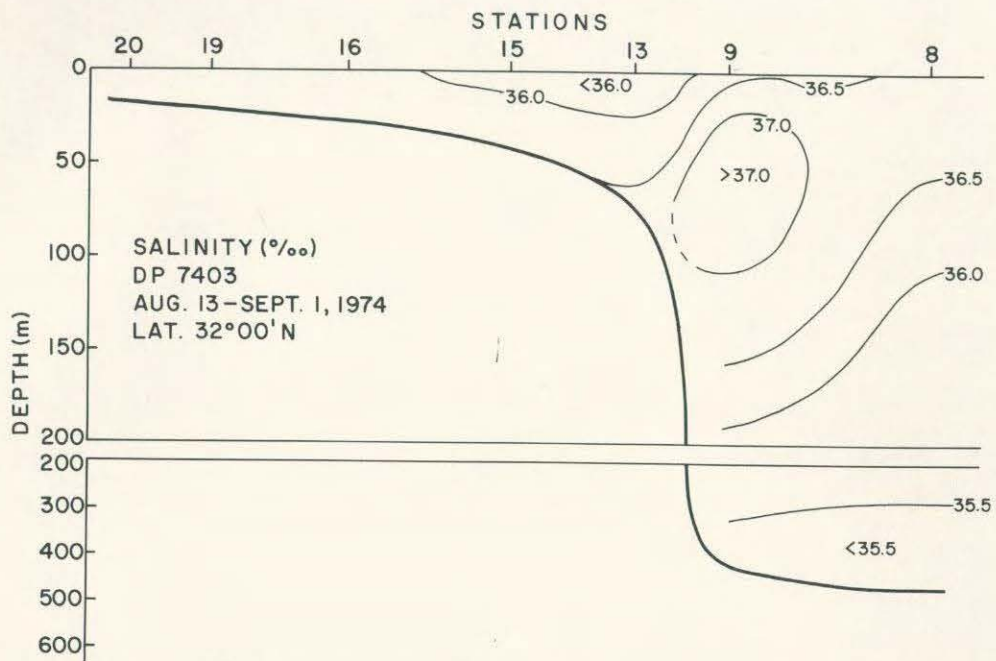


FIGURE 92.

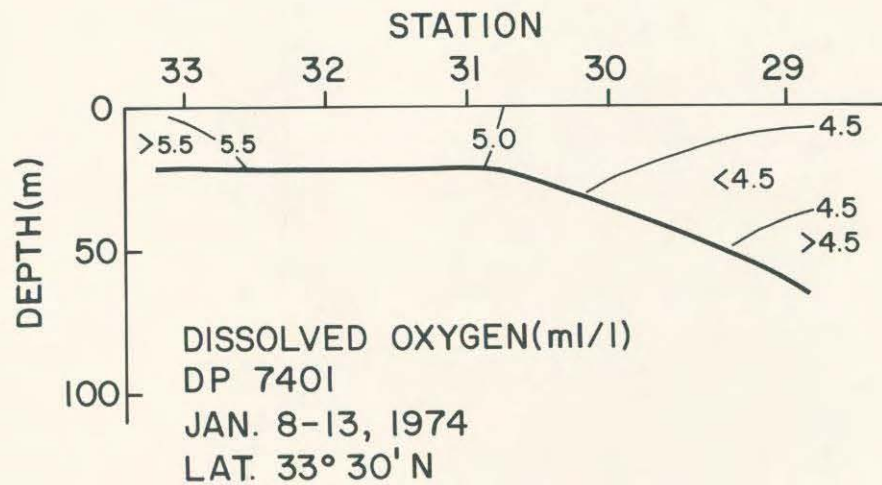
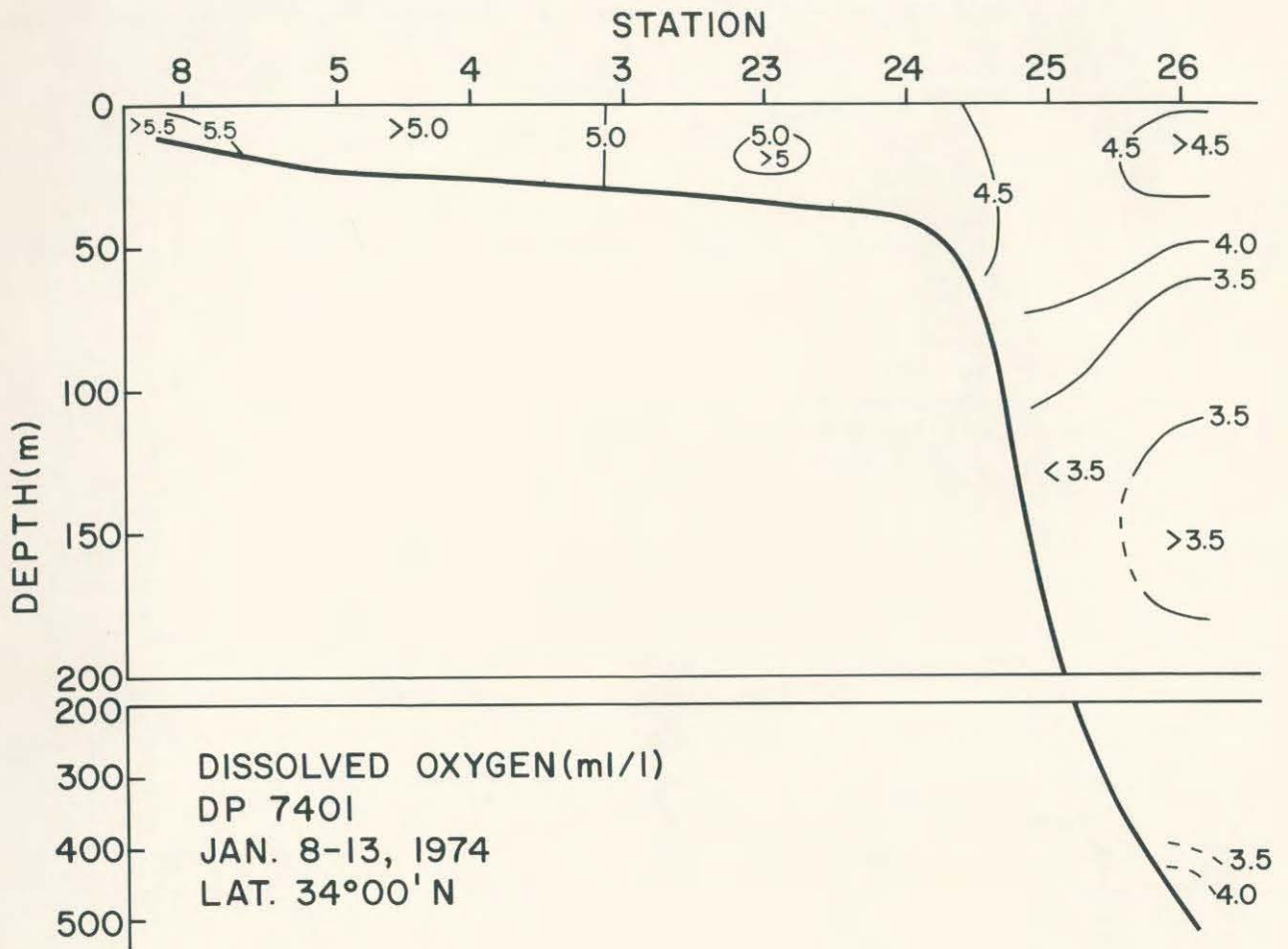


FIGURE 93.

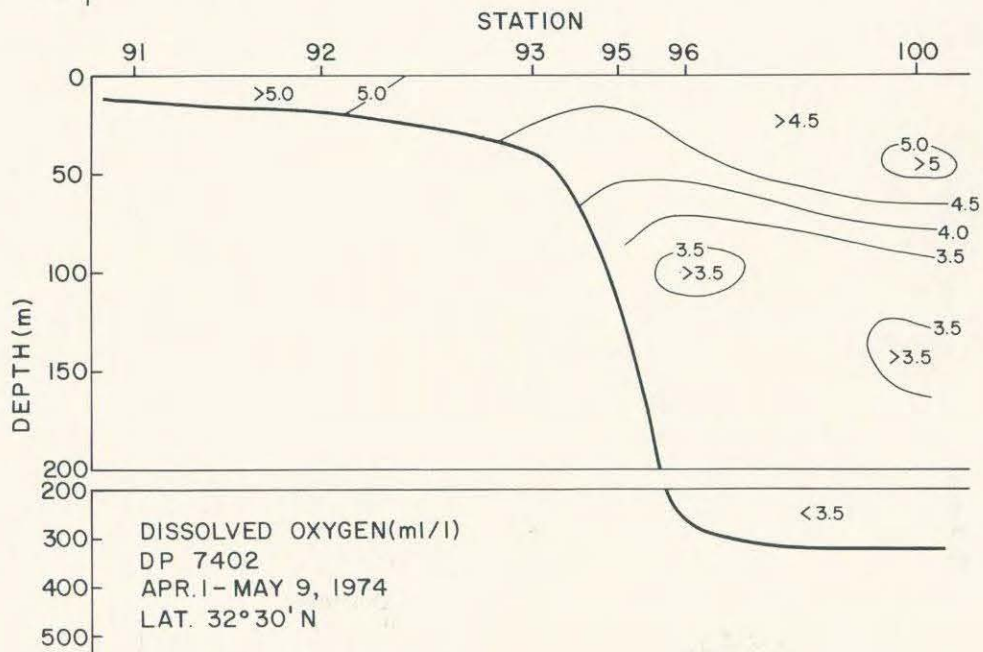
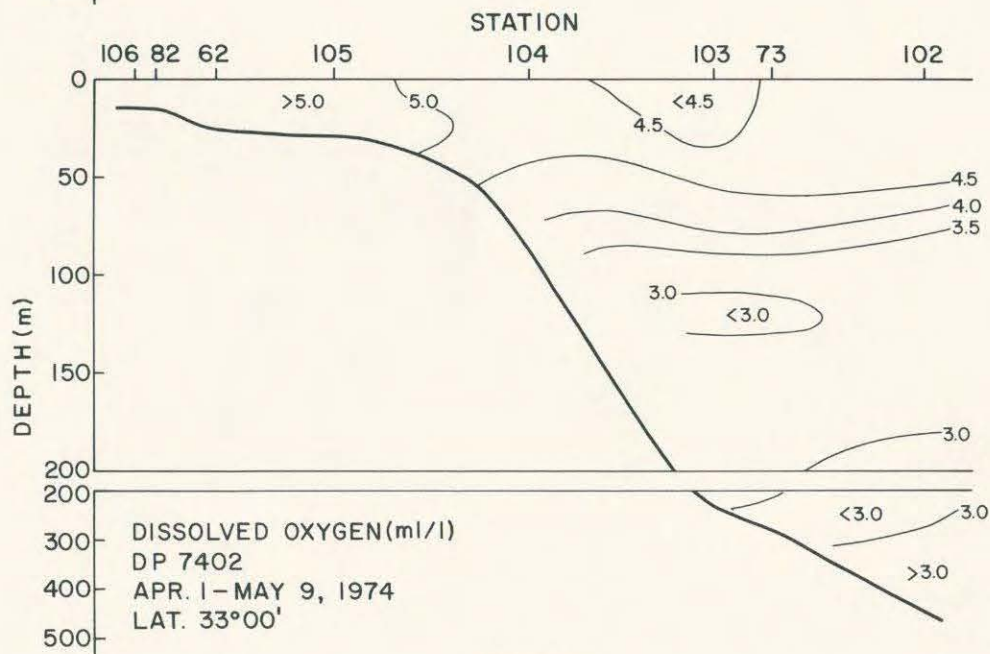
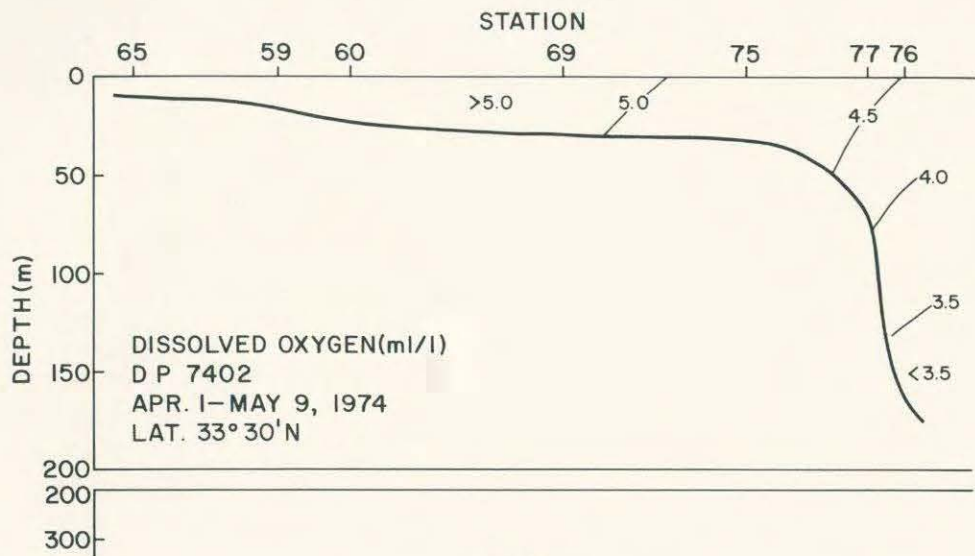


FIGURE 94.

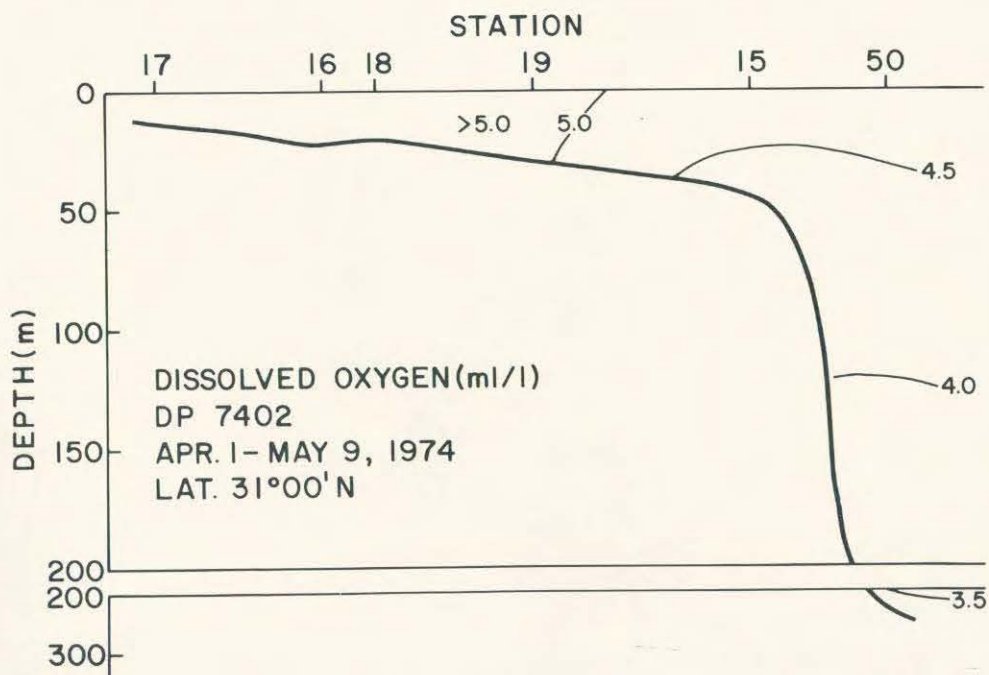
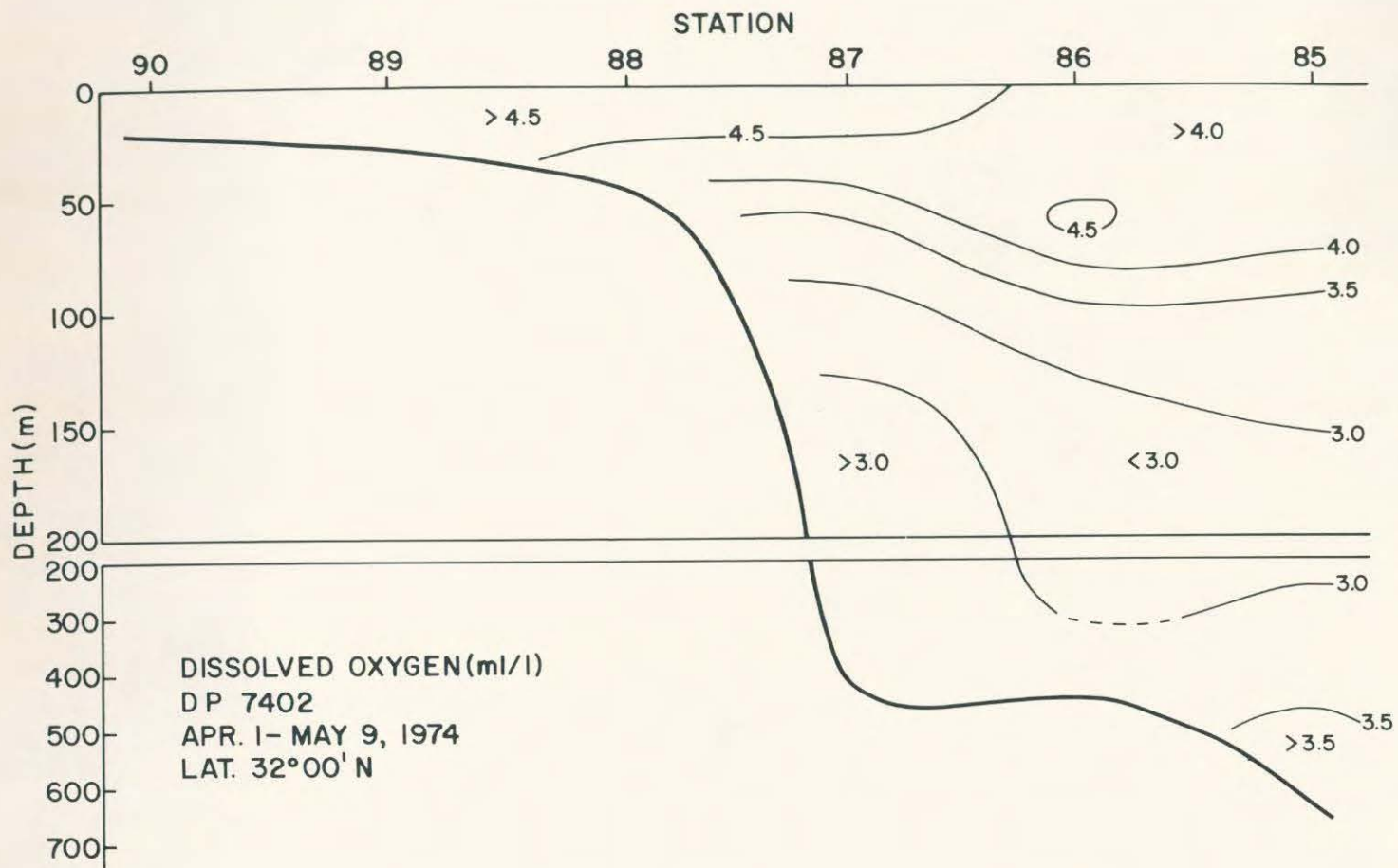


FIGURE 95.

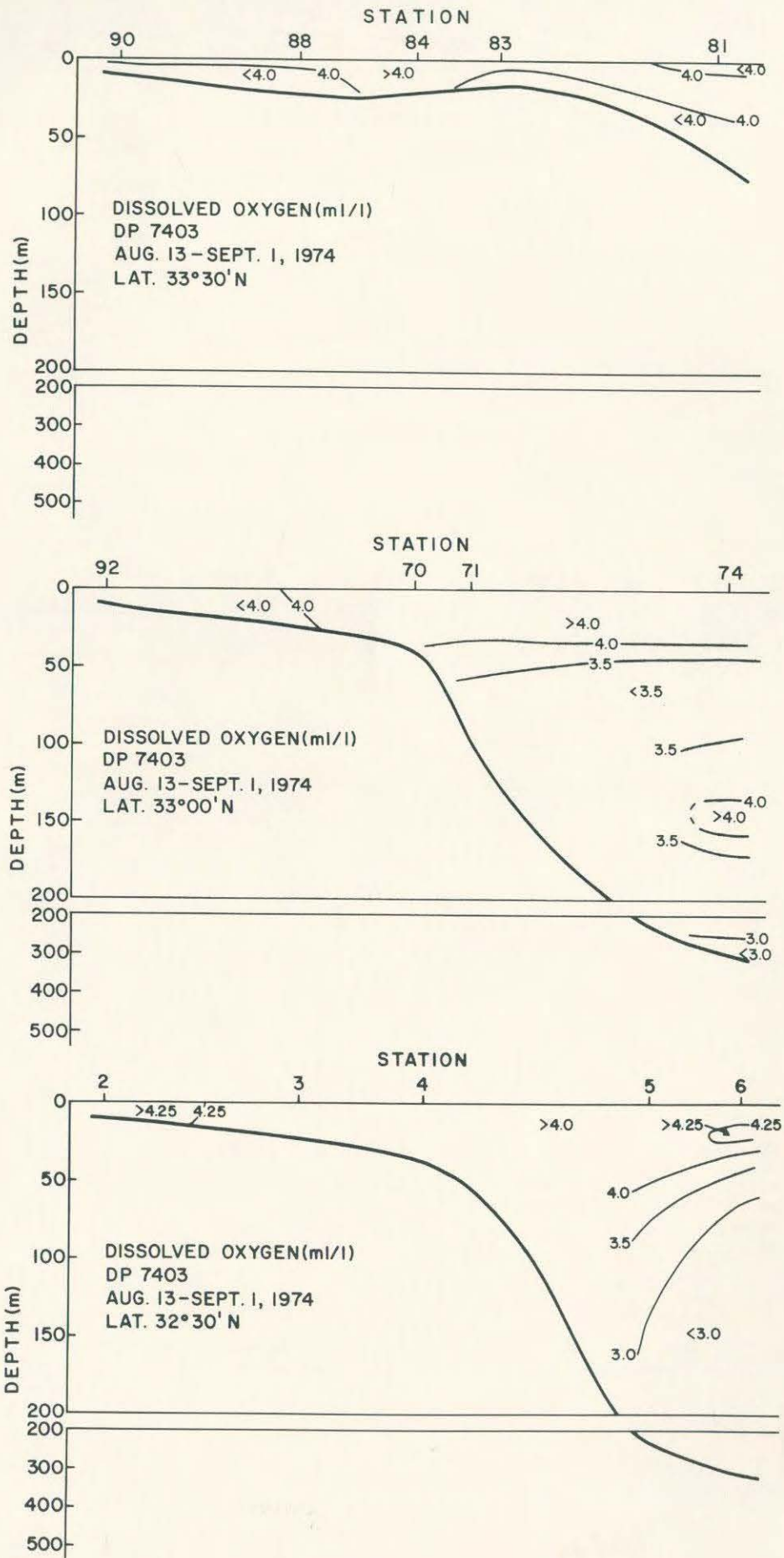


FIGURE 96.

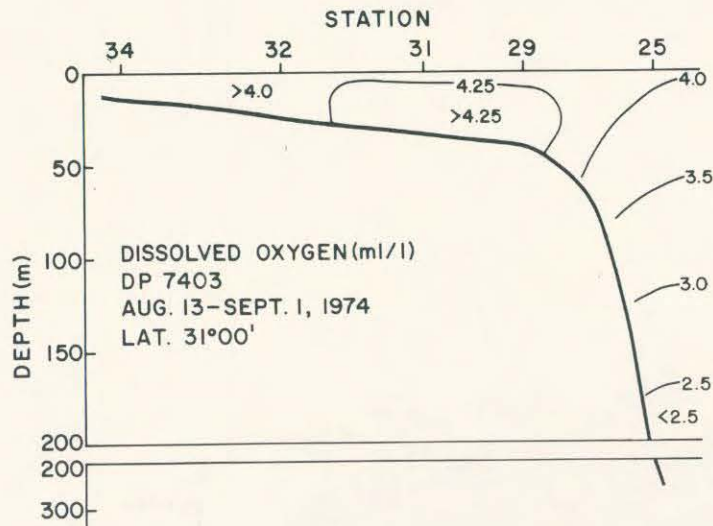
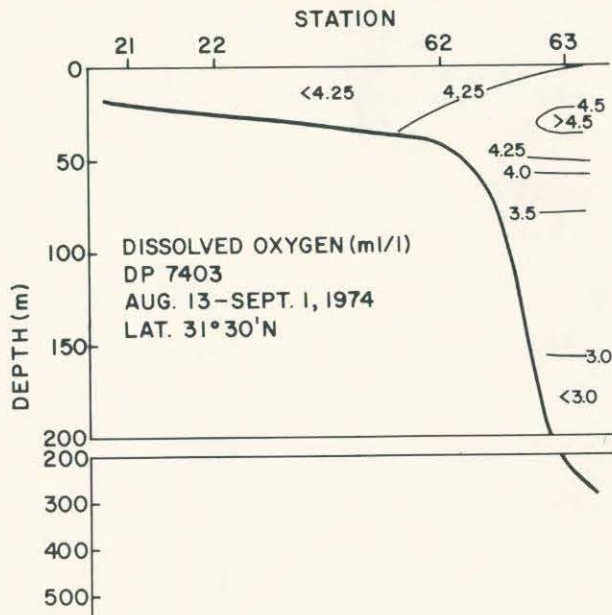
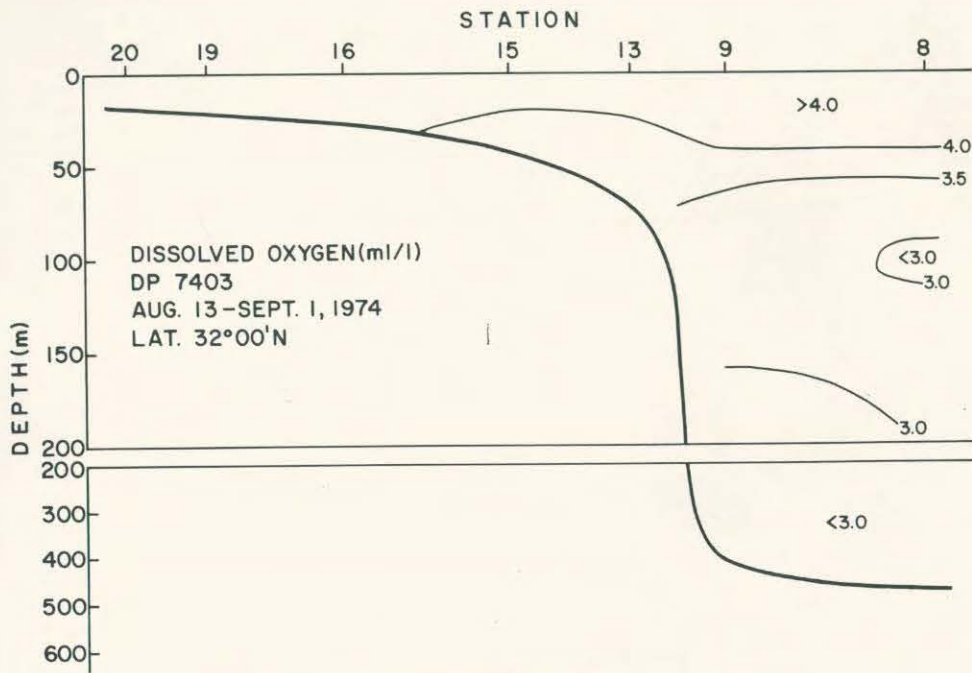


FIGURE 97.

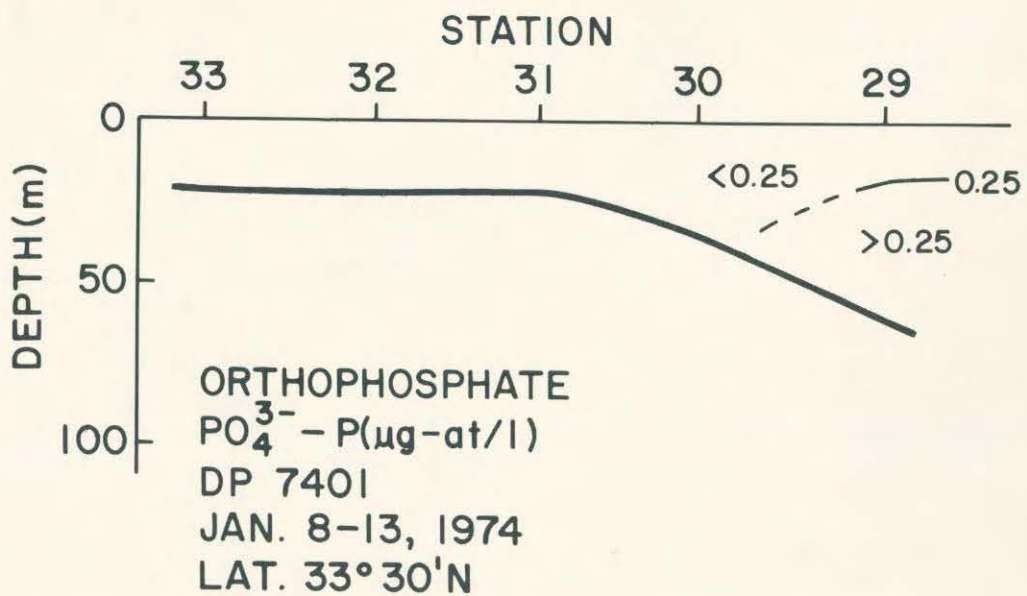
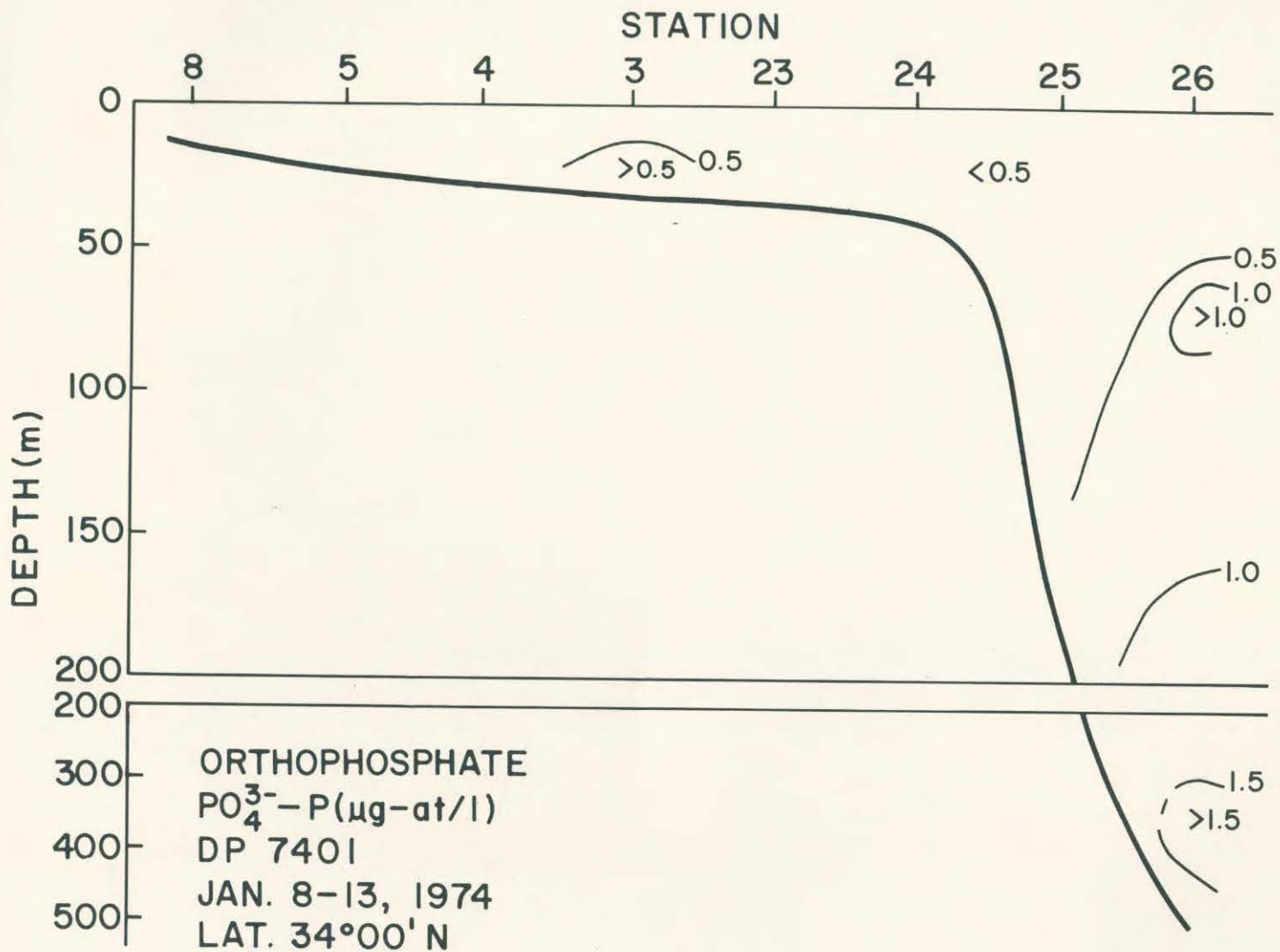


FIGURE 98.

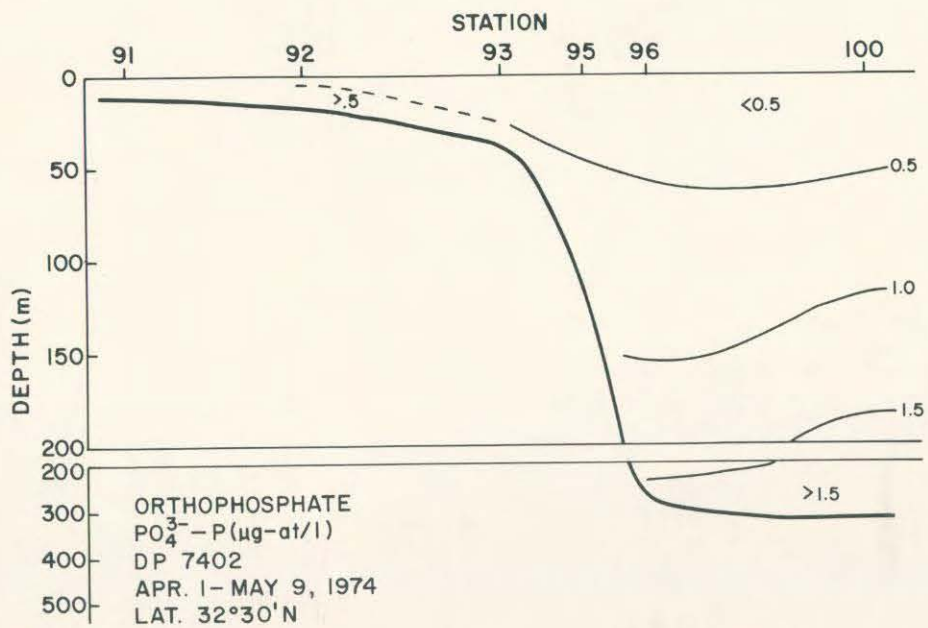
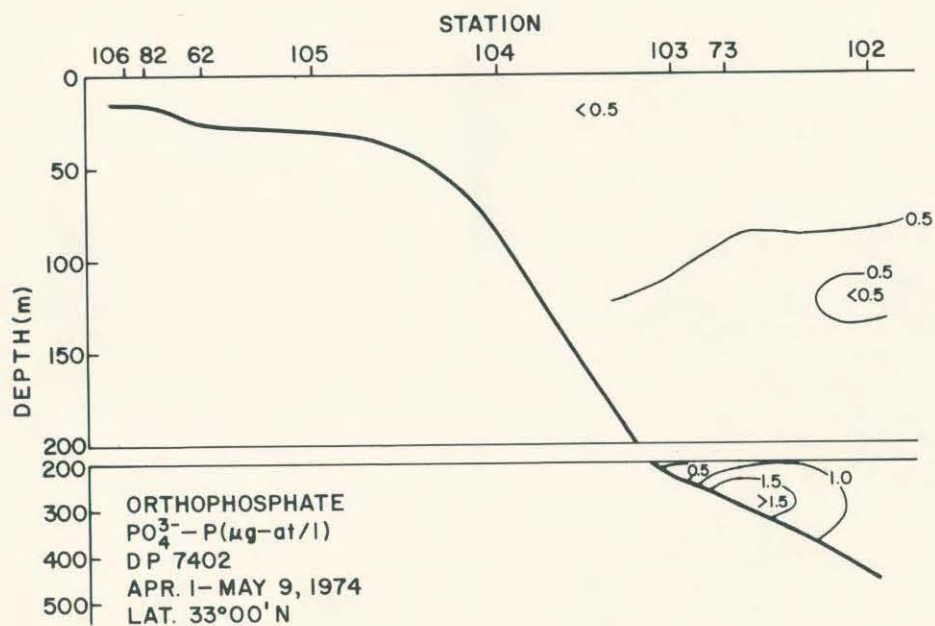
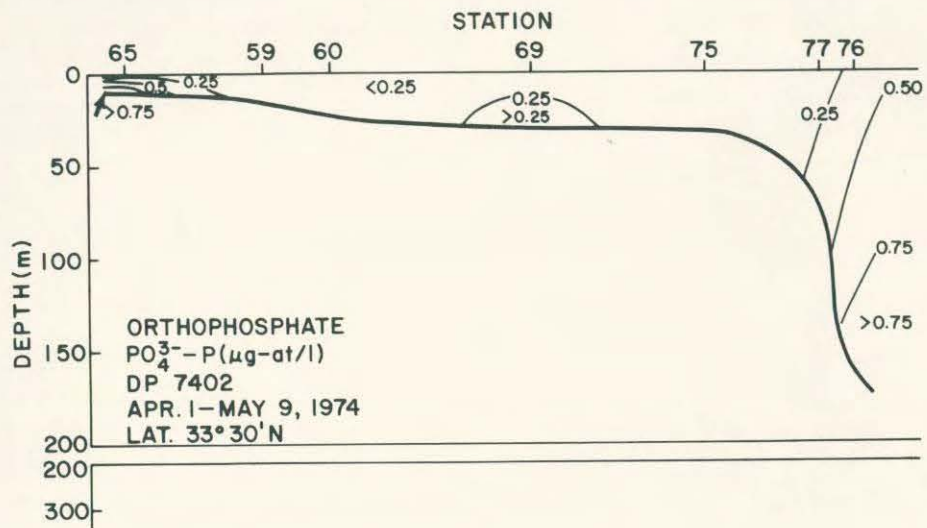


FIGURE 99.

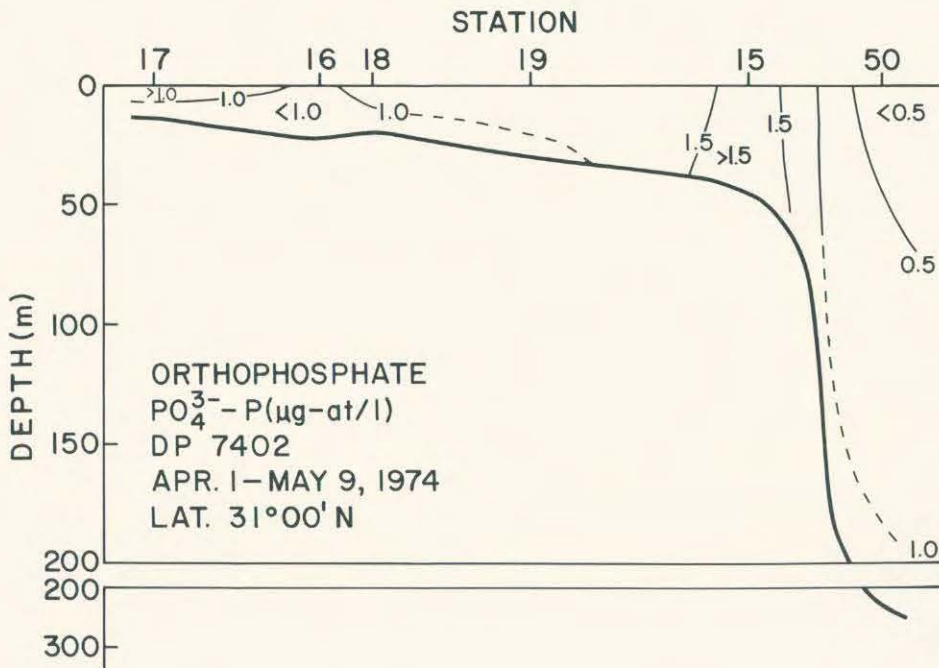
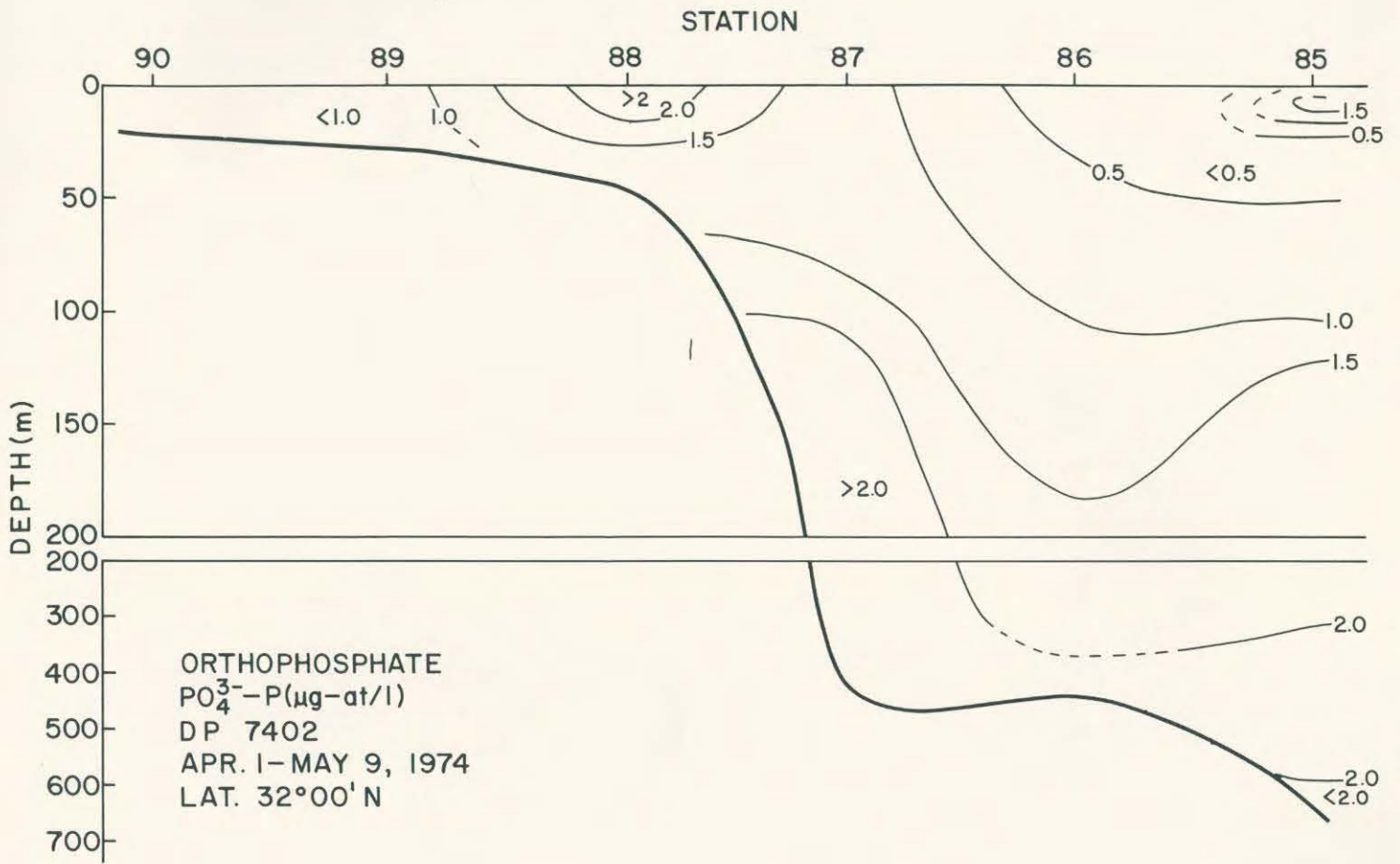


FIGURE 100.

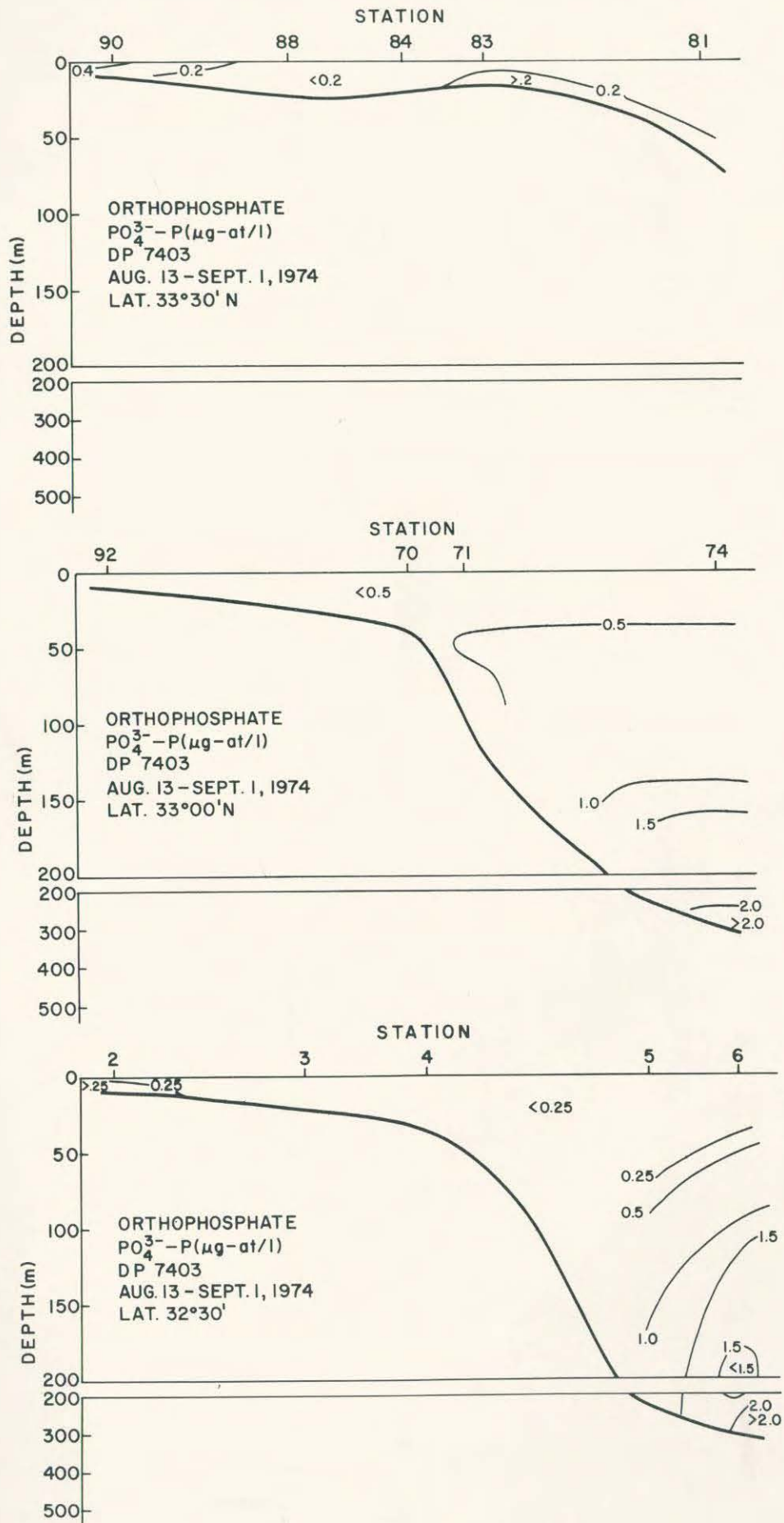


FIGURE 101.

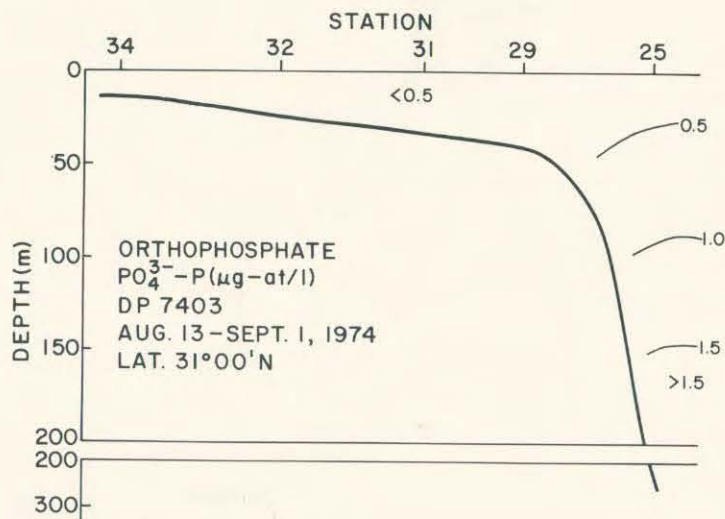
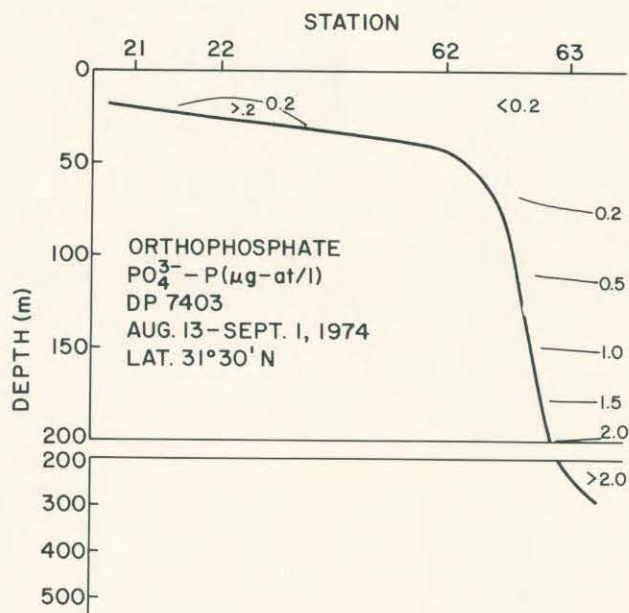
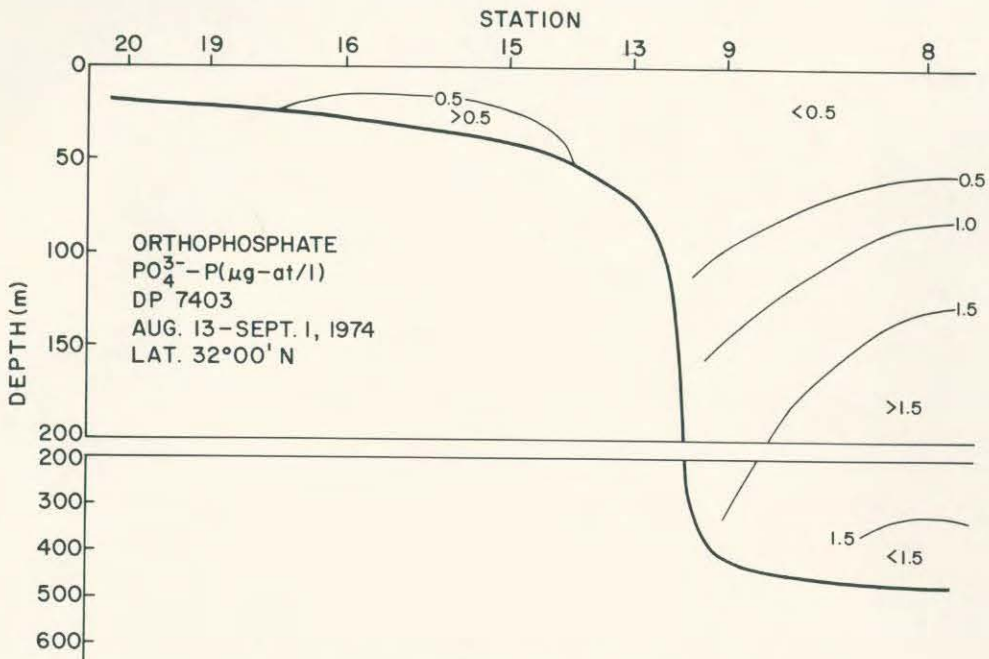


FIGURE 102.

COOPER RIVER DISCHARGE

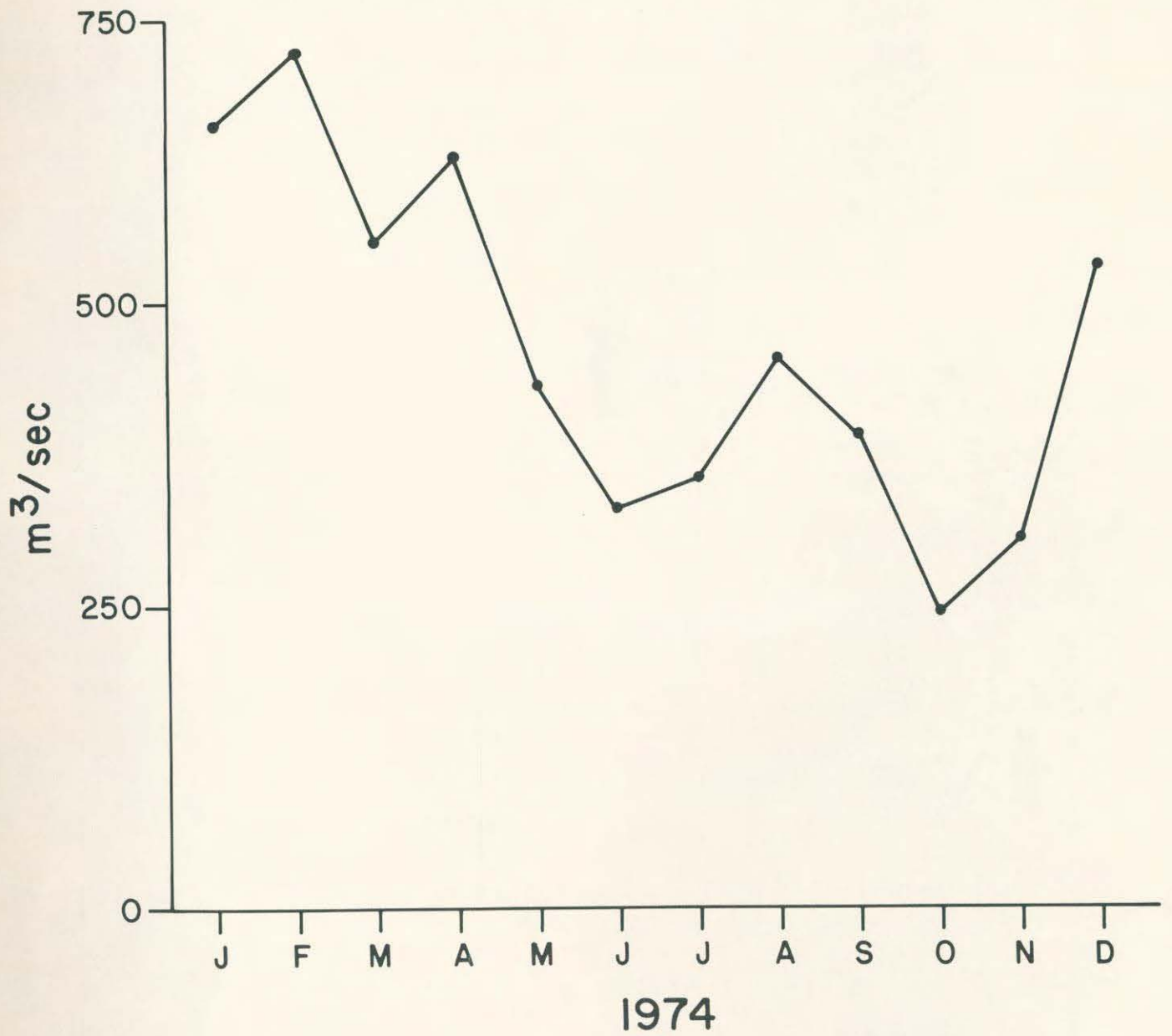


FIGURE 103.

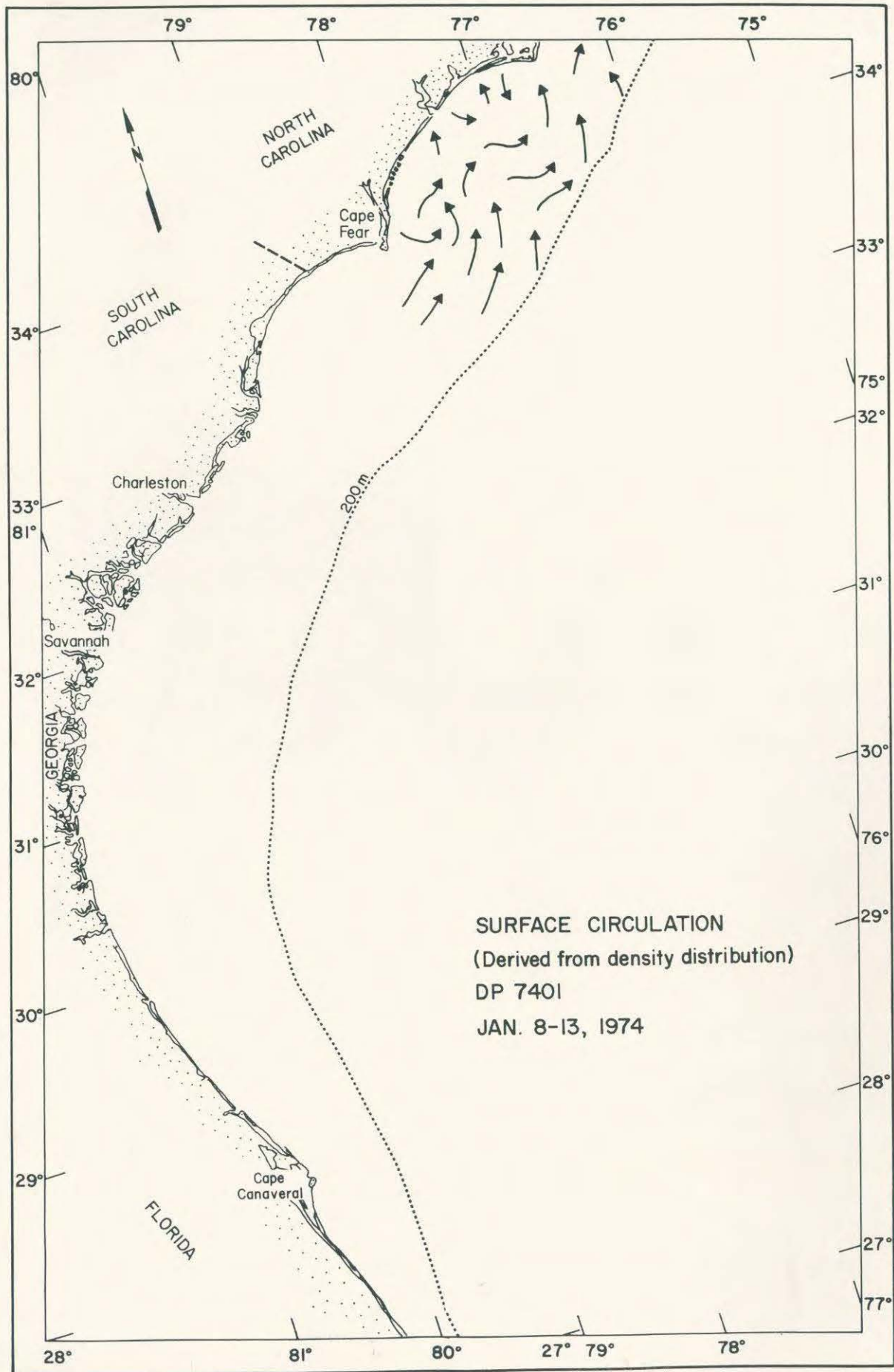


FIGURE 104.

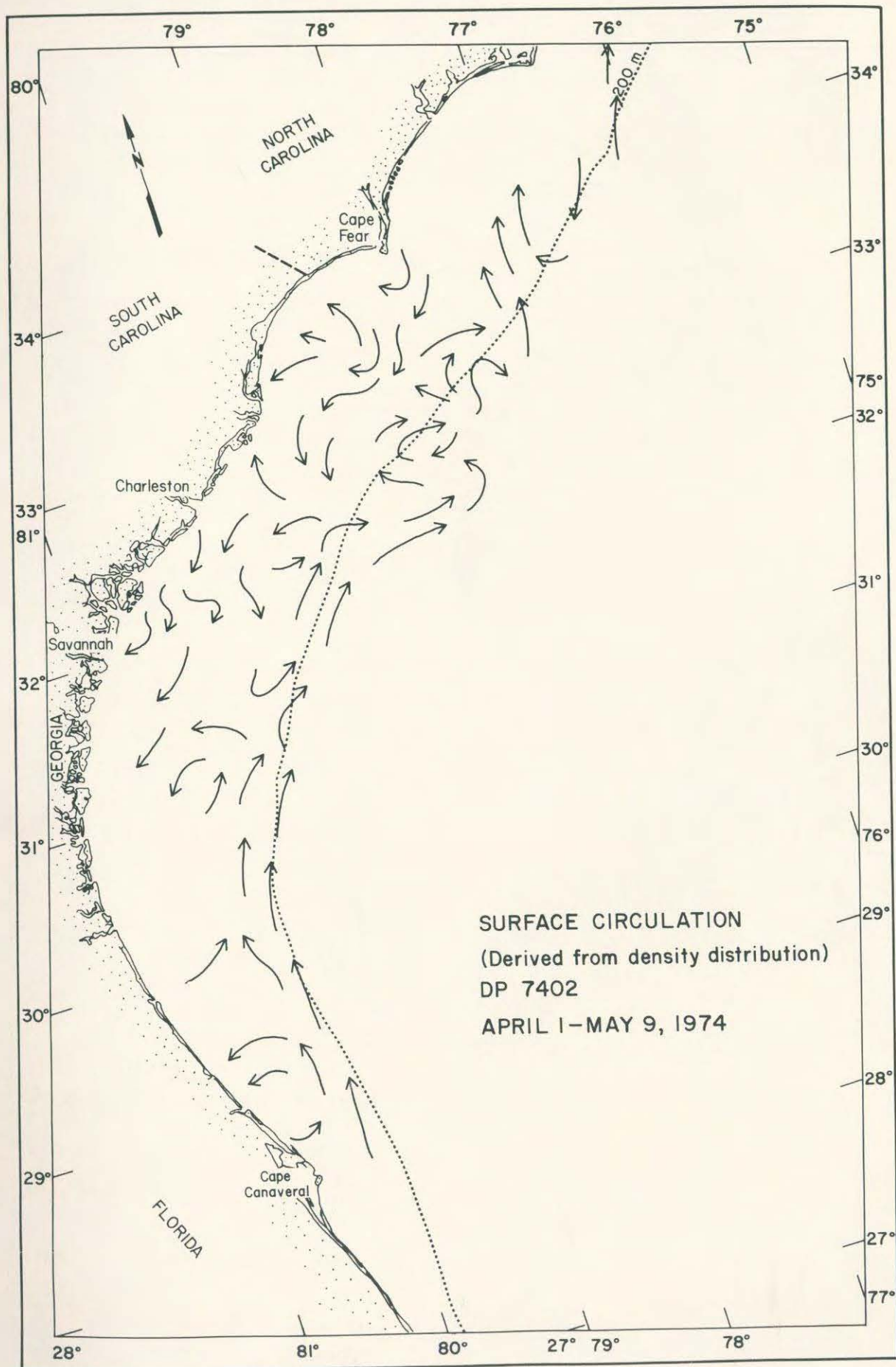


FIGURE 105.

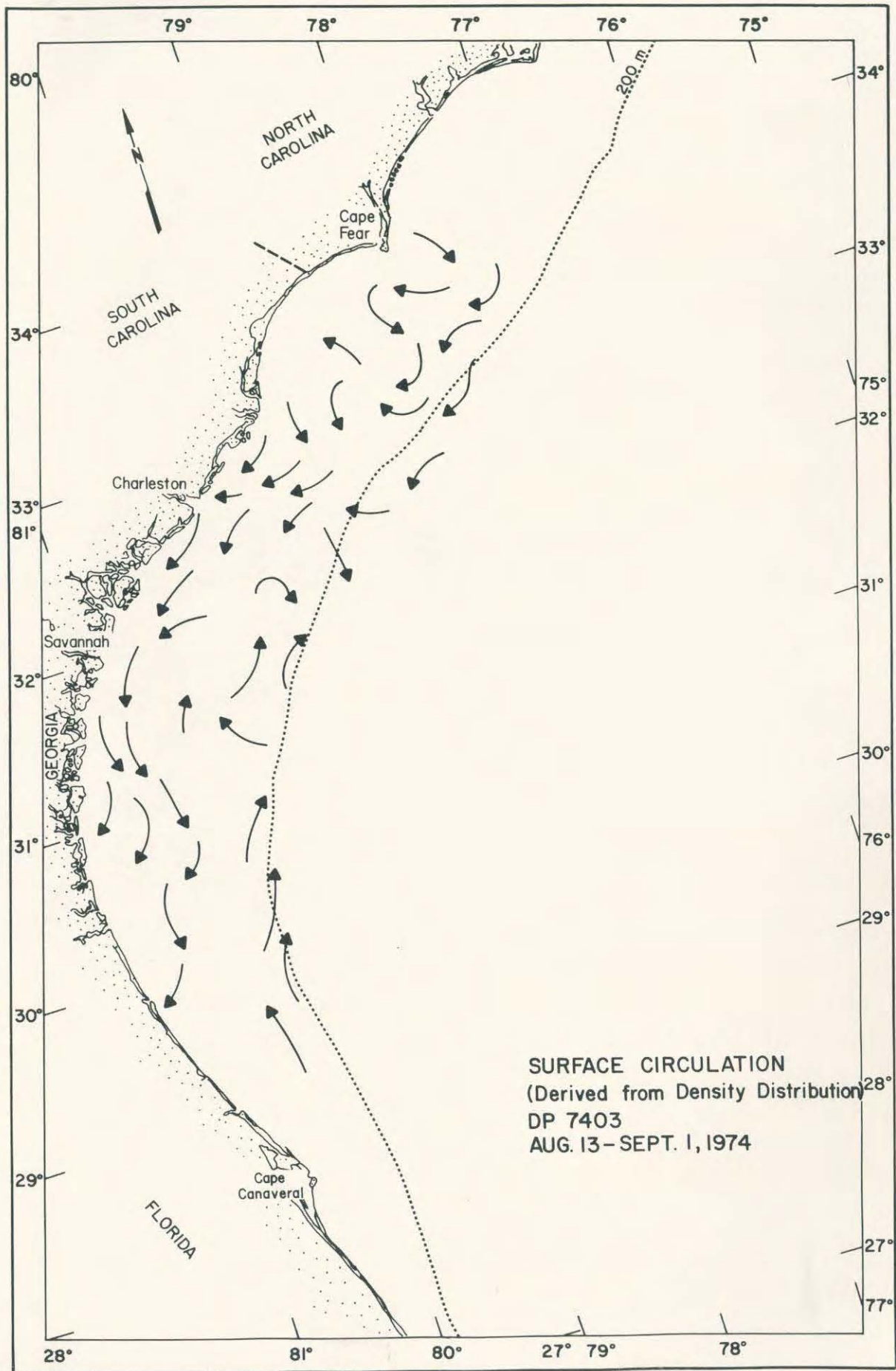


FIGURE 106.

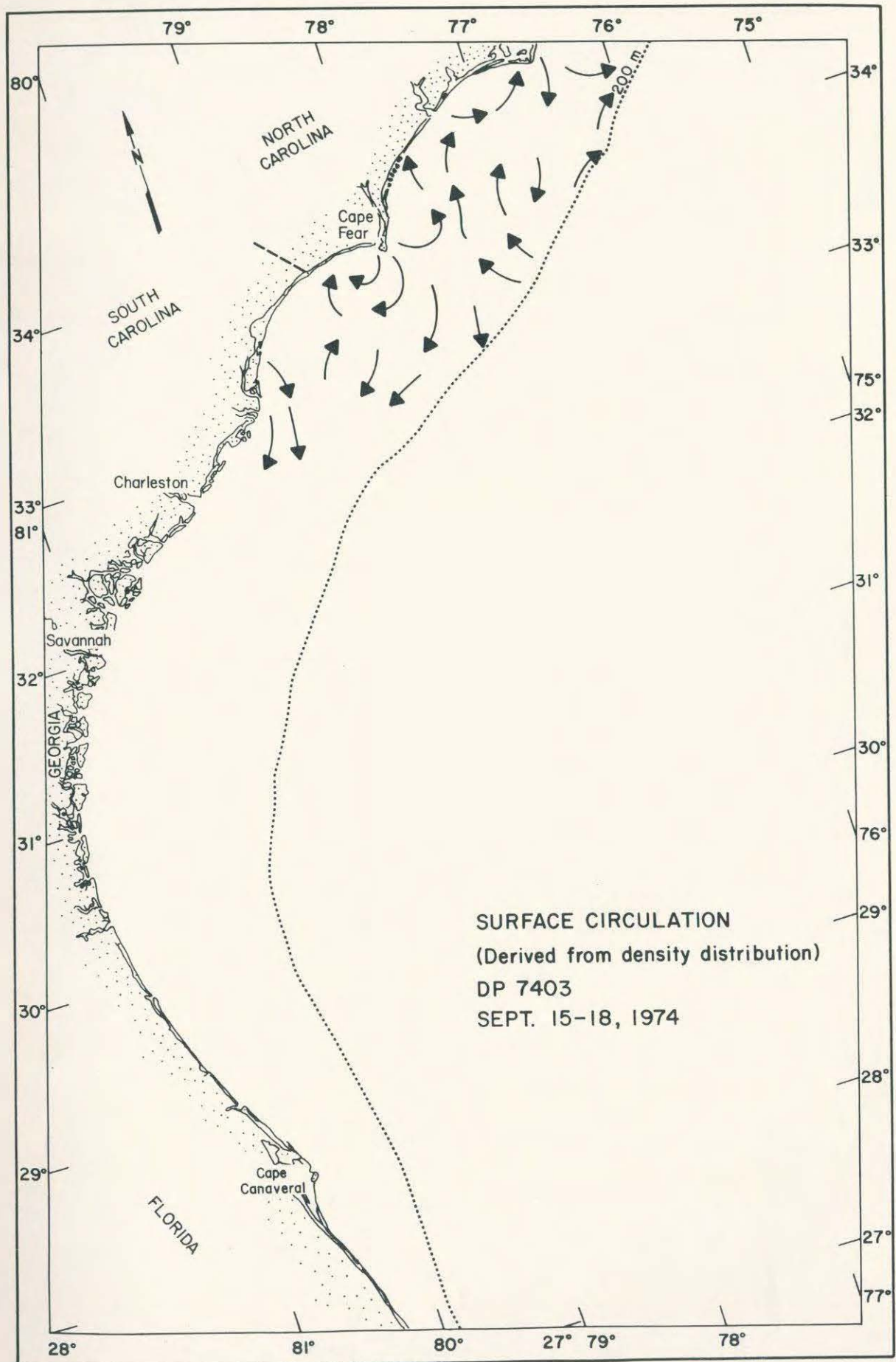


FIGURE 107.

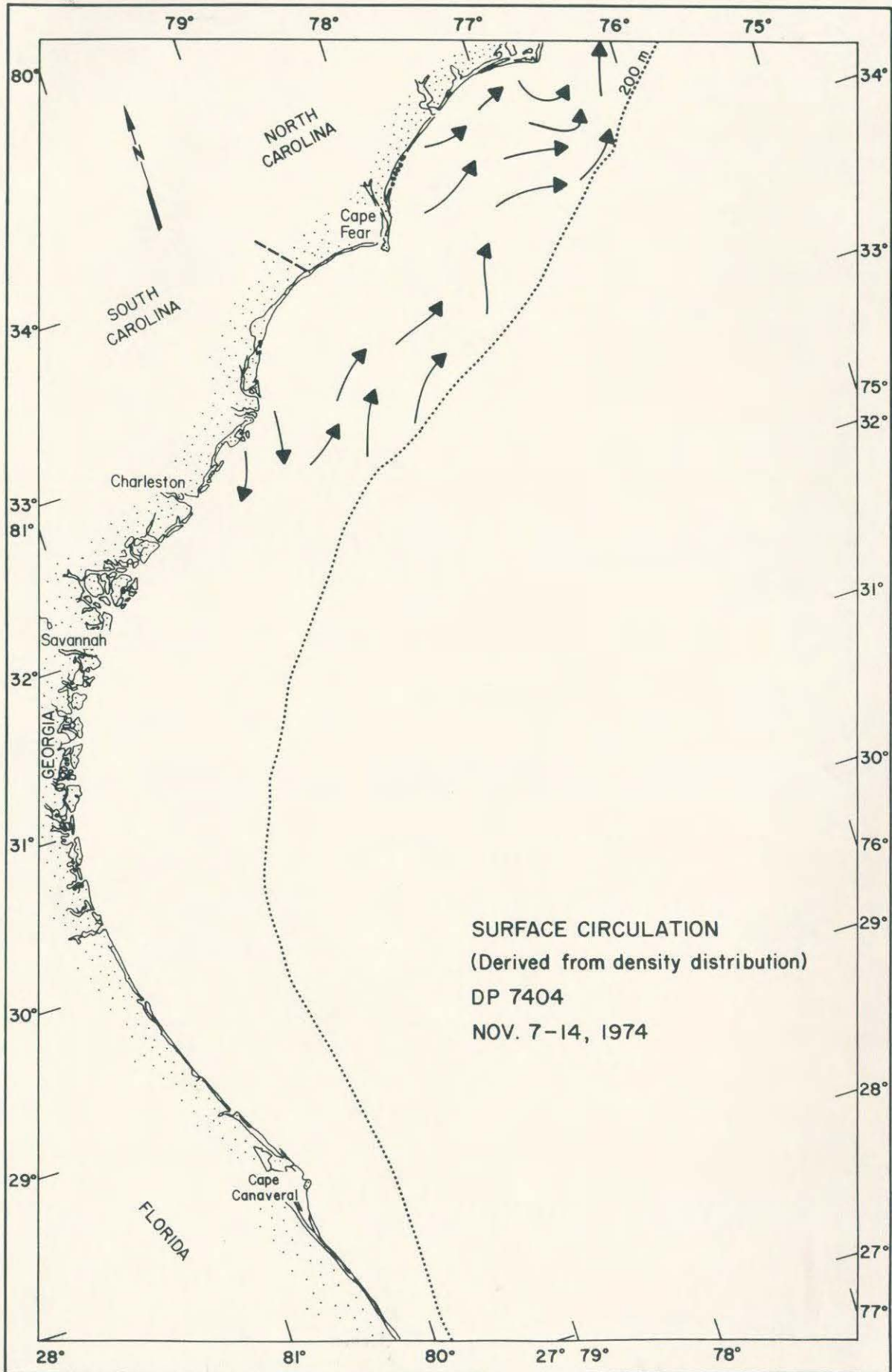


FIGURE 108.

