Temperature, Salinity, and Sigma-t Distributions in the Southeastern Magdalen Shallows, Eastern Northumberland Strait, and St. Georges Bay during July, 1981

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ABSTRACT

Drinkwater, Ken, George Taylor and Liam Petrie. 1983. Temperature, salinity and sigma-t distributions in the southeastern Magdalen Shallows, eastern Northumberland Strait and St. Georges Bay during July, 1981. Can. Tech. Rep. Fish. Aquat. Sci. 1144.

Temperature, salinity and sigma-t (σ_t) data collected from the southeastern Magdalen Shallows, Northumberland Strait and St. Georges Bay during July, 1981, are presented. The surface layer in St. Georges Bay is deeper and contains warmer, higher salinity waters than that on the Magdalen Shallows. The characteristics of the Bay's surface waters more closely resemble the surface waters found nearshore (within $\sim$ 10 km) along the coastlines of Cape Breton Island and mainland Nova Scotia. This similarity is consistent with the northeastward residual surface circulation along the Nova Scotia coast inferred from surface drifter data by Lauzier (1965) and Drinkwater and Taylor (1979).

RÉSUMÉ

Drinkwater, Ken, George Taylor and Liam Petrie. 1983. Temperature, salinity and sigma-t distributions in the southeastern Magdalen Shallows, eastern Northumberland Strait and St. Georges Bay during July, 1981. Can. Tech. Rep. Fish. Aquat. Sci. 1144.

On présente des données sur la température, la salinité et le sigma-t (σ_t) recueillies en 1981 au sud-est du haut-fond de la Madeleine, dans le détroit de Northumberland et la baie St. George. La couche de surface est plus épaisse et renferme des eaux plus chaudes et d'une salinité plus élevée dans la baie St. Georges que sur le haut-fond de la Madeleine. Les caractéristiques des eaux de surface de la baie ressemblent plus à celles des eaux de surface de la zone littorale (à moins de 10 km environ) le long des cotes de l'île du Cap-Breton et de la Nouvelle-Écosse. Cette ressemblance est conforme à la circulation résiduelle en surface en direction du nord-est le long de la côte de la Nouvelle-Écosse déduite de données obtenues à l'aide de bouées dérivantes en surface par Lauzier (1965) et Drinkwater et Taylor (1979).

Introduction

In July 1981 scientists from the Marine Ecology Laboratory of the Bedford Institute conducted an oceanographic cruise (81-036) onto the southeastern Magdalen Shallows, eastern Northumberland Strait and St. Georges Bay. The main objective of the cruise was to determine how representative the biological and hydrographic properties within St. Georges Bay were of the southern Gulf of St. Lawrence. Extensive physical, chemical and biological studies had been undertaken within the Bay during the 1970's (Ware 1977, Prouse and Hargrave 1977, Petrie and Drinkwater 1978a, b, Drinkwater and Taylor 1979, Harding et al. 1979, Marine Ecology Laboratory 1980, Hargrave and Prouse 1980, Lambert 1980, Harding et al. 1982). The cruise consisted of two parts. First, studies of the vertical structure of particulates, phytoplankton and zooplankton were undertaken at two stations, one on the Magdalen Shallows (67 m) over a 30 hr period and the other in St. Georges Bay (34 m) over 38 hr (see Fig. 1 for locations). Temperature and salinity profiles were monitored at both stations. The second part of the cruise consisted of a grid of stations (Fig. 1) which was designed to obtain details of any spatial variability. Temperature and salinity were recorded at all stations while zooplankton and particle spectra samples were collected at approximately half of the stations. This report presents the temperature and salinity data collected during the cruise while the biological data will be discussed in future reports.

The temperature and salinity measurements were taken using a continuous profiling Guildline CTD. Salinities are reported in the Practical Salinity Scale 1978 (Lewis 1980). Densities were calculated from the temperature and salinity measurements using the UNESCO 1980 formulation and are expressed in sigma-t (σ_t) units.

Time Series Stations

Time-depth plots of the temperature, salinity and σ_t at the Magdalen Shallows and St. Georges Bay stations are shown in Fig. 2 and 3 respectively. Data were available only for the first 20 hr of the St. Georges Bay station after which the CTD malfunctioned.

On the Magdalen Shallows the water column consisted of a warm (15°C), low salinity (<28.5) upper layer of approximately 5-10 m depth, a high gradient region between 10 and 20 m and a cold (<2°C), high salinity (>30.5) bottom layer. This two layer structure is typical of the Gulf of St. Lawrence in summer (Dawson 1913, Lauzier 1957). The characteristics of the cold, bottom layer waters are formed within the Gulf and are reminants of the previous winter's 'in situ' cooling (Banks 1966, Forrester 1964). The characteristics of the upper layer waters are determined through the combination of solar heating, freshwater discharge and reduced wind-mixing in the spring and summer (Lauzier et al. 1957). No significant changes were observed in either temperature, salinity or density over the 27 hours although some tidal and higher frequency variability was evident.

In St. Georges Bay the upper layer was 20 m deep and consisted of water >17°C and <29.0 practical salinity units. The pycnocline extended from the bottom of the upper layer to the ocean floor with near-bottom temperatures of 11° to 13°C and salinities >29.5. The upper layer in the Bay was 2° warmer, 0.5 higher in salinity and 10 m deeper than that observed at the Magdalen Shallows station. Near-bottom waters were warmer and of lower salinity in the Bay than at the Magdalen Shallows station primarily due to the differences in bottom depth.

The major changes over the 20 hours at the St. Georges Bay station were the disappearance of the cold (11°-12°C), high salinity (30) bottom waters observed at the beginning of the record and the arrival of the 18°C upper layer water near

the end of the record. These changes are not related to the tides but may be advective changes due to wind-induced or density-driven flows.

Grid Stations

Contours of temperature, salinity and sigma-t with depth along transects A to F, a longitudinal transect (A4 to E6) and the St. Georges Bay grid are shown in Figs. 4 to 11 respectively. Horizontal contours of the surface temperature, salinity and sigma-t over the entire grid area are shown in Fig. 12.

Temperatures within the grid of stations ranged from over 18°C in the surface waters of St. Georges Bay (Fig. 11) to less than 0°C in the bottom waters (> 50 m) on the Magdalen Shallows (Fig. 8). Surface layer temperatures were generally 15° to 17°C with the colder values found off the northeastern tip of Prince Edward Island (Figs. 7,8,9). The warmest surface layer waters were found within 10 km of the coastlines of mainland Nova Scotia and Cape Breton Island (Figs. 4-8), throughout St. Georges Bay (Fig. 11) and along transect C (Fig. 6). The general increase in the surface layer temperatures southward from the Magdalen Shallows towards St. Georges Bay can also be seen in Fig. 9 and Fig. 12A. Near-bottom temperatures were primarily dependent upon the station depth, varying from less than 0°C below 50 m on the Magdalen Shallows (Fig. 8) to 17°C at 20 m in St. Georges Bay (Fig. 11). There was, however, a downward slope in the bottom layer isotherms from the Magdalen Shallows towards Cape Breton Island (Fig. 8) and Northumberland Strait (Fig. 10).

The minimum near-surface salinities in the region (<27) were located between the northeastern tip of Prince Edward Island and Cape Breton Island (Figs. 7,8,9). Surface layer salinities on the western most stations on the Magdalen Shallows were 28 (Figs. 8,9) while along the Nova Scotia and Cape Breton Island

coastlines (Figs. 5-8), in St. Georges Bay (Fig. 11) and in eastern Northumberland Strait (Fig. 4), surface layer salinities were greater than 28 (see also Fig. 12B). The near-bottom salinities were principally dependent upon the bottom depth, increasing with the depth of the water column. The maximum salinities (>31) were observed in the waters below 45 m on the Magdalen Shallows (Fig. 8).

Maximum surface layer densities (σ_t >20) were found along the coastlines of mainland Nova Scotia and Cape Breton Island (Figs. 5-8), in St. Georges Bay (Fig. 11), along transect A in Northumberland Strait (Fig. 4) and on the Magdalen Shallows (Figs. 8,9). Between these two regions, the surface layer sigma-t was <20 (Fig. 12C). The similarities between the surface salinity and sigma-t distributions are shown in Fig. 12B and 12C with low density associated with low salinity. The highest density waters in the region (σ_t >25) were found on the Magdalen Shallows (Fig. 8) below 60 m. Sigma-t surfaces generally sloped down from the Magdalen Shallows towards Cape Breton Island (Fig. 8) and to a lesser degree towards Northumberland Strait (Fig. 10). Density differences between the surface layer and near-bottom waters are dependent on the bottom depth and were generally 3 to 5 sigma-t units. An exception was in Northumberland Strait (transect A, Fig. 4) where the density differences in the vertical were < 1 σ_t unit over 30 m.

The surface layer waters within St. Georges Bay in July 1981 were similar to those found nearshore (within $\sim$ 10 km) along the coastlines of Cape Breton Island to the northeast and mainland Nova Scotia to the west. These waters were 1° to 2°C warmer and 1 to 1.5 higher in salinity than the surface layer waters to the north between St. Georges Bay and Prince Edward Island and 0.5 higher in salinity than the waters towards the central Magdalen Shallows. A comparison of the Magdalen Shallows (Bugden 1981) with St. Georges Bay indicates that the warmer, higher salinity surface layer waters in the latter are typical during

summer (Drinkwater 1983). The nearshore continuity suggested by the similarities in surface layer temperatures and salinities along the Nova Scotia coast are consistent with the northeastward residual surface circulation inferred from surface drifters (Lauzier 1965, Drinkwater and Taylor 1979).

It is also interesting to note that the low salinity, low density tongue of surface layer water (see Fig. 12B,C) stretching from the Magdalen Shallows towards the southeastern tip of Prince Edward Island is likewise consistent with the southwestward surface residual circulation (Lauzier 1965) along the eastern coast of Prince Edward Island. The likely source of this low salinity, low density surface layer from the Magdalen Shallows is freshwater discharge from the St. Lawrence River system (Lauzier 1957, Sutcliffe et al. 1976).

REFERENCES

Banks, R.E. 1966. The cold layer in the Gulf of St. Lawrence. J. Geophys. Res. 71: 1603-1610.

Bugden, G. 1981. Heat and salt budgets for the Gulf of St. Lawrence. Can. J. Fish. Aquat. Sci. 38: 1153-1167.

Dawson, W.B. 1913. The currents in the Gulf of St. Lawrence from investigations of the tidal and current survey in the seasons of 1894, 1895, 1896, 1906, 1908, 1911 and 1912. Dept. of the Naval Service, Ottawa. 46 p.

Drinkwater, K.F. 1983. Heat and salt budgets for St. Georges Bay, Nova Scotia (in preparation).

Drinkwater, K. and G. Taylor. 1979. Physical oceanographic measurements in St. Georges Bay, Nova Scotia 1976 and 1977. Fish. Mar. Ser. Tech. Rept. No. 869: 46 p.

Forrester, W.D. 1964. A quantitative temperature-salinity study of the Gulf of St. Lawrence. BIO Report 64-11: 21 p. (Unpubl.)

Harding, G.C., W.P. Vass and K.F. Drinkwater. 1982. Aspects of larval American lobster (Homarus americanus) ecology in St. Georges Bay, Nova Scotia. Can. J. Fish. Aquat. Sci. 39: 1117-1129.

Harding, G.C., P.G. Wells and K.F. Drinkwater. 1979. The distribution and abundance of lobster larvae (Homarus americanus) in St. Georges Bay, Nova Scotia, in 1975 and 1976 and the possible effect that the Canso Causeway has had on the Chedabucto Bay lobster fishery. Fish. Mar. Serv. Tech. Rep. 834, Part 3: 101-111.

Hargrave, B.T. and N.J. Prouse. 1981. Observations of dissolved nutrients, phytoplankton, biomass, sedimentation and sediment organic matter in St. Georges Bay, 1978. Can. Tech. Rept. Fish. Aquat. Sci. No. 1001: 91 p.

Lambert, T. 1980. Daily and seasonal variation in the size and distribution of zooplankton in St. Georges Bay, Nova Scotia. Can. Tech. Rept. Fish. Aquat. Sci. No. 980: 73 p.

Lauzier, L.M. 1957. Variations of temperature and salinity in shallow waters of the southwestern Gulf of St. Lawrence. Bull. Fish. Res. Board Can. No. 111: 251-268.

Lauzier, L.M. 1965. Drift bottle observations in Northumberland Strait, Gulf of St. Lawrence. J. Fish. Res. Board Can. 22: 353-368.

Lauzier, L.M., R.W. Trites and H. B. Hachey. 1957. Some features of the surface layer of the Gulf of St. Lawrence. Bull. Fish. Res. Board Can. No. 111: 195-212.

Lewis, E.L. 1980. The Practical Salinity Scale 1978 and its antecedents. J. Oceanic Engin. 5: 3-8.

Marine Ecology Laboratory. 1980. Physical oceanography, dissolved nutrients, phytoplankton production, plankton biomass and sedimentation in St. Georges Bay, N.S. 1977. Can. Tech. Rept. Fish. Aquat. Sci. No. 934: 162 p.

Petrie, B. and K. Drinkwater. 1978a. Circulation in an open bay. J. Fish. Res. Board Can. 35: 1116-1123.

Petrie, B. and K. Drinkwater. 1978b. Numerical model of the circulation in an open bay. J. Fish. Res. Board Can. 35: 1631-1635.

Prouse, N.J. and B.T. Hargrave. 1977. Chlorophyll, carbon and nitrogen in suspended and sedimented particulate matter in St. Georges Bay, Nova Scotia. Fish. Mar. Ser. Tech. Rept. No. 721: 69 p.

Sutcliffe, W.H. Jr., R.H. Loucks, and K.F. Drinkwater. 1976. Coastal circulation and physical oceanography of the Scotian Shelf and the Gulf of Maine. J. Fish. Res. Board Can. 33: 98-115.

Ware, D.M. 1977. Spawning time and egg size of Atlantic mackerel, Scomber scombrus, in relation to the plankton. J. Fish. Res. Board Can. 34: 2308-2315.

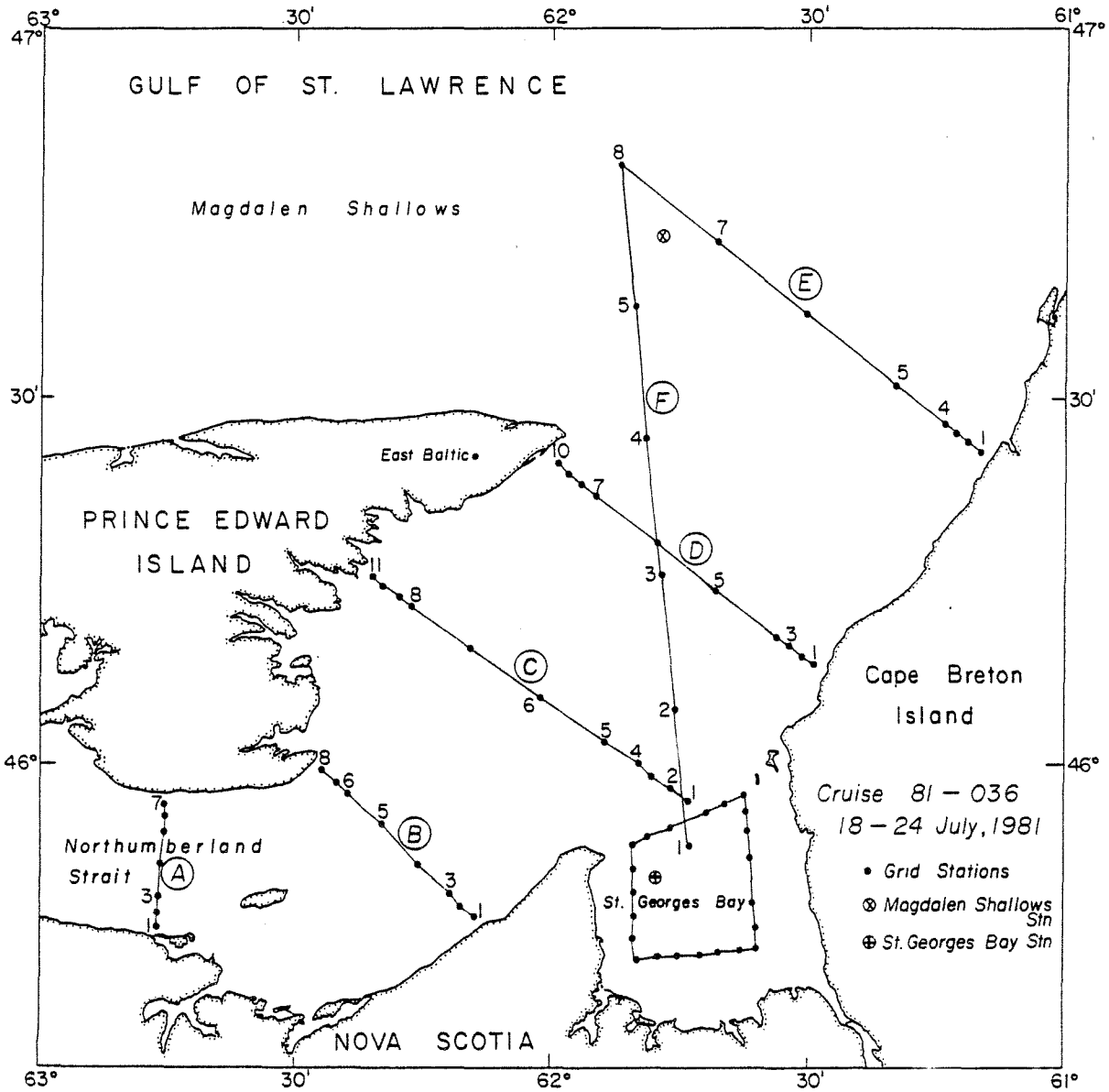


Fig. 1 Southern Gulf of St. Lawrence showing station locations for July 1981 cruise.

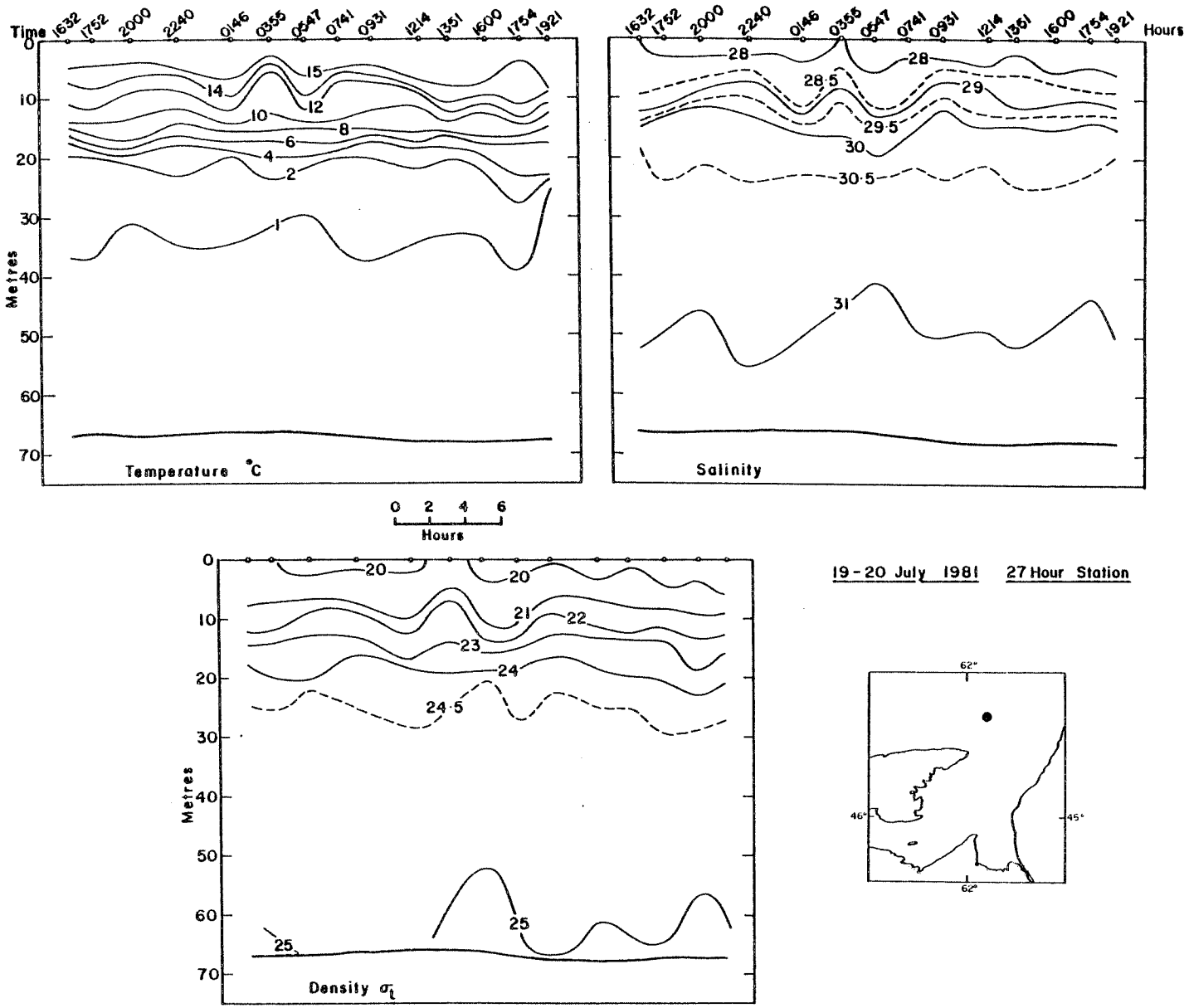


Fig. 2 Time series of temperature, salinity and sigma-t at the Magdalen Shallows station.

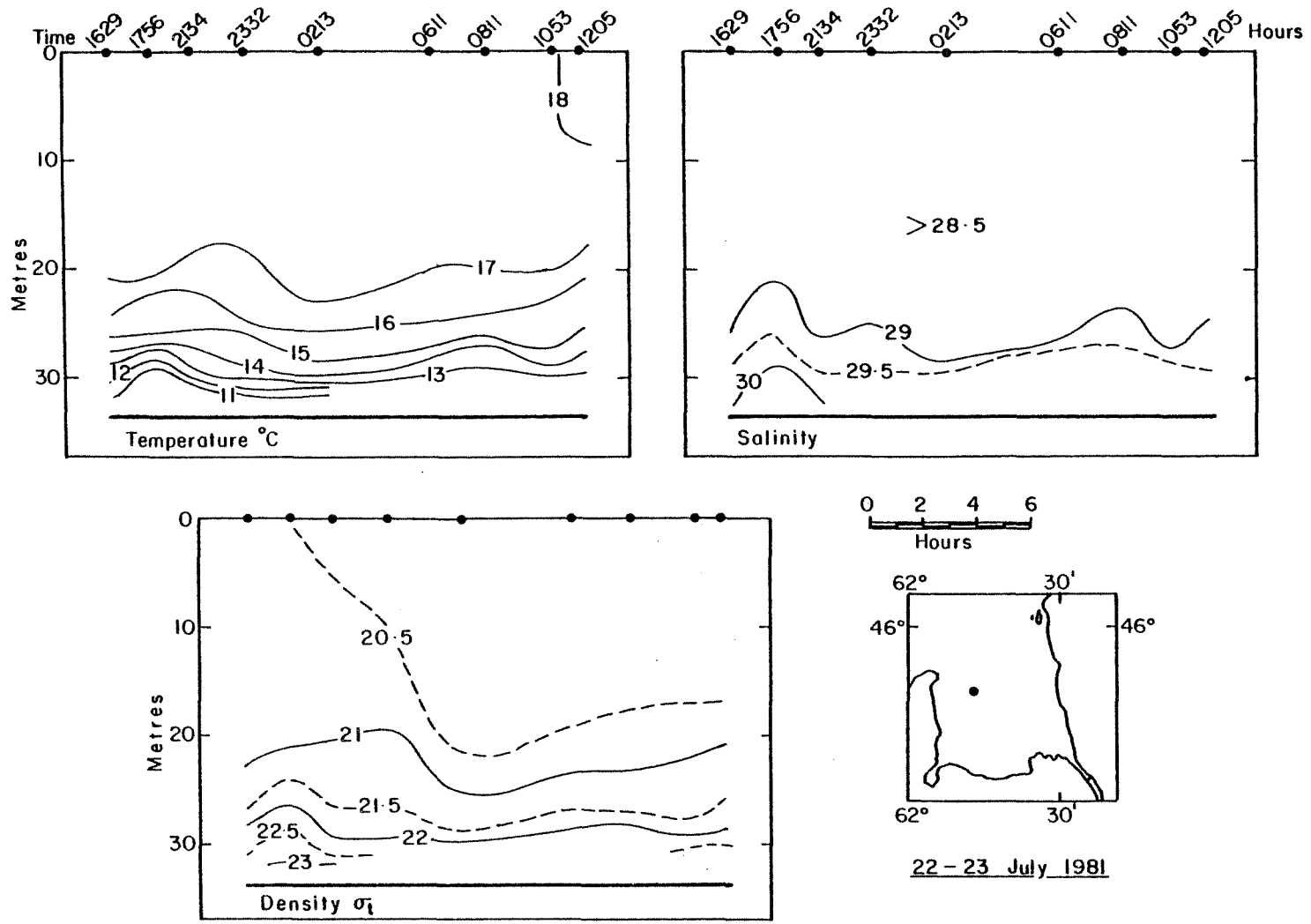


Fig. 3 Time series of temperature, salinity and sigma-t at the St. Georges Bay station.

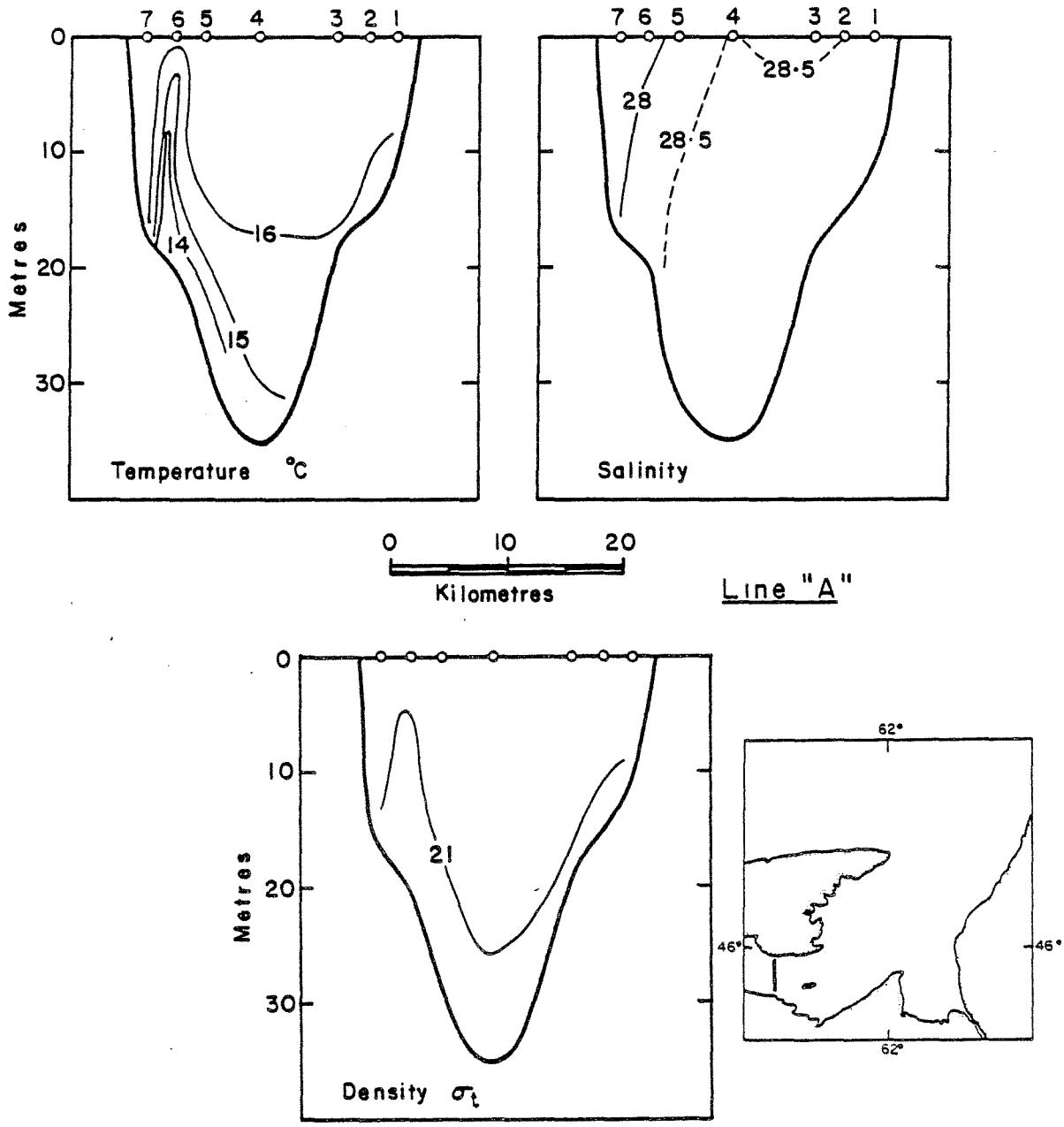


Fig. 4 Temperature, salinity and sigma-t on transect A.

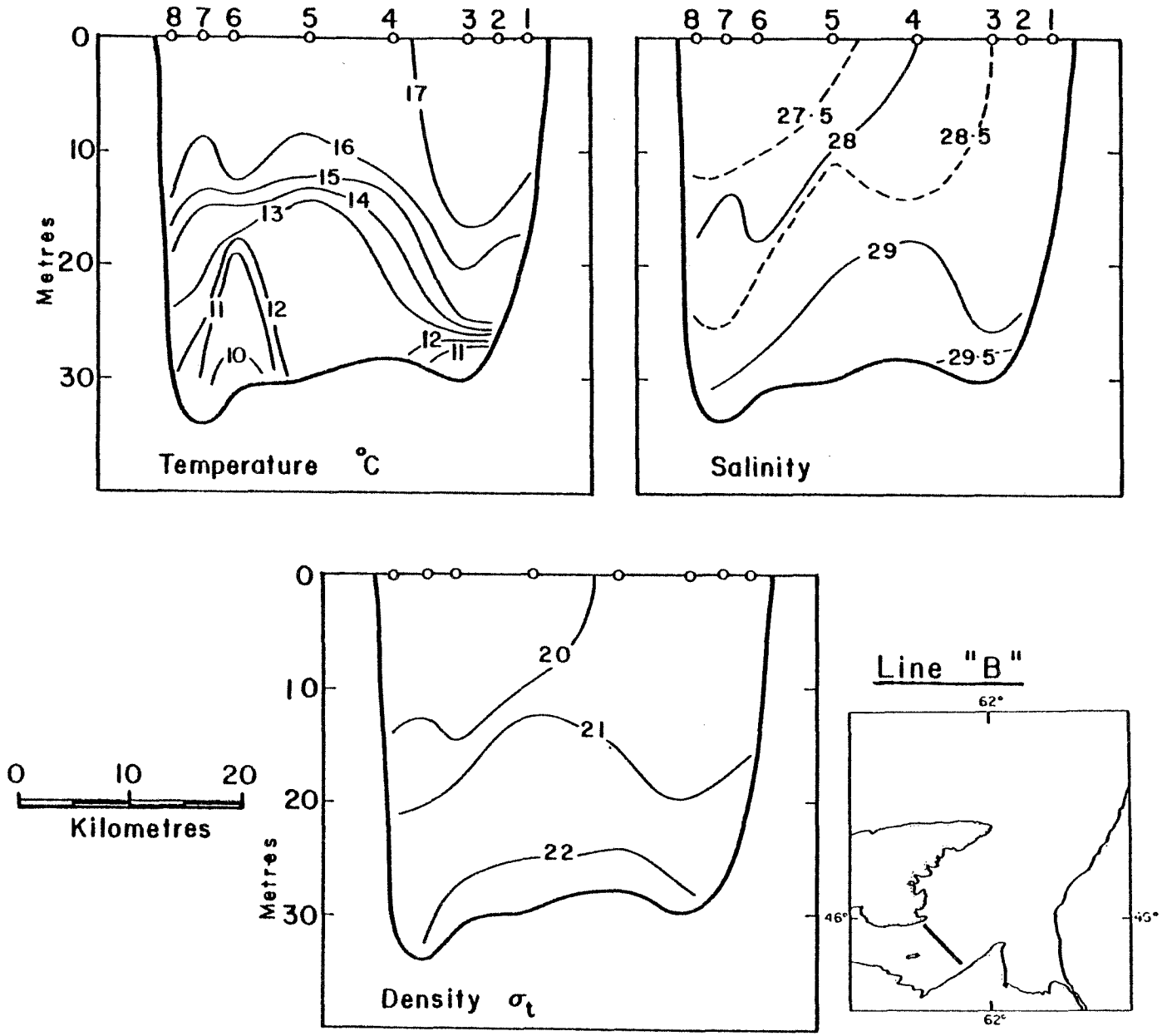


Fig. 5 Temperature, salinity and sigma-t on transect B.

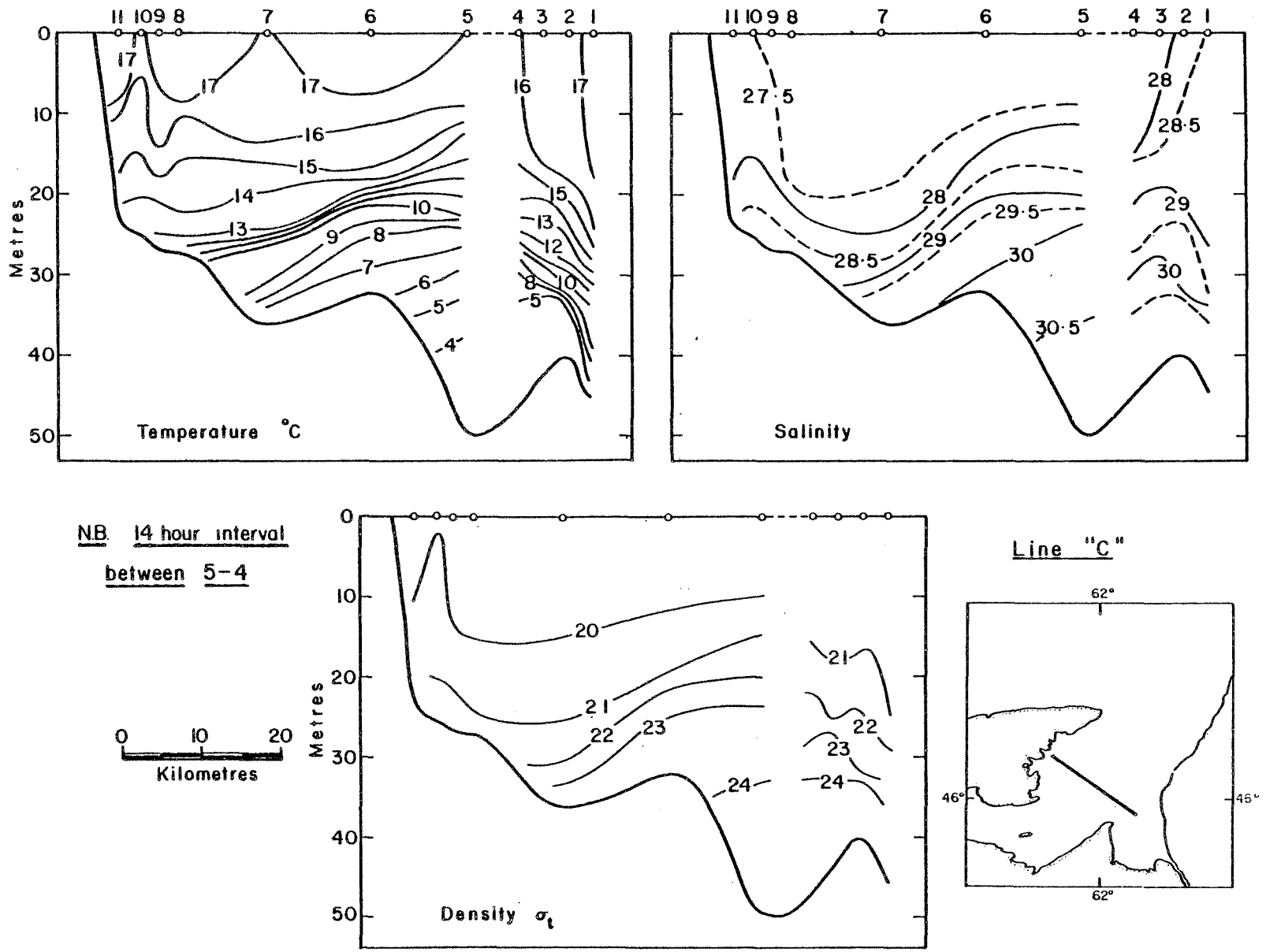


Fig. 6 Temperature, salinity and sigma-t on transect C.

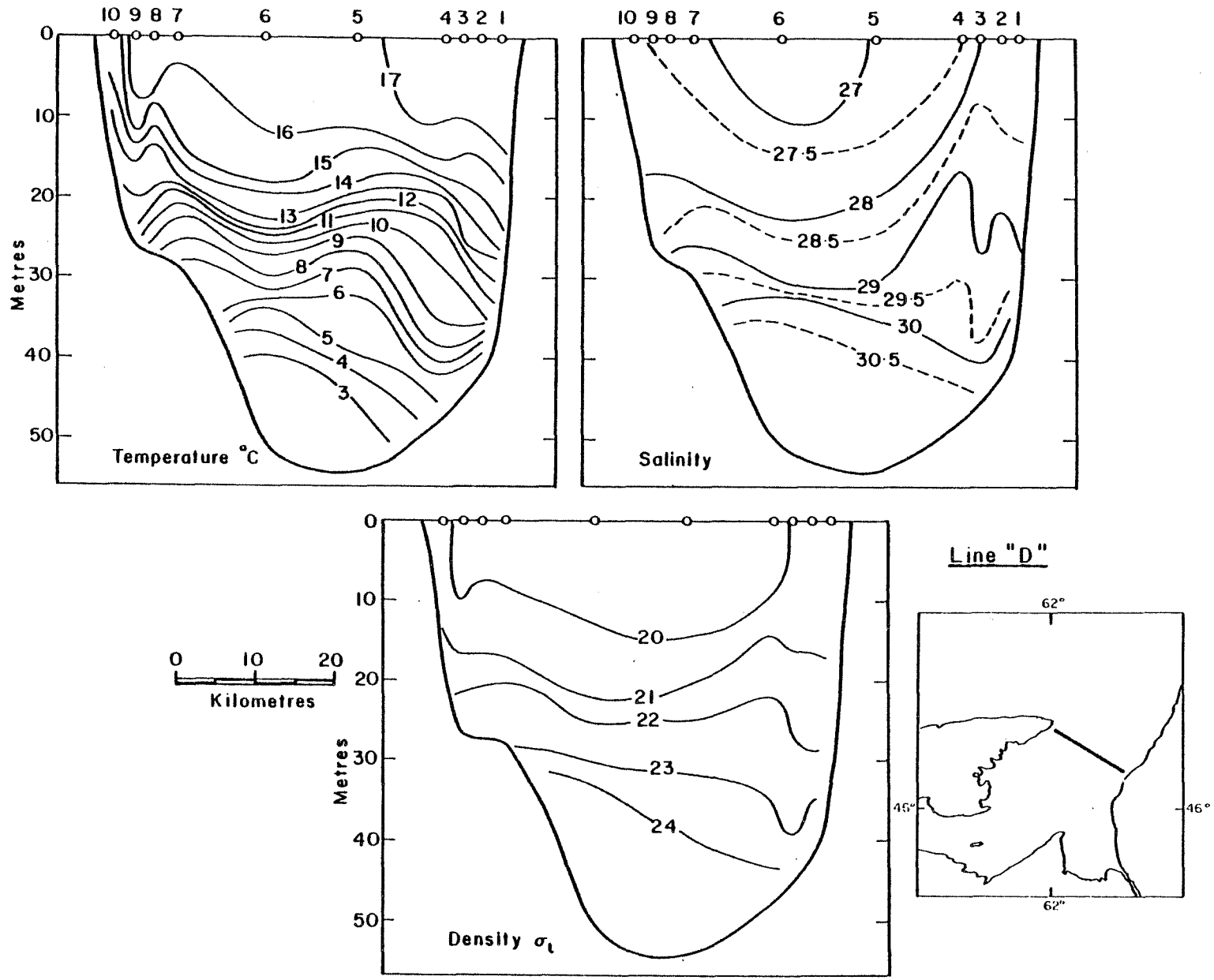


Fig. 7 Temperature, salinity and sigma-t on transect D.

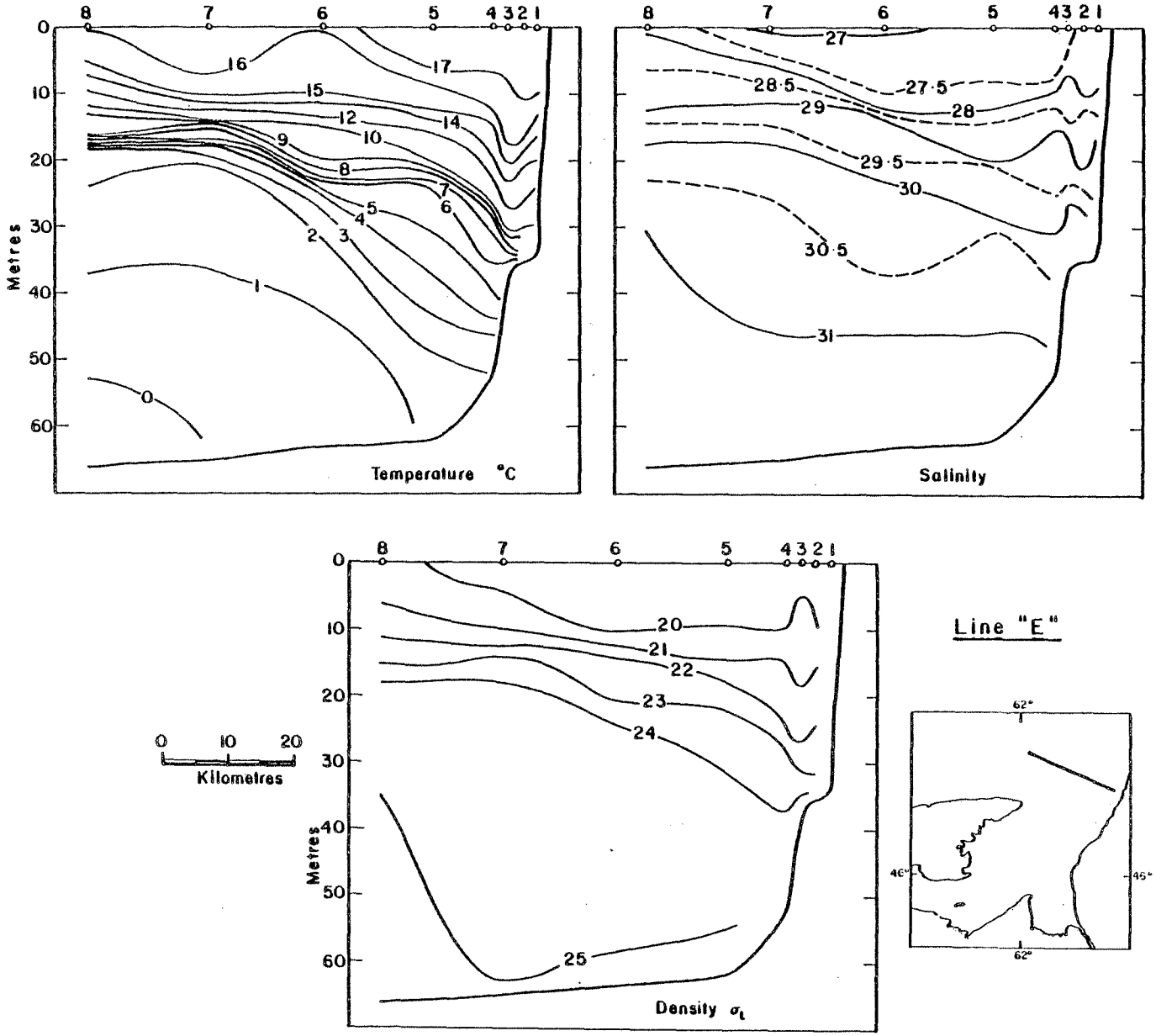


Fig. 8 Temperature, salinity and sigma-t on transect E.

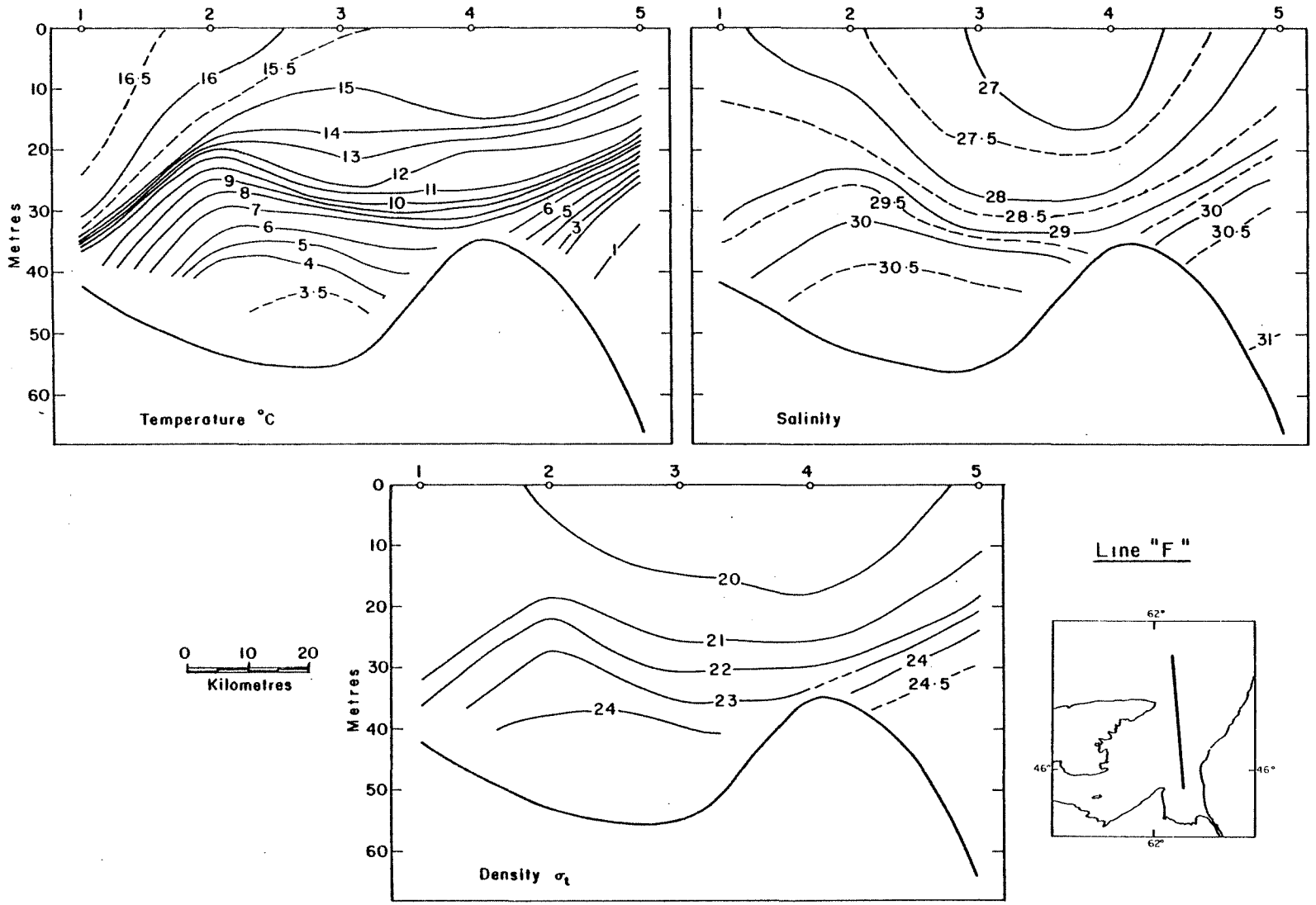
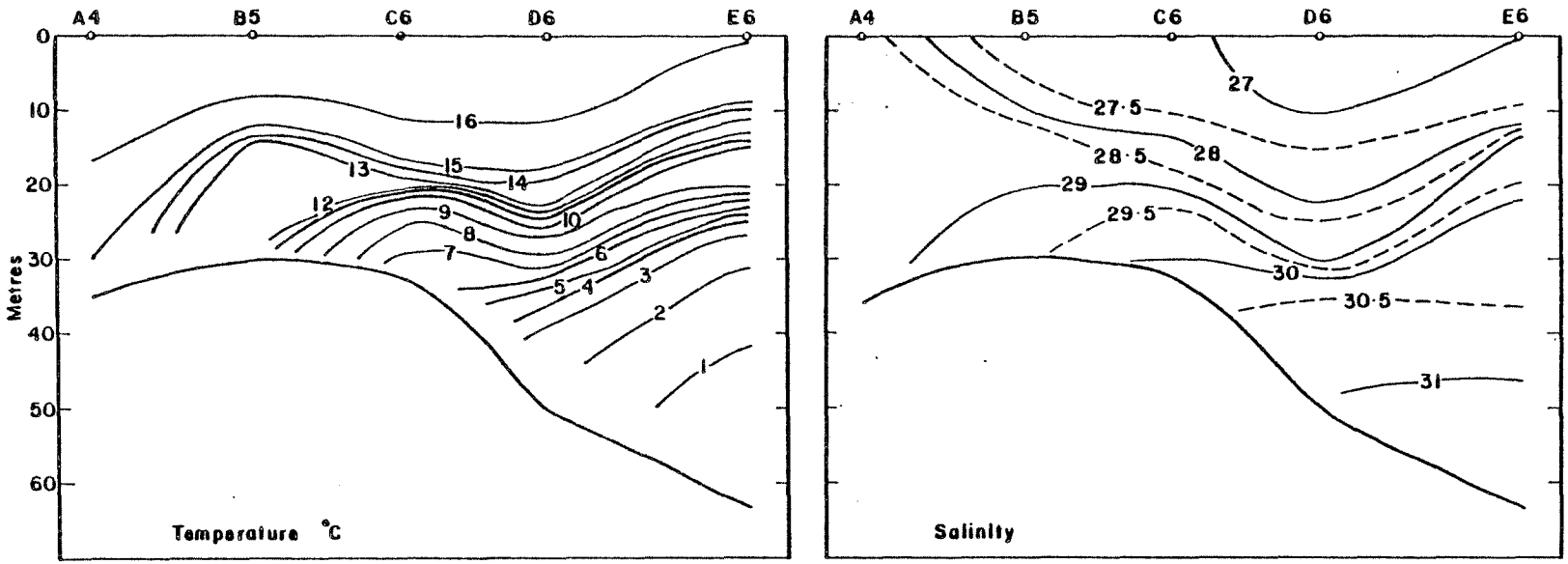


Fig. 9 Temperature, salinity and sigma-t on transect F.



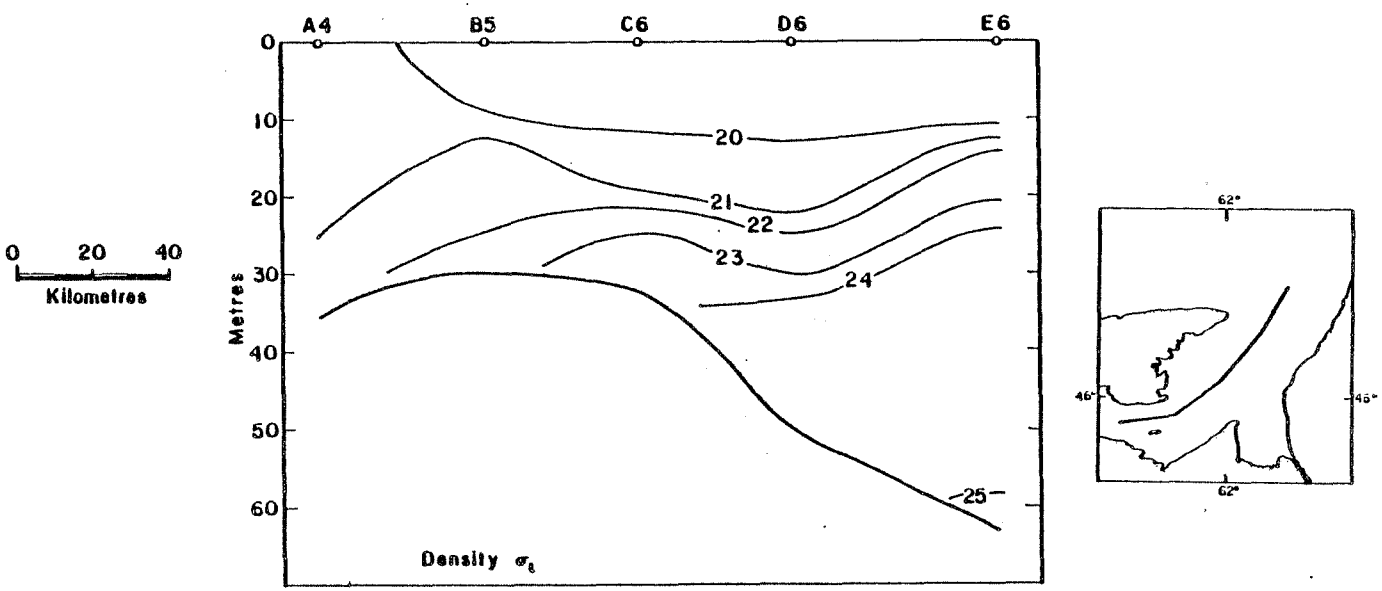


Fig. 10 Temperature, salinity and sigma-t on longitudinal transect (E6 to A4).

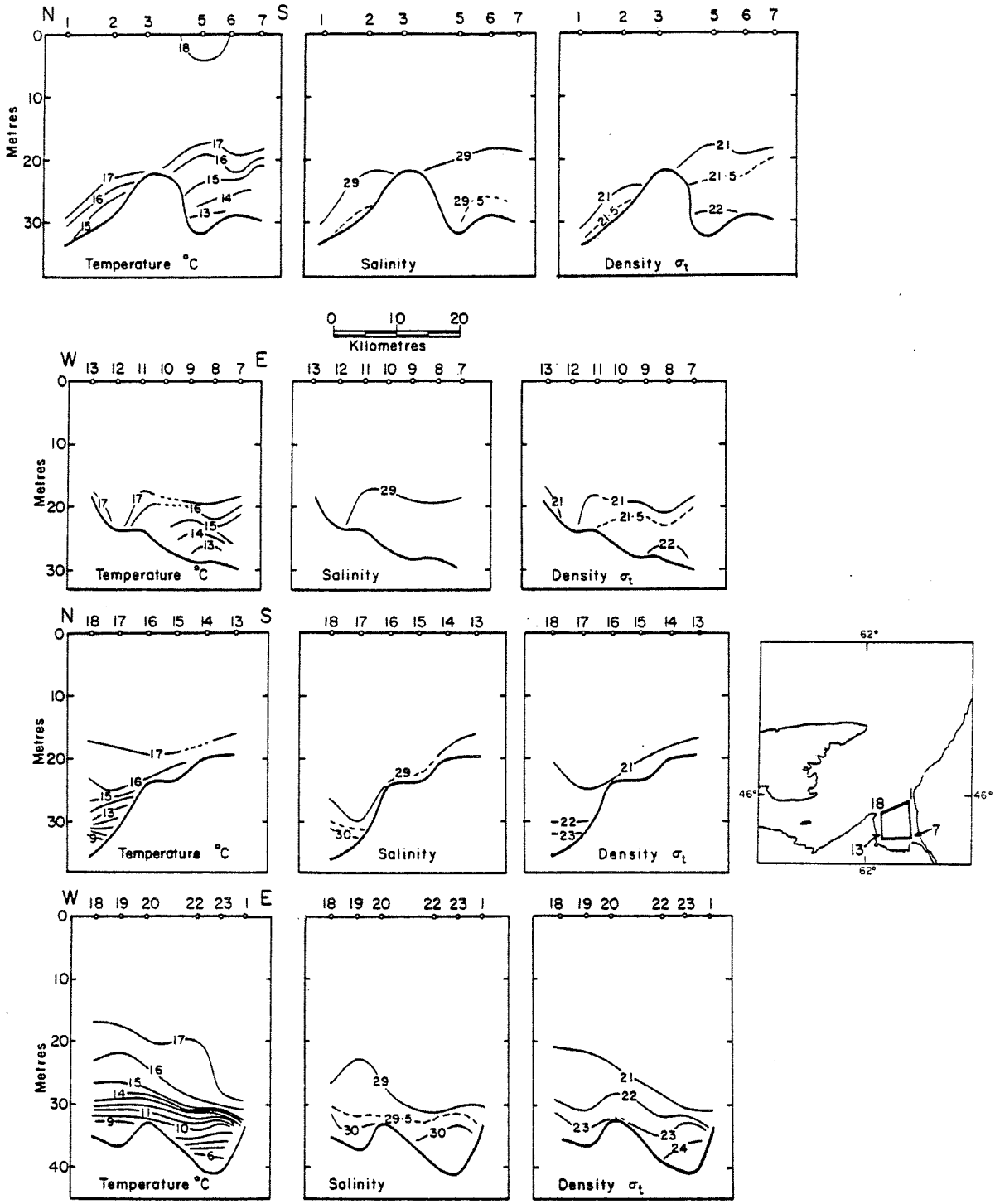


Fig. 11 Temperature, salinity and sigma-t on St. Georges Bay grid.

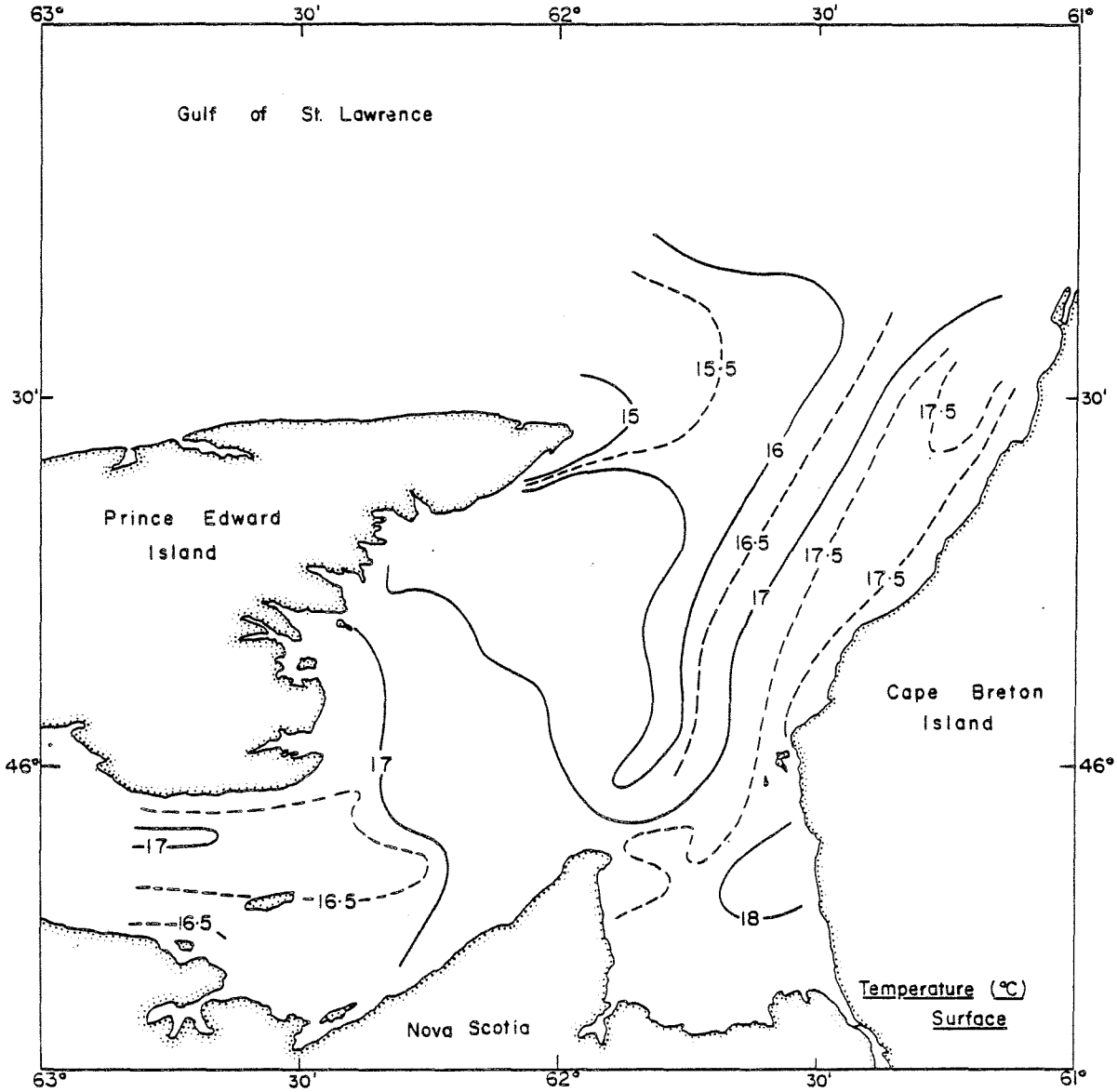


Fig. 12A Surface temperature distributions.

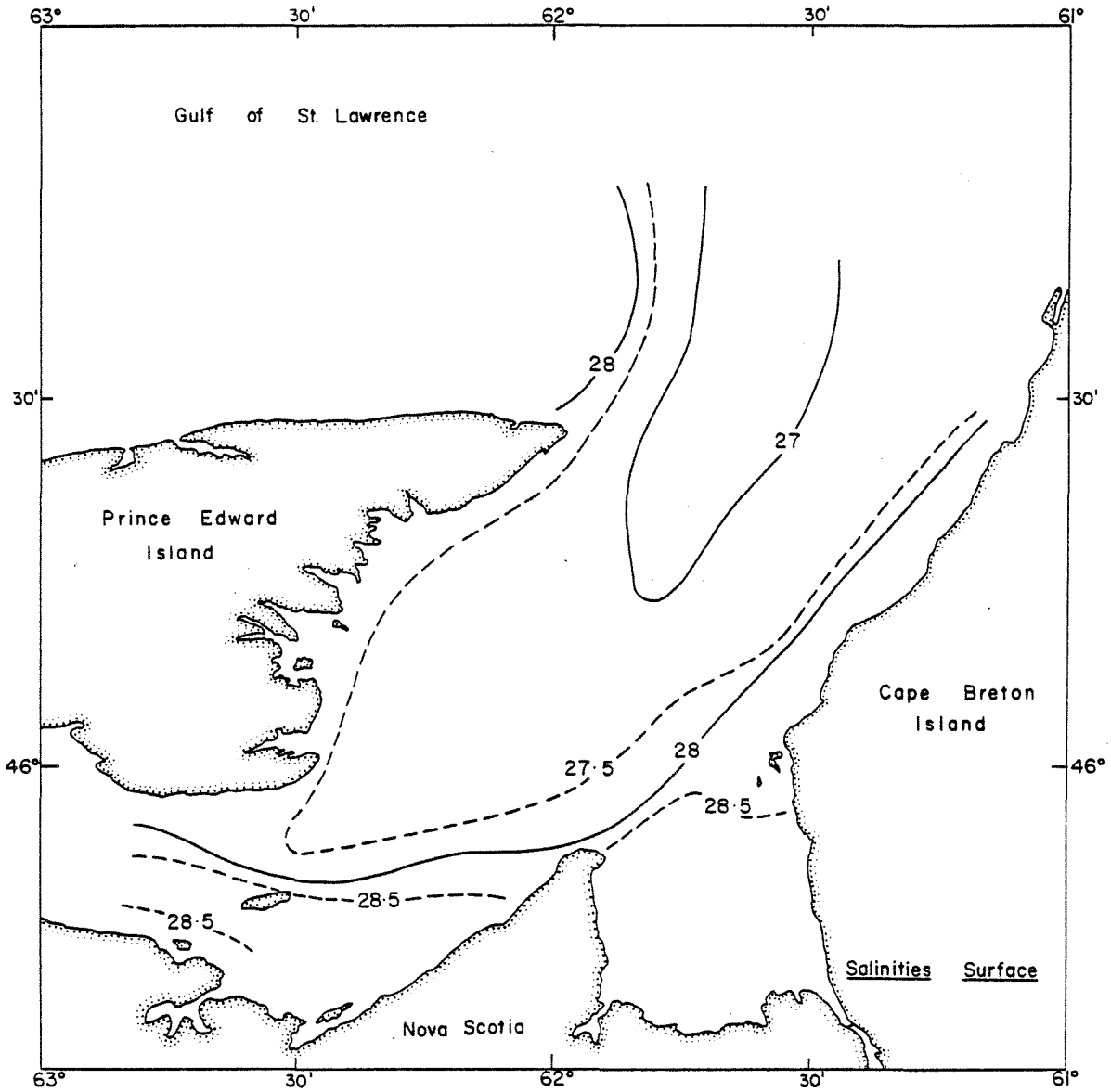


Fig. 12B Surface salinity distributions.

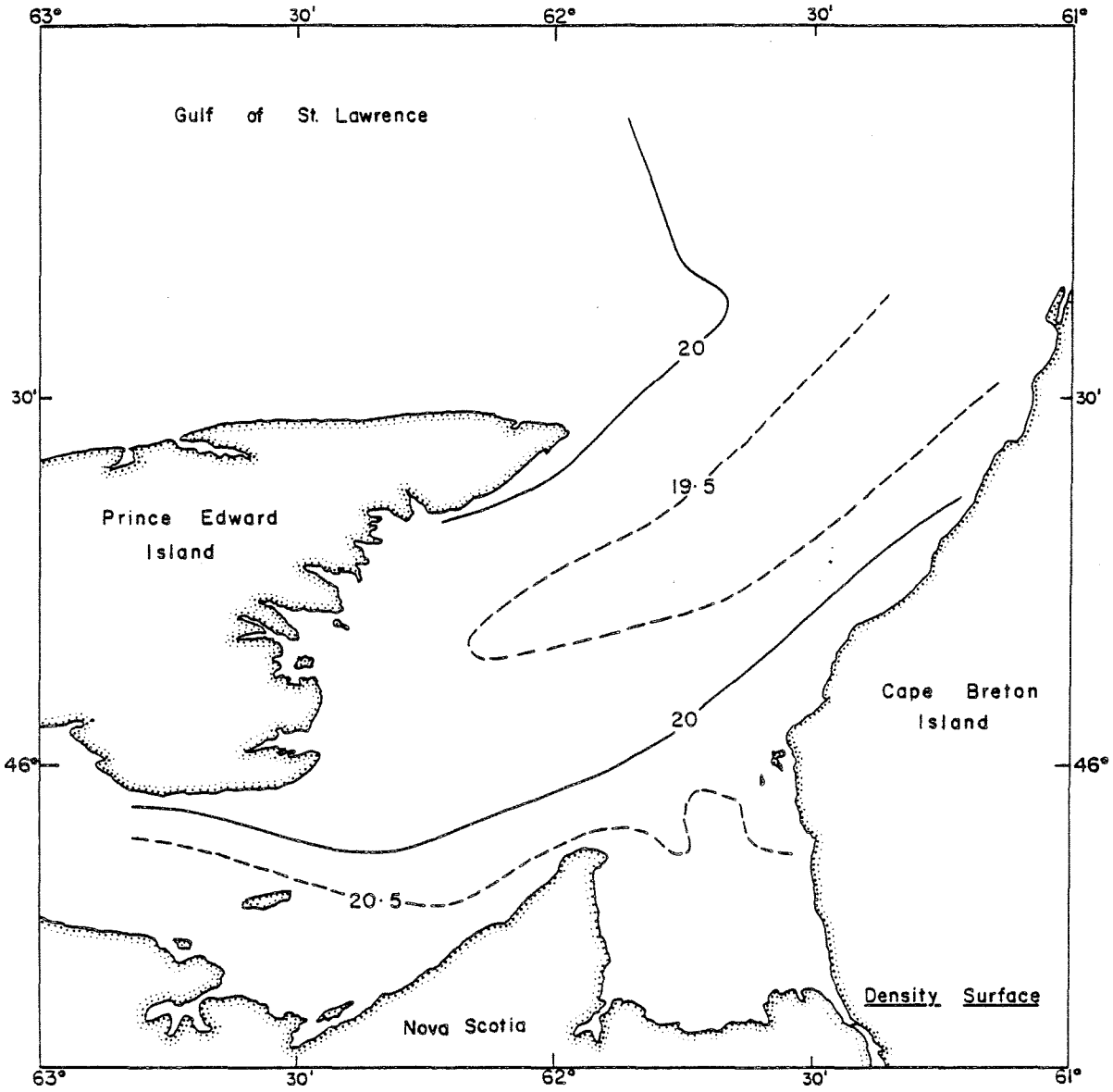


Fig. 12C Surface sigma-t distributions.