

NEW ZEALAND
DEPARTMENT OF SCIENTIFIC AND INDUSTRIAL RESEARCH

BULLETIN 162

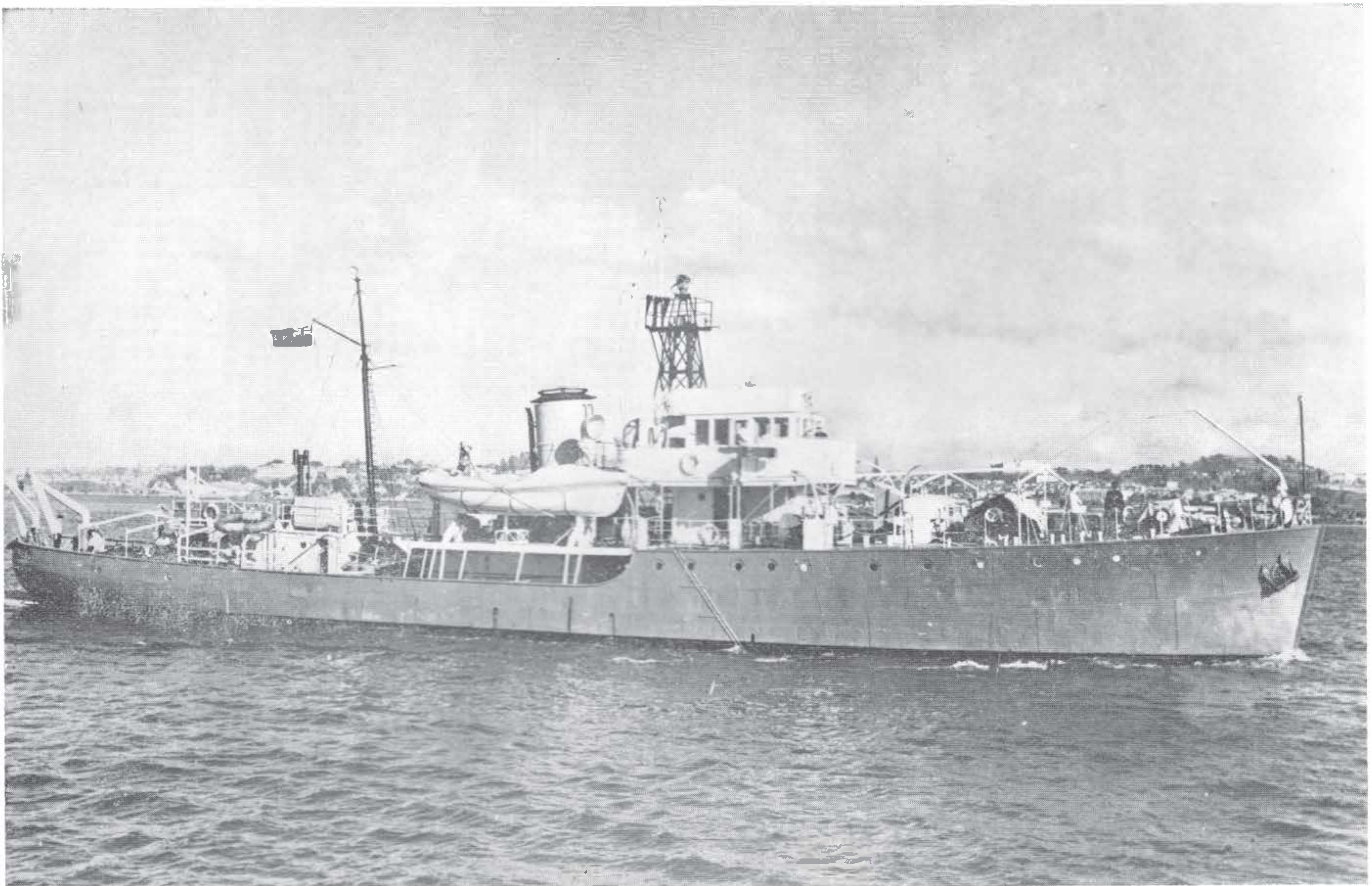
HYDROLOGY OF NEW ZEALAND OFFSHORE WATERS

by

D. M. GARNER and N. M. RIDGWAY

New Zealand Oceanographic Institute
Memoir No. 12

1965



RNZFA *Tui* from which the observations described in this memoir were carried out.

Photograph: RNZ Navy.

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FOREWORD

THE initial ocean-going cruises of the New Zealand Oceanographic Institute carried out in 1956 and early 1957 were designed principally to throw light on the hydrological situation in the waters offshore from both islands of New Zealand. At the same time as hydrological stations were worked plankton tows and sediment samples were obtained; this work will be described elsewhere.

The observations dealt with in this memoir represent the hydrological work of the winter cruises of mid 1956 and the second series of cruises made during succeeding summer months. The results complete a preliminary definition of seasonal situations and changes in the offshore hydrological environment.

The manuscript has been prepared for publication by Mrs P. M. Cullen, and final editing has been carried out by Miss G. L. Smith, Information Service, D.S.I.R.

J. W. BRODIE, Director,
New Zealand Oceanographic Institute.

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THE HYDROLOGY OF NEW ZEALAND OFFSHORE WATERS

INTRODUCTION

DURING the winter of 1956 and the summer of 1957, a series of exploratory oceanographic cruises in offshore waters around New Zealand was made by the New Zealand Oceanographic Institute from the Royal New Zealand Fleet Auxiliary *Tui* (frontispiece), made available by the New Zealand Naval Board. The following report presents the hydrological results of these cruises, with a discussion of their relation to the oceanic circulation around New Zealand.

These cruises were designed to investigate the hydrological environment around New Zealand and its seasonal variation, to a distance of roughly 500 miles offshore. Results reported here are derived from a series of winter cruises centred on the surface sea temperature minimum in July and a series of summer cruises centred on the surface sea temperature maximum in February. Cruises were made over as short a period as was consistent with adequate coverage of the area selected.

PREVIOUS WORK

SURFACE CIRCULATION

A survey of New Zealand coastal hydrology made in 1955 (Garner, 1961) illustrated the relation between coastal waters and oceanic waters just offshore from the shelf. A system of nomenclature for the main surface water movements around the New Zealand coast was defined as follows:

A north-flowing stream of cool water with predominantly subantarctic properties found in coastal waters off the east coast of the South Island, typically off the Canterbury coast, was

called the *Canterbury Current*. This current reached the vicinity of southern Cook Strait and there converged with the *East Cape Current*, a south-flowing stream of Subtropical Water. A branch of the Tasman Current, subtropical in origin, which flowed eastwards through Foveaux Strait and entered surface waters off the south-east coast of the South Island, was called the *Southland Current*. Off the north-west coast of the North Island a south-flowing tongue of Subtropical Water derived from the Trade Wind Drift, was called the *West Auckland Current*. This met the northward-moving section of the Tasman Current in the

eastern Tasman Sea – in coastal waters, called the *Westland Current* – at the *East Tasman Convergence*. This is a boundary region between two currents with differing, but mainly subtropical, characteristics, and probably varies its position in west coast waters between Cape Reinga at the northern tip of New Zealand and northern Cook Strait.

The *Subtropical Convergence* region in coastal waters can thus be regarded as the boundary between the East Cape Current and the Canterbury Current in the east and between the Tasman or Westland Current and the West Wind Drift, in the south-west. The general surface characteristics of the boundary in New Zealand surface waters has been discussed elsewhere (Garner, 1959a). Burling (1961) has pointed out that the cool water of the Canterbury Current while deriving ultimately from subantarctic surface water probably upwells from shallow depths (about 40 m). He postulated that the Southland Current is directed eastward at about the latitude of Banks Peninsula to flow towards the Chatham Islands along the southern margin of a narrow “Convergence Region”.

Brodie (1960) considered the coastal surface current pattern derived from drift card data. The circulation pattern derived is consistent with that summarised here. In addition, an inflow into Cook Strait from the west was found, and named the *D’Urville Current*. A well defined current flowing south-eastwards along the East Auckland coast was called the *East Auckland Current*.

HYDROLOGY

A summary and analysis of all available serial hydrological stations worked in New Zealand waters up to the time of the work presently discussed (Garner, 1962) outlined the state of knowledge of the distribution of Subtropical, Subantarctic, Antarctic Intermediate, Deep, and Bottom waters around New Zealand.

The Subtropical Convergence to the west of New Zealand generally approaches the coast near the south-west corner of the South Island and extends to the east from the vicinity of Cook Strait across the Chatham Rise, turning sharply southwards just west of the Chatham Islands. High salinity Subtropical Water is found to the north of this Convergence. Salinities of 35.8‰ were the highest surface values found in the data surveyed, occurring in the north-east Tasman Sea. Salinities reaching about 36‰ were present around the northern part of North Island during 1955

(Garner, 1961), indicating a strong southward flow of subtropical water. A narrow tongue of warm, high-salinity water off the East Coast of North Island and a broader tongue directed southward to the west of the Chatham Islands, accounts for the typically wavy configuration of the Subtropical Convergence.

In the subantarctic zone between the Antarctic Convergence and the Subtropical Convergence two distinct water types may be described. In addition to the Subantarctic Water whose salinity is between 34‰ and 34.2‰ and which extends around the whole circumpolar belt (Sverdrup *et al.*, 1946), Garner (1962) described relatively highly saline, warmer water found over the Campbell Plateau (Campbell Plateau Water).

The core of Antarctic Intermediate Water is represented by a salinity minimum, varying in depth from 800 to 1,000 m, north of the Subtropical Convergence and sloping up towards the surface in the region of the Antarctic Convergence. The horizontal extent of this salinity minimum appears to be controlled mainly by the bottom topography and its lowest salinity occurs to the east of the Campbell Plateau in the Bounty Trough. Generally, no salinity maximum is found below the Antarctic Intermediate Water in the South Pacific according to Sverdrup *et al.* (1946). However, in Deep Water between the Macquarie Island Ridge and the Campbell Plateau and in the region east of the Campbell Plateau, a salinity maximum is found at depths of 2,500 to 3,500 m. This salinity maximum has originated from water whose properties were formed at the surface in the North Atlantic Ocean and which has been carried into the Pacific via the Antarctic Circumpolar current with some modification in the South Indian Ocean.

Burling (1961) carried out an analysis of the northern limits of Subantarctic Water over a wide geographical region extending from the Indian Ocean to the south of New Zealand. He postulated that a current flows southward along the western edge of the Campbell Plateau where the Subantarctic Water of the Circumpolar Current approaches its steep slopes. Burling defined two types of Subantarctic Water, a *Circumpolar Subantarctic Water* of salinity below 34.5‰ existing through all circumpolar regions, and a warmer more saline *Australasian Subantarctic Water* (c.f. Campbell Plateau Water, described above) found to the south of the Eastern Indian Ocean, the Australian Continent, and the Tasman Sea. The Southland Current was shown to extend to a depth of several hundred metres from the boundary between the two types of Subantarctic Water and

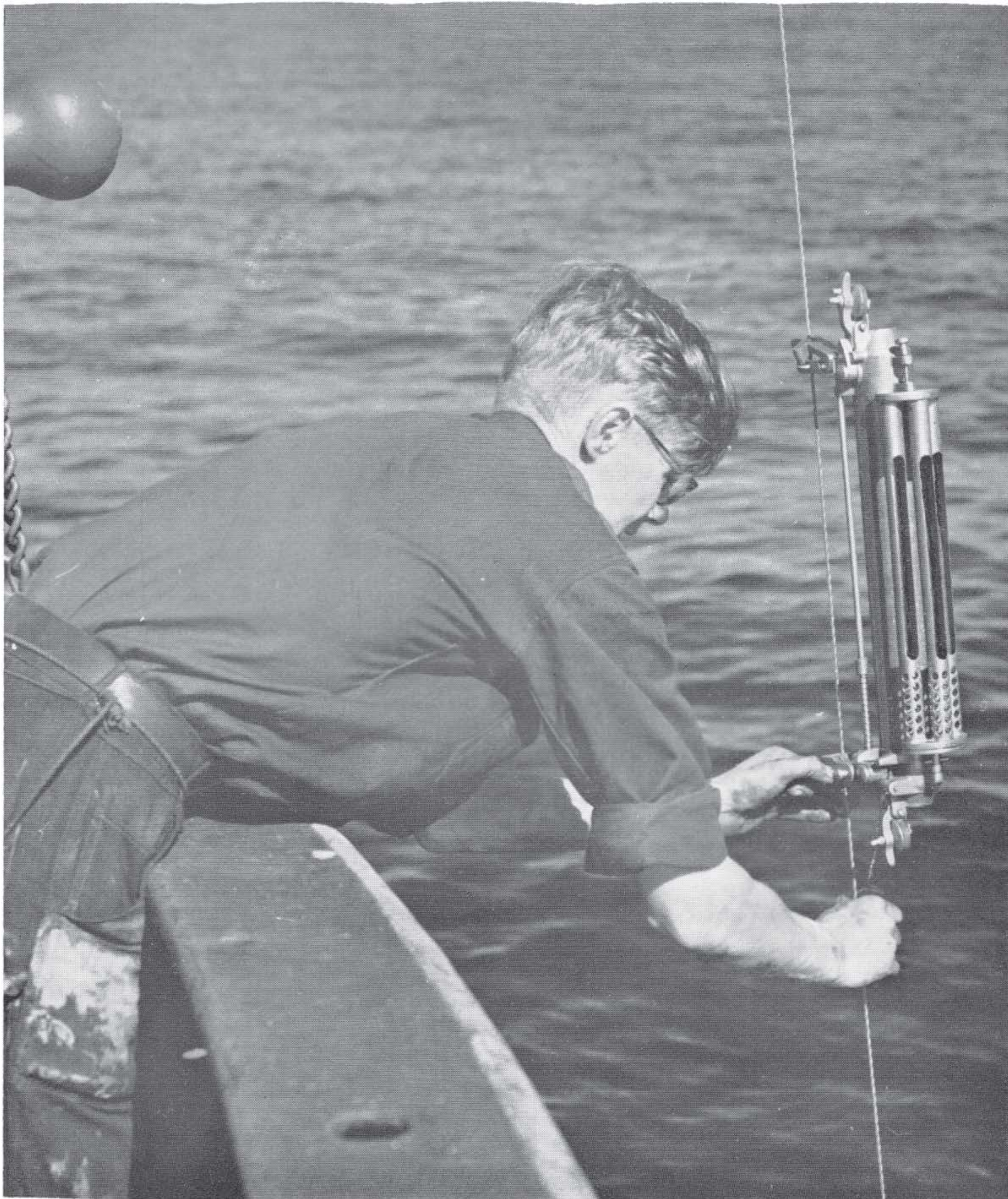


Plate 1—P. C. Spence attaches a messenger to the sounding wire before lowering the Knudsen reversing bottle.

Photograph: E. J. Thornley.

the continental slope. The existence of an anti-cyclonic eddy, the *Bounty-Campbell Gyral* which extends over the Bounty Trough and the northern Campbell Plateau, was introduced to account for a westwards flow of Circumpolar Subantarctic Water to the north of Campbell Island. Burling defined limits on the temperature – salinity diagram which characterised water found in the Subtropical Convergence region. Within this region, salinity above 200 m is between 34.7‰ and 35‰ and the density (σ_t) is less than 26.8.

BATHYMETRY

A sketch chart of the bathymetry of New Zealand waters prepared from soundings on file

at the New Zealand Oceanographic Institute is reproduced in fig. 1. Brodie (1958) described the general bathymetry around New Zealand.

The shelf around New Zealand is narrow, averaging approximately 20 miles in width. The sea floor around New Zealand does not fall away simply from the continental shelf edge to oceanic depths but is broken into a complex pattern of oceanic ridges and deeps. Within 300 miles of the coastline these deeps extend on the average down to 4,000 m. The manner in which topography modifies the horizontal movement of subsurface currents is of particular significance in a study of the oceanic hydrology of the New Zealand region.

OBSERVATIONS AND REDUCTIONS

A continuous record of near-surface sea temperature was kept by a thermograph recording in the engine-room condenser intake at a depth of about 3 m below the surface. Bathythermograph soundings giving a record of sea temperature continuous in depth to a maximum of 900 ft (274 m) were made as circumstances permitted. Surface water samples for salinity analysis were obtained by bucket over the ship's side where possible. At station positions serial measurements of temperature were made, and water samples for determination of salinity were collected at or near the I.A.P.O. standard sampling depths, in Knudsen reversing bottles.

SURFACE TEMPERATURES

Temperature measurements were corrected by reference to surface reversing thermometer readings. Surface thermograms, once adjusted to station reversing thermometer readings, were then used as a check on intermediate bathythermograph soundings.

Surface temperatures were plotted from thermograph records after these were compared with instrument calibration and surface reversing thermometer readings.

BATHYTHERMOGRAPH SOUNDINGS

The temperature scale of each trace was set according to the corrected thermograph reading at the time of the sounding. At station positions, a check against reversing thermometer readings was also available. Vertical cross sections of

temperature down to 900 ft were constructed from these soundings.

SERIAL TEMPERATURES

Negretti and Zambra reversing thermometers, with National Physical Laboratory Certificates, were used to obtain serial station temperatures and thermometric depths. A protected and an unprotected pair of thermometers were used on each reversing bottle. Thermometer corrections were computed by using Culbertson's (1955) Oceanographic Slide Rule. The mean density of the water column used in computing thermometric depths was averaged from the station data (table 4). Thermometric depths were compared with those obtained from wire lengths and wire angles in the manner described by LaFond (1951). Station bathythermograph soundings were used to control the shape of the temperature – depth curve in and above the thermocline.

SALINITIES

Water samples were stored in 4-oz glass mission bottles stopped with waxed bark corks. Surface salinities were determined with a Hamon (1956) chlorinity meter, and station salinities were derived from density and temperature measurements as described by Gilmour (1958). All salinities were referred to Copenhagen "Normal Water" as standard.

SERIAL T/S DATA

Temperature – depth, salinity – depth and temperature – salinity curves were drawn from the observed data for each station, and the shapes of these curves adjusted for mutual consistency within the limits imposed by the observations. Values of temperature and salinity for standard depths were derived from these curves.

DERIVED QUANTITIES

Values of density for standard depths were calculated, as were values of the anomaly of dynamic height from the surface to each level, by following the methods given by LaFond (1951).

TOWED-ELECTRODE CURRENT FIXES

Geomagnetically induced potentials in the sea were measured on one cruise to estimate surface

water movement, by the method described by von Arx (1950). Silver/silver chloride electrodes were used, towed in tandem 90 m apart, the nearer electrode lying 90 m from the ship's stern. Induced potentials were recorded on a strip chart potentiometer, and converted into the maximum possible apparent surface water speeds normal to the ship's track by using the formula:

$$E = H_z / v$$

where E is the inter-electrode potential difference, H_z is the local vertical component of the geomagnetic field, l is the inter-electrode distance and v is the current speed. The ocean current velocity vector was defined by sailing along and back on a 5-min leg normal to the ship's established track, giving two components of flow and the electrode-pair zero point.

CRUISE PLAN

WINTER

Six separate cruises were undertaken (table 1); tracks followed and positions of hydrological stations worked are shown in fig. 1.

The cruise plan was, in general, designed around the requirements of the hydrology programme, subject to an independent schedule for *Tui* to call at Norfolk Island, Raoul Island, the Chatham Islands, and Campbell Island en route. The original plan was further modified at sea by illness and accident on board ship, and by heavy weather. Absence of stations in the southern parts of cruises I and II, and curtailment of underway observations in cruise IV are due to these causes. Nevertheless, a representative coverage of the area of interest was obtained. During 57 days at sea, surface and bathythermograph data were obtained on 7,000 miles of ocean passage around New Zealand and 20 hydrological stations were occupied. The work lasted from 1 June to 21 August 1956.

Surface temperatures and salinities, bathythermograph soundings, and vertical profiles of temperature and salinity were taken as far as Norfolk and Raoul Islands in the north (500 and 600 miles offshore respectively) in the east to the Chatham Islands (300 miles) and towards the Bounty Islands (250 miles); to Campbell Island 300 miles south of New Zealand, and 300 miles into the south-west Tasman Sea. No observations were obtained immediately west of the North

Island. Stations were distributed mainly over the deep water of the Tasman and South Fiji Basins, the Bounty Trough, and the Hikurangi and Kermadec Trenches. Station A 292 was worked over a previously unlocated seamount in 493 m situated north of North Cape, and Station A 311 on the Campbell Plateau in 139 m.

In hydrological terms, the Subtropical Convergence region, Subtropical Water to the north, and Subantarctic Surface Water south of New Zealand were all covered by the survey.

SUMMER

Four cruises were completed (table 1); track and station configuration is shown in fig. 1. Heavy weather was this time responsible for an absence of stations east of New Zealand, but a good station coverage was achieved in the eastern Tasman Sea and to the north of New Zealand. During 37 days at sea between 7 January and 4 May 1957, about 6,000 miles of surface observations and bathythermograph soundings were obtained, and 20 hydrological stations were occupied. No observations were made from *Tui* to the south of New Zealand. Surface observations made from Antarctic cruises during the same season (Burling, 1961) have been used to extend the survey coverage, where appropriate, and several stations worked in the eastern Tasman Sea by the Australian Division of Fisheries and Oceanography during January 1957 (Rochford, 1959) also provide complementary data (see fig. 1A).

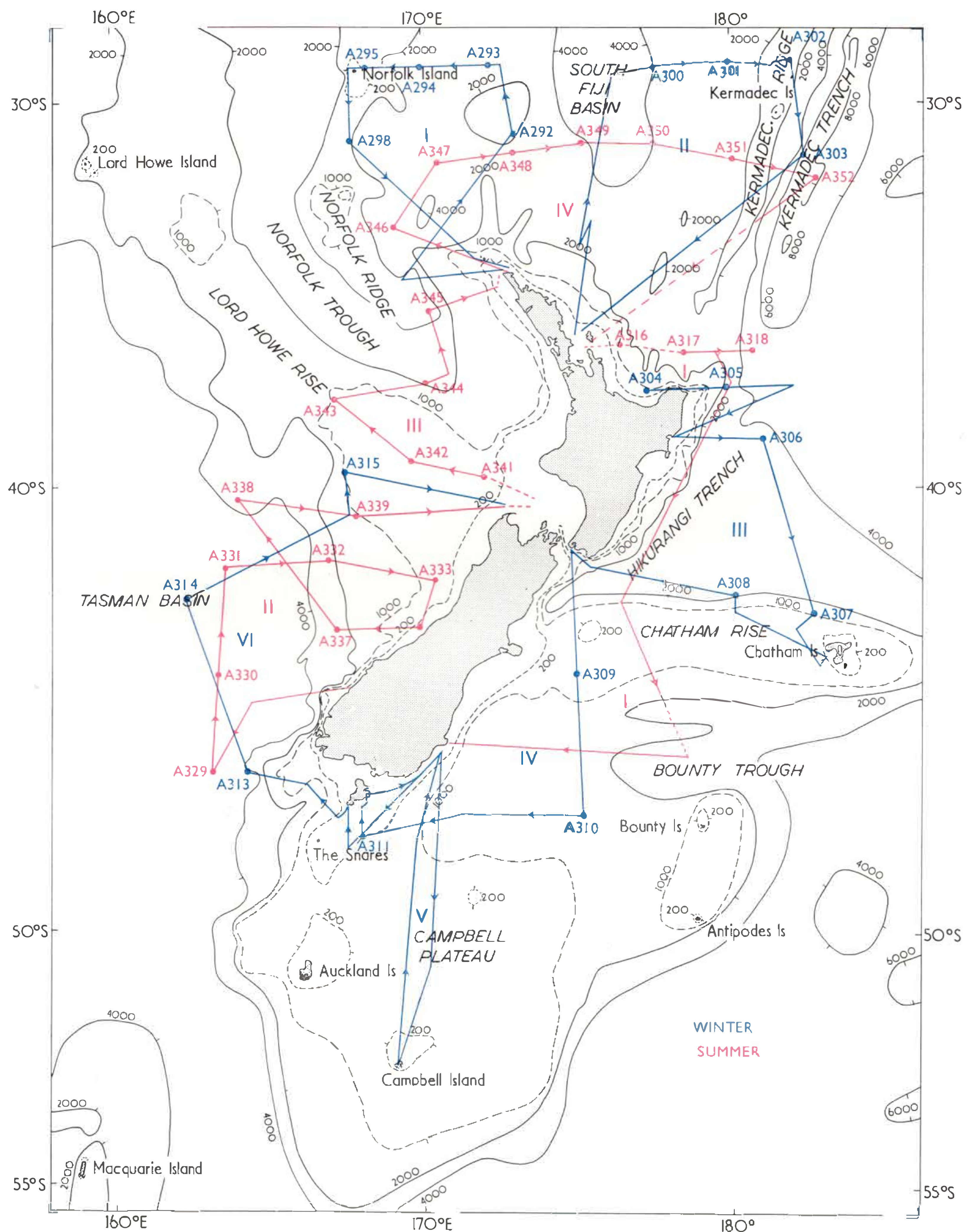


Fig. 1: Chart of the New Zealand region showing: (a) Sketch bathymetry of the sea floor in black; (b) Winter cruise track and station positions in blue; (c) Summer cruise track and station positions in red.

TABLE 1—DETAILS OF CRUISES

Cruise	Region			Dates		Miles covered	Stations completed	In charge of hydrology
(a) <i>Winter (1956)</i>								
I	Norfolk	..	..	1-13/vi	..	1,600	5	D. M. Garner
II	Kermadec	..	..	27/vi-6/vii	..	1,400	4	R. W. Burling
III	Chatham	..	..	10-23/vii	..	1,400	5	R. W. Burling
IV	Bounty	..	..	27/vii-3/viii	..	750	3	R. M. Cassie
V	Campbell	..	..	6-10/viii	..	650	..	D. M. Garner
VI	S.E. Tasman	..	..	13-21/viii	..	1,350	3	D. M. Garner
(b) <i>Summer (1957)</i>								
I	East Coast	..	..	7-19/i	..	1,550	..	D. M. Garner
II	S.E. Tasman	..	..	29/i-7/ii	..	1,800	9	D. M. Garner
III	N.E. Tasman	..	..	8/i-18/ii	..	950	5	R. W. Burling
IV	Norfolk/Kermadec	..	..	26/ii-4/iii	..	1,800	6	R. W. Burling

PRESENTATION OF DATA

SURFACE TEMPERATURE

Plots of corrected surface thermograph readings have been contoured in degrees centigrade and winter and summer isotherm configurations are reproduced as charts 1 and 2. [These were issued as New Zealand Oceanographic Institute Charts Miscellaneous Series No. 2 and 3 (1962) and were prepared for special purposes before the completion of the present report.]

SURFACE SALINITY

Continuity of closely spaced surface salinity samples could not be maintained during these cruises. Since surface salinity data were thus not available in detail comparable with that from the automatic thermograph, it was not thought profitable to attempt to construct charts similar to those for surface temperature. On the basis of previous data, the pattern of isohalines may be assumed to be similar in structure to that of the isotherms, and the relation between these two distributions is shown by figs. 36 and 37, in which the salinity of each sample collected is plotted as a function of the sea temperature at the time of sampling for each of the two seasons.

BATHYTHERMOGRAPH SECTIONS

Data from bathythermograph soundings have been presented in the form of vertical cross sections, with temperature contoured, in general, at intervals of whole degrees centigrade. These cross sections are reproduced, together with location maps, in

figs. 2-14 for the winter series of observations and in figs. 15-35 for the summer series.

HYDROLOGICAL STATIONS

Station temperature and salinity data reduced from reversing bottle measurements are listed in table 3, together with the derived quantities of density (σ_t) and cumulative dynamic height anomaly ($\Sigma \Delta D$). The station circumstances (date, time, position, and water depth) are listed in table 2. Temperature-salinity diagrams are shown in figs. 36 and 37 respectively for the winter and summer stations. These show the area occupied by station data in block form only; temperature-salinity curves for individual stations may readily be constructed from table 3 as required. Selected vertical cross sections of temperature and salinity, constructed from the station data, appear in figs. 38-43 for the winter series, and in figs. 44-54 for the summer series.

The bottom topography shown on these cross sections is highly schematic and only notes the presence of the major structural features. The temperature cross sections constructed from station data similarly do not attempt to reconstruct the detail shown in corresponding sections derived from bathythermograph soundings. The salinity cross sections contain a superposition of selected isopycnals, calculated from the measured temperature and salinity data to show the relation between salinity and density structure in the water column.

TOWED-ELECTRODE CURRENT FIXES

A series of geomagnetically derived current determinations were made on the southern section

of summer cruise I, north-east of the Bounty Islands. The results are tabulated in table 5 and plotted in fig. 55.

DISCUSSION OF DATA

SURFACE TEMPERATURE

Sea surface temperature in the vicinity of New Zealand generally reaches its seasonal minimum during the period July–September and its maximum around January–February. Some detailed curves have been published earlier (Garner, 1953, 1954, 1955, 1959a). Temperature may thus be expected to be varying fairly slowly during the period covered by these *Tui* cruises. The relative positions in time of each cruise, as given in table 1, should be kept in mind while the temperature distributions shown in charts 1 and 2 are studied, however, since isotherms have been drawn on a synoptic basis.

(a) Winter (Chart 1)

The highest surface temperatures measured were found in the northern part of the area covered,

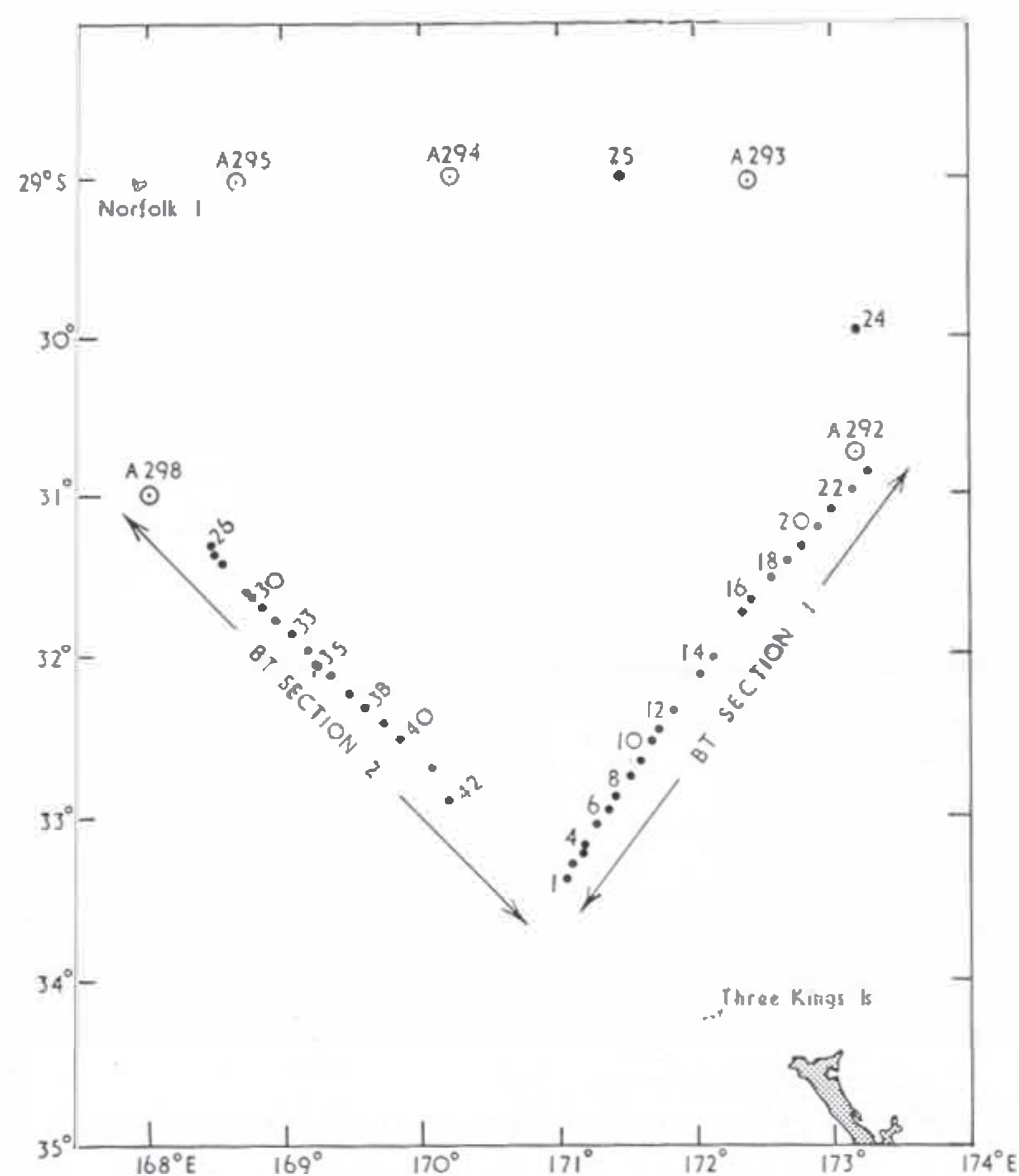


Fig. 2: Location of bathythermograph sections 1 and 2 (see figs. 3 and 4) from winter cruise I north-west of New Zealand.

reaching values of just over 21°C in the vicinity of the Norfolk and Kermadec Islands. The lowest surface temperature reached almost 7°C around Campbell Island – a range of about 14°C over some 24° of latitude.

North of New Zealand, the surface water in the western sector covered by cruise I was somewhat warmer than that covered to the east by cruise II, although this may have been due to the time which elapsed between the two cruises, rather than to any real difference in surface temperature in the north Tasman Sea as compared with the region north-east of New Zealand. The warmest water off the north-east coast of North Island was confined to a fairly narrow tongue between North Cape and the Bay of Plenty. South from East Cape, the tongue of warm water which has appeared consistently in east coast investigations, and which has been associated with the south-flowing East Cape Current, was well in evidence, reaching the latitude, offshore, of the mid-Canterbury coast. A mass of relatively cold water was crossed south-east of Cape Palliser on the final leg of cruise III. Whether this represented upwelled water, or colder southern water cut off by a recent advance of the East Cape Current, is not known, as no subsurface measurements or surface salinity samples could be collected at this time. Coastal features, which have previously been described (Garner, 1961), are the cold-water regions of upwelling off Cape Reinga and the winter cooling of the enclosed shallow waters of the Hauraki Gulf. Insufficient data were obtained to the west of New Zealand to show any detail of the surface temperature pattern in the eastern Tasman Sea. A variation in surface temperature of less than 2°C was recorded off the west coast of South Island between the latitudes of Cape Farewell and Foveaux Strait. The time difference of over two months between observations made off Cape Reinga and off Cape Farewell almost certainly accounts for the much larger difference in sea surface temperature shown between these points. The absence of data from the west of North Island prevents matching of isotherm patterns in these areas.

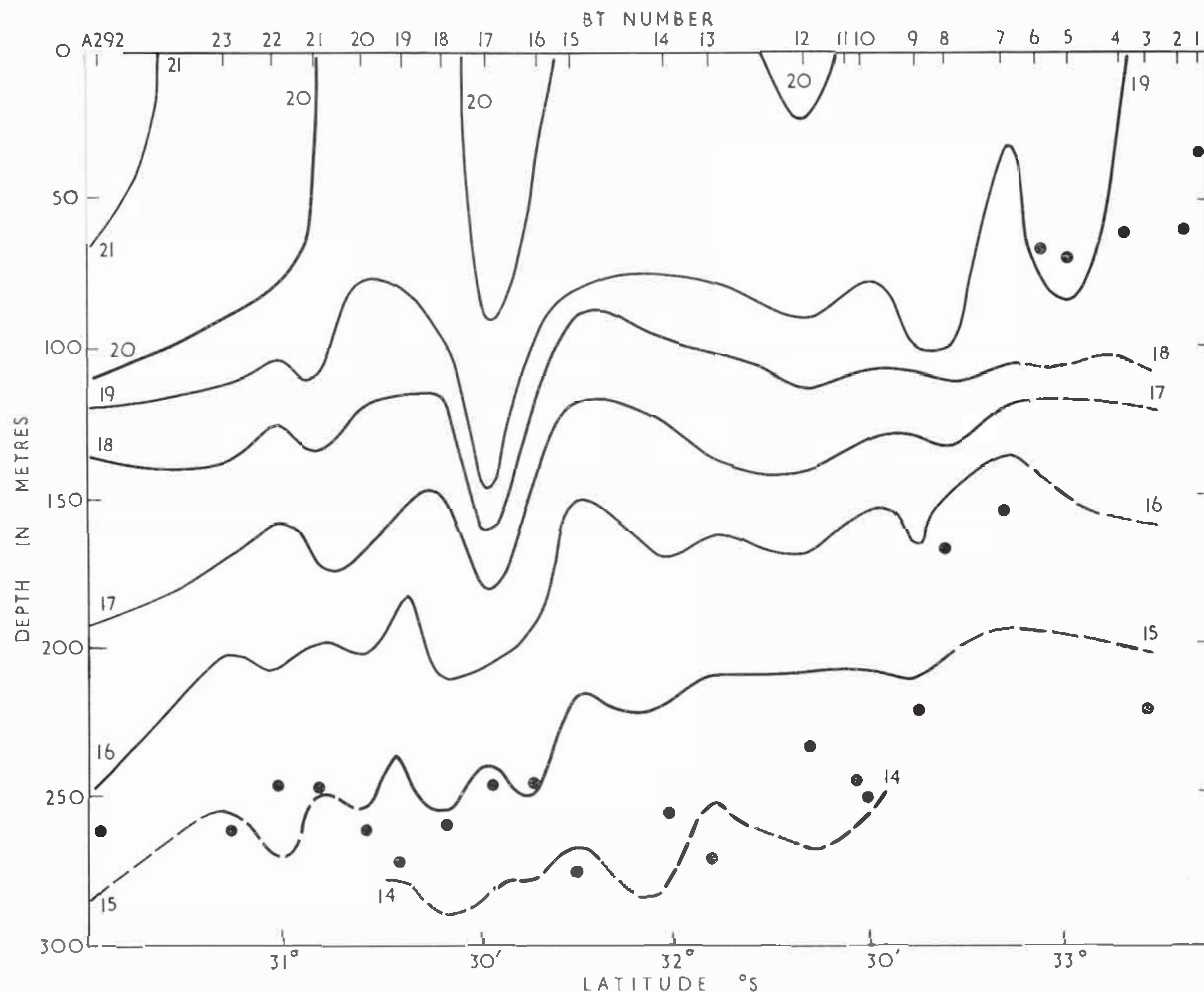


Fig. 3: Vertical cross section of temperature ($^{\circ}\text{C}$) along bathythermograph section 1 (see fig. 2).

The steepest gradient in surface temperature may be expected at the Subtropical Convergence. Previous experience (Garner, 1959a, 1961) has shown that this boundary will follow the trend of the 10°C surface isotherm in winter, and very pronounced temperature boundaries were indeed found with a mid-temperature of this value south-east of Banks Peninsula on the southward leg of cruise IV (south of Station A 309), and off the east coasts of Otago and Stewart Island. New Zealand appears to lie wholly on the subtropical side of the Subtropical Convergence during this winter survey. An attempt to locate the position of the Convergence to the south of Stewart Island was turned back by heavy weather, but the boundary apparently lay southwards of the Snares. A considerable area of water was thus occupied by the Southland Current bringing Tasman Water of subtropical origin south of New Zealand. East of the South Island, the Convergence apparently passed well south of the Chatham Islands. Whether

the boundary found south of Station A 309 is continuous with that found off the Otago coast is not known from the data available. Comparison with the situation in this area found during the winter of 1955 (Garner, 1961, fig. 32), suggests that the 10°C isotherm on Chart 2 may terminate on the east coast of South Island, thus defining the limits of the warm tongues of the East Cape and Southland Currents; on the other hand, these currents may have merged to form a continuous band of warm water along the east coast.

Surface water over the Campbell Plateau was remarkably uniform in temperature at about 8°C .

(b) Summer (Chart 2)

Approximately the same range of surface temperature ($13\text{--}14^{\circ}\text{C}$) was encountered over the range of latitude surveyed both in summer and in winter. Summer surface temperatures were some 3°C higher than the winter values.

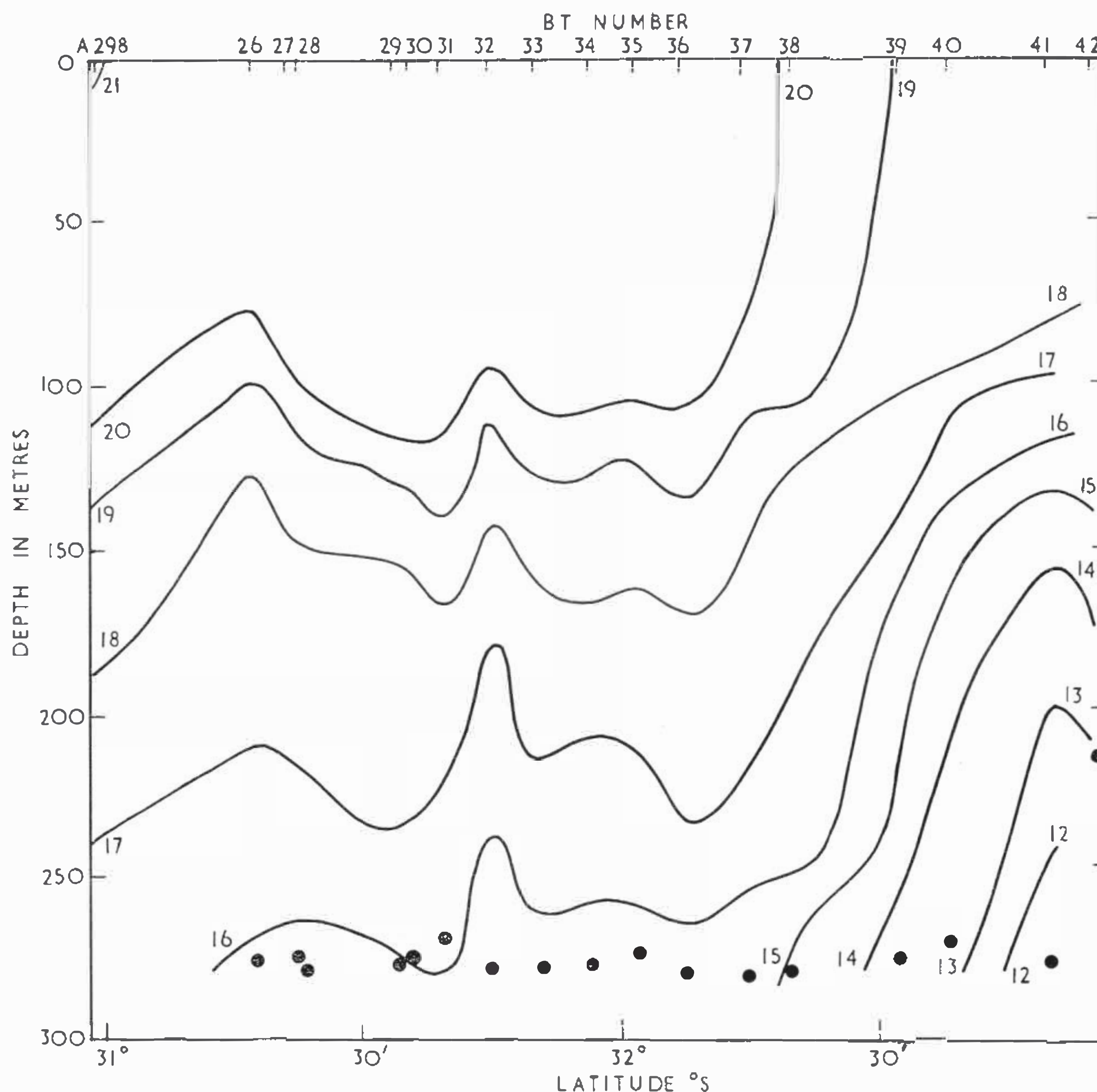


Fig. 4: Vertical cross section of temperature ($^{\circ}\text{C}$) along bathythermograph section 2 (see fig. 2).

The most pronounced seasonal change in the detail of the surface temperature pattern occurred in the region of the “East Cape” warm tongue. The summer pattern shows that this tongue extended about 2° of latitude further southwards towards the Bounty Islands than it did in winter.

The summer survey yielded more detail in the Tasman Sea than did its winter counterpart. A large warm tongue was mapped pointing towards Cape Farewell from the north-east Tasman Sea. A coastal extension of this tongue reached southwards along the west coast of the South Island almost to Jacksons Bay. This coastal feature is reminiscent of a similar tongue mapped in the summer of 1952 (Garner, 1959a, fig. 12).

The Subtropical Convergence region has moved southwards between the summer and winter surveys, following the movement of the “East Cape” tongue. The summer results indicate that

the South Otago Coast was washed by Subantarctic Surface waters.

The surface water over the Campbell Plateau was again very uniform in temperature, the summer level being around 11.5°C .

SURFACE SALINITY

(a) *Winter*—The surface salinity–temperature relationship for winter was plotted in fig. 36 from a relatively large number of samples taken throughout the cruise.

A marked change of slope is shown in this relationship around 10°C , the indicator of the Subtropical Convergence on Chart 1. The salinity corresponding to this water temperature is around $35.0^{\circ}/_{\infty}$ —slightly higher than has been found previously, a value around $34.8^{\circ}/_{\infty}$ having been characteristic of the Subtropical Convergence in previous investigations (Garner, 1959a).

The steeper slope of the surface temperature – salinity curve on the northern side of the Subtropical Convergence has been commented on previously (Knox, 1957, p. 27).

In Antarctic waters, for example at surface temperatures below 5°C, presumably this temperature–salinity relationship must steepen again to account for the observed properties of southern waters (e.g. Burling, 1961, fig. 2). The region of small slope on the surface temperature–salinity pattern of fig. 36 is thus perhaps indicative of the Campbell Plateau section of the Australasian Subantarctic Water mass.

(b) *Summer*—Very few surface salinities were determined between stations during the summer work. The heavy line in the temperature–salinity diagram of fig. 37 contains the surface water properties measured at stations, all of which were occupied to the north of the Subtropical Con-

vergence. The few salinities available from the southern part of summer cruise I (table I) indicated that the relationship should be extended as shown in fig. 37 by the broken line. Relatively small seasonal variations in salinity are found in the open ocean around New Zealand (Garner, 1962, p. 15). If the surface temperature–salinity characteristic for summer is moved parallel with the temperature axis through the mean seasonal range in temperature of 3°C, it comes into close coincidence with the corresponding winter characteristic. Summer samples were too few to determine the presence of a change in slope of the summer characteristic curve in the region of the Subtropical Convergence.

SUBSURFACE MEASUREMENTS

Measurements of subsurface temperature and salinity distributions were made with two objects

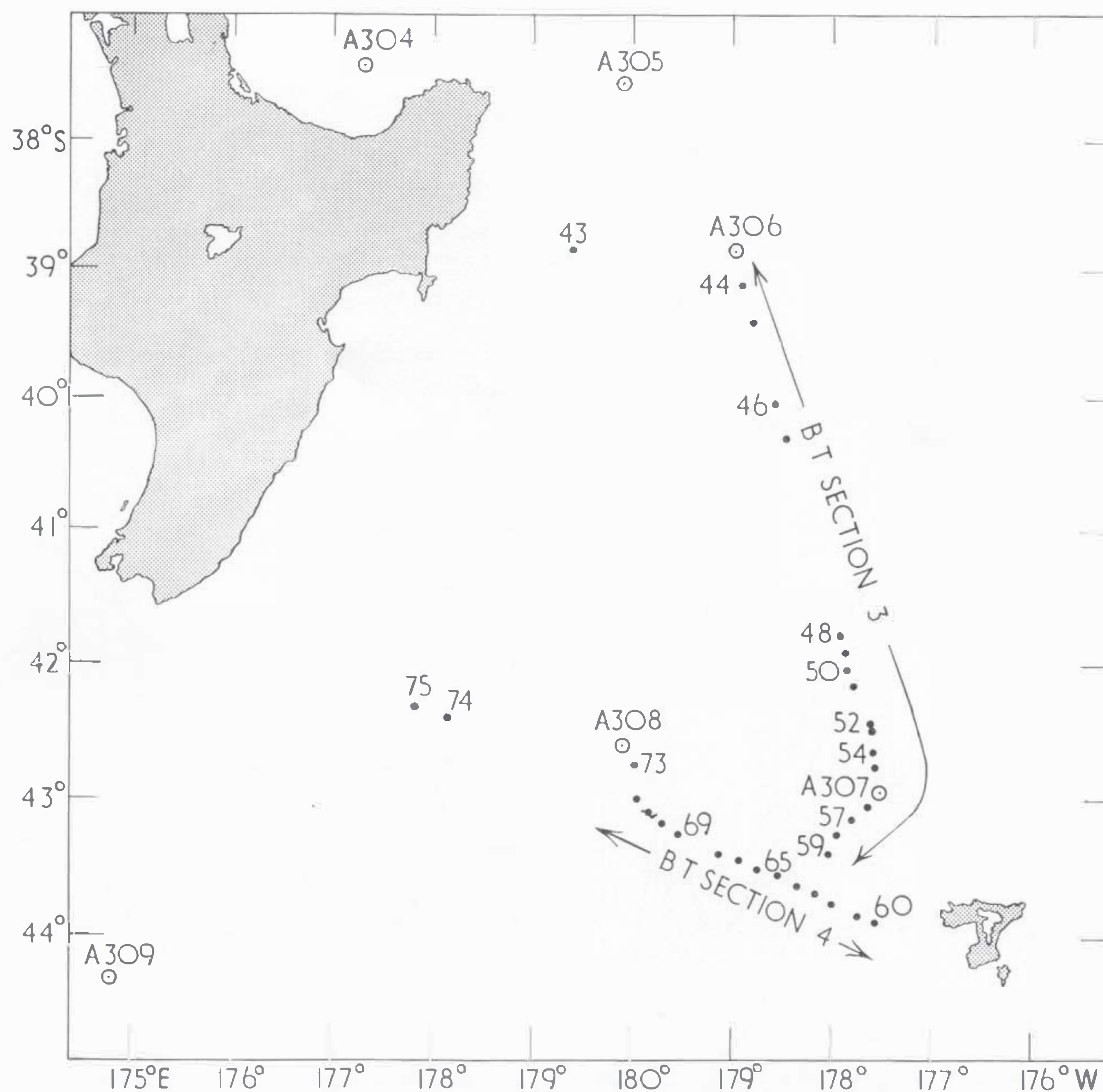


Fig. 5: Location of bathythermograph sections 3 and 4 (see figs. 6 and 7) from winter cruise III east of New Zealand.

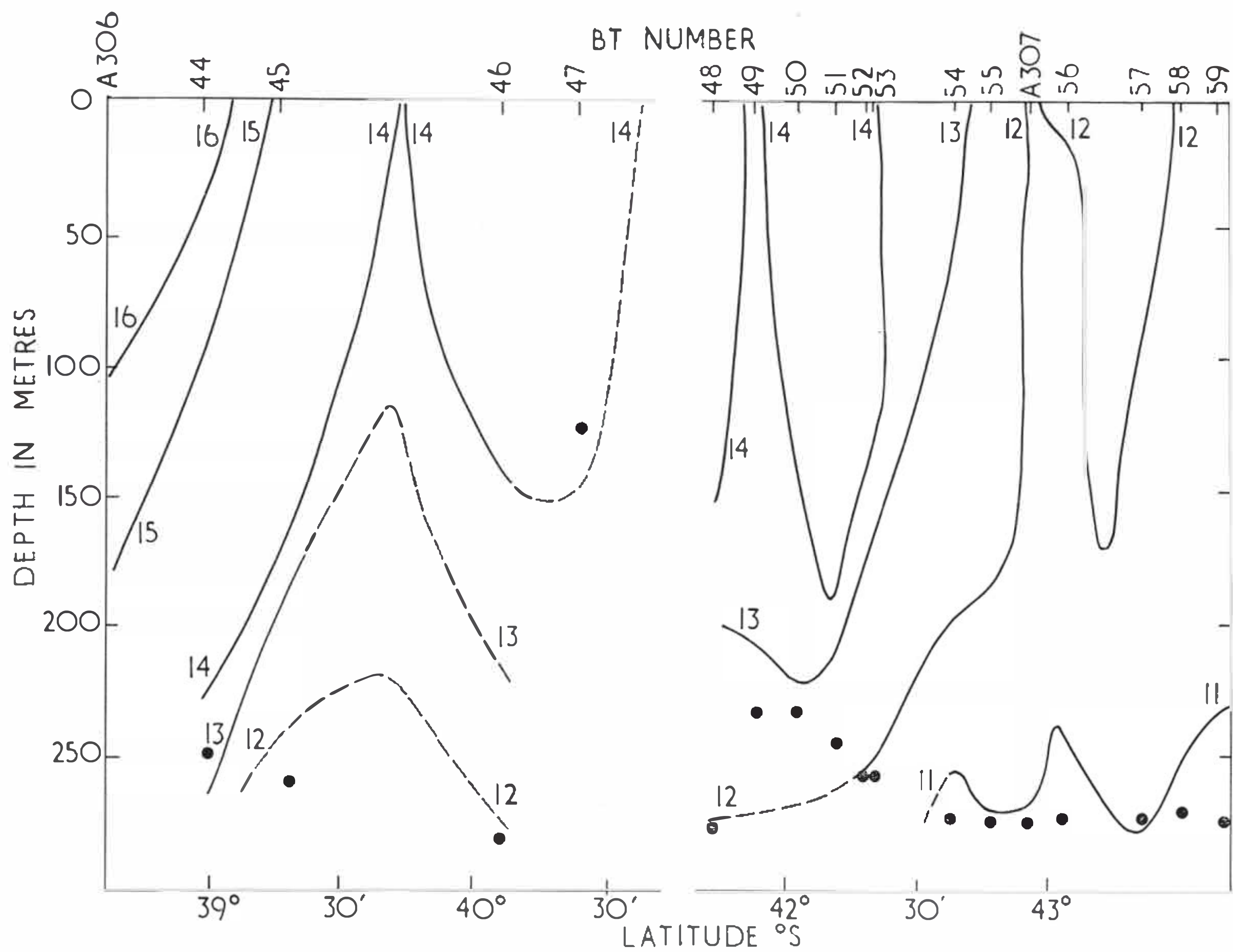


Fig. 6: Vertical cross section of temperature ($^{\circ}\text{C}$) along bathythermograph section 3 (see fig. 5).

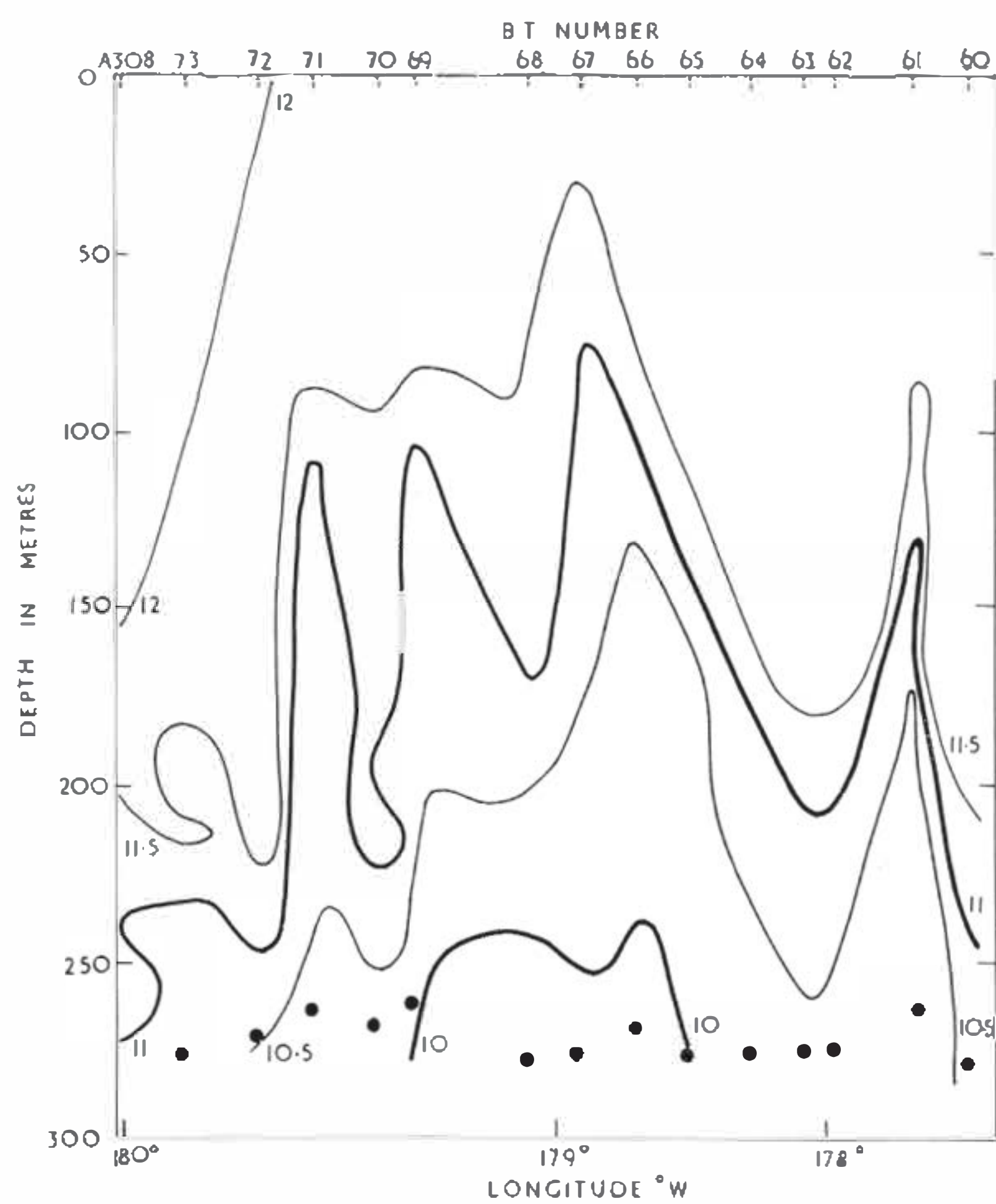


Fig. 7: Vertical cross section of temperature ($^{\circ}\text{C}$) along bathythermograph section 4 (see fig. 5).

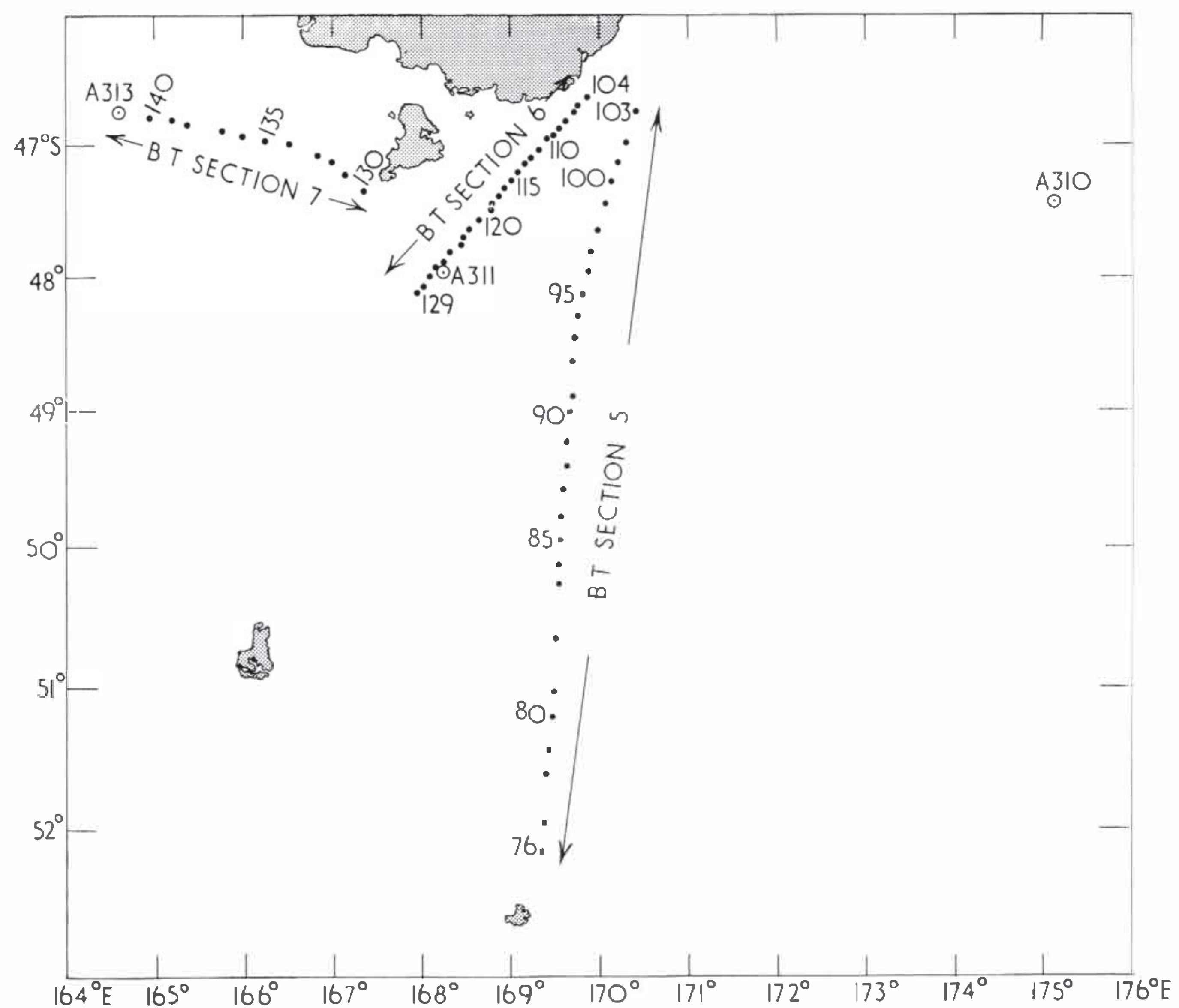


Fig. 8: Location of bathythermograph sections 5, 6, and 7 (see figs. 9, 10, and 11) from winter cruises V and VI south of New Zealand.

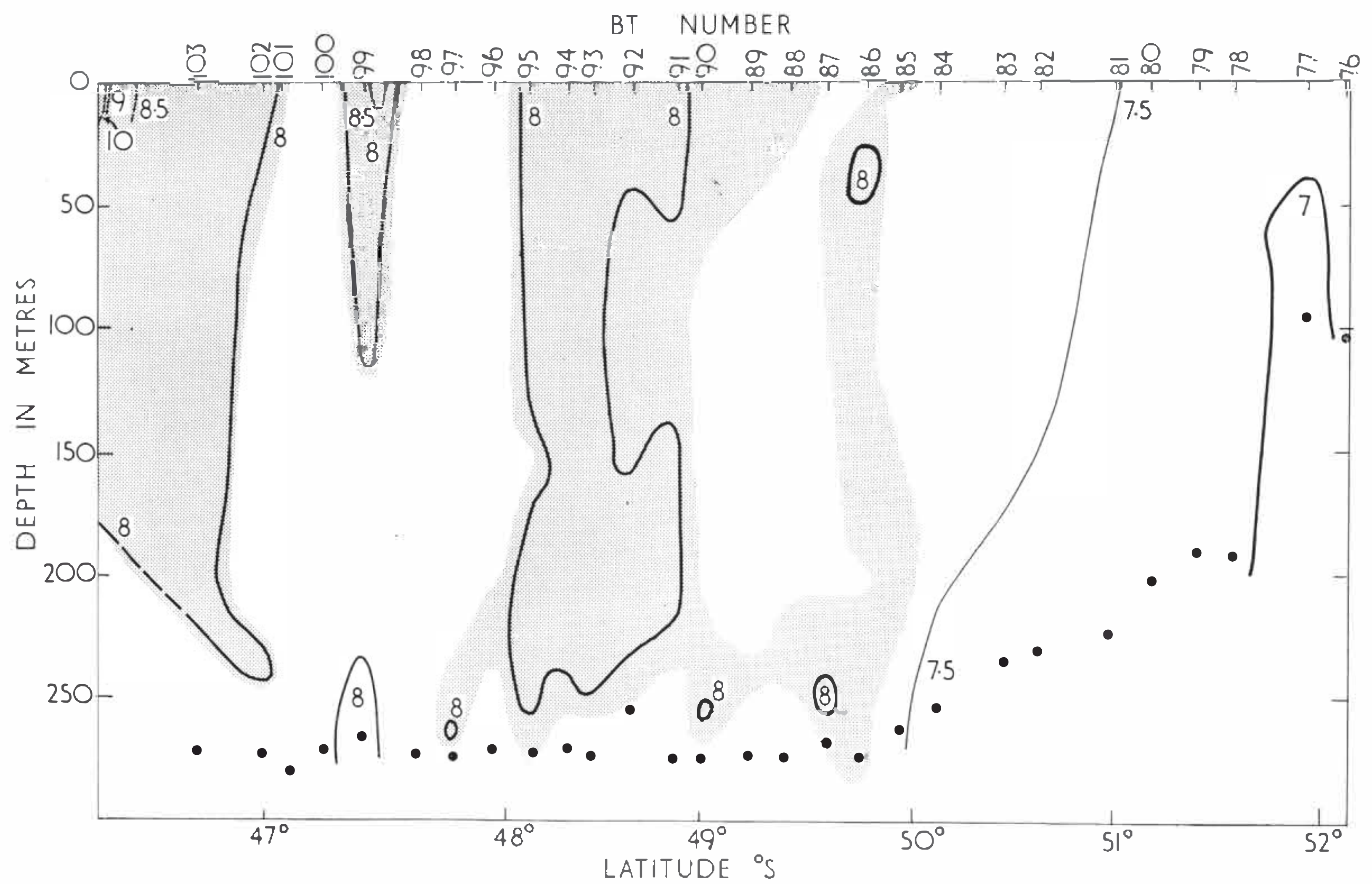


Fig. 9: Vertical cross section of temperature ($^{\circ}\text{C}$) along bathythermograph section 5 (see fig. 8). The shaded area marks the intrusion of water of subtropical origin.

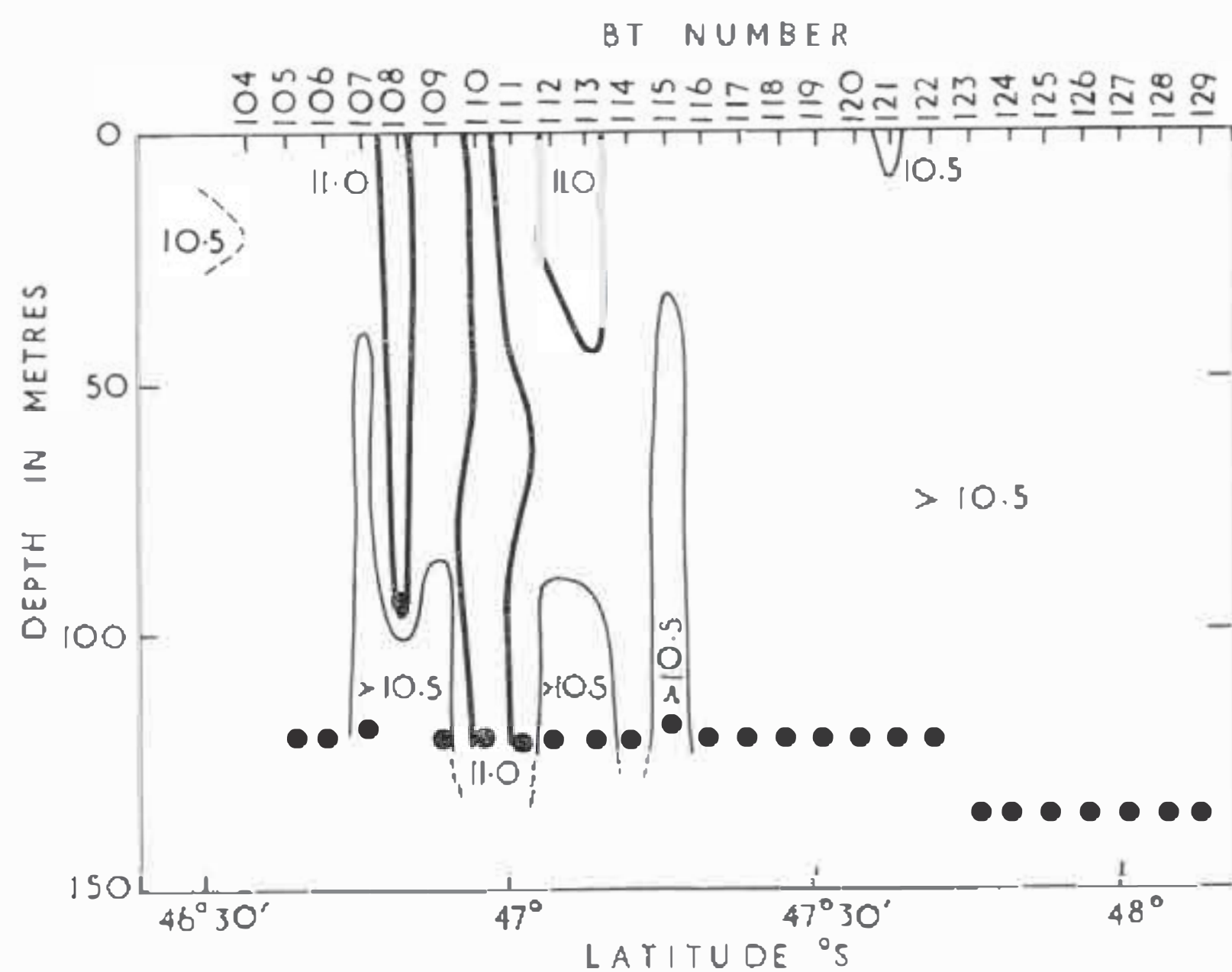


Fig. 10: Vertical cross section of temperature ($^{\circ}\text{C}$) along bathythermograph section 6 (see fig. 8).

in view. The first was to provide a recent description of the distribution of these variables which are the dominant features of the marine environment for many applications. The second was to relate the field of mass to the geostrophic circulation of ocean waters around New Zealand.

(a) Description

The method of presentation of the data in the present work should fulfil the first purpose with little additional written description. Since the data reported here complement the situation already described in the Expedition Summary (Garner, 1962) and provide little contrasting material, perhaps the most useful commentary on the station data would be provided by comparison with this analysis of previous work. This last-mentioned reference was prepared as a background to the discussion of the *Tui* cruise results, and should be studied in conjunction with the present work.

The hydrological character of the *Tui* stations is illustrated by the temperature-salinity correlation diagrams of figs. 36 and 37. These figures show simply the limits within which individual station characteristic curves lie, but it is apparent how the admixture of relatively high salinity Subtropical Water near the surface, and Deep Water near the bottom, with the less-saline Antarctic Intermediate Water, results in the domination of the hydrological pattern by the salinity minimum which marks the almost isentropic spread of this latter water mass along the density surface of $\sigma_t \doteq 27.2$. A chart of the distribution of salinity in this surface of minimum salinity around New Zealand was shown in the Expedition Summary (fig. 6).

The *Tui* data fit in quite well with this general picture which showed:

- Lowest salinities (around 34.30‰) in the Bounty Trough and the south-east Tasman Sea (confirmed at Stations A 310 and A 314, respectively).
- Partial “mixing out” of the salinity minimum over the shallower water of the New Zealand Plateau resulting in relatively higher salinities of $34.5\text{--}34.6\text{‰}$, reproduced in numerous *Tui* stations.
- The occurrence of relatively low salinity ($<34.4\text{‰}$) east of the Kermadec Ridge, in spite of the greatly increased surface salinity in this region compared with that, for example, over the Bounty Trough. This suggests a relatively strong movement of Antarctic Intermediate Water in the area.

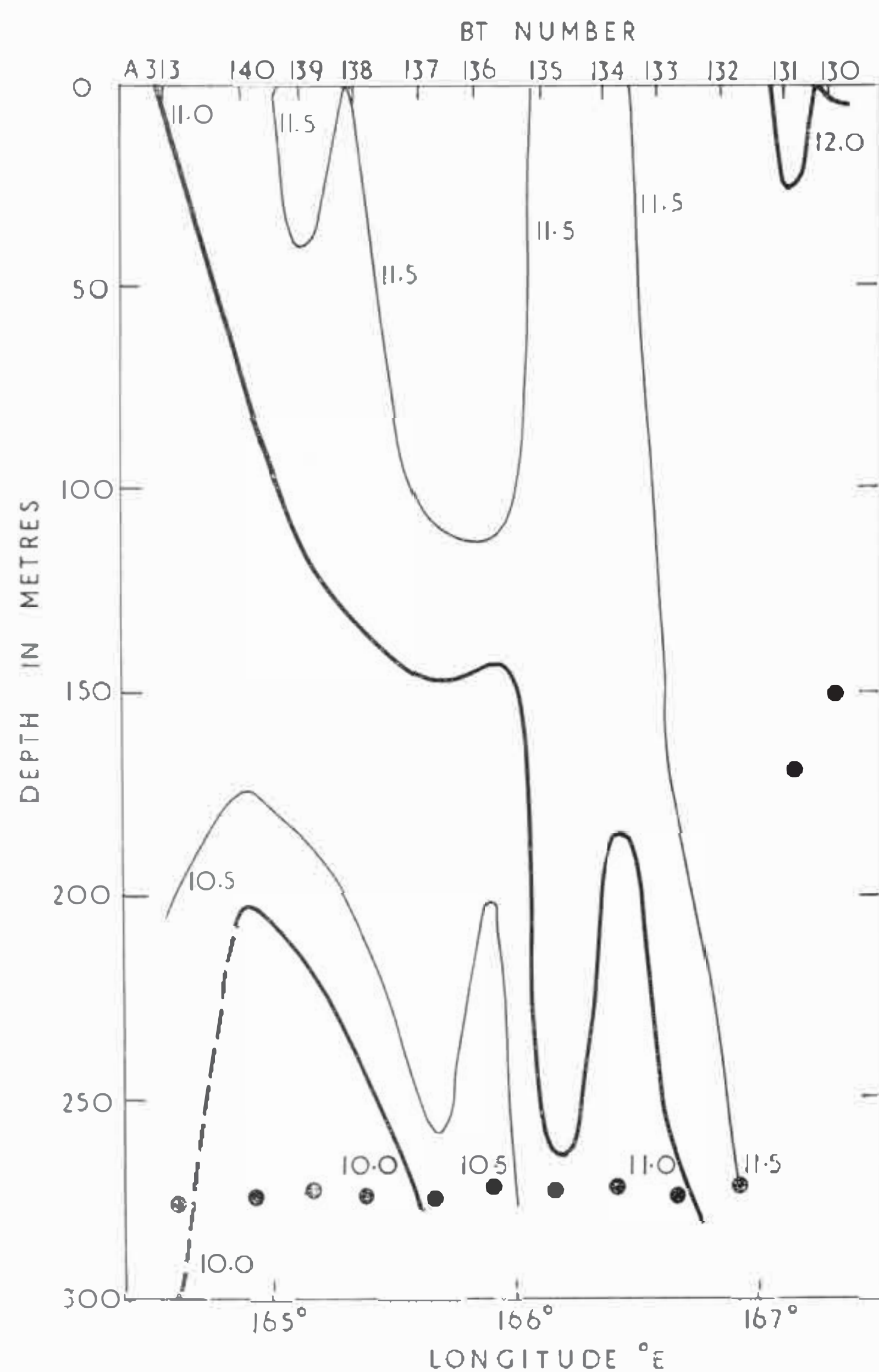


Fig. 11: Vertical cross section of temperature ($^{\circ}\text{C}$) along bathythermograph section 7 (see fig. 8).

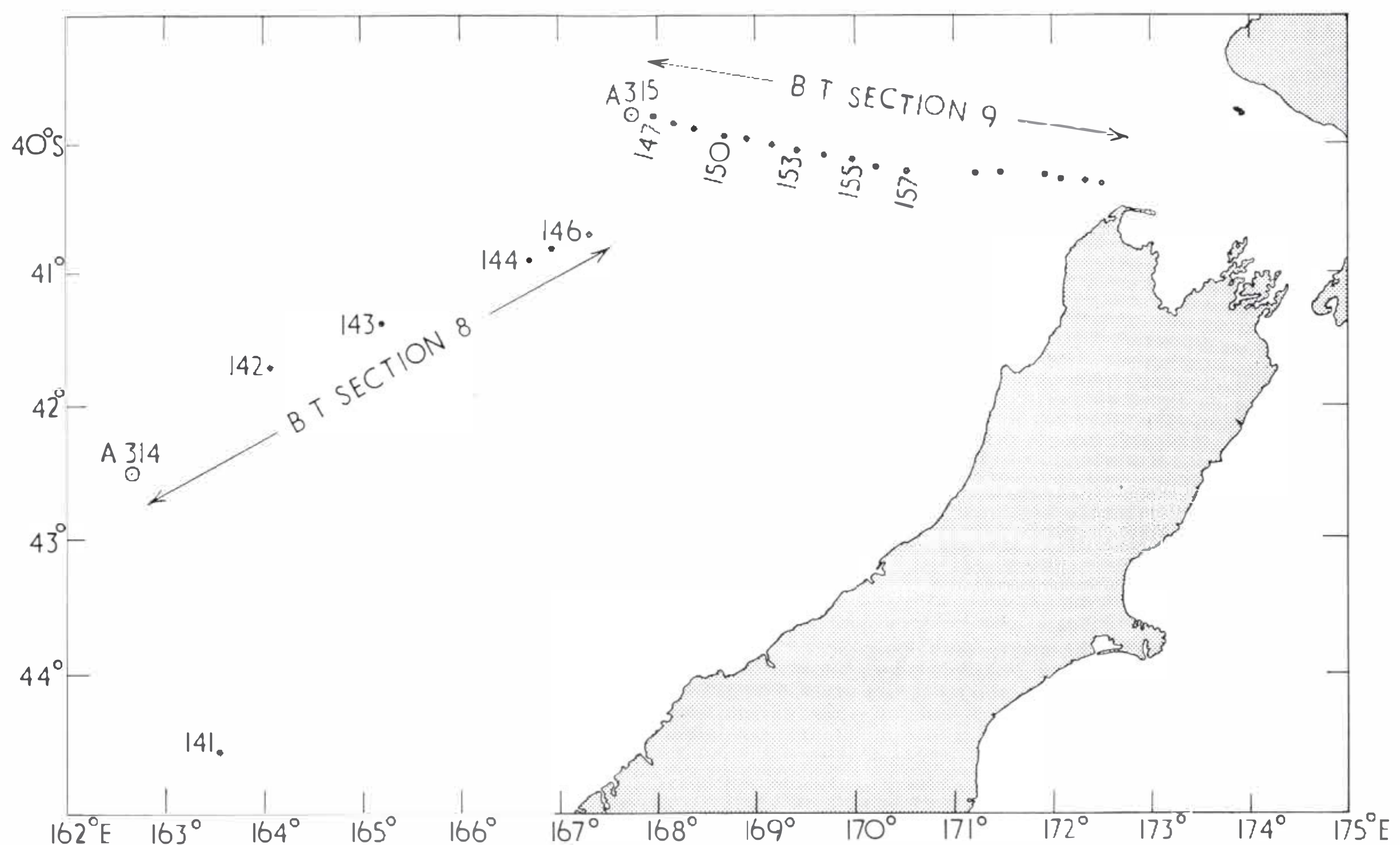


Fig. 12: Location of bathythermograph sections 8 and 9 (see figs. 13 and 14) from winter cruise VI west of South Island.

This effect was confirmed in the summer stations A 351 and A 352, but much higher values ($< 34.5\text{‰}$) were recorded at the salinity minimum for the nearby winter stations A 302 and A 303.

The *Tui* stations served to fill a region north of New Zealand from which no stations were recorded in the Expedition Summary. These stations indicated a strong “mixing out” of the Antarctic Intermediate layer over the Rise to the north of North Cape. The effect is best illustrated by the zonal cross-sections of salinity plotted from stations A 295 to A 302 in fig. 39 and from stations A 347 to A 352 in fig. 45. In the latter case, particularly, the effect apparently of non-isentropic mixing may be seen, the Intermediate layer appearing in water of greater density as the minimum salinity increases in value. In both of these sections, too, the rise in salinity in the Intermediate layer is associated with the appearance of the shallow subsurface salinity maximum associated with the spreading of high salinity water from the region under the South Pacific subtropical anticyclone (Garner, 1959b, fig. 2). This apparent control of

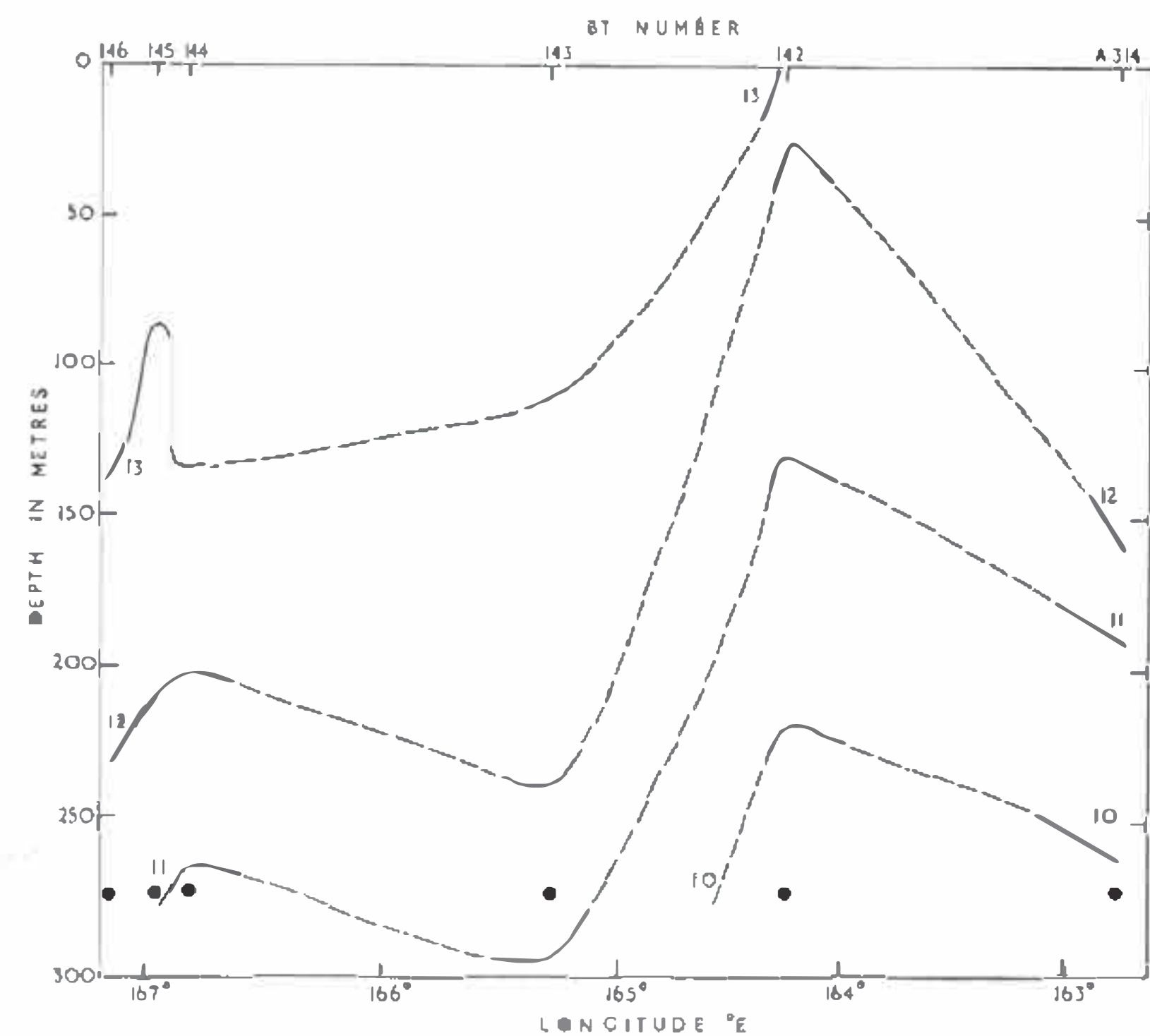


Fig. 13: Vertical cross section of temperature ($^{\circ}\text{C}$) along bathythermograph section 8 (see fig. 12).

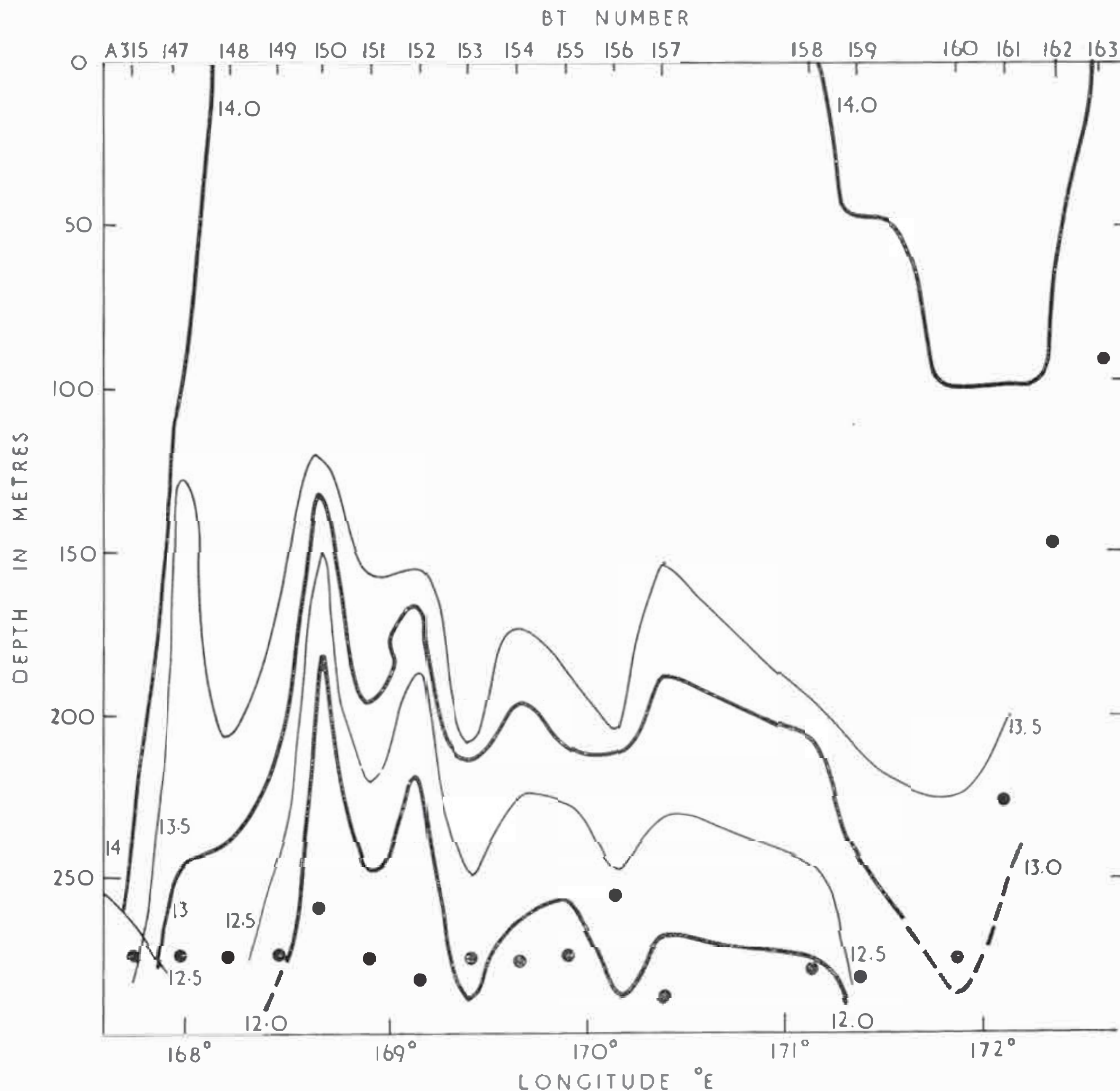


Fig. 14: Vertical cross section of temperature ($^{\circ}\text{C}$) along bathythermograph section 9 (see fig. 12).

the spreading of Antarctic Intermediate Water by the subtropical salinity maximum, presumably through vertical mixing, will be the subject of a later study. The situation is encountered in various places in lower latitudes of the south-west Pacific, and is illustrated in striking fashion in the salinity distribution across the Melanesian Border Plateau, Efate Basin, and the New Caledonia Ridge described by *Dana* stations 3585, 3587, 3592, 3602 and 3604.

None of the *Tui* stations was worked to a depth sufficiently great to define either the salinity maximum characteristic of the Pacific Deep Water or the underlying Pacific Bottom Water of lower salinity.

The isotherm sections constructed from bathythermograph soundings define the temperature structure of upper water layers in considerably greater detail than did the hydrological stations.

As the work presently reported forms the first measurement of such detail in New Zealand's offshore waters, full definition of those factors which form a permanent feature of the thermal structure in this area must wait for comparison with similar observations made at other times. Undoubtedly much of the finer detail evident in the bathythermograph sections shown in figs. 3-35 represent the transient effects of internal waves and eddies, and are thus of limited interest in a discussion of average conditions. In the present context, however, the presentation of this detail provides some measure of the variability of the temperature likely to be encountered at a particular position and depth in upper water layers. The major structural feature of the bathythermograph sections is the *thermocline* layer, or layer of maximum vertical temperature gradient, which separates the "surface mixed layer" from the deeper waters. Relative to the summer patterns,

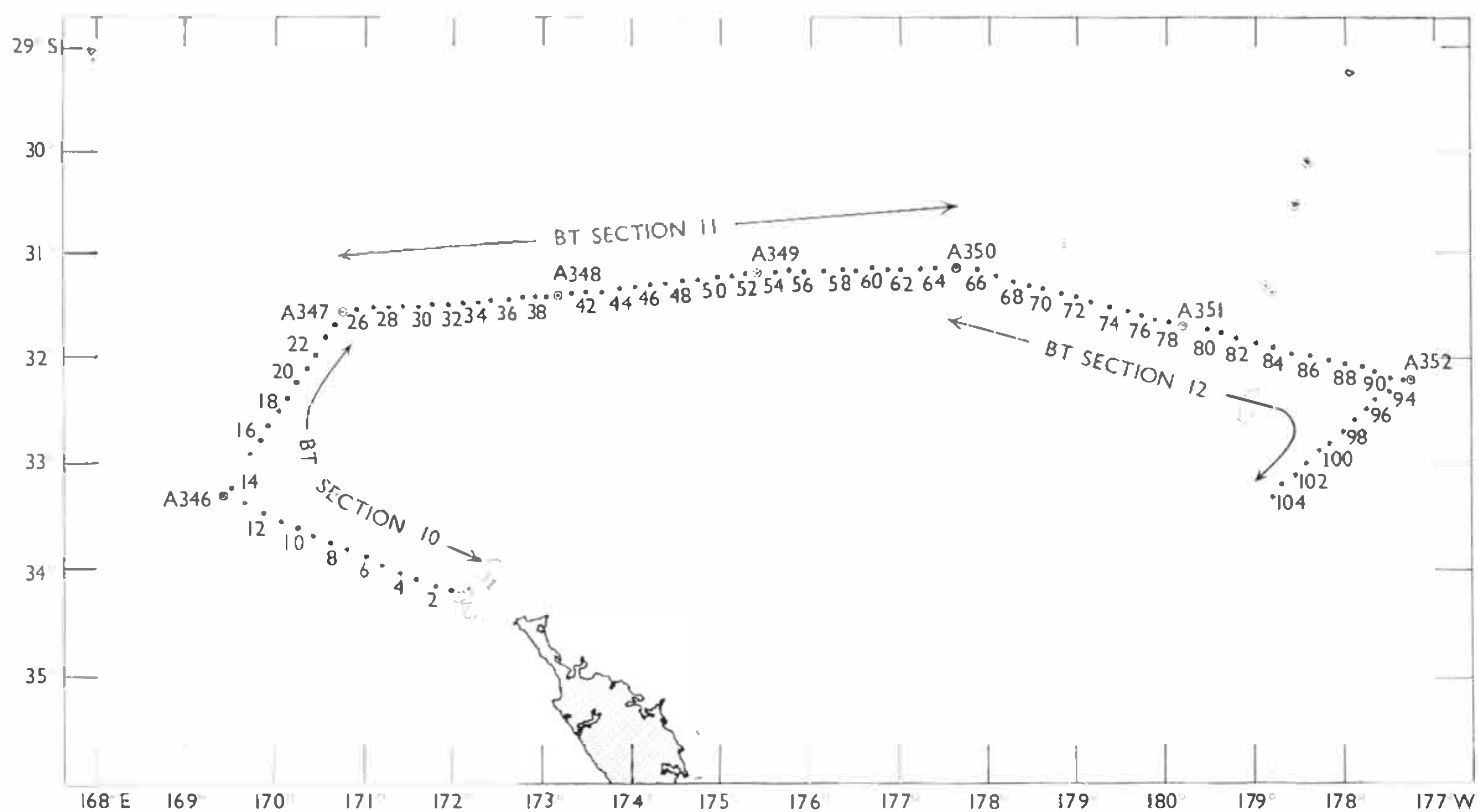


Fig. 15: Location of bathythermograph sections 10, 11, and 12 (see figs. 16, 17, and 18) from summer cruise 1 north of New Zealand.

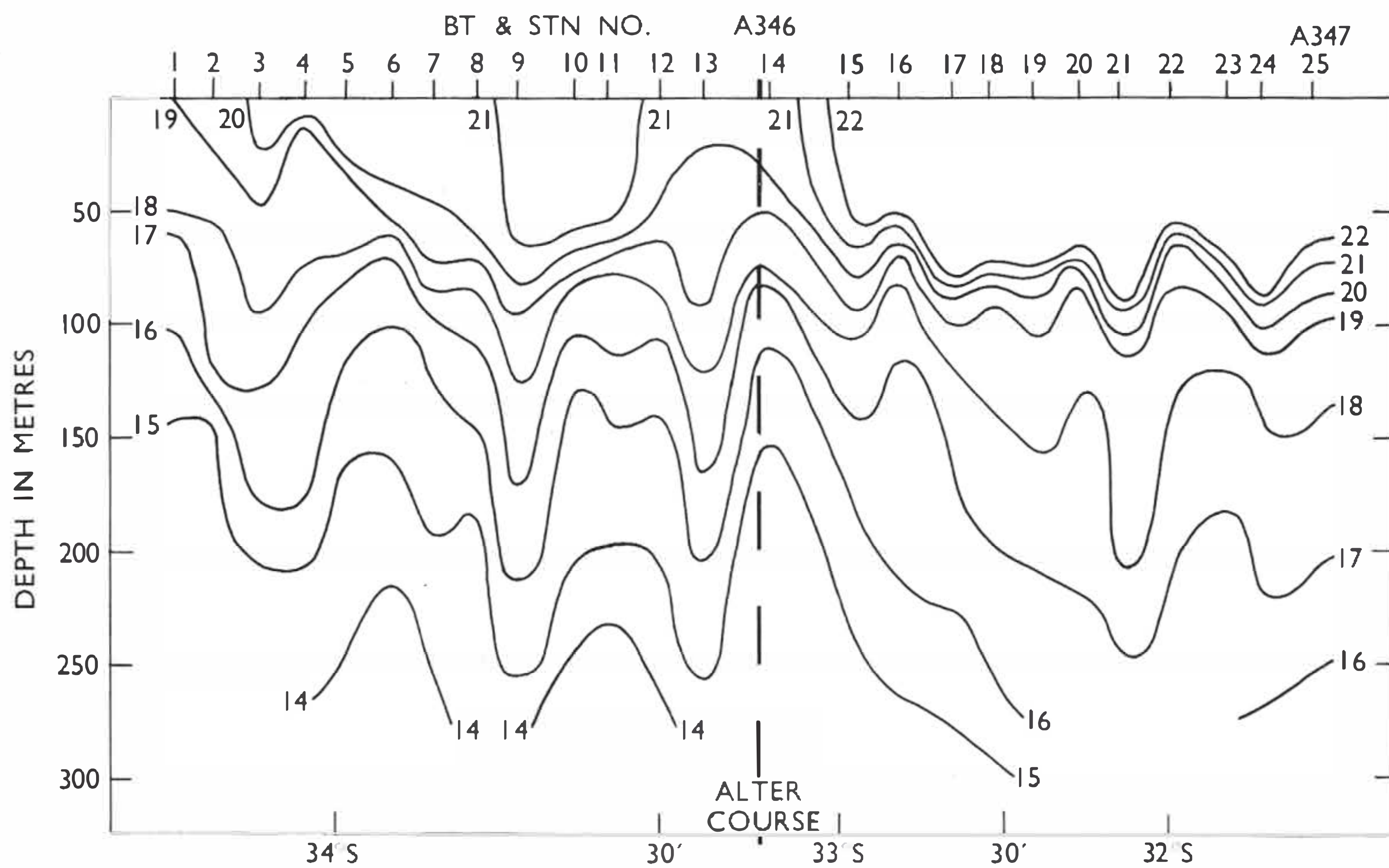


Fig. 16: Vertical cross section of temperature ($^{\circ}\text{C}$) along bathythermograph section 10 (see fig. 15).

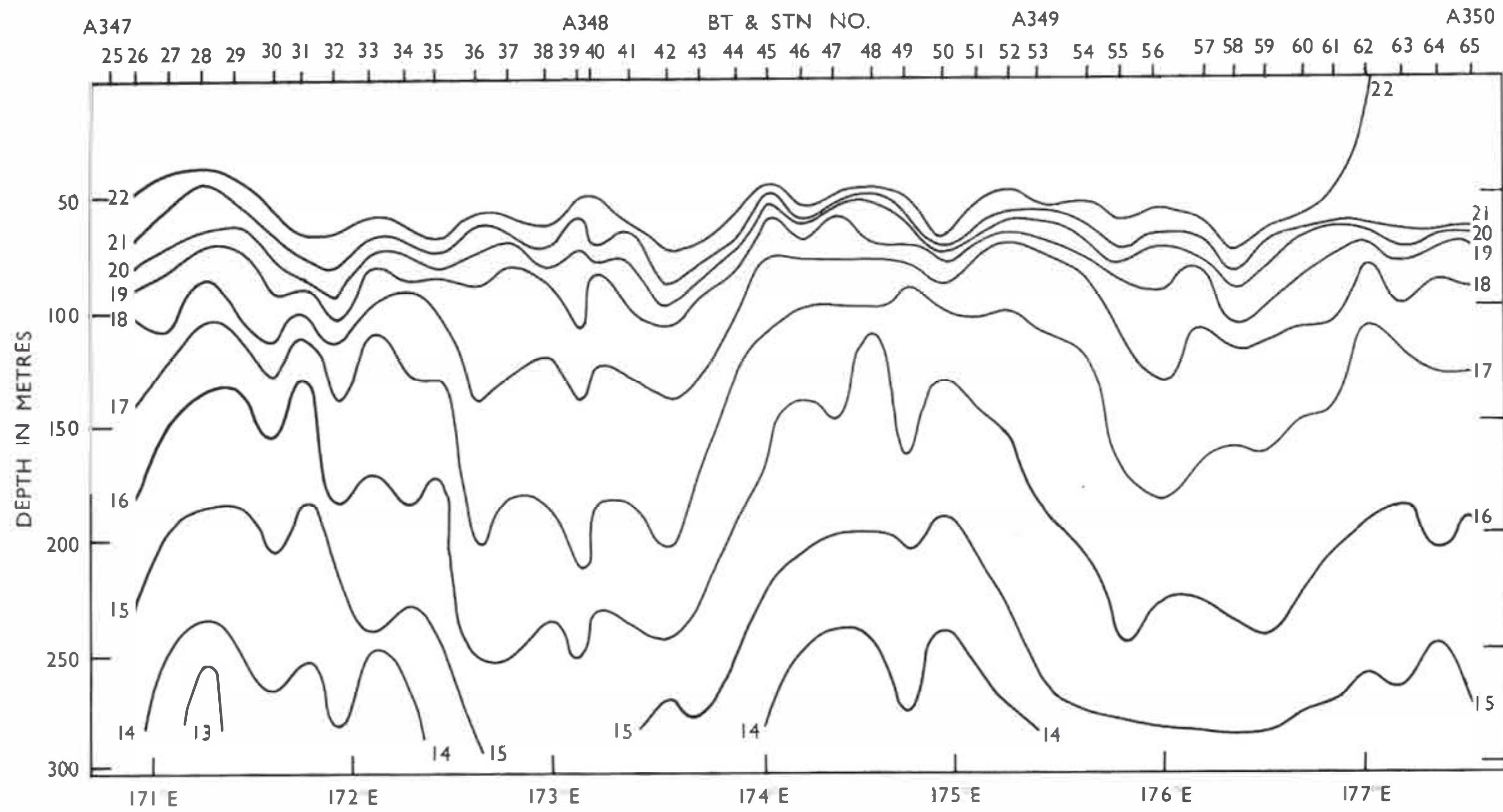


Fig. 17: Vertical cross section of temperature (°C) along bathythermograph section 11 (see fig. 15).

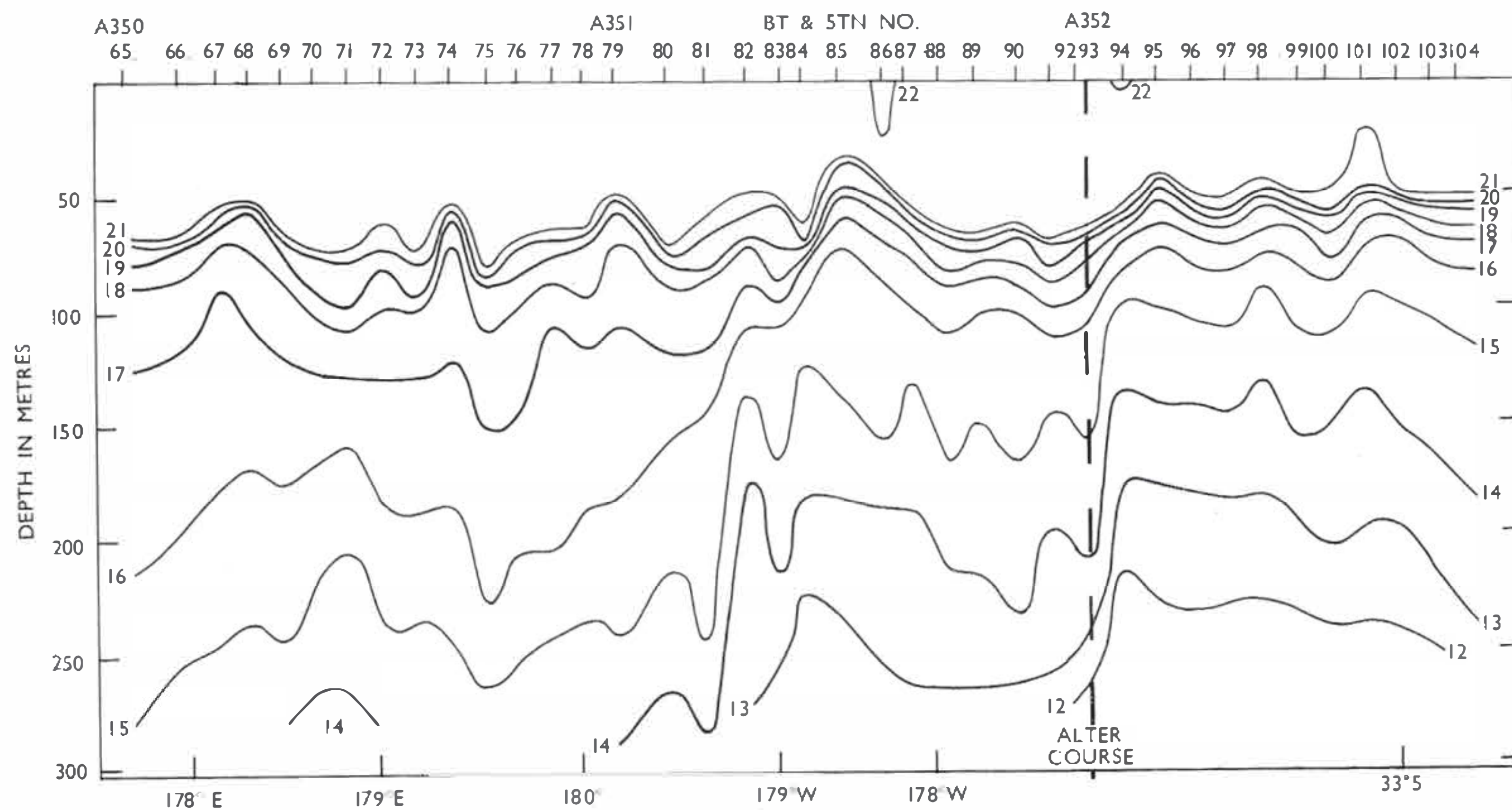


Fig. 18: Vertical cross section of temperature (°C) along bathythermograph section 12 (see fig. 15).

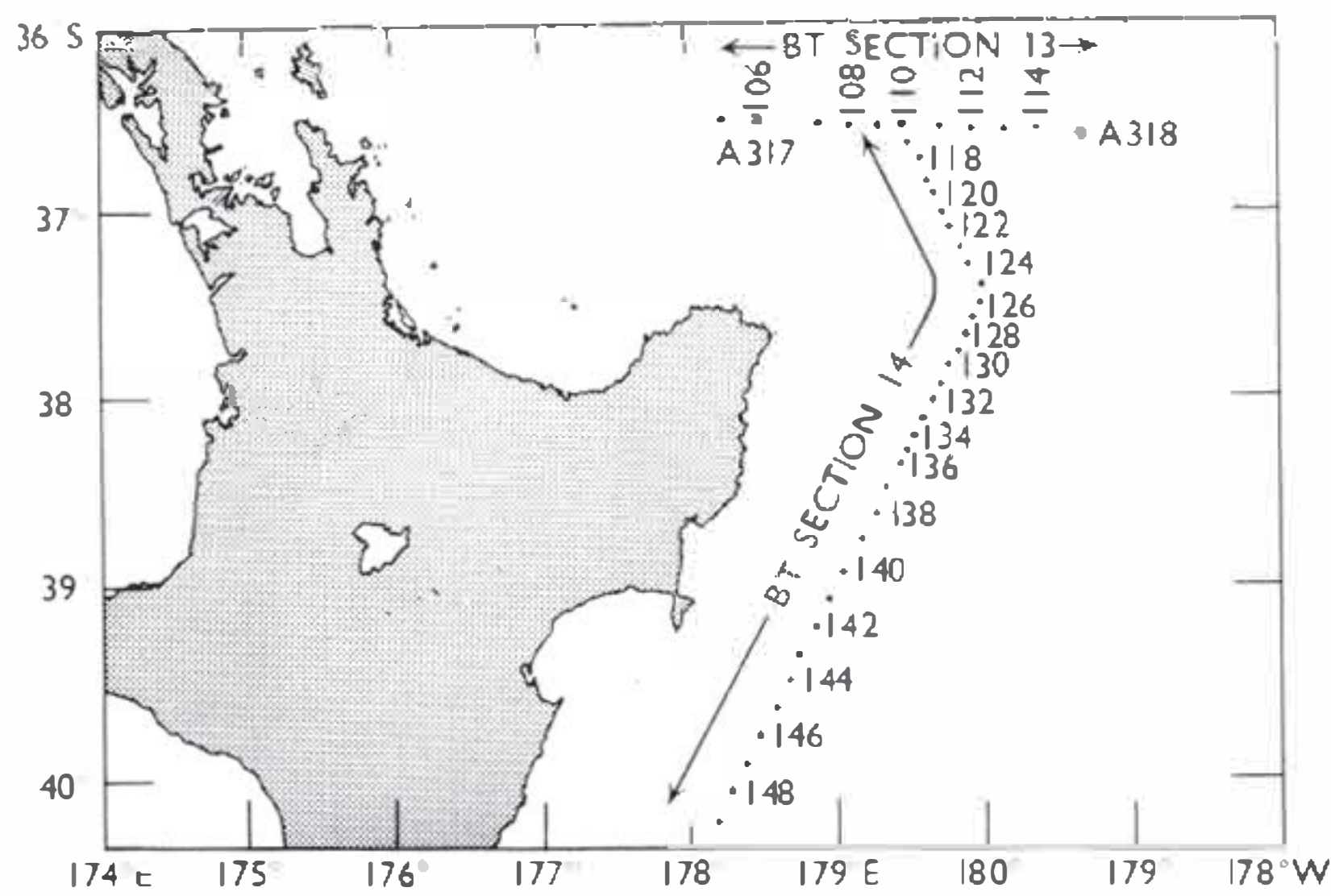


Fig. 19: Location of bathythermograph sections 13 and 14 (see figs. 20 and 21) from summer cruise II east of New Zealand.

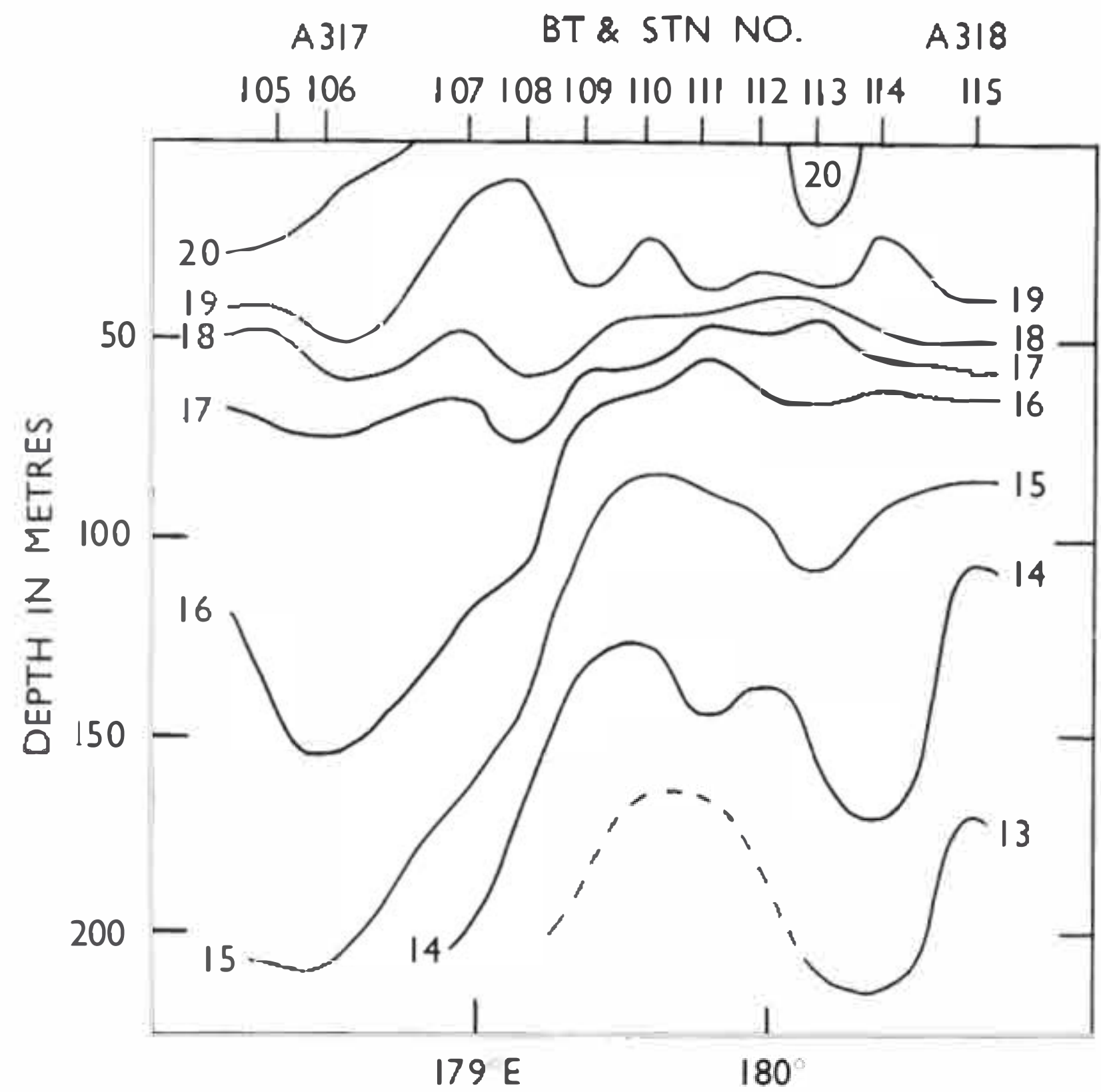


Fig. 20: Vertical cross section of temperature ($^{\circ}\text{C}$) along bathythermograph section 13 (see fig. 19).

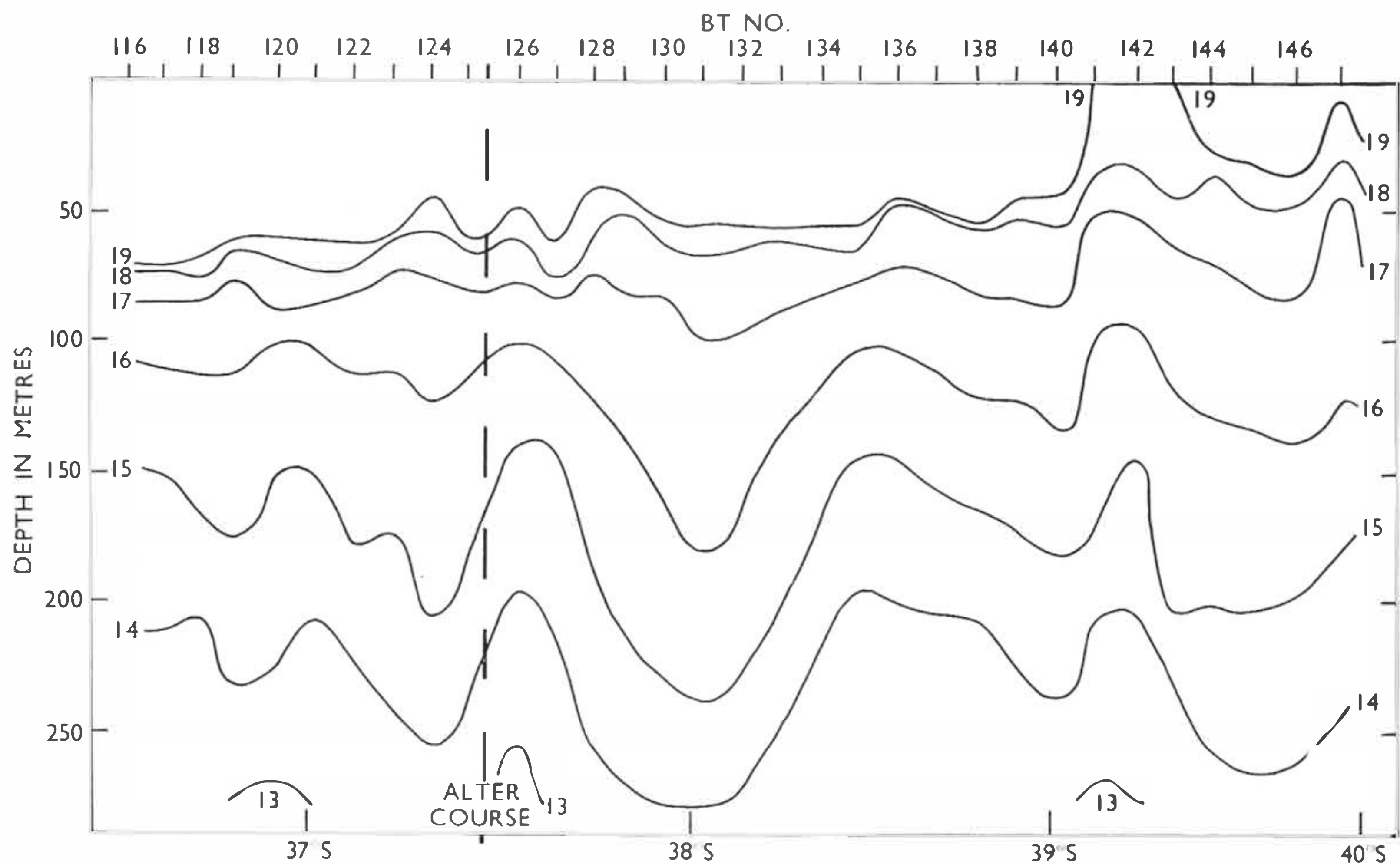


Fig. 21: Vertical cross section of temperature ($^{\circ}\text{C}$) along bathythermograph section 14 (see fig. 19).

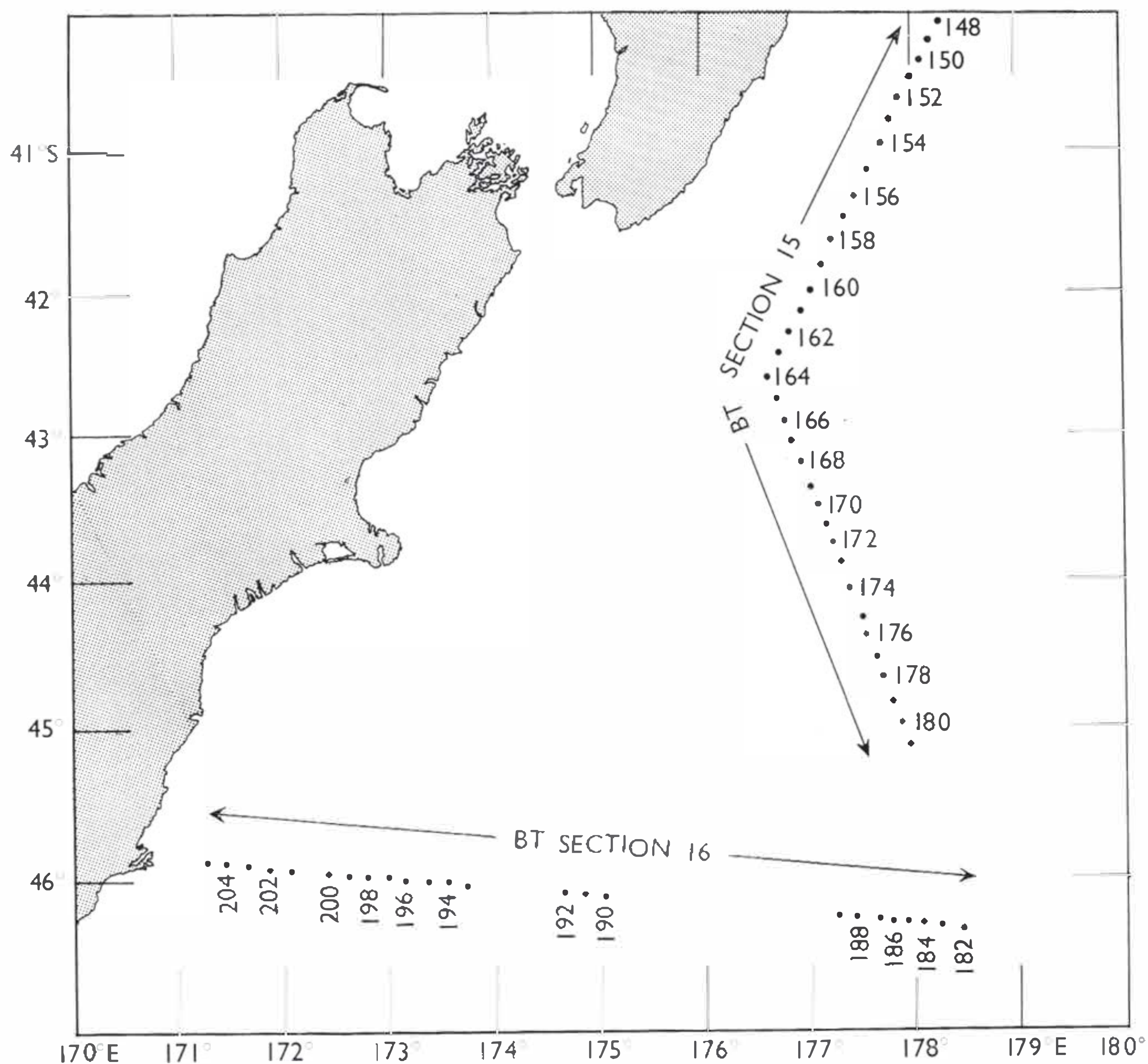


Fig. 22: Location of bathythermograph sections 15 and 16 (see figs. 23 and 24) from summer cruise 11 east of New Zealand.

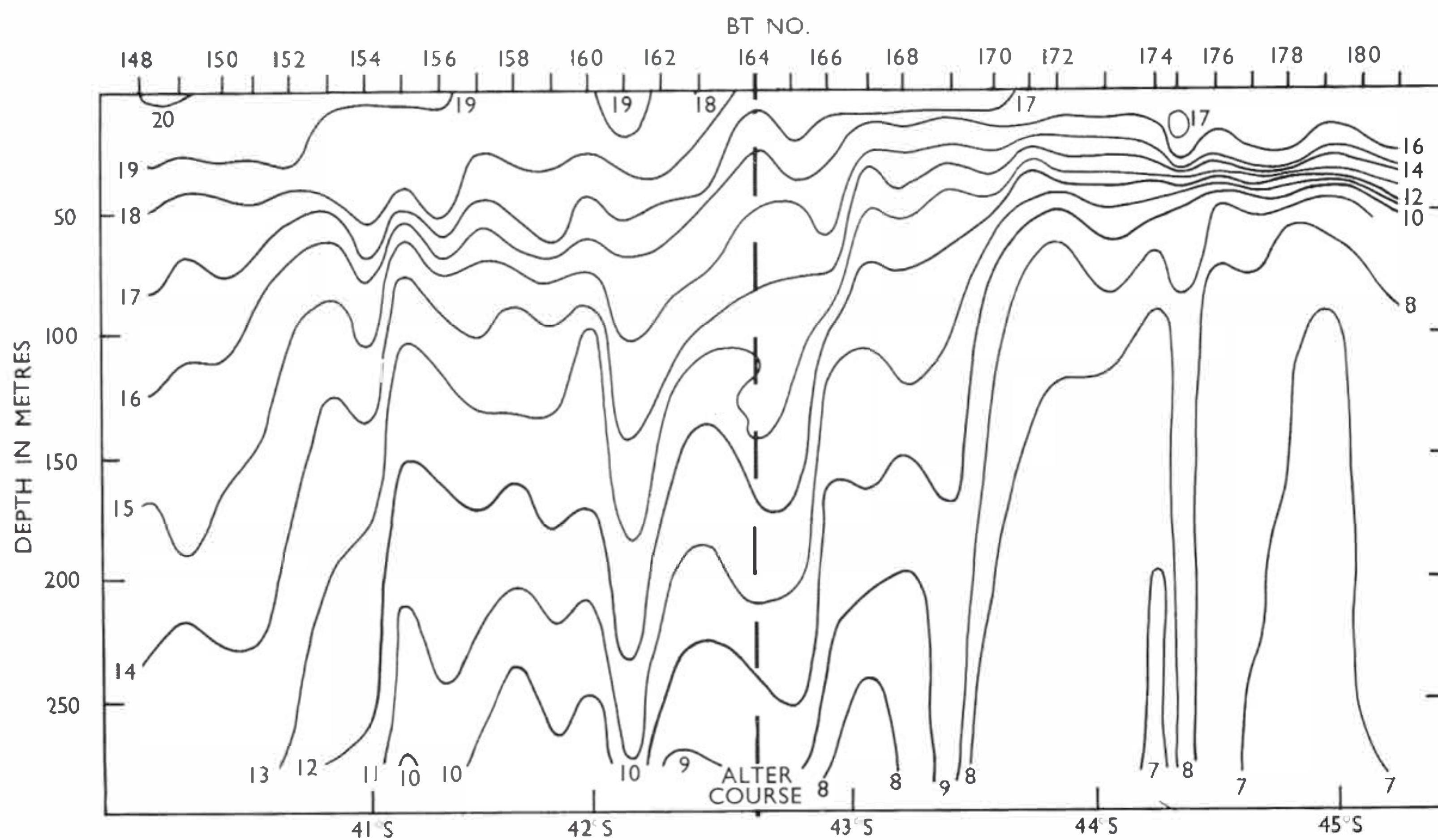


Fig. 23: Vertical cross section of temperature (°C) along bathythermograph section 15 (see fig. 22).

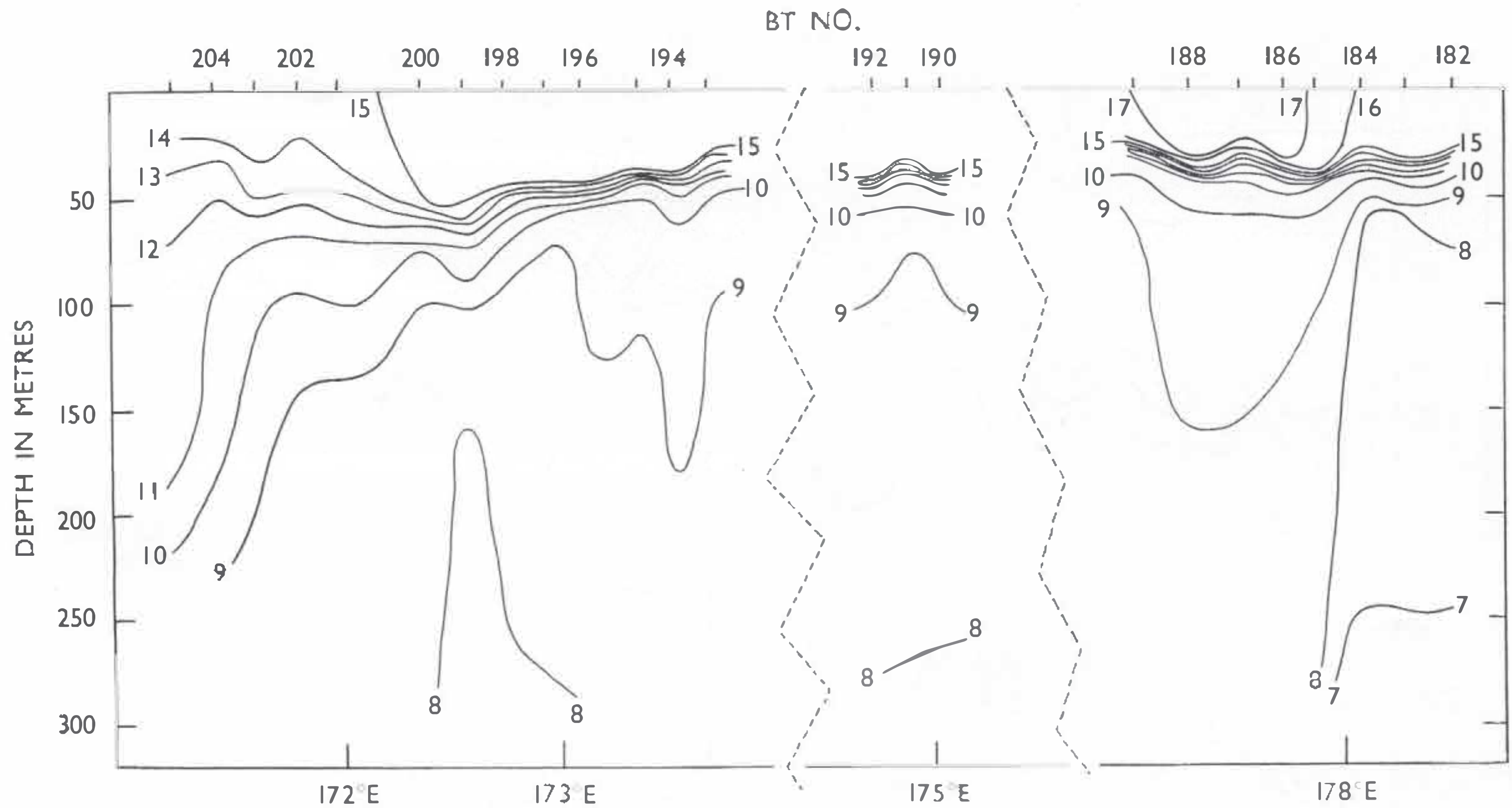


Fig. 24: Vertical cross section of temperature ($^{\circ}\text{C}$) along bathythermograph section 16 (see fig. 22).

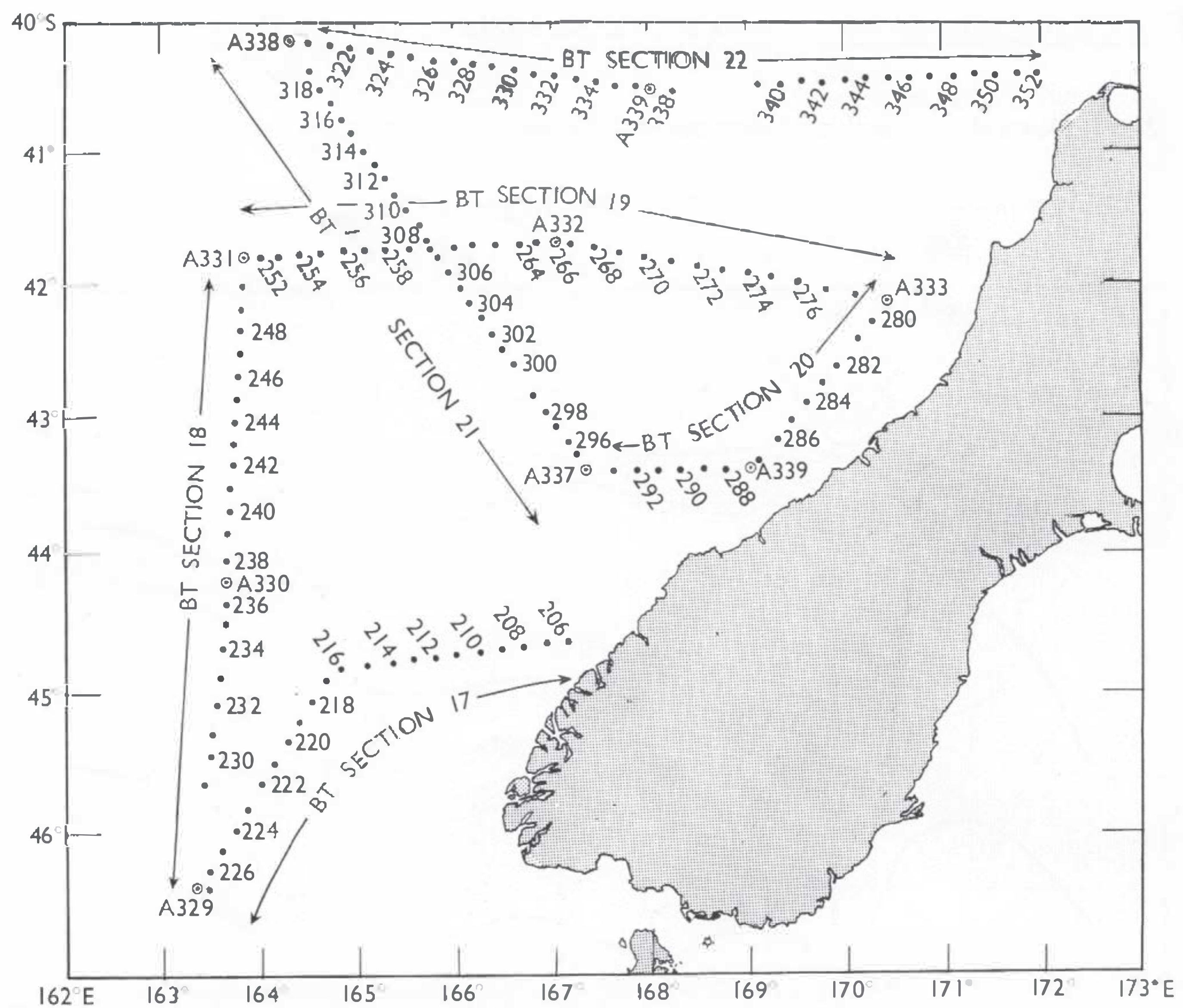


Fig. 25: Location of bathythermograph sections 17 to 22 (see figs. 26 to 31) from summer cruise III west of South Island.

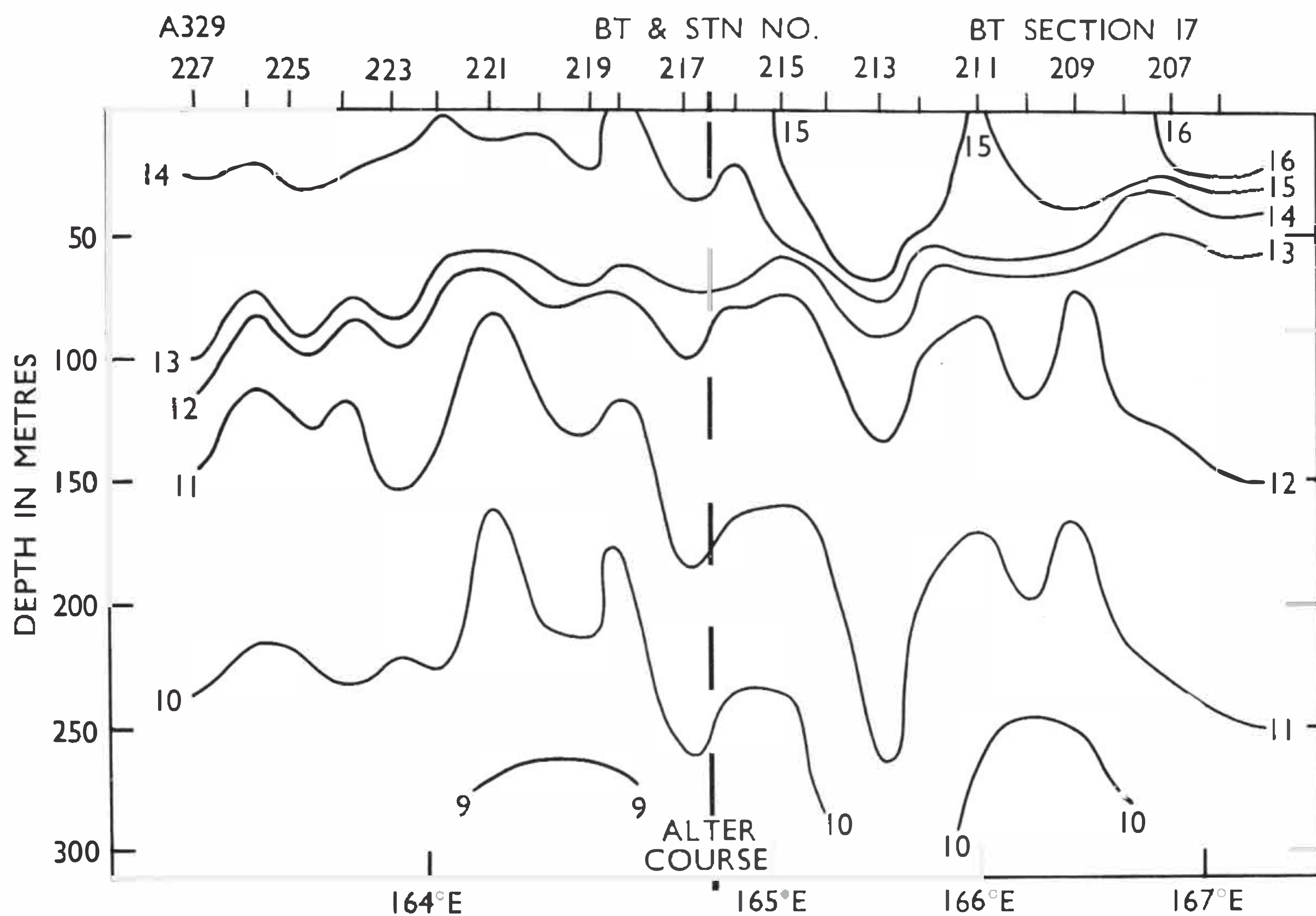


Fig. 26: Vertical cross section of temperature (°C) along bathythermograph section 17 (see fig. 25).

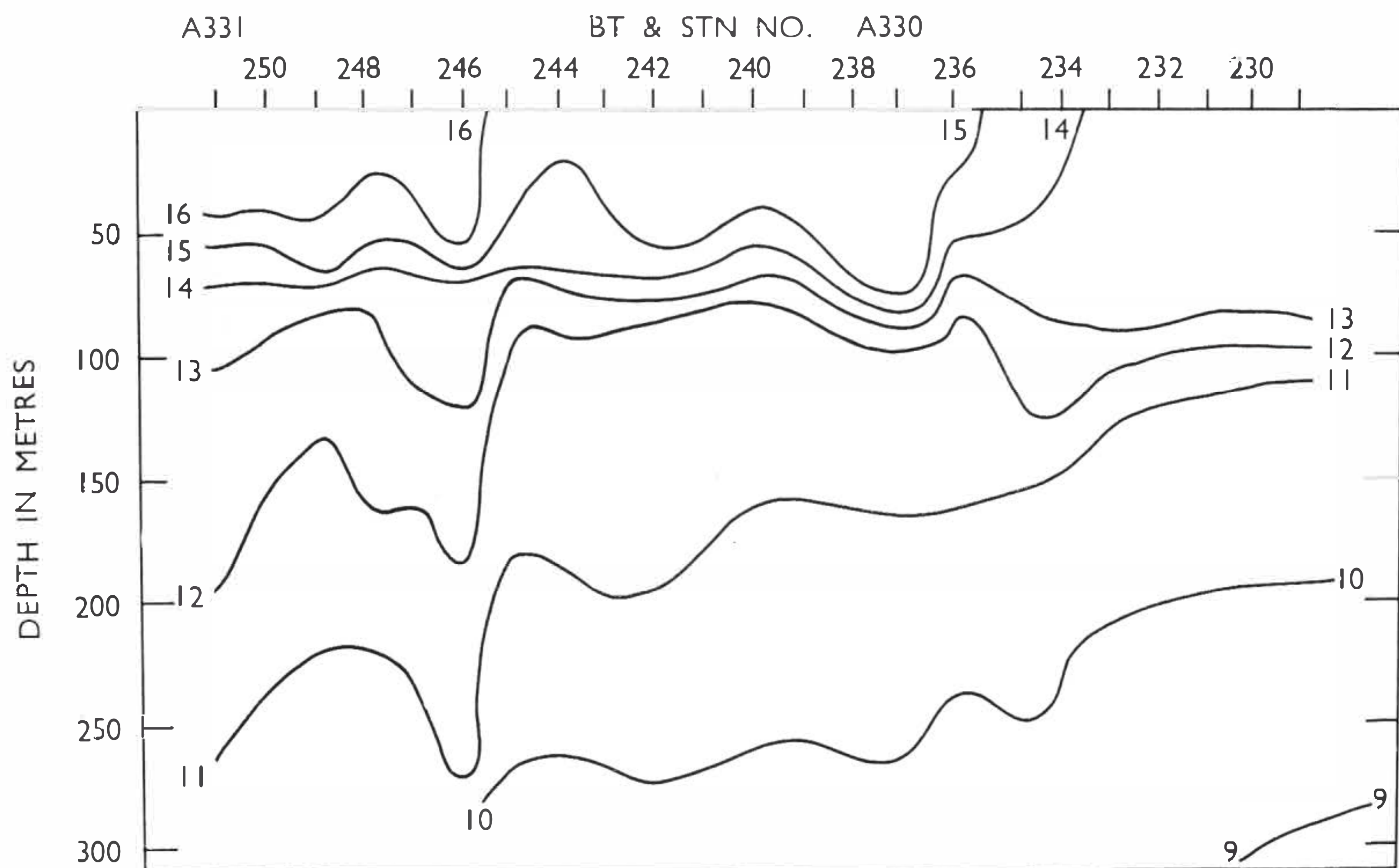


Fig. 27: Vertical cross section of temperature (°C) along bathythermograph section 18 (see fig. 25).

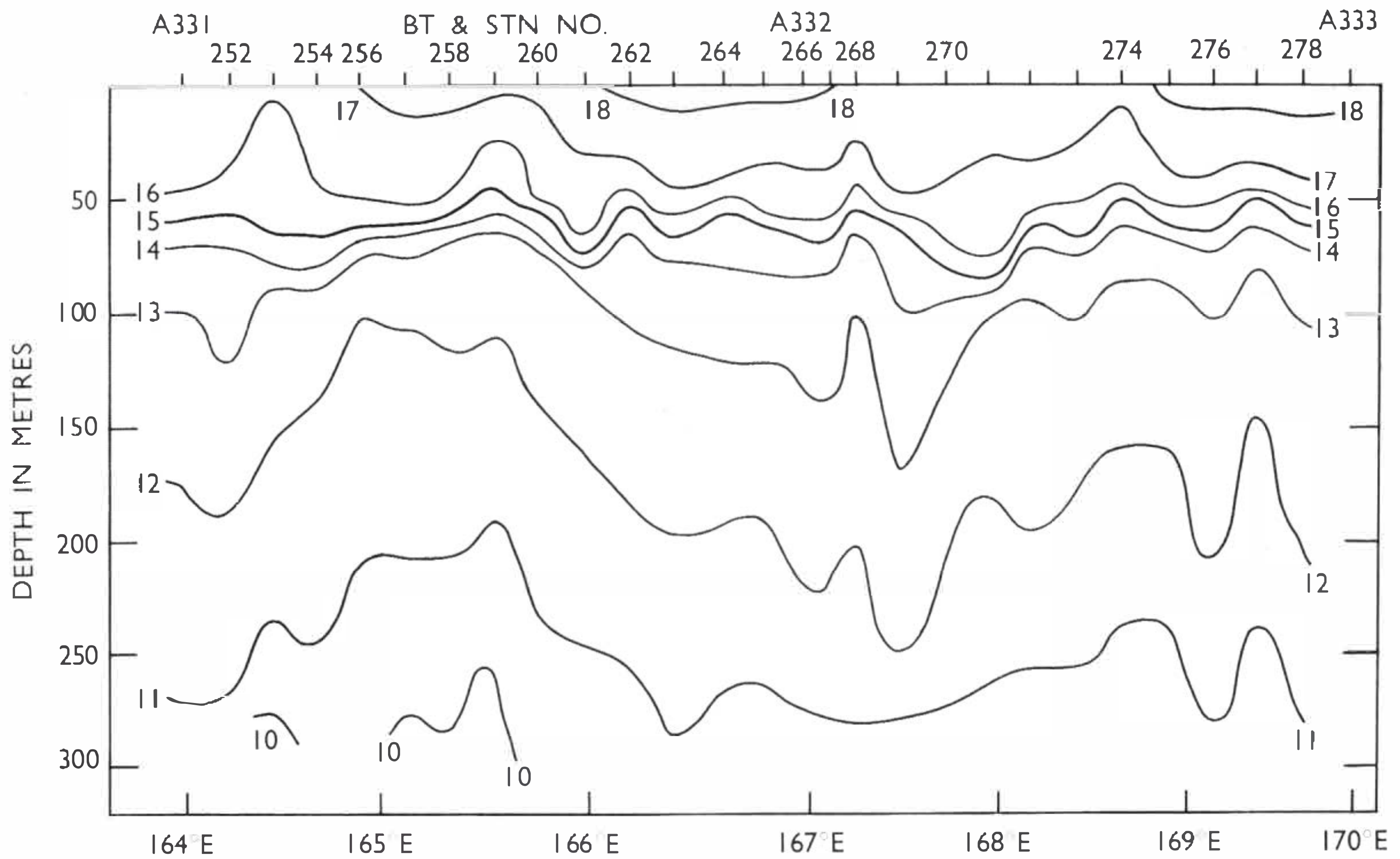


Fig. 28: Vertical cross section of temperature (°C) along bathythermograph section 19 (see fig. 25).

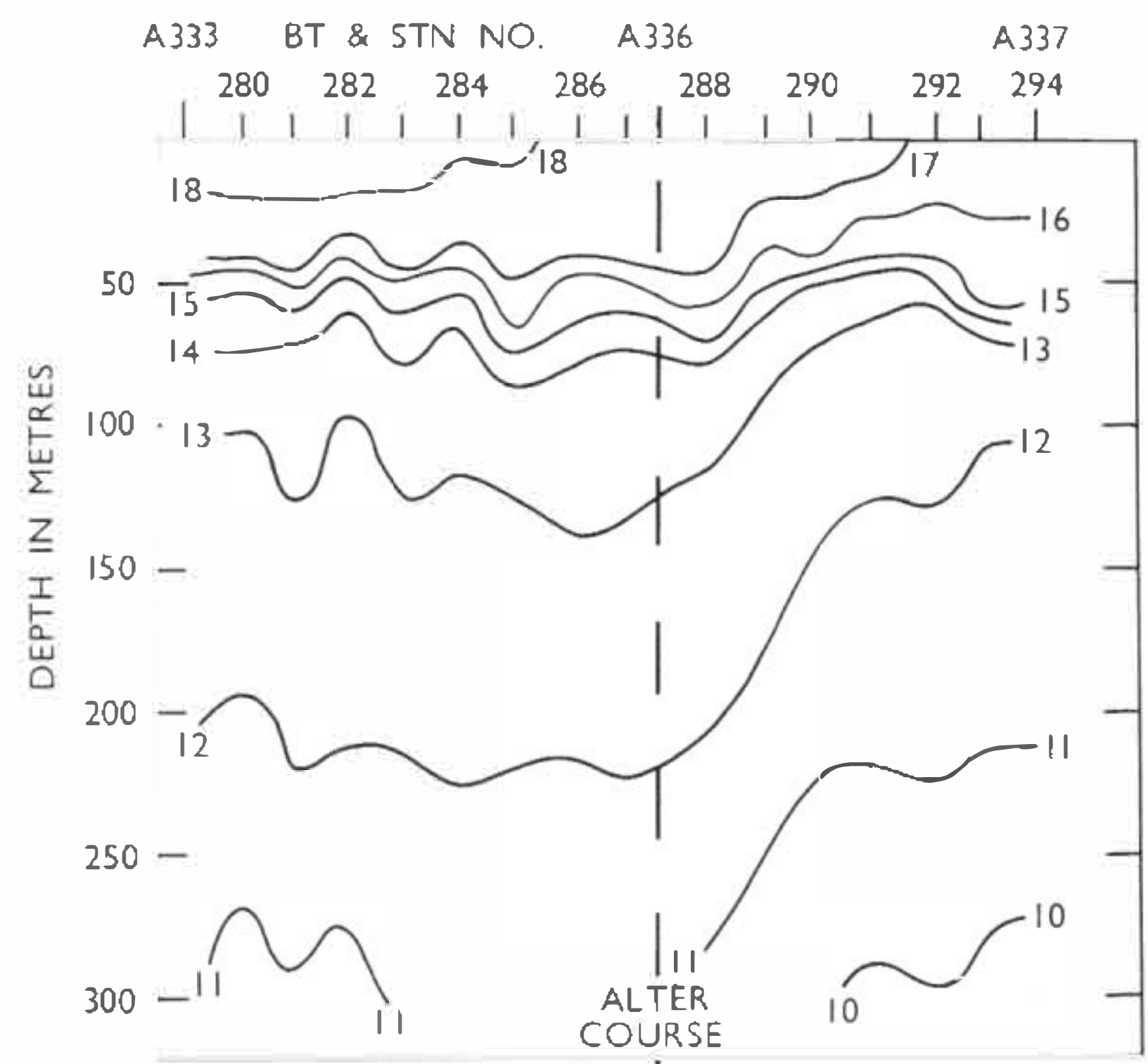


Fig. 29: Vertical cross section of temperature (°C) along bathythermograph section 20 (see fig. 25).

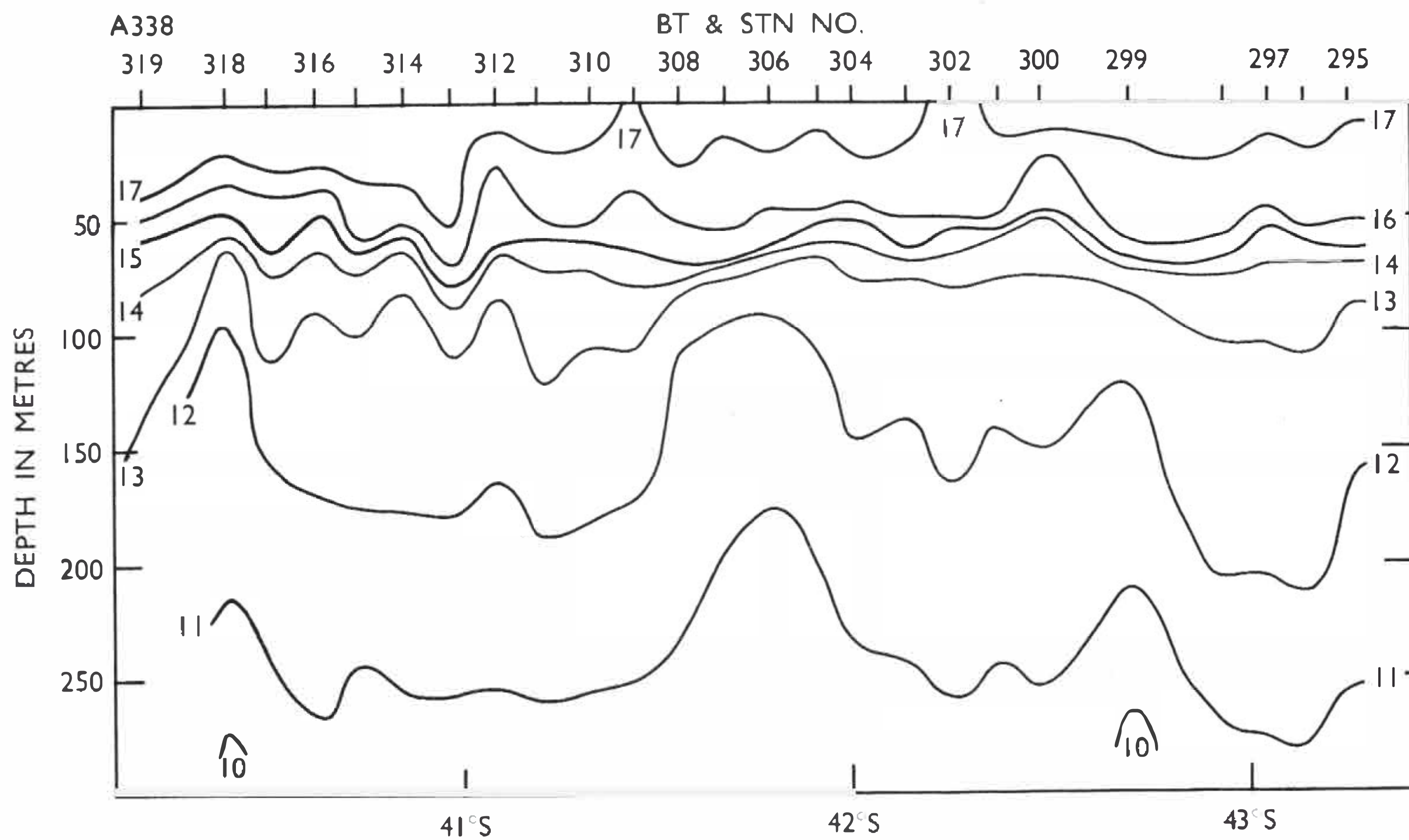


Fig. 30: Vertical cross section of temperature ($^{\circ}\text{C}$) along bathythermograph section 21 (see fig. 25).

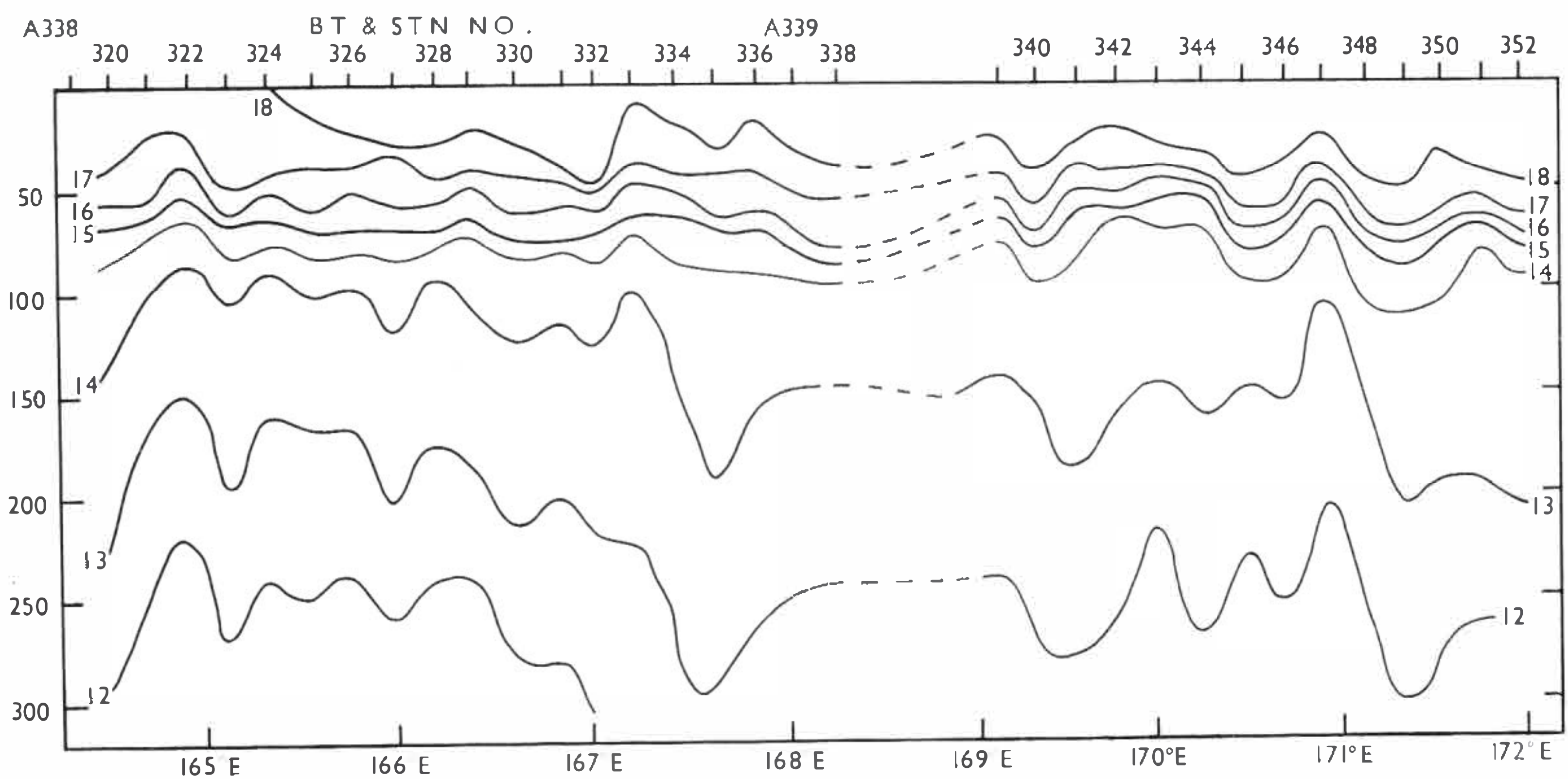


Fig. 31: Vertical cross section of temperature ($^{\circ}\text{C}$) along bathythermograph section 22 (see fig. 25).

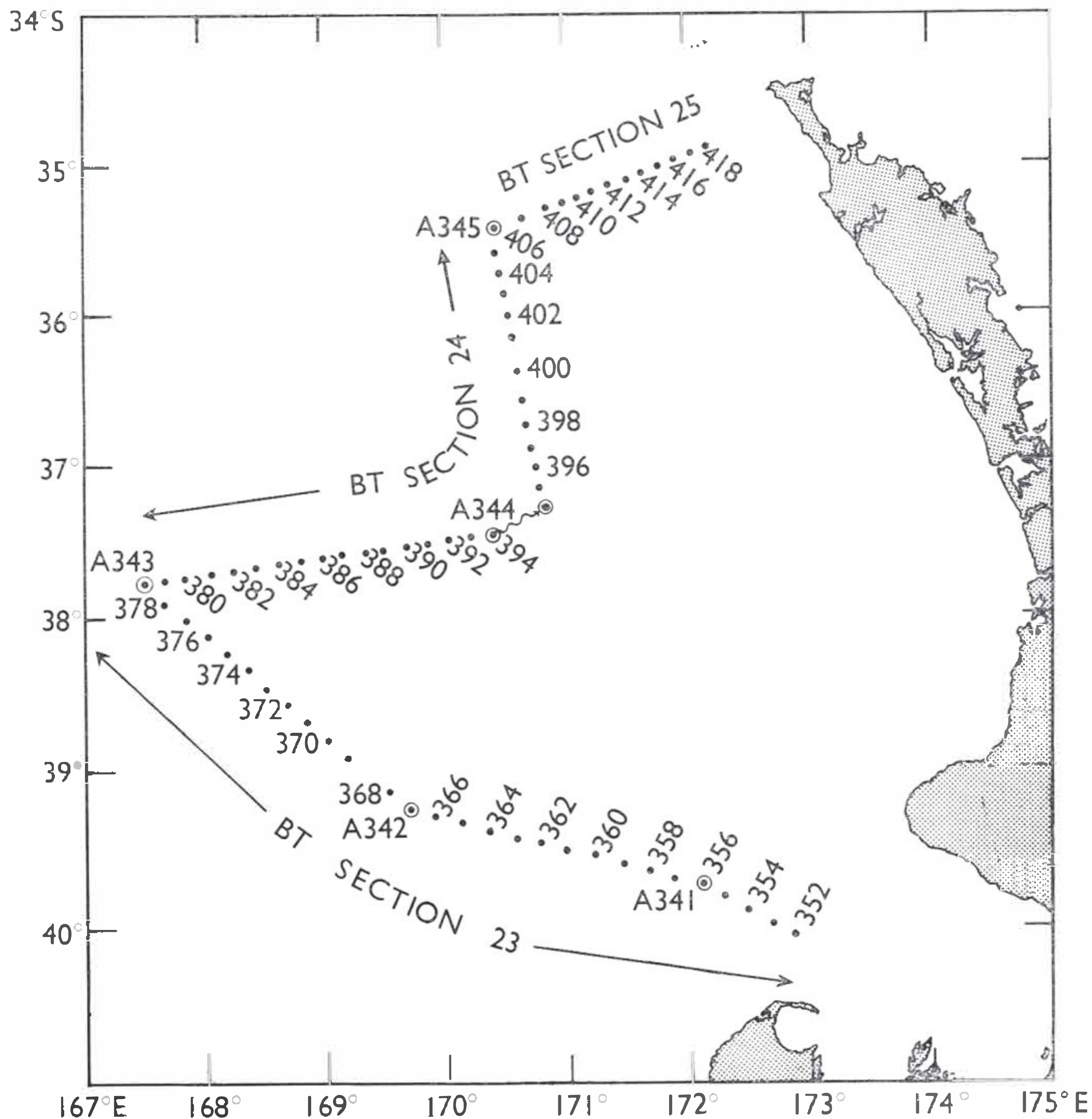


Fig. 32: Location of bathythermograph sections 23, 24, and 25 (see figs. 33, 34, and 35) from summer cruise IV west of North Island.

the winter sections were rather featureless in this respect. The thermocline was rather weakly developed, and the upper mixed layer tended to be fairly isothermal, occupying a depth of some 100 m in the north of the area surveyed, and 150–200 m in the south. The appearance of frequent small temperature inversions in winter sections 5 and 6 (figs. 9 and 10) lying to the south of New Zealand is noteworthy: these features are typical of the weak stability of near-surface waters subject to convective cooling from the surface by the colder climate prevailing in winter.

The warming of near-surface waters during the spring and summer seasons typically results in an increase in the stability of upper water layers,

owing to the creation of a relatively shallow and intense thermocline layer. This feature was found in the summer bathythermograph sections (figs. 16–35) where the thermocline depth lay in general, at 50–70 m. Intensification of the vertical temperature gradient in the thermocline layer may be traced to effects other than climatic, in several instances: for instance, in section 10 (fig. 16) to the north-west of North Cape, an example of thermocline intensification due to the advection of warm water across the section may be found to the east of station A 346. This intensification had occurred in spite of a pronounced slope of isotherms under the thermocline layer, associated dynamically with the surface advection. The opposite effect is ap-

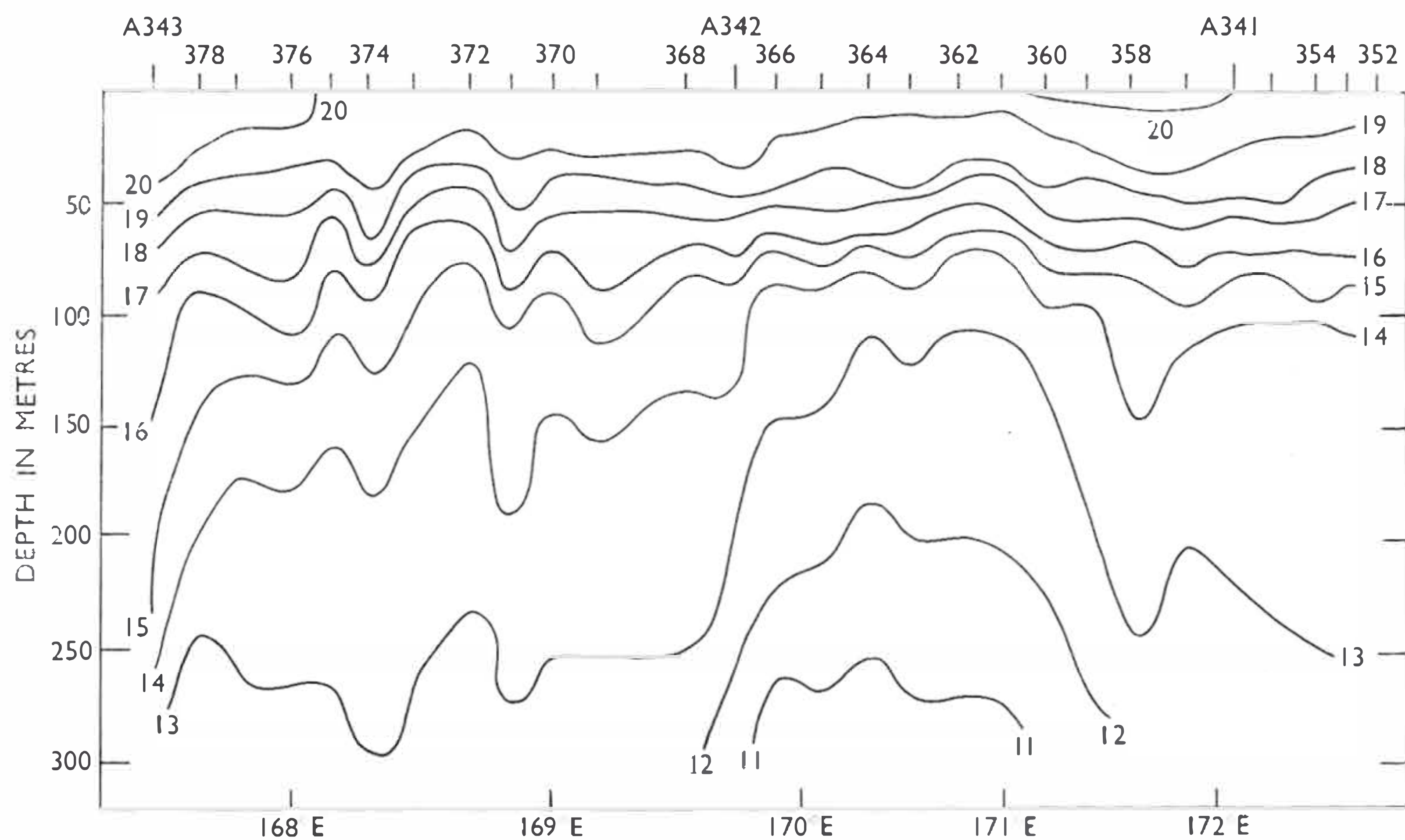


Fig. 33: Vertical cross section of temperature (°C) along bathythermograph section 23 (see fig. 32).

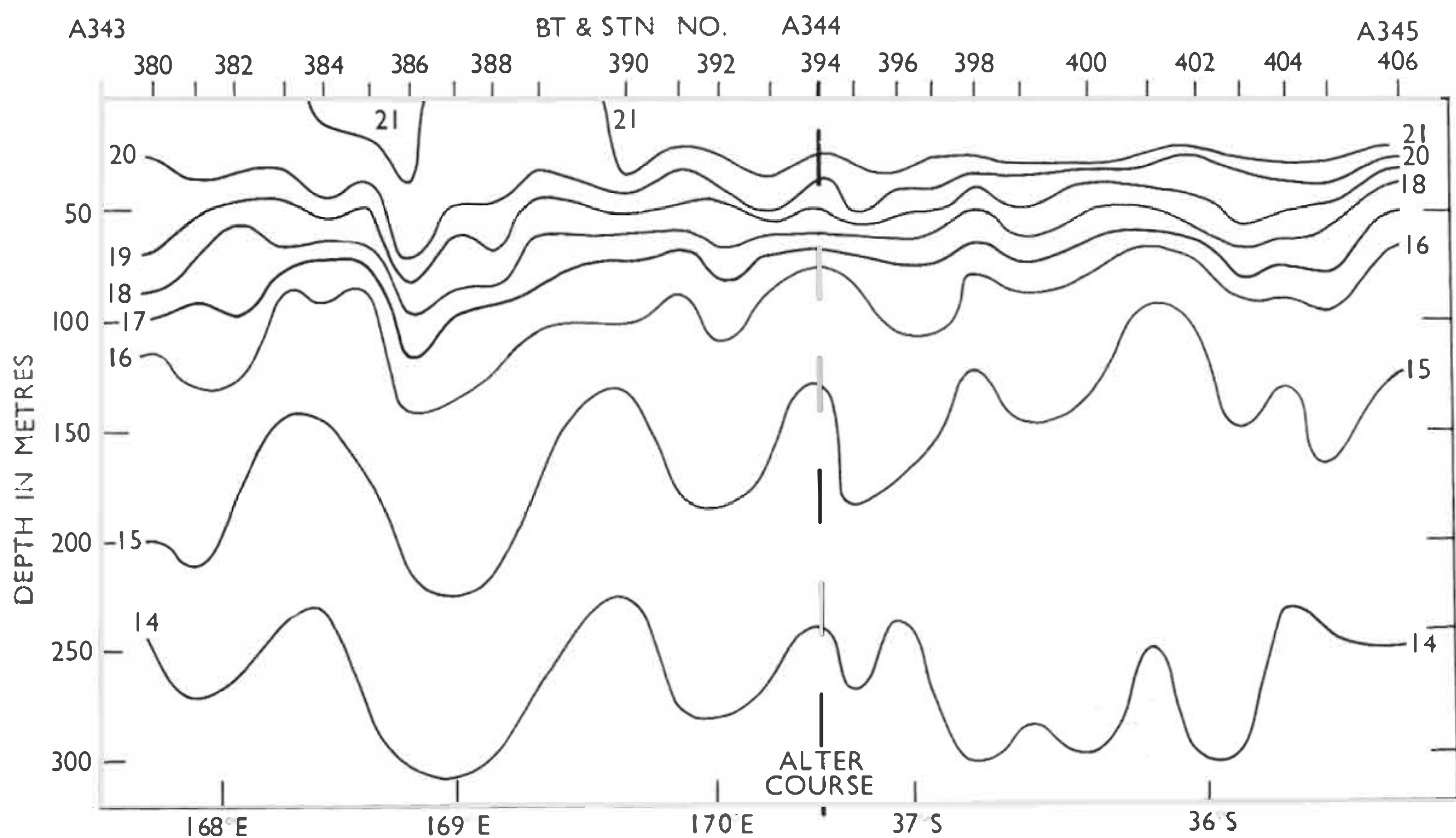


Fig. 34: Vertical cross section of temperature (°C) along bathythermograph section 24 (see fig. 32).

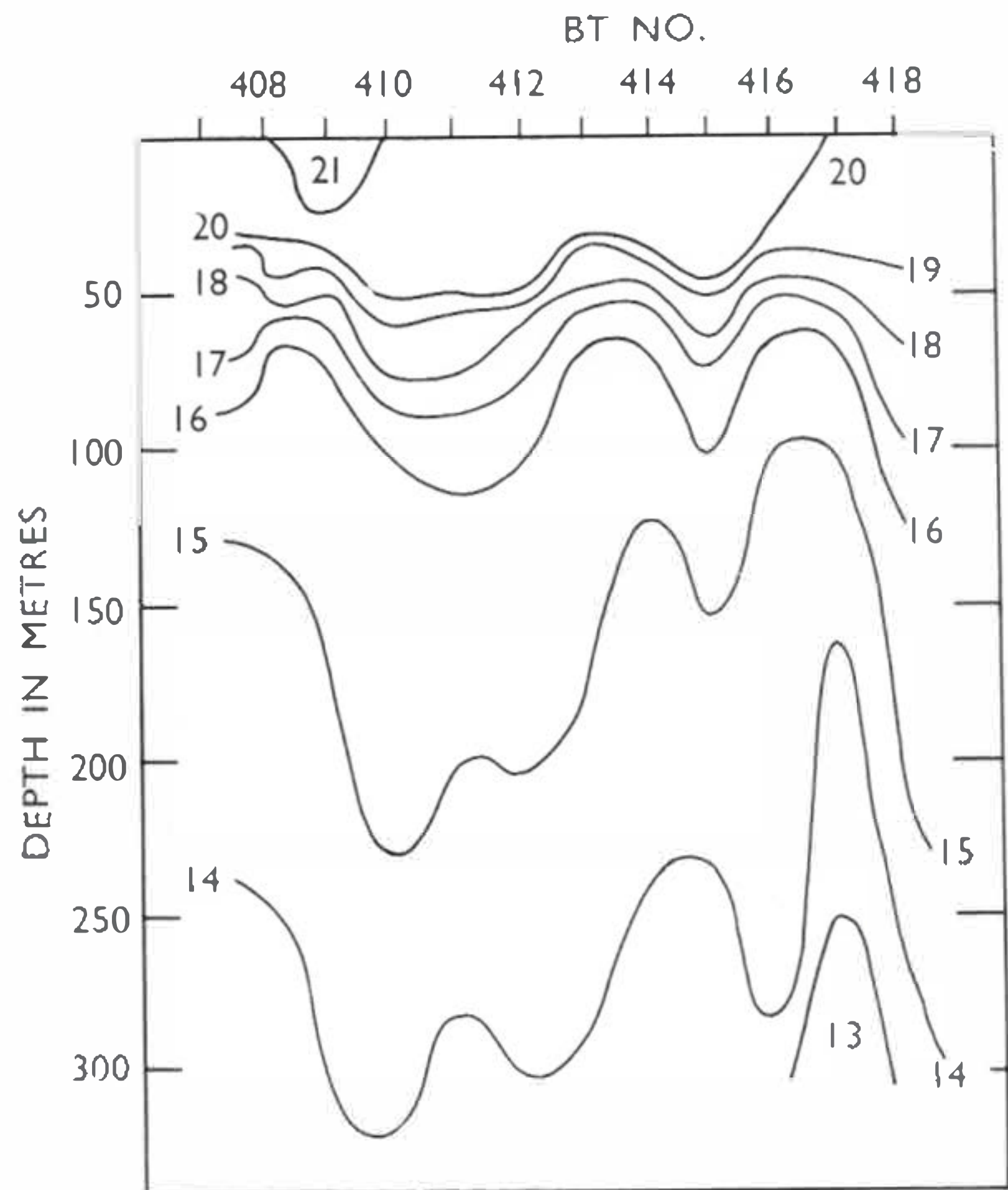


Fig. 35: Vertical cross section of temperature ($^{\circ}\text{C}$) along bathythermograph section 25 (see fig. 32).

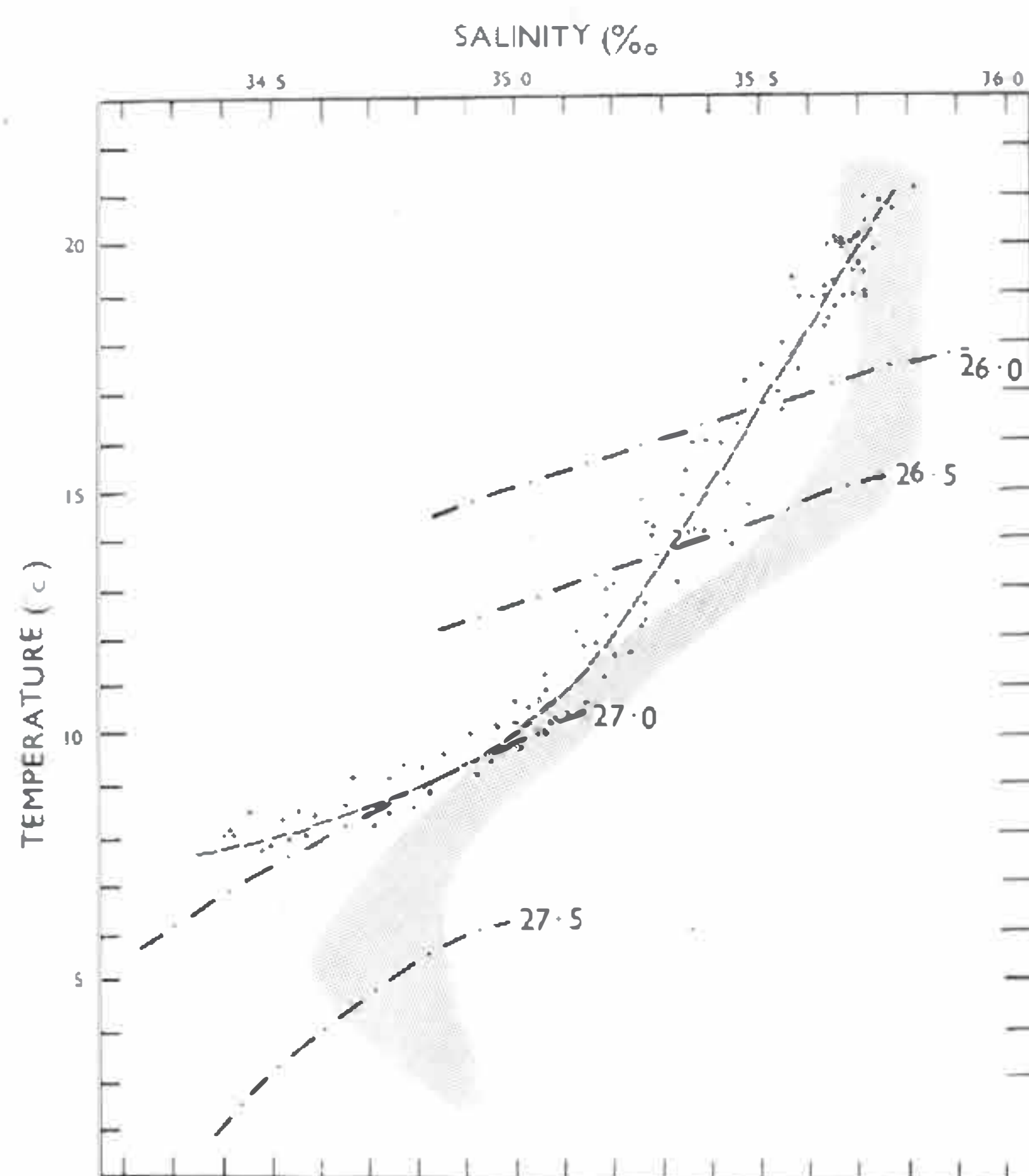


Fig. 36: Temperature-salinity correlation curves for the winter survey. Dots represent surface observations; serial station data are contained within the shaded area. Isopleths of constant density (σ_t) are entered as dash-dot curves.

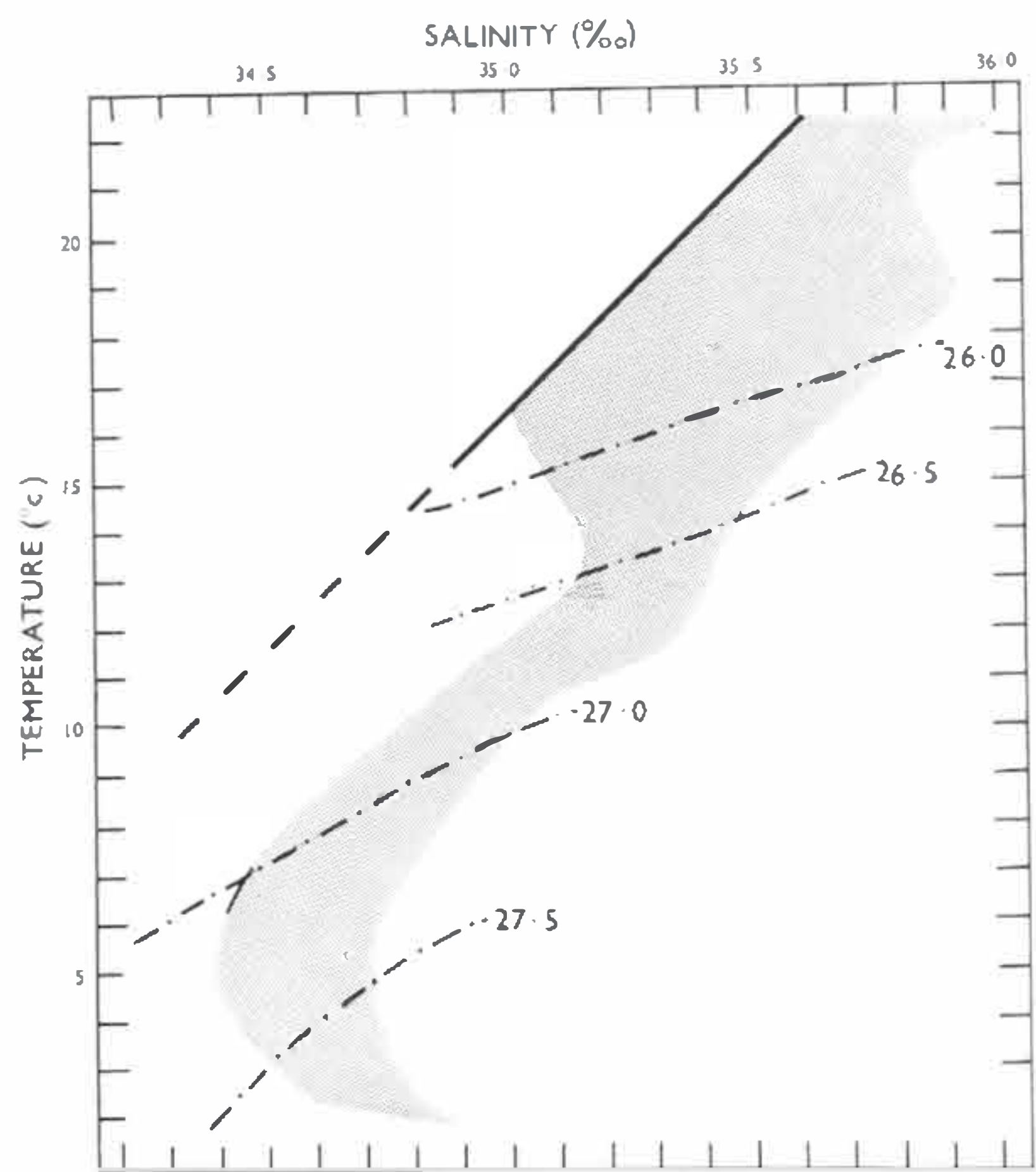


Fig. 37: Temperature-salinity correlation curves for the summer survey. The heavy broken line shows the trend described by surface observations; serial station data are contained within the shaded area. Isopleths of constant density (σ_t) are entered as dash-dot curves.

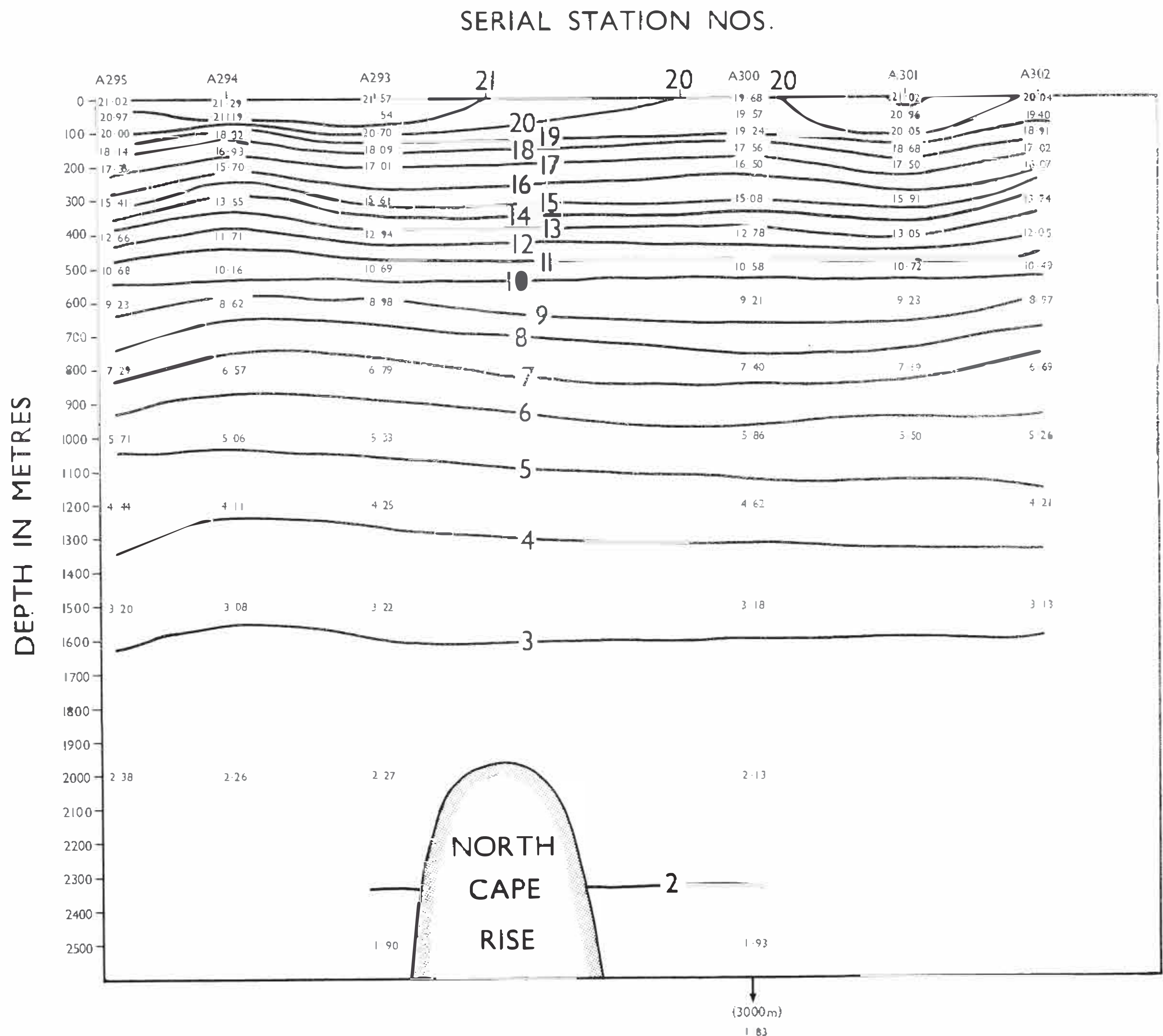


Fig. 38: Vertical cross section of temperature ($^{\circ}\text{C}$) between Norfolk Island and the Kermadec Islands constructed from winter survey data.

parent in sections 15 and 16 (figs. 23 and 24). A great mass of cold, Subantarctic Water lay offshore east of the South Island under a superficial warmer mass. The edges of this cold mass were met to the south of bathythermograph sounding 166 in section 15 and to the west of sounding 200 in section 16. The presence of this cold water so close to the surface has resulted in the formation of the most intensely developed thermocline found during the *Tui* operations. At the eastern end of section 16, this thermocline lay at a depth of only 30 to 40 m but its stability was such that the close proximity of the cold water mass is reflected little, if at all, in the temperature structure of the surface mixed layer.

(b) Dynamics

It is a fact of experience that the major oceanic circulation systems are nearly geostrophic, that is they may be dynamically represented closely by a frictionless, non-accelerated flow resulting from a balance between the horizontal pressure gradient force, associated with the oceanic density distribution, and the Coriolis force, associated with the rotation of the earth. The geostrophic circulation in any chosen isobaric surface, relative to that in some deeper surface, may be related to the three-dimensional distribution of temperature and salinity between the two surfaces, through calculations of the thickness of the layer. The standard computa-

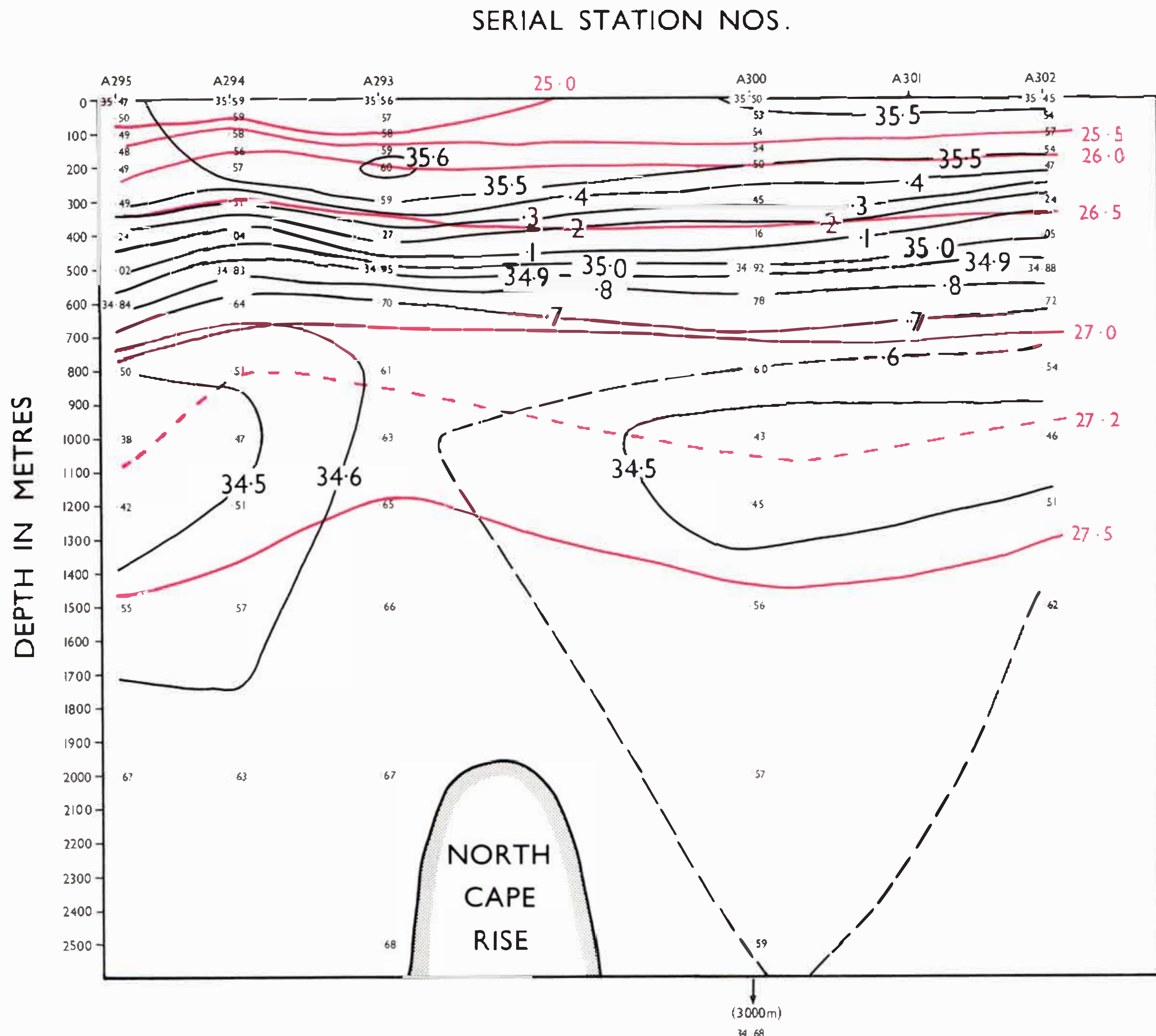


Fig. 39: Vertical cross section of salinity (‰) corresponding to the temperature section of fig. 38. Selected isopycnals (σ_t) are superimposed in red.

tions (e.g. LaFond, 1951) yield the anomaly of dynamic height from sea surface to each of the standard sampling depths, and these values are given (" $\Sigma\Delta D$ ") in table 3. The mean geostrophic surface current, V , normal to the line joining any two stations A and B for instance, *relative to that at any given deeper level*, may be calculated from the relation:

$$V = [(\Sigma\Delta D)_A - (\Sigma\Delta D)_B] / 0.015 L \sin \phi.$$

where V is in cm sec^{-1} ; L , the station separation, in km; ϕ the mean latitude of the stations; $\Sigma\Delta D$, that value (dynamic m) tabulated for the deep reference level.

The use of these dynamic computations becomes most rewarding when applied to a set of stations

which lie on a grid pattern systematically covering the area under investigation. It is then possible to construct the topography of the sea surface relative to some deep isobaric surface and the contours of dynamic height become also streamlines of the relative geostrophic circulation. The *Tui* survey presently reported was designed to yield a reconnaissance of the hydrological properties of as extensive an area around New Zealand as possible within the time limitations imposed. These requirements are not consistent with those for the systematic coverage described above, and thus only limited quantitative use may be made of the dynamic computations derived from these *Tui* stations, in the present context.

The areal distribution of stations to the west and north of New Zealand during the summer survey

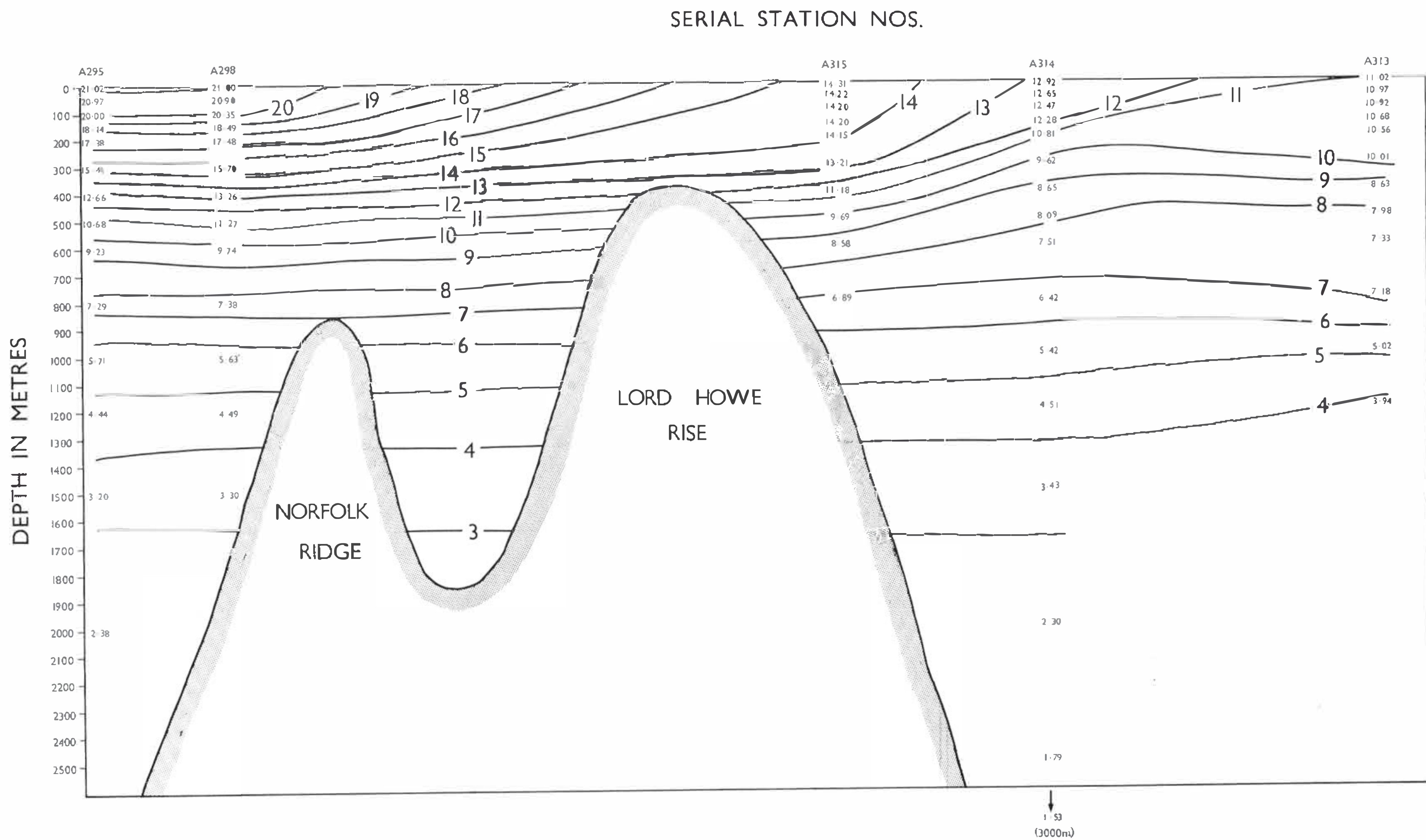


Fig. 40: Vertical cross section of temperature ($^{\circ}\text{C}$) approximately meridionally oriented to the west of New Zealand, constructed from winter survey data.

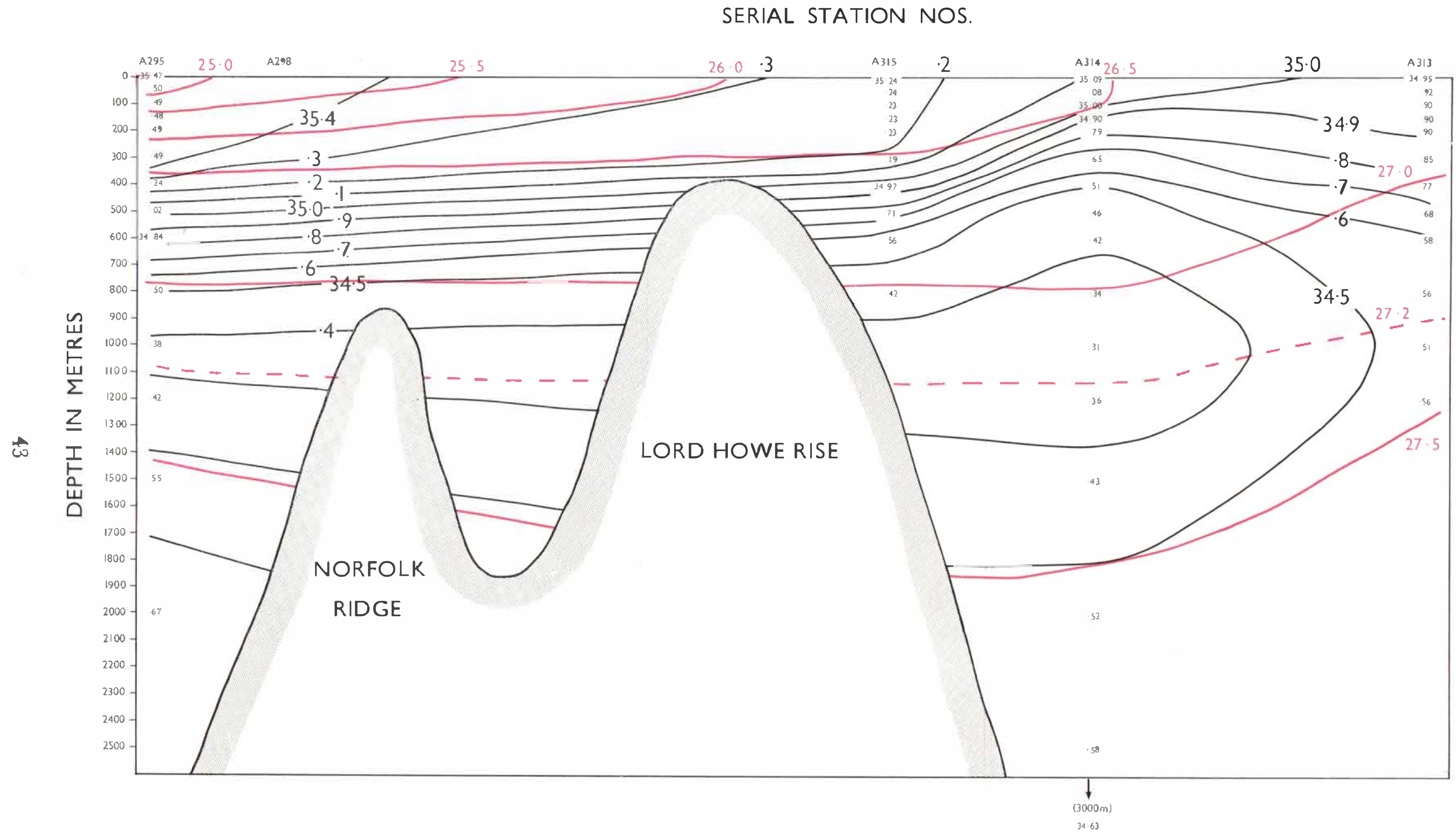


Fig. 41: Vertical cross section of salinity (‰) corresponding to the temperature section of fig. 40. Selected isopycnals (σ_t) are superimposed in red.

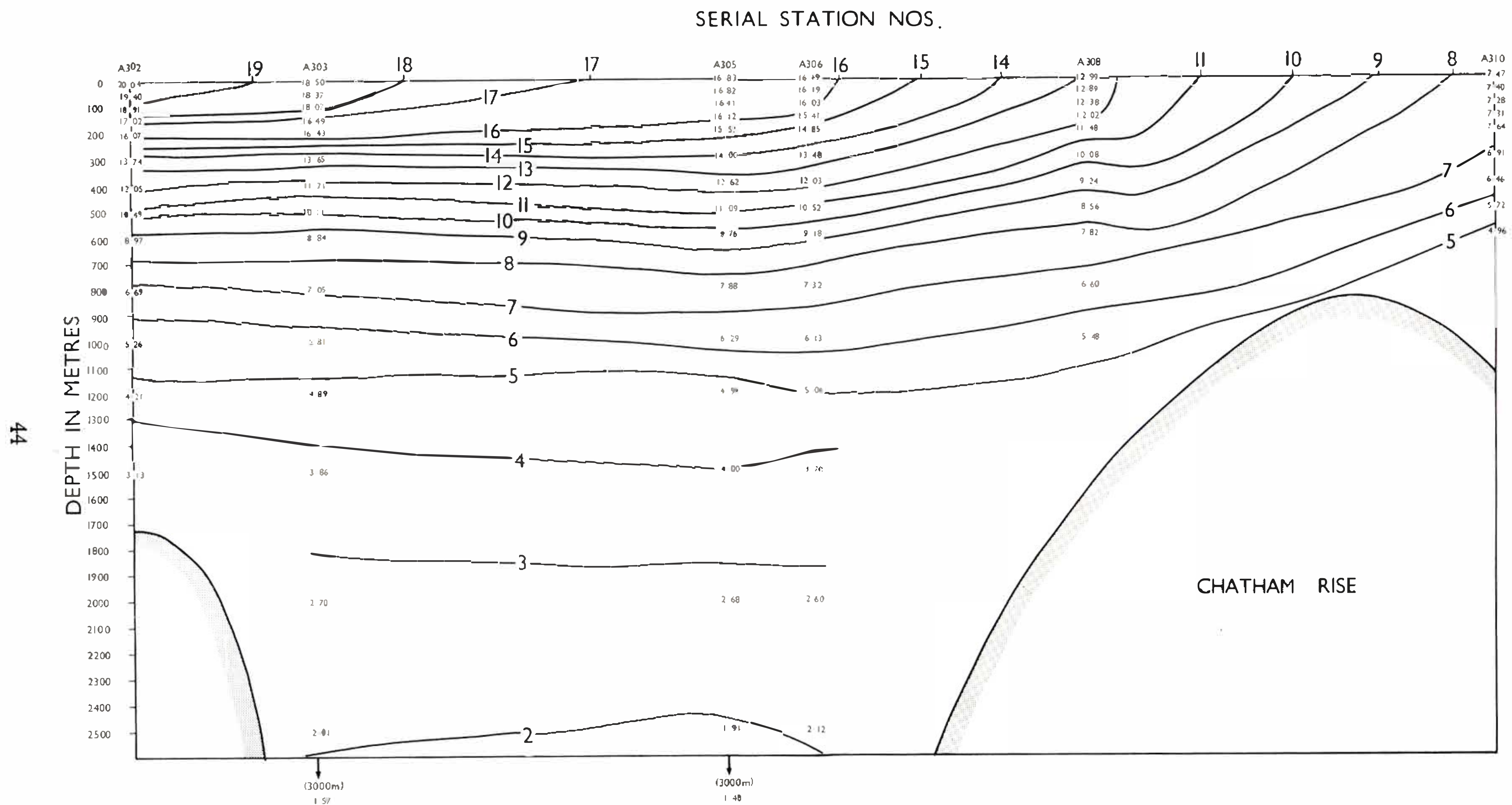


Fig. 42: Vertical cross section of temperature ($^{\circ}\text{C}$) approximately meridionally oriented to the east of New Zealand, constructed from winter survey data.

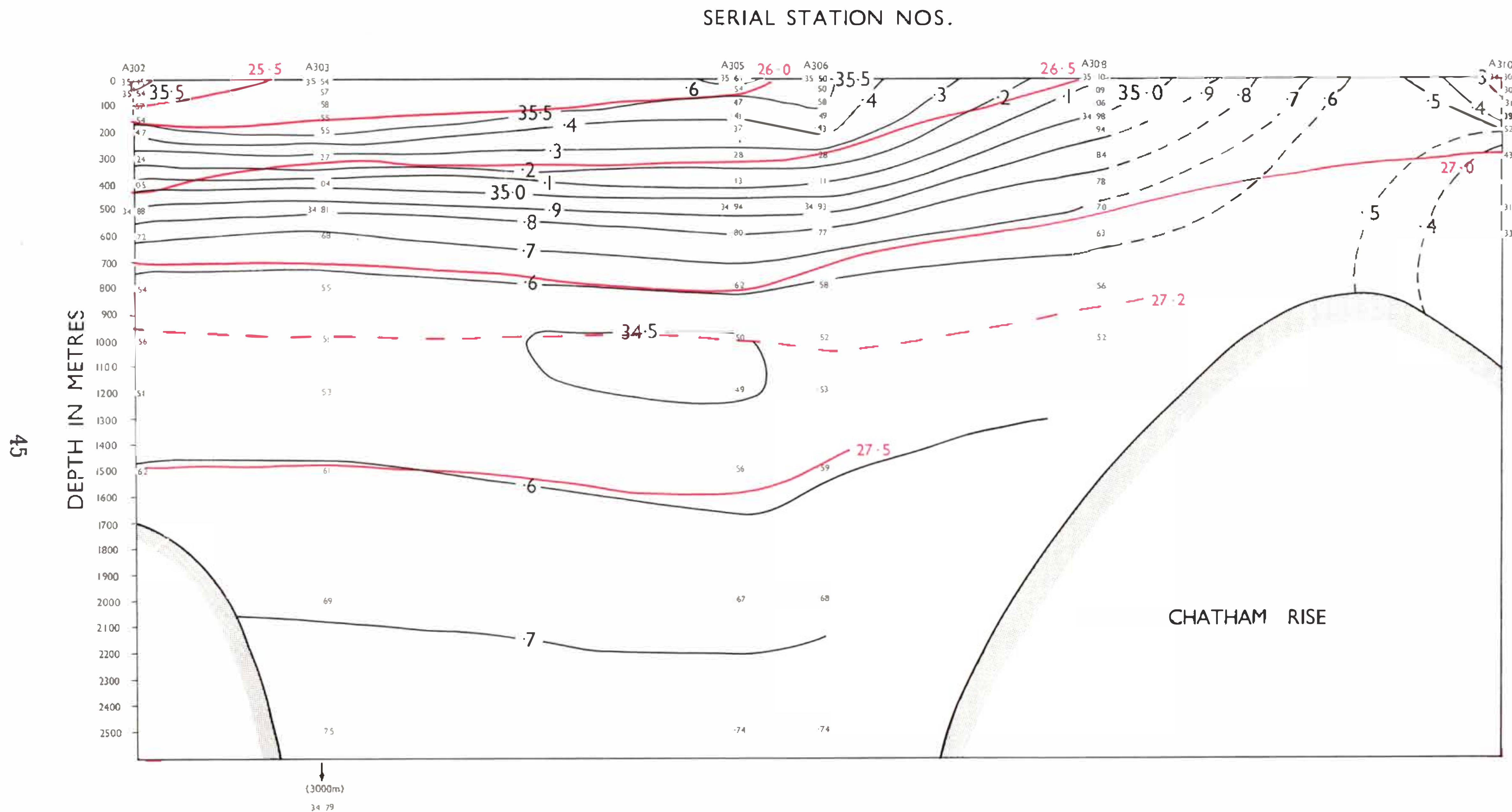


Fig. 43: Vertical cross section of salinity (‰) corresponding to the temperature section of fig. 42. Selected isopycnals (σ_t) are superimposed in red.

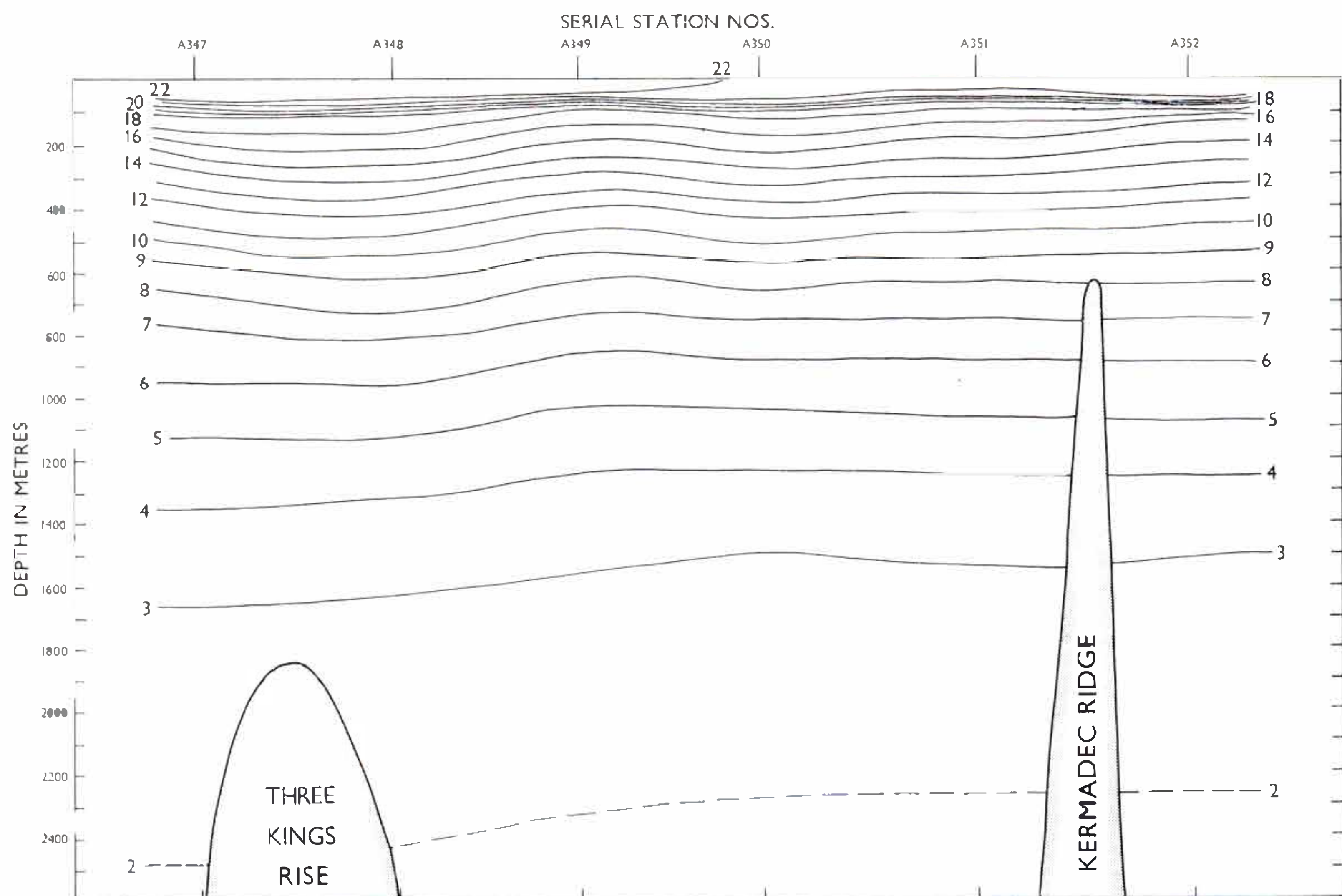


Fig. 44: Vertical cross section of temperature ($^{\circ}\text{C}$) zonally oriented north of New Zealand, constructed from summer survey data.

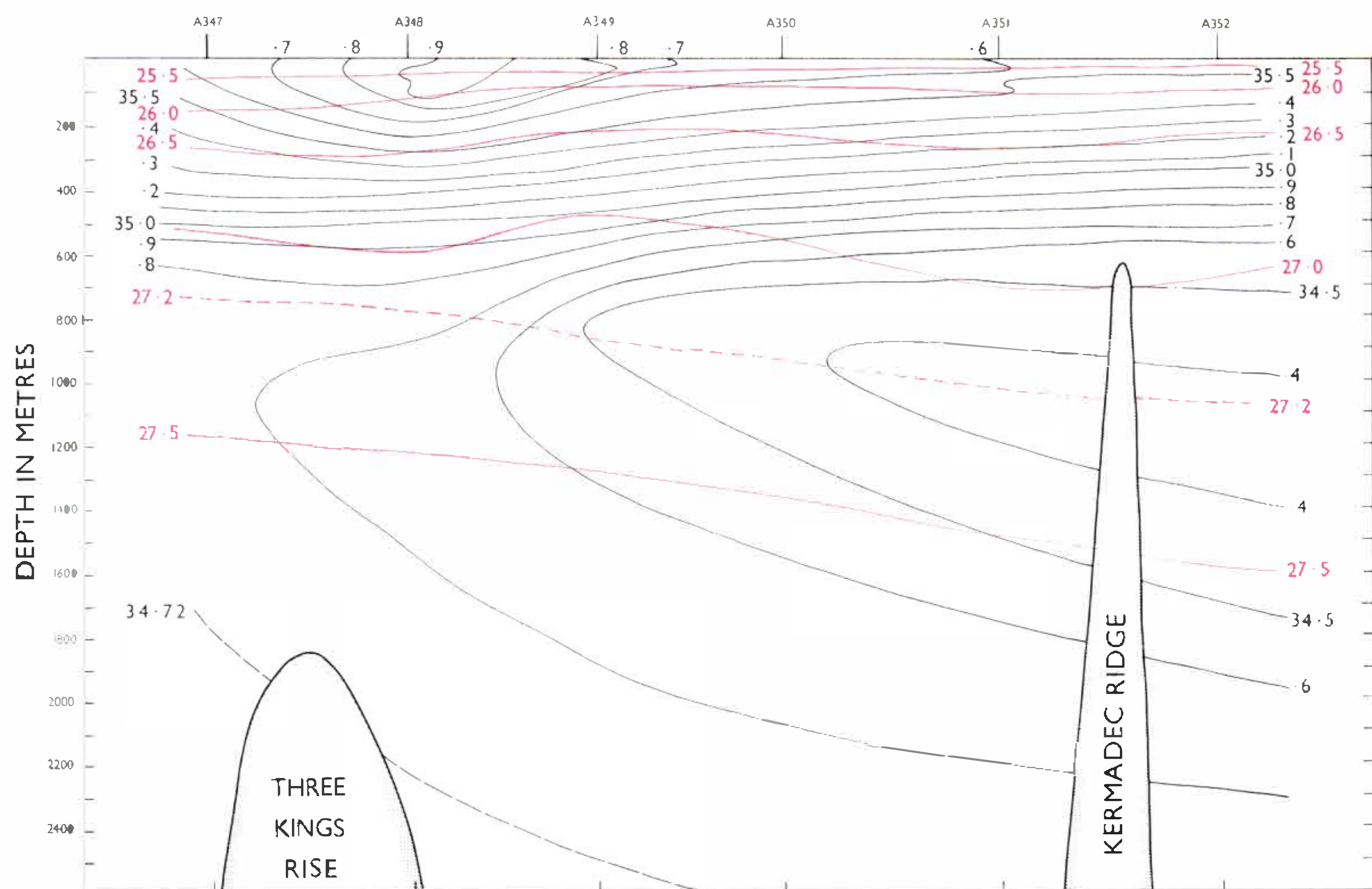


Fig. 45: Vertical cross section of salinity (‰) corresponding to the temperature section of fig. 44. Selected isopycnals (σ_t) are superimposed in red.

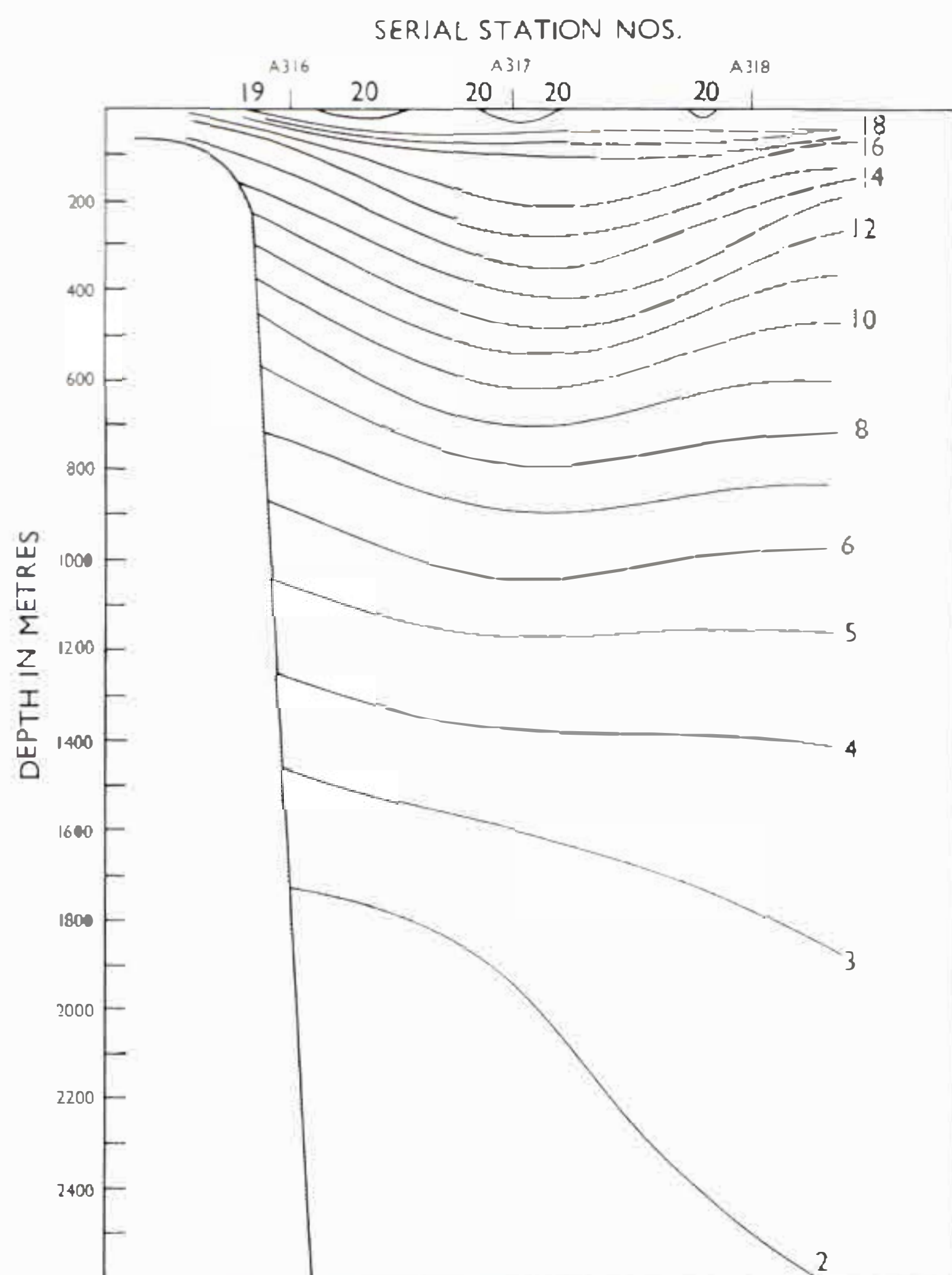


Fig. 46: Vertical cross section of temperature ($^{\circ}\text{C}$) along a line directed eastwards from Cape Colville, constructed from summer survey data.

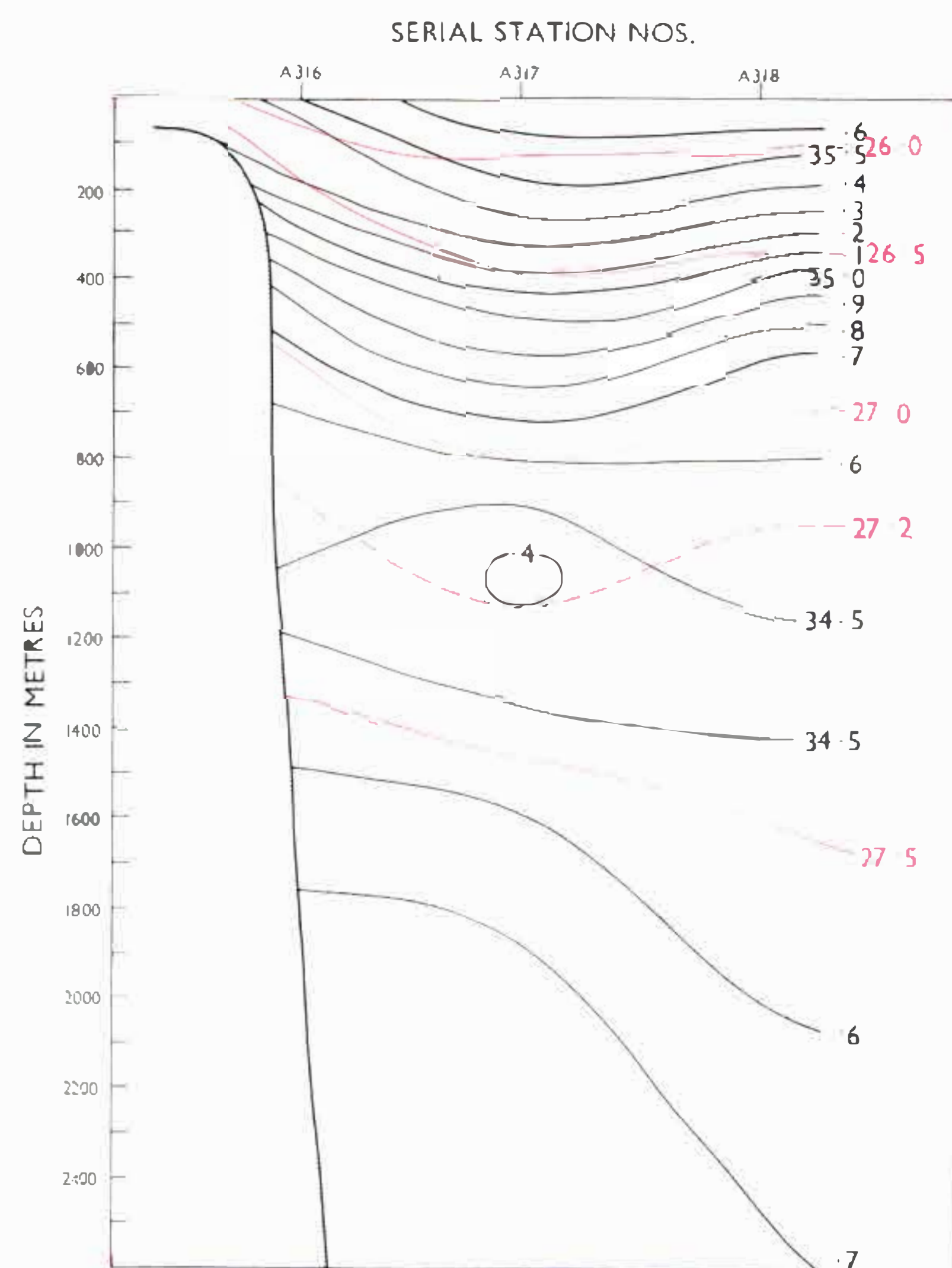
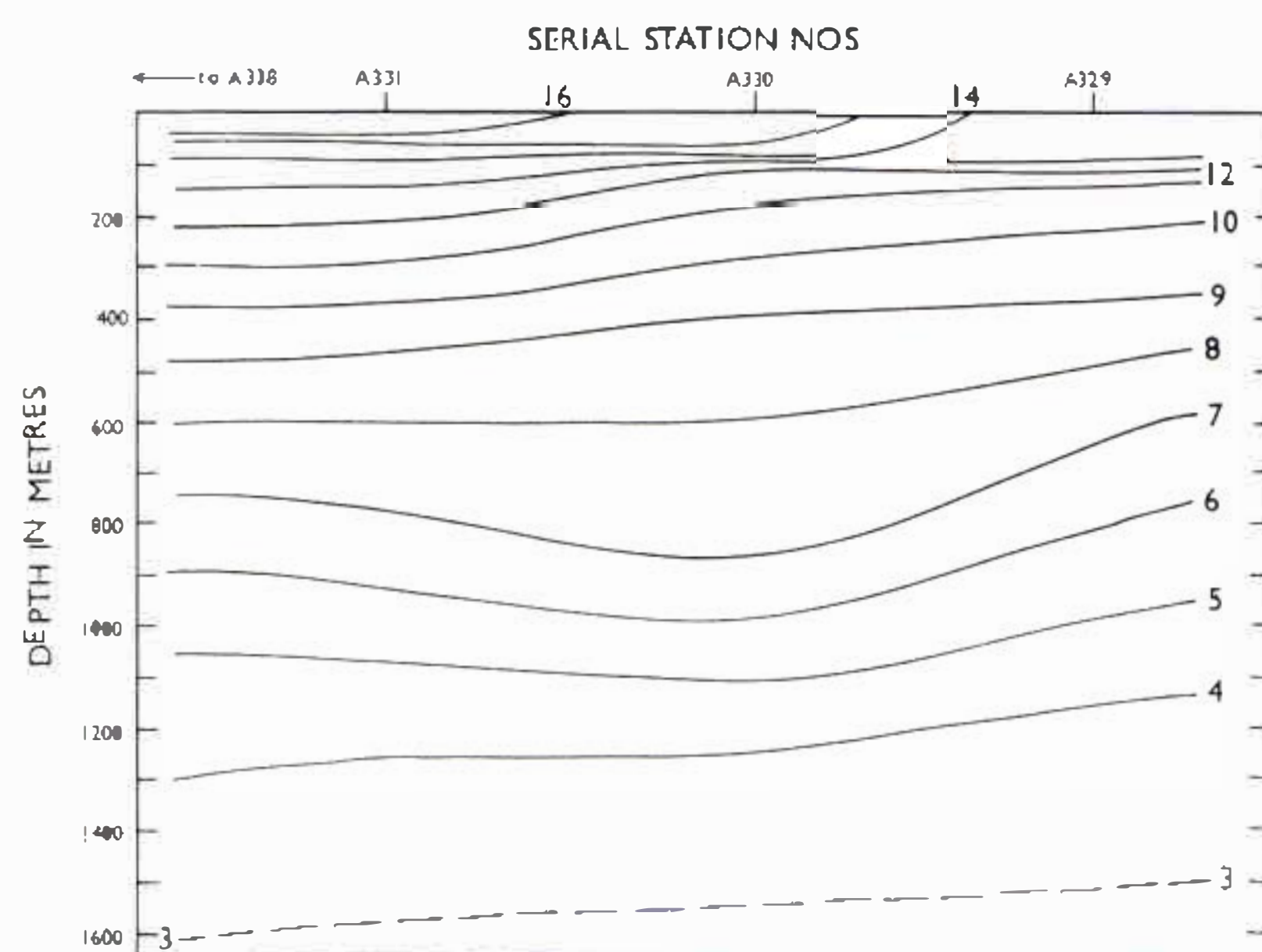


Fig. 47: Vertical cross section of salinity (‰) corresponding to the temperature section of fig. 46. Selected isopycnals (σ_t) are superimposed in red.

Fig. 48: Vertical cross section of temperature ($^{\circ}\text{C}$) meridionally oriented off the south-west of the South Island, constructed from summer survey data.



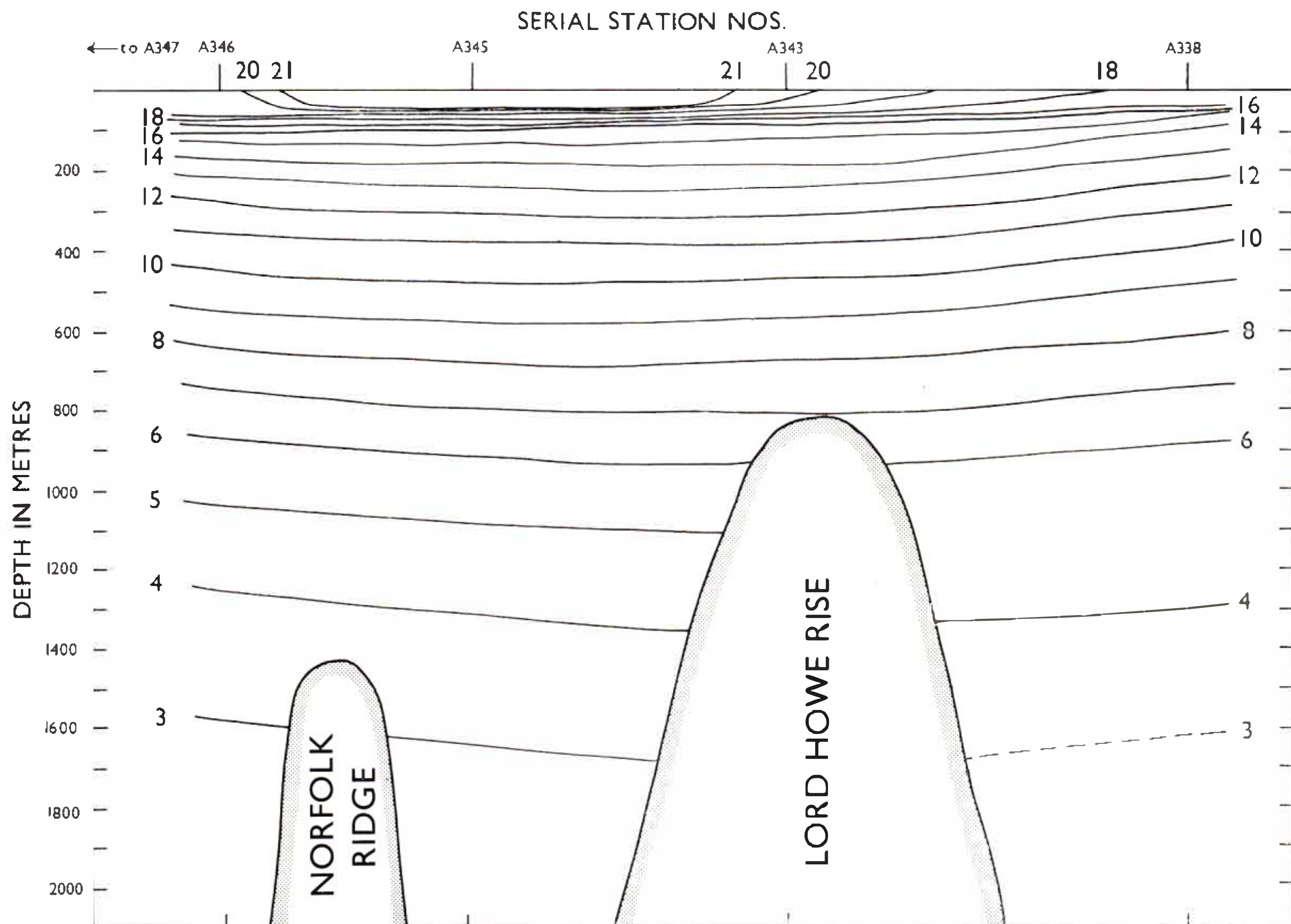


Fig. 49: Vertical cross section of temperature ($^{\circ}\text{C}$) approximately meridionally oriented, offshore to the west of New Zealand constructed from summer survey data.

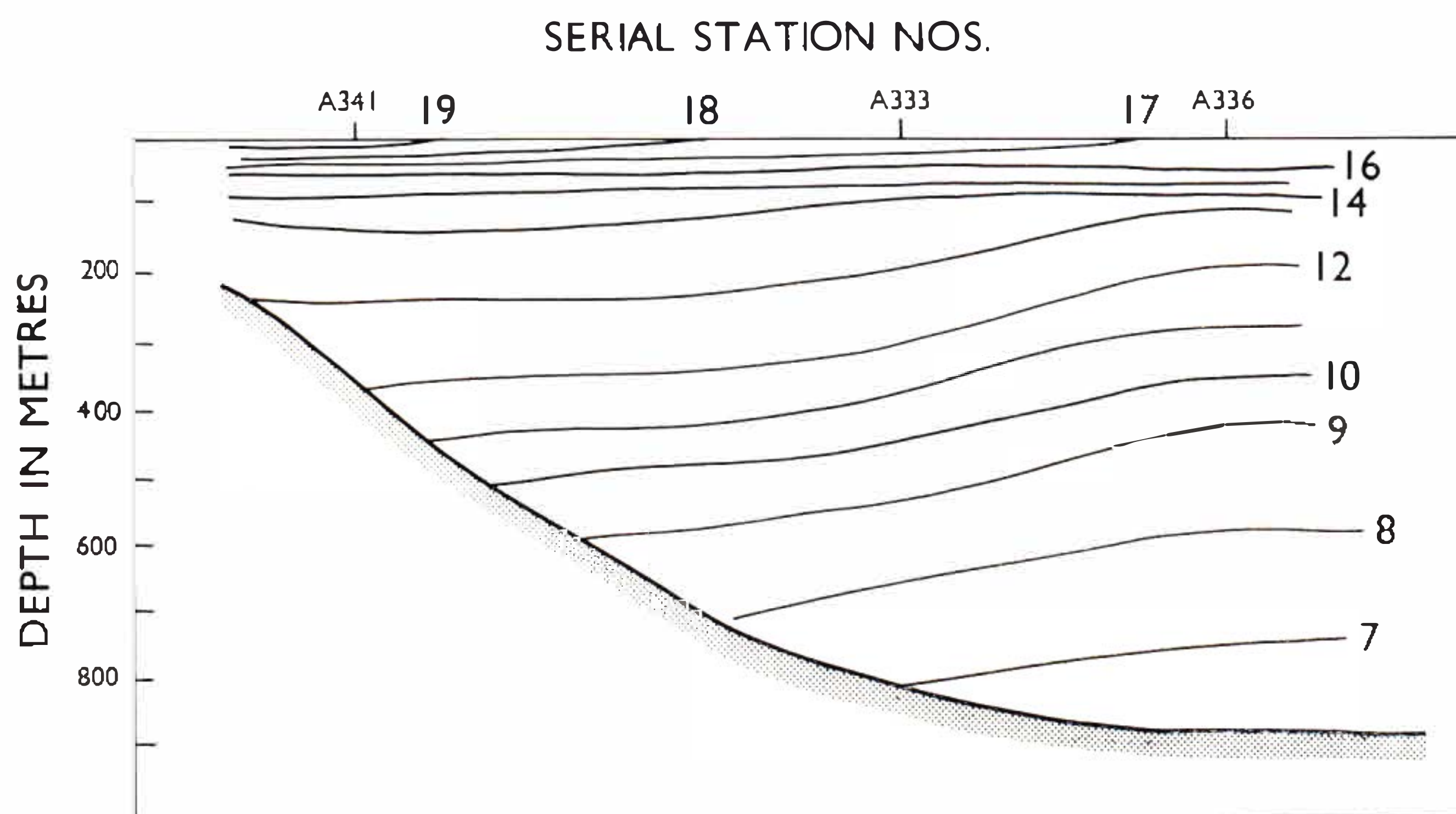


Fig. 50: Vertical cross section of temperature ($^{\circ}\text{C}$) approximately meridionally oriented onshore to the west of New Zealand constructed from summer survey data.

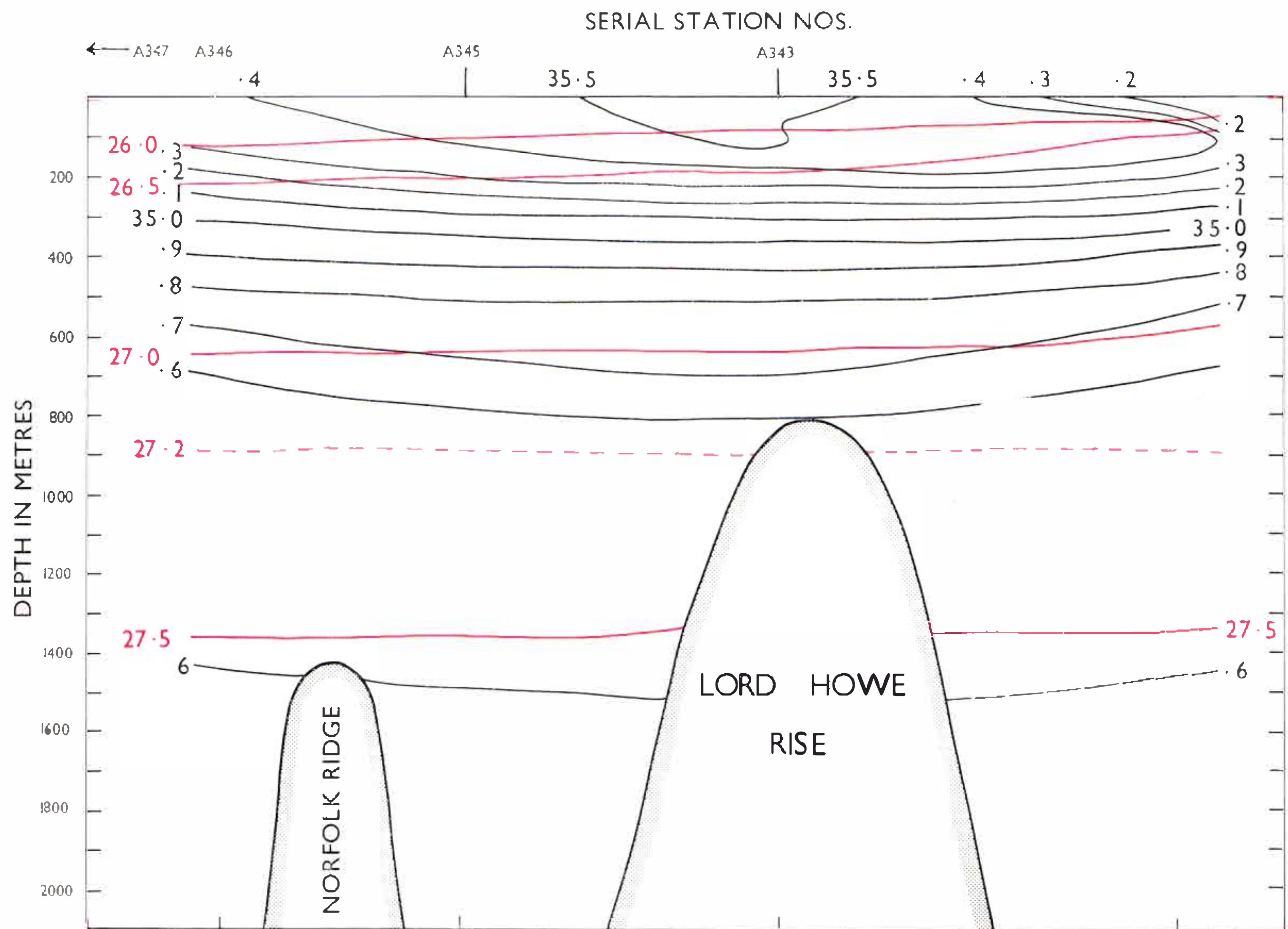


Fig. 51: Vertical cross section of salinity (‰) corresponding to the temperature section of fig. 49. Selected isopycnals (σ_t) are superimposed in red.

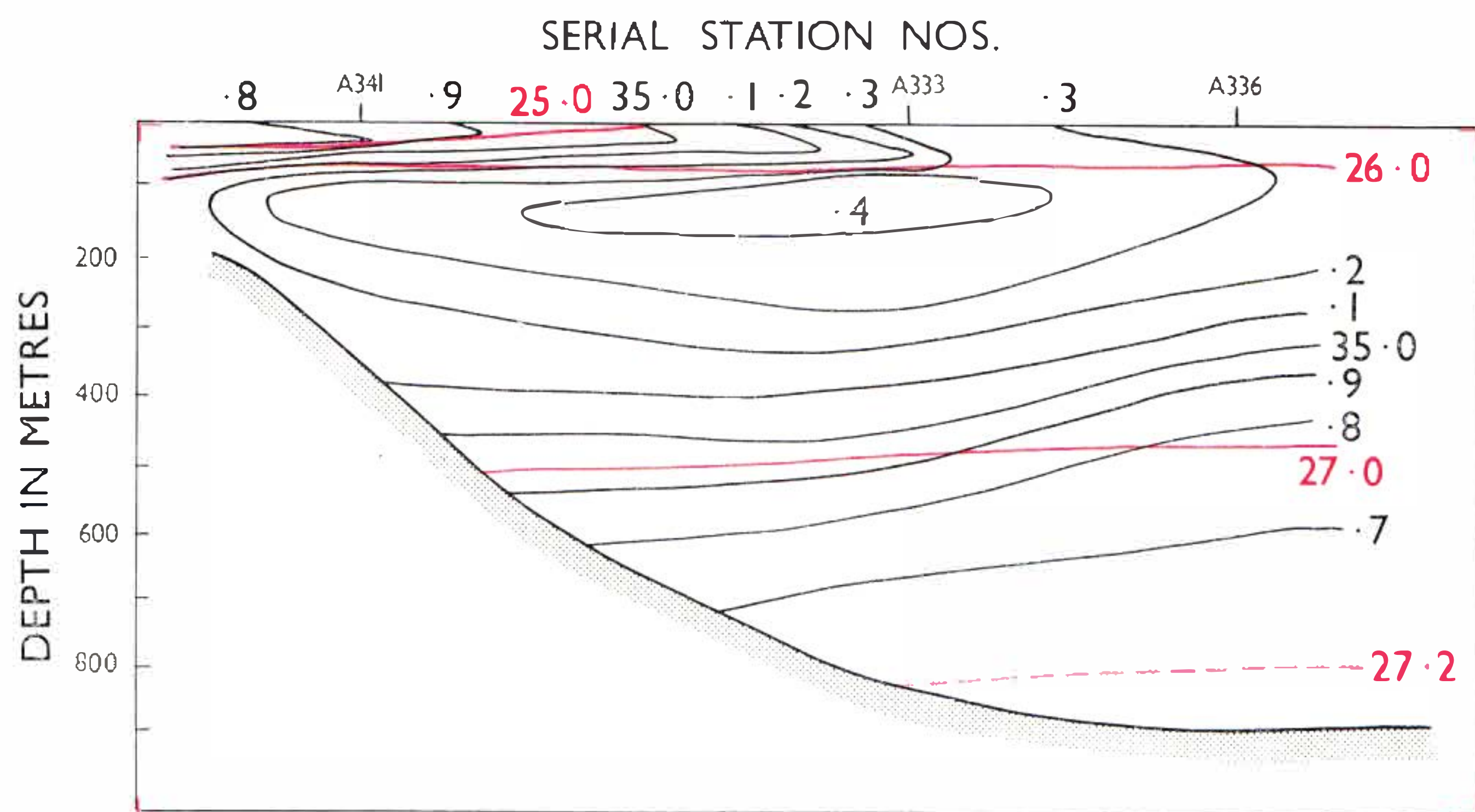


Fig. 52: Vertical cross section of salinity (‰) corresponding to the temperature section of fig. 53. Selected isopycnals (σ_t) are superimposed in red.

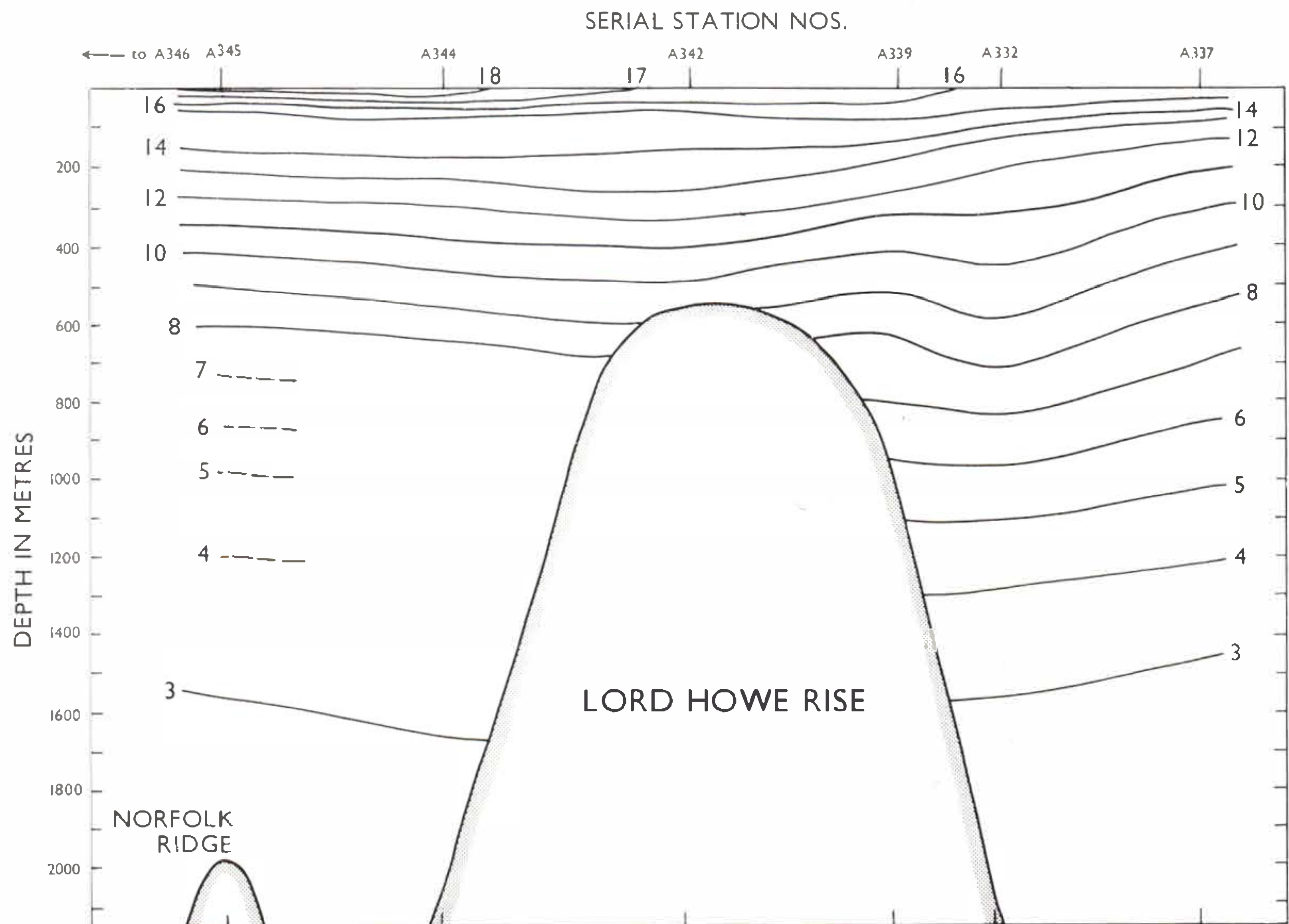


Fig. 53: Vertical cross section of temperature ($^{\circ}\text{C}$) approximately meridionally oriented, inshore to the west of New Zealand constructed from summer survey data.

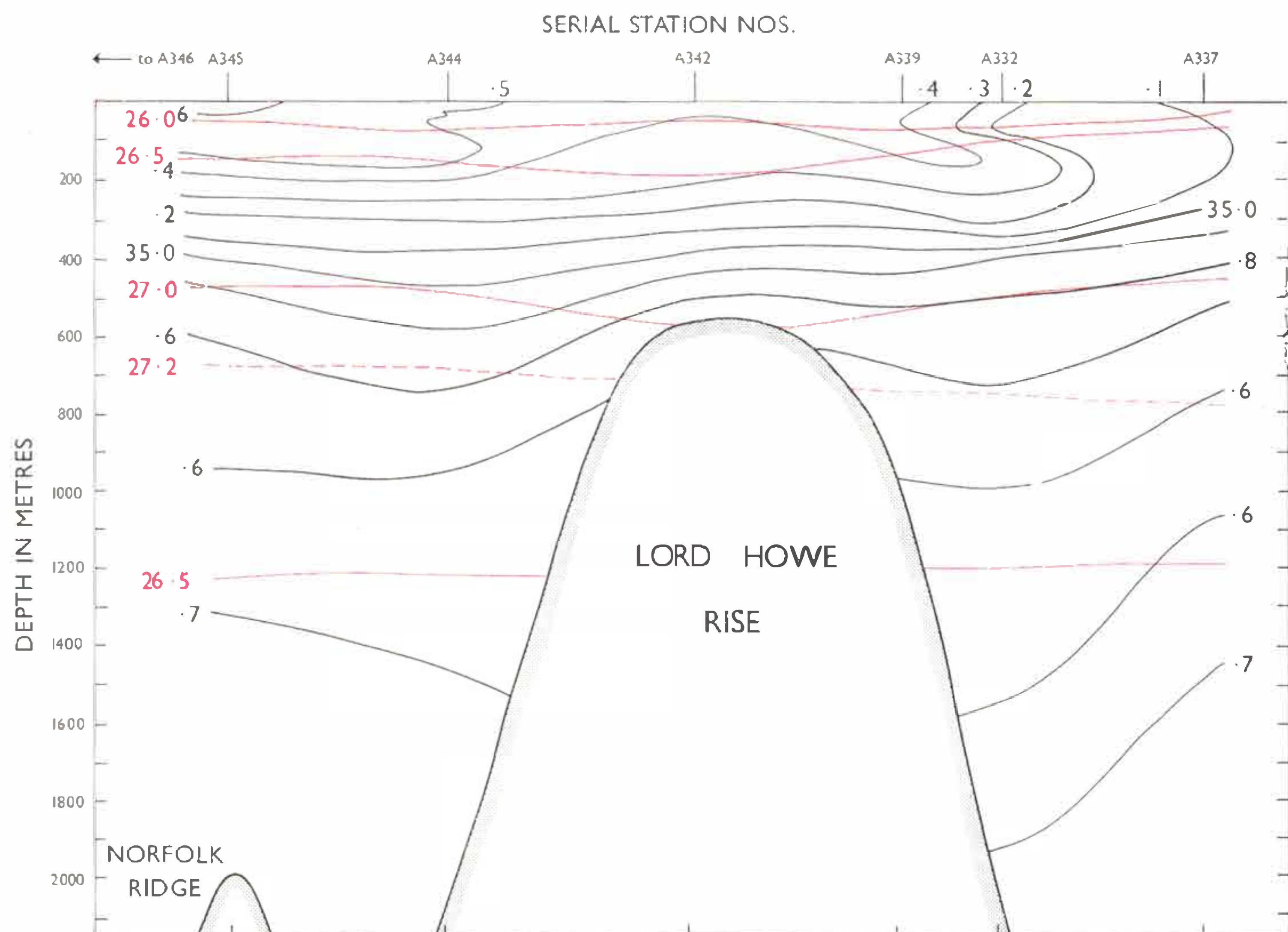


Fig. 54: Vertical cross section of salinity (‰) corresponding to the temperature section of fig. 51. Selected isopycnals (σ_t) are superimposed in red.

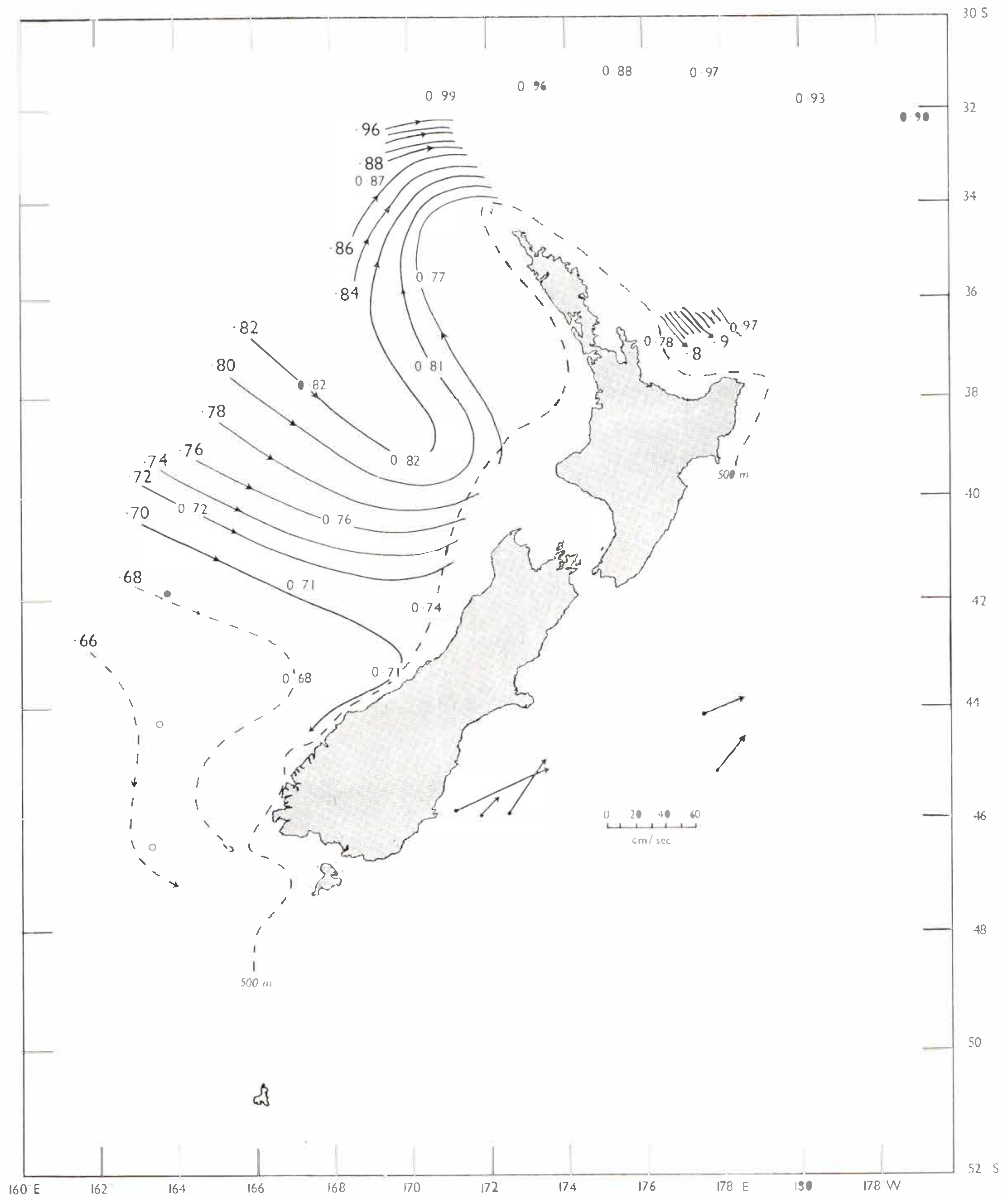


Fig. 55: An estimate of the geopotential topography (dynamic metres) of the sea surface, relative to the 500 decibar surface, to the west, north, and north-east of New Zealand, derived from the summer survey data. The dashed line sketches the 500 m isobath. Contours are also streamlines of the surface relative geostrophic circulation in the sense shown by the arrows. Also shown are surface current vectors east and north-east of the Otago Peninsula estimated from towed-electrode current fixes.

permits the best application of dynamical computations to be made in this study. Fig. 55 sketches the topography of the sea surface in this region relative to the 500 decibar isobaric surface (approximately 500 m deep). The station distribution is by no means adequate to define the contours of dynamic height uniquely, particularly to the north-east of New Zealand. The interpretation of fig. 55 is offered, however, since it provides interesting comparison with earlier work based on the temperature and salinity distribution used simply as a tracer of water movement.

The divergence of flow shown off the Westland coast recalls earlier definition (Garner, 1961, p. 62) of the Southland Current as a branch of the Tasman Current flowing through Foveaux Strait to account for the subtropical influence found in surface waters in this region. The accidental loss, before analysis, of water samples from stations A 329, 330, and 331 prevented better definition of this divergence, but salinities estimated from the regional temperature – salinity relationship yield

dynamic heights compatible with the situation shown in fig. 55.

The Westland Current is portrayed extending along the entire west coast of New Zealand from Greymouth to Cape Maria van Diemen. The station configuration would not have been adequate to describe any flow into northern Cook Strait in the D'Urville Current that may have been present. The Westland Current has been shown turning around the northern tip of New Zealand to form a relatively strong flow southwards along the east Northland and Auckland coasts. This interpretation has been influenced by the measurement of a marked slope of isopycnals on the continental slope, downwards away from the coast, measured in the summer of 1955 on a section extending north-eastwards from North Cape (Garner, 1961, fig. 5). A movement of surface water around North Cape from the west coast was also indicated by drift records (*ibid.* figs. 4 and 30).

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Members of the New Zealand Oceanographic Institute's staff who were in charge of the scientific operations of each cruise are named in table 1: they were assisted in the work at sea at various times by the following Institute personnel: Messrs N. M. Dann, D. G. McKnight, P. C. Spence, and R. P. Willis.

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Mr R. Webb, navigator of *Tui*, was responsible for providing plotting sheets containing basic navigational data for the cruises. At the New Zealand Oceanographic Institute, Mr A. G. York corrected sonic soundings and provided final track charts, and Mr R. P. Willis supervised the maintenance of machinery and instruments used in the field work. Lt. Cha-Erb Sdubbundhit, Royal Thai Navy, assisted with processing and plotting of data. Drawings were prepared for publication under the supervision of Mr C. T. T. Webb, Chief Cartographer, Information Service.

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TABLE 2—STATION CIRCUMSTANCES

Stn. No.	Date	N.Z. time (start)	N.Z. time (finish)	Depth (m)	Latitude (S)	Longitude
<i>Winter Series</i>						
A 292	5/6/56	1030	1526	493	30° 45'	173° 16' E
A 293	6/6/56	0844	1745	1,433	29° 03'	172° 27' E
A 294	7/6/56	0530	1020	2,270	29° 00'	170° 15' E
A 295	7-8/6/56	2045	0241	3,206	29° 04'	168° 36' E
A 298	9/6/56	0015	0520	1,801	30° 57'	167° 59' E
A 300	30/6/56	0830	1520	3,852	29° 20'	177° 47' E
A 301	1/7/56	0700	1030	1,023	28° 56'	179° 56' W
A 302	1-2/7/56	2055	0420	1,741	28° 52'	178° 05' W
A 303	3/7/56	0805	1500	5,304	31° 40'	177° 33' W
A 304	11/7/56	0650	1130	1,463	37° 28'	177° 17' E
A 305	11-12/7/56	2230	0530	3,142	37° 32'	179° 50' E
A 306	19/7/56	0330	0900	3,515	38° 50'	178° 59' W
A 307	20/7/56	1630	2000	640	42° 55'	177° 26' W
A 308	22/7/56	1200	1500	1,591	42° 35'	179° 58' W
A 309	28/7/56	0825	1220	545	44° 17'	174° 52' E
A 310	29/7/56	0830	1130	1,170	47° 26'	175° 07' E
A 311	31/7/56	0050	0220	139	47° 57'	168° 10' E
A 313	17/8/56	0245	0606	4,676	46° 46'	164° 35' E
A 314	18/8/56	0700	1240	4,883	42° 30'	162° 40' E
A 315	19/8/56	1700	2005	1,149	39° 46'	167° 45' E
<i>Summer Series</i>						
A 316	9/1/57	0240	0820	1,088	36° 26'	176° 17' E
A 317	9/1/57	0900	2200	2,423	36° 30'	178° 29' E
A 318	10/1/57	0845	1430	5,304	36° 36'	179° 18' W
A 329	30/1/57	1555	2056	4,533	46° 22'	163° 20' E
A 330	31/1/57	1055	1344	4,859	44° 09'	163° 38' E
A 331	1/2/57	0420	0810	3,840	41° 46'	163° 51' E
A 332	1/2/2/57	2300	0220	2,423	41° 41'	167° 03' E
A 333	2/2/57	1530	1848	739	42° 05'	170° 17' E
A 336	3/2/57	0645	0915	873	43° 21'	169° 00' E
A 337	3/2/57	1600	2000	3,184	43° 22'	167° 19' E
A 338	4/5/2/57	2345	0320	2,686	40° 06'	164° 18' E
A 339	5/2/57	2112	2330	1,094	40° 31'	168° 02' E
A 341	12/2/57	0900	1045	274	39° 41'	172° 06' E
A 342	12/13/2/57	2230	0055	576	39° 15'	169° 40' E
A 343	13/2/57	1400	1700	814	37° 46'	167° 28' E
A 344	14/2/57	0900	1415	1,902	37° 18'	170° 47' E
A 345	15/2/57	1500	1736	1,317	35° 29'	170° 22' E
A 346	28/2-1/3/57	2330	0240	2,279	33° 21'	169° 25' E
A 347	1/3/57	1500	1830	3,886	31° 33'	170° 43' E
A 348	2/3/57	0830	1100	1,554	31° 24'	173° 08' E
A 349	3/3/57	0000	0245	4,177	31° 08'	175° 25' E
A 350	3/3/57	1536	1824	4,014	31° 07'	177° 38' E
A 351	4/3/57	0900	1130	3,135	31° 41'	179° 48' W
A 352	5/3/57	0120	0345	7,699	32° 12'	177° 14' W



ERRATA

Station A 317. Temperature at 30 m should be 19.92.
Station A 348. Sigma-T at 10 m should be 24.79.

TABLE 3—STATION DATA

In the columns under each station number are listed, from left to right, depth (m), temperature (°C), salinity (parts per thousand), density, σ_t and geopotential anomaly (dynamic metres). The position data and water depth at each station is given in table 2.

Stn. No.	Depth (m)	Temp. (°C)	Salinity (‰)	σ_t g. l. ⁻¹	Geo-potential anomaly (dyn. m)	Stn. No.	Depth (m)	Temp. (°C)	Salinity (‰)	σ_t g. l. ⁻¹	Geo-potential anomaly (dyn. m)
A 292	0	21.19	35.63	24.94	0.000	A 295	0	21.02	35.47	24.87	0.000
	10	21.15	35.63	24.95	0.030		10	21.01	35.49	24.88	0.031
	20	21.13	35.63	24.96	0.059		20	21.00	35.50	24.89	0.062
	30	21.11	35.63	24.96	0.089		30	20.99	35.50	24.89	0.092
	50	21.10	35.63	24.96	0.147		50	20.97	35.50	24.89	0.154
	75	20.87	35.63	25.03	0.221		75	20.95	35.50	24.91	0.231
	100	20.42	35.62	25.14	0.282		100	20.00	35.49	25.15	0.305
	150	17.43	35.59	25.87	0.405		150	18.14	35.48	25.62	0.437
	200	16.69	35.36	25.88	0.507		200	17.38	35.49	25.82	0.554
	300	14.68	35.40	26.36	0.690		300	15.41	35.49	26.27	0.759
	400	12.72	35.20	26.62	0.848		400	12.66	35.24	26.67	0.925
							500	10.68	35.02	26.86	1.066
A 293	0	21.57	35.56	24.78	0.000	A 298	0	21.00			
	10	21.56	35.56	24.79	0.031		10	21.00			
	20	21.55	35.57	24.80	0.062		20	20.99			
	30	21.54	35.57	24.80	0.093		30	20.95			
	50	21.54	35.57	24.80	0.155		50	20.90			
	75	21.44	35.58	24.84	0.233		75	20.87			
	100	20.70	35.58	25.04	0.307		100	20.35			
	150	18.09	35.59	25.72	0.436		120	19.21			
	200	17.01	35.60	25.98	0.543		150	18.49			
	300	15.61	35.59	26.29	0.732		200	17.48			
	400	12.94	35.27	26.64	0.892		300	15.70			
	500	10.69	34.95	26.82	1.029		400	13.26			
A 294	0	21.28	35.59	24.89	0.000		500	11.27			
	10	21.25	35.59	24.89	0.031		600	9.74			
	20	21.23	35.59	24.90	0.062		800	7.38			
	30	21.20	35.59	24.91	0.092		1,000	5.63			
	50	21.19	35.59	24.91	0.154		1,200	4.49			
	75	19.21	35.59	25.44	0.225		1,500	3.30			
	100	18.32	35.58	25.65	0.287	A 300	0	19.68	35.50	25.25	0.000
	150	16.93	35.56	25.98	0.399		10	19.68	35.50	25.25	0.027
	200	15.70	35.57	26.26	0.496		20	19.67	35.51	25.26	0.055
	300	13.55	35.31	26.54	0.667		30	19.61	35.52	25.28	0.082
	400	11.71	35.04	26.70	0.819		50	19.57	35.53	25.30	0.136
	500	10.16	34.83	26.81	0.960		75	19.46	35.54	25.33	0.203
	600	8.62	34.64	26.92	1.091		100	19.24	35.54	25.39	0.269
	800	6.57	34.51	27.11	1.325		150	17.56	35.54	25.81	0.391
	1,000	5.06	34.47	27.27	1.525		200	16.50	35.50	26.03	0.499
	1,200	4.11	34.51	27.41	1.696		300	15.08	35.45	26.30	0.691
	1,500	3.08	34.57	27.56	1.810		400	12.78	35.16	26.59	0.860
	2,000	2.26	34.63	27.68	2.200		500	10.58	34.92	26.81	1.006
A 295	0	21.02	35.47	24.87	0.000		600	9.21	34.78	26.93	1.137
	10	21.01	35.49	24.88	0.031		800	7.40	34.60	27.04	1.375
	20	21.00	35.50	24.89	0.062		1,000	5.86	34.53	27.22	1.587
	30	20.99	35.50	24.89	0.092		1,200	4.62	34.45	27.31	1.776
	50	20.97	35.50	24.89	0.154		1,500	3.18	34.56	27.54	2.010
	75	20.95	35.50	24.91	0.231		2,000	2.13	34.57	27.64	2.313
	100	20.00	35.49	25.15	0.305		2,500	1.93	34.59	27.67	2.585
	150	18.14	35.48	25.62	0.437		3,000	1.83	34.68	27.75	2.838
	200	17.38	35.49	25.82	0.554						
	300	15.41	35.49	26.27	0.759						
	400	12.66	35.24	26.67	0.925						
	500	10.68	35.02	26.86	1.066						



Stn. No.	Depth (m)	Temp. (°C)	Salinity (‰)	σ_t g.l. ⁻¹	Geo-potential anomaly (dyn. m)
A 301	0	21.02			
	10	21.01			
	20	21.00			
	30	20.99			
	50	20.96			
	75	20.94			
	100	20.05			
	120	19.49			
	150	18.68			
	200	17.50			
	250	16.57			
	300	15.91			
	400	13.05			
	500	10.72			
	600	9.23			
	800	7.19			
	1,000	5.50			

Stn. No.	Depth (m)	Temp. °C)	Salinity (‰)	σ_t g.l. ⁻¹	Geo-potential anomaly (dyn. m)
A 304	0	17.00	35.58	25.98	0.000
	10	17.00	35.57	25.97	0.020
	20	17.00	35.56	25.96	0.041
	30	17.00	35.55	25.95	0.062
	50	17.00	35.56	25.96	0.103
	75	17.00	35.58	25.98	0.155
	100	16.99	35.59	25.99	0.206
	120	16.98	35.53	25.95	0.248
	150	16.03	35.58	26.20	0.308
	200	14.72	35.54	26.46	0.396
	300	12.46	35.32	26.76	0.546
	400	10.99	35.12	26.89	0.678
	500	9.78	34.91	26.94	0.802
	600	8.80	34.78	26.99	0.922
	800	7.05	34.63	27.15	1.146
	900	6.31	34.61	27.22	1.248

A 302	0	20.04	35.45	25.11	0.000
	10	19.92	35.65	25.30	0.032
	20	19.80	35.47	25.19	0.065
	30	19.44	35.53	25.33	0.087
	50	19.40	35.54	25.35	0.134
	75	19.28	35.55	25.39	0.201
	100	18.91	35.57	25.50	0.266
	150	17.02	35.54	25.94	0.378
	200	16.07	35.47	26.11	0.473
	300	13.74	35.24	26.44	0.659
	400	12.05	35.05	26.64	0.805
	500	10.49	34.88	26.78	0.942
	600	8.97	34.72	26.92	1.067
	800	6.69	34.54	27.12	1.284
	1,000	5.26	34.46	27.24	1.473
	1,200	4.21	34.51	27.40	1.641
	1,500	3.13	34.62	27.59	1.840

A 305	0	16.83	35.61	26.04	0.000
	10	16.83	35.58	26.00	0.020
	20	16.83	35.60	25.99	0.040
	30	16.83	35.54	25.99	0.060
	50	16.82	35.54	25.99	0.101
	75	16.70	35.50	25.99	0.152
	100	16.34	35.47	26.03	0.203
	120	16.25	35.45	26.05	0.248
	150	16.12	35.41	26.05	0.303
	200	15.52	35.37	26.15	0.402
	300	14.00	35.28	26.42	0.583
	400	12.64	35.13	26.60	0.747
	500	11.09	34.94	26.73	0.897
	600	9.76	34.80	26.86	1.036
	800	7.88	34.62	27.00	1.288
	1,000	6.29	34.50	27.14	1.514
	1,200	4.95	34.49	27.30	1.712
	1,500	4.00	34.56	27.46	1.965
	2,000	2.68	34.67	27.72	2.293
	2,500	1.91	34.74	27.76	2.540
	3,000	1.48	34.80	27.87	2.735

A 303	0	18.50	35.54	25.58	0.000
	10	18.48	35.55	25.59	0.024
	20	18.46	35.56	25.60	0.048
	30	18.44	35.56	25.61	0.072
	50	18.37	35.57	25.63	0.120
	75	18.26	35.58	25.67	0.185
	100	18.07	35.58	25.72	0.243
	150	16.49	35.53	26.07	0.351
	200	16.43	35.55	26.09	0.452
	300	13.65	35.27	26.48	0.629
	400	11.71	35.04	26.70	0.784
	500	10.11	34.81	26.80	0.931
	600	8.84	34.68	26.92	1.062
	800	7.05	34.55	27.10	1.300
	1,000	5.81	34.51	27.21	1.510
	1,200	4.89	34.53	27.34	1.696
	1,500	3.86	34.61	27.52	1.933
	2,000	2.70	34.69	27.69	2.251
	2,500	2.01	34.75	27.79	2.491
	3,000	1.57	34.79	27.86	2.688

A 306	0	16.19	35.50	26.11	0.000
	10	16.19	35.50	26.11	0.019
	20	16.19	35.50	26.11	0.038
	30	16.19	35.50	26.11	0.058
	50	16.19	35.50	26.11	0.078
	75	16.12	35.50	26.12	0.126
	100	16.03	35.50	26.14	0.174
	120	15.52	35.49	26.24	0.212
	150	15.41	35.49	26.25	0.266
	200	14.85	35.43	26.34	0.356
	300	13.48	35.28	26.53	0.523
	400	12.03	35.11	26.70	0.676
	500	10.52	34.93	26.83	0.815
	600	9.18	34.77	26.93	0.945
	800	7.32	34.58	27.07	1.183
	1,000	6.13	34.52	27.18	1.399
	1,200	5.01	34.53	27.32	1.592
	1,500	3.70	34.59	27.53	1.830
	2,000	2.60	34.68	27.69	2.136
	2,500	2.12	34.74	27.78	2.381



Stn. No.	Depth (m)	Temp. (°C)	Salinity (‰)	σ_t g.l.−1	Geo-potential anomaly (dyn. m)
A 307	0	11.75	35.06	26.70	0.000
	10	11.75	35.06	26.70	0.014
	20	11.75	35.06	26.70	0.027
	30	11.75	35.06	26.70	0.041
	50	11.75	35.05	26.70	0.068
	75	11.74	35.06	26.70	0.095
	100	11.74	35.07	26.72	0.122
	120	11.73	35.07	26.72	0.149
	150	11.73	35.06	26.71	0.191
	200	11.60	35.06	26.73	0.259
	300	10.61	35.04	26.89	0.390
	400	9.37	34.98	27.06	0.509
	500	8.56	34.90	27.13	0.613
	600	7.96	34.80	27.14	0.723
A 308	0	12.99	35.10	26.50	0.000
	10	12.99	35.10	26.50	0.015
	20	12.99	35.10	26.50	0.031
	30	12.99	35.10	26.50	0.046
	50	12.89	35.09	26.51	0.077
	75	12.70	35.08	26.54	0.116
	100	12.38	35.06	26.58	0.153
	120	12.25	35.03	26.59	0.183
	150	12.02	34.98	26.60	0.228
	200	11.48	34.94	26.66	0.301
	300	10.08	34.84	26.83	0.437
	400	9.24	34.78	26.92	0.563
	500	8.56	34.70	26.97	0.688
	600	7.82	34.63	27.03	0.804
	800	6.60	34.56	27.15	1.025
	1,000	5.48	34.52	27.26	1.225
A 309	0	11.06	34.87	26.69	0.000
	10	11.05	34.84	26.66	0.014
	20	11.02	34.86	26.69	0.028
	30	11.01	34.87	26.70	0.041
	50	10.72	34.84	26.72	0.068
	75	10.34	34.79	26.75	0.102
	100	10.21	34.78	26.76	0.135
	120	10.18	34.77	26.76	0.161
	150	10.12	34.77	26.77	0.201
	200	9.79	34.74	26.80	0.266
	300	8.31	34.55	26.92	0.390
	400	7.15	34.47	27.01	0.506
	500	6.49	34.45	27.08	0.615
	600	5.89	34.46	27.16	0.718
A 310	0	7.47	34.30	26.82	0.000
	10	7.46	34.30	26.82	0.012
	20	7.44	34.30	26.83	0.025
	30	7.43	34.30	26.84	0.037
	50	7.40	34.30	26.84	0.062
	75	7.34	34.30	26.85	0.092
	100	7.28	34.31	26.86	0.123
	120	7.23	34.32	26.88	0.147
	150	7.31	34.38	26.92	0.182
	200	7.64	34.52	26.97	0.240
	300	6.91	34.43	27.01	0.351
	400	6.46	34.37	27.02	0.462
	500	5.72	34.31	27.06	0.570
	600	4.96	34.33	27.17	0.673

Stn. No.	Depth (m)	Temp. (°C)	Salinity (‰)	σ_t g.l.−1	Geo-potential anomaly (dyn. m)
A 311	0	10.37	34.87	26.81	
	10	10.31	34.87	26.82	
	20	10.25	34.87	26.82	
	30	10.19	34.87	26.84	
	50	10.07	34.87	26.86	
	70	9.95	34.87	26.88	
	80	9.89	34.87	26.89	
	90	9.83	34.87	26.90	
A 313	0	11.02	34.95	26.75	0.000
	10	11.00	34.95	26.76	0.013
	20	10.98	34.94	26.75	0.026
	30	10.97	34.94	26.75	0.039
	50	10.97	33.92	26.74	0.066
	75	10.97	34.91	26.73	0.100
	100	10.92	34.90	26.73	0.132
	120	10.83	34.90	26.75	0.159
	150	10.68	34.90	26.77	0.200
	200	10.56	34.90	26.79	0.212
	300	10.01	34.85	26.85	0.344
	400	8.63	34.77	27.02	0.477
	500	7.98	34.68	27.04	0.589
	600	7.33	34.58	27.06	0.701
	800	7.18	34.56	27.07	0.923
	1,000	5.02	34.51	27.31	1.122
	1,200	3.94	34.56	27.47	1.280
A 314	0	12.92	35.09	26.50	0.000
	10	12.92	35.09	26.50	0.015
	20	12.78	35.09	26.53	0.031
	30	12.75	35.09	26.54	0.046
	50	12.65	35.08	26.55	0.076
	75	12.54	35.05	26.55	0.114
	100	12.47	35.00	26.52	0.152
	120	12.40	34.96	26.50	0.183
	150	12.28	34.90	26.48	0.230
	200	10.81	34.79	26.67	0.305
	300	9.62	34.65	26.76	0.444
	400	8.65	34.52	26.82	0.577
	500	8.09	34.46	26.86	0.707
	600	7.51	34.42	26.91	0.834
	800	6.42	34.34	27.00	1.077
	1,000	5.42	34.31	27.10	1.304
	1,200	4.51	34.36	27.24	1.509
	1,500	3.43	34.43	27.42	1.770
	2,000	2.30	34.52	27.57	2.123
	2,500	1.79	34.58	27.68	2.410
	3,000	1.53	34.63	27.73	2.657
A 315	0	14.31	35.24	26.32	0.000
	10	14.29	35.24	26.32	0.017
	20	14.27	35.24	26.33	0.034
	30	14.25	35.24	26.33	0.051
	50	14.22	35.24	26.34	0.086
	75	14.20	35.23	26.34	0.128
	100	14.20	35.23	26.34	0.171
	120	14.20	35.23	26.34	0.206
	150	14.20	35.23	26.34	0.257
	200	14.15	35.23	26.34	0.344
	250	14.05	35.22	26.36	0.432
	300	13.21	35.19	26.52	0.516
	400	11.18	34.97	26.74	0.665
	500	9.69	34.71	26.80	0.802
	600	8.58	34.56	26.86	0.936
	800	6.89	34.42	27.01	1.185



Stn. No.	Depth (m)	Temp. (°C)	Salinity (‰)	σ_t g.l. ⁻¹	Geo-potential anomaly (dyn. m)	Stn. No.	Depth (m)	Temp. (°C)	Salinity (‰)	σ_t g.l. ⁻¹	Geo-potential anomaly (dyn. m)
316	0	19.58	35.50	25.27	0.000	A 330	0	15.32			
	10	19.44	35.49	25.30	0.027		10	15.32			
	20	19.05	35.45	25.37	0.054		20	15.29			
	30	18.15	35.40	25.56	0.079		30	15.25			
	50	16.06	35.37	26.04	0.123		50	15.17			
	75	15.22	35.37	26.23	0.171		75	14.50			
	100	14.70	35.36	26.33	0.215		100	12.07			
	150	13.94	35.33	26.47	0.299		150	11.20			
	200	13.10	35.27	26.60	0.377		200	10.75			
	300	11.42	35.05	26.76	0.520		300	9.72			
	400	10.08	34.88	26.86	0.653		400	8.91			
	500	8.90	34.74	26.95	0.777		500	8.30			
	600	8.00	34.65	27.02	0.896		600	7.96			
	800	6.48	34.54	27.15	1.115		800	7.54			
						A 331	0	16.60			
							10	16.59			
A 317	0	20.24	35.61	25.18	0.000		20	16.55			
	10	20.22	35.61	25.19	0.028		30	16.34			
	20	20.02	35.61	25.24	0.056		50	15.27			
	30	19.02	35.61	25.27	0.083		75	14.37			
	50	19.80	35.61	25.30	0.137		100	13.75			
	75	18.25	35.60	25.69	0.200		150	12.83			
	100	17.00	35.57	25.97	0.256		200	12.08			
	150	16.60	35.54	26.04	0.358		300	10.85			
	200	16.08	35.48	26.12	0.458		400	9.50			
	300	14.65	35.33	26.32	0.646		500	8.62			
	400	13.00	35.16	26.54	0.817		600	7.99			
	500	11.45	34.99	26.70	0.971		800	6.80			
	600	10.12	34.85	26.83	1.112		1,000	5.36			
	800	7.85	34.60	27.00	1.367		1,200	4.20			
	1,000	6.10	34.42	27.10	1.598		1,500	3.08			
	1,200	4.75	34.44	27.28	1.800						
	1,500	3.30	34.58	27.54	2.039						
						A 332	0	17.43	35.26	25.63	0.000
							10	17.43	35.26	25.63	0.024
							20	17.17	35.26	25.69	0.048
							30	16.90	35.25	25.75	0.071
							50	16.30	35.20	25.85	0.115
							75	14.25	35.15	26.27	0.164
A 318	600	9.00	34.69	26.90	..		100	13.45	35.33	26.58	0.205
	800	7.25	34.60	27.09	..		150	12.60	35.39	26.79	0.275
	1,000	5.82	34.53	27.23	..		200	12.07	35.35	26.87	0.339
	1,200	4.63	34.49	27.34	..		300	11.15	35.22	26.94	0.461
	1,500	3.50	34.51	27.47	..		400	10.40	34.89	26.82	0.586
	2,000	2.56	34.60	27.63	..		500	9.68	34.80	26.87	0.716
							600	8.94	34.75	26.95	0.846
							800	7.30	34.67	27.14	1.084
							1,000	5.70	34.60	27.30	1.282
							1,200	4.36	34.56	27.42	1.451
							1,500	3.03	34.59	27.58	1.662
							2,000	2.30	34.71	27.74	1.935
A 329	0	13.38				A 333	0	18.67	35.34	25.38	0.000
	10	13.38					10	18.35	35.34	25.46	0.026
	20	13.38					20	17.91	35.34	25.57	0.051
	30	13.37					30	17.63	35.11	25.47	0.075
	50	13.37					50	16.36	35.16	25.81	0.123
	75	13.15					75	14.45	35.43	26.44	0.171
	100	12.35					100	13.83	35.44	26.58	0.210
	150	10.59					150	13.33	35.40	26.65	0.283
	200	10.15					200	12.95	35.37	26.71	0.354
	300	9.45					300	12.00	35.24	26.79	0.491
	400	8.70					400	10.60	35.06	26.91	0.620
	500	7.91					500	9.30	34.91	27.02	0.739
	600	7.22					600	8.55	34.78	27.04	0.854
	800	6.00									
	1,000	4.89									
	1,200	3.75									

Stn. No.	Depth (m)	Temp. (°C)	Salinity (‰)	σ_t g.l. ⁻¹	Geo-potential anomaly (dyn. m)	Stn. No.	Depth (m)	Temp. (°C)	Salinity (‰)	σ_t g.l. ⁻¹	Geo-potential anomaly (dyn. m)
A 336	0	17.75	35.25	25.54	0.000	A 341	0	20.07	34.87	24.66	0.000
	10	17.75	35.25	25.54	0.025		10	19.35	34.83	24.82	0.032
	20	17.55	35.25	25.59	0.049		20	19.05	34.79	24.87	0.063
	30	17.33	35.25	25.64	0.073		30	18.10	34.89	25.18	0.093
	50	16.75	35.28	25.81	0.119		50	17.00	35.04	25.56	0.145
	75	14.15	35.34	26.44	0.167		75	15.39	35.28	26.12	0.200
	100	13.10	35.32	26.64	0.205		100	14.50	35.33	26.35	0.245
	150	12.40	35.27	26.74	0.295		150	13.87	35.31	26.47	0.328
	200	11.95	35.23	26.80	0.341		200	13.60	35.29	26.51	0.408
	300	10.78	35.09	26.90	0.468		250	12.80	35.19	26.60	
	400	9.32	34.84	26.96	0.589	A 342	0	19.69	35.41	25.18	0.000
	500	8.49	34.74	27.02	0.705		10	19.62	35.41	25.19	0.028
	600	7.95	34.70	27.07	0.818		20	19.38	35.41	25.26	0.056
	800	6.72	34.65	27.20	1.027		30	18.85	35.41	25.39	0.082
A 337	0	16.28	35.01	25.71	0.000		50	16.65	35.37	25.90	0.130
	10	16.26	35.02	25.72	0.023		75	15.18	35.37	26.24	0.179
	20	16.00	35.03	25.79	0.045		100	14.65	35.37	26.35	0.223
	30	15.60	35.05	25.89	0.067		150	14.10	35.34	26.45	0.307
	50	14.10	35.13	26.28	0.106		200	13.70	35.30	26.50	0.387
	75	13.05	35.18	26.54	0.147		300	12.60	35.16	26.62	0.543
	100	12.55	35.18	26.65	0.184		400	11.15	34.98	26.75	0.688
	150	11.85	35.16	26.76	0.253		500	9.82	34.82	26.86	0.823
	200	11.15	35.10	26.84	0.318	A 343	0	19.90	35.57	25.24	0.000
	300	10.06	34.95	26.92	0.441		10	19.87	35.57	25.25	0.027
	400	9.23	34.83	26.97	0.561		20	19.80	35.57	25.27	0.055
	500	8.40	34.73	27.02	0.676		30	19.60	35.37	25.32	0.082
	600	7.68	34.66	27.07	0.788		50	18.35	35.55	25.62	0.132
	800	6.35	34.59	27.21	0.997		75	16.15	35.50	26.11	0.186
	1,000	5.15	34.58	27.35	1.181		100	15.43	35.52	26.29	0.232
	1,200	4.10	34.63	27.50	1.337		150	14.50	35.48	26.47	0.317
A 338	0	17.89	35.21	25.48	0.000		200	13.73	35.35	26.53	0.397
	10	17.89	35.21	25.48	0.025		300	12.20	35.11	26.66	0.549
	20	17.70	35.21	25.52	0.050		400	10.85	34.94	26.78	0.691
	30	17.05	35.19	25.67	0.074		500	9.75	34.81	26.87	0.824
	50	15.40	35.29	26.12	0.117		600	8.75	34.74	26.97	0.950
	75	14.40	35.44	26.46	0.161	A 344*	0	21.15	35.35	24.74	0.0000
	100	13.85	35.46	26.59	0.200		10	21.14	35.36	24.75	0.0321
	150	13.10	35.40	26.70	0.271		20	21.11	35.36	24.75	0.0642
	200	12.35	35.30	26.77	0.340		30	21.00	35.35	24.78	0.0962
	300	10.98	35.06	26.85	0.471		50	19.86	35.34	25.08	0.1572
	400	9.85	34.87	26.90	0.597		75	16.94	35.35	25.82	0.2213
	500	8.90	34.74	26.95	0.720		100	16.10	35.36	26.02	0.2743
	600	8.08	34.66	27.02	0.839		150	14.90	35.36	26.28	0.3697
	800	6.60	34.54	27.13	1.060		200	14.09	35.33	26.44	0.4557
	1,000	5.30	34.52	27.28	1.258		300	12.61	35.16	26.63	0.6141
A 339	0	18.55	35.41	25.47	0.000		400	11.10	35.01	26.78	0.7580
	10	18.55	35.41	25.47	0.025		500	9.76	34.89	26.93	0.8884
	20	18.54	35.41	25.47	0.051		600	8.70	34.80	27.12	1.0082
	30	18.43	35.41	25.50	0.076		800	6.88	34.66	27.20	1.2244
	50	17.25	35.39	25.77	0.123		1,000	5.47	34.56	27.30	1.4166
	75	16.15	35.43	26.06	0.176		1,200	4.39	34.54	27.41	1.5884
	100	15.03	35.42	26.31	0.223		1,500	3.36	34.61	27.56	1.8065
	150	13.48	35.39	26.62	0.304		1,800	2.71	34.69	27.69	1.9835
	200	12.75	35.32	26.71	0.375	in the derivation of salinities from water analyses that led to the publication of incorrect values in <i>Nature</i> vol. 181, pp. 466-468, 1958. These incorrect values were also used by Rochford in the <i>Australian Journal of Marine and Freshwater Research</i> Vol. 11, pp. 166-181, 1960					
	300	11.35	35.14	26.84	0.510						
	400	10.12	34.96	26.92	0.636						
	500	9.20	34.83	26.97	0.757						
	600	8.30	34.74	27.05	0.873						

Stn. No.	Depth (m)	Temp. (°C)	Salinity (‰)	σ_t g.l. ⁻¹	Geo-potential anomaly (dyn. m)
A 345	0	21.01	35.44	24.84	0.000
	10	20.98	35.44	24.85	0.031
	20	20.25	35.44	25.05	0.061
	30	18.60	35.45	25.48	0.089
	50	16.40	35.46	26.03	0.134
	75	15.55	35.48	26.24	0.182
	100	15.02	35.50	26.37	0.225
	150	14.12	35.44	26.52	0.307
	200	13.30	35.39	26.65	0.382
	300	11.70	35.19	26.81	0.521
	400	10.32	35.01	26.92	0.648
	500	9.10	34.89	27.04	0.766
	600	8.12	34.81	27.13	0.878
	800	6.35	34.73	27.32	1.069
A 346	0	19.87	35.39	25.11	0.000
	10	19.86	35.38	25.11	0.029
	20	19.85	35.37	25.10	0.058
	30	19.84	35.37	25.11	0.086
	50	19.80	35.37	25.12	0.144
	75	17.80	35.37	25.62	0.210
	100	16.28	35.36	25.98	0.266
	150	14.40	35.28	26.34	0.361
	200	13.35	35.19	26.49	0.445
	300	11.65	35.02	26.69	0.597
	400	10.45	34.89	26.81	0.735
	500	9.55	34.78	26.88	0.866
	600	8.48	34.68	26.97	0.991
	800	6.50	34.53	27.14	1.217
A 347	1,000	5.15	34.51	27.29	1.413
	1,200	4.15	34.53	27.42	1.582
	1,500	3.15	34.62	27.59	1.792
A 347	0	22.58	35.64	24.56	0.000
	10	22.59	35.64	24.56	0.034
	20	22.60	35.64	24.55	0.074
	30	22.53	35.63	24.57	0.108
	50	22.15	35.62	24.67	0.175
	75	20.30	35.57	25.13	0.252
	100	18.25	35.53	25.63	0.318
	150	17.05	35.50	25.90	0.432
	200	15.95	35.44	26.12	0.535
	300	13.82	35.35	26.53	0.714
	400	11.92	35.24	26.81	0.862
	500	10.25	35.03	26.95	0.991
	600	8.70	34.83	27.05	1.109
	800	6.87	34.72	27.24	1.318
A 348	1,000	5.72	34.71	27.38	1.499
	1,200	4.65	34.71	27.51	1.654
	1,500	3.40	34.72	27.65	1.845
A 348	0	22.25	35.81	24.78	0.000
	10	22.26	35.82	24.29	0.032
	20	22.25	35.86	24.82	0.063
	30	22.25	35.93	24.87	0.095
	50	22.03	35.93	24.93	0.156
	75	20.30	35.85	25.35	0.228
	100	18.33	35.90	25.90	0.288
	150	17.32	35.78	26.05	0.392
	200	16.40	35.69	26.20	0.489
	300	14.30	35.46	26.50	0.664
	400	12.30	35.21	26.71	0.818
	500	10.68	35.01	26.86	0.955
	600	9.30	34.87	26.99	1.081
	800	7.12	34.72	27.20	1.301
	1,000	5.70	34.67	27.35	1.488

Stn. No.	Depth (m)	Temp. (°C)	Salinity (‰)	σ_t g.l. ⁻¹	Geo-potential anomaly (dyn. m)
A 349	0	22.36	35.79	24.74	0.000
	10	22.36	35.80	24.74	0.032
	20	22.34	35.82	24.76	0.064
	30	22.30	35.82	24.78	0.096
	50	21.65	35.80	24.94	0.159
	75	17.75	35.65	25.85	0.224
	100	16.90	35.63	26.04	0.277
	150	15.90	35.59	26.24	0.373
	200	15.00	35.53	26.40	0.461
	300	13.00	35.35	26.68	0.618
	400	11.15	35.14	26.88	0.755
	500	9.62	34.95	27.00	0.877
	600	8.35	34.75	27.05	0.993
	800	6.45	34.50	27.12	1.213
A 350	1,000	5.20	34.52	27.29	1.410
	1,200	4.20	34.57	27.44	1.577
	1,500	3.12	34.64	27.61	1.781
A 350	0	21.93	35.66	24.76	0.000
	10	21.91	35.66	24.76	0.032
	20	21.84	35.67	24.79	0.064
	30	21.81	35.68	24.81	0.096
	50	21.75	35.62	24.78	0.159
	75	20.60	35.59	25.07	0.236
	100	17.95	35.57	25.74	0.300
	150	16.35	35.50	26.07	0.406
	200	15.30	35.42	26.23	0.502
	300	13.35	35.22	26.51	0.676
	400	11.60	35.03	26.70	0.829
	500	10.10	34.82	26.82	0.973
	600	8.82	34.64	26.88	1.106
	800	6.75	34.46	27.05	1.339
A 351	1,000	5.25	34.44	27.22	1.548
	1,200	4.20	34.48	27.37	1.726
	1,500	3.00	34.58	27.50	1.951
	2,000	2.28	34.68	27.72	2.248
A 351	0	21.07	35.53	24.90	0.000
	10	21.07	35.56	24.92	0.031
	20	21.07	35.61	24.96	0.061
	30	21.00	35.61	24.98	0.091
	50	20.05	35.58	25.21	0.149
	75	17.75	35.50	25.73	0.212
	100	16.93	35.52	25.95	0.267
	150	15.90	35.44	26.13	0.368
	200	14.97	35.37	26.28	0.462
	300	13.05	35.15	26.52	0.633
	400	11.30	34.94	26.69	0.786
	500	9.75	34.74	26.81	0.926
	600	8.45	34.58	26.90	1.058
	800	6.64	34.42	27.03	1.300
A 352	1,000	5.30	34.38	27.17	1.518
	1,200	4.25	34.40	27.31	1.709
	1,500	3.12	34.50	27.50	1.948
A 352	0	21.77	35.50	24.68	0.000
	10	21.80	35.50	24.67	0.033
	20	21.85	35.50	24.66	0.066
	30	21.85	35.49	24.65	0.099
	50	21.65	35.49	24.71	0.162
	75	18.30	35.47	25.58	0.231
	100	16.40	35.45	26.04	0.286
	150	14.70	35.39	26.35	0.380
	200	14.00	35.30	26.44	0.464
	300	12.30	35.11	26.65	0.621
	400	10.75	34.91	26.77	0.763
	500	9.40	34.74	26.87	0.897
	600	8.25	34.58	26.93	1.023
	800	6.58	34.47	27.09	1.257
A 353	1,000	5.32	34.39	27.18	1.468
	1,200	4.22	34.38	27.29	1.660
	1,500	3.00	34.44	27.46	1.905
	2,000	2.38	34.62	27.66	2.225



TABLE 4—MEAN DENSITY OF NEW ZEALAND WATERS ESTABLISHED FROM STATIONS A 300 AND A 314

Depth (m)	Mean density of water column above indicated depth (g/ml)	Depth (m)	Mean density of water column above indicated depth (g/ml)
0	1·0258	1500	1·0343
100	1·0264	1600	1·0348
200	1·0271	1700	1·0353
300	1·0277	1800	1·0358
400	1·0284	1900	1·0363
500	1·0290	2000	1·0368
600	1·0296	2100	1·0373
700	1·0301	2200	1·0378
800	1·0307	2300	1·0382
900	1·0312	2400	1·0387
1000	1·0318	2500	1·0391
1100	1·0323	2600	1·0396
1200	1·0328	2700	1·0400
1300	1·0333	2800	1·0404
1400	1·0338	2900	1·0408

TABLE 5—TOWED-ELECTRODE SURFACE CURRENT DETERMINATIONS

No.	Date	N.Z. time	Lat. (S)	Long. (E)	Dir. (°T)	Speed (cm/sec)
1	16/1/57	1840	44° 08'	177° 35'	065	30
2	17/1/57	0030	45° 03'	177° 55'	038	30
3	18/1/57	2130	45° 57'	172° 33'	040	45
4	19/1/57	0030	45° 55'	171° 57'	045	15
5	19/1/57	0430	45° 52'	171° 09'	061	70



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NEW ZEALAND REGION SUMMER SEA SURFACE TEMPERATURES 1957

TO ACCOMPANY N.Z. OCEANOGRAPHIC
INSTITUTE MEMOIR No. 12 CHART No. 2

MISCELLANEOUS SERIES J



Drawn by: B. M. Crane

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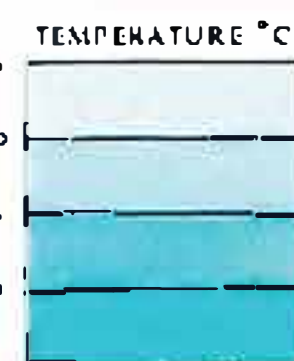
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Subtropical Convergence Zone	▨



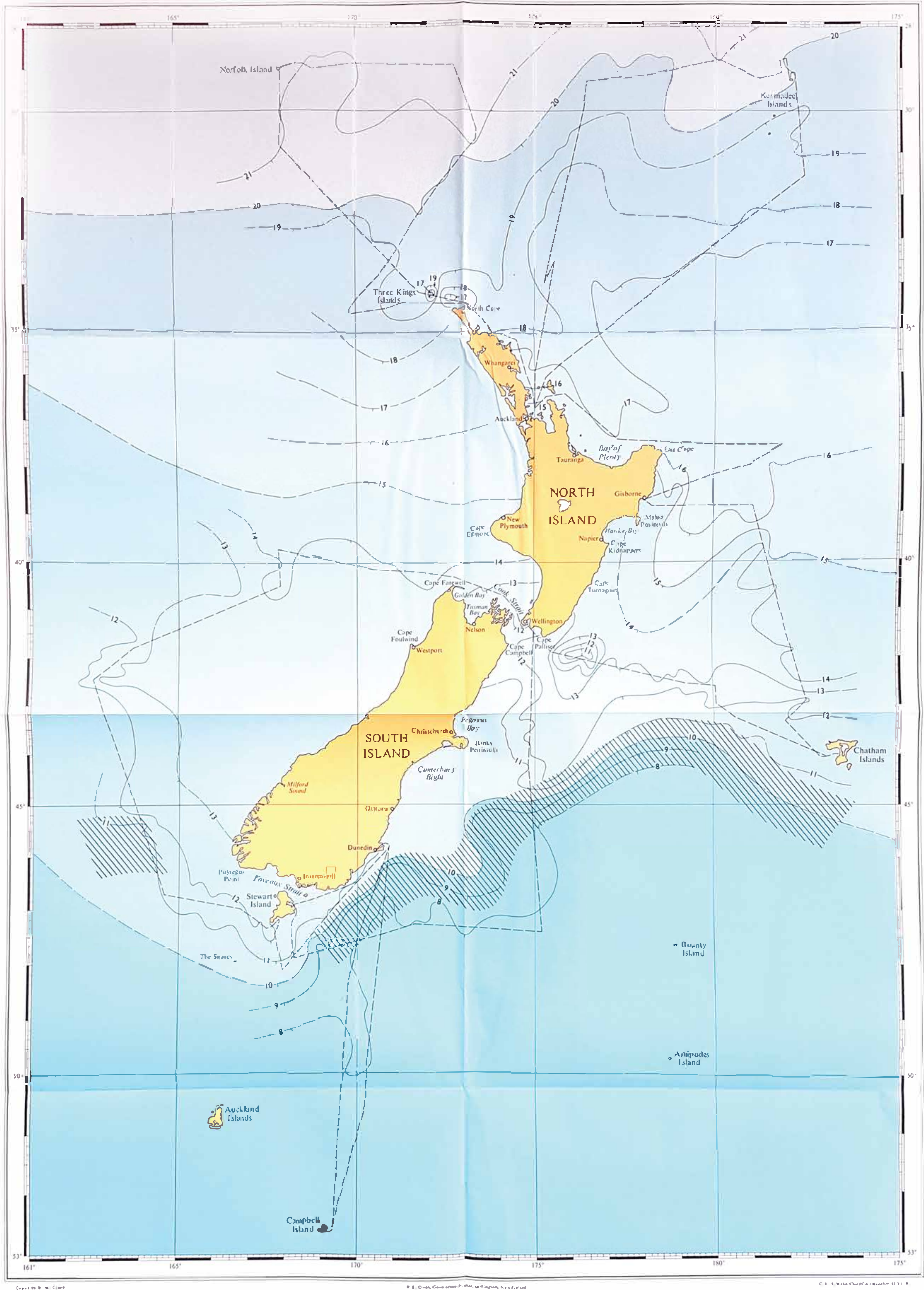
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Compiled from continuous recording thermograph data obtained in January, February and March, 1957, each 2.5 km. isotherms drawn on R.N.Z. A. 101, 102, 103, 104, 105, 106, 107, 108, 109, 110, 111, 112, 113, 114, 115, 116, 117, 118, 119, 120, 121, 122, 123, 124, 125, 126, 127, 128, 129, 130, 131, 132, 133, 134, 135, 136, 137, 138, 139, 140, 141, 142, 143, 144, 145, 146, 147, 148, 149, 150, 151, 152, 153, 154, 155, 156, 157, 158, 159, 160, 161, 162, 163, 164, 165, 166, 167, 168, 169, 170, 171, 172, 173, 174, 175, 176, 177, 178, 179, 180, 181, 182, 183, 184, 185, 186, 187, 188, 189, 190, 191, 192, 193, 194, 195, 196, 197, 198, 199, 200, 201, 202, 203, 204, 205, 206, 207, 208, 209, 210, 211, 212, 213, 214, 215, 216, 217, 218, 219, 220, 221, 222, 223, 224, 225, 226, 227, 228, 229, 230, 231, 232, 233, 234, 235, 236, 237, 238, 239, 240, 241, 242, 243, 244, 245, 246, 247, 248, 249, 250, 251, 252, 253, 254, 255, 256, 257, 258, 259, 260, 261, 262, 263, 264, 265, 266, 267, 268, 269, 270, 271, 272, 273, 274, 275, 276, 277, 278, 279, 280, 281, 282, 283, 284, 285, 286, 287, 288, 289, 290, 291, 292, 293, 294, 295, 296, 297, 298, 299, 300, 301, 302, 303, 304, 305, 306, 307, 308, 309, 310, 311, 312, 313, 314, 315, 316, 317, 318, 319, 320, 321, 322, 323, 324, 325, 326, 327, 328, 329, 330, 331, 332, 333, 334, 335, 336, 337, 338, 339, 340, 341, 342, 343, 344, 345, 346, 347, 348, 349, 350, 351, 352, 353, 354, 355, 356, 357, 358, 359, 360, 361, 362, 363, 364, 365, 366, 367, 368, 369, 370, 371, 372, 373, 374, 375, 376, 377, 378, 379, 380, 381, 382, 383, 384, 385, 386, 387, 388, 389, 390, 391, 392, 393, 394, 395, 396, 397, 398, 399, 400, 401, 402, 403, 404, 405, 406, 407, 408, 409, 410, 411, 412, 413, 414, 415, 416, 417, 418, 419, 420, 421, 422, 423, 424, 425, 426, 427, 428, 429, 430, 431, 432, 433, 434, 435, 436, 437, 438, 439, 440, 441, 442, 443, 444, 445, 446, 447, 448, 449, 450, 451, 452, 453, 454, 455, 456, 457, 458, 459, 460, 461, 462, 463, 464, 465, 466, 467, 468, 469, 470, 471, 472, 473, 474, 475, 476, 477, 478, 479, 480, 481, 482, 483, 484, 485, 486, 487, 488, 489, 490, 491, 492, 493, 494, 495, 496, 497, 498, 499, 500, 501, 502, 503, 504, 505, 506, 507, 508, 509, 510, 511, 512, 513, 514, 515, 516, 517, 518, 519, 520, 521, 522, 523, 524, 525, 526, 527, 528, 529, 530, 531, 532, 533, 534, 535, 536, 537, 538, 539, 540, 541, 542, 543, 544, 545, 546, 547, 548, 549, 550, 551, 552, 553, 554, 555, 556, 557, 558, 559, 560, 561, 562, 563, 564, 565, 566, 567, 568, 569, 570, 571, 572, 573, 574, 575, 576, 577, 578, 579, 580, 581, 582, 583, 584, 585, 586, 587, 588, 589, 590, 591, 592, 593, 594, 595, 596, 597, 598, 599, 600, 601, 602, 603, 604, 605, 606, 607, 608, 609, 610, 611, 612, 613, 614, 615, 616, 617, 618, 619, 620, 621, 622, 623, 624, 625, 626, 627, 628, 629, 630, 631, 632, 633, 634, 635, 636, 637, 638, 639, 640, 641, 642, 643, 644, 645, 646, 647, 648, 649, 650, 651, 652, 653, 654, 655, 656, 657, 658, 659, 660, 661, 662, 663, 664, 665, 666, 667, 668, 669, 670, 671, 672, 673, 674, 675, 676, 677, 678, 679, 680, 681, 682, 683, 684, 685, 686, 687, 688, 689, 690, 691, 692, 693, 694, 695, 696, 697, 698, 699, 700, 701, 702, 703, 704, 705, 706, 707, 708, 709, 710, 711, 712, 713, 714, 715, 716, 717, 718, 719, 720, 721, 722, 723, 724, 725, 726, 727, 728, 729, 730, 731, 732, 733, 734, 735, 736, 737, 738, 739, 740, 741, 742, 743, 744, 745, 746, 747, 748, 749, 750, 751, 752, 753, 754, 755, 756, 757, 758, 759, 760, 761, 762, 763, 764, 765, 766, 767, 768, 769, 770, 771, 772, 773, 774, 775, 776, 777, 778, 779, 780, 781, 782, 783, 784, 785, 786, 787, 788, 789, 790, 791, 792, 793, 794, 795, 796, 797, 798, 799, 800, 801, 802, 803, 804, 805, 806, 807, 808, 809, 810, 811, 812, 813, 814, 815, 816, 817, 818, 819, 820, 821, 822, 823, 824, 825, 826, 827, 828, 829, 830, 831, 832, 833, 834, 835, 836, 837, 838, 839, 840, 841, 842, 843, 844, 845, 846, 847, 848, 849, 850, 851, 852, 853, 854, 855, 856, 857, 858, 859, 860, 861, 862, 863, 864, 865, 866, 867, 868, 869, 870, 871, 872, 873, 874, 875, 876, 877, 878, 879, 880, 881, 882, 883, 884, 885, 886, 887, 888, 889, 890, 891, 892, 893, 894, 895, 896, 897, 898, 899, 900, 901, 902, 903, 904, 905, 906, 907, 908, 909, 910, 911, 912, 913, 914, 915, 916, 917, 918, 919, 920, 921, 922, 923, 924, 925, 926, 927, 928, 929, 930, 931, 932, 933, 934, 935, 936, 937, 938, 939, 940, 941, 942, 943, 944, 945, 946, 947, 948, 949, 950, 951, 952, 953, 954, 955, 956, 957, 958, 959, 960, 961, 962, 963, 964, 965, 966, 967, 968, 969, 970, 971, 972, 973, 974, 975, 976, 977, 978, 979, 980, 981, 982, 983, 984, 985, 986, 987, 988, 989, 990, 991, 992, 993, 994, 995, 996, 997, 998, 999, 1000.

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