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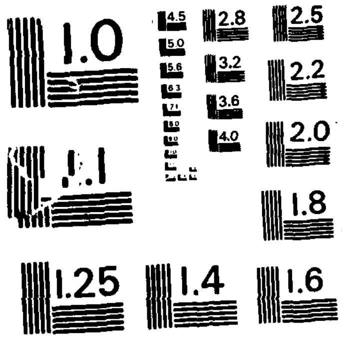

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RANRL TECHNICAL MEMORANDUM (EXTERNAL) 18/85

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P.J. Mulhearn

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A DEEP HYDROGRAPHIC SECTION ACROSS THE TASMAN SEA

P.J. MULHEARN

ABSTRACT

This memorandum reports on the results obtained from a deep hydrographic section across the Tasman Sea in December 1983. Data were obtained on temperature, salinity and oxygen concentration. Cross-sections of these variables and of potential temperature, density and geostrophic current are presented. A small cold region, suggestive of a boundary current, was found at the foot of the NSW Continental Slope, near 36°S, as well as a relatively cold water mass near 37-1/2°S, 155-1/2°E over the now dormant, mid-Tasman spreading ridge. The latter water mass is probably associated with a north-westwards flow of water derived from Antarctic bottom water. Deep geostrophic currents relative to 2,000 m were weak and of order 3 cm/sec northwards near 37-1/2°S, 155°E, and 2.5 cm/sec southwards over the abyssal plain near 36-1/2°S, 152-1/2°E.

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INTRODUCTION

In December 1983 a line of deep hydrographic stations across the Tasman Sea was occupied using the oceanographic vessel HMAS COOK. The line extended approximately at right angles to the New South Wales coast between 38°48.6'S, 159°44.5'E and 35°44.7'S, 150°45.89'E, with an additional station out at 38°30'S, 162°52.8'E. Two more stations near the coast and off this line were occupied to obtain geostrophic current vectors. This work was part of the Royal Australian Navy Research Laboratory's (RANRL) contribution to a project carried out in conjunction with Scripps Institution of Oceanography (SIO) and the Research School of Earth Sciences, Australian National University (ANU) (Lilley and others, 1986, Ferguson and others, 1986). SIO provided a series of sea-floor magnetotelluric moorings, primarily designed to examine the electrical conductivity structure of the solid earth, using measurements of ambient electric and magnetic fields (see e.g. Filloux, 1982). ANU is performing the bulk of the analysis on the data obtained. The low-frequency (sub-tidal) part of the horizontal electric field measurements provides information on the depth-averaged ocean current (Filloux, 1980) while the vertical electric field data are a measure of the zonal, bottom water velocity (Bindoff and others, 1985). It is hoped, in the near future, to relate the magnetotelluric results to data obtained concurrently from other sources, such as geostrophic currents from the hydrographic stations.

The deep hydrographic section is of interest in its own right as it shows a number of previously unobserved features such as a possible cold, boundary current at the foot of the New South Wales Continental Slope and a region of relatively cold bottom water near the centre of the Tasman Sea. It was hoped that the section would pass through a warm-core eddy, whose depth could then be obtained, but this did not eventuate.

The data presented here were obtained on the same cruise, TC1, as that on which the magneto-telluric moorings (plus a RANRL recording current-meter) were deployed. A small number of deep hydrographic stations were also occupied on the recovery cruise, TC2, in March/April 1984.

Amongst the earliest work on the deep hydrology of the Tasman was that of Wyrtki (1961) who described the different water masses of this area and the northward movement of deep waters from Antarctica. Boland and Hamon (1970) and Hamon (1970) on two occasions obtained absolute velocity profiles through the whole water column with a combination of Swallow floats and hydro-casts. The deep (3000 m) currents they obtained, below the East Australian Current, were of order 5 cm s^{-1}. In one case deep and shallow currents were unrelated, but in the other the deep flow direction remained similar to the surface current direction as they varied together. Mulhearn (1983a) showed from historical hydrographic data that the deep structure was highly correlated with that near the surface in the Tasman Sea, at least south of 30°S, and he inferred that currents at 4000 m depth below the East Australian Current System would be of order 6 cm/sec, relative to 2000 m, but their direction could not be specified. Some level near 2000 m is traditionally taken as one of no motion, but the validity of this remains to be verified. A short series of current-meter measurements at 31°S reported in Laird and Ryan, (1969) found bottom currents of order 5 cm/sec to the north-east.

EXPERIMENTAL TECHNIQUES

Measurements were obtained of temperature, salinity, oxygen and sample depth using Nansen bottles equipped with deep-sea reversing thermometers. Casts were performed in two stages - a shallow cast to

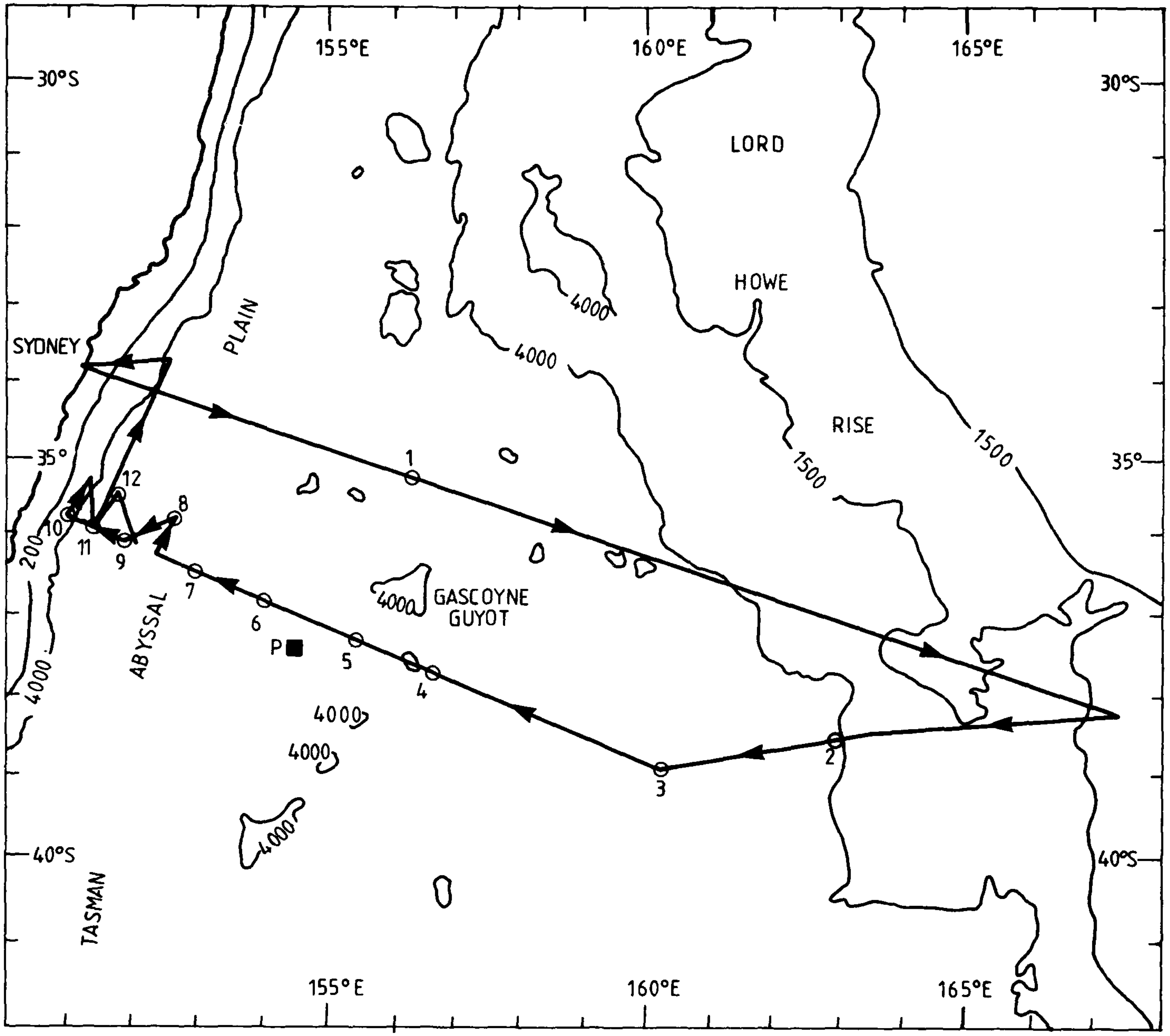

Fig. 1. Track chart of cruise T.C.1. (Hydrostations are numbered)

approximately 1,100 m and a deep one usually to within 180 m of the sea-floor. During a cast the ship, HMAS COOK, was manoeuvred using bow thruster and active rudder so as to keep the hydrology-winch wire vertical. During a station the distance of the deepest Nansen bottle above the sea-floor was estimated from sonic depth and length of wire out. Later analysis showed that this distance varied between 80 m and 180 m, except for one cast over the Continental Slope (380 m) and one over the Abyssal Plain at 36°11'S, 151°56'E (290 m).

The reversing protected thermometers on the lowest three to five bottles were made by Gohla and had a range of -2°C to + 6°C with divisions marked every 0.02°C. The unprotected ones were Watanabe Keiki with a range of -2°C to + 60°C. All other reversing thermometers were Watanabe Keiki, the unprotected ones having a range of -2°C to + 30°C or + 35°C and the protected having a range of -2°C to + 30°C. Nansen bottles were also made by Watanabe Keiki. Conservatively estimated accuracies for temperatures were ±0.01°C below 3000 m and ±.05° above. Salinities were measured with an Autolab inductively coupled salinometer model 601 Mk III to an accuracy of approximately 0.003×10^{-3}. Oxygen concentrations were obtained by the Winkler method.

Measurement and data analysis procedures were standard. From the data, values for potential density relative to 3,000 dbars, potential temperature, sound-speed and geostrophic current relative to 2000 m were calculated.

RESULTS

The ship's track on cruise TC1 with positions of Nansen casts is shown in fig. 1. Cross-sections along the track from cast 2 to cast 10, omitting casts 8 and 12 which are off the line between casts 3 and 10, are presented for temperature, potential temperature, salinity, potential density, geostrophic current and oxygen concentration, in figs 2 to 7.

The temperature section (fig.2) shows a cold core centred at 4000 m near 155.3°E, above a low broad ridge near the middle of the Tasman Basin. Temperature increases with depth below approximately 3,950 m at the above longitude because of compressibility effects. Another cold zone, suggestive of a small western boundary undercurrent flowing northwards, can be seen near 151.4°E, near the foot of the New South Wales continental slope. Further results on the existence of this deep boundary current will be discussed elsewhere.

The potential temperature section (fig.3) shows temperatures decreasing continually with depth, but the zones of low temperature near 155.3°E and near the foot of the Continental Slope are still apparent.

The salinity section (fig.4), shows a typical salinity maximum near 3000 m depth across the basin, but above the broad ridge near 155.3°E there appears to be a minimum in the value of the salinity maximum. This minimum depends on only one salinity value and so must be viewed with caution.

A section of potential density relative to 3000 dbar is shown on fig. 5. 3000 dbar was chosen as a suitable reference level for property variations in the deep water below 2000 m. As expected from the temperature measurements, there is a broad high density region over the ridge near 155°E and a concentrated, high density region at the foot of the Continental Slope. Close to the bottom near 155°E there is an apparent decrease in density because of compressibility effects.

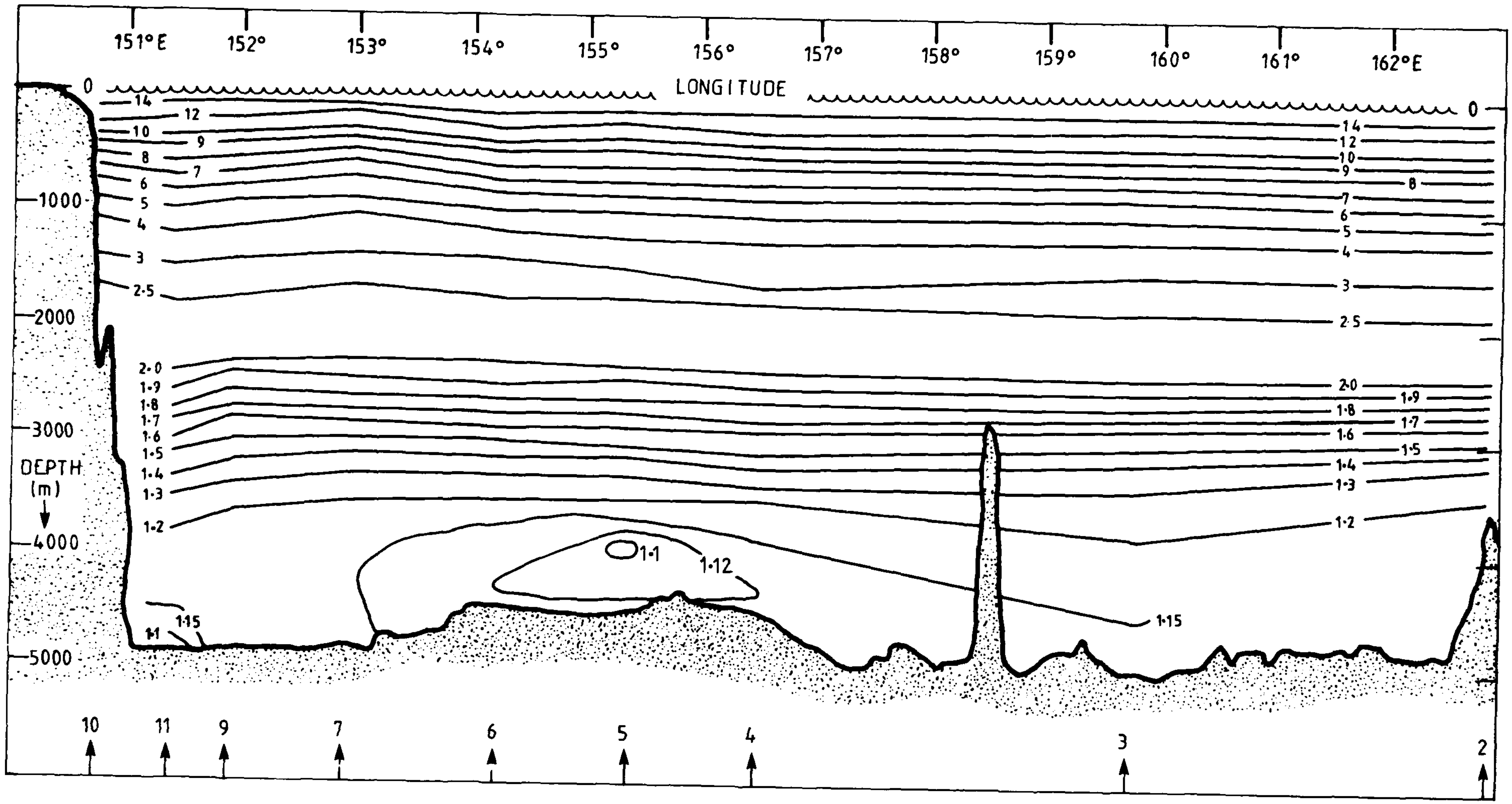

Fig. 2. Temperature cross-section of December 1983 (°C).

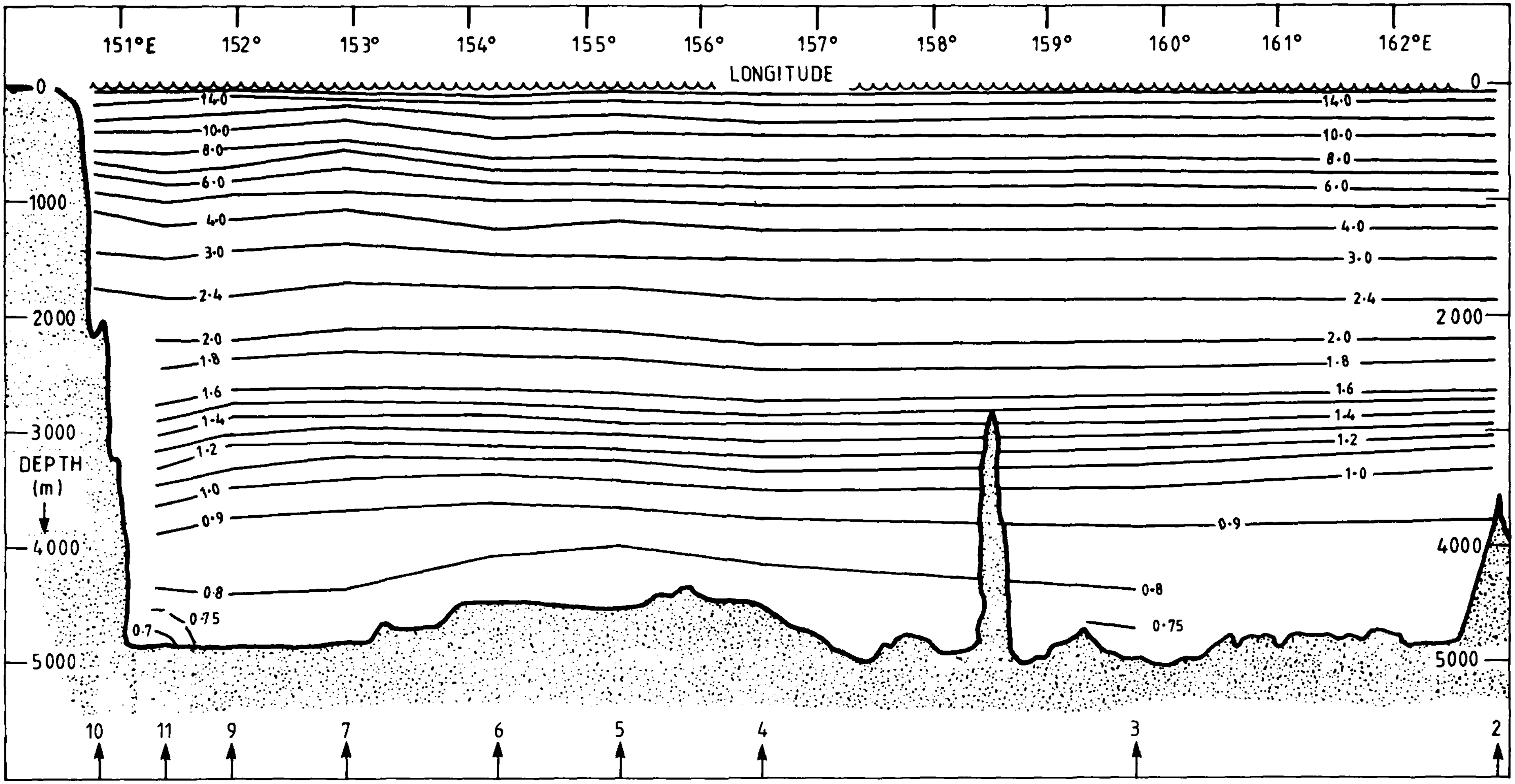

Fig. 3. Potential Temperature section of December 1983 (°C).

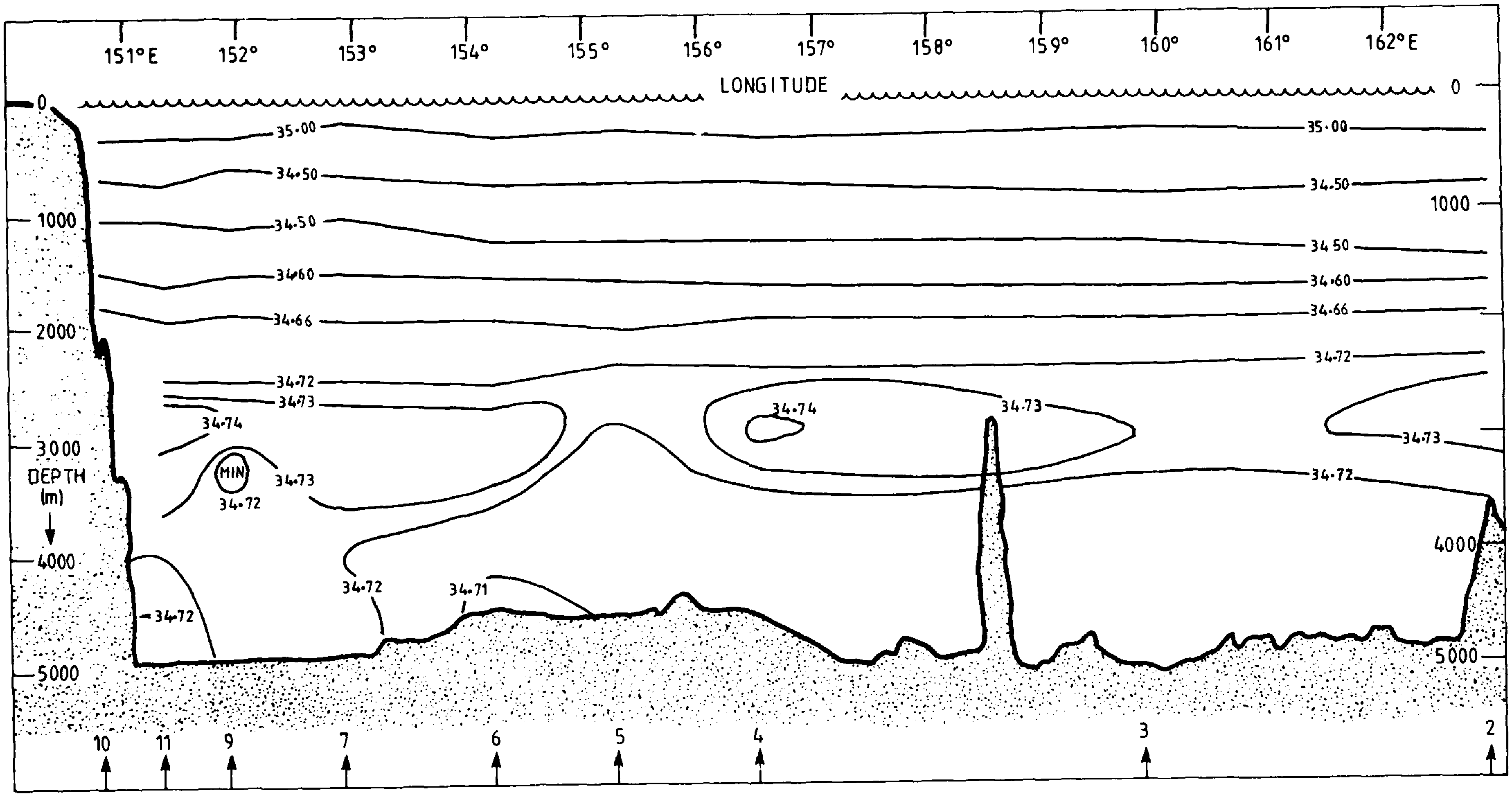

Fig. 4. Salinity section of December 1983 (parts per thousand)

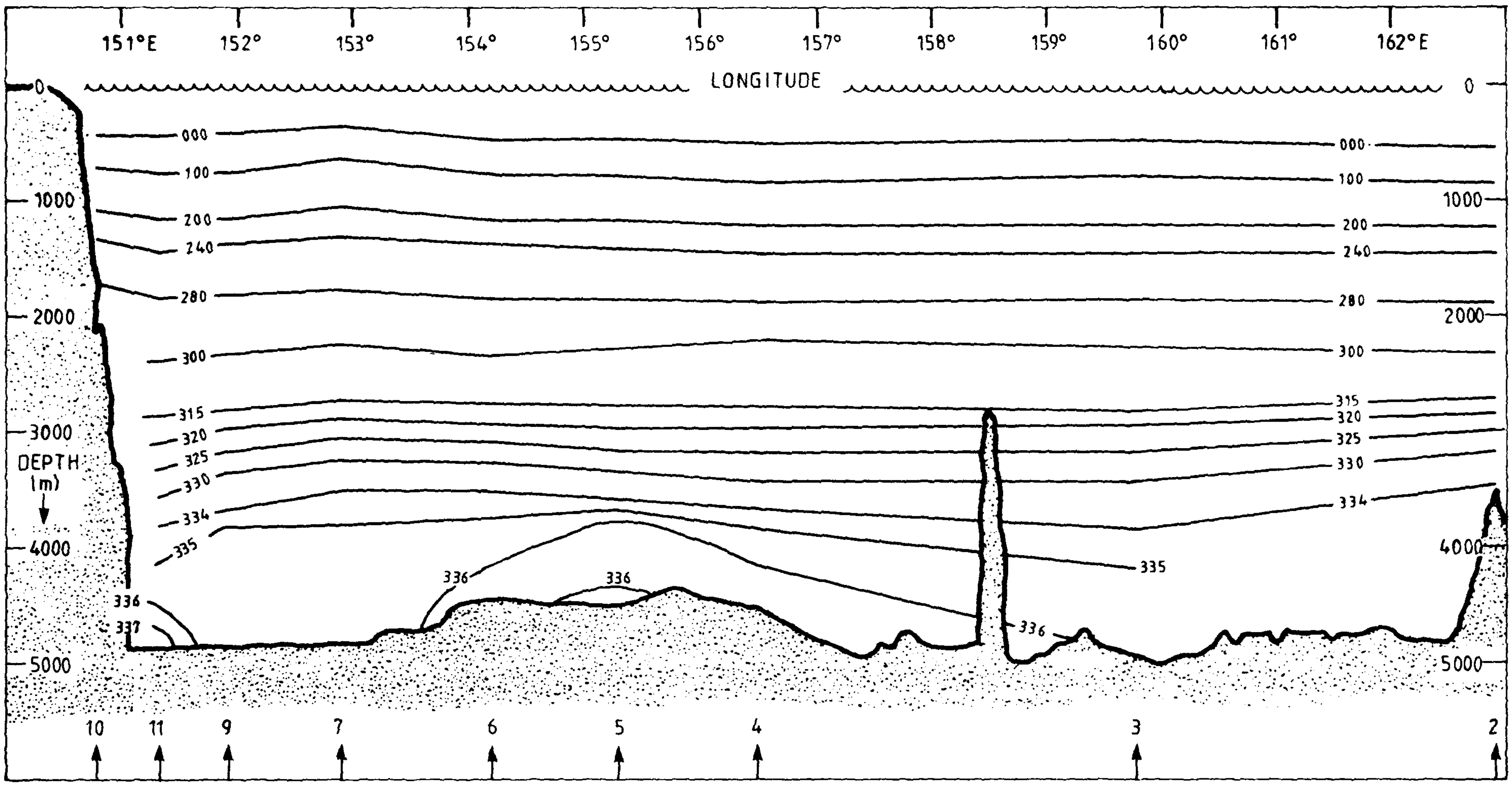

Fig. 5. Potential density re 3 000 dbar. Numbers on contours are $[\rho(s, \theta, 3000\ \mathrm{dbar}) - 1,130.00] \times 10^2$ (kg/m^3)

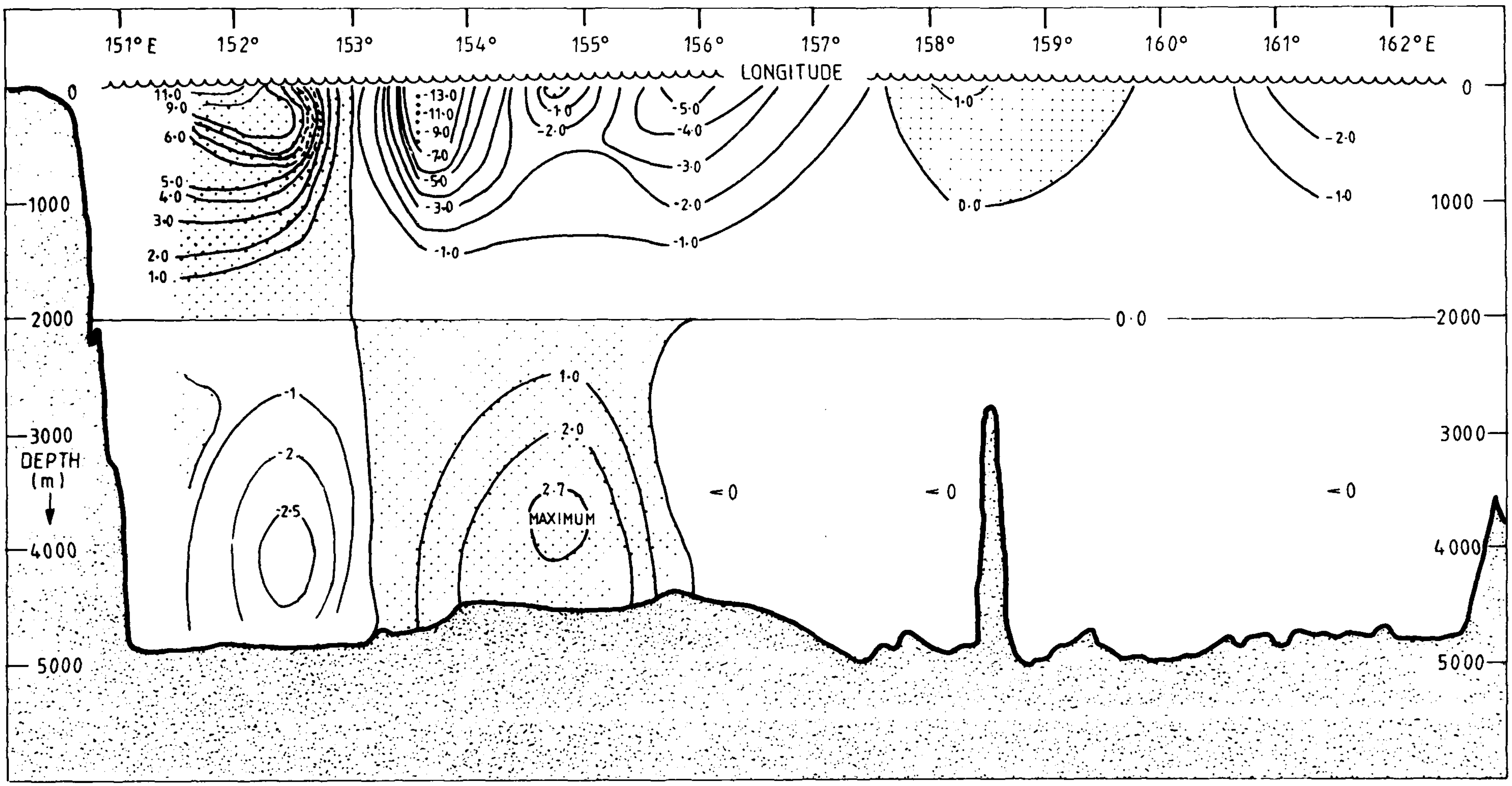

Fig. 6. Cross - section of Geostrophic currents relative to 2000m (cm/sec) (regions of northwards current are positive and shaded).

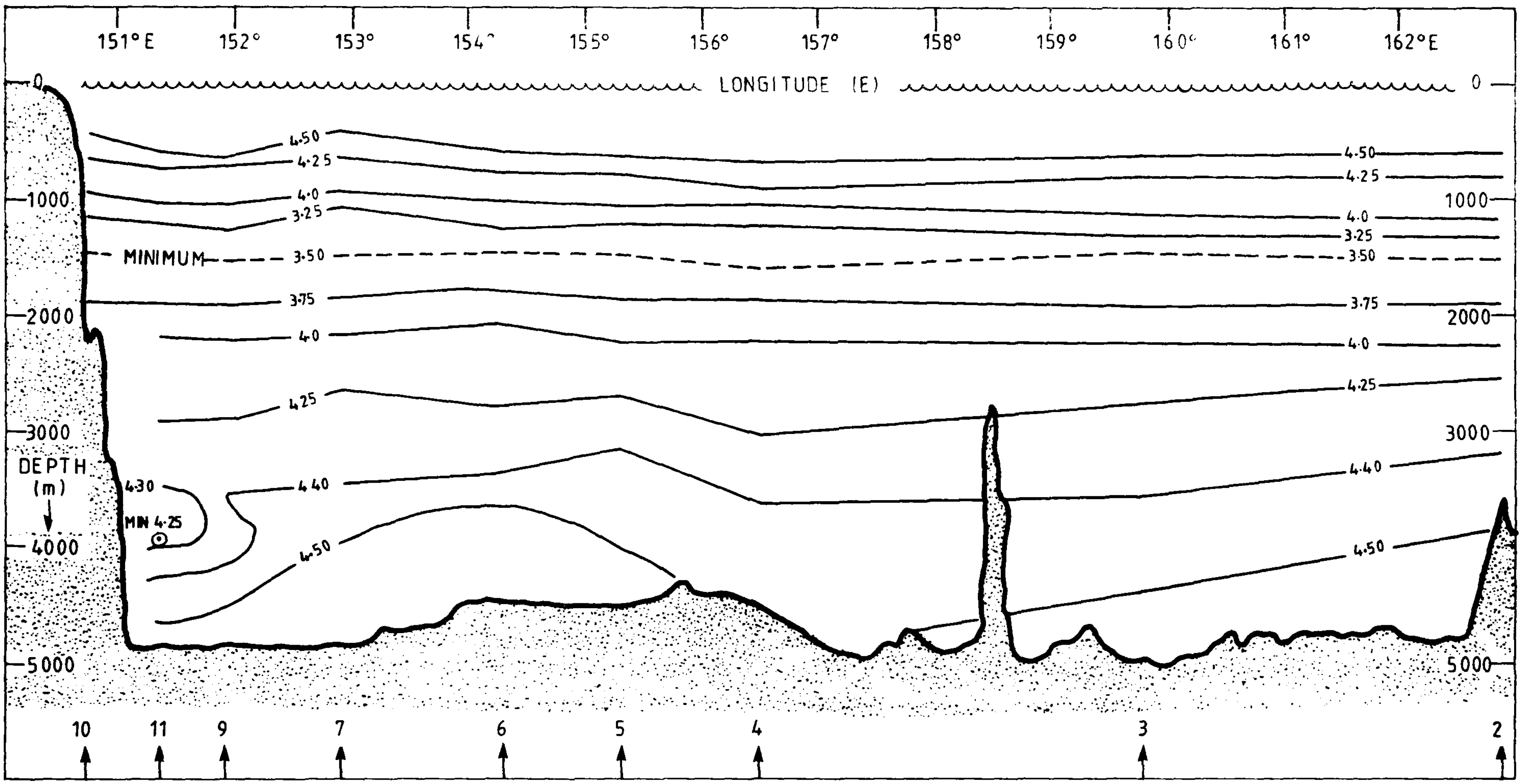

Fig. 7. Oxygen concentration cross section of December 1983 (ml/l)

From the data geostrophic currents relative to 2000 m were calculated (fig.6). 2000 m is the reference level used by Warren (1973) and receives some justification from the work of Fiadeiro and Veronis (1982). These are average velocities between stations and so values at the foot of the slope cannot be obtained. Currents are only accurate to about 30%, and are generally weak (of order 3 cm/sec). Deep northwards flow can be seen near 155°E. A bottom photograph, obtained just to the south of the cross-section in January 1984 (see P on Fig. 1), suggested weak bottom currents of this order (Beavis & Jenkins, 1984).

On the oxygen cross-section (fig. 7) there is a weak minimum adjacent to the Continental Slope above the cool region at the foot of the slope and deep oxygen concentration values are slightly lower near 157°E than elswhere.

Using the additional stations 8 and 12, geostrophic current vectors relative to 2,000 m were calculated using stations in groups of three namely, stations 7, 8, 9; stations 9, 11, 12 and stations 8, 9, 12. Velocity hodographs using these three triplets are shown, together with their average, in fig. 8. Above 2,000 m currents are generally eastwards to northeastwards, but are more variable below that depth. However, the currents below 2,000 m are small and of lower percentage accuracy than those above.

DISCUSSION

On potential temperature-salinity and potential temperature-oxygen plots the deep data from cruise TC1 all lie in the region of typical circumpolar deep water (Rodman & Gordon, 1982). Regions where northwards, near-bottom currents have been inferred have relatively low temperature and

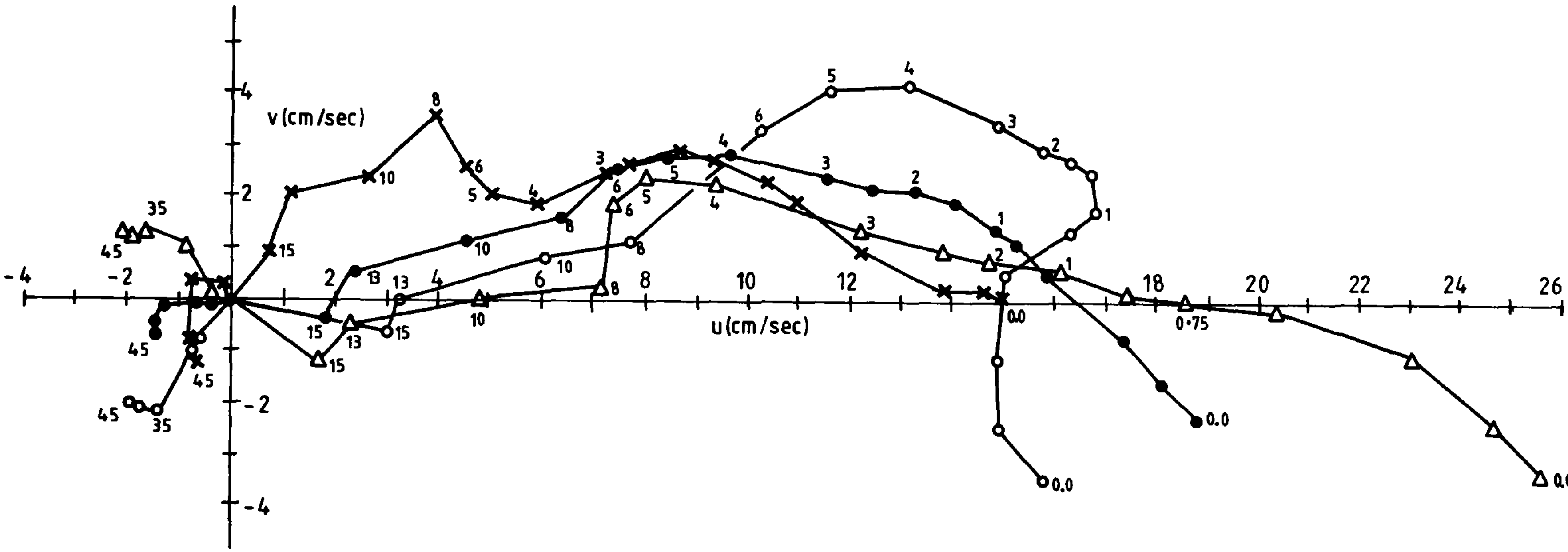

Fig. 8. Hodographs of geostrophic velocity relative to 2000m. ○, from station 7, 8 and 9; x from stations 9, 11, and 12; △ from stations 8, 9 and 12; ● average of all three. u is eastwards velocity, v is northward velocity, Numbers on curves are depth in 100's of metres.

salinity, i.e. at the foot of the NSW Continental Slope and in a broad zone near 155°E. These regions do not correspond very closely to regions of relatively high oxygen concentration but horizontal gradients below 4,000 m are rather too weak to infer very much from the oxygen data.

Work on sediment seismic stratigraphy (Jenkins, 1984) indicates the presence in geologically recent times of a north-westward flowing bottom current from southwest of New Zealand, near 45°S, 160°E to near the NSW coast at approximately 33°S. This current flows (or flowed) just to the southwest of the Gascoyne sea-mount and would have intersected the TC1 cross-section near 155°E. This corresponds reasonably well with the low temperature region, near this longitude, found on TC1.

The TC1 sections can be compared with those from the SCORPIO Expedition presented in Warren (1973). On the SCORPIO sections at 43°S, temperatures in the Tasman Sea were lowest at the foot of the continental slope of the East Tasman Plateau (near 153°E), suggestive of a boundary current, and were also relatively low between 156° and 159°E, but the differences were small. Slight salinity minima and oxygen maxima were also found near the foot of the slope off the East Tasman Plateau and between 156° and 157°E. In addition a third, slight oxygen maximum was found on the eastern side of the basin near 163°E. The low temperature, low salinity region in the mid-Tasman corresponds reasonably well with the bottom current found via seismic studies in Jenkins (1984). Deep geostrophic currents, relative to 2,000 m, were of order 1.5 cm/sec between 149°E and 152°E and were even weaker elswehere. At 28°S the Tasman Basin is narrow and obstructed by the Britannia Seamount and few features are discernible in the SCORPIO cross-sections. While the property variations at 43°S are too small for strong inferences to be drawn, they support the results from cruise TC1. The results of Rodman and Gordon (1982) based on archived hydrographic data on bottom water, show a broad region of low salinity and low temperature up the middle of the Tasman Sea, which is also consistent with the TC1 findings.

The northwards bottom current in the mid-Tasman inferred from our results is in disagreement with the simple model of Stommel and Arons (1960), which was used by Mulhearn (1983b) to model the abyssal circulation in the Tasman. In such a model there is an equatorwards flowing western boundary current and a broad southwards flow throughout the basin interior. Factors not included in the model are clearly important, but it is unclear at this stage which phenomena have to be included to provide a more realistic theory.

ACKNOWLEDGEMENTS

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