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XII. BOTTOM WATER TEMPERATURE IN THE PENRHYN BASIN, SOUTH PACIFIC (GH83-3 AREA)

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Introduction

Direction of regional drift of bottom water mass can be deduced from temperature difference of the bottom water because it is warmed up by the heat flow from the seafloor as it drifts. Such information will be useful for better understanding influence of bottom water on growth of manganese nodules.

Vertical temperature profiles of bottom water were measured at 16 sites in the western part of the Penrhyn Basin, to the east of the Manihiki Plateau (GH83-3 area) (Fig. XII-1). Flow direction of bottom water in this area was estimated from the temperature data. Further, pathway of bottom water movement around the Manihiki Plateau was estimated together with the data of GH82-4 area (Yamazaki, 1992) north of the Manihiki Plateau. A preliminary result of Matsubayashi and Mizuno (1982) suggested that bottom water in the Penrhyn Basin comes from the Tokelau Basin through a topographically controlled pathway between the Manihiki Plateau and the southern ridge of the Nova-Canton Trough, which is based on a difference of bottom water temperature between the two sites in the Tokelau Basin and the Penrhyn Basin. The present study supports their estimation with more measurements.

Measurements and Results

The 16 sites of bottom-water temperature measurements are shown in Figure XII-1. Water depths of the measurement sites range from 4900 to 5700 m. The measurements were carried out simultaneously with piston coring and heat flow measurements using a GH80-1 type thermograd-meter (Matsubayashi, 1982). Temperature of sea water was measured at one-minute intervals for about 10 minutes while the core was being heaved up at a velocity of 60 to 80 m/min. after its completion of geothermal gradient measurement in sediments. Because the thermograd-meter was designed for heat flow measurements, the accuracy in temperature difference determination is as high as 0.01°C, while that of an absolute temperature value is about 0.2°C. It is due to non-uniformity of resistance of thermistors at a standard temperature.

Vertical profiles of in-situ temperature of bottom water are presented in Figure XII-2. The same thermistor set was used and specific constants of these thermistors did not change at sites from H90 to H100. Temperature profiles of these sites can thus be

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compared with each other with an accuracy of 0.01°C. However, another thermistor set was used at sites from H101 to H105 since the former set was unfortunately destroyed during a heat flow measurement. Discrepancy in the temperature scale of horizontal axes between the former group and the latter was caused by a difference of resistances of the two thermistor set at a fixed temperature. The data of the two groups

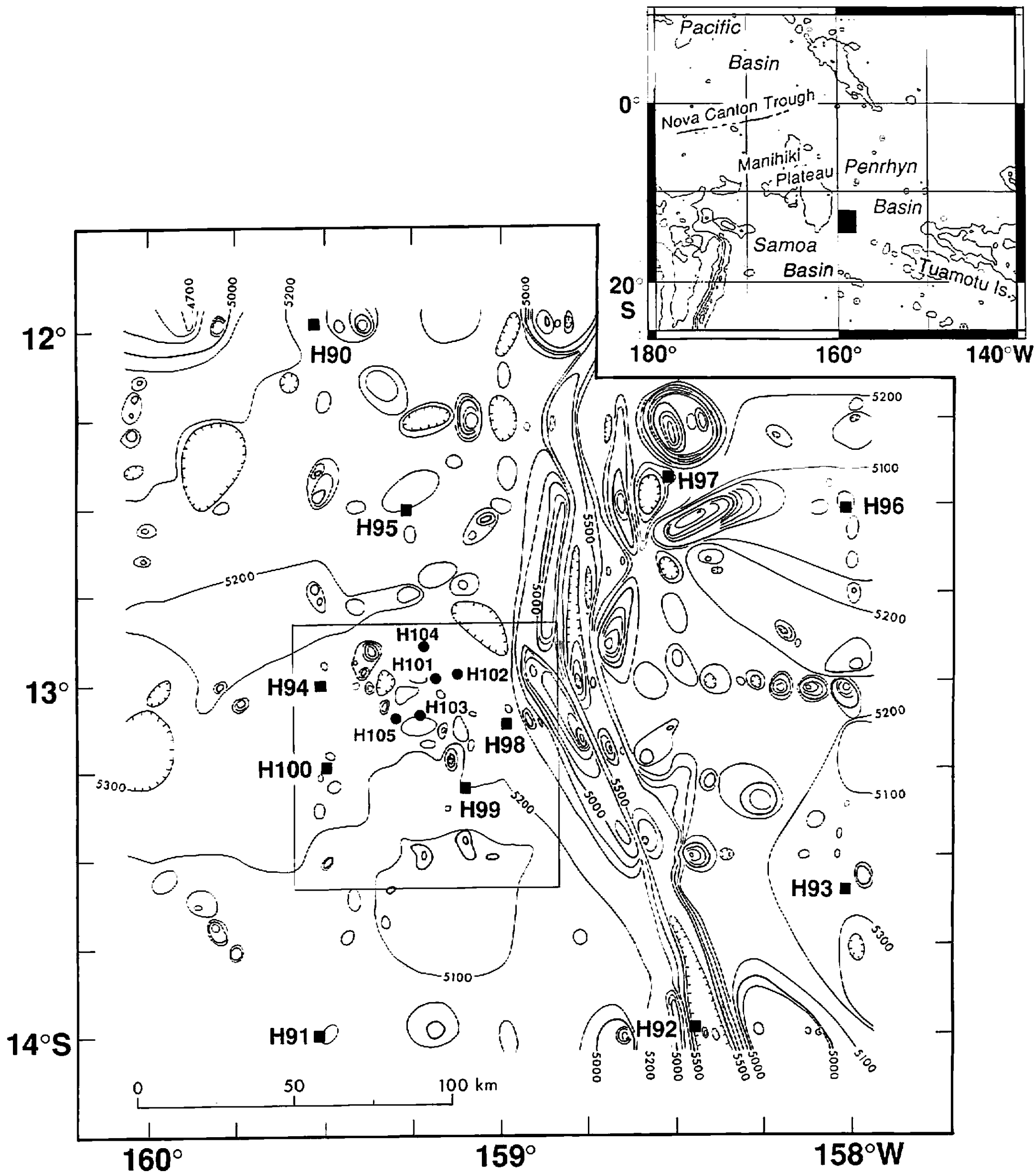

Fig. XII-1 Location of bottom water temperature measurements indicated on a topographic contour map. Data of Sites H101 to H105 (circles) cannot be compared directly with others (see text), and they are excluded in Figures XII-3 and 4.

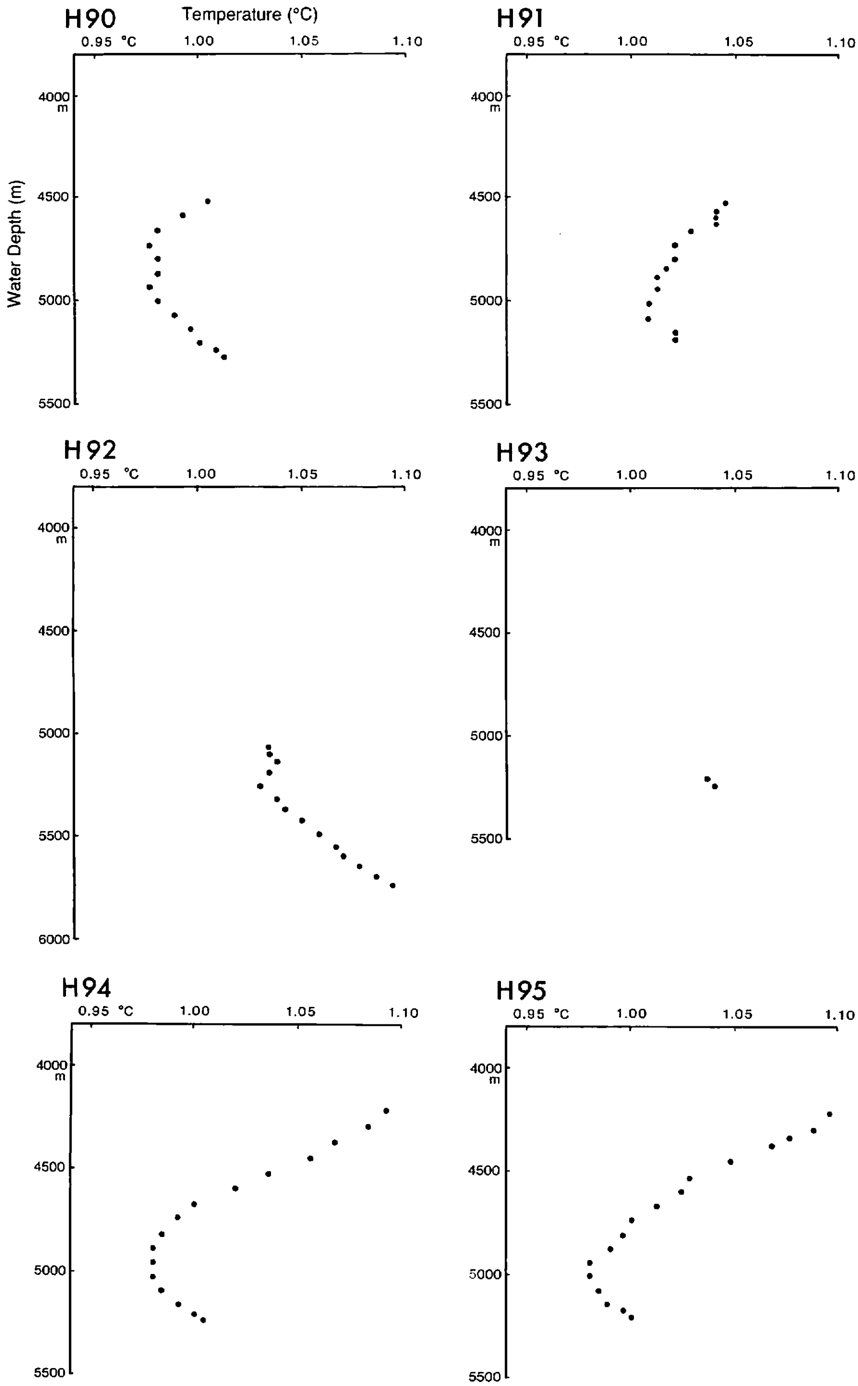

Fig. XII-2 Vertical temperature profile (in-situ temperature) of bottom water at each site.

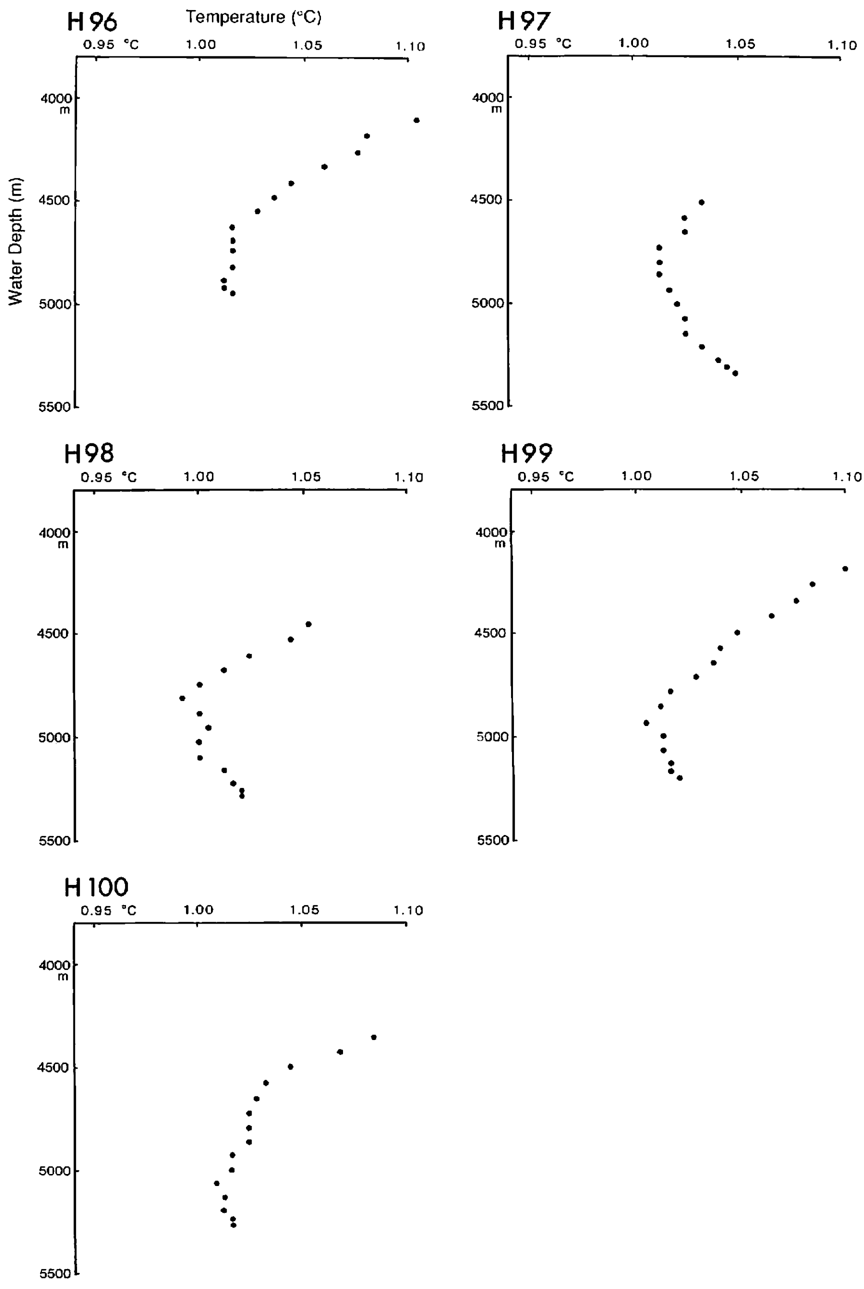

Fig. XII-2 (continued)

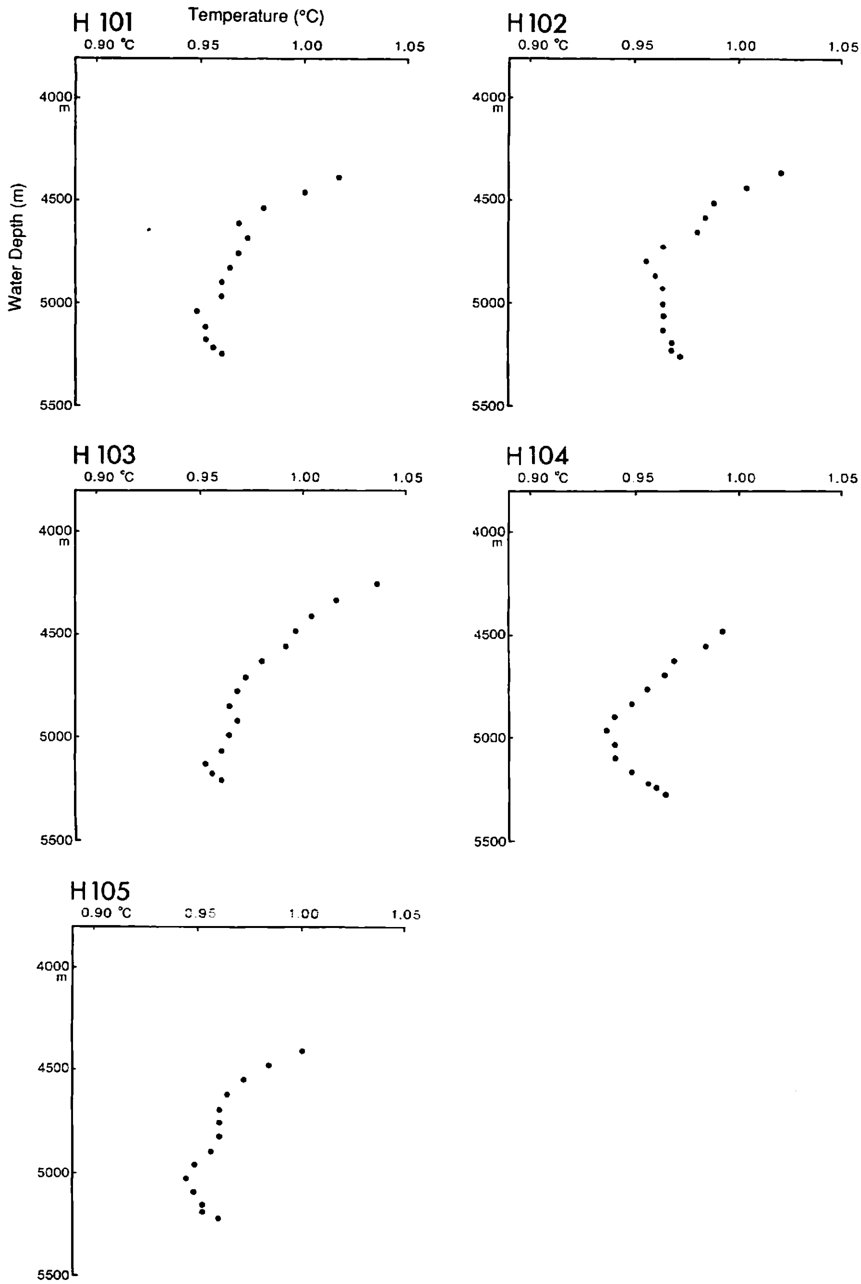

Fig. XII-2 (continued)

cannot be compared directly with each other.

Temperature profiles at sites from H90 to H100 are superimposed in Figure XII-3. A temperature minimum exists at a depth of about 5000 m. The rate of increase in temperature below this depth is close to the adiabatic temperature gradient, about 1.3°C/km for the bottom water of this area (Bryden, 1973). A reconnaissance measurement of Matubayashi and Mizuno (1982) suggests the possibility that bottom water mass which shows no temperature minimum coexists with bottom water having a temperature minimum in the Penrhyn Basin. Detailed measurements of this study, however, revealed that a temperature minimum does exist. The depth of the temperature minimum is larger than that in the Central Pacific Basin (at about 4500 m in the GH81-4 area; Yamazaki, 1986).

A new finding is that temperature of the bottom water below about 4800 m increases southeastward gradually (Fig. XII-4). Cold bottom water, the Pacific

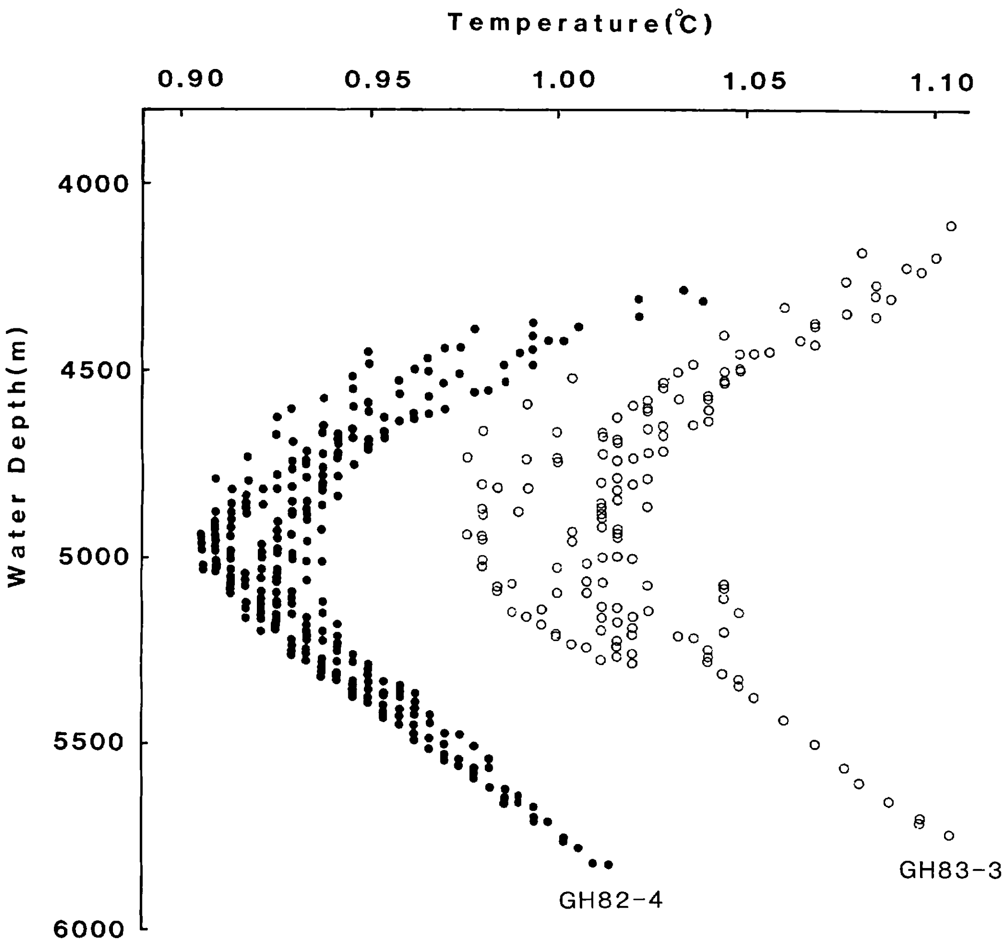

Fig. XII-3. Plots of temperature vs. depth of bottom water. Open circles are data from the GH83-3 area in the Penrhyn Basin (Sites H90 to H100). Solid circles are from the GH82-4 area north of the Manihiki Plateau (Yamazaki, 1992).

Bottom Water (PBW) originating from the Antarctic Bottom Water (AABW), becomes warmer as it moves through mixing with warmer, shallower water and heat flow from the seafloor. Thus, southeastward drift of the bottom water can be estimated from the observed temperatures. For depths shallower than 4800 m, on the other hand, this regional trend in the bottom water temperature gradually diminishes as the depth decreases and fades out at about 4500 m. This suggests that the movement of the water mass of the shallower part would be different from that of the deeper part even under the benthic front (the boundary between the PBW and the Pacific Deep Water (PDW), which is thought to be about 4000 m in this area (Craig *et al.*, 1972).

Discussion

The temperature data of this study area are compared with those of the GH82-4 area (Yamazaki, 1992) (Fig. XII-3) which lies between the Nova-Canton Trough and the Manihiki Plateau (Fig. XII-5). All temperature data in the GH82-4 area and the profiles at sites from H90 to H100 in the GH83-3 area (Fig. XII-2) can be compared directly with each other because the same thermistor set was used through the measurements over the two cruises, and no change in specific constants of the thermistors were examined. The temperature of the bottom water below 4800 m in the GH 83- 3 area is about 0.08°C higher than that of the GH82-4 area. This supports the preliminary result of Matsubayashi and Mizuno (1982). The temperature difference between the two areas can be explained by slow drift of bottom water mass from the

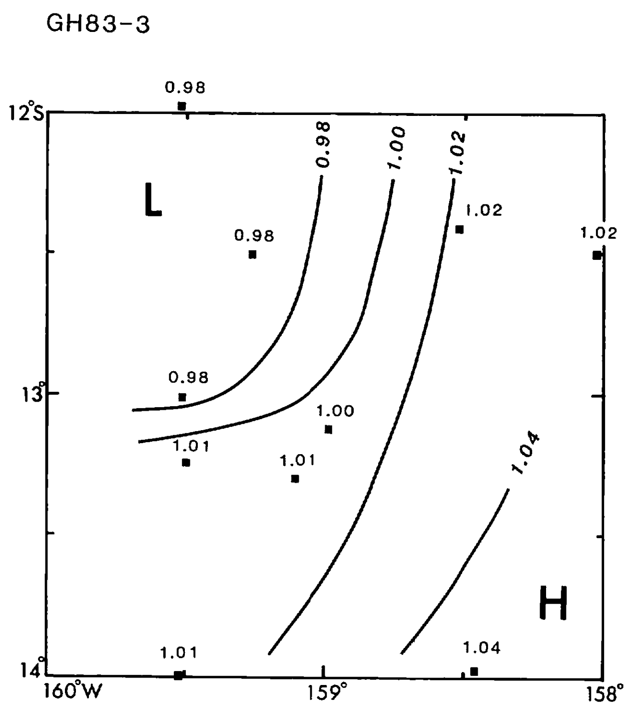

Fig. XII-4 Temperature of bottom water in the GH83-3 area at a depth of 5000 m (Sites H90 to H100). The temperature increases southeastward.

GH82-4 area to the GH83-3 area. This direction is consistent with the eastward flow inferred in the GH82-4 area (Yamazaki, 1991) and southeastward flow in this study area. Above 4800 m, on the other hand, the temperature difference between the two areas decreases gradually. The difference at 4300 m is 0.04°C.

The pathway of bottom water movement can be summarized as follows (Fig. XII-5). Upon entering the Tokelau Basin through the Samoan Passage (Reid and

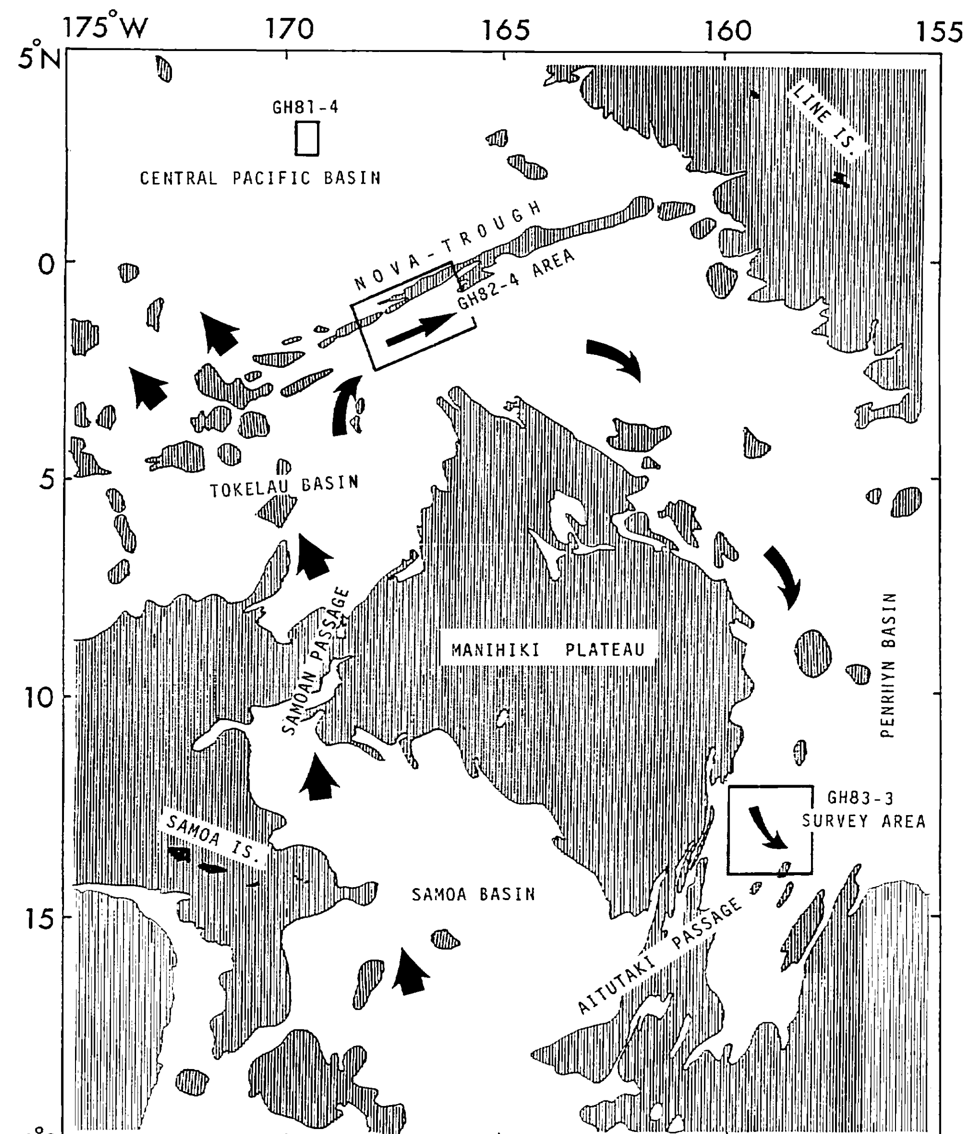

Fig. XII-5 Estimated flow direction of bottom water at present. Wide arrows indicate main flow (Lonsdale and Smith, 1980). Narrow ones are based on this study. Water depths of the shaded areas are shallower than 5000m.

Lonsdale, 1974), the PBW flows mainly northwestward as the western boundary current (Lonsdale and Smith, 1980). A part of the PBW, however, drifts eastward on a topographically controlled pathway between the Manihiki Plateau and the ridge just south of the Nova-Canton Trough. Then it drifts clockwise around the eastern margin of the Manihiki Plateau, and finally reaches to the southern end of the Penrhyn Basin.

Several authors (Wong, 1972; Pautot and Melguen, 1979; Lonsdale, 1981) thought that the cold PBW in the Samoan Basin flows into the Penrhyn Basin through the "Aitutaki Passage" (Pautot and Melguen, 1975) between the Manihiki Plateau and the South Cook Islands. This flow is, however, considered to be negligibly small below 4800 m, otherwise it is difficult to explain the southeastward flow in the GH 83-3 area and the lower temperature north of the Manihiki Plateau (GH82-4 area) than in the GH83-3 area. As the depth of the topographic barrier in the "Aitutaki Passage", which prevents flow of bottom water into the Penrhyn Basin, ranges from 4500 to 5000 m, the water mass in the Penrhyn Basin shallower than that depth may be affected by an influx from the Samoa Basin. The decrease of the regional temperature change in the GH83-3 area above 4800 m and decrease in the temperature difference between the GH82-4 and GH83-3 areas above that depth would be explained by this influx.

From hydrographical studies like this study, present state of bottom-water movement can be deduced. However, studies of pelagic sedimentation, in particular sedimentary hiatuses, are needed to know paleo-currents of the bottom water.

Summary

(1) Sixteen new measurements of vertical temperature profiles of bottom water mass were carried out in the southern part of the Penrhyn Basin (GH83-3 area) to the southeast of the Manihiki Plateau. Southeastward flow of bottom water below 4800 m was deduced in the GH83-3 area.

(2) Considering together with the result from the GH82-4 area lying between the southern ridge of the Nova-Canton Trough and the Manihiki Plateau (Yamazaki, 1992), it is inferred that a part of the Pacific Bottom Water drifts clockwise along the eastern margin of the Manihiki Plateau.

(3) Previously estimated influx of the Pacific Bottom Water into the Penrhyn Basin from the Samoan Basin through the "Aitutaki Passage" is negligibly small below 4800 m at present.

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