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Oceanic structure in the vicinity of a seamount, the Daini Kinan Kaizan, south of Japan*

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Abstract: The hydrographic observations in the vicinity of a seamount, the Daini Kinan Kaizan, south of Japan have been carried out three times in summer of 1989 and 1990. It is suggested that a pattern with week downward shift of isotherms and isohalines in the eastern side above the top of the seamount and upward shift of them just above the top of the seamount are maintained more than ten days. Vertical displacement of isotherms and isohalines at depths below the top of the seamount was always observed over the flank of the seamount. In relation to this water structure, prominent geostrophic flow with large vertical difference existed in the deep water below 1000 m. This suggests that topographic effect of the seamount is confined to depths with large vertical geostrophic shear and to greater depths. Micro-structures were observed over the seamount. In particular, a remarkable vertical temperature inversion with zonally coherent structure over the top of the seamount was observed in the first cruise made in July 1990.

1. Introduction

The interaction of ocean currents with seamounts has been of interest to oceanographers (e.g., HOGG, 1980; RODEN, 1987). As oceanic condition of seamounts may be different in localities, hydrographic observations should be made for each of seamounts. The present study is directed toward oceanic conditions in relation to circulation over the Daini Kinan Kaizan south of Japan.

The Daini Kinan Kaizan locates in a central region of the Shikoku Basin (Fig. 1) and has an elliptic shape with a longer axis form southeast to northwest. The top of this seamount is at a depth of 670 m. Up to this time, few observations have been carried out focusing on the topographic effects of the Daini Kinan Kaizan. KONAGA *et al.* (1980) observed that the detached cold eddy from the large meander of the Kuroshio, "Harukaze" , (cf. KONAGA and NISHIYAMA, 1978) has a tendency to stay over this seamount. As the main axis of the Kuroshio passes over or near the seamount when it meanders, it is suggested that this seamount has a material topographic effect on the dynamics of large meander path of the Kuroshio.

We have observed temperature and salinity fields in the vicinity of the Daini Kinan Kaizan three times in summer (Table 1). In the following, details of the three observations and some noteworthy results are shown.

Table 1. Hydrographic observations around the Daini Kinan Kaizan.

Cruise Name	Periods of observation	Main instruments	Stations
KS-89JUL	17 Jul. 1989	CTD, ADCP	Fig. 2-a
KS-90JUL1	15 Jul. 1990	Mi-com. BT	Fig. 2-b
KS-90JUL2	24-25 Jul. 1990	CTD, ADCP	Fig. 2-b

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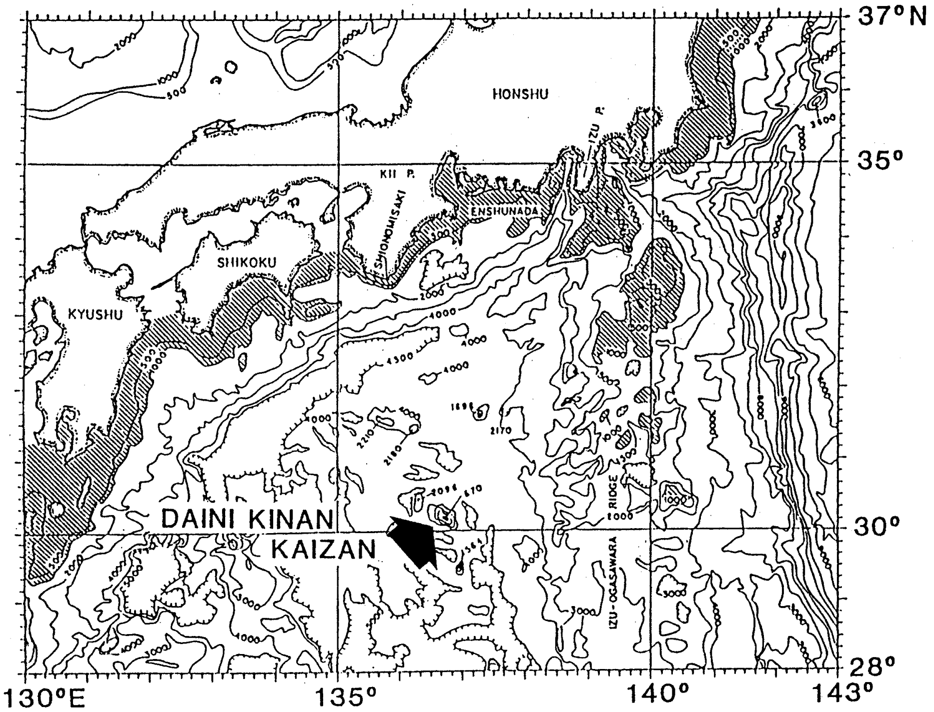

Fig. 1. Location of the seamount, the Daini Kinan Kaizan south of Japan. Isoplethes of depth (in meter) are also shown (after TAFT, 1972).

2. Observations

The hydrographic observations by CTD were carried out for three times by use of the Training Vessel Seisui-maru of Mie University (Table 1). The locations of the observational points for each cruise are shown in Fig. 2. Unfortunately, because the trouble of CTD system occurred in the second cruise, the micro-computer BT (mi-com. BT) was used for the stations 1 to 8 shown

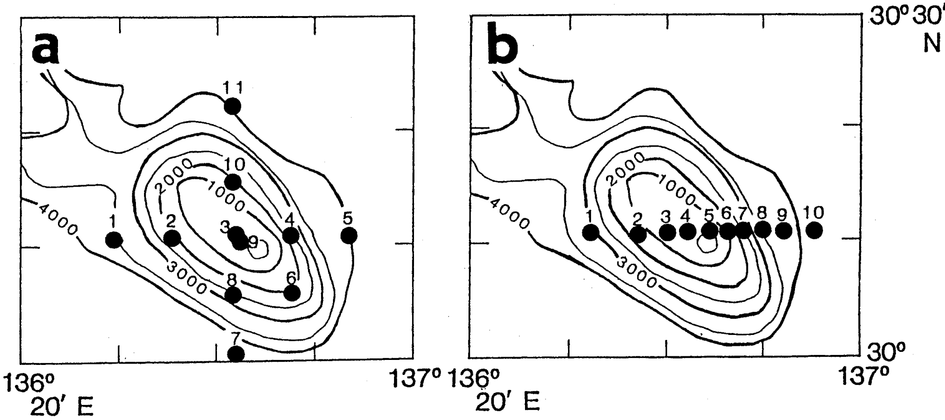

Fig. 2. Bathymetry (in meter) in the vicinity of the Daini Kinan Kaizan and observational points of CTD (closed circles). (a) Cruise KS-89JUL and (b) Cruise KS-90JUL1 (Mi-com. BT observational points from 1 to 8) and KS-90JUL2 (from 1 to 10).

in Fig. 2b. The current measurements by acoustic doppler current profiler (ADCP) were carried out for three depths, 50 m 100 m and 150 m. CTD of the upper 700 db layer at station 1 of cruise KS-89JUL1 and ADCP current data at mid-point between stations 7 and 8 of KS-90JUL2 had been lost by miss in data processing.

Here, we refer to the location of the main axis of the Kuroshio during the three cruises. Fig. 3 shows the main axis of the Kuroshio during three observational periods presented by Maritime Safety Agency. For the first cruise made in July 1989, which is hereafter referred to as KS-89JUL, no meander path was formed and the distance of this seamount from the main axis of the Kuroshio was relatively large. However, a large meander path was formed in winter of 1989 and the large meander path existed in the period of last two cruises made in July 1990, in which the main axis of the Kuroshio approached this seamount.

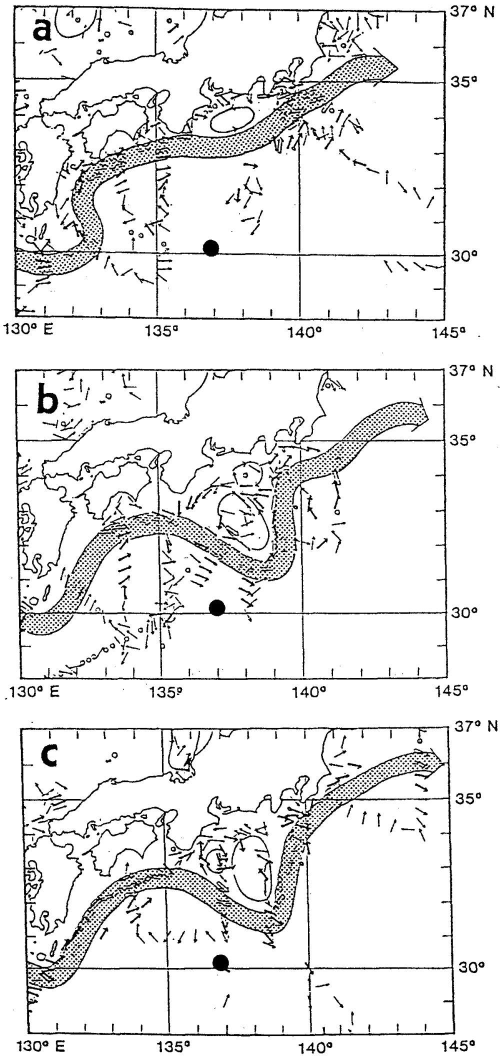

Fig. 3. Main path of the Kuroshio (stippled region) for each of the three observational periods (after, Prompt Report of Oceanic Condition compiled by Maritime Safety Agency, 1989, 1990). (a) Cruise KS-89 JUL in later half of July 1989, (b) Cruise KS-90JUL1 in early half of July 1990 and (c) Cruise KS-90JUL2 in later half of July 1990. Closed circle in each panel shows the location of the Daini Kinan Kaizan.

3. Results

The vertical distributions of temperature, salinity and density (σ_t) along two observational lines of the Cruise KS-89JUL are shown in Fig. 4. A seasonal thermocline with less saline water was formed in a surface layer shallower than 50 m. No remarkable vertical change in isotherms and isohalines are detected over the top of the seamount, of which detailed structure is unclear by the coarse distribution of observational points. However, vertical displacement of the isotherms was observed at depths below the top of the seamount. The vertical displacement has been also detected around other seamounts near the Daini Kinan Kaizan: the Tosa-bae off Shikoku (YOSHIOKA *et al.*, 1986; SEKINE and MATSUDA, 1987) and the Komahashi Daini Kaizan locating at the northern end of the Kyushu-Parau Ridge (SEKINE and SATO, 1993). The gradient changes at a depth from 1700 - 1900 db: upward (downward) shift was observed in southeastward (northwestward) in water shallower than 1700 db, while a definite upward (downward) shift existed in northwestward (southeastward) in water deeper than 1900 db.

The salinity minimum layer was observed at depths just above the top of the seamount. Because of the gradient of

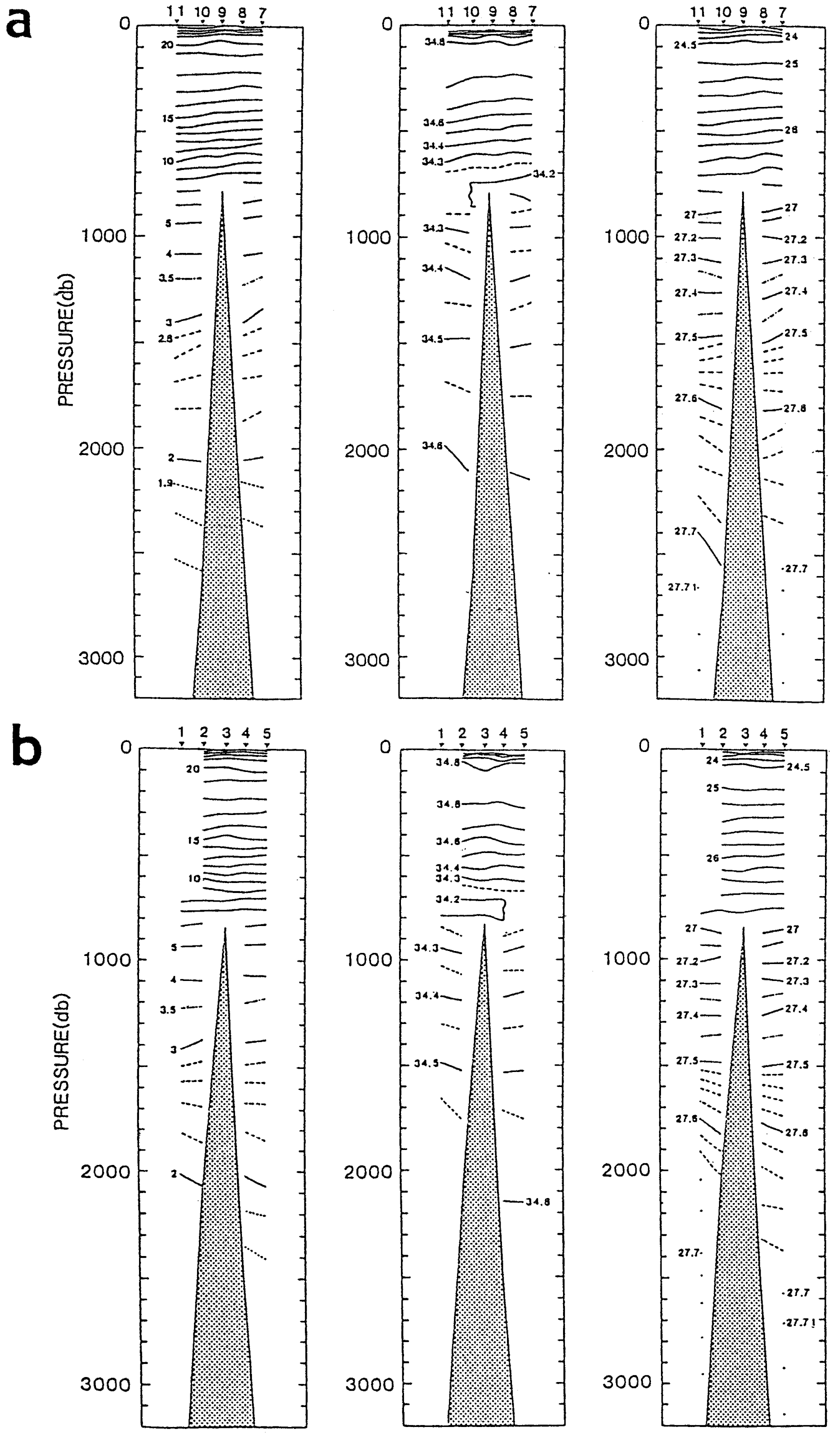

Fig. 4. Temperature, salinity and density (σt) sections of the Cruise KS-89JUL. (a) Meridional section and (b) zonal section. The locations of the observational points are shown on the top.

isohalines, less saline water than 34.5 PSU existed over the flank of the seamount at depths of 800-1500 db. Similar vertical structures to isotherms were observed also for isohalines in deeper layer than 1800. db. The vertical desplacement of isopycnal was also found in the greater depths, which suggests the existence of prominent geostrophic flow in the greater depths. Then, a geostrophic flow along the meridional section is displayed in Fig. 5. Here, owing to the difference in depth of each observational point, the reference level is assumed to be 750 db. Although absolute current velocity cannot be obtained from the present analysis, the gradient of isopycnals yields a large vertical difference in geostrophic flow more than 20 cm s^{-1} between 750 db and 1500 db in the south of the seamount. This prominent vertical change in geostrophic flow suggests that a topographic effect of this seamount

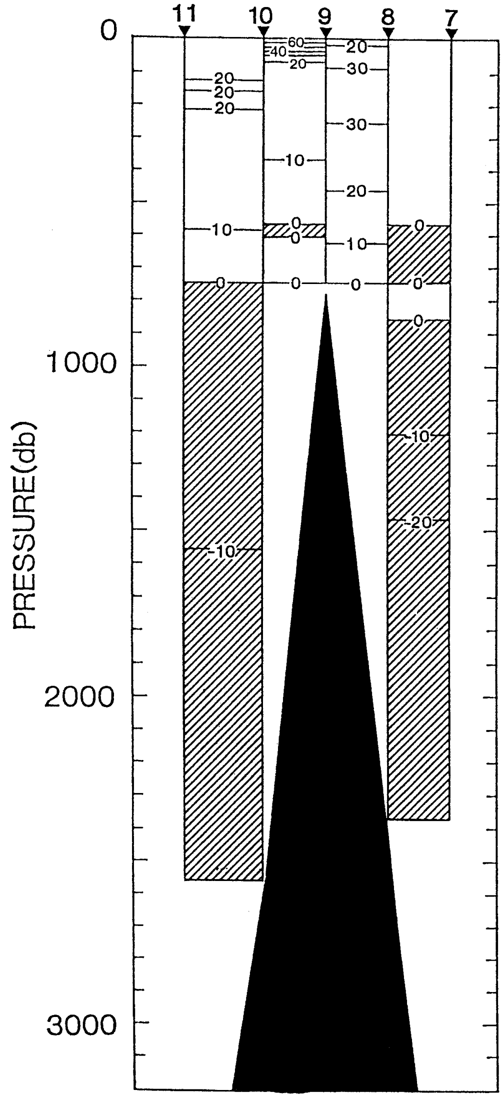

Fig. 5. Geostrophic flow (in cm s^{-1}) along the meridional section of KS-89JUL. The reference level is 750 db. Positive (negative) values show eastward (westward) flow. The regions with westward flow are shown by oblique lines.

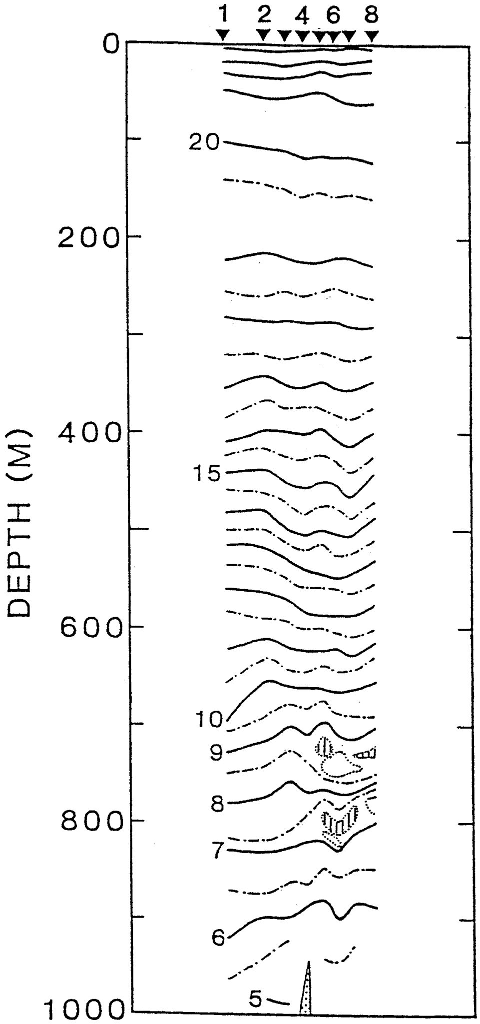

Fig. 6. Zonal temperature section of KS-90JUL1. Sectional areas with vertical inversion of temperature are shown by regions with vertical lines.

is confined to a relatively thin layer below the main thermocline.

The vertical temperature section observed in the Cruise KS-90JUL1 is shown in Fig. 6. As the observations were carried out in closer spacing than the previous one, KS-89JUL, many vertical unevenness in isotherms were detected : downward shift of the isotherms existed at depths of 450-600 m to the east of the top of the seamount and upward shift was found at depths of 650-800 m to the west. Complex upward and downward shifts were detected below 700 m. The some temperature inversions were observed at depths of 720-830 m. These temperature inversions are considered as micro-structures formed over the seamount. Upward shift of the isotherm of 6℃ is found just above the top of seamount.

To examine the temperature fields more closely, vertical profiles at eight stations are shown in Fig. 7. It is shown that noticeable temperature inversions found at depths from 710 m to 750 m have a zonally coherent structure. Below these inversions, other weak inversions are detected at depths of 790-820 m. Zonally coherent temperature inversions are considered to be due to the interleaving of warmer water.

The results of the cruise KS-90JUL2 are shown in Fig. 8. Similar vertical temperature structure to that found during the previous cruise KS-90JUL1 (Fig. 6) was observed over the seamount: deepening of isotherms are found in the east of the seamount at depths 400-650 db. This isotherm deepening, which seems to be the same as during the KS-90JUL1, must be maintained more than ten days, it is rather stable over the seamount. Upward shifts of the isotherm and isohaline just above the top of the seamount are also detected. At depth below the top of the seamount, a distinctive upward displacement of isotherms and isohalines were observed over the eastern flank of the seamount. This vertically coherent displacement may reveal

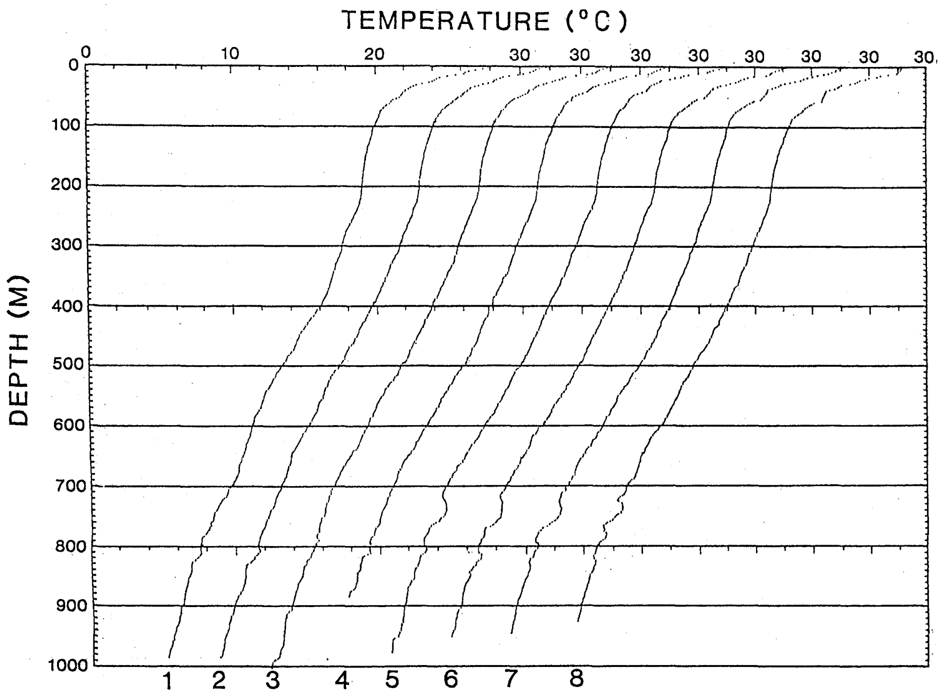

Fig. 7. Vertical change in temperature of the Cruise KS-90JUL1. Station numbers are given at the bottom.

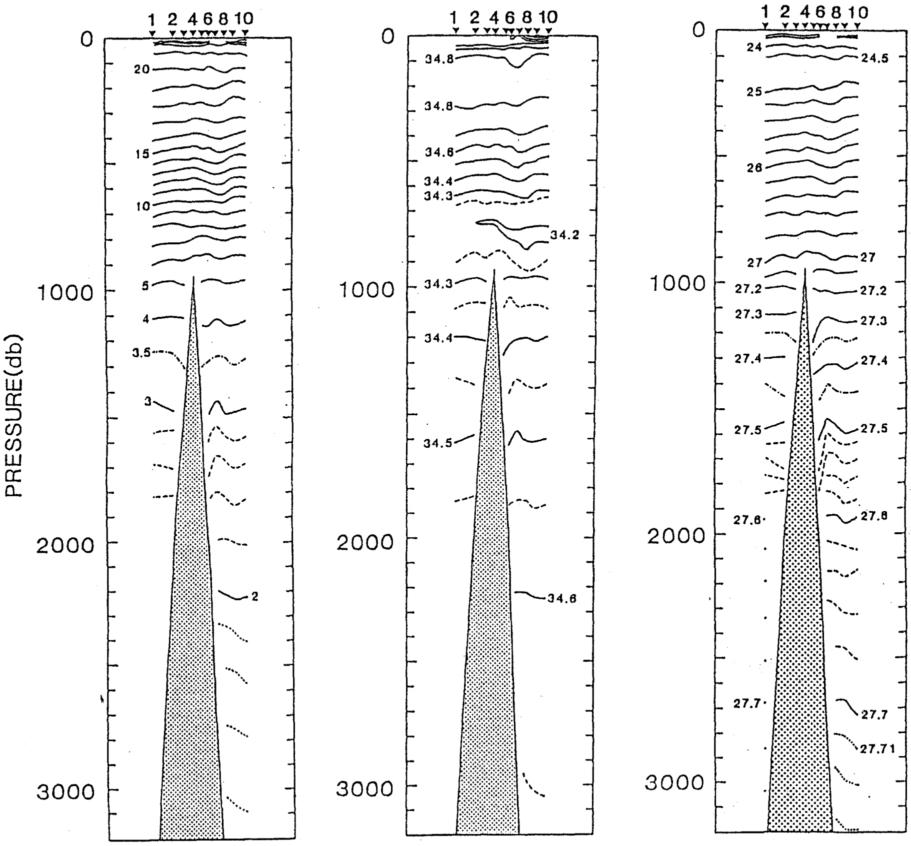

Fig. 8. Temperature (left), salinity (middle) and density (σ t) (right) sections of the Cruise KS-90JUL2.

the upwelling of deep water along the slope.

Density fields are quite similar patterns to temperature fileds. The geostrophic flow referred to 750 db is shown in Fig. 9. Because of the uplift of isopycnal, a large northward geostrophic flow with vertical velocity difference of 30 cm s^{-1} between at depths of 1000 db and 1300 db existed between two stations 5 and 6. Furthermore, southward flow between stations 6 and 7 had a vertical flow difference of 60 cm s^{-1} between at depths of 1100 db and 1800 db. This large vertical geostrophic difference in deeper water agrees with the results of the cruise KS-89JUL. It is suggested that there exists a strong current in the deep water around the seamount.

To make sure of validity of the reference level and to examine the geostrophic balance in the surface layer shallower than 150 db, in which ADCP current data were obtained, correlations between the geostrophic flow and the velocity by ADCP is shown in Fig. 10. Here, vertical differences of the northward velocities between 50 db and 100 db and those between 100 db and 150 db are compared. It is shown that no clear positive correlation is found for both the cases. A weak negative correlation (-0.41) is found for the latter case. Because of a geostrophic flow in the ADCP data, we are not able to estimate the reference level by adjusting the geostrophic velocities to those of ADCP.

4. Summary and discussion

The hydrographic observations in the

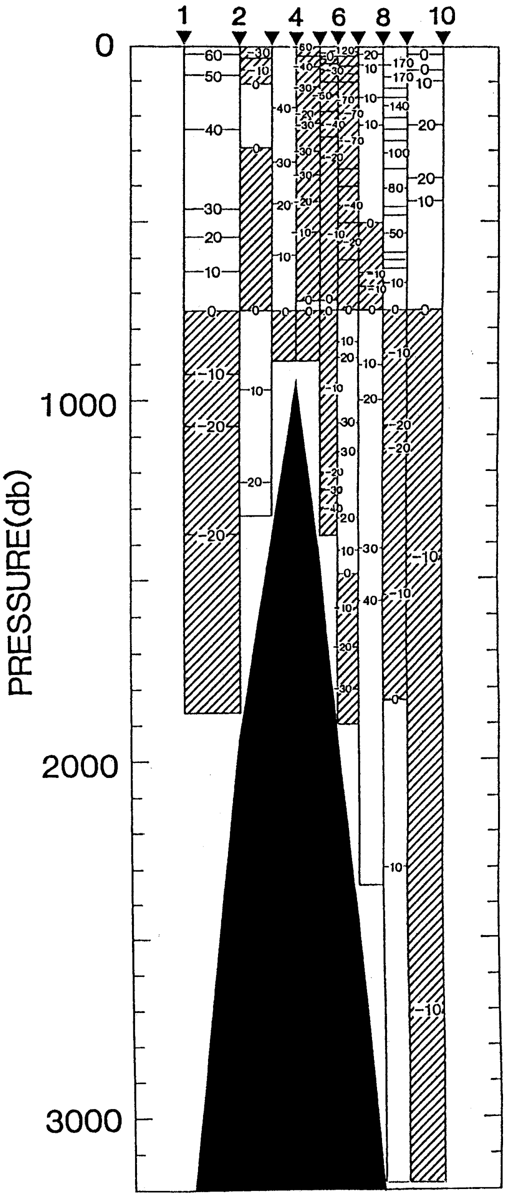

Fig. 9. Geostrophic flow on the zonal section of KS-90JUL2 referred to 750 db. Northward (southward) velocity is positive (negative).

vicinity of the Daini Kinan Kaizan south of Japan were made by the Training Vessel Seisui-maru of Mie University three times in summer of 1989 and 1990. Notable results of the observations are summarized as follows.

(1) During the first cruise (KS-89JUL), a weak undulation of isotherms and isohalines was observed in the upper 500 db layer; however, vertically coherent temperature and salinity gradients were observed over the flank of the seamount.

(2) As for the second cruise (KS-90JUL1), weak downward shift of isotherms at depths of 450–600 m in the east of the seamount, upward shift of isotherms just above of the seamount and complicated vertical temperature structure below 800 m were observed. Micro-structures of temperature with zonally coherent inversions were detected at a depth of 730 m.

(3) As for the third cruise (KS-90JUL2), similar temperature distribution to that of KS-90JUL1 was observed in depths above 1000 db. So, this temperature pattern must have continued more than 10 days; this temperature structure is considered to be stable near the seamount. Furthermore, a distinct shallowing of the isotherms and isohalines were observed in the east of the seamount.

(4) In the east of the seamount, the horizontal gradient of isopycnals suggests that a remarkable geostrophic flow with large vertical shear existed in depths greater than the top of the seamount during cruises of KS-89JUL and KS-90JUL2.

(5) The vertical difference in the geostrophic velocity shows no clear correlation with those of the ADCP in the surface water within 150 db. Since this suggests that ageostrophic flow is included in the current obtained by ADCP, the ADCP current data are not useful for estimation of the reference level of the geostrophic calculation.

The oceanic conditions around this seamount must be influenced by the seasonal variation and also by Kuroshio paths. It should be noted that no clear correlation between the geostrophic velocities and those of ADCP offers a serious problem in the current observation: ADCP data do not give the information for reference level of geostrophic caluculation. Long term direct

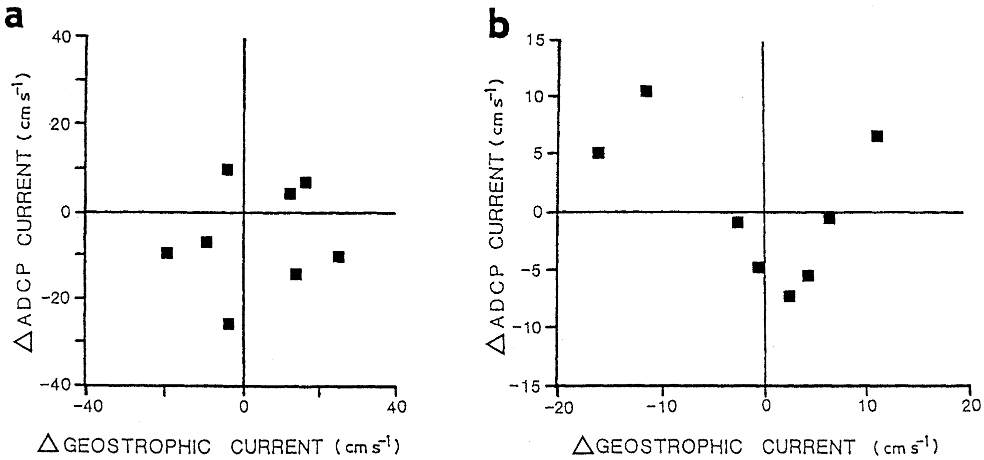

Fig. 10. Comparison between vertical differences in northward geostrophic velocity and those in velocity by ADCP along the observational line of KS-90JUL2. Velocity differences between 50 db and 100 db (a) and between 100 db and 150 db (b).

current measurements which are able to exclude ageostrophic component are needed to obtain the real velocity fields around this seamount.

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日本南岸の第二紀南海山周辺の海洋観測

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要旨：日本南岸にある第二紀南海山周辺の海洋観測を1989年夏，1990年夏に計３回行った。その結果，海山山頂以浅では海山東に等温度線と等塩分線の下降があり，海山直上でそれらの上昇を伴うパターンが10日以上維持されることが示唆された。また海山周囲の頂上以深の斜面上では等温度線と等塩分線の鉛直変位が共通して認められた。この鉛直変位により，1000m以深の深層で地衡流が顕著な鉛直シアーを伴い，海山の地形効果はこの鉛直シアー層以深に限られる可能性が示唆された。また，海山の山頂直上では微細構造が認められた。特に水平方向に同じような構造を持つ水温の逆転が1990年７月の１回目の航海で観測された。