Geological Survey of Japan Cruise Report No. 22, p. 39–69, 1992

IV. SEISMIC REFLECTION SURVEY IN THE SOUTHERN PART OF THE CENTRAL PACIFIC BASIN (GH82–4 AREA)

Manabu Tanahashi

Introduction

A detailed single-channel seismic reflection survey was carried out south of the eastern part of the Nova-Canton Trough (also called as the Canton Trough by Rosendahl *et al.*, 1975), in the Central Pacific Basin during R/V Hakurei-maru GH82–4 cruise to clarify the geological background of the manganese nodule province (Fig. IV–1). The regional survey area enclosed by 0°20′S–2°40′S, 168°40′W–165°40′W (300 km × 200 km) was selected on a regional transect survey during GH80–1 cruise (Mizuno and Nakao, 1982). The small area enclosed by 0°45′S–1°05′S, 166°30′W–166°05′W (50 km × 40 km) was selected for a detailed survey after reconnaissance study within the GH82–4 area.

Data acquisition

The track lines are shown in Figures IV–2 and IV–3. The seismic profiles were collected along 2580 km lines in 23 days. The survey area is covered by the tracks with about 10 mile line spacings. Six days (238d, 239d, 240d, 267d, 270d and 272d) were spent for the regional survey of the Nova-Canton Trough structure (Fig. IV–3). Four days (246d–249d) were spent in the detailed survey area (Fig. IV–4). Spacing between survey lines is typically about 2.5 miles in the area. The whole data set of 4–sec range seismic profiles collected during the cruise is shown in Figure IV–12.

Survey equipment and operating conditions are listed on Table IV–1. Two 150–cubic inch air guns were used in the general survey area to determine geological structures together with 3.5 kHz subbottom profiler. Two 120–cubic inch air guns with wave shaping kits were used for detailed survey to clarify the fine structure of surficial sediments. Two different recording ranges, 2 and 4 sec, were applied simultaneously for rough and fine recording throughout the survey.

Two-way travel time is used in the following description of event depths and layer thickness on seismic profiles.

Tectonic setting of the survey area

The Nova-Canton Trough is composed of several deep grabens and high ridges. The maximum water depth of the main graben exceeds 8000 m. It is the deepest trough in the Central Pacific Basin.

The origin of the trough is controversial. Winterer *et al.* (1974), Winterer (1976)

Keywords: air gun, turbidite, antarctic bottom water, volcanic activity, spreading center, transform fault, Cretaceous, Central Pacific Basin, Hakurei-Maru, Nova-Canton Trough

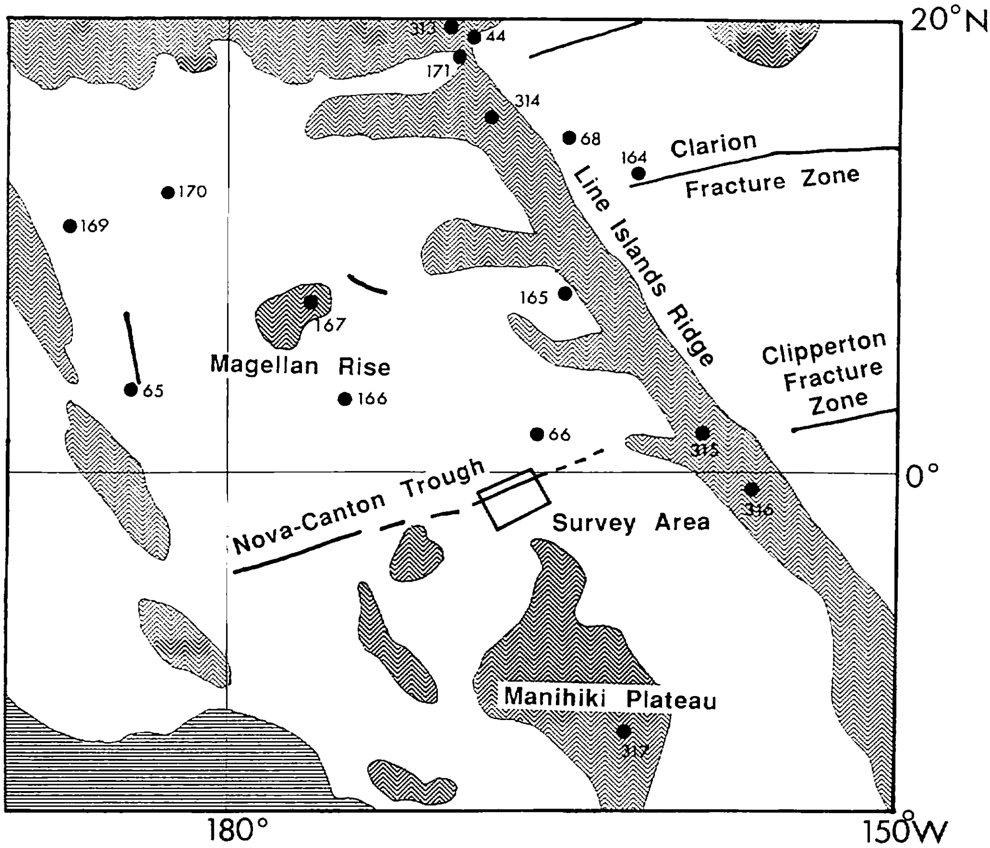

Fig. IV-1 Location of GH82-4 survey area. Shaded areas are submarine ridges or rises shallower than 5000 m. Circles show the location and number of DSDP sites. Lines show the fracture zones. Hatched area shows the northern part of the Melanesian boarder land.

and Rosendahl *et al.* (1975) interpreted the Nova-Canton Trough as an abandoned spreading center rather than a transform fault in extension of the Clipperton Fracture Zone. They interpreted from extrapolation of the Phoenix lineation set that it developed at the abrupt change of spreading direction at about 110 Ma.

Although there are parallel magnetic anomaly lineations along the trough, the anomalies are reasonably explained by the topographic effect of a simple uniformly thick magnetized layer that formed during the Cretaceous Normal Epoch (110-80 Ma) as shown by Yamazaki and Tanahashi (chapter II, this volume). No remarkable difference in structure between north and south over the trough suggests an abandoned spreading center model rather than the transform fault model. On the other hand, Joseph *et al.* (1990; 1991) regarded the trough as a fracture zone based on obliqueness of trends between the trough and the abyssal hills in the southern limb of the trough seen on the SeaMARC II imagery.

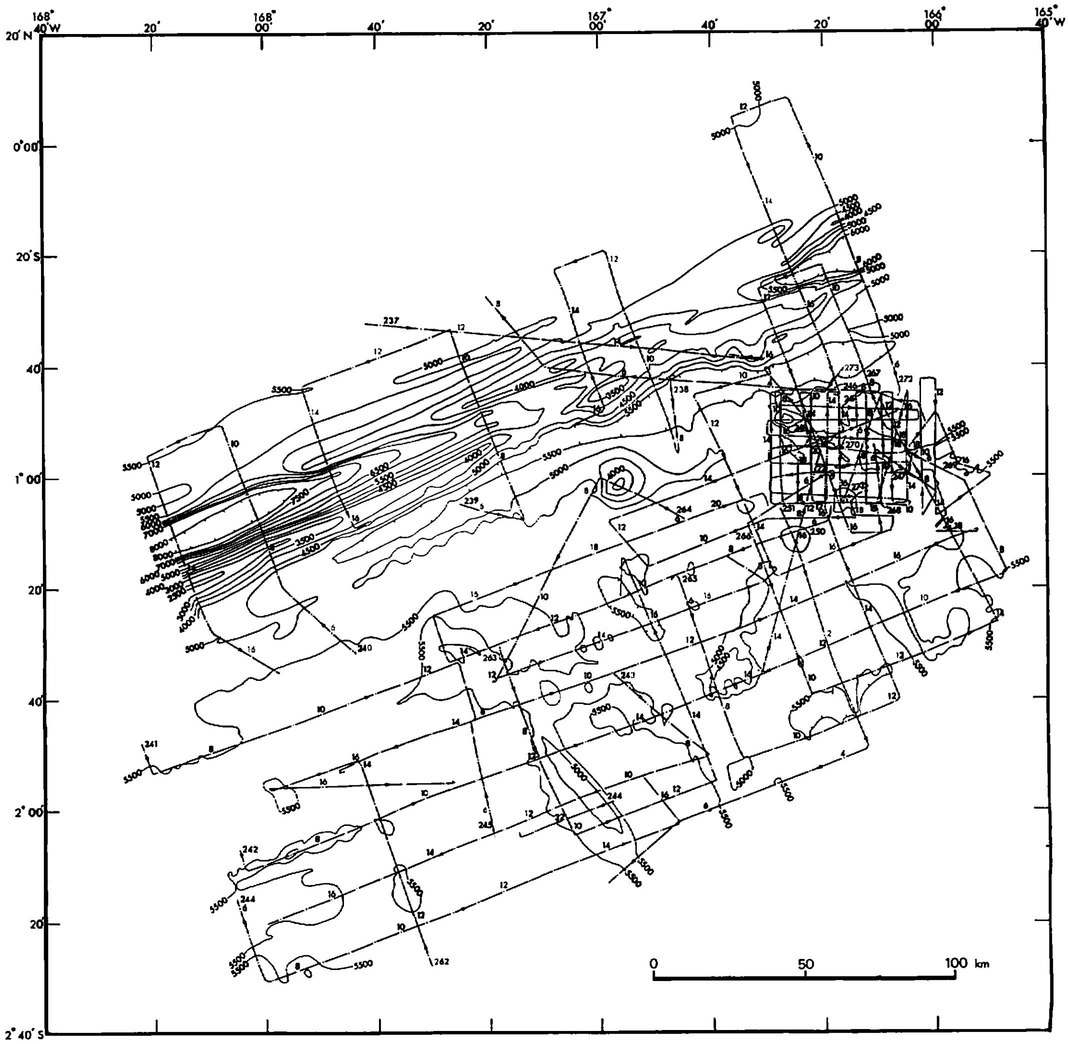

Fig. IV-2 Survey track lines and topography of GH82-4 survey area.

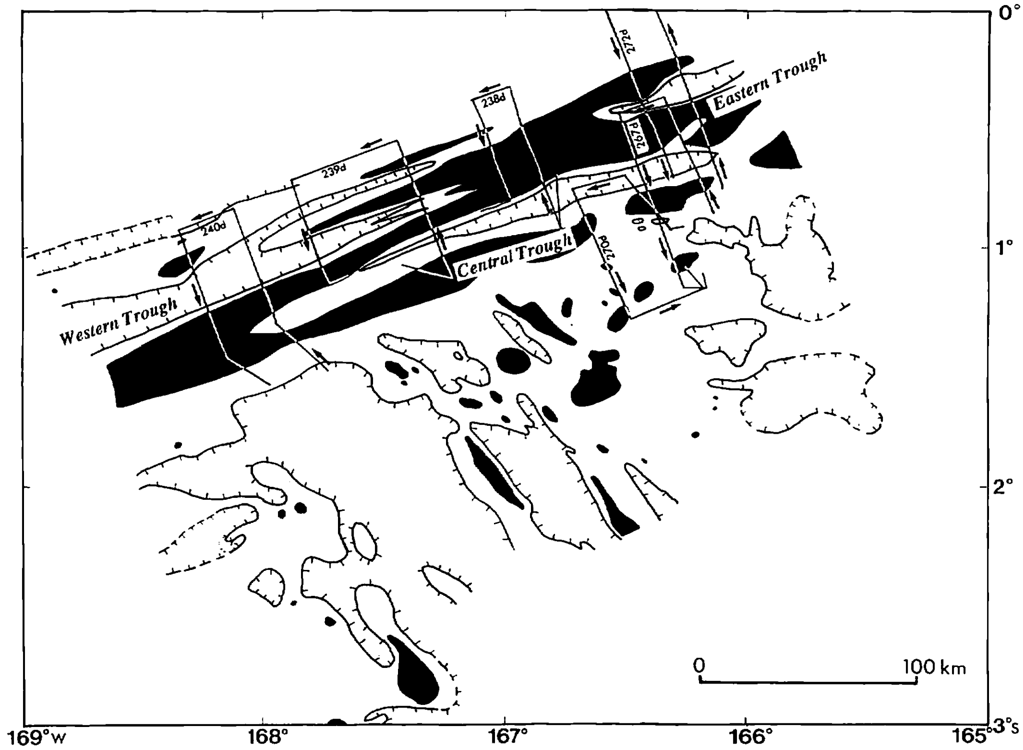

Fig. IV-3 Outline of topography and survey track lines over Nova Canton Trough area. Black areas show the area shallower than 5100 m. Lines with tick-mark show the area deeper than 5500 m.

Acoustic stratigraphy

Ewing *et al.* (1968) have shown a general distribution of sediment thickness in the Pacific Ocean. Heezen *et al.* (1973) pointed out that the areas in low latitudes in the Pacific Ocean belong to the high productivity area since Paleogene. Then the Tertiary sedimentary basins are remarkably thicker in the low latitudes than those in the higher latitudes.

Two prominent continuous reflectors recognized by seismic studies are compared with DSDP stratigraphy of the Central Pacific Basin (Tamaki, 1977; Tamaki and Tanahashi, 1981; Tanahashi, 1986). They are named Reflectors A′ and B′ in descending order (Tamaki and Tanahashi, 1981). Reflector A′ is an upper surface of Eocene to Early Oligocene chert layer of chert and radiolarian ooze and/or pelagic clay. Reflector B′ is less continuous than A′ and correlated to surfaces of various layers, e.g. Cretaceous limestone layer, volcanoclastic rocks, pelagic clay, and basaltic sills, based on DSDP results. The lithology of the layers whose surface is recognized as reflector B′ probably depends on local geological setting rather than the regional setting in the Pacific Ocean.

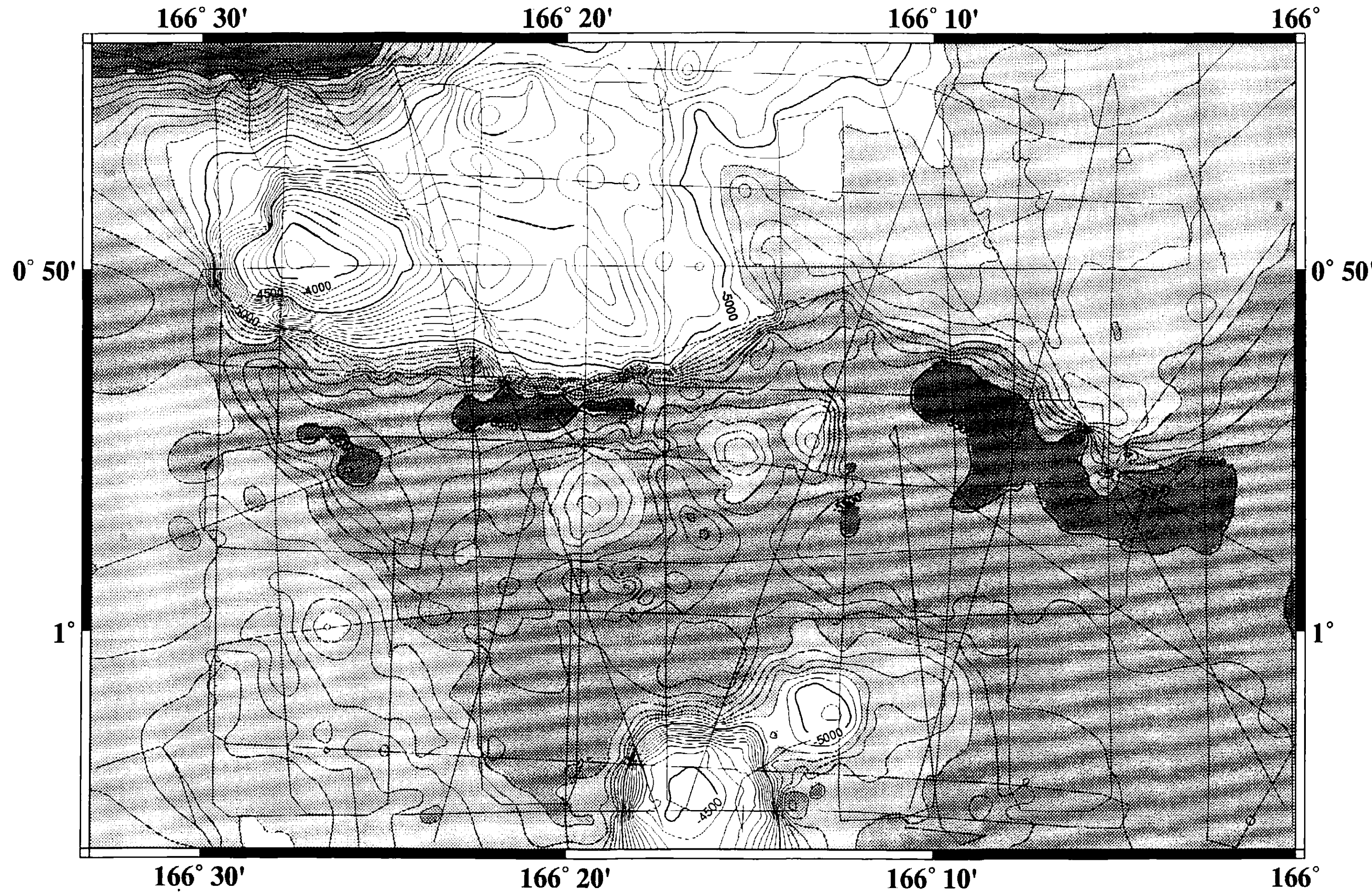

Fig. IV-4 Survey track lines and topography in the detailed survey area.

The uppermost layer, between the sea floor and the reflector A′, is called as Unit I by Tamaki and Tanahashi (1981). It is correlated to the Upper transparent layer by Ewing *et al.* (1968). It is composed mainly of Oligocene to Recent pelagic clay and radiolarian ooze. Channel-fill calcareous turbidite sediment intercalates with Unit I in the eastern margin of the Central Pacific Basin (Orwig, 1981).

The middle layer between the Reflectors A′ and B′ is called Unit IIA by Tamaki and Tanahashi (1981). It is correlated to the Upper opaque and lower transparent layers of Ewing *et al.* (1968). It is composed mainly of Eocene chert in the upper part and of Late Cretaceous pelagic clay in the lower part.

The lower layer between Reflector B′ and the acoustic basement is called as Unit IIB by Tamaki and Tanahashi (1981). Unit IIB is correlatable to lower opaque layer and usually to acoustic basement of Ewing *et al.* (1968). It is distinguished from volcanic basement with the smooth upper surface. The material of the unit is interpreted as limestone or volcanoclastic layer in the Late Cretaceous (Houtz and Ludwig, 1979).

Acoustic basement on seismic profiles is most probably oceanic tholeiite if correlated with DSDP cores.

General description of acoustic units

The distribution of seismic character of Unit I in the survey area is given on Figure IV-5. The map shows the characteristic distribution of (1) transparent layer, (2) turbidite, (3) mixture of transparent and turbidite, and (4) exposed basement.

Thickness of Unit I of the survey area is the largest in basins and smallest on gentle slopes of abyssal hills. Unit I is locally distributed in the basin where the basement morphology is fairly rough. Unit II and basement are in places exposed in steep slopes of the abyssal hills and ridges. The typical seismic profile of the survey area is shown in Figure IV-6.

Unit I is usually an acousticaly transparent and intercalates turbidites in the deep troughs where basement is very deep. Unconformities can be recognized sporadically in the middle of Unit I in basins and in the Nova-Canton Trough. The moat structure occurs locally in the margin of the basin. These unconformities and moat structures suggest strong activity of bottom current during the deposition of Unit I.

Reflector A′ is not always discriminated from the smooth basement because of the similar opaqueness of Unit II to basement. Thus, the distribution of Unit II is not traced all over the survey area. Obvious Reflector B′ is rarely observed in the survey area. The basement has variable morphology. The piercement structures which develop in the turbidite-fill troughs, north of the ridge of the Nova-Canton Trough, suggest diapir-like material ascending during turbidite deposition. The deformation of Unit II and Unit I suggest that unusual structural movements in the abyssal basin occurred during deposition.

Nova-Canton Trough

Seismic profiles over the Nova-Canton Trough are shown in Figure IV-7. It is composed of three isolated troughs, namely the western, central and eastern troughs, in the survey area. The most part of those troughs is filled with transparent layers.

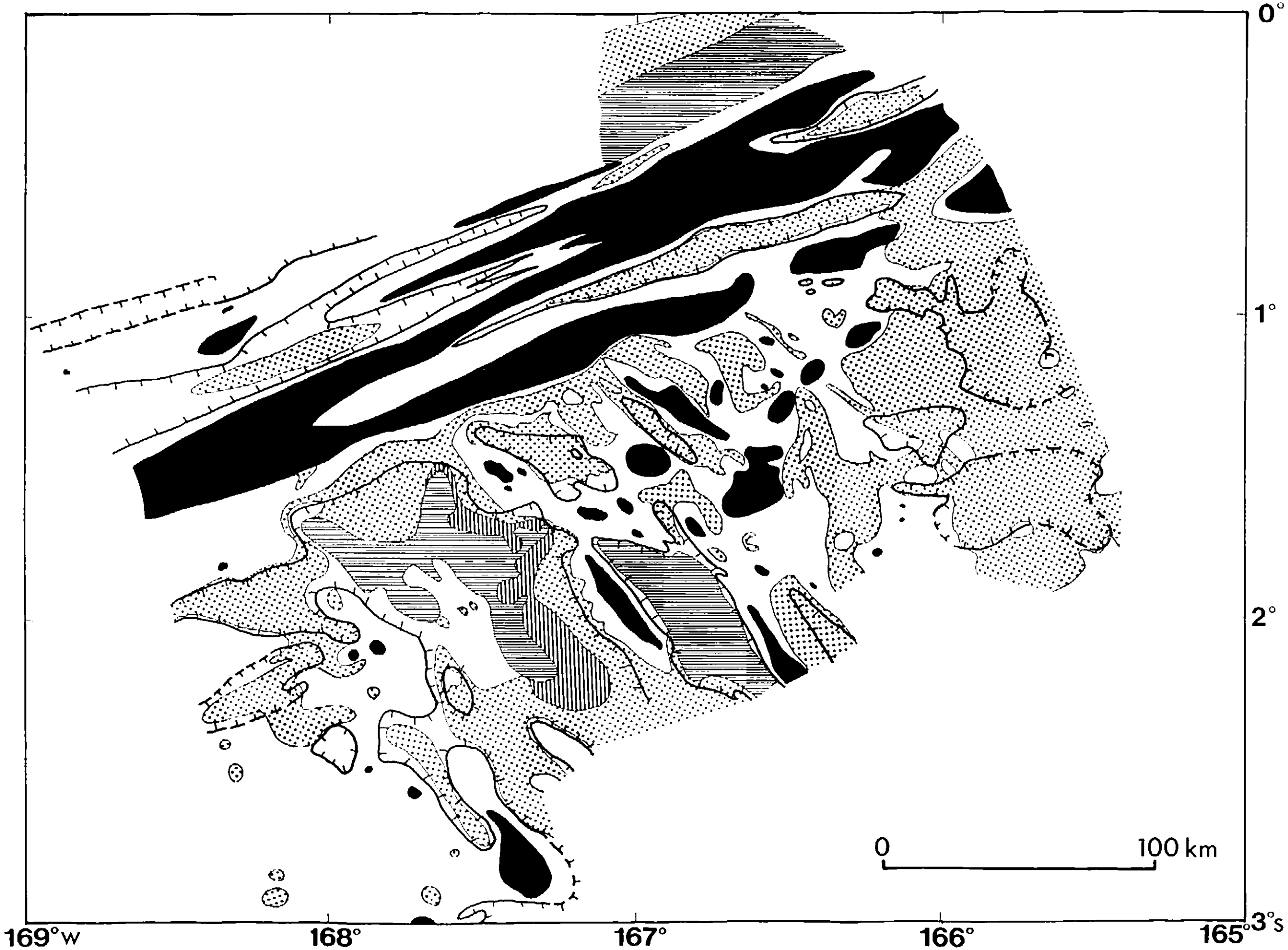

Fig. IV-5 Seismic character distribution map. Dotted area is the transparent layer distributed area. Horizontally lined area is turbidite distributed area. Vertically lined area is the mixture of transparent layer and turbidite distributed area. Black area is basement exposed area. Black and white areas are the area of basement exposed or thin sediment. Black area is the area shallower than 5100 m in water depth.

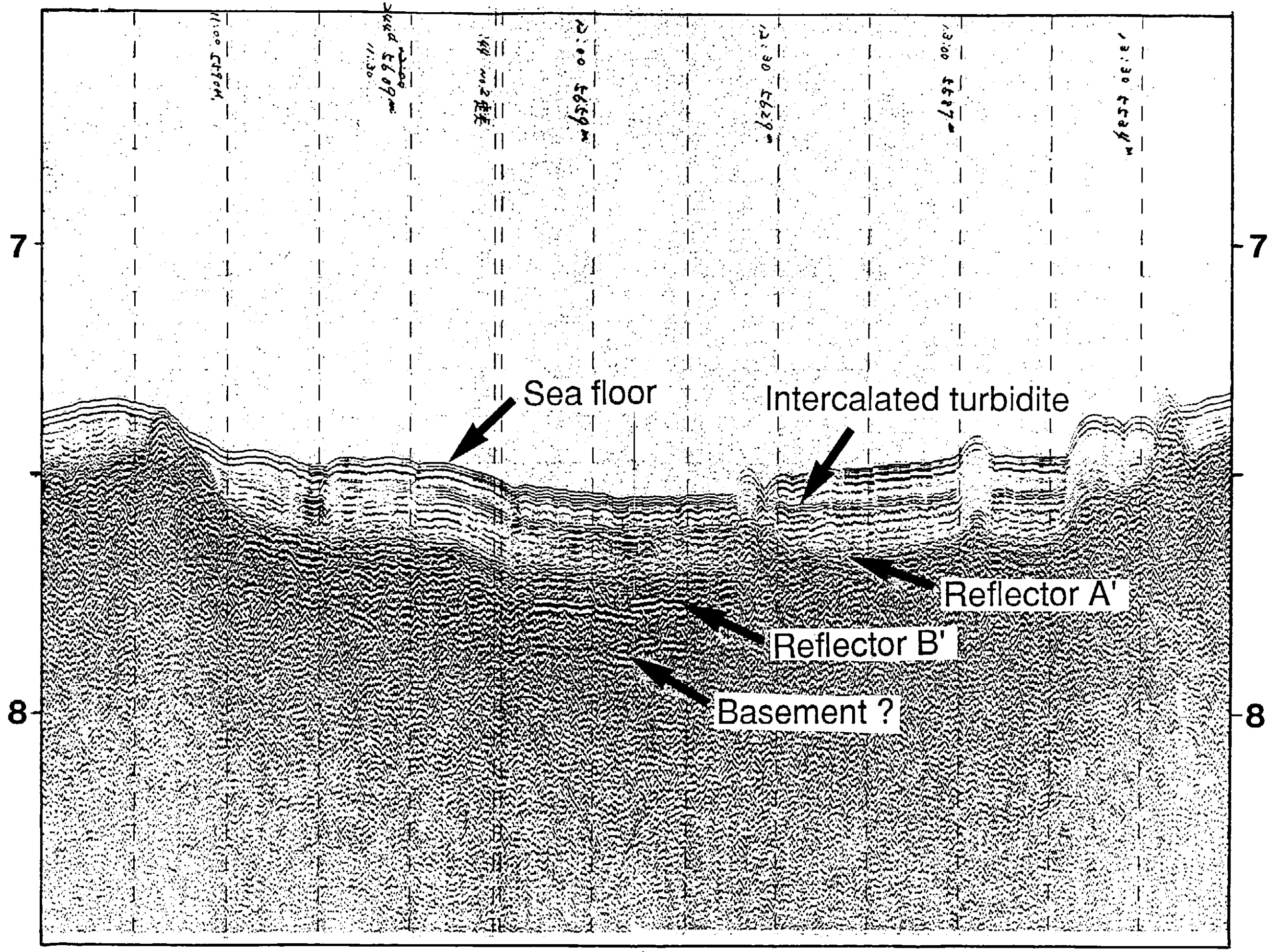

Fig. IV-6 Typical seismic profile of the area. Unit I is defined between the sea floor and the Reflector A′; Unit IIA between Reflectors A′ and B′, and Unit IIB between Reflector B′ and the basement.

a)

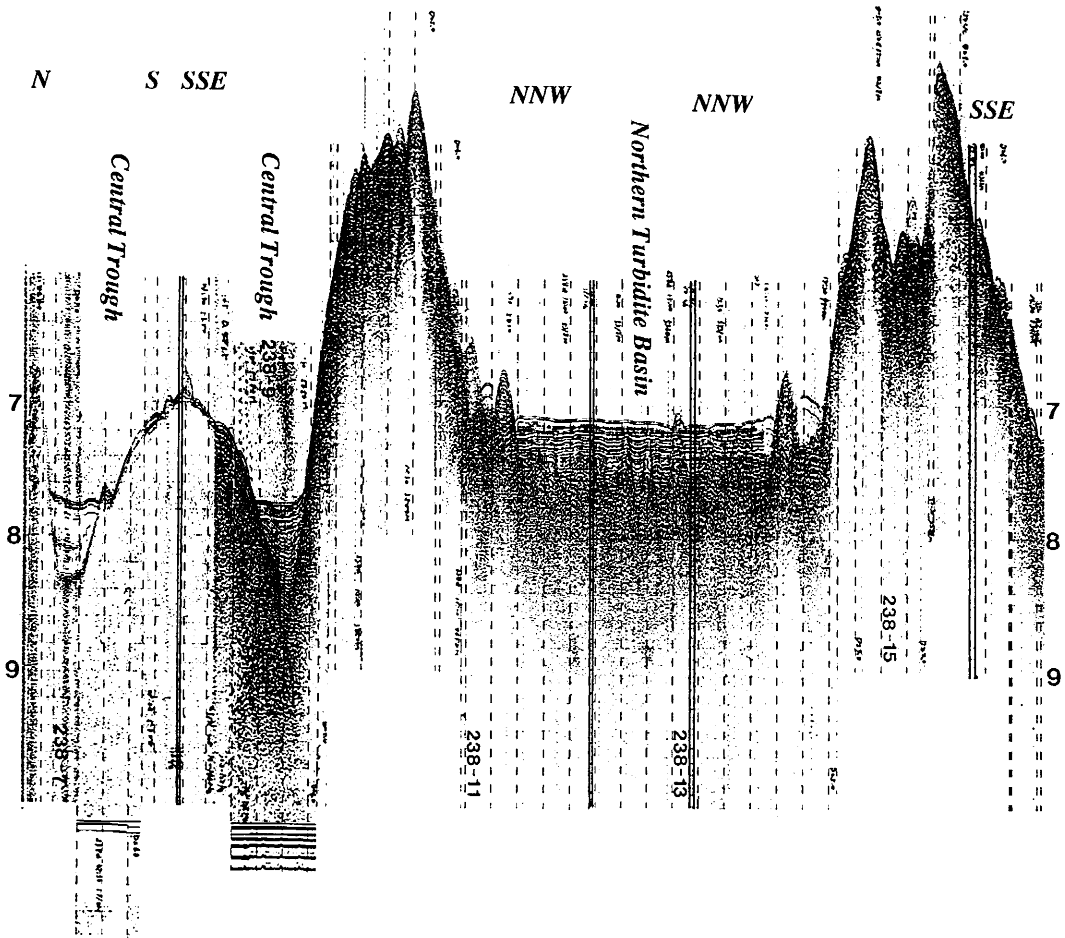

Fig. IV-7 Seismic profiles over the Nova Canton Trough. The tracks for the profiles are shown on Fig. IV-3. a: 238d, b: 239d, c: 240d, d: 267d, e: 270d, f:272d.

b)

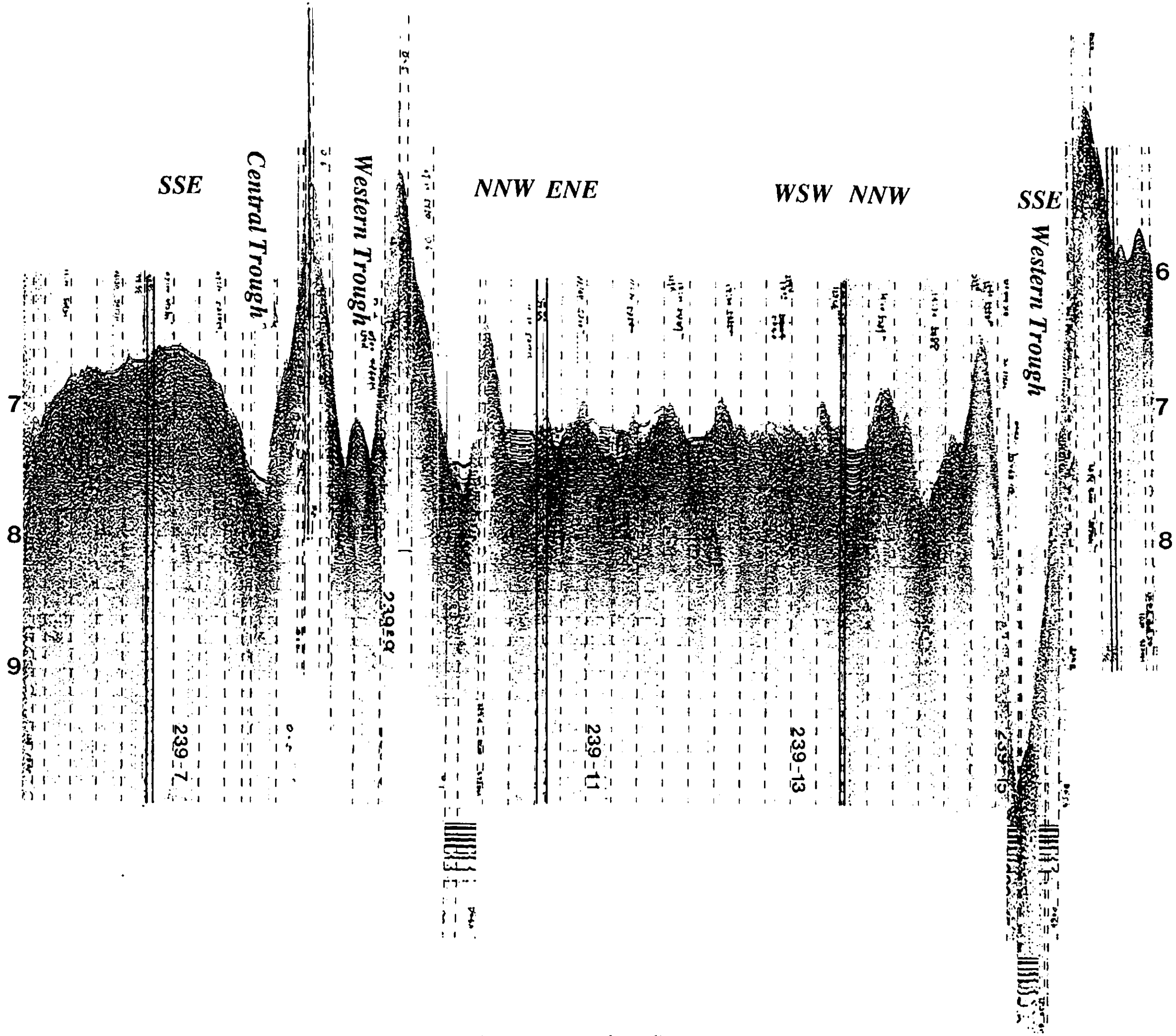

Fig. IV-7 (continued)

c)

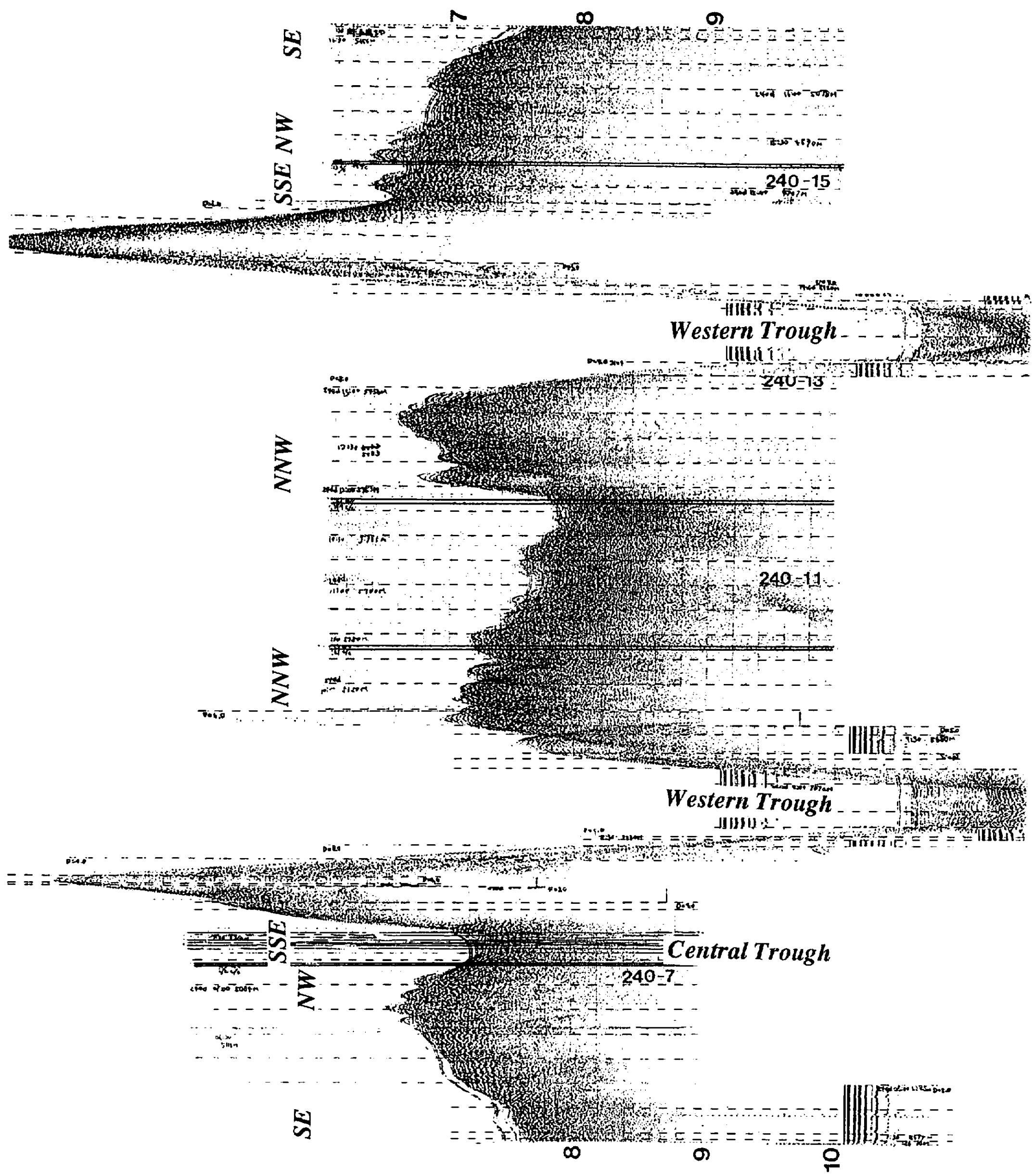

Fig. IV-7 (continued)

d)

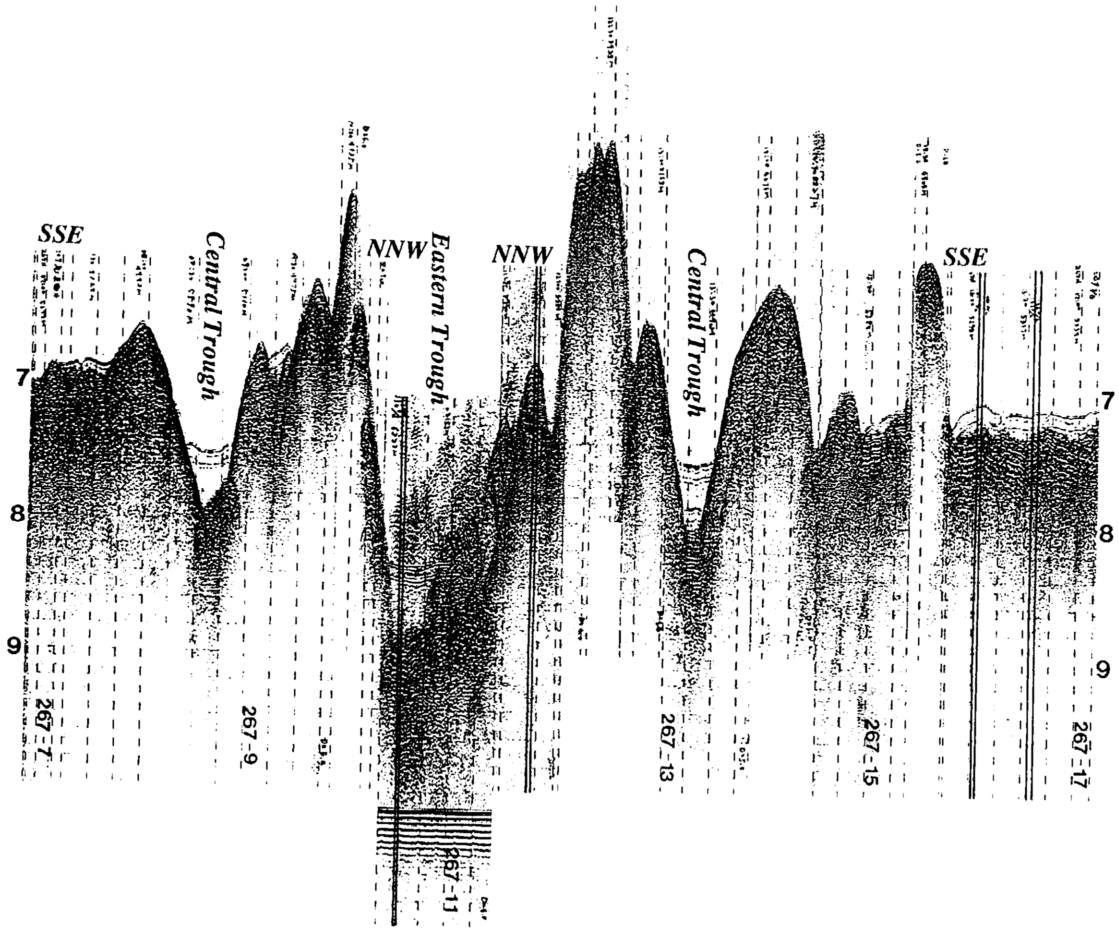

Fig. IV-7 (continued)

e)

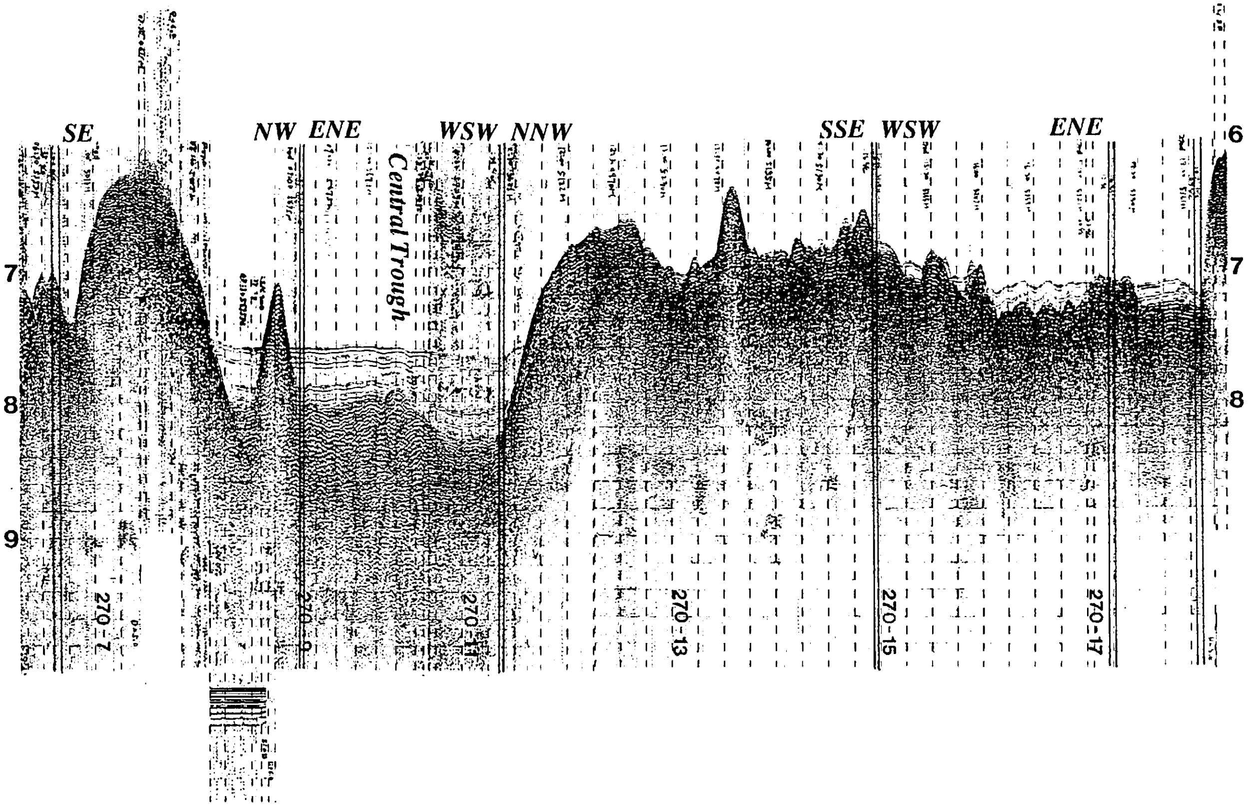

Fig. IV-7 (continued)

f)

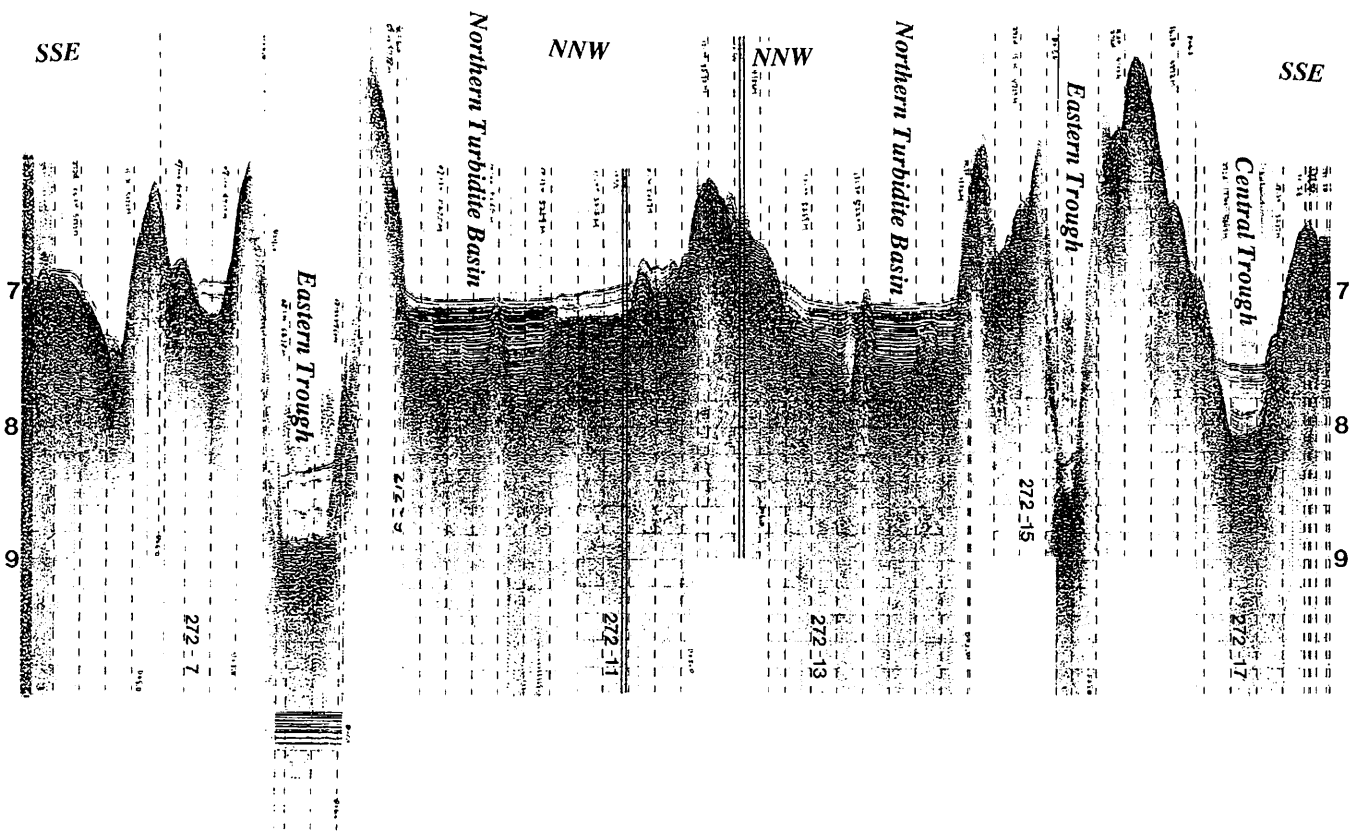

Fig. IV-7 (continued)

The western trough is the deepest and extends to about 170°W (Rosendahl *et al.*, 1975). The uncorrected depth of the trough reaches 7870 m on the 240d (240th Julian day) profile (Fig. IV-7c). The width of the trough is about 10 km. The southern bounding ridge is a narrow and well developed one. The peak depth is shallower than 2400 m. The elevation of the peak from the trough floor is about 6500 m over 10 km horizontal distances whose slope exceeds 30°. Although the northern ridge is not clear along the developed trough and southern ridge, it is developed in the eastern end of the trough (Fig. IV-7b). The trough is bisected at its eastern end, shallows, and disappears. In the trough, a 0.12 sec-thick transparent layer and 0.60 sec-thick semi-opaque layer overlie the relatively smooth opaque basement. The transparent layer shows weak stratifications. This stratification is interpreted as the reflection of interbedded turbidite. The semi-opaque layer shows unclear stratifications and structural disturbances. The layer may contain some volcanic material and deformed after the deposition.

The central trough is developed in the south of the southern boundary ridge of the western trough. It is 5600–5700 m in depth, 10 km in width, and extends about 130 km. The average water depth (about 5300 m) of the adjacent basins in the north, the depth of in the south (5500 m), and the depth of the central trough are not anomalous. Bordering ridges are not prominent ones. The sedimentary layer in the trough has typical acoustic characters; stratified and deformed (Fig. IV-7a), almost transparent (Fig. IV-7d left), and transparent including prominent reflections (Fig. IV-7d right, Fig. IV-7e, and Fig. IV-7f). The maximum thickness of the layer is 0.64 sec. Prominent reflections are observed about two-thirds depth of the sedimentary column from the sea floor. Those reflections show deformed shape. Most of the deformation may have occurred with synsedimentary deepening of the trough. This deformation with possible deepening can be seen on the top section of Figure IV-7a.

The eastern trough is 6250 m in depth and 10 km in width. It has relatively prominent bordering ridges. The sedimentary layer in the trough shows the same character as in the eastern part of the central trough. It is transparent and includes prominent reflections about two-third depth of the column (Fig. IV-8). The reflector does not show the structural contrast between layers on and below. Sedimentary events, possibly Eocene chert deposition, can be correlated with the reflector. A structural gap is observed 0.1 sec below sea floor. It shows some local tectonic episode in the late Neogene time.

Lack of major faults and strong foldings implies that the major tectonic events, which generated the Nova-Canton Trough framework, ceased prior to the deposition of the Tertiary transparent and slightly stratified layers. Trough deepening and some minor reactivation occurred during the deposition. The western trough trapped considerably thick semi-opaque layer of volcanogenic sediments. This volcanism was possibly accompanied with the maturation of the trough structure. After the end of semi-opaque layer deposition and deformation, undeformed very weakly stratified transparent layer was deposited. The weak volcanic and structural activities ceased completely at that time, possibly the late Neogene.

Northern turbidite basin

A typical turbidite basin is observed just to the north of the northern ridge of the

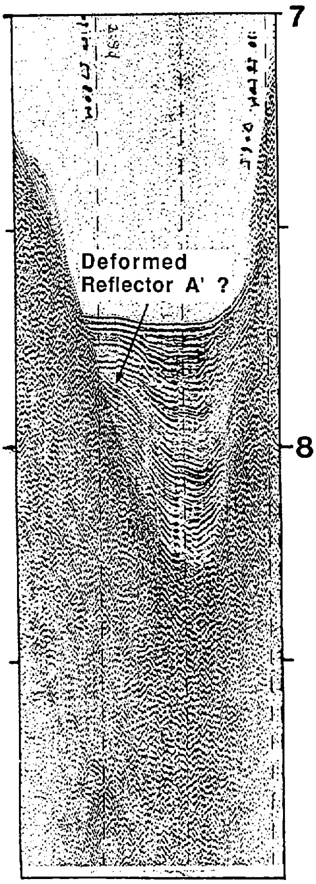

Fig. IV-8
Seismic profile over the eastern trough on 238d. Note the deformed prominent reflector, Eocene chert, at 8.05 sec. The deformation is concordant with overlying column with 0.2 sec thickness. Structural contrast is seen 0.1 sec below the sea floor.

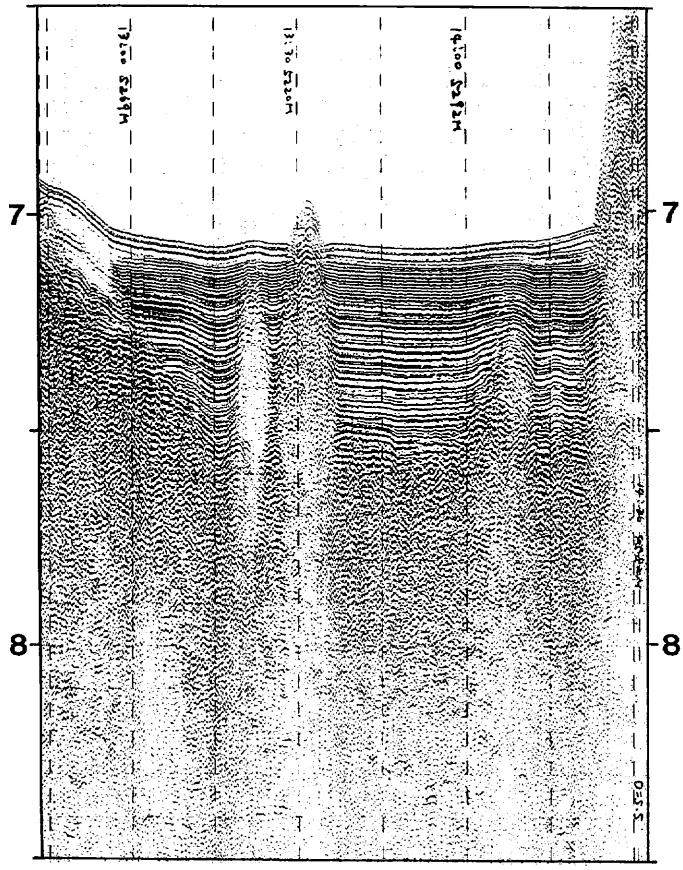

Fig. IV-9
Enlarged seismic profile which intersects the turbidite basin on 272d. Note the exposed piercement structure and dragged reflectors around it. The uppermost layer around the structure is eroded by the bottom current. The layer has less defined stratification than the lower layer, suggesting appearance of the piercement on the sea floor during the deposition.

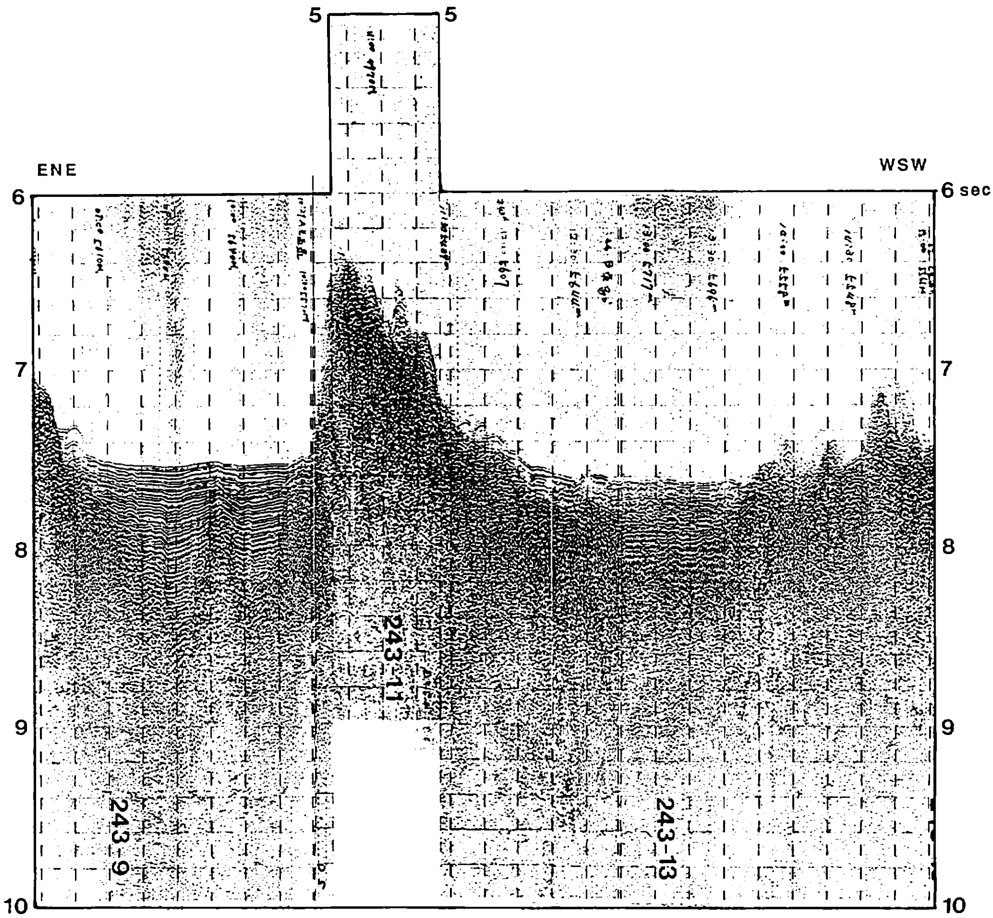

Fig. IV-10 Seismic profile in the two turbidite basins.

Nova-Canton Trough (Figs. IV-7a and IV-7f). It is characterized by a continuous accumulation of finely stratified flat layers. The basin is bordered by the nearly vertical clear boundary with the margin of transparent layer basin or the ridge flank. The width of the basin on two intersection (Fig. IV-7a) are about 25 km. The maximum thickness of the turbidite layer is 0.6 sec.

The water depth of the basin varies from 5260 m in the east (272d east) to 5330 m in the west (238d west). On 239d profile (Fig. IV-7b), poorly developed small turbidite-filled channels whose depth is about 5400 m are observed. On 240d profile (Fig. IV-7c) no turbidite can be seen even in the depression with 5700 m depth. These profiles strongly suggest that the turbidity currents flowed from the east. Turbidite terminates to the west at about 168°W. It is conformable with the distribution of channeled turbidite along the eastern continuation of the Nova-Canton Trough from the Line Islands Ridge and the Central Basin Rise (Orwig, 1981).

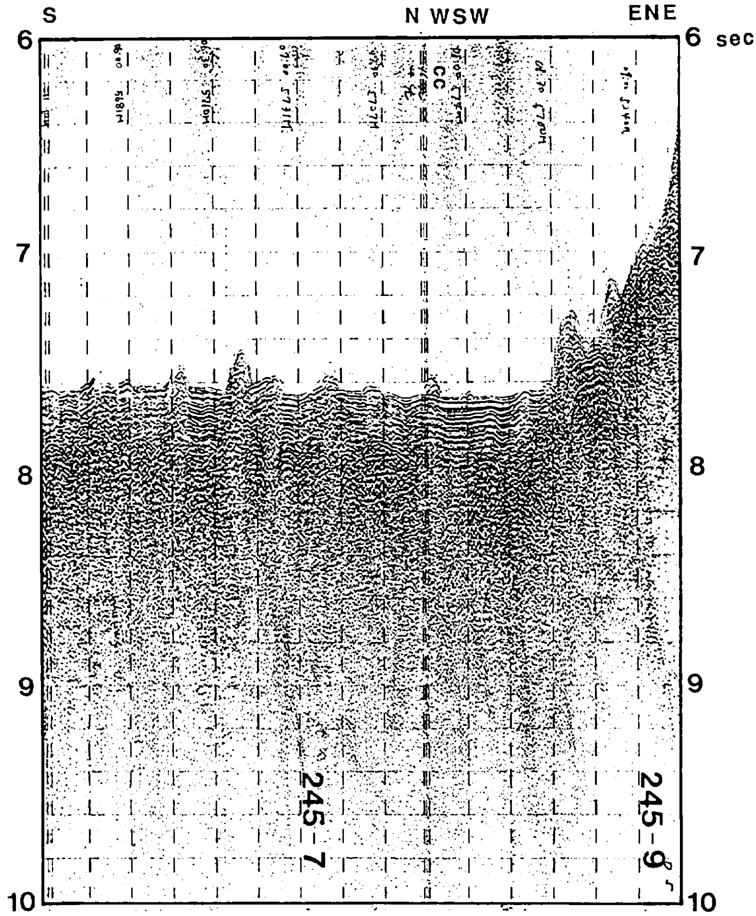

Fig. IV-11 Seismic profile in the western turbidite basin. Note many possible volcanic intrusions.

The uppermost layer (0.06 sec in maximum) of the turbidite basin is relatively transparent. It shows that the frequency of turbidity currents which flowed toward the basin abruptly decreased at probably late Miocene (ca. 10 Ma) based on the thickness of the transparent layer over the turbidite, one-fourth to one-fifth of normal Unit I without turbidite.

Many piercement structures are observed in the turbidite basin. Some of them appeared on the sea floor. Its structureless and dispersed character (Fig. IV-9) is similar to the volcanic basement highs around the basin. They have drag structure of the surrounding turbidite and the moat structures which developed at the end of prominent turbidite deposition. Moat structures caused by bottom current erosion develop around submarine highs (Davies and Laughton, 1972). Then the synsedimentary development of the piercement is strongly inferred.

Lancelot and Embley (1977) discussed the origin of piercement structures in deep oceans. They showed five possible mechanisms, i.e. differential compaction, salt diapirism, igneous intrusion, sediment diapirism, water circulation within the sediments. An existence of basaltic basement high in a piercement structure was revealed by DSDP Site 141 north of the Cape Verde Islands. But Lancelot and Embley (1977) estimated that a plausible mechanism is sediment diapirism, because the mechanism appears to have acted contemporaneously with a sedimentation and there is no evidence of widespread igneous intrusions. Such sedimentary diapirism occurred when old pelagic sediments move upward by loading of thick terrigenous turbidite. They suggested that volcanic intrusion may sometimes trigger such diapirism.

The model by Lancelot and Embley (1977) is based on the fact that a general sedimentary layer assemblage of a lower pelagic layer and overlying turbidite layer on rough basement is recognized where piercement structure is dominant. In the survey area, a turbidite layer rests directly on rough basement. The alternative water-circulation model of Lancelot and Embley (1977) in the case of thinly covered sedimentary layer on the basement is also ruled out. The frequent appearance of the structure over the sea floor is difficult to explain with sedimentary diapirism. Therefore, it is concluded that the piercement structures in the northern turbidite basin in the survey area were developed by igneous intrusion.

Southern hills and basins

Northwesterly-elongated submarine hills and basins area rest on the south of the Nova-Canton Trough. Northwestern trend coincides with those of the North Plateau of Manihiki Plateau (Winterer *et al.*, 1974) to the south of survey area. The obvious trend of the survey area may be interpreted normal to the spreading system consisting the trough which formed around 105 Ma just after the rearrangement of spreading geometry (Model I by Winterer *et al.*, 1974). But recent studies of SeaMARC II (a long-range side-scan sonar) imagery strongly suggest that these northwesterly trending hills and basins are parallel to the spreading system (Joseph *et al.*, 1990, 1991). Many knolls are observed between the depressions and southern slope of the southern ridge of the Nova-Canton Trough.

Two parallel NNW-SSE elongated sedimentary basins, which trapped considerable turbidite deposits, develop in the western and central portion (Fig. IV-10). The water depths of these basins are about 5500 to 5750 m. Turbidite is generally distributed in the area whose depths are deeper than 5600 m. Although the basement depth is not clear, the thickness in the central turbidite basin is 0.4 sec or more. In the western turbidite basin, the thickness of turbidite is about 0.25 sec or more. The most probable source of the turbidity currents is the Manihiki Plateau to the south.

The acoustic character of the turbidite sequence varies from clearly to moderately stratified but not so clear when disturbed by fine to small scale deformations. The deformation may be caused by sedimentary slumping, and piercement structure or foldings associated with the volcanic intrusions. Many possible igneous intrusions are observed in the western turbidite basin (Fig. IV-10). These intrusions drag and deform the stratified sequences.

The transparent layer is usually developed on the gentle slopes and depressions

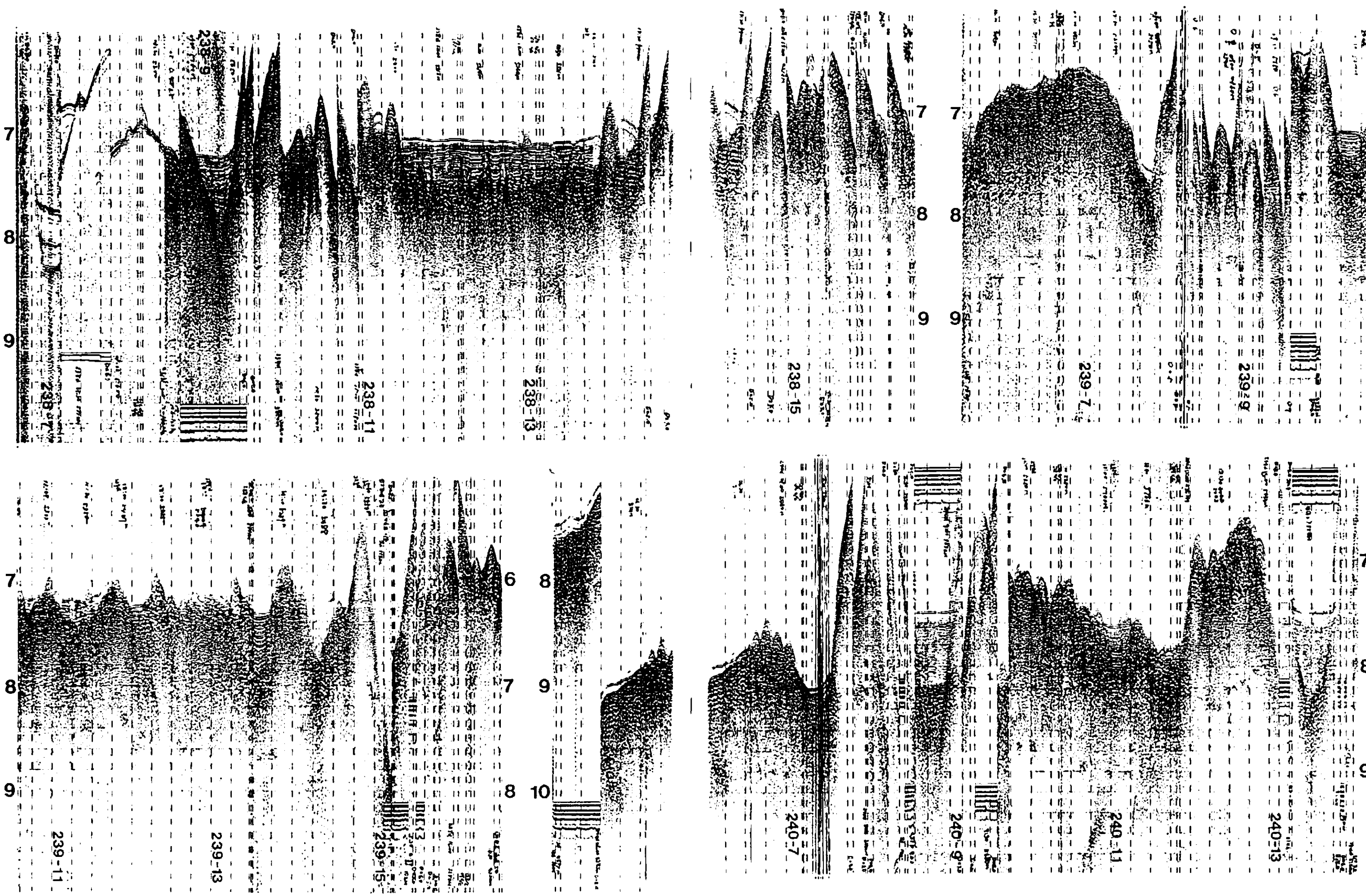

Fig. IV-12 All the seismic reflection records during GH82-4 cruise, with the indication of the GMT days and hours and two-way travel time in seconds.

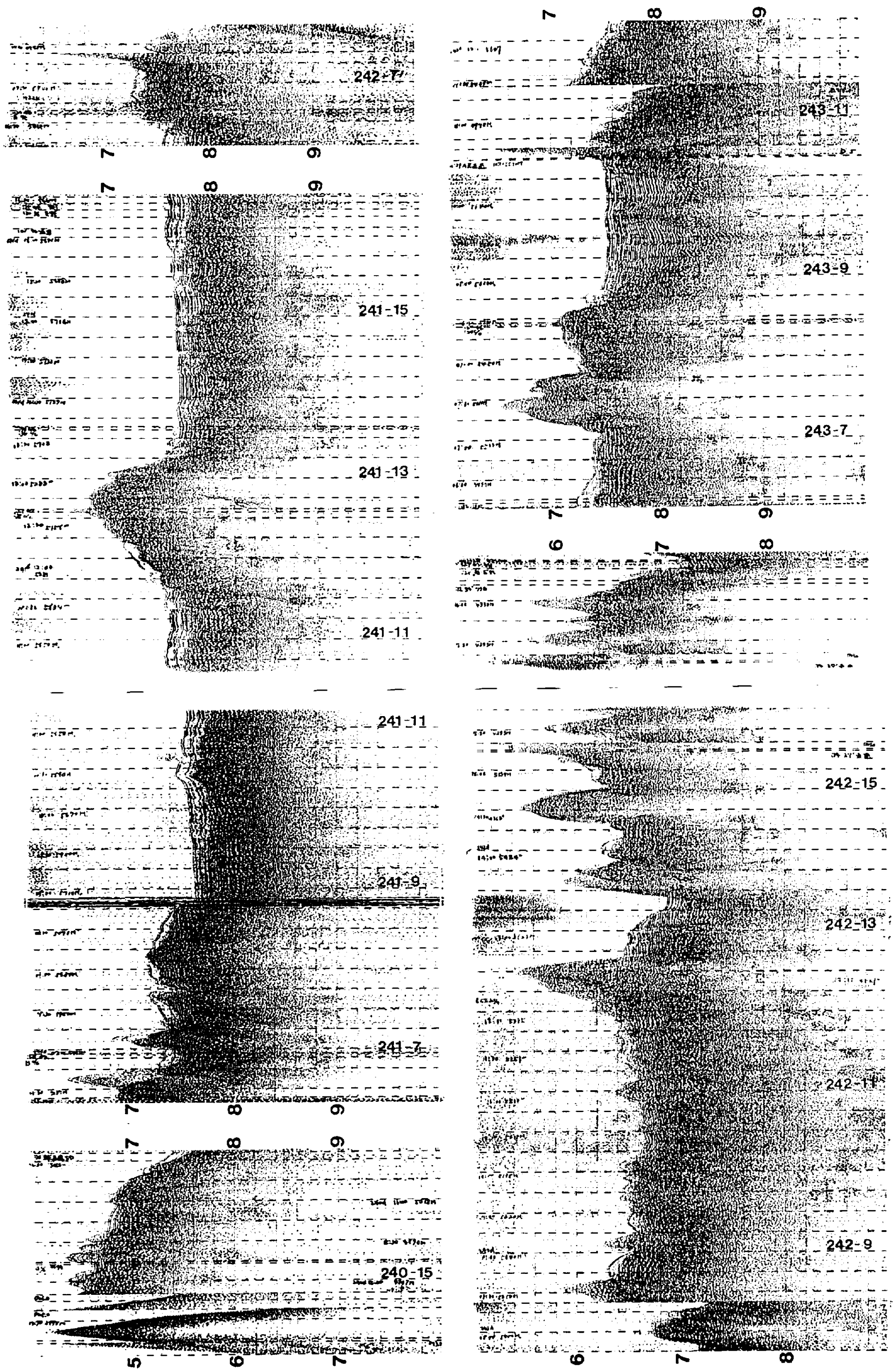

Fig. IV-12 (continued)

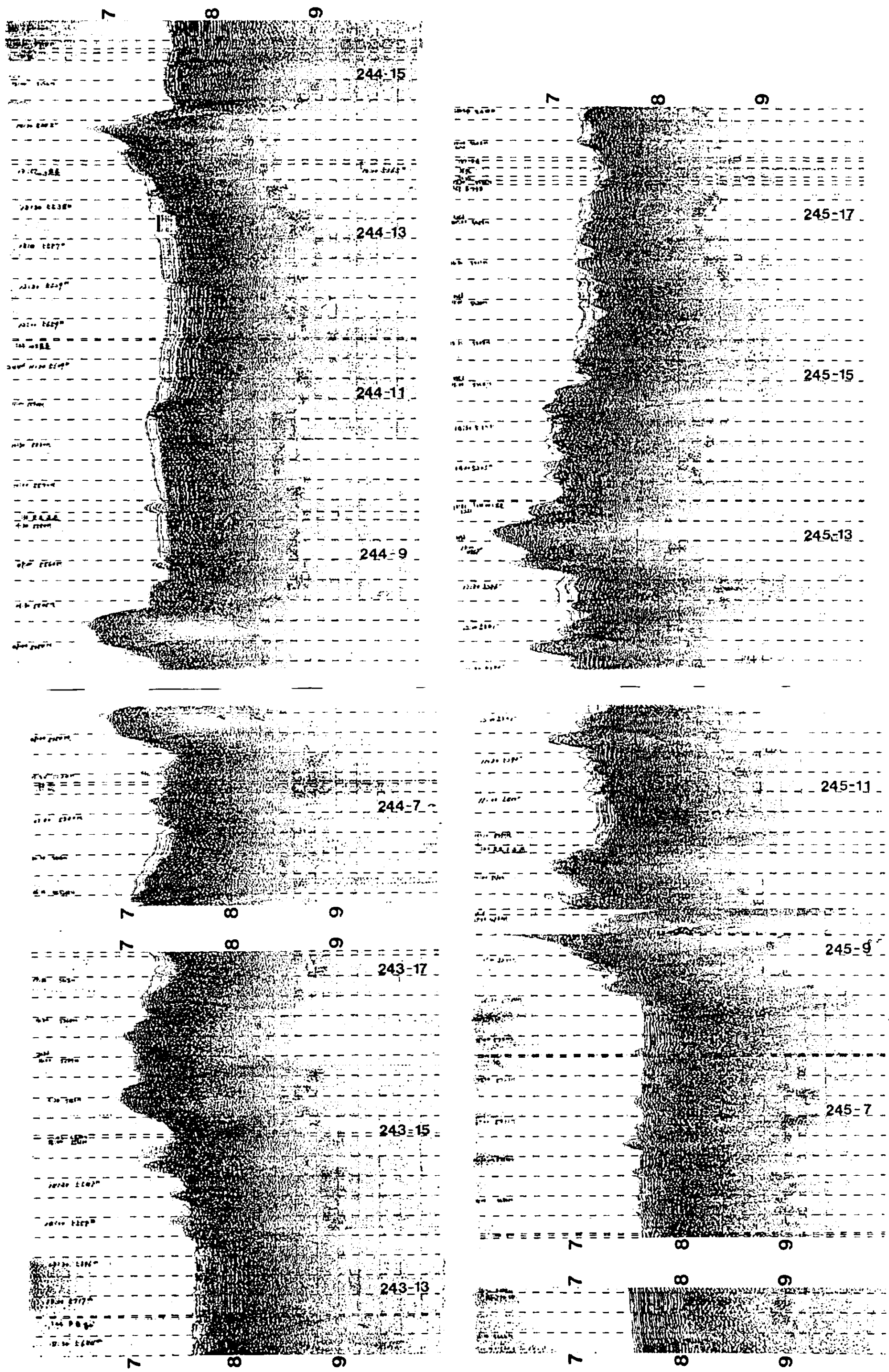

Fig. IV-12 (continued)

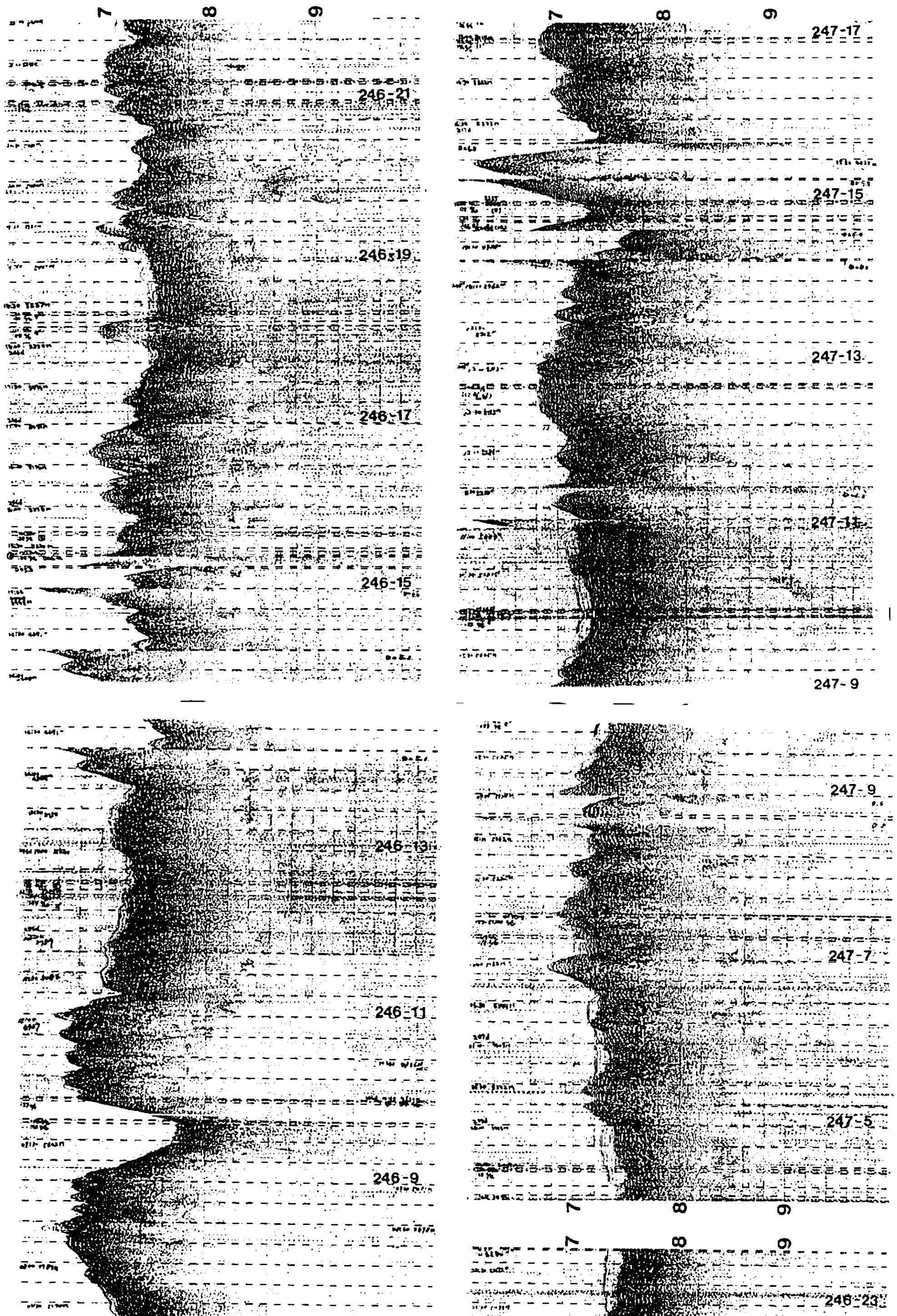

Fig. IV-12 (continued)

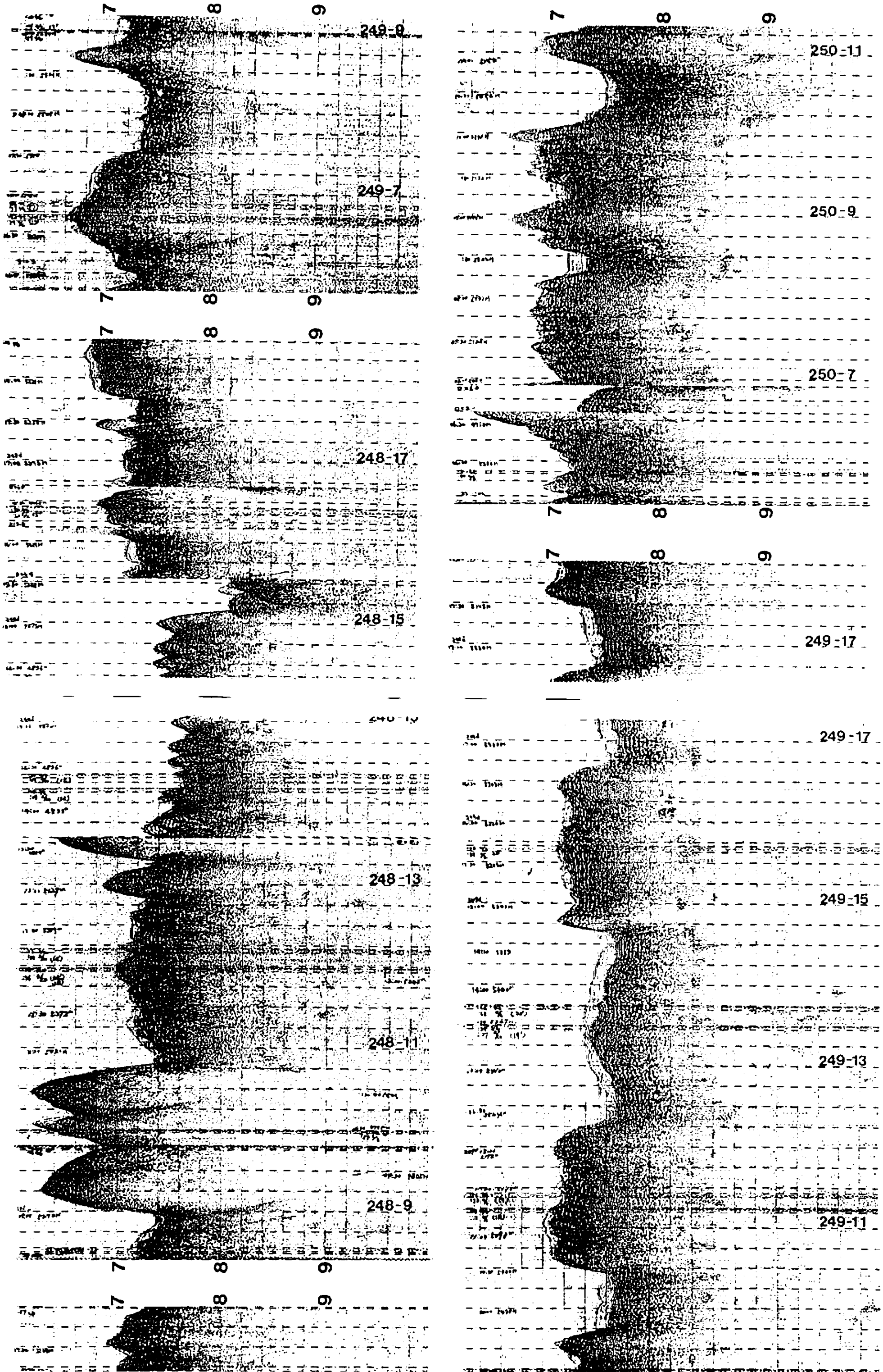

Fig. IV-12 (continued)

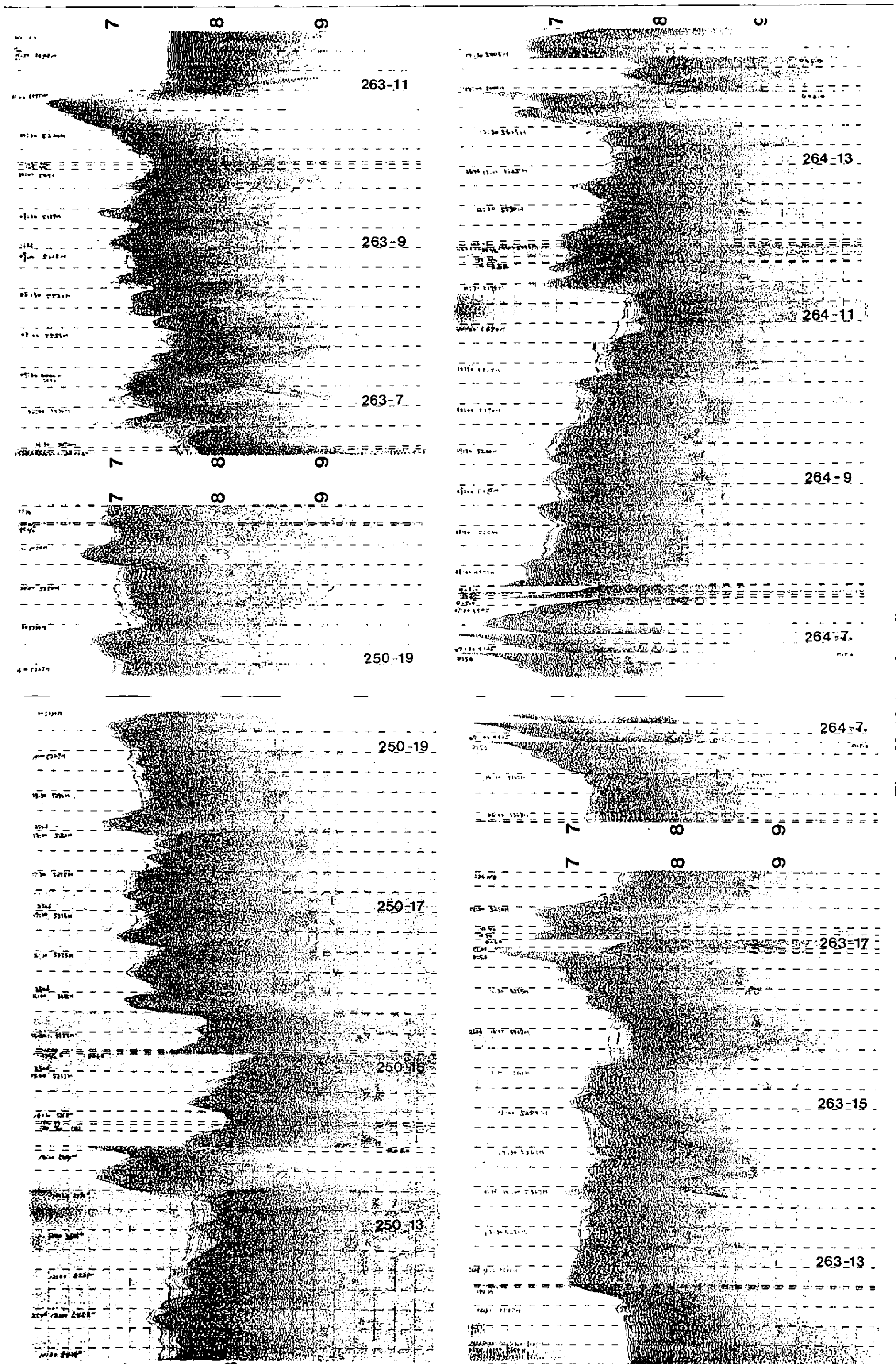

Fig. IV-12 (continued)

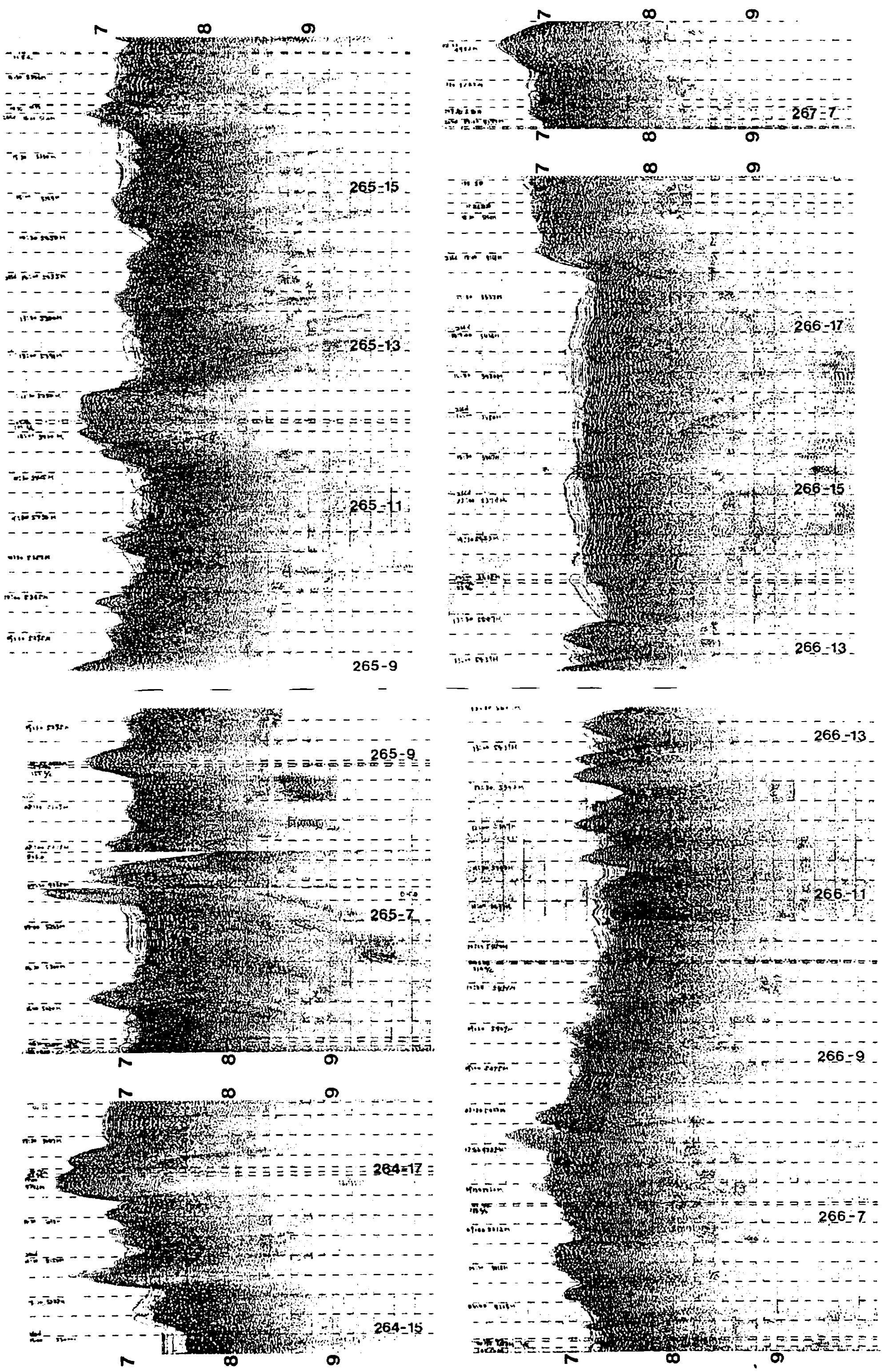

Fig. IV-12 (continued)

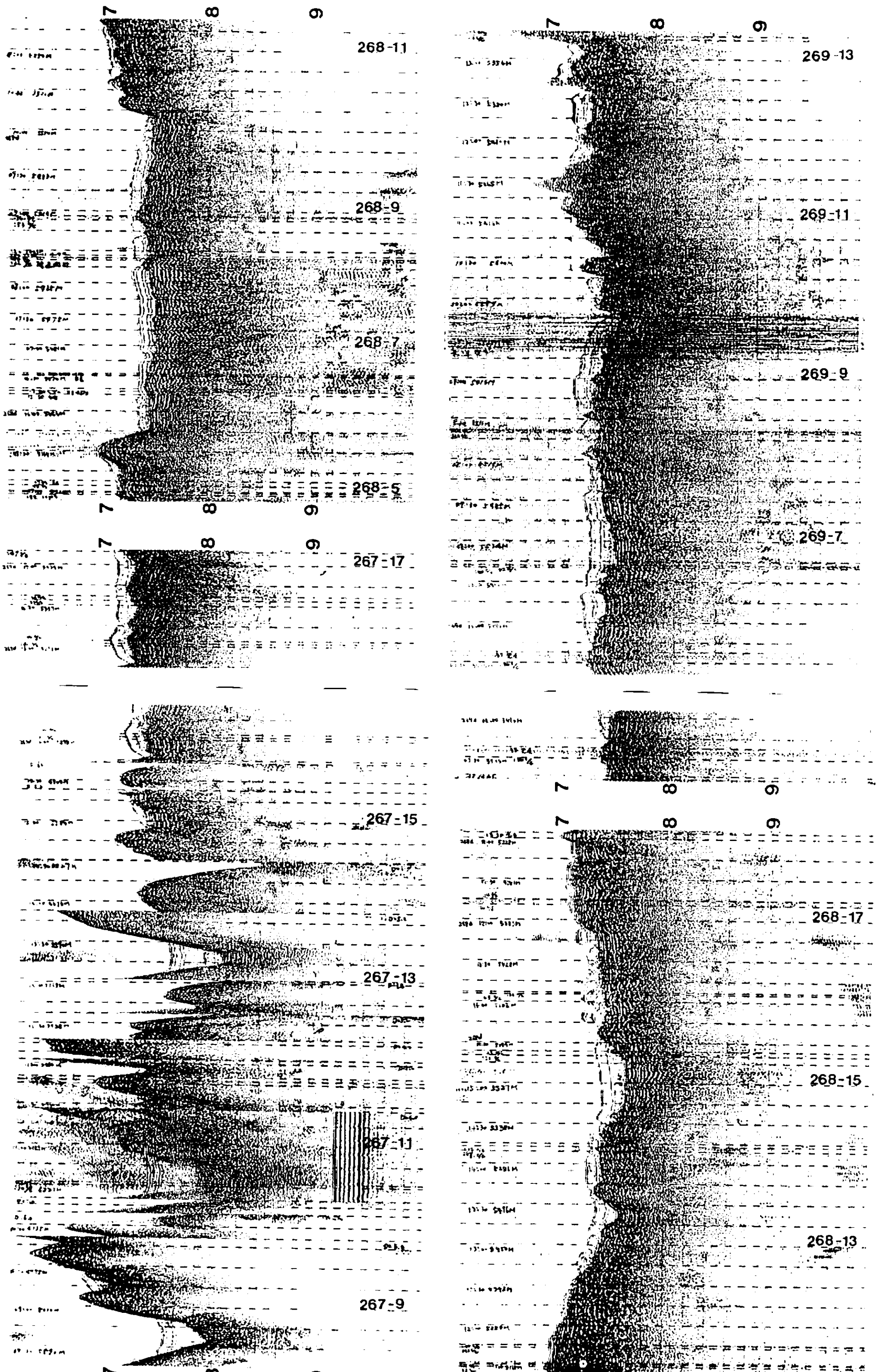

Fig. IV-12 (continued)

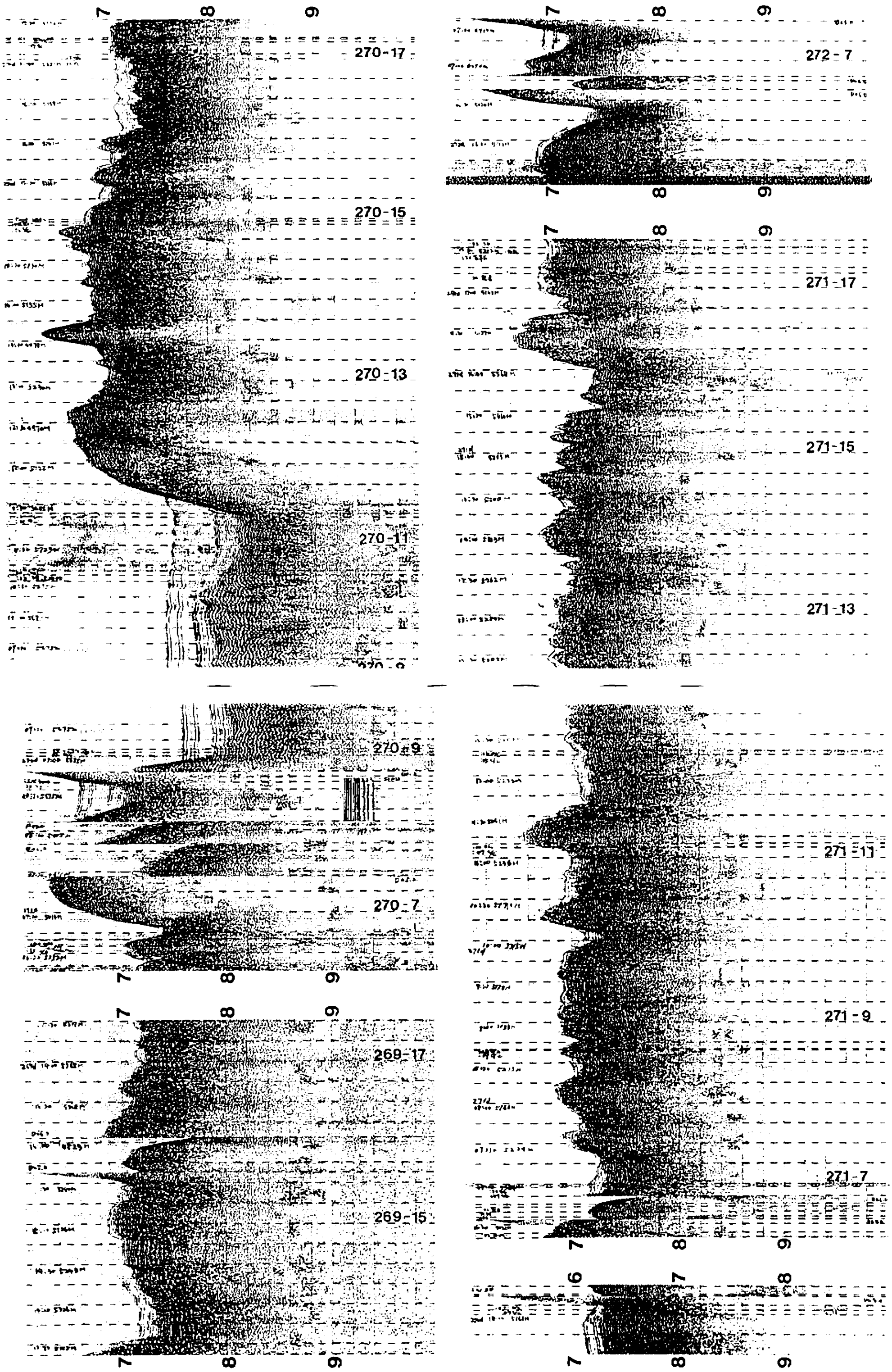

Fig. IV-12 (continued)

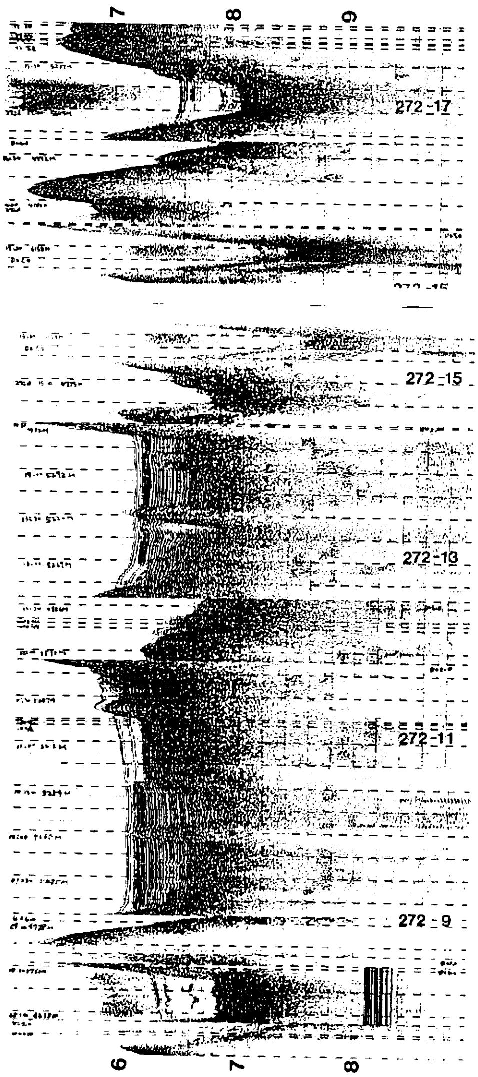

Fig. IV-12 (continued)

Table IV-1 Equipment and conditions of seismic reflection survey during GH82-4 cruise.

survey area	General Survey Area		Detailed Survey Area	
Seismic source	Bolt PAR air gun		Bolt PAR air gun	
Firing chamber volume	150 ci without WSK		120 ci with WSK	
Air compressor	Norwalk APS120 type (120 SCFM)			
Operating pressure	1600-1700 psi (110 - 115 kg/cm^2)			
Shot interval	10 sec		10 sec	
Towing speed	10 knot		10 knot	
Hydrophone streamer	GSJ type with 150 GeoSpace MP18-200 elements			
Recorder		LSR 1811		
Amplifier		Ithaco 451 and 3171		
Filter		Ithaco 4111		
Filtered range (Hz)	16 -125	60 -300	20 - 125	60 -300
Record length(sec)	4	2	4	2
Paper feeding rate (lines/inch)	100	50	100	50
Vertical exaggeration	32.2	32.2	32.2	32.2

where water depths are shallower than 5600 m. The layer is not very thick where the water depth is shallower than 5100 m. The thickness of the layer varies from a maximum of 0.22 sec to zero. On the gentle basement, it usually covers the lower unit with almost constant thickness. A relatively thick transparent layer develops in the eastern sedimentary basins at water depths of 5500 m or more.

Structural movement of the area

If the NNW topographic trend is normal to spreading system, structural roll of the Nova-Canton Trough changed from accreting oceanic rift to active transform plate boundary at the rearrangement of sea floor spreading geometry at 110 Ma. But if the trend is parallel to spreading system, the trough originally developed as an transform faults. The transform movement probably deepened the original structure with a possible slight extensional component and resulted in the present great depth of the Nova-Canton Trough. Minor deformations concordant with basement topography are observed in the transparent or semi-opaque sedimentary fills in the trough. Rare deformation of the sediments in the trough suggests no major structural movement after construction of the framework of the trough until the supposed transform activity.

References

Davies, T. A. and Laughton, A. S. (1972) Sedimentary processes in the North Atlantic. In: A. S. Laughton, W. A. Berggren *et al.* (eds.) *Init. Rept. DSDP*, vol. 12, Washington, D.C., U.S. Government Printing Office, p. 905-934.

Ewing, J., Ewing, M., Aitken, T. and Ludwig, W. J. (1968) North Pacific sediment layers measured by seismic profiling. In: L. Knopoff, C. L. Drake and P. V. Hart (eds.), The Crust and Upper Mantle of the Pacific Area. *Amer. Geophys. Union, Monogr.*, vol. 12, p. 147-173.

Heezen, B. C., MacGregor, I. D., Foreman, H. P., Forristal, G., Hekel, G., Hesse, R., Hoskins, R. H., Jones, E. J. W., Kaneps, A., Krasheninnikov, V., A., Okada, H. and Ruef, M. H. (1973) Diachronous deposits: a kinematic interpretation of the post Jurassic sedimentary sequence on the Pacific Plate. *Nature*, vol. 241, p. 25-32.

Houtz, R. E. and Ludwig, W. J. (1979) Distribution of reverberant subbottom layers in the southwest Pacific Basin. *Jour. Geophys. Res.*, 84, p. 3497-3504.

Joseph, D., Shor, A. N., Hussong, D. M. and Malikides, M. (1990) The origin of the Nova Canton Trough reexamined. *Transactions, Amer. Geophys. Union*, vol. 71, p. 1640.

———, Taylor, B. and Shor, A. N. (1991) New sidescan sonar and gravity evidence that the Nova-Canton Trough is a fracture zone. *Transactions, Amer. Geopys. Union*, vol. 72, p. 444.

Lancelot, Y. and Embley, R. W. (1977) Piercement structures in deep ocean. *Amer. Assoc. Petrol. Geol. Bull.*, vol. 61, p. 1991-2000.

Mizuno, A. and Nakao, S. (1982) Regional Data of Marine Geology, Geophysics, and Manganese Nodules: The Wake-Tahiti Transect in the Central Pacific, January-March, 1980 (GH80-1 cruise). *Geol. Surv. Japan Cruise Rept.*, no. 18, p. 1-399.

Orwig, T. L. (1981) Channeled turbidites in the eastern Central Pacific Basin. *Mar. Geol.*, vol. 39, p. 33-57.

Rosendahl, B. R., Moberly, R., Halunen, A. J., Rose, J. C. and Kroenke, L. W. (1975) Geological and geophysical studies of the Canton Trough Region. *Jour. Geophys. Res.*, vol. 80, p. 2565-2574.

Tamaki, K. (1977) Study on substrate stratigraphy and structure by continuous seismic reflection profiling survey. *Geol. Surv. Japan Cruise Rept.*, no. 8, p. 51-74.

——— and Tanahashi, M. (1981) Seismic reflection survey in the northeastern margin of the central Pacific Basin. *Geol. Surv. Japan Cruise Rept.*, no. 15, p. 77-99.

Tanahashi, M. (1986) Seismic reflection survey in eastern part of Central Pacific Basin (GH81-4 Area). *Geol. Surv. Japan Cruise Rept.*, no. 21, p. 33-48.

Winterer, E. L. (1973) Regional problems. In: E. L. Winterer, J. L. Ewing *et al.* (eds.), *Init. Rept. DSDP*, vol. 17, U.S.Govt. Printing Office, Washington, D.C., p. 911-922.

——— (1976) Anomalies in the tectonic evolution of the Pacific. in "The Geophysics of the Pacific Ocean Basin and its margin", *Amer. Geophys. Union. Geophysical monograph*, vol. 19, p. 269-278.

———, Riedel, W. R. *et al.* (1971) Site 66. *Initial Rept. DSDP*, vol. 7. U.S. Govt. Printing Office, Washington, D.C., p. 725-819.

———, Lonsdale, P. F., Matthews, J. L. and Rosendahl, B. R. (1974) Structure and acoustic stratigraphy of the Manihiki Plateau. *Deep-Sea Res.*, vol. 21, p. 793-814.