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IV. SEISMIC REFLECTION SURVEY IN EASTERN PART OF CENTRAL PACIFIC BASIN (GH81-4 AREA)

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Introduction

This paper presents results of detailed seismic reflection survey, which was carried out in eastern part of Central Pacific Basin (2° 30′–3° 30′ N, 169° 15′–169° 55′ W) at R/V Hakurei-maru GH81-4 cruise. The surveyed area is shown in Fig. IV-1. The area was selected, based on the data of GH80-1 cruise, to study the relation between manganese nodule distribution and geologic environments. The area is belonged to the Central Pacific Basin, which is bordered by Mid-Pacific Seamounts in the north, Marshall-Gilbert Ridge in the west, Nova-Canton Trough in the south, and Line Islands Ridge in the east.

The GH81-4 survey area is located between eastern mountainous area to the west of Central Basin Rise and western relatively flat area where the Phoenix lineation zone is developped. At GH81-4 cruise, detailed seismic reflection and refraction, gravity, and magnetic surveys, and many sediment samplings were carried on in a small rectangular area with 40 and 30 nautical miles in N-S and E-W directions, respectively.

Survey track lines are shown in Fig. IV-2. The average water depth of the survey

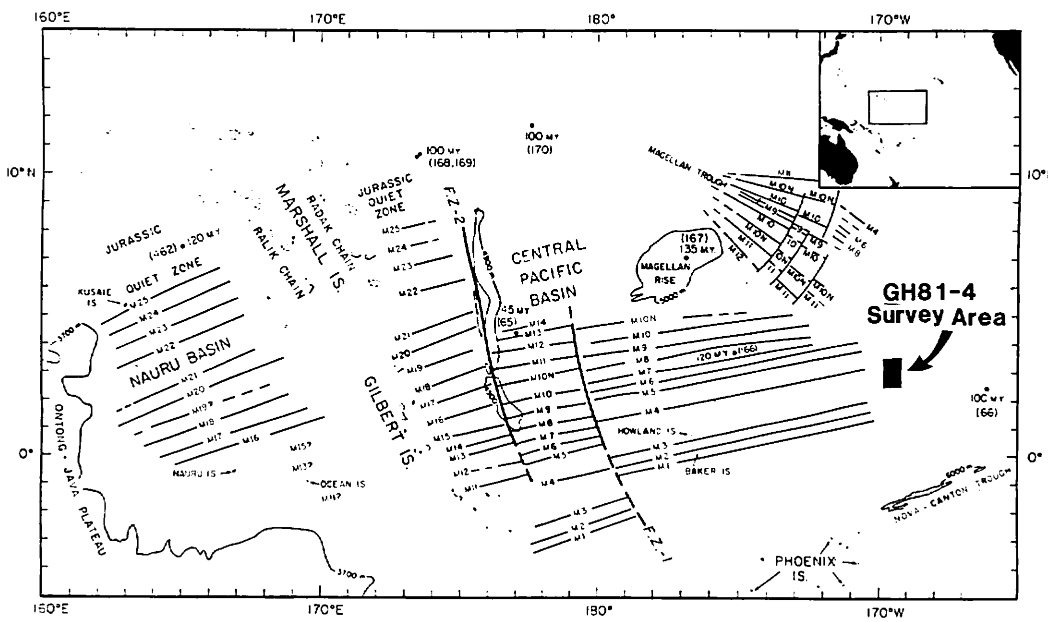


Fig. IV-1 Location of GH81-4 survey area. Base map is the magnetic lineation distribution map by TAMAKI *et al.* (1979).

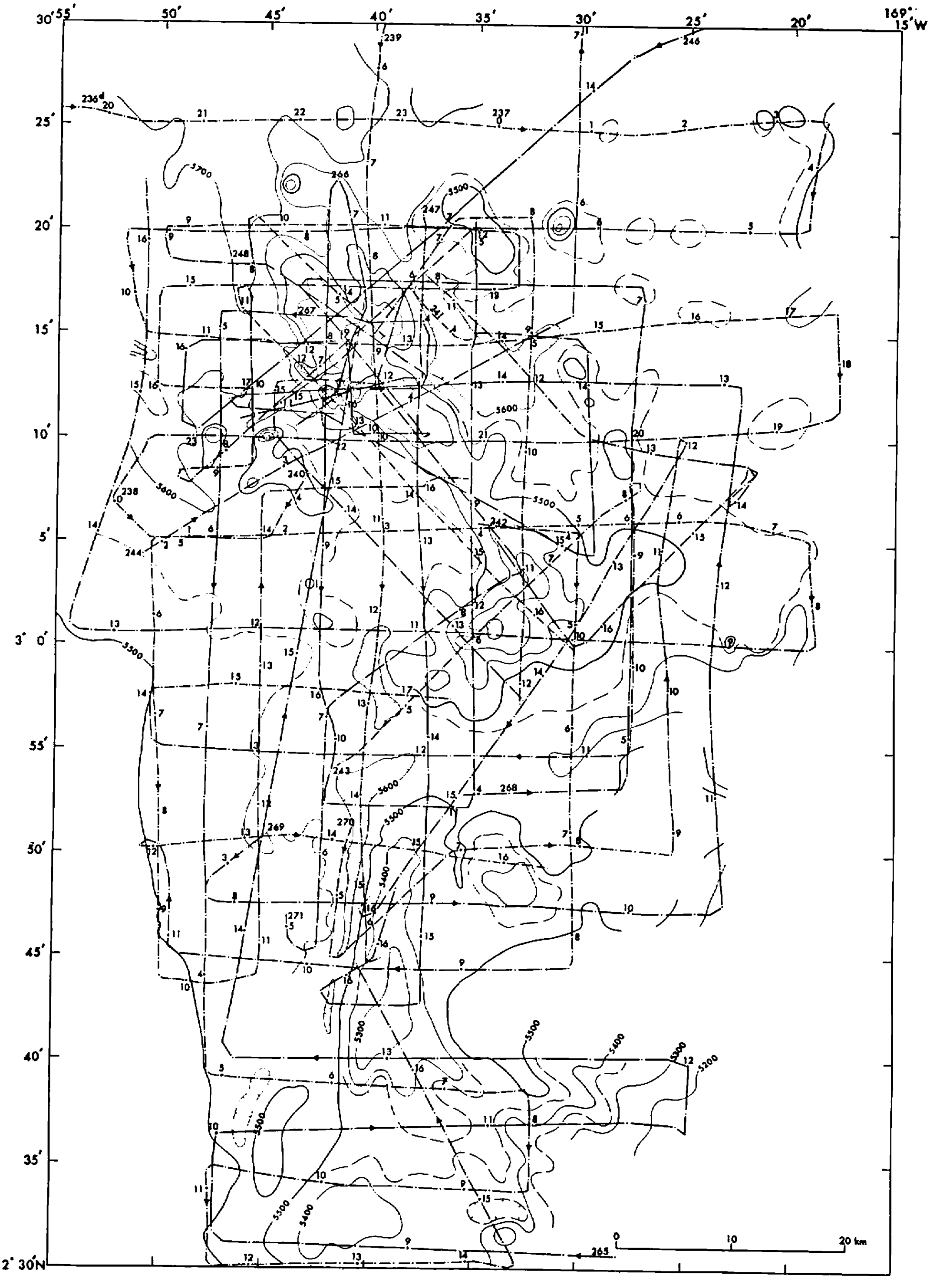


Fig. IV-2 Survey track lines and topography in GH81-4 survey area.

Table IV-1 Equipment and conditions of seismic reflection survey in GH81-4.

source name	T-water gun	PAR air gun
firing chamber volume	80 ci	150 ci without WSK
trigger interval	10 sec	
towing speed	6 knots	
air compressor	Norwalk APS120 type (120 SCFM)	
operating pressure	1600 ~ 1700 psi (110 ~ 115 kg/cm^2)	
hydrophone streamer	GSJ type with 100 Teledyne T-1 elements	
filterd range	31.5 ~ 250 Hz	25 ~ 125 Hz
recorder	LSR 1811	UGR 196C
record length	2 sec/scan	4 sec/scan
paper feeding rate	50 lines/inch	100 lines/inch
vertical exaggeration	17.4	

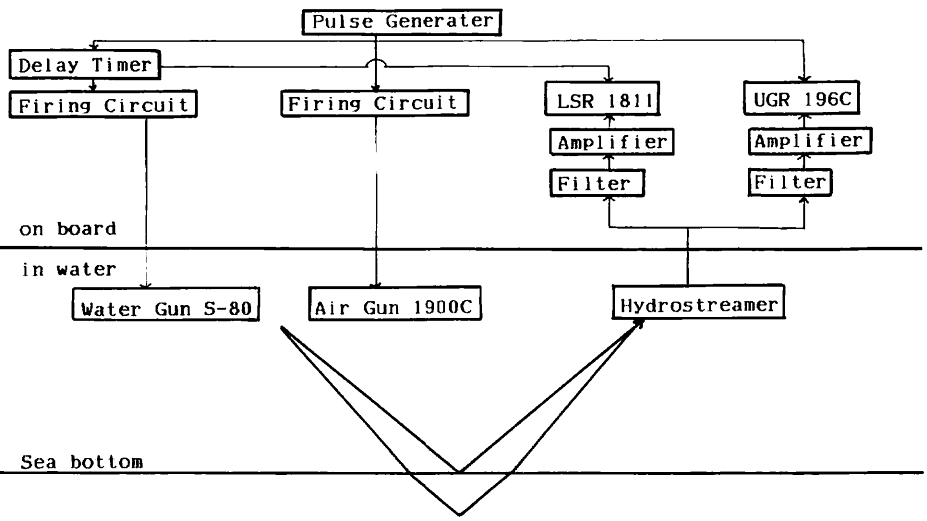


Fig. IV-3 Block diagram of the seismic reflection survey system in GH81-4.

area is about 5,500 m. There are two knolls and many small topographic highs in the area. Northern and southern knolls elongates in northwest-southeast and in north-south, respectively. They are shallower in the tops about 300 ~ 500 m than the surrounding basin.

Instrumentation and data collection in GH81-4

Survey equipment and operating conditions are listed on Table IV-1. The conceptual block diagram of the reflection survey system is shown on Fig. IV-3. In order to get reflection profiles with both high resolution and deep penetration, two types of seismic sources were used. Bolt PAR 1900C air gun with 150 ci firing chamber was used for deep penetration on the one hand, and Seismic Systems Inc. S-80 water gun was used for higher resolution on the other. They were operated reciprocally in the time sequence as shown on Fig. IV-4. The source pulse shapes in time domain, which were observed as direct waves by recording system of the cruise, are shown on Fig. IV-

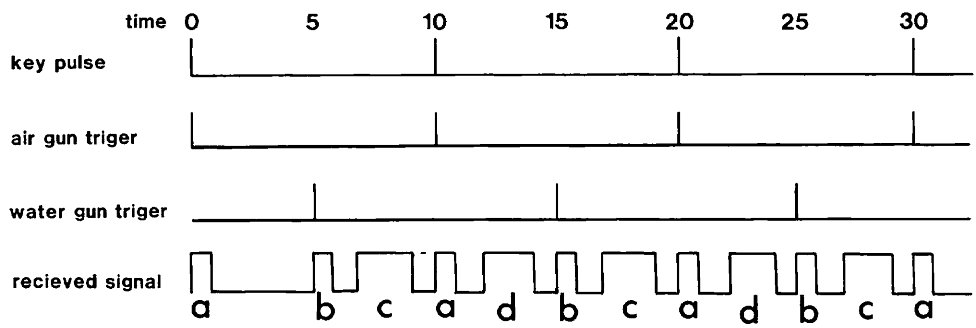


Fig. IV-4 Time chart of operation of sources in reflection survey in GH81-4. Key pulse means base control timing signal of pulse generator. a: direct wave by air gun. b: direct wave by water gun. c: reflected signal by air gun. d: reflected signal by water gun.

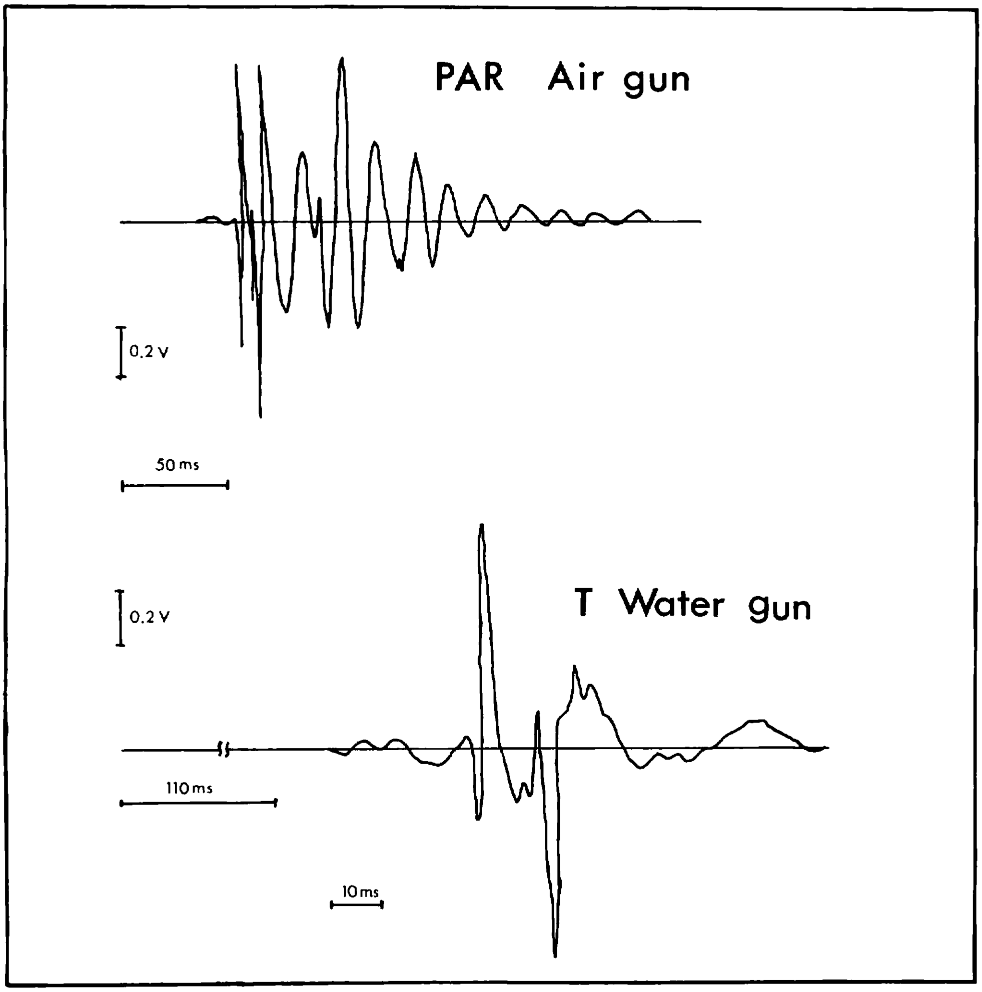


Fig. IV-5 Source pulse wave shapes of Bolt air gun 1900C and SSI water gun S-80. Firing chamber volume of air gun is 150 ci. Note the defferences of pulse length and main pulse delays between two guns.

Table IV-2 Characters of air gun and water gun hired in GH81-4.

name of source	T-water gun	PAR air gun
developped by	Seismic Systems Inc.	Bolt
type	S-80	1900C
firing chamber volume	80 ci	150 ci
minimum shot interval	8 sec	1 sec
sound generation type	implosive	explosive
water reverberation	none	long
pulse shape (see Fig. 4)	mixed delayed	near minimum delayed
frequency band	wider	narrower
towing speed	<7 knots	<12 knots

5. Air gun is one of explosive sources, and water gun is the implosive one. The shape of generated sound by water gun is simpler and shorter than that by air gun. It shows that reflection record by water gun has higher resolution. The air gun has higher total acoustic energy than water gun. It is convenient for deep penetration reflection survey. Time delays after the trigger of the guns are different between them. In the case of water gun, the highest peak appears after 120 ms delayed weak oscillation for 30 ms time length. It means the pulse shape of water gun is mixed delay wavelet. These time delay has to be corrected when we measure the travel times of events.

Water gun was hired for the first time as a seismic source of reflection profiling in GSJ manganese nodule project. The character as seismic source is listed on Table IV-2.

Tectonic framework around the survey area

Some seamounts are distributed in the north of the Central Pacific Basin. They gradually continues to Mid-Pacific Mountains in the north. There are Cross Trend Ridge and Central Basin Rise, which continue from Line Islands Ridge and enclose small Kingman Basin, in the eastern part of the basin. There is a Magellan Rise in the center of the Central Pacific Basin. Magellan Trough is developped to southeast of the rise. It is estimated as the remnant spreading center (TAMAKI *et al.*, 1979). Western part of the Central Pacific Basin is relatively flat and the many distinct transform faults in N-S direction are developped.

The studies of geomagnetic anomaly lineation identification in the Central Pacific Basin show east-west directional Phoenix lineation in west (Late Jurassic to Early Cretaceous: LARSON, 1972), northwest-southeast directional fan shaped Magellan anomalies in north (Early Cretaceous: TAMAKI *et al.*, 1979), vague east-west anomalies in east (possible Late Cretaceous (100-85 Ma: ORWIG and KRONKE, 1981). All of these lineations show that the basement around the survey area is formed in Cretaceous. The GH81-4 survey area located between the areas of Phoenix lineation and eastern east-west lineations. The results of magnetic survey of this cruise shows the northwest-southeast anomalies along the direction of northern knoll (ISHIHARA *et al.*, in this report).

EWING *et al.* (1968) have shown the rough distribution of sedimentary layer thickness of Pacific Ocean, already. HEEZEN *et al.* (1973) pointed out that areas in the low latitude, including GH81-4 area, is belonged to the high productivity area since Paleogene and the sediments are remarkably thicker than in ordinary abyssal basin.

Acoustic stratigraphy

General acoustic stratigraphy in the Central Pacific Basin

Two continuous reflectors were recongized by many seismic reflection surveys and correlated with DSDP stratigraphy of the Central Pacific Basin. They are named Reflector A′ and B′ in descending order (TAMAKI and TANAHASHI, 1981). Reflector A′ is an upper surface of Eocene to Early Oligocene chert layer or alternation of chert and radiolarian ooze and/or pelagic clay. Reflector B′ is an upper surface of some various layers, i.e. Early Cretaceous limestone layer, volcanoclastic layer, pelagic clay, and basaltic sills, probably depending on rather local geology.

Upper layer, between the sea floor and the reflector A′, is called as Unit I by TAMAKI and TANAHASHI (1981). It is correlatable with Upper transparent layer by EWING *et al.* (1968). It is composed mainly of Oligocene to Recent pelagic clay to radiolarian ooze. There are channelled calcareous turbidite sediments in this unit in the eastern margin of the Central Pacific Basin (ORWIG, 1981).

Middle layer between the reflectors A′ and B′ is called as Unit IIA by TAMAKI and TANAHASHI (1981). It is correlated with Upper opaque and lower transparent layers by EWING *et al.* (1968). It is composed mainly of Eocene chert layer in upper part and of Late Cretaceous pelagic clay in lower part.

Lower layer between the reflector B′ and the acoustic basement is called as Unit IIB by TAMAKI and TANAHASHI (1981). It is correlated to lower opaque layer and usually is the acoustic basement by EWING *et al.* It is identified from acoustic basement originated by volcanic basement by the smooth upper surface of reflector B′. The consisted material of the unit is interpreted as limestone or volcanoclastic layer in Late Cretaceous (HOUTZ and LUDWIG, 1979).

Acoustic basement on seismic profiles is probably oceanic basalt by the correlation with DSDP core.

Acoustic stratigraphy of the survey area

The sea floor is vague on every seismic profile (Fig. IV-6). It means that acoustic impedance contrast at sea floor is very weak.

Reflector A′: There is a very clear and well continuous reflector under highly transparent upper layer in a basinal area of GH81-4 survey area. It is named as reflector A′. It is roughly parallel with sea floor in a basin areas.

Reflector B′: There is another continuous reflector, reflector B′, between reflector A′ and acoustic basement. The reflectivity of it is higher than that of A′ on profiles by water gun. Although it is flat in basin areas, usually, it is cut by minor faults in some places and show lesser continuity than reflector A′.

Acoustic Basement: In the knoll areas, the acoustic basement is observed with rough surface which is characterized by hyperbola. But in the basin areas, the reflectors below reflector B′ are intermittently recognized.

The tentative correlation between GH81-4 seismic record and the results at DSDP site 66 is shown on Fig. IV-6.

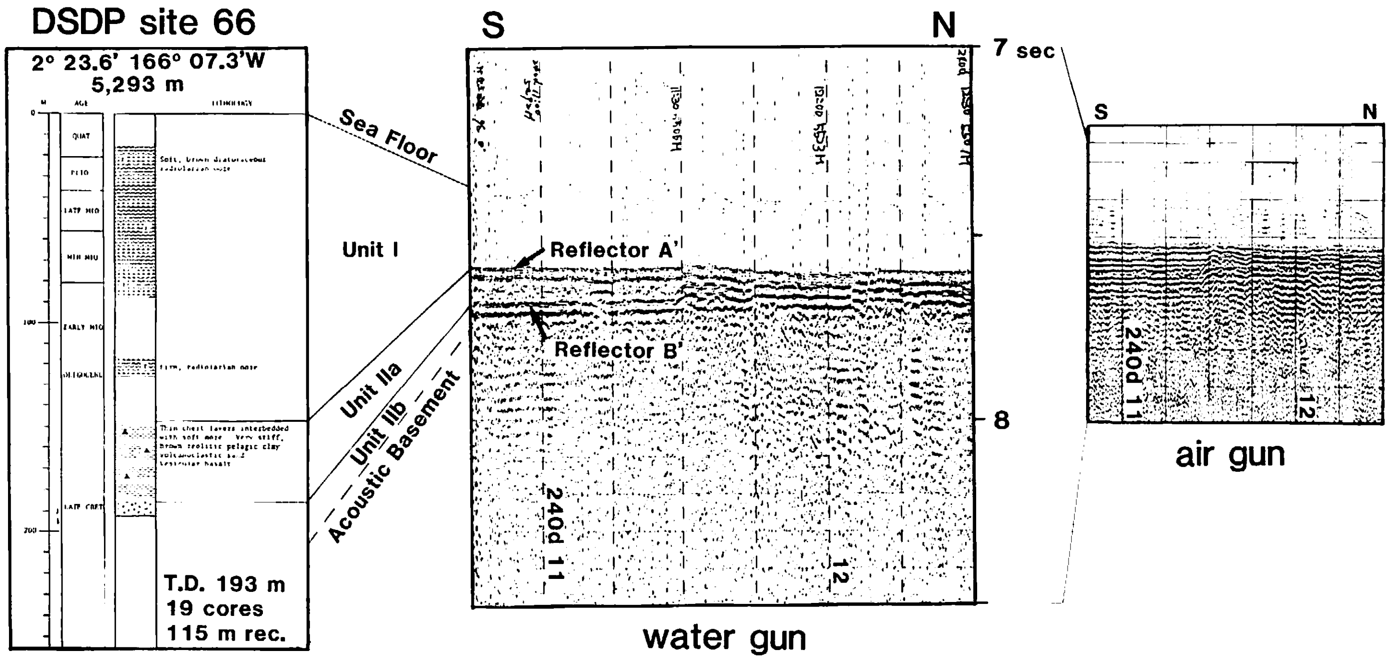


Fig. IV-6 Stratigraphic correlation with DSDP site 66. Stratigraphic diagram is based on WINTERER *et al.* (1971). There are two types of profiles using water gun and air gun for sound sources, respectively.

Unit I, which overlies the reflector A′, is acoustically almost transparent anywhere. There is almost no internal reflections in the unit. Unit I of this area corresponds to Type A in the GH76-1 area by TAMAKI (1977). The high transparency of the whole unit and low reflectivity at sea floor suggests the acoustic character of the upper part of the unit is almost same as sea water and it gradually changes through the unit. The transparency gradually decreases northward from this area to 5°-12°N (GH74-5, 76-1, 77-1, 78-1, 79-1 area). It suggests that the degree of consolidation of Unit I gragually increases northward, and that the unit of the survey area was not consolidated by extensive biogenic high productivity in tropic environments. This unit can be correlated with the unit which is composed of Oligocene to Quaternary firm to soft diatomaceous radiolarian ooze at the Hole DSDP 66 (2°23.6′, 166°07.3′), about 350 km east of the area.

After the analysis of surface sediments in survey area by NISHIMURA (in this report), it is composed mainly of siliceous fossil rich clay or clayey radiolarian ooze in the basin area and of radiolarian ooze in the knoll area. Erosion and hiatus are interpreted in the area by him. Although any differences cannot be observed on seismic reflection profiles, it is suggested that there are some hiatuses in the unit in the knoll area, and that some sedimentological variations through the unit in the basin. It is probably that those hiatuses and variations cannot be detected because of the small differences of acoustic character.

Unit IIa between reflectors A′ and B′ is acoustically semiopaque and homogeneous. Although it is identified as upper opaque layer and lower transparent layer by EWING *et al.* (1968), the opaque reflection is restricted only the upper boundary, i.e. reflector A′. Comparing with the results of DSDP site 66, Unit IIa is correlated to thin chert layers interbedded with soft sediment in upper part and very stiff, brown pelagic clay and volcanoclastic sand in lower part at DSDP 66. The age of lower clay were estimated as Turonian or Cenomanian (WINTERER *et al.*, 1971).

Unit IIb between reflector B′ and acoustic basement is very thin and it is usually masked by reflector B′. It fills the rough of acoustic basement. And Unit IIb may be correlated to Late Cretaceous basalt at DSDP 66. Basalt sampled in DSDP 66 core was correlated to the smooth lowermost reflector which would be identified as Horizon B by EWING *et al.* (1968) (WINTERER, RIEDEL *et al.*, 1971). The smoothness of reflector B′ shows the possibility that the basalt at the bottom of site 66 is an intercurrent flow in sediments as well as at the site 165. The age of the basalt in DSDP 66 core was suggested approximately 100 Ma (WINTERER, 1973).

Acoustic basement is probably correlated to Cretaceous oceanic basalt which is confirmed at some DSDP drillings in Central Pacific Basin (sites 165, 166).

Distribution of acoustic Units in GH81-4 survey area

The thickness distribution of Unit I is shown on Fig. IV-7. The average thickness in the basin area is about 150 m. It is generally thicker in the eastern basin of northern knoll than in the western one. In the knoll area it is generally thinner than 100 m and it lacks in western slope here and there (see the report on the survey by subbottom profiler in this report).

The thickness distribution of Unit IIa is shown in Fig. IV-8. Average thickness in

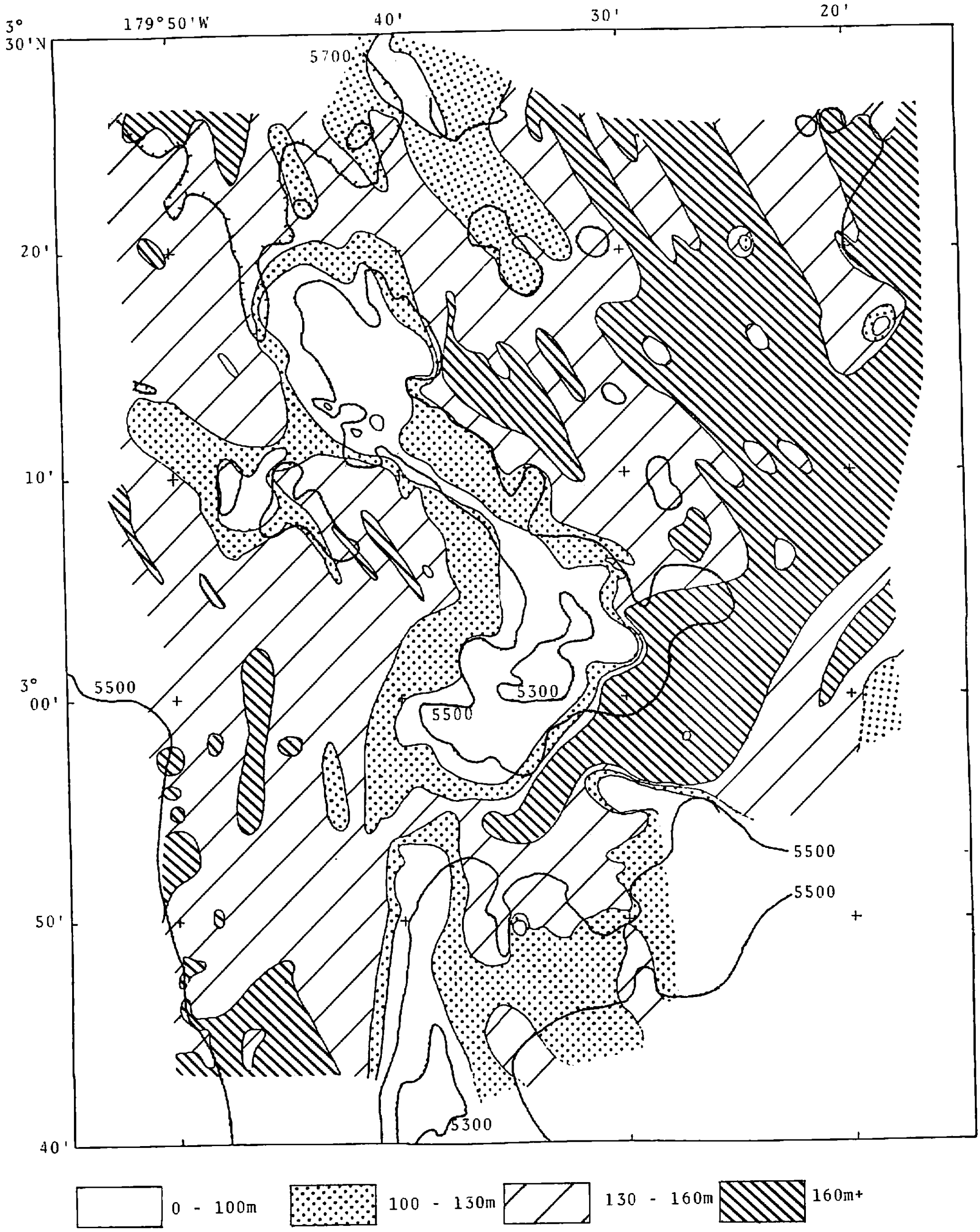


Fig. IV-7 Distribution of thickness of Unit I.

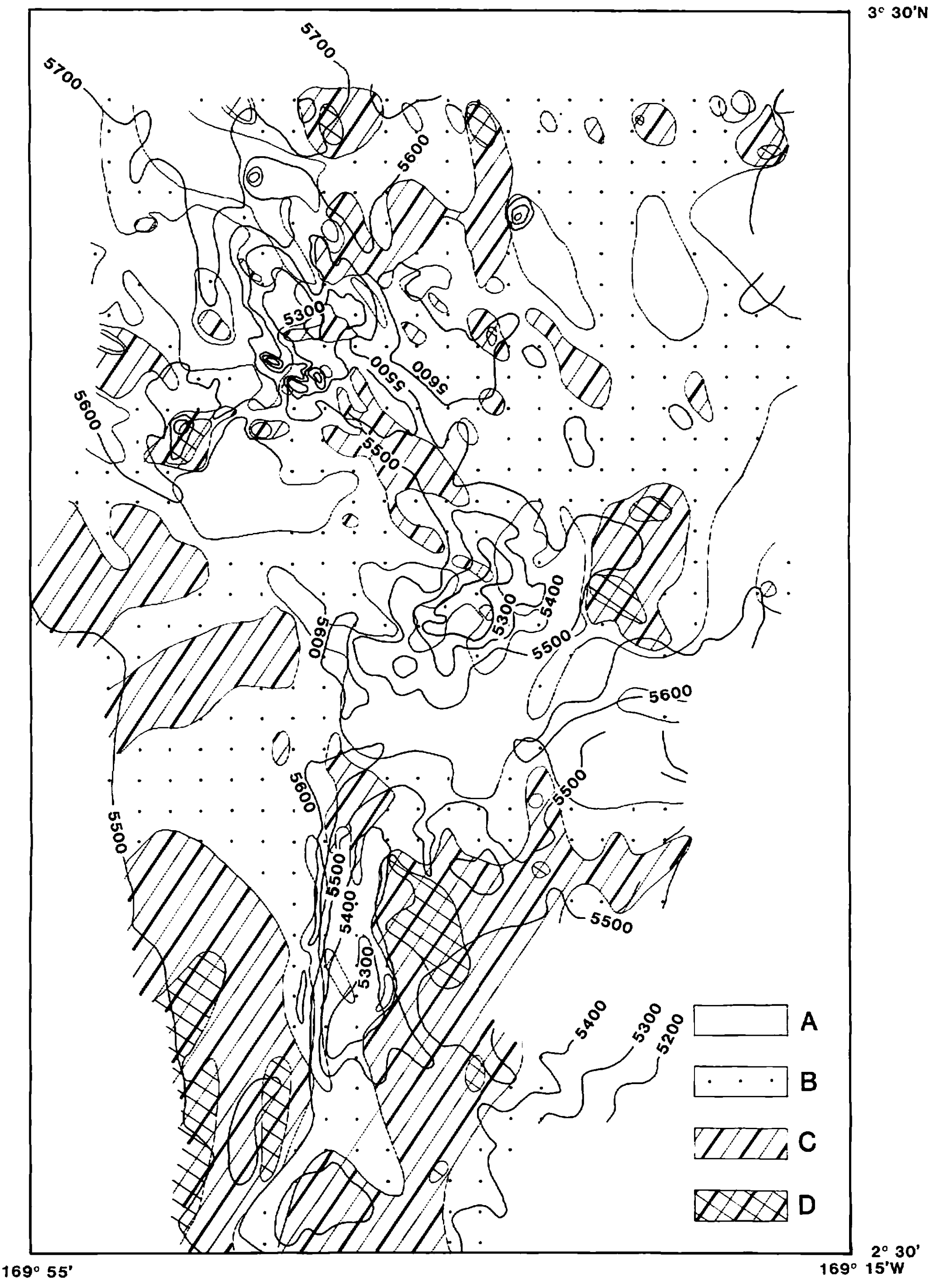
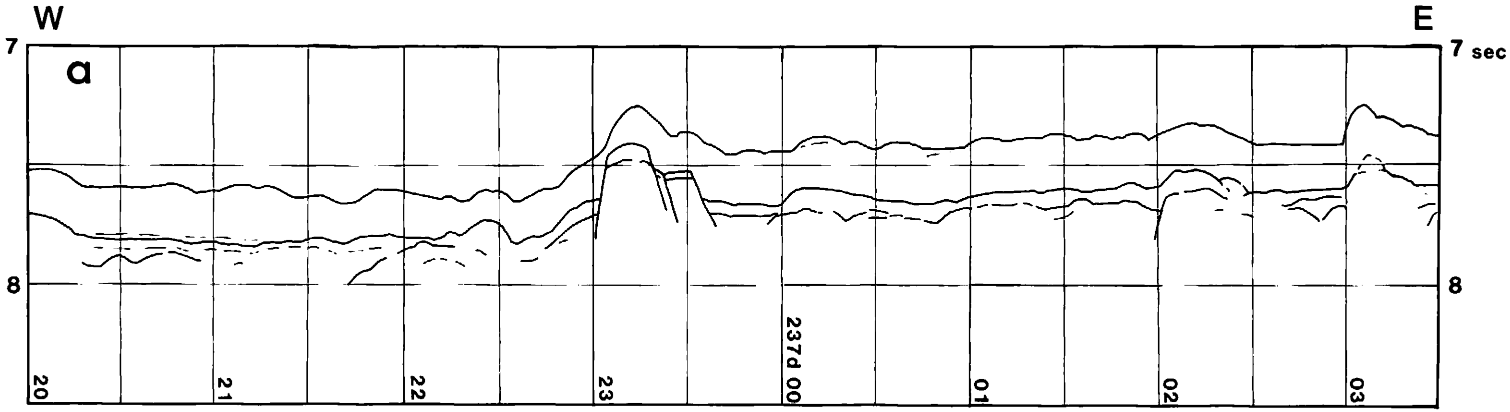


Fig. IV-8 Distribution of the thickness of Unit IIa. A: <0.02 sec, B: 0.02~0.06 sec, C: 0.06~0.10 sec, D: 0.1 sec<.



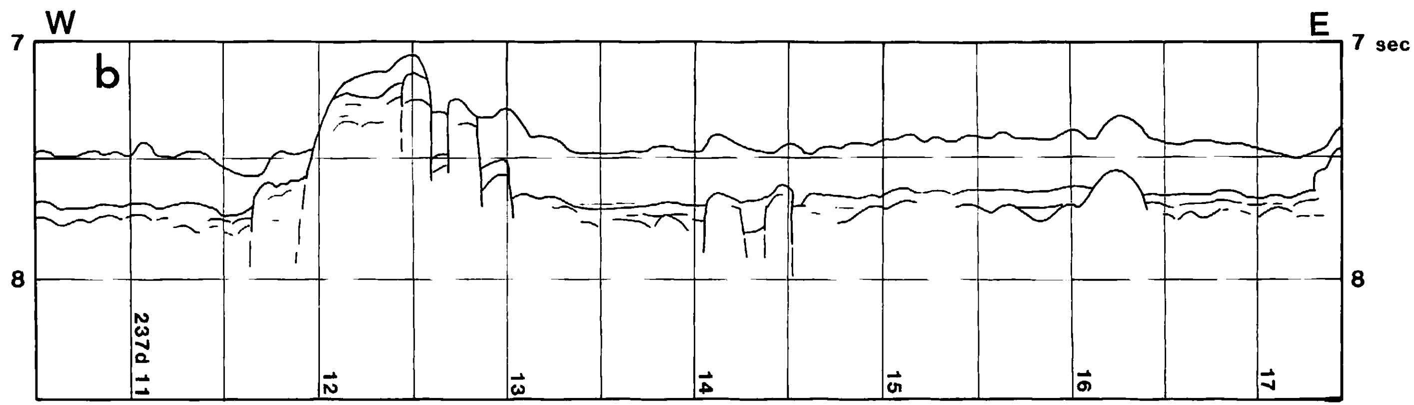


Fig. IV-9(1)

Fig. IV-9 Interpreted seismic profiles in east to west directions. a: profile along 3°25′N, across small high north of northern knoll. b: profile along 3° 15′N, across northern part of northern knoll. c: profile along 3° 05′N, across central part of northern knoll. d: profile along 3" 00′N, across southern part of northern knoll. e: profile along 2° 55′N, among northern and southern knoll. f: profile along 2° 47.5′N, across northern part of southern knoll. g: profile along 2° 40′N, across central part of southern knoll. h: profile along 2° 30N, across southern part of southern knoll.

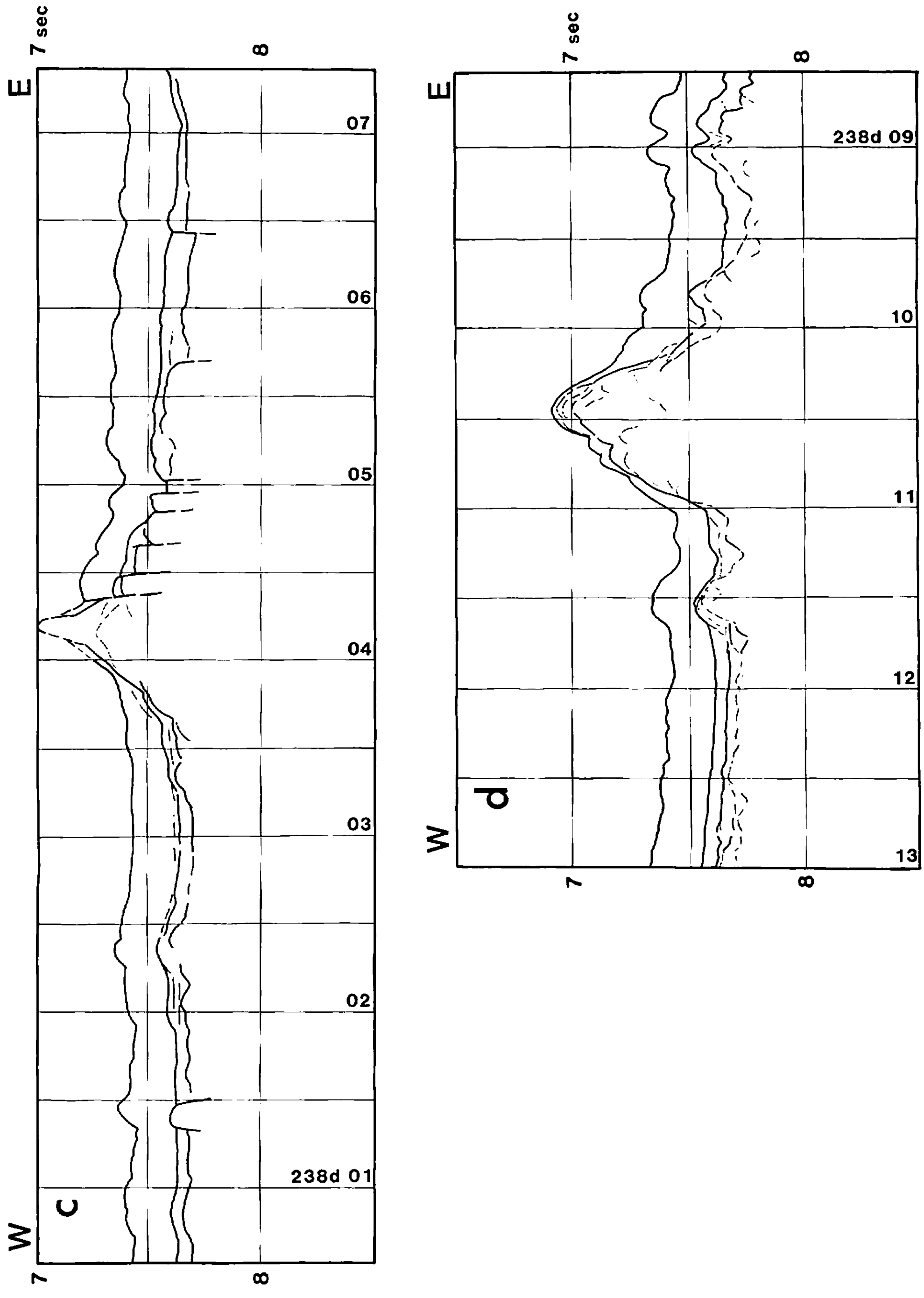


Fig. IV-9(2)

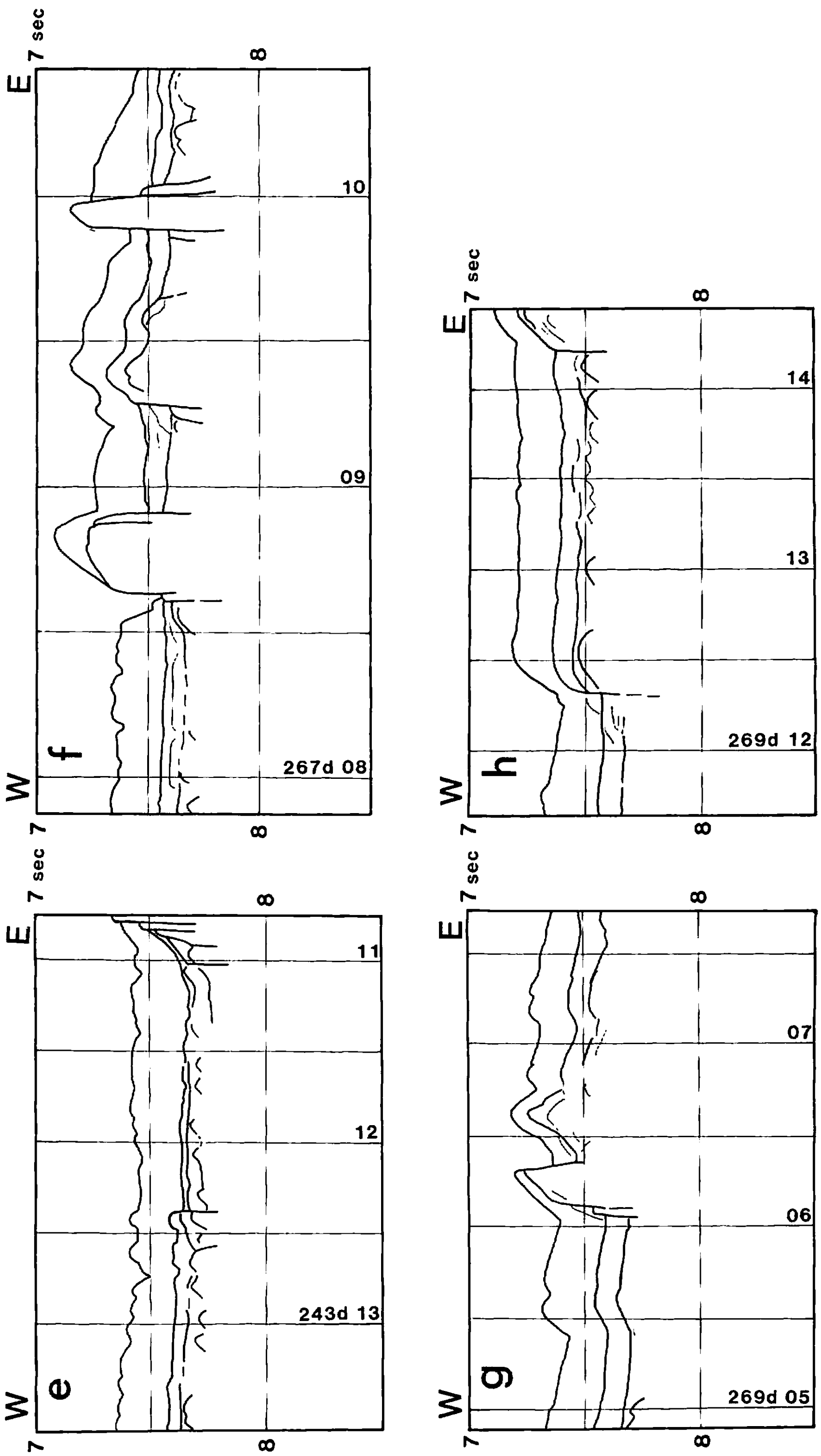


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Fig. IV-9(3)

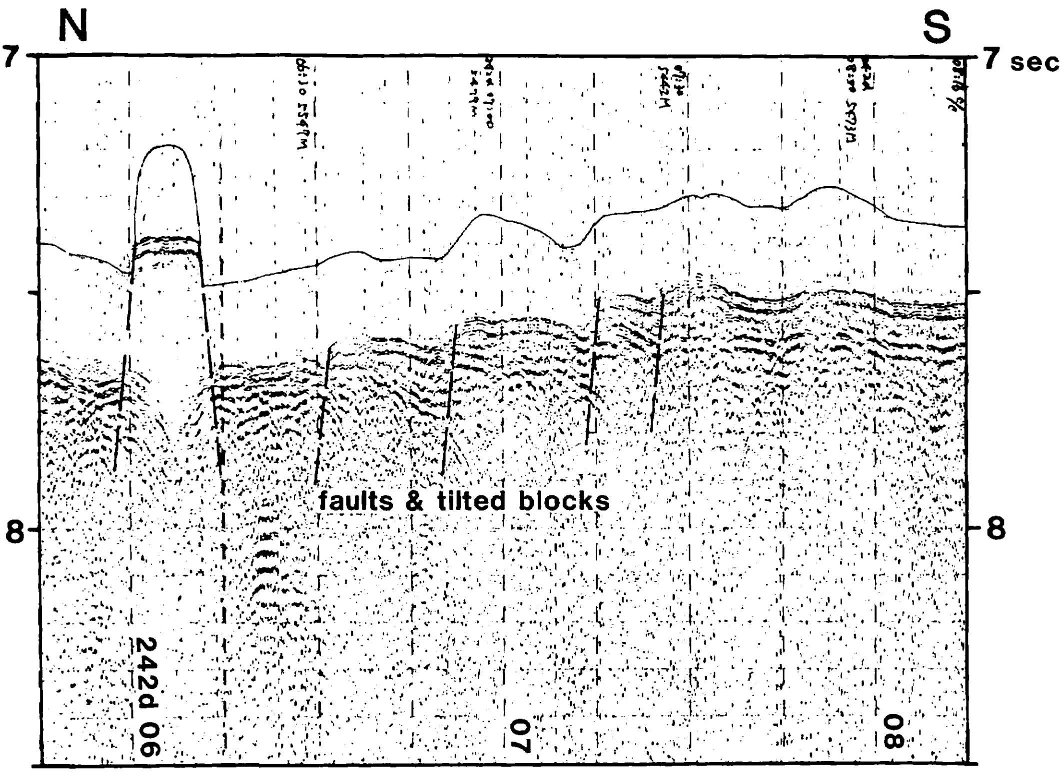

Fig. IV-10 Faults and tilted blocks on the N-S profile along 169° 30'W southeast of northern knoll. Faults cut reflectors A′ and B′.

the basin area is about 50 m. Generally it is thinner in the knoll area. There is no obvious thickness differences between western and eastern basins of northern knoll. The unit is generally thick in southern part of survey area. It cannot be identified in some small highs and knolls.

The thickness of Unit IIb is not clear because the bottom of this unit, i.e. acoustic basement, usually cannot be identified from reflector B′. The unit is too thin and two reflectors cannot be identified each other. Then the thickness is very thin possibly about 20 m.

Geological structure of GH81-4 survey area

Interpreted diagram of some typical seismic reflection profiles across the knolls are shown in Figs. IV-9a to 9h.

Generally, all of the reflectors (sea floor, A′, B′ and acoustic basement) are deeper and smooth in the western basin area than in the eastern basin area. It may suggest that the basement of the western basin is older than that of the eastern basin, and that the row of knolls shows the transform type plate boundary.

The knolls are probably composed of basaltic basement which was affected with faultings. There is clear moat-like structure on the western foot of southern knoll (Fig.

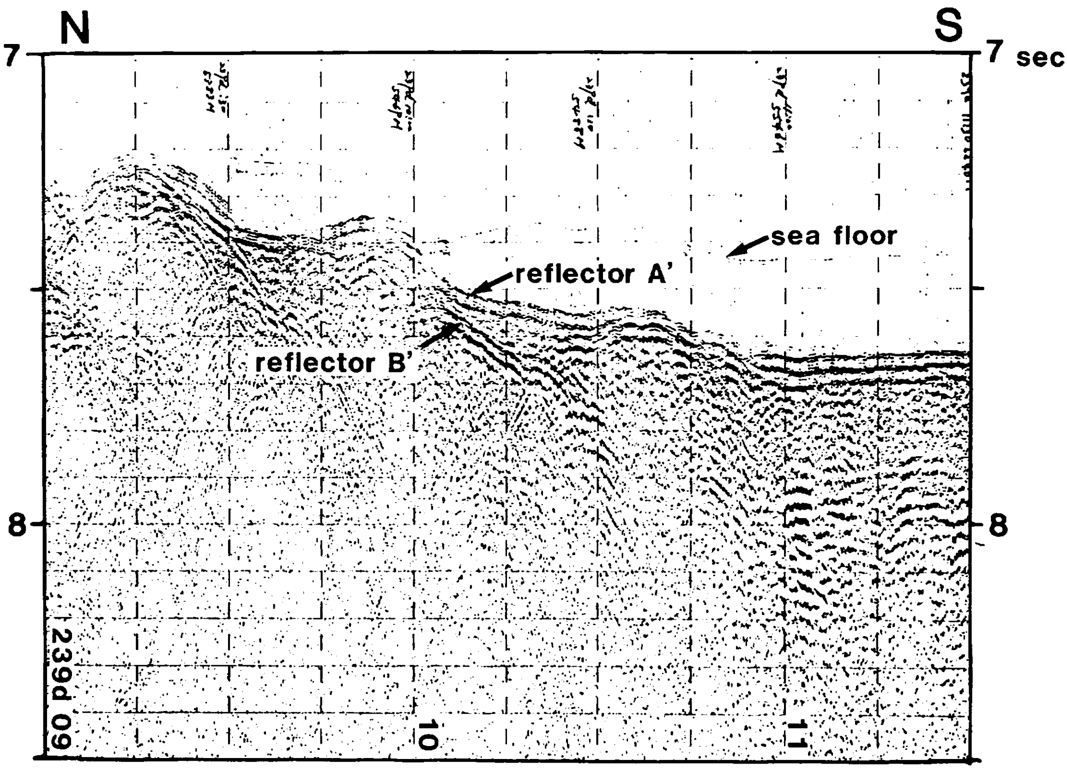

Fig. IV-11 Faults and successively tilted block on the N-S profile along 169° 40'W south of northern part of northern knoll.

IV-9f). However possible uplift of basement is observed at the bottom of moat. It is suposed, therefore, that the structure is generated by sedimentological processes.

Structural movement in GH81-4 survey area

There are many small faults which dislocated both reflectors A′ and B′ (Fig. IV-10). They show block upliftings and tiltings. It suggests the some structural movement after the deposition of thin chert in Eocene to Oligocene.

The profile across the northern knoll (Fig. IV-11) shows inclined reflectors A′ and B′. If the correlation of reflector B′ to basaltic flow is correct, well continuous reflector B′ should had been on the same topographic level in this small area in late Cretaceous age. Reflector B′ inclines steeper than A′. It suggests progressive uplifting of the knoll after the formation of reflector B′, possible late Cretaceous volcanism, untill post deposition of Eocene/Oligocene cherty layer (reflector A′). It suggests that the present knoll topography formed by the structural movement from late Cretaceous to post chert deposition.

The trends of knoll elongation and geomagnetic anomaly are northwest-southeast.

It may suggest that young structural movement was constrained by the original oneanic basement structural trend.

References

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.* Am. Geophys. Union. Monogr., 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*, 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, B7, p. 3497–3504.

LARSON, R. L. (1976) Late Jurassic and Early Cretaceous evolution of the western Central Pacific Ocean. *J. Geomag. Geoelectr.*, 28, p. 219–236.

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

——— and KRONKE, L. W. (1981) Tectonics of the eastern Central Pacific Basin. *Mar. Geol.*, 34, p. 29–43.

TAMAKI, K. (1977) Study on substrate stratigraphy and structure by continous seismic reflection profiling survey. *Geol. Surv. Cruise Rept.*, No. 8, p. 51–74.

———, JOSHIMA, M. and LARSON, R. L. (1979) Remanent Early Cretaceous spreading center in the Central Pacific Basin. *Jour. Geophys. Res.*, vol. 84, p. 4501–4510.

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

WINTERER, E. L. (1973) Regional problems. *In* E. L. WINTERER, J. L. EWING *et al.*, *Initial Reports of the Deep Sea Drilling Project*, 17, U. S. Govt. Printing Office, Washington. D. C., p. 911–922.

———, RIEDEL, W. R., *et al.* (1971) Site 66. *Initial Reports of the Deep Sea Drilling Project*, 7. U.S. Govt. Printing Office, Washington, D. C., p. 725–819.