BULLETIN OF THE EARTHQUAKE
RESEARCH INSTITUTE
UNIVERSITY OF TOKYO
Vol. 62 (1987) pp. 367-390

Report on DELP 1985 Cruises in the Japan Sea Part III: Seismic Reflection Studies in the Yamato Basin and the Yamato Rise Area

Hidekazu TOKUYAMA[1], Makoto SUYEMASU[2], Kensaku TAMAKI[1], Ei-ichiro NISHIYAMA[1], Shin-ichi KURAMOTO[1], Kiyoshi SUYEHIRO[2], Hajimu KINOSHITA[2] and Asahiko TAIRA[1]

[1] Ocean Research Institute, University of Tokyo
[2] Department of Earth Sciences, Chiba University

(Received October 23, 1987)

Abstract

A stratigraphic sequence in the Yamato Basin is acoustically distinguished between the central and northeastern portions. In the central portion we can identify at least six acoustic units. Units except acoustic basement and volcanic apron sediments distributed around the Yamato Seamounts Chain are correlated with four detrital turbidites from middle Miocene to Recent.

The Toyama Deep Sea Fan, uppermost unit, has been formed since 0.5 Ma based on the drilling result of DSDP Site 299. The huge sediments supply to the Yamato Basin through the Toyama Deep Sea Channel was presumably caused by the uplift of the Hida Mountains.

The acoustic basement of the Yamato Basin is characterized by smooth morphology associated with low frequency stratified reflectors when compared to normal oceanic layer II. We propose that the acoustic basement is composed of an alternation of sediments and sill. The Yamato Seamounts Chain aligning in NE-SW direction in the central portion of the Yamato Basin was built by the same volcanism responsible for the basalt sill.

Northeast of 39°40′N, an acoustic basement shows morphologically high relief and the stratigraphic sequence differs from that in the central portion. The high relief is identified with the eastern extension of the Yamato Rise. It is thought that the high relief of the acoustic basement and the Yamato Rise structurally separate the Yamato Basin from the Japan Basin.

1. Introduction

The Japan Sea is a marginal basin located between the Honshu Arc and the Asian continent. The sea is morphologically divided into four

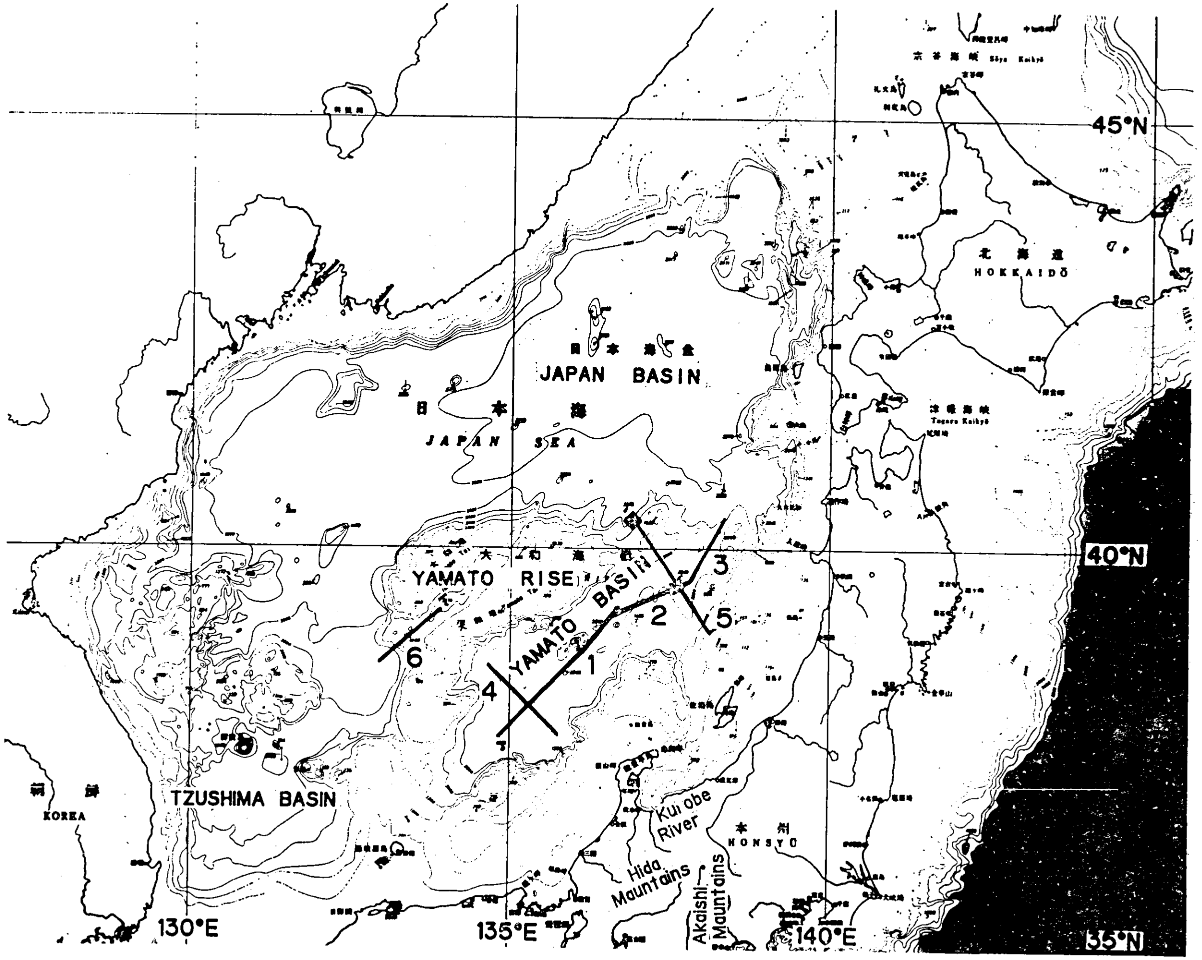

Fig. III-1. Physiography of the Japan Sea and track lines (after bathymetric chart 6301 by the Hydrographic Office of Japan). (◆: DSDP Site 302, ★: DSDP Site 299)

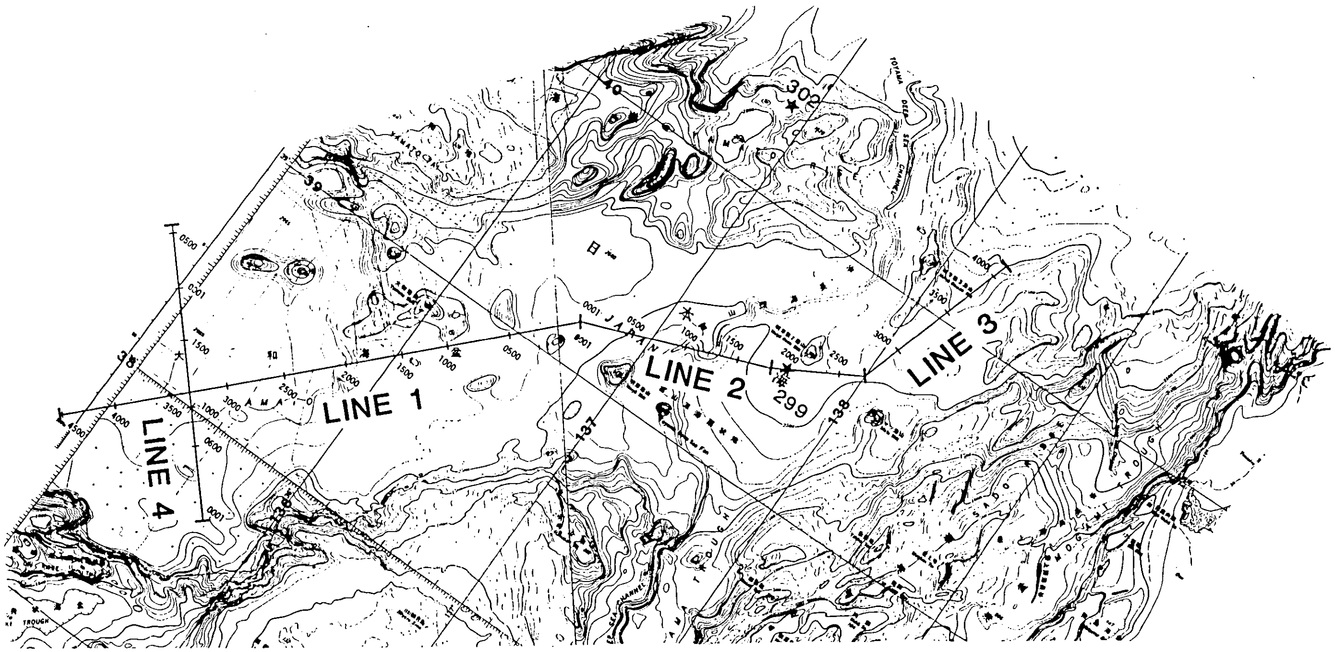

Fig. III-2. Physiography of the Yamato Basin and detailed track lines of processed profiles with shot points. (★299; DSDP Site 299, ★302; DSDP Site 302)

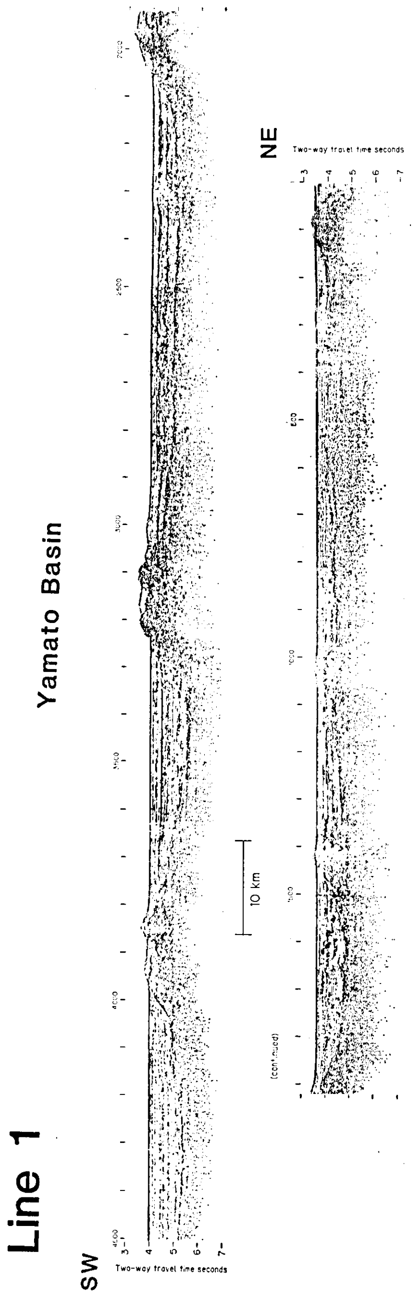

Fig. III-3 (a)

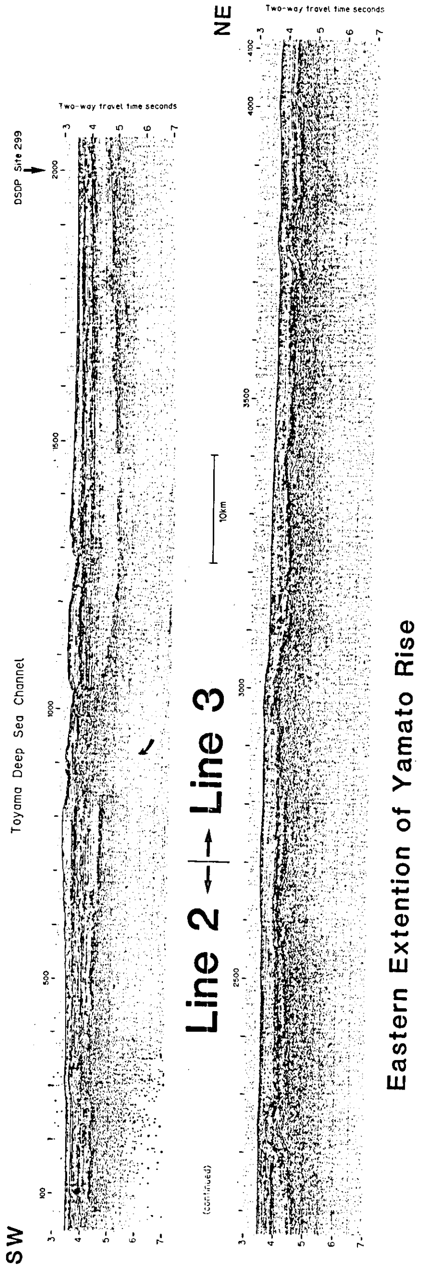

Fig. III-3 (b)

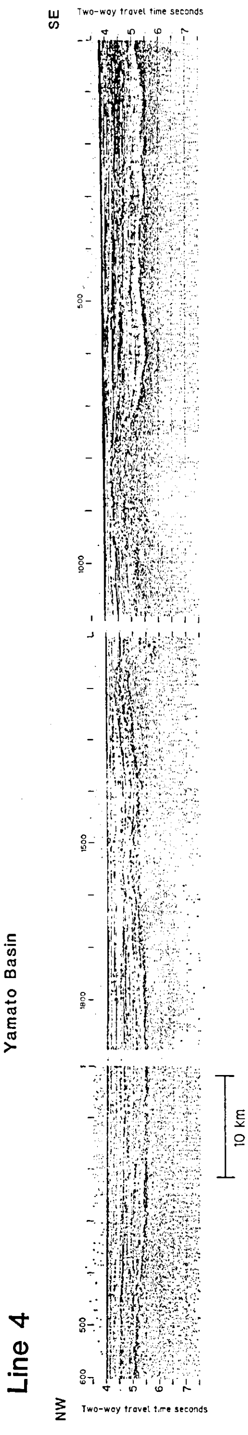

Fig. III-3(c)

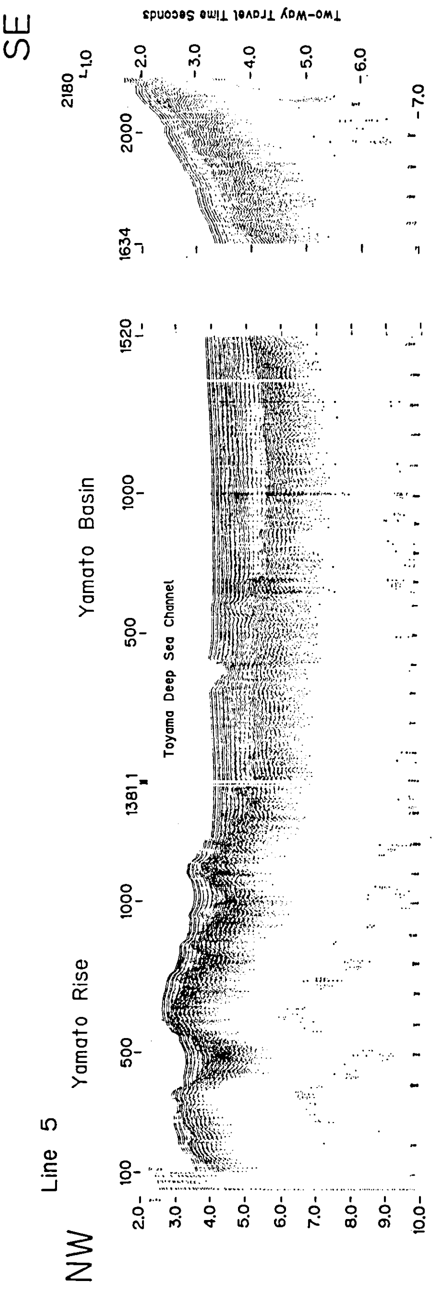

Fig. III-3(d)

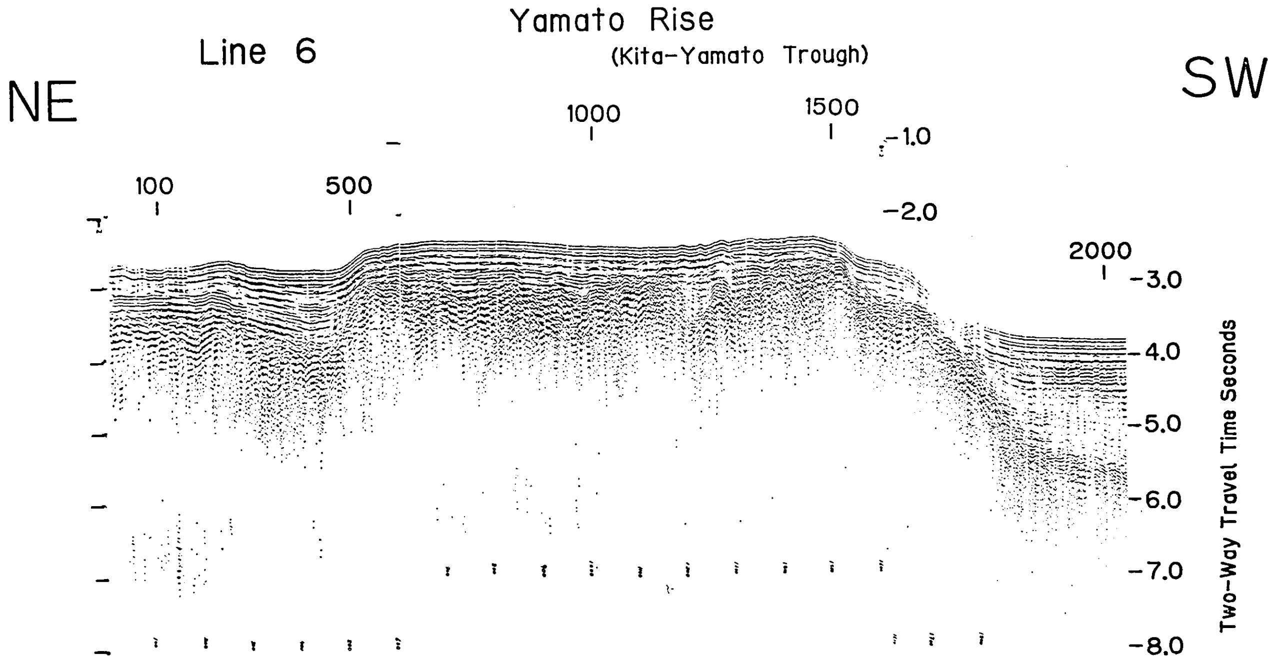

Fig. III-3(e)

Fig. III-3. Seismic profiles.
Lines 1, 2, 3, and 4 are processed profiles.
Lines 5 and 6 are on-board monitors.

parts, which are the Japan Basin in the northern part, the Yamato Basin in the southeastern part, the Tsushima Basin in the southwestern part, and the Yamato Rise in the central part (Fig. III-1).

Seismic reflection surveys were carried out by using six channel digital seismic profiling system in the Yamato Basin and the Yamato Rise, and six seismic profiles were obtained (Figs. III-1 and III-2). Lines 1, 2, 3, and 4 were obtained during the DELP 85 Cruise of the Wakashio-Maru, and lines 5 and 6 during the KT85-15 of the Tansei-Maru, the Ocean Research Institute, University of Tokyo (Fig. III-3). During the DELP 85 Cruise a refraction survey was performed by using twenty OBS's deployed along lines 1 and 4.

Various kinds of studies for the Japan Sea have been done by many workers. The lithosphere of the Japan Sea was determined to be approximately 30 km in thickness based upon surface wave analyses (ABE and KANAMORI, 1970). Refraction studies indicate that the crust of the Japan Basin has an oceanic structure (LUDWIG *et al.*, 1975). However, we have few data for the crustal structure of the Yamato Basin. ISEZAKI and UYEDA (1973) reported that magnetic anomalies are less clear in the Japan Sea, especially in the Yamato Basin. ISHIWADA *et al.* (1984) discussed the distribution of the sedimentary basins and E-W compressional tectonics since the Pliocene to Present epochs along the eastern margin of the Japan Sea.

There are two controversial opinions with regard to the age of the formation of the Japan Sea. By combining paleo-magnetic and radiometric data OTOFUJI *et al.* (1985) proposed that the Japan Sea was rapidly formed at approximately 15 Ma. On the other hand, TAMAKI (1986) estimated that the Japan Sea was formed 30 Ma to 15 Ma on the basis of sediment stratigraphy, basement depth, and heat flow value.

The purpose of this study is to elucidate seismic stratigraphy in the Yamato Basin and the Yamato Rise by using new seismic reflection data obtained during DELP-85 and KT85-15 in order to reveal geological and tectonic events not only in the basin but also in surrounding regions after the formation of the Yamato Basin. We hold discussions based on seismic stratigraphy i) the development of sedimentation in the Yamato Basin, ii) the origin of acoustic basements of the Yamato Basin and the Yamato Seamount Chain, and iii) the structural boundary between the Yamato Basin and the Japan Basin.

2. Seismic stratigraphy

Based on seismic profiles from the Yamato Basin, six acoustic units are identified southwest of 39°40′N. They are units A, B, C, D, E, and

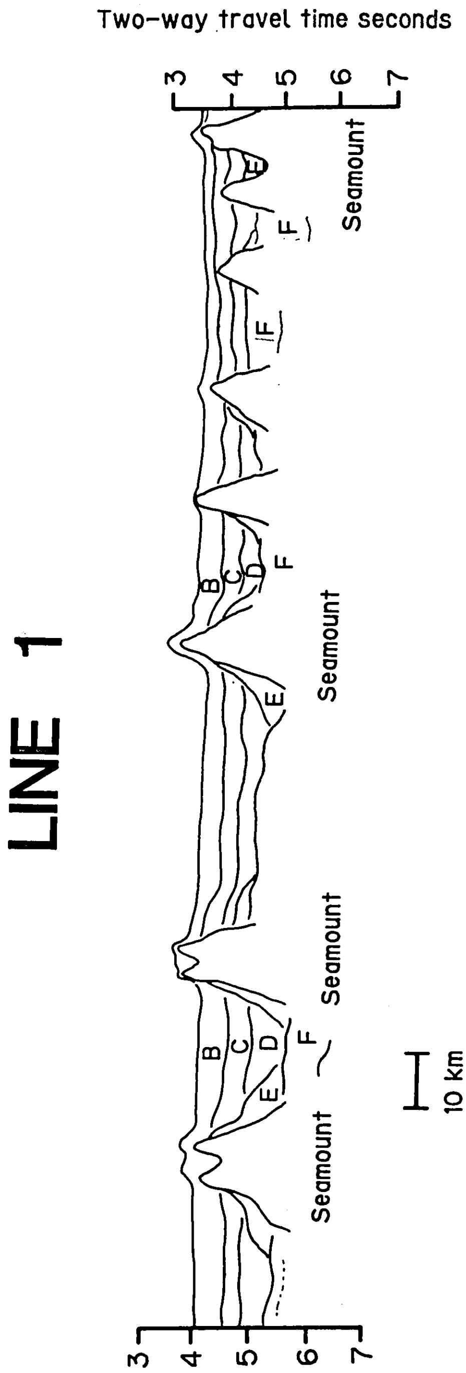
Two-way travel time seconds
LINE 1
3
4
5
6
7
Seamount
Seamount
Seamount
Seamount
Seamount
B
C
D
E
F
10 km

Fig. III-4 (a)

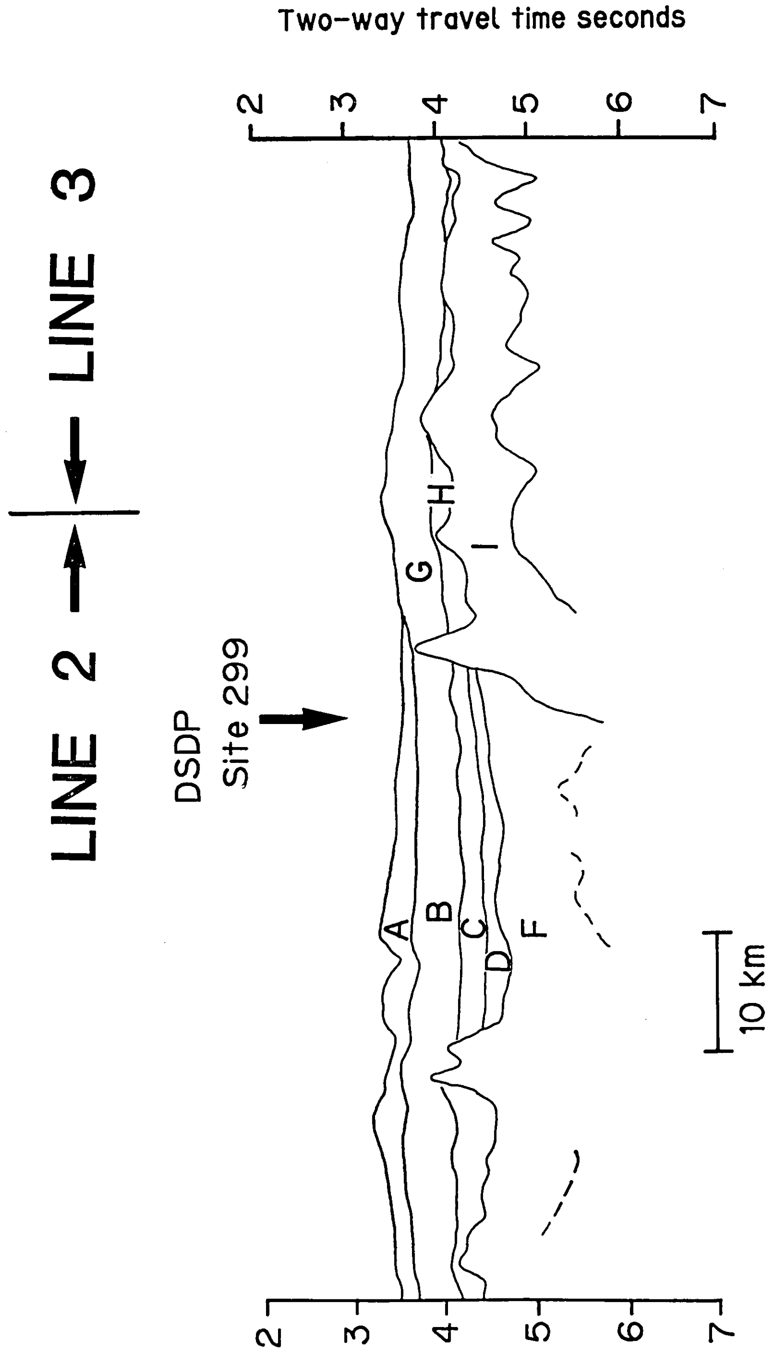
Two-way travel time seconds
2
3
4
5
6
7
LINE 2
LINE 3
DSDP
Site 299
A
B
C
D
F
G
H
I
10 km

Fig. III-4 (b)

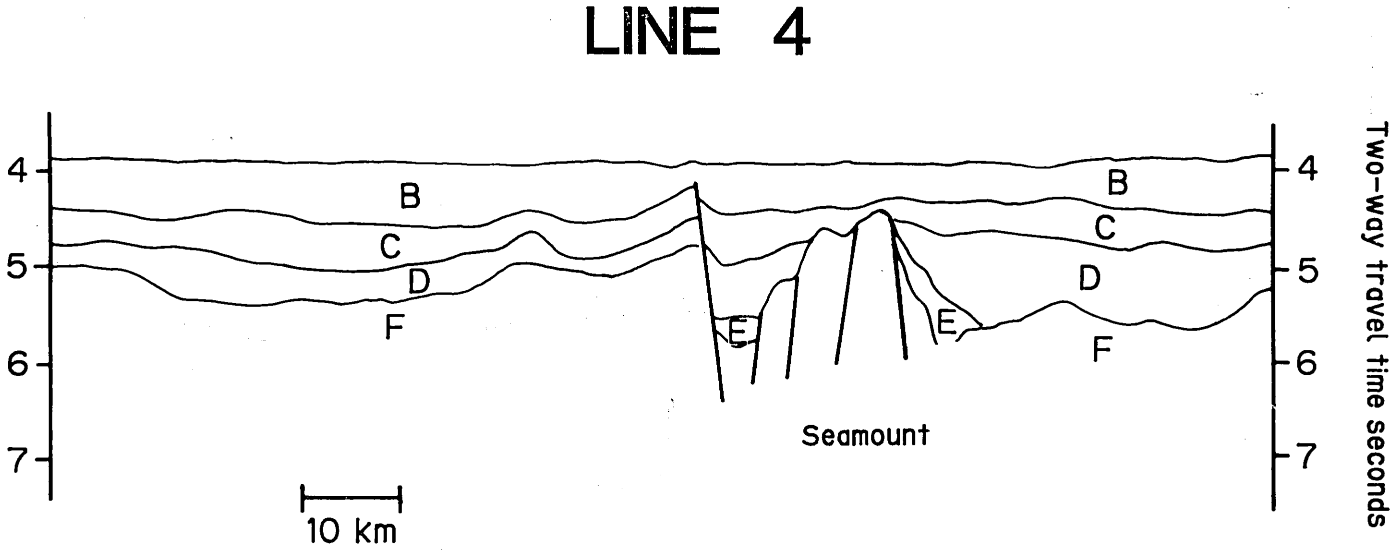

Fig. III-4 (c)

Fig. III-4. Stratigraphic sequences of Lines 1, 2, 3, and 4.

F from descending stratigraphic order (Figs. III-3 and III-4). Unit A, the uppermost layer, is forming the Toyama Deep Sea Fan and covers the underlying unit B with a contact relation of unconformity. Unit A shows its maximum thickness of 0.4 seconds in two way travel time at well-developed natural levees on both sides of the Toyama Deep Sea Channel and decreases its thickness with increasing distance from the levees to less than 0.1 second when the distance from the levees exceeds 50 km. We can identity several sheets of coarse-grained channel-lag deposits underneath the present channel system which are represented by hummocky to relatively flat high amplitude reflectors indicated by an arrow in Fig. III-3(b). Unit B with a thickness of 0.35 to 0.75 seconds is characterized by stratified reflectors. Unit C is characterized by high amplitude and low frequency stratified reflectors with a thickness of 0.25 to 0.50 seconds. Unit D with a thickness up to 1.0 second is acoustically semitransparent and is well developed in the area where the acoustic basement is deeply seated. Unit E is only distributed around the Yamato Seamount Chain aligning in a NE-SW direction in the central portion of the Yamato Basin and is traced upward as far as the slope of the seamounts (Lines 1 and 4). Unit F is the acoustic basement. Compared with normal oceanic layer II, the acoustic basement is characterized by smooth surface topography with high amplitude and low frequency reflectors.

Northeast of 30°40′N, we identify units G, H, and I in descending stratigraphic order (Fig. III-4(b)). Unit G is acoustically transparent and shows a relatively constant thickness of 0.5 seconds. Unit H is acoustically semitransparent with a thickness less than 0.25 seconds. The unit is only distributed where an acoustic basement is depressed. Unit I, the acoustic basement, is bounded by unit F at shot point approximately 2200 on Line 2 (Fig. III-2) and is characterized by stratified low frequency reflectors. Topography of the acoustic basement shows structural high relief so that the depth of unit I is shallower than that of unit F.

On the Yamato Rise several acoustic units are identified. They are upper unit, lower unit, and acoustic basement from descending stratigraphic order (Fig. III-3). Upper unit is acoustically transparent with a thickness of less than 0.5 seconds. Lower unit thickly accumulated in graben structures is represented by high amplitude reflectors. Normal faults forming the graben structures disturbed the structures of the lower unit, although no deformation is identified in the upper unit. An acoustic basement is rugged because of many normal faults and is divided into two types. One type is characterized by high amplitude and low frequency stratified reflectors, observed on the Line 6 in the Kita-Yamato Trough. The other is acoustically opaque as observed on Lines 5 and 6.

3. Discussion

DSDP Site 299 is located on Line 2 and sediments to 532 meters depth were recovered there (KARIG, INGLE, *et al.*, 1975). The stratigraphic section of Site 299 is divided into 6 sedimentation stages based on lithology (KARIG, INGLE, *et al.*, 1975). Sedimentation stage 1 with a length of 142.5 meters is composed of clayey silt and silty clay with small amounts of sand beds in the lower portion. Seismic data indicate that unit A forming the Toyama Deep Sea Fan has a thickness of 0.2 seconds at Site 299. The thickness of 0.2 seconds in two way travel time is calculated to be approximately 150 meters based on the fact that the P-wave velocity of unit A is determined to be 1.5 to 1.6 km/s by using RMS velocity and sonic wave. These pieces of evidence lead to the conclusion that unit A is correlated to be Holocene to late Pleistocene in age by calcareous nannofossil (*Emiliania huxleyi* Zone to *Gephyrocapsa oceanica* Zone) (KARIG, INGLE, *et al.*, 1975). Then, the Toyama Deep Sea Fan has been formed since approximately 0.5 Ma (BERGGREN *et al.*, 1980). Sedimentation stages 2 to 5 whose length is 345.5 meters are mainly composed of clayey silt to silty clay derived from distal turbidites and are correlated to unit B. The age of sedimentation stages 2 to 5 is reported to be early Pleistocene to Pliocene. Sedimentation stage 6, recovered only 57 meters, is reported to be of proximal distal turbidite origin because of the existence of graded beddings of ash layer and slump zone and is correlated to the upper part of unit C. The age of the unit is estimated to be earlier than Pliocene.

We have no drilling data for units D, E, and F, but it is possible to discuss these units based on seismic stratigraphy and all available data. Unit F, the acoustic basement of the Yamato Basin, is characterized by smooth morphology associated with low frequency stratified reflectors. Many workers (LUDWIG *et al.*, 1975; TAMAKI *et al.*, 1985) reported that unit F is correlated to the Green Tuff Formation that is a basement rock of the western coast region of Northeast Japan because the unit has a large thickness and the P-wave velocity of approximately 3.5 km/s, significantly lower than that of the normal oceanic layer II. New OBS data obtained during the DELP-85 Cruise, however, reveal that the P-wave velocity of the acoustic basement is more than 4 km/s with an increasing velocity gradient downward (HIRATA *et al.*, 1987). The acoustic basement of the Minami-Daito Basin shows quite similar morphology and acoustic properties as that of the Yamato Basin (TOKUYAMA, *et al.*, 1986). DSDP Site 446 recovered sediments intruded by 23 basalt sills from the basement (KLEIN, KOBAYASHI, *et al.*, 1980). These facts suggest that the acoustic basement, unit F, is composed of interlayered sediments and basalt sills. Unit E overlying an acoustic basement is only observed around the Yamato Seamount Chain and is traced upward as far as the slope of the seamounts. This suggests that unit E is composed of volcanic apron sediments transported from the Yamato Seamount Chain. KANEOKA (1986) reported that the ages of the seamounts are around 15 Ma by the K/Ar method. OTOFUJI *et al.* (1985) concluded, based on combining paleomagnetic and radiometric data, that the Japan Sea was rapidly formed at approximately 15 Ma. Consequently we suggest that unit F is sediment-sill complex derived from the volcanism just after formation of the Yamato Basin and unit E is volcanic apron sediments transported from the Yamato Seamount Chain built by the same volcanism responsible for the basalt sill. Unit D is assumed to be of turbidity current origin because the unit distributed in topographic depressions formed by the acoustic basement. Judging from the fact that unit D is interlayered between units C and E, unit D is assumed to be early late Miocene to late middle Miocene in age.

Various kinds of igneous rocks were dredged and cored from the Yamato Rise (IWABUCHI, 1968; HONZA ed., 1979; KARIG, INGLE *et al.*, 1975). They are classified into two groups. One group is composed of acidic pulutonics whose ages were older than Mesozoic (UENO *et al.*, 1974). The acidic pulutonics are considered as pre-Tertiary continental basement rocks. The other is composed of middle Miocene volcanics "Green Tuff". As was mentioned previously two types of acoustic basement are identified on the Yamato Rise. We interpret that one type characterized by high amplitude and low frequency stratified reflectors is composed of the Green Tuff Formation and the other is composed of pre-Tertiary continental basement. Sedimentary layer overlying the acoustic basements is acoustically classified into lower and upper units. That the lower unit is represented by high amplitude reflectors and is thickly accumulated in garben structures suggests that the lower unit is composed of turbidites. TAMAKI and HONZA (1985) reported that the graben structures were formed at the rifting stage of the Japan Sea. We interpret that the deposition of the lower unit was almost simultaneous with the rifting of the Japan Sea (possibly about 15 Ma) and the unit is mainly composed of sediments supplied by fragmentation of the basement. The age of the lower unit, then, is assumed to be middle Miocene. The upper unit is thought to be composed of pelagic sediments because the unit is acoustically transparent. We guess the age of the upper unit to be late Miocene to Holocene.

Unit I is acoustic basement northeast of 39°40′N. Fig. III-5 is the distribution map of the acoustic basement of the Yamato Rise after removal of overlying units by summarizing all available seismic data. The acoustic basement shown in Fig. III-5 includes two different types

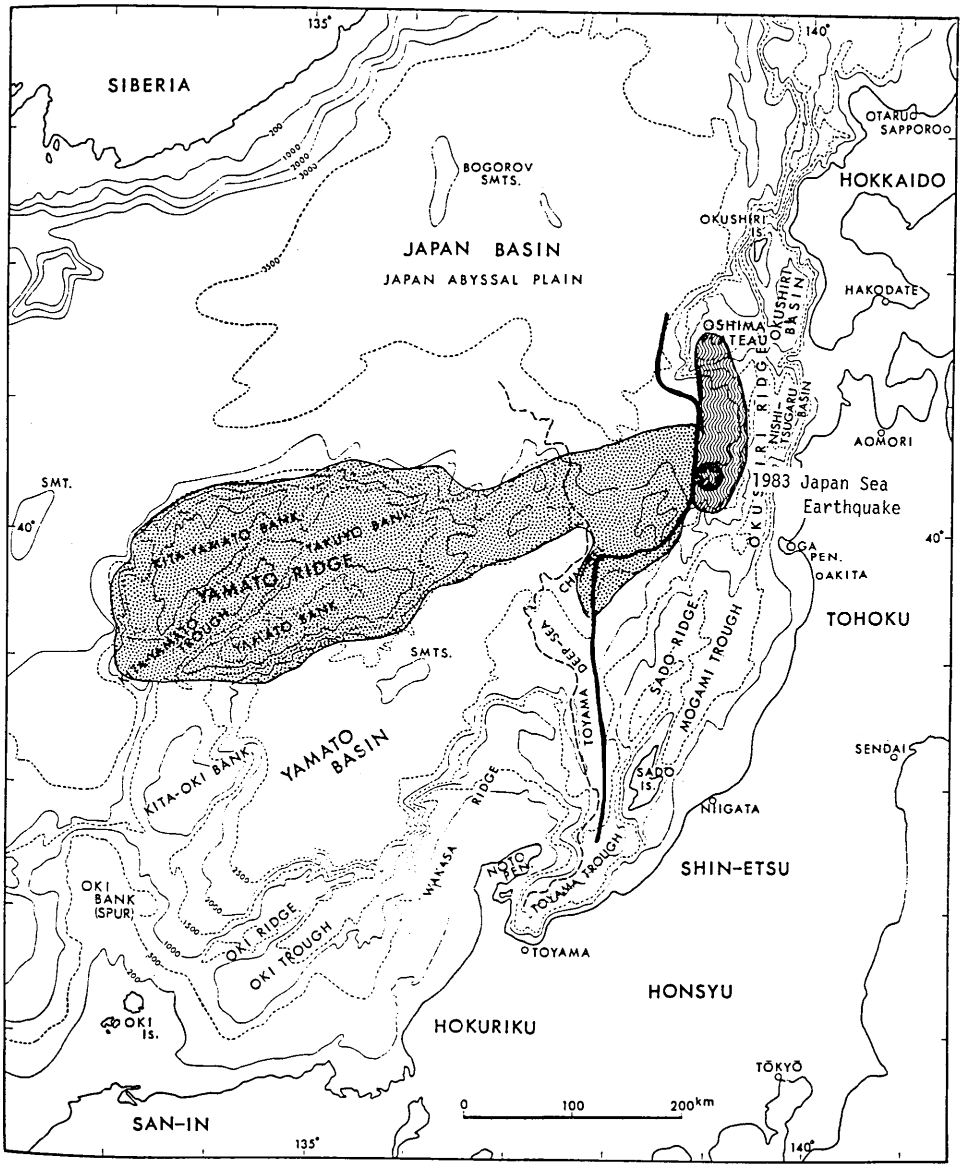

Fig. III-5. Distribution map of the acoustic basement of the Yamato Rise after removal of overlying units.

░: acoustic basement of the Yamato Rise

★: epicenter of the 1983 Japan Sea Earthquake

≋: after shock region of the 1983 Japan Sea Earthquake

Solid line indicates plate boundary between the North American plate and the Eurasian plate (NAKAMURA, 1983).

Yamato Basin

	lithology	age
Unit A	Toyama Deep Sea Fan deposits	Holocene-late Pleistocene
Unit B	distal turbidites	early Pleistocene-Pliocene
Unit C	proximal distal turbidites	Pliocene-late Miocene
Unit D	turbidites	early late Miocene-late middle Miocene
Unit E	volcanic apron sediments	middle Miocene
Unit F	interlayered sediments and basalt sills (acoustic basement)	middle Miocene

Eastern extension of Yamato Rise

	lithology	age
Unit G	pelagic sediments	Holocene-late Miocene (?)
Unit H	turbidites mainly transported from Yamato Rise	middle Miocene (?)
Unit I	Green Tuff (acoustic basement)	middle Miocene

Fig. 6. Summaries of acoustically identified units in the Yamato Basin and the eastern extension of the Yamato Rise.

which were mentioned previously. The map indicates that the acoustic basement of the Yamato Rise extends to the Yamato Basin northeast of 39°49′N. This fact leads to the conclusion that unit I is the eastern extension of the Yamato Rise. We propose that unit I is possibly correlated to the Green Tuff Formation. Unit H is semitransparent and is only distributed where the acoustic basement is depressed. We interpret that the unit is composed of terrigeous sediments of middle Miocene mainly transported from the Yamato Rise like the lower unit identified on the Yamato Rise. That unit G is acoustically transparent and has a relatively constant thickness suggests that the unit is mainly composed of pelagic sediments of Holocene to late Miocene like the upper unit identified on the Yamato Rise. Summaries of acoustically identified units in the Yamato Basin and the eastern extension of the Yamato Rise are represented Fig. III-6.

Terrigeous sediments comprising the Toyama Deep Sea Fan are transported through the Toyama Deep Sea Channel, which locate from the Toyama Bay through the Yamato Basin to the Japan Basin with a length of approximately 500 km. Most of the sediments input to the Toyama Bay are assumed to be supplied from the Hida Mountains through the Kurobe River. A total uplift of the Hida Mountains exceeds 1500 meters during the Quaternary period (KAIZUKA, 1977). We consider that the formation of the Toyama Deep Sea Fan initiated simultaneous with or shortly after the uplift of the Hida Mountains. This implies that the Hida Mountains have uplifted since approximately 0.5 Ma and the rate of the uplift is calculated to be 4 to 2 mm/year. This uplift is consistent with that of the Akaishi Mountains.

Results of cooperative OBS refraction and multichannel reflection surveys performed during the DELP-85 Cruise reveal that a trend of change in the P-wave velocity in the crust of the Yamato Basin is similar to that of the typical oceanic crust, however, anomalous thick oceanic crust (HIRATA *et al.*, 1987). The crust of the basin is 2.3 times thicker than that of the normal oceanic crust (Fig. III-7). The oceanic layer II which is identical to unit F is considered to be composed of sediment-sill complex based upon the P-wave velocity and acoustic characteristics as discussed previously. This is consistent with the evidence that the oceanic layer II has a thickness of more than 2 km. The oceanic layer III of the basin is up to 10 km in thickness with the P-wave velocity of 6.8 km/s to 7.6 km/s. We interpret that the thickening of the oceanic layer III in the Yamato Basin was caused by the same igneous activity associated with the huge injection of igneous rocks as occurred in the oceanic layer II. Some of rises and plateaus located on the oceanic floor represent thick crusts whose P-wave velocity structure is similar to that of the typical oceanic crust (Fig. III-7) (HUSSONG *et al.*, 1979). We propose that these rises and plateaus suffered from igneous activity associated with the huge injection of igneous rocks after they were formed at spreading ridge.

The distribution map of the acoustic basement of the Yamato Rise suggests that the Yamato Rise extends eastward as far as the continental slope of the Northeast Japan Arc. The after shock region of the 1983 Japan Sea Earthquake bounds the eastern margin of the Yamato Rise (MOGI, 1985). NAKAMURA (1983) proposed a new plate boundary with convergent movement between the North American plate and the Eurasia plate located along the eastern Japan Sea (Fig. III-5). The boundary represents east facing convex at approximately 40°N to 41°N. This corresponds to the eastern extension of the Yamato Rise. Because of the continental structure of the Yamato Rise (ISHIWADA *et al.*, 1984), the Yamato Rise

Fig. III-7. The relation of an average Pacific crustal model to linearly reduced crustal thickness for Ontong Java Plateau, Manihiki Plateau, Shatsky Rise, and Yamato Basin. Velocities are in kilometers per second.

presumably collided with the Northeast Japan Arc. The 1983 Japan Sea Earthquake is assumed to be caused by the collision.

Acknowledgements

We are grateful to the cruise members of the R/V Tansei-Maru and Wakashio-Maru, and to the scientific members of DELP-85, Wakashio-Maru Cruise and KT85-15, Tansei-Maru Cruise. The authors wish to thank Professor S. Uyeda for critical reviews of this manuscript. We would also like to thank Professor M. Saito for helping in digital processing of the seismic data.

References

ABE, K. and H. KANAMORI, 1970, Mantle structure beneath the Japan Sea as revealed by surface wave, *Bull. Earthq. Res. Inst. Univ. Tokyo*, **48**, 1011-1021.

BERGGREN, W. A., L. H. BURCKLE, M. B. CITA, H. B. S. COOKE, B. M. FUNNEL, S. GARTNER, J. D. HAYES, J. T. KENNETT, N. D. OPDYKE, L. PASTOURET, N. J. SHACKLETON and Y. TAKAYANAGI, 1980, Towers a Quaternary time scale, *Quaternary Research*, **13**, 277-302.

DEN, N., S. ANDO, T. ASANUMA, N. T. EDGAR, J. I. EWING, K. HAGIWARA, H. HOTTA, W. J. LUDWIG, S. MURAUCHI, T. SATO and T. YOSHII, 1969, Seismic-refraction measurements in the northwest Pacific basin, *J. Geophys. Res.*, **74**, 1421-1434.

HIRATA, N., H. KINOSHITA, K. SUYEHIRO, M. SUYEMASU, N. MATSUDA, T. OUCHI, H. KATAO, S. KORESAWA and S. NAGUMO, 1987, Report on DELP 1985 cruises in the Japan Sea, Part II: Seismic refraction experiment conducted in the Yamato Basin, southeast Japan Sea, *Bull. Earthq. Res. Inst., Univ. Tokyo*, **62**, 347-365.

HONZA, E., M. INOUE, M. JOSHIMA, H. KANAYA, M. KATO, I. KOIZUMI, T. MIYAZAKI, F. MURAKAMI, K. NISHIMURA, K. OKAMOTO, R. SUGISAKI, K. TAMAKI, T. TERASHIMA and M. YUASA, 1979, Geological investigation of the Japan Sea, *Cruise Rept. Geological Surv. Japan*, **13**, 1-99.

HOUTZ, R. E. and J. I. EWING, 1976, Upper crustal structure as a function of plate age, *J. Geophys. Res.*, **81**, 2490-2498.

HUSSONG, D. M., 1972, Detailed structural interpretations of the Pacific oceanic crust using Asper and ocean-bottom seismometer methods, Ph. D. dissertation, Univ. of Hawaii, Honolulu, 1-165.

HUSSONG, D. M., L. K. WIPPERMAN and L. W. KROENKE, 1979, The crustal structure of the Ontong Java and Manihiki oceanic plateaus, *J. Geophys. Res.*, **84**, 6003-6010.

ISEZAKI, N. and S. UYEDA, 1973, Geomagnetic anomaly pattern of the Japan Sea, *Marine Geophys. Res.*, **2**, 51-59.

ISHIWADA, Y., E. HONZA and K. TAMAKI, 1984, Sedimentary basins of the Japan Sea, *Proc. 27th Int. Geol. Congr.*, **23**, 43-65.

IWABUCHI, Y., 1968, Submarine geology of the southeastern part of the Japan Sea, *Geology and Paleontology Contr., Tohoku Univ. Inst.*, **66**, 1-76 (in Japanese with English abstract).

KAIZUKA, S., 1977, Geography of Japan, Iwanami Shinsho, 1-234 (in Japanese).

KANEOKA, I., 1986, Radioactive ages of the igneous rocks in the Japan Sea, *Earth monthly*, **8**, 376-382 (in Japanese).

KARIG, D. E., J. C. INGLE, A. H. BOUMA, N. S. HAILE, C. HOWARD, I. KOIZUMI, I. MACGREGOR, J. C. MOORE, H. UJIIE, T. WATANABE, M. WHITE, M. YASUI and H. YI LING, 1975, *Init. Repts. DSDP*, **31**, Washington (U. S. Govt. Printing Office).

KLEIN, G. DEV., K. KOBAYASHI, H. CHAMLEY, D. CURTIS, H. DICK, D. J. ECHOLS, D. M. FOUNTAIN, H. KINOSHITA, N. G. MARSH, A. MIZUNO, G. V. NISTERENKO, H. OKADA, J. R. SLOON, D. WAPLES and S. M. WHITE, 1980, *Init. Repts. DSDP*, **58**, Washington (U. S. Govt. Printing Office).

LUDWIG, W. J., S. MURAUCHI and R. E. HOUTZ, 1975, Sediments and structure of the Japan Sea, *Geol. Soc. Am. Bull.*, **86**, 651-664.

MOGI, K., 1985, Tectonic singularities of the epicentral region of the 1983 Japan Sea Earthquake, *J. Seismol. Soc. Japan*, **38**, 262-265 (in Japanese).

NAKAMURA, K., 1983, Possible nascent trench along the eastern Japan Sea as the convergent boundary between Eurasian and North American plates, *Bull. Earthq. Res. Inst., Univ. Tokyo*, **58**, 711-722 (in Japanese).

OTOFUJI, Y., A. HAYASHIDA and M. TORII, 1985, When was the Japan Sea opened?: paleomagnetic evidence for Southwest Japan, in *Formation of Active Ocean Margins*, edited by Nasu, N., I. Kushiro, K. Kobayashi and H. Kagami, Terapub., Tokyo, 551-566.

TAMAKI, K., 1986, Age estimation of the Japan Sea on the basis of stratigraphy, basement depth, and heat flow data, *J. Geomag. Geoelectr.*, **38**, 427-446.

TAMAKI, K. and E. HONZA, 1985, Incipient subduction and obduction along the eastern margin of the Japan Sea, *Tectonophysics*, **119**, 381-406.

TOKUYAMA, H., H. KAGAMI and N. NASU, 1986, Marine geology and subcrustal structure of the Shikoku Basin and the Daito Ridges Region in the Northern Philippin Sea, *Bull. Ocean Res. Inst. Univ. Tokyo*, **22**, 1-168.

UENO, N., I. KANEOKA and M OZIMA, 1974, Isotopic ages and strontium isotopic ratios of submarine rocks in the Japan Sea, *Geochem. J.*, **8**, 157-164.

Appendix

Table of Shot Point Position

Line 1

Shot No.	Time	Lat.	Long
0001	Jul 15 21:51		
0100	22:24	39°04.57′	136°35.90′
0200	22:57	03.64′	32.54′
0300	23:30	01.65′	30.27′
0400	Jul 16 00:04	38°59.75′	28.06′
0500	00:37	57.80′	26.00′
0600	01:10	55.84′	24.23′
0700	01:44	53.62′	22.44′
0800	02:17	51.64′	20.53′
0900	02:51	49.50′	18.36′
1000	03:24	47.70′	15.94′
1100	03:57	45.80′	13.52′
1200	04:31	44.20′	10.10′

(to be continued)

Line 1 (Continued)

Shot No.	Time	Lat.	Long
1300	Jul 16 05:04	38°42.75′	136°07.86′
1400	05:37	41.27′	05.06′
1500	06:11	39.71′	02.45′
1600	06:44	38.04′	135°59.87′
1700	07:17	35.96′	57.46′
1800	07:50	—	—
1900	08:24	31.88′	53.18′
2000	08:57	29.66′	50.96′
2100	09:31	27.68′	48.71′
2200	10:04	25.68′	46.56′
2300	10:37	23.57′	44.50′
2400	11:11	21.51′	42.52′
2500	11:44	19.31′	40.23′
2600	12:14	17.10′	37.83′
2700	12:51	14.97′	35.37′
2800	13:24	12.93′	32.89′
2900	13:57	11.07′	30.18′
3000	14:31	09.21′	27.16′
3100	15:05	07.48′	24.05′
3200	15:39	05.64′	21.31′
3300	16:12	03.66′	18.83′
3400	16:46	01.61′	16.42′
3500	17:20	37°59.53′	13.77′
3600	17:53	57.70′	11.55′
3700	18:26	55.55′	09.02′
3800	18:59	53.61′	06.55′
3900	19:31	51.70′	04.24′
4000	20:02	49.69′	01.77′
4100	20:34	47.92′	134°59.50′
4200	21:06	45.95′	56.77′
4300	21:37	—	—
4400	22:09	—	—
4500	22:41	40.05′	50.02′
4507	22:43	39.94′	49.94′

Line 2

Shot No.	Time	Lat.	Long
0001	Jul 23 23:11	39°09.88′	136°36.68′
0100	23:37	10.33′	39.84′
0200	24 00:04	11.32′	43.28′
0300	00:31	12.19′	46.66′
0400	00:58	12.91′	50.26′
0500	01:25	13.82′	53.75′
0600	01:52	14.87′	57.21′
0700	02:19	16.16′	137°00.42′
0800	02:46	17.49′	03.13′
0900	03:13	18.49′	06.22′
1000	03:40	19.30′	09.21′
1100	04:09	20.25′	12.03′
1200	04:39	21.26′	15.11′
1300	05:10	22.25′	18.23′
1400	05:41	23.11′	21.58′
1500	06:12	24.18′	24.57′
1600	06:43	25.15′	27.68′
1700	07:14	26.16′	30.74′
1800	07:45	27.13′	34.11′
1900	08:15	28.38′	36.79′
2000	08:47	29.59′	39.68′
2100	09:17	30.87′	42.30′
2200	09:48	32.38′	44.57′
2300	10:18	33.95′	47.60′
2400	10:49	35.06′	50.37′
2500	11:21	37.11′	53.62′
2600	11:51	38.24′	56.80′

Line 3

Shot No.	Time	Lat.	Long
2700	Jul 24 12:22	39°39.44′	138°00.07′
2800	12:53	42.33′	01.12′
2900	13:24	45.42′	02.42′
3000	13:52	—	—
3100	14:19	—	—
3200	14:46	—	—
3300	15:13	—	—
3400	15:14	—	—
3500	16:08	40°02.25′	08.44′
3600	16:35	05.21′	09.97′

(to be continued)

Line 3 (Continued)

Shot No.	Time	Lat.	Long
3700	Jul 24 17:01	40°07.70′	138°11.56′
3800	17:27	10.18′	12.99′
3900	17:53	12.76′	14.29′
4000	18:18	15.38′	15.51′
4100	18:44	17.74′	16.67′

Line 4

Shot No.	Time	Lat.	Long
0001	Jul 17 06:17	37°40.18′	135°42.70′
0100	06:52	41.99′	40.01′
0200	07:25	44.00′	37.63′
0300	07:59	46.35′	35.30′
0400	08:31	48.39′	33.29′
0516	09:12	—	—
0600	09:38	52.87′	28.82′
0700	10:10	54.87′	26.64′
0800	10:43	56.77′	24.30′
0900	11:16	58.74′	21.92′
1000	11:48	38°00.74′	19.50′
1101	12:29	03.31′	16.51′
1200	13:01	05.37′	14.46′
1300	13:34	07.68′	12.27′
1400	14:06	09.32′	09.63′
1500	14:39	11.68′	06.92′
1600	15:11	13.71′	04.69′
1700	15:44	15.68′	02.32′
1800	16:17	17.54′	00.14′
0300	19:35	—	—
0400	20:07	—	—
0500	20:40	30.22′	44.33′
0594	21:11	32.53′	42.42′

Line 5

Shot No.	Time	Lat.	Long
1	Sep 17 03:46	—	—
20	03:53	40°20.78′	136°53.14′
100	04:18	18.98′	54.95′
200	04:49	16.83′	57.11′
300	05:19	14.63′	59.16′

(to be continued)

Line 5 (Continued)

Shot No.	Time	Lat.	Long
400	Sep 17 05:50	40°12.53′	137°00.97′
500	06:27	10.17′	03.13′
600	06:53	07.88′	05.21′
710	07:27	05.29′	07.51′
800	07:54	03.24′	09.24′
900	08:25	00.94′	11.26′
1000	08:56	39°58.58′	13.47′
1100	09:27	56.26′	15.51′
1200	09:58	53.89′	17.76′
1300	10:28	51.61′	19.83′
0010	11:14	47.98′	23.33′
0100	11:41	45.99′	24.96′
0200	12:10	43.77′	26.65′
0300	12:40	41.55′	28.77′
0400	13:09	39.22′	31.09′
0500	13:38	36.97′	33.03′
0600	14:08	34.80′	35.12′
0700	14:37	32.64′	37.01′
0800	15:07	30.45′	39.12′
0900	15:36	28.01′	41.00′
1000	16:06	25.81′	43.05′
1100	16:36	23.66′	44.91′
1200	17:06	21.45′	46.87′
1300	17:36	19.28′	48.89′
1400	18:06	17.20′	50.91′
1500	18:36	15.08′	52.98′
1600	19:06	12.96′	54.94′
1700	19:36	10.97′	56.89′
1800	20:06	09.00′	58.69′
1900	20:35	06.36′	138°00.67′
2000	21:05	04.68′	02.79′
2100	21:35	02.48′	04.65′
2180	22:00	00.67′	06.34′

Line 6

Shot No.	Time	Lat.	Long
0001	Sep 23 16:50	39°12.41′	133°58.04′
0100	17:21	11.01′	55.14′
0200	17:53	09.52′	52.38′
0300	18:23	08.06′	49.79′
0400	18:54	06.66′	47.07′
0500	19:26	05.16′	44.44′
0600	19:59	03.46′	41.96′
0700	20:32	01.67′	39.60′
0800	21:04	38°59.82′	37.40′
0900	21:36	57.96′	35.15′
1000	22:09	56.38′	32.36′
1100	22:42	54.54′	29.55′
1200	23:14	52.89′	26.41′
1300	23:47	51.14′	23.71′
1400	Sep 24 00:19	49.37′	21.04′
1500	00:52	47.64′	18.12′
1600	01:24	45.84′	15.29′
1700	01:57	44.27′	12.15′
1800	02:28	42.27′	09.53′
1900	03:00	40.45′	06.96′
2000	03:31	38.54′	03.73′
2092	04:00	36.80′	00.80′

DELP 1985 年度日本海研究航海報告
III. 大和海盆および大和堆の反射地震探査

徳山英一[1)]・末益　誠[2)]・玉木賢策[1)]・西山英一郎[1)]
倉本真一[1)]・末広　潔[2)]・木下　肇[2)]・平　朝彦[1)]
[1)] 東京大学海洋研究所　[2)] 千葉大学理学部

大和海盆の音響層序は中央部と北東部で区別される．中央部では少なくとも6層が音響的に識別される．基盤および大和海山列周辺に見らる volcanic apron sediments をのぞいた各層は Middle Miocene から Holocene の4層の砕屑性乱泥流堆積物に対比される．

富山深海扇状地は最上位層に相当し，その形成は約 50 万年前から始まったと考えられ，これは飛騨山脈の隆起により大量の堆積物がもたらされた結果であろう．音響的基盤はその上面が平坦であること，また内部に反射面を持つことで特徴づけられ，堆積物とそれに貫入したシルから構成されていると推測される．海盆中央に北東—南西方向に配列している大和海山列はシルをもたらしたと同じ火成活動により形成されたものと思われる．この火成活動の年代は，背弧拡大により海盆が形成されたと考えられる 15 Ma 前と同時かあるいはわずかに後と思われる．

大和海盆の北緯 39°40′ より北東では層序が異なり，しかも音響的基盤は地形的にせり上がっている．この基盤の高まりの西延長が大和堆に当たる．つまり大和堆を含めた基盤の高まりが大和海盆と日本海盆を構造的に区分している．