VI. SEISMIC REFLECTION PROFILING IN THE OGASAWARA (BONIN) ARC AND THE NORTHERN MARIANA ARC

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Introduction

Seismic reflection profiling was carried out along the ship's tracks shown in Fig. I-1 during cruises GH79-2, 3 and 4. Equipment and conditions for the survey are summarized in Table VI-1 and VI-2 respectively. The shot interval of the air guns, which was maintained at 10 sec in general, was varied from 9 to 12 sec during the crossing of the trench in order to avoid contamination of direct shot wave and reflection arrivals. The vertical exaggeration of the seismic profiler record. however, was maintained at a constant by controlling the speed of the paper feed.

Eight selected profiles (Lines 43, 37, 30, 25, 19, 14, 10 and 4) with interpretative line drawings are shown in Fig. VI-1-a, b, c, d, e, f, g and h respectively.

The survey area is divided here into three provinces based on physiographic features; the northern Ogasawara Arc, the southern Ogasawara Arc, and the northernmost Mariana Arc. The boundary dividing the northern and southern Ogasawara Arc areas lies along latitude 30°N. The southern Ogasawara Arc is characterized by the Ogasawara Ridge and the Ogasawara Trough in the fore-arc region.

In the text, sediment thickness is expressed in terms of the two-way acoustic travel time.

(1) Northwest Pacific Basin

Fig. VI-2 (part of Line 22) shows one of the typical profiles in the northwestern Pacific Basin. Two subbottom reflective horizons with smooth surfaces are observed above the acoustic basement. The acoustic sequence is divided into three units by two reflective horizons. The uppermost unit is transparent with a thickness ranging from 0.1 to 0.5 sec, but generally less than 0.2 sec. The second unit shows a stratified, semi-opaque pattern while the third, lowermost, unit shows a more strongly reflective, stratified pattern. The lower reflective horizon is often difficult to detect, and the difference between the second and the third unit is not as clear in the other profiles as it is in Fig. VI-2. The thickness of the second unit varies a little, ranging from 0.2 to 0.4 sec in the areas where the lower reflective horizon can be detected. The strongly reflective horizon commonly hides the basement reflector. Several DSDP data (sites 194, 195, 196, and 197, HEEZEN, MACGREGOR *et al.*, 1973 and site 452, HUSSONG, UYEDA *et al.*, 1978) show that the uppermost unit is composed of silty and clay and the second unit is an assemblage of chert, chalk,

Table VI-1 Equipment used for the seismic reflection survey during cruises GH79-2, 3 and 4

Air Gun	Bolt PAR Air Gun 1900C
Compressor	Norwalk APS-120
Hydrostreamer	GSJ type hydrostreamer with 100 to 200 hydrophones
Hydrophone	T-1 (Teledyne) or MP-18-200 (Geospace)
Amplifier	Ithaco 451 and Ithaco 3171
Recorder	Raytheon UGR 196B and LSR 1811

Table VI-2 Conditions during the seismic reflection survey of cruises GH79-2, 3 and 4

Volume of air gun	150 in^3 × 2
Pressure	1600 to 1800 psi
Shot interval	generally 10 sec. variable from 9 to 12 sec across the deepest part of the trench
Filter range	20-100 Hz variable
Ship speed	10 to 11 knots
Record range	4 sec and 8 sec
Paper feed of recorder	controlled to maintain the constant vertical exaggeration of the profile

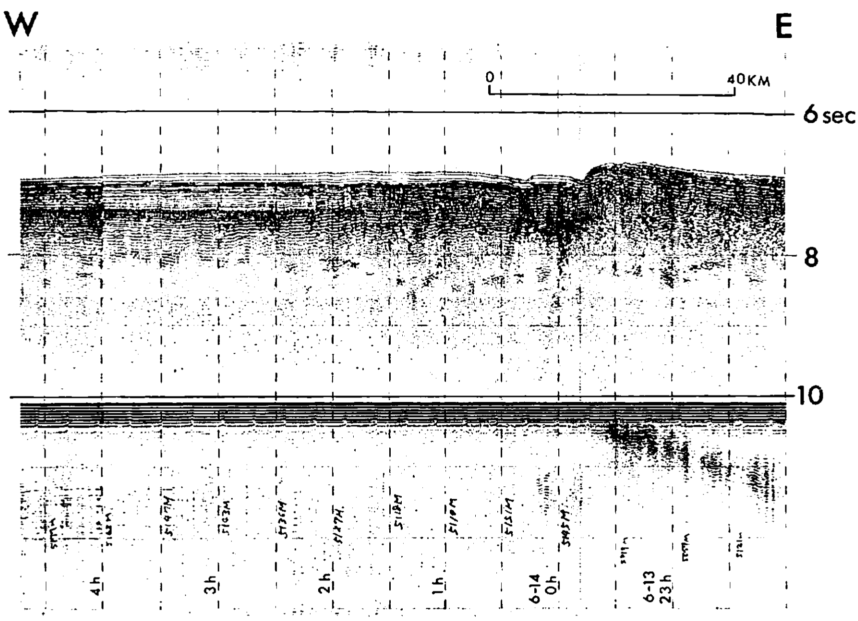

Fig. VI-2 Seismic profile in the Northwestern Pacific Basin. Part of Line 22.

limestone, and sandstone. Constituents of the third unit cannot be known from the DSDP data.

Densely stratified sediments of nearly 1.0 sec in thickness are observed on the Ogasawara Plateau and the guyot east of the Plateau (Fig. VI-1-e, Line 19). SHIBA (1979) reported Cretaceous limestone from the sedimentary layer of the guyot.

(2) Trench

The outer trench slope is characterized by the horst and graben structure which is commonly observed on the outer trench slopes of many other trenches. This horst and graben structure is well developed in the Ogasawara Trench but poorly developed in the northern Mariana Trench. The trends of the faults are unknown because our traverse interval was too wide to deduce them. Dredging (D361) was carried out at one such fault where the displacement measures about 400 m (Fig. VI-3, part of Line 34). Some cherty rock fragments and claystone were obtained at this site. They are thought to be constituents of the second unit mentioned in the section (1). The maximum displacement of the faults attain 1,200 m on Line 36. It is assumed that oceanic basement almost 1,000 m thick outcrops along the fault scarp in this place, and that it would be possible to dredge up samples of the lower part of Oceanic layer 2 here.

Fig. VI-1-e (Line 19) shows the junction area of the Ogasawara Arc and the Ogasawara Plateau. Although the trench is shallow here (about 4,500 m deep), faulted structures are observed on the outer trench slope where the faults appear

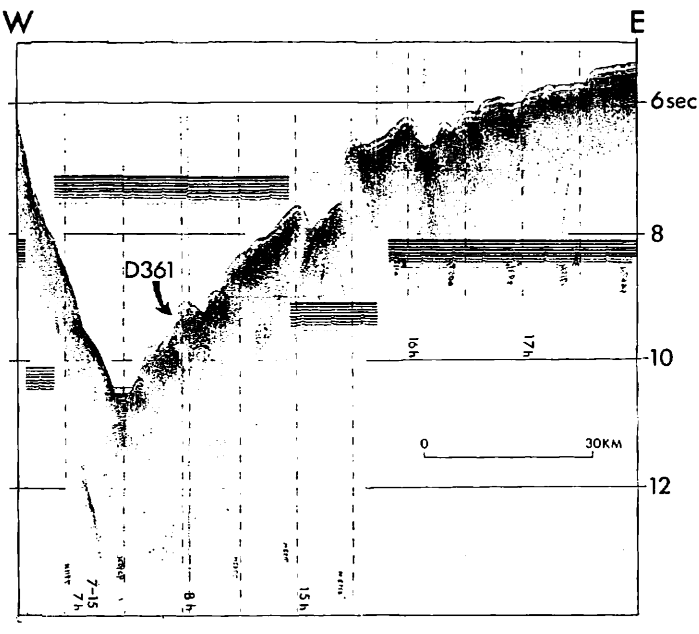

Fig. VI-3 Seismic profile across the Ogasawara Trench with sampling site D361. Part of Line 34.

to be predominantly thrusts. The trench axis shows two right-lateral offsets of about 20 km in the junction area.

Trench fill—possible turbidites deposits with a flat surface along the trench bottom—is commonly observed in the Izu-Ogasawara Trench north of the latitude 30°45′N. The maximum thickness of the trench fill exceeds 1.0 sec along Line 46. The width of the fill generally measures about 5 km or less. The axes of the Ogasawara Trench south of latitude 30°30′N and the northern Mariana Trench are free of sediment fill and are v-shaped in profile. The trench axes show offsets of 10 to 20 km in several places.

The inner trench slope shows several ridges and benches with weak subbottom reflections. Ridges on the inner trench slope are prevalent in the northern Mariana Trench, but are only locally developed in the Ogasawara Trench.

(3) Northern Ogasawara Arc

A well-developed basement high is associated with the trench slope break in the forearc region of the northern Ogasawara Arc (Figs. VI-1-a and b, Lines 43 and 37). Sediments in the forearc basin, which exceed 2.0 sec in thickness, onlap the basement high along the trench slope break. The sediments show a different relationship to the Shichito Ridge. The sediments of the forearc basin, increasing in extent of opaqueness to the west, are generally continuous with the acoustic basement of the Shichito Ridge and there is no boundary. This means that the sediments of the basin were derived from the Shichito-Iwojima Ridge in association with its volcanic activity. There are, however, some exceptions. In Fig. VI-4 (part of Line 34) the sediments of the forearc basin clearly onlap the basement of the Shichito Ridge. This exception suggests that the Shichito-Iwojima Ridge includes not only active volcanic ridge but also ridges which were non-active during deposition of the sediments. Such non-active ridges are found east of Tori-shima Island and Smithjima Island.

The sediments of the forearc basin in the northern Izu-Ogasawara Arc are divided into two units (upper and lower) by a subbottom reflective horizon. The units show different internal patterns; in the upper unit, internal reflectors are commonly discontinuous and show overlapped wave forms; in the lower unit, reflectors are continuous and stratified. The two distinct sedimentary units imply two different sedimentary stages. The thickness of the upper unit is generally 1.0 sec while that of the lower unit exceeds 1.0 sec. The forearc basin is cut by several active canyons (Fig. VI-1-a, Line 43).

The features mentioned above indicate that the sediments of the forearc basin have come from the chain of active volcanos and trapped behind the basement high on the trench slope break. Sedimentary structures around trench slope break, such as the onlap of the sediments over the basement high without deformation, suggest that there were no appreciable tectonic movements of the basement high, in terms of uplift or subsidence, during deposition of the sediments.

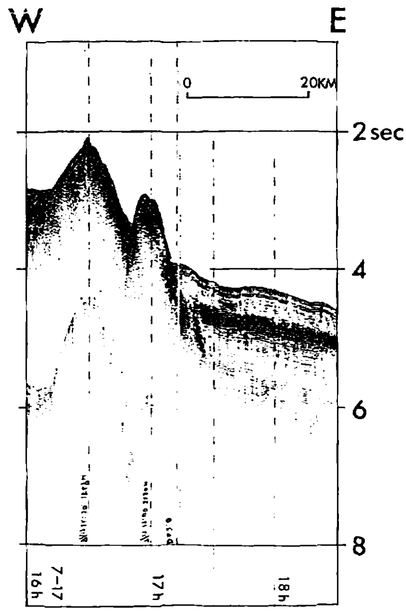

Fig. VI-4 Seismic profile across forearc basin of the northern Ogasawara Arc. Part of Line 34.

(4) Southern Ogasawara Arc

A general view of the Ogasawara Arc shows that the Ogasawara Ridge belongs to the trench slope break. KARIG and MOORE (1975) stated that the Ogasawara Ridge lies just at the trench slope break. Strictly, however, the trench slope break lies to the east of the Ogasawara Ridge, as shown in Fig. VI-1-d (Line 25).

The Ogasawara Ridge does not continue to the basement high of the trench slope break in the northern Ogasawara Arc. The discontinuity between the basement high of the northern trench slope break and the Ogasawara Ridge coincides with a right-lateral offset along latitude 29°45′N. This discontinuity can be related to the EW trending topographic depression between the northern and the southern Ogasawara Arc. The discontinuity, which crosses the forearc region, does not appear to continue to the east beyond the trench nor to the western backarc region.

Sediments over 2.0 sec thick have been deposited in the Ogasawara Trough. The sediments show strong reflectivity and become more opaque to the west towards Shichito-Iwojima Ridge. The internal reflectors of the sediments are generally continuous, although reverberant horizons, which may be slumping deposits, are often observed (Fig. VI-1-d, Line 25). The upper sedimentary layer of the trough is evenly stratified, while the lower layer is appreciably deformed. The lower sedimentary layer of the trough tilts up to the eastern margin along the Ogasawara Ridge with the lower part tiling more steeply than the upper part. A slight disconformity can be observed here, as shown in Fig. VI-1-e (Line 19). Such a sedimentary structure suggests uplift of the Ogasawara Ridge both during and after the deposition of the lower sedimentary layer. The uplift of the Ogasawara Ridge, which seems to have continued during the deposition of the upper sedimentary layer, shows marked contrast with the stable basement high at the trench slope break in the northern Ogasawara Arc.

The sediments in the Ogasawara Trough onlap the Ogasawara Ridge. To the Shichito-Iwojima Ridge, however, the sedimentary structures show the same relationship as in the northern arc. Fig. VI-1-d (Line 25) shows that the sediments of the trough are continuous with the Shichito-Iwojima Ridge and that the sediments have derived from the ridge and its volcanic activity. In Fig. VI-1-c (Line 30), however, it can be seen that the sediments in the trough onlap the basement of the Shichito-Iwojima Ridge in the same manner as they do the Ogasawara Ridge. Such a feature, as mentioned before, suggests that the Shichito Ridge is composed of two different constituents; active volcanic ridge and non-active ridge.

(5) Northern Mariana Arc

The basement high at the trench slope break is also observed in the northern Mariana Arc (Figs. VI-1-g and h, Lines 10 and 4), although its structure is complicated and its continuity from profile to profile is very poor. The forearc basin is less developed on the northern Mariana Arc than in the Ogasawara Arc. The depositional structure of the sediments of the forearc basin indicates that the sediments have been derived from the Mariana Ridge and trapped behind the basement high of the trench slope break and that the basement high was uplifted after the deposition of the lower sedimentary layer, causing a slight disconformity in the sediments of the forearc basin.

(6) Shichito Ridge and Izu Ridge region

The Shichito Ridge is a well-developed chain of active volcanos which extends to the Mariana Ridge. It should be noticed that the Mariana Ridge and the West Mariana Ridge meet at Minami-Iwojima Island and extend northward as the Shichito-Iwojima Ridge. Non-volcanic parts of the Shichito Ridge, mentioned above in sections (2) and (3), often protrude to the east of the ridge chain, and may be the northern continuation of the West Mariana Ridge which could be an old volcanic chain.

Topographic depressions are often observed just behind the Shichito Ridge (Figs. VI-1-a, b, c, and d, Lines 43, 37, 30, and 25). We tentatively called these depressions "backarc depressions". The backarc depressions, which are nearly free of sediments and often flanked by scarps on both sides, are observed discontinuously, just behind the volcanic chain, from west of Hachijo Island to north-west of Nishinoshima Island. They are absent between Nishinoshima Island and Minami-Iwojima Island. The width of the depressions range from less than 20 km to 60 km, while the displacements of the scarps vary from 500 m to 1,300 m. Fig. VI-1-b (Line 37) implies that the backarc depression is an extensional basin younger than the Shikoku Basin which was generated by backarc spreading during the Late Oligocene to Middle Miocene, because the depression is nearly free of the sediments and has a central high which resembles to a spreading center. These backarc depressions are identical with the young extensional basin of KARIG and

MOORE (1975), although the arrangement of the backarc depression is different in detail from that of KARIG and MOORE'S young extensional basin. The Mariana Trough of the Mariana Arc is a well-documented young extensional basin. The backarc depressions of the Ogasawara Arc may be young backarc basins which have been simultaneously active with the Mariana Trough. It should be noticed that there is no young extensional basin in the backarc area between Nishino-shima Island and Minami-Iwojima Island, i.e. just in the junction area of the Ogasawara Arc and the Ogasawara Plateau.

The Izu Ridge is discontinuously developed west of the Shichito Ridge, along the eastern margin of the Shikoku Basin. The ridge is a remarkable north—northeasterly en-echelon arrangement, and is found in the northern Ogasawara Arc. The Izu Ridge can be discontinuously traced to southwest of Minami-Iwojima Island, west of the northernmost West Mariana Ridge. It does not appear to continue to the West Mariana Ridge.

A zone between the backarc depression and the Izu Ridge is termed the "backarc gap" in this chapter. The backarc gap, ranging from 50 km to 100 km in width, is generally a depressional structure between the Izu Ridge and the Shichito Ridge, and represents rugged basement overlain by acoustically stratified sediments 1.0 sec thick. The basement of the backarc gap often deepens along the western margin and a thick deposition of sediments can be observed here (Figs. VI-1-b, c, and d, Lines 37, 30, and 25). The sedimentary layer in the backarc gap is continuous with the basement of the Shichito-Iwojima Ridge while it onlaps the Izu Ridge as shown in Fig. VI-1-e (Line 19). This suggests that the sediments in the backarc gap have been derived predominantly from the Shichito Ridge and its volcanic activity and that the Izu Ridge is considerably older than the Shichito Ridge. The trend of the basement in the backarc gap is unknown from the present traverses. The water depth in the backarc gap deepens southward from less than 1,000 m to 3,500 m. Understanding of the origin of the backarc gap depends on future comprehensive study of the GH79-2, 3, and 4 data.

(7) Mariana Trough

The northern Mariana Trough decreases in width discontinuously to the north, and suddenly disappears just south of Minami-Iwojima Island. The northernmost appearance of the Mariana Trough is shown on Line 11′ where it has a width of about 9 km, Lines 10″ and 11, south of Line 11′, show no sign of the trough (Fig. VI-5). The narrowest width of the trough observed at the northern end of the Mariana Trough is 7 km, just south of Minami-Iwojima Island (Fig. VI-5 and Fig. VI-1-g, Line 10).

The bottom of the trough shows a ruggedness, whose trend is unknown from our survey tracks which have an interval of 7.5 nautical miles. It deepens southward from 1,700 m (Line 10) to 4,200 m (Line 1). The trough is generally free of sediments except in a few depressions within the trough. The maximum thickness of sediments observed on the trough measures 0.3 sec in a small trap among some knolls.

It has been deduced from the active spreading basin hypothesis that sediments

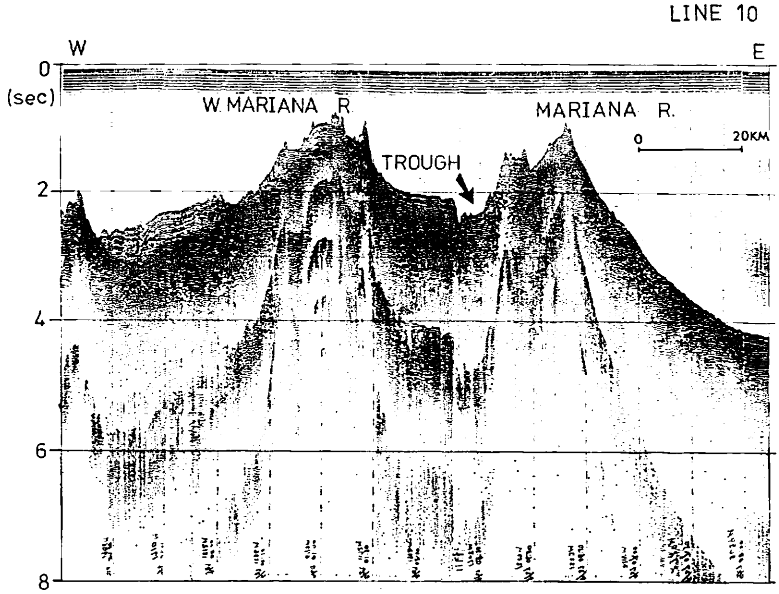

Fig. VI-5 Seismic profiles across the northern end of the Mariana Trough.

should be thin or absent along the center and thick along the margins of the trough, but such a distribution of sediments was not observed in the northern Mariana Trough.

(8) Shikoku Basin

Two complete transects (Lines 10 and 11) were carried out in the southern part of the Shikoku Basin, while other survey lines were restricted to the eastern margin of the Basin. A complete transect (Fig. VI-1-g, Line 10) shows that deposits of sediment occur only along the eastern margin of the Shikoku Basin and that deposition has taken place in a ponded environment with flat sea bottom. From this it appears that the sediments have derived from the east and were transported by turbidity-currents to their present site.

The western margin of Line 10 (Fig. VI-1-g), which crosses the saddle part of the Kyushu-Palau Ridge, clearly shows the differences between the Shikoku Basin and the Minami-Daito Basin in the Daito Ridges Region west of the Kyushu-Palau Ridge. Well-stratified sediments of 0.5 to 0.8 sec in thickness are observed in the Minami-Daito Basin, where the basement is not clear, while a clear basement overlain by a transparent layer can be observed in the Shikoku Basin. The feature suggests that the basins are different from each other in origin.

Basement relief in the Shikoku Basin increases its amplitude from north to south, while the thickness of the sedimentary layer decreases to the south.

A sedimentary layer 1.0 to 2.0 sec thick is observed along the eastern margin of the Shikoku Basin and increases its reflectivity to the east as shown in Figs. VI-1-a and b (Lines 43 and 37). This sedimentary layer contains a reflective horizon near the Nishi-shichito Ridge. The strong reflectivity sometimes hides the basement arrivals. Line 30 (Fig. VI-1-c) shows that a reflective horizon is exposed along the western slope of the Nishi-shichito Ridge. RC 51 (Line 30) and RC 55 (Line 38) were carried out specifically for the purpose of obtaining such a reflective horizon.

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