XVII. THE GEOLOGICAL SETTINGS OF THE OGASAWARA AND THE NORTHERN MARIANA ARCS

— CONCLUDING REMARKS —

Eiichi Honza

The Ogasawara Arc is continues into by the Tohoku Arc to the north and the Mariana Arc to the south. The Mariana Arc is on the southern extension of the Ogasawara Arc, separated from it by the Ogasawara Plateau on the Pacific side, which is why they are often referred to jointly as the Ogasawara-Mariana Arc. The northern margin of the Ogasawara Arc has a deviation from the ancient arc mass of the Seinan Japan Arc to the west. The modern Seinan Japan Arc is superimposed on the ancient Seinan Japan Arc and is associated with the subduction of the Shikoku Basin plate which might have been formed as a resultant marginal basin of Ogasawara Arc. The junctions of the three arcs on the northern margin of the Ogasawara Arc apparently show a triple junction of the trench-trench-transform fault type, which is somewhat difficult to perceive since the transform fault lies along the Sagami Trough, so that there appears to be one continuous trench throughout the Tohoku and Ogasawara Arcs. The weak development of the transform fault may result from the stability of the Seinan Japan Arc which forced the northern Ogasawara Arc to press northward and resulted in deformation and complexities with possible shear zones developing at oblique angles to the Arc (MOGI, 1972; KARIG and MOORE, 1975). The modern Nankai Trough is a trench associated with subduction of the Shikoku plate. Two possibilities exist for the initial position of the Ogasawara Arc; one assumes that the Nankai Trough was a transform fault and the Arc used to be in the position of the Kyushu-Palau Ridge and shifted toward the east along the south of the Seinan Japan until it reached a position in line with the Tohoku Arc to the north, thus creating the Shikoku Basin (KARIG, 1975; KARIG and MOORE, 1975). The other possibility is that the Ogasawara and the Mariana Arcs stable in their present position during the Late Cenozoic, while migration of the Kyushu-Palau Ridge took place toward the west. This theory is supported by the westward migration of the Philippine plate to result in subduction under Ryukyu and Philippine Arc during the Late Cenozoic (HONZA, 1977; MATSUDA, 1979).

A few morphological variations occur on both the forearc and the backarc sides of the Ogasawara and the Mariana Arcs. Some of the morphological variations of the arc system may be caused by the position of the volcanic chain which may result from the subduction of the oceanic plate under the arc.

The Mariana Trough is thought to be a modern, spreading backarc basin within the Mariana Arc (KARIG, 1971; HUSSONG and UYEDA *et al.*, 1979). A modern backarc basin does not exist in the Ogasawara Arc. Nevertheless geological environments in the Arc are almost the same as those in the Mariana Arc. A dominant volcanic ridge, which is joined to the forearc basement high on the Mariana

Arc is also distinguishable in the Ogasawara Arc with local grabens in the center of the ridge, which may suggest a modern spreading center. Some of the forearc morphological variation may result from original differences in morphology, before the start of arc activity. Backarc morphological variations may depend on other factors such as the direction of subduction, some obstruction on the oceanic plate which prevents smooth subduction and environmental factors such as the continental mass, which are well illustrated in the Ryukyu Arc (HONZA, 1977).

The volcanic rocks of the Shichito Ridge are composed of tholetic basalt, pyroxene andesite, dacite and rhyolite of Quatenary and latest Pliocene age (ISSHIKI, 1977). Dacite and rhyolite are observed only on the Zenisu Spur at the northwestern margin of the Ogasawara Arc.

The Ogasawara Ridge, which has one of the highest gravity anomalies in the world, comprises lave flows, pyrocrastic rocks and volcano-clastic sediment with fossiliferous beds of middle to late Eocene and late Oligocene age (HANZAWA, 1925; IWASAKI and AOSHIMA, 1970; MATSUMARU, 1974; KANEOKA *et al.*, 1970; SHIRAKI *et al.*, 1978; UJIIE and MATSUMARU, 1977). The volcanic rocks of the Ogasawara Ridge are composed of island arc tholeiites of middle to late Eocene age and calc-alklic volcanic rocks (boninite) of late Oligocene age, indicating the island arc volcanic history (KUNO, 1968; MIYASHIRO, 1974, SHIRAKI *et al.*, 1978).

Volcanic activity on the Ogasawara Ridge might have ceased during late Oligocene and modern volcanism have only taken place since the latest Pliocene to the west of the older volcanic ridge. The Ogasawara Ridge is a basement high on which volcanic activity has been infrequent in Recent times. The geological constituents of the Ogasawara and the Mariana Arcs are almost the same, with volcanic rocks of middle to late Eocene and late Oligocene age forming the forearc basement highs in both (Table XVII-1). The Hahajima Group is correlated to the Alutom Formation of the Mariana Arc and the Chichijima Group to the Umatac Formation of the Mariana Arc. There is no evidence of volcanic activity in either the Ogasawara or the Mariana Arc during the Miocene and early Pliocene, although outcrops which become a proof of these non-volcanic activity of this age are found on small islands on the ridges. The magnetic lineations suggest spreading of the Shikoku Basin during the late Oligocene to late Miocene, or later (WATTS and WEISSEL, 1975). It is inferred that volcanism is in direct opposition to spreading of a marginal sea. Less spreading takes place in the marginal sea when volcanism is active in the associated volcanic chain and conversely, spreading occures in the marginal sea when there is less volcanic activity in the volcanic chain.

Convection currents caused by frictional heating of the oceanic plate subducted under the arc is proposed as one possible mechanism for the spreading of a marginal sea. In this mechanism, upwelling heat energy under the backarc might provide the energy for volcanism in the volcanic chain (HONZA, 1978b). It is inferred that the upwelling heat energy is consumed by the spreading of the marginal sea when there is less volcanism, and that there is no horizontal component of the convection current when volcanism is taking place (Fig. XVII-1).

The volcanic rocks of the Ogasawara Ridge form a forearc basement high in the modern Ogasawara Arc, which may suggest its formation prior to the start of

Table XVII-1 Stratigraphical correlation between the Ogasawara and the Mariana Arcs. There is no evidence of volcanism in the Arcs during the early Oligocene, Miocene and early Pliocene.

	SHIKOKU BASIN	SHICHITO RIDGE	OGASAWARA RIDGE	MARIANA RIDGE
Quaternary	hemipelagic sediments and turbidites	volcanic rocks		Mariana Limestone
Pliocene				
Miocene	volcano-clastics			Alifan Ls. Bonya Ls.
Oligocene			Minamizaki F. volcanoclastics	Umatac Formation
Eocene			Sekimon F. Okimura F. Yusan F.	Alutom Formation
Paleocene				
References	DSDP results (KARIG, INGLE *et al.*, 1975; KLEIN, KOBAYASHI, *et al.*, 1980); WATTS and WEISSEL, 1974.	KUNO, 1968 MIYASHIRO, 1974; KANEOKA *et al.*, 1970.	HANZAWA, 1947; IWASAKI and AOSHIMA, 1970; MATSUMARU, 1974; UJIIE and MATSUMARU, 1977.	LADD, 1966.

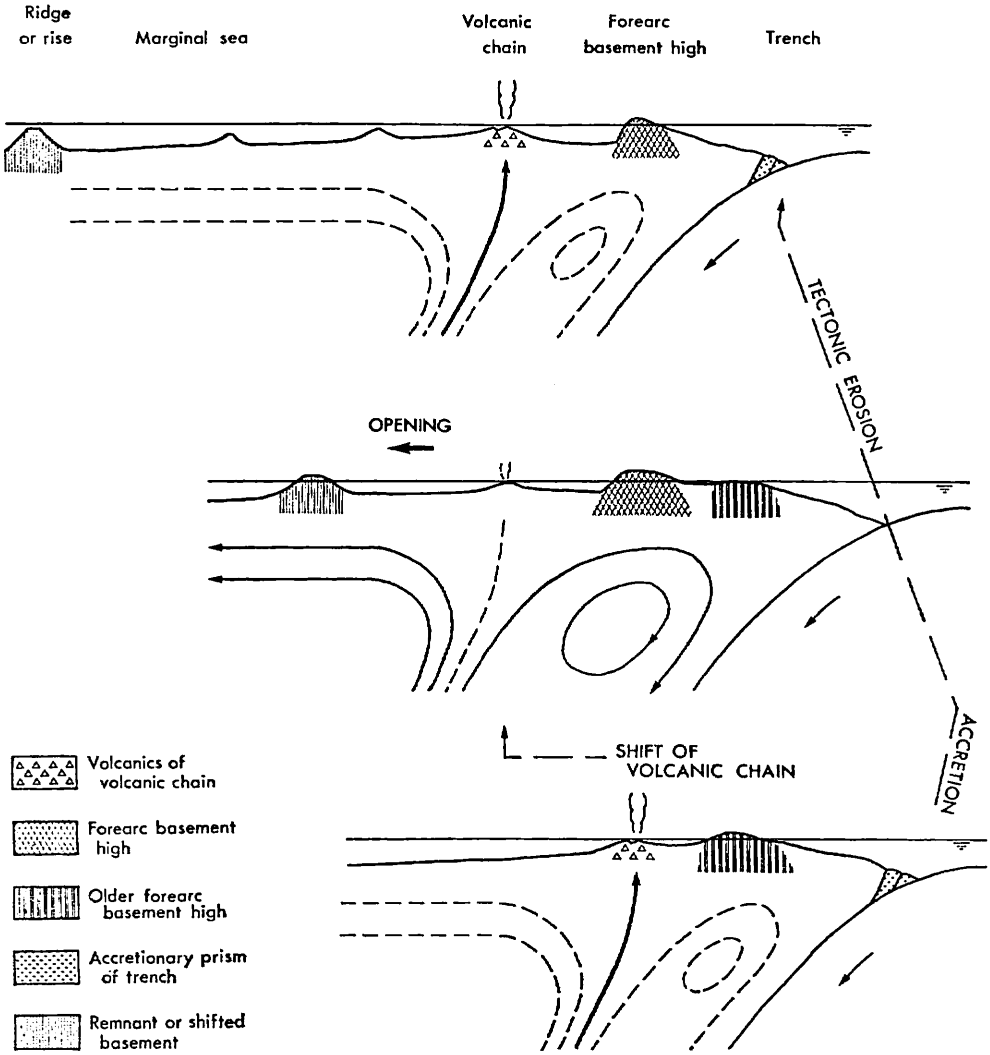

Fig. XVII-1 Schematic model for fundamental framework of the arc system based on a convection current model in which heating is caused by frictional heating of the subducted oceanic plate under the arc (Honza, 1978b). Less spreading occurs in the marginal sea when the volcanism is active on the volcanic chain associated with the accretionary prism on the trench. Less volcanism occurs in the volcanic chain when the marginal sea is opening associated with tectonic erosion and shortening of horizontal distance between the forearc basement high and the trench.

modern arc activity (HONZA in press). The framework of the modern Ogasawara Arc may have been formed since the late Pliocene in association with the formation of the Shichito Volcanic Ridge. It is inferred that there might have been a shift in the position of the volcanic chain from the Ogasawara Ridge to the Shichito

Ridge during the late Oligocene or Miocene.

There might have been a forearc basement high in the Eocene and Oligocene Ogasawara Arc on the eastern front of the Ogasawara Ridge which have been formed a volcanic chain. However, the older basement high is unrecognizable on the eastern front of the Ogasawara Ridge which is forming a forearc basement high in the modern Ogasawara Arc. It is inferred from the possibility that an older basement high was consumed, and from the horizontally short distance between the Ogasawara Ridge and the Ogasawara Trench, that shortening may have taken place between the Ogasawara Ridge and the Ogasawara Trench, in other wards, there might have been tectonic erosion at the trench. The period of consumption at the trench is also correlated with the period of opening and to a period of less volcanic activity in the Arc System during the late Oligocene to early Pliocene.

References Cited

HANZAWA, S. (1925) On foraminifera bearing rocks of Okinawa and Ogasawara Islands, *Jour. Geol. Soc. Japan,* vol. 32, p. 461–484.

HONZA, E. (1977) An island arc activity in the Ryukyu Arc and its difference in the northern and southern parts of the Arc, *in* K. KIZAKI *ed., Geology of Ryukyu Islands, Marine Science*, Tokyo, vol. 9, p. 607–611. (in Japanese with English abstract)

————, in press, Subduction and accretion in the Japan Trench, 26th IGC in Paris, Coll. 3–6.

———— (1978a) Geological development in the junction of the Seinan (SW) Japan and Ryukyu Arcs, *in* E. HONZA *ed., Geological investigations in the northern margin of the Okinawa Trough and the western margin of the Japan Sea,* Geol. Survey Japan, p. 69–73.

———— (1978b) Geological history of the Kuril Basin and the Tertary Trough, *in* E. HONZA *ed., Geological investigation of the Okhotsk and Japan seas off Hokkaido,* Geol. Survey Japan, p. 60–64.

HUSSONG, D., UYEDA, S., *et al.* (1978) Leg 60 ends in Guam, Geotimes, Oct. p. 19–22.

ISSHIKI, N. (1977) Neogene and Quaternary, *in* K. TANAKA and K. NOZAWA *eds.,* Geology and mineral resources of Japan, Part IV, igneous activity and metamorphism, Geol. Survey Japan, p. 373–414.

IWASAKI, Y., and AOSHIMA, M. (1970) Report on geology of the Bonin Islands, in Nature of the Bonin Islands, *Ministry of Education,* p. 205–220.

KANEOKA, I., ISSHIKI, N., and ZASHU, S. (1970) K-Ar ages of the Izu-Bonin Islands, *Geochemical Jour.,* vol. 4, p. 53–60.

KARIG, D. E. (1971) Structural history of the Mariana island arc system, *Geol. Soc. Amer. Bull.,* vol. 82, p. 323–344.

———— (1975) Basin genesis in the Philippine Sea, in KARIG, INGLE *et al., Initial Rept. DSDP,* vol. XXXI, p. 857–879, Washington.

————, INGLE, J. C., *et al.* (1975) *Initial Rept. DSDP,* vol. XXXI, Washington, 879p.

————, Moore, G. F. (1975) Tectonic complexities in the Bonin arc system, *Tectonophysics,* vol. 27, p. 97–118.

Klein, deV., G., Kobayashi, K. (1980) *Initial Rept. DSDP*, vol. LVIII, Washington.

Kuno, H. (1968) Differentiation of basalt magmas, *in* Hess *and* Poldervaart (*eds.*), *Basalt,* John Wiley and Sons, New York, vol. 2, p. 623–688.

Ladd, H. S. (1966) Chitons and Gastropods (Haliotidae trough Adeorbidae) from the western Pacific island. *Geol. Survey Prof. Paper,* no. 531.

Matsuda, T. (1979) Collision of the Izu-Gonon arc with Central Honshu: Cenozoic tectonics of the Fossa Magna, Japan, *in* Uyeda *et al.* (*eds.*), Geody*namics of the Western Pacific*, Japan Sci. Soc. Press Tokyo, p. 409–421.

Matsumaru K. (1974) The transition of the Larger foraminiferal assemblages in the Western Pacific Ocean—Especially from the Tertiary period. *Jour. Geograph. Soc. Japan*, vol. 83, p. 281–300.

Miyashiro, A. (1974) Volcanic rock series in island arcs and active continental margins. *Amer. Jour. Sci.*, vol. 274, p. 321–355.

Mogi, A. (1972) Bathymetry of the Kuroshio region, *in* K. Yoshida (*ed.*), *Kuroshio, its physical aspects,* Tokyo Univ. Press, p. 53–80.

Shiraki, K., Kuroda, N., and Maruyama, S. (1978) Evolution of the Tertiary volcanic rocks in the Izu-Mariana Arc. *Bull. Volcanol.*, vol. 41, p. 548–562.

Ujiie, H., and Matsumaru, K. (1977) Stratigraphic outline of Hahajima (Hillsborough Island), Bonin Islands. *Memo. Nation. Sci. Museum,* no. 10, p. 5–18.

Watts, A. B. and Weissel, J. K. (1975) Tectonic history of the Shikoku marginal basin. *Earth Planet Sci. Lett.*, vol. 25, p. 239–250.