38. *Island Arcs and Superposition of Structures in Japan*

The Developments of the Japanese Islands. VI

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The formation of the Japanese Island arcs. The Japanese Islands have developed through several stages under different subduction systems, since Silurian, possibly since Ordovician (Kimura, 1986). Disposition of geosynclines—marginal seas or fore-arc basins—, island arcs and belts of igneous activity varied with stages in accordance with the change of subduction systems (Fig. 1). During the Silurian-Early Carboniferous *Motai-Nagasaki rift stage* and the Late Carboniferous-Middle Permian *Mikabu rift stage*, the Chichibu geosyncline was produced and extended. Until the end of the Late Permian-Middle Jurassic *Akiyoshi stage* the Hida continental marginal area and the Kurosegawa-Ofunato islands on both sides of the Marginal sea of the Chichibu geosyncline formed two belts of granite, rhyolite and andesite activities. On the oceanic side of the Kurosegawa-Ofunato islands, there was the Sambosan geosyncline as a fore-arc basin. Further on the oceanic side of the Sambosan, there were subduction zones of those stages, and in the present-day central part of Hokkaido there was a oceanic crust area of the Sorachi geosyncline of the Akiyoshi stage (Kimura, 1987).

In the Late Jurassic-Cretaceous *Sakawa stage*, a new fore-arc basin of the Shimanto-Ezo-Hidaka geosyncline was produced on the oceanic side of the Sambosan belt and a subduction zone was outside the geosyncline. The granite and andesite belt in this stage was made on the continental side of Proto-Median Tectonic Line (Kimura, 1987a) which was created in the early Sakawa stage diagonally to the older tectonic belts and parallel to the new subduction zone and fore-arc basin. Granite and andesite activities occurred for the first time in the northern part of the Chichibu geosyncline in Southwest Japan and in the extension of the Sambosan geosyncline in West Hokkaido, but revived in the old Ofunato islands in southern Kitakami. Through the earth-movements during the early Sakawa stage, the Chichibu geosyncline and the northeastern part of the Sambosan geosyncline were changed to the land or continental shelf areas, and the framework of the Honshu arc extending to West Hokkaido was firmly produced (Kobayashi, 1941) diagonally to the older tectonic framework.

During the *transitional stage from the Sakawa to the Hidaka* (1987b), the Honshu arc bent strongly and shifted toward the ocean leaving Proto-Japan Sea behind. The bending and shifting were accompanied with the formation of the grand strike slip faults along the Akaishi and Kanto tectonic lines in central Honshu, and the grand low angled overthrust along the Butsuzo tectonic line. The igneous activities of the stage occurred in the central Honshu arc and in the adjacent area to the Japan Sea—the Izumo-Oga area—. In Hokkaido, the N-S trending axial mountains were uplifted to form a structural belt extending to Sakhalin. Then, Northeast Japan which is composed of the northeastern part

of the Honshu arc and the Hokkaido-Sakhalin arc has been first produced in the transitional stage from the Sakawa to Hidaka. In Kyushu, N-S trending structures, diagonal to the E-W structures of the preceding Sakawa stage, began to be formed. The Kyushu-Ryukyu arc began to be produced in this way.

In the Paleogene *Hidaka stage*, the granite and/or andesite activities occurred in the Izumo-Oga area, and on the west and on the north side of the Akaishi and the Kanto tectonic line in Honshu, in the Hidaka belt and East Hokkaido, and at Amami and Ishigaki islands in the Ryukyu arc. Geologic structures produced in the stage were running in Hokkaido parallel to the northern Honshu arc and diagonal to the extension of the Miocene Kuril islands arc, but in Kyushu almost parallel to the Miocene Ryukyu arc. The subduction zone of the Hidaka stage lay on the oceanic side of the Setogawa-Nakamura fore-arc basin in Southwest Japan and off East Hokkaido.

In the Neogene and Quaternary *Mizuho stage* (Kimura, 1987c), the oceanic plate was separated into two: The Pacific and the Philippine Sea plates. The former began to be subducted about 25 Ma and the latter 20 Ma. The Honshu arc was separated into its northeastern part, and its southwestern part—Southwest Japan—, according to the separation of the oceanic plate, but its outline as an arc was maintained because the basement construction made until the previous stage was too strong to be broken. The belt of andesite and granite was also separated in the Mizuho stage into two belts: The one is running from Kurils through Tohoku to southern Fossa Magna and another from Southwest Japan to Ryukyu. However, volcanism of Southwest Japan extended in Miocene to southern Kanto, the southern end of Northeast Japan, where superposition of volcanism of two belts occurred in the same area (Fig. 1, A6). Furthermore, the Izumo-Oga area was a continuous andesite belt from Southwest Japan to southern Northeast Japan in early Miocene. Northeast Japan and Southwest Japan have not been sharply separated. The volcanism of the Izumo-Oga area is thought to have been related to the older subduction slab of the preceding Hidaka stage when the Honshu arc has not been separated into two. In Southwest Japan, late Miocene subduction slab lay beneath the San'in area and caused the volcanism there. However, present subduction slab disappears beneath the northern part of Shikoku and does not reach San'in. Latest Quaternary volcanism in San'in may be related to the late Miocene subduction slab.

In Tohoku and Hokkaido the main topography is produced by up-and-down movements of basement fault block. Therefore the N-S trending crustal blocks in Hokkaido, which have been made in the Hidaka stage, hinder in the Mizuho stage to form a topographic arc parallel to Kuril-Japan trench. In contrast, a continuous topographic arc from Outer Zone of Southwest Japan to Ryukyu islands was made in the Mizuho stage, where warping in the N-S direction parallel to the northern Ryukyu arc had occurred in the preceding Hidaka stage.

The island arcs of Japan were produced as superposed composite products of earth-movements of several stages (Fig. 1, B). The Honshu arc was already made before Miocene, but was separated into two in the last Mizuho stage. However, the granite plutonism of the Sakawa stage formed a firm crustal construction and fixed the present-day general outline of the Honshu arc.

Ophiolite, olistostrome and high pressure metamorphism. Most ultra-mafic rocks appear in Japan as solid intrusive bodies or as sliding blocks in olistostrome. Those in Kurosegawa tectonic zone, in some parts of the Kamuikotan belt, at Setogawa in eastern Tokai and at Mineoka in Southern Kanto are the intrusive

Fig. 1. Developments of Japanese island arcs and changes of belts of igneous activity. A1-A6: Japanese Islands in each stage. B: Japanese Islands at present. Ultra-mafic Rocks: mo, in Motai-Nagasaki rift; mi, in Mikabu rift; s, in Sorachi geosyncline. n: Submarine basaltic rocks in Nikoro belt. Tectonic belt: k.o.i., Kurosegawa-Ofunato islands; F, Fossa Magna. Faults: P.M.T.L., Proto-Median Tectonic Line; T.L., Tectonic line; IT, Itoigawa-Shizuoka line. MVF: Miocene volcanic front in southern Northeast Japan-Kurils. MIF: Miocene front of igneous activity in Southwest Japan.

masses. There are abundant olistostromes in Japan, but a few contain ultra-mafic blocks. Olistostromes in the Motai-Nagasaki rift and Sorachi geosyncline contain those blocks. However, they are covered by thick succeeding clastic sediments. The Paleogene Setogawa group (Kimura, 1987c) and the Neogene Hota formation near Mineoka yield locally distributed olistostromes containing ultra-mafic blocks which have been supplied from solid intrusive bodies. Olistostromes in Permian, Jurassic and earliest Cretaceous Chichibu marginal Sea, and in Cretaceous Shimanto and Hidaka fore-arc basins are remarkable. They contain few blocks of ultra-mafic rock, and contain blocks of chert which is of rather shallow water origin (Iijima *et al.*, 1978), except for those of the Sorachi geosyncline, and blocks of quartz-feldspathic sandstone of continental shelf or slope origin. Chert in the Sambosan geosyncline on the oceanic side of the Kurosegawa-Ofunato islands deposited in the area not far from land

(Ohashi, 1984). The geosynclinal strata, as well as olistostromes, are not accretionary strata of oceanic deposits.

The Sangun high pressure metamorphism was produced by the overburden of submarine sliding nappes originated by uplift of the Hida high temperature belt. The Sambagawa and Kamuikotan metamorphism in the early Sakawa stage occurred on the oceanic side of Proto-Median Tectonic Line running diagonally to the older tectonic belt. It was produced by the overburden of tectonic and submarine sliding nappes originated by the uplift of the Paleo-Ryoke belt and West Hokkaido. High pressure metamorphic rocks in Japan are not the products in Subduction zone.

Accretionary prisms of oceanic crust fragments and oceanic deposits, and products in subduction zones do not appear on the earth surface in Japan. The Japanese islands arcs are not conglomerates of ancient micro-continent, which have been transported from remote areas and produced independently with each other, and of accretionary prisms.

Superposition of deformation. Tectonic deformations occurred in the high temperature belts of igneous activity and in the low temperature belts within the Chichibu and Sorachi geosynclines during subduction stages when submarine sliding nappes were also produced. Foldings and thrustings in the fore-arc basins, the low temperature belts, occurred at the end of the geosynclinal stage. The grand Butsuzo overthrust and the grand strike-slip faults along the Akaishi and Kanto tectonic lines were produced in the transitional stage from the Sakawa to Hidaka. The deformations in Japan are not limited to those related to subduction.

The folding in the high temperature belts formed structural layers of flow-shear-flexure fold series. The folds of southern Northeast Japan in the Mizuho stage are flexure ones of this series, but many are products of block faulting without features made by strong compression. The Butsuzo thrust, and the Akaishi and Kanto strike-slip faults have been also produced due to mobilization of deep earth crust under high temperature condition (Kimura, 1983). The folds in the low temperature belts are of flow-lens-flexure fold series (Kimura, 1979). The Japanese Islands were suffered from deformations of several stages. Shift and rotation of tectonic belts and variation of structural horizons due to uplift and subsidence occurred according to the change of stages. Therefore, superposition of older and younger deformations produced complicated geologic structures in Japan, especially in old strata. Even the young strata in southern Fossa Magna and southern Kanto form composite geologic structures, because the area is strongly influenced in the Neogene and Quaternary Mizuho stage by the subduction of two oceanic plates: the Pacific and the Philippine Sea plates.

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