OBLIQUE SUBDUCTION AND COLLISION : FOREARC TECTONICS OF THE KURIL ARC¹

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Abstract : The tectonics of the southwestern Kuril are a result of the oblique subduction of the Pacific plate at the Kuril Trench. In association with forearc sliver migration caused by the oblique subduction, collision tectonics occur at the leading margin of the sliver and tensional tectonics take place at the tapering margin. As a result of the collision, a deep crustal section of island arc is observed at the leading margin of the forearc sliver. Tectonics of the Kuril arc related to oblique subduction are different from those of the western Sunda arc, where backarc spreading occurs at the leading margin. This difference is due to margin morphology of the oblique subduction zone.

Key words : Oblique subduction, Forearc tectonics, Collision, Kuril arc.

Introduction

Oblique subduction is the most common mode of subduction. The tectonics of oblique subduction zones are important keys in analyzing ancient orogenic zones. The tectonics of oblique subduction have been synthesized mainly from study of the western Sunda arc (*e. g.*, Fitch, 1972 ; Karig, 1978). In this paper, I introduce another example of oblique subduction-related tectonics, the Kuril arc. The western Sunda arc represents backarc spreading at the leading margin of the forearc sliver, whereas the Kuril arc is characterized by a forearc collision at the margin.

Geologic and Tectonic Framework of the Kuril Arc

The Kuril extends from Hokkaido Island in Japan to the Kamchatka Peninsula in the U. S. S. R. (Fig. 1). The arc is divided into two parts, the southwestern and northeastern parts, which are different from each other in strike and geomorphic features (Fig. 1). The Kuril arc trends northeast in its northeastern part, bends at the Bussol Straits, and continues to the east-northeast-trending southwestern segment. I call these parts the northeast Kuril arc and the southwest Kuril arc, respec-

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Fig. 1. Submarine topography of Kuril arc. Depth contours in kilometres ; 0.5-km intervals. Areas surrounded by dashed lines indicate localities of Figures 2, 3 and 4.

tively. The southwest Kuril arc has conspicuous geomorphic features. The volcanic islands are arranged en echelon, and the frontal arc is traced from the Nemuro Peninsula in Hokkaido to the middle part of the Kuril arc. A buried narrow basin is located between the volcanic and frontal arcs. The northern margin of the basin is bounded by active faults, and deeper parts of the basin are arranged en echelon along the fault (Gnibidengo *et al.*, 1984) (Fig. 2). This structural pattern suggests that the basin has been formed by strike-slip movement of the northern margin faults. The westernmost part of the fault between the volcanic and frontal arcs is observed on land in Hokkaido. It is a dextral strike-slip fault (Kimura, 1981 ; Kimura *et al.*, 1983). Focal mechanism of an earthquake along the fault (Teshikaga earthquake, 1959) also shows a strike-slip movement (Seno, 1985). Volcanic islands of the southwest Kuril arc are composed mainly of Tertiary to Quaternary volcanic and marine sedimentary rocks. Northeast-trending folds are associated with post-Miocene (Kimura, 1981) dextral strike-slip movement between the frontal and volcanic arcs (Kaizuka, 1975). The frontal arc consists of gently deformed Upper Cretaceous to Paleogene volcanics and volcanic sediments. The inner trench slope region of the southwest Kuril arc is made up mainly of the Upper Cretaceous to Paleogene accretionary prism. A zone of high-amplitude magnetic anomalies is observed along the frontal arc (Segawa and Furuta, 1978). The zone appears to consist of serpentinite bodies (Iijima, 1962).

The geomorphic features of the northeast Kuril arc differ from those of the southwest arc. The volcanic islands are not arranged en echelon but are linear. The frontal arc of the northeast Kuril arc is poorly developed, whereas that of the southwest arc is well developed. The geologic structure of the northeast and southwest Kuril arc is interrupted by a gap at the Bussol Straits in the central part of the Kuril arc (Gnibidenko *et al.*, 1984). This geomorphic difference between the northeast and southwest Kuril arcs appears to be related to the difference in mode of the Pacific

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Fig. 2. Narrow basin in front of Kuril volcanic arc.

plate along the Kuril Trench. The subduction of the Pacific plate is mostly perpendicular at the northeast Kuril Trench, whereas it is oblique at the southwest Kuril Trench. The observed geologic and geomorphic features of the southwest Kuril arc: the dextral strike-slip movement between the volcanic and frontal arcs, the formation of the en echelon islands, and serpentinite bodies rising due to strike-slip faulting (Kimura and Tamaki, 1985) are all features associated with the oblique subduction of the Pacific Plate.

Tectonics and Geology of Both Margins of the Southwest Kuril Arc

At the northeastern end of the southwest Kuril arc, a deep trough (Fig. 3B) trending perpendicular to the arc is situated between Urup and Simsir islands, southeast of the Bussol Straits. The trough is about 5000m deep. A seismic profile across the Bussol Straits indicates that thick sediments have accumulated and the margins are bounded by normal faults (Gnibidenko *et al.*, 1984). The trough appears to have been formed as a graben caused by northeast-southwest tension. Submarine topography shows that the landward extension of the trough axis turns to the west at the south of Urup Island and continues to the basin between the volcanic and frontal arcs (Fig. 3B). This basin has been formed in association with the dextral strike-slip movement between the volcanic and frontal arcs as mentioned before. The graben and the strike-slip faulting are interpreted by the southwestward translation of the southwest Kuril forearc.

In contrast, at the southwestern end of the southwest Kuril arc a collision is in progress. The

Fig. 3. Tectonic features of northeastern and southwestern margins of southwest Kuril arc. P indicates profile line in Figure 4.

Hidaka Mountains rise in the central part of Hokkaido just south of the present volcanic front. The Hidaka Mountains trend north-south and are convex westward (Fig. 3A). The mountains are made up mainly of high-temperature metamorphic and intrusive rocks (the Hidaka metamorphic belt). The metamorphics are mainly granulite, gneiss, migmatite, and granite (Komatsu *et al.*, 1982) and are concordantly piled up from deeper metamorphics to shallower ones. K-Ar ages of these rocks show that they were formed in the Tertiary, dominantly during Miocene time (Shibata and Ishihara, 1981). Komatsu *et al.* (1982) pointed out that this section shows the crust of the island arc, which thrusts up on the western Cretaceous subduction complex (Fig. 4), to be about 20 km thick. The Hidaka metamorphic and intrusive rocks appear to constitute the lower crust of the Miocene Kuril arc. The Hidaka Mountains are truncated by the recent volcanic front with a northeast-trending dextral strike-slip fault, which has been active since late Miocene time (Kimura *et al.*, 1983). The fault marks the northern limit of the distribution of metamorphics. The late Miocene uplift of the metamorphics is well constrained by sediments surrounding the Hidaka Mountains (Miyasaka and Kikuchi, 1978). The northeast-trending dextral strike-slip movement and the westward upthrust of the Hidaka metamorphics started concurrently in the late Miocene. This movement suggests that the southwestward migration of the Kuril forearc sliver resulted in collision with the northeast Japan arc. Recently, the French-Japanese KAIKO Project has found a northwest-southeast-trending fault just north of the recent Japan-Kuril Trench junction (Fig. 2). Le Pichon *et al.* (1984) pointed out that this fault is a counterpart of the dextral strike-slip fault at the volcanic front, and they supported the southwestward migration of the forearc sliver of the southwest Kuril arc.

Fig. 4. Geologic profile of Hokkaido. Location shown in Figure 3.

Seismicity within the continental plate is higher around the Hidaka Mountains than in other regions in Hokkaido (Seno, 1985). The northeast-southwest compressional focal mechanisms are parallel to the elongation of the southwest Kuril arc and perpendicular to the Hidaka Mountains. Tada and Kimura (1985) pointed out that the maximum contracting directions and movements of triangulation points revealed by geodetic data are also consistent with the forearc collision model. The seismicity and geodetic data indicate that the collision is still going on.

The forearc region south of the Hidaka Mountains is a unique forearc where collision is in progress near the trench. As the Hidaka Mountains represent the lower crust of the volcanic arc, exposure of the deeper rocks under the trench slope area is expected to be near the trench.

Discussion

As mentioned above, the southwest Kuril arc is characterized by strike-slip movement between the volcanic and frontal arcs, a graben at the northeastern end of the forearc, and collision at the southwestern margin of the forearc. These tectonic features suggest the southwestward migration of the Kuril forearc sliver. This is the typical tectonic mode in oblique subduction zones suggested by Fitch (1972). Similar tectonic events are occurring in the western Sunda arc. A forearc sliver of the Sunda arc (Burma plate) is migrating northwestward. Recently, Huchon and Le Pichon (1984) pointed out that a graben is formed at the southern margin of the Sunda arc (the Sunda Strait). This graben is analogous to that of the northeastern end of the southwest Kuril arc. At the northern end of the Sunda arc, tectonics different from those of the southwest Kuril arc are occurring. The Andaman Sea is actively opening at the northern margin of the Sunda arc. The sea is considered to have

spread by diverging movement between the Sunda forearc sliver and the Eurasia plate (*e.g.*, Seno and Eguchi, 1983). The opening of the northern margin of the Sunda arc contrasts with the collision at the southern margin of the Kuril arc. This difference is due to the margin morphology and plate boundary condition. The Kuril forearc sliver is straighter than that of the Sunda arc around the leading margin of the sliver. As a result, the migration of the sliver does not introduce backarc spreading between the forearc sliver and the backarc plate. Moreover, in the case of the Kuril arc, the migration of the forearc sliver is constrained by another plate, the Eurasia or Amurian plate (Kimura and Tamaki, 1985) at its southwestern margin. In the case of the Sunda arc, however, the forearc sliver is able to migrate northward because there is no continental mass resisting the northward movement (Fig. 5). This difference introduces the contrast in island-arc mar-

gin tectonics between the two arcs when the oblique subduction causes forearc sliver migration. The collision occurring in the Kuril arc is significant for arc material accumulation and uplift of the metamorphic rock at the island-arc margin. Oblique subduction is the general mode of subduction and took place dominantly along the western and eastern Pacific subduction zone during the Mesozoic (Taira *et al.*, 1983; Maruyama and Seno, 1985; Kimura, 1985; Beck, 1983). Oblique subduction-related collision or backarc spreading at that time would have been common.

Fig. 5. Comprison of Kuril and western Sunda arcs. Kuril arc is characterized by collision of forearc sliver with other arc at margin. Sunda arc indicates backarc spreading at margin caused by forearc sliver migration.

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