Mechanism of mantle upwelling: difference between northwestern Kyushu and Chugoku district in southwestern Japan

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Origin of Cenozoic volcanism in the southwestern Japan, including the eastern part of China and Korea, has been argued to have been related to a mantle plume or plumes in a hot region (Miyashiro, 1986) with minor involvement of a subducting plate (Nakamura et al., 1985). Although volcanic activities in the Chugoku district in southwestern Japan have been interpreted to have been triggered by a mantle upwelling associated with opening of the Sea of Japan (Iwamori, 1989; Kimura et al., 2003), the volcanic activity in northwestern Kyushu as a whole has not been clarified yet. The basaltic activity in northwestern Kyushu differs in some characteristics from that of the Chugoku district. It is later in initiation, larger in amount to form plateau, more dominant in basalt, and more depleted in incompatible trace elements and isotopic composition (Kakubuchi et al., 1995) than the activity of the Chugoku district. This research aims at clarification of the origin of the volcanic activities of northwestern Kyushu and to reveal the genetic differences in Cenozoic volcanic activity between northwestern Kyushu and the Chugoku district.

Kita-Matsuura basalt, which is located in the center of Cenozoic basalts in northwestern Kyushu and is the largest in volume has subalkaline–alkaline basalt lavas with SiO2 ranging from 47 to 54 wt%. Newly established volcanic stratigraphy has revealed systematic temporal and spatial variations. Eruption K-Ar ages are almost equivalent in each area as 8-6Ma. Mildly alkaline basalts with common occurrence of clinopyroxene and plagioclase together with olivine phenocrysts dominate in the eastern area, whereas subalkaline olivine-phyric basalts are common in the western area. Variation of groundmass composition without evidence for mixing can be explained by cpx, ol, and pl in the eastern area, ol, cpx, and (pl) in the western area, but the variation cannot be explained from each other by crystal fractionation model. Comparison of estimated primary melt composition for each area with high pressure experiment of dry spinel lherzolite (Hirose and Kushiro, 1993) reveals that melt segregation pressure and temperature were 0.8-1.4 GPa and 1325-1400C in the western area and 1.6-2.2 GPa and 1330-1415C in the eastern area. The melting degrees are estimated to be 11.6-16.1% in the western area and 10.2-14.2% in the eastern area according to the abundance of incompatible trace elements. The Nb/Th ratio of each area decreases gradually with time, and this temporal change can be explained partly by small amount of assimilation of partial melt of a crustal material around Kyushu in addition to crystal fractionation (AFC, DePaolo(1981)). The Nb/Th ratio of undifferentiated basalt in each area, however, cannot be explained from each other by AFC. The difference is attributable to the difference in the source composition because pressure, melting degree, and separation efficiency cannot explain the contrast.

Kita-Matsuura basalt lies just on the extension of the axis of Okinawa Trough currently propagating in the southern part. The early rifting phase of Okinawa trough was dated Late Miocene in the northern part (Letouzey and Kimura, 1985). Concentrical propagation of basaltic activity from Kita-Matsuura, and the largest erupted volume in Kita-Matsuura on the central part of northwestern Kyushu suggest that the heat source of Cenozoic volcanic activity beneath northwestern Kyushu is centered beneath Kita-Matsuura, and the asthenospheric upwelling was associated with opening of Okinawa Trough. This does not conflict with the suggestion after Uto et al. (2004).

In contrast to fluid enriched plume in Chugoku district (Iwamori, 1992), high temperature plume was responsible for Cenozoic volcanic activities in northwestern Kyushu. Higher melting temperature in northwestern Kyushu than that in Chugoku district may cause voluminous basaltic activities characteristic in northwestern Kyushu.