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Thermo-chemical evolution of mantle wedge during the incipient stage of the Izu-Ogasawara-Mariana subduction zone

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It is essential to understand the processes of subduction zone initiation and evolution of oceanic arcs which promote the development of Earth's structure and composition. We present the genetic conditions of the Eocene magmas from the Ogasawara (Bonin) Ridge and discuss the thermo-chemical structure of the mantle wedge beneath the Ogasawara region during the incipient stages of the IBM arc. On the Ogasawara Ridge, MORB-like basalt (forearc basalt: FAB) is generated just after the beginning of subduction of the Pacific Plate at 52 Ma, followed by ultra-depleted high-Si boninite activities began at 48Ma. This high-Si boninite magmatism gradually changed through less-depleted low-Si boninite at 45 Ma to arc tholeiite and calc-alkaline magmatism [1, 2].

Major element compositions of high- and low-Si boninites are similar to those of experimentally produced melts of harzburgite [3] and lherzolite [e.g. 4], respectively. Ultra low concentrations in rare earth elements (Yb$>$0.3 ppm) of high-Si boninite also indicate a depleted harzburgite source. On the other hand, characteristically high Zr/Ti ratio ($<$0.04) of boninites from the Ogasawara Islands reflects high contributions of slab melt [2]. FAB is produced by less than 10 % fractional melting of MORB source mantle, leaving residue of moderately depleted lherzolite. This suggests that the residue of FAB cannot be the highly depleted source of high-Si boninite.

P-T conditions at which the most primitive boninitic melts can coexist with harzburgite are 1430 ℃ and 0.83-0.96 GPa for high-Si boninite (MgO=23, H_2O=3.2 wt%) and 1380 ℃ and 0.86 GPa for low-Si boninite (MgO=19, H_2O=2.6 wt%) [5]. Genetic conditions of magmas other than boninite are dry, ~1350 ℃ and 1.3-1.7 GPa for FAB and water-undersaturated (0-0.5 wt%), 1300-1350 ℃ and 1-1.2 GPa for arc tholeiitic and calc-alkaline magmas, which were estimated by comparing calculated primitive liquid compositions with experimentally produced liquid compositions of lherzolite melting [e.g.4].

Mantle potential temperatures (T_p) calculated based on MgO content of primary magmas are 1500 ℃ for high-Si boninite and 1450 ℃ for low-Si boninite, which are higher than the ambient mantle (T_p=1300-1400). Especially Tp for high-Si boninite is comparable to T_ps of mantle plumes [6]. This result is consistent with plume-related magmatism (51-45Ma) in the West Philippine Basin simultaneously with the high-Si boninite magmatism in the Ogasawara Ridge [7]. The ultra-depleted source of high-Si boninite is possibly the residue of the plume-related magmatism. T_p of FAB and arc tholeiitic and calc-alkaline magmas is 1400 ℃, equivalent to the ordinary oceanic mantle.

From the above, the thermo-chemical history of the mantle wedge beneath the Ogasawara Ridge during the incipient stage of the IBM subduction zone is advocated as follows; Spontaneous sinking of old, dense Pacific Plate induced upwelling of asthenosphere which melted to produce FAB in eastern margin of the Philippine Sea Plate at 52 Ma. At 48 Ma, depleted residual harzburgite of plume-related magmatism upwelled from deeper (~3.5 GPa ?) asthenosphere to 1 GPa, suffering flux melting incorporating slab melt to generate the high-Si boninite magma. By 45 Ma, shallow mantle wedge was cooled by the subducted slab and asthenosphere began circulating in the wedge. As a result, magma composition changed from high-Si boninite through low-Si boninite to arc tholeiite and calc-alkaline magmas more fertile than the Quaternary frontal lava. Subsequently the IBM subduction zone changed to a stable arc-trench system.

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