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Origin of geochemical variations of primary boninite magmas of the Ogasawara (Bonin) Archipelago

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Stratigraphy and ages of volcanic rocks of the Ogasawara Archipelago indicate secular variations of magmas generated during the early Izu-Ogasawara-Marina Arc with the progress of subduction of the Pacific Plate. The onset of subduction of the Pacific Plate beneath the Philippine Sea Plate at 52 Ma forced upwelling of depleted mid-ocean ridge basalt mantle (DMM; Workman and Hart, 2005), which was adiabatically melted to yield proto-arc basalt (PAB). With the rise of DMM, refractory harzburgite ascended without melting, and hence retained its high temperature. At 48-46 Ma, introduction of slab fluids caused remelting of the PAB residue and high-T harzburgite, resulted in the low-Si and high-Si boninites, respectively. Meanwhile, convection within the mantle wedge brought the less depleted residue of PAB and DMM into the region fluxed by slab fluids, which melted at 45 Ma to yield less depleted low-Si boninite and fertile arc basalts, respectively. By 40 Ma boninite magmatism was replaced by arc tholeiite and calc-alkaline magmatism (Ishizuka et al., 2006, 2011; Umino and Nakano, 2007; Kanayama et al., 2012; Umino et al., 2015). Here, we discuss the origin of the geochemical variations of primary boninite magmas on the basis of melt inclusions in chrome spinel from the Ogasawara Archipelago.

48-46Ma ultra-depleted high-silica boninitic melt inclusions (SiO_2 >54.7 wt%, MgO <23.3 wt%) exhibit V-shaped and dish-shaped rare earth element (REE) patterns. The former inclusions have higher LILEs/La ratios than the latters. V-shaped REE patterns are unique to melt inclusions and have never been found among the bulk boninites. On the other hand, all 48-46Ma low-silica boninitic inclusions (SiO_2 >54.6 wt%, MgO <17.7 wt%) show dish-shaped REE patterns, which are common to bulk boninites. On the contrary, 45Ma less-depleted boninitic melt inclusions have the lowest SiO2 (SiO_2 >53.5 wt%, MgO <18.9 wt%) and flat REE patterns.

We have modeled the geochemical variations of primary boninite magmas, which are assumed to be the highest MgO melt inclusions of each geochemical type, by using the Arc Basalt Simulator (Kimura et al, 2010). Ultra-depleted boninite magmas were generated by partial melting of residue of 10% to 20% fractional melting of DMM, with the introduction of fluid liberated from eclogitic slab. LILEs/La variations of the ultra-depleted melts could be explained by the varying degrees of dehydration of the mantle just above the subducting slab, depending on the thermal status of the mantle wedge. The 45-Ma less-depleted boninite magma requires less depleted source mantle which experienced 4 to 8% fractional melt from DMM with relatively high contribution of sediment fluid.

Major and trace element variations of boninitic melt inclusions can be explained by the mixing of primitive boninite magmas with felsic melts during ascent in the upper mantle. Mixed magmas entered into the stability field of chrome spinel, resulted in rapid crystallization of chrome spinel which trapped melt with a broad compositional range (Arai and Yurimoto, 1994).

Different compositional variations of the bulk boninites from the melt inclusions were formed by crystallization of spinel, olivine and pyroxenes from primitive magmas enhanced by degassing at shallow depths, combined with mixing with evolved magmas.

Keywords: boninite, melt inclusion, trace element composition, subduction zone, island arc, primary magma