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Petrologic evolution of boninite lavas from the IBM Fore-arc, IODP Expedition 352: Evidence for open-system processes during early subduction zone magmatism

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Abstract

Boninite samples from several intervals within Hole U1439C, recovered during IODP Expedition 352, show highly variable mineral chemistries that imply complex crystallization histories. Small pyroxene grains show oscillatory zoning with cores and zones ranging from pigeonite to augite. Late crystallizing augite has highly variable Al_2O_3 contents (1.9–13.7 wt%) and Ca-Tschermak component contents (3–13 mol%), which reflect disequilibrium conditions. Large, euhedral, low-Ca pyroxene (i.e., enstatite/clinoenstatite) crystals exhibit complex sector and oscillatory zoning patterns. Cr-rich spinel is found as inclusions both in olivine and low-Ca pyroxene. Early crystallized olivine phenocrysts have embayed and reacted margins, and some early crystallized olivines exhibit zoning. A few olivines have multiple zones, with both normal and reverse zoning between $Fo_{86–92}$. Olivine xenocrysts also have embayed and reacted margins; however, xenocrysts do not exhibit chemical zoning patterns and have consistent Fo_{88} compositions. Disequilibrium crystallization of pyroxene rims reflects rapid cooling during an eruption. Sector zoning in low-Ca pyroxenes is the result of crystallization during periods of moderate undercooling between mixing events. Oscillatory, normal, and reverse zoning in olivine and pyroxene appears to have formed in response to multi-stage magma mingling or mixing processes, which introduced additional Ca, Fe, Ti, and Al into parental boninitic melts. The presence of olivine xenocrysts and orthopyroxene indicate equilibrium at 2–4 kbar (Whattam et al. 2020) indicates that boninite magma mixing events likely occurred within shallow magma chambers containing olivine-rich cumulate piles. Large mixing events probably destabilized the magma chamber, resulting in devolatilization and eruption. In contrast, small mixing events lacked the energy to destabilize the chamber, resulting in repeated compositional oscillations in minerals affected by multiple small mixing events.

Keywords: Boninite, magma mixing, olivine, pyroxene, zoning