HIGH-Ca BONINITES: A RESULT OF THE INTERFERENCE OF MANTLE PLUMES INTO THE AFFAIRS OF SUBDUCTION ZONES?

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Boninites, a subduction-related magmatic suite, are characterized by relatively high SiO_2, H_2O, and low TiO_2 contents compared to tholeiitic suites, and by the presence of very magnesian olivine phenocrysts. It is generally accepted that these rocks originated from mantle which has been variably depleted in the basaltic component compared to a typical mid-ocean ridge basalt source, but is always extremely depleted in incompatible elements. Variations in the degree of depletion of the boninite sources in the basaltic component are reflected by a wide range of CaO/Al_2O_3 (0.4–0.85) in primitive boninites, which is negatively correlated with the degree of depletion. Variations in CaO/Al_2O_3 values recorded in several boninite suites have been explained as a result of progressive source depletion during boninite magma genesis. It is widely accepted that boninite petrogenesis requires mantle temperatures of 1200–1350 ^oC and depths below 10 kbar.

High-Ca boninite (CaO/Al_2O_3 greater than 0.75) suites which are not spatially associated with low-Ca boninites are known from three regions: in the Troodos ophiolite, at the northern termination of the Tonga Trench, and at the southern termination of the Vanuatu Trench. These suites are volumetrically small and, in addition to typical boninite features, are characterized by (1) abundant olivine phenocryst-rich rocks, (2) a large temperature interval of olivine-only crystallization (up to 150 ^oC) and (3) a correspondingly large difference between compositions of the most magnesian olivines and low-Ca pyroxene, (4) common presence of very magnesian clinopyroxenes (Mg no. around 92) which crystallized early during fractionation, reflecting the high CaO content of these melts. The tectonic environment of two modern settings is characterized by (1) termination of the trench and a transition from subduction to tranform tectonics, and (2) propagation of a back-arc spreading system into the forearc.

Experimental studies of melt inclusions in olivine phenocrysts from Tongan and Troodos boninites have demonstrated that their primary melts had high MgO (21–24 wt. %) and moderate H_2O (around 2 wt. %), and crystallization temperatures of 1350–1389 ^oC at about 1 kbar. A high-pressure experimental study has demonstrated that such melts are in equilibrium with a harzburgite mantle residue at 15–17 kbar and 1430–1470 ^oC.

The high temperature of the high-Ca boninite primary melts is explained by their derivation from hot mantle plumes. The transition from subduction to transform tectonics is proposed as a major factor in allowing the intrusion of hot mantle plume in the mantle wedge above the slab, as such transition forms a window connecting the wedge with the astenosphere under the subducting plate. The mantle source for high-Ca boninites was a mantle plume previously depleted by the extraction of OIB-type magmas. Intrusion of this hot mantle triggers extensive degassing of the slab, and the derived fluids cause the “second-stage” melting of the depleted plume, producing high-Ca boninites.

Geochemical and mineralogical features and the geological setting of well-studied modern Tongan high-Ca boninites provide convincing arguments in support of such model. These boninites were erupted 1.5–2 Ma BP on the inner slope of the Tonga Trench opposite to the ocean islands formed by the currently active Samoan mantle plume. Contemporaneous OIB-type lavas originated from the Samoan plume, were erupted 60 km to the west of boninites on the inner trench slope, confirming plume penetration in the mantle wedge. Boninites have a wide range of REE contents, from stronly depleted with $(La/Yb)_N$ close to 0.5 to strongly enriched with $(La/Yb)_N$ close to 16, and are characterized by similar Nd, Sr, and Pb isotopic values regardless of their degree of LREE enrichment. These isotopic values are within the range of Samoan IOB and differ significantly from those of any lavas erupted in the modern Tonga-Lau back-arc system. Also, the primitive mantle normalized incompatible element patterns of the most enriched Tongan boninites resemble closely those of adjacent OIB lavas.