Melt impregnation revealed by clinopyroxene geochemistry in abyssal peridotites

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Analyses of abyssal peridotites from the Atlantis II Fracture Zone on the Southwest Indian Ridge provide evidence for both shallow and deep melt impregnation. The samples, collected by dredging and submersible dives, have variable amounts of modal clinopyroxene, ranging in composition from lherzolitic to harzburgitic. While most peridotites from the fracture zone have depleted rare earth element (REE) and trace element signatures, several samples are enriched in REE and other trace elements. Enrichment in light rare earth elements (LREE) is up to three orders of magnitude that of typical depleted peridotites.

Two samples collected within 100 meters of each other at the ridge transform intersection show contrasting styles of melt impregnation. In one sample, melt impregnation appears to have occurred by chromatographic reaction at depths greater than 30km. In the other sample, melt impregnation occurs as a shallow level vein.

In the first sample, a gradient in rare earth element patterns is observed over a few centimeters, varying from a depleted signature in the clinopyroxenes to an enriched REE and trace element signature. No vein is present in the sample and no significant variation in major element composition of the clinopyroxenes is observed, suggesting that the enrichment was produced by chromatographic reaction with an impregnating melt. The absence of Eu anomalies in the cores of all the clinopyroxenes indicates that melt impregnation occurred at depths greater than the plagioclase stability field.

In comparison, the other peridotite sample is cut by a vein of Fe-rich clinopyroxene, pargasite, and ilmenite. All clinopyroxenes are highly enriched in REE, by up to 3 orders of magnitude. The equilibrium melt for such an enrichment is an order of magnitude more enriched in REE than MORB. Zr is enriched with respect to Ti, also indicating re-enrichment of the peridotite by the impregnating melt. Plagioclase is distributed throughout the rock and all clinopyroxenes have Eu anomalies in their REE signatures, indicating crystallization within the plagioclase stability field. Hence, melt impregnation was shallow, probably at less than 20 km depth based on plagioclase albite content.

The occurrence of two peridotites in close proximity on the sea floor with different melt enrichment histories suggests complex melt pathways beneath mid-ocean ridges, beginning at depths greater than 30 km and continuing to shallow levels.

Evolution of a chemically zoned magma chamber: The 1707 eruption of Fuji Volcano, Japan

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The eruptive history of Fuji Volcano has been dominated by basaltic volcanism. However, the 1707 eruption of Fuji Volcano resulted in a chemically zoned volcanic deposit ranging from basalt to dacite. The processes responsible for generating these siliceous magmas at Fuji Volcano are not well understood, although it has been proposed that liquid immiscibility played a major role (Kawamoto, 1992). Other possible explanations for a chemically zoned volcanic deposit are magma mixing, crystal fractionation, and crustal assimilation.

In order to further constrain the petrogenetic processes that occurred prior to the 1707 eruption, we have done a detailed petrographic, major and trace element, and Sr, Nd, and Pb isotope study of samples from throughout the 1707 deposit. A comprehensive suite of samples spans a wide range of SiO_2 from 50 to 67 wt % (basalt to dacite); however, there is a compositional gap between 52 to 57 wt % SiO_2. The compositional gap may indicate basaltic intrusion into a silicic magma chamber, possibly triggering the eruption.

Most major and trace element variation diagrams show strong correlations with kinks in the trends, indicative of fractional crystallization with changing fractionating assemblages. These kinks eliminate magma mixing as a model to explain the observed compositional trends. Variations in REE abundance also support crystal fractionation with relative enrichment from basalt to dacite. Negative Eu anomalies increase from andesite to dacite, indicative of feldspar fractionation. Sr, Nd, and Pb isotopes show identical signatures throughout the deposit. These results indicate either that assimilation did not play a major role in magma evolution or that the contaminants have very similar isotopic signatures to the magma.

Although liquid immiscibility is a common small-scale process in basaltic magmas, it has not been recognized as a magma chamber-scale process in silicic magmas. Crystal fractionation with or without assimilation can explain the above observations.

Reference

Kawamoto, T., (1992). *International Geological Congress Abs*., v. 29, p. 558.