Carbon in the Icelandic Mantle: Constraints from Melt Inclusions

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Abundances of water, carbon dioxide, fluorine, sulfur, chlorine and lithophile trace elements were measured by SIMS in over 100 melt inclusions in olivine, Cr-diopside and spinel from Borgarhraun, a small-volume post-glacial volcano from the Theistareykir segment of northern Iceland. Trace element variations can be modeled by incomplete mixing of melts generated by polybaric dynamic melting of a passively-upwelling MORB mantle, sufficient to generate a crustal thickness of 19 km [Slater et al., 2001; Elliott et al., 1991].

Water abundances in the melt inclusions are nearly uniform despite wide variations in trace element abundance. This is likely due to extensive hydrogen diffusion and exchange with the host magma [Hauri, 2002]. Carbon dioxide concentrations in the melt inclusions vary widely (100-1000 ppm), and correlate with abundances of highly incompatible elements (Ba, Nb, La). The melt inclusions must have been trapped at sufficiently high pressures (>3.5 kbar) to prevent degassing and preserve correlations between CO_2 and lithophile trace elements. Trace element correlations with CO_2 demonstrate clearly the highly incompatible nature of carbon during mantle melting.

The CO_2/Nb ratio of the Icelandic melt inclusions is 314 (±40%). Given an estimate for Nb abundance in the depleted MORB mantle of 0.45 ppm, the CO_2 concentration of the depleted mantle beneath Iceland is estimated at 140±56 ppm; an upper limit of 270 ppm is indicated by those melt inclusions with the highest CO_2/Nb ratios. These estimates are much lower than those derived from CO_2 in "popping rocks" and degassing models based on C isotopes in MORB, but are remarkably consistent with the CO_2 flux at ridges derived from C-He relationships and helium degassing into the oceans [Marty & Tolstikhin, 1998].

References

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Magma Evolution and Emplacement Time Scales beneath Montserrat

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Samples erupted in the last 300ky on Montserrat range from low- to medium-K calc-alkaline basalts to andesites, and three geochemically unrelated rock suites can be distinguished: the South Soufrière Hills suite; the Soufrière Hills suite, including the new lava; and the mafic inclusions. Calculated primary magmas typically contain ~3% sediments from the subducting slab, and slab fluid contributions are identified on basis of elevated U/Th, Ba/Th and Sr/Th ratios. However, the U-Th isotopes are close to secular equilibrium. Nomarski images of plagioclase phenocrysts from six andesites erupted since 150 ka reveal multiple crystal resorption events, and major shifts in anorthite content suggest that these are due to temperature variations. A model is developed that uses partitioning data for Ba and Sr to quantify the degree of intracrystalline disequilibrium of these elements with respect to anorthite content in 12 selected plagioclase phenocrysts. Intracrystalline diffusive equilibration of both Ba and Sr profiles is incomplete, but the local disequilibria do not consistently decrease towards crystal cores. Thus, the time scale for crystal growth is considerably shorter than their residence time at magmatic temperatures. Finite difference modelling of intracrystalline Sr diffusion is used to calculate bulk crystal residence times at the Soufrière Hills magmatic temperature of 850ºC. These range from ~10 to ~1200 years, independent of eruption age. Such results can be explained by repeated intrusion of small volumes of andesitic material to upper crustal levels followed by rapid crystallisation during degassing and rapid cooling. Remobilization of the intruded andesites by influx of hotter, more mafic magma, and amalgamation of andesites of different crystallisation ages and/or temperature histories by associated convective processes, produced the currently erupting andesite that contains abundant inclusions of mafic magma. The short residence times of andesite magma in the upper crust, and the episodic character of volcanism at the Soufrière Hills with short periods of intense volcanism alternating with much longer periods of dormancy, are consistent with deep magma generation and storage with episodic ascent to form ephemeral shallow chambers.