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The geochemical cycle of boron: Experiments on boron isotope partitioning between micas and fluids

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The enrichment of boron in IAB relative to MORB and mantle indicates transport of boron from subducted pelagic sediments and altered oceanic crust into the arc by a metasomatic agent. Boron concentrations and $^{11}B/^{10}B$-ratios in IAB systematically decrease with increasing distance from the trench. Several models have been suggested for explaining this variation across the arc as a function of the Benioff zone depth. One is that continuous dehydration reactions within the slab produce boron isotope fractionations between OH-bearing minerals and expelled fluids, and that the melts formed within the mantel wedge directly record the isotopic signature of the slab fluid. To test this, we experimentally determined the $\delta^{11}B$-fractionation between micas and coexisting fluids at P-T conditions relevant for subduction zones. Experiments involve boron-rich muscovites that are representative of phengitic micas, which are the major boron- and OH-bearing minerals present in many subduction zone rocks.

Time-dependent equilibrium experiments between B-bearing muscovite and fluid performed at 500°C, 3.0 GPa produced large isotopic fractionations of $\Delta^{11}B = -11.7(2.6)$ ‰. At 700°C, 3.0 GPa complete equilibrium at $\Delta^{11}B = -6.2(1.3)$ ‰ was attained after 28 days. Extrapolation to lower and higher temperatures shows excellent agreement with $\Delta^{11}B$-values between clay and fluid at low temperatures, and between melt and fluid at high temperatures. The combination of experimentally determined fractionations at all temperatures results in

$\Delta^{11}B(\text{clay, mica, melt–fluid}) = -10.70 \bullet (1000/T(K)) + 3.94$

Our study indicates that the first-order fractionation effect for boron is induced by its change from 4-fold (clay, mica, melt) to 3-fold (fluid) coordination, largely independent of the specific structure. Tourmaline - fluid fractionation is much smaller because boron is uniformly 3-fold coordinated in both phases.

Several examples have shown that B-concentrations and $\delta^{11}B$-variations in IAB across the arc are strongly correlated to the thermal structure of the subducting slab. Results of our experiments indicate that slab dehydration and boron transport via fluid into the wedge is mainly responsible for the boron isotopic signature in IAB, rather than slab melting processes.

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Partitioning of light lithophyle elements at high pressure: Implications for the degassing of martian magmas

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Introduction

Lentz et al. [1] examined zoning trends of the light lithophyle elements (LLE) B, Be and Li in pyroxenes in the martian basaltic shergottites Shergottty and Zagami. Based on these trends, they suggested that B and Li partitioned into a separate water-rich fluid phase which formed during ascent and decompression of the parent magmas. This degassing of the magma occured following the onset of pyroxene crystallization explaining the decrease in B and Li contents from core to rim. Be increases from core to rim which is explained by its relatively low solubility in magmatic fluids.

Previous experimental work

This idea is tentatively born out by experiment. Herd et al. [2] conducted Li and B mineral/melt partitioning experiments for shergottite-composition minerals and bulk rock. Results from these experiments show that Li and B are incompatible in all phases studied. (Partition coeffients for terestrial compositions [3] are similar.) Therefore, the crystallization of these phases cannot account for a core-to-rim decrease in Li and B in the pyroxene. Thus, fluid-phase partitioning of Li and B remains a viable model for the observed pyroxene zoning trends in the shergottites. However, more work needs to be done to test this idea.

High pressure LLE partitioning experiments

Towards this end, we are conducting mineral/melt and hydrous-fluid/melt partitioning experiments for the LLEs at pressures up to 30 kbars using a piston cylindar apparatus. Starting composition is the same as [2]. Mineral/melt experiments are run both wet and dry. Based on these results, hydrous-fluid/melt experiments are run initially at high-pressure at which water is soluble in the melt at both liquidus and super-liquidus temperatures. Then pressure is reduced to exsolve a fluid phase. Major and trace elements are measured by Cameca SX100 electron microprobe at NASA/JSC. Additionally LLEs are measured with Cameca IMS 4f ion probe at the University of New Mexico.

References

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