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The behavior of Li and B in lunar mare basalts during crystallization, shock, and thermal metamorphism: Implications for volatile element contents of martian basalts

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Abstract

Late-stage rims of magmatic pyroxenes from some martian basalts show decreases in Li and B contents relative to earlier-formed pyroxene cores. This behavior is different than expected from their documented incompatible element behavior. Previous workers interpreted such depletions to reflect the loss of several wt% magmatic water during basalt crystallization. This interpretation has profound implications for the nature of the martian mantle and recent exchange of volatiles between the martian mantle and atmosphere. To assess alternative mechanisms that may influence the behavior of Li and B in the absence of aqueous fluid activity, the effects of changing pyroxene composition during crystallization, shock pressure, and shock-associated thermal metamorphism were studied. Lithium and B depletions are documented in late-stage rims of pyroxenes from anhydrous lunar basalts indicating that mechanisms other than aqueous fluid activity must have influenced Li and B partitioning in these pyroxenes. Depletions of Li and B are most likely associated with changing pyroxene composition during crystallization, and occur in lunar and martian pyroxenes with late-stage Fe-enrichment. It is interesting that pyroxenes without late-stage Fe-enrichment show no concomitant Li and B increases. Lithium loss may occur during breakdown of metastable pyroxferroite. Additionally, changes in Cr content may influence the substitution mechanism involved for incorporating Li. Shock does not redistribute Li or B but may facilitate subsequent thermally driven diffusion by the introduction of mechanical defects in grains. Thermally metamorphosed pyroxenes exhibit higher Li and lower B contents relative to unheated pyroxenes. It is likely, therefore, that Li and B are redistributed through interactions between pyroxenes and surrounding zones of mesostasis during thermal metamorphism.

Keywords: Lithium, boron, lunar mare basalts, martian basalts, shock pressure, thermal metamorphism, crystal chemistry, pyroxenes