

Boron isotopes in the nakhlites: Implications for crustal fluids on Mars

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The nakhlites are the most altered Martian meteorites, and contain a relatively abundant secondary mineral assemblage known as iddingsite, that is believed to have been deposited by low-temperature aqueous fluids on Mars [1]. Boron isotopes can be useful tracers of fluid-rock interactions and B isotope systematics of Martian meteorites may help to constrain the compositions of aqueous crustal fluids on Mars. We recently reported measurements of the B isotopic compositions of iddingsite and igneous phases in Nakhla [2-3]. Here we additionally report $^{11}\text{B}/^{10}\text{B}$ ratios in mesostasis of Nakhla and in igneous (pyroxenes) and secondary alteration (iddingsite) phases of Lafayette.

The average $\delta^{11}\text{B}$ values of pyroxenes in Nakhla ($-4.5 \pm 3.0\%$) and Lafayette ($-6.0 \pm 2.9\%$) are identical within errors ($\pm 1\sigma$ mean). Boron concentrations of pyroxenes in both meteorites are low ($< \sim 0.5$ ppm). Nakhla mesostasis is enriched in B ($\sim 4-7$ ppm) compared to the pyroxenes but has an average $\delta^{11}\text{B}$ ($-7.3 \pm 1.8\%$) that is indistinguishable, within errors, from the value in the pyroxenes. A glassy melt inclusion in an olivine in Nakhla has a B concentration comparable to that in the mesostasis (~ 5 ppm) and the same $\delta^{11}\text{B}$ ($-4.4 \pm 2.5\%$) as the other igneous phases. The iddingsite in both nakhlites is the most B rich phase (~ 15 ppm). Nevertheless, the average $\delta^{11}\text{B}$ values of iddingsite in Nakhla ($-5.4 \pm 1.0\%$) and Lafayette ($-7.8 \pm 1.5\%$) are also the same, within errors, as those of the nakhlite magmatic phases.

The lack of isotopic fractionation between the igneous and secondary alteration phases in the nakhlites indicates that (1) the B in the fluid that deposited the iddingsite was derived from the primary igneous minerals and (2) there was minimal B isotope fractionation between the fluid and the iddingsite. This further suggests that the coordination state of B was the same in the alteration products and the fluids from which they precipitated, which could be explained by the fluids having a slightly alkaline composition.

[1] Bridges J. C. *et al.* (2001) *Sp. Sci. Rev.* **96**, 365-392.

[2] Spivak-Birndorf L. J. *et al.* (2008) *LPS XXXIX*, Abstract #1904. [3] Spivak-Birndorf L. J. *et al.* (2008) *LPI Ground Truth from Mars*, submitted abstract.

Is the Hf isotope composition of the bulk silicate Earth chondritic?

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The initial isotope composition of Hf in solar system materials holds valuable information about the evolution of the early solar system and planetary bodies. The short-lived ^{182}Hf - ^{182}W and the long-lived ^{176}Lu - ^{176}Hf systems have been used to date metal-silicate segregation and global-scale silicate differentiation processes, respectively. Both applications require a well-constrained initial composition: Hf-W dating assumes that the $^{182}\text{Hf}/^{180}\text{Hf}$ was homogeneous in the early solar system, and that this ratio changed only by decay of ^{182}Hf . Likewise, using Lu-Hf to study the timing and degree of silicate differentiation in planetary bodies requires knowing their initial $^{176}\text{Hf}/^{177}\text{Hf}$. The Earth and other planetary bodies are commonly assumed to be chondritic with respect to the abundances and isotope compositions of non-volatile elements. These fundamental assumptions remain to be rigorously tested. In light of recent reports of nucleosynthetic anomalies for other elements in *bulk* meteoritic materials (e.g. [1-3]) we initiated a test for variations in ratios of nonradiogenic stable isotopes of Hf in chondrites and terrestrial rocks. Barring any secondary effects such as neutron capture, the respective ratios in these two groups must be identical if chondritic meteorites are to be used as a proxy for bulk Earth isotope composition.

Replicate MC-ICP-MS analyses of individual terrestrial rock standards performed during multiple measurement sessions yielded a typical external reproducibility (2σ) of 17-25 ppm on $^{178}\text{Hf}/^{177}\text{Hf}$ and 26-38 ppm on $^{180}\text{Hf}/^{177}\text{Hf}$, for ~ 80 ppb Hf and using $^{179}\text{Hf}/^{177}\text{Hf}$ for the mass bias correction. Given these analytical limits, excesses of >105 ppm pure s-process or >72 ppm pure r-process Hf should be resolvable. Our first data on different groups of chondrites show no unequivocal variation from terrestrial rocks.

[1] Bizarro *et al.* (2007) *Science* **316**, 1178-1181. [2] Carlson *et al.* (2007) *Science* **316**, 1175-1178. [3] Ranen & Jacobsen (2006) *Science* **314**, 809-812.