Meteoritical evidence for the timing of surface or near-surface liquid water on Mars

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There is widespread photogeological evidence for ubiquitous water flowing on the surface of Mars. Despite this observation, the absolute age of surface and near-surface water cannot be deduced from photogeology, because the uncertainty in the absolute calibration of the Martian crater flux results in uncertainties of ±1.5 Ga in the middle period of Martian geologic history. Aqueous alteration of primary igneous minerals produces secondary minerals in Martian meteorites. Here we use the ages of secondary alteration minerals in Martian meteorites to obtain absolute ages when liquid water was at or near the surface of Mars. We find definitive evidence in Martian meteorites for aqueous alteration events at 3929±37 Ma, 633±23 Ma, and 0-170 Ma. These ages are based on absolute Rb-Sr and Pb-Pb ages of carbonates in ALH84001, Rb-Sr and K-Ar ages of iddingsite in two nakhlites, and the presence of secondary alteration products in several of the 170 Ma shergottites. These events appear to be of short duration, suggesting episodic rather than continuous aqueous alteration. Furthermore, the amount of secondary mineralization that is present in the meteorites appears to be decreasing with time. The 4500 Ma ALH84001 is made up of ~1% carbonates, the 1330 Ma nakhlites have obvious iddingsite alteration products that make up trace amounts of the meteorites, whereas some of the 170 Ma shergottites have vanishingly small amounts of various salts and clays. Although not definitive, this correlation is certainly consistent with the hypothesis that Mars has become dryer through time. The high $^{129}Xe/^{132}Xe$ ratio in the Martian atmosphere compared to Martian meteorites indicates fractionation of I from Xe within ~100 Ma after nucleosynthesis of ^{129}I. Such fractionation is difficult to achieve through magmatic processes. However, water very efficiently fractionates I from Xe, raising the intriguing possibility that Mars had a liquid water ocean within its first 100 Ma.

LI, CL, and BR in Martian (Shergottite) basalts: No evidence of water loss

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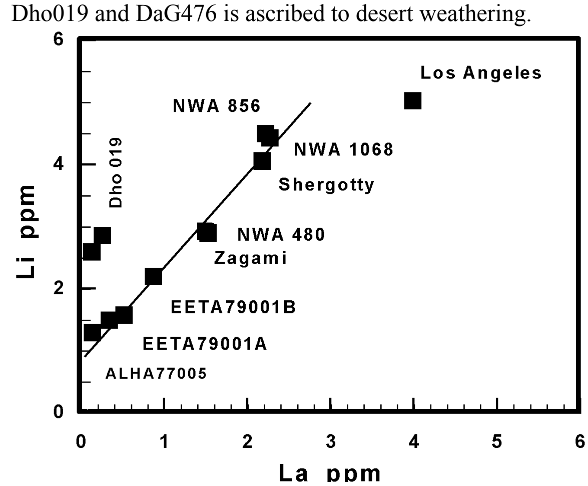
Shergotty and Zagami, Martian basalt meteorites (shergottites), are nearly anhydrous but may have crystallized from water-rich magmas. *McSween et al.* [2001] and *Lentz et al.* [2001] argued that decreasing abundances of Li and B, core-to-rim, in pyroxenes of Shergotty and Zagami reflect loss of an aqueous fluid from their parent magmas during crystallization. Losses of Li and B are inferred at 60-75% for Shergotty and ~30% for Zagami. The bulk compositions of Shergotty and Zagami should be similarly depleted in Li and B, and also be depleted in other elements that would be lost to an aqueous fluid, like Cl and Br. However, whole rock abundances of Li (Fig. 1), Cl, and Br in the shergottites show no evidence that Shergotty and Zagami were depleted (no analyses for B are available). Thus, core-to-rim decreases in Li and B in shergottite pyroxenes do not imply loss of a fluid phase, and must reflect other processes.

Fig. 1. Abundances of Li and La, both highly incompatible elements, in bulk shergottites. Nearly all fall on a single trajectory, suggesting that Shergotty and Zagami are not depleted in Li. Los Angeles is inhomogeneous. High Li in Dho019 and DaG476 is ascribed to desert weathering.



References

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