Geophysical Research Abstracts, Vol. 8, 05685, 2006
SRef-ID: 1607-7962/gra/EGU06-A-05685

Redox equilibria and crystallization of Martian basaltic meteorites

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Introduction: Multiple length scale observations in Martian basaltic meteorites reveal fairly complex igneous crystallization paths and late-stage mineral-melt interaction [1, 2]. Nonetheless, a consensus on the interpretations has not been reached, and the observed range of oxygen fugacity conditions in Martian meteorites and the implications for Martian basaltic volcanism is a matter of debate, e.g. reduced Mantle vs. oxidized Crust.

Cosmochemists presently appear to accept that Martian basaltic meteorites are less oxidized than initially thought [3] and likely crystallized within 2 to 4 log units below the FMQ reference buffer curve [1, 4, 5, 6, 7]. This is in line with the late crystallization of Fe-Ti oxides in these rocks and their Fe-rich nature. Herd and coworkers [5-7] have correlated compositional and isotopic parameters to oxygen fugacity variations arguing that relative oxidation of initial reduced Martian basaltic magmas resulted from interaction with putative crustal materials.

Discussion: Even though chemical fingerprinting of Martian meteorites supports arguments for interaction between melt and soil the correlation of compositional and isotopic ratios to oxygen fugacity variations seems problematic. First, it strongly depends on the amount and quality of data and may change according to the addition or exclusion of samples. Second, it assumes that mixing between melt and soils or other crustal materials is ideal and the end products may derive via linear mixing even though the process may be adiabatic. Third, the putative crustal component is compositionally elusive. Fourth, part or all of the advocated melt-“soil” interaction may arise from the impact that expelled the meteorites from Mars.

Alternatively, phase equilibria may impose a strong control over oxygen fugacity which in return may result in the observed oxygen fugacity variations. For instance, it has been argued [8, 9] that during cooling equilibria among oxides, olivine, and pyroxenes result in relative oxidation, in contrast, for rocks that exhibit Fe enrichment or in Fe metal-saturated systems, such as Lunar basalts [10], phase equilibria among Fe metal, oxides, and silicates result in relative reduction.

Computations of oxygen fugacity in Martian meteorites and Fe metal-bearing Lunar basalts are in line with the above arguments. Therefore, it is permissible that the range and variations in fO_2 among the Martian basaltic meteorites reflect different stages of oxide-silicate interaction as it is recorded by the minerals in these rocks. Besides, in general, contrasting oxygen fugacity trends (relative oxidation vs. relative reduction) should be expected in metal- and non-metal bearing planetary silicate-oxide systems.

References: **[1]** Xirouchakis et al. (2002) GCA 66, 1867–1880. **[2]** Aramovich et al. (2001), LPSC, XXXII, #1003 **[3]** Stolper E. & McSween H.Y., Jr. (1979) GCA 43, 1475–1498**.** **[4]** Ghosal et al. (1998), CMP, 130, 346-357. **[5]** *Herd C. D. K. et al. (2001a), Am. Min. 86***,** *1015–10024.* **[6]** Herd C. D. K. et al., (2001b), *LPSC, XXXII,* #1150. **[7]** *Herd C. D. K. et al. (2000), 63rd Ann. Meteor. Soc. Meet. #5085*. **[8]** *Lindsley and Frost (1992), Am. Min., 77.* **[9]** *Lindsley D. H. and Frost B. R. (1992), Am. Mineral. 77, 987–1003.* **[10]** *Collins et al. (2005) LPSC XXXVI, #1141.*