**Constraints on Mars Mantle Redox Conditions from Studies of Martian Meteorites: A Review.** C. D. K. Herd, Department of Earth and Atmospheric Sciences, 1-26 Earth Sciences Building, University of Alberta, Edmonton, AB, T6G 2E3, Canada, herd@ualberta.ca.

**Introduction:** All martian meteorites are derived from mafic magmas by variable degrees of accumulation. By inverting crystallization products to parental magmas, the conditions of partial melting and the compositions of their mantle sources may be inferred. All but 11 of the 61 unique (i.e., unpaired) martian meteorites are shergottites. These rocks have little to no cumulate texture and are therefore useful probes of the interior of Mars.

Several oxybarometers are applicable to planetary basalts such as the shergottites (see [1] for a review); the olivine-pyroxene-spinel and Fe-Ti oxide oxybarometers have since been updated, and are now readily available as online tools through http://ctserver.ofm-research.org/webcalculators.html.

**Models of shergottite formation:** A distinct characteristic of the shergottites is that they record a wide range of time-integrated incompatible element enrichment, clustering into three distinct geochemical groups based on their Rb-Sr and Sm-Nd isotopic compositions and REE patterns (depleted, intermediate, and enriched; see [2] for a recent review). Early and rapid differentiation of the silicate portion of Mars is called upon to generate enriched and depleted reservoirs by ~4.5 Ga, either through formation of primitive martian crust by partial melting of the mantle, or crystallization of a magma ocean [3-4]. In the latter model, the last dregs of magma ocean crystallization comprise the enriched portion, and the cumulate mantle is the depleted counterpart [4-5]; whether a basalt eruptive is depleted or enriched depends on the mix of depleted or enriched components in its mantle source.

A correlation between oxygen fugacity, as determined by application of oxybarometers to shergottites, and time-integrated incompatible element enrichment was recognized on the basis of a handful of shergottites [6-7]. Interpreted in the context of mantle source variation, this trend implies that the depleted, cumulate portion of the Martian mantle is reduced, near Iron-Wüstite (IW), whereas the enriched portion is oxidized, near Fayalite-Magnetite-Quartz (FMQ; equal to ~IW + 3.5 log units)[8]. As such, the oxygen fugacity of an Amazonian shergottite is strongly dependent on the redox state of its mantle source, which was set during magma ocean crystallization at ~ 4.5 Ga.

**Do all shergottites follow the trend?** Most shergottites follow the expected trend of increasing incompatible element enrichment (e.g., La/Yb ratio) with increasing oxygen fugacity (Figure 1). However, recent studies have shown some exceptions among the olivine-phyric shergottites. NWA 1068/1110 contains an early, megacrystic olivine+pyroxene+chromite assemblage that records an oxygen fugacity 2.5 log units below FMQ (FMQ – 2.5), whereas oxides in the groundmass record FMQ + 0.3 (Fig. 1); this difference is interpreted as representing incorporation of xenocrysts into an oxidized magma [9]. LAR 06319 shows a similar range between early and late assemblages (Fig. 1); in this case, however, the increase of ~2 log units likely occurred during fractional crystallization and ascent [10]. When estimates of the oxygen fugacity of the parental magmas to the poikilitic ("lherzolitic") shergottites are included (Fig. 1) [11], it appears that the shergottite mantle sources have a more limited range of redox state, from FMQ – 4 to FMQ – 2, and that the higher oxygen fugacities of some shergottites are a combination of mantle source characteristics and oxidation during ascent and emplacement.

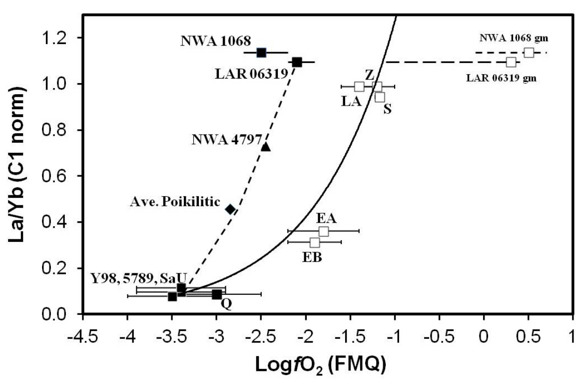


**Figure 1.** Summary of oxygen fugacity estimates for shergottites vs. whole rock La/Yb. Data from [8-10] and references therein. Solid line is polynomial fit to Y980459 (Y98), NWA 5789, SaU 005 (SaU), QUE 94201 (Q), EET 79001 (EA, EB), Los Angeles (LA), Shergotty (S) and Zagami (Z). Dashed line is inferred trend for mantle sources.

**References:** [1] Herd C. D. K. (2008) *RIMG, 68,* 527-553. [2] McCoy T. J. et al. (2011) *PNAS, 108*, 19159-19164. [3] Borg L. E. et al. (1997) *GCA, 61,* 4915-4931. [4] Blinova A. and Herd C. D. K. (2009) *GCA, 73,* 3471-3492. [5] Borg L. E. and Draper D. S. (2003) *M&PS, 38,* 1713-1731. [6] Herd C. D. K. et al. (2002) *GCA, 66,* 2025-2036. [7] Wadhwa M. (2001) *Science, 291,* 1527-1530. [8] Herd C. D. K. (2003) GCA, 38, 1793-1805. [9] Herd C. D. K. (2006) *Am. Mineral., 91,* 1616-1627. [10] Peslier A. H. et al. (2010) *GCA, 74,* 4543-4576. [11] Walton et al. (in press) *M&PS.*