Goldschmidt 2026 Abstract
https://doi.org/10.46427/gold2026.37464

Revisiting fO_2 in the martian meteorites: The primordial redox state of the mantle of Mars

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The shergottite subgroup of martian meteorites is enigmatic – these are mainly basaltic eruptives that formed between ~150 and 800 Ma, but their parental magmas tapped ancient geochemical reservoirs in the mantle that were most likely established during magma ocean crystallization ~4.52 Ga [e.g., 1]. These reservoirs vary in incompatible trace element (ITE) enrichment (as parameterized by CI-normalized La/Yb) and Sm/Nd, Lu/Hf, and Rb/Sr isotopic compositions. The oxygen fugacity (fO_2) of crystallization of shergottites appears to correlate with ITE, indicating that the redox states of these reservoirs was established during magma ocean crystallization [2]. However, constraining the redox states of these primordial mantle reservoirs is complicated by the petrogenetic histories of the shergottite meteorites – including differences in fO_2 between early and late crystallizing assemblages, which are likely due to the effects of volatile degassing – and by limitations of oxybarometers.

We recently completed a study in which we compiled fO_2 estimates from over 70 distinct shergottite lithologies, unraveled the effects of crystallization, modeled the extent of degassing, and critically evaluated the fO_2-ITE correlation [2]. We confirm this correlation, and postulate a mantle redox-ITE trend for Mars (Figure 1) consisting of: a depleted source (La/Yb ~ 0.1) with fO_2 ~ FMQ-4, an intermediate source (La/Yb ~ 0.5) at fO_2 ~ FMQ-3 and an enriched source (La/Yb ~ 1) at fO_2 ~ FMQ-2 (where FMQ is the fayalite-magnetite-quartz reference equilibrium). The depleted/reduced source is likely graphite saturated. The trend provides additional insights into changes in fO_2 during crystallization for basaltic shergottites, suggesting they have also undergone oxidation via degassing – a conclusion that is supported by new fO_2 estimates based on V/Sc mineral ratios [3].

The results highlight fundamental differences in the redox conditions of the interiors of Mars and Earth (Figure 1), attributable to differences in degree of mantle convective mixing throughout their histories.

[1] L. E. Borg, T. S. Kruijer (2025) *PNAS* 122, e2404257121. [2] C. D. K. Herd, S. Benaroya (2025) *GCA* 410, 121–140. [3] S. Benaroya, C. D. K. Herd (2025) *56th LPSC* (Lunar and Planetary Institute, Houston), Abstract #1215.

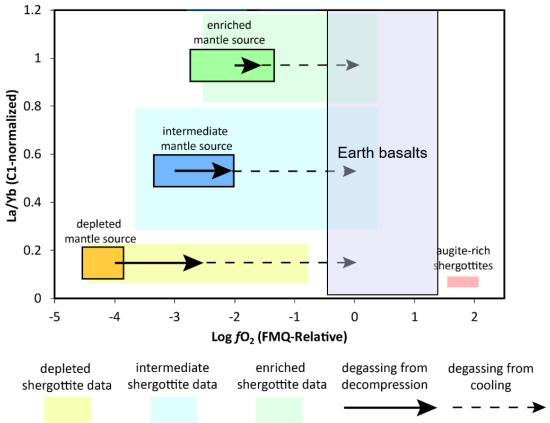


Figure 1: Mars mantle redox sources and degassing influences on shergottite fO_2. Approximate range of fO_2 of Earth basalts shown for comparison. (Herd and Benaroya, 2025)