MARTIAN IGNEOUS GEOCHEMISTRY: THE NATURE OF THE MARTIAN MANTLE. D. W. Mittlefehldt[1], L. T. Elkins-Tanton[2], Z. X. Peng[3] and J. S. Herrin[3*], [1]Astromaterials Research Office, NASA/Johnson Space Center, Houston, TX 77058, USA (davd.w.mitlefehldt@nasa.gov), [2]Dept. of Terrestrial Magnetism, Carnegie Institution for Science, Washington, DC 20015, USA, [3]Sample Analysis Research Dept., Engineering and Science Contract Group, Houston, TX 77058, USA, **Presently:* School of Materials Science and Engineering, and Earth Observatory of Singapore, Nanyang Technological University, Singapore 639798.

Introduction: Mafic igneous rocks probe the interiors of their parent objects, reflecting the compositions and mineralogies of their source regions, and the magmatic processes that engendered them. Incompatible trace element contents of mafic igneous rocks are widely used to constrain the petrologic evolution of planets. We focus on incompatible element ratios of martian meteorites to constrain the petrologic evolution of Mars in the context of magma ocean/cumulate overturn models [1]. Most martian meteorites contain some cumulus grains, but regardless, their incompatible element ratios are close to those of their parent magmas. Martian meteorites form two main petrologic/age groupings; a 1.3 Ga group composed of clinopyroxenites (nakhlites) and dunites (chassignites), and a <1 Ga group composed of basalts and lherzolites (shergottites).

Incompatible Element Considerations: A spider diagram shows that martian basalts and clinopyroxenites have mirror incompatible element patterns (Fig. 1) [*cf.* 2]. Depleted basalt QUE 94201 has positive anomalies in P, Sr and the high field strength elements (HFSE) Zr and Hf, but not in the HFSE Nb, Ta, Th or U. Depleted basalt NWA 5789 has only small positive anomalies in Zr and Hf. NWA 5789 and QUE 94201 are magma compositions [6, 7], and their incompatible element patterns approximate those of their source regions. The clinopyroxenite Nakhla has negative anomalies in P, Zr and Hf, but no Sr anomaly.

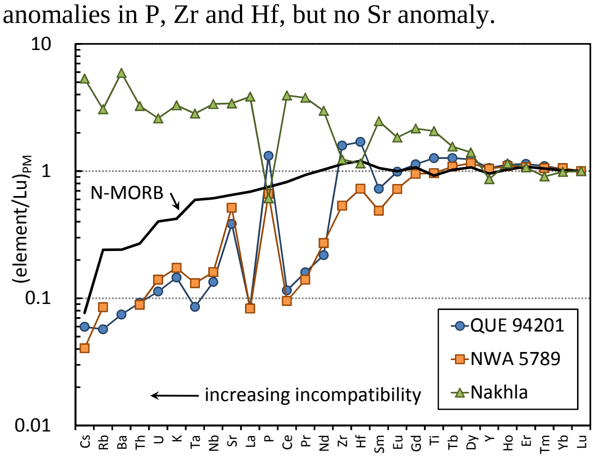

Figure 1. Arachnophilic diagram of select martian meteorites compared to terrestrial N-MORB [3], normalized to primitive mantle compositions [4, 5].

Magma Ocean Considerations: Trace element and isotopic considerations require that depleted basalts were derived from cumulates formed during a magma ocean stage on Mars [8, 9]. Coupled anomalies in P, Sr, Zr and Hf (Fig. 1) suggest that these elements are dominated by a common phase. Majorite garnet was suggested to be the phase responsible for anomalous P behavior [9]. The majorite/melt K_d for P is ~1 for Earth-relevant compositions at appropriate pressures [10], but K_ds for Zr and Hf are much less [11], suggesting that the anomalies in P, Zr and Hf may not have resulted solely from majorite accumulation.

The lowermost mantle is predicted to contain Mg-silicate perovskite [12]. This phase has Zr and Hf K_ds >1, but its P and Sr K_ds are less than unity [13]. Thus, while accumulation of Mg-silicate perovskite may have caused the Zr and Hf anomalies, it cannot also explain the P and Sr anomalies.

Martian clinopyroxenites were also derived from light REE-depleted sources [*e.g.* 14], consistent with majorite garnet accumulation. Zirconium and Hf abundances suggest that the clinopyroxenite source region accumulated later (and higher), possibly after cessation of Mg-silicate perovskite crystallization.

We will run magma ocean models incorporating trace element partition coefficients à la [1] to test the hypotheses for the generation of trace element anomalies discussed here, constrained to match growth of radiogenic isotope ratios.

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