HIGHLY SIDEROPHILE ELEMENT AND OS-SR ISOTOPE SYSTEMATICS OF SHERGOTTITES. Kim T. Tait[1,2] James M.D. Day[1] [1]Scripps Institution of Oceanography, La Jolla, CA 92093-0244, USA: [2]Royal Ontario Museum 100 Queens Park, Toronto, ON M5S 2C6, Canada E-mail: ktait@rom.on.ca

Introduction: The shergottite meteorites represent geochemically diverse, broadly basaltic and magmatically-derived rocks from Mars. Geochemical groupings, based on incompatible trace element abundances and lithophile isotope systematics have lead to classification of shergottites as depleted (low La/Yb, $^{87}Sr/^{86}Sr$ <0.710), intermediate, and enriched (high La/Yb, $^{87}Sr/^{86}Sr$ >0.712). These variations suggest long-lived incompatible trace element depleted and enriched sources in Mars, either representing crust-mantle mixing [1], or highly differentiated mantle sources [2]. We have investigated a suite of shergottite meteorites to more fully understand fractional crystallization and mixing processes that their parental magmas experienced, and to investigate and more precisely define the distribution of the highly siderophile elements (HSE: Os, Ir, Ru, Pt, Pd, Re,) within martian silicate reservoirs.

Methods: Samples were processed and analyzed for major- and trace-elements, Sr isotope compositions and Re-Os isotopes and HSE abundances at the *Scripps Isotope Geochemistry Laboratory*, using methods outlined in [3]. A goal of the current work was to generate a comprehensive suite of elemental data on the same samples for which Sr and Os isotopes were also analyzed.

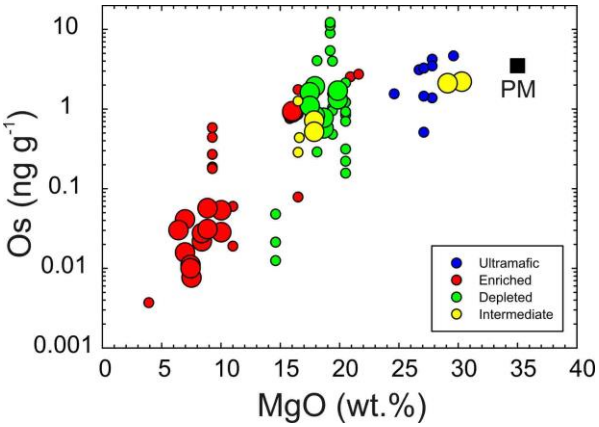

***Figure 1**: MgO versus Os contents for shergottite meteorites grouped according to geochemical classification. Data are from this study (large symbols) and [4].*

Results: We present new major- and trace-element data for NWA 7721 (30.3% MgO) and NWA 10593. New data for the other meteorites are broadly consistent with previously reported values. Relationships of MgO versus Os measured on the same sample aliquots completement and extend existing data for shergottites (*Figure 1*). In general, the enriched shergottites have lower MgO contents than depleted, intermediate or ultramafic shergottites reported previously [4].

Both published and new shergottite HSE abundances obtained by isotope dilution methods are presented in *Figure 2*. Enriched shergottites typically have strongly fractionated HSE patterns, with high Pt/Os and Pd/Os. Depleted shergotites exhibit a significant range in both absolute and relative abundances of the HSE, whereas intermediate shergottites measured to data typically have relatively flat HSE patterns at ~0.005 × CI chondrite.

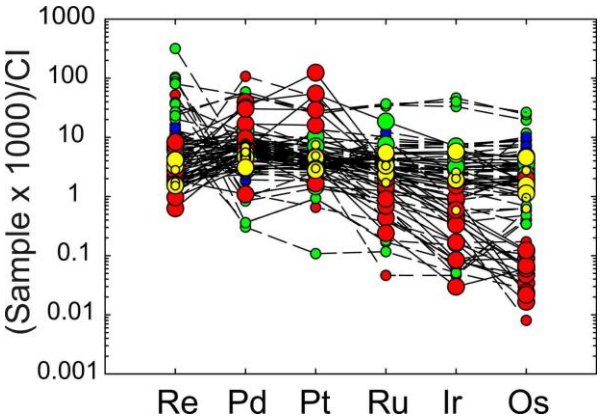

***Figure 2**: CI chondrite normalized HSE patterns for shergottite meteorites. Data are from this study (large symbols) and [4]. CI chondrite normalization from [5].*

Strontium isotope compositions were measured for the same aliquots of sample for which we also measured Re-Os isotopes. Samples were age corrected for Rb and Re decay using crystallization ages of between 187 and ~600 Ma reported in the literature (*Figure 3*). Shergottites from mantle sources with long-term melt-depleted characteristics ($^{87}Sr/^{86}Sr$ 0.700 to 0.707) have initial γOs ranging from −0.5 to +9. Shergottites with intermediate characteristics ($^{87}Sr/^{86}Sr$ 0.709 to 0.711) have intial γOs ranging from +1 to +5 and shergottites with enriched characteristics ($^{87}Sr/^{86}Sr$ 0.711 to 0.724) have initial γOs ranging from -5 to +26. This leads to a generally positive relationship between γOs and $^{87}Sr/^{86}Sr$.

Discussion: Martian shergottites show similarities with terrestrial basaltic rocks in HSE-MgO space (e.g., *Figure 3*). Using HSE-MgO regression techniques outlined in [5] we obtain a martian mantle composition at 0.008 × CI chondrite, which is similar to estimates of terrestrial mantle composition obtained from peridotites and regression of basaltic samples. Our data therefore

support a martian mantle composition with broadly chondritic relative abundances of the HSE (*Figure 4*).

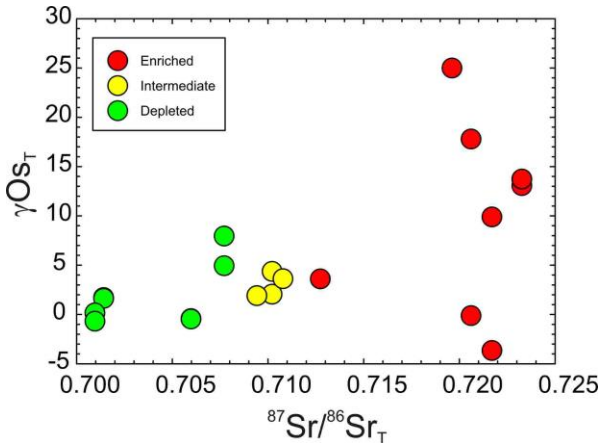

Figure 3*: Strontium versus osmium isotope plot for sample measured in this study, corrected to their crystallization ages.*

Shergottites exhibit a wide range of absolute and relative abundances of the HSE reflecting fractional crystallization superimposed upon partial melting processes. High Pt and Pd in some enriched shergotittes and correspondingly low Os and Ir are broadly consistent with fractional crystallization observed in some terrestrial continental flood basalts.

Prior models have invoked the formation of enriched and depleted reservoirs either through remixing of differentiated crust and mantle or through incompatible trace element depleted and enriched mantle reservoirs. It is notable that enriched shergotittes are not only characterized by radiogenic Sr but also by generally lower MgO contents and more fractionated HSE patterns than depleted or intermediate shergotittes. It is possible that these relationships are fortitious and we simply haven't found as many high MgO enriched shergottites. Nonetheless, the positive relationship of Sr with Os (*Figure 3*) implies that enriched shergottites originate for a long-term time-intergrated high Rb/Sr and Re/Os reservoir. In the case of a crustal origin for the enriched signature (e.g., [1]) this would be suggestive of a mafic protolith, in constrast with the typically higher Re/Os terrestrial andesitic crust.

In the scenario of different incompatible element enriched and depleted mantle reservoirs, the fractionated HSE abundances found in enriched shergottites must either be fortuitous (see above) or reflect fundamental differences in fractional crystallization and partial melting between enriched versus depleted/intermediate shergottites. We explore a third possibility to crust-mantle mixing or enriched-depleted mantle mixing, which is partial melting of fusible and refractory mantle mixtures. In this case, lower degrees of partial melting lead to preferential liberation of more fusible phases (e.g., minerals, or lithologies, such as pyroxenite), whereas higher degrees of partial melting lead to a greater contribution from more refractory minerals or lithologies (e.g., peridotite).

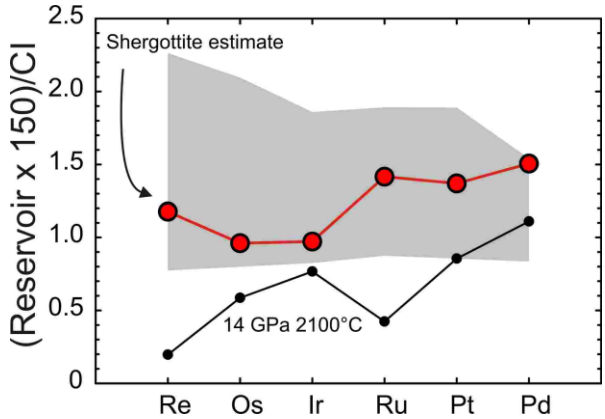

Figure 4*: Plot of the range of chondrite compositions versus martian mantle estimates from shergottites and high-P and high-T experimental constraints on martian mantle composition [6]. Estimates of martian mantle composition from shergottite meteorites are associated with large uncertainties. Note linear scale. Figure modified from [5].*

Our new results support a martian mantle with broadly similar HSE abundances to the terrestrial mantle that appear to require a late accretion component with chondritic Re/Os. This is not currently achieved in current high P-T experiments (*Figure 4*). Our results also reveal fundamental differences both in Sr-Os isotope systematics for enriched and depleted shergottites, but also in absolute and relative abundances of the HSE.

References: [1] Jones (1989) PLPSC, 19, 465 [2] Symes et al. (2008) GCA, 72, 1696. [3] Day et al. (2016) GGR, 40, 49. [4] Brandon et al. (2012) *GCA*, 76, 206. [5] Day et al. (2016) *RIMG*, 81, 161. [6] Righter et al. (2015) *MAPS*, 50, 1.