^{187}Re-^{187}Os AND HIGHLY SIDEROPHILE ELEMENT SYSTEMATICS OF SHERGOTTITES: NEW PUZZLES REGARDING THE MARTIAN MANTLE.

R.J. Walker[1], I.S. Puchtel[1], A.D. Brandon[2], J.M.D. Day[1] and A.J. Irving[3]. [1]University of Maryland, College Park, MD 20742 (rjwalker@geol.umd.edu), [2]NASA, JSC, Houston, TX 77058, [3]University of Washington, Seattle, WA 98195

Introduction. The highly siderophile elements (HSE: Re, Os, Ir, Ru, Rh, Pd, Pt, and Au) and the ^{187}Re-^{187}Os isotope system are initially strongly affected by metal-silicate partitioning in differentiating planetary bodies, then are subsequently modified by crystal-liquid fractionation within the silicate portions of the bodies, as well as by additional accretion [1-2]. $^{187}Os/^{188}Os$ initial ratios and HSE abundances in derivative lavas from planetary mantles, thus, provide important information about early, global-scale planetary processes.

Prior studies of martian meteorites have led to the conclusion that absolute HSE abundances in the martian mantle are roughly equivalent to terrestrial abundances [3-4]. Further, Os isotopic compositions of martian meteorites have been found to be within the range of compositions present in the terrestrial mantle [5]. Thus, the processes that established and modified the HSE in the martian mantle may have been generally similar to processes that acted on the terrestrial mantle. In order to decipher the dominant processes affecting the HSE in Mars it will be particularly important to compare the Os isotopic compositions of martian mantle source reservoirs with data from other long- (^{143}Nd, ^{87}Sr, ^{176}Hf) and short- (^{182}W, ^{142}Nd) lived isotope systems that may also reflect early, global differentiation events.

Here we report new HSE and Os isotopic data for five shergottites that have not been previously studied with respect to coupled $^{187}Os/^{188}Os$ ratios and HSE abundances. In addition to broadening the HSE and Os isotope database for martian samples, we are also attempting to isolate and ameliorate problems related to secondary alteration processes that have evidently affected some of these meteorites. We report results of chemical leaching experiments for one desert meteorite.

The shergottite suite studied here includes meteorites from chemically diverse sources. Prior Nd and Sr isotopic work, coupled with trace element studies have suggested that the shergottites are derived from both long-term incompatable element-enriched and depleted mantle sources [e.g. 6-8]. The possibility of crustal contamination may also have led to isotopic and elemental diversity in the suite [9].

Methods. Rhenium, Os, Ir, Ru, Pt, and Pd concentration data, and $^{187}Os/^{188}Os$ were determined for five shergottite meteorites including RBT 04262, NWA 1068, LAR 06319, Zagami and Shergotty. These meteorites span a large range of MgO from ~22 wt. % (RBT 04262) to 9.3 wt. % (Shergotty) .

Between 0.05 and 0.5g of sample powder were equilibrated with spikes and digested in Carius tubes @270^{o}C using a mixture of nitric and hydrochloric acids. For the latest analytical campaign, blanks for Re, Os, Ir, Ru, Pt, and Pd averaged 0.8, 0.17, 0.27, 0.36, 13, and 10 pg, respectively. The effects of chemical blank on individual results varied from negligible for most elements in most samples to nearly 30% for Re in one aliquant of Shergotty. Osmium concentrations and isotopic compositions were determined by negative thermal ionization mass spectrometry. The remaining HSE were analyzed by inductively coupled plasma mass spectrometry. Accuracy of these measurements was monitored via periodic interspersal and analysis of spiked solutions of known isotopic compositions. In most cases, accuracy and precision of all concentrations except Re are estimated to be ±3%.

In order to examine possible effects from desert weathering, a chunk of NWA 1068 was leached for 30 minutes using 1% acetic acid. Both leachate and residue were analyzed. An untreated bulk sample was analyzed for comparison.

Results & Discussion. Several observations are worthy of note. First, chemical leaching of NWA 1068 not only liberated a Re-rich fraction, but also a component with a much more highly radiogenic $^{187}Os/^{188}Os$ (Fig. 1). These results suggest that Re, and possibly highly radiogenic Os were added to the rock via desert alteration processes. Although chemical "repairs" to desert altered meteorites for Re-Os investigation must be interpreted cautiously, the calculated initial γ_{Os} (deviation from chondritic at the presumed time of crystallization at 185 Ma) of +8.0 for the residue is interpreted to be the composition of the original, crystallizing melt. The relatively high HSE concentrations of the bulk rock indicate that the HSE in the parental melt were likely little modified by interaction with the martian crust and that the initial γ_{Os} of +8 is representative of the mantle source.

The HSE pattern of Zagami is highly fractionated, with low abundances of Os and Ir, but moderate concentrations of Pt and Pd (Fig. 2). Consistent with a prior analysis [5], its initial γ_{Os} (calculated for 165 Ma) of +4.8 indicates either derivation from a mantle source with long-term, modestly suprachondritic Re/Os, or contamination with crust. The similarity between its Os isotopic composition and that of NWA

1068 (both are long-term incompatible element-enriched shergottites) suggest that both likely originated from a mantle source with long-term suprachondritic Re/Os and subchondritic Sm/Nd. Such a reservoir could be generated from fractionates resulting from later-stage differentiateon of a magma ocean.

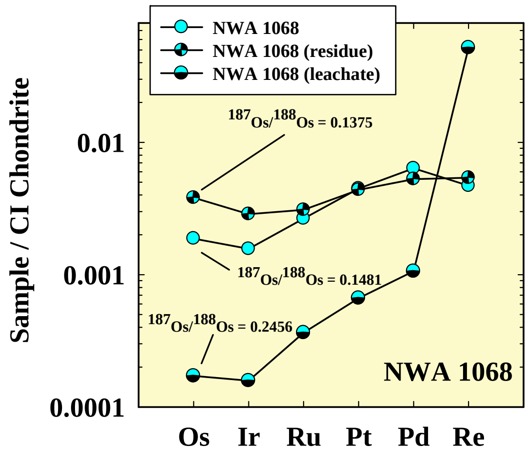

Figure 1. C1 chondrite-normalized HSE patterns for whole rock, residue and leachate fractions of NWA 1068.

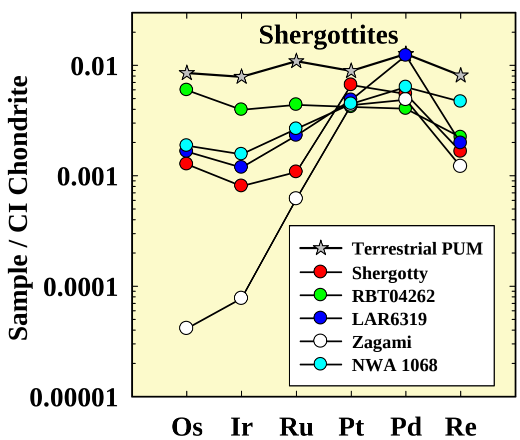

Figure 2. C1 chondrite-normalized HSE patterns for whole rock samples of diverse shergottites. The terrestrial primitive upper mantle (PUM) is shown for comparison.

RBT 04262 and LAR 6319 are characterized by slightly (RBT) to moderately (LAR) fractionated HSE patterns relative to chondrites (Fig. 2). Both are characterized by similar γ_{Os} values of +13 and +15, respectively (calculated for 225 and 185 Ma, respectively). Like NWA 1068 and Zagami, these meteorites were likely derived from a mantle source(s) with long-term, moderately suprachondritic Re/Os.

Shergotty is characterized by an HSE pattern that is fractionated considerably less than Zagami, despite a slightly lower MgO content. Perhaps of greatest note in the suite examined are the Re-Os data for Shergotty. Despite evidence that the meteorite crystallized at ~165 Ma [10], the Re-Os isotopic data for three separate aliquants plot along a best-fit isochron of ~450 Ma. If not the age of crystallization, this discrepancy could result from minor redistribution of Re either on the martian surface, or during terrestrial alteration (perhaps during sawing). More importantly, all aliquants are characterized by present day $^{187}Os/^{188}Os$ ratios substantially below chondritic. Such depleted compositions are common on Earth in samples of Archean lithospheric mantle transported to the surface as peridotite xenoliths in alkaline basalts and kimberlites. We know of no Phanerozoic terrestrial igneous rocks with such low $^{187}Os/^{188}Os$. If Shergotty records an initial $^{187}Os/^{188}Os$ of 0.105 or lower, as suggested by these data, and if this is representative of its mantle source, it must sample a previously unidentified, highly-depleted mantle source that likely lost most Re during the first 1 Ga of the solar system. This creates a conundrum in that the Nd isotopic composition of Shergotty resembles other shergottites like NWA 1068 and Zagami, which have considerably more radiogenic Os. In this case Os was somehow completely decoupled from the lithophile isotope systems in the Shergotty source. Alternately, the Os isotopic composition is a result of contamination with either ancient, high Os abundance, low Re/Os crust or lithospheric mantle that has also yet to be chemically identified.

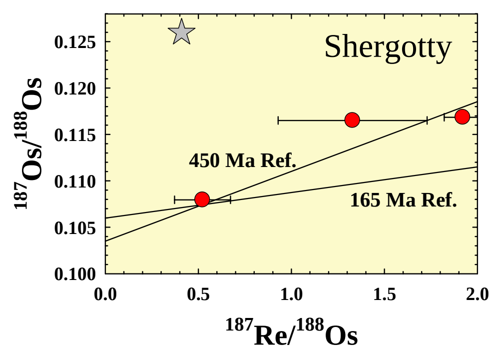

Figure 3. Isochron diagram for three aliquants of Shergotty. A 165 Ma isochron (non-chondritic initial ratio) is shown for comparison. The star represents the isotopic composition of carbonaceous chondrites at 165 Ma.

References. [1] Morgan J.W. et al. (2001) *MAPS* **36**, 1257 [2] Drake M. & Righter K. (2002) *Nature* **416**, 39 [3] Warren P.H. and Kallemeyn G.W. (1996) *MAPS* **31**, 97 [4] Kong P. *et al.* (1999) *GCA* **63**, 1865 [5] Brandon A.D. et al. (2000) *GCA* **64**, 4083 [6] Borg L. et al. (2003), *GCA* **67**, 3519. [7] Shih C. et al. (2005), *Ant. Meteor. Res.* **18**, 46 [8] Debaille V. et al. (2007), *Science* **450**, 525 [9] Jones J.H. et al. (2003) *Chem. Geol.* **196**, 21 [10] Nyquist et al. (1979) *GCA 43, 1059.*