

**HIGHLY SIDEROPHILE ELEMENT ABUNDANCES IN SNC METEORITES: AN UPDATE.** I.S. Puchtel<sup>1</sup>, R.J. Walker<sup>1</sup>, A.D. Brandon<sup>2</sup>, and A.J. Irving<sup>3</sup>. <sup>1</sup>University of Maryland, College Park, MD 20742 (ipuchtel@umd.edu), <sup>2</sup>NASA, JSC, Houston, TX 77058, <sup>3</sup>University of Washington, Seattle, WA 98195

**Introduction.** Highly siderophile elements (HSE: Re, Os, Ir, Ru, Rh, Pd, Pt, and Au) strongly partition into metal relative to silicates. As such, their abundances in planetary mantles were strongly affected by core formation. The moderate abundances of HSE in the terrestrial mantle have been explained as a consequence of one of several processes. Some have advocated that HSE abundances in the mantle were established by metal-silicate equilibration at the base of a deep magma ocean where metal-silicate distribution coefficients may have been appropriate (sufficiently low) to account for the present mantle abundances [1,2]. Others argued that continued accretion postdated the final stages of terrestrial core segregation and that the accumulation of late accreted materials increased the HSE abundances from very low immediately following completion of core segregation, to their current moderate levels [3,4].

Constraining the abundances of HSE in the mantles of other inner solar system bodies may help to distinguish between the early planetary processes that had the largest effect on the HSE budgets of the planetary mantles. Unfortunately, comparisons are difficult. The abundances of HSE in the lunar mantle have been highly problematic to constrain because of the lack of direct samples of the lunar mantle, the paucity of lunar ultramafic rocks (which are most useful for characterizing HSE abundances in mantle sources), and the likely complex stratigraphy of the lunar mantle. Nonetheless, several recent studies have concluded that HSE abundances in the lunar mantle are ~20x lower than in the terrestrial mantle, and may be in chondritic relative abundances [5,6]. These conclusions, however, remain tenuous.

Here, we report new HSE data for two lherzolitic shergottites and eight basaltic shergottites as a means of placing additional constraints on the HSE inventory of the martian mantle. This study is complementary to our ongoing study of the Re-Os isotopic systematics of SNC meteorites [7,8]. The SNC suite offers some distinct advantages for studying HSE in the martian mantle compared to studying existing lunar samples in our inventory for understanding the lunar mantle. Most notable is the substantial proportion of ultramafic samples (lherzolites) and basalts with relatively high MgO among the SNC suite. Although these rocks are not direct samples of the martian mantle, their HSE abundances likely more closely record mantle abundances compared to more evolved materials. Several previous studies have reported HSE abundances in SNC meteorites that are generally

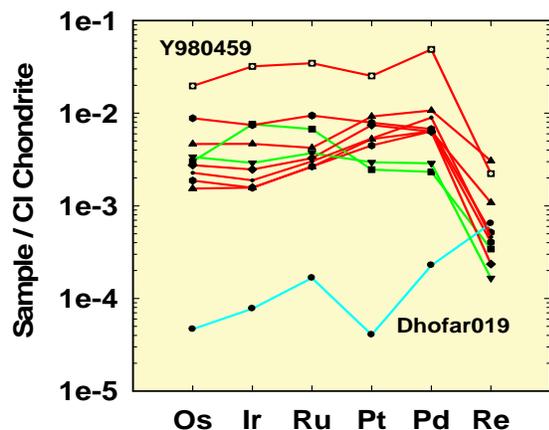
similar to abundances in terrestrial rocks with the same MgO [9,10]. Based largely on the study of ultramafic samples, the implication has been that the concentrations of the HSE in the martian mantle are roughly comparable to their concentrations in the terrestrial mantle.

**Methods.** Rhenium, Os, Ir, Ru, Pt, and Pd concentration data were determined for the following SNC meteorites: SaU094, SaU008, ALH77005, EET79001 (lithology A), NWA1195, NWA1068, Dhofar019, LEW88516, Y980459, and DaG476. Because of previous problems interpreting the Re-Os isotopic systematics of DaG476 [7], and desert SNC meteorites in general [8], we have begun a series of experiments to assess effects on HSE (and Os isotopes) resulting from desert weathering. In addition to two bulk samples (one with a pristine appearance and the other with visible alteration), we also analyzed a magnetic separate, a leachate (liberated from the rock using acetic acid) and the leach residue.

As with our previous work on SNC and lunar samples, the SNC meteorite samples were equilibrated with spikes and digested in Carius tubes @270°C using a mixture of nitric and hydrochloric acids. For the latest analytical campaign, blanks for Re, Os, Ir, Ru, Pt, and Pd averaged 1.1, 0.15, 0.39, 0.57, 27, and 9.1 pg, respectively. The effects of analytical blank on individual results varied from negligible for most elements in most samples to ~150% for Re in the magnetic separate of DaG476. Osmium concentrations (and isotopic compositions: [8]) 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%.

**Results.** Several observations are worthy of note. First, concentrations of the HSE in the meteorites are generally within the range of concentrations previously reported for SNC meteorites. The concentrations are also similar to those in terrestrial peridotites and picrites which have MgO extending over a comparable range. An exception to this is Y980459 which has an HSE pattern shape that is similar to that for NWA1195, but with substantially higher HSE content (Fig. 1). Second, all samples, except Dhofar019, are characterized by broadly flat chondrite-normalized HSE patterns that are depleted in Re relative to other HSE (Fig. 1). This result suggests that during the

production of these lavas, Re was either similarly compatible to the other HSE, or was lost from surface flows due to volatility, as has been observed for some terrestrial lavas. Finally, results for DaG476 indicate that HSE are evidently present in substantial quantities in phases that can be easily dissolved via a mild leach. This suggests that HSE patterns of desert meteorites must be interpreted with caution.



**Figure 1.** C1 chondrite-normalized HSE patterns for whole rock lherzolitic (green) and basaltic (red) shergottites. Dhofar019 and Y980459 are labeled.

**Synthesis.** These results, coupled with previously published data, indicate that the martian mantle sampled by shergottites contains similar to the terrestrial mantle abundances of the HSE. Further, the relatively unfractionated chondrite-normalized patterns

for higher MgO samples, together with the broadly chondritic initial  $^{187}\text{Os}/^{188}\text{Os}$  ratios [7,8], provide evidence that the HSE are in chondritic relative abundances in the martian mantle source regions. These conclusions, if correct, would be difficult to explain *via* magma ocean models, which may require a unique set of circumstances (p, T,  $f\text{O}_2$ ) to account for the abundances of some HSE in the terrestrial mantle. Thus, these observations seemingly favor late accretionary models for the HSE in both the terrestrial and martian mantles. If late accretion was the mechanism that controlled the HSE abundances, it is remarkable that the additions to Earth and Mars were so proportionally similar and mixed so well within the respective mantle sources.

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**Table 1.** HSE data (in ng/g) for lherzolitic and basaltic shergottites. Listed in order of decreasing MgO (in wt. %)

Sample	Wgt. (g)	MgO	Re	Os	Ir	Ru	Pt	Pd
<i>Lherzolitic Shergottite</i>								
ALH77005	0.14	28.0	0.156	1.377	3.366	4.386	2.130	1.319
LEW88516	0.09	24.0	0.076	1.546	1.291	2.413	2.559	1.636
<i>Basaltic Shergottite</i>								
SaU008	0.18	20.5	0.496	0.702	0.698	1.719	4.555	3.625
SaU094	0.18	20.5	1.399	2.129	2.071	2.743	7.968	6.075
NWA1195	0.88	19.3	0.237	4.046	3.304	6.119	6.831	3.837
Y980459	0.08	~19	1.020	8.985	14.24	22.49	21.87	27.76
DaG476 (altered)	0.08	~19	0.211	1.041	0.836	1.957	4.614	5.094
DaG476 (fresh)	0.10	~19	0.265	1.562	1.031	1.808	3.154	3.489
DaG476 (magnetic)	0.02	~19	0.048	0.483	0.462	78.04	4.687	3.098
DaG476 (residue)	0.08	~19	0.367	3.986	3.230	4.758	4.240	3.404
DaG476 (leachate)	0.02	~19	0.429	0.954	0.419	1.205	2.887	2.996
EET79001 (lith A)	0.17	~16.5	0.107	1.261	1.095	2.127	6.443	3.586
NWA1068	0.19	16.6	0.186	0.858	0.695	1.725	3.881	3.614
Dhofar019	0.34	14.6	0.296	0.021	0.034	0.108	0.035	0.129