Sample Return and Highly Siderophile Elements In the Martian Mantle: Why Is It Important?

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Why care about HSE in Martian rocks?

The HSE (including Re, Os, Ir, Ru, Pt, Rh, Pd and Au) are geochemically characterized as having a strong tendency (D values > 10^4) to partition into metal relative to silicates. Despite this, the abundances of the HSE in the *terrestrial* mantle are much higher than might be expected if the Earth formed via accretion of smaller bodies that had segregated distinct cores. This observation has led to the development and testing of several hypotheses to explain the apparent discrepancy:

1) Greatly lowered metal-silicate D values resulting from either composition effects, such as high S content in the segregating metal (Brett, 1984), or raised temperatures and pressures, such as would be found at the base of a deep magma ocean (Ringwood, 1977; Murthy, 1991).

2) Incomplete core separation during which some HSE-bearing metal is retained in the silicate Earth (Jones and Drake, 1986).

3) Late accretion, normally defined as continued accretion to Earth of materials with chondritic abundances of the HSE, subsequent to the termination of substantial transport of HSE into the core (Chou, 1978). **If late accretion added substantial mass to the terrestrial planets, the late accretionary process might also have contributed water and organics, in addition to the HSE.**

Rocks from Mars provide an important point of comparison to Earth. Previously reported ^{187}Re/^{188}Os isotopic systematics of SNC meteorites implicate the formation of both early enriched and depleted mantle reservoirs (Brandon et al., 2000)(as are required for Nd and W isotopes).

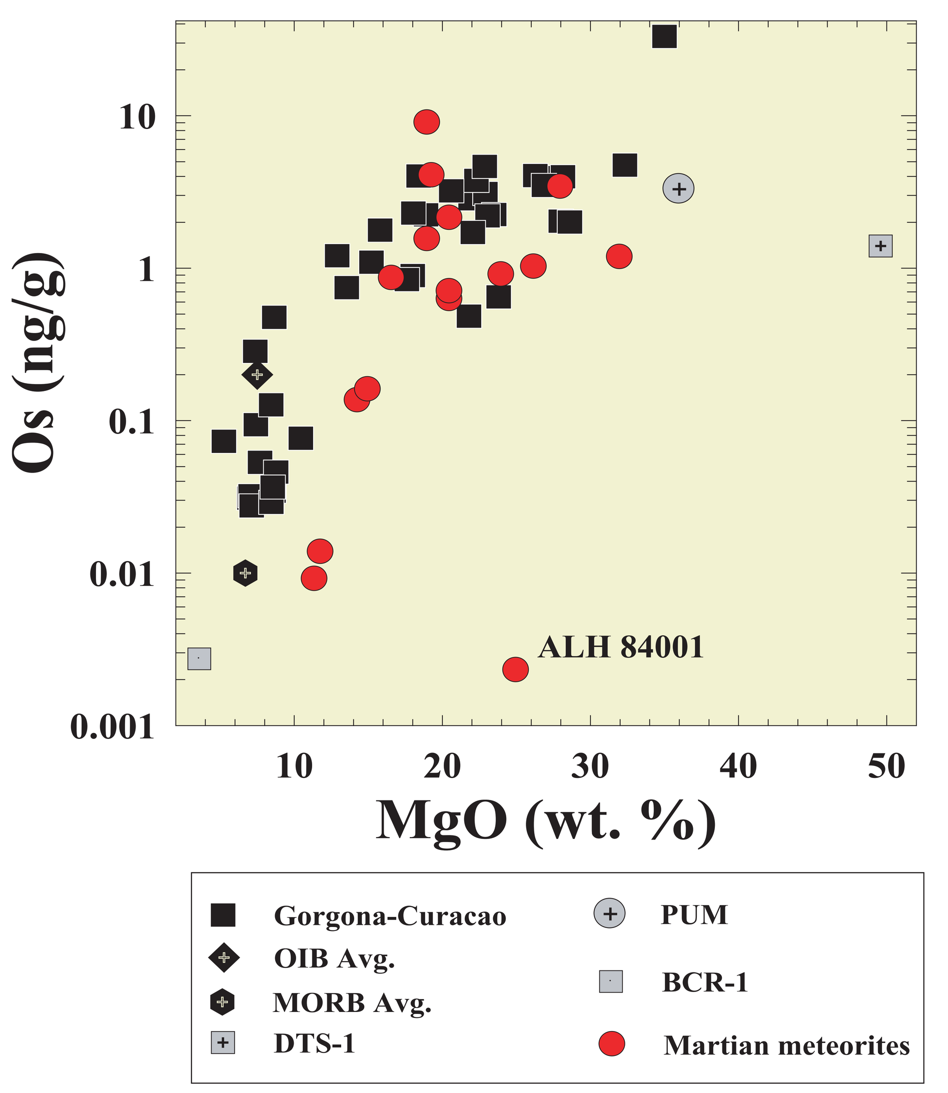

Fig. 1. Os (ppb) versus MgO (wt%) abundances in some terrestrial rocks compared to martian meteorites.

Concentrations of the HSE in martian meteorites are generally similar to those in terrestrial peridotites and picrites with comparable MgO contents (Fig. 1). This suggests that the martian mantle has HSE abundances that are generally comparable to abundances in Earth's mantle, and together with the chondritic ^{187}Os/^{188}Os initial ratios of most martian meteorites (Brandon et al., 2000), may provide strong supporting evidence that the inventories of these elements in the mantles of the Earth and Mars were established by late accretionary processes, rather than by metal-silicate equilibration under a unique set of P-T conditions at the bottom of a magma ocean...

BUT, as with other isotopic systems, the HSE in our long distance visitors from Mars are problematic to analyze and interrpret with respect to their mantle sources. In particular, desert meteorites appear to have been affected by terrestrial contamination, and possibly Martian surface contamination. We didn't consider alteration effects for the Brandon et al. (2000) study and are in the process of re-analyzing previously studied meteorites and analyzing a new group of meteorites.

Sample Issues

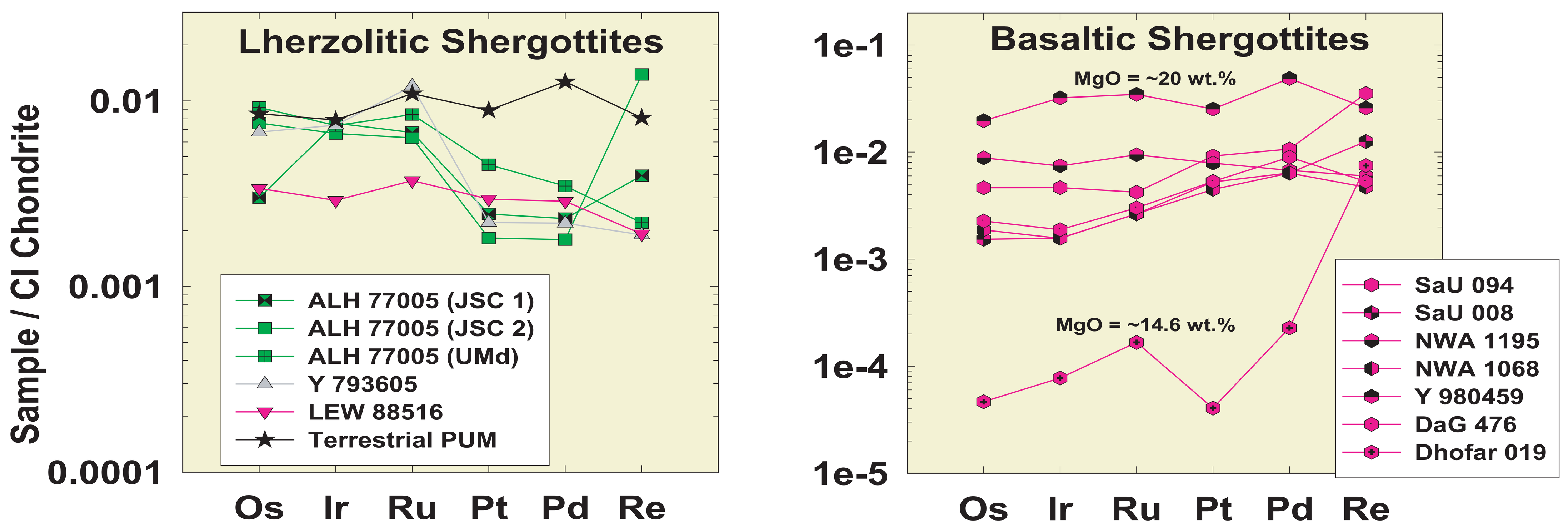

Fig. 2. CI-normalized HSE abundances in lherzolitic and basaltic shergottites.

The HSE abundances in three lherzolitic shergottites we analyzed (Fig. 2) are generally similar, and similar to some terrestrial lherzolites and Earth's Primitive Upper Mantle (PUM). Analysis of three separate chunks of ALH 77005, however, show modest variations for most HSE. Basaltic shergottites define a large range of concentrations, with HSE generally decreasing with decreasing MgO.

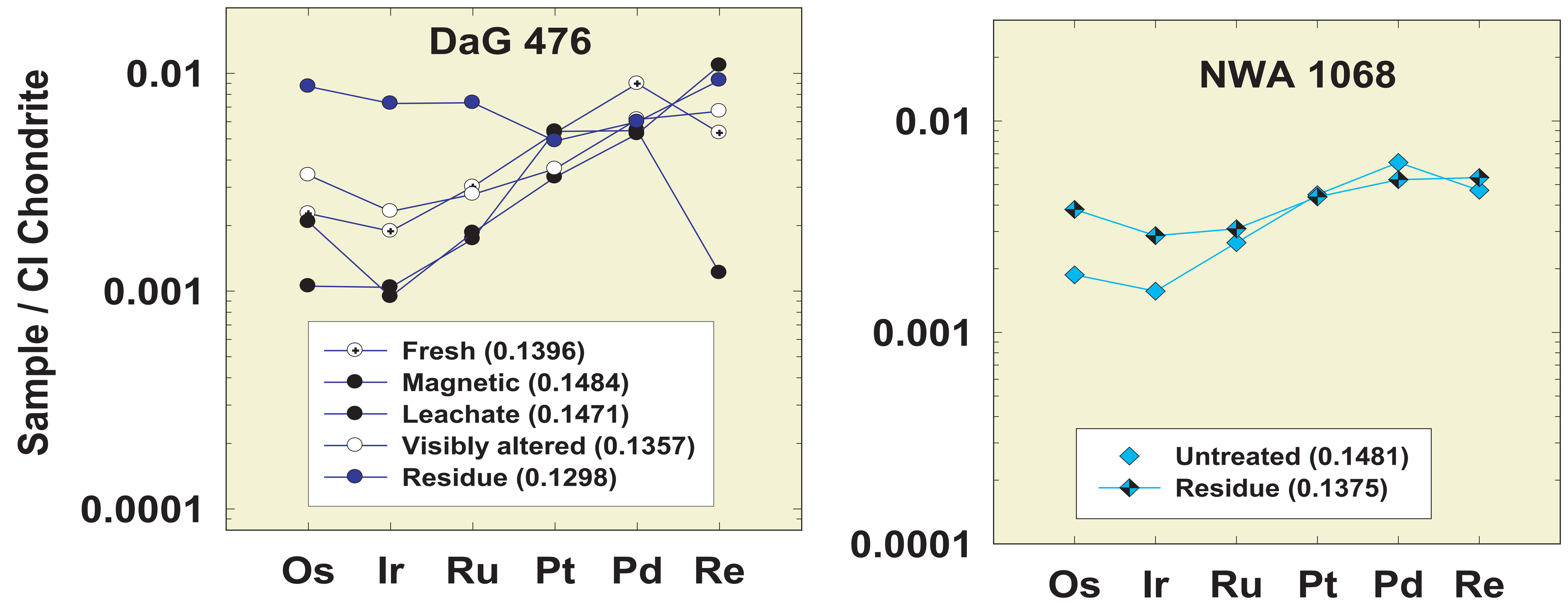

Fig. 3. CI-normalized HSE abundances in DAG 476 fractions and leached and untreated fractions of NWA 1068.

As a means of examining and attempting to circumvent desert alteration issues, we analyzed visibly fresh and altered chunks of DaG 476 (Fig. 3). We also examined a magnetic separate, and leached an additional chunk with acetic acid. The leach residue has the least radiogenic Os (^{187}Os/^{188}Os are provided in the legend) and offers the best chance at constraining the initial ^{187}Os/^{188}Os of this 474 Ma rock. Note that the residue has substantially higher Os, Ir, and Ru concentrations than the bulk samples. The pattern for a leached residue compared to an untreated bulk sample of basaltic shergottite NWA 1068 (Fig. 3) also shows higher Os, Ir, and Ru, and a less radiogenic Os isotopic composition. This indicates that a ^{187}Os/^{188}Os-rich (terrestrial desert?) phase has been removed by the leaching.

New Isotopic Results

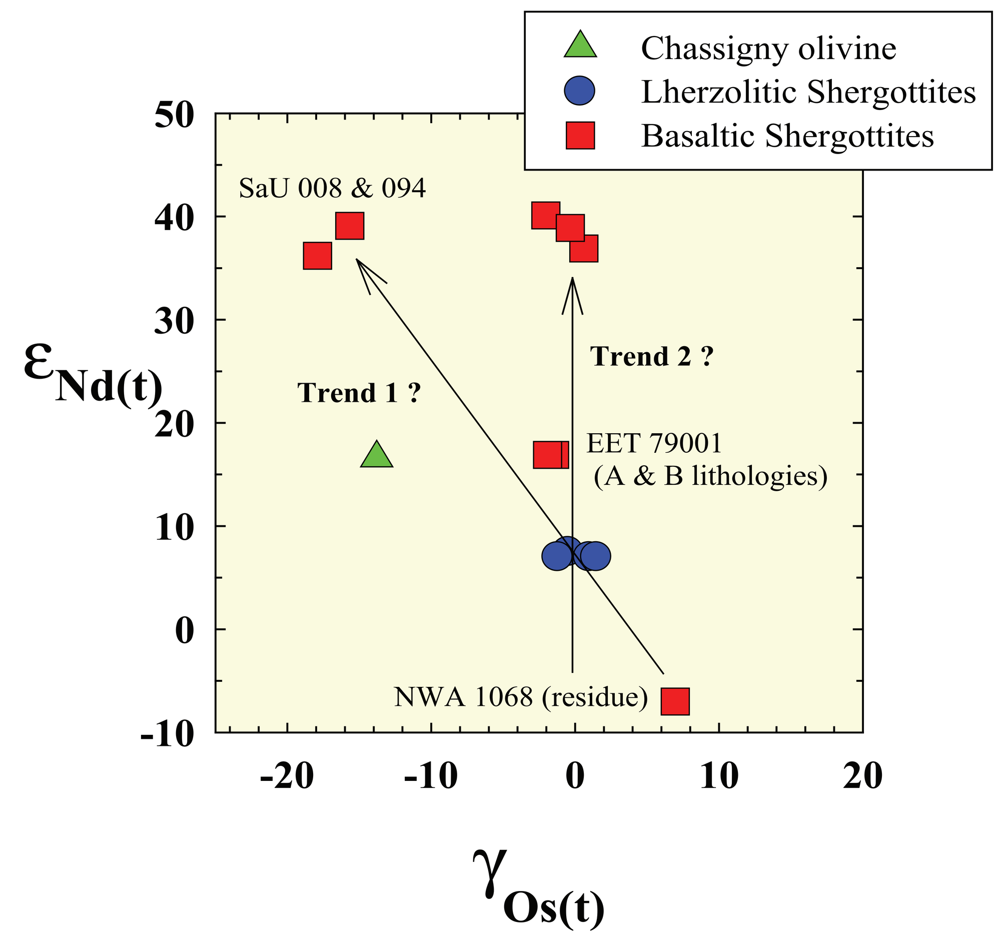

Fig. 4. $\varepsilon_{143Nd(t)}$ versus $\gamma_{Os(t)}$ for lherzolitic and basaltic shergottites. A chassigny olivine separate is also shown for comparison. An important question is whether Trend 1 or Trend 2 represent the true relation between Nd and Os isotopes.

New Os isotopic results combined with literature Nd data are problematic to interpret (Fig. 4). There is an apparent consistent depletion-enrichment trend between ε^{143}Nd(t) and γOs(t) for NWA 1068, EET 79001 and SaU 008/094, and including the lherzolitic shergottites (Trend 1). However, DaG 476, NWA 1195 and Y 980459 plot to the right of the apparent trend.

If the trend is real, Os and Nd may both track an early martian mantle fractionation trend. If the apparent trend is the result of alteration (and the real trend is vertical on the plot, Trend 2) a question regarding how Sm/Nd could have been strongly fractionation by a process that did not evidently fractionate Re/Os is raised. This is a very important distinction. If ^{187}Os and ^{143}Nd isotopic systematics are coupled, we must conclude that the Os (& other HSE were added to the martian mantle very early (within 100 Ma). If they are decoupled, it may suggest that late accretion was really late (>100 Ma after formation of SS). This would imply that Nd isotopic systematics were already established by the time most Os was added to the martian mantle.

Conclusions

It is wonderful that nature has evidently provided us with respectable samples from Mars to study in our labs. Clearly our thinking about the internal structure and dynamics of the red planet have, to some extent, been guided by geochemical data produced for these meteorites in our laboratories. HOWEVER, all of the samples studied to date have been compromised by terrestrial and martian alteration effects (including effects resulting from the impact events that released them from Mars). It is possible that some of our most fundamental assumptions about Mars, based on our geochemical data, have been biased by the alteration processes.

Samples of igneous rocks from well constrained locations are desperately needed to provide the ground truth for all of the prior work.

Acknowledgments

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