PERIDOTITES FROM ANOTHER PLANET? OSMIUM ISOTOPE AND HIGHLY SIDEROPHILE ELEMENT CONSTRAINTS ON THE EVOLUTION OF DIOGENITES AND THE HED PARENT BODY

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Diogenites and 4 Vesta: Diogenite meteorites are orthopyroxene ± olivine rich rocks that form part of the howardite-eucrite-diogenite (HED) meteorite suite [1, 2]. The HED parent-body is thought to be the ~530 km diameter asteroid 4 Vesta [3, 4], target of the recently launched DAWN mission. Homogeneous O-isotope systematics for HED meteorites are consistent with wholesale melting of their parent body [2] and initial studies indicate low abundances of highly siderophile elements (HSE) [5], implying crust-mantle-core differentiation. Thus, the HED meteorites are valuable samples for understanding early planetary differentiation processes, and as proxies for Earth, where materials formed prior to around 4 Ga are neither preserved nor sampled. Identification of olivine-rich diogenites [e.g., 6] and evidence for a range of orthopyroxene [7] and spinel compositions [8], imply diogenites represent cumulates, and possibly even mantle peridotites from their parent body [6, 9, 10]. Diogenites may, therefore, represent the only sampling of bonafide mantle materials outside of Earth and provide the rationale for this study.

Samples and Analytical Protocols: We present new osmium isotope and HSE (Os, Ir, Ru, Pt, Pd, Re) abundance data for 1 North-west African and 7 Antarctic diogenites. These include the recently discovered olivine diogenite MIL 07001, olivine diogenites NWA 1877, EETA 79002, olivine-rich diogenite LAP 05639 and olivine-poor diogenites ALHA 77256, LAP 91900, MET 00424 and SAN 03473. Textures of the samples range from cataclastic (e.g., LAP 05639, SAN 03473) through to granular aggregates (e.g., MIL 07001), but all have relatively homogeneous orthopyroxene ($Fs_{22-27}Wo_{1-2}$) and, where present, olivine (Fo_{72-79}) compositions. Spinel compositions vary within the samples, as does the presence and modal abundance of trace phases, including spinel, clinopyroxene, plagioclase, sulphides, FeNi metal and silica. Analytical protocols are outlined in [11]. Blank contributions are low (e.g., <0.2pg Os, <1.5pg Re) resulting in estimated HSE blank contributions that are variable for the samples. For example, estimated Os blank contributions are less than 0.1% for MIL 07001, but as high as 20% for NWA 1877.

Highly Siderophile Element Abundances: Diogenites range nearly five orders of magnitude in HSE abundances (0.0018 to 3.6 ng g^{-1} Os) and are characterized by broadly flat CI-chondrite normalized HSE patterns (**Fig. 1**). NWA 1877 (Ol diogenite) and MET 00424 (Ol-poor diogenite) have the lowest HSE abundances and highest Re/Os ratios. MIL 07001 and EETA 79002 (both Ol diogenites) have the highest HSE abundances.

We find no clear relationship between the modal abundance of olivine in diogenites and their HSE abundances. Although olivine diogenites MIL 07001 and EETA 79002 have the most elevated abundances of HSE in the suite of diogenites analyzed so far, NWA 1877, another olivine diogenite [6], has one of the lowest HSE abundance inventories of the suite. Nevertheless, we note that the HSE abundances of olivine diogenites MIL 07001 and EETA 79001 are remarkably close to fertile terrestrial mantle peridotite estimates (PUM; **Fig. 1**), which requires explanation.

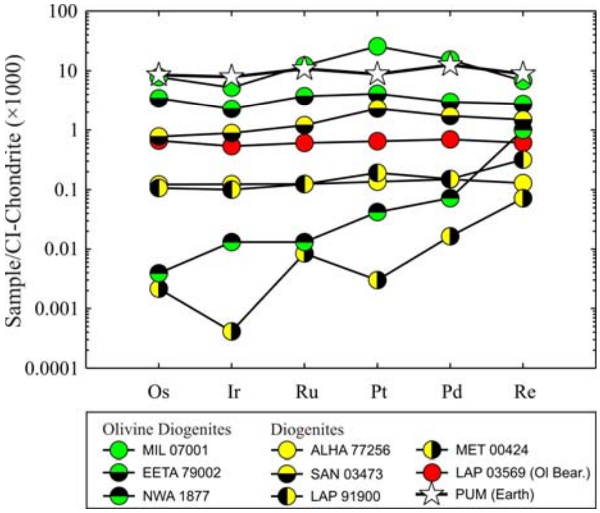

Figure 1: *CI-Chondrite normalized highly siderophile element patterns for diogenite whole-rock samples. The estimated terrestrial primitive upper mantle (PUM) is shown for comparison [12]. Normalization data from [13].*

Re-Os Isotope Systematics: Os isotope compositions for the Antarctic diogenites are broadly chondritic (Present-day $^{187}Os/^{188}Os$ = 0.1220-0.1339) whereas NWA 1877 has a more radiogenic measured $^{187}Os/^{188}Os$ (0.2128). Our Os isotope and Re and Os abundance measurements of NWA 1877 are identical, within uncertainty, to previously reported data from [6]. The Os isotope compositions of the Antarctic diogenites are marginally less radiogenic than previously reported $^{187}Os/^{188}Os$ data for diogenites Tatahouine and Roda (0.010-0.040 ng g^{-1} Os; $^{187}Os/^{188}Os$ = 0.1377-0.1448) [5].

Diogenites with the lowest Os abundances (NWA 1877; MET 00424) exhibit the youngest calculated Re-Os model ages (T_{MA} = ~0 to 46 Ma). These young ages likely relate to greater analytical uncertainty for these small mass, low abundance aliquots and to possible disturbance through desert alteration processes (e.g., NWA 1877), or even through impact-disturbance on their parent body (e.g. [6]). We plan to reduce analytical uncertainties by improving the sample/blank ratio for precisely spiked >1g aliquots of these and other diogenites in early 2009. Diogenites with higher Os and Re abundances have near-chondritic Re/Os and $^{187}Os/^{188}Os$ and so plot close to a 4.5 Ga isochron in **Fig. 2**. These data provide powerful evidence that the HSE abundances and Os isotope ratios of these diogenites were set early in the history of their parent bodies' thermal and chemical evolution.

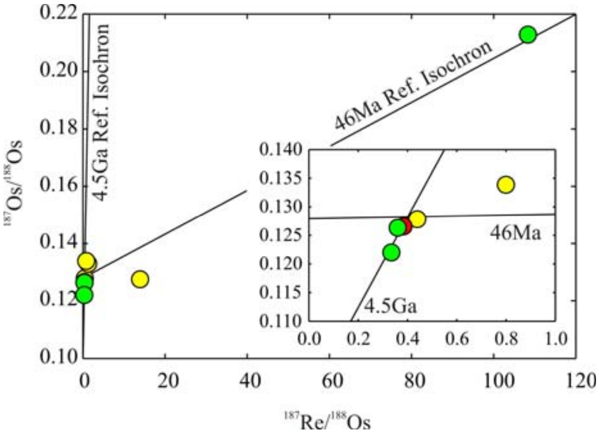

Figure 2: *Re-Os isochron diagram for diogenites. 4.5 Ga and 46 Ma chondritic reference isochrons are shown for comparison. Samples with low Os abundances and high Re/Os ratios are likely disturbed.*

Peridotites From Another Planet? The most striking aspect of the diogenite HSE dataset is the extreme range in abundances between the 8 samples analysed. This might be explained through impactor disturbance, as, observed for lunar impact melt breccias (e.g., [14]). Diogenites range in texture from cataclastic through to granulated rocks. There is, however, no clear-cut relationship between texture and HSE abundances between the samples. Furthermore, the coincident HSE abundances of MIL 07001 and EETA 79002 with PUM (**Fig. 1**) and the lack of diogenites analysed thus far with HSE abundances greater than PUM appear to argue against diogenites representing impact melt breccias. The alternative explanation is that, subsequent to core-mantle differentiation, the diogenite parent body suffered late accretion that inefficiently mixed into its crust/mantle. This scenario requires differentiation and later accretion over a very short timeframe. In one of two competing models for diogenite petrogenesis it has been postulated that all diogenites represent cumulate rocks (e.g., [7]). The alternative model is that olivine diogenites represent fragments of the HED parent body harzburgite mantle and olivine-poor diogenites represent cumulates formed in high-level magma chambers (e.g., [6, 10]). The elevated abundances of HSE in MIL 07001 and EETA 79002 might be consistent with an HED parent mantle enriched by post-core formation late accretion with the olivine-poor diogenites generated as partial melts from such sources.

Implications for Late Accretion: It is generally accepted that at low pressures, such as those estimated for the mantle of 4 Vesta, metal-silicate equilibrium will act to fractionate the HSE, especially Re/Os, leading to non-chondritic HSE patterns and $^{187}Os/^{188}Os$. Therefore, chondritic Os isotope compositions and flat CI-chondrite normalized HSE patterns for diogenites imply accretion of HSE-rich impactors subsequent to whole-sale differentiation of the HED parent body as evidenced from O isotopes [2]. These observations have implications for the 'late accretion' hypothesis for the Earth-Moon system (e.g., [15-17]) and may lend some support to this model. Based on Re-Os chronology, any replenishment event occurred soon after differentiation of the HED parent body. What is less clear is how such variable HSE abundances have been preserved within the diogenite meteorite suite. We are actively pursuing the answers to these uncertainties.

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