

HIGHLY SIDEROPHILE ELEMENT ABUNDANCE VARIATIONS IN DIOGENITES DETERMINED FROM MINERAL-SCALE AND WHOLE-ROCK INVESTIGATIONS J. M. D. Day¹, L. Qin², D. Rumble³, R. J. Walker¹, A. J. Irving⁴, R. D. Ash¹, P. M. Piccoli¹. ¹Dept. Geology, University of Maryland, College Park, MD 20742 (jamesday@geol.umd.edu); ²Dept. Terrestrial Magnetism, Carnegie Institution for Science, Washington, D.C., 20015; ³Geophysical Laboratory, Carnegie Institution for Science, Washington, D.C., 20015; ⁴Dept. Earth and Planetary Sciences, University of Washington, Seattle, WA 98195-1310

Planetary Mantle Mysteries: Diogenite meteorites may represent the only sampling of bonafide mantle and deep crustal materials for any planetary body outside of Earth [1-4]. Consequently, they rank as high-priority targets for detailed geochemical investigations and for comparison with terrestrial peridotites. Previously, we presented coupled $^{187}\text{Os}/^{188}\text{Os}$ and highly siderophile element (HSE: Os, Ir, Ru, Pt, Pd, Re) abundance data for diogenite meteorites and demonstrated that they span a remarkable range in HSE abundances [3]. However, it was not possible to distinguish between post-core formation ‘late accretion’ to the HED mantle prior to diogenites petrogenesis, or meteoritic contamination to the rocks themselves, as the cause of this variation. Here, we present petrology, major- and trace-element mineral chemistry, O-Cr-Os isotope systematics, and further HSE abundance data for 9 diogenite meteorites to constrain the origin of HSE variations within diogenites.

Methods: Petrology and mineral chemistry was performed on thin- and thick-sections of ALHA 77256, EETA 79002, LAP 91900, MET 00424, LAP 03569, SAN 03473 and MIL 07001 provided by MWG. Quantitative mineral chemistry was performed using a JEOL superprobe and a UP 213nm laser ablation system coupled to an Element 2 ICP-MS. Whole-rock Re-Os isotopes and HSE (Os, Ir, Ru, Pt, Pd and Re) abundance measurements were performed in triplicate on the 7 Antarctic meteorites, and on NWA 1877 and NWA 5480 [3,4], using methods described in [5]. Digestion was accomplished using both Carius tubes (CT) and a high-pressure asher (HPA). Oxygen isotopes were measured at the Geophysical Laboratory, using the methods of [6], and Cr isotope measurements were performed at the Department of Terrestrial Magnetism, using the methods of [7].

Mineral-Scale Observations: The 9 studied diogenites exhibit a range of textures, from granular aggregates to brecciated and cataclastic rocks. As with previous studies (*c.f.*, [1-4,8,9]), we find that spinel (sp), orthopyroxene (opx), and olivine (ol) are fairly compositionally homogeneous within each diogenite, but that a chemical continuum exists in spinel chemistry from low Al, high Cr (MET 00424) to high Al, low Cr (ALH 77256) in the diogenites as a whole. Silicate-oxide compositions co-vary from high Cr# sp, low Mg# opx to low Cr# sp, high Mg# opx (**Fig. 1**).

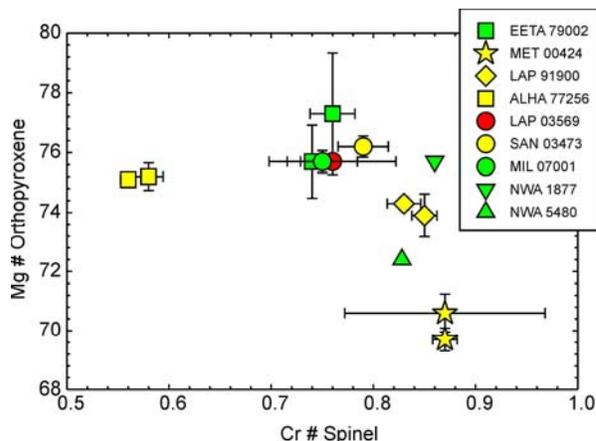


Fig 1: *Sp-opx* relations for ol-diogenites (green), ol-bearing diogenites (red) and diogenites (yellow).

Sulfide (ubiquitously troilite) and metal grains are present in all studied diogenites. FeS grains form irregular masses that range in size from a few microns to 5mm in width. Metals occur either as separate grains, or as inclusions within FeS. Brecciated samples typically have smaller and more dispersed sulfides within their silicate grains. Sulfides and metals were never observed within cataclastic or breccia matrices. There is a correlation between the composition of the metal grains within the diogenites, and their bulk-rock HSE abundances (**Fig. 2**).

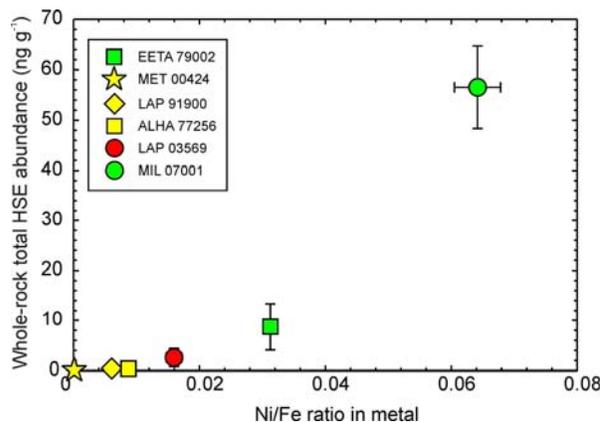


Fig 2: Diogenite whole-rock total HSE abundances correlate with increasing Ni/Fe contents in their metals.

LA-ICP-MS analyses reveal that the HSE are almost exclusively hosted within Fe-Ni metal. MIL

07001, which has some of the largest metal grains and highest whole-rock HSE abundance of the analyzed suite, has two populations of Fe-Ni metals; type 1 (~40%), with ~7ppm Os and Ir and ~10ppm Pt and type 2 (~60%), with ~0.4ppm Os and Ir and ~1.5ppm Pt. Remarkably, the two different metal types can be located within the same sulfide grain (Fig. 3).

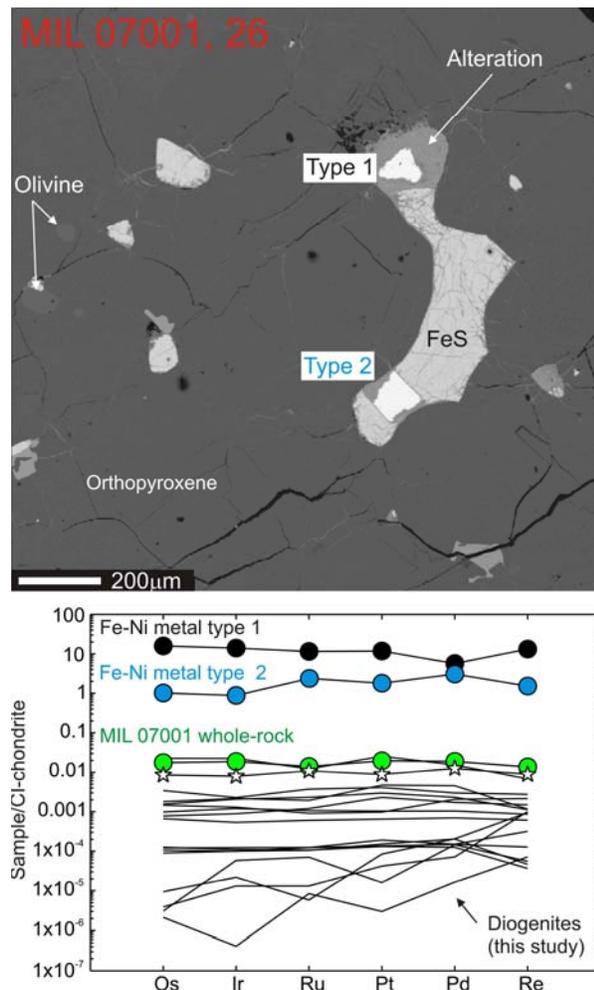


Fig 3: Back-scatter electron image of silicate, sulfide and metal mineral assemblage in MIL 07001 (upper) and comparison of type 1 and type 2 metal grains versus the whole-rock composition. Primitive upper mantle [10] shown for comparison (unfilled stars).

HSE and Re-Os Isotope Systematics: New data for HSE abundances and $^{187}\text{Os}/^{188}\text{Os}$ were obtained using a split-sampling method to assess the degree of heterogeneity within diogenite whole-rocks. This method has been successfully used to constrain levels of meteoritic contamination within lunar crustal rocks [5]. Triplicate analyses of samples by CT and HPA digestions indicate that the HSE are fairly evenly distributed within samples. HPA digestions appear to be accessing more unradiogenic Os within resistant mineral phases (likely Cr-spinel) relative to CT digestions

for some samples. Like [3], we find that the majority of diogenites have chondritic relative abundances of the HSE and close-to-chondritic $^{187}\text{Os}/^{188}\text{Os}$ (Fig. 3).

Origin and Age Constraints: Oxygen isotopic compositions of acid-washed diogenite powders have been measured in duplicate and yield $\Delta^{17}\text{O}$ ranging from -0.209 to -0.262. All plot within the range of HED meteorites previously defined by [11-13]. Chromium isotopic measurements have been performed on 3 diogenites that span the range in HSE abundances; MIL 07001, LAP 03569 and MET 00424. $\epsilon^{54}\text{Cr}$ for these samples (Av. = -0.73 ± 0.10 ; 2σ SD) are within uncertainty of measurements made for Shalka, Johnstown and Tatahouine (Av. = -0.75 ± 0.10 ; 2σ SD [14]). $\epsilon^{53}\text{Cr}$ ranges from -0.01 to +0.19. Mn and Cr abundances are being determined to assess consistency of this data with the whole-rock isochron determined by [15] for eucrites and diogenites (4564.9 ± 1.1 Ma). The O and Cr isotopic compositions of diogenites in this study are consistent with their derivation from the same parent body, and possibly for crystallization of these rocks within the first few Ma of Solar System history.

Origin of the HSE in Diogenites: The chondritic relative abundances of the HSE in most diogenites, and the correlation of increasing Ni contents in metals and HSE contents in the whole-rock (Fig. 2), provide persuasive evidence for replenishment of the HSE to some diogenites by meteoritic contamination processes. The range in HSE abundances for the diogenites were likely set in a two stage process of initial core-segregation, and resultant ultra-low HSE abundances in the HED silicate mantle, followed by variable impactor contributions to the HED parent body. The timing of post-core formation accretion events is still unclear, but given temporal constraints, both from extinct radionuclides (e.g. Cr) and eucrite crystallization ages [16], it is permissible that the HED parent suffered a relatively early (>4.5 Ga) post-core formation HSE replenishment event. Further analyses are in progress to assess this possibility.

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