PETROLOGIC AND IN SITU GEOCHEMICAL CONSTRAINTS ON DIOGENITE GENESIS. D. W. Mittlefehldt[1] and Z. X. Peng[2], [1]Astromaterials Research Office, NASA/Johnson Space Center, Houston, TX, USA (david.w.mittlefehldt@nasa.gov), [2]Science Analysis and Research Development, Engineering and Science Contract Group, Houston, TX, USA.

Introduction: Diogenites, members of the howardite, eucrite and diogenite (HED) clan, are orthopyroxenite, harzburgite and dunite meteorites [1-3]. Most are breccias, but remnant textures indicate they were originally coarse-grained rocks, with grain sizes of order of cm. Their petrography and compositions support an origin as crustal cumulates from a differentiated asteroid. Astronomical observations, and surface mineralogy and composition of Vesta determined by the Dawn spacecraft suggest that asteroid (4) Vesta is the parent object for HED meteorites [4-6].

The origin of diogenites is an unsettled issue. It is difficult to fit their bulk compositional characteristics into global magma ocean models that successfully describe the compositions of basaltic and cumulate eucrites [7]. Compositional analyses of acid-leached bulk samples have led to the hypothesis that many diogenites were formed late by interaction of their parent melts with a eucritic crust [8]. Those observations may alternatively be explained by subsolidus equilibration of trace elements between orthopyroxene and minor/accessory phases in the rocks such as plagioclase and phosphate [7]. These competing hypotheses can be tested through *in situ* measurements of trace and minor elements in orthopyroxene. Our new petrologic observations and *in situ* minor and trace element data for a suite of diogenites are used to discuss the petrologic evolution of diogenites.

Samples and Methods: We have done electron microprobe analyses (EMPA) on orthopyroxene, olivine, chromite and plagioclase on numerous diogenites. Laser ablation inductively coupled plasma mass spectrometry (LA-ICP-MS) analyses focusing on the rare-earth-elements (REE) are in progress for select diogenites. We will concentrate the discussion here on MIL 07001 and LEW 88679. Earlier EMPA and LA-ICP-MS analyses done at JSC [7, 9] are included.

MIL 07001: This is an unusual unbrecciated harzburgitic diogenite with numerous small olivine grains (<0.4 mm; mg# 72.0-76.2) poikilitically enclosed in mm-sized orthopyroxene (mg# 76.7). Previously, we noted that there were correlated variations for some elements, *e.g.* Al-Ca, but not others, *e.g.* Yb-Ca [9]. Measurements on two new thick sections show good Al-Ca, Ti-Ca and Ti-Al correlations, but no Cr-Ca correlation, for averaged analyses of different regions. There are fine-scale element variations that suggest original magmatic variations are preserved. Figure 1 shows an Al x-ray map and data from three EMPA traverses. The borders of the central pyroxene grain are discernible at the top where Al reaches a maximum (brown). The dotted line encloses the lowest Ca core of the grain. Traverse ***a*** crosses a localized linear enrichment in Al that is tracked by Cr (and Ti; not shown). Calcium increases slightly along the traverse with no break in the trend at the Al high. Traverse ***b*** has correlated spikes in Al and Cr (and Ti) at a linear feature, but otherwise Al and Cr do not track. Calcium is relatively constant and does not spike at the Al high. Traverse ***c*** (towards a 0.7 mm chromite grain, just out of the image to the lower left) shows a series of "ripples" in the Al map that represent modest lows and highs in Al and Cr; Cr generally decreases towards the large chromite grain.

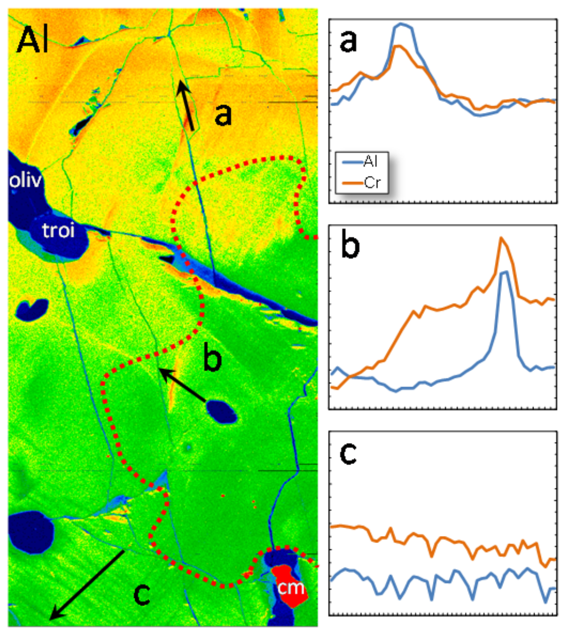

Fig. 1. Al x-ray map (blue-low; red-high), and Al and Cr traverses for MIL 07001,55. Green to brown – orthopyroxene; red - chromite (cm); blue - olivine (oliv) and troilite (troi). Red dotted line encloses core of lowest Ca pyroxene. Image is 1.0 × 0.5 mm. Vertical scales on all plots are the same.

The localized, linear highs in minor element contents (traverses ***a*** and ***b***) and the "ripples" along traverse ***c*** are unlikely to have resulted from subsolidus diffusional redistribution, which would result in exponential variations in the elements [11]. The data are plausibly explained as resulting from magmatic processes where differences in crystal growth rate allow localized "pile-up" of slower diffusing elements in the melt adjacent to the growth front and subsequent enhancement in the orthopyroxene [*e.g.* 12]. MIL 07001 has high Eu/Eu* in unleached and acid-leached bulk samples [8] and its composition is consistent with a cumulate containing a trapped melt component [7].

LEW 88679: LEW 88679 is a dimict harzburgite-orthopyroxenite diogenite [2] with plagioclase present in both lithologies [7]. It has anomalously low contents of many incompatible lithophile trace elements and low Eu/Eu* [7]. These characteristics were thought to have been engendered by a post-brecciation process that mobilized trace elements [7]. Our preliminary EMPA data showed that the rock contains zones of varying mg# and minor element contents. These form a vein network through pyroxene grains [10]. We find that the vein network is present in the Fe-rich orthopyroxenitic and the Mg-rich harzburgitic components (Fig. 2). Across the veins, increases in mg# are tracked by decreases in Cr (Fig. 3) and Mn (not shown). In some cases, Ca also decreases, while Al and Ti can increase across the veins. However, at least some of the magnesian veins are associated with what may be melt veins (arrow c in Fig. 2). X-ray maps show they have higher Al and Ca contents than the magnesian veins or orthopyroxenes. Magnesian veins occur in both lithologies and along clast borders, showing that they post-date brecciation; they are not related to magmatic processes.

LEW 88679 has a low bulk rock Eu/Eu* [7], within the range of those considered to have formed by interaction of diogenite parent magmas and basaltic crust [8]. The clear evidence for post-brecciation element mobility in this sample suggests that subsolidus processes may have engendered the low Eu/Eu* [7].

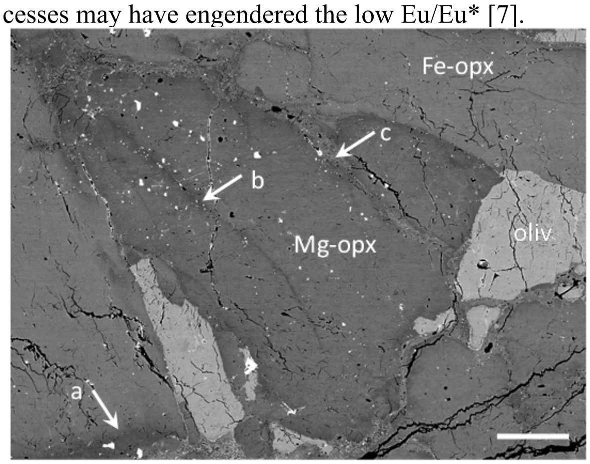

Figure 2. BSE images of magnesian veins the orthopyroxenite (a) and harzburgite (b) lithologies, and a possible melt vein (c). Scale bar is 0.1 mm.

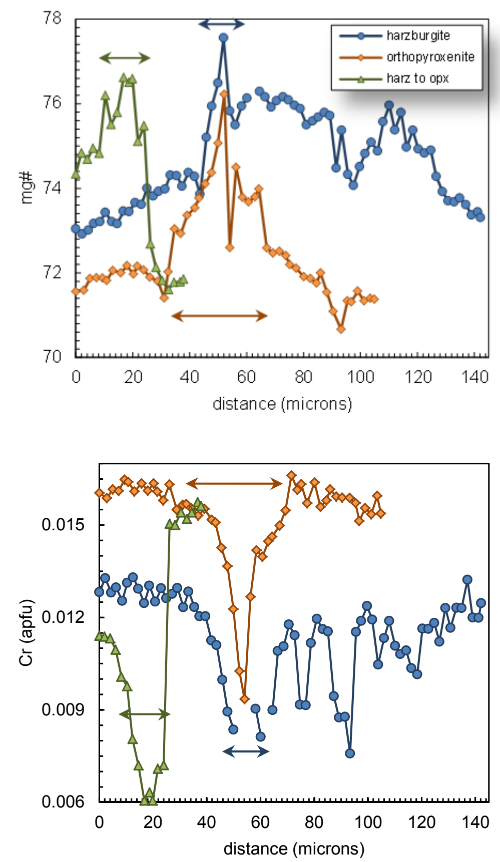

Figure 3. Traverses across Mg-veins in the orthopyroxenitic and harzburgitic lithologies, and across the contact between clasts of the two. Arrows indicate approximate locations of the veins in the traverses.

Summary: Our *preliminary* data on *two* diogenites are consistent with the hypothesis that subsolidus element mobilization processes caused unusual trace element signatures seen in some diogenites [7]. *We cannot stress strongly enough, however, that the sample set is too small and that additional data are required before definitive conclusions can be made.*

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References: [1] Mittlefehldt D.W. *et al.* (1998) *Planetary Materials*, RiM **36,** Ch. 4. [2] Beck A.W. & McSween H.Y. Jr. (2010) *MAPS* **45,** 850. [3] Beck A.W. *et al.* (2011) *MAPS* **46,** 1133. [4] Binzel R.P. & Xu S. (1993) *Science* **260,** 186. [5] De Sanctis M.C. *et al.* (2012) *Science* **336,** 697. [6] Prettyman T.H. *et al.* (2012) *Science* **338,** 242. [7] Mittlefehldt D.W. *et al.* (2012) *MAPS* **47,** 72. [8] Barrat J.-A. *et al.* (2010) *GCA* **74,** 6218. [9] Ek M. *et al.* (2012) *LPSC* **43,** #2096. [10] Balta J.B. *et al.* (2012) *LPSC* 43, #1189. [11] Cherniak D.J. & Liang Y. (2007) *GCA* **71,** 1324. [12] Milman-Barris M.S. *et al.* (2008) *CMP* **155,** 739.