FURTHER EVIDENCE FOR MULTIPLE DIOGENITE LITHOLOGIES: TRACE ELEMENT VARIATIONS IN DIMICT DIOGENITES. A. W. Beck[1], H. Y. McSween Jr.[1] and R. J. Bodnar[2], [1]Planetary Geosciences Institute, Department of Earth and Planetary Sciences, University of Tennessee, Knoxville, TN 37996-1410, (abeck3@utk.edu), [2]Department of Geosciences, Virginia Tech.

Introduction: "Olivine diogenites" were initially characterized as mantle residuals based on petrology (>10% Ol) and mineral chemistries [1]. However, subsequent investigations have shown that they are likely crustal cumulates akin to the diogenites [2, 3]. [4] found further evidence for a common origin between the two by identifying a breccia which contained clasts of both olivine and regular diogenites, which could have both fractionated from a similar parent magma.

In a recent study, [5] provided evidence linking olivine diogenites to a crustal origin, and demonstrated that all of the regular, olivine-bearing, diogenites are actually dimict breccias containing fragments of a harzburgitic (Hzbg.) lithology (magnesian orthopyroxene (OPX) + olivine (OL), i.e. "olivine diogenite"), and fragments of orthopyroxenitic (Opxn.) lithology (ferroan OPX ± plagioclase (PLAG), i.e. unbrecciated, regular diogenite) (Fig 1a).

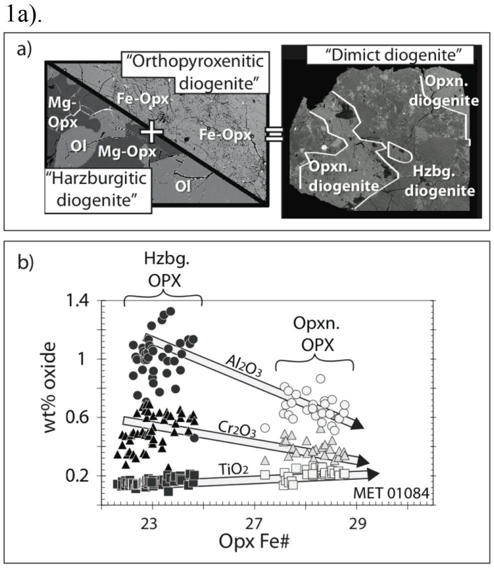

Fig 1. (a) A mixing model for dimict diogenites. (b) Minor element variation plot showing decreases in OPX Al_2O3 and Cr_2O_3 from Hzbg to Opxn. Figures modified from [5].

Processes separating the Hzbg and Opxn diogenite lithologies on Vesta were predicted by examining minor element trends in OPX between the Hzbg and Opxn clasts within a given sample. The majority of the samples displayed trends typical of OPX + minor OL fractionation (↑Al_2O_3, ↑Cr_2O_3, ↑TiO_2 from Hzbg to Opxn). However, a few samples displayed a different trend, ↓Al_2O_3, ↓Cr_2O_3, ↑TiO_2, from Hzbg to Opxn, which is best explained by PLAG crystallization within the Opxn lithology (Fig 1b). This was supported by the identification of minor amounts of plagioclase localized in the Opxn fragments of those samples displaying this trend [5].

To provide further evidence that the regular, olivine-bearing diogenites are composed of two distinct lithologies, we have analyzed the in situ trace element compositions of OPX, OL and PLAG in the Hzbg. and Opxn. fragments in 5 of those samples. These trace element compositional variations will also aid in constraining the processes that separated these lithologies on Vesta.

Methods: Trace element concentrations were measured using an Agilent 7500ce LA ICP-MS. We selected 5 dimict diogenites for this study [MET01084 (MET), LEW88679 (LEW6), LEW88008 (LEW0), MIL04468 (MIL), and PCA02008 (PCA)]. ~8 analyses were made per phase, per sample. Summation of major elements was used as an internal standard. For the purposes of this abstract, only phase averages are plotted. All reported data are above the 3σ detection limit, unless otherwise noted.

Results and Discussion: OL shows little variation in trace element concentration from sample to sample. Approximately 0.05 ppm Y and Zr are typical. V concentrations range from 3-16 ppm in OL, which is typical for diogenites [6]. The only REEs detectable in OL are Er, Yb, and in some cases Dy, which range from below detection to 0.04, 0.05 and 0.09 ppm, respectively.

OPX trace elements vary considerably from Hzbg. to Opxn. clasts in most samples. Y and Yb, both incompatible in OPX, increase from Hzbg. to Opxn. in MET, LEW6, and to a lesser extent, LEW0 (Fig 2a, b). This trend of increasing incompatible elements from Hzbg. to Opxn. suggests that the Hzbg. lithology fractionated from a magma prior to the Opxn. lithology in these 3 dimict diogenites, which supports our findings in [5]. These findings conflict with those of [6], who note no variation in OPX Y or Yb concentrations corresponding to olivine abundance.

PCA displays a decreasing trend in OPX Y and Yb concentration from Hzbg. to Opxn. (Fig 2a, b). PCA also has a wide variability of Y concentrations in Hzbg. OPX (Fig 2a, see PCA error bars). Both of these results are difficult to explain by igneous processes. However, these results would be expected if OPXs from multiple, unrelated lithologies were incorporated via brecciation and mixing. This hypothesis for PCA is supported by its pairing with a large group of howardites, regolith breccias comprised of unrelated eucritic and diogenitic clasts [7].

OPX from fragments of Hzbg. and Opxn. in MIL have nearly identical Y and Yb concentrations (Figs 2a and b). Likewise, Al_2O_3, Cr_2O_3 and TiO_2 concentrations in MIL Hzbg. and Opxn. OPX grains are similar as well [5]. The lack of variation in minor and trace elements may be an indication that MIL has not sampled two distinct lithologies. Instead, a second, distinct OPX Fe# composition may be a product of grains which equilibrated near OL. This equilibration would lead to lower Fe#'s for those grains adjacent to OL, while minor and trace element compositions would remain unchanged.

MET, LEW6 and LEW0 also have REE patterns in OPX and PLAG supporting the fractionation of Hzbg. and Opxn. lithologies. OPX from Hzbg. fragments in MET have a relatively small negative Eu anomaly and lower concentrations of the HREEs (Dy, Er, and Yb), compared to OPX in Opxn. fragments in the same sample (Fig 3a). MET Hzbg. OPX also has slightly higher concentrations of the LREE (La and Ce), relative to Opxn. OPX. LEW6 and LEW0 also display these same REE variations from Hzbg. to Opxn. OPX, though the difference in negative Eu anomaly from Hzbg. to Opxn. is not as pronounced. PLAG in MET and LEW6, which is found almost exclusively in Opxn. fragments, has a large positive Eu anomaly, and is enriched in LREE (Fig 3a).

The REE trends of OPX in MET, LEW6, and LEW0 suggest PLAG crystallization in the Opxn. lithology, after the formation of a Hzbg. lithology. The crystallization of PLAG in the Opxn. would cause both the large negative Eu anomaly, and the depletion in LREE observed in Opxn. OPX relative to Hzbg. OPX. Based on minor element trends and petrographic evidence, [5] first proposed PLAG crystallization with the Opxn. lithology, which is supported here by our REE data. Using the Eu concentration measured in PLAG, we modeled the amount of PLAG crystallization needed for the development of the negative Eu anomaly from OPXs in Hzbg. to Opxn. In MET, this corresponded to ~4% PLAG, while in LEW6 only ~2% was needed. These amounts correspond very closely to the respective modal abundances of PLAG in MET and LEW6, which are 3.6 and 0.4 vol.% PLAG, respectively [5].

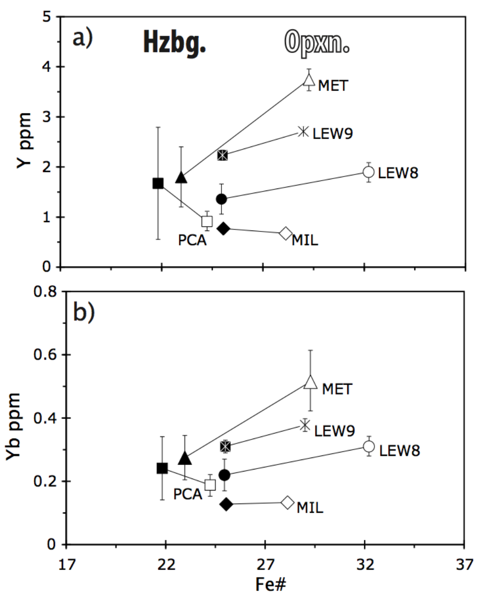

Fig 2. Variation plots for (a) Y and (b) Yb vs. Fe# in OPX. One open/closed symbol pair, joined by tie lines, represents each sample. Filled symbols are Hzbg OPX, open symbols are Opxn OPX. Error bars are 1σ from mean. Increasing Y and Yb from Hzbg to Opxn OPX can be seen in 3 of the samples. This supports the fractionation of Hzbg from a melt prior to Opxn.

The above conclusion suggests that in at least some of the diogenites, negative Eu anomalies can be attributed to PLAG crystallization. Note, however, that only a few analyses of Opxn OPX in MET and LEW6 yielded Eu concentrations above 3σ detection limits, and the Opxn concentrations used in these calculations were using a 2σ detection limit. It is possible that the actual Eu concentrations in Opxn OPX are much lower, and thus would require significantly more PLAG crystallization to produce these anomalies, as hypothesized by [8].

Hzbg. and Opxn. OPX in MIL display near identical REE patterns, and both contain Eu that falls below detection limits (Fig 3b). As with OPX Y and Yb concentrations, identical REE concentrations suggests that the variation in OPX Fe# can be attributed to equilibration with OL.

PCA OPX REE concentrations support the hypothesis that this sample is a breccia composed of fragments from unrelated lithologies. Hzbg. OPX in PCA has higher concentrations of all REEs compared to those in Opxn. fragments. It would seem improbable for Hzbg. OPX to be more enriched in all REEs than an associated Opxn., unless that Hzbg. was a residuum from which melts were extracted. Because this scenario has been widely dismissed for Hzbgs. on Vesta [4, 5], we interpret the REE patterns in PCA as further evidence that this is a breccia composed of unrelated material.

References: [1] Sack et al. (1991) *GCA*, 55, 1111. [2] Bowman et al. (1997) *MAPS*, 32, 869. [3] Mittlefehldt (1994) *GCA*, 58, 1537. [4] Mittlefehldt (2000) *MAPS*, 35, 901. [5] Beck & McSween (2010) *MAPS*, 45, 850. [6] Shearer et al. (2010) *GCA*, 74, 4865. [7] Welten et al. (2009) *MAPS*, 44, A216. [8] Barrat et al. (2010) *GCA*, 74, 6218. [9] Anders & Grevesse (1989) *GCA*, 53, 197.

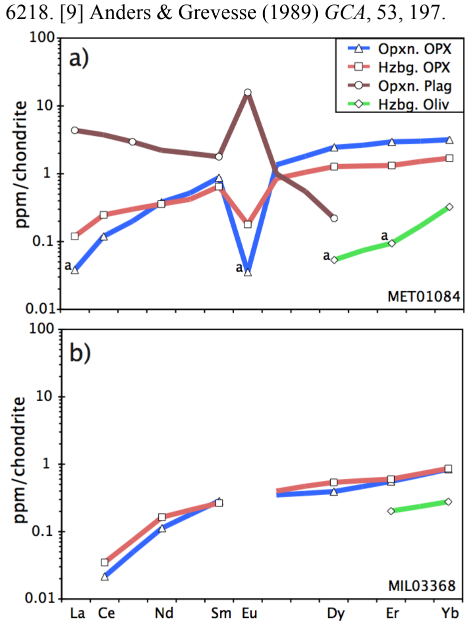

Fig 3. REE plot for (a) MET, showing development of a negative Eu anomaly, HREE enrichment, and LREE depletion between Hzbg and Opxn OPX. These were likely caused by PLAG crystallization, which has a corresponding large, positive Eu anomaly and LREE enrichment. (b) Similar REE pattern between OPX from Hzbg and Opxn in MIL, possibly indicating they do not come from separate lithologies. Chondrite values from [9]. a = 2σ detection limit.