INTERPRETATION OF THE ORIGIN OF OLIVINE IN DIOGENITE BRECCIAS. A. W. Beck[1] and H. Y. McSween Jr.[1], [1]Dept. of Earth and Planetary Sciences, University of Tennessee, Knoxville, TN (abeck3@utk.edu)

Introduction: Diogenites are orthopyroxenite meteorites that are believed to be cumulates from the lower crust of a differentiated asteroid. Generally, diogenites display a narrow range in mineral major element compositions, due to subsolidus equilibration [1]. Most diogenites are brecciated, presumably resulting from the extensive impact gardening needed to excavate them from the lower crust of their parent body. They are composed primarily of orthopyroxene, +/- olivine and chromite. The diogenites, together with the basaltic and cumulate eucrites and howardite breccias, make up the most abundant group of achondrites, the HEDs [2]. Spectroscopic observations of basaltic asteroids, coupled with laboratory analyses of the HEDs, have led to the hypothesis that the asteroid 4 Vesta is the parent body for the HEDs [5].

Petrogenetic models for HEDs entail partial melting (perhaps on a magma-ocean scale) and fractional crystallization. Both scenarios can accommodate an olivine + orthopyroxene (harzburgite) layer below the diogenites [2]. The few samples of this member in the collection are named "olivine diogenites". Several theories concerning their geological relationship to the other HEDs have been proposed [3,4]. The classification of olivine diogenites requires only that they contain ≥10% olivine [4]. The present study provides further evidence for harzburgite units on Vesta. Also, we propose 1) a mixing model of harzburgite (olivine diogenite) + regular diogenite lithic fragments to produce these olivine-bearing diogenite breccias and 2) a revision to the classification scheme for olivine diogenites.

Samples and Methods: Six olivine-bearing diogenites (1-6% olivine) and two olivine diogenites (>10% olivine) were studied. The primary selection criteria were the presence of olivine, limited weathering and large mass. Phase composition measurements, modal abundances and textural observations were conducted using a CAMECA SX-100 electron microprobe and microscopy.

Results: Orthopyroxene and olivine have narrow major element compositional ranges in the olivine diogenites (Fig 1, F&G). This is coupled with a pristine igneous texture between olivine and orthopyroxene in these samples (Fig 2, D). Conversely, the olivine-bearing diogenites contain a generally bimodal distribution of pyroxene compositions. These orthopyroxenes can be divided into ferroan and magnesian groups (Fig 1, A-D). Several of the samples contain what can be interpreted as a second magnesian phase of orthopyroxene (mg II). However, only MET01084 has sufficient abundance of the mg II phase to distinguish between a magnesian and an mg II phase. This sample also contains two distinct phases of olivine, ~Fa_{28} and ~Fa_{30} (Fig 1, C). The six diogenites with <10% olivine have been extensively brecciated, and in some cases annealed. In these samples, olivine is only found in non-brecciated contact with the magnesian orthopyroxene phase (Fig 2, A-C). In MET01084 the mg II phase is found in lithic clasts with the more magnesian phase of olivine as well (Fig 2, C). The magnesian pyroxene and olivine phases appear to be in equilibrium.

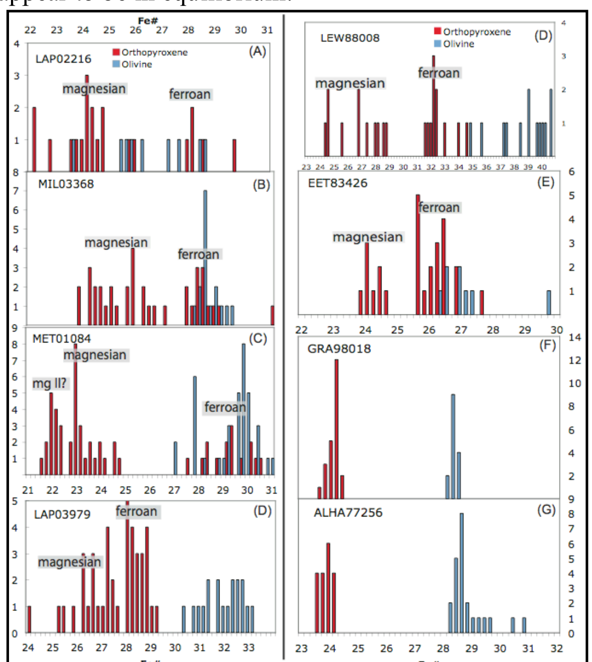

Fig. 1. Histograms showing the distribution of orthopyroxene (red) and olivine (blue) Fe# for nine diogenites. Olivine diogenites ALHA77256 and GRA98018 (F&G) have uniform orthopyroxene Fe#. The other samples contain bimodal distributions of orthopyroxene Fe# and have been divided into magnesian and ferroan groups.

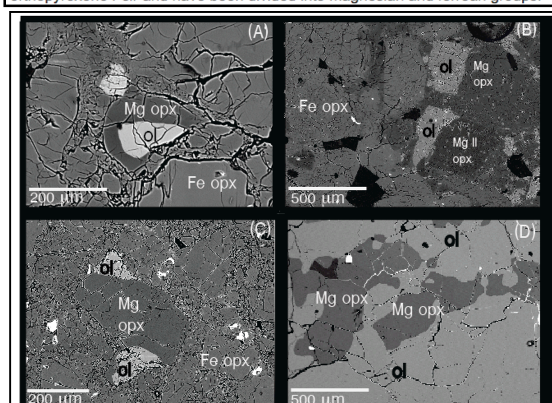

Fig. 2. BSE images of olivine (ol) and magnesian orthopyroxene (Mg opx) harzburg--ite lithic clasts in breccia contact with ferroan orthopyroxene (Fe opx) in samples LEW88008 (A), MET01084 (B), and MIL03368 (C). An example of the primary textures between Mg opx and olivine in harzburgite GRA98018 is also shown (D).

Discussion: To confirm the petrologic relationship seen in textural observations described above, we investigated Fe/Mg partitioning between olivine and both orthopyroxene phases. Average Fe# for the two pyroxenes in each sample were plotted against average Fe# of olivine. These were then compared to previously determined $Fe\#_{PYX}/Fe\#_{Ol}$ ratios for equilibrium assemblages of olivine and pyroxene in other meteorites (Fig 3, after [3]). The magnesian orthopyroxene in each sample appears to be in equilibrium with olivine (falls along the trendline), whereas the ferroan pyroxene clearly is not. This indicates that these samples are brecciated mixtures of harzburgite (Mg opx + ol) and orthopyroxenite (Fe opx) clasts. Given the genetic similarity between these two units and the presence of two distinct lithic fragments, these samples should be considered genomict [6].

As mentioned above, MET01084 seems contain two distinct groups of magnesian pyroxene and olivine. The mg II pyroxene phase of MET01084 has been separated and plotted with the more magnesian group of olivine in Fig 3. The proximity of this second group to the equilibrium line suggests that MET01084 contains two distinct harzburgite lithologies.

Phase relationships and major element concentrations of the olivine diogenites and harzburgite lithic clasts found in the other samples are very similar. We propose a simple mixing model for the formation of these breccias in which harzburgite (olivine diogenite) is incorporated into the overlying ferroan orthopyroxenite (Fig 4). This model can be augmented by the incorporation of two distinct harzburgite units, as identified in MET01084. Post brecciation annealing may also distort the model we present.

In this study, the diogenites that contain olivine are either harzburgites (olivine diogenites) or genomict breccias of harzburgite and orthopyroxenite lithic clasts. Besides olivine abundance, the main observable difference between the two is the range in pyroxene compositions. Instead of classifying olivine diogenites solely based on olivine abundance, we propose also using the presence of one composition of pyroxene as classification criteria.

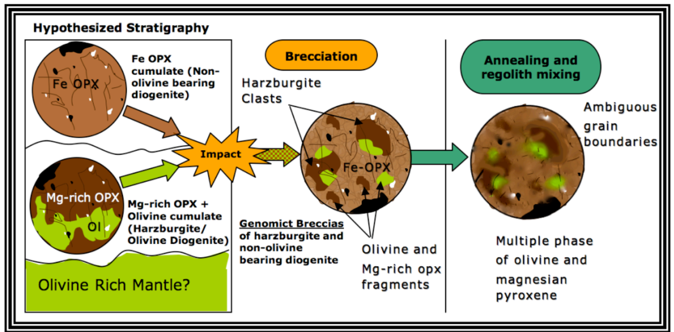

Fig. 4. Proposed mixing model for the generation of genomict breccias.

Conclusions: Investigation of the textural and chemical relationships between phases in olivine-bearing diogenites has revealed that the majority of these samples are genomict breccias composed of harzburgite and Fe-rich orthopyroxene clasts. Based on the similarities between harzburgite clasts and the olivine diogenites, we propose a model in which olivine diogenite fragments are mixed with overlying Fe-rich orthopyroxenites to form these genomict breccias.

References: [1] Mittlefehldt D.W. (1994) *Geochim. Cosmochim. Acta* **58**, 5. [2] Mittlefehldt D.W. *et al.* (1998) *Planetary Materials*, RiM **36,** Ch. 4. [3] Mittlefehldt D.W. (2000) *Meteoritics Planet. Sci.* **35**, [4] Sack R.O. *et al.* (1991) *Geochim. Cosmochim. Acta* **55**. [5] Binzel R.P. & Xu S. (1993) *Science* **260,** 186. [6] Wasson J.T. (1974) *Meteorites: Classification and Properties.* Springer-Verlag Berlin, Germany.

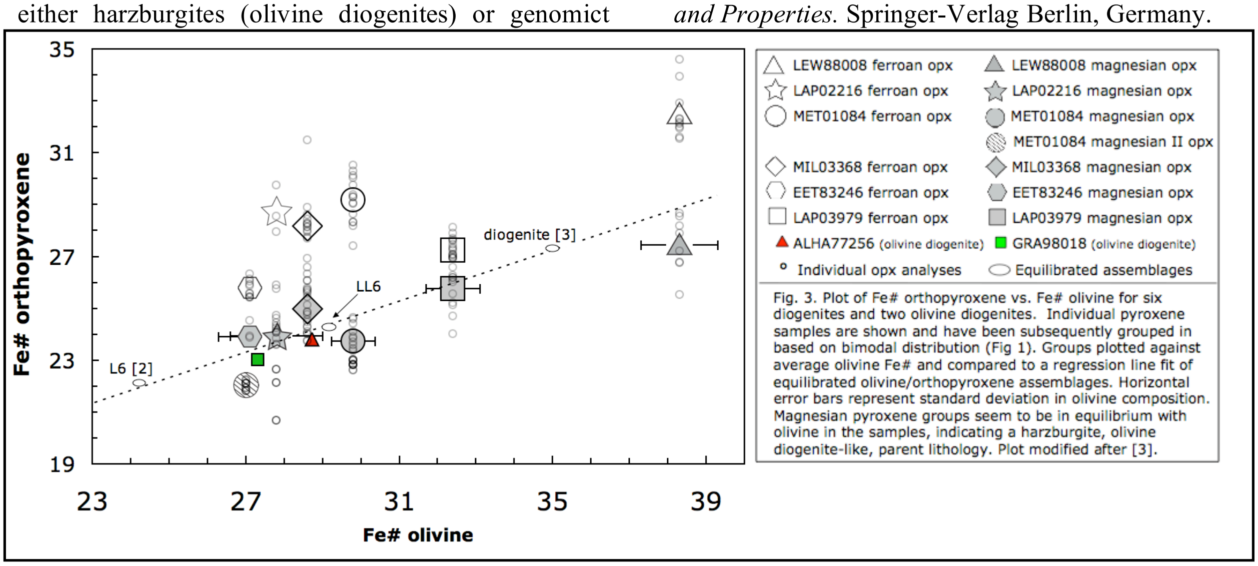

Fig. 3. Plot of Fe# orthopyroxene vs. Fe# olivine for six diogenites and two olivine diogenites. Individual pyroxene samples are shown and have been subsequently grouped in based on bimodal distribution (Fig 1). Groups plotted against average olivine Fe# and compared to a regression line fit of equilibrated olivine/orthopyroxene assemblages. Horizontal error bars represent standard deviation in olivine composition. Magnesian pyroxene groups seem to be in equilibrium with olivine in the samples, indicating a harzburgite, olivine diogenite-like, parent lithology. Plot modified after [3].