Olivine diogenites and QUE 93148. Remnants of the HED parent body mantle? C.K. Shearer[1], P.V. Burger[1], and J.J. Papike[1]. [1]Institute of Meteoritics, Department of Earth and Planetary Sciences, University of New Mexico, Albuquerque, New Mexico 87131 (cshearer@unm.edu).

Introduction: The howardites, eucrites, and diogenites constitute a suite of meteorite lithologies (HED) known to be related through O isotope systematics [1-3]. These lithologies are believed to be remnants of an ancient and complex basaltic magma system on asteroid 4 Vesta [4,5,6,7]. There are several distinctly different chemical-thermal models that have been proposed for the anatomy of the HED parent body and the petrogenetic relationship between its dominant magmatic components [i.e. 4,8-15]. The rarity of olivine in many of the HED mineral assemblages has always been a point of apprehension in these petrogenetic models.

Diogenites range in olivine from 0% to almost 50%. The orthopyroxenites with significant olivine have been referred to as olivine diogenites (greater than 5% olivine), while olivine-bearing diogenites are those diogenites with between 1 to 5% olivine. The proposed relationship among the diogenites range from (1) being coupled in which all the diogenites represent accumulations of orthopyroxene (opx) ± olivine during crystallization of layered intrusive complexes or a magma ocean [13-15] to (2) being uncoupled in which the diogenites represent pyroxene cumulates and the olivine diogenites represent HED parent body mantle from which eucritic melts were extracted. Interpreting the magmatic history of the diogenites is made difficult due to the varying degrees of post-magmatic thermal metamorphism experienced by the olivine and opx [i.e. 16,17].

Meteorite QUE 93148 (QUE) is an olivine-rich achondrite which contains minor to trace amounts of opx, metal, troilite, chromite, and phosphate. It has oxygen isotopic compositions that overlap with that of the HED meteorites [18]. Major and trace element studies of the opx and olivine led Floss [19] and Goodrich and Righter [18] to suggest that this lithology may represent a sample of the mantle from the pallasite and/or HED parent body.

Here, we use electron and ion microprobe data derived from opx, olivine, and spinel from diogenites with varying amounts of olivine and QUE to determine (1) if a petrogenetic relationship exists among the diogenites, olivine diogenites, and QUE and (2) if these lithologies represent mantle assemblages from either the HED or pallasite parent body.

Analytical approach: Olivine-bearing diogenites (LAP03569, MET00424, MET01084), olivine diogenites (GRA98108, LAP03979, EETA79002), diogenite clasts in a howardite (GRA98030), and QUE 93148 were analyzed in this study. Olivine, opx, and spinel in these basaltic lithologies were first imaged and mapped by SEM followed by major element analysis using a JEOL JXA-8200 electron microprobe. The olivine, opx, and spinel were analyzed for a suite of trace elements (Sc, V, Cr, Ti, Mn, Co, Ni, and Y) using a Cameca 4f ims ion microprobe.

Results:

Abundance and distribution of olivine. In the diogenites studied, the modal abundance of olivine ranges from <1% to 20%. However, as shown for EETA79002, the distribution of olivine within each diogenite is very heterogeneous [19] and we anticipate that examination of additional thin sections will show a much more varied abundance of olivine in individual samples. In the single sample of QUE 93148(,14) analyzed for this study, olivine made up approximately 96% of the mineral assemblage. The model abundance of olivine in other thin sections ranged from 23 to 100% [20].

Major-Minor Elements. The chemical composition of olivine in the diogenites and howardite analyzed in this study exhibited limited variation within individual grains and between samples. The olivine compositions in the olivine diogenites range between Mg#=73-70, olivine-bearing diogenites between Mg# =73-63, and the diogenite clasts between Mg# 71-68. CaO ranged from .004 to .118 wt. % in our samples and does not appear to be related to model abundance of olivine. In QUE 93148, the Mg# and CaO exhibit limited variation, at ≈85.5 and 0.11% respectively.

Fowler et al. [14,15] analyzed opx from a suite of 21 diogenites using both electron and ion microprobe techniques. Opx from our data set and the data set produced by Fowler et al. [14] exhibits a range of Mg# from 81 to 66. The opx in the olivine diogenites and olivine-bearing diogenites from our study ranged in composition from Mg# 77 to 68, whereas the opx in QUE is approximately 86.8. The Ti and Al abundances in the opx from these two data sets are shown in Fig. 1. The Al (wt.%) ranges from approximately 0.1 to 0.75% and is generally correlated with Ti (<0.01 to 0.2 wt%). Although the opx from QUE has a higher Mg# its Ti and Al overalp withthat of the diogenites (Fig. 1).

Trace Elements. While the Mg# of olivine in the diogenites exhibit very limited variation, Ni and Co in olivine exhibit significant differences among the diogenites and Ni-Co zoning is apparent in several samples (Fig. 2). Nickel and Co range from 3-104 ppm and 10-126 ppm, respectively. Nickel and Co are strongly correlated within individual samples and among the diogenites. Olivine exhibiting textural characteristics indicative of substantial metamorphism and recrystallization exhibit no Ni or Co zoning. The Ni in QUE overlaps with some of the olivine diogenites (Fig. 2), but is generally lower in Co. MnO ranges from 0.3 to 0.6 (wt.%) and generally exhibits a negative correlation with both Ni and Co. In the diogenites thus far analyzed in this study, Ni, Co, and Mn in olivine appear not to be related to the modal abundance of olivine in the diogenite lithologies. At these fO2, V (primarily V3+) should behave as a slightly incompatible element in olivine. The distribution of V is consistantly spinel >>opx >olivine. In the olivine diogenites, the V (3-15 ppm) in olivine increases with decreasing Ni. In QUE, the V in both the olivine (42-53 ppm) and spinel (0.80-1.30%) is higher than in the diogenites.

Previous studies [11,14,15] determined that incompatible trace elements (Zr, Yb, Y) in opx from diogenites exhibited a strong positive correlation with incompatible elements such as Ti (wt.%). In the opx, Y ranges from less than 0.1 ppm to 4 ppm, Yb ranges from less than 0.03 ppm to 0.7 ppm, and Zr ranges from less than 0.5 ppm to 10 ppm. The incompatible elements in the opx exhibit little relationship to the model abundance of olivine. The opx in QUE has incompatible element concentrations at the lower end of this range (Y≈0.2 ppm, Yb≈0.036 ppm, Zr≈0.1 ppm) [19].

Discussion: The overlap of olivine and opx in minor and trace element characteristics among the diogenites suggests that they represent a continuum rather than two distinct processes. The lack of correlation between Ni-Co and modal abundance of olivine is consistent with the observations of Bowman et al. [17] that the modal abundance of olivine in many samples is a product of small scale modal variations. It has been suggested that QUE may be related to main group pallasites or the HEDs [18]. QUE illustrates an interesting comparison to the olivine diogenites. The assemblage is significantly higher in modal olivine, the silicates have higher Mg#, and generally lower incompatible element concentrations. However, Co and Ni in the olivine are generally lower than in the olivine diogenites. If QUE was either a mantle source that experienced melting to produce eucritic melts or represented olivine-dominated cumulates from a HED magma ocean, it would be expected that the Ni and Co concentrations would be significantly higher. The role of metal during these processes makes the relationship more complex. These observations are consistant with QUE representing a mantle lithology from a planetary body distinct from the HED parent body or that the diogenite-olivine diogenite petrogenesis is distinct from QUE.

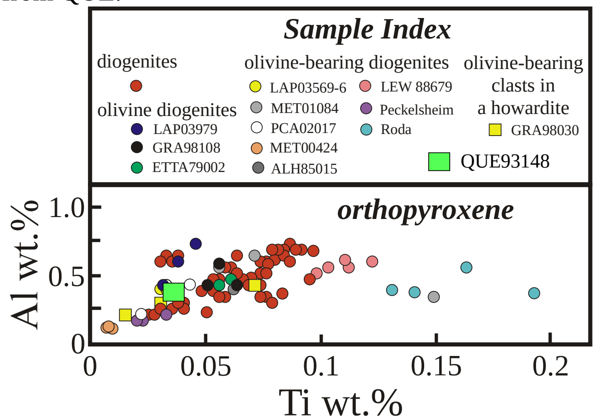

Fig. 1. Ti (wt.%) versus Al (wt.%) in opx [11,14, this study].

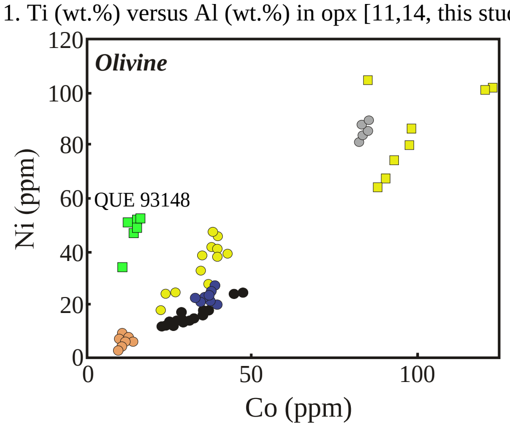

Fig. 2. Ni (ppm) versus Co (ppm) in olivine from olivine-bearing diogenites, olivine diogenites and olivine-bearing clasts in a howardite. Symbols are defined in Fig. 1.

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