PERIDOTITES RELATED TO 4VESTA: DEEP CRUSTAL IGNEOUS CUMULATES AND MANTLE SAMPLES.

A. J. Irving [1], T. E. Bunch[2], S. M. Kuehner[1], J. H. Wittke[2] and D. Rumble, III[3] [1]Dept. of Earth & Space Sciences, University of Washington, Seattle, WA 98195 (irving@ess.washington.edu), [2]Dept. of Geology, Northern Arizona University, Flagstaff, AZ 86011, [3]Geophysical Laboratory, Carnegie Institution, Washington, DC 20015.

In advance of the arrival of the DAWN spacecraft at 4Vesta in 2011, it is useful to reassess our knowledge of the constitution and probable evolution of this ancient differentiated asteroid. It has been recognized for some time that the eucrite, diogenite and howardite meteorites likely represent samples from 4Vesta or from related Vestoids based upon the good match of reflectance spectra of these bodies to those of eucrites [1]. Oxygen isotopic compositions for eucrites, diogenites and howardites [2] exhibit more dispersion than for terrestrial samples and angrites, which may imply a shorter-lived period of parent body differentiation. The likelihood that mesosiderites also derive from this same body is strongly supported by (a) similar oxygen isotopic compositions [3], (b) overlapping Fe/Mn ratios in constituent olivines and pyroxenes, (c) similar calcic plagioclase compositions, (d) silica polymorph in both, and (e) eucritic and diogenitic clasts in some mesosiderites (e.g., NWA 2907) and vice versa.

Diogenite Diversity: Newly discovered diogenites from Northwest Africa have expanded our knowledge of the ranges in modal mineralogy and mineral compositions beyond those reported previously [4]. For example, Northwest Africa 5405 contains ~10 vol. % olivine ($Fa_{28.5}$, FeO/MnO = 49.4) in addition to major orthopyroxene ($Fs_{23.8}Wo_{2.1}$, FeO/MnO = 26.8) and accessory clinopyroxene, calcic plagioclase, chromite [Cr/(Cr+Al) = 0.675], troilite and kamacite. Northwest Africa 5312 is even more olivine- and troilite-rich, and is composed of 46 vol.% orthopyroxene ($Fs_{20.6}Wo_{1.5}$, FeO/MnO = 31), 24 vol.% olivine ($Fa_{22.1}$, FeO/MnO = 48), 18 vol.% troilite, 6 vol.% merrillite, chromite [Cr/(Cr+Al) = 0.73] and taenite.

The molar ferrosilite content in orthopyroxene for 32 diogenites with less than 25 vol.% olivine (most with 0-5 vol.%) ranges from 0.14 to 0.31 with a median of 0.24 (see Figure 1). This and the variations in major and accessory modal mineralogy support the hypothesis that diogenites represent a series of orthopyroxene-olivine-(plagioclase) cumulates from "basaltic" liquids ranging widely in Mg/(Mg+Fe) ratio (utilizing orthopyroxene/liquid $K_D^{Fe/Mg}$ values of [5]).

Vesta Peridotites: Spectral evidence [6] suggests that the interior of 4Vesta contains significant olivine. There are 8 different diogenitic specimens that contain more than 40 vol.% olivine, including ALHA 77256, NWA 1459, GRA 98108, EETA 79002, NWA 4223, NWA 1877 and MIL 07001 [e.g., 7]. These chromite-bearing olivine-orthopyroxene rocks would be called harzburgites on Earth, but have been called olivine diogenites. In addition there are two Vesta-related dunites composed of more than 90 vol.% olivine: NWA 2968 [8] and MIL 03443 [9]. Thus, the common acronym for all these rocks should be expanded to HEDOD. Olivine diogenite Northwest Africa 4223 is very coarse grained (up to 4 mm) with a primarily protogranular texture, and some areas of cataclasis. It is composed of 50 vol.% olivine ($Fa_{30.0-31.2}$, FeO/MnO = 46.5) and 45 vol.% orthopyroxene ($Fs_{24.2-25.2}Wo_{2.8-3.2}$, FeO/MnO = 28.8) with minor chromite [Cr/(Cr+Al) = 0.703-0.715], troilite, kamacite, and no plagioclase.

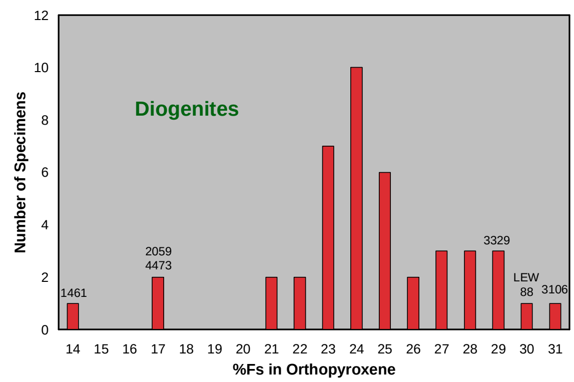


Figure 1. *Orthopyroxene compositions for 43 olivine-poor diogenites (numbers refer to NWA specimens)*

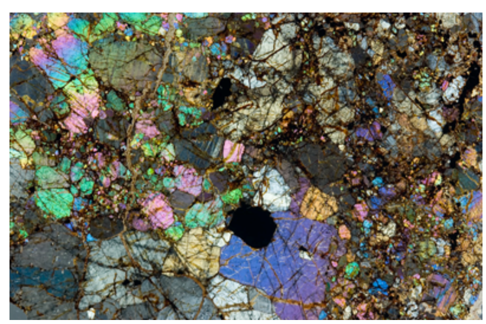
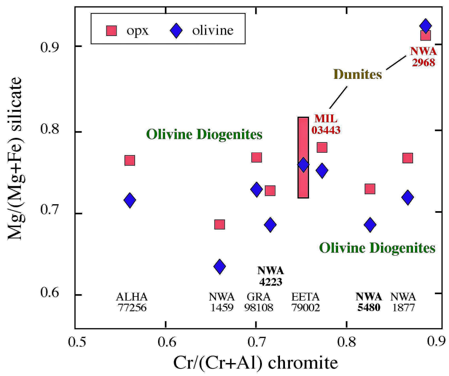


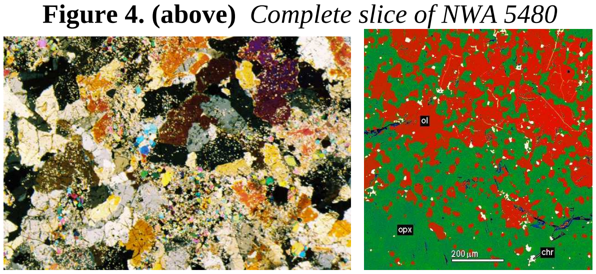
Figure 2. *Cross-polarized light image of NWA 4223*

The Mg/(Mg+Fe) of mafic silicates and Cr/(Cr+Al) in chromite for olivine diogenites and dunites range widely (see **Figure 3** below). This range and textural similarities to more olivine-poor diogenites favor the interpretation that these olivine-rich rocks also are cumulates formed in the deep crust of their parent body.



Northwest Africa 5480: This fresh, dense, heterogeneous specimen is texturally very different from those already described. It consists of 57 vol.% olivine ($Fa_{30.2}$, FeO/MnO = 46.6) and 42 vol.% orthopyroxene ($Fs_{24.8}Wo_{1.8}$, FeO/MnO = 25.6) with minor chromite [Cr/(Cr+Al) = 0.828, TiO_2 = 0.71 wt.%], troilite and Ni-free metal. Plagioclase is absent. Olivine occurs as brown polygranular clusters and as tiny rounded grains within larger yellow-green oikocrysts of orthopyroxene; most chromite is very fine grained but sporadic, larger grains are up to 1.5 cm across. At "hand specimen" scales, olivine is seen to be distributed in schlieren-like bands, possibly consistent with magmatic or plastic flow within a stress field (see Figure 4).

Figure 4. (above) *Complete slice of NWA 5480*



(left) *Protogranular orthopyroxene with olivine chadacrysts (8 mm)* **(right)** *BSE image of olivine-rich zone*

We suggest that NWA 5480 may be a sample of the Vestan mantle, representing a partial melting residue that has experienced recrystallization and plastic deformation at relatively high temperatures and pressures.

Oxygen Isotopes: Acid-washed samples analyzed by laser fluorination gave (all in per mil):

	$\delta^{17}O$	$\delta^{18}O$	$\Delta^{17}O$
NWA 4223	1.677	3.470	-0.148
	1.545	3.353	-0.218
NWA 5312	1.545	3.364	-0.224
	1.484	3.149	-0.172
NWA 5480	1.459	3.215	-0.232
	1.611	3.509	-0.234

The "Opis" Model: The current model for HEDOD meteorites is that they derive from asteroid 4Vesta itself or from related Vestoids [e.g., 11]. But what if these bodies represent only portions of the disaggregated remains of an even larger former differentiated planetary body? And what if there are other related small bodies which are the proximate sources of mesosiderites, plus peridotites like NWA 5480 and IIAB irons? The silicated IIAB irons have $\Delta^{17}O$ values (-0.22 ± 0.06 per mil) overlapping those of HEDOD meteorites, but at lower $\delta^{17}O$ and $\delta^{18}O$ values [10]; in other words, they plot on the same fractionation line. Based on plausible models for the origin of the various iron meteorites [12], it is possible that all of these materials once were part of a single, much larger body (here named Opis), which may have originally resided in the inner Solar System but closer to the Sun.

A test for these ideas will be whether instruments on the DAWN spacecraft can establish the presence of olivine-rich rocks and/or metal-rich regions in 4Vesta. The relatively high density of 4Vesta (3.3 ± 0.5 g cm^{-3}) [13] is not inconsistent with either or both of these possibilities. Perhaps such materials are exposed within the large crater on this asteroid and will be amenable to orbital spectral sensing.

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