

**OLIVINE DIOGENITE NWA 1459: PLUMBING THE DEPTHS OF 4 VESTA.** A. J. Irving<sup>1</sup>, S. M. Kuehner<sup>1</sup>, D. Rumble, III<sup>2</sup>, A. C. Hupé<sup>3</sup> and G. M. Hupé<sup>3</sup>, <sup>1</sup>Dept. of Earth and Space Sciences, University of Washington, Seattle, WA 98195, irving@ess.washington.edu, <sup>2</sup>Geophysical Laboratory, Carnegie Institution, Washington, DC 20015, <sup>3</sup>The Hupé Collection, Renton, WA.

**Introduction:** A 49 gram complete stone found near Iriqui, Morocco in March 2002 can be classified as an olivine diogenite. The interior of the sample (provisional number NWA 1459) is dark yellow-green with minor orange staining (from terrestrial weathering of metal), and the exterior is coated by a thin, weathered fusion crust with protruding large (up to 4 mm), subhedral chromite grains (Figure 1).

**Description:** NWA 1459 is a harzburgitic peridotite that evidently is related to the HED meteorites from Vesta. Three other samples (ALHA77256, EETA79002 and GRA98108) have been termed olivine diogenites, although the heterogeneous distributions of olivine and pyroxene in these coarse grained rocks have hampered classification [1-4]. NWA 1459 differs from the other three samples in that it is richer in olivine and has a higher Fe/Mg ratio. Minor anorthitic plagioclase is present in NWA 1459, EETA 79002 and GRA98108, but plagioclase reported in initial descriptions of ALHA77256 was not confirmed subsequently [1, 2]. The oxygen isotopic composition obtained on three aliquots of hand-picked, acid-washed orthopyroxene from NWA 1459 by laser fluorination is  $\delta^{17}\text{O} = +1.72 \pm 0.02$ ,  $\delta^{18}\text{O} = +3.62 \pm 0.05$ ,  $\Delta^{17}\text{O} = -0.19 \pm 0.02$  per mil. These data are similar to those measured in the same laboratory for acid-washed orthopyroxene from the Bilanga diogenite ( $\delta^{17}\text{O} = +1.67 \pm 0.1$ ,  $\delta^{18}\text{O} = +3.60 \pm 0.1$ ,  $\Delta^{17}\text{O} = -0.23 \pm 0.02$  per mil) and for other HED meteorites.

Although NWA 1459 has been shocked and cataclazied, the original coarse grained, protogranular texture is evident, with primary contacts between olivine and pyroxene grains, both up to 10 mm in size (Figure 2). Some olivine grains exhibit multiple tilt boundaries consistent with high temperature, plastic deformation. The sample consists 52% orthopyroxene ( $\text{Fs}_{28}\text{Wo}_{3.3}$  to  $\text{Fs}_{30}\text{Wo}_{6.5}$ ,  $\text{FeO/MnO} = 27-32$ ) and 41% olivine ( $\text{Fa}_{36}$ ;  $\text{FeO/MnO} = 46-52$ ), with 4% chromite (core to rim:  $\text{Cr/Cr+Al} = 0.62$  to  $0.66$ ,  $\text{Mg/Mg+Fe} = 0.17$  to  $0.13$ ), 2% anorthitic plagioclase ( $\text{Ab}_{6.8}\text{-Ab}_{9.3}$ ), 0.5% troilite, and 0.5% metal (almost pure Fe, with only 0.06 wt.% Ni). Minor clinopyroxene ( $\text{Fs}_{10}\text{Wo}_{46}$  to  $\text{Fs}_{11}\text{Wo}_{45}$ ;  $\text{FeO/MnO} = 20-24$ ) is present as sparse lamellae within orthopyroxene, and some plagioclase occurs as partial coronas around chromite grains (Figure 3). Intricate symplectitic intergrowths of chromite (similar in composition to the rims of discrete chromite grains) within orthopyroxene occur along grain



Figure 1

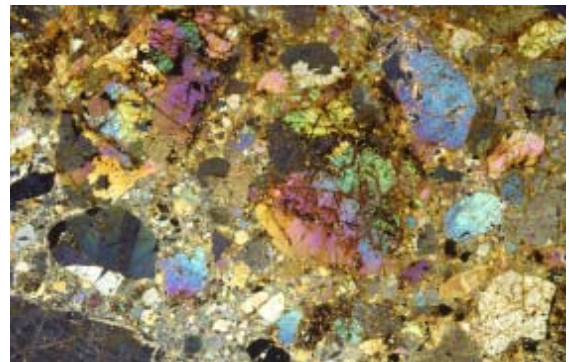


Figure 2 Width of view = 25 mm

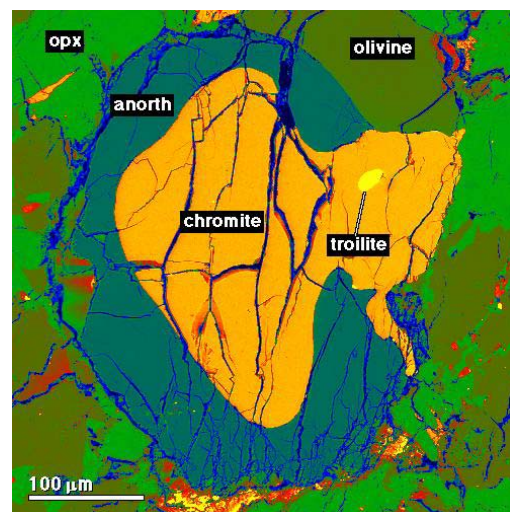


Figure 3

OLIVINE DIOGENITE NWA 1459: A. J. Irving, S. M. Kuehner, D. Rumble, III, A. C. Hupé and G. M. Hupé

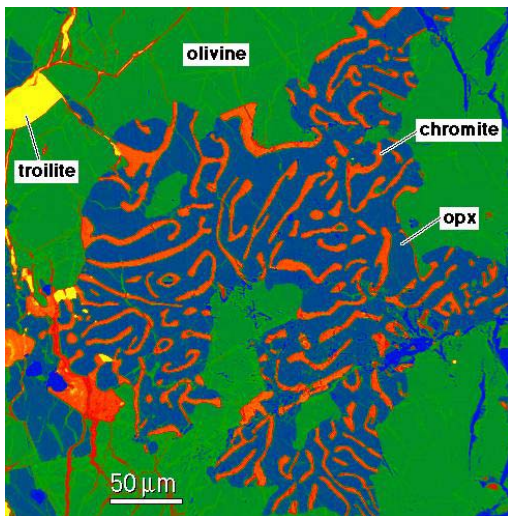


Figure 4

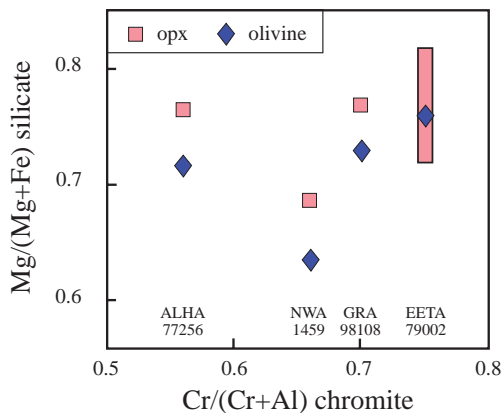


Figure 5

## Representative mineral compositions

	Oliv	Opx	Cpx lam	Opx	Cpx lam
SiO <sub>2</sub>	36.52	53.93	52.59	53.52	52.65
TiO <sub>2</sub>		0.14	0.26	0.19	0.30
Al <sub>2</sub> O <sub>3</sub>		0.60	1.27	1.13	1.50
Cr <sub>2</sub> O <sub>3</sub>	0.00	0.29	0.42	0.37	0.60
FeO	31.76	18.95	7.05	18.55	6.02
MnO	0.64	0.70	0.30	0.66	0.30
MgO	31.29	23.22	15.85	24.54	15.70
NiO	0.00	0.00	0.03	0.00	0.00
CaO	0.023	3.12	22.44	1.63	22.66
Na <sub>2</sub> O		0.01	0.08	0.01	0.07
K <sub>2</sub> O					
SUM	100.96	100.96	100.29	100.60	99.82
mg	0.637	0.686	0.800	0.702	0.828
An					
Cr/Cr+Al					

boundaries and as irregular patches (Figure 4), and imply late infiltration of a reduced fluid.

Compositions of ferromagnesian silicates and chromites in the four olivine diogenites (Figure 5) support the suggestion [1] that at least some of these samples may represent a series of partial melting residues; however, NWA 1459 deviates from the trend shown by the other three samples. Alternatively, NWA 1459 could be a recrystallized cumulate. Estimated equilibration temperatures are  $770 \pm 10^\circ\text{C}$  for cpx-opx pairs [5] and  $820 \pm 10^\circ\text{C}$  for olivine-chromite pairs [6]. For these temperatures, the Ca content (162 ppm) in olivine implies very low pressures [5], consistent with the presence of plagioclase.

**Conclusions:** NWA 1459 might represent a shallow cumulate from a Vestan mafic magma, or else a sample of the shallow feldspathic peridotite mantle of Vesta (or perhaps its larger precursor). In the latter hypothesis, the combination of higher modal olivine yet more Fe-rich olivine composition compared with other olivine diogenites would not be expected if NWA 1459 were a residue from higher degrees of partial melting than experienced by the other examples. The coarse grain size may suggest that NWA 1459 is derived from hotter, deeper levels than the other examples, and if so may imply that the Vestan mantle might become more iron-rich with depth.

**References:** [1] Sack R. O. et al. (1991) GCA, 55, 1111-1120. [2] Bowman L. E. et al. (1997) Meteoritics Planet. Sci., 32, 869-876. [3] Ant. Met. Newsletter (2000) 23; Righter K. (2001) LPS XXXII, #1765. [4] Mittlefehldt, D. W. (1994) GCA, 58, 1537-1553. [5] Brey G. P. and Köhler T. (1990) J. Petrology, 31, 1353-1378. [6] Sack R. O. and Ghiorso M. S. (1991) Am. Mineral., 76, 827-847.

## Representative mineral compositions

	Plag	Chr core	Chr rim	Chr in opx sympl
SiO <sub>2</sub>	43.28	0.01	0.01	0.05
TiO <sub>2</sub>		1.68	1.55	1.30
Al <sub>2</sub> O <sub>3</sub>	35.93	18.55	16.59	16.34
Cr <sub>2</sub> O <sub>3</sub>		45.30	47.66	47.58
FeO	0.17	30.67	30.61	31.32
MnO		0.68	0.67	0.65
MgO		3.47	2.95	2.74
NiO		0.00	0.02	0.05
CaO	19.71			
Na <sub>2</sub> O	0.94			
K <sub>2</sub> O	0.05			
SUM	100.08	100.36	100.06	100.03
mg		0.168	0.146	0.135
An	0.921			
Cr/Cr+Al		0.621	0.658	0.661