PETROLOGY AND OXYGEN ISOTOPIC COMPOSITION OF BRACHINITE-LIKE ACHONDRITES NORTHWEST AFRICA 7388 AND NORTHWEST AFRICA 7605, AND EVIDENCE FOR LATE-STAGE METHANE-TRIGGERED REDUCTION. A. J. Irving[1], S. M. Kuehner[1] and K. Ziegler[2] [1]Dept. of Earth & Space Sciences, University of Washington, Seattle, WA 98195 (irving@ess.washington.edu), [2]Institute of Meteoritics, University of New Mexico, Albuquerque, NM.

Introduction: Field investigations in both hot and cold desert regions continue to reveal random, unexpected meteorite specimens which expand our knowledge of the nature of the Solar System (even if it is difficult to decipher their provenance). Two such specimens were discovered in Northwest Africa in 2007 and 2010 – yet only now have detailed forensic studies revealed both to be special finds. As is typical of such discoveries, both were not initially recognized as special – one was sold as a common chondrite and the other was regarded as a possibly terrestrial rock!

To the contrary, our investigations of Northwest Africa 7388 and Northwest Africa 7605 have shown that these possibly related specimens possess some tantalizing similarities to the complex brachinite group of achondrites, which evidence suggests may derive from multiple parent bodies [1]. Both meteorites are very fresh, and both are composed predominantly of olivine + pyroxenes with accessory chromite (i.e., they are medium-grained spinel peridotites); they may represent mantle specimens or else cumulates. The preferentially-oriented crystal shape fabric in NWA 7605 might be indicative of plastic flow within its parent body.

Petrography: NWA 7388 is a protogranular wehrlite composed mainly of olivine ($Fa_{29.8}$, FeO/MnO = 56; rim $Fa_{27.9}$) with less abundant augite ($Fs_{9.0-9.1}Wo_{47.4-47.3}$; FeO/MnO = 58-60; Al_2O_3 = 1.2 wt.%; Cr_2O_3 = 0.8 wt.%) and accessory Ti-V-bearing chromite (translucent dark brown in thin section). Olivine contains rare inclusions of Ni-poor taenite, and chromite contains sparse inclusions of chlorapatite, merrillite and metal.

NWA 7605 is similar to NWA 7388 in being composed mainly of olivine ($Fa_{26.1-26.2}$, FeO/MnO = 43-49) with subordinate augite ($Fs_{10.2-10.66}Wo_{44.0-47.5}$; FeO/MnO = 23-31; Al_2O_3 = 0.7-0.8 wt.%; Cr_2O_3 = 0.7-0.9 wt.%) and accessory Ti-V-bearing chromite, pyrrhotite and kamacite. However, NWA 7605 also contains large, elongate oikocrysts or poikiloblasts (up to 15 mm long × 5 mm wide) of both orthopyroxene ($Fs_{25.8}Wo_{2.5}$; FeO/MnO = 39; Cr_2O_3 = 0.2 wt.%) and clinopyroxene ($Fs_{10.2}Wo_{43.6}$; FeO/ MnO = 32; Al_2O_3 = 0.7 wt.%; Cr_2O_3 = 0.7 wt.%) enclosing ovoid grains of olivine ($Fa_{24.8-24.9}$, FeO/MnO = 43-52) – see Figure 3. The long dimensions of the oikocrysts are aligned with the preferentially-oriented fabric of olivine and augite grains in the rest of this specimen.

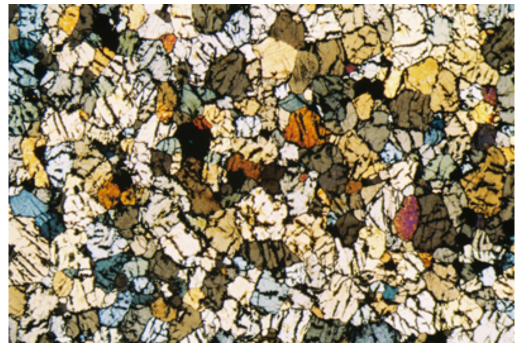
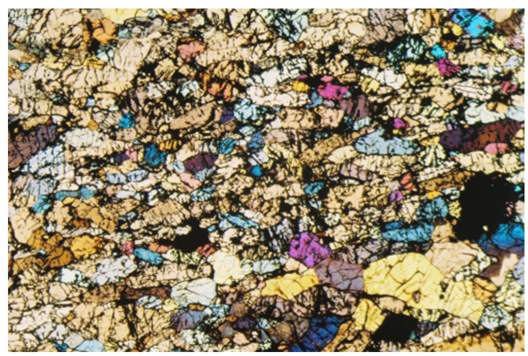


Figure 2. *Cross-polarized light thin section images of NWA 7388* ***(above)*** *and NWA 7605* ***(below)*** *showing protogranular textures of olivine and pyroxene decorated by metal+opx reduction assemblages (black) along grain boundaries. Large opaque grains are chromite. Note the preferentially-oriented fabric in NWA 7605. Width = 9 mm. Photos by T. Bunch.*



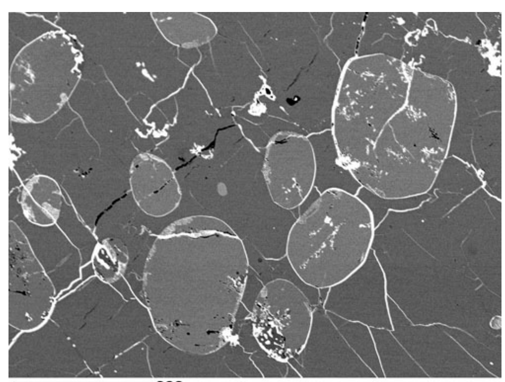


Figure 3. *BSE image showing ovoid olivine chadacrysts within pyroxene in NWA 7605. Note that only locally have olivines reacted to metal+opx (dark gray).*

Secondary Reduction Assemblages: Olivine grains in both NWA 7388 and NWA 7605 are associated with intergrowths of orthopyroxene and fine grained, blebby pure iron metal, either on grain boundaries or along interior fractures (see Figure 4). In NWA 7605 olivine chadacrysts enclosed within primary orthopyroxene have been so transformed only locally along penetrative fractures (see Figure 3), where fluids may have had access. The secondary orthopyroxenes in both meteorites have similar compositions ($Fs_{20.4-20.8}Wo_{1.7-1.4}$; $Fs_{21.8-21.9}Wo_{1.0-2.1}$). Very similar features were described in several other brachinites by [2]. It seems that all of these specimens have experienced a post-consolidation (?deuteric) reduction process, possibly involving methane infiltration and reaction with primary olivine, for example:

$$4(FeMg)SiO_4 + CH_4 = 4Fe + 4MgSiO_3 + CO_2 + 2H_2O$$

In such a reaction the amounts of metallic iron produced and the Fe/Mg ratios in both reactant olivine and product orthopyroxene could be variable. As noted by [3], such a reaction differs from that proposed for the well-known marginal olivine reduction in ureilites, which probably instead involves primary carbon.

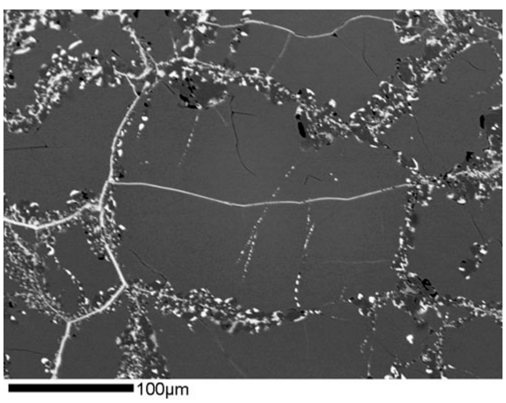
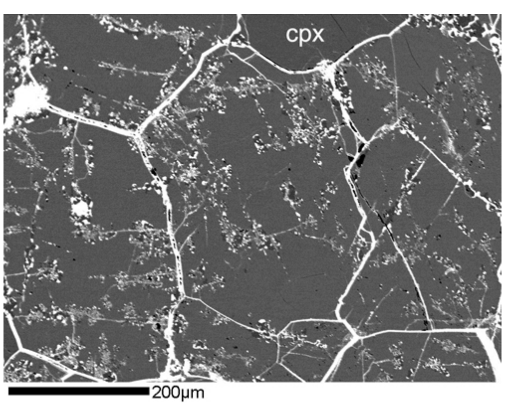


Figure 4. *BSE images of NWA 7388 (above) and NWA 7605 (below) showing reaction assemblages of metal (bright)+opx (dark gray) on and within olivine grains.*



Oxygen Isotopic Compositions: Laser fluorination analyses on acid-washed subsamples gave, respectively: ***NWA 7388*** $\delta^{17}O$ = 2.862, 2.705; $\delta^{18}O$ = 5.635, 5.413; $\Delta^{17}O$ = -0.113, -0.153 per mil; ***NWA 7605*** $\delta^{17}O$ = 2.370, 2.345; $\delta^{18}O$ = 4.822, 4.776; $\Delta^{17}O$ = -0.176, 0.177 per mil. These compositions plot close to or within the broad field for brachinites and other similar/related achondrites, but do not overlap with data for brachinite-like achondrite NWA 5400 and pairings (see Figure 4). Another anomalous, ferroan brachinite-like specimen (***NWA 6962***) has $\delta^{17}O$ = 2.190, 2.191; $\delta^{18}O$ = 6.144, 6.130; $\Delta^{17}O$ = -1.041, -1.032 per mil [4].

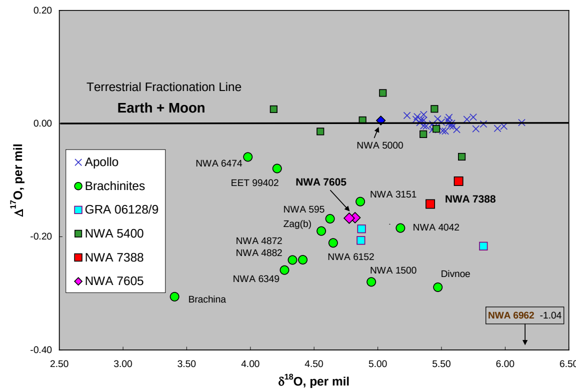


Figure 4. *Oxygen isotopic compositions of NWA 7388 and NWA 7605 compared with laser fluorination data for brachinites and other achondrites [1, 4, 5]. NWA 5400 data points also include mean values for paired specimens NWA 5363 [6], NWA 5548, NWA 6065, NWA 6077, NWA 6172, NWA 6292, NWA 6424 and NWA 6572 (analysts: D. Rumble, R. Tanaka).*

Discussion: The two specimens characterized here have some petrologic and oxygen isotopic similarities to brachinites – a diverse group of ultramafic achondrites which (like pallasites) might not all be cogenetic (see earlier discussion in [1]). However, the distinctive secondary reduction features in NWA 7388 and NWA 7605 (and also in Hughes 026, Reid 013 and NWA 1500 [2]) may provide evidence for mobility of methane-rich fluids. Some of these ultramafic specimens may be samples from the mantle of a parent body which has experienced plastic flow processes.

References: [1] Rumble D. et al. (2008) *Lunar Planet. Sci.* **XXXIX**, #1391 [2] Goodrich C. (2010) *Lunar Planet. Sci.* **XLI**, #1091 [3] Langendam A. and Tomkins A. (2012) *75th Meteorit. Soc. Mtg.*, #5164 [4] *Meteorit. Bulletin* (2012) **101** [5] Greenwood R. et al. (2007) *Lunar Planet. Sci.* **XXXVIII**, #2163; Irving A. et al. (2009) *Lunar Planet. Sci.* **XL**, #2332; Goodrich C. et al. (2011) *Meteorit. Planet. Sci.* **45**, 1906-1928; Day J. et al. (2012) *Geochim. Cosmochim. Acta* **81**, 94-128 [6] *Meteorit. Bulletin* (2010) **99**.