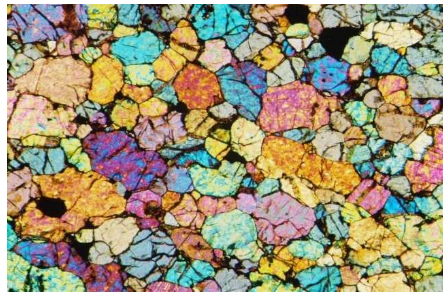
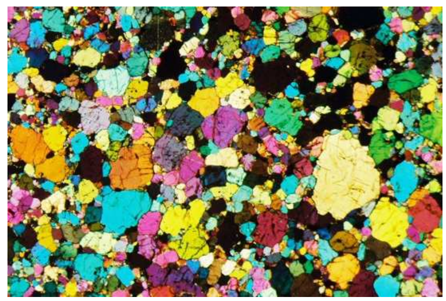
OXYGEN ISOTOPIC AND PETROLOGICAL DIVERSITY AMONG BRACHINITES NWA 4872, NWA 4874, NWA 4882 AND NWA 4969: HOW MANY ANCIENT PARENT BODIES? D. Rumble III[1], A. J. Irving[2], T. E. Bunch[3], J. H. Wittke[3] and S. M. Kuehner[2] [1]Geophysical Laboratory, Carnegie Institution, Washington, DC 20015 (rumble@gl.ciw.edu), [2]Dept. of Earth & Space Sciences, University of Washington, Seattle, WA 98195, [3]Dept. of Geology, Northern Arizona University, Flagstaff, AZ 86011.

Four brachinite specimens found recently in Northwest Africa exhibit variations in textures and mineral compositions, suggesting that they could represent separately ejected samples from one or more heterogeneous sources. When coupled with the observed wide range in oxygen isotope compositions for these and other brachinites, the presumption of a single, very ancient (>4.56 Ga) brachinite parent body may be called into question. Alternatively the observed oxygen isotopic variation could signify incomplete mixing within a single brachinite parent body, and likewise within parent bodies for some other achondrites as a function of body size and duration of interior heating.

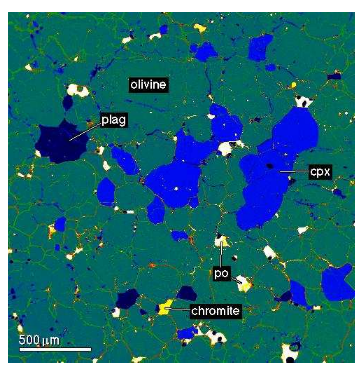
Petrology: Although all four separate specimens came to light in Morocco at about the same time, details of their discovery in the desert are not known. All are composed predominantly of olivine (85-90 vol.%) with minor clinopyroxene, chromite, iron sulfides and Fe-Ni metal; plagioclase was found in all but NWA 4872, and accessory phosphates are present in NWA 4872 (chlorapatite, Na-merrillite) and NWA 4874 (Na-merrillite). Two specimens (NWA 4874, NWA 4882) are more equigranular and medium grained (0.7±0.5 mm), whereas NWA 4872 and NWA 4969 have distinctly bimodal grainsize distributions (see Figure 1). Mineral compositions for NWA 4872, 4874, 4882 and 4969, respectively, are: olivine $Fa_{35.1}$, $Fa_{34.1}$, $Fa_{35.1}$, $Fa_{34.7}$, (FeO/MnO = 71-84); clinopyroxene ($Fs_{10..3}$ Wo_{47}, Fs_{12} $Wo_{48.3}$, $Fs_{9.3}Wo_{47.1}$, $Fs_{10.0}Wo_{46.4}$ (Cr_2O_3 = 0.76-1.2 wt.%); chromite *cr#* = 74, 73, 72, 71; plagioclase [none], $An_{40.7}Or_{0.3}$, $An_{32.1-37.6}Or_{0.3-0.5}$, $An_{34.6}Or_{0.3}$. The plagioclase is distributed quite irregularly and is notably K-poor (as found also in brachinite NWA 3151 [1]), and that in NWA 4874 is more calcic than in other specimens. The modal and compositional heterogeneities of plagioclase and phosphates support the hypothesis [1, 2] that brachinites are igneous cumulates.

Olivine in all of these specimens contains small, very fine-grained aggregates of orthopyroxene + Fe metal ± fayalite ± chromite, some of which occur around pyrrhotite grains (see Figure 2a). These polyphase aggregates appear to represent post-igneous reaction assemblages formed perhaps in response to a change in redox conditions, as also observed in some lodranites [3]. Such intergrowths also are present in Reid 013 (Figure 2b), but are absent from NWA 3151.


NWA 4874


NWA 4969


NWA 4872



NWA 4882

Figure 1: XPL thin section images of NWA 4874, NWA 4969 (both 6 mm), NWA 4872 (9 mm) and BSE image of NWA 4882. All specimens have protogranular textures like those in terrestrial mantle xenoliths.

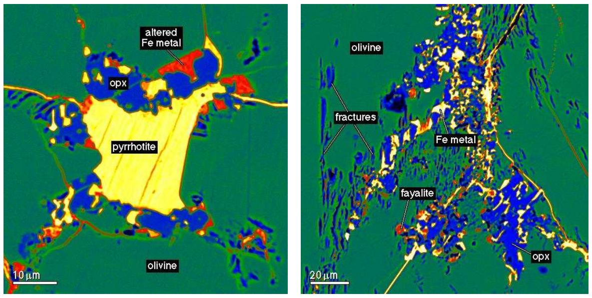


Figure 2: BSE images of reduced reaction assemblages in NWA 4882 (left) and Reid 013 (right).

Oxygen Isotopes: Replicate measurements by laser fusion on acid-washed samples gave (in per mil): ***NWA 4872*** $\delta^{17}O$ = 2.061, 2.012; $\delta^{18}O$ = 4.354, 4.308; $\Delta^{17}O$ = -0.229, -0.254; ***NWA 4882*** $\delta^{17}O$ = 2.064, 2.095; $\delta^{18}O$ = 4.368, 4.455; $\Delta^{17}O$ = -0.234, -0.248; ***Divnoe*** $\delta^{17}O$ = 2.537, 2.523, 2.627; $\delta^{18}O$ = 5.359, 5.369, 5.580; $\Delta^{17}O$ = -0.282, -0.301, -0.288; ***Zag(b)*** $\delta^{17}O$ = 2.279, 2.135; $\delta^{18}O$ = 4.703, 4.410; $\Delta^{17}O$ = -0.195, -0.185.

These results and data for other brachinites and potentially related ultramafic achondrites (including NWA 4042 [5]) are plotted in Figure 3. Based on oxygen isotopic compositions, there appear to be ***three*** groups of specimens: one with $\Delta^{17}O$ of -0.16 ± 0.03 (NWA 3151, NWA 595, Zag(b), NWA 4042), another with $\Delta^{17}O$ of -0.24 ± 0.02 (including NWA 4872 and NWA 4882), and a third with $\Delta^{17}O$ near -0.30 per mil (Brachina, Divnoe). No correlation between $\Delta^{17}O$ and Fa content of olivine is evident.

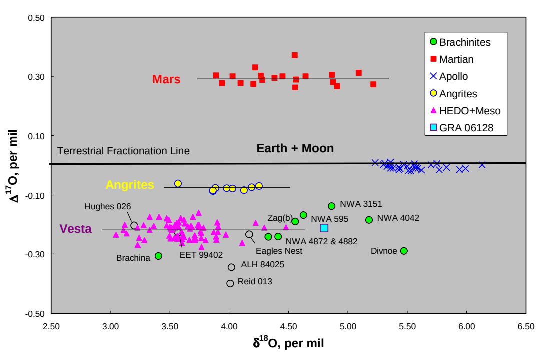


Figure 3: Oxygen isotope plot for brachinites [1, 5, 6] and other planetary achondrites [7, 13]; all plotted data are by laser fluorination, except open circles [4].

Discussion: The complete range in laser $\Delta^{17}O$ values for 8 brachinites *sensu lato* is 0.17 per mil, which is beyond the reproducibility for replicate analyses of individual specimens. This begs the question: *How much mass-independent variation in oxygen isotopic composition can be expected within a single planetary or asteroidal body?* The dispersions for laser data among many more samples from Earth, Moon and Mars are considerably less than this. Even in comparison with the dispersion (-0.15 to -0.27 per mil) measured [8, 9] for the much larger sampling of HEDO meteorites and mesosiderites (ostensibly from 4Vesta), the brachinites analyzed to date exhibit a larger range of $\Delta^{17}O$ values (at overlapping absolute values). Even larger dispersions are observed for winonaites (0.3 per mil) and for acapulcoites+lodranites (0.75 per mil) [10], and polymict ureilites also show heterogeneity [11]. If each of these achondrite groups derives from a single parent body, then it must be concluded that some bodies exhibit more heterogeneity in oxygen isotopic composition than others, perhaps as an inverse function of parent body size (and consequently the duration of interior heating and potential convective overturn).

Conclusions: Brachinites may represent a series of cumulate rocks formed within a single, very ancient "planetary" body, which was large enough to permit internal partial melting, but perhaps too small and/or heated for insufficient time to erase accretional oxygen isotopic heterogeneities. In contrast the more extreme variations among pallasite subgroups [4, 9, 12] definitely appear to require more than one parent body. New data (see Figure 3, [13]) suggest that GRA 06128 may be a felsic crustal rock complementary to brachinites and from the same parent body.

References: [1] Irving A. J. et al. (2005) *Meteorit. Planet. Sci.* **40**, 5213 [2] Mittlefehldt D. W. et al. (2003) *Meteorit. Planet. Sci.* **38**, 1601-1625 [3] Irving A. J. et al. (2007) *Meteorit. Planet. Sci.* **42**, #5129 [4] Clayton R. N. and Mayeda T. (1996) *Geochim. Cosmochim. Acta* **60**, 1999-2018; *Antarctic Meteorite Newsletter* **23(2)** [5] *Meteorit. Bull.* **90** [6] Irving A. J. and Rumble D. (2006) *Meteorit. Planet. Sci.* **41**, #5288 [7] GL-OU-UWO data compilation [8] Wiechert U. et al. (2004) *Earth Planet. Sci. Lett.* **221**, 373-382; Greenwood R. C. et al. (2005) *Nature* **435**, 916-918 [9] Greenwood R. C. et al. (2006) *Science* **313**, 1763-1765 [10] Rumble D. et al. (2005) *Meteorit. Planet. Sci.* **40**, #5138; Irving A. J. et al. (2007) *Lunar Planet. Sci.* **XXVIII**, #2254; Greenwood R. C. et al. (2007) *Lunar Planet. Sci.* **XXVIII**, #2163 [11] Ash R. D. et al. (2000) *Meteorit. Planet. Sci.* **35**, #5288 [12] Bunch T. E. et al. (2005) *Meteorit. Planet. Sci.* **40**, #5219; Mittlefehldt D. W. and Rumble D. (2006) *Meteorit. Planet. Sci.* **41**, A123 [13] Zeigler R. A. et al. (2008) This conference.

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