UNGROUPED MAFIC ACHONDRITE NORTHWEST AFRICA 7325: A REDUCED, IRON-POOR CUMULATE OLIVINE GABBRO FROM A DIFFERENTIATED PLANETARY PARENT BODY.
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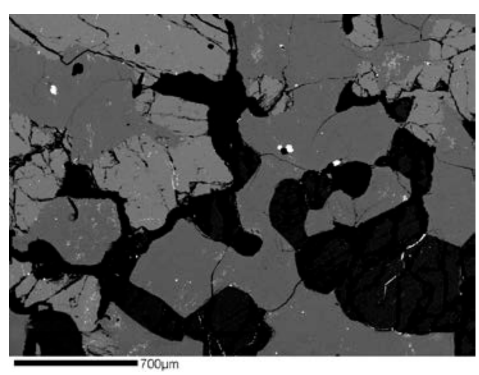
Introduction: Several years prior to the Messenger mission's encounter with Mercury, the first three authors speculated [1] that angrites might possibly be samples derived indirectly from that planet. Orbital X-ray/γ-ray spectrometry results showing very low iron contents and measurable Na and K abundances in exposed surface rocks on Mercury [2] now appear to exclude any connection with the 13 known angrite meteorites. However, we still maintain that these very ancient refractory achondrites derive from a differentiated protoplanet (see [3]), which originally accreted not in the asteroid main belt but much closer to the Sun.

Recently another candidate achondrite has come to light which has some bulk compositional and mineralogical features compatible with the known chemical attributes of Hermean rocks. Northwest Africa 7325 is a 345 gram dark green, igneous achondrite with partial chartreuse-colored fusion crust found in 35 pieces in Western Sahara in February 2012. This specimen is notable for the distinctive "frosty" luster of plagioclase and bright green color of clinopyroxene.

Figure 1. *Closeup view of polished cut face of one Northwest Africa 7325 stone showing emerald green chromian diopside and gray "frosty" plagioclase. Width = 3 cm. Image © S. Ralew.*

Petrography: NWA 7325 has a medium-grained plutonic igneous texture consistent with subsurface crystal accumulation from its parent magma (see Figure 2). It is composed of 56 vol.% calcic plagioclase ($An_{88.1-89.2}Or_{0.0}$), 27 vol.% diopside ($Fs_{1.1-2.6}Wo_{45.1-44.5}$, FeO/MnO = 12-21, Al_2O_3 = 2.6-2.8 wt.%, Cr_2O_3 = 1.0 wt.%), and 16 vol.% lobate (possibly resorbed) grains of forsterite ($Fa_{2.7-2.8}$, FeO/MnO = 30-36, CaO = 0.27-0.32 wt.%, Cr_2O_3 = 0.32-0.35 wt.%), with accessory Cr-bearing iron sulfide (probably troilite), very sparse ferrochromite, kamacite, taenite, and rare eskolaite (associated with iron sulfide). Some forsterite grains are mantled by aprons of diopside against the plagioclase phase, which appears to have been molten (as a result of shock?), and then reacted with forsterite to generate secondary diopside. The plagioclase phase is finely mottled and birefringent, but levels of birefringence are much less than normal, and also there are included clusters of very fine sulfide and kamacite.

Figure 2. ***A (above)***. *Cross-polarized light thin section image. Note the mottled appearance of plagioclase (e.g., at right, gray). Width of field = 5 mm.* ***B (below).*** *Back-scattered electron image showing forsterite (dark), plagioclase (medium gray), diopside light gray) and Cr-bearing iron sulfide (bright).*



Oxygen Isotopic Composition: Laser fluorination analyses on acid-washed subsamples gave, respectively $\delta^{17}O$ = 3.214, 3.670, 3.249; $\delta^{18}O$ = 7.566, 8.204, 7.957; $\Delta^{17}O$ = -0.781, -0.662, -0.952 per mil. These compositions plot on the broad trend for ureilites, but also on extensions of the established trends for winonaites and for acapulcoites/lodranites (see Figure 3). This probably is fortuitous, since NWA 7325 bears no petrologic resemblance to any of these achondrites.

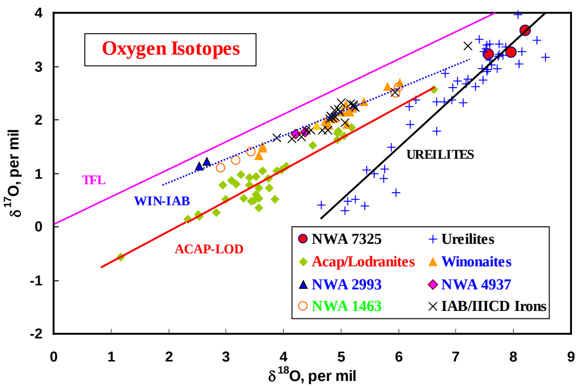


Figure 3. *Plot of oxygen isotopic compositions of NWA 7325 and other achondrites (data from [4]).*

Bulk Major and Trace Element Composition: Analyses of representative, clean bulk cutting dust by XRF and ICP-MS gave: (in wt.%) SiO_2 47.09, TiO_2 0.01, Al_2O_3 18.60, Cr_2O_3 0.40, FeO 1.57, MnO 0.03, MgO 12.13, CaO 17.94, Na_2O 0.60, K_2O 0.01, P_2O_5 0.02; (in ppm) La 0.15, Ce 0.34, Nd 0.16, Sm 0.05, Eu 0.58, Gd 0.05, Ba 54/61, Rb 0.37, Sr 198, Li 0.53, Hf 0.44, Zr 1.3, Nb 2.5, Th 0.27, Ni (61/78).

This specimen is significantly depleted in lithophile trace elements relative to chondrites, and its REE pattern (Figure 4) has a large positive Eu anomaly, consistent with its formation as a plagioclase-rich cumulate from a mafic magma. The chondrite-normalized ratios of Sm/Nd (0.96) and Hf/Sm (12.6) imply significant REE and HFSE fractionation. The Lu/Hf ratio of the bulk rock should be very different from chondritic, and should permit determination of a precise Lu-Hf model age (in progress). The high abundances of plagioclase and clinopyroxene also make NWA 7325 very amenable to determination of a precise crystallization age utilizing the Rb-Sr, Sm-Nd and Pb-Pb isotopic systems.

Discussion: The combination of highly magnesian mafic silicates and calcic plagioclase with chromium-bearing sulfides in NWA 7325 is unique among achondrites, as is the oxygen isotopic composition for such a mineral assemblage. This specimen evidently crystallized from a relatively high temperature, Mg-Ca-rich but unusually Fe-poor silicate magma under extremely low oxygen fugacity conditions (approaching those inferred for enstatite-rich meteorites).

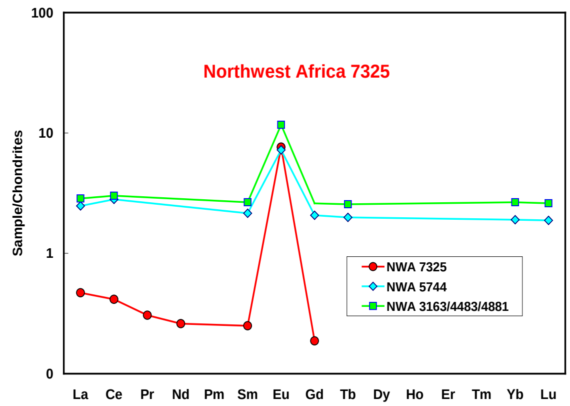


Figure 4. *Chondrite-normalized bulk REE abundances for NWA 7325 compared with those for two lunar gabbroic/troctolitic meteorites [5]. The positive Eu anomalies imply that the calcic plagioclase in all specimens accumulated from mafic parental magmas.*

The ratios of Al/Si (0.224) and Mg/Si (0.332) plus the very low Fe content of NWA 7325 are consistent with the compositions of surface rocks on Mercury [6], but the Ca/Si ratio (0.582) is far too high. However, since NWA 7325 is evidently a plagioclase cumulate (and presumably excavated from depth), it may not match surface rocks on its parent body. The abundance of diopside rather than enstatite might be consistent with some earlier spectral observations of Mercury [7].

Because the gravitational acceleration on Mercury is almost the same as for Mars (~0.38 that for Earth), it might be expected that a Hermean meteorite would be shocked to a degree similar to that observed in shergottites. Even though the plagioclase in NWA 7325 is not now maskelynite, it has undergone significant transformation and evidently complete melting (most likely in response to shock). Whether NWA 7325 is such a candidate Hermean specimen remains to be more fully evaluated by further studies, and ultimately only a sample return from Mercury may provide an answer.

References: [1] Irving A. et al. (2005) *Fall AGU Mtg.*, #P51A-0898; Kuehner S. et al. (2006) *Lunar Planet. Sci.* **XXXVII**, #1344; Irving A. & Kuehner S. (2007) *LPI Workshop on the Chronology of Meteorites & the Early Solar System, Kauai*, #1374 [2] Nittler L. et al. (2011) *Science* **333**, 1847-1850 [3] Kleine T. et al. (2012) *Geochim. Cosmochim. Acta* **84**, 186-203 [4] Clayton R. and Mayeda T. (1996) *Geochim. Cosmochim. Acta* **60**, 1999-2017; Irving A. et al. (2007) *Lunar Planet. Sci.* **XXXVIII**, #2254 [5] Irving A. et al. (2006) *Lunar Planet. Sci.* **XXXVII**, #1365; Kuehner S. et al. (2010) *Lunar Planet. Sci.* **XLI**, #1552 [6] Weider S. et al. (2012) *J. Geophys. Res.* **117**, 15 pp. [7] Sprague A. et al. (2009) *Planet. Space Sci.* **57**, 364-383.