NORTHWEST AFRICA 8659: A STANNERN-TREND EUCRITE RICH IN LATE/SECONDARY OLIVINE.

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NWA 8659 is a 46-gram eucrite with unusual composition and mineralogy. A set of slices indicate that most of the material is thoroughly brecciated. However, one large clast comprising about 40% of the stone is essentially unbrecciated: subopthitic with grain size typically 2 mm. Clast and groundmass show the same distinctive mineralogical features described below. Affinity with the Stannern Trend is suggested by the bulk composition: (INAA plus fused-bead EPMA, in wt%, average of similar results from two groundmass chips totaling 0.52 g) SiO_2 49.4, TiO_2 1.2, Al_2O_3 11.5, Cr_2O_3 0.27, MgO 5.7, CaO 11.6, FeO 18.6, MnO 0.50, Na_2O 0.58; trace elements (µg/g) Sc 29.9, V 43, Ni 11, Co 7.5, La 7.1, Sm 4.1, Eu 0.90, Lu 0.49, Hf 2.6. Oxygen isotopes are normal-eucritic: $\delta'^{17}O$ 2.083, $\delta'^{18}O$ 4.376, $\Delta'^{17}O$ – 0.227. The only known eucrite with higher TiO_2 is NWA 5738 [1], yet the Sc and *mg* (35.3 mol%) are Stannern-like (moderate).

Pyroxene is mostly equilibrated to a tie-line between low-Ca pyroxene ($En_{32.0\pm0.7}Wo_{3.4}$), and high-Ca pyroxene ($En_{26.6}Wo_{42.3}$), but in the cores of a few large grains a low-Ca zoning trend survives with composition as magnesian as $En_{58}Wo_7$. Such a truncated thermal metamorphism, “type 2” on the Takeda-Graham scale [2], is rare among eucrites; the best precedent is probably QUE 97053 [3], although NWA 8675 [4] is apparently another instance (and, we suspect, paired with 8659). The pyroxenes are to an unusual extent pervaded by secondary olivine-dominated veins (cf. NWA 5738), but in NWA 8659 olivine also occurs largely along pyroxene-plag grain boundaries, and in some areas as a splotchy replacement pervasive within individual pyroxene grains. In one such grain, an area 700 µm across is now dominantly (~60%) olivine. The olivine in all its various habits is compositionally uniform at ~Fa_{84}. Primary-igneous plagioclase is $An_{81.3\pm2.4}$ (n=40), but plag amidst the olivine-dominated veins (and replacement splotches) within pyroxene is typically $An_{97\text{-}98}$. Minor Fe-metal is very pure Fe.

NWA 8659 affords clues to the enigma of the process(es) responsible for olivine-rich veins in eucrites [1,5,6]. Simple igneous derivation (i.e., without appeal to some sort of fluid), even with shock-mobilization [6] as a redistributive wild card, has difficulty accounting for the association with nearly Na-free plag, the avoidance by the vein networks of plag grain interiors (suggesting a host-composition controlled distribution process), and the lack of immediate association with other late-igneous phases such as ilmenite, silica, FeS and Na-rich plag. Difficulties with the aqueous fluid model [5] include absence of accompanying hydrated phases and the implausibility that hydrothermal flow could last long, given the vast difference between fluid and rock density in the context of even a very large asteroid’s crust. However, the flow-longevity issue also mitigates the former (hydrated phases) issue. Secondary Fe-metals, found in some of the same meteorites [1], are similarly enigmatic.

References: [1] Warren P. H. et al. 2014. *GCA* 141: 199–227. [2] Takeda H. and Graham A. L. 1991. *Meteoritics* 26: 129-134. [3] Righter M. and Lapen T. J. 2010. Abs. #2629. 41st Lunar Planet. Sci. Conf. [4] Irving A. and Kuehner S. 2015. *Meteorit. Bull.* 103. [5] Barrat J. A. et al. 2011. *GCA* 75: 3839-3852. [6] Takeda H. et al. 1994. *EPSL* 122: 183-194.