NORTHWEST AFRICA 2993: A COARSE-GRAINED LODRAN-LIKE ACHONDRITE WITH AFFINITIES TO WINONAITES.

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Discovery: A fully crusted, complete and very fresh metal-rich stone of 625 grams was recovered from the lower Algerian desert in June 2006 and purchased in Erfoud in August 2006.

Figure 1: Cut face (3.3 cm wide) of NWA 2993 showing 30 vol.% fresh metal and coarse mafic silicates.

Petrology: NWA 2993 has a coarse granular or protogranular texture with a grain size range of 0.3 to 3.4 mm (mean = 1.35 mm) for silicates and 0.3 to 5 mm for metal (mean = 2.4 mm). Metal-silicate grain boundaries are commonly cuspate. Modal analyses were conducted on BSE images over a 6.4 cm^2 area. The specimen is composed of orthopyroxene (37 vol.%; $Fs_{11.2\pm0.2}Wo_{1.2}$, FeO/MnO = 19), olivine (32 vol.%; $Fa_{12.3\pm0.2}$, FeO/MnO = 32), metal (30 vol.%; taenite, Ni = 7.9 wt %; kamacite, Ni = 4.6 wt %) and accessory sulfide. Several metal grains have taenite cores mantled by kamacite. Taenite grain shape is roughly similar to the outline of the entire metal grain, and embryonic plessite is evident in a few taenite cores. No directional fabric was recognized. The fusion crust is lightly to moderately altered, and weathering is limited to minor oxidation of kamacite and minor oxide veining along grain boundaries.

Oxygen Isotopes: This specimen is strikingly similar in overall appearance and mineral compositions to Lodran (the eponymous lodranite which fell in Pakistan in 1868), but oxygen isotopic analyses held a surprise. Replicate analysis of a cleaned and metal-free sample by laser fluorination gave: $\delta^{17}O$ 1.129, 1.220;

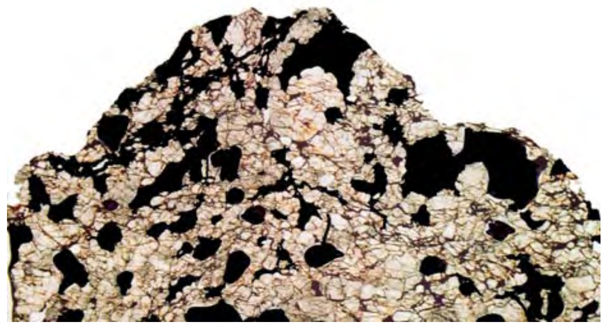
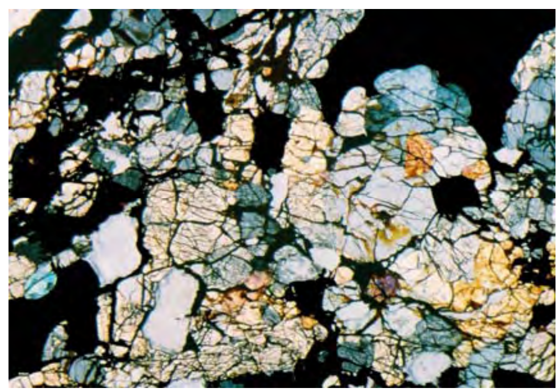


Figure 2: Plane-polarized (above) and cross-polarized (below) optical thin section images of NWA 2993. Width of field is 17 mm above and 7 mm below.



$\delta^{18}O$ 2.527, 2.661; $\Delta^{17}O$ -0.2006, -0.1802 per mil, respectively. These values are very different from, and much closer to the TFL than, those of lodranites and acapulcoites (see Figure 3). In fact these compositions fall very close to a best fit regression line through data for winonaites and IAB irons, and are very similar to values obtained in the same laboratory for related "W chondrites" NWA 1463 and NWA 1054 [1]. The winonaite-IAB iron regression line has a shallower slope than a similar line for lodranites and acapulcoites, and would pass close to the origin ($\delta^{18}O = 0$, $\delta^{17}O = 0$).

On a plot of Fa content in olivine versus $\Delta^{17}O$ (Figure 4) NWA 2993 is displaced from the broad array for lodranites and acapulcoites documented by Rumble et al. [1], and also possibly forms an extension of the main winonaite array. The slopes of these arrays and their possible implications for mixing processes on their parent bodies are discussed by Irving et al. [3].

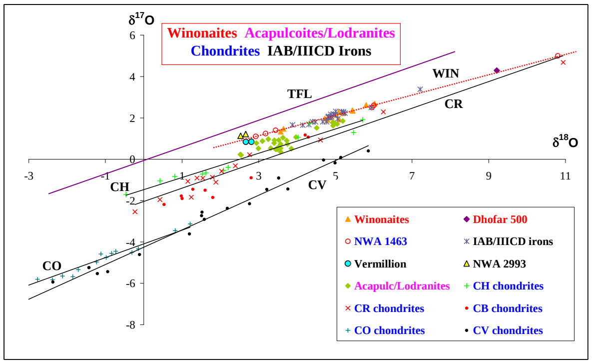


Figure 3: Oxygen isotopic composition of NWA 2993, winonaites, lodranites and acapulcoites (data from [1], [3], [4] and this work).

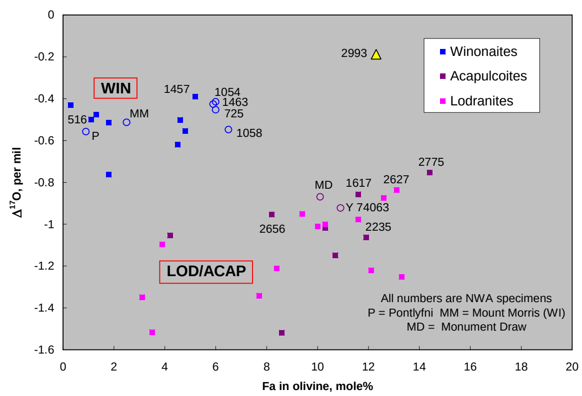


Figure 4: Correlation of olivine composition with $\Delta^{17}O$ for NWA 2993, winonaites, lodranites, acapulcoites, and related chondrites (circles).

Discussion: The overall texture, olivine and orthopyroxene compositions, lack of plagioclase, and occurrence of kamacite-rimmed taenite in NWA 2993 are all features of ferroan lodranites, *but* the oxygen isotopic composition categorically excludes a relationship to lodranites. Instead we conclude that NWA 2993 represents the first known coarse grained specimen related to the winonaite parent body (WPB). It has been proposed [2, 5] that lodranites are deeper plutonic samples located beneath shallower acapulcoite samples on a common parent body. In a similar fashion NWA 2993 possibly is a deeper plutonic sample from the winonaite parent body.

Nevertheless, the exact physical association of NWA 2993 with winonaites and IAB irons remains uncertain, given that IAB irons contain regions of winonaite-like silicates [6] and, like pallasites, may derive from a "mantle" region of mixed metal and silicate-rich components. Partial melt extraction has been proposed to have affected lodranites [2, 7], but the role of such a process in the formation of NWA 2993 has yet to be assessed.

Related Specimens: Laser fluorination oxygen isotope analyses on olivine from Vermillion, a metal-rich pallasite [8] or silicated iron [9], gave $\delta^{17}O$ 0.843, 0.838; $\delta^{18}O$ 2.809, 2.663; $\Delta^{17}O$ -0.635, -0.563 per mil, respectively. These results differ from those obtained earlier by [4], but may support the opinion of [9] that Vermillion probably is closely related to IAB irons. In contrast to the situation for the WPB, there are no candidate iron meteorites yet discovered that might be related to the acapulcoite-lodranite parent body (ALPB).

Another similarity between the WPB and ALPB is that both evidently possess chondrule-bearing regoliths, represented respectively by "W chondrites" such as Pontlyfni, Mount Morris (Wis.), and paired African specimens NWA 725/1052/1054/1058/1463 [1], and by "AC chondrites" such as Monument Draw, Y 74063, GRA 98028 and Dhofar 1222.

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