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NWA 8614: The Least Heated Winonaite

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Introduction: Northwest Africa 8614 is classified as a winonaite on the basis of oxygen isotope ratios, mineralogy, and highly reduced chemistry [1]. Unlike other winonaites, it contains numerous and readily apparent chondrules, with over a dozen chondrules apparent in two small thin sections. Figure 1 below helps to illustrate the abundance of the chondrules in NWA 8614, which are circled in white. The large number of chondrules sets apart this meteorite from other winonaites. One other winonaite, NWA 1463, is reported to have multiple relict chondrules [2, 3]. Here we discuss various features of NWA 8614.

Mineralogy and Texture:
- Primarily granoblastic (Fig. 1, 2)
- Barred and microporphyrhetic chondrule textures (Fig. 1, 2)
- Chondrules rich in olivine or low-Ca pyroxene, diopside enriched in chondrules compared to host (Fig 2)
- Chondrule diameters 0.42 ± 0.21 mm (N = 23) for better-defined chondrules, and 0.41 ± 0.20 mm (N = 35) including all possible chondrules
- NWA 8614 is pyroxene and metal rich (Fig. 1) with presence of daubreelite and schreibersite [4, 5]
- Collection of metal grains that form vein-like structure (Fig. 1), similar structures in other winonaites [4, 5]

Mineral Chemistry: Mineral chemistry is summarized in Table 1. Features:
- Mineral compositions overlap winonaites at the ferroan end (Fig. 3). Ferroan composition of NWA 8614 similar to NWA 4937 (Fig. 3), but not paired due to differing modal abundances [1]
- NWA 1463 contains chondrules [2, 3], not paired due to differing mineral chemistries (Fig. 3)
- Olivine and pyroxene compositions are highly uniform, suggests approach to equilibrium
- Two pyroxene and olivine-spinel geothermometry (Table 2) suggests that ferromagnesioan phases largely equilibrated at ~820-860 °C, which are similar to but slightly lower than other winonaites
- Despite highly uniform compositions, olivine is too magnesian for equilibrium relative to low-Ca pyroxene (Fig. 3)
- Oxygen isotope ratios plot with winonaites and extend the field to the left (Fig. 4)

Discussion and conclusions: Owing to the abundance of chondrules, NWA 8614 may be one of the least heated winonaites, and therefore may provide clues to the chondritic protolith of the winonaite parent body.
- Overall textures are similar to those found in type 6 chondrites that escaped significant melting.
- Despite similar geothermometer temperatures for various mineral pairs, NWA 8614 apparently did not attain Fe-Mg equilibrium between olivine and pyroxene.
- Like other winonaites, NWA 8614 has olivine compositions that are too magnesian for equilibrium relative to low-Ca pyroxene (Fig. 3). This discrepancy could be caused by preferential FeO-reduction of olivine [5].
- Although NWA 8614 lies closer to olivine-pyroxene Fe-Mg equilibrium than some winonaites, other winonaites with different Fe/Mg plot similarly close to the equilibrium line (Fig. 3).
- Among winonaites as a whole, there is no evidence for a curved trend between Fa and Fs compositions as would be expected for FeO-reduction during metamorphism [5], nor for mineral compositions that correlate with geothermometry temperatures (Fig. 3).
- This argues against a single metamorphic FeO-reduction trend from a common chondritic precursor. Instead, protoliths for different winonaites may have varied slightly in composition.