MINERALOGY, PETROLOGY AND MINERAL CHEMISTRY OF NORTHWEST AFRICA 8173: AN ANOMALOUS ENSTATITE ACHONDRITE WITH EVIDENCE FOR HIGH-TEMPERATURE SILICATE SULPHIDATION. D.D. Uribe1, M.R.M. Izawa1,2,3, P.J.A. McCausland1, R.L. Flemming1

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Introduction: A small but growing subset of enstatite-rich meteorites are outside the usual textural and (sometimes) mineralogical ranges of the enstatite chondrites, and are distinct from the aubrites [e.g., 1-3]. These anomalous enstatite meteorites may result from ‘ultrametamorphism’ of enstatite chondrite precursors, driven by impact-related (or possibly inductive) heating, or heating by short-lived nuclides (e.g., 26Al). We have begun an in-depth study of Northwest Africa (NWA) 8173, a new member of the anomalous enstatite chondrite group that has some novel features that further expand the range of enstatite meteorite texture and mineralogy.

Methods: Quantitative mineral compositions were measured using a JEOL JXA-8530F field emission electron microprobe at the Earth and Planetary materials analysis laboratory at Western University. The probe was operated at an accelerating voltage of 15 kV and a beam current of 20 A. Natural and synthetic standards were used for calibration.

Micro X-ray diffraction analysis was performed with the Bruker D8 Discover µXRD at Western University [4]. The instrument has a 60 mm cobalt Gobel mirror and was operated with a 300 µm pinhole colimator snout. Both meteorites were scanned in omega scan mode at two frames of 30 minutes each.

Results and Discussion: NWA 8173 is a unique, achondritic, enstatite-rich meteorite with two similar lithologies visible in hand specimen. Both lithologies are dominated by (nearly) chemically-pure orthoenstatite with Si-bearing kamacite, albitic plagioclase, silica (tridymite), ninnerite containing exsolved daubréelite lamellae, and trace schreibersite, oldhamite, keilite (as irregular elongate grains in local exsolution-lamella poor zones within ninnerite), graphite (as inclusions in kamacite), and fluorphlogopite. Terrestrial weathering assemblages occur along fractures and replacing susceptible minerals, and consist predominantly of Fe-oxhydroxide and calcite.

Enstatite is near end-member composition in both lithologies, and occurs in two textural forms: Large (~100-300 µm) subhedral to anhedral enstatite crystals and small (~10-100 µm) subhedral to anhedral enstatite grains located in areas with interstitial plagioclase; this texture is better-developed in lithology A (Fig. 1). The plagioclase that surrounds the smaller enstatite crystals exhibits micrographic to granophyric intergrowth is not present in the plagioclase grains that surround the more massive enstatite crystals (Fig 1). Metal and sulphides occur in rounded, interstitial masses. Kamacite contains inclusions of graphite (Fig 2A,B), as well as schreibersite and (rarely) free silica. Plagioclase in both lithologies is albite (~Ab90An4Or6), with some more potassic compositions up to ~Ab86An13Or13. Tridymite occurs along with plagioclase in the interstices between enstatite grains in both lithologies, and contains minor Al, Na, and K. Isolated occurrences of a micrographic intergrowth of plagioclase and silica were observed (Fig. 2C-D)

Figure 1: Petrographic textures in NWA 8173 lithologies. A) Mg Kα X-ray map, and B) Al Kα X-ray map in lithology A. C) Mg Kα X-ray map, and D) Al Kα X-ray map in lithology B. Note lower aluminum in interstitial plagioclase that surrounds secondary enstatites in NWA8173A.
Niningerite in NWA 8173 contains micon-scale lamellae of a Cr- and Fe-rich sulphide that is interpreted as daubréeelite (Fig. 3). The lamellae form octahedra and are therefore presumed to form along the \{111\} planes of the niningerite host. Daubréeelite within niningerite shows evidence of local remobilization, with linear trails of irregular, elongate Fe-dominant sulphide grains in zones that contain few daubréeelite lamellae (Fig. 3A-C). The Fe-dominant sulphide grains within niningerite of both lithologies contain significant Cr, Ca, Mg and Mn, therefore we tentatively identify this phase as keilite. Some of the larger daubréeelite and keilite grains within niningerite of both lithologies contain minute low atomic number inclusions with backscattered electron signals similar to oldhamite, tentatively identified as oldhamite ‘inclusions-within-inclusions’ (Fig. 3D). The Ni, Cu, Zn, and Co contents of all sulphides are at or below detection limits, but niningerite contains minor Ti and Na.

Kamacite in NWA 8173 in both lithologies contains \(~5.8~\%~\) atomic Ni, \(0.4\%~\) atomic Co, and \(~0.6~\%~\) atomic P. Lithology A kamacite is slightly more Si-rich, with \(\sim6.3\%~\) atomic Si vs. \(\sim6.0\%~\) atomic Si in lithology B. Schreibersite contains \(~4.2~\%~\) atomic Ni and \(~0.7~\%~\) atomic Si.

Conclusions: NWA 8173 has several unique features, including the near absence of troilite, with niningerite instead being the predominant sulphide phase. This, combined with the extreme chemical purity of enstatite and the presence of abundant free SiO₂, is consistent with a role for the sulphidation of ferromagnesian silicates in the formation of NWA 8173 in reactions such as:

\[(\text{Fe}_x\text{Mg}_{2-x})\text{Si}_2\text{O}_6^+ \text{S}_2 = (2-x)\text{MgS} + x\text{FeS} + 2\text{SiO}_2 + \text{O}_2\]

Evidence for silicate sulphidation has been documented in EH3 chondrites [5], and is thought to be most efficient at high temperatures (1400-1600K) and very reducing conditions. The high abundances of Ca in NWA 8173 niningerite are also consistent with formation by quenching of a very high temperature sulphide melt followed by substantial subsolidus annealing, exsolution, and local remobilization within the sulphide phase.


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