**A PETROLOGIC STUDY OF METAL-RICH NODULES IN ANOMALOUS EL3 METEORITE NORTHWEST AFRICA (NWA) 8785.**

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**Introduction:** NWA 8785 is a remarkable, recently identified unequilibrated enstatite chondrite collected in Morocco in 2014. It was classified as an EL3 based on the Si content in the metal and the presence of ferroan alabandite [1], but it contains unusual characteristics unobserved in other EL3s. For example, it has a high abundance of FeO-rich matrix (34% by area) [2]. Our aim is to study the mineral assemblages and compositions in metal-rich nodules in this anomalous EL3 chondrite and compare them to nodules in other EL3s. The goals are to evaluate models of formation for metal-rich nodules in EL3 chondrites and identify primary phases and any evidence of secondary alteration to gain insight into secondary processes that may have been active on the EL3 parent body asteroid. Most notable in NWA 8785 is the abundance of the rare mineral roedderite ($(Na,K)_2(Mg,Fe)_5Si_{12}O_{30}$), an alkali-rich silicate that may reveal more about the meteorite's origin and evolution.

**Methods:** We studied thin section NWA 8785-2 using a petrographic microscope and the Hitachi S4700 FE-SEM equipped with Bruker Energy Dispersive Spectrometer (EDS) and BackScattered Electron imaging. Element maps and mineral compositions were obtained using the Cameca SX100 electron probe.

**Results:** 10 out of a total of 40 identified metal-rich nodules were selected for detailed study. These 10 metal-rich nodules vary drastically in physical structure and texture despite similar mineral assemblages. The nodules were grouped based on whether they are (1) roedderite-bearing, and those that lack roedderite are further classified as (2) kamacite-rich and (3) kamacite-poor. (1) roedderite-bearing nodules include M1, M2, and M7. M1 is mainly kamacite surrounding assemblages of mainly roedderite and silica, with minor enstatite, djerfisherite ($K_6(Fe, Cu, Ni)_{25}S_{26}Cl$) and albite (Fig. 1). M2 is an aggregate of multiple kamacite nodules with interstitial roedderite and troilite and again, minor djerfisherite and albite (Fig. 2). M7 has concentric layers of kamacite and troilite, with roedderite and djerfisherite (Fig. 3). The presence of roedderite and djerfisherite in these nodules is significant because these minerals have been previously reported in EH chondrites [3], but not in an EL3. Additionally, the association of roedderite with djerfisherite suggests a relationship between the two minerals. (2) Five (M5, M18, M27, M33, and M40) kamacite-rich nodules lacking roedderite were studied. M5 has a layered structure of kamacite and troilite which seem to follow the curvature of the nodule. M18 has two halves of kamacite bracketing a central inclusion of troilite. M33 consists of two connected nodules of kamacite separated by a layer of matrix, and M40 is dominated by enstatite crystals intruding on the Fe-Ni metal. The kamacite-rich nodules contain variable amounts of troilite, djerfisherite, alabandite, oldhamite, enstatite, albite, graphite, and silicon. (3) Kamacite-poor nodules (M38 and M40) are dominated by sulfides.

Kamacite in NWA 8785 contains (in wt%) ~0.9 Si, 6.1 Ni, and 0.3 Co, which generally match previously reported values [1]. Notably, the silica content falls within the (<1.4 wt% range) characteristic of EL3s [4]. Roedderite is measured (in wt. %) as ~70 $SiO_2$, 0.8 $Al_2O_3$, 1.7 FeO, 20.3 MgO, 3.0 $Na_2O$ and 4.3 $K_2O$, and is compositionally similar to roedderite reported in the Qingzhen EH3 and Indarch EH4 chondrites [3, 5].

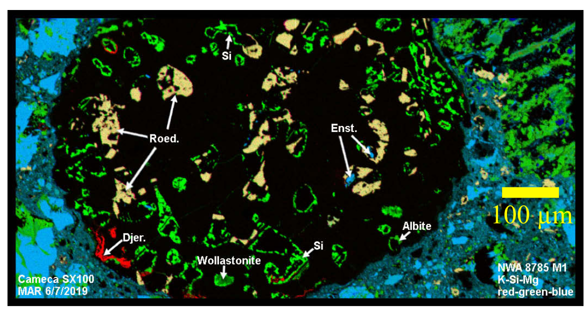


Figure 1: A K-Si-Mg red-green-blue element map of M1 showing roedderite (yellow), silica (green), enstatite (blue), djerfisherite (red), and kamacite (black).

**Discussion:** *Classification of NWA 8785*. The unusual structure and mineralogy of the metal-rich nodules and the high abundance of matrix bring to question whether NWA 8785 is an EL3. However, the silica content in the kamacite and Cr and Ti content in the troilite, as well as the presence of alabandite, are all characteristic of EL3s and indicate classification of NWA 8785 as an EL3 chondrite. Nevertheless, the highly unusual structure, texture, and mineralogy of the metal nodules leads us to classify this meteorite as an anomalous EL3.

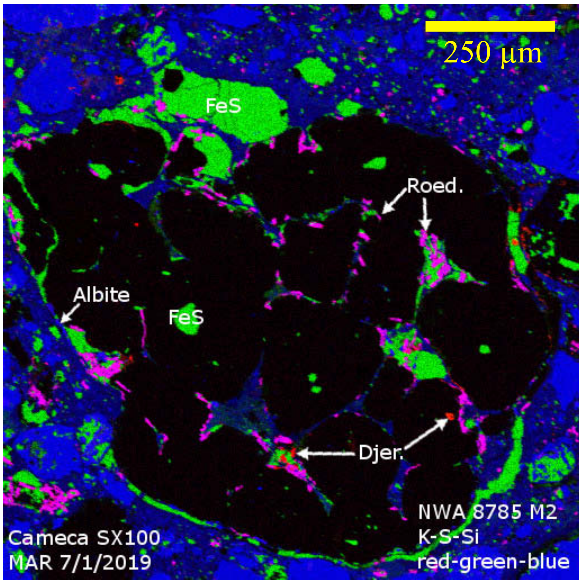


Figure 2: A K-S-Si red-green-blue element map of M2 showing kamacite (black) with interstitial roedderite (purple), troilite (green), and djerfisherite (red).

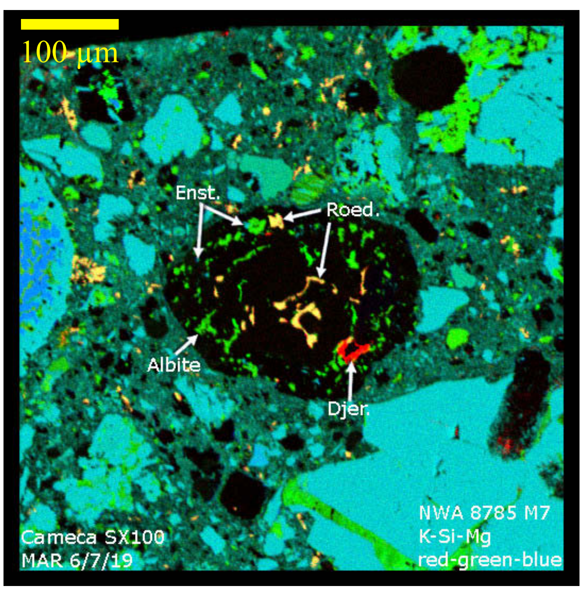


Figure 3: A K-Si-Mg red-green-blue element map of M7 showing roedderite (yellow), djerfisherite (red), silica (green), enstatite (blue), and Kamacite (black).

*Significance of roedderite in NWA 8785*. NWA 8785 contains a significant amount of roedderite, not previously observed in other EL3 chondrites. [3] interpreted the association of the roedderite in Qingzhen (EH3) with volatile-rich phases as an indication that roedderite formed in the presence of a fluid phase. This is consistent with interpretation of a rare terrestrial occurrence of roedderite, in ejecta of the Eifel eruption in West Germany, as a precipitate from an alkali-rich vapor phase formed during contact metamorphism of gneisses [6]. Formation of the roedderite in NWA 8785 may be due to alkali-rich fluids formed during alteration on the EL chondrite parent asteroid. Additional evidence of secondary alteration in NWA 8785 is observed in the FeO-rich matrix [2]. Also, we observed the association of roedderite with djerfisherite in M1 and M2 (Fig. 1, 2) which may indicate breakdown of the djerfisherite. Nevertheless, we cannot rule out the hypothesis of roedderite crystallization from a peralkaline melt [e.g., 7].

*Origin of metal-rich nodules in EL3 chondrites*. Four proposed hypotheses regarding the formation of the metal-rich nodules found in EL3 meteorites include origin by 1) impact melting [8], 2) melting of nebular material [9], 3) aggregation of nebular condensates [10], and 4) melting of debris from planetesimal-scale collisions [11]. Many of the metal-rich nodules display igneous textures, and the unique qualities of each nodule suggest that they formed independently from each other, by melting of nebular dust prior to accretion.

**Conclusion:** (1) NWA 8785 is an EL3 chondrite based on mineral compositions, but the abundance of matrix and presence of roedderite and djerfisherite make it anomalous. (2) The diversity of metal-rich nodules in NWA 8785 suggests that each nodule formed independently and supports an origin by primary processes prior to accretion. Presence of roedderite, a first in EL3 meteorites, as well as the FeO-rich matrix, suggests the possibility of hydrothermal alteration occurring on the E chondrite parent body.

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