CLASSIFICATION OF METAL SULFIDE NODULES IN CHONDRITIC METEORITES

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Introduction: Metal sulfide nodules (MSN), represent a small portion of the total volume of many chondrites [1]. However, MSN may contain significant amounts of untapped information pertaining to the formation of metal in chondrites and to metal fractionation from silicates in the early Solar System. MSN have been described in EH3, EL3, ordinary, and CK chondrites [e.g. 2-6]. The nodules were described by [7] as M-type (metallic) chondrules, primarily metal, with accessory sulfides, phosphides, and magnetite. MSN are distinct from inter-chondrule metal based on their concentrations of refractory siderophile elements [8] and less spherical textures.

Metal-silicate fractionation was an important process in the evolution of solids in the Solar System, and perhaps inherited in the compositions of the planets. Metal content is one of the major characteristics distinguishing chondrite groups [e.g., 8]. This study presents a detailed report on a significant number (58) of nodules in the unequilibrated ordinary and enstatite chondrites (UOC and UEC respectively). The primary goals are to document and characterize this chondrite component, understand its origin in relation to the chondrules and matrix, and better constrain potential processes that may have driven metal-silicate fractionation.

Methods: Element x-ray intensity maps were collected using the Cameca SX100 electron microprobe (EMP) at the AMNH for nine polished sections of four UOC (Semarkona [LL3.00; 4128-t1-ps2a, 4128-t4-ps7b, 4128-5, 4128-t6-ps1a, 4128-t5-ps1a], Krymka [LL3.2; 4847-1, 4847-2], Watonga [LL3.1; wat-1, wat-3], and Bishunpur [LL3.15; 532-2]) and two polished sections of two UEC (Kota-Kota [EH3; 4075-ps2a] and Qingzhen [EH3; 4653-1]). 62 individual nodules were identified and re-mapped at 1µm/pixel resolution, 15ms dwell time, 40nA beam current. Individual element maps were exported in grayscale 32-bit files and combined into color-balanced 24-bit three-element, red-green-blue (RGB) composite maps (Fig. 1). Quantitative point analysis was conducted on the EMP for Mg, Fe, Cr, Si, S, Na, Co, Ti, Al, P, Ni, Mn, and Ca at 20nA and 15kV, with a 1µm spot size.

Preliminary Results and Implications: MSN occur in primitive (O and E) chondrite groups but their mineral assemblages differ in relation to their host chondrite. MSN in both UOC and UEC range in size from 50 to 600µm (larger than some chondrules). MSN in UOC contain four primary phases: Fe-oxides ranging from magnetite to ulvospinel, troilite (20-35wt% S), taenite (up to 64wt% Ni, 0.7wt% Co), and kamacite (7-8wt% Ni). Phases are distributed heterogeneously but appear to exhibit two distinct mineralogies: Ni-dominated and S-dominated (Fig. 1). Some also contain olivine (Fo$_{\sim 93}$) and CAI-like inclusions which occur in both Ni- and S-dominated mineralogies. MSN in UEC exhibit distinctly reduced or sulfidized mineral assemblages as described by [3].

As described by [3,10] MSN in some UOC and UEC are sharply bound objects with some having layered structures. Additionally the occurrence of refractory inclusions and forsteritic olivine in some UOC MSN suggest an origin prior to accretion, similar to the chondrules. Some of the MSN in EH3 chondrites have layering consistent with condensation of minerals from a nebular gas with high C/O or formation in a sulfidizing environment. Further analysis of O-isotope ratios in olivines and siderophile elements in the MSN will help resolve their origin and relationship to other components (chondrules and CAIs) in their host chondrites.

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References: [1] Rhamdor (1973) *The Opaque Minerals in Stony Meteorites,* Elsevier, 10-15. [2] Weisberg M. K. et al. (2006) *Meteorit. Planet. Sci. 69,* 5317. [3] Lehner S. W. et al. (2010) *Meteorit. Planet. Sci. 45,* 289–303. [4] Van Nierkirk D. and Keil K. (2011) *Meteorit. Planet. Sci. 46,* 1487–1494. [5] Horstmann M. et al. (2014) *Geochimica et Cosmochimica Acta 140,* 720–744. [6] Lauretta D. S. and Buseck P. R. (2003) *Meteorit. Planet. Sci. 38,* 59-79. [7] Gooding J. L. and Keil K. (1981) *Meteoritics, 16, 1,* 24. [8] Grossman J. N. and Wasson J. T. (1985) *Geochem. et Cosmochim. Acta, 49,* 925-939. [10] Weisberg M. K. et al. (2016) *Meteor. Soc. LXXIX #6549.*

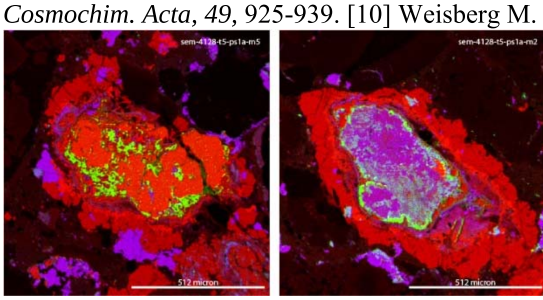

Figure 1 – Fe-Ni-S (RGB) element maps of two metal nodules in Semarkona. Phases represented are: kamacite (bright red), taenite (green), Fe-oxide (dark red), and sulfide (purple).