MICRO-INCLUSIONS IN A LAYERED CLAST IN SEMARKONA.

D. S. Ebel[1,2,3], M. K. Weisberg[1,3,4], E. Dobrică[5], J. N. Bigolski[3,1], A. J. Brearley[5], and K. Ziegler[5,6]. [1]Dept. of Earth & Planetary Sciences, American Museum of Natural History, New York, USA (debel@amnh.org); [2]Dept. of Earth & Environmental Sci., Columbia University, New York; [3]Graduate Center, City University of New York, NY; [4]Dept. of Physical Sciences, Kingsborough College, Brooklyn, NY 11235, USA; [5]Dept. of Earth & Planetary Sciences, MSC03-2040, University of New Mexico, Albuquerque, NM 87131-0001, USA; [6]Institute of Meteoritics, University of New Mexico.

Introduction: Xenoliths (*sensu stricto*) in ordinary chondrites are rare, found nearly exclusively in regolith breccias [1, 2]. We have not located any previous reports of xenoliths in the Semarkona (LL3.00) ordinary chondrite. Here, we report preliminary petrological analysis of a large object in Semarkona that may or may not be genetically related to the other objects, primarily chondrules, which accreted to form this body.

While LL chondrites exhibit complementary chondrule/matrix chemistry in some elements [3], ^{26}Al-^{26}Mg* evidence points to formation of LL chondrite components over a nearly 5 Myr period [4]. Is the object exotic, or a new kind of clast cogenetic with chondrules? Assuming Semarkona's accumulation over 5 Myrs, from a nearly chondritic (whole rock) ensemble of matrix and chondrules, what conditions in that region could have formed this clast? Alternatively, its origin as an exotic lithic fragment begs the question: From what kind of parent rock or planetesimal?

Tiny (<100 μm) spherical "microchondrules" have been reported in the sintered or accretionary rims of 200-1000 μm "normal" chondrules in least-equilibrated LL chondrites [5, 6]. Here, we report ≤100 μm Ca-, Al-rich micro-inclusions in a rim of this unusual object (Fig 1.). Such inclusions are not previously reported.

Methods: A significant part of Semarkona (LL3.00) sample AMNH #4128 was selected for serial sectioning, and cut from the main mass with a diamond blade using water. This sample (#4128-t4) was serially sectioned into four 80 - 300 μm thick sections with a 30 μm tungsten wire saw with fine boron carbide grit in oil slurry. A large clast or xenolith was found to extend through all the sections. Wow! Section 4128-t4-ps8 (~80 μm) was partially consumed for paleomagnetic study of chondrules [7], and the remaining part of ps8 is being explored in detail at UNM [8]. Section 4128-t4-ps2B was commercially prepared, and mapped at 3 μm/pixel (15kV, 40nA, 20ms/pxl) for Mg, Ni, P, Al, Ca (WDS) and Si, S, Ti, Cr, Fe (EDS) on the AMNH electron microprobe. Subregions were mapped at 1 μm/pixel (Fig. 1). Electron microprobe spot analyses (nominally 1 μm) and EDS spectra were obtained on many points of interest.

Results: The object itself appears to be unfragmented (Fig. 2), with multiple layers of differing chemistry, with an uneven, fine-grained accretionary rim. Cracks interpretable as cooling-related are roughly concentric in the interior (Fig. 2). The apparently

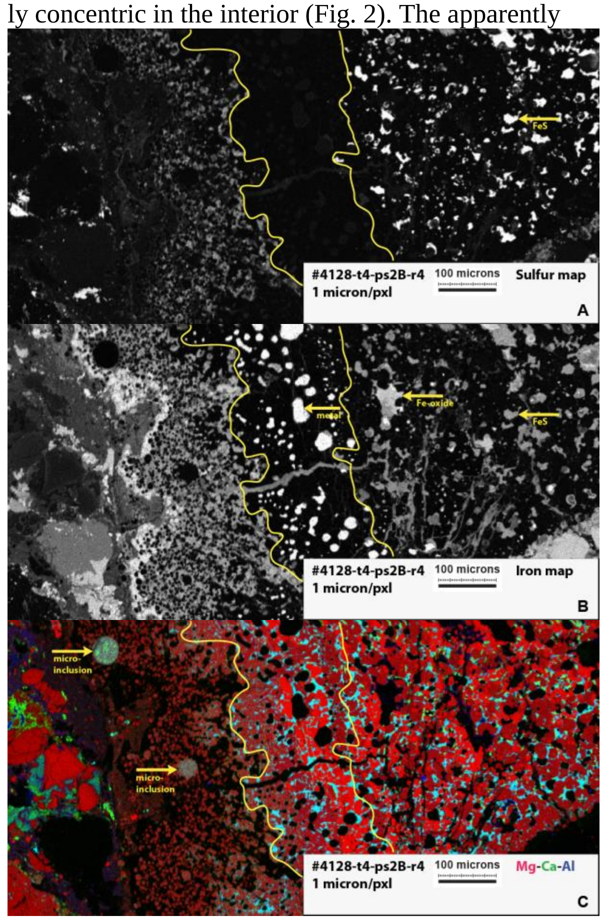

Figure 1. Sulfur, iron, and composite Mg-Ca-Al = red-green-blue x-ray maps of region r4 (Fig. 2), with S-free layer outlined (yellow). In C, forsterite is bright red, enstatite dark red, and glass blue-green.

homogeneous interior is a mixture of intimately intergrown metal-sulfide and silicate assemblages. Silicates are nearly FeO-free forsterite and enstatite, in a sparse Ca-, Al-rich mesostasis. Metal-sulfide assemblages contain Fe-rich metal grains with Ni-rich rims, Fe-sulfide, and magnetite (Fig. 1B). The assemblage may be similar to heavy-oxygen enriched "cosmic symplectite" found in the matrix of Acfer 094 (C2-ung) [9] and in comet Wild 2 samples [10]. Refractory micro-inclusions are observed in this section, in 4128-t4-7B, and in 4128-t4-ps8 [8]. These Ca-, Al-rich, spherical micro-inclusions (d ≤ 100 μm) inhabit the outer, sintered or melted layer (Fig. 1C, 2).

A remarkable feature is the S-free layer inward of the outermost sintered layer (Fig. 1A). This layer also contains little Fe-oxide (Fig. 1B), and is zoned in Mg/Si ratio, having a forsterite-rich interior and enstatite-rich layers on either side (Fig. 1C). No chemical zoning is observed in the inner part (Fig. 2).

Discussion: The refractory micro-inclusions appear to predate the rapid, short-lived heating of their host layer, based on their textural relations with surrounding pyroxene and metal sulfide. These and the layering should rule out its formation after accretion of Semarkona's LL parent body.

How did this object form, and how did it become part of Semarkona? Does it offer any clues to the formation of the chondrules in Semarkona and other LL chondrites? Is it some exotic clast thrown in from the parent-body formation going on in another part of the nebula? If so, where are the other such objects? Under what plausible nebular or contrived planetary impact conditions could such a clast form? Addressing these questions certainly requires sub-micron chemical and mineralogical analysis, and high-resolution isotopic measurements, which are in progress.

References: [1] Bischoff A. et al. (2006). Meteorites and the Early Solar System II, pp 679-712. [2] Briani G. et al. (2012). *Meteorit. Planet. Sci.* **47**:880-902. [3] Lobo A. et al. *LPSC* 45, #1423. [4] Russell S. S. et al. (1996) *Science* **273**:757-762. [5] Rubin A. E. et al. (1982) *GCA* **46**:1763-1776. [6] Bigolski et al. (2015) *MaPS* in press [7] Fu R. R., Weiss B. P., et al. (2014) *Science* **346**:1089-1092. [8] Dobrică E. et al. (2016) *LPSC* Abs. #2307. [9] Sakamoto et al. (2007) *Science* **317**:231-233. [10] Nguyen A. et al. (2015) *78th Annual Met. Soc.*, Abs. #5375.

Acknowledgments: This work is supported by NASA COS grants NNX10AI42G (DSE) and NNX12AI06G (MKW).

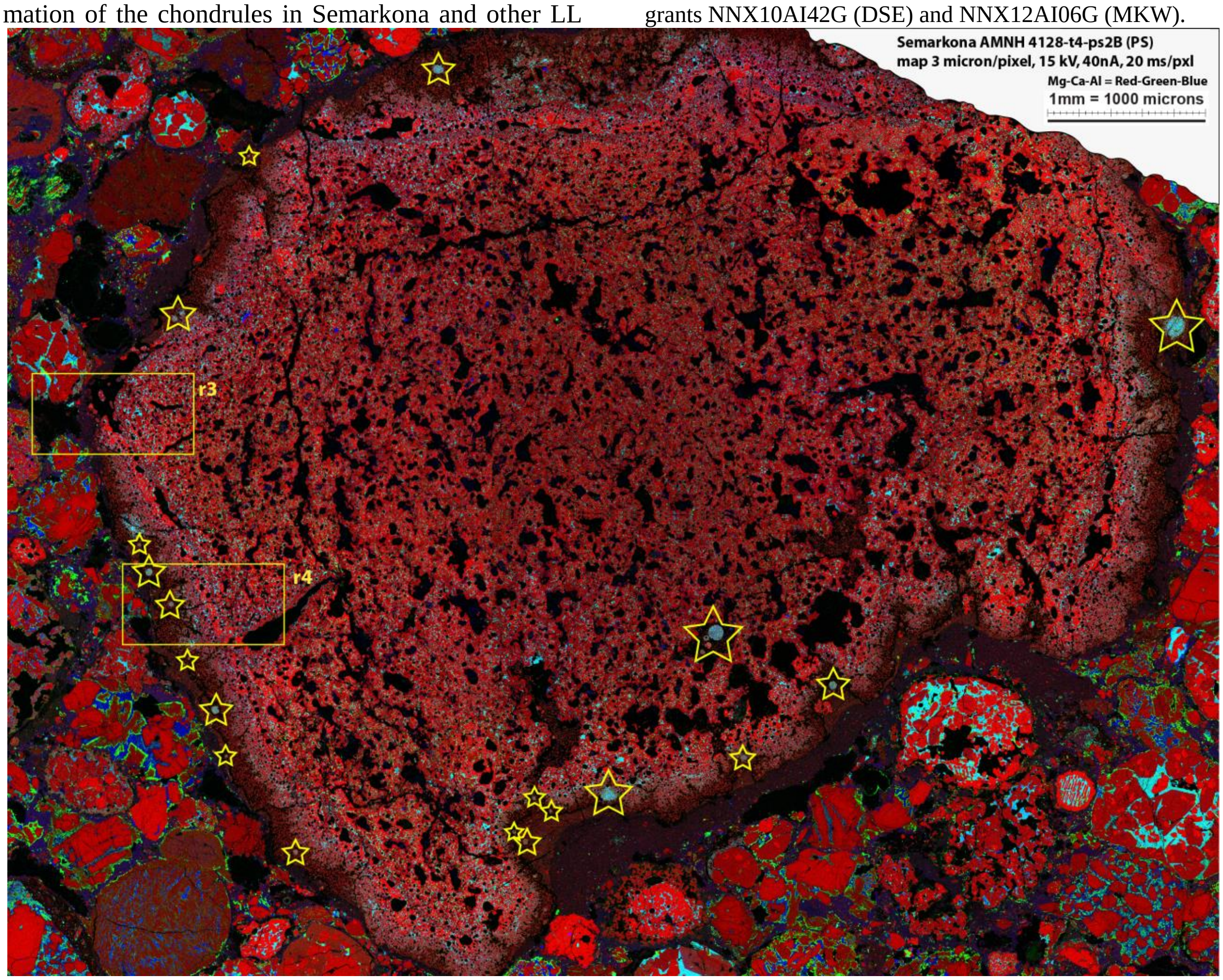

Figure 2. Mg-Ca-Al = red-green-blue x-ray composite mosaic map of polished section 1428-t4-ps2B, mapped at 3 μm/pxl. Subregions r3 and r4 were mapped at 1 μm/pxl (Fig. 2). "Micro-CAIs" are highlighted with stars. Metal-sulfide assemblages (and cracks) are black.