ANALYTICAL ELECTRON MICROSCOPY OF A CAI-LIKE PRESOLAR GRAIN AND ASSOCIATED FINE-GRAINED MATRIX MATERIALS IN THE DOMINION RANGE 08006 CO3 METEORITE.

R. M. Stroud[1], L. R. Nittler[2], and C. M. O'D. Alexander[2], [1]Naval Research Laboratory Code 6366, 4555 Overlook Ave. SW, Washington, DC 20375, USA (rhonda.stroud@nrl.navy.mil), [2]Department of Terrestrial Magnetism, Carnegie Institution of Washington, 5241 Broad Branch Rd., Washington, DC 20015, USA.

Introduction: The abundance of preserved presolar grains with isotopic compositions indicative of origins in circumstellar outflows is dramatically influenced by the degree of parent body alteration and terrestrial weathering of the host meteorite. Whereas anhydrous interplanetary dust particles have typical O-rich presolar grain abundances in the range of 375 ppm [1] and higher, the highest reported meteoritic abundances are ~200 ppm in Acfer 094 (CC ungrouped) [2] and ~190 ppm in Allan Hills (ALHA) 77307 (CO3.0) [3]. Although these meteorites are highly primitive, secondary alteration has likely had some effect on the retained distribution of presolar grain elemental compositions and microstructures in comparison with the distribution of circumstellar condensates. Preferential destruction of amorphous grains, or diffusion of matrix FeO into presolar silicates, may have skewed the meteoritic grain population. Further, *in situ* mineralogy-petrology studies of presolar silicates are needed to constrain the alteration signatures, and for identification of even more primitive meteorites that better preserve the inventory of circumstellar dust grains at the time of solar nebula formation.

We recently began a coordinated structure-isotope study of Dominion Range (DOM) 08006 (CO3), to determine its presolar grain abundance, and to characterize the mineralogy and petrology of the grains and the surrounding fine-grained matrix. The only prior study of this meteorite addresses the amino acids in CV and CO meteorites [4]. We report here preliminary results from our mineralogy study, which include the discovery of a presolar silicate with a calcium-aluminum-rich inclusion (CAI)-like core-rim structure, and the confirmation of minimal levels of aqueous and metamorphic alteration present in DOM 08006. Results from the coordinated isotope study, which demonstrate an O-rich presolar grain abundance of >240 ppm, are presented in a companion abstract [5].

Methods: A thin section of DOM 08006 was allocated by the Antarctic Meteorite Working group for these coordinated studies. Presolar grains were identified in the thin section by O-isotope measurements with the Cameca NanoSIMS 50L at the Carnegie Institution of Washington [5].

We prepared a 5 × 10-μm ultrathin-section of grain A3C-CN1 and adjacent matrix material, using *in situ* focused ion beam (FIB) lift-out methods. This grain is enriched in ^{17}O and depleted in ^{18}O ($\delta^{17}O$ = 570 ‰, $\delta^{18}O$=−370 ‰) indicating an origin in a low-mass asymptotic giant branch star. The FIB sample preparation was conducted at the Naval Research Laboratory with an FEI Nova 600 FIB-SEM equipped with an Ascend Extreme Access micromanipulator. A Pt fiducial mark to indicate the position of grain A3C-CN1 was deposited with electron beam deposition, and a C protective mask was deposited over the length of the section with the ion beam.

TEM characterization of the FIB section was performed with the NRL JEOL 2200FS scanning transmission field-emission microscope and attached Thermo Noran energy dispersive x-ray spectrometer (EDS). The EDS data were quantified with a combination of laboratory K factors determined from San Carlos olivine and Tanzanian hibonite standards, and instrument default K factors for carbon and sulfur.

Results: The extracted cross-section of the A3C-CN1 grain is ~260 nm in width (Fig. 1a), consistent with the size determined from the O isotope measurements [5]. Scanning TEM-based EDS mapping (Fig. 1b) shows that the grain is compositionally zoned, with a Mg-silicate rim surrounding inner zones of Ca- and Al-rich material. High-resolution TEM (HRTEM) imaging reveals that the Mg-silicate region is polycrystalline with lattice fringe spacings consistent with forsteritic olivine. Lattice fringes from the Ca-rich zone index to hibonite, anorthite or monticellite, but not grossite, gehlenite or akermanite. No lattice fringes definitively associated with the Al-rich zone were identified. The whole grain average composition in wt% is: 31.6% MgO, 1.81% Al_2O_3, 39.42% SiO_2, 2.29% CaO, 0.46% Cr_2O_3, 0.39% MnO, 19.7% Fe, 4.34% NiO. The olivine at the top surface of the grain, where it is most easily distinguished from adjacent matrix, shows Mg/(Mg+Fe) ~0.93. The high Ca:Al ratio indicates that hibonite is not the dominant Ca-bearing phase. However, the distinct Ca and Al-rich subgrain compositions cannot be accurately determined because they are smaller than the thickness of the FIB section.

The matrix of DOM 08006 (Fig. 1c) consists of a highly unequilibrated assemblage of amorphous Fe-rich silicate, olivines (<200 nm), pyroxenes (mostly < 500 nm), Fe and Fe,Ni sulfides (10-200 nm). No clastic grains were identified. The sulfides include both pyrrohtite and pentlandite. The polycrystalline appearance and intermediate Ni content (Ni:Fe ~ 0.3) of many of the pentlandites indicates that they may be intergrowths of metal and sulfide. The A3c-CN1 grain is located near a crack that cross-cuts the FIB section. The crack is partially filled with spongy carbon that is identified as epoxy on the basis of Cl in the EDS spectra and terrestrial C and N isotope compositions. The grains on the right side of the image below the epoxy are somewhat larger, and include a group of 3 sulfides that appear to have begun coarsening, although the Ni content of the individual grains ranges from 1.8 to 20 wt%. Two ~ 5 nm chromite grains appear at interior grain boundaries of ~1μm polycrystalline pyroxene grains. No phyllosilicates were detected in the amorphous material by either selected area diffraction or HRTEM imaging. In addition, no rims large enough to be distinguished from the matrix in dark-field STEM imaging or EDS maps were observed enclosing Mg-rich olivines or amorphous silicates.

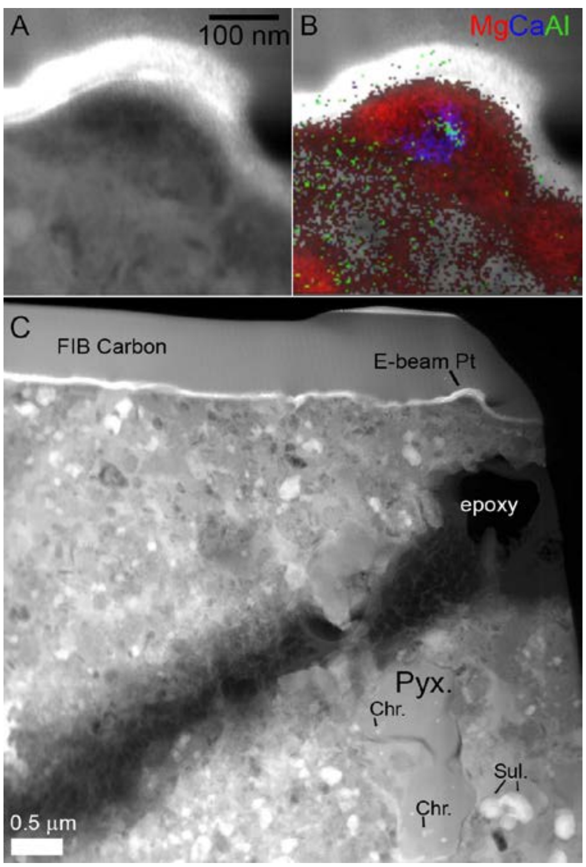

Figure 1. a) Dark field STEM image of the cross-section of presolar grain A3C-CN1. b) RGB overlay of EDS net count maps for Mg, Al and Ca. c) Dark field STEM image of the DOM 08006 matrix FIB section.

Discussion and Conclusions: To our knowledge**,** only one CAI-like presolar silicate has been identified previously, on the basis of isotope imaging and Auger electron spectroscopy elemental mapping, in Acfer 094 [2]. Attempts to section that grain for TEM analysis were unsuccessful; however the Auger analysis indicated a linear stacking of grossite, melilite and non-stoichiometric heterogeneous silicate. In contrast, the three phases present in A3c-CN1 appear to be concentric, in a sequence from interior to exterior that is in general agreement with equilibrium condensation calculations, i.e., Al-rich-oxide, Ca-rich oxide/silicate, Mg-rich olivine. The high level of Fe observed in the whole-grain average composition is common among presolar silicates, but is inconsistent with equilibrium condensation calculations for most astrophysically plausible gas compositions and pressures. Some of the detected Fe may be due to the excitation of X-rays from the adjacent Fe-rich amorphous matrix, but some incorporation of matrix Fe into presolar grain is also possible.

The TEM analyses of the surrounding matrix indicate only very modest levels of alteration. The mineralogy is very similar to that reported previously for ALHA 77307 [6, 7] and Acfer 094 [8]; all three comprise unequilibrated mixtures of amorphous silicate, olivine, pyroxene, metal and sulfides with similar grain sizes. In ALHA 77307, only the very initial stages of thermal metamorphism are recorded, as represented by 10-30 nm Fe-rich rims on sub-micron matrix olivines and amorphous Mg-Fe silicates, and minor, localized aqueous alteration in the form of layered silicates of a few nm's in size. DOM 08006 also shows only very minor indications of metamorphism and aqueous alteration, e.g., limited mobilization of Cr and coarsening of sulfides. Based on these characteristics, our data indicate that DOM 08006 is a CO3.0 to CO3.05, and that it is an excellent candidate for additional presolar grain studies. The mineralogy in the immediate vicinity of the large epoxy filled crack may be somewhat affected by terrestrial weathering. TEM studies of additional sections, and microprobe analysis of Cr contents in ferroan olivines [9] to provide a more precise determination of metamorphic grade are planned.

References: [1] Floss C. et al. (2006) *GCA 70*, 2371-2399. [2] Vollmer et al. (2009) *GCA* 73, 7127-7149. [3] Ngyuen A. et al.(2007) *ApJ. 656*, 1223-1240**.** [4] Burton et al. (2012) *MAPS 47*, 374-386. [5] Nittler L.R., et al. (2013) *LPSC XLIV* (this volume). [6] Brearley A.J. (1993) *GCA 57*, 1521-1550. [7] Brunner C.E. and Brearley A.J. (2012) *MAPS* 5403. [8] Greshake A. (1997) *GCA 61*, 437-452. [9] Grossman J.N. and Brearley A.J. (2005) *MAPS 40*, 87-122.