ABUNDANCES AND ELEMENTAL COMPOSITIONS OF PRESOLAR SILICATES IN CO3.0 CHONDRITES: POSSIBLE INDICATORS OF SECONDARY PROCESSING? P. Haenecour[1,2], T. J. Zega[3], C. Floss[1], T. K. Croat[1], B. L. Jolliff[2]. [1]Laboratory for Space Sciences and Physics Department, [2]Department of Earth and Planetary Sciences, Washington University, St. Louis, MO 63130 (haenecour@wustl.edu). [3]Lunar and Planetary Laboratory and Department of Materials Science and Engineering, University of Arizona, 1629 E. University Blvd, Tucson, AZ 85721-0092, USA.

Introduction: Presolar silicates are more susceptible to secondary heating and aqueous alteration than presolar oxides and SiC [1]. Comparison of the abundances and elemental compositions of presolar silicates in distinct matrix regions and fine-grained chondrule rims (FGCRs) in chondrites might thus be a useful tool for understanding such secondary processes [2]. CO3.0 chondrites specifically provide direct information on the processes affecting fine-grained material in the early solar system because they have only experienced minimal secondary processing [3]. Here we report on the abundances and elemental composition of presolar silicates, as well as the chemical composition and mineralogy of different fine-grained areas in the CO3.0 chondrites LaPaz Icefield (LAP) 031117, Dominion Range (DOM) 08006, and Allan Hills (ALHA)77307.

Experimental methods: Presolar grains were identified by NanoSIMS raster ion imaging of $^{12,13}C^-$ and $^{16,17,18}O^-$ secondary ions in thin sections of the three meteorites [2]. Subsequently, high-resolution secondary electron images, Auger energy spectra (from 30 to 1730 eV), and high resolution elemental maps were also acquired for most of the grains using the PHI 700 Auger Nanoprobe. We also acquired X-ray elemental maps and determined the major-element concentrations in several matrix areas and FGCRs using a JEOL JXA-8200 Superprobe [4]. Several regions of interest were extracted and thinned to electron transparency for detailed mineralogic analysis using the FEI Nova 200 FIB-SEM at ASU and FEI Quanta 3D FIB-SEM at NASA-JSC and Washington University. The FIB sections were then analyzed using the 200 keV JEOL 2500SE TEM at JSC, the 200 keV JEOL ARM TEM at ASU, and the JEOL 2000FX TEM at Washington University.

Presolar silicate and oxide grains in DOM 08006. We identified a total of 51 O-anomalous grains (49 silicates and 2 oxides) and six C-anomalous grains in the matrix of DOM 08006. This result corresponds to presolar silicate and oxide abundances (ratio of total area of the presolar grains to the total area analyzed) of 179 ± 26 ppm and 9 ± 7 ppm, respectively. Previous work [5] suggested that the silicate-to-oxide ratio may be an indicator of the degree of secondary processing experienced by a meteorite, with high ratios reflecting less processing because silicates are more susceptible to thermal/aqueous alteration than oxide grains. As shown in Fig. 1, DOM 08006 has a silicate/oxide ratio of 24.5, which is similar to the estimated ratio for dust from AGB stars (silicate/oxide ≈ 23, [6]). The presolar silicates in this meteorite are also characterized by a relatively low median Fe content (14 at.%). The high silicate/oxide ratio and presolar silicate abundance suggest that DOM 08006 is a very pristine meteorite. Initial data acquired from a FGCR in DOM 08006 show that it has a significantly lower presolar silicate abundance (58 ± 29 ppm) than the matrix, consistent with our previous report of systematic differences in the O-anomalous grain abundances between the matrix and FGCRs in CO3.0 chondrites [3].

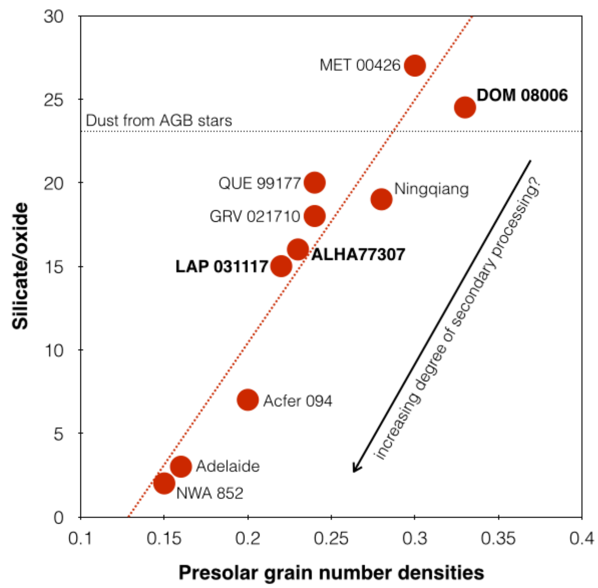

Figure 1. Comparison of the presolar grain number densities (number of grains per 100 μm^2) with the silicate/oxide ratio of carbonaceous chondrites.

Grain number densities, silicate/oxide ratios and Fe content in presolar silicates as possible tracers of secondary processing? As shown in Fig. 1, a statistical correlation ($R^2 = 0.9$) exists between the silicate/oxide ratios and presolar grain number densities measured in carbonaceous chondrites. The most pristine meteorites (e.g., DOM 08006) are characterized by high grain number densities and silicate/oxide ratios, while more altered meteorites (e.g., Adelaide) have significantly lower number densities and silicate/oxide ratios. The presolar grain number density and silicate/oxide ratio are thus useful tracers of secondary processing in carbonaceous chondrites. The median Fe content in presolar silicates in a meteorite might also provide some information on the degree of secondary processing that the meteorite experienced, as it can enhance Fe contents in presolar silicates [1]. However, we did not find any clear correlation between the number densities (or silicate/oxide ratio) and the median Fe content in presolar silicates in meteorites.

Spatial variation of presolar silicate abundances in LAP 031117. While the overall presolar silicate abundance in LAP 031117 (150 ± 13 ppm) is similar to other CO3 chondrites (overall abundance = 161 ± 9 ppm), further comparison of the presolar grain abundances between distinct matrix regions in LAP 031117 shows that there are also large variations of the O-anomalous grains abundances (up to ~200 ppm) between those areas. In particular, the abundances in FGCRs (area 6 & 7) are systematically lower than in some matrix areas (area 1 & 4) but similar to abundances in other regions (areas 5, 8, 9 & 10; Fig. 2). Because presolar silicates are more susceptible to thermal or aqueous alteration than other presolar phases, the spatial variation of presolar silicate abundances between different fine-grained areas in LAP 031117 might reflect the destruction or isotopic re-equilibration of some presolar silicates by thermal metamorphism or aqueous alteration.

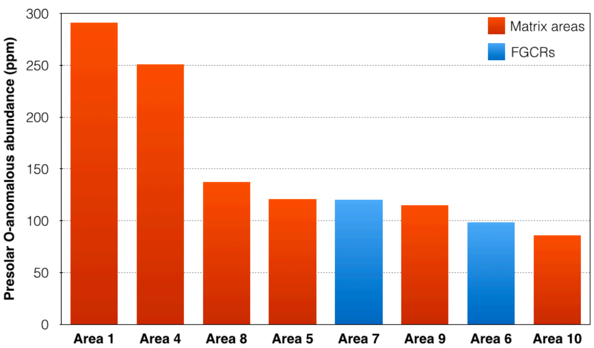

Figure 2. Presolar O-anomalous abundances in different fine-grained areas in LAP 031117.

We carried out FIB/TEM analyses of a matrix area (area 1) and FGCR (area 6) in LAP 031117 to investigate the cause of these spatial variations. Our data shows that the matrix area is mostly composed of nanocrystalline (and/or amorphous) anhydrous Fe-Mg silicates, whereas the FGCR contains abundant hydrated fine-grained material (e.g., phyllosilicates, Fig. 3). Similar local occurrences of hydrous minerals were also reported in ALHA77307 [3]. Our data indicate a possible correlation between secondary processing and presolar silicate abundances. Indeed, the more pristine matrix area is characterized by a significantly higher abundance of O-anomalous grains (291 ± 54 ppm, area 1) than in the aqueously altered FGCR (98 ± 25 ppm, area 6). The presolar grain number densities are also in agreement with these abundances; the grain number density is higher in area 1 (0.25 grains per 100 μm^2) than in area 6 (0.15 grains per 100 μm^2). These observations provide evidence that aqueous alteration might account for the spatial variation of presolar silicate abundances in LAP 031117 (Fig. 2). We are currently acquiring FIB-TEM data in additional areas within LAP 031117 (areas 4, 5, 8, 10) to confirm this observation.

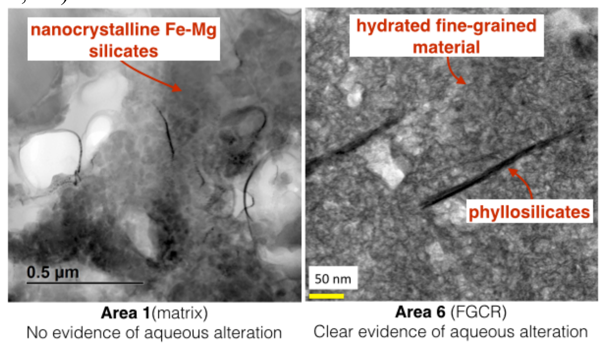

Figure 3. Bright-field scanning TEM (STEM) images of two areas in LAP 031117.

Based on the EPMA measurements, we found no clear correlation between the observed variations in O-anomalous grain abundances in different regions in LAP 031117 (Fig. 2) and the average chemical composition of these areas. Similarly, a comparison of the O-anomalous grain abundances with the elemental composition of presolar silicate grains in the different areas doesn't show any correlation. Indeed, depsite the higher degree of aqueous alteration in area 6 than area 1, the presolar silicates in these areas have the same median Fe content (about 16 at%).

Summary and conclusion. Our study indicates that DOM 08006 is characterized by both a high presolar silicate abundance and silicate/oxide ratio, confirming that this meteorite has experienced only minimal secondary processing. Moreover, comparison of the presolar silicate abundances and the mineralogy of distinct matrix areas in LAP 031117 suggests that, while CO3.0 chondrites are very primitive meteorites, they experienced some localized (μm-scale) aqueous alteration, which might be responsible for the destruction or re-equilibration of the oxygen isotopic compositions of some presolar silicates. However, the identification of presolar silicates, even in the altered areas, indicates that aqueous processing was limited.

References. [1] Floss and Stadermann (2012) MAPS 47, 992-1009. [2] Haenecour et al. (2014) MAPS 49, #5042. [3] Brearley A.J. (1993) *GCA* 57, 1521–1550. [4] Haenecour et al. (2013) LPSC XLV, #1316. [5] Floss C. and Stadermann F.J. (2009) GCA 73:2415–2440. [6] Leitner et al. (2012) ApJ 745.

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