FIB-TEM STUDIES OF A PRESOLAR SIC AND THE SURROUNDING MATRIX IN A PRIMITIVE CO3.0 CHONDRITE. T. K. Croat[1,2], P. Haenecour[1,3], and C. Floss[1,2] and [1]Laboratory for Space Sciences, [2]Physics Department, [3]Earth and Planetary Science Department, Washington University, St. Louis, MO 63130, USA, tkc@wustl.edu.

Introduction: We present results from FIB-TEM investigations of a presolar SiC grain found in a thin section from the CO3.0 meteorite LaPaz Icefield (LAP) 031117. Preparation of electron transparent sections using focused ion beam (FIB) preserves the petrographic context of presolar grains, which allows us to study any associated phases or grain coatings that are otherwise destroyed by the acid etching process used to produce presolar grain rich separates [1]. We also present transmission electron microscopy (TEM) characterization of three matrix regions (areas 1, 5, and 8) from LAP 031117, to both confirm their unequilibrated nature, and to aid in the explanation of observed variations in presolar grain abundances in this meteorite [2,3].

Samples and 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 LAP 031117, followed by acquisition of Auger spectra and elemental maps [2, 3]. FIB was then used to extract presolar grains along with adjacent meteorite matrix. These sections were studied with TEM using imaging, energy-dispersive x-ray spectrometry (EDXS), and electron diffraction for crystal structure determinations. The results from a presolar SiC in area 1 (LAP-31) and a comparison of matrix material from three FIB sections are presented, but results from the other presolar grains are still pending.

Results – *Matrix characterization*: The matrix from all three LAP 031117 sections was dominated by amorphous silicates (Fig. 1), which is similar to another CO3.0 chondrite ALHA 77307 [4]. Pyroxene grains (diameter = 500 ± 300 nm) are present in all FIB sections (comprising up to ~20% of the area; Fig. 1), and are predominantly enstatite (Fig 2a) but also include Ca-rich pyroxenes such as diopside. Olivine grains (diameters = 250 ± 150 nm) were also present in all sections, and showed a wide range of iron content (from $Fo_{99}Fa_1$ to $Fo_{28}Fa_{72}$; Figs. 2c and 2d). Fig. 3 shows a Mg-Fe-Si ternary phase diagram that contains the compositions of crystalline grains found in all three sections (with a different symbol shape for each section) along with the wide-area composition of the entire section including both amorphous and crystalline regions (3 large black symbols). Although the amount of matrix observed in each TEM section is quite limited, the abundance of crystalline grains varies among the sections and is higher in those with higher Fe content. Area 1 (with lowest wide-area Fe content) has the

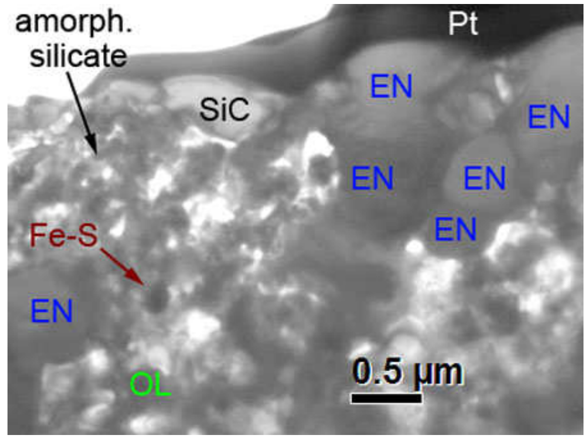

Fig. 1. TEM image of FIB section from matrix area 1 surrounding presolar SiC with crystalline phases and amorphous silicate regions labeled (same color code as ternary diagram).

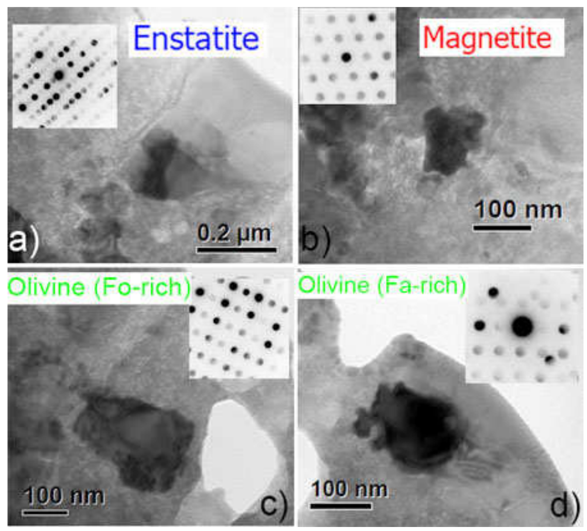

Fig. 2. TEM images and electron microdiffraction patterns from a) orthoenstatite ($MgSiO_3$; orthorhombic; a=4.8Å, b= 10.2Å, c= 6.0Å) at [100] zone, b) magnetite (Fe_3O_4; FCC; a=8.4Å) at [011] zone, c) Fo-rich olivine ($(Mg,Fe)_2O_4$; orthorhombic; a = 18.2Å, b = 8.8Å, c = 5.2Å) at [-1-1 0] zone and d) Fa-rich olivine at [1 0 0] zone.

highest fraction of amorphous silicate material, with few crystalline grains other than enstatite (Fig. 1). The area 8 FIB section (with ~40 at. % Fe on average) contains more olivine grains, whereas the Fe-rich area 5 contains significant olivine as well as magnetite (Fig. 2b) grains. However, even in the Fe-rich sections, the olivine compositions are not equilibrated (i.e. wide compositional range and forsterite is still present), which can occur with appreciable secondary alteration.

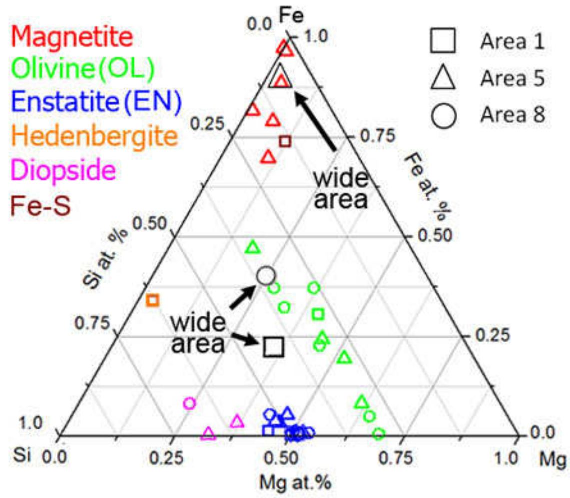

Fig. 3. Ternary phase diagram showing TEM-EDXS compositions of LAP 031117 matrix crystalline grains (color coded by phase). The three larger black symbols are the wide-area compositions of each section. These metals-basis compositions are normalized to Mg+Fe+Si=1 (Ca and Al excluded).

In-situ presolar SiC (LAP-31): C and O isotopic imaging of matrix regions in LAP 031117 located a ~1 µm diameter C anomalous grain with a $^{12}C/^{13}C$ ratio of 62.3 ± 0.3 (Fig. 4a,b). Subsequent Auger spectra (Fig. 4c) and maps of the grain showed predominately C, O and Si but lacked Mg or Fe, indicating a possible SiC grain. The presolar SiC was successfully extracted in the FIB section (Fig. 1), and the subsequent TEM image is shown (Fig. 3c). Electron diffraction patterns from the [011], [112] and [111] zones identify this grain as the 3C-SiC polytype. The EDX spectrum from the bulk of the SiC is entirely Si and C; no Al and Mg of the type often found in SiC-X grains was detected (with <0.6 and <0.2 at.% upper limits, respectively,) which is consistent with a mainstream SiC. Several TiC crystals (~50 nm diameter) were found within the SiC, and these are believed to form via exsolution from the SiC after its condensation [5]. The composition around the perimeter of the SiC is $Si_{35\text{-}48}Mg_{16\text{-}33}Fe_{8\text{-}33}Al_{3\text{-}10}Ca_{2\text{-}3}$, which is atypically Al-rich compared with most other fine-grained regions.

Discussion: The high Fe content in presolar silicates from CR chondrites may reflect the kinetic conditions during grain condensation, but can also reflect secondary processing [6]. The extent of secondary alteration of silicates and the accuracy of compositional measurements of fine-grained mixtures can both depend on grain microstructures, which can be revealed by FIB-TEM. The high abundances of both amorphous silicates and presolar grains [2, 3] along with the wide compositional range of olivine grains

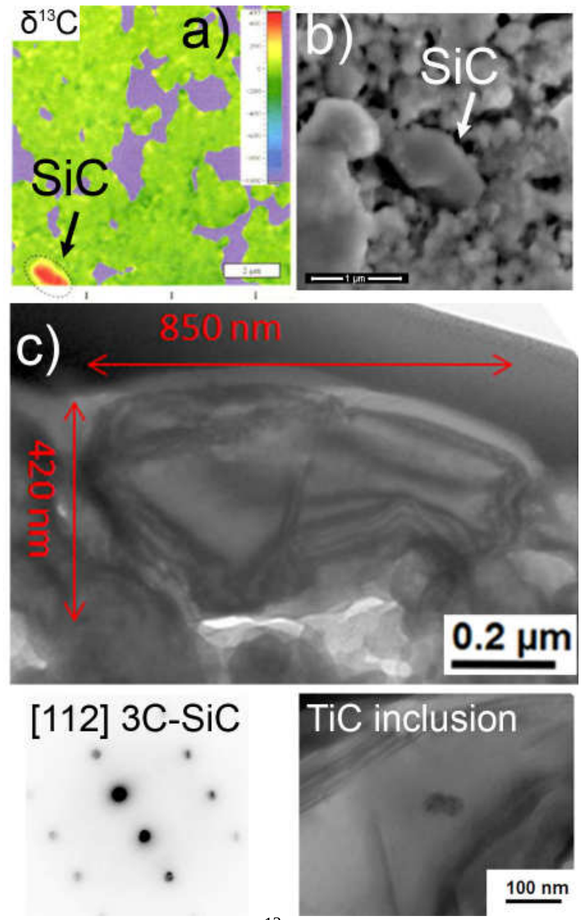

Fig. 4. a) NanoSIMS $\delta^{13}C$ ion image with apparent presolar SiC, b) secondary electron image of presolar SiC LAP-31 (post-SIMS), and c) image and microdiffraction pattern of presolar SiC at [112] orientation and close-up of ~50 nm TiC inclusion found within presolar SiC.

suggest that LAP 031117 is a relatively primitive and unequilibrated meteorite (in agreement with [7]). However, further comparative FIB-TEM studies (e.g., [8]) in different regions may uncover secondary alteration features that accompany the observed differences in presolar grain abundances [2, 3]. Features found on presolar SiC surfaces (such as apparent Al enrichment) may be primary condensation features, but further studies of such grain populations are needed to confirm their significance.

References: : [1] Bernatowicz et al. (2003) *GCA* 49, #5042. [2] Haenecour et al. (2014) *LPSC* 45, #1316. [3] Haenecour et al. (2015) *LPSC* 46, *submitted*. [4] Brearley (1993) *GCA* 57, 1521. [5] Stroud and Bernatowicz (2005) *LPSC* 36, #2010. [6] Floss and Stadermann (2009) *GCA* 73, 2415. [7] Chizmadia and Cabret-Lebrón (2009) *LPSC* 40, #2031. [8] Zega et al. (2014) *LPSC* 45, #2256.