INVESTIGATION OF FABRICS IN CO CHONDRITE MILLER RANGE 05024 USING XCT AND EBSD

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Introduction: Fine-grained rims (FGRs) are found in most classes of carbonaceous chondrites and are typically composed of grains having a similar mineralogy and grain size compared to the surrounding matrix (e.g., [1-2]). Recent studies have examined the alignment of fayalite grains within FGRs and matrix areas in CV Allende to infer its formation and impact history [3-5]. These studies are complicated however by the significant hydrothermal metamorphism that Allende has experienced which likely formed the fayalite [e.g., 4]. For example, [4] attributed the radially flattened alignment of fayalite within FGRs to have formed from a nebular compaction event(s) of original forsterite grains. These grains were then replaced by fayalite during thermal metamorphism on the parent body, but preserved the original forsterite crystal orientation and habit. For our study, we seek to test this hypothesis by checking for a preferred alignment of fortersite grains within chondrite FGRs that have experienced minimal thermal and aqueous alteration.

Methods: We selected CO Miller Range (MIL) 05024 for this study because it has been previously assigned a petrologic type of 3.1 indicating minimal thermal modification [6]. We first imaged the 1.93 g sample (MIL 05024, 31) with X-ray computed tomography (XCT) to check for brecciation and deformation fabrics. The sample was imaged on a Zeiss Versa 620 XRM at 100 kV, 12W on the 4X detector using a 10 s acquisition time and 3001 views. The data was reconstructed to 2.49 µm per voxel. We used Dragonfly software to manually segment 121 chondrules using the orthogonal plane approach described in [7] and checked for a preferred orientation of chondrules using Blob3D [8] and Stereonet 11 [9] software. The sample was then sent to JSC for sectioning and polishing (with 1 µm diamond paste and water-free colloidal silica) for electron backscatter diffraction (EBSD). Further hand polishing was done in our lab to increase the quality of EBSD diffraction patterns: 20 minutes of 0.25 µm diamond grit suspended in ethyl alcohol followed by 55 minutes of water-free colloidal silica polishing.

From the polished (uncoated) thin section, we utilized a JEOL 6490LV SEM to acquire backscattered electron (BSE) and energy dispersive X-ray spectroscopy (EDS) maps of the whole section to select an optimal chondrule FGR to investigate with EBSD. For one selected chondrule we acquired four EBSD maps within its FGR with an Oxford Instruments Nordlys Nano EBSD detector. For EBSD acquisition the section was mounted at a 70° tilt with patterns acquired at 20 kV and 20 Pa with spot size ranging from 68-88, a working distance of 18.0 mm, and a step size of 0.3 microns per pixel. Each individual FGR map was cleaned in the Oxford Aztec 2.2 software using three steps of wild spike removal followed by four steps of low to medium iterative zero solution removal. The MATLAB toolkit MTEX 5.8.1 was utilized for shape preferred orientation (SPO) and crystallographic preferred orientation (CPO) analysis [10]. Only grains that had a minimum of five contiguous pixels were included in the analysis to ensure the SPO was not biased by small grain sizes. We utilized the M Index to quantify the strength of the CPO, where M=0 indicates no fabric (random orientations) and M=1 is indicative of a strong CPO [11].

Results: XCT revealed the sample was pristine with no indications of brecciation and XCT fabric analysis found no preferred orientation of deformed chondrules suggesting the sample has not experienced significant deformation [e.g., 7]. All four FGR site maps reveal a completely random CPO with all M Indexes less than 0.01. We do find evidence for a moderate SPO within all four FGR sites that are all aligned in the same orientation within the sample. This could be evidence of a sample-wide, grain-scale compression fabric, similar to that found in CV Allende [3,5], but unlike for CV Allende there is no CPO aligned with the SPO. In addition, our XCT analysis did not indicate the presence of a deformation fabric. Therefore, we cannot yet rule out that the SPO is a data acquisition artifact caused in part by the small grain size of the FGRs relative to the EBSD map step size (0.3 µm).

Ongoing Work: To verify that the SPO is a real sample signature, we are collecting more EBSD data of this and other FGRs within the section as well as checking matrix areas for a compaction fabric.

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