ANALYSIS OF THE SHAPES OF THE CAIS IN CV CHONDRITES USING 2D AND 3D PETROGRAPHY.

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Introduction: Calcium-aluminum rich inclusions (CAIs) are some of the earliest formed materials in the solar system, with some forming before and concurrently with chondrules [1]. Interestingly, the shapes of CAIs vary in an almost extreme fashion, with some exhibiting perfectly round (molten droplet) shapes and others being highly irregular and amoeboid. Their primary structures, particularly the fluffy inclusions, indicate aggregation of small nodular structures into larger aggregates [2]. However, many CAIs were plastically and brittlely deformed during transport through the nebular gas [3-5] and/or deformation during impact-induced lithification and compaction [e.g., 6]. Thus study of the shapes of CAIs and their deformation features can provide important information on primary accretion processes in the early nebula and chondrite lithification and modification.

Here we present the preliminary results of our study of the shapes of CAIs and AOAs in a polished slab of the Allende CV3 chondrite. We also re-visit a highly deformed type B CAI from the NWA 2364 CV3 chondrite called "The Crucible" (Fig.1, [7]). Our goals are to decipher the process that resulted in the shapes of CAIs from their primary aggregation through chondrite compaction, lithification, impact modification and alteration.

Methods: CV chondrites were selected for this study due to the relative abundance and size of their CAIs. We have thus far studied 16 inclusions from a large (19.08 cm^2) polished slab of Allende from the American Museum of Natural History collection (Allende AMNH 4884). An element map of the entire slab was produced using the Cameca SX 100 electron probe (AMNH) [8] and individual inclusions were studied in detail using the JEOL JSM-6390 LV/LGS scanning electron microscope (SEM) with a Quantax 200 energy dispersive X-ray spectrometer at Kingsborough College (CUNY). Additionally we reprocessed earlier 2D images and 3D x-ray tomography data on "The Crucible".

Results and Discussion: *Allende 4884 slab #2*. The 16 inclusions studied range in size from 700 microns to 5 mm. Most appear to be elongated with some having dimensions of 2mm x 100µm. Additionally, they appear to be aligned parallel to their longest dimensions. Most of the inclusions studied are unmelted fluffy or compact varieties. All of the 16 CAIs studied in Allende 4884 show various degrees of deformation. Some CAIs exhibit plastic deformation, being indented by adjacent chondrules (Fig. 2a) and in extreme cases wrapping around chondrules (Fig. 2b). A CAI wrapped around a chondrule (Fig. 2b) is evidence for plastic deformation, most likely during or post accretion on the meteorite parent body. This highly deformed inclusion is mainly composed of MgAl spinel and hedenbergite. Hedenbergite with sodalite or nepheline is common in most of the CAIs studied indicating secondary alteration, as is characteristic of Allende inclusions. All of the deformed inclusions studied are highly altered. It is worth noting that many of the inclusions in less altered (reduced) CV chondrites, such as Vigarano do not show the same degree of deformation. Thus, there may be a relationship between degree of alteration and deformation in CV chondrites. If the oxidized CV Allende accreted with more ices as suggested by [8], impact compaction and deformation may have provided the heat and pressure necessary for mobilization and reaction with fluids on the Allende parent body. However, further observation is needed and planned to test this hypothesis.

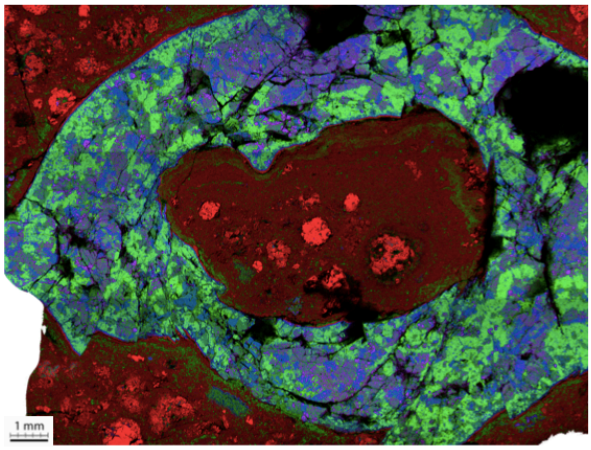

Figure 1- Red-Green-Blue/Magnesium-Calcium-Aluminum EMPA image of The Crucible, a cup-shaped CAI found in NWA 2364 (CV3). Friedrich et al. [7] shows shearing microstructures.

NWA 2364 - The Crucible. The crucible is a remarkably large (18mm in its longest dimension) bowl shaped CAI. It consists of coarse melilite, fassaite, and anorthite with abundant, heterogeneously distributed MgAl spinel. Its unusual shape is due to extensive plastic deformation and is similar to the deformed re-

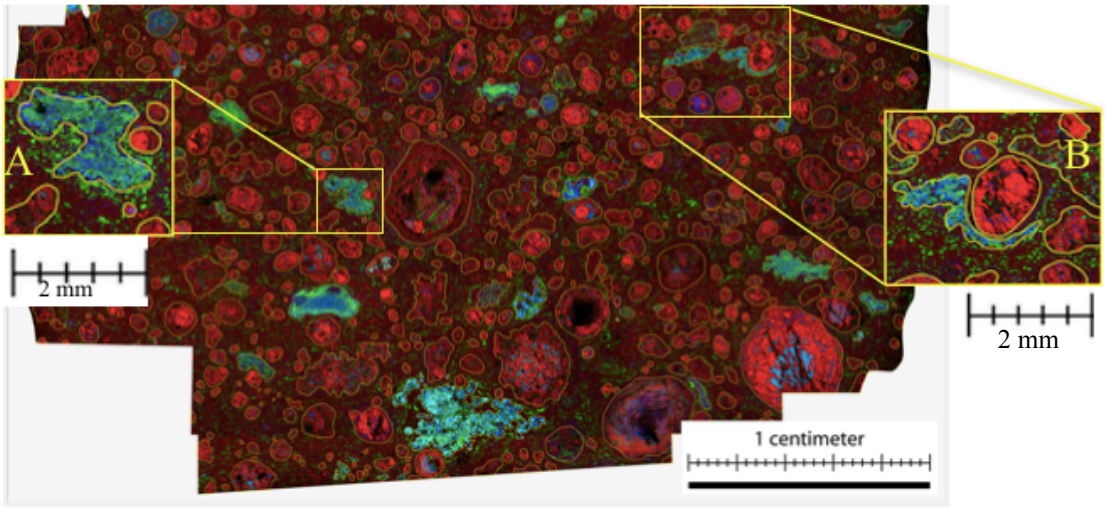

Figure 2 -A section of the Red-Green-Blue/Magnesium-Calcium-Aluminum EMPA composite x-ray map of Allende 4884 slab #2 - (A) A CAI partially wrapped around a chondrule (B) Fine grained spinel-rich CAI exhibiting plastic deformation almost entirely wrapped around a chondrule.

fractory inclusions described by [3-5]. Sections of the crucible also show sets of parallel fractures with shearing along fractures, suggesting areas of high stress. (Fig. 1) Rimming the crucible is matrix-like material that pinches and swells along deformed areas and is dislocated along some fractures suggesting rim formation prior to deformation. Filling the crucible are undeformed chondrules and matrix. More detailed study of these areas is planned to better discern the timing and location of deformation.

Conclusions: Every CAI in Allende 4884 slab #2 has undergone some degree of plastic deformation. We consider four hypotheses for the timing and environment of CAI deformation in the CV chondrites: (1) Rapid transport through a gaseous nebular environment [3-5], (2) Transport through an impact plume, (3) During chondrite compaction and lithification (either due to rapid hot accretion or lithification and compaction due to shock), (4) Post accretion impact modification.

The elongated shapes, parallel alignment, indentation by chondrules and structures that wrap around chondrules of Allende CAIs seem to favor deformation either during or after chondrite lithification, on the chondrite parent body. Although Allende has a low shock grade of S1, based on the shock classification scheme of [9], Forman et al. [6] demonstrated a more complex shock history for Allende. They showed that the chondrules and inclusions contain microstructural deformation features indicating impact-induced compaction for Allende. Thus, the Allende CAIs we studied were likely deformed during this event. The evidence of secondary alteration that is pervasive throughout Allende may have occurred simultaneously with compaction.

The Crucible, however, exhibits common features described in other deformed inclusions by [3-5]. It is a large, highly deformed inclusion, whereas other inclusions in NWA 2364 do not show evidence of the same degree of deformation. Thus, deformation likely occurred prior to accretion. Plastic deformation may have occurred during transport through the nebular gas as described by [3-5] or in an impact plume scenario.

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