THE AGUAS ZARCAS CARBONACEOUS CHONDRITE METEORITE: A STUDY OF CHONDRULES, FINE-GRAINED RIMS, AND INDICATIONS FOR A HETEROGENEOUS PARENT BODY

I. Kouvatsis[1], J.A. Cartwright[1], and W. E. Hames[2] , [1]Department of Geological Sciences, University of Alabama, Tuscaloosa, AL 35487, USA, [2]Department of Geology and Geography, Auburn University, Auburn, AL 36849, USA. E-mail: ikouvatsis@crimson.ua.edu

Introduction: Aguas Zarcas is classified as a CM2 (Carbonaceous Mighei-like, petrologic type 2) chondrite, and was recovered following a meteorite event in Aguas Zarcas, Costa Rica, on 23rd April 2019. CM chondrites are samples from primitive, water-rich asteroids that formed early in the Solar System, and are known to have recorded interactions between liquid water and silicate rock [e.g., 1, 2]. They also exhibit sizeable fine-grained rims (FGRs) – dust-like mantles that surround chondrules and refractory inclusions. The formation of FGRs and their relationship with their encompassing chondrules remains unclear, with two proposed scenarios - that they formed either within the solar nebula (e.g., [3]); or within the parent body (e.g., [4]). Here, we investigate the chondrules and FGRs within pristine Aguas Zarcas to further our understanding of formation scenarios, and processes on the CM parent body.

Methods: We performed standard microscopy observations using a Zeiss Axio Imager within the Cartwright Cosmochemistry Lab (CCL) at the University of Alabama (UA). Electron probe micro analysis (EPMA) measurements were performed on two JEOL JXA-8600 at UA and at Auburn University (AU), both equipped with Energy-Dispersive Spectroscopy (EDS) detectors. Both instruments were run at 15 kV and 20 nA for spot analyses and 15 kV and 50 nA for wavelength dispersive spectroscopy (WDS) mapping, with a 1 µm (up to 5 µm) spot size.

Results: In preliminary observations of our sample using reflected light, we identified a distinct boundary (likely the result of brecciation), while further investigation revealed two different lithologies eitherside of the boundary. Further detailed SEM analyses confirmed our observations, revealing: 1) a lithology with high chondrule abundances 'chondrule rich lithology' (CHR); and 2) a lithology with low chondrule abundances 'chondrule poor lithology' (CHP). In general, chondrules in the CHR lithology are larger than in the CHP. CHR chondrules also have larger FGRs than equivalent-sized chondrules in the CHP lithology. Additionally, several FGRs in the CHR lithology show sequential layering of different textures and compositions. We acquired EDS elemental maps of select areas in both lithologies to determine any differences in element distribution across the boundary. Most chondrules had magnesium (Mg) enrichments, while iron (Fe) enrichments were observed within FGRs The matrix appears to be further enriched in Fe. EPMA analyses show antithetic MgO and FeO changes from chondrule core to rim, with elevated Mg in the cores, and elevated Fe in the rims, towards the matrix. These changes correspond to a mineralogy change from Mg-rich serpentine (antigorite) to an Fe-rich serpentine (cronstedtite), and is likely a function of hydration temperature.

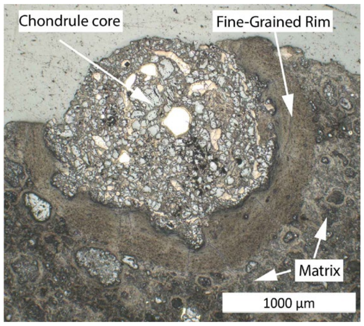

Fig. 1. A chondrule in Aguas Zarcas exhibiting a thick (~400µm) FGR.

Discussion: The boundary that separates the two lithologies likely results from brecciation, though captures two chondrule and FGR scenarios. The observed elemental discrepancies between chondrules, FGRs, and the matrix in both the CHR and CHP lithologies could be a result of: a) chondrules, FGRs, and matrix originating from different reservoirs within the solar nebula with distinct chemical compositions; b) alteration on the parent body; c) formation at different times and/or temperatures; d) a result of complementarity [5]; or e) a mixture of the above. The observed antigorite-cronstedtite assemblage, which forms layers around some of the FGRs (Mg-rich inner; Fe-rich outer) formed at different temperatures (~250 and 50-120 °C, respectively), which could be indicative of FGR alteration during progressive changes in temperature [e.g., 6, 7]. Alternatively, the serpentine sequence could have formed by pre-accretionary hydration in the solar nebula (possibly ice accretion) and later adhesion around chondrules refractory inclusions. Some potential scenarios include: i) accretion of ice within the FGRs and subsequent melting of ice and aqueous alteration of FGRs; b) pre-accretionary hydration of FGRs' components; c) existence of uncompacted altered precursor planetesimals that were destroyed and dispersed by collisions before the accretion of FGRs [3].

Acknowledgments: We are thankful to Curator Dr. Laurence Garvie from the Center of Meteorite Studies, Arizona State University for supplying the sample of Aguas Zarcas.

References: [1] Suttle M. D., et al., 2021. Geochim et Cosmochimica Acta, v. 299, p. 219-256. [2] Brearley A. J., 2006. The Action of Water, Meteorites and the early solar system II, eds. A. J. Brearley, & H. Y. McSween, p. 587-624. [3] Metzler K., et al., 1992, Geochimica Et Cosmochimica Acta, v. 56, no. 7, p. 2873-2897. [4] Sears D. W. G., et al., 1993. Meteoritics, v. 28, no. 5, p. 669-675. [5] van Kooten E., et al., 2019. Proc Natl Acad Sci USA, v. 116, no. 38, p. 18860-18866. [6] Vacher L.G., et al., 2019. Meteoritics & Planetary Science, v. 54, no. 8, 1870–1889. [7] Mellini M., et al., 1987. Contr. Mineral. and Petrol. v. 97, p. 147–155