FINE-GRAINED RIMS IN MIGHEI-LIKE CARBONACEOUS CHONDRITES: SUPPORT FOR A NEBULAR ORIGIN

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Introduction: Mighei-like carbonaceous (CM) chondrites are the most abundant carbonaceous chondrite group and are good analogues for comparison with carbonaceous asteroid returned samples [e.g., 1]. Fine-grained rims (FGRs) of silicate and opaque minerals often encircle chondrules in CM chondrites [2]. Their formation process(es) is disputed with two opposing hypotheses: (1) FGRs formed in the protoplanetary disk; fine-grained material accreted around chondrules prior to parent body accretion [2–5]; and (2) FGRs formed on the parent body after accretion via secondary processes such as aqueous alteration and impact processing [6–9]. The main objective of this study was to determine whether FGRs in CMs formed in the nebula or on the parent body. We address this by analyzing six CMs that have experienced a range of parent body processes, including heating and aqueous alteration.

Samples and Analytical Methods: The CM chondrites studied were Allan Hills (ALH) 83100,189, Elephant Moraine (EET) 96029,27, Meteorite Hills (MET) 01072,23, Murchison USNM 5376-1, Pecora Escarpment (PCA) 91008,21, and Yamato (Y)-793321,60-4. X-ray element maps of each sample were obtained with the Cameca SX-100 electron microprobe (EPMA) at the University of Arizona or the JEOL JXA-8530F EPMA at the Carnegie Institution for Science; element maps were combined into three-color FeMgSi (RGB) images using Adobe Photoshop. High-resolution images of all samples were obtained with the JEOL JXA-8530F EPMA at Arizona State University. The lengths and orientations of the major and minor axes of ~300 chondrules per sample were measured using Adobe Photoshop (chondrules in clearly distinct clasts were excluded). The abundances and sizes of FGRs were also determined using Adobe Photoshop; only FGRs around complete chondrules were included.

Results: The average chondrule diameter of 1893 complete chondrules in the six CMs was ~170 µm, smaller than previous studies (~270 µm [10]) and within error of the average CO chondrule diameter (~150 µm [10]). In this study, ALH 83100 (unheated/Stage 0, [11,12]) and MET 01072 (~Stage I heating, [12]) contained the lowest (3.3%) and highest (44.6%) proportions of FGR-bearing chondrules, respectively. Murchison (unheated, [13,14]), EET 96029 (Stage II, [14,15]), and Y-793321 (Stage II, [13]) contained abundant FGRs, while the more heated PCA 91008 (Stage III-IV, [13,14]) contained a similar proportion of FGRs, ~22 to ~36%. FGR area measurements yielded similar results; samples with the largest and the smallest FGRs both exhibit ≤Stage I heating. There was generally a positive correlation between the area of a FGR and the area of the corresponding interior chondrule. However, this correlation was weaker in more heated samples and showed that some heated CM chondrules had smaller FGRs than unheated CMs.

Discussion: Given our smaller average chondrule diameter for CM chondrites than previously accepted, we suggest that chondrule size not be solely used to differentiate between CMs and COs. The difference observed between our value and previous studies is likely due to the greater number of chondrules measured here (from a wider range of CMs) via pixel-counting of high-resolution electron images rather than by optical microscopy, thus allowing us to measure smaller chondrules. Considering the heating stages of the analyzed samples, we found no correlation between the size or abundance of FGRs and degree of heating. Additionally, the most aqueously altered sample, the CM1/2 ALH 83100, had the least number of FGRs and a larger average FGR area; chondrules with smaller FGRs were likely altered more quickly and therefore "erased" by aqueous alteration. Furthermore, our data indicates that during heating in the parent body FGRs were destroyed rather than formed. Overall, our data support a nebular origin for FGRs in CM chondrites, with parent body processes subsequently altering them significantly.

Acknowledgements: Mouti Al-Hashimi thanks the ASU/NASA Space Grant Program, the ASU Buseck Center for Meteorite Studies, and the Barrett College Fellows Program for supporting this research. We also thank the Smithsonian Institution, the Japanese National Institute for Polar Research, and the ANSMET program for the samples used in this work.

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