A NEW RECORD OF CHONDRULE SIZES WITHIN CARBONACEOUS CM CHONDRITES AND IMPLICATIONS FOR UNDERSTANDING THE CM-CO CHONDRITE CLAN

C. J. Floyd[1] and M. R. Lee[1], [1]School of Geographical and Earth Sciences, University of Glasgow, G12 8QQ, U.K. (c.floyd.1@research.gla.ac.uk)

Introduction: Variations in the sizes of chondrules between the classes of chondritic meteotites are well known [1] and are thought to result from sorting processes in the solar nebula between the periods of chondrule formation and chondrite parent body accretion [2]. Similarities in the sizes of chondrules are used as one line of evidence to link chondritic classes, e.g. the proposed CM-CO clan [1]. Unlike for other chondritic groups (e.g. CO, CV, CH, H and L chondrites) chondrule sizes within the CM carbonaceous chondrites have not been the subject of a recent, comprehensive study [3]. CM chondrules are frequently cited as being 270-300 µm in size [1,3,4], with highly variable chondrule abundances. However, several studies have reported average sizes differing significantly from the 270-300 µm value (5-6). Here we present results from a study of just under 2000 chondrules in a suite of CM chondrites with the aim of better quantifying their size ranges, and understanding potential relationships to the CO chondrites.

Methods and Samples: The meteorites studied were: Winchcombe (CM2) [7], Cold Bokkeveld (CM2.2) [8], Kolang (CM2.2) [9], Shidian (CM2.2) [10], Aguas Zarcas (CM2.2±0.1) [11], Mighei (petrologic type 1.6) [8], LaPaz Icefield (LAP) 02239 (petrologic type 1.7) [8], Murchison (CM2.5) [8], Lewis Cliff (LEW) 85311 (CM2.7) [8] and Paris (CM2.7) [12]. The apparent sizes of chondrules in 2D were measured from backscattered electron and energy dispersive electron spectroscopy mosaics. Whole chondrules were measured using the CIS method described by [13]. Chondrule sizes in 3D were measured from X-ray computed tomography (XCT) scans of meteorite chips. Chondrules were segmented and measured using the method set out by [14]. XCT scan resolution varied between samples from 12.1 - 2.1 µm/voxel.

Results: The results of 2D and 3D chondrule size analysis are in Table 1. 2D analysis used 983 chondrules and reveals an average apparent chondrule size of 2.277 ± 0.896 ϕ-units; 206 µm with individual sample averages consistently < 300 µm. Whole chondrule abundances ranged between 1.23 – 10.38 areal %. 3D analysis of 954 chondrules revealed significant variation in sizes with an average of 1.752 ± 0.832 ϕ-units; 297 µm. In those XCT datasets conducted at higher resolution (LEW 85311 and Winchcombe; <4 µm/voxel) average 3D sizes were comparable with those measured in 2D.

Table 1. A table of the average chondrule sizes within 10 CM Chondrites

Chondrule Sizes Within the CM Chondrite

Sample	Method	*n*	Major Axis Average: Phi (ϕ) ± 1σ	Major Axis Average: ϕ - mm
Kolang	BSE	80	1.723 ± 0.675	0.303
Shidian	BSE	90	1.755 ± 0.697	0.296
Aguas Zarcas	BSE	47	2.679 ± 1.045	0.156
Winchcombe	BSE	38	2.756 ± 0.726	0.148
Mighei	BSE	30	1.637 ± 0.723	0.322
LAP 02239	BSE	150	2.100 ± 0.794	0.233
Murchison	BSE	200	2.640 ± 0.833	0.160
LEW 85311	BSE	133	2.541 ± 0.839	0.172
Paris	BSE	215	2.239 ± 0.920	0.212
Cold Bokkeveld	XCT	103	1.130 ± 0.499	0.457
Aguas Zarcas	XCT	313	1.454 ± 0.500	0.365
Winchcombe	XCT	204	2.500 ± 0.665	0.177
Murchison	XCT	180	1.101 ± 0.579	0.466
LEW 85311	XCT	154	2.542 ± 0.583	0.172
BSE Average	-	-	2.277 ± 0.896	0.206
XCT Average	-	-	1.752 ± 0.832	0.297

Discussion: Results presented here indicate a potential overestimate withinin the literature of the true CM chondrule size, with chondrules significantly closer in size to those observed in the CO chondrites (CO reported average: 2.76 ± 0.923 ϕ-units; 148 $^{+132}_{-70}$ µm [15]). This finding further supports a genetic link between the CM and CO chondrites (CM-CO clan) and consequently, the use chondrule size differences between the two classes should not be considered evidence of distinct parent asteroid origins with respect to these two chondritic classes [16].

References: [1] Weisberg M. et al. (2006) *Meteorites and the Early Solar System II,* 19-5 [2] Teitler S. et al. (2011) *Meteoritics and Planetary Science*, 45, 1124-1135 [3] Friedrich J. et al. (2015) *Chemie der Erde, 75,* 419-443 [4] Rubin A.E. & Wasson J.T. (1986) *Geochimica et Cosmochimica Acta,* 50, 307-315 [5] Mouti X. et al. (2018) *LXXXIV Meteoritical Society Meeting*, Abstract #6129 [6] Fendrich K. & Ebel D. (2021) *Meteoritics and Planetary Science*, 56, 77-95 [7] Meteoritical Bulletin Database, accessed 4 May, 2022 [8] Lee M. et al. (2019) *Geochimica et Cosmochimica Acta* , 264, 224-244 [9] King A. et al. (2021) LPSC LII, #1909 [10] Fan Y. et al. (2020) *LPSC LI*, #1234 [11] Martin P. M. C & Lee M..R (2021) *LPSC LII,* #2068 [12] Rubin A. (2015) *Meteoritics and Planetary Science,* 50, 1595-1612 [13] Floyd C. & Lee. M (2022) *Meteoritical Society Meeting* LXXV (This Meeting) [14] Hanna R. et al. (2015) *Geochimica et Cosmochimica Acata,* 171, 256-282 [15] Rubin A. (1989) *Meteoritics,* 24, 179-189 [16] Schrader D. & Davidson J (2017)) *Geochimica et Cosmochimica Acta,* 214, 157-171

Acknowledgements: We would like to thank ISAAC at the University of Glasgow alongside funders STFC and SAGES.