EXPLORING THE CONNECTION BETWEEN CM-CO CLAN CHONDRITES THROUGH ANOMALOUS AND MISCLASSIFIED MEMBERS

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Introduction: In addition to CM and CO chondrites, the CM-CO clan contains a large diversity of members with intermediate or unique geochemical and/or petrographic characteristics. Consequently, various authors have suggested that multiple parent bodies were involved in producing the clan [1,2]. Strong affinities have recently been found between many of them [3,4]. Others may be primitive CMs [5]. Here we further explore the connection between CM-CO clan chondrites by studying the classification of eight anomalous members. To do this we combined bulk oxygen isotopic measurements (most from [2,6,7,8]), petrographic observations as well as IR transmission spectroscopy (method: [9]). Raman spectra (method: [10]) were measured of Miller Range (MIL) 090073 carbonaceous matter.

Designation	Matrix	Magnetite	Metal	Sulfides	Chondrule size	$\delta^{18}O$ (‰)	$\delta^{17}O$ (‰)	Minerals from IR spectra	Classification
MET 00633	72 vol%	0.3 vol%	0.2 vol%	0.9 vol%	308±203 μm (n=69)	2.34	−1.57	Phyll, Ol	CM2
MET 01077	45 vol%	2.4 vol%	0.2 vol%	3.3 vol%	193±132 μm (n=202)	−3.33	−5.99	Ol, Enst	CO3
MIL 090785	69 vol%	trace	0.3 vol%	0.5 vol%	257±117 μm (n=101)	−9.36 [6]	−8.87 [6]	Sulfa?,Ol, Enst	Uncertain
EET 83355	34 vol%	4.0 vol%	0.4 vol%	0.8 vol%	254±104 μm (n=84)	−4.67 [2]	−7.44 [2]	Ol, Enst	Heated CO2? (TIII [13])
NWA 13689	49 vol%	9.3 vol%	trace	1.2 vol%	237±131 μm (n=161)	0.47 [8]	−4.08 [8]	Ol, Enst	C3-ung
MAC 88107	49 vol%	8.6 vol%	trace	1.6 vol%	174±108 μm (n=332)	−1.71 [2]; −0.94 [7]	−5.52 [2]; −4.88 [7]	Ol, Enst	C3-ung
MAC 87300	53 vol%	5.6 vol%	trace	0.7 vol%	178±109 μm (n=195)	−3.48 [2]; −1.00 [7]	−6.74 [2]; −4.47 [7]	Phyll, Ol, Enst	C2-ung
MIL 090073	72 vol%	trace	trace	3.4 vol%	252±201 μm (n=113)	4.50 [6]	−1.27 [6]	Ol, Enst	Heated CM2 (TIII?)
CO average [15]	34 vol%				~150 μm	Aprox. −5 to 0 [1]	Aprox. −5 to 10 [1]	Ol, Enst	type-3
CM average [15]	70 vol%				~300 μm	Aprox. 2 to 12 [1]	Aprox. −3 to 4 [1]	Phyll, Ol	type-2

Summary of geochemical and petrographic analysis (plus data from [15]), and minerals detected by IR spectra. In our samples, the chondrule size refers to the apparent average diameter of equivalent circular chondrules. Abundances were determined by point counting. Ol = Olivine, Enst = Enstatite, Sulfa= Sulfates, Phyll= Phyllosilicates.

Primary classification: Petrographic observations and bulk oxygen isotopic analysis are consistent with: *(i)* Meteorite Hills (MET) 00633 and MIL 090073 being CM chondrites (in agreement with [6]); *(ii)* Elephant Moraine (EET) 83355 and MET 01077 being possible CO chondrites, and *(iii)* MIL 090785 being distinct from typical CMs and COs. MacAlpine Hills (MAC) 87300 (C2-ung), MAC 88107 (C3-ung) and Northwest Africa (NWA) 13689 (C3-ung) have particularly similar petrographic and comparable oxygen isotopic compositions, perhaps suggesting they may form a "grouplet". The oxygen isotopic compositions of MET 00633 and MIL 090073 are similar to that of Paris [11], typical of CMs having experienced low levels of aqueous alteration [5].

Secondary History: The IR spectra of MET 00633 is similar to CM(-like)s having experienced low degrees of aqueous alteration [13]. MIL 090073 appears somewhat dehydrated (consistent with [6]), much like the most heated CMs [9,14]. However, raman spectroscopy suggests that it is only slightly heated, indicating that the meteorite was initially not very hydrated. MET 01077 and MIL 090785 display petrographic and spectroscopic evidence supporting a type-3 classification. EET 83355 mainly differs from typical COs due to its secondary history, which is closer to heated CM2s rather than CO3s [15]. Thus, seen that it was likely once hydrated [14], EET 83355 could be considered a dehydrated CO2. Despite a similar magnetite distribution in MAC 87300, MAC 88107 and NWA 13689, only the former shows phyllosilicates in its IR spectrum. This suggests that the latter two may have been heated.

Discussion: Many of our samples display overlapping traits with CMs and COs, whether it be their petrography, oxygen isotopic composition and/or secondary history. At first glance, this may support a common parent body origin for the CM-CO clan, in which the parent body was highly heterogeneous. However, the diversity may also be an indication of a large number of parent bodies having accreted in proximity. In particular, MAC 87300, MAC 88107 and NWA 13689 could represent fragments of a single parent asteroid. MIL 090785, being distinct from typical CMs and COs, may have originated from a separate parent body. Seen its thermal history, one could speculate that EET 83355 originated close to the surface of the CO parent(s) asteroid(s).

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