PRIMITIVE CM-RELATED CHONDRITES: THEIR CHARACTERISTIC FEATURES AND CLASSIFICATION.

M. Kimura[1], N. Imae[1], A. Yamaguchi[1], R. C. Greenwood[2], M. Komatsu[3], and T. Noguchi[4], [1]National Institute of Polar Research, Tokyo 190-8518, Japan (kimura.makoto@nipr.ac.jp), [2]The Open University, Milton Keynes MK7 6AA, United Kingdom, [3]SOKENDAI, Kanagawa 240-0193, Japan, [4]Kyushu University, Fukuoka 819-0395, Japan

Introduction: CM chondrites are the most abundant group of carbonaceous chondrites (CC) (37 % of CC falls according to the Met. Bull. Database) and appear to be widely distributed within the inner Solar System, occurring as brecciated fragments and clasts in a wide range of meteorite types [1]. In addition, CM chondrites are likely to be related to samples returned by the Hayabusa2 and OSIRIS-REx missions. CMs experienced varying degrees of aqueous alteration and thermal metamorphism [2,3]. Their primitive features are not well understood, although some weakly altered CM and related chondrites have been identified [4]. Recently, Yamaguchi et al. [5] reported three CM chondrites, Asuka (A) 12085, A 12169, and A 12236, that experienced very low degrees of thermal metamorphism and aqueous alteration. Here we present our preliminary results on these samples and discuss their classification and primary features.

Results: A 12085, A 12169, and A 12236 show typical carbonaceous chondritic textures and mineral assemblages, including refractory inclusions (CAIs and AOAs) (4.2, 4.3, and 3.8 vol.%, respectively), abundant chondrules (36.0, 38.6, and 28.9 %), and matrices (57.7, 53.4, and 64.8 %). Melilite commonly occurs in CAIs. Secondary phases, such as nepheline and phyllosilicates, in these CAIs and AOAs are extremely rare. FeO-rich rims on magnesian olivines in AOAs, which are often present in more metamorphosed COs [6], are absent in these meteorites. The average chondrule diameters in A 12085, A 12169, and A 12236 are 0.31, 0.26, and 0.29 mm, respectively. Glass and unaltered anorthite commonly occur in A 12169 chondrules and were also identified by Raman spectroscopy. These phases are also present in some chondrules from A 12236, but occur only rarely in A 12085. The distribution of olivine compositions in Type II chondrules in these chondrites are similar to those in primitive COs [7] and some CM chondrites [8]. The abundances of Fe-Ni metal are 1.2, 2.3, and 1.5 vol.% in A 12085, A 12169, and A 12236, respectively. Metal in chondrules is usually homogeneous. Positive Ni-Co relationships were detected in metal grains present within the matrices of these meteorites. The mean totals of the matrices by electron microprobe measurement are 91.3, 95.9, and 90.1 wt. % in A 12085, A 12169, and A 12236, respectively. No typical tochilinite-cronstedtite intergrowth (TCI) was observed and carbonate minerals are very rare in these chondrites. The X-ray diffraction patterns, measured by the method of [9], show no detectable phyllosilicates or tochilinite in A 12169 and A 12236. Cronstedtite was detected only in A 12085. Troilite was identified in A 12085, A 12169, and A 12236 by the X-ray diffraction and is often accompanied by pentlandite.

Discussion: The modal abundance and chondrule size distribution of A 12085, A 12169, and A 12236 are typical of CM chondrites. However, the common occurrence of melilite in CAIs and glass in chondrules, abundant Fe-Ni metal, no TCI, almost no phyllosilicate, and high total weight % of the matrix in A 12169, suggest that this chondrite experienced only minimal aqueous alteration. Based on petrographic evidence, the degree of the alteration increases from A 12169, through A 12236, to A 12085. The texture and compositional distribution of Fe-Ni metal in these chondrites is closely similar to that of the ungrouped, primitive chondrite Acfer 094 [10]. Sulfide features are typical of CM chondrites that did not experience dehydration [11]. Therefore, petrographic and compositional evidence indicates that these chondrites did not experience either significant thermal metamorphism or dehydration. The occurrence of glass, lack ferroan rims on AOA olivines and compositional distribution of olivine in Type II chondrules, also support this conclusion. From these features, we suggest that these chondrites, especially A 12169, are the most primitive CM or CM-related chondrites so far reported. Therefore, these new primitive CMs and in particular A 12169, provide a unique opportunity to investigate the primary features of CM chondrites, as well as the genetic relationships of CM-CO clan chondrites. These chondrites are of particular significance in view of the imminent return of sample material from CM-related asteroids Ryugu and Bennu.

References: [1] Zolensky M. E. et al. 1996. *Meteoritics & Planetary Science* 31:518-537. [2] Rubin A. E. et al. 2007. *Geochim. Cosmochim. Acta* 71:2361-2382. [3] Nakamura T. 2005. Journal of Mineralogical and Petrological Science 100:260-272. [4] Ebert S. et al. 2019. *Meteoritics & Planetary Science* 54: 328-356. [5] Yamaguchi A. et al. 2018. *Meteorite Newsletter* 26. [6] Chizmadia L. J. et al. 2002. *Meteoritics & Planetary Science* 37:1781-1796. [7] Grossman J. N. and Brearley A. J. 2005. *Meteoritics & Planetary Science* 40:87-122. [8] Schrader D. L. and Davidson J. 2017. *Geochim. Cosmochim. Acta* 214:157-171. [9] Imae N. et al. 2019. *Meteoritics & Planetary Science* 54:919-937. [10] Kimura M. et al. 2008. *Meteoritics & Planetary Science* 43:1161-1177. [11] Kimura M. et al. 2011. *Meteoritics & Planetary Science* 46:431-442.