

## Petrologic subtypes of CM chondrites: Reinvestigation and proposal of subtypes 3.0 to 2.8

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CM chondrites are the most abundant group of carbonaceous chondrites, and 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 [1-4]. Recently, Kimura et al. [5] reported three CM (or -related) chondrites, Asuka (A) 12085, A 12169, and A 12236, that experienced very low degrees of aqueous alteration and thermal metamorphism. Here we discuss the classification system of CM chondrites, based on the petrological and mineralogical data on these Asuka chondrites [5].

A 12085, A 12169, and A 12236 show the modal abundance and chondrule size distribution typical of CMs. However, the common occurrence of melilite in CAIs and glass in chondrules, abundant Fe-Ni metal and troilite, no tochilinite-cronstedtite intergrowth (TCI), low abundance of phyllosilicate, and high total weight % of the matrix suggest that these CMs experienced only minimal aqueous alteration. The degree of the alteration increases from A 12169, through A 12236, to A 12085. The texture and compositional distribution of Fe-Ni metal, sulfide texture, and Raman spectroscopic data for the matrices indicate that these CMs did not experience dehydration. Therefore, they experienced neither significant aqueous alteration nor thermal metamorphism. These chondrites are the most primitive CM or CM-related chondrites so far reported [5].

CM chondrites have been classified into CM2.7-2.0 [2], based on the criteria such as the alteration degree, matrix composition, metal abundance, TCI feature, sulfide mineralogy, and occurrence of carbonate. However, most of these criteria cannot be applied for the classification of A 12085, A 12169, and A 12236. Instead, many characteristic features of these chondrites show very low degrees of the aqueous alteration, higher than subtype 2.7.

Rubin [2] hypothesized that CM3.0 should have some distinct features if it present, such as the occurrence of chondrule glass and minor phyllosilicate. We modified his criteria, and propose the following criteria for CM3.0 to 2.8. CM3.0: abundant primary glass and feldspar in chondrule, rare or no phyllosilicate in the matrix, unaltered phenocryst, abundant metal (>2 vol.%), no TCI, abundant troilite, and no carbonate. CM2.9: glass>phyllosilicate in chondrule mesostasis, and rare phyllosilicate in the matrix. CM 2.8: phyllosilicate>glass in chondrule, minor phyllosilicate in the matrix, and rare carbonate. From these criteria, A 12169, A 12236, and A 12085 are classified as subtype 3.0, 2.9, and 2.8, respectively.

Some heavily altered CM chondrites are often classified as CM1. However, Rubin [1] proposed that they should be called as CM2.0, not CM1. We support his suggestion. Some heavily altered CMs, such as A 12248 CM2.0, contain only relict (pseudomorph) chondrules almost replaced by phyllosilicate, which is in contrast to typical CI1 chondrites. Petrologic type 1 was defined as chondrite without any chondrules [6]. Therefore, if CM chondrites have relict chondrules, they are CM2. Thus, almost all CM chondrites so far reported are classified as subtypes 3.0 to 2.0.

CMs experienced the complicated evolutionary history in various degrees. However, the classification system proposed here is useful not only for classification of them, but significant to clarify the history in the parent body.

### References

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