Variations of CM chondrites evaluated from X-ray diffraction

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Introduction: CM chondrite is the most major chemical group of carbonaceous chondrites, characterized of various degrees of hydrous alteration (Rubin et al. 2007) and various degrees of secondary dehydration (Nakamura 2005; Kimura et al. 2011). In the present study, we obtained emulating powder X-ray diffraction patterns from polished thin sections of 10 CM chondrites, analyzed the obtained data using the modal abundance by Howard et al. (2011), and compared these data with the textures and mineral compositions.

Experiments: Cu Kα was used, removing Cu Kβ using Ni filter, which was produced at tube voltage 40 kV and tube current 40 mA for X-ray diffractometer at NIPR (SmartLab, RIGAKU). The length limiting slit size was 5 mm with divergence angle (1/6)º, and the X-ray irradiated area on the sample is ~40 mm^2 at 2θ = 20º, ~30 mm^2 at 30º, and 25 mm^2 at 40º. Measured 2θ was 3-90º. Samples are Queen Alexandra Range (QUE) 97990 2.6 (82 mm^2), Murchison 2.5 (469 mm^2), DOM 03183 2.5 (9 mm^2), Y-791198 2.4 (70 mm^2), QUE 99355 2.3 (60 mm^2), Scott Glacier (SCO) 06043 2.0 (45 mm^2), Meteorite Hills (MET) 01070 2.0 (38 mm^2), Y 980036 2.4-2.5 II (100 m^2), Y 980051 2.4-2.5 II (28 mm^2), and Jbilet Winselwan 2.4-2.7 II (109 mm^2). The number such as 2.x shows subtype (Rubin et al. 2007). Roman numeral is the heating stage (Nakamura 2005), and no Roman numeral means unheated sample. The number in parentheses are the surface area of polished thin section. Focused Miller indices are serpentine (001) and (002), olivine (020), (130), (021), (041), (122), (140), clinopyroxene (021), (220), (310), diopside (310), kamacite (110), troilite (114), pyrrhotite (102), gypsum (100), calcite (104), and so on. Textures and compositions were studied for comparison and for compensation using field emission scanning electron microscope (JSM-7100F, JEOL) and electron probe micro analyzer (JXA-8200, JEOL).

Results and Discussion: Serpentine consists of cronstedtite (Fe-rich) and antigorite (Mg-rich), and both increase in decreasing subtype (2.6 to 2.0). Instead, olivine, clinopyroxene, kamacite, and troilite decrease in decreasing subtype. While heated types are dehydrated, showing different feature. Tochilinite occurs intermediate subtypes mainly for 2.3-2.6, but not for 2.0 and heated samples. The S/SiO_2 and "FeO"/SiO_2 plot for compositions of tochilinite-cronstedtite-intergrowths (TCIs) by EPMA reflects the subtype to some extent. The calibration of intensity ratios for olivine, pyroxene, and serpentine were carried out using the modal abundances by Howard et al. (2011). Then, DOM 03183 and QUE 99355 for these phases are obtained to be 5.7% and 11.8%, 4.0% and 3.4%, and 70.0% and 88.0%, respectively.

Recently the least altered CM chondrites were identified, and they are A 12169 3.0, A 12236 2.9, and A 12085 2.8 (Kimura et al. 2020) as well as Paris 2.7 (Hewins et al. 2014). Thus, the combination of 11 alteration degree and 5 heating stage is 55. The variation and identification are important for clarifying the geological history of CM chondrite parent body. The present technique would be useful for the identification.

Implications: Ryugu is the target asteroid for the HAYABUA2 sample return mission, and the capsule with sample will return to the Earth on 6 December 2020. The CM chondrite is one of the most plausible candidates (Kitazato et al., 2019). It is rubble pile asteroid with the accretion to form top-shaped body via catastrophic destruction onion shell structure (Watanabe et al., 2019).

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