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Dehydration and rehydration of hydrous carbonaceous chondrites

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Asteroidal water in hydrous C-complex asteroids is one of the possible source of Earth's ocean. The hydrous C-complex asteroids consist of hydrous carbonaceous chondrites and therefore the water came to the earth as such hydrated meteorites. CM chondrites are the most abundant group of carbonaceous chondrites, composed mainly of hydrous minerals such as serpentine (cronstedtite) and tochilinite. They show 0.7-μm and 3-μm absorption bands in the reflectance spectra. The 0.7-μm band is a spectral feature characteristic of CM chondrites, because it is common in CM chondrites and rare in other hydrated carbonaceous chondrites (Cloutis et al. 2011). Recent investigation on spectral data of asteroids indicated that 30$\pm$5% of C-complex asteroids shows 0.7-μm band (Rivkin, 2012), suggesting that CM materials are also common at main belt asteroids.

Some CM chondrites have been heated to temperature sufficient for dehydration of hydrous minerals (e.g., Akai, 1990: Nakato et al. 2008) and are classified to heating stage I to IV based on the degree of heating (Nakamura, 2005). On the other hand, not a few C-complex asteroids show reflectance spectra similar to dehydrated CM chondrites (Hiroi et al. 1993). In the present study, we performed analyses of reflectance spectra, X-ray diffraction, and water contents of hydrated and dehydrated CM chondrite samples. In addition, heating experiments were conducted in order to observe changes of reflectance spectra, X-ray diffraction, and water content with increasing temperature. Murchison CM chondrite was heated for 50 hours at temperatures of 400, 600, and 900 ℃ at IW oxygen buffer.

Heating experiments showed that tochilinite decomposes and serpentine partly becomes amorphous at 400 ℃, serpentine completely decomposes and secondary olivine nucleates at 600 ℃, and olivine becomes well crystalline and metallic FeNi generates at 900 ℃. The samples heated at 400, 600, and 900 ℃ reproduced the mineralogy of CM chondrites with heating stage II, III, and IV, respectively. The 0.7-μm band disappears by heating at 400 ℃. The 3-μm band strength decreases with increasing temperature, but does not disappear even at 900 ℃. Water contents of unheated and experimentally heated Murchison samples were determined by the Karl Fischer titration method with stepped heating: 10.0, 6.6, 1.2, and 0.6 wt% of water recovered from unheated, 400, 600, and 900 ℃ samples, respectively. The result clearly indicates that the dehydration proceeds with increasing temperature. On the other hand, in the stepped heating analysis, most of the water was released below 600 and 900 ℃ from 600 and 900 ℃ heated samples, respectively. This indicates that water in the 600 and 900 ℃ samples (1.2, and 0.6wt%, respectively) was acquired into samples by rehydration in the atmosphere after heating experiments. The rehydration water is tightly bounded to samples, because the largest release of water was detected at 400 ℃ from both 600 and 900 ℃ heated samples. If we omit rehydration water from the total water contents, then dehydration is completed in Murchison by heating at 600 ℃ for 50 hours (heating stage III).

On the other hand, the results of reflectance spectra measurement of naturally heated CM chondrites reveals that even samples of heating stage IV such as Dho735, B7904 and Y86720 show 3-μm absorption band, which suggests rehydration. Water-content analysis of Dho735 confirms the rehydration: most of water was released at 300~600 ℃. The water analysis concludes that dehydrated CM chondrites are a strong water absorber. This suggests that dehydrated-CM materials on the surface of C-complex asteroids would resorb the water released upon impacts of hydrous micrometeorites from other asteroids and comets.

Keywords: aqueous alteration, C-complex asteroids, reflectance spectra, water analysis