

Characterization of aqueous alteration of CR chondrites based on reflectance spectra

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Aqueous alteration is the earliest chemical reaction taken place in primitive asteroids. It is important to study the conditions of the reactions to understand the early evolution of asteroids. C-complex asteroids, which are most abundant in the outer asteroid belt, retain the records of aqueous alteration. Therefore, we need to investigate the mineralogy and the degree of aqueous alteration of the C-complex asteroids using reflectance spectroscopy. The surface mineral composition of these asteroids can be inferred based on reflectance spectra of carbonaceous chondrites. CR chondrites are known to have experienced aqueous alteration to varying degrees and no or weak thermal metamorphism (e.g., Wasson and Rubin, 2010; Alexander et al., 2013). However the effects of aqueous alteration on reflectance spectral features for CR chondrites are not fully clarified yet mainly due to Fe oxyhydroxides (terrestrial weathering products of Fe metal: FeOOH (e.g., Garenne et al., 2016)). Therefore, we need to measure reflectance spectra of CR chondrites with no Fe oxyhydroxides. In the present study, we measured reflectance spectra of 9 CR carbonaceous chondrite fragments (~1 cm in size) with a wavelength range from 0.38-25 μm under vacuum (~2 hPa) using a normal FT-IR (Fourier Transform Infrared) spectrometer with a beam size about 4 mm in diameter. We also measured reflectance spectra of 3 CR chondrites under N₂ purge using a micro-FT-IR spectrometer with a beam size (~150×150 μm). Micro-FT-IR enables to obtain spectra of fine-grained matrix areas with no Fe oxyhydroxides to avoid the effect of oxyhydroxides. Then, we investigated relationships between features of reflectance spectra and mineralogical properties and reflectance spectral features, especially between the degree of aqueous alteration and properties of the 3- μm absorption bands that are related to hydrous minerals. All CR chondrite matrices were characterized for mineralogy by synchrotron X-ray diffraction performed at KEK. Matrix of the 3 CR samples measured by micro-FT-IR were observed by FE-SEM/EDS.

When we measured CR chondrites fragments using normal FT-IR to measure bulk composition, no correlation was found between the alteration degree and the 3- μm band position and depth. The 3- μm band has a wide and sharpened shape. This feature is similar to that of Fe oxyhydroxide Akaganeite and unlike serpentine. In addition, this characteristic 3- μm band features are observed from CR chondrites with lots of Fe oxyhydroxides (e.g., GRO03116). The results suggest that the 3- μm band features of highly terrestrially weathered samples were heavily influenced by oxyhydroxides.

LAP04721 is one of the most heavily weathered CR chondrite in our samples. However, the shape of the 3- μm band of matrix of this meteorite is fit to the 3- μm band of serpentine and is not similar to absorbed water and Fe oxyhydroxides. Therefore, we suggest that micro-FT-IR analyses focused on matrix of CR chondrites is an appropriate way to avoid the effects of Fe oxyhydroxides.

When we measured chondrites matrix with no Fe oxyhydroxide using micro-FT-IR, the 3- μm band of matrix regions become sharpened and deepened as alteration proceeds. The 3- μm band position is shifted to shorter wavelength, with the abundance of phyllosilicates increasing. In addition, a correlation between the 3- μm band position and Fe/Mg ratio of matrix regions was found, which indicates cation ratios of phyllosilicates affect the 3- μm band position, as is observed in CM chondrites. Since this trend is consistent with mineralogical changes of aqueous alteration of CR chondrites, the 3- μm band features able to use to estimate the alteration degree of CR chondrites, as suggested by Beck et al. (2014).

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