Dehydration process of hydrous asteroids inferred from mineralogy and noble gas signatures of dehydrated CI and CM chondrites

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CI and CM carbonaceous chondrites are the most primitive materials in the solar system in terms of their unfractionated chemical compositions. But they have experienced aqueous alteration to various degrees and thus retain little or no primordial mineralogy. Their parent bodies are believed to be hydrous C-type asteroids based on the similarity of reflectance spectra between the meteorites and the asteroids [1]. However, reflectance spectra of a subset of hydrous C-type asteroids are similar to those of hydrous carbonaceous chondrites that experienced heating and dehydration [2] and thus it was suggested that dehydration has occurred in hydrated asteroids. Since more than 20 meteorites showing evidence of dehydration have been found, dehydration is a common process of primitive hydrous asteroids. However, dehydration process especially for CI chondrites and the heat source for dehydration remain unknown. The purpose of this study is to evaluate the degrees of heating and to constrain the heating temperatures based on mineralogical properties and noble gas signatures of the two meteorites. In this study, we used two samples; Yamato (Y)-982086 and Y-980115, which are classified as CM and CI chondrites, respectively.

The two meteorites were analyzed using an optical microscope, a field-emission scanning electron microscope (SEM) equipped with an energy dispersive X-ray spectrometry (EDS), an electron probe micro-analyzer (EPMA) and synchrotron X-ray diffraction (S-XRD) for petrology and mineralogy. Y-980115 was analyzed for noble gas isotopes.

Petrologic observation indicates that Y-982086 has experienced a moderate degree of aqueous alteration and is classified to CM 2.3 based on the classification scheme [3]. S-XRD shows that matrix phyllosilicate exhibits no 001 basal reflection, but remains prism reflections and secondary olivine is not identified, suggesting that phyllosilicate starts to decompose to be poorly crystalline. Based on (1) the presence of pentlandite and pyrrhotite with pentlandite lamellae and (2) the mean and standard deviation of Cr_2O_3 contents in FeO-rich olivine [4], it is suggested that the meteorites was heated at a temperature of 400 to 450 °C, which corresponds to the heating stage II [5].

Y-980115 contains coarser phyllosilicates and higher abundance of Fe sulfide than the Orgueil CI chondrite, suggesting that Y-980115 has not experienced advanced aqueous alteration compared with Orgueil, because it is known that phyllosilicate becomes smaller and Fe sulfide becomes less abundant with progressive aqueous alteration of CI chondrites [6]. Very weak 001 reflection of matrix phyllosilicate suggests that phyllosilicate is poorly crystalline, like Y-982086. Coexistence of carbonate and carbonate-decomposed product, periclase, suggests a heating temperature of 520 to 550 °C, which corresponds to the heating stage II to III [5]. This is consistent with similarity of noble gas release patterns of Y-980115 to those of CM chondrites of heating stage II [7]. Cosmic-ray exposure age estimated from cosmogenic ^{3}He (0.16 Ma) is shorter than that from cosmogenic ^{21}Ne (0.48 Ma). We argue that thermal dehydration occurred along with diffusive loss of cosmogenic ^{3}He not on its parent asteroid but during transit to the Earth by solar heating.

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