Yamato-980115: CI chondrite experienced incomplete dehydration deduced from mineralogy and noble gas signatures

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Introduction: CI chondrites have experienced aqueous alteration to various degrees and thus retain little or no intact mineralogy in spite of their unfractionated chemistry. Their parent bodies are believed to be hydrous C-type asteroids based on reflectance spectra [1], but 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 [e. g., 3, 4]. However, dehydration process especially for CI chondrites and the heat source for dehydration remain unknown. The purpose of this study is to evaluate the degree of heating and to constrain the heating temperature of the Y-980115 CI chondrite based on mineralogical properties, heating experiments and noble gas signatures. Y-980115 was classified as a partially dehydrated CI chondrite based on mineralogy, reflectance spectra, and water content [5, 6].

Methods: Y-980115 was analyzed using an optical microscope, a field-emission scanning electron microscope (FE-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. Heating experiments were performed using a furnace. A piece of carbonate approximately 100μm in size was picked up from the meteorite slice and used for heating experiments. The sample was heated at 400°C, 500°C and 600°C for 30 min under vacuum at 10^{-5} to 10^{-6} torr. In addition, a chip of Y-980115 was analyzed for noble gas isotopes with the modified-VG5400 "MS-II" noble gas mass spectrometer at University of Tokyo.

Results and discussions: 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 [3]. On the other hand, Y-980115 experienced dehydration after aqueous alteration and the degree of dehydration varies between places in the meteorite. EPMA analysis and S-XRD measurement indicate variable degrees of the dehydration and decomposition of phyllosilicates. One lithology that experienced higher degree of dehydration shows high totals of EPMA analysis and the absence of phyllosilicate reflections instead the presence secondary olivine reflections in S-XRD analysis. In contrast, other lithology that experienced lower degree of dehydration shows low totals of EPMA analysis and incomplete decomposition of phyllosilicates based on S-XRD patterns. Large aggregates of Mg-Fe carbonate are present. In the aggregates, carbonate and carbonate-decomposed product magnesiowustite coexist, suggesting that heat-induced decomposition is incomplete. We experimentally heated the aggregate to estimate heating temperature experienced by it. The result of heating shows that the carbonates start to decompose at 500°C and all carbonates completely decompose at 600°C to form magnesiowustite. Coexistence of carbonate and carbonate-decomposed product suggests two possibilities of heating conditions. One is that two carbonates having different compositions were heated at certain temperature and one survived because of high decomposition temperature. The other possibility is that one uniform carbonate was heated at high temperature for a short time so that the decomposition is incomplete. In the former case, heating temperature is 500 to 600°C. In the latter case, heating temperature is >500°C for less than 100 min which is the time enough to decompose carbonate completely [7]. The incomplete to complete decomposition of phyllosilicates indicates that the meteorite is classified to the heating stage II/III [4]. This is consistent with similarity of noble gas release patterns of Y-980115 to those of CM chondrites of heating stage II [5]. 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 diffusive loss of cosmogenic ^{3}He by thermal dehydration occurred on its parent asteroid or during transit to the Earth by solar heating.

References

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