Synchrotron X-ray diffraction analysis of pulse-heated Orgueil carbonaceous chondrite : experimental reproduction of micrometeorites

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Introduction

Micrometeorites are small (<1mm) extraterrestrial material, which constitute the major fraction of extraterrestrial material fall onto the Earth [1,2]. To identify their parent body is one of the major objective of micrometeorite researches. Although bulk mineralogy provides an important clue to the origins of micrometeorites, primary mineralogy of micrometeorites has been altered by various degrees of heating during atmospheric entry. Thus, it is important to clarify the mineralogical changes in micrometeorites during atmospheric entry heating.

Experiment

We performed pulse-heating experiments of a small piece of Orgueil (CI1) carbonaceous chondrite from 200ºC to 1000ºC with 100°C interval under ambient atmospheric pressure of 1.5x10-2 torr. In each step, the sample was heated for 120 sec and bulk mineralogy was analyzed by X-ray diffraction with monochromatic X-rays of 2.164 Å wavelength at the beamline 3A.

Results

Before heating, the Orgueil sample consisted of saponite, serpentine, magnetite, ferrihydrite, carbonate (dolomite), Ca-sulfate, and minor amount of Fe-Sulfide. By heating at 200 and 300ºC, the bulk mineralogy did not change. At 400ºC, diffraction peaks of Ca-sulfate disappeared and those of newly formed anhydrite appeared. Relative intensity of diffraction peaks of serpentine decreased at 500ºC and disappeared at 600ºC. Intensities of diffraction peaks of saponite decreased and the basal spacing (001) of saponite shrunk to ~12Å at 600ºC. Diffraction peaks of saponite were hardly identified at 700ºC. TEM observation of another Orgueil sample heated at this temperature revealed both of saponite and serpentine have only remnant layer structure and the majority of them are almost completely decomposed into amorphous material. Dolomite and ferrihydrite also decomposed at 700ºC. At 800ºC, newly formed olivine and Fe-oxide (magnesiowüstite) appeared. At 900 to 1000ºC, the abundance and crystallinity of olivine increased progressively.

Discussion

Phyllosilicate-bearing micrometeorites are thought to be the least heated samples, because saponite and serpentine are decomposed below ~700ºC [3]. Most of phyllosilicate-bearing micrometeorites can be classified into three major mineralogical types based on the major minerals in them; type A: mainly consist of saponite, serpentine, and magnetite, type B: saponite and magnetite, and type C: serpentine [4]. We also found micrometeorites that consist of amorphous material and magnetite (hereafter type D).

It is likely that type A and B micrometeorites were formed by weak heating of CI chondrite-like material, which is composed mainly of saponite, serpentine, and magnetite. Because serpentine is decomposed at lower temperature than saponite, it is plausible that serpentine was preferentially decomposed into amorphous material by weak atmospheric entry heating. Therefore, there is a possibility that type B micrometeorites were made from CI chondrite-like material.

The heating experiments show that the mineralogy of the Orgueil sample heated below 500ºC matches well with that of type A phyllosilicate-rich micrometeorites. The Orgueil sample heated at 600ºC, where serpentine has decomposed while saponite and magnetite still remains, show similar bulk mineralogy to type B micrometeorites. However, there is a great difference in mineralogy between the heated Orgueil sample and type B micrometeorites. In the heated Orgueil sample, basal spacing of saponite has shrunk down to ~12Å by weak heating, while that in the majority of the type B micrometeorites show no shrinkage (13 ~ 14Å), suggesting that type B micrometeorites have not been heated above 600ºC and originally not contained serpentine. Thus, precursor material of type B micrometeorites may contain abundant saponite and magnetite, such mineralogy can be found in 'Carbonate-poor lithology' of Tagish Lake CI2 chondrite [5,6].

References

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