Synchrotron X-ray diffraction analysis of pulse-heated Tagish Lake carbonaceous chondrite: experimental reproduction of micrometeorites.

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Introduction

A major goal of micrometeorite research is to identify the parental source objects. The bulk mineralogy gives an important clue for that purpose. Major components of micrometeorites are similar to those of chondrites, but approximately 40% of micrometeorites contain magnesiowüstite (Fe,Mg)O [1] that is very rare in meteorites. Thus, the common occurrence of magnesiowüstite is a key mineralogical difference to meteorites that needs to be explained. Magnesiowüstite in some micrometeorites contains appreciable amounts of MnO and thus it was proposed that magnesiowüstite was produced by decomposition of Mn-bearing Fe-Mg carbonates [2]. Tagish Lake is a new meteorite characterized by the presence of abundant Fe-Mg carbonates [3]. We performed a brief heating experiment of small pieces of Tagish Lake, in order to reproduce the magnesiowüstite-rich bulk mineralogy of micrometeorites.

Experiment

Stepped heating was performed on two small fragment (< 200μm) of Tagish Lake matrix (TLM1) using a vacuumed furnace for 120 sec. TLM1 was heated from 400°C to 900°C with 100°C interval under ambient atmospheric pressure of $1.5\text{x}10^{-2}$ torr. At each step, bulk mineralogy of both samples were analyzed using synchrotron X-ray diffraction analysis with monochromatic X-rays of 2.164 Å wavelength at the beamline 3A.

Results

Before heating, TLM1 consisted of abundant Fe-Mg carbonate and saponite and minor pyrrhotite. Heating at 400°C and 500°C did not change anything except for a slight shrinkage of saponite basal spacing and a decrease of carbonate abundance. Carbonate disappeared at 600°C, while magnesiowüstite appeared at the same temperature, indicating that magnesiowüstite was formed at the expense of Fe-Mg carbonate. Saponite decreased greatly at 600°C and, at 700°C, it was decomposed almost completely, but the abundance of newly formed anhydrous silicates is very low, suggesting that silicate phases were amorphous at this temperature. At 800°C, the abundance of anhydrous silicates such as olivine and pyroxene increased. Magnesiowüstite abundance became very high. At 900°C, the abundance and crystallinity of olivine and pyroxene increased progressively. Pyrrhotite still remained at 900°C, although the abundance was reduced.

Unlike IDPs, the bulk mineralogy of most micrometeorites has been strongly modified during the short, high-temperature heating upon atmospheric entry. But a few micrometeorites retain the mineralogy before the atmospheric entry and provide crucial information. Saponite-rich micrometeorites are such 'survived' samples and some of them show high abundance of magnesiowüstite and shrinkage of basal spacing of saponite down to 10Å [1-2]. The bulk mineralogy of these saponite-rich micrometeorites is markedly similar to that of TLM1 heated at 600°C (Fig. 1). This indicates that, prior to the atmospheric entry, these micrometeorites had bulk mineralogy very similar to Tagish Lake matrix. In addition, there are many anhydrous micrometeorites containing abundant magnesiowüstite [1]. The relative mineral abundance of olivine, pyroxene, and magnesiowüstite in such anhydrous micrometeorites is similar to that of TLM1 heated at 900°C. This also suggests that pre-atmospheric mineralogy of these micrometeorites might have resembled to that of Tagish Lake. The reflectance spectra of Tagish Lake matches well that of D-type asteroids [4]. Therefore, our results suggest that D-type asteroids are one of the parental objects of micrometeorites.

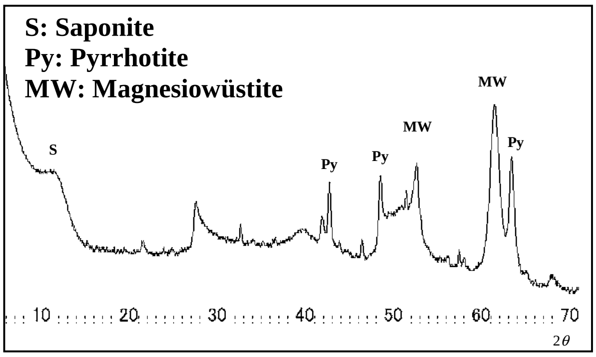

Fig.1 Diffraction pattern of TLM1 at 600°C.

References

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