Formation process of a unique hydrous micrometeorite with abundant Fe-rich saponite and Fe sulfide

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The Antarctic micrometeorites (AMMs) collected from recent snow are almost free of terrestrial alteration and heavy impacts upon collection and therefore are the best dust samples that coming from outer asteroids and comets [1]. We have collected AMMs from filters that gathered dust particles in the snow recovered by CSNSM with support from IPEV. Among the AMMs we identified, detailed analysis was done for one AMM SSP4E5 for its mineralogy and chemistry. SSP4E was first analyzed by synchrotron-XRD at KEK, Japan. Ultrathin sections were prepared by ultramicrotomy and the sections are observed by FE-TEM/EDS and the remaining putted butt was observed by FE-SEM/EDS and FE-EPMA.

SSP4E5 is a fine-grained, unmelted carbonaceous chondrite-like AMM with 80 μm in diameter. Synchrotron XRD analysis of SSP4E5 indicates that strong diffractions from pyrrhotite and saponite are detected and no other diffractions such as serpentine, carbonates, and anhydrous silicates are not detected, suggesting that pyrrhotite and saponite are dominant phases. Observation of the cross section showed that pyrrhotite abundantly occurs and distributes entirely in this sample as aggregates (grain size ~1 μm), isolated grains (~10 μm) and numerous submicron particles. Submicron particles are arranged along the outline edge of voids. Average composition of the entire cross section indicates that sulfur is enriched and concentration is 3 times higher than solar abundance.

Saponite in SSP4E5 has Fe-rich chemical composition and an average Fe:Mg ratio was estimated as 55:45, which is higher than saponite in any carbonaceous chondrites reported so far (e. g., 2 for Tagish Lake). The relative mineral abundance is 45wt% of pyrrhotite, 49wt% of saponite, and other ~5% amorphous phases of rich in SiO_2. The mineral assemblage and chemical composition imply that SSP4E5 has experienced aqueous alteration in the unique conditions. We explored thermodynamically the condition of the alteration that reproduces the relative mineral abundance and the saponite composition.

We examined aqueous alteration at various water/rock weight ratios (0.1-100) and temperatures (25, 100, 200, and 350℃). The fluid is supposed to be composed mainly of H_2O and small amounts of H_2S (0.5 and 1.5 mol %: 0.5 mol% of H_2S is comet value [3]). We assumed that half of S originally exists as FeS in the rock and the rest half is supplied by H_2S in the water. The results of the calculations indicate that the relative mineral abundance and the saponite composition of SSP4E5 are reproduced well by the alteration at temperatures higher than 200℃ with water/rock ratios higher than 7 (in case of 0.5 mol% of H_2S in the solution) and 2.5 (in case of 1.5 mol% of H_2S in the solution). Therefore, the calculation envisions that SSP4E5 was likely to have been produced by high temperature aqueous alteration at a location where water and FeS are abundant. This is consistent with observation. The absence of anhydrous minerals such as olivine in SSP4E5, which suggests pervasive aqueous alteration at high temperature. The presence of small pyrrhotite around rims of pore spaces, which suggests pyrrhotite precipitation from a fluid that filled pore spaces where local high water-rock ratios were attained. Our results imply that high-temperature aqueous alteration caused local concentrations of Fe-rich saponite and pyrrhotite in the primitive small body formed in the early solar system.

References [1] Duprat et al. (2007) Adv. Space Res. 39, 605-611. [2] Nakamura et al. (2003) EPSL 207, 83-101. [3] Mumma and Charnley (2011) Annu. Rev. Astron. Astrophys.49, 471–524.

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