Evolution of inorganic and organic matters during the early stages of aqueous activity in a cometary body recorded in Antarctic micrometeorites

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Introduction: The interactive evolution of inorganic and organic materials is one of the hot issues of planetary science with a special interest to the search of possibility of life in planetary systems. Micrometeorites (MMs) recovered from surface snow of the Antarctica are extremely primitive, which contains ultracarbonaceous and chondritic porous MMs (CP MMs), and we have made a systematic investigation of MMs by using SEM, TEM, XANES, and SIMS to get through understanding of the evolution and interaction of inorganic and organic materials in planetary environments.
Samples and methods: We collected ~400 MMs preserved in ~300 kg snow, and selected seven porous MMs, which were embedded in annealed Au sheet with a hydraulic press in the clean room and coated by Pt, from which ~100 nm-thick FIB sections were prepared without using organic epoxy resin. The FIB sections were processed with a low voltage argon ion milling machine to minimize the damage during FIB sample preparation. Carbon-, N-, and O-XANES spectra of the FIB sections were acquired using STXM, and then, TEM observation was performed. Isotope imaging was performed for the remainder of D10IB009 CP MM pressed into a Au sheet for isotopographs of $^{1}H^{-}$, $^{2}H^{-}$, $^{12}C^{14}N^{-}$, $^{12}C^{15}N^{-}$.
Results and discussion: The MMs show evidence for very early stages of aqueous activities for both inorganic and organic components, and we recognize three stages based on mineralogy and chemistry of organic and inorganic materials. Stage I is characterized by alteration only in organic materials, but inorganic materials do not show evidence for aqueous alteration. The inorganic materials are totally anhydrous including GEMS and enstatite whiskers/platelets, which are almost identical to those in anhydrous IDPs. Organic materials in two MMs at this stage have abundant high carboxyl functionality, and one of them contains nitrile and/or nitrogen heterocyclic groups with D and ^{15}N enrichments, which are thus highly pristine. However, other two CP MMs are poorer in organic materials and show high aromaticity, which are indistinguishable from those of hydrated carbonaceous chondrites. Stage II is characterized by alteration of inorganic matter. GEMS was changed into GEMS-like amorphous silicate by hydration and oxidation, and the GEMS-like amorphous silicate in Stage II has relatively homogenous compositions than GEMS in Stage I. Nano-phase Fe metal that was abundant in the stage I was depleted, and instead, Fe-rich phyllosilicate was found coexisting with GEMS-like amorphous silicate. Stage III is defined by the appearance of Mg-rich phyllosilicate and Mg-Fe carbonate, which indicates reactions among Fe-rich phyllosilicate in Stage II, Mg-rich olivine and pyroxene, and organic materials and/or C-bearing ice.
The MMs are porous and “freeze-dry” processes took place during and after aqueous alteration, where liquid water was sublimated. The temperature of the reaction would be kept at near zero degree C. Possible parent bodies would be comets or icy asteroids. If further aqueous alteration took place, magnetite would be formed, which is often observed as framboidal aggregates and

plaquettes in IDPs. The aqueous alteration in comets and porous icy bodies differ from that in chondrite parent bodies in that it took place locally and heterogeneously. On the other hand, aqueous alteration in chondrite parent bodies took place more homogeneously due to pervasive liquid water distribution in more compact bodies.

Keywords: comet, aqueous alteration, inorganic-organic matter

