

Organic chemical variation between hydrous and anhydrous Antarctic micrometeorites

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Introduction: In order to obtain the earlier records of the Solar System history, a number of studies have investigated the least altered solar system materials, such as IDPs, cometary dusts, Antarctic micrometeorites (MMs) and CR3 carbonaceous chondrites. For instance, one of the approaches is to compare between anhydrous and hydrous IDPs which are classified based on silicate compositions. However, some of anhydrous MMs might have experienced a very weak degree of aqueous process in an icy body, which does not affect silicate compositions. Actually, several evidences of aqueous alteration without hydrated silicates were found from Wild 2 cometary dust particles [1-2] and our recent study on ultracarbonaceous micrometeorite [3]. Organic compounds should have been modified even under the weak condition, because of their highly sensitive reactivity. Therefore, it is important to reveal what kind of processes and conditions existed in this interface window to trace them to the origin of organic compounds in space. In this study, variations in functional group distributions of organic materials between hydrous and anhydrous Antarctic micrometeorites were investigated through the coordinated analyses using scanning transmission x-ray microscope (STXM) – x-ray absorption near edge structure (XANES), transmission electron microscopy (TEM), and secondary ion mass spectrometry (SIMS).

Samples and methods: Five micrometeorites (MMs) (D10IB-004, 009, 017, 163, 356) which were found from the surface snow collected in the 2010 period by the Japan Antarctic Research Expedition teams near the Dome Fuji Station, Antarctica, were studied. The collected snow was melted and filtered in a class 1000 clean room at Ibaraki Univ. MMs were identified by using SEM-EDS. The MMs were embedded in gold for the isotope imaging by Cameca ims-1270 SIMS equipped with SCAPS [4]. Afterward, a thin section was prepared by the dual beam FIB-SEM. C-, N-, and O-XANES spectra of the FIB sections were acquired using a STXM at the beamline 5.3.2.2., Advanced Light Source, Lawrence Berkeley Laboratory.

Results and discussion: Through SEM-EDS and TEM analyses, GEMS were identified from D10IB-004, 009, 356 and these MMs were classified as anhydrous MMs that were similar to CP-IDPs [5]. In particular, D10IB004 had the highest abundance of GEMS. D10IB163 was classified weakly-hydrated MM due to small abundance of Fe-rich phyllosilicates. D10IB017 was enriched in Fe-rich phyllosilicates and classified as hydrous MM. In the isotopic analyses, for D10IB004, moderate enrichment of $d^{15}\text{N}$ of 300 permil was measured while there was no difference in $d\text{D}$ from terrestrial value. On the other hand, for D10IB009, $d^{15}\text{N}$ was 300-1000 permil in an entire region and $d\text{D}$ hotspots were 2000-5000 permil. STXM carbon maps showed that organic carbon was widely diffused in size of several to 10 micron in D10IB009, while they were distributed in a space of a few micron or less between minerals in D10IB-009 and 163. C-XANES spectra of all the MMs exhibited the peaks of aromatic C=C, aromatic ketone, and carbonyl C=O, while the relative ratios of C=O to C=C for anhydrous D10IB-009 and 356 were higher than those for hydrous D10IB017 whose spectral pattern was chondritic insoluble organic matter (IOM)-like. The weakly-hydrated MM, D10IB163, had both C=O rich regions and C=C rich regions. The observed mixture of anhydrous and hydrous organic features in D10IB163 indicates that precursor of IOM could be C=O rich structure, and that local fluid chemistry in the early stage of aqueous alteration promoted the conversion to IOM. One of the anhydrous MMs, D10IB004, showed IOM-like organics, implying that some anhydrous MMs could have experienced fluid chemistry but its condition is much weaker than that to produce hydrated silicates. Nitrogen was depleted in most of the MMs. Exceptionally, an anhydrous MM, D10IB009, was enriched in nitrogen heterocycles. Furthermore, several numbers of nitrogen (elemental) hotspots were detected in D10IB009. Some of them were organic nanoglobules. Their N-XANES spectra showed extremely developed peaks of nitrogen heterocycles and C=O, compared to those of the surrounding organic matrix. Assuming that the nanoglobules correspond to the ^{15}N isotopic enrichment, N-heterocycles and carboxyls could be the key molecules to refine their precursors in interstellar or outer solar nebula environment.

References: [1] Zolensky et al. (2006) *Science* 314: 1735–1739. [2] Berger et al. (2015) *GCA* 75: 3501–3513. [3] Yabuta et al. (2012) The 43th LPSC Conference, Abstract #2239. [4] Yurimoto H. et al. (2003) *Appl. Surf. Sci.*, 203-204 : 793-797. [5] Noguchi T. et al. (2015) *EPSL* 410: 1-11.