

EARLY STAGES OF AQUEOUS ALTERATION IN COMETARY BODIES.

T. Noguchi^{1*}, H. Yabuta², S. Itoh³, N. Sakamoto⁴, T. Mitsunari⁵, A. Okubo⁶, R. Okazaki⁷, T. Nakamura⁸, S. Tachibana⁹, K. Tera-da², M. Ebihara¹⁰, N. Imae¹¹, M. Kimura⁴, H. Nagahara⁵, ¹Fac. Arts Sci., Kyushu Univ. (noguchi.takaaki.906@m.kyushu-u.ac.jp), ²Osaka Univ., ³Kyoto Univ., ⁴Ibaraki Uni., ⁵Tokyo Uni., ⁶Univ. Tokyo, ⁷Kyushu Univ., ⁸Tohoku Univ., ⁹Hokkaido Univ., ¹⁰Tokyo Metropol. Univ., ¹¹NIPR

Introduction: Interaction of inorganic and organic materials in the evolution of primitive materials at low temperature environments is one of the important issues of planetary science, which is related to the origin and evolution of life in planetary systems. Micrometeorites (MMs) including ultracarbonaceous and chondritic porous MMs recovered from surface snow near the Dome Fuji Station, Antarctica are almost free from terrestrial weathering and contain very primitive materials, and are suitable for investigation of the evolution and interaction of inorganic and organic materials in the early solar system. We have carried out comprehensive study of seven highly primitive MMs and have revealed a sequence of aqueous alteration at very early stage, which has not been previously recognized and which well explains the compositional diversity of amorphous silicates and phyllosilicates in IDPs and chondrites.

Samples and Methods: About ~300kg Antarctic snow collected by the Japanese team was filtered and seven fine-grained micrometeorites with porous morphology, D10IB009, 356, 064, 004, 178, 163, and 017, were selected for detailed study. One compact MM was also investigated for comparison. They were embedded in an annealed Au sheet, from which ~100 nm-thick FIB sections were prepared. A series of Carbon (C)-, Nitrogen (N)-, and Oxygen (O)- XANES analysis, TEM analysis, and SIMS analysis were performed.

Results: The MMs show very early stages of aqueous activities, which are seen in both inorganic and organic components. We have defined four stage of aqueous alteration on the basis of chemistry and mineralogy of organic and inorganic materials. Four porous MMs contain GEMS and enstatite whiskers/platelets, which are almost identical to those in anhydrous IDPs (CP MMs). Despite the similarity in mineralogy, organic chemistry showed diversity among these MMs. Two of them contain considerable amounts of OMs with high carboxyl functionality, and one of them also contains nitrile and/or nitrogen heterocyclic groups with D and ¹⁵N enrichments, suggesting formation in the molecular cloud or a very low temperature region of the outer solar system. On the other hand, other CP MMs are poor in OMs, which are aromatic, being indistinguishable from those of hydrated carbonaceous chondrites. Thus, functional group of the OMs in the CP MMs transforms in the earliest stage of aqueous alteration leaving silicates unchanged (Stage I). At Stage II, Fe-rich amorphous silicate was formed from GEMS, which has relatively homogenous compositions than GEMS in Stage I, and it contains little or no nanophase Fe metal, which suggests consumption of nanophase Fe metal resulted in formation of Fe-rich amorphous silicate. The GEMS-like amorphous silicate is a transient product, which quickly changed to Fe-rich phyllosilicate. Stage III, is characterized by the formation of Mg-rich phyllosilicate and Mg-Fe carbonate through the reaction of Fe-rich phyllosilicate, Mg-rich olivine and pyroxene, and water with C-bearing species. Further aqueous alteration would form magnetite, which is typical in non-porous hydrated MMs, where magnetite occurs often as framboidal aggregates and plaquettes.

Discussions: The present work revealed a sequence of aqueous activity in low temperature bodies. It is in particular important that the previously reported wide compositional range of amorphous silicate in IDPs [1] includes the compositional change due to various degrees of aqueous alteration. The most pristine materials contained only Mg- and Si-rich amorphous silicates in addition to crystalline materials (olivine, pyroxene, and Fe-metal/Fe-sulfide). Another importance is that the inorganic materials are embedded in organic materials with low aromaticity, of which large δD and $\delta^{15}N$ enrichments imply their origin in a very low temperature environment. The aqueous activity should have occurred in highly porous icy bodies, where liquid water is unstable to be vaporized away instantaneously leaving heterogeneously formed alteration. Thus, the aqueous alteration in cometary bodies is different from that in chondrite parent bodies where liquid water was stable and where phyllosilicates were pervasively formed.

References: [1] Keller L. P. and Messenger S. 2011. GCA 75, 5336.