Interactive evolution of inorganic and organic materials and water in comets and icy bodies

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Interactive evolution of inorganic and organic materials in the presence of water is one of top theme of planetary science specifically with an interest to the origin and evolution of life in the outer solar and exoplanetary system. Interplanetary dusts (IDPs) are so far the most extensively studied material that keep records of chemical reaction at low temperatures. Antarctic micrometeorites (MMs) recently found in the vergin ice of the Antarctic keep more primitive records due to survival of high temperature at the time of the atmospheric entry. We have cariied out a systematic study on seven highly primitive MMs with SEM, TEM, XANES, and SIMS and found a systematic evolution and interaction at low temperatures.

The seven MMs were collected from ~400kg snow, and they were prepared for further observation without using epoxy. We have recognized three evolutionary stages; Stage I is the stage where inorganics, such as GEMS and olivine and pyroxene crystals, do not suffered any reactions. Only organic materials changes from carboxyl functionality-rich to aromatic functionality-rich chemistry, wich would be helped by the presence of a small amout of liquid water, and the former often have D- and 15N-enrichments. Stage II is characterized by aqueous alteration of inorganic materials, where Fe metal disapper and altered GEMS and Fe-phyllosilicate are formed. At stage III, olivine and pyoroxene disappear and Mg-phylllosilicates and carbonates are formed, which was possible in the presence of C-bearing liquid water. The source of C can be ice and orgnics.

On the basis of previous experiments on the aqueous reaction of amorphous silicate (Nakamura-Messenger et al., 2011), the conditions of aqueous alteration are estimated to be short and at around zero degree C, suggesting that the early stage of aqueous alteration of organic and inorganic materials took place instantaneously and heterogeneously, which was possible by a shock in a comet or icy body. The highly porous nature of comets by recent Rosetta mission strongly supports the environments estimated in the present work.