

## Hydrothermal alteration experiments of amorphous silicates: implication to aqueous alteration in CM chondrites.

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Carbonaceous chondrites, such as CI, CM, CR, CV chondrites and Tagish Lake (TL) chondrite, have primitive chemical compositions, but have experienced strong aqueous alteration in their parent bodies. In order to examine the aqueous alteration process, many hydrothermal experiments using silicate crystals and natural samples, such as chondrites and IDPs, have been performed (e.g., Ohnishi and Tomeoka, 2007). Based on infrared astronomical observations, circumstellar silicate dusts around young stars are mixture of amorphous and crystalline silicates (Honda et al., 2003). In addition, unique primitive carbonaceous chondrites, such as Acfer 094, have partly crystallized amorphous silicates as abundant component in matrix (Greshake, 1997). It is thought that amorphous silicates were originally present in the parent bodies of carbonaceous chondrites. Therefore, it is important to investigate the aqueous alteration of amorphous silicates as well as crystalline silicates.

In order to understand the aqueous alteration process and its conditions, we have carried out hydrothermal alteration experiments using Fe-free and Fe-bearing amorphous silicates with CI-like compositions. In the experiments of the Fe-free system, we synthesized amorphous silicates of the system,  $\text{SiO}_2\text{-MgO-Al}_2\text{O}_3\text{-CaO-NiO-Na}_2\text{O}$ , with the CI ratios. Two major elements, Fe and S, were excluded from the system for simplicity to avoid problems of controlling their redox states. The amorphous silicate was preheated at  $750^\circ\text{C}$  for 20 hours to prepare a mixture of  $\text{SiO}_2$ -rich amorphous silicate and forsterite. The starting materials were heated in de-ionized water at  $100 - 200^\circ\text{C}$  for 24 - 5692 hours with the water/rock ratio of 646 under water saturated vapor pressures. Run products were analyzed with XRD and FE-SEM/EDX. In contrast to the previous alteration experiments using crystalline silicates (Ohnishi and Tomeoka, 2007), saponite, serpentine and calcite, which are present in aqueously altered carbonaceous chondrites, were easily formed in pure water at 100, 150 and  $200^\circ\text{C}$ . This is due to high reactivities of metastable amorphous silicate and nano-crystals of forsterite and to the chemical composition of the amorphous silicate including Na, Ca and Al. Saponite was formed first from the  $\text{SiO}_2$ -rich amorphous silicates, and then serpentine was formed by consuming saponite and forsterite. Calcite was formed at later stages of the experiments. Time evolution diagram as a function of temperature of the hydrothermal alteration was obtained. The mineral assemblage of serpentine, calcite and a minor amount of forsterite even at  $100^\circ\text{C}$  is consistent with that of CM chondrite matrix except for Fe- and/or S-bearing minerals.

In the experiments of the Fe-bearing systems, we synthesized amorphous silicates of the system,  $\text{SiO}_2\text{-MgO-FeO-Al}_2\text{O}_3\text{-CaO-NiO-Na}_2\text{O}$ . A part of Fe that forms FeS was excluded from the CI composition. Amorphous silicates and amorphous silicates with metallic iron or FeS were heated in de-ionized water at  $300^\circ\text{C}$  for 120 and 720 hours with the water/rock ratio of 11.3 under the magnetite-wuestite buffer using a double capsule method. Serpentine, calcite and magnetite were formed in the all run products. Relatively large crystals of metallic iron and FeS almost do not react with water. The mineral assemblage is also similar to that of CM matrix, although cronstedtite and tochilinite were not formed.

The present results in the two systems suggest that matrix of CM chondrites can be formed by alteration of CI-like materials, probably of  $\text{SiO}_2$ -rich amorphous silicates and anhydrous silicates such as olivine, with pure water. As saponite is not stable at least in the Fe-free system, saponite-rich carbonaceous chondrites, such as CI and TL, might have experienced different conditions, such as different water/rock ratios and/or pHs.