Experimental study of organic matter-induced formation of phyllosilicates from olivine in meteorite parent bodies

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Introduction: Phyllosilicate, which is one of hydrated minerals, exists dominantly in CI and CM chondrites. The existence of phyllosilicate in chondrites indicates the water activity in their parent bodies or preaccretional alteration. Some ordinary chondrites, CV chondrites and CO chondrites also contain small amount of phyllosilicates. Serpentine is a representative phyllosilicate in these chondrites and it could be formed at <300 ˚C (Brearley, 2006).

Nakano et al. (2003) conducted a heating experiment of a molecular cloud organic matter analog, which was described in Kouchi et al. (2002) in detail. H_2O was generated through the decomposition of the organic matter in their experiment. In present study, we investigated the possibility of the formation of phyllosilicates induced by co-existing organic matter simulating thermal metamorphism in meteorite parent bodies.

Method: Olivine powder (0.25 g, San Carlos, <50 μm) and molecular cloud organic matter analog (1.25 g, Kouchi et al., 2002) were put in a Swagelok tube fitting. The tube was sealed under N_2 atmosphere, then heated in an autoclave at 300 ˚C for 10 days. After cooling to room temperature, the experimental product was sonificated with hexane (2 mL), methanol (2 mL) and water (2 mL), respectively. Washed sample was left for 12 hours, then the precipitates were recovered. We analyzed the sample using X-ray diffraction (XRD) to identify the mineral phase, scanning electron microscopy (SEM) to observe the morphology, energy dispersive X-ray spectroscopy (EDS) to get chemical composition and transmission electron microscopy (TEM) to investigate the microstructures.

Results:

XRD: The diffraction pattern of the experimental product was almost the same as olivine prepared as the starting material. A pattern of Mg-carbonate was also found in the experimental product.

SEM/EDS: Olivine used as the starting material showed an angular and a smooth surface. Etch pits and insoluble organic matter were observed on the surface of olivine particles after the experiment. Si-Mg-Fe composition of the product particles partially showed Si-rich/Mg-poor structures.

TEM/EDS: Phyllosilicate-like tubular structures were detected at the surface area, which were anastomosed and poorly crystalline textures. The electron diffraction patterns of the textures were not clear. The area with this tubular structure was richer in Si than olivine. This area also showed a high carbon concentration.

Discussion: It is known that mineral replacement such as serpentinization takes place primarily by dissolution-precipitation processes (Putnis, 2002; Lafay et al., 2012). Thus, the etch pits on the surface of altered olivine indicate the dissolution to the surrounding fluid. Si-rich structures observed using SEM, which could be formed through the precipitation from the fluid, probably attributed to the Si-rich area with phyllosilicate-like tubular structures observed using TEM. The tubular structures were similar to proto-serpentine described in Lafay et al. (2016), thus development of chrysotile or talc could be in progress on olivine surfaces. Phyllosilicates and Mg-carbonate are the most thermodynamically stable solids in the MgO-SiO_2-H_2O-CO_2 closed system at 300 ˚C and under 1-100 bar of partial pressure of CO_2 (Oelkers et al., 2018). In our experiment, Mg-carbonate could be produced by CO_2 generated from decomposition of organic matter. These results indicate the possibility of the organic matter-induced formation of phyllosilicates and Mg-carbonate in meteorite parent bodies. In that case, H_2O derived from organic matter could be fixed in the surrounding silicates even in the parent bodies formed inside the snow line in the protoplanetary disk.

Keywords: serpentinization, meteorite parent body

