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Hydro thermal experiments of Allende CV3 chondrite under reducing condition

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Introduction

Of a range of small asteroidal bodies, aqueous alteration is one of the most important processes affecting early cosmic materials including carbonaceous chondrites. Aqueous fluids in the chondrite parent bodies modified the primary mineralogical characteristics formed in the solar nebula, and resulted in formation of a variety of secondary phases, including phyllosilicates, magnetite and carbonates. CI and CM chondrites are widely recognized as extensively aqueous-altered meteorites. Other carbonaceous chondrites of types 3 (CR, CO, and CV) and some unequilibrated ordinary chondrites have also clear evidences of various degrees of aqueous alteration. The diversity in alteration assemblages among various chondrites likely reflect the aqueous environment (e.g., temperature, dissolved ion, water/rock ratio, fO_2, etc.) of the parent bodies. Although many mineralogical, isotopic and theoretical studies has been made to unravel the complex effects of aqueous alteration in the carbonaceous chondrites, re-productive experimental approaches using chondritic materials were not really examined. Here, in order to elucidate the actual behavior of chondrite toward aqueous fluid, we report hydrothermal alteration experiments of Allende meteorites.

Methods

We use Allende CV3 carbonaceous chondrites as starting materials. We cut out block-shaped Allende meteorites (2.5 mm $\times$ 2.5 mm $\times$ 6 mm) by diamond blades, and never crushed ones in order to examine micro-textures before and after aqueous alteration experiments. All blocks were preliminary observed by an SEM, and blocks containing extremely large chondrules, dark inclusions and fusion clasts were not used as starting materials. Hydrothermal alteration experiments were performed with PTFE double-vessels (1 ml and 25 ml) loaded into a steel autoclave. To maintain a reducing ambient during experiments, H_2 gas was generated in an outer vessel (25 ml) by reaction with HCl solution and magnesium metal, while the stating materials (Allende block and reaction solution) were set in a small (1ml) inner vessel with screw-on lid. All hydro-thermal experiments were carried out at 200 degree C and pressure of liquid-vapor saturation (˜15 bar) for 168 hours. Four different pH solutions (7.0, 8.5, 10.0, 14.0) were reacted with the Allende block with three different water/rock (W/R) ratios (0.5, 2.0, 8.0 vol./vol.), and total 12 runs were performed. After the recovered samples dried for 24 hours in an oven maintained at 60 degree C, these were analyzed by a scanning electron microscope (SEM) equipped with an energy-dispersive X-ray spectrometer (EDS), synchrotron X-ray diffraction (XRD), and a transmission electron microscope (TEM).

Results and Discussion

Most of recovered sample blocks retained their original shapes, and no brown or reddish coloration on their surface was developed. A variety of alteration phases (e.g., magnetite, anhydrite and calcite) have been precipitated on the surface, which are ubiquitously distributed regardless of substrates. SEM observations of the inner texture showed that, in all 12 runs, serpentine formed as a main secondary phase at interstitial space of olivine grains in the matrices. Smectite coexists with serpentine only in low W/R (0.5) and strong alkaline (pH 14) condition. A silica-rich amorphous material is observed in low W/R (0.5) and neutral solutions (pH 7) condition. From analyses of SR-XRD and image processing of SEM, these phyllosilicates are generally more abundant as pH value or W/R ratio increases. TEM observations show serpentine and smectite are topotaxially crystallized on the surface of olivine grains, with the crystallographic relation of (010)olivine parallel to (001)serpentine and (001)smectite. The present study indicate that i) W/R ratios affect the mineral assemblage and abundance of secondary phases and ii) hydrated mineral formation under a reducing ambient easily proceeds (even in neutral solution) compared with the previous studies.

Keywords: carbonaceous chondrite, hydrothermal experiment, Allende, phyllosilicate, serpentine