Hydrothermal experiments of clinoenstatite: simulation of aqueous alteration in chondritic meteorites.

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1.Introduction

Clinoenstatite is one of the major minerals in chondritic meteorites, and its alteration processes provide much information about the evolution of chondrites. Many studies of aqueous altered textures in chondrites indicate that clinoenstatite has been much highly altered than olivine and orthoenstatite, and it has been replaced by phyllosilicates such as serpentine. We conducted hydrothermal experiments of clinoenstatite in order to estimate conditions that such altered texture has been formed.

2.Experimental conditions

Clinoenstatite (size less than 1 mm) were prepared by heating (1473 K, 48 hrs) and quenching of orthoenstatite synthesized by Flux method. Clinoenstatite and Fe powder were sealed in gold tubes with neutral or 1N-HCl or 1N-NaOHaq in the proportion of 3:3:1 (weight %), and heated in autoclaves at 573 K and 100 bars for 1 week. Run products were examined by a JEOL JSM-5800 SEM operated at 15kV and a JEOL JEM-2010 TEM operated at 200kV. Both electron microscopes are equipped with EDS.

3.Results

Clinoenstatite and Fe with neutral water (pH~7.2): Serpentines (size ~2 microns) were formed along fractures as mesh-like textures in clinoenstatite crystals. The texture is similar to aqueous altered textures of clinoenstatite in chondritic meteorites. Serpentines are rich in Mg (Fe# = Fe/(Mg+Fe) less than 10 (atomic %)). From TEM observations, serpentines show fluffy appearance (size ~200-300 nm) and were directly formed from enstatite crystals, but no characteristic relationship in crystallographic orientation between serpentine and enstatite was observed. Diffuse and streaking spots in SAED patterns suggest that the serpentines have low crystallinity.

Clinoenstatite and Fe with 1N-NaOHaq (pH~13.1): Like the experiments with neutral water, mesh-like textures were observed, and abundant serpentines were formed along with fractures in enstatite crystals. Two types of serpentine were found: Mg-rich serpentine (Fe# less than 8 (atomic %)) and Fe-rich serpentine (Fe# ~10-21 (atomic %)). The former (size less than 5 microns) directly replaces enstatite, while the latter fills fractures, which forms veins (width ~2 microns). From SAED and HRTEM, both serpentines were identified as chrysotile. Mg-rich serpentines are relative large (size ~1 micron) crystals which have crystallographic relation to enstatite as c*(serp) // a*(cen), while Fe-rich serpentines are small (size less than 500 nm) crystals with random orientations. Both serpentines tend to show higher crystallinity than those from neutral conditions

Clinoenstatite and Fe with 1N-HCl (pH~0.3): No hydrous phyllosilicates were observed.

4.Discussion

In this study, the degrees of alteration of clinoenstatite differ among different pH conditions. Clinoenstatite are much highly altered under basic condition than neutral or acidic conditions. Fe-rich serpentines tend to be easily formed under basic condition. In CM-type among aqueous altered chondrites, clinoenstatite are much highly altered and replaced by Fe-rich serpentine. Therefore, the fluids, which have reacted with clinoenstatite in CM-type meteorites, were probably high pH. Hanowsky and Brearley (2001) studied aqueous altered textures in ALH81002 CM-type chondrites. They suggested that glass and Fe-Ni metal were more easily altered than clinoenstatite, and therefore, the fluids, which would react with clinoenstatite, must be enriched in alkali-component and Fe. The results of the present study are consistent with their suggestion.