

**AQUEOUS ALTERATION EXPERIMENTS WITH HYDROTHERMAL FLUID BASED ON THE SOLAR ABUNDANCE IN THE EARLY SOLAR SYSTEM.** M. Tokunaga<sup>1</sup> and H. Isobe<sup>1</sup>, <sup>1</sup>Dept. Earth Envi. Sci., Grad. Sch. Sci. Tech., Kumamoto Univ., Kurokami, Kumamoto, 860-8555, Japan. e-mail: isobe@sci.kumamoto-u.ac.jp

**Introduction:** Some kinds of carbonaceous chondrites have hydrous minerals and carbonate minerals as aqueous alteration products on the parent bodies. Quantity and compositions of phyllosilicates and carbonate minerals represent conditions of carbonaceous chondrites parent bodies. Especially, total abundance of phyllosilicates in carbonaceous chondrites can be used for classification scheme [1]. CI1 has the greatest influence of aqueous alteration and has the most similar compositions to the solar abundance. Various carbonate minerals, phyllosilicates and magnetite occur in CI1. CI chondrites may be intense hydrous alteration product in dynamic regolith to subsurface depth of parent bodies [2]. The influence of aqueous alteration of CR2 is smaller than CMs [1]. CO3s show trace influence of aqueous alteration and may be the most primitive meteorite. Some of them have phyllosilicates. CV3s have variations on oxidization state. They show, however, characteristics on abundance of chondrules and high temperature condensates. Allende meteorite, typical oxidized CV3 chondrite, is the least hydrous CV3.

CM chondrites are characterized by various carbonates and phyllosilicates as aqueous alteration products. They show variations in the compositions and abundances of the anhydrous precursor and alteration environments [3].

Aqueous alteration processes on the meteorite parent bodies are subject to experimental studies. However, most of them discussed on phyllosilicate produced by aqueous fluid without CO<sub>2</sub> [4, 5]. Carbonate minerals never occur in aqueous alteration without CO<sub>2</sub>.

In the parent bodies undergoing aqueous alteration, not only solid materials but also fluid phases should be derived from the solar nebula. In this study, aqueous alteration experiments with CO<sub>2</sub> and ethanol solution representing the solar abundance were carried out. The concentration of ethanol and CO<sub>2</sub> in the experimental fluid was calculated based on the assumption that carbon was equally distributed to CO<sub>2</sub> and CH<sub>4</sub>. Oxygen in the solar abundance should be consumed first by cations from Na<sub>2</sub>O to FeO and secondary by CO<sub>2</sub>. Remaining oxygen made H<sub>2</sub>O. The concentration of C<sub>2</sub>H<sub>5</sub>OH solution has been decided by CH<sub>4</sub> and H<sub>2</sub>O determined following these steps. The starting material was Allende meteorite representing anhydrous primitive material at the early solar system before aqueous alteration.

**Experimental:** Au capsules in which powdered Allende meteorite and experimental fluid were enclosed in pressure vessels were heated. CO<sub>2</sub> was provided by dissociation of Ag<sub>2</sub>C<sub>2</sub>O<sub>4</sub> in Au capsules. The weight of powdered Allende meteorite is approximately 2.2 mg with 11.4 mg of Ag<sub>2</sub>C<sub>2</sub>O<sub>4</sub> and 2.3 μl of C<sub>2</sub>H<sub>5</sub>OH solution. The weight of Ag<sub>2</sub>C<sub>2</sub>O<sub>4</sub> was limited by initial internal pressure of CO<sub>2</sub> in the capsule.

Experimental temperatures were 100, 150, 200, 250, 300, 400 and 500 °C, and run durations were 4, 8, 16 weeks at 100, 150, 200, 250 °C, 4, 8 weeks at 300 °C and 4 weeks at 400, 500 °C. Run products, powdered Allende meteorite and the starting material after dissociation of Ag<sub>2</sub>C<sub>2</sub>O<sub>4</sub> were observed by Scanning Electron Microscope (SEM).

**Result and Discussion:** Powdered Allende meteorite was composed with particles derived from chondrules of olivine, pyroxene and plagioclase with approximately 30 μm in diameter and fine particles with approximately 1 μm in diameter of olivine, pyroxene, plagioclase and sulfide derived from matrix, CAI and AOA. The starting material after dissociation of Ag<sub>2</sub>C<sub>2</sub>O<sub>4</sub> at 250 °C, 1 hour does not show any effects of heating.

Ca-poor carbonate minerals occurred in the run products of 100 °C, 8 and 16 weeks as minor components. Carbonate minerals of 8 week run product were formed approximately 1 μm rim surrounding a mass formed by spinel-hercynite series oxide and diopside. Carbonate minerals of 16 weeks were formed about 0.5 μm rim surrounding a part of mass formed by olivine and orthopyroxene. In the run products of 100 °C, any phyllosilicates weren't found.

Phyllosilicates occurred in the mixed phase with Ni sulfide in the run products of 200 °C, 4 weeks. The run products of 8 and 16 weeks, zeolite were formed. Almost pure calcite was observed at 16 weeks.

In the run products of 250 °C at 8 weeks, phyllosilicates were abundant and carbonate minerals were found. Carbonate minerals can be classified to two types. One was aggregates of quadrilaterals about 5 μm in dimension. The other was an aggregate of about 10 μm quadrilaterals with rimmed structure. Fe oxide, possibly magnetite was formed.

Carbonate minerals were found in the run products of 4 weeks at 300 °C, but phyllosilicates weren't observed. In the run products of 150 °C, 400 °C and 500 °C, no carbonate minerals occur.

Carbonate minerals in 100 °C show the magnesite-siderite series compositions (Fig. 1a). The carbonate composition at 16 weeks was more Mg-rich than that at 8 weeks. In the run product of 200 °C, calcite occurs. Between 100 °C and 200 °C, carbonate minerals compositions change drastically (Fig. 1a). In the run product of 16 weeks, sulfide compositions were Ni-rich. It is considered Fe selectively eluviated so that Fe-rich carbonate minerals were formed.

In this study, carbonates and phyllosilicates were formed in 250 °C, 8 weeks. The abundance of carbonate minerals is largest at 250 °C. The carbonate crystals with zoned structure have ankerite composition-poor rim overgrown by ankerite composition-rich rim. Carbonate crystals with homogeneous composition show variations in ankerite components depending on locations and textures in the run product. Ankerite components have Mg:Fe ratio of approximately 2:1.

Because no carbonate occur in the run product with 16 weeks 250 °C, and Ca-bearing siderite occur at 8 weeks 300 °C. Ankerite-calcite series carbonate may not be stable at 250 °C with the hydrothermal fluid used in this study.

Phyllosilicates occur from 200 °C to 300 °C in this study. Especially, it is most abundant in 250 °C 8 weeks. Compositions of phyllosilicates are limited to serpentine-talc region with Mg:Fe = 7:3 ~ 5:5 (Fig. 1b). EET83334 meteorite has aggregates and matrix of serpentine which have wide variations in texture [7]. These have same compositions. Mixtures of serpentine and smectite containing of Na<sub>2</sub>O and Cr<sub>2</sub>O<sub>3</sub> in coarse grains and matrix were reported and those have wide range of Fe-Mg ratio [8]. Matrix was closer to serpentine. Phyllosilicates have serpentine-talc compositions close to serpentine (Fig. 1b).

In this study, carbonates are not abundant but show wide variety in composition (Fig. 1a). Ivuna meteorite has dolomite, mostly pure calcite and siderite [6]. Calcite and dolomite were reported in EET83334 meteorite [7]. Magnesite and dolomite in matrix, and ankerite, dolomite and S-rich composition for rounded grains were observed in Y-86029 meteorite [8]. The compositions of carbonate in 250 °C 8 weeks are not reported from meteorites. This may support that carbonate minerals are not stable at 250 °C with oxidative CO<sub>2</sub>-rich fluid. At higher temperature, siderite may be stable carbonate with oxidative hydrothermal fluid. Siderite was observed in the products of 300 °C, 8 weeks. This component was Fe-richer than the observation of Ivuna meteorite. Carbonate decomposition temperature might be approximately 250 °C in thermal metamorphism of CI-like and CM chondrites [9].

**References:** [1] Howard K. T. and Alexander C.M.O'D. (2013) *LPS XXXIV*, Abstract #2598. [2]

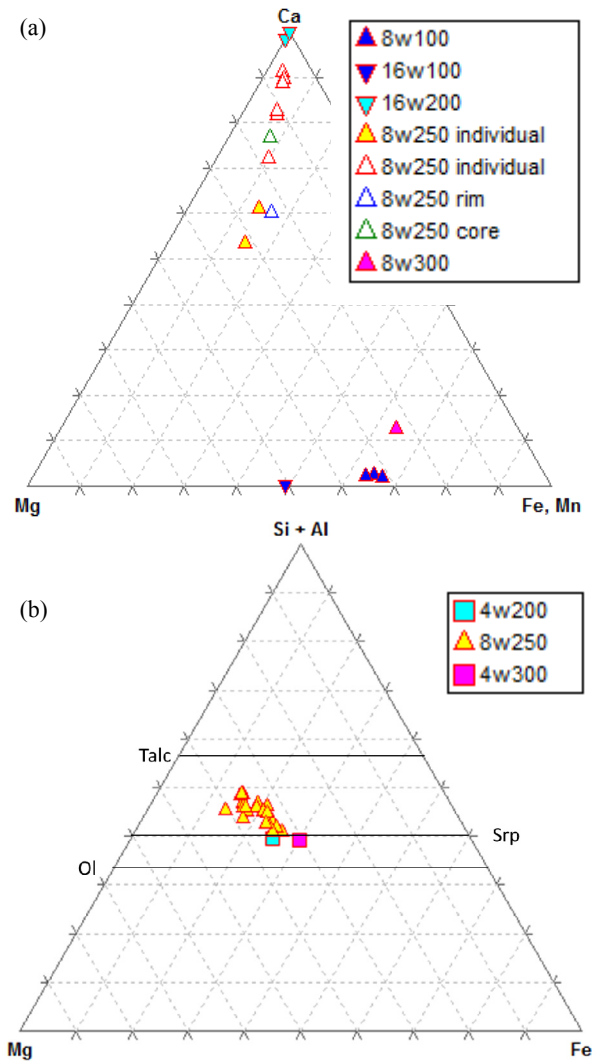


Fig. 1 Molar ratio of carbonate minerals (a) and phyllosilicates (b) in the run products. e.g. 8w100: 8 weeks 100°C.

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