

FORMATION PROCESSES OF SECONDARY DMISTEINBERGITE AND ANORTHITE IN ALLENDE CAI.

Y. Enokido¹, T. Nakamura¹, M. Matsumoto¹, A. Miyake², ¹Division of Earth and Planetary Sciences, Graduate School of Science, Tohoku University, Japan (yuma.enokido.r8@dc.tohoku.ac.jp), ²Division of Earth and Planetary Sciences, Graduate School of Science, Kyoto University.

Introduction: Polymorph of anorthite, “dmisteinbergite” ($\text{CaAl}_2\text{Si}_2\text{O}_8$) has been reported only in some CV_{oxA} CAIs [1-5]. Previous studies have shown that there are two types of dmisteinbergite which have different origins; one crystallized from melts [6] (we call this type “primary dmisteinbergite”) and one by aqueous alteration of primary minerals [7] (secondary dmisteinbergite). In CV_{oxA} chondrites, the secondary dmisteinbergite often co-occurs with secondary anorthite in the same CAI [2]. Formation condition of these secondary phases and relationships between them still remain unknown. To uncover these problems, we performed mineralogical and petrological observation of one large CAI in Allende meteorite.

Methods: We studied one coarse-grained CAI (~1 mm in diameter) in a polished thin section of Allende chondrite. The mineralogy and petrology of the sample were examined using scanning electron microscopy (FE-SEM/EDS: JEOL JSM-7001F/Oxford INCA), and electron probe microprobe analyzer (FE-EPMA/WDS: JEOL JXA-8530F). Mineral identification was based on micro-laser Raman spectroscopy (NRS-5100 532nm). We extracted two ultra-thin sections using a focused ion beam (FIB: Thermo Fisher Scientific Quanta 200 3DS) and investigated them using a transmission electron microscopy (TEM: JEOL JEM-2100F).

Results and Discussion: In the CAI, secondary dmisteinbergite and anorthite mostly occur in different areas. Only in limited areas, they intergrow in μm -scales. Dmisteinbergite crystal shows platy morphology and coexists with grossular and gehlenite-rich melilite (Geh_{80-85}). Melilite is one of the major primary minerals in CAI. We found that dmisteinbergite only formed in outer margin of coarser melilite grains by partial alteration and that grossular occurs between dmisteinbergite and melilite. Therefore, it is suggested that melilite is the precursor of dmisteinbergite (i.e. dmisteinbergite is pseudomorph of melilite). Sequential alteration seems to occur from melilite to grossular and then grossular to dmisteinbergite. These formation orders are consistent with previous experimental studies [7, 8]. These studies have shown that the alterations could have occurred at moderate temperature (200–250 °C) and high-pH fluids environment. Therefore, moderate temperature and high-pH had been kept during the sequence alteration to form dmisteinbergite.

Secondary anorthite is more abundant than dmisteinbergite and coexists with grossular and melilite. What is the formation process of secondary anorthite? What caused the difference between formation of secondary anorthite and dmisteinbergite? To uncover this problem, we performed TEM observations of the area where dmisteinbergite and anorthite intergrow in μm -scale. TEM observation shows that coarse-grained dmisteinbergite is dominant and partially replaced by fine-grained anorthite. This texture indicates that secondary anorthite was formed through phase transition from secondary dmisteinbergite. There are two possible mechanisms for the phase transition: further water-rock interactions and shock induced transformation. The occurrence of both dmisteinbergite and anorthite mean that distribution of aqueous solution and/or shock induced pressure were heterogeneous at a few hundreds of μm scale inside the CAI. What caused this heterogeneity? We found that many dmisteinbergite grains are enclosed by other primary minerals such as Ca, Ti-rich pyroxene, which limits the exposure to solution or shock deformation. In either case, the position and distribution of dmisteinbergite is important for phase transition to occur.

Chemical composition of the secondary anorthite is close to the stoichiometry. On the other hands, composition of dmisteinbergite shows some variation of Si, Al-contents. This variation is resulted from (1) the presence of co-existing micron-size mineral grains and/or (2) just the chemical variation of dmisteinbergite itself. Especially, the variation caused by (2) is important because, during phase transition from dmisteinbergite to anorthite, chemical composition must have changed. We found that some anorthites coexist with Al-rich unknown phase. This phase may have been formed during the phase transition.

Conclusion: Our observation strongly supports the idea that, in CV_{oxA} CAI, secondary dmisteinbergite was formed from melilite via grossular in presence of liquid water of high pH at moderate temperature (200–250 °C). And we suggested the new idea that secondary anorthite formed from secondary dmisteinbergite probably caused by continuous water-rock reaction or shock induced transformation.

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