

Martian water environment of iddingsite formation in Yamato 000593 studied by the detailed analysis of secondary minerals and the investigation of the analog site on Earth

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【Motivation】

Olivine in nakhlite has altered structure iddingsite formed by water reaction on the Mars [e.g., 1]. Iddingsite is expected to be helpful to elucidate the water environment of the past Mars because it holds physicochemical information of water such as Eh-pH and trace elements distribution at the time of its formation. The iddingsite mainly composed by smectite groups clay minerals such as saponite and/or Si-rich amorphous materials [e.g., 2], and includes redox-sensitive sulfate type and carbonate type secondary minerals as an accessory component. Sulfate-bearing iddingsite had sulfate and iron oxide veins mainly consisted of jarosite ($\text{KFe}_3(\text{SO}_4)_2(\text{OH})_6$) and goethite/hematite ($\text{FeOOH}/\text{Fe}_2\text{O}_3$) [2], and a carbonate type one is mainly composed by Mg-Ca-Mn-bearing siderite (FeCO_3) [1,3]. Details of Eh-pH conditions and process of these minerals formation, however, have not been clarified yet. In this research, we tried to elucidate the water environment of alteration fluid formed iddingsite in nakhlite Y 000593 using electron and X-ray microscopic analyses.

【Sample and experiments】

Polished thin section (PTS: #58-1) of Y 000593 was used for this study. As for the first step of analyses, we conducted SEM-EDS observation to search iddingsite and find accessory components (such as sulfate and carbonate). Then, we analyzed trace elements distribution and their chemical species in the accessory minerals by synchrotron-based X-ray microscopic analysis (μ -XRF-XAFS) of secondary minerals in iddingsite of Y 000593 at BL-4A in KEK-Photon Factory and BL-37XU in SPring-8. In addition, as for the Martian analog site, Kusatsu-Anajigoku (Gunma prefecture) deposit was investigated. Kusatsu-deposit has layer jarosite/goethite sedimentation, which implies that this site is a similar formation environment to the sulfate type iddingsite on Mars. Collected mineral identification was conducted by XRD analysis (at the University of Tokyo) and bulk XANES (BL-12C in KEK-Photon Factory). Then, deposition environment was calculated by geochemical workbench software to obtain the Eh-pH in the fluid. The concentration of cations and anions in the fluid in the calculation was obtained by ion chromatography.

【Results and Discussion】

From SEM-EDS observation, we found the carbonate type iddingsite, and sulfate-bearing iddingsite was not found in the PTS #58-1 of Y 000593. Elemental correlation of anions (scattering plot results) indicated that carbonate of iddingsite is separated into two types: Ca-rich siderite, and Mg-related rhodochrosite (MnCO_3). The chemical composition of these carbonates is roughly similar to previous researches [e.g., 3,4]. One of the trace element chromium (Cr) distributed with the Mn, and Cr is identified as Cr_2O_3 . These results implied that the possibility of a part of the Mn species exist as Mn(III)OOH (MnCO_3 coexist with minor MnOOH in very fine scale). But we cannot mention whether Cr(III) was initially contained the Mn species or not. On the other hand, in the portions of Ca-rich siderite, approximately 20 percent goethite was contained by XANES fitting (REX software), suggested that pre-material of the Ca-rich siderite related to goethite.

As for Kusatsu-deposit, jarosite with minor goethite assemblage was confirmed by XRD and bulk XANES fitting results. Calculated Eh-pH environment of Kusatsu-fluid indicated goethite stability region. Therefore, we should be obtained the goethite deposition (with minor jarosite) ideally, there is a mismatch between ideal and real condition. This mismatch might be related to the kinetics of each mineral formation. In an acidic environment, goethite is a thermodynamically stable phase but actually, jarosite and ferric hydroxides occur in the environment because the goethite formation rates are very slow [5]. We expect this kinetics is limited to the formation of deposition in the Kusatsu site and iddingsite formation environment.

【Conclusion】

In this study, it was confirmed that rhodochrosite (MnCO_3) and calcite (CaCO_3) coexist and distribute in carbonate type iddingsite in Y 000593, indicates that it was formed by a reductive alkaline fluid ($\text{Eh} \leq 0.2$: $\text{pH} = 9-11$) [6], opposite to sulfate formation. We could not mention about the formation event(s) of these carbonates was contentious or discontinuous. In contrast, the jarosite in the sulfate type iddingsite formed in the high water/rock ratio and fluid was rapidly depleted in

iddingsite. These results indicated that Y 000593 have heterogeneous alteration events, and jarosite survived iddingsite did not experience carbonates forming alteration of alkaline fluid. Goethite presented as 20 percent of Ca-rich siderite portion implied that the Martian initial iddingsite experienced was jarosite/goethite formed type alteration, although Y000593 have terrestrial jarosite [7].

References

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