# Aqueous Alteration of Y-000593 Deduced from Chemical Speciation

HIROKI SUGA[1]*, N. SAGO[1], M. MIYAHARA[1], T. OHIGASHI[2], A. YAMAGUCHI[3], AND E. OHTANI[4]

[1] Hiroshima University, Japan.
(*correspondence: hiro-suga@hiroshima-u.ac.jp)
[2] UVSOR Synchrotron., [3] NIPR., [4] Tohoku University.

A member of nakhlites, Yamato (Y-) 000593 and Millar Range (MIL) 03346, have a remarkable amount of jarosite ($[KFe_3(SO_4)_2(OH)_6]$)-bearing iddingsite which is observed in and around the olivine grain as a representative alteration textures [1-3]. Iron sulfates including jarosite were detected on several provinces of Mars's surface such as Meridiani plume, strongly suggesting the existence of surface (or sub-surface) liquid water (high acidic brine) at least one period in the Martian history [4, 5]. These jarosite-bearing nakhlites therefore would become a keystone for direct linkage between Martian meteorites and Martian surface materials.

We have tried to describe secondary minerals in the Y-000593 for elucidating environment on the Mars during a wet-period by using a microscopic speciation technique; a FIB-assisted STXM, combined with TEM/STEM observation.

As a remarkable finding of our research, natrojarosite $[NaFe_3(SO_4)_2(OH)_6]$ was identified from the iddingsite. The presence of natrojarosite, one of the quad phases of jarosite [6], suggests that Y-000593 experienced low pH (= 1-4), low temperature (80-240 °C), and $SO_4$-rich aqueous alteration process. Iddingsite can form below 500 °C, and most of them form between 50 and 100 °C [7], which is consistent with the alteration temperature of Y-000593 deduced from the existence of natrojarosite. Y-000593 is a better sample than the other siderite ($[FeCO_3]$)-bearing near-surface nakhlites (mid pH (= 6-8), low temperature (150-200 °C) in [8]) to understand the late-stage acid-sulfate alteration event. Our analyses also revealed the alteration process from original olivine to laihunite $[(Fe^{2+}Fe^{3+})_2(SiO_4)_2]$ (a nonstoichiometric distorted olivine-type mineral); $Fe^{2+}/Fe^{3+}$ ratio gradually decreases from olivine to laihunite, which probably corresponds to the difference of superlattices of laihunite (2M and 3M phase) [9]. We found mismatch on the formation temperatures between natrojarosite and laihunite (400-800 °C in [10]). The discrepancy may indicate that these minerals were formed different alteration events; i.e., laihunite was formed before the late-stage acid-sulfate alteration event.

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