

DEHYDRATION AND RECRYSTALLIZATION EXPERIMENTS OF SERPENTINE FOR UNDERSTANDING THERMAL HISTORY OF HYDRATED ASTEROIDS.

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Introduction: JAXA's Hayabusa2 and NASA's OSIRIS-REx spacecrafts have been exploring asteroids (162173) Ryugu and (101955) Bennu, respectively [1, 2]. Spectroscopic observations revealed that Ryugu shows a weak absorption feature of hydrous minerals at 2.7 μm [3], while Bennu shows a clear 2.7 μm absorption feature of hydrous minerals [4]. This indicates that two asteroids experienced different thermal histories, and dehydration of hydrous phases could have occurred more effectively on Ryugu [5], similarly to parent bodies of heated CM chondrites [6]. If this is the case, it is important to understand thermal transformation processes of hydrous minerals to constrain the thermal histories of the asteroids. With the aim of understanding thermal processes on Ryugu and Bennu, we conducted dehydration and recrystallization experiments of serpentine in vacuum to obtain kinetic data for dehydration and recrystallization processes.

Methods: Natural serpentine (lizardite, occurrence), ground into 1- μm sized powder, was used as a starting material. Samples were heated at 500–800°C for durations of 2–88 hours in a vacuum furnace. The furnace consists of a tubular electric heating system with a silica glass tube connected to a pumping system. The pressure inside the silica glass tube during experiments was 10^{-4} – 10^{-5} Pa. The starting material and heated samples were examined with XRD (PANalytical X'Pert Pro MPD) and FTIR (JASCO FT-IR4200). The weight losses of the samples were obtained by weighing them before and after the experiments using an electric balance.

Results: The serpentine samples heated at 500°C were dehydrated with heating, but crystalline serpentine was still present in the sample heated for 36 hours. The samples heated at 600°C were decomposed into amorphous with a small amount of recrystallized olivine after heating for 8–48 hours. The XRD patterns of the samples heated at 650°C clearly show the presence of olivine that recrystallized from the dehydrated amorphous with a weak halo representing the presence of dehydrated amorphous phase. The samples heated at 700°C for 2–84 hours also show the evidence of recrystallization of olivine from the dehydrated amorphous phase. There seems no evident amorphous halo in their XRD patterns. The XRD spectra of the samples heated at 800°C for 8–66 hours show the strongest peak of enstatite in addition to the peaks of olivine, suggesting that crystallization of enstatite occurred at 800°C. The dehydration and crystallization behavior of the sample at different temperatures are roughly consistent with [7], where dehydration and recrystallization of serpentine were examined with TEM. FTIR analysis of the samples also confirmed the recrystallization of olivine from the dehydrated amorphous phase.

Discussion: The 10- μm features of FTIR spectra of the samples heated at 650 and 700°C were analyzed further to obtain the kinetics of recrystallization of olivine from dehydrated serpentine. We focused on the absorbance ratio of the peaks of olivine at 10.4 and 11.4 μm because the absorbance of olivine at 10.4 μm is affected by a broad 10 μm peak of amorphous silicate and its relative strength to the 11.4- μm strong feature could be a measure of the crystallization degree of olivine. We used the absorbance data of 10.4 and 11.4 μm of a mixture of crystalline and amorphous forsterite [8] to produce a calibration curve for the abundance ratio of olivine and amorphous silicate. Temporal changes of olivine abundance in heated samples, evaluated from the absorbance ratio of 10.4- and 11.4- μm peaks, at 650 and 700°C were fitted by the Johnson-Mehl-Avrami-Kolmogorov equation with the Avrami exponent of 1.5 [8] to obtain a crystallization rate constant. Our preliminary data give the rate constant [$\text{h}^{-1.5}$] of ~ 0.03 and 0.34 at 650 and 700°C, respectively. The activation energy for the olivine recrystallization is estimated to be ~ 360 kJ mol^{-1} . Assuming that the present data can be extrapolated to lower temperatures, combined with the dehydration kinetics of serpentine [9], dehydration of serpentine and recrystallization of olivine from dehydrated serpentine could occur at ~ 350 and ~ 550 K for a million years.

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