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Simultaneous observations of dehydration and AE activities during the deformation of antigorite at high pressures

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Intermediate-depth earthquakes are seismic activities at depths of 60-300 km, where subducting plates deform plastically rather than brittle failure. Because dehydration embrittlement (Raleigh and Paterson, 1965) may not work for serpentinite at pressures more than ~2 GPa, it is important to understand the mechanisms of shear instability at higher pressure. To conduct simultaneous observation of dehydration reaction, plastic flow and shear instability, we developed an in-situ observation system combined with synchrotron monochromatic X-ray and AE 6-6 system (multiple acoustic emission measurement for multi-anvil 6-6 type system) using Deformation-DIA (D-DIA) apparatus. Using this system, we carried out antigorite deformation experiments up to ~4.5 GPa and ~850 K including the condition of the antigorite dehydration to talc and forsterite.

Deformation experiments were conducted at high pressure and high temperature using a 1500-ton uniaxial press (SPEED Mk. II) with a D-DIA type guide block installed at BL-04B1, SPring-8 (Katsura et al., 2004; Kawazoe et al., 2011). 50 keV monochromatic X-ray were used to measure two-dimensional X-ray diffraction (2D-XRD) patterns and X-ray radiography images, which give reaction kinetics, differential stress, and strain. We developed MA 6-6 type system (Nishiyama et al., 2008) to monitor shear instabilities by AEs from maximum six piezoelectric devices positioned between first and second stage anvils. AE waveforms were recorded in trigger mode using six-channel 8-bit digital oscilloscopes at a sampling rate of 50MHz. Starting material of polycrystalline antigorite cylinder (1.7 mm in diameter and 2.7 mm in length) cored from high-temperature serpetinite (Eigami, Nagasaki, Japan) were first compressed at room temperature, then heated at constant load, and finally deformed with constant strain-rate mode. In some runs, dehydration occurred during heating or deformation. Microstructures of recovered samples were preliminarily observed by optical microscopy.

A total of ten deformation experiments of polycrystalline antigorite were conducted at 1.1~4.5 GPa, 300~850 K, and strain rates of 3.4~6.7 x 10^{-5} s^{-1}. AEs were frequently generated from the sample during the cold compression. Relatively large AEs were also detected when heating the sample to 673 K, while AE activities became zero at higher temperatures. During the constant strain-rate deformation, the flow stress reached steady state at the sample strain of more than 5%, and no stress drops were observed until the final strain of ~30-40%. These flow behaviors and the flow strength are almost consistent with the previous study (Hilairet et al., 2007). We also detected AEs during the deformation stage although the frequency was lower compared to the cold compression and heating stages. The AE activities during the deformation became large at lower temperature and larger stain conditions. Optical microscopic observation revealed that some faults are present in the antigorite samples recovered from each stage. On the other hand, we observed dehydration reaction from antigorite to talc-like phase during the deformation at 800 K. The reaction was very slow and only one AE event was detected at the strain of ~25%. Because the faults were only observed in the relict antigorite region, the AE was possibly originated from antigorite. At higher temperature of 850 K, complete dehydration quickly occurred before the deformation. No AEs were detected during the dehydration and the following deformation of dehydrated materials to more than 30% strain. No faults were observed in the recovered sample. Our simultaneous observations of reaction and AE activities showed that the AE is not generated by dehydration of antigorite at more than ~2 GPa. Instead, the unstable fault slipping that generates AEs occurs during heating and deformation of antigorite without dehydration.

Keywords: Acoustic emission, In situ X-ray observation, deformation-DIA, antigorite, dehydration, stress and strain