Deformation experiments of chlorite at high pressures and temperatures: A preliminary study

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Intermediate-depth earthquakes (IDEQs) occur within subducting oceanic plates at depths of about 60-300 km beyond the brittle-plastic transition. Dehydration embrittlement of serpentine (antigorite) has been considered as one of possible mechanisms for generating IDEQs, however previous studies have not provided sufficient experimental evidences especially at higher pressures than 3.5 GPa (~100km depth) (e.g., Ferrand et al., 2017; Gasc et al., 2017; Ikehara et al., JPGU2019). According to the thermal-petrologic model by Hacker et al. (2003), IDEQs seem to be distributed beyond the dehydration region of serpentine over the stability field of chlorite that dehydrates at higher temperatures. Therefore, the deformation behavior of chlorite might be related to the occurrence of IDEQs. Chlorite has 4 kinds of polytype, I*a*, I*b* (β=90°), I*b* (β=97°) and II*b*, and causes discontinuous structural change in the stacking (c-axis) direction during compression at room temperature. (Welch et al., 2004, 2005). For example, the d-value of the c-plane decreases discontinuously at ~6-7 GPa in I*a*, and ~9-10 GPa in II*b*, respectively. The former is accompanied by polytype change to I*b*. Acoustic emission (AE) associated with this structural change was also detected at room temperature (Dobson et al., 2007). However, deformation behaviors in chlorite has not been studied at high pressures and temperatures. In this study, we carried out deformation experiments of chlorite at the P-T conditions under which IDEQs occur, in order to investigate the relationship between the structural change and shear instability.

Uniaxial deformation experiments were conducted at 5 GPa, 230-800℃ using Deformation-DIA apparatuses at SPring-8 (BL04B1). Monochromatic X-rays (60 keV) were used as an incident beam to observe compression behavior, dehydration reaction, and deformation behaviors with recording AEs. The starting material is natural clinochlore from Brazil. We put a powder and a stacking of disk-shaped single crystals (c plane is perpendicular to the compression axis) in tandem in a hBN capsule. Au foils are placed at the upper and lower edges of the sample as a strain marker. Deformation experiments were carried out with a constant anvil displacement rate of 200 μm/h and a temperature ramping rate of 0.1K/s.

In the experiment at 5 GPa, the d_{004} spacing in clinochlore decreased during compression at room temperature and increased with heating. It decreased when the deformation started at 230℃, then increased again above ~500℃. Both powdered and single-crystal samples exhibited similar changes in values of d_{004}. AEs were detected during cold compression, heating, and deformation, whereas no AEs were observed above ~400℃ including during dehydration. These AE activities may be related to the changes in the d_{004} spacing, although we did not observe the abrupt changes implying the structural transition. The strain rate and the final strain in the powdered sample (7.2e-5/s and 37%) were about 8-9 times larger than those of the disk-shaped single crystal sample (8.5e-6/s and 5%), suggesting the large difference in the deformation mechanism during the uniaxial compression. This may also cause the difference in AE activities, which will be discussed after the quantitative determination of AE locations. We are also planning to conduct shear deformation experiments, in which the c-plane of clinochlore is parallel to the shear plane, to investigate deformation-induced structural changes in the stacking layer and shear instability.

Keywords: chlorite, high pressure, shear instability, intermediate-depth earthquakes