Rheology and frictional instability of lawsonite in high pressure deformation experiments

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The cause of intermediate-depth earthquakes (50-300 km) in subducting slabs have been proposed to be the dehydration embrittlement (e.g., Raleigh and Paterson, 1965), because there are many kinds of hydrous minerals in a subducting slab and hypocenter distribution coincides with the dehydration boundary determined by high pressure experiments (e.g., Hacker et al., 2003). Many experimental studies on antigorite have been conducted, but a few previous works about dehydration embrittlement of lawsonite-bearing rocks experimentally. Lawsonite, $CaAl_2Si_2O_7(OH)_2H_2O$, is a hydrous mineral which contains 11 wt% water in its structure as both water molecules and a hydroxy group (Cmodi and Zanazzi, 1996). Lawsonite is one of the candidate for dehydration embrittlement in cold subducting slabs, however previous works have apparently contradictory results. Okazaki and Hirth (2016) showed that lawsonite dehydration induced unstable fault slip based on deformation experiments of pure lawsonite using Griggs-type deformation apparatus at 1 GPa. On the other hand, Incel et al. (2017) also investigated deformation properties of lawsonite and glaucophane mixture at 1.5 to 3.0 GPa using deformation-DIA apparatus. They insisted that there is no evidence for a straightforward relation to the dehydration of lawsonite and the brittle failure of samples. So, we have conducted the deformation experiments of lawsonite under the cold slab conditions in order to clarify the deformation property of lawsonite and understand the relationship between dehydration and brittle failure.

Experiments were carried out using Deformation-Cubic Anvil Press (D-CAP) installed at KEK PF AR-NE7A beamline. Pure lawsonite powder (98%) was used as starting materials. Deformation experiments were carried out at a pressure of 6 GPa and temperatures of 300 - 800 ˚C. The temperature was increased at the same time as deformation started. The temperature ramping rate over the strain rate was set the ranges for the real subducting slab, which ranges from 10^2 to 10^4 ˚C (Chernak and Hirth, 2011; Okazaki and Hirth, 2016). During deformation stages, strain, stress and transformation rate were measured for in-situ using a monochromatic X-ray beam with an energy of 60 keV.

Four experiments showed rapid stress drop during temperature ramping before lawsonite dehydration starts. We observed microstructure of recovered samples, there are many through going faults and microcracks but no dehydration products. Our results indicate that brittle process and frictional sliding occur without dehydration of lawsonite. This suggests that the intermediate-depth earthquakes can be caused by the deformation itself of lawsonite without the dehydration of lawsonite.

Keywords: intermediate-depth earthquakes, dehydration embrittlement, Lawsonite

