Experimental study of the relation between lawsonite dehydration and intermediate-depth earthquakes

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The mechanism of intermediate-depth earthquakes in subduction zone is considered to be fundamentally different from that of shallow earthquakes. This is because the frictional strength of rocks in the intermediate-depth range is estimated to be too high to cause unstable slip. Based on previous researches, three major hypotheses have been proposed to explain the mechanism: transformational faulting (Kirby, 1987), shear instabilities and frictional melting (Ogawa, 1987), dehydration embrittlement (Raleigh and Paterson, 1965). Among them, dehydration embrittlement is a model that fluid caused by dehydration of hydrous minerals decreases the effective normal stress of rocks and enables sudden embrittlement under high pressure equivalent to the intermediate depth range where hydrous minerals are stable (Kita et al., 2006). Experimental studies testing the model have been recently published on the potential role of lawsonite as an important hydrous mineral. Okazaki and Hirth (2016) conducted deformation experiments on lawsonite using Griggs-type deformation apparatus. The experiment was initiated at a confining pressure of 1.0 GPa and a temperature of 300℃ with constant displacement rates, then the temperature was increased to 600℃ to induce dehydration reaction while the sample continued to deform. As a result, unstable slip occurred and anorthite-rich layer was observed subparallel to the fault surface as a reaction product. Based on the result, they concluded that dehydration of lawsonite could directly trigger earthquakes in subducting oceanic crust in the intermediate depth range. On the contrary to this result, Incel et al. (2017) claimed that there are no straightforward link between dehydration of lawsonite and the failure of rocks. They conducted deformation experiment on powder mixture of lawsonite and glaucophane at a confining pressure of 2.5GPa using D-DIA apparatus. In the experiment, failure of the sample was observed without lawsonite dehydration (i.e., failure within the stability field of lawsonite). These two results indicate that whether lawsonite dehydration could trigger intermediate-depth earthquakes or not is uncertain yet.

So we reconsidered dehydration embrittlemet by experiments. We conducted high-pressure deformation experiments using a D-CAP 700 apparatus installed at a synchrotron beamline (KEK, Tsukuba) continuously monitoring stress, strain and mineral reactions. Powder of lawsonite with a grain size of 20~45 μm was used as a starting material. Firstly, the powder was compressed to 4.5GPa at a room temperature and annealed at 270℃ for 1 hour. Then sample was deformed with a strain rate of 3.4×10^{-5} s^{-1} and heated to 670℃ for 3 hours. Although this experiment was conducted within lawsonite stability field, significant strain weakening after reaching the peak stress of 4.5 GPa was measured. Microstructure indicates that brittle failure and clear slip surface without any evidence of plastic deformation was observed. Our result agreed with Incel et al (2017)' s results in the point of lawsonite fracture without dehydration even under high pressure. Compared with Okazaki and Hirth (2016) and Incel et al. (2017), fracture strengths of lawsonite found to be depending on confining pressures. Therefore, lawsonite could be brittle even under high pressure up to 4.5GPa equivalent to a depth of 150 km where intermediate-depth earthquakes happen.

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