Shear deformation experiments of two-phase aggregates of antigorite and olivine at high pressure: A preliminary study

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Intermediate-depth earthquakes are observed to occur within subducting slabs at depths of about 60-300 km where most rocks exhibit plastic deformation rather than brittle failure, owing to high pressures and temperatures. Dehydration embrittlement of hydrous minerals, particularly antigorite serpentine, is one of the most popular hypotheses for explaining shear instability under such conditions (e.g., Raleigh and Paterson, 1965). Although there have been many experimental studies on this topic, the direct relationship between seismicity and serpentine dehydration remains unclear at high pressure conditions. Previous deformation experiments have often been conducted on a single-phase antigorite in axial compression at relatively low pressures (<2 GPa). However, it is also important to investigate effects of shear deformation on partially hydrated rocks at higher pressures for discussing intermediate-depth earthquakes. In this study, we are conducting shear deformation experiments on two-phase aggregates of antigorite and olivine, considering partially serpentinized peridotites within subducting slabs, in order to constrain how faults could be formed under high pressures and temperatures in the laboratory. Here we report preliminary results of these experiments.

High-pressure deformation experiments were conducted within antigorite stability field using a Deformation-DIA apparatus. We used a powder mixture of antigorite and olivine (3:7 in vol.) as a starting material. Firstly, the starting powder was compressed to 5 GPa at room temperature and, annealed at 400 ℃ for 1 h. The hot-pressed sample was recovered and cut into disks having thickness of 300 μm. The sintered disk was used for a shear deformation study by being assembled between two 45°-cut alumina pistons. In shear deformation experiments, the starting disk was annealed in the same steps (i.e., at 5 GPa and 400 ℃ for 1 h), and then deformed with an anvil displacement rate of 200 μm/h. Microstructures of the recovered samples were examined by an optical microscope and a scanning electron microscope. We also observed microstructures of a sample recovered just before the shear deformation and a sample deformed in uniaxial compression for comparison.

The sample deformed in shear showed brittle-plastic transitional microstructures and regional variations in shear strain (γ = 1.7-3.8), and has a through-going crack. A shear zone was formed in the middle of the entire sample along the crack, in which the plastic deformation of antigorite was significant. Whereas in small shear-strain regions, brittle failures within the olivine crystals were evident. This was also observed in the sample recovered just before the deformation stage (γ = 0.8), which indicates the brittle texture could be developed during the cold compression stage. Olivine also deformed plastically when shear strain was accommodated and localized during the deformation stage. On the other hand, the sample deformed in uniaxial compression (ε = 0.16) had a similar texture as observed in the small shear-strain regions, and the shear localization was not developed. Thus, the two-phase aggregates deformed in large shear strains showed unique microstructures involving shear zones and faults, which may provide important insights into shear instability at high pressure.

Keywords: intermediate-depth earthquakes, shear deformation, antigorite, olivine

