# Stable fault slip in antigorite-olivine aggregates at high pressures

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Intermediate-depth earthquakes are observed to occur within subducting oceanic plates at depths of about 60-300 km where most materials 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). Recent high-pressure deformation experiments, monitoring Acoustic Emission (AE) activities upon syndeformational antigorite dehydration, showed that dehydration embrittlement was not observed on single-phase antigorite (Gasc et al., 2017), whereas dehydration related faulting was formed on antigorite-olivine aggregates with strong AEs (Ferrand et al., 2017). However, most of the previous high-pressure studies have been conducted in axial compression at relatively low pressures (< 3.5 GPa), insufficient to consider intermediate-depth earthquakes. Therefore, in this study, we conducted high-pressure shear deformation experiments on two-phase aggregates of antigorite and olivine, considering partially serpentinized peridotites, in order to investigate possible shear localization and shear instability up to 7 GPa.
Deformation experiments were conducted at 5-7 GPa, 350-700 ℃ using Deformation-DIA apparatuses at SPring-8 (BL04B1). Monochromatic X-rays (50-60 keV) were used to measure dehydration kinetics, shear strain and stress with recording AEs. We used three kinds of starting materials; natural cored antigorite from Kawarakoba in Nagasaki prefecture, forsterite polycrystal, and two-phase sintered mixtures of antigorite and San Carlos olivine (antigorite 10, 30, 50 vol %). The samples were cut into disks having thickness of 300 μm and used for a shear deformation study by being assembled between two 45°-cut alumina pistons. In shear deformation experiments, the starting disk was compressed to 5 or 7 GPa at room temperature, annealed at 350 or 400 ℃ for 1 h, and then deformed with an anvil displacement rate of 200 μm/h. In some experiments, we increased temperature during shear deformation with a ramping rate of 0.1 ℃/sec to induce dehydration reaction. Microstructures of the recovered samples were examined by an optical microscope and a scanning electron microscope (SEM).
From X-ray radiography images, we observed shear localization in all two-phase samples deformed within the antigorite stability field at 5 GPa. The locallization occurred when homogeneous shear strain $\gamma$ reached 0.4-0.9 (strain rate $1.3\text{-}2.2 \times 10^{-4}$/s), and then most strains were partitioned to the fault zone with the slip velocity of $4.6\text{-}9.1 \times 10^{-2}$ μm/s. Because no AEs were detected from the sample region, the localized deformation is thought to occur by stable sliding. SEM observations revealed that a thin shear deformation zone was formed along the fault, where the plastic deformation of both antigorite and olivine was significant. Striation and nanograins were observed on the fault plane, suggesting the formation of nanogouge. In contrast, homogeneous deformation was developed during antigorite dehydration with temperature ramping, even in the sample showing shear localization in the antigorite stability field. Under higher pressure condition 7 GPa, shear localization did not occur in all samples regardless of temperature. These results suggest that, although AE activities were detected with the dehydration in the antigorite-olivine aggregates up to 3.5 GPa in the previous study, further increase of pressure inhibits shear instability and shear localization. Thus, other dehydration reactions and/or instability mechanisms are required to explain intermediate-depth earthquakes deeper than ~100 km.

 