Grain Size Dependency of Olivine-Spinel Phase Transformational Mechanism Responsible for Deep-focus Earthquakes

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Deep-focus earthquakes occur at the depth from 440 km to 660 km in the subducting slab. The mechanism responsible for the earthquakes is thought to be different from that of shallow earthquakes, so that previous studies have reported the various mechanisms. By the geophysical observations and deformation experiments, the phase transformational faulting mechanism is presumed as the precursor of deep-focus earthquakes (e.g., Zhan et al., 2014). The phase transformational faulting mechanism is that metastable olivine in the slab undergoes the phase transformation to fine-grained spinel and faulting occurs with strain localization into the fine-grained spinel. This shear instability depends on grain size. Furthermore, the grain size may restrict the pressure- and temperature-conditions where the shear instability occurs, that is, the region of slab where deep-focus earthquakes occur. However, previous studies have conducted deformation experiments with finer grain size than expected in the slab (e.g., Burnley et al., 1991). Hence, the results from the laboratory experiments cannot directly apply to the geophysical observation. In this study, to reveal the grain size dependency on the phase transformational faulting, we conducted the deformation experiments of germanate olivine (about 3 μm), which is an analogue material of silicate olivine, finer-grained than that in previous studies (30 μm). We used a Griggs-type solid-confining media deformation apparatus. The confining pressure, temperature and strain rate are 1.2 GPa, 400~900 ℃ and 2.0×10^{-4} s^{-1}, respectively. Even though deformation experiments were conducted under wider temperature conditions than previous studies, we did not observe any shear instability event with apparent stress drops. Also, Raman spectroscopy clarified that the germanate olivine underwent the transformation to spinel at temperatures higher than 500 ℃. Shear instability does not occur because the difference in grain sizes between olivine and nucleated spinel in this study was smaller than those in previous studies. Also, the transformation temperature in this study was much lower than those in previous study (T > 1000 ℃ in Burnley et al., 1991). Considering the rate equation of the transformation (Chan, 1956), small grain size promotes the transformation, but these fast rates of the transformation cannot be explained only by the effect of the grain size. Therefore, the presence of water such as absorbed water in a starting material can also contribute to promote the transformation. Hence, both small initial grain size and a little amount of water promote the transformation even at lower temperature. These results indicate that the phase transformational faulting mechanism has strong grain size dependency. In summary, the pressure- and temperature-conditions where the faulting occurs depends on the grain size of olivine and amount of water. Because the grain size in the slab is larger than that in the experiments, by extrapolating from these results, we may restrict the region of slab where deep-focus earthquakes occur.

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[Reference]

Burnley et al. (1991), JGR, vol 96, 425-443.
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Zhan et al. (2014), EPSL, vol 385, 89-96.

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