The 527th Geodynamics Seminar

Deformation of olivine transforming to wadsleyite: implications for the process triggering the occurrence of deep earthquakes

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The subduction zone produces a major fraction of the Earth's seismic activity. The mechanisms of intermediate-depth (> 40 km depth) and deep-focus (> 300 km) earthquakes are fundamentally different from those of shallow (≤ 40 km) earthquakes. This is because the frictional strength of silicate rocks is proportional to the confining pressure and it exceeds the upper limit of the stress level in the upper mantle (< 300 MPa: Obata and Karato, 1995) at pressures higher than 1 GPa (~30 km depth). Therefore, the cause of intraslab seismicity at deeper parts have been attributed to dehydration of hydrous minerals (i.e., the dehydration embrittlement model: e.g., Peakock, 2001) or pressure-induced phase transformation of olivine (e.g., Green and Burnley, 1989). The latter hypothesis is now widely accepted, because the depth dependence of seismic activity monotonically decreases with depth down to 400 km but it increases at depths between 400 and 660 km (e.g., Florich, 1989). Experimental studies on faulting of metastable Mg_2GeO_4 olivine, which undergoes incipient transformation to a spinel, have been conducted by many researches. Green and Burnley (1989) proposed that propagation and linking-up of spinel-filled anticracks. Shubnel et al. (2013) conducted deformation experiments on metastable Mg_2GeO_4 olivine combined with acoustic emission (AE) monitoring. They reported that fractures nucleate at the onset of the olivine-spinel transition followed by a faulting triggered by superplasticity of the nanocrystalline spinel reaction product. However, it is still unclear whether the germanatc analogue is reliable (Green et al., 1990). This is because Mg_2GeO_4 olivine directly transform to the spinel phase and the latent heat of the phase transition is much lower than that for silicate olivine.

To investigate the role of phase transformation of olivine on deep-focus earthquakes, I conducted uniaxial deformation experiments on dunite and at pressures 10-16 GPa and temperatures 960-1450 K with a constant displacement rate using a deformation-DIA apparatus. Pressure, stress, and strain were measured in situ by using x-ray diffraction patterns and radiographs. Ductile deformation is dominant at temperatures exceeding 1250 K. Grain boundary fractures were developed at lower temperatures, at which olivine-wadsleyite transition did not proceed. Nucleation of wadsleyite induced softening of the fine-grained domain, resulting in formation of mylonitic microstructures. Microcracks preferentially occurred in porphylocrastic large grains of olivine. Because grain-boundary nucleation of wadsleyite homogeneously proceed in the samples, shear localization induced by the phase transition could be difficult.

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