

Faulting in deforming harzburgite under wet conditions

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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 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 intermediate depths has been attributed to dehydration of serpentinite (e.g., Peakock, 2001) because the water released during dehydration reaction of serpentinite reduces the effective confining pressure. The dehydration embrittlement model is now widely accepted, because the location of the double seismic zone in the subducting Pacific slab corresponds to the main dehydration field in the pressure-temperature diagram of the hydrous peridotite (Omori et al., 2002).

To evaluate the effect of water on semi-brittle behavior of harzburgite, we conducted in-situ uniaxial deformation experiments on as-is/water-saturated harzburgite at pressures 1.2-3.0 GPa and temperatures 770-1250 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. Acoustic emissions (AEs) were also recorded continuously on six sensors, and three-dimensional AE source location were determined.

Formation of throughgoing faults was observed even when differential stress is much lower than the confining pressure (i.e., > 0.3 times of confining pressure) in water-saturated harzburgite. This is contrast to the case of water-saturated dunite (Ohuchi et al., 2018), in which fracture strength exceeds the confining pressure (i.e., Goetze's criterion). Creep strength of water-saturated harzburgite was lower than that of as-is harzburgite (~0.5-1 GPa at each temperature). Weakening of the harzburgite by the aqueous fluid resulted in the reduction in the number of AE events and decrease in fault slip rate (< $3.6\text{E-}4\text{ s}^{-1}$ at a stress of < 1.05 GPa). Stress/pressure drop around the timing of a faulting was limited at strains of $1\text{E-}4\text{ s}^{-1}$. The aseismic faulting observed in the water-saturated harzburgite implies that silent slip events around the subduction interface is due to semi-brittle flow of water-saturated harzburgite (i.e., a dehydration product of antigorite).

Keywords: harzburgite, water, semi-brittle flow