The 472nd Geodynamics Seminar

Shear localization in peridotites and the occurrence of intermediate-depth earthquakes

Dr. Tomohiro Ohuch (Lecturer, GRC)

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EHIME UNIVERSITY
GRC
GEODYNAMICS RESEARCH CENTER

Abstract

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). The fracture strength of silicate rocks is much higher than 300 MPa at upper mantle pressures due to the positive pressure dependence of the strength (Masuda et al., 1987). Therefore, the cause of intraslab seismicity at intermediate depths have been attributed to dehydration of serpentinite (i.e., the dehydration embrittlement model: 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). Another explanation for the origin of intermediate-depth earthquakes is the hypothesis of a periodic shear-heating mechanism (Kelemen & Hirth, 2007). Partial melting due to the adiabatic instability (i.e., plastic faulting) has been reported in some metals, ice, and ice and granitoid at pressures less than 0.5 GPa (Golding et al., 2012; Di Toro et al., 2007). The hypothesis of a periodic shear-heating mechanism explains the origin of seismicity in dry slabs.

To revisit the origin of intraslab earthquakes in wet slabs, I conducted uniaxial deformation experiments on wet dunite and harzburgite at pressures 1-3 GPa and temperatures 860-1250 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 radiographies. AEs were also recorded continuously on six sensors, and three-dimensional AE source location were determined. At temperatures lower than 1060 K, formation of throughgoing faults was observed in dunite (at stress > 1.7 GPa and strain rate > 2×10^{-5} s^{-1}). AEs were recorded during sampled deformation at temperatures below 1250 ^{o}C. In contrast to dunite, faulting was observed at lower stress (< 0.5 GPa) in water-saturated harzburgite. Formation of any gouge was not observed in water-saturated samples, implying that the formation process of faults is different between water-undersaturated and saturated conditions.

Contact : Dr. Nishi (e-mail: nishi@sci.ehime-u.ac.jp)