Study of generation mechanism of intermediate-focus earthquakes based on a deformation experiment of serpentinite

Jun-ichi Ando[1]; Toru Takeshita[2]; Tetsuo Irifune[3]; Kyuichi Kanagawa[4]

[1] Earth and Planetary Systems Sci., Hiroshima Univ.; [2] Dept. Earth and Planet. Sci., Hokkaido Univ.; [3] GRC, Ehime Univ.; [4] Dept. Earth Sci., Chiba Univ.

Intermediate-focus earthquakes occur at depths ca. 60 km - 300 km. In general, the brittle failure generating the earthquakes is inhibited at such depths due to the high pressure and temperature conditions. The triggering by embrittlement accompanying dehydration of serpentine is proposed to explain this paradox. Yamasaki and Seno (2003) recently calculated temperature structures of the descending oceanic plates. It is possible to think from their results that some intermediate-focus earthquakes occur at the region of stability field of serpentine. This interpretation is disagreement of the hypotheses of the dehydration embrittlement of serpentine. Here we proposed embrittlement due to plastic deformation of serpentine as a generation mechanism of intermediate-focus earthquakes, based on deformation experiments of serpentine and microstructural observation of the recovered samples.

Deformation experiment: We conducted a constant displacement rate test of serpentinite by a triaxial solid medium deformation apparatus installed at Hiroshima University under stability field and dehydration conditions of serpentine. Experimental conditions are P = 0.9 GPa, T = 450 C to 800 C and strain rate of digit of 10-5 /sec. Samples are cylindrical shape cored from serpentinite and their sizes are 7 mm x 7 mm and 5 mm x 5 mm in diameter by length. Lizardite is a main constituent mineral of used serpentinite.

Result and discussion: Faults are observed in recovered samples from all temperature conditions. Mechanical data of the experiments whose recovered samples were faulted show the stress drop of several 10 MPa during experiments. The followings summarize microstructures of the recovered samples from stability field and dehydration conditions of serpentine, and generation processes of fault at each condition.

1) Stability field condition: Serpentine grains along a fault develop a lattice preferred orientation (LPO) characterized by (001) parallel to fault plane. (001) of serpentine is a cleavage face. It is known that LPO of minerals is formed during plastic deformation. Therefore, this fact suggests the fault is generated by the following process. i) Serpentine grains along a maximum shear stress surface are preferentially deformed plastically, and then develop LPO such as describe above. ii) The arrangement of cleavage face reduces gradually the strength of this plane. iii) Eventually, embrittlement occurs at the critical point when the rock strength along this weak plane becomes smaller than shear stress.

2) Dehydration condition: Fine grained dehydration phases less than 1 micrometer in size such as olivine and talc are detected as a thin vein in the serpentine existed along the fault. Moreover, serpentine and olivine, or serpentine only ca. 1 - 5 micrometers in size with angular shape stick to the sharp fault plane. These angular grains should be a fault gauge. These facts support the hypotheses of dehydration embrittlement and suggest the following generation process of fault. i) Dehydration reaction of serpentine begins at some area on a maximum shear stress surface and expands along this plane. ii) The dehydration along the maximum shear stress surface reduces gradually the strength of this plane. iii) Eventually, embrittlement occurs at the critical point when the rock strength along this weak plane becomes smaller than shear stress.

The present results indicate that faults are able to generate in serpentinite under both conditions of stability field and dehydration of serpentine by different mechanisms. Descending oceanic plates become warmer with increasing depth, and then probably pass through plastic deformation regime before reaching the dehydration condition of serpentine. Therefore, the embrittlement due to plastic deformation of serpentine is thought be an important candidate for generation mechanism of intermediate-focus earthquakes as much as dehydration mechanism.