Dehydration weakening of serpentine and its roles in seismogenic processes in subducting slabs

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In the past decade it has been discussed that generation and migration of H_2O fluids and hydration/dehydration of minerals play essential roles in seismic processes in the subduction zones; dehydration of serpentine might trigger earthquakes in the double seismic zone in the slab mantle. Earthquakes generation in the oceanic crust might be attributed to dehydration of metamorphic minerals such as chrolite, hornblende, lawsonite and glaucophene. Occurrence of low frequency earthquakes and deep tremors might be related to fluid migration and/or serpentinized wedge mantle. Geophysical observations, numerical simulation of thermal structures in subduction zones, and phase analysis of hydrous minerals support these ideas. However, influence of fluids and hydrous minerals on the mechanical properties of deep seated rocks and their roles in earthquake generation are poorly understood. In this paper, we focus on the mechanism of intra-slab earthquakes.

A popular hypothesis for the occurrence of double seismic zones, observed at the intermediate depth of about 50-200 km, is dehydration embrittlement of the serpentinized slab mantle. It has been demonstrated by high P-T deformation experiments that brittle failure of antigorite serpentinites occurred at temperatures over 550 ^{o}C. The weakening of serpentinite was attributed to excess pore fluid pressure caused by dehydration reaction of serpentine. However, the confining pressure of these experiments using gas-medium apparatus was limited up to 500 MPa (corresponding to 15 km depth). It is questionable if the same mechanism could be effective in subducting slabs at higher pressures. We conducted constant strain-rate experiments of antigorite-serpentinite using a solid-medium deformation apparatus (MK65S) developed by M. Kumazawa (Kumazawa and Shimizu, 2006, *Japan J. Struct. Geology*, No. 49, 5-14; Shimizu et al., 2006, *Japan J. Struct. Geology* , No. 49, 15-26).

Cylindrical specimens with the diameter of 10 mm and the length of 15 mm were cut from the serpentinite sample and jacketed in Ag tubes. Deformation experiments were conducted at 500 ^{o}C and 700 ^{o}C under confining pressure of 800 MPa. Dehydration reaction starts at ca. 650 ^{o}C at this pressure. ‘Slow’ and ‘fast’ experiments were performed at the strain rate of 3.3x10^{-5} /sec and 2x10^{-4} /sec, respectively.

At 500 ^{o}C, serpentinite was not yielded even after differential stress exceeded 900 MPa. The microstructure of the sample after deformation experiment was almost the same as the original one. The samples deformed at 700 ^{o}C without pre-heating were also hard. Although antigorite is not stable at 700 ^{o}C, dehydration reaction had not occurred in these runs. On the contrary, samples deformed at 700 ^{o}C after static heating exhibit steady creep behaviors. The yield strength of heated samples were 200-280 MPa. The differential stress was slightly increased when the sample strain exceeds 5%. Velocity step tests revealed that the yield stress is not sensitive to the strain rate.

In the pre-heated samples, reaction products of olivine (forsterite) was observed and intergranular pores were developed. No cracks nor microfaults were recognized. The color of antigorite was changed from dark green to pink, possibly due to highly oxidized atmosphere caused by free water released from antigorite. Significant volume loss is recognized in these samples. It is inferred that a large part of free water and excess silica produced by the dehydration reaction were escaped from the Ag jacket during deformation. The reaction weakening of antigorite is considered to have occurred by cataclastic flow forsterite. Drastic weakening of serpentinized mantle slabs and abnormal pore pressure caused by pore collapse would trigger earthquakes in surrounding peridotite mantle and non-dehydrated parts of the serpentinized mantle at low-temperature sides.