Rheological weakening of serpentinite induced by dehydration reaction at 0.8GPa pressure

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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. Raleigh & Paterson (1965) first demonstrated the dehydration embrittlement of serpentinite in high P-T deformation experiments using a gas-medium apparatus. Brittle failure occurred at temperature over 550 C was attributed to the excess pore fluid pressure caused by dehydration reaction of antigorite (antigorite = forsterite + talc + H2O). However, it is questionable whether or not the same mechanism is effective at higher pressure over 500 MPa.

We conducted constant strain-rate experiments of serpentinite at the confining pressure of 800 MPa by using a solid-medium deformation apparatus MK65S. To evaluate the influence of friction between the inner piston and the solid confining media and measure the differential stress accurately, MK65S has two sets of load cells; one set is used for the measurement of confining pressure, and the other is for the measurement of axial stress.

The serpentinite sample (taken from the Oeyama Ultramafic Body in the Maizuru Belt, southwest Japan) is constitute mostly of antigorite associated with a small amount of magnetite and residual olivine crystals. Foliation is well-defined by preferred orientation of fibrous antigorite crystals.

Cylindrical specimens with the diameter of 10 mm and the hight of 15 mm were cut from the serpentinite sample and jacketed by Ag foils. The angle between foliation and the maximum compression axis (parallel to the symmetry axis of the cylinders) is about 30 degrees. Deformation experiments were performed at 500 C and 700 C, under and over the temperature of dehydration reaction.

In a deformation experiment at temperature 500 C and constant strain rate of 3.3 x10-5 /sec (Atg1), serpentinite was not yielded even when the differential stress exceeds 900 MPa. The microstructure of the sample after deformation experiment was almost the same as the original one. In the 700 C run (Atg2) at the same strain rate after static annealing for an hour, serpentinite was yielded at the differential stress of about 300 MPa. Steady creep was achieved, while no failure is recognized in mechanical data and microstructures. The strength was slightly increased after the sample strain exceeds 6%. Reaction products of olivine and talc, and pore spaces are observed under a microscope. Olivine is pink in color, possibly due to precipitation of hematite in defects or grain boundaries. Water release in dehydration reaction is considered as the cause of highly oxidized atmosphere. In the 700 C run (Atg4) at a faster strain rate of 2x10-4 /sec without annealing time, strain hardening occurred and the differential stress exceeds 1 GPa.

The difference in mechanical behaviors of antigorite may be attributed to: (1) temperature and strain-rate dependence of antigorite, (2) hydraulic weakening of antigorite or reaction products, (3) hardening due to production of a hard mineral of olivine, and (4) superplastic flow of fine-grained reaction products and subsequent hardening caused by grain growth.