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Rheology in subduction zones at the presence of serpentine

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Serpentinite is expected to present at the subducting plate interface, where released water from the descending slab reacts to the mantle rocks. Serpentinites are characterized by seismic low velocity and high Poisson ration, and such anomalies are detected in various subduction systems (e.g. Kamiya and Kobayashi 2000; Matsubara et al. 2008). In order to understand rheological behavior of serpentine at the plate interface, we are performing deformation experiments of serpentine at high pressures and temperatures. In this study, we introduce several topics related to serpentine rheology in subduction systems, including (1) down-dip limit of interplate earthquake, (2) excess pore pressure and low-frequency tremor and (3) coupling-decoupling at the subducting plate interface.

(1) Down-dip limit of interplate earthquake is generally controlled by the brittle-ductile transition at temperature around 350-400C. However, in some subduction zones where cold plate is subducting, the down-dip limit coincides with depth of crustal Moho at temperatures lower than the brittle-ductile transition (Oleskevich et al. 1999). Seno (2005) proposed this seaward shift of down-dip limit resulted of weak serpentine at the plate interface. To test this hypothesis, we performed deformation experiments of serpentine at conditions corresponding to the Moho of cold subduction systems (P=1GPa, T=200-300C). Experimental results show that deformation of serpentine is mostly controlled by plastic flow rather than brittle failure, suggesting that the presence of serpentine at plate interface inhibits the initiation of subduction interplate earthquake.
(2) Low-frequency tremor is mostly located at depths of 35-40 km, where the subducting plate meets the island arc Moho (Shelley et al. 2006). Such regions are characterized by low velocity anomaly and high Poisson ration, suggesting the presence of serpentine with excess aqueous fluids. This can be resulted of back stopped fluid migration at the island arc Moho due to the permeability contrast between serpentinite and gabbro. The excess fluids could cause a stick-slip type unstable sliding of serpentinite, and may trigger the low-frequency earthquake at the tip of mantle wedge.
(3) Coupling/decoupling between mantle wedge and subducting plate is a key for material circulation and thermal structure of subduction systems. Numerical modeling shows that the low-viscosity layer such as serpentinite at the plate interface causes decoupling, and the forearc mantle wedge becomes stagnant (Wada et al. 2008). We are investigating the viscosity contrast between serpentines and olivine by laboratory experiments. Preliminary results show that the high-temperature serpentine (antigorite) is slightly weaker than olivine by a factor of 2, whereas low-temperature serpentines (lizardite, chrysotile) are characterized by one order of magnitude lower viscosity than that of olivine. This indicates that the coupling-decoupling phenomena are largely influenced by the type of serpentine stable at the subducting plate interface.

Keywords: serpentinite, rheology, subduction zone, seismic activity, low-frequency tremor, decoupling