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Rheological contrast between serpentines and olivine and weakening of the subducting plate interface

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Recent seismic observations have suggested that water released by dehydration reactions within a subducting slab is transported through the base of the overlying mantle, making serpentinization. The degrees of viscous coupling between the serpentinite layer and the mantle wedge might influence the style of mantle convection and the thermal state of a subduction zone (Wada et al., 2008). Serpentine minerals (lizardite, chrysotile, and antigorite) are hydrous phyllosilicates (13 wt% H_2O). In subduction zone environments, lizardite and chrysotile are stable at temperatures below 300C, whereas antigorite is stable at temperatures of 300 to 600C. Although Hilairet et al. (2007) indicated that the strength of antigorite is one order of magnitude lower than olivine, the viscosity contrast between lizardite/chrysotile and antigorite under the mantle wedge conditions is not directly constrained. We therefore conducted two-layer shear deformation experiments on serpentines and olivine under P-T conditions that correspond to the mantle wedge corner in both cool and warm subduction zones (P = 1 GPa, T = 300, 500C).
The experimental results show that strain rates in lizardite/chrysotile are approximately one order of magnitude higher than those in olivine, whereas strain rates in antigorite are only 1 to 2 times higher than those in olivine. The contrasts in strain rates between lizardite/chrysotile and antigorite are represented by factors of 5 to 6.
Based on the results of our experiments, we suggest that the rheology of lizardite/chrysotile can only explain strong decoupling at the subducting plate interface. Our experiments also show that antigorite is not significantly weaker than olivine in the dislocation-accommodated creep regime, as compared to Hilairet et al. (2007), resulting in weak decoupling at the plate interface. Therefore, we suggest that the degrees of viscous coupling in subduction zones are strongly controlled by the serpentine species stable in the base of the mantle wedge.

Keywords: serpentine, olivine, subduction zone, rheology