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High-pressure deformation experiments on olivine-orthopyroxene aggregates under hydrothermal conditions

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For plate tectonics to operate on a terrestrial planet, the strength of faults within the oceanic lithosphere must be low, with the coefficient of friction below 0.05. However, standard strength profile using olivine flow law far exceeds this threshold value, particularly at depths of 20 to 40 km, where fluids passed through the faults may interact with peridotites to form hydrous minerals (e.g., serpentine). Here, we conducted deformation experiments on harzburgitic olivine-orthopyroxene aggregates under hydrothermal conditions, at a temperature of 500 ℃, a confining pressure of 1.0 GPa, and shear strain rates of 5.9 x 10^{-5} to 4.3 x 10^{-6} s^{-1}. All experiments showed a peak shear strength (about 400 MPa) at shear strains of 0.7, followed by a large stress drop (up to 150 MPa), after which steady-state sliding was observed until significant strain weakening started to occur at shear strains of 1.5. The drop in shear stress was initially caused by unstable slip, which resulted from the development of localized shear planes (Riedel or boundary shears) after yielding. The strain weakening after shear strains of 1.5 is related to shearing of newly formed talc along the shear planes. Talc may form from preferential dissolution of orthopyroxene rather than olivine. The final shear strength (down to 30 MPa) decreased with decreasing shear strain rates, reflecting widening of the talc layer along the shear planes. These results suggest that hydrothermal alteration of peridotites along the deep faults play an important role in forming the extremely weak zone for subduction initiation.

Keywords: olivine, orthopyroxene, talc, hydration reaction, strength weakening, subduction initiation