Shear resistance of faults during frictional melting of tonalite, gabbro and peridotite with marked contrast in viscosity

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Occurrence of pseudotachylite along large-scale faults implies that melt produced by frictional heating could lubricate a fault, leading to large earthquakes at times. Recent high-velocity frictional-melting experiments have demonstrated the process of melt lubrication successfully, and clearly indicated that frictional melts dramatically weaken fault strength [Hirose & Shimamoto, 2005]. During melt lubrication of a fault, the fault strength is governed by shear strain rate and viscosity of molten zone. Depending on the achieved temperature and the composition of melt, melt viscosity varies greatly and hence may significantly control the strength of a fault during an earthquake. In this study, high velocity experiments were performed on three types of rocks with different SiO2 content, thus their melts possess different viscosity, to evaluate how the fault strength changes with rock type with marked contrast in melt viscosity.

We slid a pair of cylindrical specimen of tonalite (from Adamello batholith, Italy), peridotite (from Ivrea-Verbano Zone, Italy) and gabbro (from India) at a 1.2 m/s slip rate and 2-16 MPa normal stresses under room temperature and unconfined conditions, using a high-velocity rotary-shear apparatus in Kyoto University. The specimen diameter was ˜22 mm. An aluminum sleeve with 1.5 mm thickness and 8 mm length was placed at the tip of the specimen to prevent thermally induced fracturing. For peridotite at 4-16 MPa and gabbro at 12-16 MPa normal stress, melt lubrication occurred just after the slip starts and the fault strength decreased exponentially from an initial peak stress towards a steady-state shear stress. For tonalite at 4-16 MPa and gabbro at 2-8 MPa normal stress, an initial slip-weakening stage just after the onset of the run and a following slip-strengthening stage were observed before melt lubrication initiated, which is identical to the behavior found on gabbro at lower normal stress conditions (0.9-2 MPa) [Hirose & Shimamoto, 2005]. The slip-weakening distance during the melt lubrication was about several tens of centimeters at normal stress above 12 MPa and was almost independent of rock type and normal stress. The slopes of steady-state shear stress versus normal stress curves for these rocks indicated a similar value of ˜0.1, well below the Byerlee's law. This clearly indicates that the melt could lubricate the simulated fault, although the shear stress was not completely independent of normal stress. The observed weak dependence of the steady-state shear stress on normal stress could be explained by the thinner molten (lubrication) zone by higher normal stresses, which would lead to higher shear strain rate within the zone, and thus greater the steady-state shear stress.

The comparison of the steady-state shear stress of these rocks exhibited more or less the same shear strength during melt lubrication, even though the melt viscosity of these rocks is different by more than two orders of magnitude at a given temperature. This may be interpreted as a feed-back process between temperature, melt viscosity and shear stress. Since the slip rate was held constant during the experiments, the more viscous the melt, higher the viscous shear heating, and higher the temperature in the molten zone which lowers the viscosity of the melt. Thus, once frictional melting takes place and the steady-state shear stress is achieved, rock types and their melt composition do not affect dramatically the fault strength during melt lubrication.