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Dynamic strength of peridotite during frictional melting at seismic slip rates: experimental results

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Ultramafic pseudotachylytes (solidified clast-laden friction-induced melts produced during coseismic slip) decorate exhumed faults within the Balmuccia (spinel lherzolite) peridotite from the Ivrea-Verbano zone (Northern Italy) [1]. Recent unpublished studies suggest that these pseudotachylytes were produced in the upper-mantle/lower continental crust during the extension that preceded the Alpine orogeny. Kanamori et al. [2] assumed extensive production of seismic melts during the M_w = 8.3 Bolivian 1994 deep focus ($\sim$ 600 km in depth) earthquake to justify the low seismic efficiency of this earthquake. It follows that seismic faulting and extensive coseismic melting might occur in the mantle.

To determine the dynamic strength of faults in the presence of ultramafic melts, we conducted a series of high-velocity rock friction experiments on solid cylinders (21.8 mm in diameter) of the Balmuccia peridotite in the rotary-shear apparatus in Kyoto [3]. Samples were kept under fresh air or dry argon fluxes and experiments were performed at slip rates comprised between 0.37 and 1.14 m/s (i.e. within the range seismic slip rates), normal stress between 5 and 13 MPa and displacements up to 60 m.

During each experiment, shear stress evolved with displacement: after an initial peak shear stress, fault strength gradually decreased towards a steady-state value. Dynamic fault weakening was associated to the formation and growth of a molten layer along

the slipping zone. By performing several experiments at different normal stresses and slip rates, we observed that steady-state shear stress: (1) slightly increased with increasing normal stress and (2), for a given normal stress, decreased with increasing slip rate. The ratio between steady-state shear stress and normal stress was ~ 0.13, well below the Byerlee solid frictional strength (~ 0.8). Under a normal stress of 13 MPa, the temperature (measured with a radiation thermometer) of the slipping zone, increased from 800˚C at slip rate of 0.37 m/s to 1250˚C at slip rate of 1.14 m/s, with the lowest steady-state shear stress achieved at the highest temperature. Experiments conducted under argon or fresh air flux yielded similar shear stress magnitudes, suggesting that olivine oxidation did not affect significantly the fault strength.

The fact that steady-state shear stress increased with decreasing melt temperature and slip rate is evidence for the dependence of dynamic fault strength with melt viscosity. This is confirmed by the slight dependence of shear stress with normal stress, which suggests melt lubrication in the presence of ultramafic melts. It follows that since physics of viscous flow is predictable [4], these experimental results might be of some relevance in the study of rupture dynamics in mantle rocks.

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