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Talc lubrication of faults at seismic velocities: an experimental approach

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Exposures of fossil or active mature faults at the Earth's surface show that in the shallow crust most of co-seismic slip occurs within a clay-rich gouge zone. Field observations, theories and laboratory experiments show that the thermo-poro-mechanical properties of the gouge zone significantly influence the dynamic fault strength by controlling the efficiency of the slip-weakening.

Talc represents a simple case for phyllosilicates in terms of water adsorption, thermal decomposition temperature, chemical processes and oxidation. In addition, talc is considered as a potential mineral for explaining fault weakness over the entire seismogenic zone out of any pore pressure consideration (e.g., the San Andreas fault in USA; the Zuccale fault in Italy). However, the mechanical behavior of talc at seismic velocities remains purely speculative. Thus, we have conducted rotary-shear friction experiments conducted on a natural pure talc gouge at constant slip-velocities of 0.01, 0.13 and 1.31 m s^{-1} and normal stresses of 0.3-1.8 MPa for saturated and non-saturated conditions.

At 1.31 m s^{-1} we invariably observe $i)$ a weakening behavior and the development of a μm-thick Principal Slip Zone (PSZ), *ii)* progressive re-orientation of talc grain long axis parallel to the shear direction and talc grain sheet plane parallel to the shear plane in the central part of the gouge zone. In dry conditions, the slip-weakening is attributed to *solid lubrication* (i.e., frictional sliding between favorably C-oriented (001) planes of pervasively delaminated talc lamellae) in the central part of the gouge zone and the PSZ. In wet conditions, the slip-weakening is attributed to *solid lubrication* and *fluid lubrication* (i.e., shear of a thin film of fluid between talc grains) in both the central part of the gouge zone and the PSZ.

At 0.13 and 0.01 m s^{-1} we observe a strengthening behavior, the development of a μm-thick PSZ, and re-orientation talc grain long axis parallel to the shear direction and talc grain sheet plane parallel to the shear plane as well. However, strengthening mechanisms are not well understood.

Mechanical data show a decrease of the gouge zone viscosity over time for V = 1.31 m s^{-1} experiments, but an increase of viscosity over time for $V < 1.31$ m s^{-1}. Finally, a decrease of viscosity with increasing rate of shear is observed. This indicates a non-newtonian behavior of the gouge zone, and so we expect an extraordinary low dynamic strength of the simulated fault for slip-velocities greater than 1.31 m s^{-1}.

Last investigations focus on the self-organization of the PSZ grains to provide minimum dynamic friction during strain localization. At 1.31 m s^{-1} in non-saturated conditions the PSZ shows an alternation of two types of microfabrics at the frictional steady-state. The first one is composed exclusively of delaminated talc grains with long axis parallel to the shear direction and sheet plane parallel to the shear plane. This suggests a sliding regime, that is a low friction. The second one is composed of tiny highly delaminated talc grains together with spherules of aggregates. This suggests a dominant rolling regime, that is an even lower friction. The presence of spherules of aggregates prior to the frictional steady-state indicates that rolling and sliding friction operate during the slip-weakening. This suggests that powder lubrication process represents a possible additional weakening mechanism for dry conditions.