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Laboratory simulation of rockslide creep and hydro-mechanical coupling

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Deep-seated rockslides are major threats in mountain areas, evolving over hundreds or thousands of years in changing morpho-climatic settings. They usually exhibit time-dependent displacements with superposed long-term and seasonal creep components, the latter related to hydrologic forcing (e.g. rainfall and snowmelt). Most rockslide deformation usually localizes in one or more shear zones, especially in crystalline anisotropic rocks. Shear zones are made of cataclastic breccia and gouge layers similar to those occurring in tectonic faults zones. While several mathematical models have been proposed to reproduce observed rockslide behaviour, only a few laboratory investigations, mostly limited to the assessment of residual friction properties, have been carried out.

Here we present laboratory experiments to characterize the frictional stability and time-dependent slip behaviour of real rockslide shear zones, using a biaxial apparatus within a pressure vessel (BRAVA). In order to compare experimental results with in situ observations, we characterized samples collected by full-core boreholes at a depth of 90m from the shear zones of the 50 Mm3 Spriana rockslide (Central Alps, Italy). The rockslide is characterised by long-term evolution after the Last Glacial Maximum, over a century of documented activity and over 25 years of deformation and hydrological monitoring. The rockslide creeps at slow rates of 0.4-3 cm/yr and undergoes order-of-magnitude acceleration stages correlated with groundwater fluctuations. We performed the experiments on 5x5cm samples of phyllosilicate-rich gouge under stress conditions characteristic of the sampled shear zones. We designed experiments in order to evaluate: 1) shear zone strength and permeability; 2) rate- and state- frictional properties for shear displacement rates (0.1-500 microns/s) covering the range of real rockslide slow-to-fast transition; 3) shear zone creep and hydro-mechanical coupling behaviour in response to pore pressure variations.

Rate- and state- frictional properties reveal a velocity strengthening behaviour, which is intrinsic of stable creep. However, during creep experiments we document a complex slip behaviour characterized by accelerations and self-decelerations associated with variation in fluid pressure. The accurate monitoring of displacement and displacement rates in response to fluid pressure variations indicate that the different styles of rockslide creep result from the competition between velocity-dependent friction, stress and hydro-mechanical coupling modes. Comparable properties, displacement patterns and rates between experiments and in situ conditions show that, despite scale and heterogeneity issues, rockslide behaviour can be captured by laboratory experiments.