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Deformation transients in the brittle regime: Insights from spring-wedge experiments

Matthias Rosenau, Tasca Santimano, and Onno Oncken
GFZ Potsdam, Geodynamics, Potsdam, Germany (rosen@gfz-potsdam.de)

Deformation of the earth's crust varies over timescales ranging from the seismic cycle to plate tectonic phases. Seismic cycles can generically be explained by sudden coseismic release of strain energy accumulated slowly over the interseismic period. The simplest models of such transient behavior is a spring-slider system where the spring stores elastic energy and the slider is characterized by static and dynamic friction at its base allowing cyclic occurrence of slip instabilities. Here we extend this model by allowing the slider to deform in an accretionary wedge type system. Because cyclic thrust formation is associated with bulk strain weakening this should introduce slip instabilities at the time-scale of accretionary cycles superimposed on seismic cycles which are controlled by static and dynamic friction at the wedge base.

To test this hypothesis we set up sandbox-type experiments where the backwall is not rigid but elastic. We vary stiffness, friction coefficients and amount of strain weakening during fault formation and reactivation within realistic ranges when scaled to nature and monitor backwall push force and surface deformation at high resolution. We observe slip instabilities both at seismic and accretionary cycle scale. Depending on the ratio of the amount of strain weakening to elastic stiffness, shortening rate increases transiently by a factor of 2-3 during fault growth.

Applied to nature our observation suggests that episodic deformation transients might be interpreted as longterm slip instabilities related to crustal weakening at all relevant spatial scales: At local scale "slow earthquakes" might be interpreted as the result of the interplay between matrix stiffness and strain weakening in fault gouge material. At regional scale, applying buckling theory, we predict that deformation zones bordered by "soft" oceanic plates (e.g. the Andes) are more susceptible to deformation transients than "stiff" intracontinental settings (e.g. the Himalaya).