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Slip dynamics in an analogue faultzone

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Elastic stress in the lithosphere releases through slip along pre-existing planes of weakness (fault zones). Slip events may occur on many spatial and temporal scales. They range from short-term localised seismic slip (earthquakes) to aseismic slip transients and long-term distributed slip in cataclastic or ductile shear zones. The interplay of seismic and aseismic fault slip is poorly understood, potentially complex and very costly to model numerically. Therefore, we designed an analogue experiment using a rate-and-state frictional material (fused glass beads), that shows unstable (seismic) and stable (aseismic) slip. This is embedded in an elastic material (ballistic gelatin) that models upper crustal elastic rebound.

In the analogue model presented here, we examine the influence of multiple parameters on the slip dynamics and overall statistics of ruptures within a glass bead shear zone. We use a customised rotary shear apparatus (Schulze ring-shear tester) to monitor shear stress during shear. The apparatus allows a direct control of shear rate and normal stress. Its transparent lid enables concurrent monitoring of the frictional contact surface. Digital image correlation is used to measure on-fault deformation. Because of the rate-and-state frictional properties of glass beads (a-b = -0.0138), the used setup produces regular stick-slip events under certain normal loading and strain rate conditions.

Preliminary analysis shows the following: The events feature statistics similar to natural slip systems, i.e. a magnitude distribution similar to single faults. Estimated moment magnitudes of the laboratory earthquakes range from MW = -7 to -6. A Gutenberg-Richter like decay up to a certain corner magnitude followed by a characteristic peak is observable. With decreasing loading rate the recurrence time and size of events increase exponentially with exponents similar to natural events. Rupture dynamics are characterised by a transition from two-dimensional crack expansion to one-dimensional pulse propagation as is typical for strike-slip earthquakes: In the experiment slip is usually initiated along the high strain rate boundary (outer perimeter), expands spherically until it reaches the low strain rate boundary (inner perimeter), and continues propagating in a bidirectional manner sweeping around the full perimeter of the analogue fault zone. The observations verify that our setup generates slip characteristics similar to natural seismogenic fault zones. Future analysis and experiments will test the influence of extrinsic parameters (load, loading rate), fault geometry (roughness) and state (shear stress level) on seismic and aseismic slip dynamics.