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Constant loading experiments yield non-constant slip rates: Implications for seismic moment budget and time-dependent seismic hazard analysis

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As crustal faults accrue earthquakes and slip, they interact and evolve so that their slip rates may be non-constant through time. With improved fidelity of slip rate records, we see increasing geologic evidence for non-constant fault slip rates. However, the drivers for non-steady state slip rate remain elusive. Scaled physical experiments of fault evolution allow us to directly document fault evolution and measure changes in slip rates associated with reorganization of fault systems. In these experiments, we use wet kaolin to simulate the upper crust material, a stepper motor-controlled deformation apparatus moving at a constant rate, and digital image correlation to record details of deformation.

Our experiments of slip partitioned fault systems (i.e. restraining bends and oblique convergence) show episodic variations in slip rate among the faults. During some temporal phases of fault system evolution, reverse faulting dominates the deformation while strike-slip dominates during other phases. Consequently, the slip rates on the reverse and strike-slip faults are anti-correlated. The transition from strike-slip to reverse dominated phases corresponds to development of new reverse fault segments within the fault system. Small, local increments of reverse fault growth affect slip rate, not only on the nearby reverse fault but also on the strike-slip fault far from the new fault growth. The transition from reverse fault dominated to strike-slip fault dominated phases is associated with unclamping of the strike-slip fault. Slip along the reverse fault induces extension within its hanging-wall that subsequently unclamps the strike-slip fault.

We use the product of slip rate and active fault area to estimate the evolution of seismic moment rate throughout the experiments. Seismic moment rate is non-constant in time and covaries with slip rate. These experiments reveal that interaction among faults within the system can temporally alter slip rate so that seismic moment rate can be non-constant even while the tectonic loading remains constant. This result is consistent with geologic evidence for slip rate changes at time scales not associated with tectonic loading changes. This implies that recent seismic hazard on faults may not always accurately predict future hazard.