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Early fault geometry has greater influence than rheology on strike-slip fault development

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We investigate strike-slip fault development using bi-viscous wet kaolin under different strain rates. Because the viscoelastic properties of the kaolin produce greater viscous flow and less accumulation of shear stress under slower strain rates, we can alter the rheology of the kaolin by varying plate velocities. In these experiments plate velocities range from 0.1 to 1.5 mm/min so that 100 mm of plate displacement occurs over 4-66 times the 15-minute Maxwell relaxation time for wet kaolin. Because the Earth's crust also has viscoelastic behavior over long time scales, the sensitivity of strike-slip fault growth in wet kaolin to strain rate may replicate strain rate sensitivity of crustal strike-slip systems.

In one suite of experiments, the clay is placed over juxtaposed basal plates, one of which is driven by a motor to produce dextral motion. In another suite of experiments, the plates are separated by an elastic sheet to apply distributed basal shear. Both suites of experiments show that in the early stages of fault development, faster strain rate produce more closely spaced and shorter echelon faults than slower strain rate experiments. The increased degree of stress relaxation in the slower experiments reduces stress concentration at small flaws so that only the largest flaws develop faults, which accounts for the wider spacing of initial faults. Furthermore, the closely spaced echelon faults of the fast experiments propagate into each other's stress shadow, which limits their length.

Tracking of individual echelon faults during their propagation reveals that they do not rotate; rather, the linkage of faults gives the appearance of rotation of the active fault surface. Numerical simulations of the onset of linkage show that shorter and more closely spaced faults don't accommodate as much slip as faults that are longer and farther apart, which account for the higher kinematic efficiency in the initial stage of echelon fault development for the slower experiments. The shorter echelon faults of the faster strain experiment link to produce smoother and more efficient mature fault surfaces, while the longer echelon faults of the slower strain experiments produce larger, inefficient irregularities along the mature fault that persists throughout the experiment.

To test the role of early fault geometry we ran experiments where strain rate was changed after the development of the initial echelon faults. In experiment that start with slow plate velocity until early echelon fault development (farther spaced and longer initial echelon faults) and then change to fast velocity, the kinematic efficiency of the system was very close to that of the constant rate slow experiments. Similarly, the experiments that start fast then change to slow after the development of closely spaced echelon faults evolve similarly to the constant rate fast experiments. Despite the significant change in clay rheology under different strain rates, the strike-slip fault evolution develops in response to the configuration of early echelon faults.