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Load-strengthening versus load-weakening faulting in gouge-bearing faults: insights from triaxial saw-cut experiments

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Brittle reactivation of pre-existing faults is theoretically constrained by their friction, the stress field orientation, and magnitude. Thus, following the Mohr-Coulomb failure criterion, the increase in tectonic shear stress leads to the reactivation of the fault whenever the shear stress achieves its frictional strength. Moreover, the increase in shear stress can occur following different fault loading paths: commonly, reverse faulting is accompanied by an increase in normal stress (load-strengthening path), while normal faulting is accompanied by a decrease in normal stress (load-weakening path). However, how the loading of the fault influences its frictional strength, i.e. its reactivation as well as its seismic behavior, is still poorly understood. To investigate this, we conducted triaxial saw-cut experiments under different loading conditions. We simulated pre-existing fault zones placing a layer of quartz gouge in a saw-cut through a cylinder of Rothbach sandstone. We investigated faults favorably and unfavorably oriented for reactivation, i.e. oriented at 30° and 50° to the maximum principal stress. These experimental faults were subjected to load-strengthening and load-weakening paths. Different confining pressures (i.e. minimum principal stress) were tested in such a way as to reactivate faults, that undergo different loading paths, at comparable shear and normal stresses. In addition, acoustic emissions were monitored during fault deformation. Consistently with previous studies, our results show that increasing the angle to the maximum principal stress from 30° to 50°, the frictional strength (i.e. the apparent friction) of gouge-bearing faults decreases. Furthermore, the frictional strength of unfavorably oriented faults (50°) is affected by the loading path, showing slightly lower frictional strength for load-strengthening than for load-weakening path. These observations suggest that the potential for reactivation of thick, gouge-bearing faults depends on the loading conditions and it cannot be properly assessed assuming a zero-thickness fault plane.