Rapid fault healing after seismic slip: The role of adsorbed water in fault restrengthening

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When faults slip at seismic velocities (>1 m/s) they experience a dynamic reduction in frictional strength as a result of shear heating. However, the rate at which faults regain their strength after an earthquake, and the mechanisms that cause restrengthening as the fault cools, are poorly constrained. Here, we perform a series of frictional slide-hold-slide experiments on gabbro and granite gouges at seismic slip rates in order to investigate how strength recovers between seismic slip events. We find that the gouges rapidly recover their strength during the hold period, with healing rates an order of magnitude faster than typically observed in slow-slip slide-hold-slide experiments. After the experiments we analyzed the surface of sheared fault materials using Raman spectroscopy. We find a Raman peak at 1600 cm^{-1}, associated with the bending vibration mode of adsorbed water, in all samples where the fault temperature increased above 250 °C during shearing (i.e., in experiments where rapid frictional healing was also observed). We propose that during sliding at seismic slip rates adsorbed water is driven off the surface of the gouge materials by shear heating, then, as the gouge cools during the hold period, water re-adsorbs in the bending vibration mode rather than the more common stretching vibration mode. We hypothesize that the switch in vibration mode of adsorbed water might enhance the chemical bonding at frictional contacts in the gouge, leading to the rapid healing observed in our experiments. Preliminary data from slide-hold-slide experiments performed in a controlled nitrogen atmosphere suggest that rapid healing can be suppressed when the availability of water to re-adsorb on to the surface of the gouge is restricted. Our results demonstrate that the desorption and adsorption of water onto fault materials can play an important role in dynamic weakening and subsequent restrengthening during the seismic cycle.

Keywords: Fault, Friction, Earthquake, High-velocity experiments, Raman spectroscopy