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Influence of fault slip rate on shear-induced permeability

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We measured permeability in sandstone and granite sheared at slip rates from 0.1 to 1300 m/s under low normal stress at confining pressures up to 120 MPa. As slip rate increased, the permeability of Berea sandstone (5*10-14 m2 of permeability at 10 MPa effective pressure) decreased by an order of magnitude, whereas that of Indian sandstone (10-16 m2) and Aji granite (10-19 m2) increased by three orders of magnitude at high slip rates. A fine-grained gouge layer of thickness proportional to slip rate developed during slip. Microcracks and mesoscale fractures formed at slip rates above 0.13 m/s. Numerical modeling showed that the slip surface temperature increased by several hundred degrees for slip velocities above 0.13 m/s and exceeded the – phase transition temperature of quartz at 1.3 m/s. Both temperature rise and the temperature gradient at the slip surface were high at fast slip rates. We attributed reduced permeability after slip in porous sandstone to the low permeability gouge layer. An abrupt permeability increase in low permeability rocks at high slip rates was caused by heat-induced cracks. An increase in the rate of wear of gouge with increasing slip velocity was caused by frictional heating that reduced rock strength. The host-rock permeability that separated reductions and increases of permeability was around 10-16 m2 at 10 MPa effective pressure. Our results suggest that abrupt increases of shear stress during slip in a low permeability fault zone cause thermal cracks, which decrease slip displacement. The abrupt permeability increase at high slip rates in low permeability rocks agrees with hydrogeochemical phenomena observed after earthquakes.