Fault rheology at the depth limits of the seismogenic zone

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The limits of the seismogenic zone demarcate changes in fault behaviour with increasing depth in Earth’s crust, from aseismic, velocity (*v*-)strengthening to seismogenic, *v*-weakening, and vice versa. Significantly, the *v*-dependence of fault strength is a material property of the sliding medium present in the core of fault, or the fault gouge. I conducted shear tests using simulated fault gouge composed of calcite ($CaCO_3$) at an effective normal stress of 50 MPa, at temperatures of 20 to 600ºC, employing sliding velocities (*v*) of 0.03 to 300 μm/s –sufficient to span the brittle-plastic transition in this material. Mechanical results showed (unstable) *v*-weakening behaviour from ~80-100ºC to ~550ºC, but stable *v*-strengthening for <80-100ºC and >550ºC. All gouges sheared at temperatures <=550˚C showed localization into nanocrystalline principal slip zones, while samples sheared at >550˚C were characterized by distributed deformation. Using the post-test micro- and nanostructures observed in calcite gouge as a basis, plus a previously established microphysical model, I argue that transitions in fault stability are caused by changes in the (nano)granular flow processes accommodating shear. Specifically, the rate of intergranular compaction by Arrhenius-type processes such as diffusion or crystal plasticity, is key to thermally-activated transitions in the velocity dependence of gouge-filled faults. At the low-temperature transition from *v*-strengthening to *v*-weakening, at shallow crustal levels representing the upper-limit of the seismogenic zone, diffusion creep (e.g. pressure solution) may be dramatically accelerated due to the nanogranular nature of the fault rock that forms. At higher temperatures, towards the base of the seismogenic zone, a transition occurs from nanogranular flow in localized faults to distributed, fully creep-controlled flow in ductile shear zones.

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