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Brittle-viscous oscillations and different slip behaviours in a conjugate set of strike-slip faults

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Fault zones hosted in granitic gneisses in the Olkiluoto nuclear waste disposal site in SW Finland exhibit a mixed brittle-viscous deformation style, and represent excellent targets to study coexisting ductile and brittle deformation in quartz-rich systems. Here we investigate the microstructural record of mutually overprinting brittle and viscous deformation events in a conjugate set of subvertical strike slip faults, in order to derive a conceptual model of the failure modes experienced by the faults at seismogenic depth.

One of the two faults (BFZ045) exploits a mylonitic precursor and contains foliation-parallel veins that are cut by cataclasites and pseudotachylytes. The other fault (BFZ300) manifests itself as multiple generations of subparallel quartz-chlorite veins. Fluid inclusion microthermometry and chlorite and graphite geothermometry constrain the deformation T within the conjugate set to the 250-400°C range, which is the typical T range defining the greenschist facies metamorphism at the base of the seismogenic crust.

Both faults show mutual overprinting relationships between viscous and brittle deformation. BFZ045 shows bulging and subgrain rotation recrystallization of quartz veins emplaced along the mylonitic foliation. The oldest generation of veins in BFZ300 contains a variety of quartz deformation features (extinction bands, bulging and subgrain rotation recrystallization) overprinting and overprinted by mixed brittle-viscous textures (recrystallized cataclasites and healed fractures). Quartz recrystallized grain size piezometry was used to estimate the oscillations in differential stress during the deformation cycles. Mohr failure diagrams were derived to model the switches in slip behaviours experienced by the conjugate faults.

We propose that the brittle-viscous deformation cycles were controlled by transient oscillations in fluid pressure and in differential stress during the earthquake cycle. Thus, we suggest that the exhumed brittle microstructural record witnesses discrete failure events during the shocks, while the viscous deformation microstructures instead represent the interseismic creep.