Fault rheology near the downdip limit of the seismogenic zone: new insights from fault core microstructures and geochemistry

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Résumé

While the dynamic evolution of fault rheology during coseismic slip has been the foundation of many studies, little is known about the processes and laws that govern fault recovery after slip. To shed light on this issue, we investigated fault zones from the Kodiak Central Belt, Alaska, which were active under peak metamorphic conditions (3.0 ± 0.4 kbar, 320 ± 20 ◦C).
At outcrop scale, these faults cut across metamorphosed turbidites and extend for tens of meters, with fault cores up to 5 cm-thick. Injections of the core material into ˍ˜10 cm-long cracks in the host rock, perpendicular to the main slip plane, are locally present. At thin section-scale, the fault cores show a multilayered structure, indicative of multiple slip events. The microstructures of these layers include cataclasites with clasts of various size surrounded by a quartz-rich cement, as well as quartz or calcite veins.

The cement is to a large extent composed of idiomorphic quartz crystals that exhibit successive growth increments, highlighted by rims of micrometric chlorite inclusions. The growth history of idiomorphic quartz crystals is further revealed by sharp variations of Al concentrations. Most crystals display isotropic growth microstructures, indicating that the crystal growth occurred without steric constraints, hence presumably within a fluid. Additionally, crack-seal microstructures formed in a dilatation jog along a microfault show similarly cyclical variations in Al content of the quartz cement, with incorporation of up to 0.6 wt% Al2O3.

These microstructures indicate that quartz crystal growth spanned multiple slip events and occurred under variable physico-chemical conditions, which influenced the differential incorporation of Al and solid inclusions into the quartz. The geometry of the growth microstructures suggests that the density and viscosity of the fault-core-filling fluid were sufficiently high to prevent the crystals from settling down by gravity during their growth.
Based on these observations, we propose that the fault core was filled by a water-rich slurry that persisted over multiple slip cycles. This persistent slurry implies that the fault cores remained at low viscosity over protracted periods, until the fluid was eventually consumed by the growth of the crystals it contained.

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