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# Grain-scale processes and inferred stress drops during the formation of shear zone networks at the brittle-to-viscous transition (BVT)

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The microstructural evolution of a mid-crustal shear zone network (SZN) was investigated within a greenschist-facies shear belt that formed in metapelitic and -psammitic rocks exposed at the northern Cap de Creus (Spain). It could be shown that decametre-wide shear zones form in a three-stage process: First, fractures nucleate and interconnect to form mylonitic shear zones. This represents a strain-dependent switch from brittle to viscous deformation. Second, these host shear zones interconnect laterally by step-over shear zones that propagate parallel or at low angles to the pre-existing foliation, oriented at high angles to the host shear zones. Thus forms a SZN. Third, domains of less-deformed host rock enclosed by the SZN are compartmentalized and overprinted; deformation becomes homogenized on a larger scale than at the onset of strain localization.

Microstructures interpreted as partially overprinted and recrystallized fractures can be found in the tip process zones of propagating mylonitic shear zones. These extremely narrow, conjugate fractures cut both along and across grain boundaries, and offset the pre-existing foliation. The geometry of these inferred hybrid and shear fractures is consistent with estimated differential stresses of 80 to 110 MPa at an assumed tensile strength of 20 MPa. Synkinematic mineral assemblages indicate upper-greenschist facies metamorphic conditions for the formation of these fractures, which are in structural continuity with quartz-rich parts of the rock undergoing dynamic recrystallization. We therefore infer that brittle and viscous deformation were coeval.

Within the step-over shear zones, very fine-grained, polyphase, ultramylonitic fault rock shows evidence of diffusion-accommodated viscous grain boundary sliding. Matrix grains in these ultramylonites (Bt, Qtz, Plag, Ms, Grt up to $\sim 5\mu$m) result from

recrystallization of porphyroclastic Plag and Bt. Grt-Bt thermometry indicates syntectonic temperatures of 460$\pm$50˚C.

With progressive deformation, step-over shear zones are interpreted to rotate towards the host shear zones, and grain-size sensitive creep seems to give way to deformation by intracrystalline, dislocation creep in Qtz. Dislocation creep in Qtz is also the dominant defomation mechanisms in the decametre-wide shear zones. Paleopiezometric estimates from dynamically recrystallized Qtz layers indicate differential flow stresses of 30-50 MPa in these shear zones.

Networking of fractures, ultimately to form mature, crustal scale shear zones, is associated with a strain-dependent change in grain-scale deformation mechanisms, from fracturing in the presence of fluid to viscous creep (transient grain-size sensitive creep in polymineralic aggregates, dislocation creep in Qtz in mature shear zones). This brittle-to-viscous transition is inferred to coincide with a strength drop of ca. 30-80 MPa, based on the stress estimates cited above. Such values may be typical of decoupling in 8-12 km deep parts of continental strike-slip faults.