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The propagation of greenschist-facies mylonitic shear zones in
rocks with structural anisotropy

F. Fusseis (1), M.R. Handy (2)

(1) School of Earth and Geographical Sciences, The University of Western Australia, (florian@fusseis.at), (2) Deptartment of Earth Sciences, Freie Universität Berlin, Germany

Detailed micro- to macro-scale studies describing the contribution and interaction of various strain softening mechanisms and brittle fracturing to the propagation of natural greenschist-facies mylonitic shear zones are rare, though these are of special interest for understanding localization at the brittle-viscous transition. Progressively strained samples collected across the marginal damage zones of several metre- to decametre-long mylonitic shear zones at the Cap de Creus, NE Spain preserve a time-sequence of microstructural development during the propagation of mylonitic shear zones. Our study shows how brittle deformation mechanisms influence the propagation of viscously deforming mylonitic shear zones.

The host rock of the investigated shear zones are metapelites and -psammites whose mineralogy is dominated by varied amounts of quartz, plagioclase and biotite. Biotite in disjunctive cleavage domains and quartz and plagioclase in microlithons form a composite foliation that is generally oriented at high angles to the bulk shearing plane.

This foliation is monoclinally folded in the damage zones at the shear zone tips where it is also segmented by planar discontinuities with markers offset subparallel to the shear zone centre. This indicates that the terminations of mylonitic shear zones involve a combination of distributed and localized strain. The progressively strained samples show that strain localization in damage zones basically involves three microscale processes: dislocation creep in quartz, the reaction of biotite and microfracturing. Our observations suggest that the relative contributions of these deformation mechanisms are strain-dependent.

Early stages of deformation are dominated by intragranular fracturing and microcataclasis of quartz and plagioclase as well as by the formation of fluid inclusion planes. Undulatory extinction, grain boundary migration and subgrain formation in quartz, as well as the reaction of primary biotite to form neocrystallized grains of secondary biotite, muscovite, ilmenite and minor chlorite do occur, but are less pronounced. The latter processes become more important in samples collected closer to the mylonitic shear zone centre. However, microfabrics in samples with intermediate deformation are characterized by centimetre-long transgranular shear fractures that seem to have formed by segment linkage and are the microscale pendants to up to decimetre-long planar discontinuities in the outcrops. Their often antithetically rotated orientations with respect to the shearing plane resulted from a microscale deflection of propagating fractures in pre-existing disjunctive cleavage domains.

Fractures in the tip damage zones of mylonitic shear zones probably resulted from stress rises characterizing the terminations of shear zones. The attainment of a critical length of decimetre-long shear fractures is interpreted to have enhanced fluid access, which in turn lead to hydrolytic weakening and reaction softening. Highly strained samples from mylonitic shear zone centres which experienced critical shear strains of about 1 do not exhibit any fractures; most quartz is dynamically recrystallized and all primary biotite has reacted. The mylonite comprises a fine-grained polyphase mixture of quartz, biotite, plagioclase, muscovite and ilmenite. Deformation was likely accommodated by a combination of diffusion and dislocation creep. We interpret this to indicate a strain-dependent transition from brittle to viscous creep following the formation of a rheological phase that was weak enough to accommodate all the imposed deformation.