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Strain localization in the lower crust: brittle precursors versus lithological heterogeneities (Musgrave Ranges, Central Australia)

Friedrich Hawemann (1), Neil Mancktelow (1), Sebastian Wex (1), Giorgio Pennacchioni (2), and Alfredo Camacho (3)

(1) ETH Zürich, Geological Institute, Earth Sciences, Zuerich, Switzerland (friedrich.hawemann@erdw.ethz.ch), (2) Department of Geosciences, University of Padua, Padua, Italy, (3) Department of Geological Sciences, University of Manitoba, Winnipeg, Canada

The Davenport shear zone in Central Australia is a strike-slip ductile shear zone developed during the Petermann Orogeny ($\sim$ 550 Ma). The conditions of shearing are estimated to be amphibolite-eclogite facies (650 °C, 1.2 GPa). The up to seven kilometre thick mylonite zone encloses several large low strain domains with excellent exposure, thus allowing a thorough study of the initiation of shear zones.
Quartzo-feldspathic gneisses and granitoids inherit a suite of lithological heterogeneities such as quartz-rich pegmatites, mafic layers and dykes. When in a favourable orientation to the shortening direction, these rheologically different pre-existing layers might be expected to localize deformation. However, with the singular exception of long, continuous and fine-grained dolerite dykes, this is not observed. Quartz-rich pegmatites are mostly unsheared, even if in a favourable orientation, and sometimes boudinaged or folded. There are instead many shear zones only a few mm to cm in width, extending up to tens of metres, which are in fact oriented at a very high angle to the shortening direction. Parallel to these, a network of little to moderately overprinted brittle fractures are observed, commonly marked by pseudotachylyte (pst) and sometimes new biotite. Shear reactivation of these precursor fractures is generally limited to the length of the initial fracture and typically re-uses and shears the pst. The recrystallized mineral assemblage in the sheared pst consists of Cpx+Grt+Fsp$\pm$Ky and is the same to that in the adjacent sheared gneiss, with the same PT estimates (650 °C, 1.2 GPa). In some cases, multiple generations of cross-cutting and sheared pst demonstrate alternating fracture and flow during progressive shear zone development and a clear tendency for subsequent pst formation to also localize in the existing shear zone. The latest pst may be both unsheared and unrecrystallized (no grt) and is probably related to a late stage, still localized within the same shear zone. The observation that pst is preferentially sheared indicates that it is weaker than the host rock, although their bulk compositions are about the same, suggesting that the governing factors for localization are the finer grain size and the elongate, nearly planar geometry of the original pst generation zone. The same may be true of the sheared dolerite dykes, which are long, narrow and generally finer grained than the surrounding gneiss or granite. Although quartz-rich pegmatites are not preferred sites of localization, quartzo-feldspathic mylonites are fully recrystallized with a relatively coarse grain size (typically > 50 microns) typical of rather low long-term flow stress.
We therefore propose that localization in the lower crust only occurs on long planar layers with a finer grain size that can promote weakening by grain-size sensitive creep. Coarser-grained lithological layers and boundaries are not exploited during the initiation of a shear zone and, in particular, quartz-rich layers are not preferentially sheared.