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Natural constraints on the rheology of the lower continental crust (Musgrave Ranges, Central Australia)

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Current models and extrapolated laboratory data generally predict viscous flow in the lower continental crust and any localized brittle deformation at these depths has been proposed to reflect downward propagation of the frictional-viscous transition zone during short-term seismic events and related high strain rates. Better natural constraints on this proposed rheological behaviour can be obtained directly from currently exposed lower crust that has not been strongly overprinted during its exhumation. One of the largest and best preserved lower crustal sections is located in the Musgrave Ranges, Central Australia.

The Petermann Orogeny (550 Ma) in this area is characterized by the development of localized shear zones on a wide range of scales, overprinting water-deficient granulites of Musgravian age (1.2 Ga) as well as younger granites and gabbros. Shearing is rarely localized on lithological inhomogeneities, but rather on precursor fractures and on commonly associated pseudotachylytes. The only exception is that older dolerite dykes are often exploited, possibly because they are planar layers of markedly smaller grain size. Sheared pseudotachylyte often appears caramel-coloured in the field and has a fine grained assemblage of Grt+Cpx+Fsp. Multiple generations of pseudotachylyte formed broadly coeval with shearing are indicated by clasts of sheared pseudotachylyte within pseudotachylyte veins that then themselves subsequently sheared.

The ductile shear zones formed under sub-eclogitic conditions of ca. 650°C and 1.2 GPa, generally typical of the lower continental crust. However, the P-T conditions during pseudotachylyte formation cannot be readily determined using classical geothermobarometry, because of the fine grain sizes and possible disequilibrium. The software “Xmaptools” (by Pierre Lanari) allows the quantification of X-ray maps produced by EDS or WDS. It provides both very precise definition of local mineral compositions for exchange geothermobarometry on a statistical basis, and an estimate of the bulk pseudotachylyte composition for small areas, avoiding clasts and heterogeneous composition of the former melt. The combination with thermodynamic modelling using PerpleX is used to test the results from geothermobarometry. The estimated conditions are similar to the ductile shear zones and support evidence for synchronous action of brittle faulting and viscous shearing in the lower crust.