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Non-steady state microstructures recording transient stresses during repeated earthquake cycles in the lower crust (Musgrave Block, Central Australia)

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The Musgrave Block in Central Australia provides generally excellent exposures of water-deficient felsic lower crustal rocks that were little affected during exhumation. During the Petermann Orogeny (550 Ma), several large-scale shear zones were developed in an overall transpressional setting. The Davenport Shear Zone is a ca. 5 km-wide mylonite zone, showing an intimate interplay between fracture and flow, expressed by multiple generations of pseudotachylyte that may crosscut the mylonitic fabric but are themselves subsequently sheared and foliated. Conditions of pseudotachylyte formation and shearing are constrained to be around 650°C and 1.2 GPa, corresponding to lower crustal depths. This interplay between brittle and ductile deformation in the lower crust is interpreted to represent cycles of seismic fracture and aseismic creep. The grain size of quartz in the mylonites is generally relatively coarse, usually between 50 and 100 μm. The crystallographic preferred orientation (CPO) of the quartz grains shows a Y-maximum for the c-axis, indicating dominant prism <a> slip and consistent with the estimated upper amphibolite to sub-eclogitic metamorphic conditions. However, almost all grains also host subgrains that are usually smaller than 5 μm, with misorientation angles across the subgrain boundary on the order of 5°, showing the same CPO. We interpret these subgrains to record transient stress increases prior to the fracturing that produced pseudotachylyte. The grain size of quartz is commonly used as a paleo-piezometer, but application is usually limited to steady-state microstructures. However, from laboratory experiments it is now established that pulses of high stress can lead to the local formation of small subgrains, which might be preserved. The natural quartz microstructures described here are interpreted to document stress fluctuations on the order of 10 to at least 500 MPa. It follows that although the long-term stresses during aseismic creep in this example of water-deficient lower crust were relatively low (a few 10's of MPa), transient high stresses ($\geq$ 500 MPa), as would be required for brittle fracturing and pseudotachylyte formation in effectively "dry" rock at 1.2 GPa, may also be recorded and still preserved in the quartz microstructure of lower crustal rocks.