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Lower crustal seismicity as a signature of strain compatibility within localised shear zone networks

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Whilst continental earthquakes nucleate predominantly in the seismogenic upper crust, deeper seismicity along intracontinental fault zones may also cause significant destruction, though deep crustal earthquakes remain relatively poorly understood. The strength of the lower crust is a crucial parameter in understanding how earthquakes may nucleate within a deformation regime that is generally regarded as viscous. Dry, plagioclase-rich crust may remain strong under high-grade conditions and able to deform by frictional failure at high differential stress, potentially enabling transient seismic behaviour.

Granulite-facies mylonitic shear zones within an anorthosite intrusion in Lofoten, northern Norway, provide a field case in which to test rheological models of transient switching between frictional and viscous deformation behaviour. A network of shear zones localised on continuous pseudotachylyte-bearing faults systematically dissects the region. These mylonitised pseudotachylytes record high strain rates, and the surrounding anorthosite is typically undeformed, excluding some microcracking. Pristine pseudotachylytes, however, may form fault sets cutting between adjacent or intersecting shear zones. These seismogenic faults are rarely >15 m in length and yet record displacements of tens of centimetres, a ratio that implies high stress drops. The kinematics of the pseudotachylyte faults are consistent with rotation of the strong internal block, accommodated via frictional failure, to maintain strain compatibility with localised high strain along the bounding shear zones. Hence, these pseudotachylytes represent a local structural environment where earthquake nucleation is identified as a transient consequence of ongoing, localised aseismic creep. These observations are significant in widening our understanding of the interplay between brittle and ductile deformation along the deep roots of large seismic intracontinental faults.