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The Nusfjord exhumed earthquake source (Lofoten, Norway): deep crustal seismicity driven by bending of the lower plate during continental collision

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The origin of earthquakes in the lower crust at depth of 20-40 km, where dominantly ductile deformation is expected, is highly debated. Exhumed networks of lower crustal coeval pseudotachylytes (quenched frictional melt produced during seismic slip) and mylonites (produced during the post- and interseismic viscous creep) provide a snapshot of the earthquake cycle at anomalously deep conditions in the crust. Such natural laboratories offer the opportunity to investigate the origin and the tectonic setting of lower crustal earthquakes.

The Nusfjord East shear zone network (Lofoten, northern Norway) represents an exhumed lower crustal earthquake source, where mutually overprinting mylonites and pseudotachylytes record the interplay between coseismic slip and viscous creep (Menegon et al., 2017; Campbell and Menegon, 2019). The network is well exposed over an area of 4 km^2 and consists of three main intersecting sets of ductile shear zones ranging in width from 1 cm to 1 m, which commonly nucleate on former pseudotachylyte veins. Mutual crosscutting relationships indicate that the three sets were active at the same time. Amphibole-plagioclase geothermobarometry yields consistent P-T estimates in all three sets (700-750 °C, 0.7-0.8 GPa). The shear zones separate relatively undeformed blocks of anorthosite that contain pristine pseudotachylyte fault veins. These pseudotachylytes link adjacent or intersecting shear zones, and are interpreted as fossil seismogenic faults representing earthquake nucleation as a transient consequence of ongoing, localised aseismic creep along the shear zones (Campbell et al., under review).

The coeval activity of the three shear zone sets is consistent with a local extensional setting, with a bulk vertical shortening and a horizontal NNW-SSE extension. This extension direction is subparallel to the convergence direction between Baltica and Laurentia during the Caledonian Orogeny, and with the dominant direction of nappe thrusting in the Scandinavian Caledonides. ^{40}Ar□^{39}Ar dating of localized upper amphibolite facies shear zones in the Nusfjord area with similar orientation to the Nusfjord East network yielded an age range of 433–413 Ma (Fournier et al., 2014; Steltenpohl et al., 2003), which indicates an origin during the collisional (Scandian) stage of the Caledonian Orogeny.

We propose that the Nusfjord East brittle-viscous extensional shear zone network represents the rheological response of the lower crust to the bending of the lower plate during continental collision. (Micro)seismicity in the lower crust in collisional orogens is commonly localized in the lower plate and has extensional focal mechanisms. This has been tentatively correlated with slab rollback and bending of the lower plate (Singer et al., 2014). We interpret the Nusfjord East shear zone network as the geological record of this type of lower crustal seismicity.