Weakening mechanisms in dry, lower-crustal pseudotachylytes

Kristina G. Dunkel¹, Luca Menegon², and Bjørn Jamtveit²
¹The Njord Centre, University of Oslo, Oslo, Norway (kristina.dunkel@geo.uio.no)
²The Njord Centre, University of Oslo, Oslo, Norway

Earthquakes are often regarded as agents of rheological weakening of the dry and mechanically strong lower crust. The weakening is typically attributed to fluid infiltration and resulting fluid-mediated metamorphism along the seismic fault.

On Moskenesøya in SW Lofoten (Northern Norway), we observe lower-crustal pseudotachylytes (frozen frictional melts that record fossil earthquakes) that are unusually dry. This presents us with an exceptional opportunity to study the processes affecting the rocks during and after an earthquake:

- We can observe the pristine microstructures of the pseudotachylytes, not overprinted by later metamorphism, to elucidate the earthquake-generating mechanism.
- We can study the further development of these dry pseudotachylytes after the seismic event.

We have previously described the composition and microstructures of the pristine pseudotachylytes, and concluded that transient stress pulses caused by shallower earthquakes are the most likely explanation for the occurrence of fossil earthquakes in the analysed rocks from Lofoten, with no evidence of other mechanisms such as thermal runaway or dehydration embrittlement.

In this contribution, we focus on the evolution of the pseudotachylytes after their formation. We study their development from the initial, pristine pseudotachylytes, via pseudotachylytes with slightly mylonitized margins, to ultramylonites. We use compositional and microstructural analyses, including electron backscatter diffraction (EBSD), to understand the weakening mechanisms in this dry system.

In the mylonitized margins of the pseudotachylytes, a slight shape-preferred orientation is developed and the quenching microstructures, such as microlites, are lost. The mineralogical composition (dominantly feldspars and pyroxenes) stays the same as in the pristine pseudotachylytes. In the ultramylonite, quartz and amphibole appear as accessory minerals, which means that we cannot completely exclude the presence of minor amounts of hydrous fluids; however, feldspars and pyroxenes persist as the main components of the rock. The foliation of the ultramylonite is not defined by phyllosilicates, but by a compositional banding, which suggest a phase separation and aggregation during shearing. EBSD data indicate that the main constituent
phases deformed dominantly by grain size sensitive creep.

Our preliminary results suggest that even in the absence of fluids, pseudotachylyte-bearing seismic faults represent weak zones in the lower crust that are localizing viscous shear during post- and interseismic deformation, presumably due to the intense grain size reduction that facilitates grain-size sensitive mechanisms.