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High temperature pseudotachylytes and ductile shear zones in dry rocks from the continental lower crust (Lofoten, Norway)

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Understanding the mechanisms of initiation and growth of shear zones under lower crustal conditions is of fundamental importance when assessing lithosphere rheology and strength. In this study we investigate brittle-ductile shear zones developed under lower crustal conditions in anorthosites from Nusfjord, Lofoten (northern Norway).
Steep ductile shear zones trend E-W to ESE-WSW and have a stretching lineation plunging steeply to the SSW or SSE. The shear sense is normal (south block down to the south) as indicated by SC and SC' fabrics and sigmoidal foliations. The shear zone show a mylonitic to ultramylonitic fabric, sharp boundaries to the host anorthosites, and abundant anastomosing dark fine-grained layers along the main foliation. The fine-grained layers localized much of the strain. Relatively lower strain domains within or adjacent to shear zones indicate that the fine dark bands of mylonites represent transposed pseudotachylyte which still locally preserve the pristine structures such as chilled margins, breccia textures with angular clasts of the host rock and injection veins; intersecting veins of pseudotachylyte record multiple stages of seismic slip. The orientation of injection veins and marker offset along the most preserved pseudotachylyte fault veins indicate approximately a sinistral strike slip kinematic during faulting event responsible for the friction-induced melting.
These observations indicate that ductile shear zones exploited pre-existing brittle fault zones including a network of pseudotachylytes, and that the fine-grained "ultramylonites" derive from former fine-grained pseudotachylytes. The pseudotachylyte microstructure is dominated by plagioclase microlites dispersed in a groundmass of fine-grained clinopyroxene. Clinopyroxene recrystallizes in the damage zone flanking the pseudotachylytes, indicating high metamorphic grade during pseudotachylyte formation. Small idioblastic or cauliflower garnet are scattered through the matrix and overgrow the plagioclase porphyroclasts; in some cases small garnets nucleated along thin microfractures discordant to the pseudotachylyte vein or along the pseudotachylyte boundary. In the host rock garnet form thin continuous coronitic rims surrounding biotite and opaque and discontinuous one around pyroxene. The mineral assemblage of ultramlylonites is also consistent with high grade metamorphic conditions (recrystallized plagioclase and clinopyroxene, biotite and amphibole).
Nucleation of ductile shear zones is dictated by the availability of pseudotachylyte veins; remarkably, lithological boundaries have not been exploited by ductile shear zones. Brittle deformation and extreme grain size reduction are likely to be necessary conditions in order to promote ductile strain localization in dry rocks in the lower crust.