

## Strain localization in pseudotachylyte veins at lower crustal conditions

Luca Menegon (1), Giorgio Pennacchioni (2), and Nadia Malaspina (3)

(1) Plymouth University, School of Geography, Earth and Environmental Sciences, Plymouth, United Kingdom (luca.menegon@plymouth.ac.uk), (2) Department of Geosciences, University of Padua, Padua, Italy, (3) Dipartimento di Scienze dell'Ambiente e del Territorio e di Scienze della Terra, Università di Milan-Bicocca, Milan, Italy

Viscous shearing in the dry and strong lower crust often localizes in pseudotachylyte veins (i.e. quenched molten rocks formed by the frictional heat released during seismic slip), and it has been suggested that brittle (coseismic) grain-size reduction and fluid infiltration in the fractured domains are necessary to weaken the anhydrous granulitic lower crust. However, the deformation mechanisms responsible for the associated strain weakening and viscous shear localization in pseudotachylytes are yet to be explored.

This study investigates the deformation microstructures of mylonitized pseudotachylytes in anorthosites from Nusfjord, northern Norway, where ductile shear zones invariably nucleate in pseudotachylyte veins. Thus, pseudotachylytes are weaker than the host rock during superposed ductile deformation.

Pristine pseudotachylytes contain microlites of plagioclase, clinopyroxene, amphibole and orthopyroxene, flow structures, and chilled margins. Some pseudotachylytes have lost the pristine microstructure and have recrystallized into a fine-grained ( $< 10 \mu\text{m}$ ) mixture of plagioclase, amphibole, clinopyroxene, biotite, quartz  $\pm$  K-feldspar  $\pm$  orthopyroxene. Thus, the fine grain size in the mylonites ( $< 20 \mu\text{m}$ ) is not the product of progressive grain-size reduction with increasing strain, but is an initial characteristic of the shear zone (pseudotachylyte) precursor. The stable mineral assemblage in the mylonitic foliation consists of plagioclase, hornblende, clinopyroxene  $\pm$  quartz  $\pm$  biotite  $\pm$  orthoclase. Geothermobarometry and thermodynamic modelling indicate that pristine pseudotachylytes and their mylonitized equivalents formed at ca. 700°C and 0.6-0.9 GPa. Diffusion creep and grain boundary sliding were identified as the main deformation mechanisms in the mylonite on the basis of the lack of crystallographic preferred orientations, the high degree of phase mixing, and the nucleation of hornblende in dilatant sites.

In contrast with common observations that fluid infiltration is required to trigger viscous deformation, thermodynamic modelling indicates that a limited amount of fluid (0.4 wt%, similar to the bulk fluid content measured in the host rock) is sufficient to stabilize the mineral assemblage in the mylonite. This suggests that coseismic grain size reduction resulted in fluid redistribution into the fractured domains and not necessarily in fluid infiltration. Recent experiments suggest that very small amount of water (tens of ppm) are effective in facilitating mineral reactions if sufficient porosity is present. Coseismic fracturing and creep cavitation in the mylonitized pseudotachylytes enhance the porosity of the shear zone and result in nucleation of new phases in dilatant sites. This process keeps the grain size of the polymineralic aggregate in the grain-size sensitive creep field, thereby stabilizing strain localization in the mylonitized pseudotachylytes.

This study highlights that pseudotachylytes caused by brittle faulting can be precursors of viscous, weak shear zones in the dry lower crust, indicating lower crustal earthquakes as agents of rheological change from strong, brittle lower crust, to strong lower crust with embedded fine grained, weak viscous shear zones.