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Do pseudotachylytes limit the thickness of the seismogenic continental crust?

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The strength of the continental crust is commonly approximated using flow laws for quartz and feldspar aggregates. Comparison of these flow laws to models of brittle behavior predicts brittle deformation will dominate at temperatures up to ∼500 to 600°C. However, geophysical observations indicate that seismicity is rare at temperatures above ∼350°C. The discrepancy between laboratory derived flow laws and geophysical observations suggests that other mechanisms or materials control the transition from brittle to plastic behavior in the continental crust. Pseudotachylytes, which remain the best marker for seismic rupture, commonly form at temperatures ranging from 250 to 500°C, due to coseismic or aseismic melting. Deformation of pseudotachylyte in the lower part of the crust has been highlighted by the observation of natural mylonitized pseudotachylytes, suggesting their ductile reactivations and highlighting the importance to study their strength in natural pressure and temperature conditions.

In this study, we conducted experiments under deep crust PT conditions on natural pseudotachylyte and tonalite from the Gole Larghe fault zone. Deformation experiments were carried out using a gas-medium apparatus at temperatures of 700° to 900°C, a confining pressure of 300 MPa, and differential stress stages of 5 to 400 MPa resulting in different strain rates. The mechanical data from these experiments were used to derive flow law parameters for plastically deforming pseudotachylytes.

In pseudotachylyte-bearing tonalite, strain is strongly localized within pseudotachylyte-rich regions. While the rocks samples remain strong at 700°C, weakening initiates at 800°C. The dependence of strain rate on stress follows a power-law relationship with a stress exponent (n) of 1 at low differential stress, and ∼3 at high differential stress. At 900°C, the strength of the pseudotachylyte vein samples drastically weaken and values of n of ∼3 are observed even at low differential stress. Microstructural analyses demonstrate that strain localization in pseudotachylite-bearing rocks corresponds with the initiation of partial melting at 800°C. In contrast, tonalite that is free of pseudotachylyte only exhibits brittle processes. Evidence of the initiation of mylonitization is observed at low strain conditions. Our results suggest that the presence of pseudotachylyte in crustal rocks drastically reduces the strength of the system. Extrapolating our experimental flow law parameters to natural strain rate conditions demonstrate that pseudotachylytes are expected to become weak around 250°C, which may explain further the cut-off of the seismicity of the continental crust.