Field and experimental evidence of frictional melting in fluid-rich faults

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Pseudotachylytes (solidified friction melts produced during seismic slip) are considered to be rare in the geological record because they should be typical of particular seismogenic environments characterized by water-deficient cohesive rocks. Here we present field and experimental evidence that frictional melting can occur in “fluid-rich” faults hosted in the continental crust.

Pseudotachylytes were found in the >40 km long Bolfin Fault Zone of the Atacama Fault System (Northern Chile). The pseudotachylytes (1) are associated with a ~1 m thick ultracataclastic fault core which accommodated > 5 km of strike-slip displacement at 6-8 km depth and 280-350°C ambient temperature, (2) cut a ca. 50 m thick damage zone made of sub-greenschists facies hydrothermally altered diorites and gabbros, (3) cut and are cut by epidote+chlorite+calcite bearing veins. The microstructure of the pseudotachylytes include (1) tabular microlites of feldspar hosted in a glassy-like matrix and (2) vesicles filled by post-seismic sub-greenschist facies minerals hosted in a strongly altered matrix of albite, chlorite, and epidote crystals.

Experiments reproducing seismic slip in the presence of pressurized water and conducted with the rotary shear apparatus SHIVA on experimental faults made of the sub-greenschists (hydrothermally altered) facies damage zone rocks from the Bolfin Fault Zone, resulted in the production of vesiculated pseudotachylytes. In these experiments, fault weakening mainly occurred by melt lubrication rather than by pore fluid thermal pressurization.

The identification of pseudotachylytes and its association with intense pre- and post-seismic hydrothermal alteration challenges the common belief that pseudotachylytes are rare. Consistent with the experimental evidence, pseudotachylytes (1) could be a common coseismic fault product.
in the continental crust, (2) may easily be produced in fluid-rich hydrothermal environments but, (3) are easily lost from the geological record because they are prone to alteration.