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Pseudotachylytes alteration and their loss from the geological record

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Tectonic pseudotachylytes are solidified friction-induced melts produced along faults by seismic slip associated to the propagation of earthquake ruptures. Though pseudotachylytes remain the most convincing marker of seismic ruptures among fault rocks, the report of pseudotachylytes within fault zones is rare if compared with the frequency and distribution of earthquakes in crustal rocks. This observation reinforces the idea that pseudotachylytes are produced only in very dry tectonic settings or at fault asperities sustaining very high shear stresses. However, the ubiquitous production of pseudotachylytes both in dry and wet conditions during laboratory earthquakes indicates frictional melting as a diffuse and efficient fault weakening mechanism. Reconciling such a dispute implies to address a long-lasting question in the earthquake mechanics community: are pseudotachylytes rarely generated or are they only rarely preserved?

We addressed this question by performing hydrothermal alteration tests on fresh pseudotachylyte samples. Pseudotachylytes hosted in different lithologies (tonalite, microgabbro, ultramafic gabbro) were produced under vacuum by sliding at seismic slip rates (> 1 m/s) solid rock cylinders using the rotary shear apparatus SHIVA at INGV-Rome. The melt-welded rock samples were then cored along the fault interface to obtain smaller rock cylinders with the experimental pseudotachylyte oriented parallel to the long axis. These samples were finally cooked with water as pore fluid at confining (Pc) and pore pressure (Pp) of 150-200 MPa and temperatures (T) of 300-600°C for 18-35 days using two Nimonic triaxial apparatuses at the Rock Deformation Laboratory of the University of Manchester. The experimental conditions were chosen to be representative of the pressures and temperatures at which natural pseudotachylytes occurred in their host rocks.

Detailed microstructural and mineralogical investigations (FE-SEM, EDX, X-ray micro-diffraction, micro-Raman) documented that post alteration pseudotachylytes were very different from the original ones. In particular, altered pseudotachylytes were characterized by a peculiar clastic micro-texture deriving from the intense dissolution of the original glassy to cryptocrystalline matrix. This process determined the formation of a significant amount of porosity and the growth within the matrix of few micrometres in size acicular mineral aggregates with random orientation. In the case of the tonalite-derived pseudotachylyte, the original glassy matrix was K-rich in composition, had no porosity and quartz clasts displayed cuspate-lobate boundaries. After hydrothermal alteration, the sample contained only few relics of the original micro-texture embedded within a highly porous matrix depleted in alkali. Preliminary micro-analyses suggest that the acicular aggregates likely were Ca-Mg smectitic clays.

This study first demonstrates that the preservation potential of pseudotachylytes is very short (days to months) and is likely to increase only within very dry tectonic settings. The presence of pore fluids instead determines the alteration of the pseudotachylyte matrix and the development of a clastic micro-texture which resembles well the one of other much common fault rocks such as ultracataclasites.