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Mylonitic pseudotachylyte from the brittle-ductile transition produced during exhumation of the Balmuccia peridotite

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Pseudotachylyte is the only known fault rock indicative of ancient seismicity. However, the identification of pseudotachylyte is often difficult when primary textures (directly derived from melt solidification) are obliterated by subsequent recrystallization and deformation. Major earthquakes are supposed to nucleate at depths typical of the brittle-ductile transition regime of rocks, where the ambient temperature might promote static and dynamic recrystallization after seismic slip. It is, therefore, important to establish textural criteria to recognize seismic deformation in the brittle-ductile transition regime for understanding the seismogenic processes in such depth from the materialistic point of view.

Here, we report the occurrence and describe the microstructure of mylonitic pseudotachylyte (abbreviated MPT hereafter) probably of a frictional-melt origin, that crop out in the Balmuccia peridotite massif located in western Alps, Italy.

MPT occurs in fault veins associated with non-molten mylonites, in contrast to the close association between cataclasite and glass-bearing pseudotachylyte. The fault veins of MPT are sub-mm to 1cm thick, and are rarely associated with injection veins intruding the wall rocks. The boundary between the MPT and its wall rocks is relatively sharp. The MPT often contains porphyroclasts with delta-/sigma-type tails. The MPT matrix is brownish in color under the optical microscope, and it is made of olivine, enstatite, diopside, spinel, dolomite, and/or plagioclase in holocrystalline texture (all grains less than few microns in size). This mylonitic-type matrix has an optical anisotropy recognized under cross Nicols, which is consistent with the olivine crystallographic preferred orientation as detected by Electron Back-Scattered Diffraction analysis. We found a MPT fault vein in which the mylonitic-type fabric grades into an igneous-type fabric characterized by dendritic clinopyroxene crystals.

Fault rocks other than MPT are; i) porphyroclastic-type mylonite (with matrix grain size about several tens of micrometer; spinel peridotite facies), ii) S-C-type mylonite (plagioclase peridotite facies), iii) cataclasite (with interstice-filling low-grade hydrous mineral), iv) pseudotachylyte containing glass or clear igneous textures.
The wall rock is a coarse grained (several hundreds of microns to several millimeters) spinel peridotite or a peridotitic protomylonite.

MPT and porphyroclastic-type mylonite and S-C-type mylonite are associated with each other (high-grade fault set). Pargasite-bearing chlorite-free peridotite facies of high-grade fault fillings indicates high ambient temperature (>~600 degree C). On the other hand, glass-bearing pseudotachylyte and low-grade cataclasite form a distinct set of faults (low-grade fault set), and this indicates low ambient temperature. High-grade faults are cut by low-grade faults.

The MPT-bearing high-grade faults are exposed along the polished outcrops of the Sesia River valley. The crosscutting relationship of the MPT-bearing faults may be inferred to some extent. The mineral paragenesis of the fault filling varies, in accordance with the fault crosscutting relationship found in the field, from high-pressure (>700MPa-1GPa), spinel peridotite facies to low-pressure (< 700MPa-1GPa), plagioclase peridotite facies. This suggests that the fault/fracture network is the cumulative result of progressive deformation during exhumation of the peridotite from mantle depths. The peridotite ascended from a spinel-lherzolite stability depth to a plagioclase-lherzolite stability depth recording repeated seismic ruptures and crystal plastic deformation. Fault rocks during exhumation evolved from porphyroclastic mylonites to MPT and eventually to S-C mylonites associated with pseudotachylyte.

It follows that the Balmuccia peridotite fault network records the brittle-ductile transition in mantle rocks.

Keywords: seismogenic process, pseudotachylyte, mylonite, brittle-ductile transition