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Cyclic production of pseudotachylyte at the brittle/ductile transition: evidence for a large-scale fault asperity

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Within the Dent Blanche nappe of the North-Western Alps (Italy), thrusting of the Valpelline Series on the Arolla Series is marked by an approximately 50 m thick and a few 10's of km long horizon of phyllonites (a muscovite- and chlorite-rich fault rock). The phyllonites developed at ca. 350 ^{o}C and 12-14 km depth (greenschist facies conditions).

Along the thrust, pseudotachylytes (solidified friction-induced melts produced during seismic slip) occur only over a zone a few 10's of meters thick and a few 100's of meters long near the village of Valpelline. Crosscutting relationships indicate multiple generations of pseudotachylyte veins that, in this zone of the thrust, form an important volumetric fraction of the fault rock assemblage. Pseudotachylytes occur as diffuse networks with sharp boundaries to the host rock and thickness ranging from less than 1 mm to, in dilational jogs, 2 cm.

Microstructural and geochemical observations indicate that:

(1) every pseudotachylyte generation is recrystallized to a fine-grained quartz-free matrix consisting of albite, chlorite, muscovite, epidote and titanite (mineral assemblage typical of greenschist facies conditions);

(2) pseudotachylyte veins (both concordant and discordant to the phyllonitic foliation) display a weak ductile overprint;

(3) average chemical composition of pseudotachylyte is enriched in TiO_2, FeO, MnO, MgO and loss on ignition with respect to the phyllonite.

These observations suggest ductile overprint of the pseudotachylyte at the same ambient conditions of the phyllonite and preferential assimilation of water rich minerals (chlorite and muscovite) during frictional melting.

Dynamically recrystallized quartz within the phyllonite in the pseudotachylytes-rich zone has average grain size of 4 μm. Recrystallized quartz within the phyllonites but 200 m and 10 km away from the pseudotachylyte-rich zone has average grain size of 14 μm and 24 μm, respectively. The quartz paleopiezometer of Stipp & Tullis (2003) yields mean differential stress of about 200 MPa in the pseudotachylyte-rich zone, which decreases to $\sim$ 80 and 50 MPa outside.

We speculate that the pseudotachylyte-rich zone corresponded to a large-scale fault asperity that acted as a stress raiser in an otherwise ductile environment, given:

1) the occurrence of pseudotachylytes in a limited zone of the thrust where the differential stresses were higher;

2) the weak ductile reworking of the pseudotachylytes;

3) the crosscutting/overprinting relationship between pseudotachylytes.

The cumulative large volume of pseudotachylyte was produced through multiple seismic ruptures and was probably triggered in this zone by the local high differential stress and by the low melting point of the mica-rich phyllonites. At the inferred ambient conditions, we calculated a displacement of few centimetres ($<$M4 earthquakes) to produce 1-5 mm thick pseudotachylytes at seismic slip rates of 1 m/s. We therefore infer that the stress rising associated with the fault asperity was cyclically released through small seismic ruptures.