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ultramylonitic (or sheared) pseudotachylyte and its seismogenic significance

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Frictional melting along a seismic fault is important because it may greatly influence mechanical properties and slip behavior along the fault. The generation of thin layers of melt along the fault plain virtually diminishes friction (particularly for ultramafic composition), causing unstable slip and thereby a rapid release of the elastic strain energy stored in the wall rocks, leading to a large earthquake. The pseudotachylyte, which is formed by quenching of a frictional melt generated upon a coseismic slip, may provide details of the slip behavior of the seismic fault. The question is how petrological analysis of this rock type can contribute to our understanding of earthquake source mechanics.
Some pseudotachylytes have clear evidence indicative of melt origin such as glass or quench textures, but others may be ambiguous in their origin because of the lack of such clear textural and mineralogical evidences. Some 'pseudotachylytes' are said to have formed by ultracomminution without melting, which does not match to the original definition of Shand and, therefore, may cause confusion (Lin, 2008).
We discovered a new type of fault-vein ultramafic pseudotachylyte that has an ultramylonitic texture from a mantle-derived Balmuccia peridotite exposed in the Italian Alps (Ueda et al, 2008, Geology, v. 36). This sample is extremely fine grained and can be classified as 'ultramylonite' because of the well-developed foliation and lineation. According to the fault rock classification (i. e., Sibson, 1977), 'ultramylonite' are designated for those rocks formed by subsolidus plastic deformation (i.e., the dominant deformation mechanism is crystal plasticity) accompanied with drastic grain size-reduction without melting. Instead, the sample we described is interpreted to be an igneous rock that was formed by quenching melts followed by recrystallization in a shear flow regime. Texturally, however, it is holocrystalline without clear igneous texture and so it may be difficult to distinguish from ordinary (i.e., metamorphic) ultramylonite. However, the presence of injection veins departing from main fault vein is a clear structural evidence for its melt origin. An important observation is that this injection vein is rather massive and not mylonitic in contrast to the main fault vein, which indicates that the shearing was restricted to the main fault plane and not affected the injection vein.
We consider whether or not a 'pseudotachylyte' vein acquires a mylonitic structure upon its formation depends on the timing of the cooling and solidification of the melt with respect to the deceleration of the coseismic slip. When a melt layer forms along the slipping zone, the friction dramatically decreases (particularly in the case of ultramafic melts) and the frictional heating ceases, upon which the melt starts a rapid cooling by thermal diffusion in wall rocks. If the slip ceases completely before the solidification of the melt starts, we have an 'unstructured' (i.e., massive) pseudotachylyte. Instead, if the cessation of the slip is delayed and the semi-solidified melt layer sustains the residual shear, we have a 'structured' (i.e., mylonitic) pseudotachylyte. In the latter case, high friction is recovered (i.e., viscous breaking), even for a short period, which results in a delayed cooling of the semi-solidified layer. This may promote the dynamic recrystallization and, in some cases, cause a frictional re-melting of the fault vein. We do not rule out other possibilities, however, for the occurrence of 'sheared pseudotachylyte' in which shearing

took place in a solid state in a separate post-seismic event after complete consolidation of the melt. The question is how to distinguish between the two. We review such 'structured' pseudotachylyte compared with 'unstructured' pseudotachylyte from Balmuccia and discuss how detailed petrological and microstructural work may constrain the modeling of earthquake source mechanical processes.

Keywords: mantle, pseudotachylyte, peridotite, melt, plastic flow, mylonite