Geophysical Research Abstracts
Vol. 21, EGU2019-2980-2, 2019
EGU General Assembly 2019

Magnetic fabric in pseudotachylites

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Pseudotachylytes result from frictional melting, particularly along fault surfaces during seismic slip. These materials are remarkable because the melt they originate from forms and quenches quickly (< 100 s), they rank amongst the hottest melts in the Earth's lithosphere (1000-2000ºC), and are dynamically-deformed miniature magma bodies. The anisotropy of magnetic susceptibility (AMS) has contributed to major advances in understanding magma transfer and emplacement, in dikes, sills and plutons. Magnetic fabrics inform on the deformation of these magma bodies from magmatic to solid-state conditions. In AMS studies of plutonic rocks samples are a few centimeters in size. In fault pseudotachylytes, however, this size is incompatible with the dimensions of pseudotachylyte veins (≈1-10 mm). The fundamental differences between plutonic rocks and frictional melts present at least five challenges for the application of AMS to pseudotachylytes:

1) The AMS method requires at least a few thousand grains to satisfactorily average rock fabric. This requirement is met in pseudotachylytes even using 200-250 times smaller samples (mini-AMS cubes of 3.5 mm) because pseudotachylytes have a very fine granulometry (≈10 microns), hence a 3.5 mm pseudotachylyte cube contains about 40 million grains.

2) The grains in plutonic rocks (silicates, Fe-Ti oxides and sulfides) investigated with AMS are deemed primary. In a fault pseudotachylytes, a large proportion (>50%) of the protolithic grains, including iron-bearing phases, have broken down due to heating. The iron liberated in the melt tends to oxidize forming coseismic magnetite. In rare cases where magnetite does not form during seismic slip, the AMS is carried by silicates and less well defined.

3) The presence of unmolten clasts inherited from the protolith may complicate the mini-AMS fabric, particularly when if they represent more than >50% because the viscous flow of the melt may not follow fault margins.

4) The fast nucleation of magnetite and quenching of the frictional melt along fault margins may lead to the formation of single-domain (SD) magnetite, known to have an inverse AMS, which may complicate fabric analysis.

5) The thermal and dynamic conditions prevailing during coseismic slip lead to rapid nucleation, growth and rotation of elongated magnetites along with high-temperature plastic deformation of these grains (Nabarro-Herring creep). The large shear strain responsible for frictional melting results in preferred orientation of magnetite grains in a regime close to simple shear (high Wk) where particle long axes become increasingly parallel to the seismic slip direction.

Despite these challenges, the mini-AMS method applied to pseudotachylytes provides useful information on the kinematic flow parameters of frictional melts, in a wide array of protoliths ranging from granites to mantle peridotites. The mini-AMS yields the direction of seismic slip and the sense of slip through the analysis of fabric obliquity with respect to the fault plane. This new method promises to advance our knowledge of the role played by frictional melts in lubricating fault zones and promises to become a valuable paleoseismological tool.