Geophysical Research Abstracts, Vol. 8, 06609, 2006
SRef-ID: 1607-7962/gra/EGU06-A-06609

Modelling the heat pulses generated on a fault plane during coseismic slip: Inferences from the pseudotachylites of the Copanello cliffs (Calabria, Italy)

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A pseudotachylite vein network crosscutting late Hercynian foliated tonalites can be observed along the Copanello cliffs (Calabria, Southern Italy). Pseudotachylites formed within a 60 m thick fault zone developed during the Oligocene–Miocene at intermediate crustal levels (ca. 10 km). The fault zone consists of an array of shallow-dipping faults, with spacing ranging from some tens of cm to more than 1 m. Thickness of pseudotachylites ranges from few mm in fault veins to up to 10 cm in injection veins branching from the fault planes. Pseudotachylites consist of a dark grey matrix containing rounded clasts of quartz, plagioclase or plagioclase–quartz lithic fragments. A maximum clast proportion of 30% is observed. Pseudotachylite veins are commonly associated with foliated cataclasites that contain angular feldspar clasts and elongated quartz aggregates in a sericite-rich matrix indicative of hydrous deformation conditions. Microscopic observations indicate that pseudotachylite matrix consists of plagioclase (An46–An58) and biotite microlites with very small amounts of ilmenite. Skeletal Plagioclase microlites are 10–150 μm long. Frequently, they are randomly oriented to form a framework with biotite-filled interstices, in a geometric arrangement typical of an intergranular texture. In other cases plagioclase microlites are oriented to define flow or spherulitic textures. All microstructural features are consistent with rapid crystallisation from melt. EDS analyses of rare and tiny glass veins indicated mainly a trachyandesite composition. Local occurrence of An50 plagioclase glass allowed to estimate melting temperatures exceeding 1300 to 1470°C, depending on PH_2O.

We have tried to reproduce the conditions for pseudotachylite formation by an analytical 2D thermo-mechanical model taking into account heat released by friction along a horizontal fault plane, during a seismic event. The model is based on seismic source kinematics and includes the three stages of the slip evolution process: nucleation, propagation and stopping of the rupture. This is in agreement with worldwide experimental evidence for the existence of nucleation and stopping phases. In addition, by means of a numerical approach, the model reproduces cooling that follows the deceleration stage.We have assumed hydrostatic to near-lithostatic pore pressure conditions and a seismic event which occurs at 10 km of depth. Results of modeling using an average value of rigidity μ=30 GPa and a stress drop of 100 bar, indicate that a small event, with a length of the fractured area ranging from about 100 m to about 300 m and a total amount of slip ranging from 2 to 6 cm respectively, is able to reproduce the conditions for the melting in tonalite for a thickness of about 1–2 mm. The model predicts a duration of the thermal perturbation of few minutes. Existence of melt is dramatically short-lived, typically confined within one second. These results indicate that melt accumulation in injection veins and pull-apart structures occurred rapidly, implying very fast melt migration. Forced injection of melt into dilatant cracks could be enhanced by thermal pressurization, as observed by other authors.