Geophysical Research Abstracts,
Vol. 11, EGU2009-5348-3, 2009
EGU General Assembly 2009

Thermal Pressurization Induced by Coseismic Shear Heating within Thermally Unstable Rocks

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The frictional heating generated during an earthquake can cause the thermal pressurization of the fluids trapped within the slip zone, which favours dramatic fault zone weakening and rupture propagation. Many slip weakening mechanisms have been proposed to account for coseismic fault zone weakness: flash heating, thermal pressurization, frictional melting, gel formation, thermal decomposition and moisture drainage. Thermal pressurization of fluids has not been previously reproduced in the laboratory and, as a consequence, the experimental verification of the effective normal stress principle at seismic slip rates (m/s) is lacking. Here we present data from high velocity friction experiments where a new type of thermal pressurization has been reproduced as the fluids are not initially present within the slip zone but are released by decarbonation (dolomite and Mg-rich calcite) and dehydration (gypsum) reactions, both activated by frictional heating during seismic slip. The coseismic shear strength of experimental faults dramatically reduces to almost zero when fluids are trapped and pressurized within the slip zone, in accord with the effective normal stress principle. The microstructures observed in the areas adjacent/within the slip zone can be used in future studies as new diagnostic features to aid in the recognition of seismic faulting within thermally unstable rocks and, possibly, of thermal pressurization slip weakening processes. Earthquake source parameters (e.g. slip weakening distance and fracture energy), calculated from our experimental data and extrapolated at seismogenic depths, match very closely the seismological data from the mainshocks of the 1997 Colfiorito earthquake, nucleated within dolomite/anhydrite rocks in the Northern Apennines of Italy. The gap between mechanical and seismological observations can be bridged when thermal pressurization is considered to act in combination with other slip weakening mechanisms.