Geophysical Research Abstracts,
Vol. 11, EGU2009-6562, 2009
EGU General Assembly 2009

Mid-crustal transient stress field geometry during the seismic cycle inferred from the geological record and numerical models

J.-A. Nüchter and S Ellis
GNS Science, 1 Fairway Drive 5040 Lower Hutt, New Zealand

Interpretations of exhumed metamorphic rocks and numerical models suggest that earthquakes on dip-slip faults impose a major stress increase in the middle and lower crust, commonly referred to as coseismic loading. The imposed stress peak relaxes during an episode of transient postseismic creep. Because of the low temperatures expected in the middle crust and the resulting high viscosities there, postseismic creep in the middle crust is expected to be hardly detectable by surface geodesy. However, a detailed understanding of these mid-crustal processes is required to estimate crustal stress redistribution during the seismic cycle.

During exhumation, metamorphic rocks are increasingly affected by stress cycles related to seismic activity. These rocks may therefore provide insight into the processes and conditions prevailing at deeper levels of the crust during the seismic cycle. Information on the spatial variation of these parameters is typically restricted by the size of the outcrop and the exposed surface. On the other hand, numerical techniques can model the entire crustal stress field, but the results depend highly on the applied boundary conditions. Therefore, we use the record of metamorphic quartz veins hosted in the high-pressure / low-temperature metamorphic Styra-Ochi Unit of South Evia, Greece to calibrate numerical models of the mid-crustal seismic stress cycle. The rocks of the Styra-Ochi Unit were exhumed in the footwall of a low angle normal fault. The veins formed from tensile fractures, indicated by the absence of wall parallel displacement. Crosscutting relationships between the veins and all syn-metamorphic fabrics of the host rock and the quartz microfabrics indicating crystal plastic deformation imply that the veins formed during exhumation, but still below the brittle ductile transition. The veins were sealed in a single stage and crystals grew into an open cavity. Fluid inclusions trapped in the vein quartz record a time series of fluid pressure (P) during progressive sealing, with low P at the vein walls (early stage) to high P in the vein core (final stage). The effective stress acting normal to the incompletely sealed fracture is controlled by the fracture normal stress (in the case of tensile fractures, the minimum principal stress σ_3), and P. For opening of fractures, the stress acting normal to the walls must be tensile, and P must be similar to σ_3. If P»σ_3, fracture propagation would have re-initiated, resulting in a drop in P. The evolution of P is therefore interpreted to reflect a major coseismic drop in σ_3, causing a major increase in the differential stress. During the stage of sealing, the increase in P is interpreted to reflect a restoration of σ_3, which means that the stress peak relaxes. Numerical models with simple initial and boundary conditions are in first-order agreement with the vein record. The results of these models suggest that seismic activity causes: (1) a major coseismic stress peak in the middle crust; (2) coseismic loading predominantly by a drop in σ_3 in the footwall and by an increase in $\sigma_1$in the hanging wall by values comparable to those deduced from the veins; (3) stress relaxation by thermally activated creep during the interseismic period; (4) significant deflections in stress tensor orientations compared with predictions from the Andersonian theory, which may be preserved over timescales typical for a seismic cycle.