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Spatial and temporal variations of fault zone stresses

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Constraints on the stress state in fault zones such as earthquake focal mechanisms yield information on the stress directions. Estimates of stress magnitudes require costly measurements in boreholes and are restricted to shallow depth. Inversions of the stress field along faults based on earthquake focal mechanisms are controversial and resulting stresses are often spatially complex and may change during the seismic cycle. When compared to laboratory-based estimates of rock frictional failure, stress orientations with respect to the fault zone are used to infer relative shear strength. Maximum compressive stress σ_1 directions oriented at steep angles of about $> 60^\circ$ to the fault trace are generally considered to indicate a weak fault. Here we present field and laboratory data indicating that stress inversions of focal mechanisms are scale-dependent and strongly reflect local structural heterogeneities.

We studied spatial clustering and orientation of 446 aftershock focal mechanisms of the M_w=7.4 1999 Izmit earthquake that ruptured the western North Anatolian Fault Zone (NAFZ). Aftershock activity along the rupture allows separating 4 fault segments trending N65˚-90˚E. Stress tensor inversions of aftershock focal mechanisms show systematic rotations of the local stresses following the Izmit mainshock. In the Izmit region maximum compressive stress is rotated counterclockwise with respect to mainshock and regional stress field. Towards the eastern end of the rupture near Dücze, stresses are rotated clockwise. For the Izmit and Dücze region, main shock focal mechanisms and regional stress field data indicate σ_1 direction oriented at 30-40˚ and 50-60˚ to the fault trace, respectively. This suggests that tectonic loading and increase of shear stress on differently oriented NAFZ segments resulted in rotation of the local stress field that was later partially reversed in response to earthquake stress drop. Rotation angles for differently oriented segments are about 10˚-20˚ indicating similar ratios of stress drop to shear stress magnitude. Stress orientations at low and high angles to fault segments reflect spatial and temporal changes of the stress field

and local fault structure rather than different fault strength.

To investigate the response of local stress orientations on boundary conditions we performed a series of deformation experiments on Carrara marble and Rotliegend sandstone. Samples were deformed in compression in a servohydraulic loading frame at confining pressures up to 50 MPa. Localized shear displacement along mixed-mode fractures was induced using a steel indenter or notched specimens. Analysis of acoustic emissions and crack microstructure indicates that shear fracture orientation and P-axis distribution of focal mechanisms vary significantly depending on magnitude of initial fault normal compression.