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Multi-scale investigation into the mechanisms of fault mirror formation in seismically active carbonate rocks

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Mirror surfaces along principal slip zones in carbonate rocks have recently received considerable attention as they are thought to form during fault slip at seismic velocities and thus may be a marker for paleo-seismicity (Siman-Tov et al., 2013). Therefore, these structures represent an opportunity to improve our understanding of earthquake mechanics in carbonate faults. Recent investigations reported the formation of fault mirrors in natural rocks as well as in laboratory experiments and connected their occurrence to the development of nano-sized granular material (Spagnuolo et al., 2015). However, the underlying formation and deformation mechanisms of these fault mirrors are still poorly constrained and warrant further research. In order to understand the influence and significance of these fault products on the overall fault behavior, we analysed the micro-, and nanostructural inventory of natural fault samples containing mirror slip surfaces. Here we present first results on the possible formation mechanisms of fault mirrors and associated deformation mechanisms operating in the carbonate fault gouge from two seismically active fault zones in central Greece. Our study specifically focuses on mirror slip surfaces obtained from the Arkitsa fault in the Gulf of Evia and the Schinos fault in the Gulf of Corinth. The Schinos fault was reactivated by a magnitude 6.7 earthquake in 1981 while the Arkitsa fault is thought to have been reactivated by a magnitude 6.9 earthquake in 1894.
Our investigations encompass a combination of state-of-the-art analytical techniques including X-ray computed tomography, focused ion beam scanning electron microscopy (FIB-SEM), transmission electron microscopy (TEM) and Raman spectroscopy. Using this multiscale analytical approach, we report decarbonation-reaction structures, considerable calcite twinning and grain welding immediately below the mirror slip surface. Grains or areas indicating decarbonation reactions show a foam-like, grainy texture. Some areas show a lamellar structure of decarbonated and intact calcite, representing former calcite twins. The average grain size of welded grains is between 100 – 200 nm. In addition, we identified the formation of an amorphous calcium-bearing phase that is enriched in Al, Fe, Si and Mg compared to the host calcite. This phase covers the coarser calcite grains as a thin film and welds them together as well as infiltrating cleavage planes, cracks and surface corrugations on top of the principal mirror slip surface. Thus, it contributes to creating a highly smooth slip surface.

References:

Siman-Tov et al., 2013, Nanograins form carbonate fault mirrors: Geology, v. 41; no. 6; p. 703–706.

Spagnuolo et al., 2015, Fast-moving dislocations trigger flash weakening in carbonate bearing faults during earthquakes: Nature Scientific Reports 5:1611