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Physical properties of laboratory faults inferred from seismic event statistics during stick-slip experiments

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Seismicity contains information about the in-situ faulting process from the plate boundary scale down to the scale of individual asperities. In this study, we consider the possibly smallest, seismically recordable earthquakes: those generated during stick-slip experiments, a laboratory analog to earthquakes. In the laboratory, seismic energy, radiated from brittle micro-cracking in form of acoustics emissions (AEs), has successfully been used to monitor the initiation and propagation of intact-rock failure. In contrast to much of the previous work, we concentrate on AEs that occur within or close to laboratory-created fault zones.

We present results from experiments on complex faults that were created by initial sample fracture. The fracture surfaces evolve due to successive stick-slips until they exhibit many of the hallmarks of upper crustal faults after the experiments. The structure of laboratory faults can be categorized into a gouge layer containing localized shear zones and a broader damage zone that marks the transition to the country rock. The transitional damage zone is generally associated with high AE activity that decreases as a power-law at larger fault-normal distances. The exponent of this power-law is connected to the roughness of the fault as revealed by saw-cut experiments with specific, pre-defined roughness.

We examined along-strike fault heterogeneity in X-ray computer tomography (CT) scans and spatial maps of AE statistics. We performed a detailed spatial analysis of event clusters before and after stick slip events, primarily focusing on b value, seismic moment release and AE event density. AE hypocenter distributions showed a high degree of spatial clustering close to low b value regions. Slip events and the connected acoustic emission 'aftershocks' nucleated within or at the periphery of areas of low b. To identify larger scale geometric asperities we combined fault structural information from post-experimental CT-scans with AE statistics. Asperities were connected to low b value regions, high moment release and areas of large AE event density gradients. The faults were anomalous thin in these areas.

Rough fracture surfaces during laboratory experiments, strongly favor the creation of spatial and temporal distinct AE clusters which have similar characteristics to seismicity observed on crustal scales. Specific seismicity anomalies may be an expression of fault heterogeneity and mark areas of larger seismic hazard.

Keywords: Earthquake Physics, Statistical Seismology, Laboratory Experiment, Seismic b-Value, Seismic Hazard