Geophysical Research Abstracts
Vol. 18, EGU2016-17828, 2016
EGU General Assembly 2016

A comparative study of seismicity statistics in laboratory stick-slip experiments and nature: Implications for fault mechanics

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Fault properties can rarely be monitored under in-situ conditions at seismogenic depth. At these depths seismicity records are possibly the only high-resolution data that can provide insight into state of stress and mechanics of faulting. We analyze series of laboratory experiments on faults that developed during stick-slip on saw-cut and fractured surfaces under upper crustal stress conditions. Stick-slip experiments were performed on surfaces with varying roughness and fracture surfaces that evolved into fault zones with pronounced damage zones.

We monitor and analyze acoustic emission events that exhibit many striking similarities to natural seismicity across all examined scales. These similarities include pronounced Gutenberg-Richter-type magnitude distributions, Omori-type aftershock decay, and off-fault seismicity distributions that decay as a power law with distance. In the laboratory, fault roughness and heterogeneity are critical in concentrating stresses that lead to local AE clustering, and differences in off-fault activities and lower b-values. Similar observations of earthquake clustering and b-value variations were made for natural faults such as the Parkfield segment of the San Andreas fault.

In addition to seismicity statistics, we conducted a detailed analysis of moment tensors, focusing on relative contributions from isotropic and deviatoric components to laboratory seismicity. In contrast to natural seismicity, our results revealed a larger contribution from isotropic components. These contributions are a result of ongoing fracture processes within the evolving fault which are most pronounced after stick-slip events. Our study shows, that seismicity analyses in laboratory experiments can significantly advance our understanding of fault mechanics from the scale of single asperities to large fault zones.