Geophysical Research Abstracts
Vol. 20, EGU2018-18317, 2018
EGU General Assembly 2018

Fault stability during an experimental seismic cycle. The effect of controlled conditions of the loading rate.

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Earthquake nucleation is the last stage of the inter-seismic cycle where the fault surface evolves through the interplay of friction, healing, stress perturbations and strain events. Slip stability under rate-and state friction has been extensively discussed in terms of loading point velocity and equivalent fault sti[U+FB00]ness, but fault evolution towards seismic runaway under complex loading histories (e.g. slow variations of tectonic stress, stress transfer from impulsive nearby seismic events) is not yet fully investigated. Nevertheless, the short term earthquake forecasting is based precisely on a relation between seismic productivity and loading history which remains up to date still largely unresolved.

To this end we propose a novel approach which avails of a closed loop control of the shear stress imposed on the experimental fault, a nominally infinite equivalent slip and transducers for continuous monitoring of acoustic emissions. The experimental fault has an initial roughness which mimics a population of randomly distributed asperities, here used as a proxy for natural fault patches, either far or close to failure on an extended fault. This experimental simulation allows us to study the stress dependency and temporal evolution of spontaneous slip events occurring on a pre-existing fault subjected to different loading histories and, at the same time, monitoring the evolution of the rough surface using the acoustic emissions source locations.

Our observations suggest that the increase of shear stress may trigger either spontaneous slow slip events (creep) or short-lived stick-slip bursts, eventually leading to a fast slip instability (seismic runaway) when slip rates are larger than a few cm/s. Event types and their occurrence are related to the number of asperities brought to failure as mapped by the acoustic emission source locations. The creep vs. stick-slip behavior and the magnitude of the slip rate are regulated in principle by the background shear stress whereas the effect of the cumulated slip is negligible. However, the slip history is conditional at first order on the loading type and an empirical relation can be established between the loading rate and the evolution of slip with time.

The extrapolation of these results to natural conditions might explain the plethora of events that often characterize seismic sequences. Nonetheless this experimental approach helps the definition of a scaling relation between the loading rate and cumulated slip which is relevant to the definition of a recurrence model for the seismic cycle.