Geophysical Research Abstracts
Vol. 21, EGU2019-6850, 2019
EGU General Assembly 2019

The complexity of laboratory analogues for earthquake rupture

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The nucleation of earthquakes is a challenging but crucial topic to study. Despite recent results from seismological observations, laboratory and numerical models, it is still unclear what controls the prevalence of slow slip during the precursory phase of earthquakes, and if the concept of critical nucleation length derived theoretically can be applied to nature.

Here we attempt to reconcile laboratory and numerical models with seismological observations. Using digital image correlation, we show that when using laboratory analogue (pre-cut polycarbonate plates), a large zone ($\sim$ 10 cm long) starts slipping in the middle of the 30 cm long simulated fault several milliseconds before a dynamic rupture initiates. Then, in accordance with previous nucleation models, we observe thanks to photoelasticity that the stress drops in a smaller part of the fault (1 to 3 cm long) situated within the large slipping area. The zone of stress drop expands first slowly during a few hundreds of nanoseconds, and then at accelerating speeds until a limiting rupture front speed (Rayleigh wave velocity or P-wave velocity) is reached. To eliminate the ambiguity in the measurement of slow nucleation length, which may not be visible at its very initiation, we define a reference critical breakout length at the start of acceleration, when the rupture becomes self-sustained and does not depend on the applied load any more. We show that the latter length depends on the imposed loading rate, i.e. the experimental equivalent of tectonic loading. Our observation can be explained in the framework of rate-and-state friction laws, which predict a variation of nucleation size depending on how close the system is to the steady-state. The theoretically predicted range is compatible with our measurements.

One implication of these results regards megathrusts, where small to moderate shocks appear in response to accelerated slip in areas which are usually silent. This study highlights the complexity of analogue models of earthquake ruptures, providing clues on how numerical models can be made more realistic, possibly producing a better match of seismological observations.