Modelling precursory seismicity in the laboratory using a roughness derived rate and state friction model

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Growing amounts of seismologic observations appear to be capturing a larger diversity in slip behavior along natural faults. One such behavior is the appearance of localized high-frequency events occurring within a larger preparatory region of accelerated preslip. A mechanism explaining this phenomenon is that fault zones have contrasting strength, which may affect the spatial variability of seismic coupling. Recent numerical studies of faults governed by rate-and-state (RS) friction, show that systematic variations in the strength heterogeneity could explain diverse slip behaviors, such as, stable sliding without spontaneous slip transients, or unstable with spontaneous rupture [Liu and Ampuero, 2017].

Here we detail results from a direct shear friction experiment where a well-instrumented fault was formed by pressing together mature (worn) surfaces of poly(methyl methacrylate), then subjecting it to shear, until gross 'stick-slip' failure occurred. Prior to failure, spontaneous ruptures were found to nucleate within a region of accelerated slip, but *arrested locally within a seismogenic section* of the interface. Seismic waves produced by these high-frequency events were measured by an array of calibrated piezoelectric transducers. The seismogenic section was found to form where a slow slip front propagated into a relatively locked region [Selvadurai and Glaser, 2015].

To model the behavior of this lab-scale seismogenic region, we use multi-cycle simulations and linear stability analysis in the open source software QDYN, which utilizes boundary element method and adaptive time-stepping [Luo et al., 2017]. We studied the postmortem surfaces and found that the worn fault displayed a clear bimodal Gaussian distribution of surface height. This unique distribution of surface roughness was determined to be a proxy for a heterogeneous description of the critical slip distance D_c used in numerical calculation that modelled the seismogenic region as a VW section with constant normal stress that obeyed the slip law in terms of RS friction.

Our model showed that it was capable of producing the same diversity in slip behaviors from stable sliding to unstable with localized spontaneous ruptures and this was dependent on parameter selection. Preferentially smooth (polished) sections of fault exhibited low D_c and were susceptible to rupture nucleation. However, the extent to which they propagated along the fault depended on the level strength heterogeneity. Wearing of the fault also led to a natural periodicity in the spatial distribution of strength, which produced numerical estimates of source characteristics that matched those made from an independent analysis of seismic waves. Matching numerical and experimental estimates of source characteristics (seismic moment, source length scale and stress drop) was used a calibration tool to accurately tune the model behavior and better understand conditions leading to the production of seismicity attributed to the interaction of a slow slip front into a relatively locked section of fault.

References:

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