Earthquake Nucleation on Fractal Rough Faults

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Previous research have revealed that natural faults in the field, as similar to rock surfaces in the laboratory, are not flat but rough with a wide range of spatial scales, which can be described as a self-affine fractal with its Hurst exponent being 0.5-1.0 (e.g. Brown & Scholz, 1985; Candela et al., 2012). The roughness causes significant effects on slip mechanics (Dieterich & Smith, 2009; Fang & Dunham, 2013) and to understand the effect of roughness is required.

Here we focus on the effect of fault roughness on earthquake nucleation by mean of the boundary integral equation method. In order to investigate the effect of roughness, we synthesize various self-affine fractal fault traces, which is specified by its amplitude and minimum wavelength. The fault trace is assumed to consist of abrupt kinks and discretized into 4096 straight segments. We use the rate and state friction law (RSF) to solve spatiotemporal evolution of nucleation processes. Because nucleation is sensitive to the evolution law of RSF (Ampuero & Rubin, 2008), we use both of the aging law and slip law.

The simulation results with a uniform initial condition show that the location of nucleation is strongly affected by the roughness through non-uniform stressing rates determined by the local orientation. On fractal faults with the small amplitude and large minimum wavelength, the nucleation processes are found to be almost similar to those of planar faults. In contrast, on faults with large amplitude and small minimum wavelength, the slip velocity is significantly suppressed by the roughness and fails to accelerate to the dynamic regime. These simulated tendencies are common to both evolution laws.

The results that the slip growth is significantly suppressed by the fault roughness can be interpreted by the concept of background stress as pointed out in the previous studies (Dieterich & Smith, 2009, Fang & Dunham, 2013). On a kinked fault model in an elastic solid, background stress in the vicinity of each kink becomes “singular”. Such singularity is pathological on a natural fault and may be relaxed by off-fault brittle damage. The effects of off-fault damage on the nucleation are to be included in the future study.