Concurrent slow and fast frictional ruptures

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Abstract

Frictional motion is triggered by interface failure, akin to earthquakes that occur along faults. As in rapid earthquakes, these ruptures generally accelerate rapidly, eventually propagating at velocities approaching the Rayleigh wave speed. Slow ruptures, however, may occur in both laboratory and natural fault settings, but the mechanisms that drive them are not fully understood. Here we experimentally show, by direct measurements of the real contact area and local strains, that both extremely slow (cm/sec) and fast (km/sec) ruptures can repeatably propagate within the same frictional interface. We demonstrate that a dynamic equilibrium between loading rates and velocity-dependences of both interface resistance and fracture energy enable slow ruptures to nucleate and propagate at very low applied shear stresses. In the same interfaces, fast ruptures also occur, but only when their nucleation becomes possible at higher stress conditions. We find that the dynamics and structure of both rupture classes are well-described by Fracture Mechanics. Their existence results from close interplay between interface properties and rupture velocity. These results provide a fundamental understanding of the mechanisms driving both slow to fast ruptures and their transitions and offer key insights into fault mechanisms and frictional motion.

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