Energy partitioning during (fluid-induced) earthquake

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During an earthquake, the propagating rupture leads to strong spatial variations of temperature, pressure, slip rate, generating in turn a spatially non-uniform stress drop. Friction, and fracture mechanics provides theoretical frameworks to study the stress singularity generated by this stress drop, as well as energetic conditions to describe its nucleation and propagation. They allow to bridge the gap between the physical mechanisms influencing rock friction and their impact on the nucleation and propagation of an earthquake, as well as on the energy portioning.

Here, we compute the energy budget during earthquake, by conducting stick-slip experiments in a biaxial configuration apparatus. The energy partitioning shows that heat energy is the largest fraction of the energy partitioning, with values ranging from 200 to 2500 J/m², that radiated energy is the second largest energy, with values ranging between 80 and 300 J/m². We also estimate fracture energy through both Linear Elastic Fracture Mechanics (LEFM) and the integration of the near-fault stress-slip evolution. We show that, at the scale of our experiments, fault weakening is divided into a near-tip weakening, corresponding to an energy of few J=m², consistent with the one estimated through LEFM, and a long-tailed weakening corresponding to a larger energy not localized at the rupture tip, increasing with slip. We demonstrate that only near-tip weakening controls the rupture initiation and that long-tailed weakening can enhance slip during rupture propagation. Then we conduct rock friction experiments to assess the nature of this second weakening and understand the role of water on it. We show that both the flash heating, thermal pressurization of fluids and elastohydrodynamic lubrications occur during co-seismic slip, and their relative contributions are controlled by the fluid pressure levels, the fluid viscosity and the evolution of water’s thermophysical properties during thermodynamic phase transitions. We conclude that the origin of the seismological estimates of breakdown work could be related to the energy dissipated in the long-tailed weakening (which is in turn controlled by the in-situ pressure and temperature conditions, rock type and fluid presence) rather than to the one dissipated near the tip.