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Measuring fracture energy under coseismic conditions

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Experiments performed on rocks at deformation conditions typical of seismic slip, show an extremely low friction coefficient, the activation of lubrication processes and a power-law strength decay from a peak value to a residual, steady-state value. The weakening curve has an initially very abrupt decay which can be approximated by a power-law. The resulting experimental fracture energy (defined, for a given slip amount u, as the integral between the frictional curve and the minimum frictional level reached $\sigma_f(u)$) scales on most of the slip range as $G \propto u^{\alpha}$, a power-law in some aspects in agreement with the seismological estimates of $G' \propto u^{1.28}$ proposed by Abercrombie and Rice (2005). The values of G and G' are comparable for slips of about $u = 1$cm ($G \approx 10^4$ J/m^2). Both gradually increase with slip up to about 10^6 J/m^2, however, it appears that fracture energy G' is slightly larger than G in the range of slip $0.1 < u < 10$. The effective G' observed at the seismological scale should implicitly incorporate energy sinks other than frictional dissipation alone, which we discuss (anelastic damage due to high off-fault dynamic stress close to the rupture tip; dissipation during slip-localizing process within fault gouge of finite thickness; strain accomodating fault roughness at different scales). Since G' is obtained by estimating the amount of dissipation with respect to strain energy and radiated energy, it will implicitly incorporate the sum of all dissipative processes due to rupture propagation and fault slip. From the comparison of G obtained in the lab and in earthquakes, it appears that friction alone explains most of the dissipation, except maybe at the larger magnitudes.