Experimental Fracture Mechanics of Brittle & Ductile Faults
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1. Take Away

- Increase in fault stability with increasing T reflects change in frictional rate behavior. Here, we investigate alternative hypothesis: thermally-activated damage along propagating fault alters fracture energy & fault stability. We explore how fault nucleation & propagation vary w/ T.

A1) For both brittle & ductile faulting, interaction of mesoscale shear bands is the critical nucleation process for macroscopic faults. Brittle & ductile faulting are distinguished by whether tensile cracks can propagate across grains.

A2) Brittle faults nucleate via propagation of mesoscale shear bands, and, once grown, propagate by break-down of intact rocks. Ductile faults nucleate and grow via coalescence of pre-existing shear bands.

A3) Temperature promotes off-fault damage via reactivation of thermally-activated cataclasis which took place before faulting. Increase in off-fault damage suggests increase in fracture energy with fault growth, leading to stabilization of fault slip. Wall-rock interaction is expected to play an important role in fault slip behavior.

2. Experiment

3. Nucleation

- Does fault nucleate by microcrack interaction?

- Crack interaction was quantified by determining length & spacing of microcracks mapped.

- At low T, tensile cracks nucleate at grain contacts and propagate across grains. At high T, tensile cracks nucleate within grain interiors and do not propagate across grains.

- For both brittle & ductile faulting, interaction of shear bands is the critical nucleation process. The two fault modes are distinguished by if tensile cracks can interact & propagate across grains.

- Does propagation of mesoscale shear bands facilitate fault nucleation?

- Fault nucleate when $G_{\text{band}} \geq G_{\text{fault}}$.

- $G_{\text{band}} = \frac{t^2 L f_{\text{interaction}}}{E}$

- Young's Modulus

- At 20°C, 900°C, length & spacing of shear bands & tensile cracks are observed.

- Microcrack Length, $\mu$m

- Shear Band

- Tensile Crack

- Grain Size

- Number/mm²

- Normalized Fault Length

- Normalized Grain Radius

- What is the energy budget of fracture energy?

- In brittle fault, Griffith criterion in Brazilian tensile loading best describe observed damage. In ductile fault, Mohr-Coulomb criterion reproduce shear damage. Fracture mechanics models can describe off-fault damage, if combined with micromechanics-informed yield criterion.

- In brittle fault, dissipation mainly within gouge layer. In ductile fault, dissipation via frictional sliding along anastomosing shear bands within damage zone. Increase in off-fault dissipation with increasing T suggests fracture energy scales w/ fault lengthening, promoting stable failure.