Fault Stabilization by Dilatant Hardening

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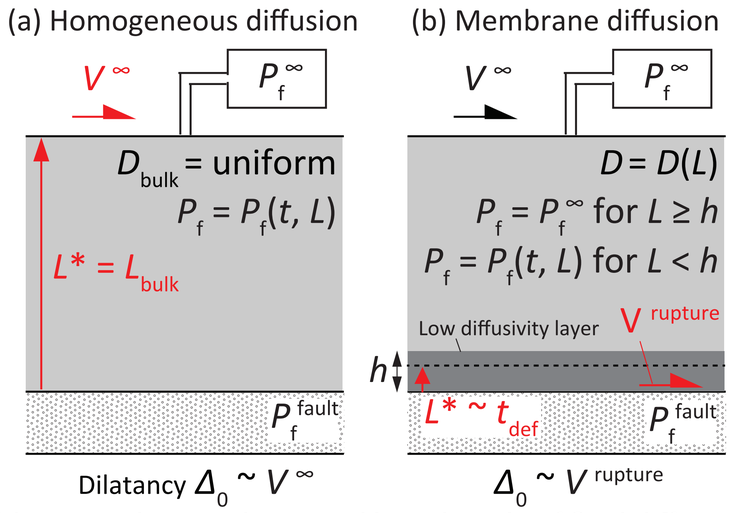
Take Away

What is the effect of bulk fluid diffusivity and strain rate on fault stabilization?

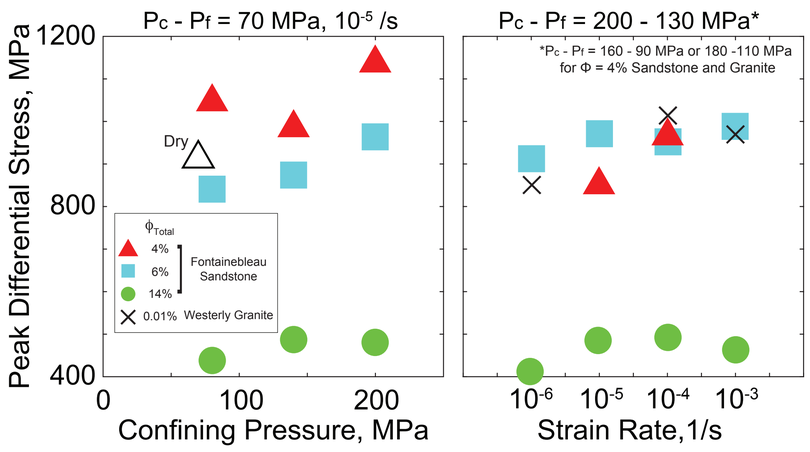
- Failure stabilizes over the entire failure events (long-term stabilization) in low-diffusivity rocks at lowest strain rates. At high strain rates, low-diffusivity rocks show entirely unstable failure where strengthening is observed. These observations indicate that failure stabilization by dilatant hardening occurs only when bulk samples are partially drained.
- Following long-term stabilization, low-diffusivity sandstones also show prolonged unstable failure (short-term stabilization) with tremor-like seismicity.
- Both bulk fluid diffusivity and strain rate govern long-term stabilization. Short-term stabilization is controlled by bulk diffusivity and lithology, but is independent of strain rate.

1. Models of Dilatant Hardening



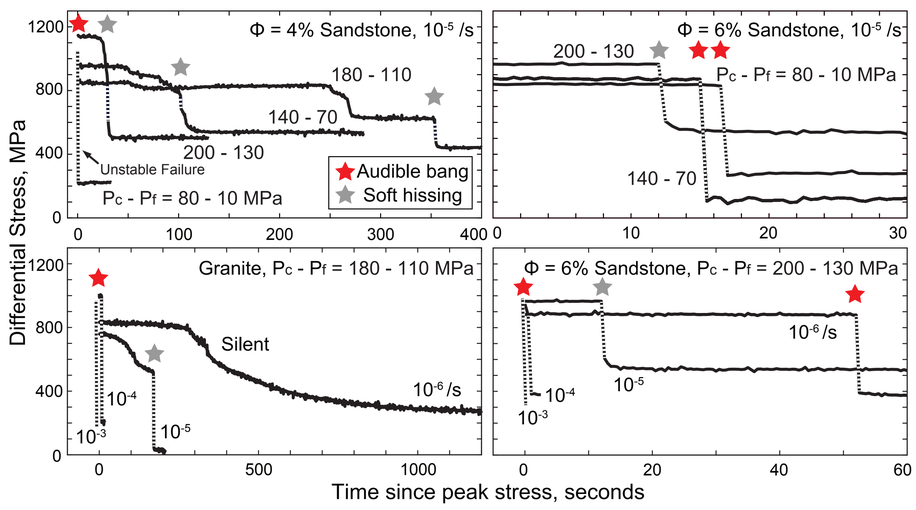
- This study addresses: What are the critical length scale of fluid diffusion & the timescale of deformation governing the fault drainage and failure stability?

2. Role of Dilatant Hardening on Peak Strength

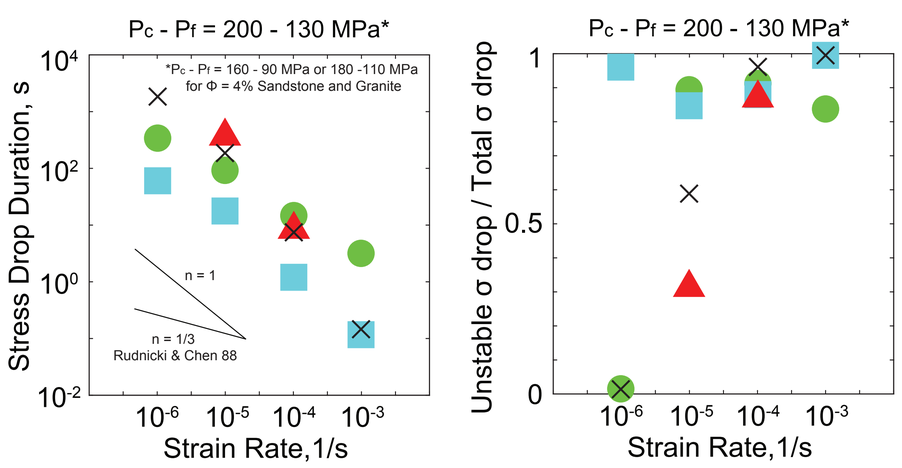


- Low diffusivity rocks show higher peak strengths at greater strain rates (as well as at higher Pc and Pf at the same Pc - Pf), indicating increased effective pressure by dilatant hardening.

3. Role of Dilatant Hardening on Long-Term Failure

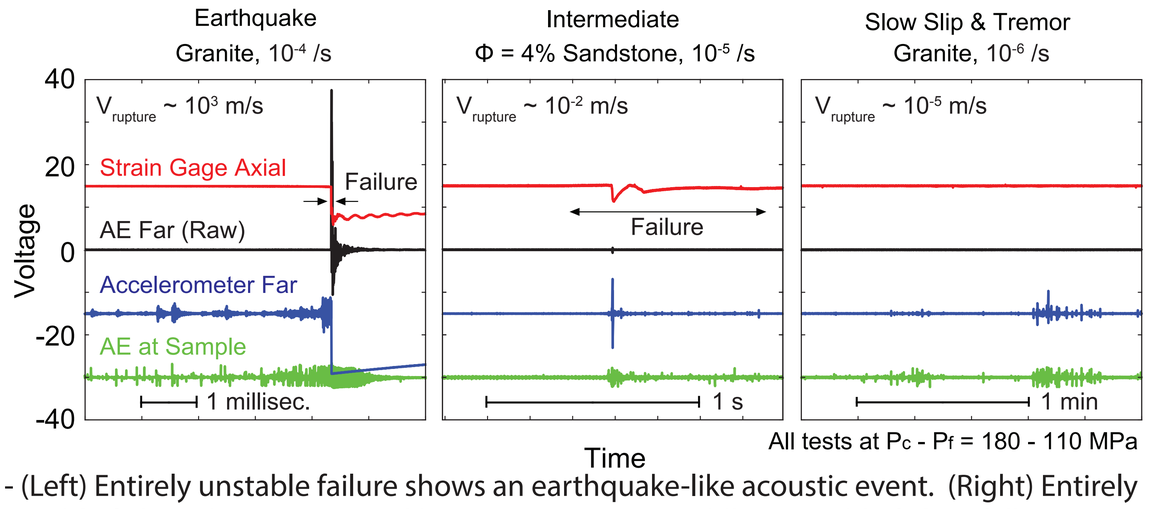


- (Left) In low bulk diffusivity rocks, failure is stabilized at higher Pc and Pf and lower strain rates. Failure consists of initial stable failure and subsequent unstable failure. (Right) In high diffusivity rocks, failure is entirely unstable at all conditions.

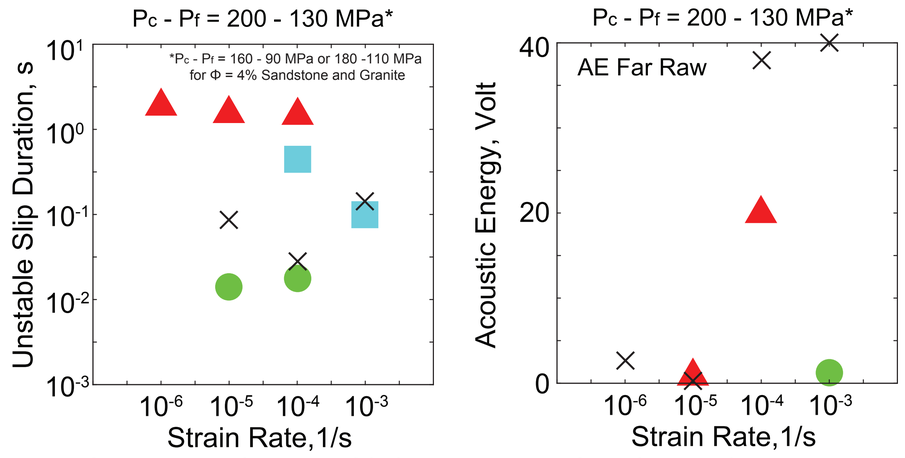


- Stress drop durations for long-term stabilization show a distinct scaling relationship with the timescale of deformation from that of drained, non-stabilized failure.

4. Role of Dilatant Hardening on Short-Term Failure

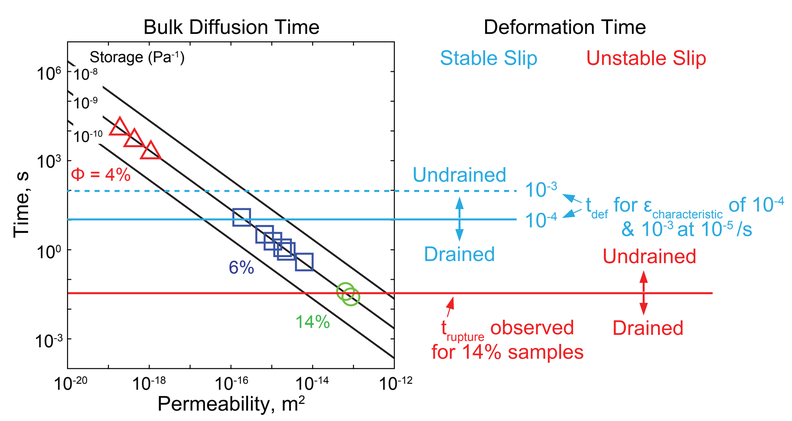


- (Left) Entirely unstable failure shows an earthquake-like acoustic event. (Right) Entirely stable failure shows a tremor-like acoustic event. (Middle) Unstable failure following initial stable failure shows intermediate acoustic behavior, where the unstable part of failure consists of multiple failure events over a prolonged period.



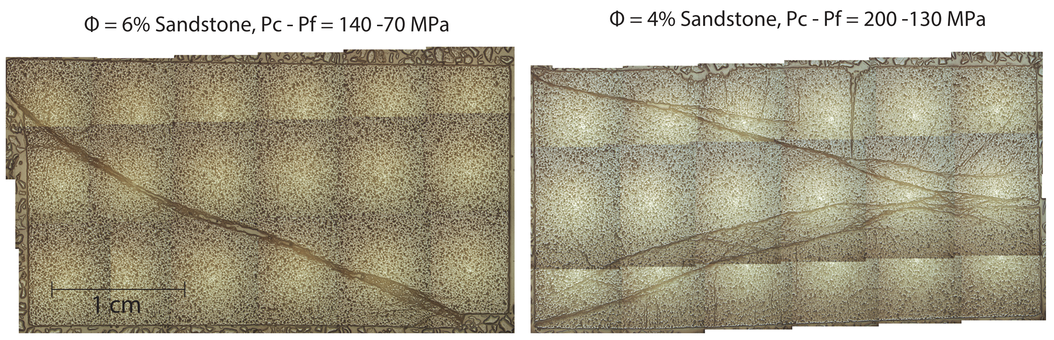
- Stabilization of the unstable part of failure occurs only in low diffusivity sandstones. Unstable failure in high diffusivity sandstones and granite is dynamic. This short-term stabilization is independent of strain rate.

5. Drainage Condition during Faulting



- Comparison of bulk diffusion times (based on permeability measurements) vs. deformation timescales. Observed long-term stabilization is consistent with drainage conditions predicted based on bulk permeability and strain rate. In contrast, observed short-term stabilization may be explained by drainage condition reflecting bulk permeability and timescale of dynamic rupture.

6. Mechanisms of Fault Stabilization



- Both long- and short-term stabilization is associated with distributed faulting consisting of multiple faults (Right). Fully unstable failure results from a single fault (Left).