The Influence of Pre-slip Healing on the Evolution of Permeability on Fractures and Faults

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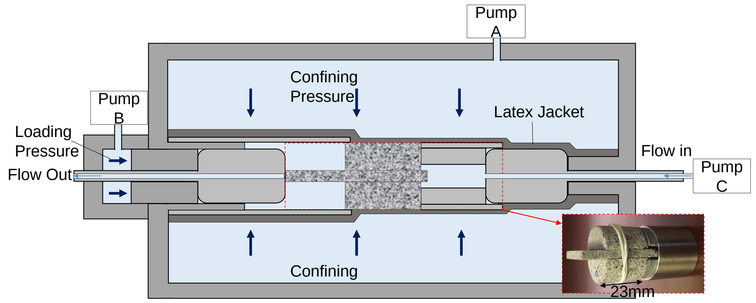
ABSTRACT

The evolution of permeability on fractures and faults during the full earthquake cycle is shown to be sensitive to healing during the repose phase. We explore the combined effect of static loading followed by fracture reactivation on permeability evolution via slide-hold-slide experiments with continuous measurement of permeability. Repose periods show a power law decay in permeability with time ($k \sim t^{0.37}$) that is uniform between different samples and fracture surface roughnesses. With increasing repose periods, permeability evolves following reactivation from net reduction to net increase with magnitude dependent on the repose period. This identifies that pre-slip sealing and healing during repose is an essential component in the cyclic destruction (repose) then creation (reactivation) of permeability throughout the seismic cycle.

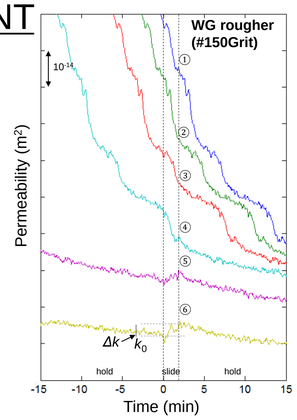
EXPERIMENTAL METHOD

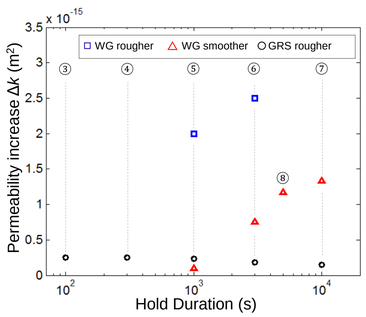
- Fluid-through-flow experiment in a triaxial pressure cell
- Westerly Granite (WG) and Green River Shale (GRS) with two surface roughness (ground by #150 grit (rougher) and #600 grit (smoother) powder)
- Slide-hold-slide with increasing hold duration. (10 s → 10000 s)

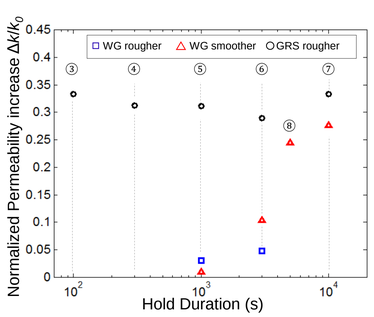


MAGNITUDE OF ENHANCEMENT AND SEQUENTIAL CHANGE

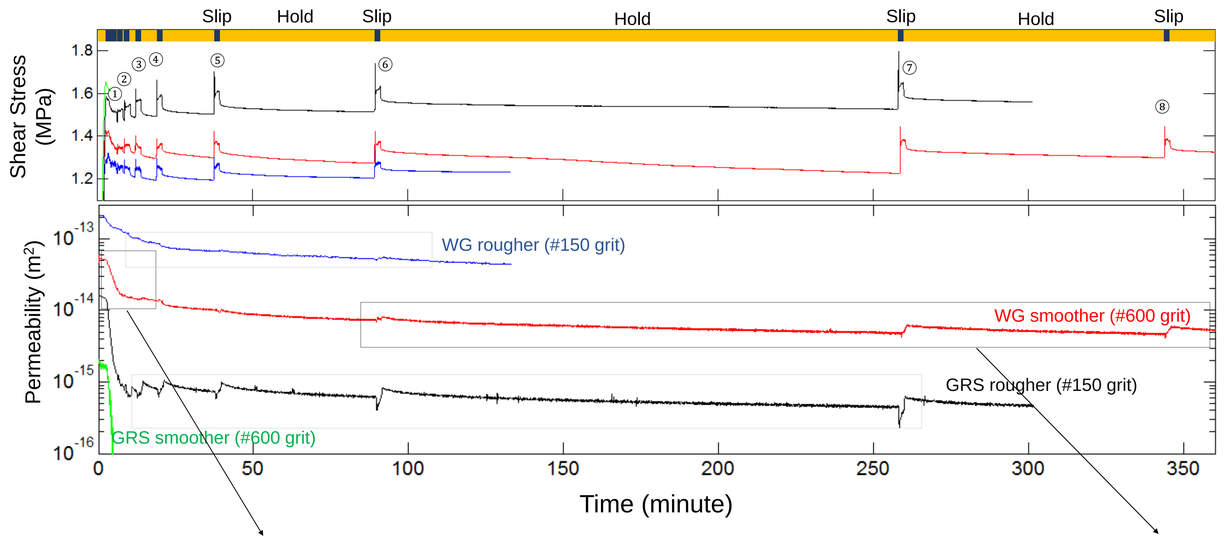
- Significant initial net declines in permeability transitioning to net increases
- Magnitude of absolute permeability
  WG rougher > WG smoother > GRS rougher
  → larger permeability change with rougher/harder surface implicating the role of shear dilation
- Magnitude of relative permeability change
  WG Rougher < WG smoother < GRS rougher
- The magnitude of shear permeability enhancement is dependent on the pre-slip sealing, especially for the harder rock (granite)



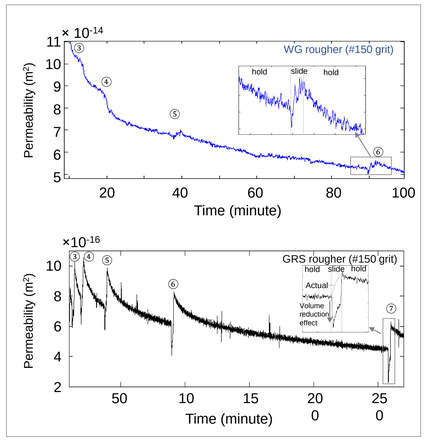




RESULTS

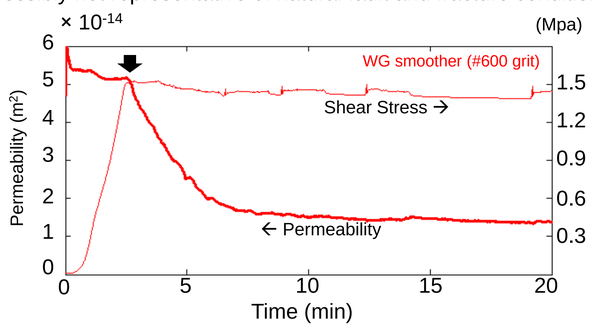


Permeability response of other two cases



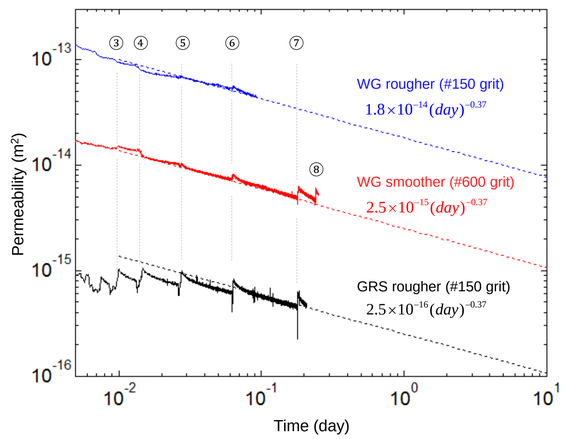
RAPID INITIAL DECLINE

- Permeability reduction follows the initiation of shear slip (driven by slip)
- Decline rate is significantly reduced after a few millimeters of displacement
- Probably driven by the generation of comminution products
- Dominant on fresh artificial surfaces
  → possibly not representative of natural fault and fracture conditions



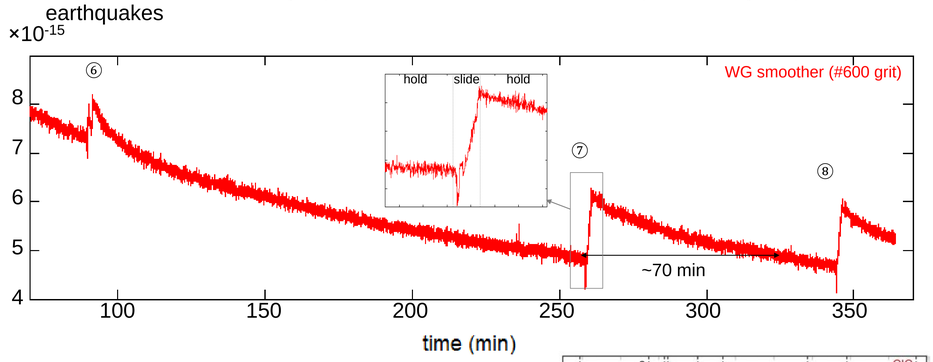
SEALING – POWER LAW DECAY

- Log-log plot exhibits that sealing follows a power law decay
- Surprisingly, these decay rates exhibits a near uniform power law exponent ~(-0.37)
- The decay does not stabilize within the duration of the experiment
  → the trend may extend into the natural inter-seismic period

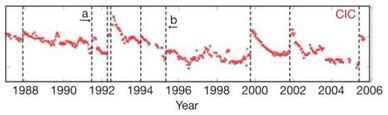


SIGNIFICANT ENHANCEMENT AFTER PRE-SLIP HEALING

- Shear reactivation following incremented durations of static loading show significant permeability enhancement
- Slow sealing follows rapid shear stimulation (recovery following slip ⑦ took 70 minutes)
- This behavior substantially reproduces observations of natural permeability response to earthquakes



Natural permeability response to earthquakes → [Elkhoury et al., 2006]



CONCLUSIONS

- Permeability decreases (seals) during repose (healing) and follows a uniform power-law response
- Repose periods are essential in resetting permeability response prior to reactivation
- Reactivated permeability response switches from net reduction (brief repose) to net increase (extended repose)

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