Hydromechanical Coupling of Shale-Quartz Mixtures and Implication for Fault Slip Behavior

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SHEAR Action

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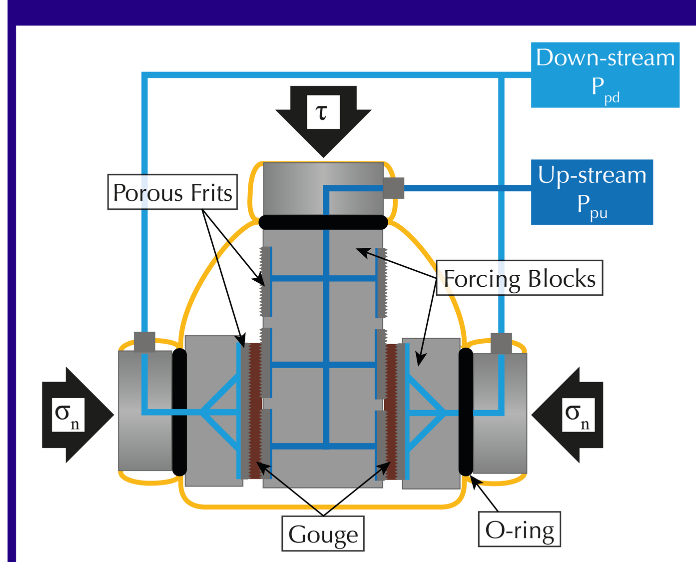
1. Introduction

Fault earthquake potential depends on its hydrological and mechanical properties. Mature fault zones, which often host earthquakes, are hetereogeous in composition.

- *How does fault permeability couple with fault frictional stability?*
- *How does compositional heterogeneity influence fault hydro-mechanics?*

2. Experimental Methods



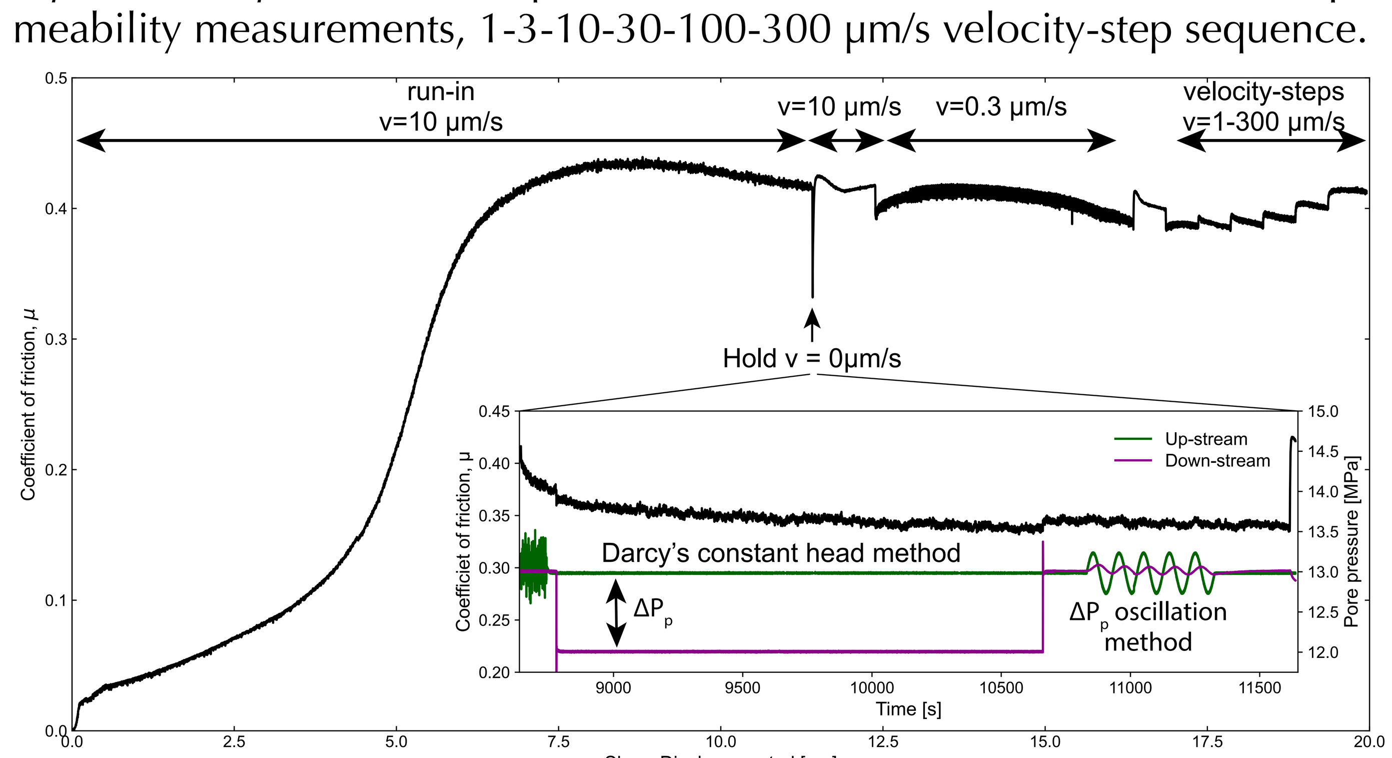
Double-direct-shear experiments on mixtures of quartz and shale gouge.

3 different stress conditions:

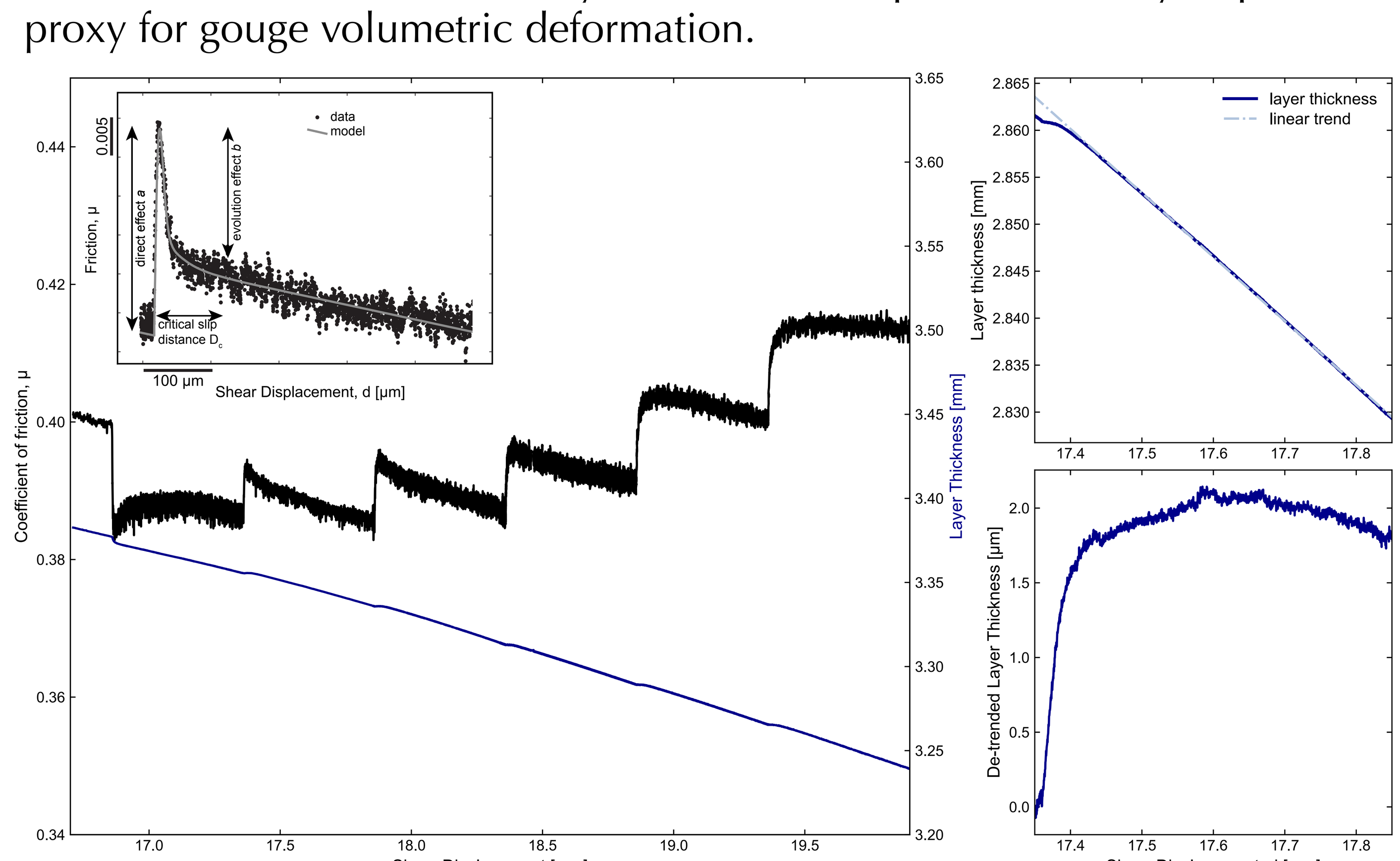
- σ'_n = 7 MPa ($\lambda=P_f/\sigma'_n$ = 0.4)
- σ'_n = 10 MPa ($\lambda=P_f/\sigma'_n$ = 0.7)
- σ'_n = 20 MPa ($\lambda=P_f/\sigma'_n$ = 0.4)

We measured friction, frictional stability and permeability.

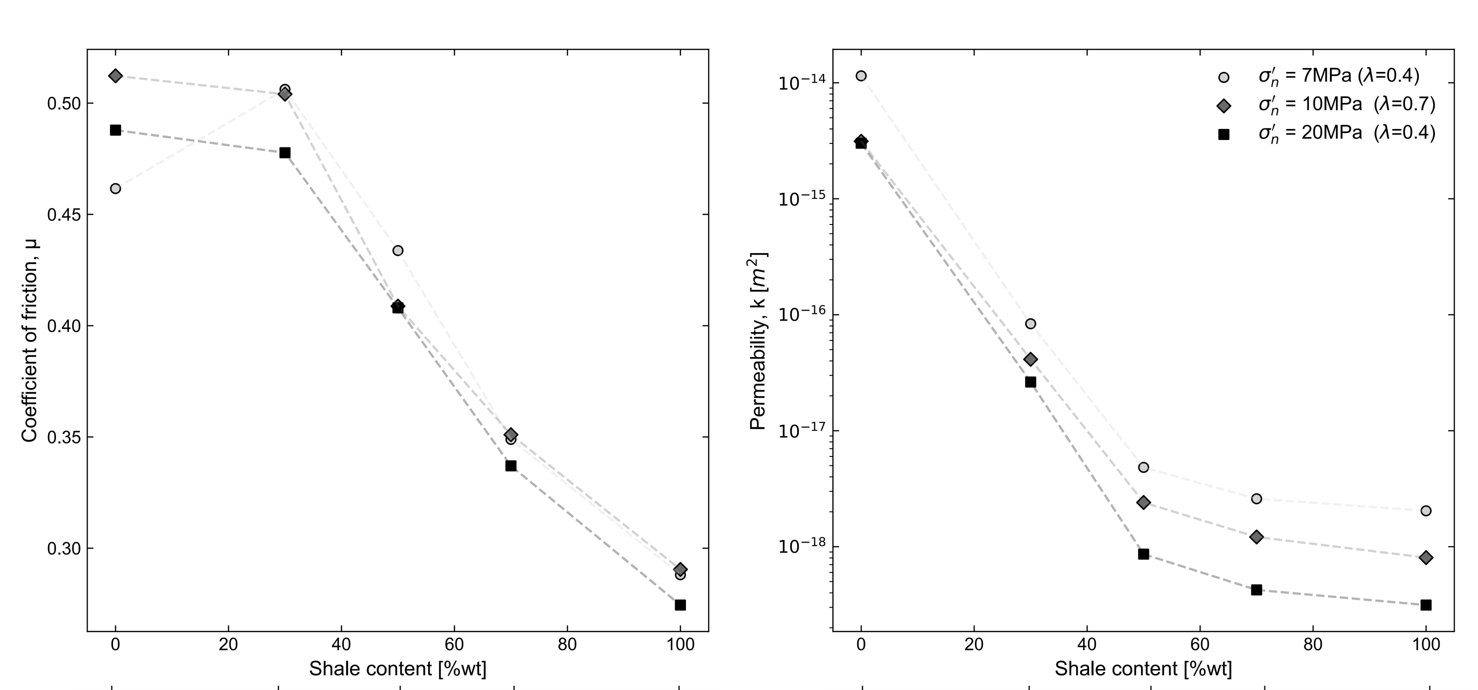
Experimental procedure: 10 μm/s run-in, constant-head and oscillations permeability measurements, 1-3-10-30-100-300 μm/s velocity-step sequence.



We measured the amount of layer dilation in respose to velocity steps, as a proxy for gouge volumetric deformation.

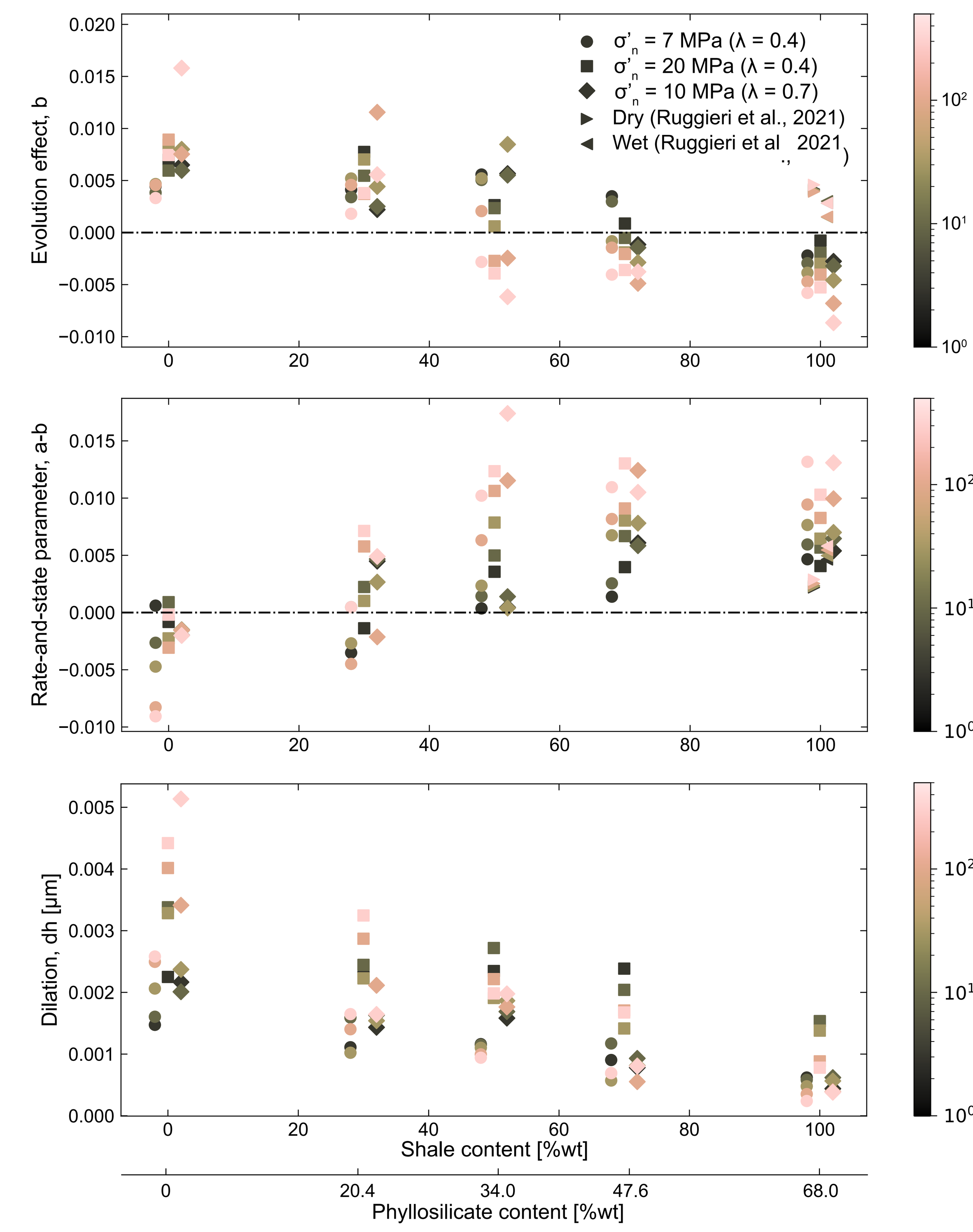


3. Results: Friction and Permebility



Friction and permeability both decrease with increasing shale content. Permebility decreases with increasing effective normal stress.

4. Results: Frictional Stability

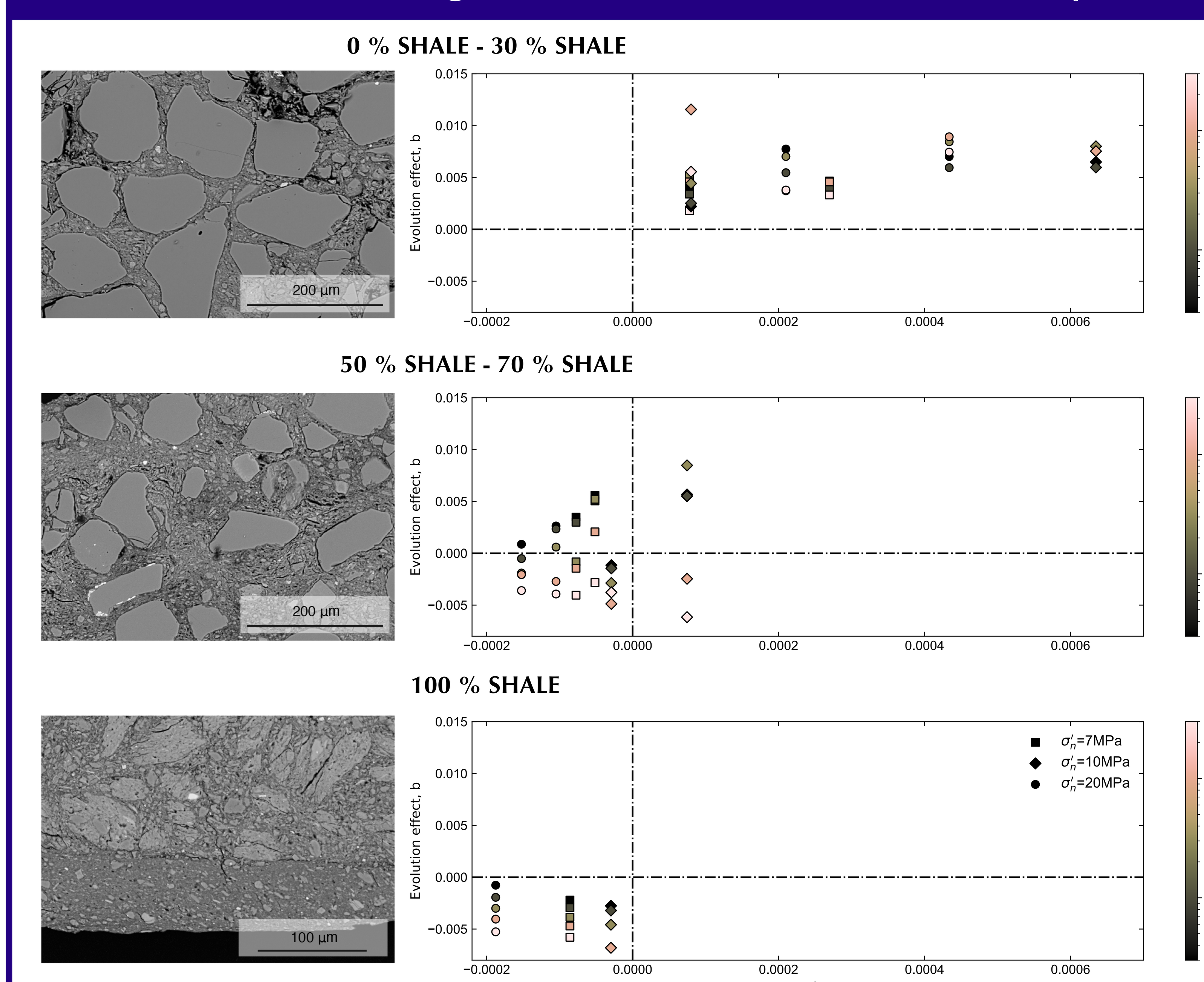


The evolution effect *b* clearly evolves as a function of shale content and shear velocity. Negative *b* values emerge with increasing shale content, with the first values observed at 50% shale and high shear velocities.

The rate-and-state parameter (*a-b*) clearly evolves as a function of shale content and shear velocity. Positive (*a-b*) values are observed at >50% shale content, particularly at high shear velocities.

Dilation in response to a velocity up-step decreases with increasing shale content. The shear velocity dependence changes according to the composition ≤30%-shale gouge dilates more at higher shear velocities; ≥50%-shale gouge dilates less at higher shear velocit

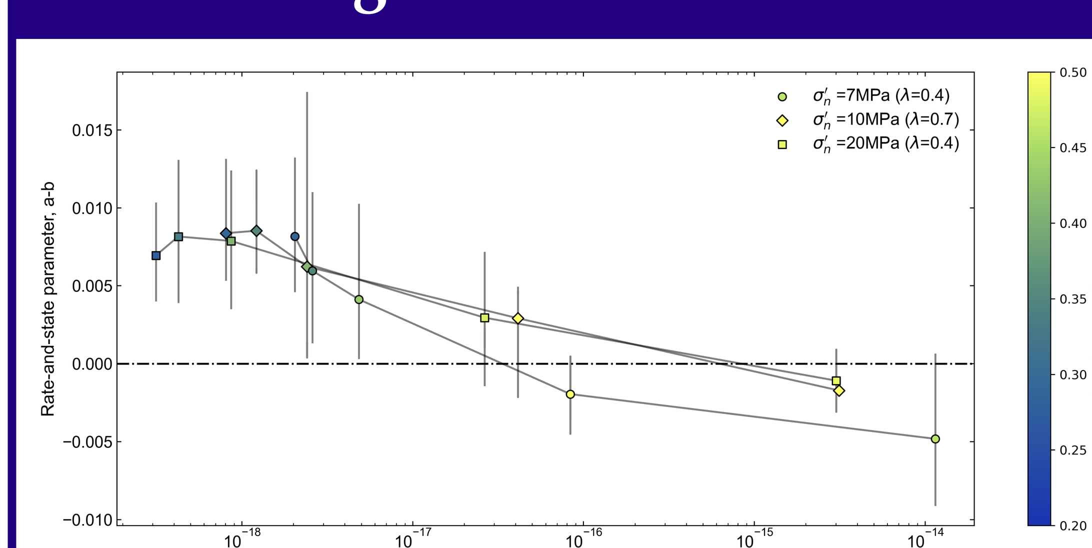
5. Discussion: Integration of Frictional Stability and Microstructures

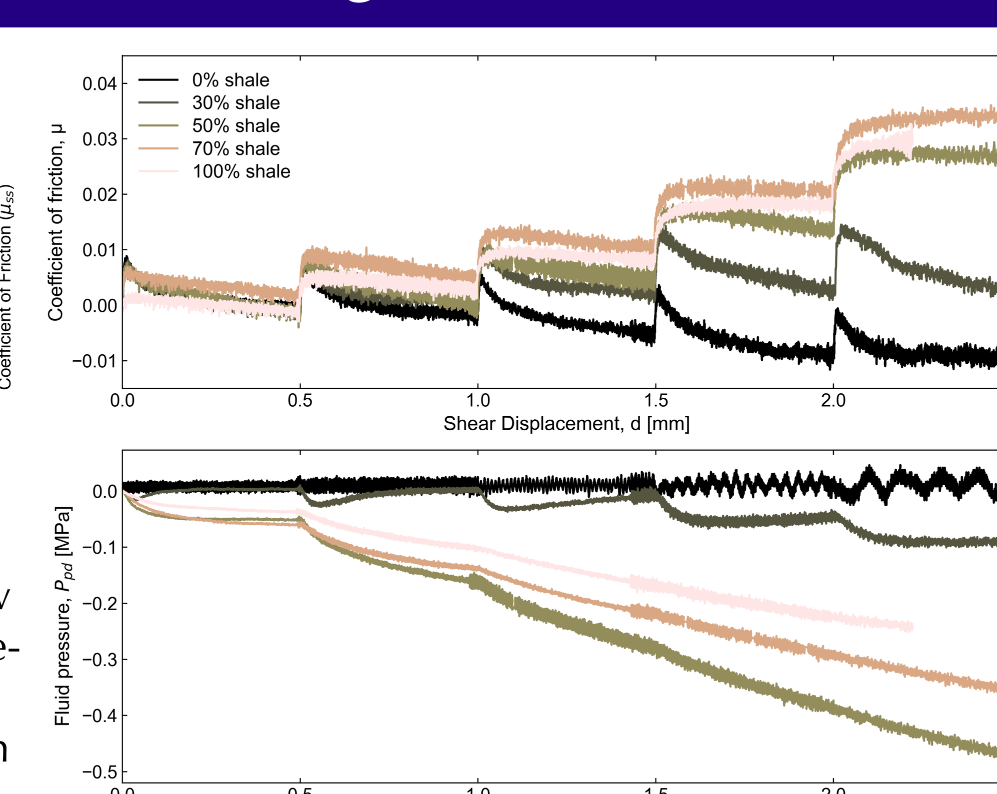


≤30%-shale gouge develops a network of quartz grains that controls the deformation. This results in more positive dilation rates, leading to positive *b* values and negative (*a-b*) values.

With increasing shale content, the deformation is progressively more localized. 100%-shale gouge shows localized shear planes where clay minerals are interconnected. This results in low *μ*, positive (*a-b*) and low *k*. The lower is *k*, the more negative is *b* value, and the lower is the dilation rate.

6. Negative *b* value and dilation hardening: is there a link?





High (*a-b*) values, and negative *b* values characterizes low *k* gouges. Increasing the shale content from 0% to 50% results in a transition from drained to undrained conditions. We infer that in response to a velocity increase a clay-rich gouge would experince a drop in fluid pressure, thus dilation hardening occurs, leading to negative *b* values.