

Impact of heterogeneities on fault friction in space and time



Srisharan Shreedharan

SCEC CRM Workshop | 6 Sept 2025

With contributions from:

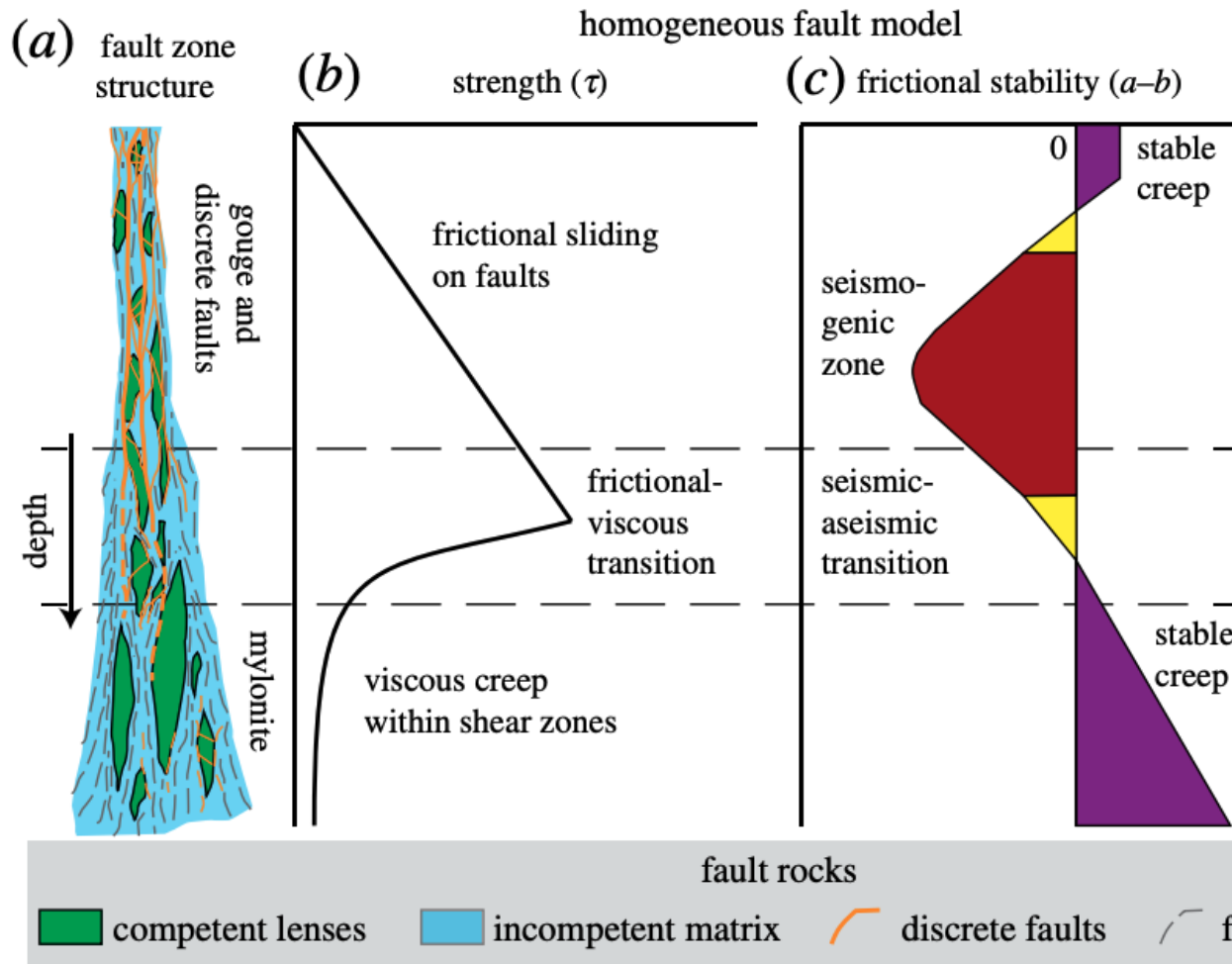
Sapana Regmi, Alejandro Aguilar, Raphael Affinito,
Alexis Ault, David Chas Bolton, Ema Armstrong,
Alex DiMonte, Monica Barbery, Greg Hirth

“A Brittle Rheology Model (are you sure you really want one...what is it that you want?)”

-Nick Beeler (2023 CRM Workshop)

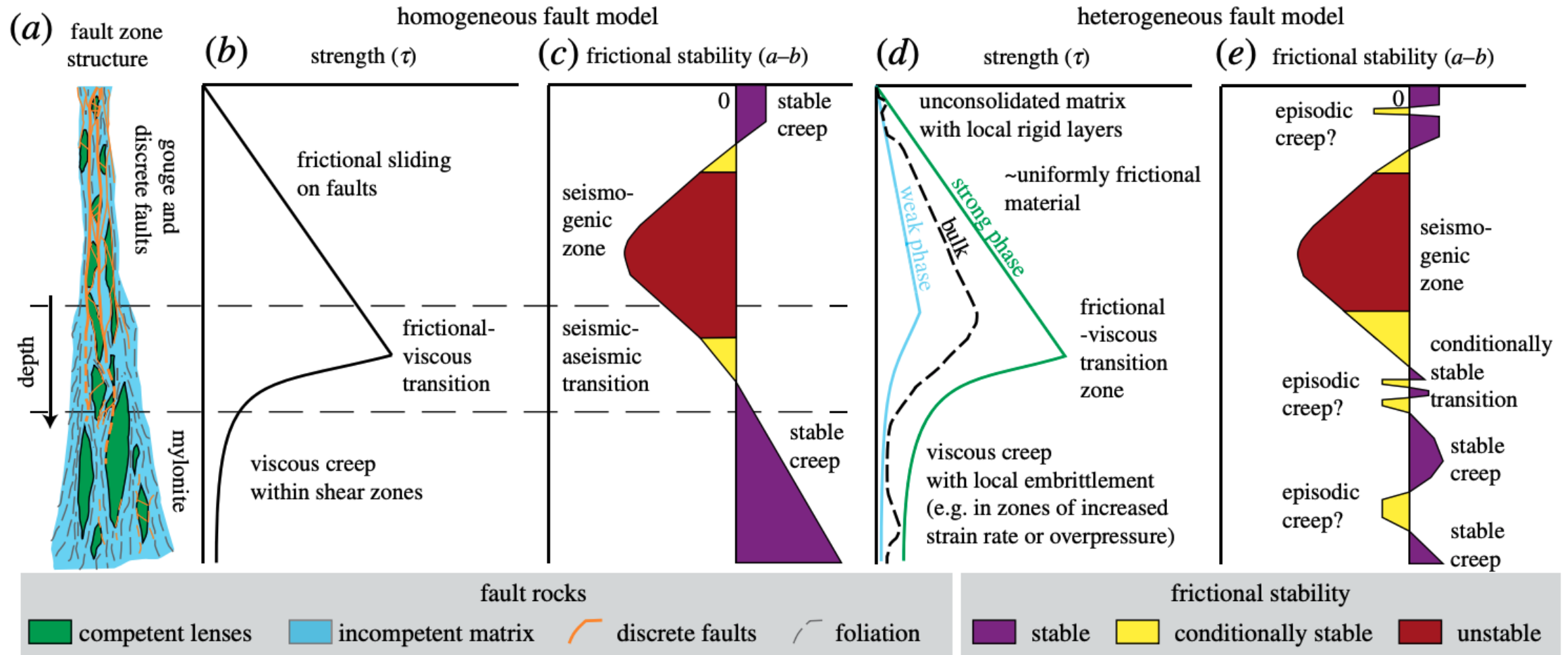
“A Brittle Rheology Model (are you sure you really want one...what is it that you want?)”

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Fagereng and Beall. (2021). *Phil. Trans. R.*

I want a model that goes beyond a bi/polyminallic friction database and acknowledges the heterogeneous context of shallow fault zones



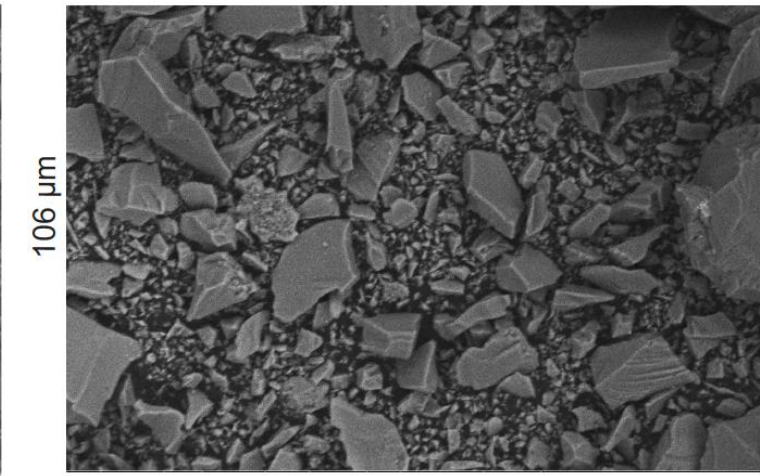
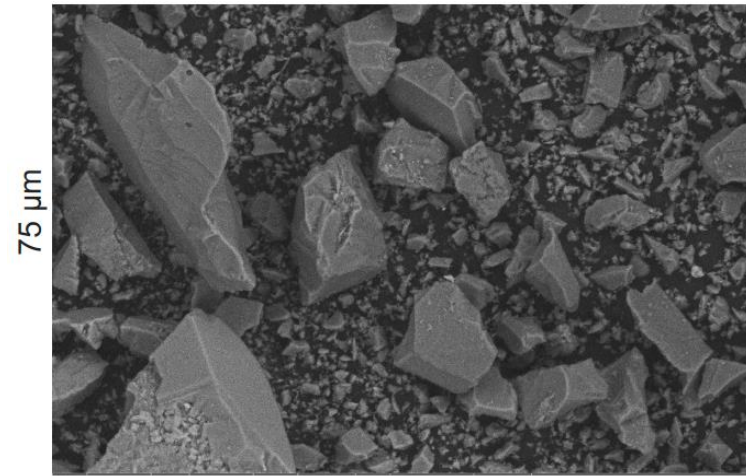
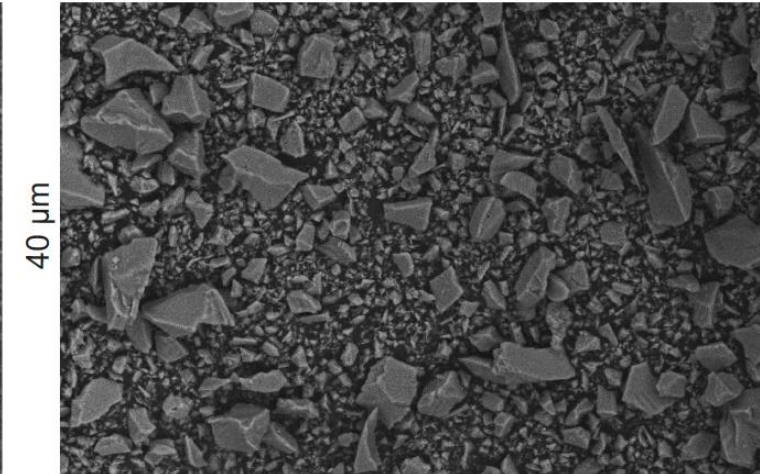
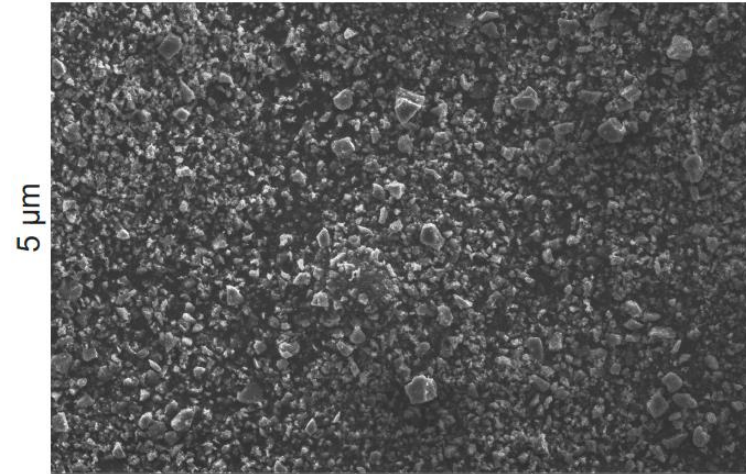
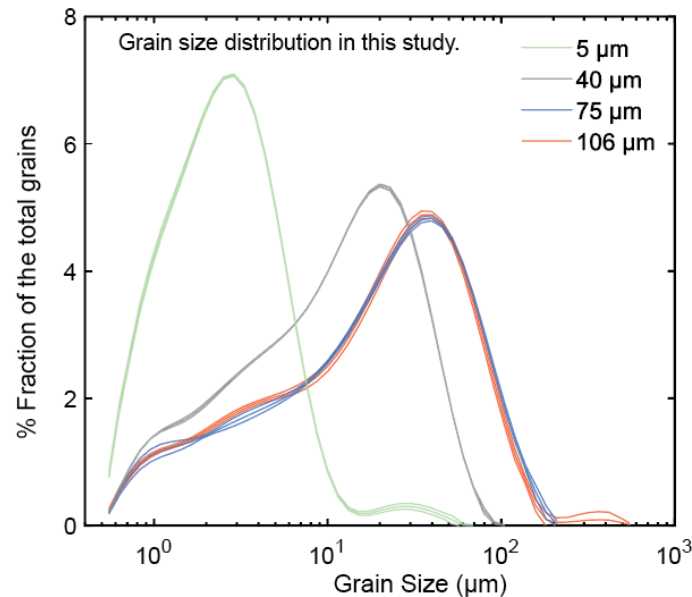
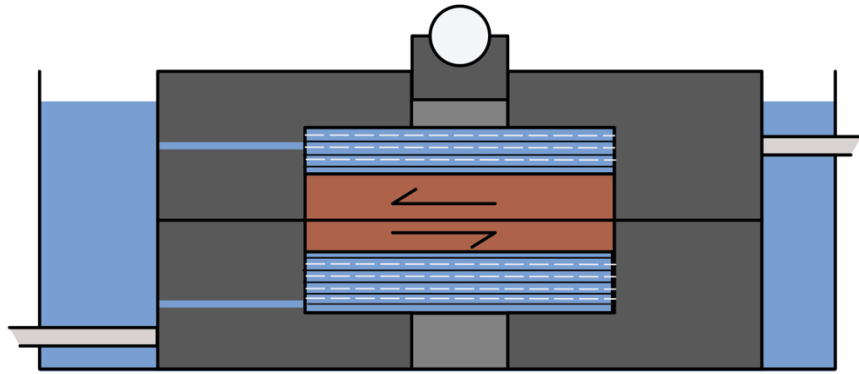
Fagereng and Beall. (2021). *Phil. Trans. R.*

Role of grain size heterogeneity on frictional stability of single-phase (quartz) faults



Sapana Regmi, MS 2025
Currently PhD student at UTIG/JSG

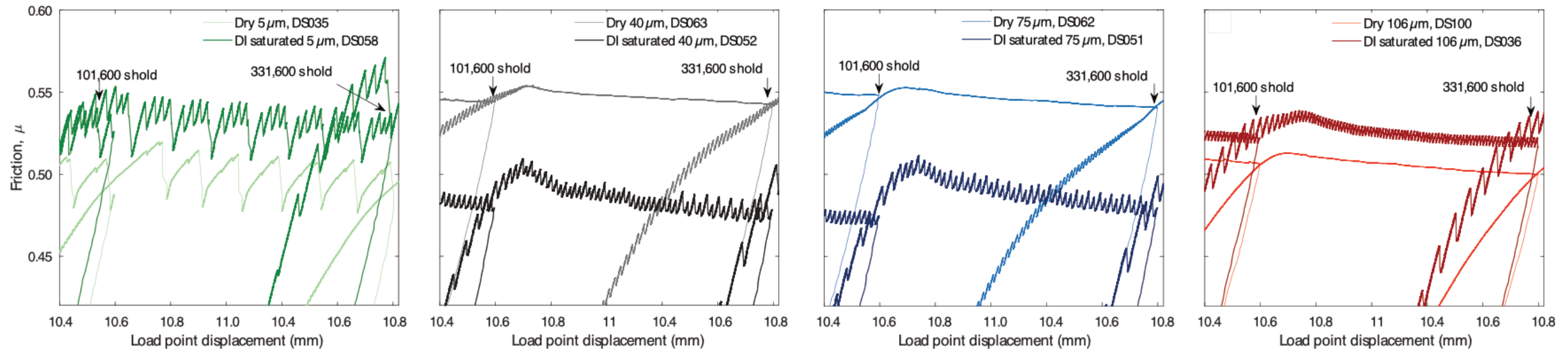
Role of grain size heterogeneity on frictional stability of single-phase (quartz) faults



50 μm

50 μm

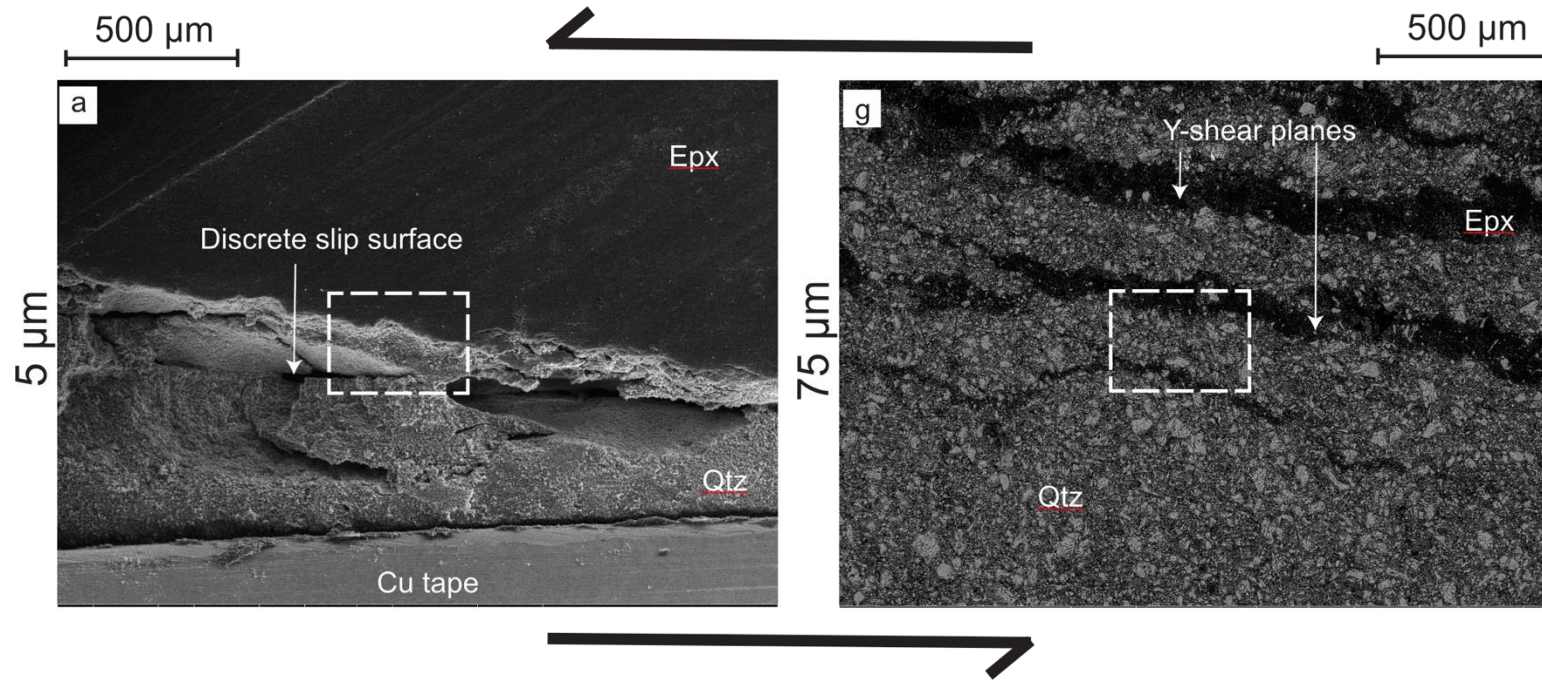
Grain size heterogeneity has a non-trivial effect on frictional stability of quartz-rich faults



Increasing grain size and overall fault stability

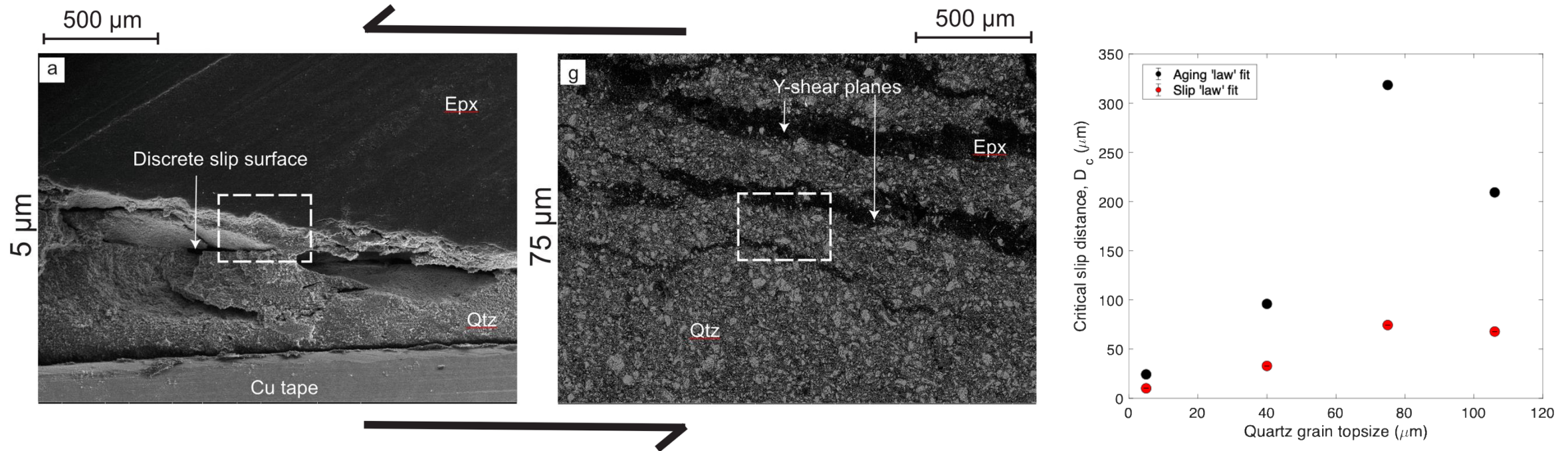
Fluid-filled fault gouges with smaller average grains, narrow grain size distributions are relatively more unstable

More efficient strain localization, fewer off-fault energy sinks in faults with small grains?



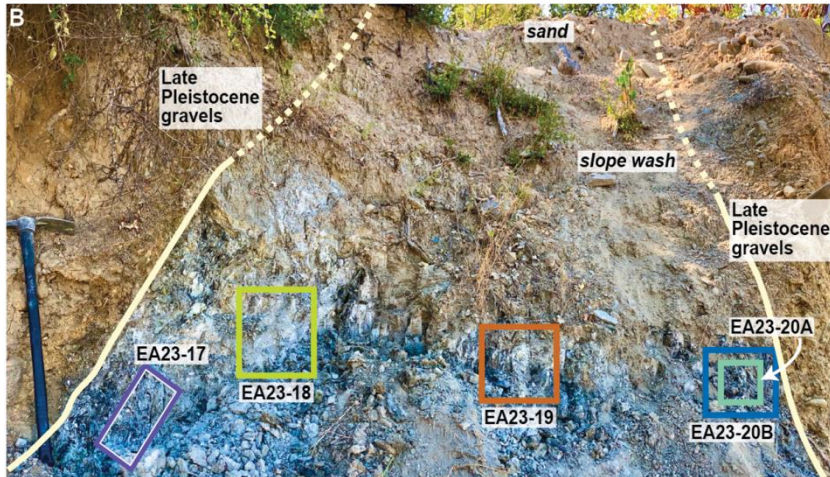
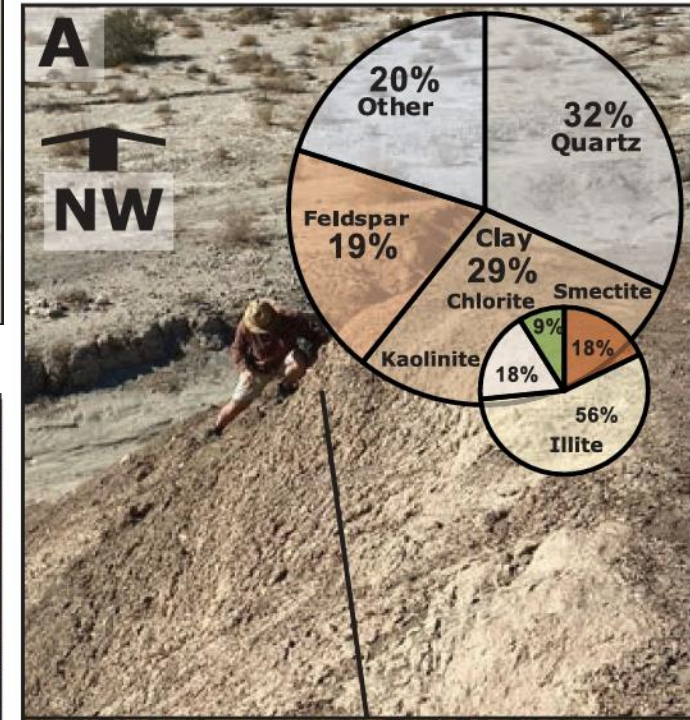
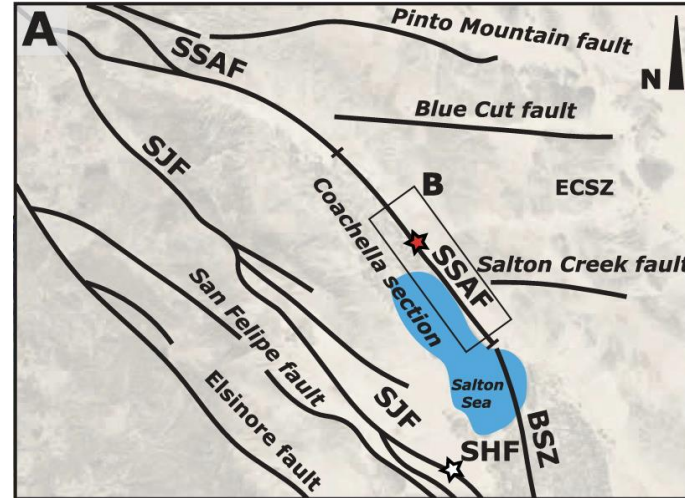
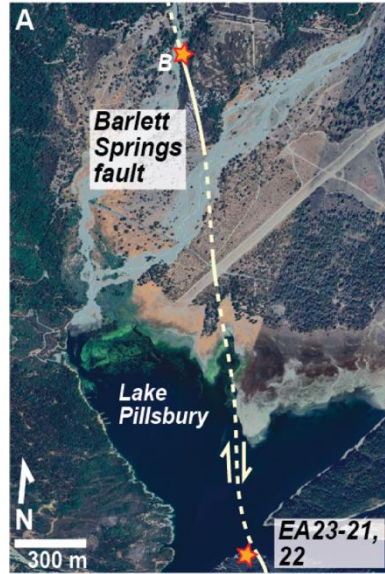
1. Enhanced localization and discrete slip surfaces in smaller grain size samples.

More efficient strain localization, fewer off-fault energy sinks in faults with small grains?

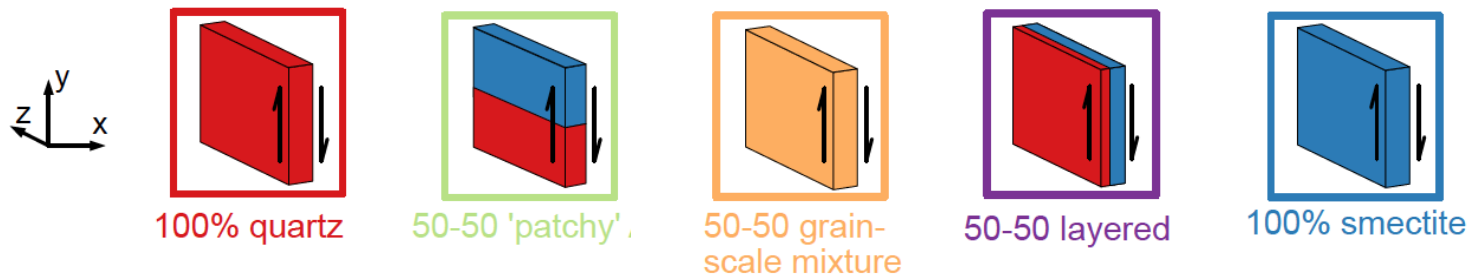


1. Enhanced localization and discrete slip surfaces in smaller grain size samples.
2. Increasing D_c with grain size supports microstructural observations.

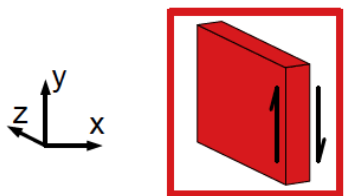
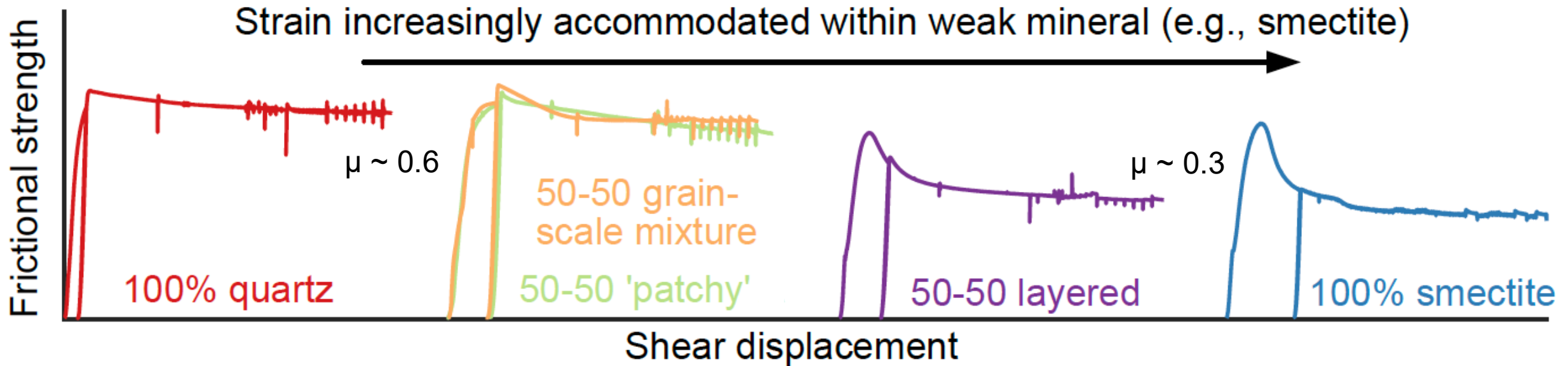
Fault zones exhibit rheological heterogeneities on many scales



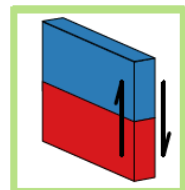
Role of rheological heterogeneity on frictional stability of two-phase faults



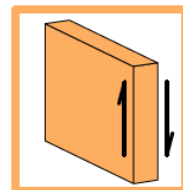
Even a simple two-phase mixture can exhibit a range of frictional behaviors depending on when/where strain localizes



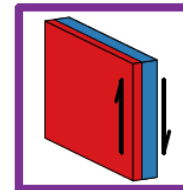
100% quartz



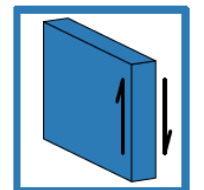
50-50 'patchy'



50-50 grain-scale mixture



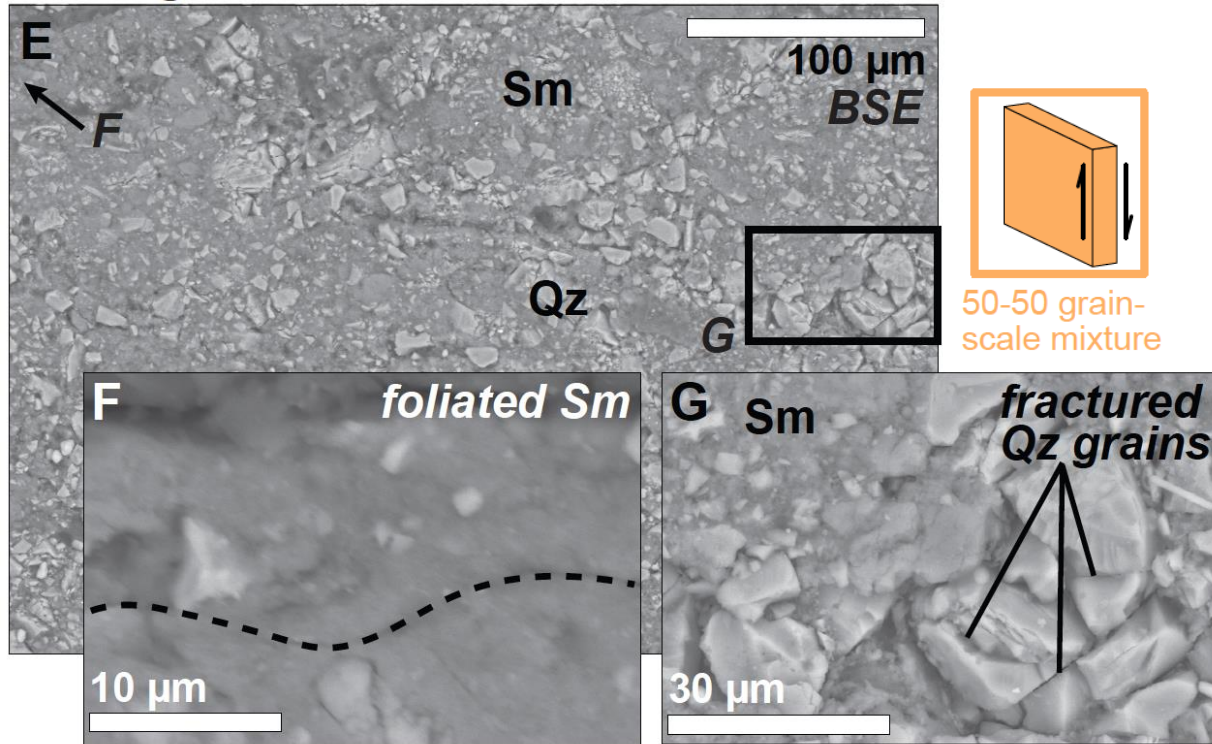
50-50 layered



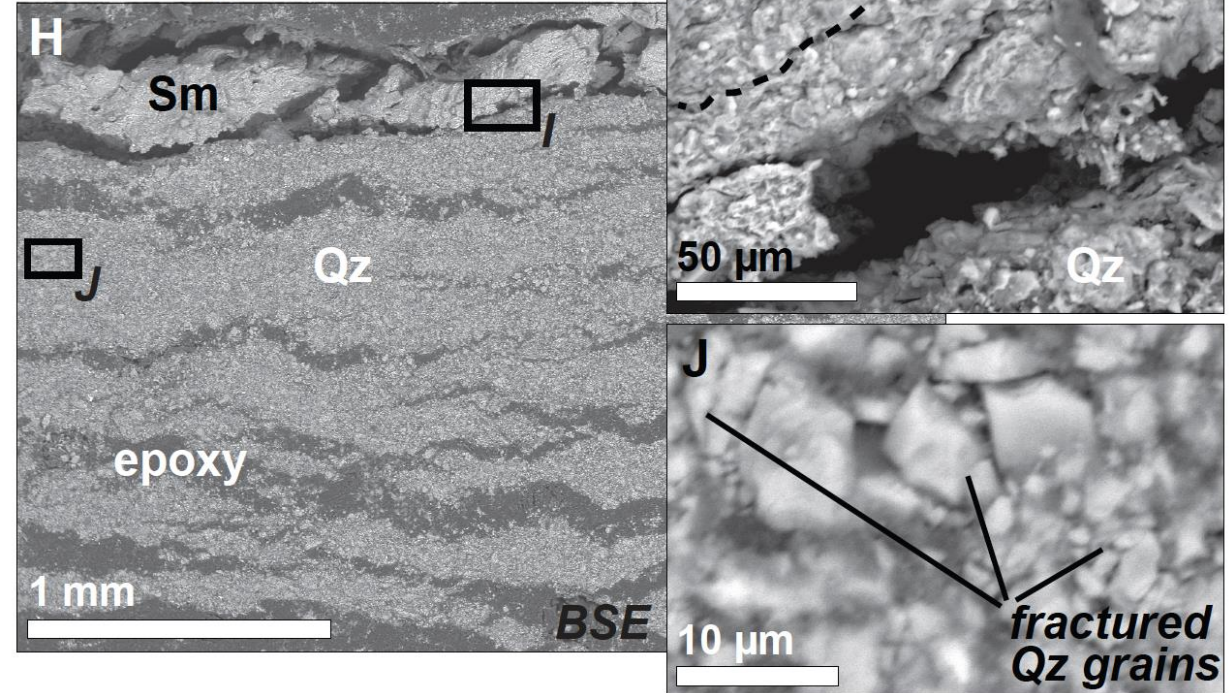
100% smectite

Different degrees of interactions between phases...

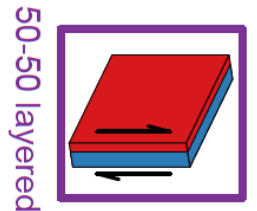
50-50 grain-scale mixture



50-50 layered

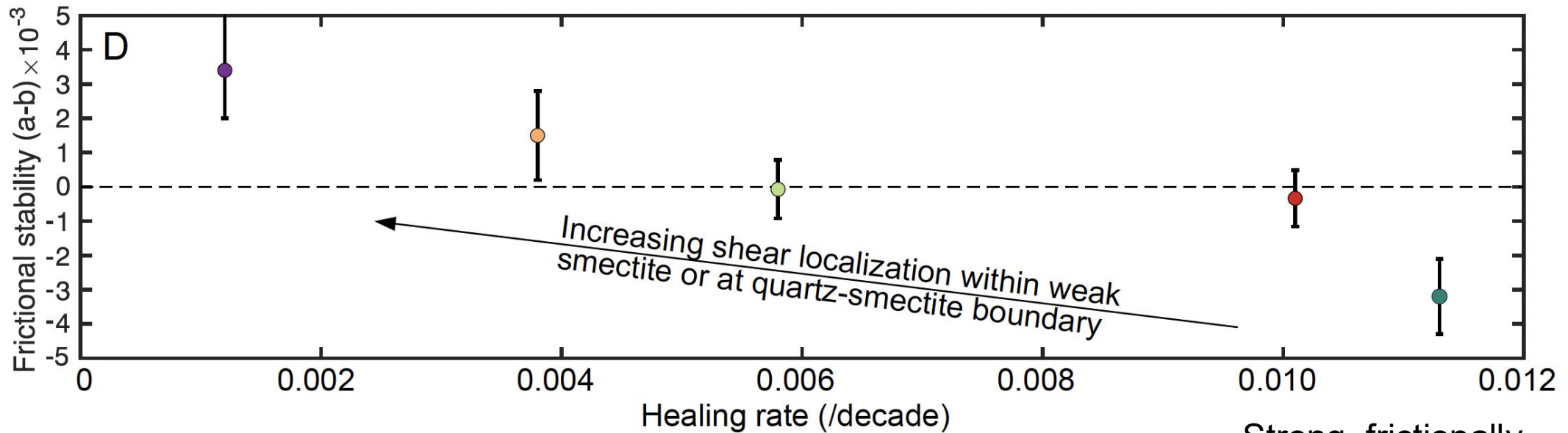


...that probably evolve in space and time

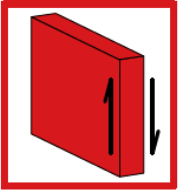
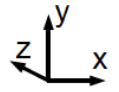


Increasing strain localization in weak phase reduces frictional strength, healing, and enhances stability

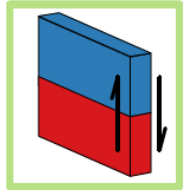
Weak, frictionally stable, heals a lot



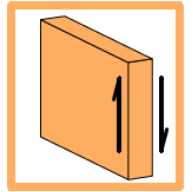
Strong, frictionally unstable, heals a lot



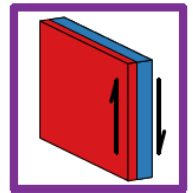
100% quartz



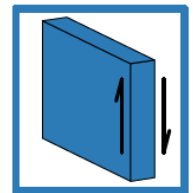
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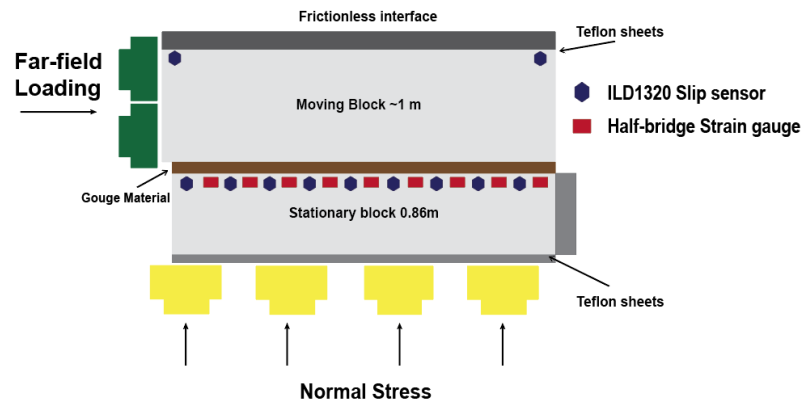


50-50 layered

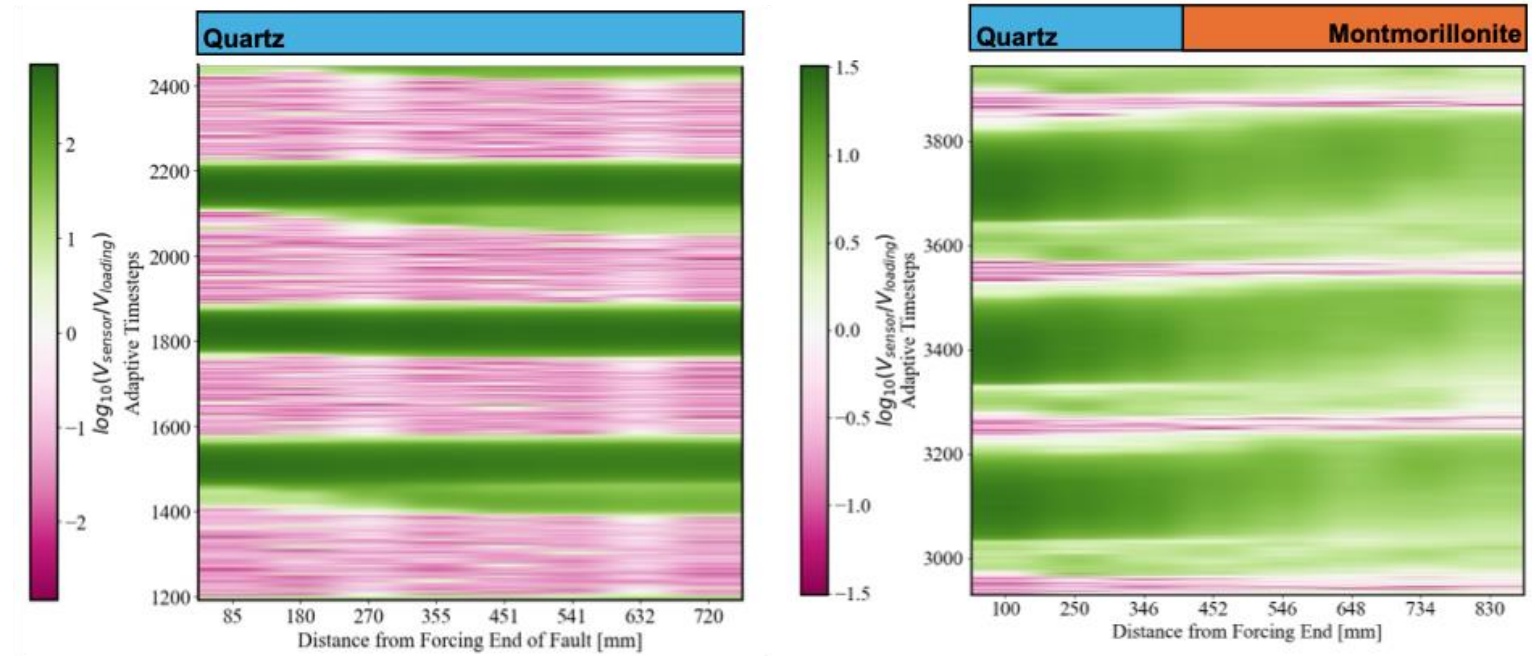


100% smectite

What about earthquakes rupturing in & through these faults?



Alejandro Aguilar, MS student



Weak phase is a barrier to rupture, experiences afterslip, in “patchy” faults.

Opportunities and Challenges

1. Frictional heterogeneities linked to presence/absence of strain localization can arise even in the simplest single/two-phase fault zones.
2. Competition between first- and second-order dependence of friction on rheological heterogeneities and dependence of friction on P-T conditions.
3. How to quantify *and* incorporate them in the CRM?
4. Integration with CxM, UCERF. What, how, when?

