EGU21-10506
Session 4.1: The mechanics of earthquake faulting: a multiscale approach
vPICO presentation: Friday, 30 April, 11:20–11:22

Investigation of Strain Localization in Sheared Granular Layer Using 3D Discrete Element Modeling

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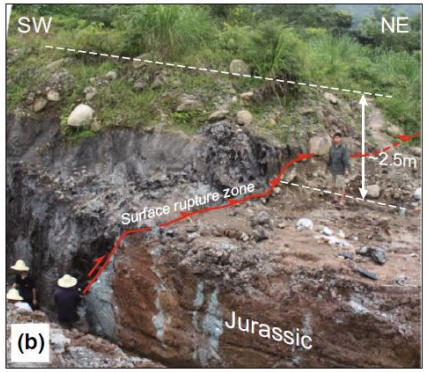
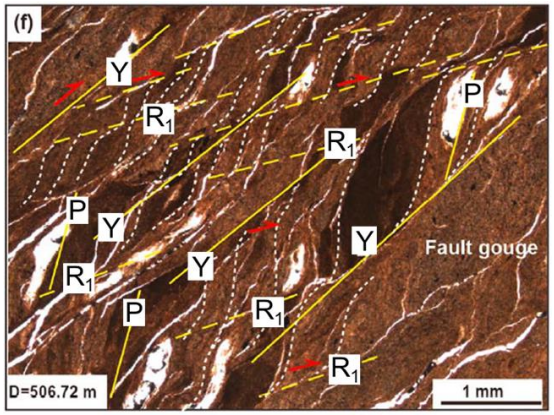
Strain localization in natural and simulated fault zones

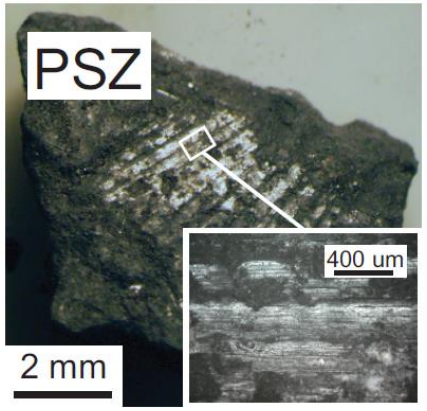
Natural fault gouges

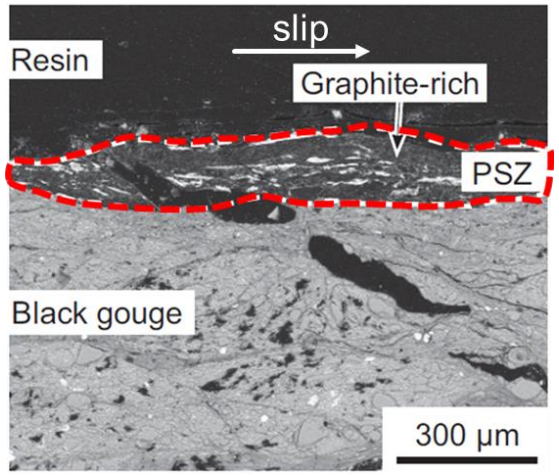
- Guanxian-Anxian fault: **Creeping fault**





- Yingxiu-Beichuan fault: **Seismically active fault**

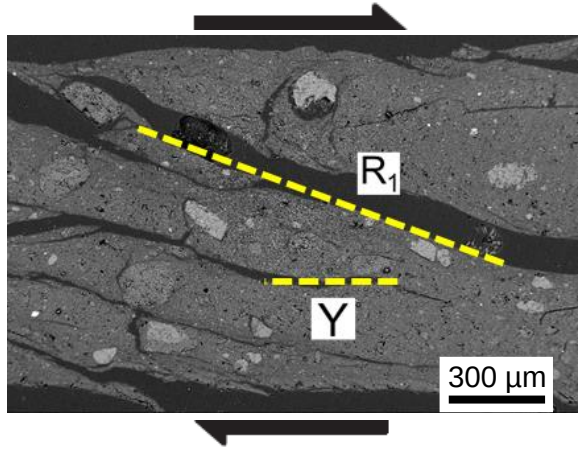




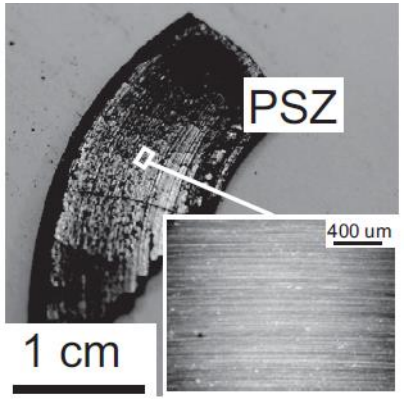
Reproduce

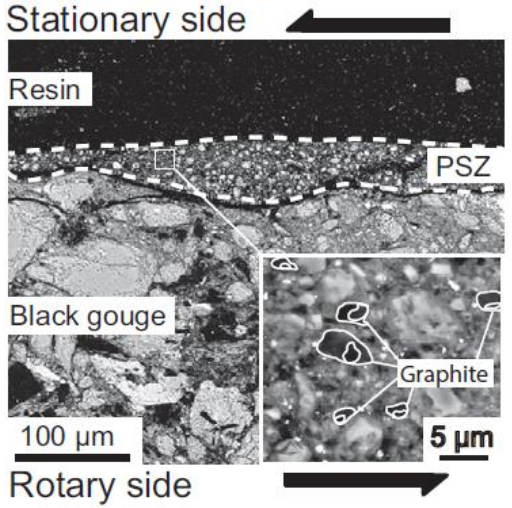
Laboratory simulated fault gouges

- WFSD-3 gouge: deformed at **10^{-5} m/s**



- WFSD-1 gouge: deformed at **3 m/s**





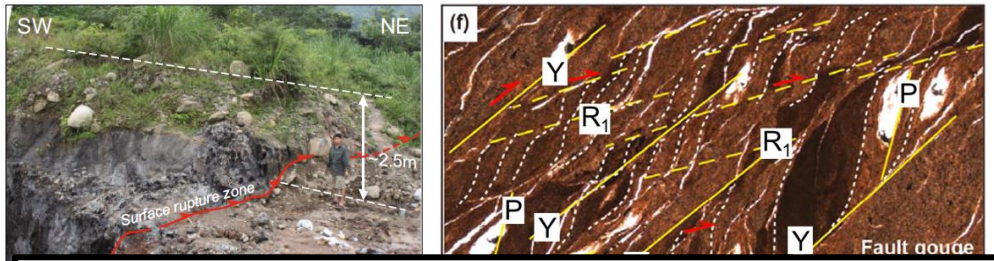
Reproduce

He et al., Tectonic, 2018; Kuo et al., Geology, 2014; Kuo et al., 2021 to be submitted

Strain localization in natural and simulated fault zones

Natural fault gouges

- Guanxian-Anxian fault: **Creeping fault**



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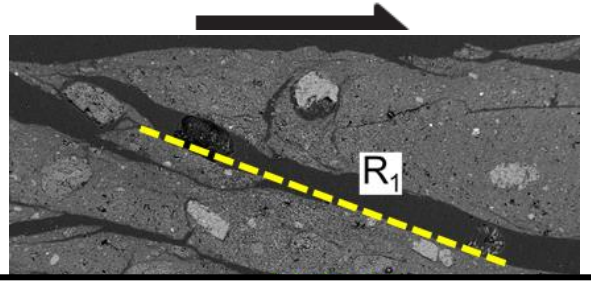
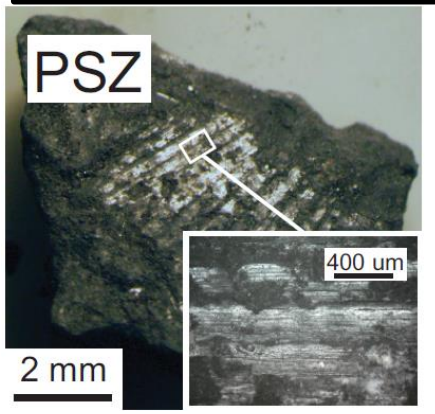
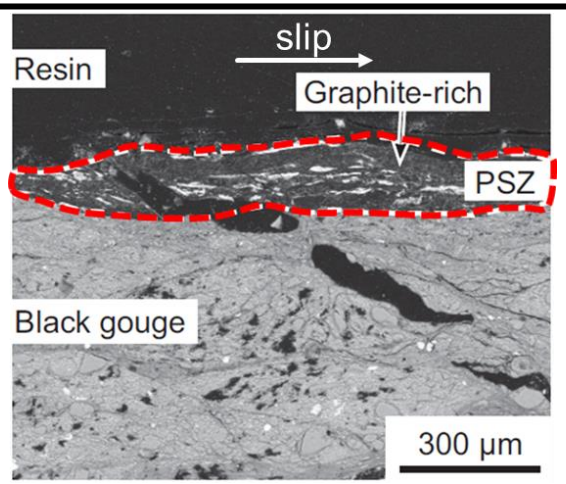
Laboratory simulated fault gouges

- WFSD-3 gouge: deformed at **10^{-5} m/s**



- Shear fabrics (R_1, P, Y shears) are often characterized with **grain size reduction** and **distinct shape orientation**.
- Similar shear fabrics are reproduced in laboratory friction experiments.





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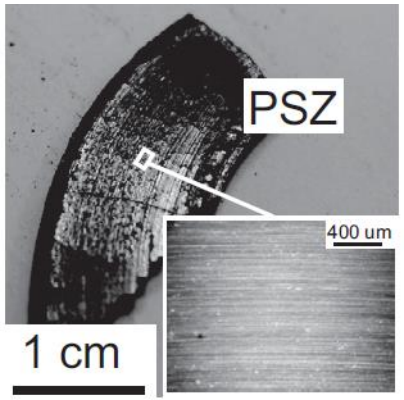
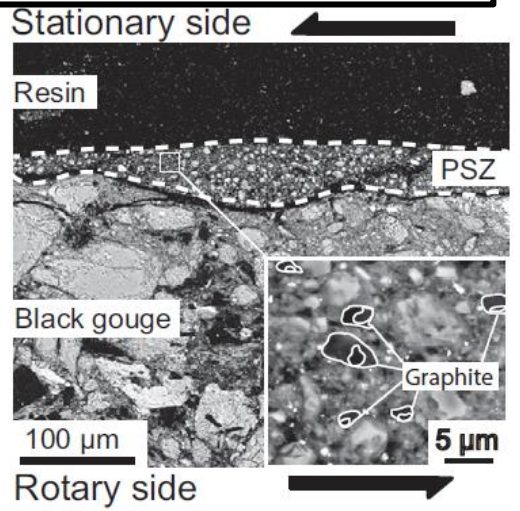




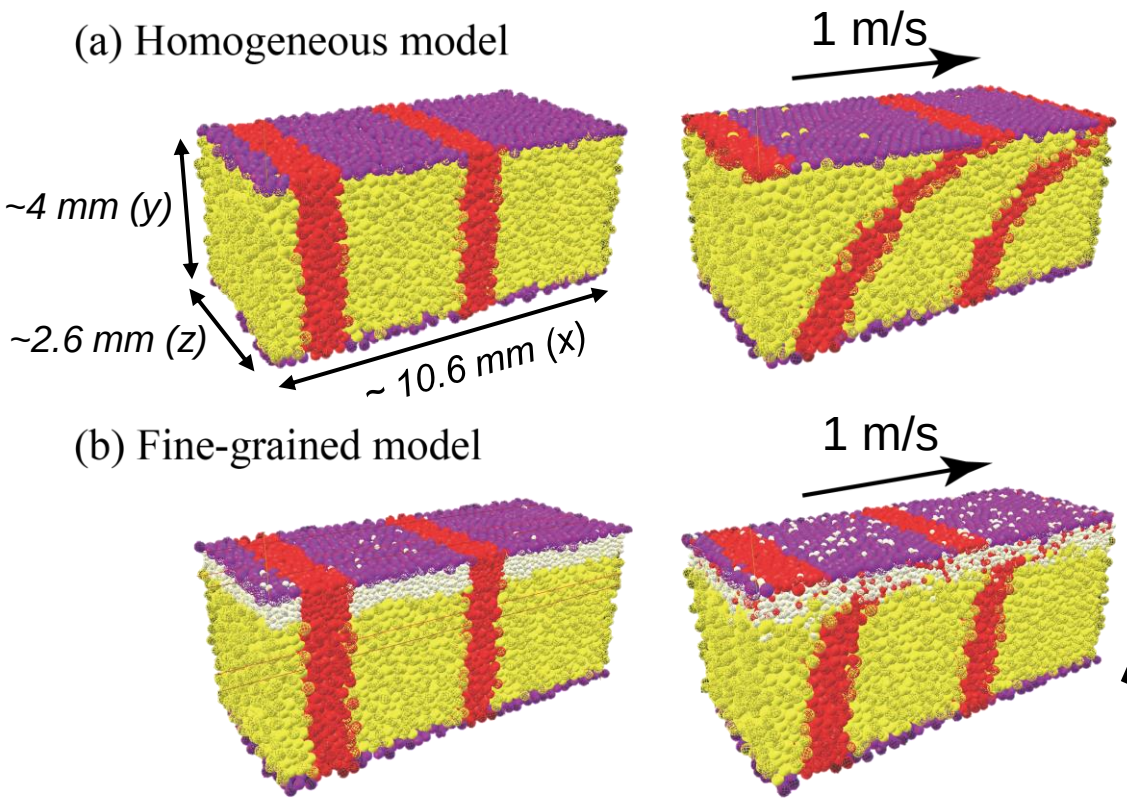
He et al., Tectonic, 2018; Kuo et al., Geology, 2014; Kuo et al., 2021 to be submitted

Questions to be addressed

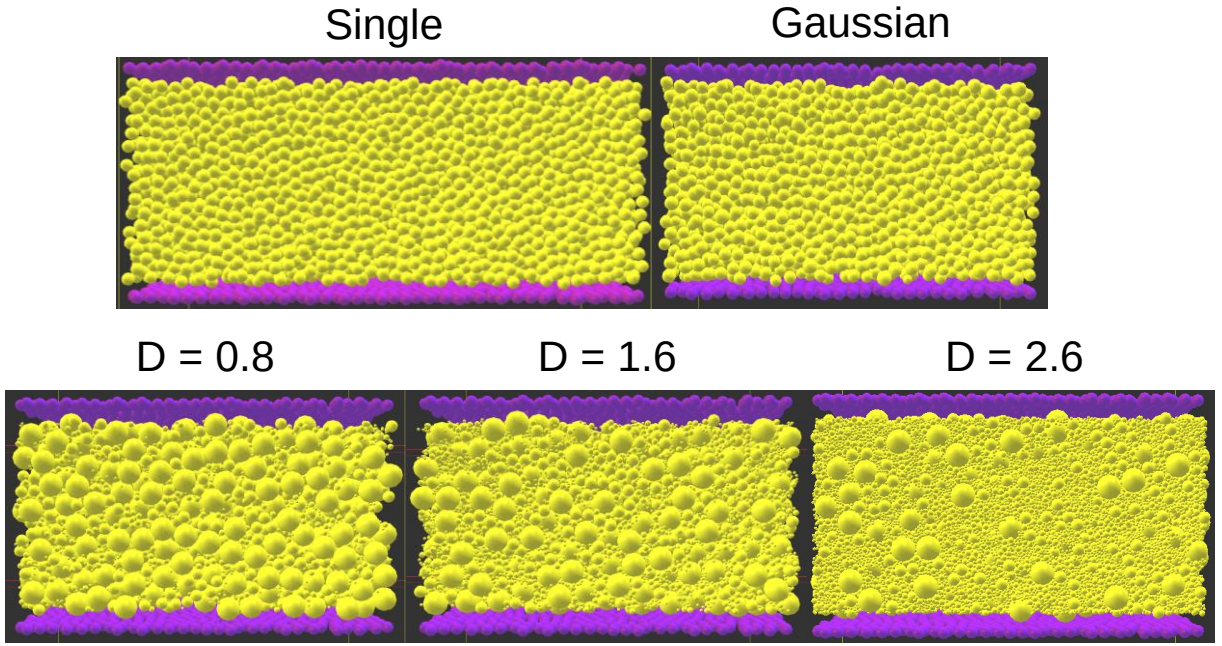
- Does slip localize in gouges with a **homogeneously distributed** grain size **at seismic slip velocity**?
- How much **grain size reduction** is required for slip to be localized?
- What is the **physical mechanism** for strain localization?
- What parameters (e.g., interparticle friction) might influence localization of slip?

3D DEM numerical direct shear model

- *Yade open-source software (https://yade-dem.org/doc/)*
- Numerical model of grain-to-grain interaction
- Hertz-Mindlin contact models with contact friction and rolling resistance



- Particle size distribution (PSD):

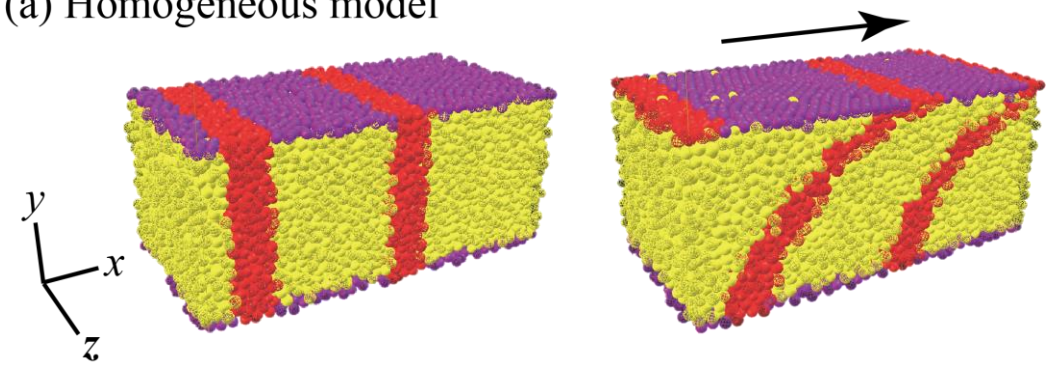


- Single distribution with contrast in grain size and layer thickness between fine- and coarse-grained layer.
- Grain-size contrast: **0.9*d*, 0.75*d*, 0.6*d*, 0.5*d*** *(d = 250 µm)*
- Thickness: **1/8*t*, 1/4*t*, 3/8*t*, 1/2*t*** *(t = ~4 mm)*

3D DEM numerical direct shear model

- Does slip localize in gouges with a homogeneously distributed grain size at seismic slip velocity? **No**

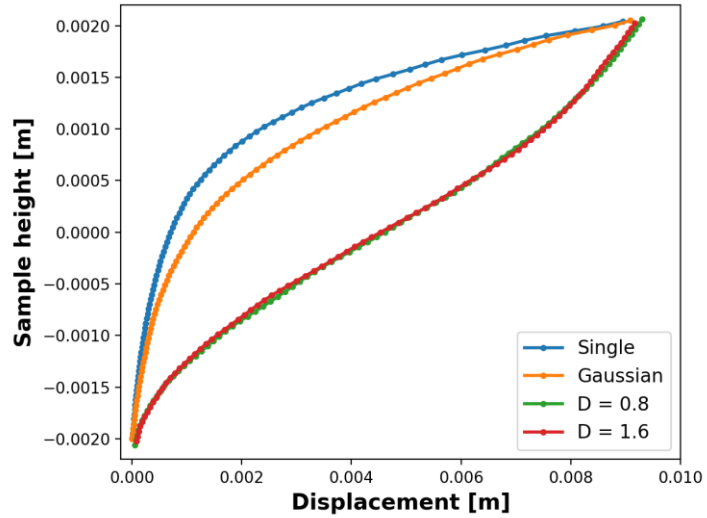
(a) Homogeneous model



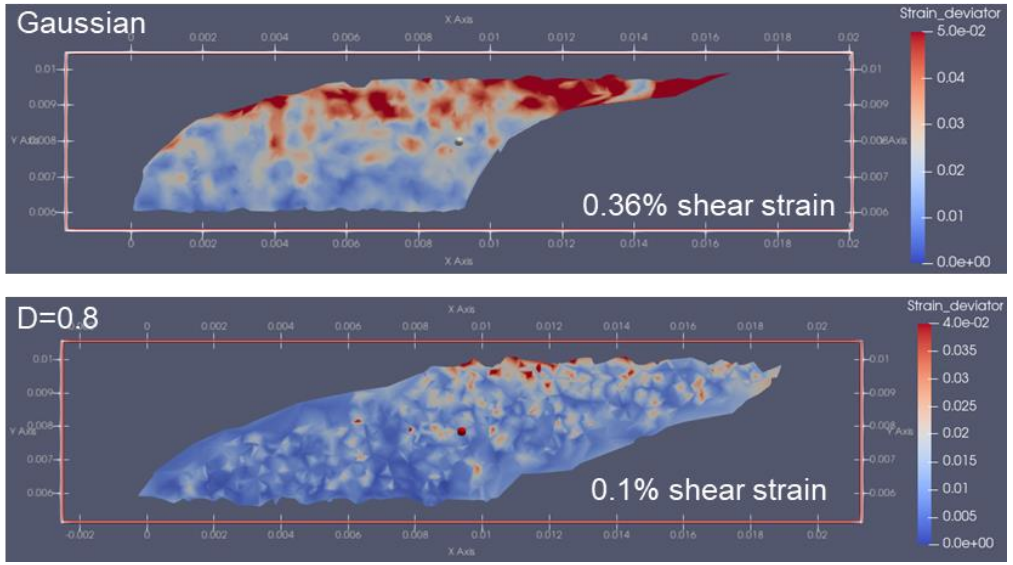
- No sign of persistent localized deformation within the granular layer.

- In a narrow PSD, rolling particles slide against each other impeding transfer of slip whereas, in wider PSD, small rolling particles serve as "roller bearings“ resulting in a more uniform deformation.

Particle displacement



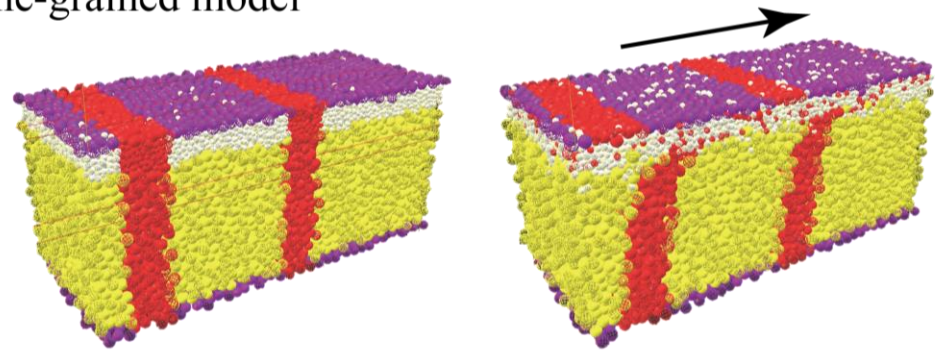
Micro-strain analysis



3D DEM numerical direct shear model

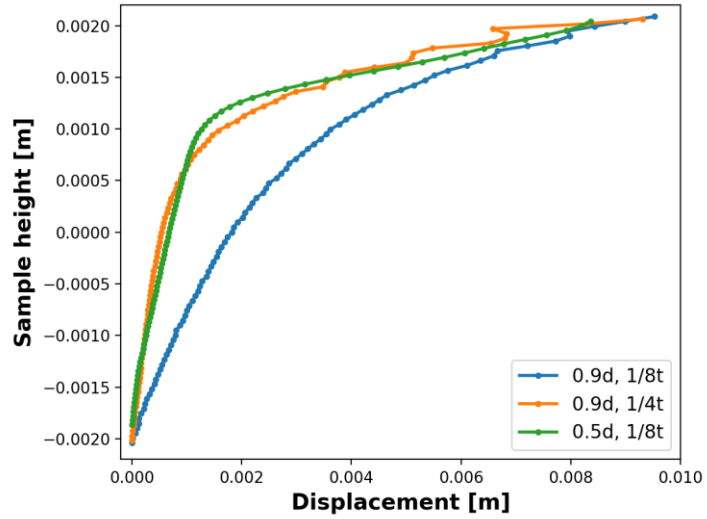
- How much **grain size reduction** is required for slip to be localized? **10% contrast**

(b) Fine-grained model

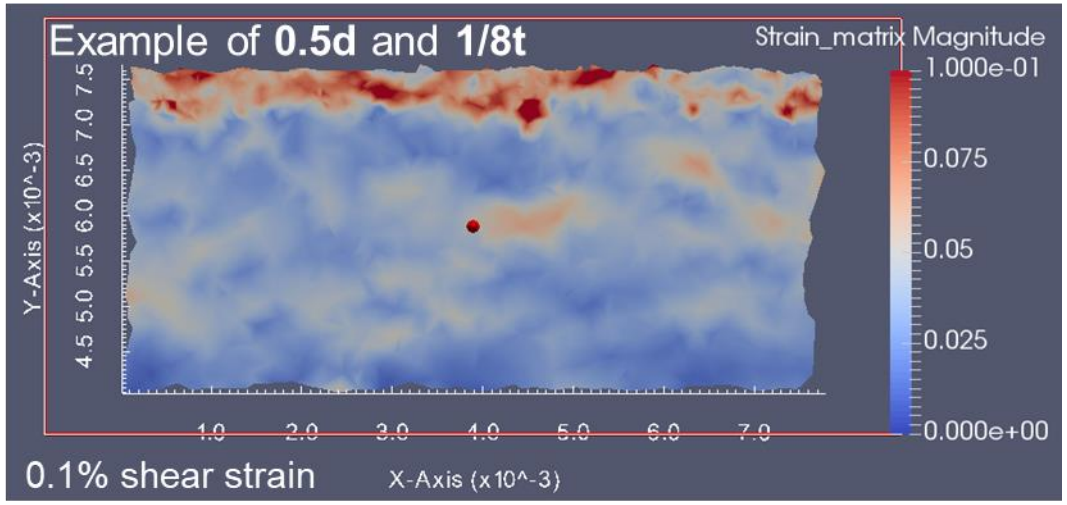


- Up to 90% of strain is accommodated within the fine-grained layer when only having 10% grain size variation and at least a thickness of five grains.

Particle displacement

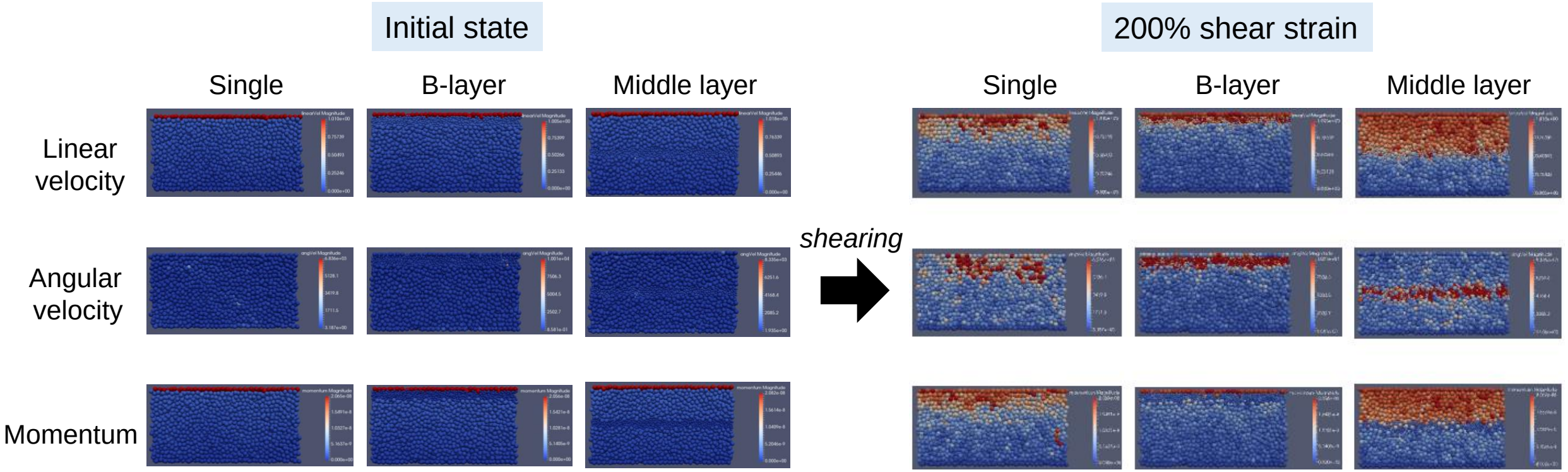


Micro-strain analysis



3D DEM numerical direct shear model

- What is the **physical mechanism** for strain localization? **Momentum transfer**

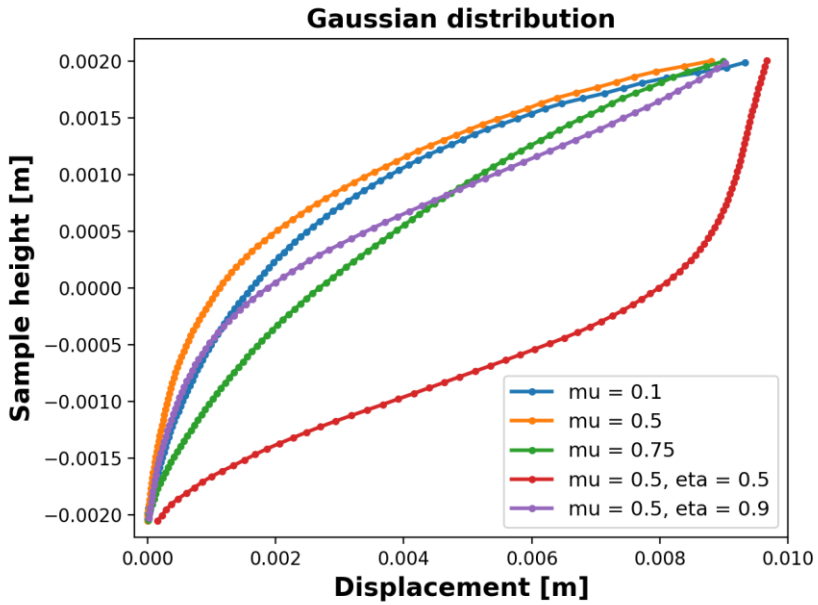


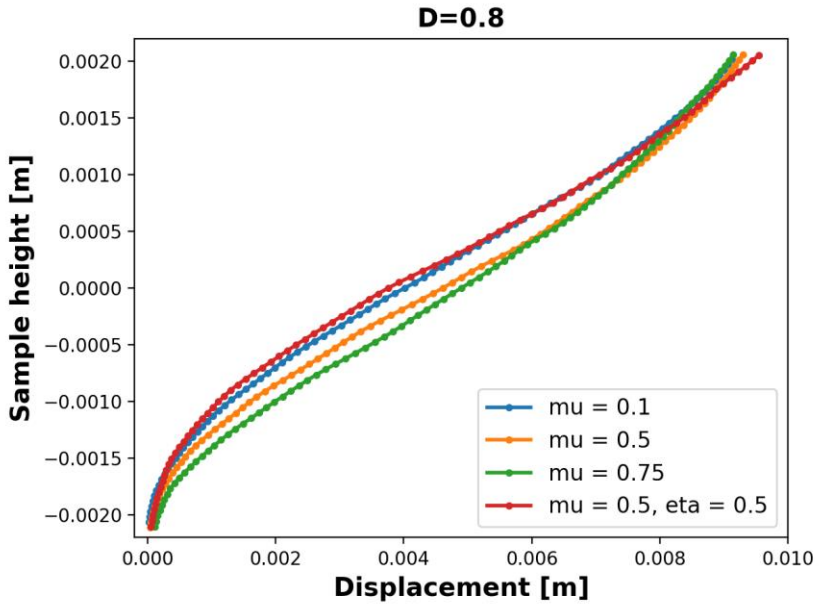
- Slip is accommodated within the fine-grained layer by interparticle rolling.

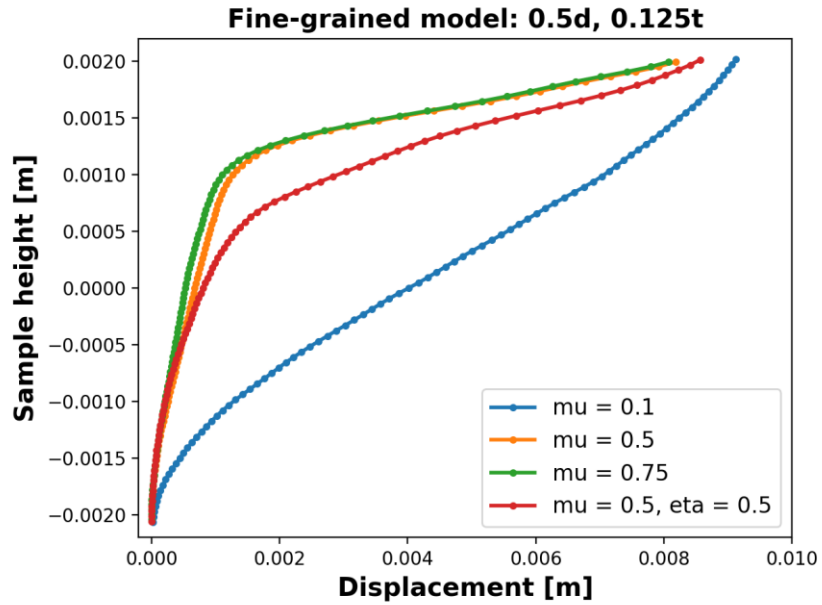
- The fine-grained layer plays a role in inhibiting transfer of particle motion (sliding and rolling) suggesting that momentum transfer, which is the only time-dependent process in our simulation, is likely to be the physical mechanism for strain localization.

3D DEM numerical direct shear model

- What parameters have influence on localization of slip?
  Interparticle sliding and rolling friction (μ = 0.1, 0.5, 0.75; η = 0.5)







- No obvious localization observed in homogeneous model while the results of the fine-grained model show a certain degree of variation.
- Interparticle rolling seems to be the dominant mechanism for slip accommodation.

Take-home message

- Does slip localize in gouges with a homogeneously distributed grain size at seismic slip velocity?
  No, we need some **localized grain size reduction** in order for strain to become localized.

- How much grain size reduction is required for slip to be localized?
  10% contrast in grain size is sufficient to cause strain localization up to **90%**. This suggests a fine-grained layer in a dense fault zone is likely to result in **self-enhanced weakening** of the fault planes.

- What is the physical mechanism for strain localization?
  Without considering grain fracturing, we think the **momentum transfer the only time-dependent mechanism** in our model is considered to be the reason for strain localization
  (Ongoing work: visualization of kinetic energy of entire system).

- What parameters have influence on localization of slip?
  Interparticle sliding and rolling
  (*Ongoing work: the effect of inertial number (change of shear velocity and normal stress))*