The evolution of fault roughness, gouge and

Emily E. Brodsky

Amir Sagy*

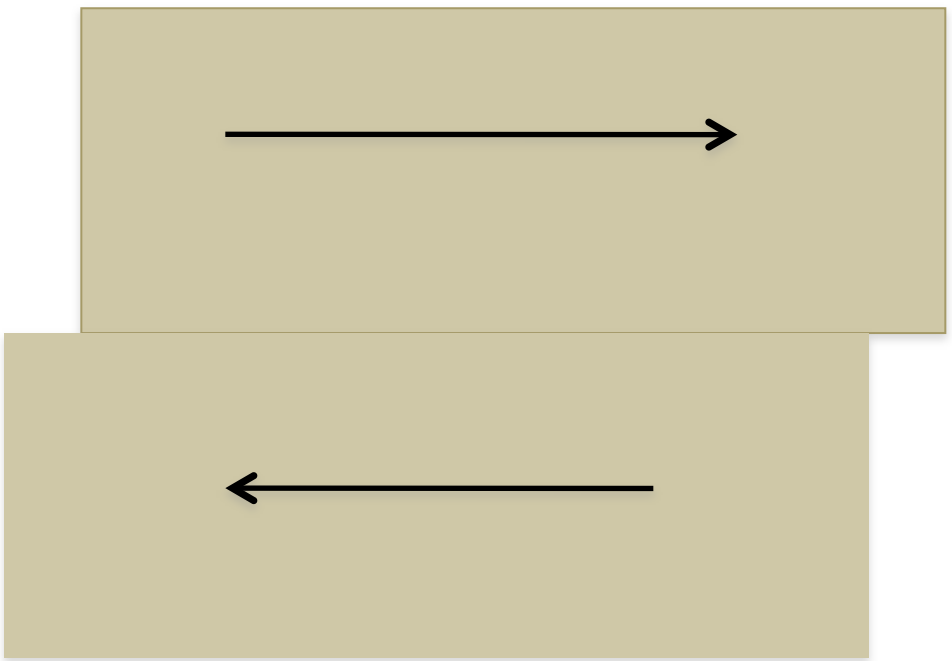
Jacqui Gilchrist**

Heather Savage***

*Now at Geological Survey of Israel

**Now at UC Riverside

A Simplified Fault



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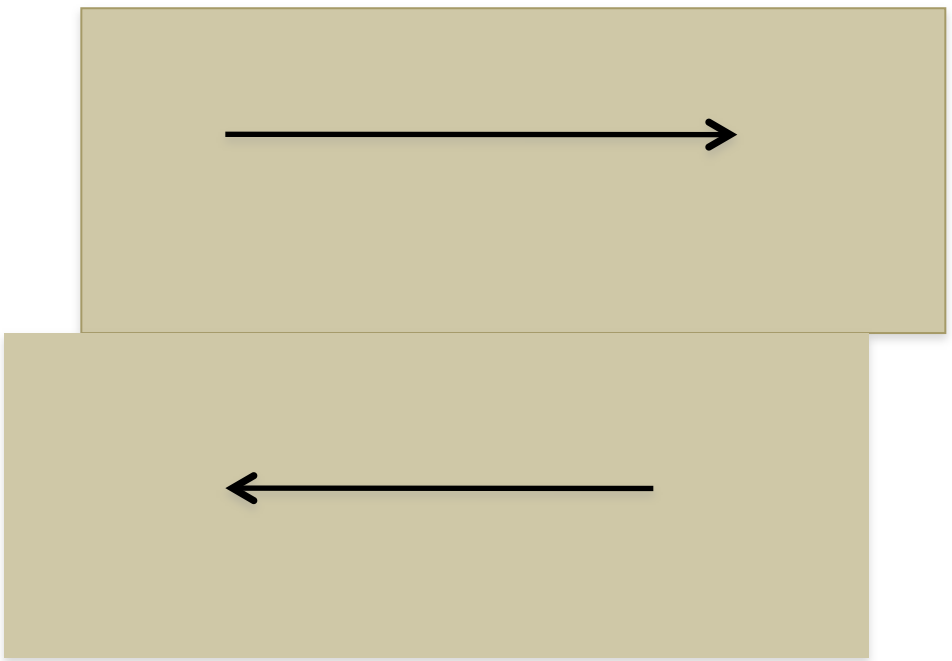

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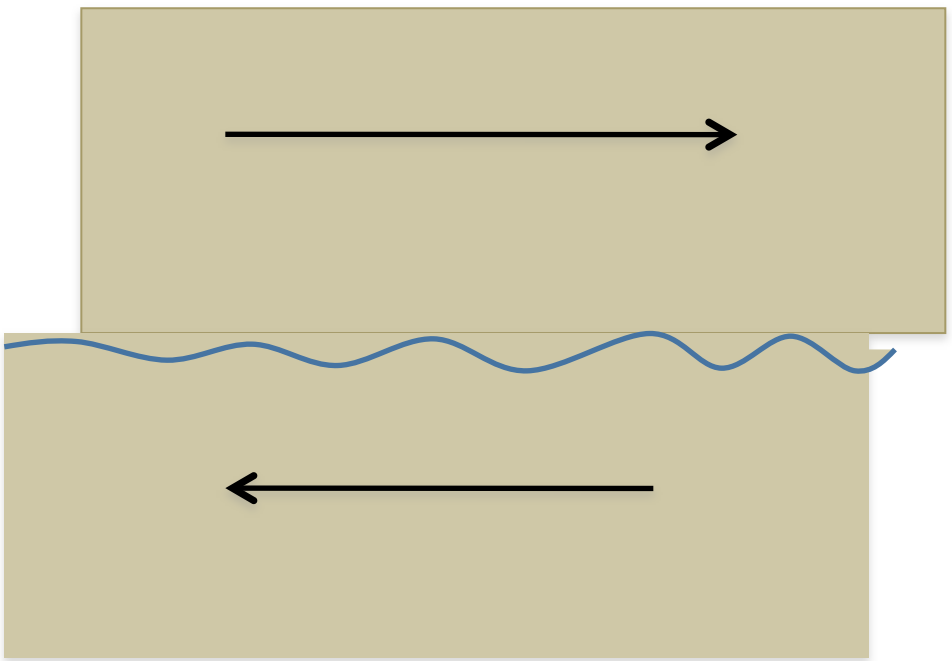
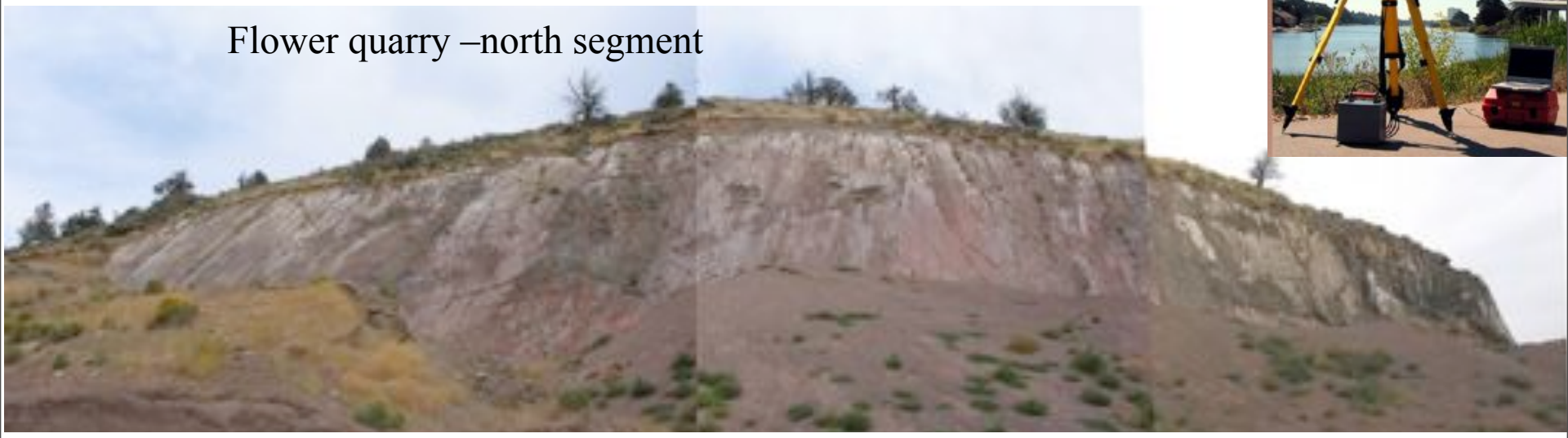


Fault Geometry at the Scale of Earthquake Slip: LiDAR



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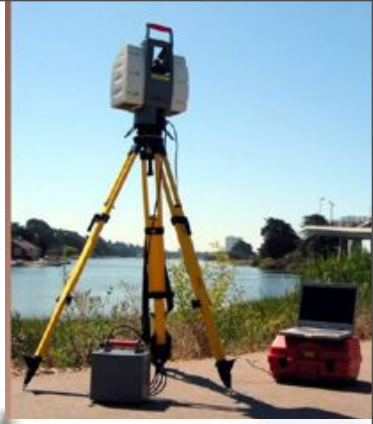
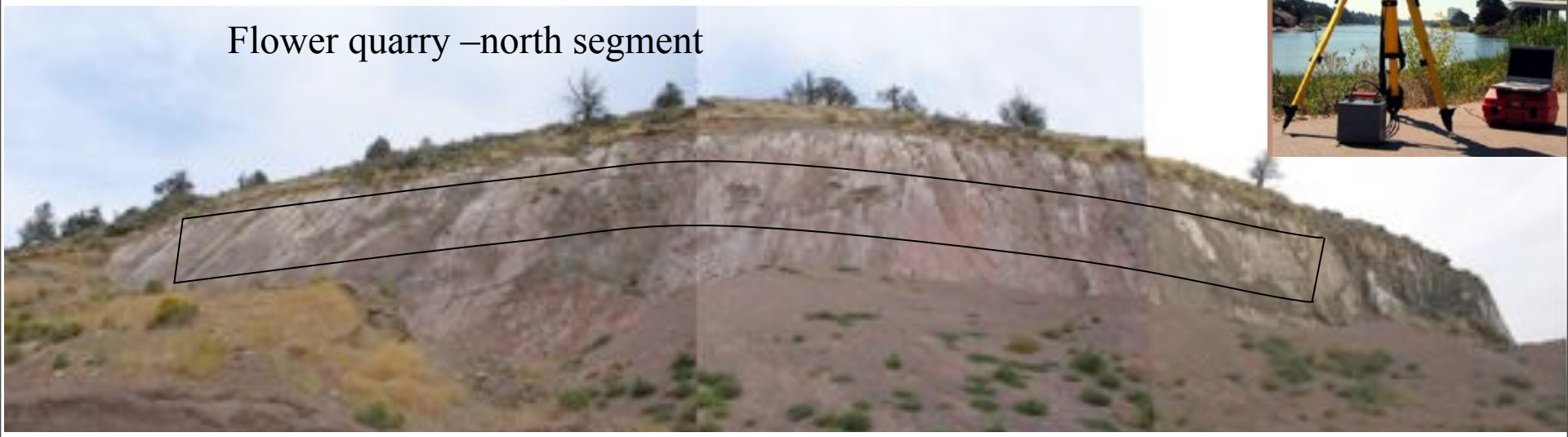
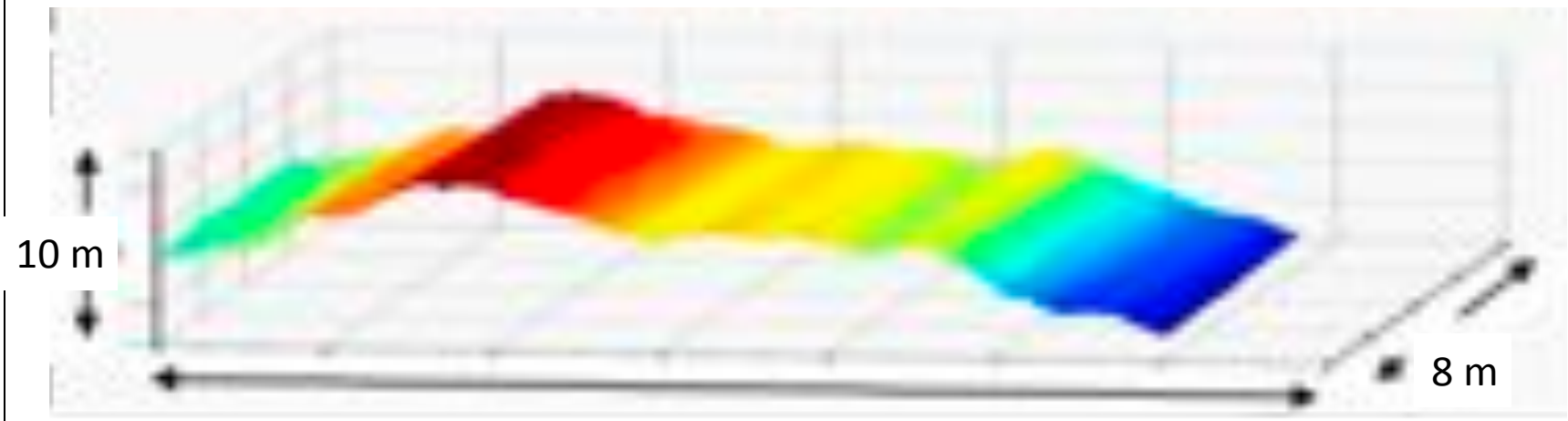
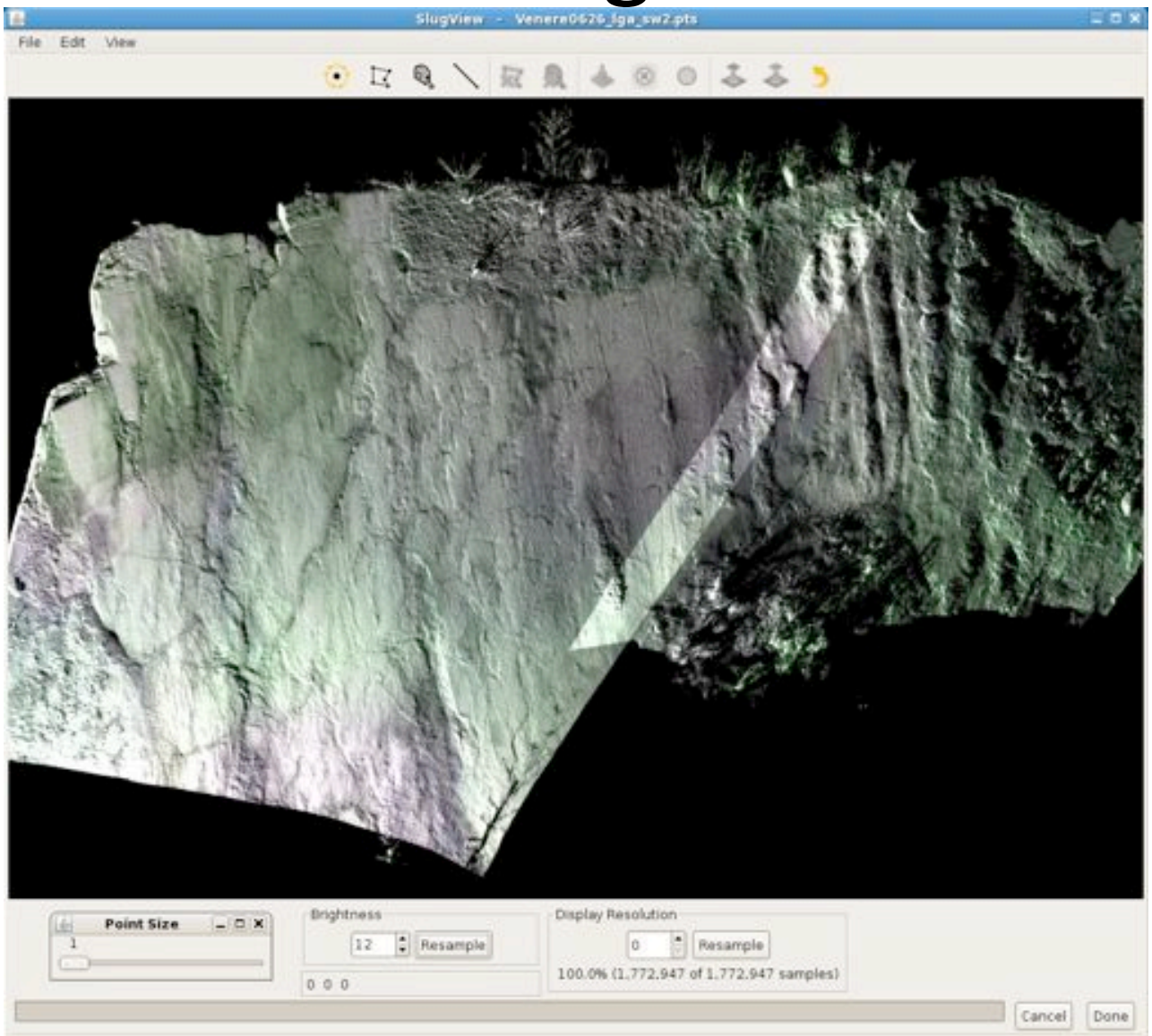




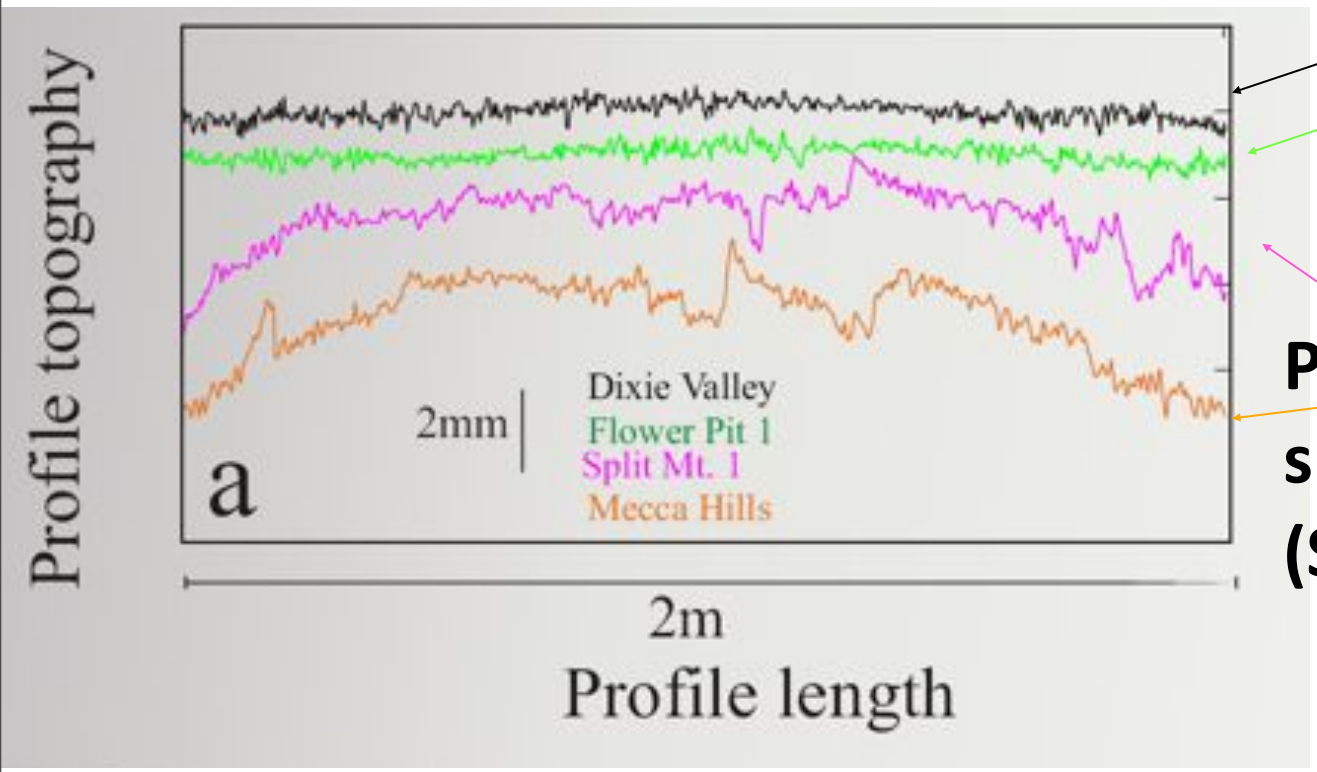


Slugview



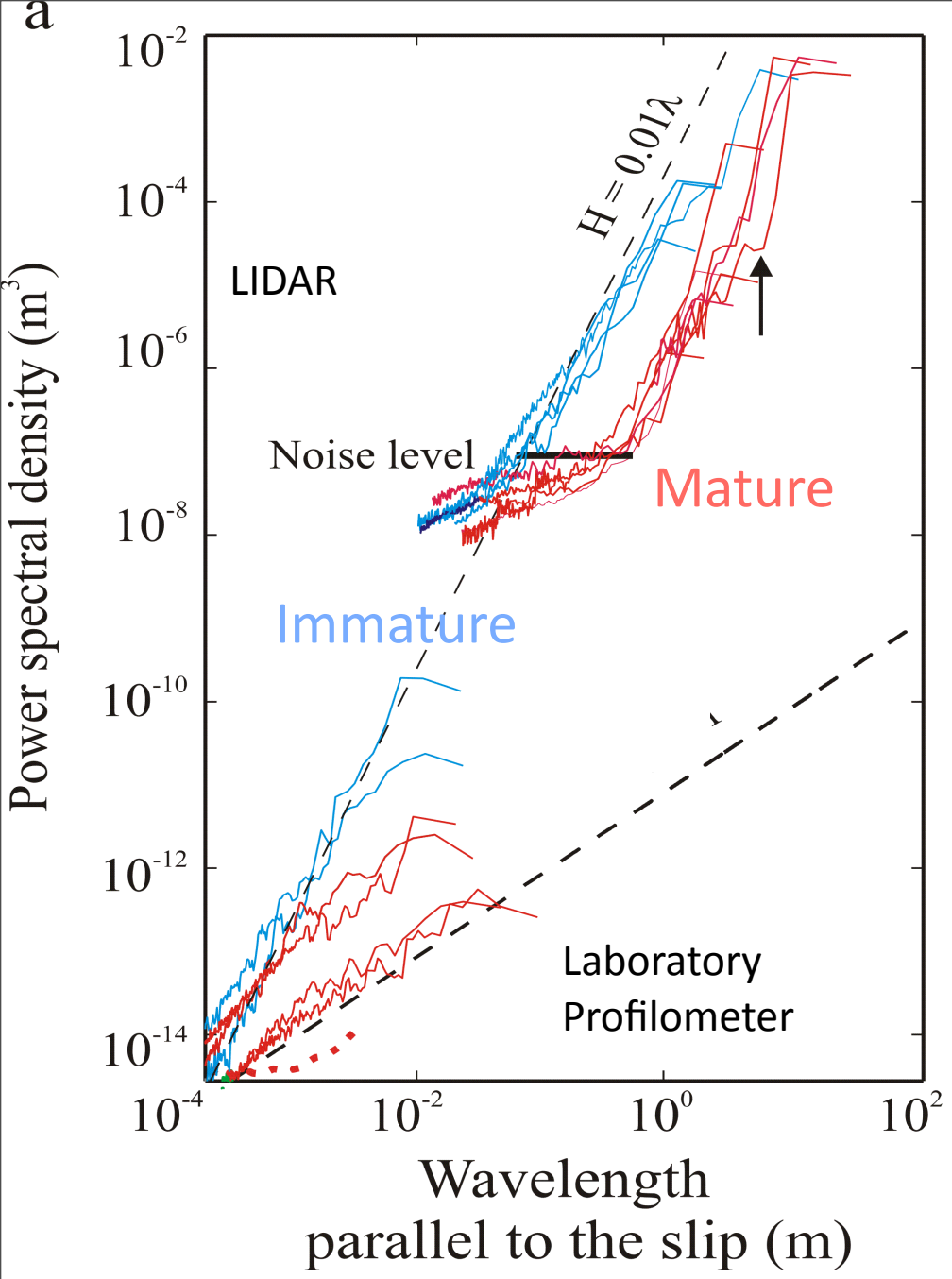
http://www.pmc.ucsc.edu/~msteffec/SlugView

Large-slip (mature) faults are smoother than small-slip (immature) faults



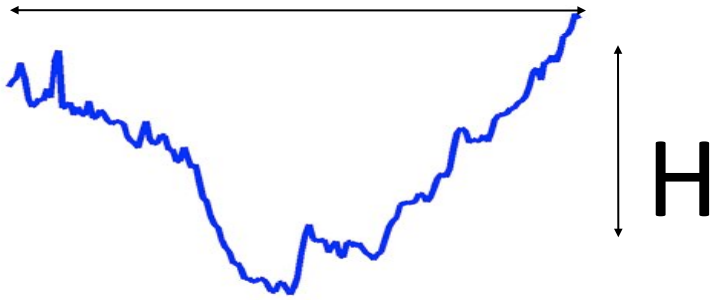
Profiles from large-slip faults (Slip >10 m)

Profiles from small-slip faults (Slip <1 m)



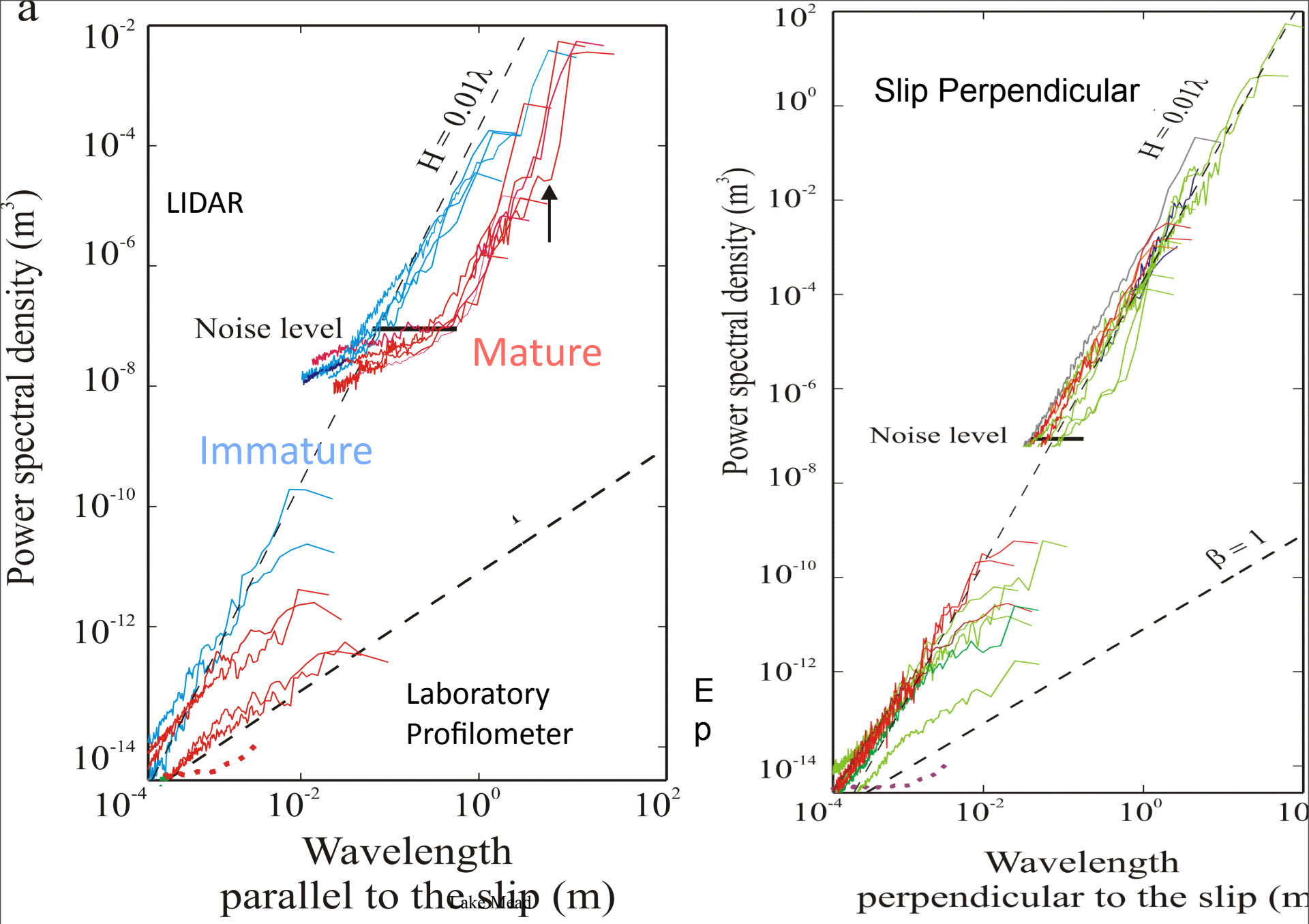
Power Spectra of Topography

λ



Each spectra averages 500+ profiles

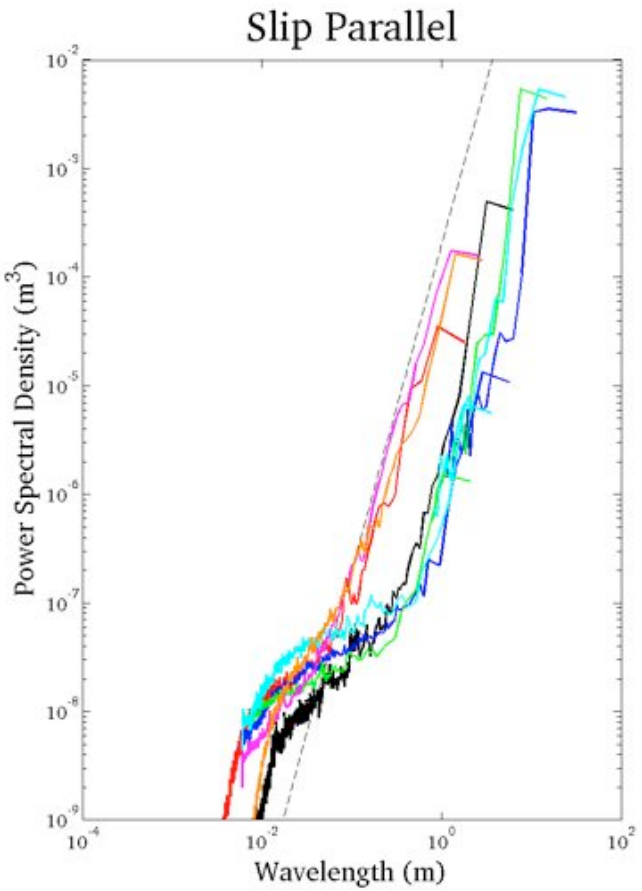
Sagy et al., *Geology*, 2007.



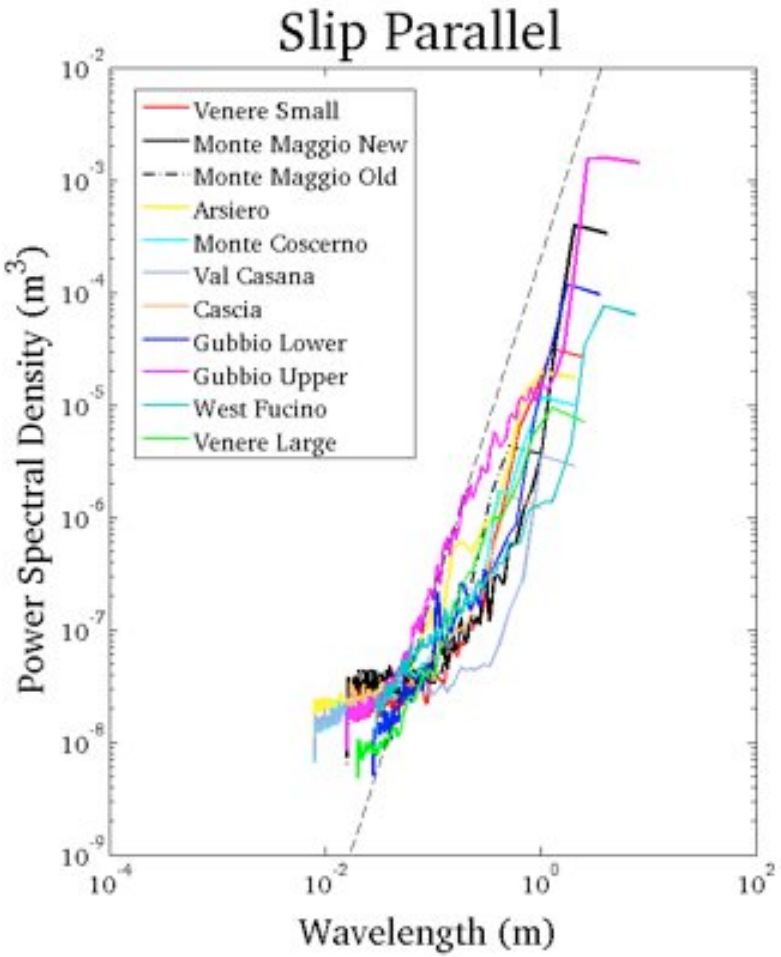
Sagy et al., *Geology*, 2007.

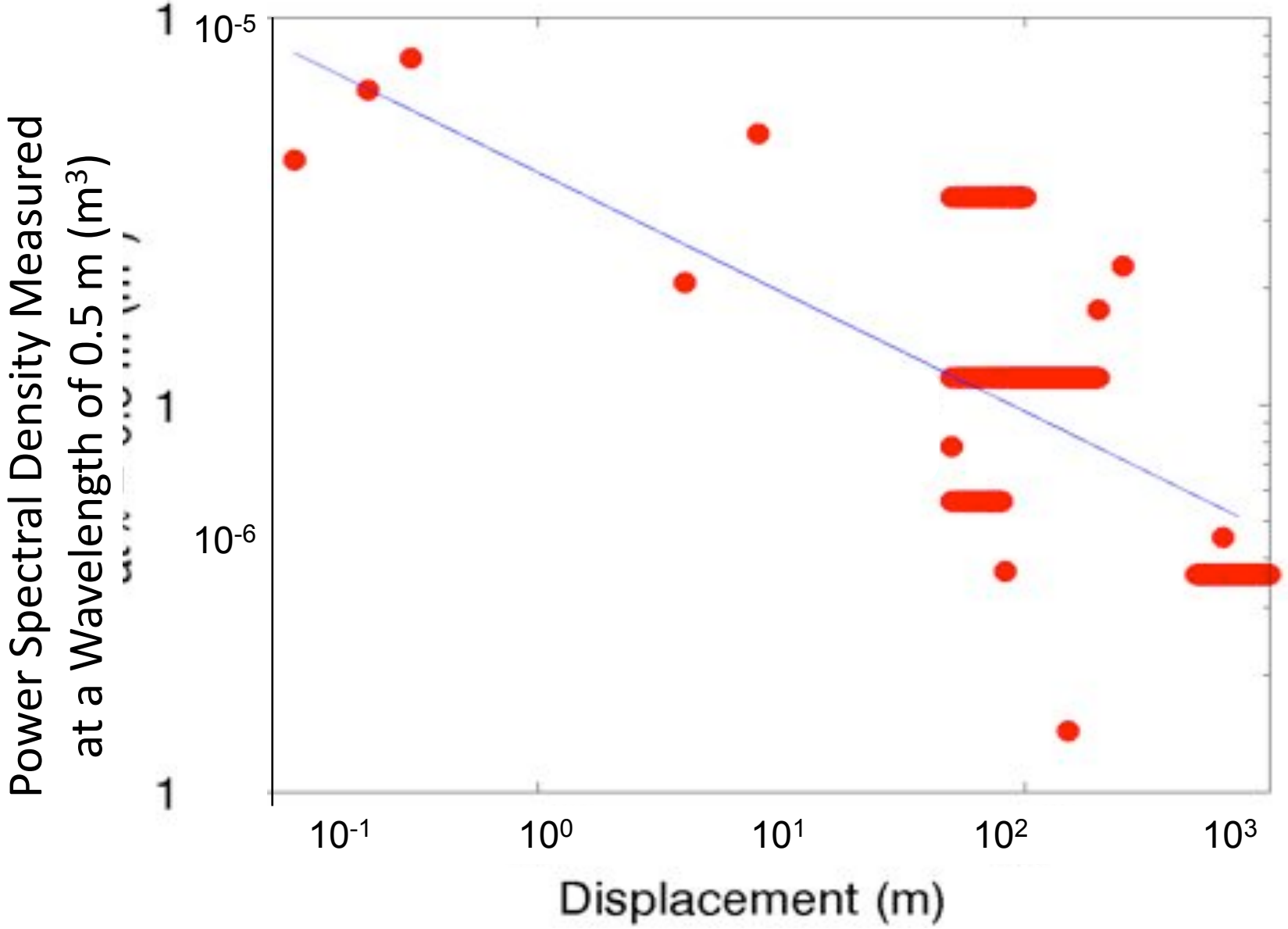
More Faults

Last Slide: Western US



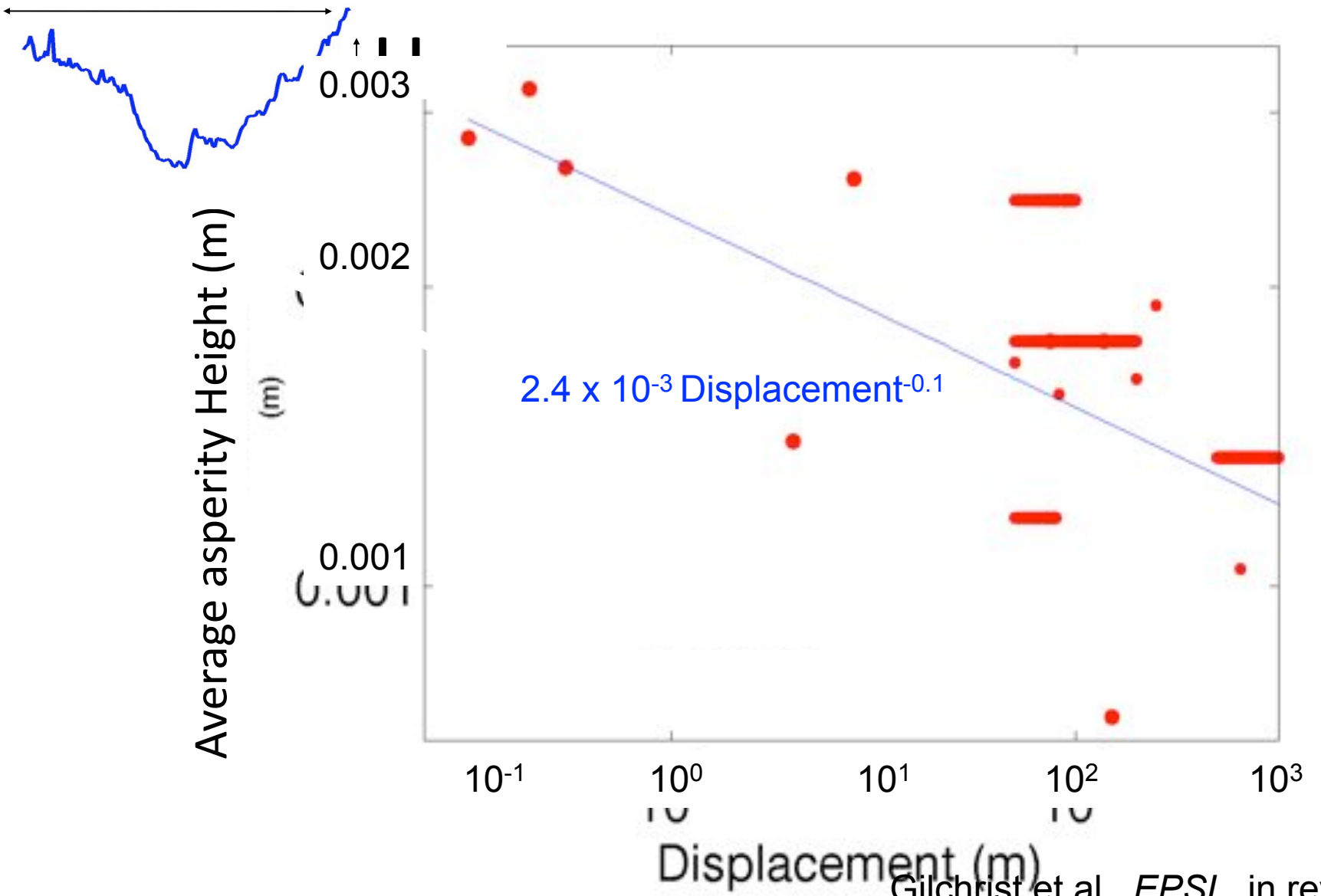
New Data: Italy



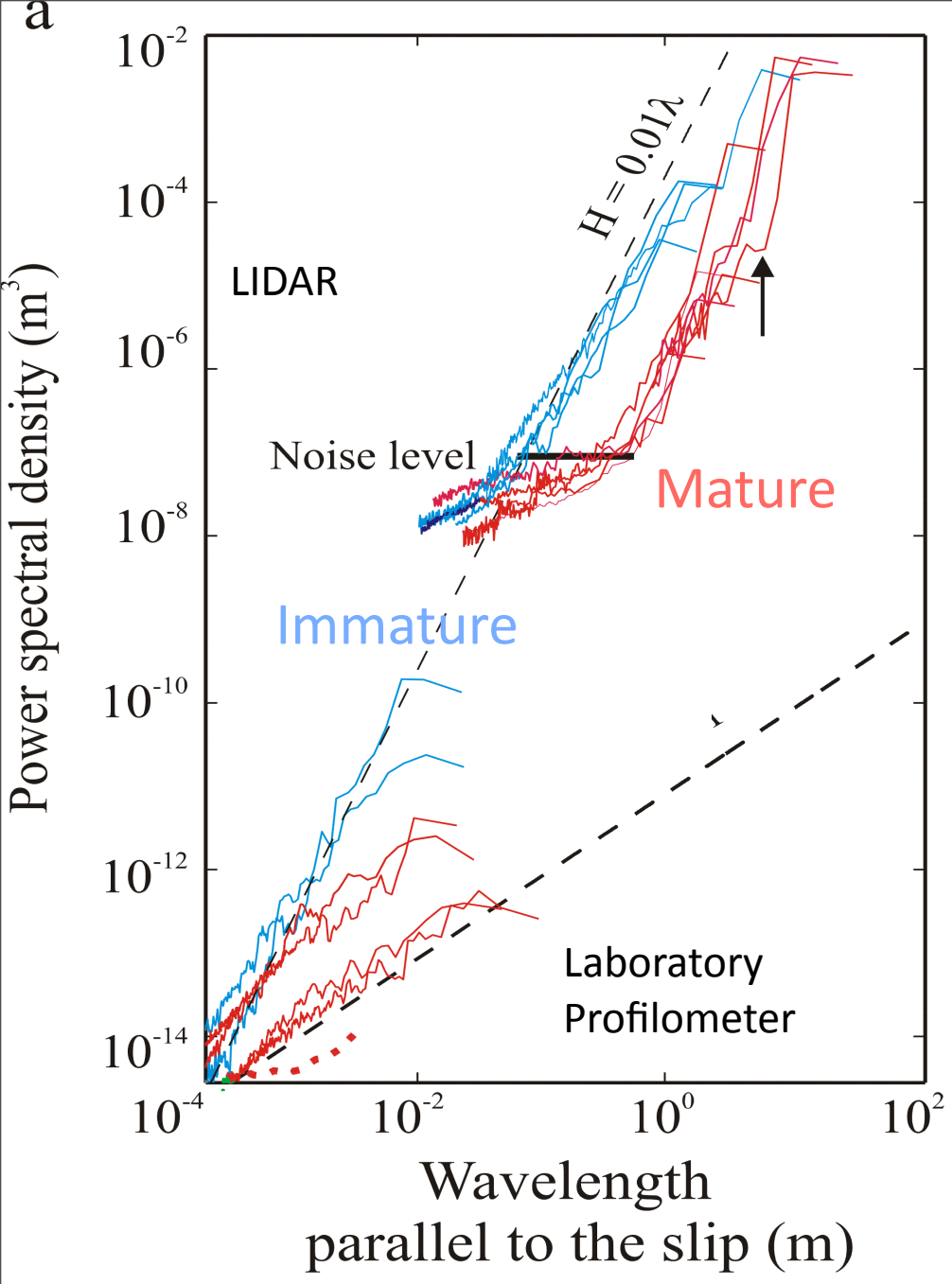


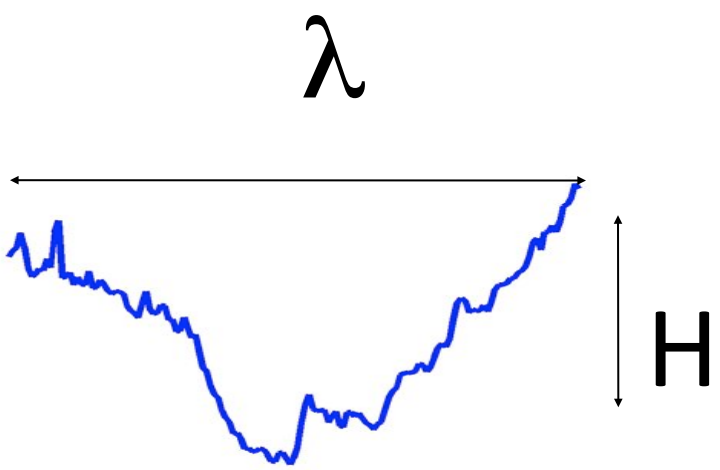
Gilchrist et al., *EPSL*, in revision.

λ=0.5 μ

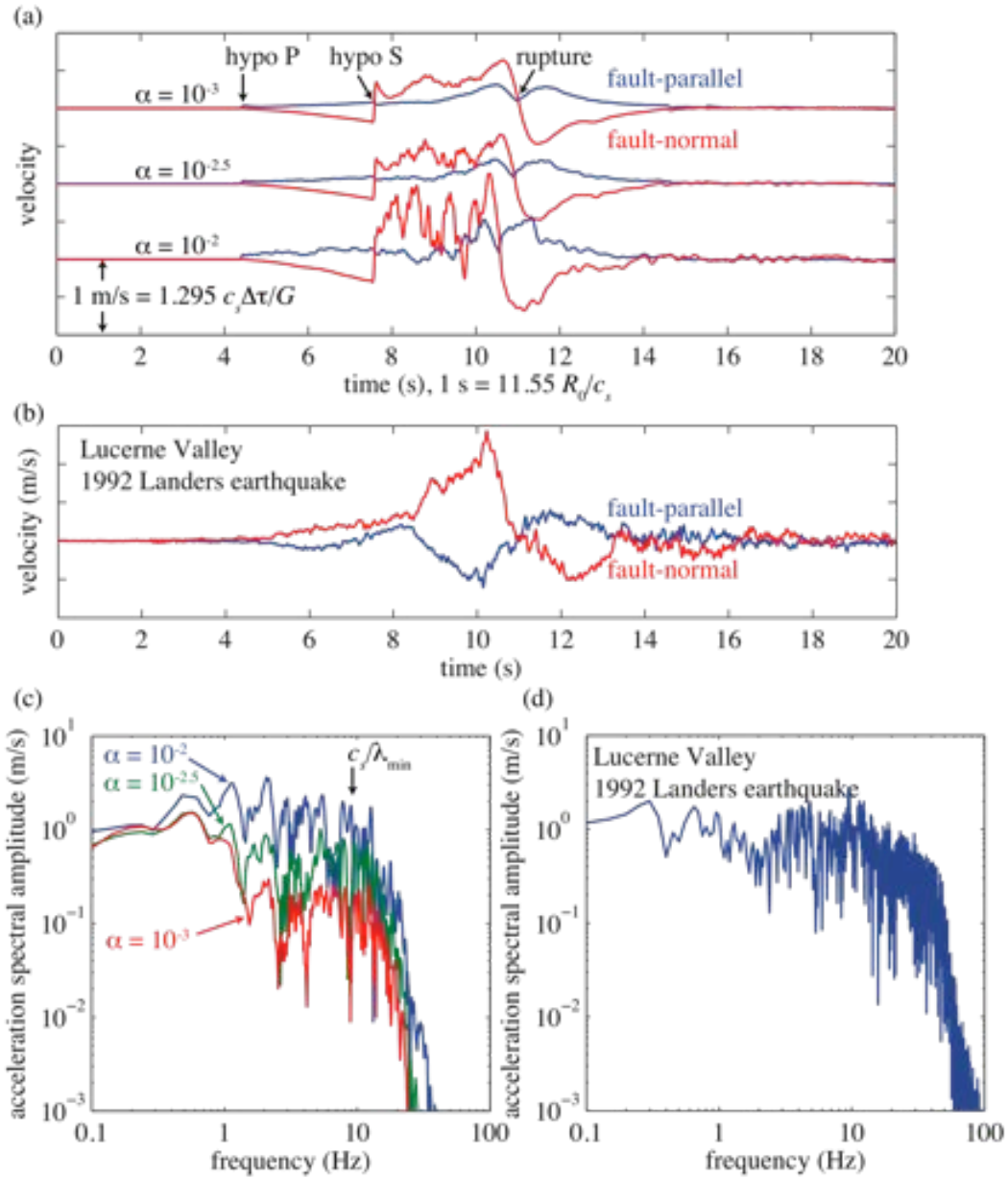


Gilchrist et al., *EPSL*, in revision.

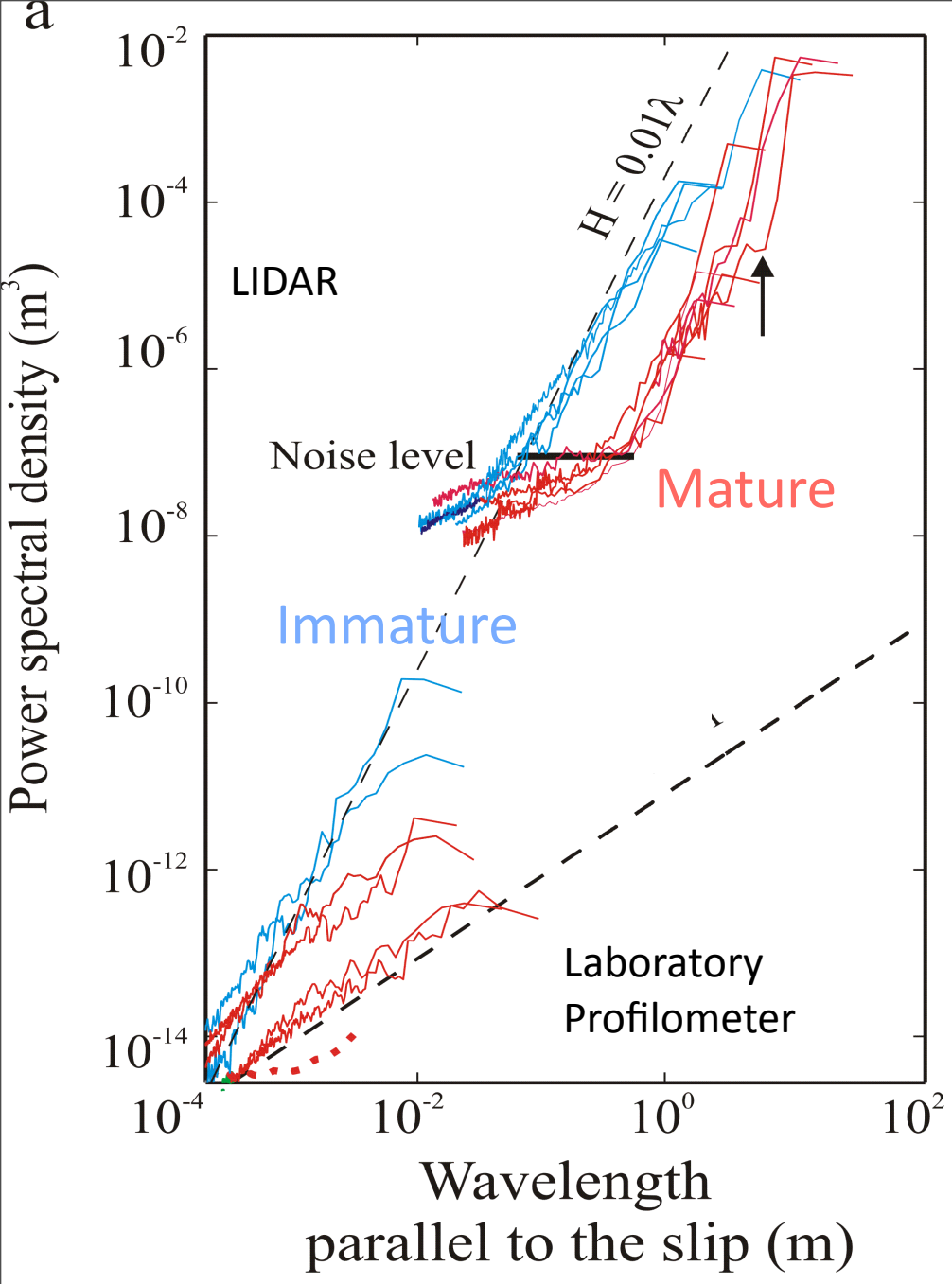


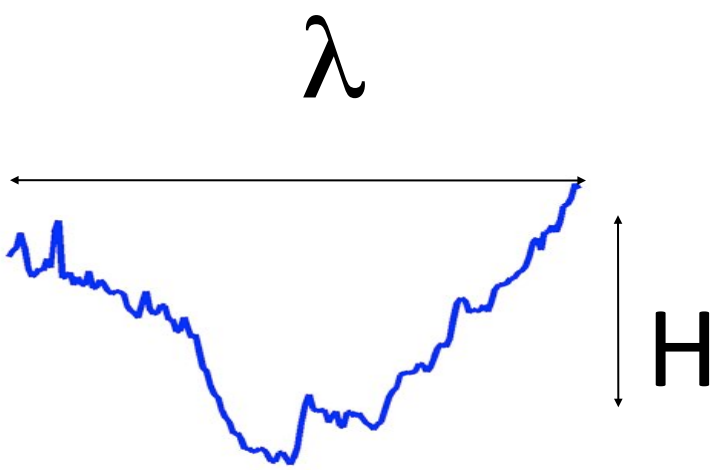


Sagy et al., *Geology*, 2007.



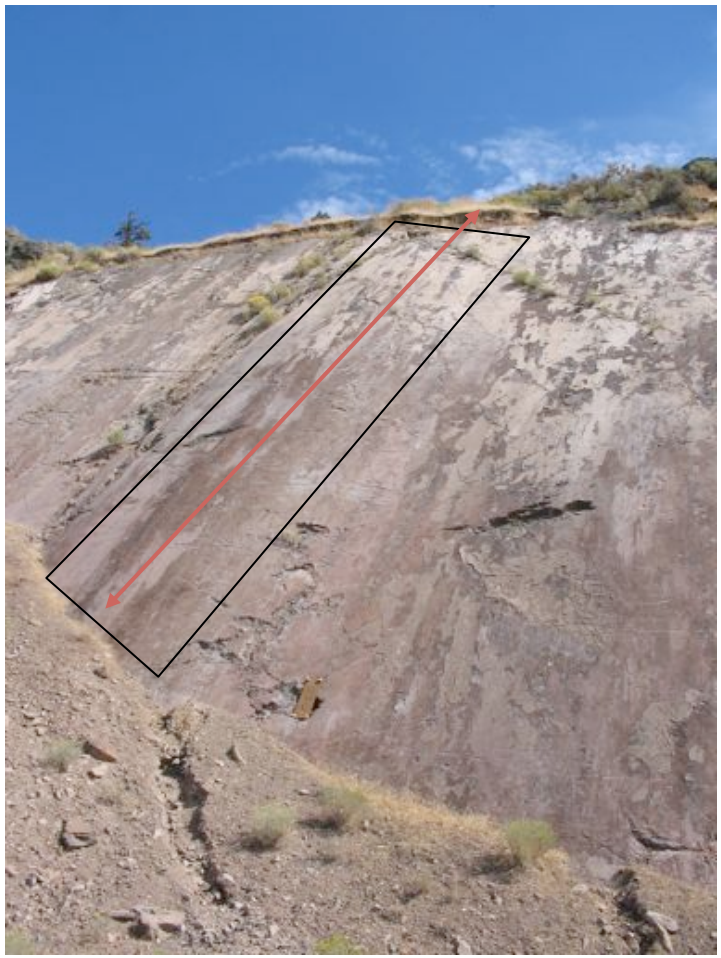
Courtesy Eric Dunham, Stanford

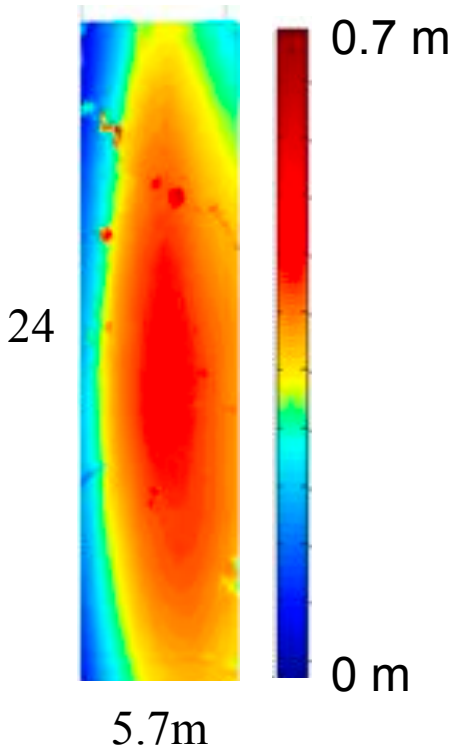




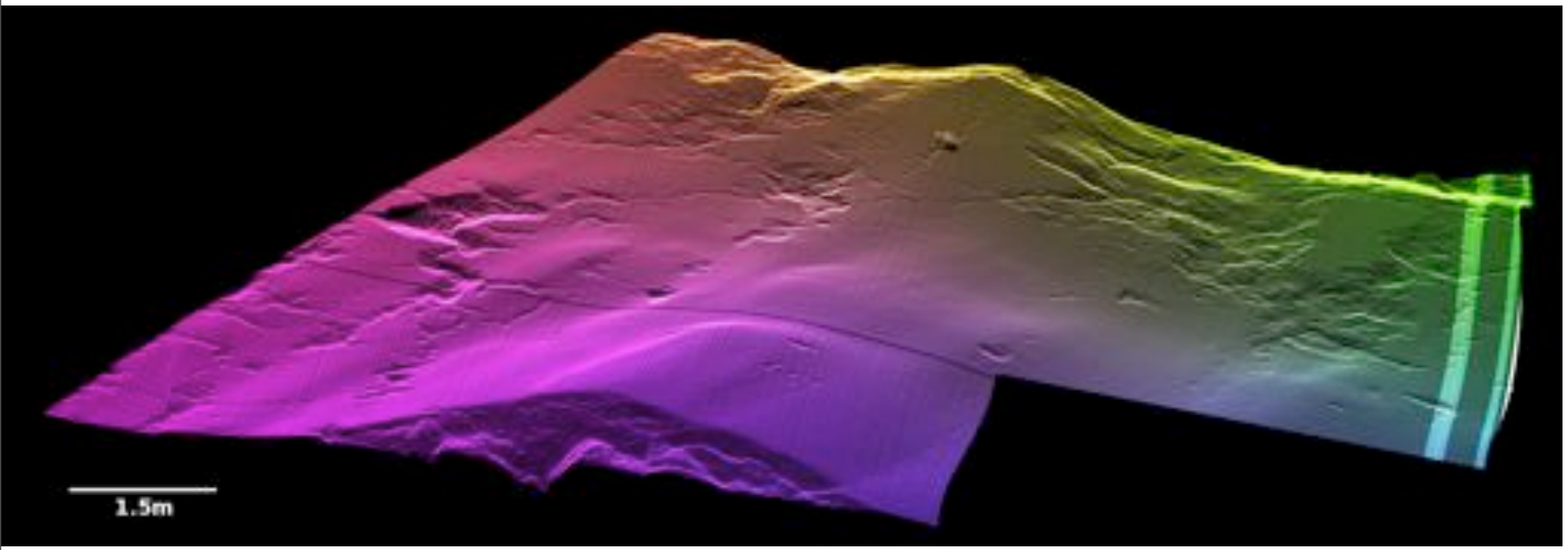
Sagy et al., *Geology*, 2007.

Geometrical Asperities (Bumps) on Mature Faults





Large-slip faults have distinct 10-m scale bumps (asperities)

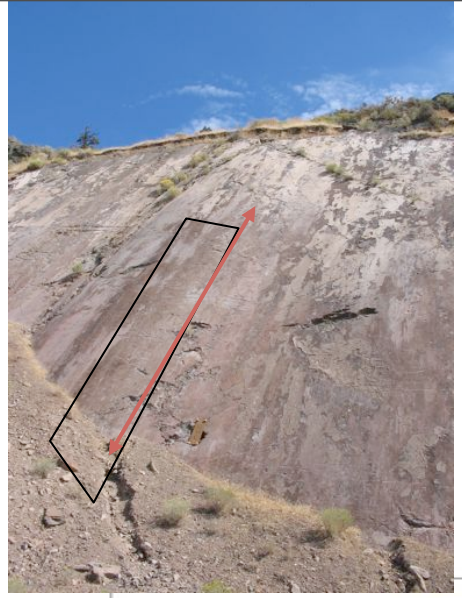


Visualization with Slugview

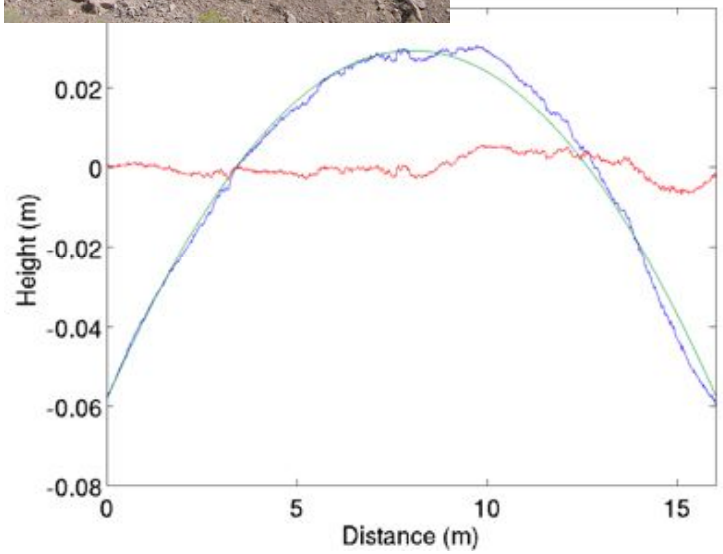
Western Fucino Basin, Italy

Monte Maggio

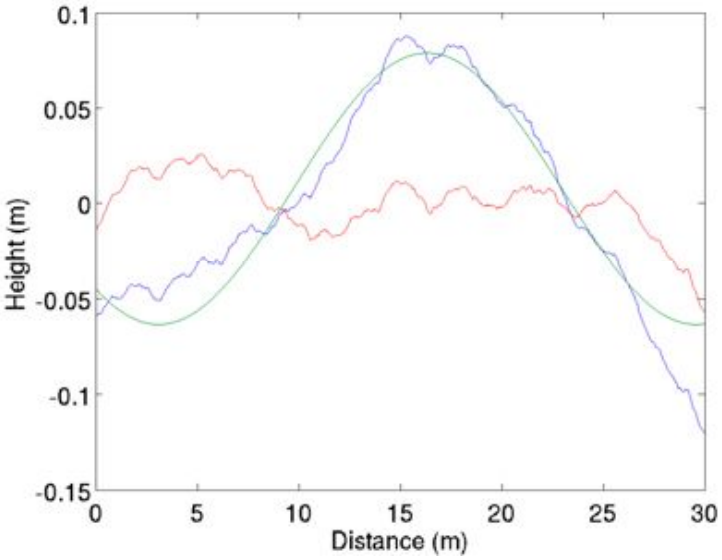
N. Borcola Pass



Is the bump scale

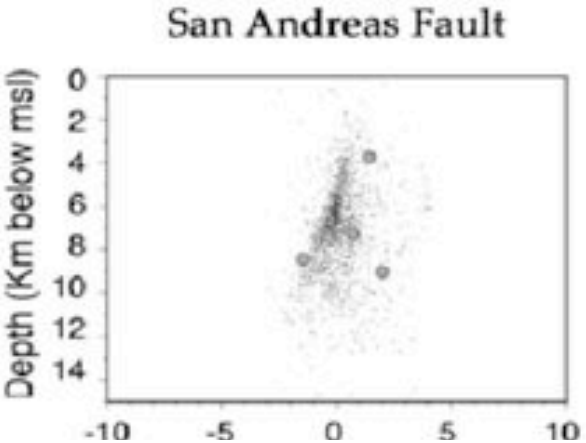


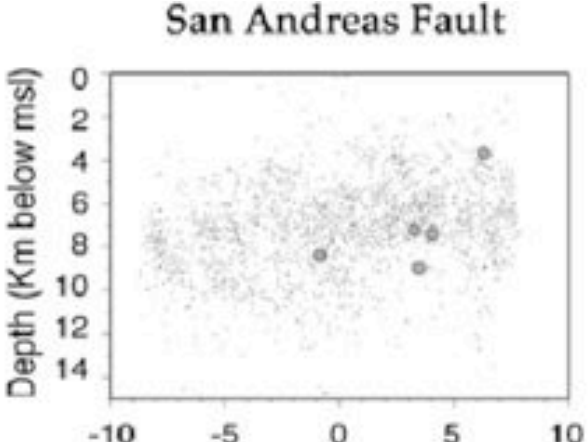
Observed bump
Monochromatic fit
Residual

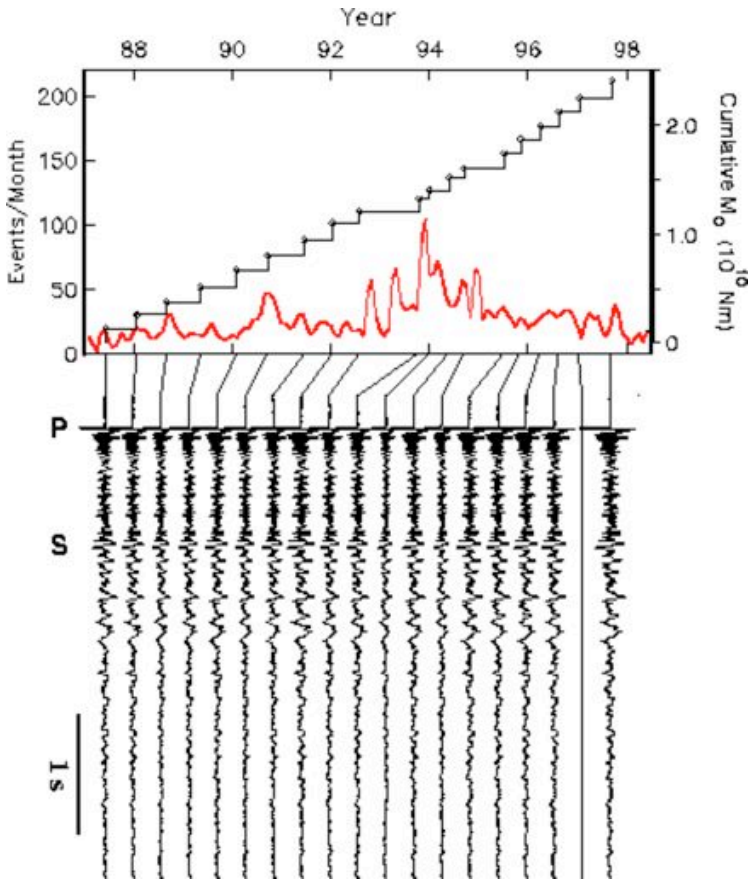


Synthetic self-affine bump
Monochromatic fit
Residual

Asperities and



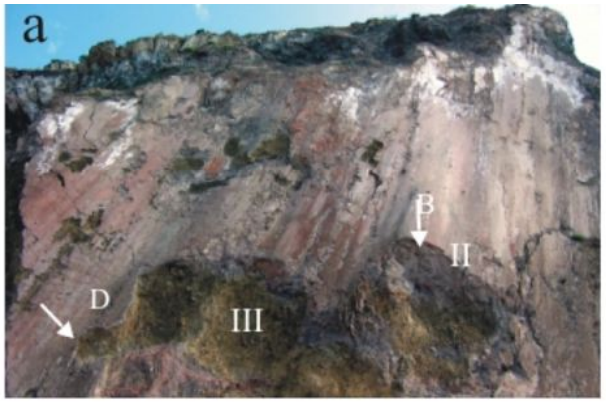


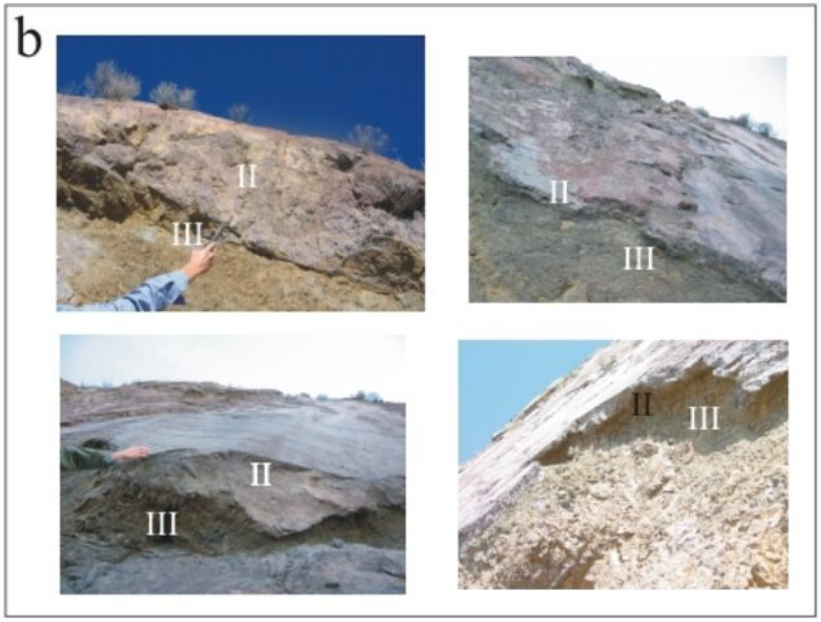


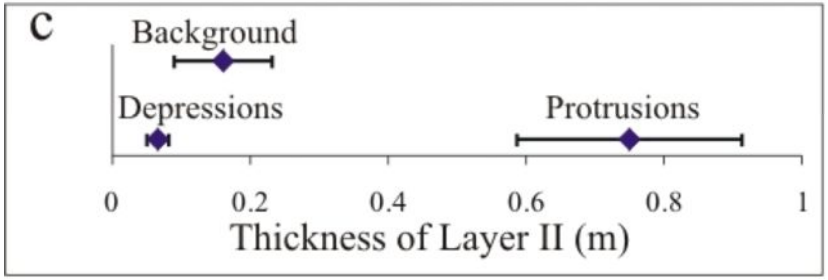
McEvilly et al.

Fault Zone Architecture

Fault Zone Architecture Under the Bumps

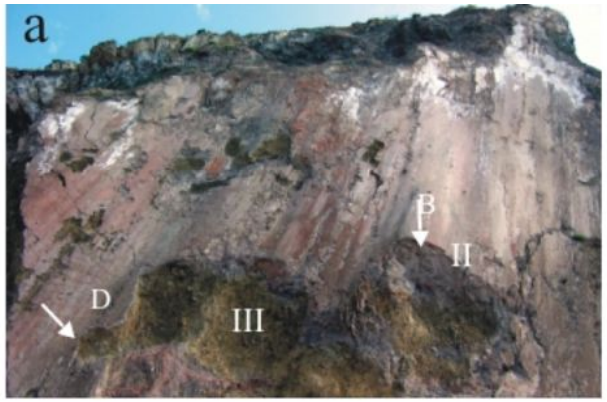


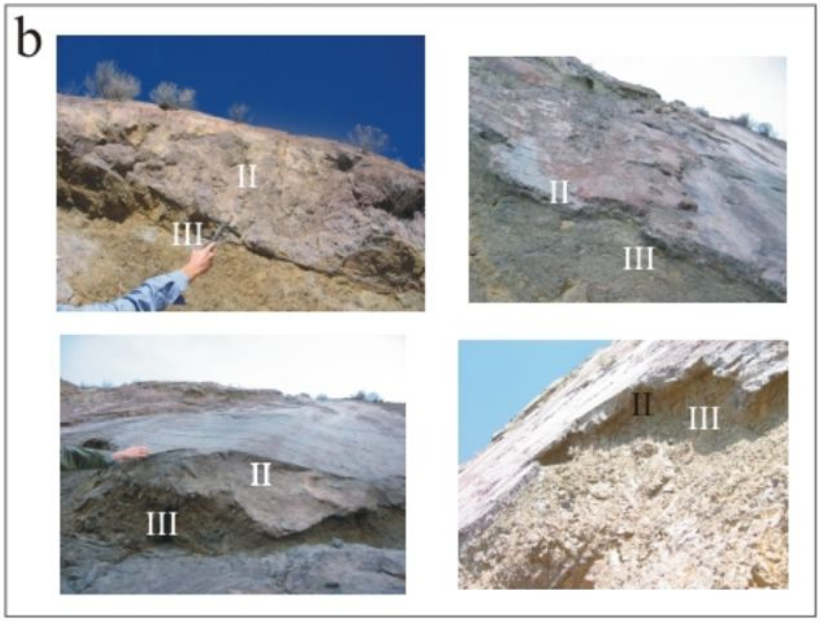


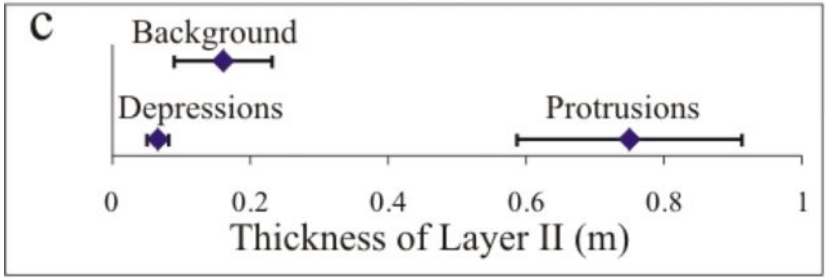


Fault Zone Architecture Under the Bumps

Bumps are due to thickening of granular flow layer.







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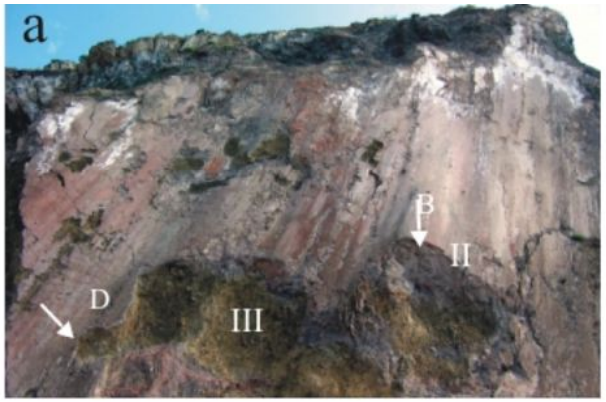
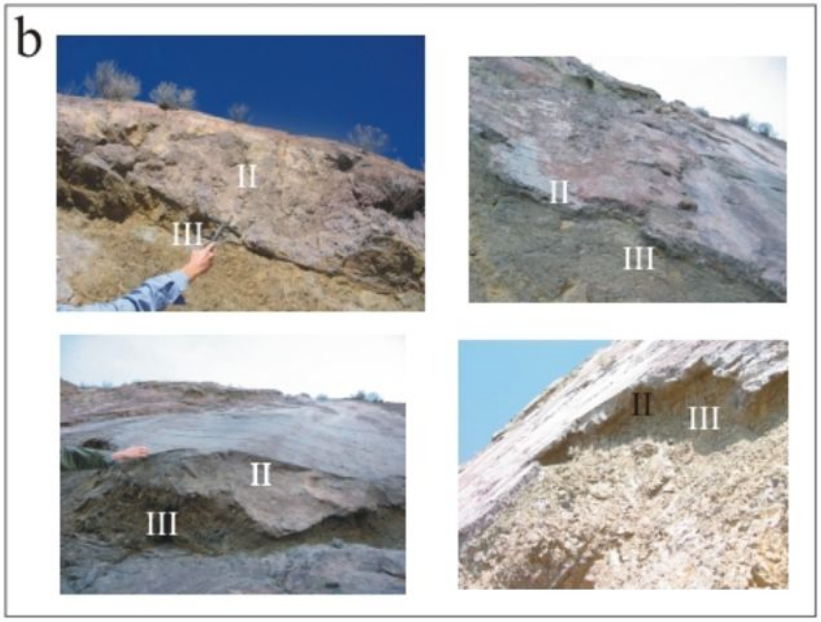
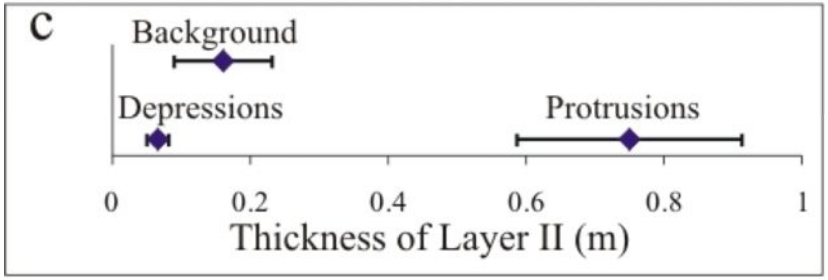




Bumps are due to thickening of granular flow layer.

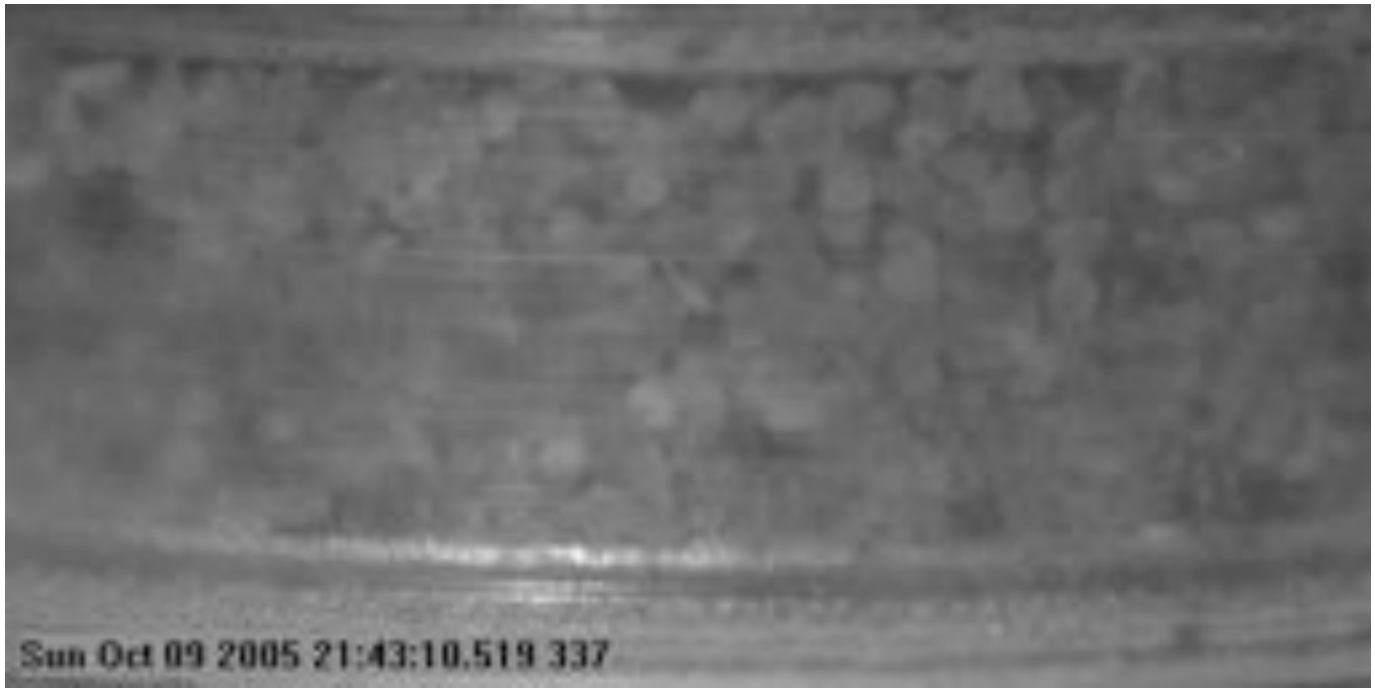
Corollary: Bumps are both rheological and geometrical asperities



Shear Localization in Granular Flows

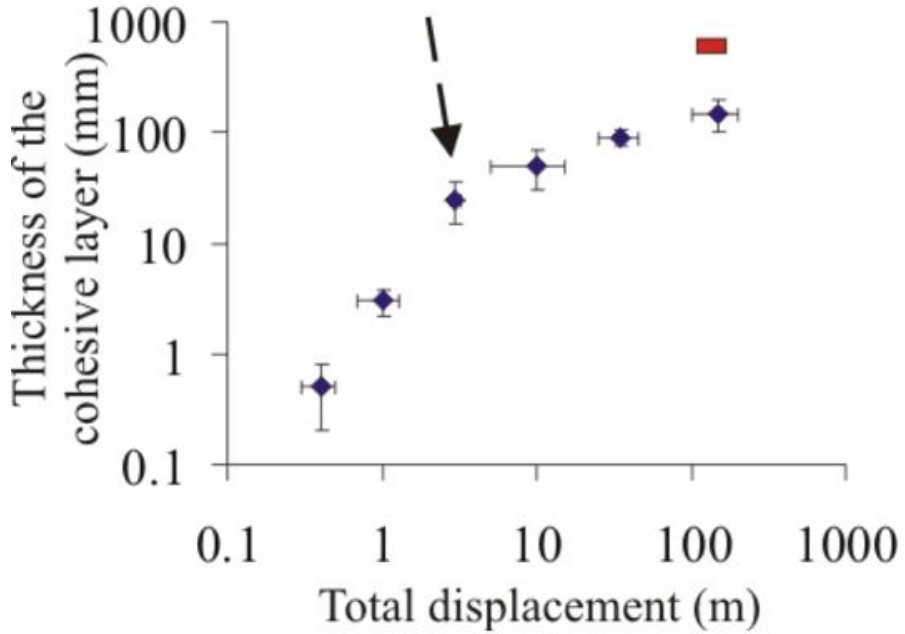
Kevin Lu, UCLA

Shear Localization in Granular Flows



Kevin Lu, UCLA

Evolution with displacement



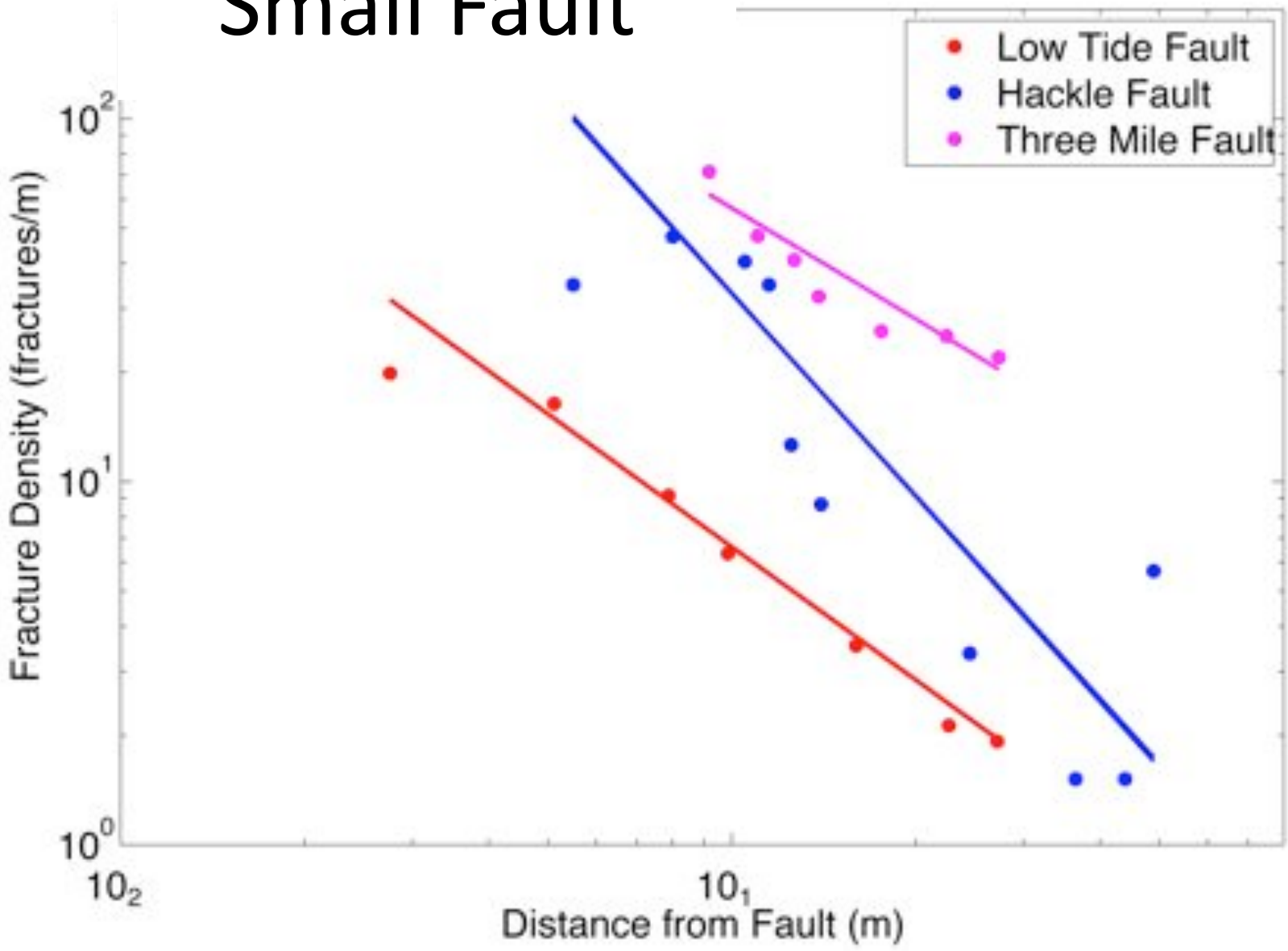
Sagy and Brodsky, JGR, 2009

BlueWate

BlueWate

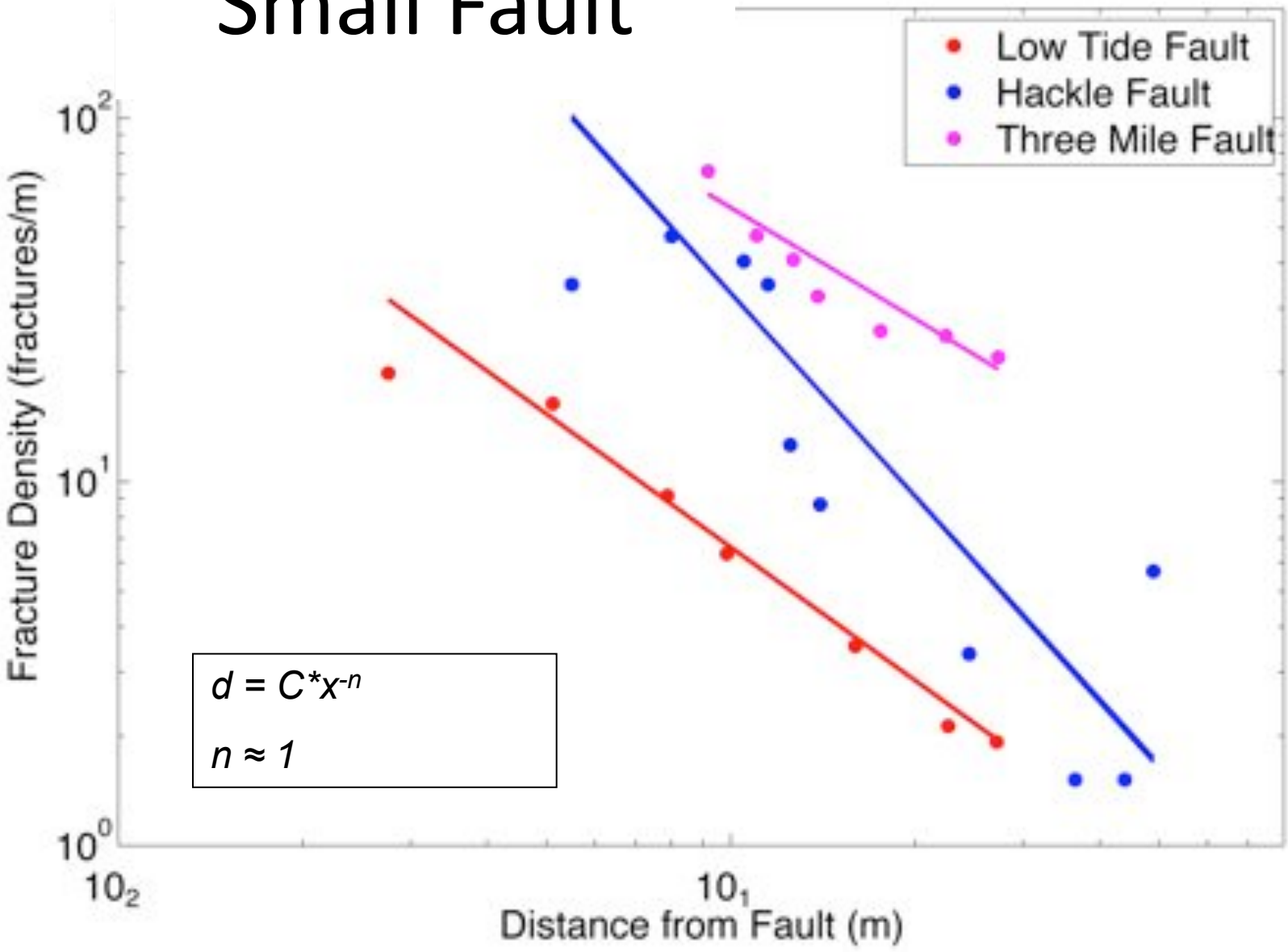
BlueWate

Small Fault



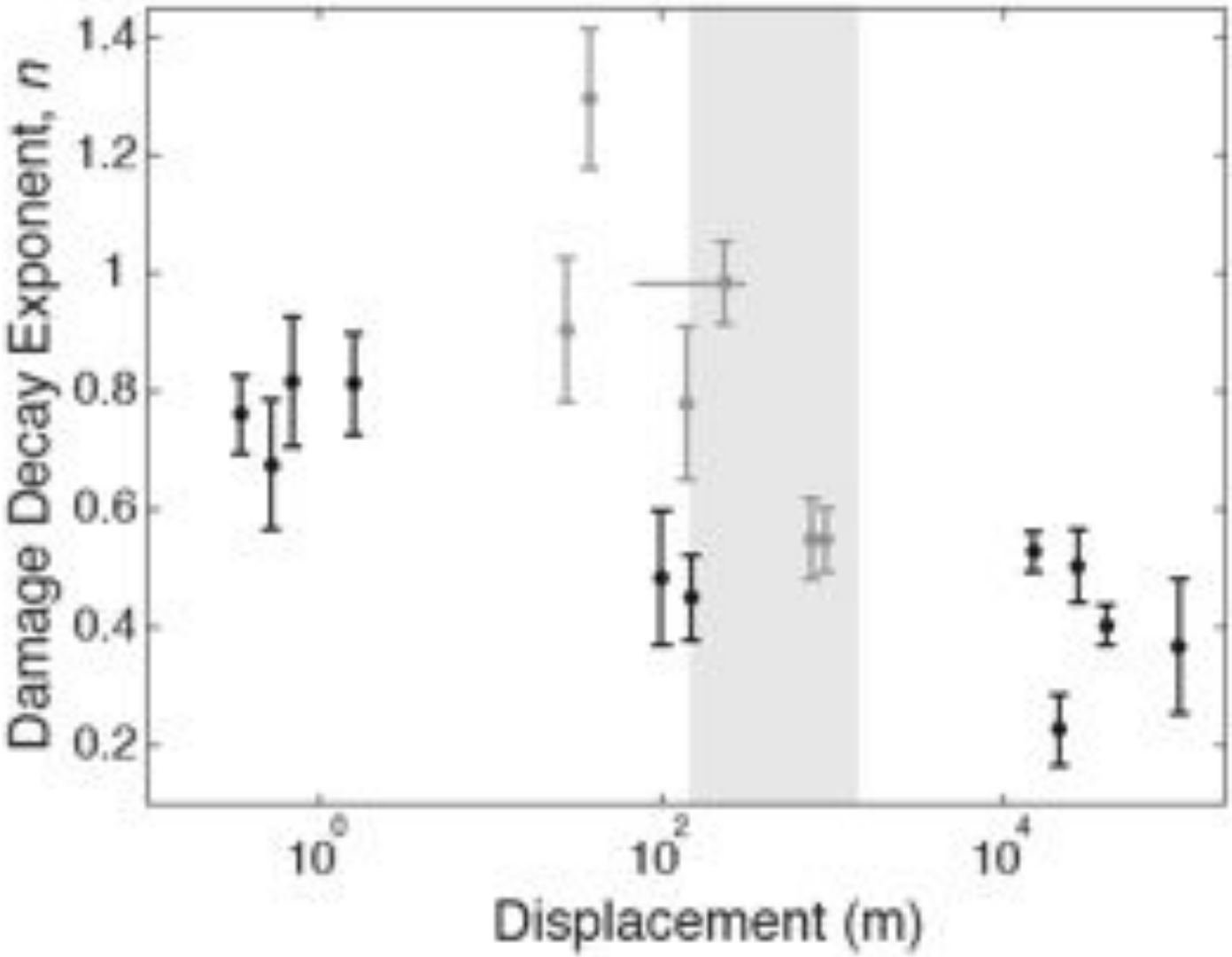
Savage and Brodsky JGR, submitted

Small Fault



Savage and Brodsky JGR, submitted

Falloff of Damage is a Function of



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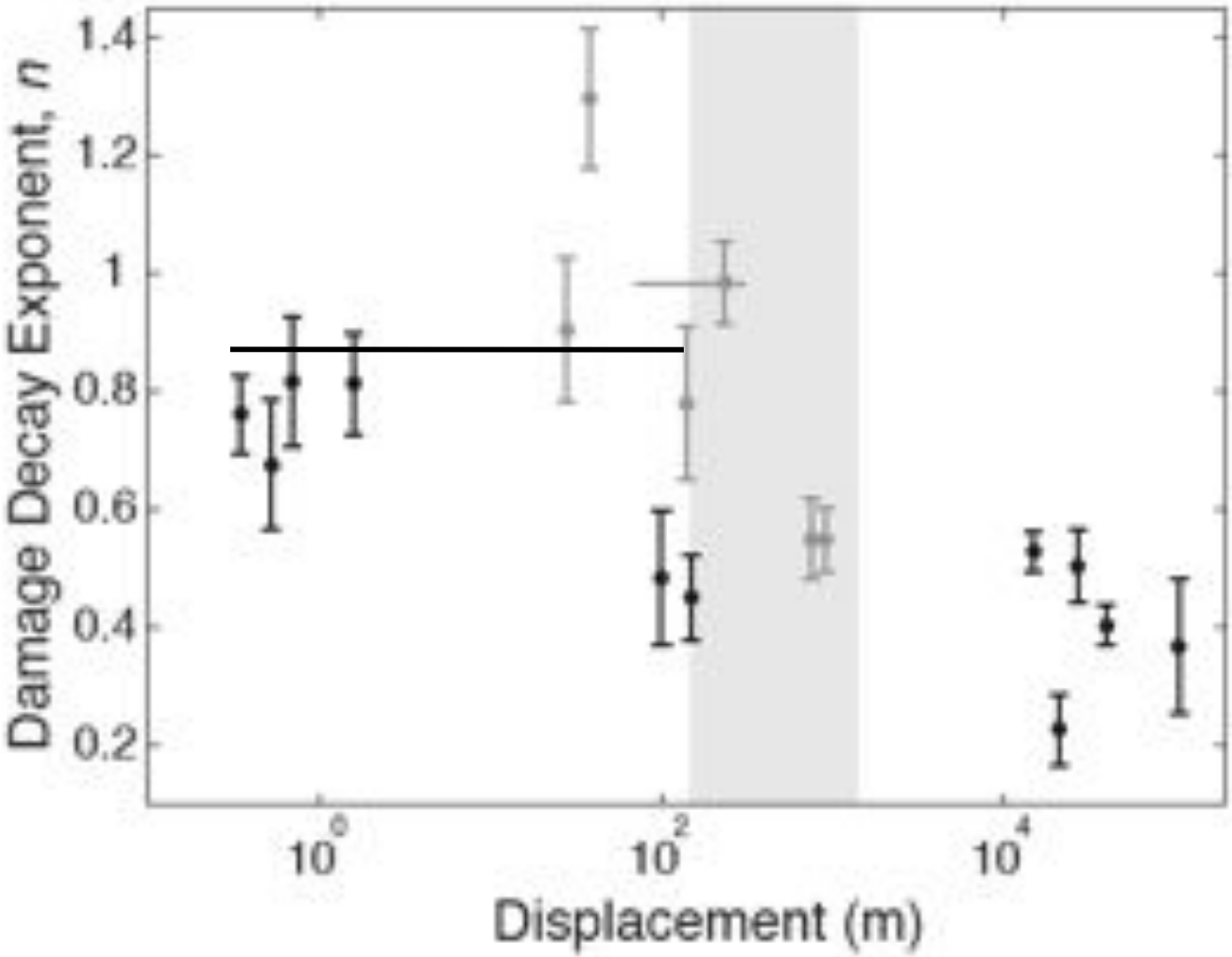

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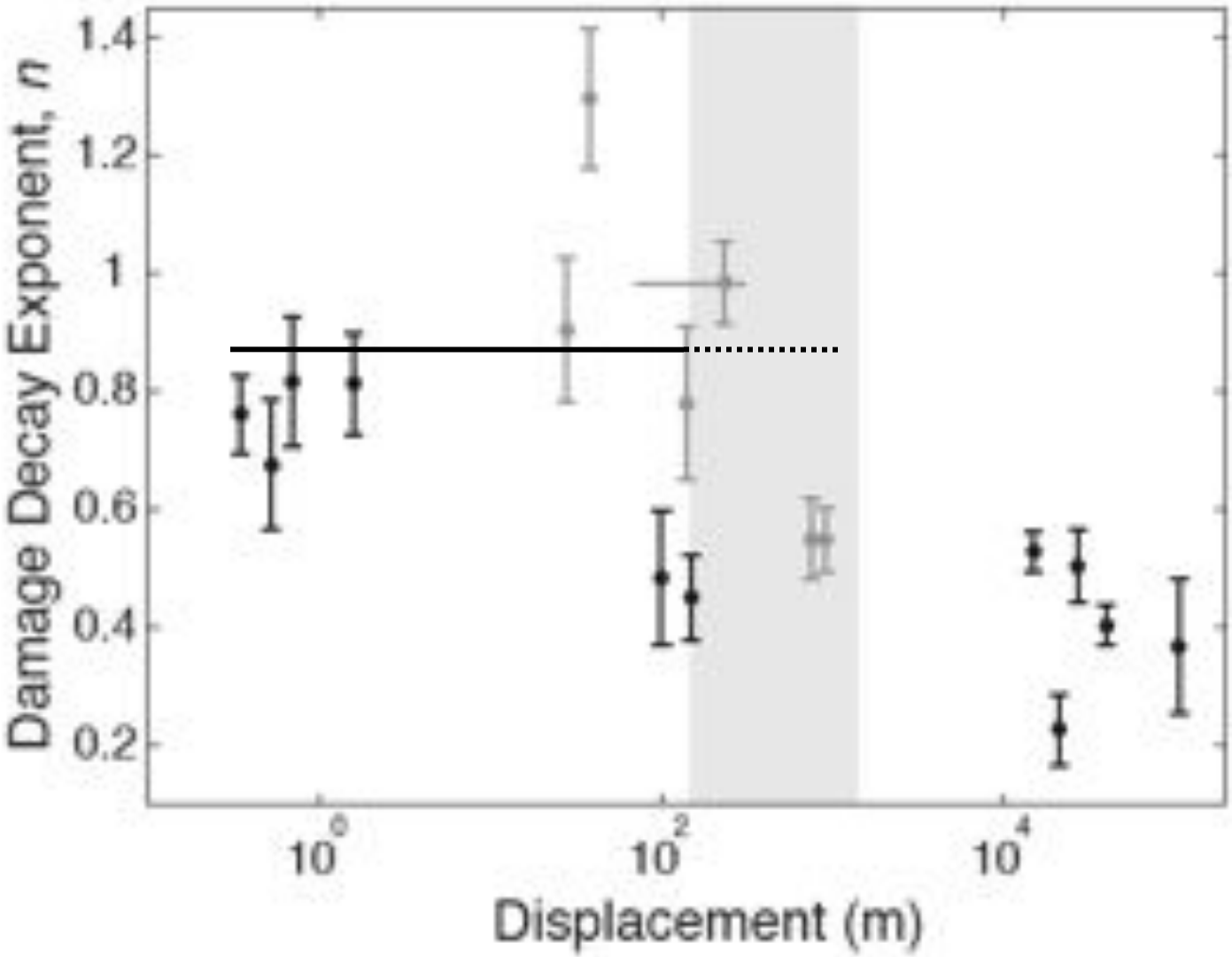

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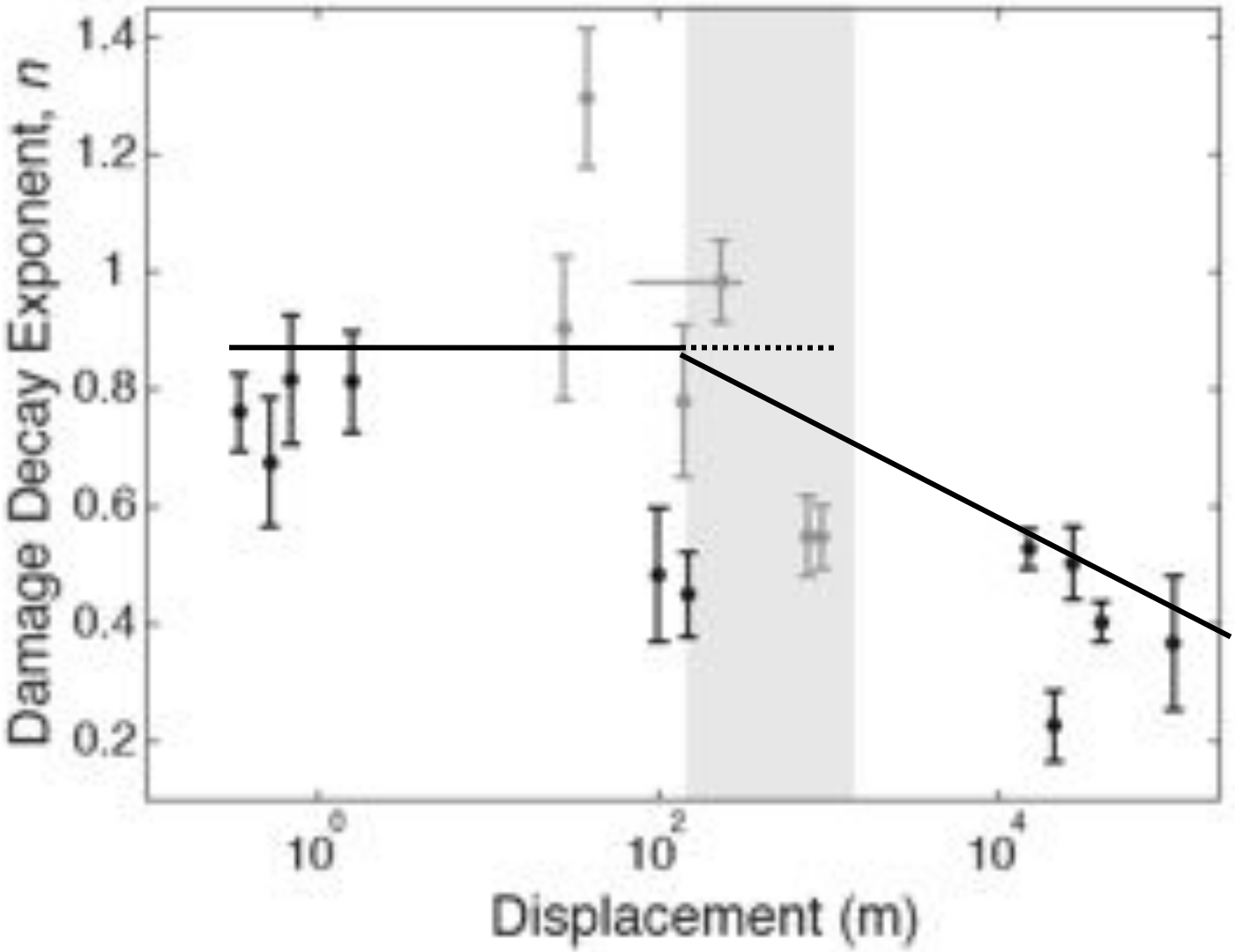

Savage and Brodsky JGR, submitted

Evolution of damage with increasing displacement

Savage and Brodsky *JGR*, submitted.

Evolution of damage with increasing displacement

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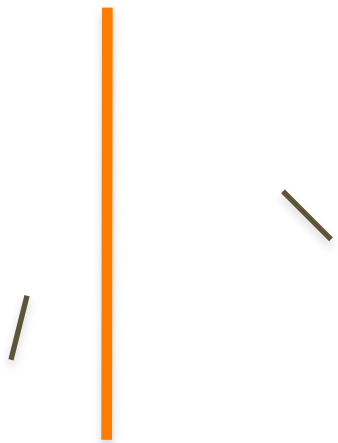
Evolution of damage with increasing displacement



Savage and Brodsky *JGR*, submitted.

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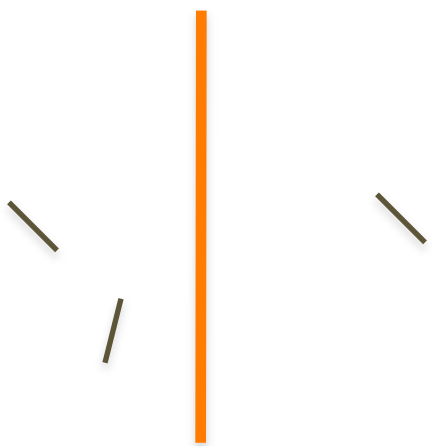

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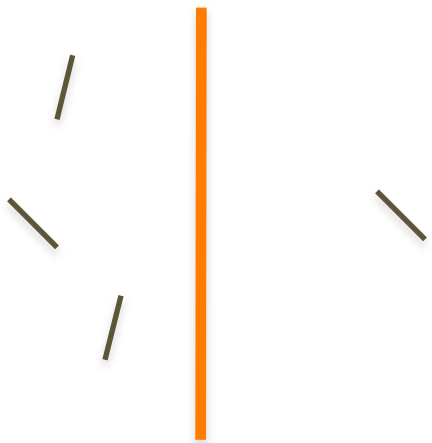

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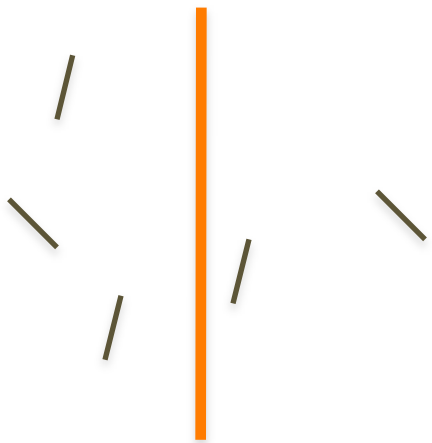

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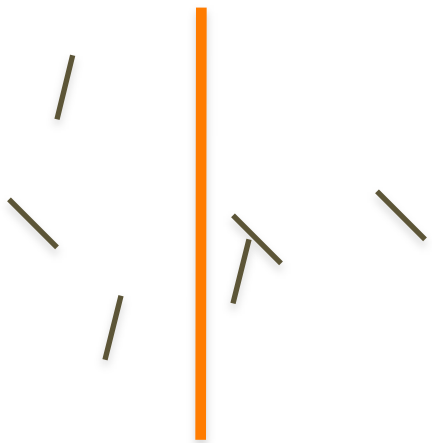
Evolution of damage with increasing displacement



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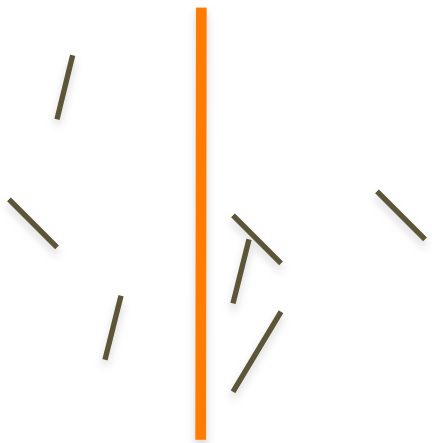

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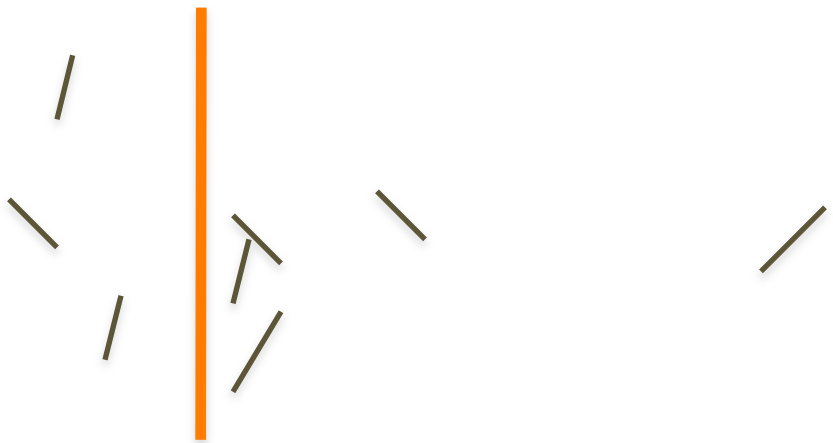

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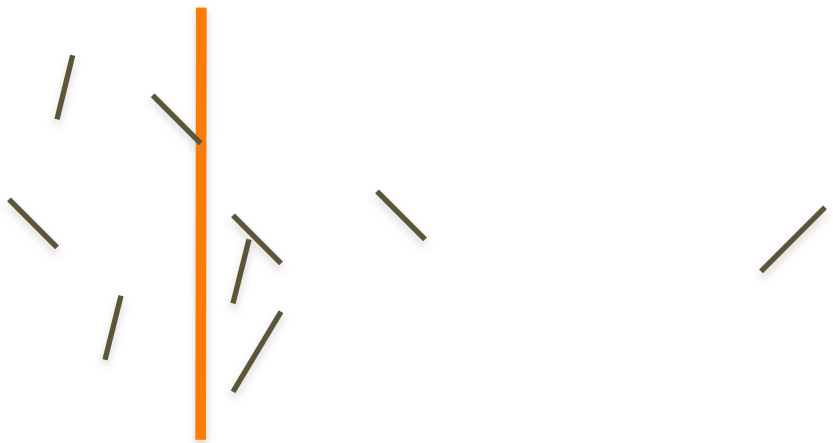

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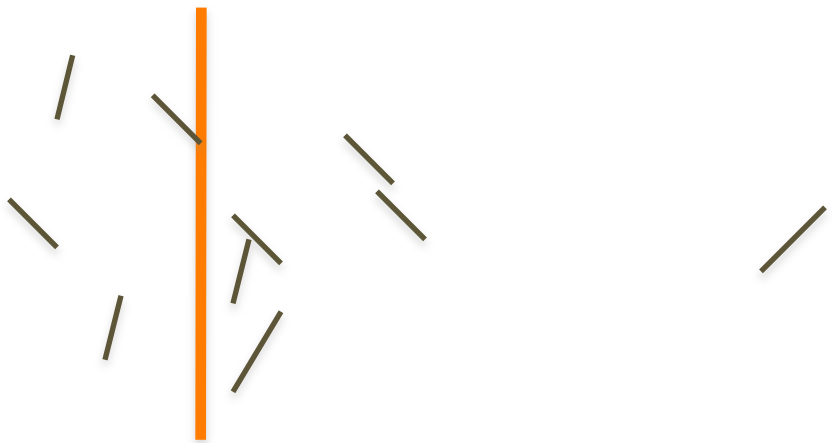

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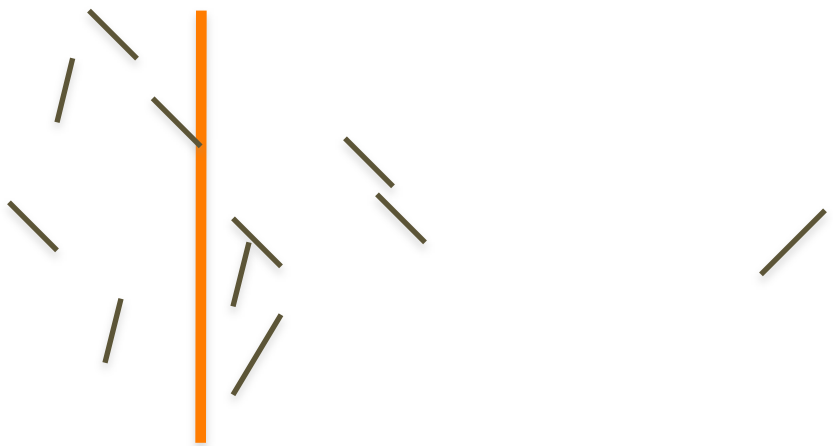

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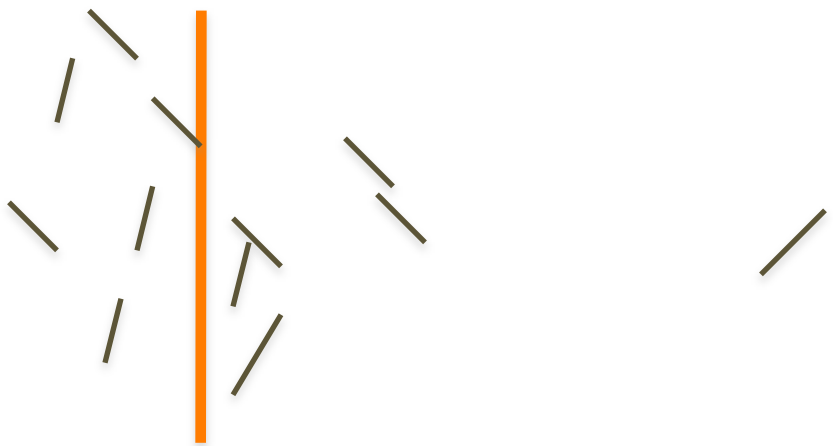

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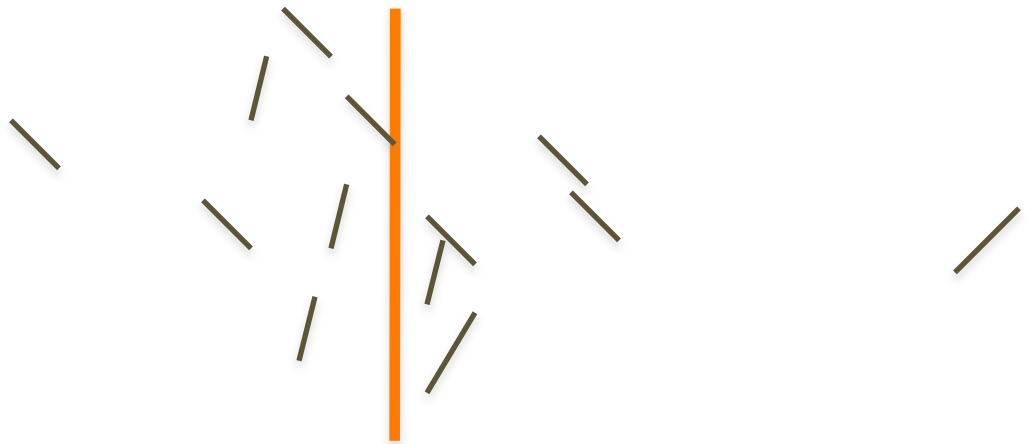

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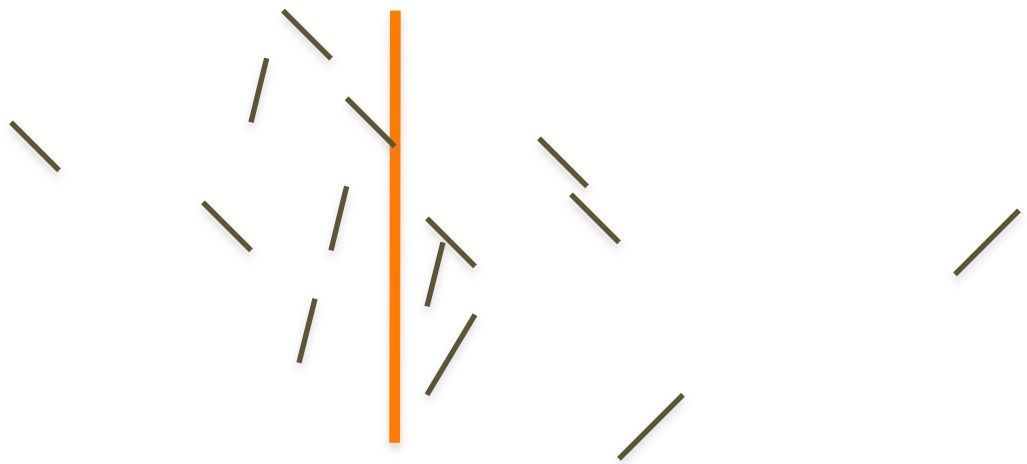

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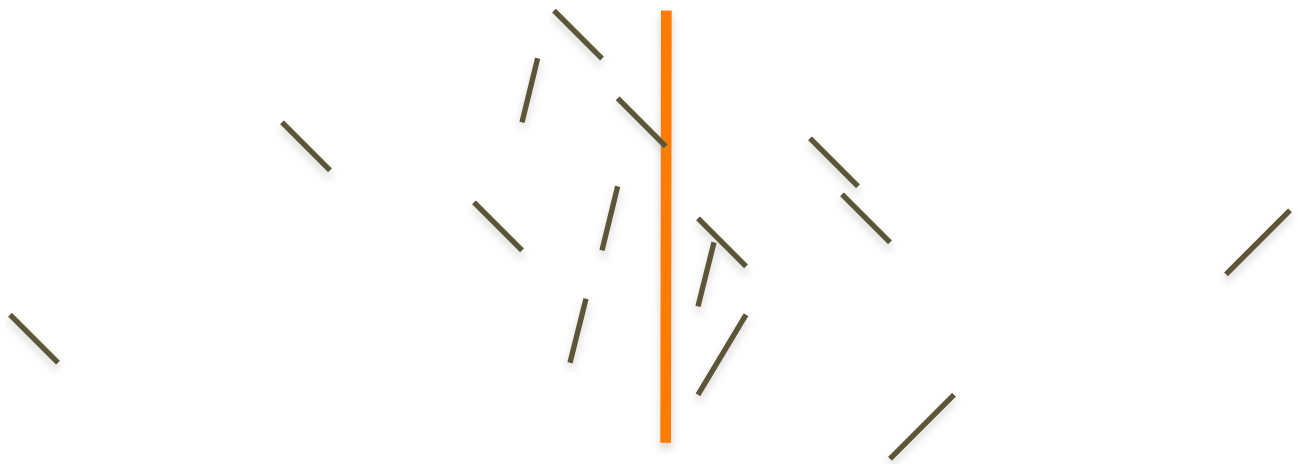

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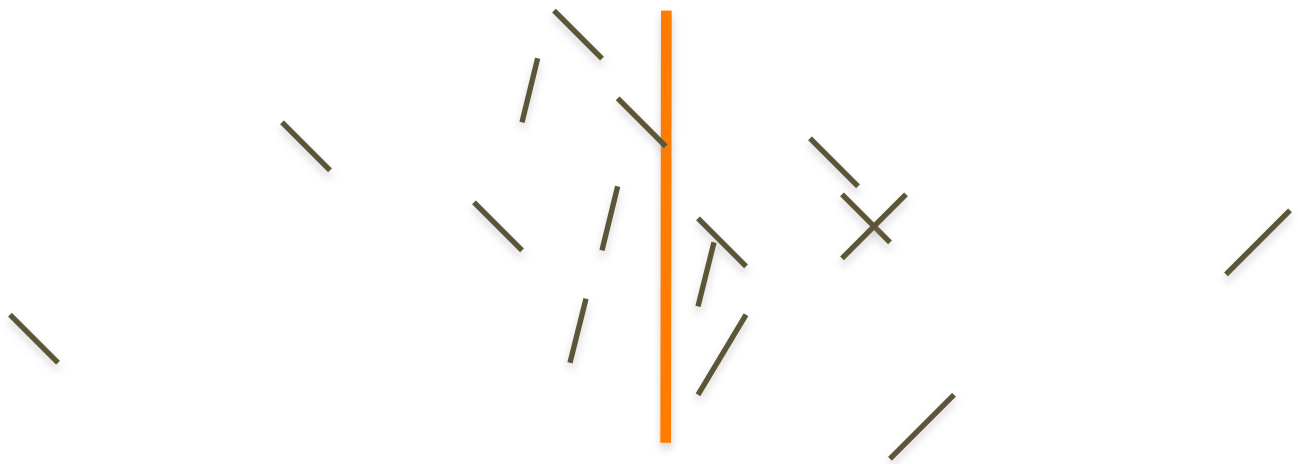

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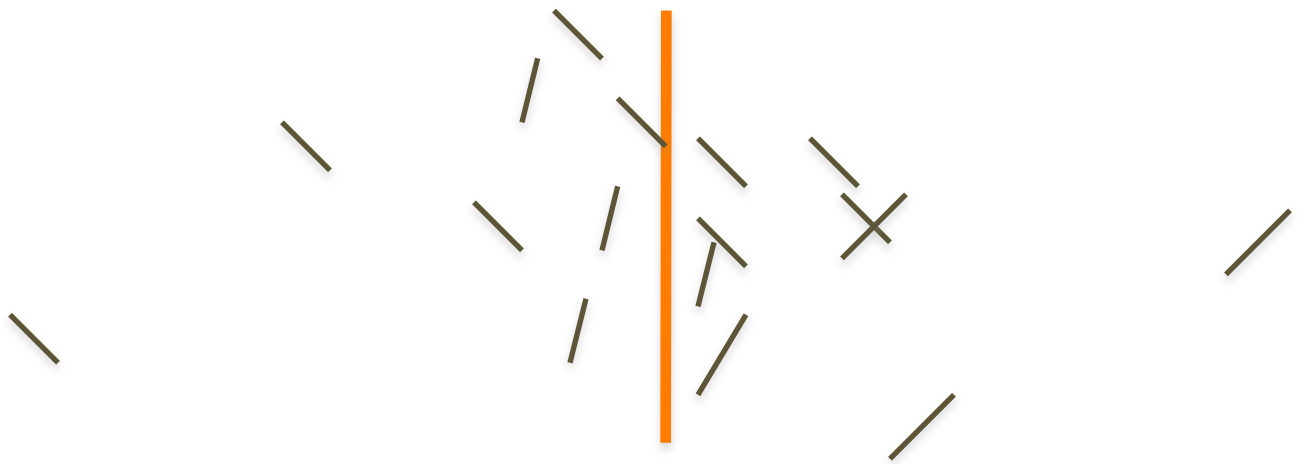

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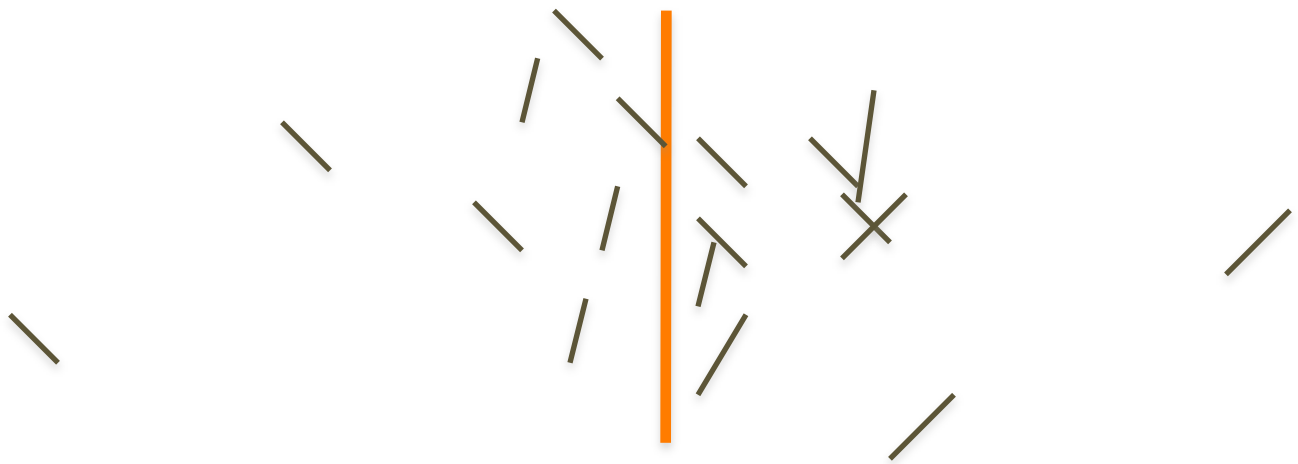

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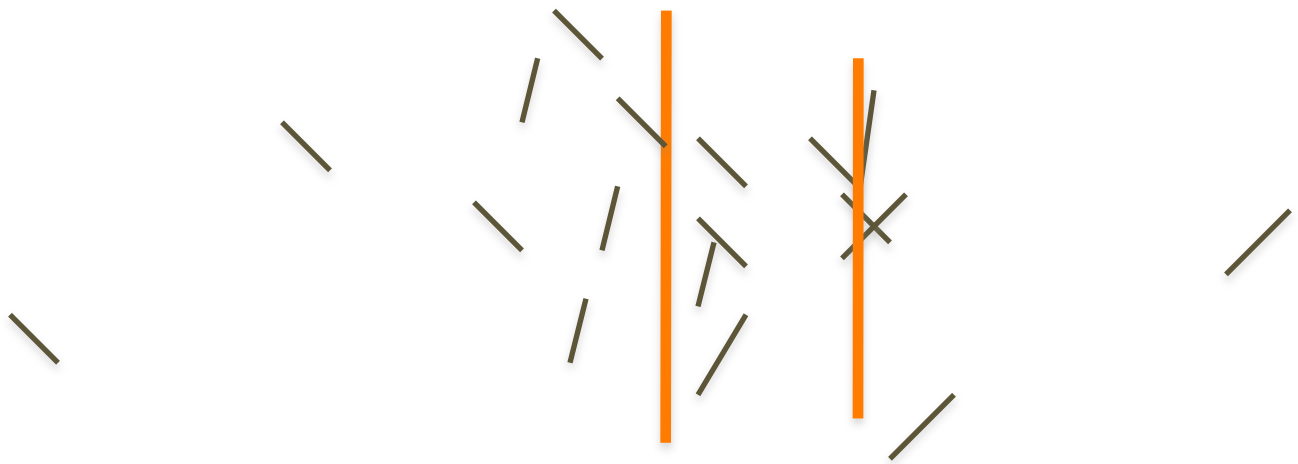

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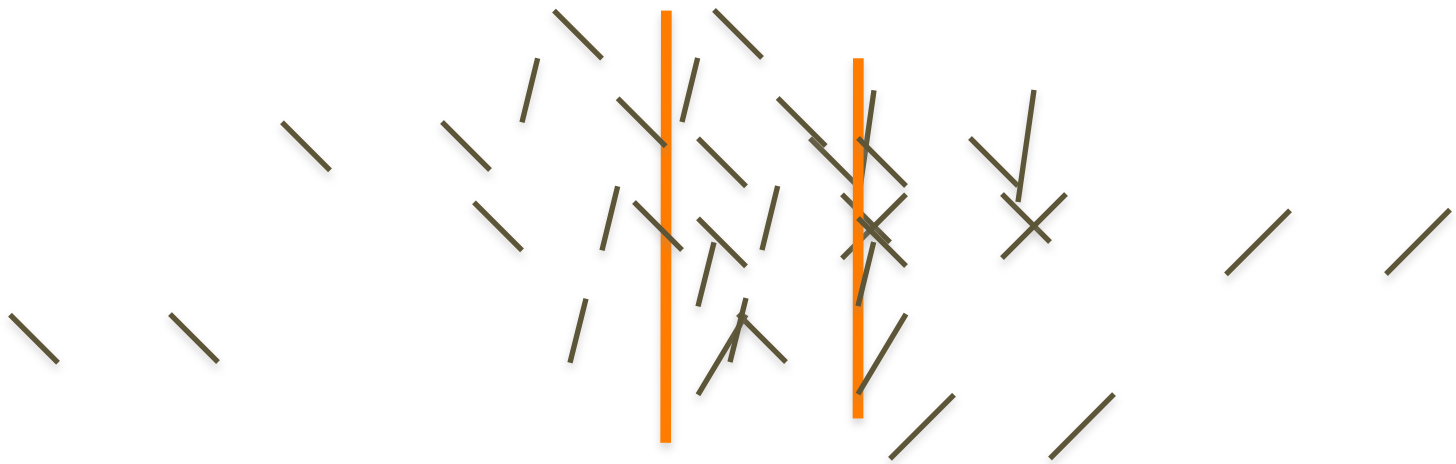

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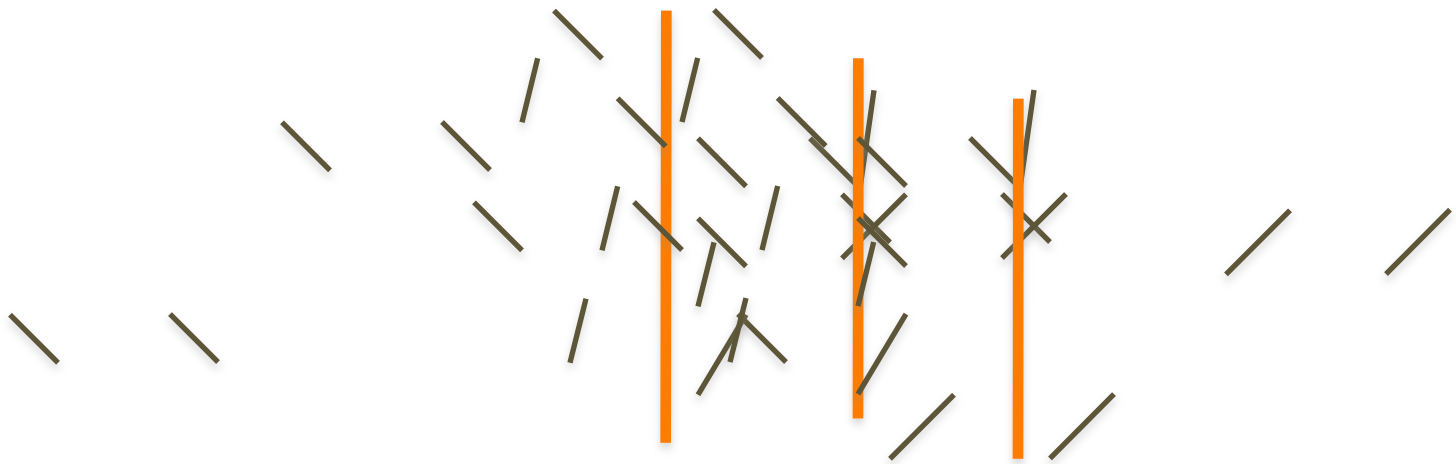

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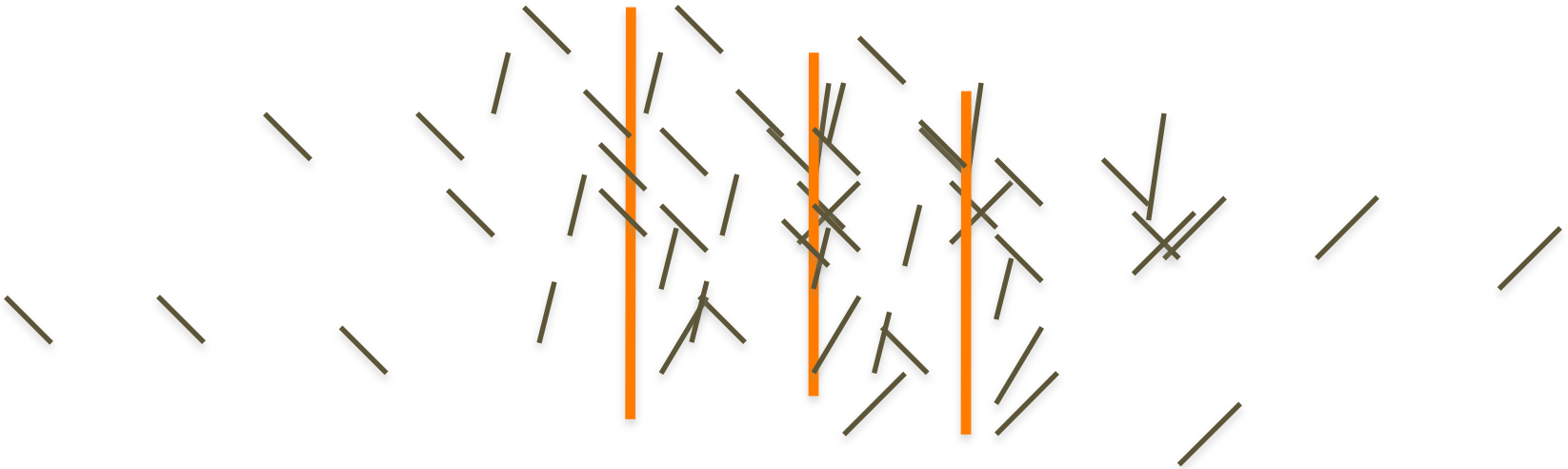

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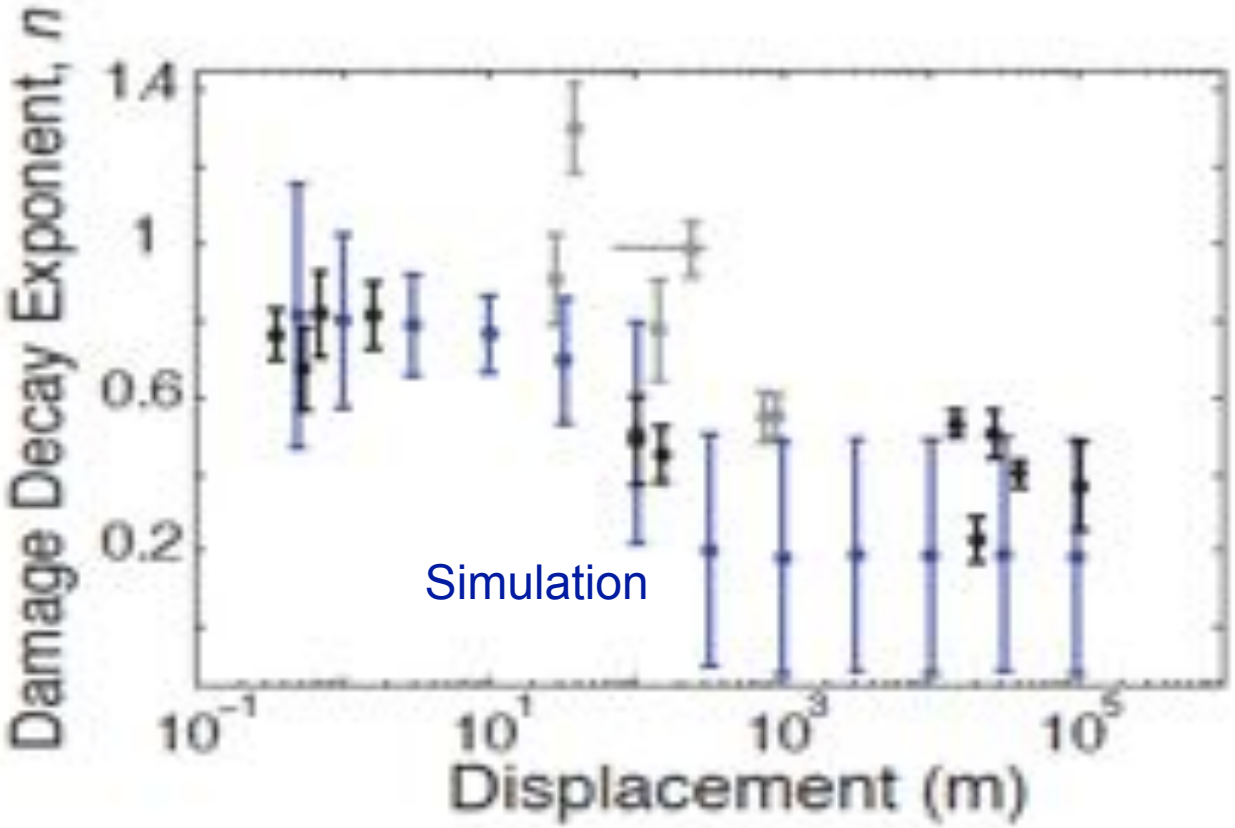
Stochastic Model of Damage Zone Creation



Savage and Brodsky JGR, submitted

What have we learned…

- Quantifying Roughness:
  - Over cm to m scales, immature faults are self-similar with ~1 % roughness
  - Faults smooth with increasing slip (but weakly)

- Nature of heterogeneity:
  - At 10's of meters anomalous bumps occur on fault surfaces
    - Indicates of thickening of the gouge layer
    - Bumps are both geometrical and rheological asperities

- Evolution of damage:
    - Damage patterns are consistent with individual strands of all maturity faults generating similar stress fields
    - Apparent changes in damage for large-displacement faults reflect secondary strand formation which occurs with a small probability (~0.05%) for each fracture

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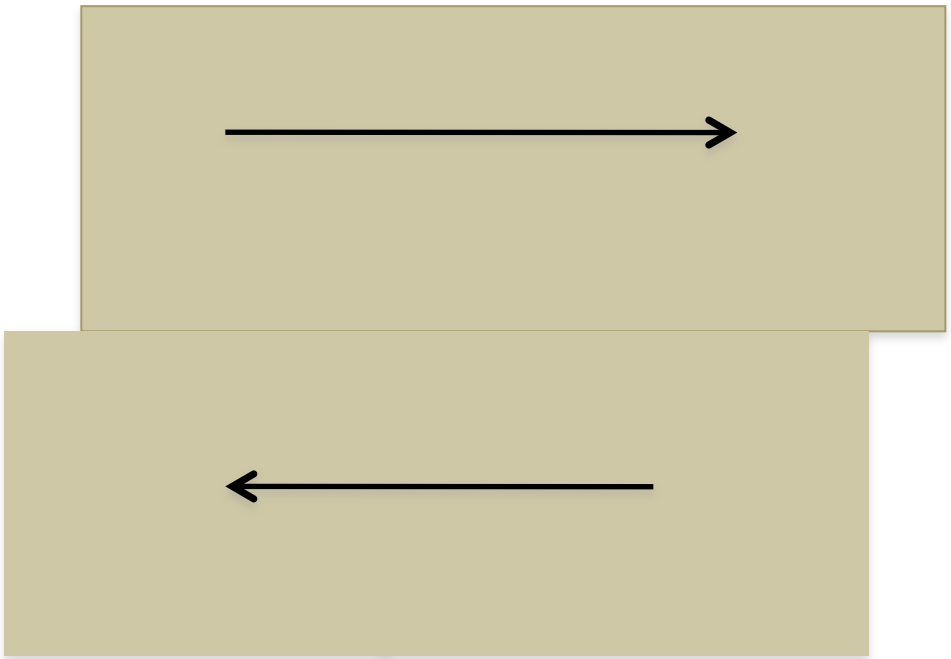
A Simplified Fault Revisited:



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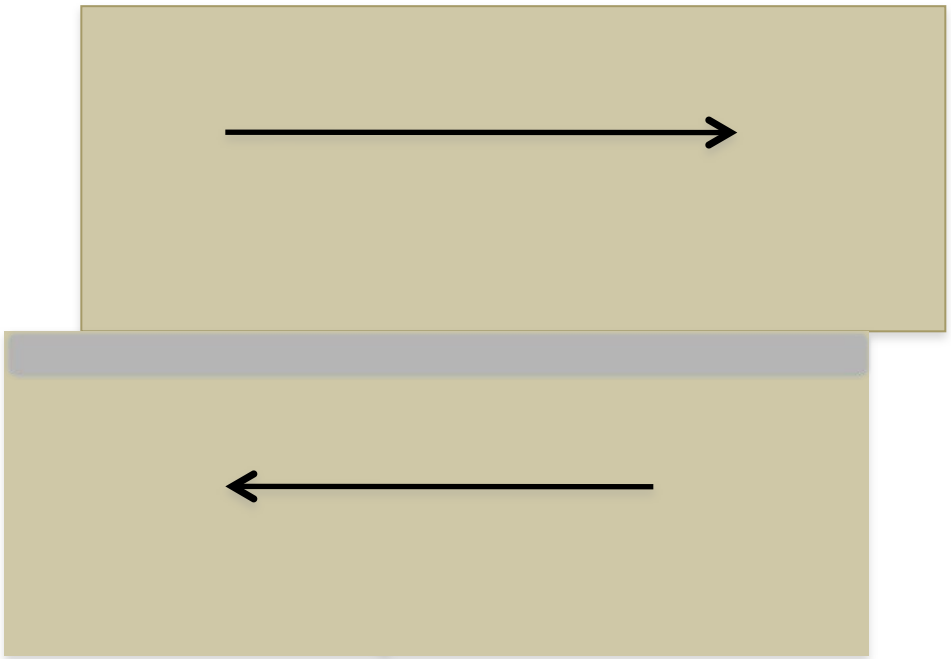

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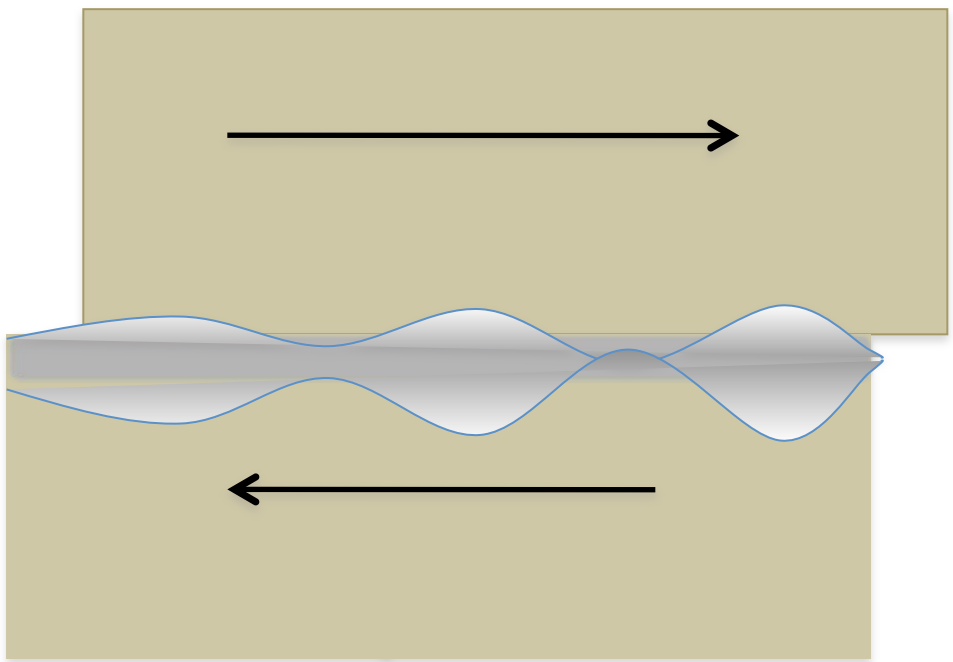

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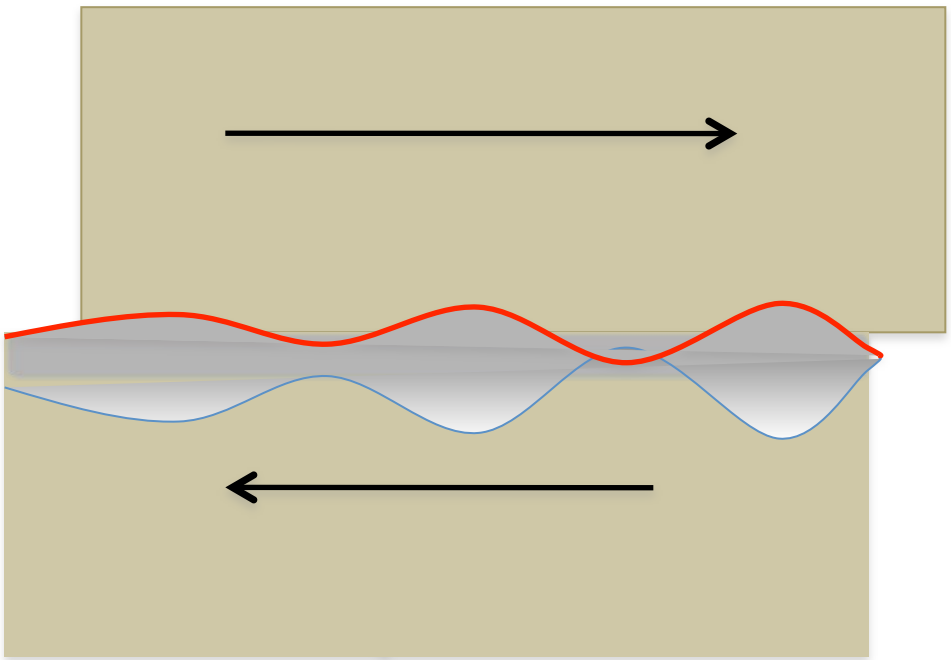

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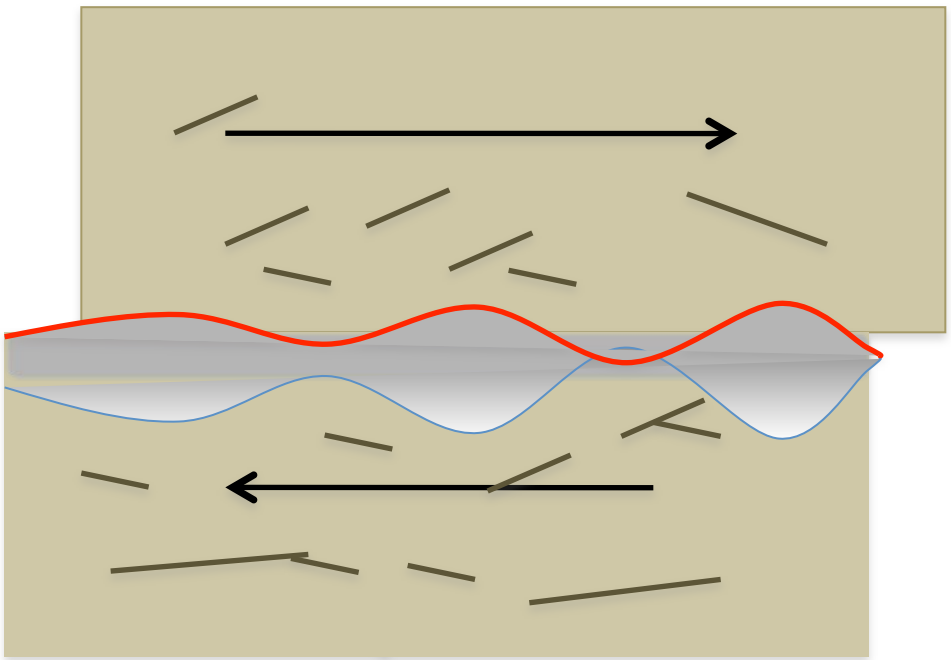
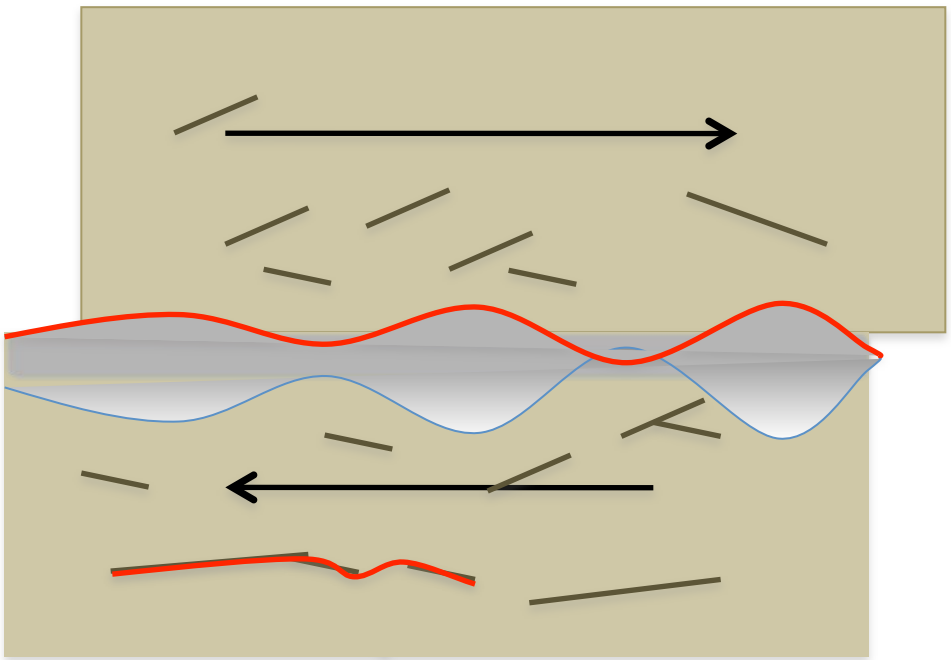
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