Fault surface geometry, wear processes and evolution: implications for earthquake mechanics and fault rock rheology

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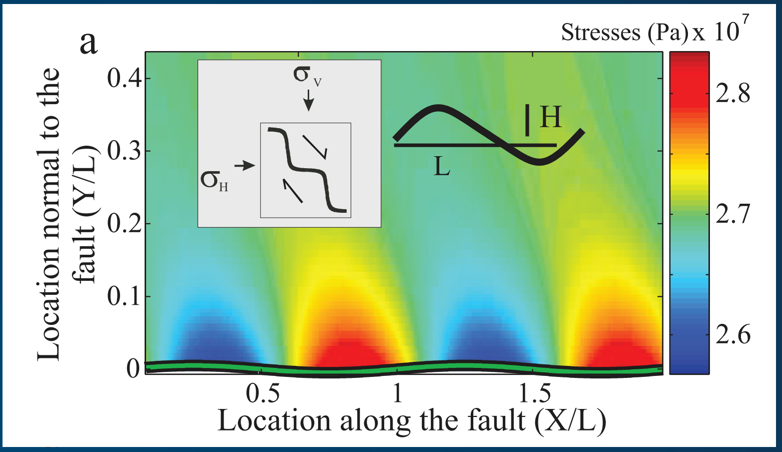
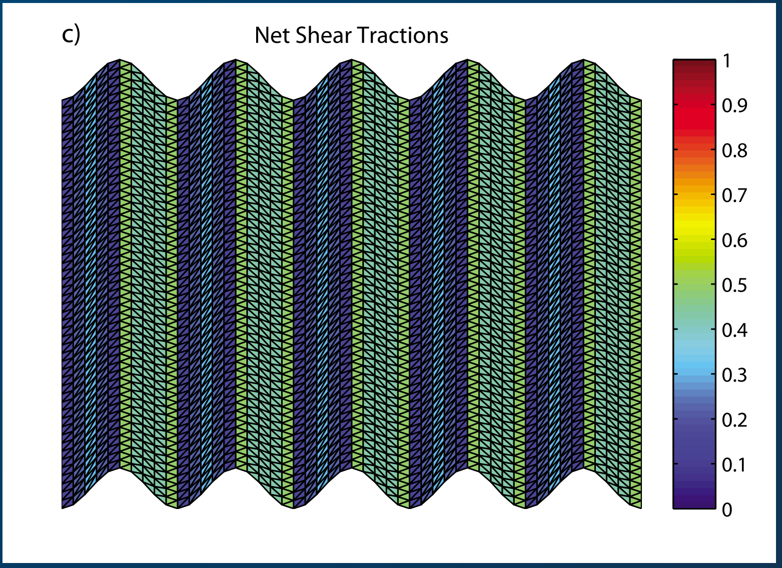
Fault surface stresses

- Interaction of opposing sides of a fault causes stress heterogeneity:
  1. How does the surface shape control shear tractions and displacement?
  2. Can we predict wear processes from surface geometry?

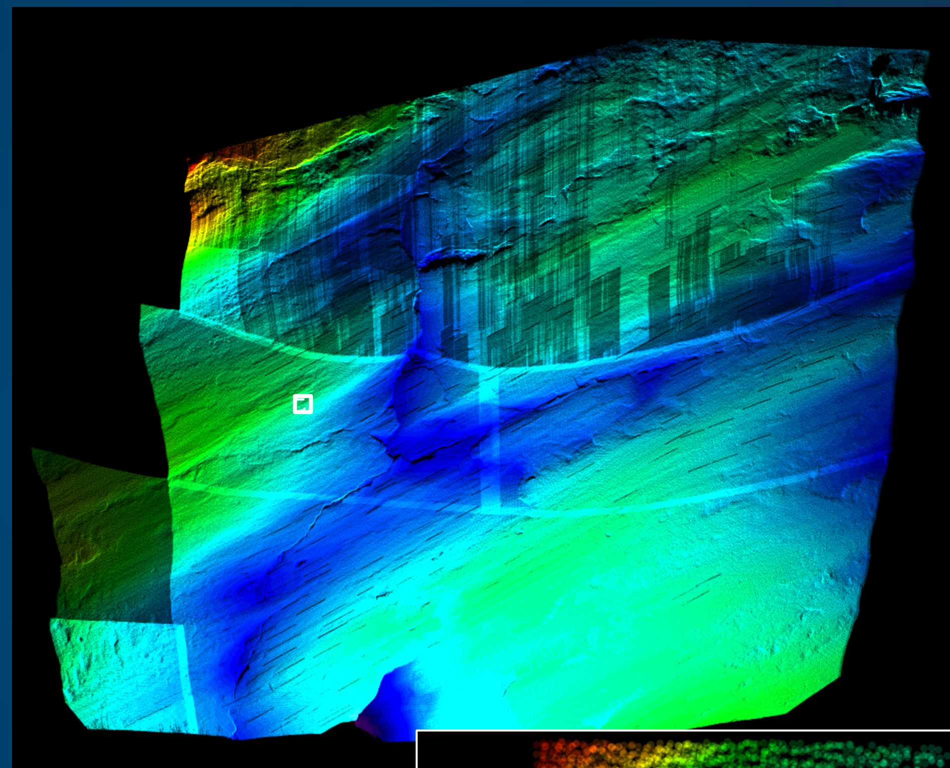


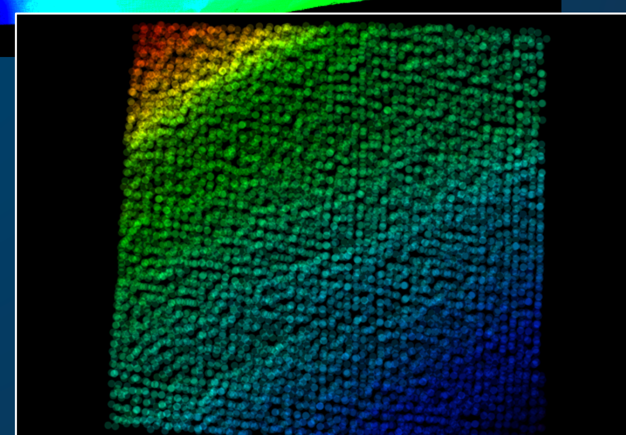
Sagy and Brodsky (2009)



Marshall and Morris (2012)

Fault surface characterization

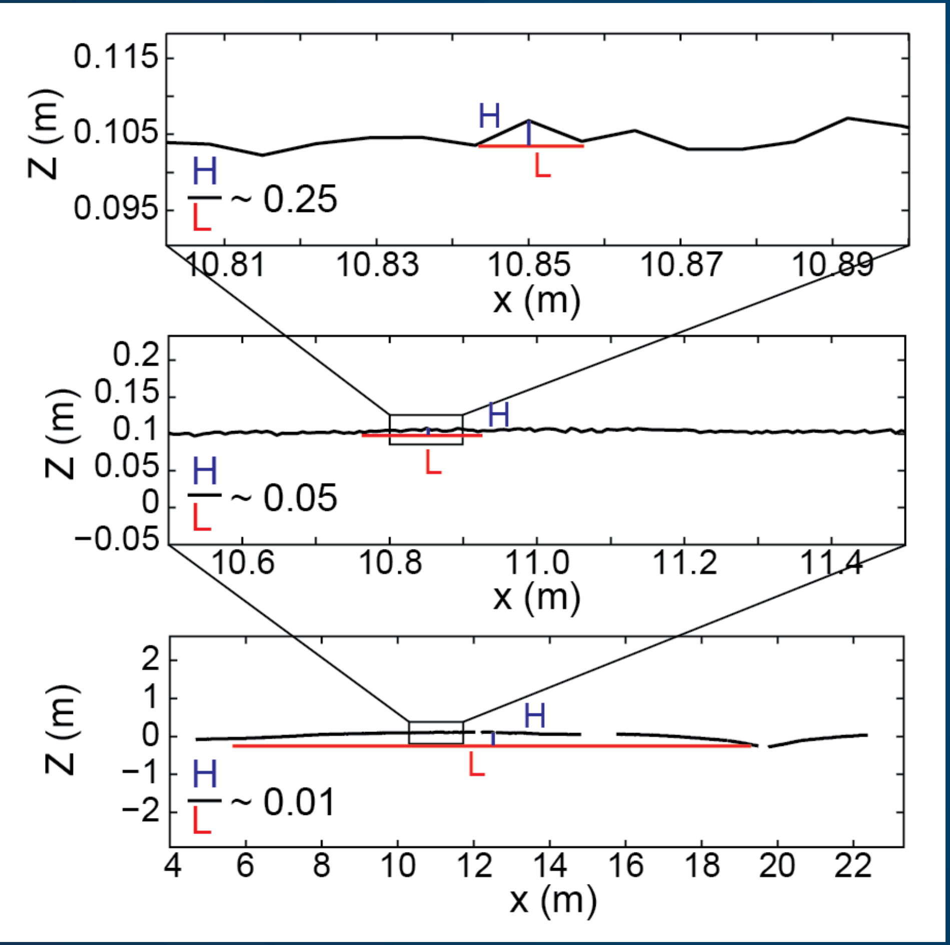


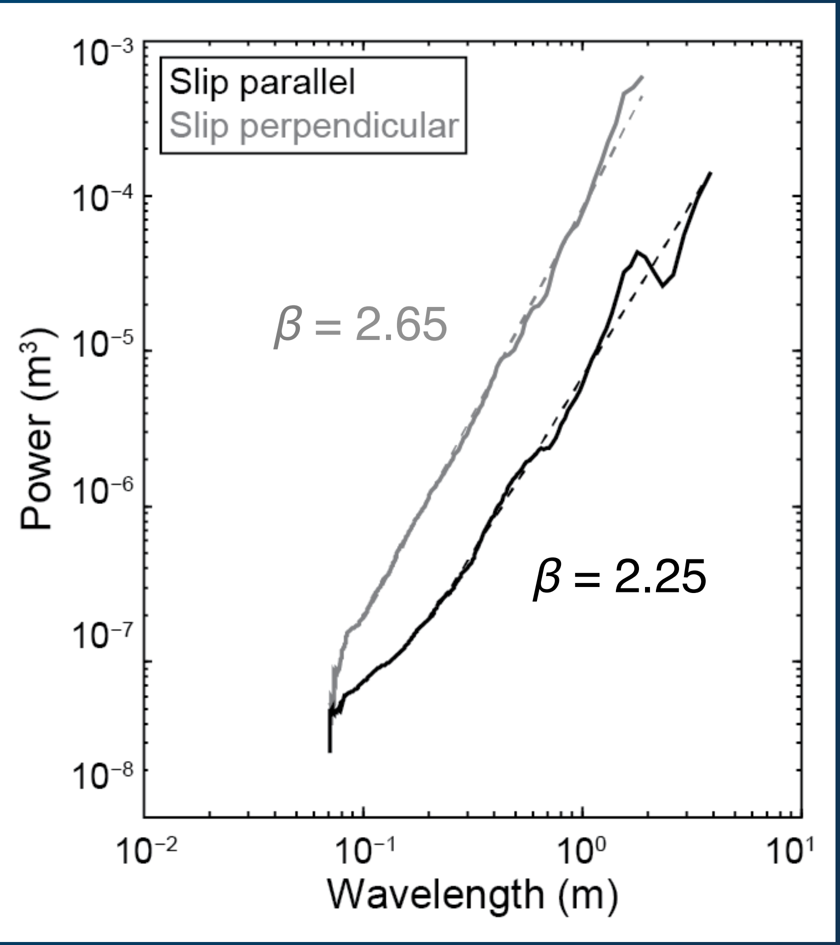


How does the surface shape control shear tractions and displacement?

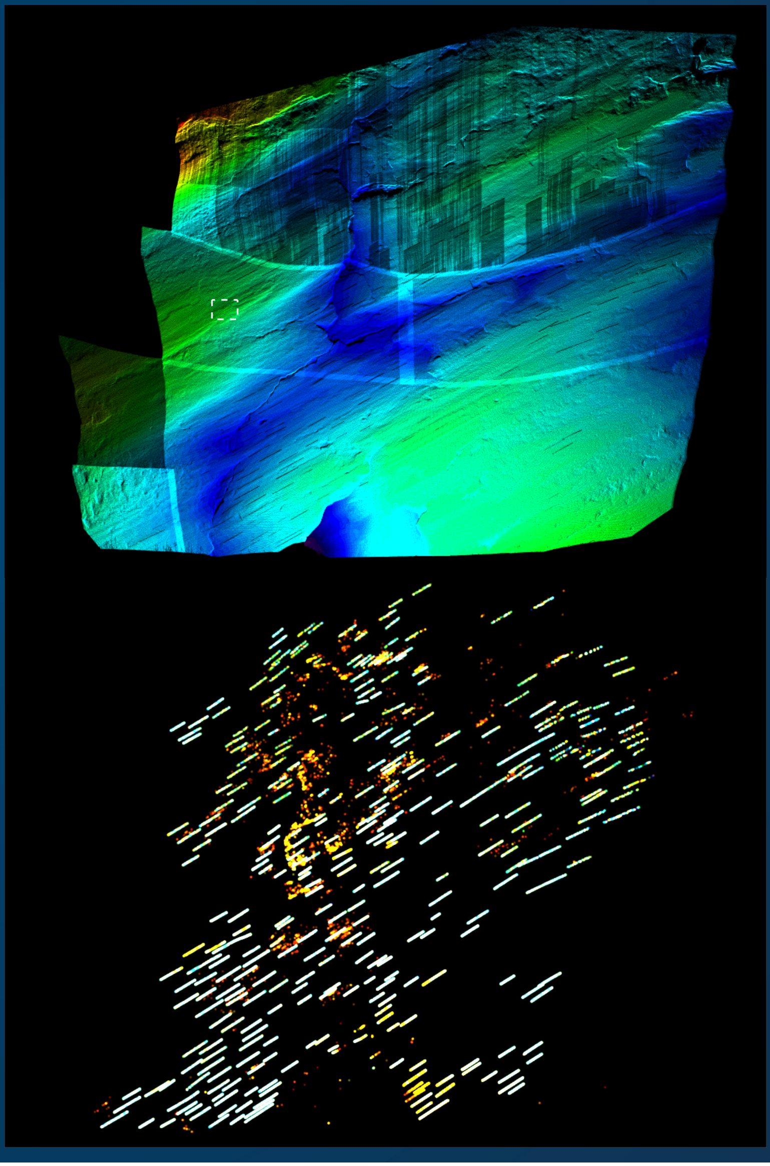
Fault roughness

- Power spectral density: $p(k) = Ck^{-\beta}$

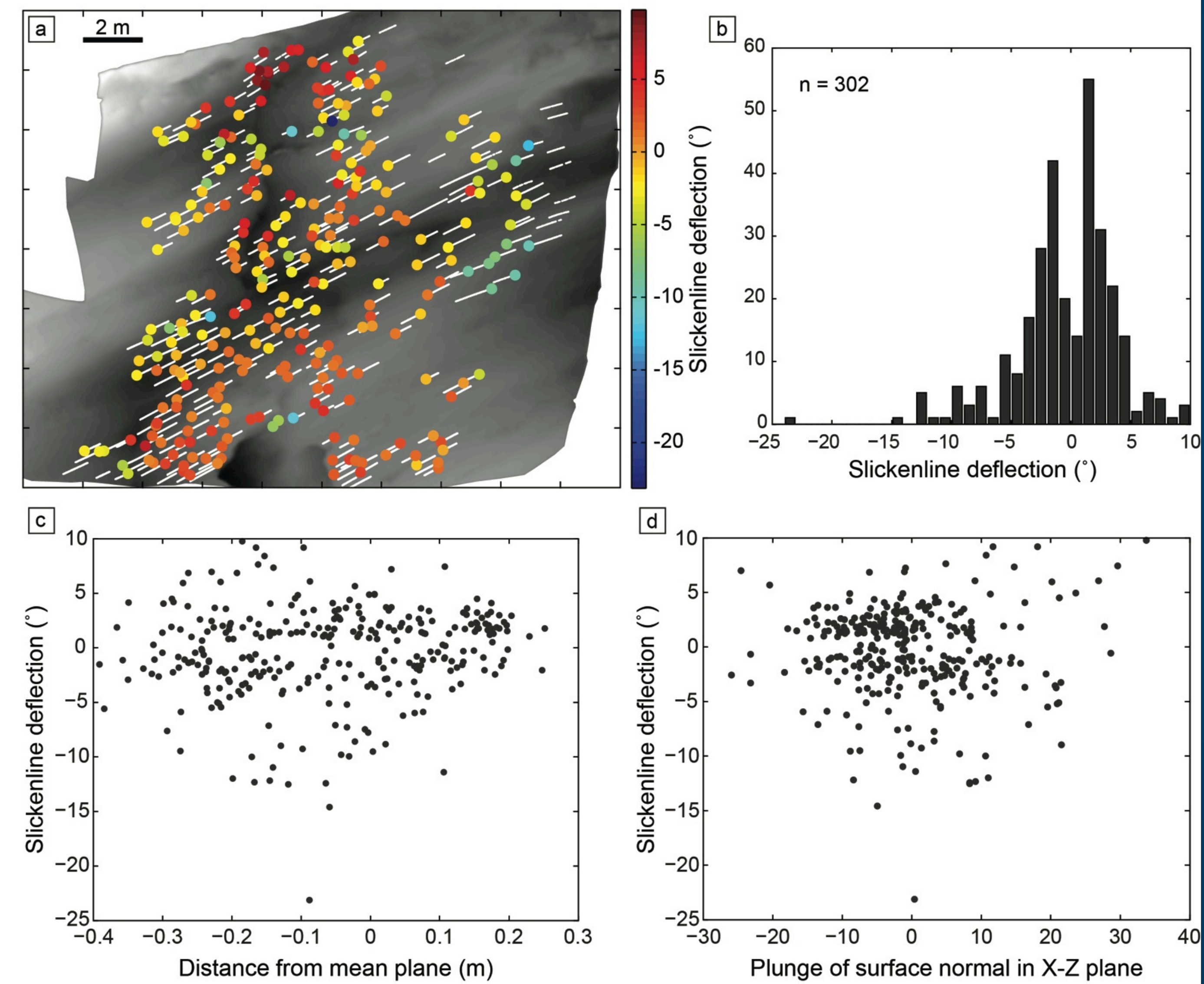




Slickenline measurements with TLS



Duct tape analysis

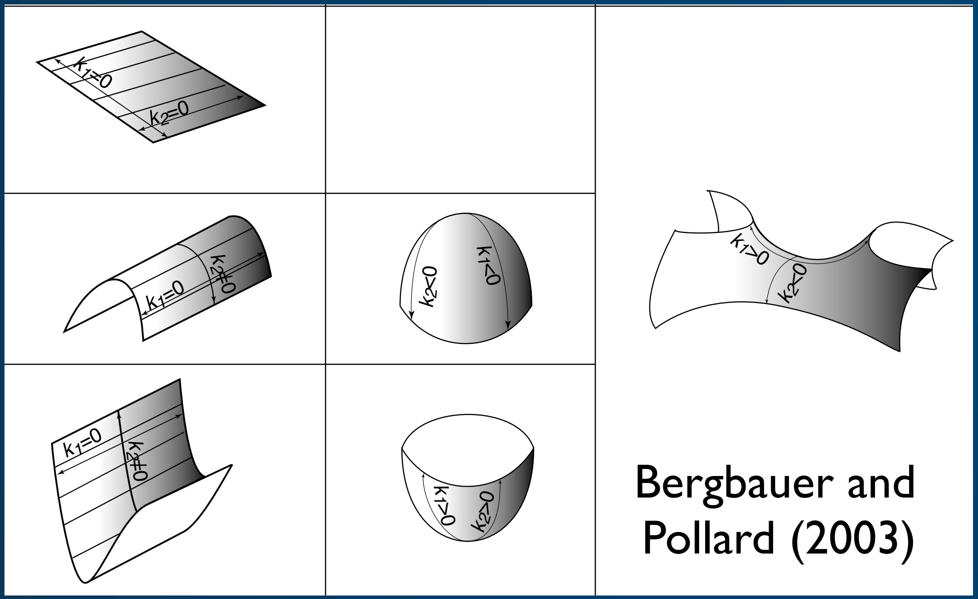


- Slickenline rake variation is ± 4° (1σ)
- No apparent correlation with surface geometry

Kirkpatrick and Brodsky, submitted

Slickenlines from curvature

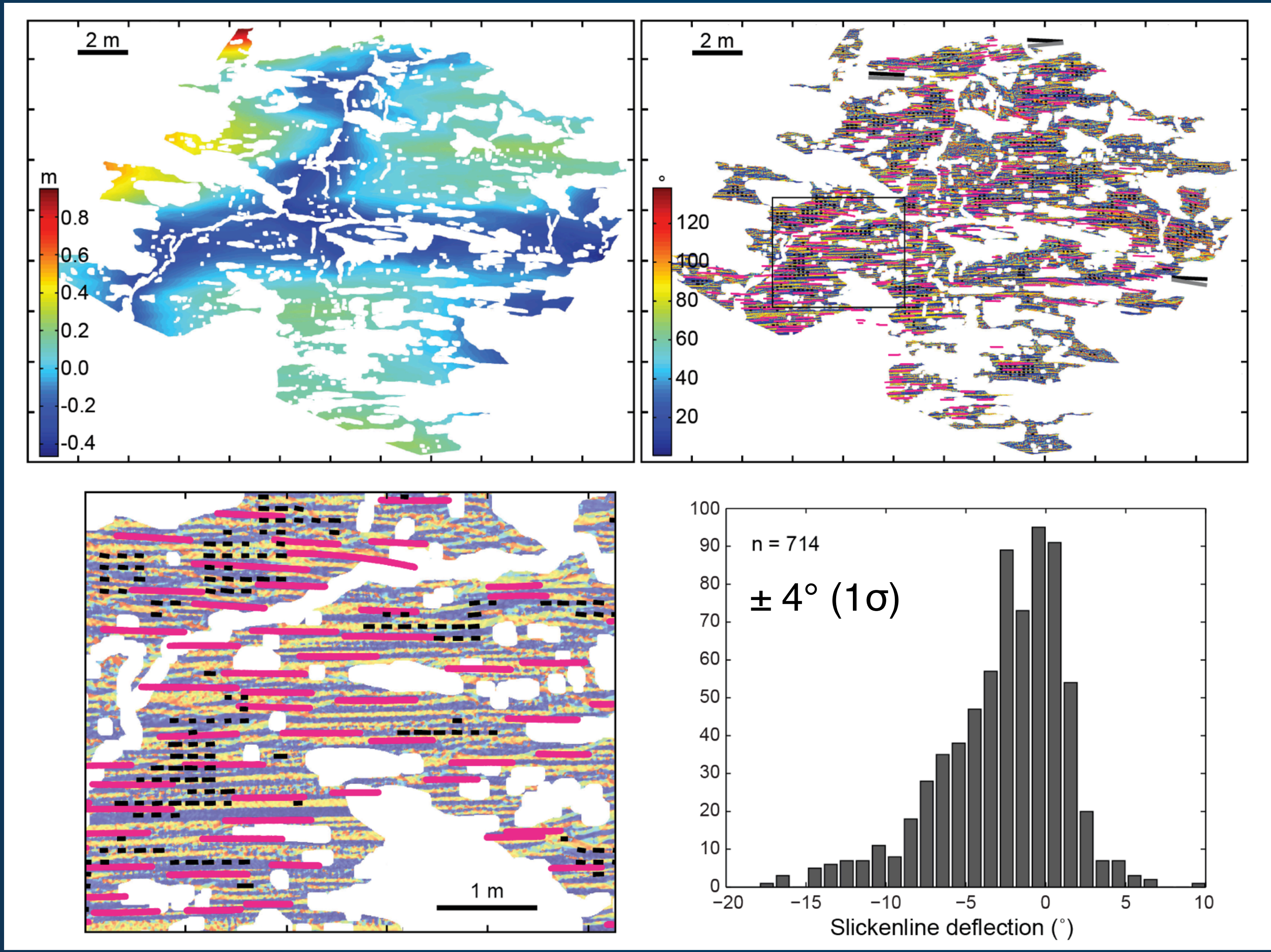
- Curvature defined by two principal curvatures



Bergbauer and Pollard (2003)

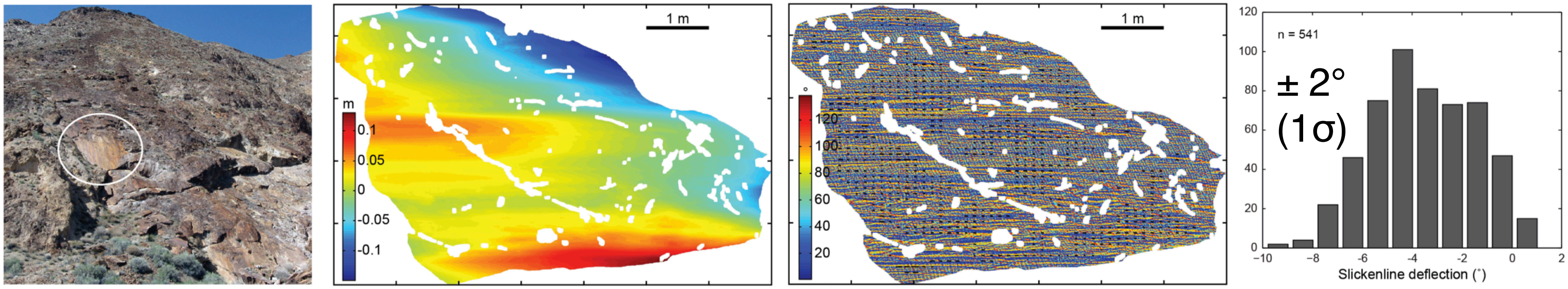
$$k_{n(\lambda)} = \frac{\mathrm{II}}{\mathrm{I}} = \frac{\beta_{xx} + 2\beta_{xy}\lambda + \beta_{yy}\lambda^2}{\alpha_{xx} + 2\alpha_{xy}\lambda + \alpha_{yy}\lambda^2}$$

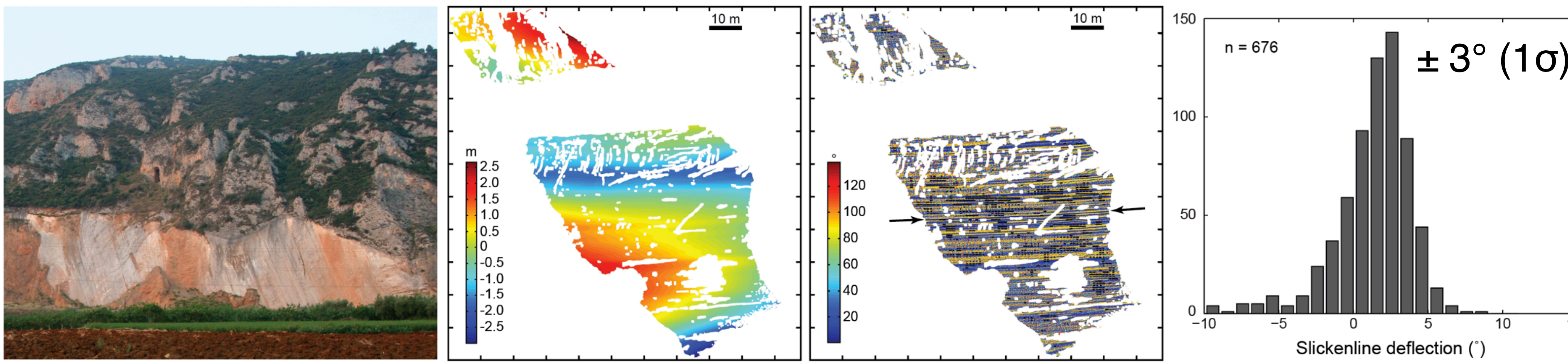
Slickenlines from curvature



Kirkpatrick and Brodsky, submitted

Slickenlines from curvature

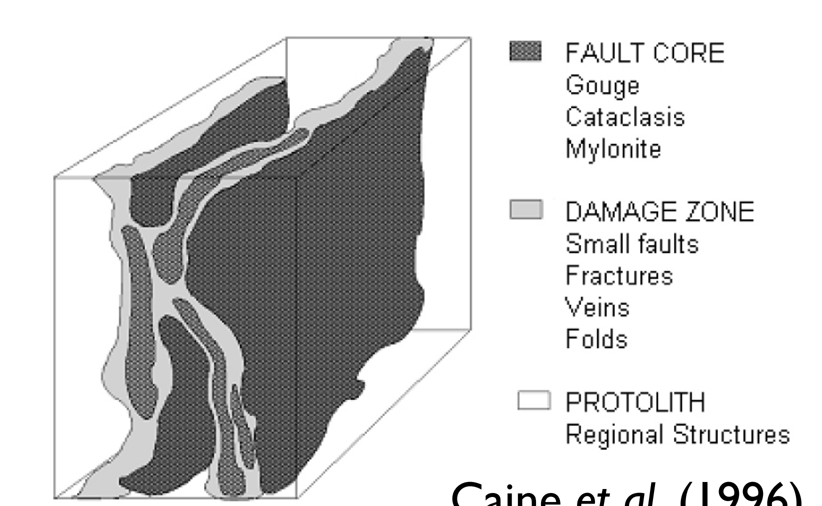




- **Observation**: Slickenlines orientations do not vary significantly over fault surfaces

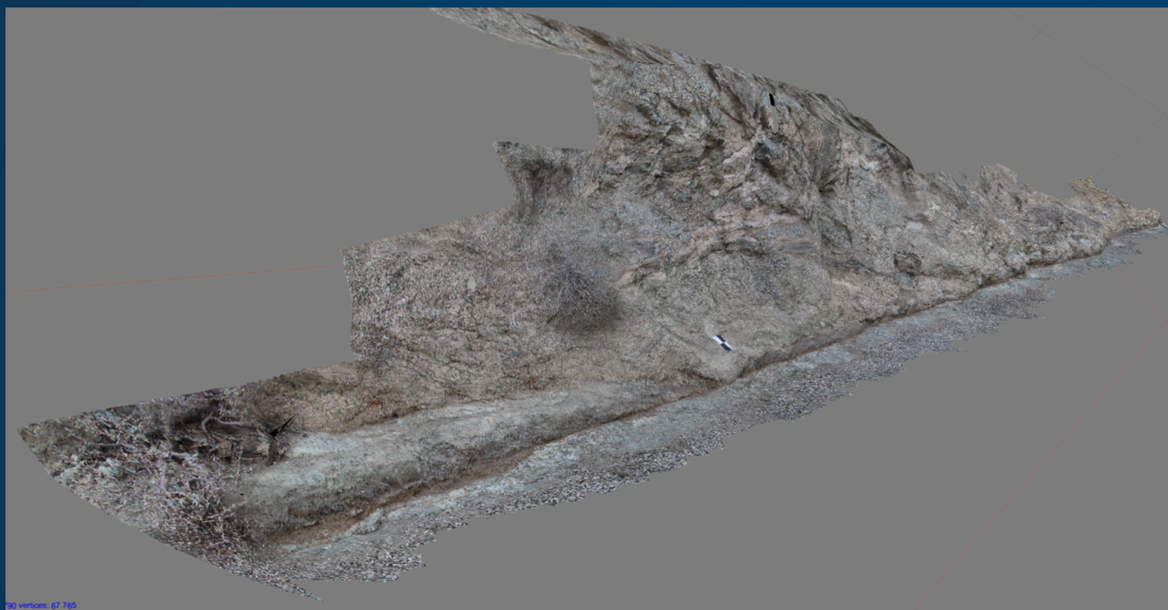
Fault cores

Can we predict wear processes from surface geometry?

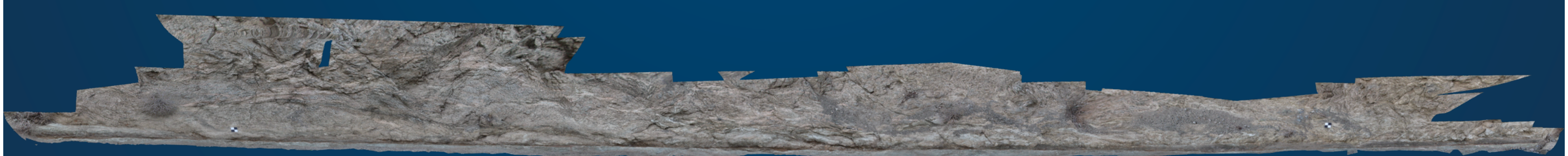


Caine *et al.* (1996)

Mapping fault core thickness



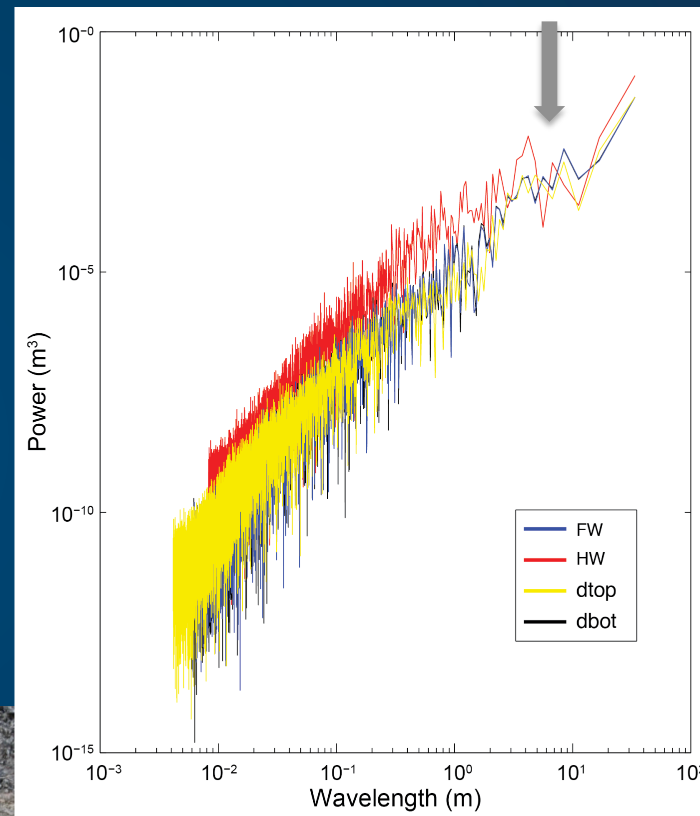
- Rectified images of the fault in the displacement direction from Agisoft PhotoScanPro

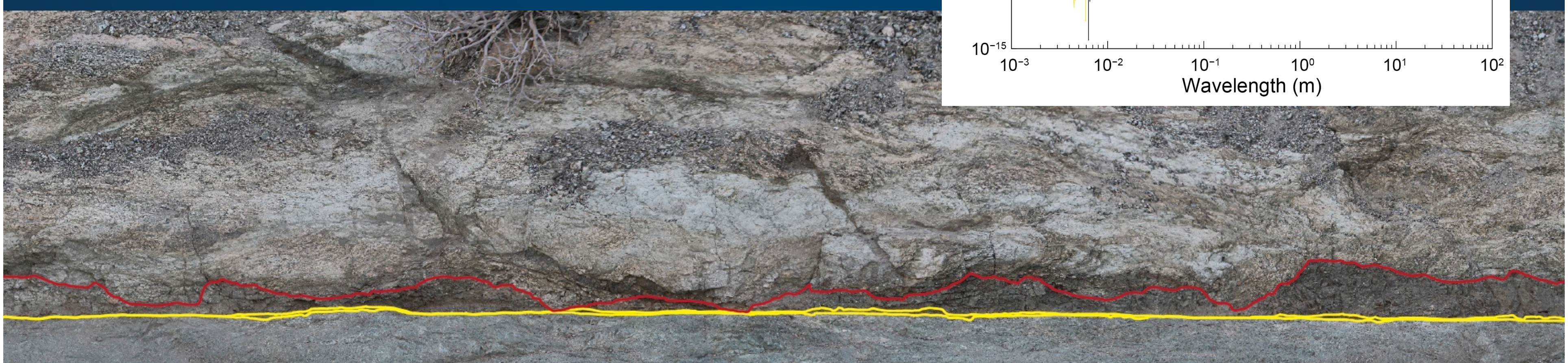


~35 m

Wear from fault core geometry

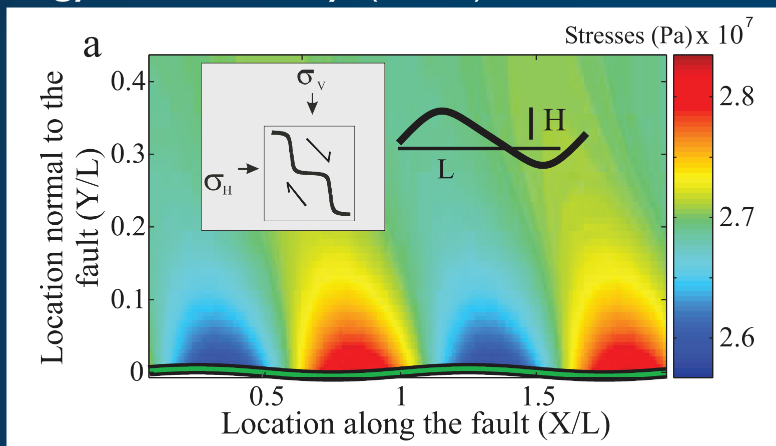
- Cross cutting relationships show the yellow layer is more recent
- The more recent layer is smoother



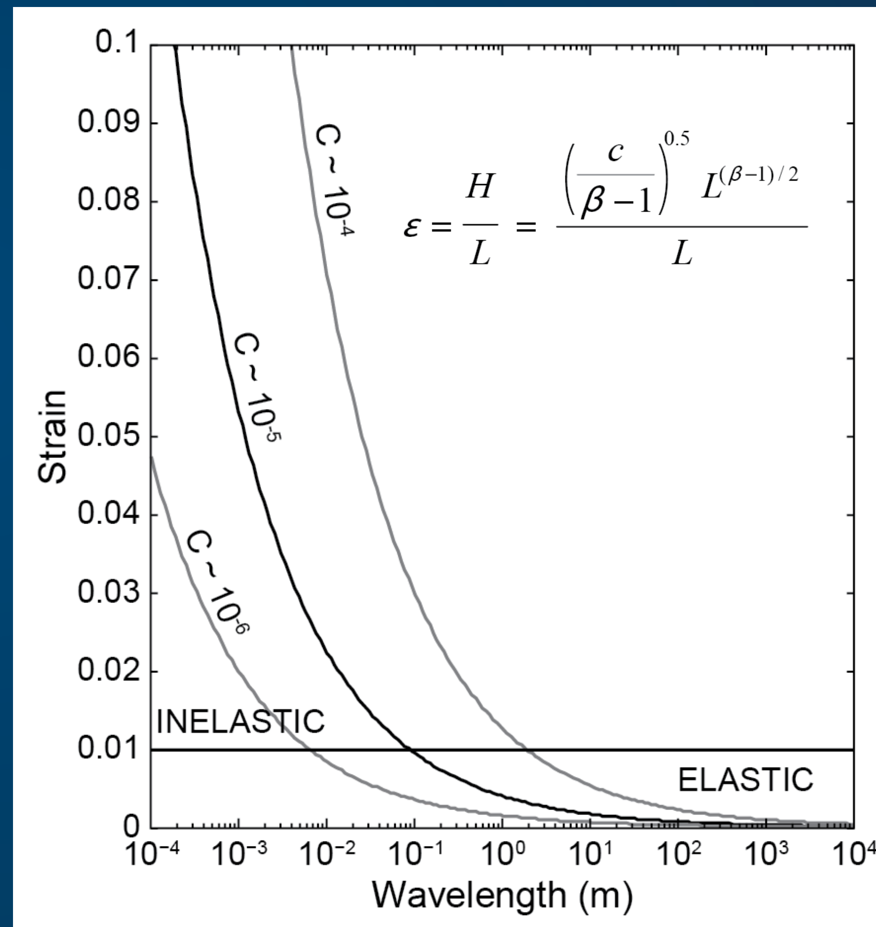


What happens to a fault surface?

Sagy and Brodsky (2009)



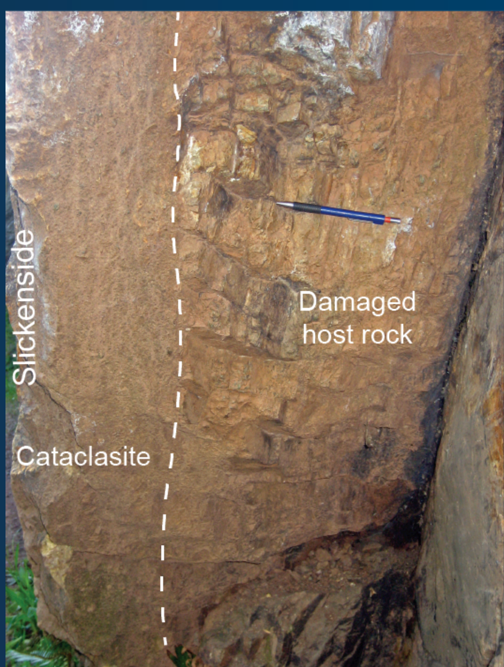
- Strain of asperities for slip scales inversely with wavelength
- The cross over length scale corresponds to the thickness of fault rock



Kirkpatrick and Brodsky, submitted

Wear products and processes

- Largest clasts in the gouge are slivers ripped off from the wall rocks – single asperity failure?
- Fault rock thickness corresponds to cross



Summary

1. Fault surface shear tractions vary spatially, but slip directions do not
2. Fault core thickness shows wear is faster at short wavelengths
3. A cross over from inelastic to elastic deformation defines the scale of strength asperities on faults
4. Fault surface shape imposes scale-dependent wear during slip