How Deep Below the Seismogenic Zone do Large Earthquakes Rupture?

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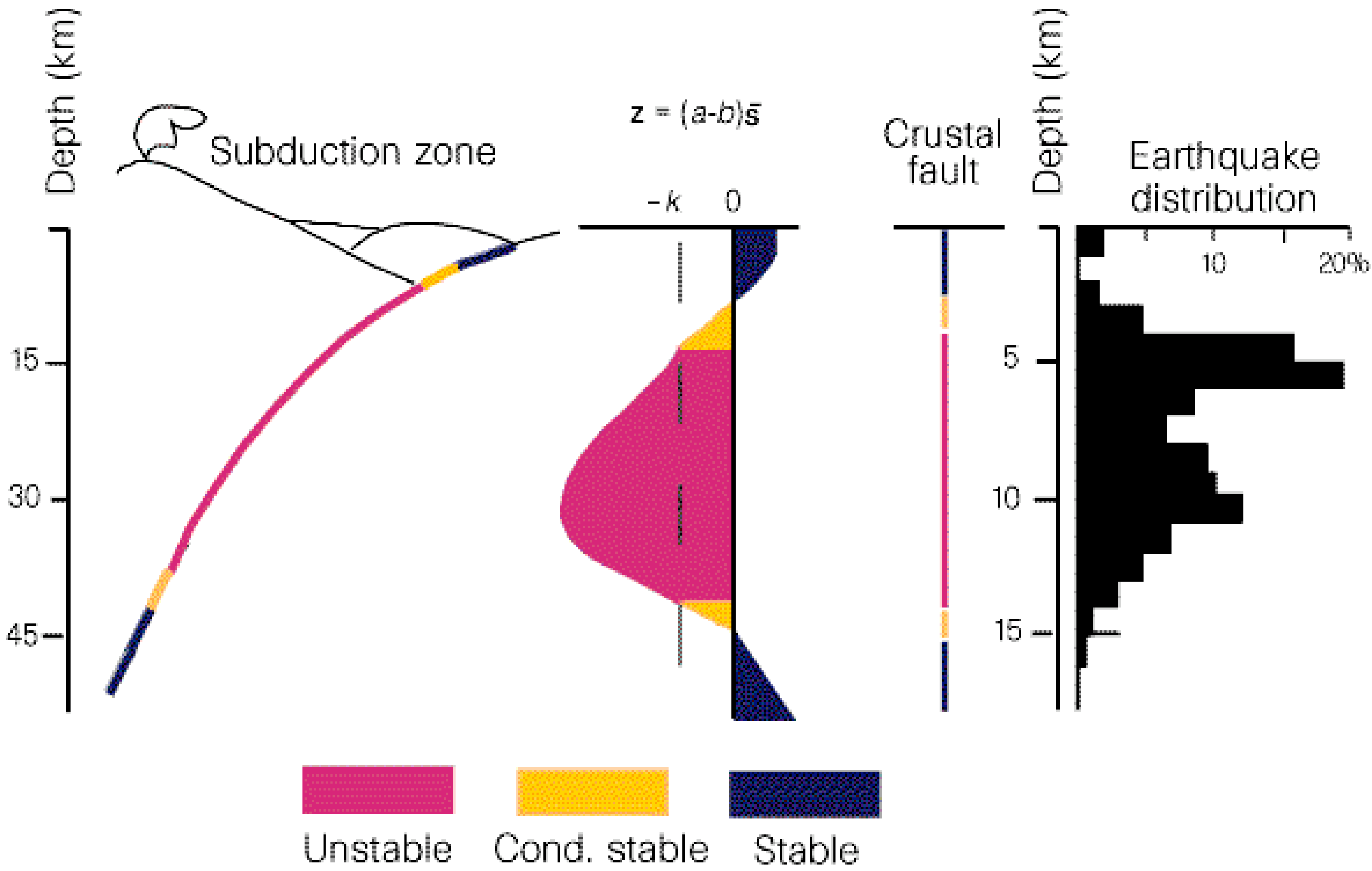
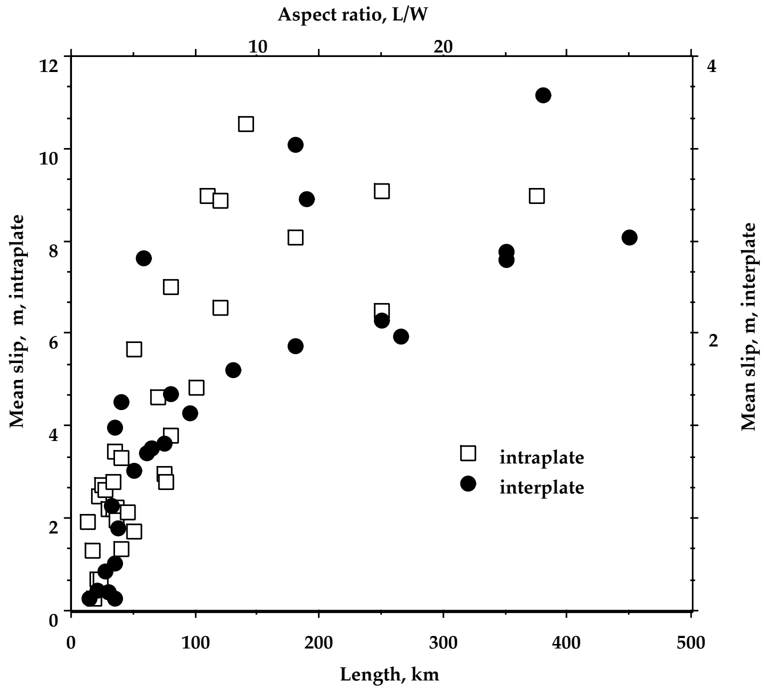
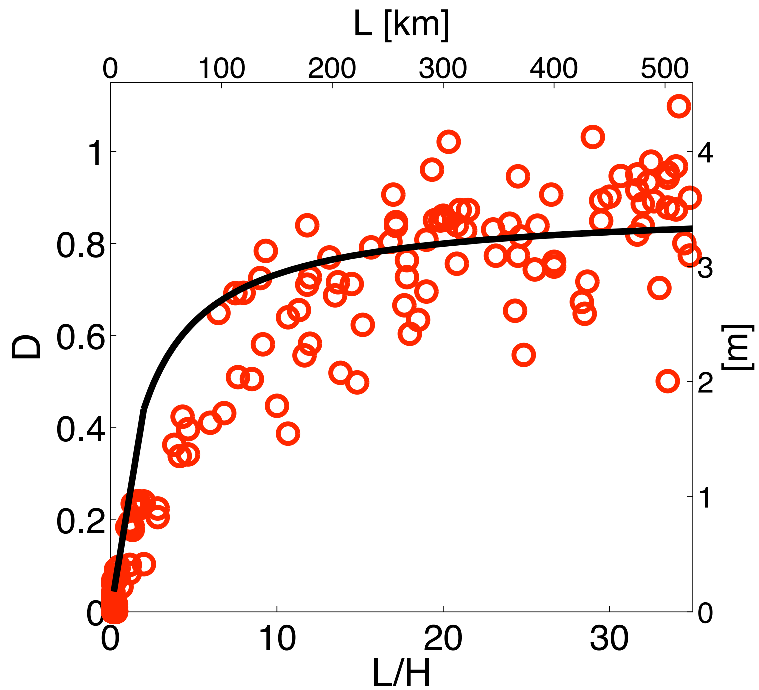
Faults and Stability of Sliding



[Scholz, 1998]

Slip-Length Scaling





Slip

Length / H

Slip

Length / H

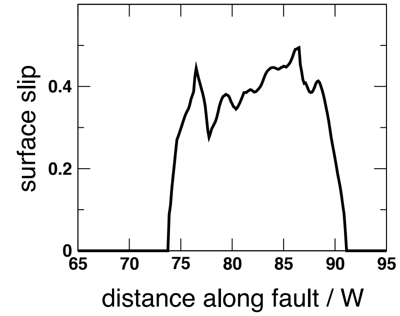
Earthquakes

Model

[Shaw and Scholz, 2001]

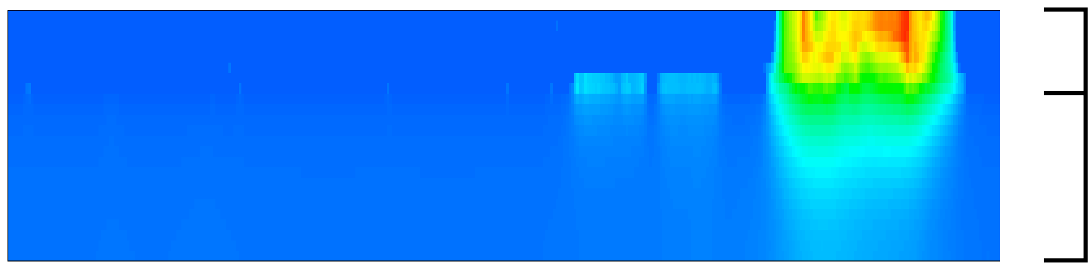
3D Model

surface slip

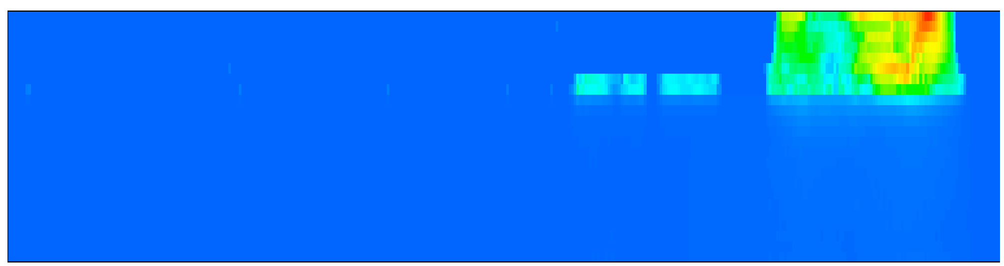


vertical exaggeration 8:1

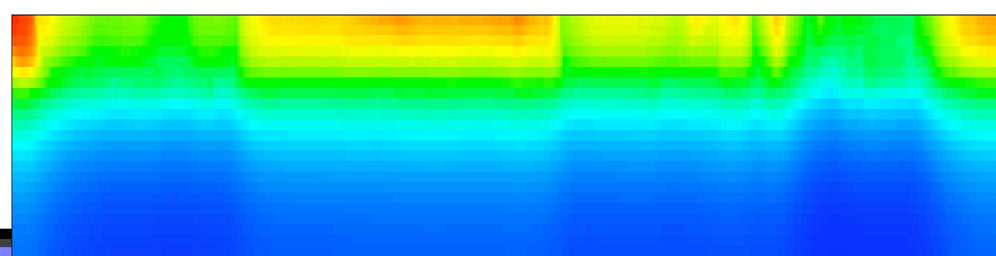
slip



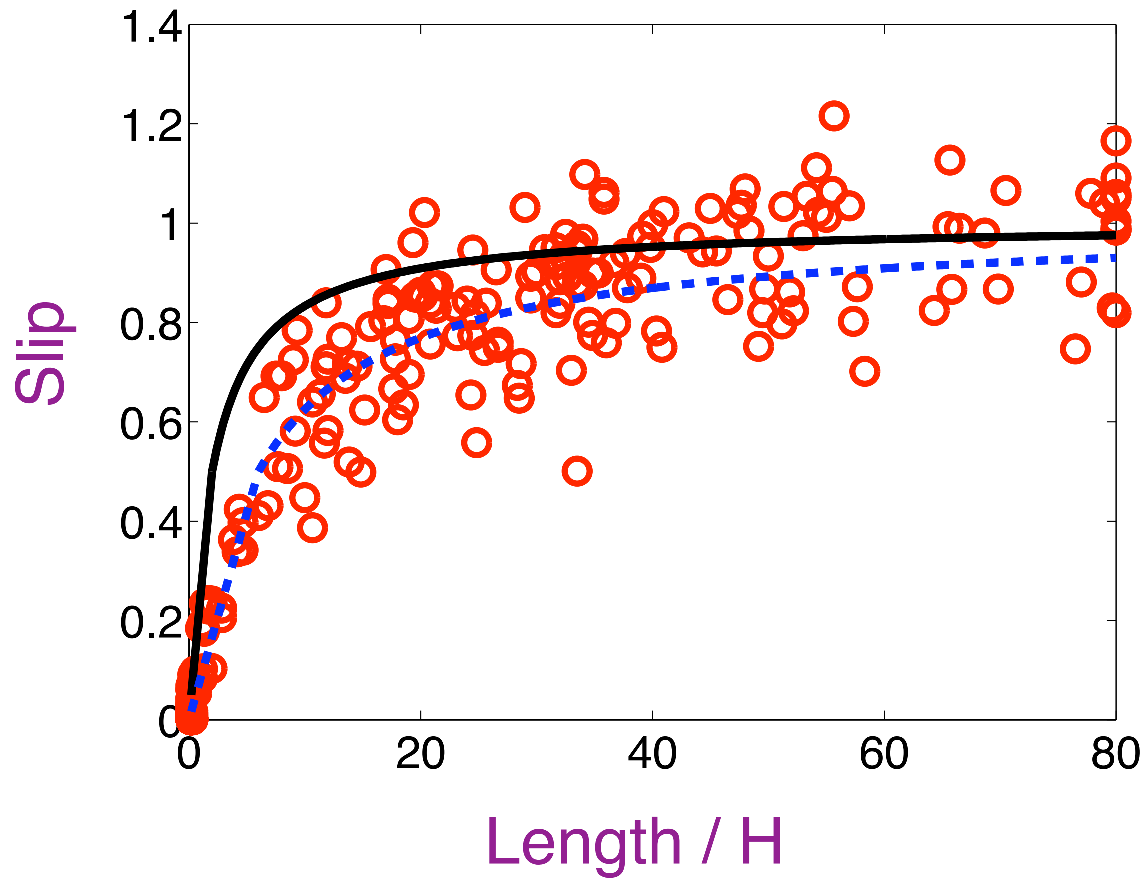
peak velocity



initial displacement

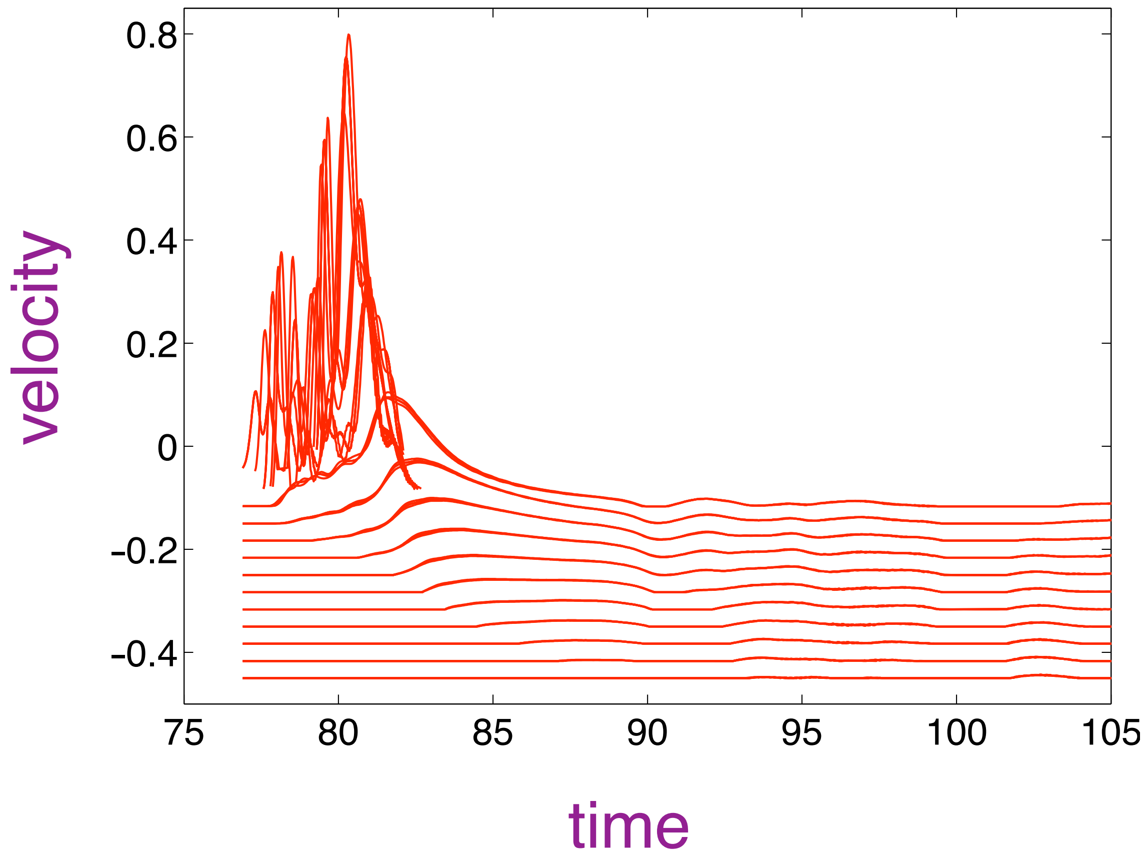


Slip-Length Scaling



- Blue dashed line fit for $W = 3H$ [H≡seismogenic depth]

Velocities During Slip Events



- High and low frequencies at seismogenic depths
- Only low frequencies below seismogenic depths
- *Coseismic* slip at depth

GPS Inversion Ambiguity

1836 G. C. P. King and S. G. Wesnousky

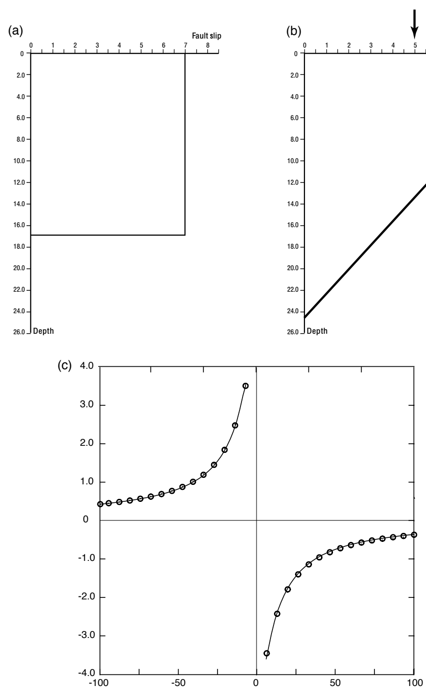
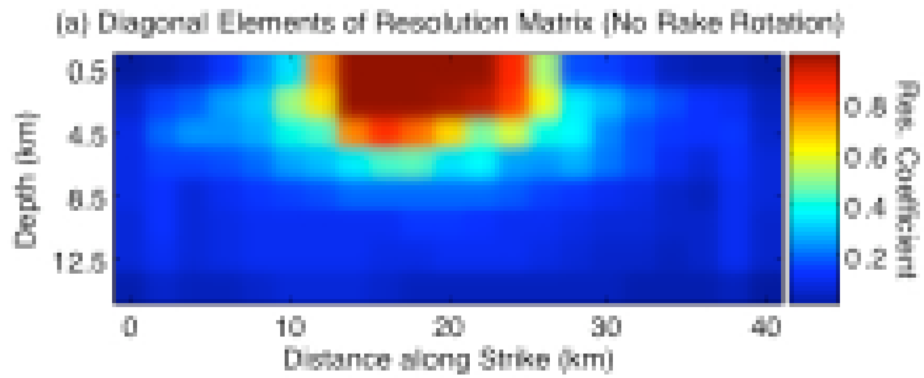


Figure 5. The (a) box and (b) tapered displacement functions produce (c) the same deformation field (circles and lines) at the earth's surface. The vertical axis is meters of surface displacement, and the horizontal axis is distance in kilometers from the fault. The downward pointing arrow indicates the average value of slip for the tapered function.



[King and Wesnousky, 2007]

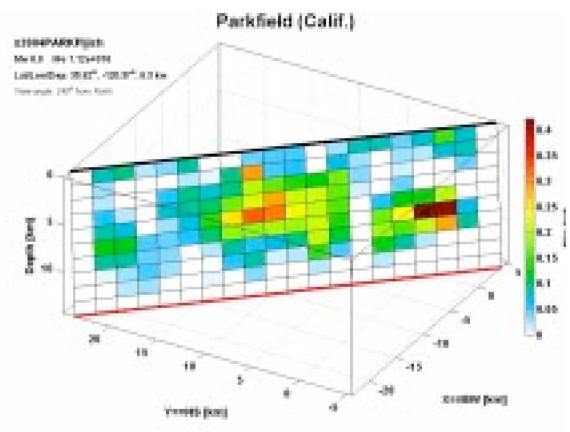
[Page et al, 2008]

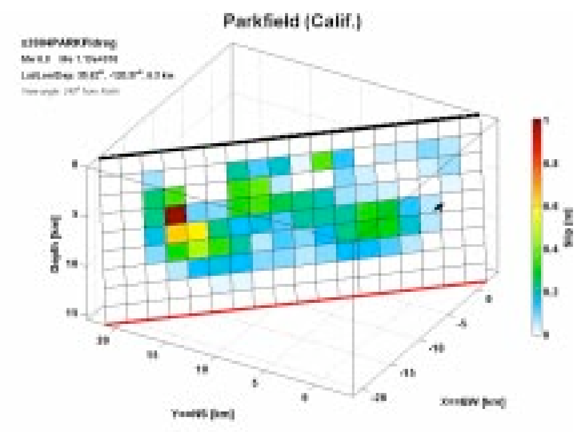
Ambiguous depth resolution

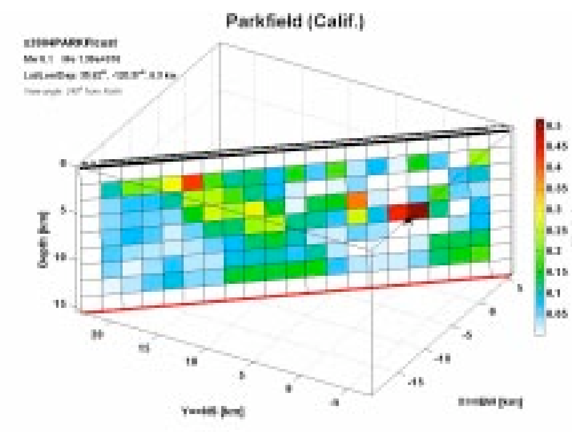
Poor resolution for Parkfield

Seismic Inversion Ambiguity

Inversions for slip in 2004 M6.0 Parkfield earthquake
(images from [Mai, 2007] database)



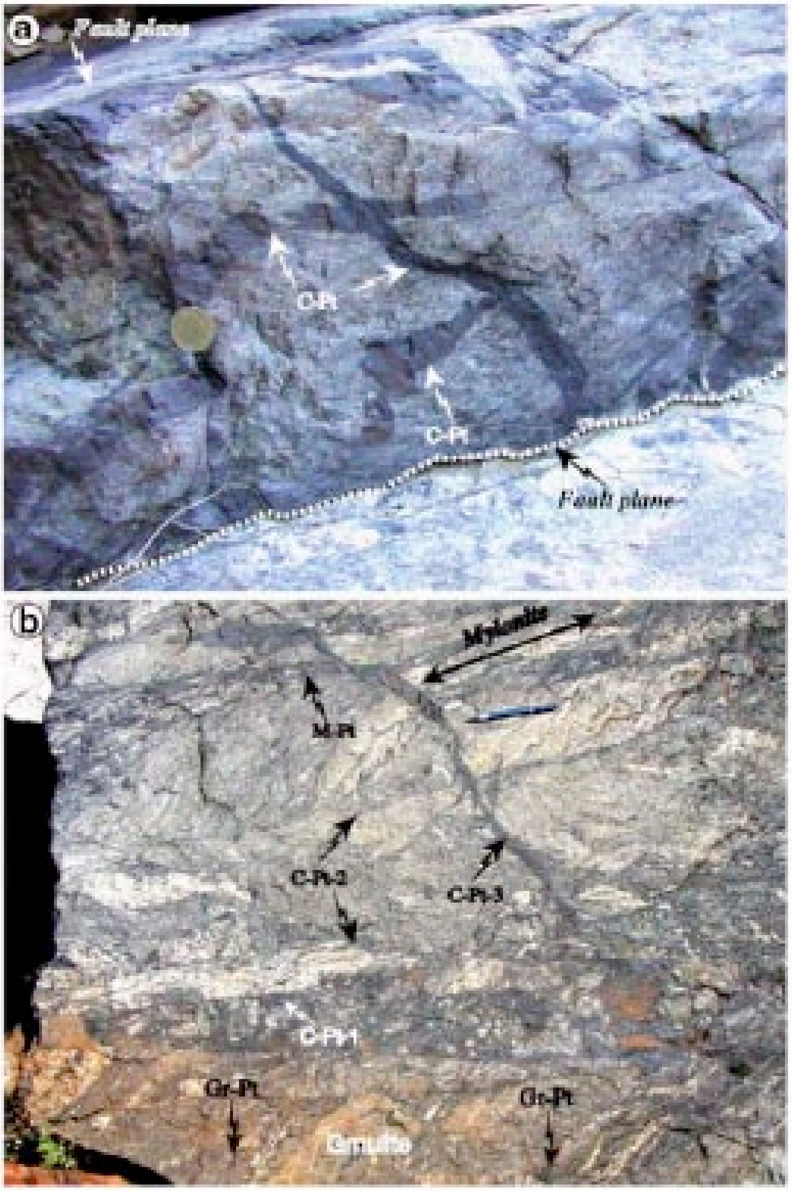




- Big differences even in extremely well networked event

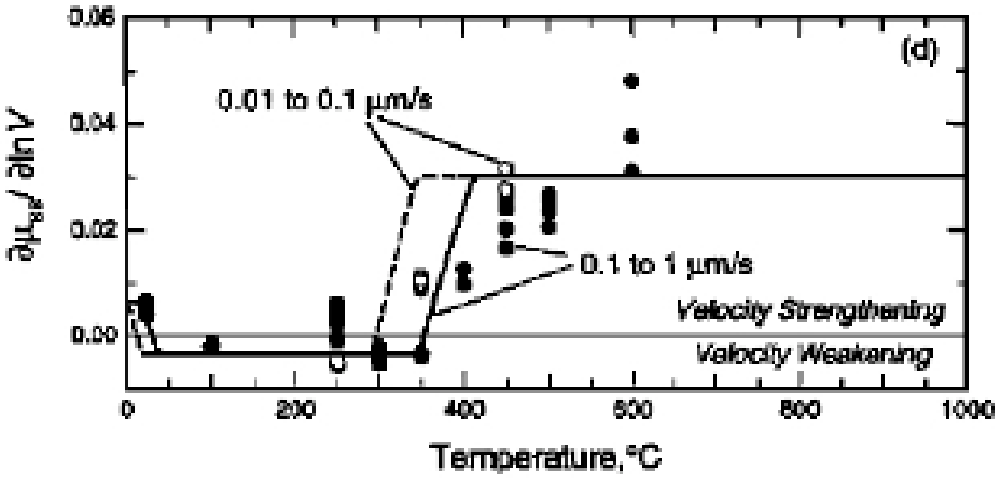
Exhumed Rocks: Fast Deep Slip

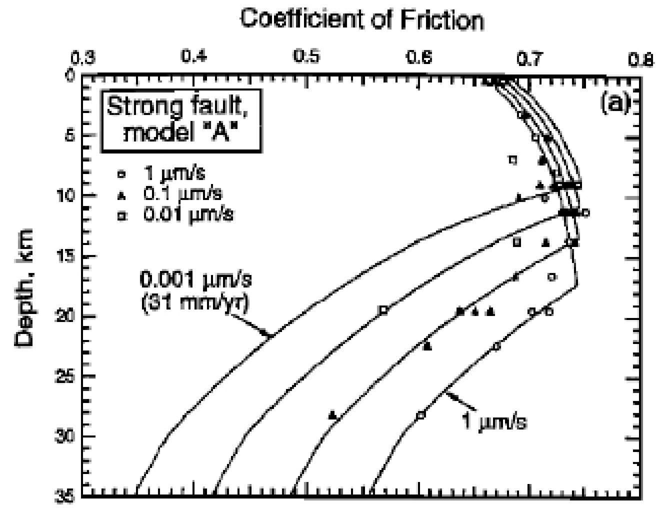
from Pseudotachylytes Crosscutting Mylonites



[Lin, 2008]

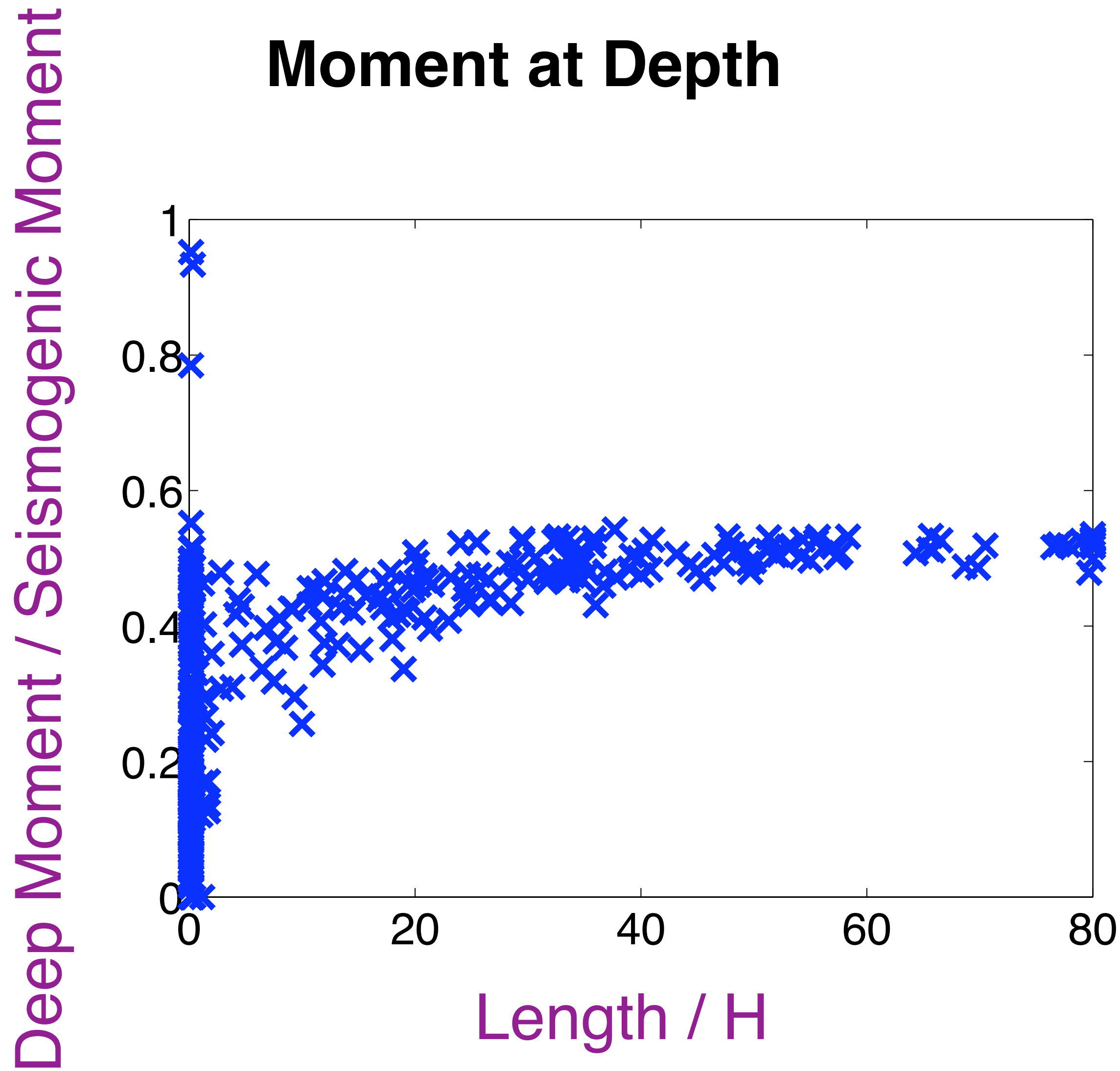
Sliding Rate Effect on Lab Friction





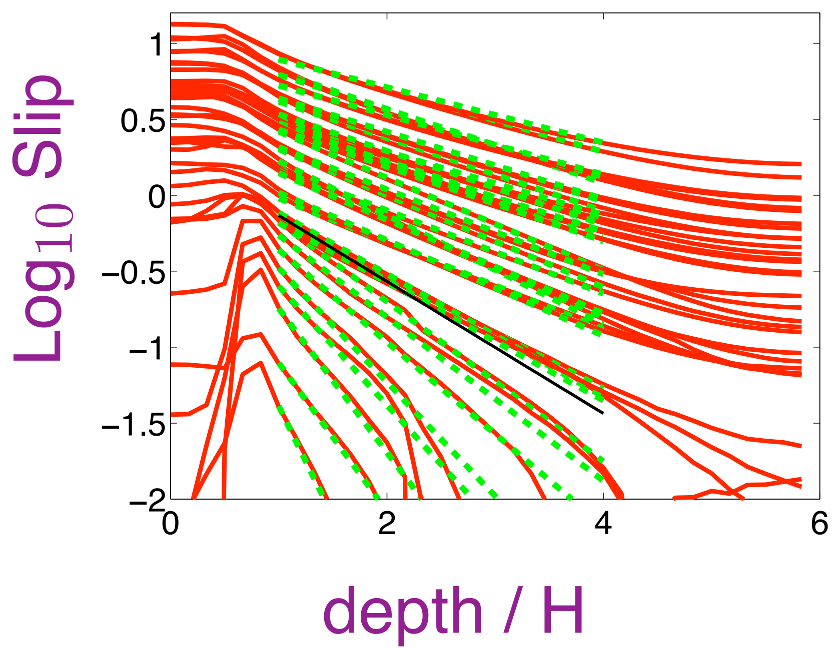
[Blanpied et al, 1995]

- Unstable sliding deepens at faster sliding rates
- Potentially big effect

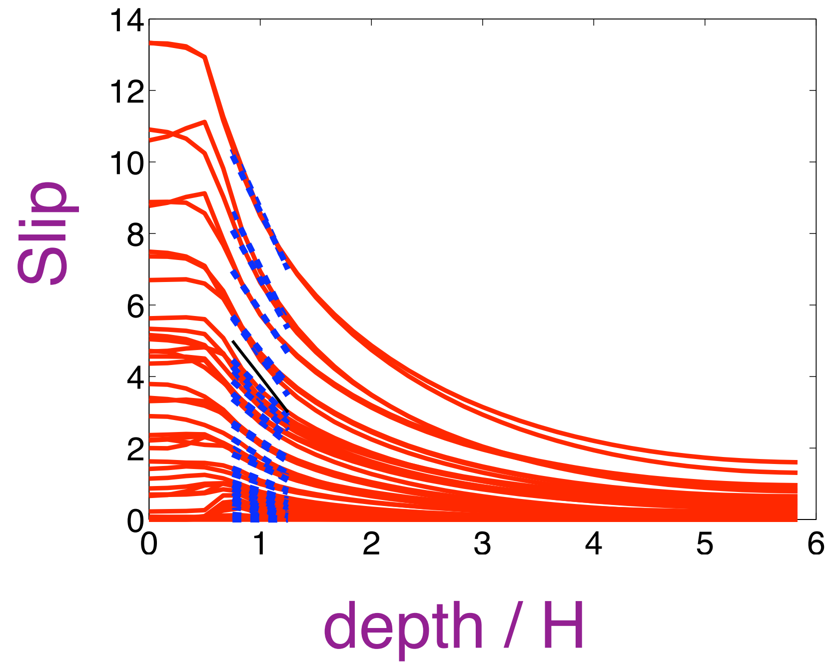


- Half of seismogenic moment, or $1/3$ total moment at depth

Effective Rupture Width: Extrapolate to zero slip

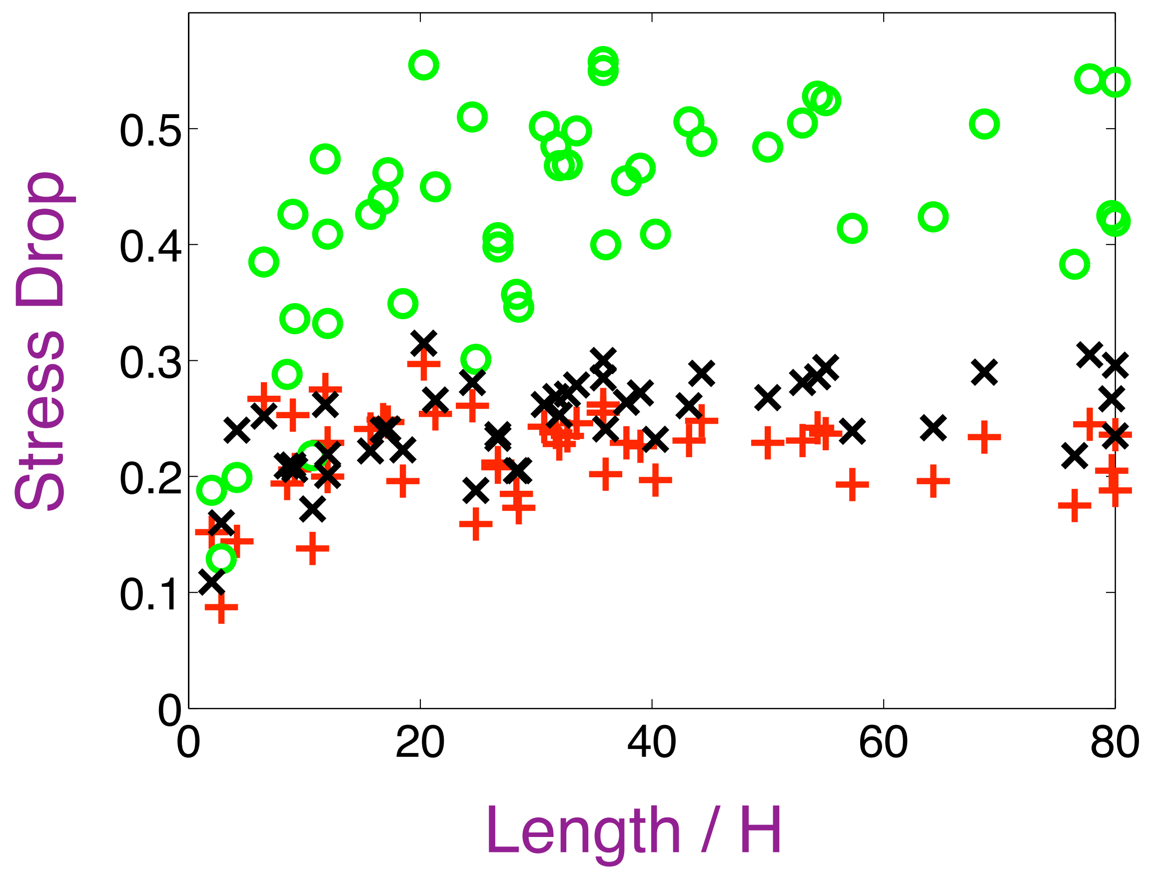


Logarithmic fit



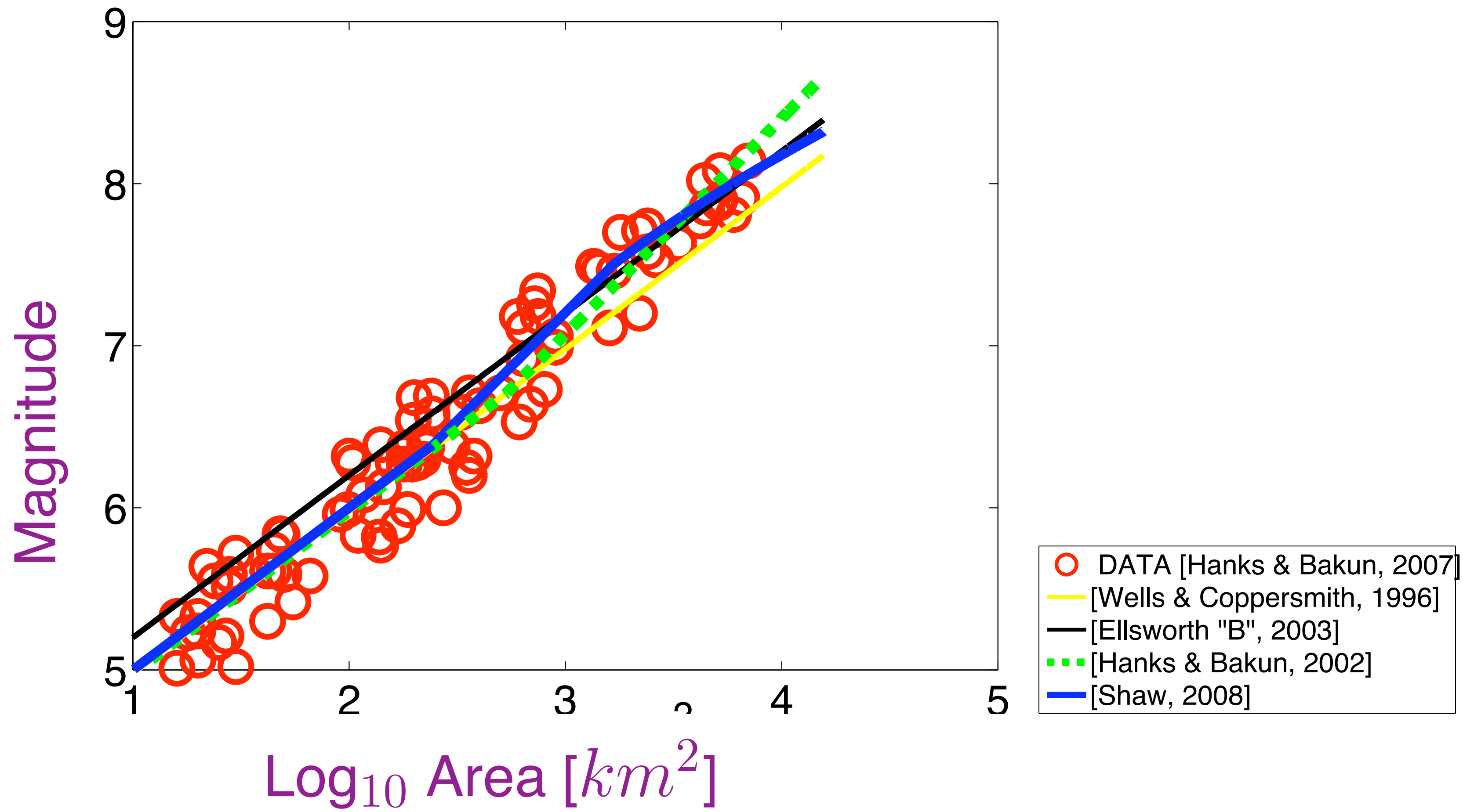
Linear fit

Stress Drop



- Macroscopic estimates with Effective W (+) matches directly measured (**x**) stress drop

Magnitude-Area Scaling [Shaw, 2007]



$$m = log_{10} A + \frac{2}{3}\log_{10}\frac{\text{max}(1,\sqrt{\frac{A}{H^2}})}{(1+\text{max}(1,\frac{A}{H^2\beta}))/2} + const$$

- Constant stress drop scaling across whole magnitude range
- Best fit parameters $H = 15km, \beta = 6.9 \rightarrow W \sim 35km$

Conclusions

- Geological, Seismological, Geodetic, Laboratory Observations allow deep slip, but do not require it
- Theoretical work suggests it may be occuring
- Direct observations needed: Perhaps subduction zones?