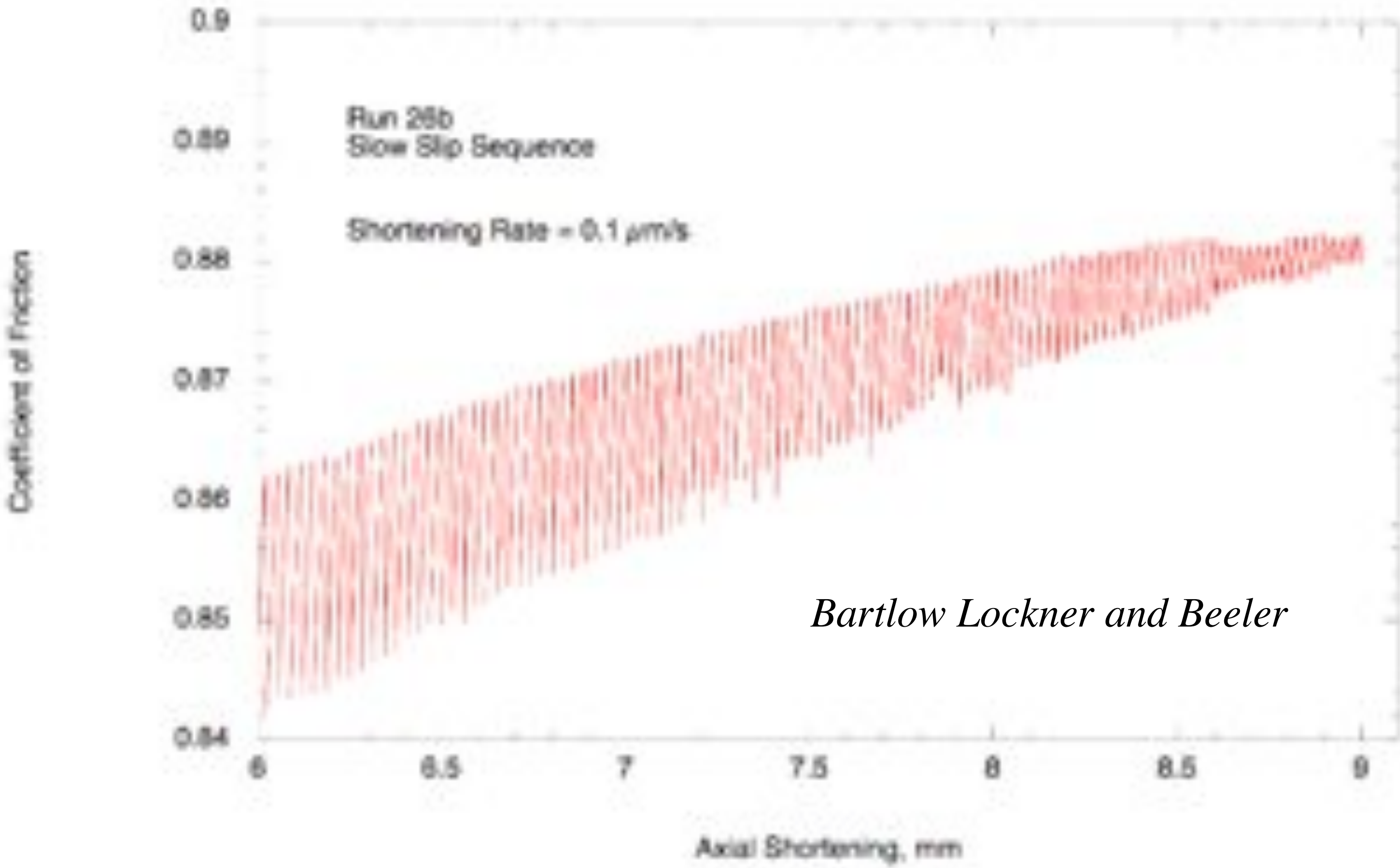
# ***Revisiting lab observations of the deep stable-unstable faulting transition, dilatancy, and the poromechanics of fault zones*** *- Earthscope Mtg Portland - 10/2010*

***Nick Beeler, David Lockner****, US Geological Survey*
***Noel Bartlow****, Department of Geophysics, Stanford University*




*Bartlow Lockner and Beeler*

## ***Revisiting lab observations relevant to deep periodic rapid slip and tremor***

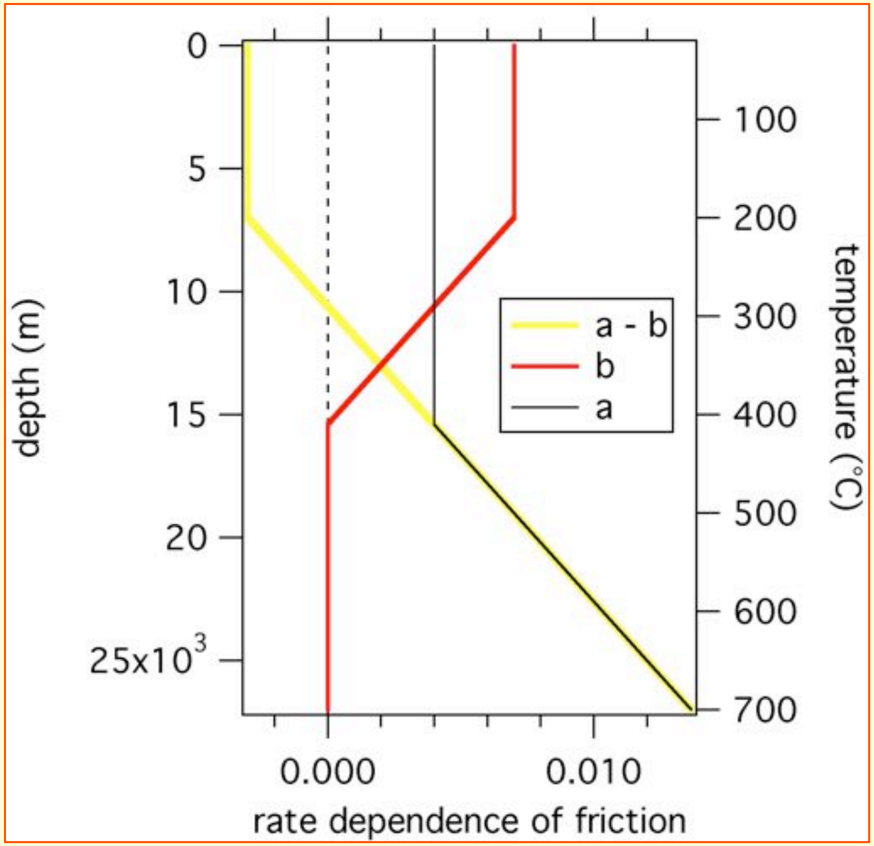
1) *the deep stable - unstable friction transition*
   *-rate dependence*

2) *the high speed cutoff - what is it (what it is)*
   *-expectations at high temperature*
   *-implications for dilatancy*

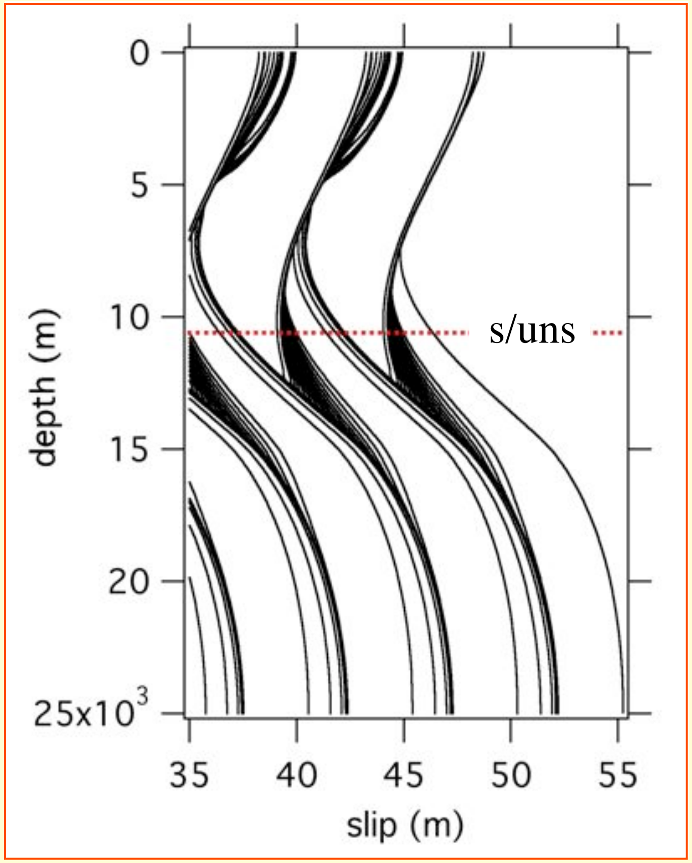
3) *stress- slip - dilatancy relations*
   *- inconsistencies*
   *- near failure behavior*
   *- poroelastic effects?*

4) *new experiments - failure with pore pressure + slow slip events in the lab*

*what does friction rate dependence have to do with the extent of the transition zone?*



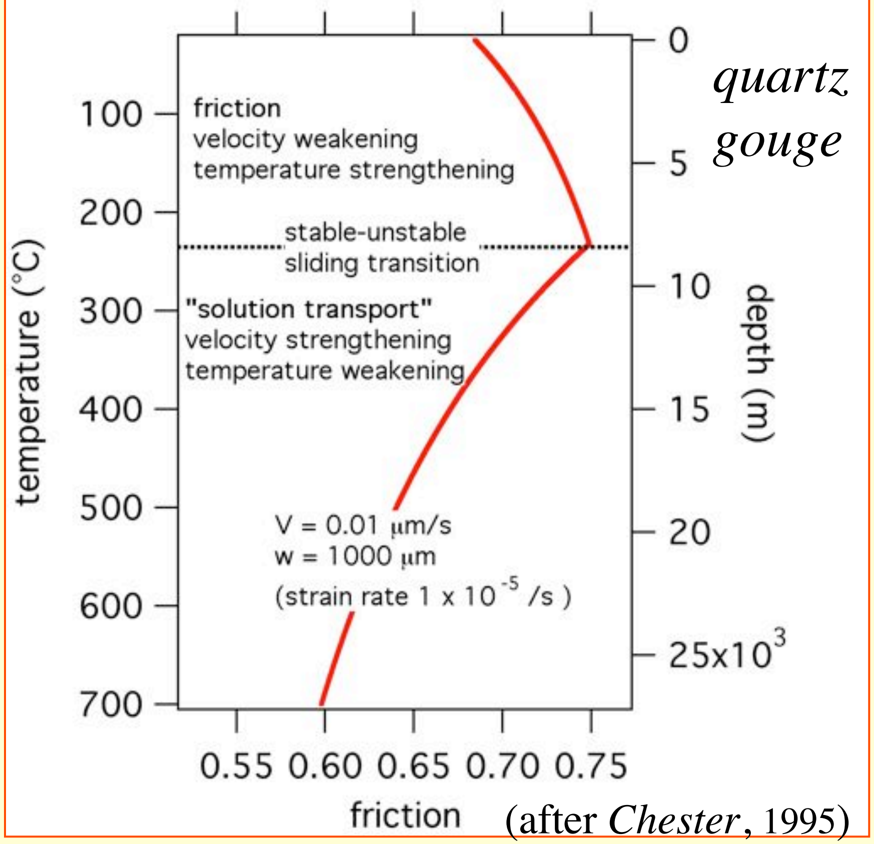

(*Stetsky*, 1978; *Tse and Rice*, 1986)



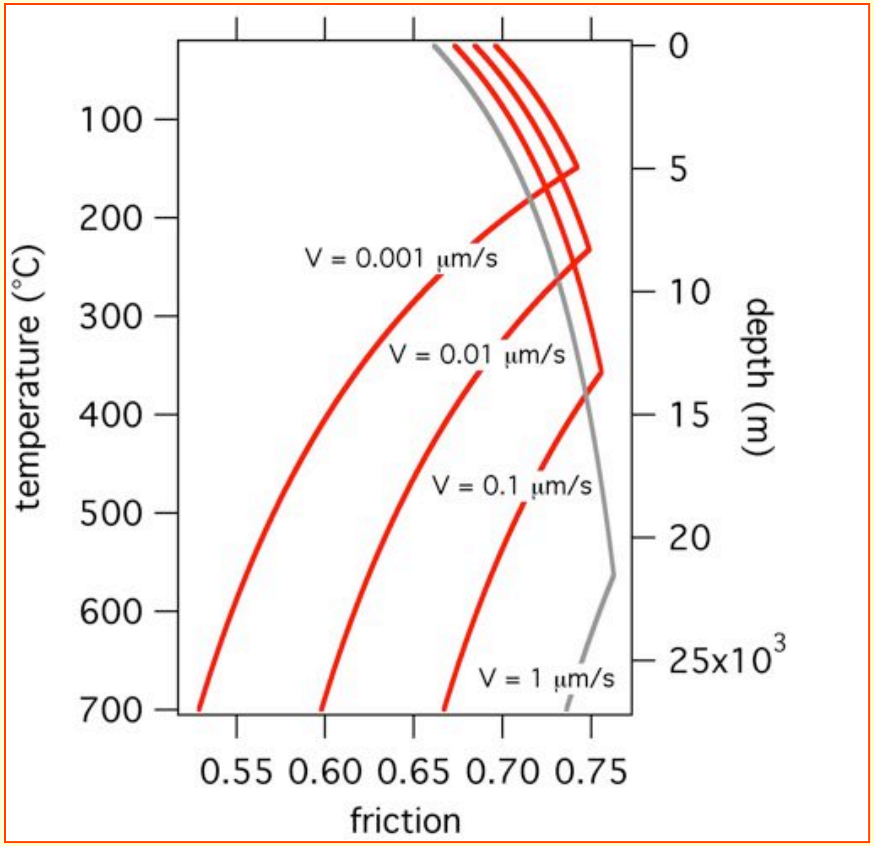

(after *Tse and Rice*, 1986)

• *'a transition zone' is between s/uns boundary and 'completely plastic' (b=0) - defines deep extent of large rupture)*

• *in the context of rate dependent friction, tremor and deep slip require negative rate dependence, at great depth* *are our models of rate and temperature dependent friction an over-simplificiation of the lab data?*

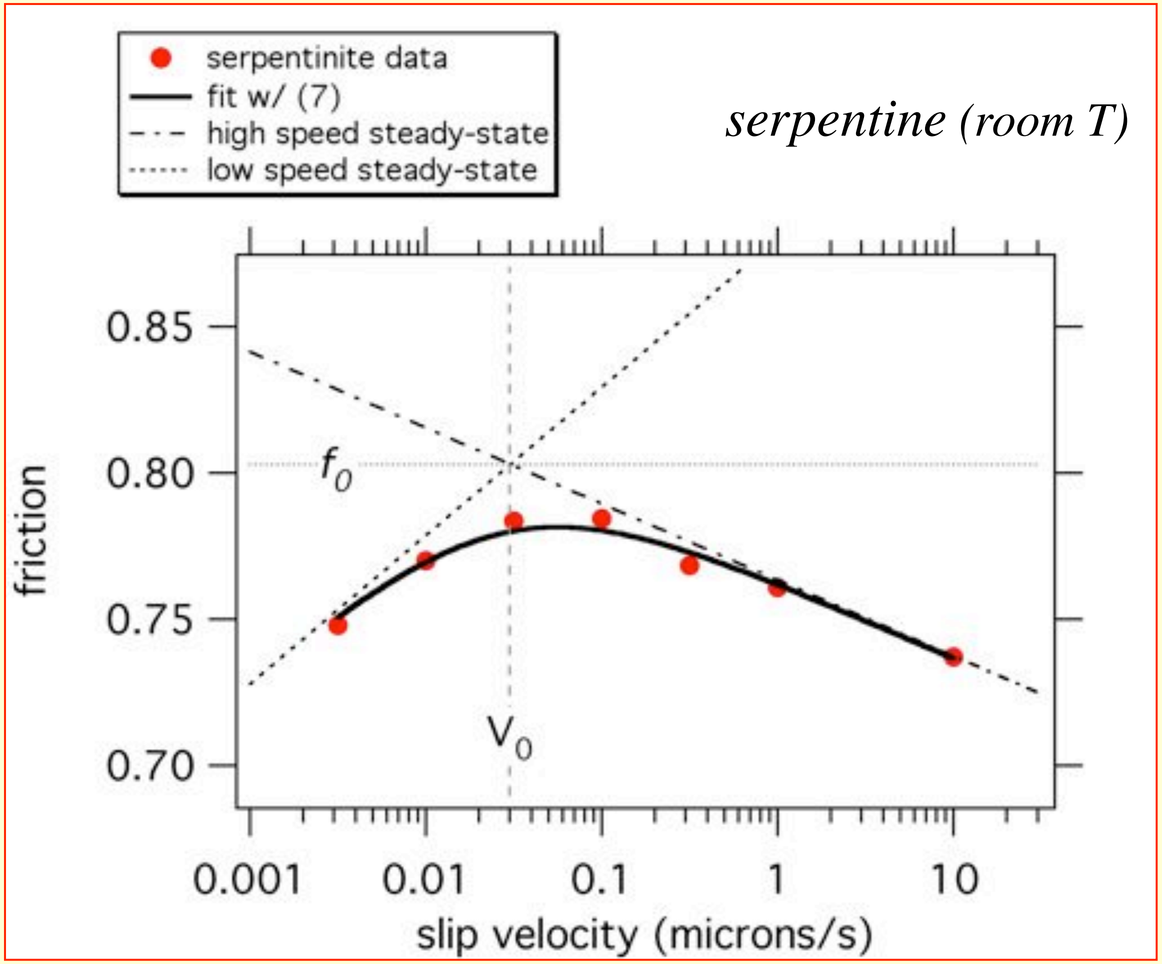



(after *Chester*, 1995)




- *s/uns transition depth depends on velocity - this is one way to produce deep, transient brittle behavior*

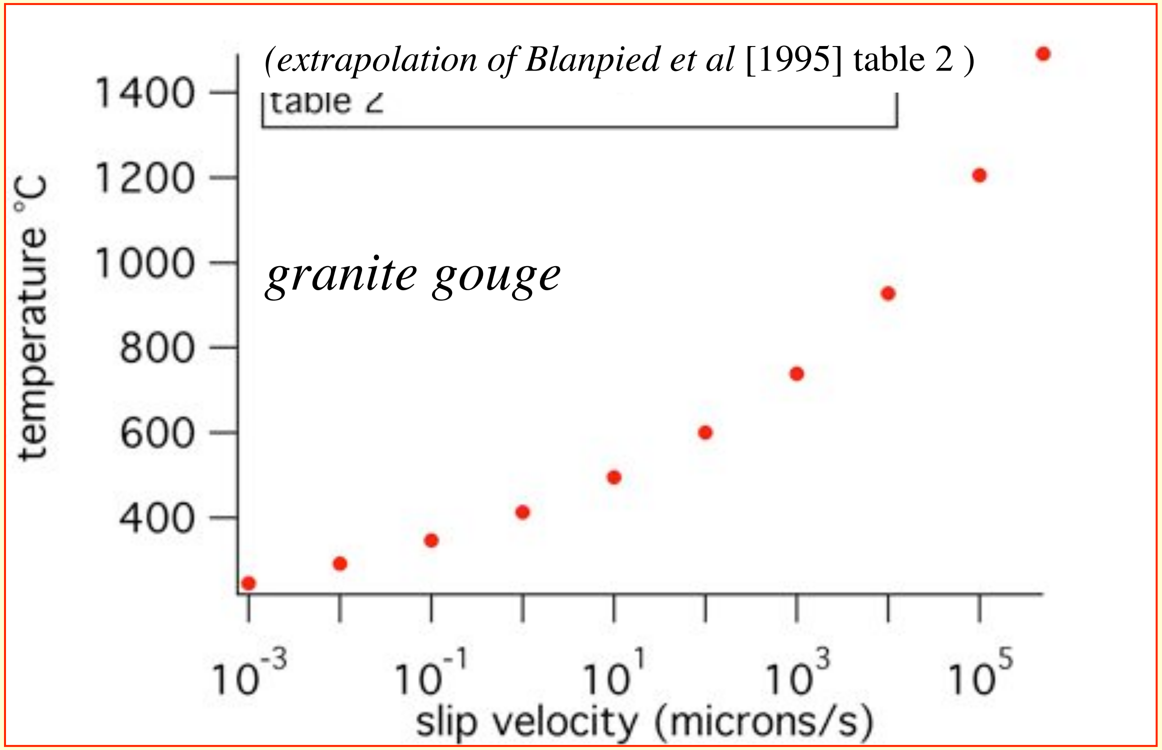
***The s/us low speed transition to rate strengthening (2 mechanisms)***




(data from *Reinen et al*. 1994)

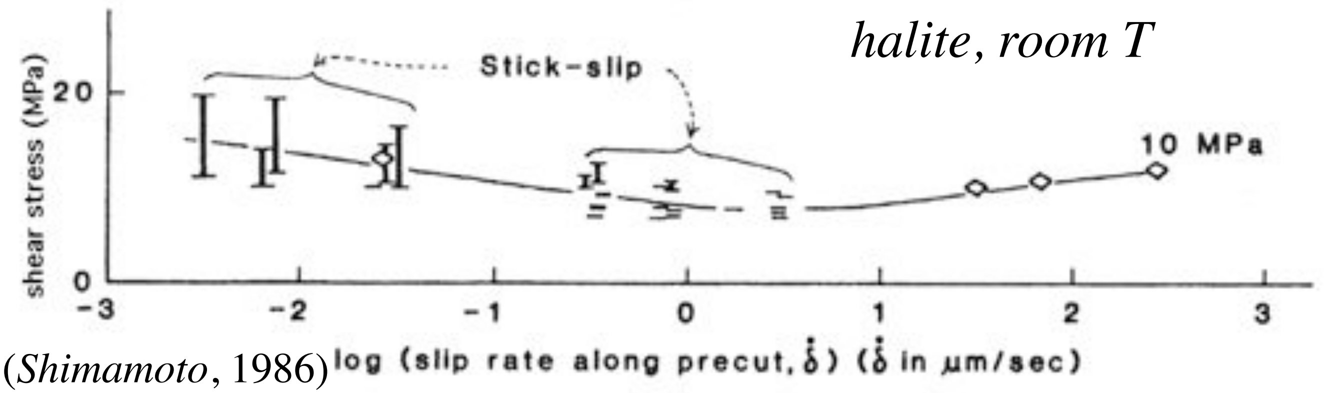
$V_0$ ——— *w/ T* ———→

- $V_0 = f(T)$ should be in models of the transition zone *s/us transition extrapolated in temperature…..*

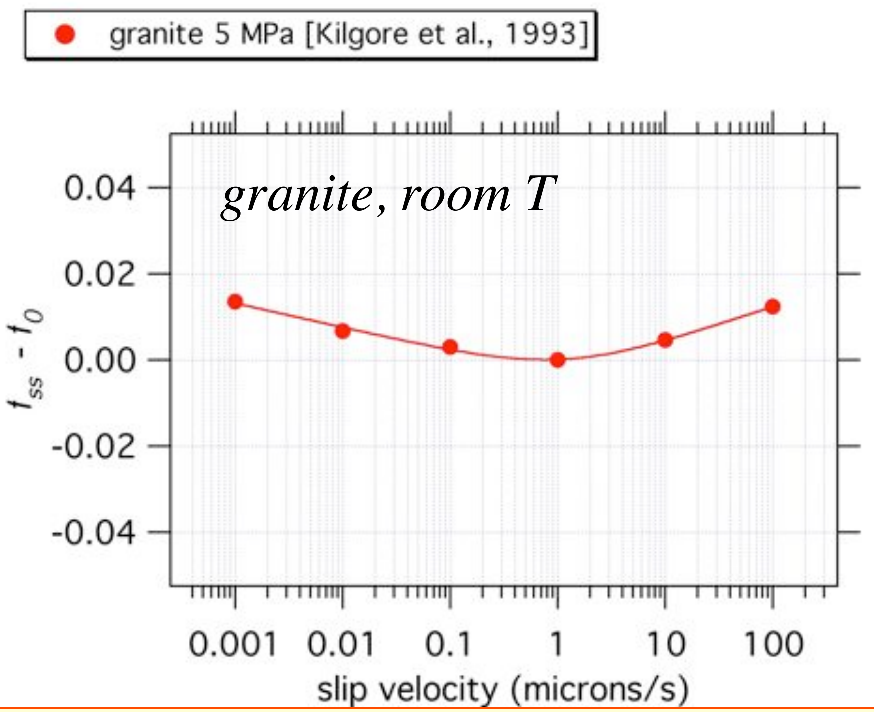



- *extrapolation of existing data to seismic speeds suggests possible transient brittle behavior to great depth*

- *this is probably not reasonable because of the high speed cutoff* *expected transition back to rate strengthening at higher slip speed:* ***'the high speed cutoff'*** *(e.g., Shibazaki and Iio, 2003)*




(*Shimamoto*, 1986)



***what's a high speed cutoff?***

*Nakatani and Scholz* (2006) also see *Dieterich* (1978; 1979)

*high speed cutoff is slip speed above which there is effectively no change in contact area*

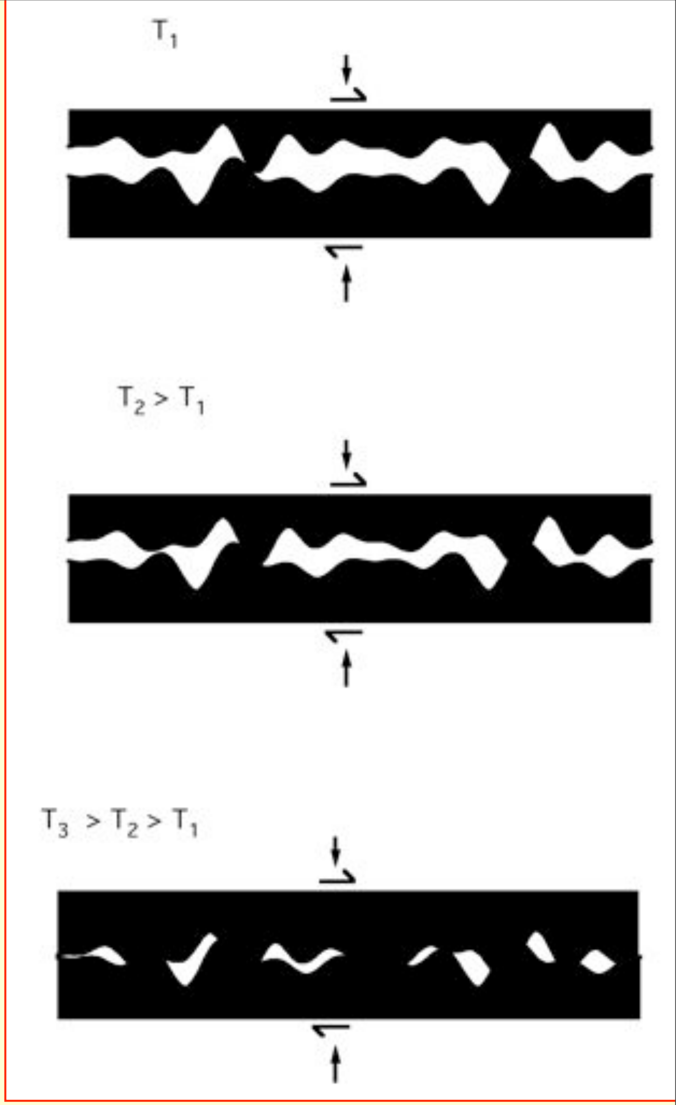
$$V_c = \frac{d_c}{t_c}$$

*contact dimension* ($d_c$)

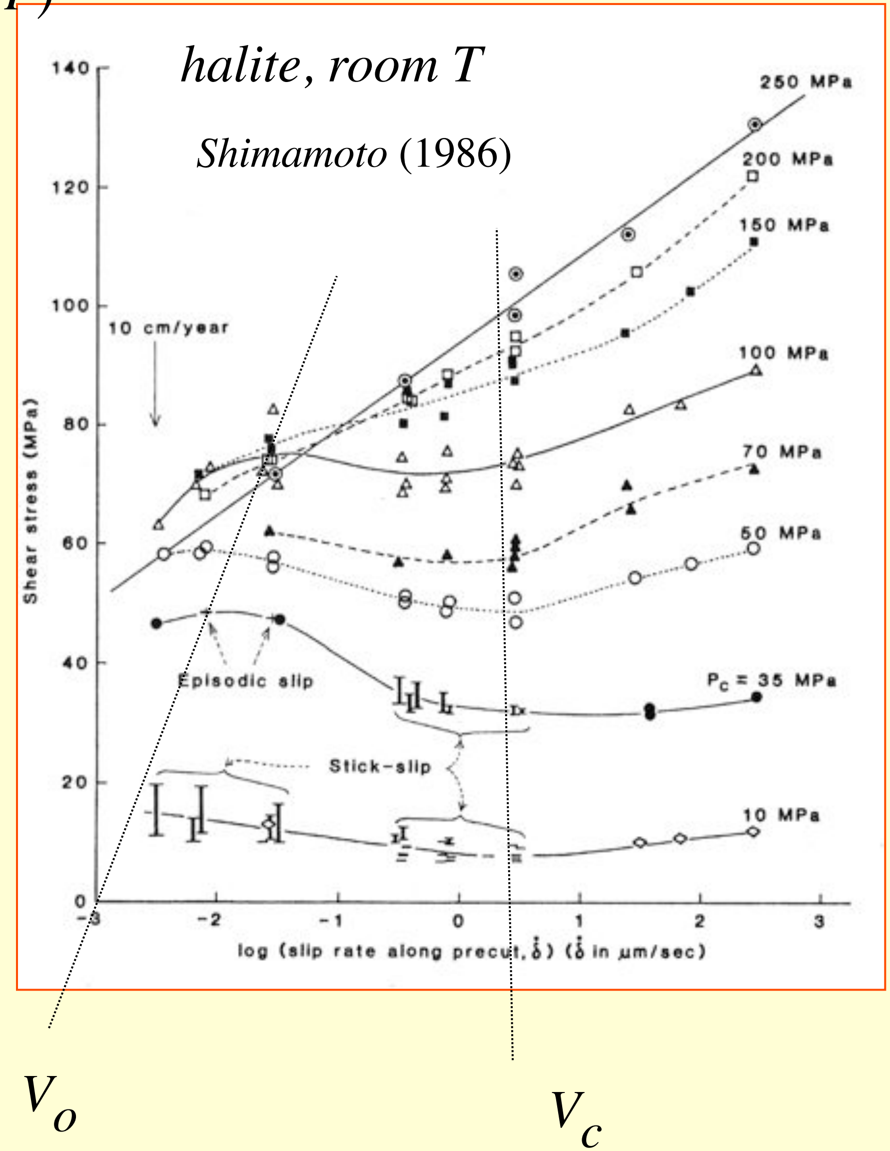
*time constant of contact scale yielding* ($t_c$)

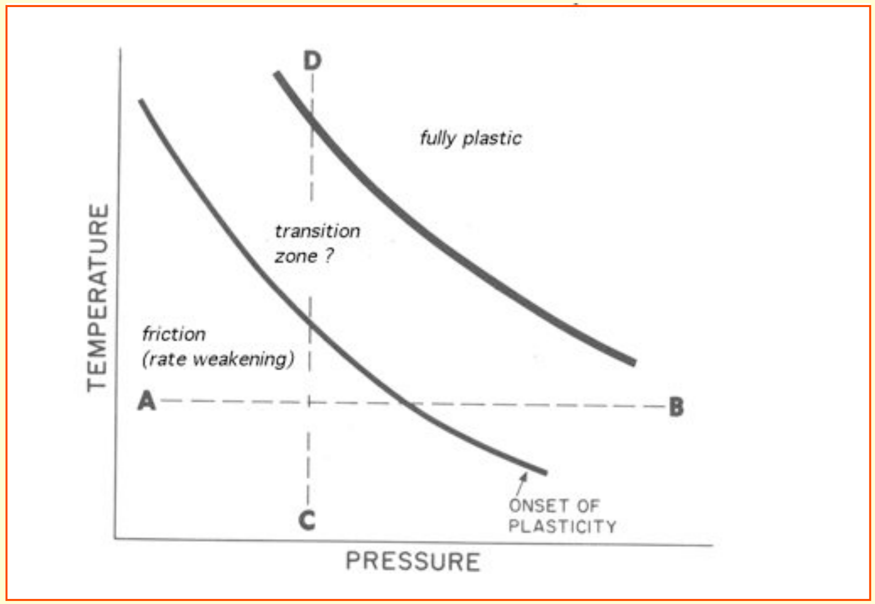
*For transition zone models the issue is at what slip speed is the cutoff at high T and P?*

*there's no lab data at temperature - the cutoff is treated as something like a free parameter in slow slip models*



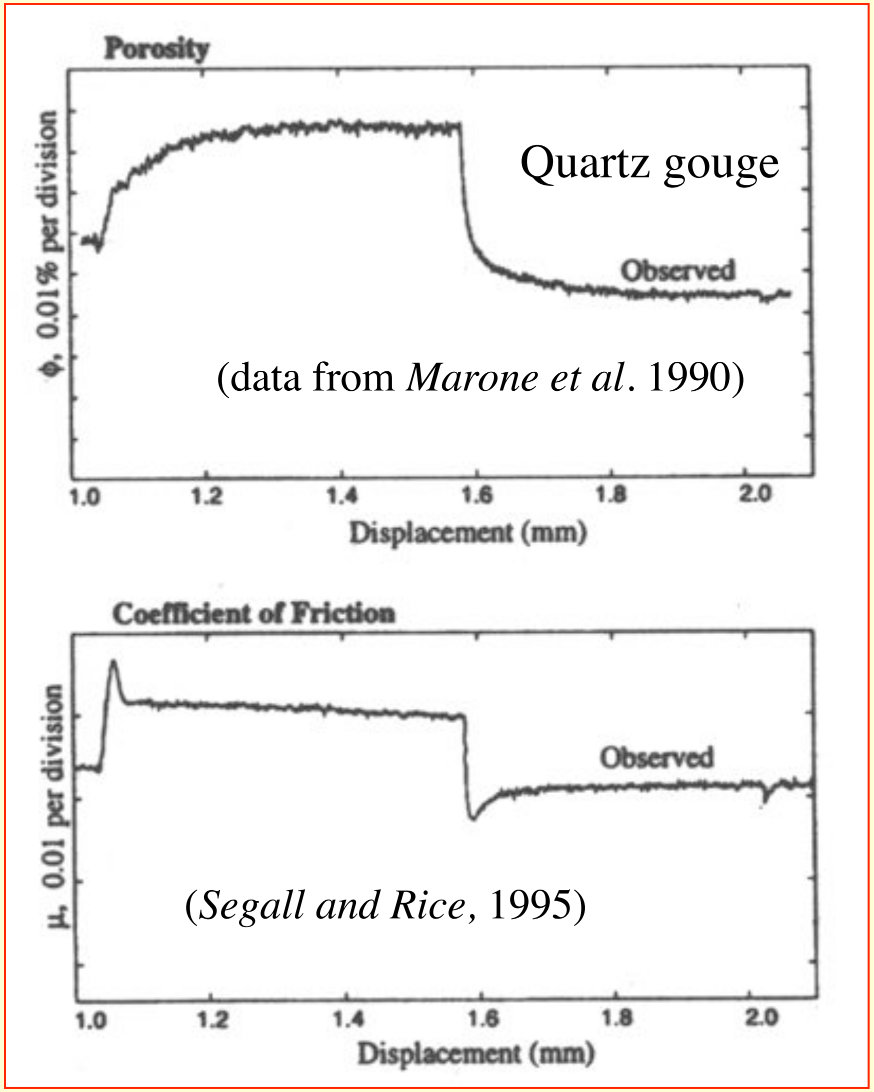
*more complete friction model of transition zone might include high speed cutoff ($V_c$) and s/uns transition ($V_0$), both depending on T (and perhaps on P)*

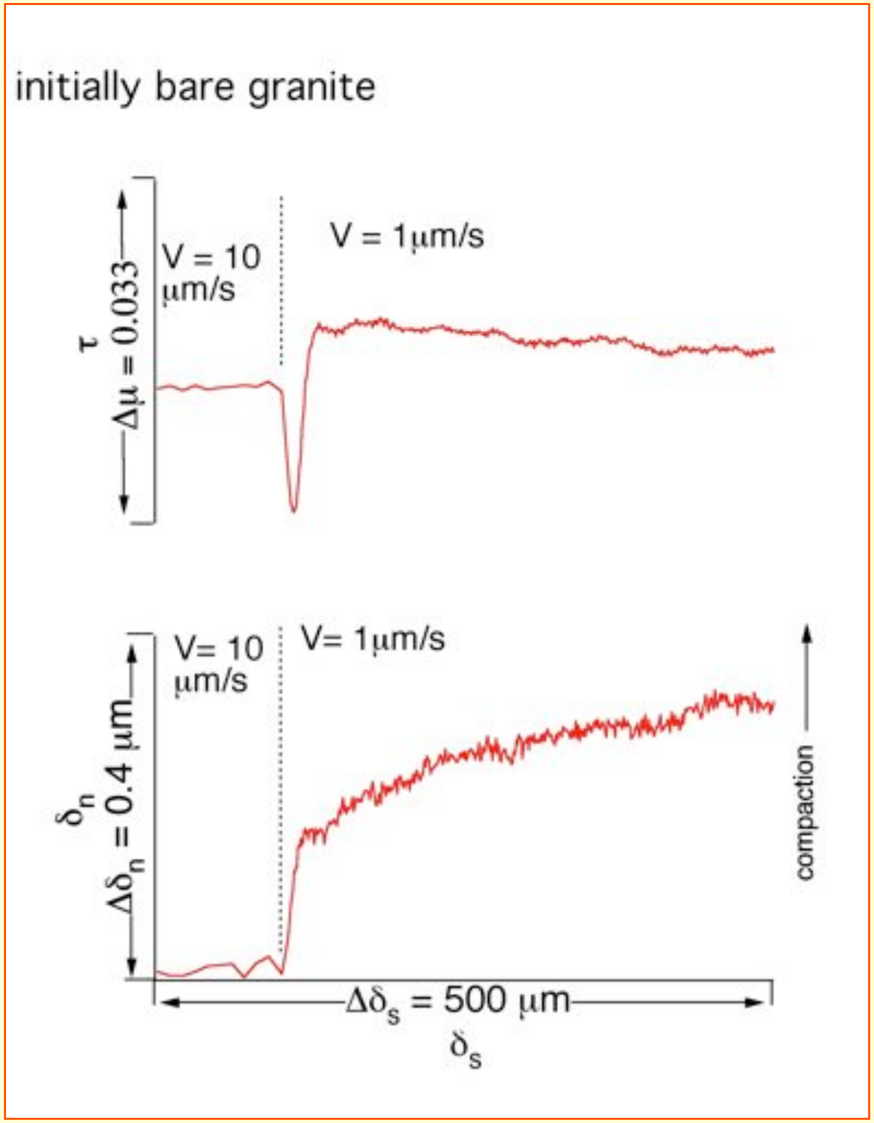



modified from *Scholz* (1990)

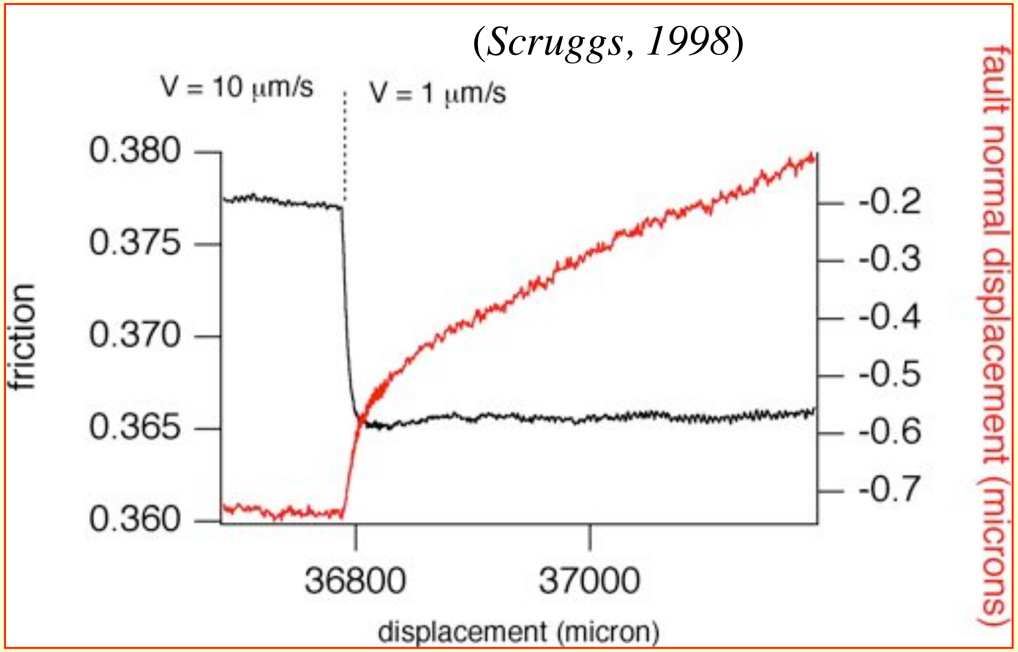
*friction dilatancy relationship used in models of slow slip* (*Segall and Rice*)*- from rate step*



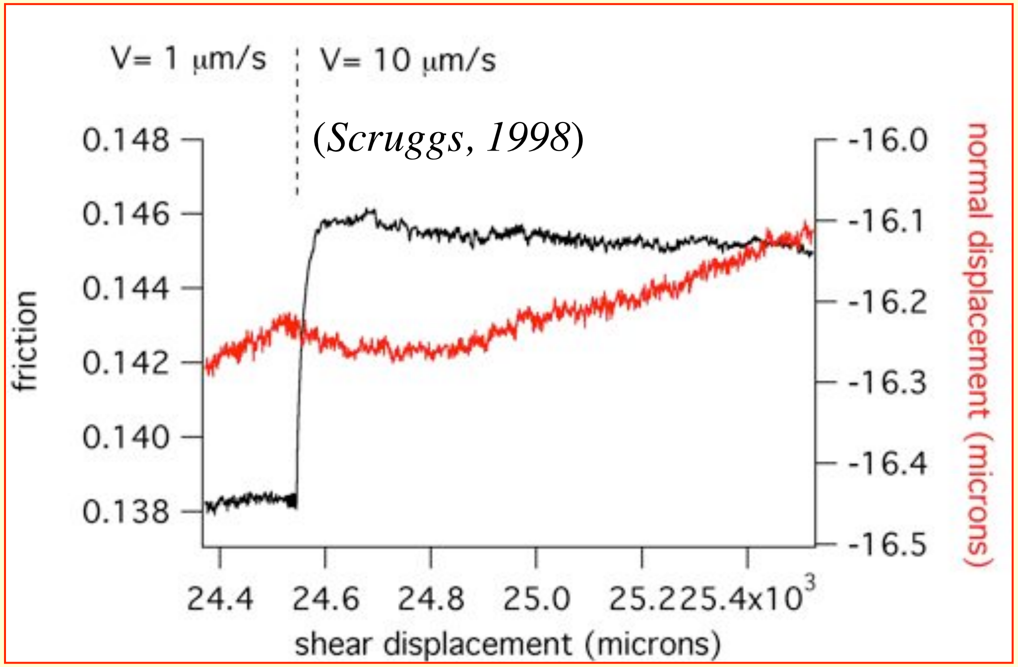



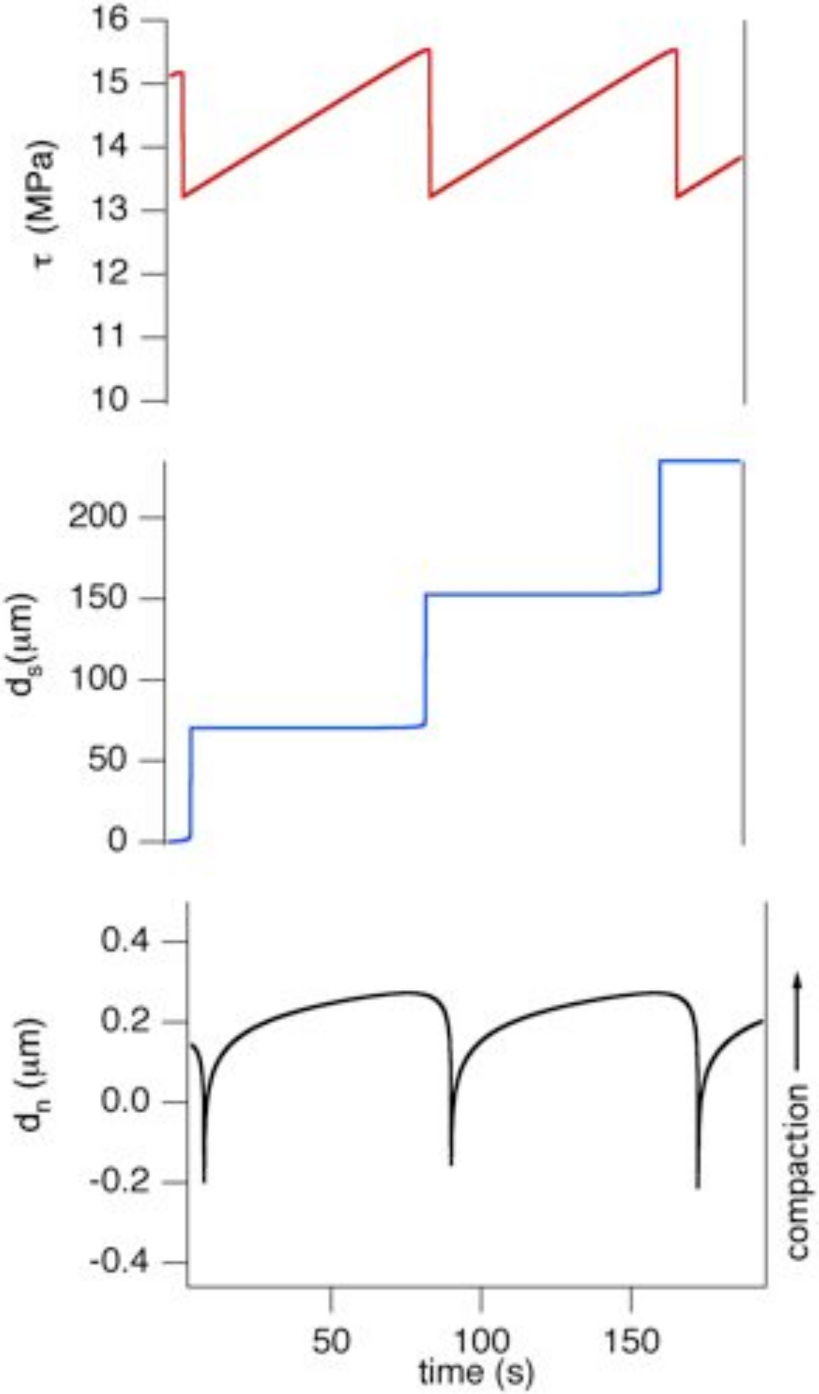

• *porosity is rate dependent - its another manifestation of the state variable (of the evolution effect )* *dilatancy in materials without a pronounced evolution effect:*

*muscovite gouge, room T*




*talc gouge, room T*






***step-test based formulation in simulation of periodic failure (dry or drained)***

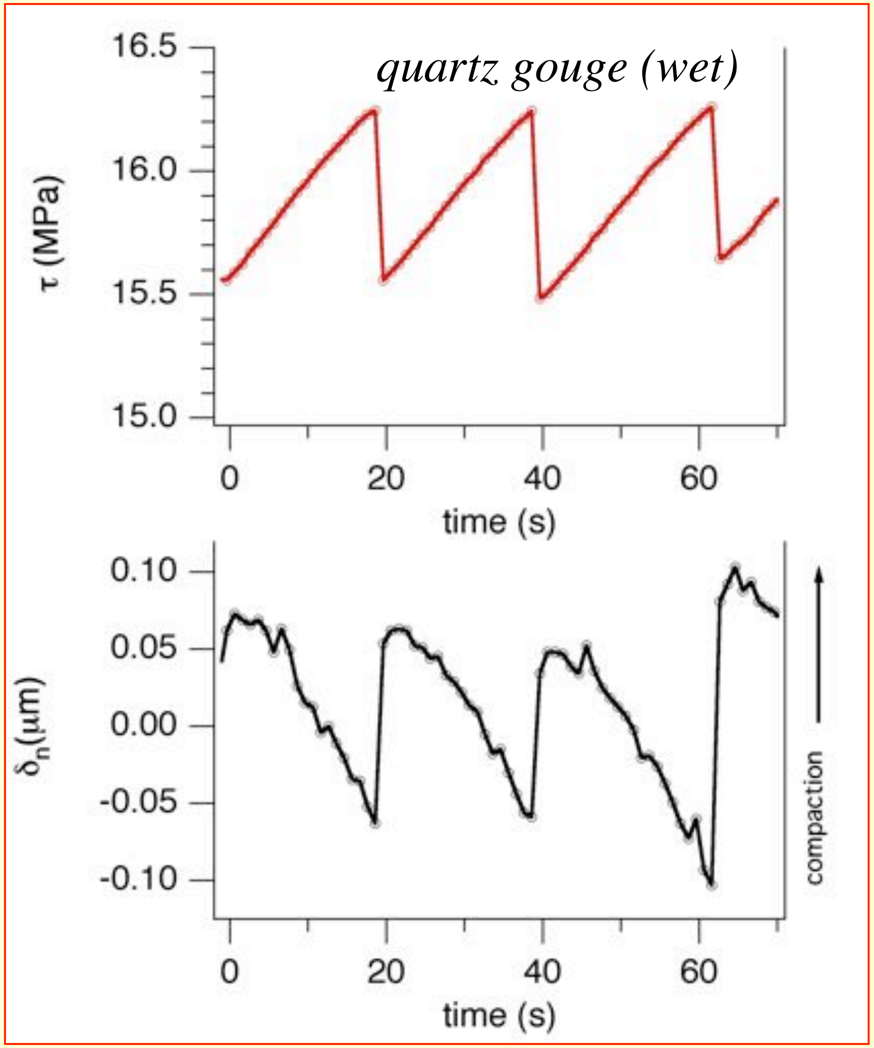
*periodic stress drop*

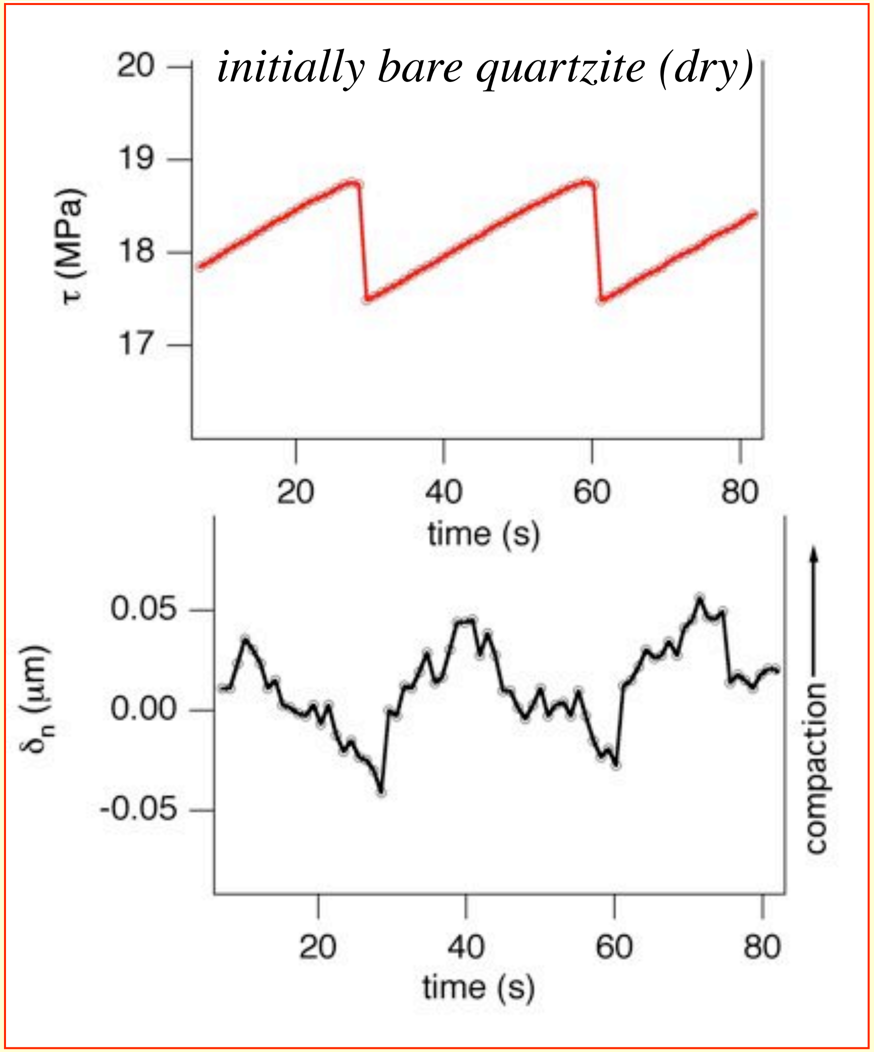
*very small amounts of precursory slip*

*'co-seismic' slip-induced dilatancy*

*inter-event time dependent compaction*

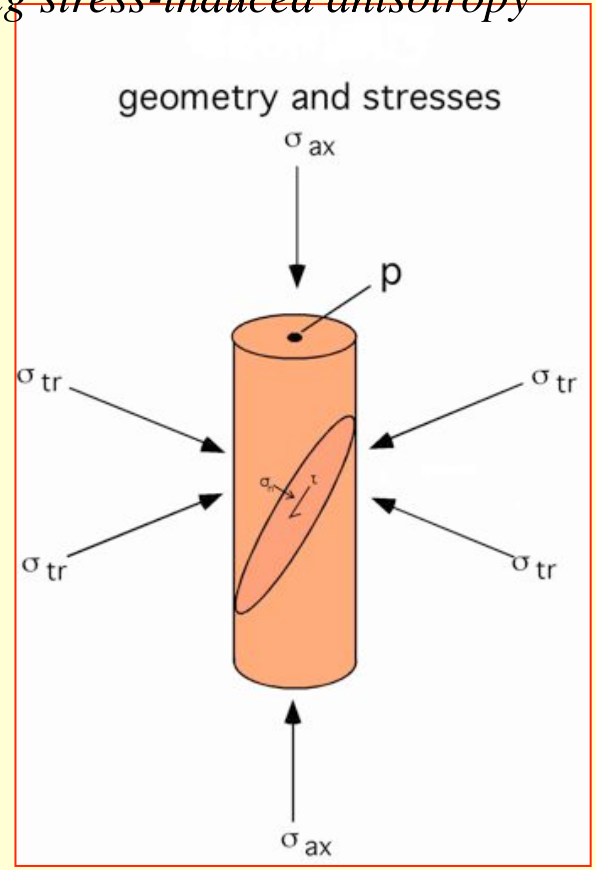
***actual periodic failure experiments***

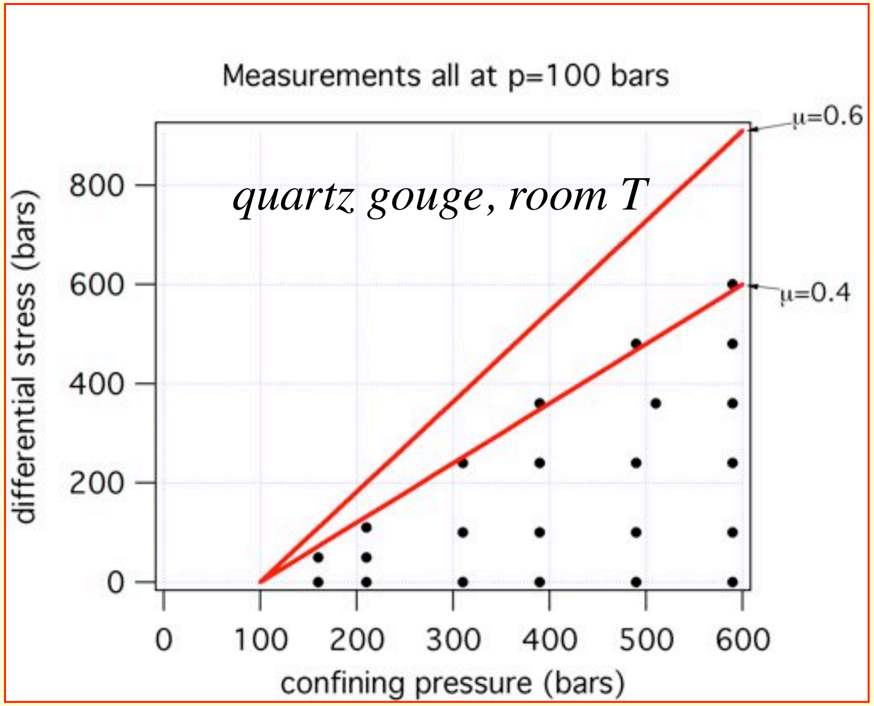


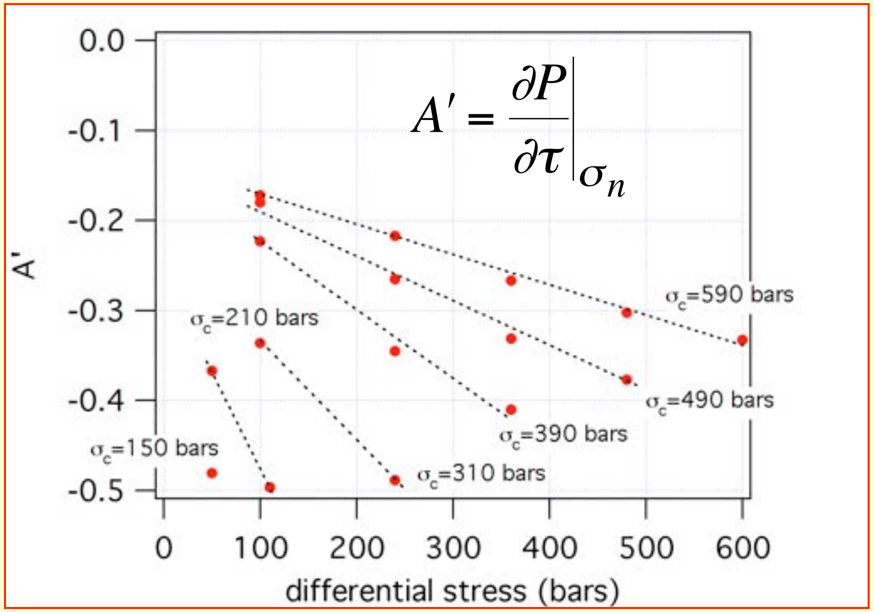




- *'co-seismic' compaction rather than dilation in experiments* *are poroelastic effects important in gouge layers?*

*strong stress-induced anisotropy*




*(Lockner and Beeler, unpublished)*

- *pore pressure increase (compaction) w/ shear stress drop*

- *this effect is largest at low effective stress*

***nmb's to do list:***

*stable - unstable - stable transitions are rate and temperature (and pressure) dependent (explore implications in fault models)*

*more experiments at higher speeds at a wider range of T and P*

*more experiments on relevant compositions*

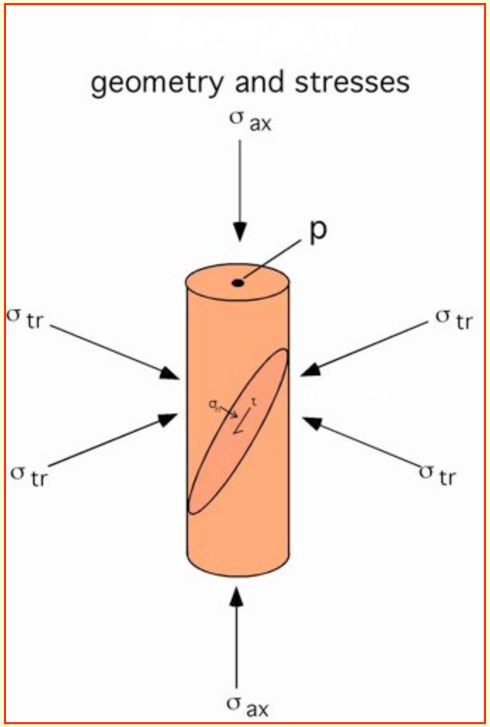
*dilatancy in fault zones approaching and during failure is not understood*

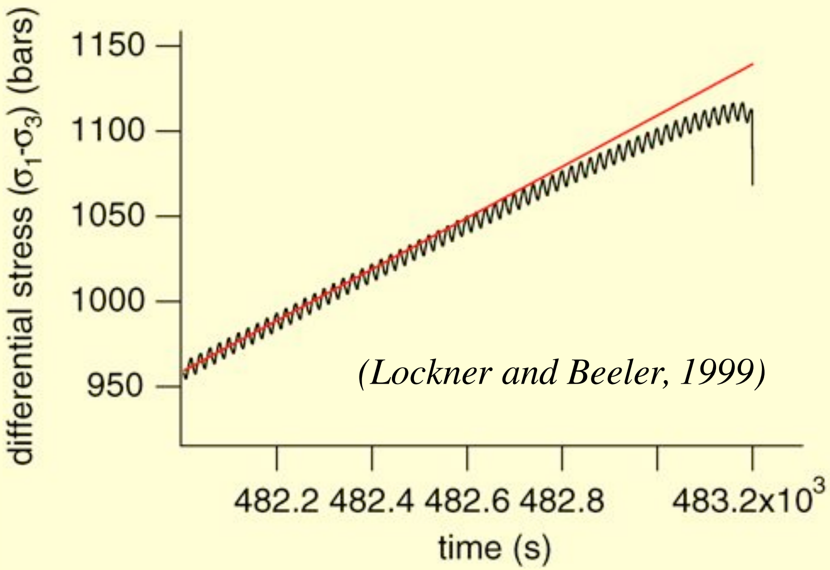
*stickslip experiments with and without pore fluid*

*experiments at elevated T*

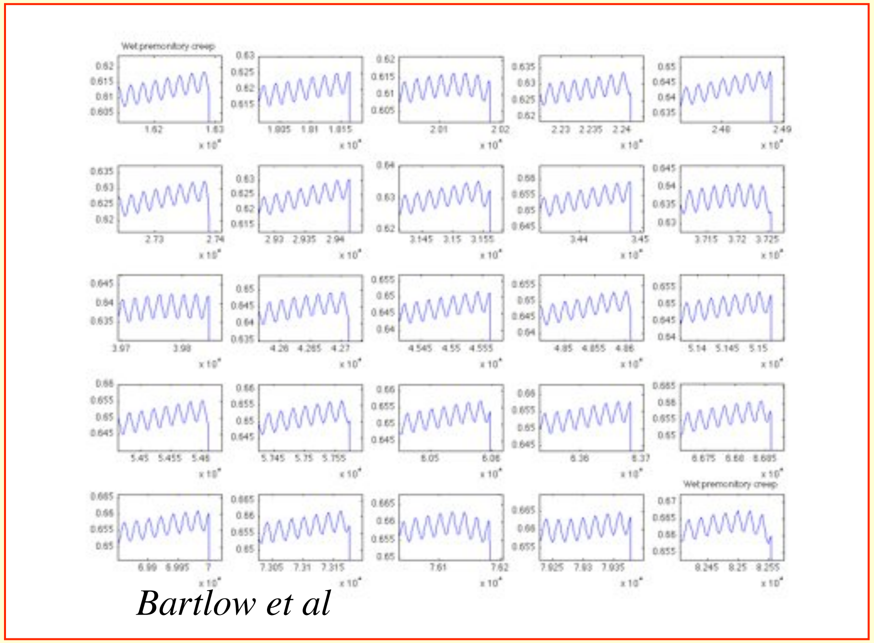
*poroelastic properties of fault zones are unexplored*

*experiments nearer failure - more relevant compositions* *new experiments: periodic failure, initially bare granite w/ pore fluid*



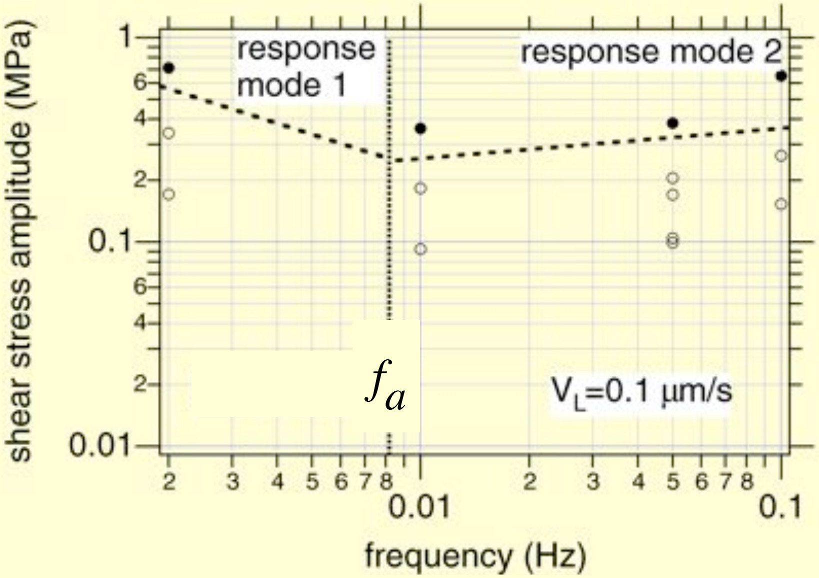




*loading: constant rate +*
*small amplitude sine wave*




Monday, November 1, 2010

***previous results: dry*** *(Lockner and Beeler, 1999)*




***objective****: determine influence of pore fluid pressure on triggered failure*

***two frequencies of interest:***

$$f_a = \frac{\dot{\tau}}{2\pi a \sigma_e}$$

*1/ nucleation duration*

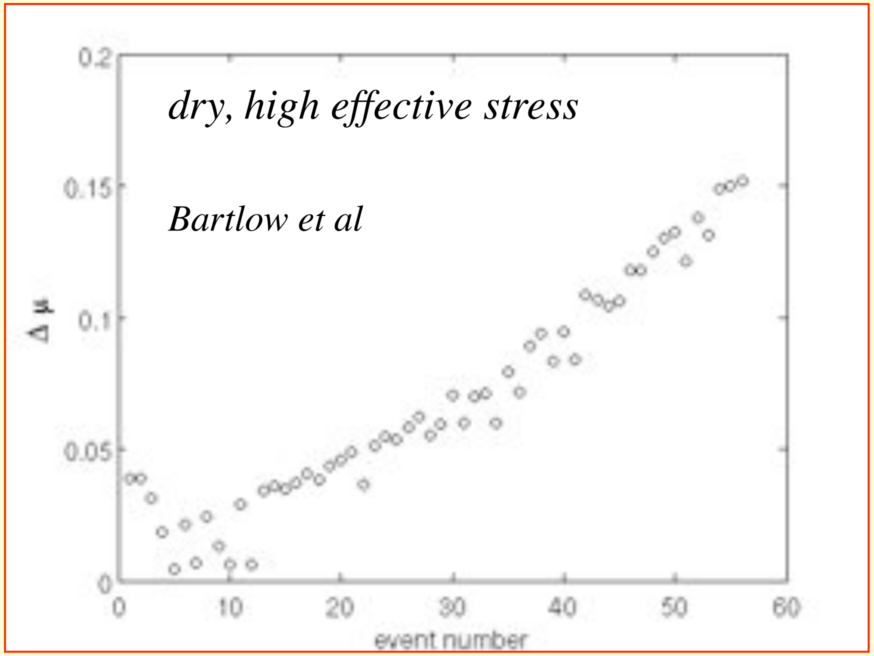
(*Dieterich*, 1992)

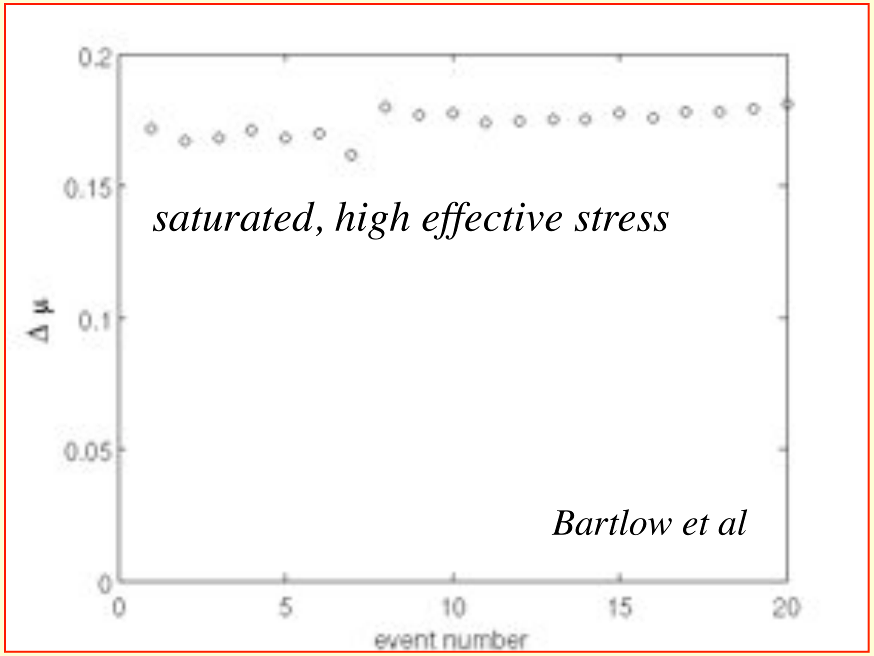
$f_{fluid}$ *undrained/drained*

***new results*** *(Bartlow et al)**:***

- *$f_a$ is larger at lower effective stress as expected*
- *correlations deviate from the dry results at frequencies of ~20s*
  *dilatancy hardening?*

*more new results (no oscillating stress): static stress drops*



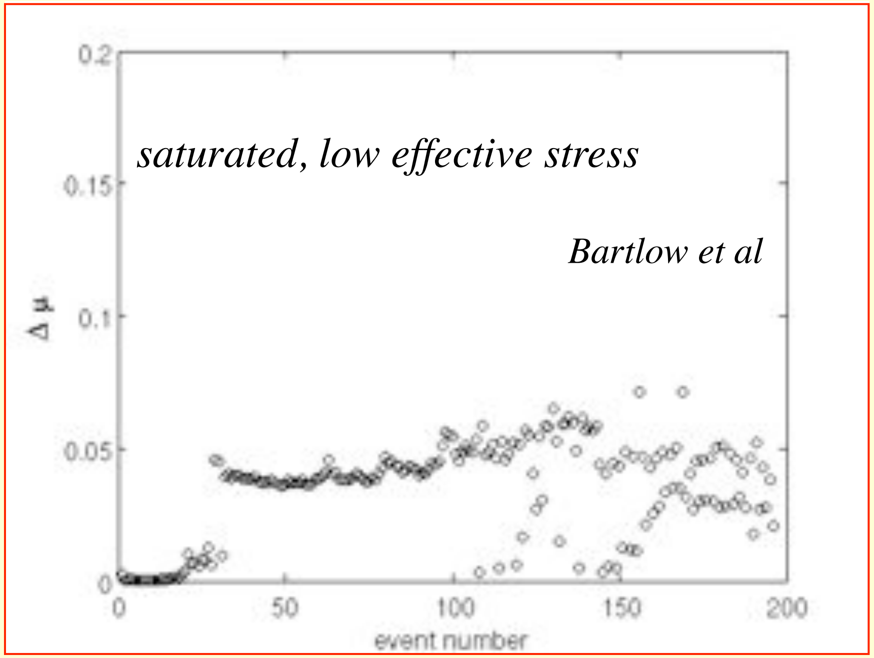




***different behavior at lower effective stress****:*

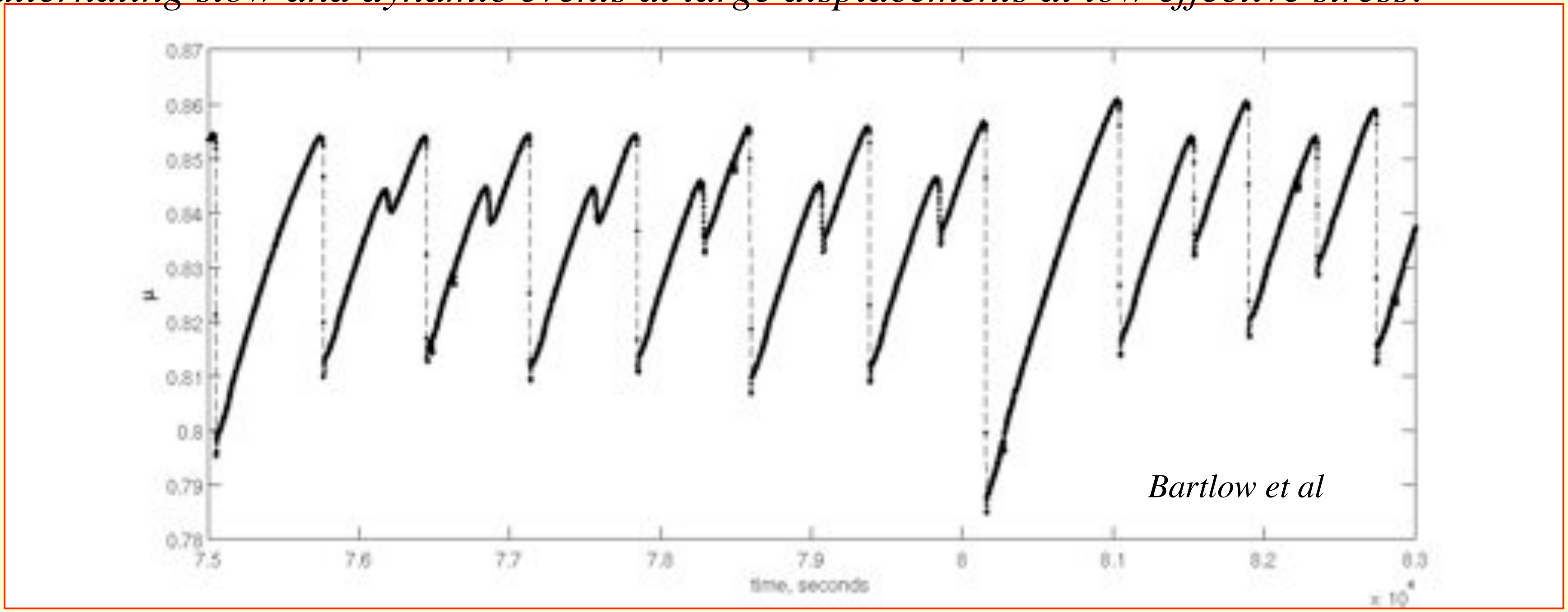
- *unusually low stress drops at lower effective stress*

- *complex stress drop history at largest displacements*

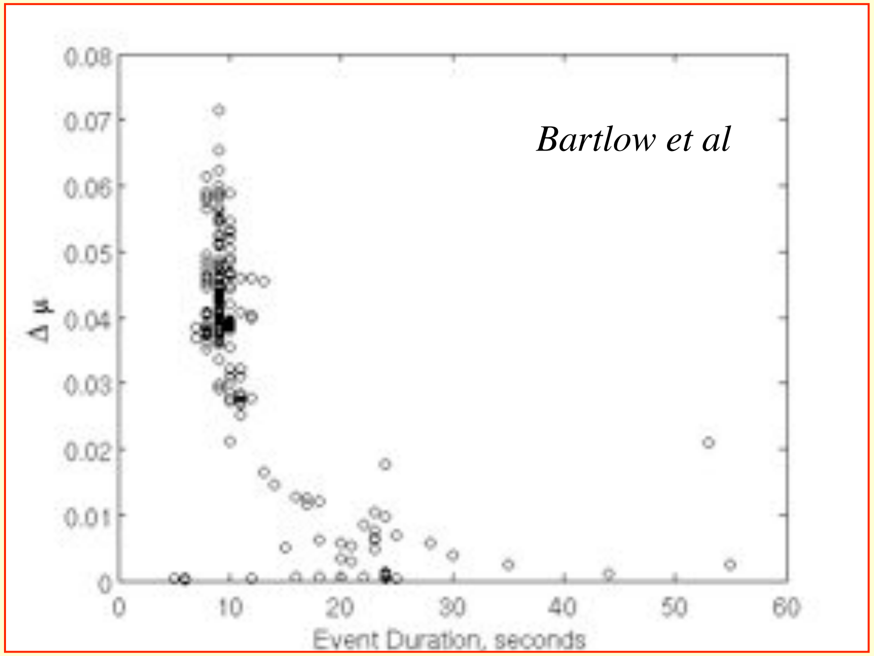
- *slow events*



*alternating slow and dynamic events at large displacements at low effective stress:*




*duration:*

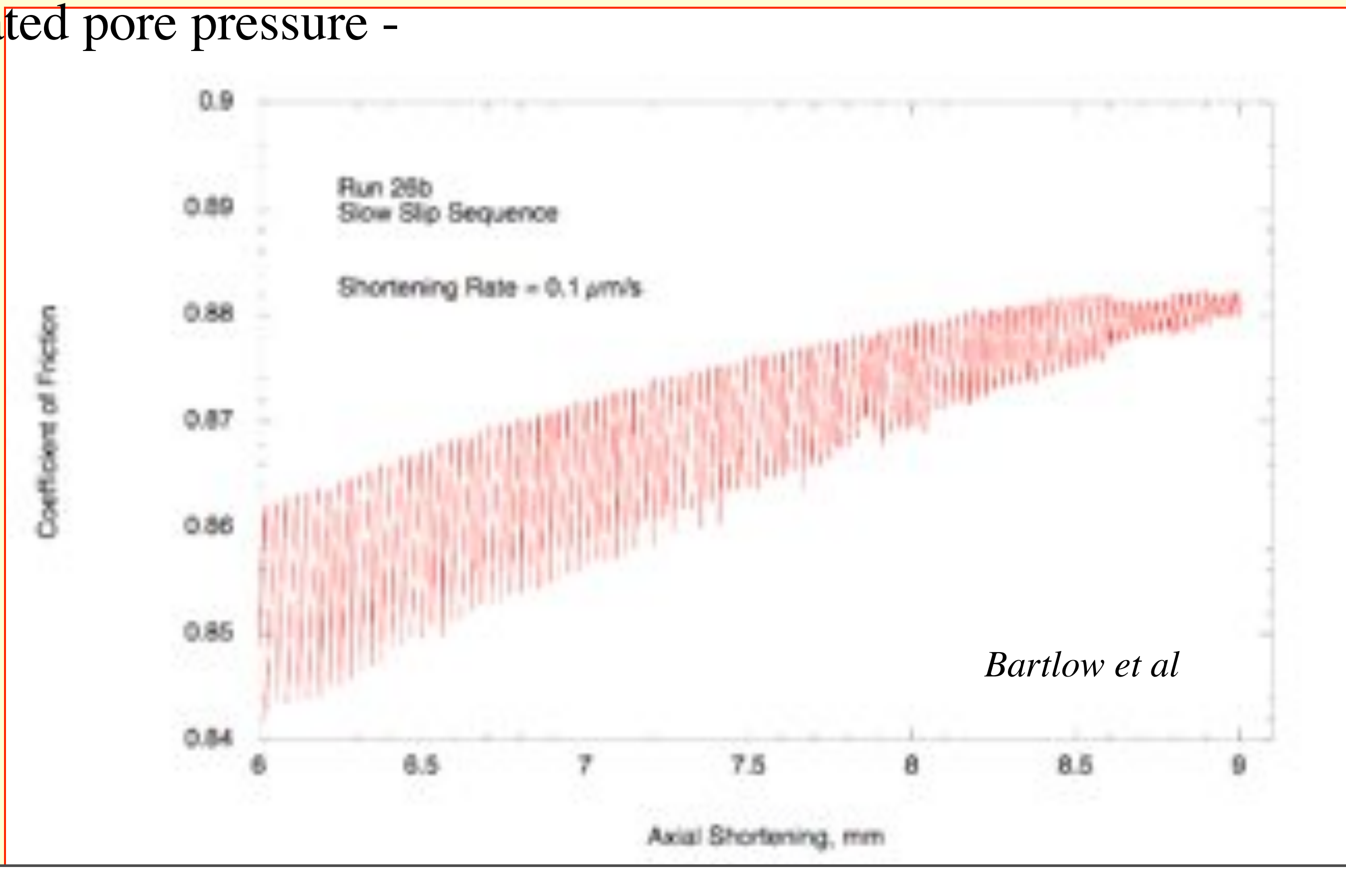


**summary of new stick-slip experiments with pore pressure (bare granite, room temperature)**

$f_a$ increases with decreasing effective stress

pore fluid affects triggered failure at frequencies of ~20 s (undrained/dilatancy effect?)

slow events at elevated pore pressure -



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