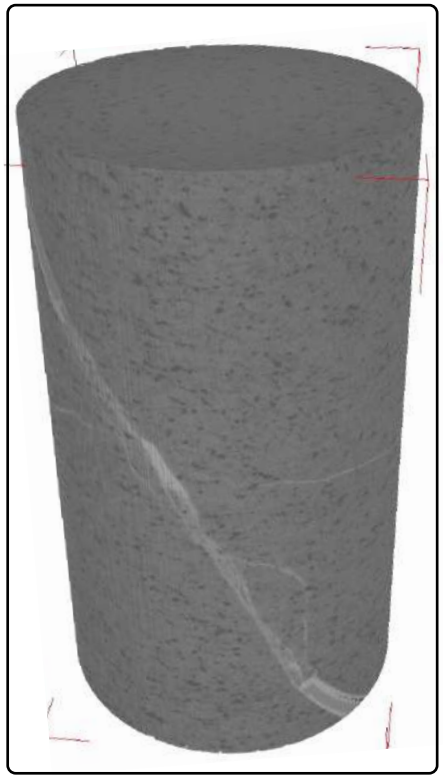
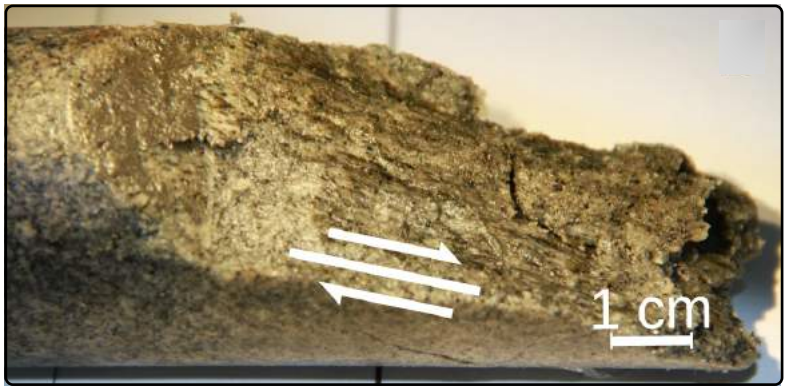
UNIVERSITY OF CALIFORNIA
SANTA CRUZ

What allows seismic events to grow big?: Insights from *b*-value and stress variations in lab and nature

T. H. W. Goebel [1], G. Kwiatek[2], T. W. Becker[3], G. Dresen[2], E.E. Brodsky[1]
1 *UC Santa Cruz*; 2 *GFZ-Potsdam*; 3 *University of Texas at Austin*





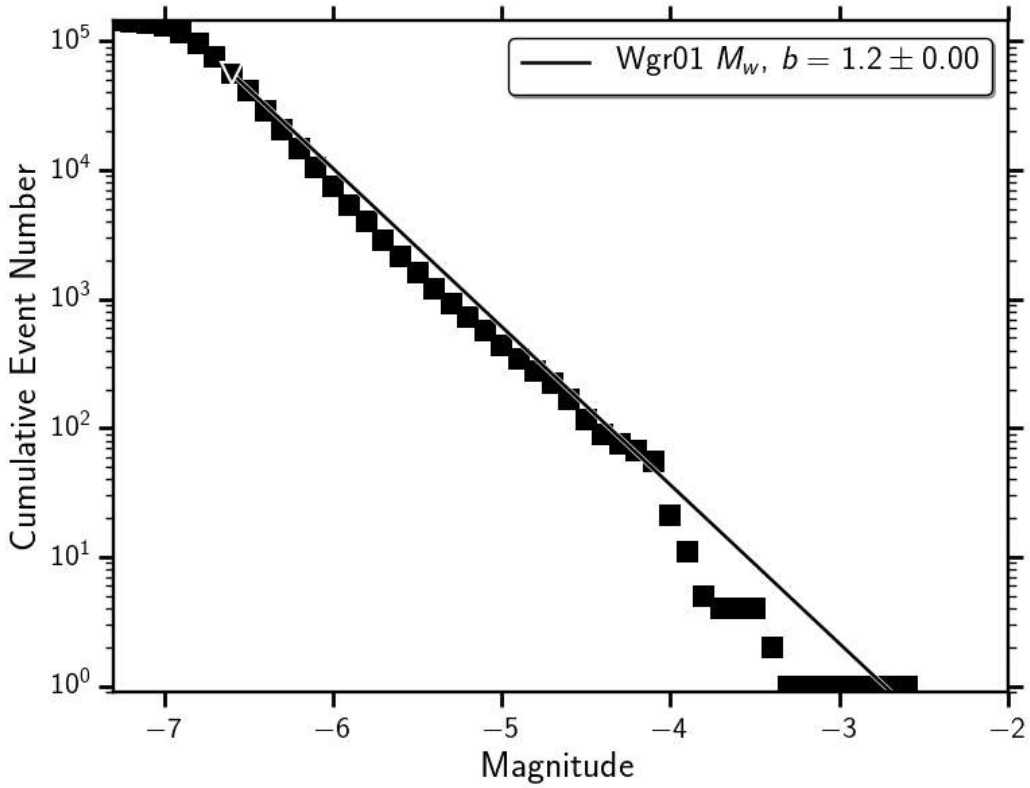
GFZ
Helmholtz-Zentrum
POTSDAM

Gutenberg-Richter frequency-magnitude distribution

$$N = 10^{a - bM}$$
$$N \sim M_0^{\beta}$$

$M_0 \sim L^3$ (constant stress drop)

$\log_{10}(N) \sim b \log_{10}(L^{3/c})$

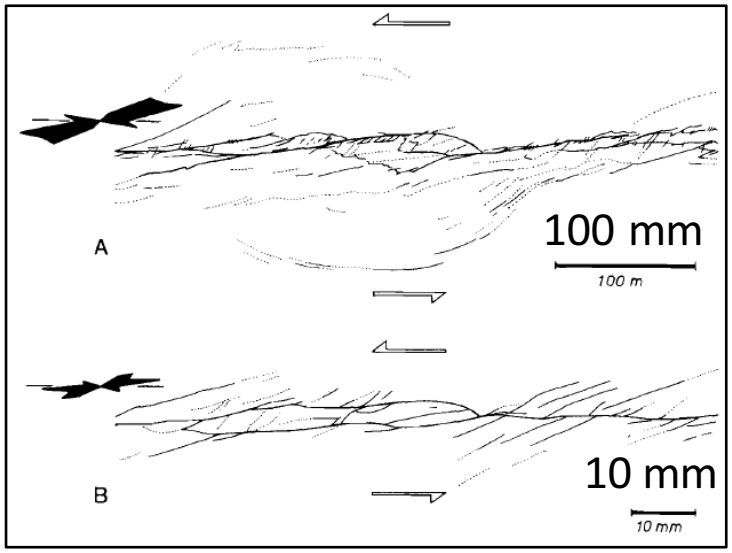


e.g. Gutenberg & Richter 1948; Aki, 1967; Hanks, 1979; King 1983; Frankel 1991, Wyss et al. 2004

What processes give rise to Gutenberg-Richter and govern *b*-value variations?

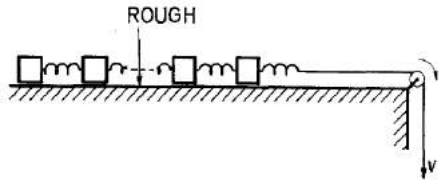
1) Geometric effects

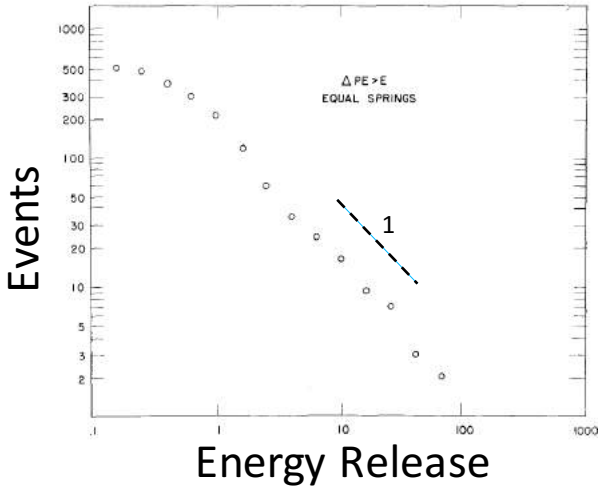
$$\log_{10}(N) \sim b \log_{10}(L^{3/c})$$



Tchalenko and Ambraseys 1970; King 1983

2) Dynamic effects and stress

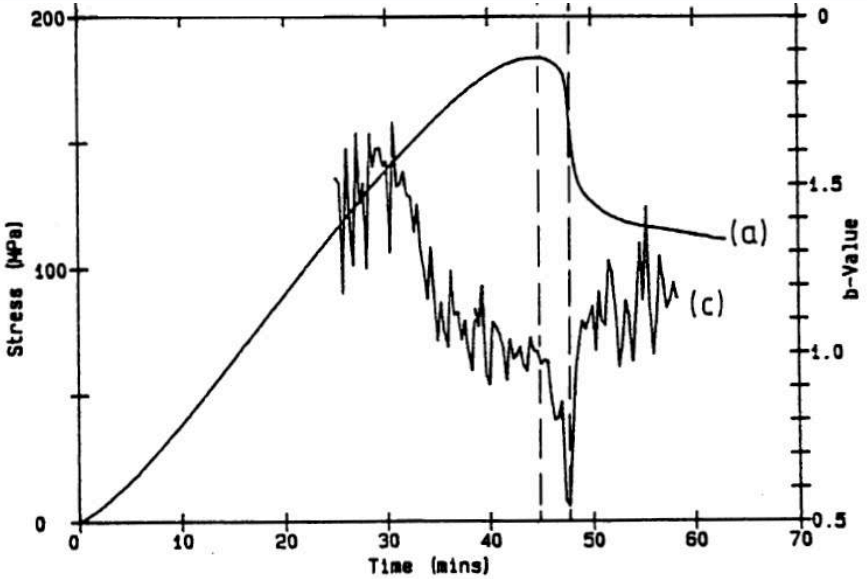




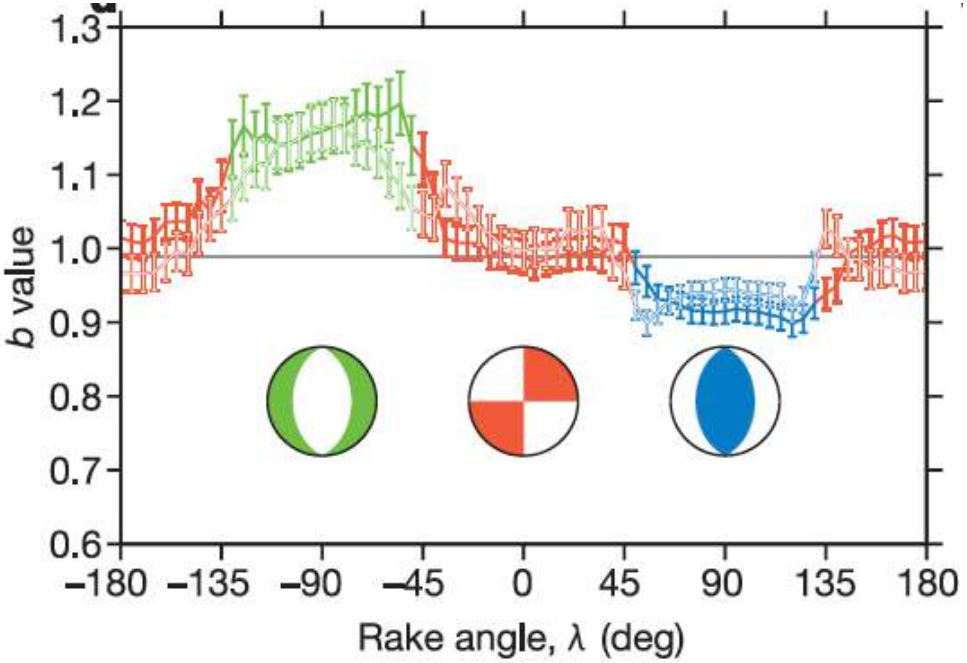
Burridge & Knopoff, *BSSA* 1967

Are *b*-value variations a measure of absolute stress?

b-value is correlated with stress in lab experiments

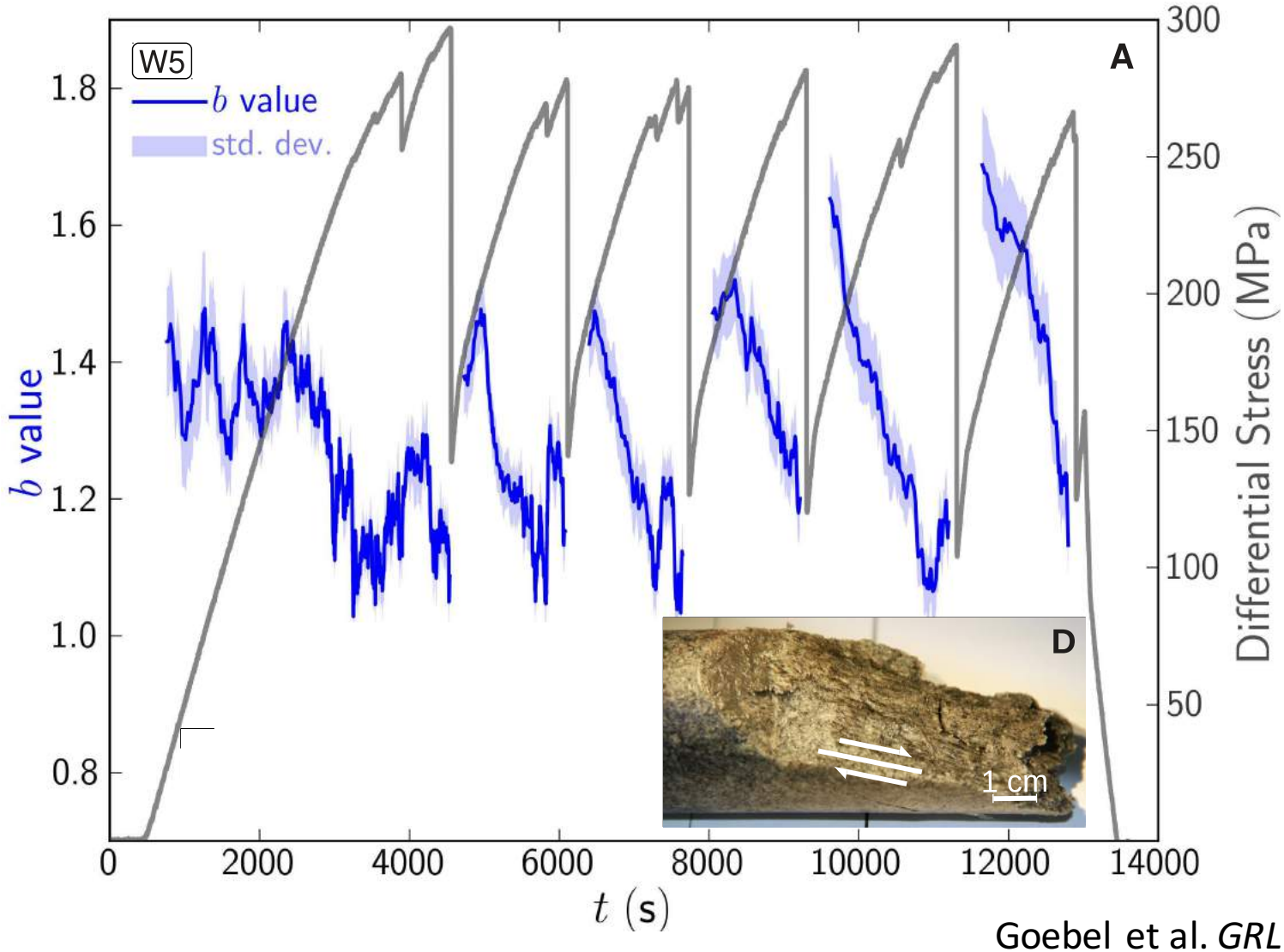


Scholz 1968; Main, Meredith, 1989, 1990, 1992



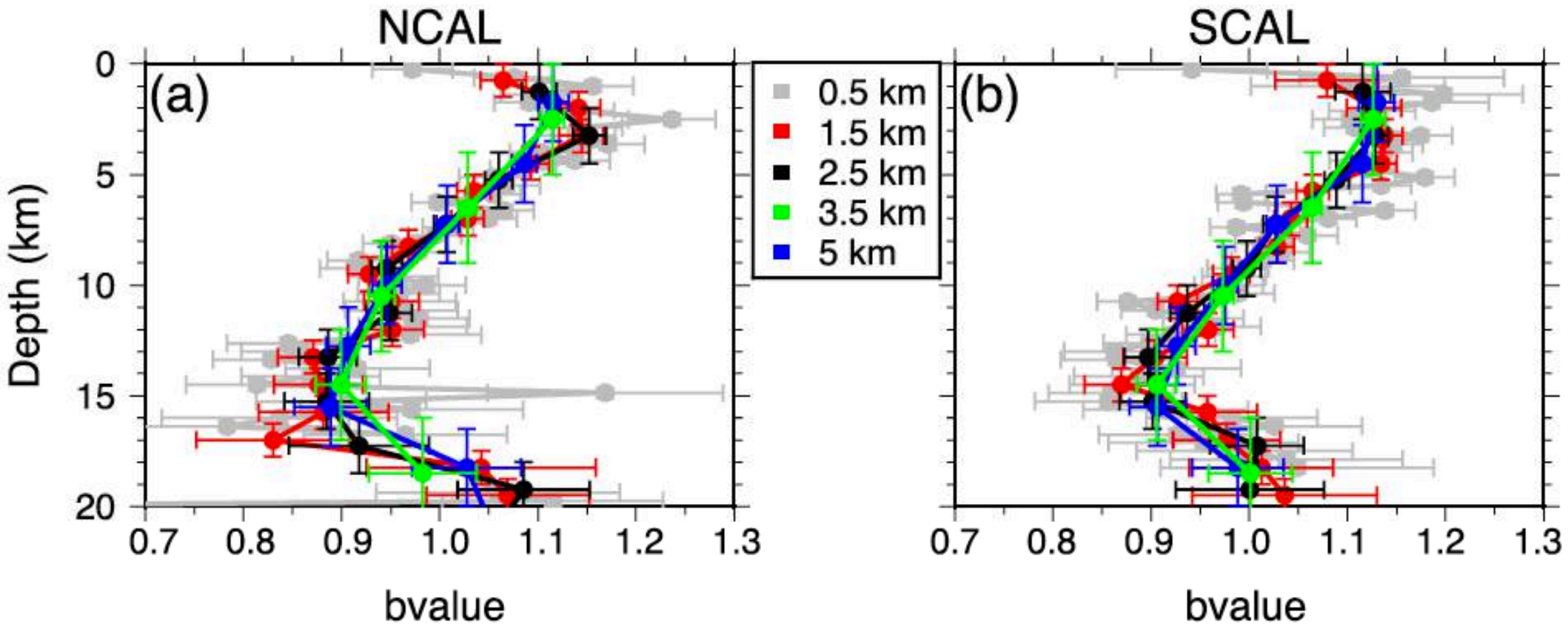
Schorlemmer et al., 2005

b-value variations track stress changes over many seismic cycles



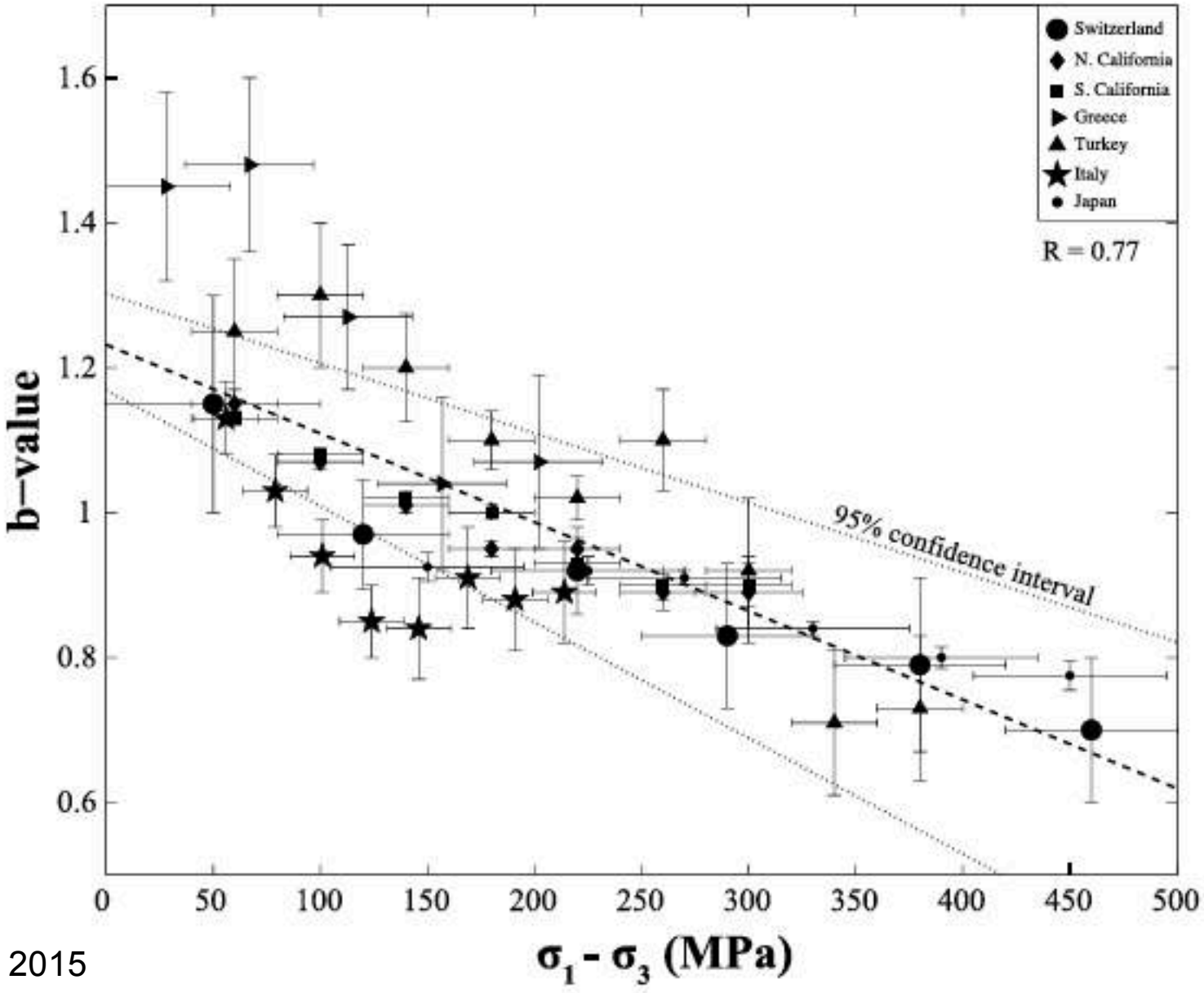
Goebel et al. *GRL*, 2013

b-values decrease with increasing crustal depths



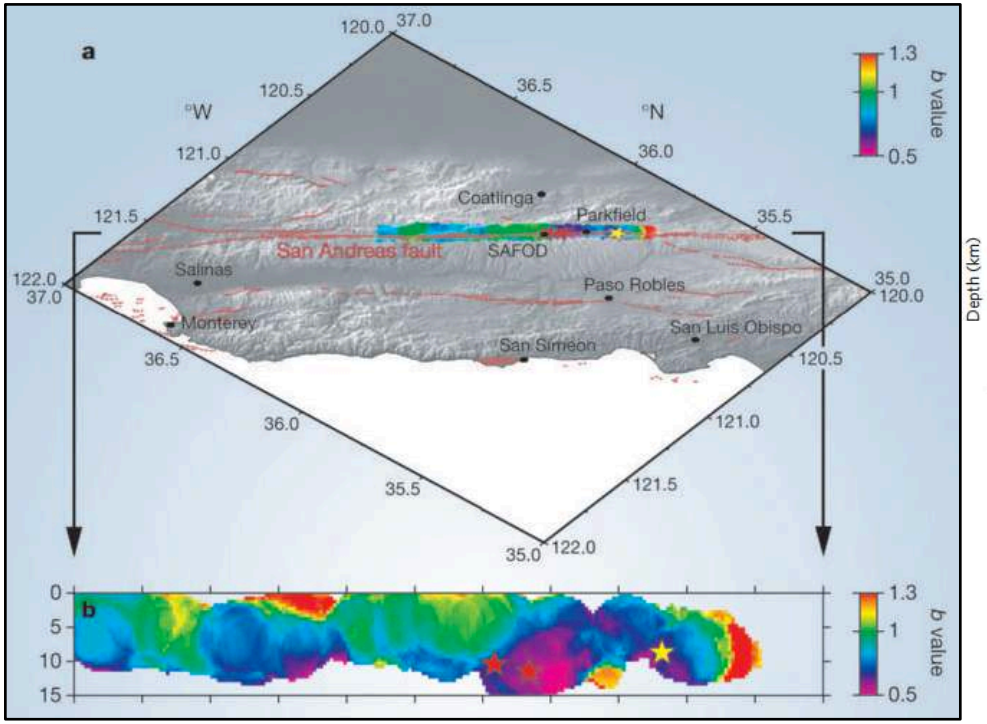
Spada et al., 2013

b-value shows linear relation with stress in different tectonic regimes

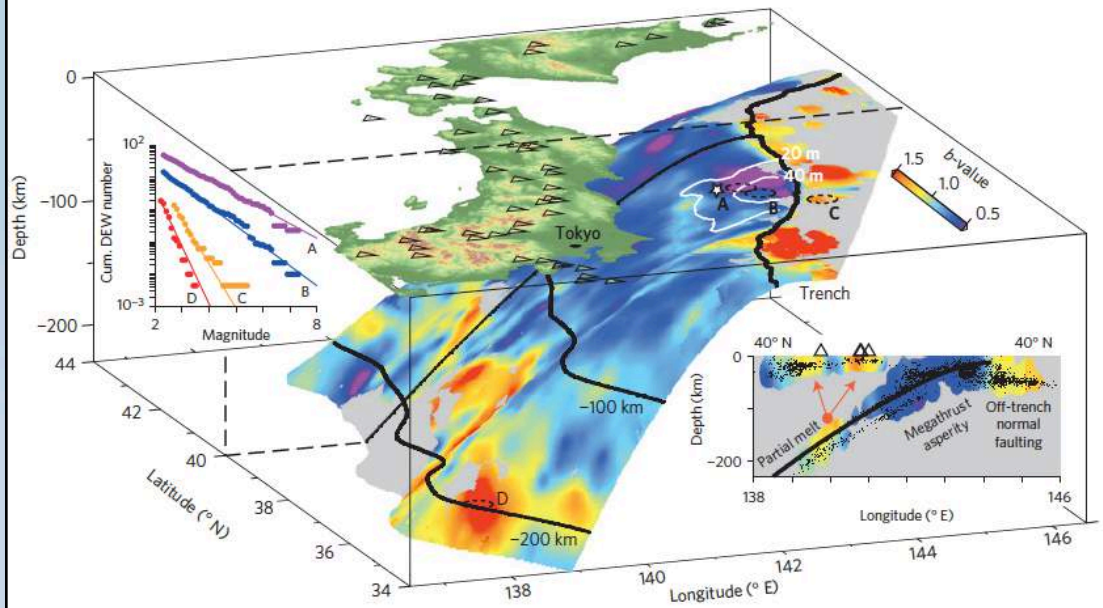


Scholz, 2015

Spatial mapping of *b*-value changes to detect highly-stressed asperity regions



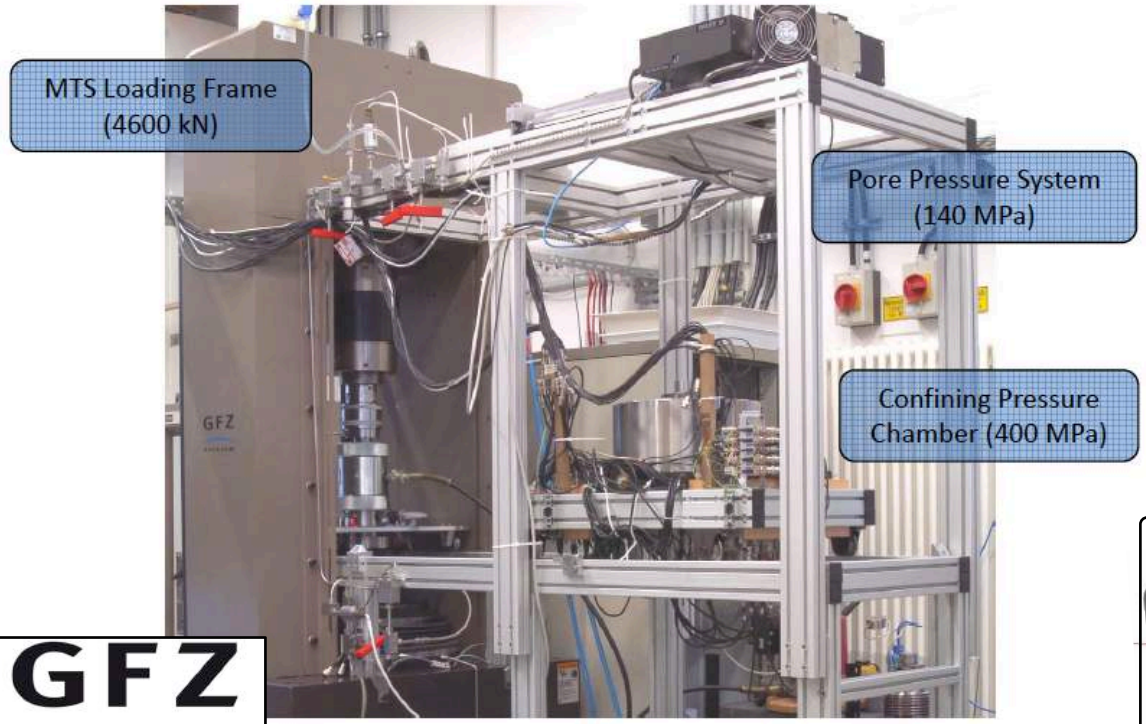
Schorlemmer et al., 2005



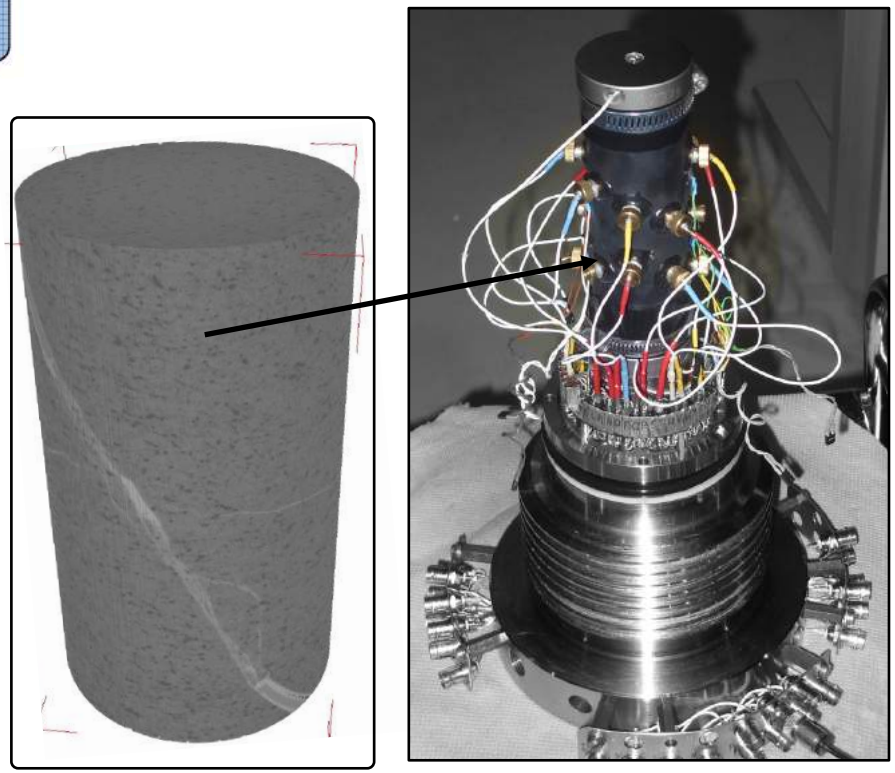
Tormann et al., 2015

What additional factors influence b?

b-value variations with fault roughness

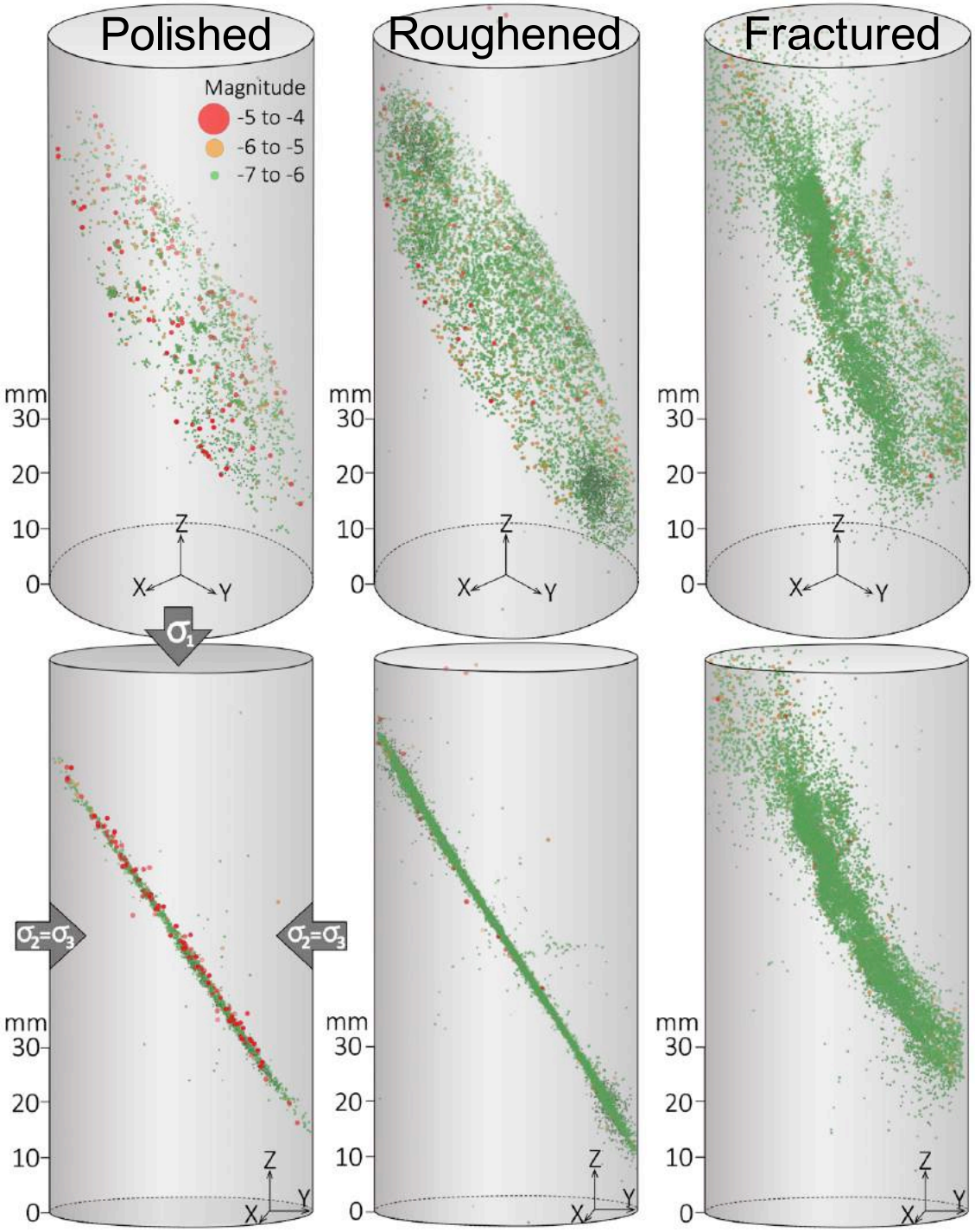


GFZ Helmholtz-Zentrum POTSDAM

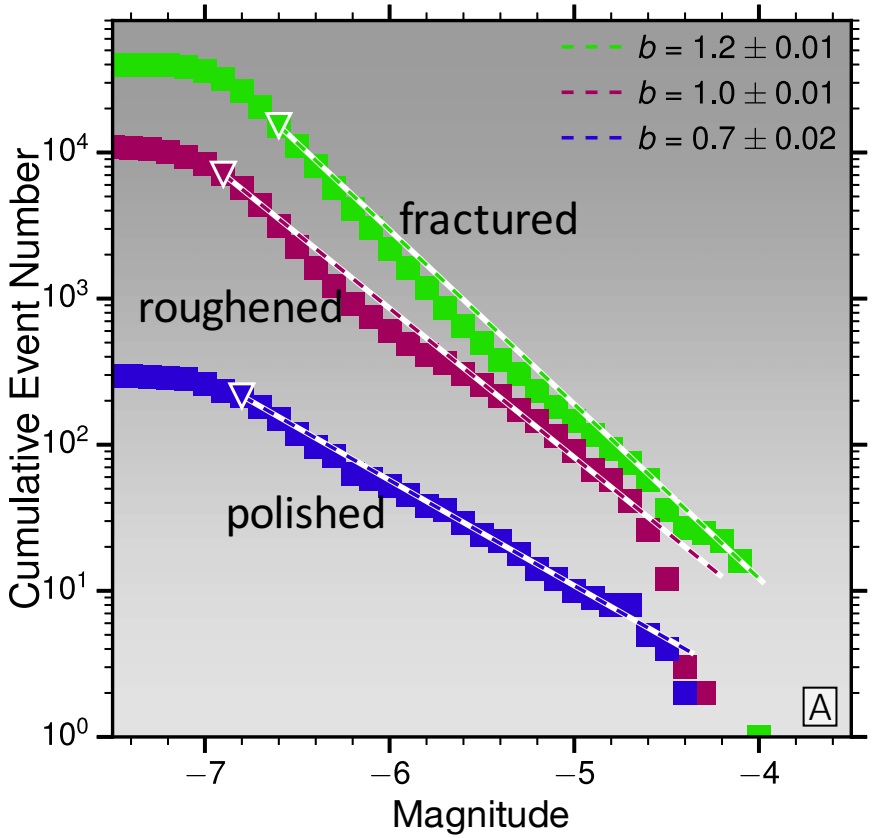


Stanchits et al. *PAAG*, 2006

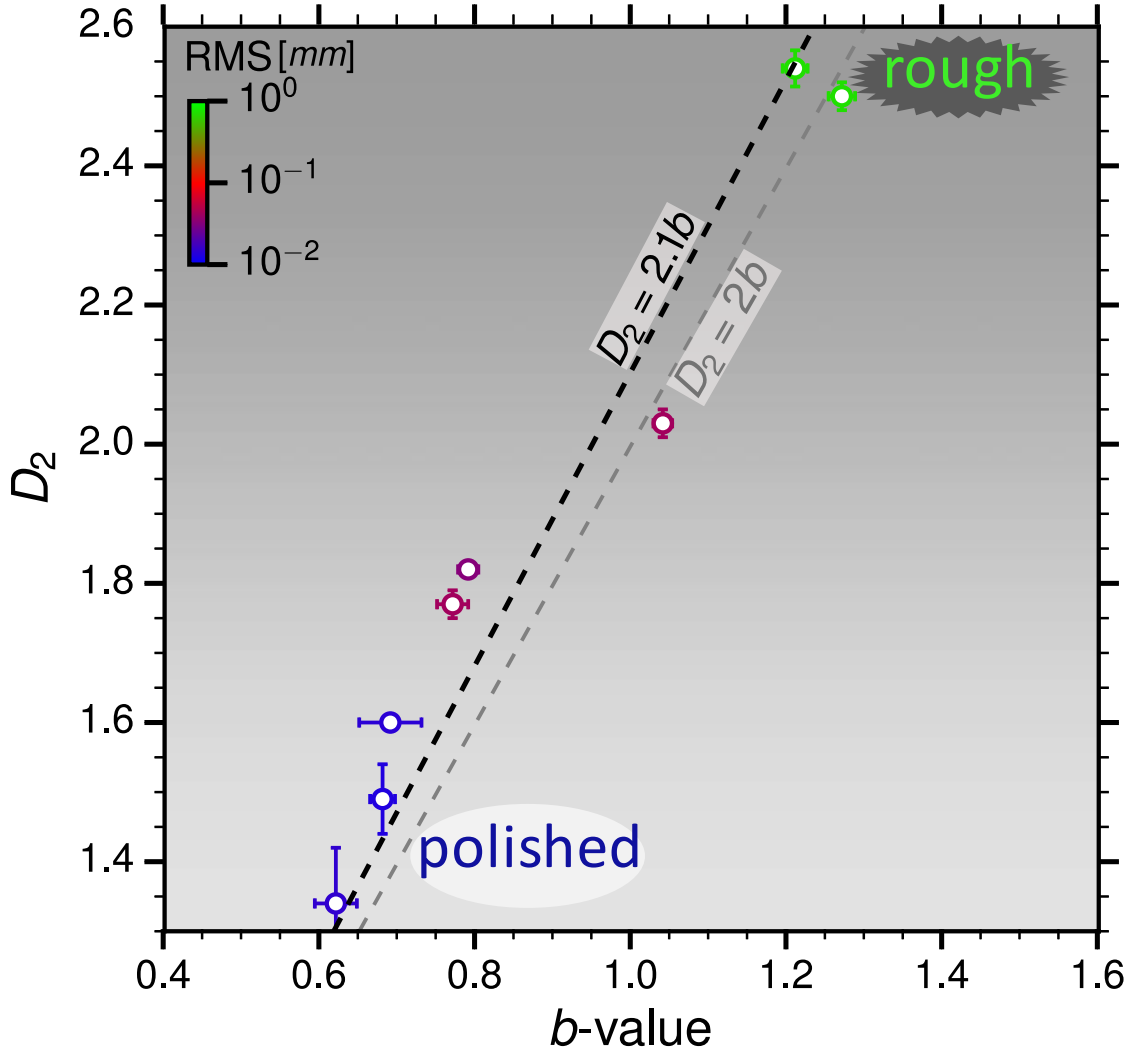
Surface roughness controls spatial distribution of acoustic emissions during stick-slip sliding



b-value increase on rougher faults

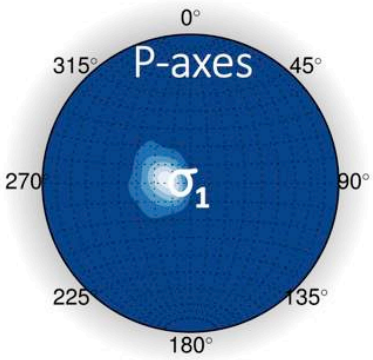


Geometric dimension and magnitude distribution is governed by fault roughness

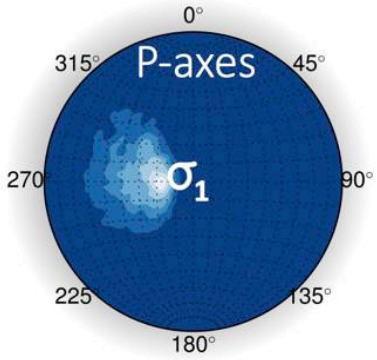


Stress fields are highly heterogenous for rough faults

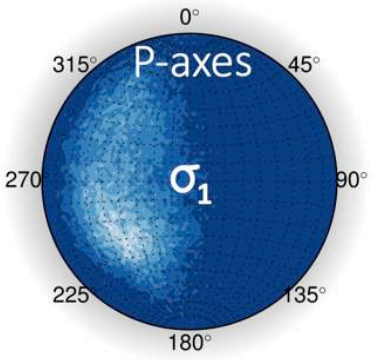
Polished

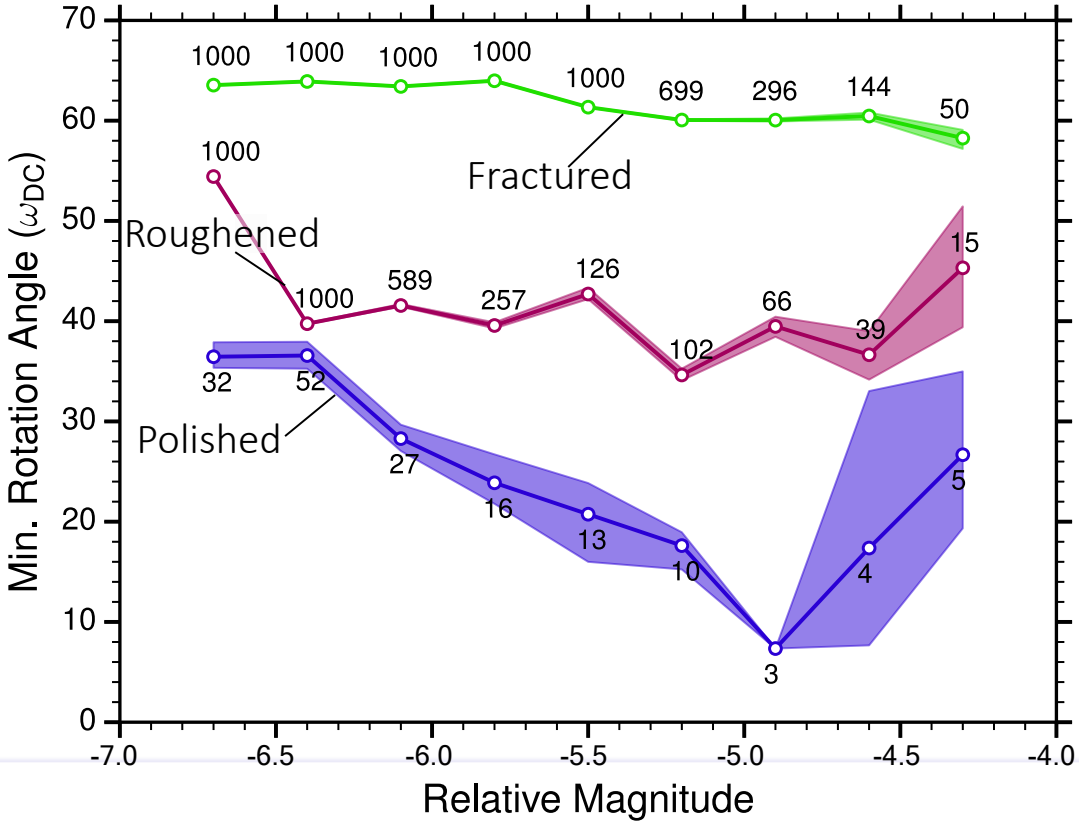


Roughened

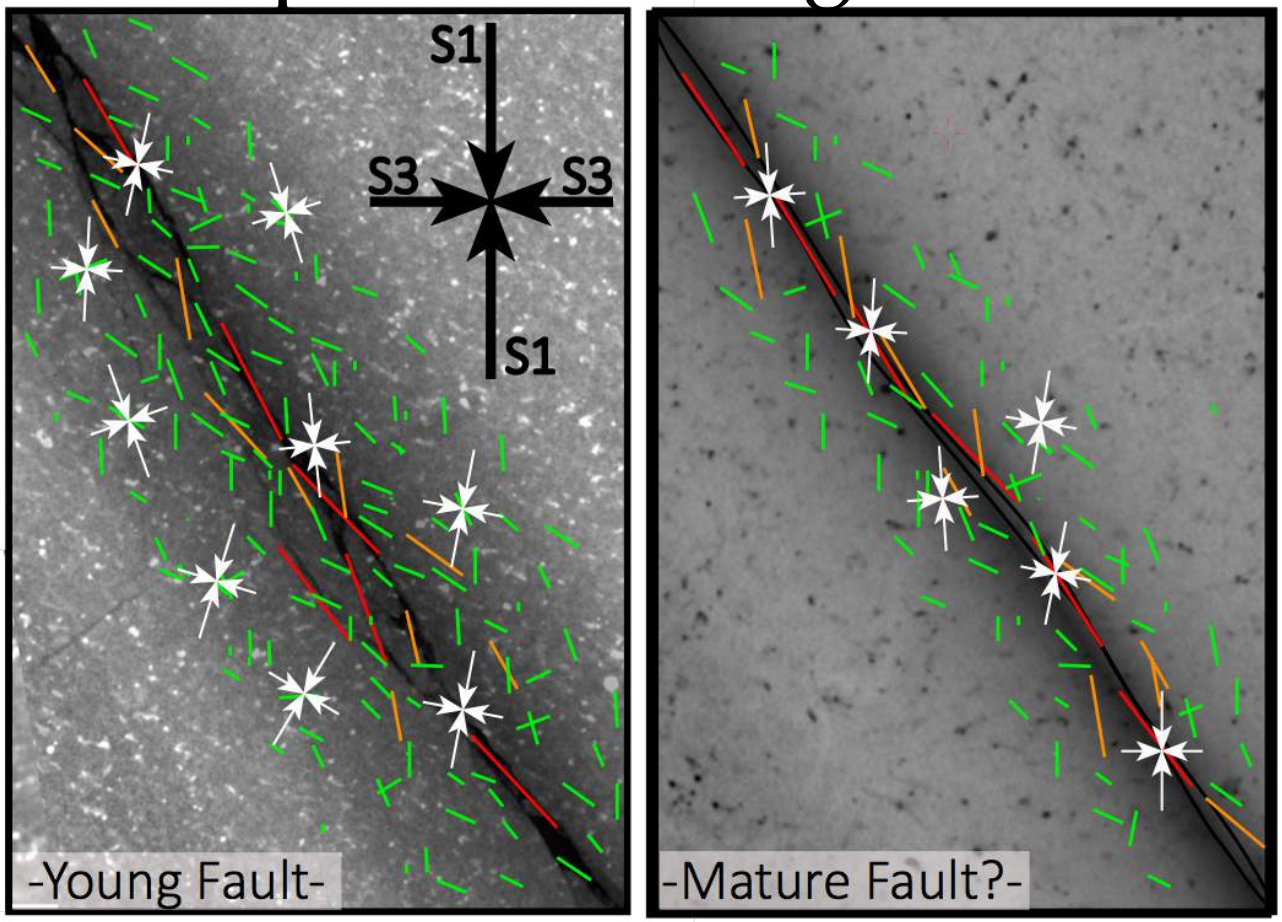


Fractured





What promotes larger seismic ruptures?



More homogeneous stress field (smooth faults or increased load)

↓

Localized deformation

↓

Lower *b*-values

Both stress and geometric effects should be consider to explain variations in *b*

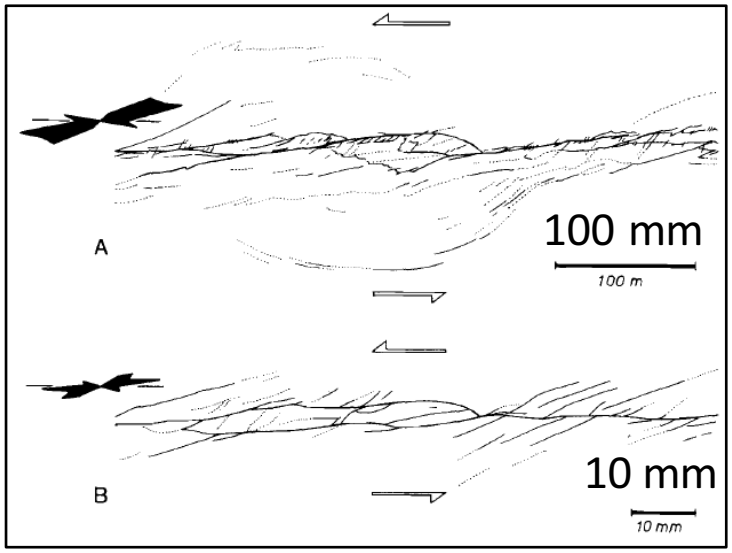
- Additional Slides -

???

Physical controls on statistical seismicity distributions such as Gutenberg-Richter distribution:

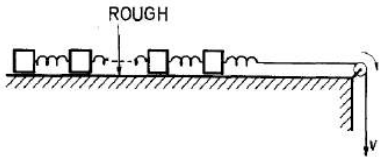
1) Geometric effects

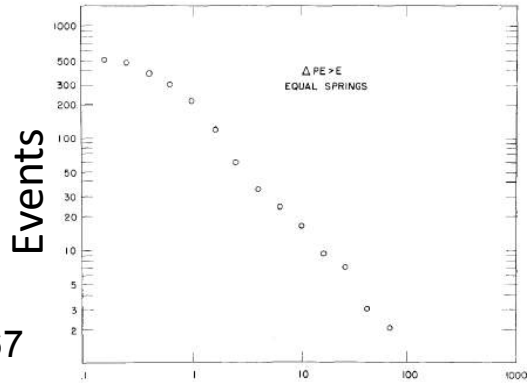
$$\log_{10}(N) \sim b \log_{10}(L^{3/c})$$



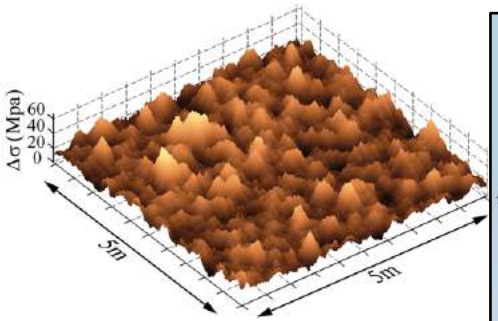
Tchalenko and Ambraseys 1970; King 1983

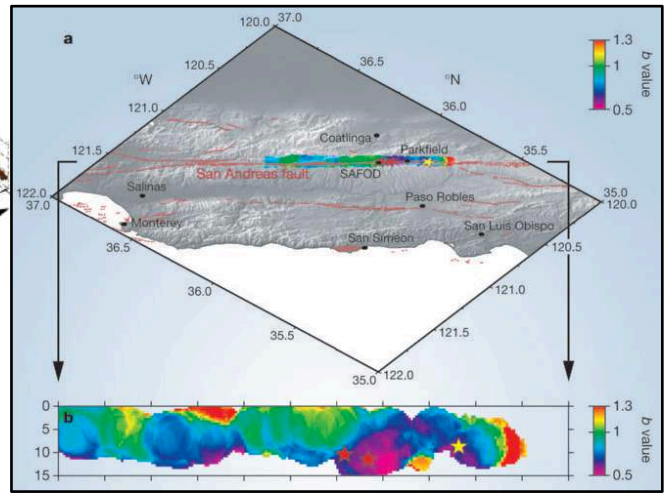
2) Dynamic effects and stress





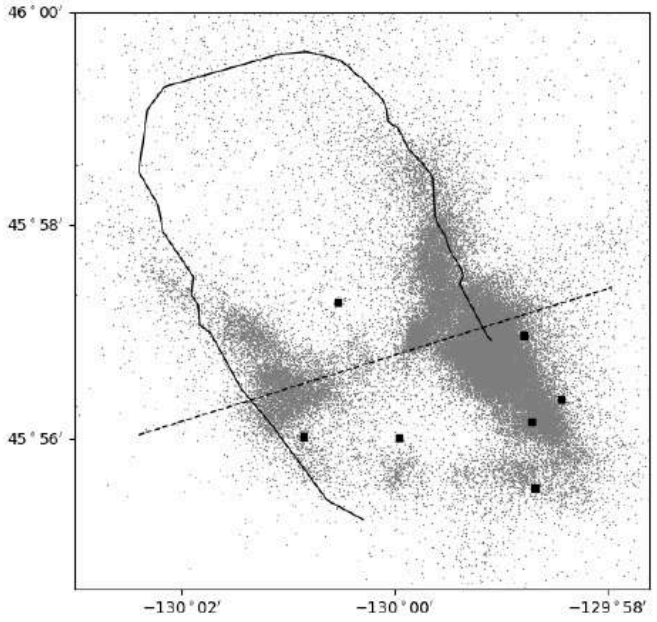
Burridge & Knopoff, *BSSA* 1967

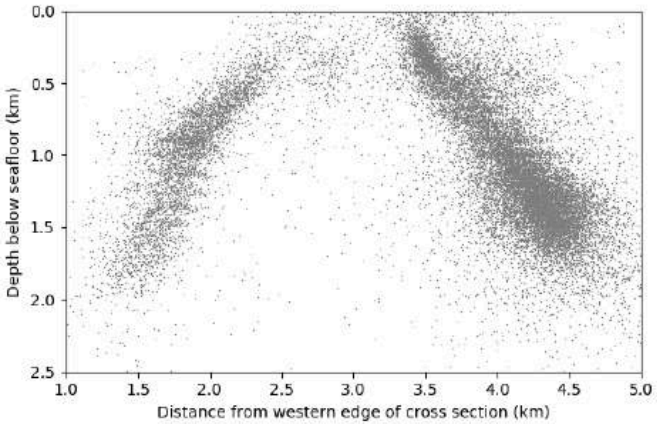


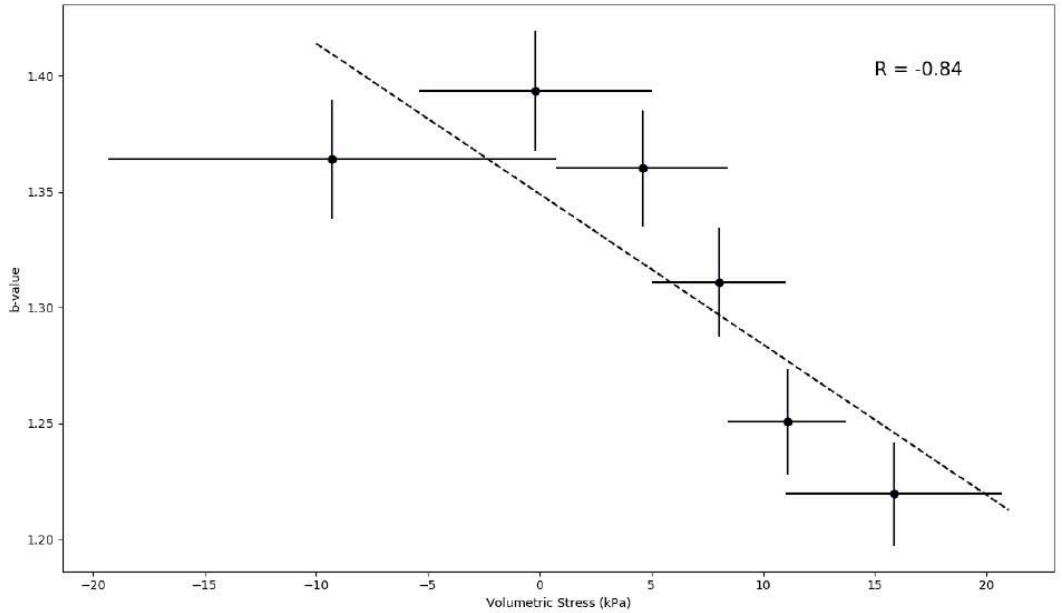


Schorlemmer et al. 2005; Candela et al., 2011

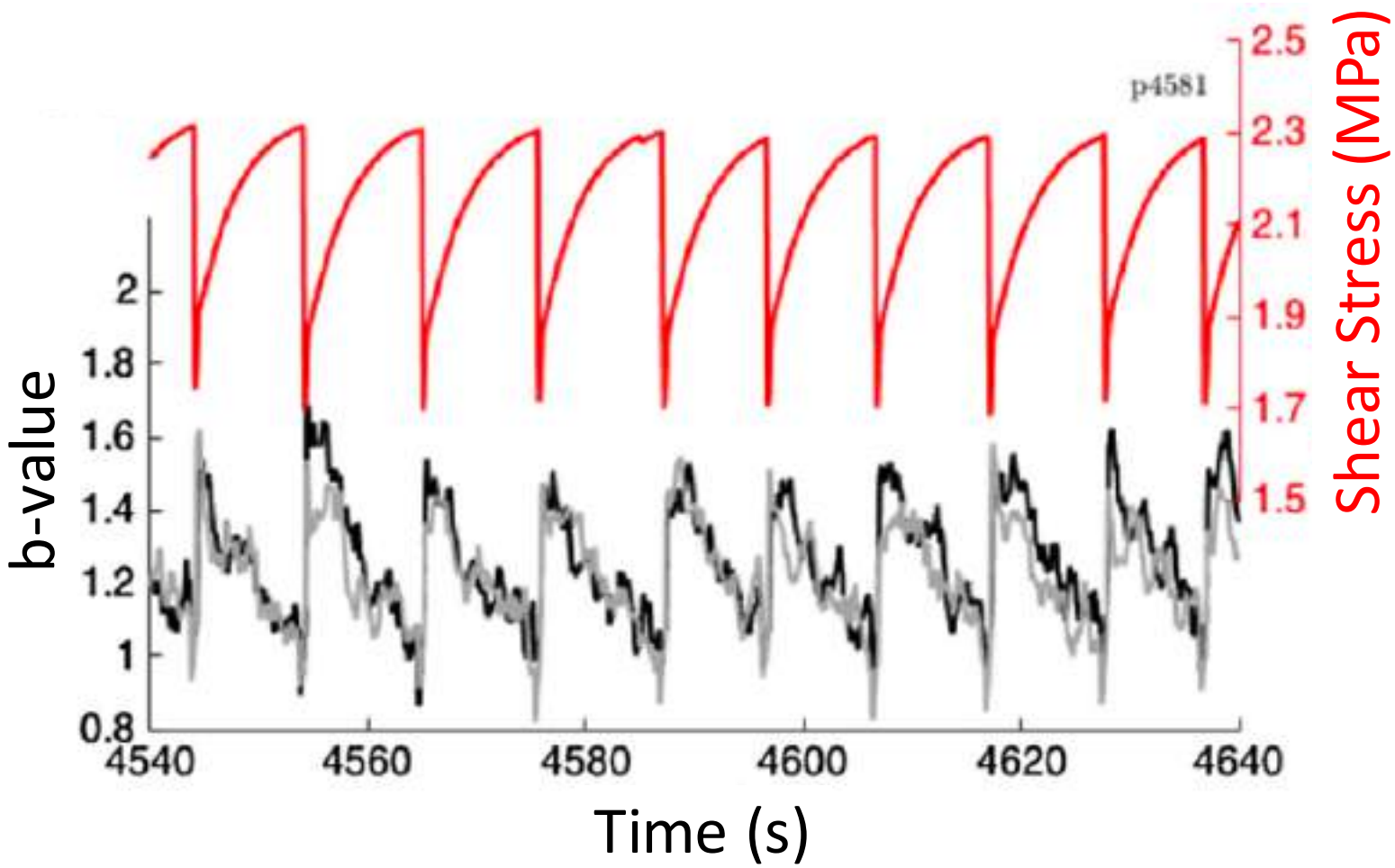
b-value changes due to tidal forcing and seismicity along a ring-shaped seamount fault





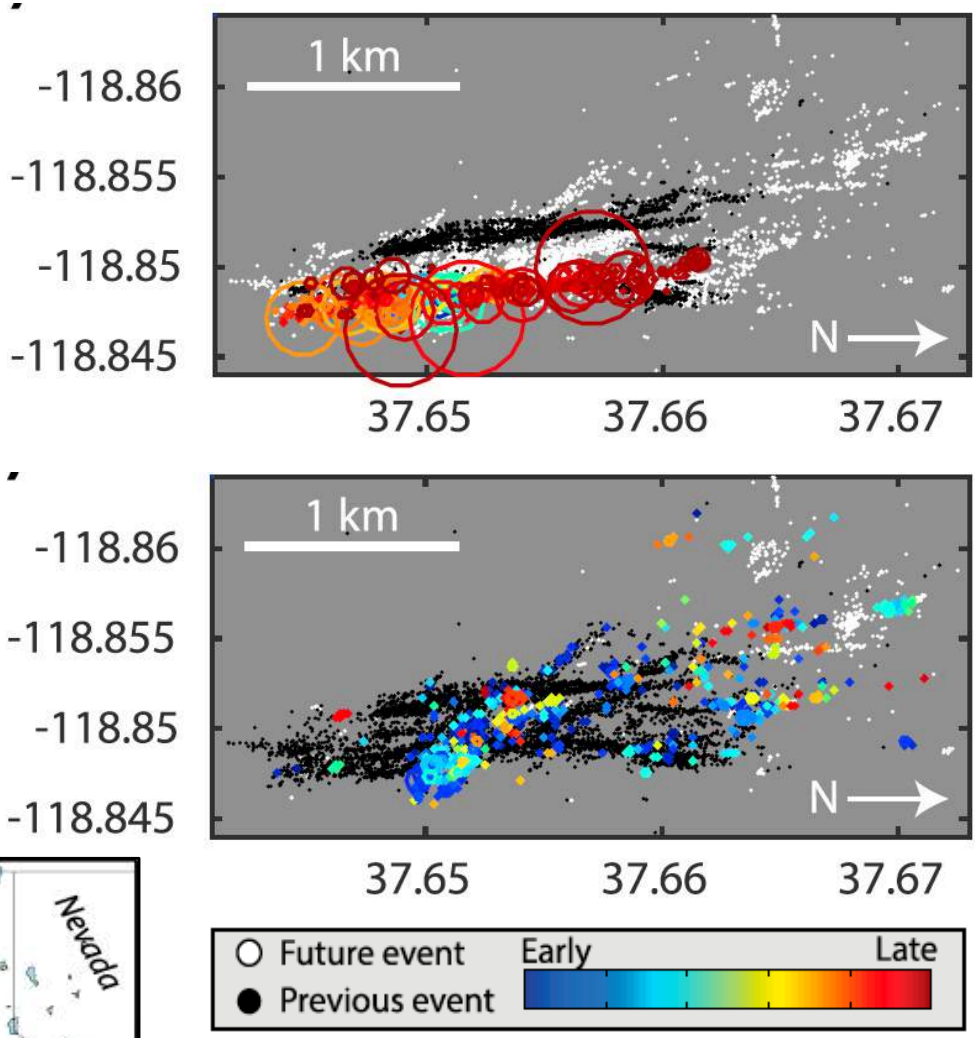


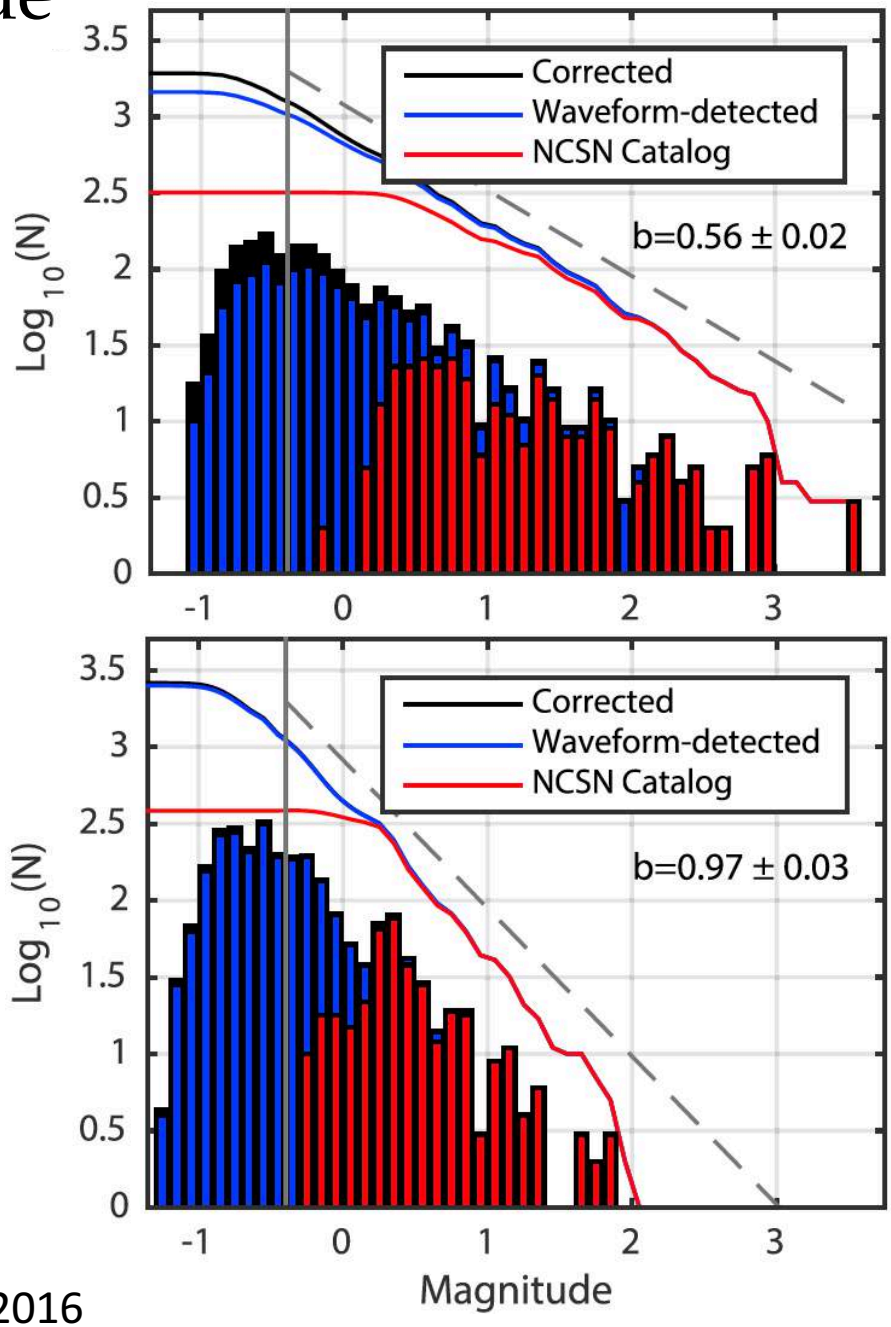
Even small stress variations in the lab can significantly modify *b*-values



Riviere et al. 2018

Spatial localization and low *b*-value during periods of swarm activity





Shelly et al. *JGR* 2016

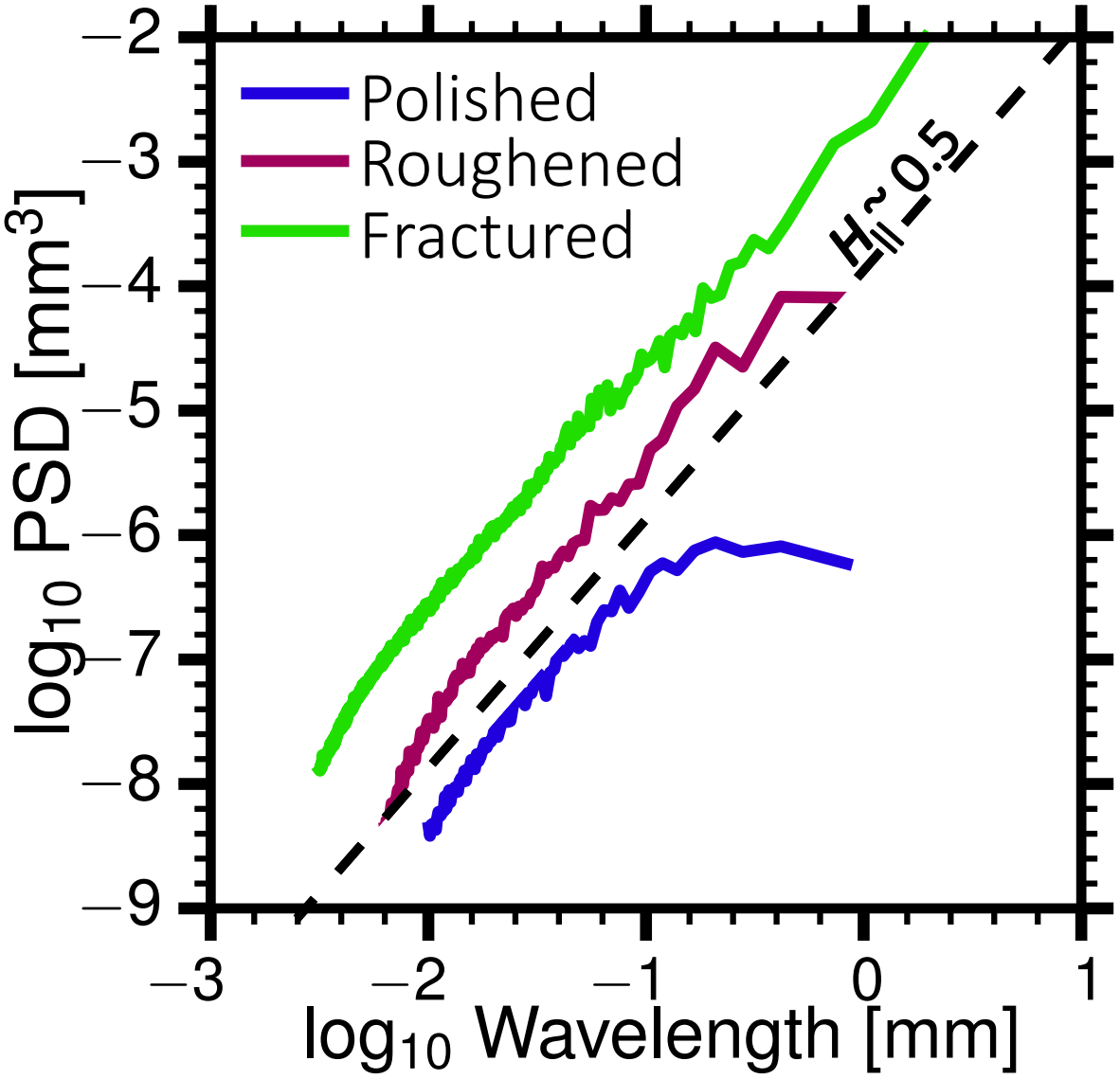
Different initial conditions, same loading procedure

Cut, Polished

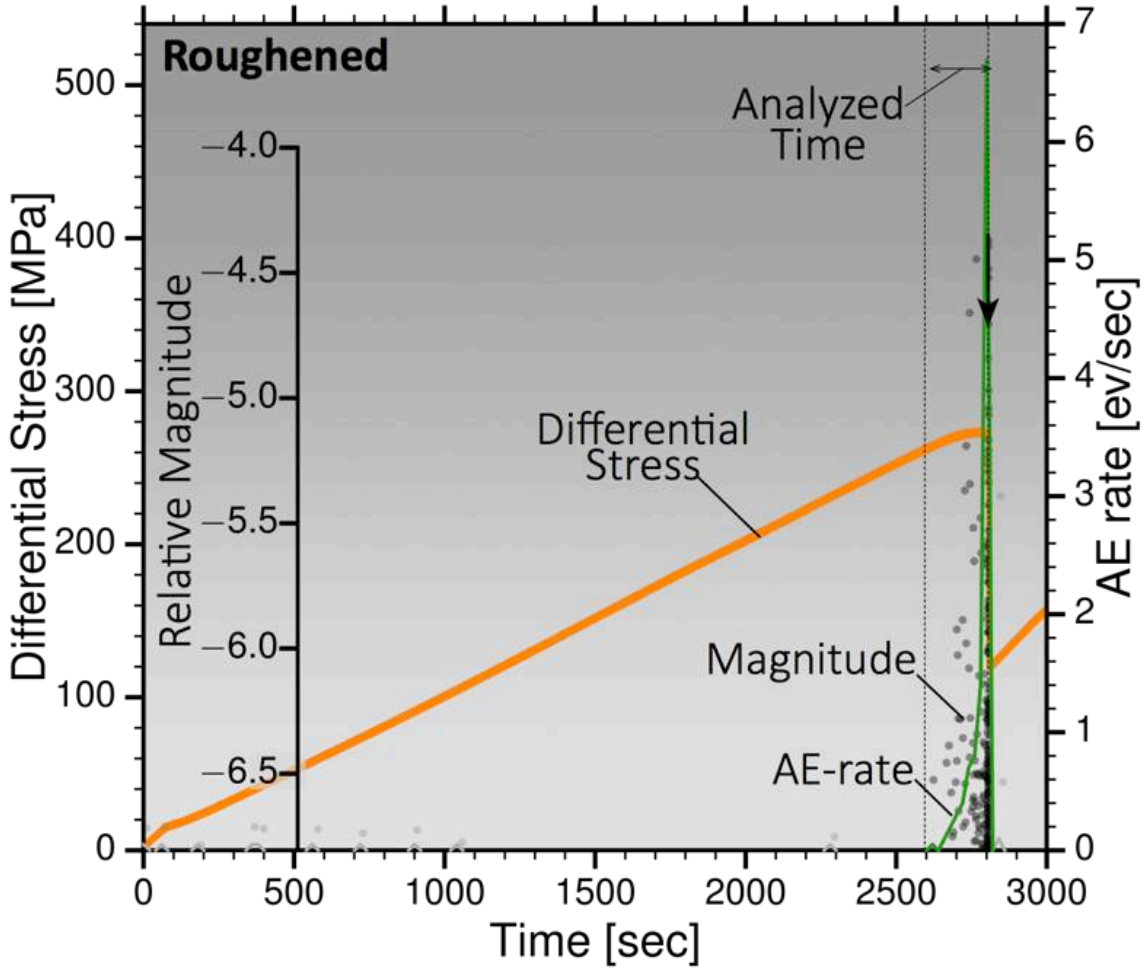
Cut, Roughened

Fractured

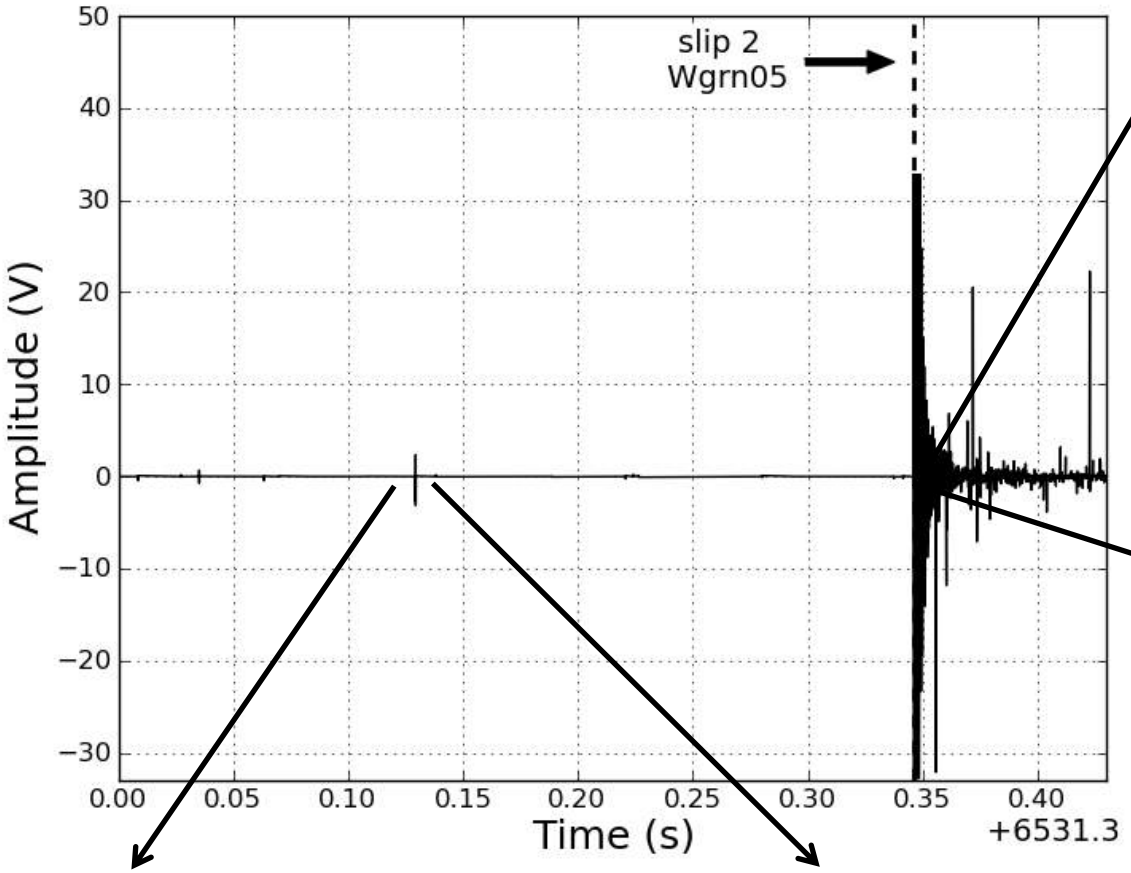
Surface roughness and power-spectral-density

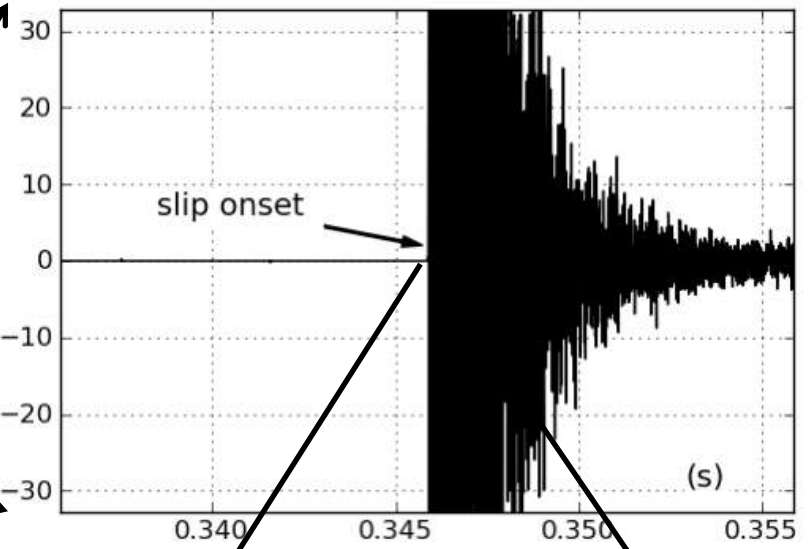


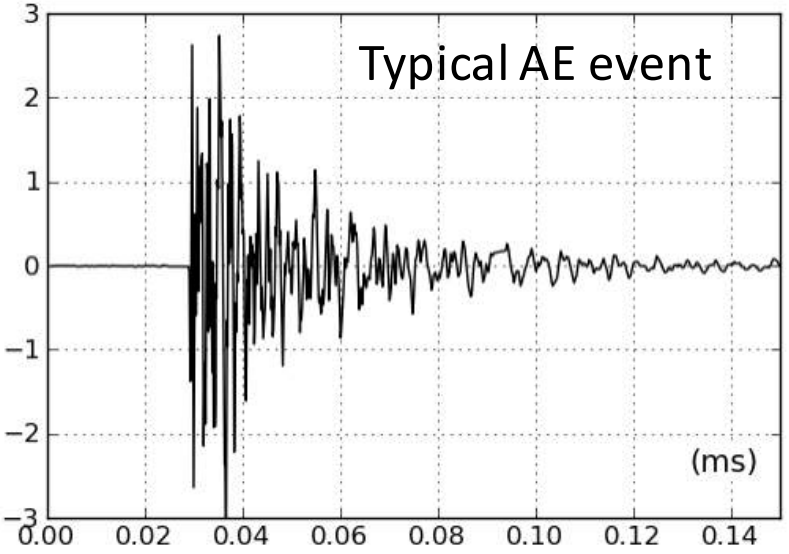
Applied stress and acoustic emission activity



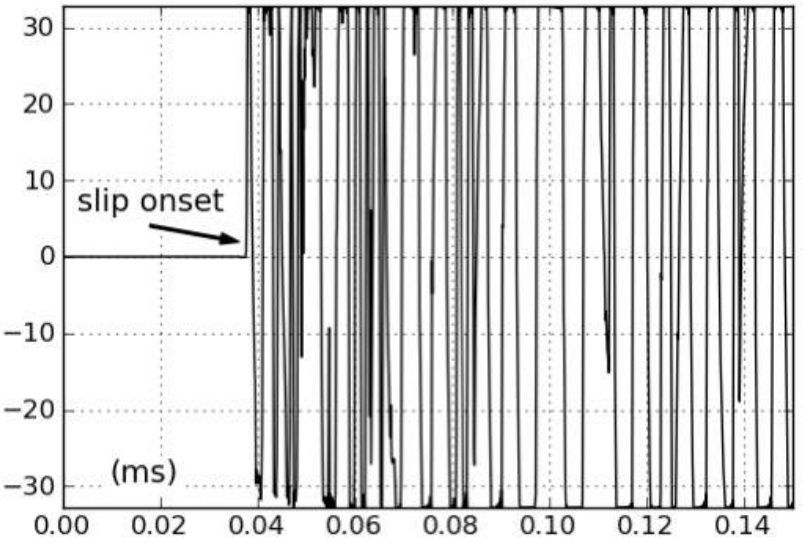
Waveforms of a large slip event and 'typical' AE



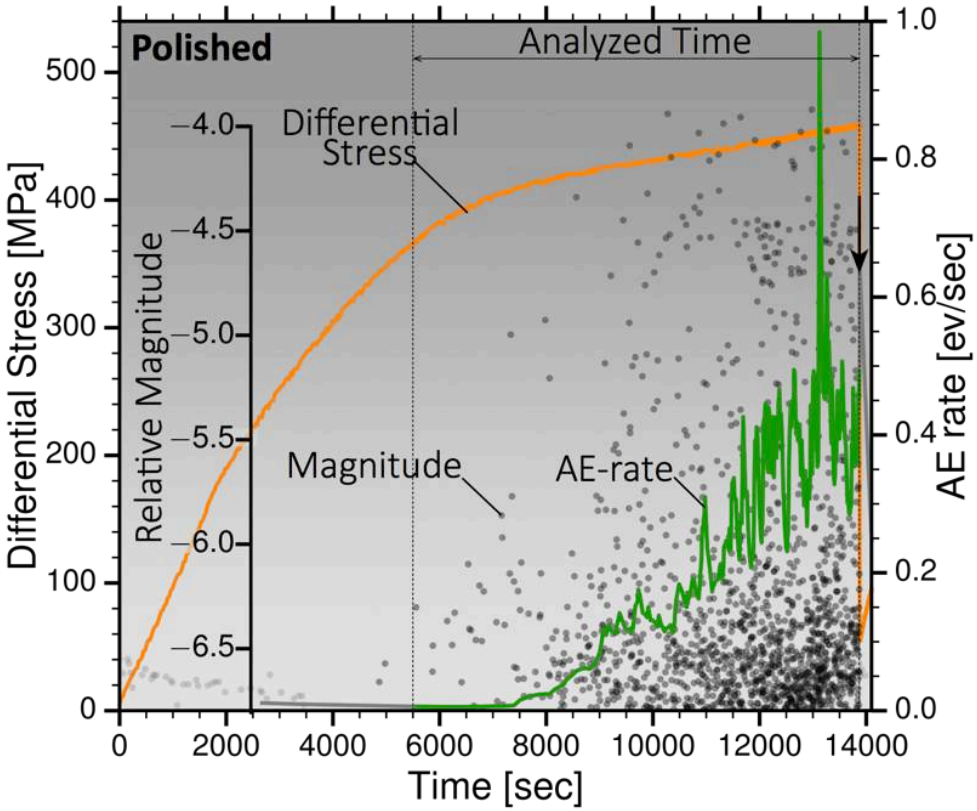


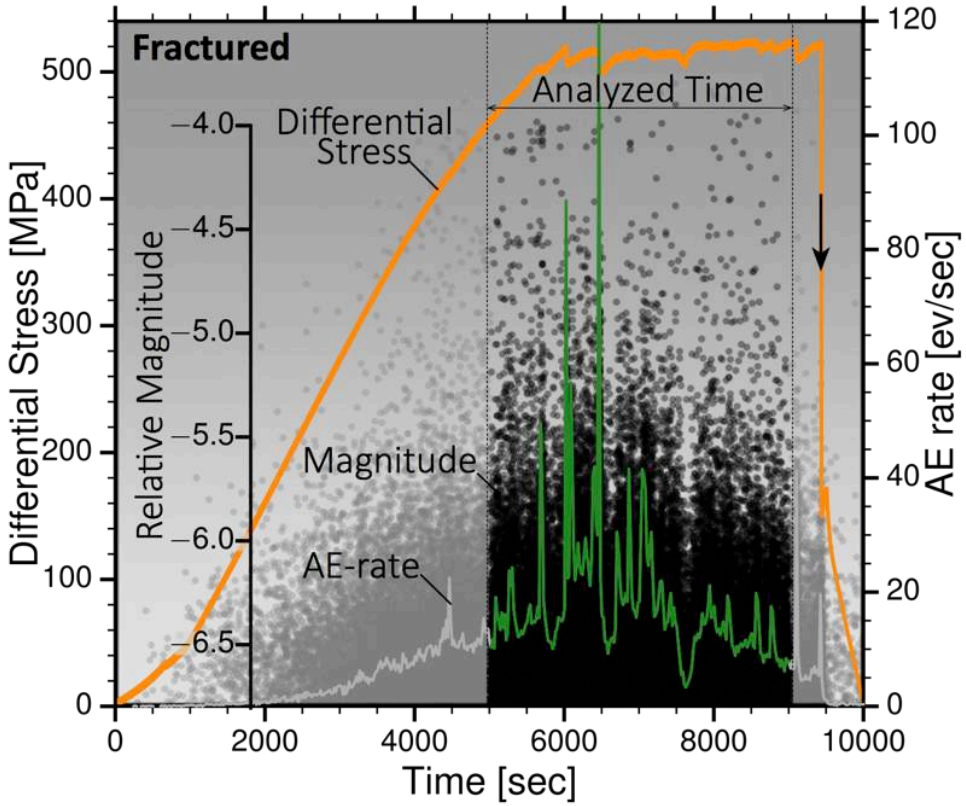


Large stress drop event

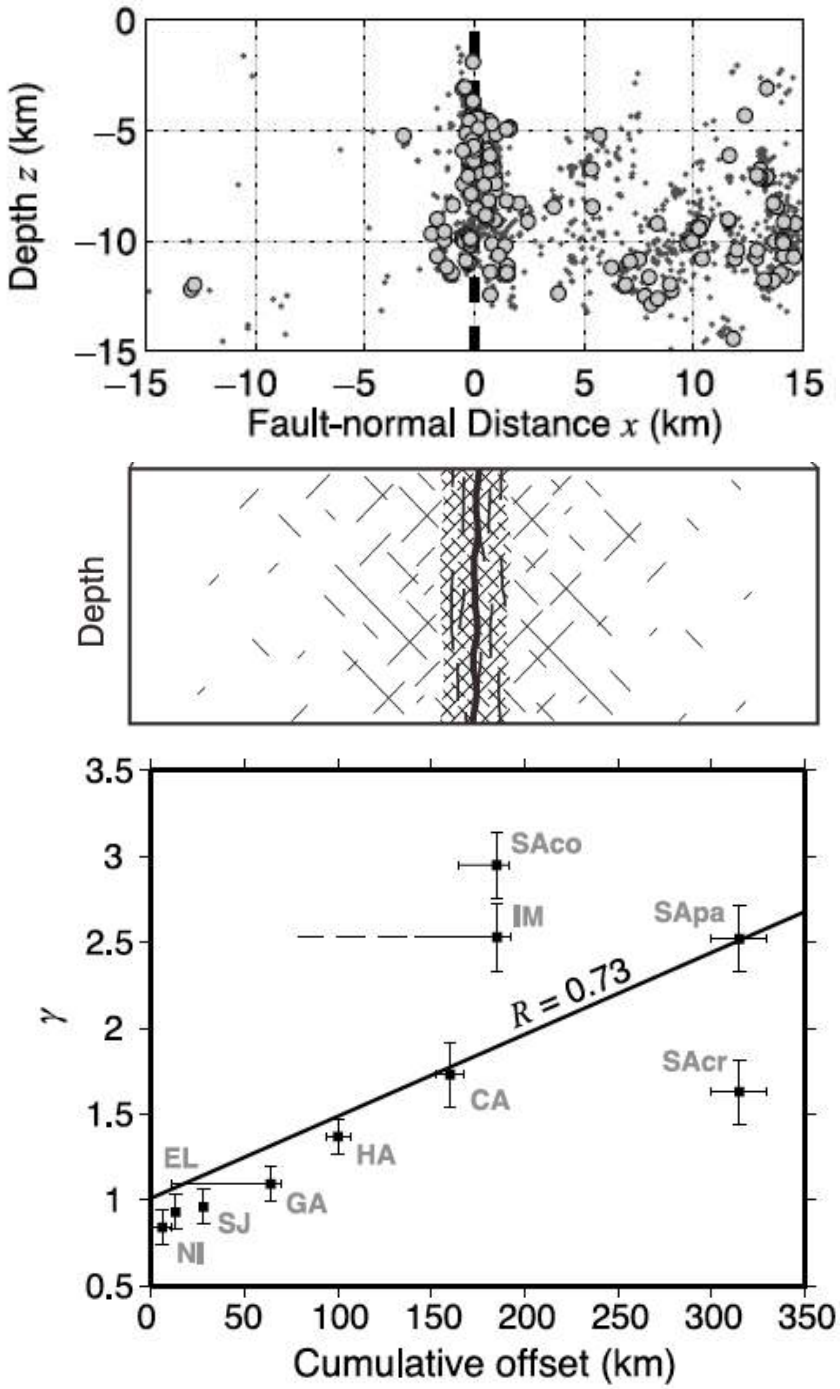


Applied stress and acoustic emission activity

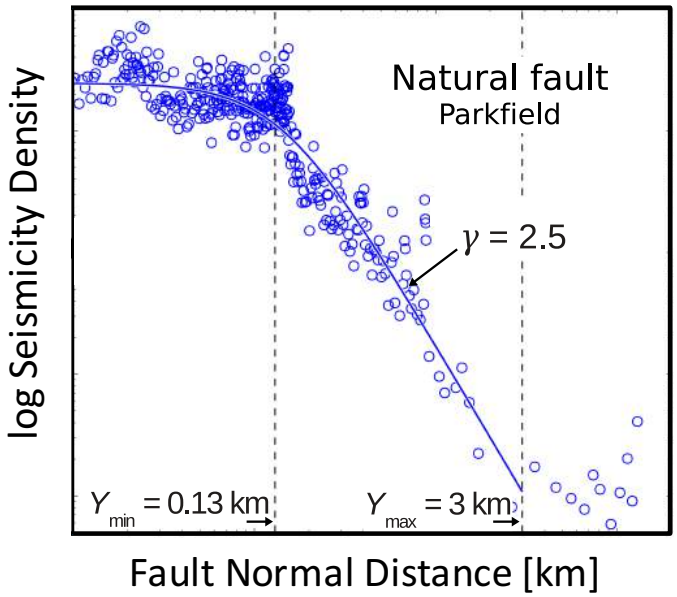


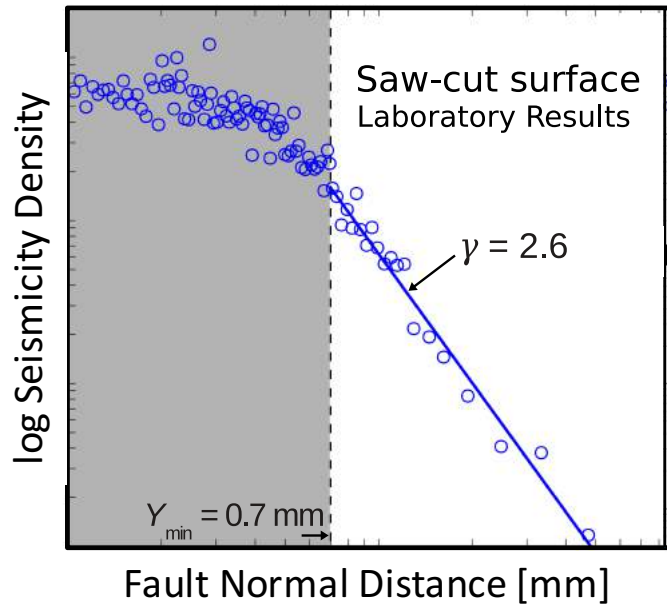


Seismicity distributions across strike-slip faults are influenced by fault roughness



Powers & Jordan, *JGR*, 2010





Goebel et al., *GJI*, 2014