Dynamics of foreshocks and pre-slip during laboratory earthquakes

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European Research Council

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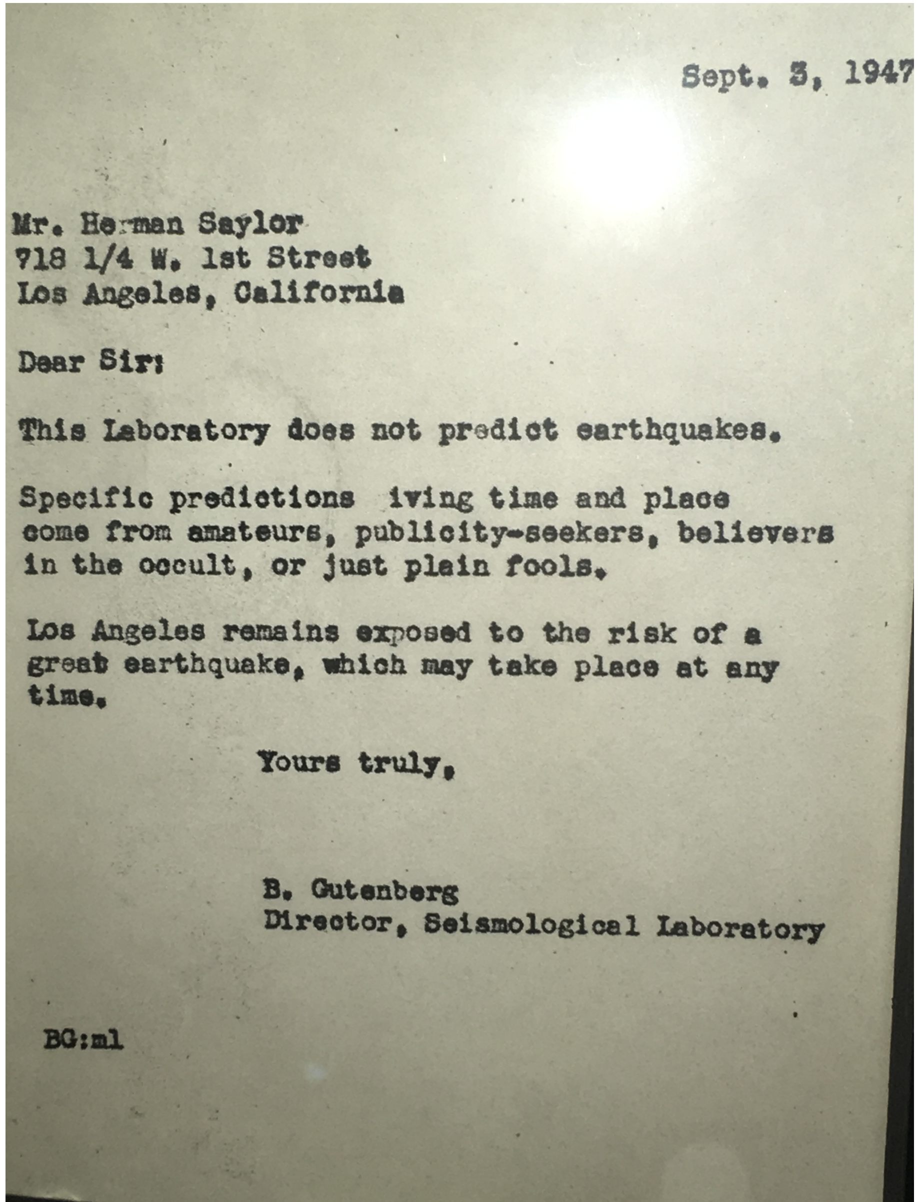
MOTIVATION



Sept. 3, 1947

Mr. Herman Saylor
718 1/4 W. 1st Street
Los Angeles, California

Dear Sir:

This Laboratory does not predict earthquakes.

Specific predictions iving time and place come from amateurs, publicity-seekers, believers in the occult, or just plain fools.

Los Angeles remains exposed to the risk of a great earthquake, which may take place at any time.

Yours truly,

B. Gutenberg
Director, Seismological Laboratory

BG:ml

Integrating 30 years of experimental rock fracture mechanics: Ohnaka’s view

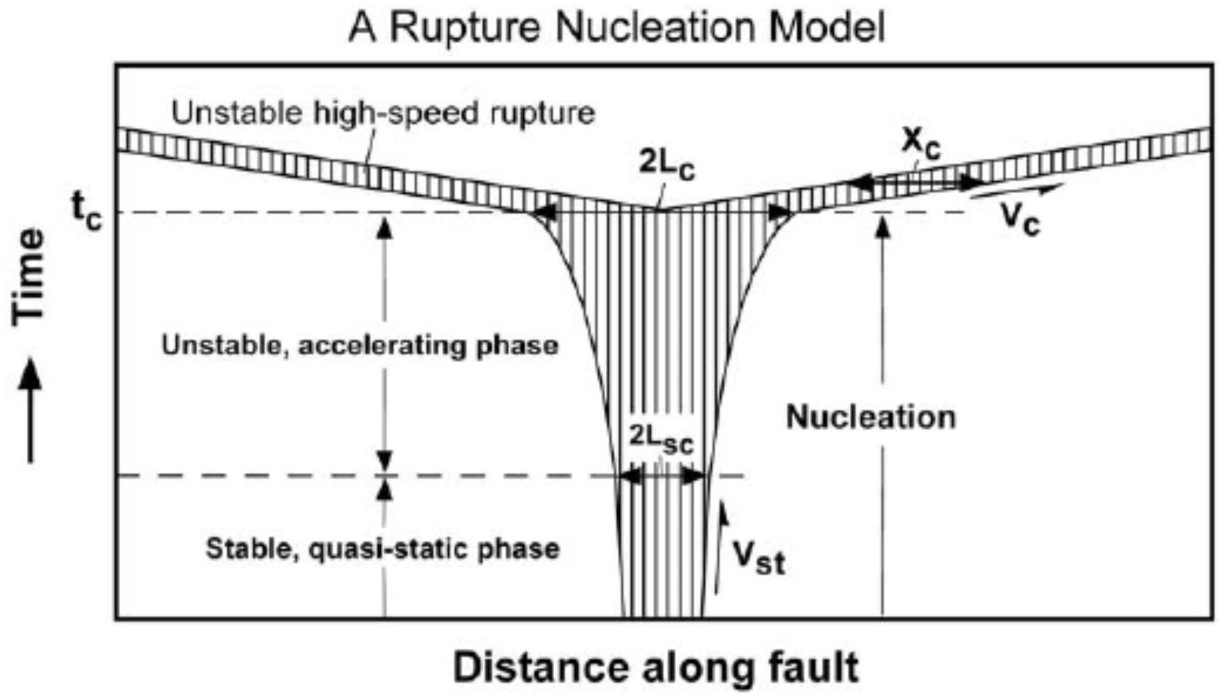


Figure 15. A physical model of rupture nucleation. Hatched portion indicates the zone in which the breakdown (or slip-weakening) proceeds with time.

Ohnaka 2003

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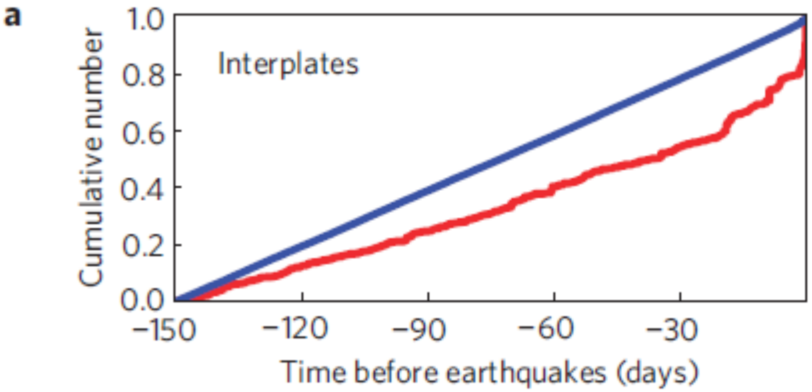
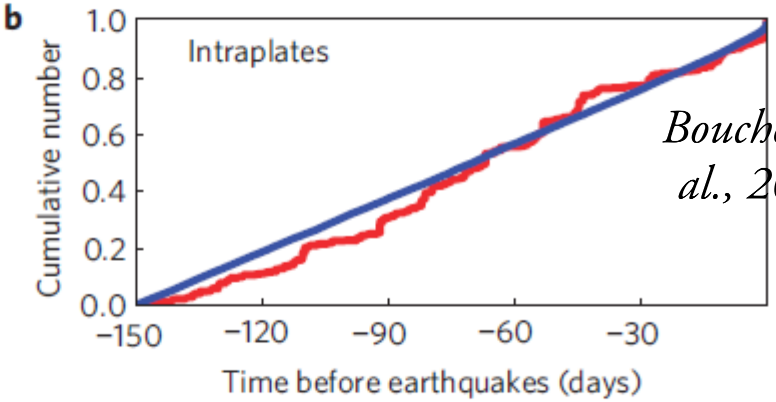
MOTIVATION

Many earthquakes are preceeded by foreshocks

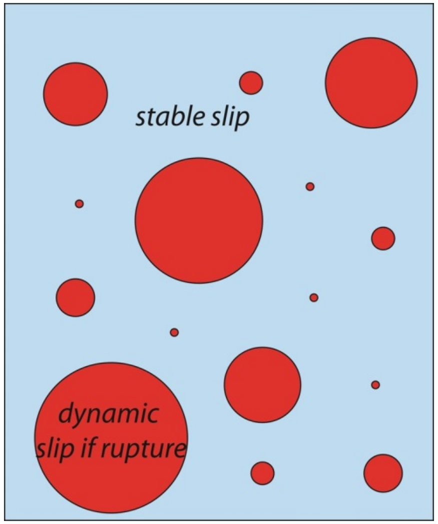




Bouchon et al., 2013

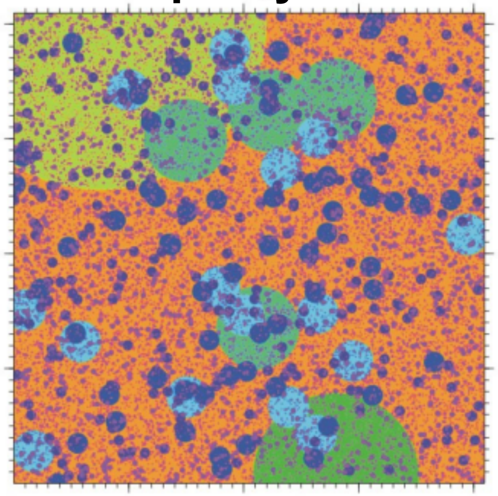
Foreshocks are due to the failure of small asperities prior the main rupture

Barrier model



Failure of the seismic asperities due to aseismic slip in the surrounded area

Asperity model



Slip due to the failure of small asperities

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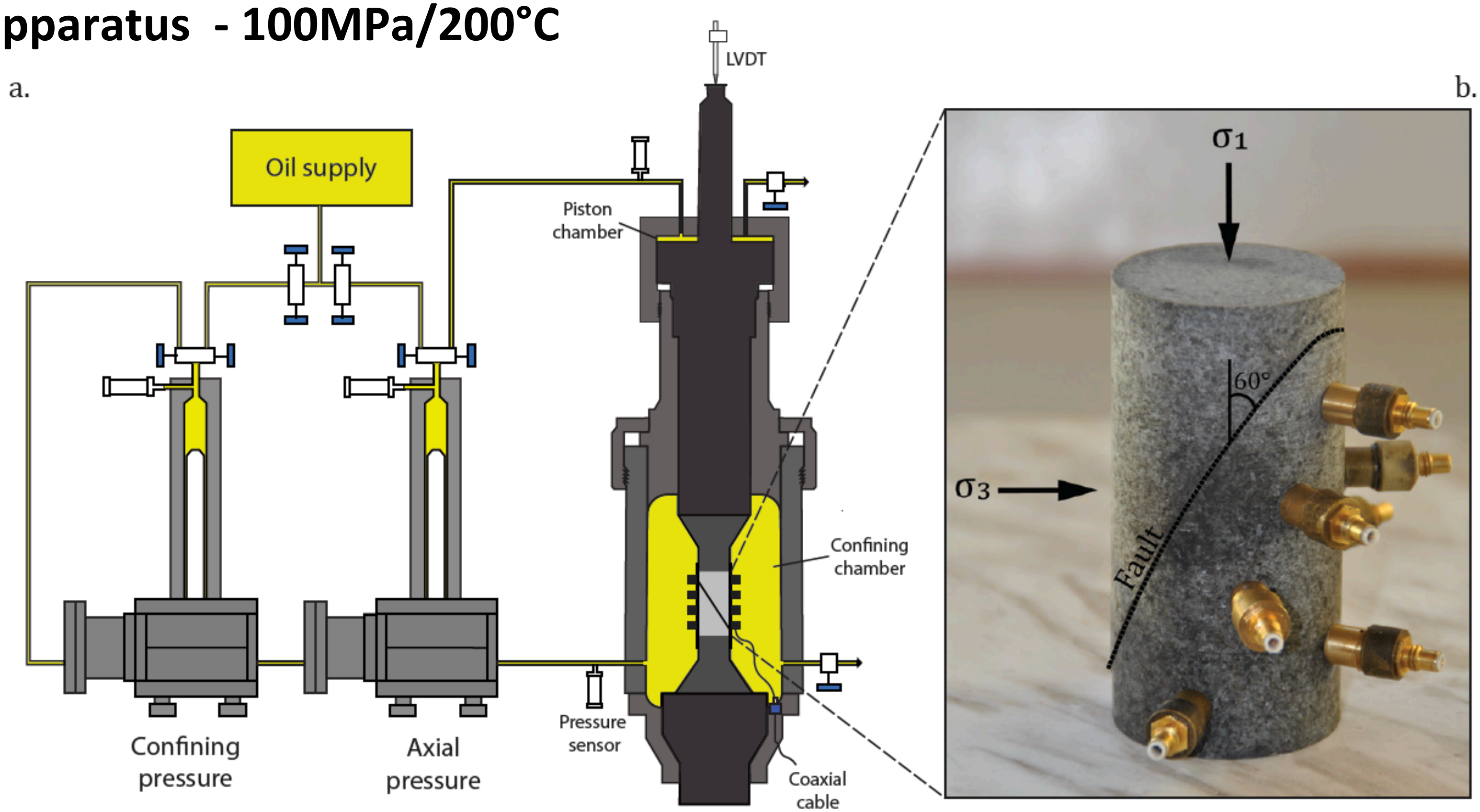
Reproducing crustal depth in the lab

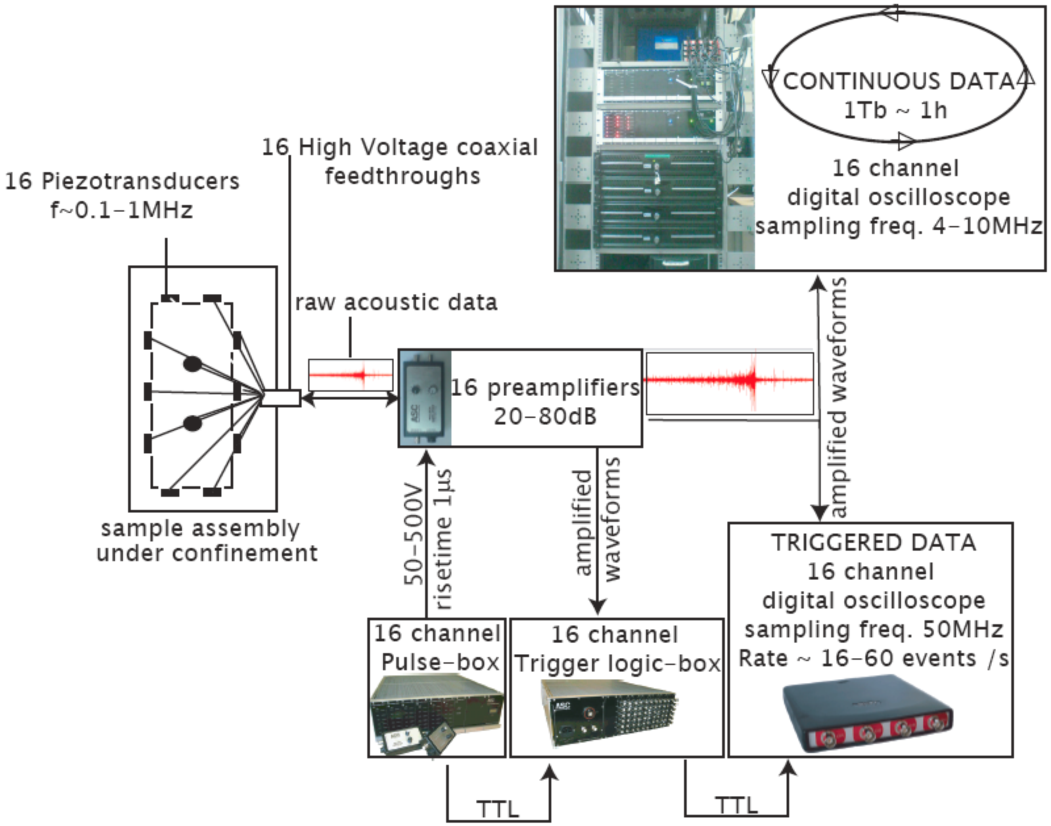
Triaxial apparatus - 100MPa/200°C



- Designed specially for HF acoustics
- Saw-cut samples of Indian gabbro (oceanic crust) deformed et 30, 45 and 60MPa
- Imposed sliding velocity 1micron/s
- Polished (smooth) initial surfaces ie < 20microns roughness

Recording nano to micro seismicity in the lab

Acoustic Recorder – 16 channels



- Calibrated sensors using laser interferometry between 0.1-2.5MHz
- Continuous acoustic wfms (10 MHz sampling freq. on 8 channels)
- Triggered data – for mainshock only

Stick-Slip as a Mechanism for Earthquakes

W. F. Brace; J. D. Byerlee

Science, New Series, Vol. 153, No. 3739. (Aug. 26, 1966), pp. 990-992.

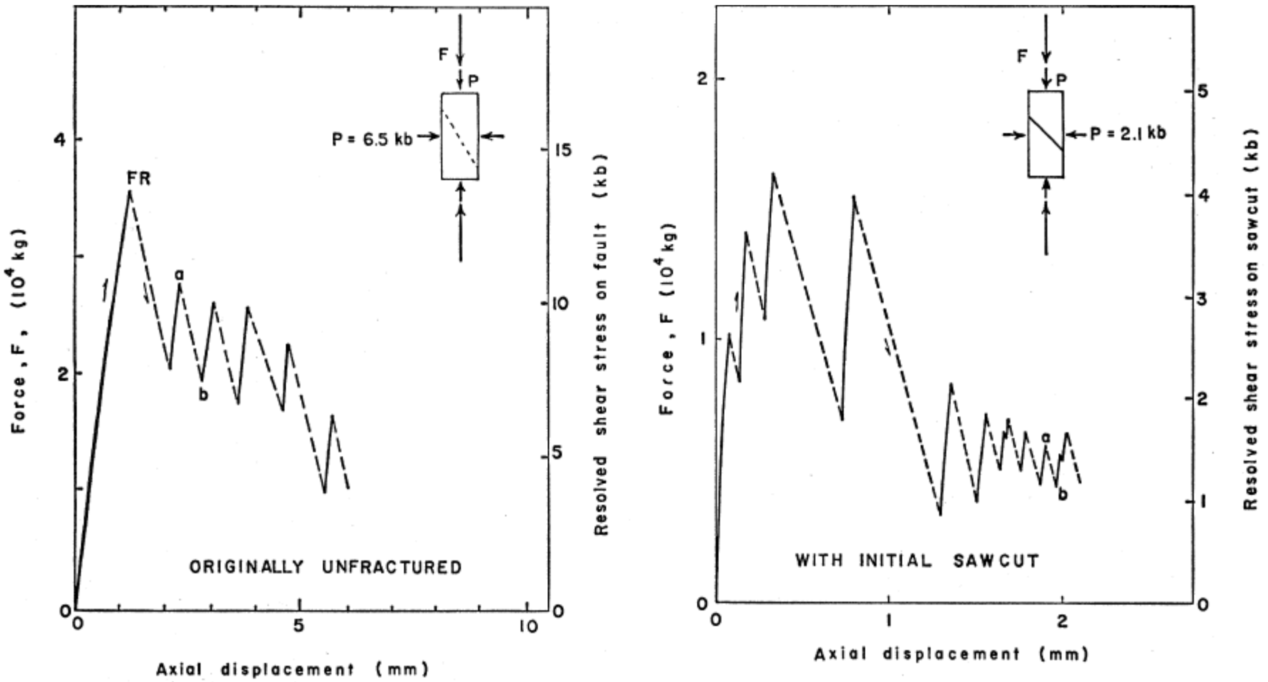


Fig. 1 (left). Force-displacement curve for the axial direction in a cylindrical sample of Westerly granite. Small diagram above the curve shows schematically how stress was applied to the sample. The sample fractured at point *FR* forming the fault which is shown as a dotted line in the small diagram. The exact shape of the curves during a stress drop (such as *ab*) is not known and is shown dotted. *P* is confining pressure. Fig. 2 (right). Same as Fig. 1 except that the sample contained a sawcut with finely ground surfaces as shown schematically (small figure) by a heavy line.

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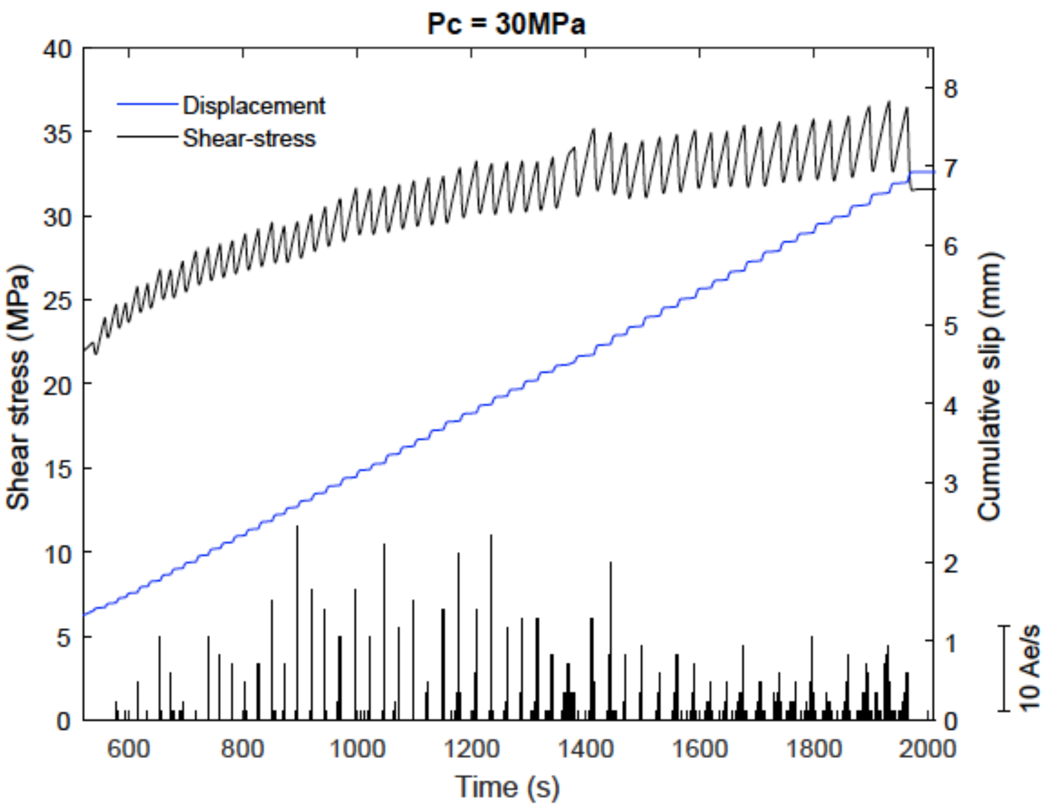
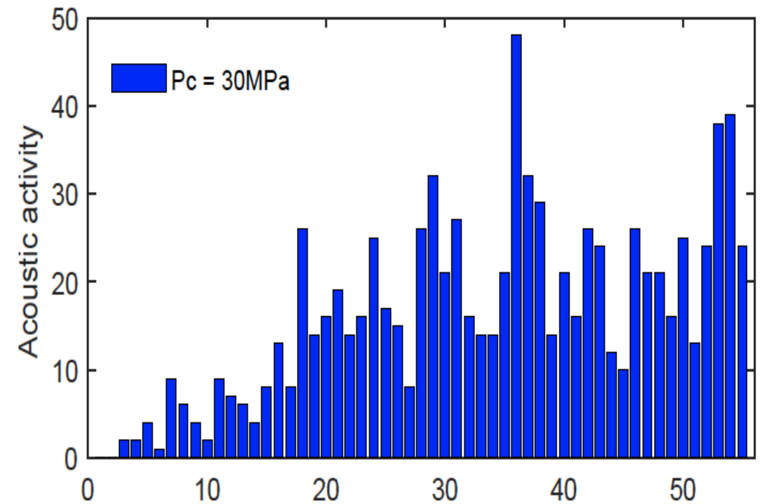
Foreshock dynamics

- Acoustic emission precursory to stick-slip failure





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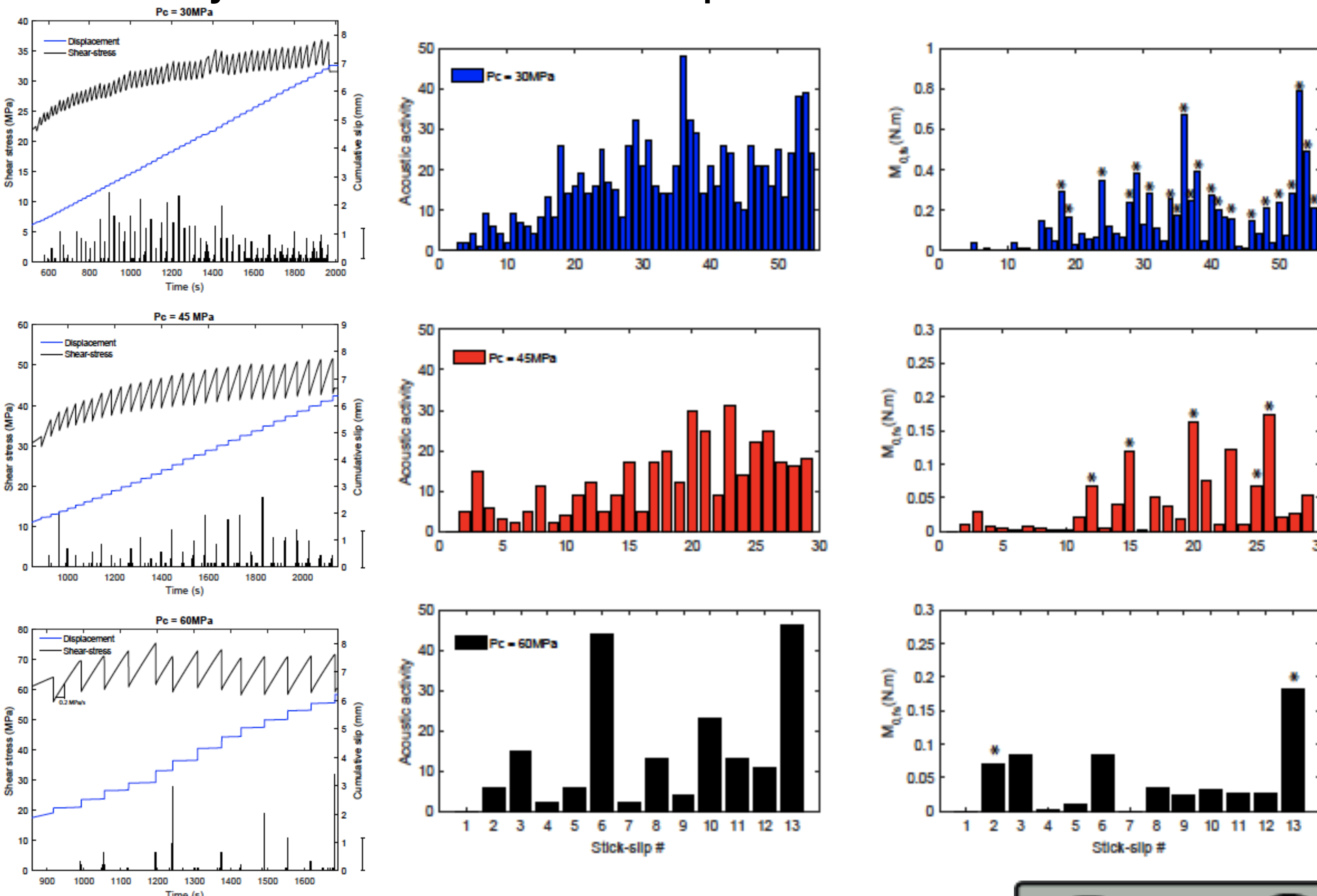
Marty et al. in prep.

Foreshock dynamics

- Variability in the foreshock sequences

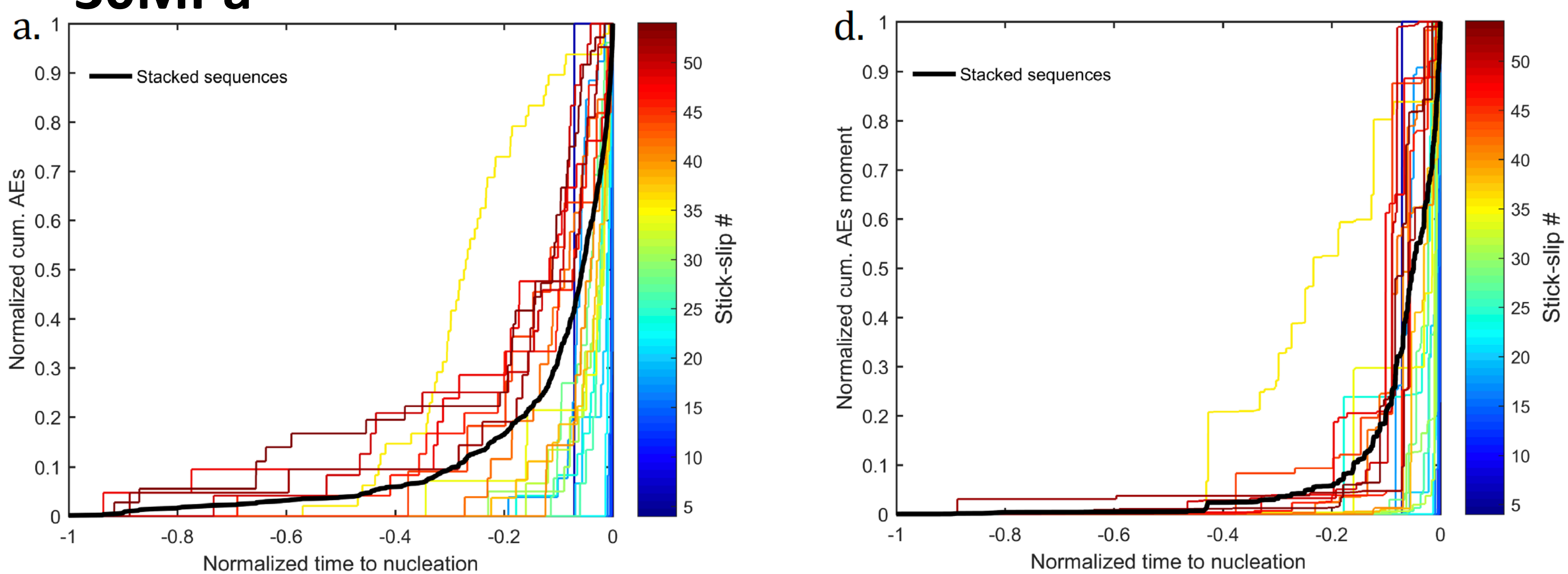


 Marty et al. in prep.

Foreshock dynamics

- Stacked sequence of foreshocks --> Inverse Omori's law

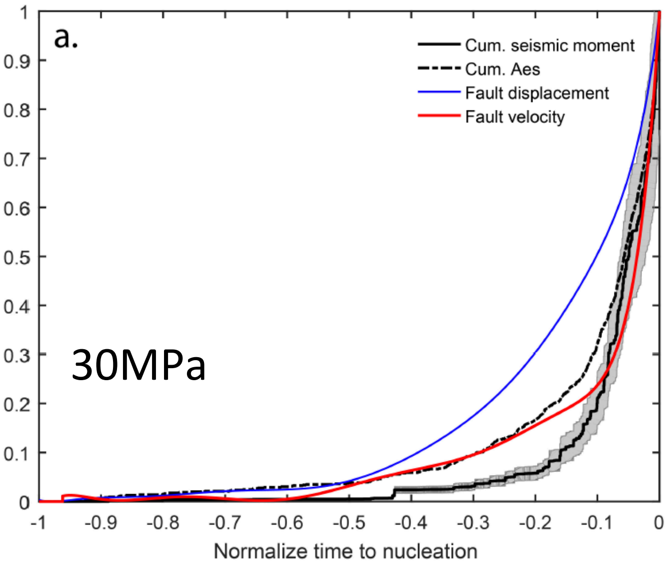
30MPa

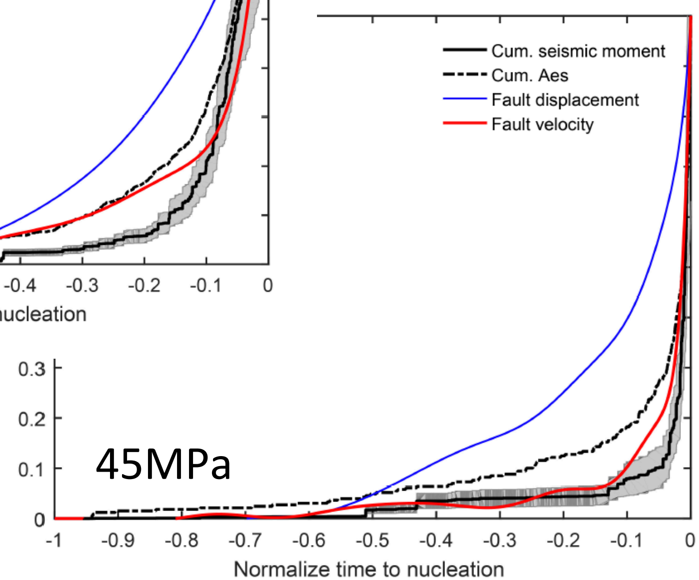


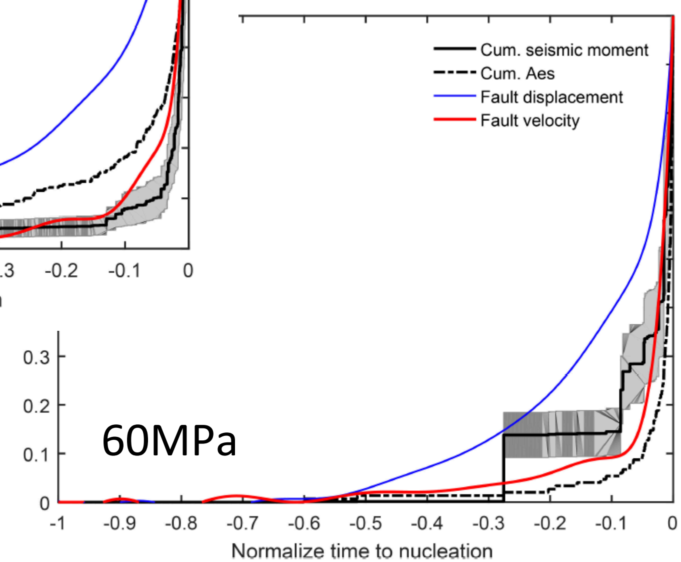
 Marty et al. in prep.

Foreshock dynamics

- Cum AEs and seismic moment scales with fault velocity







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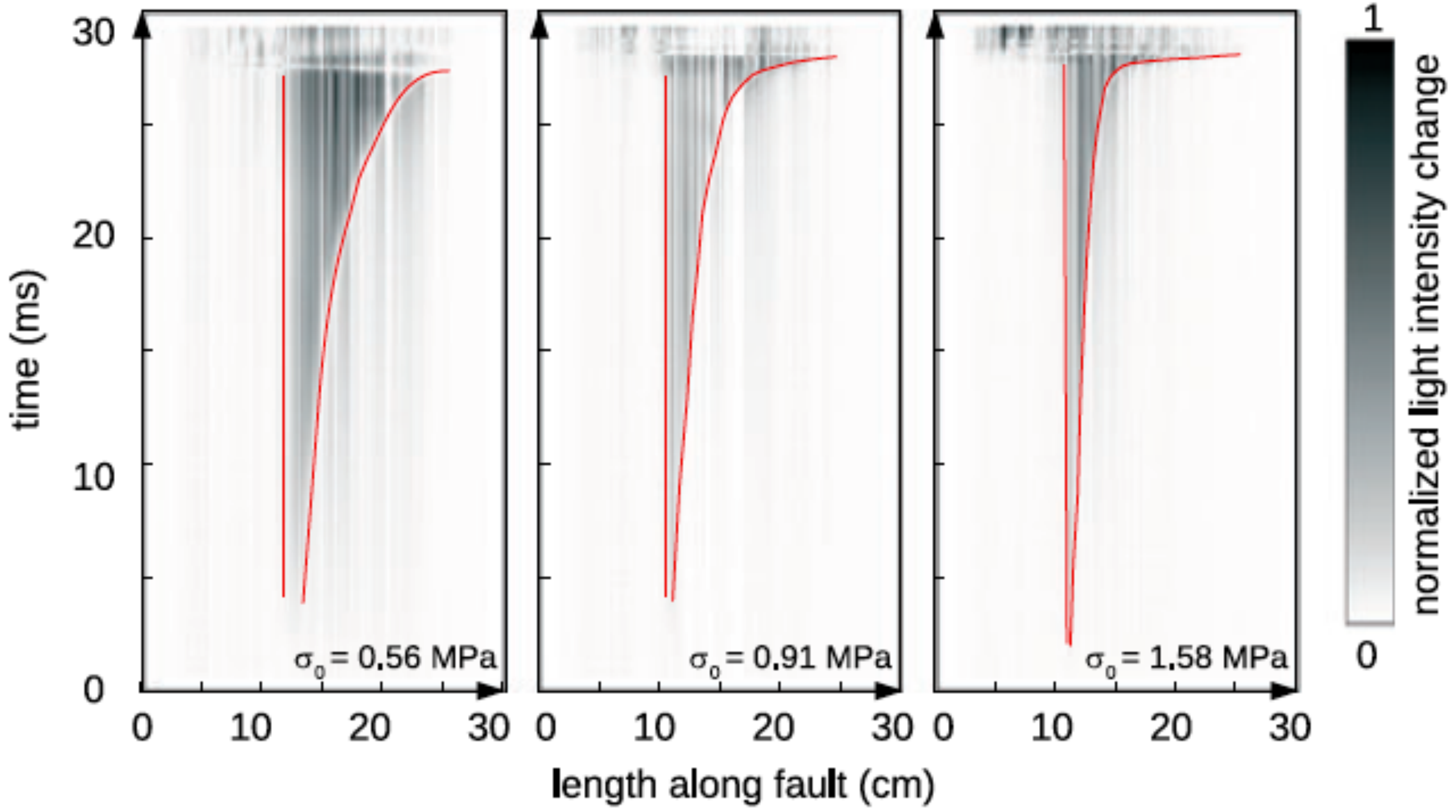
Nucleation of stick slip instabilities
Influence of normal stress

Latour et al., 2013



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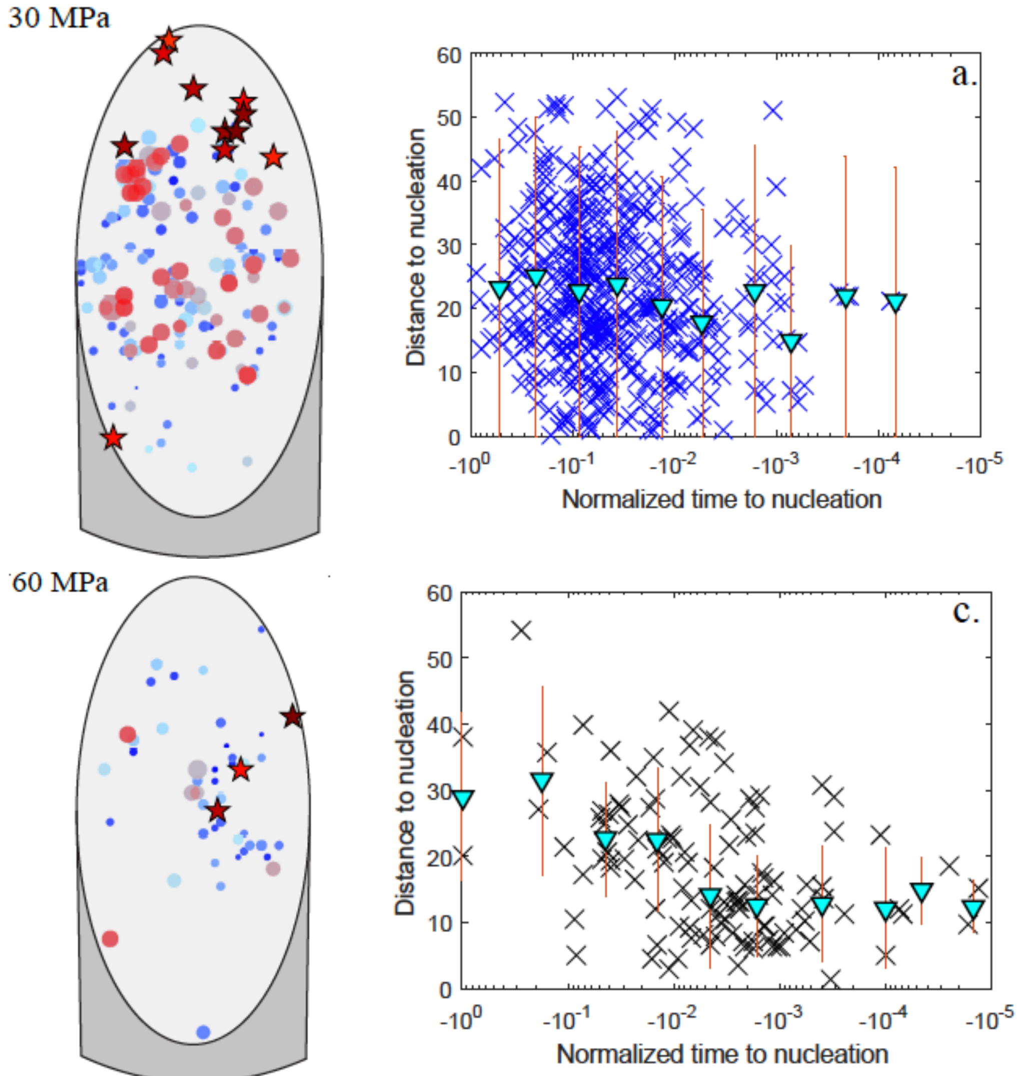
Foreshock dynamics

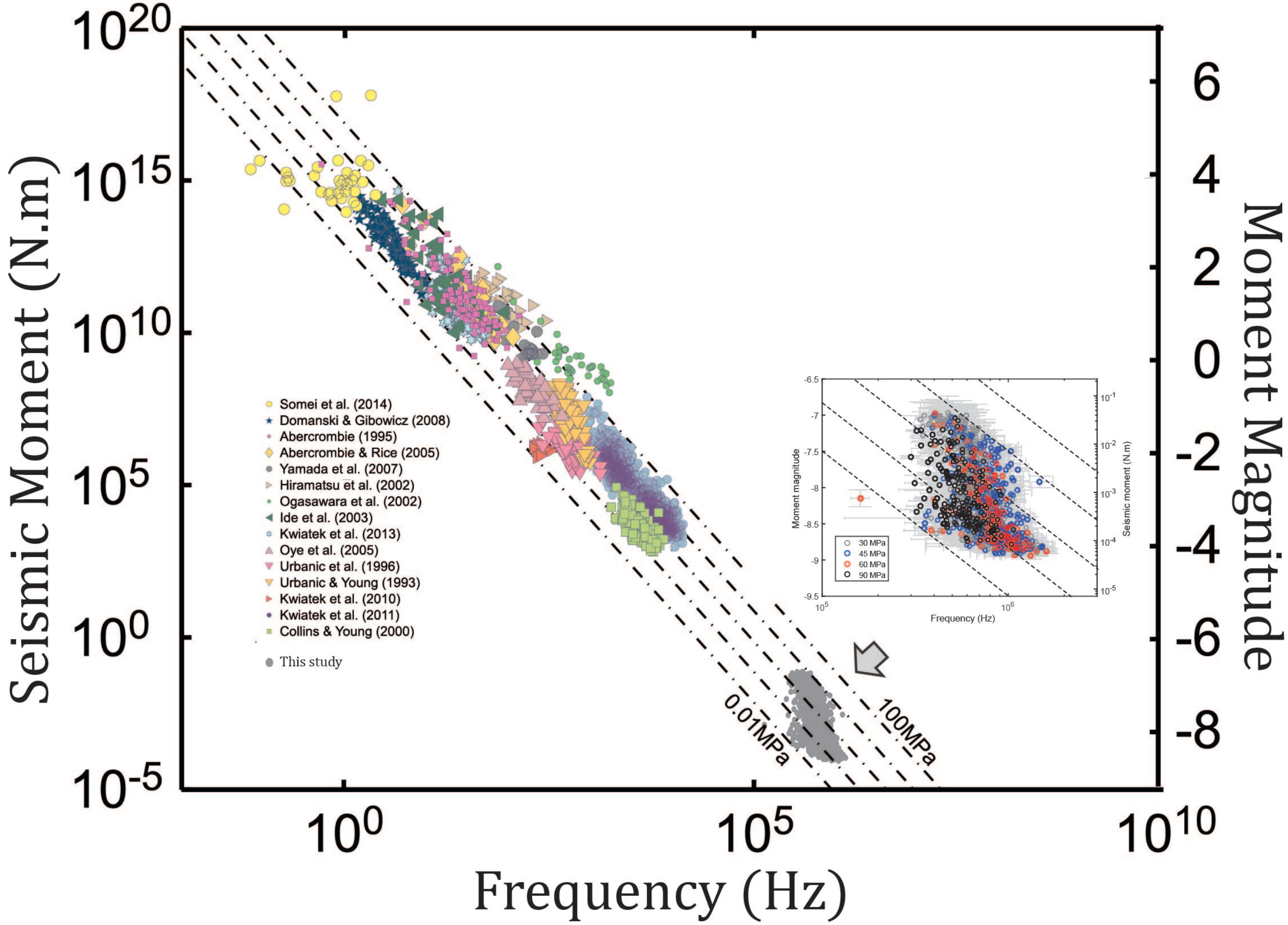
- With higher stress, foreshocks sequence are increasingly spatially and temporally correlated



Marty et al. in prep

Foreshock dynamics

Moment, stress drop and corner freq. of foreshocks



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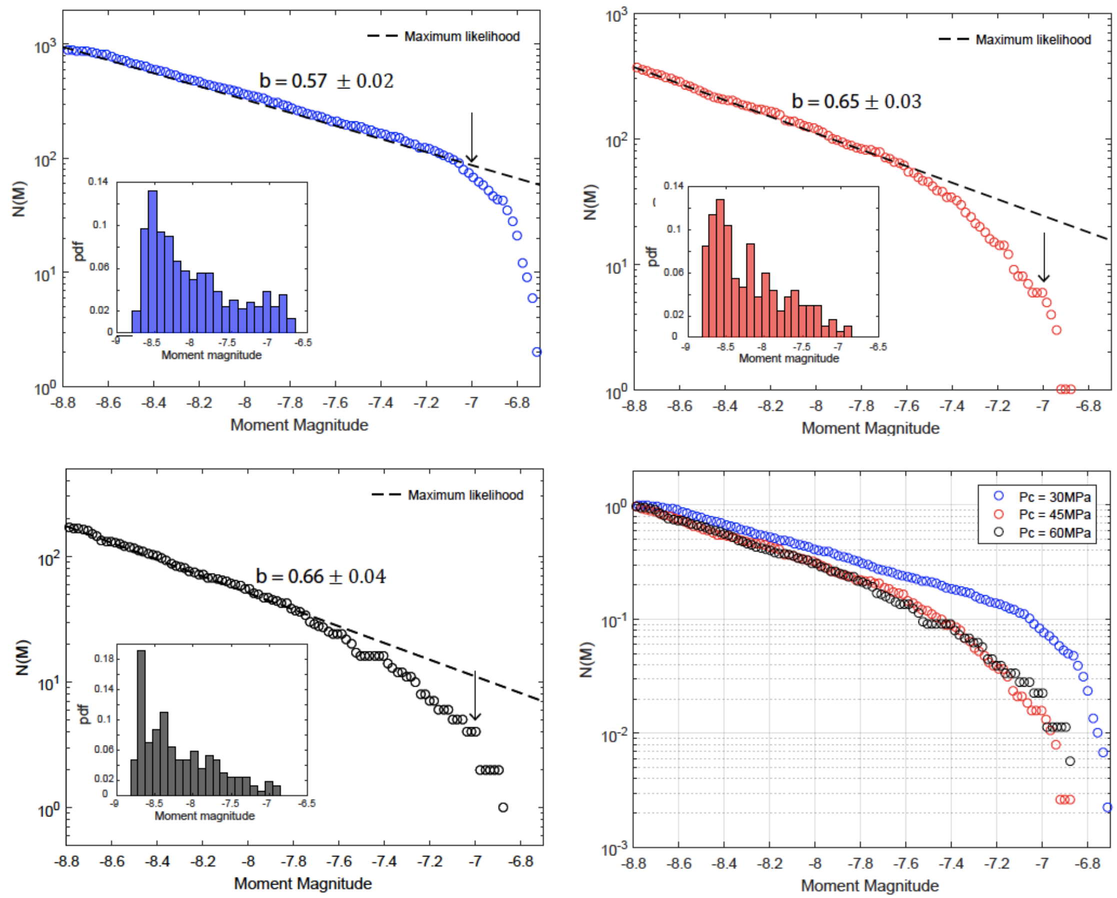
Foreshock dynamics

- GR distribution of foreshock. Cut off Mw decrease with increasing stress



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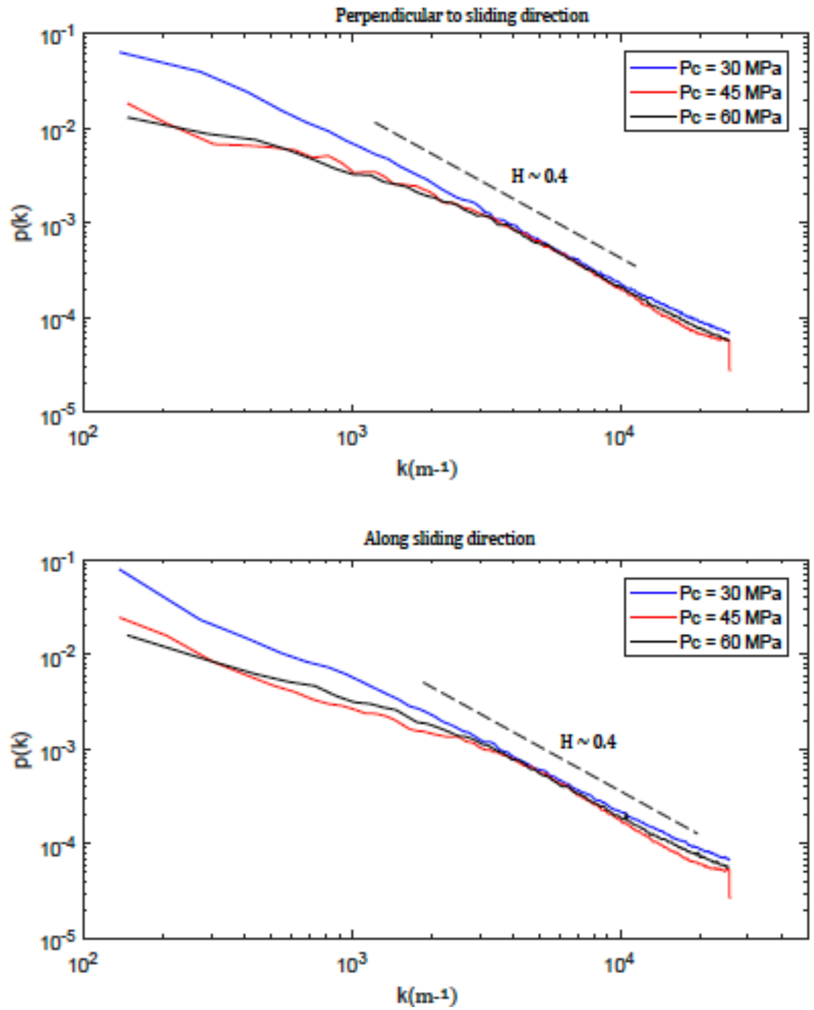
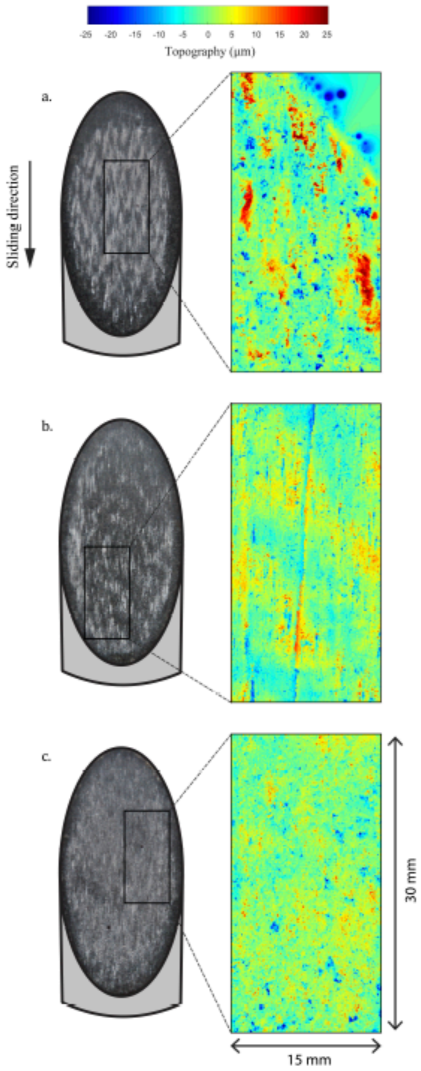
Foreshock dynamics

- A link with Hurst exponent?





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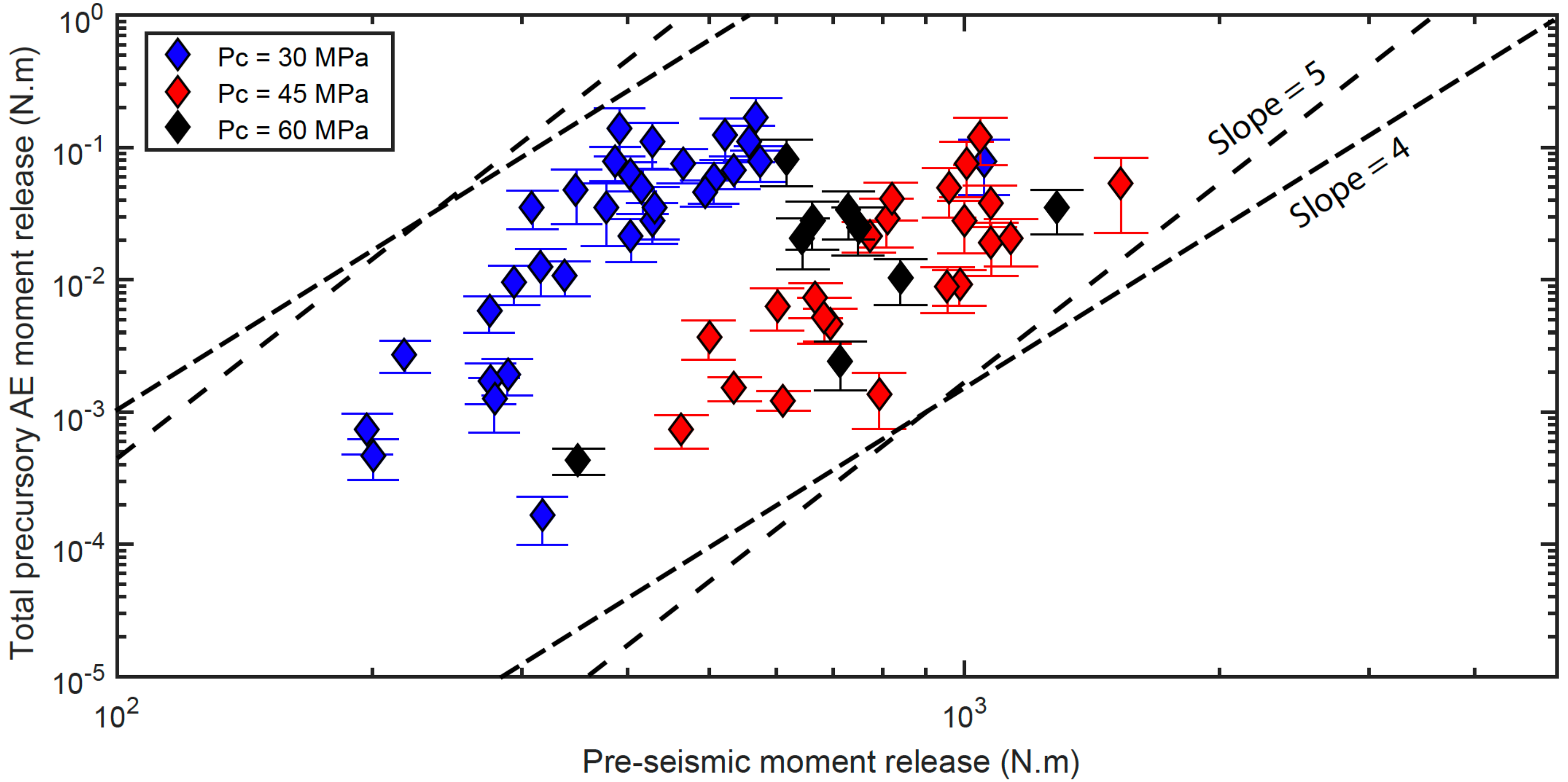
Foreshock dynamics

- Cumulative foreshock Mw scales with pre-slip
- *Ratio of 1/1000*



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Conclusions

- During nucleation of stick slip instabilities under crustal conditions, inverse Omori's law is observed for foreshocks, albeit with great variability.
- Cumulative moment of foreshock sequences follow slip velocity
- Cum. moment by foreshocks scales with pre-slip, and accounts for an increasing small portion of it. **Transition from a pre-slip w. barriers to a cascade.**
- Cum. pre-slip moment scales final slip (see Acosta et al., GRL, 2019).
- GR law is systematically observed. GR breakdown at large Mw may be correlated to Hurst exponent breakdown at long wavelength of fault roughness. Model with Hertzian contacts in progress…