SAPIENZA
UNIVERSITÀ DI ROMA
Dipartimento di Eccellenza

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INGV

Frictional strength, stability, and healing properties of basalts for geo-energy purposes

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&
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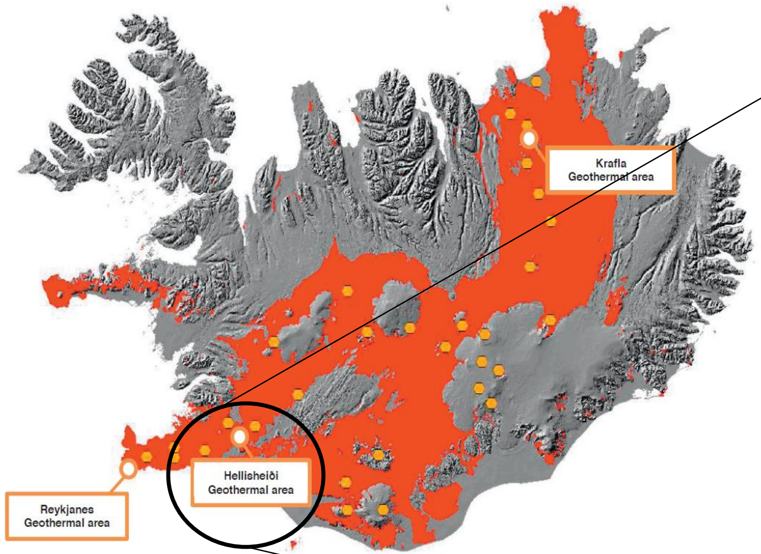
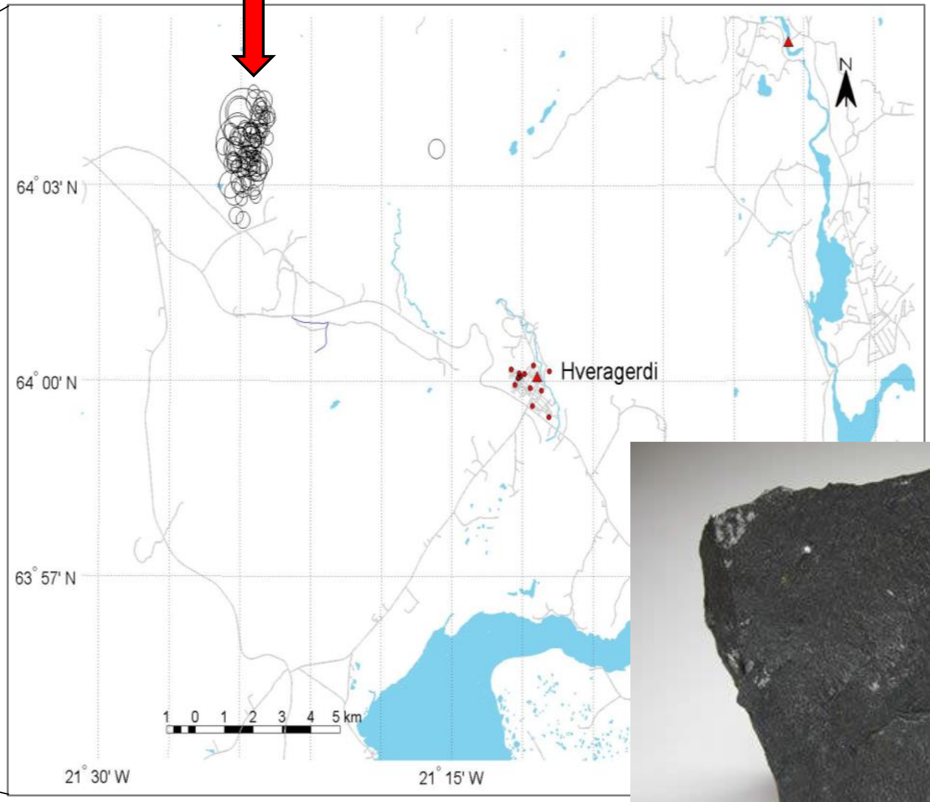
This study is part of the PhD project *INTEGRITY*: fr*I*ctio*N* – s*T*ability – h*E*alin*G* and pe*R*meab*I*li*TY* of simulated basalt faults and implications for in-situ geo-energy settings

CC BY

Frictional properties of basalt faults: key for seismic hazard assessment related to fluid injection
THE EXAMPLE OF THE HELLISHEIDI GEOTHERMAL POWER PLANT (ICELAND)



Epicenters of induced earthquakes due to fluid injection

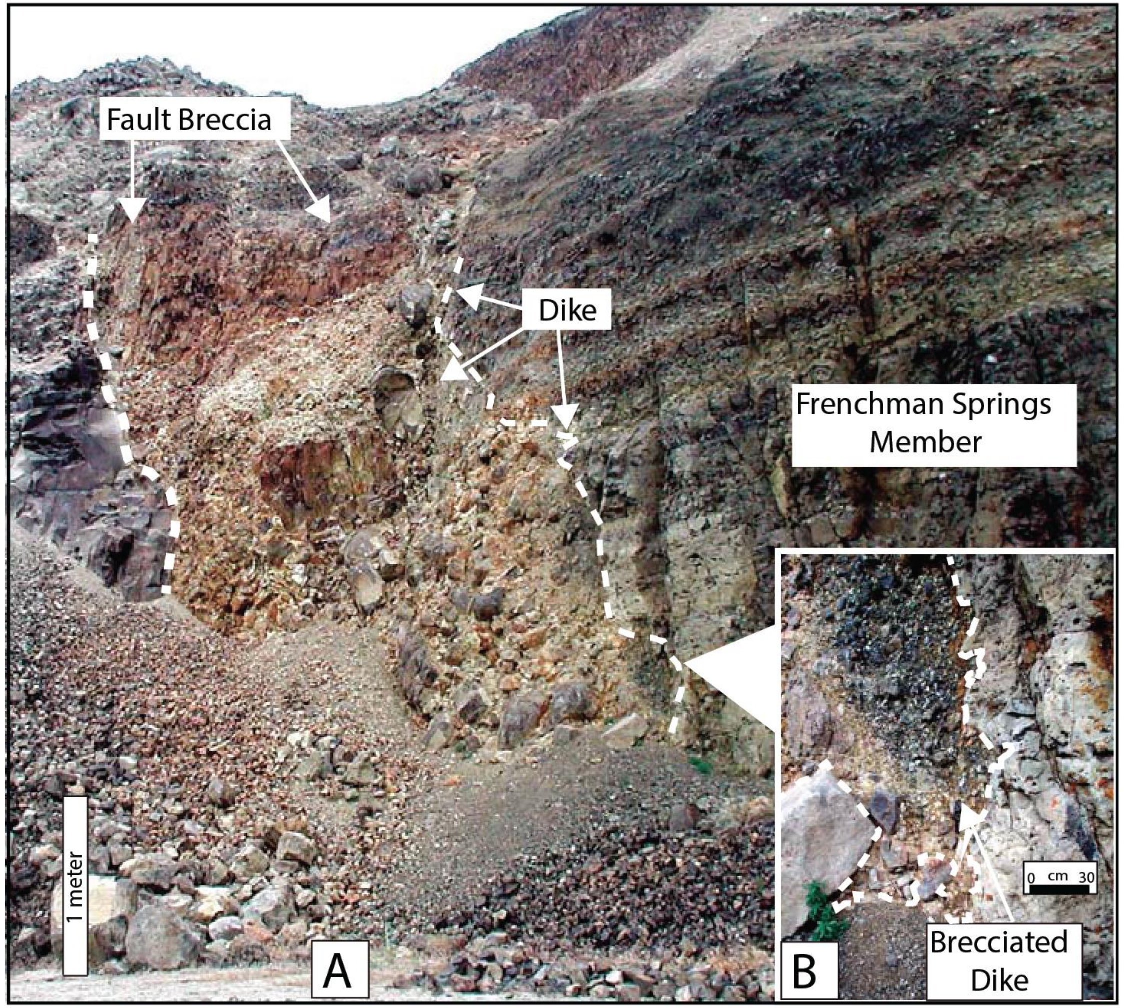


Halldorsson et al. (2012)

BASALTS

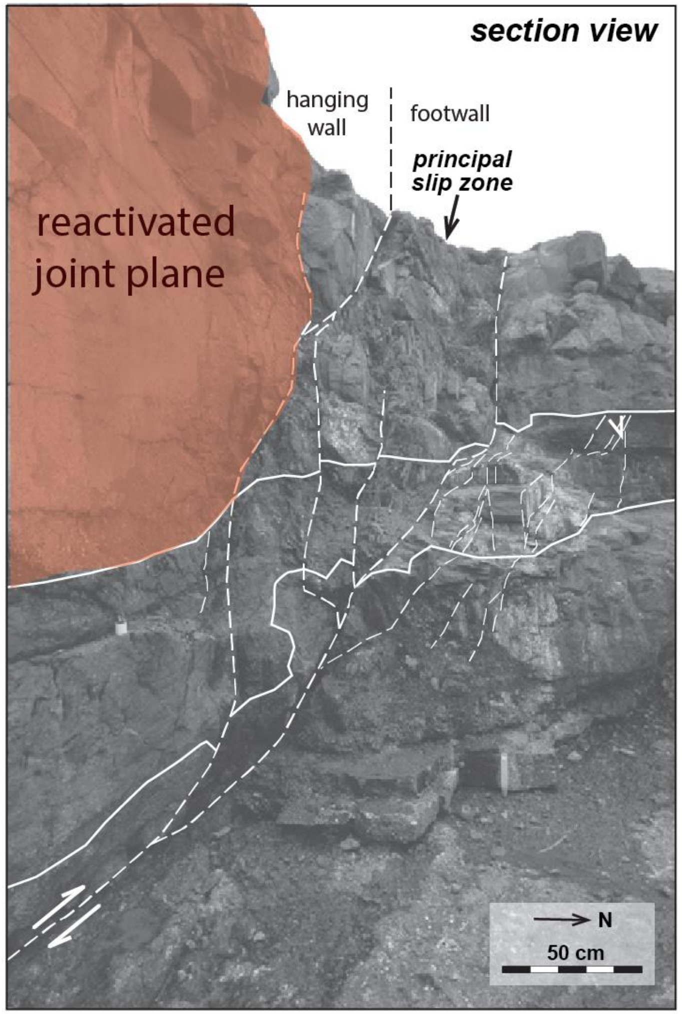
Basalt fault end members: fault gouge and fault planes

FAULT GOUGE



modified after Reidel et al. (2013)

FAULT PLANES



modified after Walker et al. (2012)

AIM: determine the frictional properties of subsurface faults (≤ 1000 m depth) defined by simulated gouge and bare rock surfaces

Room- dry and water saturated conditions

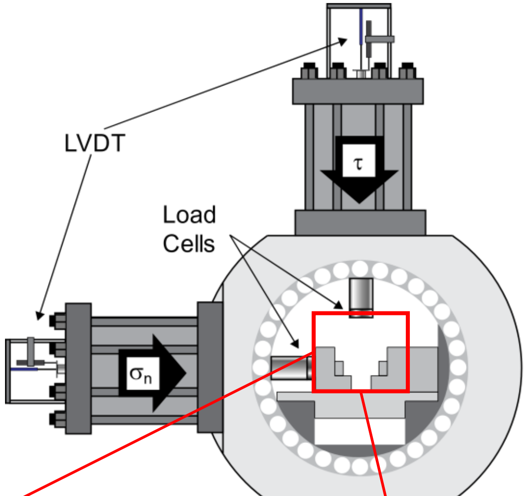
DIRECT SHEAR EXPERIMENTS BRAVA (INGV, Rome)

Experimental protocol:

1) Run-in:
   V = 10 μm/s
   until steady-state

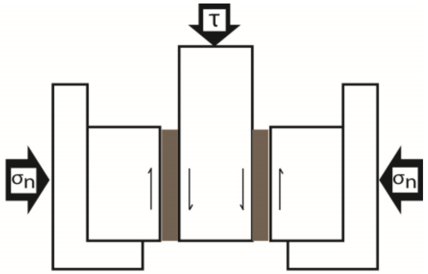
2) Vel. steps:
   V = 0.1 - 300 μm/s;
   each step : 500 μm slip

3) Slide-hold-slide sequences:
   V = 10 μm/s until 500 μm slip;
   hold time: 30 – 3000 s



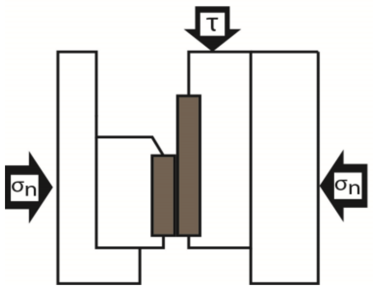
Collettini et al. (2014)

DDS: Simulated Gouge



σ_n = 5 – 30 MPa

SDS: Bare surfaces

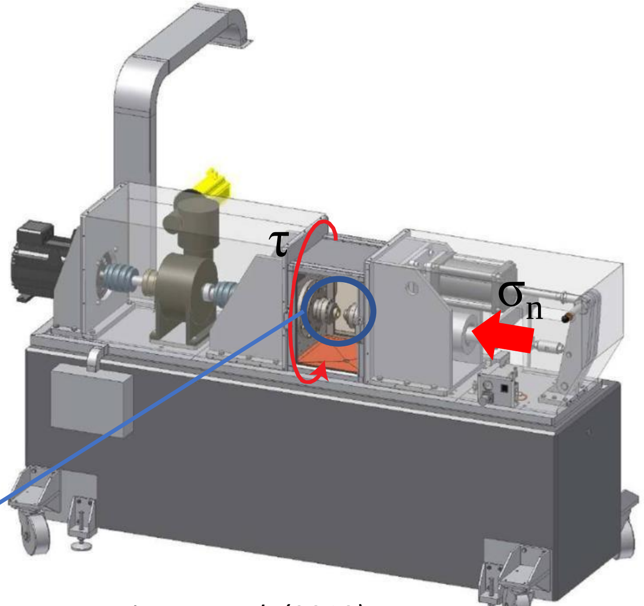


σ_n = 5 – 10 MPa

ROTARY-SHEAR EXPERIMENTS SHIVA (INGV, Rome)

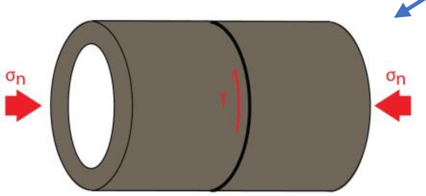
Experimental protocol:

V = 10 μm/s
until 56 mm slip



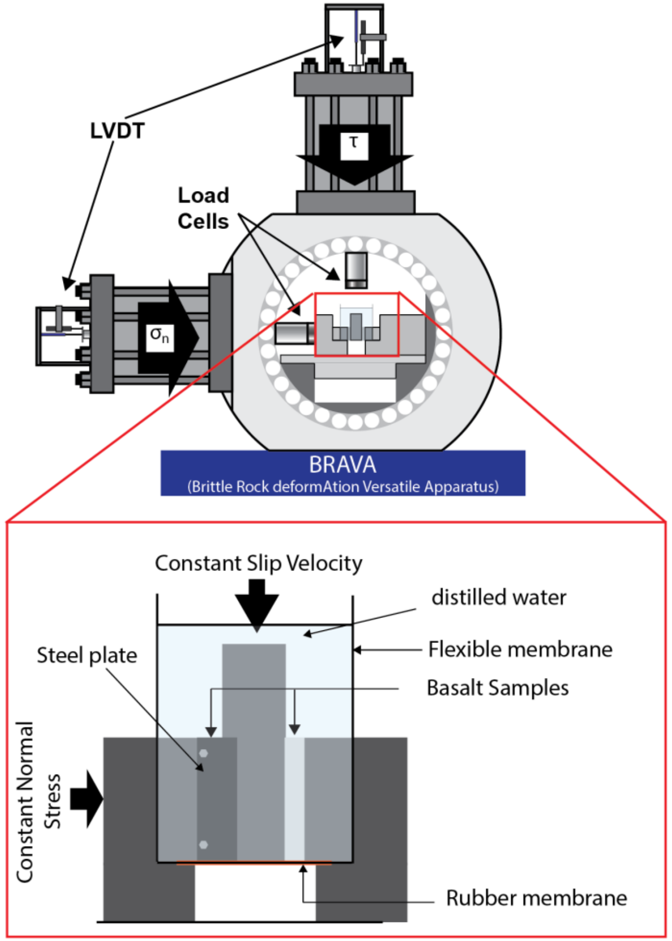
Di Toro et al. (2010)

Bare surfaces



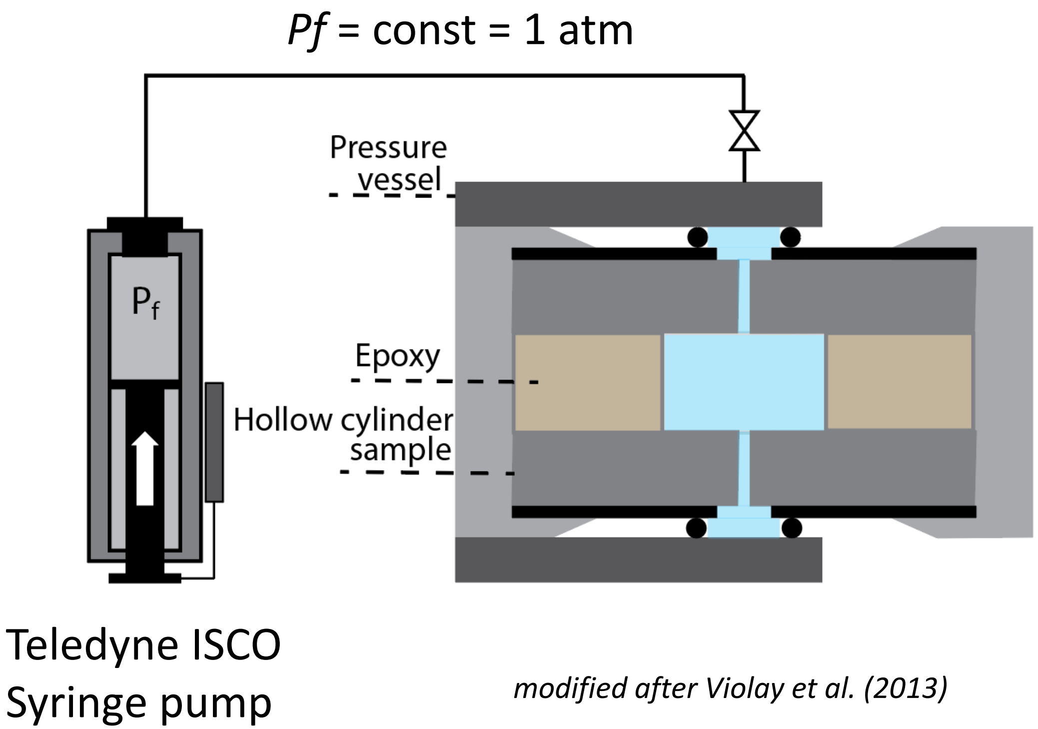
σ_n = 4 – 12 MPa

DIRECT SHEAR EXPERIMENTS→ BRAVA (INGV, Rome)



modified after Mercuri et al. (2018)

ROTARY-SHEAR EXPERIMENTS→ SHIVA (INGV, Rome)



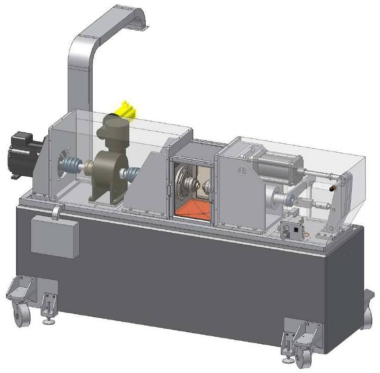
modified after Violay et al. (2013)

Selected samples

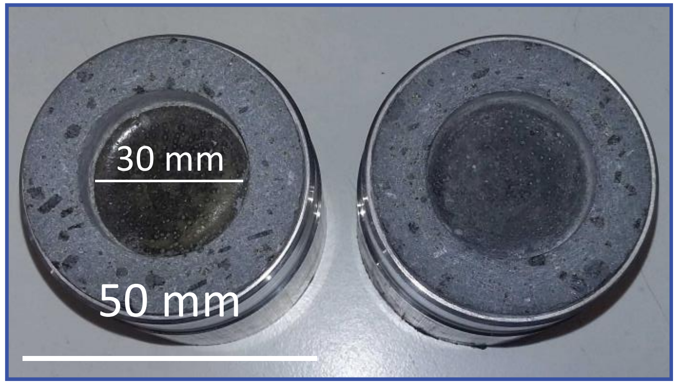
UNALTERED BASALTS (Mt. Etna, Italy): ol + cpx + plg + ox

Apparatus

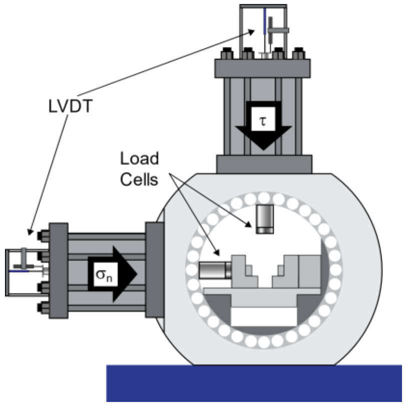
Samples employed



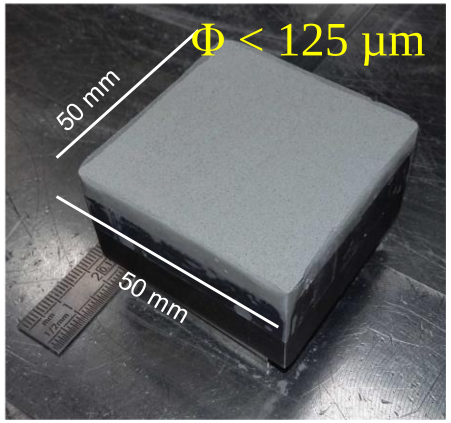
BARE SURFACES



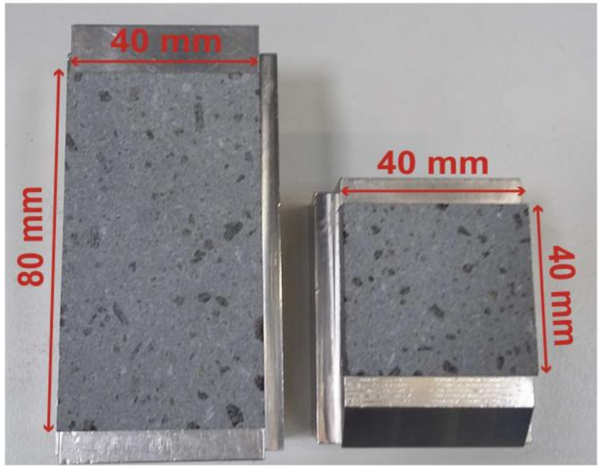
roughened with #80 grit SiC powder on glass plate



SIMULATED FAULT GOUGE

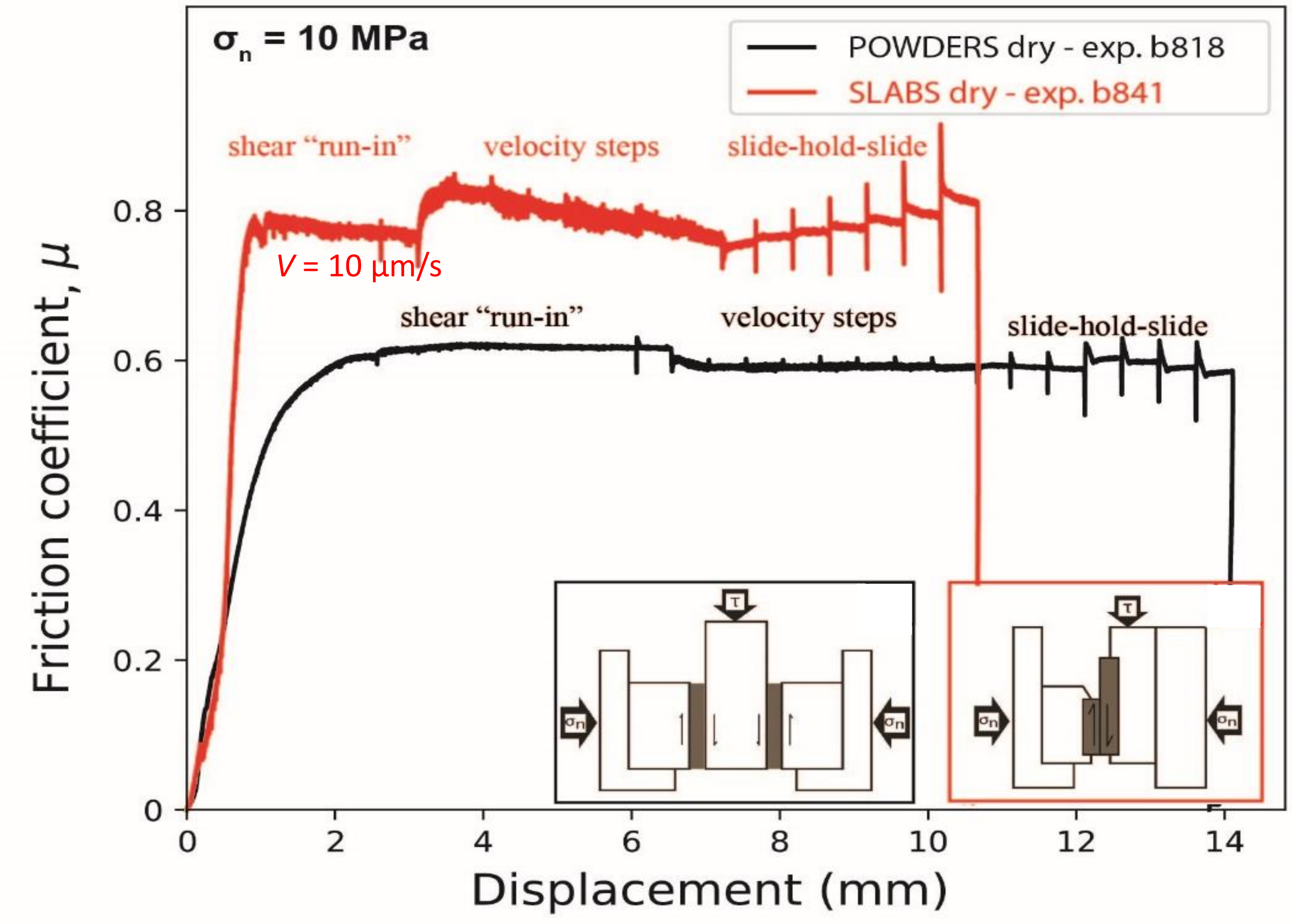


BARE SURFACES



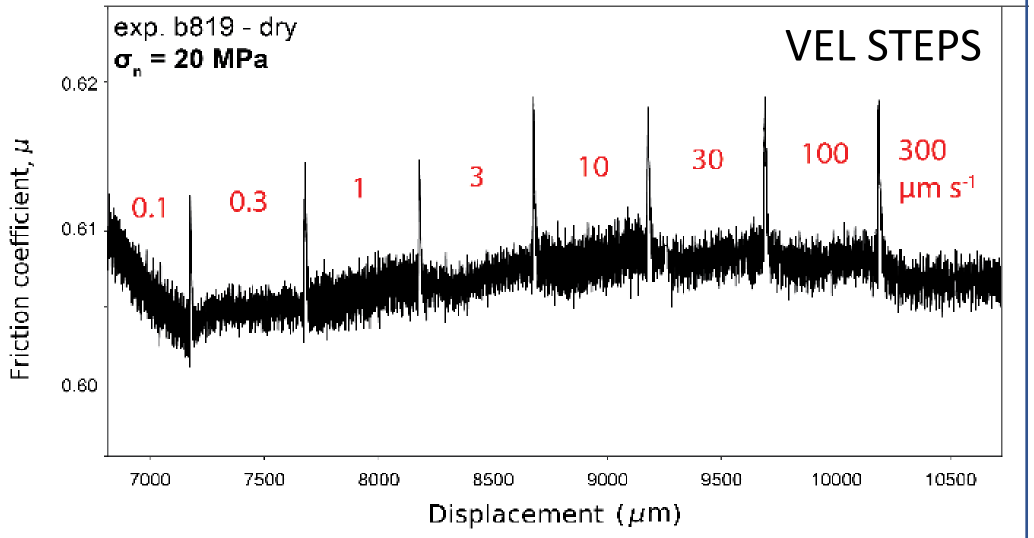
roughened with #80 grit SiC powder on glass plate

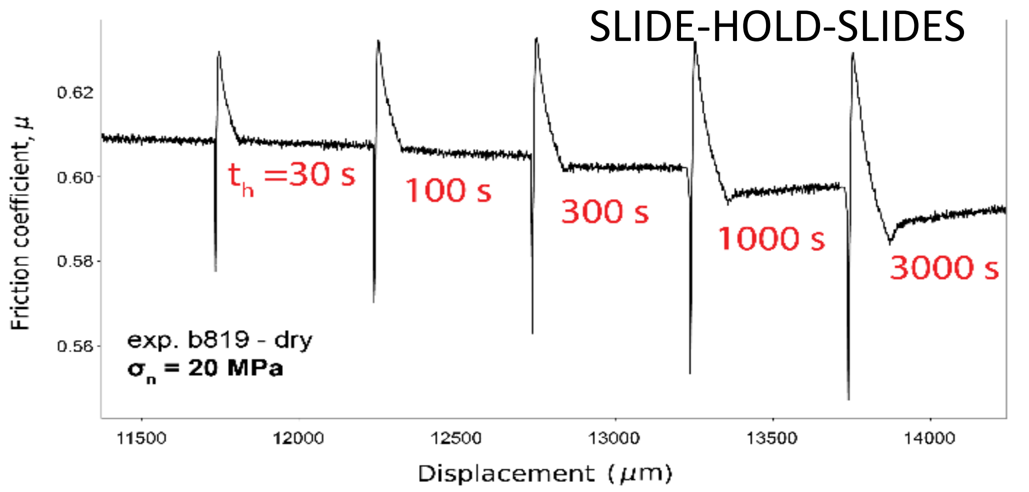
Direct shear experiments: frictional STRENGTH, STABILITY & HEALING



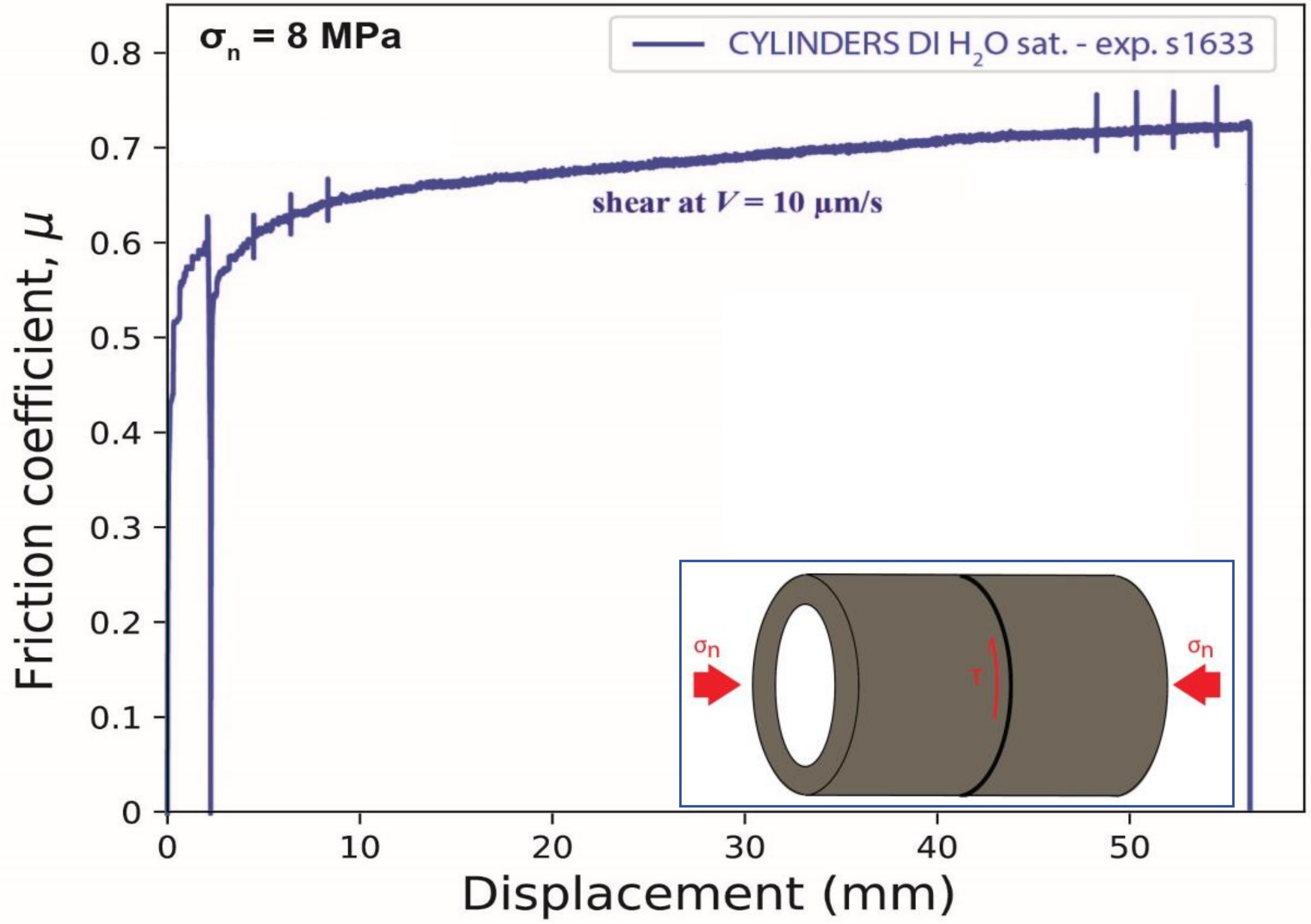
Giacomel et al. (2020) in prep.

Example: simulated fault gouge





Rotary-shear experiments: frictional STRENGTH

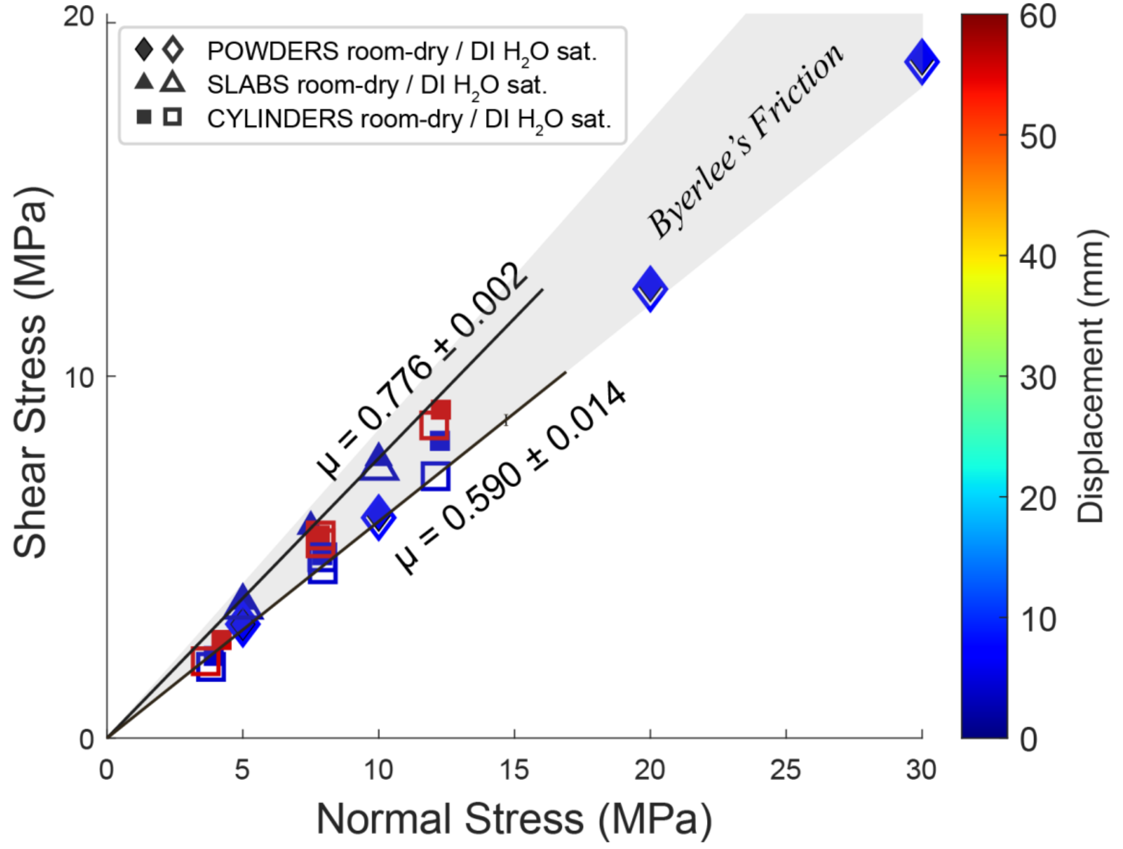


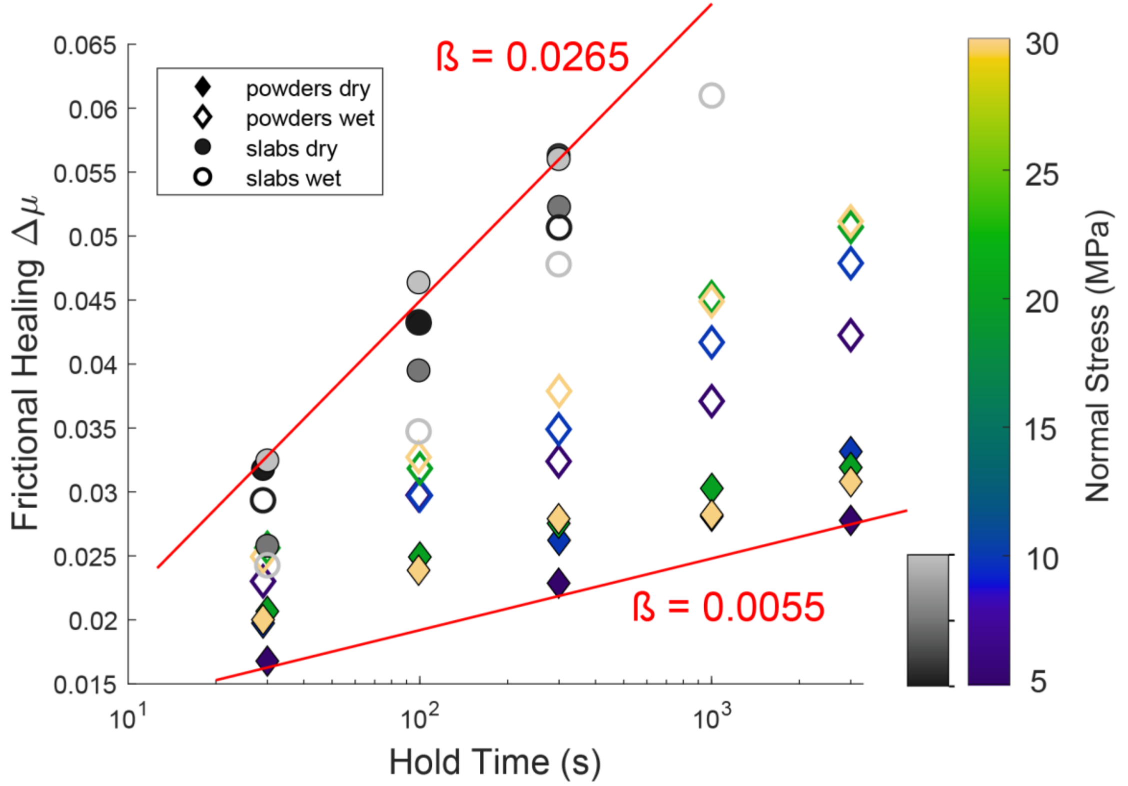
Giacomel et al. (2020) in prep.

Advantage of these rotary-shear experiments:

large accumulated slip

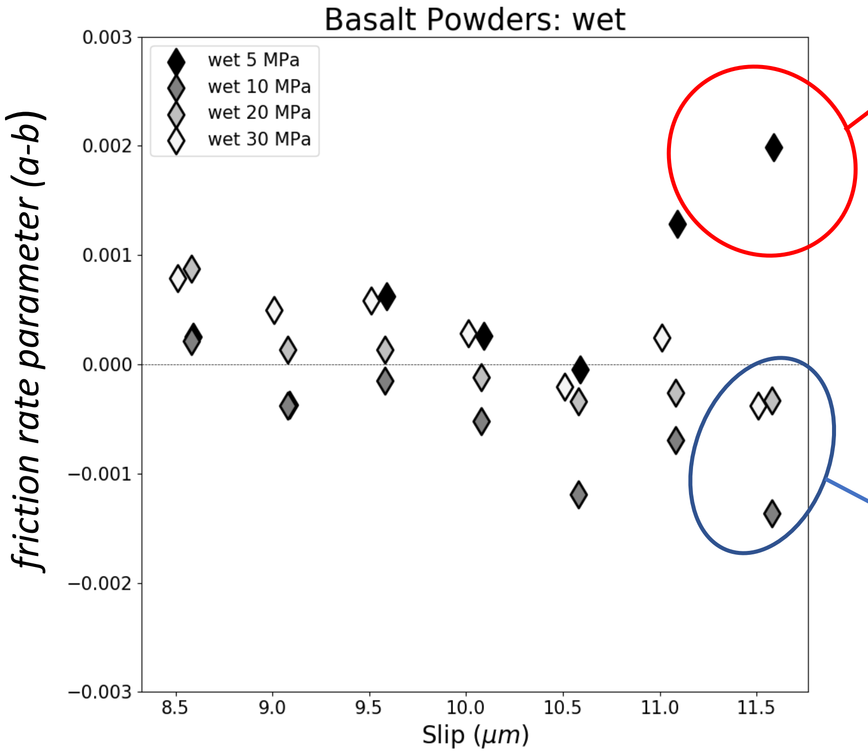
High friction + high healing rates = UNALTERED BASALT FAULTS FRICTIONALLY STRONG

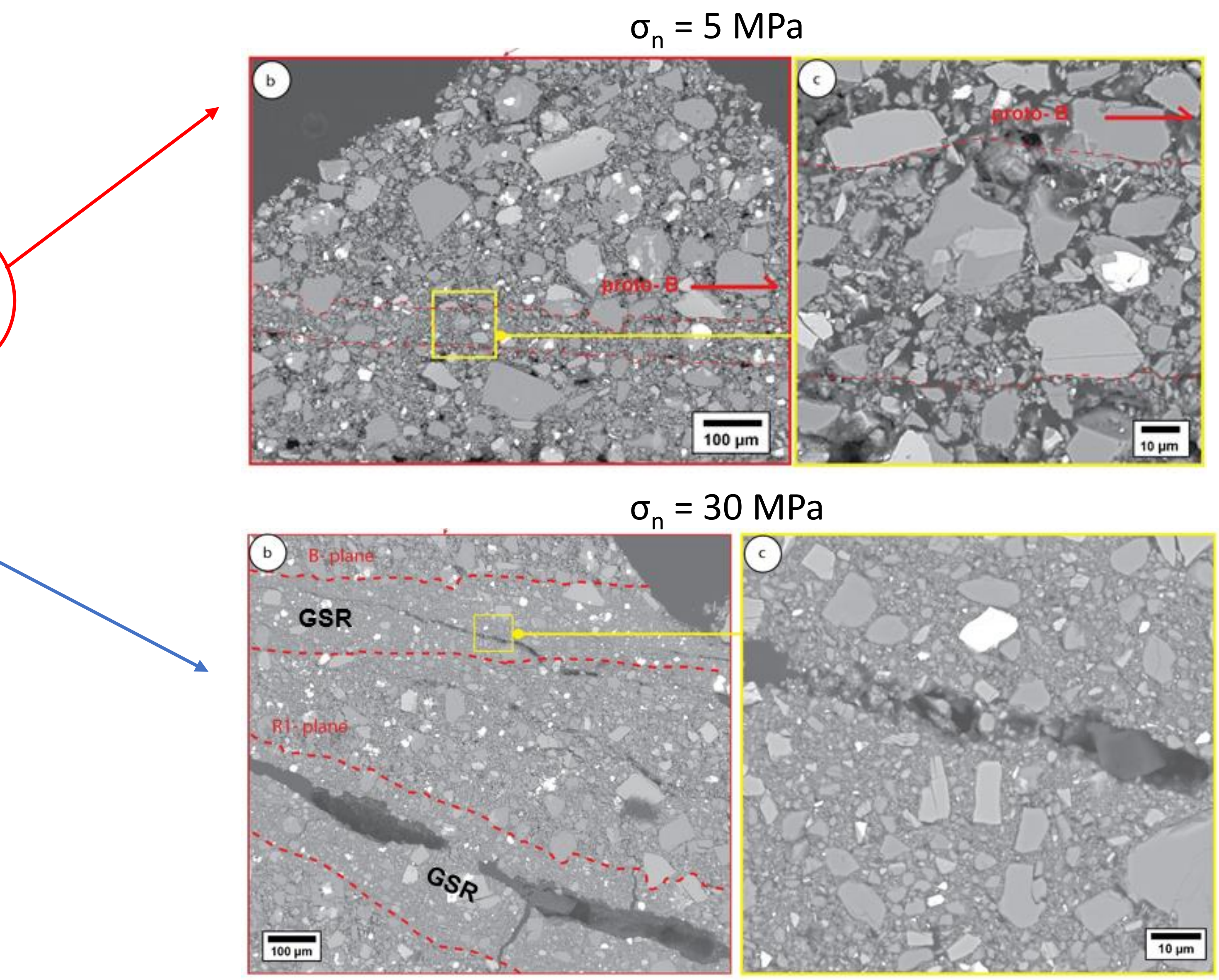




Giacomel et al. (2020) in prep.

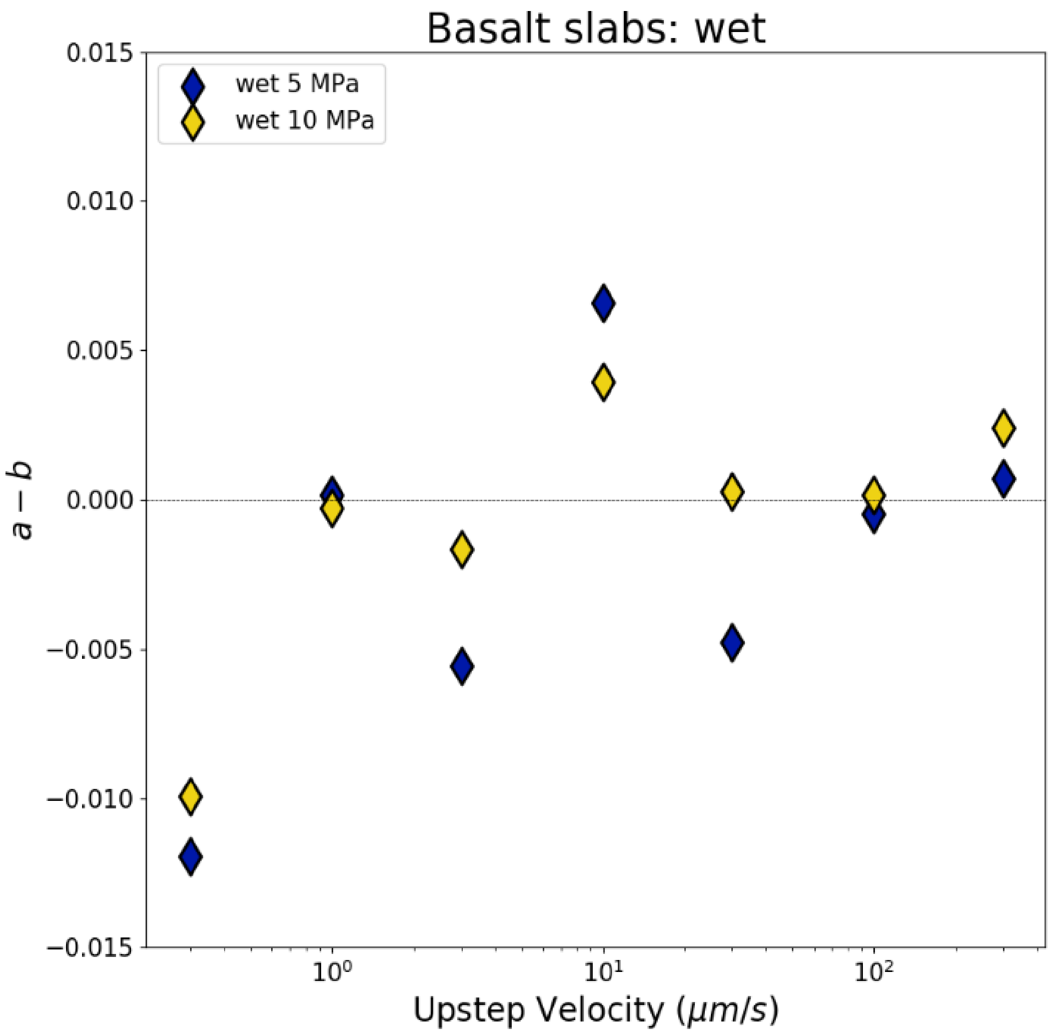
SIMULATED GOUGE: from distributed to localized deformation with increasing slip and normal stress

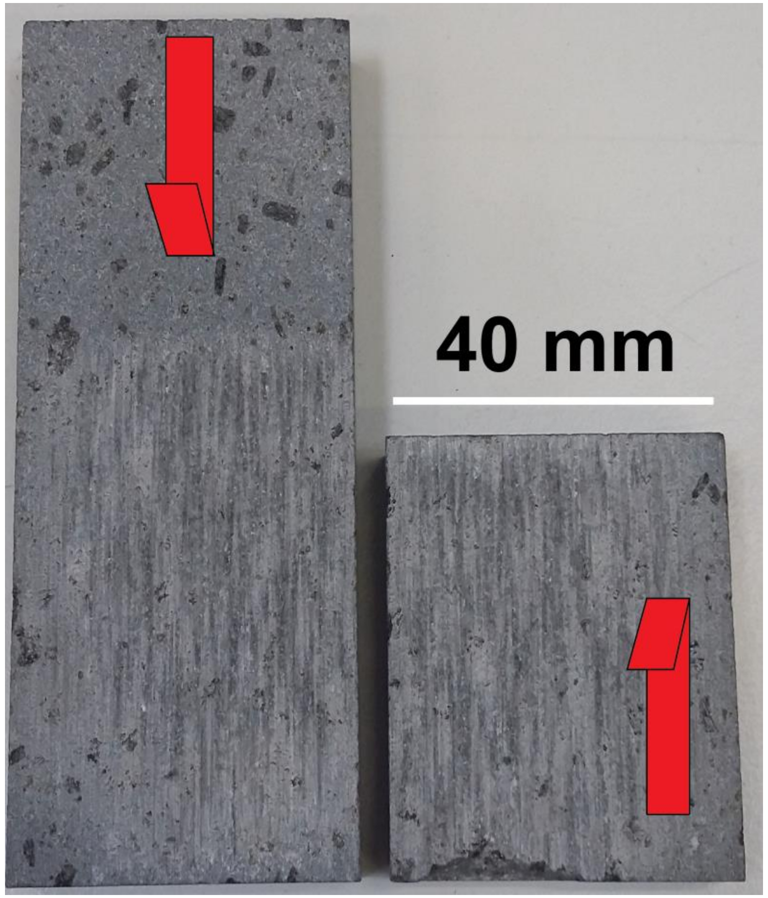




Giacomel et al. (2020) in prep.

BARE SURFACES: switch to vel. strengthening with increasing velocity
Hypothesis that gouge production with slip favors shear delocalization

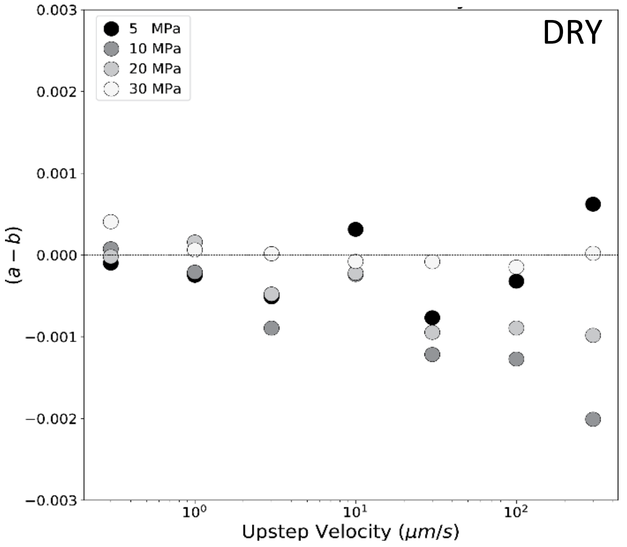


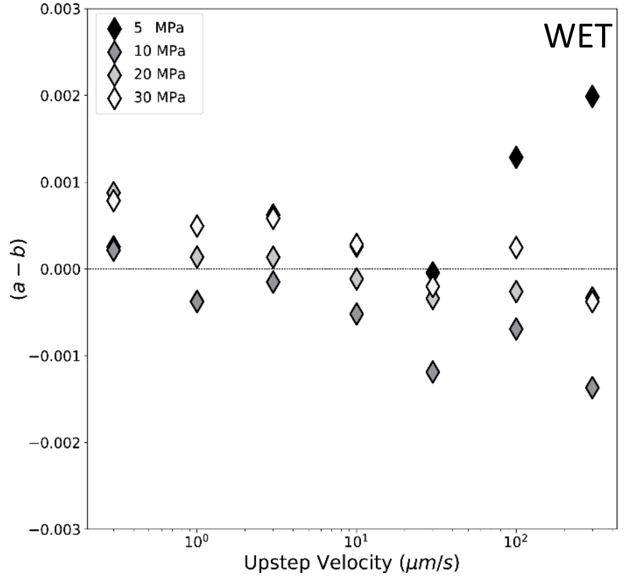


Giacomel et al. (2020) in prep.

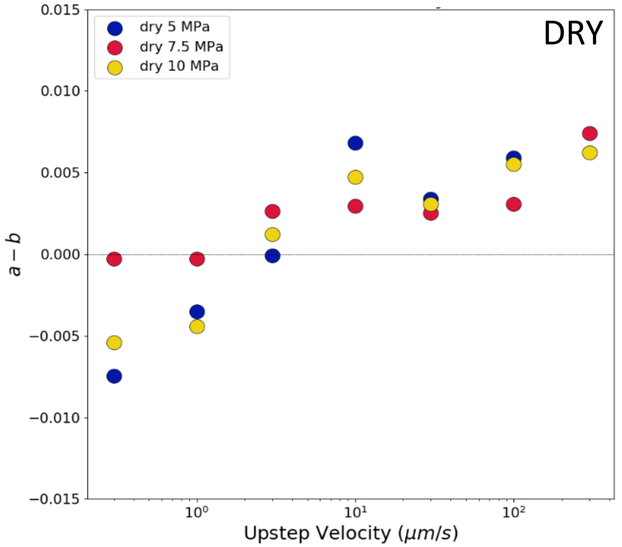
SIMULATED GOUGE VS. BARE SURFACES:
Opposite general trend with increasing velocity

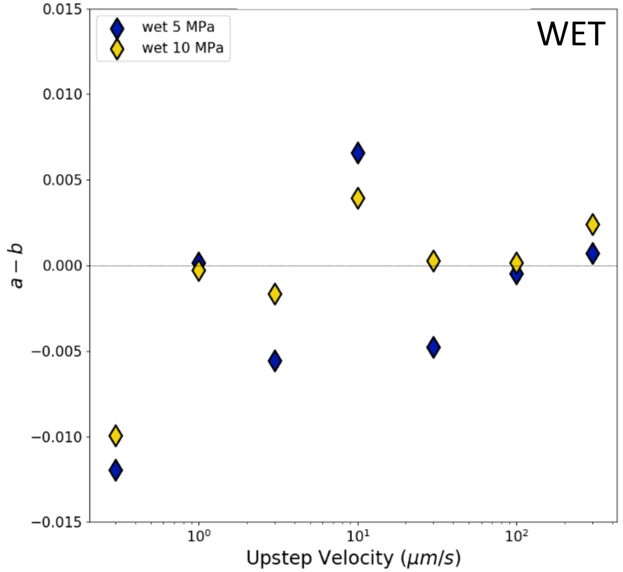
SIMULATED GOUGE





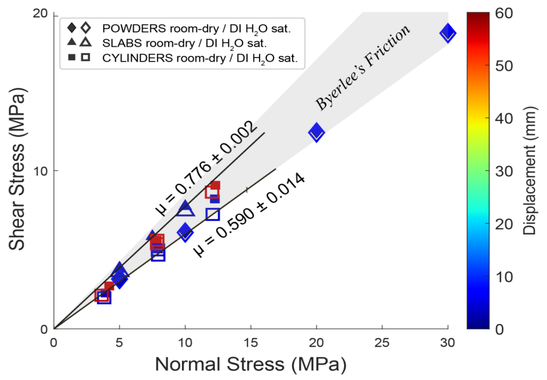
BARE SURFACES





CONCLUSIONS

- Unalterared basalt faults are frictionally strong: high friction & high healing rates



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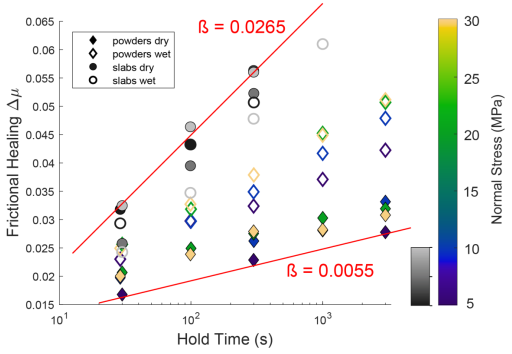
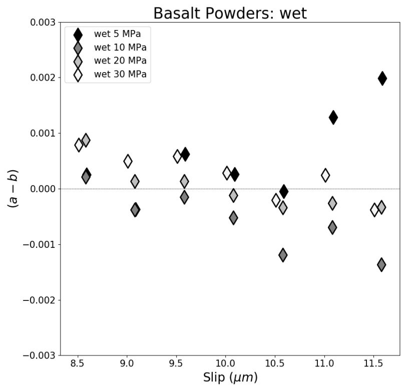
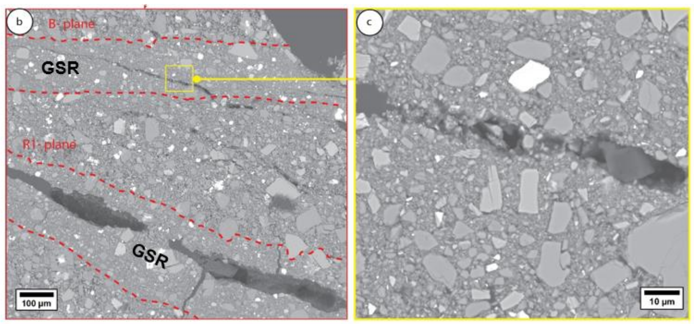


- *Gouge*: cataclasis and grain size reduction along B and R1 shear planes, which become the loci of shear localization → more prone to host seismic ruptures





- *Bare surfaces*: transition to velocity strengthening behavior with increasing slip velocity → less prone to unstable slip.