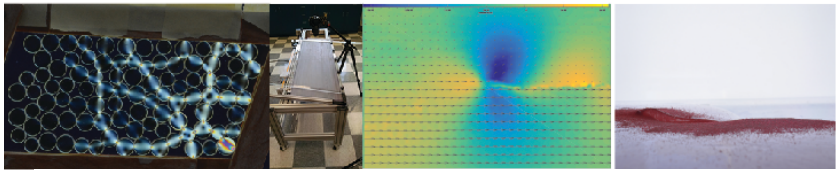
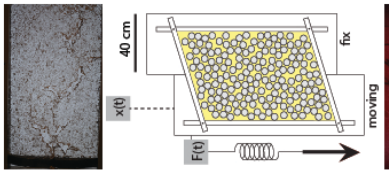
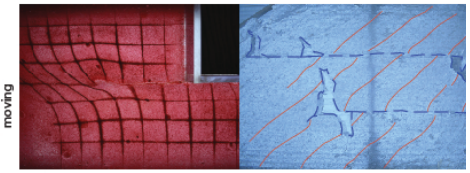






IOWA STATE UNIVERSITY
OF SCIENCE AND TECHNOLOGY

Structure Lab

Jacqueline Reber
Jeremy Randolph-Flagg (MS Student)
Tom Birren (MS Student)
Chris Ladd (Undergrad)
Zach Kornse (Undergrad)

Semi-brittle

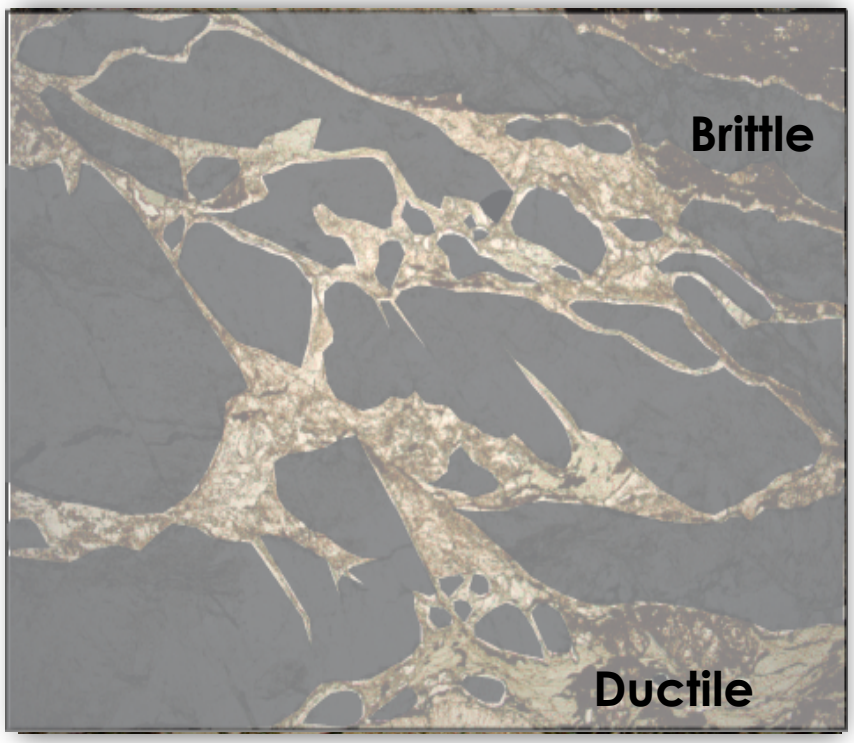
Semi-brittle

Brittle (loss of cohesion)

Ductile (continuous deformation)

Semi-brittle features in nature

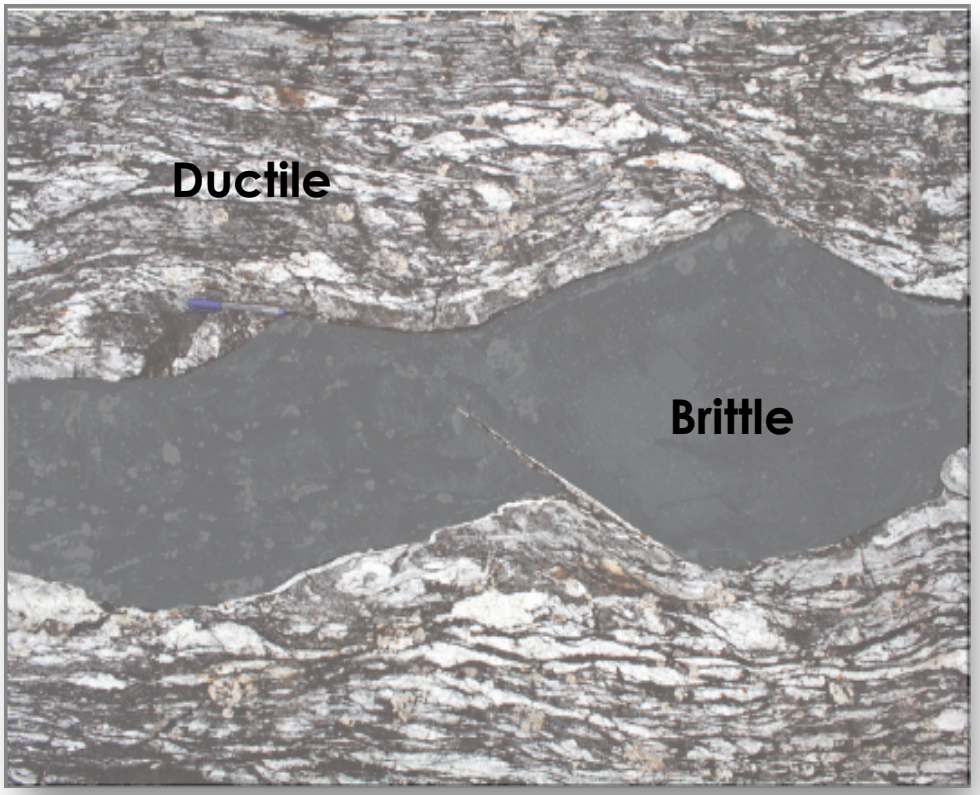
Micro scale



(Whipple Mountains, CA)

Semi-brittle features in nature

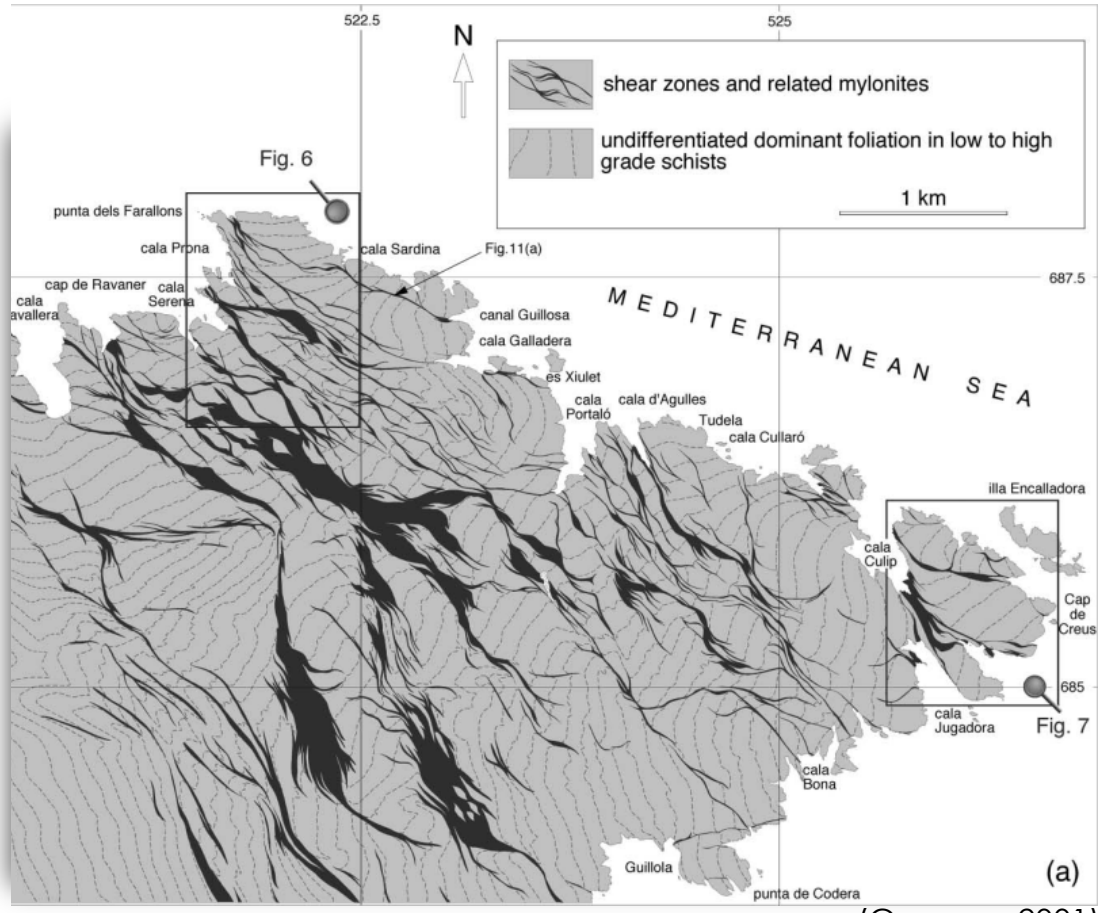
Outcrop scale



(Beagle Channel, Chile
Hayman and Lavier, 2014))

Semi-brittle features in nature

Exhumed mid-crustal shear zone



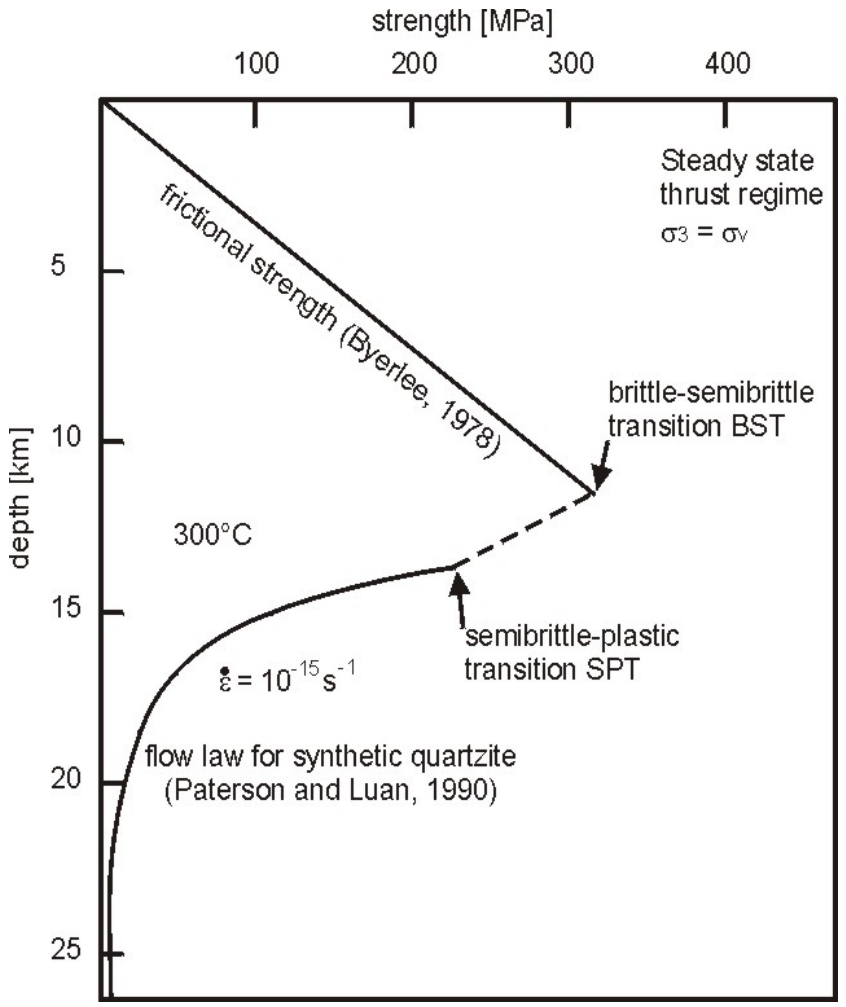
(Carreras, 2001)

(Cap de Creus, Spain)

Rock physics vs. structural geology

For given temperature pressure condition in one mineral phase

- Brittle (discontinuous): breaking process occurs over a small range of stresses
- Ductile (continuous): breaking process occurs over a wide range of stresses (ductile fracture or creep)



(Kholstedt et al., 1995)

Semi-brittle = transition from brittle to ductile

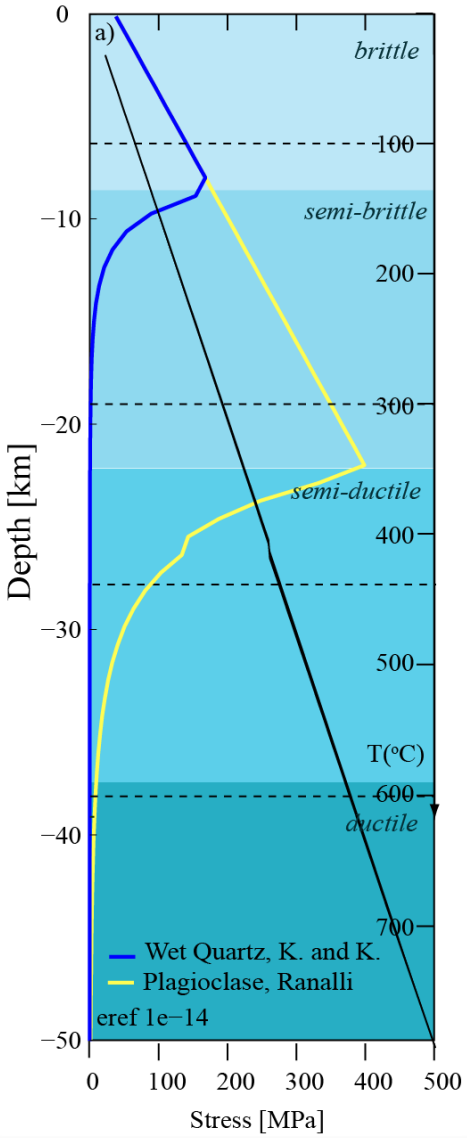
Rock physics vs. structural geology

Involves at least 2 (mineral) phases: One phase is brittle and the other viscous at given temperature and pressure conditions.

Mixed brittle-ductile deformation can be observed from large scale to micro scale.

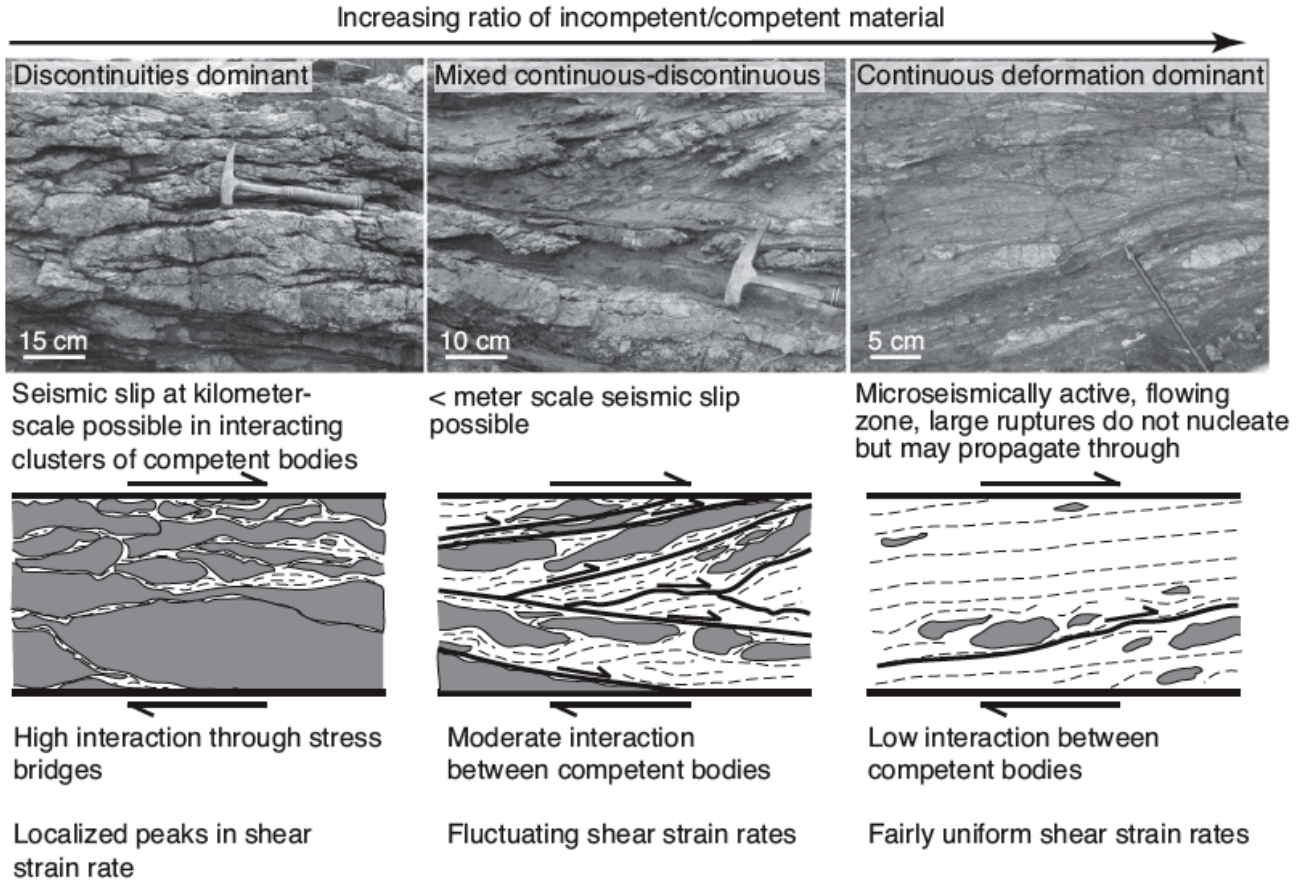
The weak viscous phase creeps and deforms in a ductile manner.

Fractures and fluid filled veins are observed in the brittle phase.



Mixed rheology

Strain partitioning between competent and incompetent material: Impact on earthquakes, tremor, and creep?



Crystals Beach Complex, New Zealand

(Fagereng and Sibson, 2010)

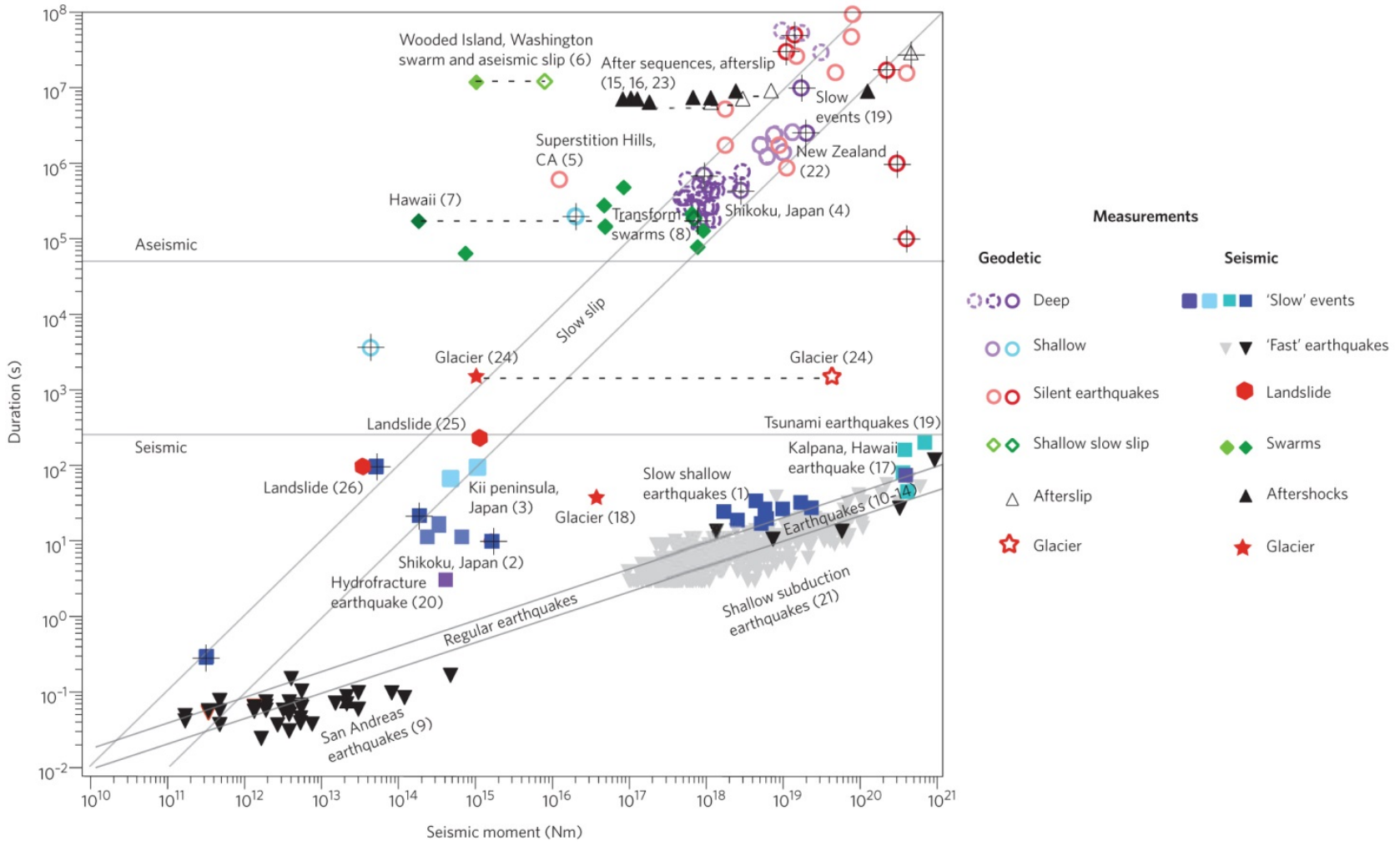
Hypothesis

90 volume percent of all rocks are polymineralic.

How does this affect the deformation dynamics?

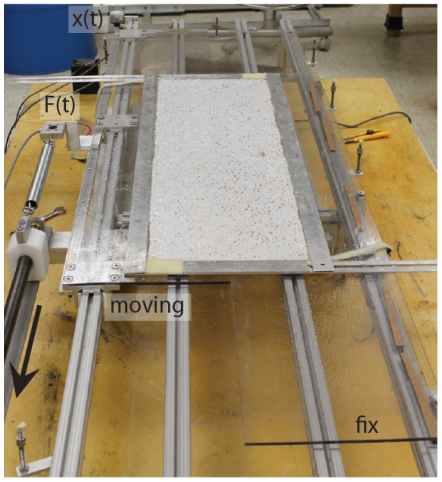
Hypothesis:
Interaction of brittle and ductile deformation processes controls slip-dynamics and can lead to strain transients.

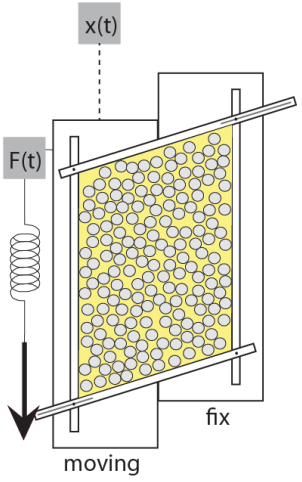
Hypothesis

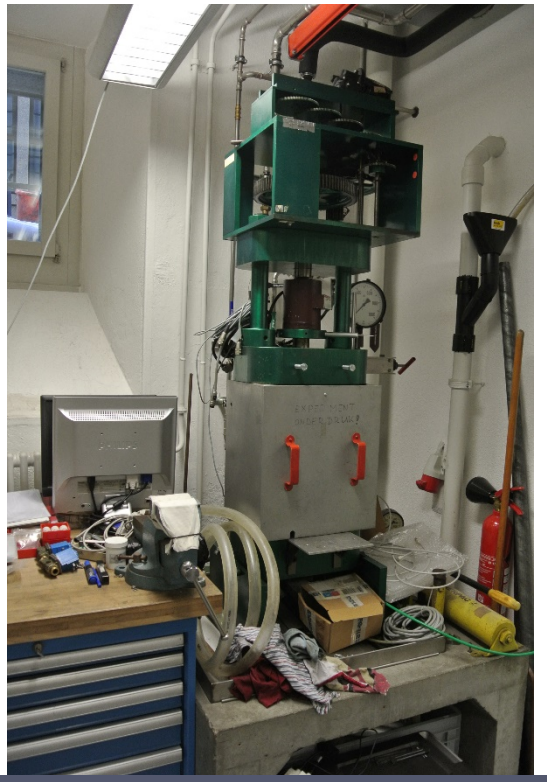


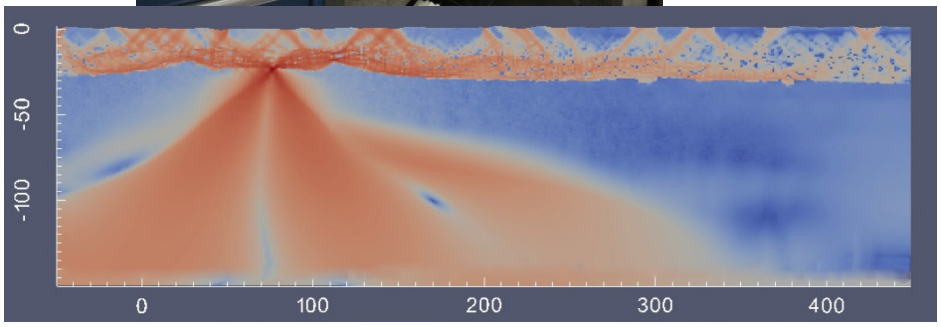
(Peng and Gomberg, 2010)

How can we study the deformation of rocks?





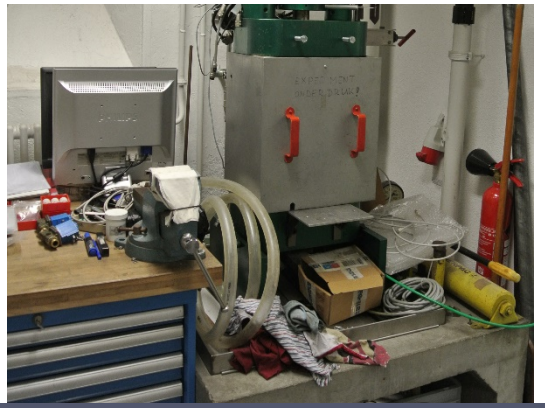




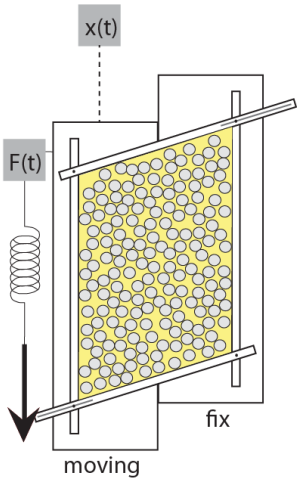
How can we study the deformation of rocks?

Only snapshot, no processes

Very small samples,
can't see what happens during deformation



Not real rocks

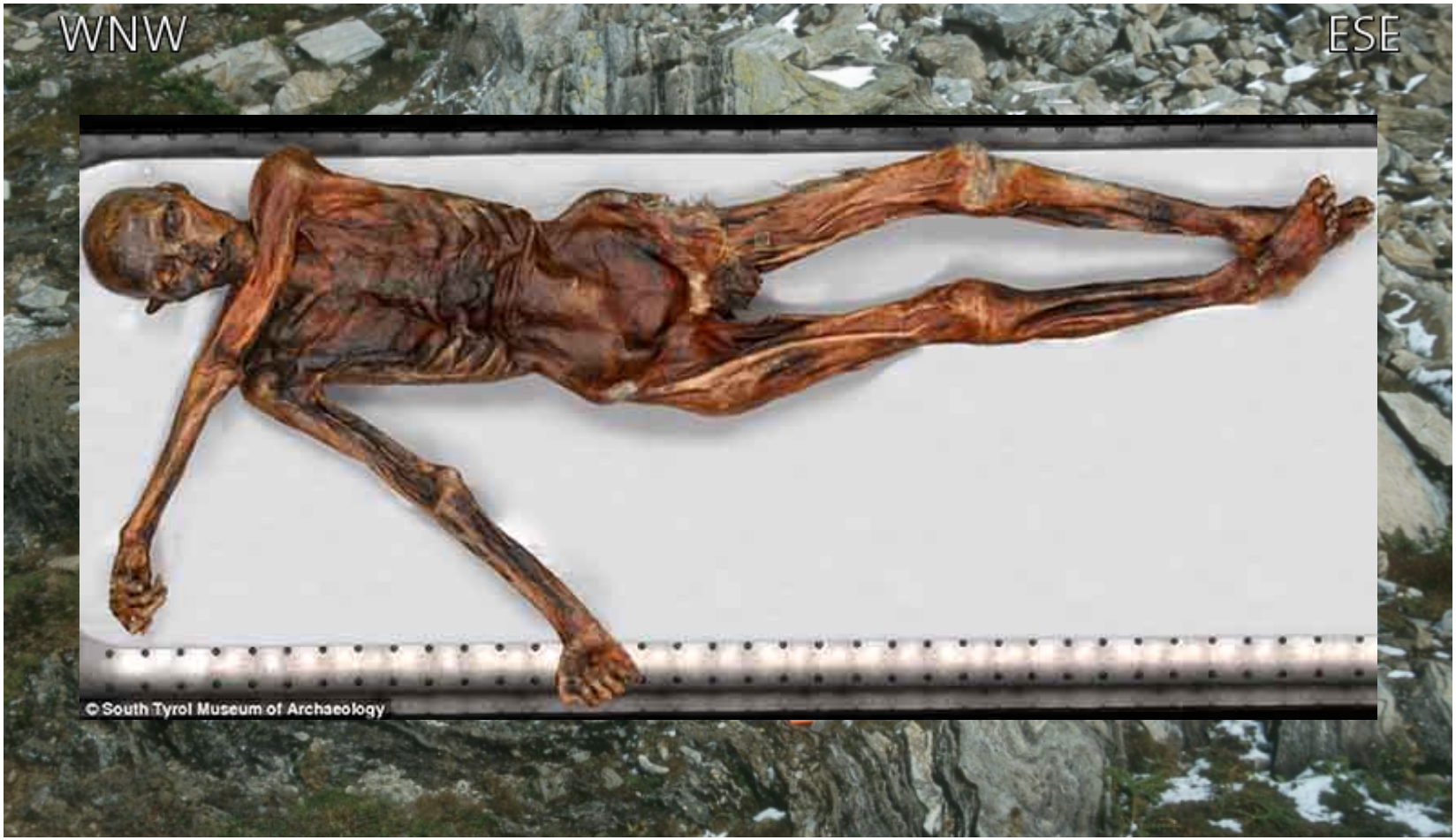


Not real,
strongly dependent on available computation power

The problem of rocks being too strong

- Geologic strain rate: $10\uparrow{-12}$ s-1
- Really super slow deformation

The problem of rocks being too strong



The solution: scaling!

50 x smaller

The solution: scaling!

Toy cars are properly scaled for shape but not for strength!

50 x smaller

The solution: scaling!

In analog experiments we scale for rheology

Pros and cons

Using **physical experiments**

Limitations:

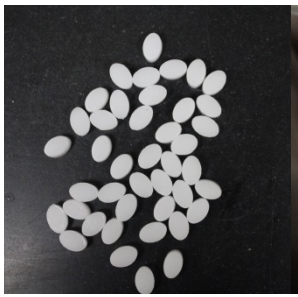
- No real rocks
- Non trivial scaling to nature
- Limited pressure, temperature, strain rate

Suitable to investigate complex rheologies:

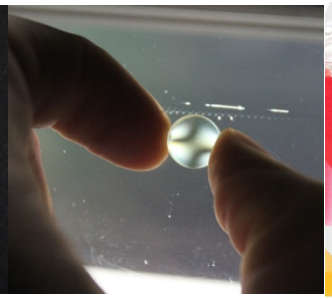
- No *a priori* rules for plastic or viscous response
- Direct observation of dynamic processes
- See-through capability

Physical models

Model materials



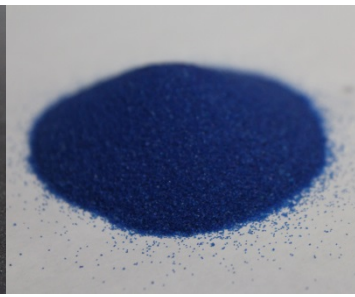
Acrylic discs



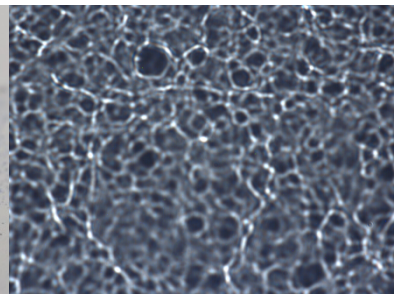
Photoelastic discs

Gelatin

Silicone



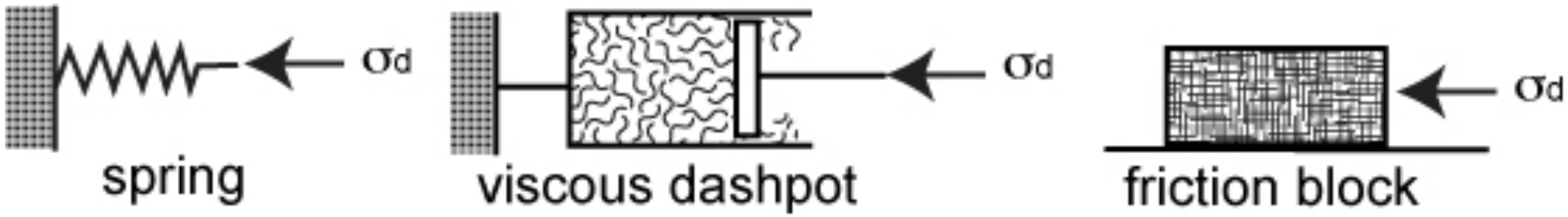
Sand



Cross-linked Polymer

Physical models

Model materials



Elastic

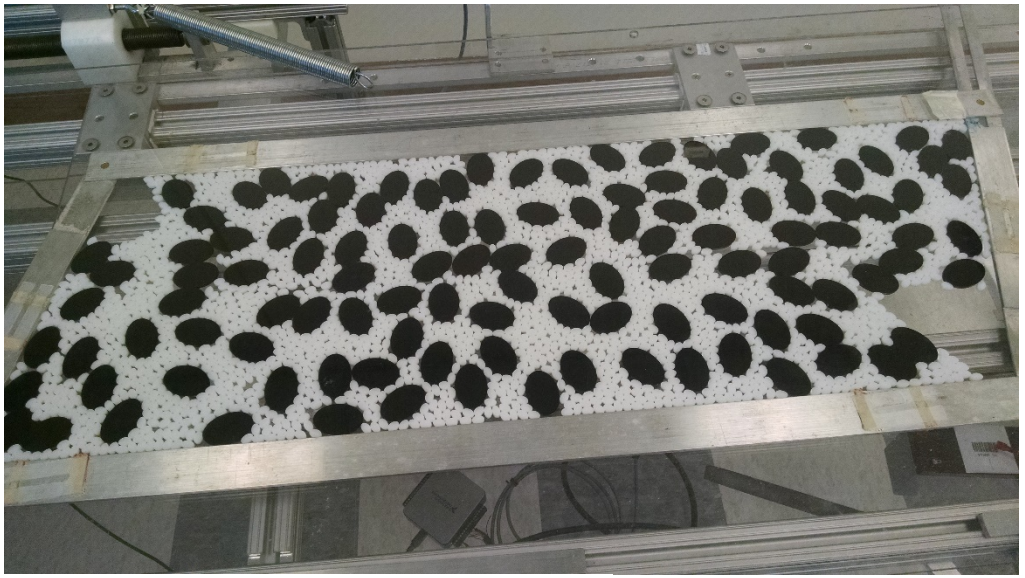
Viscous

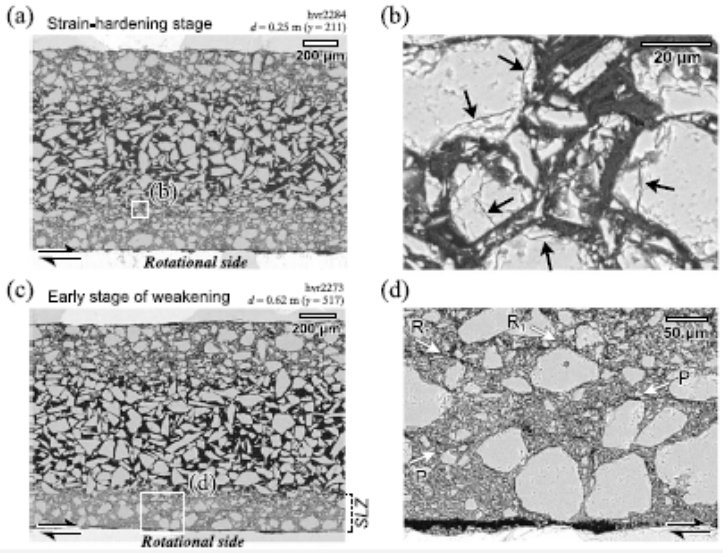
Perfect Plastic

Semi-brittle = combination of all three end members

Granular model material

- Acrylic discs (brittle, frictional)
- Changing grain sizes
- Impact on shear band width
- Impact on fault behavior
- Can be a fluid or a solid

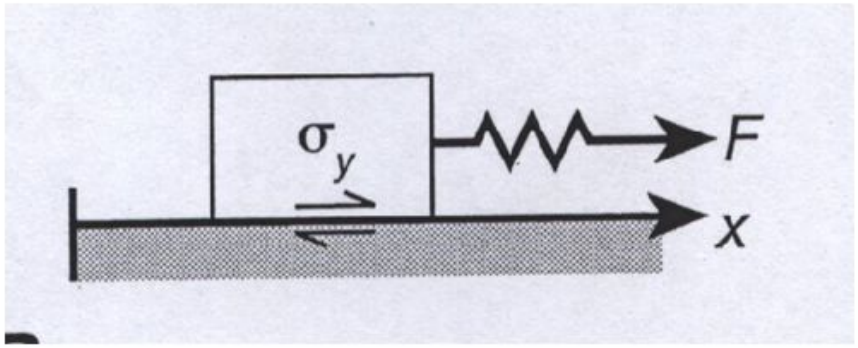


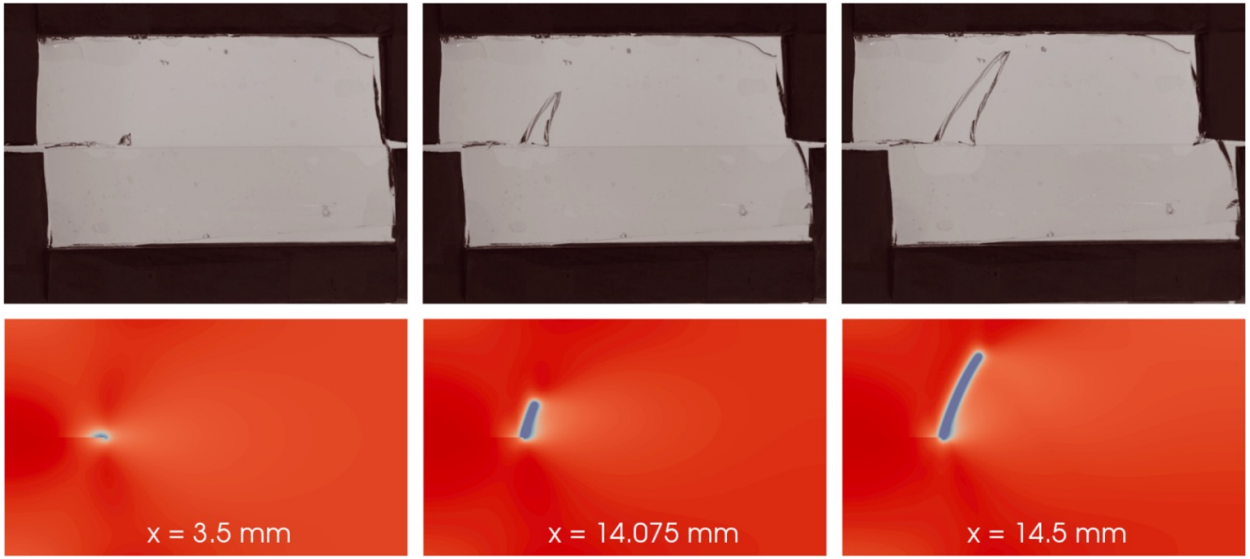


(Oohashi et al. ,2013)

Elasto-plastic model material

- Gelatin
- Incompressible
- Photoelastic
(stress can be seen in the material)
- Impact on fault behavior

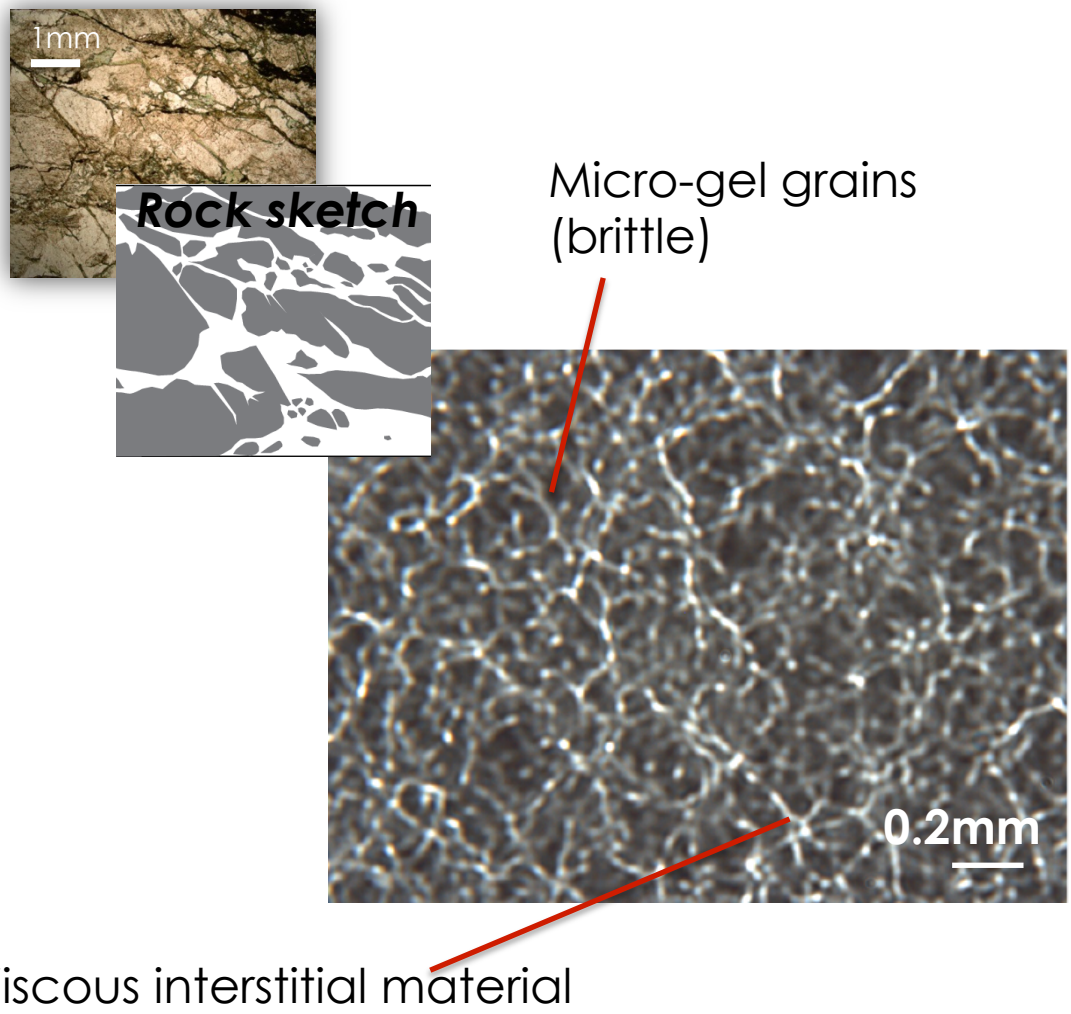




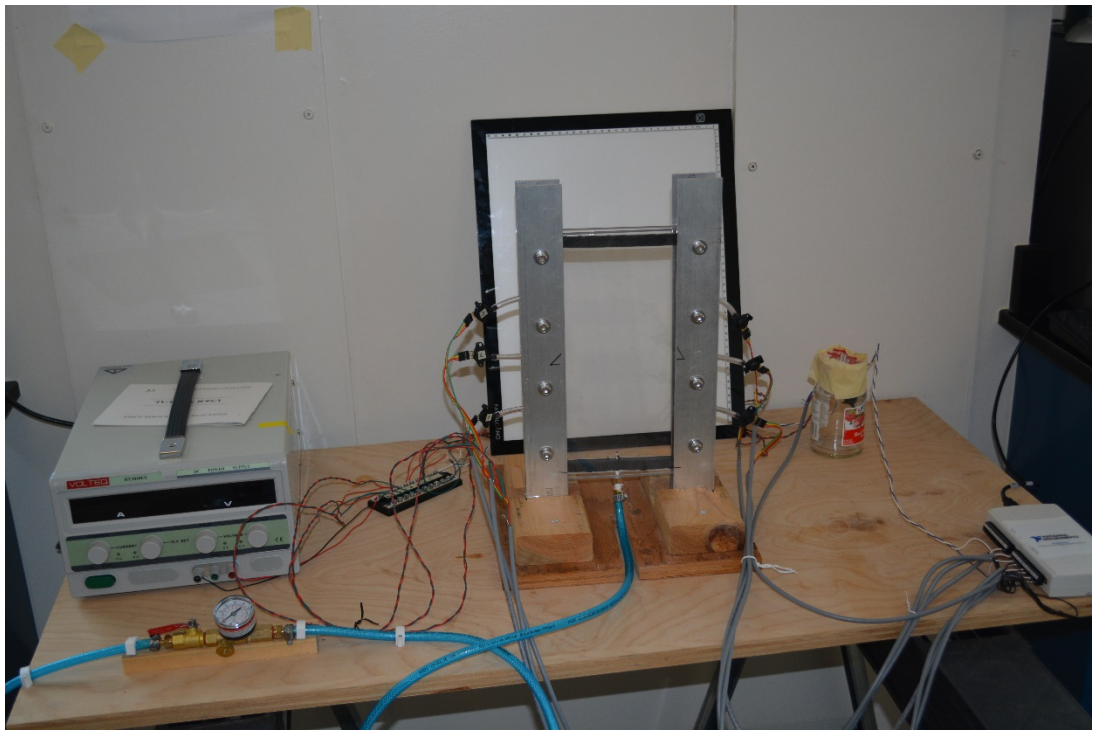
(Lee et al. ,2015)

Semi-brittle model material

- Cross-linked polymer
- ‘Two-phase’ material
- Visco-elasto-plastic
- Power-law yield stress fluid
- Yield stress is dependent on concentration
- Bulk viscosity is dependent on pH



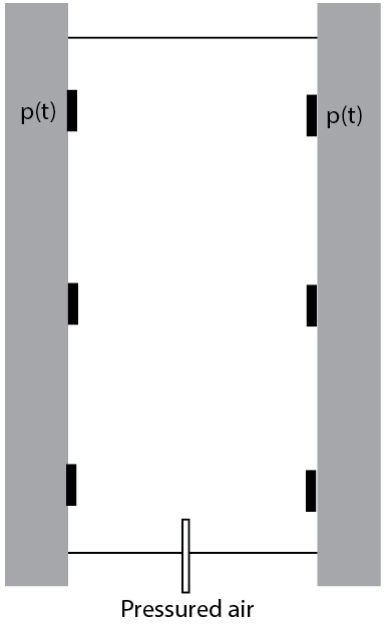
Physical models



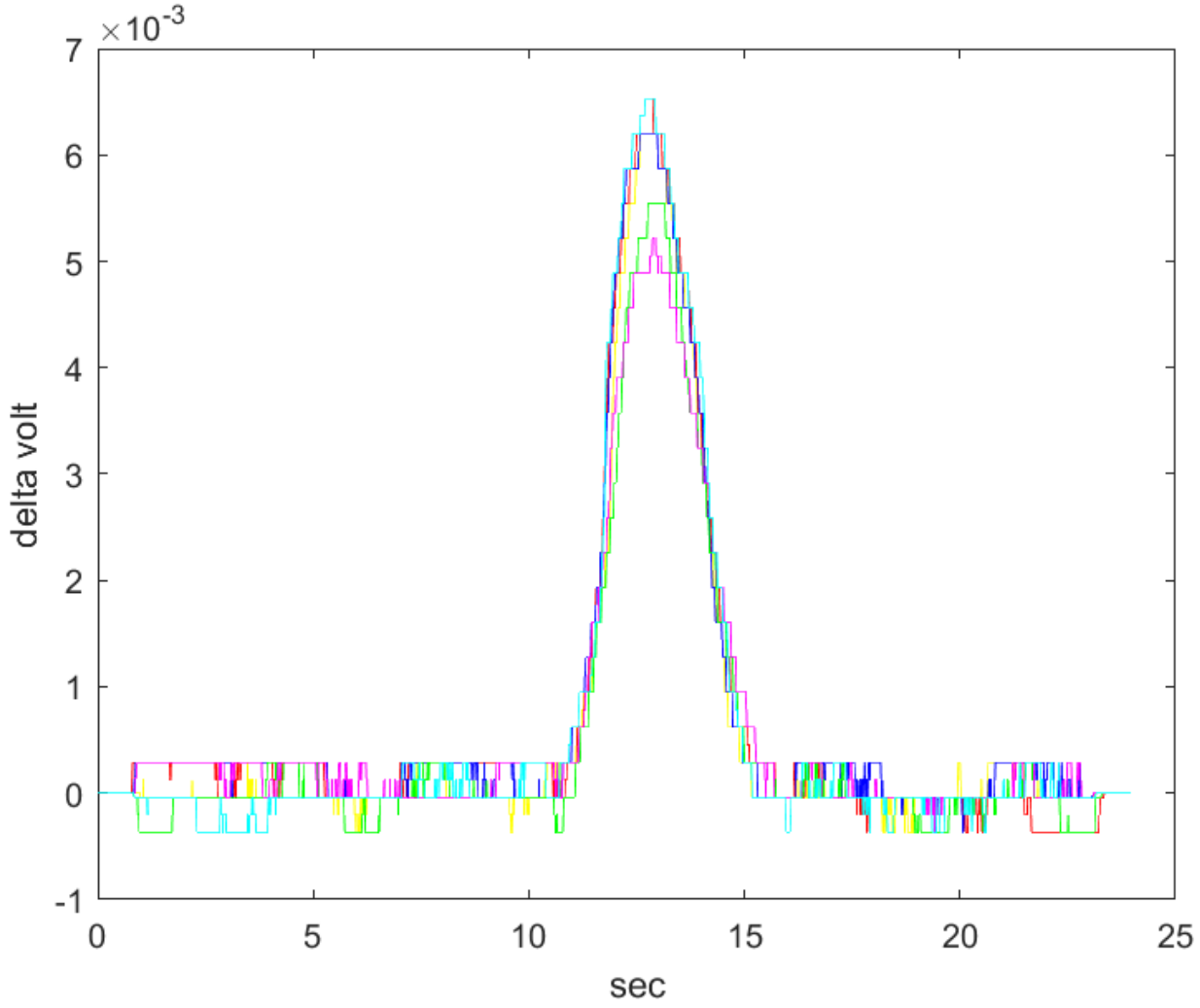
Pressure cell:

Fracture initiation due to overpressure
Recording:

- Pressure
- Fracture shape

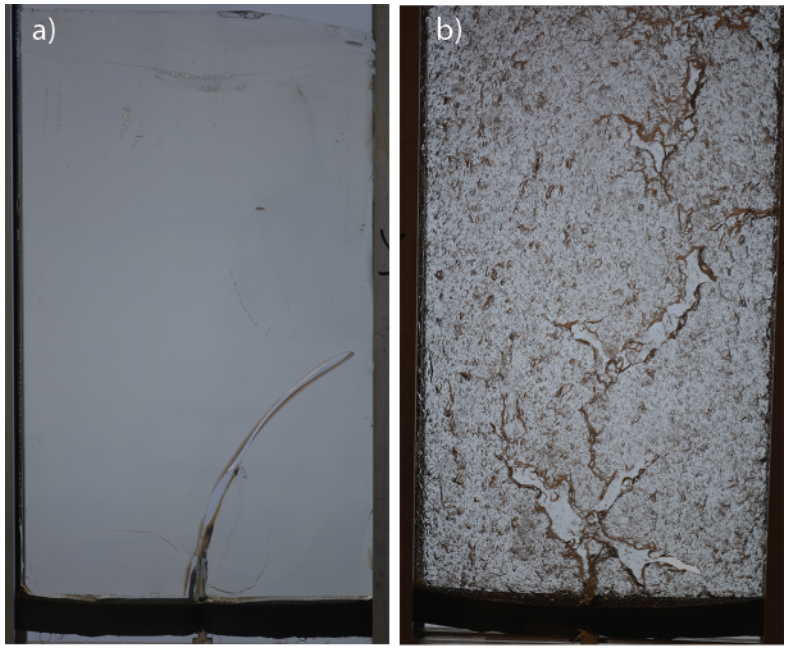


Fracture evolution under pressure

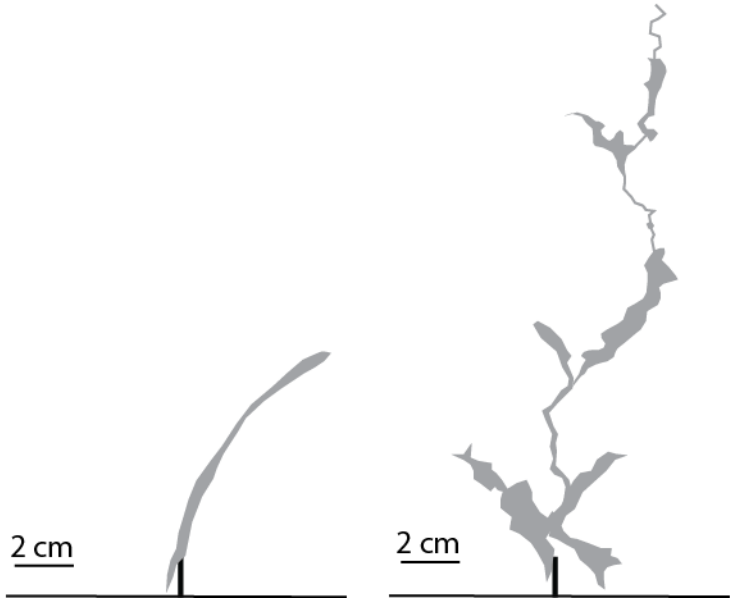


Fracture evolution under pressure

Elasto-plastic



Visco-elasto-plastic

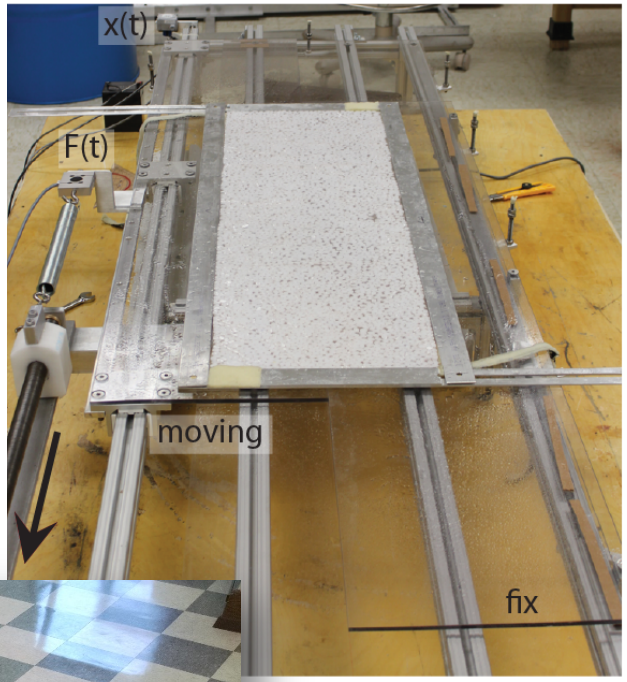


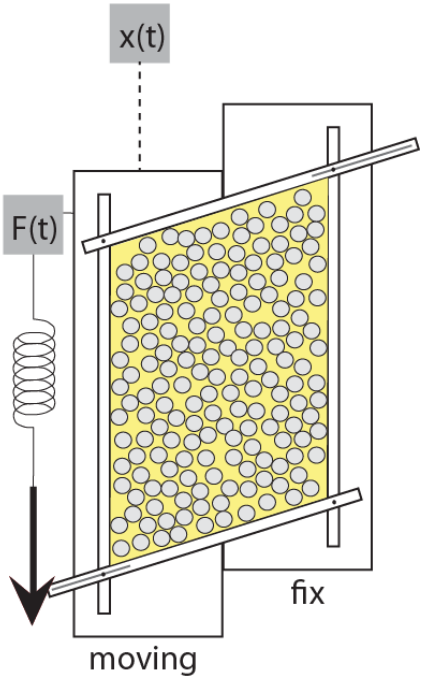
Physical models

Shear cells:

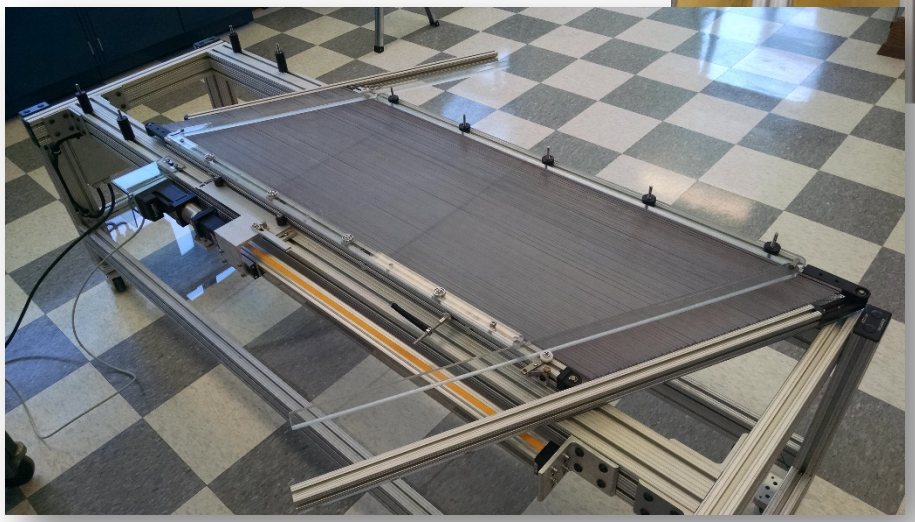
Simple shear
Spring pulled
Recording:

- Force
- Displacement
- Strain field

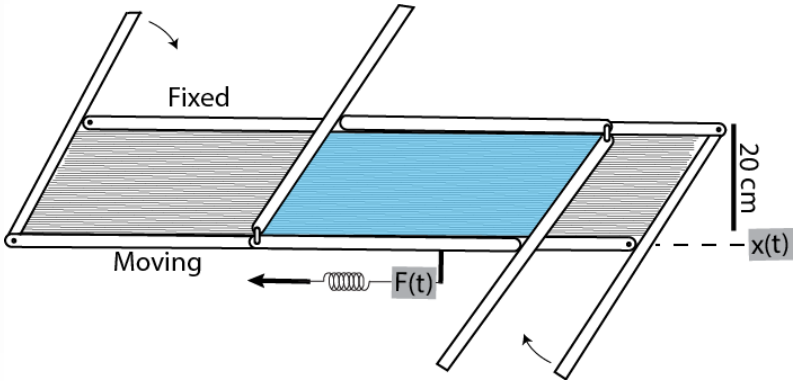




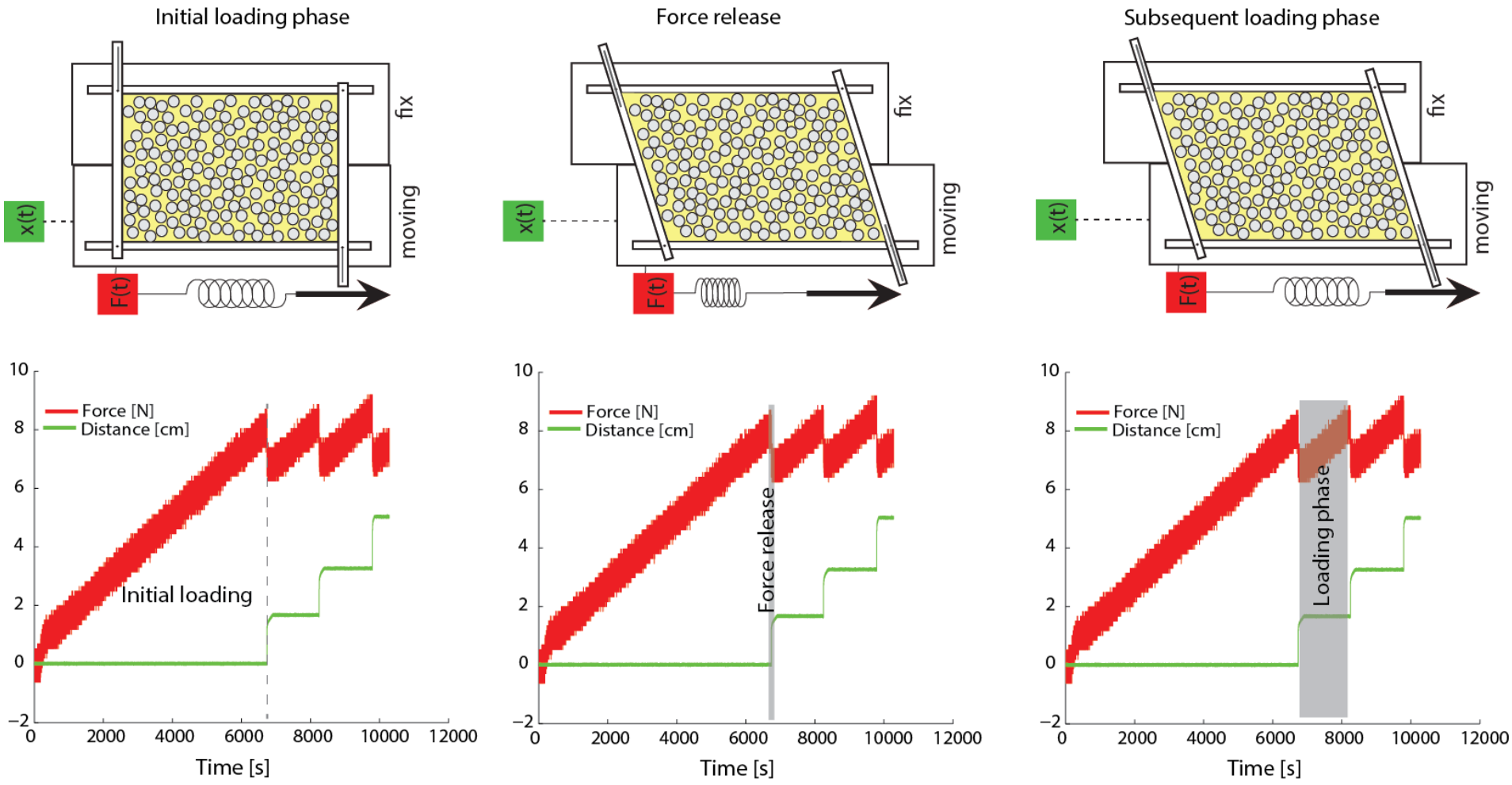
Localized simple shear



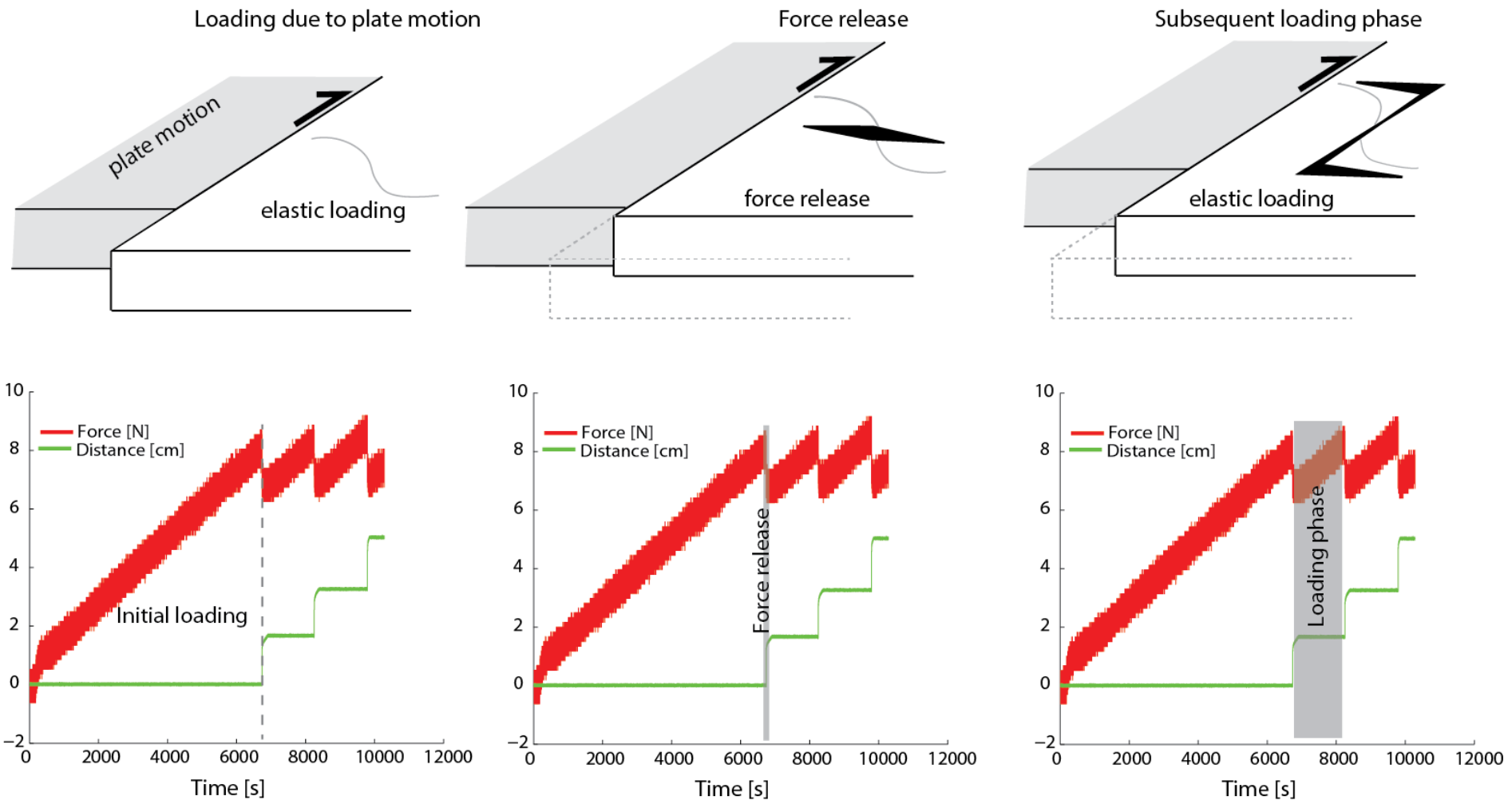
Distributed simple shear



Conservation of power

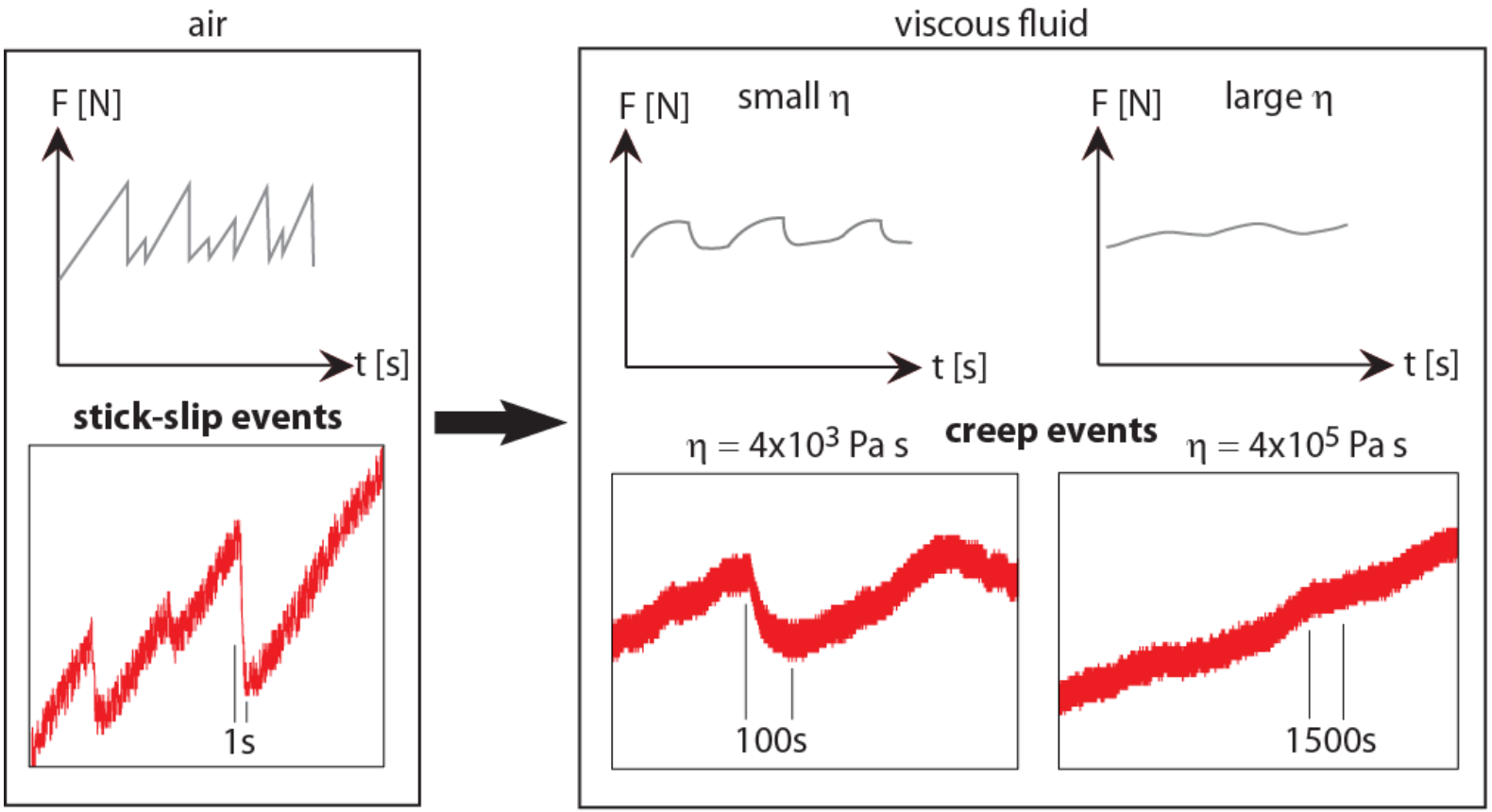


Conservation of power



Slip dynamics

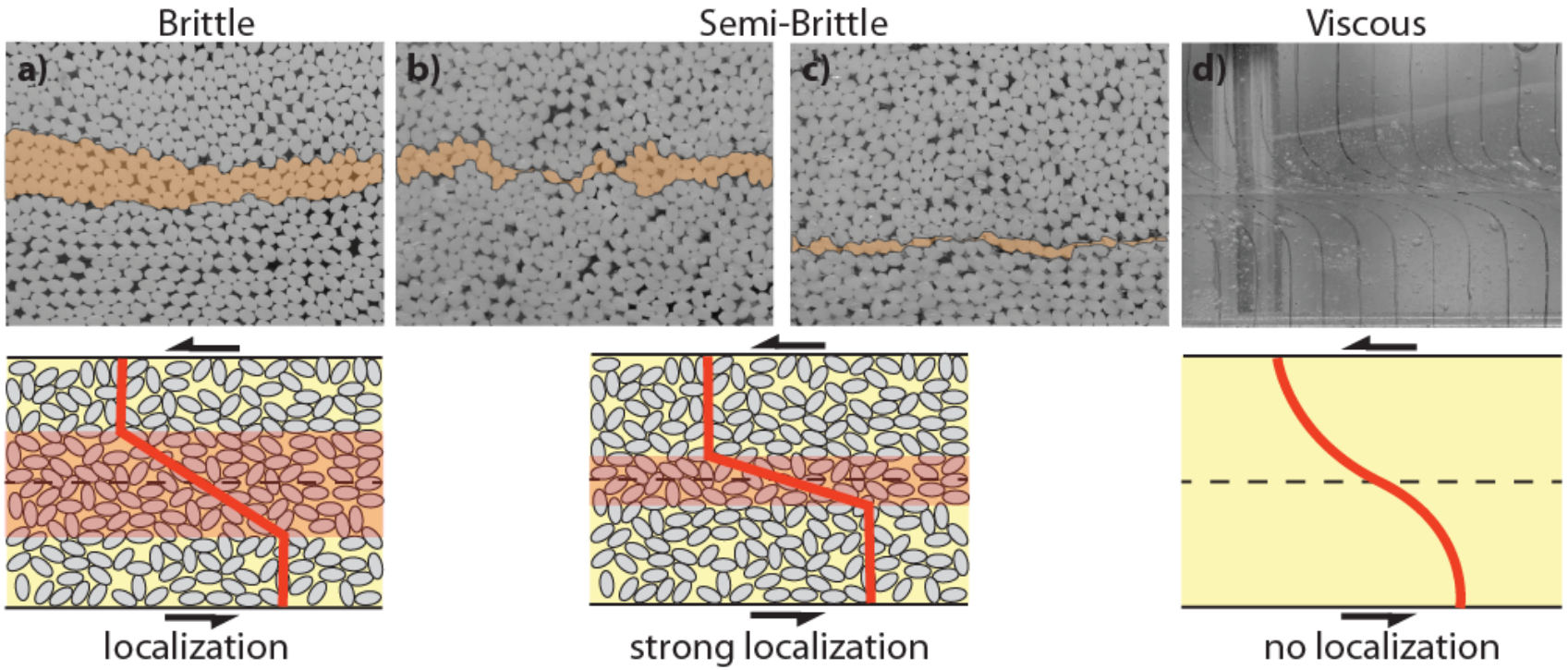
Recording slip dynamic ranging from stick-slip to creep



(Modified after Higashi&Sumita, 2009)

Localization

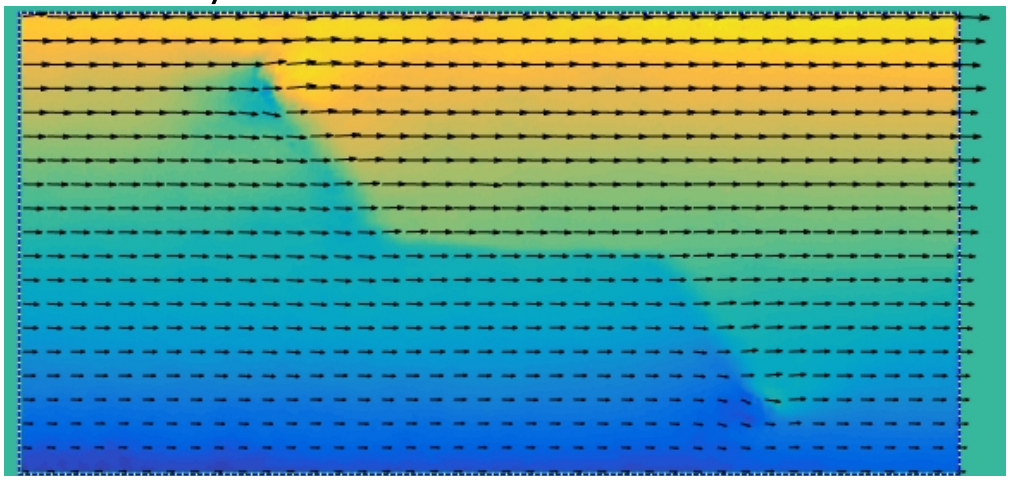
Strain localization is dependent on material.



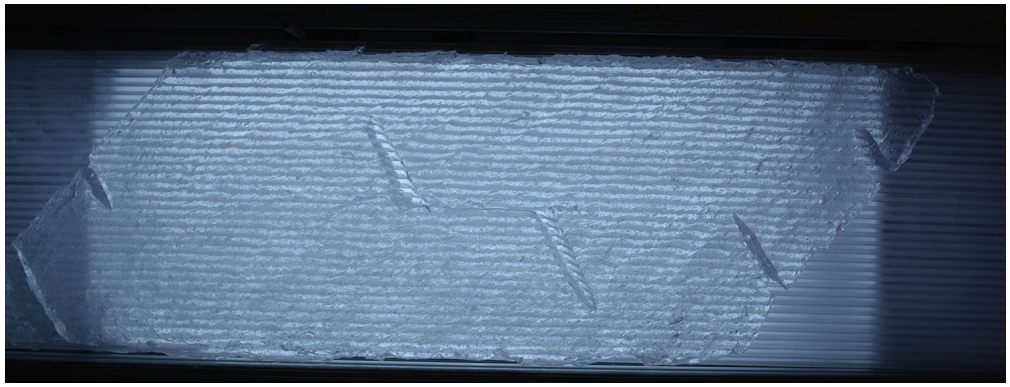
(Reber et al., 2014)

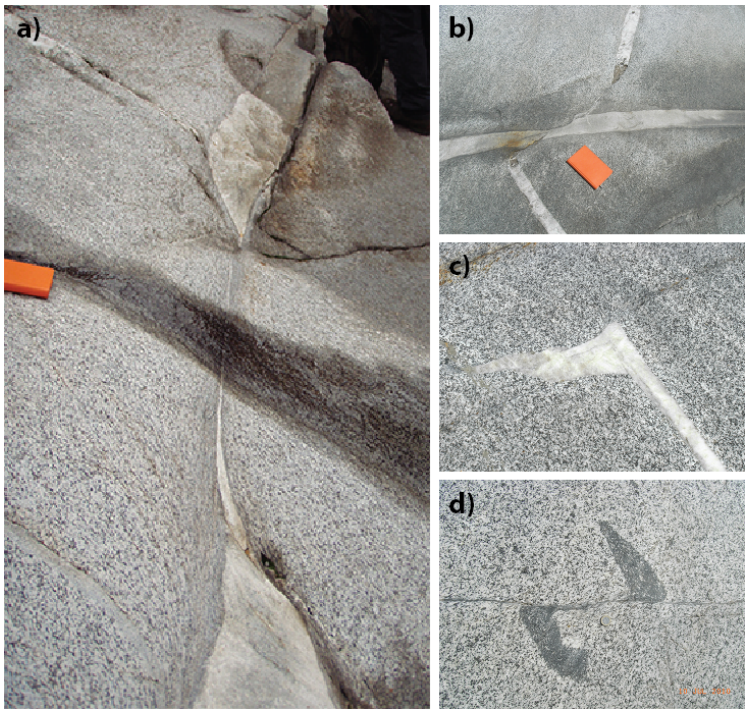
Fracture evolution and pattern

Velocity field



Fracture pattern





(Lago di Neves, Alps, Italy)

Conclusion: Rheology governs deformation

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