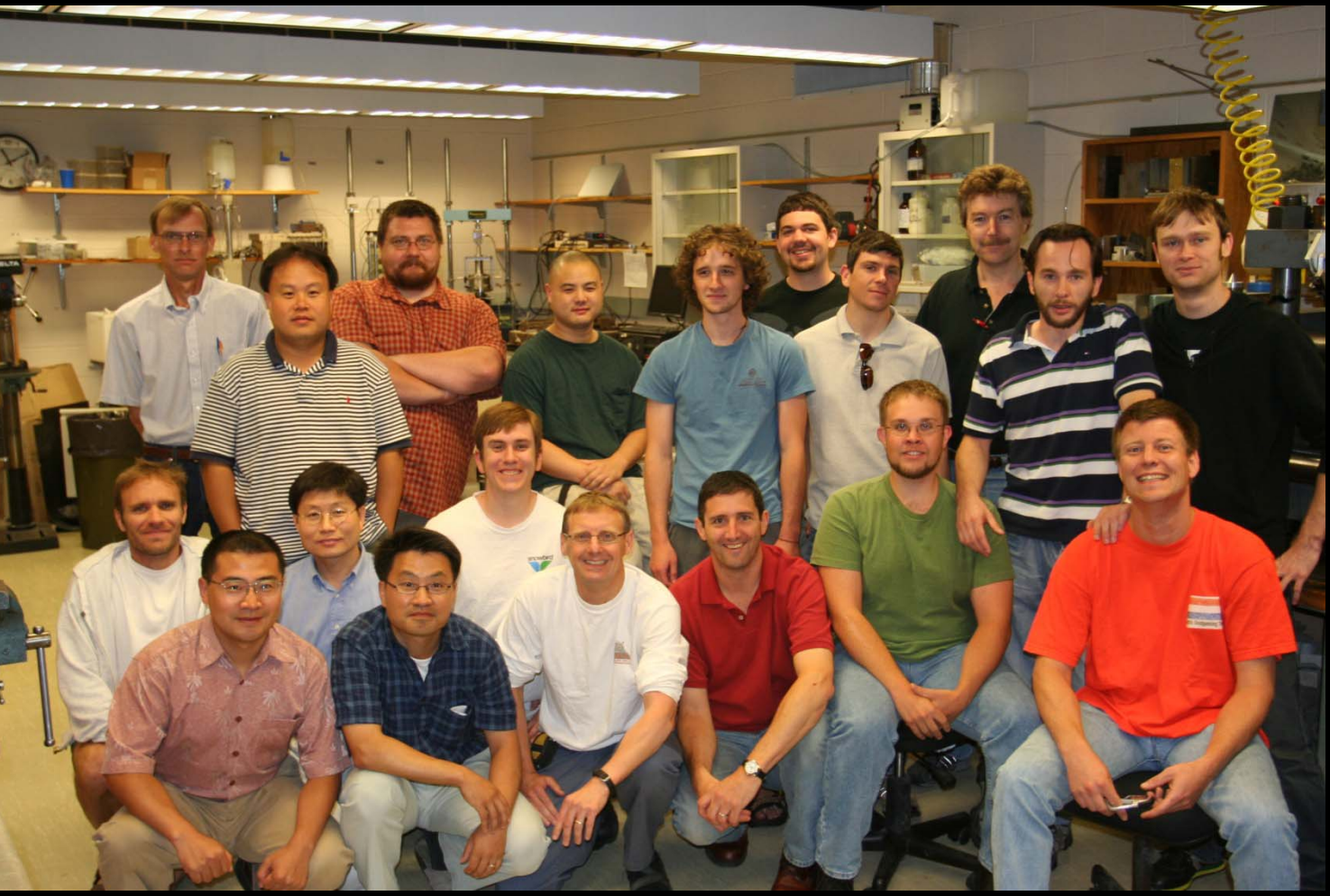
A PRESSURE VESSEL FOR TRUE-TRIAXIAL DEFORMATION & FLUID FLOW DURING FRICTIONAL SHEAR

Chris Marone, Brett Carperter, Derek Elsworth, Igor Faoro, Matt Ikari, Matt Knuth, André Niemeijer, Demian Saffer, and Jon Samuelson

Rock & Sediment Mechanics Lab and
Center for Geomechanics, Geofluids & Geohazards,
The Pennsylvania State University, USA

Rock & Sediment Mechanics Lab and Center for Geomechanics, Geofluids & Geohazards



Outline

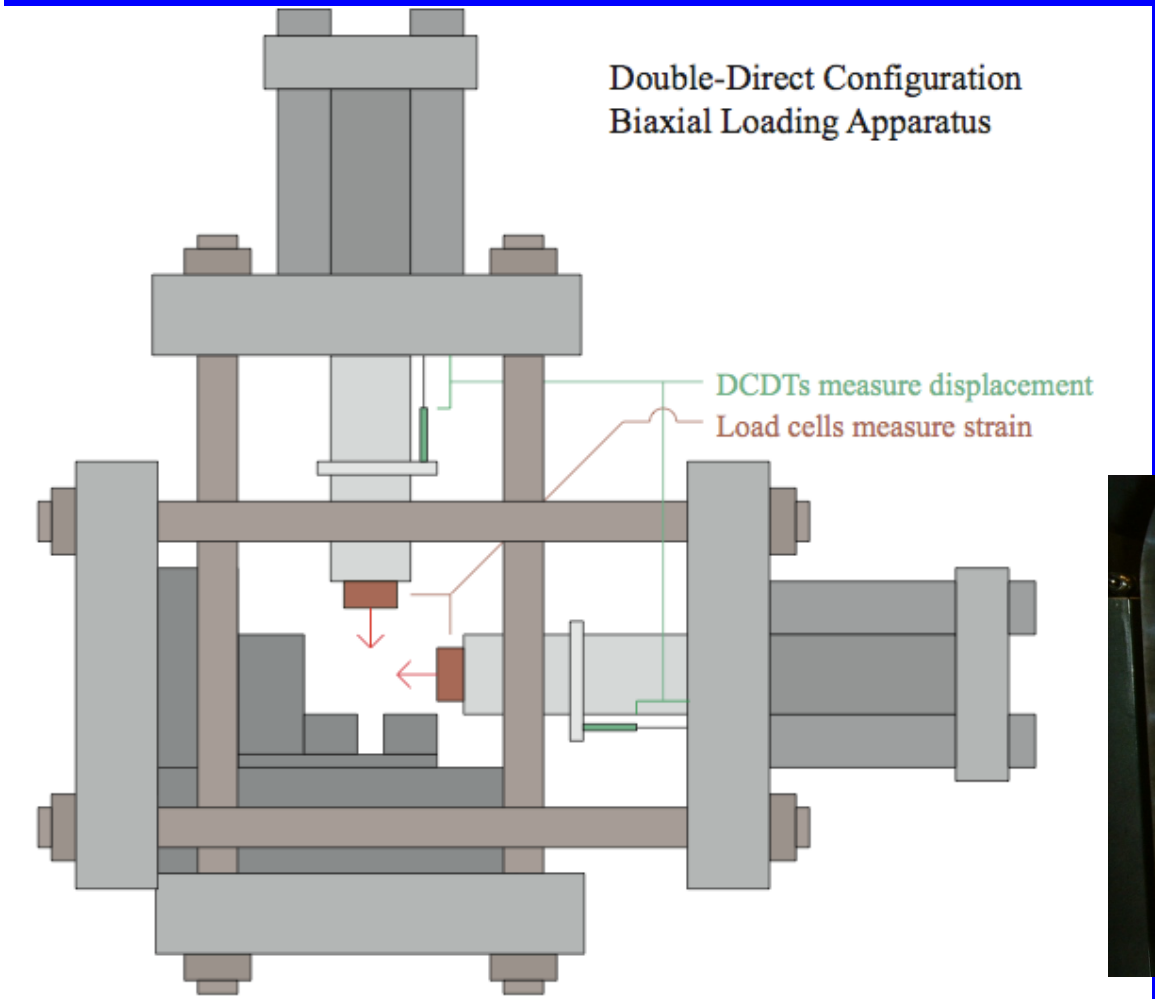
Lab

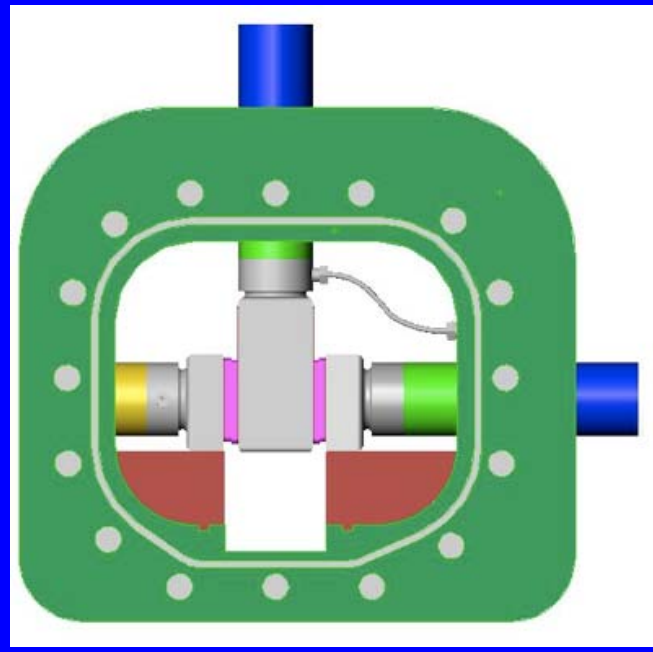
Pressure Vessel for True Triaxial Deformation & Fluid Flow

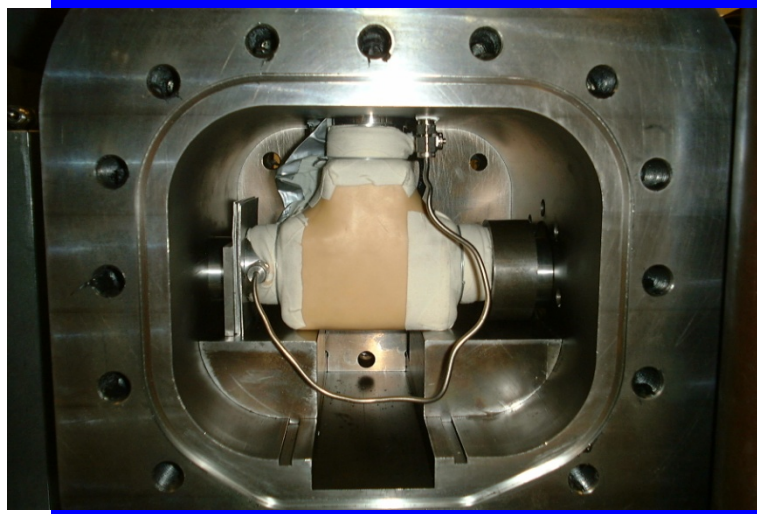
Current Research

Biaxial Load Frame + Pressure Vessel = True Triaxial Stress State

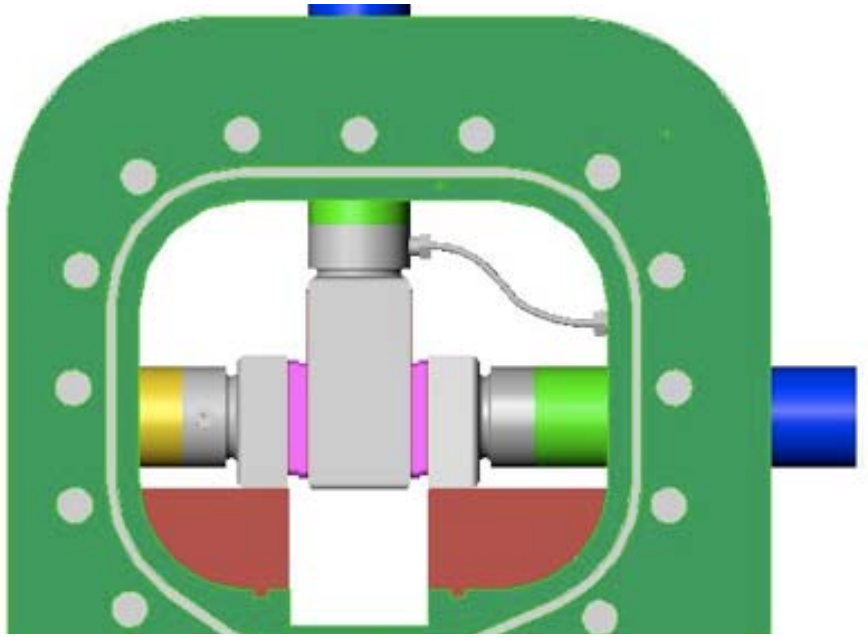
Applied Stresses to 300 MPa, Simultaneous fluid flow and shear
Pore and Confining Pressures to 70 MPa (10K psi)
Deformation rates of 0.01 µm/s to cm/s
Fluid composition: H_20, brine, CO_2, etc.

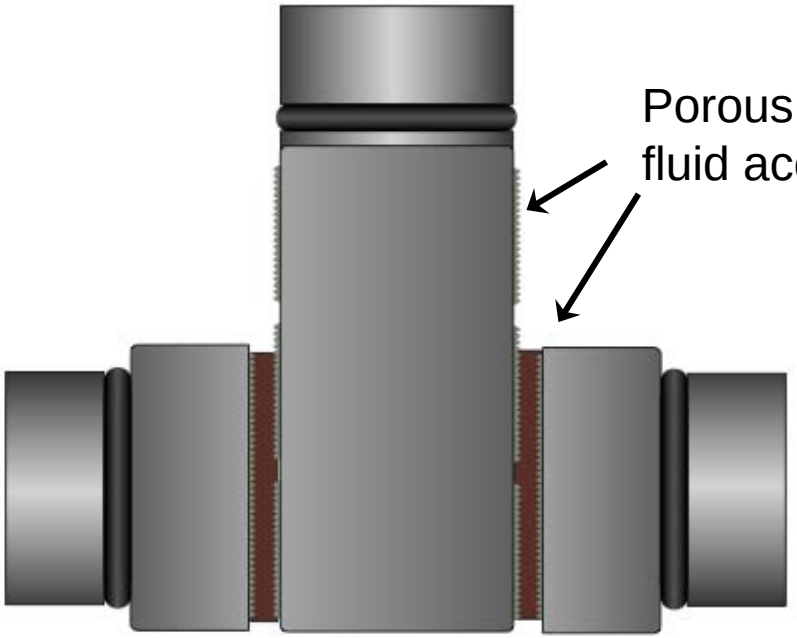


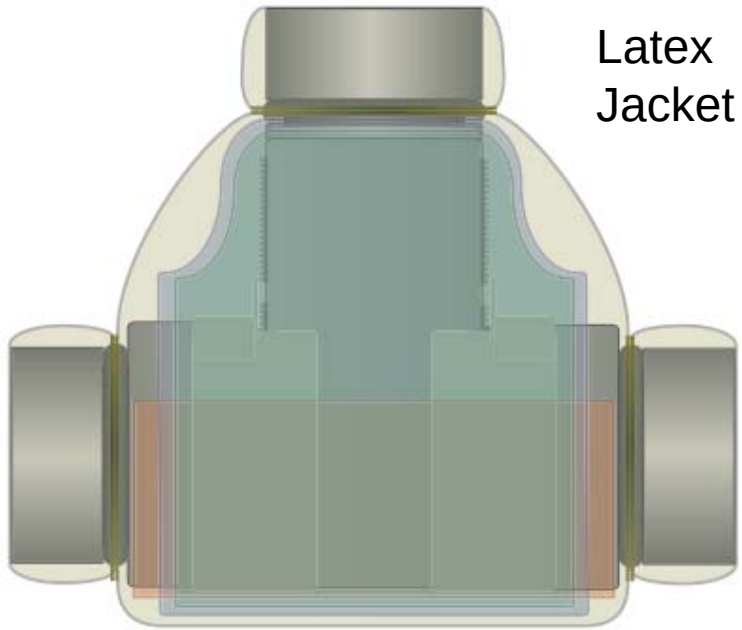


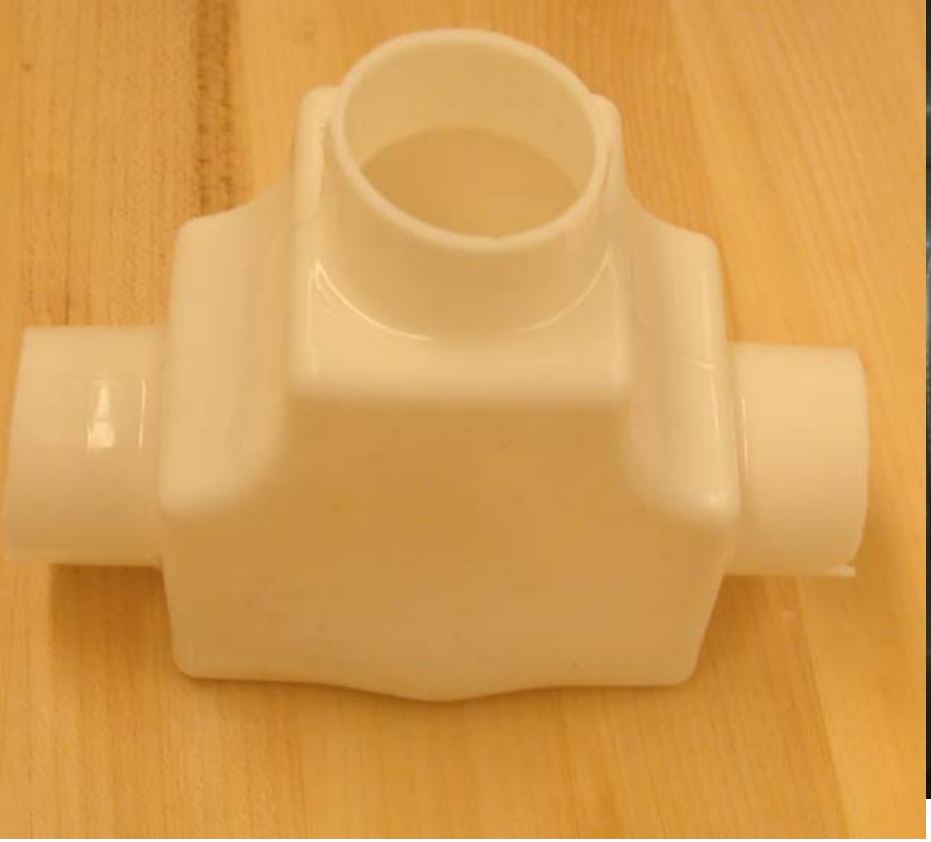


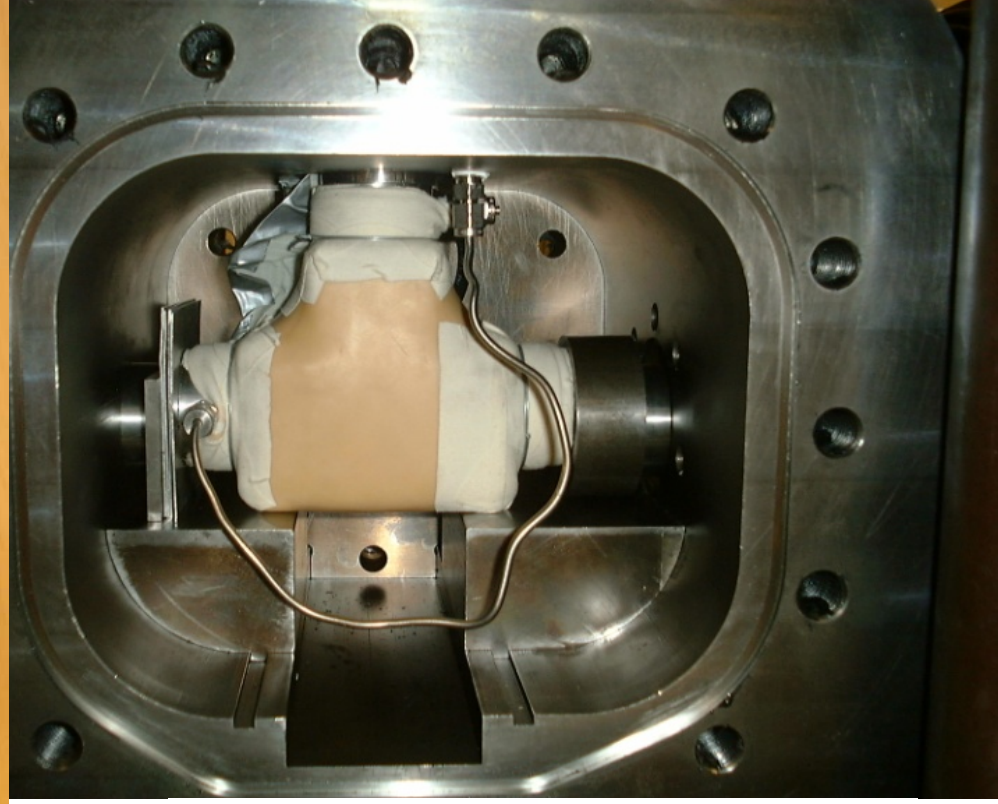
True Triaxial Stress State, Double Direct Shear

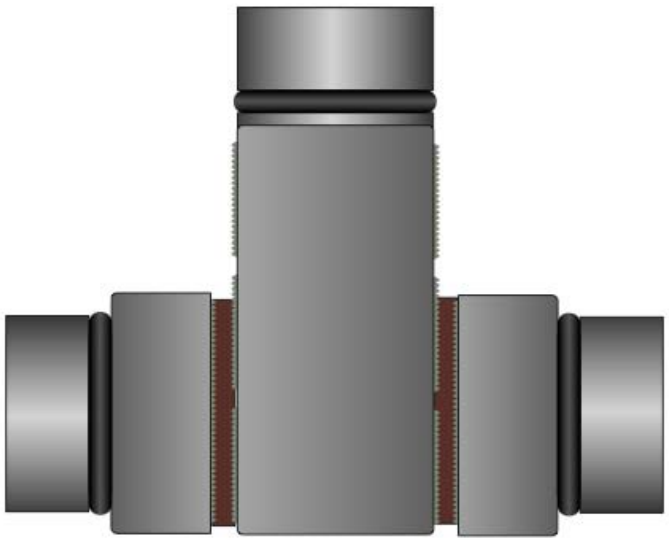


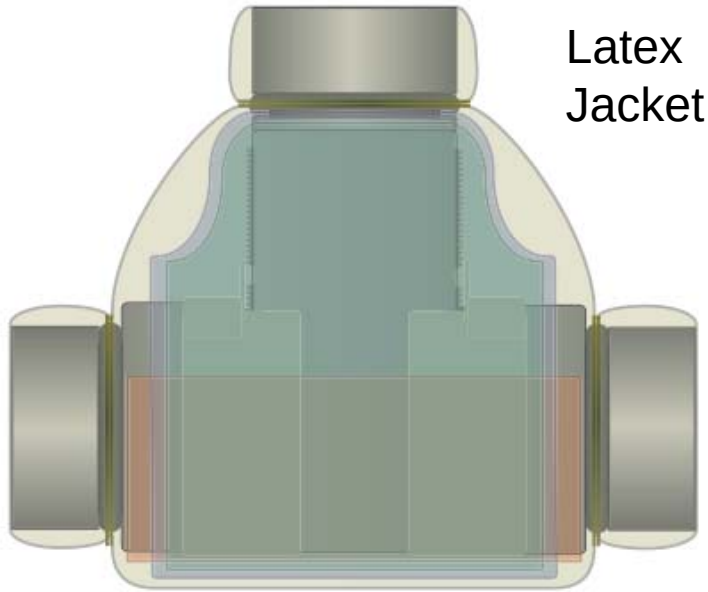






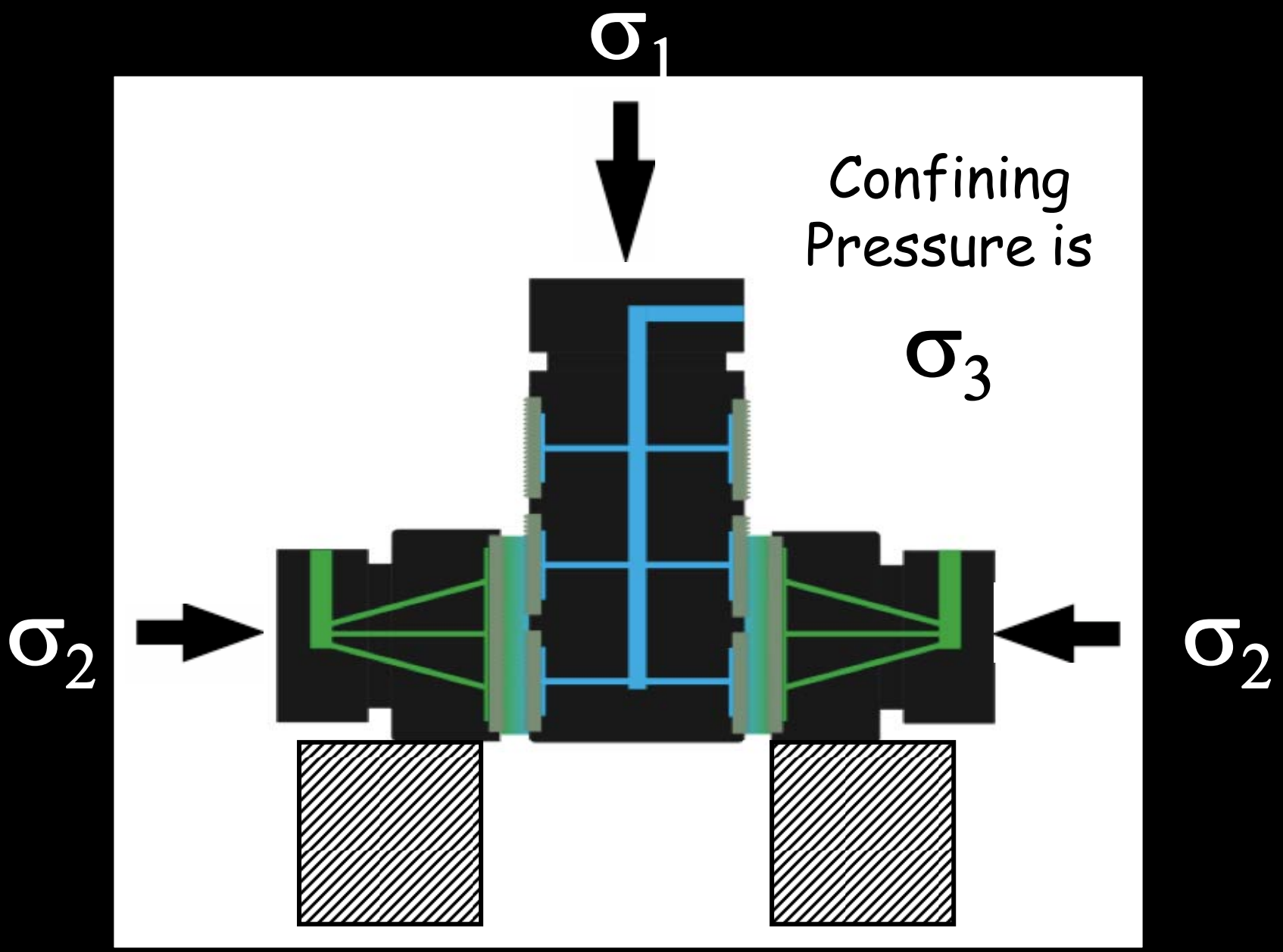






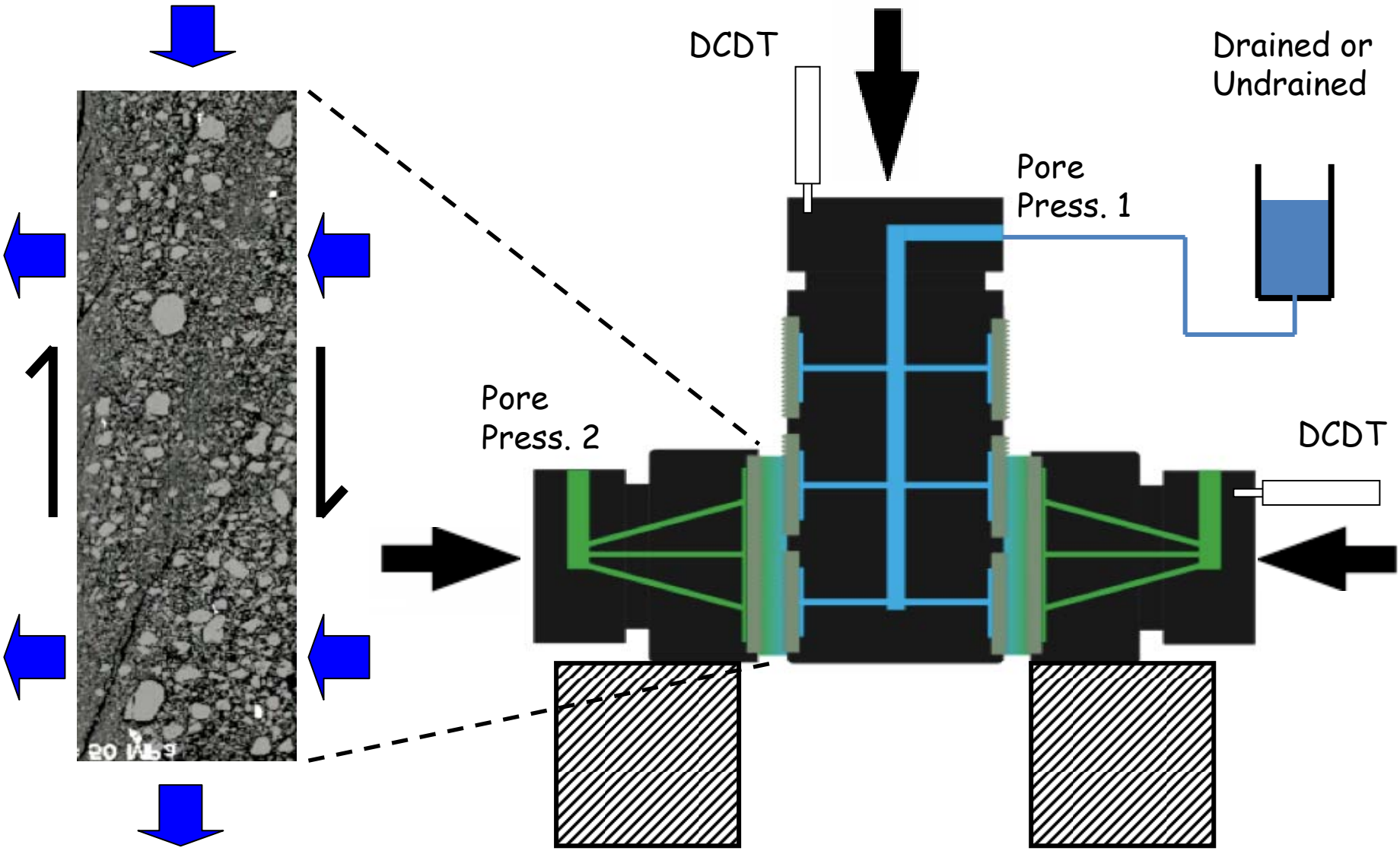
Latex
Jacket

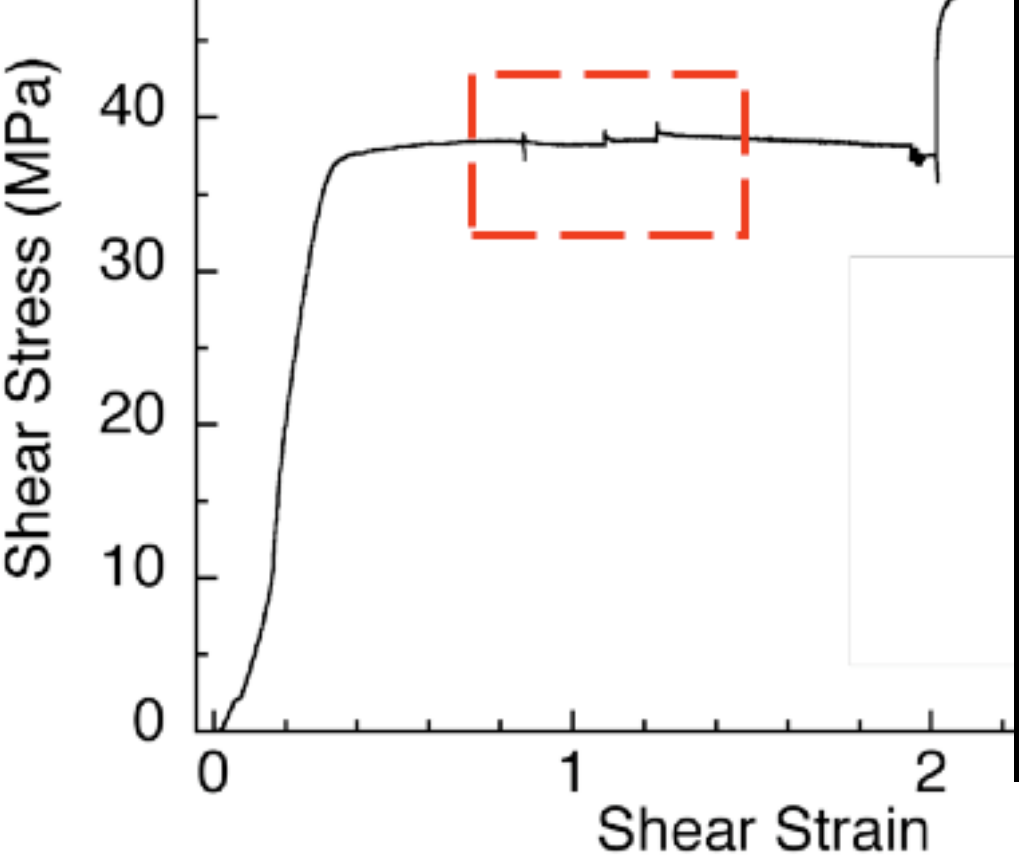
True Triaxial Stress State



Fluid flow normal and parallel to shear direction

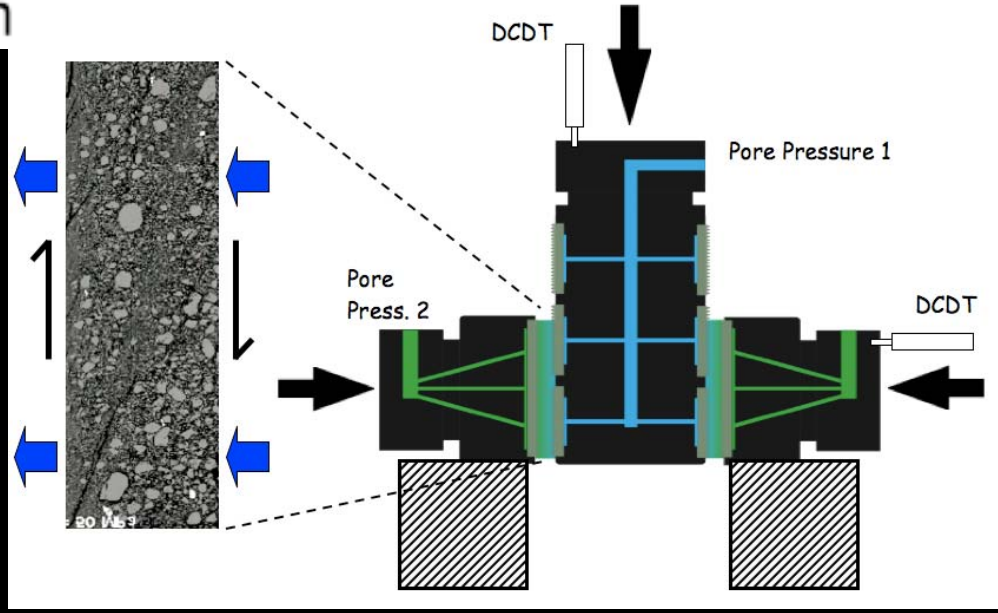
True Triaxial Stress State, Double Direct Shear





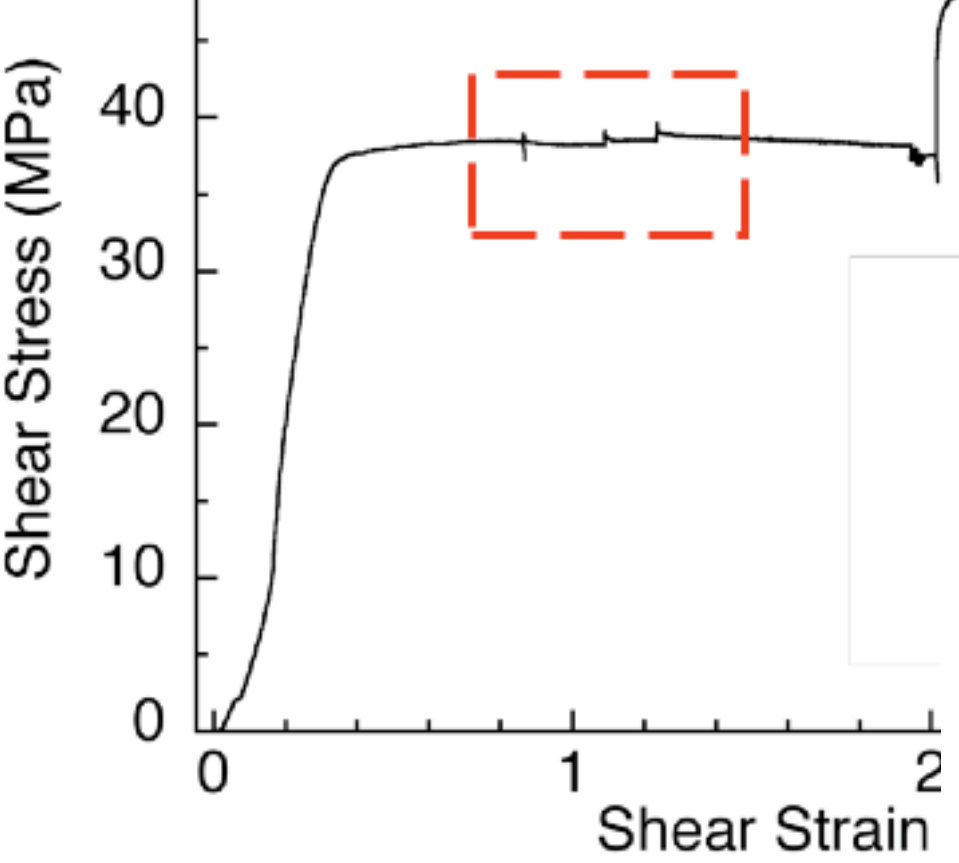
Permeability Normal to shear, Synthetic Fault Gouge

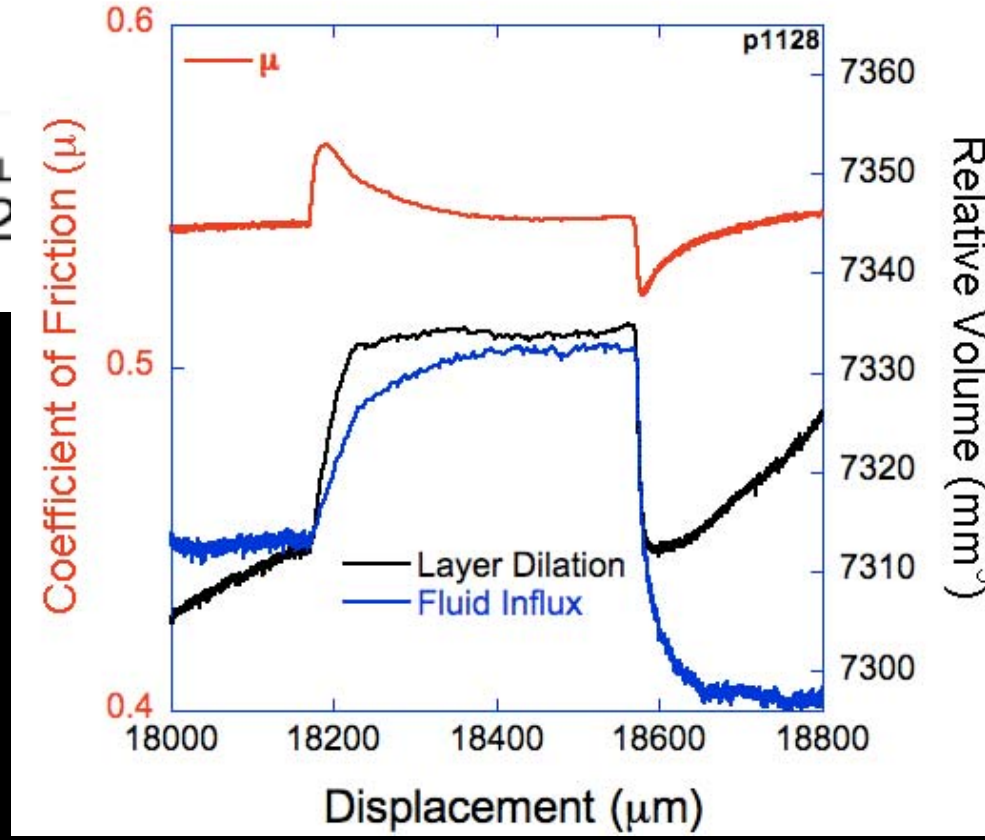
Shear velocity perturbations
Strain localization
Connection to dilation/compaction



Permeability Normal to shear, Synthetic Fault Gouge

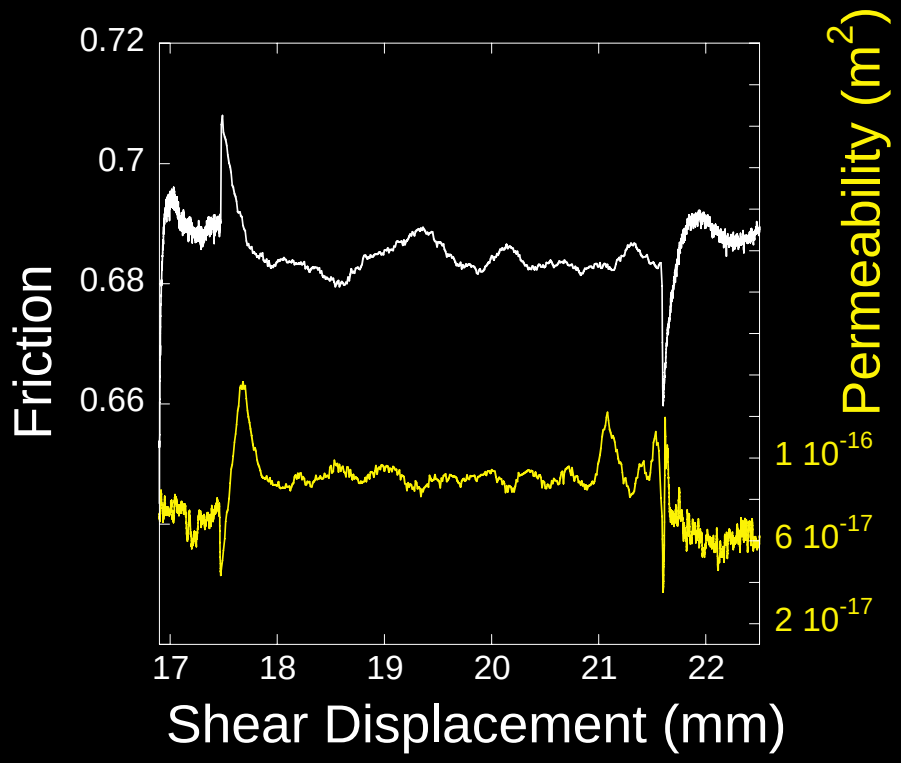
Shear velocity perturbations
Strain localization
Connection to dilation/compaction

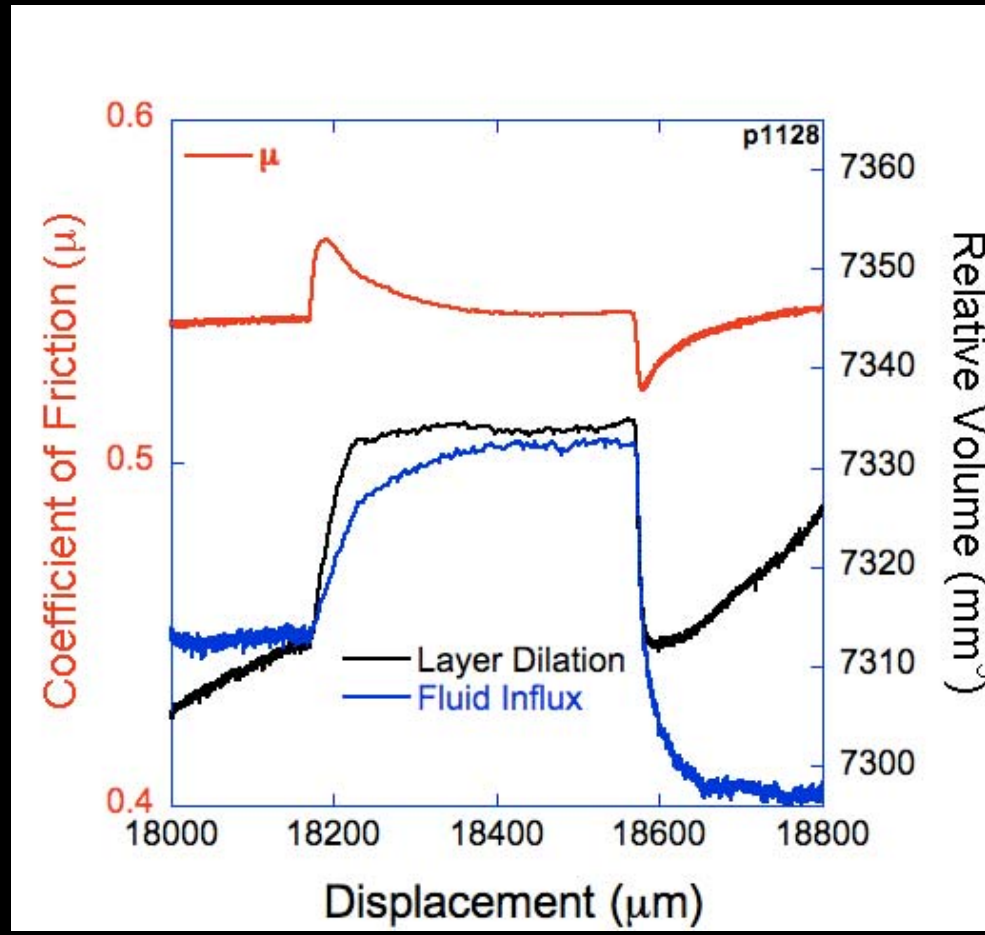




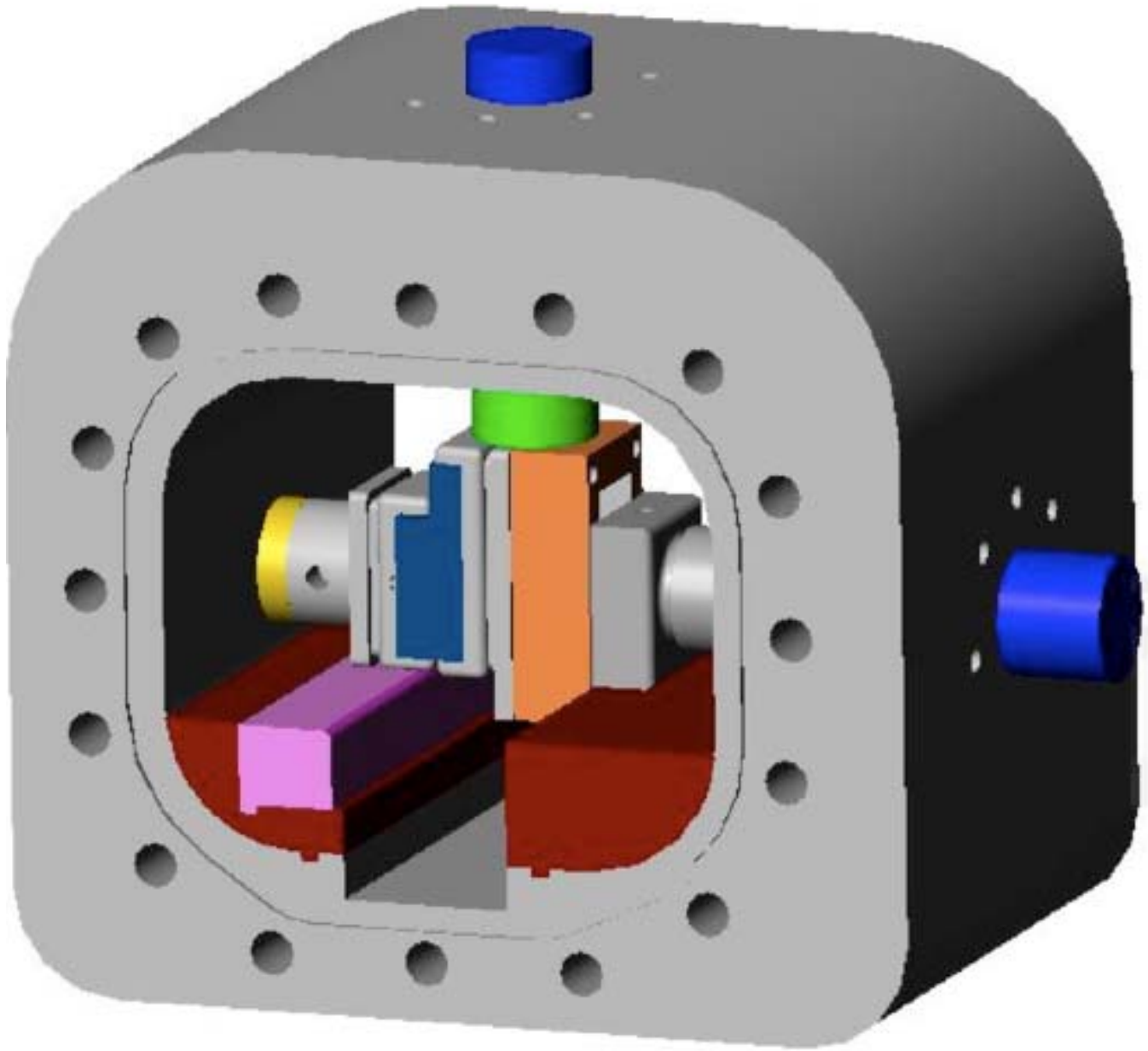
Permeability Normal to shear, Synthetic Fault Gouge

Shear velocity perturbations
Strain localization
Connection to dilation/compaction

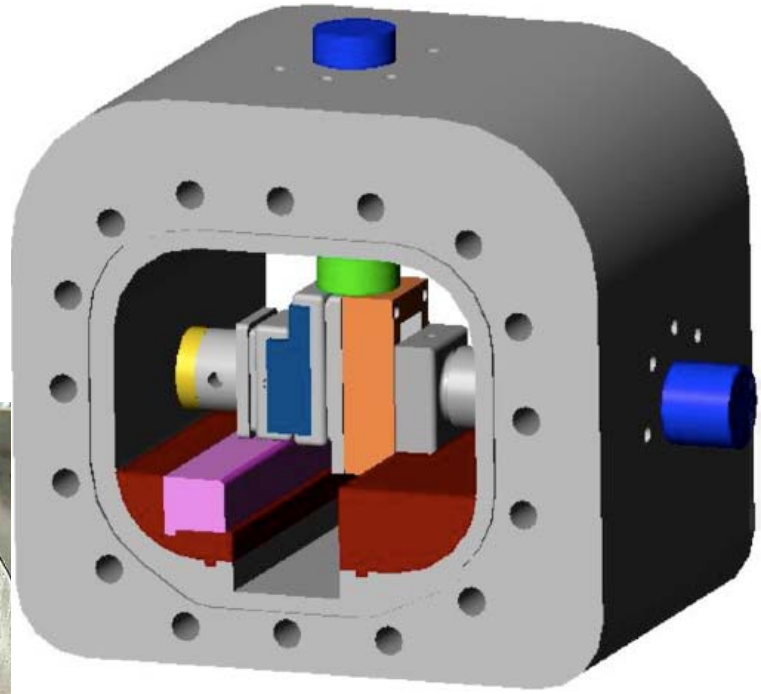


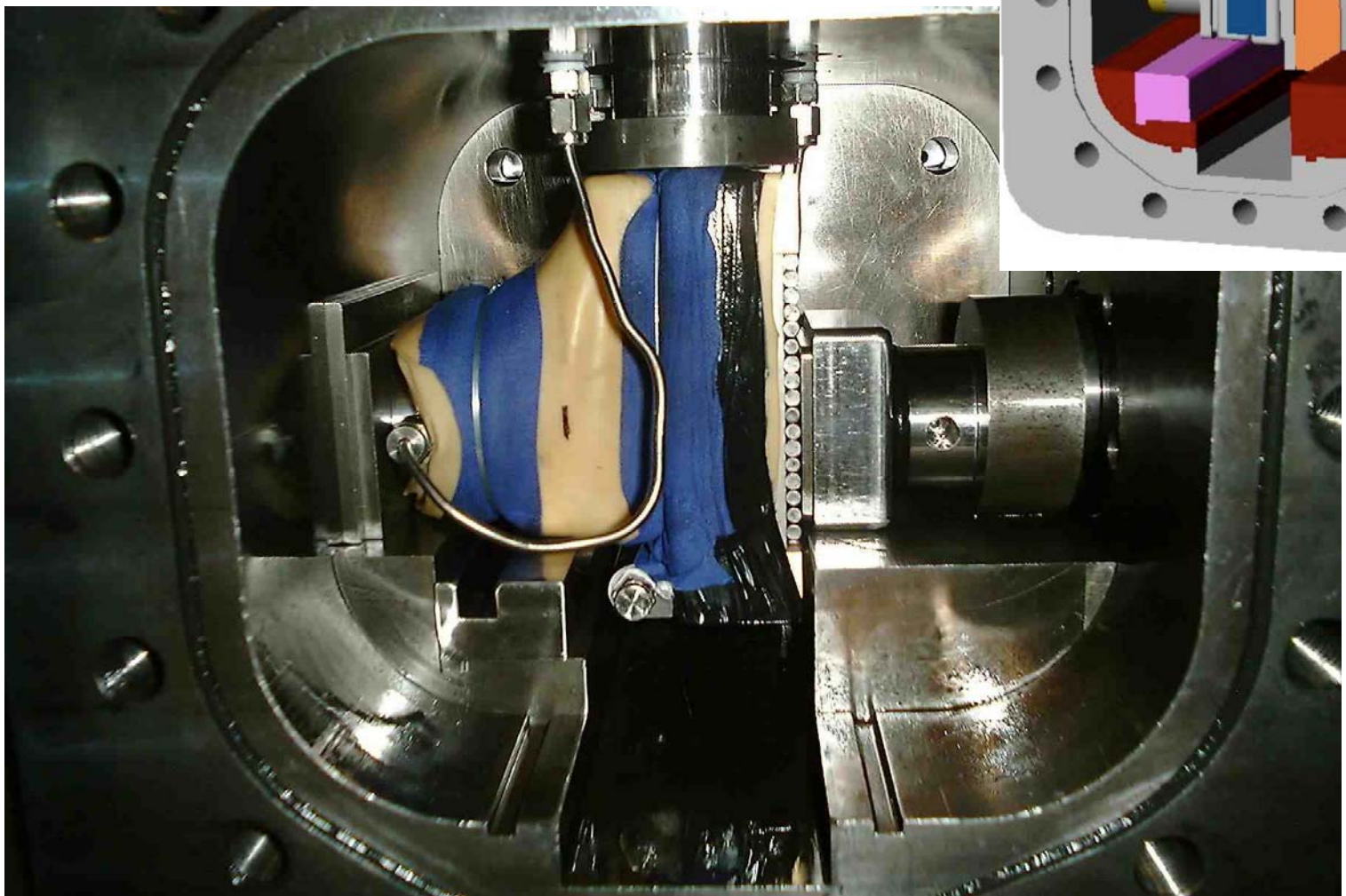


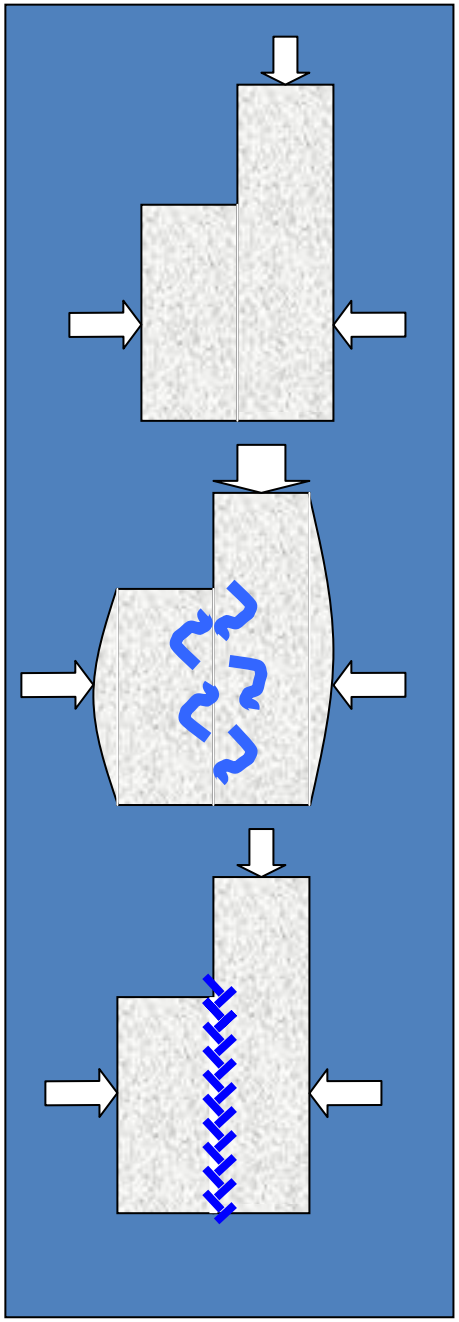
True Triaxial Stress State, Single Direct Shear

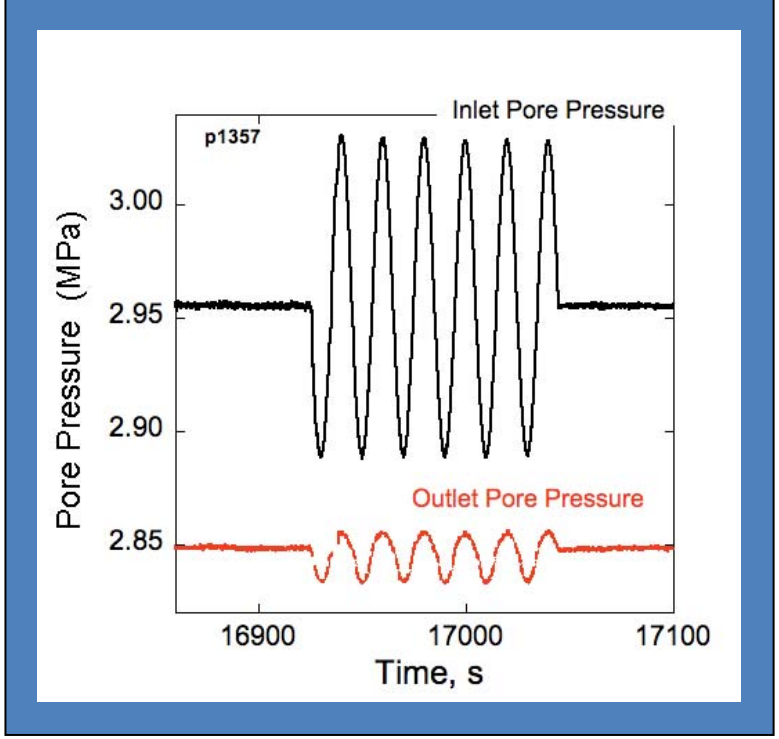


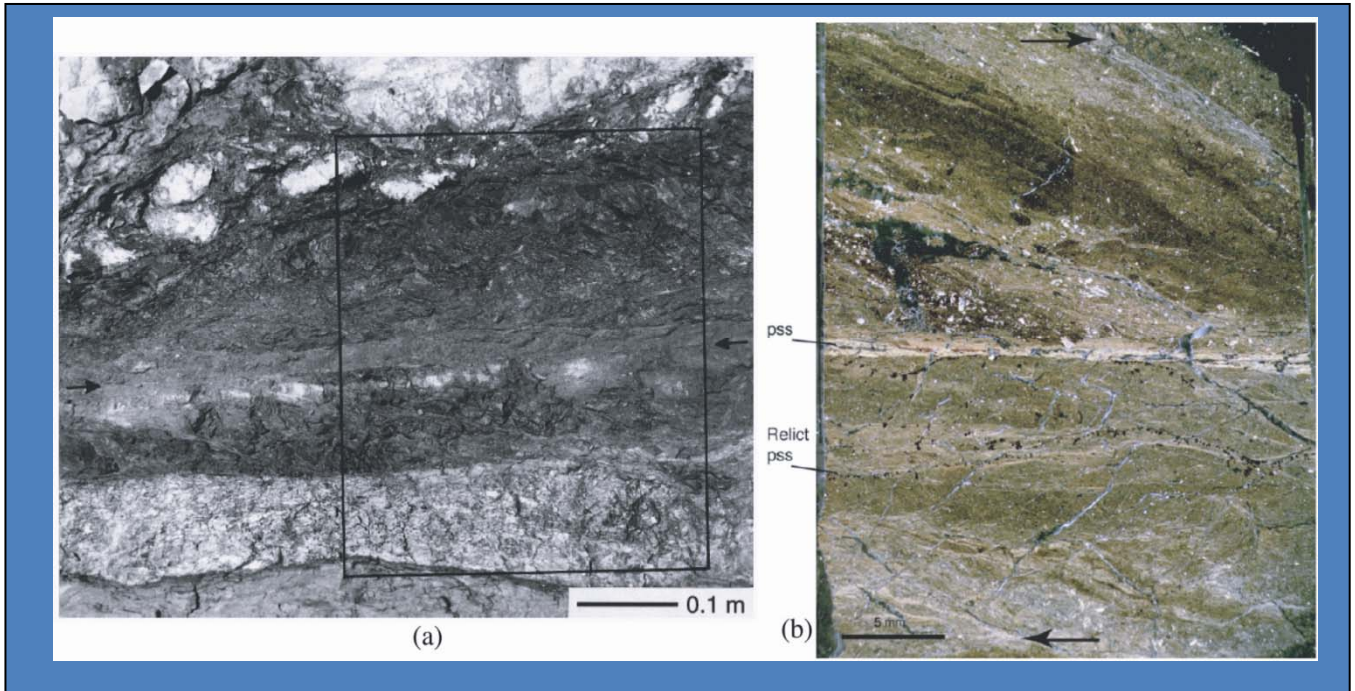
True Triaxial Stress State, Single Direct Shear



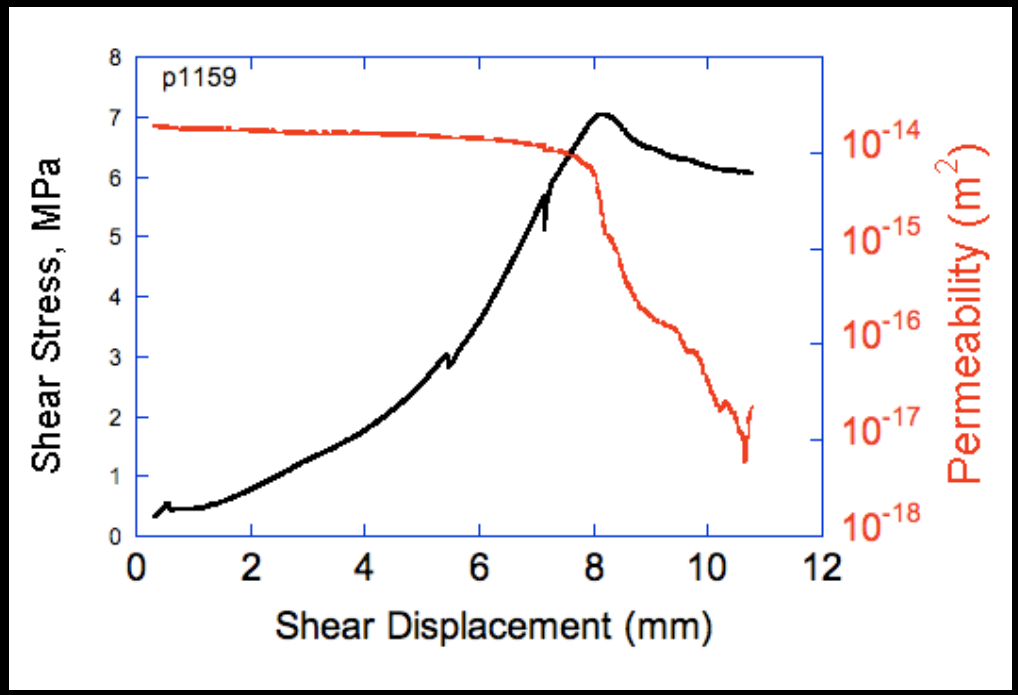


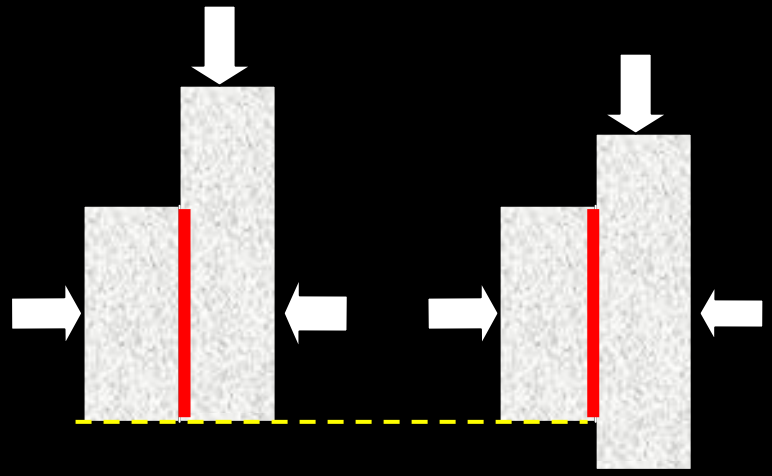



Inlet Pore Pressure
p1357
3.00
2.95
2.90
2.85
Pore Pressure (MPa)
Outlet Pore Pressure
16900
17000
17100
Time, s

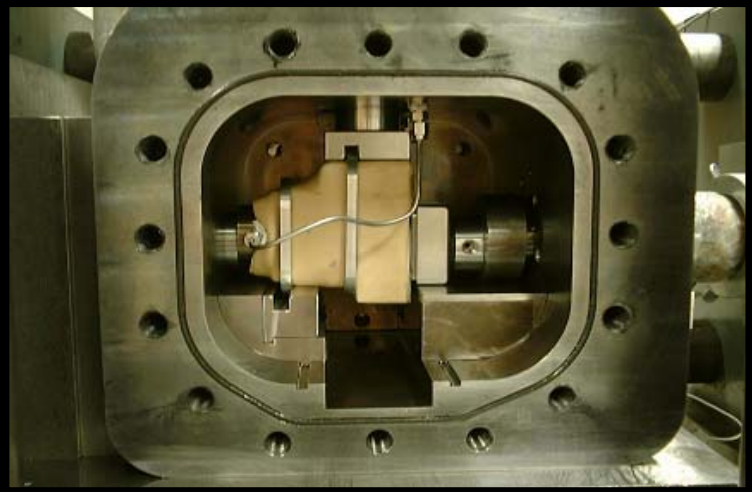

0.1 m
(a)
pss
Relict
pss
(b)
5 mm

FLUID FLOW PARALLEL TO SHEAR; Triaxial, Diorite synthetic fault





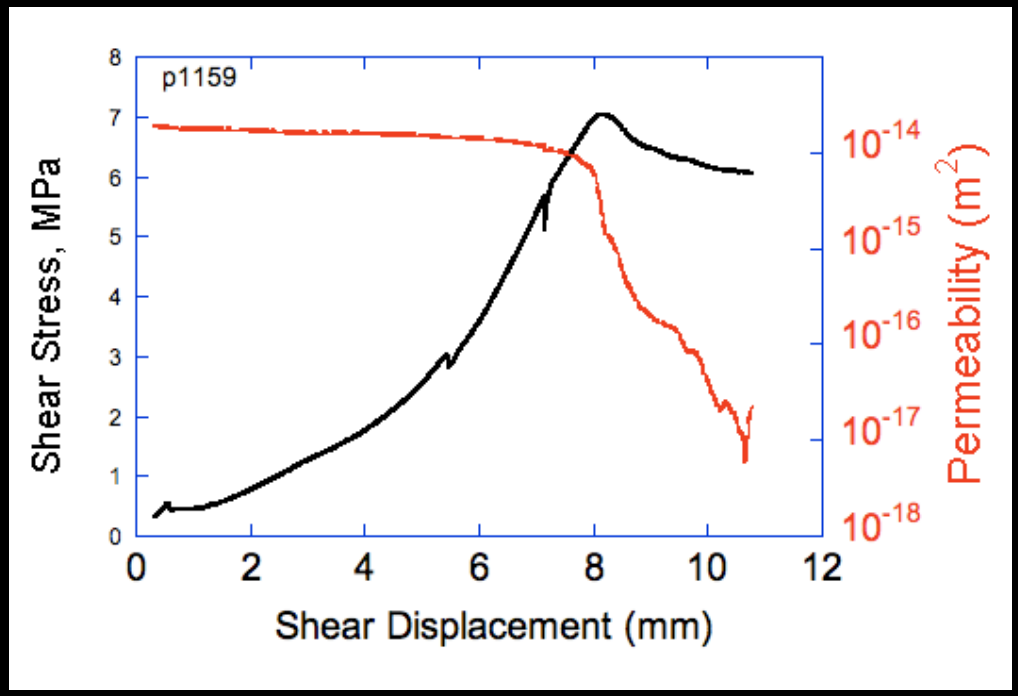
Wear & Gouge Formation Reduces Fault Parallel Permeability

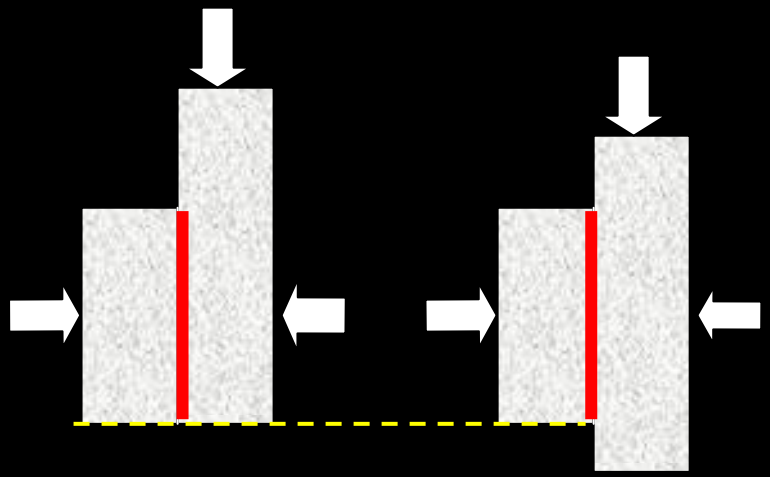


Permeability

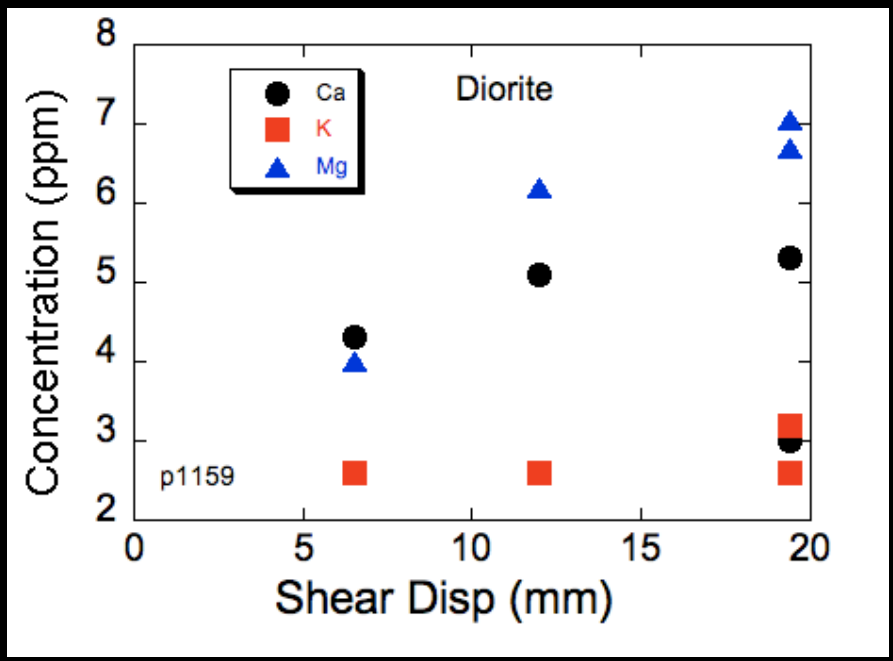
$$k = \frac{Q}{dp} \cdot \frac{\mu \cdot dl}{A_T}$$

FLUID FLOW PARALLEL TO SHEAR; Triaxial, Diorite synthetic fault



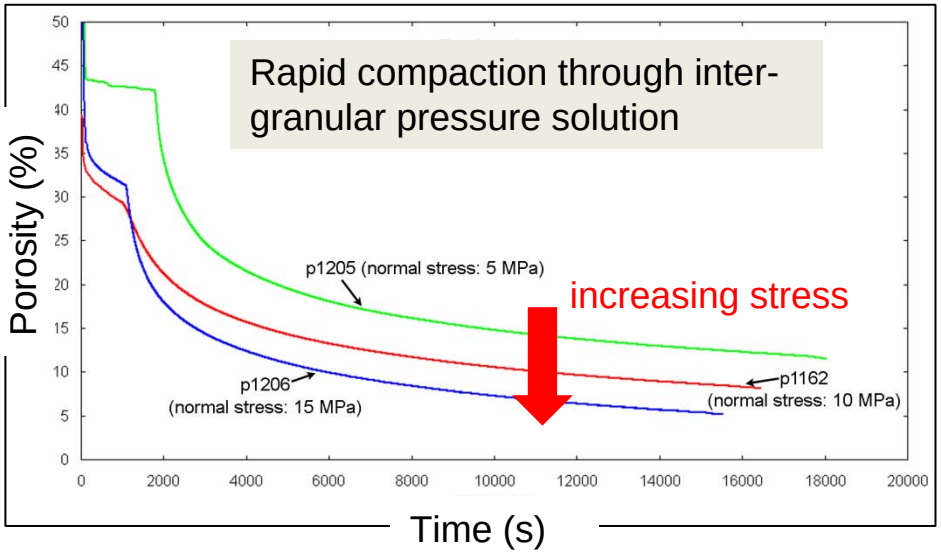


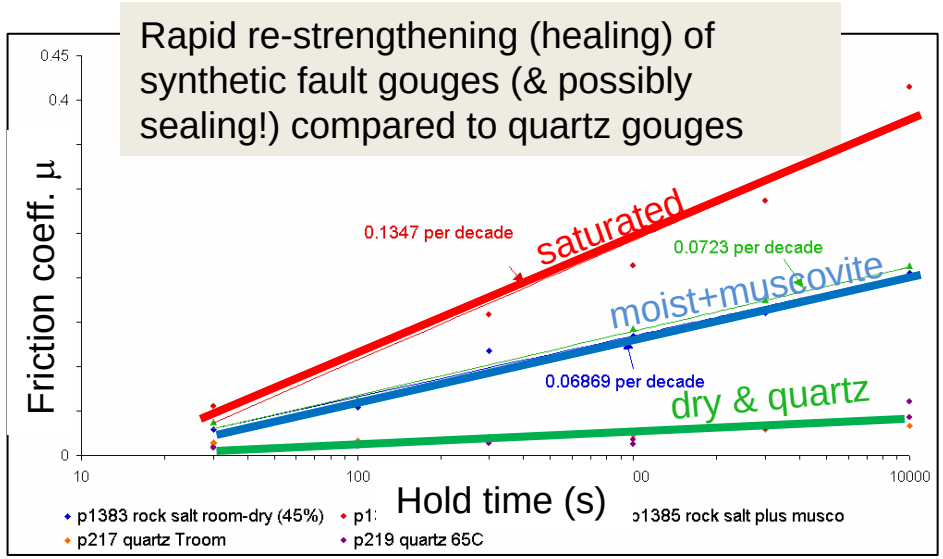
Wear & Gouge Formation Reduces Fault Parallel Permeability



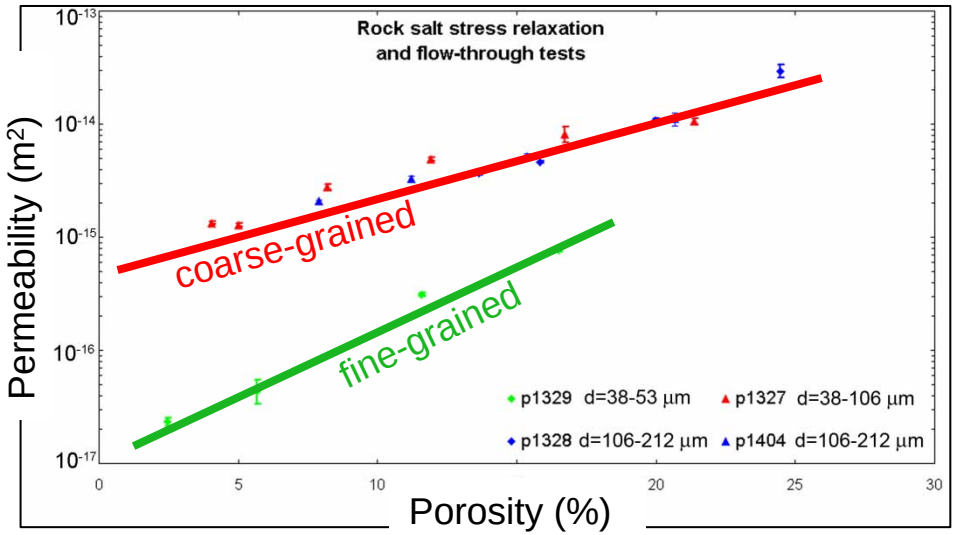
Consequences for Pore Fluid Chemistry

Salt as an Analog for Chemical-Mechanical Effects





Mechanical-chemical interactions occur at laboratory temperatures and timescales



Leading to permeability loss as a function of porosity & grain size

Current Research Areas

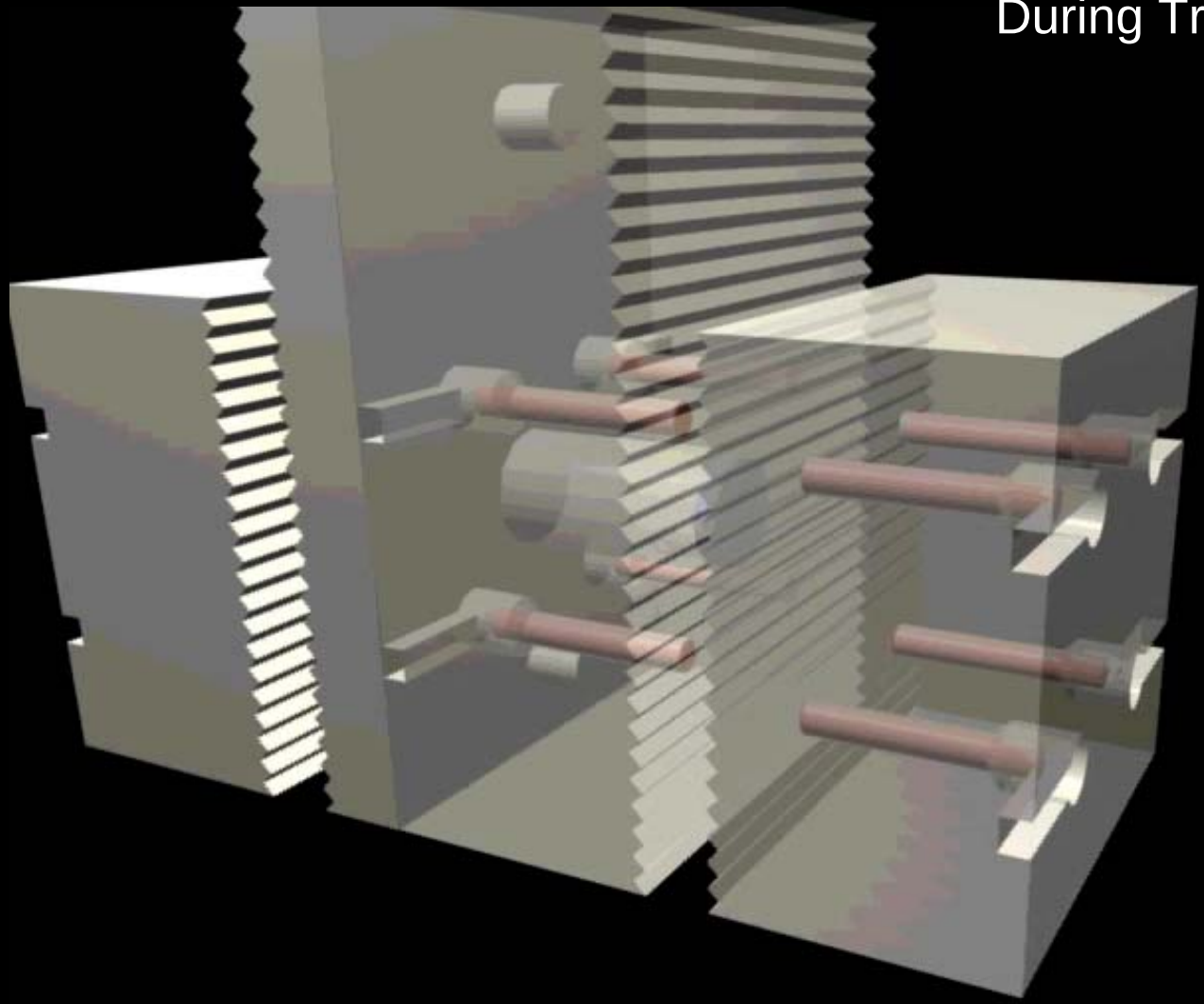
- Mechanical & transport properties of geomaterials
- Permeability measurements normal and parallel to shear
- Drained and undrained poromechanics
- Frictional properties, fracture strength
- Effect of dynamic stressing on permeability, strength, and constitutive properties
- Rock, fault gouge, clay, granular materials, mudrocks
- Reactive transport, Physicochemical deformation mechanisms
- Acoustic Emissions and Elastic properties

Applications

- Fault Seal as a function of shear
- Permeability evolution with strain and deformation, response to reservoir deformation
- Compaction, shear, overpressure, dilatancy strengthening
- The role of fabric development and shear localization in fluid compartmentalization and reservoir overpressure
- Poroelastic properties and effective stress
- Acoustic signature of strain localization
- Elastic properties and poroelastic anisotropy

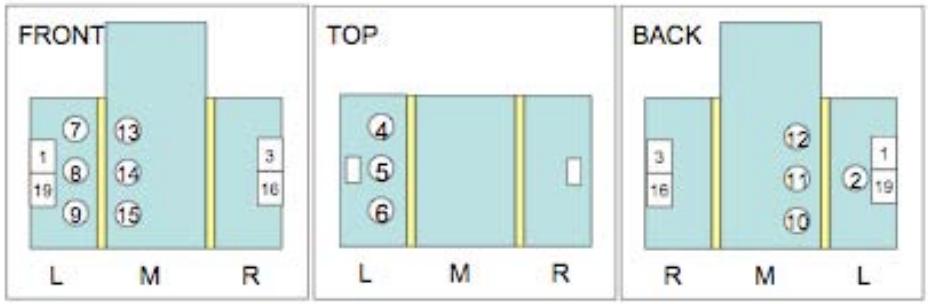
Elastic Parameters, Vp, Vs, Acoustic Emissions

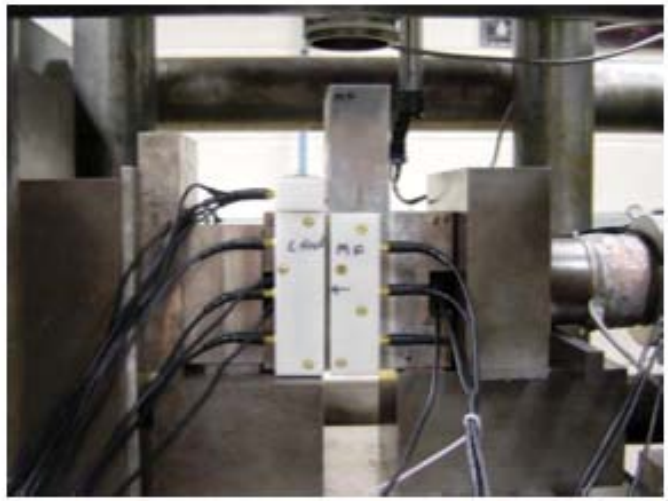
During True-Triaxial Shear

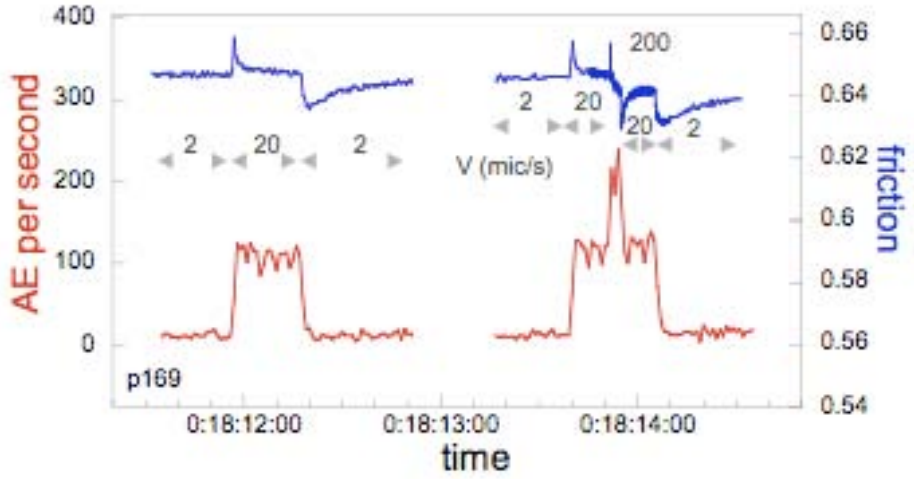


Acoustic Emissions during biaxial shear experiment

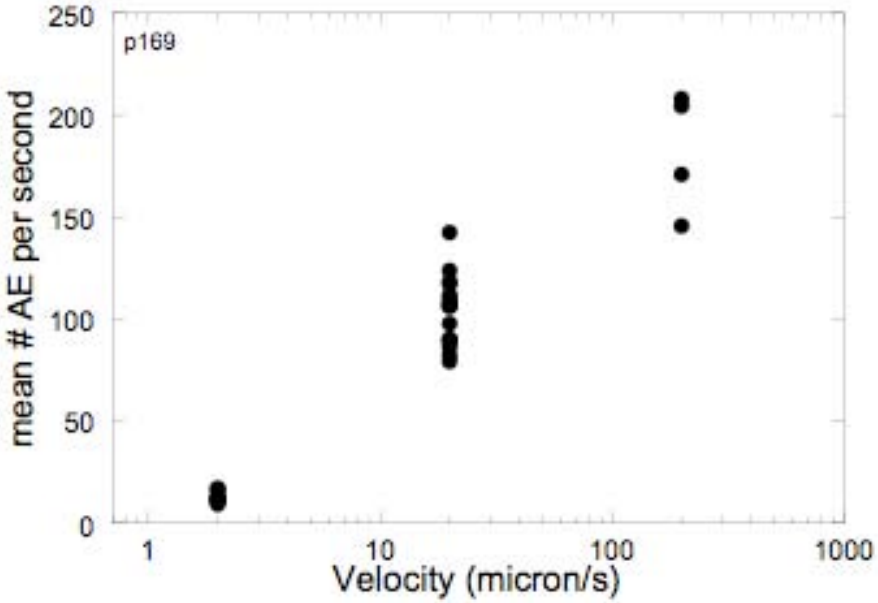
Mair, Marone & Young, BSSA, 2007

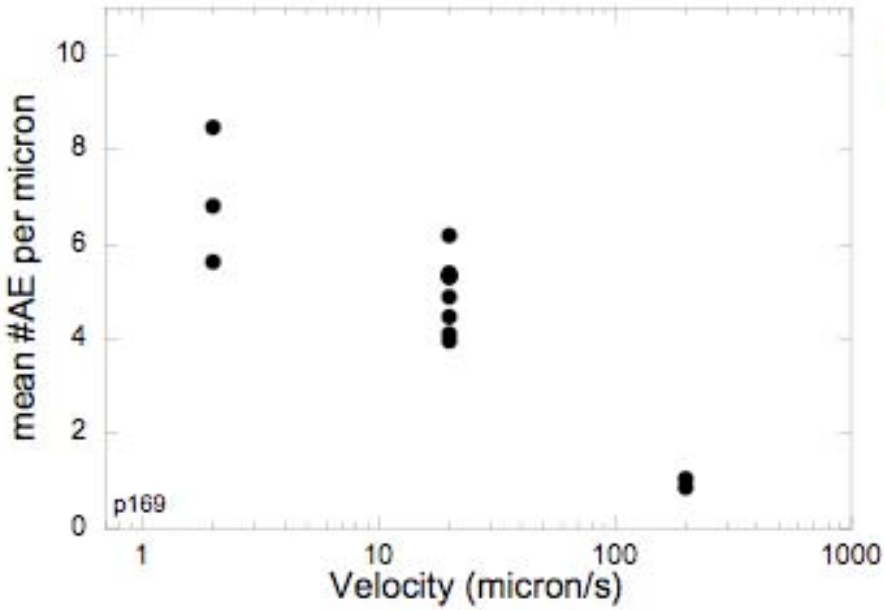






AE during biaxial shear experiment





Mair, Marone & Young, BSSA, 2007