Geochemical and Geomechanical Alteration by Acidic Brine of Fractured Sandstone under Strain

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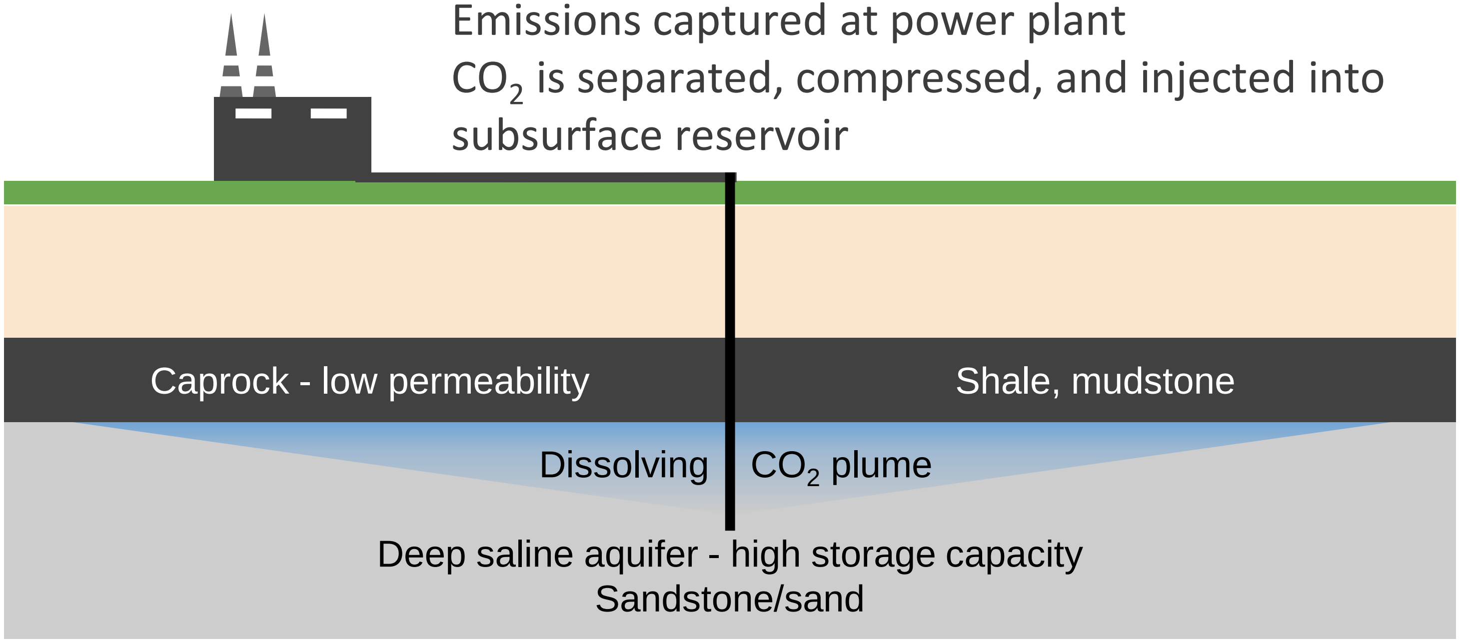
Geologic Carbon Sequestration

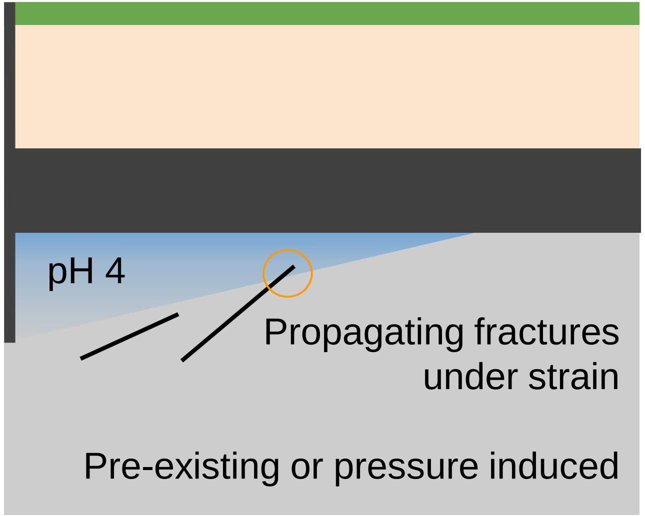
Method of reducing carbon emissions to mitigate climate change

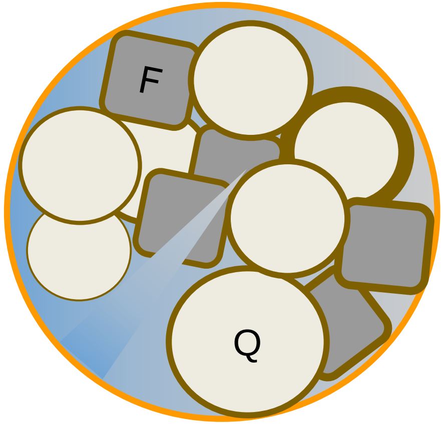
Emissions captured at power plant

CO_2 is separated, compressed, and injected into subsurface reservoir



Geochemical + Geomechanical Concerns





Acidic Reactions: Carbonates, clays, Feldspars weathering

Dissolution + fractures form preferential flow paths, weakening

Continued fracture propagation? Induced seismicity?

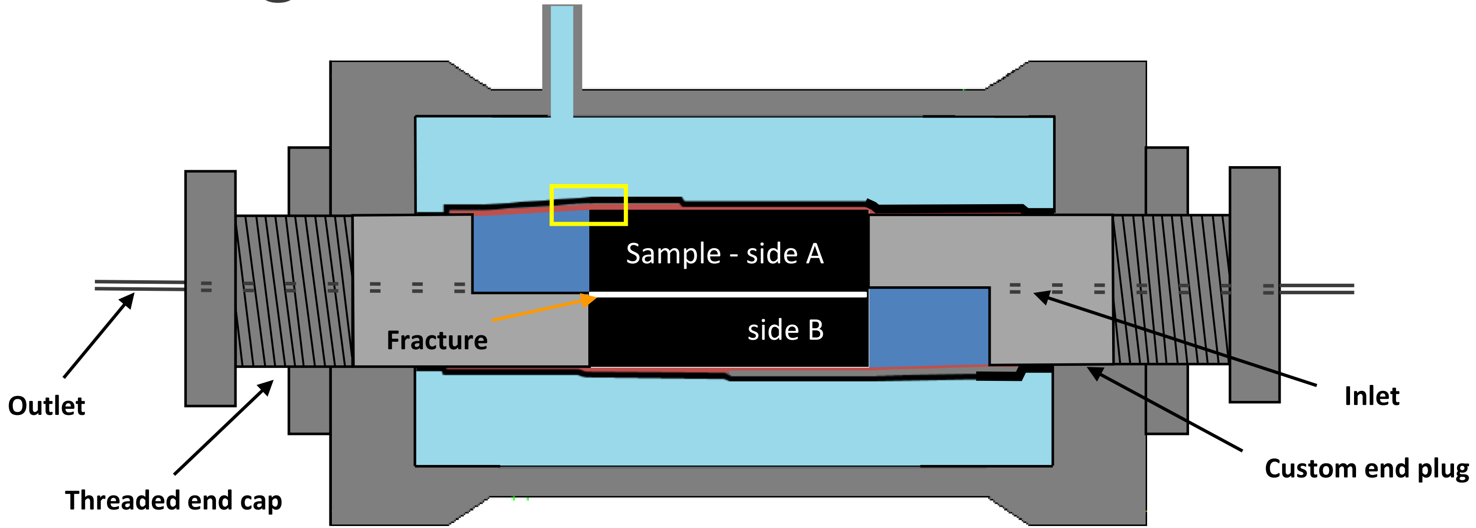
Goal: Evaluate acidic brine flow through a fractured sandstone under strain

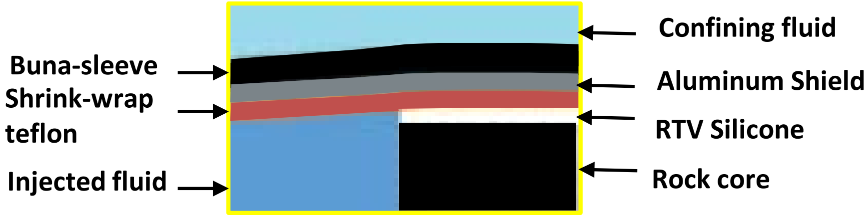
Experimental Plan

- Evaluate effects of low pH brine on strain reduction in Bandera Gray Sandstone using a shearing, pressurized, flow core holder housed in an industrial CT scanner
  - 2000 psi confining, 100 psi pore pressure, flow 0.05 mL/min for **7 days**

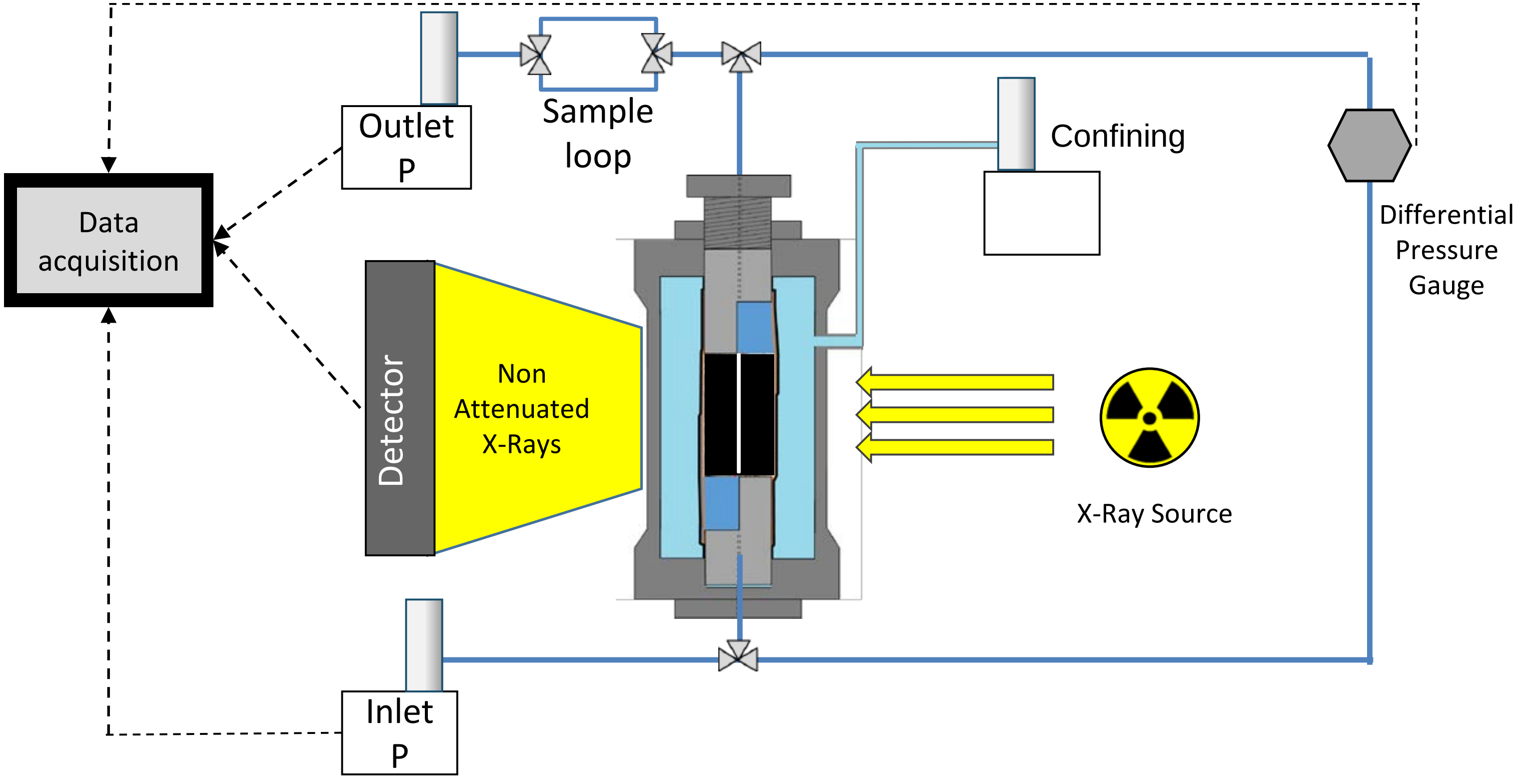
Samples	**0.5 M KI Brine**	**Geochemical Analysis**			**Geomechanical Analysis**	
BG1, BG3	pH 4 (HNO_3)	*SEM/EDS*	*XRD*	*Effluent, ICP-OES*	*CT Scan (modeling)*	*Fracture Toughness*
BG2, BG4	pH 8.3 (1 week equil.)					

Shearing Core Holder



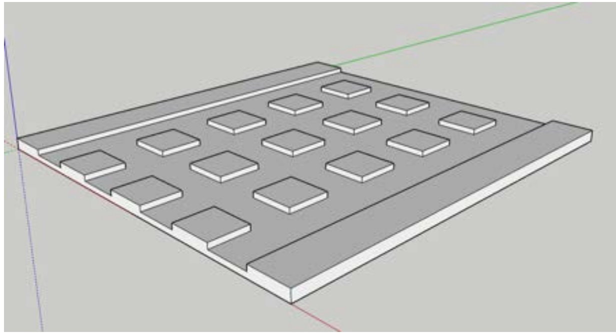


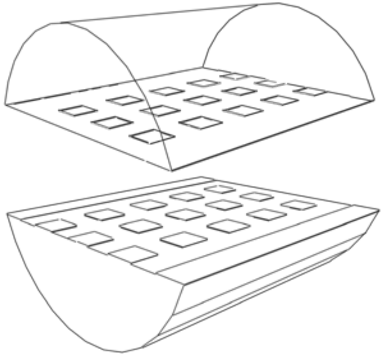
CT Scanner Set-up



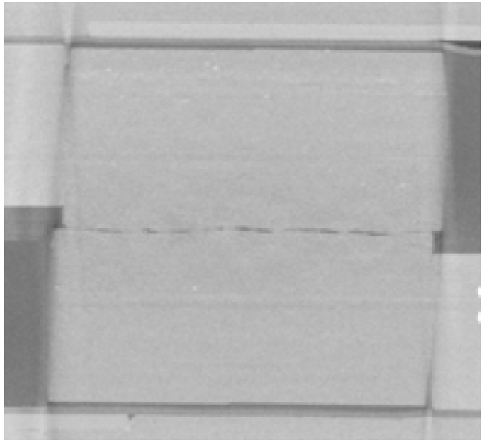
Milled Surface - Artificial Fracture

Milling Pattern





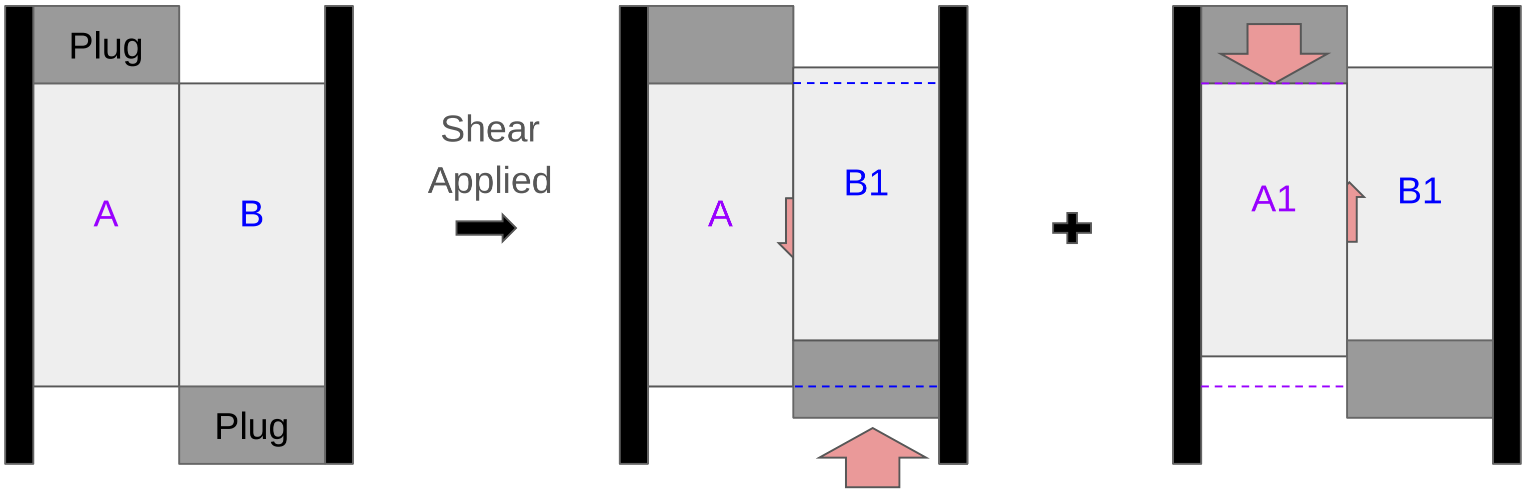
Natural Fracture



- Pattern provides manufactured asperities to interlock
- Proxy for contact points in a natural fracture
- Artificial fracture 0.1 mm deep

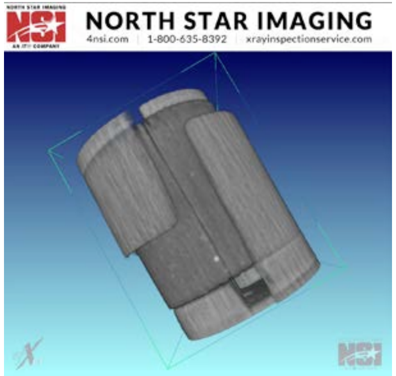
Displacement, Shear, and Strain

Strain is a change in length compared to the original length: $\boldsymbol{\varepsilon = (L-L1) / L = \Delta L/L}$



CT Scan Data Workflow

Reconstructed CT Scan
NorthStar Software
16 bit, raw data - 38 GB



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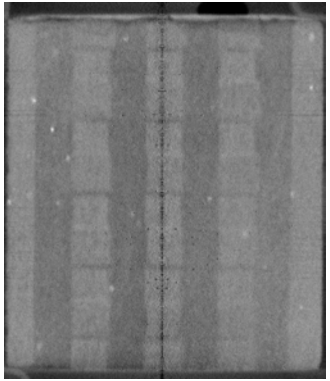
Cropped, color
normalized in ImageJ
8 bit, 14 GB



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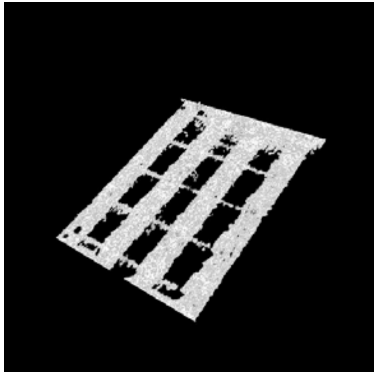
Segmentation by iLastik,
filters and user training, 8
bit, 0.8 Gb



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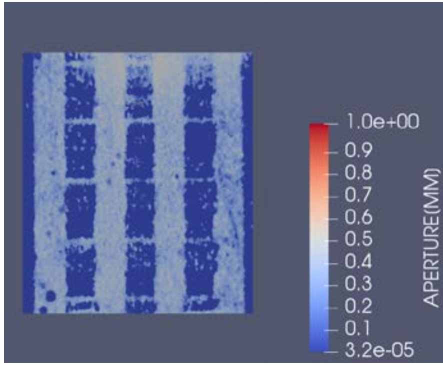
Aperture Map and Flow
by 2D NS Model, python,
8 bit, 0.1-0.4 Gb

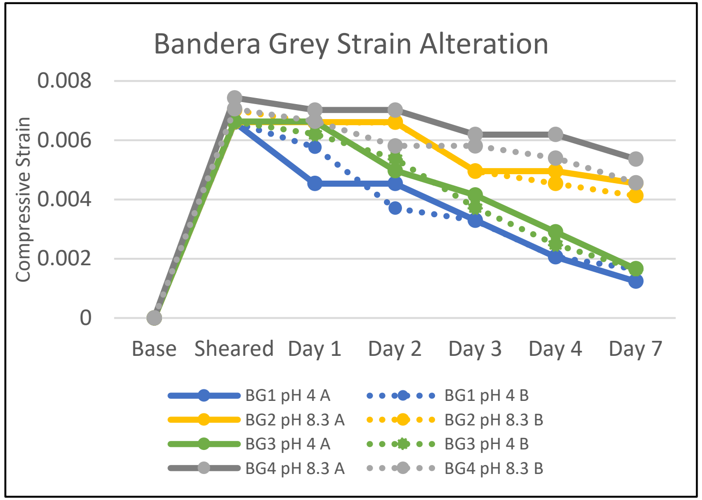


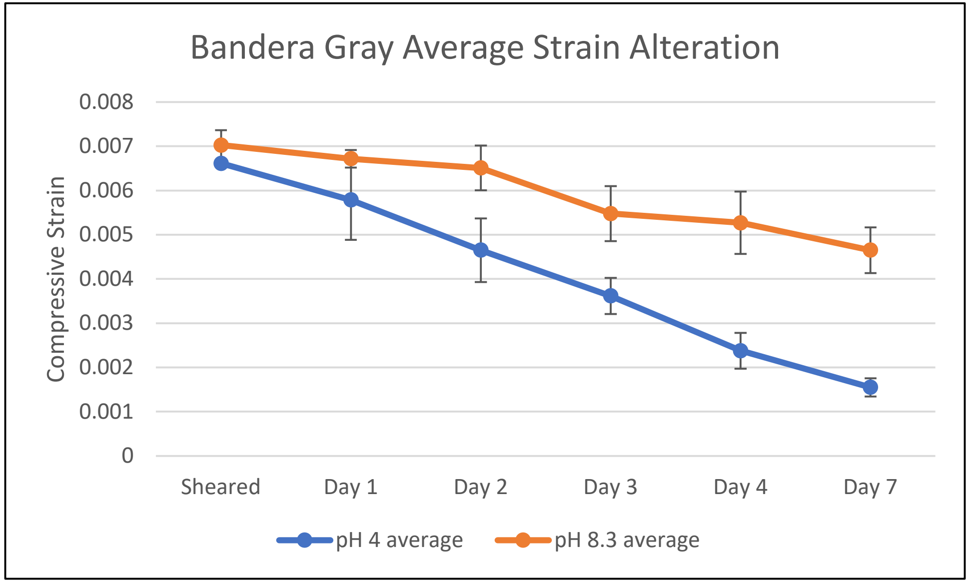
Results:

Strain Release

Petrophysical
parameters,
flow paths

Strain release

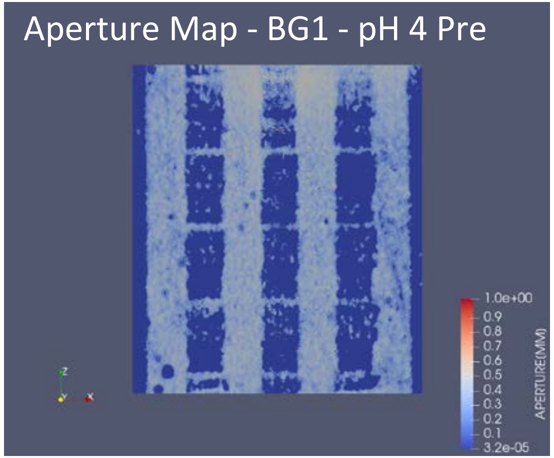


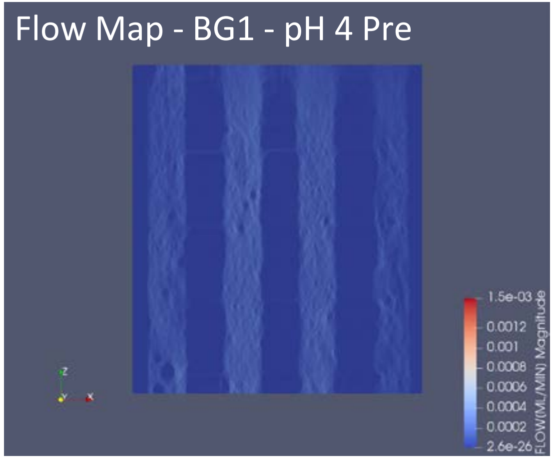


- Replicates at each condition - BG1 and BG3 acidic, BG2 and BG4 reservoir neutral
- Acidic brine experiment results in faster strain reduction
- Gradual strain release in equilibrium conditions likely due to strain relaxation

Results - Flow Modeling

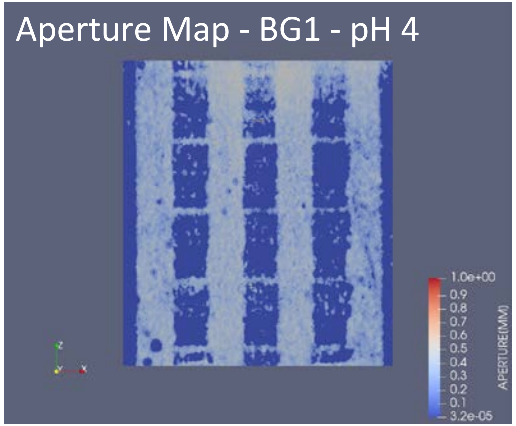
- **netl-ap-map-flow** is a modeling suite programmed in python and fortran designed by former NETL employee for fracture flow modeling
- Model performs Local Cubic Law (LCL - solves Navier Stokes) simulation of **single phase flow through a discrete fracture**
- 3D data is transformed into an aperture map, flow is simulated, and data produced

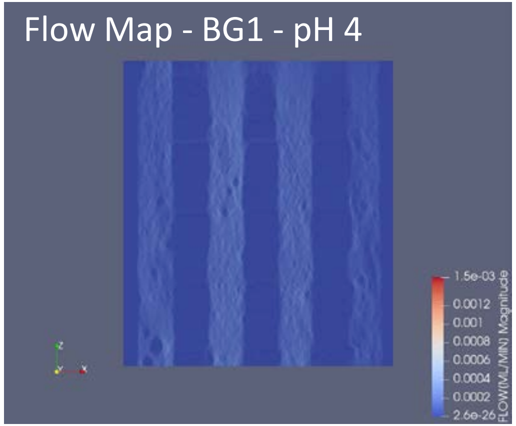


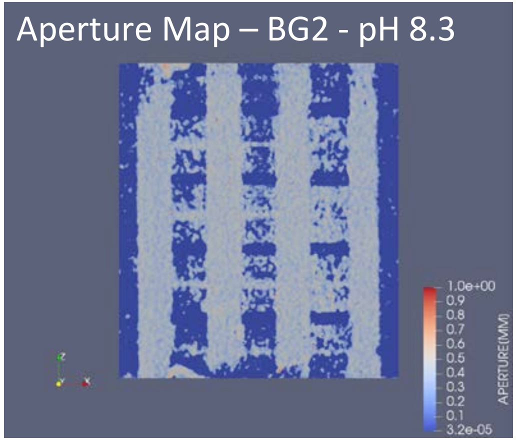


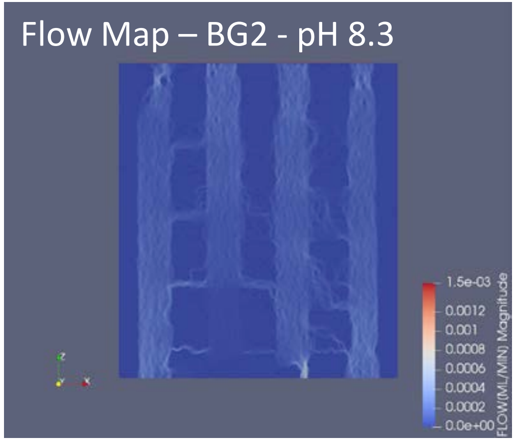
Flow Modeling

- Comparing acidic flow to reservoir neutral flow
- pH 8.3 case flow decreases significantly, has to be cropped to view flow paths
- Fracture ‘closed’ – flow reverts to standard permeability for sandstone

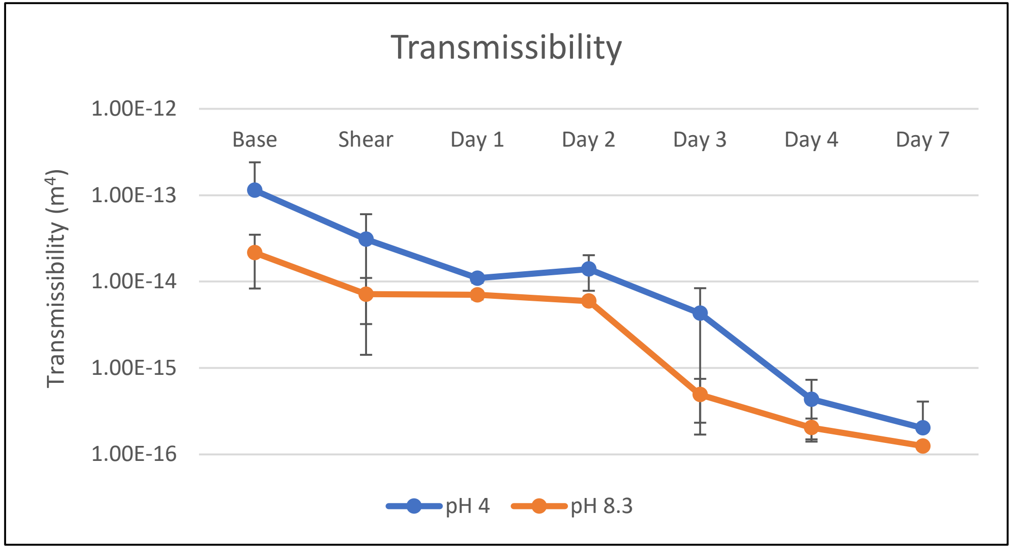








Results - Flow Modeling



- Transmissibility - permeability*area
- Channels progressively close due to compression and plasticity
- Slightly higher transmissivity in acidic cases due to limited dissolution

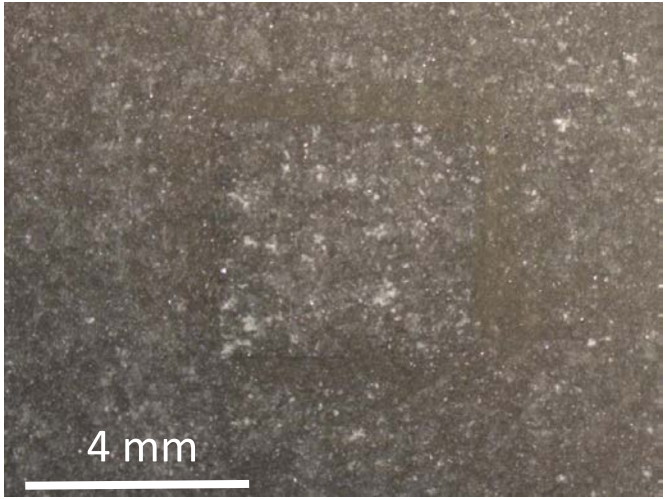
Results – Visual Alteration

Aged BG3 - pH 4

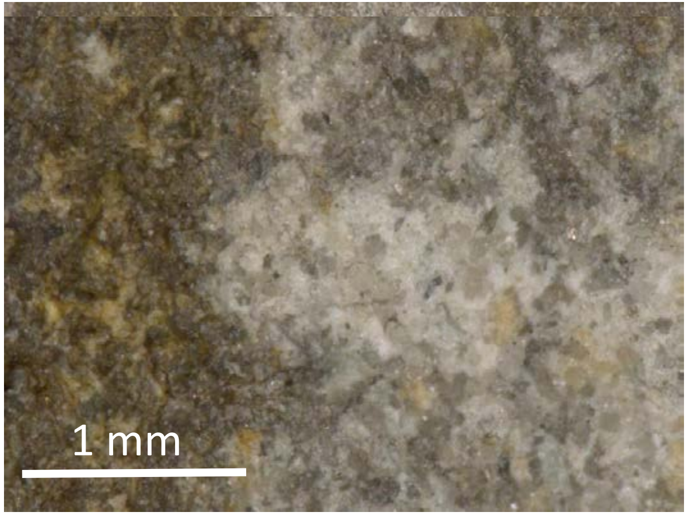
Results – Visual Alteration

- Comparison between initial and aged sandstone
- Alteration at contact points of asperities

Initial BG1



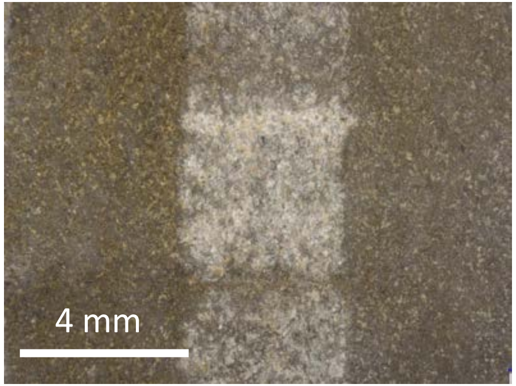
Aged BG1 - pH 4



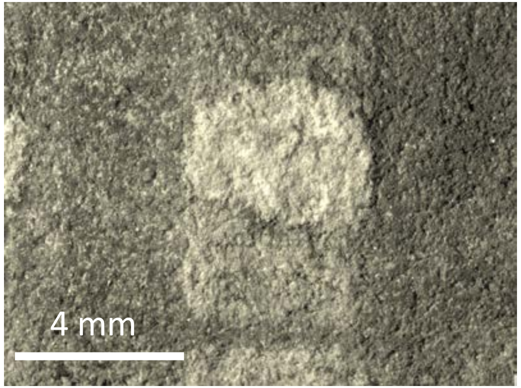
Visual

- Build up of material at contact points, fault gouge
- Greatest in pH 8.3 cases

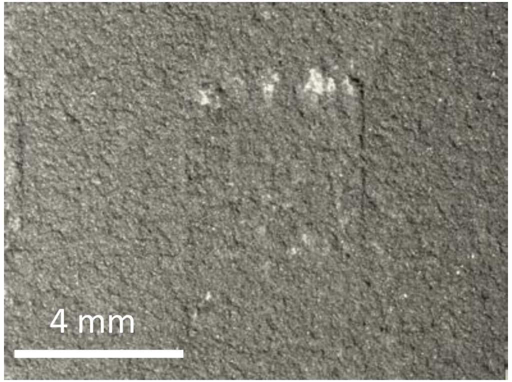
Aged BG1 - pH 4



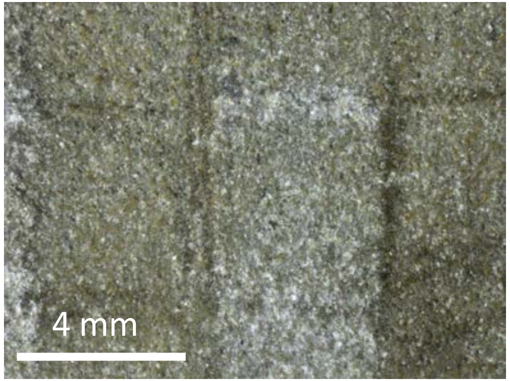
Aged BG2 - pH 8.3



Aged BG3 - pH 4



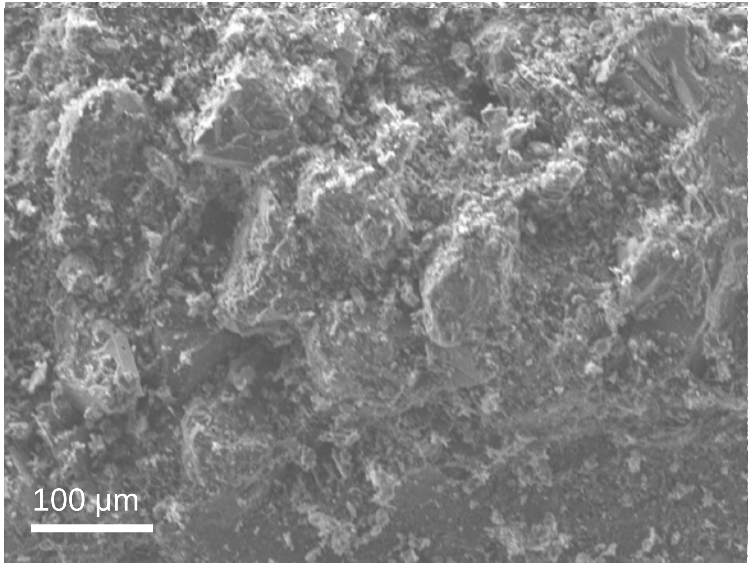
Aged BG4 - pH 8.3



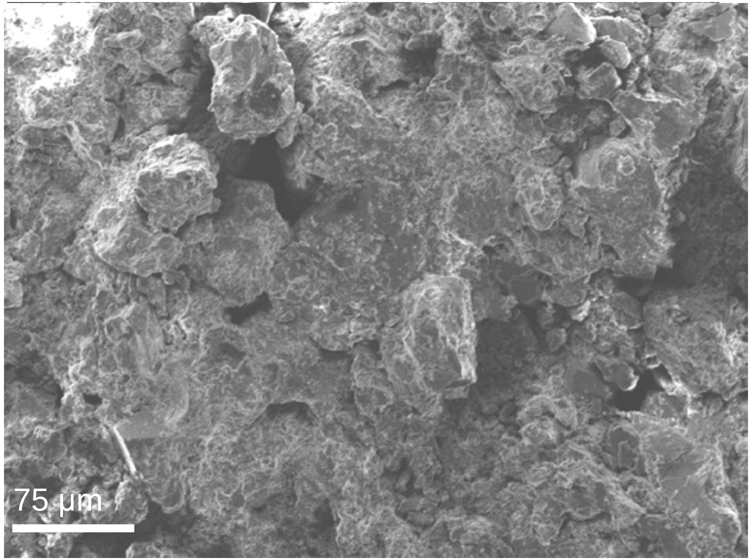
Results - SEM

- Physical displacement of material with shearing
- Alteration of cementing material

Initial BG1



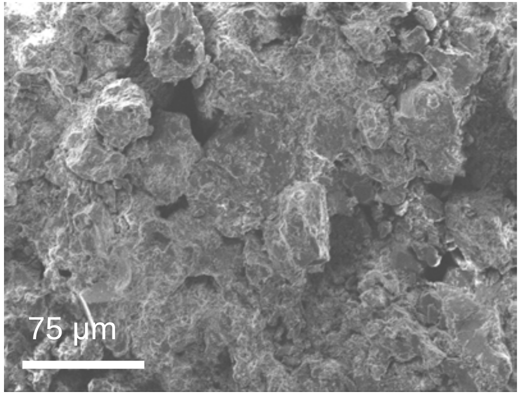
Aged BG1 - pH 4



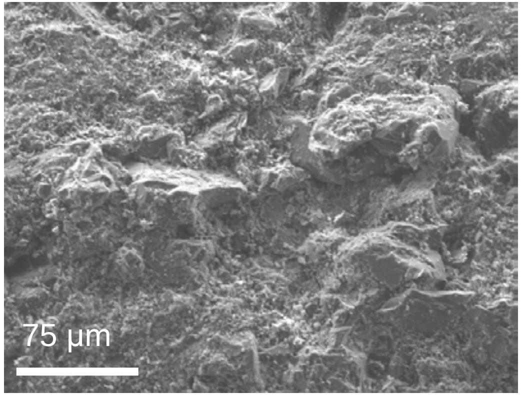
SEM

- Alteration of cementing material in acidic conditions
- Increased space between grains

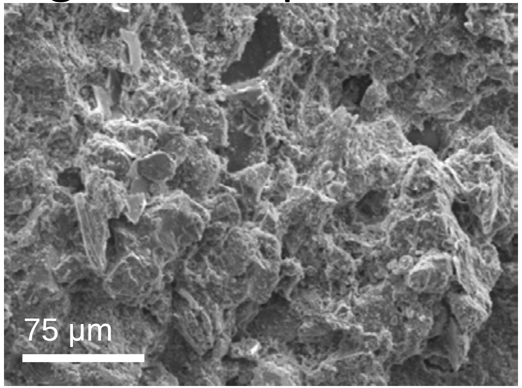
Aged BG1 - pH 4



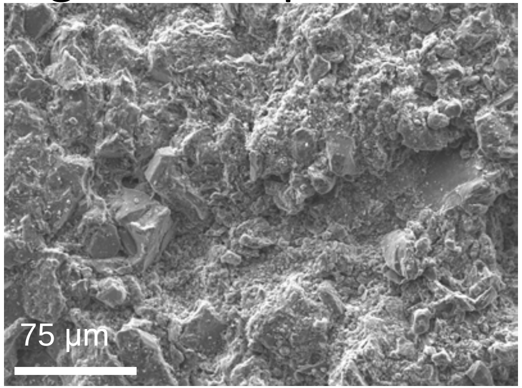
Aged BG2 - pH 8.3



Aged BG3 - pH 4



Aged BG4 - pH 8.3



Conclusions

- Sandstone exhibited **faster reduction in strain** at pH 4 compared to pH 8.3, suggesting structural weakening
  - Reduction is gradual, not at one slip
- Transmissibility decrease was less at pH 4 than pH 8.3, indicating mineral dissolution maintains flow paths
- Limited dissolution of cementing material in acidic cases
  - Fault gouge build up at points of contact at greater extent in pH 8.3 cases, suggesting acidic dissolution of sheared material

Thank You!

U.S. DEPARTMENT OF ENERGY

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