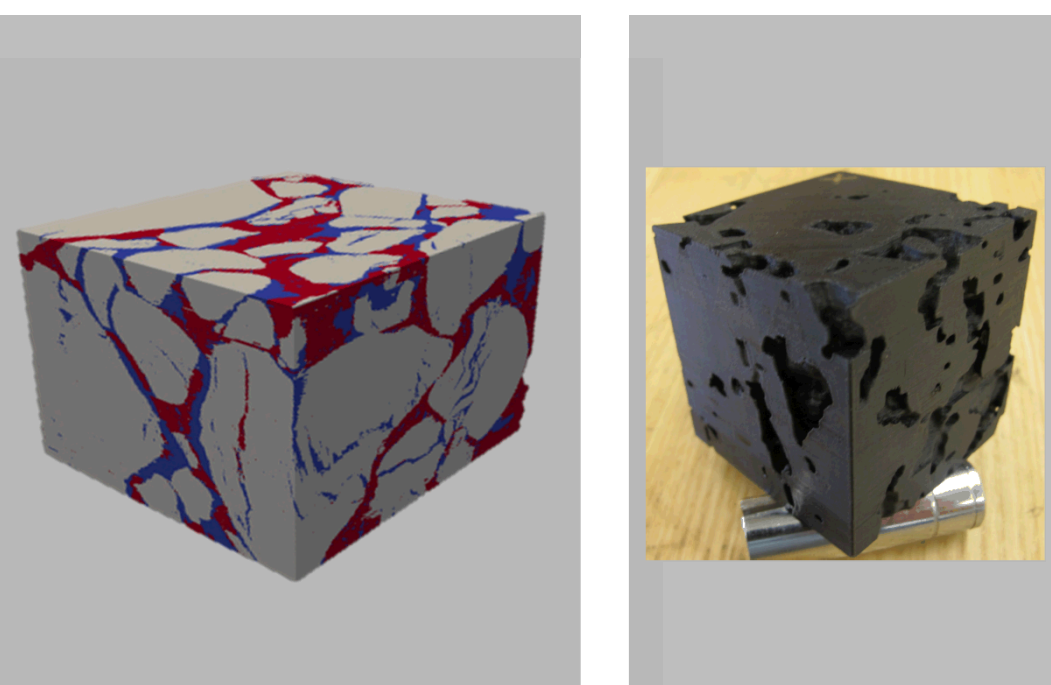
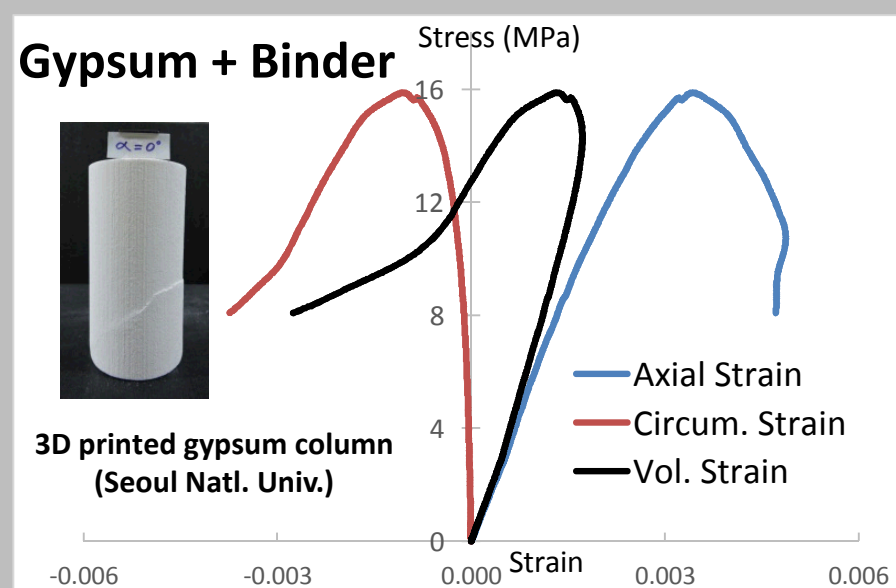


Digital Rock Physics for Experiments and Modeling of Fractured Porous Media

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3D printed core behaves like a weak sandstone



Exceptional service in the national interest

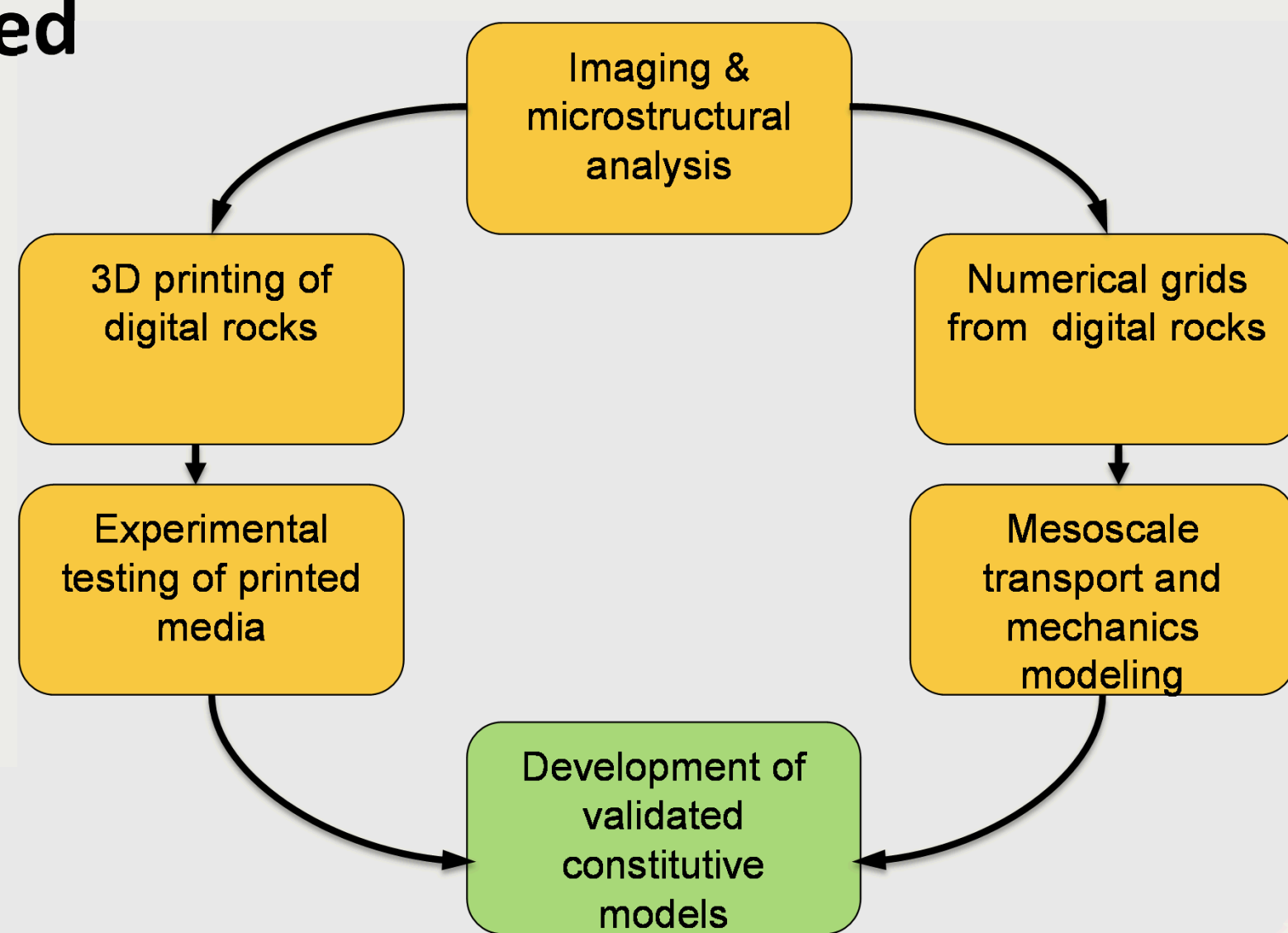
Prospectus

Digital rock schema could be improved with 3D printing

3D printing enables us to:

- surmount problems with sample-to-sample heterogeneity
- test material response independent from pore-structure variability
- develop functional porous structures
- print porous specimen with integrated test frame
- addresses issues of scale-up

Reproducible synthetic media that mimic natural media, potentially enabling a limitless set of experiments benefiting all manner of scientific research

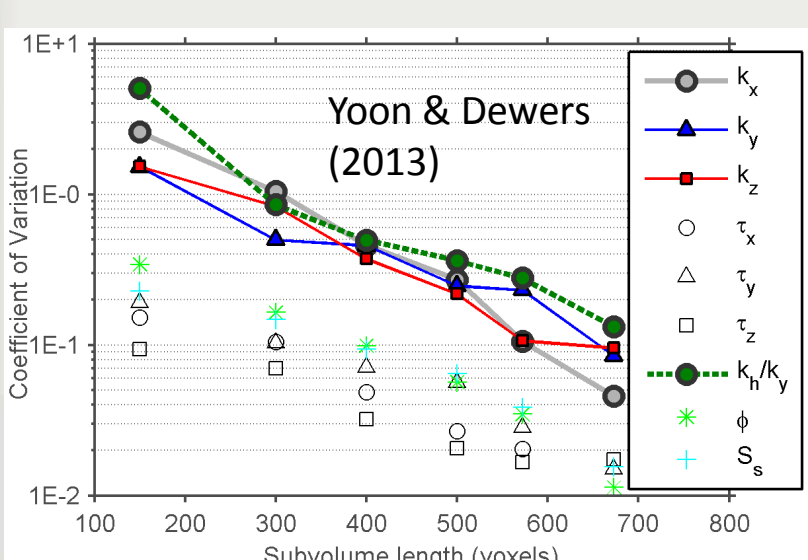
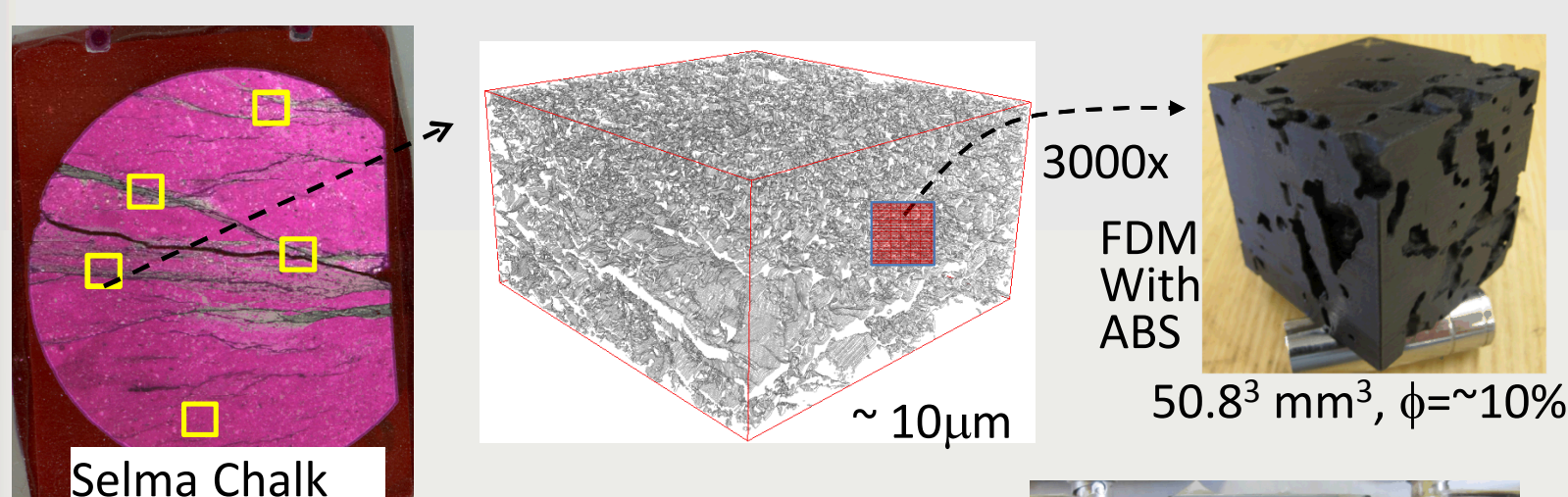


Science Challenges

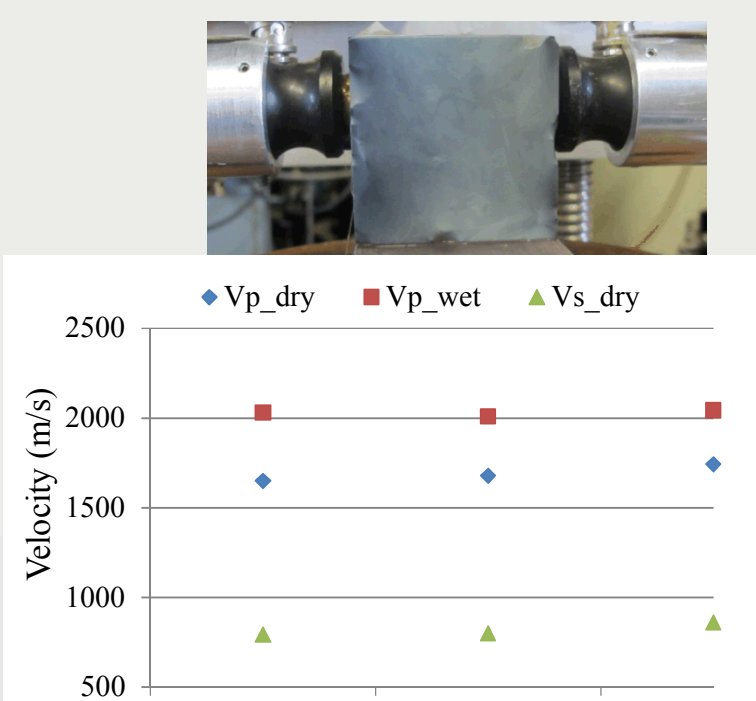
Areas of impact to frontiers of science:

- Ability to relate microstructure to bulk measurable properties and performance
- Understanding how to control flow in fractured media
- Understanding how to manipulate fracture morphology for flow path control
- Testing scale-up of digital rock properties
- Develop the methodology for experimental utilization of additively manufactured copies of real rock, a **potentially disruptive technology for geosciences**

Digital Rock Physics with 3D printing



Statistical analysis of petrophysical properties of FIB-SEM sample volume

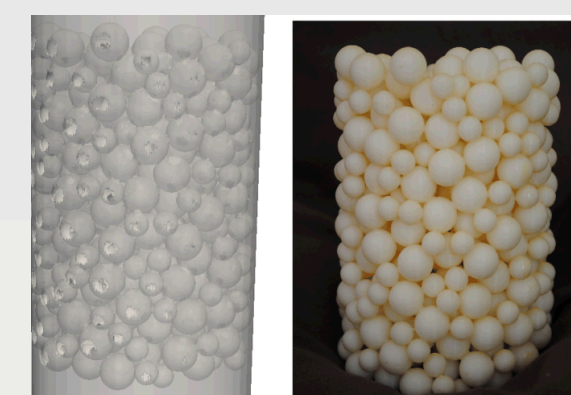


Acoustic Emission (AE) testing

3D Printing of digital rocks

Why 3D printing?

- Ability to design and realize complex geometries
- Engineered material control at new regimes
- Feature-based pore structure for proof of concept testing
- Porous structure features for this project:
 - Real pore structure on specimens ~2 cm³
 - ~100 micron pores, 100+ micron single fractures
 - Fracture network with single and multiple joints



Digital bead packing (left) and 3D printed packing (right) (Baker et al., 2014)



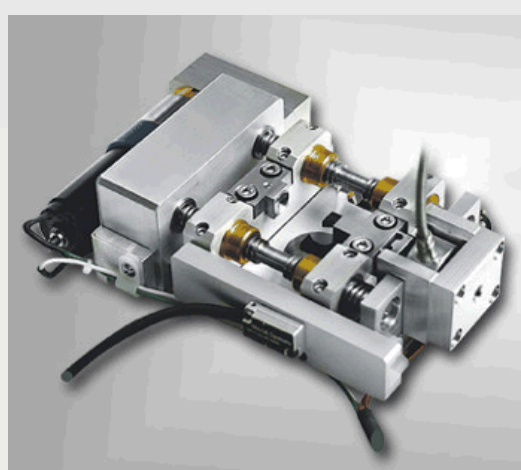
3D printed single fracture network (top) and fracture aperture (bottom)

Extensive SNL additive manufacturing capabilities and emerging 3D printing techniques with various materials will be leveraged for Geo application

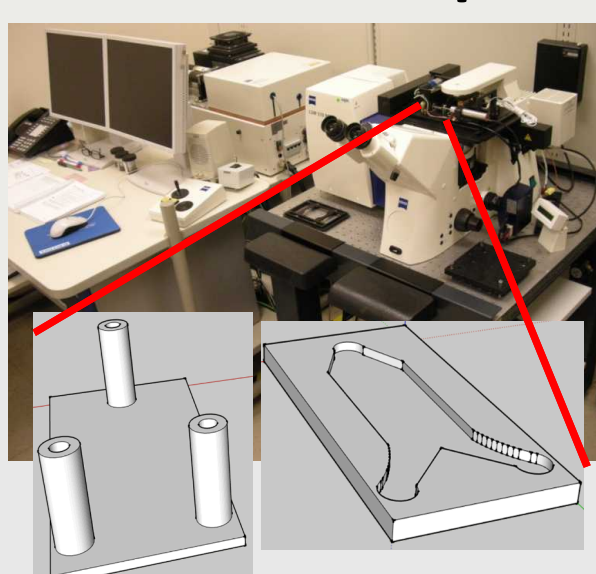
Experimental Facilities

- Fullam 1-ton compression/tension load frame (image in the left)
- Core Labs coreholder with sonic velocity, acoustic and X-ray CT imaging capability (15,000 psi and 150°C)
- Associated pressure systems for petrophysics measurements (permeability, capillary pressure, etc.)
- Conventional loading frame for tri-axial and uni-axial testing

Geomechanics



LSC Microscope

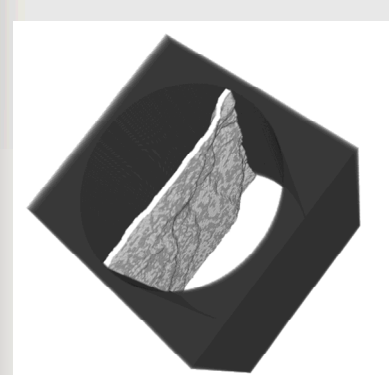


3D design of microfluidics

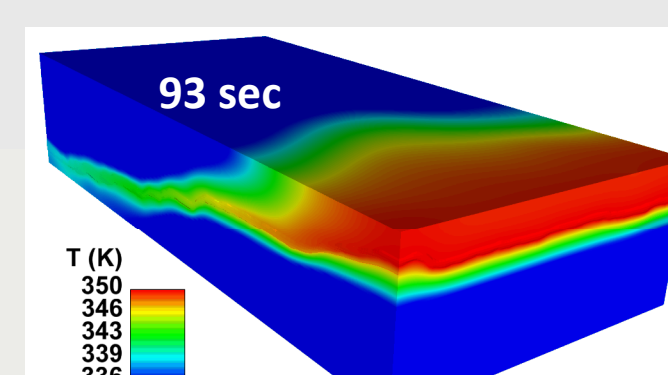
- Zeiss laser scanning confocal microscope
- Microscope stage for real time imaging
- Tension and compression, loads to 1 ton
- Digital image correlation for strain
- Microfluidic cells for multiphase flow and reactive transport
- Photoelastic stress analysis

Modeling at the Mesoscale

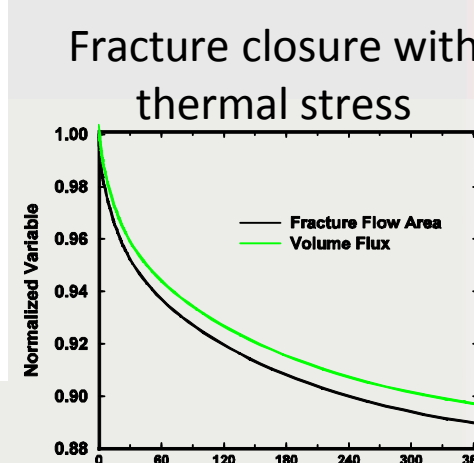
Hot water flush through fracture



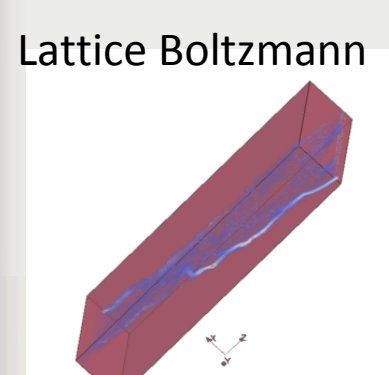
Segmented fracture network (Courtesy of Matt Ingraham)



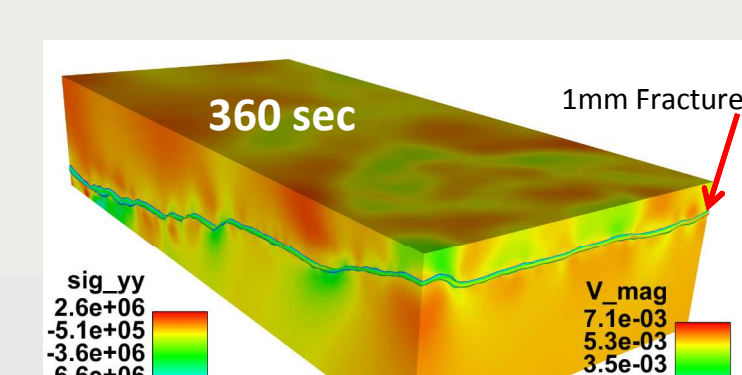
Thermal transport in fracture and diffusion into rock with hot water flush.



Fracture volume reduction with rock expansion, and flow rate reduction under fixed pressure gradient.



Flow of "frac" fluid in proppant-containing fracture



Thermal expansion stress under confinement.

Impact

- Science-based approach to develop advanced constitutive models and materials
- Testing and modeling of multiphysics processes on the same reproducible pore topologies
- Scale dependence & model validation

