Micromodels: Study of the Impact of Pore-Scale Heterogeneity

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Multiphase Flow at the Pore-Scale

Rock characteristics

$$\begin{cases} -Pore\ morphology \\ -Wettability \\ -Multiscale\ features \end{cases}$$

$\rightarrow$

Fluid flow behavior

$$\begin{cases} -Capillary\ Pressure \\ -Capillary\ Trapping/Residual\ Saturations \\ -Flow\ Patterns\ and\ Relative\ Permeability \end{cases}$$

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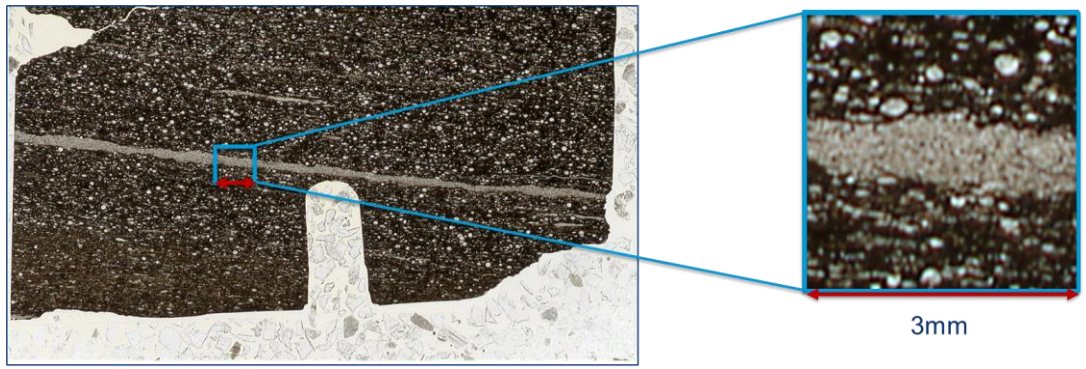
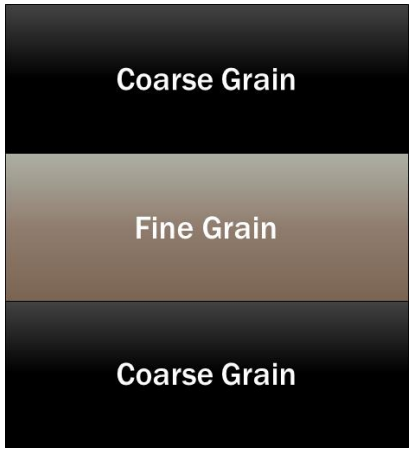
Stochastic Grain Size Contrast Models

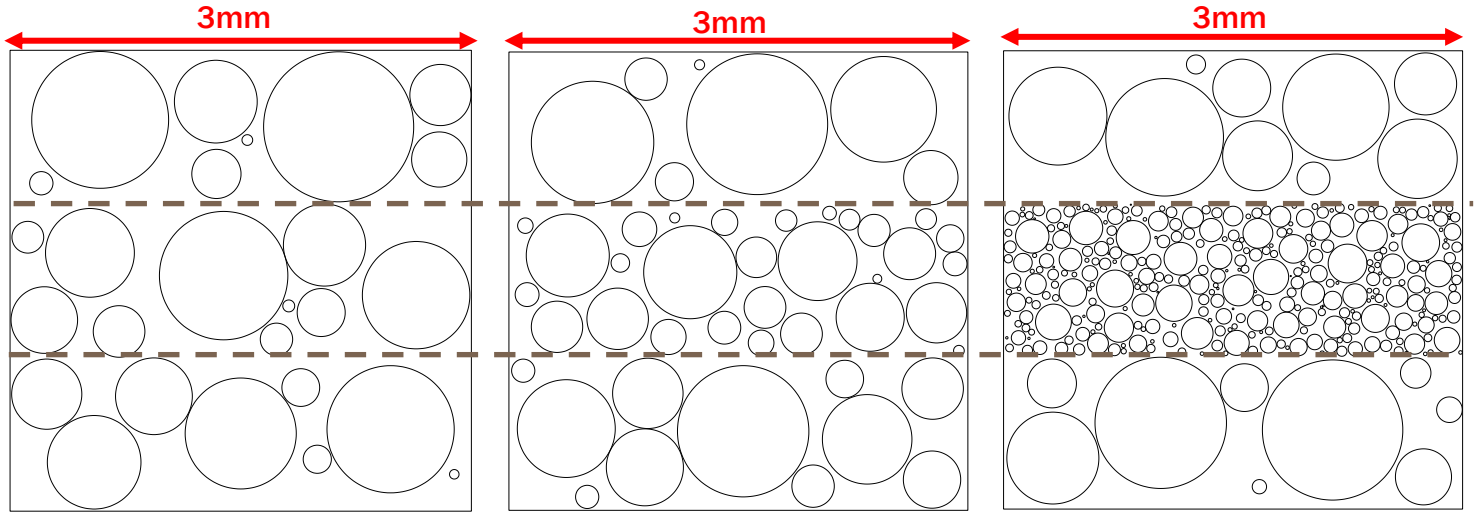


Thin section image courtesy of Evan Sivil, MSRL



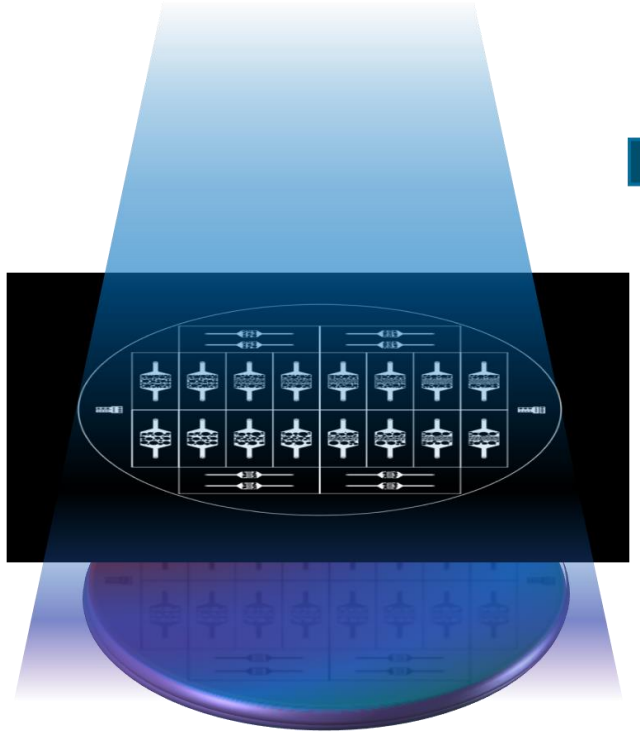
Layered zones configuration

	mu	sigma
Control	-0.87	0.78
Low Contrast	-1.6	0.78
High Contrast	-2.25	0.78



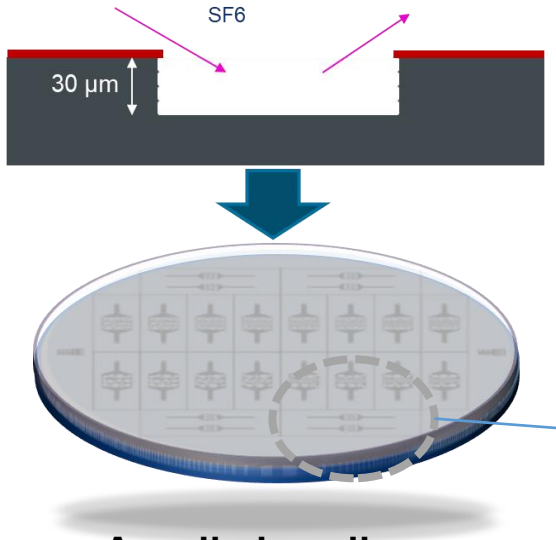
Control | Low Contrast | High Contrast

Microfluidic Fabrication

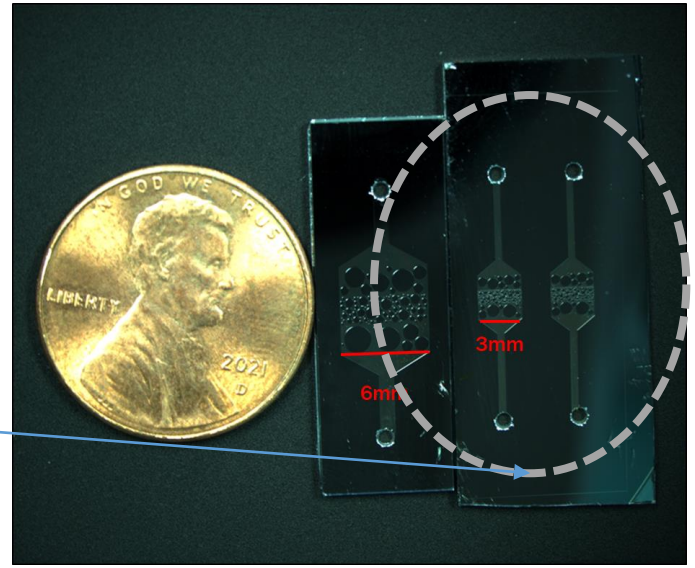


A Silicon substrate is coated and patterned with photolithography

Deep reactive ion etching

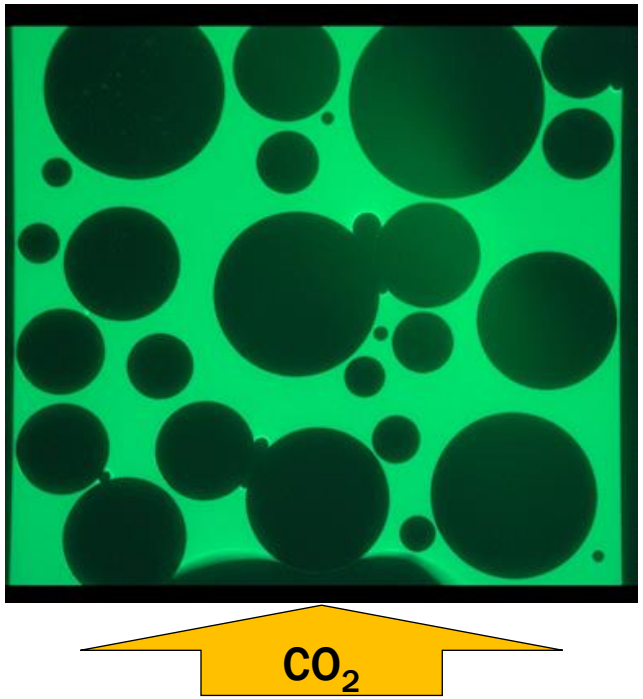


Anodic bonding

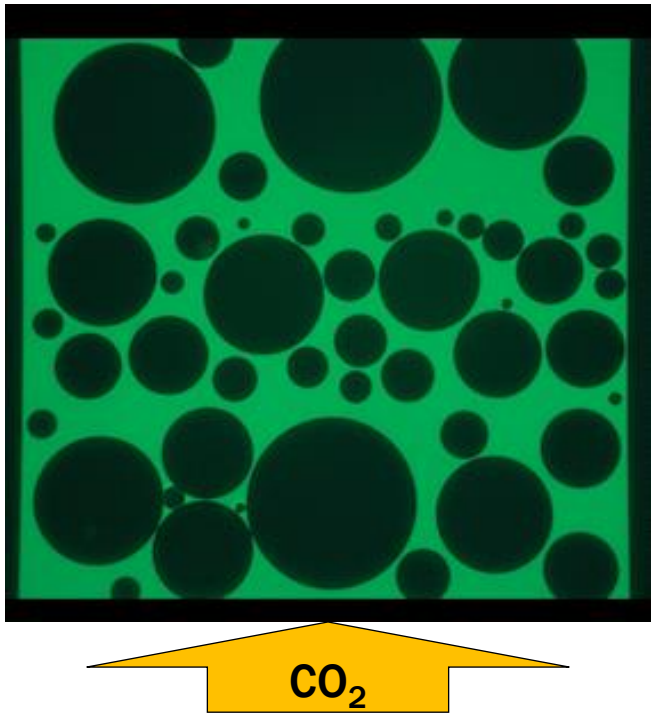


Grain size contrast models – Experimental Results

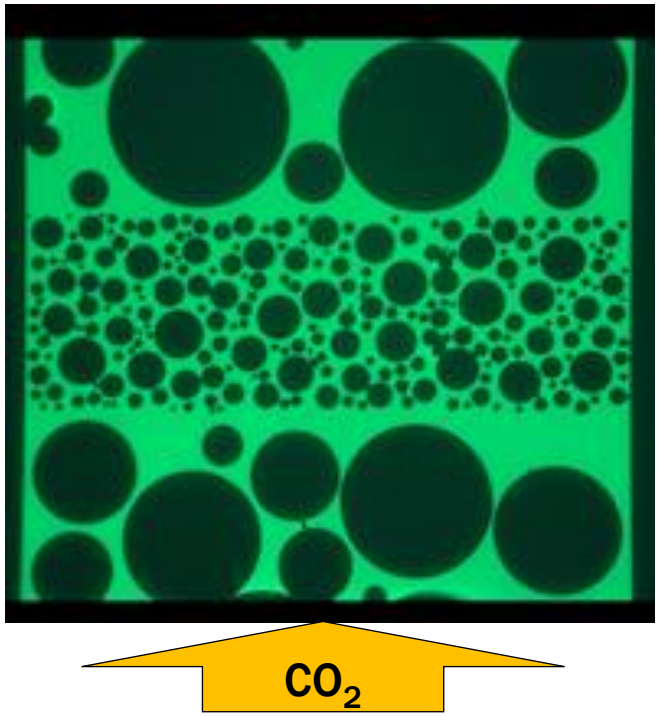
Control



Low Contrast



High Contrast



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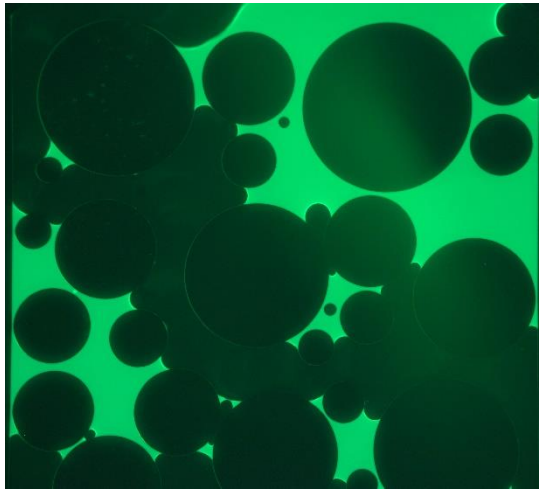
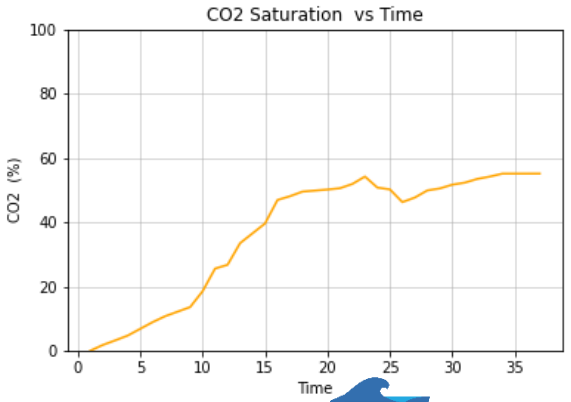
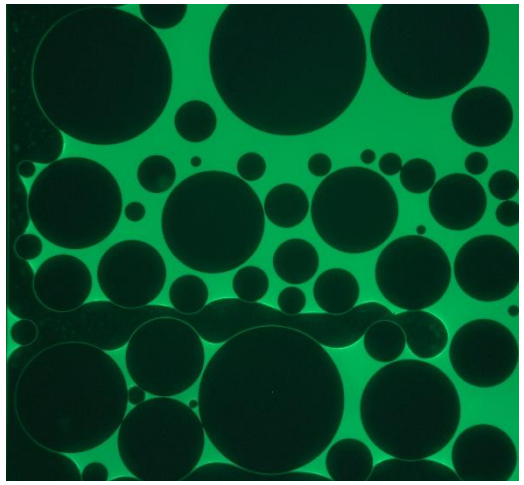
Grain size contrast models – Experimental Results

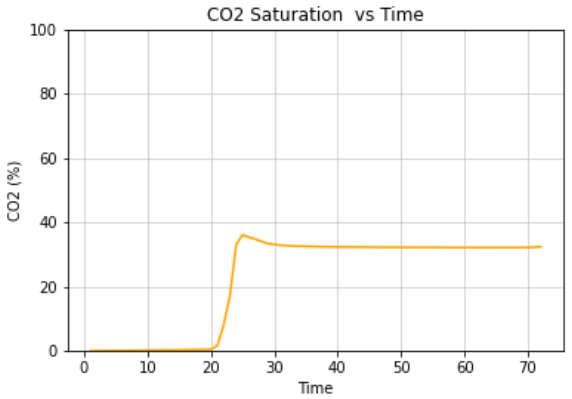
Control



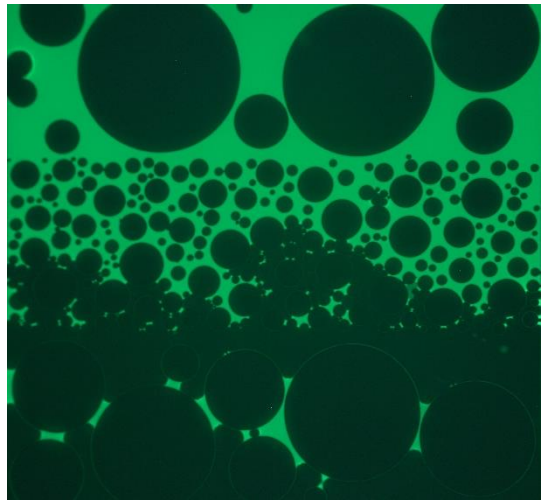


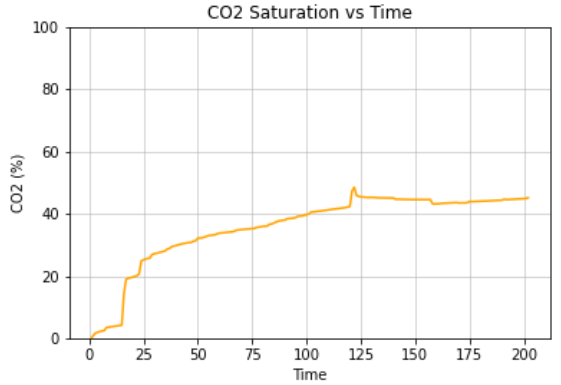
Low Contrast





High Contrast





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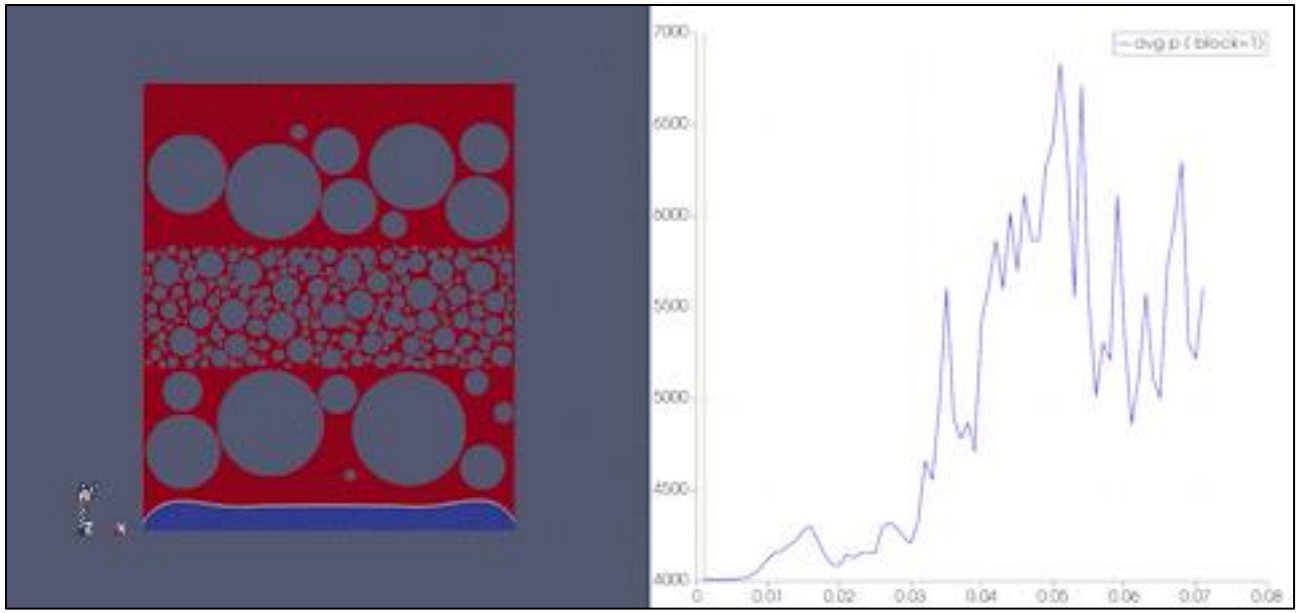
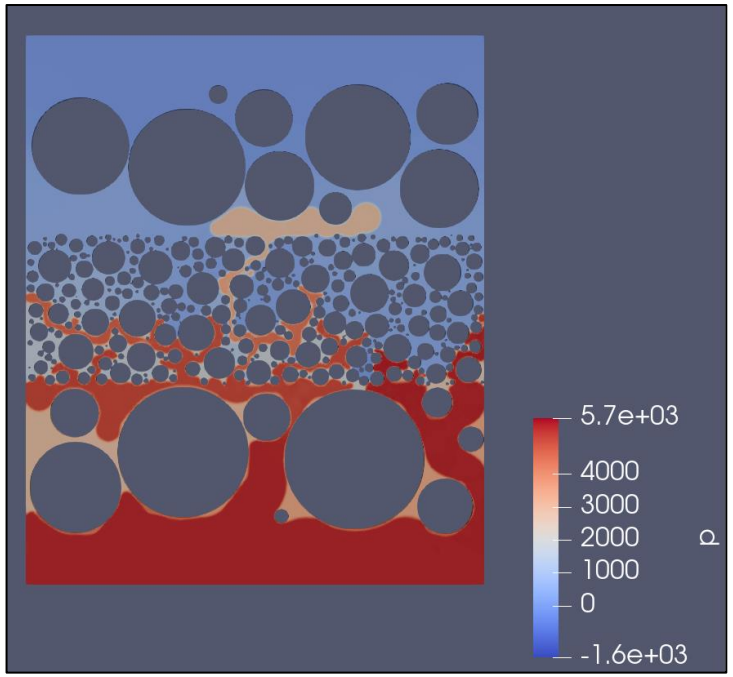
Analysis of Computational Fluid Dynamics (CFD) Simulation in OpenFOAM

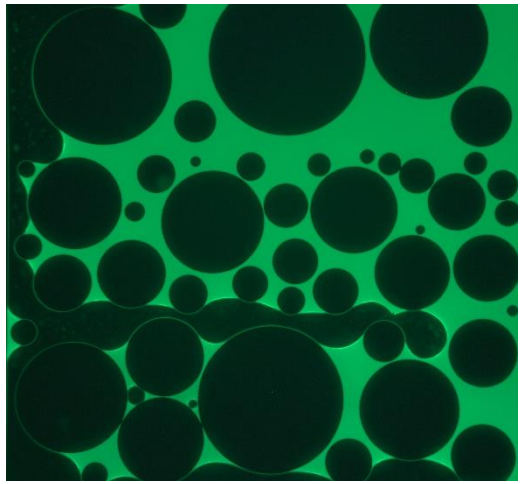


Dynamic capillary pressure in CO_2 phase showing local maximum when crossing pore throats

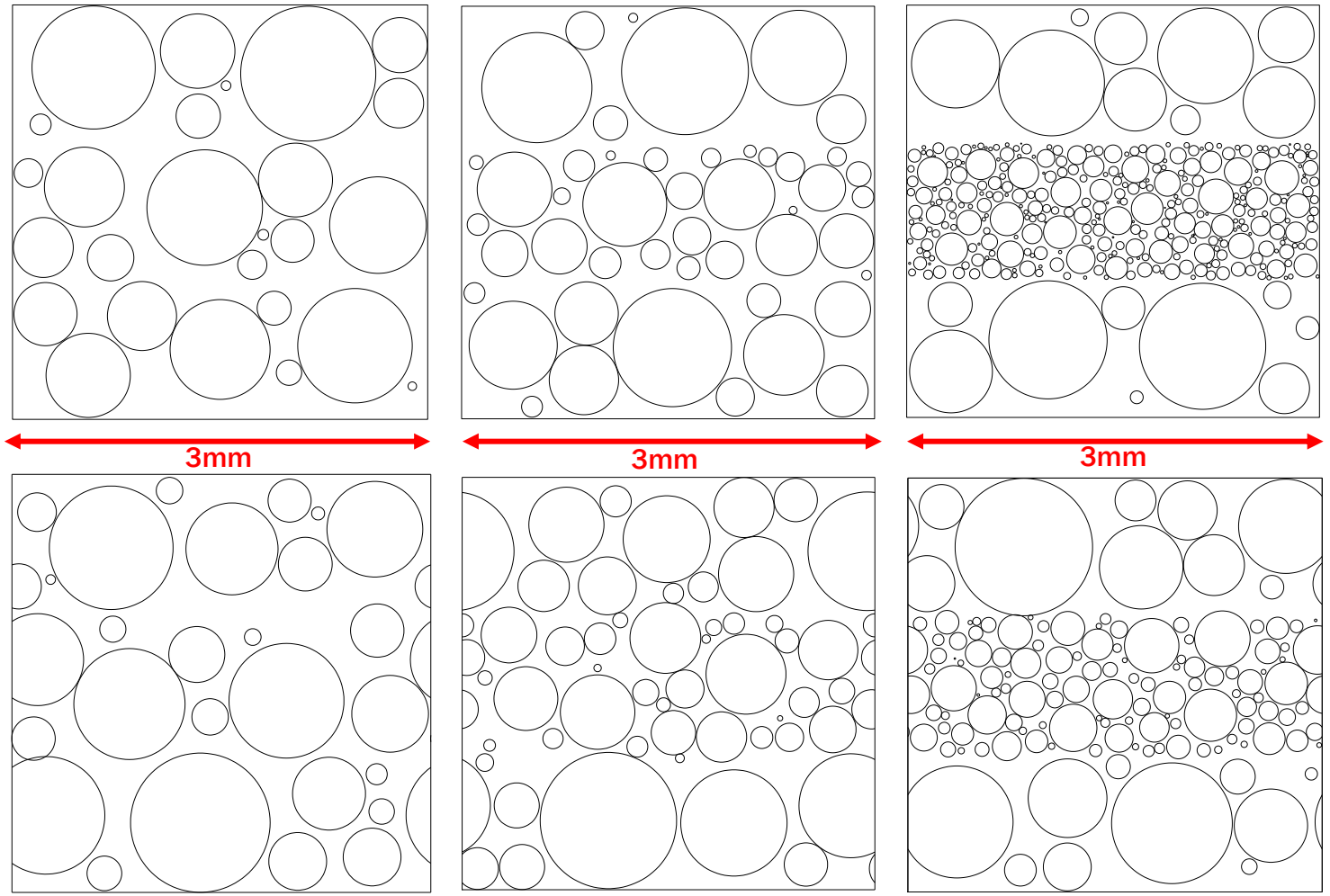


Pressure dissipation/gradient within CO_2 phase

Improving Circle Packings



- Reduce boundary effects using a periodic boundary condition



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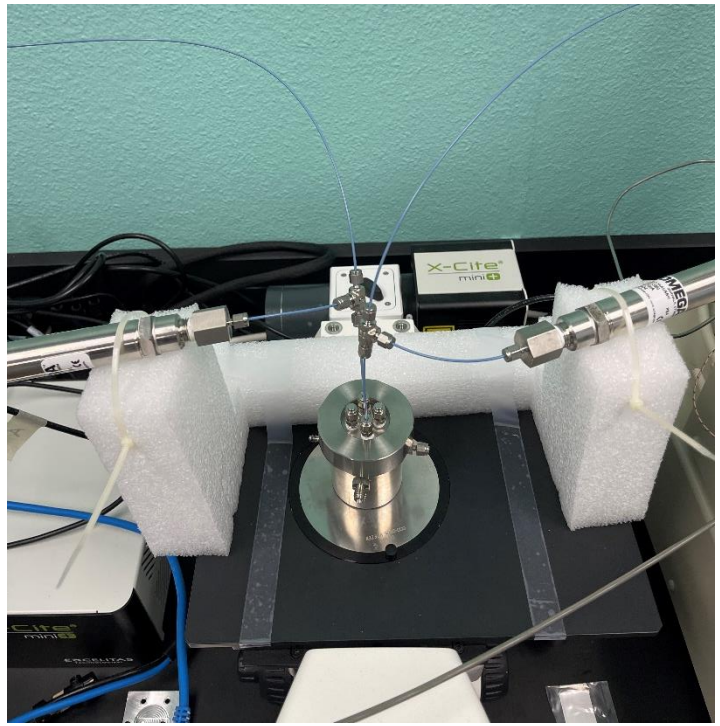
High Pressure/High Temperature Setup



- High pressure experiments underway
- Next Steps for these experiments:
- Different devices
- Revisiting and improving patterns
- Larger domains covering similar pattern concepts

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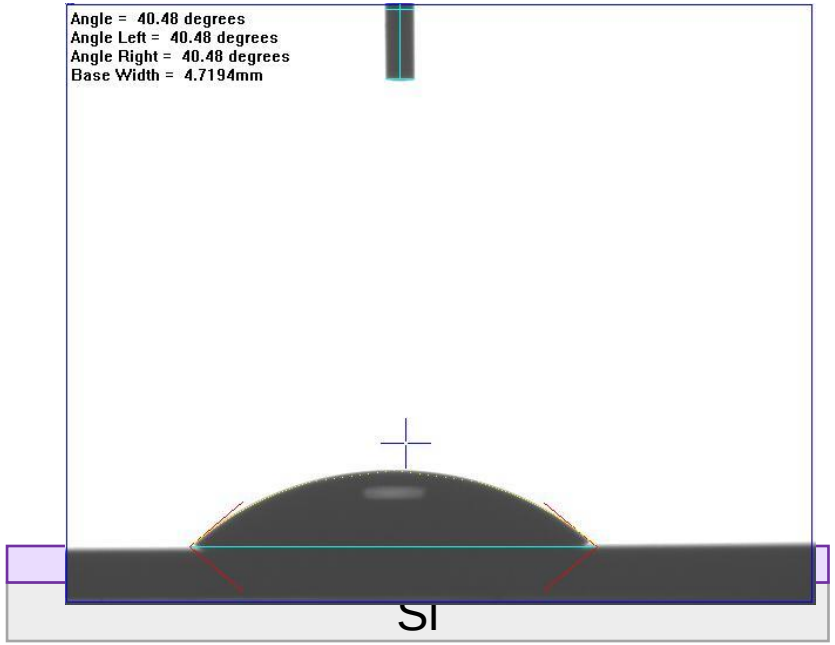
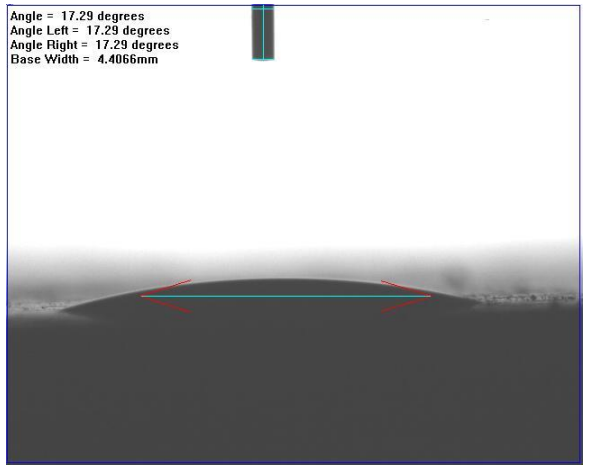
Surface Wettability

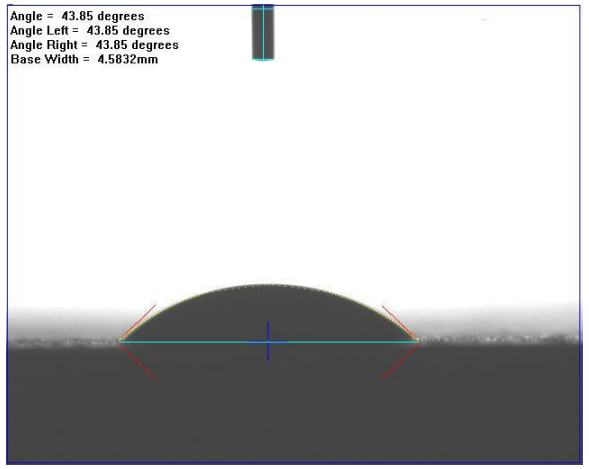


Silicon Wafer

- How do these effects present themselves in storage formations of interest?

Kaolinite

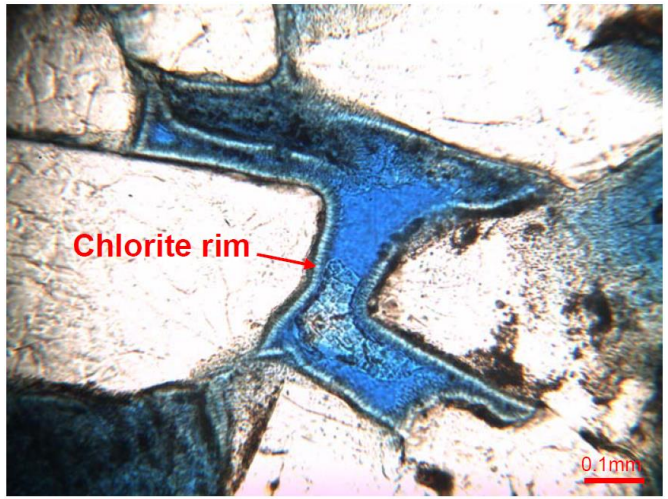




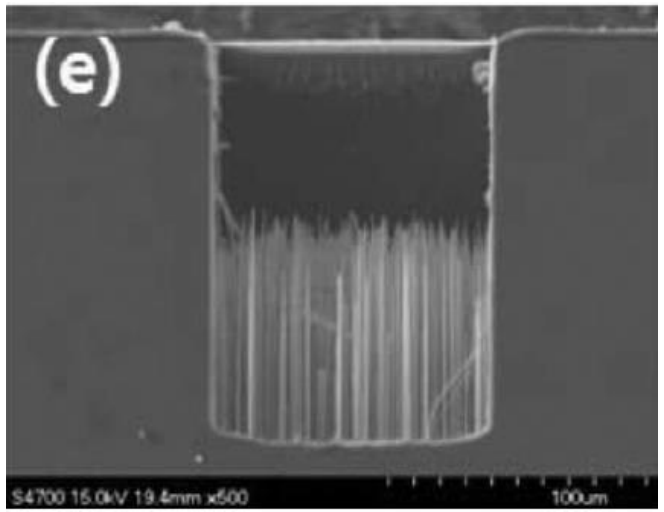
Montmorillonite

Pressed disks made from Ward-grade mineral samples

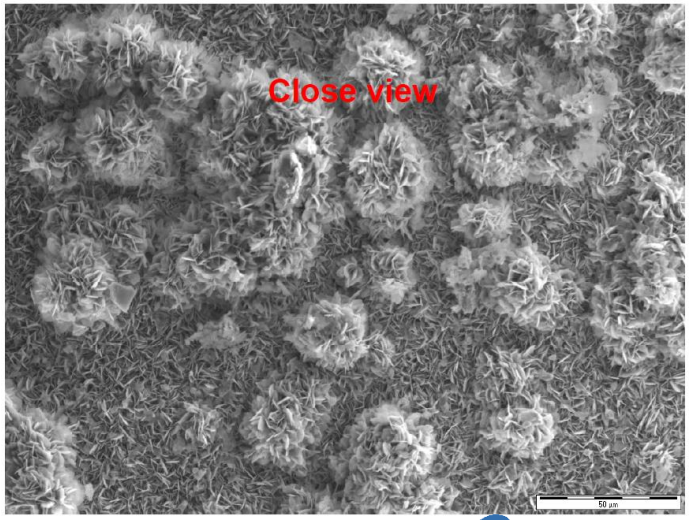
Highly Rough Mineral Representation

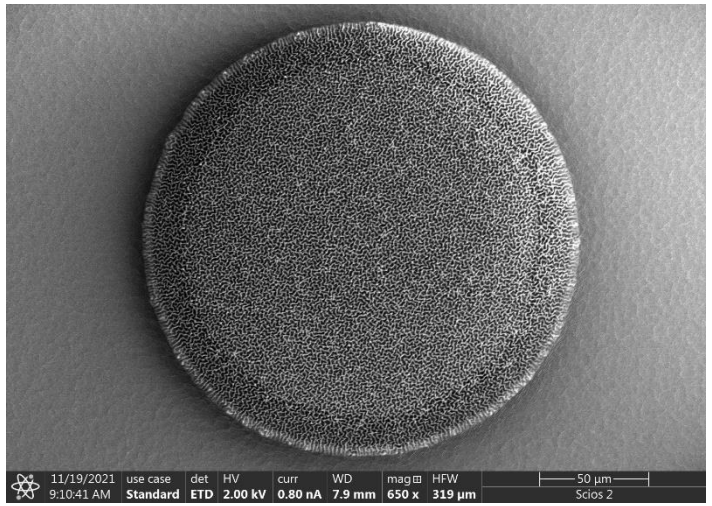


(GCCC Kordi, 2010)



Silicon grass (J. Vac. Sci. Technol. B 28, 143 (2010))





SEM of alternative roughness process

- Can we fabricate devices that are representative of degrees of roughness found in real rock samples?
- Does this have a significant impact on fluid flow?

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Thank you