Foam flow in fractured media

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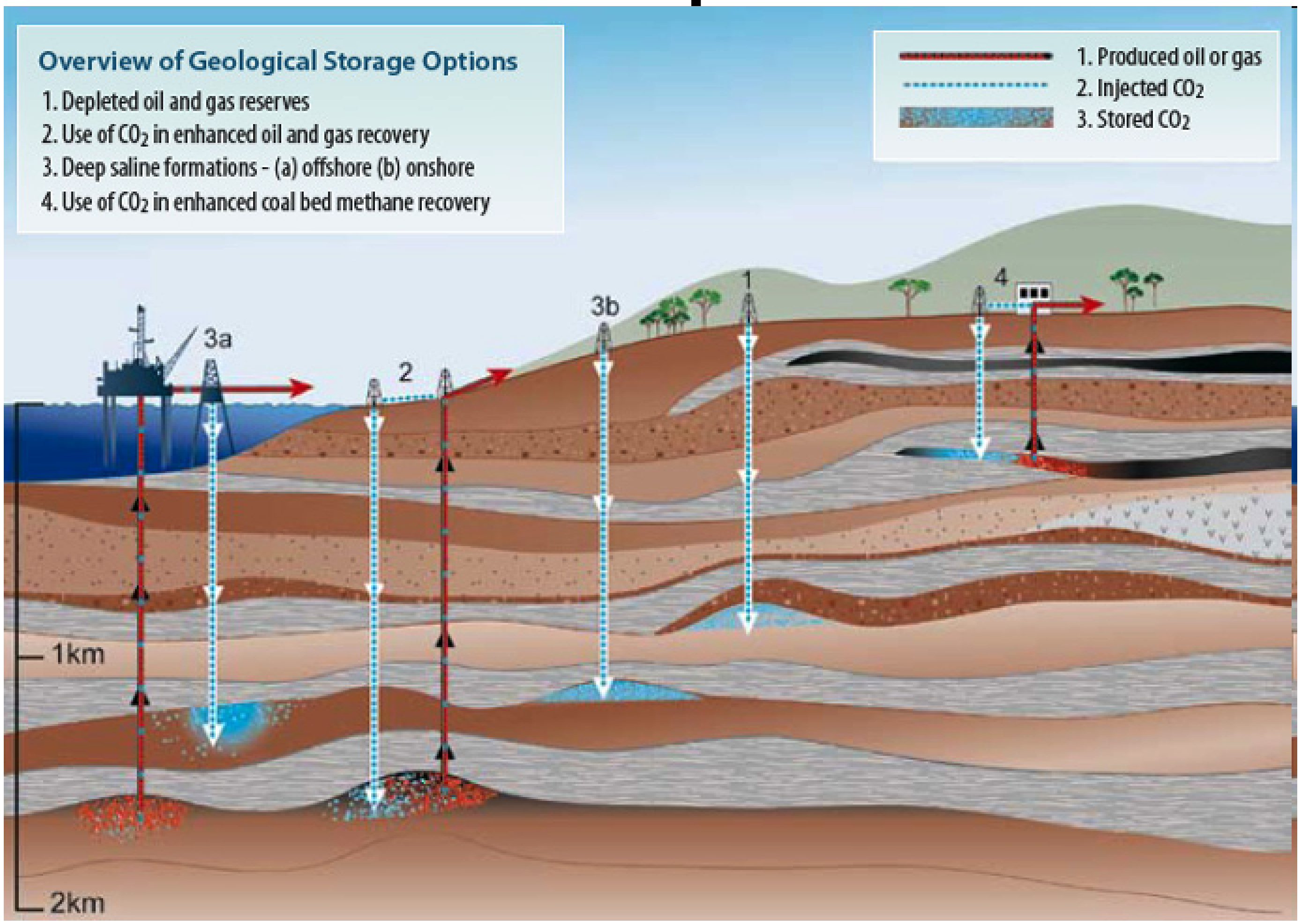
Thanks to Martin Ferno

Carbon Capture and Sequestration



Saline Aquifers

1000-10000 Gt

Oil and Gas Reservoirs

680-900 Gt

Coal

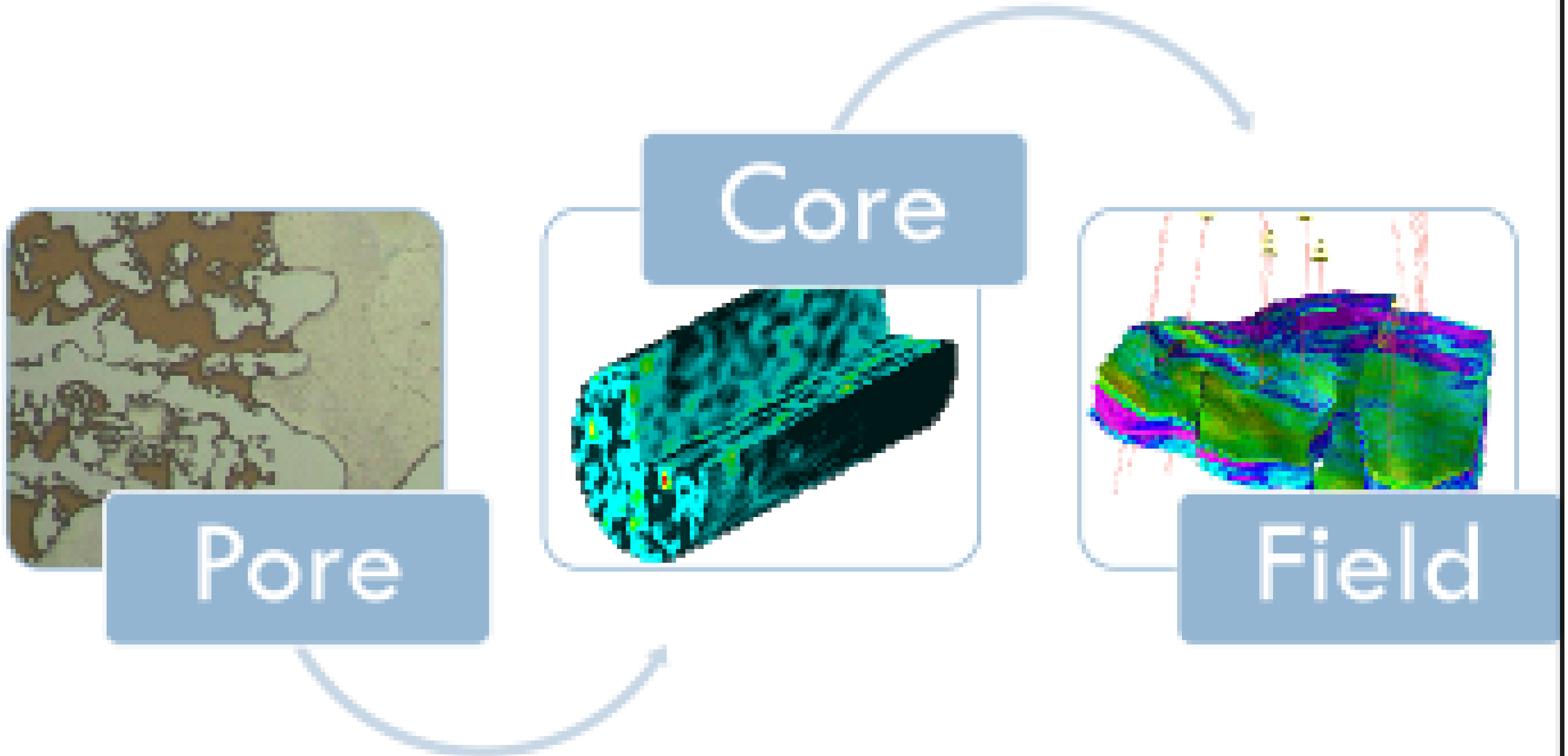
15-200 Gt

www.co2captureproject.org/about_storage.html

Why Foam?

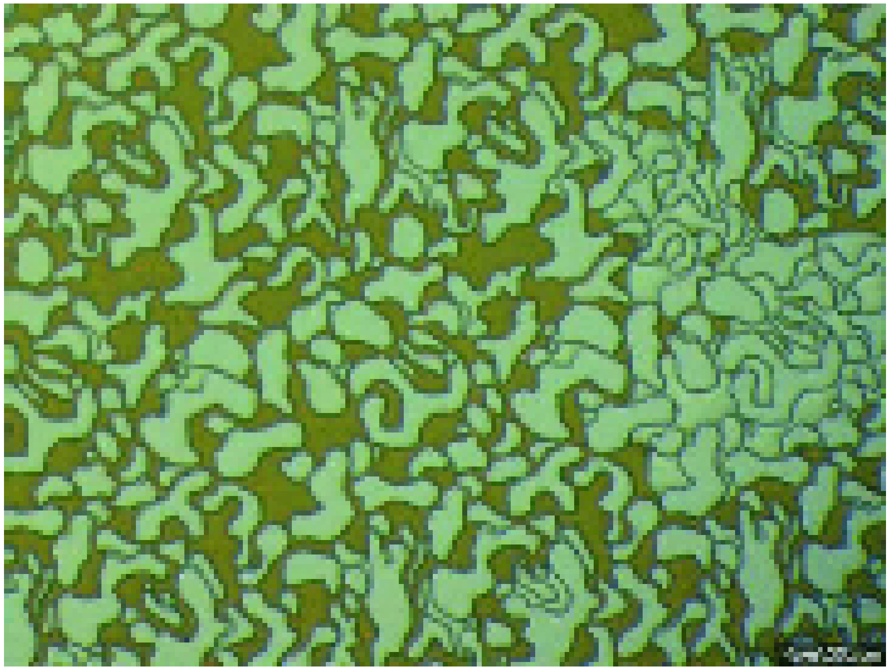
- Mobility control of injected gases
- EOR and CO_2 sequestration
- Mitigate extreme permeability contrasts
- Better economics

Upscaling - Problem



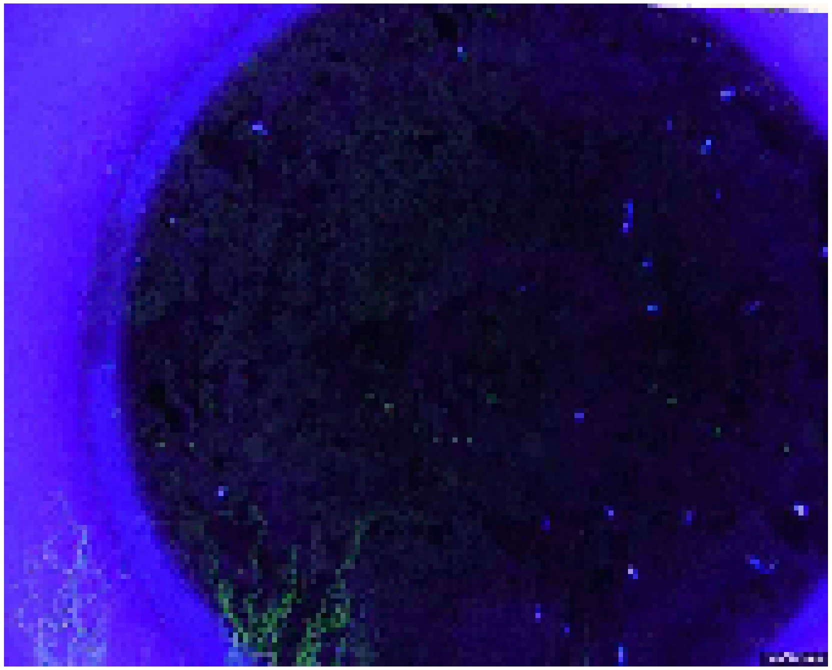
How Can We Use Micromodels

- Micro observation of flow behavior and saturation changes-left
- Macro observation of displacement patterns-all



Polymer/Oil Imbibition @ 1ft/day

Mobility Ratio = 17

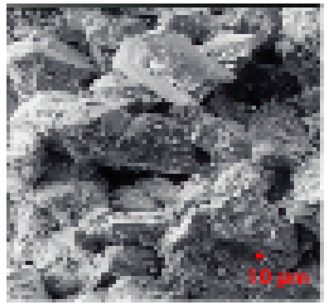


Carbonate MM

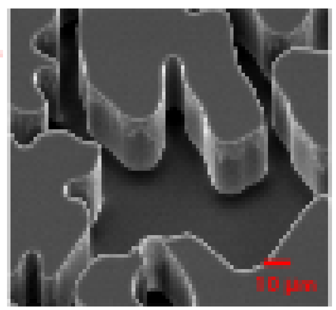
Water- Heptane

From Rock to Micromodel

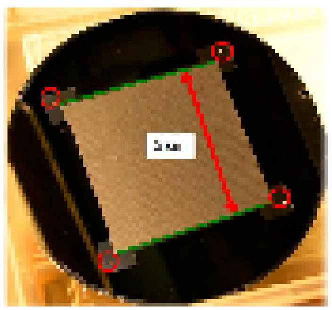
SEM image of Berea Sandstone



Digitized Berea SEM image



Etched Silicon Wafer



Micromodel

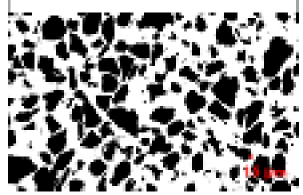
Micromodel Portfolio

Sandstone- 1

- 22% Porosity
- 900 mDarcy
- 30-300µm grains
- 500 000 pores
- 0.01 ml volume
- 25 µm grain depth

Sandstone -2

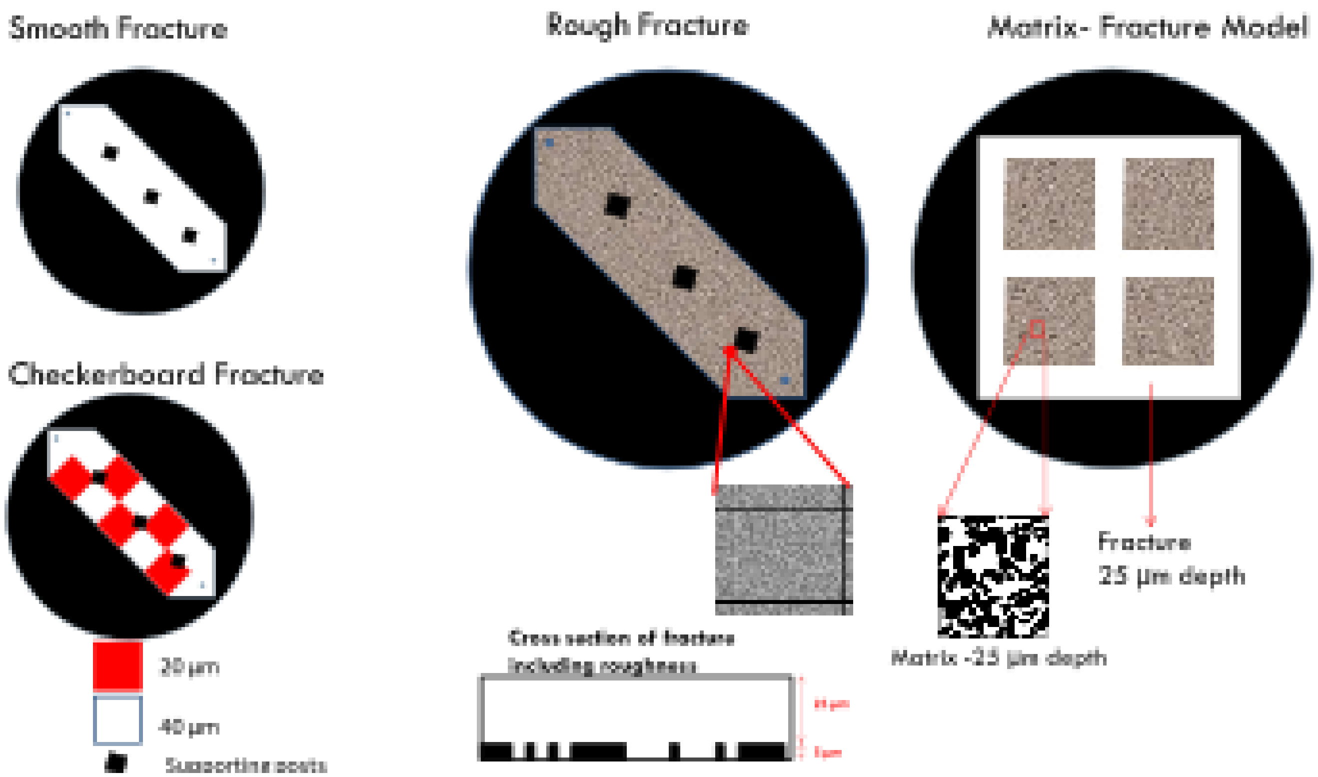
- 54% Porosity
- 3000 mDarcy
- 125-250µm grains
- 0.0245 ml volume
- 25 µm grain depth



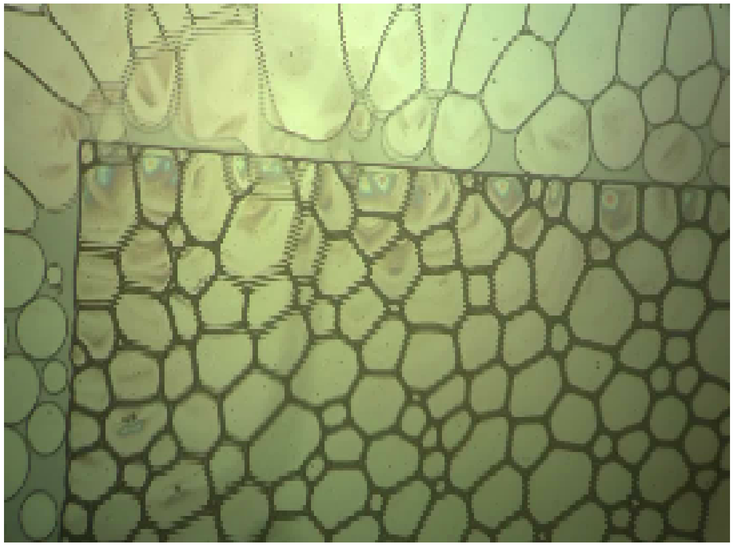
Carbonate

- 45% Porosity
- 400 mDarcy
- 2.5-800µm grains
- 0.012 ml volume
- 14 µm grain depth

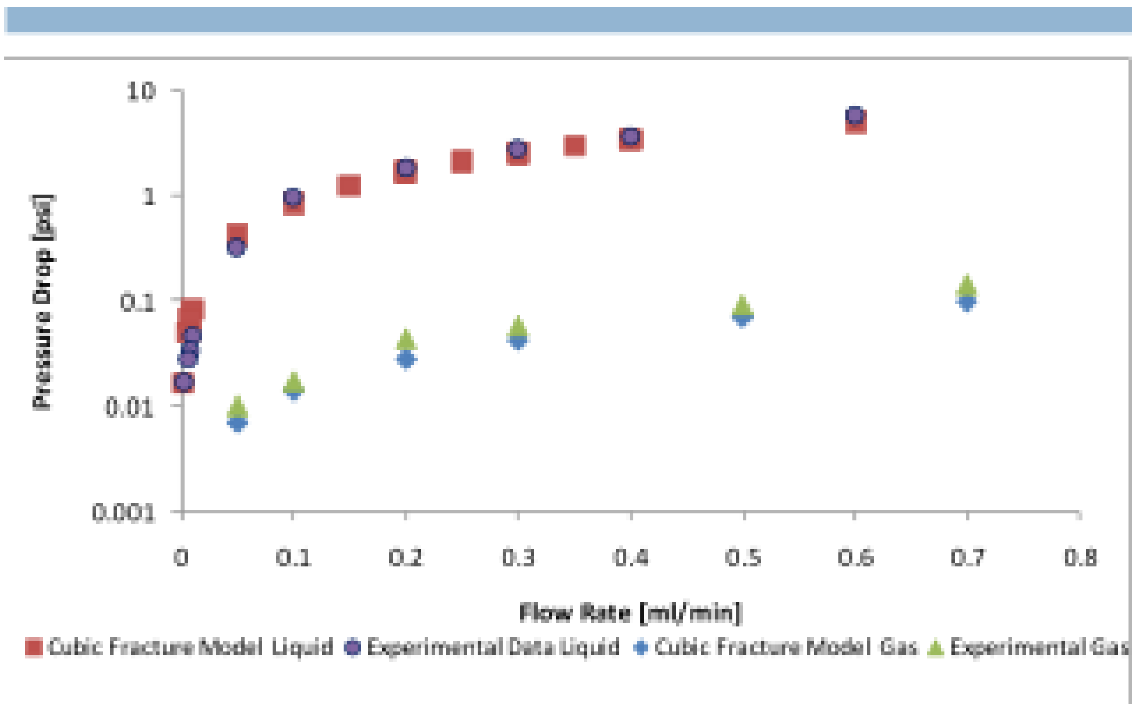
Fracture micromodel designs



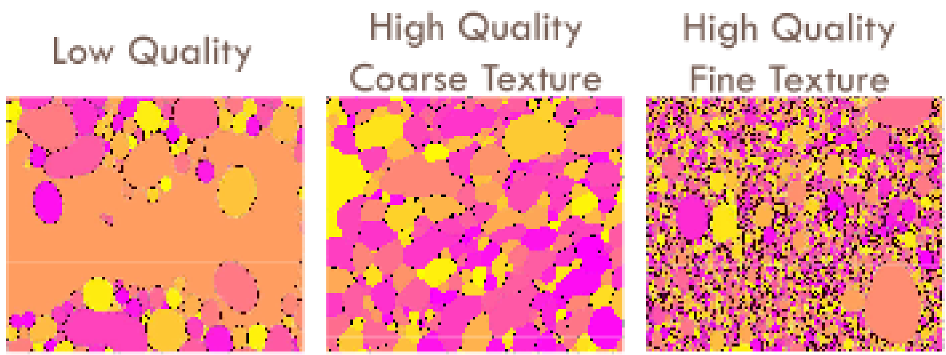
Foam Flow for Enhanced Oil Recovery



Fracture characterization

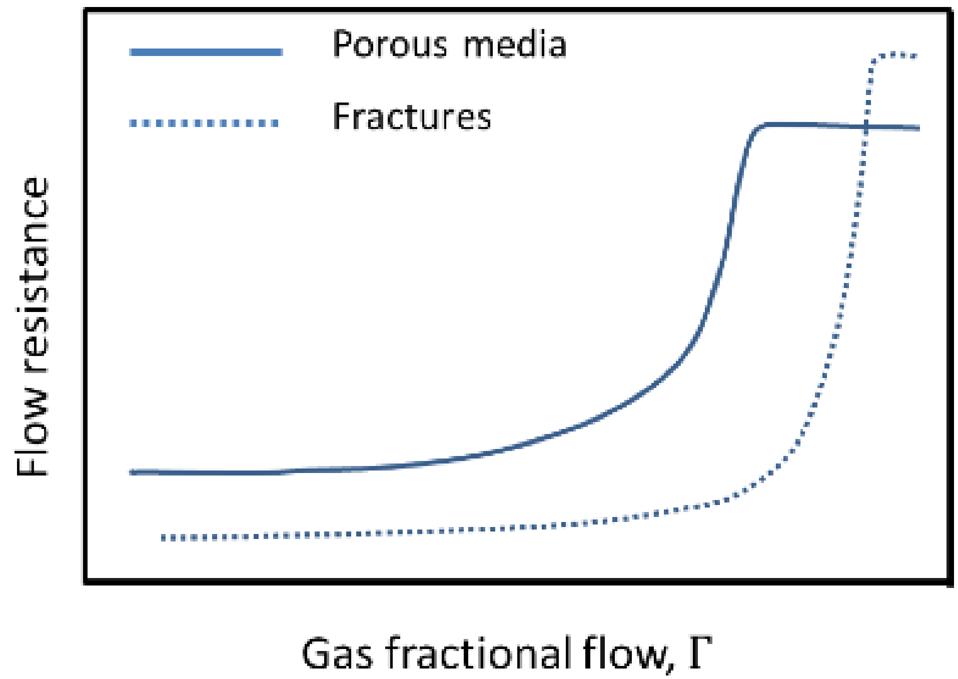


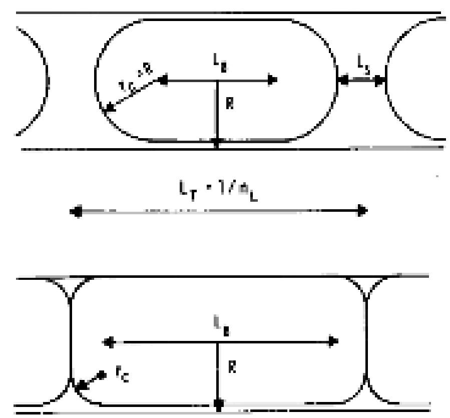
Various types of foams



theory

Foam in Simplified Systems

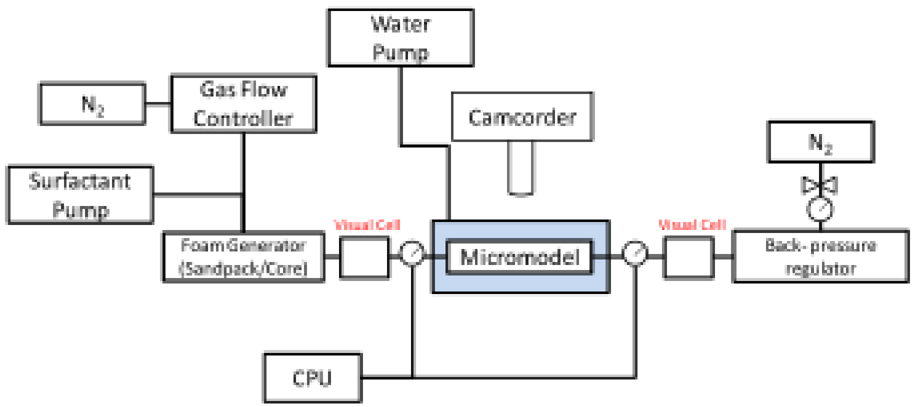




Hirasaki and Lawson (1985)

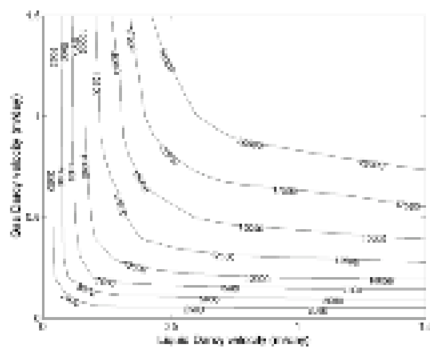
- Foam resistance in porous media reaches a constant due to limiting capillary pressure
- Fracture foam flow resistance increases monotonically and reaches a constant at very large f_g

Set up schematic



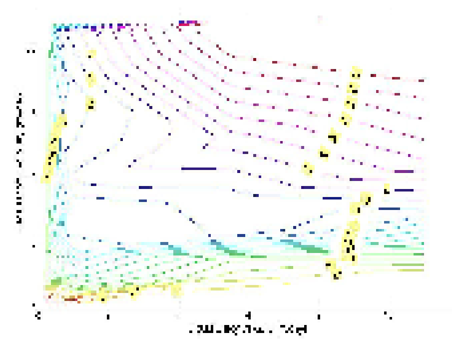
Physical Model vs. Experimental Result

Steady-state foam flow predicted by the full physics model in porous media



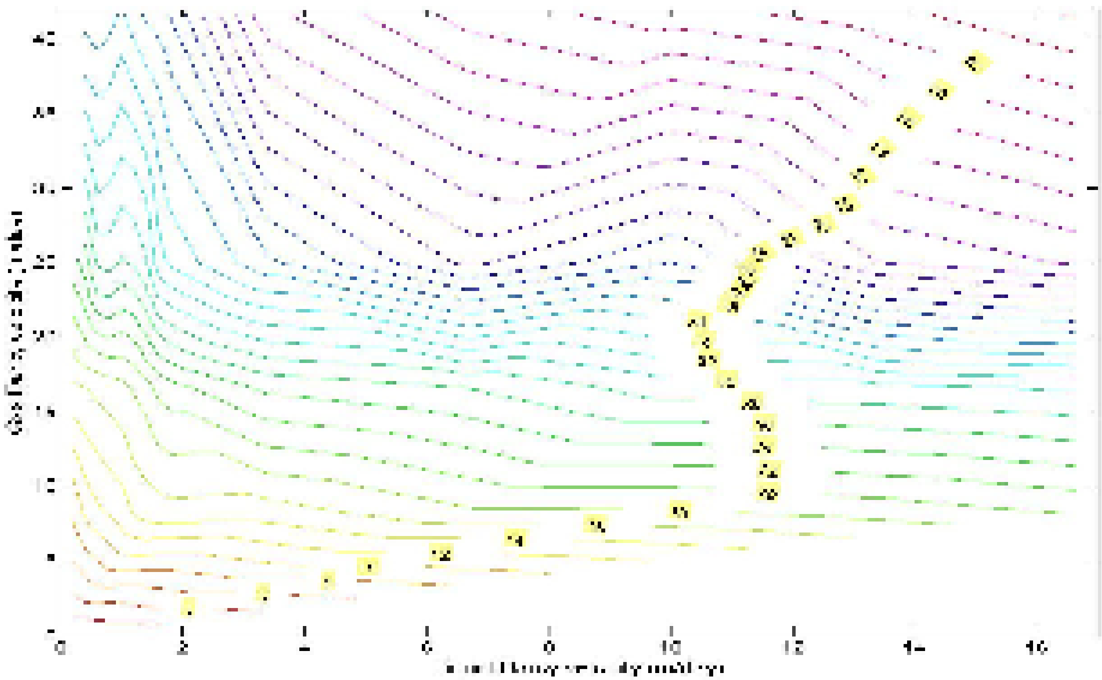
Pressure Gradient [kPa/cm]

Experimental Results of a 40μm smooth fracture

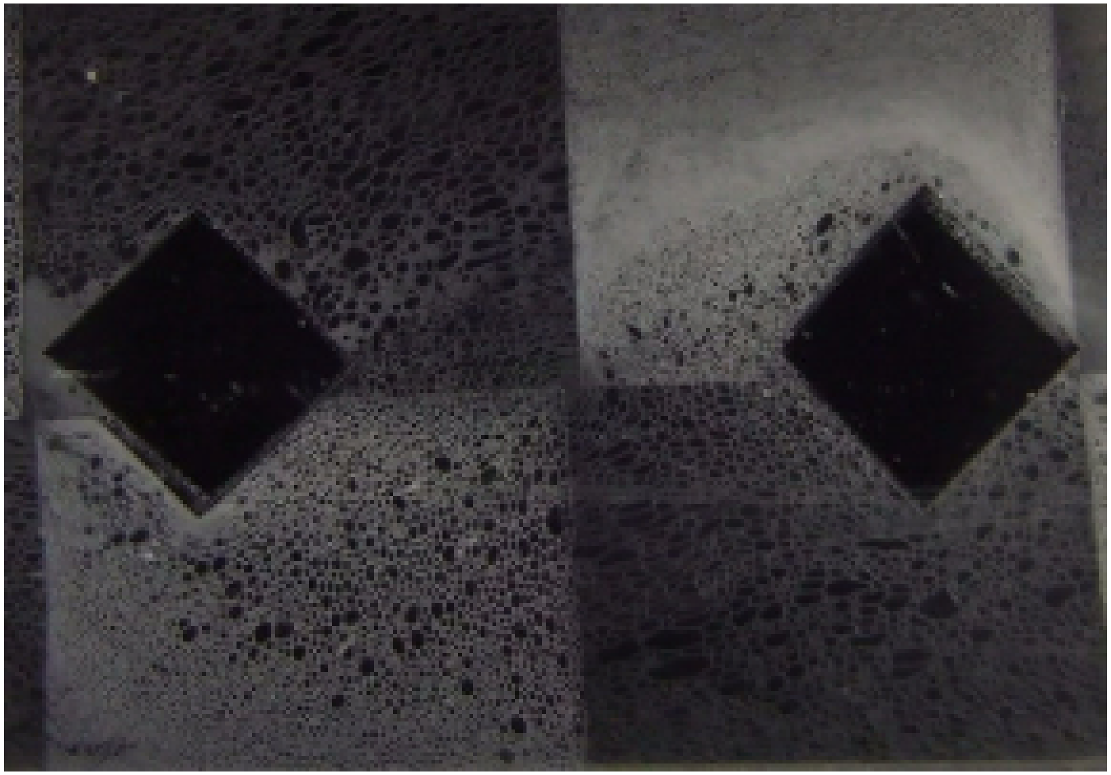


Pressure Drop [psi]

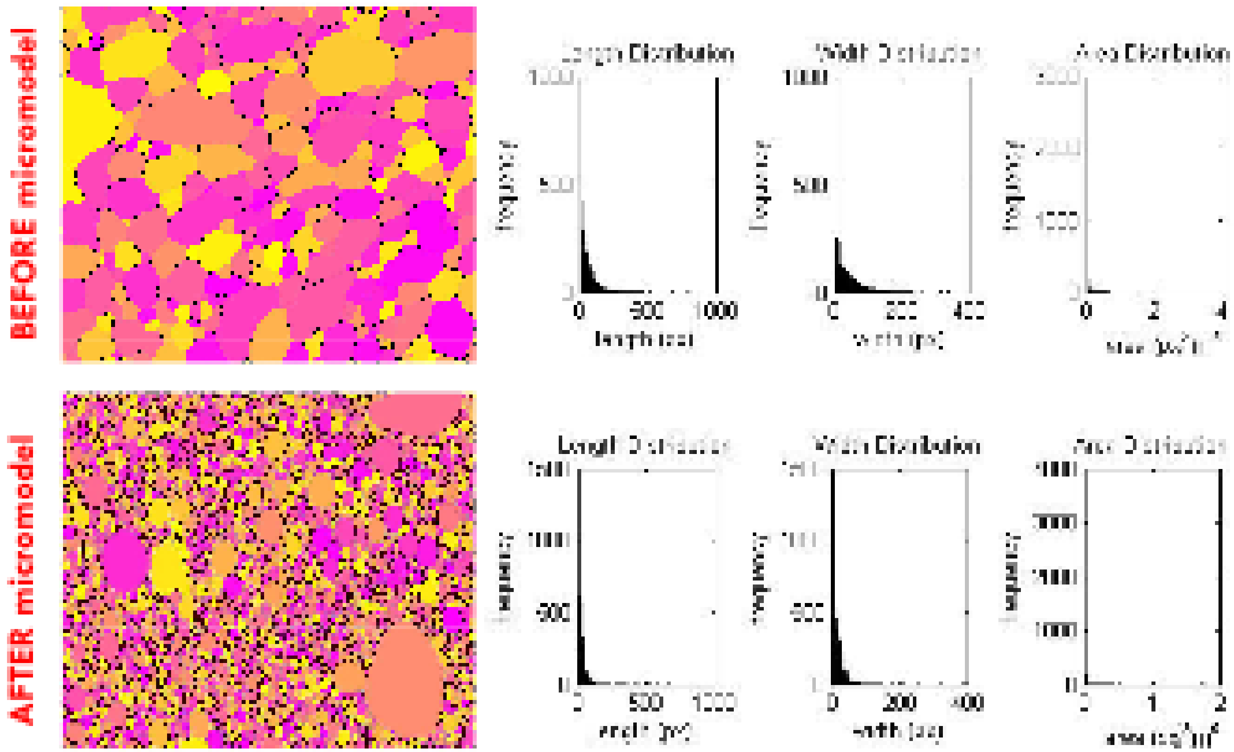
Checkerboard pressure data



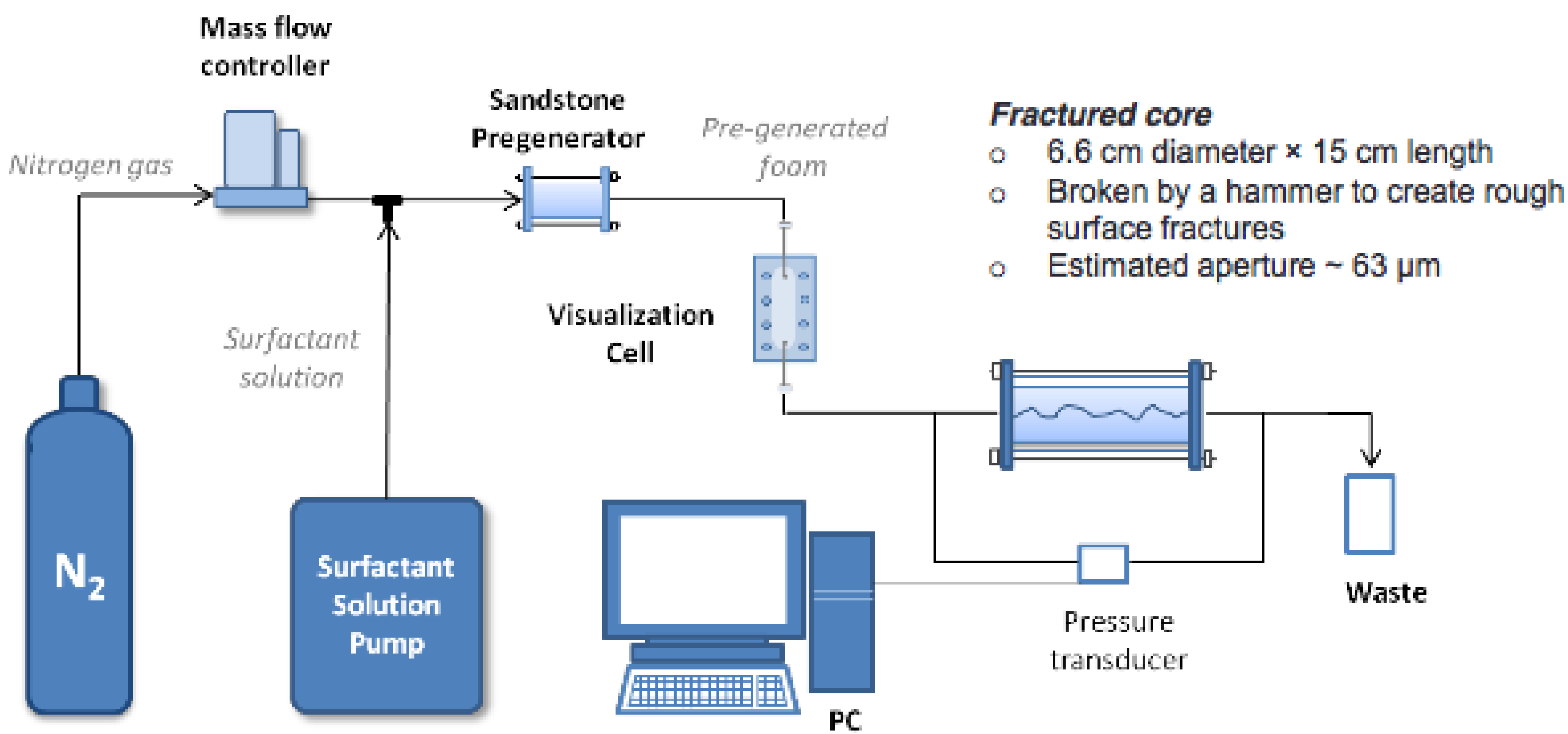
In situ foam generation

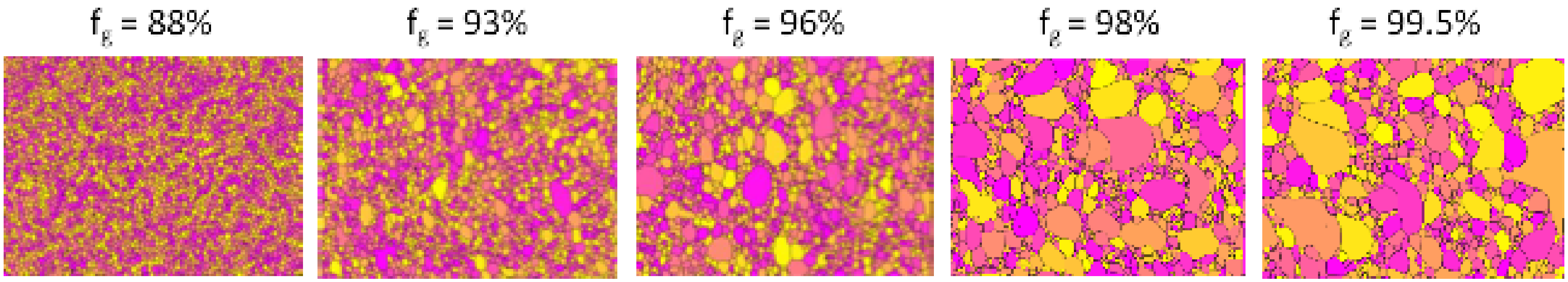


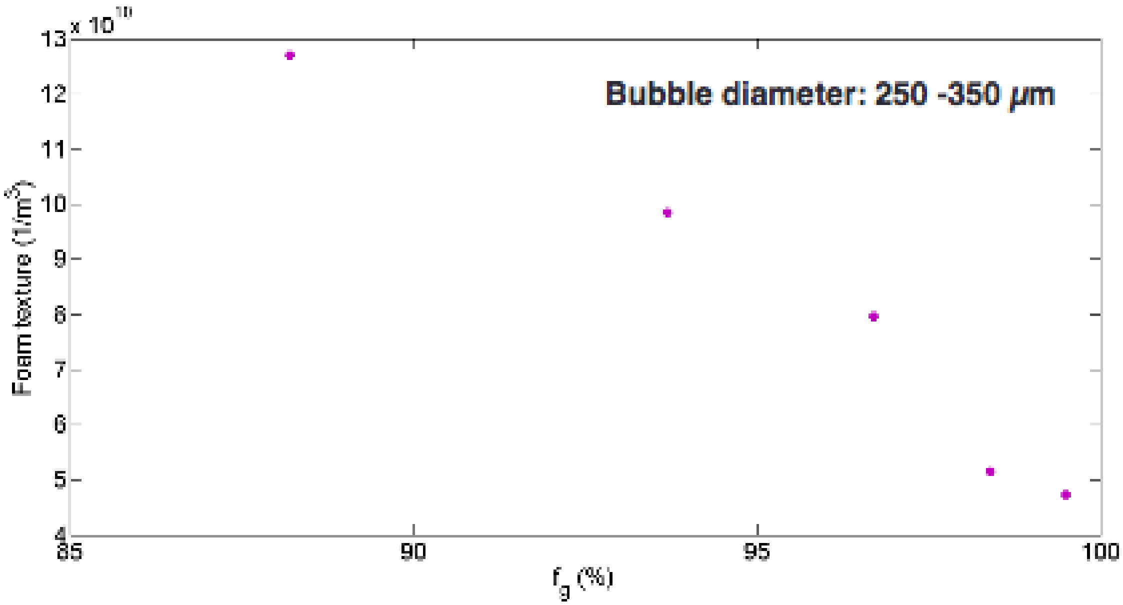
Changes in foam texture



Fractured cores set up

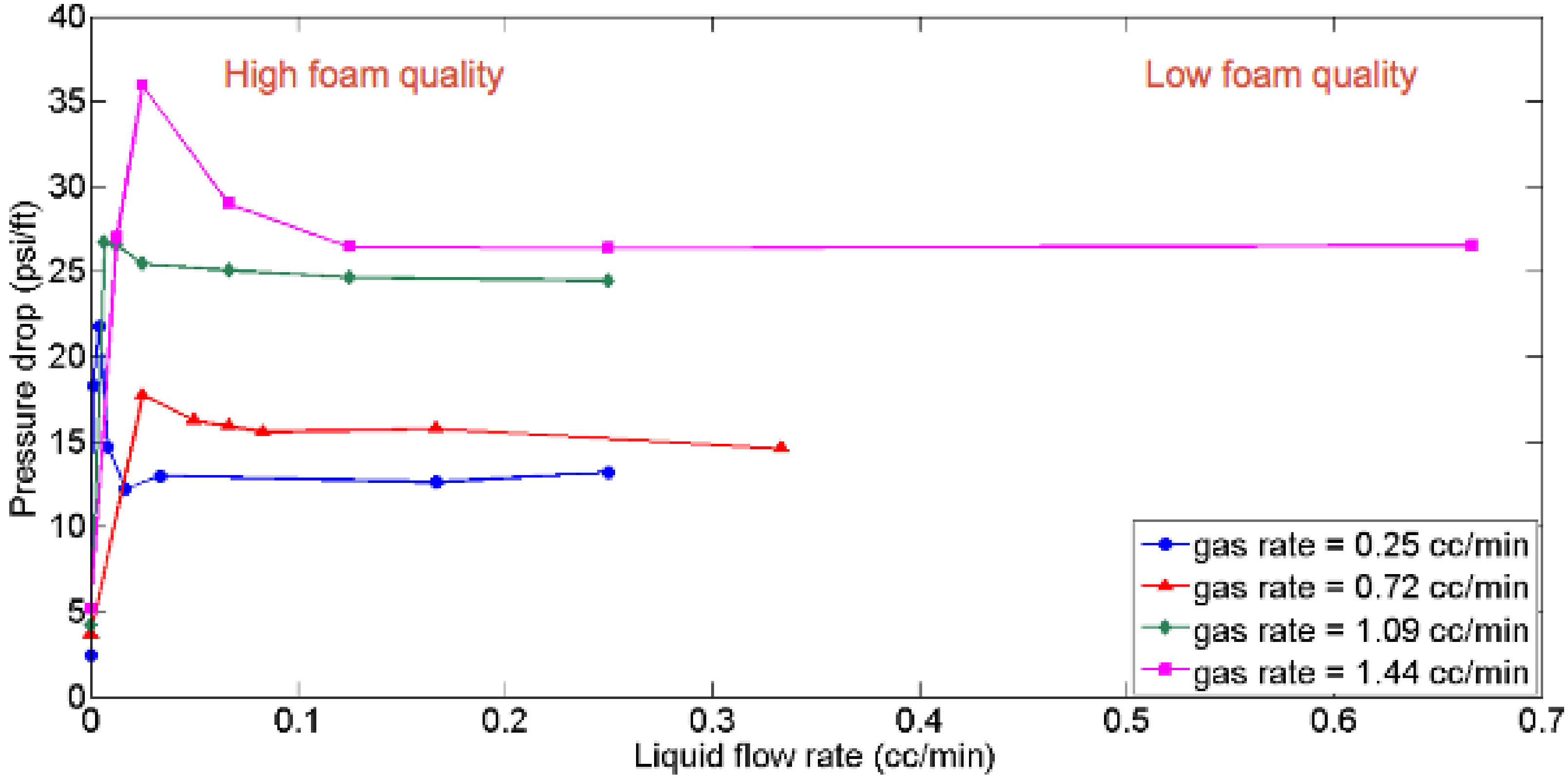






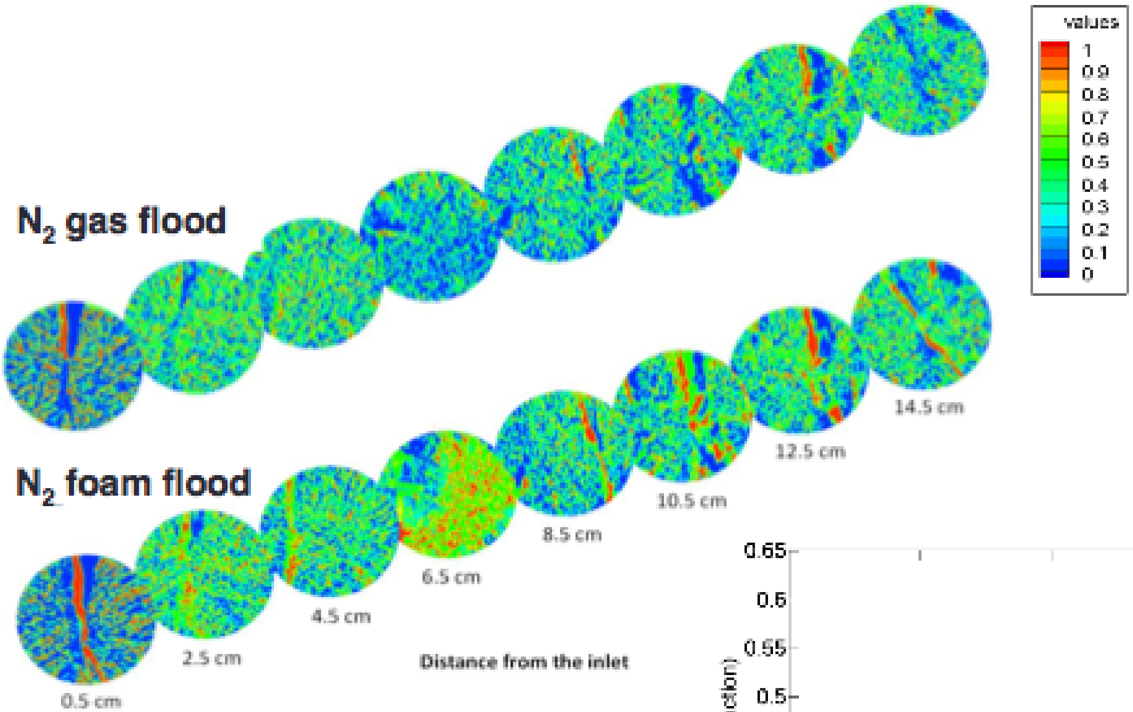
- Foam texture decreases with increasing foam quality
- No foam generation or coalescence observed within the smooth fracture.

Results rough fracture

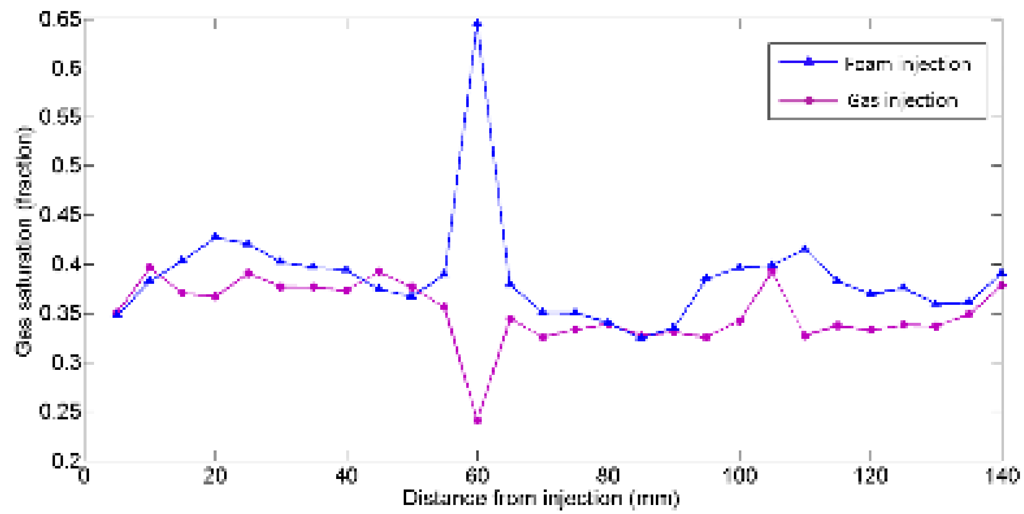


- Pressure response is insensitive to liquid flow rate for the wet foam
- At very high gas fractional flow, foam starts collapsing and the measured pressure drop declines drastically

Foam and gas flow



Fracture is fully filled with foam while it is only partially filled during N_2 flood



- Foam quality and fluid flow condition affect bubble configurations and flow resistance in smooth fractures.

- In rough fractures, foam resistance increases as foam quality increases. The resistance drops drastically at the foam quality of 99 - 99.5% due to high local capillary pressure.

- Foam has ability to divert injected fluids from fractures into rock matrix. This ability is affected by the contrast between fracture and matrix permeabilities.

Current Applications

- Gas injection in Carbonate reservoirs offshore Mexico
- CO_2 injection for EOR USA
- CO_2 sequestration projects planned
- Steam foam