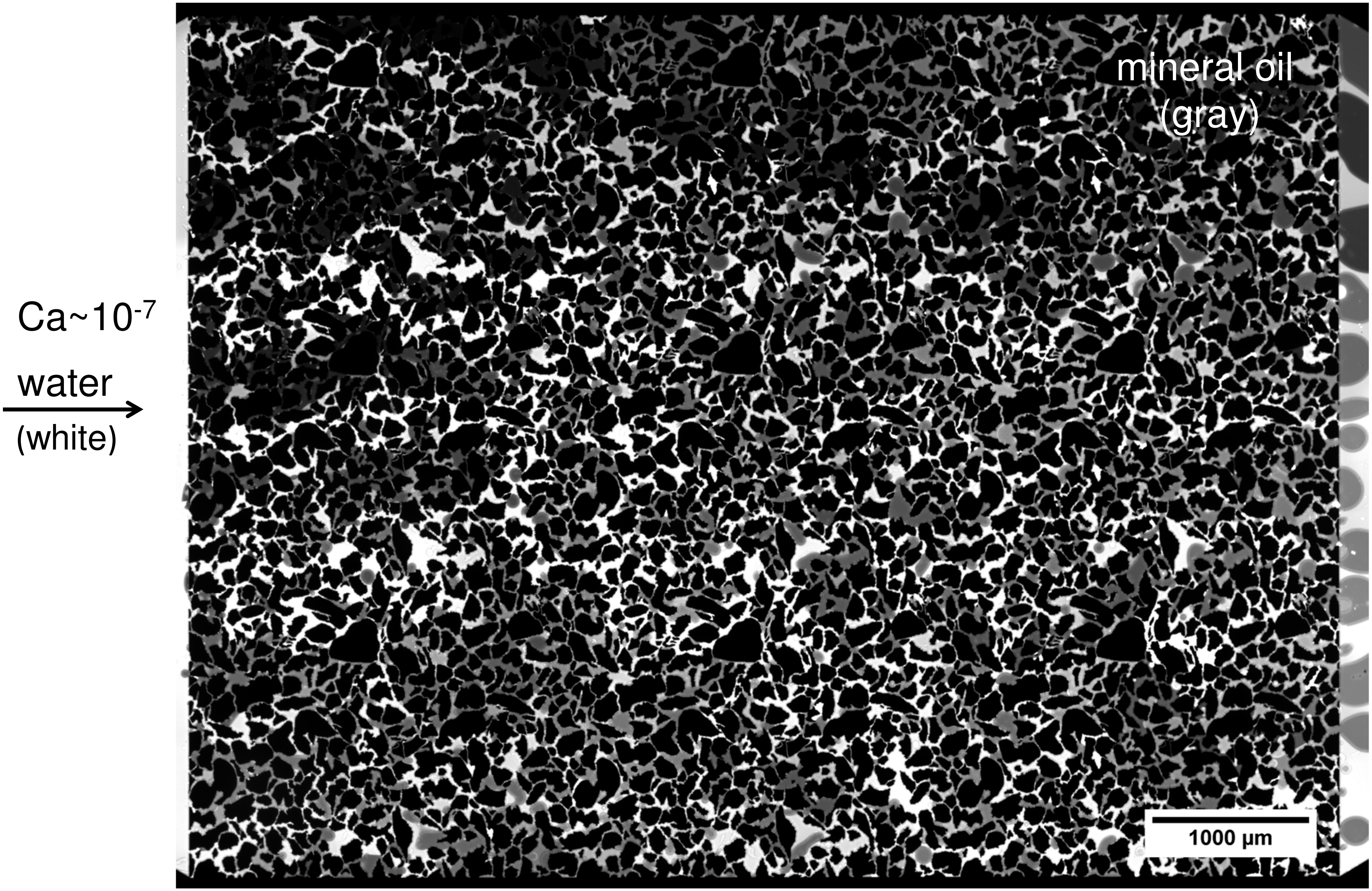
Global Climate & Energy Project
STANFORD UNIVERSITY

Water Conformance and Mobility Control by CO_2 Exsolution

Lin Zuo, Sally Benson

June 5, 2013

Imbibition

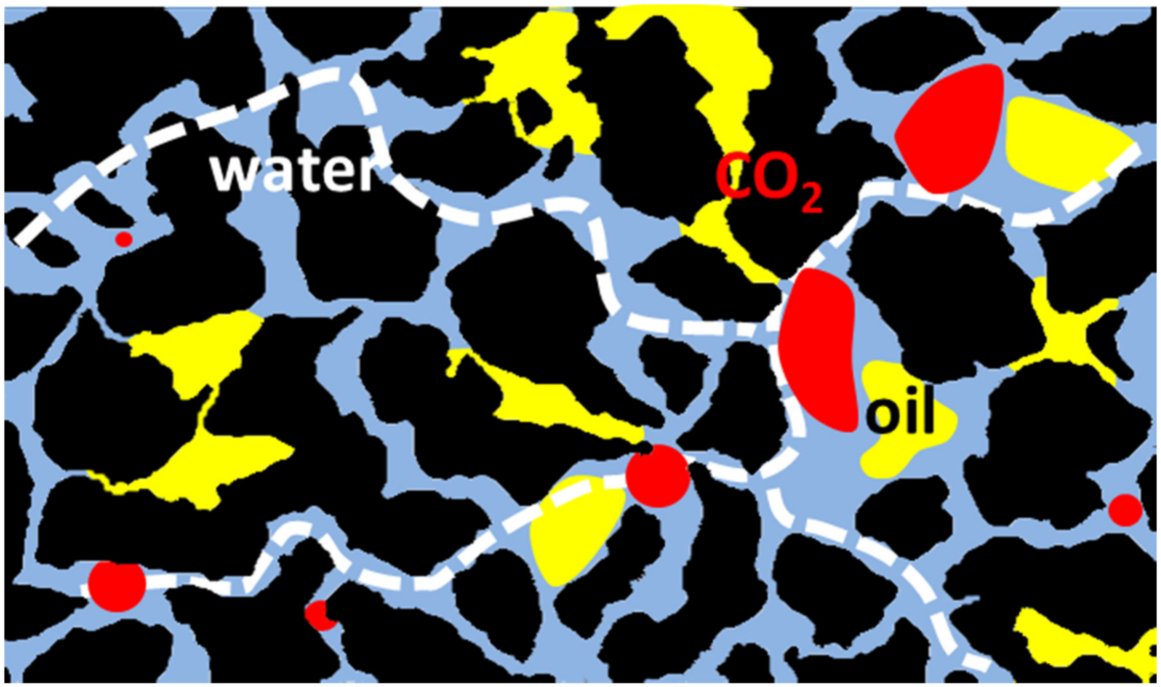


Water Mobility Control by CO_2 Exsolution

(1) Deliver CO_2 to flooded zones by carbonated water injection;

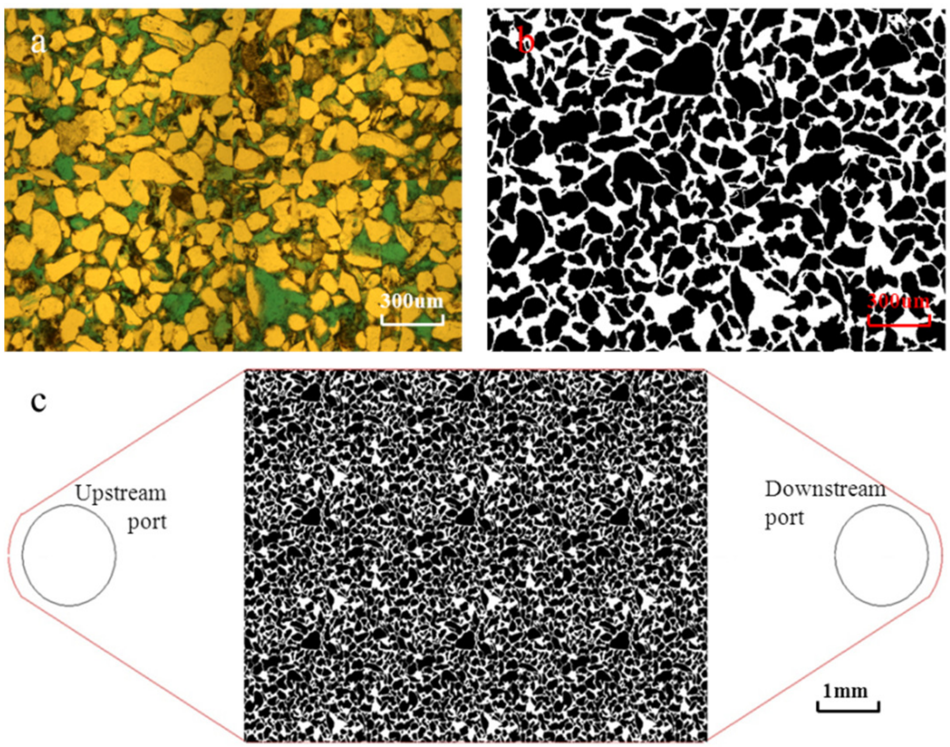
(2) Drop pressure-> CO_2 exsolves and plugs established flow paths;

(3) Establish new flow paths.

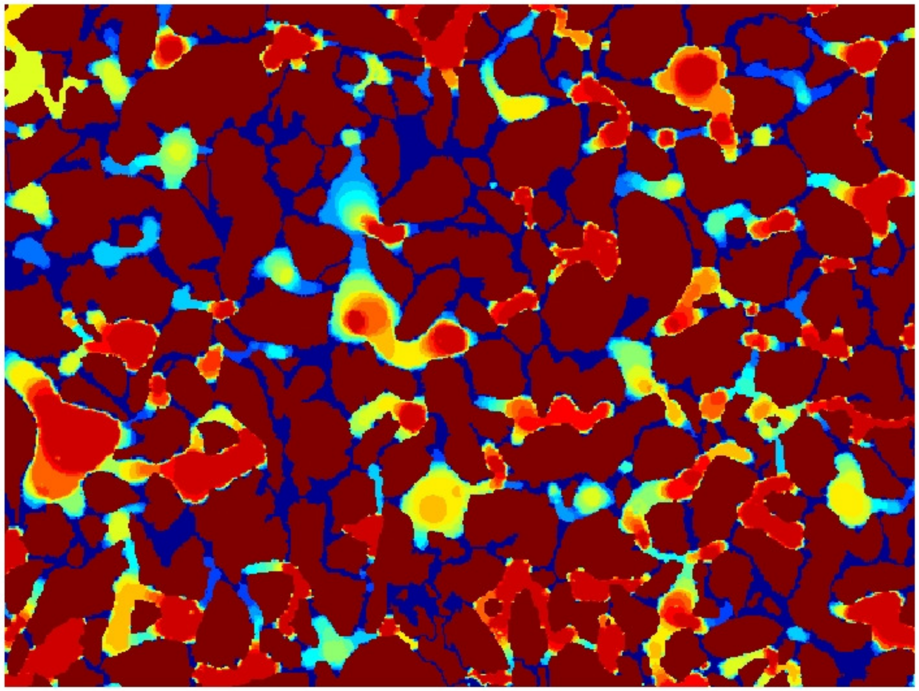


Microscopic Observation

Schematic of Pore Structure and Micromodel Configuration



Evolution of Exsolved Bubbles in Porous Medium



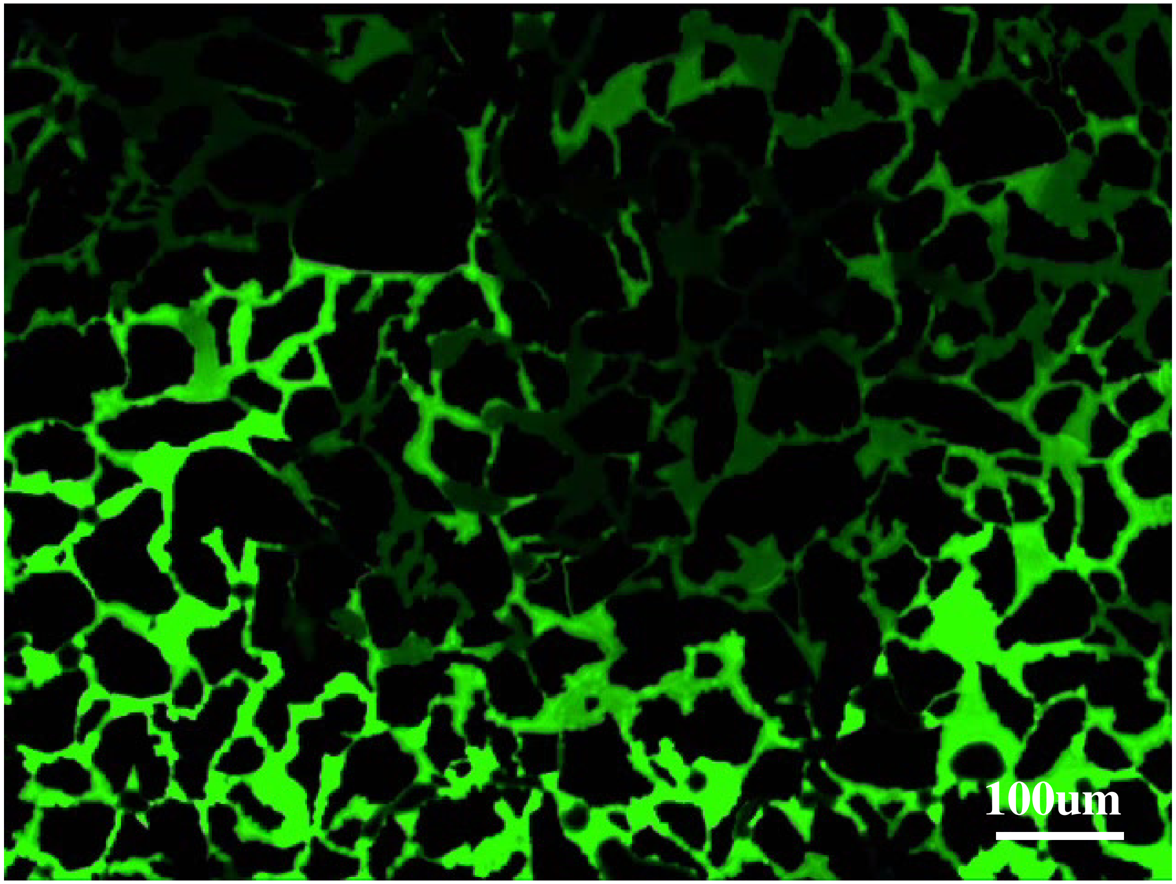
Zuo et al. (2013) *AWR*

Microscopic Observation

Illustration of Water Conformance at 650psi pore pressure and 45°C:

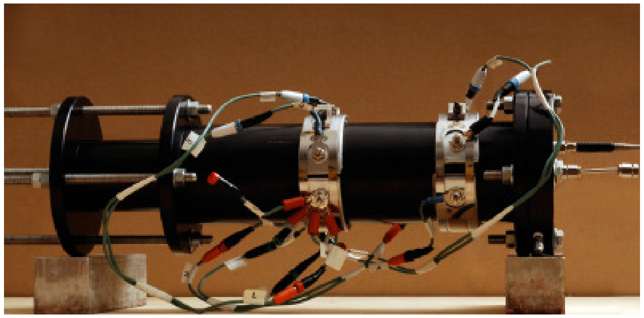
- constant upstream injection, 1m/day (CA~10^{-7})

- constant production pressure, 150psi below saturated pressure.

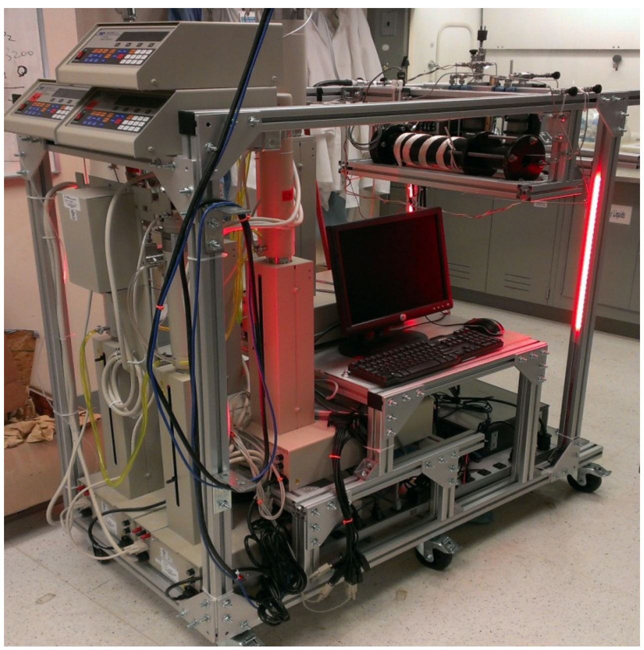


Coreflooding Experiments

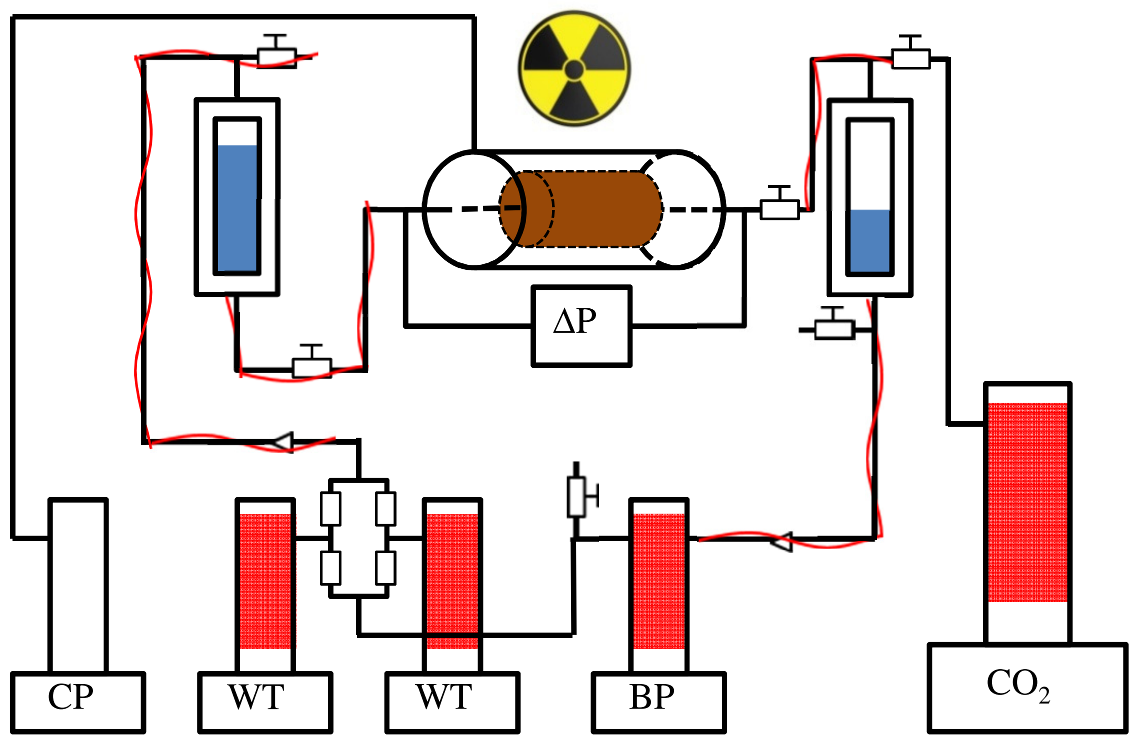
Aluminium Core Holder



Experimental Apparatus

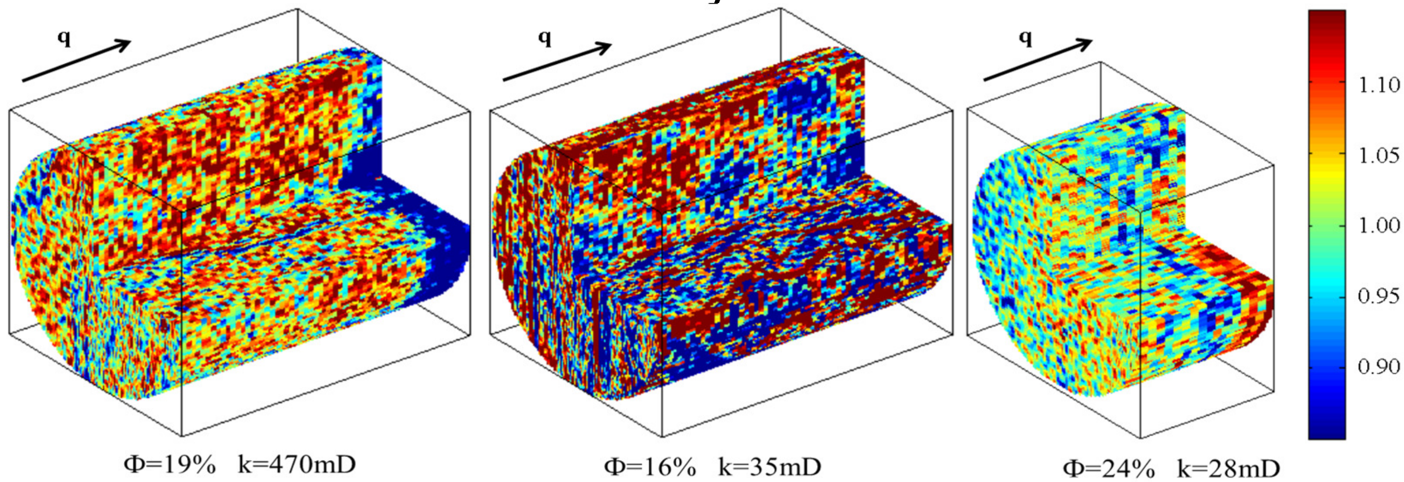


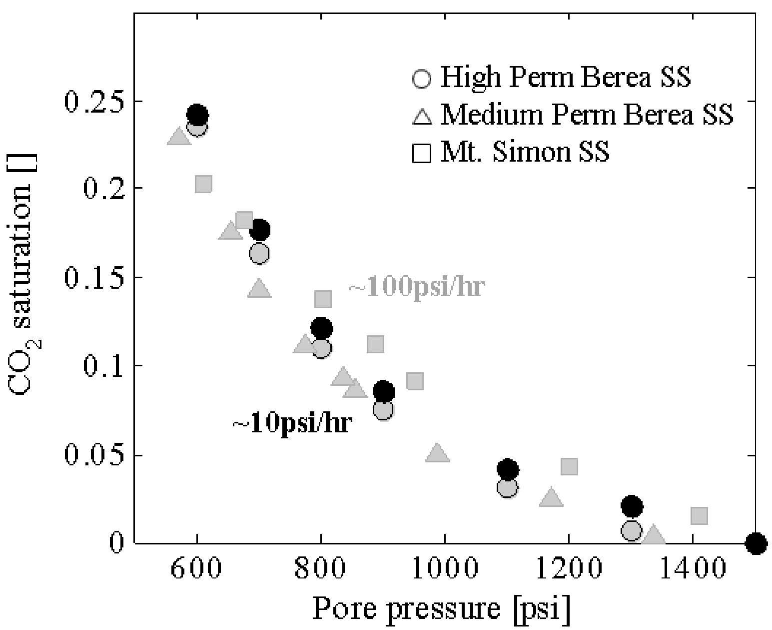
System Schematic

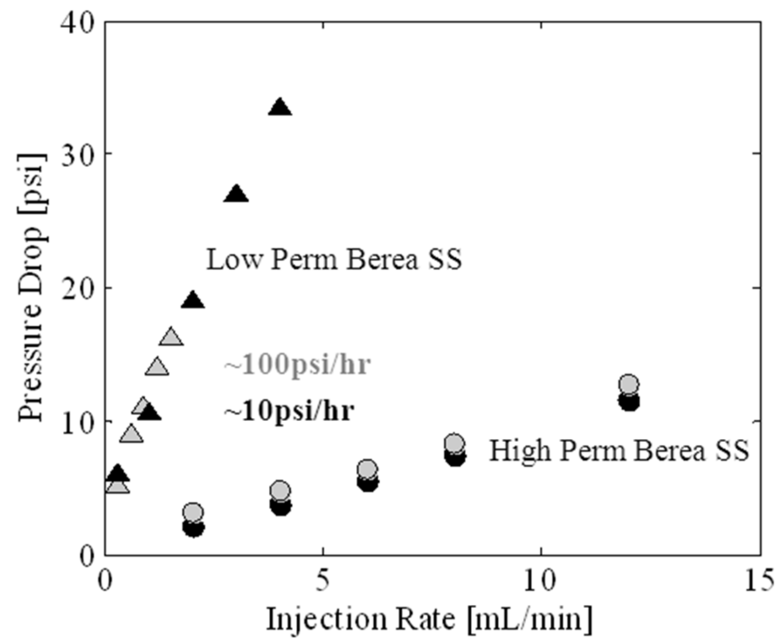


Coreflooding Experiments

Normalized Porosity Distribution





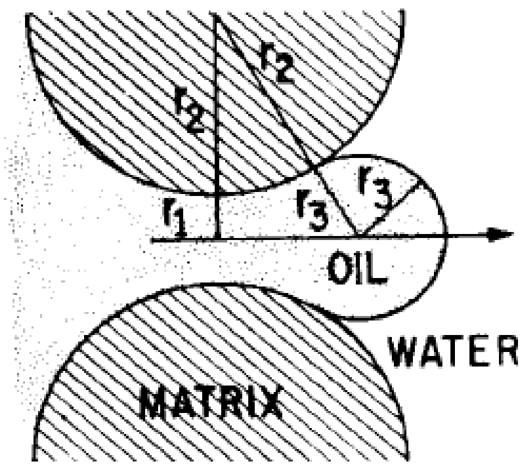


Gas Mobility

$IFT_{C1/C5}$ = 0.2~1 mN/m

$IFT_{CO2/water}$ = 30~50 mN/m

$Viscosity_{oil}$ >> $Viscosity_{water}$

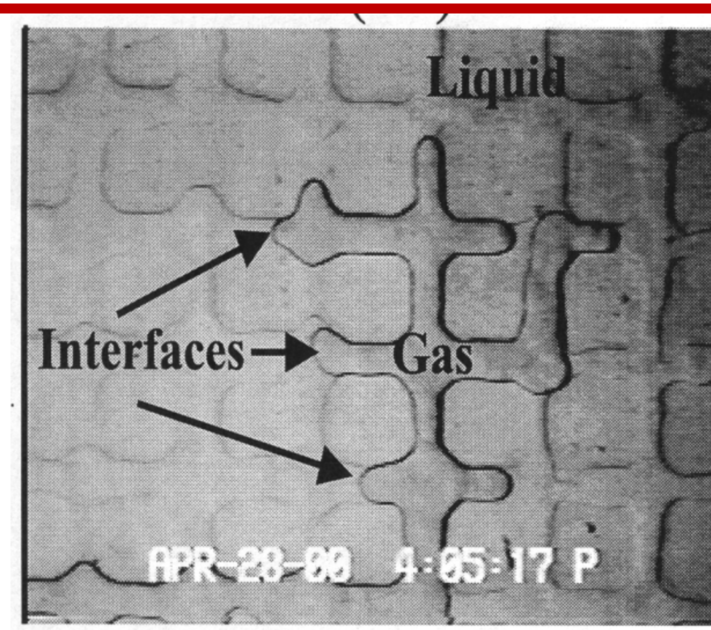


$$P_{c,f} = 2\sigma/r_3$$

$$P_{c,t} = \sigma/r_1 - \sigma/r_2$$

$$P_s = P_{c,f} - P_{c,t}$$

Roof (1970)



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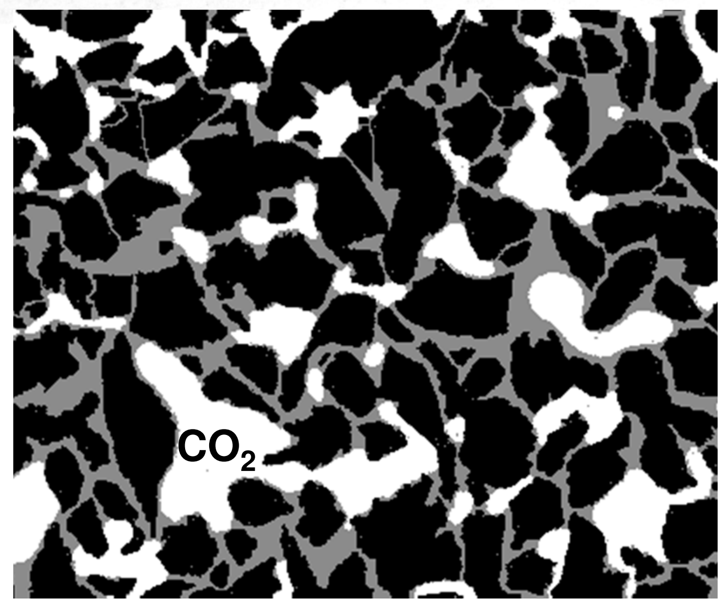

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*Tsimpanogiannis and Yortsos (2002) *AIChE Journal*

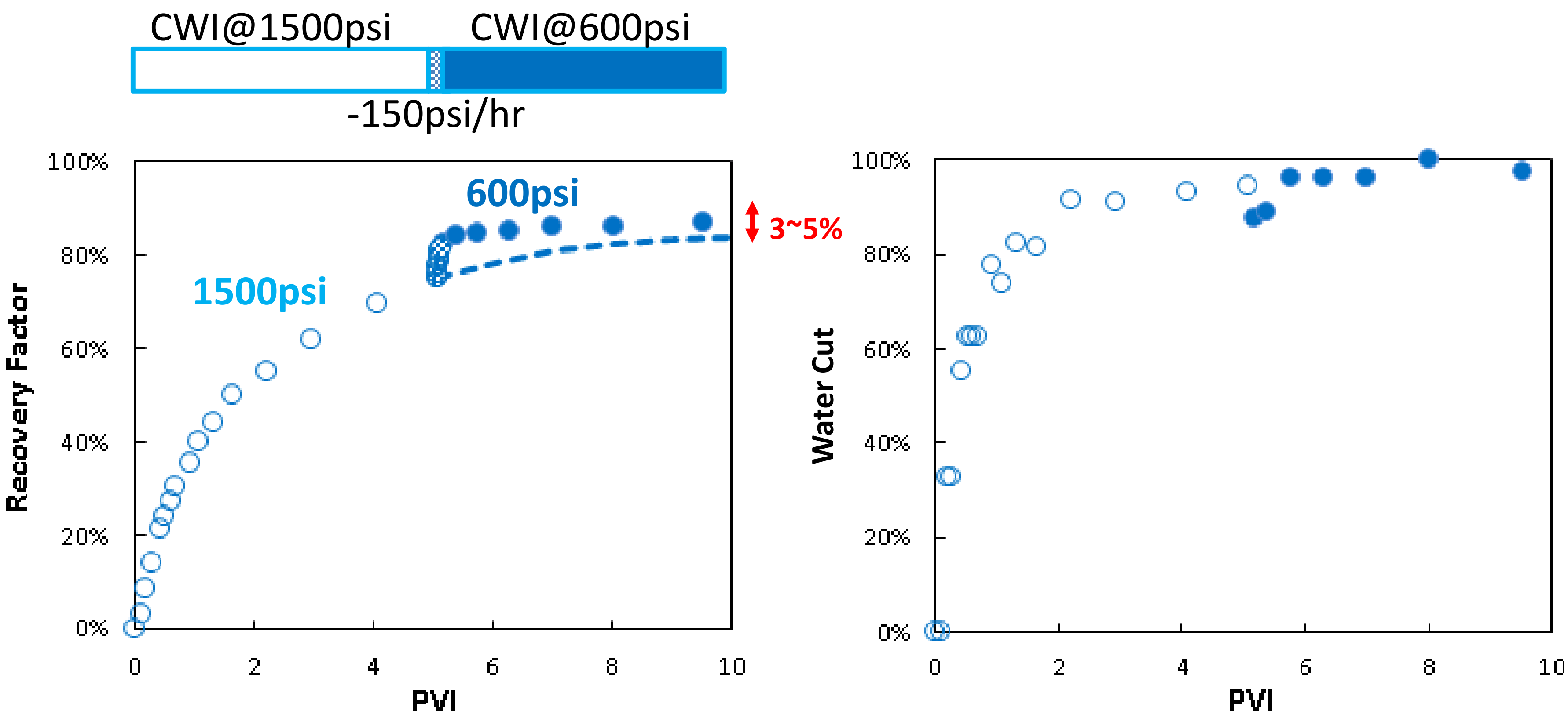
**Zuo et al. (2013) *AWR*

Coreflooding Experiments

Berea Sandstone: ~500mD, ~20% porosity;

Mineral Oil: ~60cSt @50^{o}C

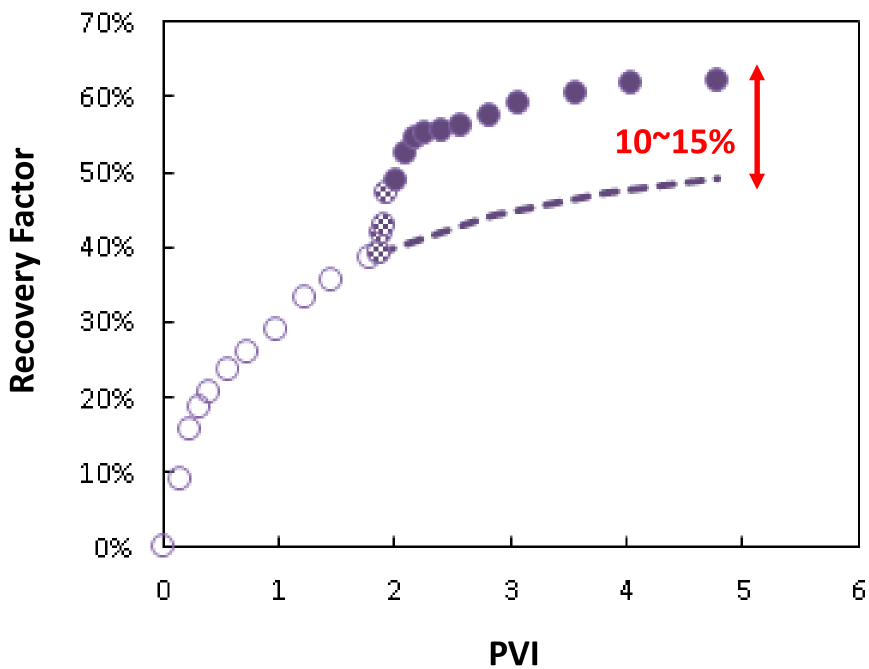
Injection: pre-equilibrated carbonated water, CA~10^{-7}

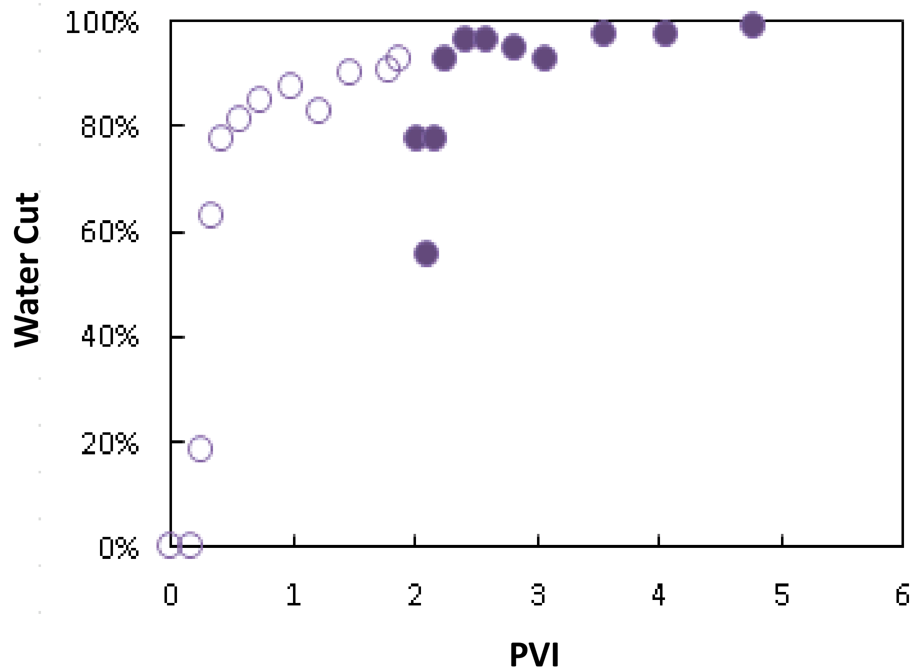


Coreflooding Experiments

Berea Sandstone: strongly oil-wet by cooking with oil

- ○ Carbonated water injection at 1500psi
- ◍ Pressure transition from 1500psi to 600psi
- ● Carbonated water injection at 600psi

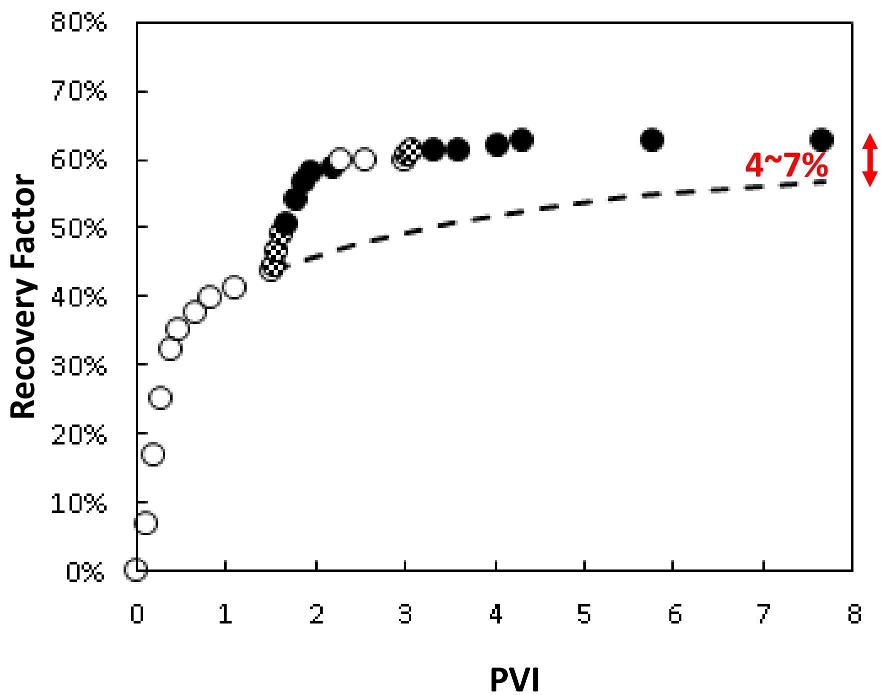


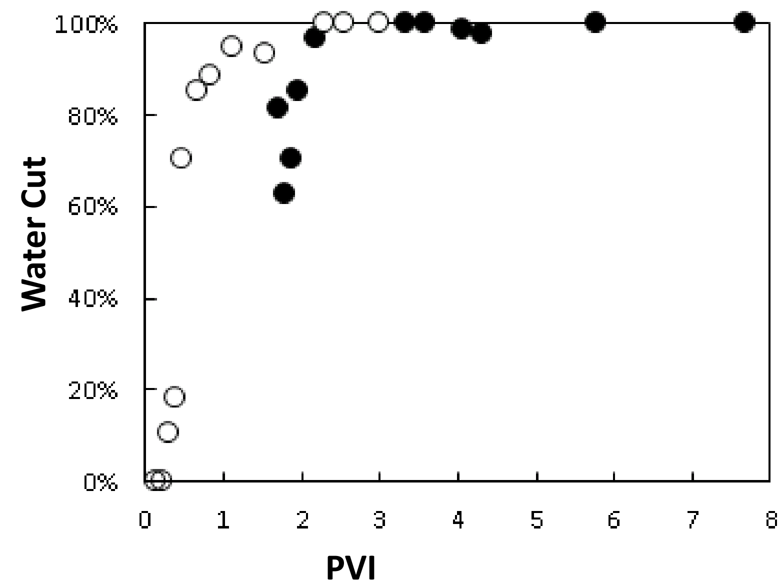


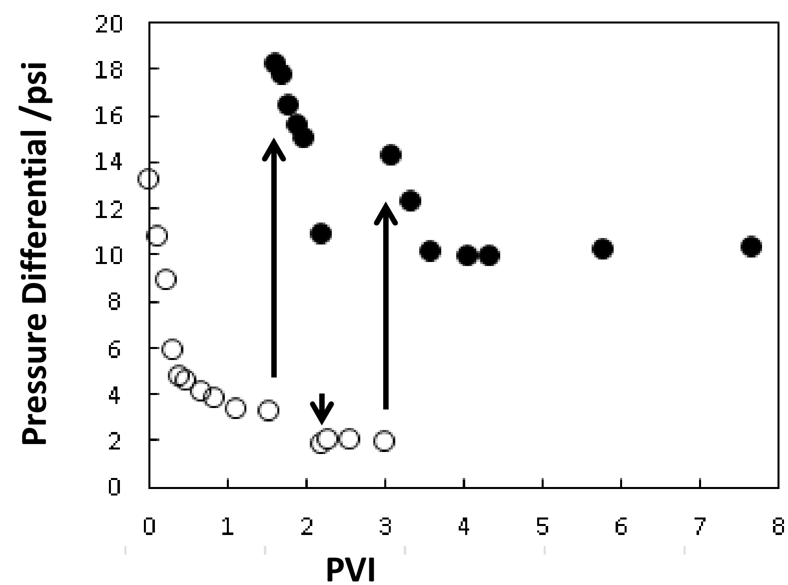
Coreflooding Experiments

Berea Sandstone: water-wet

- ○ Carbonated water injection at 1500psi
- ◍ Pressure transition from 1500psi to 600psi
- ● Carbonated water injection at 600psi







Summary

- Snap-off is favorable in CO_2/water systems which produces dispersed gas phase with low mobility;
- Water conformance can be achieved locally and water mobility reduction is sustainable;
- Effective local mobility control can be provided by CO_2 exsolution to enhance oil recovery during or after water flooding.

ACKNOWLEDGEMENTS:

This work is funded by the Global Climate and Energy Project (GCEP) at Stanford University;

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GCEP

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Solution Gas Drive

Nucleation:

$$\frac{2\sigma\cos\theta}{r_c} = KC_\infty(t) - P_l(t)$$

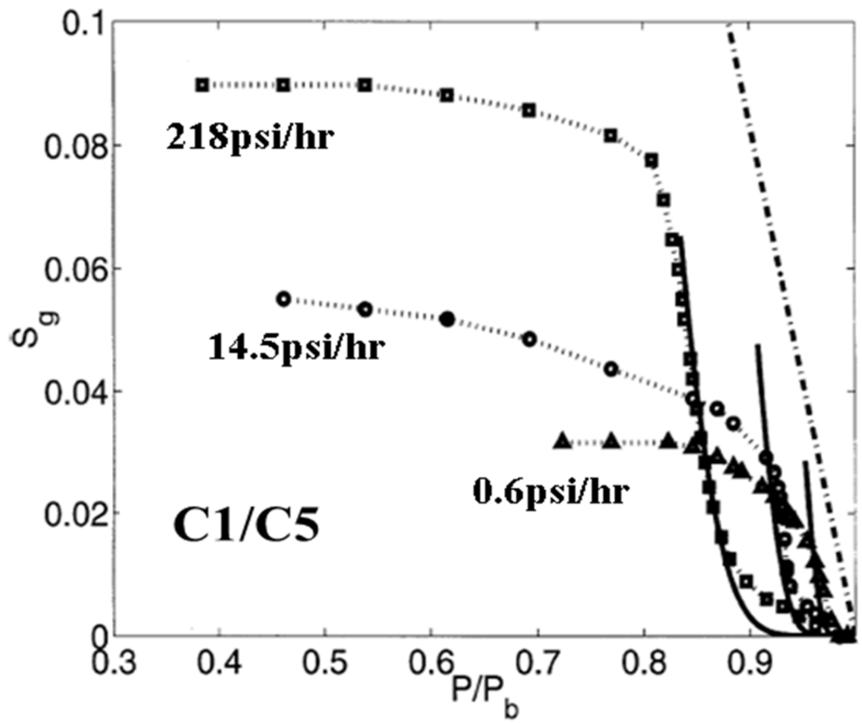
Diffusion:

$$z(\frac{M_w}{RT})\frac{d}{dt}(P_l V_g) \approx 4\pi\lambda R_j D(C_\infty - C_j)$$

$IFT_{C1/C5}$ = 0.2~1 mN/m

$IFT_{CO2/water}$ = 30~50 mN/m

Rate Dependent Gas Saturation Profile and Mobility



Scherpenisse et al. (1994)
Tsimpanogiannis and Yortsos (2002)