Laboratory Evaluation of CO$_2$ flow and EOR
*Insight through Visualization*

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Present study part of an ongoing multi-scale approach for **mobility control** in heterogeneous and fractured reservoirs during CO₂ EOR
Supercritical CO$_2$ injection in Fractured Systems

Field of view

Rock properties
Core K: 3.6 mD
Core Por: 0.45
Fracture K: > 2 D
S$_o$=1.0
CO₂ Diffusion during Injection
Development in oil saturation during CO$_2$ Injection

Oil saturation profiles

Average oil saturation

![Graphs showing oil saturation profiles and average oil saturation over time.](image-url)
Calculation of diffusion coefficient

- **Experimental data**
- **Analytical solution**

Graph showing CO₂ saturation [frac.] vs. dimensionless distance from fracture for different time periods (0 hours, 0.33 hours, 0.67 hours, 2.17 hours, 4.08 hours).
CO$_2$ EOR by diffusion at increasing length scales
Observations

• Miscible CO₂ injection for EOR is an effective oil recovery technology in laboratory floods in fractured systems
• High oil recoveries were observed:
  – 96 %OOIP
• Diffusion main production mechanism in system with open fracture
• Oil recovery is sensitive to system size
• Care should be taken when laboratory tests are used to predict field performance where diffusion is a possible production mechanism
Can we use foam in fractured reservoirs?

- Large remaining reserves in heterogeneous carbonate reservoirs. Many of these are heavily fractured
- Oil recovery low due to microscopic and macroscopic - low volumetric sweep efficiency
- Foam is a proven EOR technique in heterogeneous reservoirs – limited usage in fractured reservoirs
- Will foam be a viable option for mobility control in a fractured reservoir?
Scientific Outcome

- Scientific questions investigated
  a. Can foam generate within the fracture network itself?
  b. How will foam generate with changes in flow rate and gas fraction?
  c. What is the best injection strategy for foam?
Fracture Network – White Marble

Fracture white marble tile using ball-pen hammer
- Rough-walled fracture surface
- Surface tension equal to calcite

FRACTURE NETWORK A

FRACTURE NETWORK B

1 foot
FRACTURE NETWORK B

SIDE VIEW
- Plexiglas plates
- Fluid connectors
- Fractured marble plate

TOP VIEW

1 foot
Foam significantly improved sweep and delayed gas breakthrough compared with pure gas injection.
Sector sweep efficiency – Fracture network A

Sweep Efficiency [%]

Normalized Length

1  2  3  4  5  6

Sweep efficiency for different sectors:
- Co inj
- SAG
- CGI
Foam is consistently generated *in situ* in rough-walled, calcite fracture networks during coinjection of gas and surfactant over a range of gas fractional flows.
PET
Positron Emission Tomography

- Explicit imaging – tracking the fluids
- Enhanced signal to noise ratio compared with CT
- Varying temporal resolution – post processing
- High photon energy
- Signal is temperature and pressure independent
- Tracers used
  a. $^{18}\text{F}$ (Half life: 109 minutes)
  b. $^{22}\text{Na}$ (Half life: 2.6 years)
  c. $^{11}\text{C}$ (Half life: 20 minutes)
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References


