UNIVERSITY OF BERGEN

Department of Physics and Technology

Laboratory Evaluation of CO_2 flow and EOR *Insight through Visualization*

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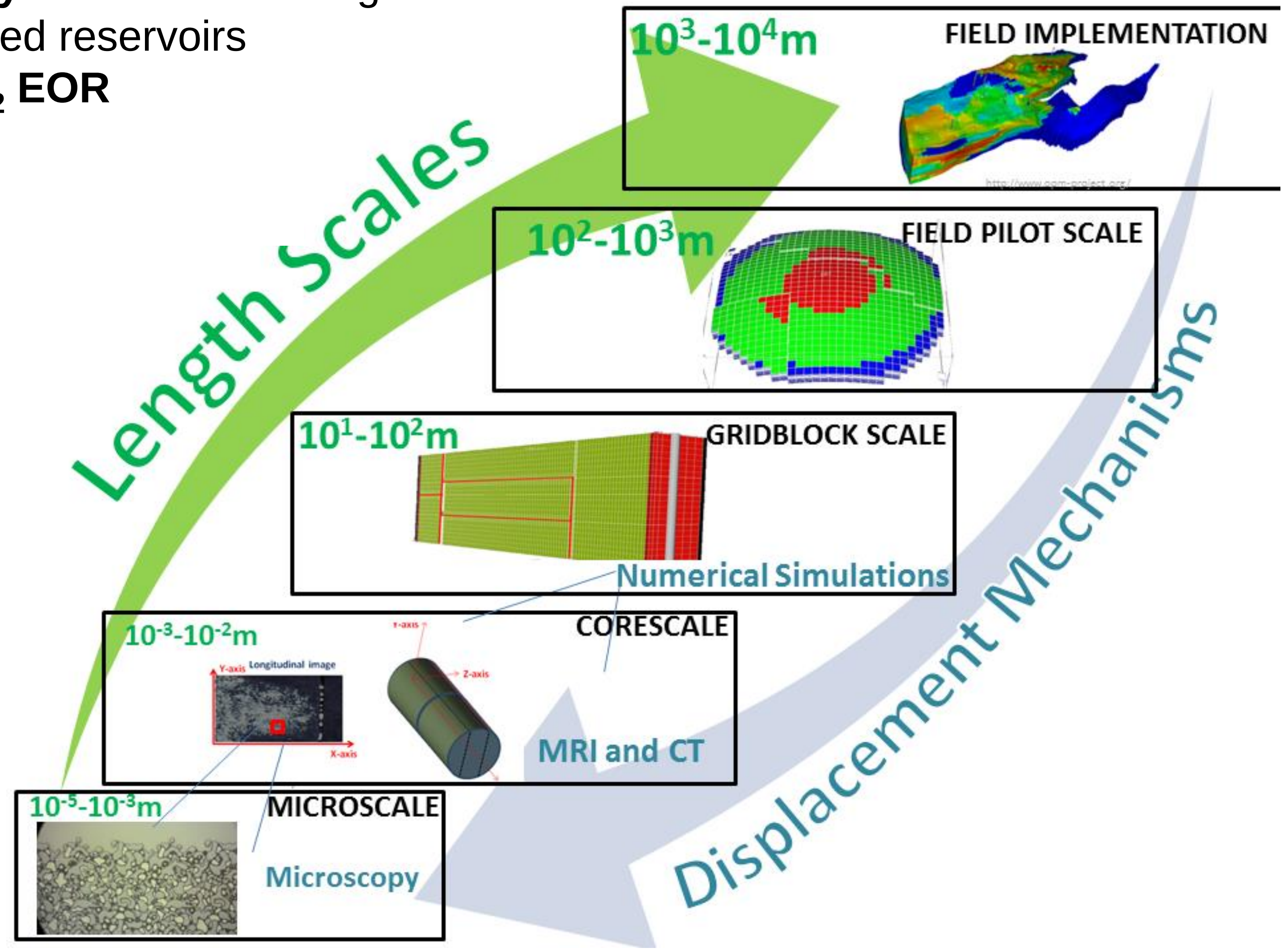
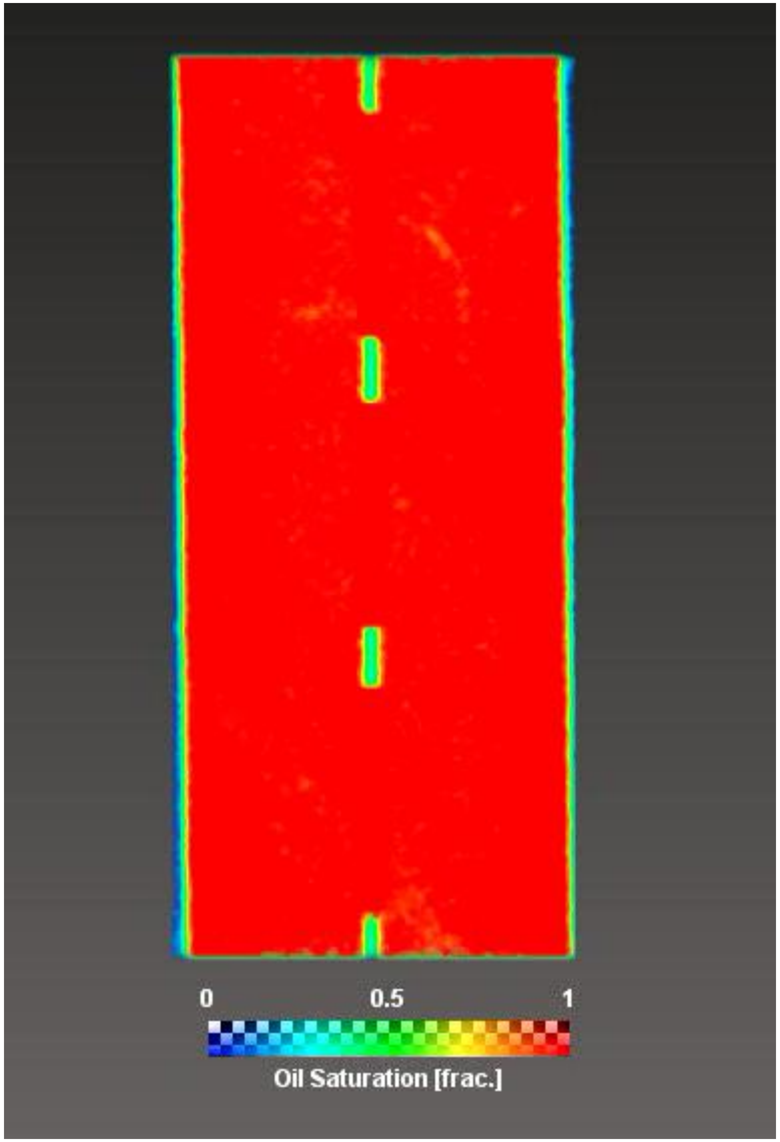
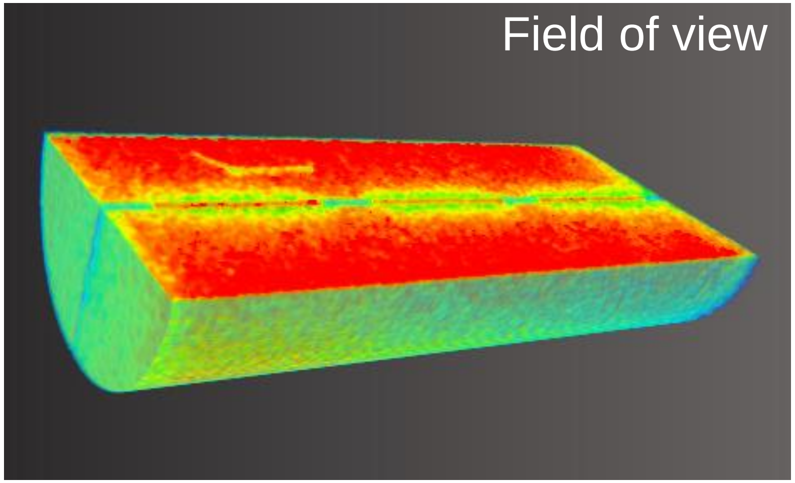
CO_2 injection for EOR

Present study part of an ongoing multi-scale approach for **mobility control** in heterogeneous and fractured reservoirs during **CO_2 EOR**



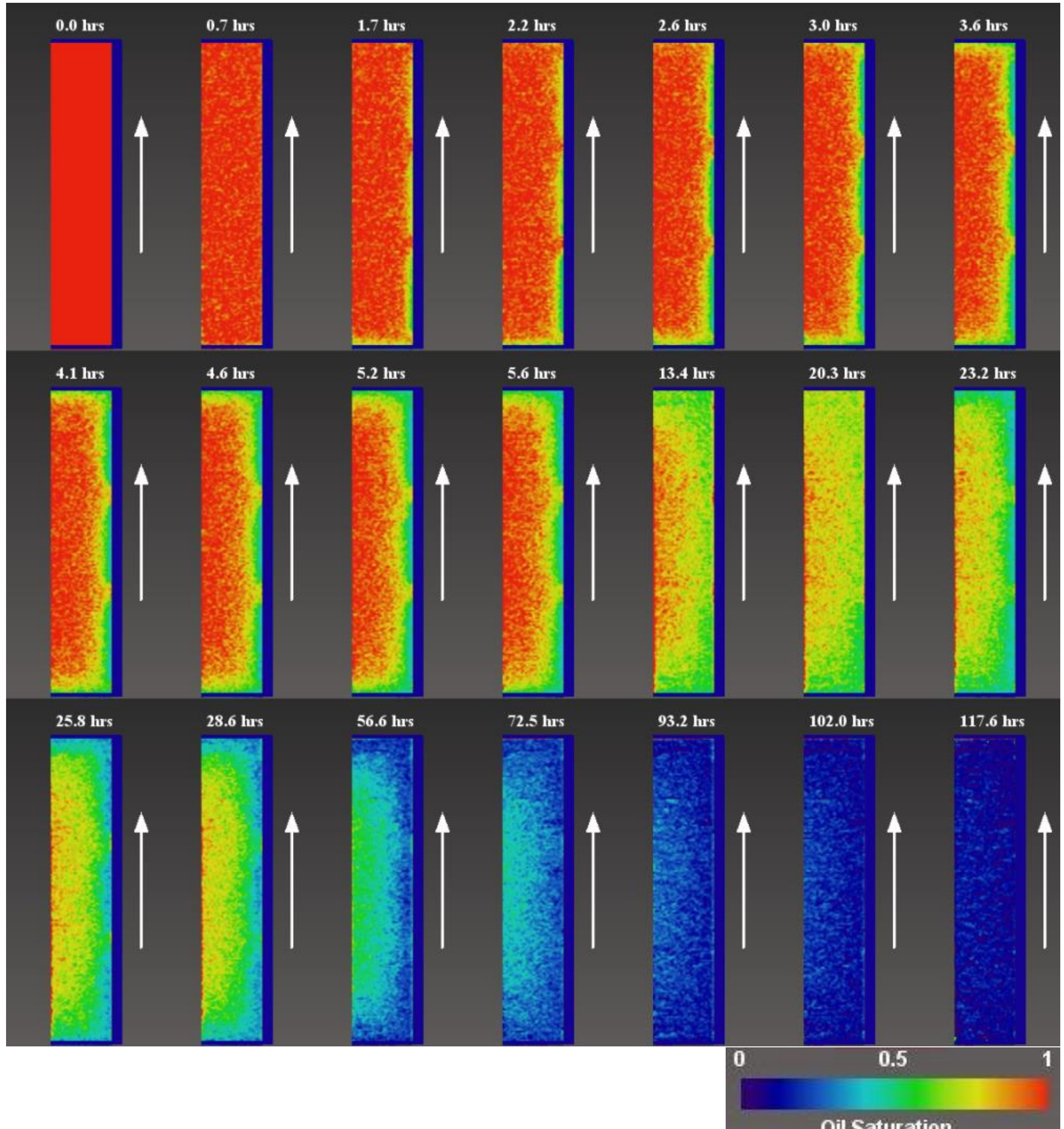
Supercritical CO_2 injection in Fractured Systems

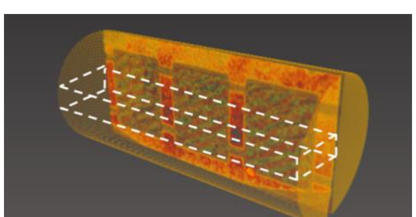




<u>Rock properties</u>
Core K: 3.6 mD
Core Por: 0.45
Fracture K: > 2 D
S_o=1.0

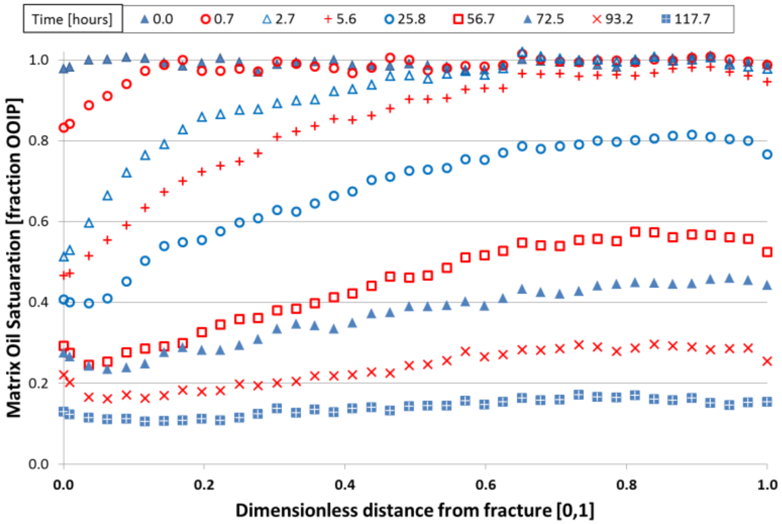
CO_2 Diffusion during Injection



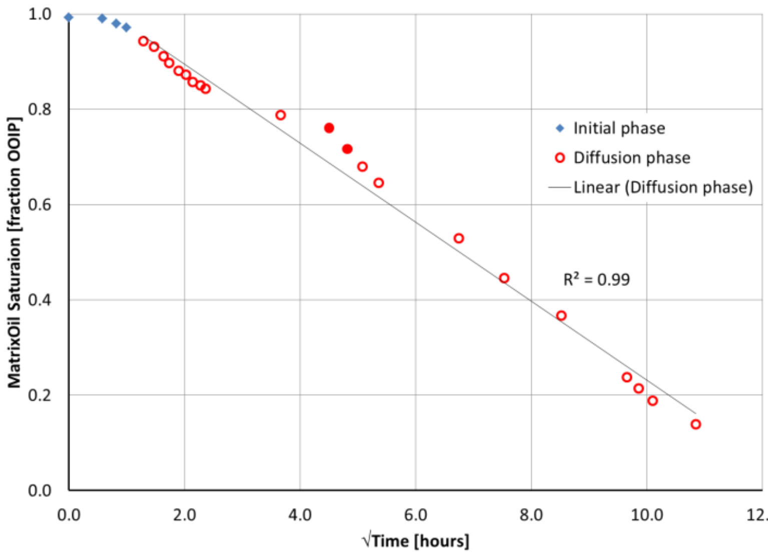


Development in oil saturation during CO_2 Injection

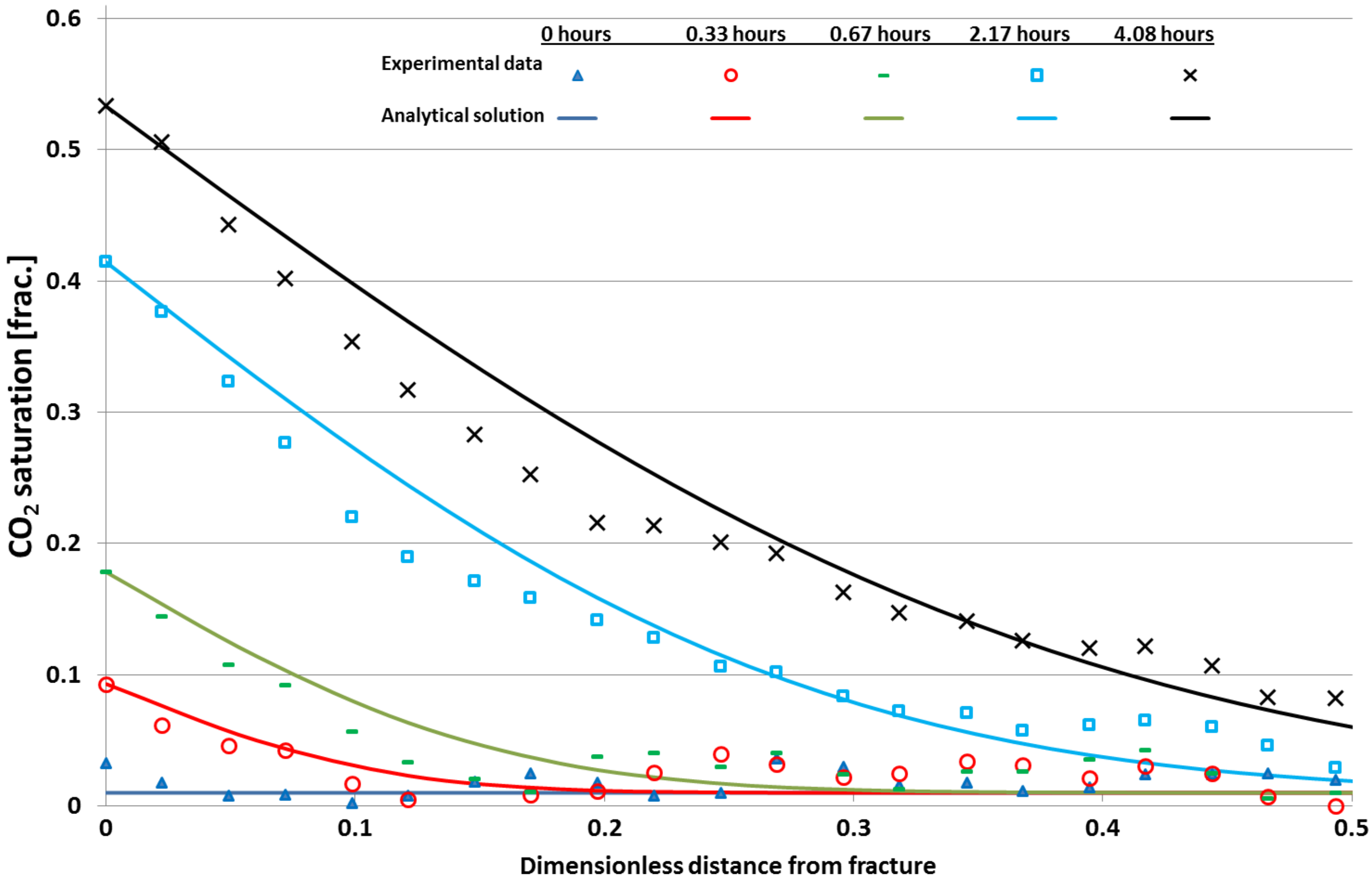
Oil saturation profiles



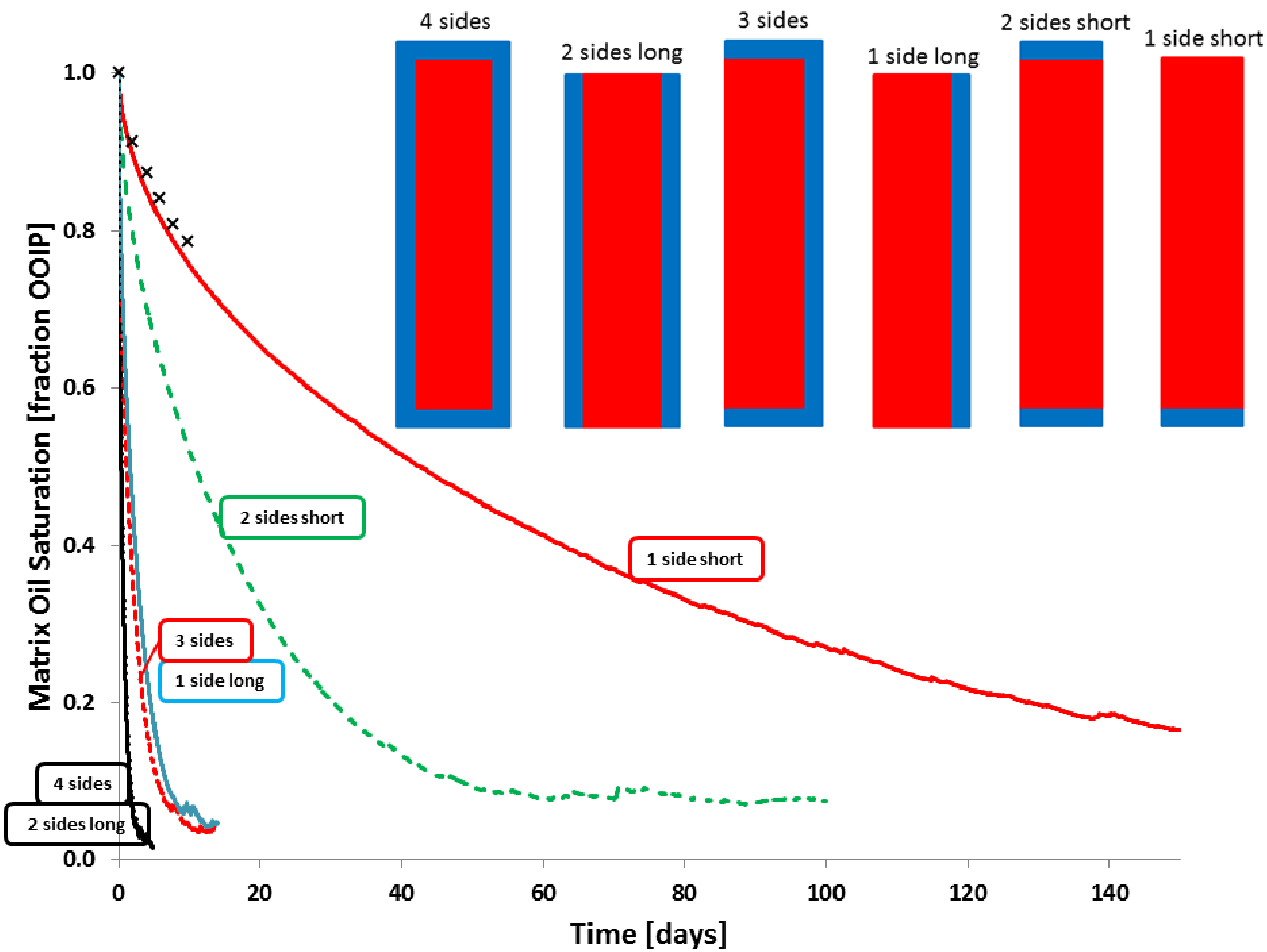
Average oil saturation



Calculation of diffusion coefficient



CO_2 EOR by diffusion at increasing length scales



Observations

- Miscible CO_2 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

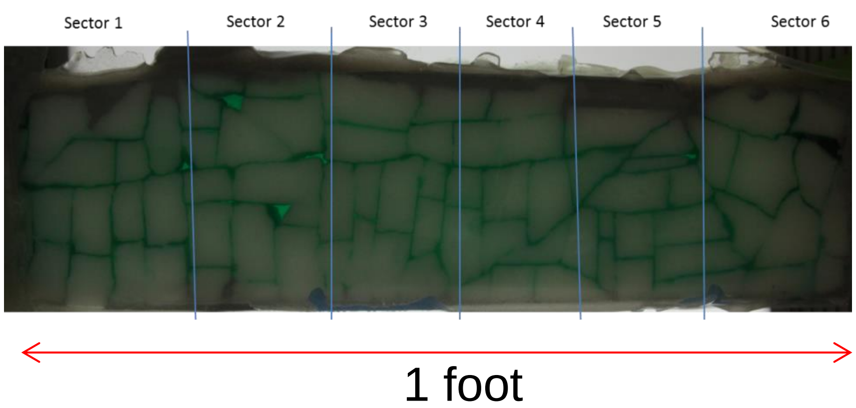
- Scientific questions investigated
  a. Can foam generate within the fracture network itself?
  b. How will foam generate with changes in flow rate and gas fraction?
  c. What it the best injection strategy for foam?

Fracture Network – White Marble

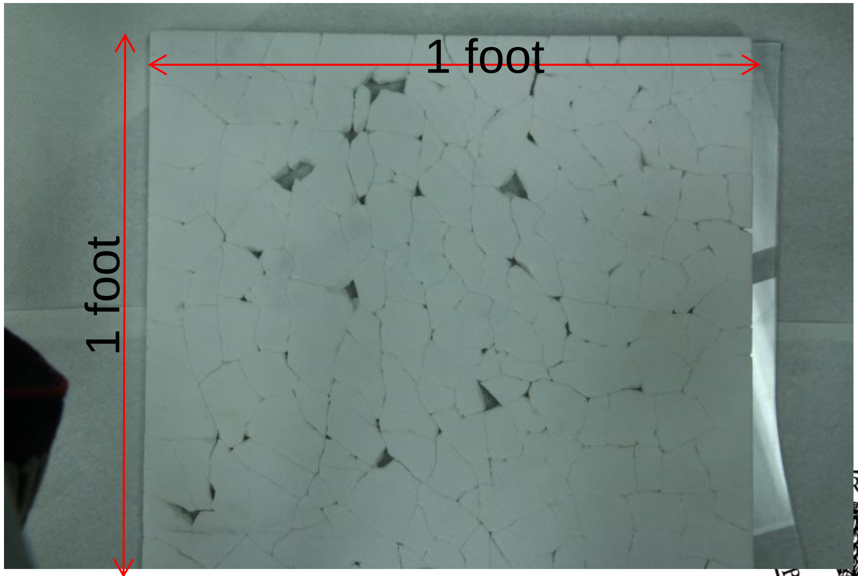
Fracture white marble tile using ball-pen hammer

- Rough-walled fracture surface
- Surface tension equal to calcite

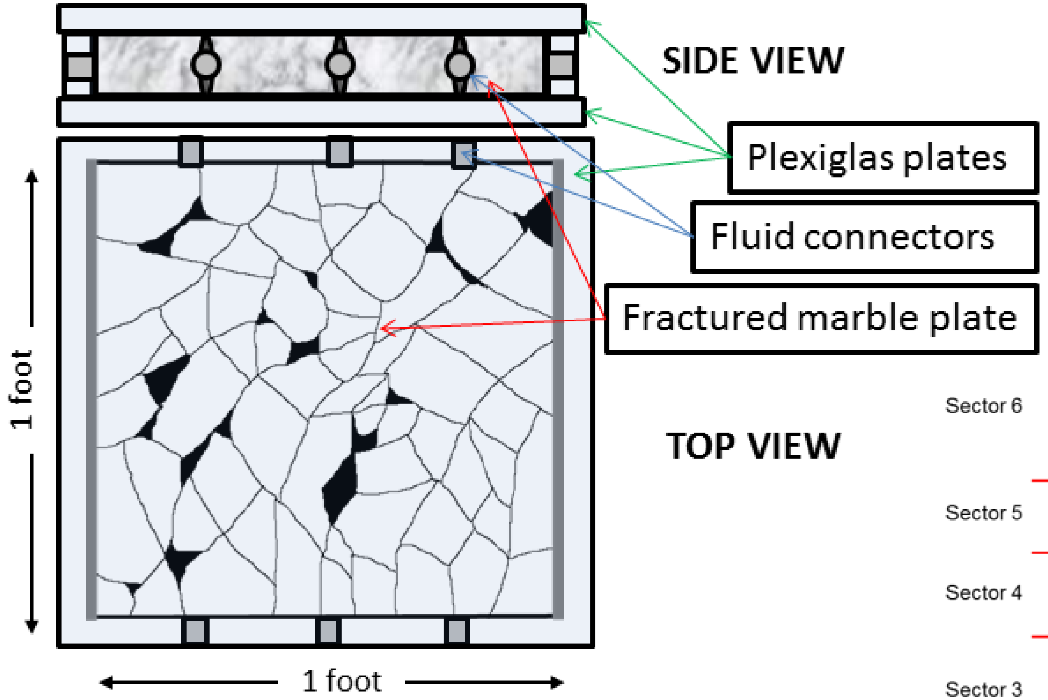
FRACTURE NETWORK A

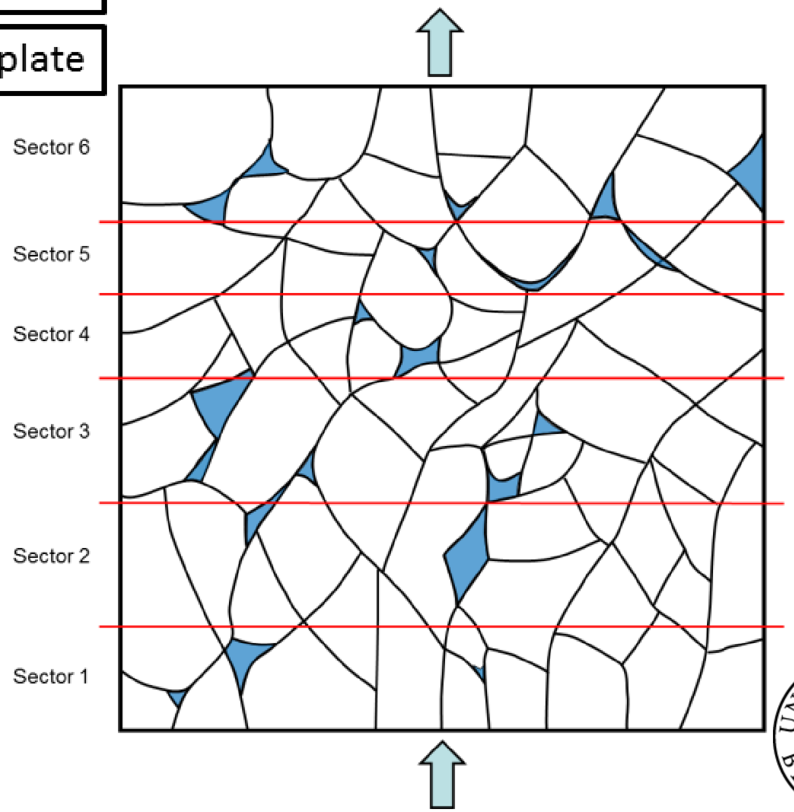


FRACTURE NETWORK B

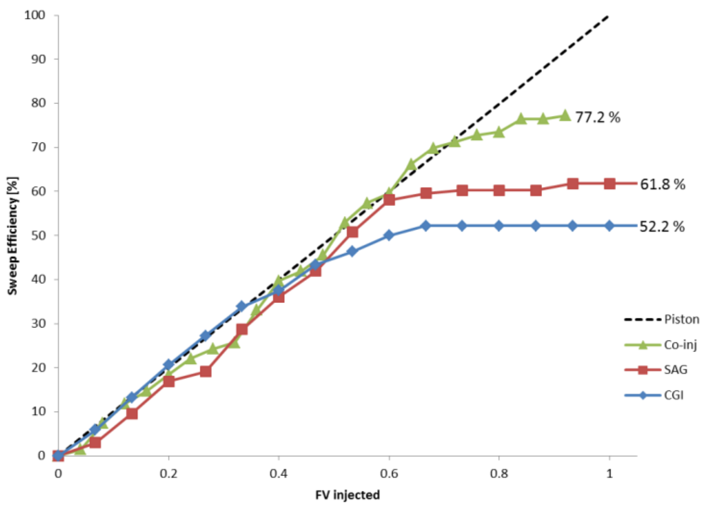


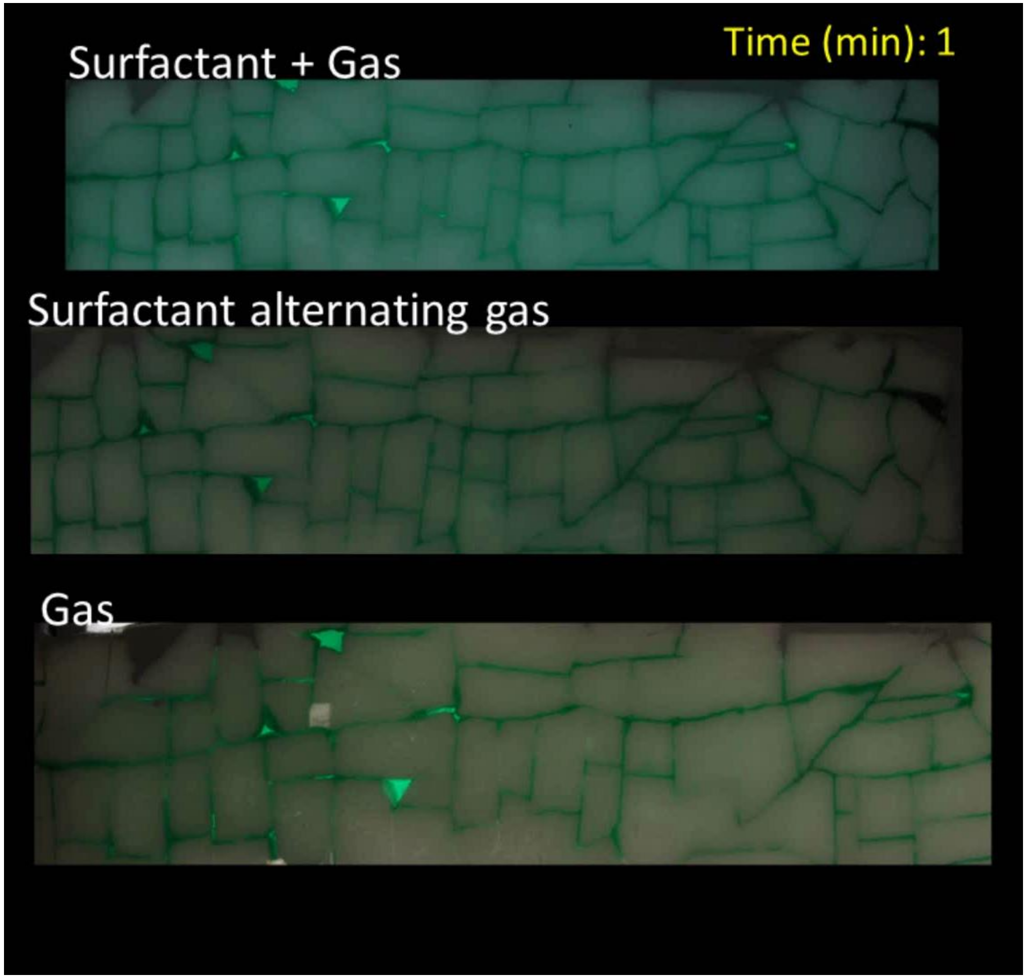
FRACTURE NETWORK B





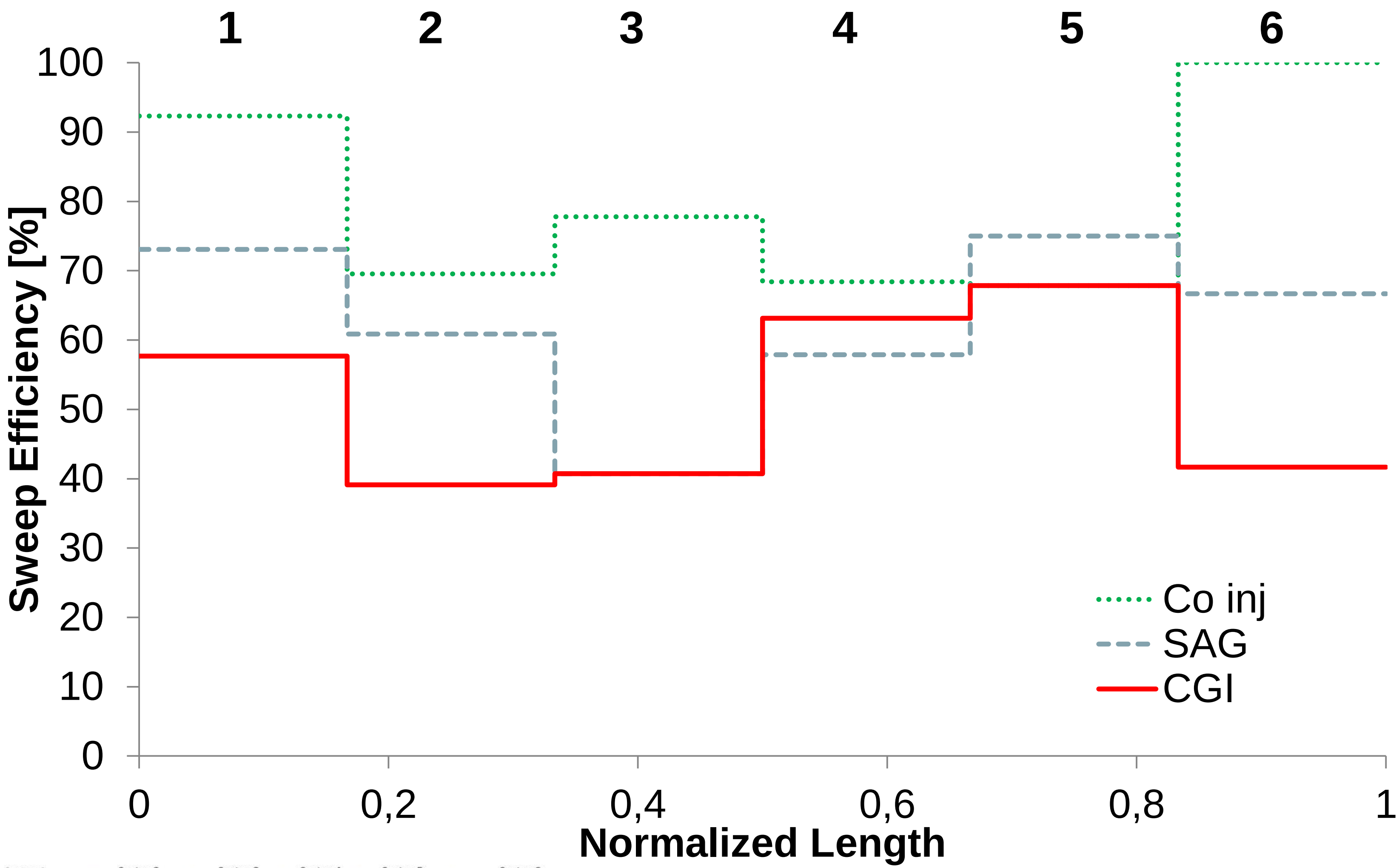
MOBILITY CONTROL WITH FOAM

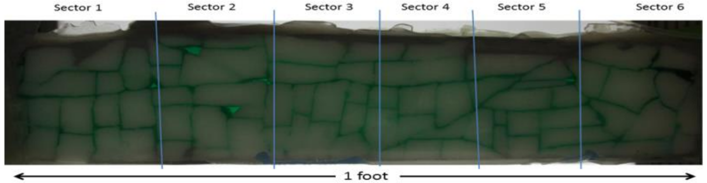




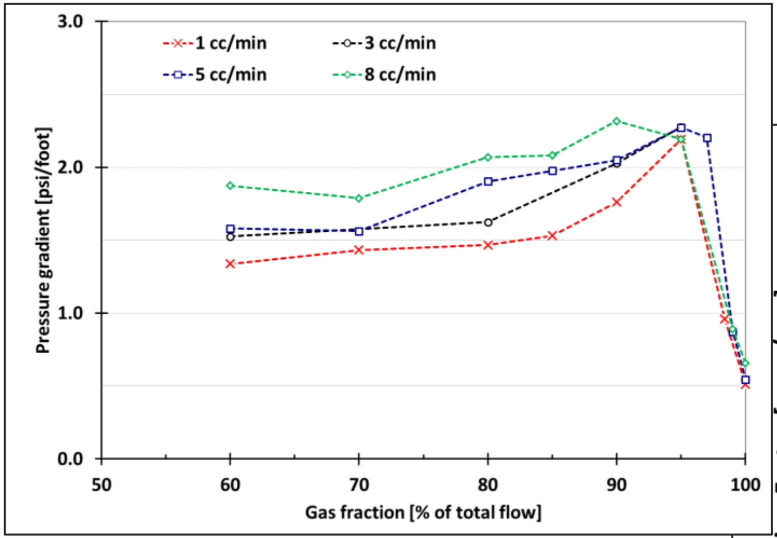
Foam significantly improved sweep and delayed gas breakthrough compared with pure gas injection

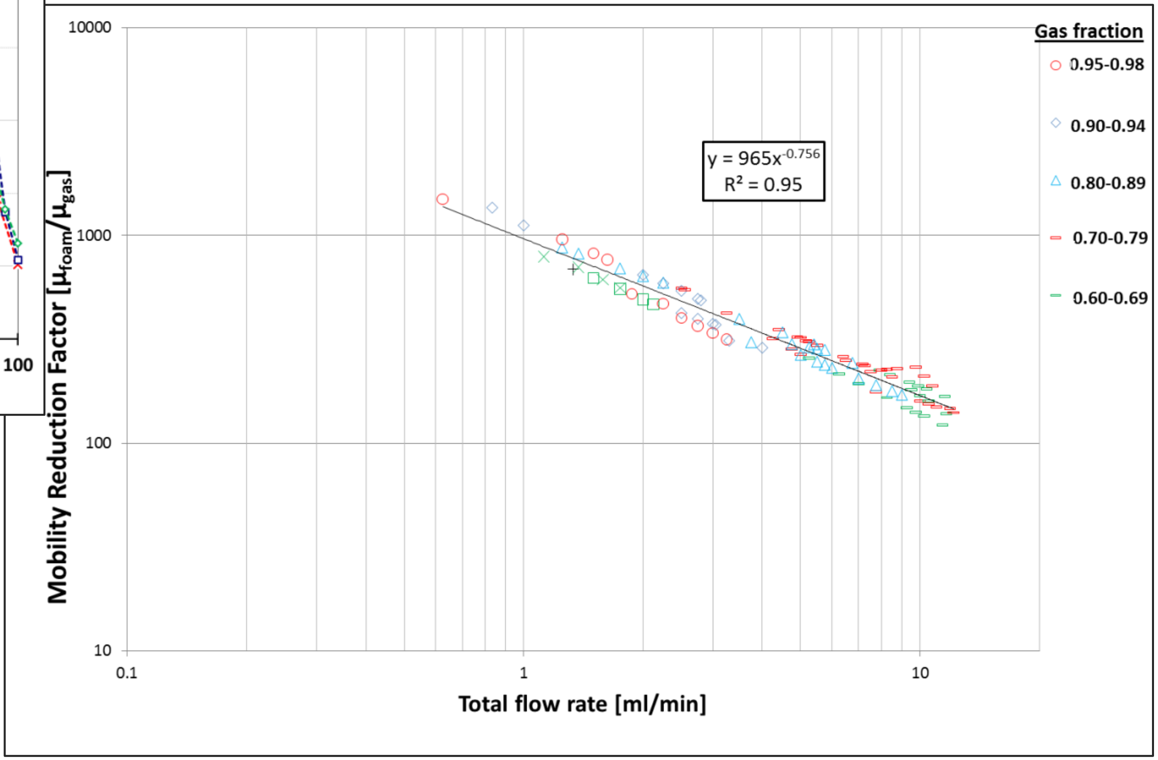
Sector sweep efficiency – Fracture network A





MOBILITY CONTROL WITH FOAM



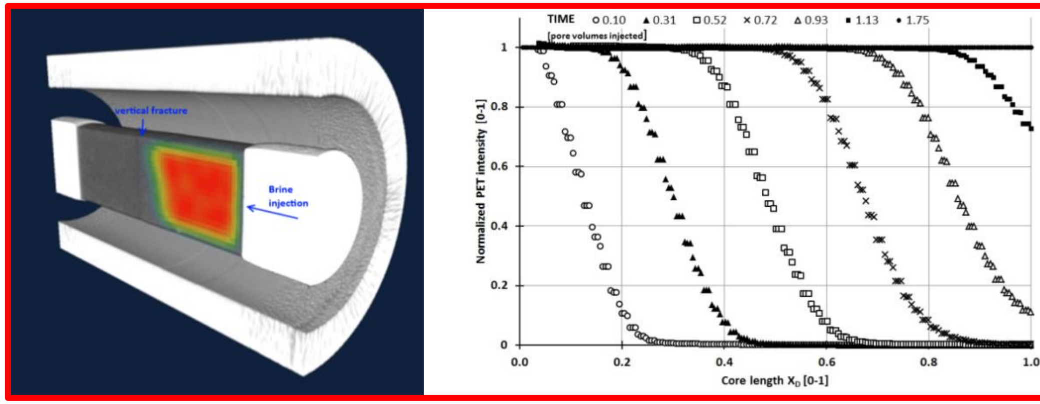


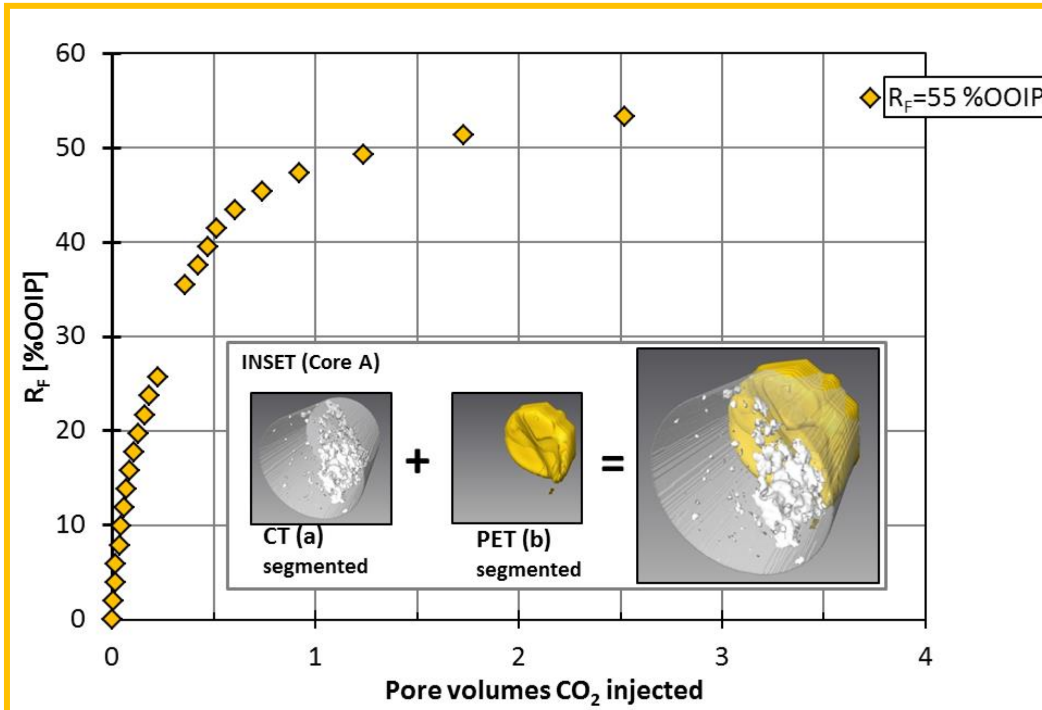
Foam is consistently **generated *in situ*** in rough-walled, calcite fracture networks during coinjection of gas and surfactant over a range of gas fractional flows

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}F (Half life: 109 minutes)**
  - b. **^{22}Na (Half life: 2.6 years)**
  - c. **^{11}C (Half life: 20 minutes)**





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