Understanding of CO₂ migration and entrapment- Cranfield site

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Assessment of CO$_2$ migration

- Having a Safe and reliable long-term storage of injected CO$_2$
- Ultimate goal: Storage over geologic time

- Our primary concerns:
  - How far will the CO$_2$ plume travel (CO$_2$ footprint)
  - How long does the CO$_2$ plume remain mobile

- Assessment framework ——> Migration mechanisms of CO$_2$
- Prediction of CO$_2$ plume migration path ——> Numerical simulation and experiments
How is CO₂ stored in a saline aquifer?

✓ CO₂ immobilization in the formation through trapping mechanisms during the injection and post-injection period.

- **Structural Trapping**: CO₂ gets physically trapped beneath the sealing caprock and low permeability layers.
- **Residual (capillary) Trapping**: CO₂ gets trapped as immobile isolated residual 'blobs' in the pore space.
- **Solubility (dissolution) Trapping**: CO₂ dissolves into brine.
- **Mineral Trapping**: CO₂ gets mineralised (formation of carbonate minerals).
Reservoir Heterogeneity

- Geological heterogeneity of subsurface reservoirs
- Scales ranging from the pore scale (microns) up to a regional CCS network (hundreds of kilometers).
- Fluvial depositional setting heterogeneity in lower Tuscaloosa formation

Core samples taken from different wells in the Cranfield site (lower Tuscaloosa)
Pore-scale simulation on Tuscaloosa rock samples

- Developed a **pore-scale multiphase flow simulator**
- Tuscaloosa core samples: depth of ~ 10465 ft.
- Using high resolution CT imaging of Tuscaloosa sample
- Study the cases which are unpredictable using experimental approach
- Computationally fast, using **high performance computing** system (parallel computing) at the Texas Advanced Computing Center at the University of Texas at Austin.
**CO₂ residual trapping - Pore-scale simulations**

- Simulation of CO₂ migration pathway during **injection period**
- Long-term stabilization of CO₂ plume during the early-stage of **post-injection period**
- Effect of **injection rate** and rock mineralogy (**wettability**) on CO₂ migration pattern and its residual trapping

**Tuscaloosa sample**

**Injection period**
- CO₂ injection

**Brine Flooding**
- Brine layer connected CO₂ layer

**Post-injection period**
- Rock

- Sahar Bakhshian
How Subtle Heterogeneity Helps Increase Trapped Saturations

Subtle changes in grain sizes and capillary entry pressures (<1 kpa) lead to drastic changes in trapped saturations

- Experimental Setup

- Crossbeds with Increasing Capillary Heterogeneity
  - Capillary Pressure Contrast: 107 pa
  - Saturation: 0.45%
  - Trapped Saturation: 0.33%
  - Capillary Pressure Contrast: 360 pa
  - Saturation: 6.33%
  - Trapped Saturation: 5.9%
  - Capillary Pressure Contrast: 760 pa
  - Saturation: 24.8%
  - Trapped Saturation: 23.5%

- Background subtracted: Bright regions Indicate Fluids

- Prasanna Krishnamurthy
1) Solubility trapping can account for 30–40% of the total capacity in long-term storage

2) Convective mass transfer greatly increases the CO₂ dissolution rate and significantly reduces the risk of leakage
**Objectives:**
- Drive a **mathematical formulation** to predict CO₂ plume extension
- finding a quicker and easier alternative to numerical simulation

**Result:**
- Very good agreement between mathematical model and numerical simulation (CMG-GEM) results.

**Conclusion:**
- The CO₂ plume extension depends on the injection rate, CO₂ viscosity, permeability, relative permeability, fluid densities, thickness, and dip angle.

- Hosseininoosheri et al., 2019 (submitted to Scientific Report)
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Conclusion

- Integrated experimental and numerical simulation approaches can be applied to access long-term fate of CO$_2$ plume during the post-injection period.

- Having knowledge about the trapping mechanisms in subsurface reservoirs can provide insight into the efficiency of CCS operations.
Thank you