Understanding of CO_2 migration and entrapment- Cranfield site

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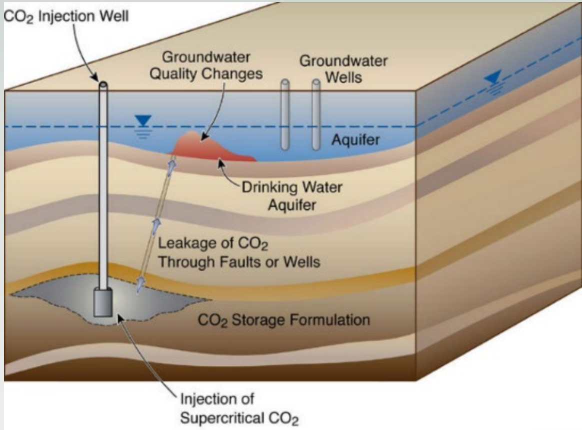
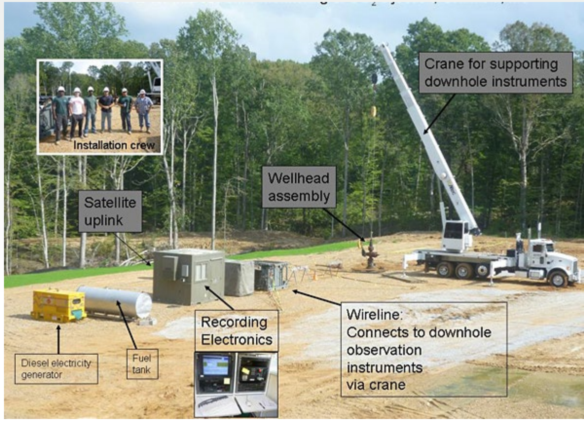
Assessment of CO_2 migration

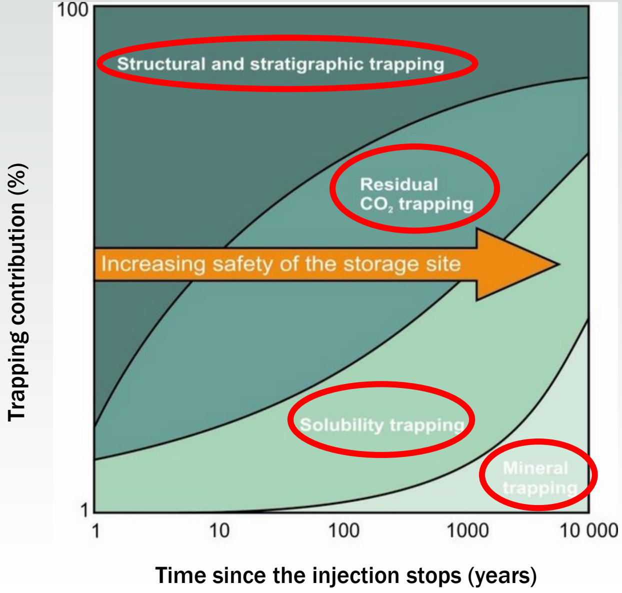
- Having a Safe and reliable long-term storage of injected CO_2
- Ultimate goal: Storage over geologic time
- Our primary concerns: → How far will the CO_2 plume travel (CO_2 footprint) → How long does the CO_2 plume remain mobile
- Assessment framework → **Migration mechanisms of CO_2**
- Prediction of CO_2 plume migration path → **Numerical simulation and experiments**

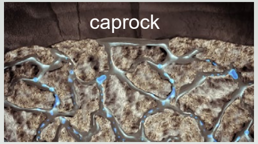




How is CO_2 stored in a saline aquifer?

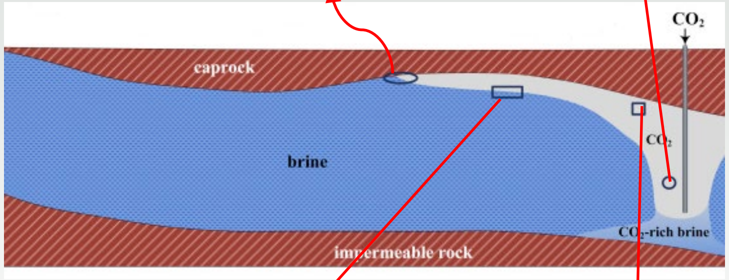
✓ CO_2 immobilization in the formation through trapping mechanisms during the **injection** and **post-injection period**





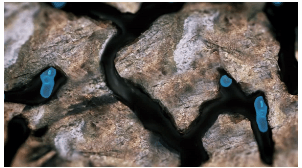
Structural Trapping: CO_2 gets physically trapped beneath the sealing cap-rock and low permeability layers

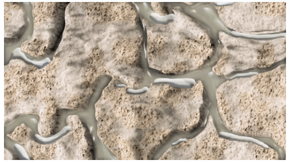
Residual (capillary) Trapping: CO_2 gets trapped as immobile isolated residual 'blobs' in the pore space



Solubility (dissolution) Trapping: CO_2 dissolves into brine

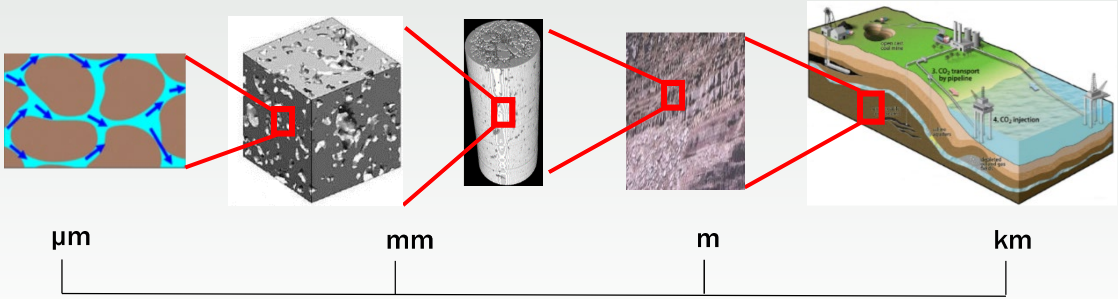
Mineral Trapping: CO_2 get mineralised (formation of carbonate minerals)



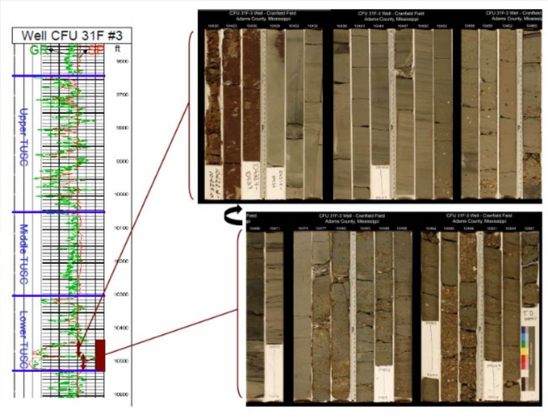


Reservoir Heterogeneity

- 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



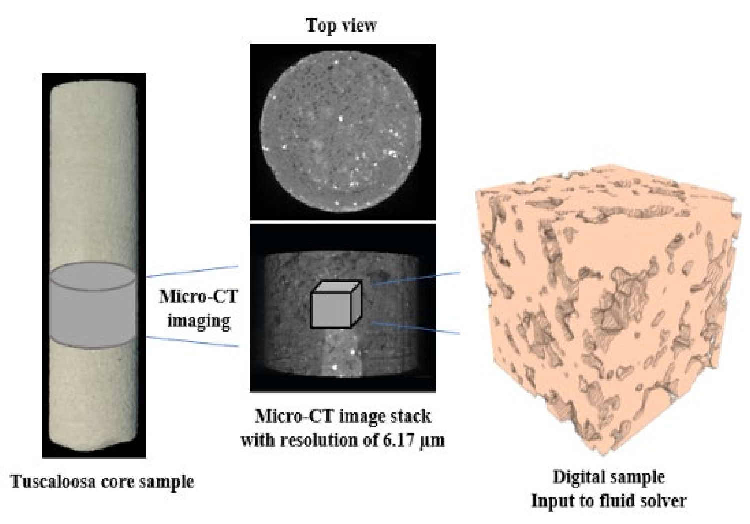
Pore (microscopic) scale **Bedform scale** **Field scale**



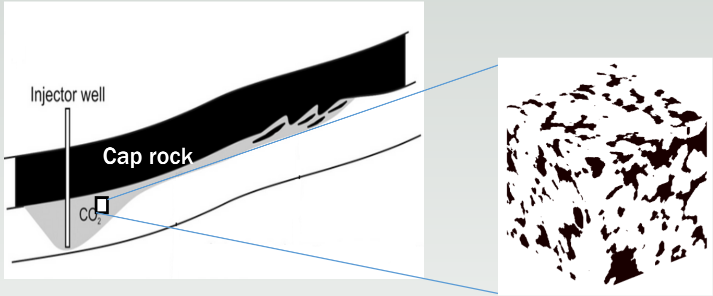
Core samples taken from different wells in the Cranfield site (lower Tuscaloosa)

Pore-scale simulation on Tuscaloosa rock samples

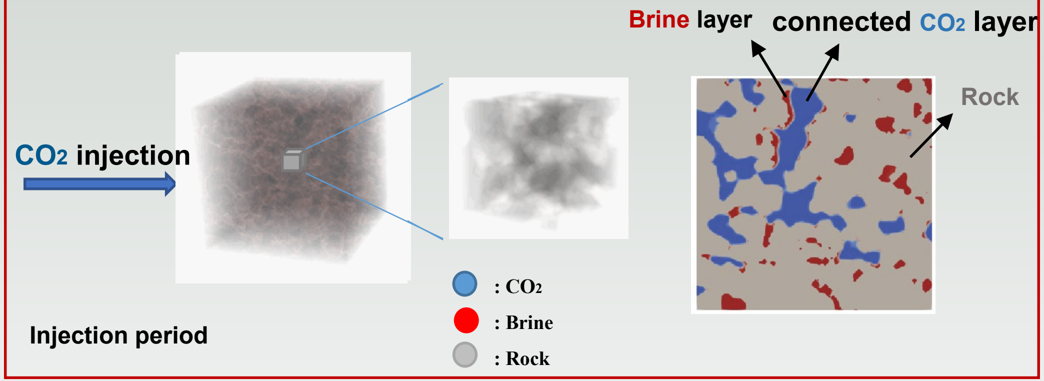
- Developed a **pore-scale multiphase flow simulator**
- Tuscaloosa core samples: depth of ~ 10465 ft.
- Using high resolution CT imaging of Tuscaloosa sample
- Study the cases which are unpredictable using experimental approach
- Computationally fast, using **high performance computing** system (parallel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

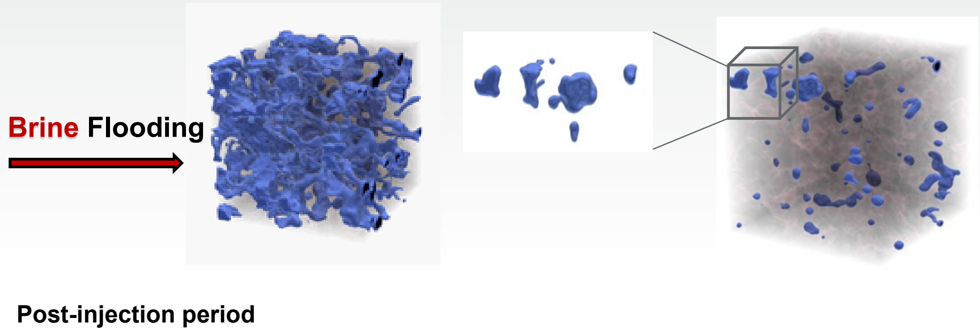


CO_2 residual trapping- Pore-scale simulations



Tuscaloosa sample

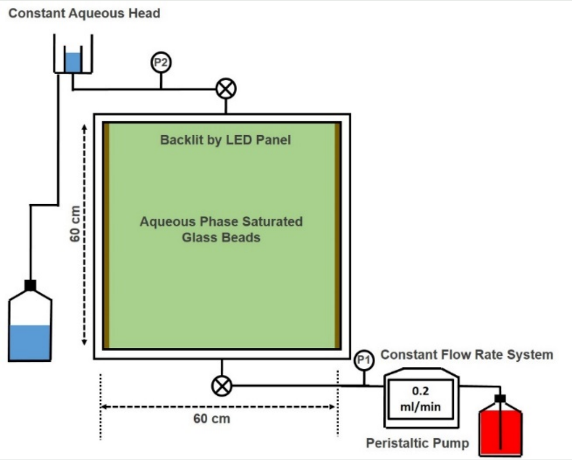




- Simulation of CO_2 migration pathway during **injection period**
- Long-term stabilization of CO_2 plume during the early-stage of **post-injection period**
- Effect of **injection rate** and rock mineralogy (**wettability**) on CO_2 migration pattern and its residual trapping

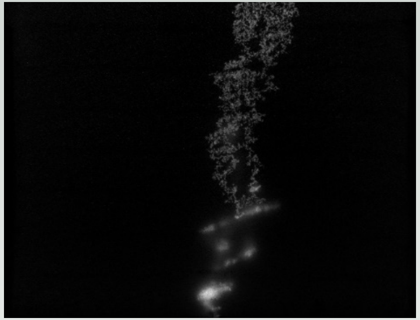
• Sahar Bakhshian

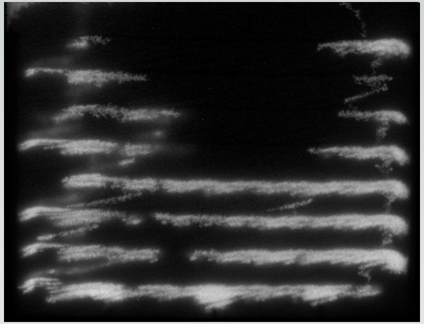
How Subtle Heterogeneity Helps Increase Trapped Saturations

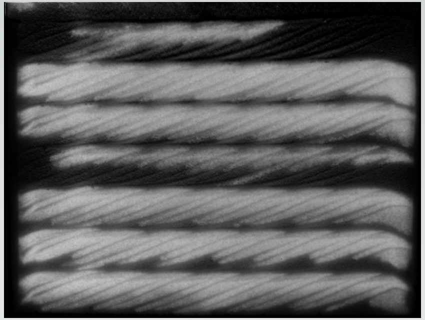


Experimental Setup

Background subtracted: Bright regions Indicate Fluids







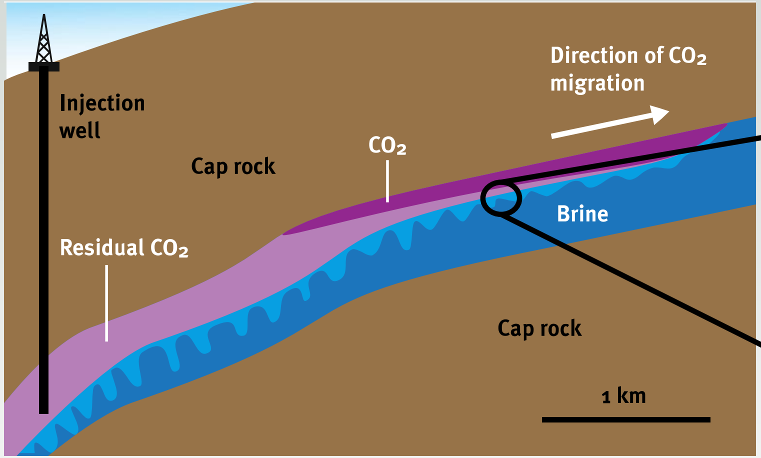
Crossbeds with Increasing Capillary Heterogeneity

Capillary Pressure Contrast: 107 pa	Capillary Pressure Contrast: 360 pa	Capillary Pressure Contrast: 760 pa
Saturation: 0.45%	Saturation: 6.33%	Saturation: 24.8%
Trapped Saturation: 0.33%	Trapped Saturation: 5.9%	Trapped Saturation: 23.5%

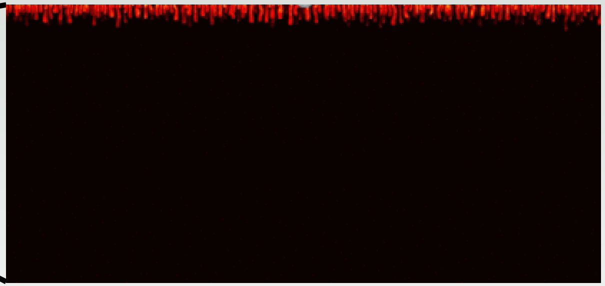
Subtle changes in grain sizes and capillary entry pressures (<1 kpa) lead to drastic changes in trapped saturations

- Prasanna Krishnamurthy

Solubility trapping- Simulation



Schematic of geologic CO_2 storage (Blunt 2010)



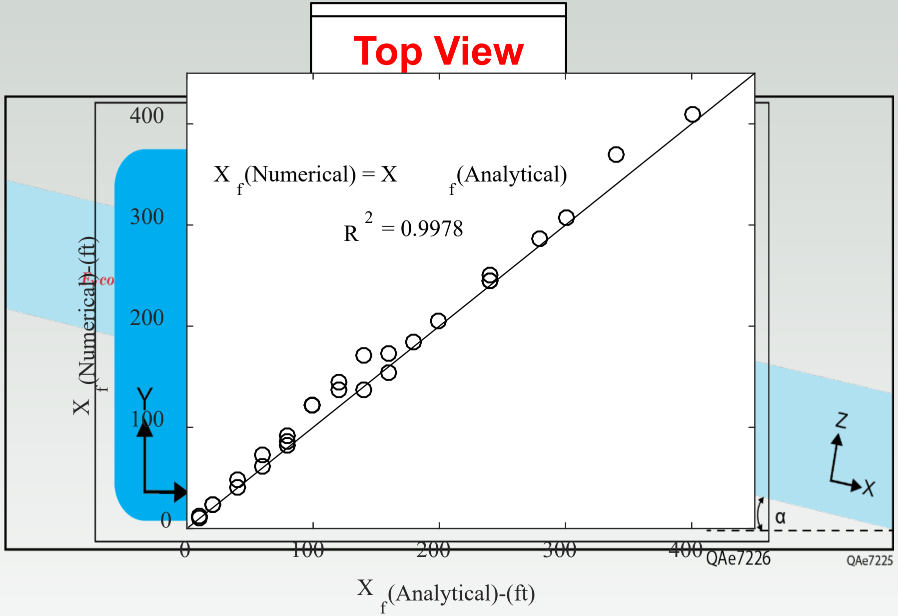
Convective CO_2 dissolution
(Darcy scale, Wen *et al*. 2018)

1) Solubility trapping can account for 30–40% of the total capacity in long-term storage
2) Convective mass transfer greatly increases the CO_2 dissolution rate and significantly reduces the risk of leakage

CO_2 Plume Migration in Dipping Aquifers- A field-scale study

Objectives:

- ➢ Drive a **mathematical formulation** to predict CO_2 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 CO_2 plume extension depends on the injection rate, CO_2 viscosity, permeability, relative permeability, fluid densities, thickness, and dip angle.

We found a correlation for effective relative permeability.

- 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