CO_2 Exsolution – Challenges and Opportunities in Subsurface Flow Management

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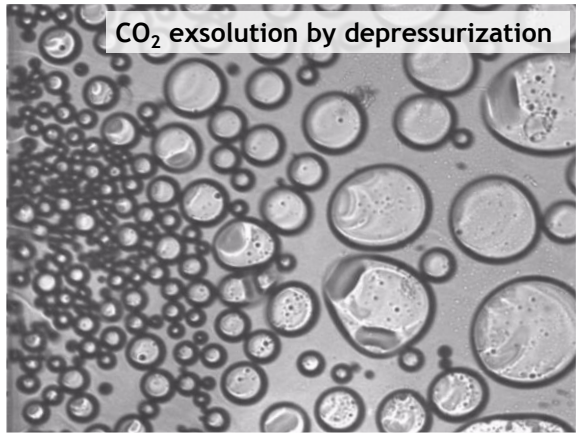
Contents

Introduction

What is exsolution ?

--- gas liberation from a solution.



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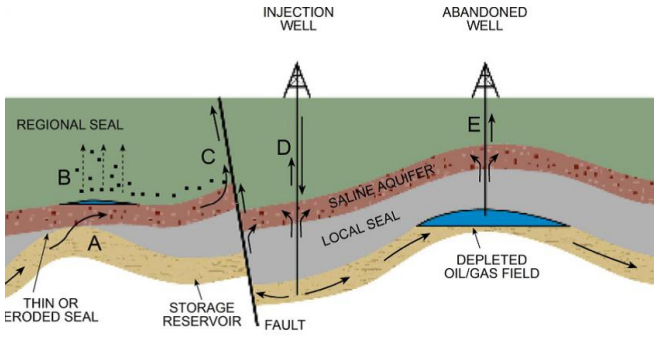
Exsolution in Geological Carbon Sequestration

Geological carbon sequestration

--- storage of CO_2 permanently in designated reservoirs.

Any possible exsolution in carbon sequestration ?

--- upward migration of carbonated water.



Kaldi and Daniel, 2010

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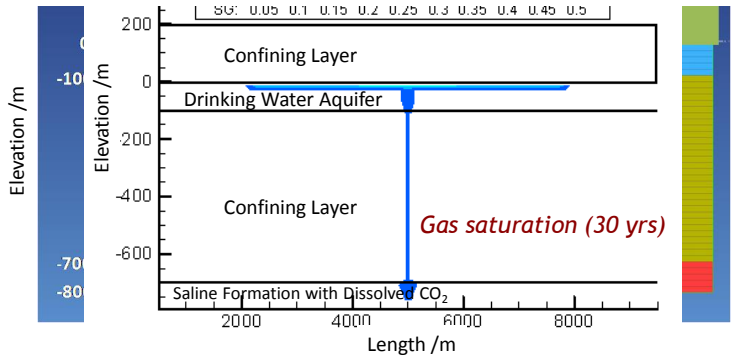
Exsolution in Geological Carbon Sequestration

Carbonated brine could migrate upward through an open fault towards a shallow drinking water aquifer*:

Does exsolution create risks for carbon storage security ?
--- the mobility of exsolved CO_2 and the influence on subsurface flow.



*Falta et al., 2013

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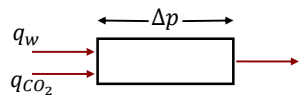
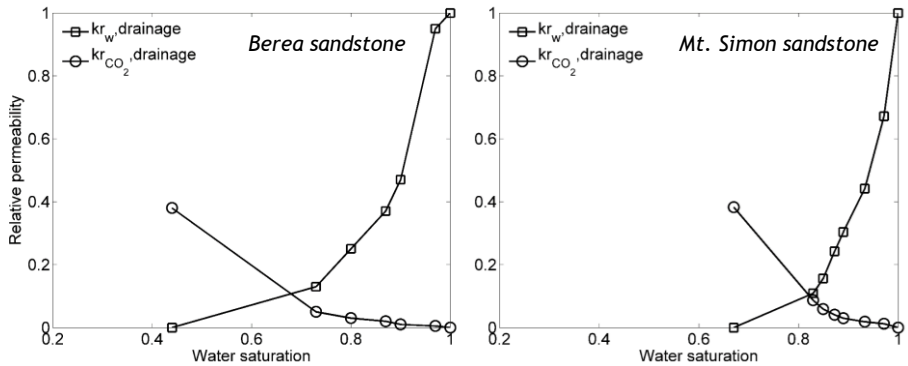
Core-scale Measurements

Relative permeability curves:





*Krevor et al., 2013

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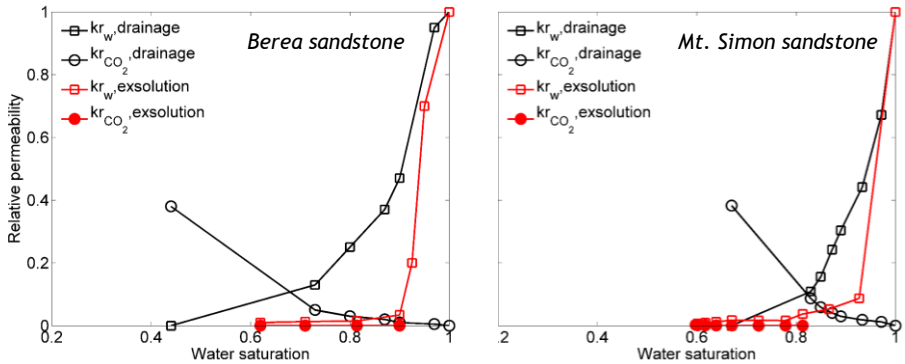
Core-scale Measurements

Relative permeability curves:

- Extremely low CO_2 relative permeabilities are recorded in both Berea and Mt. Simon sandstones (10^{-5}~10^{-3})**.
- Water mobility is largely influenced by exsolved CO_2, compared to drainage in the same rocks**.



*Krevor et al., 2013
**Zuo et al., 2012

Questions and Answers

What is the mobility of exsolved CO_2? And what is the influence on subsurface flow?

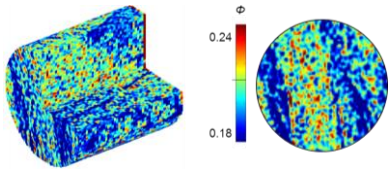
Exsolved CO_2 has extremely low relative permeabilities and it disproportionally reduces water mobility.

What causes the difference?

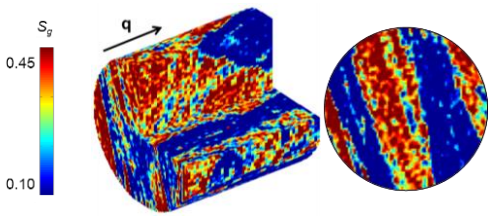
Core-scale Measurements

Where does CO_2 exsolve?

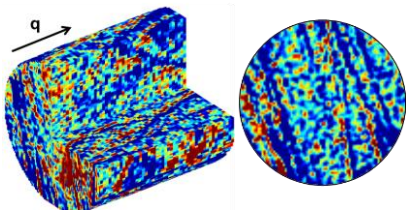
Porosity distribution of a Berea sandstone



Distribution of injected CO_2



Distribution of exsolved CO_2

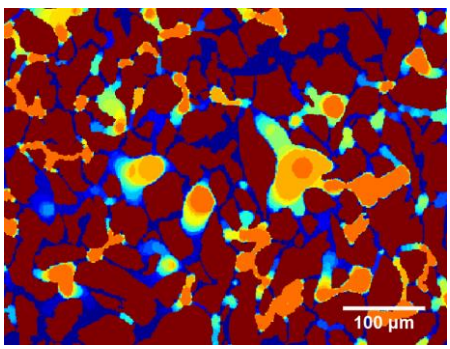


*Zuo et al., 2014

Pore-scale Observations

Micromodel observations:

- Exsolved CO_2 is distributed uniformly in the porous medium.
- Exsolved CO_2 is poorly connected, compared to CO_2 introduced by drainage.



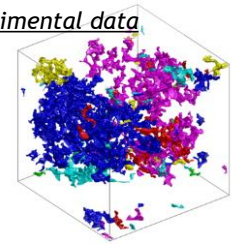
- Most of exsolved gas is trapped by capillary pressure, which leads to low gas mobility.

*Zuo et al., 2013

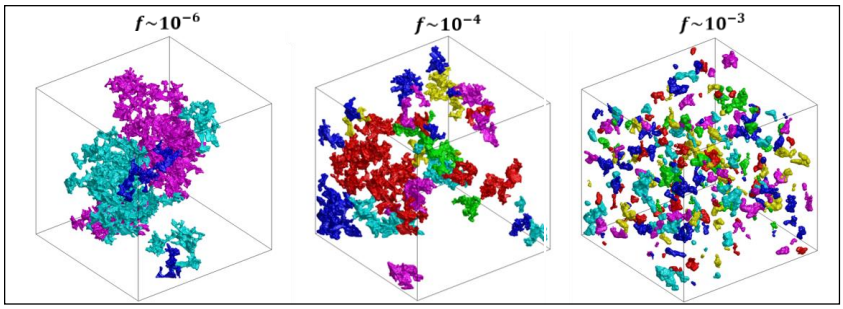
Gas Growth Modeling

- A model is developed to simulate gas exsolution in digital rock volumes.
- Influences of nucleation, mass transfer and rock types are studied.

Experimental data



Simulations



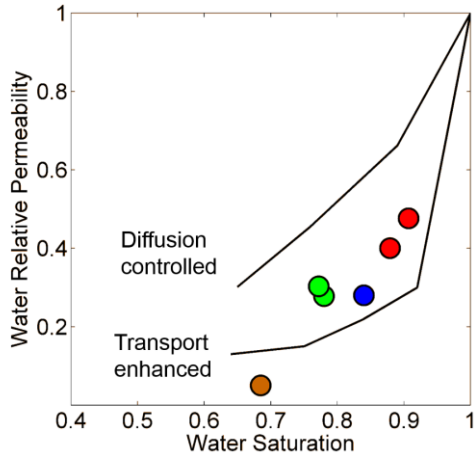
Water Relative Permeability Calculation

Calculate fluid velocity distributions with modeled exsolved gas distributions:

- Water flow is largely influenced by exsolved CO_2
- Water relative permeability curve can be estimated by assuming:
  - ✓ Rock is water-wet;
  - ✓ Capillary pressure controls fluid distribution;
  - ✓ Exsolved gas is immobile.

Water Relative Permeability Calculation

Comparison to experimental measurements:



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Questions and Answers

Exsolved CO_2 behaves differently than CO_2 introduced by drainage in the subsurface, in terms of key multiphase flow properties such as relative permeability and trapping.

What causes the difference?

Dispersed and poorly connected gas phase preferentially formed in high flow pore space leads to low gas mobility and large reduction of water mobility.

What are the implications for subsurface flow management?

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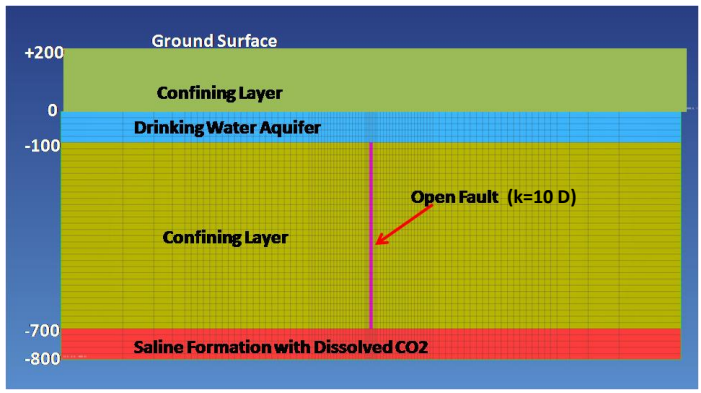
Exsolution in Geological Carbon Sequestration

Simulations are performed to illustrate how a CO_2 saturated brine could migrate upward through an open fault towards a shallow drinking water aquifer*:



*Falta et al., 2013

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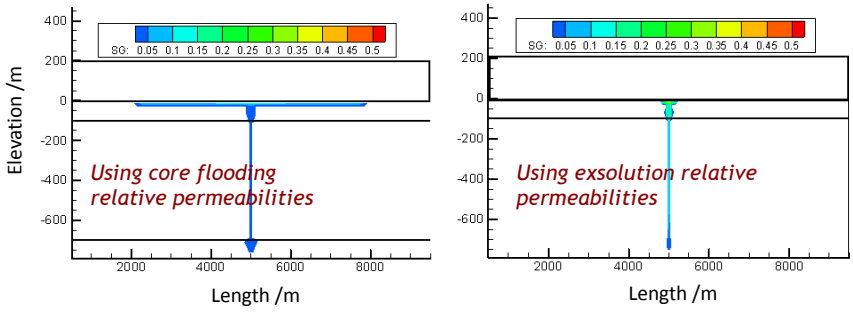
Exsolution in Geological Carbon Sequestration

Simulations are performed to illustrate how a CO_2 saturated brine could migrate upward through an open fault towards a shallow drinking water aquifer*:

Simulation results of gas saturation (30 yrs)



*Falta et al., 2013

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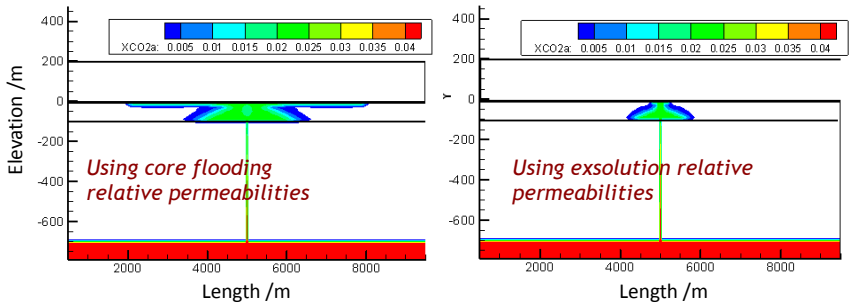
Exsolution in Geological Carbon Sequestration

Simulations are performed to illustrate how a CO_2 saturated brine could migrate upward through an open fault towards a shallow drinking water aquifer*:

Simulation results of dissolved CO_2 mass fraction (30 yrs)



1/4 of the amount of CO_2 leakage and 1/3 of the amount of brine leakage

*Falta et al., 2013

Exsolution in Geological Carbon Sequestration

Simulations are performed to illustrate how a CO_2 saturated brine could migrate upward through an open fault towards a shallow drinking water aquifer*:

Using traditional drainage multiphase flow parameterization in simulations involving exsolution will lead to overestimates of flows and large errors in transport rates.

*Falta et al., 2013

Conclusions

CO_2 Exsolution – Challenges and Opportunities in Subsurface Flow Management

Exsolved CO_2 has extremely low relative permeabilities in sedimentary rocks due to poorly interconnected distribution, and it disproportionally reduces water mobility.

Convective transfer in the aqueous phase plays an important role in bubble growth and accumulation during exsolution.

A developed mechanistic model reproduces experimental results and predicts brine mobilities under reservoir conditions.

CO_2 exsolution does not appear to create significant risks for storage security in geological carbon sequestration.

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GCEP

CO_2 Exsolution – Challenges and Opportunities in Subsurface Flow Management

Questions ?