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EXPERIMENTALLY REPLICATING BUOYANCY-DRIVEN FLOW AT RESERVOIR CONDITIONS

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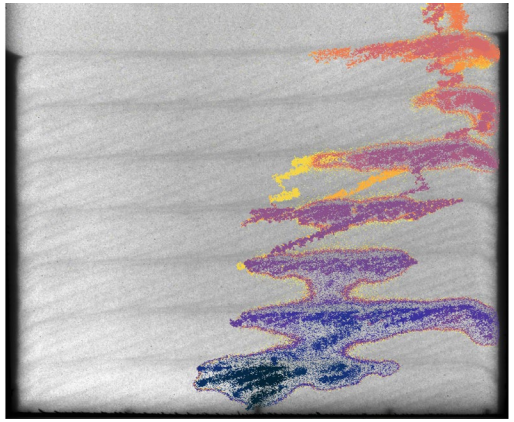
Buoyant flows in the subsurface

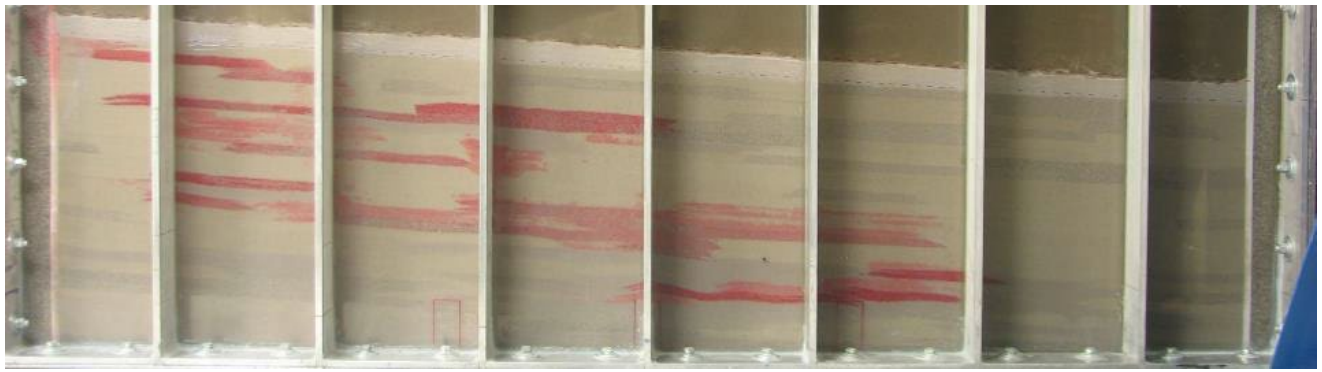
- Buoyant flows in subsurface
  - Hydrocarbon migration
  - CO2 storage
  - Gas injection
- Are they different than forced flows?
- Can we do at pressure?
- Can we image and make determinations on where flow takes place?
- Can we determine role of heterogeneity?



Krishnamurthy et al., AGU 2019

Imaging of flow in tank experiments

- Much work done in sand tanks
- Heterogeneity based on blocks
- Or can use sedimentary structures
- Only low pressure – have to use analog fluids



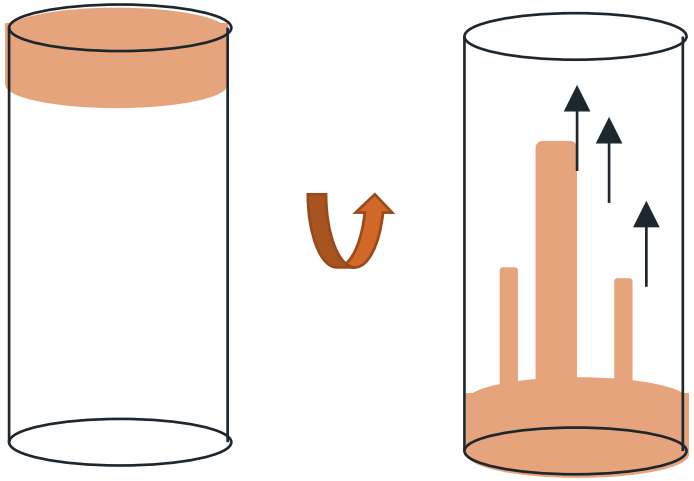
Trevisan et al., WRR 2017

High pressure buoyant flows

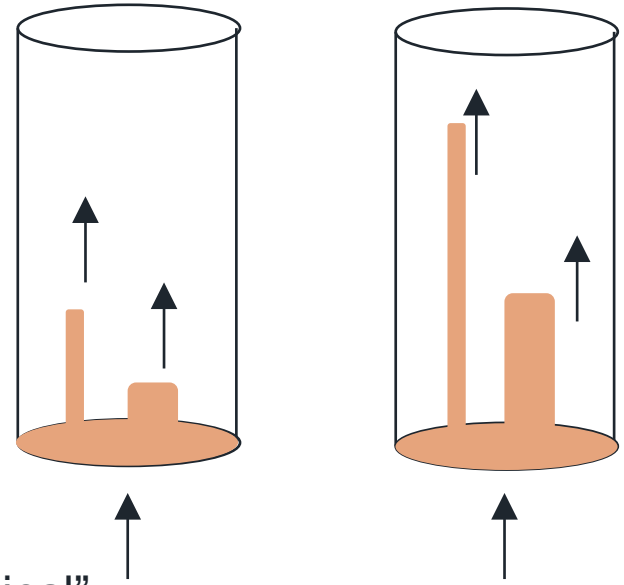
- Equipment exists to do flows at high pressures in labs – this is standard coreflooding
- Imaging can be applied through CT scanning
- Tricky part is that fluid is tightly controlled
- How to let it proceed like a buoyant flow?

Examples of buoyant flow in core holder

- Fill at top and flip over



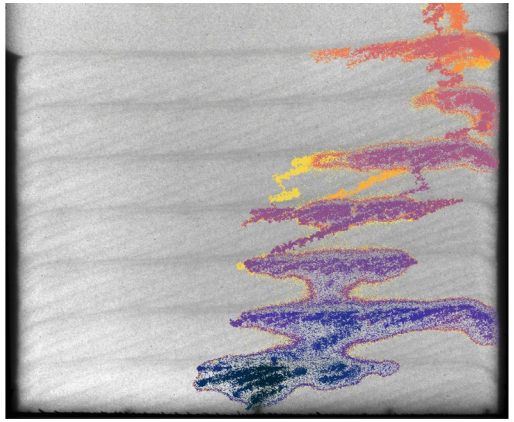
- Inject at "slow" rate



Injecting at slow rate is more "physical"

At what rate is a flow buoyant?

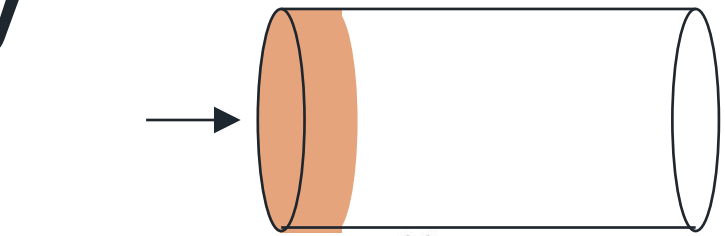
- Look at saturation distribution during displacement
- In buoyant flow gas saturation is higher upstream
- In viscous flow gas saturation is higher downstream

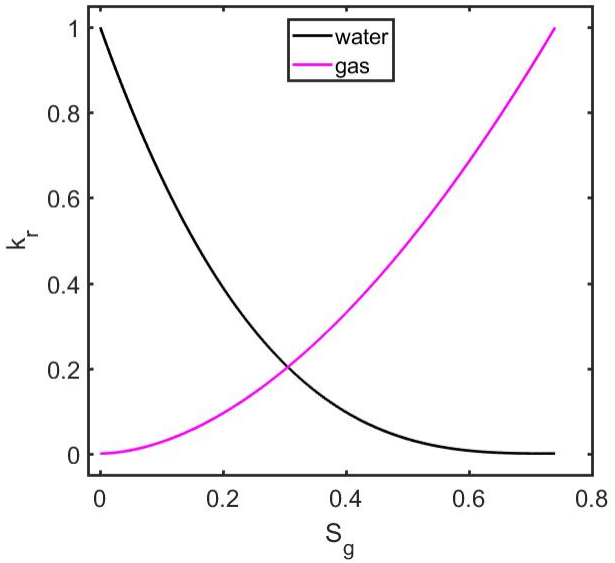


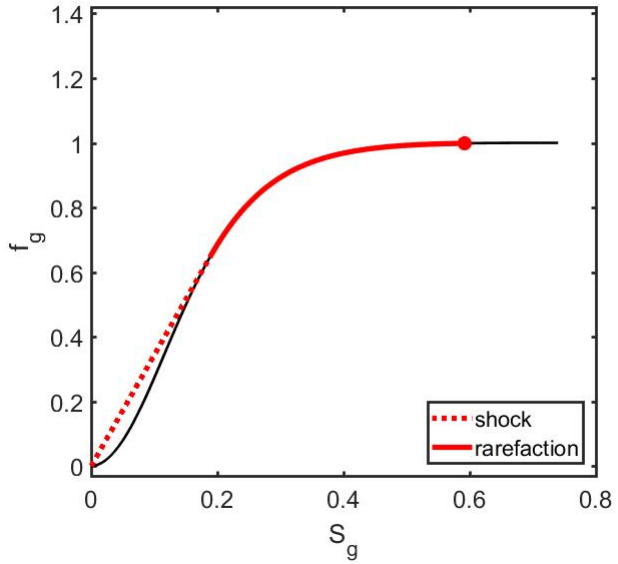
Krishnamurthy et al., AGU 2019

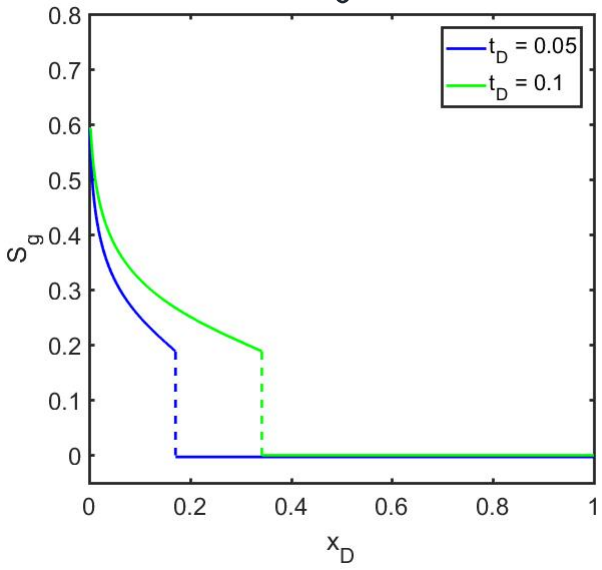
Estimating saturation profiles using fractional flow theory

- Horizontal flow – viscous flow

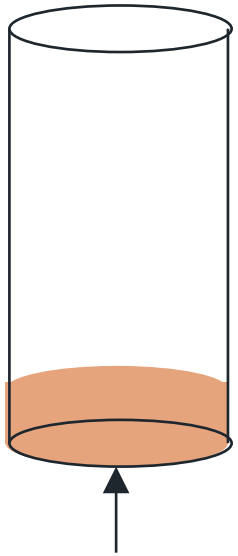






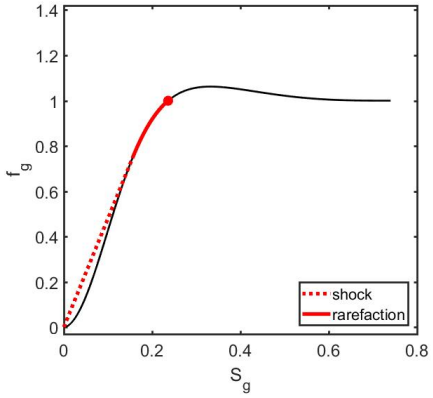


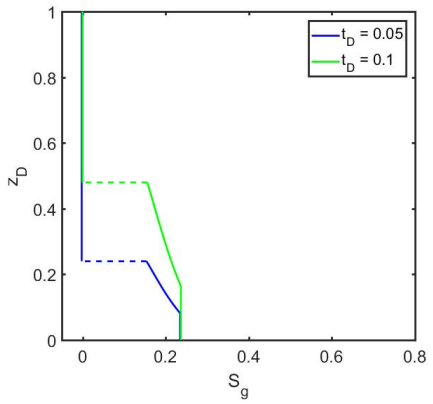
Vertical flow calculation



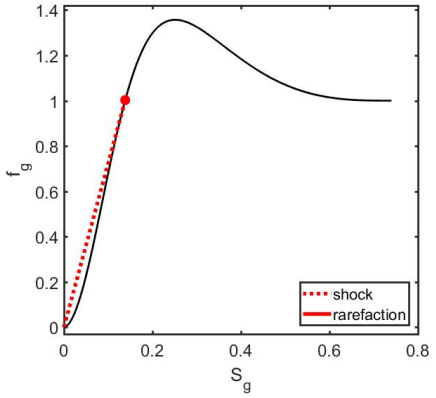
Flow is buoyant below certain flow rate

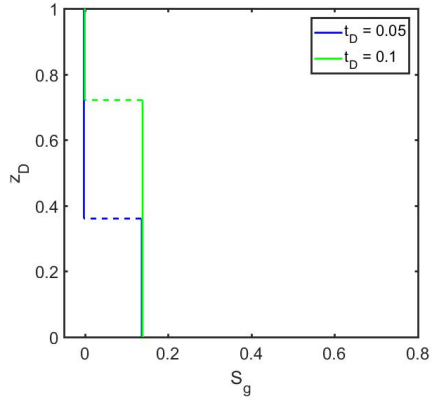
Q = 1.5 ml/min



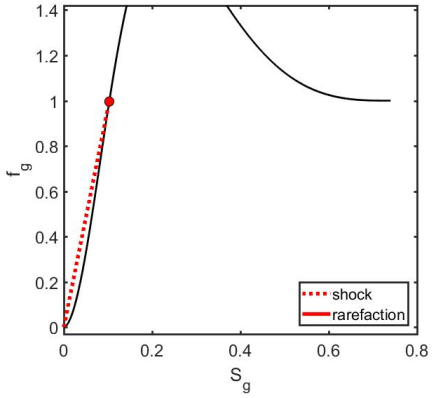


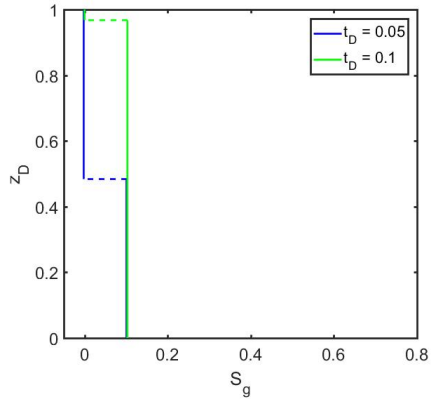
Q = 0.75 ml/min





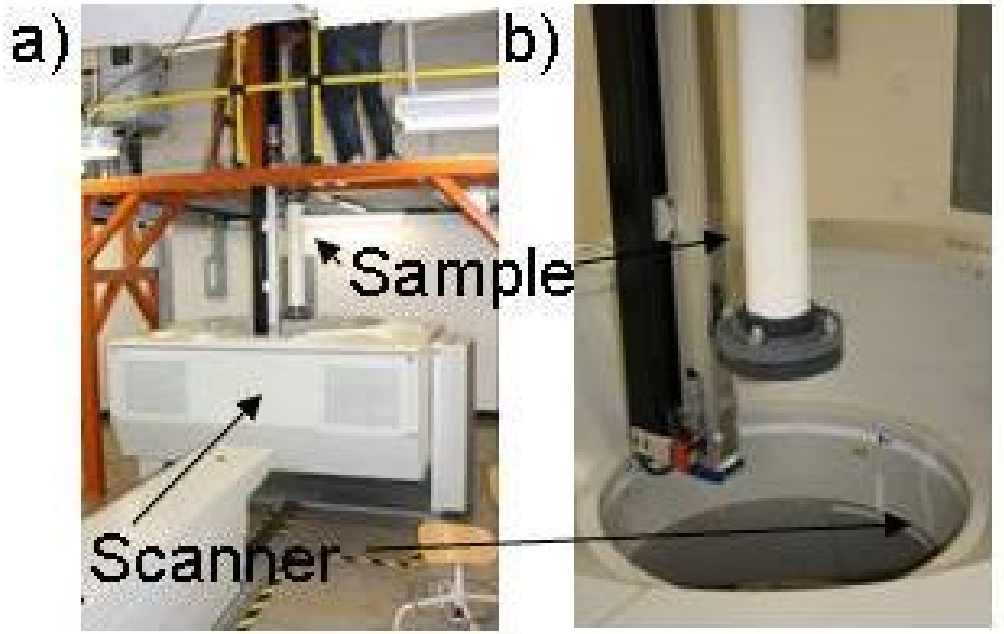
Q = 0.45 ml/min





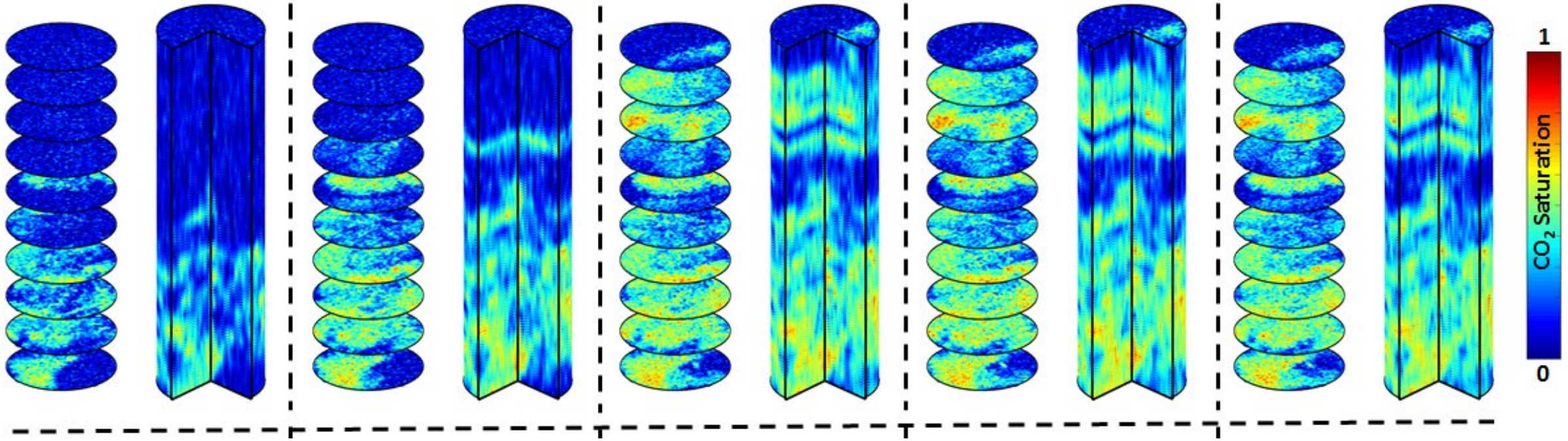
Imaging experiments

- Inject into heterogeneous cores
- Use vertical scanner and
- Use appropriate flow rates
  Q = 0.7 ml/min



Experimental results

- Can measure saturations and effects of heterogeneity



Conclusions

- Imaging needs to be combined with appropriate experimental control
- Can use in-situ imaging to measure high pressure buoyant flows
- Key is choosing rates correctly – then verifying
- Calculation involves estimated relative permeability
- Can do for both REV-scale and micro-scale tomographic scanning
- Calculation assumes homogenous porous media – what is the effect of heterogeneity?

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All buoyant flows are bei

- All buoyant flows are being fed from bottom
  - Buoyant forces pull up the phase
  - Rates determine the cross sectional area
  - Times the saturation of the phase
  - As long as phase