New sand tank experimental results on the effect of bedform architecture: ripple lamination

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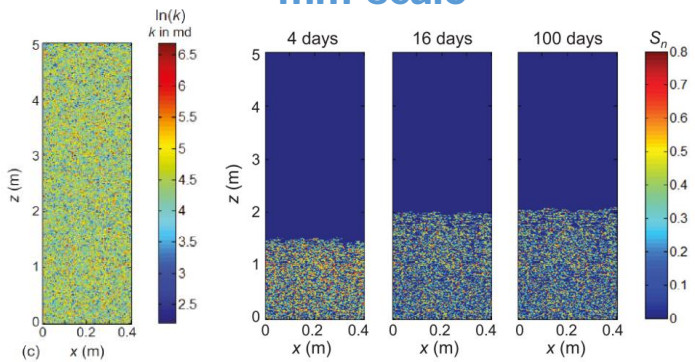
Small-scale capillary barriers can significantly impact CO_2 migration and trapping

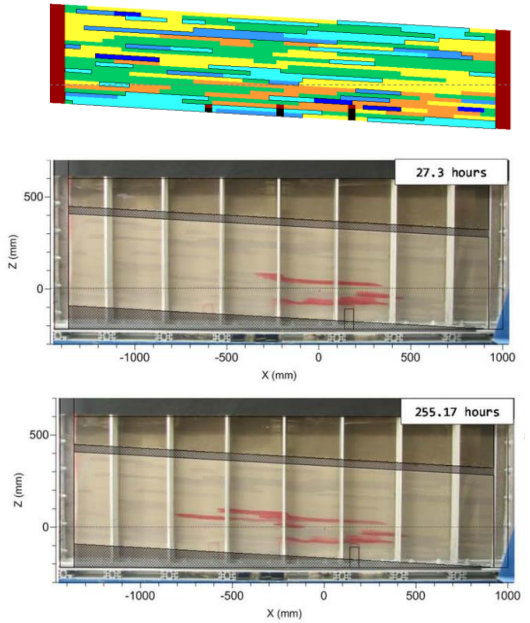
- Small-scale (mm-dm) heterogeneity can
  - Reduce plume migration speed and extent
  - Increase CO_2 storage capacity
    - Local capillary trapping

mm-scale



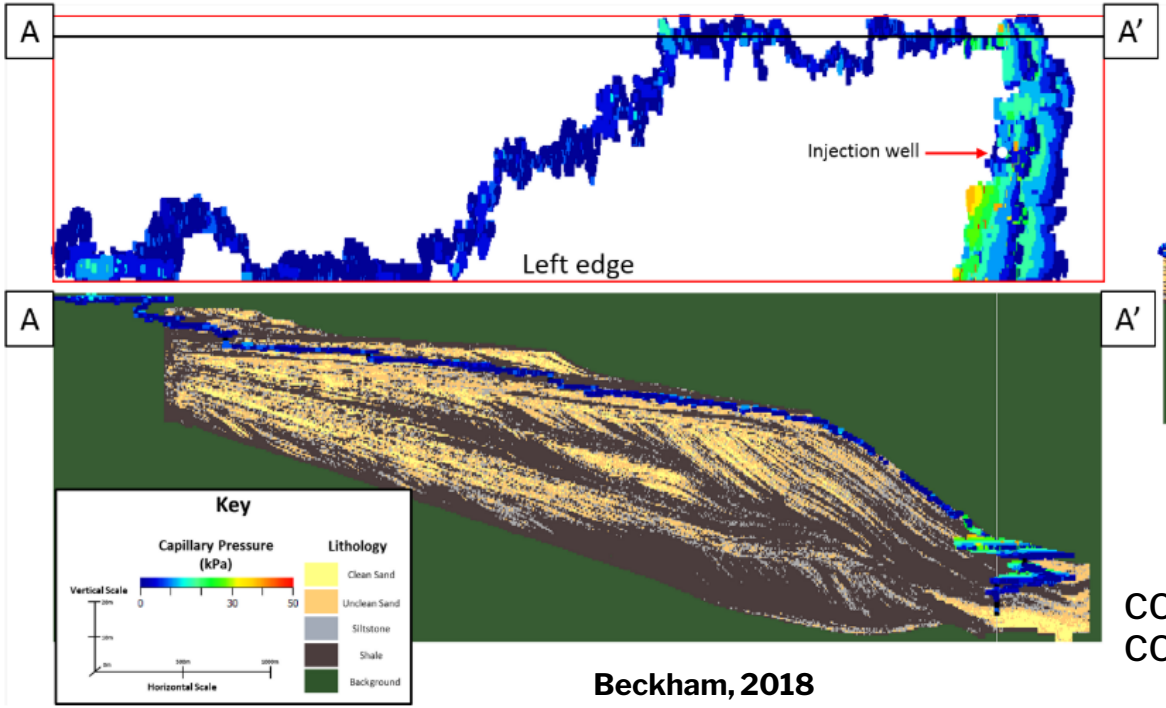
Li and Benson, 2015

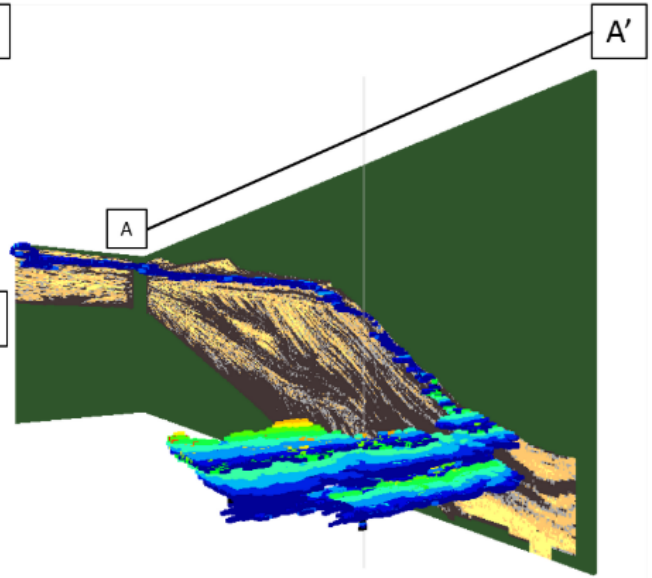
dm-scale



Trevisan et al., 2017

The effect of small-scale barriers, when not properly upscaled, can lead to inaccurate field-scale estimation of CO_2 storage capacity





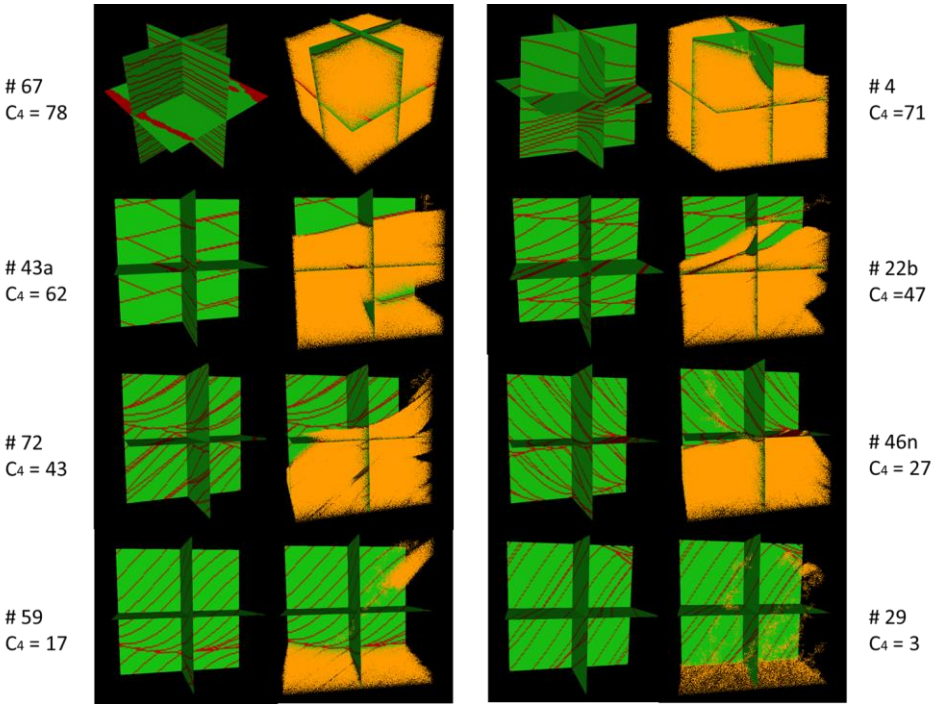
CO_2 retained per grid block: 3% -> 48%
CO_2 retained: 10% -> 21%

Beckham, 2018

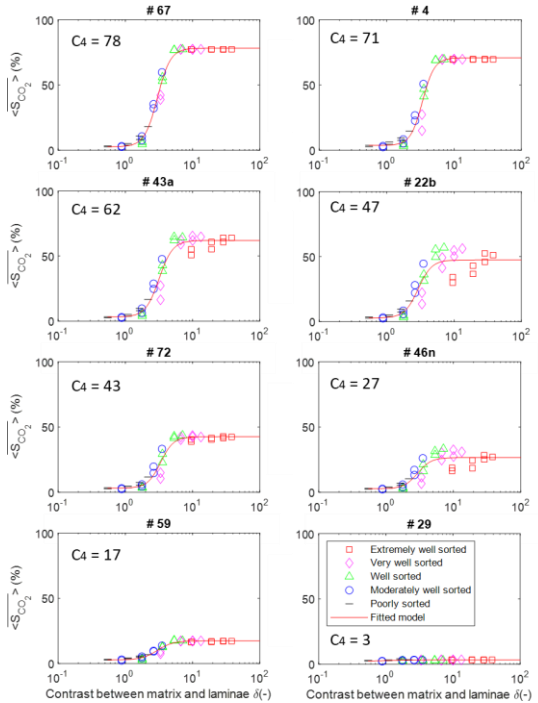
Simulation results show that CO_2 local capillary trapping is highly heterogeneity-dependent

Ni et al., 2023

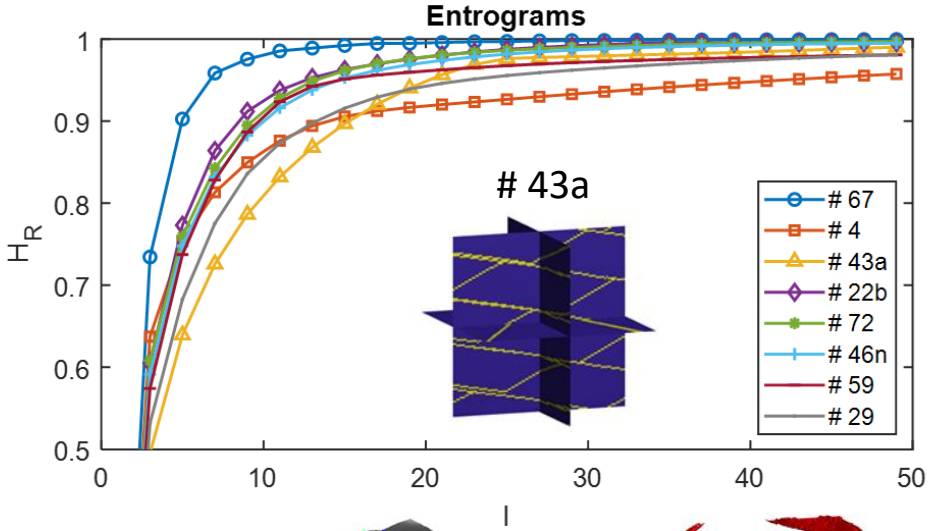
Bedform architecture
(type of heterogeneity)



Grain size contrast
(degree of heterogeneity)



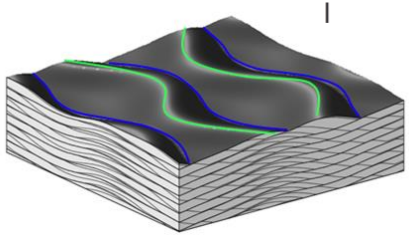
Prediction models can be developed on the simulated dataset, but lack validation

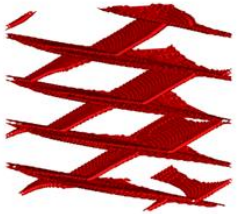


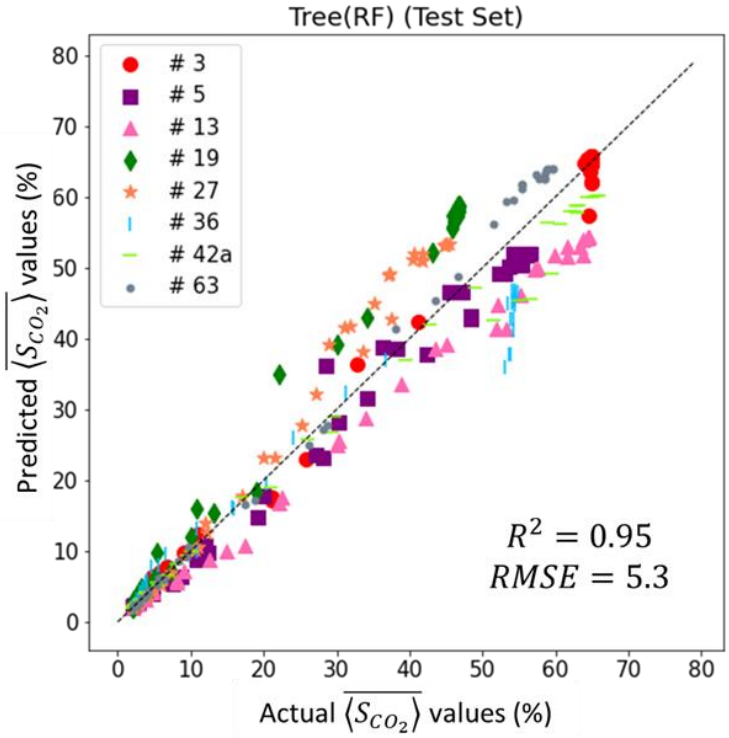
3D-sinuous

Invariable

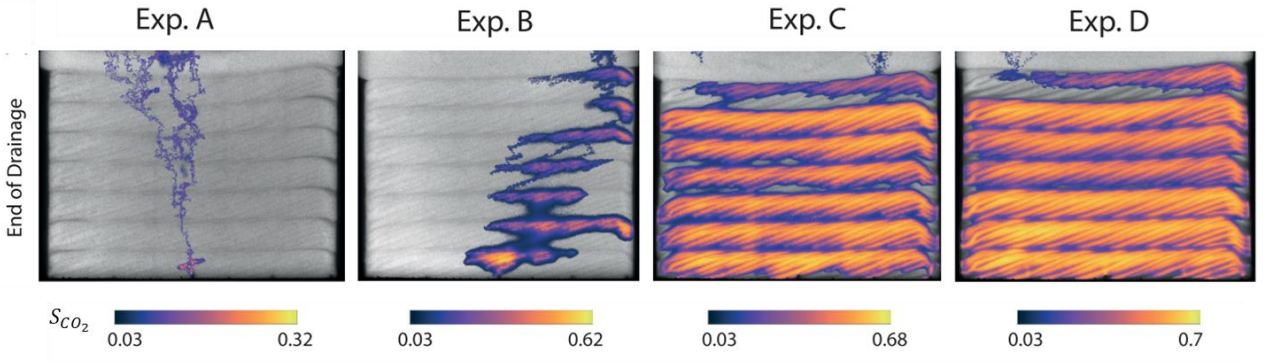
Oblique



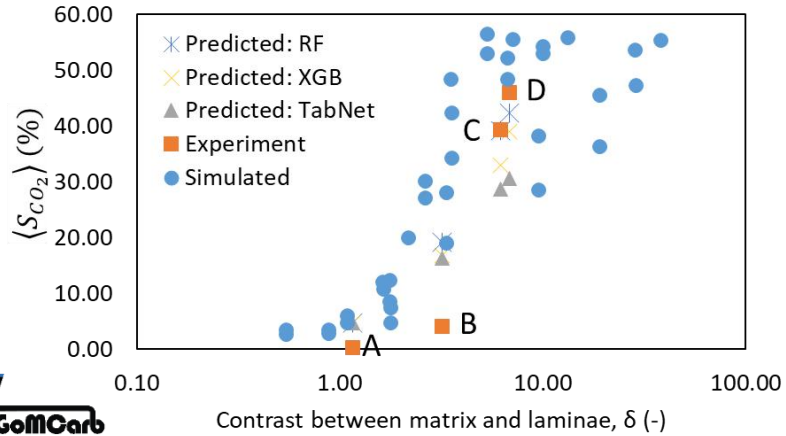


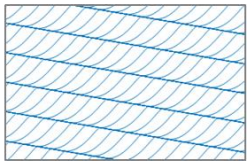


Sand tank experiments provide valuable validation data



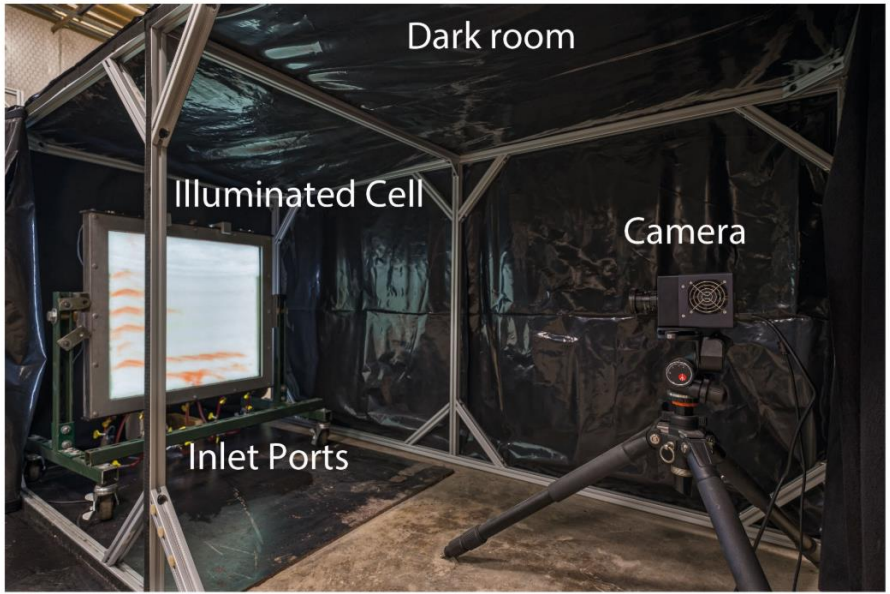
Krishnamurthy et al., 2022





BAM # 5

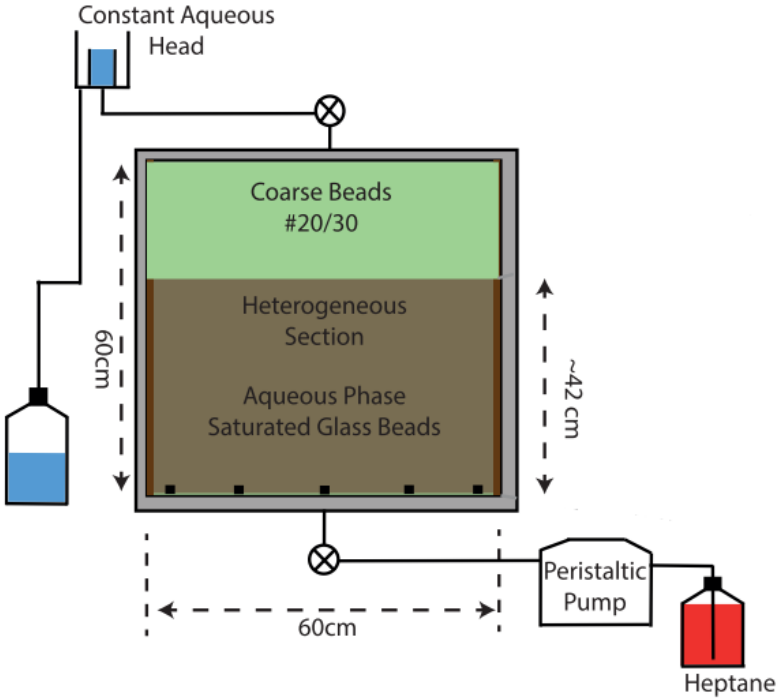
Intermediate-scale sand tank experiments have unique advantages



- Customizable domain
  - Different types and degrees of heterogeneity
- High-resolution imaging
  - Light transmission visualization
  - Both in time and space
- Buoyancy-driven flow
  - Most closely matches CO_2 geologic storage flow regime

Krishnamurthy, 2020

Experimental setup

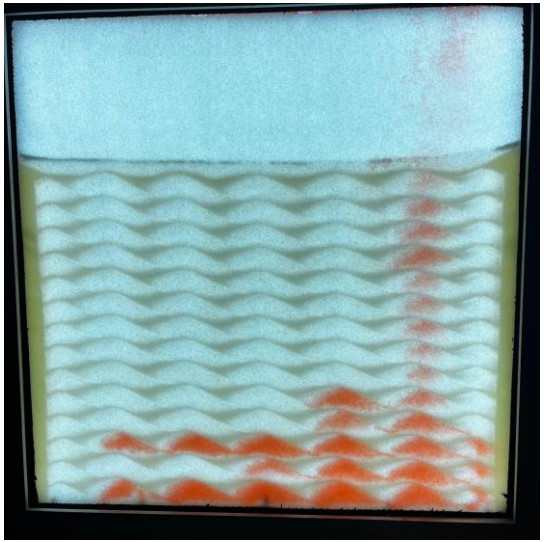


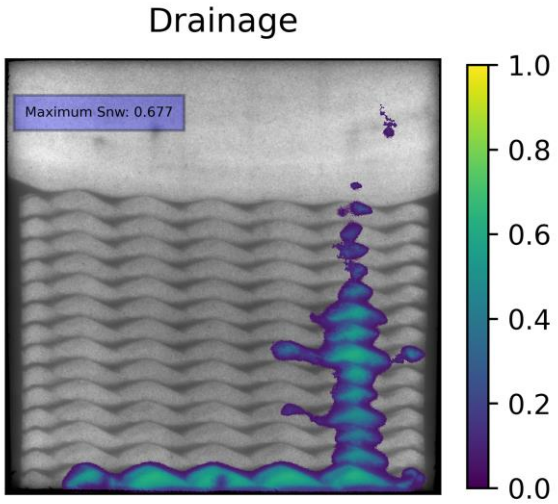
- Materials
  - Coarse/fine glass beads
  - Fluid pair: Heptane/glycerol-water mixture
- Flow regime
  - Capillary # 2×10^{-6}
  - Bond # = 6×10^{-2}
- Boundary conditions
  - Inlet: constant rate
  - Outlet: constant pressure

Krishnamurthy, 2020

How do we run a complete sandbox experiment?

Sandbox packing → Drainage and Redistribution → Data processing

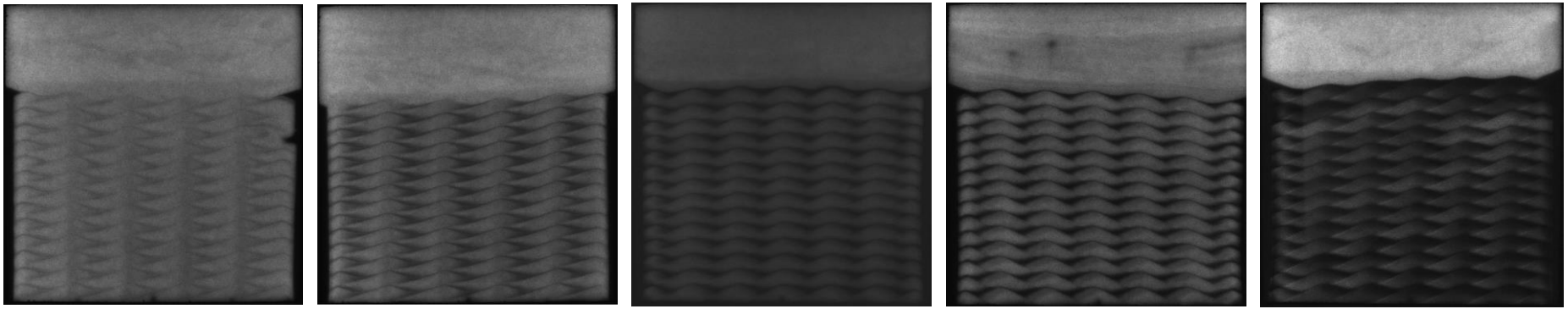




Reproducing ripples lamination using the automated feeder system

Grain size contrast between matrix and laminae increases

= Degree of heterogeneity increases

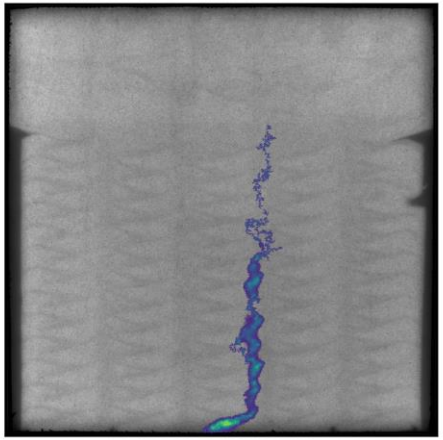


Why they look different?

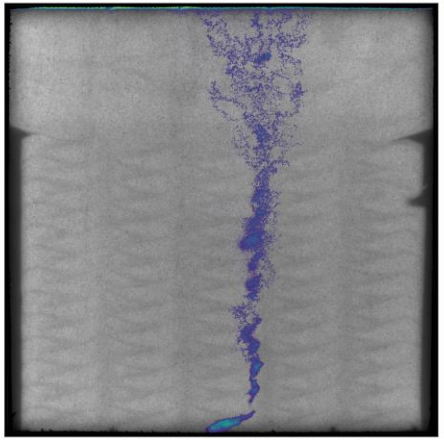
Improvements to get realistic bedforms

Heterogeneity effects on invasion patterns and redistribution dynamics

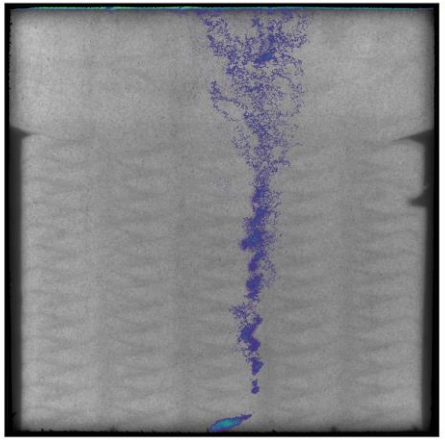
Domain breakthrough



End of drainage



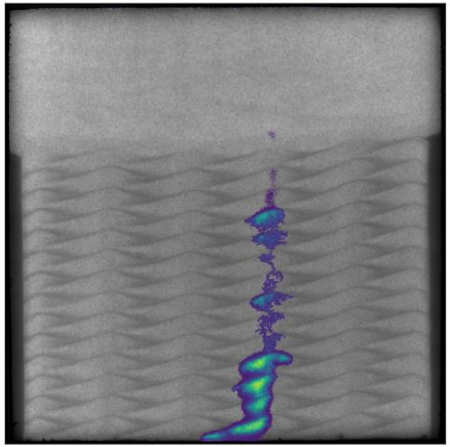
End of redistribution



EXP. E

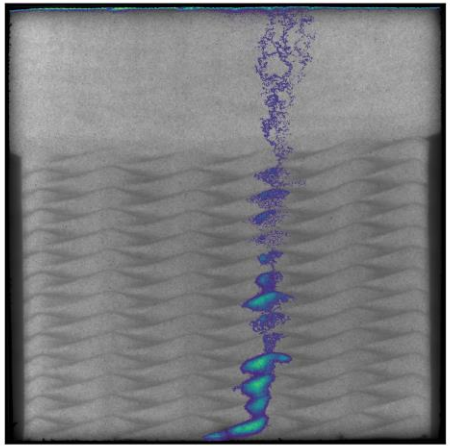
Heterogeneity effects on invasion patterns and redistribution dynamics

Domain breakthrough



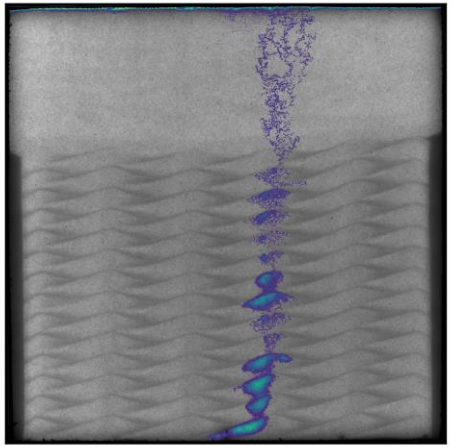
Breakthrough saturation: 0.008
Breakthrough time: 56 min

End of drainage



End of drainage saturation: 0.013

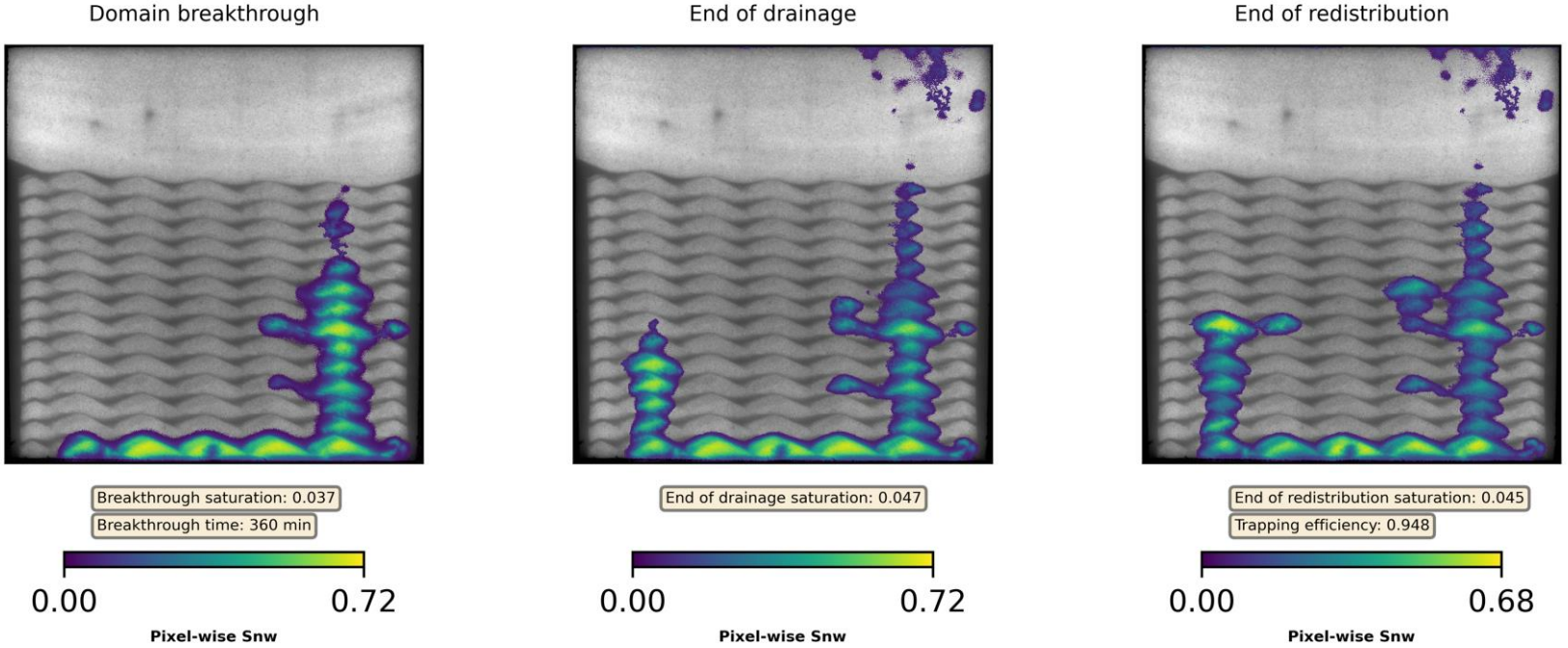
End of redistribution



End of redistribution saturation: 0.012
Trapping efficiency: 0.892

EXP. F

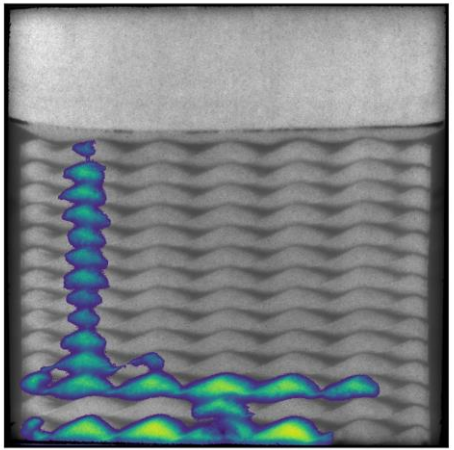
Heterogeneity effects on invasion patterns and redistribution dynamics



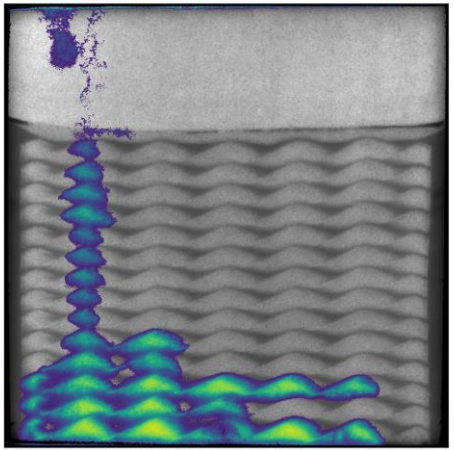
EXP. G

Heterogeneity effects on invasion patterns and redistribution dynamics

Domain breakthrough



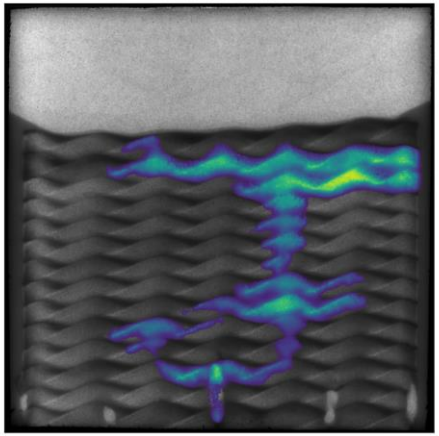
End of drainage



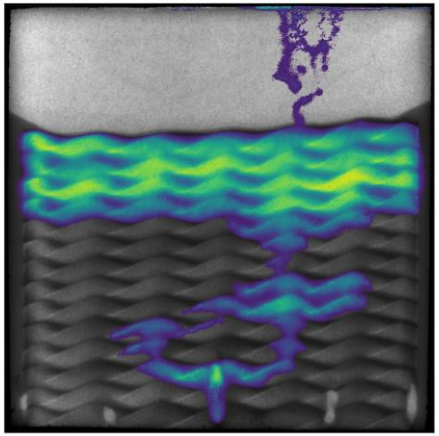
EXP. H

Heterogeneity effects on invasion patterns and redistribution dynamics

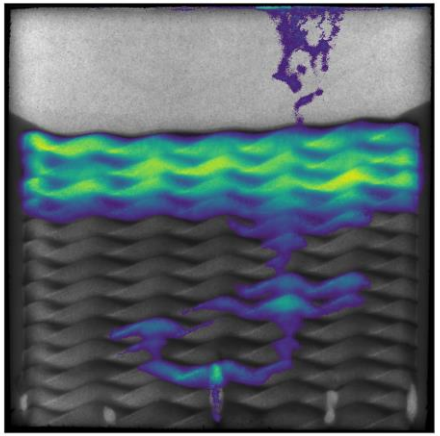
Domain breakthrough



End of drainage



End of redistribution

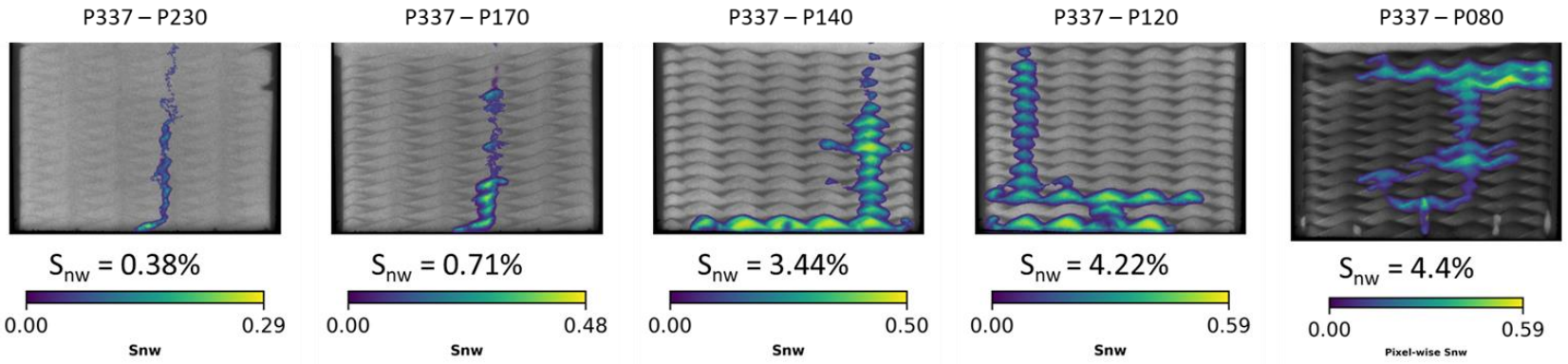


EXP. I

Non-wetting phase saturation grows with increasing degree of heterogeneity

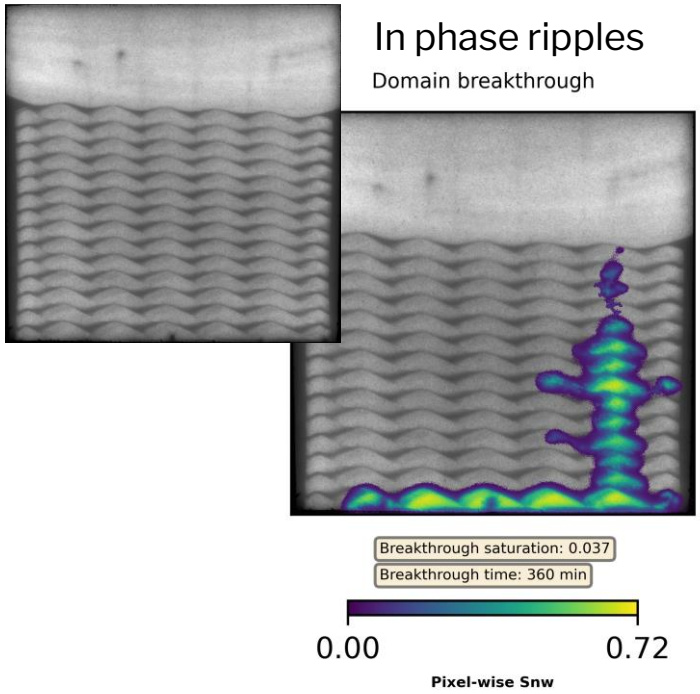
Grain size contrast between matrix and laminae increases

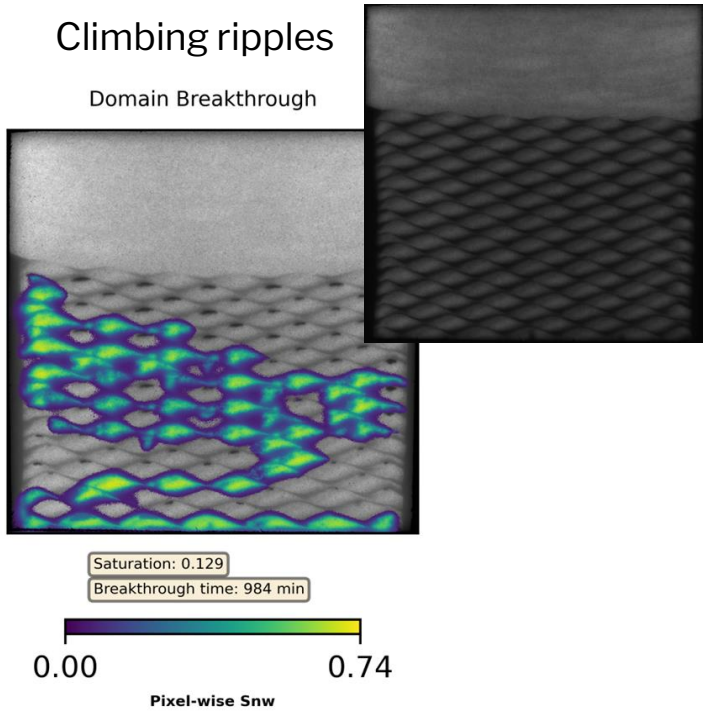
Degree of heterogeneity increases



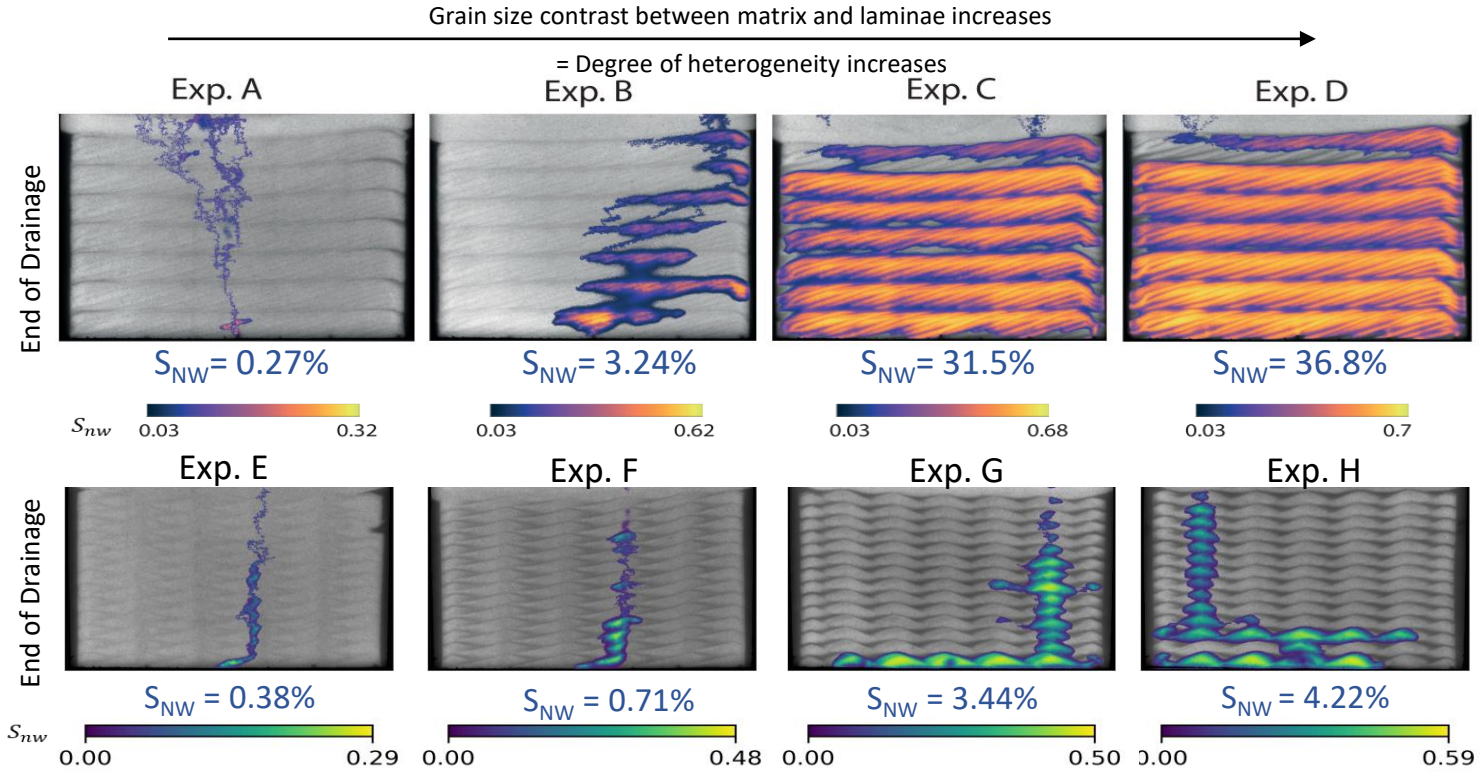
Domain breakthrough

Slightly changes in bedform architecture will affect non-wetting phase saturation

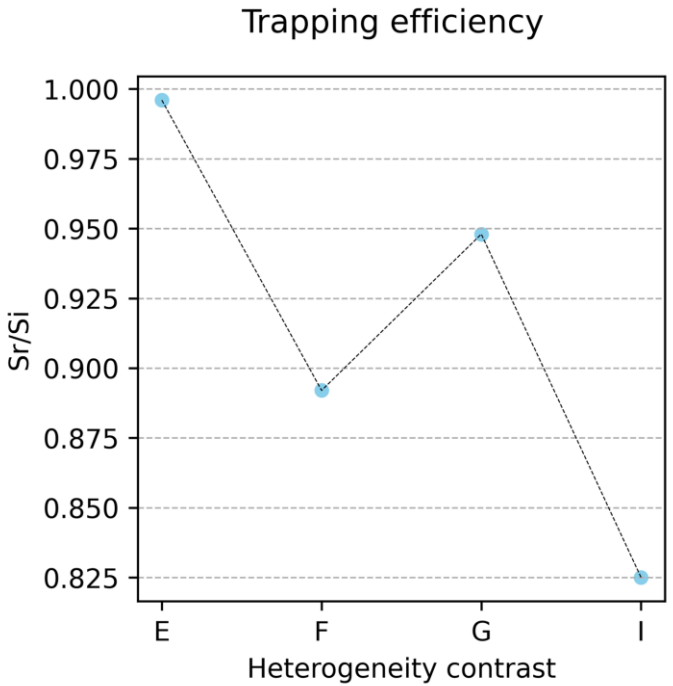


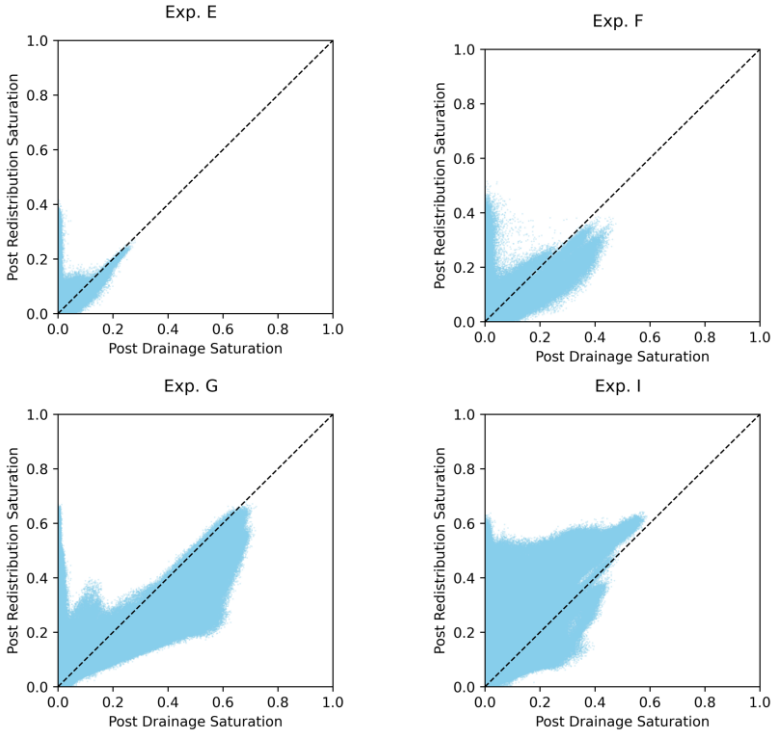


Saturation differs from one bedform architecture to another

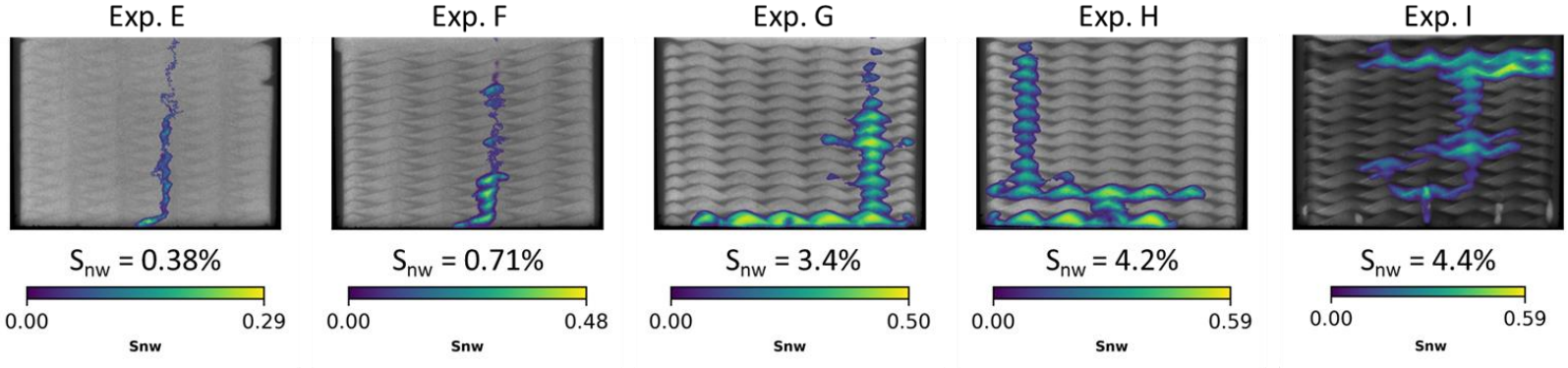


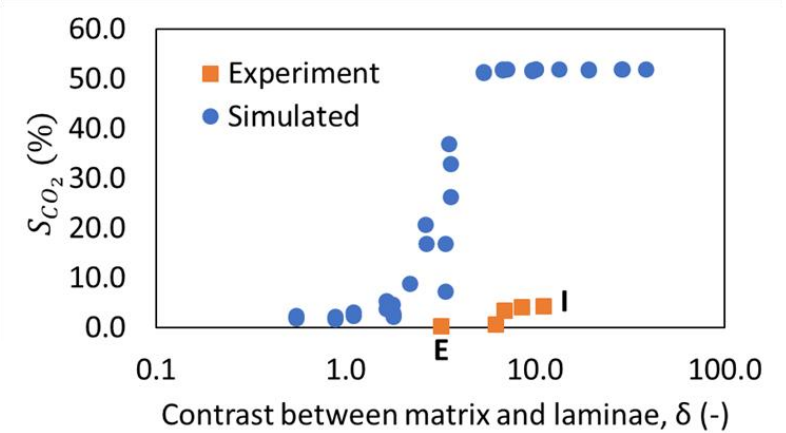
Understanding trapping efficiency of the heterogeneous domain

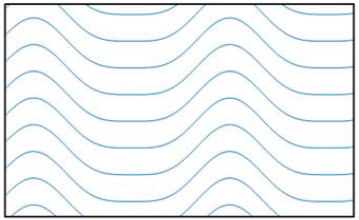




There exists discrepancy between experimental and simulated data due to lamination thickness differences







BAM #3

Thanks for your attention!

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