Predicting CO_2 Buoyant Flow Saturation in Heterogeneous Geologic Formations with Machine Learning

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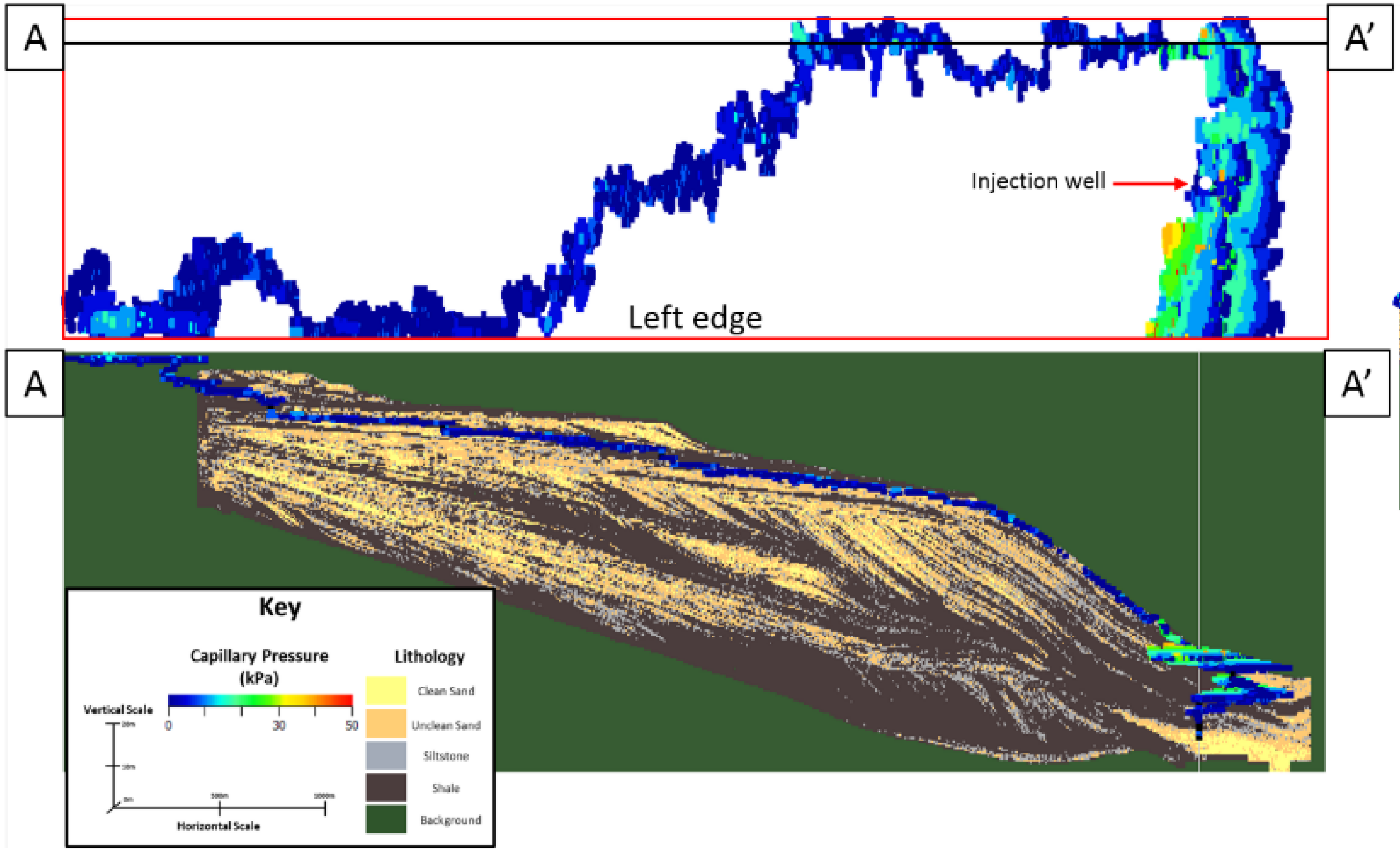
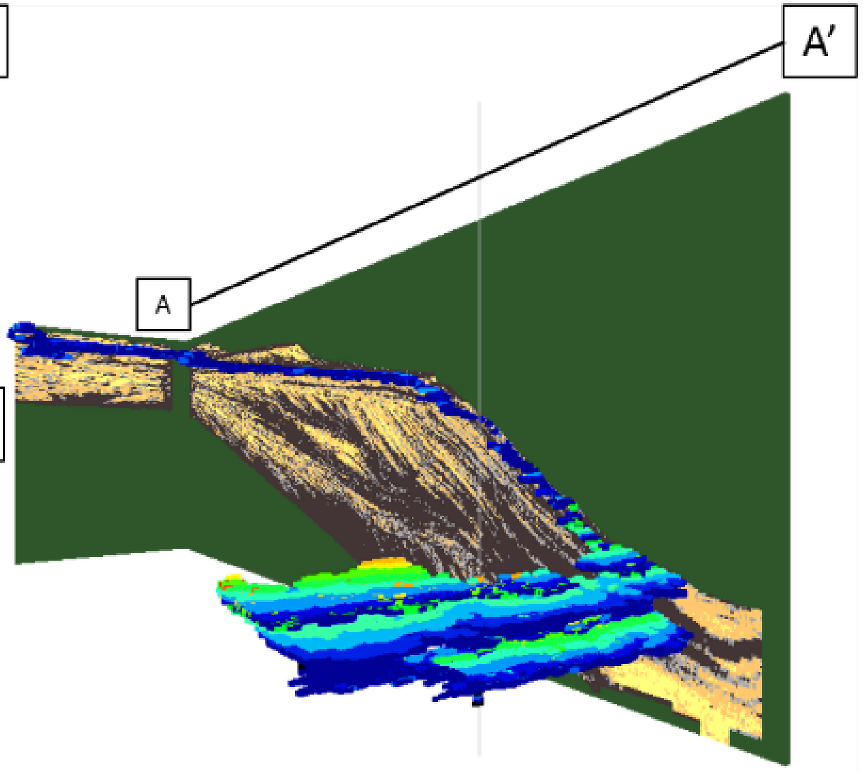
Sub-meter scale barriers can determine migration pathways, speed of plume movement, and CO_2 storage capacity





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

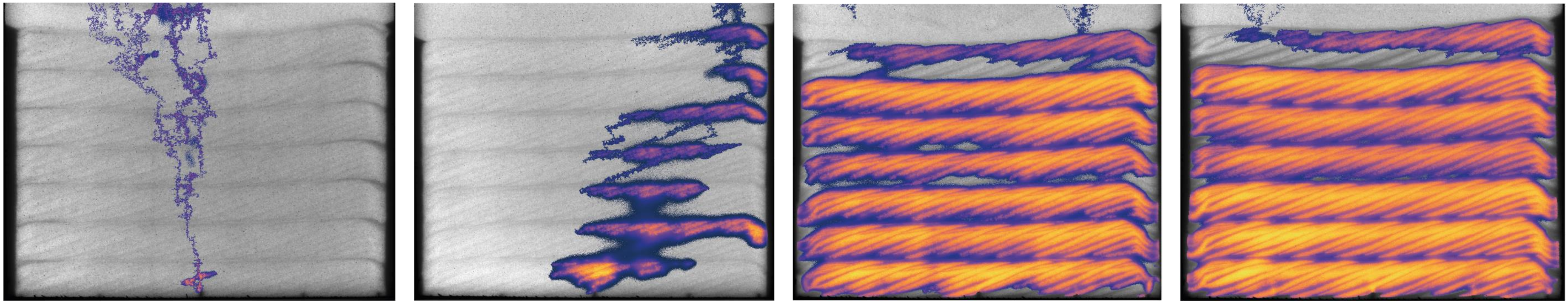
CO_2 retained: 10% -> 21%

Beckham, 2018

Sub-meter scale barriers can determine migration pathways, speed of plume movement, and CO_2 storage capacity

Increasing grain size contrast between matrix and laminae

(Increasing degree of heterogeneity)



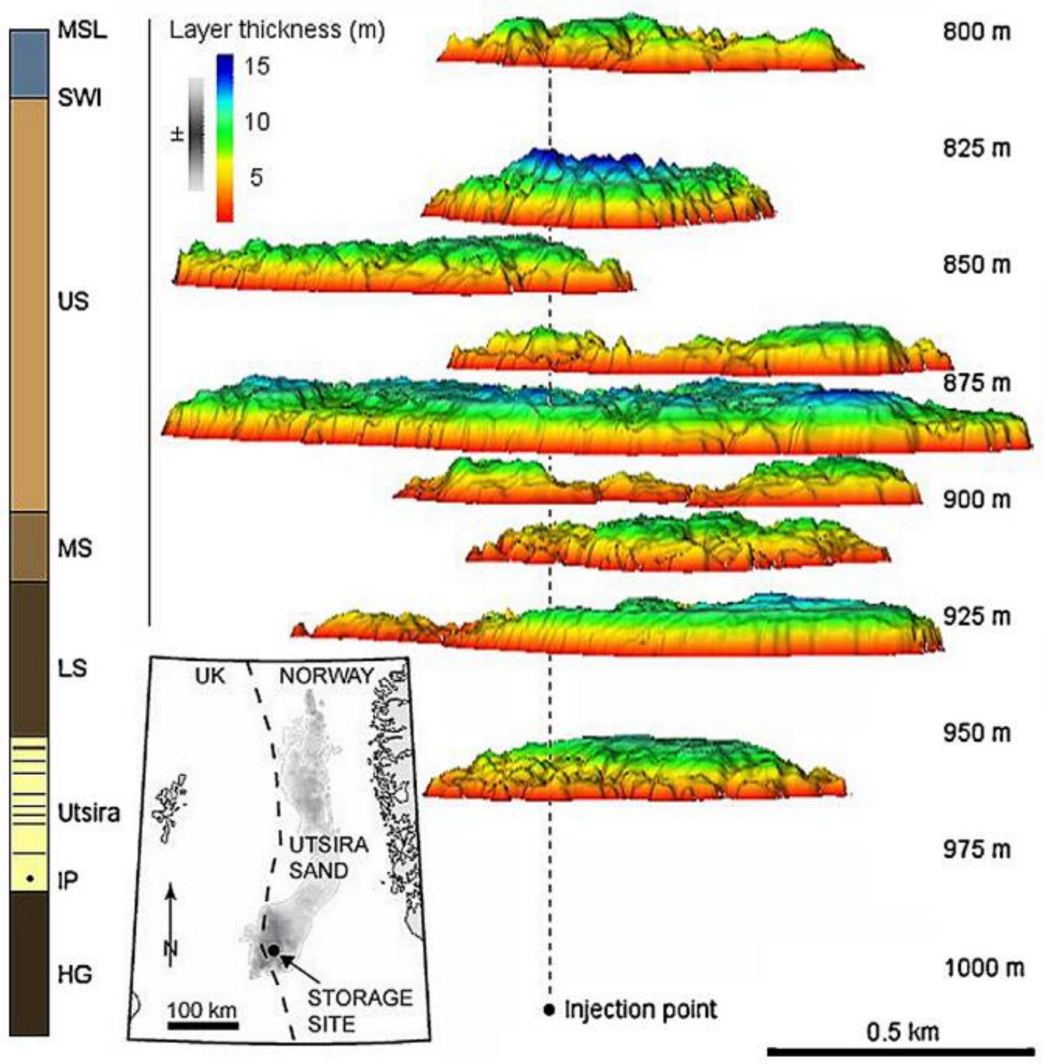
S_{NWP}= 0.27% S_{NWP}= 3.24% S_{NWP}= 31.5% S_{NWP}= 36.8%

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

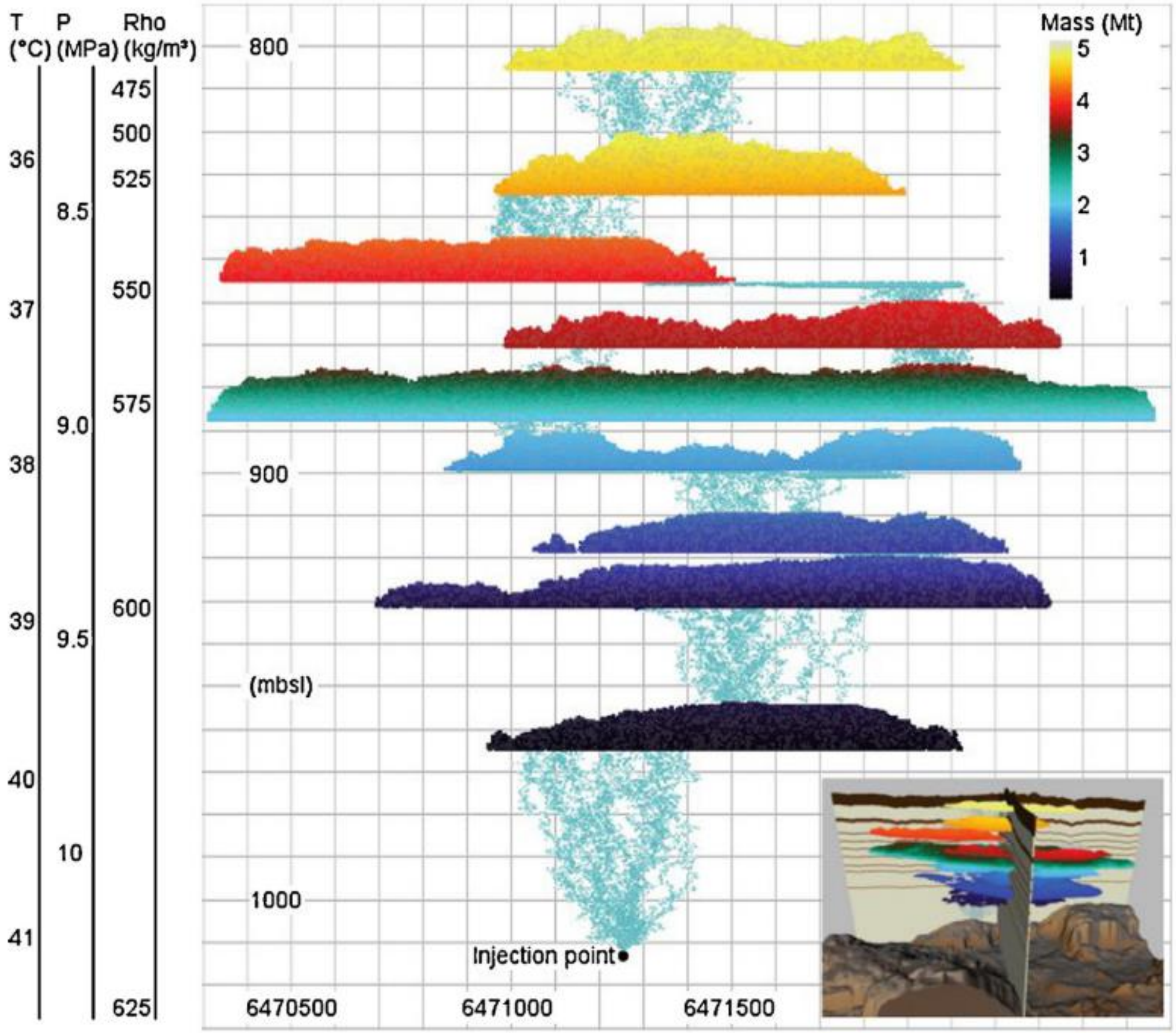
Krishnamurthy, 2020

Why do modified invasion percolation simulations?

3D representation of the monitored CO_2 plume



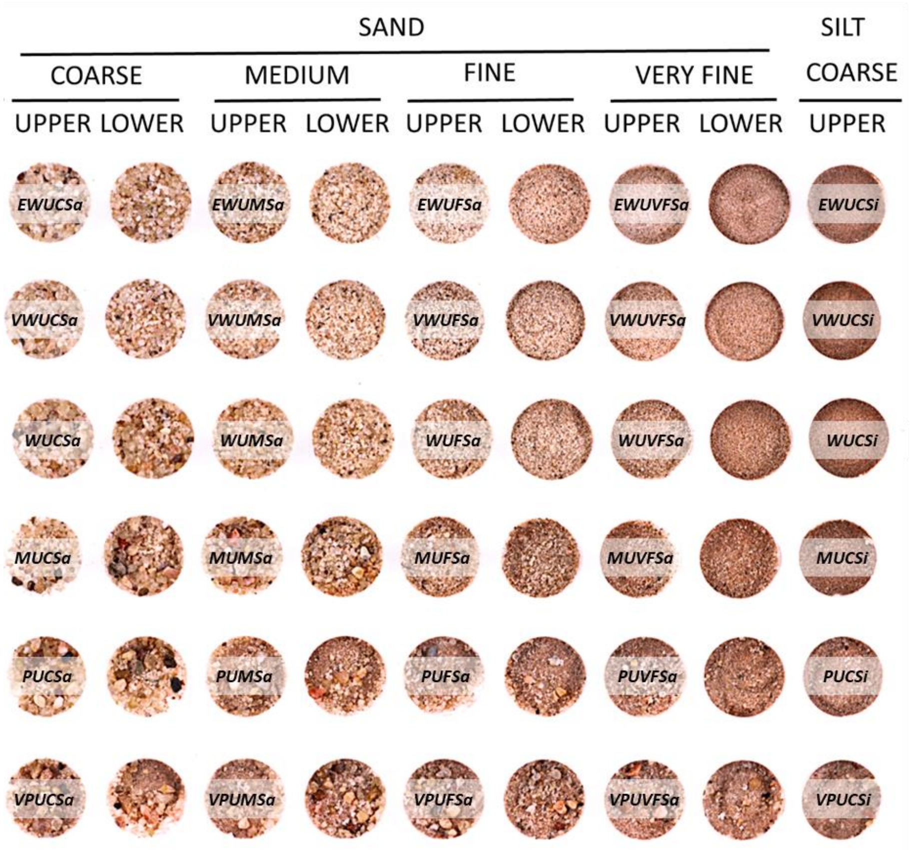
Modified invasion percolation simulation result



Cavanagh & Haszeldine, 2014

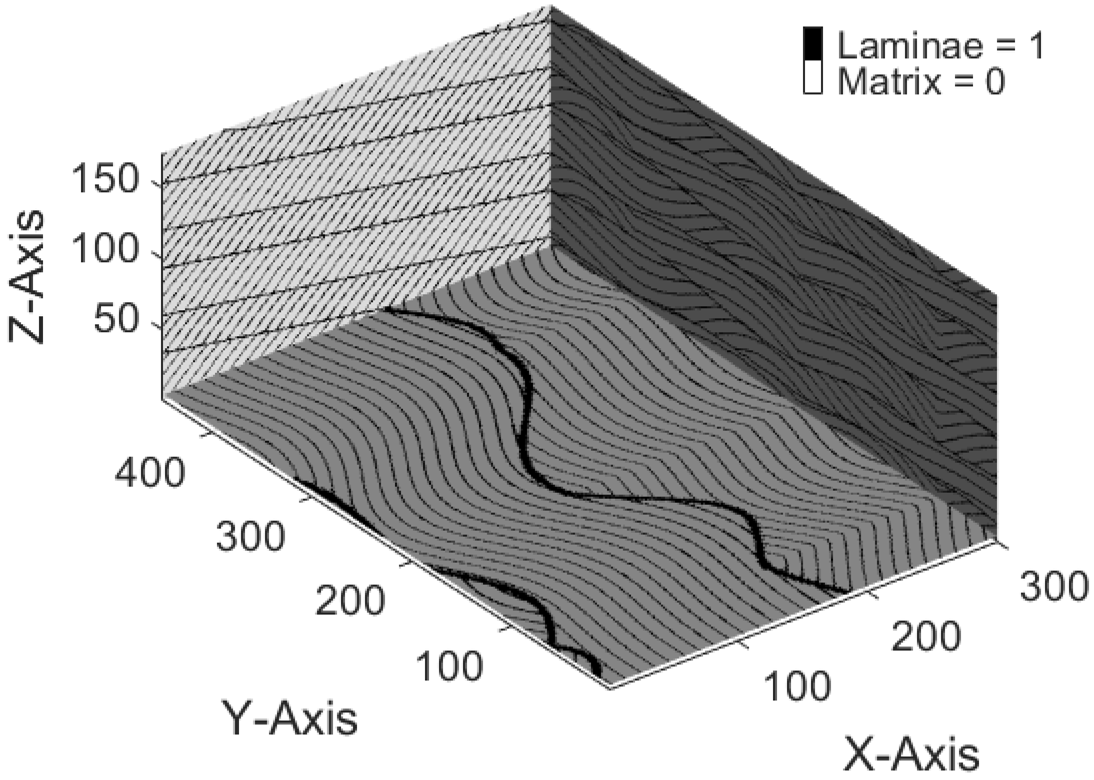
Heterogeneity in natural geologic formations is affected by two major factors

Grain size



Trevisan et al., 2017

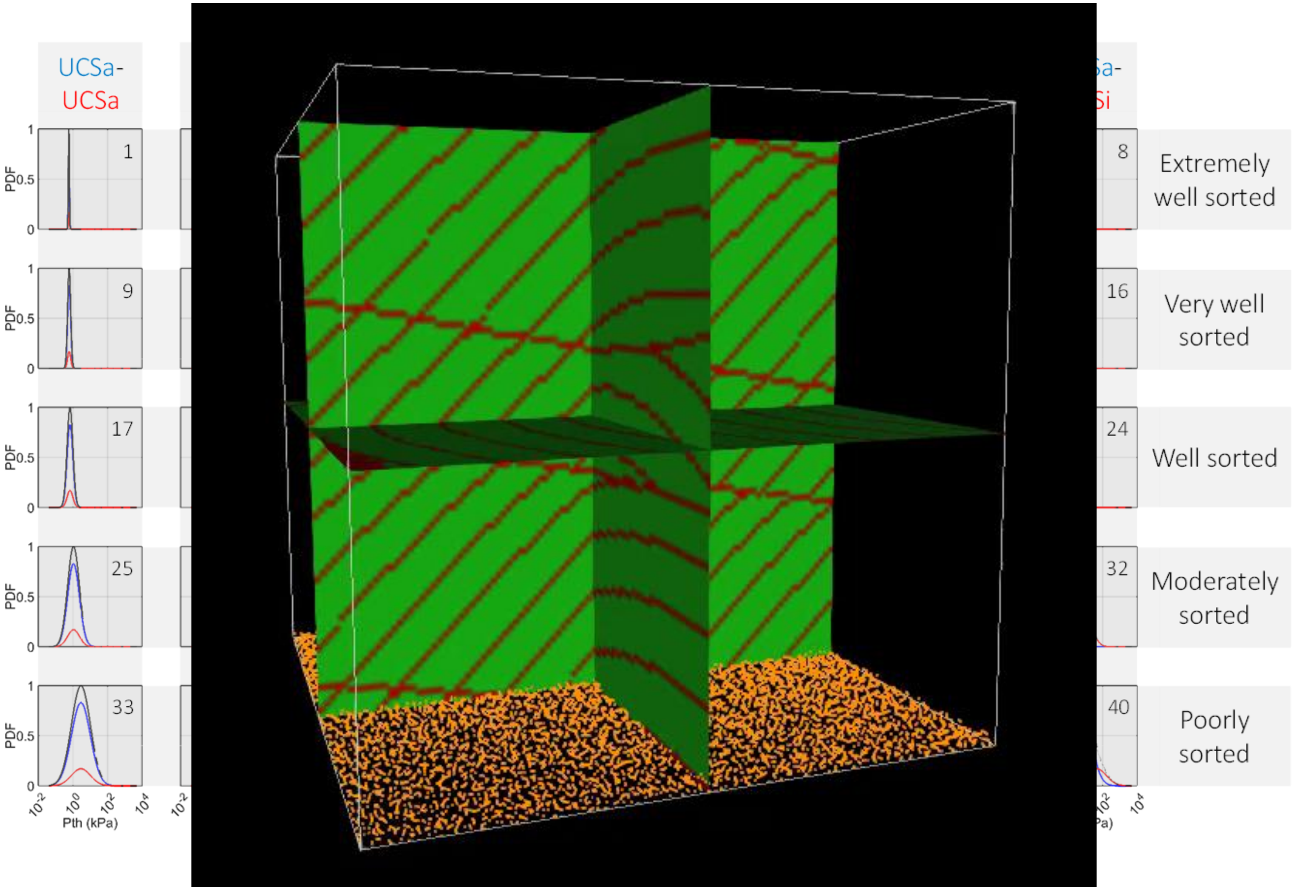
Bedform architecture



Rubin & Carter, 2005; Meckel et al., 2017

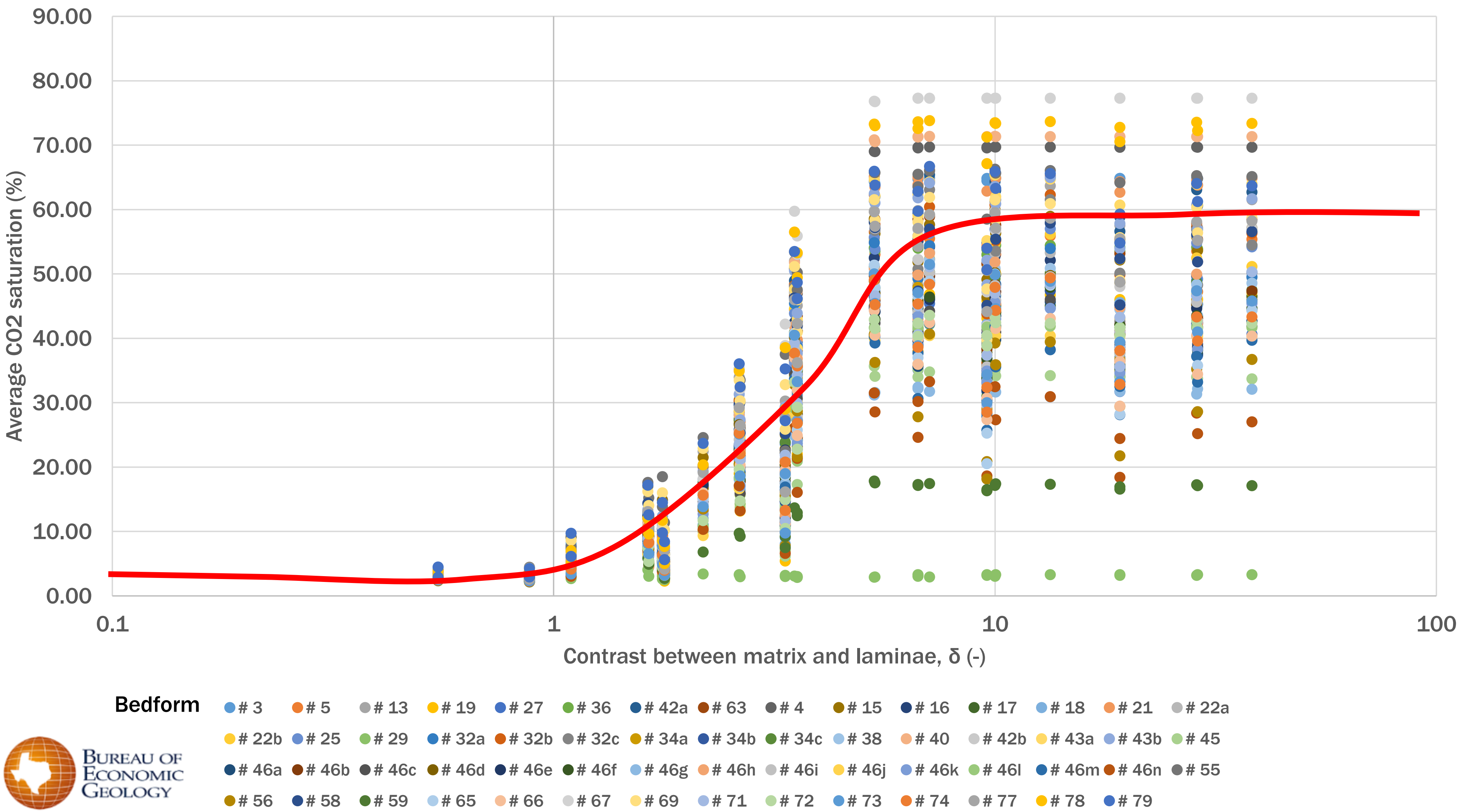
Data generation: modified invasion percolation simulations

- 59 bedform architectures X
- 40 grain size contrast cases X
- 50 stochastic realizations X
- = 118,000 simulations run



Rubin & Carter, 2005; Meckel et al., 2017; Trevisan et al., 2017

Data: first look



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Model training: training and test set

All data

59 Bedforms

51 Bedforms

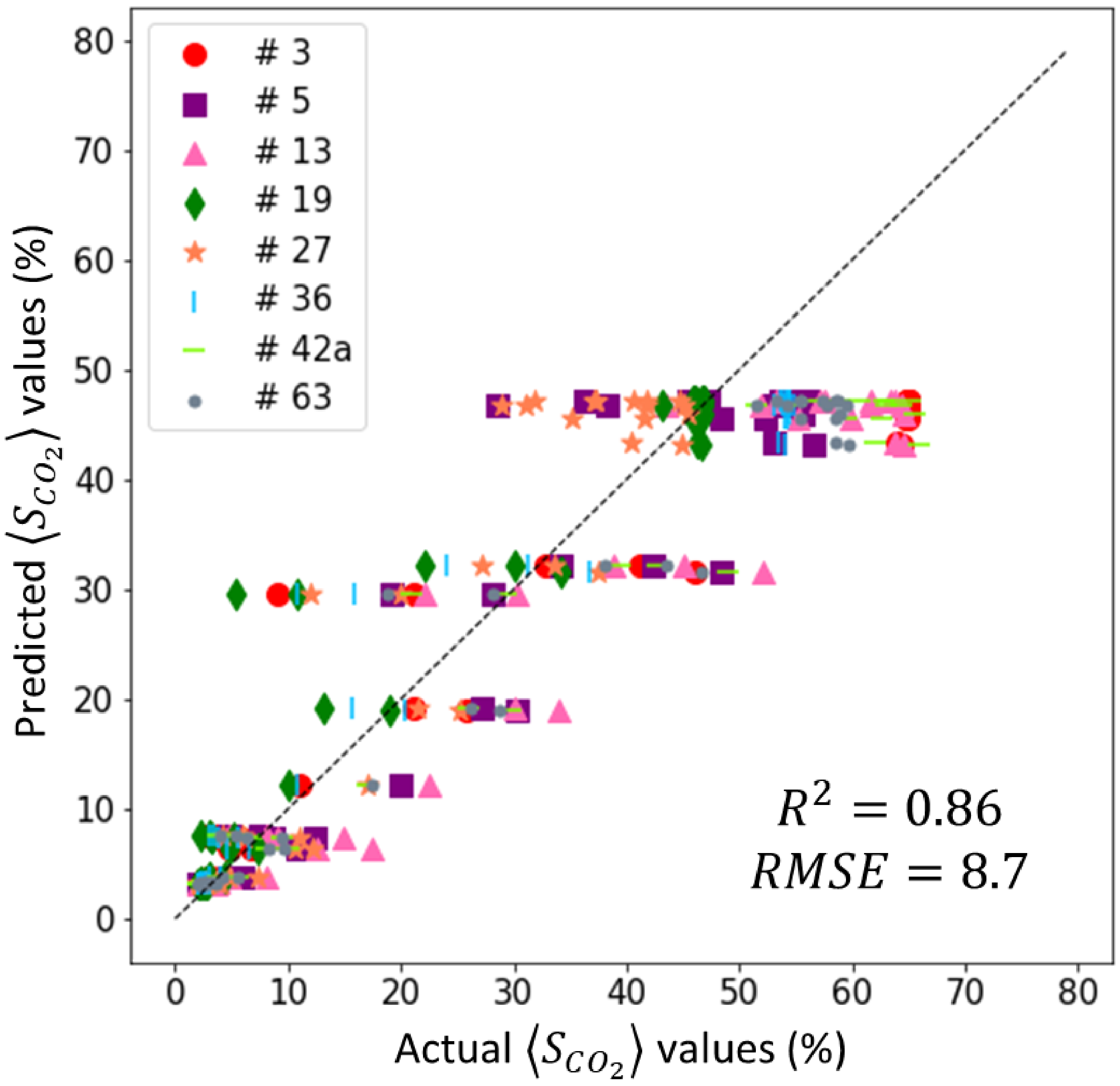
Training set

8 Bedforms

Test set

Each bedform architecture model has all of its 40 grain size contrast cases included.

Model results: first model



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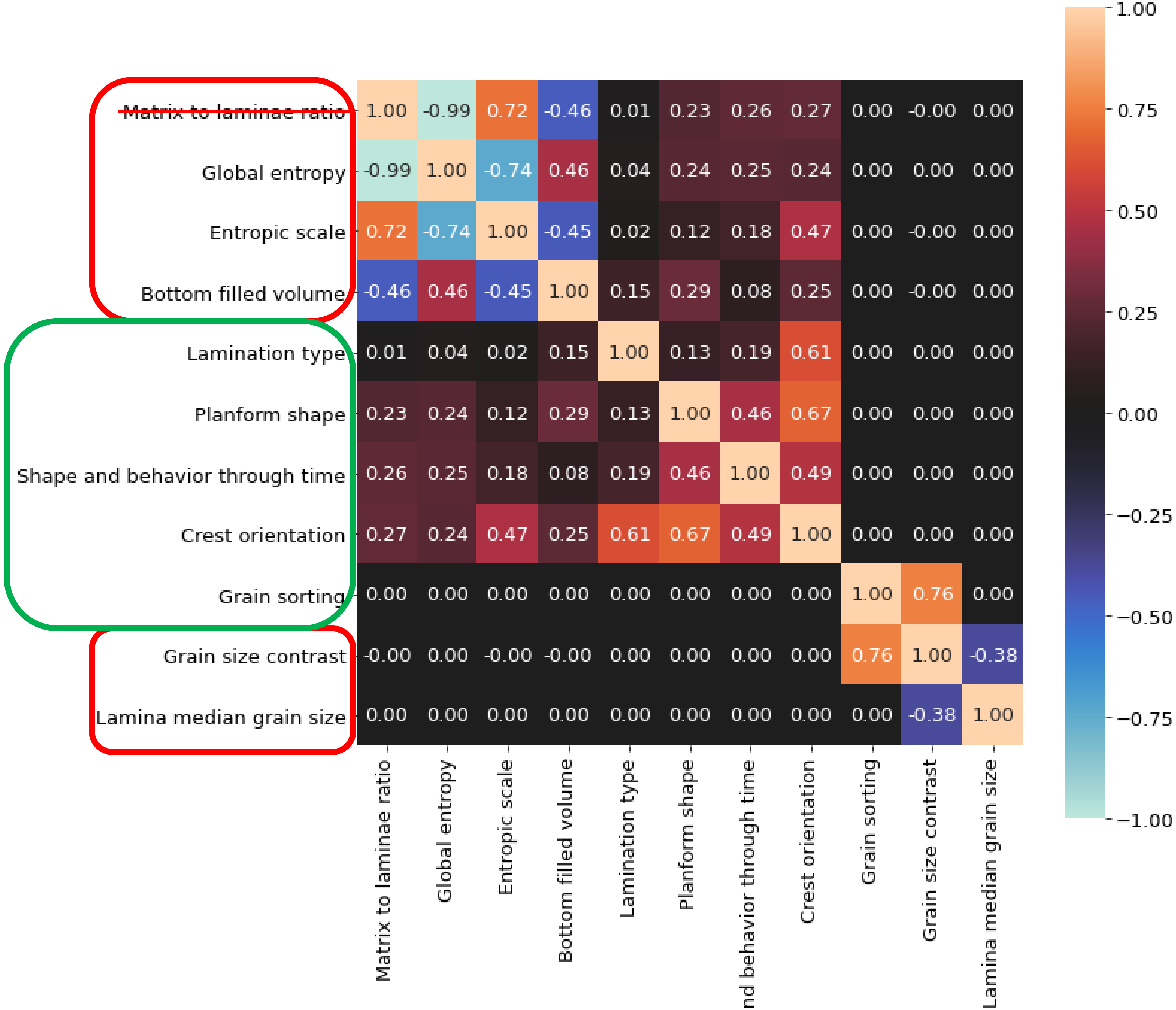
Model building: with machine learning

- Add more features
  - Grain sorting
  - Geological entropy
  - Bedform descriptors
    - Planform shape
    - Shape and behavior through time
    - Crest orientation
    - Lamination type and shape

- Try different machine learning regression models
  - K nearest neighbors
  - Linear regression
  - Tree-based ensemble models
    - Random forest
    - Gradient-boosted trees
  - Artificial neural networks

Model building: feature selection



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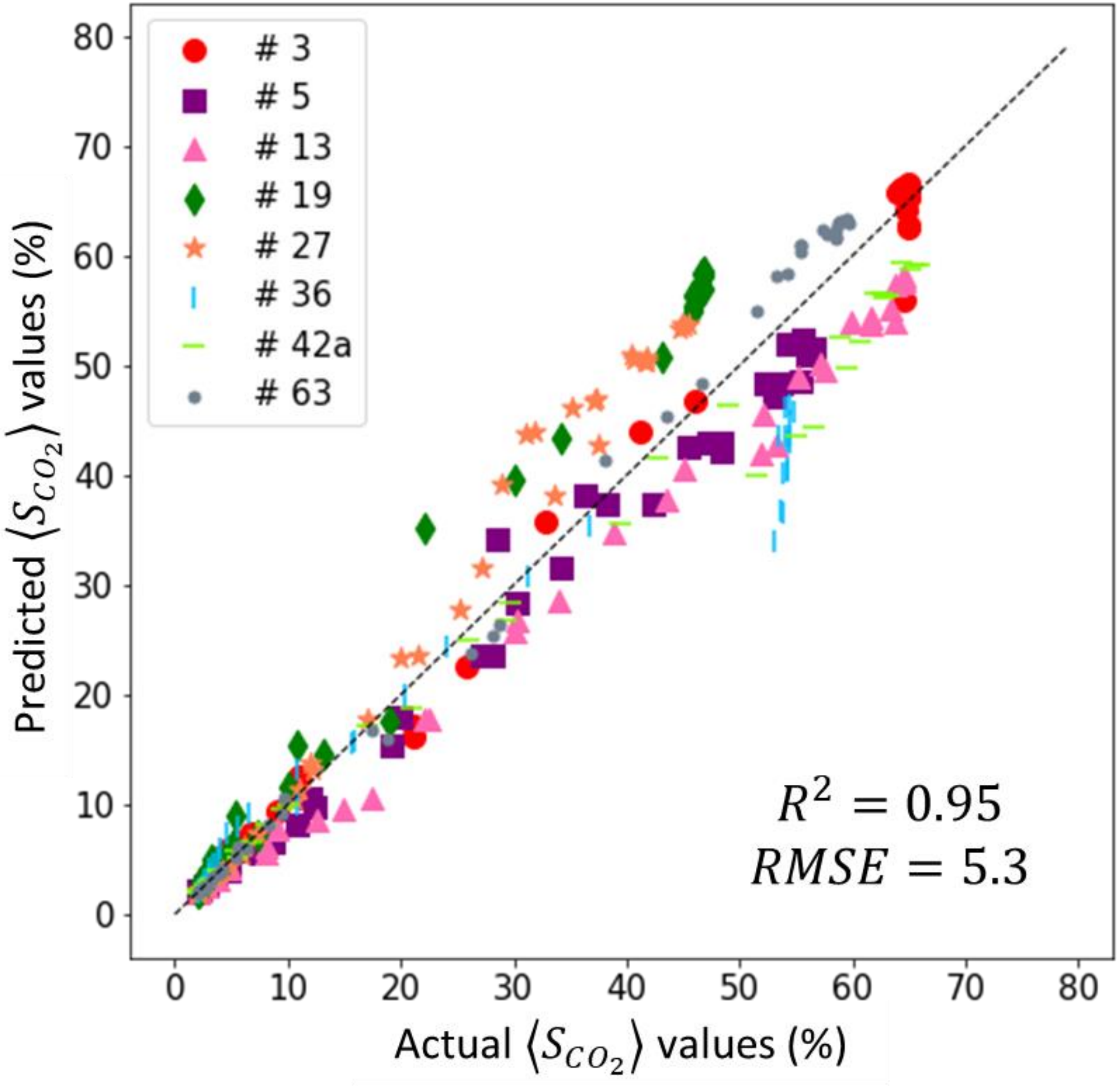
Model results: second model

- Random forest model



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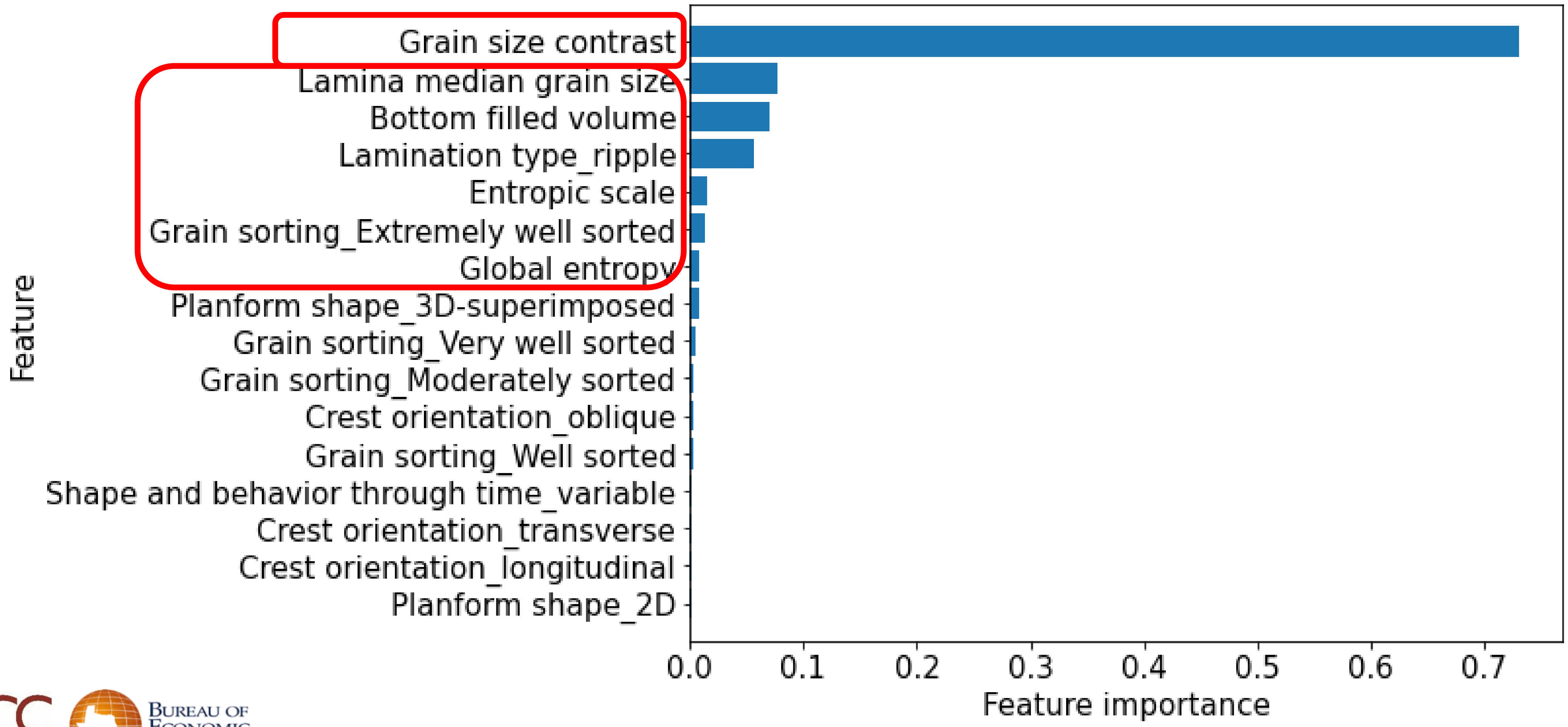
Model results: feature importance



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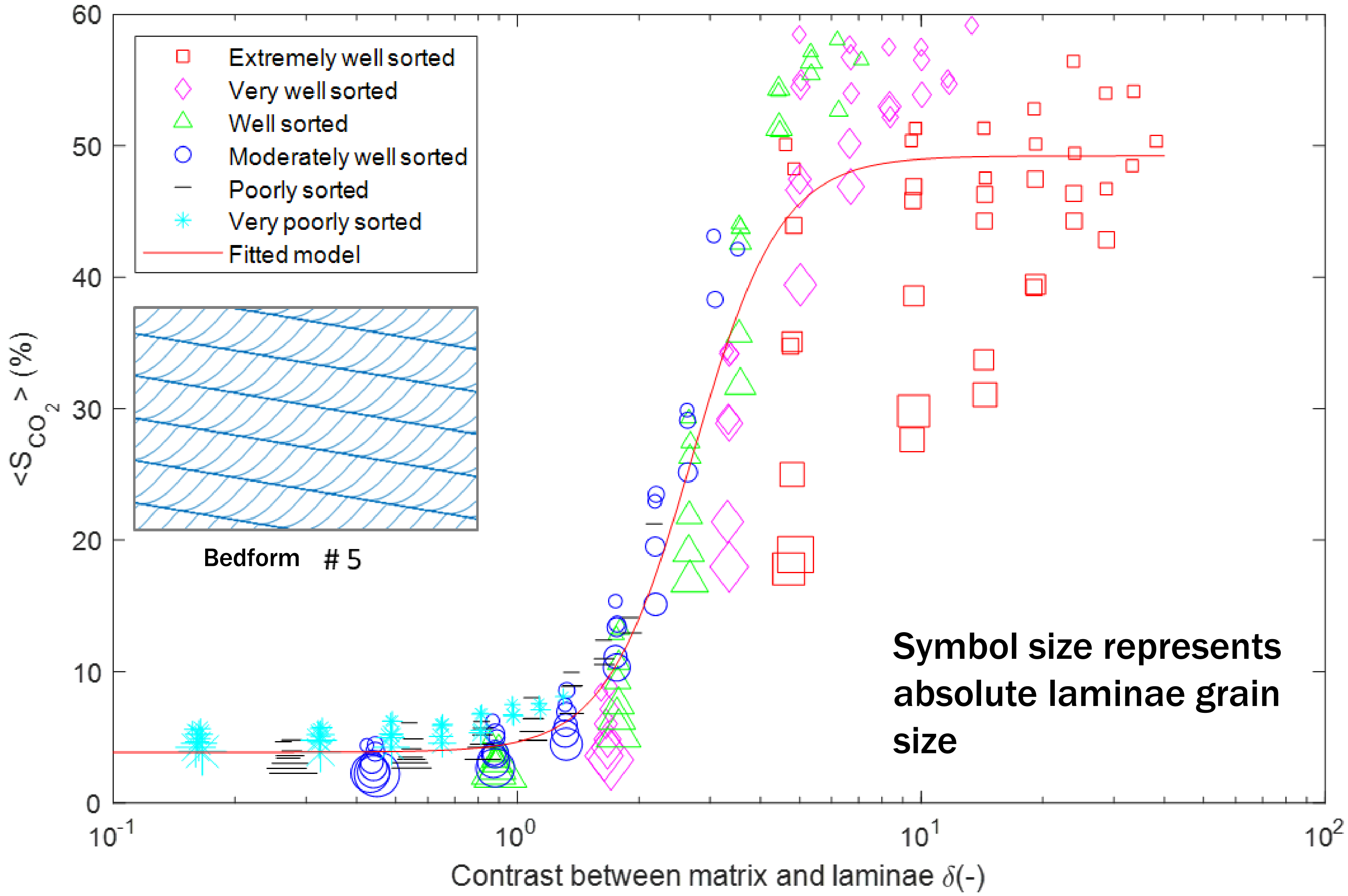
Important features: grain sorting and laminae grain size



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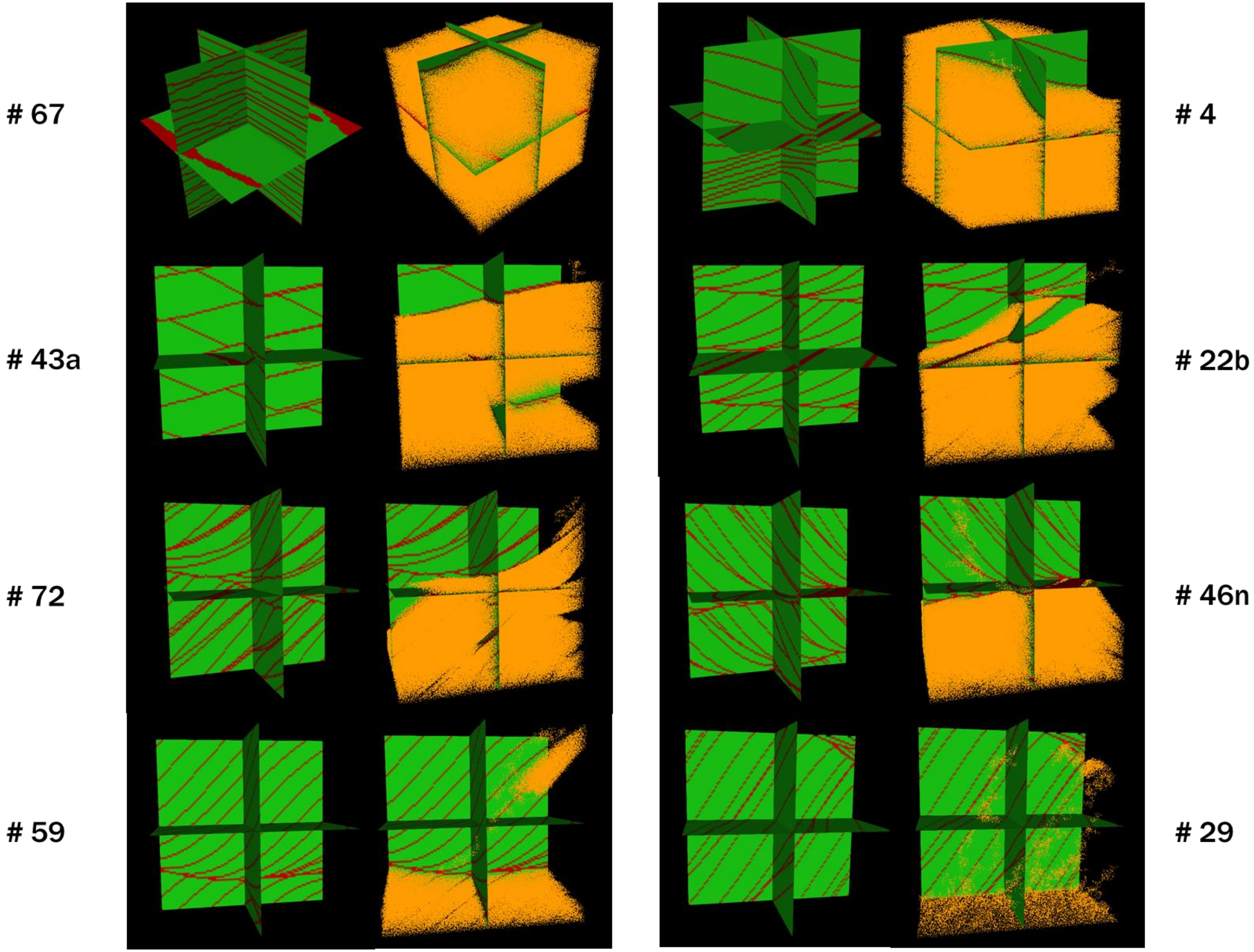
Important features: lamination type and shape

- High CO_2 saturation:
  - Continuous ripple lamination
- Low CO_2 saturation:
  - Discontinuous cross-lamination



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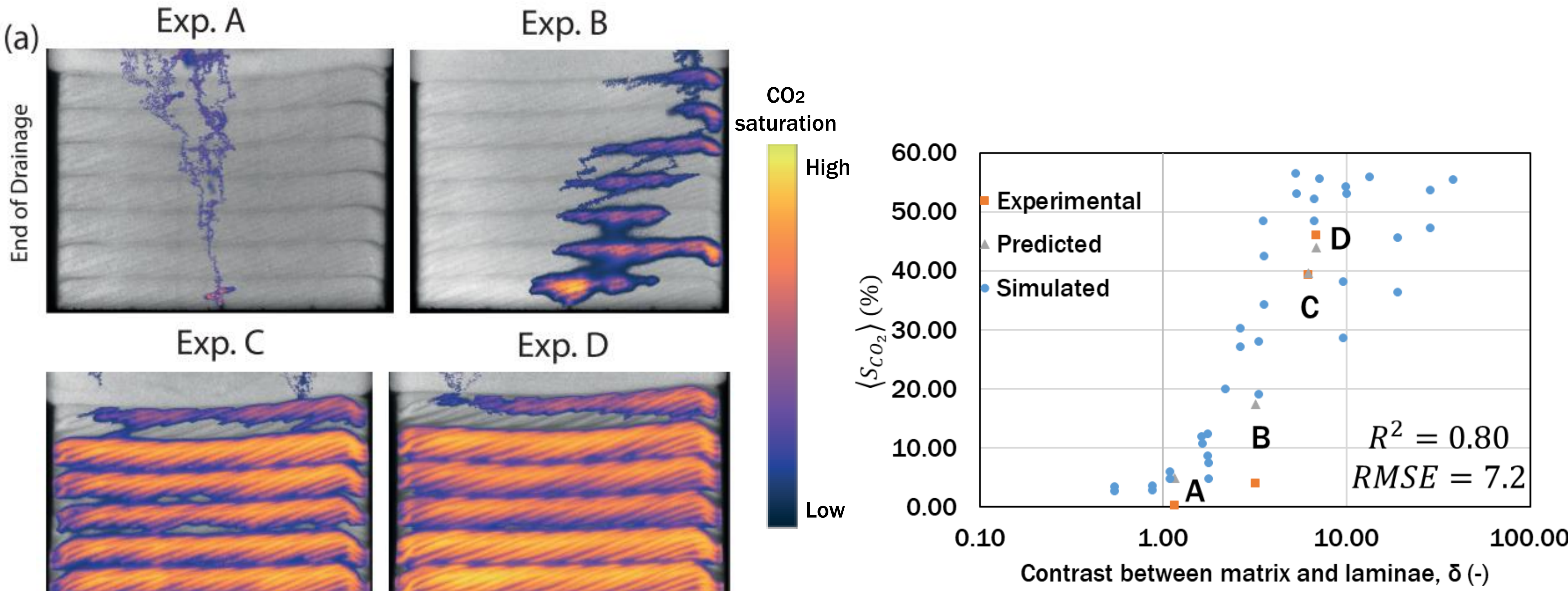
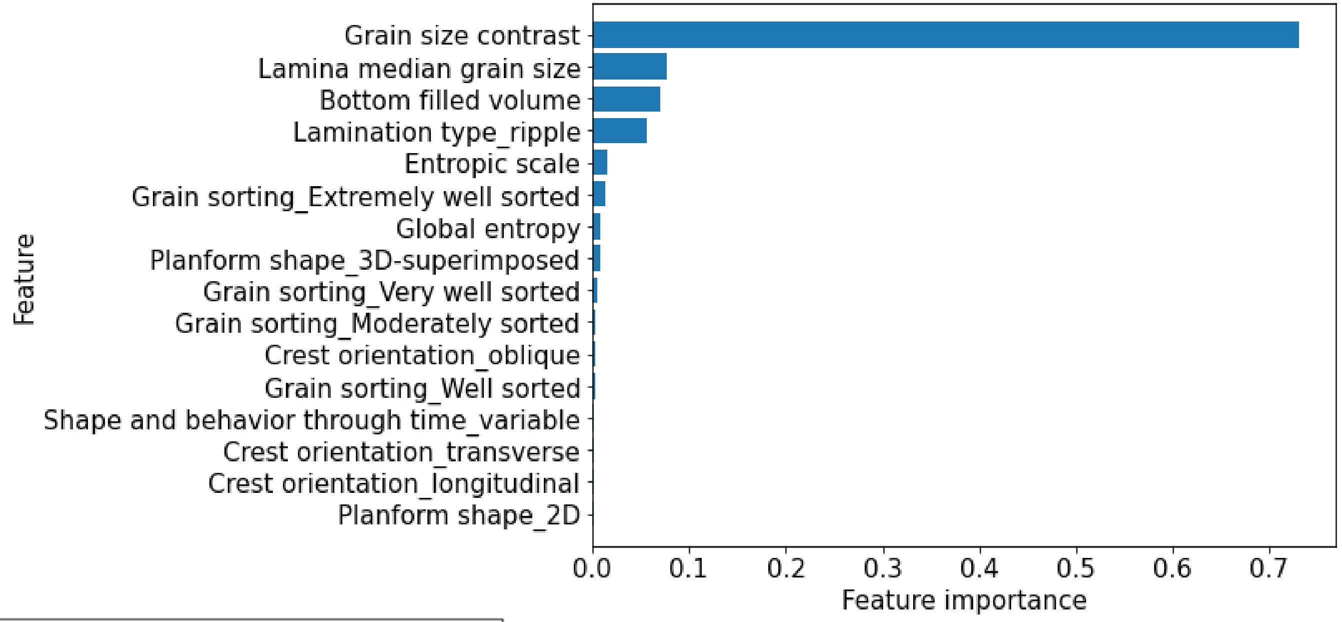
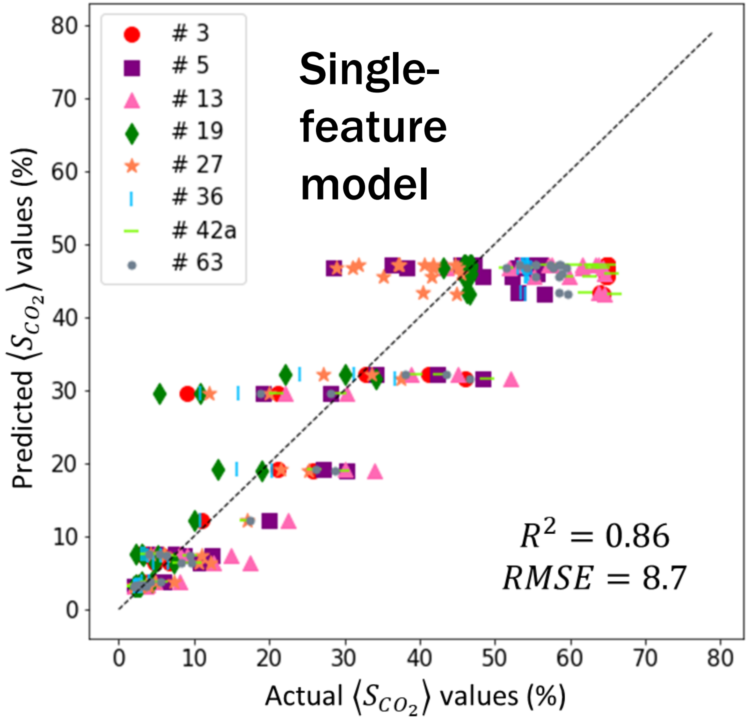
Validation: experiments

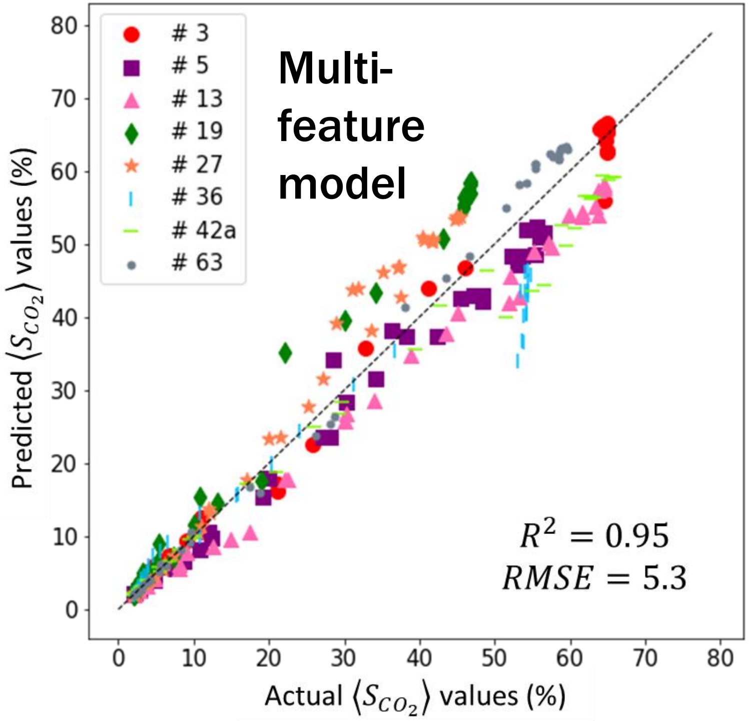


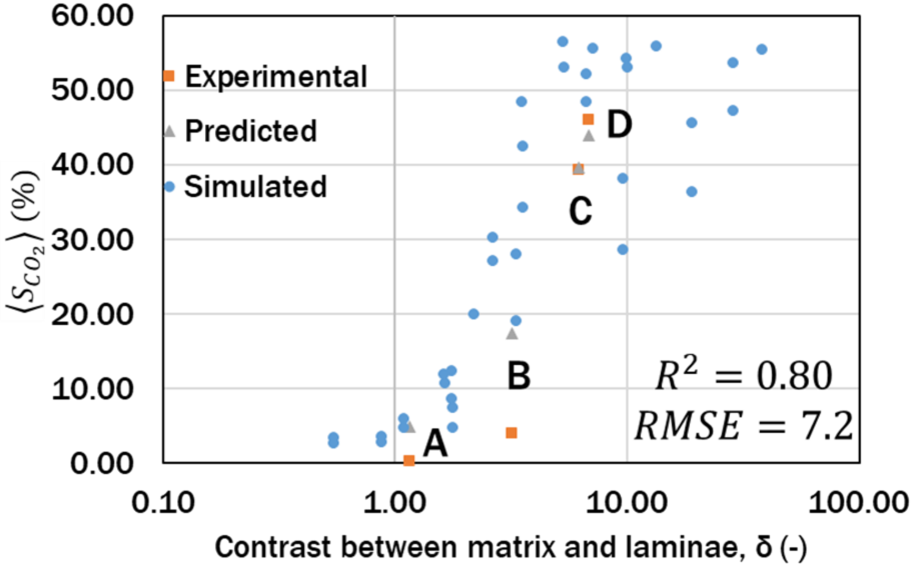
Krishnamurthy, 2020

Conclusions

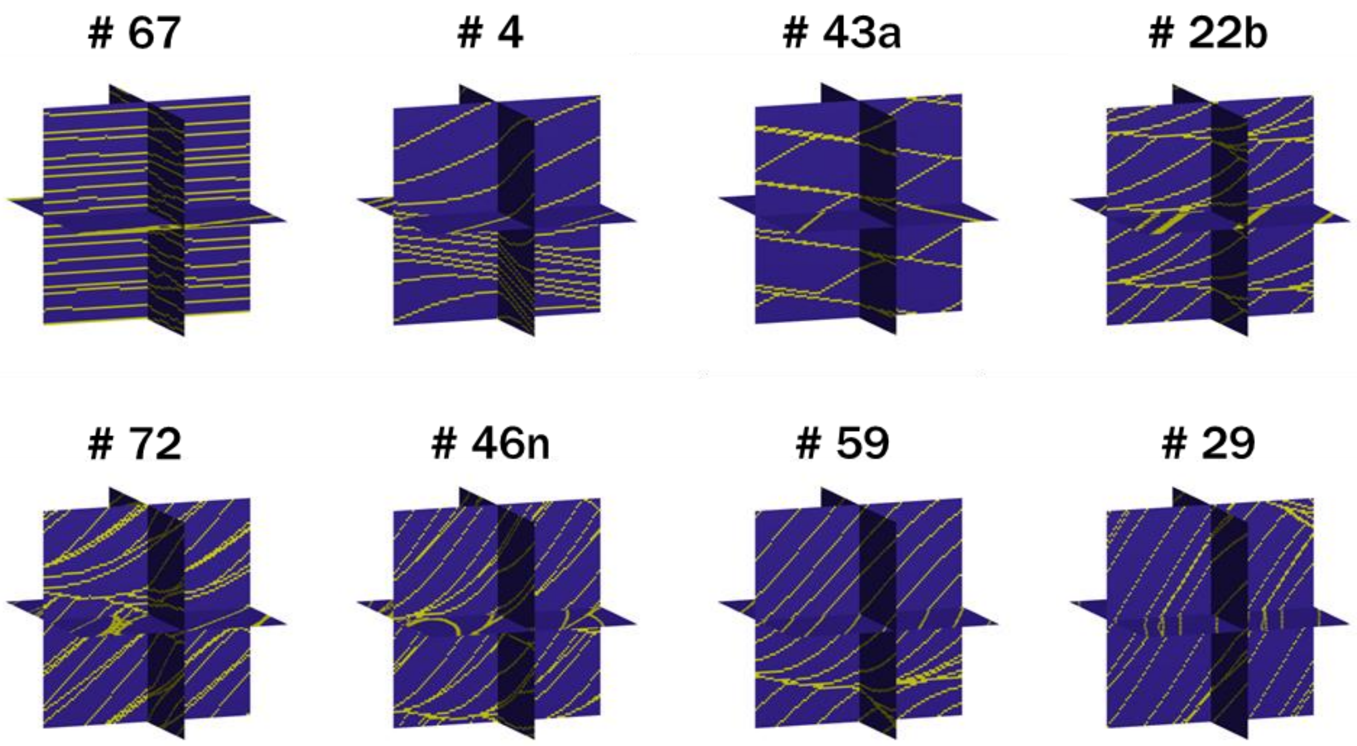


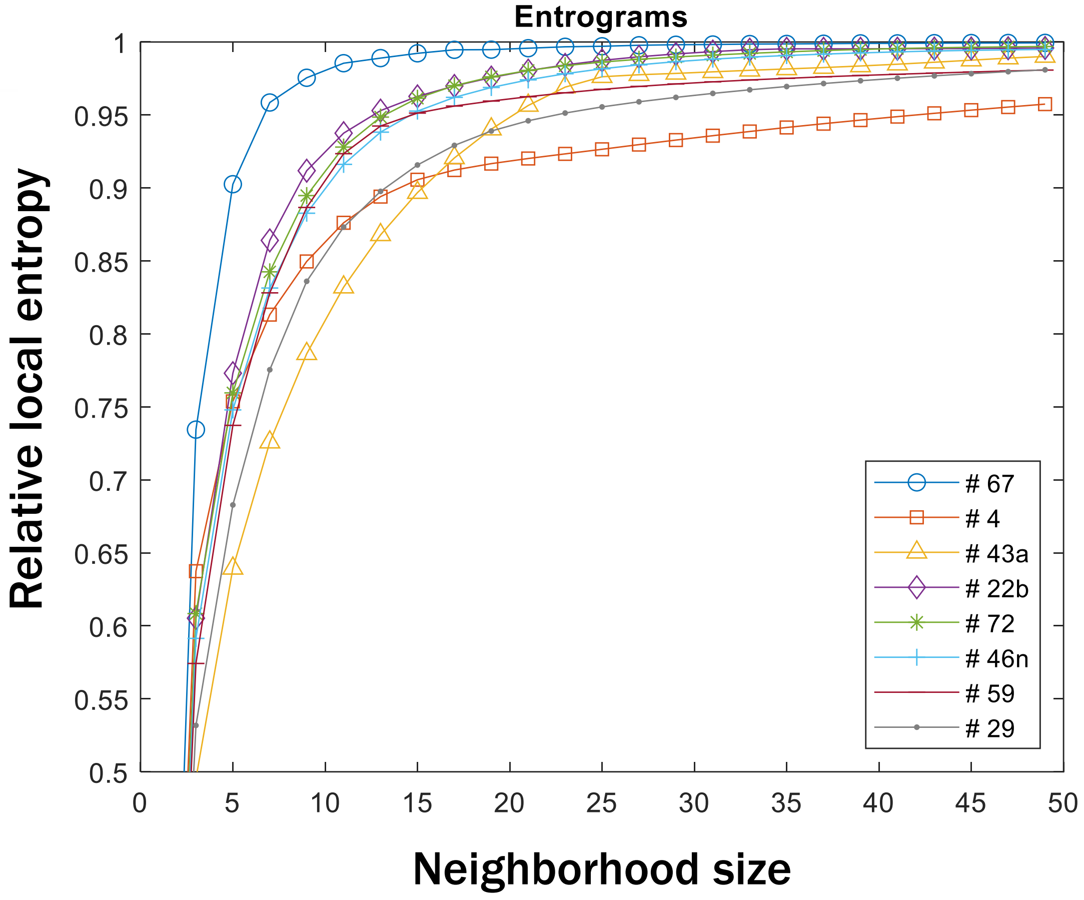






Important features: geological entropy and entrograms

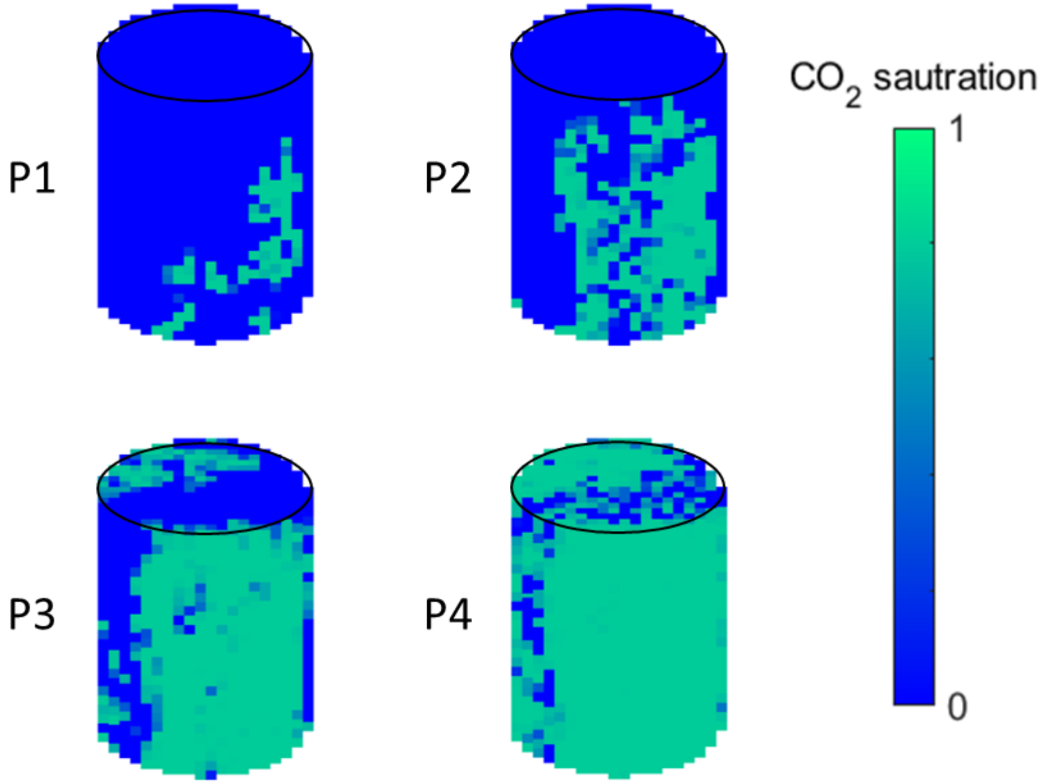


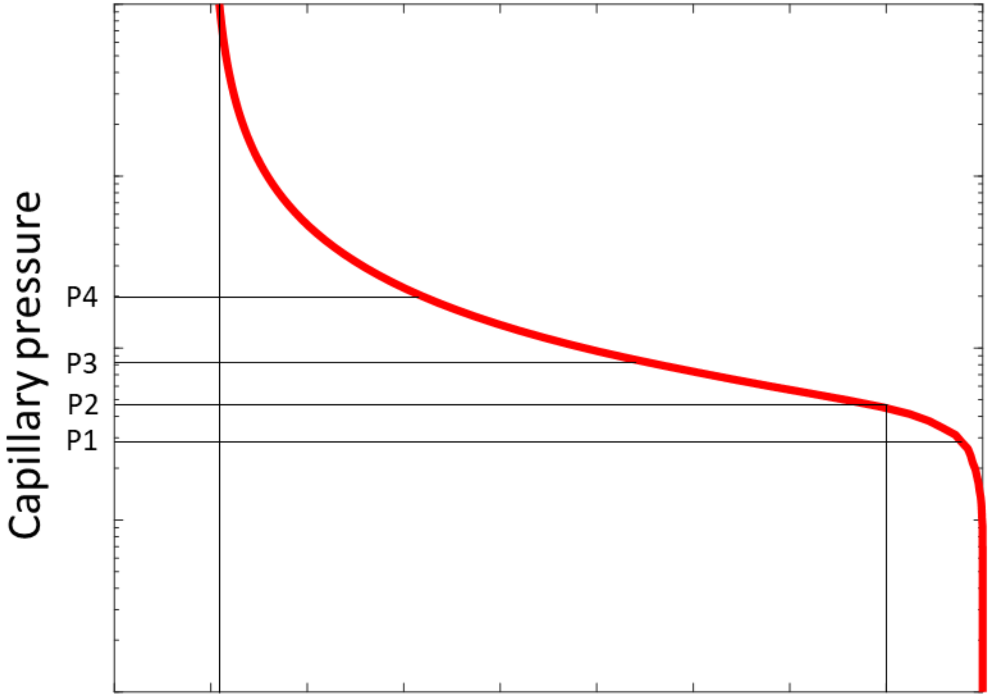


Bianchi & Pedretti, 2017; 2018

Potential model use case: upscaling critical CO_2 saturation for heterogeneous domains

Threshold capillary pressure





Irreducible water saturation

1 – critical CO_2 saturation