CO_2 Storage in Carbonate Reservoirs: Validation of the permeability model from microns to meters

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Lawrence Livermore National Laboratory

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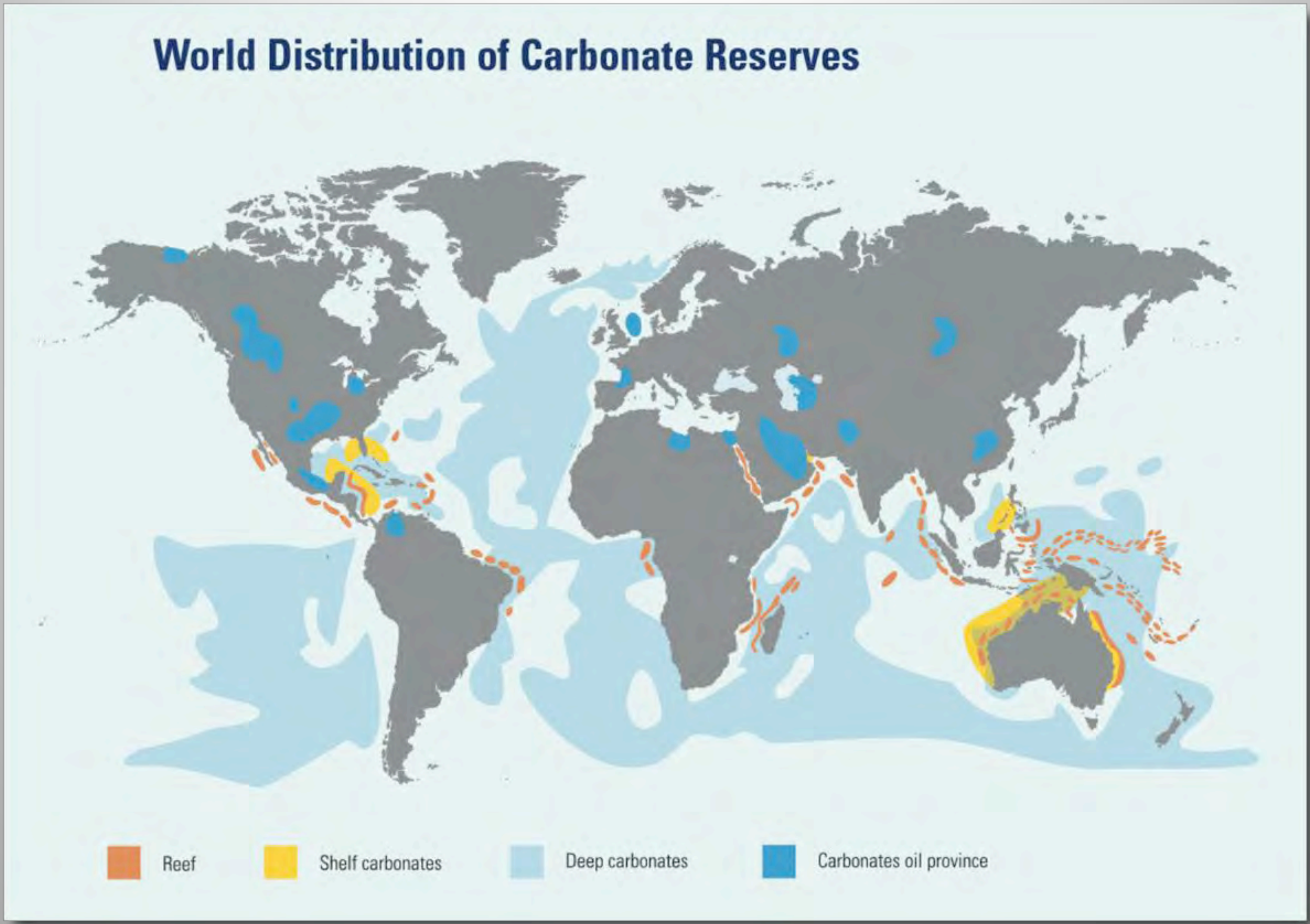
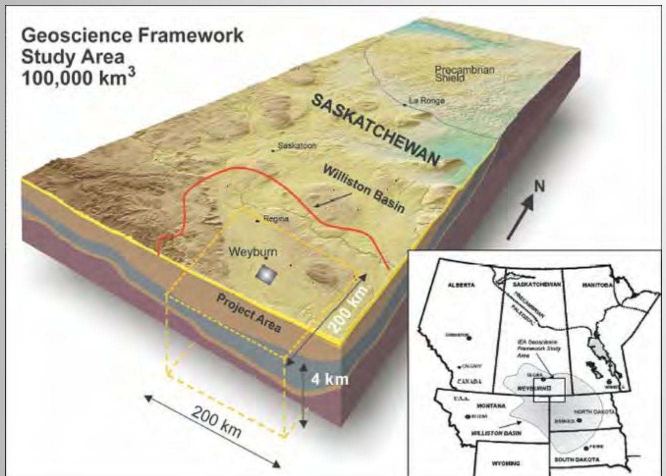


Schlumberger, “Carbonate Reservoirs,” 2007.

Weyburn, Canada



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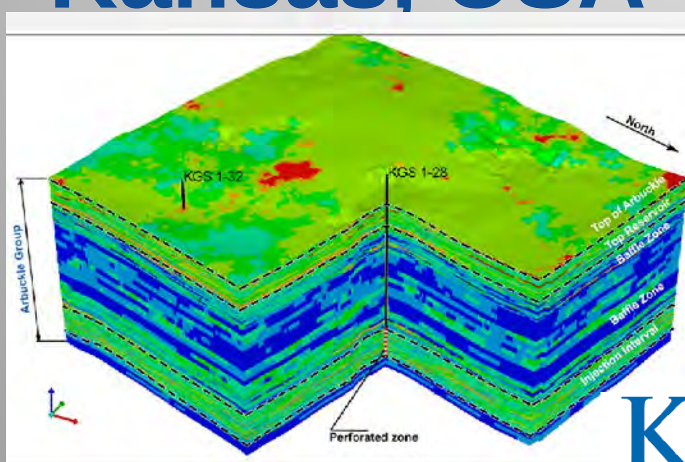
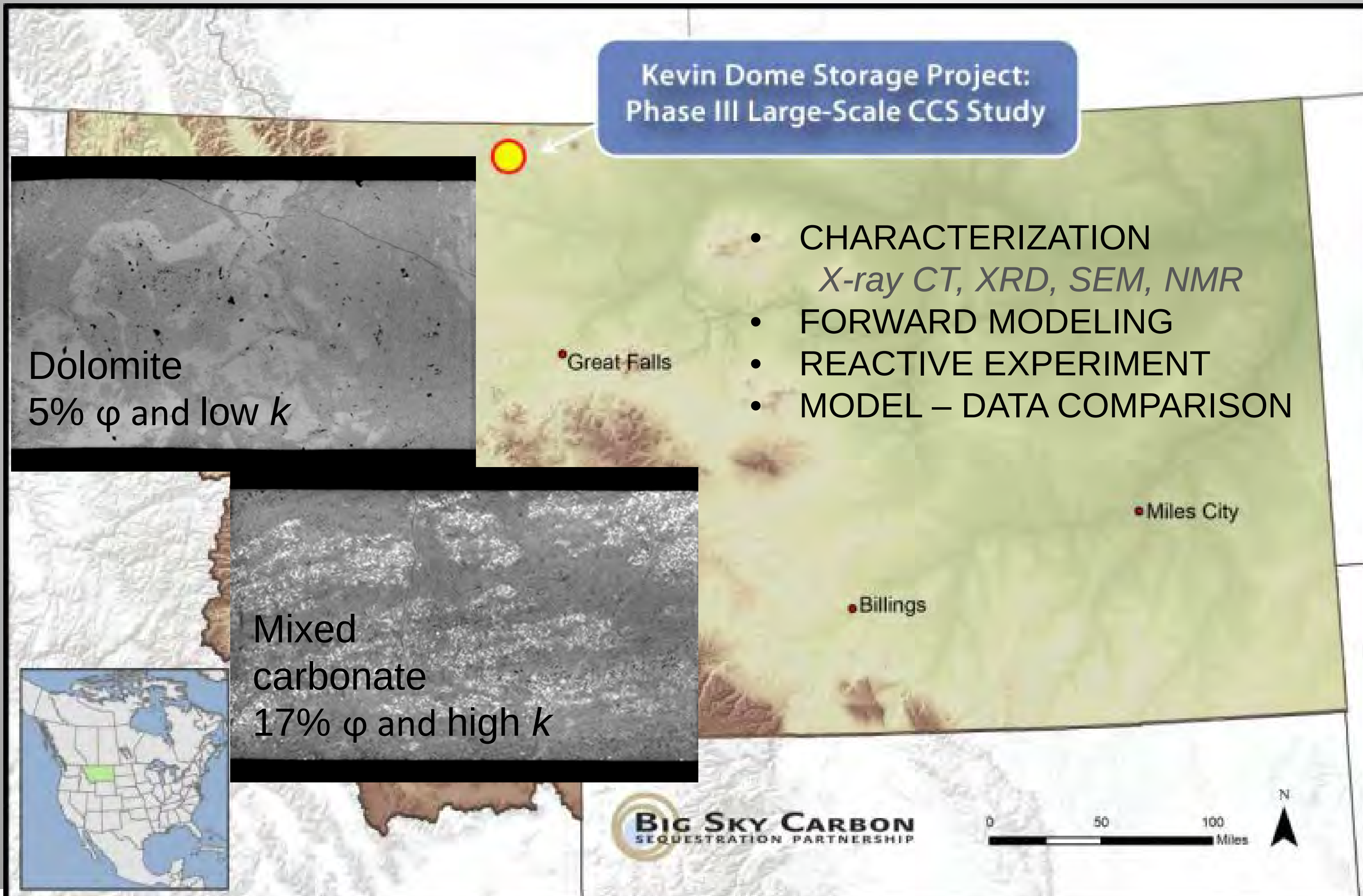


KU
KANSAS
GEOLOGICAL
SURVEY

We derived key reactive-transport parameters for carbonate rocks over a wide range of heterogeneity and initial permeability

Validation Study – Big Sky Demonstration, Duperow Formation (Lee Spangler and Stacey Fairweather)

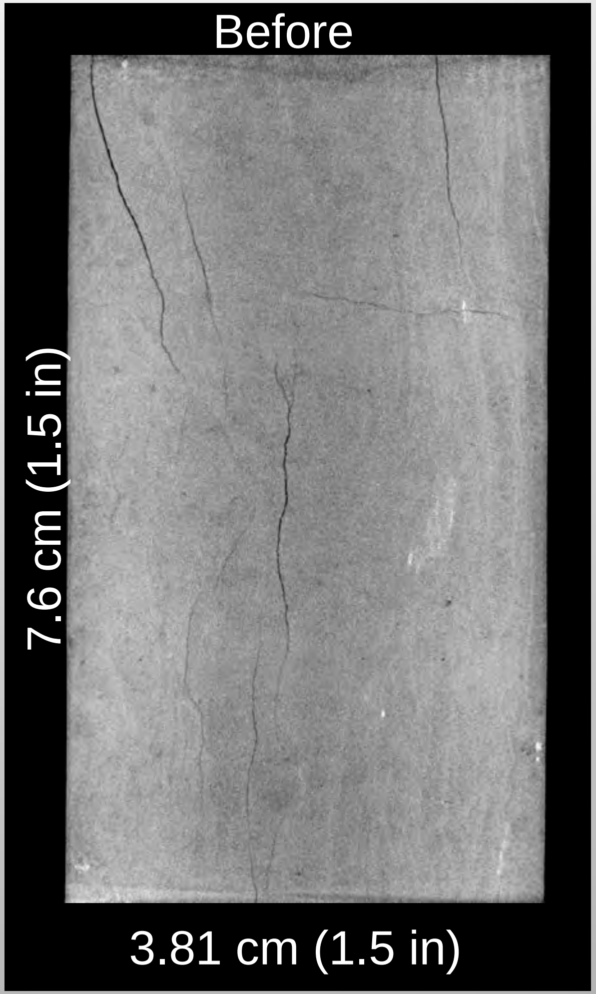


- CHARACTERIZATION
  X-ray CT, XRD, SEM, NMR
- FORWARD MODELING
- REACTIVE EXPERIMENT
- MODEL – DATA COMPARISON

Approach

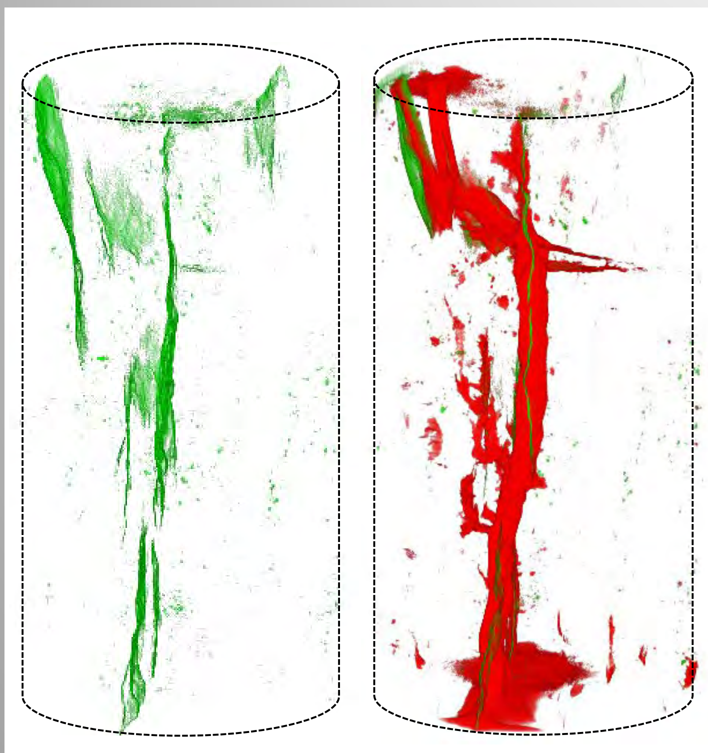
- Build the geologic model from imaging data
- Calibrate the initial model permeability against the experiment.
- Run simulations spanning model parameters (n, k)
- Compare simulated and measured results

Duperow Dolostone (1231 m)



Forecasts match change in void space

Experimental observations



pre-existing fractures

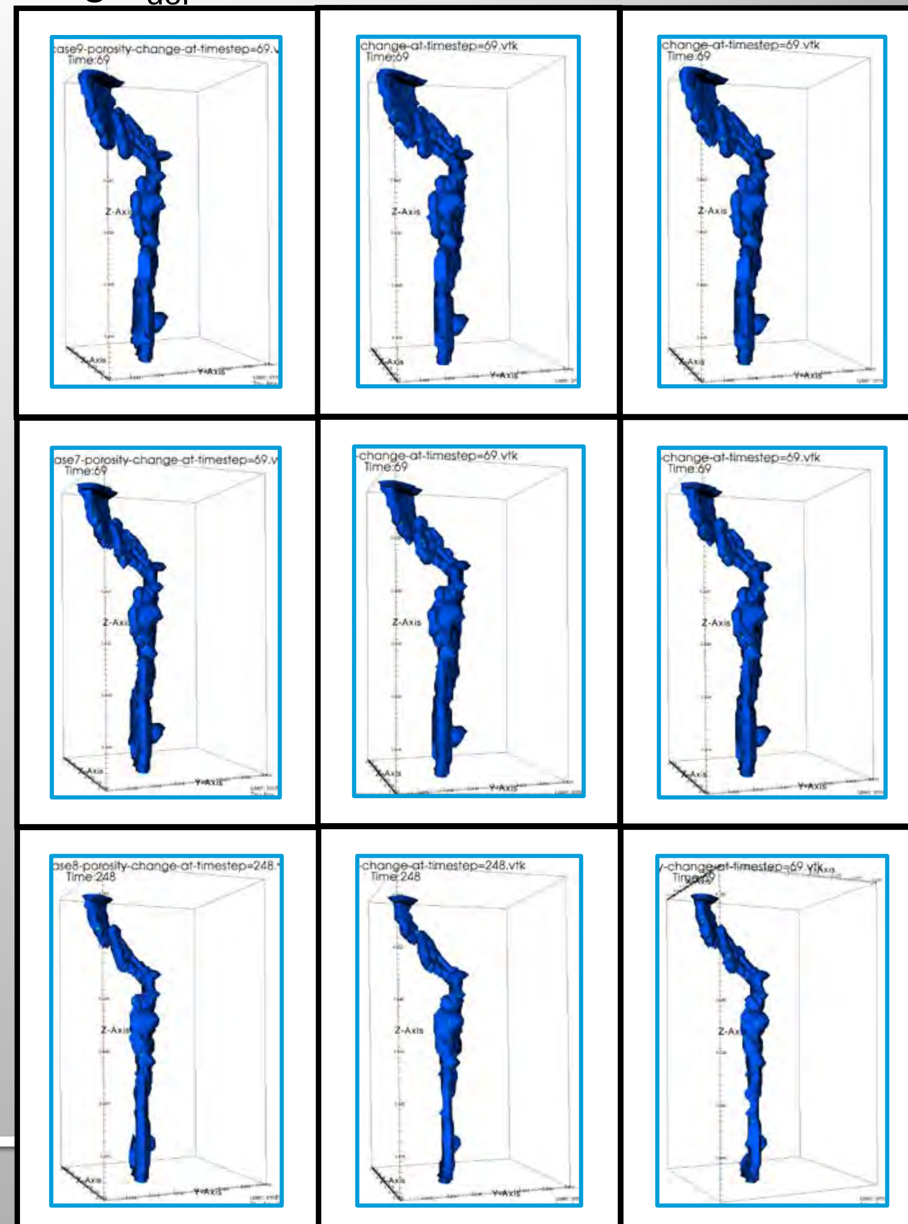
CO_2-induced dissolution pathways

log k_{dol} = -8 | -7 | -6

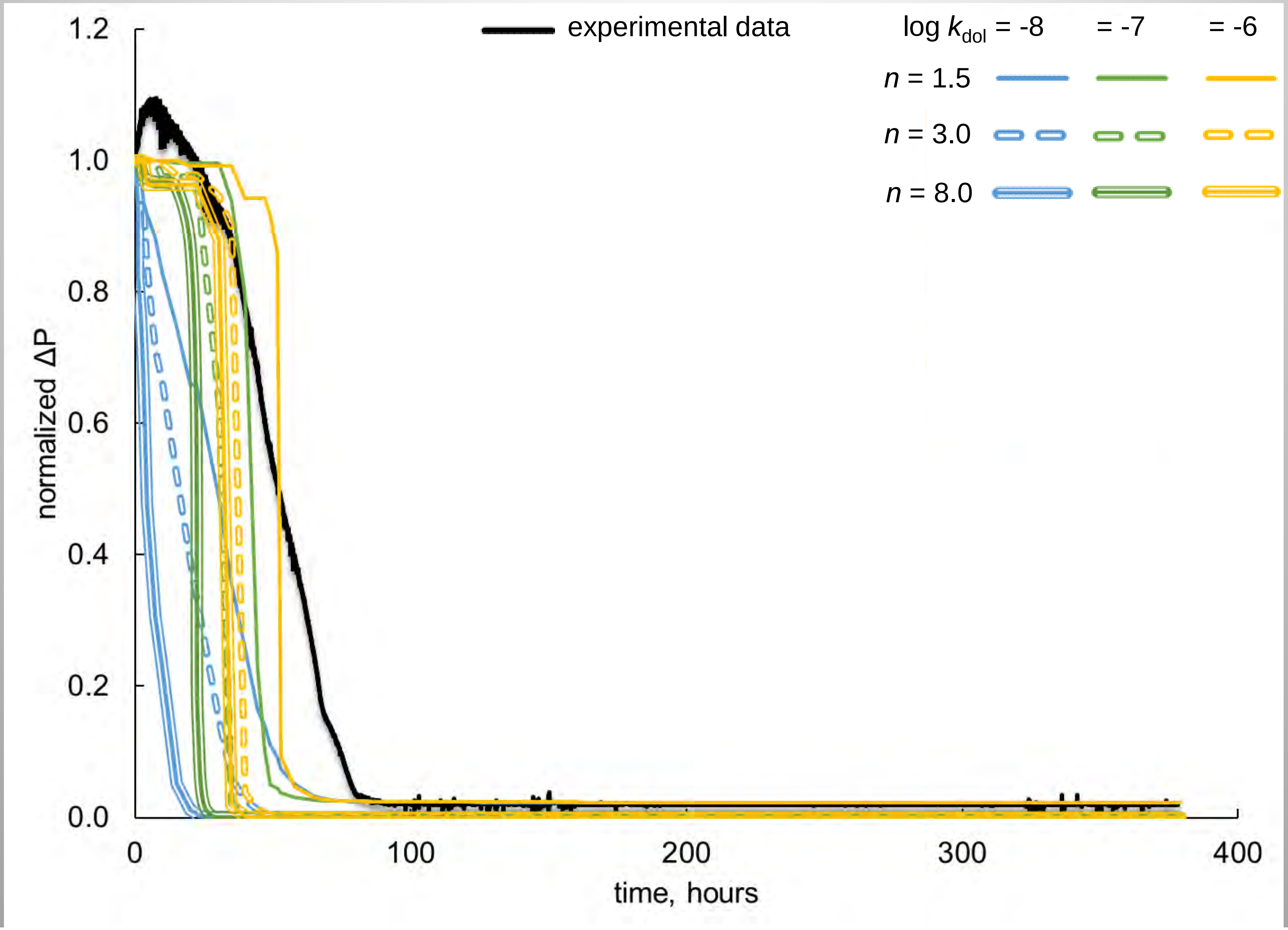
n = 1.5

n = 3.0

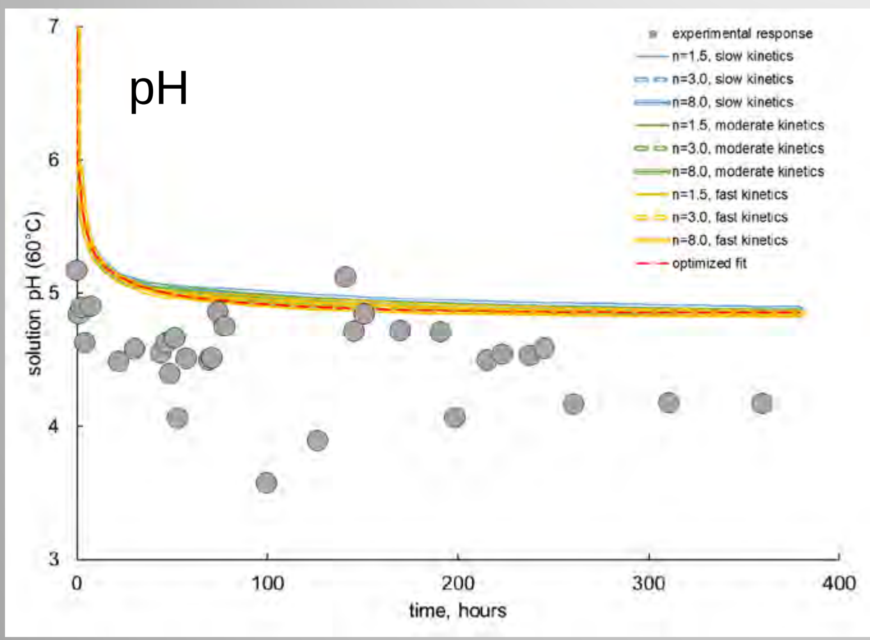
n = 8.0

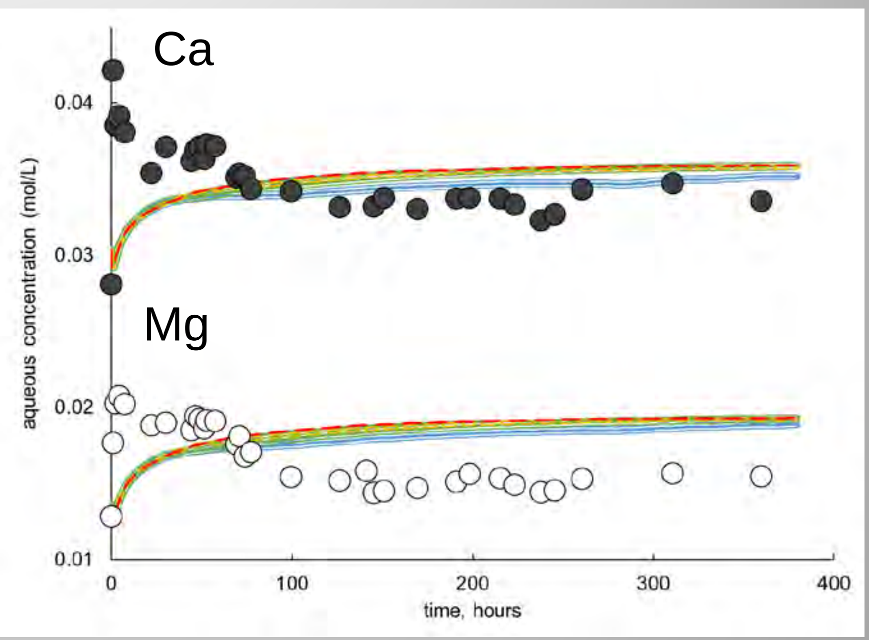


Forecasts match pressure decline and permeability increase

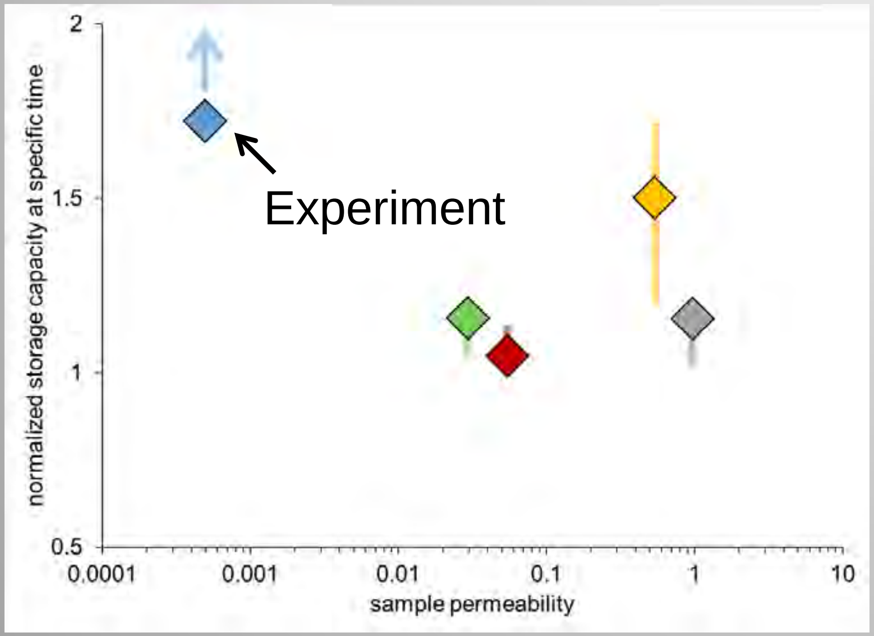


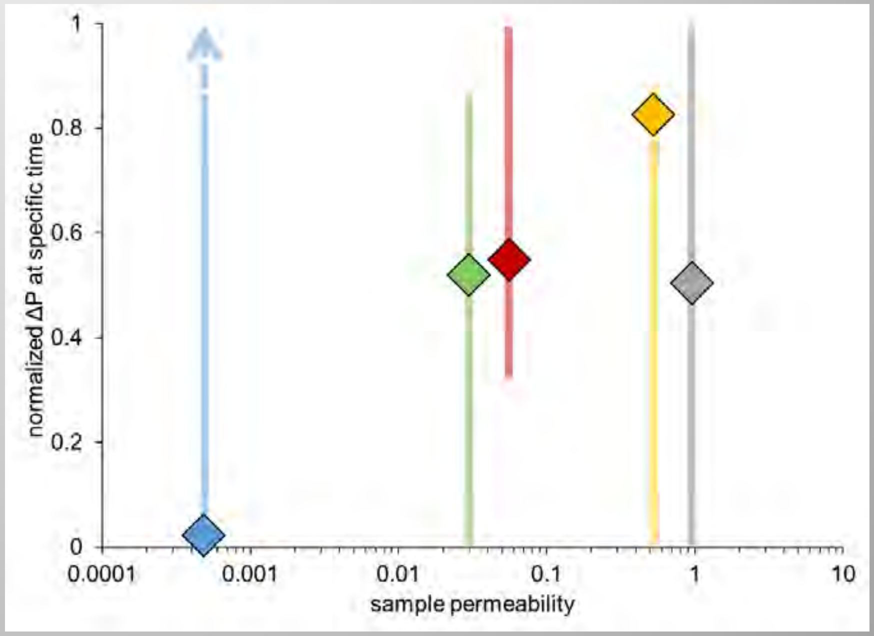
Forecasts match solution chemistry





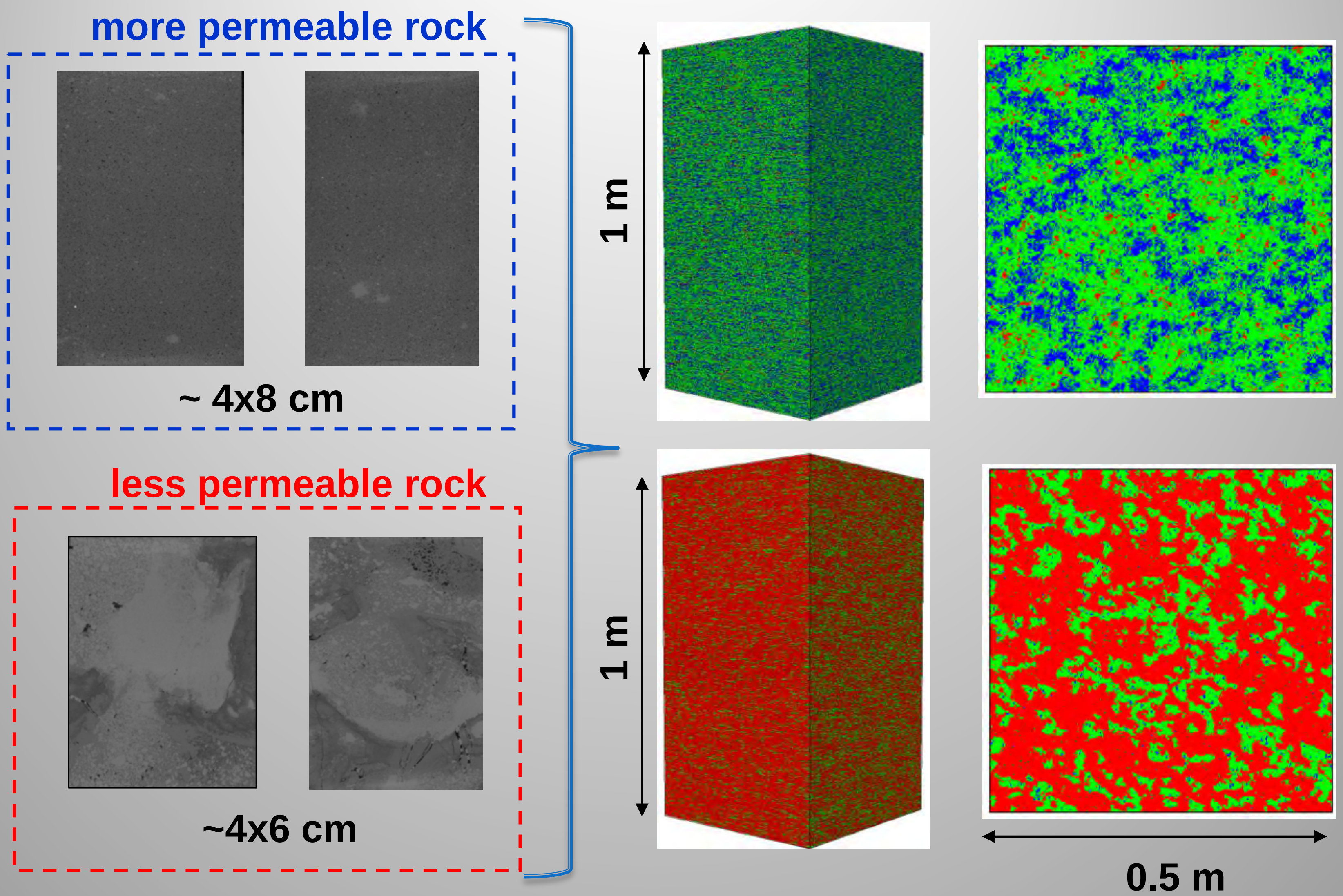
We have validated the carbonate model showing good agreement for permeability and pore space at the experimental scale



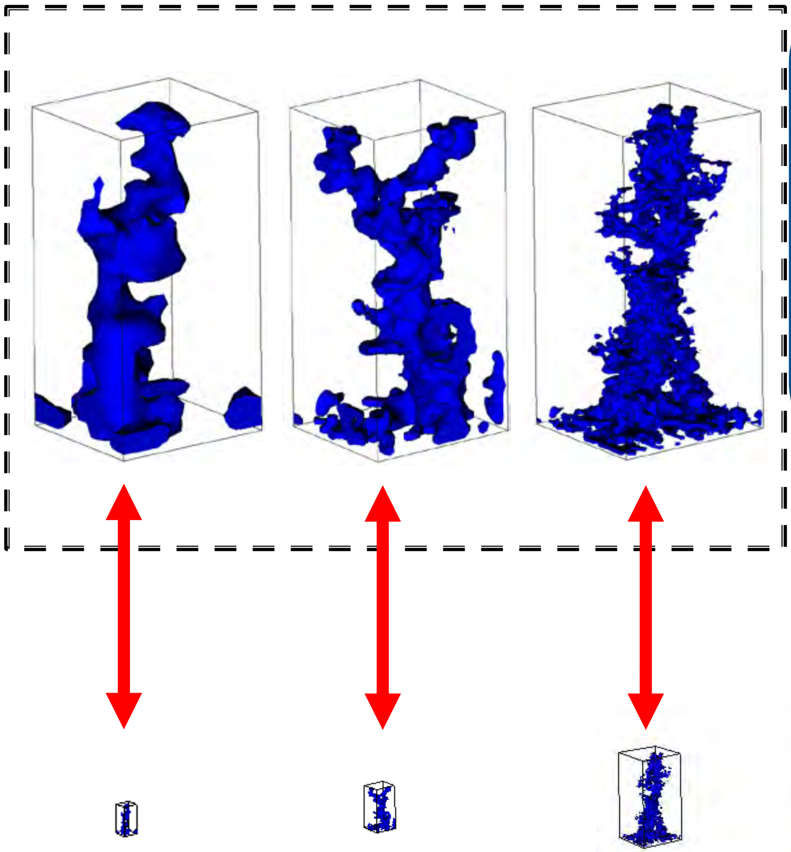


Model validation at the meter scale

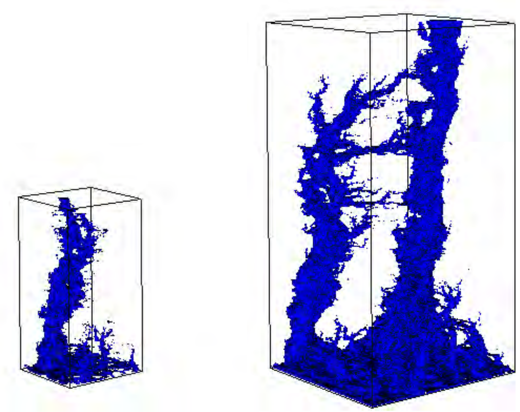
We used multiple point statistics of rocks to simulate meter scale heterogeneity

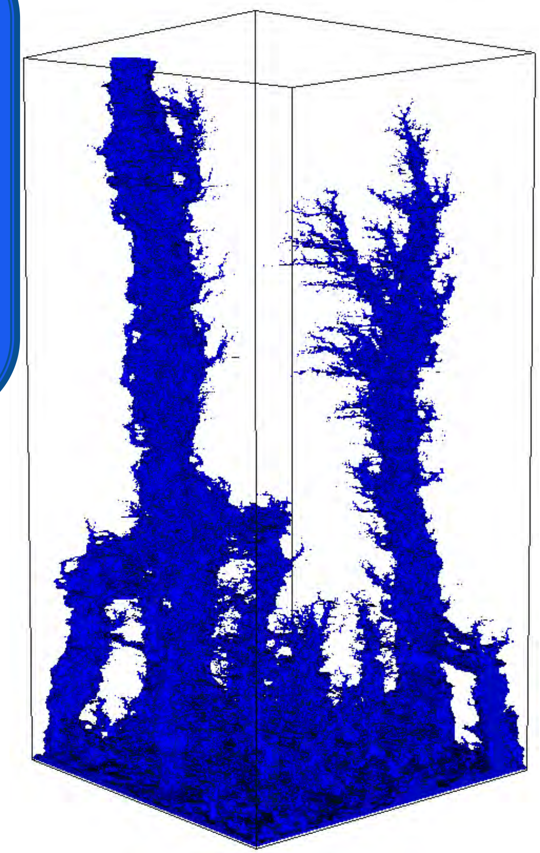


BRUTE FORCE - CALCULATION



Model is calibrated against experiment
- 250 million grid blocks
- 4096 cores
- 1,000 times increase in rock volume
- 20 times increase in reaction time

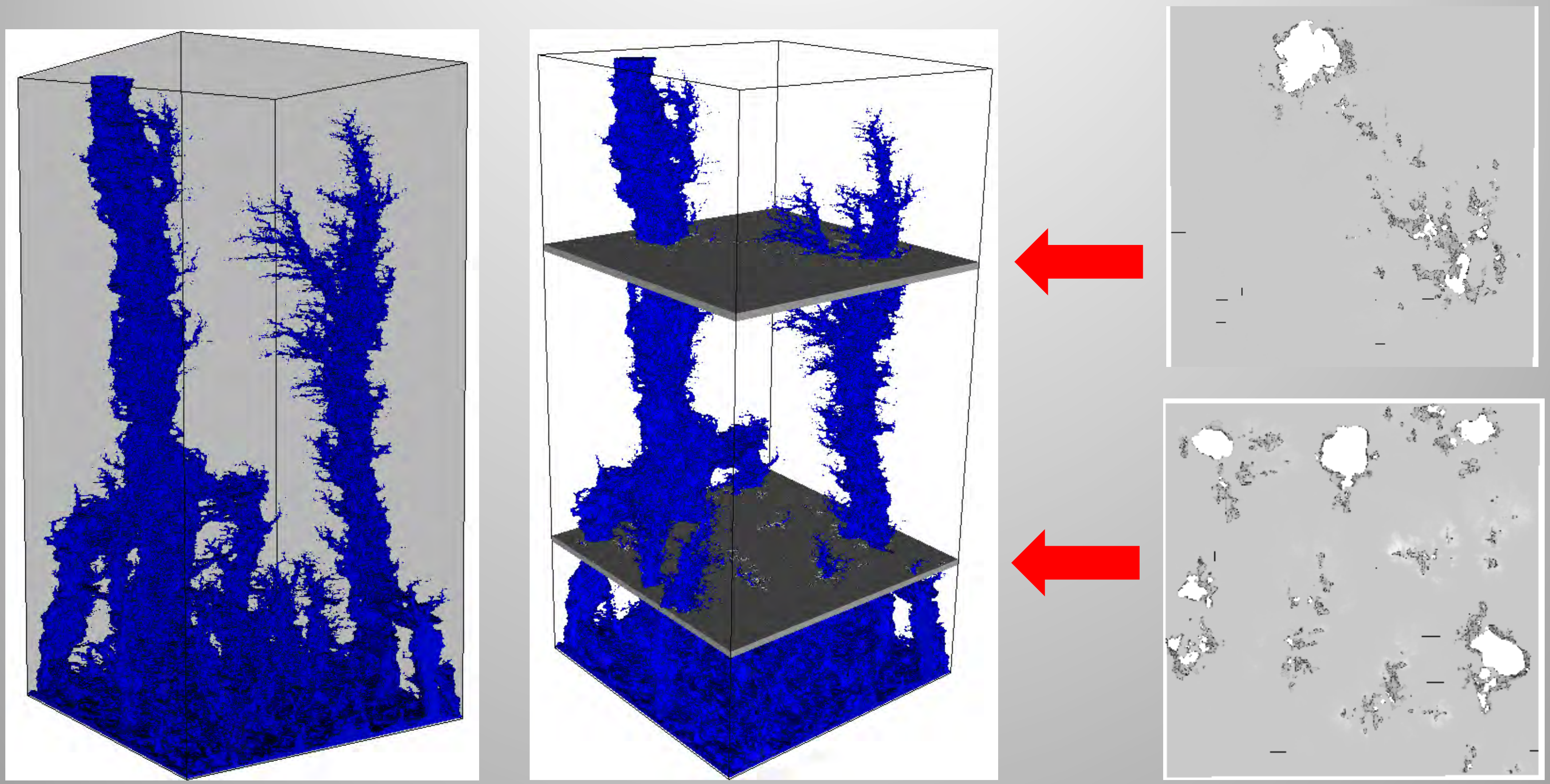




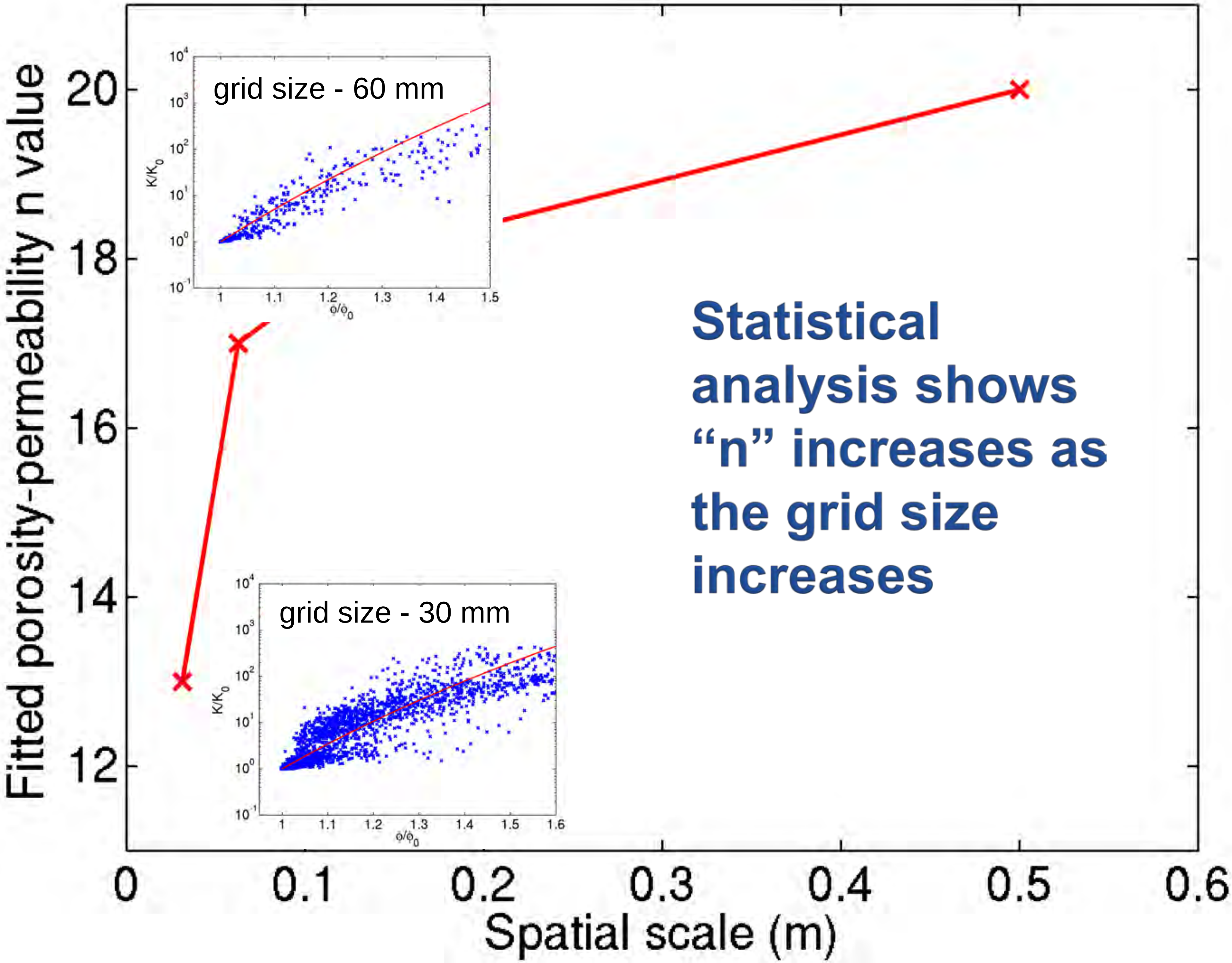
height : 30 mm **60 mm** **12.5 cm** **0.25 m** **0.5 m** **1 m**

Core-scale → **Meter-scale**

Dissolution causes a 30% increase in porosity and a 10,000% increase in permeability after 1000-hours of injection



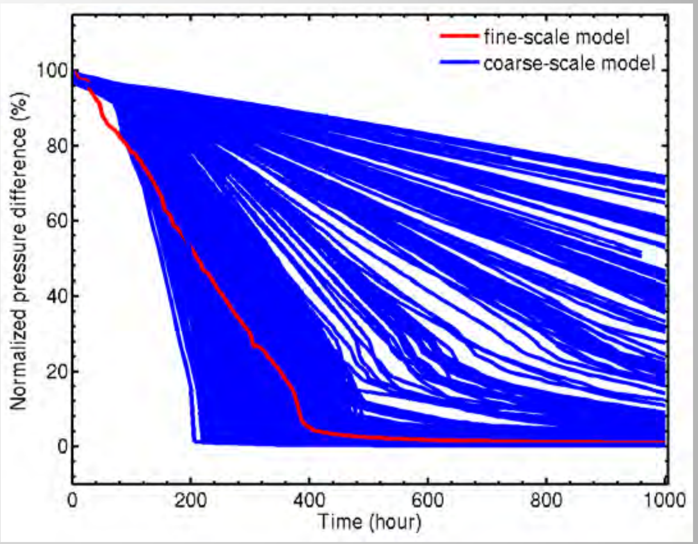
dissolution font



Statistical analysis shows "n" increases as the grid size increases

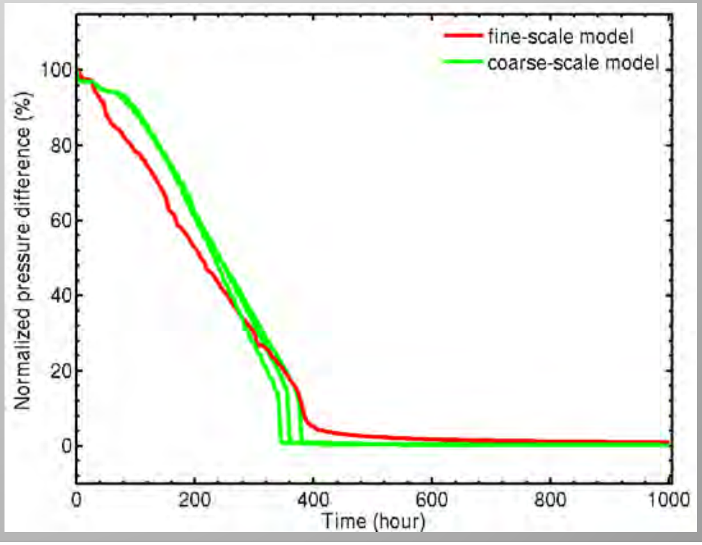
Uncertainty quantification analysis confirms higher "n" as grid size increases

Uncertainty quantification analysis
- 1000 realizations
- Latin hypercube
- porosity- permeability power n = 1 – 20
- calcite log(k) = -7.0 – -4.0
- dolomite log(k) = -8.0 – -6.0



best-matching parameters

	1	2	3	4
power n	13.2	18.1	18.5	19.5
Calcite log(k)	-5.9	-4.1	-4.9	-4.4
Dolomite log(k)	-6.6	-6.1	-6.4	-6.1

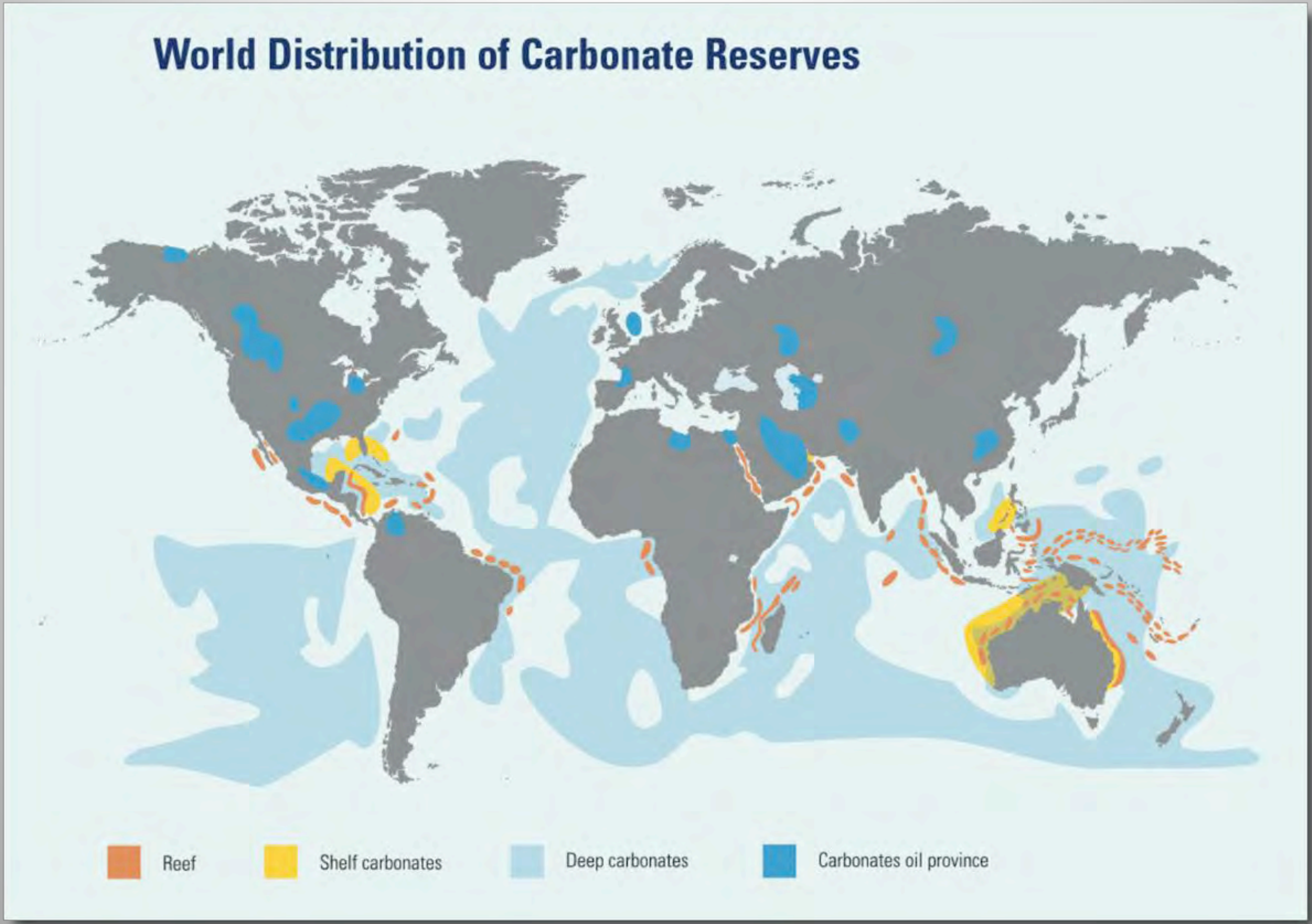


Accomplishments to date

- Calibrated permeability for carbonates using for downhole NMR measurements
- Derived key reactive-transport parameters and ranges for carbonate rocks over a wide range of heterogeneity and initial permeability
- Validated the model using core from an independent CO2 storage formation
- Used numerical methods to scale laboratory parameters to meter scale

Lessons Learned

- Carbonate formations are important reservoirs for long-term storage
- Reaction will change the pore space, altering permeability and storage space for CO_2
- Parameters that tie changes in void space to permeability depend on the grid size used in the reactive transport model



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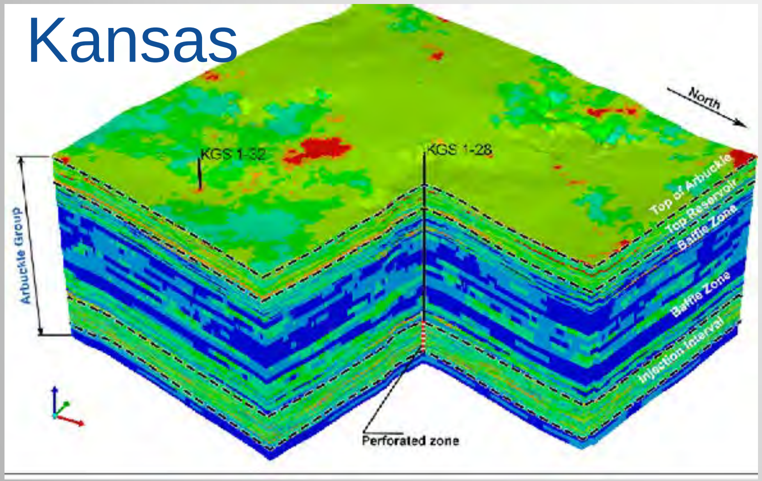
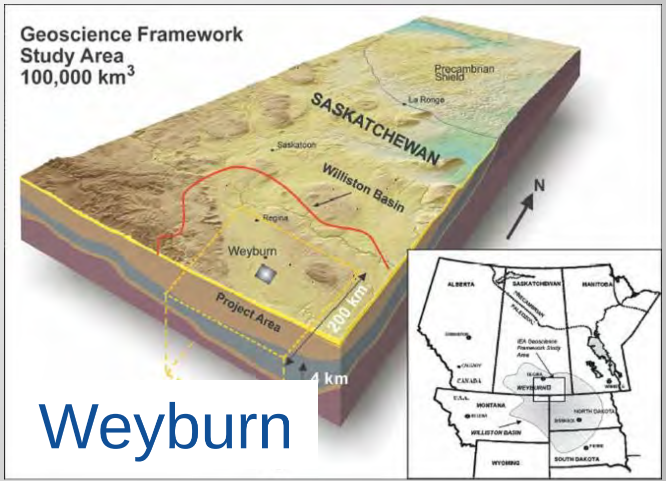
Appendix

Synergy Opportunities





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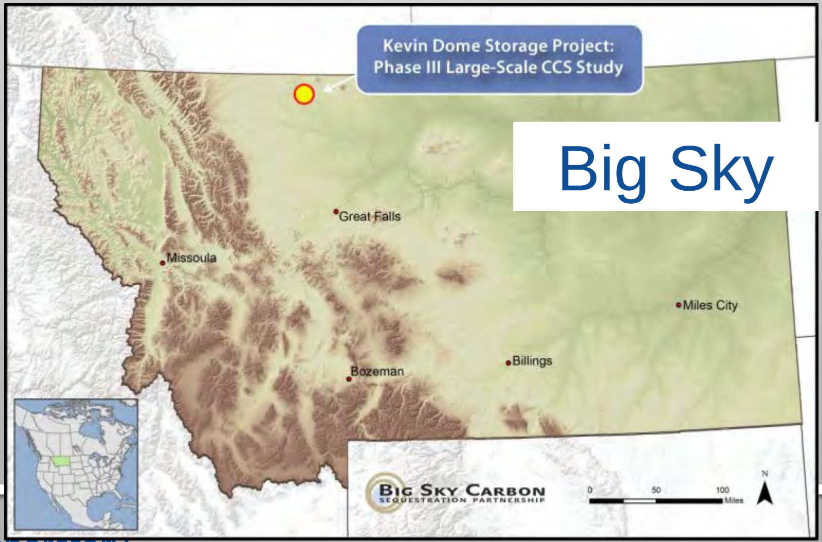

Project Summary

- This research project quantified relationships between fluid flow, heterogeneity, and reaction rates specific to carbon storage in carbonate reservoirs by integrating characterization, solution chemistry, and simulation data.

Benefit to the Program

- This research project quantifies relationships between fluid flow, heterogeneity, and reaction rates specific to carbon storage in carbonate reservoirs by integrating characterization, solution chemistry, and simulation data.

- This project meets the Carbon Storage Program goals   to develop technologies that will support industries’ ability to predict CO_2 storage capacity in geologic formations to within ±30 percent.

Project Overview

Goals and Objectives

- The goal of this project is to calibrate key parameters in reactive transport models that will be used to predict final storage of CO_2 in carbonate EOR fields.

- This project will advance science-based forecasting for the transition of CO_2 – EOR operations to storage sites.

- Success is tied to the ability to scale reactive-flow and transport parameters over a range of carbonate rock types and permeability.

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