An Evaluation of the Carbon Sequestration Potential of the Cambro-Ordovician Strata of the Illinois and Michigan Basins

Cooperative Agreement Number: DE-FE0002068

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U.S. Department of Energy

National Energy Technology Laboratory
Carbon Storage R&D Project Review Meeting
Developing the Technologies and
Infrastructure for CCS

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Presentation Outline

- Project Overview
  - Goals and Objectives
  - Benefits of Program
  - Scope of Work
- Accomplishments
- Summary
- Backup Material

Benefit to the Program

Program goals.

Reduce storage risk by documenting the uncertainties related to natural fractures, injectivity, and geochemical interactions for the St. Peter Sandstone and Knox strata.

Project benefits statement.

This project delineates potential new geologic intervals for carbon storage in Illinois, Indiana, Michigan, and Western Kentucky, which will enhance the North American carbon storage resource potential.

Support the DOE program initiative to develop BPMs for site selection, characterization, site operations, and closure practices.

Project Overview: Goals and Objectives

- Develop a Best Practices Manual that illustrates the methodology for reducing storage risks
- This Cambro-Ordovician project will highlight areas of high risk and low risk for carbon storage in the St. Peter and Knox strata in the Illinois and Michigan Basins.
- Show how seismic reflection data can be used to delineate high and low risk areas
- Study seals and reservoirs for faulting and fracture risk (geomechanical studies), as well as their interactivity and reactions with CO_2 in the presence of brine (geochemical studies).

Project Overview: Goals and Objectives

- Reservoir simulation of commercial injection into St. Peter and Knox to show carbon storage potential
- Perform CO_2 injection test in an existing well in Hancock County, Kentucky to evaluate injectivity of the Knox sandstone.
- Develop regional CO_2 storage resource estimates for the Knox and St. Peter for use in future version of DOE's North American CO_2 Storage Resource Atlas.

Partners

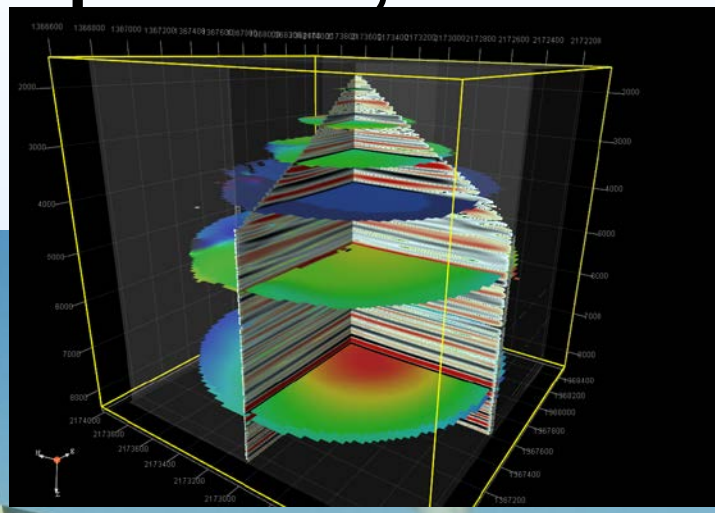
- Illinois State Geological Survey
- Western Michigan University
- Indiana Geological Survey
- Kentucky Geological Survey
- Schlumberger Carbon Services
- Brigham Young University

Leverage Other Existing Projects

- State of Kentucky
- Illinois Basin Decatur Project

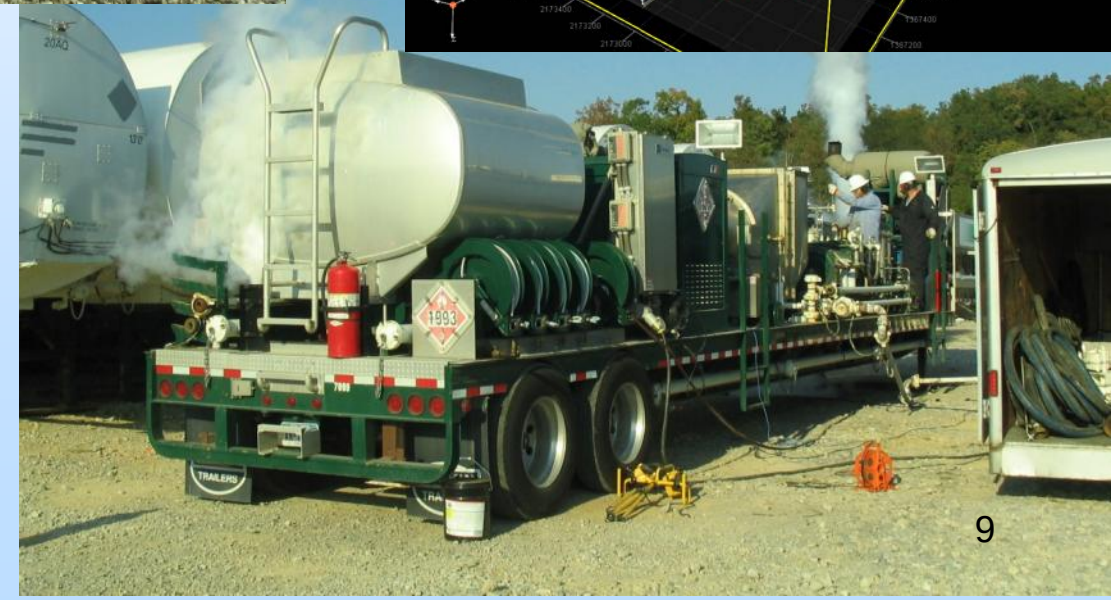
Operations

CO_2 injection test Knox sandstone, Sept. 20-21, 2010



Open-hole interval 5,038 – 5,268 ft

- 367 tonnes CO_2
- 3 bbl per minute
- 1,000 psi wellhead
- 2,538 psi final bottom hole pressure



Results of Kentucky Well Test

- CO_2 storage well comparable to the Marvin Blan No. 1 would require approximately 103 surface hectares to store 1 million tonnes of CO_2.

Lithology and Stratigraphy

Potosi Lost Circulation Zone

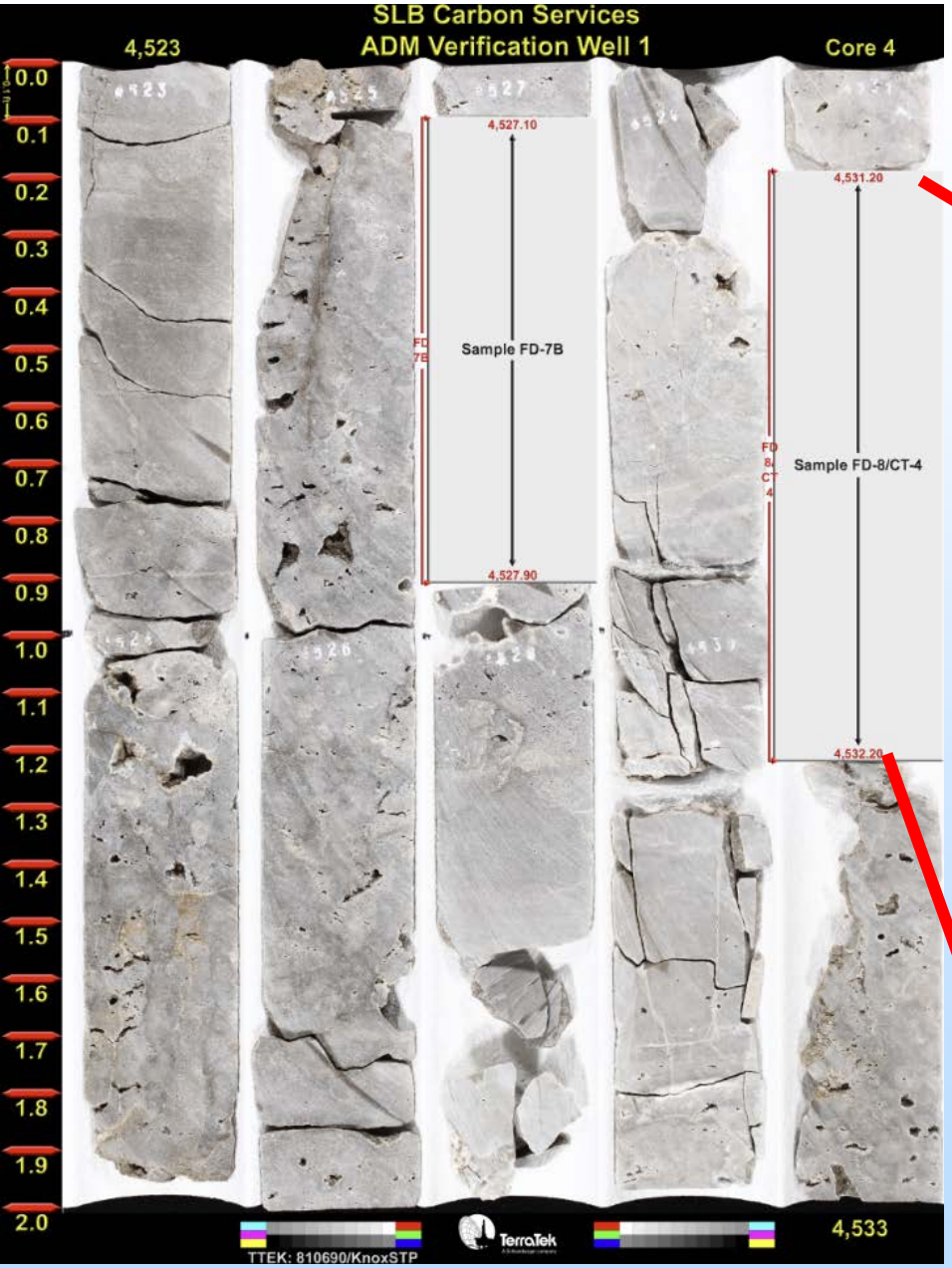
FMI Log
Core interval (4540-4600)
Potosi lost circulation zone

Solution cavities

Core was recovered from Decatur, Illinois

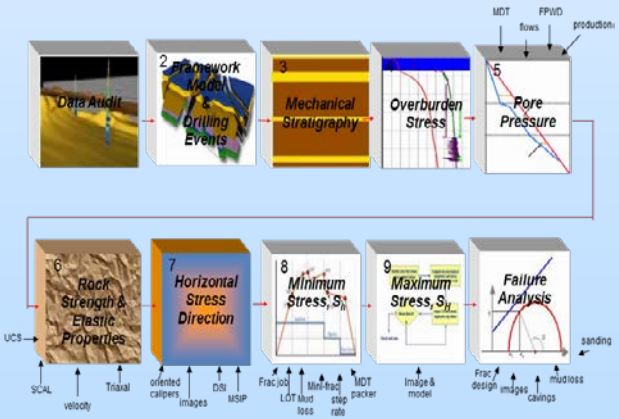
Core interval

Potosi



CT Scan

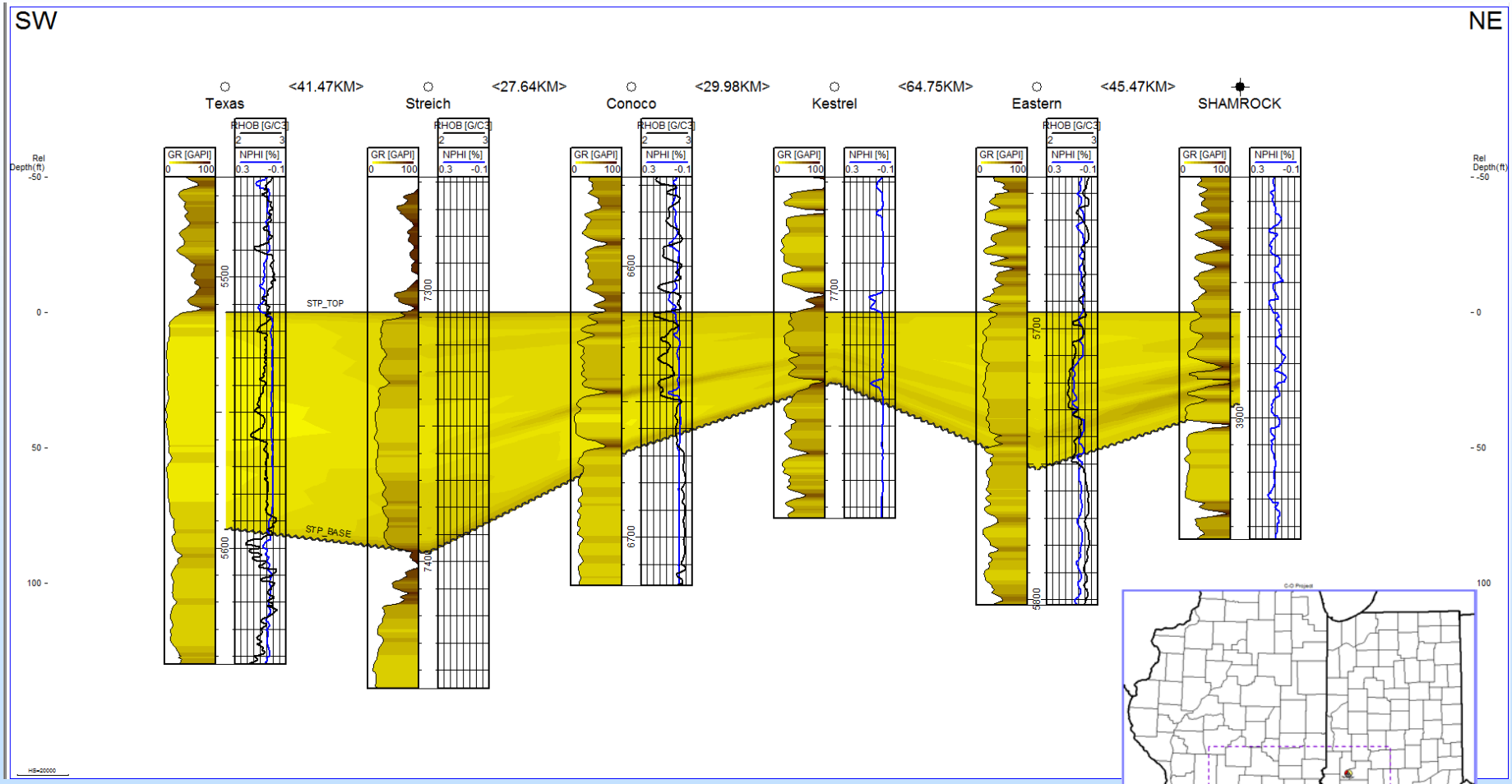
Geomechanical testing of core



Tuscola, Illinois
A real Example

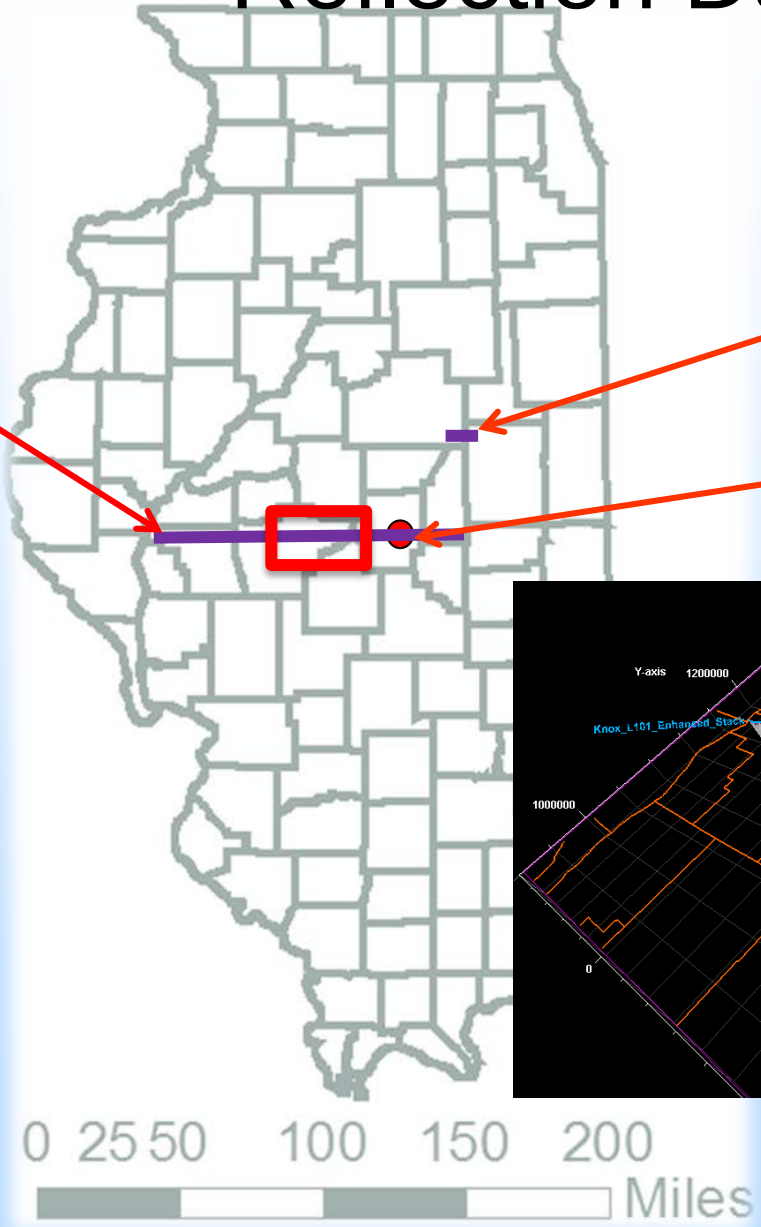
- Since 1970, the Tuscola hazardous wells have injected 18 billion Gal of liquid (68 kl) into the Potosi
  - Equivalent to injecting more than 50 million metric tons of CO_2 into the Potosi
  - Still injecting equivalent to 60,000 tonnes per month of CO_2
- From an injectivity/ falloff test, the estimates of Potosi permeabilities were greater than 9000 mD

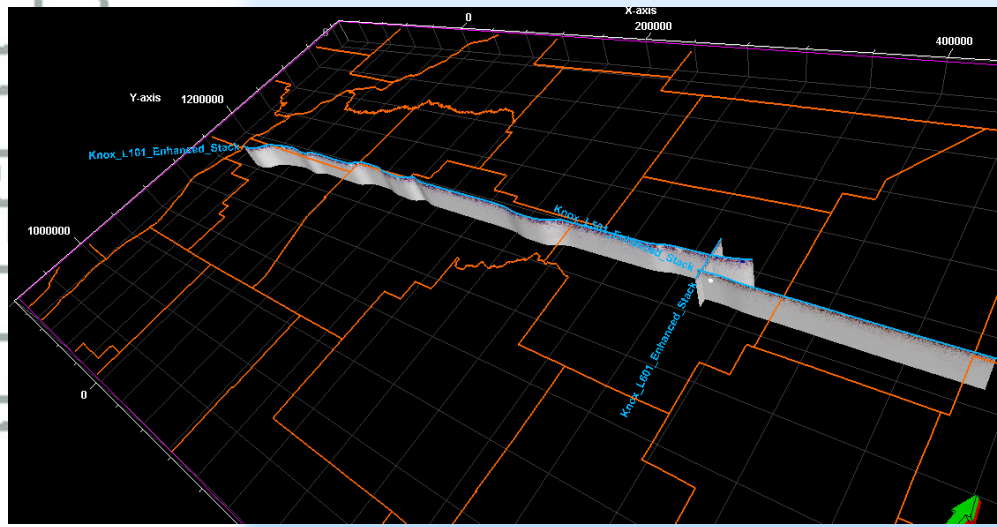
SW-NE cross section of St Peter Ss with interpretive fill from gamma-ray log



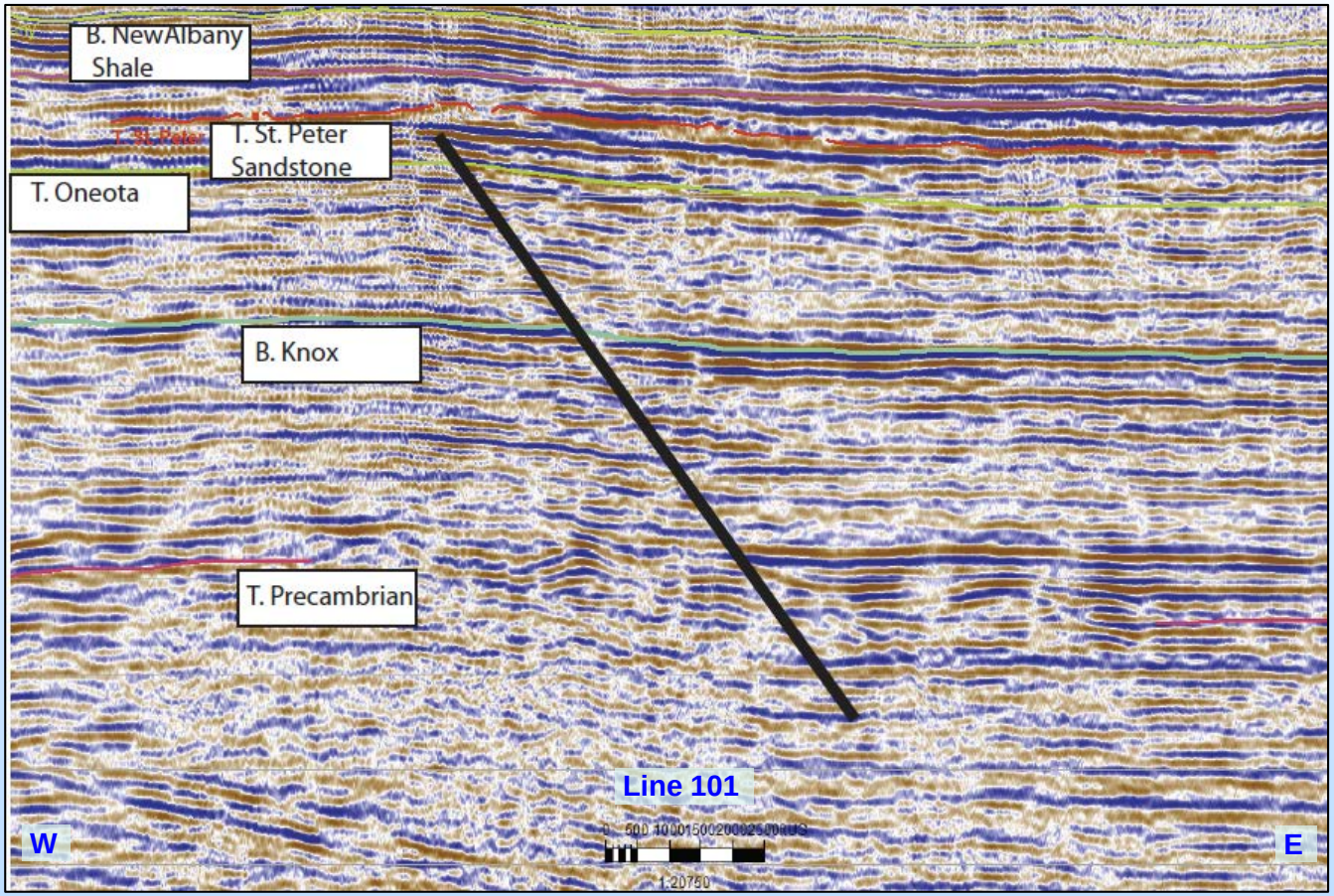
Geophysics

Acquisition of 140 miles of 2D Seismic Reflection Data

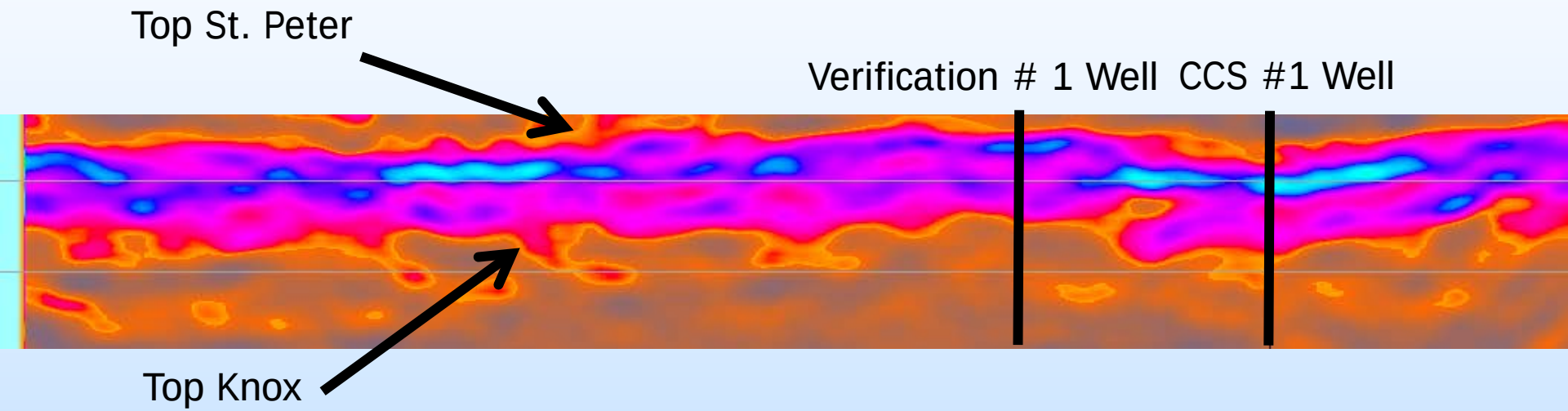




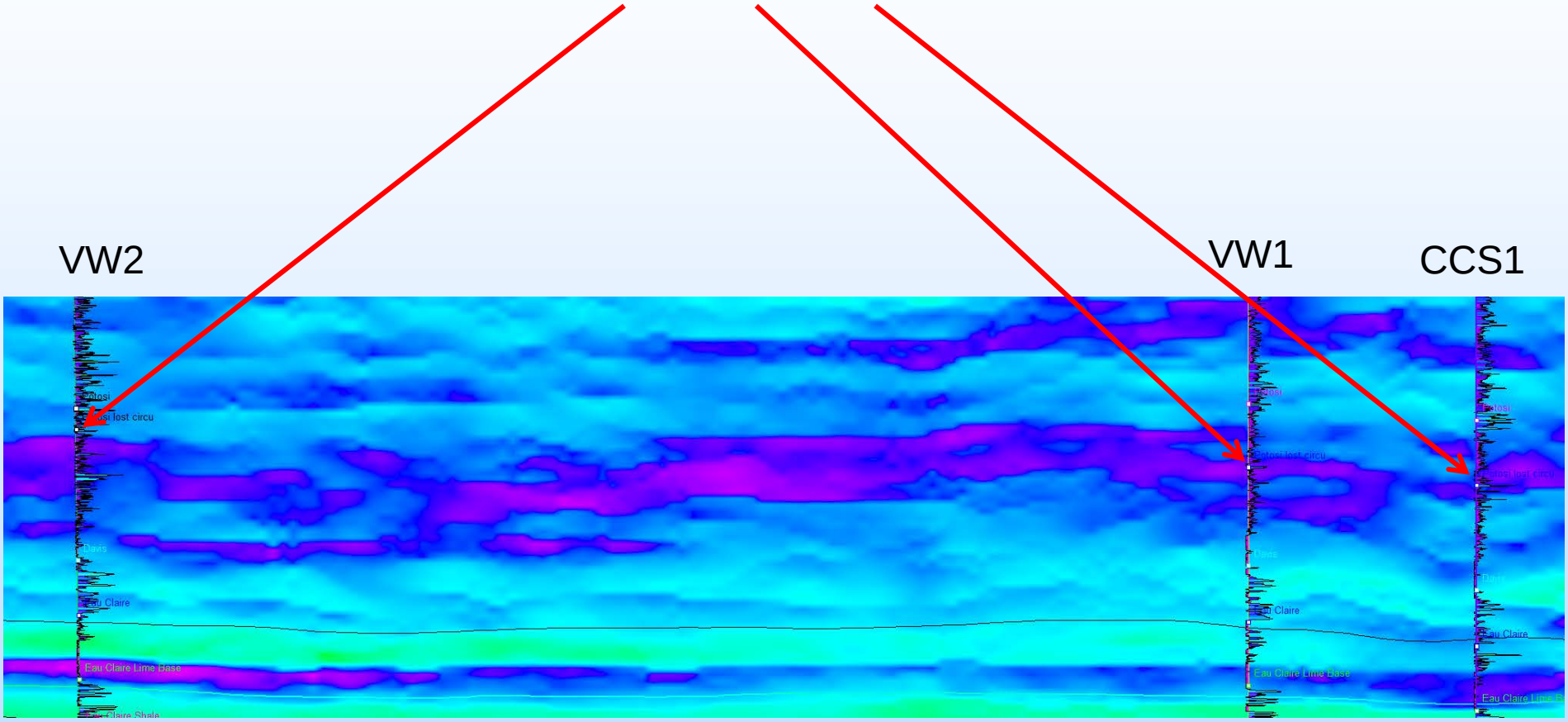
Faulting through the St. Peter Sandstone



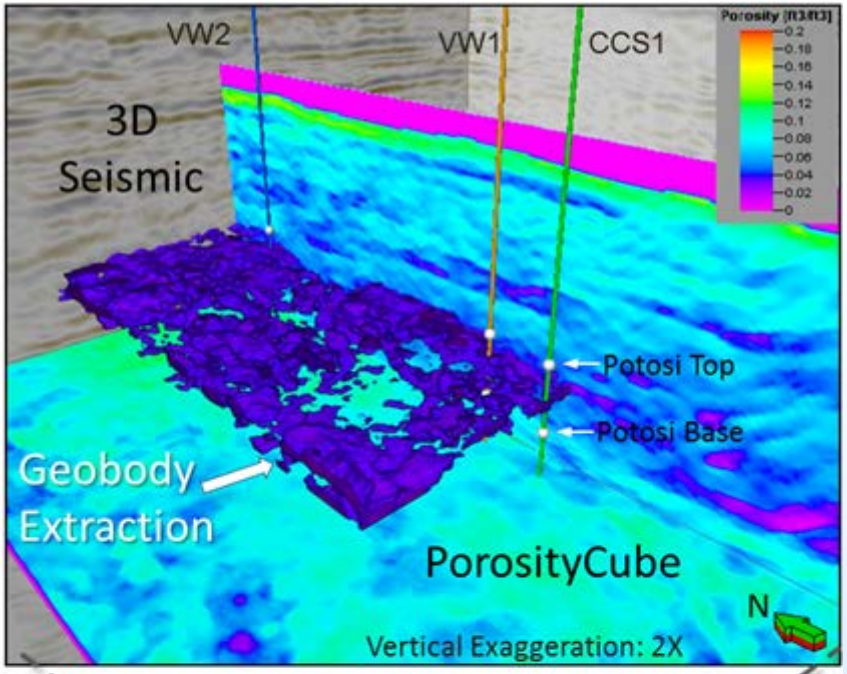
Seismic Inversion: Density
St. Peter Sandstone

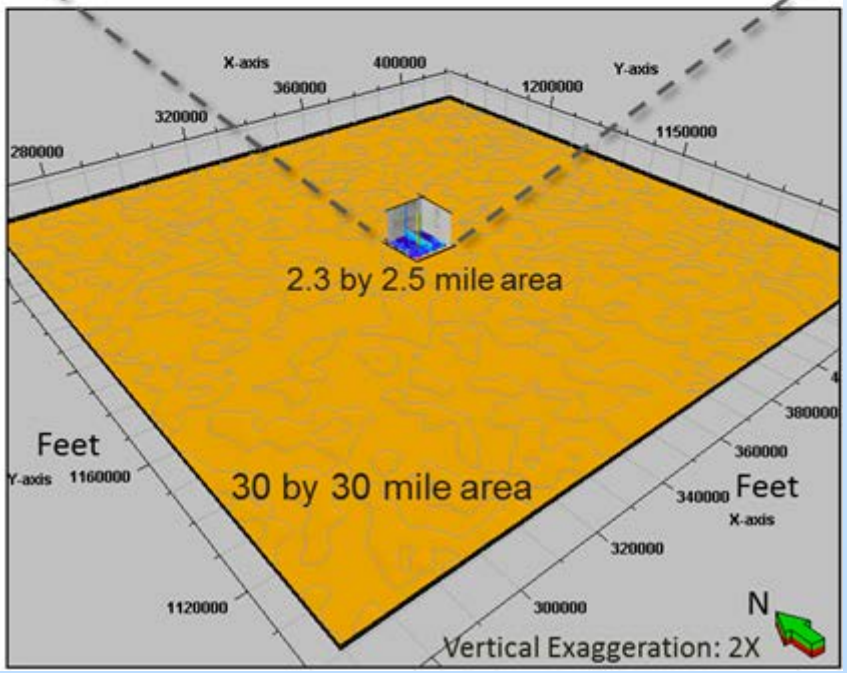


Potosi Lost Circulation Zone



Geobody extraction



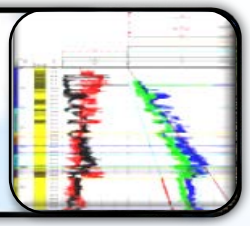


Injectivity

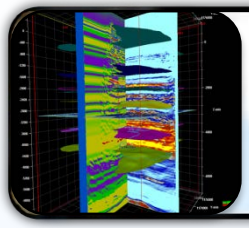
ASME Review Panel Recommendation

- NETL recommended that we increase the injection rate to 3.2 million tonnes per year for 30 years of injection and 100 years of simulation after injection ceases.
- The new simulations suggest that more realistic models with additional information do give significantly different results.

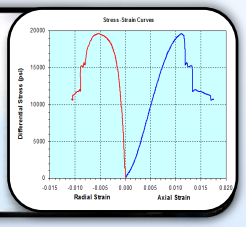
1D Mechanical Earth Model



3D Geological Model

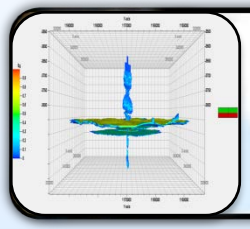


Rock Properties from Core

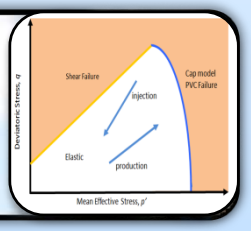


Knox Workflow

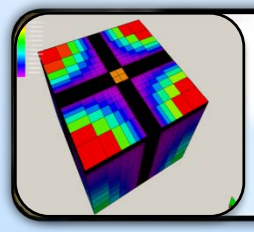
Eclipse Simulations



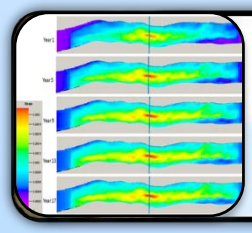
Formation Stress and Cap Rock Analysis



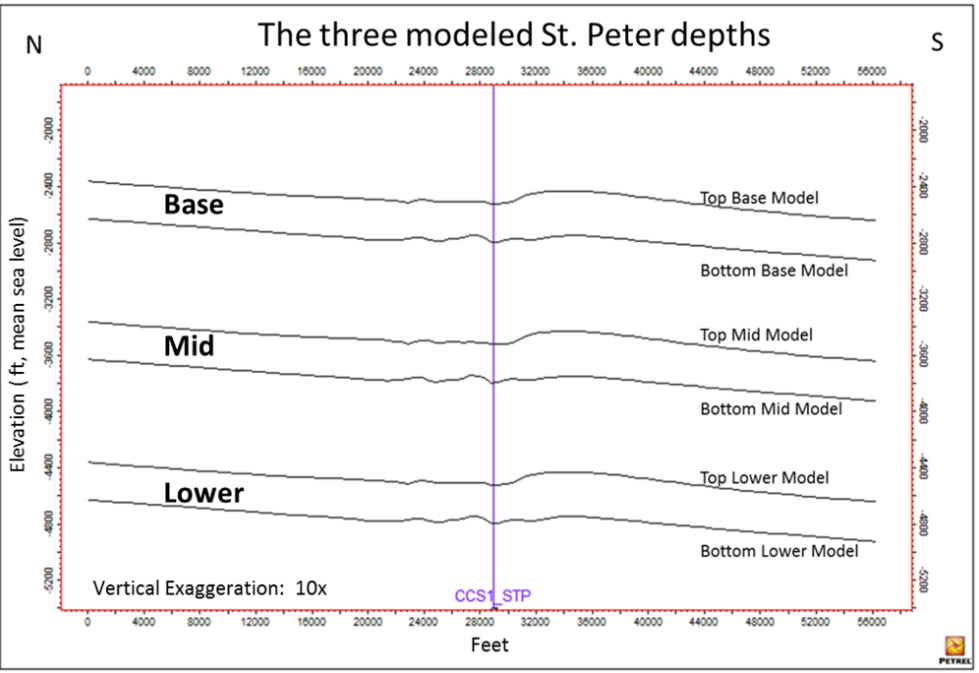
3D Mechanical Earth Model

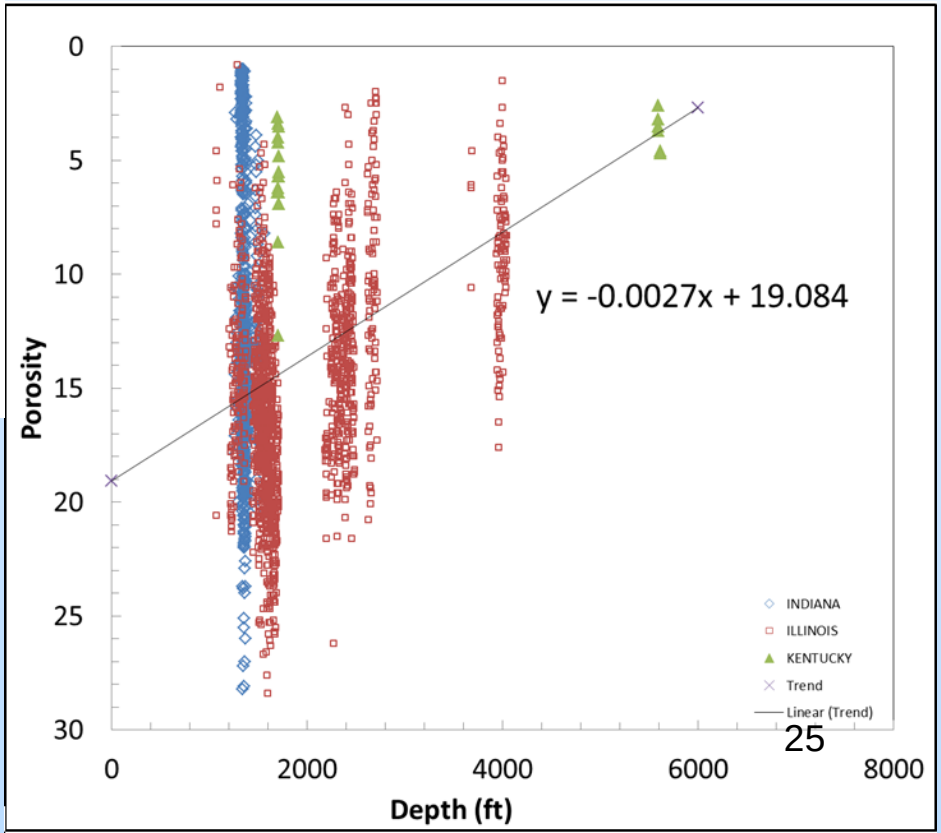


VISAGE Stress Model

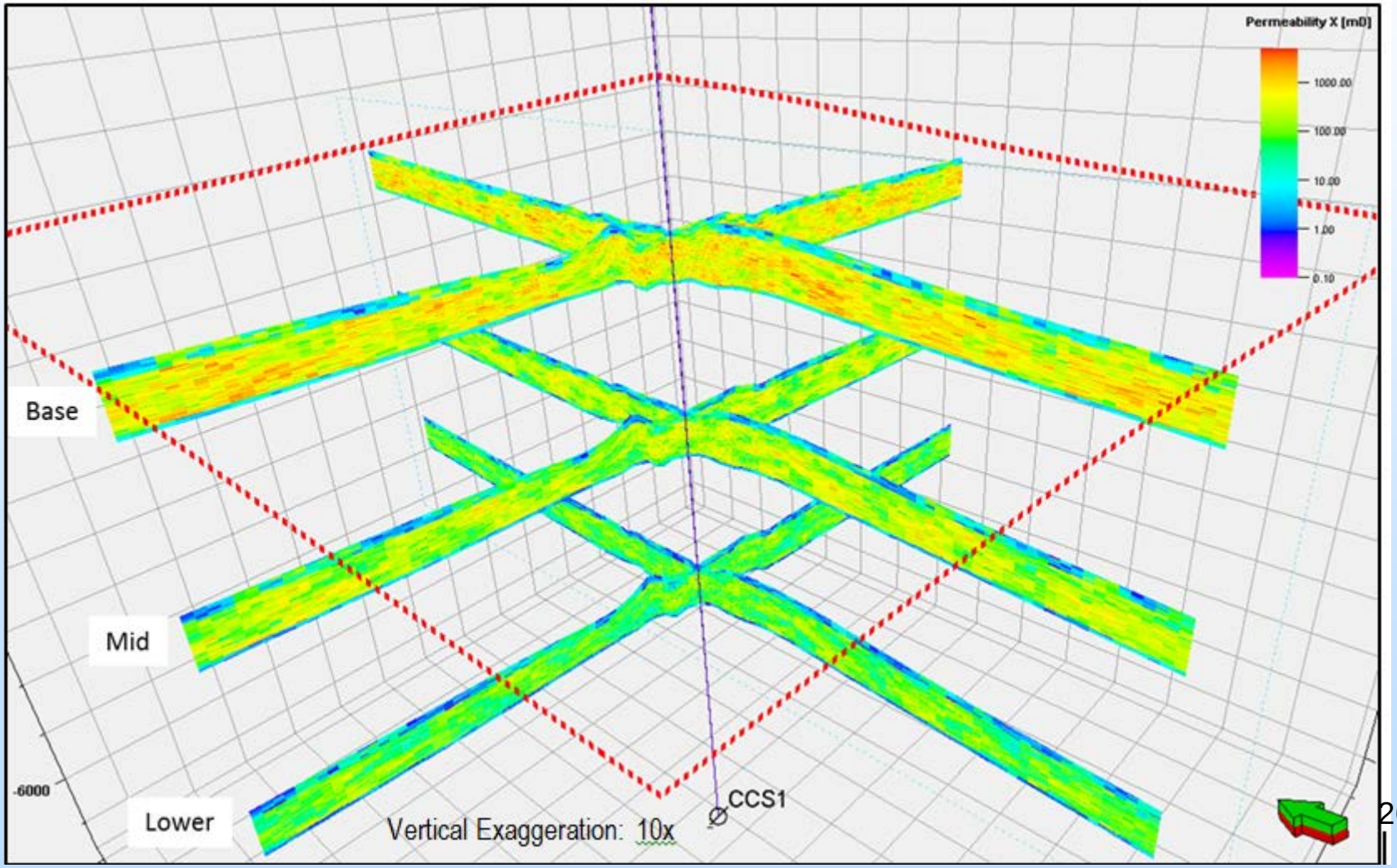


Models with different reservoir Properties



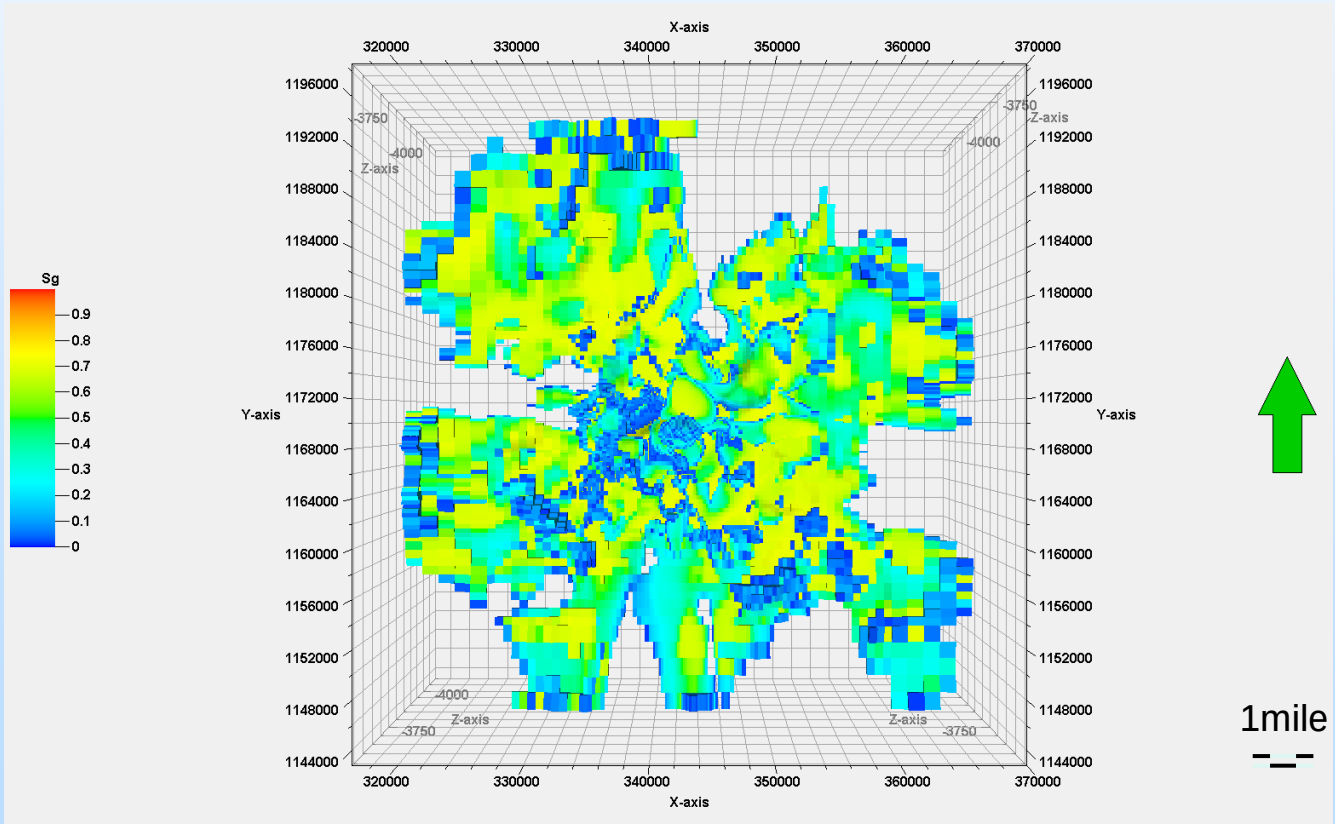


N-S and E-W oriented permeability cross-sections through Base, Mid, and Lower static models (15 mile by 15 mile).

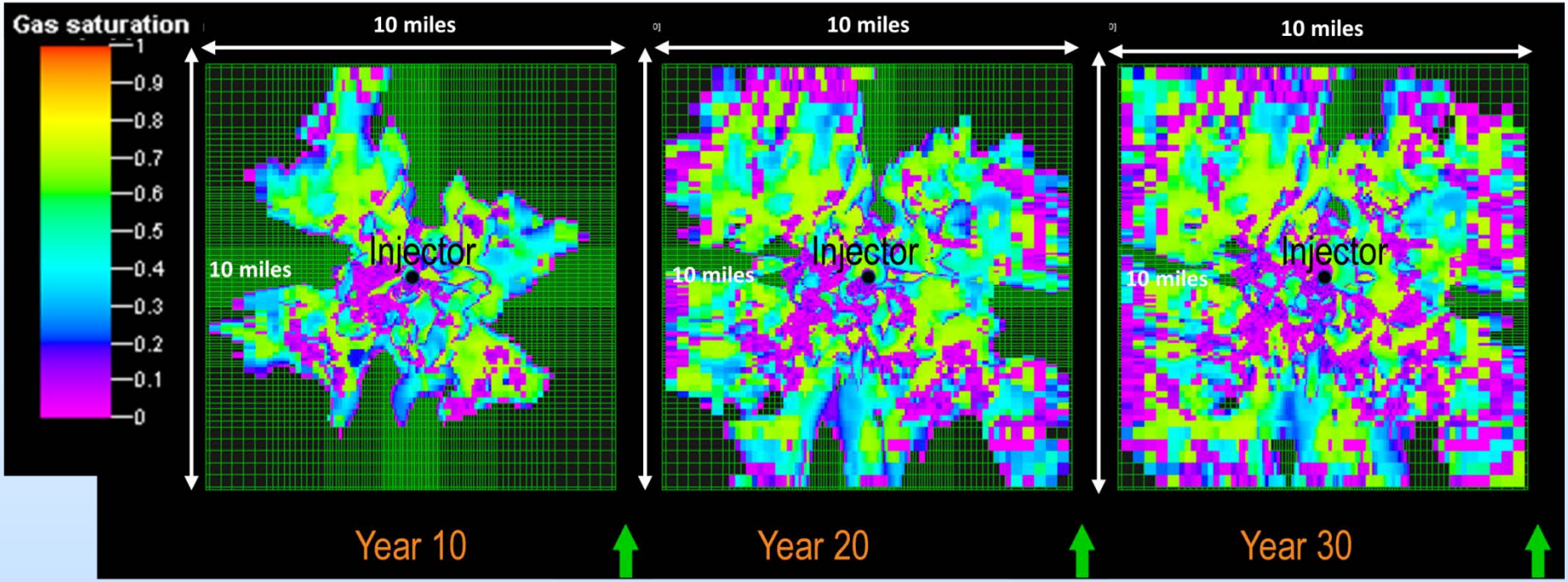


CO_2 injection into Potosi.

CO_2 plume plan view at the end of 20 years (injection rate of 2 million tonnes per year) has an approximate radius of 5 miles based on seismic and well data from Decatur Illinois

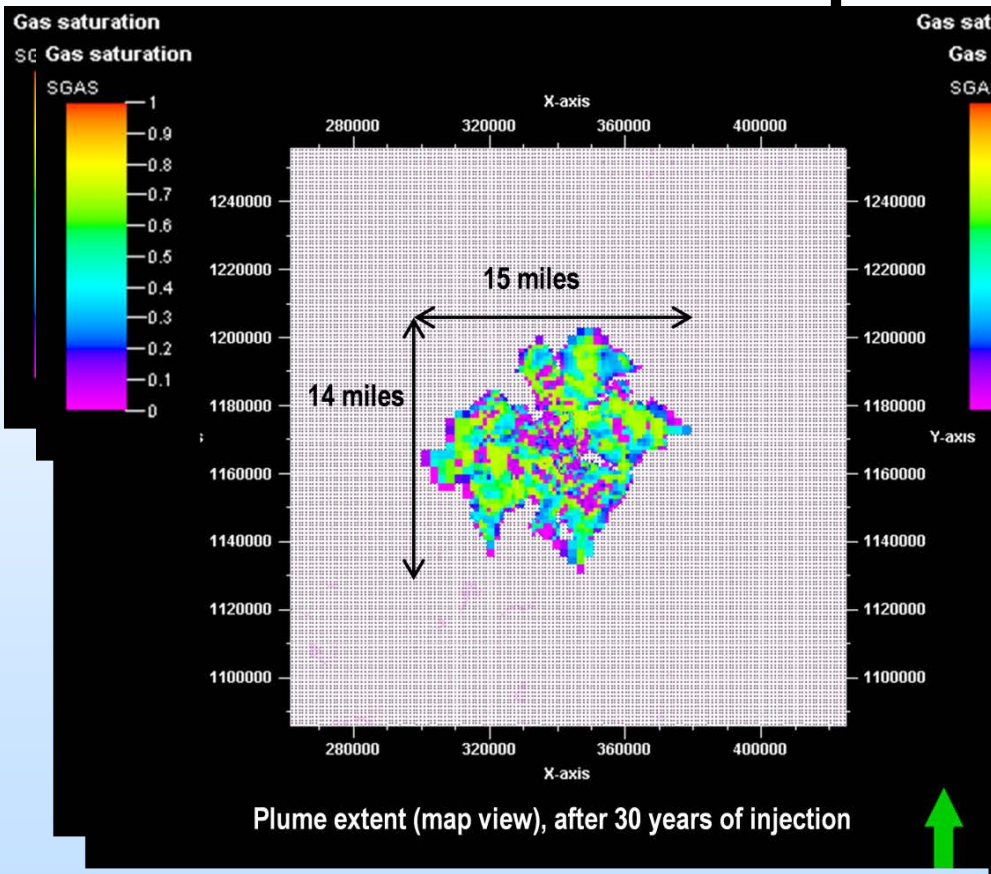


Potosi plume extent during injection

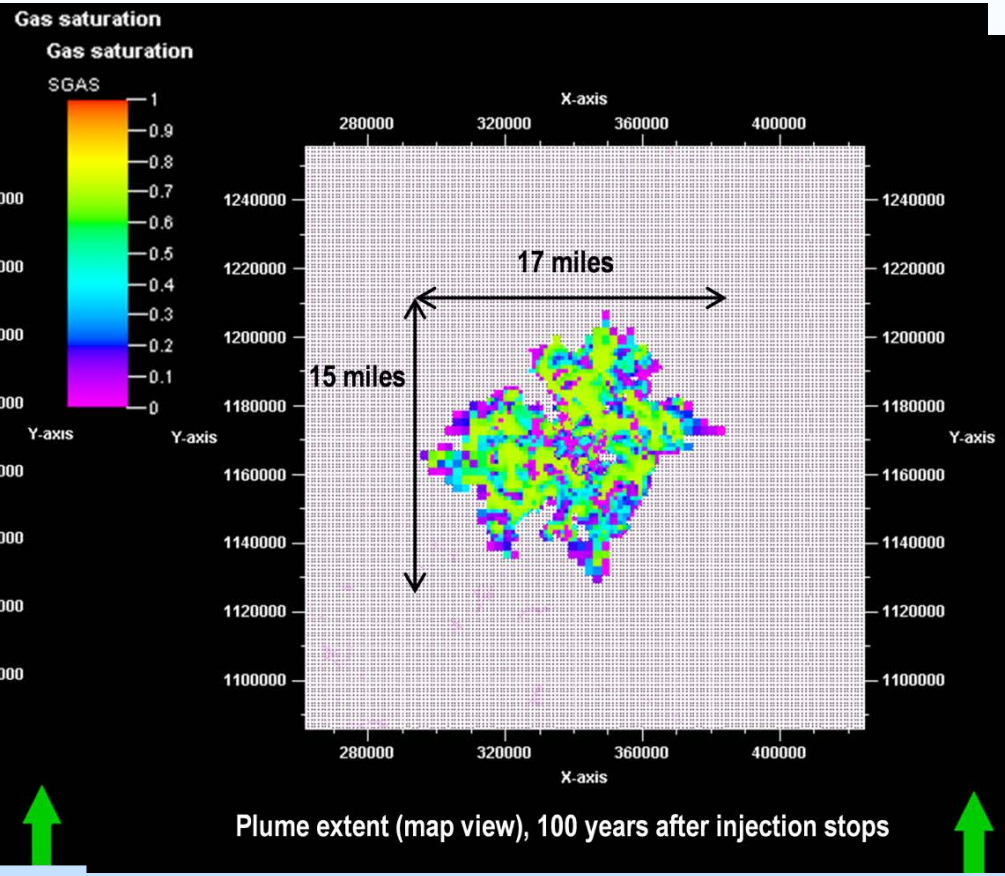


injection rate (3.2 MTPA) could not be achieved before the end of the injection period. Estimated cumulative injection after 30 years from single well

Potosi plume extent during injection



Plume extent (map view), after 30 years of injection

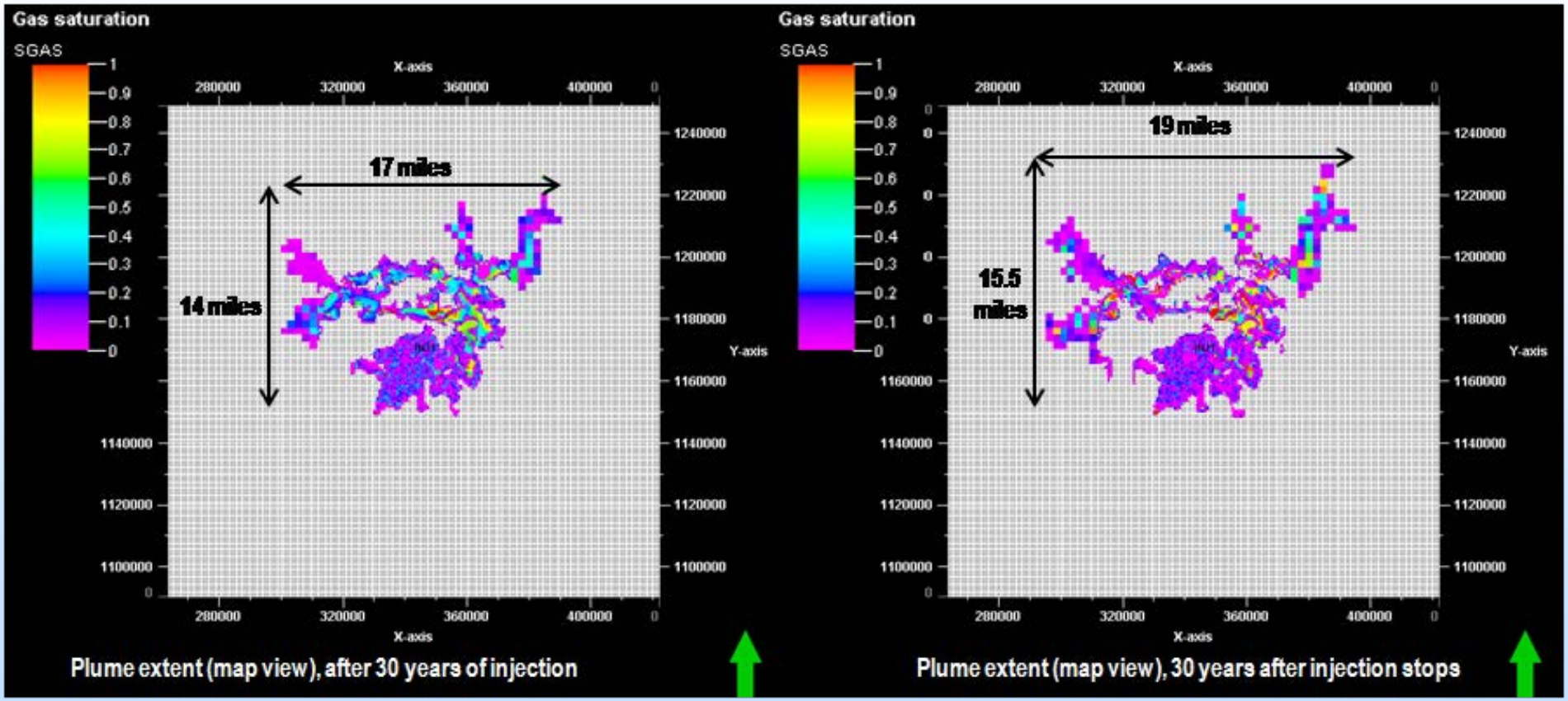


Plume extent (map view), 100 years after injection stops

With one well it would 45% of the target volume

Will take two wells

Potosi plume extent during injection



27% of the 96 Mt injection target

Will take 4 wells

Containment

- Laboratory analysis of mineral and CO_2 interactions

Before and After

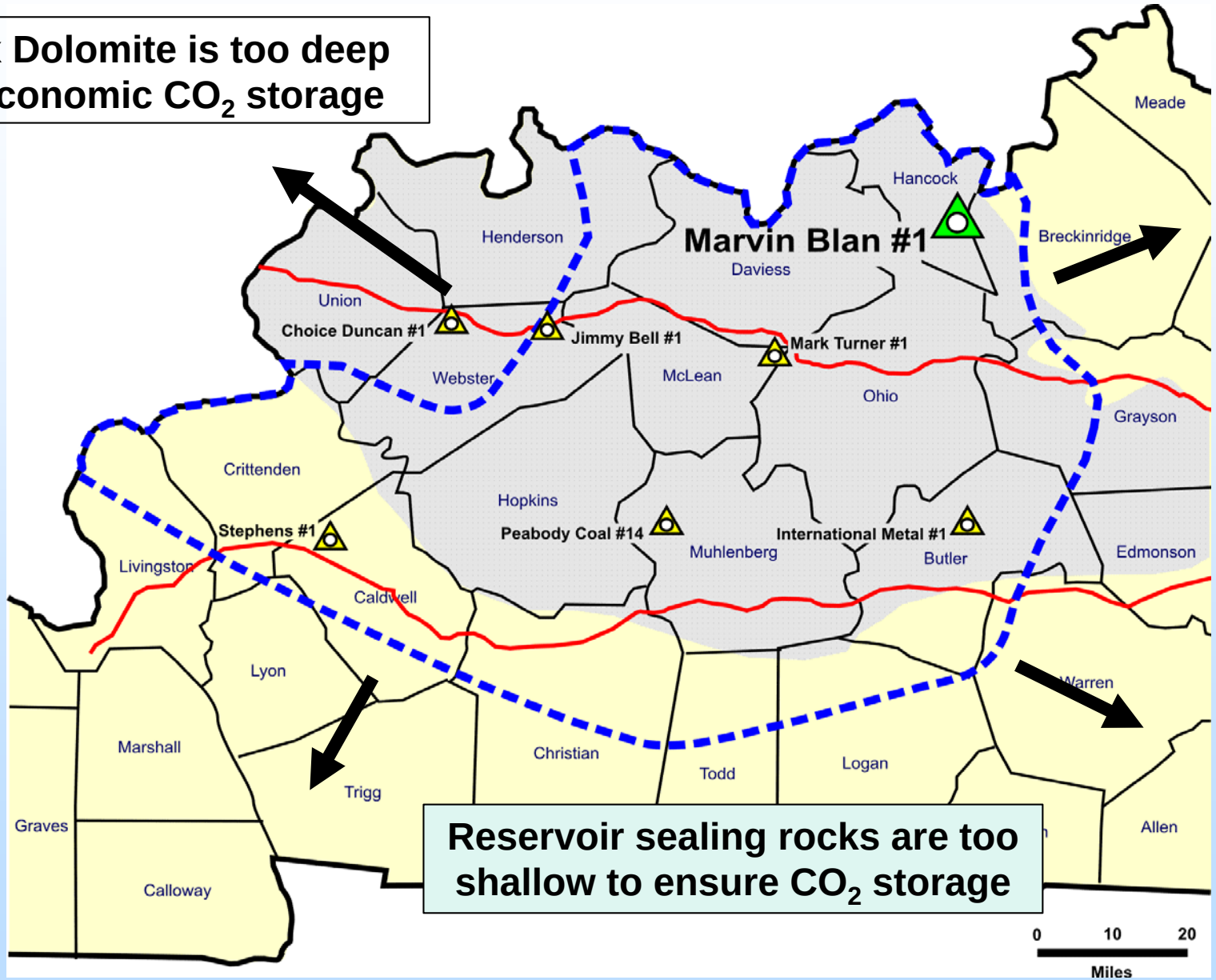
Sample	VW1-4522.3' Potosi Dolomite		VW1-4533.5' Potosi Dolomite		VW1-4536.5' Potosi Dolomite	
Bulk mineralogy						
	Pre	Post	Pre	Post	Pre	Post
%Clays	1	0	0	1	0	1
%Quartz	8	3	26	71	8	7
%K-spar	0	0	0	2	1	1
%Plag	0	0	0	1	0	0
%Calcite	1	1	1	1	0	2
%Dolomite	87	93	71	24	88	87
%Siderite	2	1	1	1	1	2
%Pyr/Mar	1	0	0	0	0	1
Clay Mineralogy from Orientated Clay Slide (% relative to each other)						
%Illite-smectite	53	42	58	55	51	40
%Illite	34	34	28	38	38	40
%Kaolinte	6	6	5	3	5	2
%Chlorite	7	17	10	5	5	18

Duration
1 month
1430 psi pressure
43 C temperature

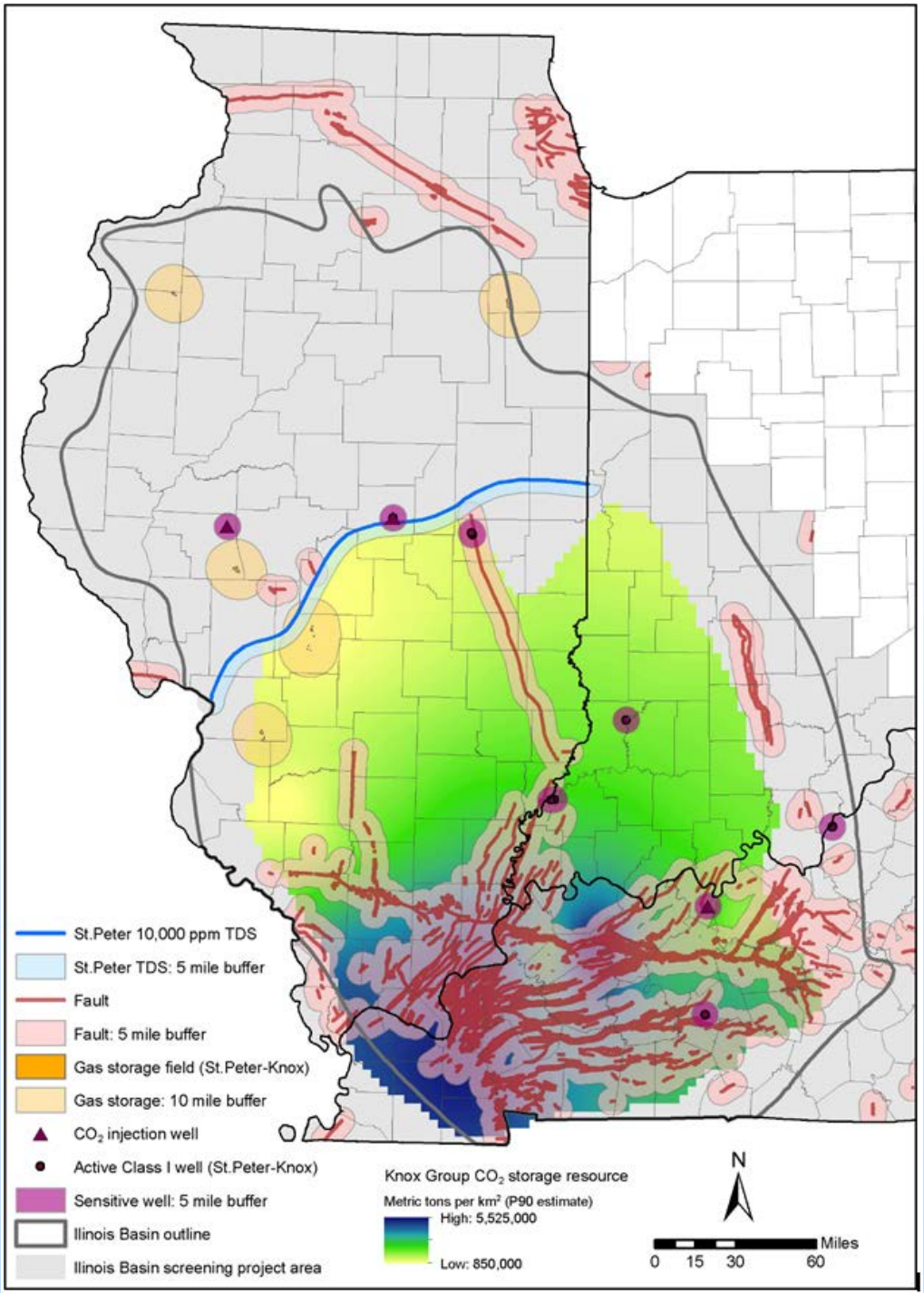
Best Practices and Risk

Early Assessment

Knox Dolomite is too deep for economic CO_2 storage



Reservoir sealing rocks are too shallow to ensure CO_2 storage



Areas of high and low risk for St. Peter and Knox CCS projects

Each risk factor is a different GIS layer

Risk Evaluation for CO_2 Geosequestration in the Knox Supergroup "Example Top Risks" polling feedback

Risks in executing a Knox CCS Project

•Reservoir injectivity: The key uncertainty is assessing the reservoir's heterogeneity permeability. To complete a well with good integrity, the vugs must be cemented, which increases uncertainty in well log measurements. Means to further understand the dual porosity / dual permeability nature of the Potosi are strongly advised.

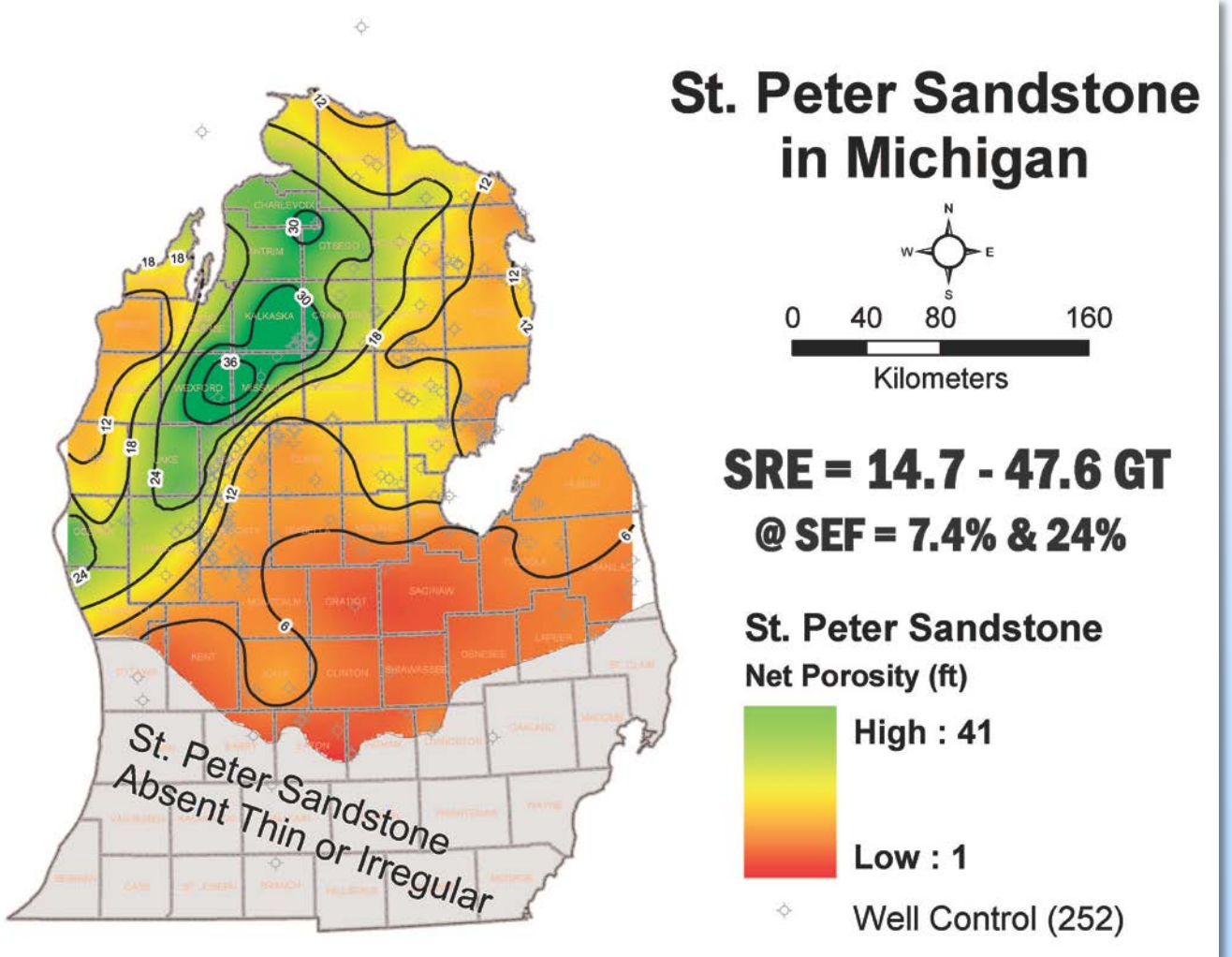
•CO_2 plume monitoring: Current modeling shows far-traveled migration and plume route may be tortuous. Monitoring may become very expensive.

•Wellbore integrity: Lost circulation events suggest possibility of a leakage pathway, though thick (900 feet) of overlying dolomite reduce the risk of contamination of shallower aquifers.

•Caprock: The seal may effectively be the 900 feet of overlying dolomite, which will complicate the monitoring scheme.

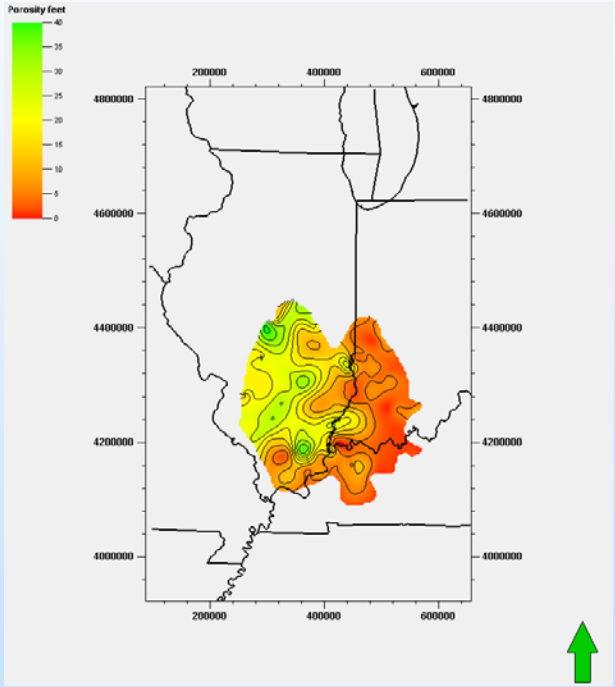
Resource Estimates

St. Peter Sandstone
Geological Carbon Storage Resource Estimate
14.7 – 47.6 Gt (@ p_{10} and p_{90})

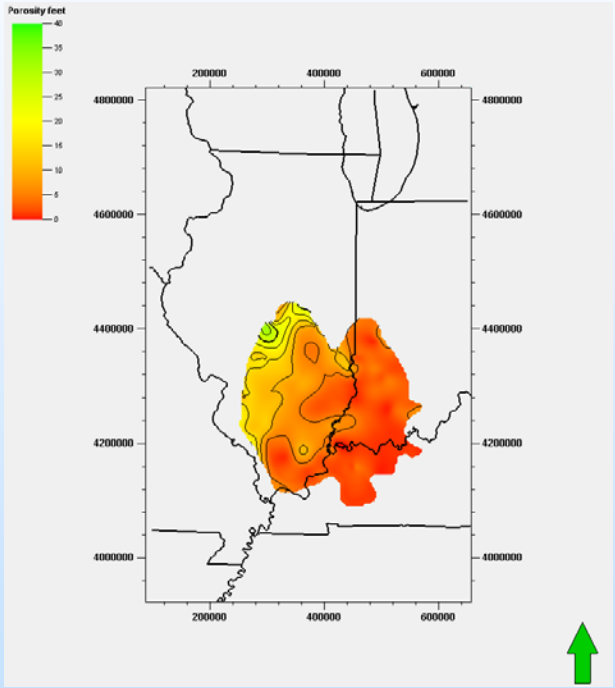


Illinois Basin St. Peter Sandstone CO_2 Storage Resource

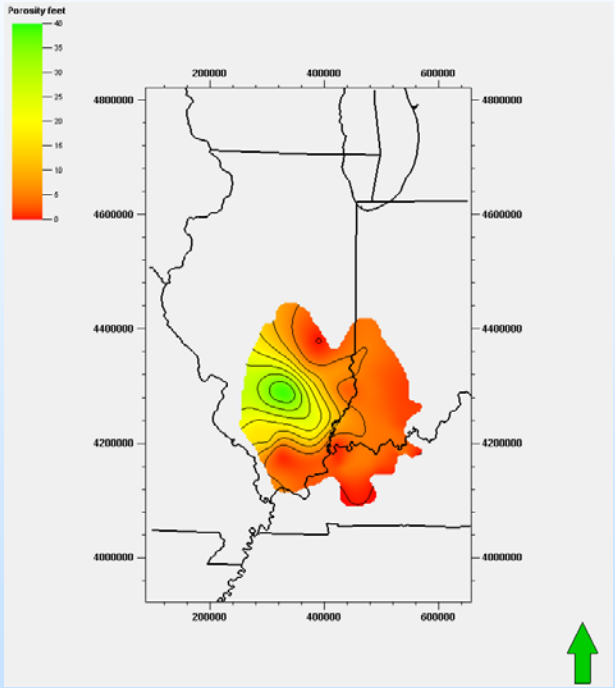
Improving resource estimation through enhanced characterization



Method 1: mean porosity



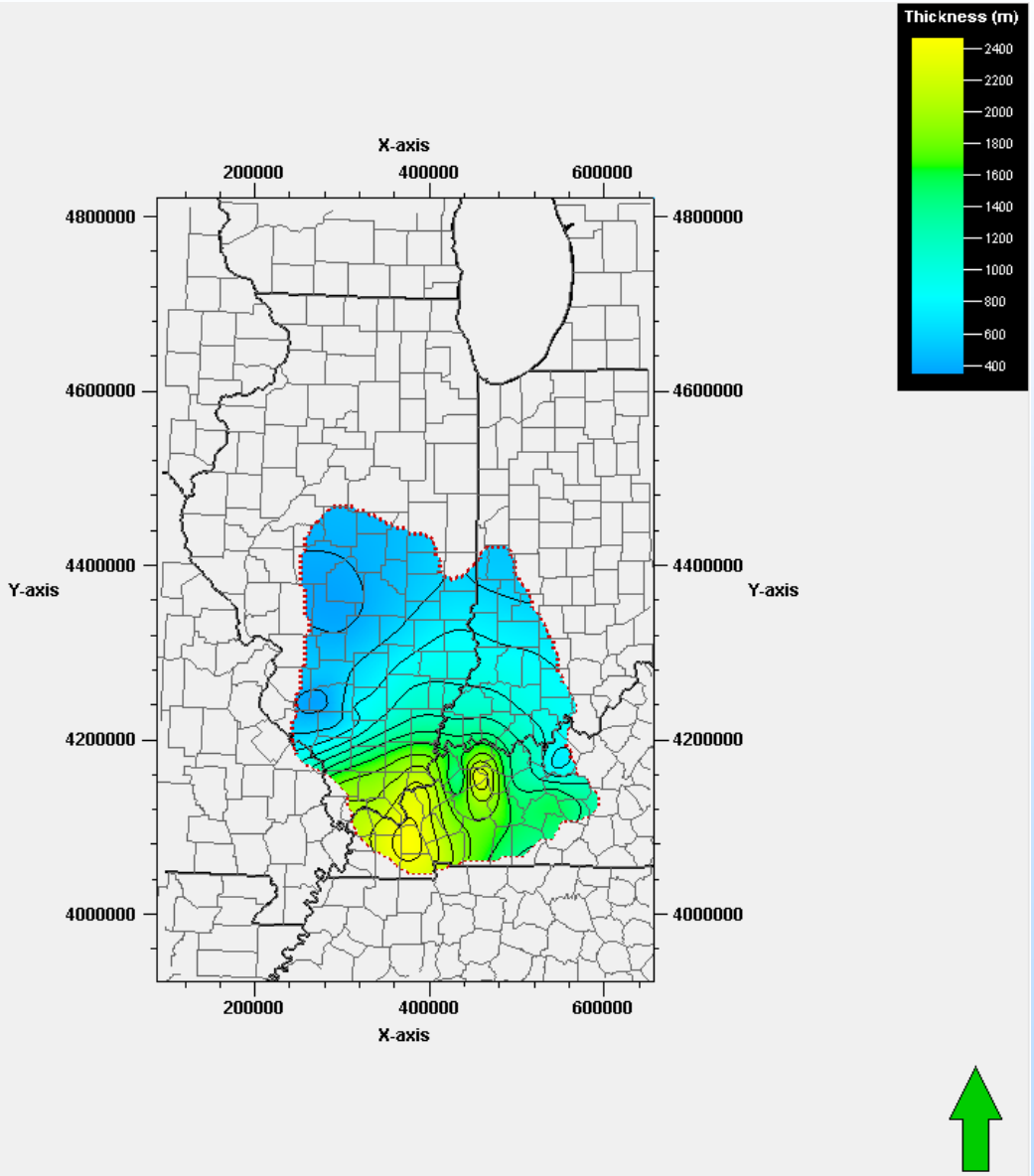
Method 2: variable porosity model



Method 3: net porosity analysis

storage resource estimate range of 12.2 to 39.7 Gt.

Gross thickness of the Knox Group



The resulting storage resource estimates are ***10 to 131 gigatonnes for the Upper Knox unit and 8 to 115 gigatonnes for the Lower Knox unit***

Accomplishments to Date

- Developed a Best Practices Manual that illustrates the methodology for reducing storage risks
- Highlight areas of high risk and low risk for carbon storage in the St. Peter and Knox strata in the Illinois and Michigan Basins.
- Showed how seismic reflection data can be used to delineate high and low risk areas
- Evaluated seals and reservoirs for faulting and fracture risk (geomechanical studies), as well as their interactivity and reactions with CO_2 in the presence of brine (geochemical studies).

Accomplishments to Date

- Reservoir simulation of commercial injection into St. Peter and Knox illustrating injectivity and storage potential
- Performed CO_2 injection test in an existing well in Hancock County, Kentucky to evaluate injectivity of the Knox sandstone.
- Developed regional CO_2 storage resource estimates for the Knox and St. Peter for use in future version of DOE's North American CO_2 Storage Resource Atlas.

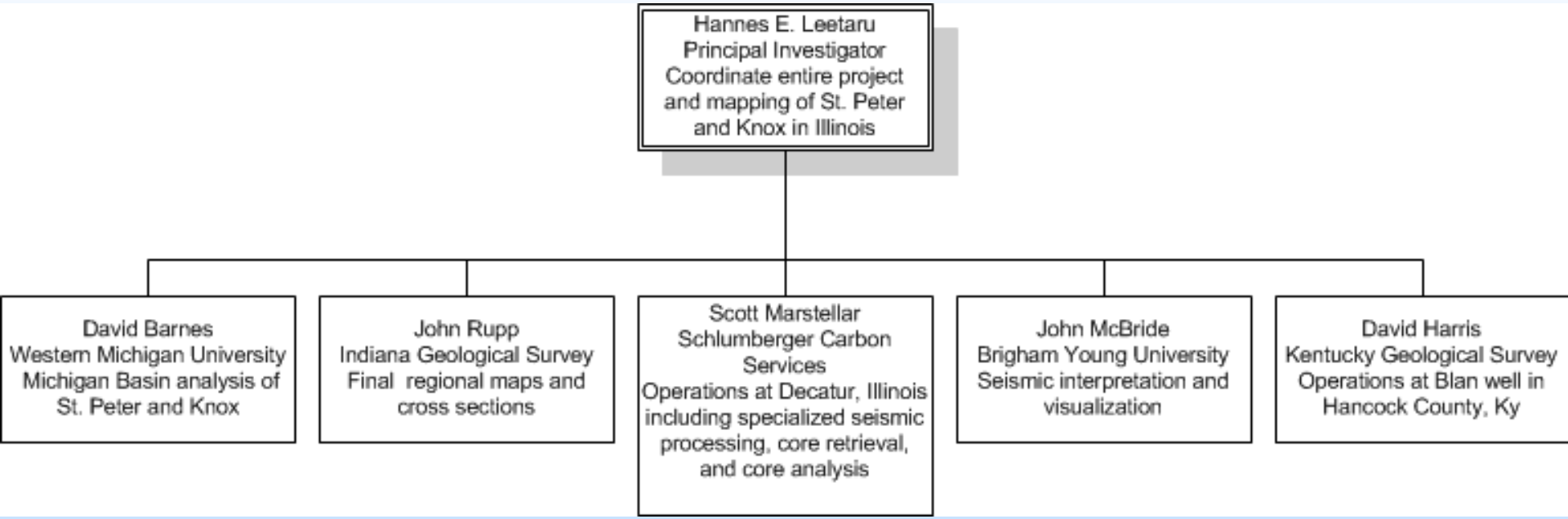
Summary

- Key Findings
  - Both the Knox and the Potosi are viable targets for CCS
- Lessons Learned
  - Karst type systems such as the Potosi would have unpredictable plume migration pathways
- Future Plans
  - Complete the final and topical reports

Appendix

– These slides will not be discussed during the presentation, but are mandatory

Organization Chart



Project Gantt Chart

ID	Task Name	% Complete
1	Task 1 Management Plan	96%
2	Compile Base Data	100%
3	Site Work	100%
4	Regional Significance	99%
5	Capacity Estimates	100%
6	Injectivity of the formation	100%
7	Containment Stratigraphic	100%
8	Containment - Brine	100%
9	Containment - Mineralogic	100%
10	Leakage Pathways	90%
11	Site Selection	95%
12	Risk Assessment	100%
13	Well Bore management	100%

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- Park, A.M., Parris, T.M., and Bowersox, J.R., 2011, CO2-Water-Rock Interaction Studies in Lower Paleozoic Strata, Illinois Basin, Kentucky [abstract]: Proceedings of the Tenth Annual Conference on Carbon Capture and Sequestration, Poster 470.
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