

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

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U.S. Department of Energy  
National Energy Technology Laboratory  
Carbon Storage R&D Project Review Meeting  
Developing the Technologies and Building the  
Infrastructure for CO<sub>2</sub> Storage  
August 21-23, 2012

# Acknowledgments

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Dave Harris, Kentucky Geological Survey

Dave Barnes, Western Michigan University

John Rupp, Indiana Geological Survey

Scott Marsteller, Schlumberger Carbon Services

John McBride, Brigham Young University

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- ConocoPhillips: in-kind match
- Western Kentucky Carbon Storage Foundation: matching funding
- SeisRes 2020, Houston: VSP acquisition and processing
- Sandia Technologies, Houston: engineering and wellsite supervision
- Landmark Graphics through their University Grant Program

# Project Overview: Goals and Objectives

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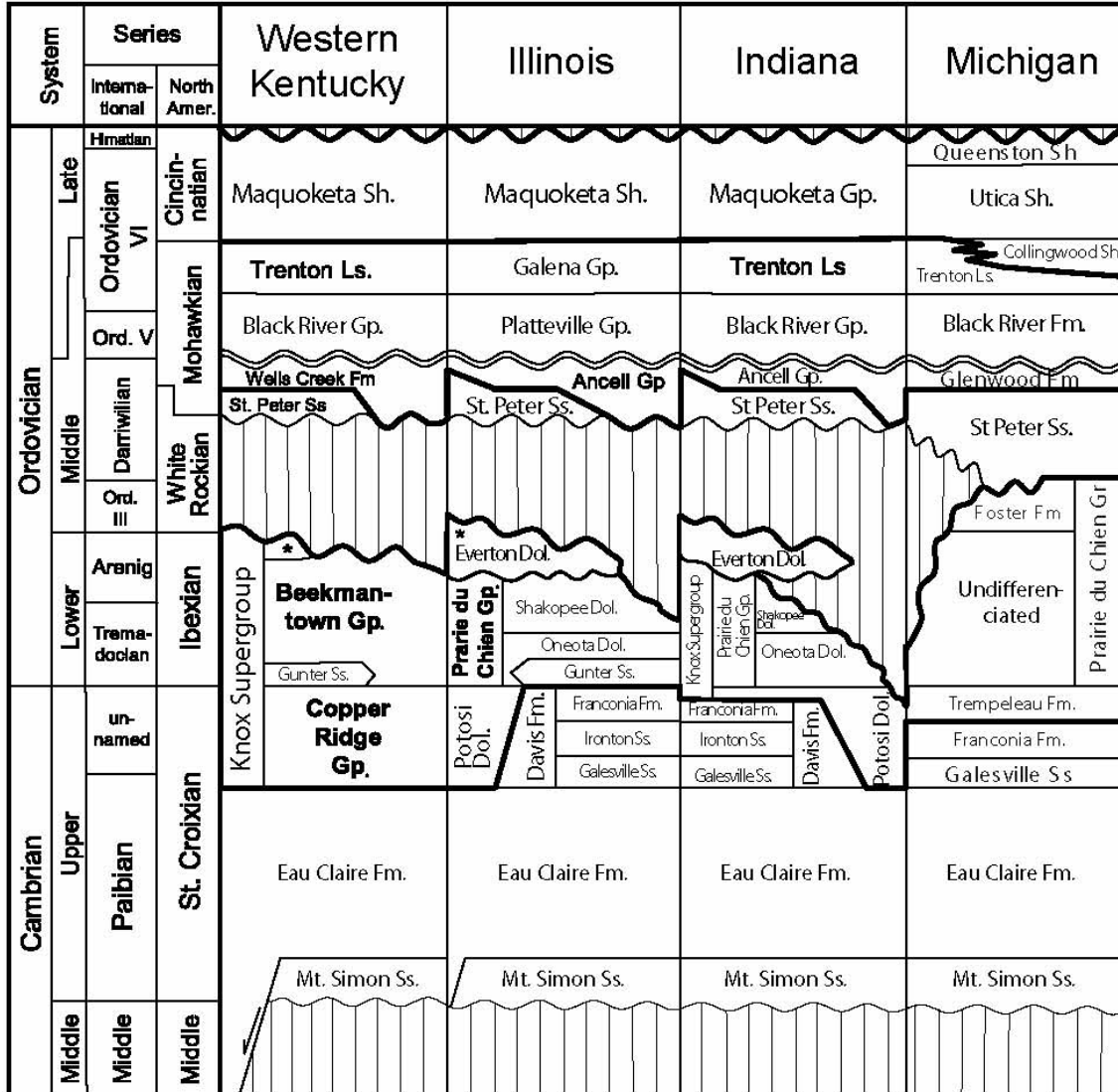
- This Cambro-Ordovician project will highlight areas of high risk and low risk for sequestration. The Best Practice Manual will show the methodology used in this selection process
  - Show how seismic reflection data can be used to delineate high and low risk areas
- Reservoir simulation of injection into St. Peter and Knox shows sequestration potential for these zones
- Successful injection of CO<sub>2</sub> into Knox shows injectivity
- Geochemical studies show no significant issues with storage of CO<sub>2</sub> in these strata
- Resource assessment for input to NATCARB

# Benefit to the Program

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- Program goals.
  - Reduce storage risk by documenting the uncertainties related to fracturing, injectivity, and geochemical interactions for the St. Peter and Knox strata.
- Project benefits statement.
  - This project will have a significant impact in delineating new geologic intervals for sequestration in Illinois, Indiana, Michigan, and Western Kentucky. It confirms the Knox and Maquoketa as secondary seals for the Mt. Simon Sandstone.

# Stratigraphic Column



- Structure Map 1
- > Isopach Map 1
- Structure Map 2
- > Isopach Map 2
- Structure Map 3
- > Isopach Map 3
- Structure Map 4
- > Isopach Map 4
- Structure Map 5

# Task 3 – Site Evaluation

- Injected CO<sub>2</sub> into the Knox at Hancock, Kentucky and monitored CO<sub>2</sub> movement using a baseline VSP and a second VSP after injection.
- Held open house for local community to show results of the project
- Status
  - Project activities completed
    - Topical report on open house submitted to USDOE
    - Topical report on injection and VSP in preparation <sup>6</sup>



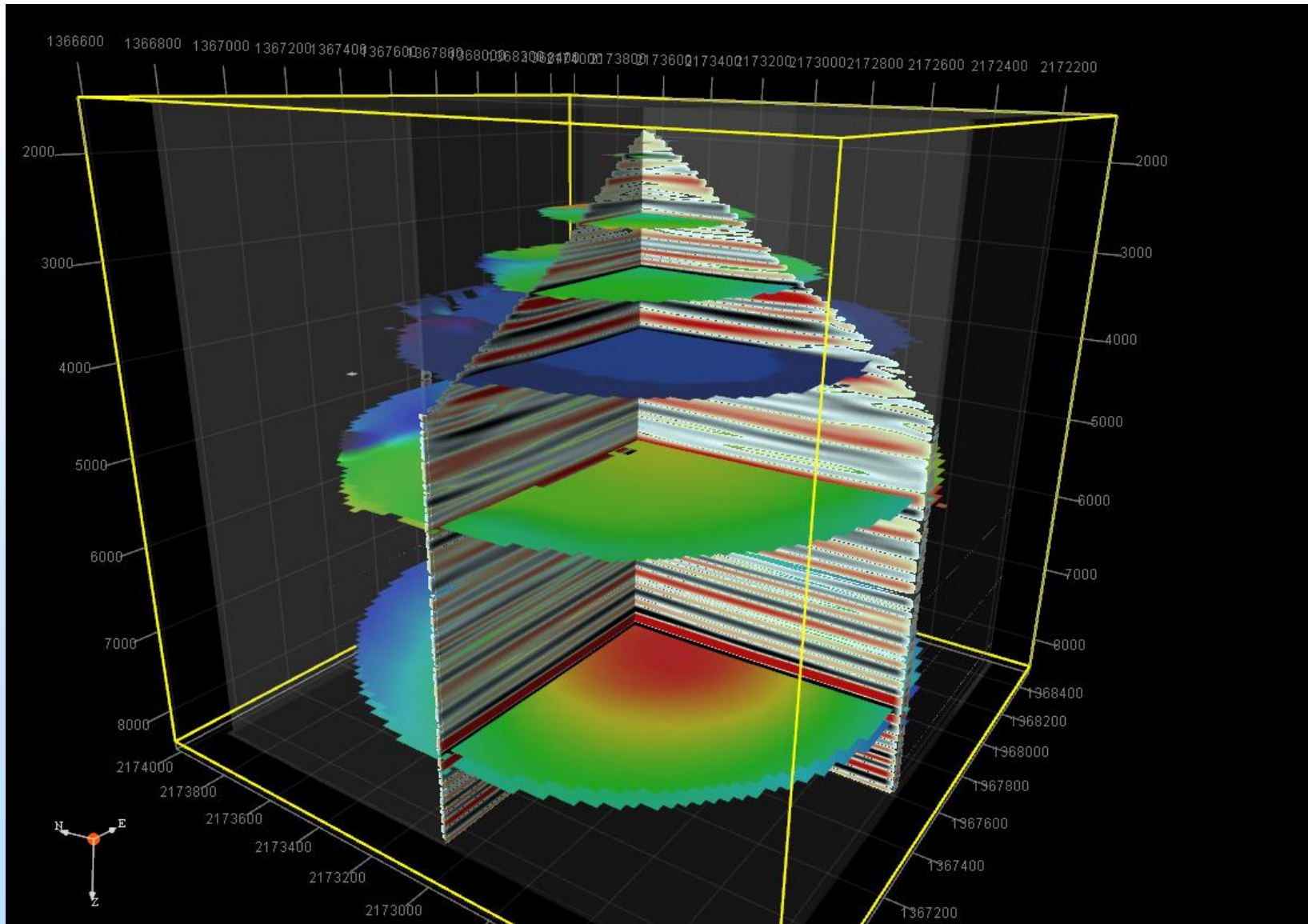
# CO<sub>2</sub> injection test Knox sandstone, Sept. 20-21, 2010

Open-hole interval 5,038 – 5,268 ft

367 tons CO<sub>2</sub>  
3 bbl per minute  
1,000 psi wellhead  
2,538 psi final bottom  
hole pressure



# 3D VSP from Blan Well





# Open House for Blan Well

- Held on October 28, 2010, at the Hancock County Career Center, Hawesville, Kentucky
- Expected 40-50 people, 19 actually attended including 3 from the news media
- Interested in economic opportunities for area



Published Oct. 21, 2010 in  
the Hancock Clarion

## Public to hear results of deep well tests

The Kentucky Geological Survey will hold a public meeting at the Hancock County Career Center, 1605 U.S. Highway 60 in Hawesville on the evening of Thursday, October 28. The meeting will start at 6:00 p.m. Central Time.

The topic of the meeting will be the research well drilled in the southeastern part of the county for testing the capacity of this region's deep geology to permanently store carbon dioxide from sources such as coal-fired power plants. KGS researchers will discuss what was done during the project, which is now complete, and what was learned from the research.

They will also discuss the work done to meet federal and state requirements for closing and sealing the well, which was drilled to a depth of over 8,100 feet. The Geological Survey is also arranging for the full reclamation of the project site and the repaving of Sweet Road, which leads to the site.

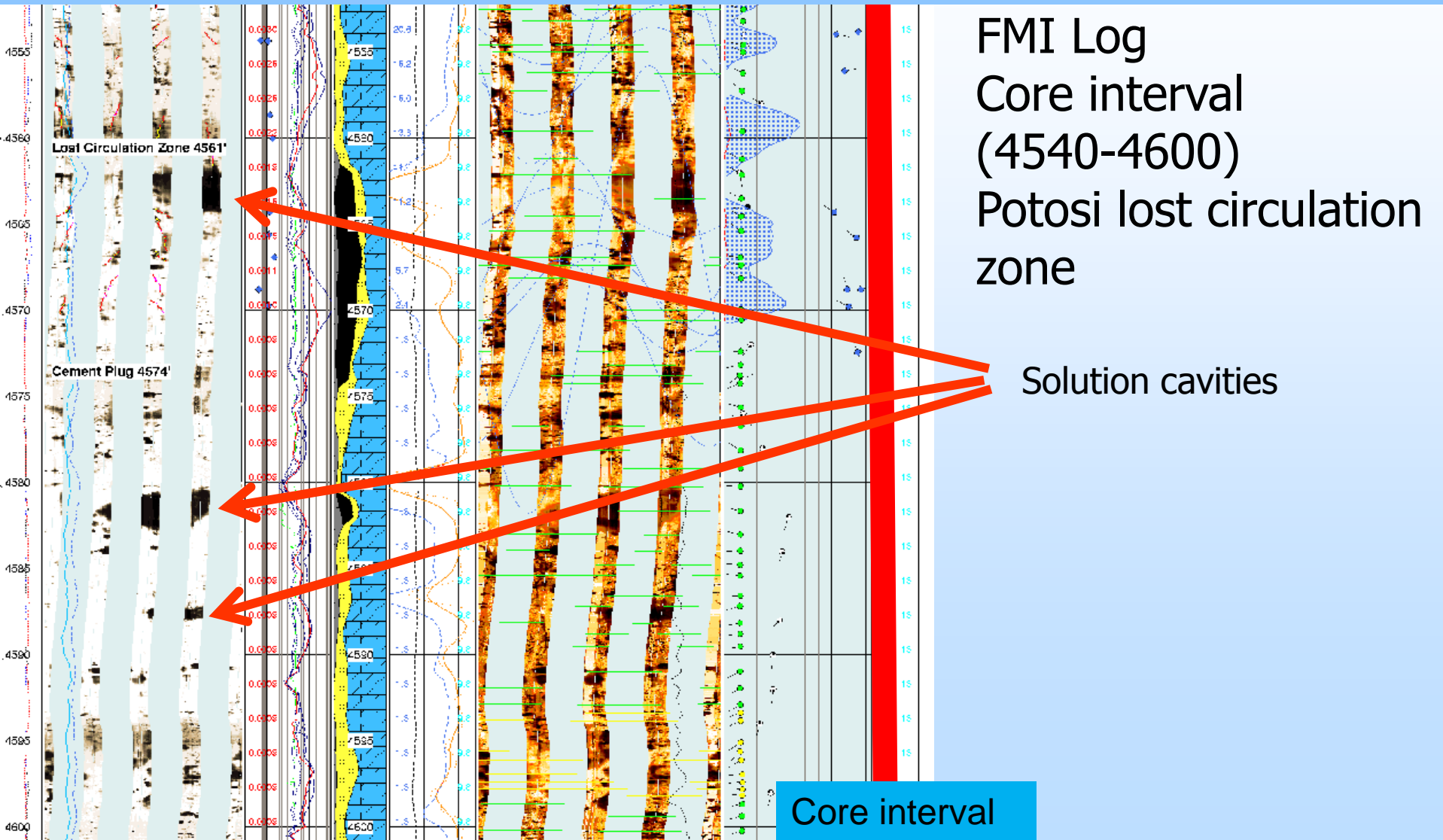
The public is invited to the meeting to hear this presentation and to ask any questions they have about the project and the restoration of the site and road.

More information can be obtained by contacting Mike Lynch at the Kentucky Geological Survey, (859) 323-0561, or [mike.lynch@uky.edu](mailto:mike.lynch@uky.edu).

# Task 3 – Site Evaluation

- Evaluate reservoirs and seals for Cambro-Ordovician section in Illinois Basin
  - Acquired 46 feet of core from Knox Dolomite at Decatur, Illinois
  - Preparing to acquire two 30-foot cores from Maquoketa in October, 2012
  - Geomechanics on Knox core completed

4513 – 4544 cut 31 feet recovered 29 ½  
4544 – 4599 cut 15 feet recovered 11 ½  
Lost almost 600 barrels of mud during coring



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

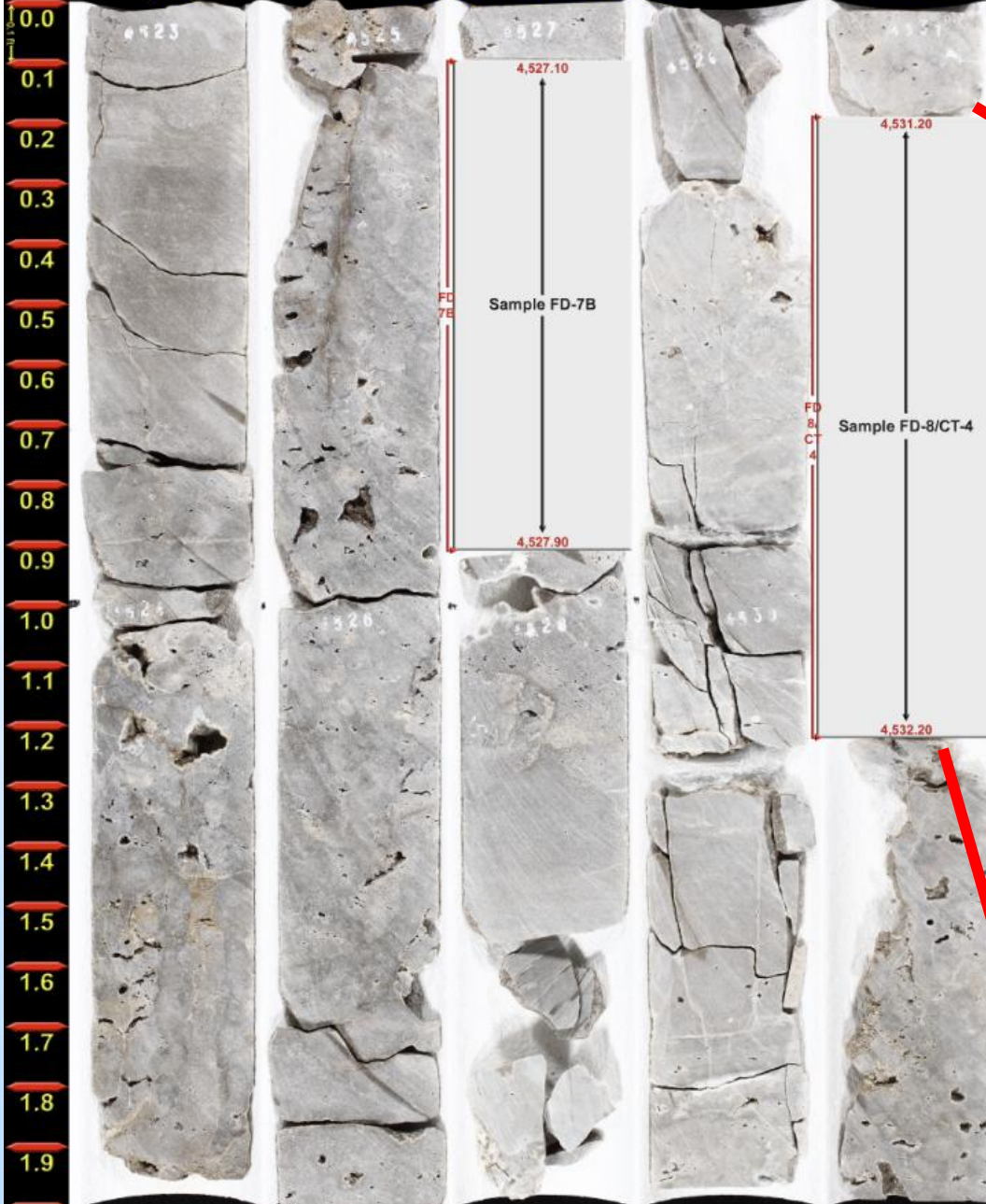
Solution cavities

Core interval

SLB Carbon Services  
ADM Verification Well 1

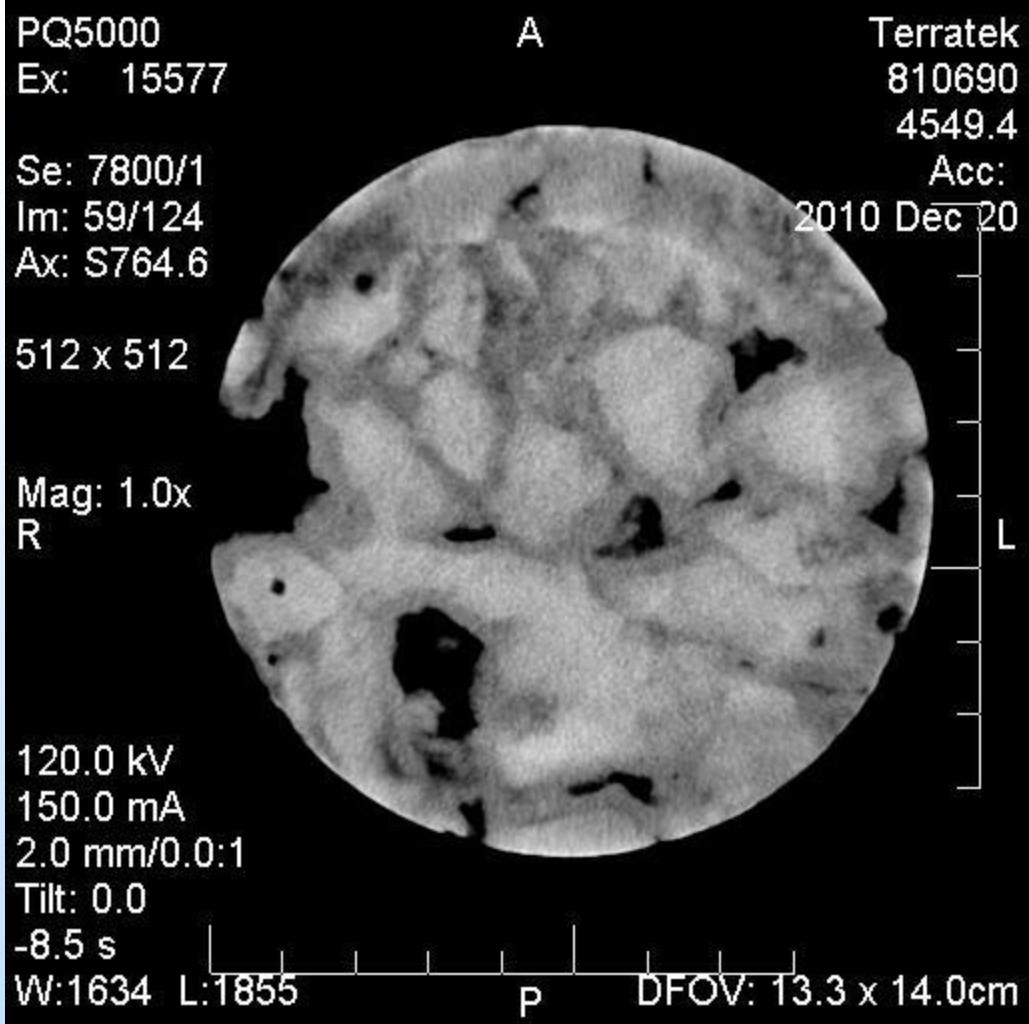
4,523

Core 4



CT Scan





# Task 4 – Regional Significance

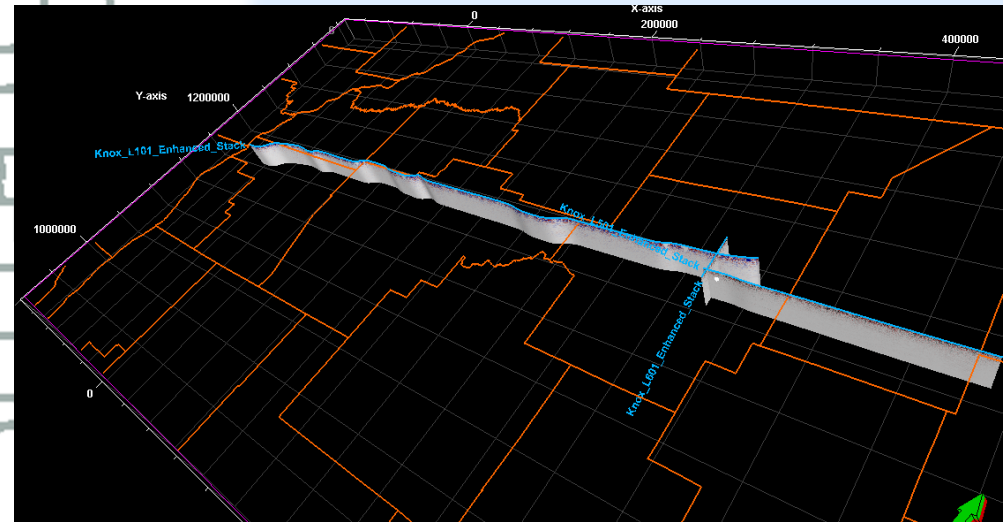
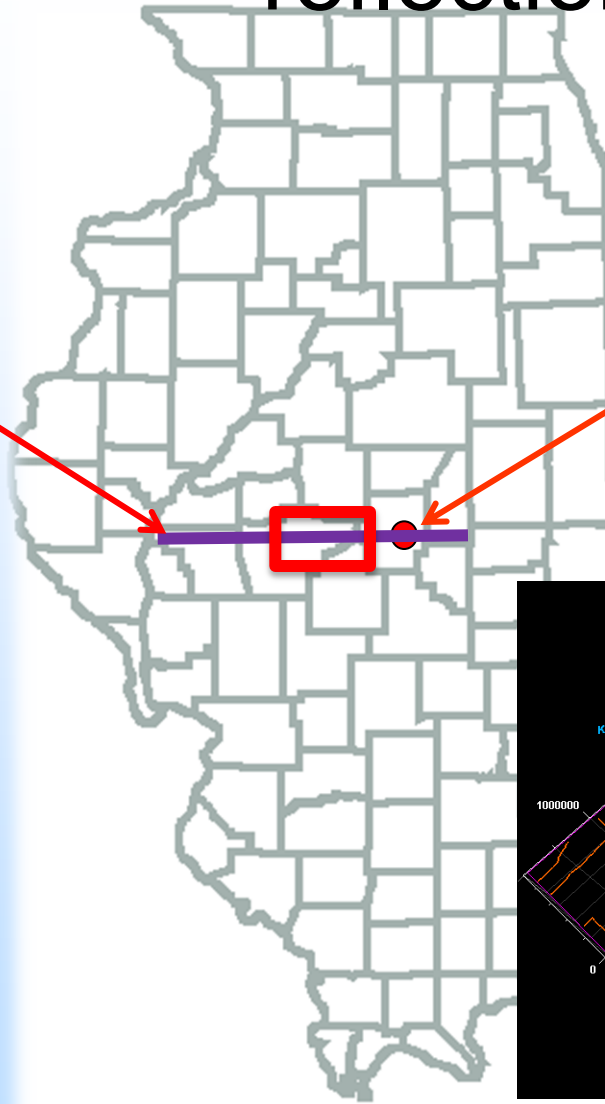
- Regional cross sections completed
- Regional maps completed and submitted to NatCarb
- Regional seismic data acquired, processed, and interpretation almost complete
  - Regional line to be released to public as economic release in Fall 2012

# Acquisition of 120 miles of 2D Seismic reflection data

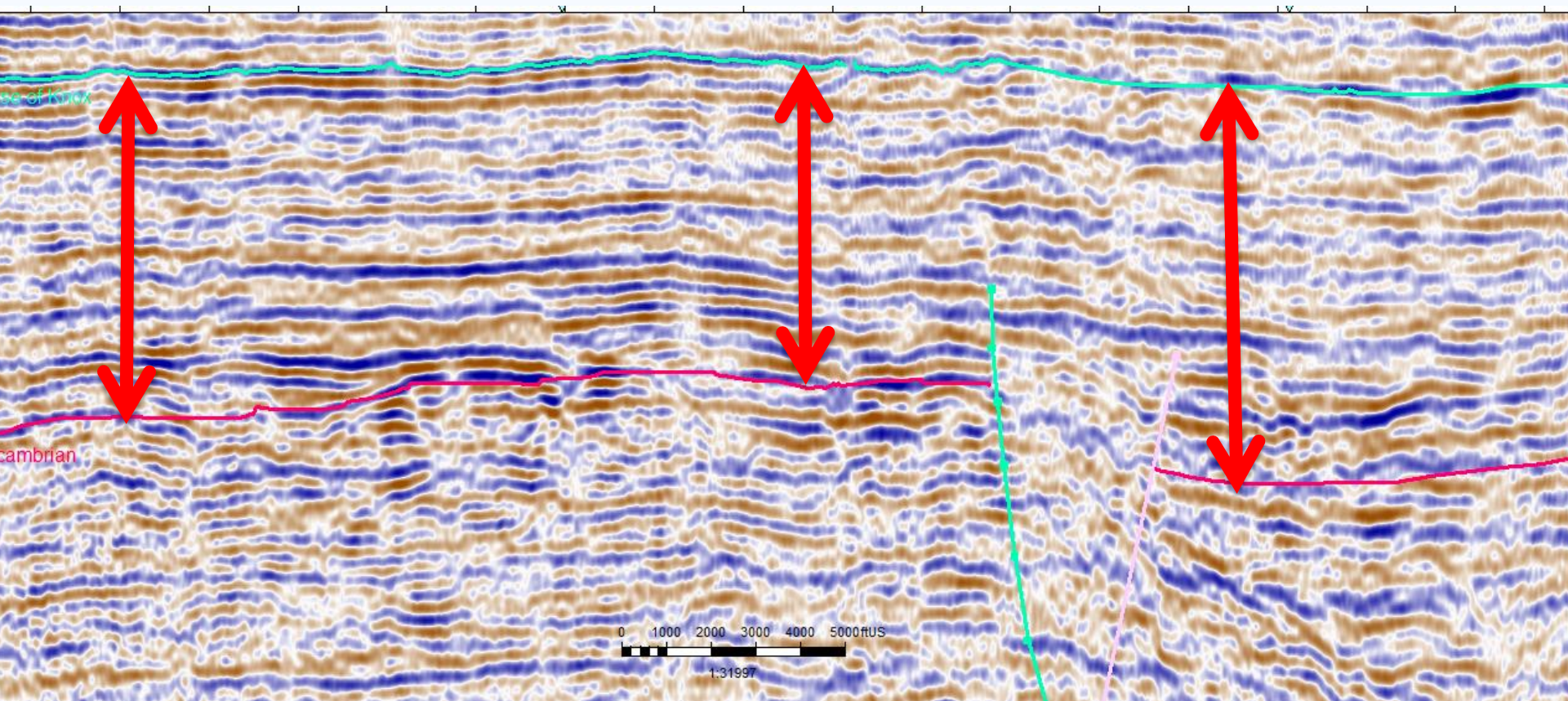
Seismic line

Decatur Project

We are currently working on the interpretation



# Thinning of Mt. Simon due to Paleotopography and Contemporaneous Faulting





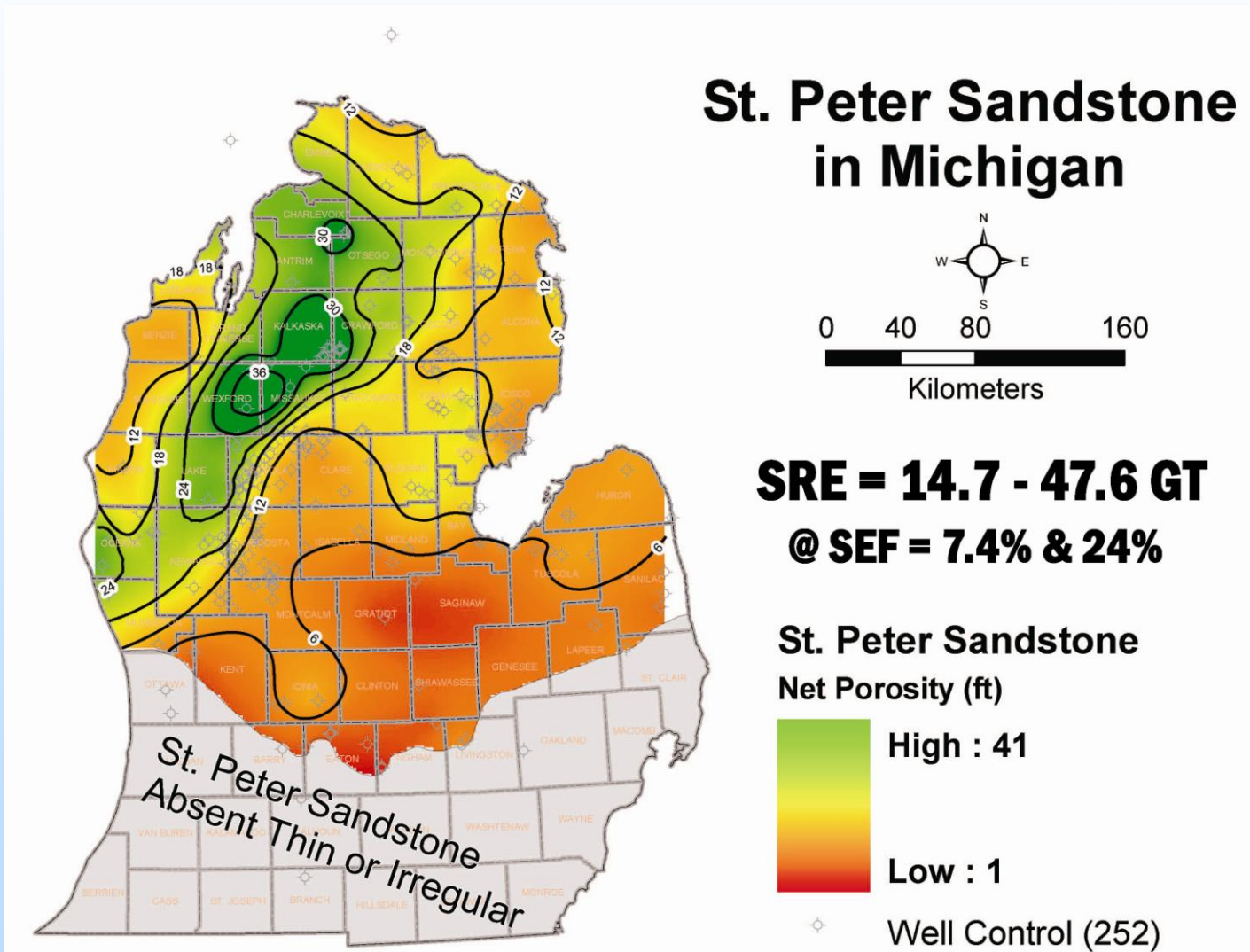
# Task 5 – Resource Estimates

- Resource estimate of the St. Peter Sandstone is almost complete
- Poster on methodology is being presented
- Resource estimates of the Knox is ongoing
  - Evaluating different methodologies

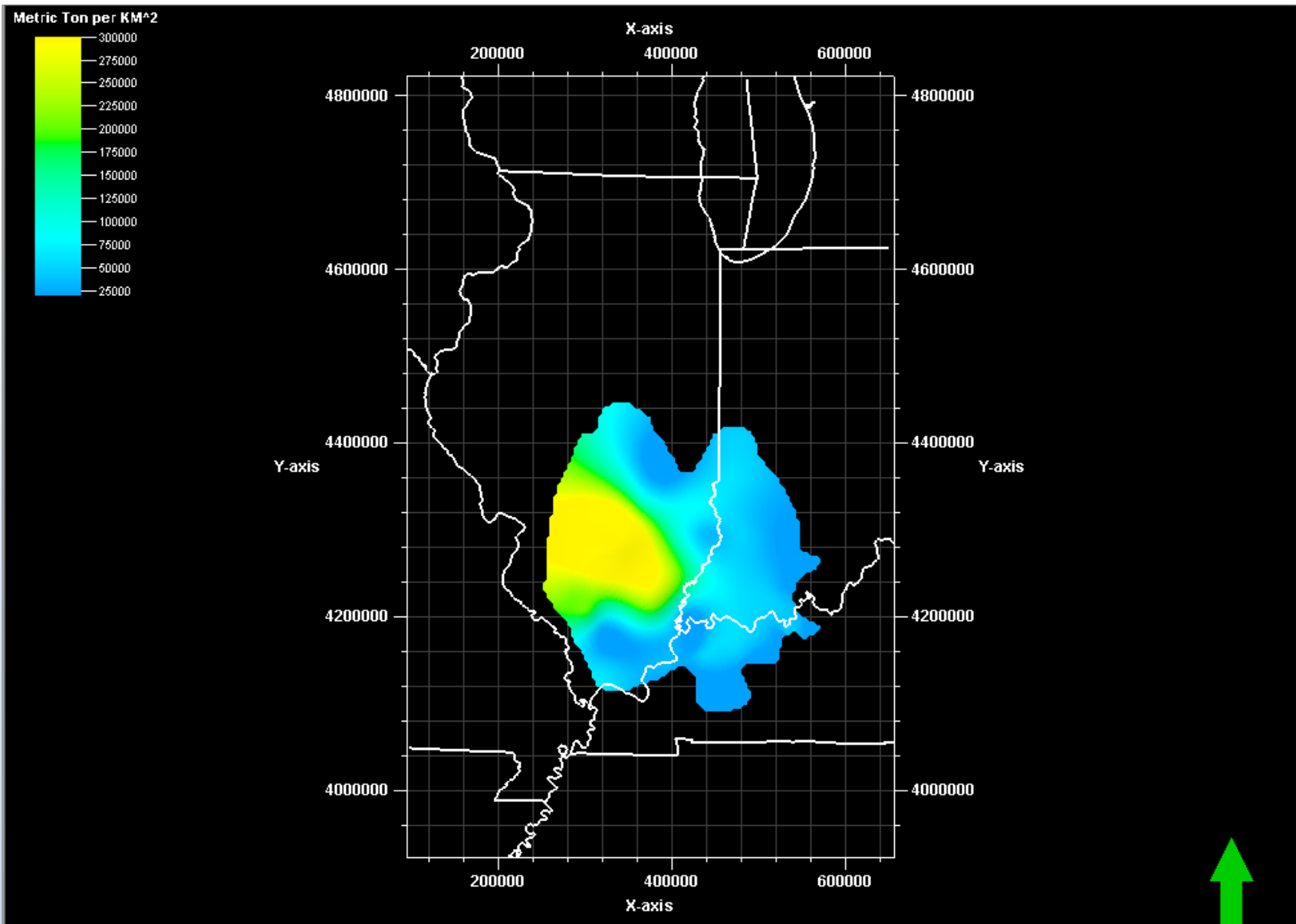
# St. Peter Sandstone

## Geological Carbon Storage Resource Estimate

14.7 – 47.6 Gt (@  $p_{10}$  and  $p_{90}$ )



# Illinois Basin St. Peter Sandstone CO<sub>2</sub> Storage Resource

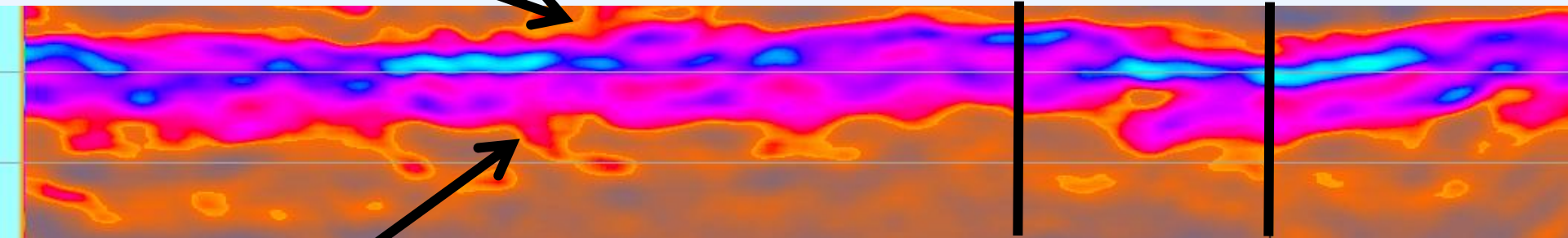


storage resource estimate range of 12.2 to 39.7 Gt.

# Seismic Inversion: Density

Top St. Peter

Verification # 1 Well CCS #1 Well



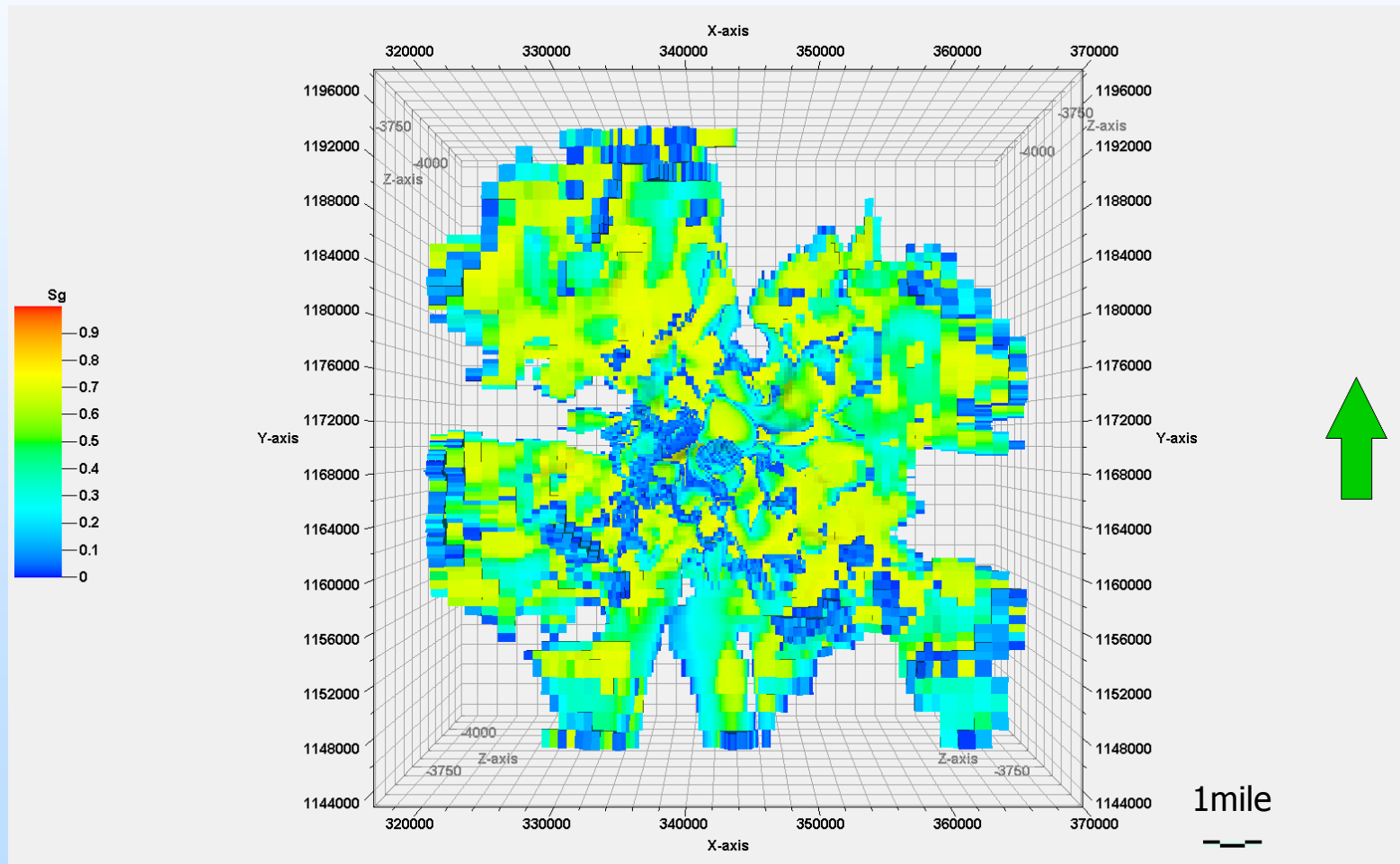
Top Knox

Top is 20 feet on seismic

# Task 6 – Injectivity

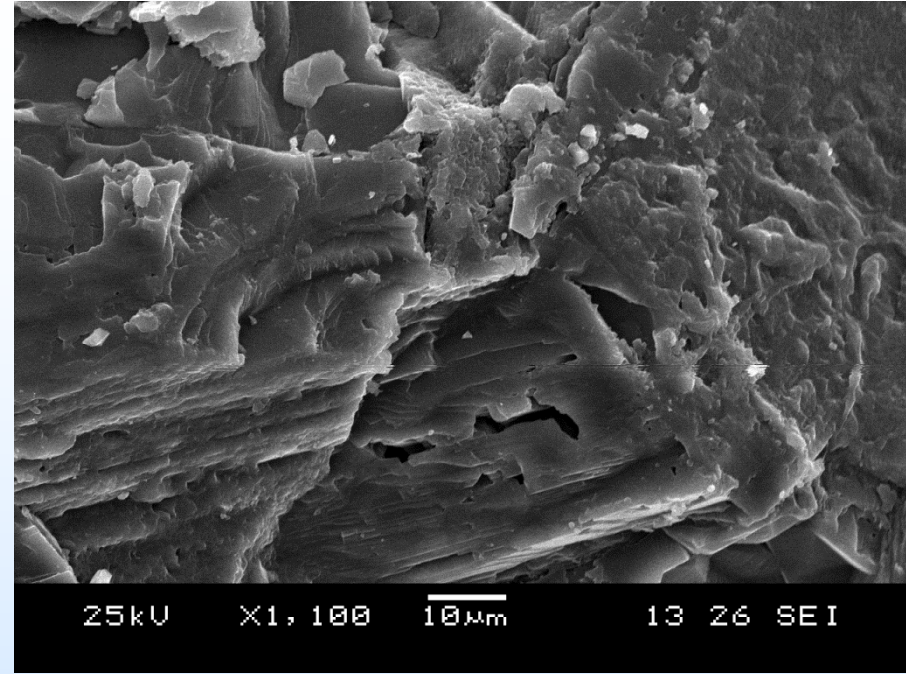
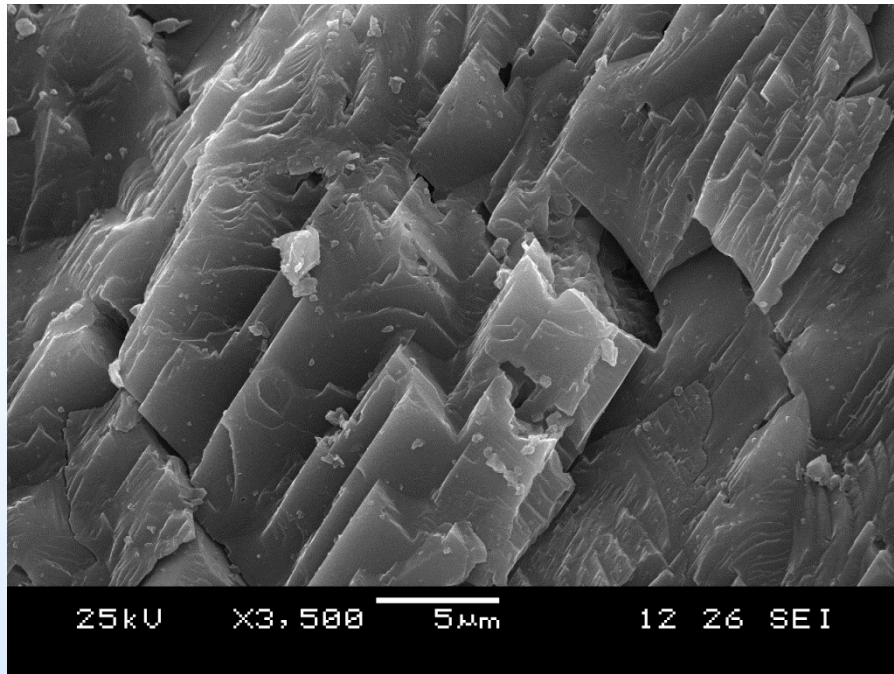
- Reservoir simulation of CO<sub>2</sub> injection in the Knox and St. Peter has been completed
  - Topical report submitted to USDOE

# Geostatistical reservoir model of Potosi. CO<sub>2</sub> plume plan view at the end of 20 years with an approximate radius of 5 miles



# Task 7, 8, 9, 10 – Containment

- Laboratory analysis of mineral and CO<sub>2</sub> interactions
- Numerical analysis of brine-CO<sub>2</sub> interactions
  - Publication in review
- Topical report on injectivity also included analysis of seal integrity

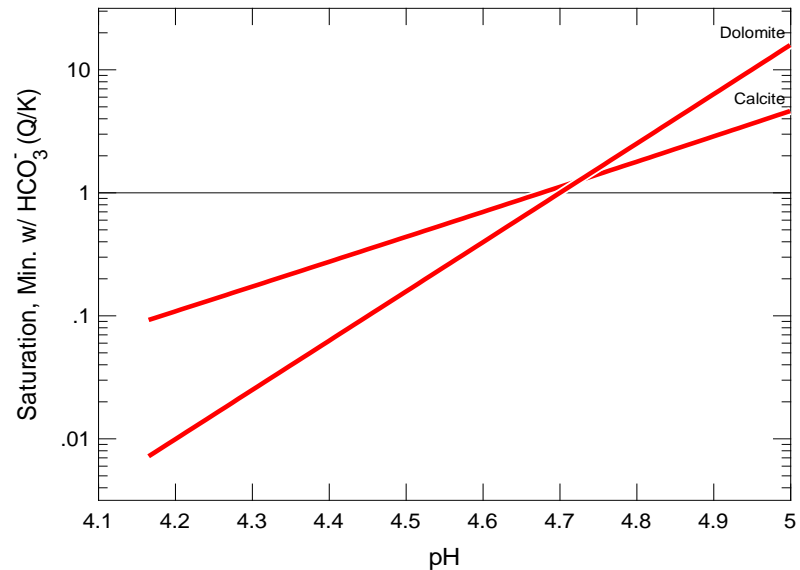


**SEM photomicrographs of Potosi Dolomite (sample MO-1-9) before (left) and after (right) exposure to carbon dioxide and brine at 311 K and 9.86 MPa pressure. After three months of exposure, extremely etched dolomite crystals and dissolution features were observed.**



# Geochemical Modeling of the Potosi Dolomite

Using the kinetic software React<sup>®</sup>, a dolomite-brine-CO<sub>2</sub> mixture equilibrated within 3 months yielding a brine pH of about 4.7. This was in agreement with measured pH values when samples of the Potosi were exposed to CO<sub>2</sub> for 3 months in pressure reactors.



# Accomplishments to Date

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- Injected CO<sub>2</sub> into Knox in Kentucky
- Acquired Knox core from Decatur, IL
- Acquired 120 miles of seismic data
- Completed reservoir simulation of CO<sub>2</sub> movement in St. Peter and Knox
- Assessment of St. Peter and Knox to CO<sub>2</sub> using laboratory experiments at reservoir conditions
- Regional cross sections across the Illinois basin and regional maps are being completed.
- Resource estimates of St. Peter are almost complete

# Summary

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## Key Findings

- St. Peter and Knox are good regional sequestration targets

## – Lessons Learned

- Movement of CO<sub>2</sub> within the Knox will be difficult to predict
- Seismic reflection data can be an important tool for evaluating uncertainty

## • Remaining Tasks

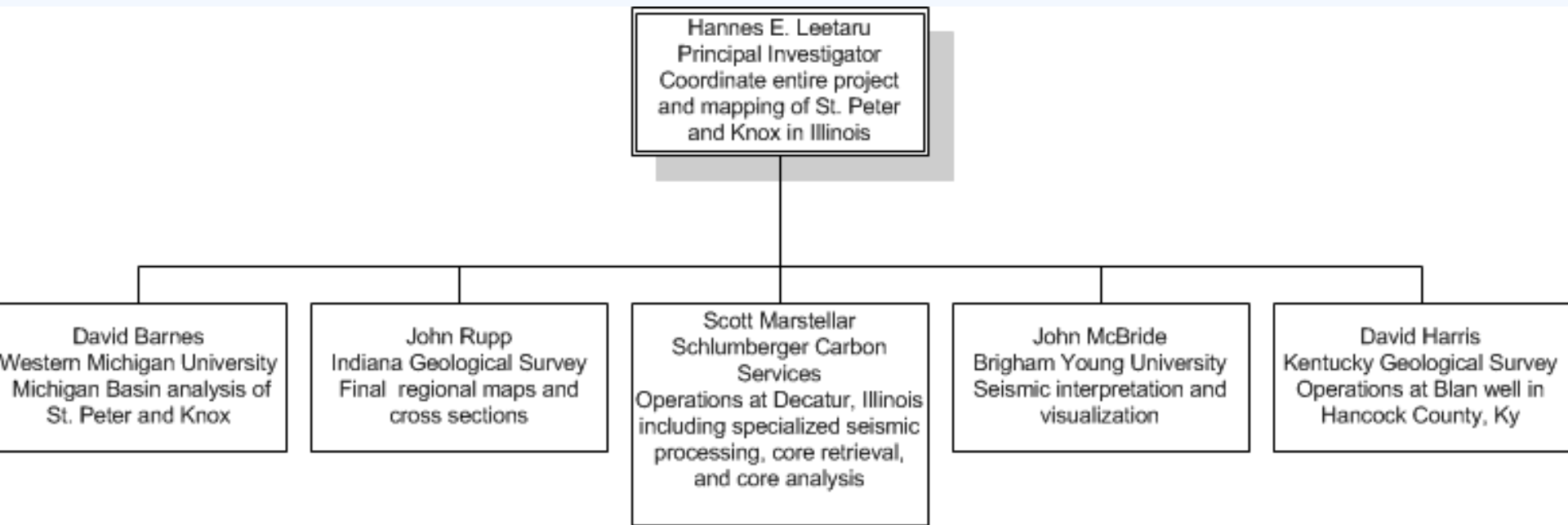
- Leakage Pathways
- Site Selection
- Risk Assessment
- Well Bore Management

# Appendix

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

# Organization Chart



ID	Task Name	Start	Finish	% Complete	2010				2011				2012				2013			
					Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	
1	Task 1 Management Plan	12/17/2009	9/30/2013	48%																
2	T1-M1 revised Management Plan submitted	3/31/2010	3/31/2010	100%																
3	T1-M2 create deliverabl schedule	9/30/2010	9/30/2010	100%																
4	T1-M3 milestone log update	4/1/2010	4/1/2010	100%																
5	HQ Kick-off meeting	2/5/2010	2/5/2010	100%																
6	Compile Base Data	1/22/2010	6/30/2011	98%																
7	T2-M1 HQ plan transfer to NATCARB	12/31/2010	12/31/2010	100%																
8	Site Work	12/1/2009	6/30/2011	94%																
9	T3-M5 Reservoir data collection initiated	11/18/2010	11/18/2010	100%																
10	T3-M6 well at Decatur completed	12/17/2010	12/17/2010	100%																
11	T3-M8 complete injection at Hancock	10/15/2010	10/15/2010	100%																
12	T3-M9 P&A Hancock well	6/1/2012	6/1/2012	100%																
13	Regional Significance	3/15/2010	12/7/2012	88%																
14	T4-M1 complete regional work	4/4/2012	4/4/2012	0%																
15	Capacity Estimates	1/17/2011	8/21/2012	81%																
16	Injectivity of the formation	11/1/2010	5/11/2012	75%																
17	T6-M1 complete injectivity analysis	3/1/2012	3/1/2012	0%																
18	Containment Stratigraphic	12/1/2010	3/22/2013	76%																
19	Containment - Brine	12/6/2010	5/31/2012	80%																
20	T8-M1 complete seal analysis	6/1/2012	6/1/2012	0%																
21	Containment - Mineralogic	1/15/2010	9/25/2013	50%																
22	Leakage Pathways	2/13/2012	6/8/2012	12%																
23	Site Selection	5/30/2012	8/30/2013	14%																
24	Risk Assessment	10/24/2012	3/14/2013	14%																
25	Well Bore management	8/29/2012	4/18/2013	0%																
26	Deliverables	3/15/2010	10/11/2013	18%																

# Bibliography

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## List peer reviewed publications

- Leetaru, H.E., Brown, A.L., Lee, D.W., Senel, O., and Couëslan, M., 2012, CO<sub>2</sub> injectivity, storage capacity, plume size, and reservoir and seal integrity of the Ordovician St. Peter Sandstone and the Cambrian Potosi Formation in the Illinois Basin. Topical Report, USDOE Report Number DOE/FE0002068, 29 p.
- Harris, D.C, Williams, D.A., Bowersox, J.R., 2012, Summary of carbon storage project public information meeting and open house, Hawesville, Kentucky, October 28, 2010: U.S. Department of Energy Topical Report DOE/FE0002068-2, June 2012, 18 p.