CarbonSAFE Illinois

Steve Whittaker ISGS

RITE CCS Workshop

January 2020 Tokyo

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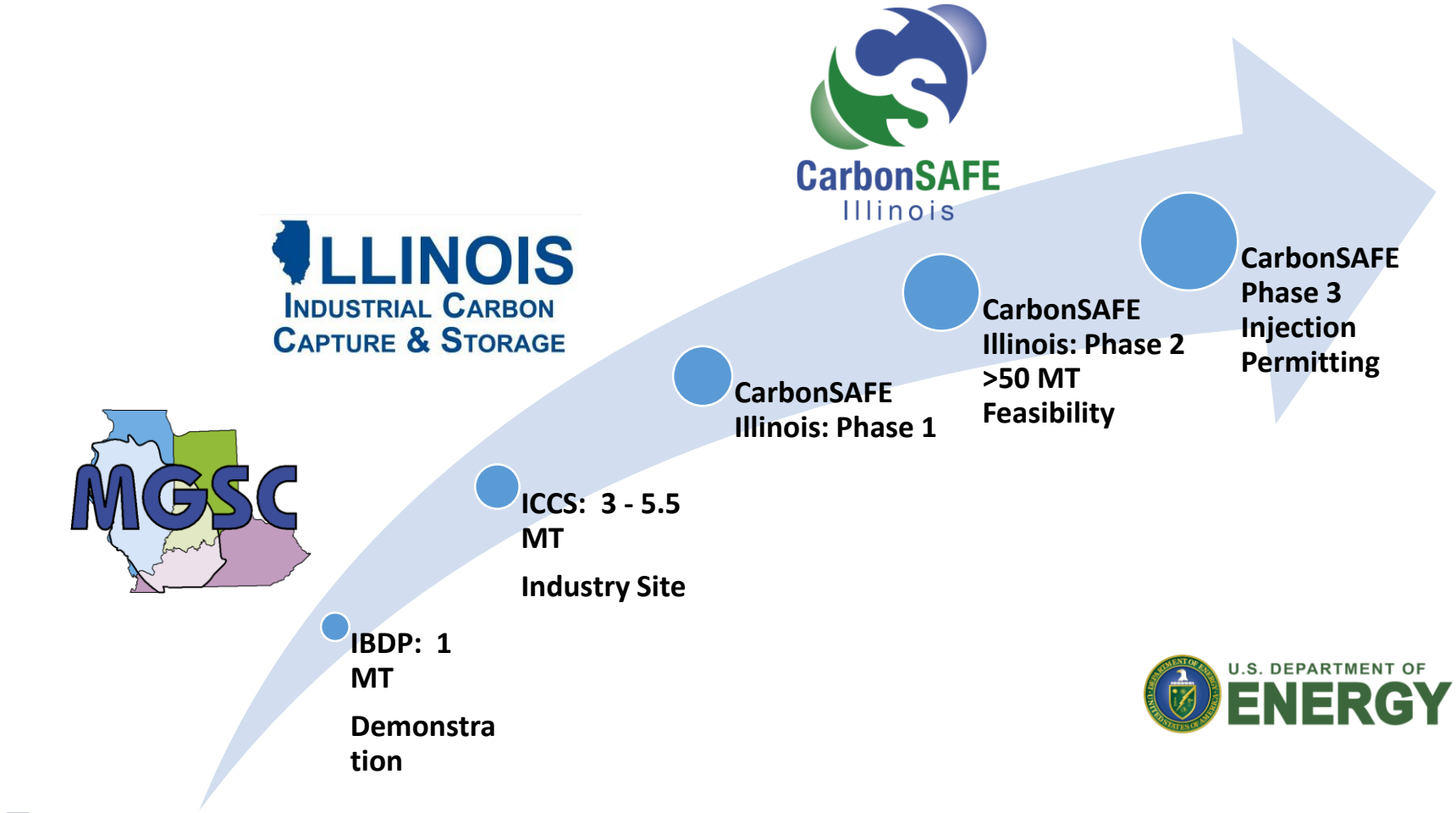
Illinois

CCS Progression in Illinois Basin



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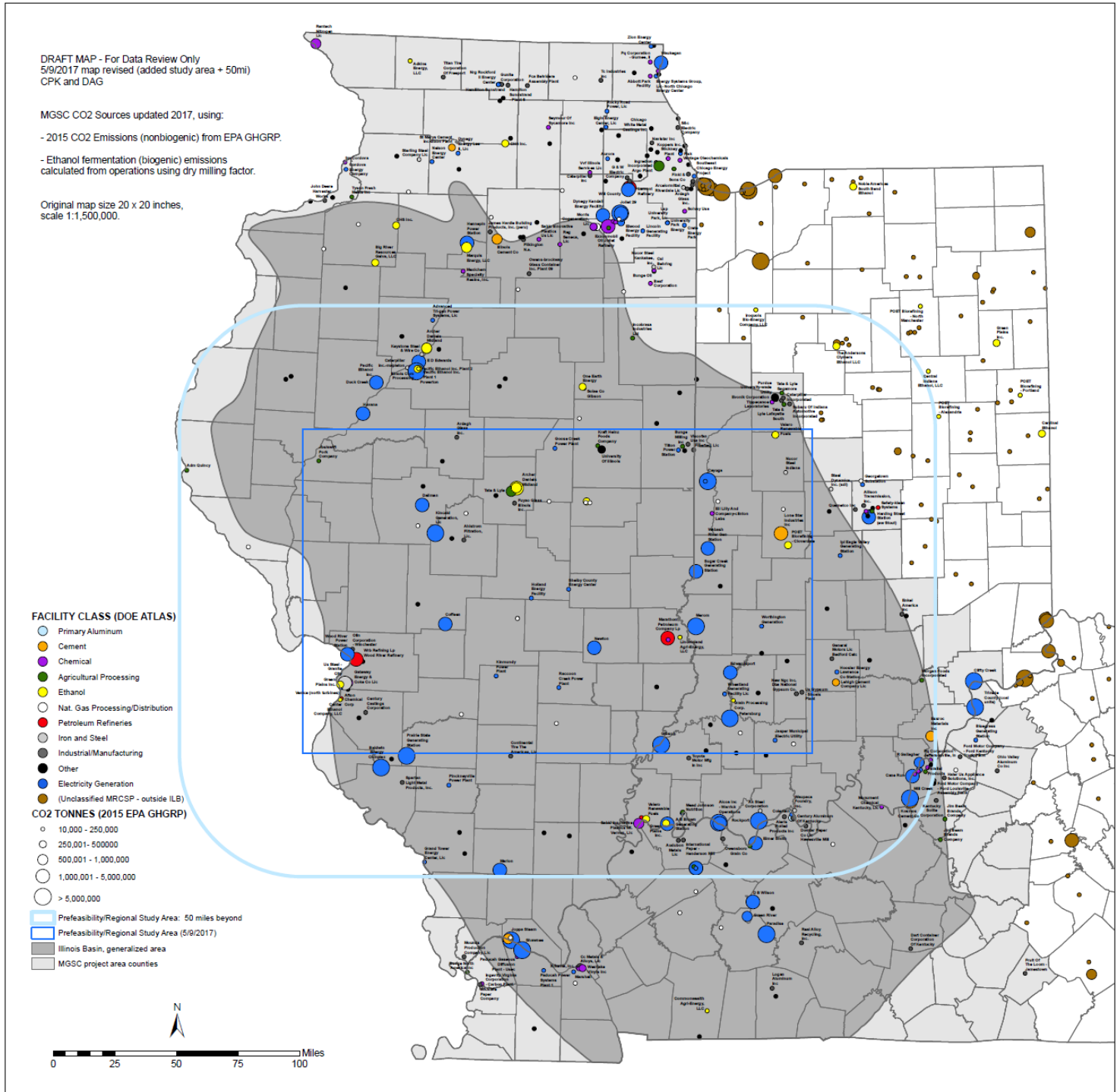
U.S. DEPARTMENT OF ENERGY | NETL NATIONAL ENERGY TECHNOLOGY LABORATORY

Scale of the challenge

Regional CO_2 Sources



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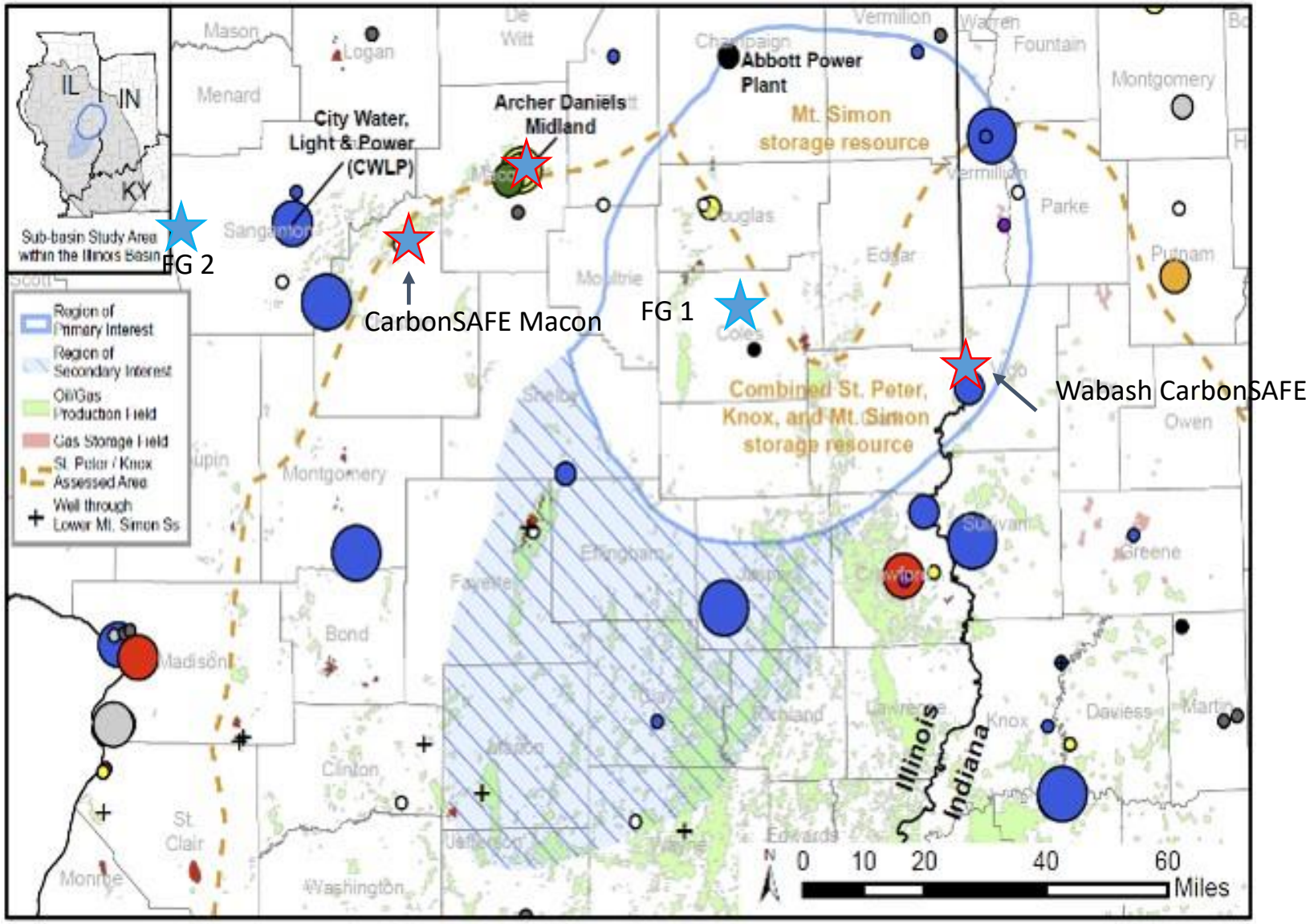
CarbonSAFE
US DOE Program to commercialize storage

Illinois Basin

1 - Phase I

2 - Phase II

2 – Phase III



Mt Simon Sandstone Storage Complex

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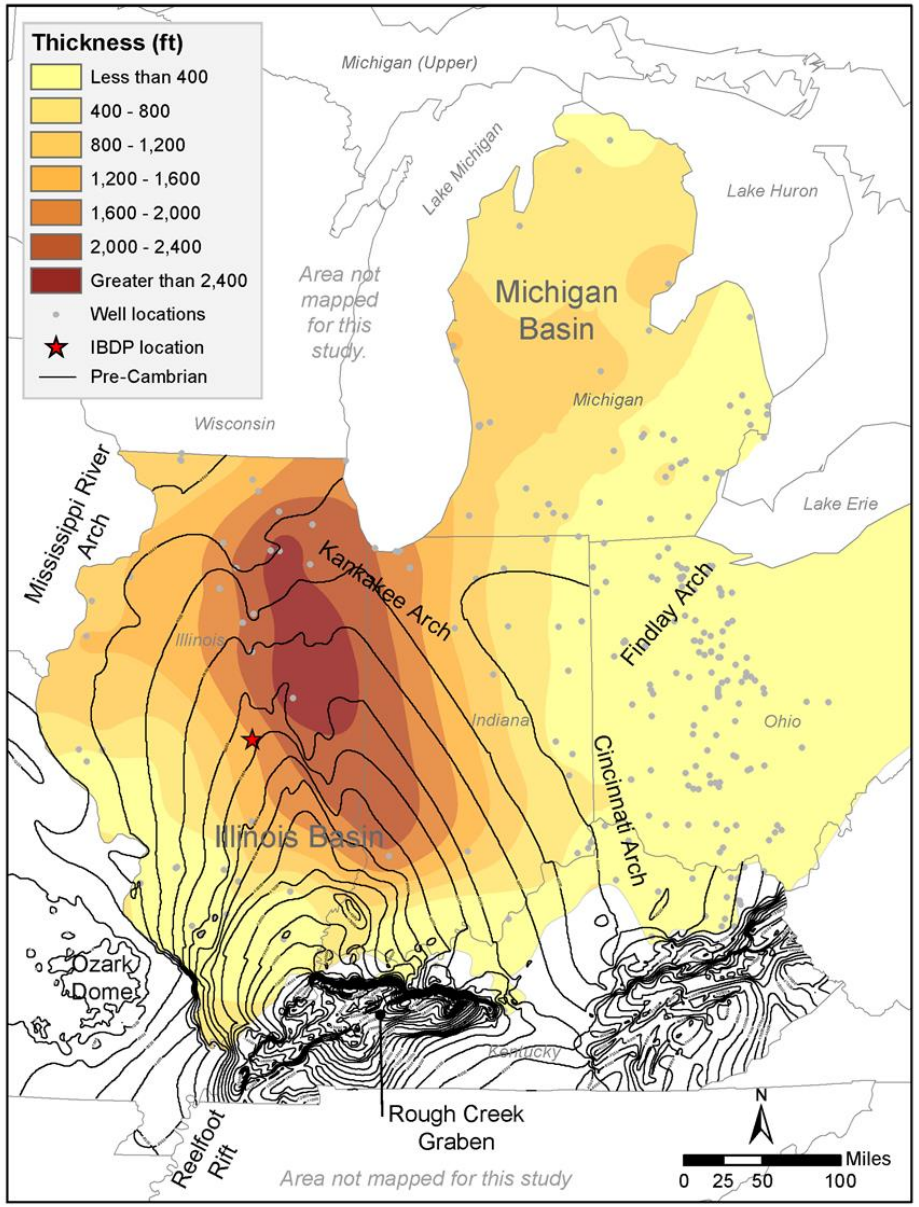


SYSTEM	GROUP	FORMATION	Storage Elements
Ordovician	Maquoketa	Brainard	Secondary Seal
		Ft. Atkinson	
		Scales	
	Galena	Kimmswick	
		Decorah	
	Plateville		
	Ancell	Joachim	
		St. Peter	Potential target
	Knox	Shakoppee	Secondary Seal/Reservoir
		New Richmond	
		Oneota	
		Gunter	
		Eminence	
		Potosi	Potential target
		Franconia	
Cambrian		Ironton-Galesville	
		Eau Claire	Primary Seal
		Mt. Simon	Target reservoir
Precambrian			

St. Peter-Knox Storage Complex

Mt. Simon Storage Complex

Cambro-Ordovician Storage Complex

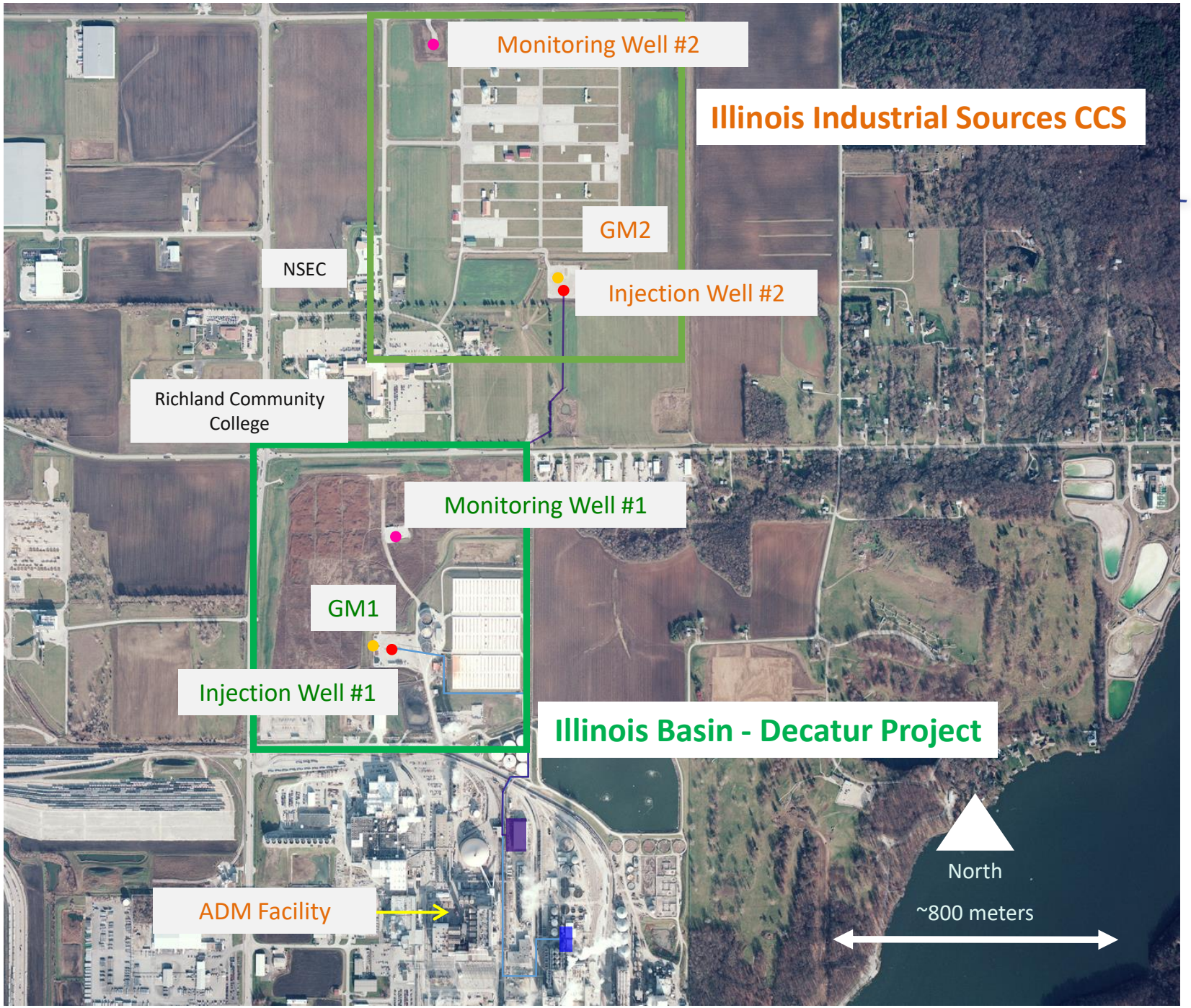
2 CCS Sites

#1: IBDP Demonstration

From 2011 to 2014 injected total of 1 million metric tons of CO_2 at a depth of 7,000 ft

#2: IL-CCS Industrial

Currently injecting ~ 1MT per year of anthropogenic CO_2



Thickness of the Mt. Simon is 1600 feet

Height of Willis Tower (Sears Tower)

Roof is 1451 feet

Antenna is 1,730 feet

Washington Monument is 555 feet tall

Porous zone is 600 feet thick)

Injection Interval

RESERVOIR CHARACTERIZATION

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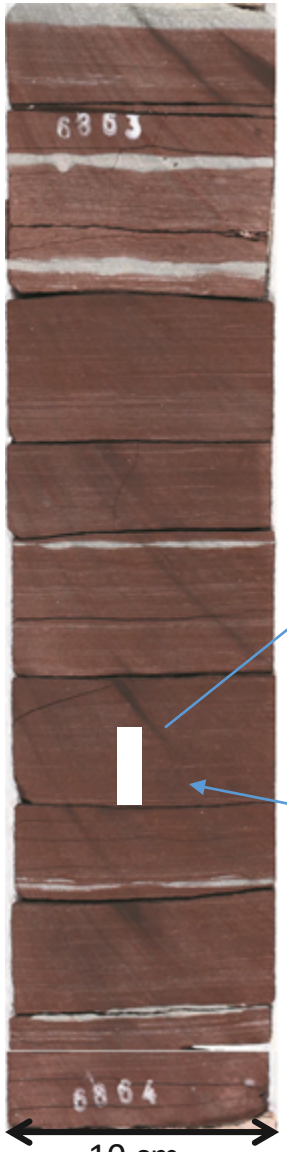
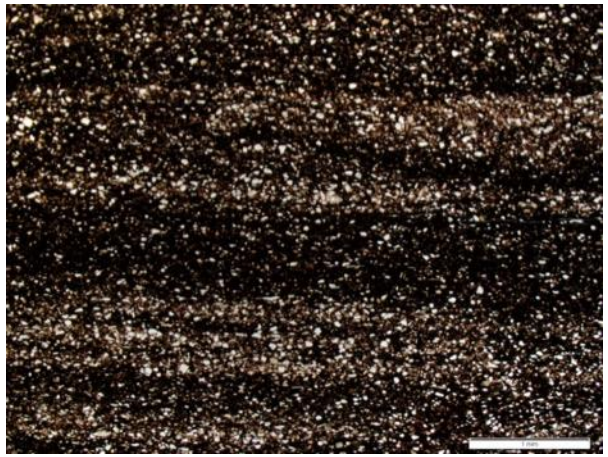
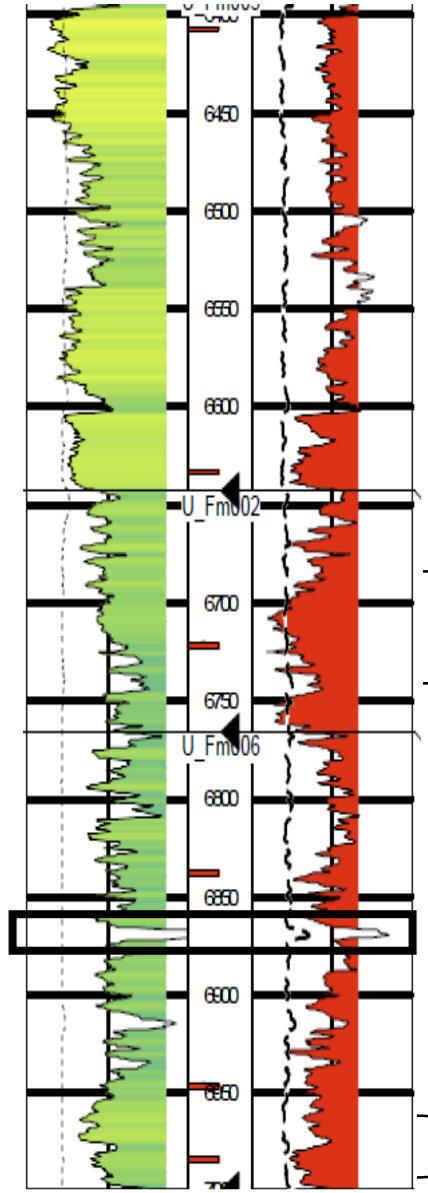
Mt Simon Core



VW1



<u>6,863 to 6,863.25</u>
Porosity: 1.5%
K_v: <0.01 mD
K_h: 4.13 mD in siltstone laminae



IL-ICCS Injection Zone

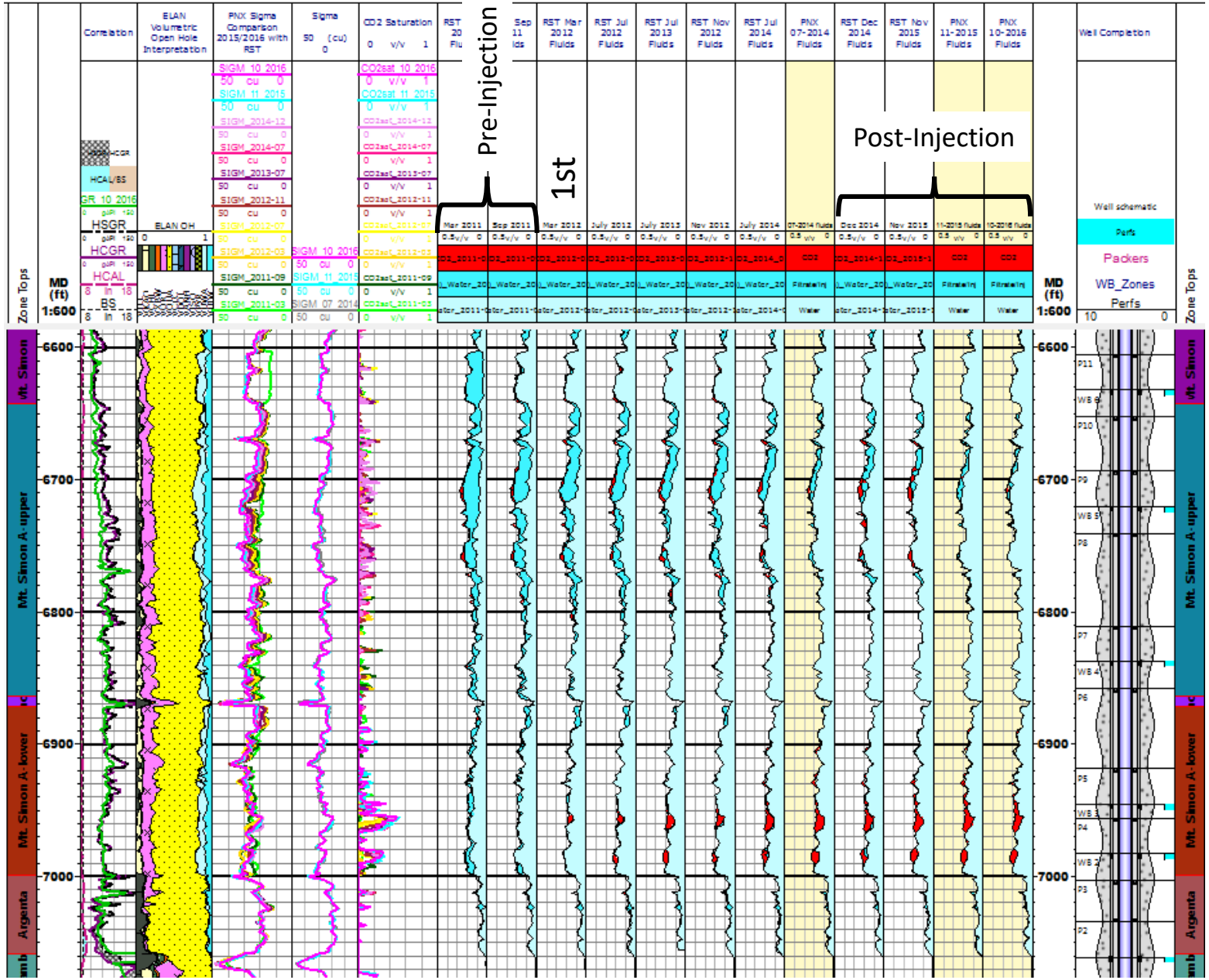
Baffle

IBDP Injection Zone

Repeat Pulsed Neutron Logging in VW1

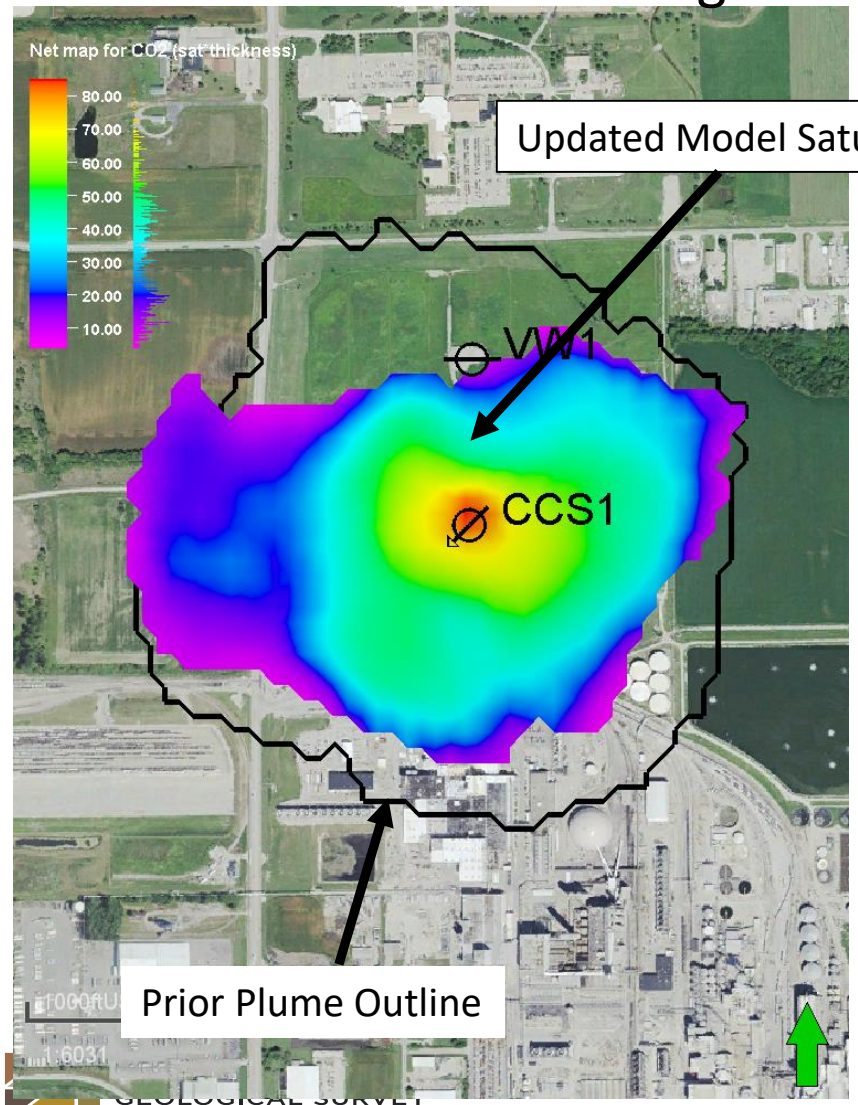
RST (Saturation) Monitoring

- Baseline surveys
- CO_2 arrival before Mar 2012
- CO_2 saturation increasing though Nov 2015

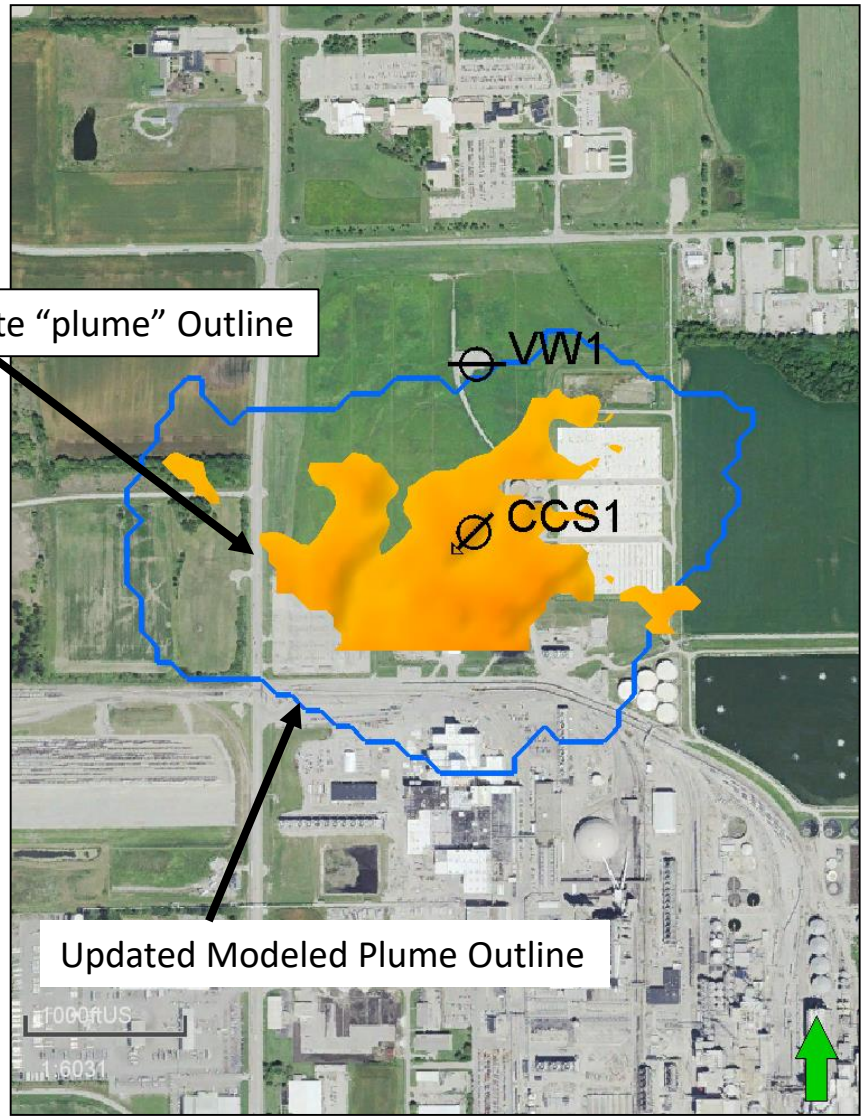


Performance Monitoring Improves Prediction

Simulation Modeling

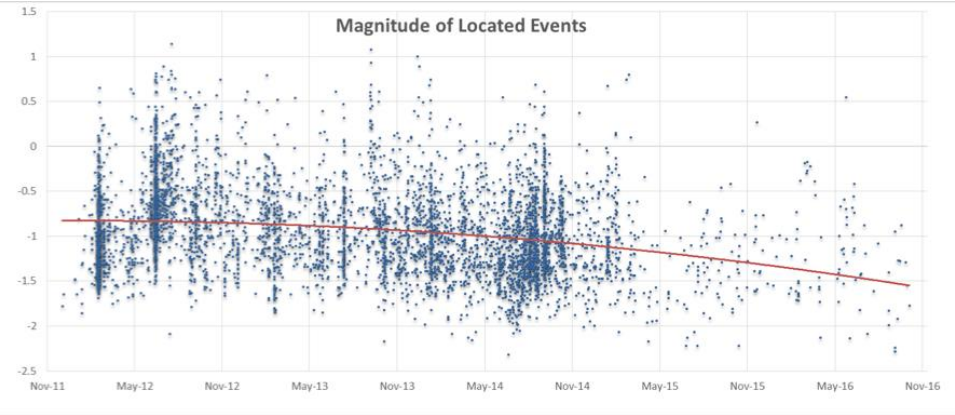


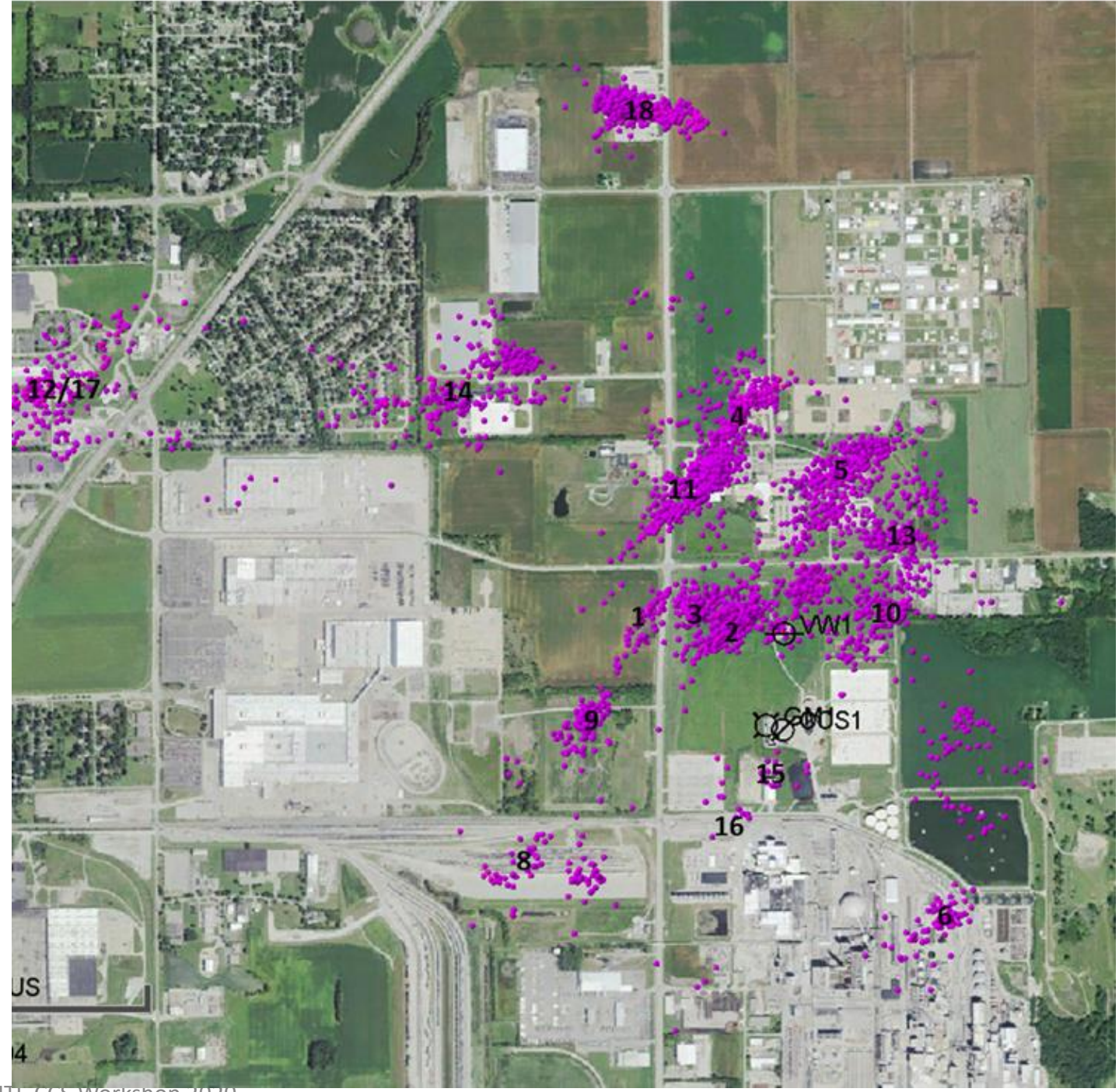
Seismic Attribute



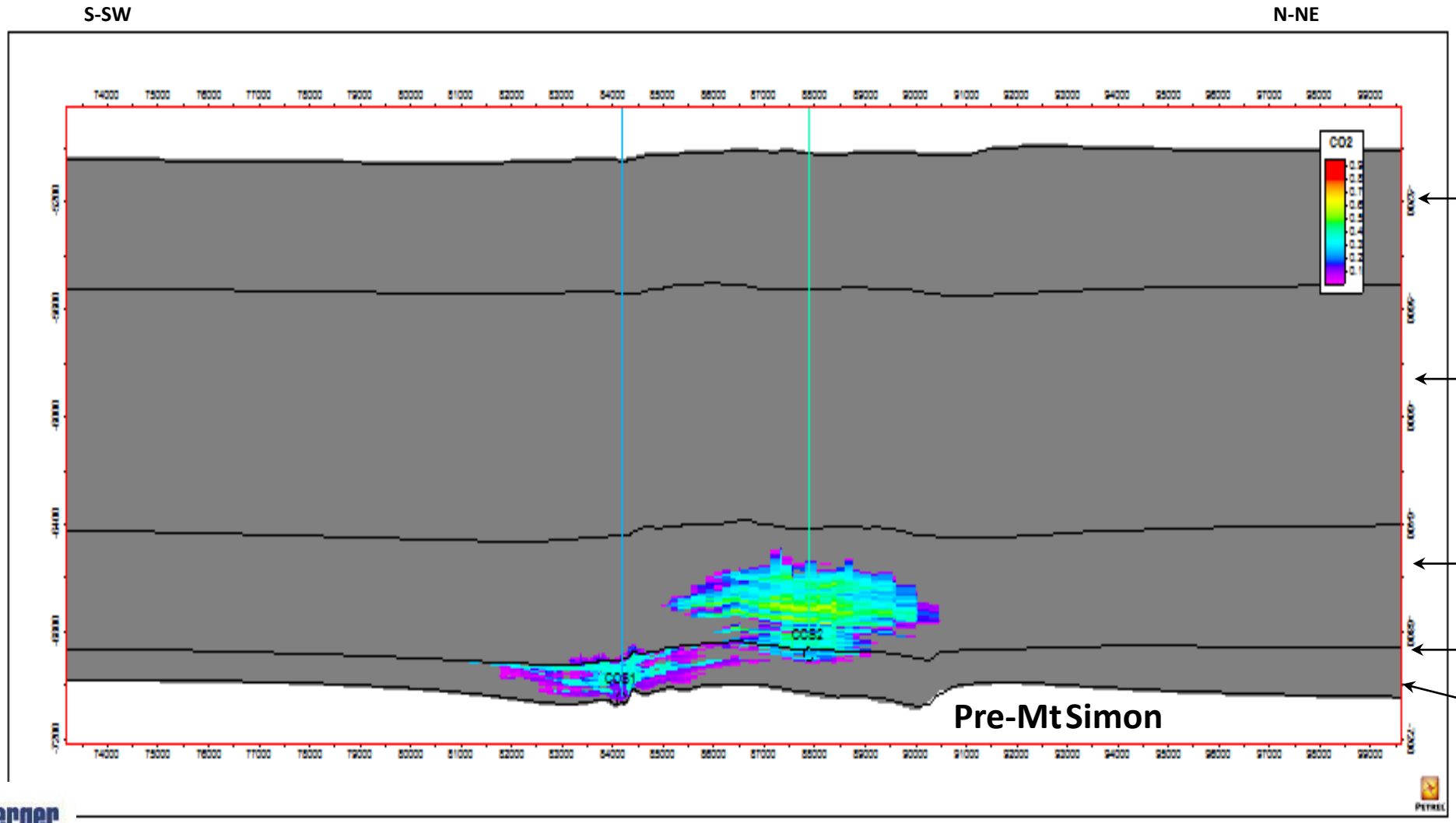
Passive Seismic (Microseismic) Monitoring

- Location critical to understanding reservoir response
- Relation of clusters to *pressure front* and *basement characteristics*
- 5 surface seismometers also used



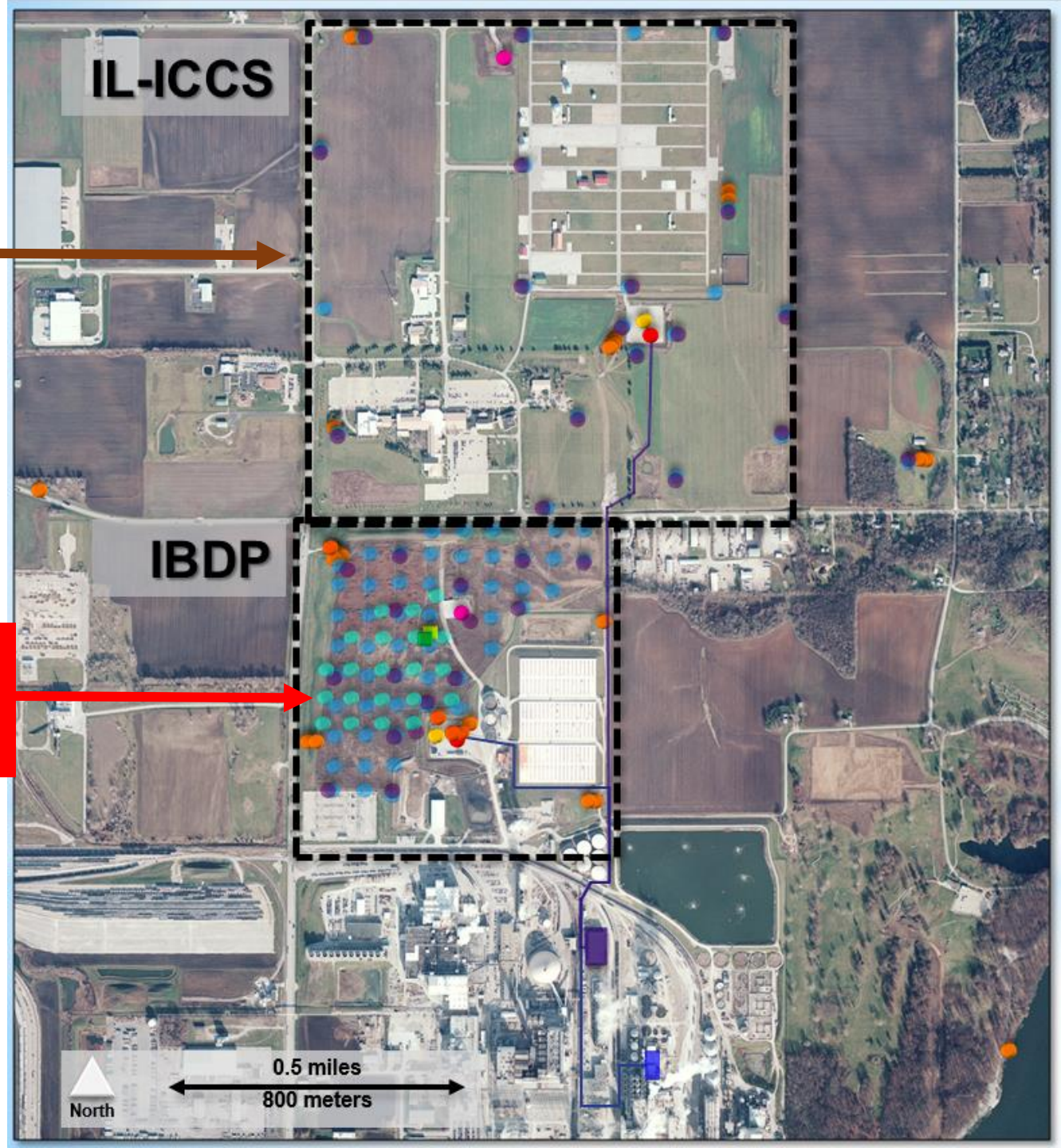


Simulated Plume Interaction (At end of CCS#2 injection)



Industrial scale
Risk based

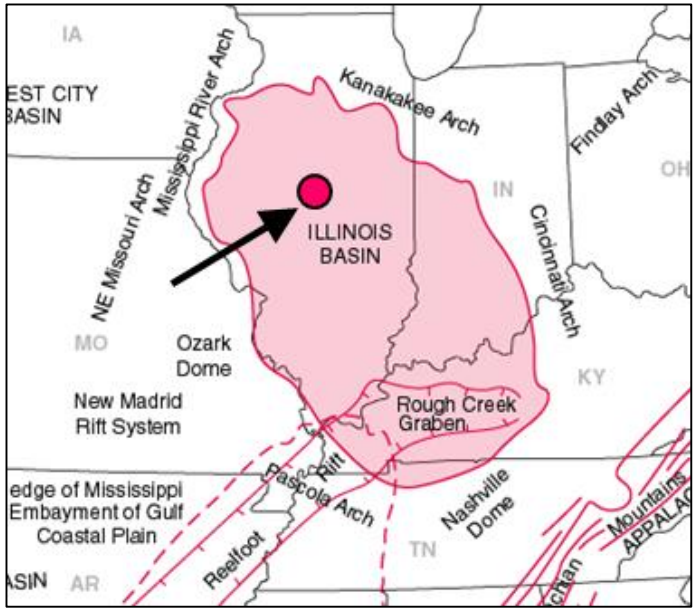
Demonstration scale
Research based

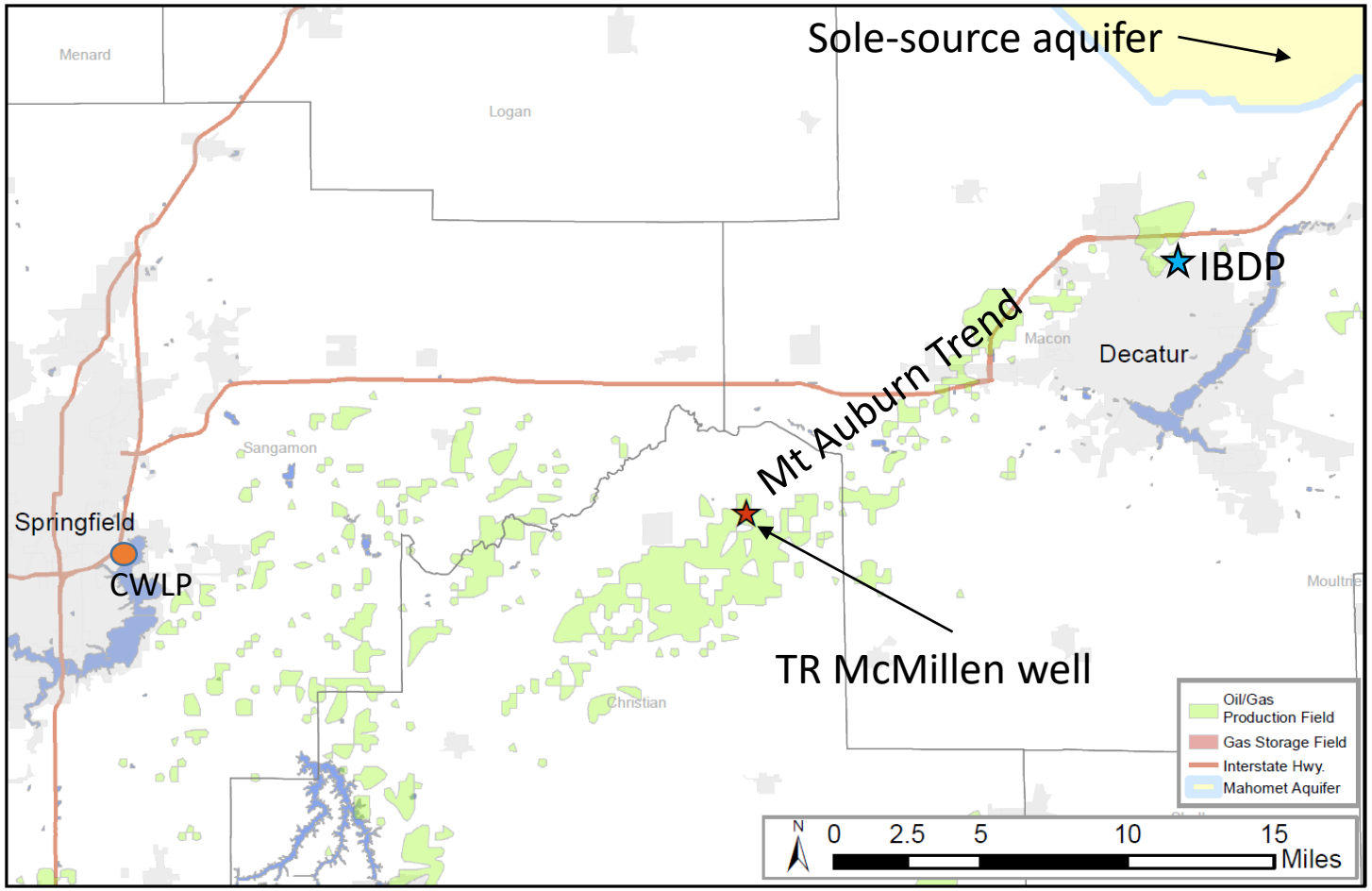


Monitoring Summary

- Injection wells (2)
- Verification wells (2)
- Geophysical wells (2)
- Compliance wells (4)
- Research wells (24)
- Soil gas points (35)
- Soil flux points (145)
- Eddy covariance station (1)
- Continuous GPS station (1)
- InSAR artificial reflectors (21)

CarbonSAFE Illinois – Macon County





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Sample Collection: McMillen #2

- Drilling completed December 2, 2018
- TD at 6,469 ft
- 150 feet of 3.5 inch core:
  - Silurian 62 ft
  - Lower Mt Simon 61
  - Precambrian 27
- 109 rotary sidewall cores
- Extensive geophysical logs

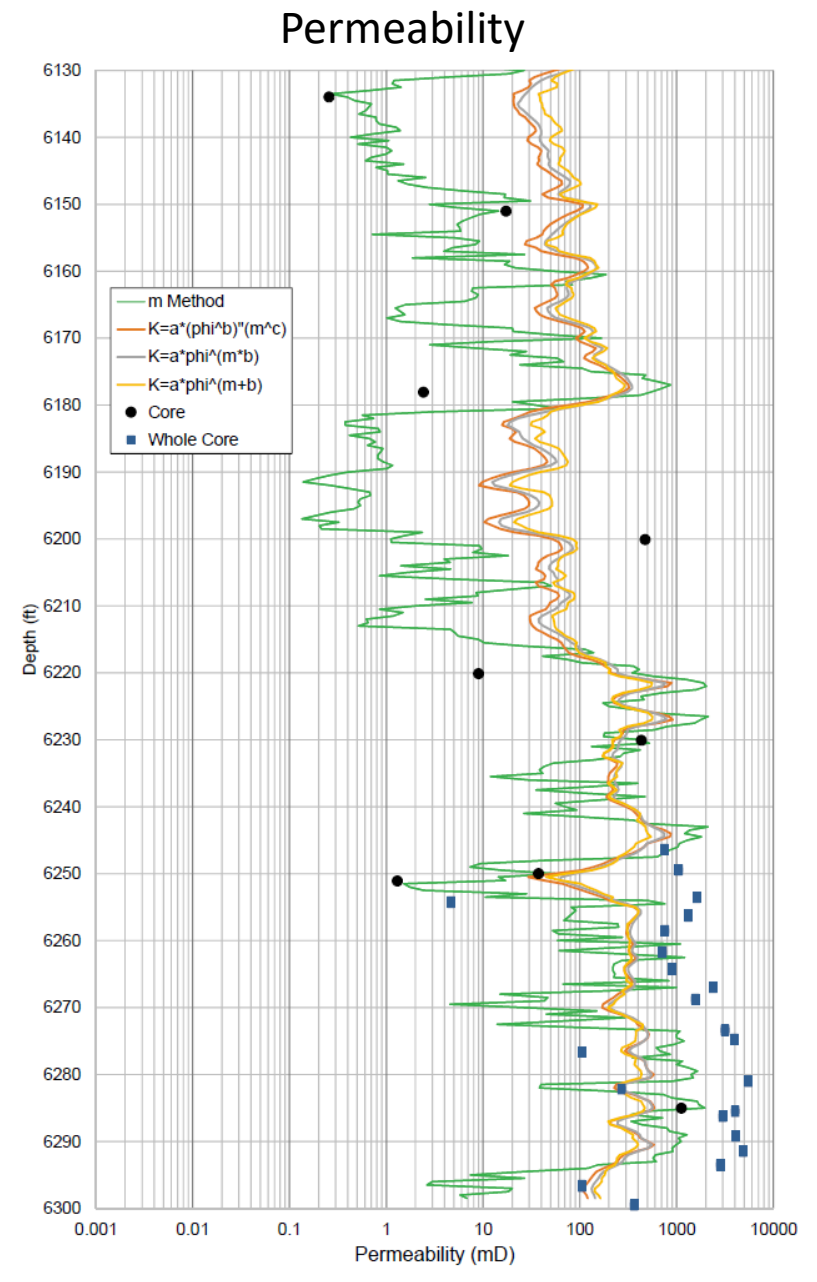
Lower Mt Simon Core: 6288-6294 ft

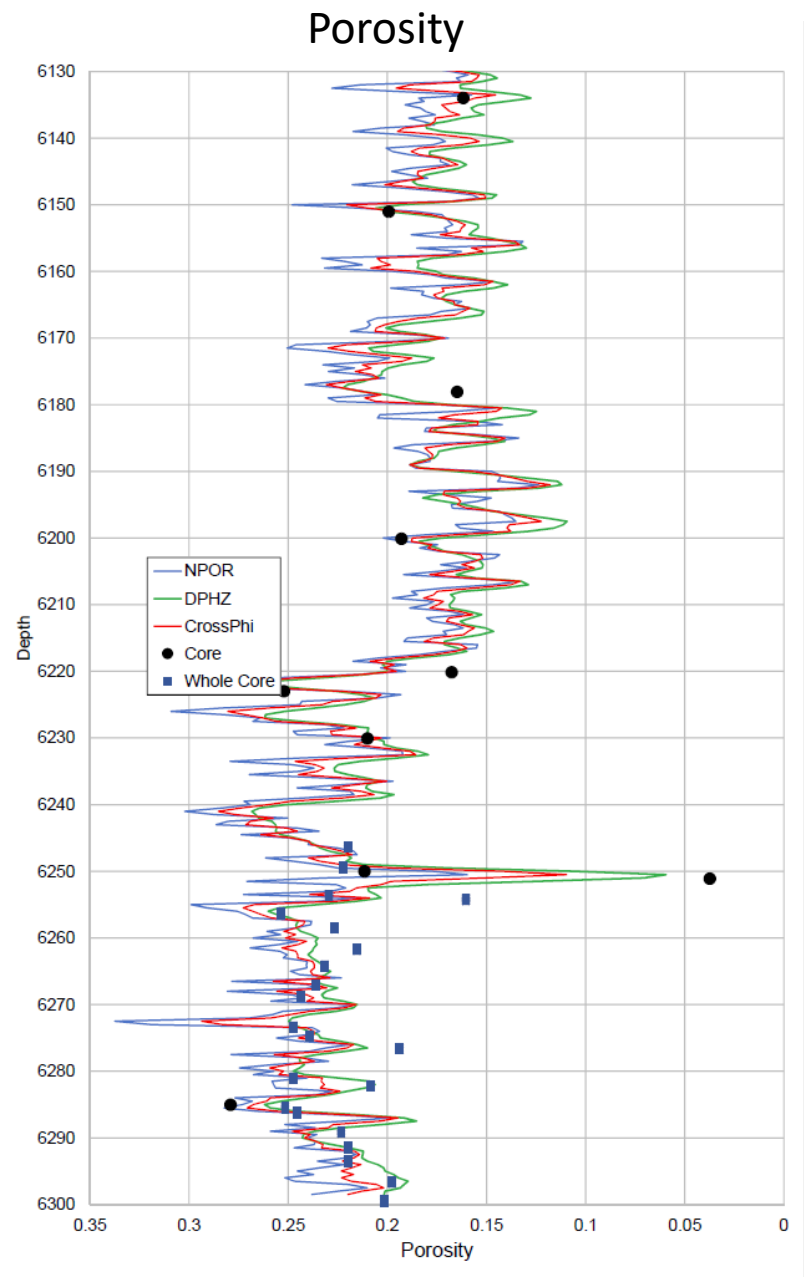
Lower Mt Simon Storage Complex

Porosity averages ~ 20%

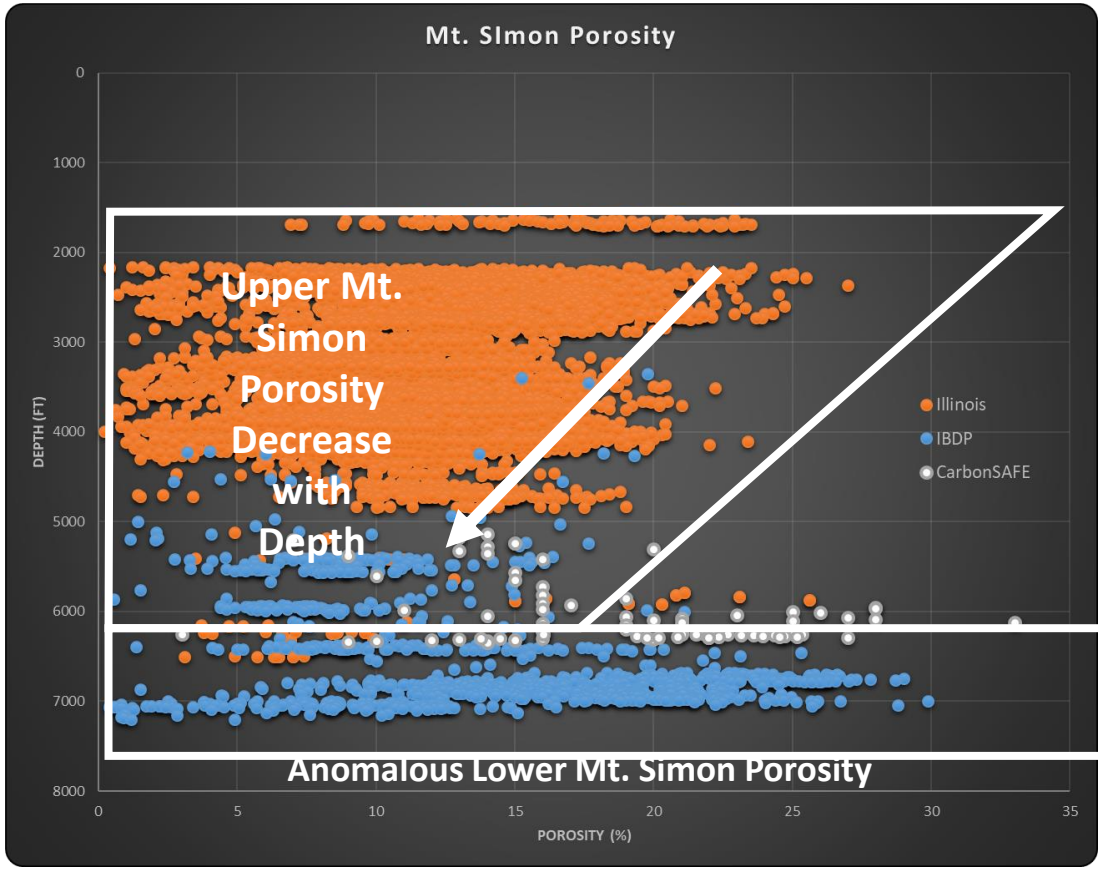
Permeability ca 100's of mD
Side wall and whole core samples with Darcy permeability (up to 5.5)!

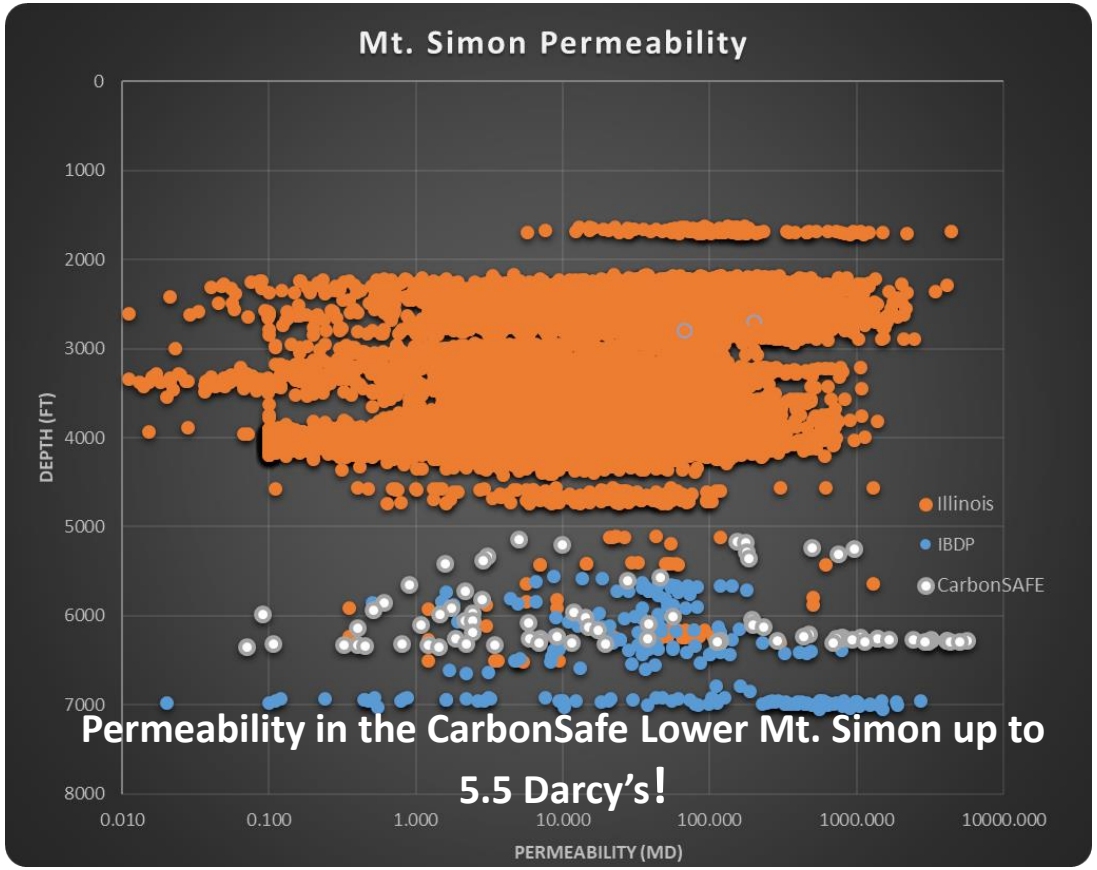
Preliminary simulation indicates CO_2 injection rates of 1.7 Mt/y with 15' perforation

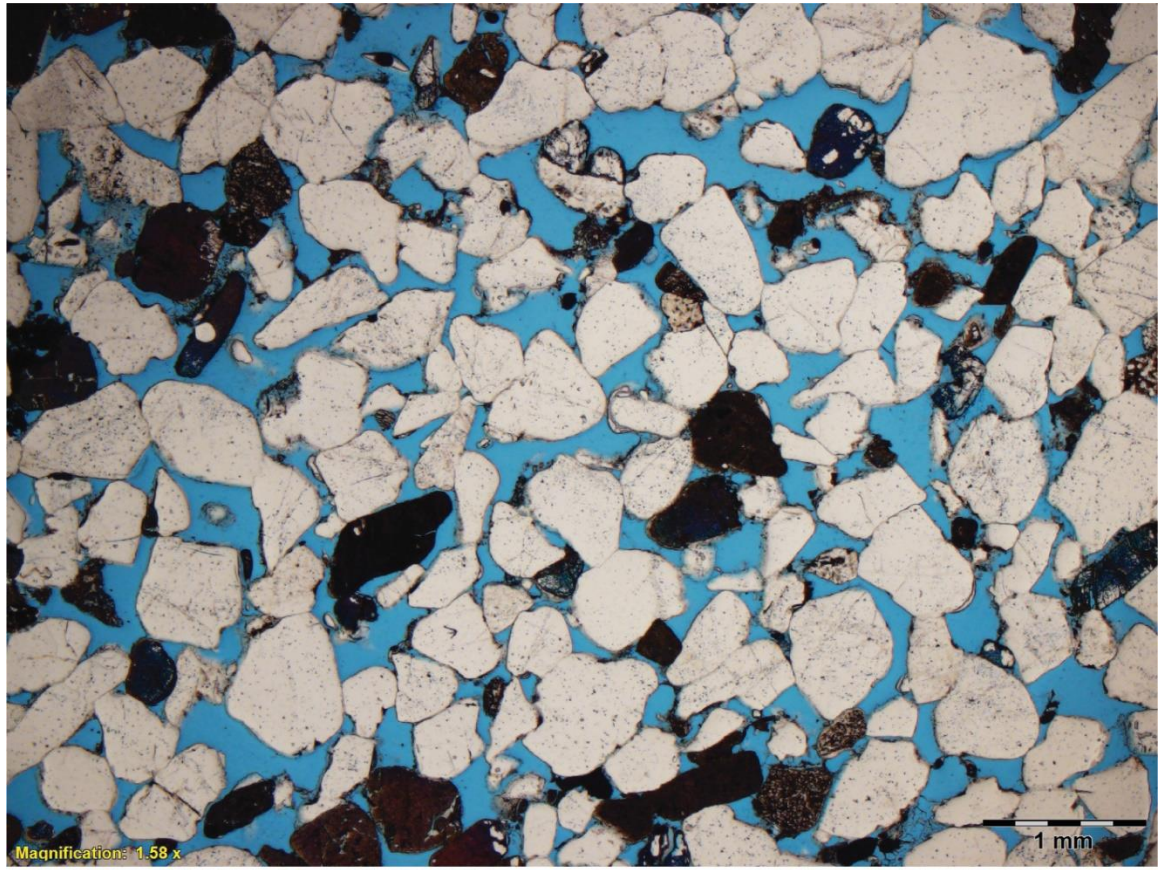


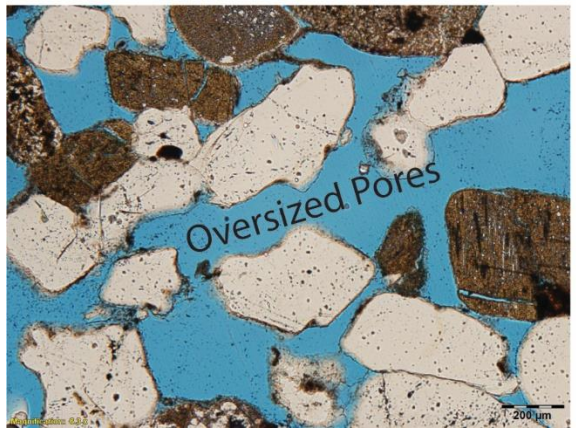


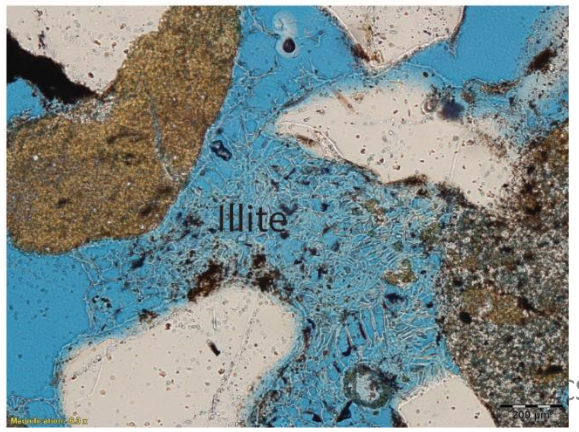
Depth trends not apparent in Lower Mt Simon







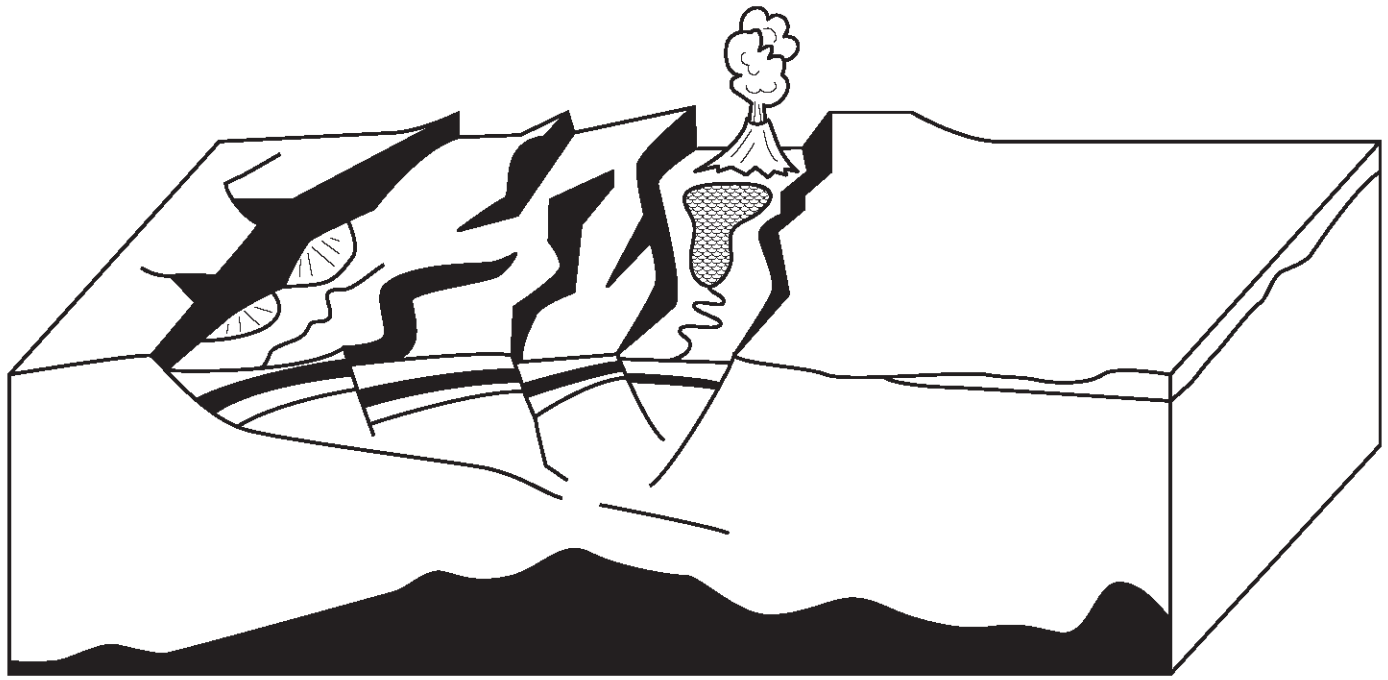




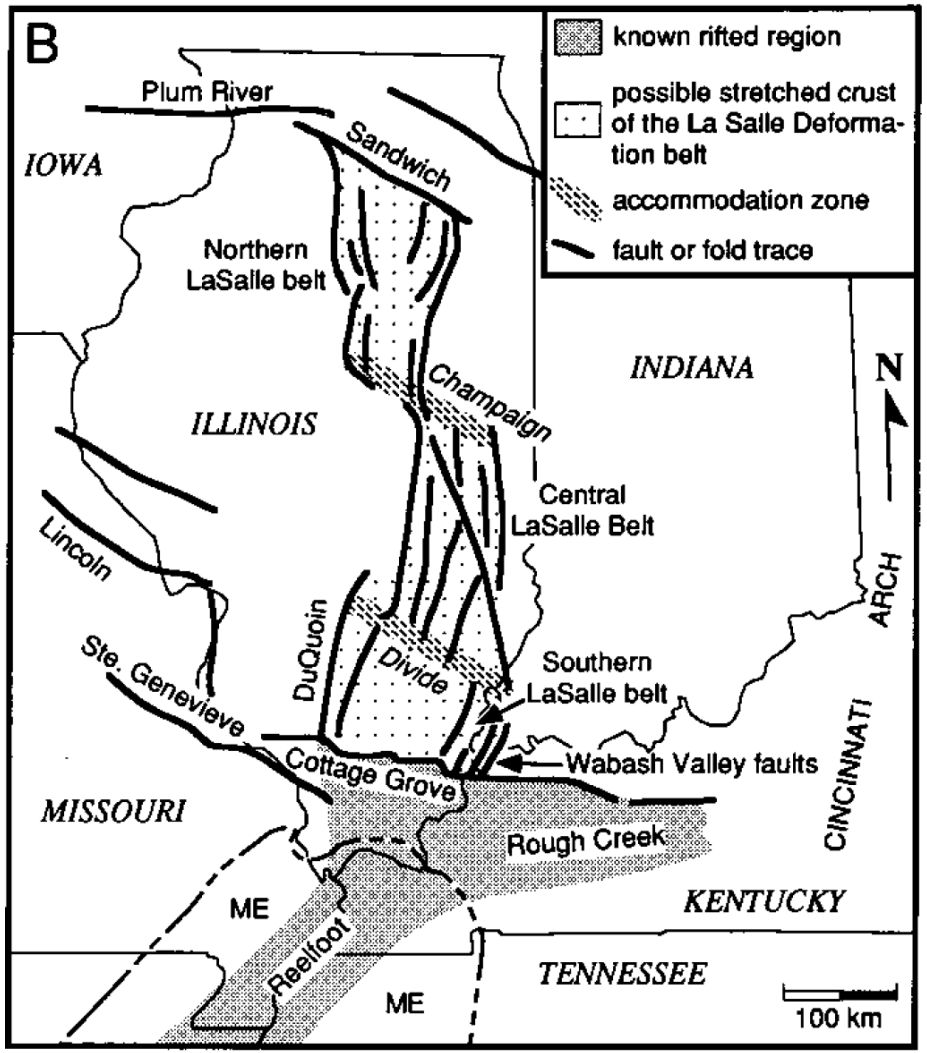
What makes the Lower Mt. Simon such a good reservoir?

- Detrital Source
- Depositional Environment
- Diagenesis

Rifting in Central Illinois

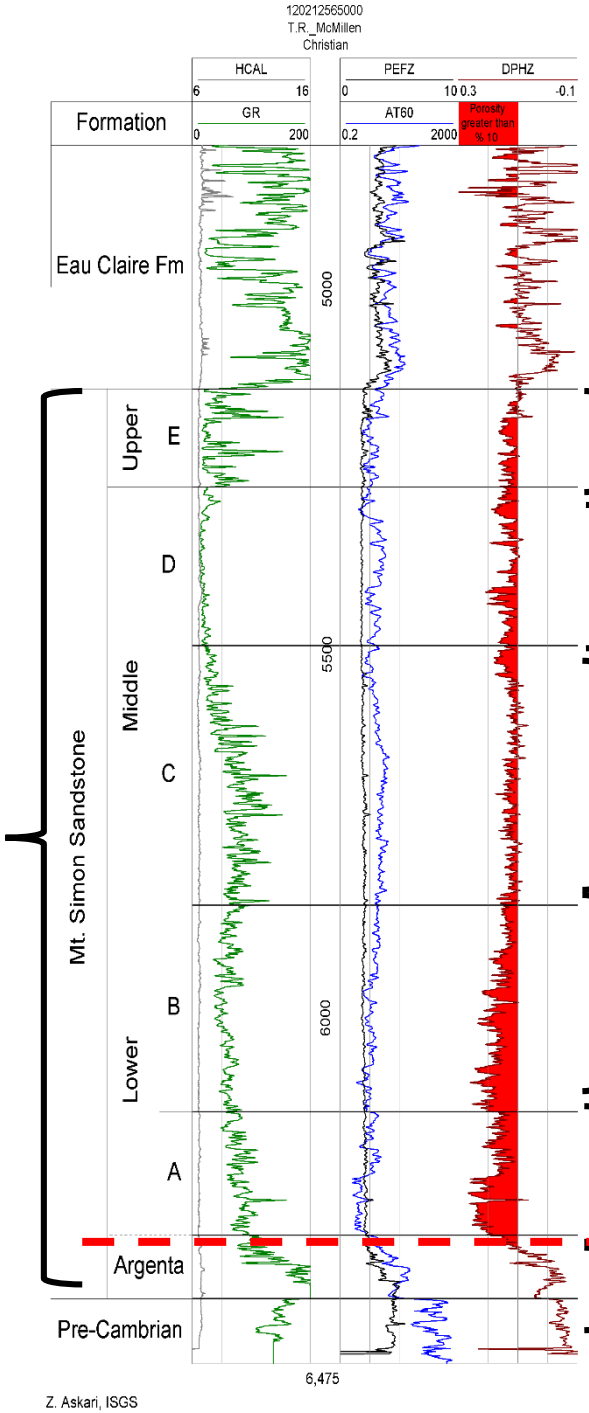


Modified from: Renaut & Ashley 2002



Marshak & Paulsen 1996

T.R. McMillen #2
Mt. Simon Sandstone



Dominant Depositional Environment

Tidal Flat

Aeolian

Fluvial

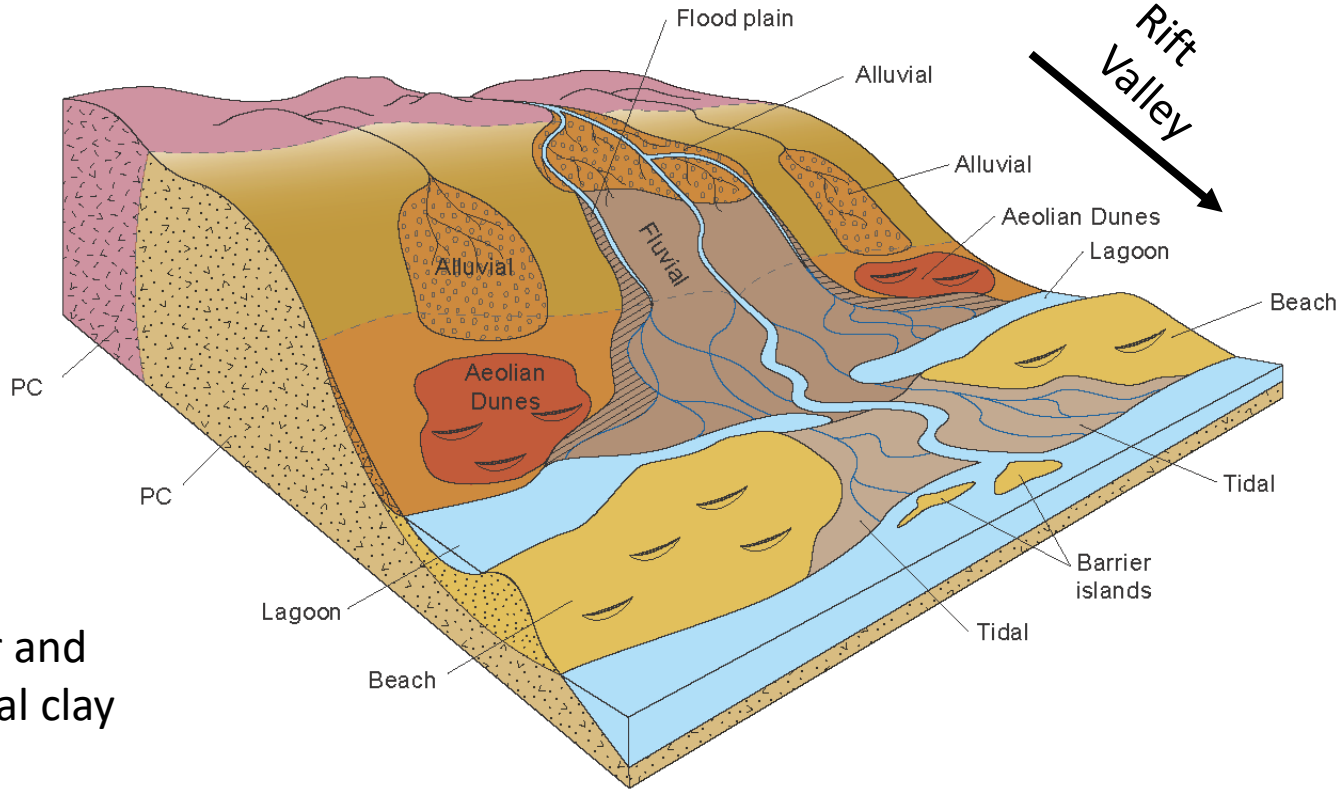
Aeolian

Fluvial/ Alluvial

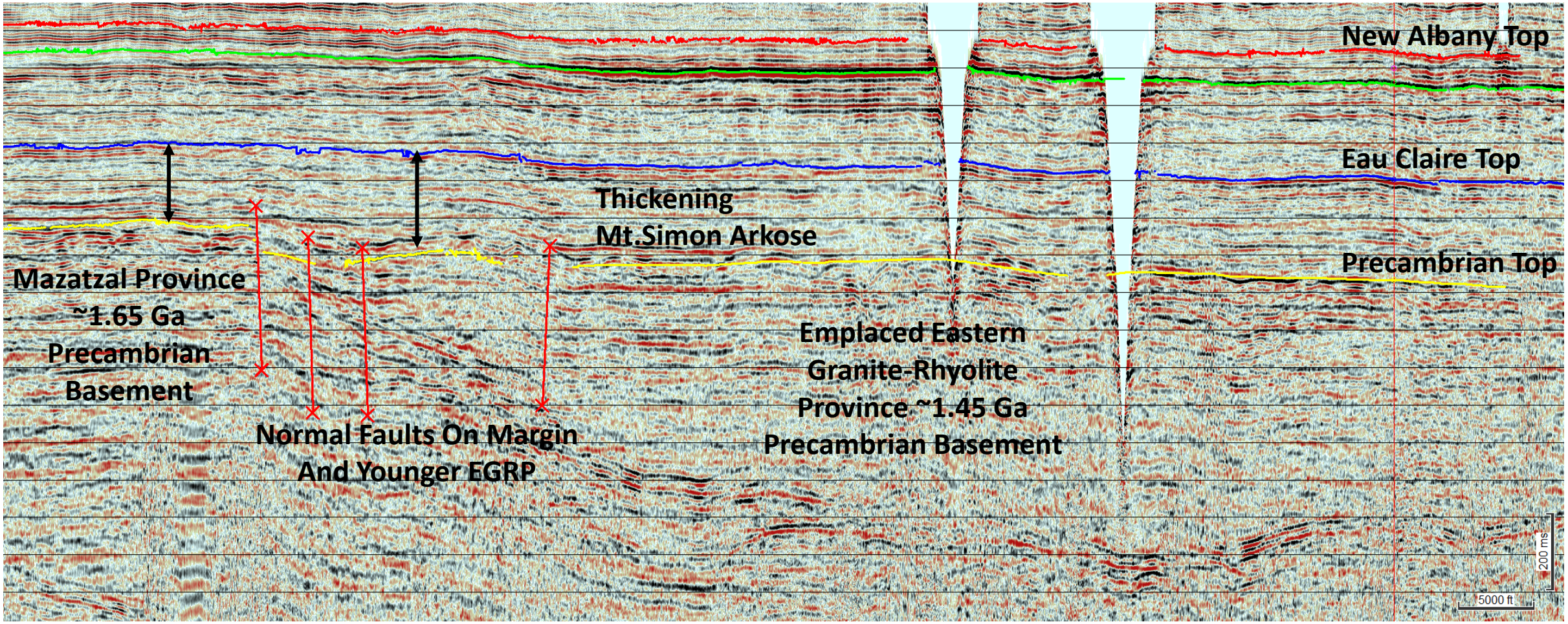
Feldspar and terrestrial clay coatings sourced from Precambrian highs

Unconformity

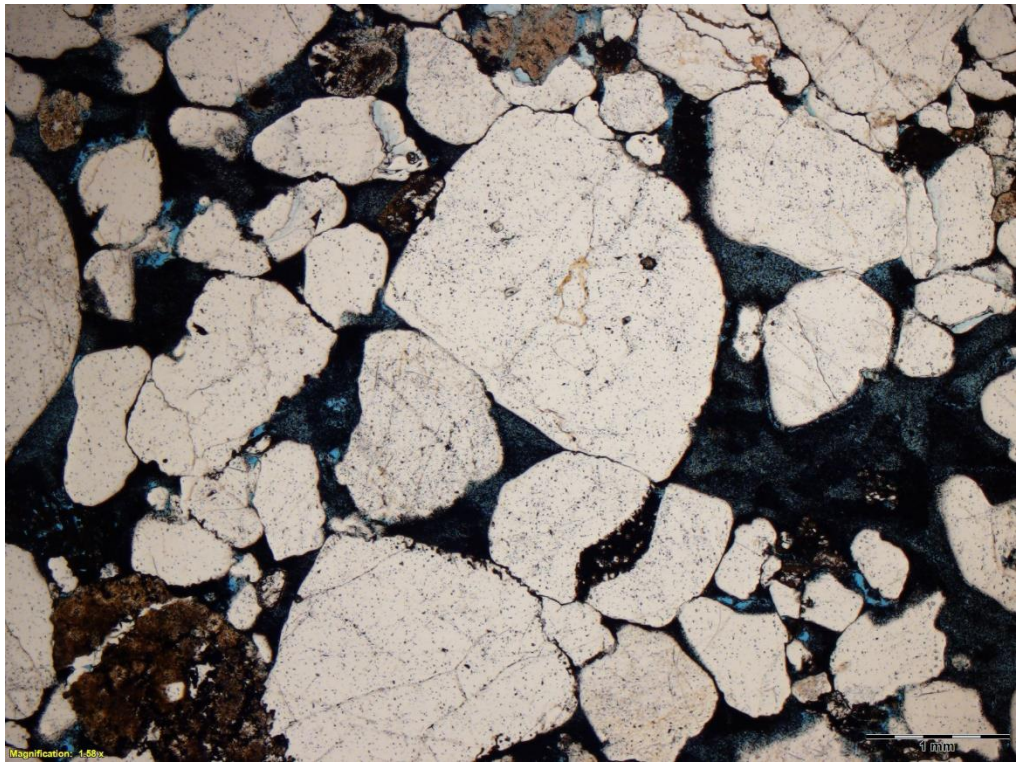
Rift Fan Delta



Crustal thinning, faulting, and development of localized depocenters during rifting. Precambrian highs are a local source of arkose.

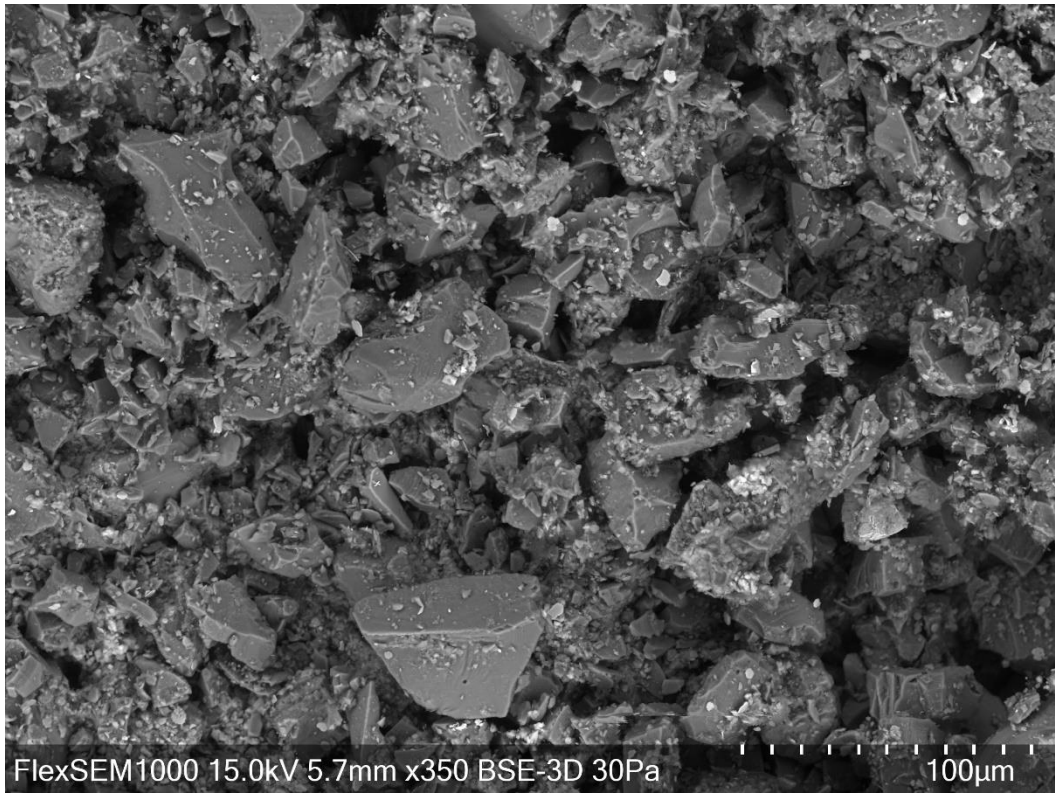


Rift Fan Delta Sediments (Argenta)

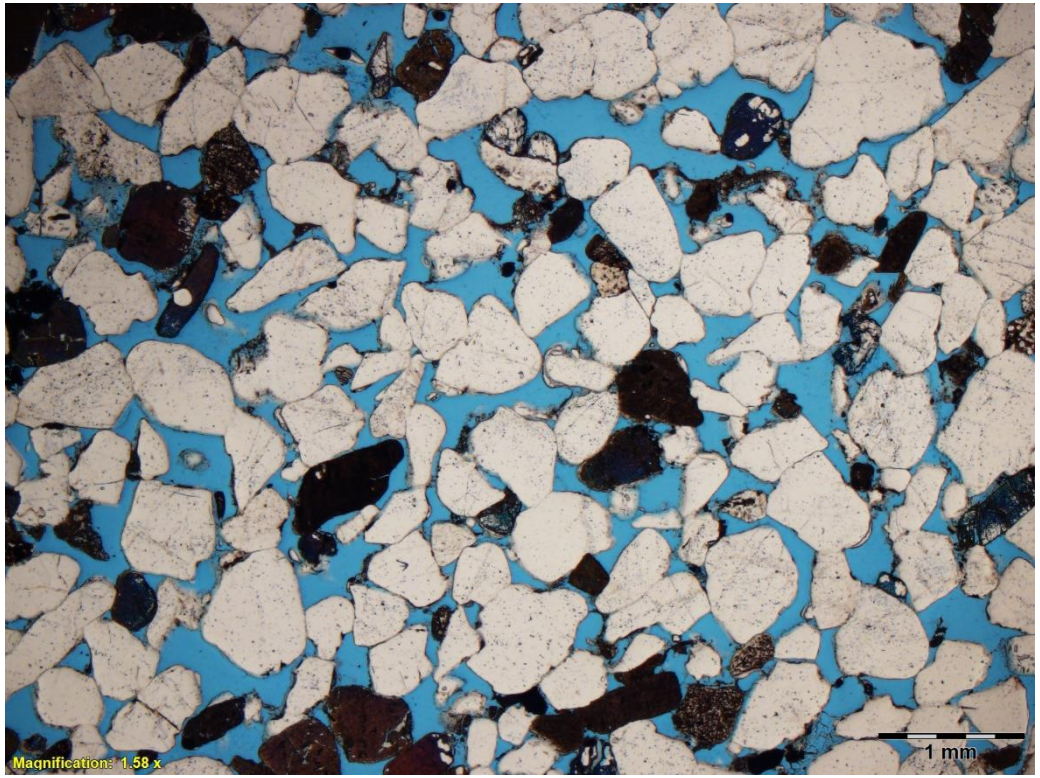


Poorly sorted grains with abundant pore filling clay

Highly angular immature detritus

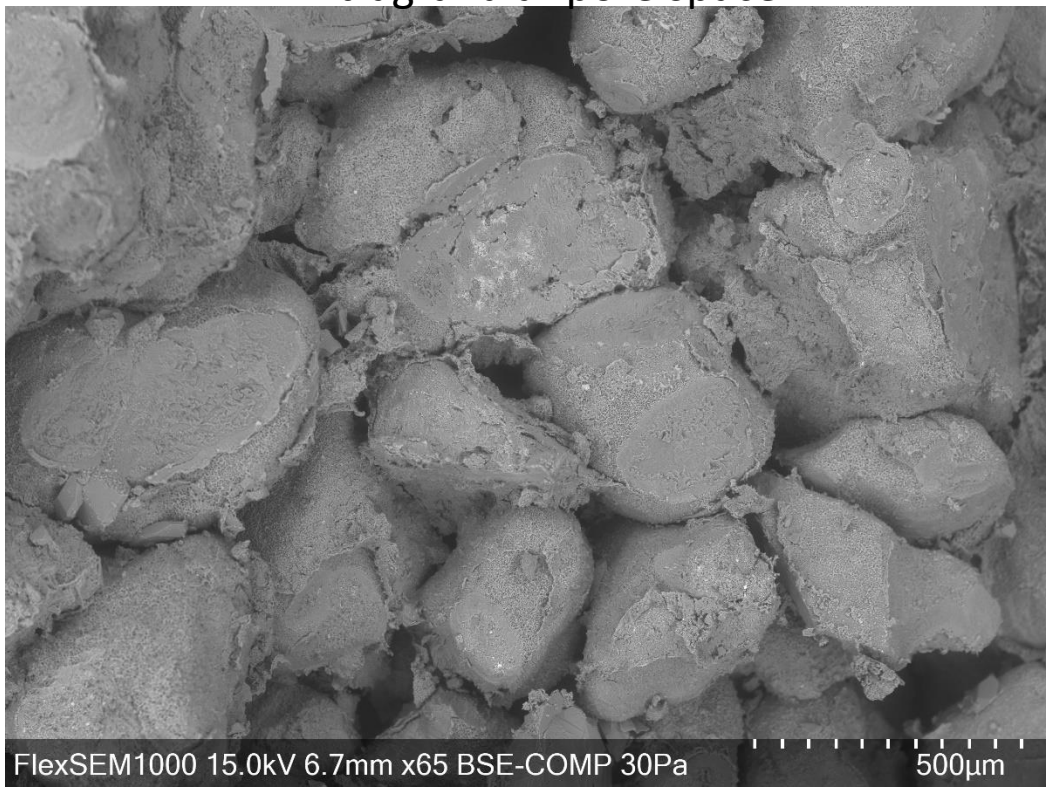


(Post-Rift) Alluvial-Fluvial-Eolian Near-shore (Lower Mt. Simon)

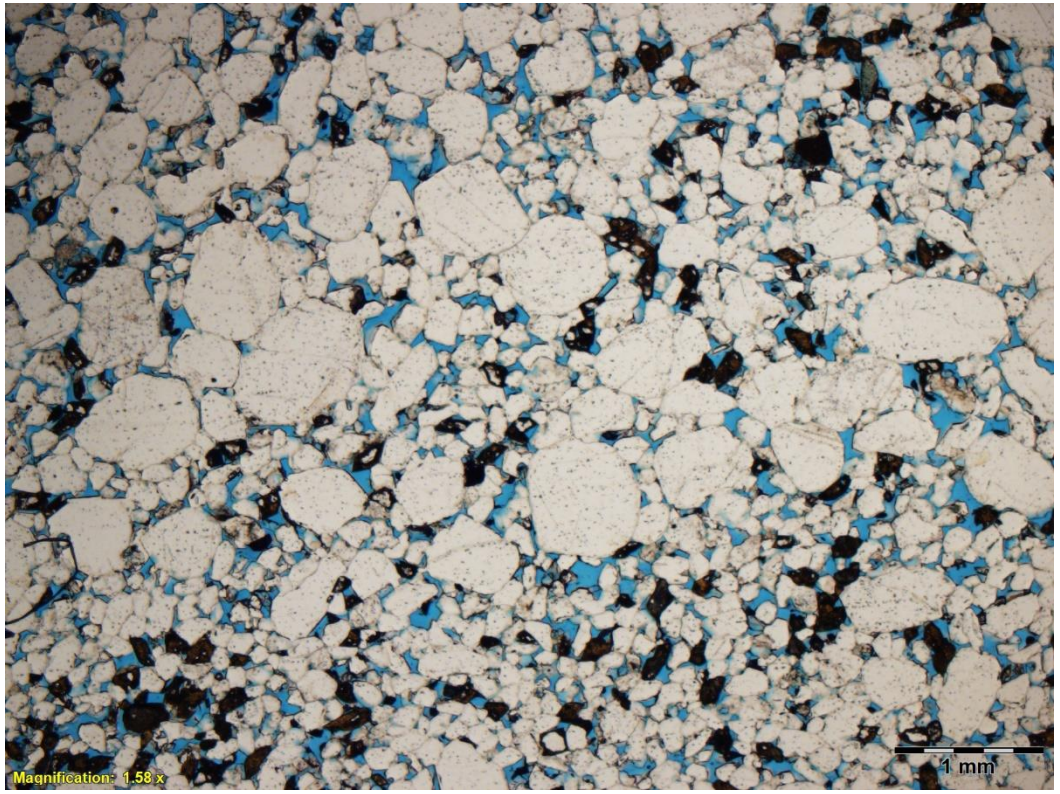


Moderately well sorted grains with open enlarged pores

Well rounded grains with abundant intragranular pore space

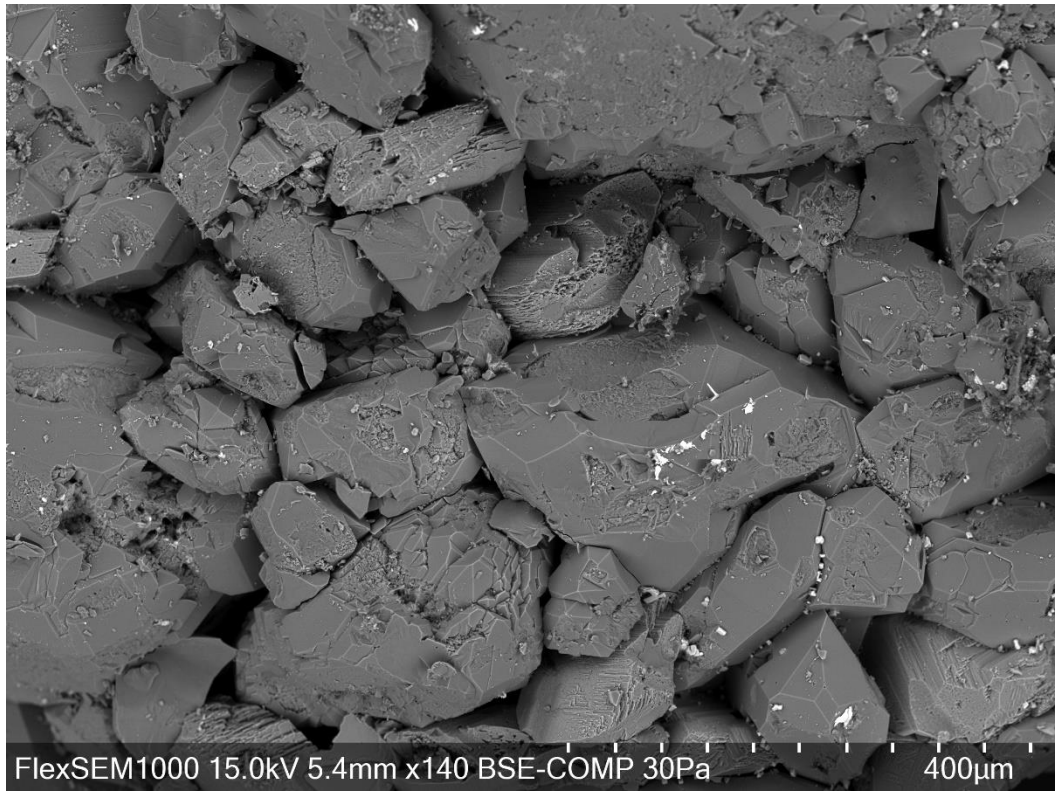


Tidal (Upper Mt. Simon)



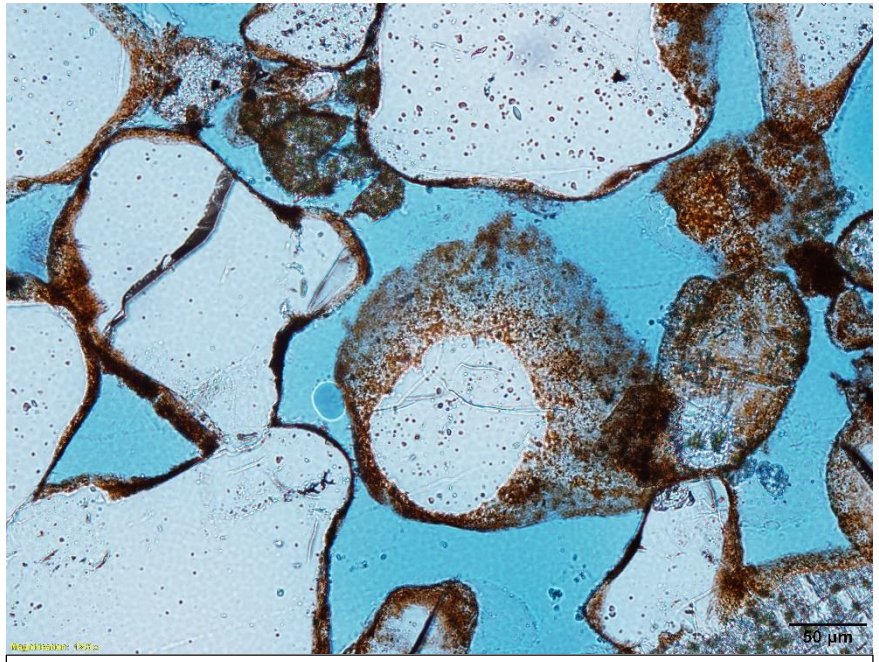
Bimodal, mature grains. Pores are generally small due to fine grains and/or abundant quartz/feldspar cement

All grains (including feldspars) have authigenic cement overgrowths

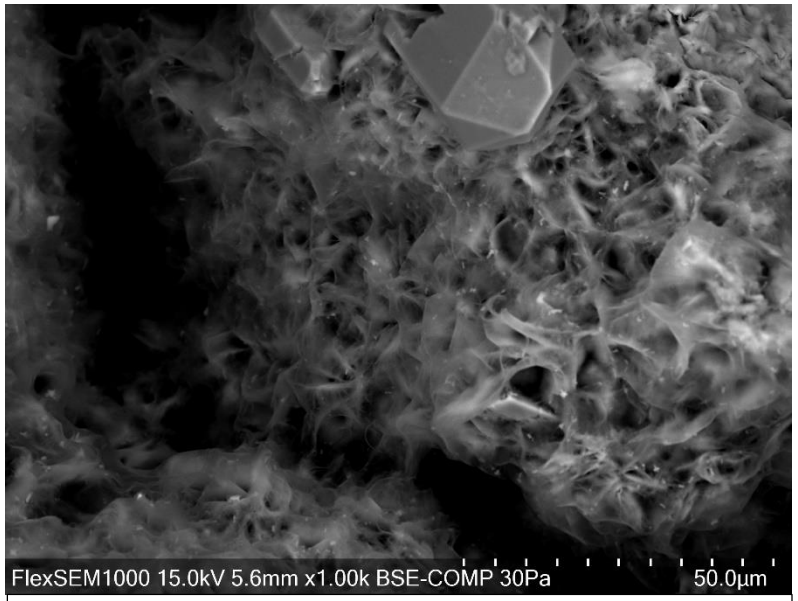


Diagenesis of the Mt. Simon and Pore Space Paragenesis

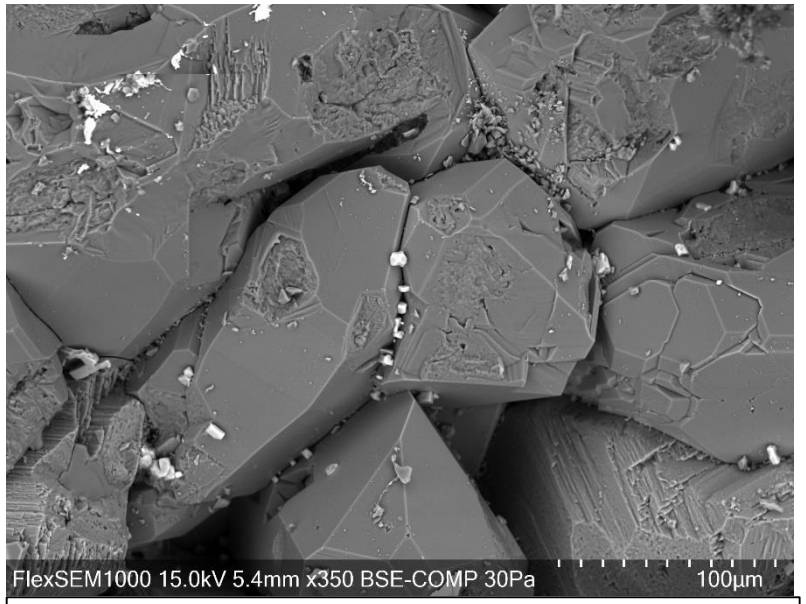
Most grains have early clay coatings



Clay coatings prevent the nucleation of major authigenic quartz overgrowths



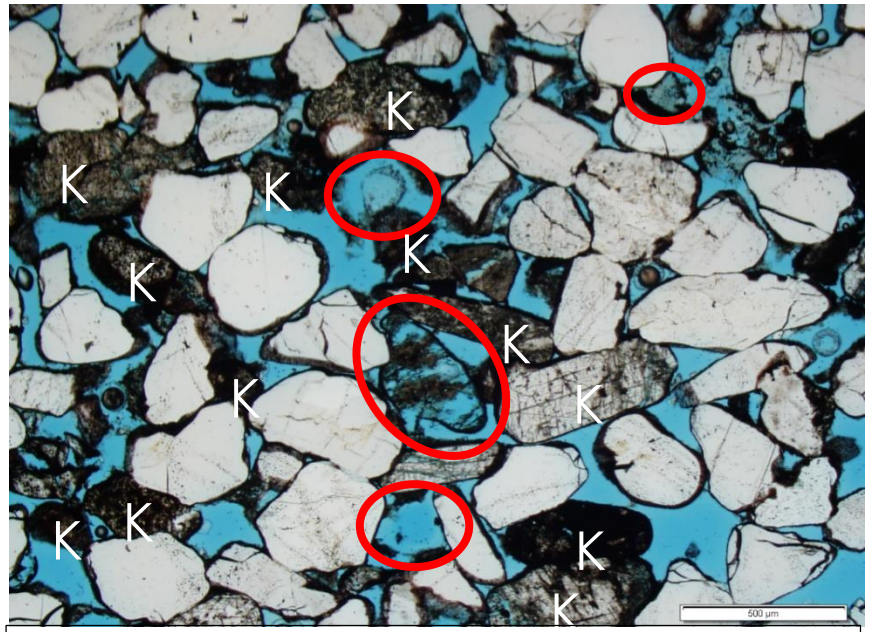
Grains coated in illite. Illite is webby and nucleation points on quartz grains are small. Thus authigenic quartz crystals are small but act as a cement to prevent extensive compaction preserving primary porosity.



When clay coating are absent, entire surface of quartz grains acts as nucleation point and large quartz overgrowths nucleate and close up pore space

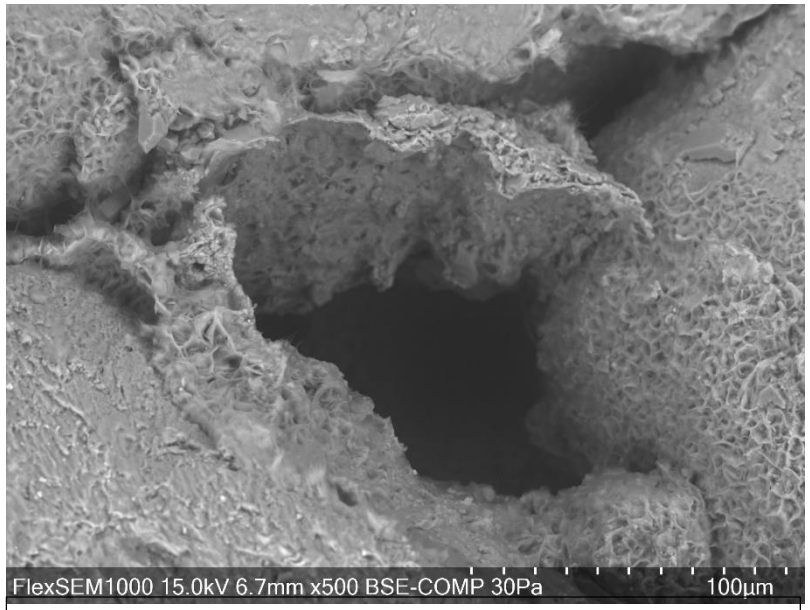
Diagenesis of the Mt. Simon and Pore Space Paragenesis

Another major contributor to porosity in the Mt. Simon is secondary porosity



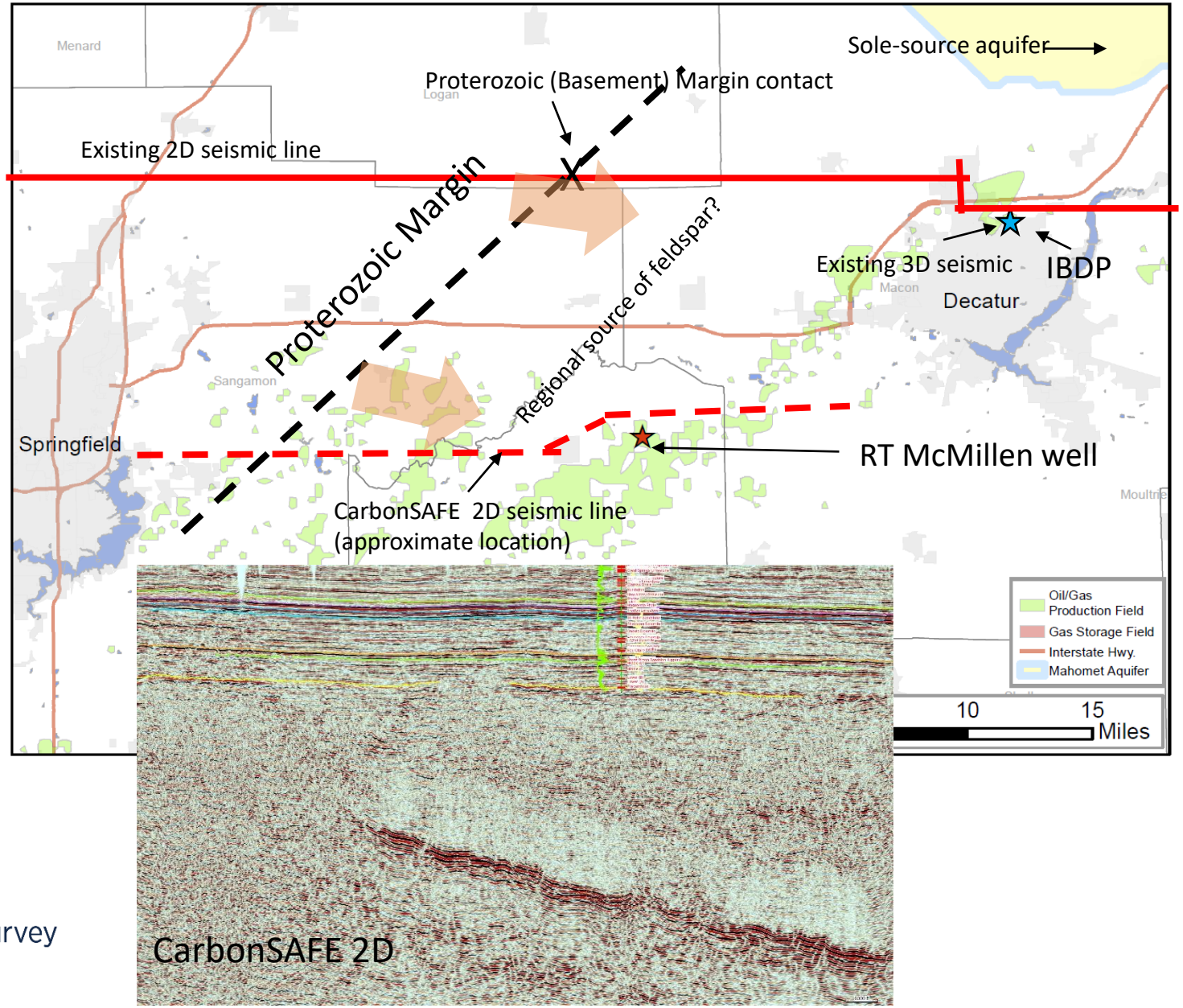
Feldspar dissolution is a late stage event and Is a major contributor to porosity

Partial dissolution of feldspar



Complete dissolution of feldspar with clay cast and large secondary pore

Geological Controls over Storage Complex Distribution



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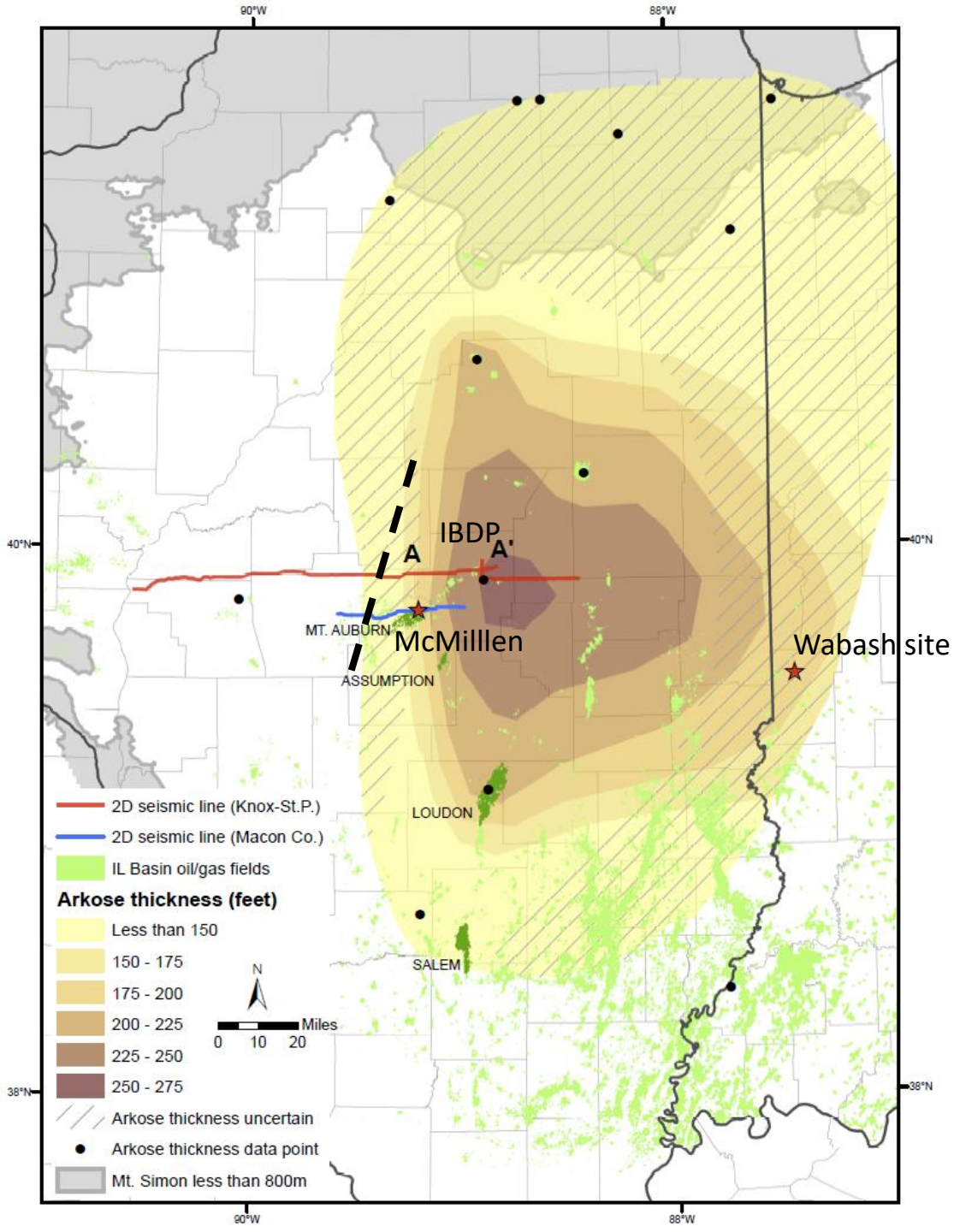
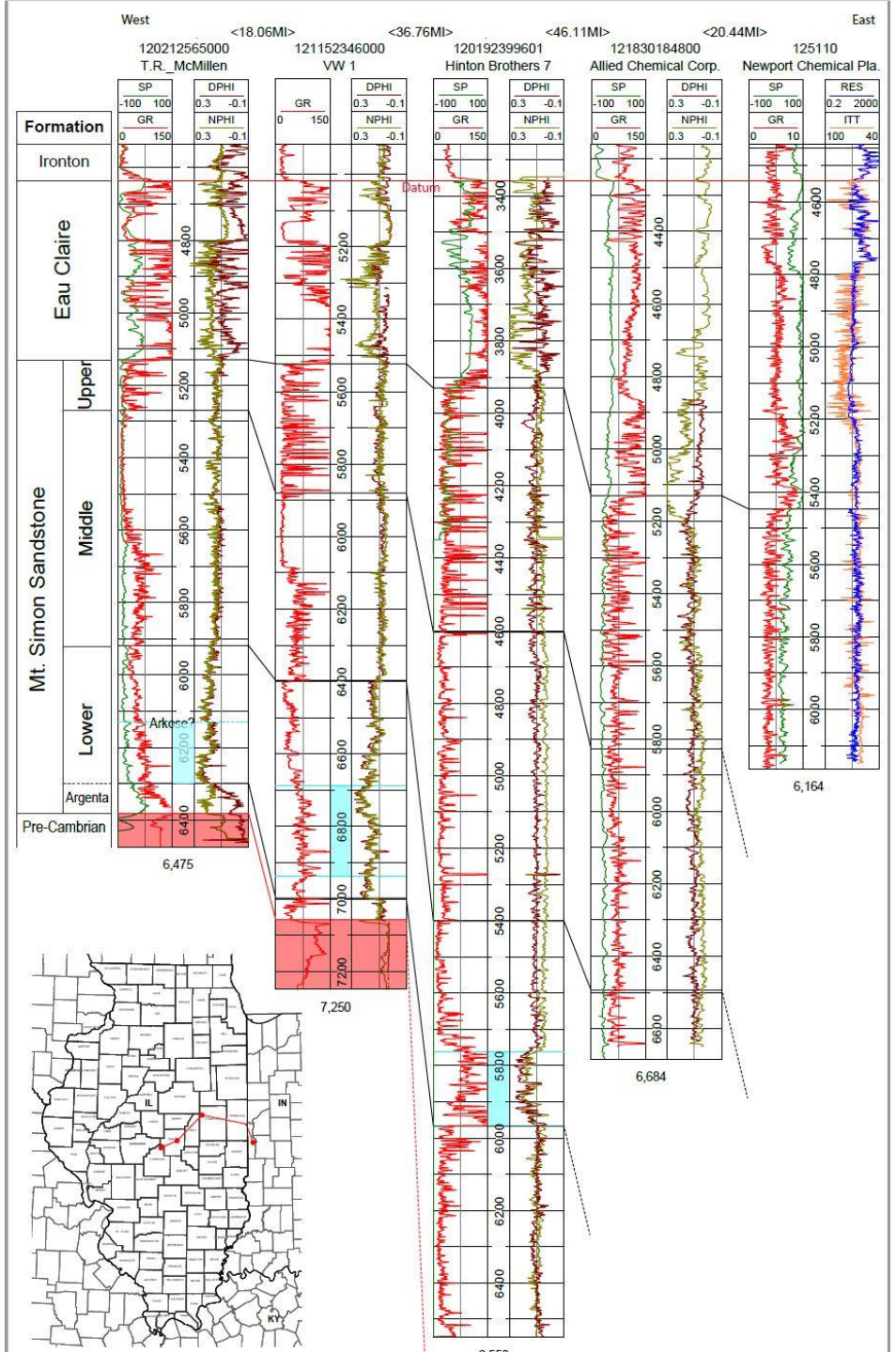

90°W
88°W
40°N
38°N
A
A'
IBDP
MT. AUBURN
McMilllen
ASSUMPTION
LOUDON
SALEM
Wabash site
2D seismic line (Knox-St.P.)
2D seismic line (Macon Co.)
IL Basin oil/gas fields
Arkose thickness (feet)
Less than 150
150 - 175
175 - 200
200 - 225
225 - 250
250 - 275
Arkose thickness uncertain
Arkose thickness data point
Mt. Simon less than 800m
N
Miles
0 10 20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East
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VW 1
120192399601
Hinton Brothers 7
121830184800
Allied Chemical Corp.
125110
Newport Chemical Pla.
Formation
Ironton
Eau Claire
Mt. Simon Sandstone
Upper
Middle
Lower
Argenta
Pre-Cambrian
Arkose?
Datum
6,475
7,250
6,684
6,164
IL
IN
KY

Section 45Q Tax Credit for Carbon Capture Projects

25,000-500,000 metric tons of CO_2/CO	At least 100,000 metric tons of CO_2/CO	At least 500,000 metric tons of CO_2/CO
Beneficial use projects other than enhanced oil recovery (EOR) projects.	All other industrial facilities (other than electric generating units), including direct air capture.	Electric generating units.

Timing: Eligible projects that begin construction within six years of the enactment of the FUTURE Act (i.e., before January 1, 2024) can claim the credit for up to 12 years after being placed in service.

Type of carbon: The type of carbon that can be captured includes all carbon oxides, including CO_2 or CO.

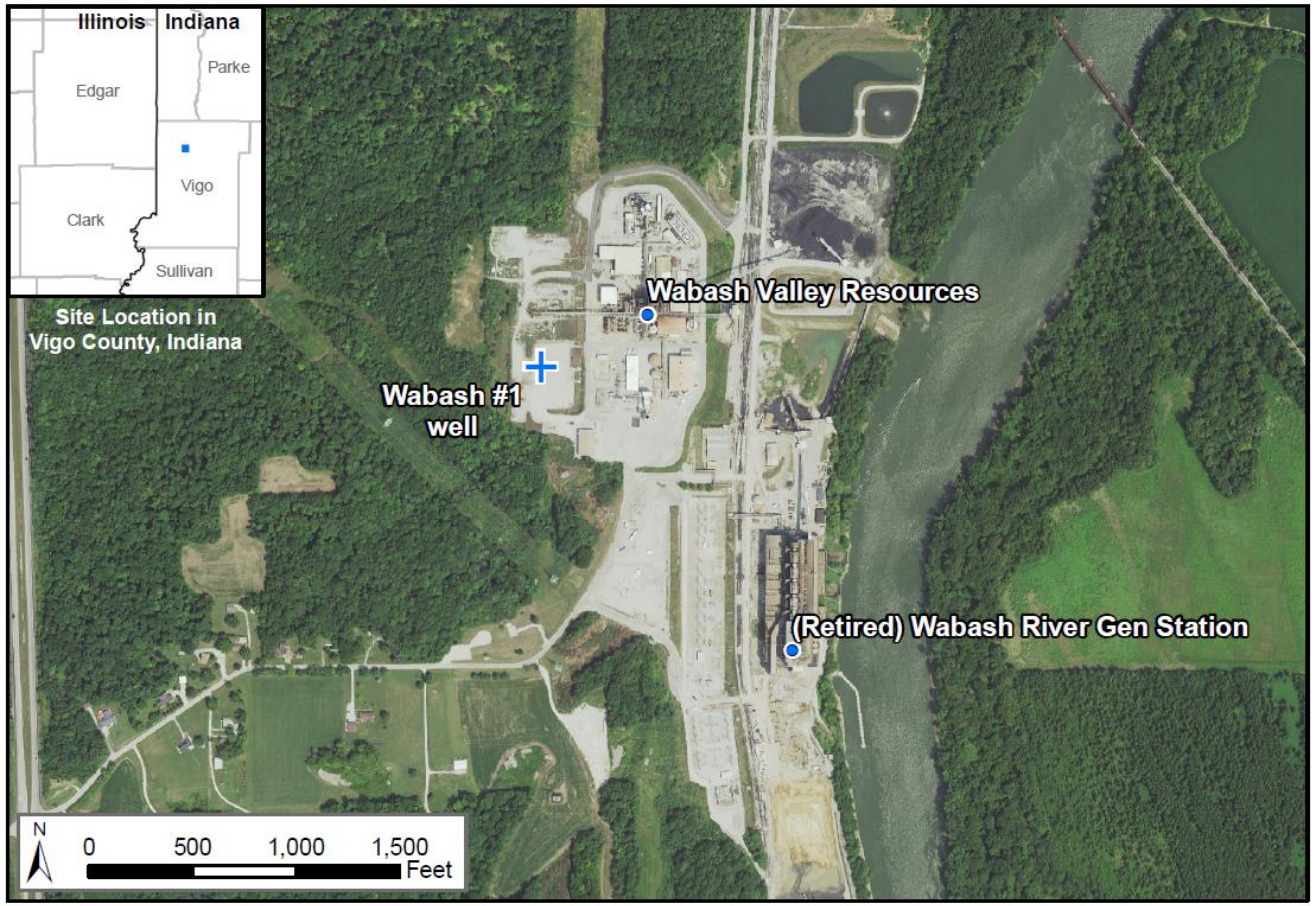
45Q Tax Credit Amount: Depends on Project Type

There is a 10-year ramp up to the following dollar per ton amounts, with the value depending on project type.

$35/ton	$35/ton	$50/ton
for CO_2 stored geologically through EOR.	for other beneficial use of CO_2 or CO such as converting carbon emissions into fuels, chemicals, or useful products like cement.	for CO_2 stored in other geologic formations and not used in EOR.

Phase II: CO_2 Source and Storage Site

Wabash Valley Resources (WVR; formerly Quasar Syngas)



- IGCC Unit 1A (DOE 1993-1995)
- WVR purchased plant May 2016 for ammonia production from petcoke. Petcoke -> Syngas -> H_2 -> Ammonia + CO_2
- Target 2023 commercial operation
- WVR business model: change plant design to maximize CO_2 recovery for storage or EOR sale (45Q credits)
  - 65% -> 98% CO_2 recovery
- >95% pure stream CO_2 @ 1.65 million tonnes/yr
- Mt Simon Storage Complex

2D Seismic

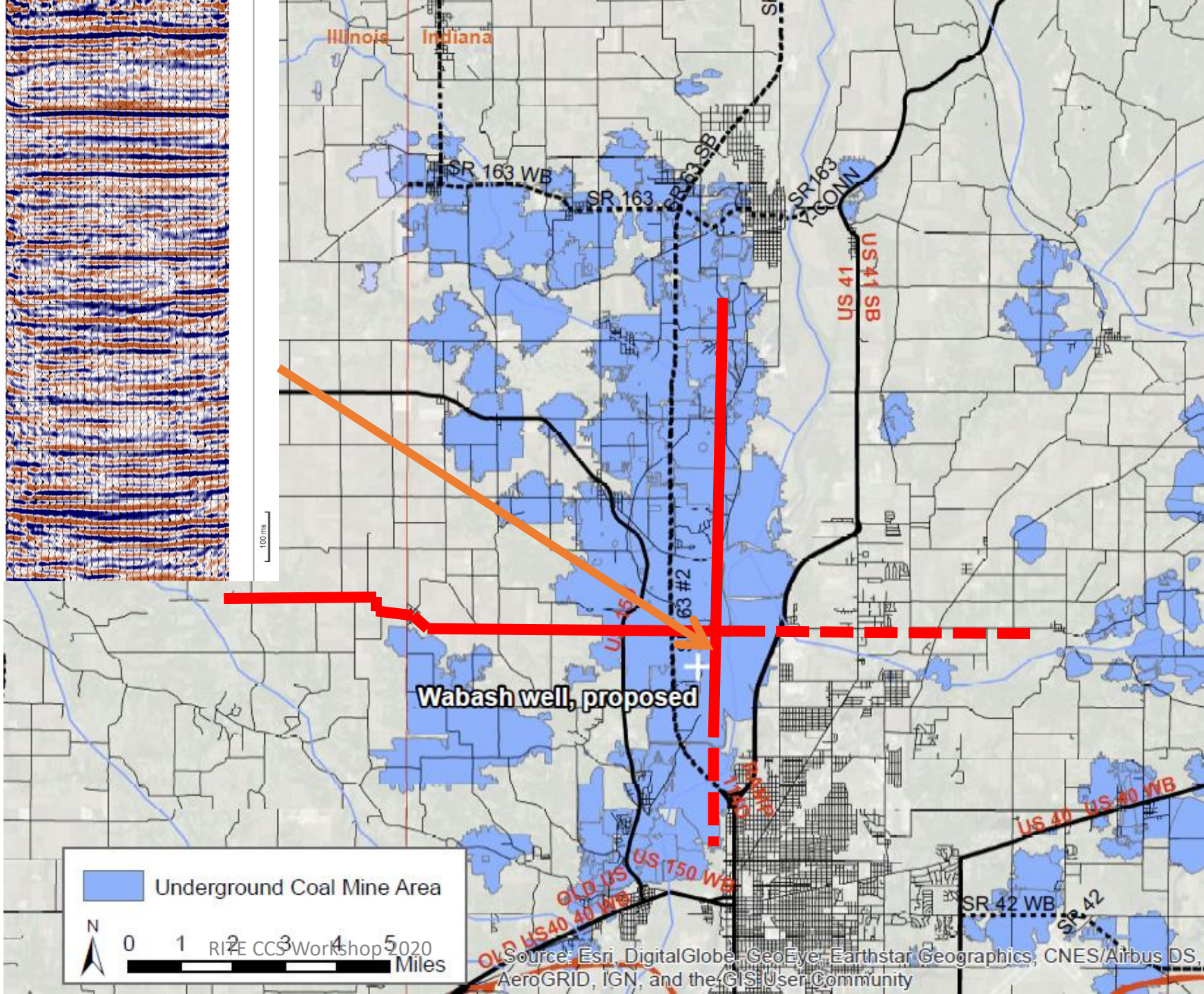
Coal mines in region

Have acquired 1 mile test line

Starting permitting process to define lines

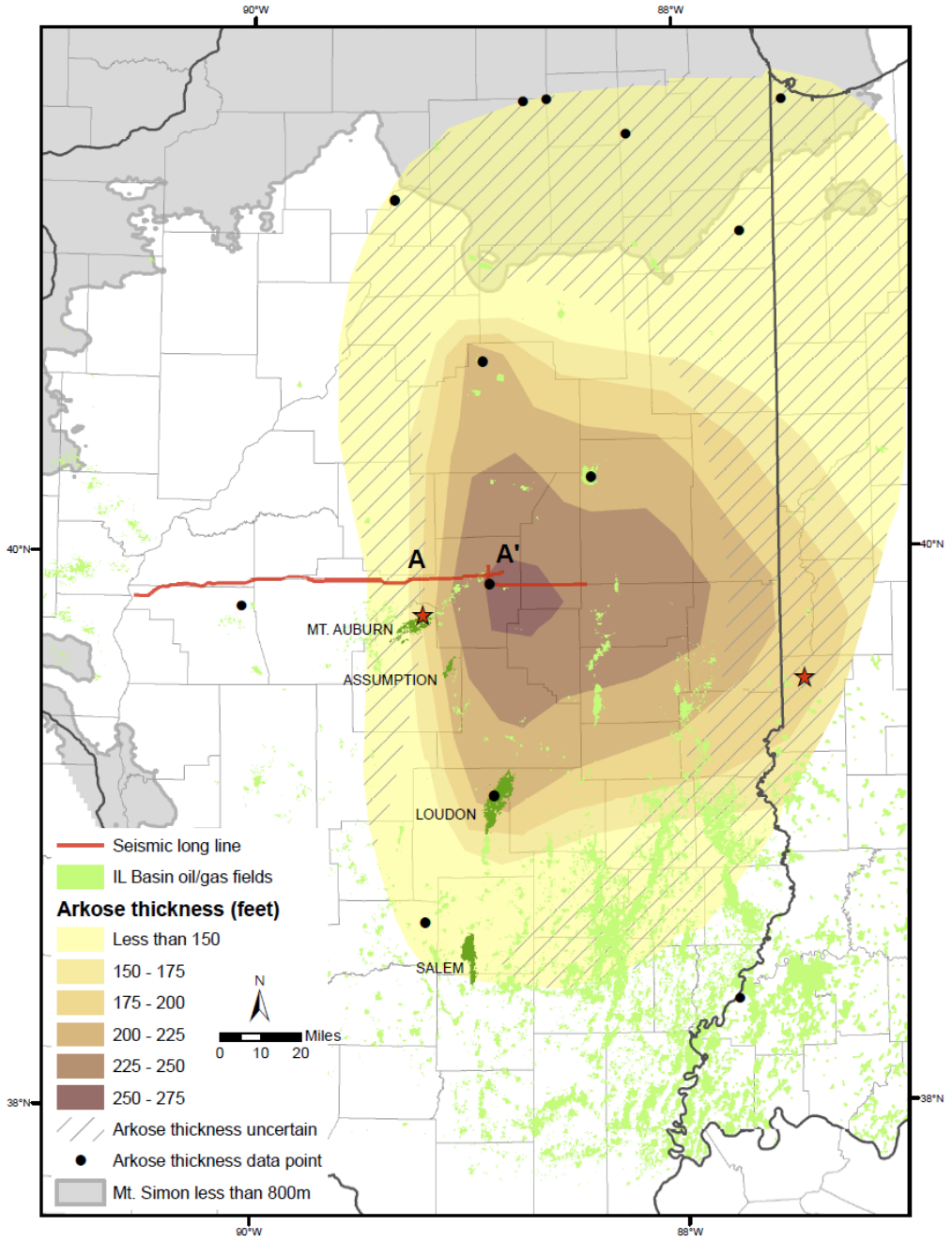
Characterize Mt Simon and Precambrian surface

Will provide data to help determine monitoring (time lapse) potential



Wabash Characterization Well

- Drill to ~8,300-8,500 ft
- Whole Core
  - Eau Claire – Upper Mt. Simon
  - Lower Mt. Simon
- Sidewall Cores
- Evaluation
  - Triple Combo
  - Formation Images
  - Full Sonic
  - Elemental Spectroscopy
  - Magnetic Resonance
- Cased Hole Testing
  - VSP
  - Fluid Sampling
  - Step Rate Tests
  - Pressure Falloff
  - EWT
- Drill into Precambrian for basement characterization



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CarbonSAFE Illinois – CO_2 Sources

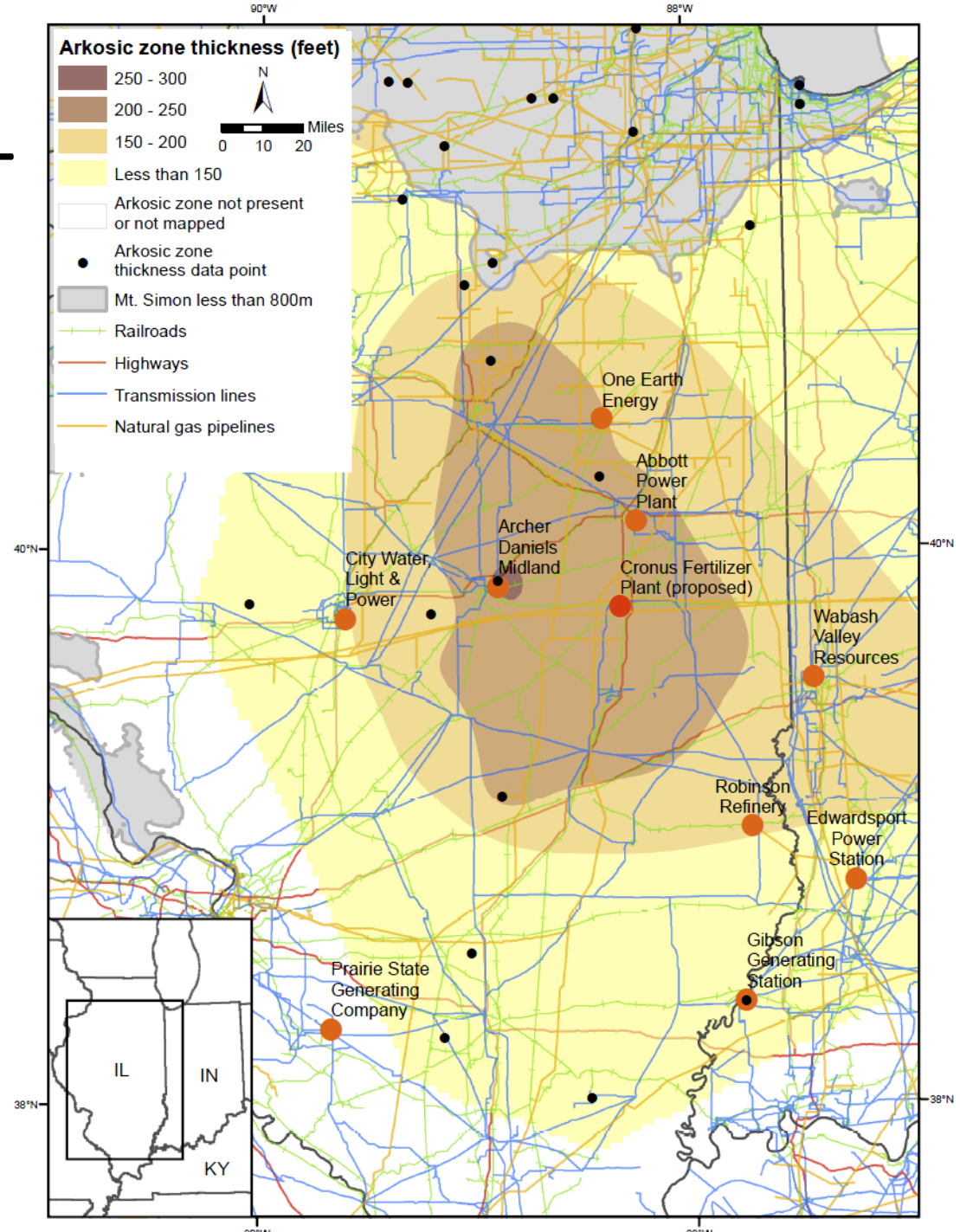
10's of MT/y CO_2

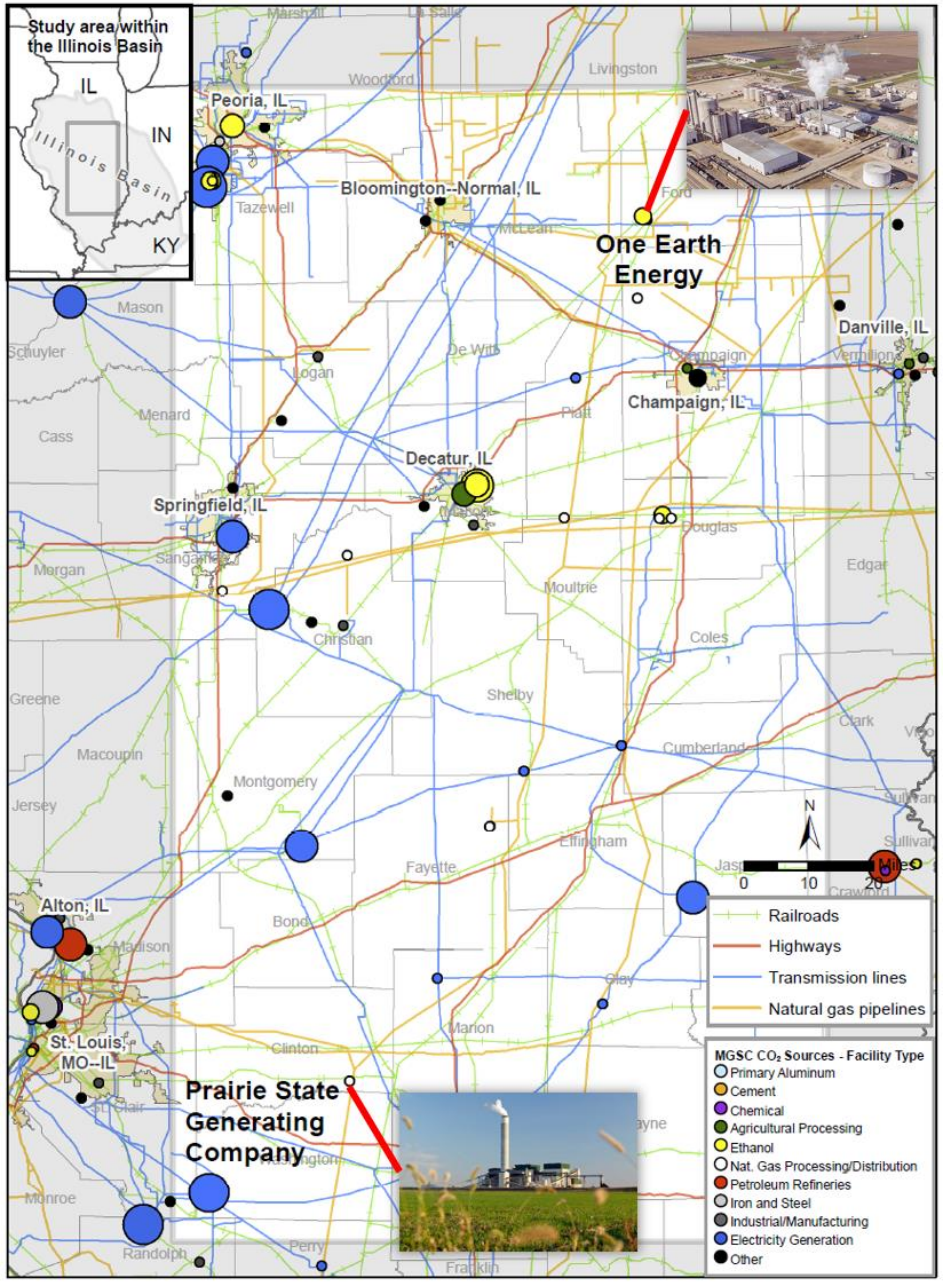
Variety of industries

Existing infrastructure

Increased interest in storage

Opportunity to greatly improve commercialization decisions by defining storage resource





Illinois Storage Corridor CarbonSAFE Phase 3

Excellent and proven storage characteristics

Multiple Industries and Multiple Sources of CO_2

One Earth Energy – Storage HUB

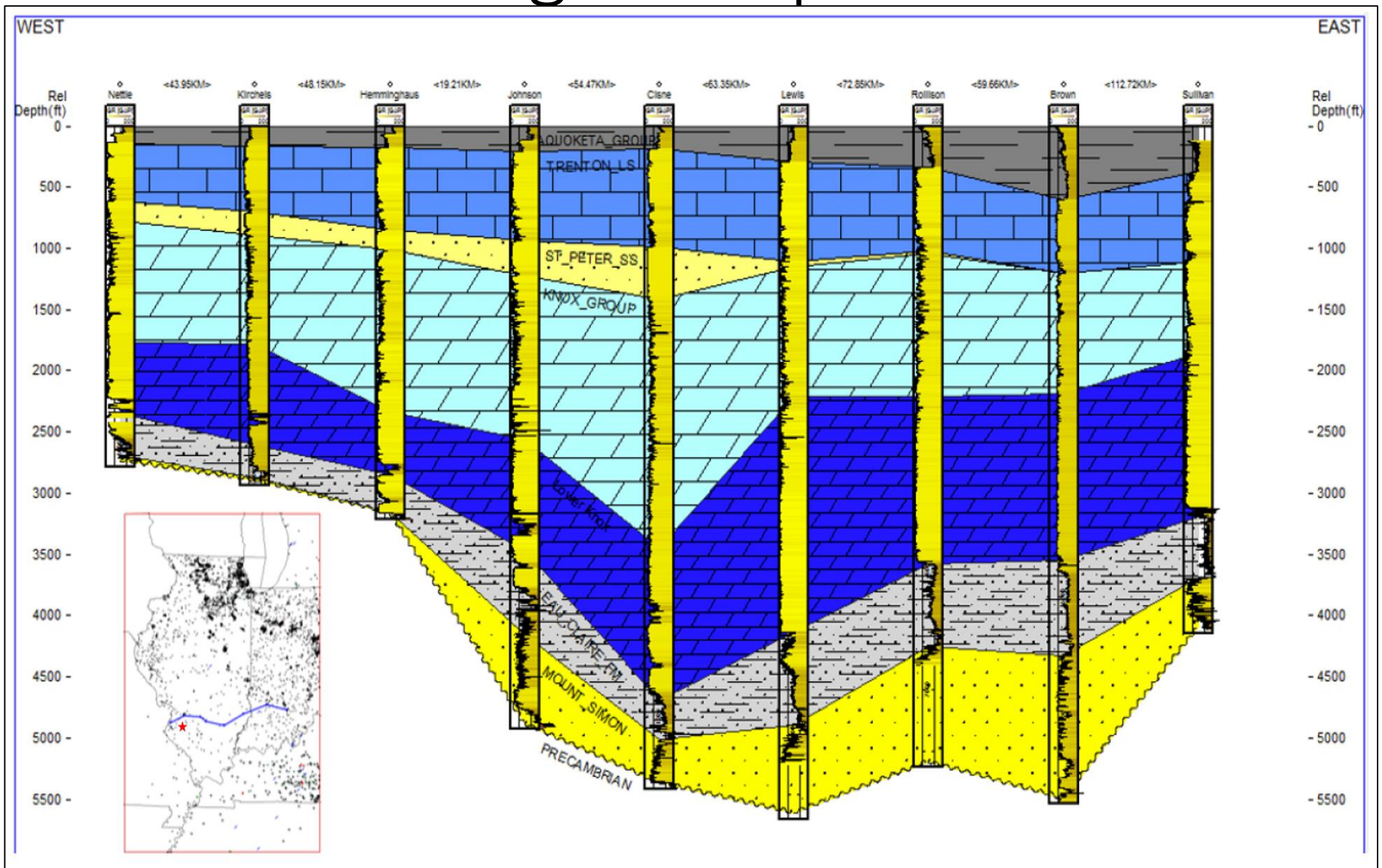
One Earth Energy – ethanol plant
Mt Simon Storage Complex – Storage HUB (0.5 to 1.7 MTPA CO_2)
Storage at site location

Prairie State Generating Company

- The Prairie State Energy Campus includes a 1600 MW coal-fired generating plant and adjacent coal mine.
- Commercial operations began in June of 2012 for Unit 1, and November of 2012 for Unit 2.
- More than $1 billion invested in environmental emissions controls and supercritical technologies.
- Prairie State's power plant is among cleanest plants in the nation.
- CO_2 emissions >12MTPA

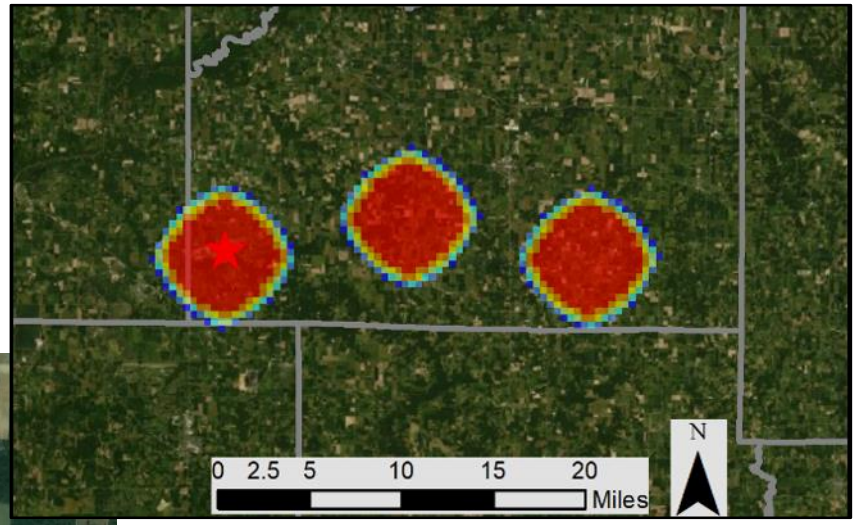
St Peter Storage Complex

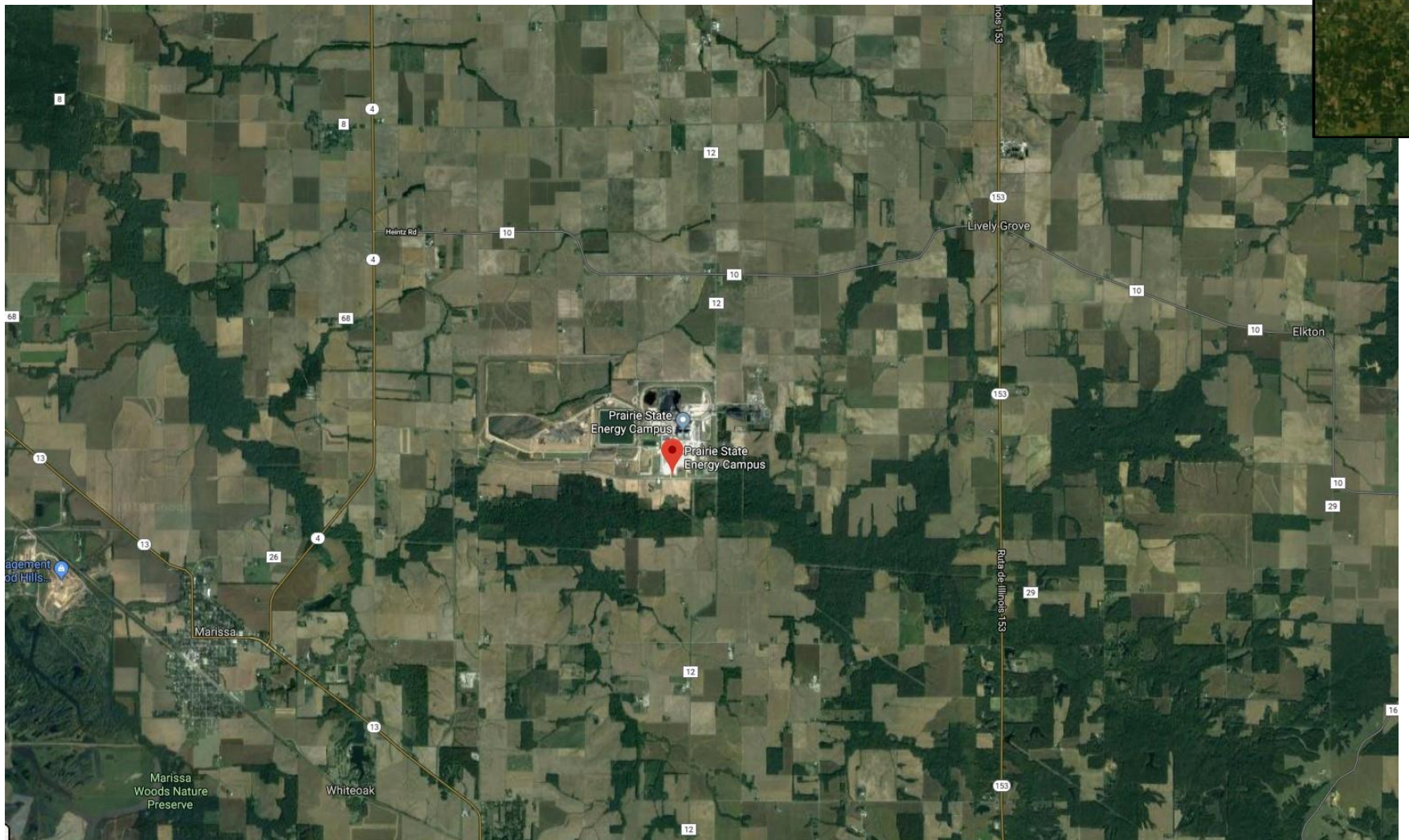
St Peter Storage Complex



- St Peter Sandstone
- 12% - 19% porosity
- 10md - 1000md (150 – 400md ave)
- Maquoketa Shale Seal
- Trenton LS barriers

Prairie State Storage Site





- Unit #2 816 Mwe
- Misubishi KM CDR Process™ CO_2
- 6MTPA CO_2
- Modular Trains

Summary

- Regional conceptual model for Mt Simon Storage Complex - target “arkosic” zone
- St Peter Storage Complex also feasbile in Illinois Basin
- Analyses suggests sites can easily accommodate > 50 Mt CO_2 over 30 years
- Industry interest in USA is high (due to 45Q) and multiple sources can exploit the Mt Simon and St Peter storage complexes in central Illinois
- Phase III CarbonSAFE to drive commercialization of sites
  - One Earth Energy
  - Prairie State Generating Company

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