# Carbon Storage in the Mt. Simon Sandstone: Field Examples of Regional Deployment

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SPE CCUS Webinar
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# Speaker

## Dr. Sallie Greenberg

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## Carbon Storage

- What is it?
- Where can we do it?
- How much can we do?
- How do we do it?
- Is it safe?

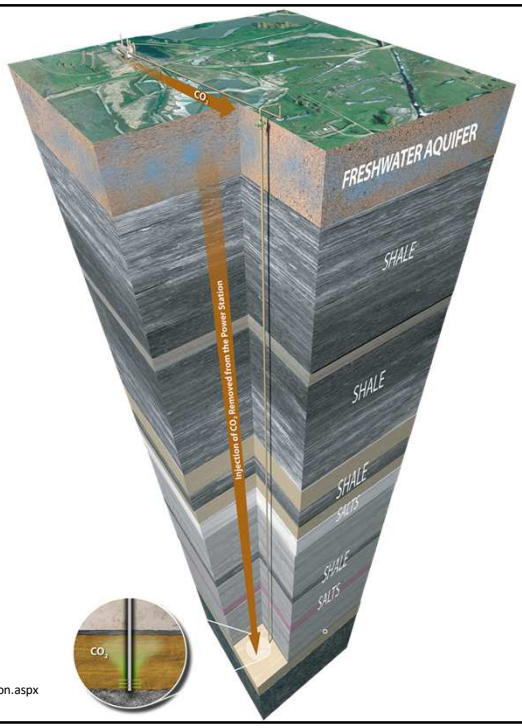



Image from: https://undeerc.org/pcor/Sequestration/WhatIsSequestration.aspx

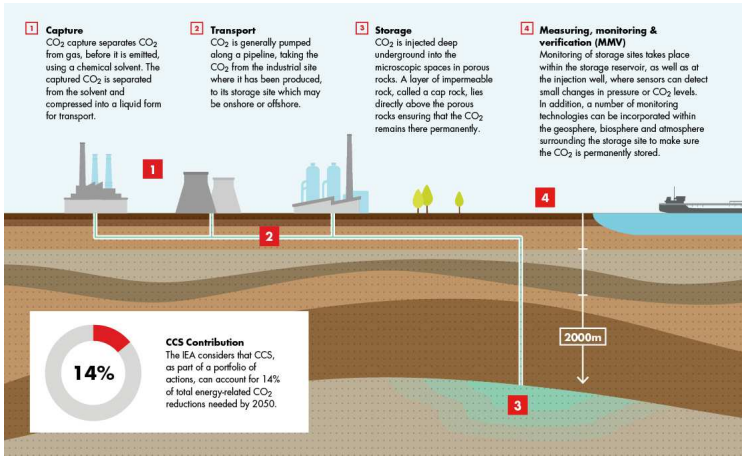
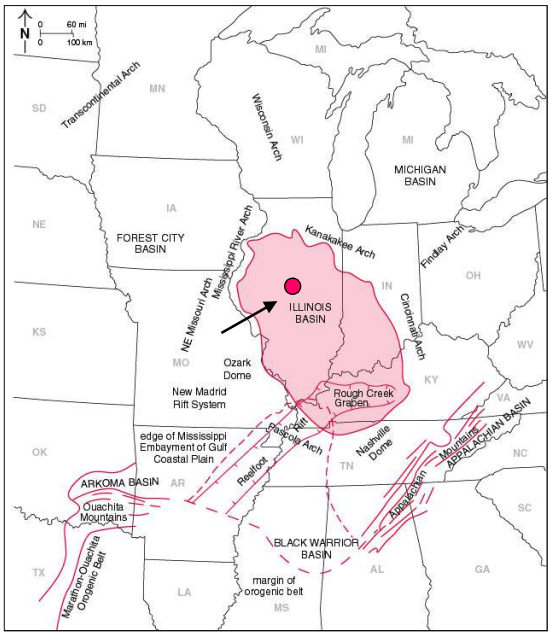



Image from: https://reports.shell.com/sustainability-report/2016/energy-transition/our-work-to-address-climate-change/carbon-capture-and-storage.html

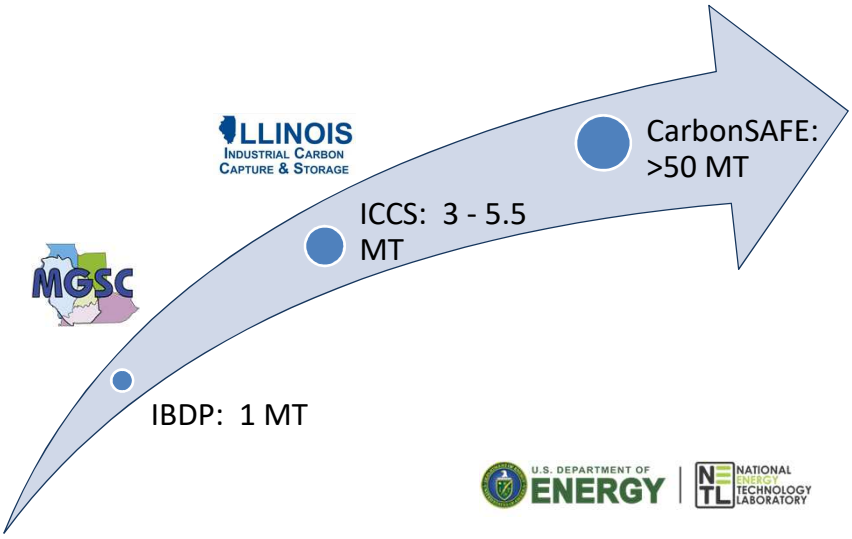
## Carbon Storage in the Illinois Basin



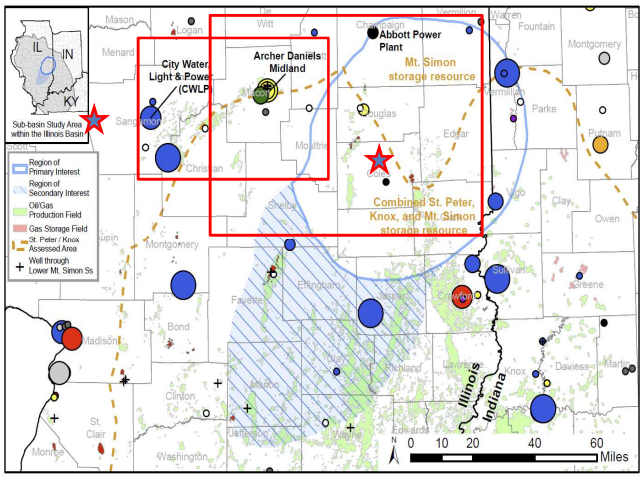

A collaboration of the Midwest Geological Sequestration Consortium, the Archer Daniels Midland Company (ADM), Schlumberger Carbon Services, Trimeric, and other subcontractors to inject 1 million metric tons of anthropogenic carbon dioxide at a depth of ~2,100 m to test geological carbon sequestration in a saline reservoir at a site in Decatur, IL

- Prove injectivity and capacity
- Demonstrate security of injection zone
- Contribution to best practices

## Illinois Basin Industrial CCS Progression




## Carbon Capture and Storage Projects in the Illinois Basin



## Current CCUS Projects in Decatur, IL USA

### Illinois Basin – Decatur Project

- Large-scale demonstration
- Volume: 1 million tonnes
- Injection period: 3 years
- Injection rate: 1,000 tonnes/d
- Compression capacity: 1,100 tonnes/day

Contribution:

- Geologic and Social Site Characterization
- Reservoir Modeling and Risk Assessment
- MVA Development and Engineering Design
- Stakeholder Engagement

Status:

- Post-injection monitoring ends April 2020
- Conceptual site model and history matching

### Illinois Industrial CCS Project

- Industrial-scale demonstration
- Volume: up to 5 million tonnes
- Injection period: 3 years (or longer)
- Injection rate: 3,000 tons/d
- Compression capacity: 2,200 tonnes/day

Contribution:

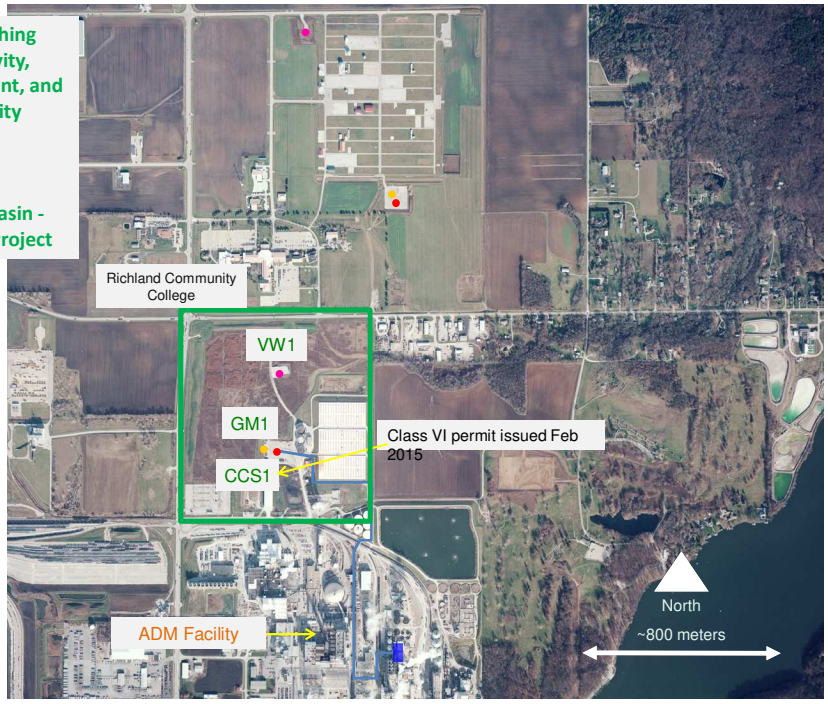
- Commercial-scale up surface and subsurface
- Intelligent Monitoring
- Class VI permitting

Status:

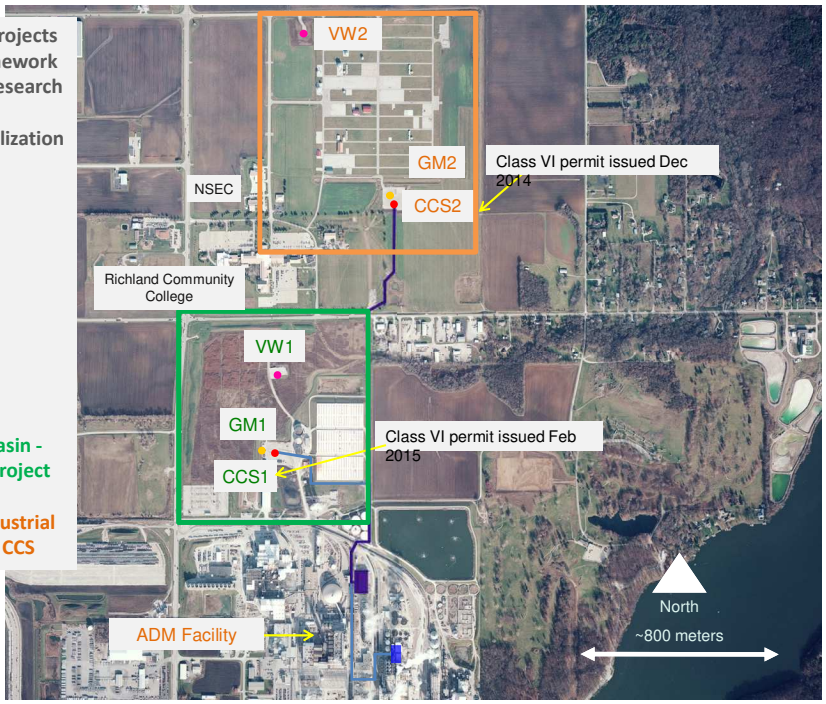
- Injection Began April 7, 2017
- Optimization of capture process
- 1,312,583+ (as of August 22, 2019)

**Establishing Injectivity, Containment, and Capacity**

**Illinois Basin - Decatur Project**



Multiple Projects Build Framework for CCUS Research and Commercialization

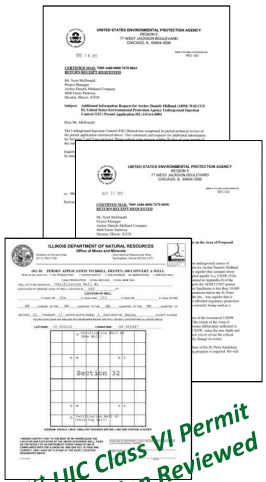



Illinois Basin - Decatur Project

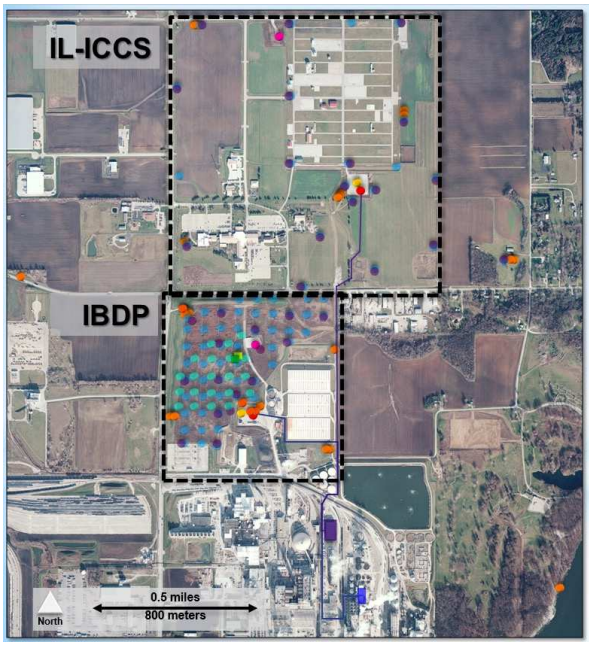
Illinois Industrial Sources CCS

## Permitting of wells for two projects linked

- Permitting has been rate-limiting step for both projects
- Permits for IBDP Post-injection Site Care and ICCS injection + Post-injection tied together
- Project expansion due to delay in injection start
- Example:
  - IBDP application submitted: Dec 2010
  - CCS application submitted: 25 Jul 2011
  - Draft permit issued: Apr 2014
  - Public hearing conducted: 21 May 2014
  - Public comment period ended: 31 May 2014
  - Final permit issued 28 Dec 2014
  - Permission to inject: 7 Apr 2017



1st UIC Class VI Permit Application Reviewed by the USEPA




## 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)

# IBDP Monitoring Summary

| | Monitoring Activity | Freq. | Pre-injection | | | Injection | | | | Post-Injection | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | 2008 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 | 2019 | 2020 |
| Surface | Aerial imagery | SA | | x | x | x | x | x | x | x | x | x | x | x | x |
| | Eddy covariance | C | | | | | x | x | x | | | | | | |
| | Soil flux - network* | W-Q | | x | x | x | x | x | x | x | | | | | |
| | Soil flux - multiplexer* | C | | | x | x | x | x | x | x | | | | | |
| | Tunable diode laser- single path | C | | | | | x | x | | | | | | | |
| | Tunable diode laser- multi path * | C | | | | | | | | x | | | | | |
| | InSAR * | BW | | | | x | x | | | | | | | | |
| | Continuous GPS * | C | | | | | x | x | x | | | | | | |
| Near-Surface | Soil gas sampling | Q-A | | | | x | x | x | x | x | x | | | | |
| | Shallow groundwater sampling | M-Q-SA | | x | x | x | x | x | x | x | x | x | x | x | x→ |
| | Shallow electrical earth resistivity* | A | x | x | x | | | | | | | | | | |
| Subsurface | Pressure/temp. - VW1 and CCS1 | C | | | | x | x | x | x | x | x | x | x | x | x→ |
| | Pulsed neutron (CCS1, VW1, GM1) | Q-A | | x | | x | x | x | x | x | | | x | | x→ |
| | Deep fluid sampling (VW1) | SA | | | | x | x | x | x | x | | x | x | x | |
| | Passive seismic monitoring (GM1) | C | | | x | x | x | x | x | x | x | x | x | x | x→ |
| | Seismic/3D VSP imaging | SA-A | | | x | x | x | x | x | x | | | | | x→ |
| | Mechanical integrity (CCS1, VW1) | A | | | x | x | x | x | x | x | | | | | x |

Abbreviations: C = Continuous, W = Weekly, BW = Biweekly, M = Monthly, Q = Quarterly, SA = Semi-Annually, A = Annually,
x = planned, not permit required; * = experimental technique or deployment; x = planned, permit required;
x→ = permit activity required beyond 2020; yellow box highlights decrease in monitoring activity during PISC phase

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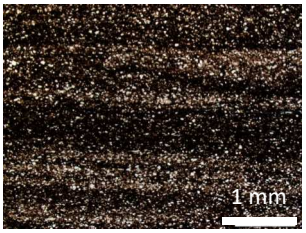
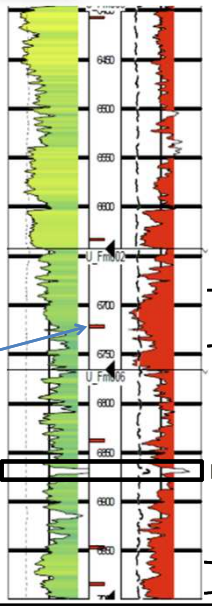
## Mudstone Baffle Between Injection Zones

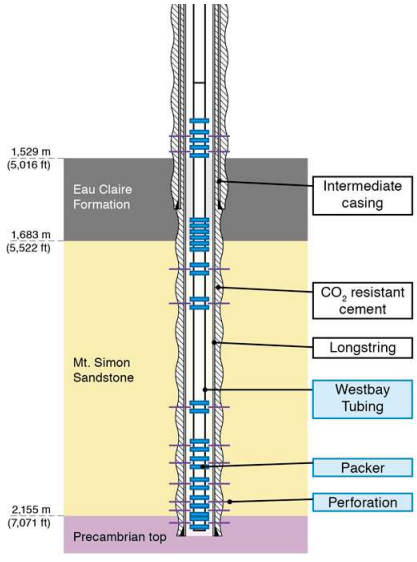



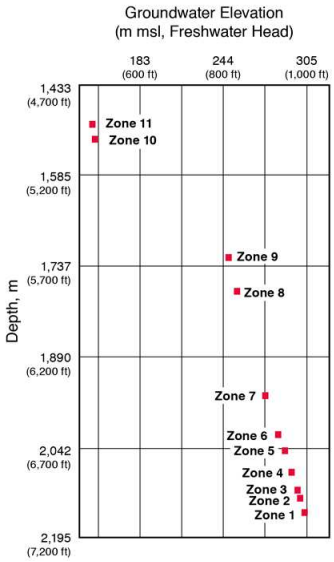

Zone 5

6,863-6,863.25 (2,092 m)
Porosity: 1.5%
$K_v$: <0.01 mD
$K_h$: 4.13 mD in siltstone laminae




## VW1 Westbay Completion



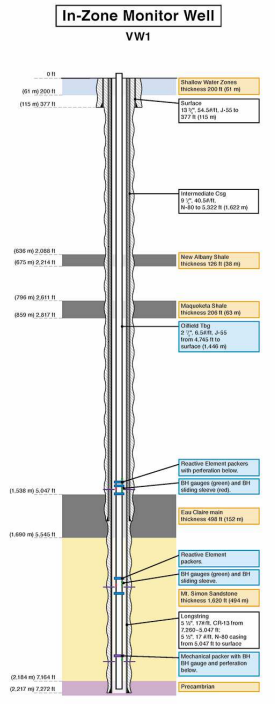



# Recompletion of VW1 Monitoring Well

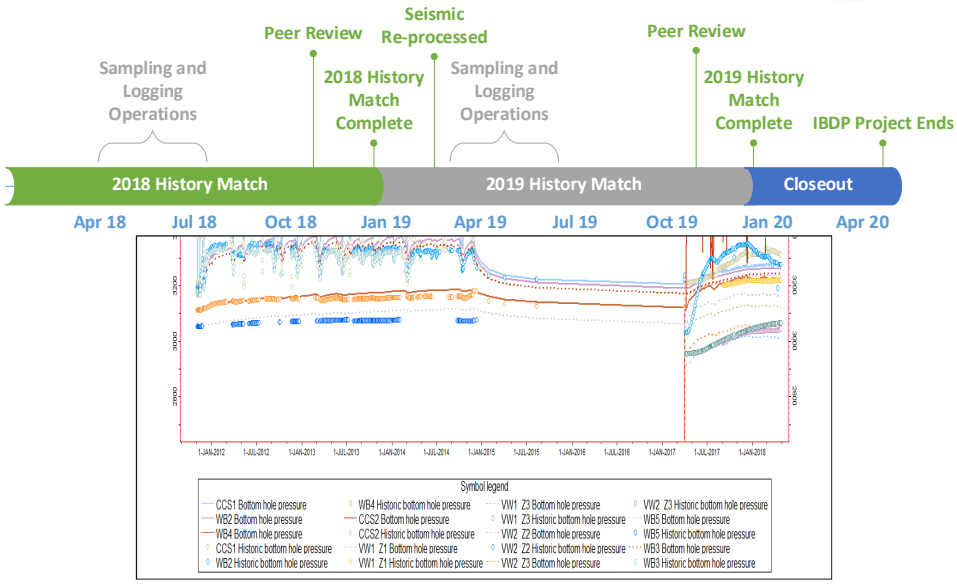


- Option 1 – Retain Westbay
- Option 2 – Schlumberger IntelliZone
- Option 3 – Baker Hughes Intelligent Monitoring
- Option 4 – Drill new well

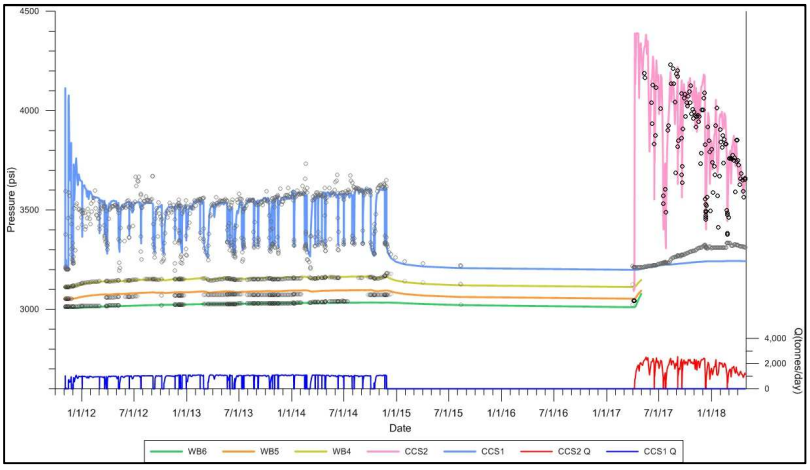
Two Fluid Sampling and Four Pressure Zones




## Modeling and History Matching Update

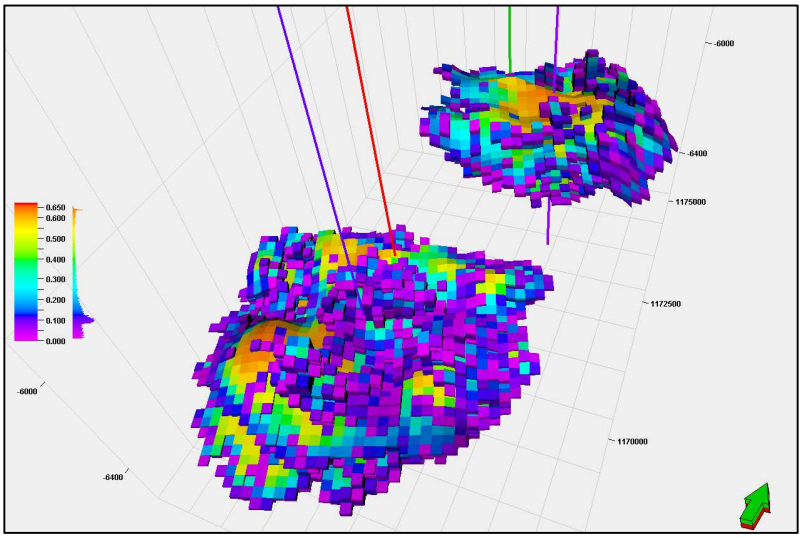



## 2018 Updated Model History Match

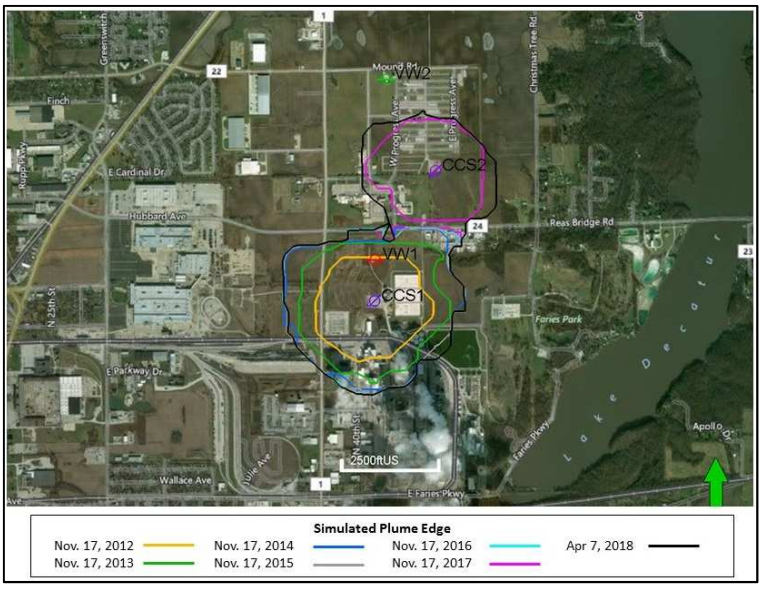



Simulation results and observed data of CCS1, CCS2, WB4, WB5, and WB6 until April 7, 2018.

# Plume Distribution of IBDP and ICCS




3D simulated $CO_2$ plume distribution on Apr. 7, 2018. Vertical exaggeration is 5x.

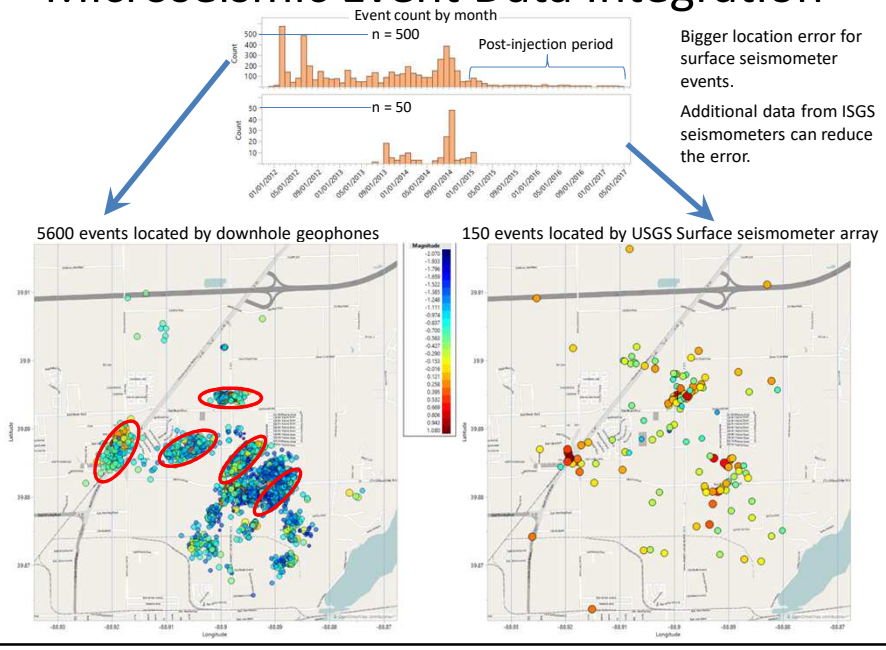



Simulated plume edge (CO2 concentration >1%)

## Seismic Data at IBDP

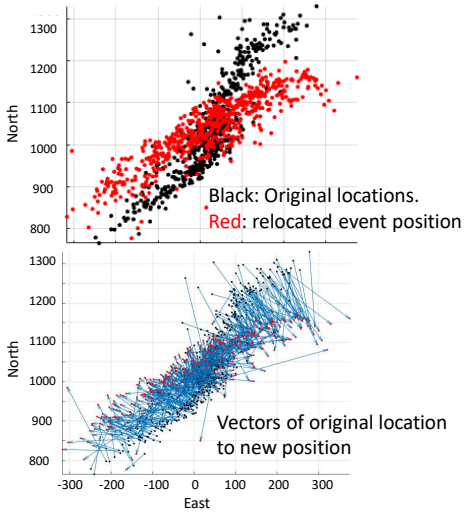
- Microseismic Data (passive seismic)
  - Integrating data acquired by ISGS seismometers with data acquired by USGS – data interpretation is underway
- Reflection Seismic Imaging Data (active seismic)
  - Reprocessing of 3D volume is complete, better resolution for fault ID, inversion volumes strongly illuminate rock properties
- 3D VSP Reprocessing (active seismic)
  - Currently underway, with preliminary results showing improved imaging

## Microseismic Event Data Integration

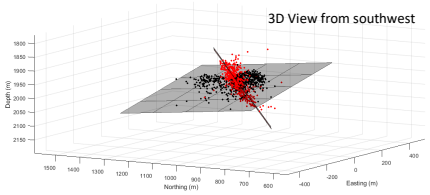


# Collaboration with NORSAR

Detailed analysis of microseismic event clusters. One cluster example.



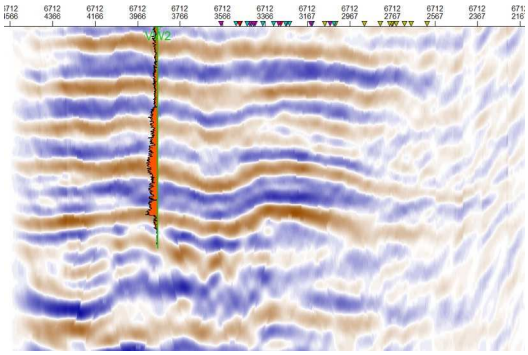

- Shape and orientation of cluster gets rotated in 3D



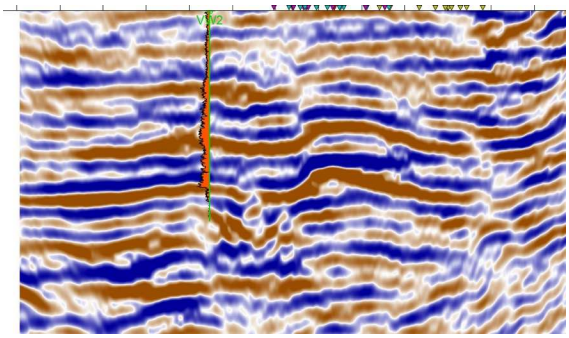

- A plane fit to the cluster dips to the south-east, consistent with stress orientation
- Improved geometry from event relocation enables better understanding of reservoir dynamics

# 3D Seismic Reprocessing

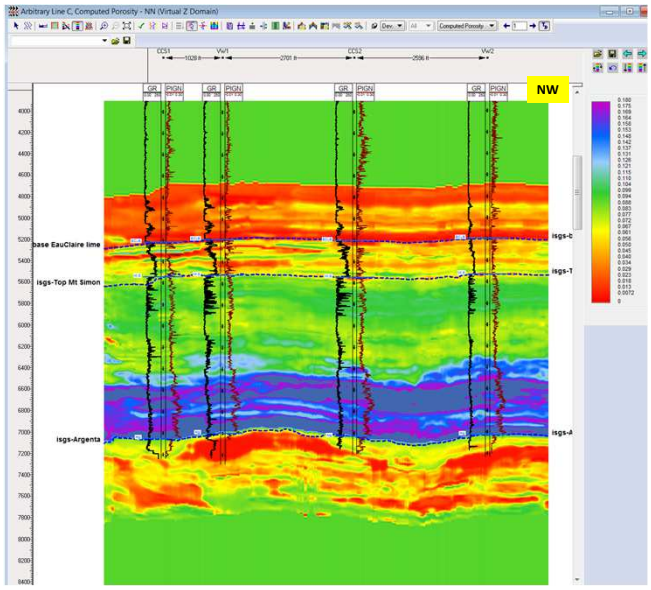
**2011 seismic**



**2019 seismic**



## Porosity Inversion




## Major IBDP Accomplishments

- Conducted successful large-scale storage demonstration at an active industrial site
- Conversion of Illinois EPA Class I permit to US EPA Class VI permit
- Stakeholder engagement strategy built trusted relationships
- Met and exceeded technical and non-technical challenges
- Extensive site characterization & modeling leading to injection, monitoring, and increased understanding of microseismic reservoir response
- Extensive regional, national, and international partnerships and collaboration

## IBDP by the numbers:

- A million tonnes stored from **biofuels** More than **5,000 meters** of drilled wells
- More than **245 meters** of collected core
- Near-surface groundwater monitoring efforts have resulted in more than **50,000 analyses**
- For basin-scale modeling, we will use **1,020,000 CPU-hours** of XSEDE* supercomputing resources.
- More than **750 visitors from 29 countries** have been to IBDP
- More than **100 people at least 10 organizations** have worked together to make this project a success

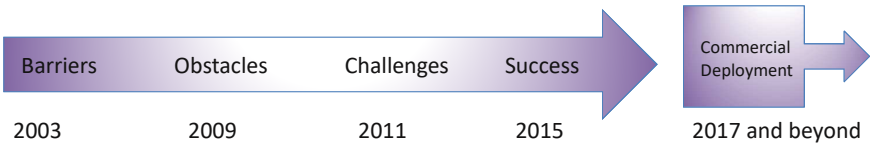
*XSEDE is an NSF-sponsored supercomputer network

## Lessons Drive Advancement

- Geology is critical and will always remain key factor
- Iterative scientific investigation allows for advancement and economy of scale
- Baseline environmental assessments are critical
- Unanticipated results provide insights into improvements that benefit all projects
- Incorporate technology changes into life cycle of project
- Occom's Razor applies to CCUS
- Scientific and engineering timeframe not aligned with policy
- Pilot and demonstration projects provide critical insights
- Policy drivers are necessary to facilitate commercialization
- Regulatory, legal, and social factors require significant time investment

## What We've Learned:

- Carbon capture and storage from biofuel sources in deep saline reservoirs can be conducted safely
- Research and scale-up demonstration projects can lead directly to industrial-scale or commercial-scale projects
- The Mt. Simon Sandstone is a viable and important deep saline storage resource for the US
- Establishment of an MVA baseline is critical to characterize site and reduce project risk, but needs to be revisited on a regular basis
- Permitting can be time intensive and should not be underestimated as a potential project risk
- Economy of scale learnings essential to commercial CCS deployment




- CCUS is unique combination of existing technologies
- US leading in
  - Saline and EOR storage
  - Safe Drinking Water Act protection
  - Incentives
- Need to ensure:
  - Choose the best geology available
  - Form good partnerships
  - Leverage resources and information
- Spheres of Engagement are critical
  - Project
  - Policy
  - Public

# Acknowledgements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