Induced Seismicity at the Illinois Basin – Decatur Project

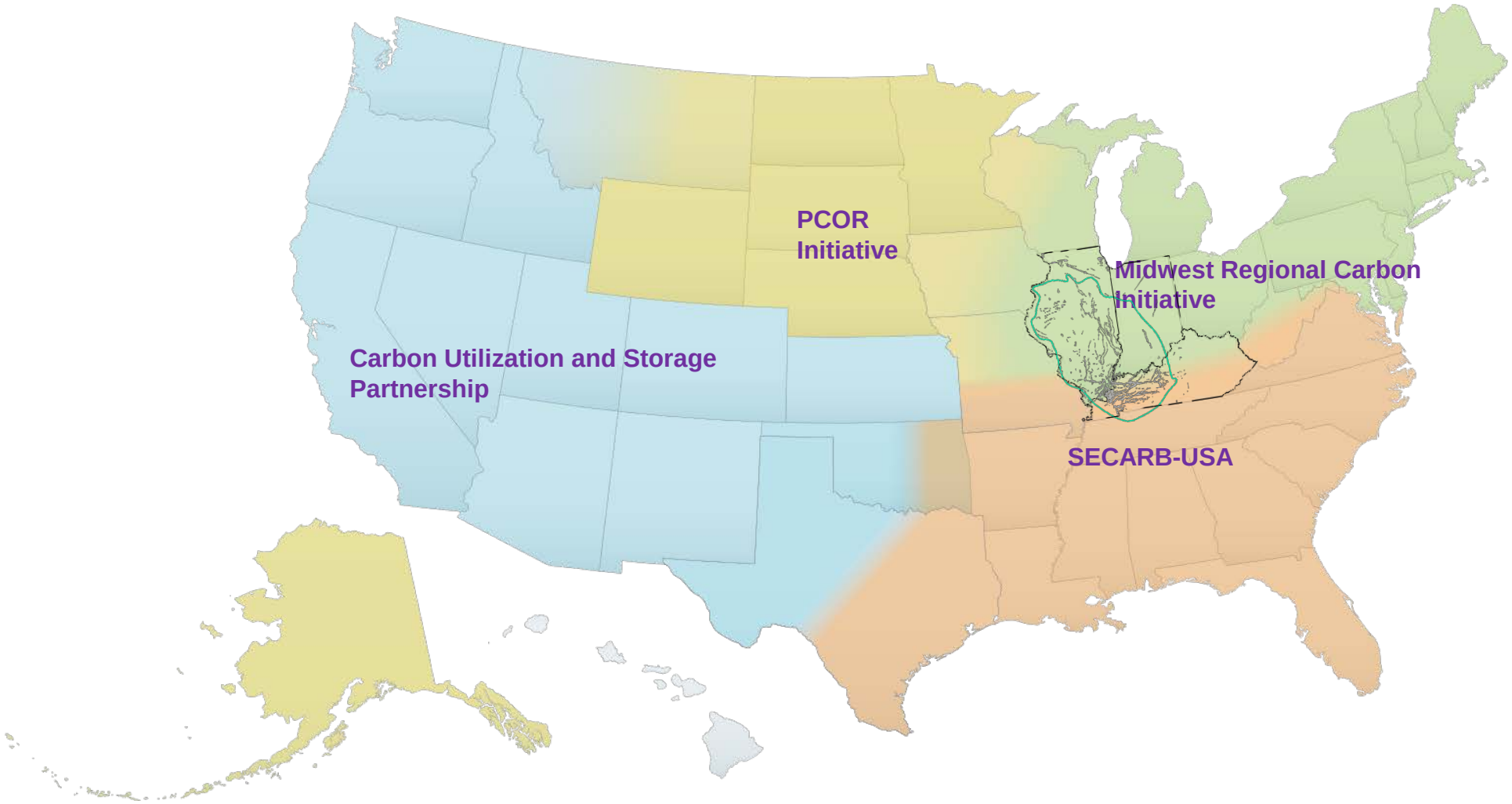
Lessons for moving monitoring from Site-Scale to Large Scale CCS

Sherilyn Williams-Stroud, Illinois State Geological Survey

Regional Induced Seismology Collaborative (RISC) Webinar

4 August 2020

Regional Initiatives to Accelerate CCUS



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

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INDUSTRIAL CARBON CAPTURE & STORAGE

- 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

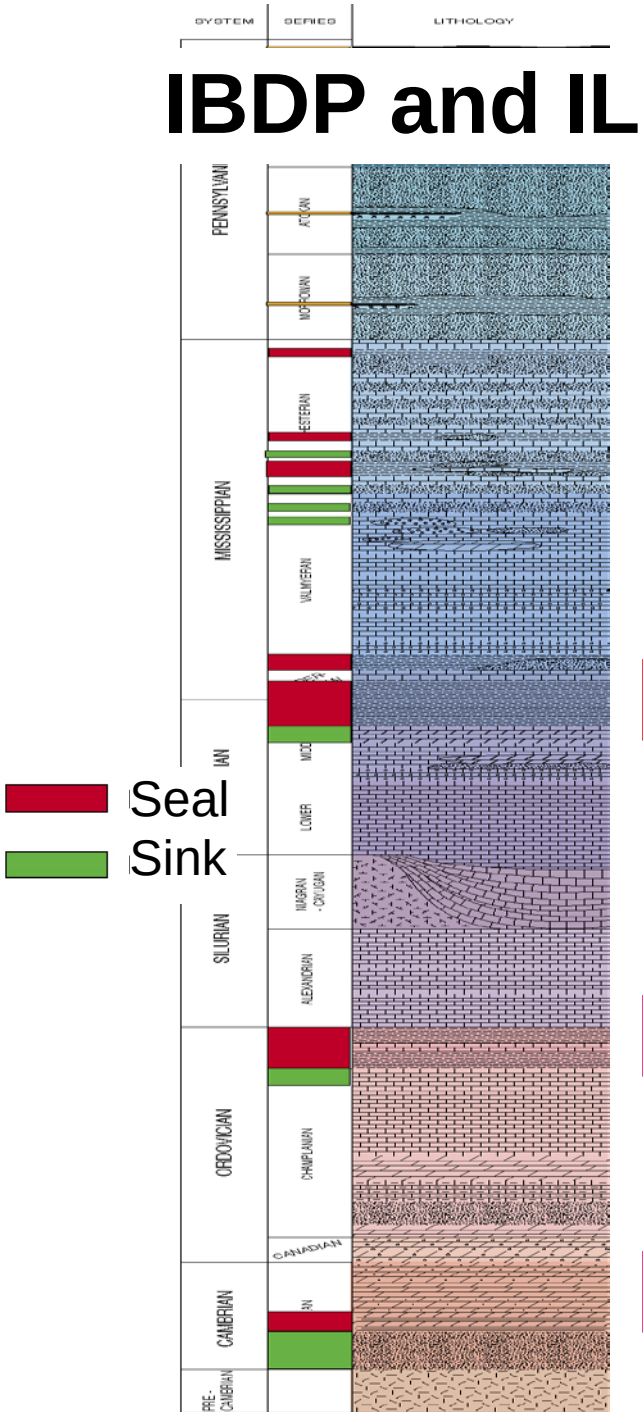
Contribution:

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

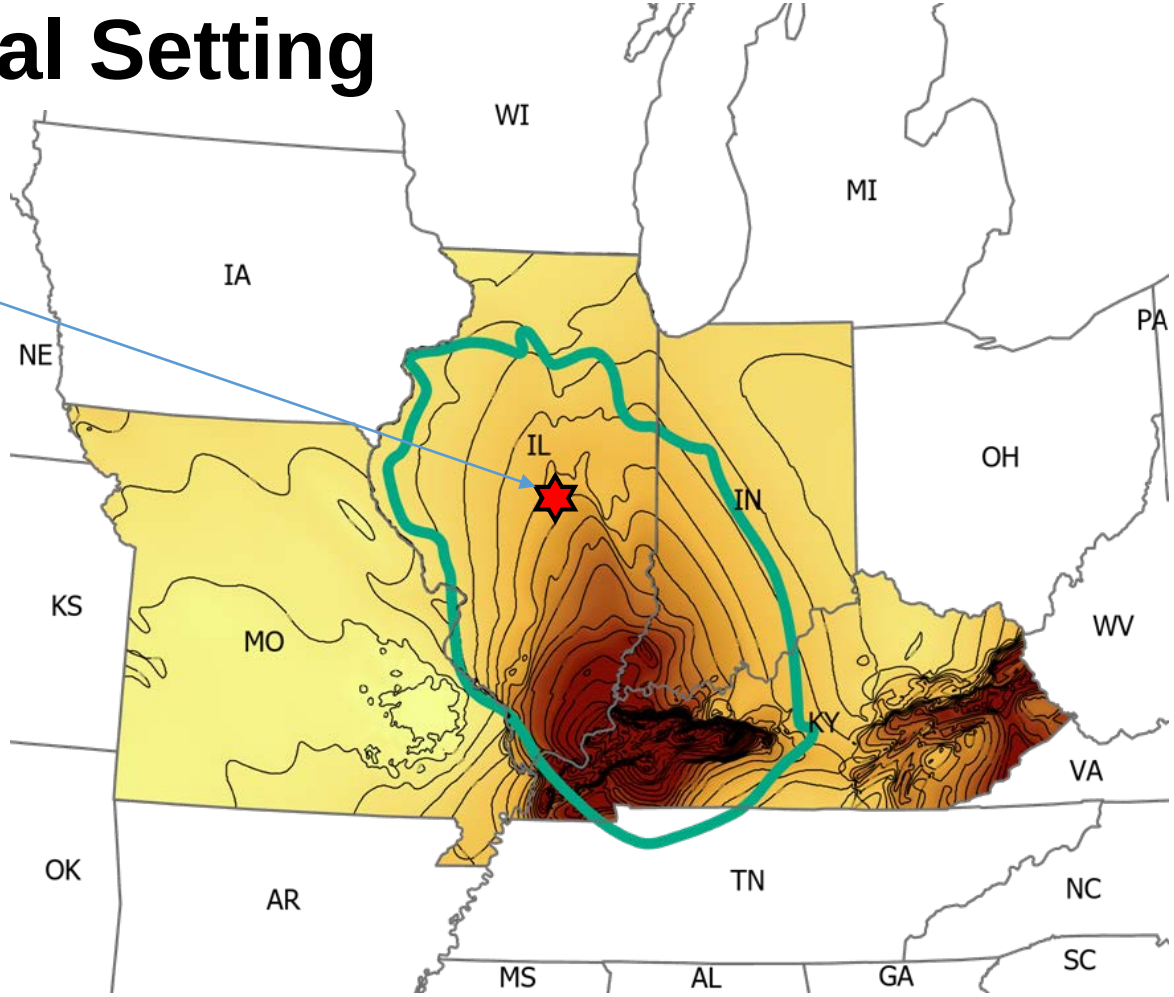
Status:

- Injection Began April 7, 2017
- Optimization of capture process
- >1,800,000 (as of April 2020)

IBDP and IL-ICCS Geological Setting



Project Location



New Albany Shale (Seal)

Maquoketa Shale (Seal)

St. Peter Sandstone (Sink)

Ironton-Galesville Sandstone (Sink)

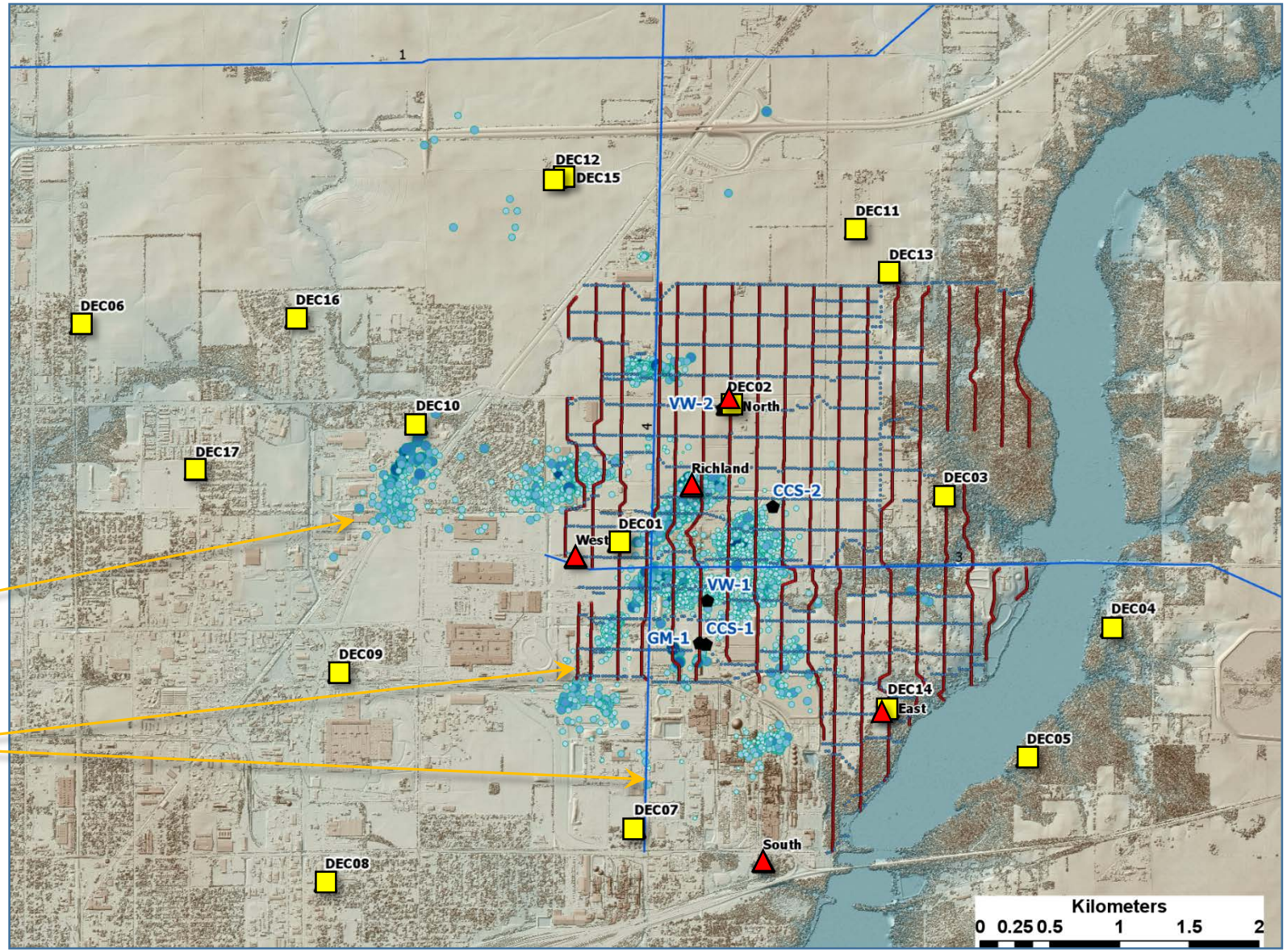
Eau Claire Shale (Seal)

Mt. Simon Sandstone (Sink)

Seismic Monitoring and Acquisition Surveys

- USGS seismometer
- ISGS seismometer
- IBDP and ICCS well

- Decatur area monitoring configuration
  - microseismic event epicenters
  - 2D and 3D seismic reflection surveys

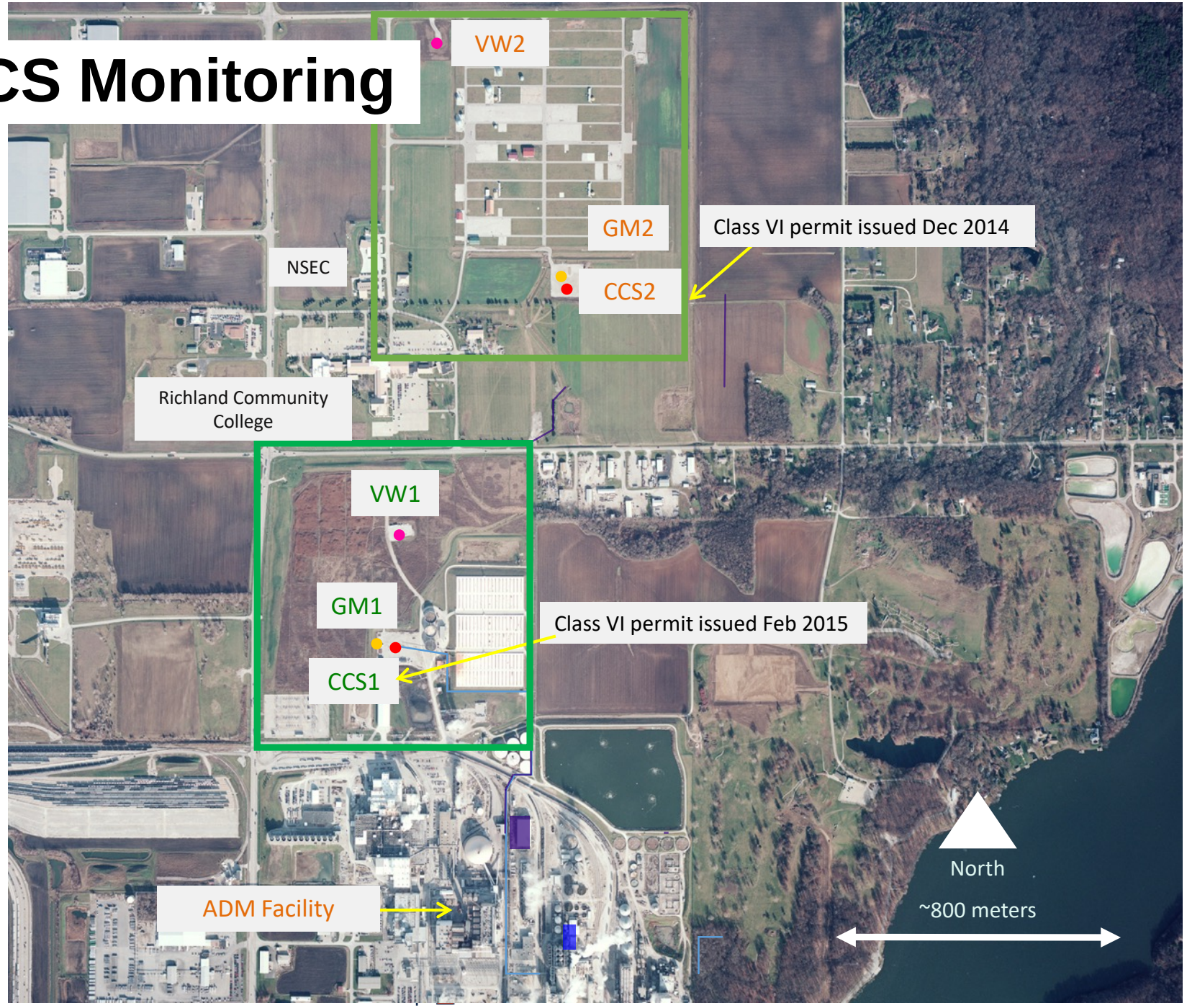


IBDP and IL-ICCS Monitoring

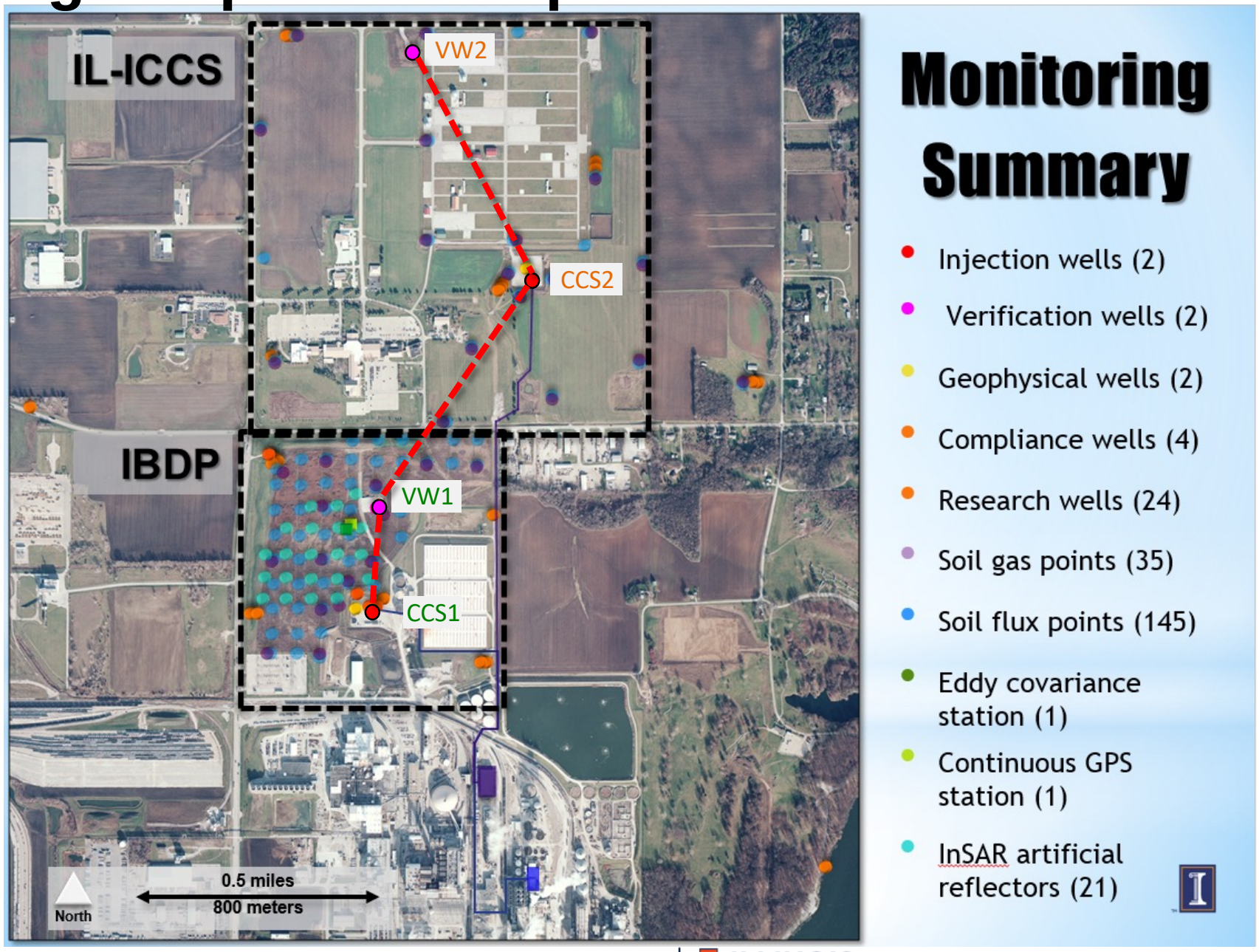
Multiple Projects Build Framework for CCUS Research and Commercialization

Illinois Basin - Decatur Project

Illinois Industrial Sources CCS

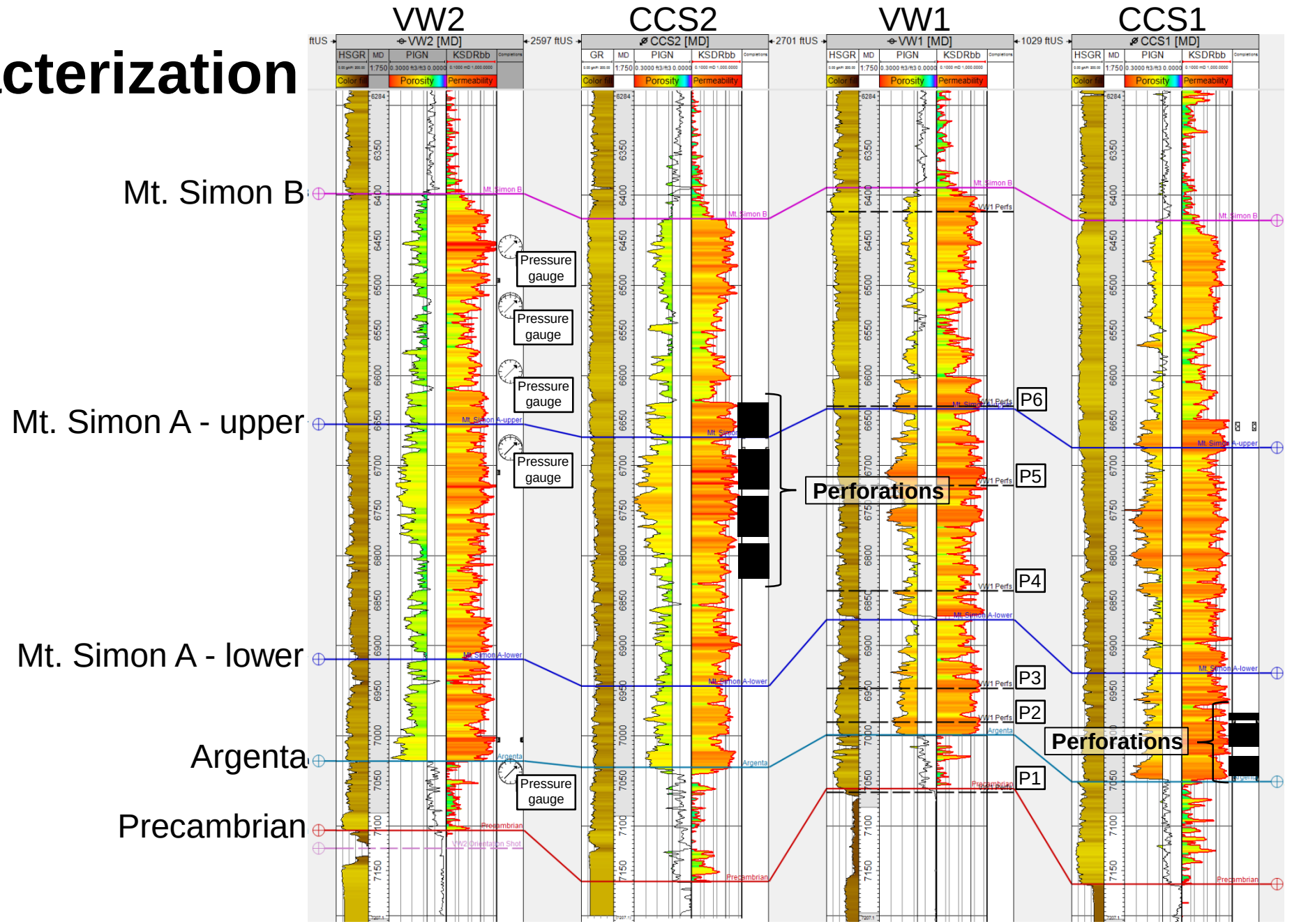


Monitoring Adapted to Acquired Data

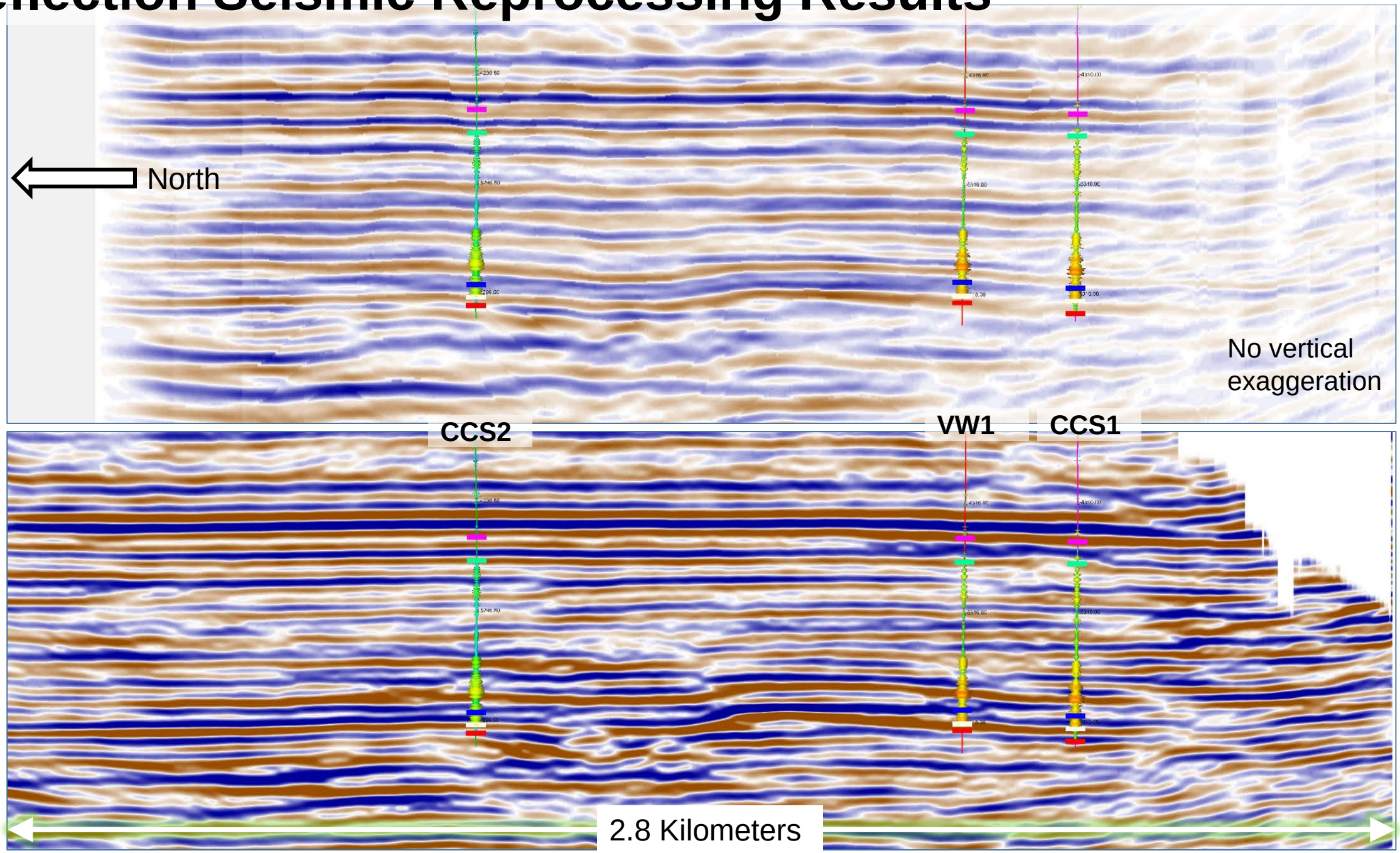


Reservoir Characterization

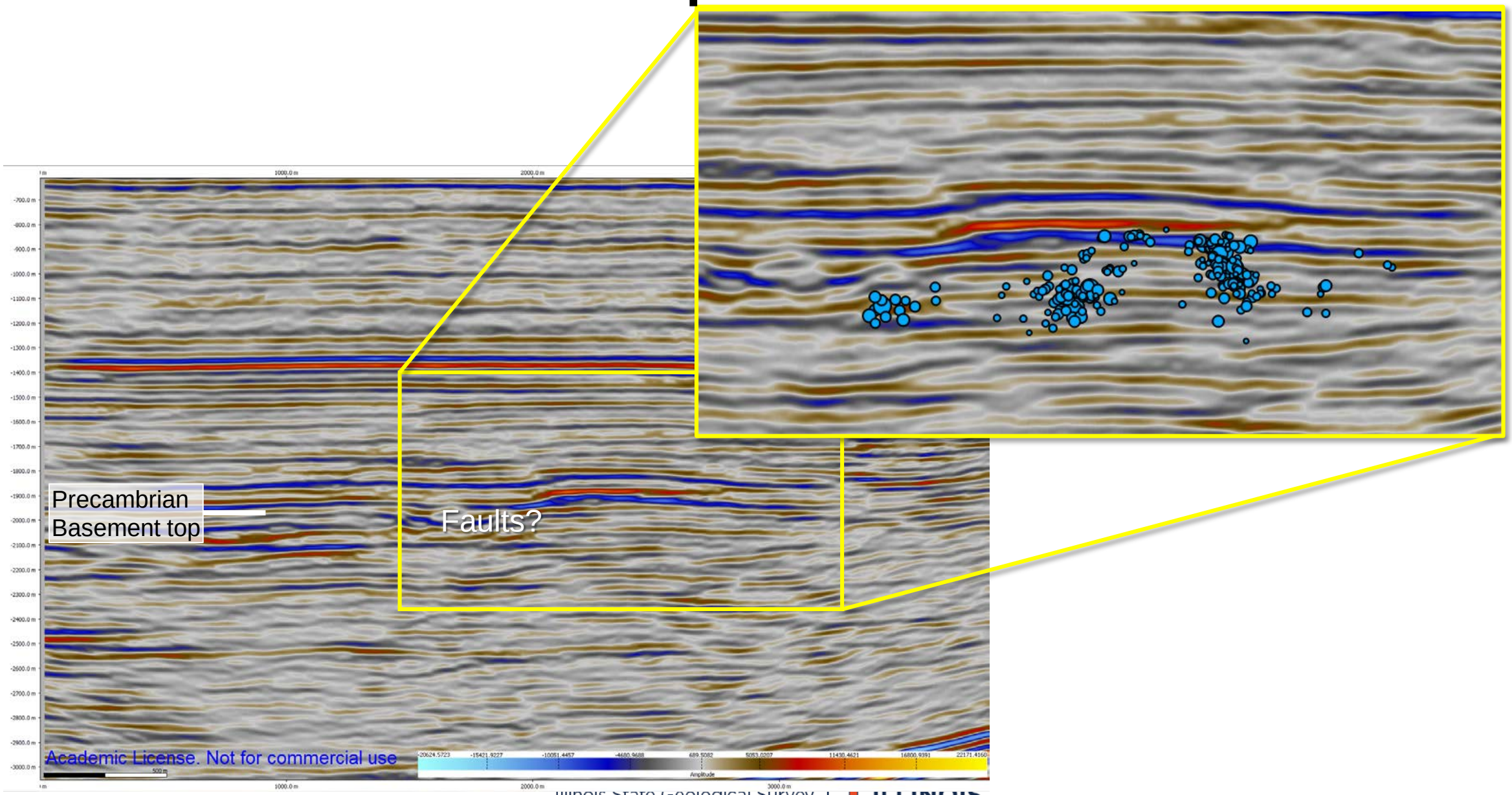
GR, Porosity, and Permeability logs for the injection and monitoring wells



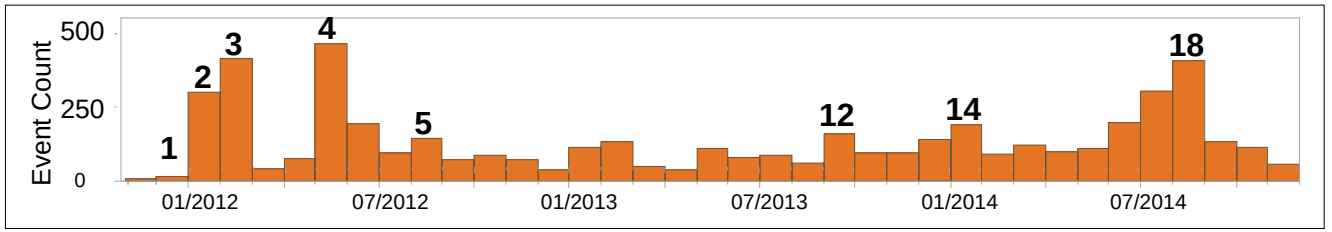
Reflection Seismic Reprocessing Results



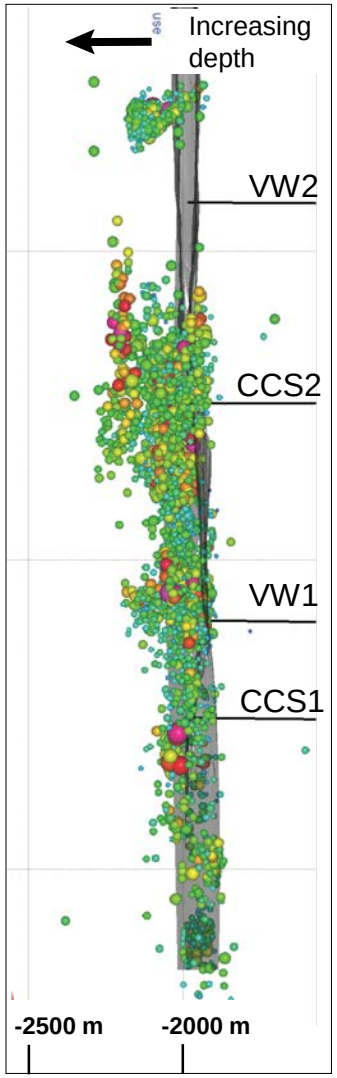
IBDP Active Seismic Depth Slice

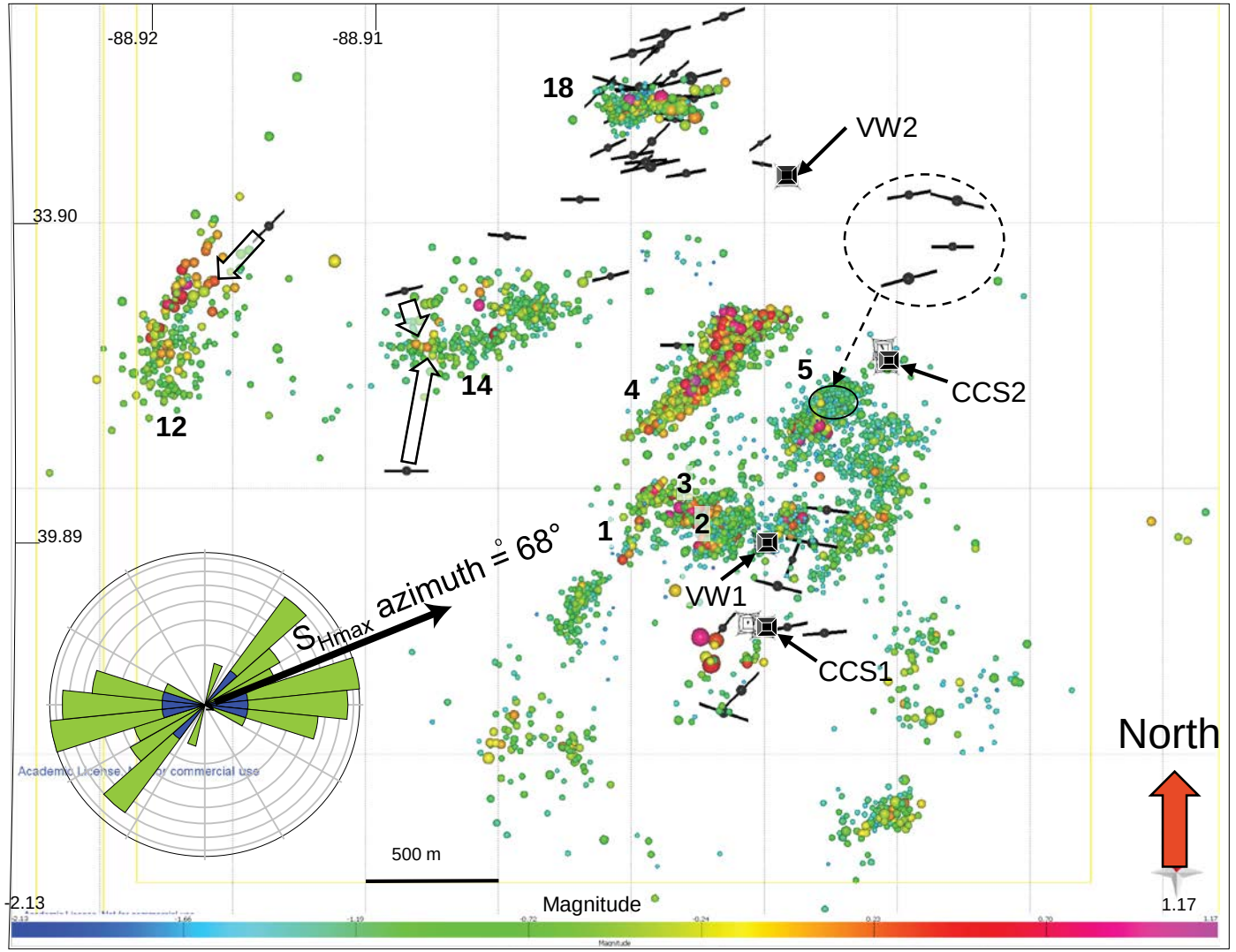


Event Cluster Development

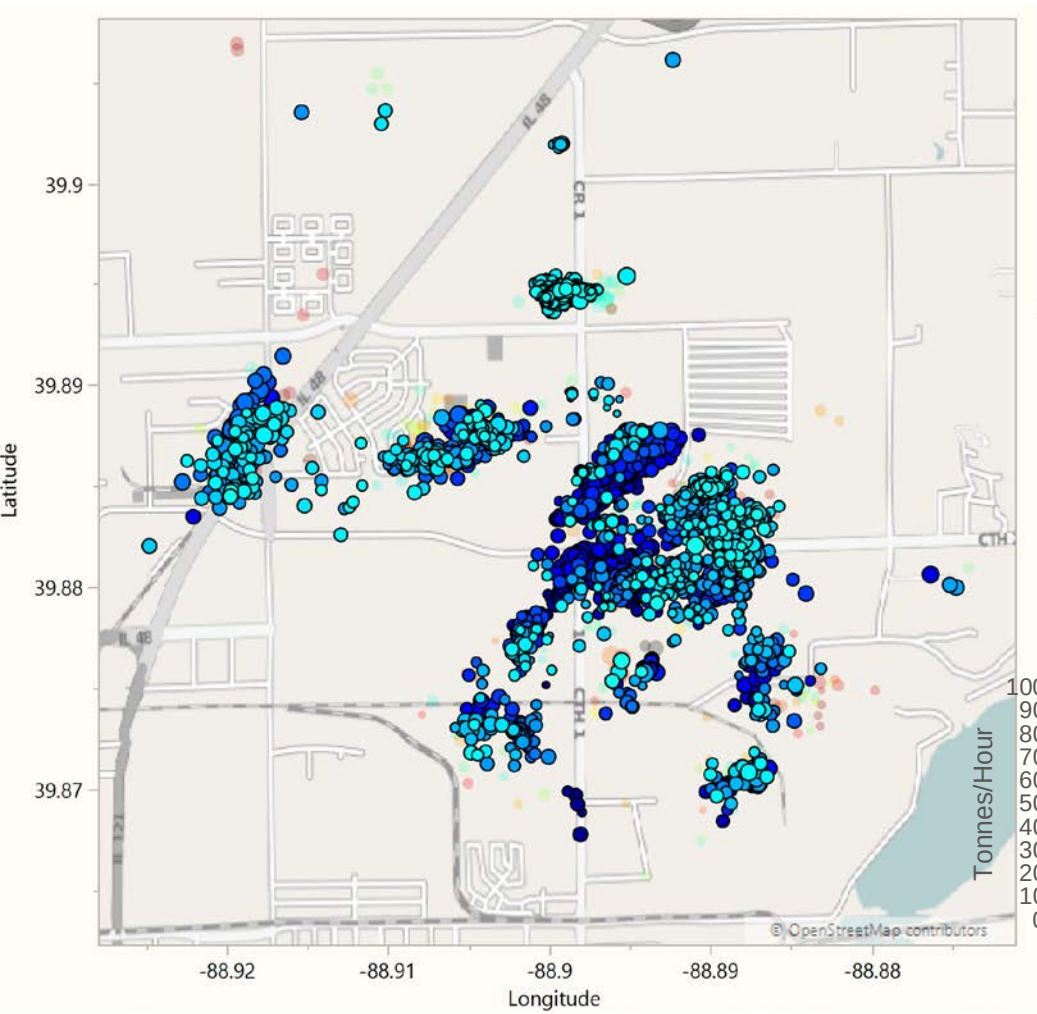


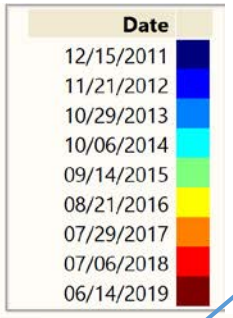
- Events detected during CCS1 injection
- Depth view shows top of Precambrian
- Clusters are numbered by sequence of first occurrence
- Cluster 4 developed early – contains ~900 events
- Source mechanisms from 50-event subset matched by origin time
- Some have large mislocation, but failure planes seem to correlate with some event cluster trends





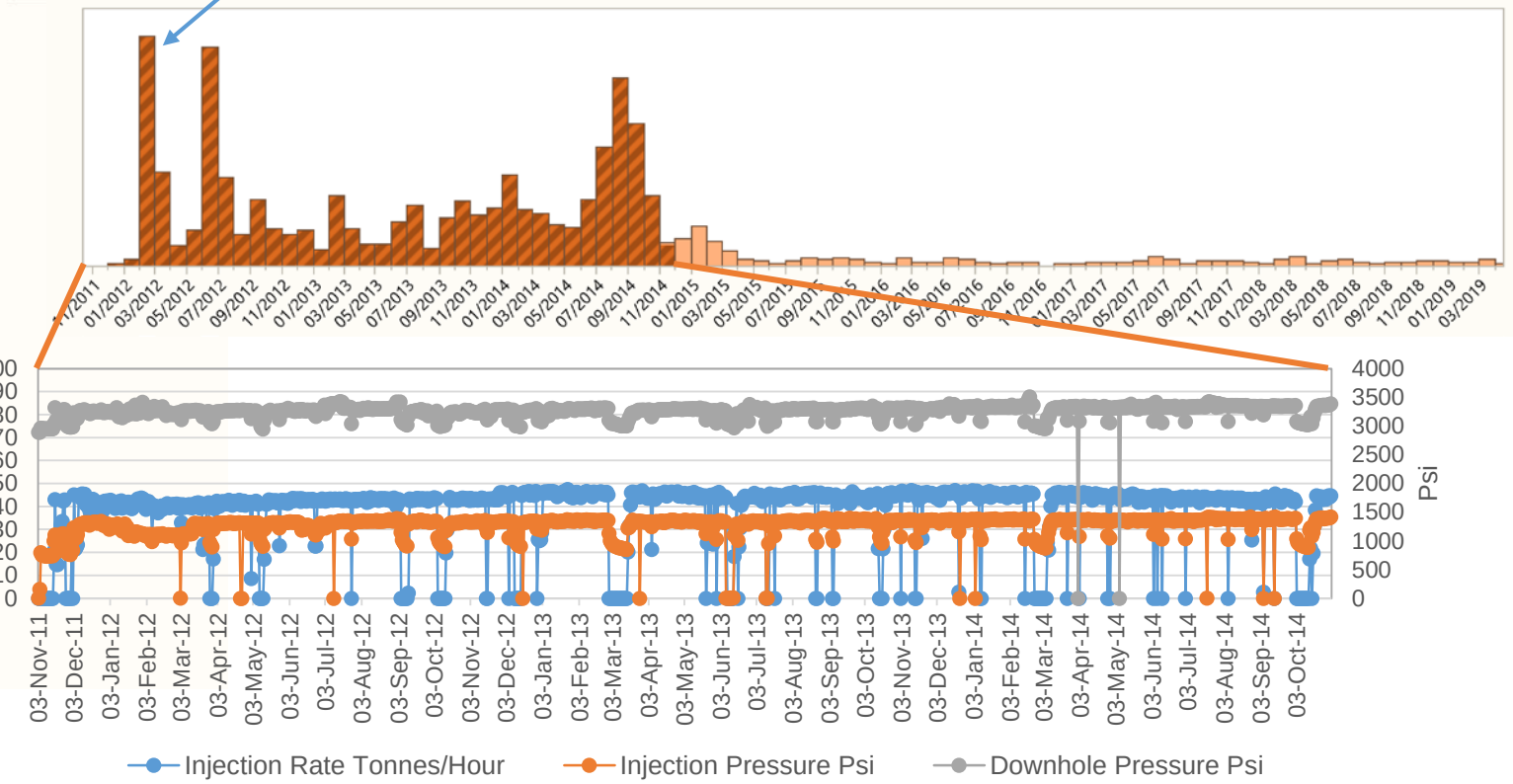
CCS1 Injection Period - IBDP



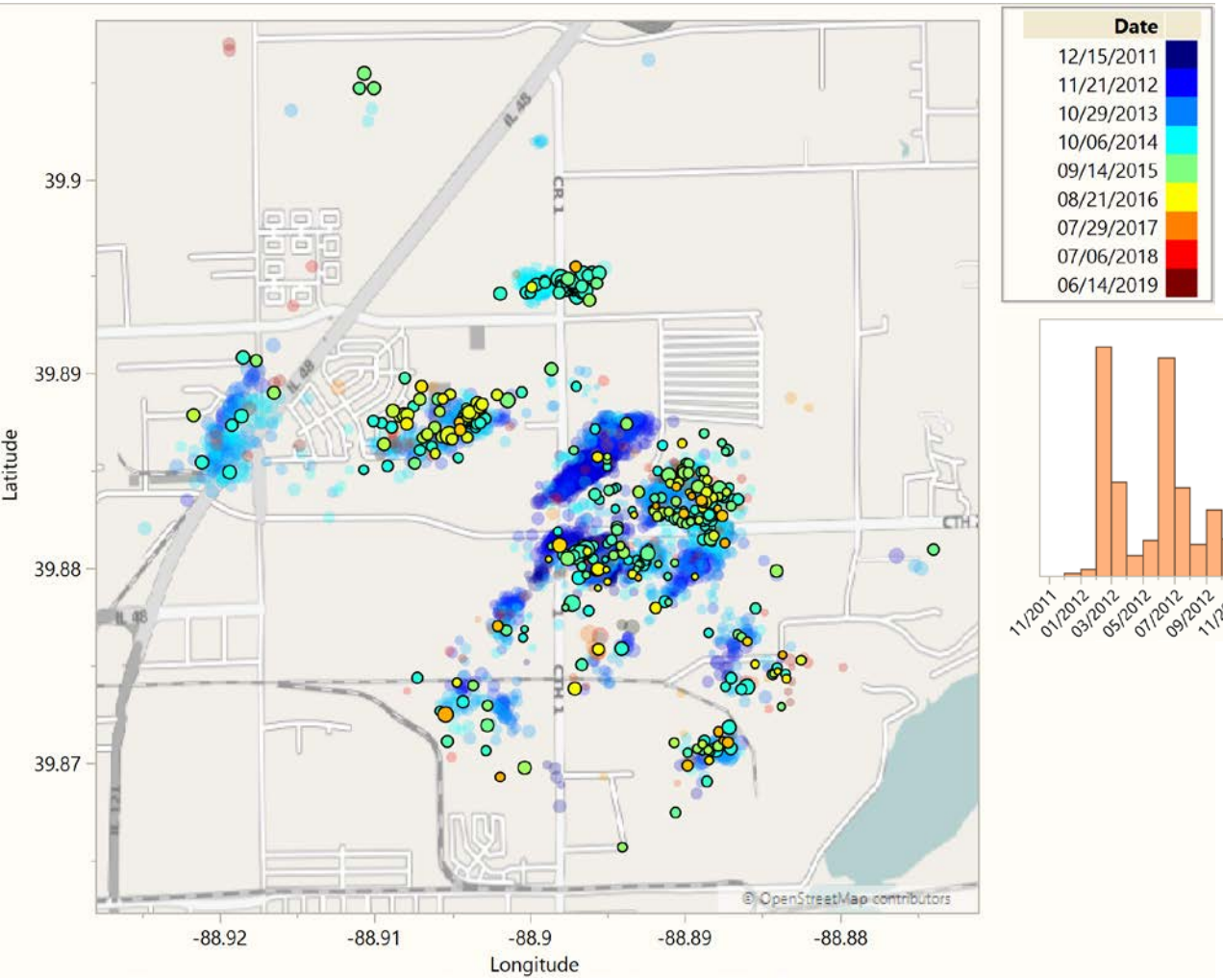


No significant microseismicity until February 2012

No apparent correlation of events with pumping rates

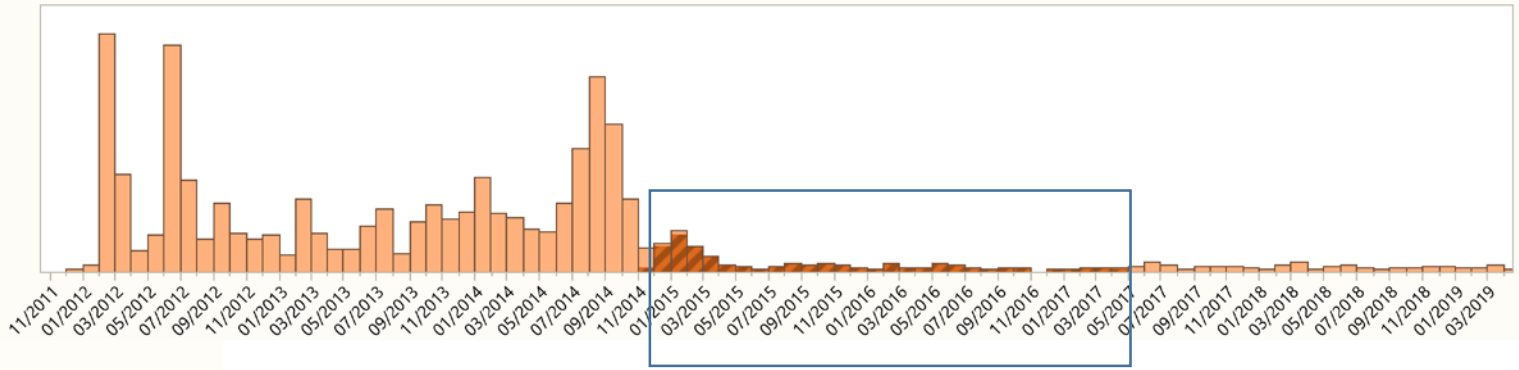


Interim Non-injection Period

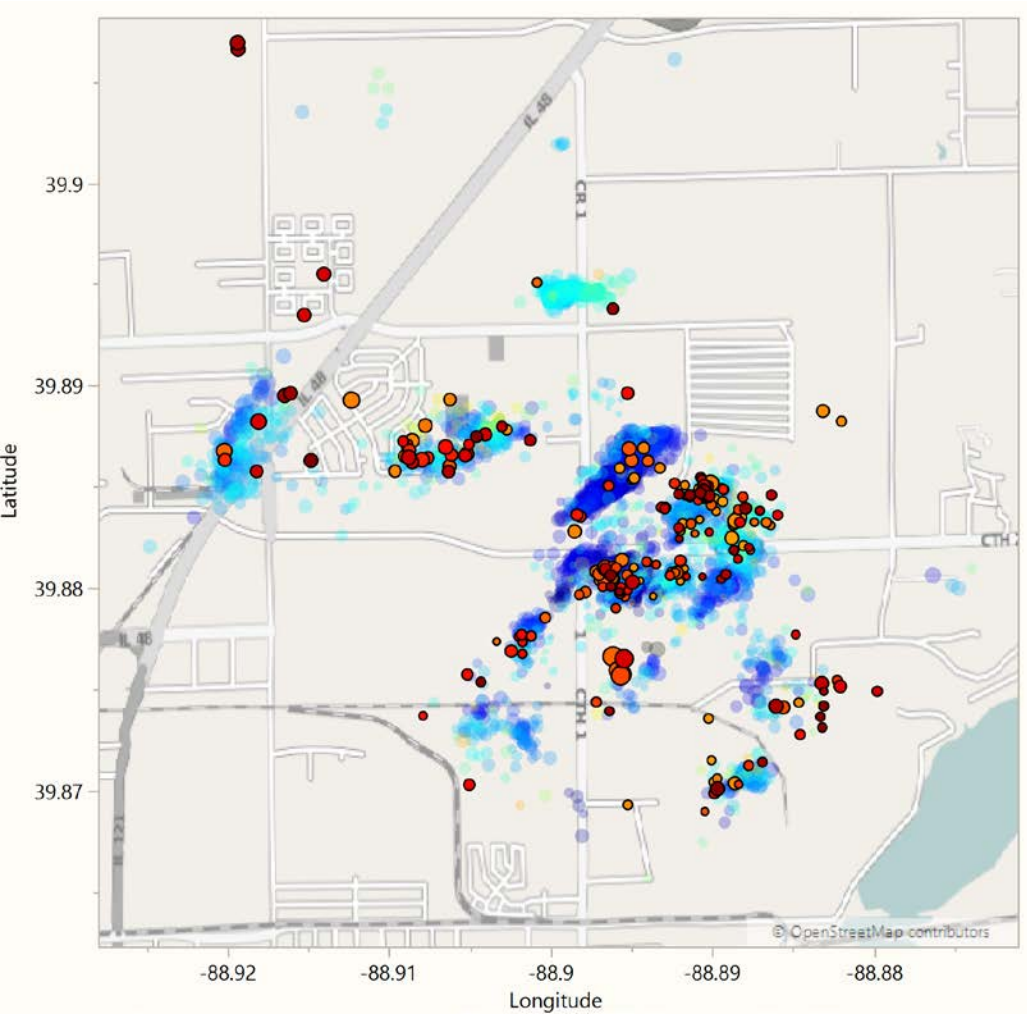


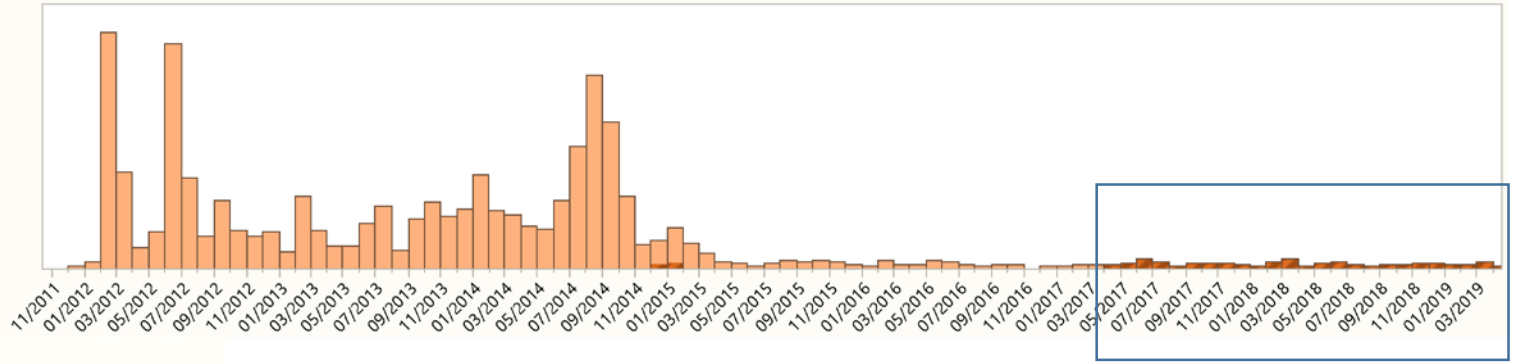
Increase in microseismicity at first

Microseismicity subsides to a background level



CCS2 Injection Period – IL-ICCS Project



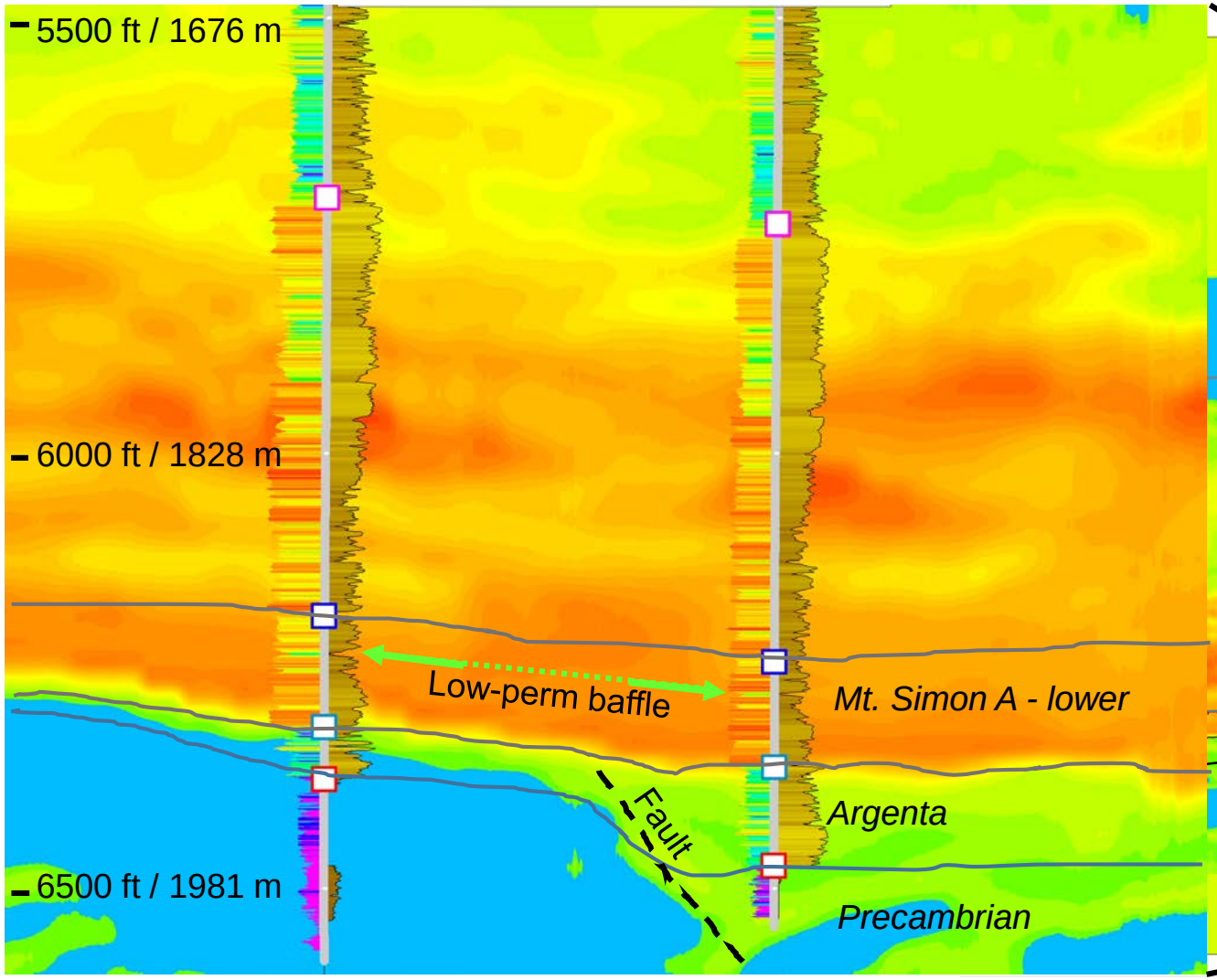


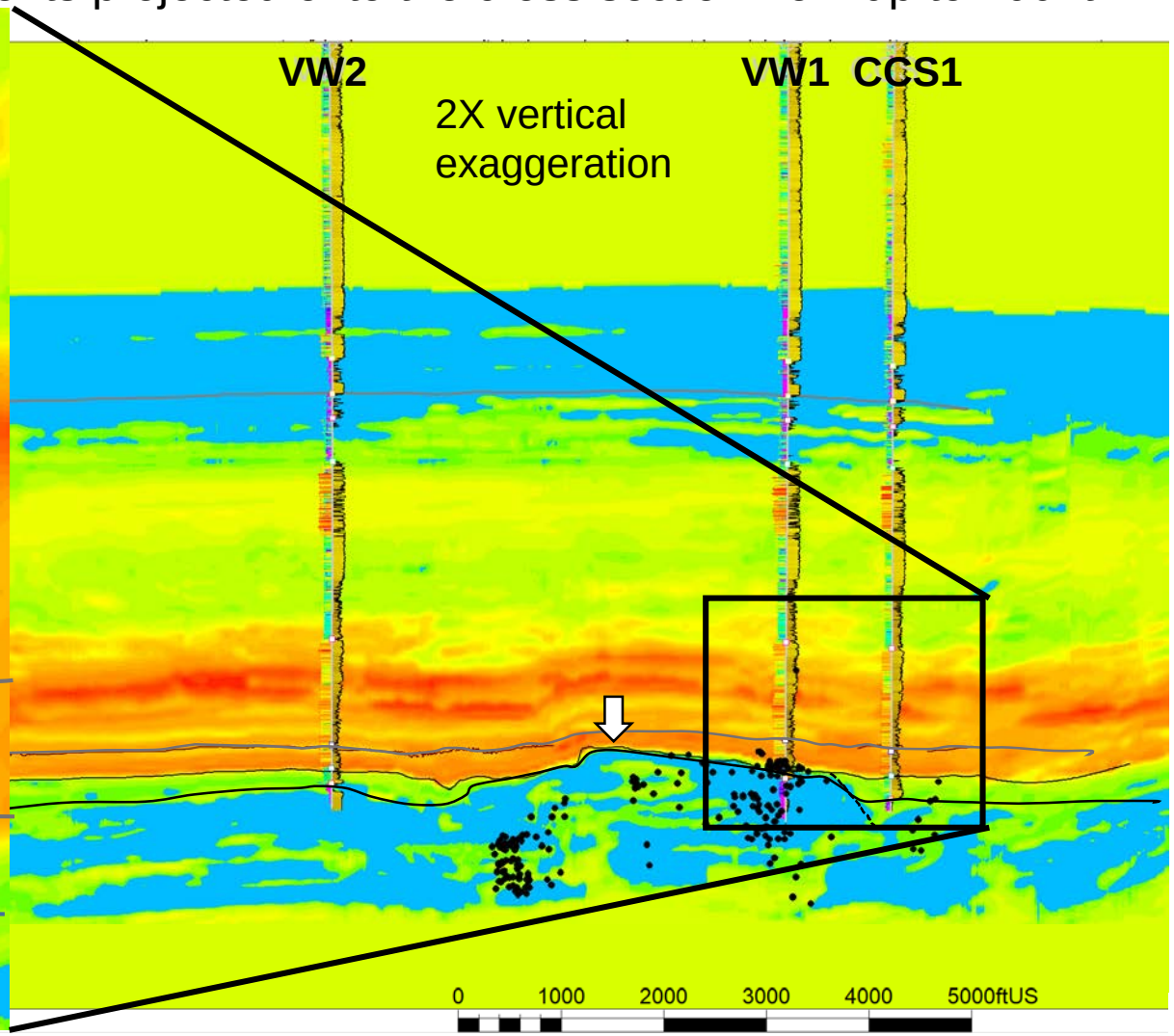
No apparent increase of events with new injection

Illinois Industrial CCS Project)

Refection Seismic Porosity Inversion

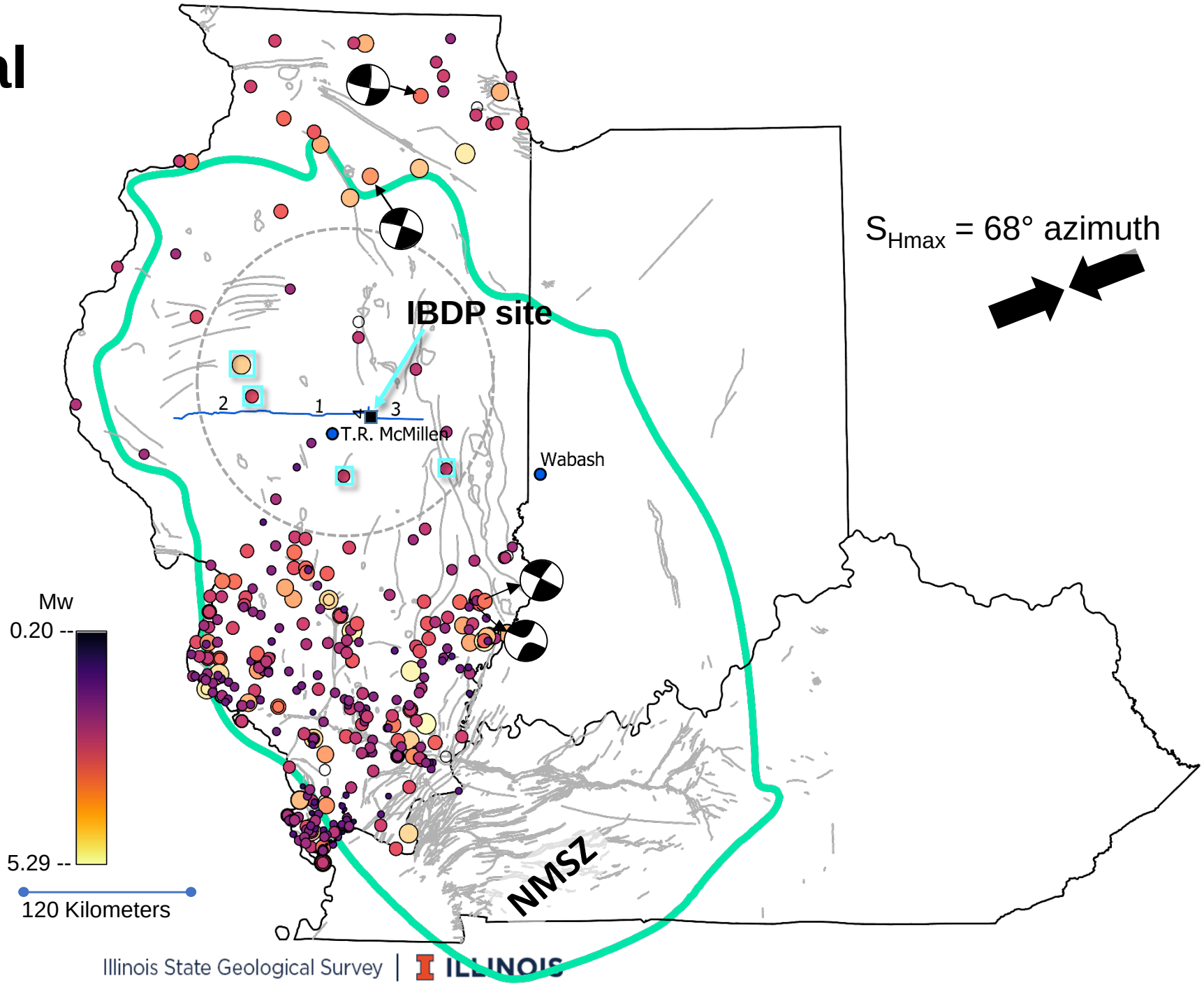
Wells and seismic events projected onto the cross section from up to 200 ft.





Historical Natural Seismicity

- Earthquakes in Illinois since 1795
- Some activity in northern Illinois
  - Moment tensors for 3.8 and 4.2 Mw earthquake
- Most activity in southern part of state, where basin is deepest and highest structural complexity
  - Moment tensors for a Mw 5.2 EQ followed by a Mw 4.0 aftershock
- Largest EQ within 100 km of IBDP = Mw 4.4

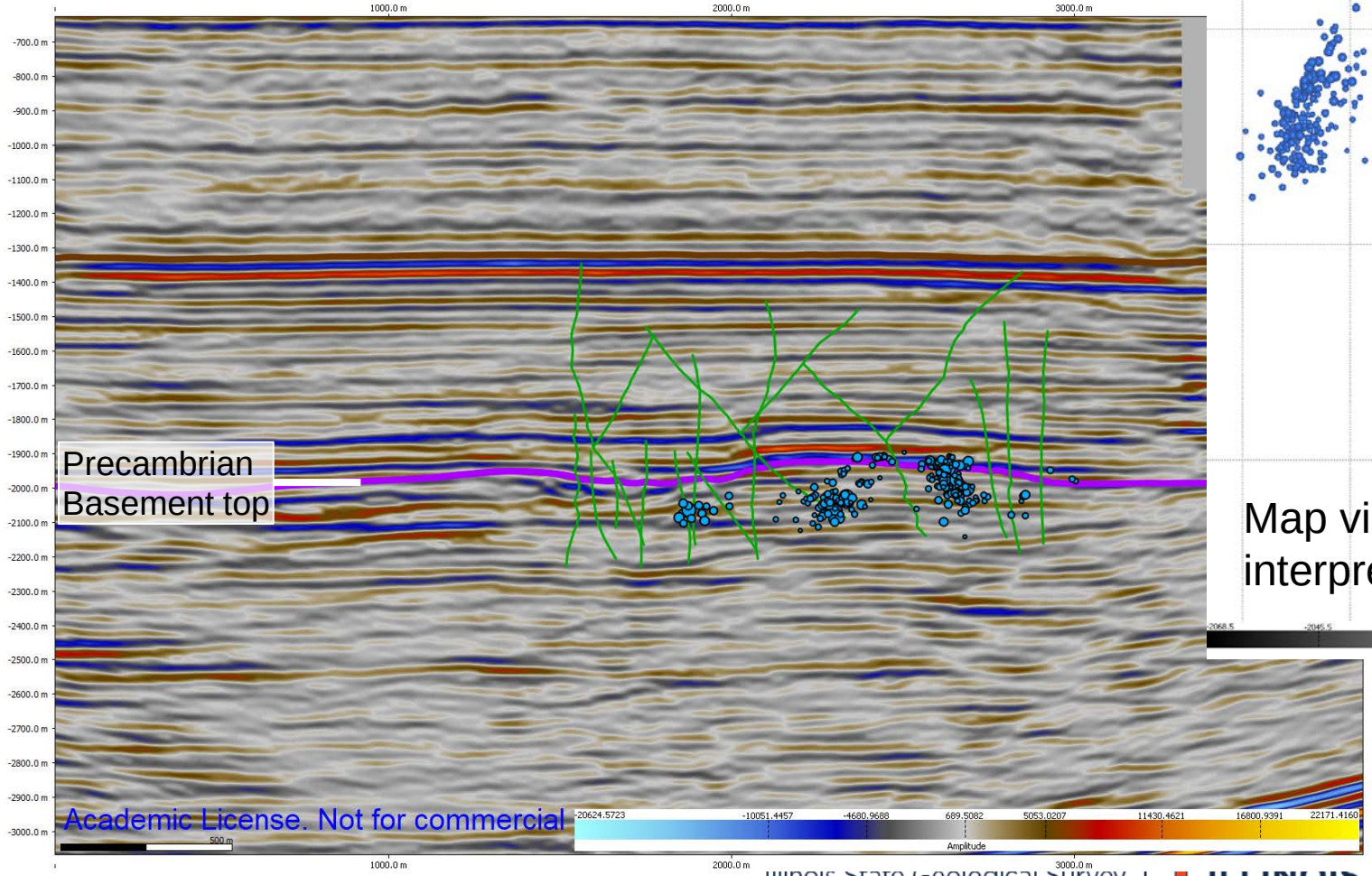


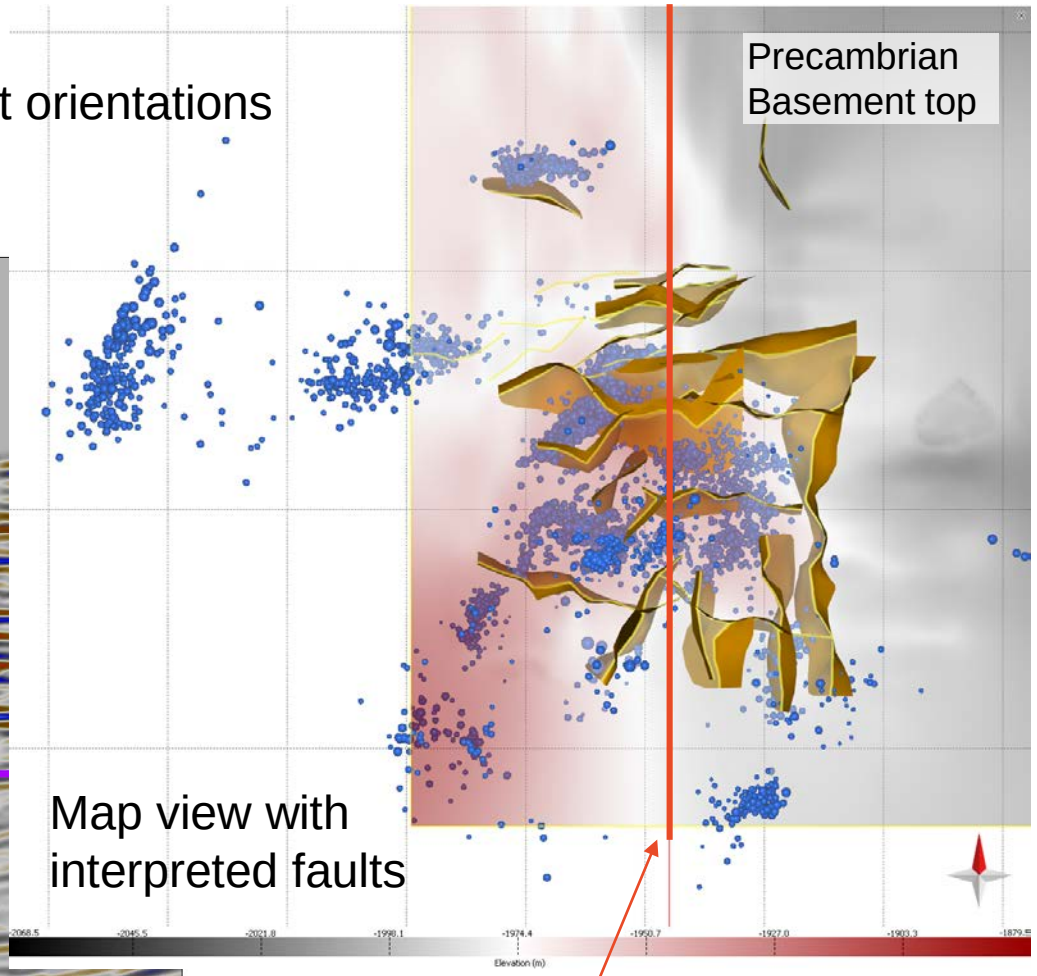
IBDP Active Seismic Depth Slice

Interpreted fault lengths range from 50 m to 1000 m

Partially coincident with microseismicity clusters, but different orientations

Largest (cluster 4) is ~ 800 in longest dimension

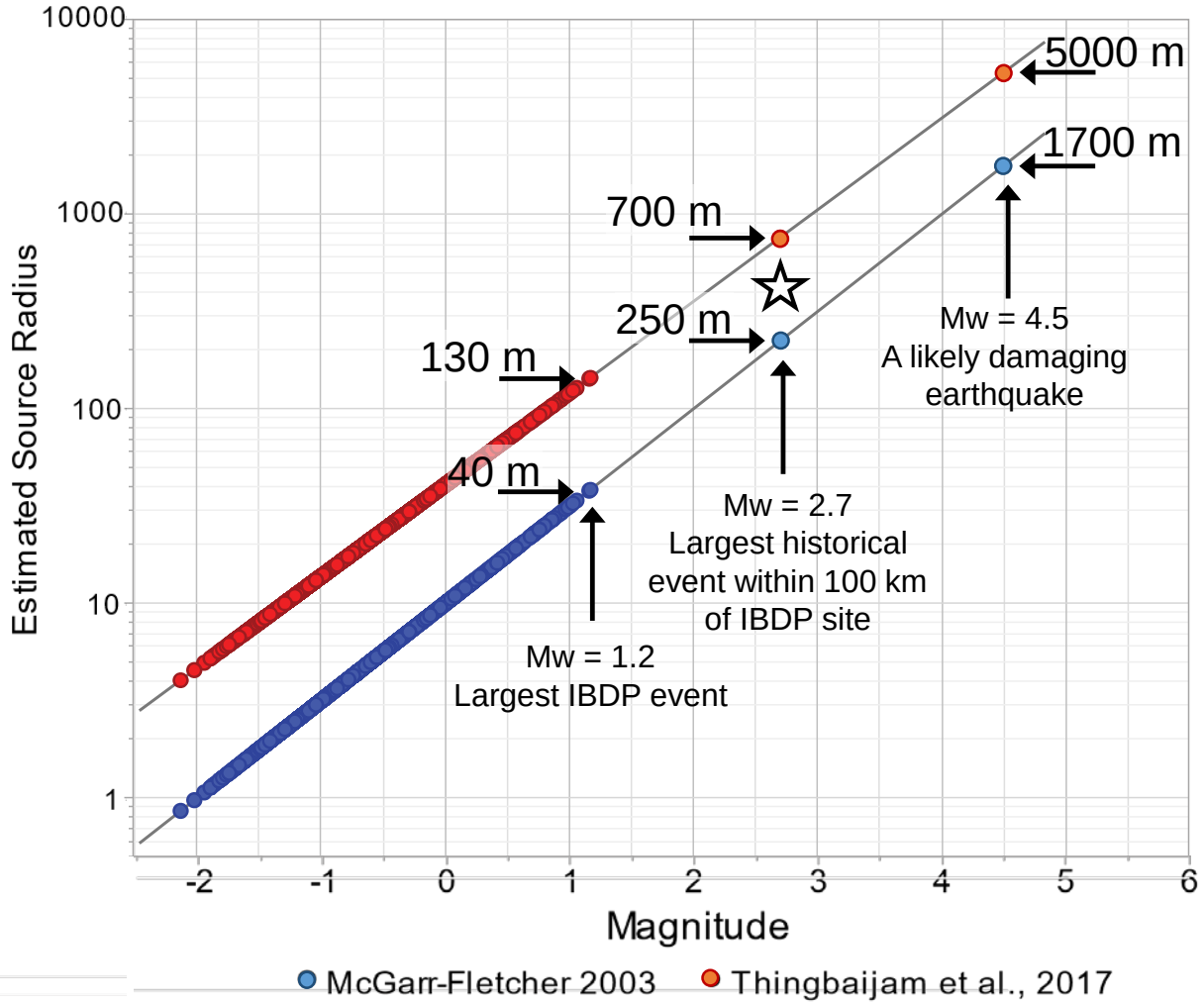




Map view with interpreted faults

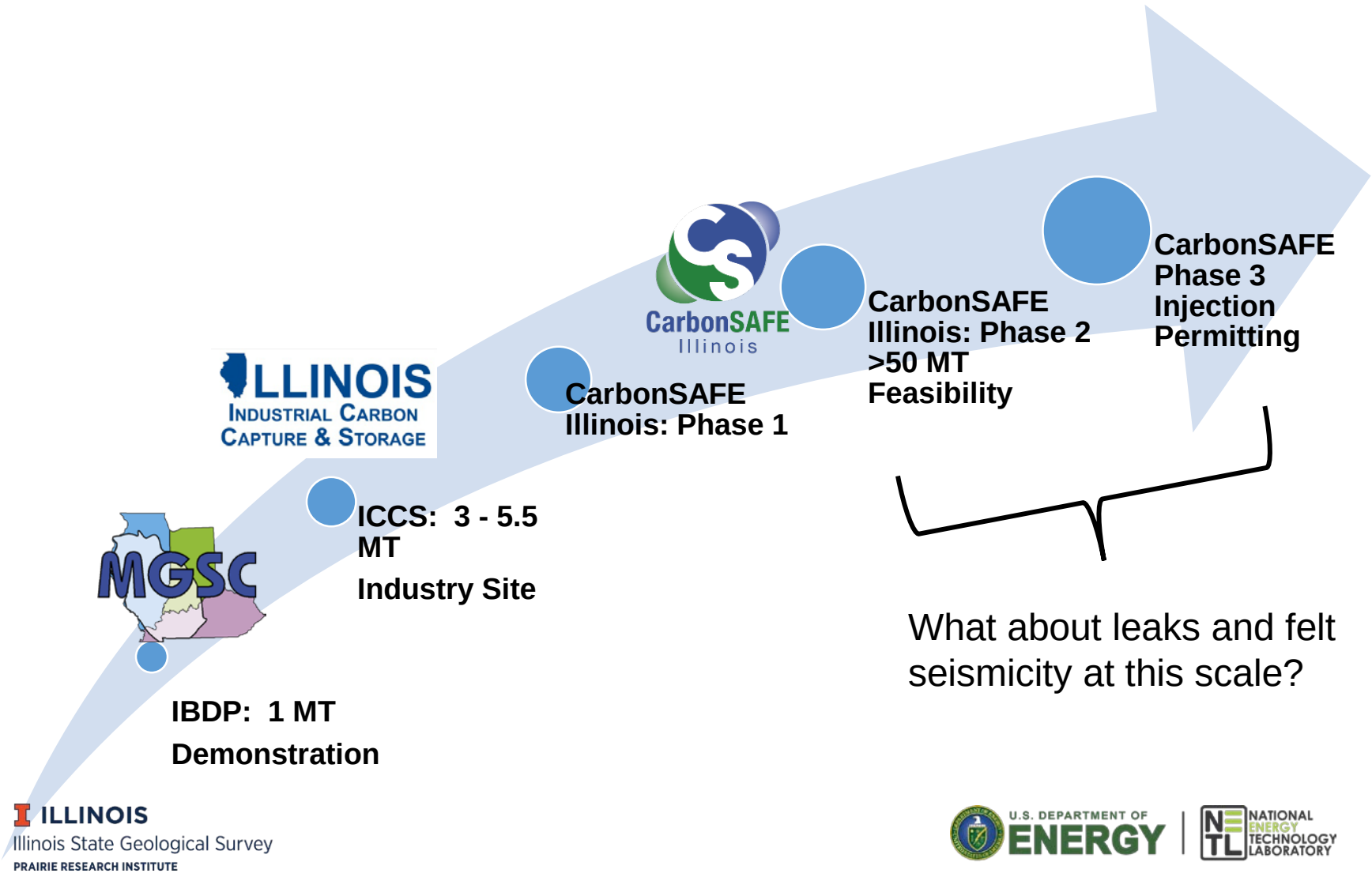
Seismic Line location

Estimated Source Radius



- Approx. 90% of events occur in Precambrian basement
- Lab-measured rigidity = *2.34x10^9 MPa*
- Source radius was estimated using published 2 different slip/moment relationships: $M = \mu AD$
- Estimated sizes are comparable to lengths of interpreted faults and lengths of seismicity clusters
- Historical EQ data suggests possible maximum for IBDP area

CCS Progression in Illinois Basin



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Comparing to Wastewater Injection

Location	Injection rate m^3/day	Injection period	Induced seismicity	Felt seismicity
IBDP CCS1 well[1]	1123	3 years	Yes (Mw -2.1 to 1.2)	No
IL-ICCS CCS2 well[1]	1950	3 years	Little (Mw -2 to 0.8)	No
East Texas[2]	2000	1 year or more	Yes (Mw 4.8)	Yes
Williston Basin[3]	3300	1 month or more	Some (Mw 1.4 to 2.8)	No
Arkansas[4]	2030	1 year or more	Yes	Yes
S. Texas (Eagle Ford)[5]	900	Several months	Yes	Yes

[1]Williams-Stroud et al., BSSA 2020
[2]Frolich, PNAS 2012
[3]Frolich et al., SRL 2015
[4]Horton, SRL 2012
[5]Frolich and Brunt, EPSL 2013

Subsurface injection – comparisons and issues

Wastewater disposal

- Volumes injected
  - 800 - 2000 m^3/day
- Associated induced seismicity
  - Felt events, Mw 5.7 in OK
- Groundwater contamination
  - Dispersal and dilution enough
  - Water-rock interaction
- Pore space needed to maintain injection without contaminating gw and causing earthquakes
  - ?
- Reservoir pressure increases linearly with H_2O injection

Carbon sequestration

- Volumes injected
  - CCS1 average 800 m^3/day
  - CCS2 average 1900 m^3/day
- No felt events
  - All detected events < Mw 2*
- Leak containment
  - Is top seal integrity sufficient?
  - Does microseismicity compromise topseal via faults?
- Reservoir pressure increase with CO_2 injection influenced by[1]:
  - $scCO_2$ behaves like gas
  - Dissolution
  - Water saturated with CO_2 denser than brine
  - Water-CO_2-rock interaction
  -
  -

[1]Vilarrasa and Carrera, PNAS 2015

Knowledge Gained from IBDP and IL-ICCS

- Impactful reservoir heterogeneity occurs at km scale
- Induced seismicity in basement – similar to other locations, but
  - Small faults consistent with small seismic events
  - Hydraulic or fluid connection to basement not guaranteed
- Large uncertainties for pre-injection fault identification
  - downside: not useful to identify reactivation risk
  - upside: it likely indicates lower induced seismicity risk
- Demonstration project provided advantage: pressure/stress data enabled applying learnings to subsequent well(s) to decide location and injection depth.
- Seismicity not closely tied to injection rates – the bigger impact appears to be horizontal to vertical permeability anisotropy. Vertical restriction due to stratigraphic architecture within the reservoir also inhibited pressure communication to the basement.

Acknowledgements

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- CarbonSAFE Illinois projects are funded by the U.S. Department of Energy through the National Energy Technology Laboratory
- The MRCI is a collaboration between Batelle, the University of Illinois, and geological surveys partners throughout the Northeast and Midwest

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