Midwest Geological Sequestration Consortium

# A Demonstration of Carbon Dioxide Storage at a Biofuel Facility in Decatur, Illinois USA: The Illinois Basin – Decatur Project (IBDP)


## Robert J. Finley and the MGSC Project Team

Midwest Geological Sequestration Consortium



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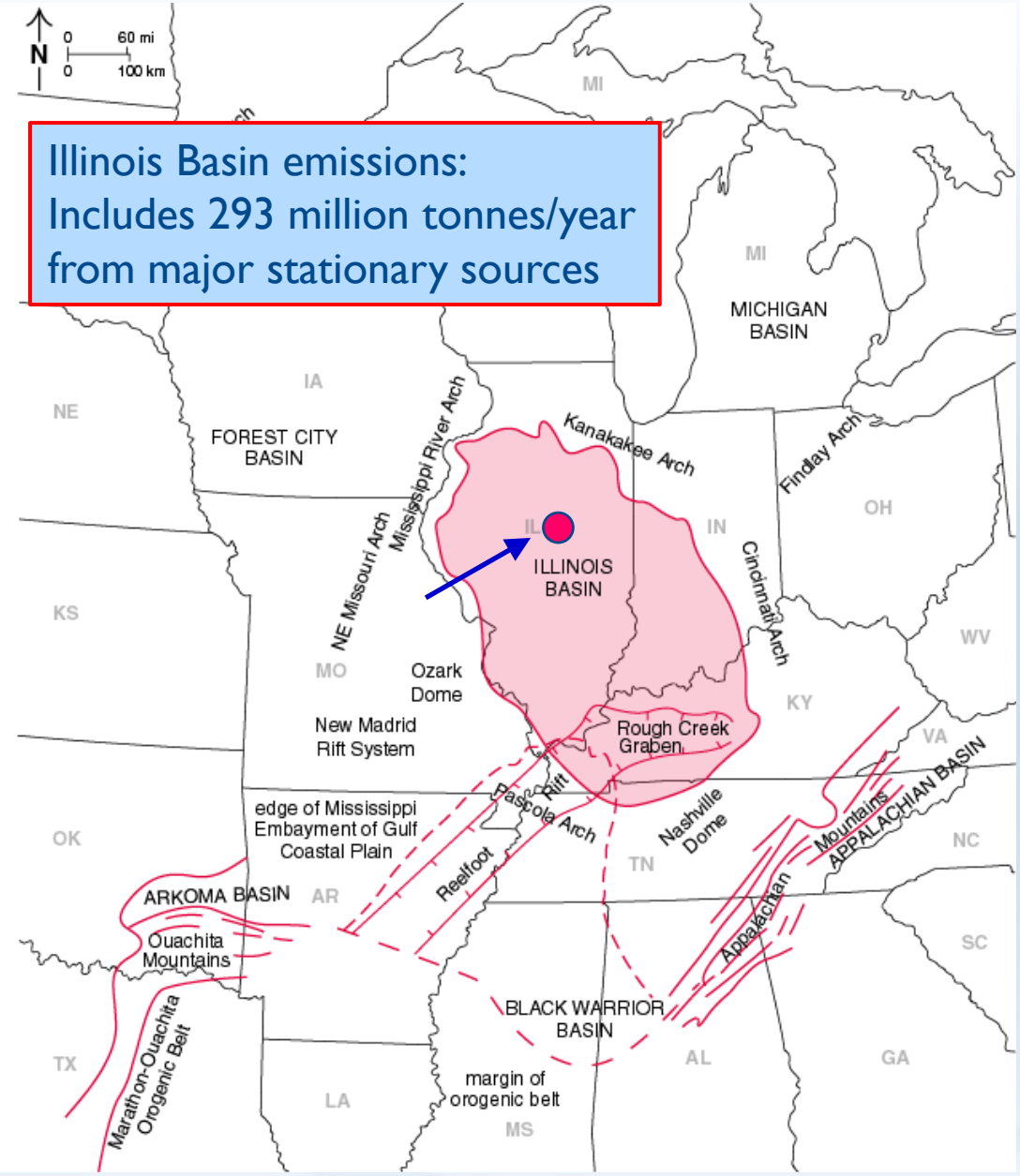
# Acknowledgements


- The Midwest Geological Sequestration Consortium is funded by the U.S. Department of Energy through the National Energy Technology Laboratory (NETL) via the Regional Carbon Sequestration Partnership Program (contract number DE-FC26-05NT42588) and by a cost share agreement with the Illinois Department of Commerce and Economic Opportunity, Office of Coal Development through the Illinois Clean Coal Institute.
- The Midwest Geological Sequestration Consortium (MGSC) is a collaboration led by the geological surveys of Illinois, Indiana, and Kentucky, USA
- Landmark Graphics software via University Donation Program and Petrel* E&P software platform via Schlumberger Carbon Services are gratefully acknowledged *Mark of Schlumberger




# Illinois Basin – Decatur Project Scope

A collaboration of the Midwest Geological Sequestration Consortium, the Archer Daniels Midland Company (ADM), Schlumberger Carbon Services, and other subcontractors to inject 1 million metric tons of anthropogenic carbon dioxide at a depth of 7,000 +/- ft (2,000 +/- m) to test geological carbon sequestration in a saline reservoir at a site in Decatur, IL

# Illinois Basin Emissions Profile

## Annual $CO_2$ Emissions from 293 Major Industrial Stationary Sources (million metric tons)

| Source | Tonnes | Percent |
|---|---|---|
| 293 sources | 291 million | 100 |
| 84 fossil-fueled electric generators | 241 million | 82.7 |
| 45 coal-fired electric generators | 228 million | 78.4 |
| 20 ethanol plants | 13.4 million | 4.6 |

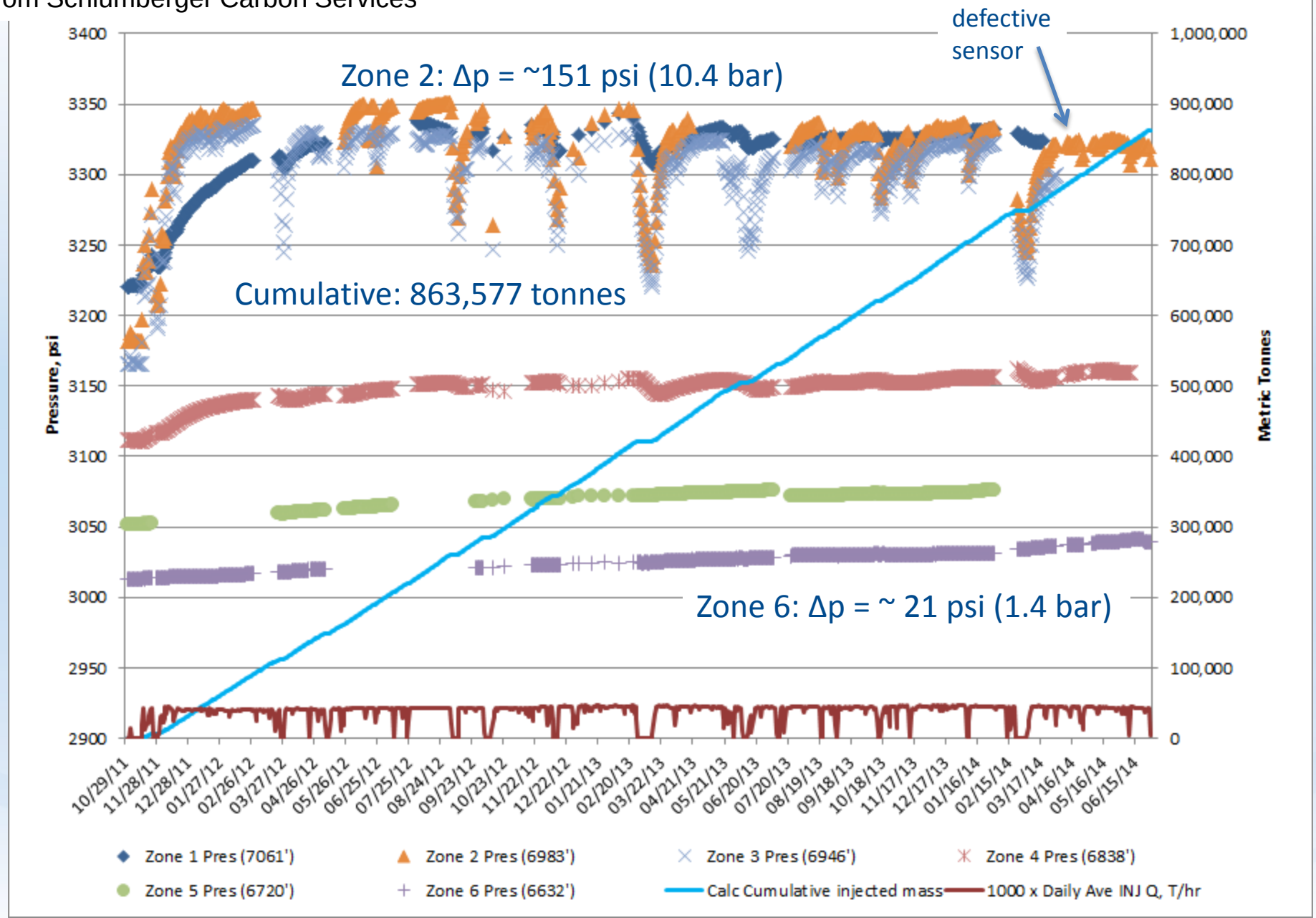
# Operational Injection: 17 November 2011

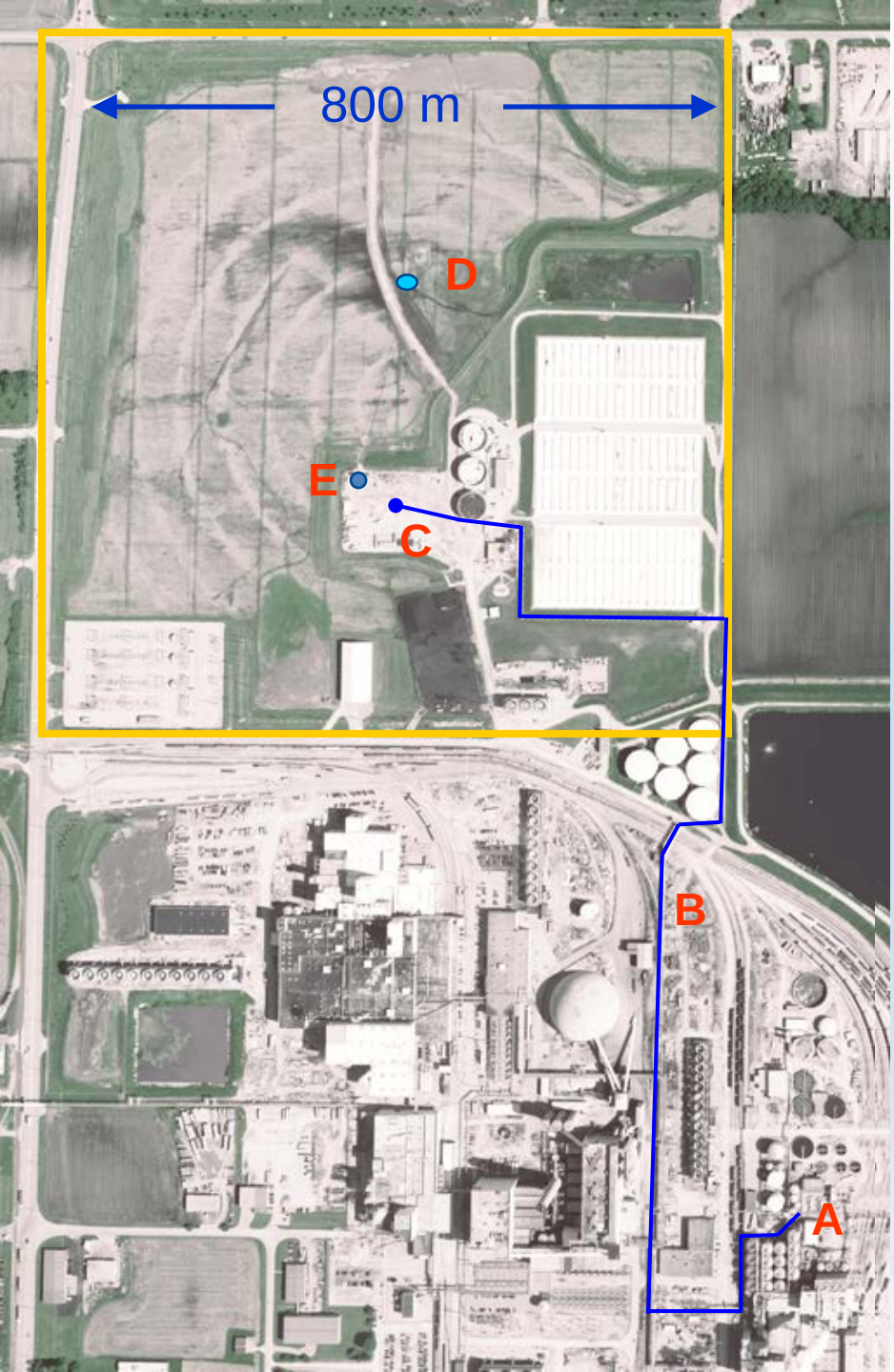
- IBDP fully operational 24/7
- IBDP is the first 1 million tonne carbon capture and storage project from a biofuel facility in the US
- Injection through November 2014
- Intensive post-injection monitoring under MGSC through November 2017

Cumulative Injection (7 August 2014): 900,554 tonnes

# Verification Well Monitoring Data (update to 7/1/14)

from Schlumberger Carbon Services






# Illinois Basin – Decatur Project Site (on ADM industrial site)

- A Dehydration/ compression facility location
- B Pipeline route (1.9 km)
- C Injection well site
- D Verification/ monitoring well site
- E Geophone well

# IBDP Environmental Monitoring Framework

## Near Surface

### Atmosphere

- Eddy covariance
- Meteorological conditions
- Ambient $CO_2$ for HHS
- Tunable diode laser for $CO_2$

### Soil/vadose zone

- CIR aerial imagery
- InSAR and GPS
- Soil gases
- Soil $CO_2$ flux
- Tunable diode laser for $CO_2$

### Shallow groundwater

- Geophysical surveys
- Geochemical sampling
- P/T monitoring

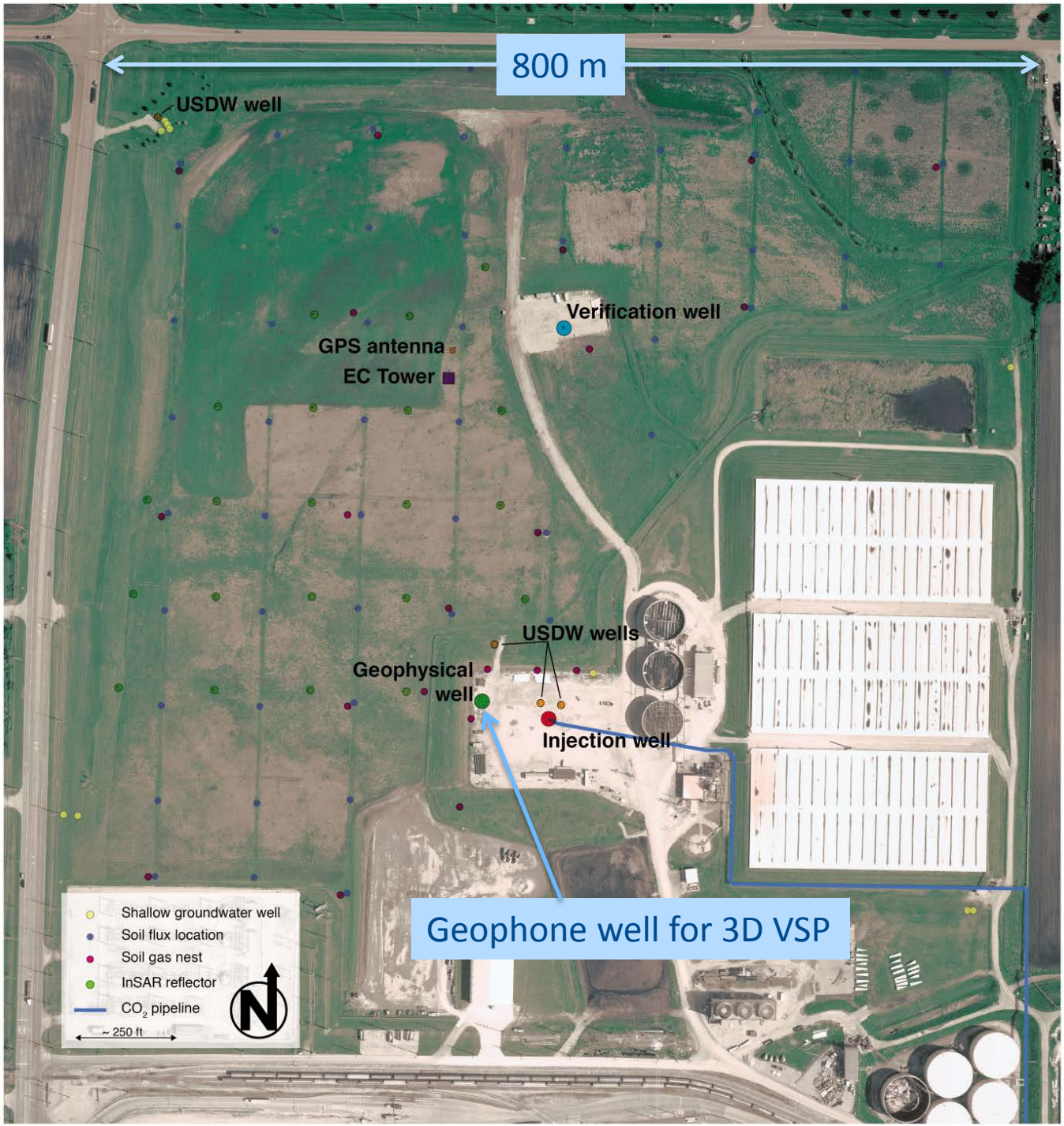
## Deep Subsurface

### Above seal

- Geophysical surveys
- Geochemical sampling
- P/T monitoring

### Injection zone

- Geophysical surveys
- Geochemical sampling
- P/T monitoring




# Near-Surface Monitoring Locations

- 17 groundwater wells, 4 permit-required
- 110 soil flux rings
- 21 InSAR reflectors
- 1 air monitoring site

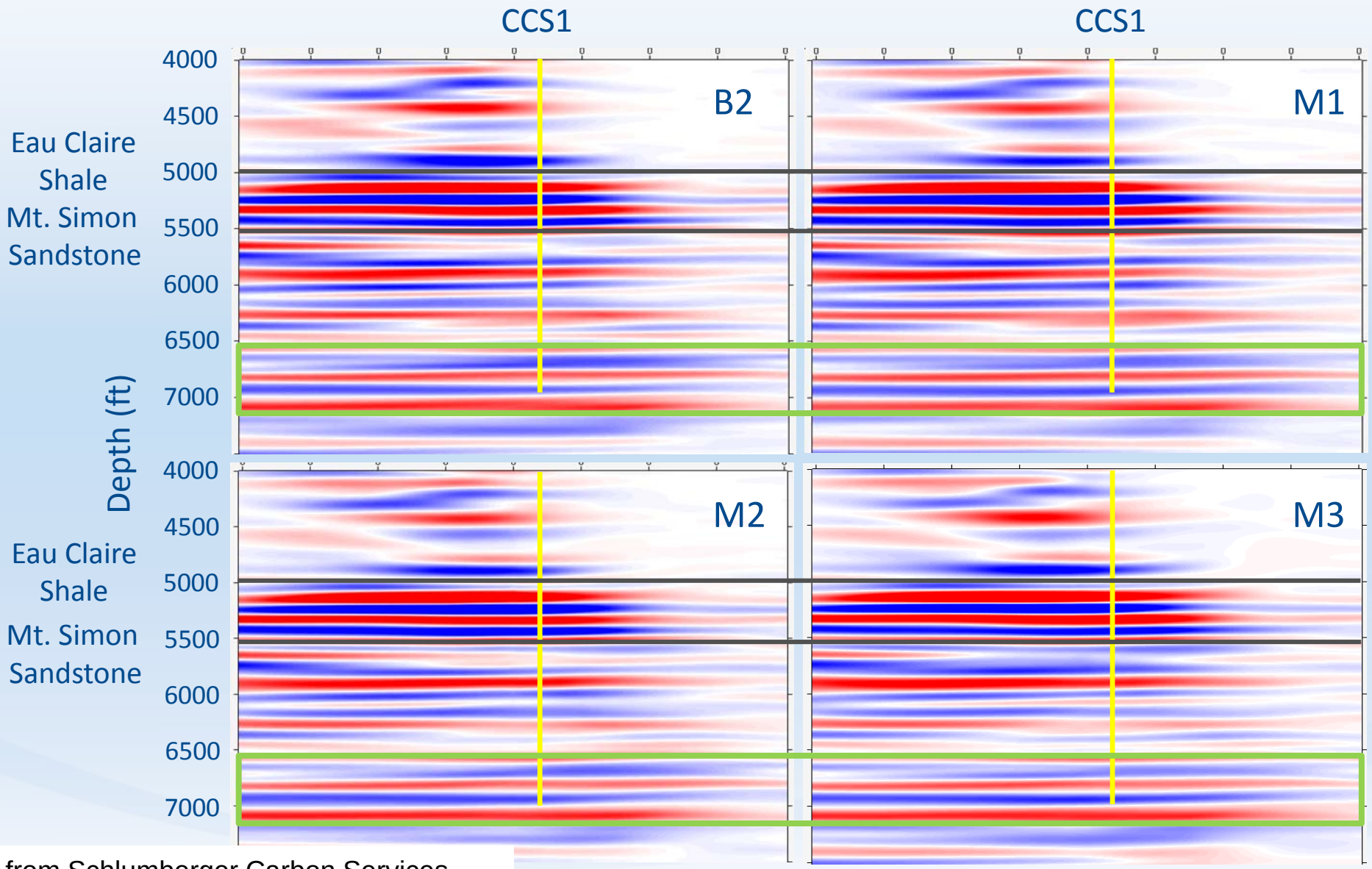
# 3D Vertical Seismic Profiles for Plume Monitoring

# Five 3D Vertical Seismic Profiles Acquired

| 3D VSP Survey Name | Survey Date | Ground Conditions | Vibrator Sweep | Repeated Shots | Volume of $CO_2$ Injected |
|---|---|---|---|---|---|
| Baseline 1 (B1) | January 2010 | Wet | 2 – 100 Hz | | |
| Baseline 2 (B2) | April 2011 | Dry | 8 – 120 Hz | | 0 |
| Monitor 1 (M1) | February 2012 | Frozen dry | 8 – 120 Hz | 467 | ~74,000 tonnes |
| Monitor 2 (M2) | April 2013 | Damp | 8 – 120 Hz | 385 | ~433,000 tonnes |
| Monitor 3 (M3) | February 2013 | Frozen | 8 – 120 Hz | 384 | ~730,000 tonnes |

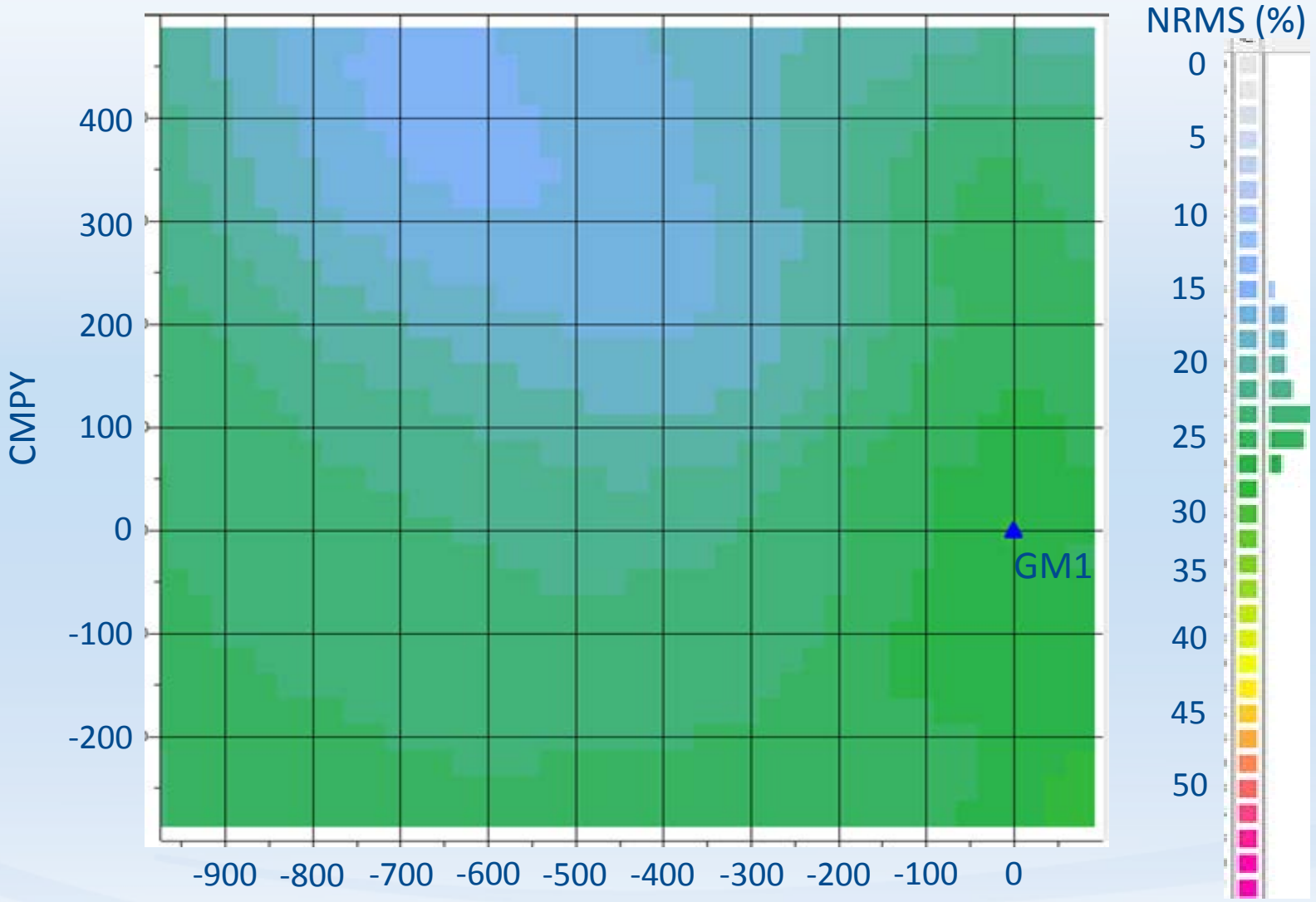
from Schlumberger Carbon Services

# Comparison of the 3D VSP Surveys




from Schlumberger Carbon Services

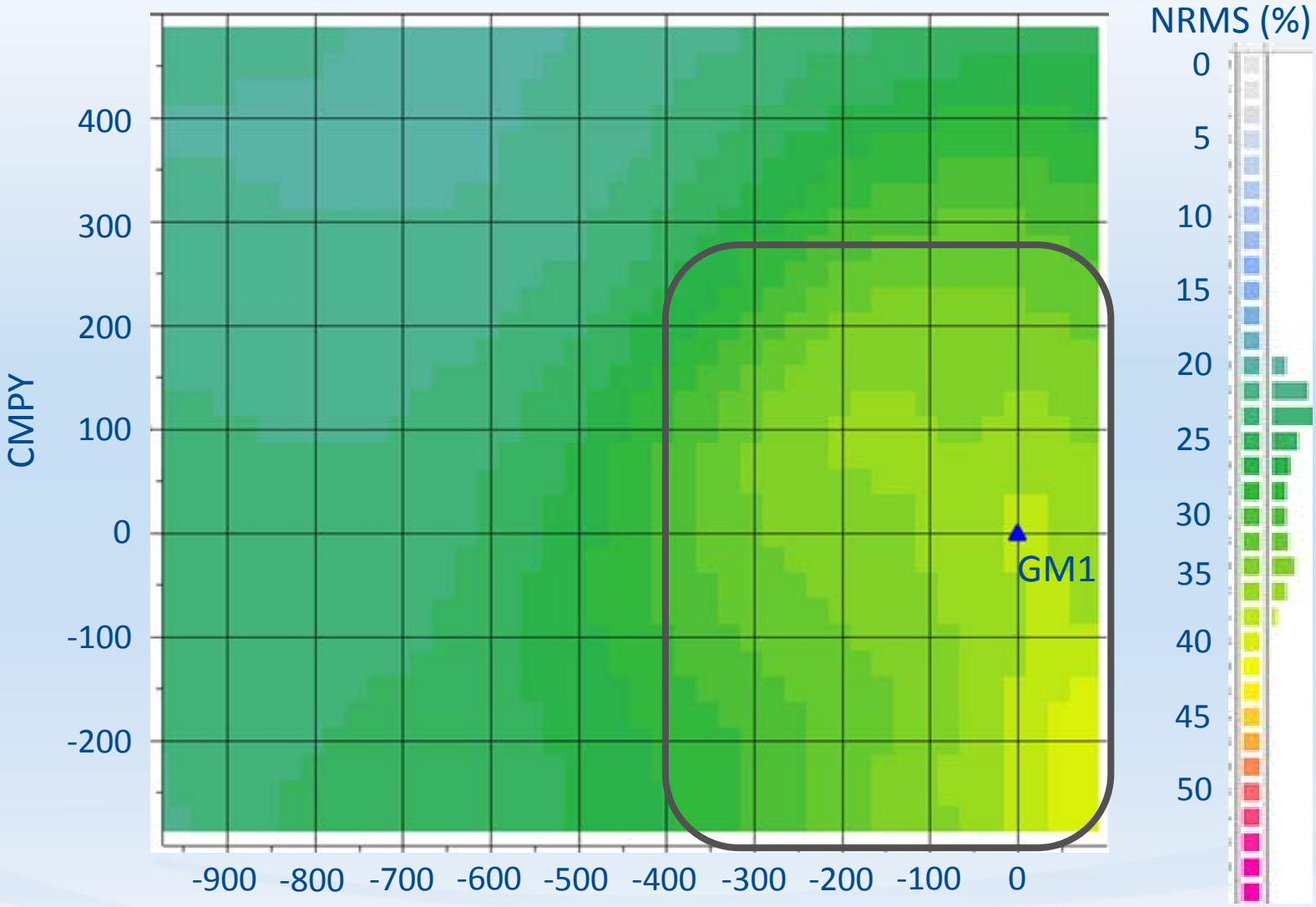
# NRMS Maps: M1 Mid- to Lower Mt. Simon Sandstone (6500 – 7200 ft)




~74,000 tonnes $CO_2$ injected

from Schlumberger Carbon Services

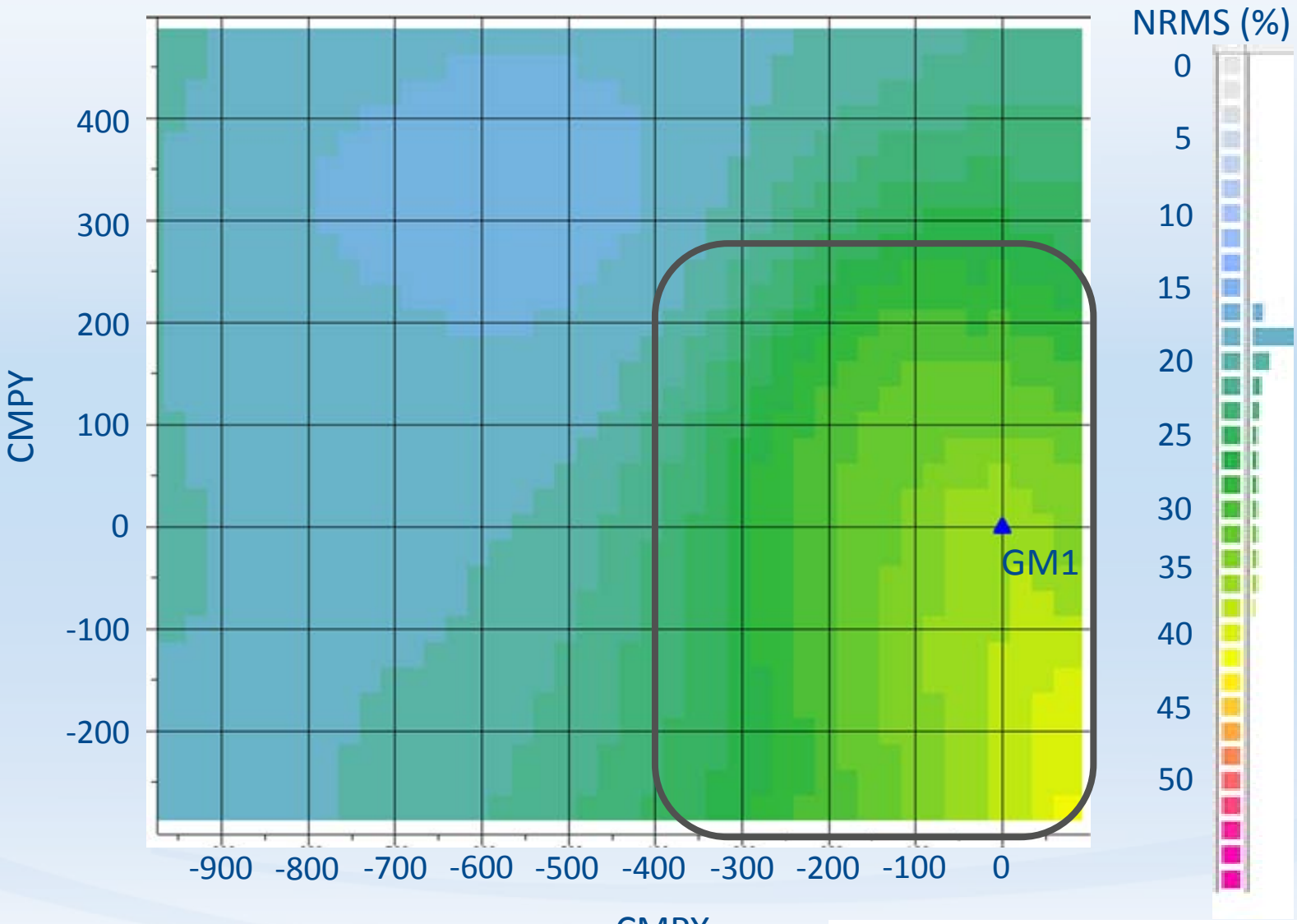
# NRMS Maps: M2 Mid- to Lower Mt. Simon Sandstone (6500 – 7200 ft)




~433,000 tonnes $CO_2$ injected

from Schlumberger Carbon Services

# NRMS Maps: M3 Mid- to Lower Mt. Simon Sandstone (6500 – 7200 ft)




~730,000 tonnes $CO_2$ injected

from Schlumberger Carbon Services

# Time-lapse 3D VSP Data Conclusions

- Time-lapse effects from the injected $CO_2$ can clearly be seen in the NRMS repeatability metric
  - Footprint and magnitude of the anomaly have increased with time through the injection interval
- Time-lapse 3D VSP data gives a sense of the aerial extent of the bulk of the $CO_2$ plume
  - Thin or low $CO_2$ saturation stringers are not being imaged
- Further constraint can be put on the vertical extent of the plume through integration with time-lapse well logging and pressure data
- Likely there is more time-lapse noise in the M2 survey as it was acquired in different ground conditions than the other surveys
  - Processing optimized the results for the B2, M1, and M3 surveys

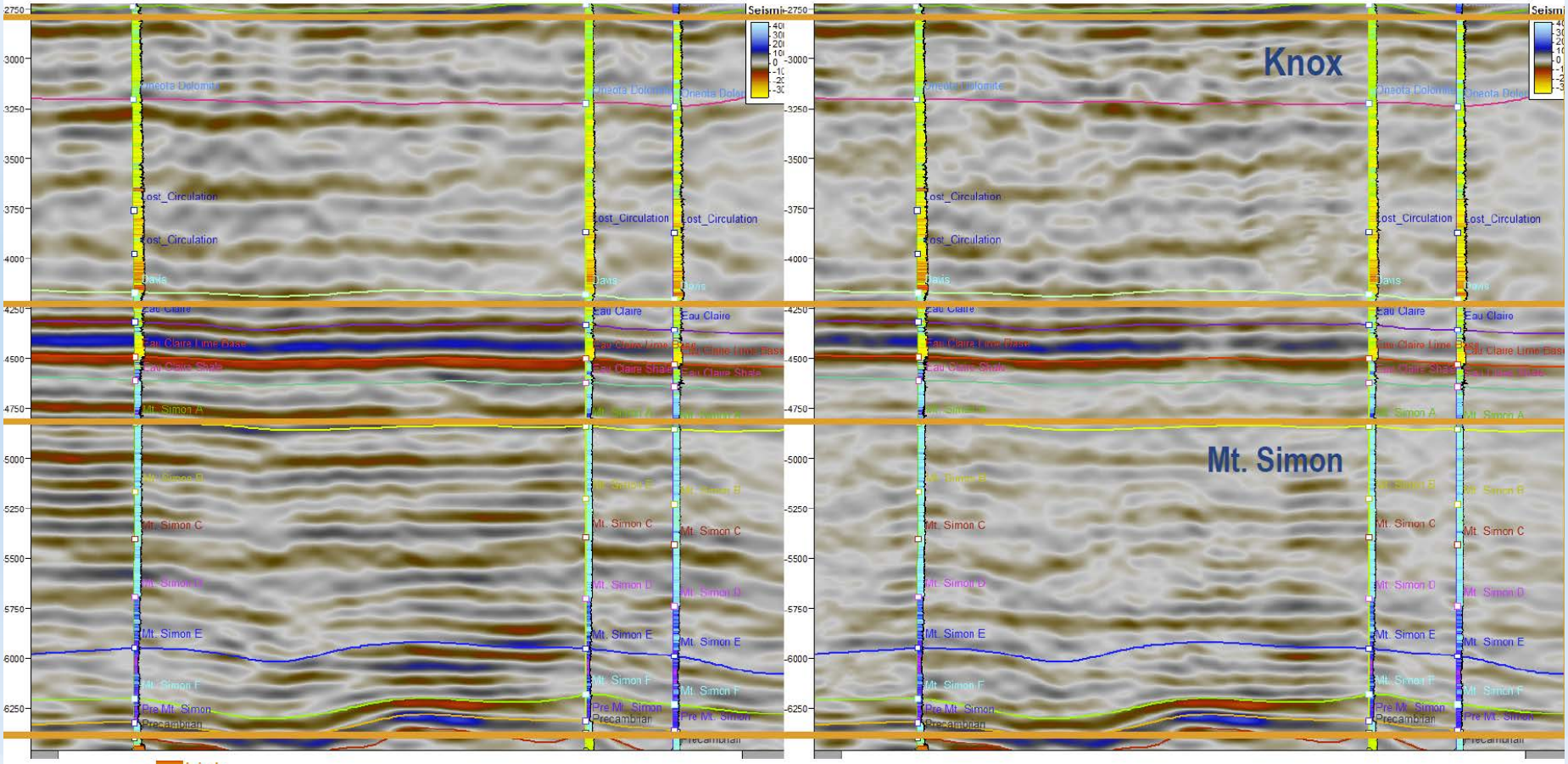
# Surface 3D Seismic Processing and Inversion for Porosity

# Seismic - Before and After Multiple Attenuation

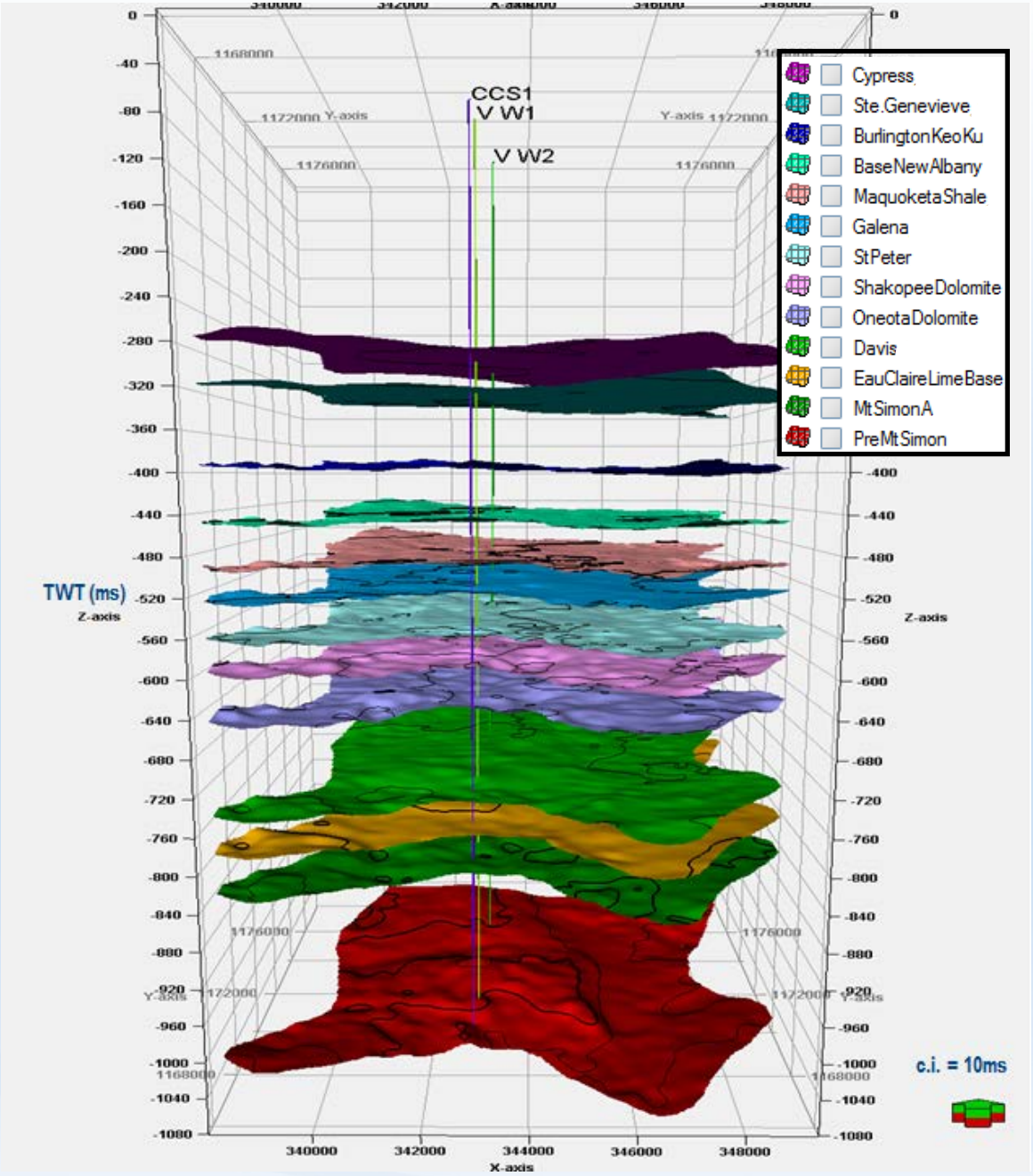
Schlumberger
Carbon Services

Zero Phase Data

(Zero Phase Data)
Multiple Attenuation




3D Surface Seismic Survey Acquired January 2010



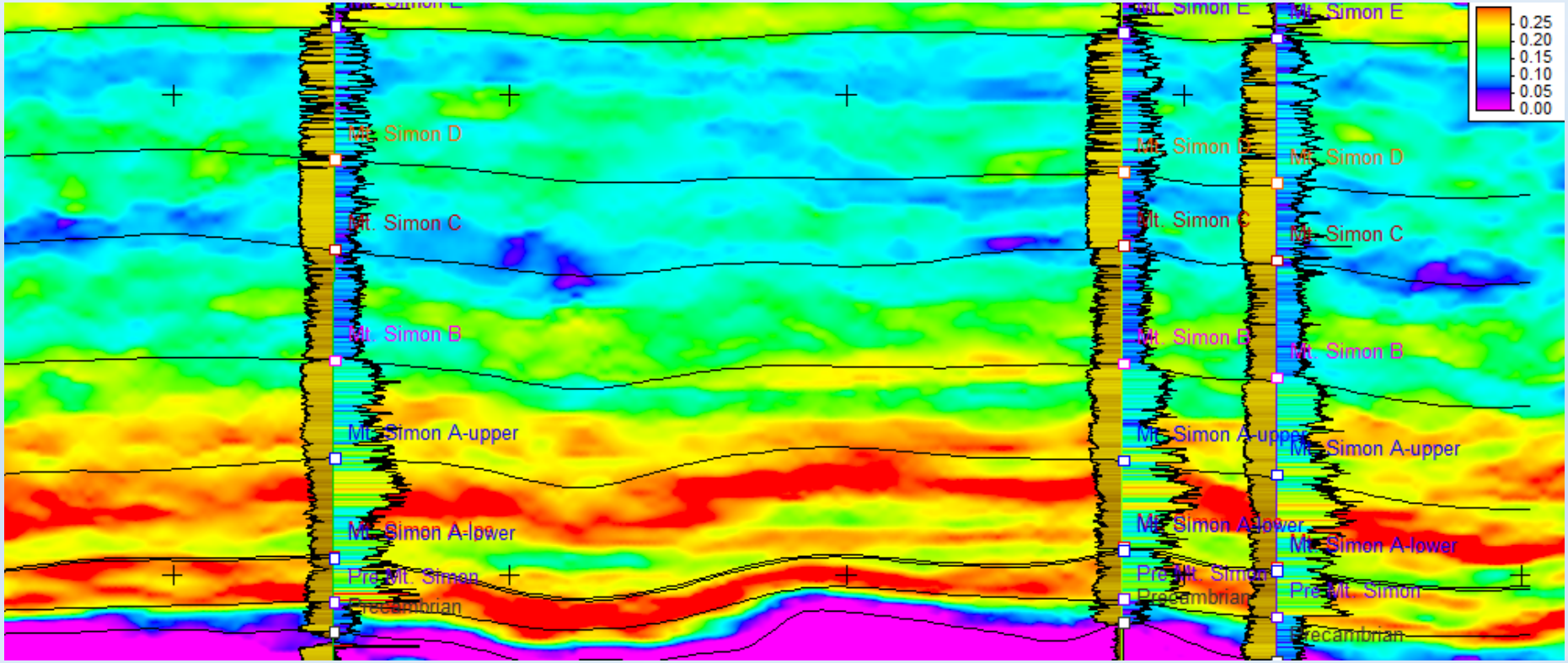

# 3D Image of Surfaces used in the Velocity Model

Used second check shot survey in VW2 well

Strong reflectors from the Cambrian into the Mississippian

# Seismic Inversion for Porosity

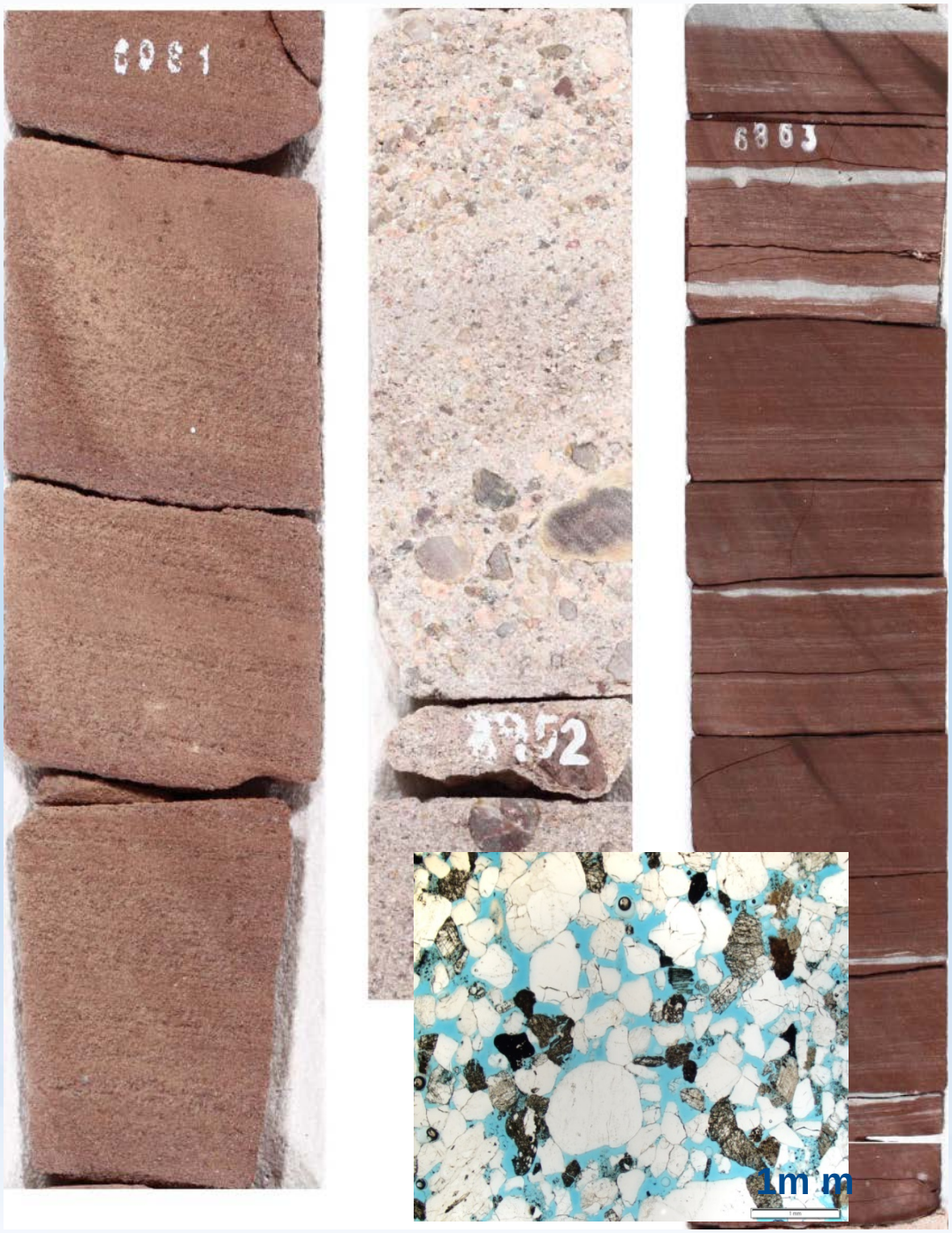
North VW2 VW1 CCS1 South




(after removal of multiples)

from Schlumberger Carbon Services

# Reservoir Quality Assessment

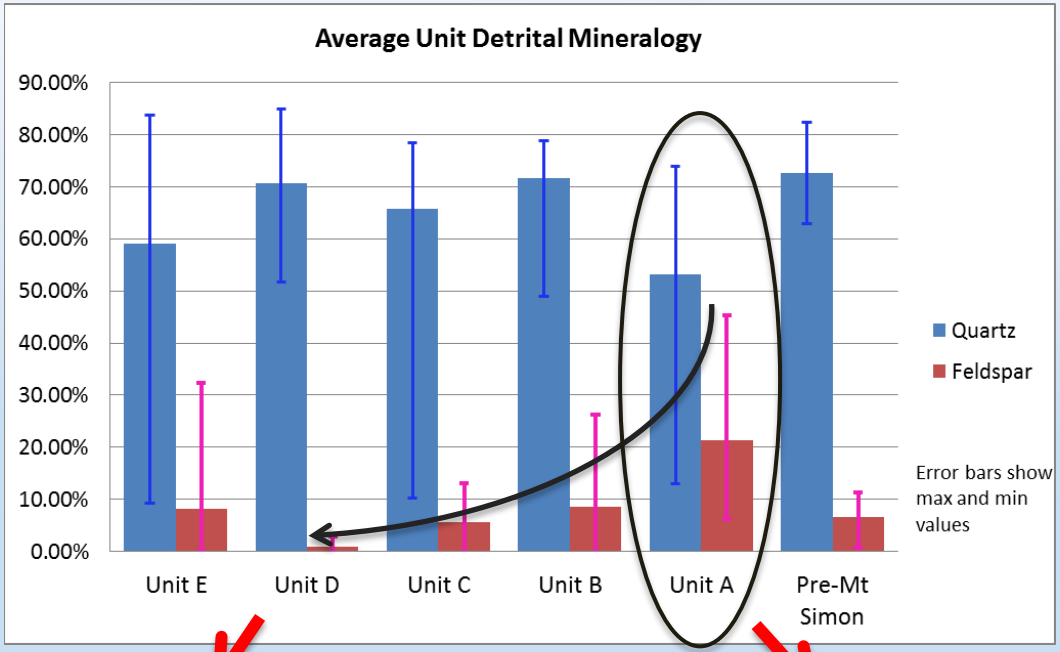



# Lower Mt. Simon Fluvial Deposits

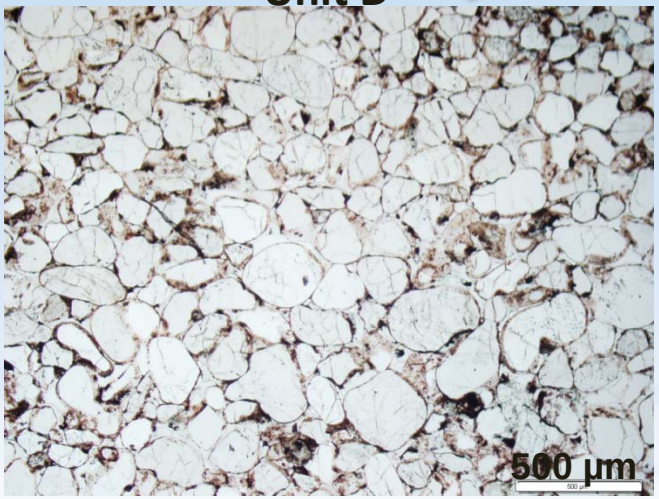
- Braid Plain and alluvial fan deposits; poorly to mod. sorted, cross-bedded sandstone to pebble conglomerate. Porosity up to 30% and 500mD permeability

- Fluvial flood plain and playa deposits; planar and ripple laminated mudstones and siltstones. Tight and impermeable

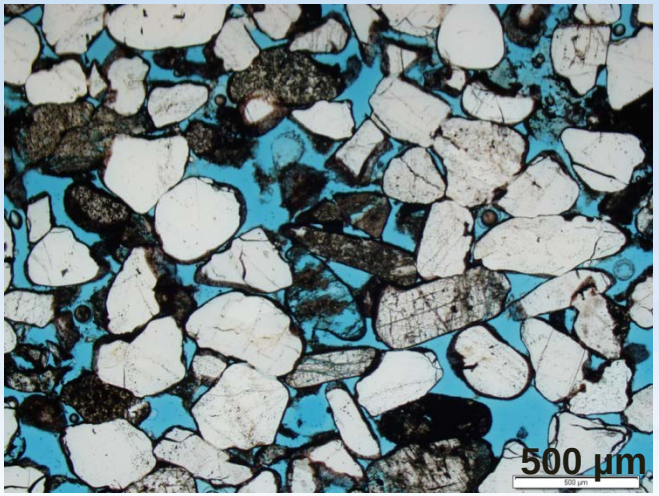
# Mt. Simon Unit Mineralogy



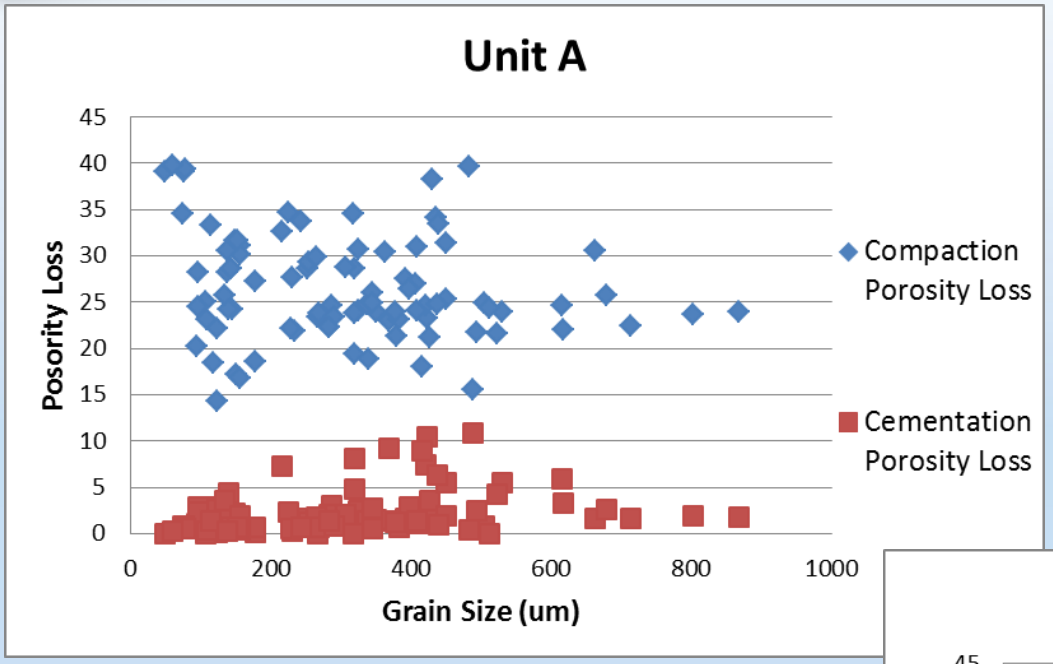

Unit D




Unit A

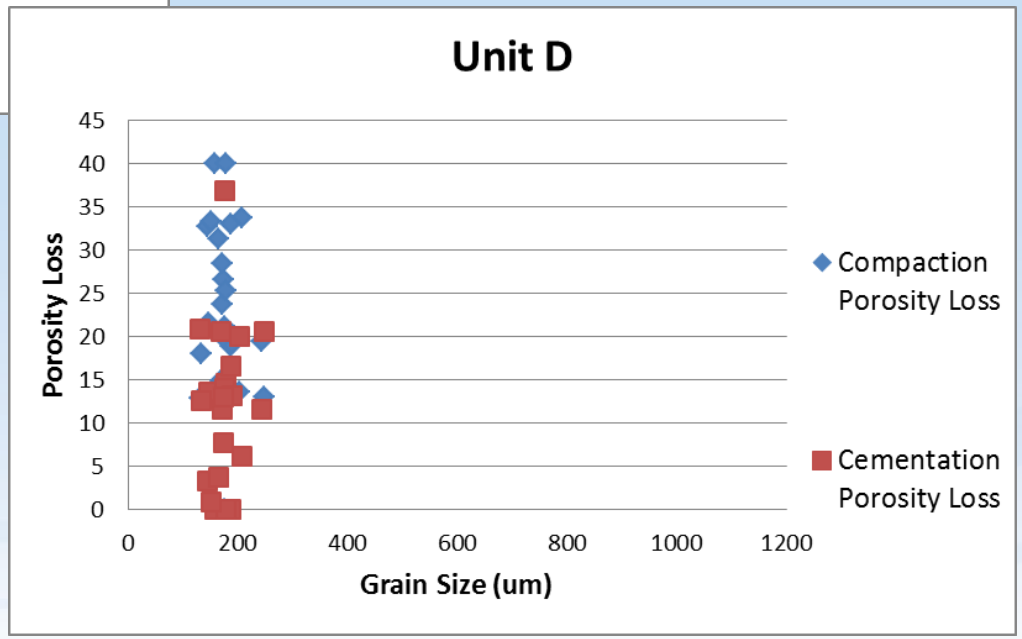


# Controls on Mt. Simon Reservoir Quality




Poorly sorted, immature, fluvial

Well sorted, mature, eolian



# Mt. Simon Depositional and Diagenetic Summary

## Unit A

- Fluvial Deposit
- Arkosic Arenite
- Poorly Sorted
- Highly Compacted
- Secondary Porosity (Feldspar Dissolution)
- Clay Grain Coatings
- Low Cementation
- High Porosity and Permeability

## Unit D

- Eolian Deposit
- Quartz Arenite
- Well-Sorted
- Highly Compacted
- Well Cemented (Quartz)
- Low Porosity and Permeability

# Mt. Simon Depositional and Diagenetic Summary

## Unit A

- Fluvial Deposit
- Arkosic Arenite
- Poorly Sorted
- Highly Compacted
- Secondary Porosity (Feldspar Dissolution)
- Clay Grain Coatings
- Low Cementation
- High Porosity and Permeability

Reservoir

## Unit D

- Eolian Deposit
- Quartz Arenite
- Well-Sorted
- Highly Compacted
- Well Cemented (Quartz)
- Low Porosity and Permeability

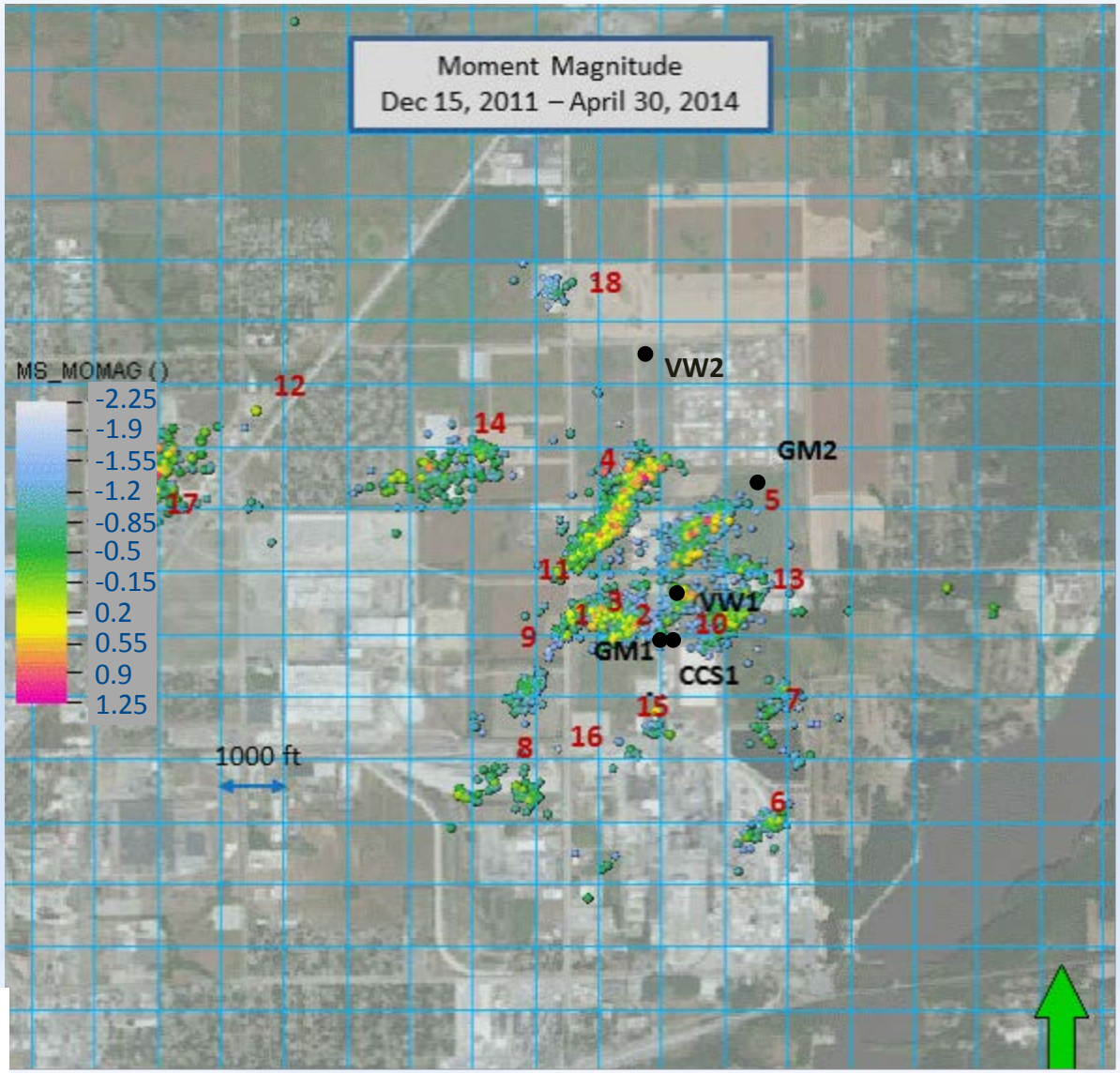
Baffle

# Microseismic Activity

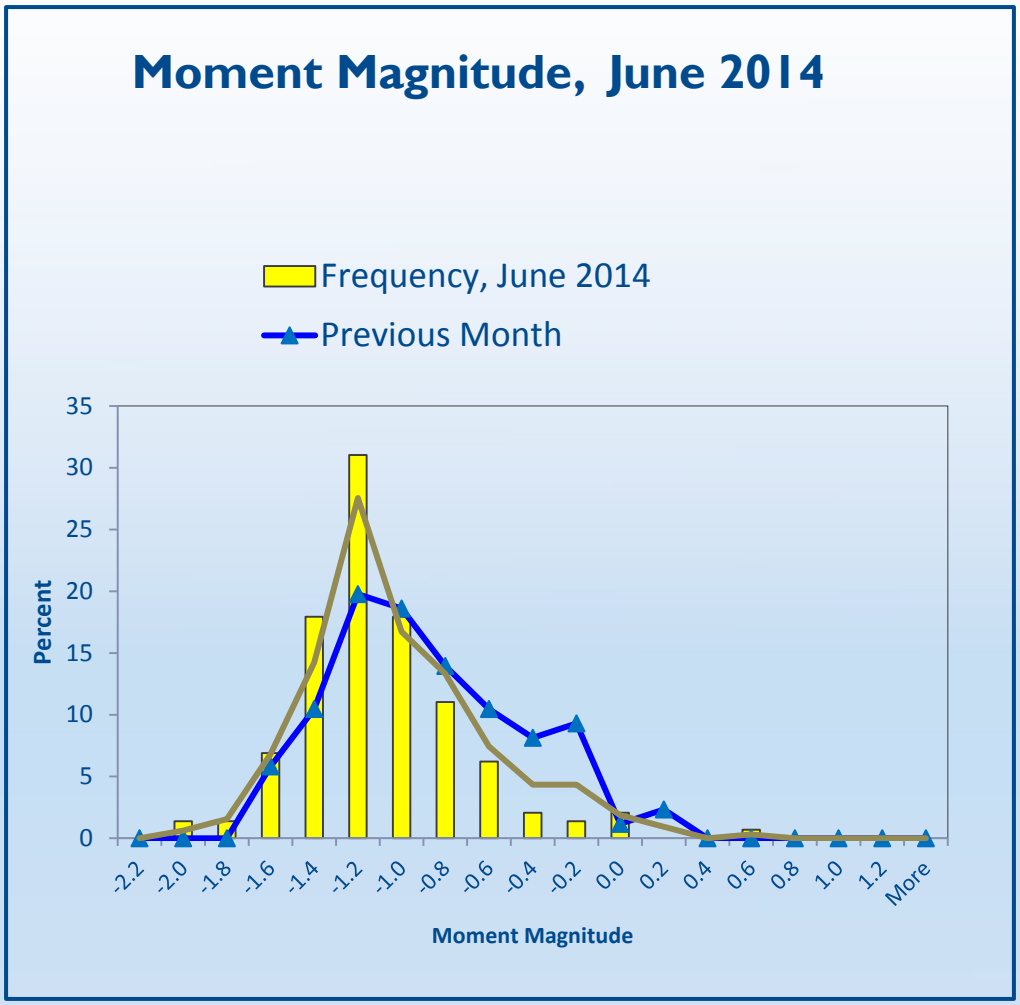
# Microseismic Activity: Overview

- Continual improvements have been made to the velocity model
  - October 2012: Acquisition of a far offset perforation shot
  - June 2013: Addition of anisotropy to the model
  - February 2014: New surface-based orientation shots for all arrays
  - April 2014: Inclusion of shallow velocities above 350 ft
- Microseismic events:
  - Magnitudes range from -2.14 to 1.14
  - Locations determined using geophone arrays in CCS1, GM1, and VW2
  - More events are being detected with the addition of the array in VW2
  - Form distinct clusters
  - Distributed between Lower Mt. Simon Sandstone, Pre-Mt. Simon Unit, and Precambrian basement
- Events are processed and delivered on a monthly basis

# Microseismic Cluster Activity: Cluster Locations in Relation to Surface Features




from Schlumberger Carbon Services



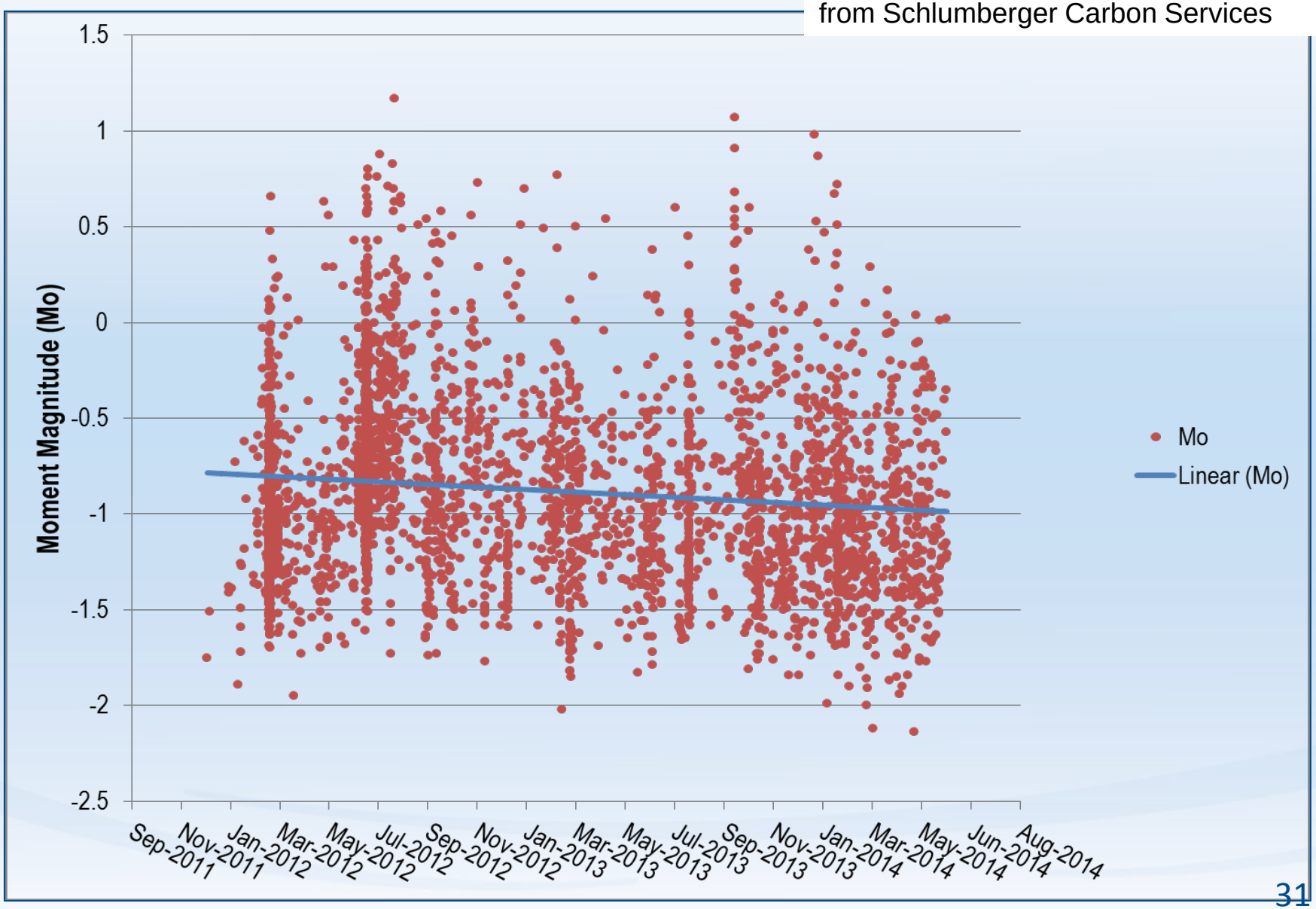

# Microseismic Activity Centered Around Magnitude -1.0 to -1.4

| | Detected | Located | Mean | StDev | Max |
|---|---|---|---|---|---|
| June-2014 | 426 | 145 | -1.20 | 0.38 | 0.54 |
| Prev. Month | 330 | 86 | -0.99 | 0.43 | 0.02 |
| 3-Month Avg. | 350 | 108 | -1.11 | 0.41 | 0.20 |

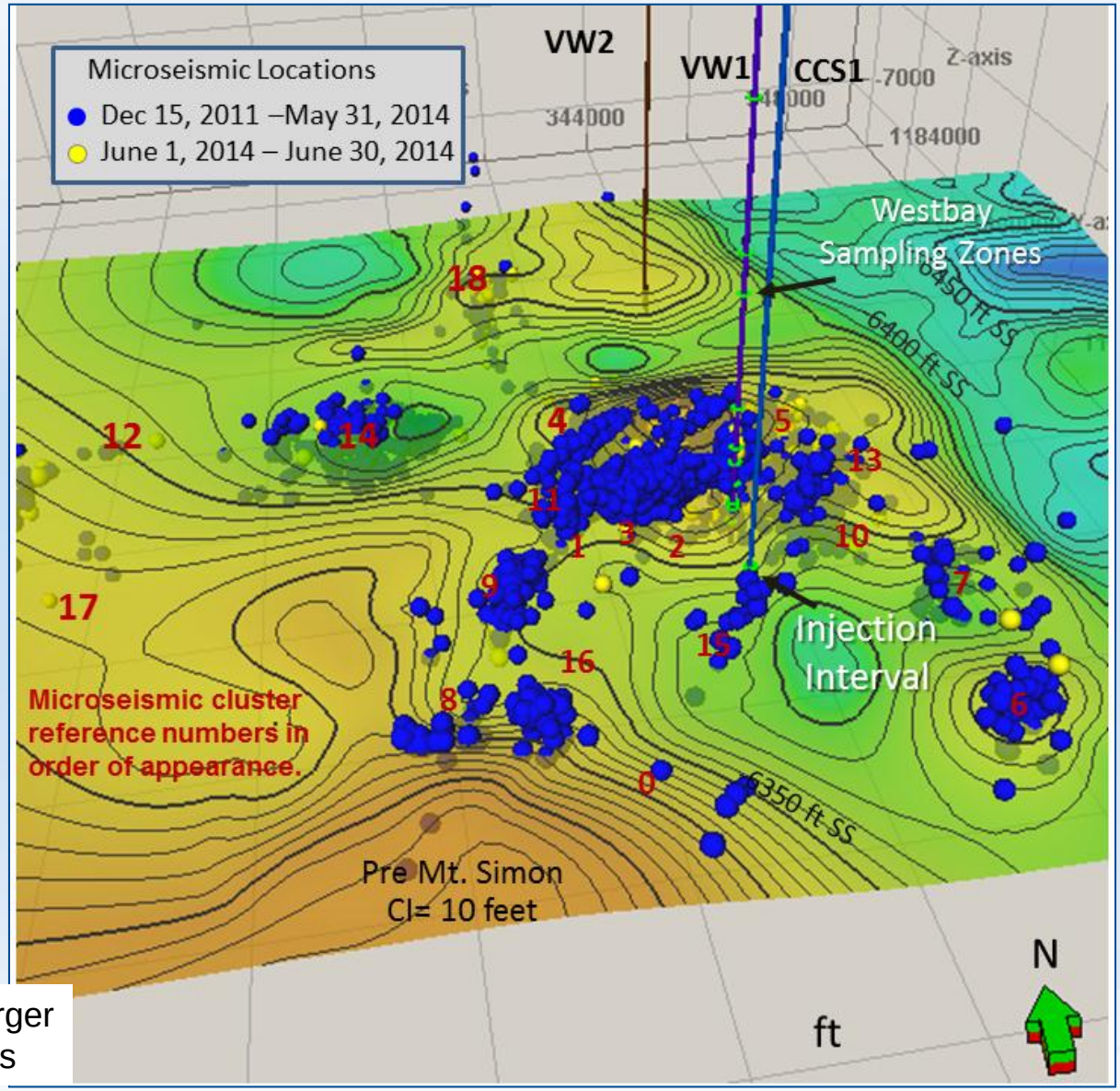
from Schlumberger Carbon Services

# General Trends in Activity: Moment Magnitudes vs. Time

from Schlumberger Carbon Services



# Microseismic Cluster Activity: Relationship to Pre-Mt. Simon Structure

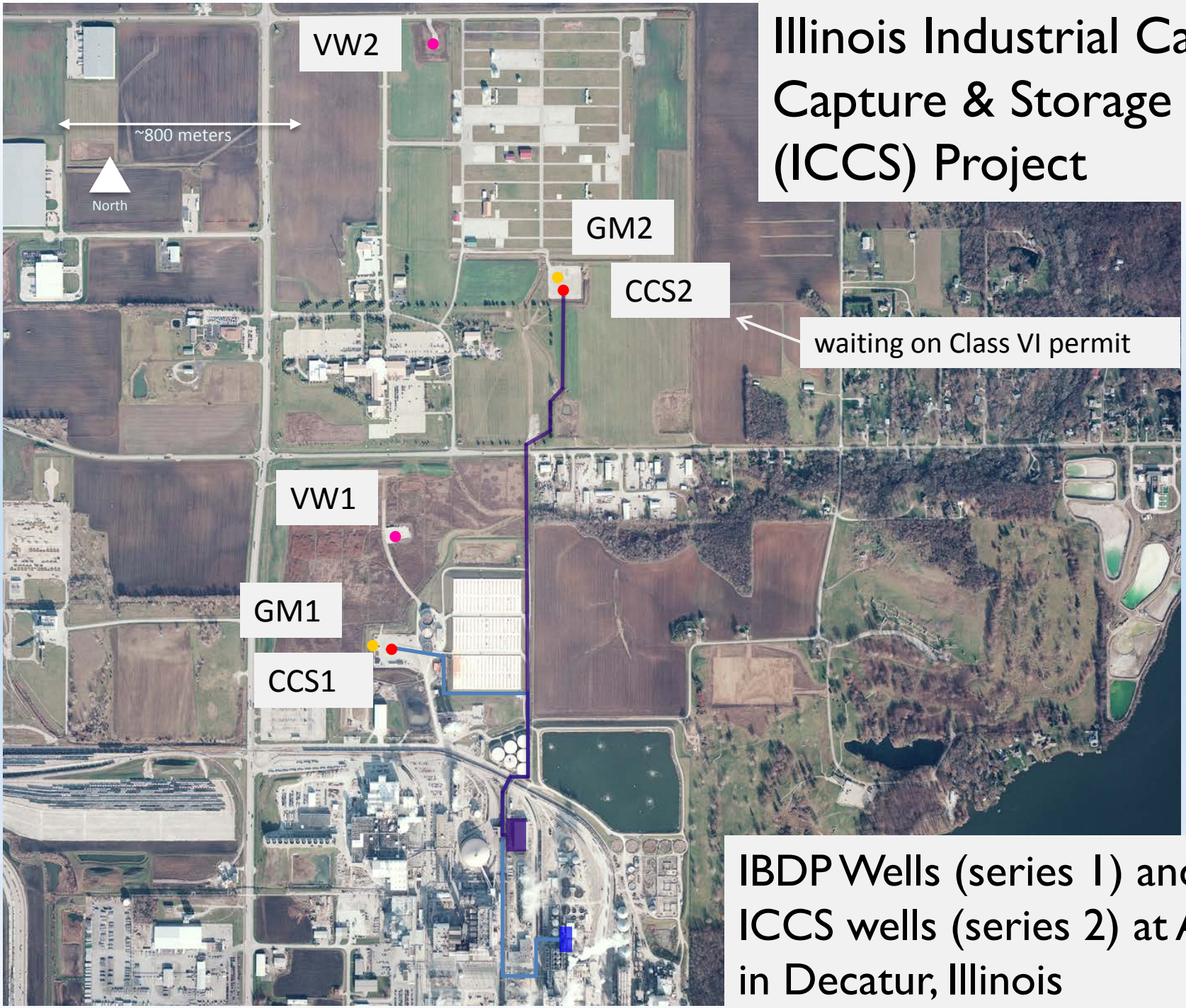



from Schlumberger Carbon Services

# Key Operational Results – IBDP at 90+% of Injection Completed

- Mount Simon Sandstone reservoir is accepting $CO_2$ more easily than expected resulting in quicker detection at verification well
- Upward plume growth limited by reservoir permeability stratification, as modeled, and confirmed by pressure observations
- Resulting plume believed thinner than expected and was not detected with a 3D vertical seismic profile until April 2013
- Mt. Simon 200,000 ppm brine is more corrosive than expected
- With >900,000 tonnes injected, $CO_2$ remains in lowermost Mt. Simon; internal reservoir heterogeneity affecting $CO_2$ distribution
- Second project (ICCS) will add opportunity to monitor assess larger-volume injectivity and reservoir response

# Illinois Industrial Carbon Capture & Storage (ICCS) Project




IBDP Wells (series 1) and ICCS wells (series 2) at ADM in Decatur, Illinois

MGSC

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ADM

Schlumberger Carbon Services

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