Development and Implementation of a Monitoring Plan at a 1-million Tonne CCS Demonstration: Decatur, Illinois USA

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CSLF Rome, Italy
18 April 2013

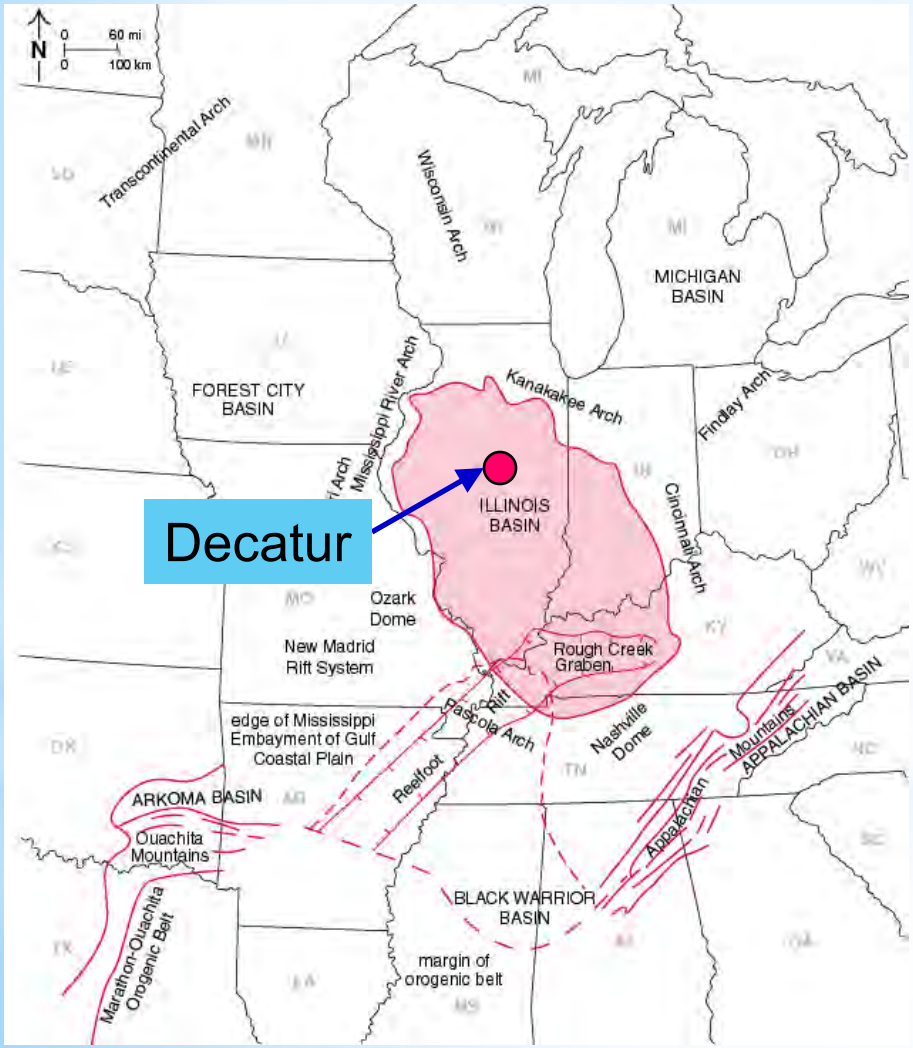
ILLINOIS STATE GEOLOGICAL SURVEY
PRAIRIE RESEARCH INSTITUTE

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
- 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

MGSC Illinois Basin-Decatur Project (IBDP) Site

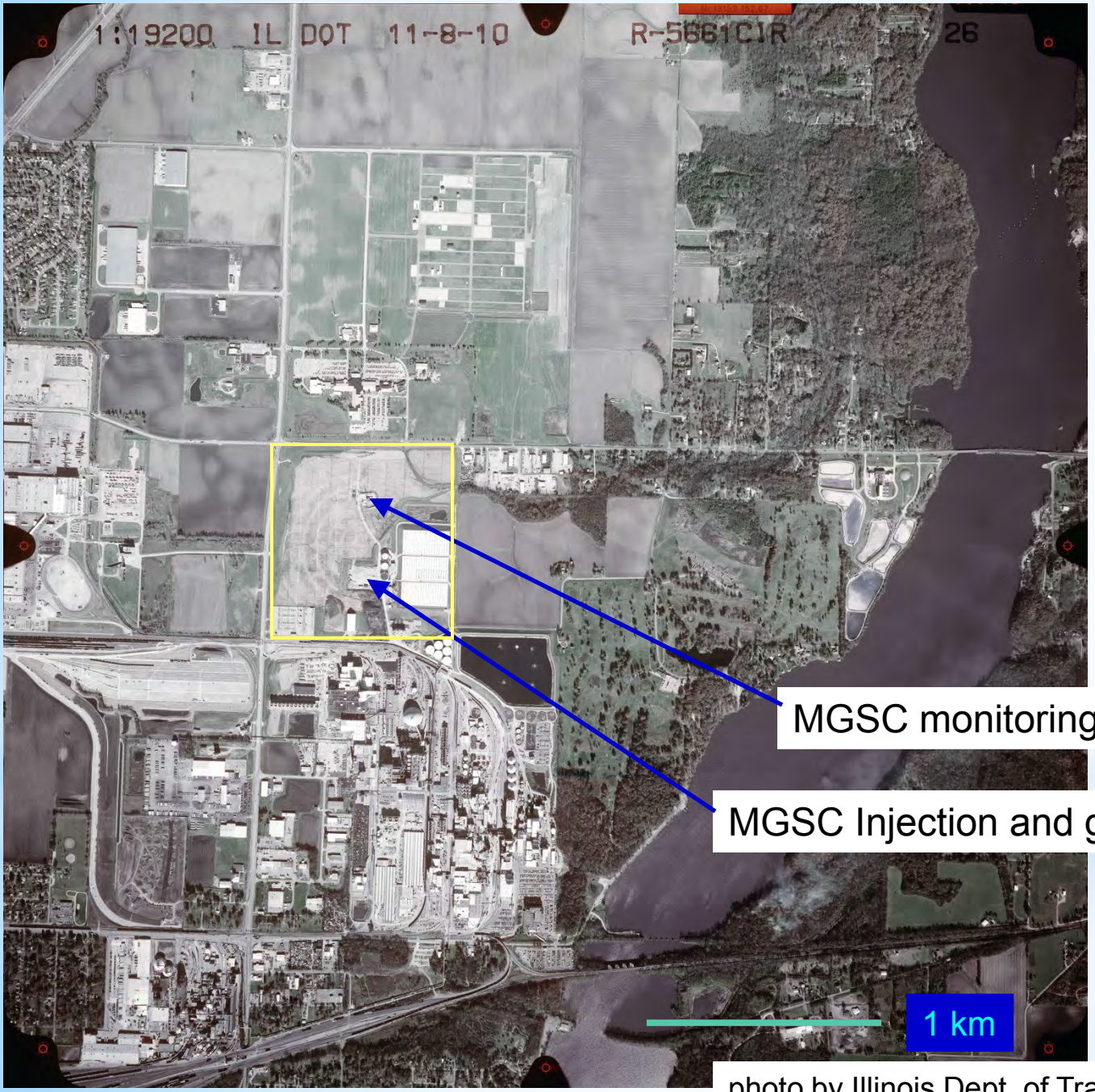
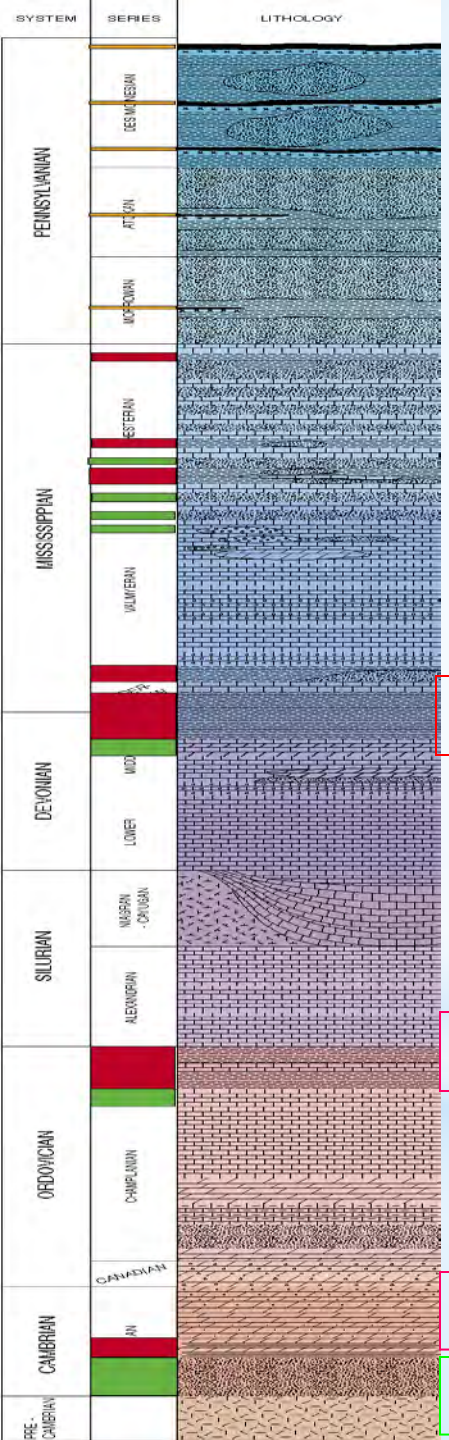


photo by Illinois Dept. of Transportation, 8 November 2010

Illinois Basin Stratigraphic Column Showing Seals and Sinks



Upper Mt. Simon used extensively for natural gas storage

Mt. Simon is overlain by three thick impermeable shales and numerous thinner shale-rich strata

New Albany (Seal)

Maquoketa (Seal)

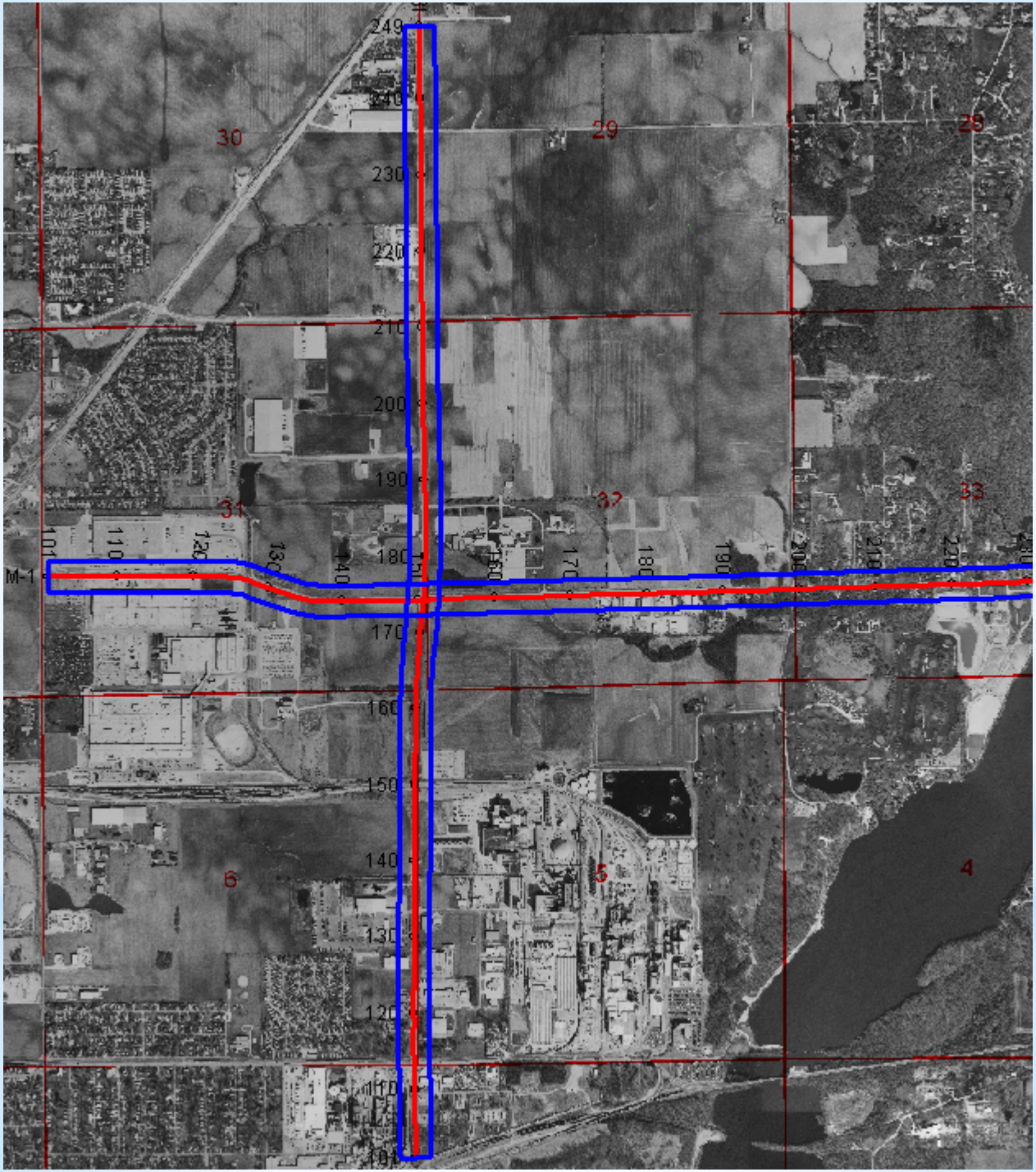
Eau Claire Shale (Seal)

Mount Simon Sandstone (Sink)

Potential Seal

Potential Sink

Coal Bed Potential Sink and Seal


30
29
28
31
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33
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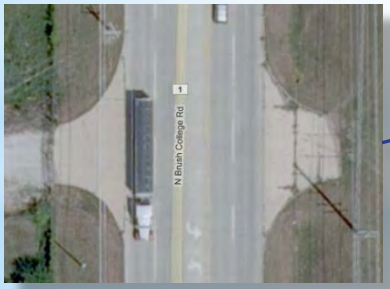
M-1

Acquisition Challenges: Noise

Thick concrete surface creating source generated noise

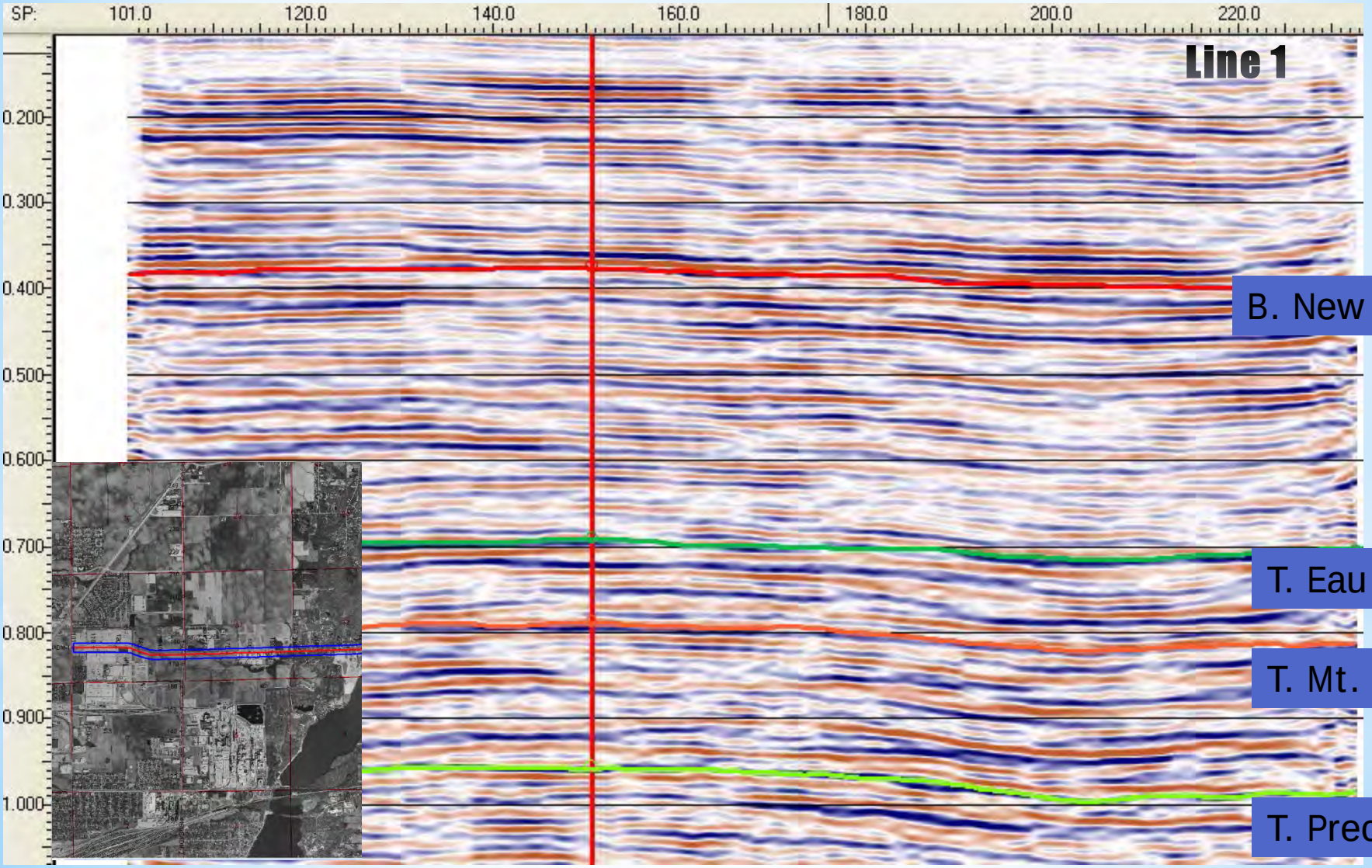
Electrical noise from power lines and 60Hz transformer plant

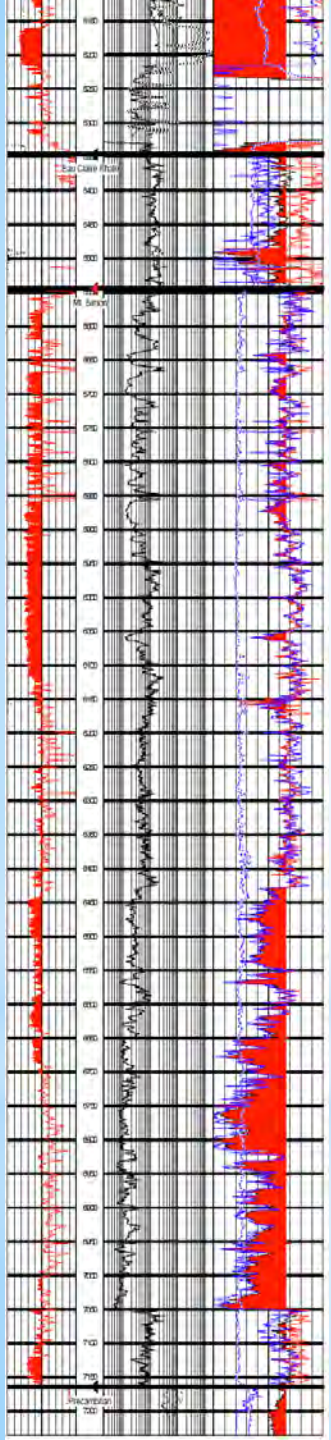


Road traffic noise due to tractor trailers visiting ADM plant.

Plant Related Noise from ADM plant

Correlate Horizons From a well 75 km to the South





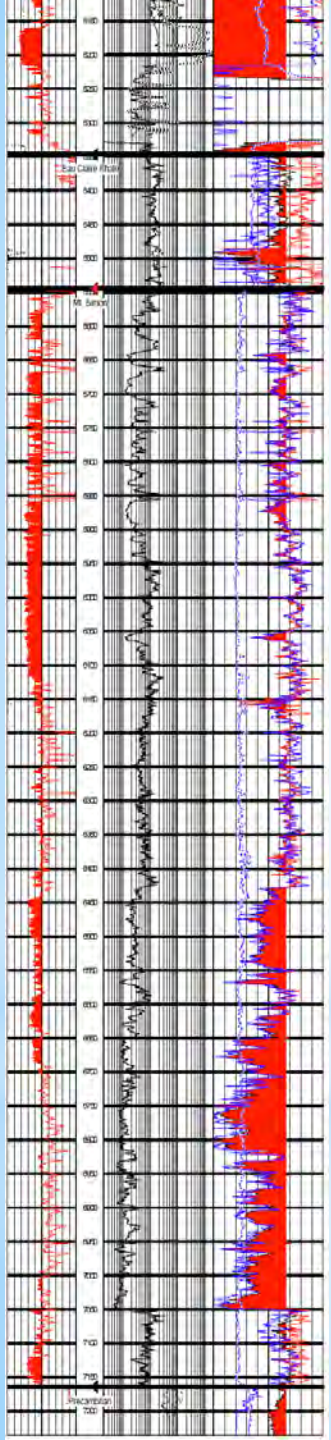
Eau Claire Shale

Upper Mt. Simon

Middle Mt. Simon

Lower Mt. Simon

Injection Interval



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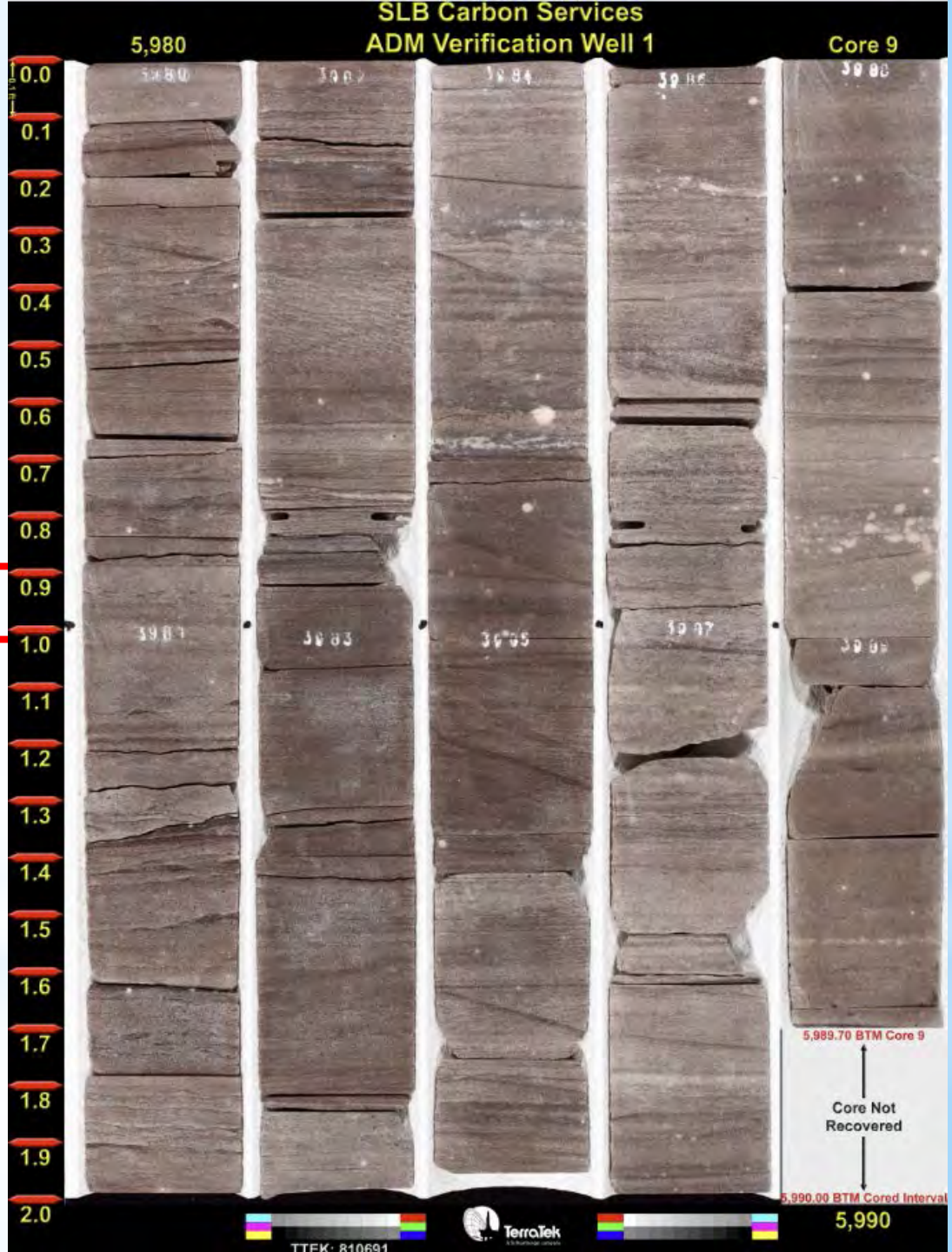
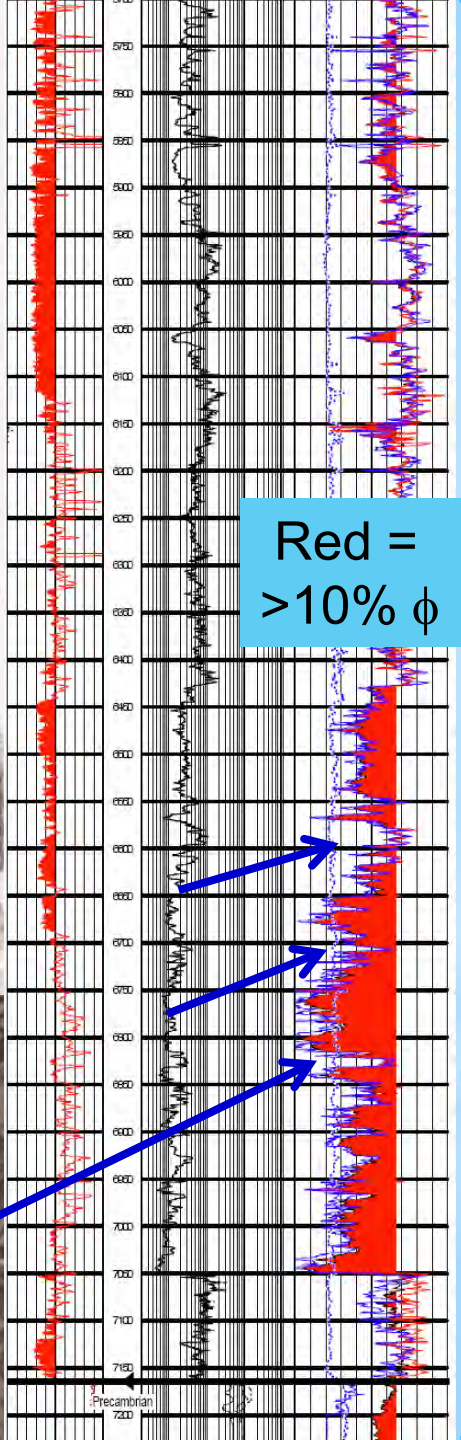
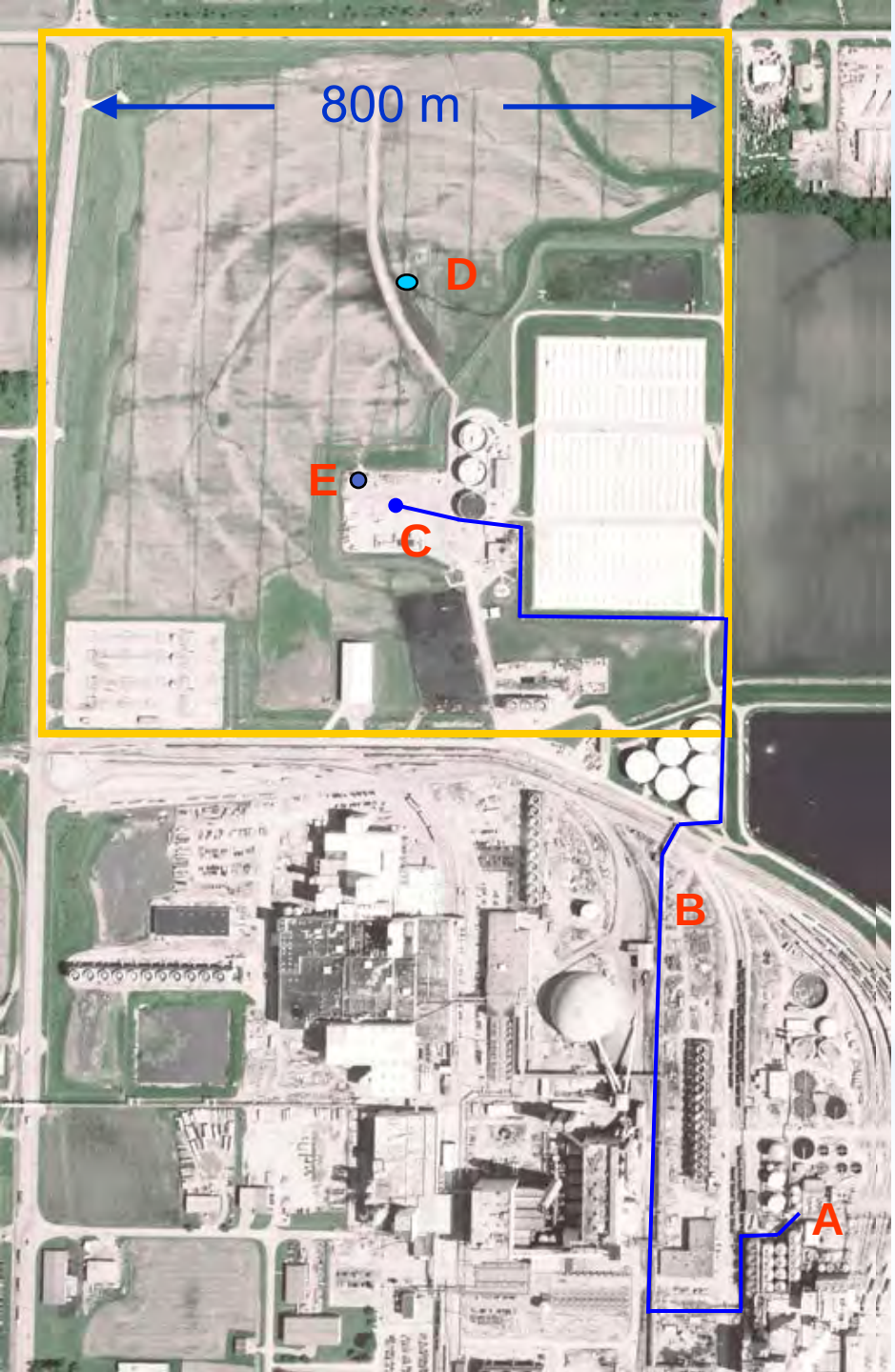


Mount Simon Depositional Analogue: Brahmaputra River System



Red = >10% ϕ

Sand-rich but low porosity/perm layers



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

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 fall 2014
- Intensive post-injection monitoring under MGSC through fall 2017

Cumulative Injection (15 April 2013): 453,144 tonnes

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
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Injection zone

- Geophysical surveys
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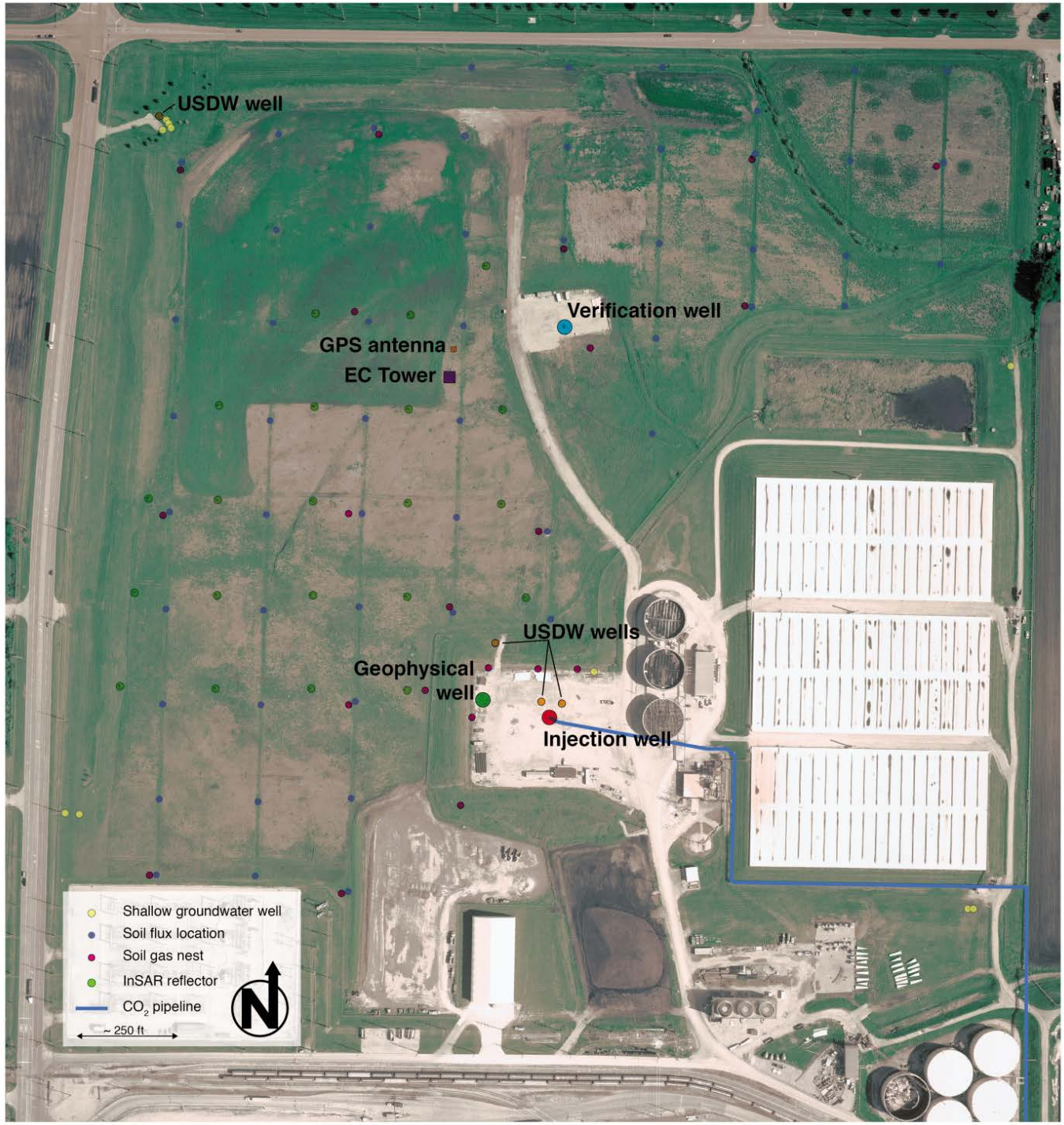


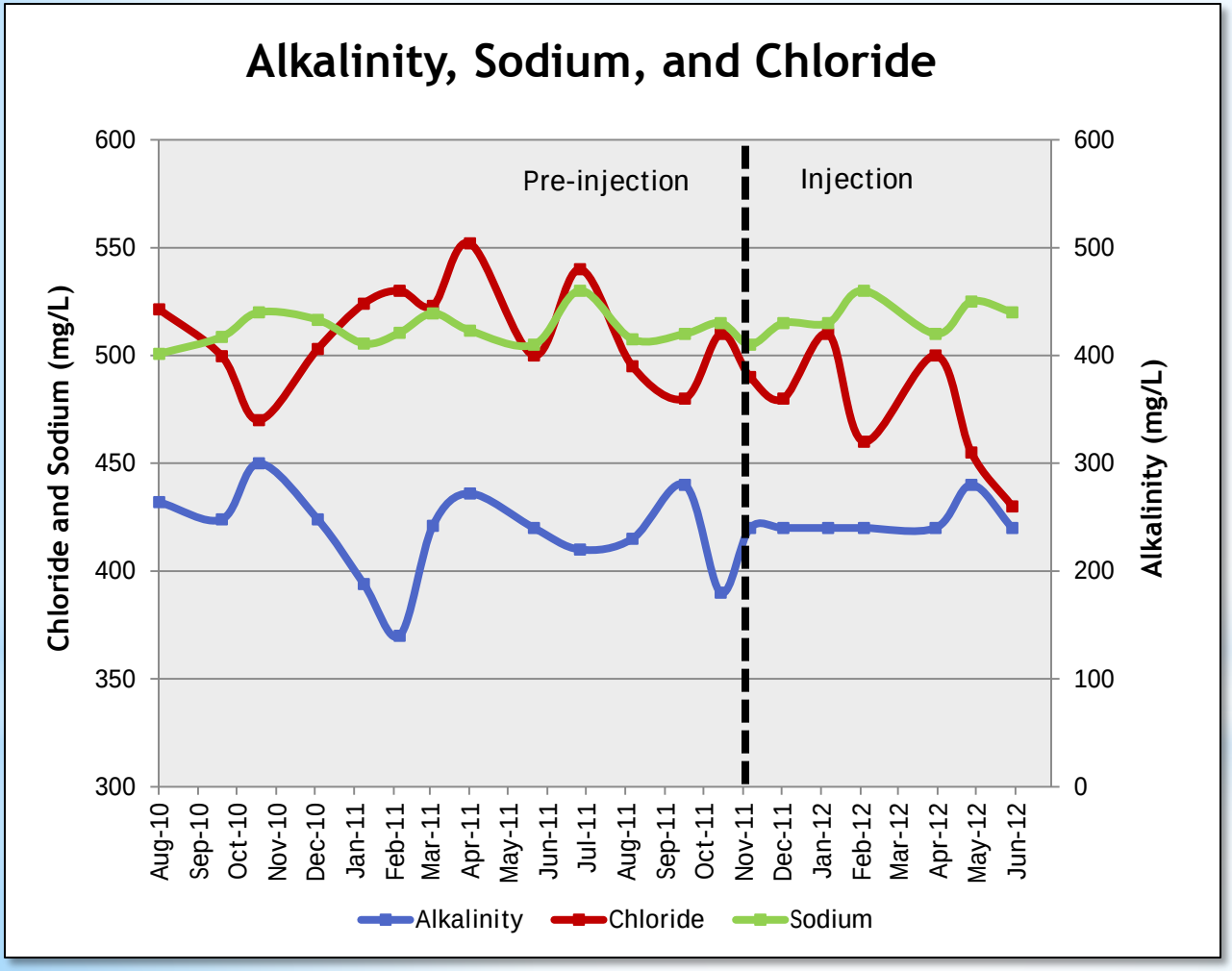
Near-Surface Monitoring Locations

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

Shallow Groundwater Network

- Installed 17 wells at 11 locations between Fall 2008 and Spring 2010
  - Well depths: 30 to 300 feet (9 to 91m)
  - Monthly sampling began in March 2009
  - Analyzed for anions, cations, alkalinity, TDS, NH_3, C and O isotopes, TOC, and TIC

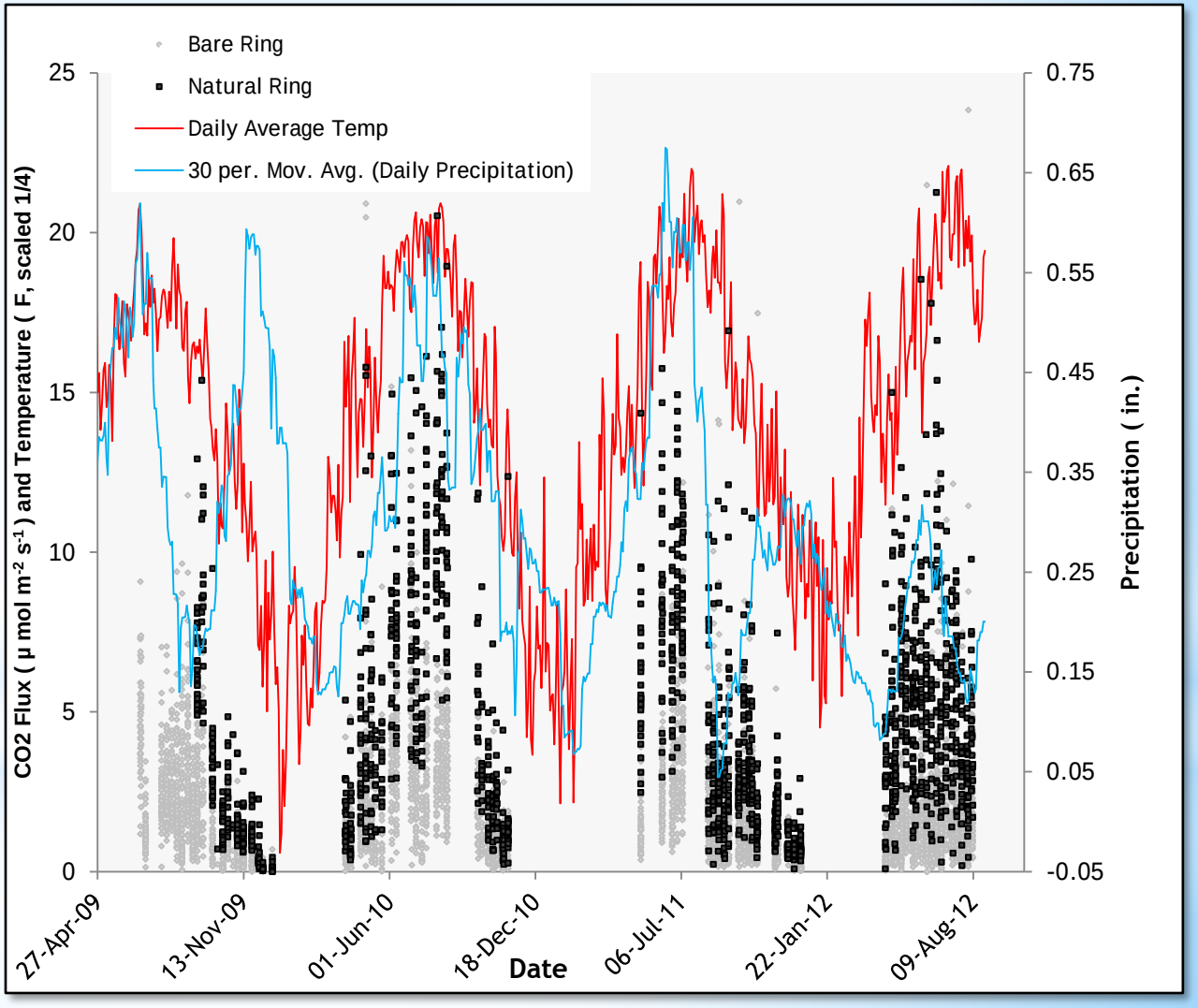
Generally Consistent Trends



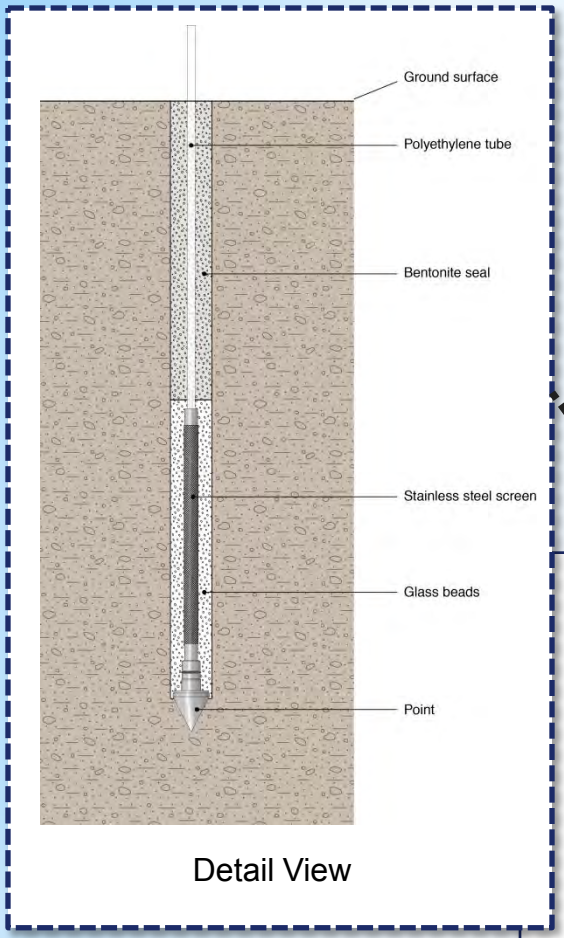
- Well G104
- Note injection period data are generally consistent with preinjection data
- Chloride decreasing

Soil Flux Monitoring

- Network of 100+ rings
- Ecosystem flux estimation, atmospheric modeling, and leak detection
- Weekly point data collection began Summer 2009
- 30-minute data from multiplexer to define diurnal variability



Soil Gas Installations



Detail View

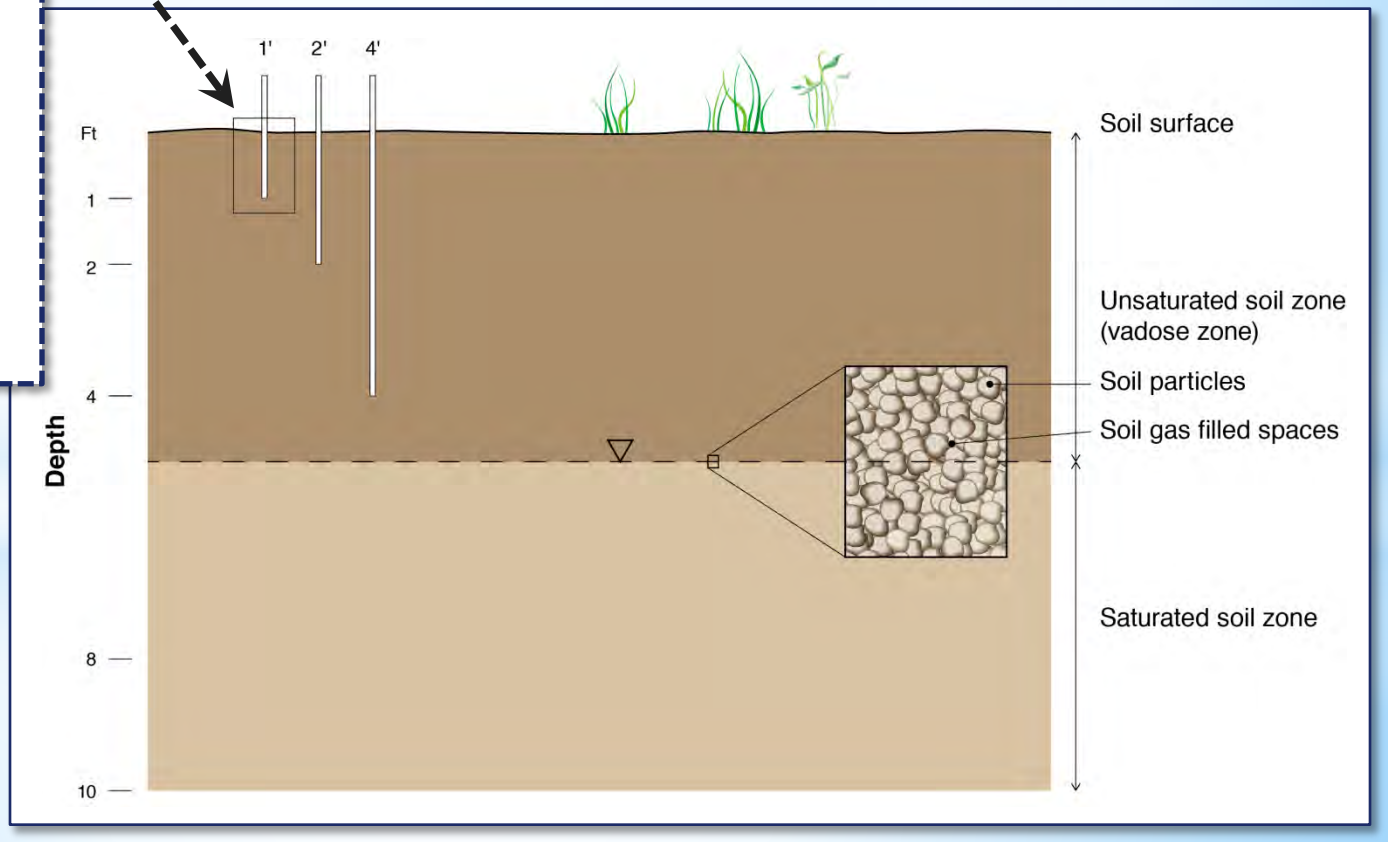
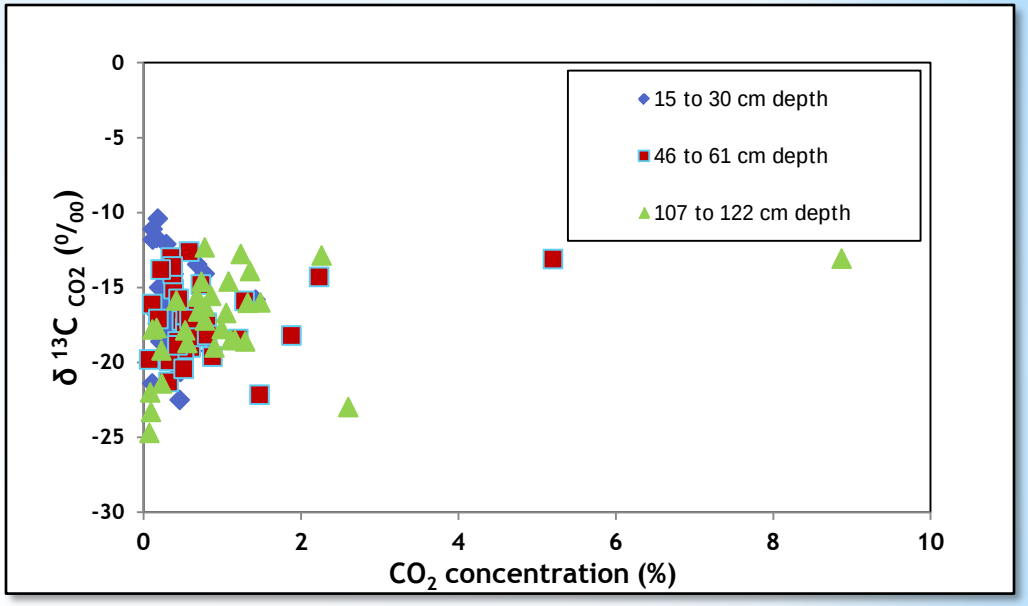
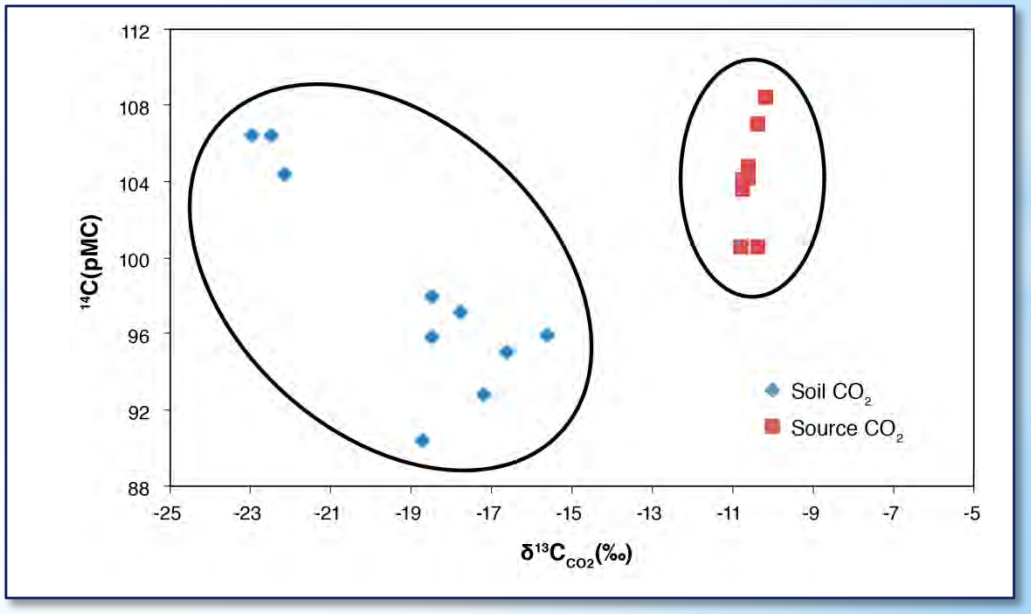


Figure Source: Daniel Byers (ISGS)

Soil Gas Characterization

- Quarterly data collection began Summer 2011
- Analyzed for CO_2, N_2, Ar + O_2, light hydrocarbons (C_1 to C_6), $\delta^{13}C_{CO2}$,and ^{14}C
- Biogenic activity consumes O_2 and generally CO_2 concentrations increase with depth
- Range of $\delta^{13}C_{CO2}$ in soil: -10 to -25 per mil
- Distinct signatures of soil CO_2 and source CO_2

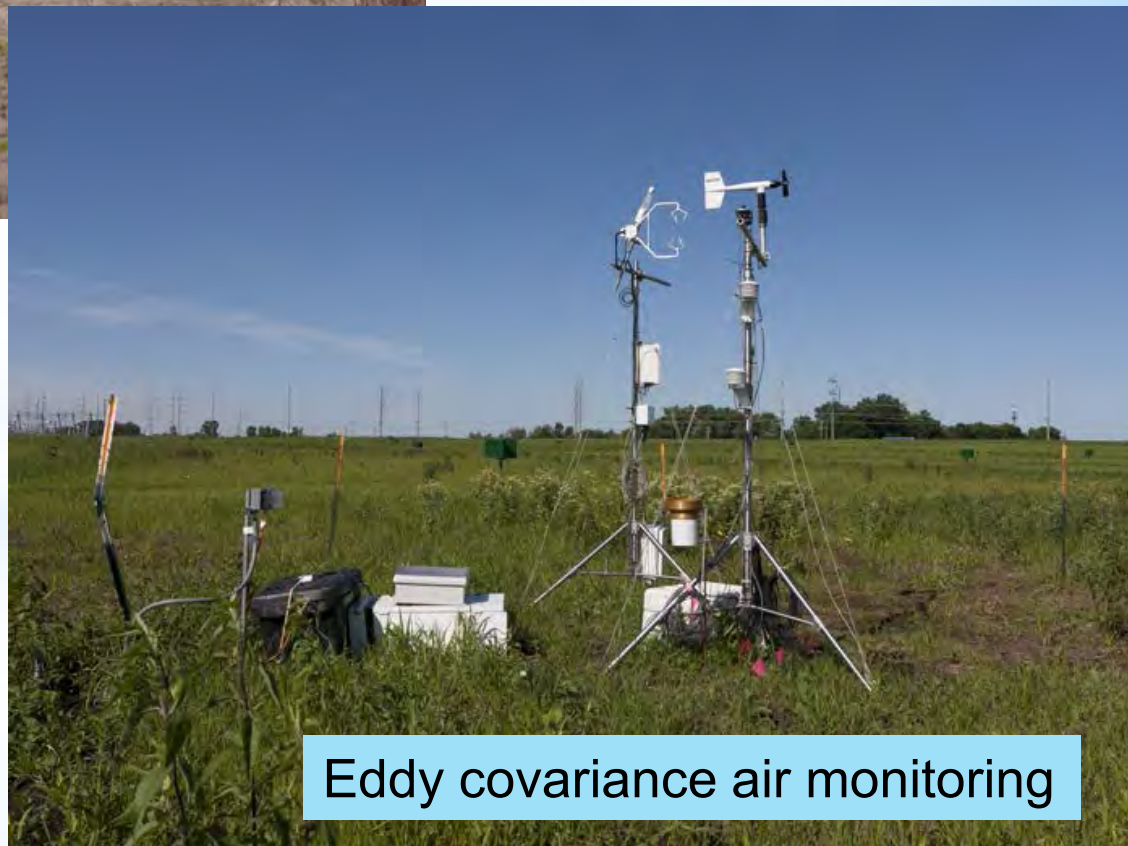




Surface Environmental Monitoring

No surface deformation as of August 2012 with about 250,000 tonnes injected

No atmospheric releases



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Injection zone

- Geophysical surveys
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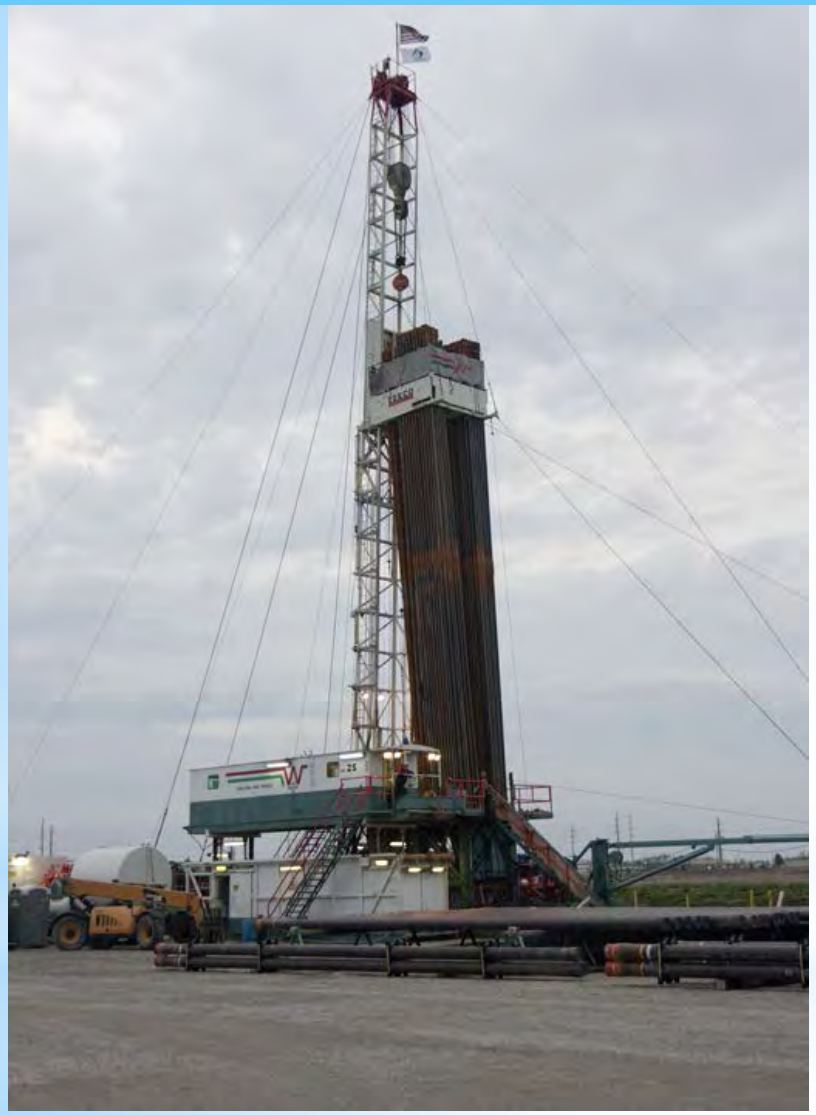
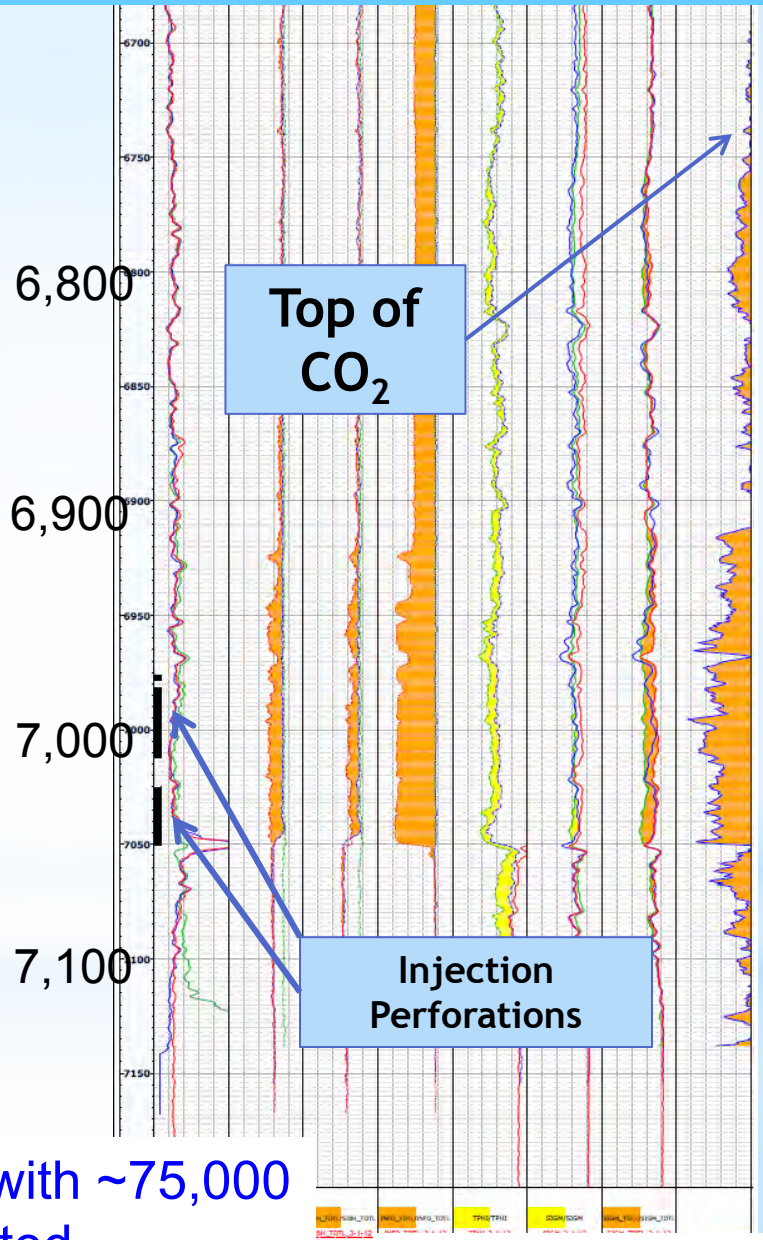
Injection Well Drilled to 2,190 m (7,230 ft) (2009)





RST* reservoir saturation tool Log

Logged March 1, 2012 with ~75,000 tonnes metric tons injected

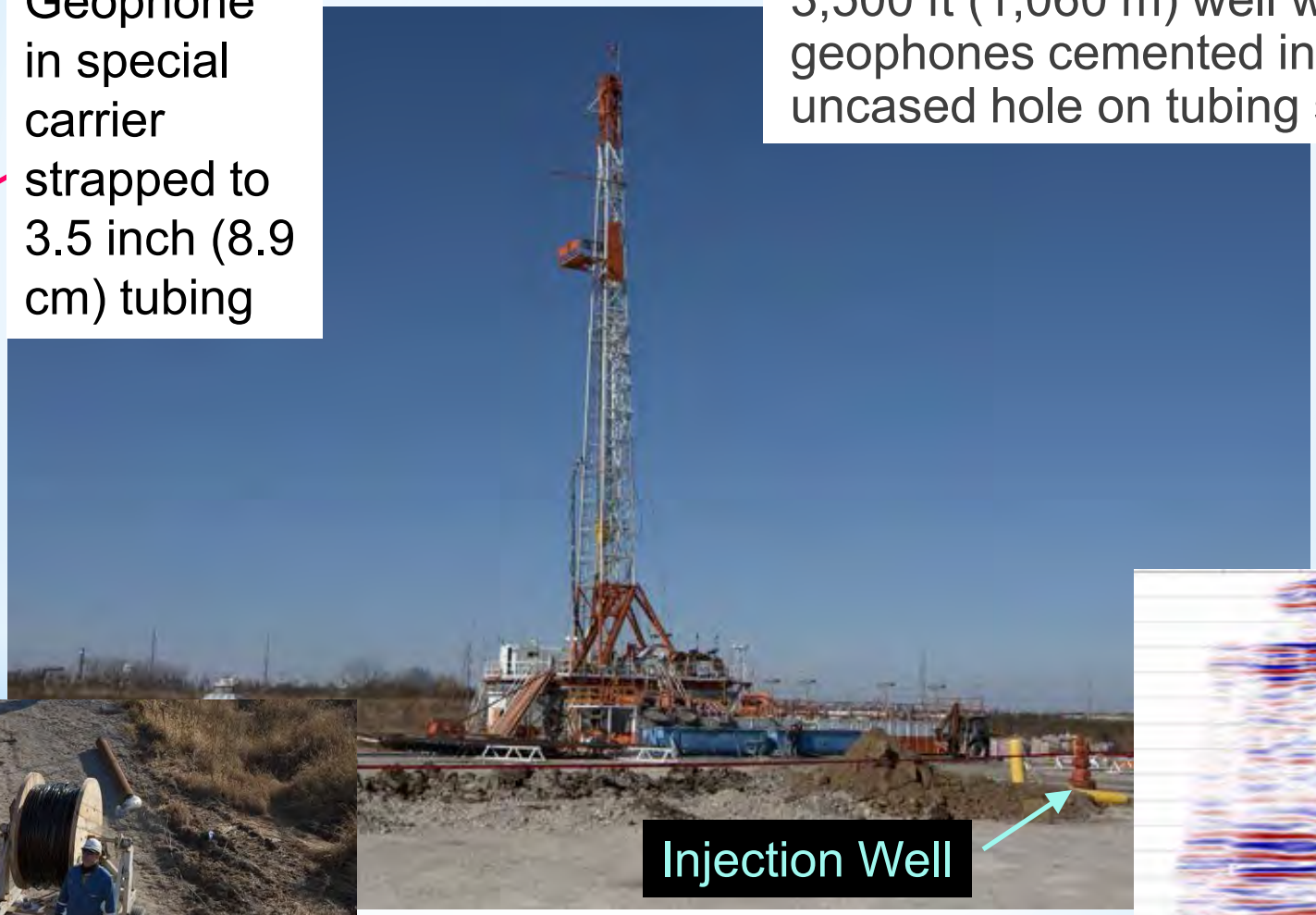
*Mark of Schlumberger

from Schlumberger Carbon Services

Geophone Well Completed November 2009

Geophone in special carrier strapped to 3.5 inch (8.9 cm) tubing

3,500 ft (1,060 m) well with 31 geophones cemented into uncased hole on tubing string



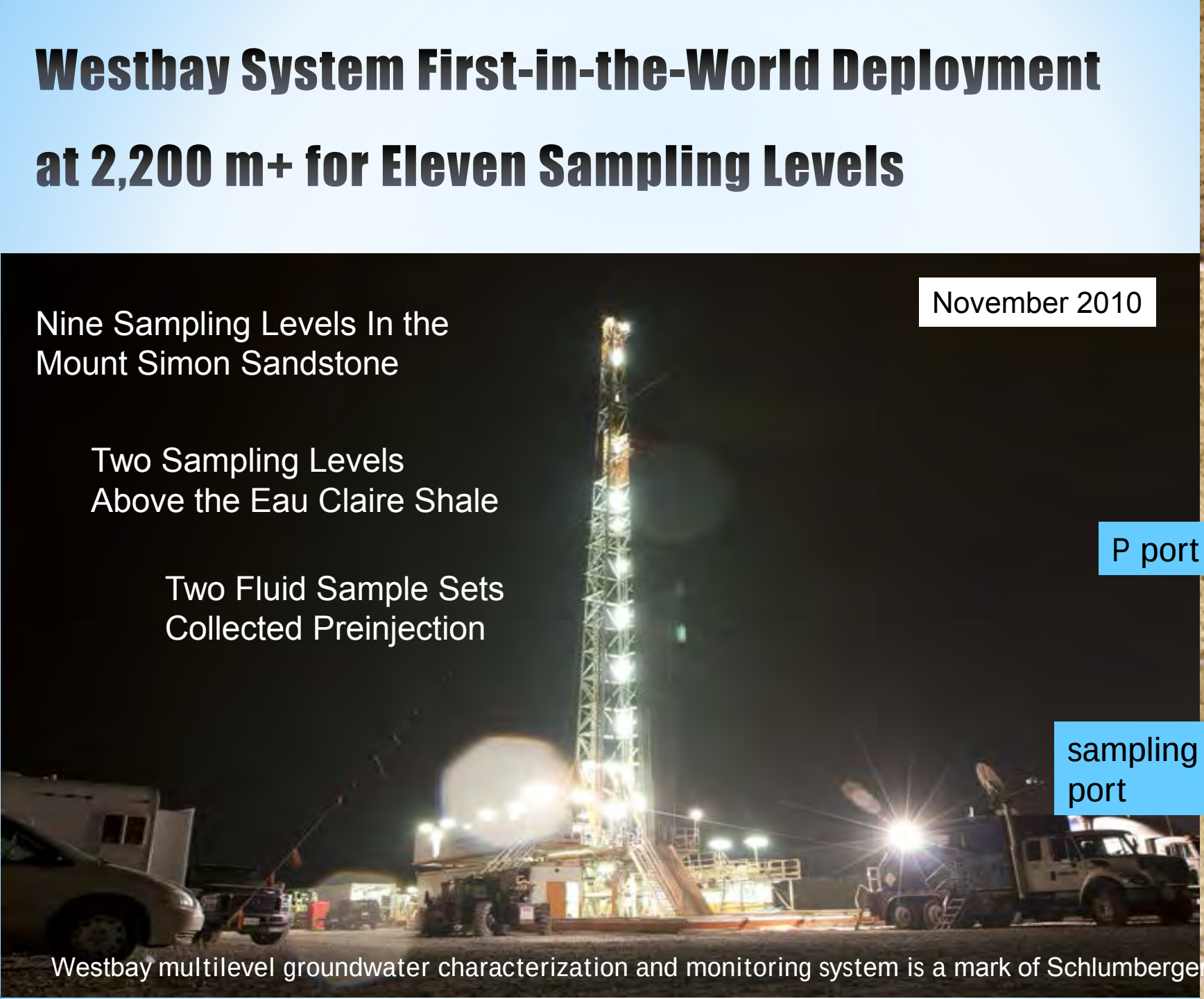
Westbay System First-in-the-World Deployment at 2,200 m+ for Eleven Sampling Levels

November 2010

Nine Sampling Levels In the Mount Simon Sandstone

Two Sampling Levels Above the Eau Claire Shale

Two Fluid Sample Sets Collected Preinjection



Westbay multilevel groundwater characterization and monitoring system is a mark of Schlumberger

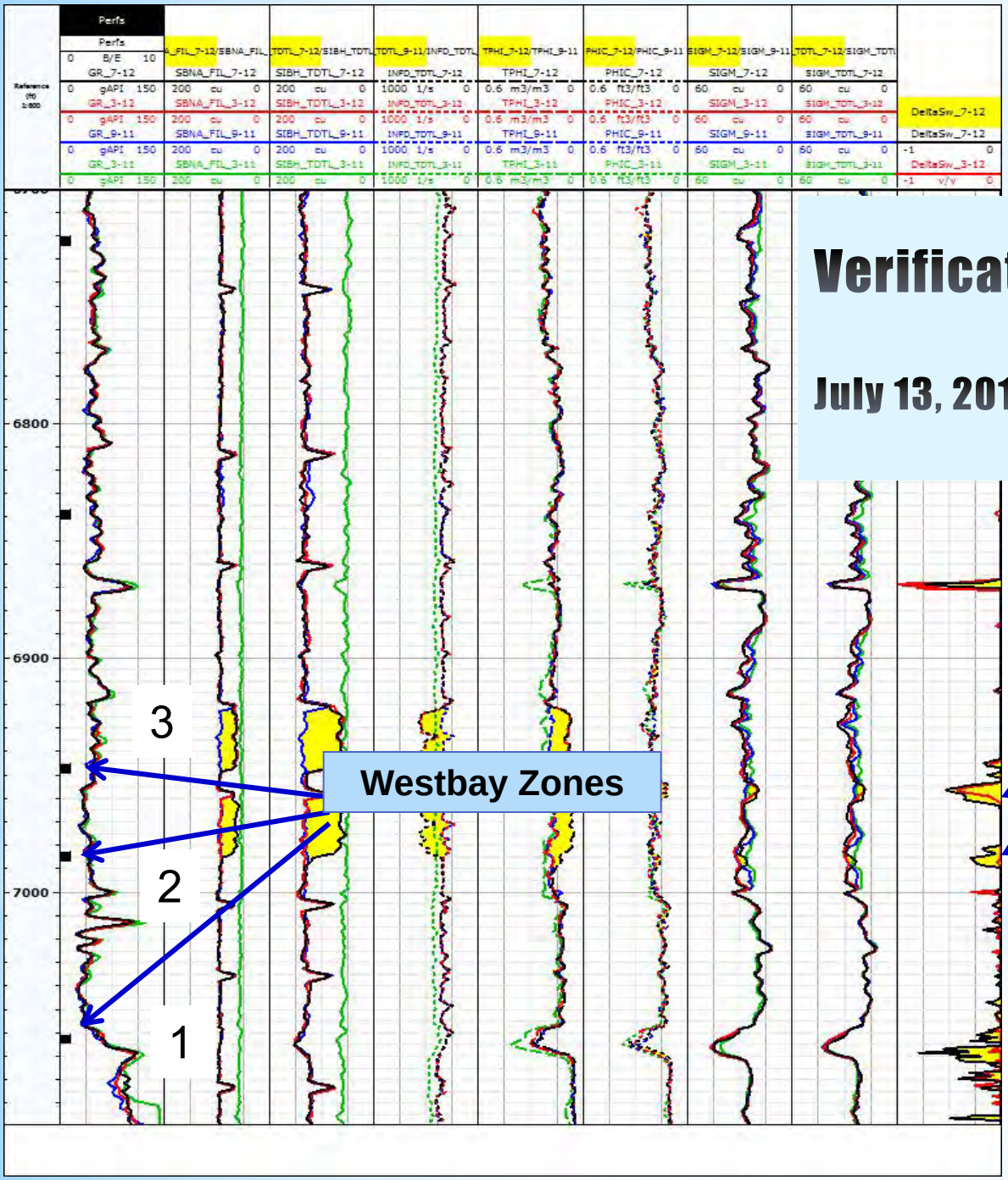
Westbay Installation and Sampling

June-August 2011

Water Quality Comparison

Constituent	Shallow Groundwater	Ironton-Galesville	Mt. Simon (injection formation)
Conductivity (mS/cm)	**1.5**	**80**	**170**
TDS (mg/L)	**1,000**	**65,600**	**190,000**
Cl^- (mg/L)	**170**	**36,900**	**120,000**
Br^- (mg/L)	**1**	**180**	**680**
Alkalinity (mg/L)	**380**	**130**	**80**
Na^+ (mg/L)	**140**	**17,200**	**50,000**
Ca^{2+} (mg/L)	**100**	**5,200**	**19,000**
K^+ (mg/L)	**1**	**520**	**1,700**
Mg^{2+} (mg/L)	**50**	**950**	**1,800**
pH (units)	**7.2**	**6.9**	**5.9**

- Shallow groundwater (16 well average)
- Ironton-Galesville (2 zone average; swab only)
- Mt. Simon (9 zone average)



Verification Well RST Logging

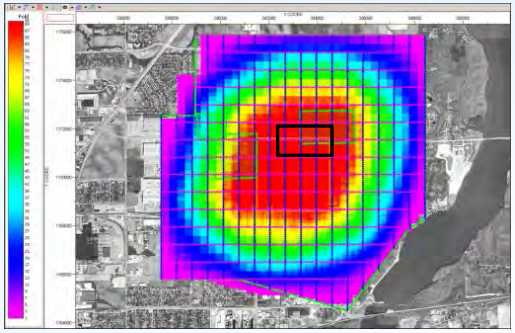
July 13, 2012

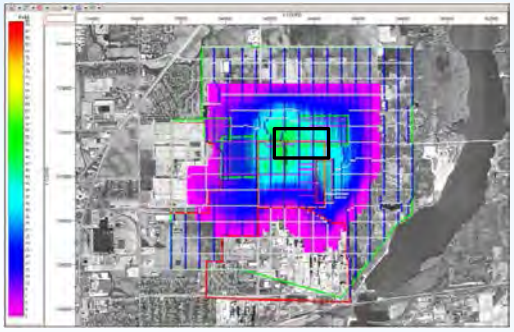
Westbay Zones 2 and 3 equivalent to lower and upper perforations, respectively

from Schlumberger Carbon Services

3D Acquisition Challenges: Design Iterations and Fold Coverage

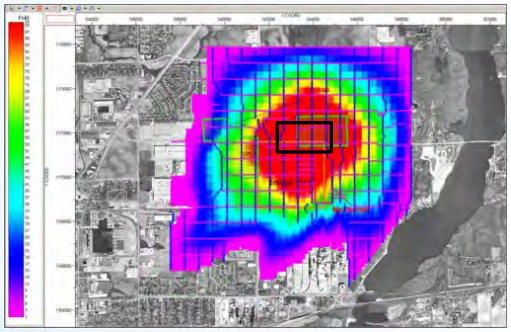
Ideal design

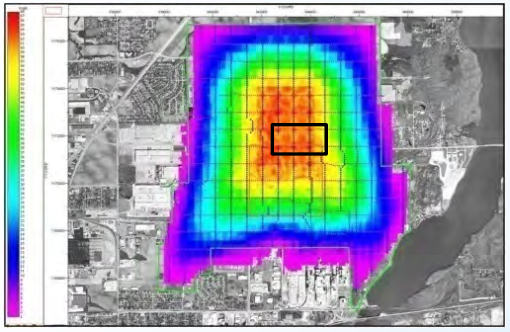




Case of shots in permitted areas only. Receiver locations relatively unrestricted

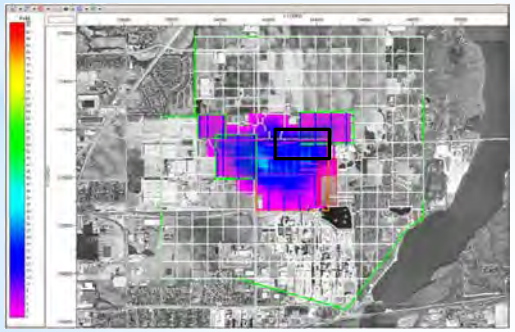
Ideal design with planned offsets

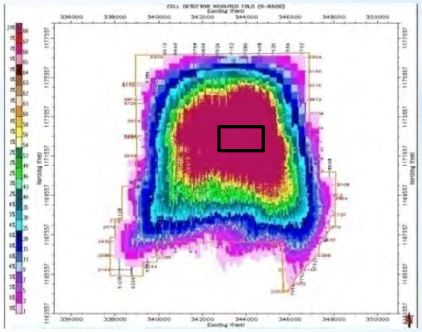




Final design

Access to known permitted areas only.

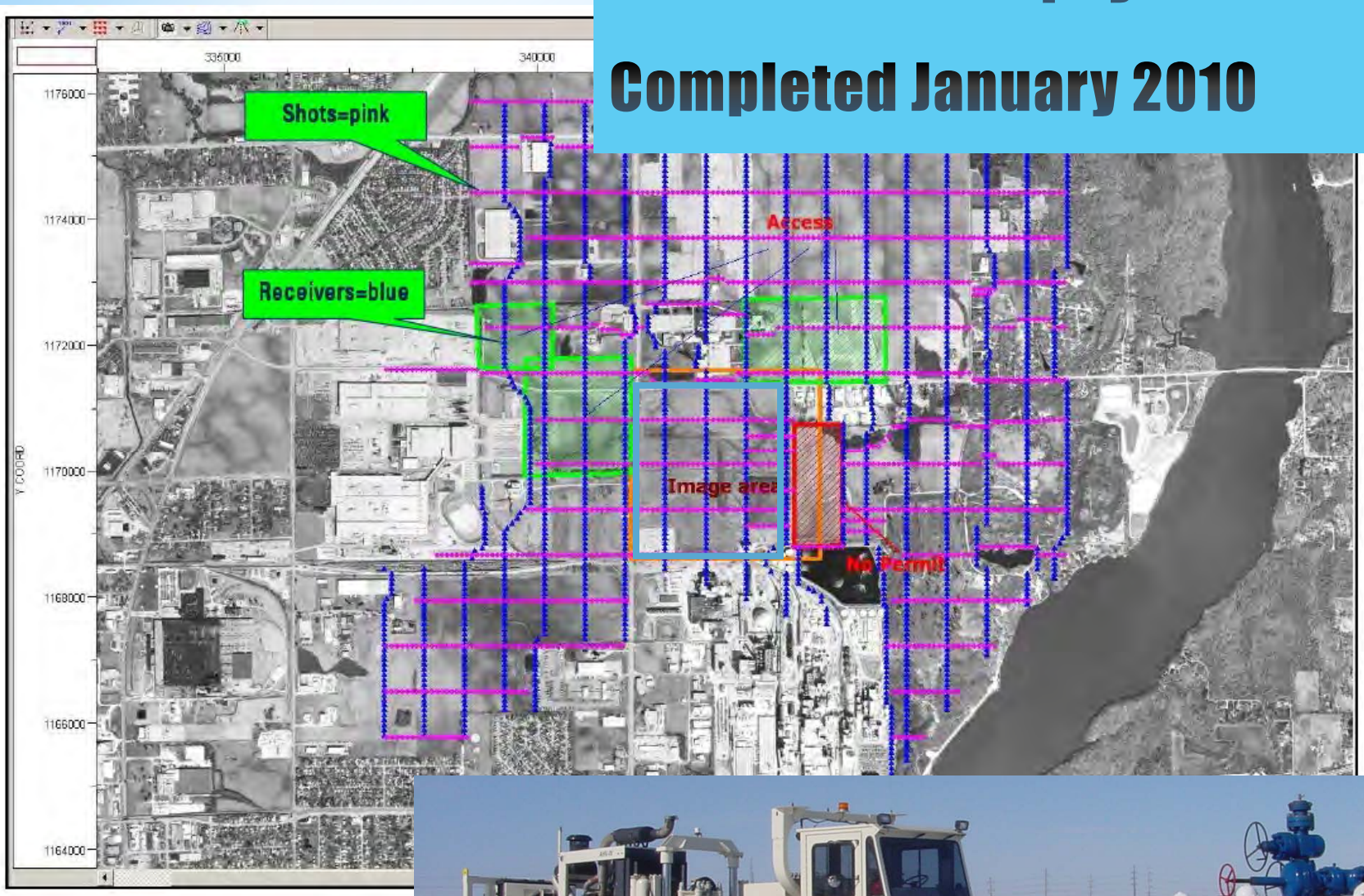




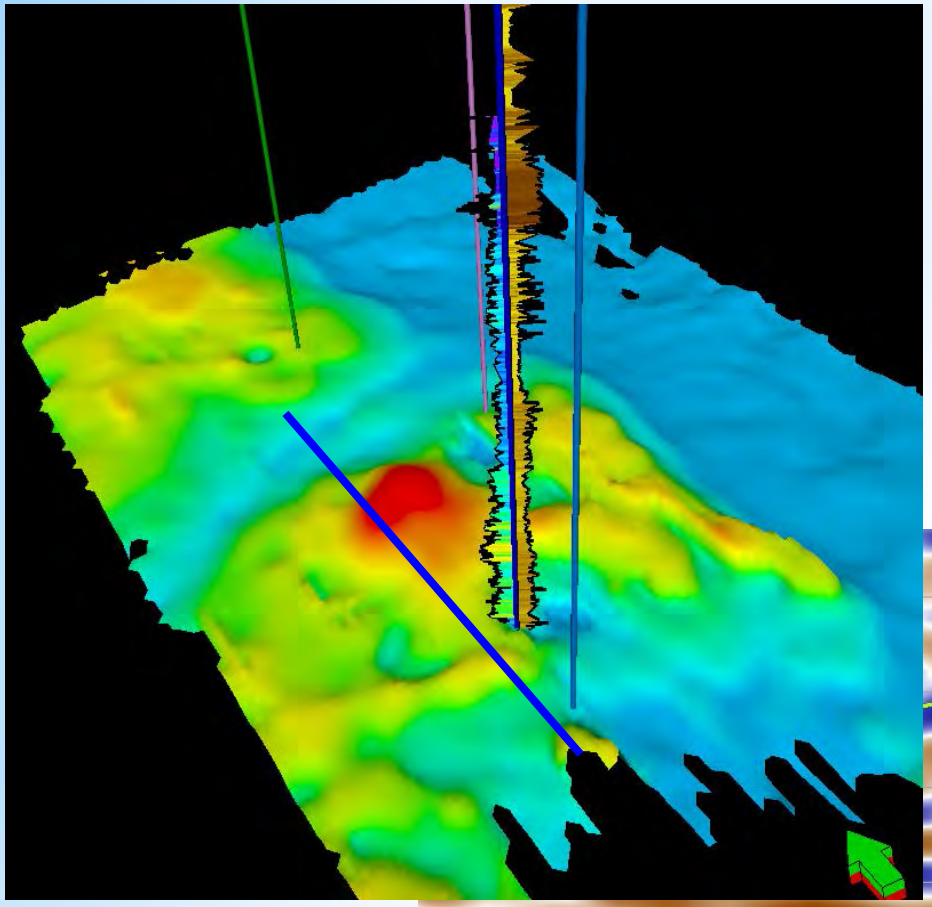
Acquired data

Baseline 3D Geophysical Survey

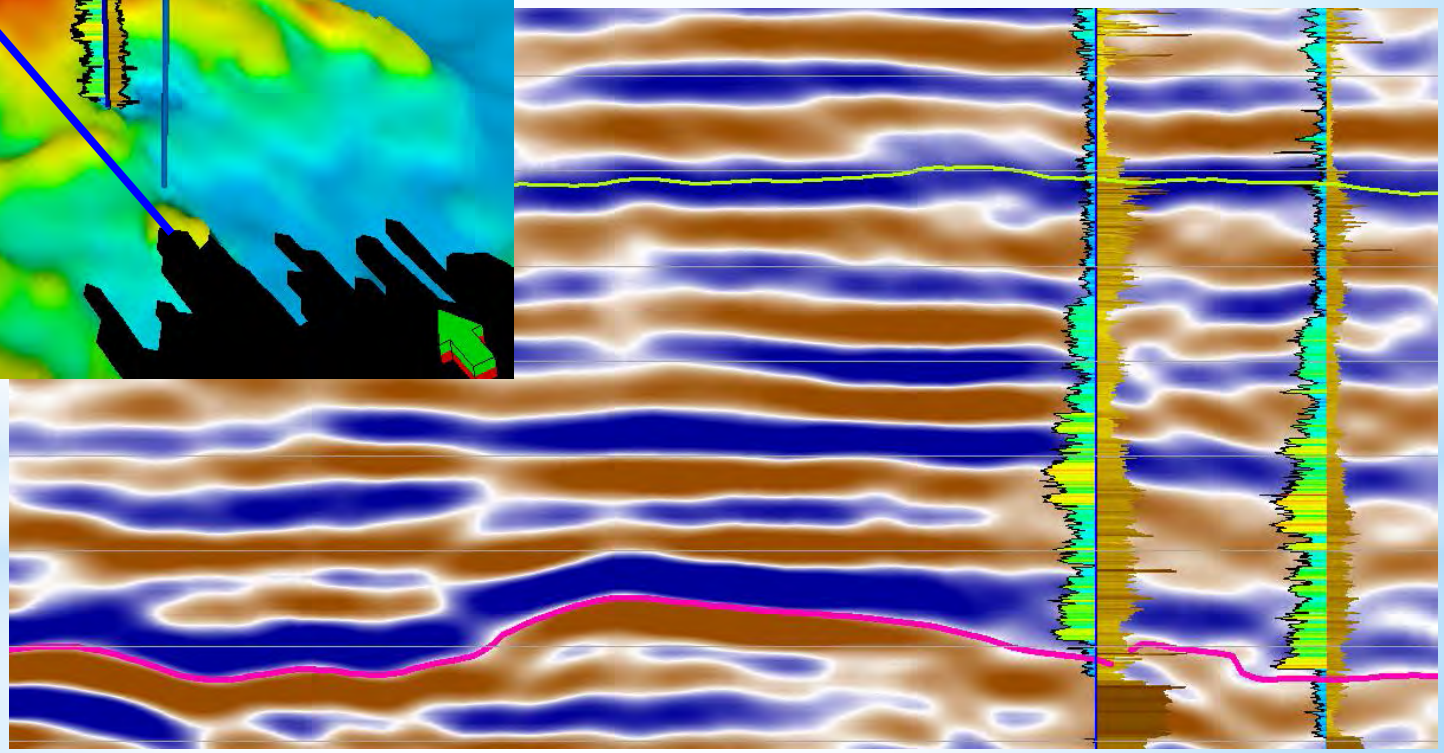
Completed January 2010



3D Seismic Reveals Precambrian Topography



from Leetaru, ISGS

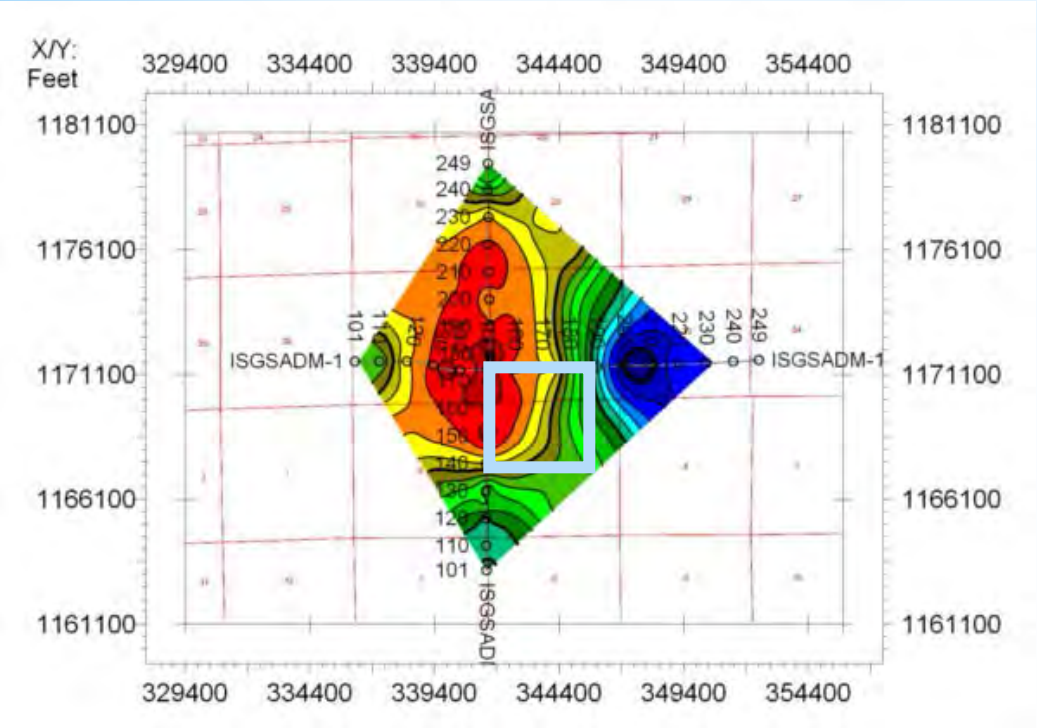


Valley eroded into Precambrian

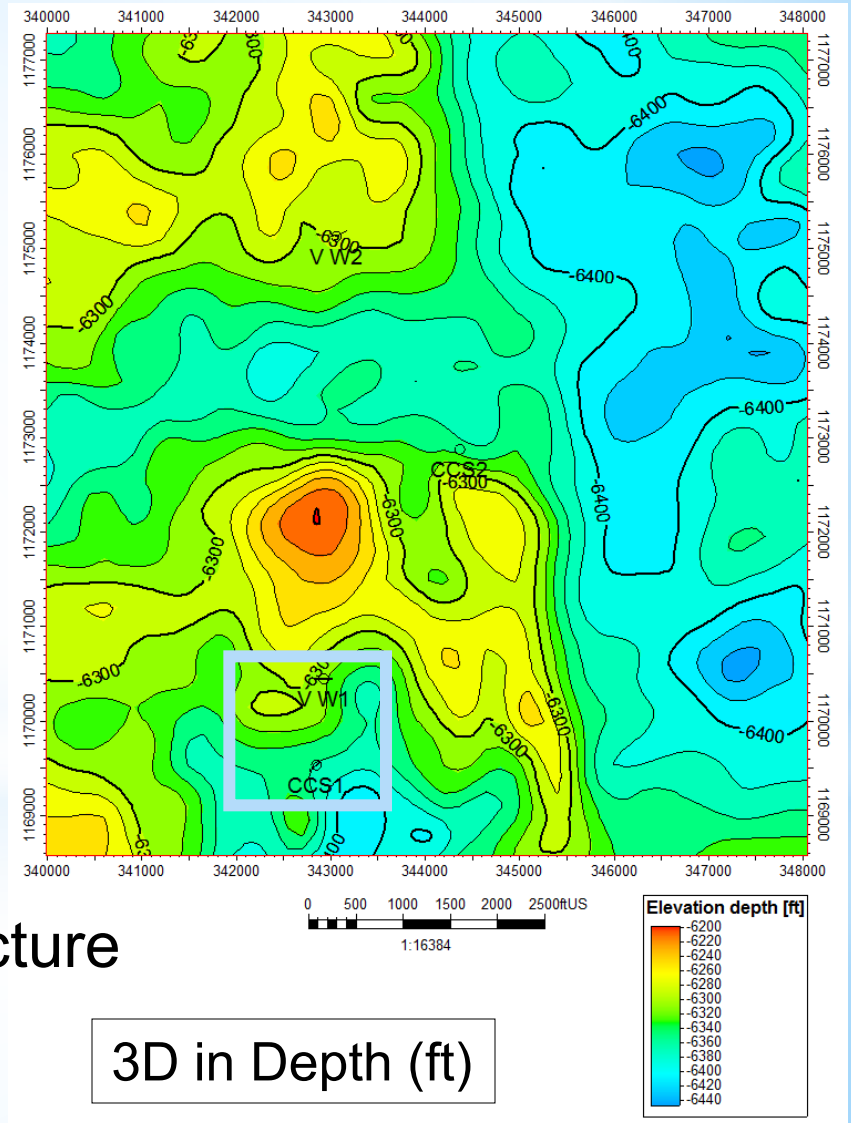
Precambrian structural high

Top of Mount Simon Structure

Comparison of 2D and 3D Seismic



2D in Time



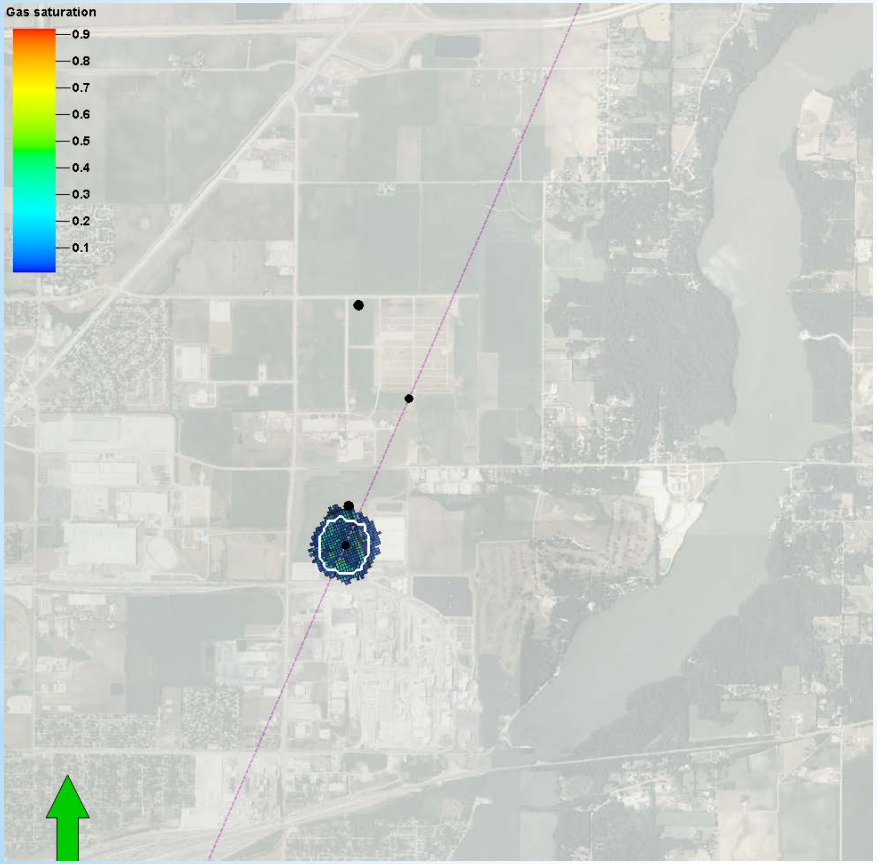
Base Mount Simon Structure

from Leetaru, ISGS

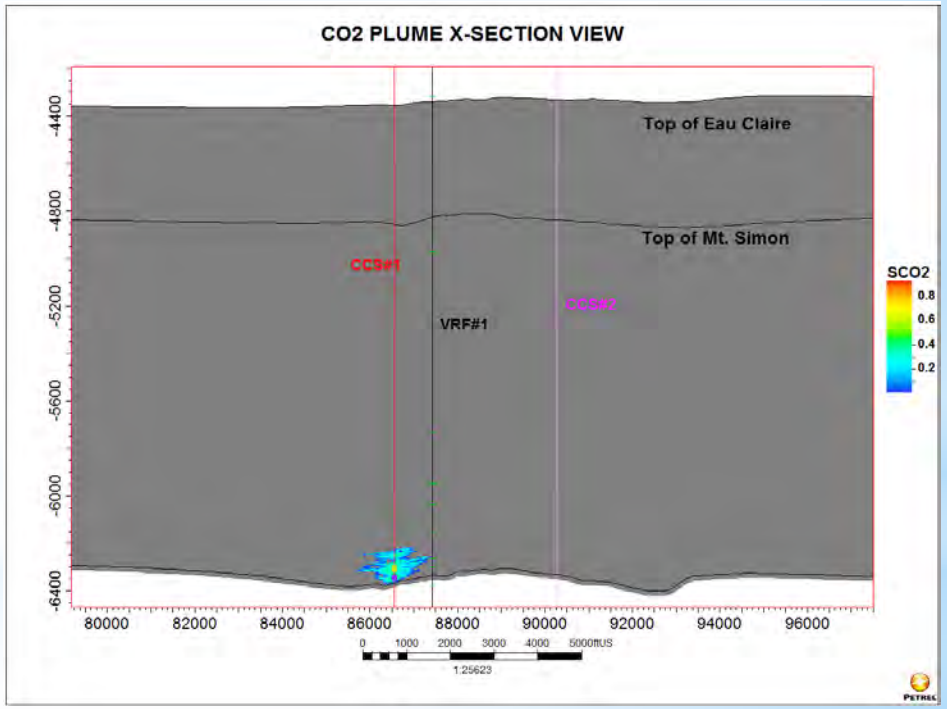
3D in Depth (ft)

Reservoir Simulation: CO_2 Plume & Pressure Pulse Evolution

March 2012



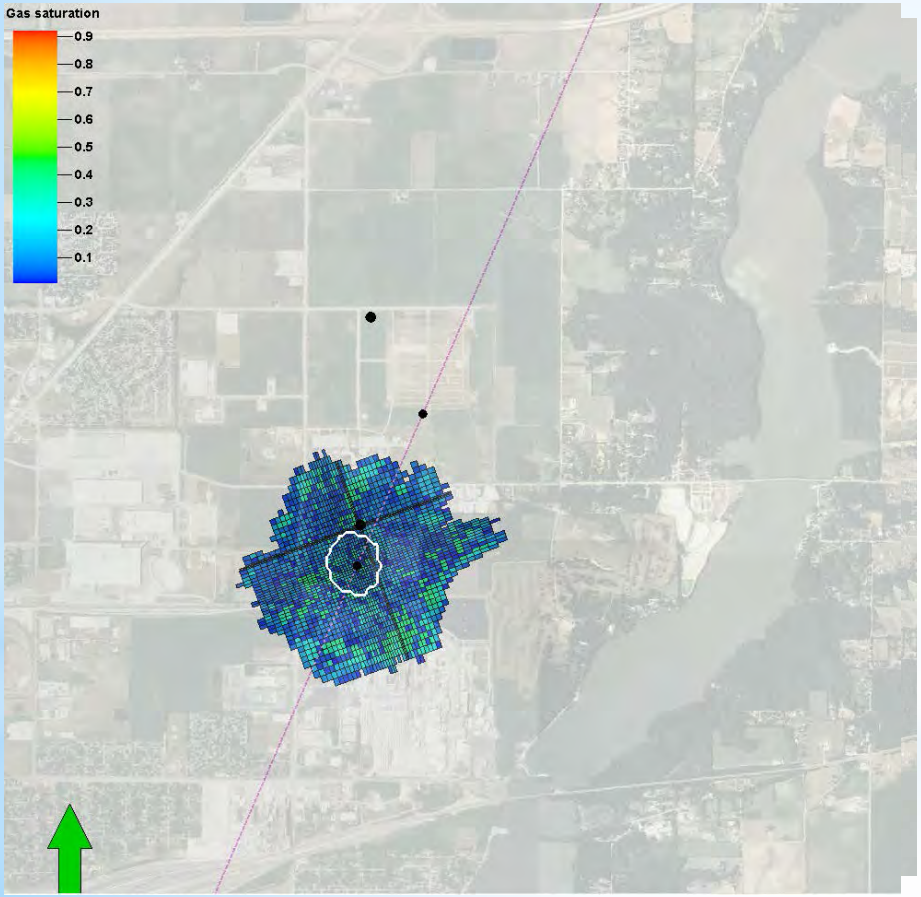
- 32 x 32 km Eclipse* reservoir model
- ~ 3 million grid cells
- variable cell dimensions



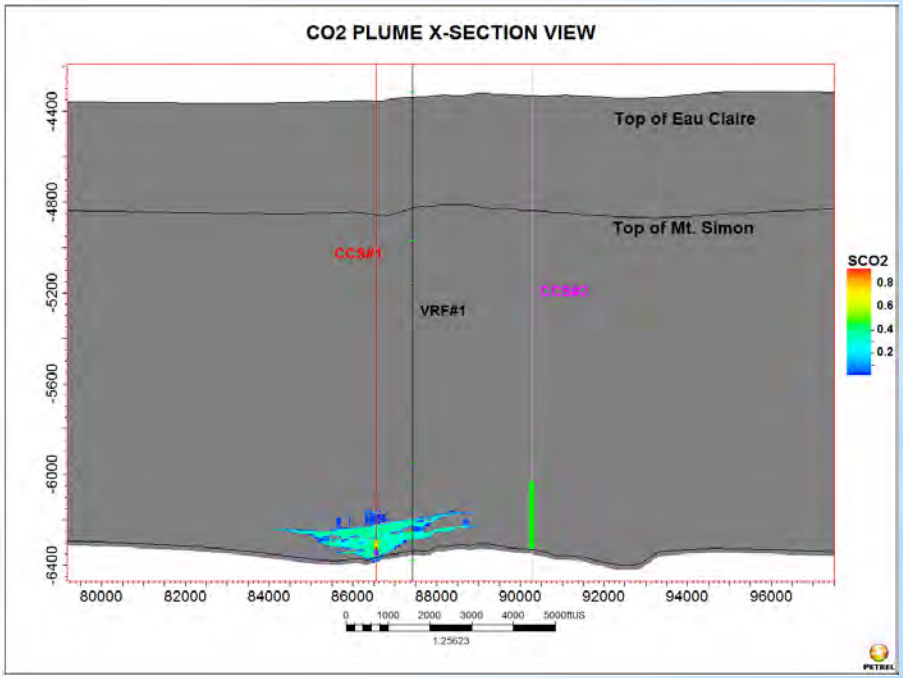
*Mark of Schlumberger

from Schlumberger Carbon Ser

CO_2 Plume & Pressure Pulse Evolution



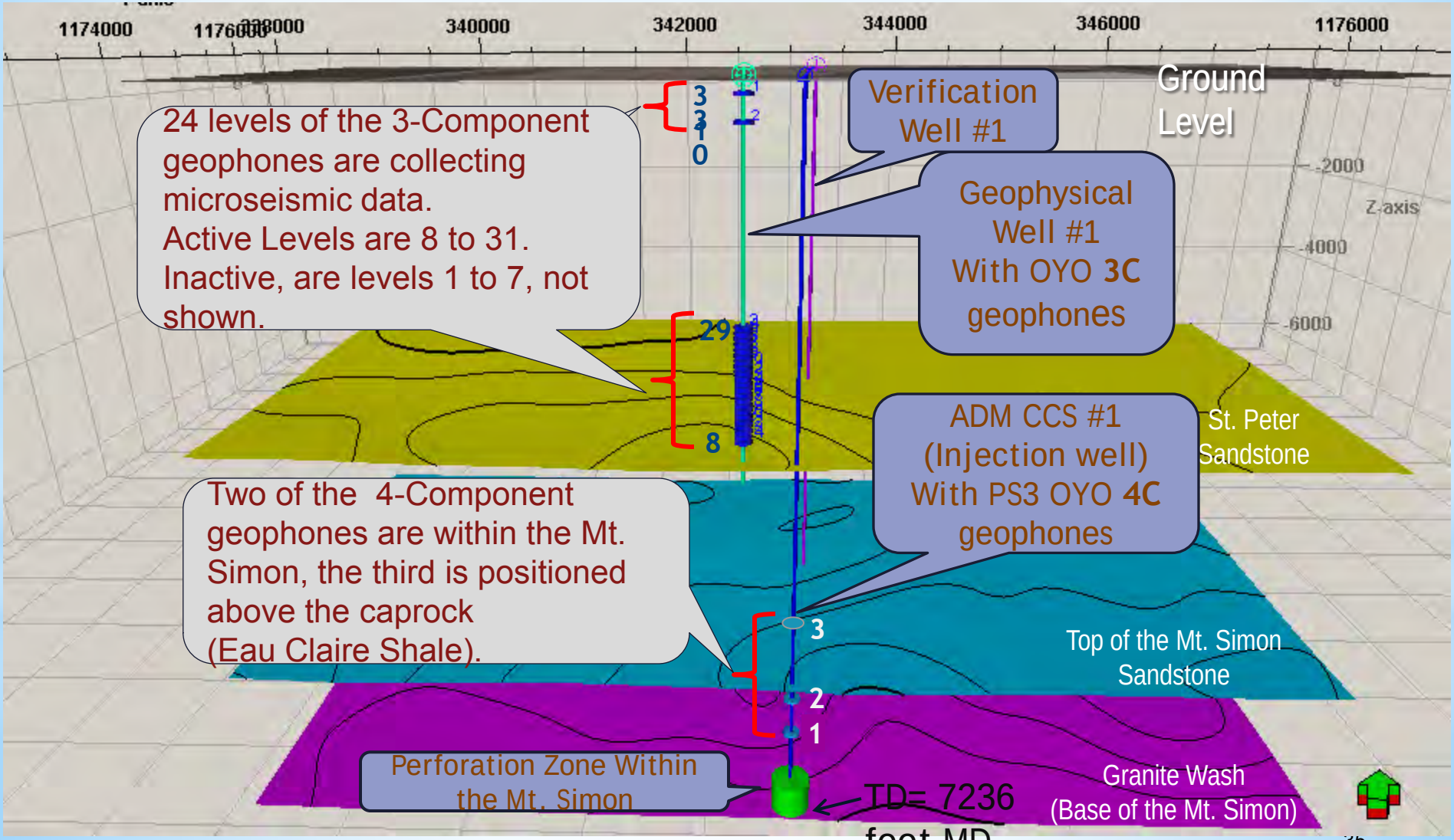
2014



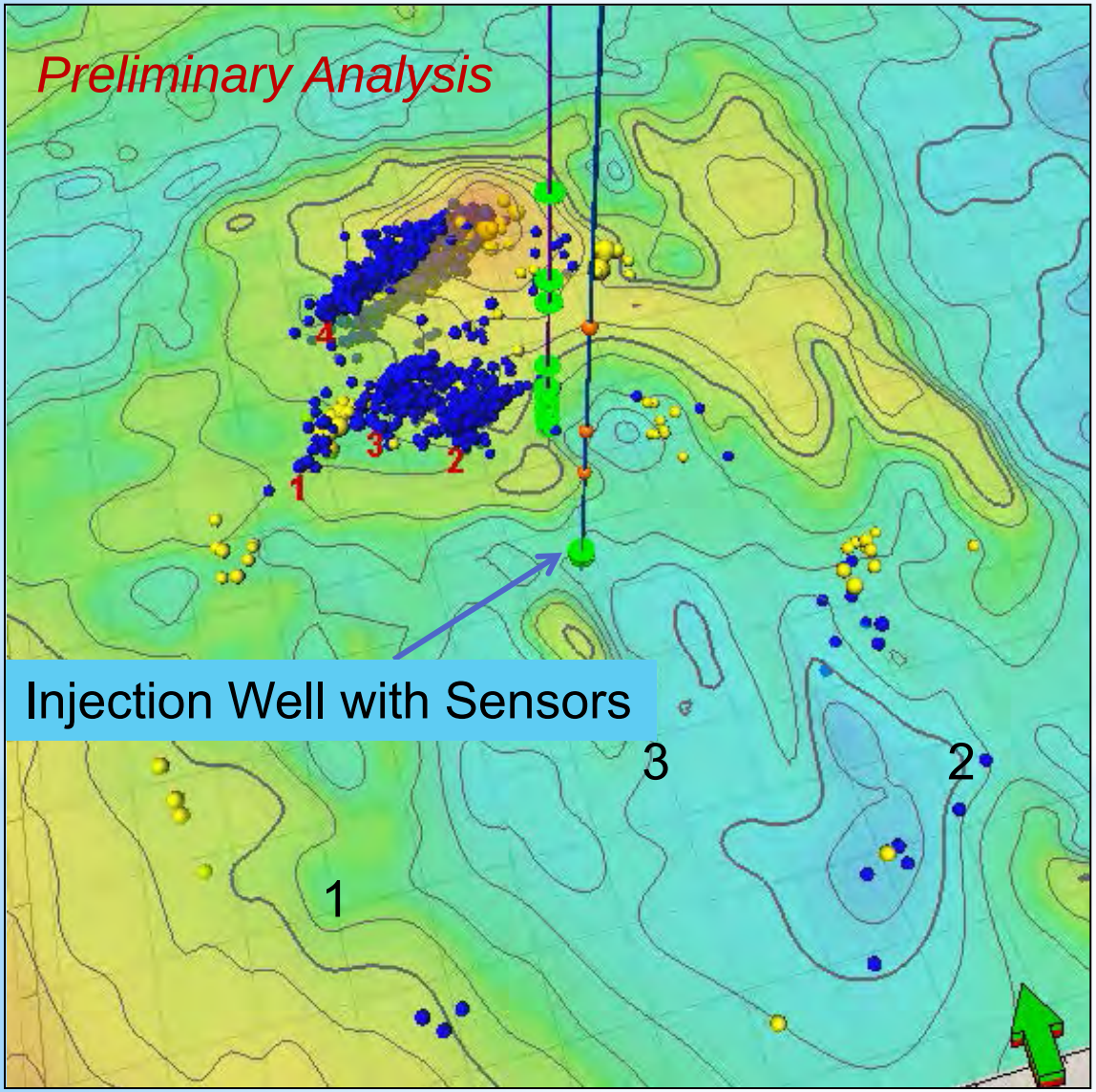
from Schlumberger Carbon Ser

Geophones, wells, and reservoir details

From Schlumberger Carbon Services



Microseismic Events Recorded NW of Verification Well

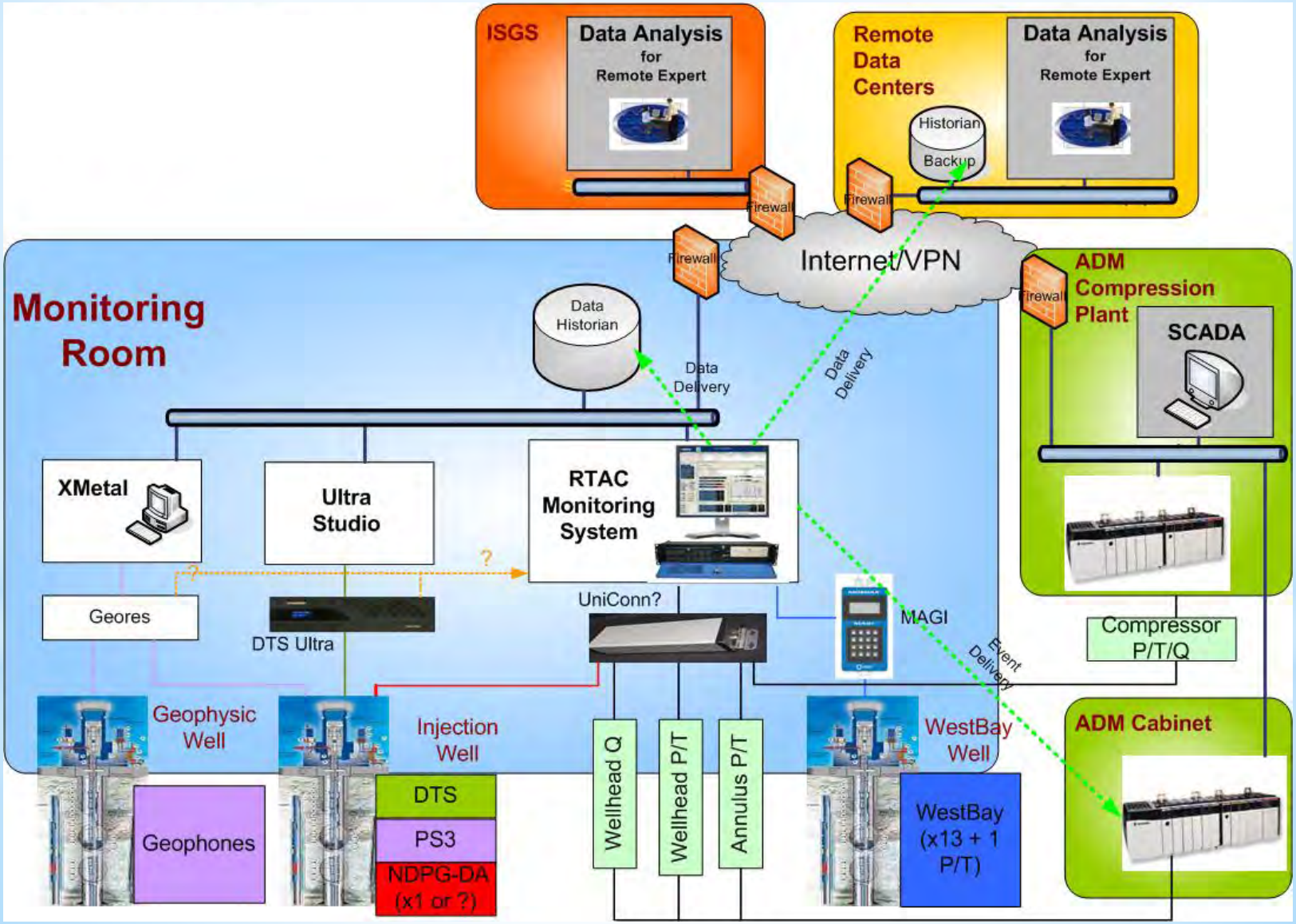


- Four component geophones deployed in injection well adequate to monitor activity
- Microseismic events clustered mainly in four groups NW of verification well
- Events predominately in minus 0.5 to minus 2.0 magnitude
- Event clusters elongated roughly parallel to basinal σ_1 direction

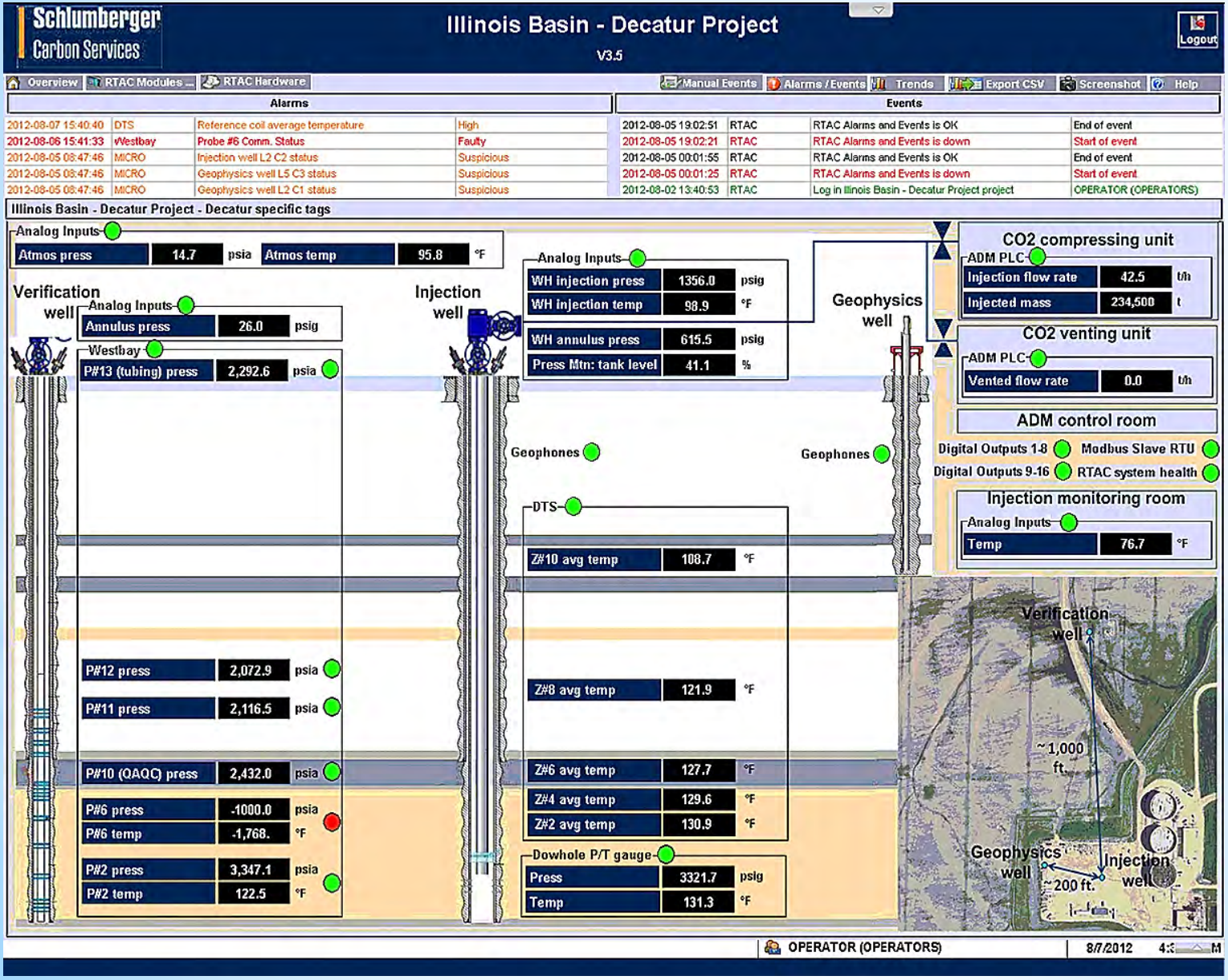
from Schlumberger Carbon Services

Data Collection System

from Schlumberger Carbon Services

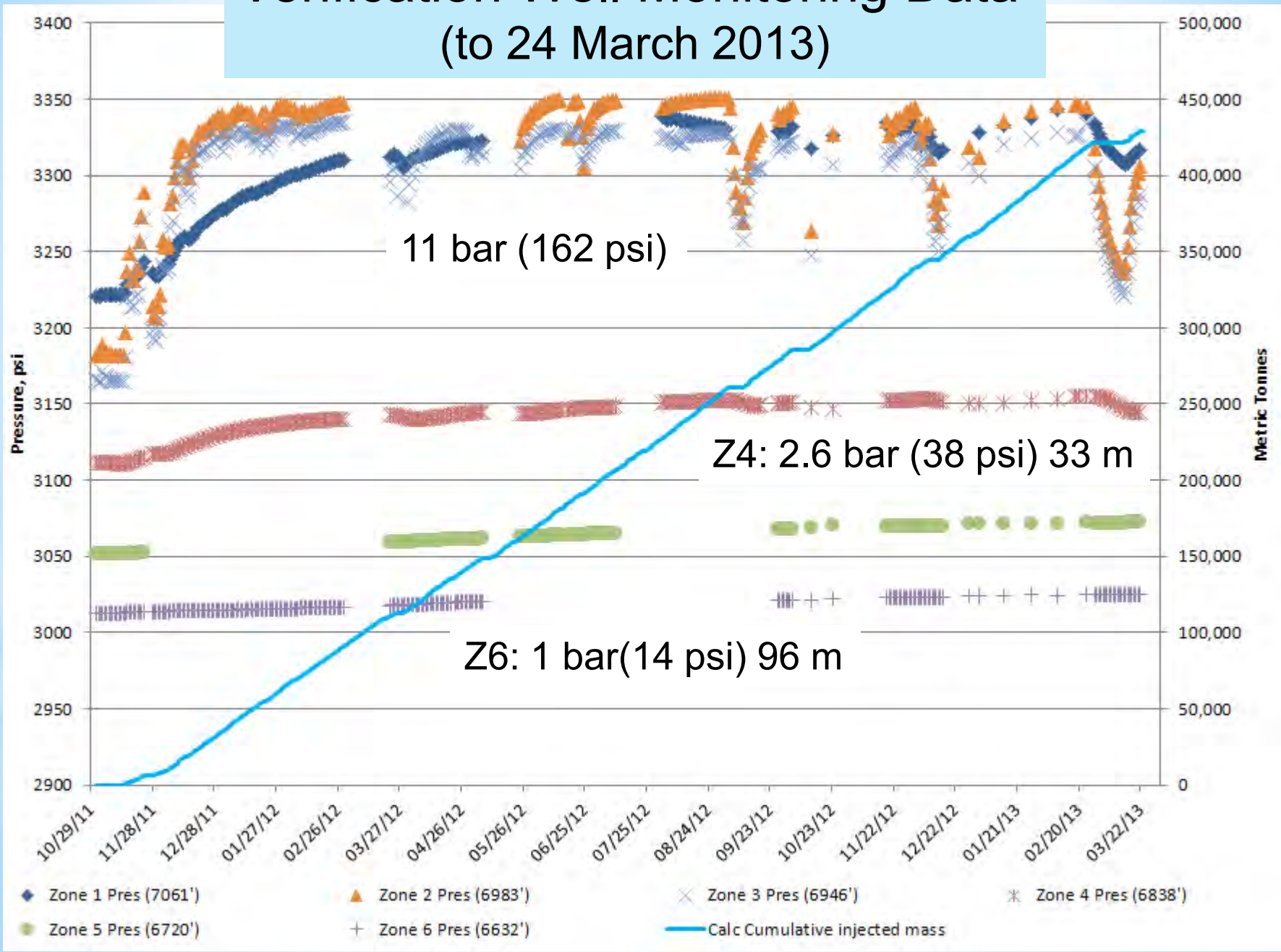


Data Collection System - System Screenshot



From Schlumberger Carbon Services

Verification Well Monitoring Data
(to 24 March 2013)



Key Operational Results – IBDP Year One

- 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 definitively detected with a 3D vertical seismic profile at 75,000 tonnes cumulative injection in March 2012; new survey shot in 4-5 April 2013
- Mt. Simon 200,000 ppm brine is more corrosive than expected, leading to corrosion of verification well cabling and need to replace corrosion inhibitor in well sooner than expected
- With 453,000+ tonnes injected, CO_2 remains in lowermost Mt. Simon; internal reservoir heterogeneity affecting CO_2 distribution

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