An Assessment of Geological Carbon Sequestration Options in the Illinois Basin

Demonstrating CO_2 Storage in the Mt. Simon Sandstone of the Illinois Basin

presented by
Robert J. Finley (ISGS) and the
MGSC Project Team

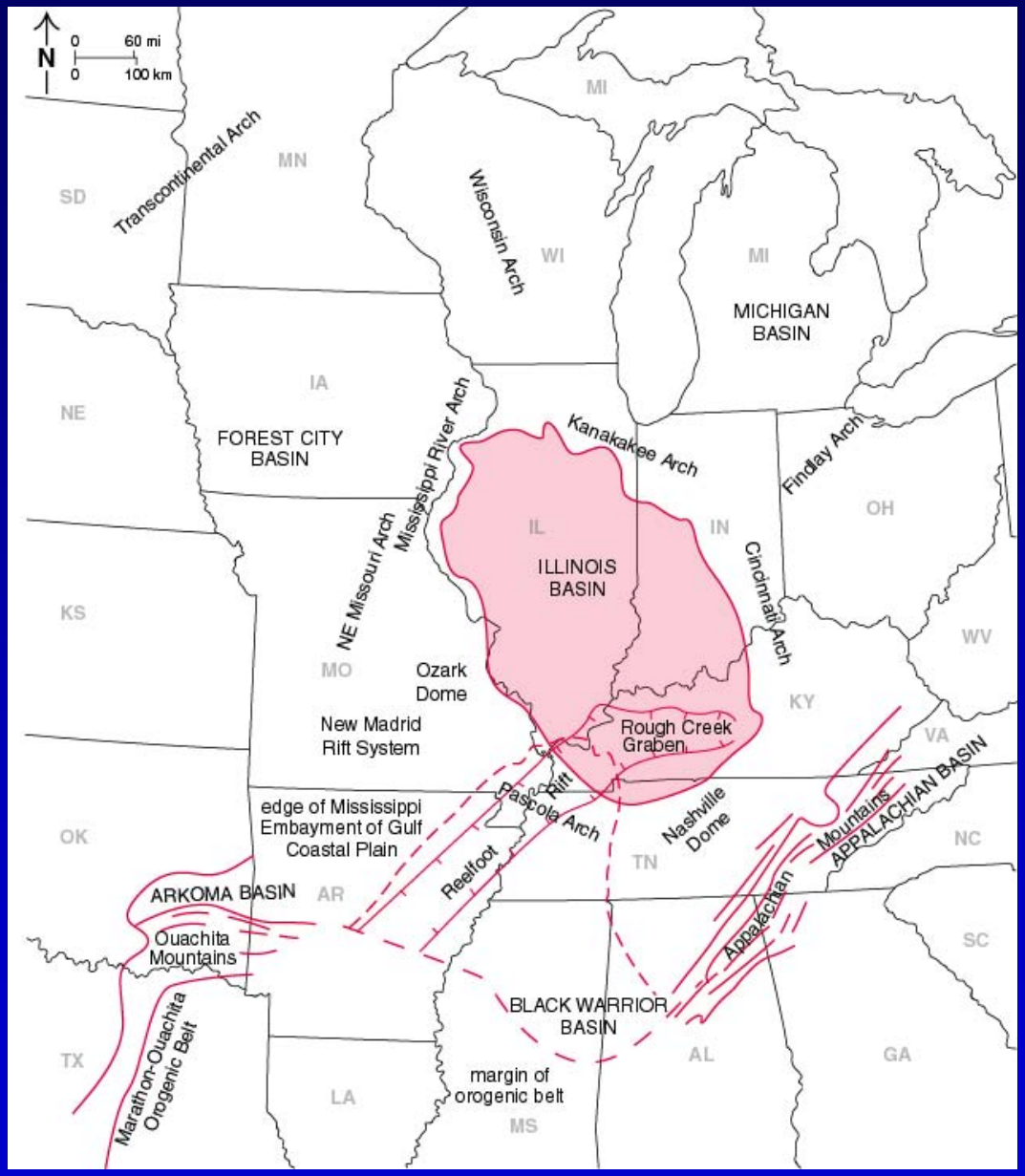
December 12, 2007
DOE Partnerships Review Meeting

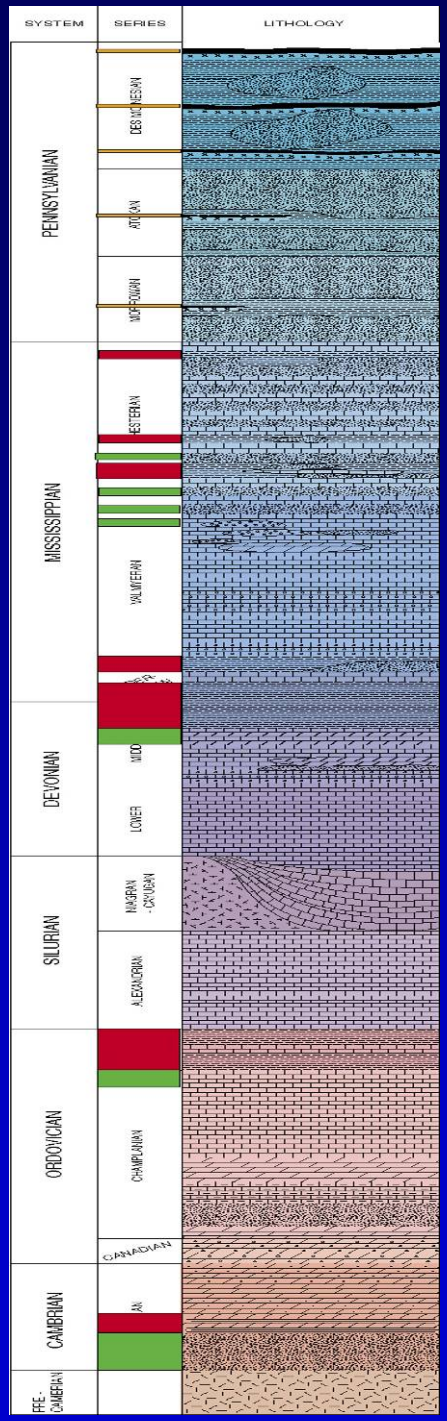
Midwest Geological
Sequestration Consortium
www.sequestration.org

Acknowledgements

- This work is being supported by the U.S. Department of Energy, Office of Fossil Energy, as part of the Regional Sequestration Partnerships Program, and by the Illinois Office of Coal Development (DCEO) through the Illinois Clean Coal Institute, under the Midwest Geological Sequestration Consortium (MGSC)
- The MGSC is a collaboration led by the geological surveys of Illinois, Indiana, and Kentucky

Illinois Basin





Pennsylvanian coal seams

adsorption on coal

Mississippian sandstone and carbonate oil reservoirs

CO_2 EOR in mature fields

New Albany Shale

adsorption on shale

Maquoketa Shale

St. Peter Sandstone

major saline reservoirs

Eau Claire Shale

Mt. Simon Sandstone

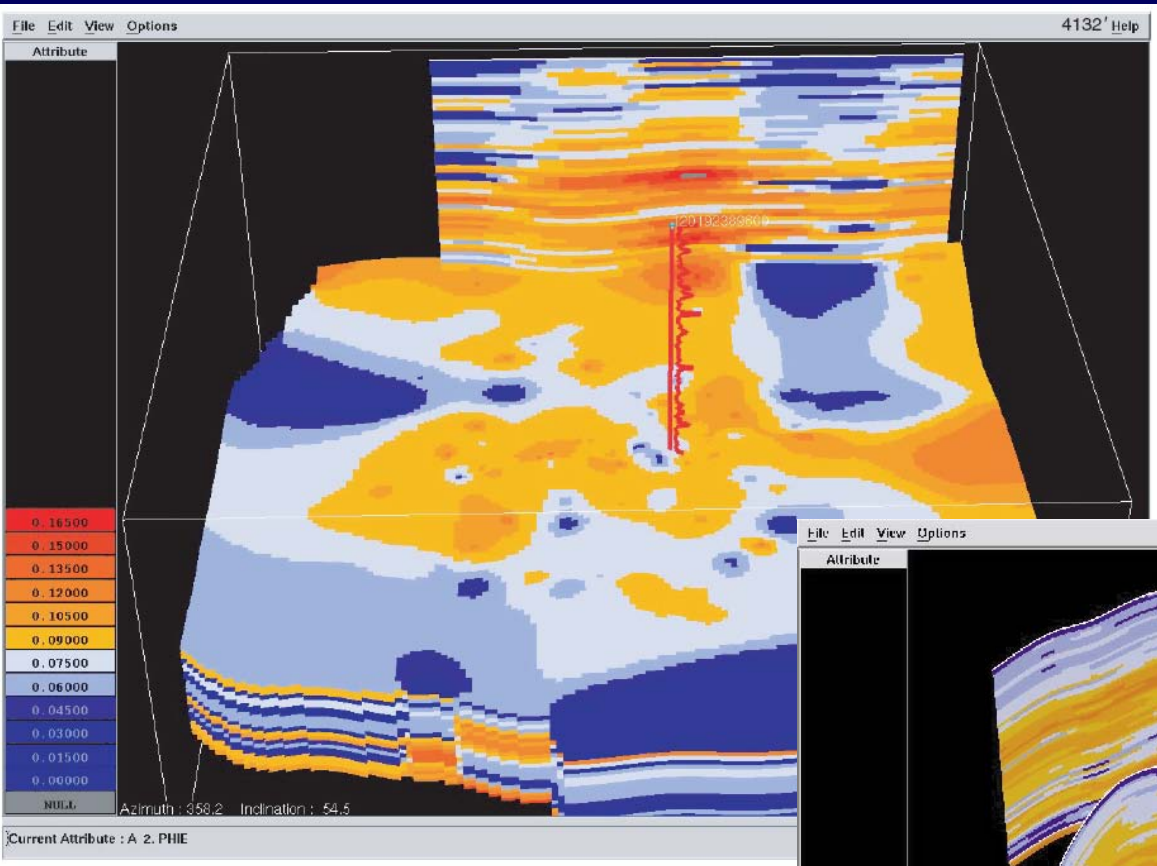
from Leetaru, 2004

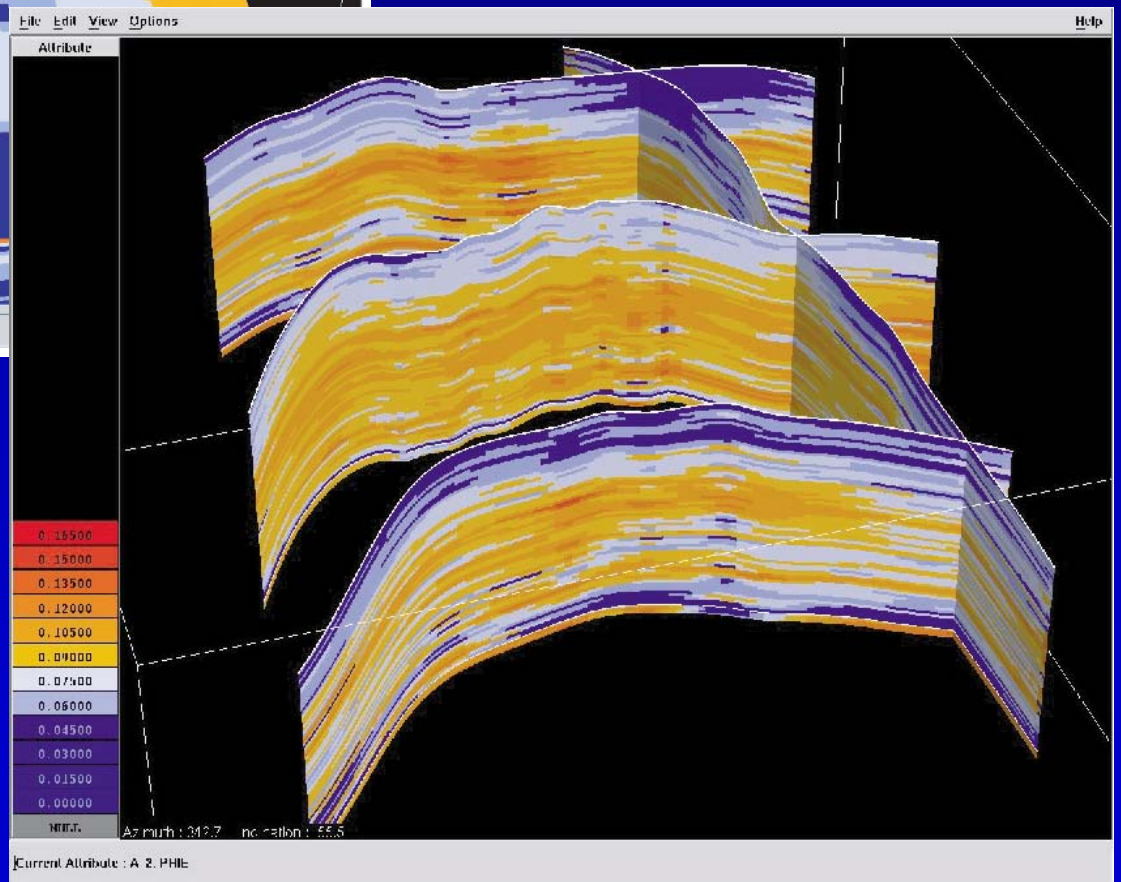
Sink Capacities*

- Seven major coal seams: 2.3-3.3 billion tonnes
  - 6.7 trillion ft^3 incremental methane(?)
- Mature oil reservoirs: 140-440 million tonnes
  - 860-1,300 million barrels incremental oil
- St. Peter Sandstone: 1.6-6.4 billion tonnes
- Mt. Simon Sandstone: 27-109 billion tonnes

*DOE, 2007, Carbon Sequestration Atlas of the United States and Canada

Mt. Simon Sandstone





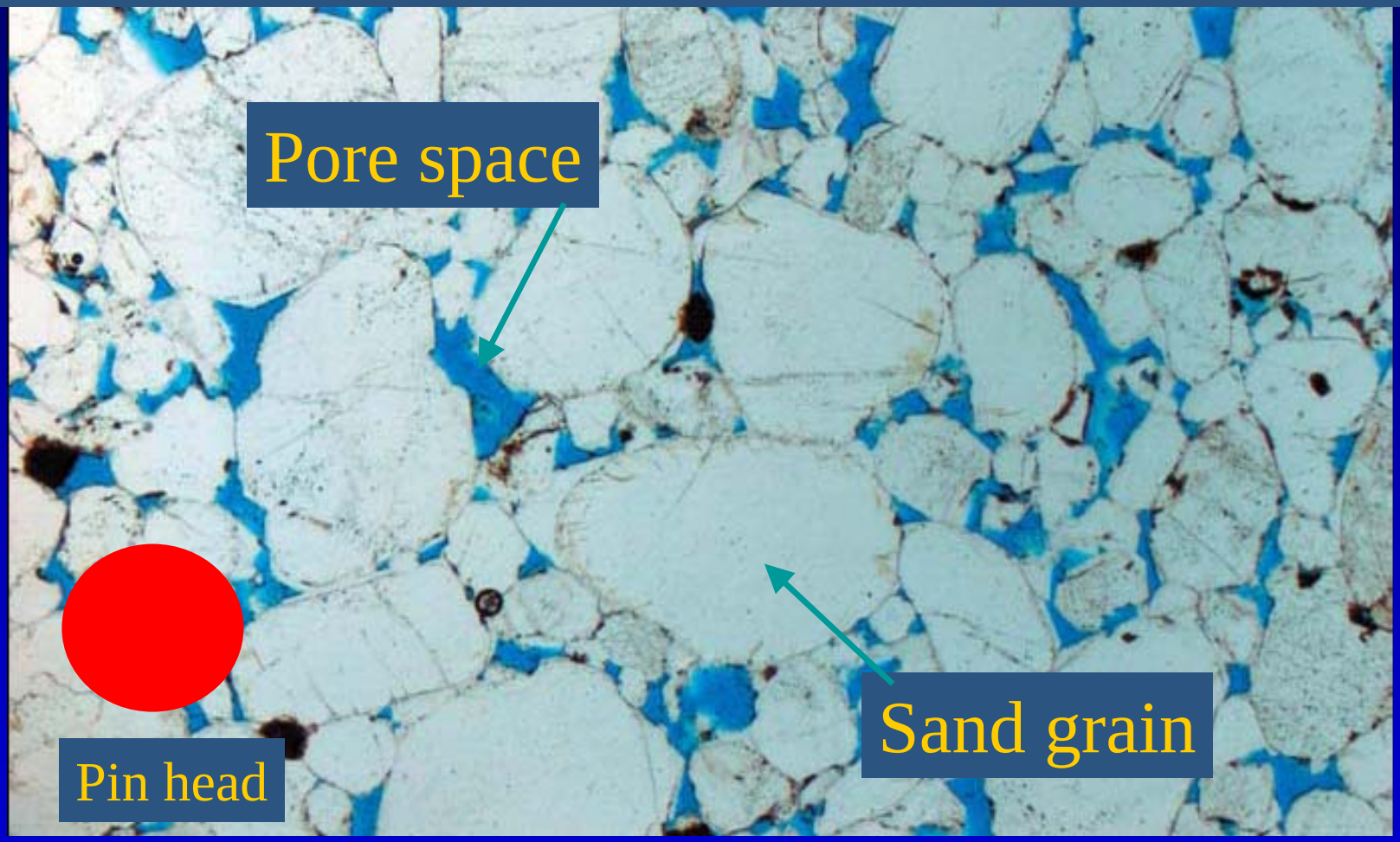
High Porosity

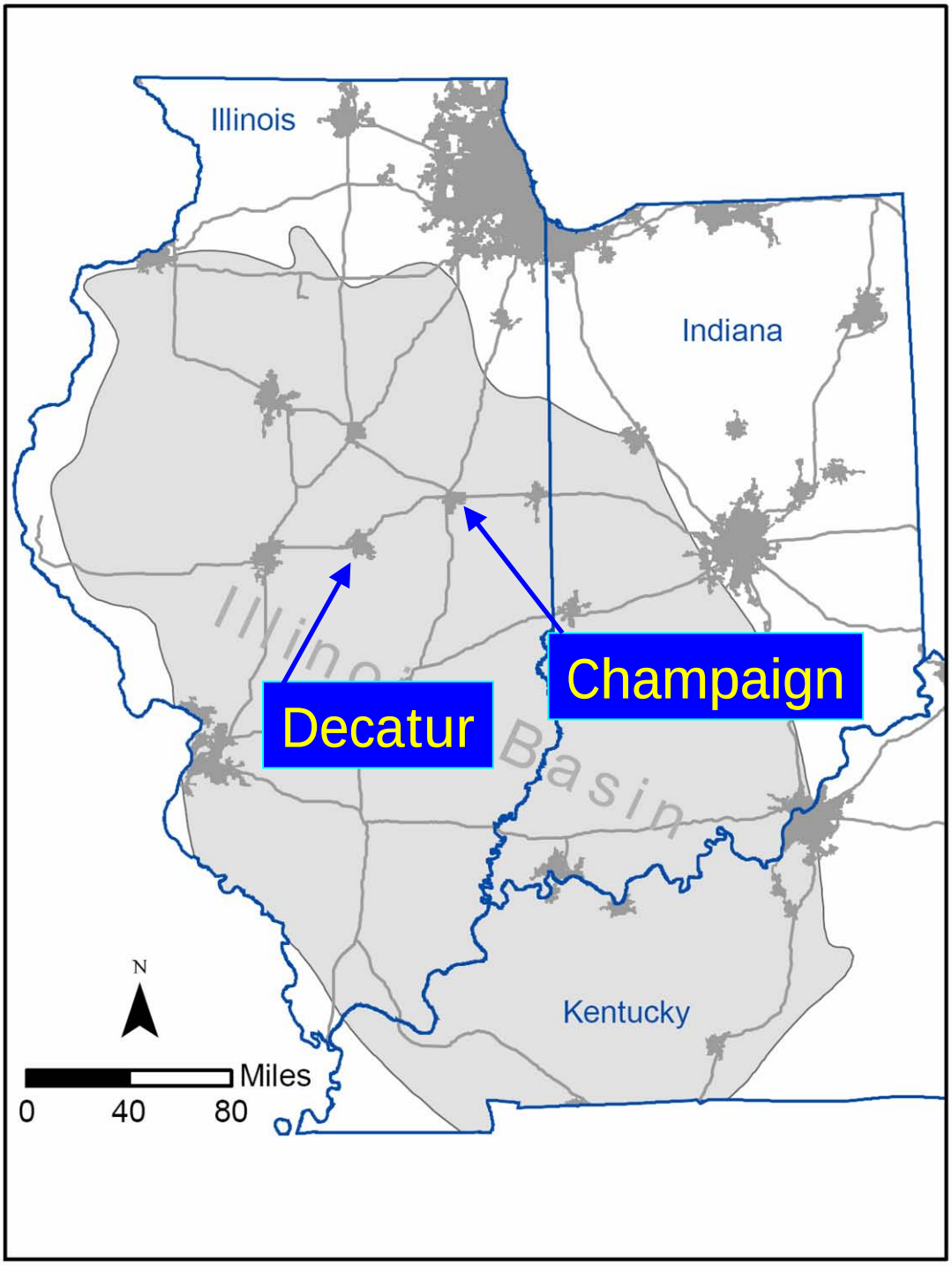
Low Porosity

Mt. Simon Sandstone Reservoir

- Mt. Simon Sandstone is used for natural gas storage in Champaign County, IL at 4,000 to 4,200 ft
- Mt. Simon core has been recovered from a few deep exploration wells, such as this sample from near Salem, IL at 8,467 drilled in 1966

CO_2 Storage in Sandstone Reservoir Pore Space

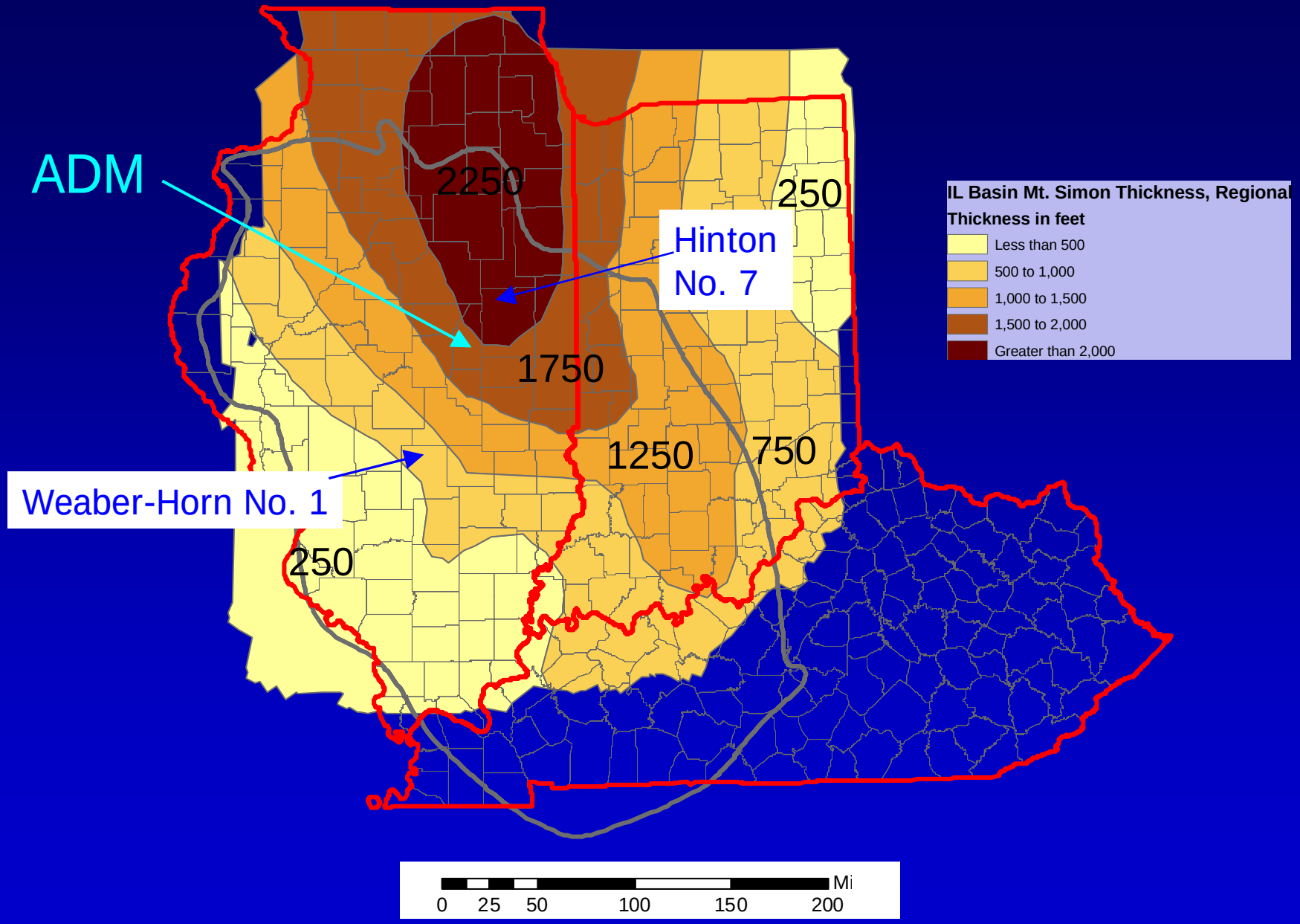




Decatur, Illinois Location

- Decatur, IL is located in central Illinois on the margin of the thickest part of the Mt. Simon Sandstone depocenter
- Field logistics simplified by proximity to ISGS offices and ADM support

Mt. Simon Thickness



Predicting Mt. Simon Reservoir Quality at the ADM Site

- Hinton No. 7 in Manlove Gas Storage Field in Champaign County has deep Mt. Simon core analysis (39 mi northeast)
- Humble Oil Weaber-Horn No. 1 well is located on the Loudon Field anticline in Fayette County and has a porosity log (54 mi southwest)

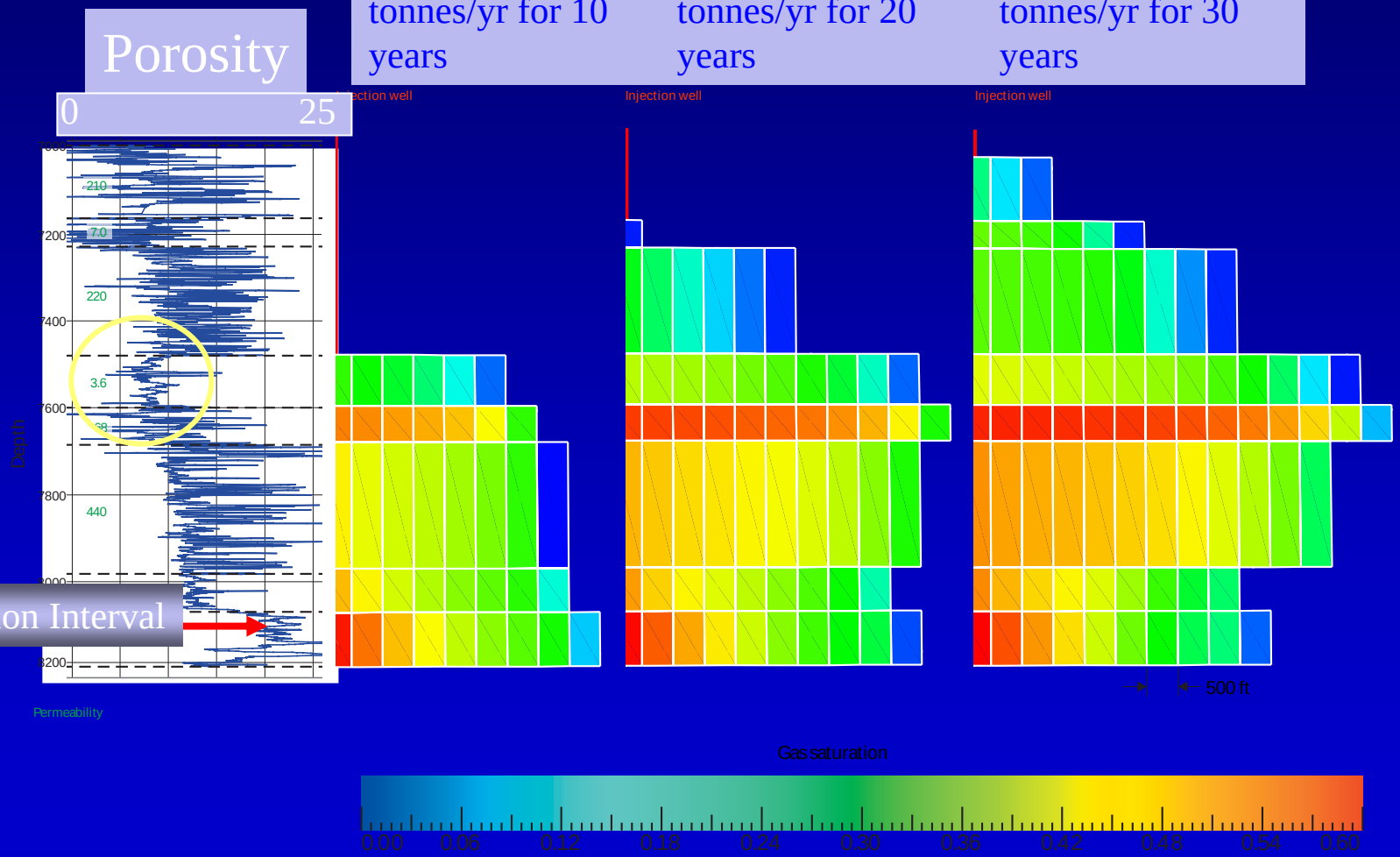
VIP Compositional Simulation

Weaber-Horn No. 1

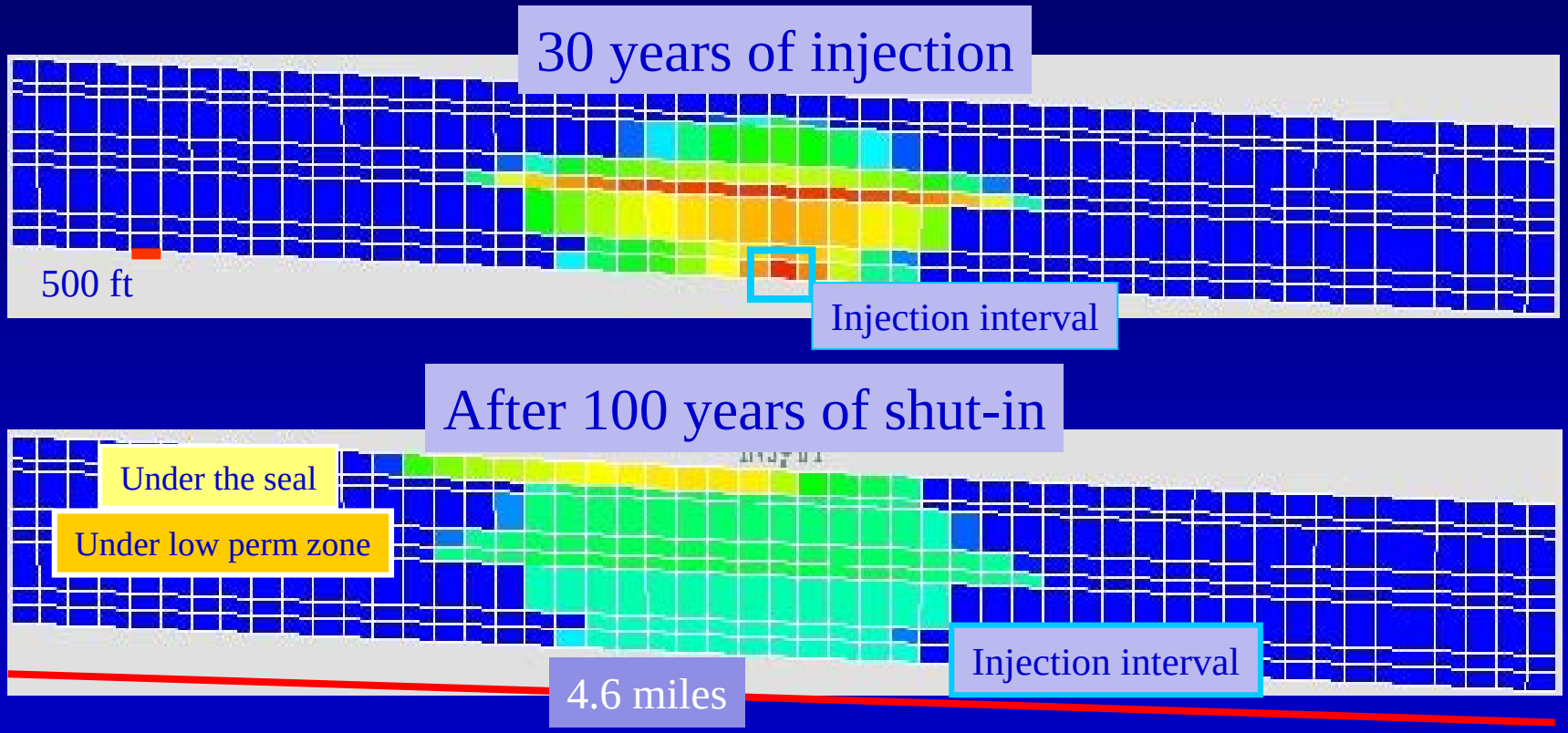
2.5 million tonnes/yr for 10 years

2.5 million tonnes/yr for 20 years

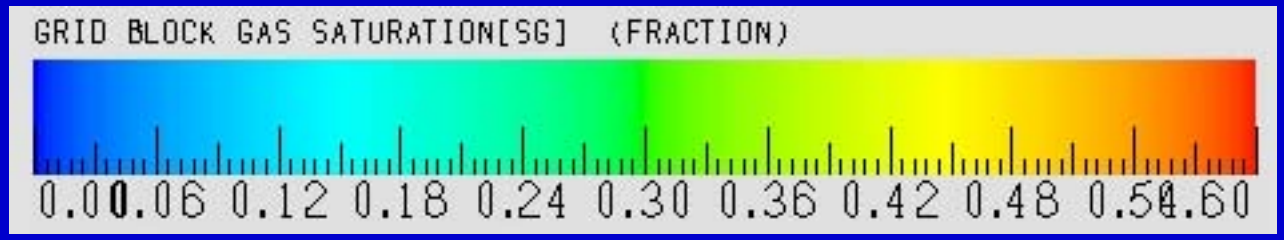
2.5 million tonnes/yr for 30 years

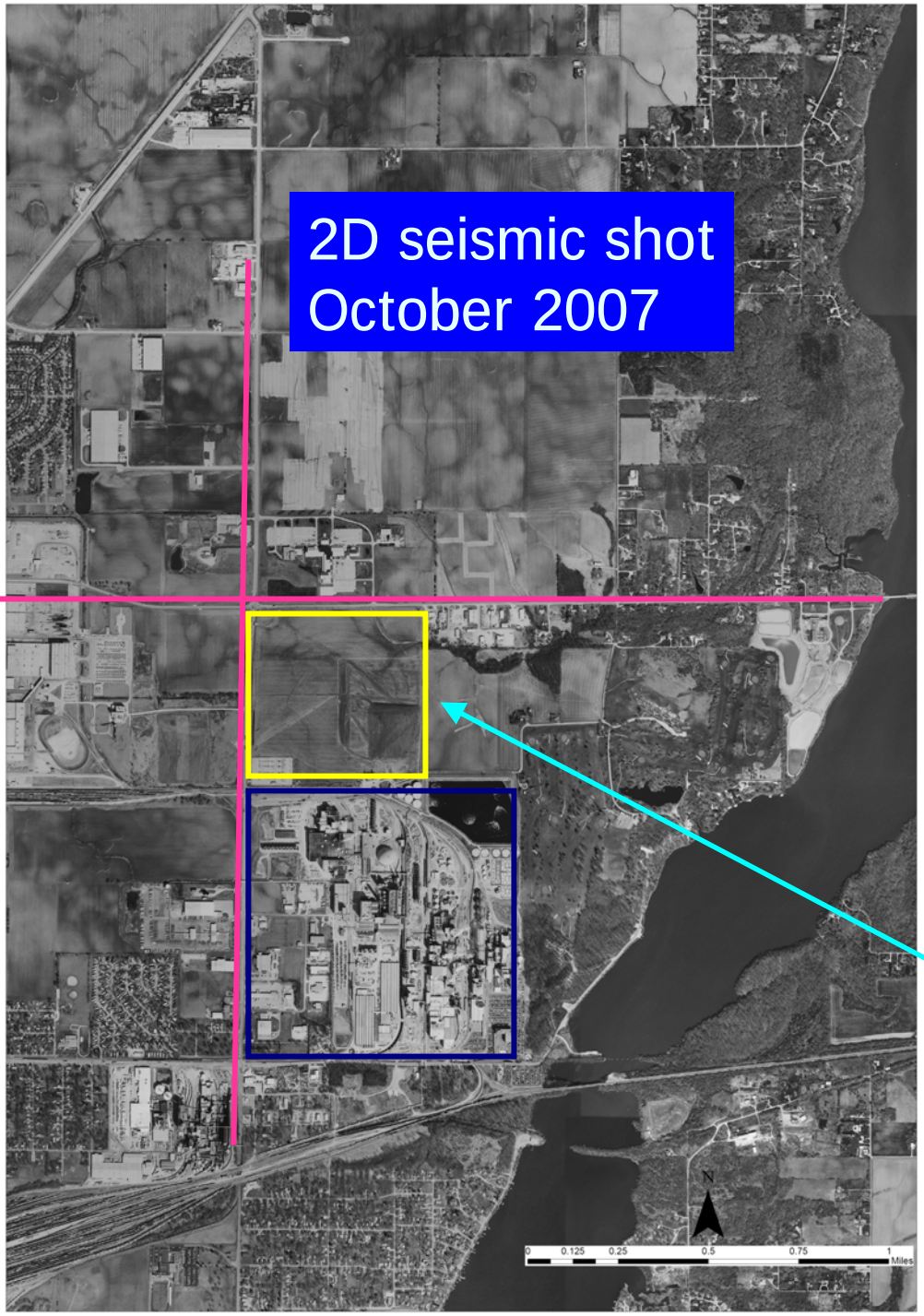


Injection into the Weaber-Horn 1 degree dipping beds



1 million tons/yr

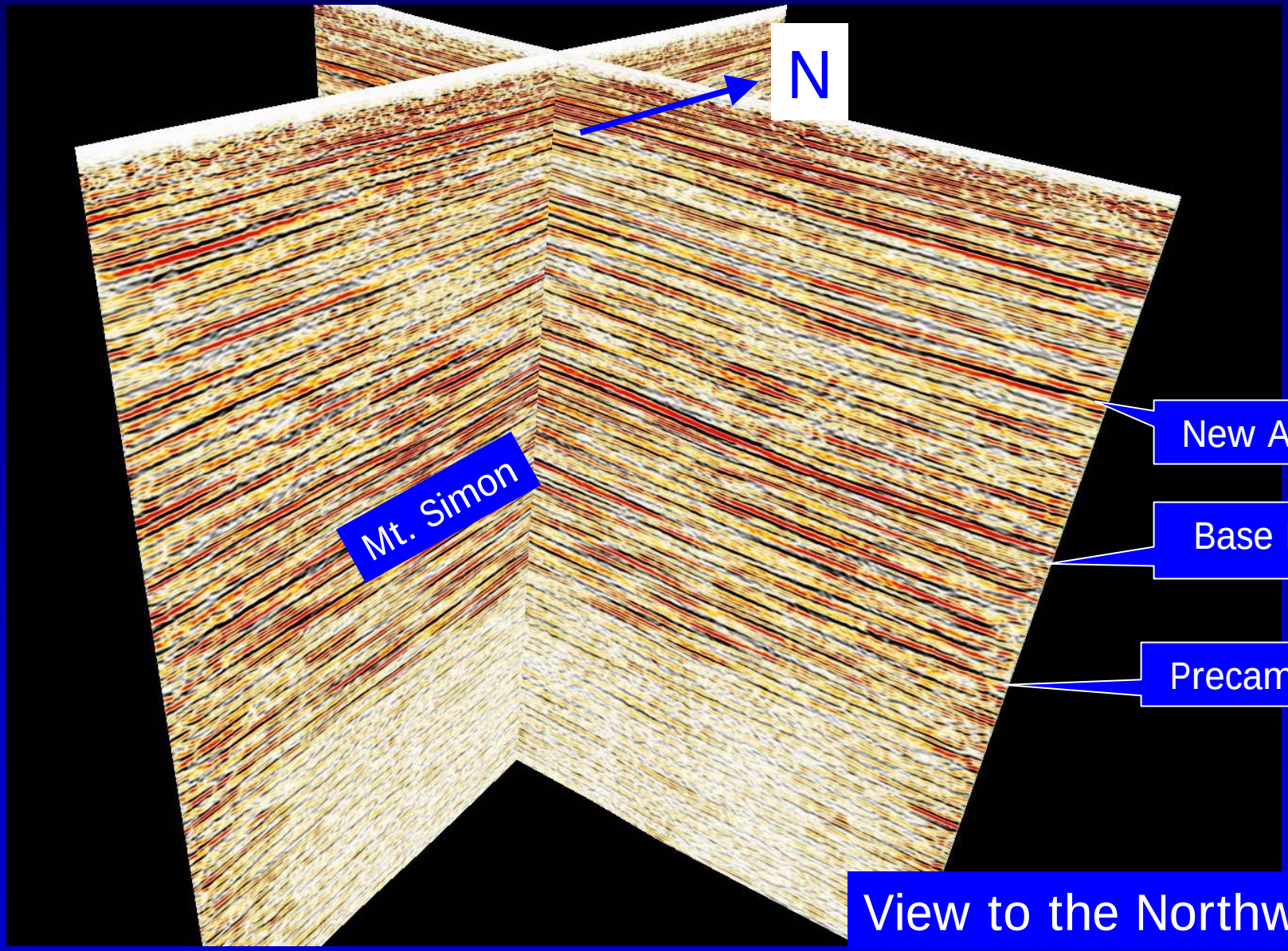


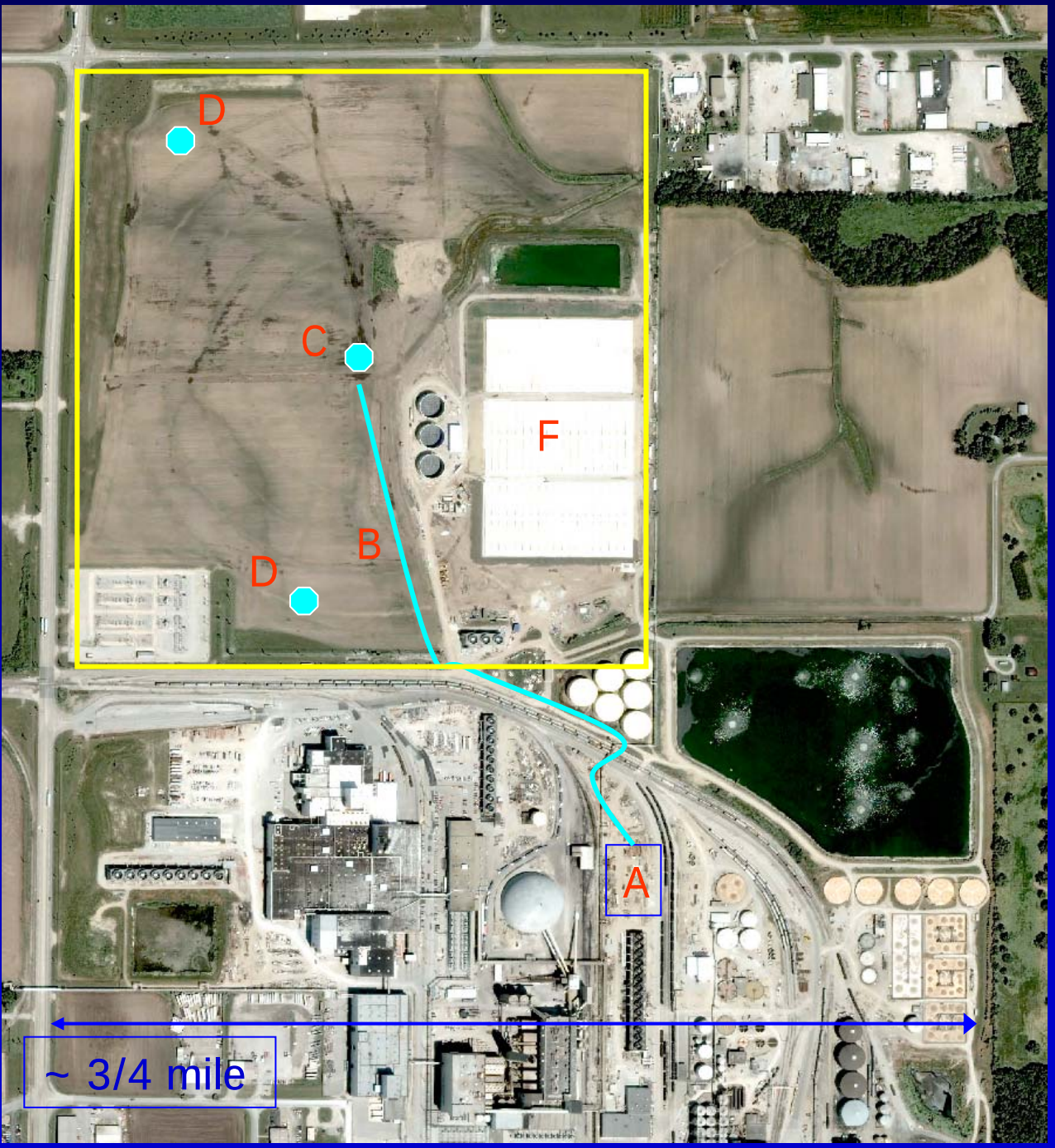


Archer Daniels Midland Company Site

- Facility processes agricultural products, produces ethanol, and is the ADM corporate headquarters
- ADM owns several surrounding tracts in addition to plant site
- Injection tract is about 2,800 x 2,800 ft immediately north of the plant

2-D Seismic at ADM Site





ADM Test Site

- A Dehydration/ compression facility location
- B Pipeline route
- C Injection well site
- D Potential verification well sites
- F Anaerobic wastewater treatment facility

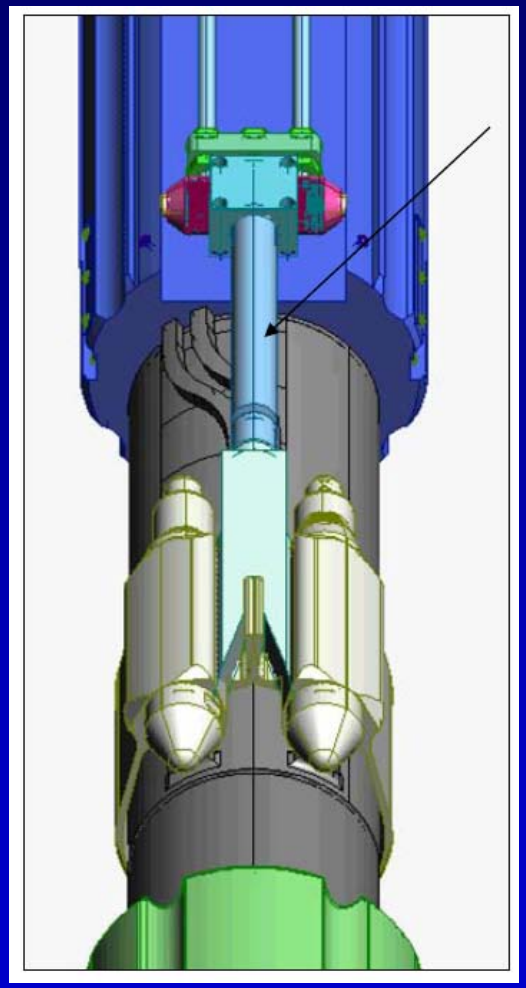
Well Configurations

- Injection well drilled to 7,500 ft max. (to granite)
- Intermediate 9 5/8”casing @~5,000 ft cemented to surface and 7” N-80 long string cemented to surface with CO_2-resistant cement
- Tubing: 3 ½” PVC lined with CO_2-capable packer
- Tubing-conveyed, permanent geophone string for microseismic monitoring and repeat VSP plume monitoring
- Whole core, fluid sampling, P/T, drilled sidewalls, logging
- Monitoring/verification wells (2) budgeted to same depth, but with 2 7/8” tubing (lower cost) pressure/temp, fluid sampling, cross-well imaging potential, repeated cased hole logging

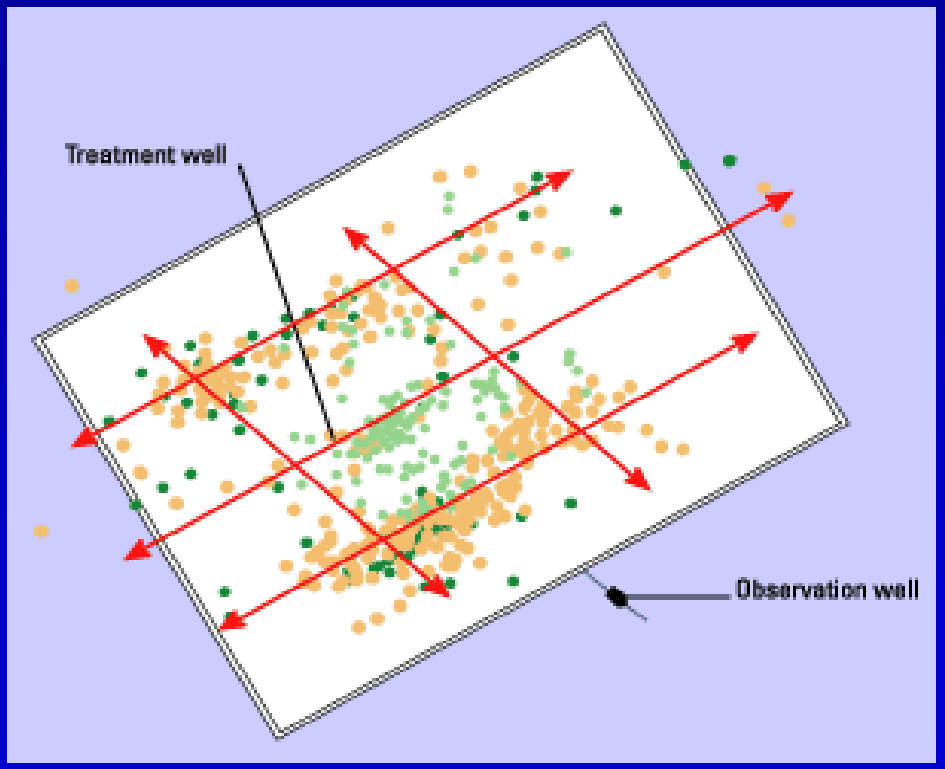
Monitoring, Mitigation and Verification

- Develop integrated geochemical/geomechanical model to guide MMV program using extensive data collection from injection well and initial geophysical surveys for site characterization
- Utilize Phase II techniques for testing ambient air, soil vadose zone, groundwater, and observation of vegetation
- Two verification wells to enhance geophysical observations of plume boundaries, confirm those boundaries by subsurface sampling, and sample formations above the primary seal
- Continue MMV for 2-3 years after I million tons injected

Matrix Monitoring Strategies

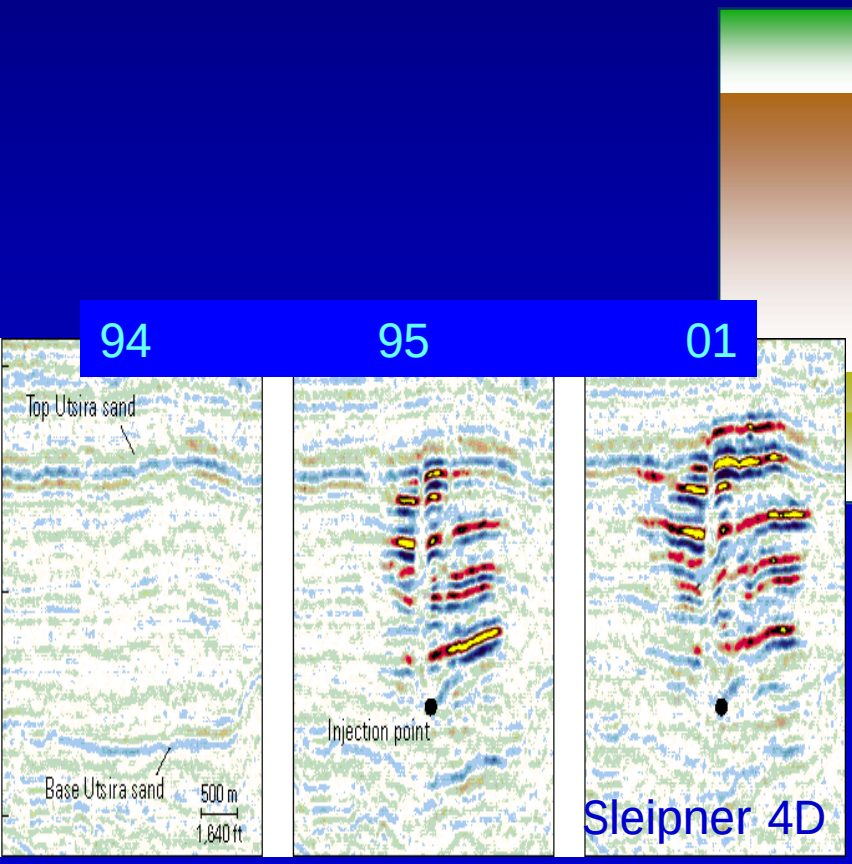


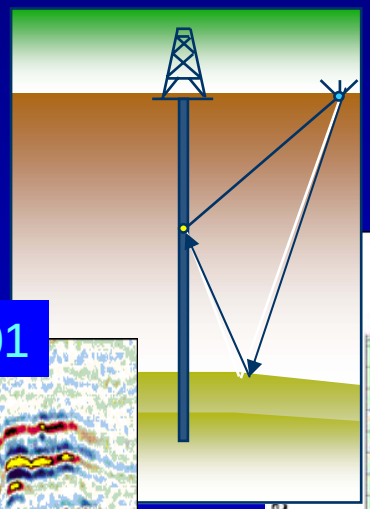
- Geophones run in on tubing, deployed to casing, avoids cement integrity problems, recoverable as needed
- Map any microseismic events monitored using clamped geophone array during active injection



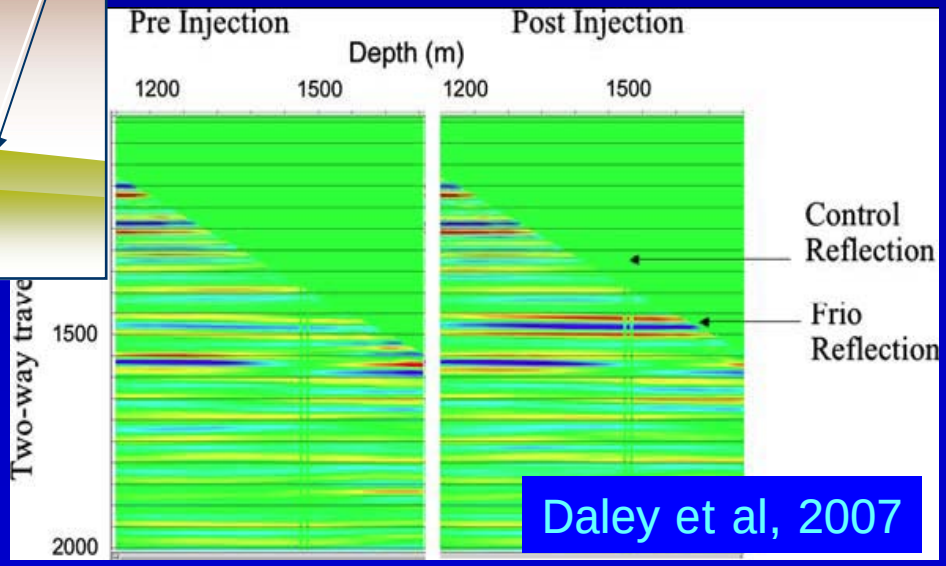
Plume Monitoring Strategies

- Seismic response of plume based on repeat surface 3D ("4D") similar to Sleipner project and offset or walkaway Vertical Seismic Profile (VSP) using geophone array





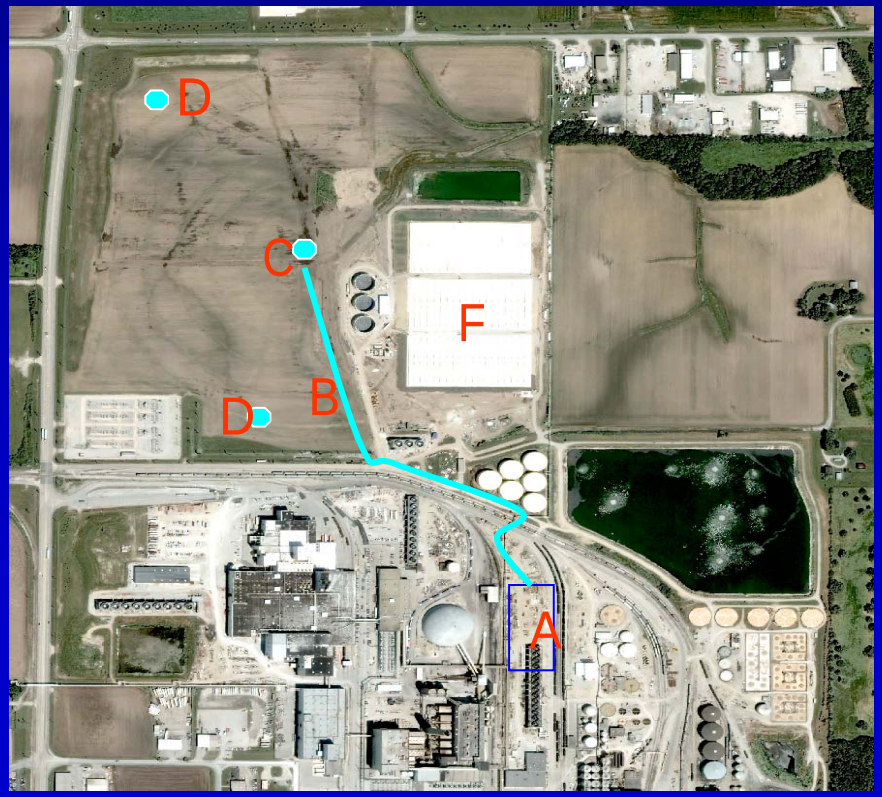
Frio Brine Pilot



Daley et al, 2007

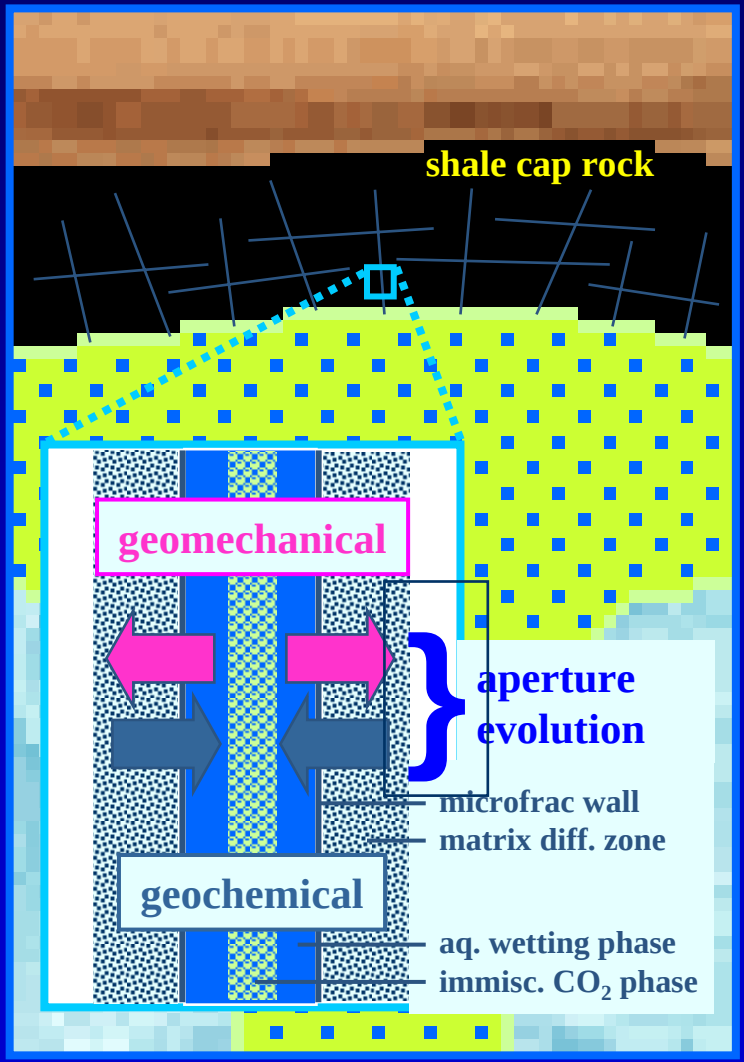
Plume Monitoring Strategies

- Drill two verification wells (D) based on surface seismic and VSP data, generally one updip and one downdip, or placed based on VSP plume boundary imaging



- Open-hole logging and flexible (Westbay) fluid sampling strategy
- Pressure/temp. monitoring
- Cased-hole logging

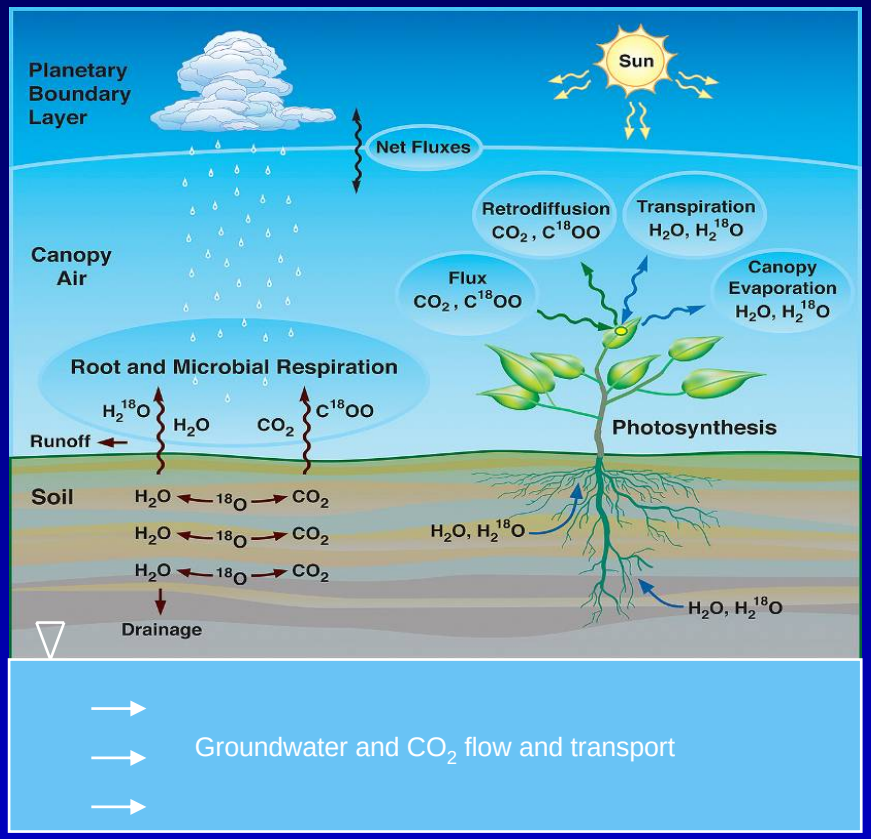
Seal Integrity Hinges on the Interplay of Geochemical & Geomechanical Processes



- Geochemical alteration
  - ✓ **Mineral diss/pptn reactions triggered by the chemical perturbation**
  - ✓ **Compositional properties of the cap rock, reservoir, & injection fluid**
  - ✓ **Tends to enhance seal integrity of shale**
- Geomechanical deformation
  - ✓ **Microfrac mobilization triggered by the pressure (effective stress) perturbation**
  - ✓ **Reservoir perm & lateral continuity; CO_2 influx rate, duration, & focality**
  - ✓ **Tends to degrade seal integrity of shale**
- Relative effectiveness controls the evolution of seal integrity

From Johnson, LLNL

Model Domains and Processes



LSM

TOUGH2

MMV for CO_2 storage is complicated by natural processes involving carbon.

from Oldenburg, LBNL

Surface flux measurements, modeling, and advanced data analysis may be needed to discern seepage signal from background variation (e.g., Lewicki, Hilley, and Oldenburg, 2005).

Accumulation Chamber (AC) and Eddy Covariance (EC) Instruments

Accumulation Chamber:
- **Local surface CO_2 flux**
- **Scale ~ cm^2**
- **Measurement time ~ minute**

from Oldenburg, LBNL

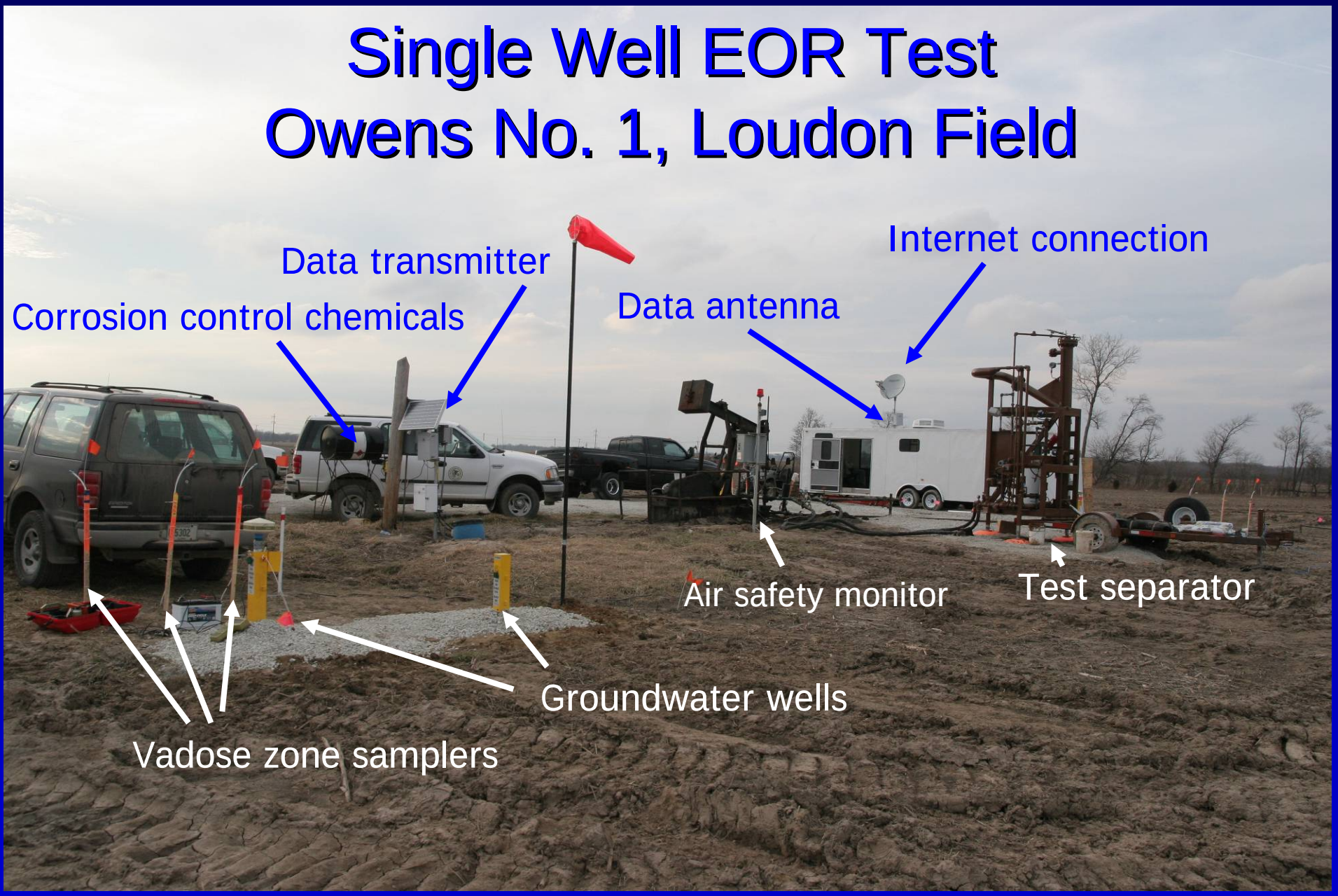
Eddy Covariance:
- **Average net surface CO_2 flux**
- **Scale ~ m^2- km^2 (scales with height)**
- **Requires time-averaging**
- **Steady-state, homogeneous, flat, horizontal surface**

MMV in the Field

- Installing monitoring wells
- Installing vadose zone samplers
- Collecting background samples

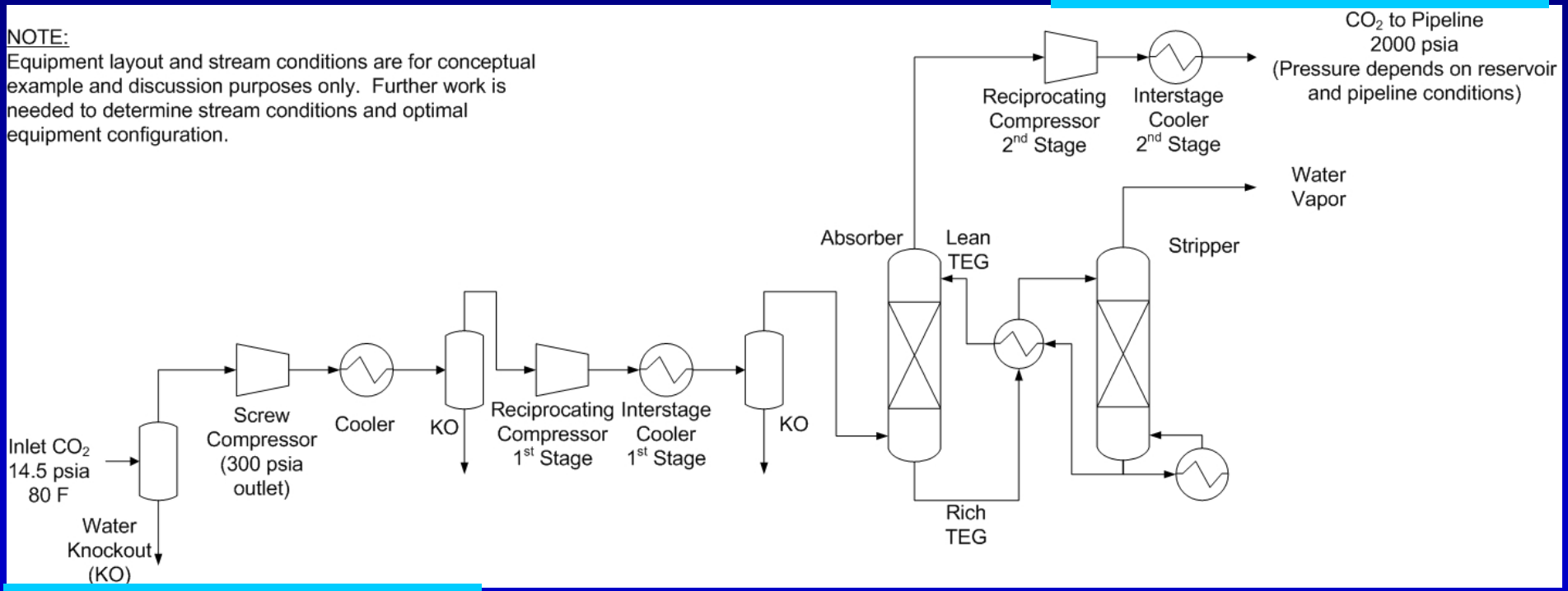
Formation brine sampling

Single Well EOR Test
Owens No. 1, Loudon Field



Preliminary CO_2 Process Flow Diagram for ADM Site

Output
Dry at 2,000 psia



Input
Wet at 14.5 psia

from Trimeric Corporation

Phase III Outcomes

- A large-scale injection of 1 million tons of CO_2 successfully demonstrated and associated safety, efficiency, and effectiveness requirements met
- Volume sufficient to monitor geophysically; dehydration/compression equipment scalable to IGCC
- A process model established for equipment, permitting, injection, MMV, and outcome assessment that will support energy facility development with integrated carbon sequestration in the Illinois Basin and elsewhere
- An “active” geological site model developed and continually updated as new data are acquired

Phase III Schedule

- Gantt chart developed showing 14 Tasks and 78 Subtasks
- Project begins October 07— merges with Phase II saline test
- Baseline MMV activities begin Winter 07
- UIC permit application: Dec 07; target receipt: March 08
- The injection well drilled in April-May 08
- Final functional testing of compression, pipeline, and wellhead initiated in July 09
- Injection would occur from October 09-September 12
- Verification wells would be drilled April-May 2010 and April-May 2012
- MMV carried out through December 2015

Midwest Geological
Sequestration Consortium
www.sequestration.org