

An Assessment of Geological Carbon Sequestration Options in the Illinois Basin

A DOE Regional Sequestration Partnership

MGSC Project Team



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Illinois State Geological Survey



Midwest Geological
Sequestration Consortium



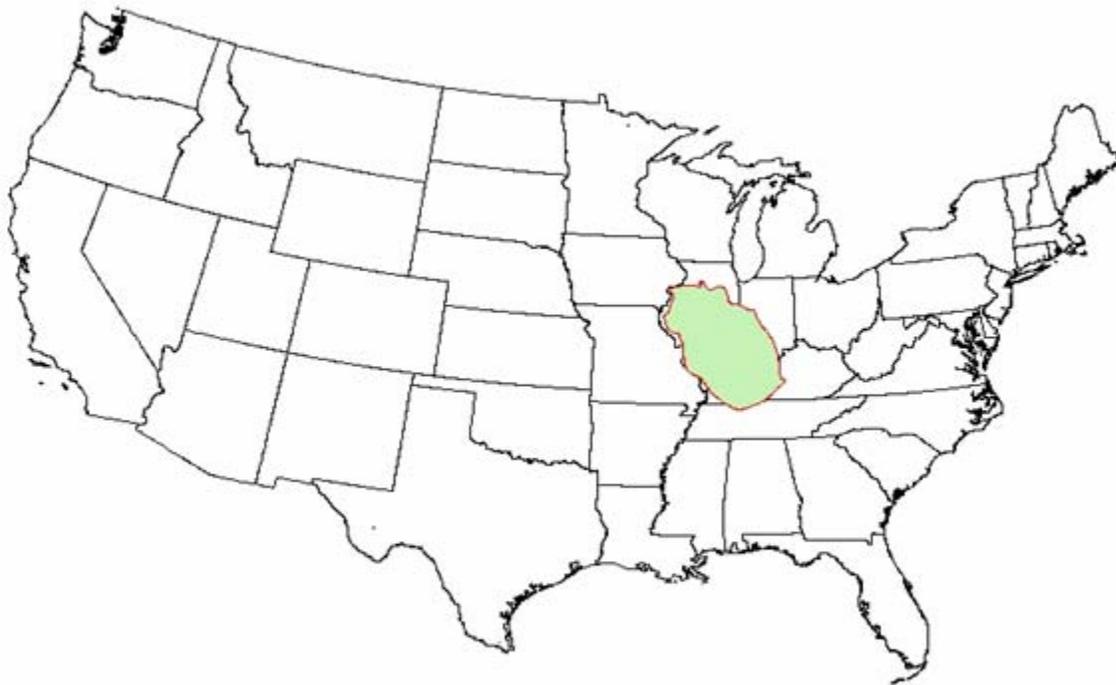
Alexandria, VA May 2006

MGSC Project Advisors and Partners

- **Utilities:** Ameren, Louisville Gas and Electric, and Cinergy
- **Industry:** Aventine Renewable Energy, American Air Liquide, British Petroleum*, Drummond Coal*, LincolnLand Agri-Energy, Peabody Energy, Power Holdings, and Schlumberger*
- **NGO and trade groups:** Environmental Defense*, IL, IN, and KY Oil & Gas Associations, IL Corn Growers Association, Electric Power Research Institute, Interstate Oil and Gas Compact Commission
- **State government:** IL Office of Coal Development, (DCEO), IL Department of Natural Resources

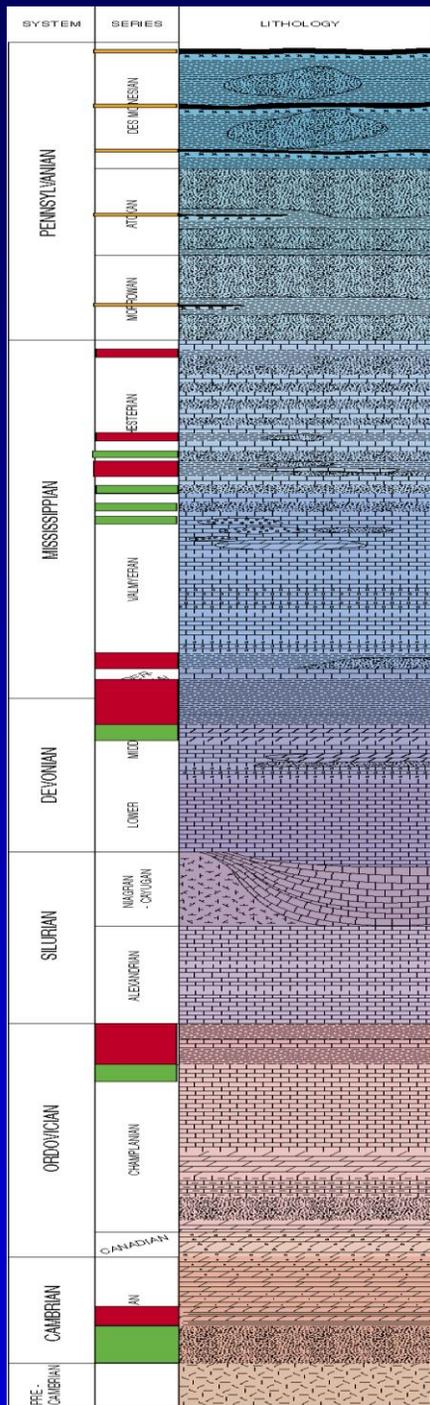
* *new in Phase II*

Midwest Geological Sequestration Consortium (MGSC) A DOE Regional Partnership—Phase II



Illinois Basin Emissions= >283 mmt CO₂/yr

- Led by Illinois State Geological Survey in collaboration with the Indiana and Kentucky Geological Surveys
- 28 other subcontractors and consultants



Pennsylvanian coal seams

Mississippian sandstone and carbonate oil reservoirs

New Albany Shale

Illinois Basin Stratigraphic Column

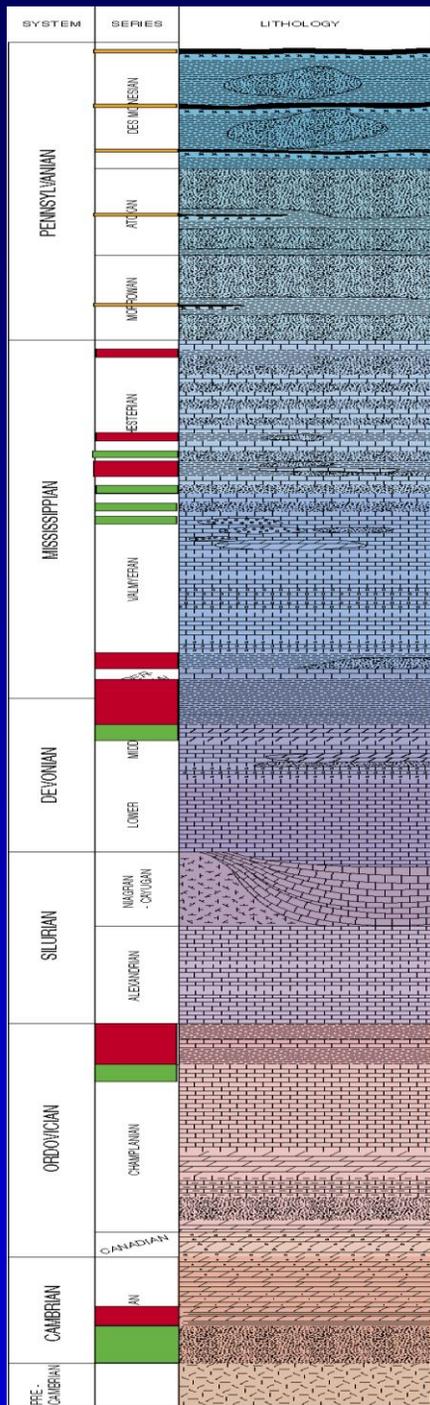
Maquoketa Shale

St. Peter Sandstone

Eau Claire Shale

Mt. Simon Sandstone

from Leetaru, 2004



Pennsylvanian coal seams

adsorption on coal

Mississippian sandstone and carbonate oil reservoirs

CO₂ EOR in mature fields

New Albany Shale

adsorption on shale

Maquoketa Shale

St. Peter Sandstone

Eau Claire Shale

Mt. Simon Sandstone

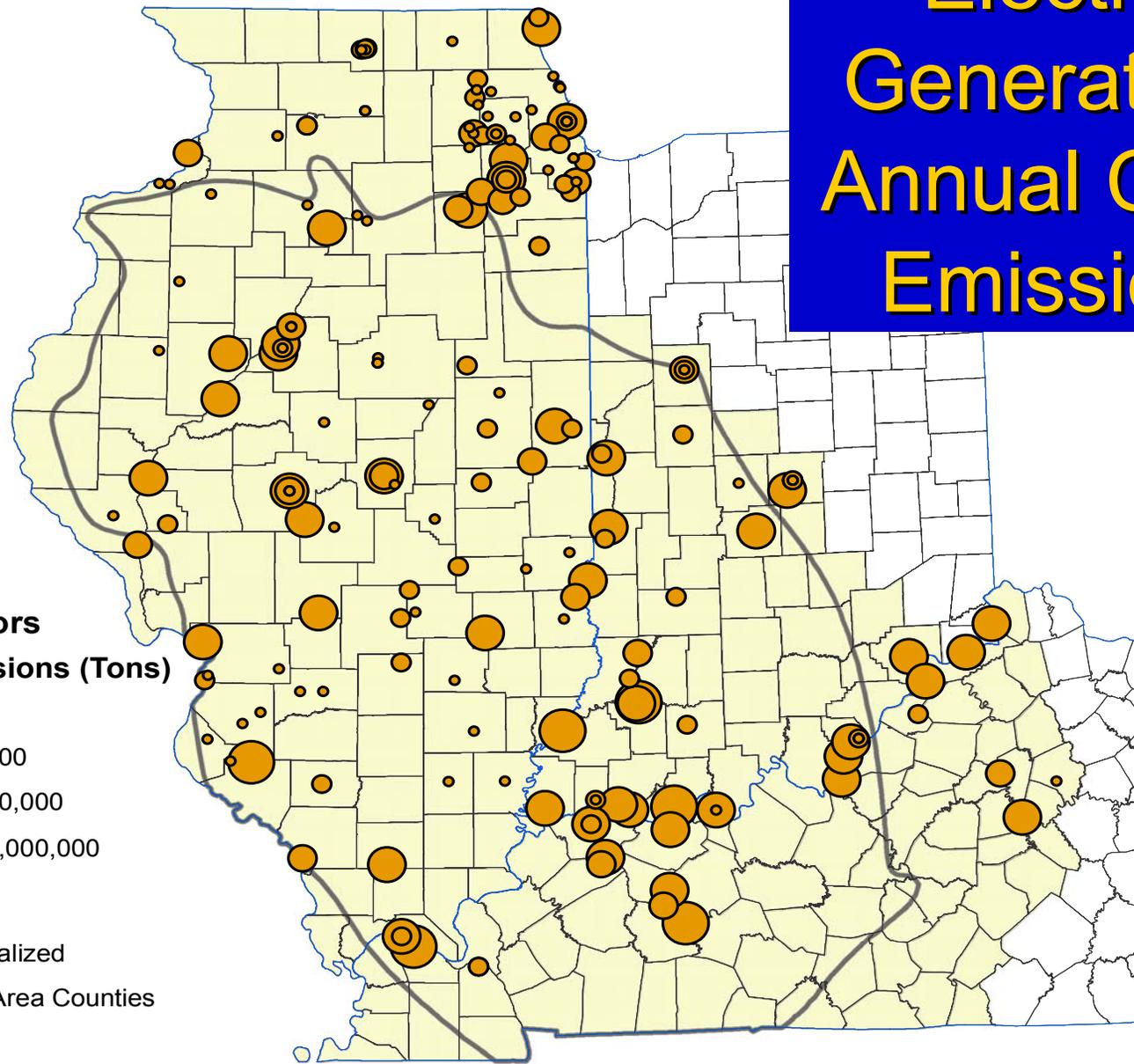
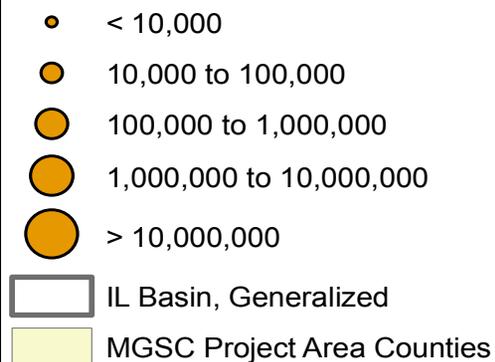


major saline reservoirs

from Leetaru, 2004

Electrical Generators Annual CO₂ Emissions

Electric Generators Annual CO₂ emissions (Tons)



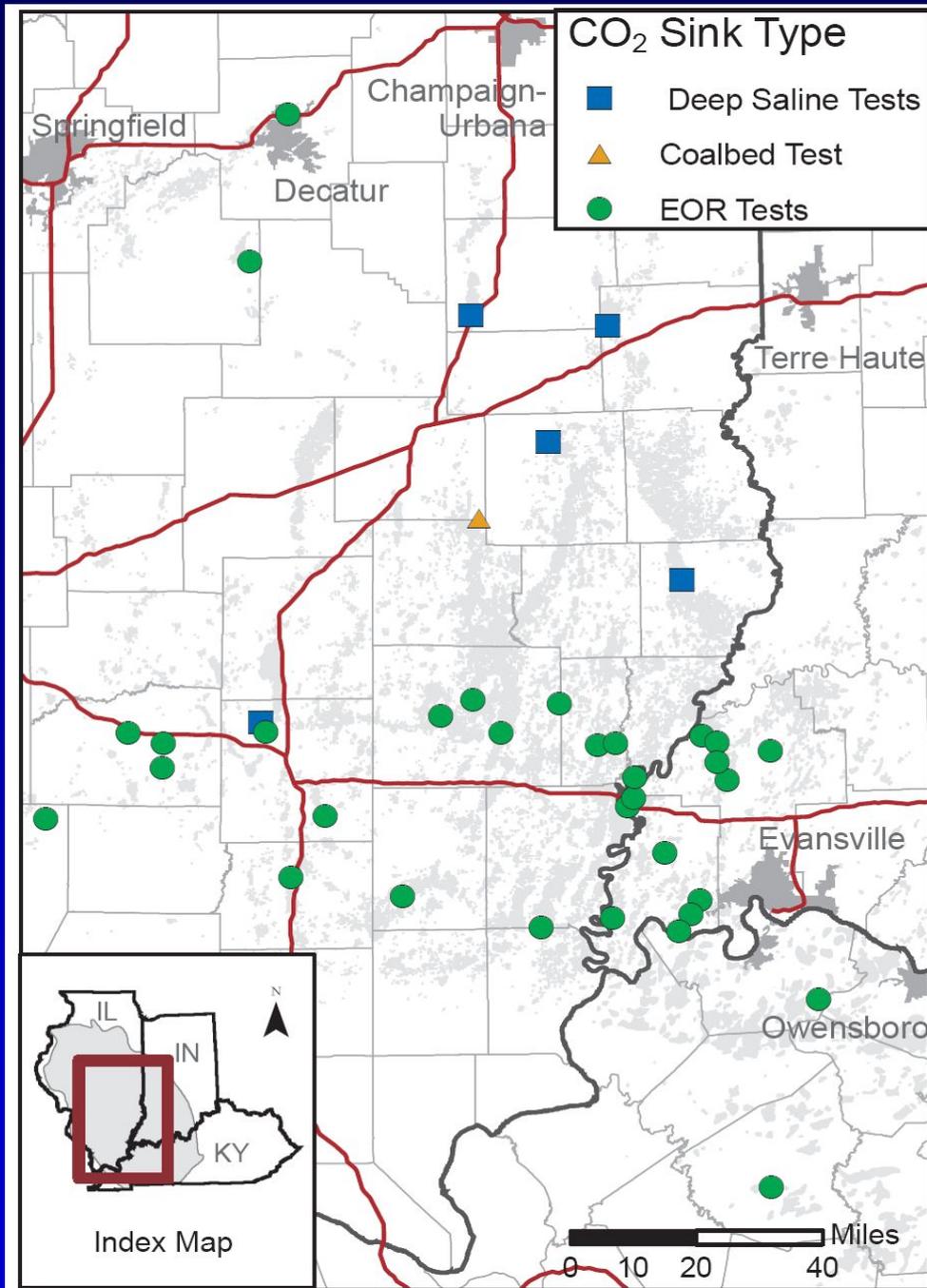
Source: US DOE Energy Information Administration 2002; US EPA Acid Rain 2002, EGRID 2000.

MGSC: Seeking Optimal Sinks

- High CO₂ storage capacity
- High CO₂ injection rate
- Storage mechanism assessment
- Six field tests proposed from portfolio of 34 potential field test sites among 11 oil operators for Phase II activities
- Coal seam site selected
- First of four EOR pilot test sites in final selection process

Sink Capacities

- Seven major coal seams: 3.6 billion tonnes
 - 6.7 trillion ft³ incremental methane
- Mature oil reservoirs: 140-440 million tonnes
 - 860-1,300 million barrels incremental oil
- Mt. Simon and St. Peter Sandstones: 7.8 billion tonnes on geological structures
- Mt. Simon and St. Peter Sandstones: 30-35 billion tonnes off structure >4,000 ft



Potential Test Phase II Sites

-1 coal seam site selected

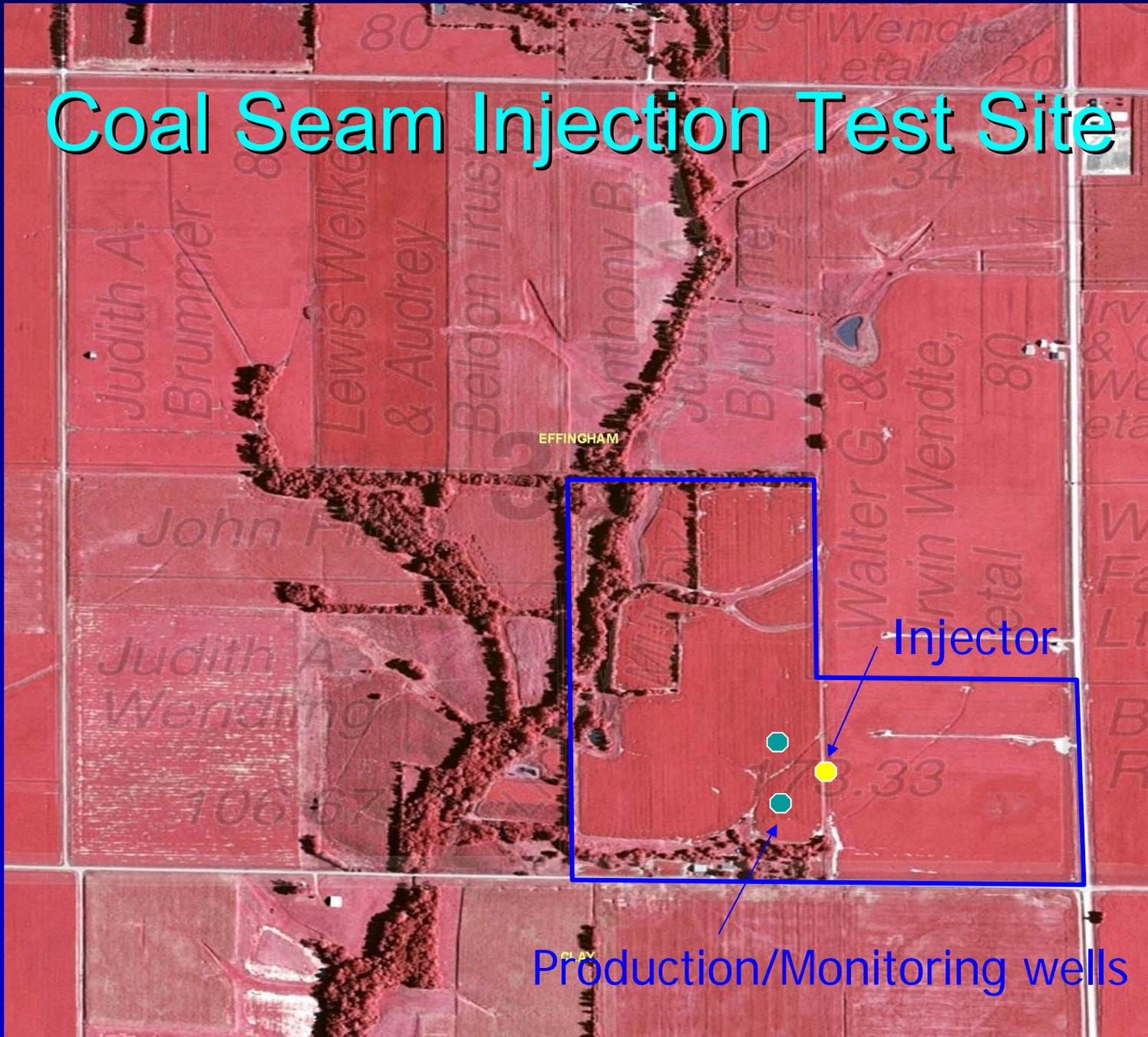
-34 mature oil field sites for EOR; 3 under consideration for first pilot: inject/soak/produce test

-5 deep saline reservoir sites in review

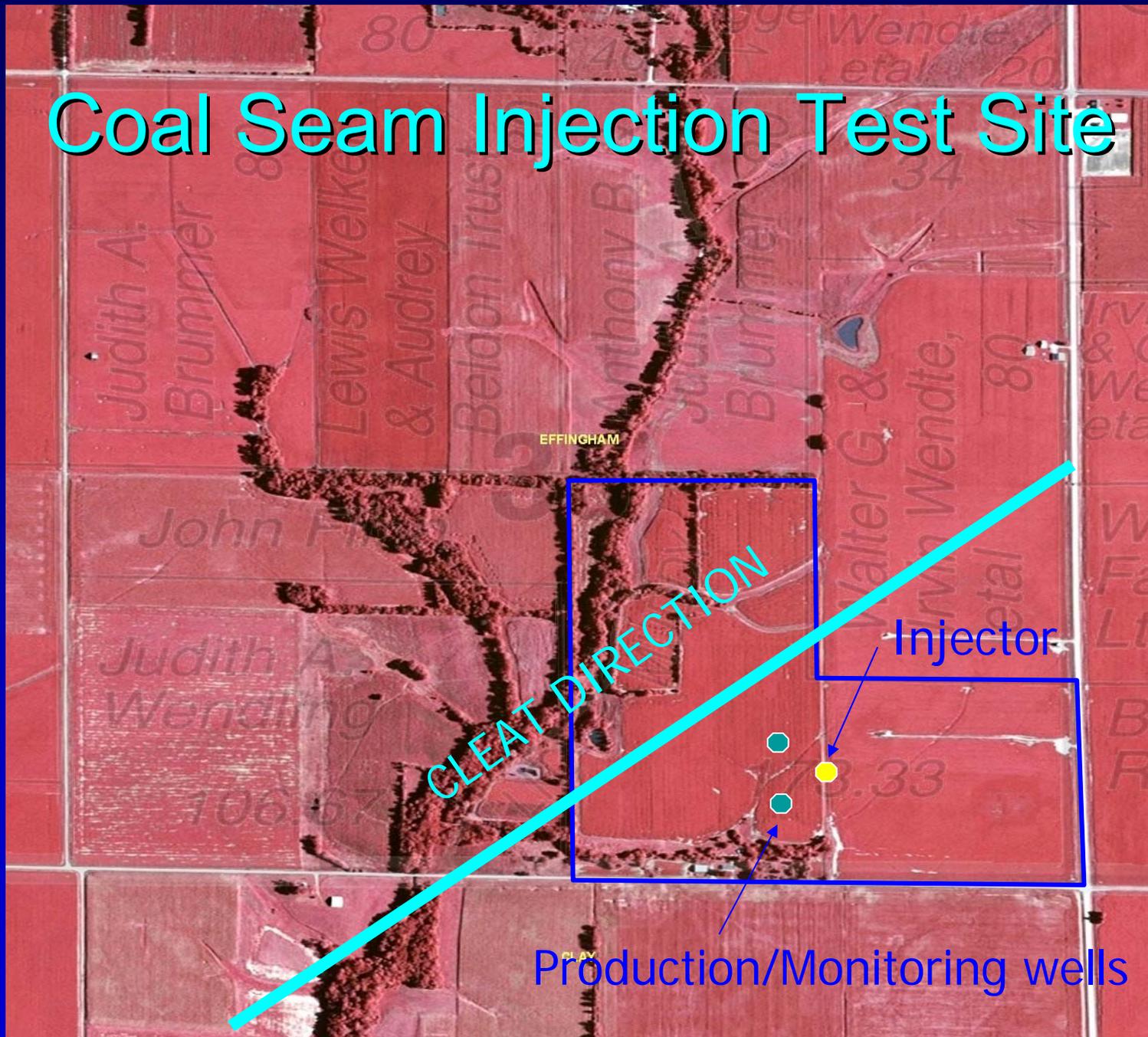
Recent Areas of Focus

- Major focus on reservoir characterization to support pilot test site selection for:
 - coal seams (site selected)
 - oil reservoirs (first site narrowed to three choices)
 - deep saline reservoirs (talking to operators)
- Structural characterization using seismic
- Outreach and teacher materials

Coal Seam Injection Test Site



Coal Seam Injection Test Site



COMET Modeling Study to Determine Well Spacing for ECBM Pilot

Pilot well spacing criteria:

- quantifiable response at observation/production wells:
 - within 30 days
 - Min. pressure Δ : 1.0 psi; min. gas saturation: 10%
- observation wells oriented orthogonal to CO₂ injector
- face cleat orientation uncertain: northeast
 - observation wells equidistant from injector
 - relatively close spacing to ensure response

Pilot:

- 1 injector, 2 observation/production wells

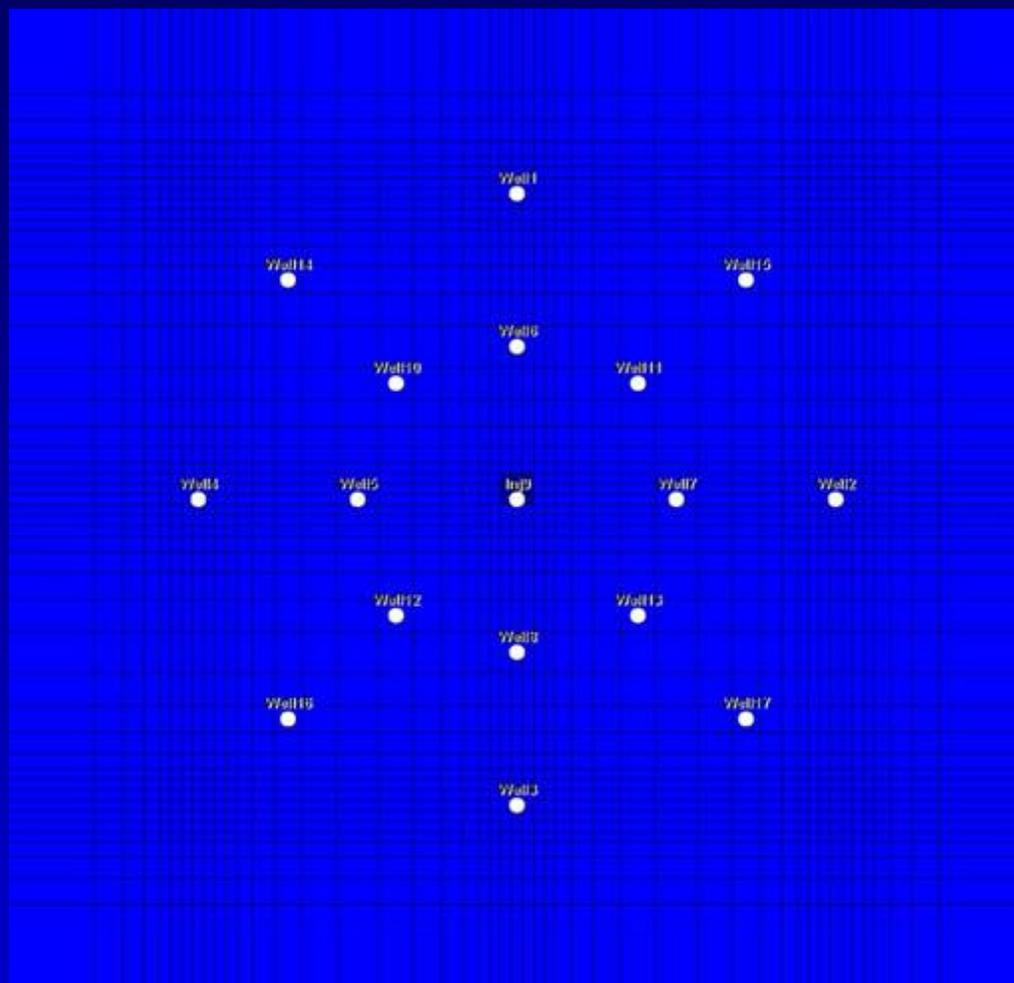
COMET Modeling Study to Determine Well Spacing for ECBM Pilot

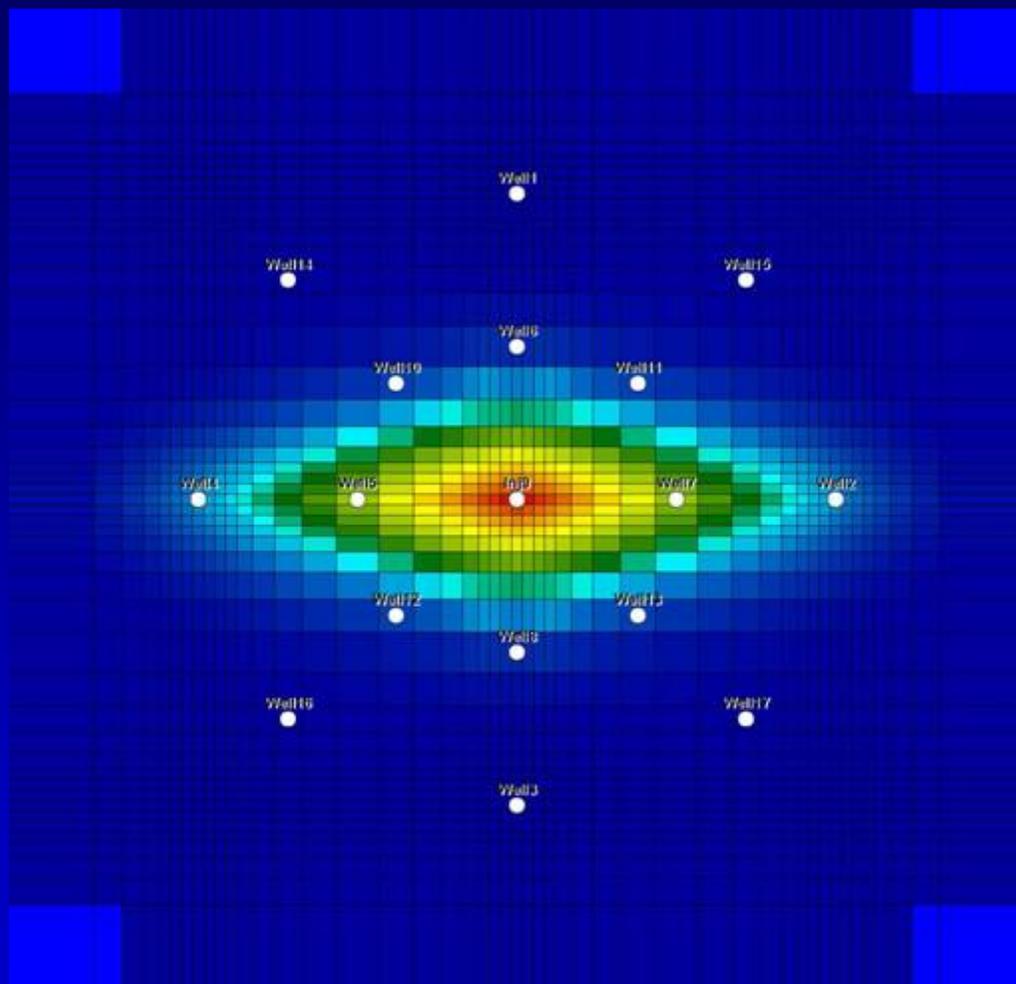
Reservoir model:

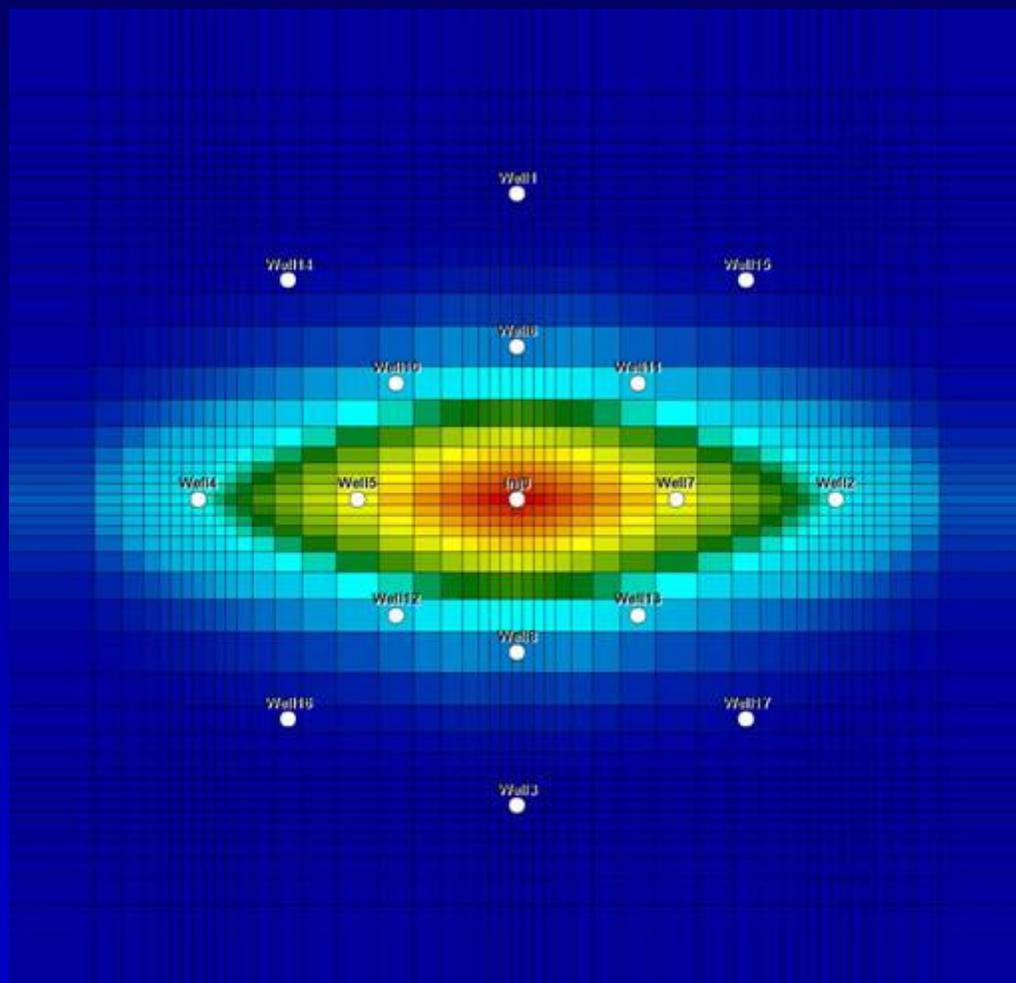
- Area: 21.53 acres
- Grid: single layer (Herrin coal, 4.0'), 5-spot hybrid grid
- Wells:
 - 16 observation/production with 150' and 300' spacing
 - observation/production wells oriented along x and y axis and 45° diagonal

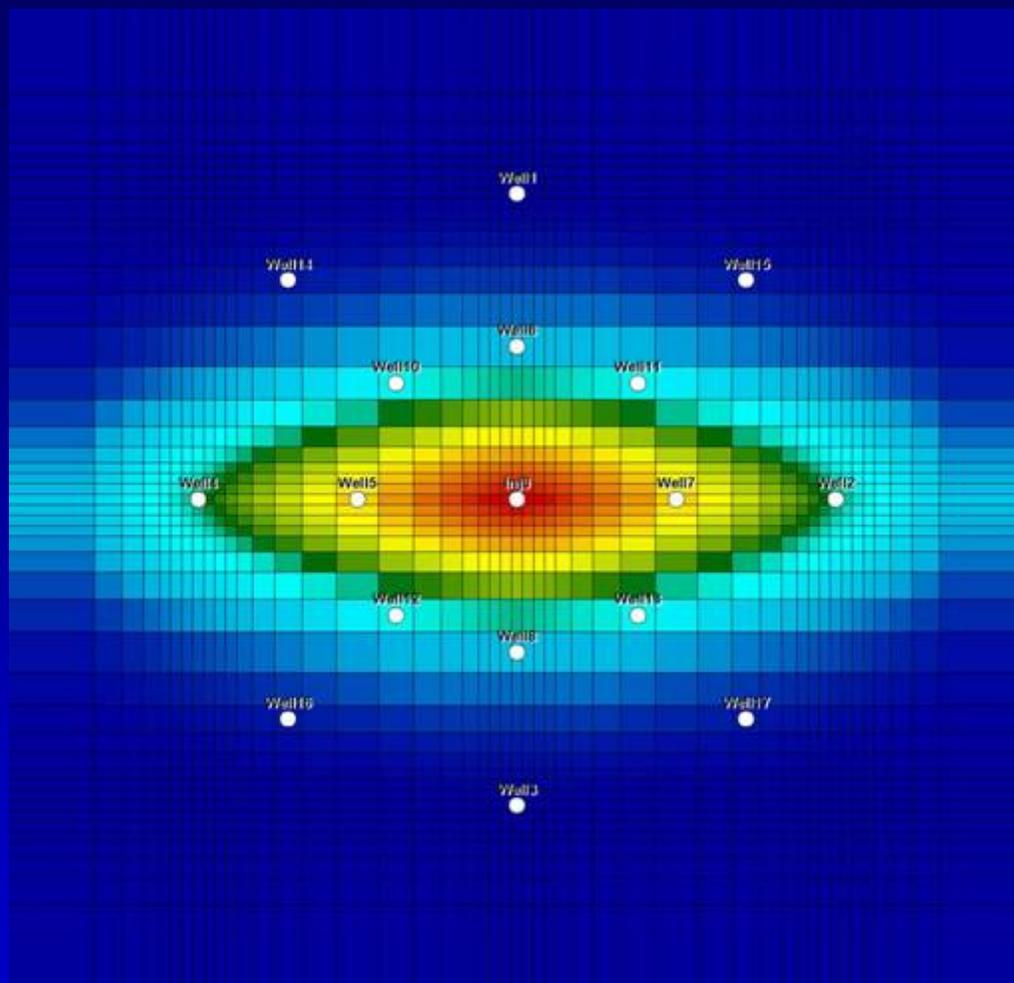
Reservoir Parameters:

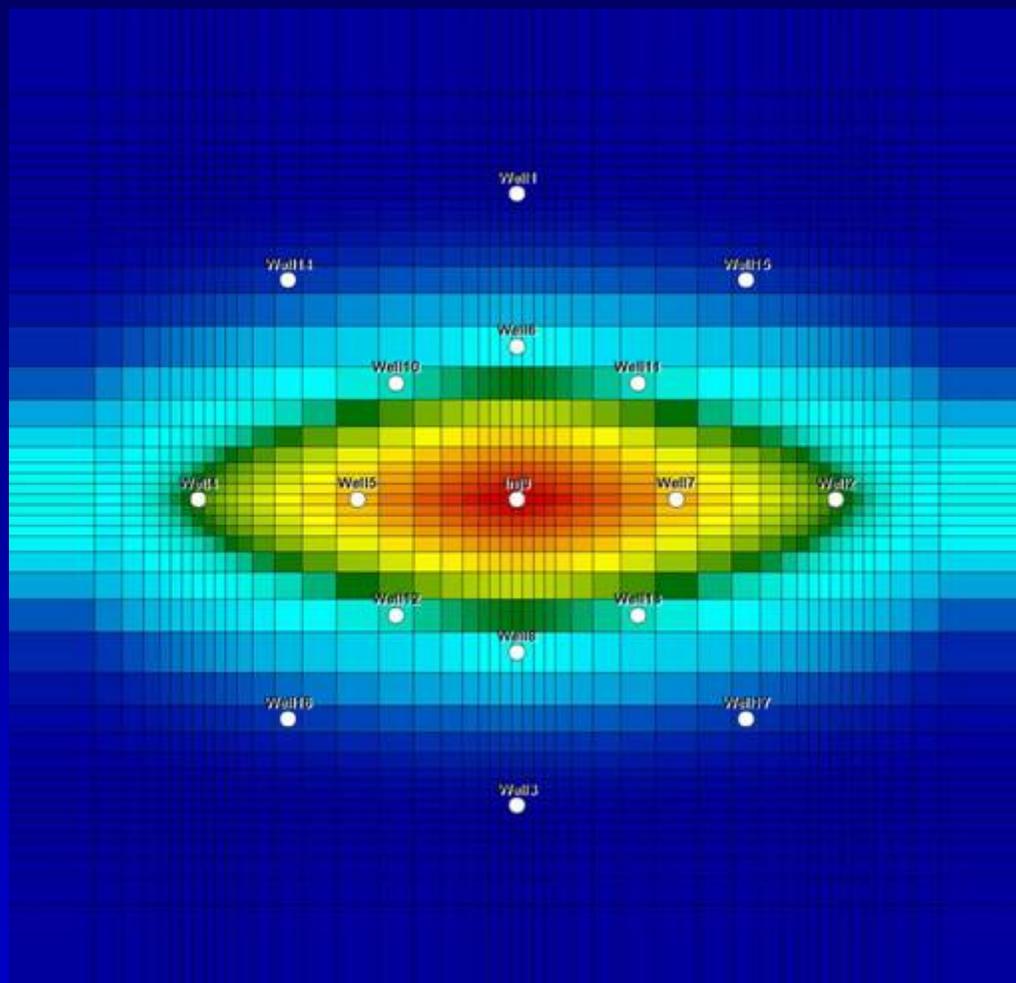
- obtained from DST, core data, recently tested area wells, and regional data

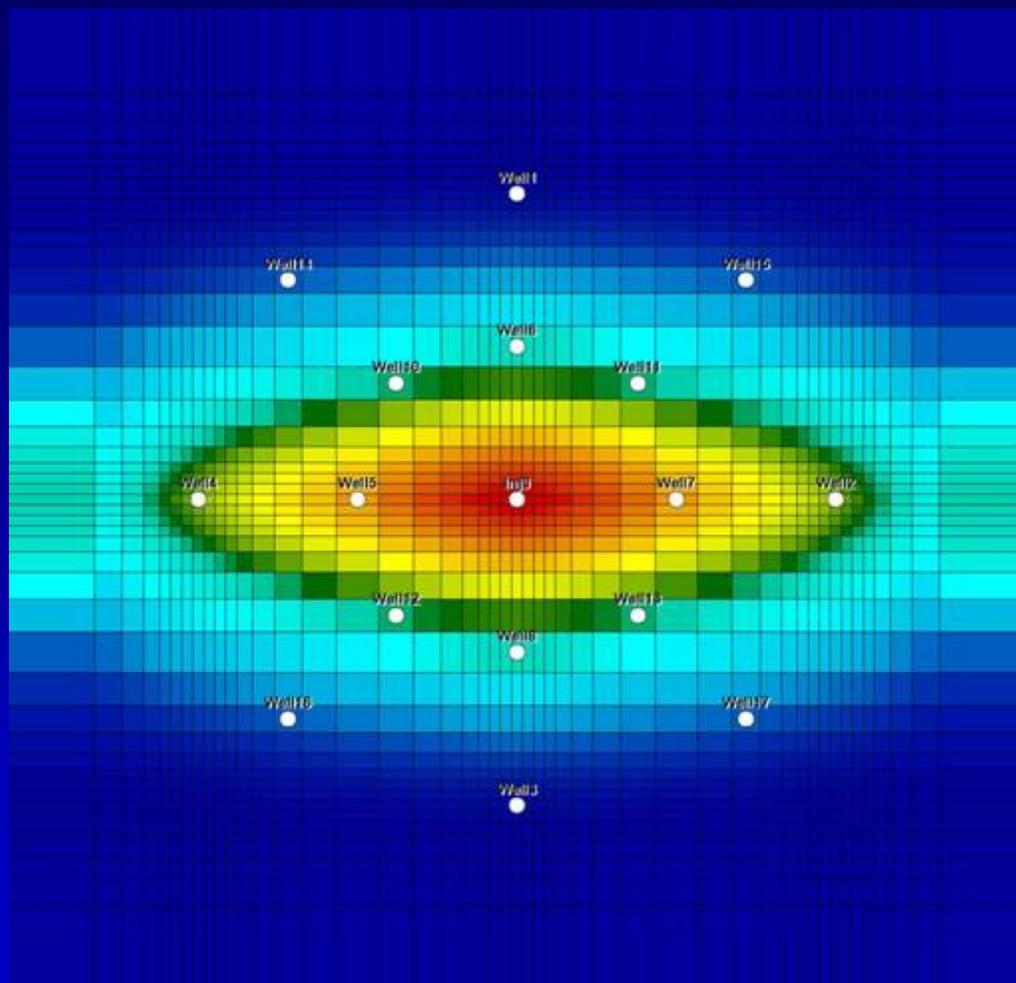


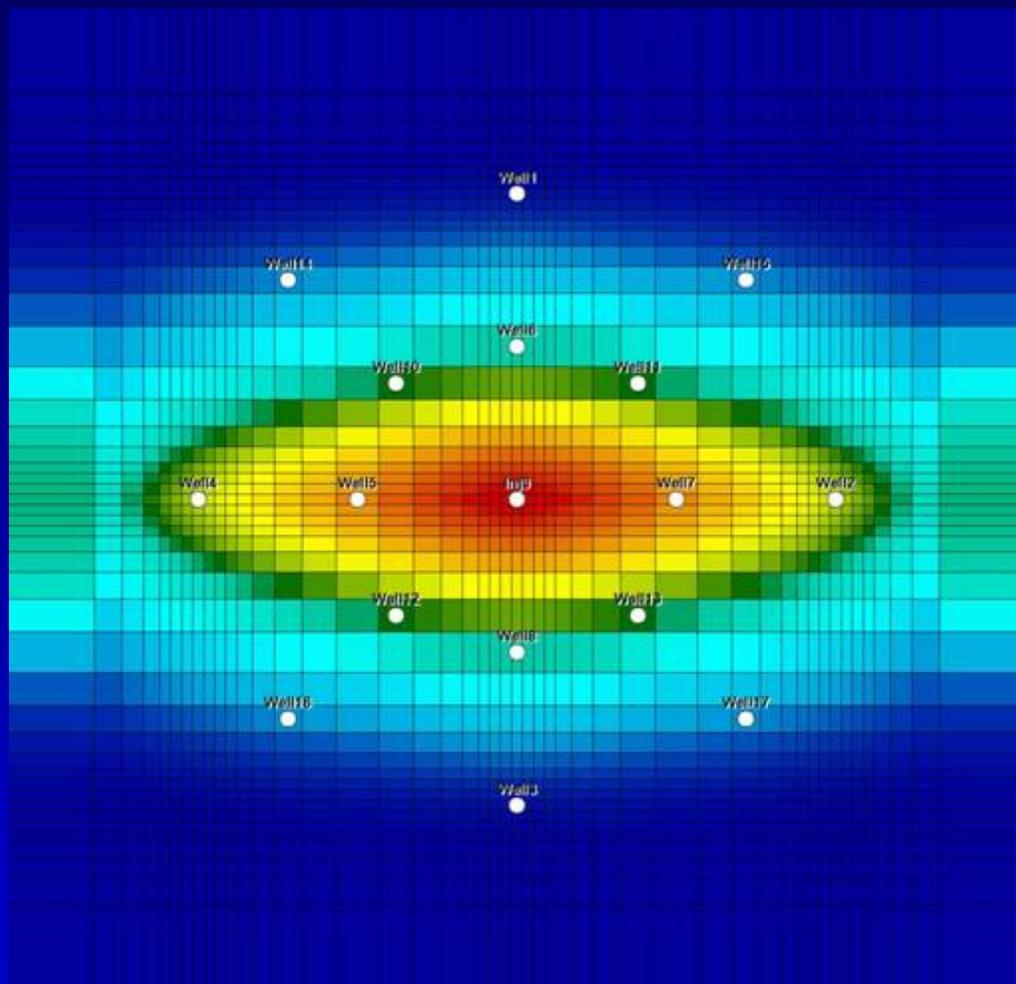










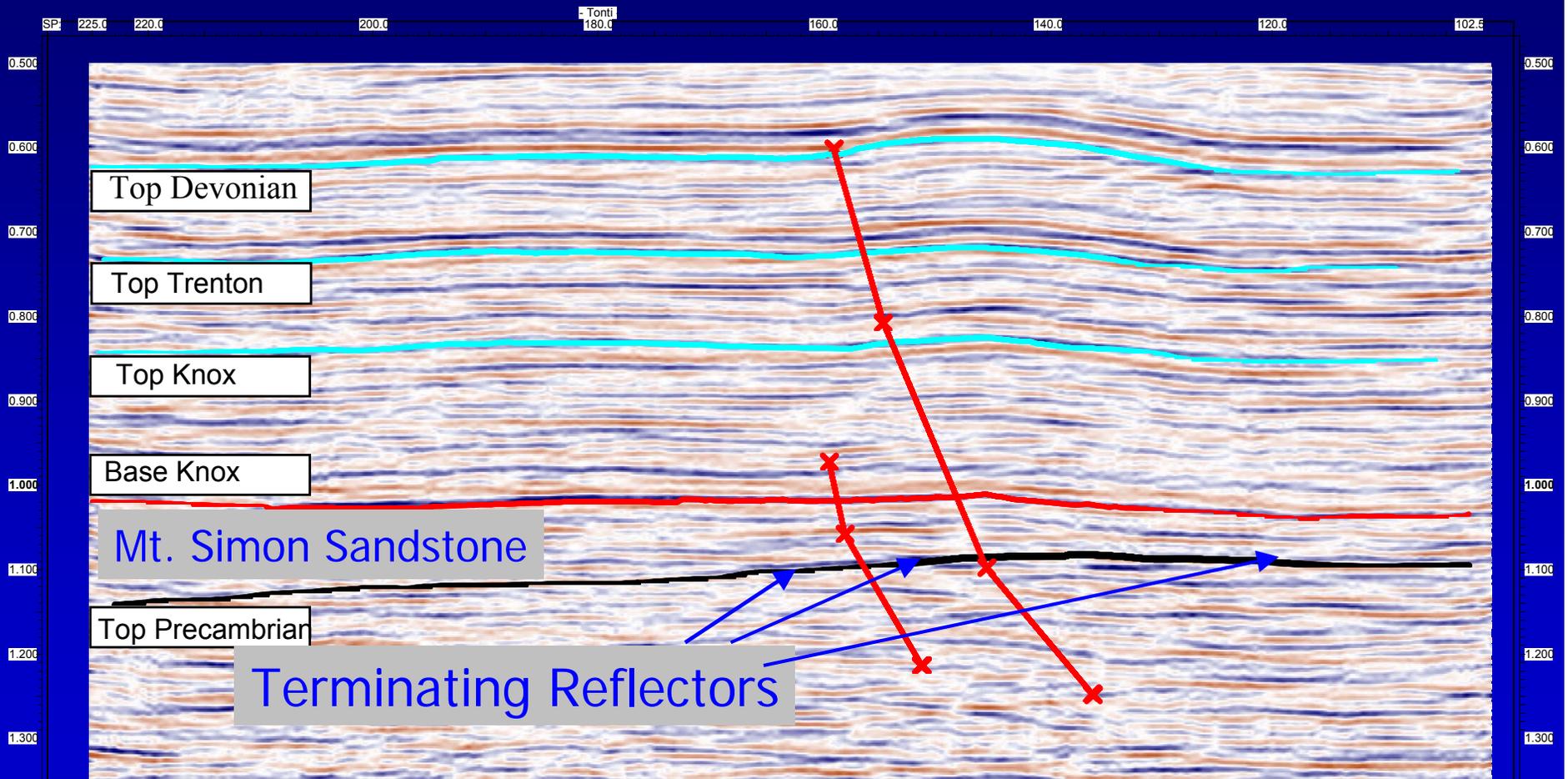


Saline Reservoir Test

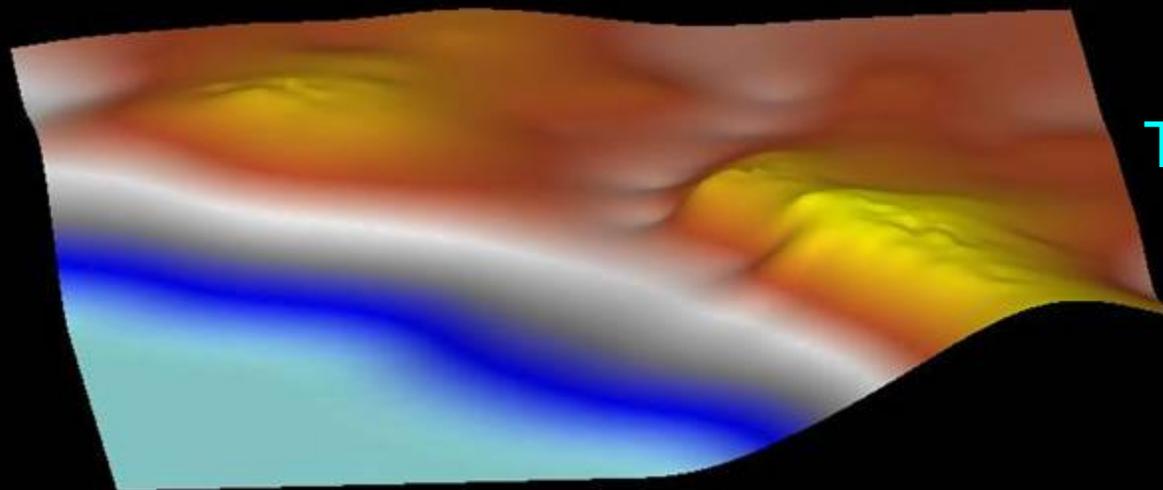
- Primary target is the Mt. Simon Sandstone; secondary target is the St. Peter
- Original proposed depth was 9,400 ft
 - trying to assess shallower sites due to cost considerations
- However, favorable geology (thickness and confidence in occurrence) and collaborative operator remain primary concerns

Tonti Reflection Seismic

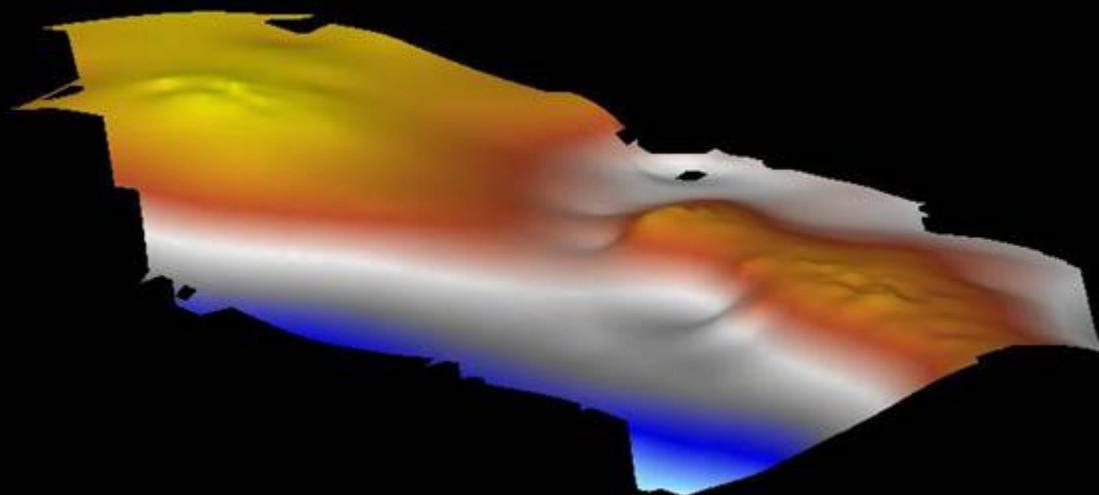
(acquired June 2005)



Hersher Gas Storage Field Structural Migration



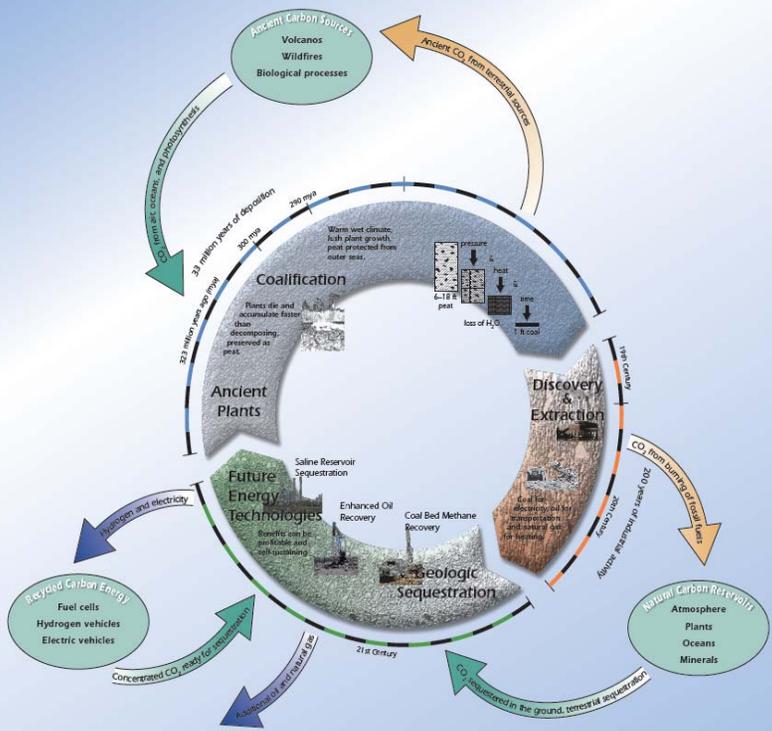
Trenton



Mt. Simon



The Geologic Carbon Cycle in the Illinois Coal Basin



The energy in our coal is really 300-million-year-old sunlight!

The energy of fossil fuels in the Illinois Basin began during the Pennsylvanian period (300 million years ago). At that time, the Illinois Basin was at the equator and was the site of a mostly, delta system. The Illinois delta was known to be a swampy area with a lot of plants. Plants in the swamp used carbon dioxide (CO₂) from the atmosphere during photosynthesis to produce their own food. The delta plants used CO₂ to create organic carbon compounds, which provided the energy necessary for them to grow. The cycle of plants growing, dying, and being buried in the delta continued for millions of years. Carbon from the dead and buried plants remained in the ground as the plants decomposed. More and more plant material was deposited over the delta cycle of plants, and, one time and another, land and pressure, the organic material turned into peat and, eventually, into the rock coal. When buried, and given off energy that has been used since then, it was called electricity. We use coal to find our power plants and factories.

Greenhouse Gases, Carbon Dioxide, Global Warming, and the Illinois Basin

Carbon dioxide is a waste product of burning fossil fuels. Carbon dioxide is also a greenhouse gas that helps trap heat from the sun rays in the Earth's atmosphere. The more carbon dioxide in the atmosphere, the more heat is trapped, which leads to global warming. The more greenhouse gases present in the atmosphere, the more heat is trapped, which leads to global warming. The more greenhouse gases present in the atmosphere, the more heat is trapped, which leads to global warming. The more greenhouse gases present in the atmosphere, the more heat is trapped, which leads to global warming.

Geological Sequestration

Carbon that has been stored in the earth for millions of years is being re-released in the form of oil, gas, and coal to provide energy for transportation, manufacturing, and heating. Geological carbon sequestration is one method of reducing CO₂ from Earth's atmosphere and returning the carbon to its original source. Geological sequestration is a process that stores CO₂ deep underground in rock formations that are not likely to be disturbed by geological activity. This process involves capturing CO₂ from power plants and other industrial sources, and then injecting it into deep underground rock formations. The CO₂ is stored in the ground for millions of years. Carbon sequestration also uses CO₂ to recover natural gas and petroleum from deep rock seams. Sequestration can play a significant role in preventing climate change by reducing the amount of CO₂ in the atmosphere and may also slow the global warming trend that has been observed in the last century.

Carbon Sequestration in the Illinois Coal Basin

The energy in our coal is really 300-million-year-old sunlight!

Burning coal oxidizes carbon atoms in the coal with oxygen in the atmosphere and creates the gas carbon dioxide (CO₂). This is a natural, unaccounting process, but too much of a good thing can be harmful. Ancient carbon is being put back into the atmosphere as much faster now than those during the millions of years it took for the plants to grow, die, get buried, and turn into coal. Returning ancient carbon, or CO₂, to the atmosphere at our present rate may be contributing to global warming.

Greenhouse Gases, Carbon Dioxide, Global Warming, and the Illinois Basin

Carbon dioxide, methane (natural gas), and other trace greenhouse gases that may be from the sun's rays in the Earth's atmosphere. The sun's rays enter the atmosphere, hit the earth, where some of the energy is absorbed and some is reflected back into space. The sun's rays warm the earth, and the greenhouse gases in the atmosphere, the more greenhouse gases remaining in the atmosphere, and the more they trap, which leads to global warming.



Geological Sequestration

Reducing the amount of CO₂ released into the atmosphere may slow the global warming trends that have been observed in the last several years. Geological carbon sequestration is one method of reducing CO₂ from Earth's atmosphere. Sequestration can play a significant role in preventing continued CO₂ buildup in the atmosphere. Geological sequestration of CO₂ by injection into the subsurface is a promising technology under study around the world. Carbon dioxide is captured from the emissions of combustion systems, processed to remove contaminants, transported to a storage site, and injected into geological formations for very long-term storage. These types of subsurface formations can be used—oil of which exist in the Illinois Basin: coal formations as deep as to be unaccounting for mining and development, depleted or mature oil and natural gas reservoirs, and saline aquifers that contain non-petroleum water. The natural processes necessary to make geological sequestration possible are known but have not been applied to sequestration of the earth's surface. Carbon dioxide injection into coal is being extensively tested for methane recovery from gassy coal that is otherwise non-minable by replacing the naturally occurring, absorbed methane with CO₂. Injection of CO₂ into oil reservoirs has been proposed as an oil recovery method for over 30 years. Saline aquifers have been used for natural gas storage in the Illinois Basin for decades.

Coal Bed Methane

Coal beds hold methane that can be recovered during sequestration. Natural gas accounts for about 20% of our annual energy consumption and is used for a variety of residential and commercial energy needs, such as cooking and heating. Using coal as a source for CO₂ provides another source of natural gas, an increasingly important fuel source. Methane is adsorbed onto the internal surface of the coal bed, but is usually replaced by CO₂. Coal beds can naturally store approximately twice the amount of CO₂ compared with natural gas. Even if we burned all the natural gas harvested from the coal beds, the net effect would still be to remove CO₂.

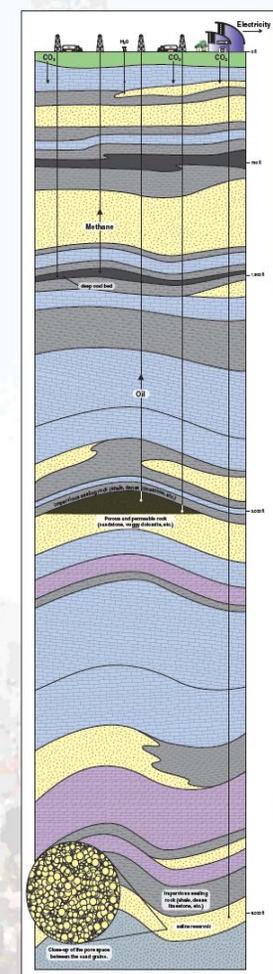
Sealing CO₂ in wells deeper than 1,000 ft and thicker than 1.1 ft does not make the coal unminable, it simply means that any CO₂ stored in the coal would be released upon mining. If coal becomes very valuable or very scarce or both in the future, then it might become economical to mine these coals.

Enhanced Oil Recovery

Enhanced oil recovery (EOR) uses CO₂ to recover the oil left behind after the oil has been pumped out of a reservoir. Oil does not always move easily through unconsolidated reservoirs, and much oil is left behind after an oil field produces under typical methods. At a certain point it is no longer cost-effective to continue pumping oil from the ground in some fields unless recovery can be enhanced. CO₂ is already being used as a secondary recovery agent in oil fields in other basins. Using CO₂ for EOR becomes more economical than other oil recovery options. A certain well is used to inject CO₂, and surrounding wells are used to recover the oil. Liquid-like CO₂ under pressure is injected into a central well and moves the oil toward the outer wells, which are used to pump the oil out. Using this method for storing CO₂ is simply the next step in the process. The CO₂ would be held in small pore spaces present in rocks. These pore spaces have held saline water, oil, and natural gas for millions of years.

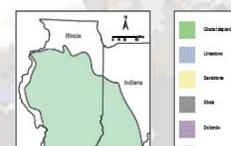
Saline Reservoirs

Saline reservoirs are bodies of rock with pore spaces containing water with high amounts of dissolved solids (TDS), especially salts. The concentration of TDS in deep saline reservoirs makes the water too salty for human consumption or for many agricultural and industrial uses. Saline reservoirs occur deep underground in rock formations that are expected to contain large quantities of CO₂ for long periods of time. The CO₂ would be held in small pore spaces present in rocks. The saline reservoirs for carbon sequestration have characteristics with the best oil-producing rocks. It should be sedimentary rock with high porosity (percentage of open pore space) and permeability (connectivity of open pore space that has a geological structure, such as an anticline or a fault, that traps oil and natural gas. Directly above it should be a caprock made of very low porosity and permeability, such as shale. The capped layer acts as a lid or a cover for the saline reservoir. The depth of the reservoir is also important. A saline reservoir should be well water draining water geologic traps, not too deep, and economically viable to drill into. Also, the volume of the potential storage space must be great enough to justify the expense of drilling a well and recovering oil and natural gas or storing CO₂.



CO₂ Storage in the Illinois Basin

The Illinois Basin, which includes Illinois, Indiana, western Ohio, and western Kentucky, is home to industrial activity that releases more than 210 million metric tons of CO₂ from stationary sources like electric power plants, refineries, cement plants, and other industrial facilities. The Basin is unique because it has two potential geological storage opportunities available in close proximity to substantial CO₂ sources that, in some cases, may be accessed from one site. This geology represents a unique research opportunity to study all three storage options economically and to carry forward one of the best opportunities for rapid commercialization of geological sequestration in the United States.





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www.sequestration.org

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