Geologic CO_2 Sequestration Characterization of America's "Engine Room"

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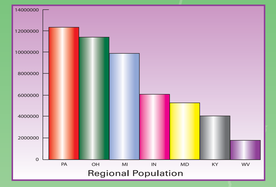
ABSTRACT

Attaining goals for reduction of greenhouse gases, while meeting the growing demand for fossil-fuel generated electricity, is dependent on rapid development of carbon-sequestration technologies. The Midwest Regional Carbon Sequestration Partnership (MRCSP) has been created to assess the technical, economic, and social merits of carbon sequestration. The MRCSP (one of seven regional centers formed under U.S. Department of Energy funding) brings together industrial and governmental partners from Indiana, Kentucky, Maryland, Michigan, Ohio, Pennsylvania, and West Virginia. This diverse area represents 16% of the U.S. population and GNP, nearly 22% of the nation's electricity generation, and 77% of electricity in the region is produced from coal-fired plants. The industrial and power-generating point sources in the region produce about 715 million tons of CO_2 annually.

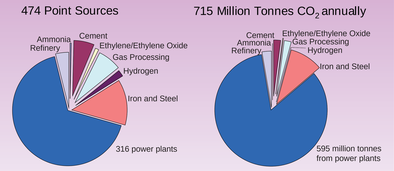
The region is geologically diverse, including 3 major sedimentary basins, intervening arches, a coastal plain, and a fold and thrust belt. Such a range in depositional environments provides many sequestration opportunities and challenges. Huge potential for sequestering CO_2 in deep saline aquifers, deep unmineable coals and organic shales, and depleted oil and gas reservoirs exists within many settings of this region. This region also has several prolific petroleum-producing areas, but has never had a ready source of CO_2 for enhanced recovery. If flue-gas separation technologies advance sufficiently to make economical sources of CO_2 widely available, CO_2 enhanced recovery may revitalize many reservoirs of the region. Examples of this region's geologic characterization, CO_2 sequestration capacity, and enhanced recovery opportunities will be presented.

Regional Characterization



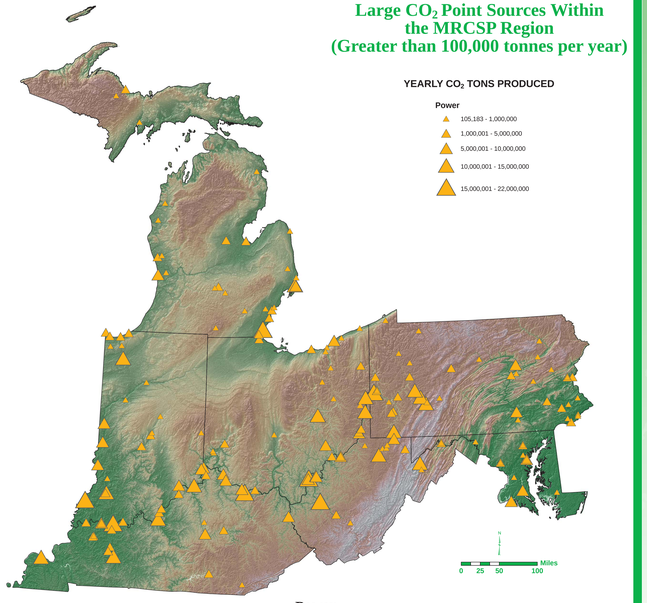
CO_2 Emissions in the MRCSP Region

Our focus is on large point sources (>100,000 tonnes CO_2/yr)

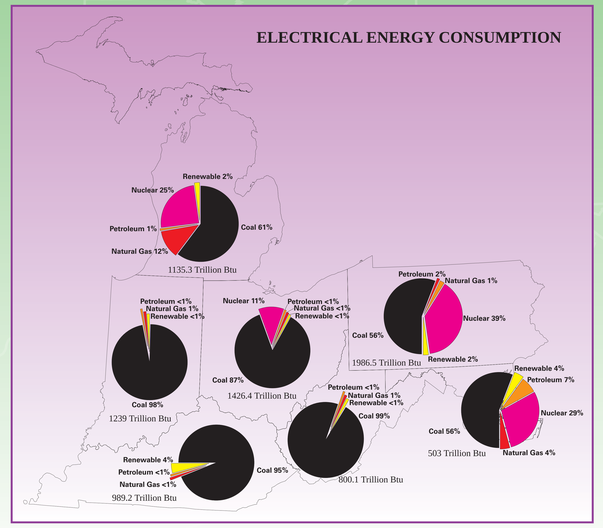


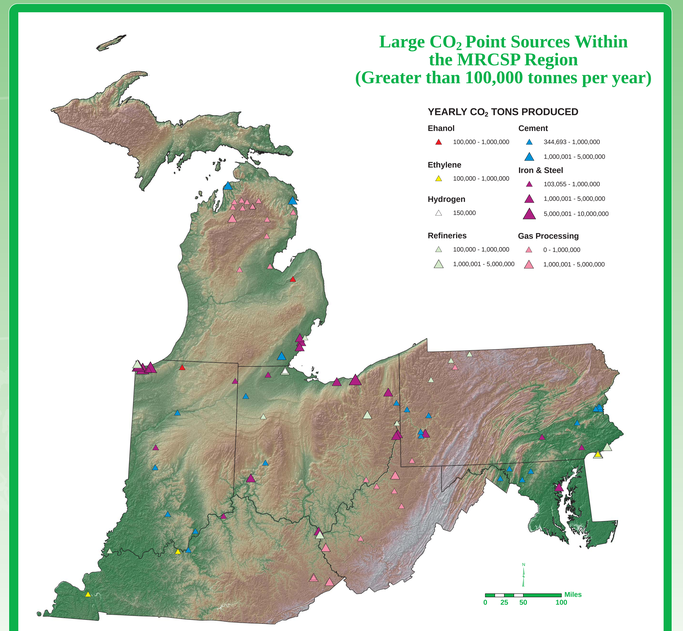
Our Region accounts for:

- Over 26% of CO_2 emissions from power plants nationwide
- Our Region's point sources alone account for over 12% of total CO_2 emissions nationwide



Power





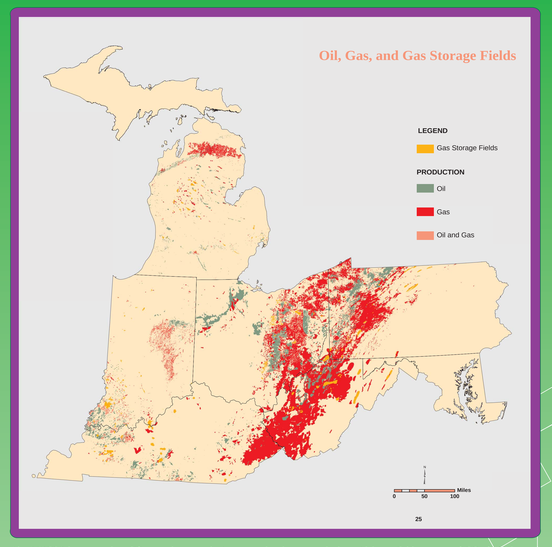
Non-Power

Partnership Research Team

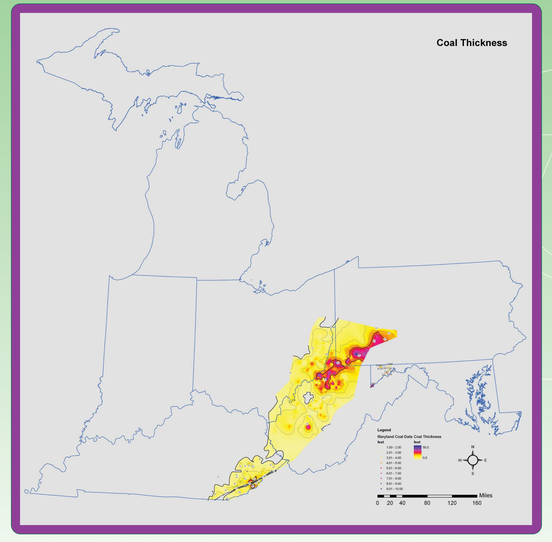
Partnership Sponsors

Geologic Sequestration Potential

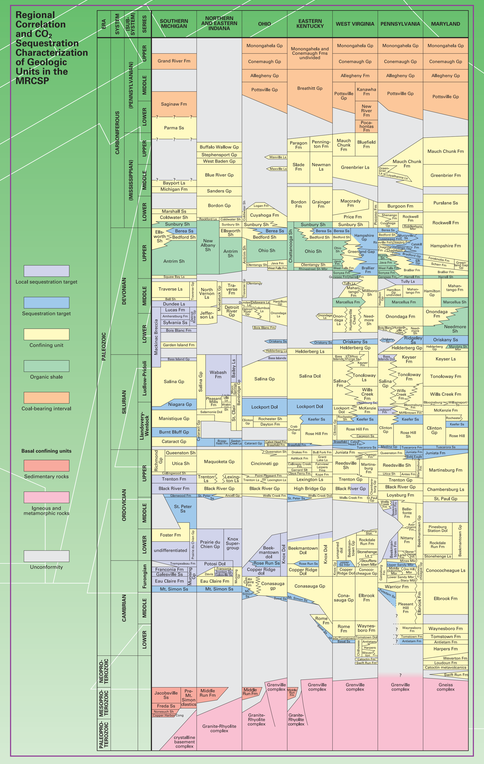
Huge potential for sequestering CO_2 in deep saline aquifers, deep unmineable coals and organic shales, and oil-and-gas-reservoirs exists within the Midwest Regional Carbon Sequestration Partnership (MRCSP) region. The geology team of the MRCSP has created numerous regional geologic structure and isopach maps. These maps are used with grids of salinity and porosity to calculate the CO_2 storage potential of each unit.

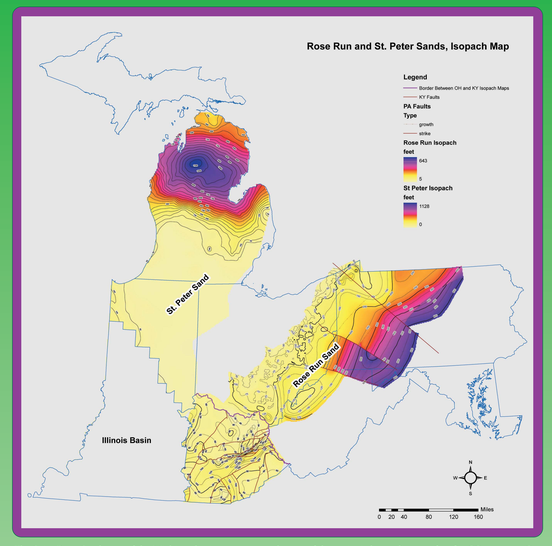


The MRCSP has several prolific petroleum-producing areas, but has never had a widely-available source of CO_2 for enhanced recovery. If flue-gas separation technologies advance sufficiently to make economical sources of CO_2 widely available, CO_2 enhanced recovery may revitalize many reservoirs of the region. Hundreds of millions of barrels of additional oil could be produced from the region while sequestering over 1 billion tons of CO_2.

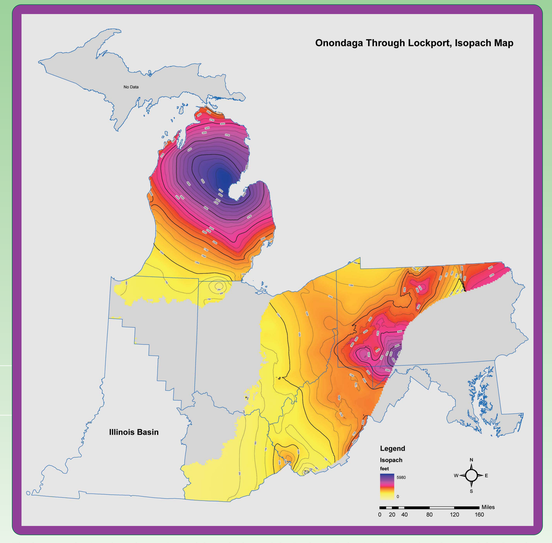


Enhanced recovery of methane from deep coals could add significant gas reserves to the northern Appalachian basin while sequestering over 200 million tons of CO_2.

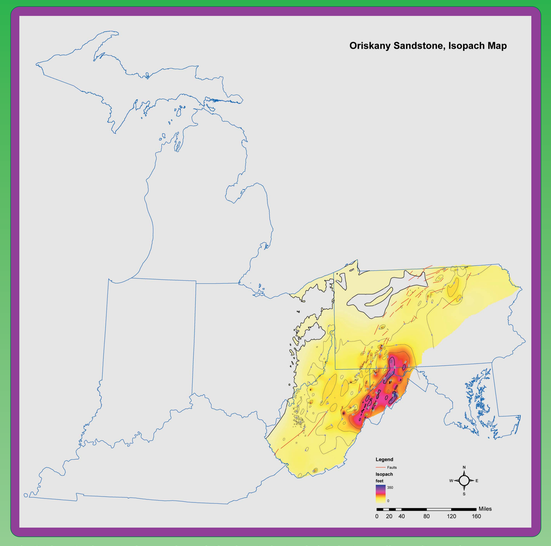




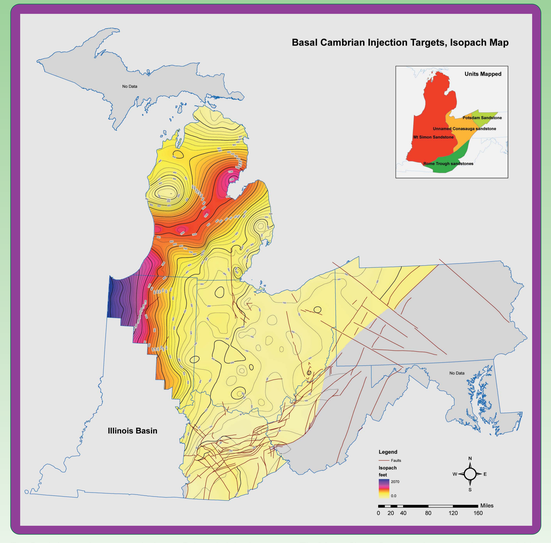
The Saint Peter Sandstone of the Michigan basin may prove to be one of the region's best saline aquifers for CO_2 storage. Our calculations indicate the St. Peter may be able to contain as much as 88 billion tons of CO_2. The Rose Run Sandstone of the Appalachian basin is both an oil-and-gas-producing horizon and saline aquifer. If used for CO_2 sequestration it may be capable of storing over 40 billion tons.



The large, predominantly carbonate interval from the base of the Lockport Dolomite (Niagaran) to the top of the Onondaga Limestone (lower Devonian) provides a excellent thick seal for lower injection horizons. In phase II work by the partnership, we will also investigate the potential of using porous horizons within this interval (e.g. Lockport Dolomite and Bass Islands Dolomite) as injection targets.



The Oriskany Sandstone is a large producer of oil and gas in the Appalachian basin as well as a saline aquifer. It may prove to be one of the region's best sequestration targets in the central Appalachian basin area where it has the potential to store nearly 20 billion tons of CO2.

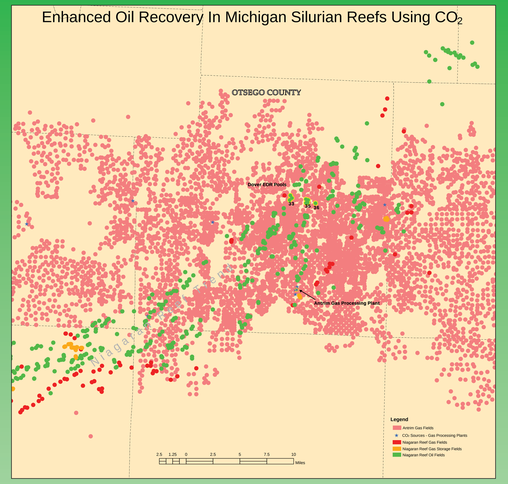


The Cambrian sands represent the lowest Paleozoic injection targets. The Mount Simon Sandstone has tremendous potential for sequestration as it attains great thickness and has high porosity and permeability. The Mount Simon goes through a facies change in central Ohio becoming dominantly dolomite in much of eastern Ohio. Thus, for the MRCSP mapping, we mapped the thickness of other basal Cambrian sands (which are typically thinner and tighter) east of this facies change. This interval has the potential to store over 200 billion tons of CO_2, most of that capacity being in the Mt. Simon proper.

MRCSP
MIDWEST REGIONAL CARBON SEQUESTRATION PARTNERSHIP

Enhanced Recovery Potential

Enhanced Oil Recovery In Michigan Silurian Reefs Using CO_2

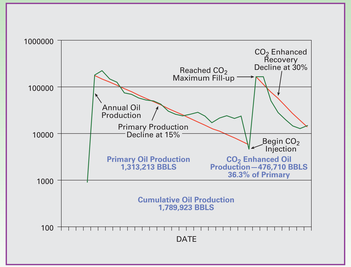


Enhanced Oil Recovery In Michigan Silurian Reefs Using CO_2

Three Niagaran reef reservoirs in Otsego County, Michigan have been converted to EOR CO_2 injection floods. They are Dover 33, Dover 35 and Dover 36 fields in sections 33, 35 and 36 of Dover Township. Dover 33 and 36 CO_2 floods began in 1996 and continue operation to date. The Dover 35 reef EOR project was initiated in early 2004. The reservoirs are in the Brown Niagara or Guelph Formation at a drilled depth of between 5,500 and 6,000 feet. High purity CO_2 is recovered from a natural gas processing plant in South Chester Township of Otsego County approximately 8 miles south of the injection sites. The CO_2 is a byproduct of natural gas produced from the Upper Devonian shales of the Antrim Formation. This plant is one of several throughout the Antrim Shale producing region of Northern Lower Michigan capable of cumulatively capturing more than 70 million cubic feet (nearly 400 tons) of CO_2 per day.

The Dover 33 field was discovered in 1974 with 4 wells drilled in the primary phase of production. In 1996 one of the original producers was converted to a CO_2 injection well. Two of the original wells were plugged prior to conversion and one was left as a producer. CO_2 fill-up was completed in 1997 and enhanced recovery production began. A second vertical well was completed in 1998. In 2000, two horizontal wells were drilled for production and the vertical wells were plugged. The reservoir is about 320 acres in area and produced 1,313,213 barrels of oil and 1,650,644 MCF gas during the primary phase through 1996. The enhanced recovery has been 476,710 barrels of oil through the end of 2004. Produced natural gas has been reinjected along with the CO_2.

The Dover 36 Field was discovered in 1973 with 3 wells drilled in the primary phase of production. In 1997 two of the original producers were converted to CO_2 injectors. The remaining well was left as a producer. CO_2 fill-up was completed in 1999 and enhanced recovery production began. A new vertical well was completed in 2000 and the original producer was plugged. The reservoir is about 240 acres in area and produced 1,146,095 barrels of oil and 1,165,011 MCF gas during the primary phase through 1996. The enhanced recovery has been 257,258 barrels of oil through the end of 2004.



Antrim Gas Processing Plant at Turtle Lake, MI— Source of High Purity CO_2

CO_2 Sequestration in Coal Seams for Enhanced Coalbed Methane Production

Through a cooperative agreement with the U.S. DOE, CONSOL Energy R&D, in conjunction with CNX Gas and CNX Land, has embarked on a seven-year field program to evaluate both coal bed methane (CBM) recovery and CO_2 adsorption capacity of an unmineable coal seam. The project will demonstrate the application of a series of wells, drilled from three surface locations and extending up to 3000 ft horizontally in the subsurface, to drain CBM from two overlying coal seams; the upper coal, the Pittsburgh, is mineable at this location and the lower coal, the Freeport, is unmineable. In time, the centrally located wells in the unmineable seam will be used for CO_2 injection/sequestration, which will further enhance CBM recovery at the exterior wells. With this unique approach, CBM will be recovered from the upper seam prior to mining, rather than venting upon mining. In addition, CBM recovery and CO_2 sequestration is accomplished over a large area extent in two coal seams from one surface location.

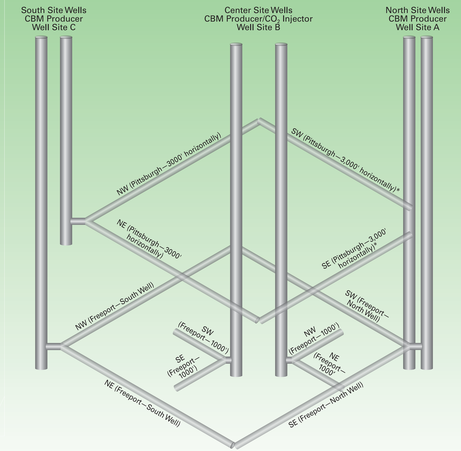
Project Objectives

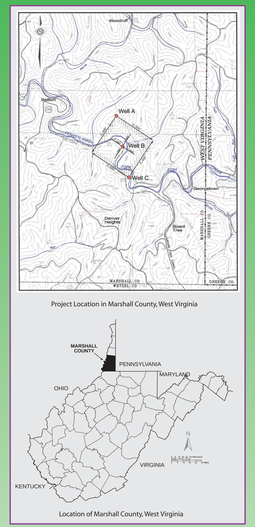
- Demonstrate horizontal drilling into underground coal seams
  - Use directional drilling to develop a series of wells extending up to 3000 feet horizontally in two overlying coal seams
- Evaluate gas content and recover CBM from both seams
- Inject at least 20,000 tons of CO_2 in lower (Unmineable) coal seam and define effective injection procedures
- Evaluate the CO_2 adsorption capacity of both coal seams
- Measure the effects of CO_2 injection on enhancing CBM recovery
- Monitor the concentration of CO_2 in recovered CBM over an extended period of time

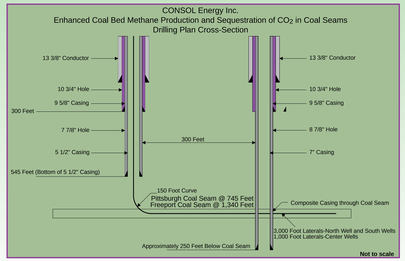
Project Accomplishments to date

- Drilling completed at south and center well sites; wells drilled at the north site are not satisfactory
- CBM production from south and center wells is approximately 500,000 cubic feet per day
- Amine plant installed for CO_2 removal from CBM

CONSOL Energy Inc. Enhanced Coal Bed Methane Production and Sequestration of CO_2 in Coal Seams Perspective View of Project Wells





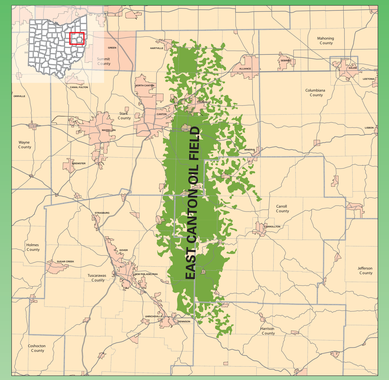


THE EAST CANTON OIL FIELD, OHIO
Candidate for CO_2-assisted EOR

Since its discovery in 1947, the East Canton oil field in northeastern Ohio has produced approximately 90 million barrels of oil from the Silurian "Clinton" sandstone. Encompassing 175,000 reservoir acres with more than 3,100 producing oil wells, this is the most significant actively producing oil field in Ohio, in terms of geographic size and produced volume of oil. Estimated original oil-in-place is approximately 1.54 billion barrels of oil. Using a 9 percent primary recovery factor, which is an average for this reservoir, the estimated original oil reserves are 138.4 million barrels of oil. Thus, an estimated 48.4 million barrels of producible oil are still remaining in place in the East Canton oil field.

In spite of the maturity of this field and quantity of remaining oil reserves, secondary recovery has not been attempted in the East Canton field. Production has been solely from primary recovery using normal 40-acre spacing. Failures in pilot waterfloods in other "Clinton" fields and general low permeability of the formation have left operators with little interest in "normal" secondary recovery operations. We believe that a combination of in-fill drilling and CO_2-assisted enhanced recovery should prove successful in selected areas in the East Canton field. If successful, this program could result in additional 100 million barrels of production from this field, extend its life for many more years, and sequester up to 68,124,863 metric tonnes of CO_2.

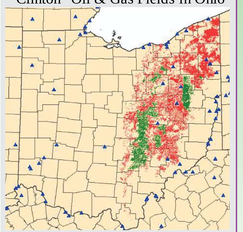
Applying successful techniques of "Clinton" enhanced recovery developed for the East Canton field, to "Clinton" fields in other parts of the state, could reap huge benefits. Estimates for the "Clinton" sandstone in Ohio indicate there are approximately 4.5 billion barrels of original oil-in-place. It is estimated that up to 200 million barrels of producible remaining oil reserves could be extracted from other "Clinton" sandstone fields through infill drilling and enhanced recovery techniques in Ohio.



EAST CANTON OIL FIELD AT A GLANCE
At a glance

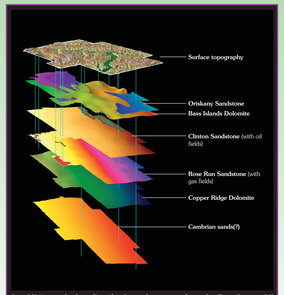
Producing Formation	Silurian "Clinton" Ss
Discovery Year	1947
No. Producing Wells	3,100
Spacing	40 Acres
Proven Acres	125,360
Reservoir Acres	175,000
Depth to Pay	4,800 - 5,700
Ave. Gross Thickness	115 Ft.
Ave. Net Pay	55 ft.
Ave. Porosity	~7.5 %
Permeability	~0.2 – 3.1 md
Estimated Cum. Prod.	90 MMBO
Original Oil Reserves	138 MMBO
Remaining Oil Reserves	48 MMBO
Primary Recovery Factor	9 - 10 %
Original Oil In Place	1.5 BBO

"Clinton" Oil & Gas Fields in Ohio



▲ CO_2 Point Sources > 100,000 tons/yr

If CO_2-assisted enhanced recovery proves successful within the "Clinton" reservoir of the East Canton field, it should be applied to other "Clinton" fields in other parts of the state and basin. Should CO_2 separation technology from large point sources become reality; there are many potential sources within the region to provide abundant, affordable CO_2 for such projects. Estimates for the "Clinton" sandstone in Ohio indicate there are approximately 4.5 billion barrels of original oil-in-place.



In addition to the benefits of enhanced recovery from the East Canton Oil Fields, this area is well positioned to sequester large amounts of CO2 in a number of stacked deep saline aquifers as depicted in this 3-D cut-out of Tuscarawas County, Ohio.