A Web-Based Decision Support System for Geologic Carbon Sequestration

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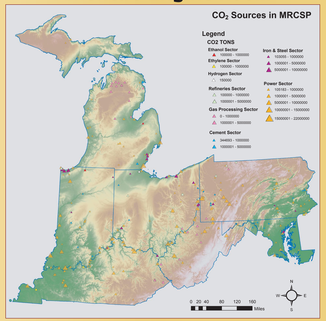
Midwest Regional Carbon Sequestration Partnership (MRCSP)—
A Collaborative Effort for the Planning and Implementation of Carbon Sequestration Technologies

"America's Engine Room"



Goals

Develop increased energy production capacity using fossil fuels while minimizing contribution to atmospheric CO_2 levels.

Geologic carbon sequestration technologies are central to meeting this goal.

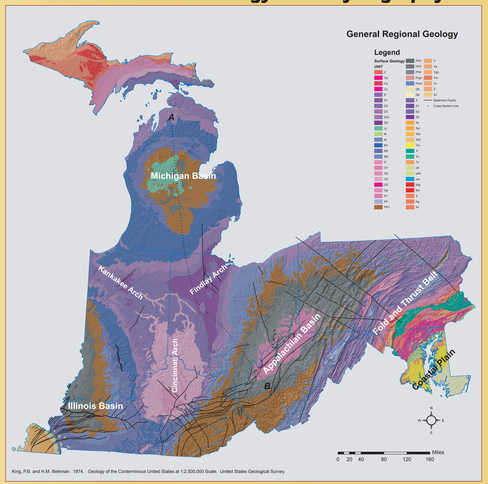
A major task of MRSCP was characterizing the region's geology to assess the potential for geologic CO_2 sequestration

Ideal region for sequestration projects

1. Large CO_2 production and large sequestration potential due to geologic diversity
2. Economic significance—Gross Regional Product—$1,534 Billion, 16% U.S. economy
3. 25% of electricity generated in the U.S.
4. Coal burning powerplants—77% of region's electricity generated using coal; 83% of the total region's large CO_2 point sources
5. Population 50.8 million with growing energy needs

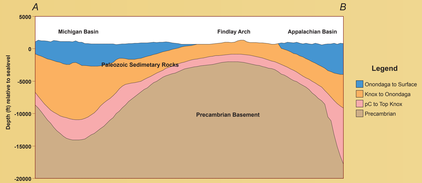
Geologic Diversity

Surface Bedrock Geology and Physiography



King, P.B. and H.M. Beikman. 1974. Geology of the Conterminous United States at 1:2,500,000 Scale. United States Geological Survey.

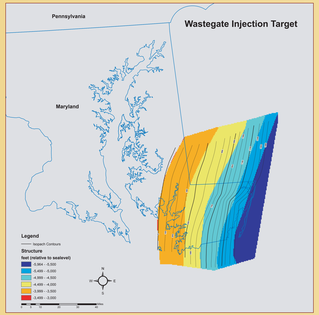
Generalized Cross Section



Regional cross section extending from the Michigan to Appalachian Basins.

Wide range of geologic features provides multiple opportunities for geologic CO_2 injection projects....

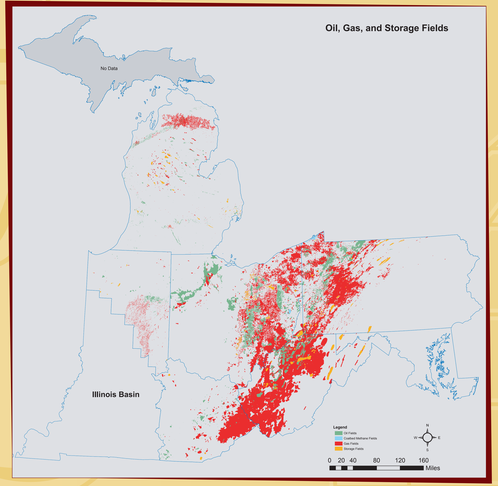
1. Major sedimentary basins with saline aquifers, depleted oil and gas fields, and opportunities for enhanced oil recovery.
2. Thick sequences of coal and organic shales appropriate for CO_2 sequestration and enhanced methane recovery.
3. Multiple injection horizons (sandstones, carbonates with good secondary porosity) and confining layers (shales and carbonates) for most geographic locations.
4. Diversity allows distances between sinks and sources of CO_2 to be easily minimized.



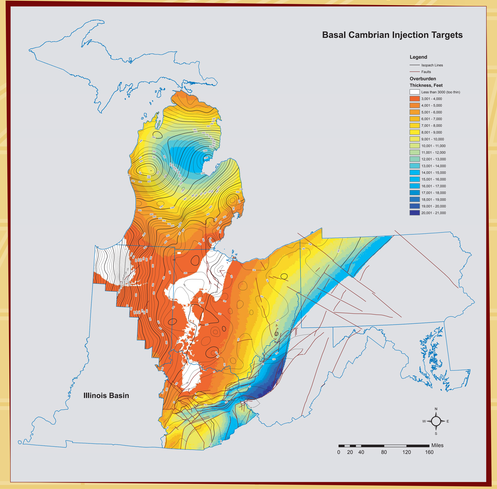
Opportunities for injection also exist on the coastal plain

Example Approaches to Geologic Carbon Sequestration

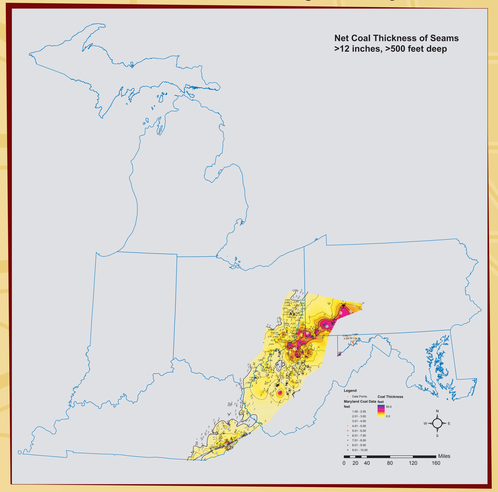
Supercritical Injection Into Oil and Gas Reservoirs



Supercritical Injection Into Saline Aquifers



CO_2 Enhanced Methane Recovery and Sequestration



ALL require geologic maps for capacity calculations and site selection....

Acknowledgments

This work was performed, in part, with funding from the Midwest Regional Carbon Sequestration Partnership, funded by the U.S. Department of Energy (Cooperative Agreement DE-FC26-03NT41981), the Ohio Coal Development Office (Agreement D-02-17) and other public and private members.

Geologic Framework—Multi-State Correlation Chart

LEGEND

- Layer with map on poster
- Local sequestration target
- Regional sequestration target
- Confining unit
- Organic shale
- Coal-bearing interval
- Unconformity

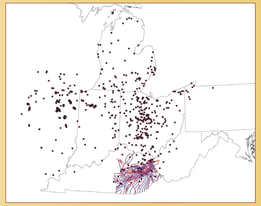
Basal Confining Units

- Sedimentary rocks
- Igneous and metamorphic rocks

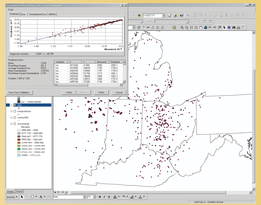
GEOLOGIC MAPS SHOWN ON POSTER

- Coals (total coal thickness map)
- Devonian shales (isopach map)
- Oriskany Sandstone (structure and isopach maps)
- Rose Run Sandstone (structure and isopach maps)
- Basal Cambrian injection targets (structure and isopach maps)
- Precambrian (structure map)

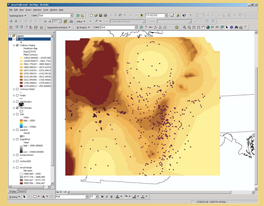
Mapping Methodology



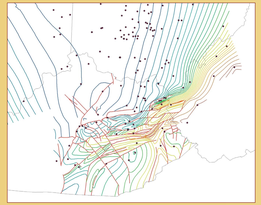
1. The original geologic data were formation picks from oil-and-gas-wells. Some picks were from completion reports, others from in-house datasets created by state geologists. In addition, the Kentucky Geological Survey provided hand contoured maps to represent the complex geology of the Rome Trough.



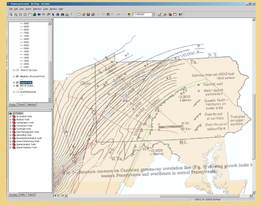
2. Geostatistical methods were used to grid and contour the study area outside of Kentucky.



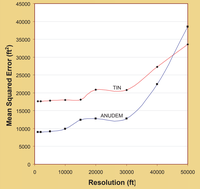
3. Grids from kriging were used to generate contour maps.



4. Contours are hand-merged with those from Kentucky to complete the map.



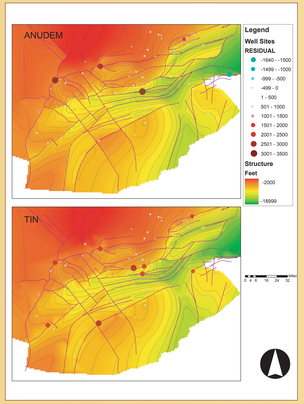
5. Literature maps were used as guidance in data poor areas.



The fit of the grid (Basal Cambrian) improves as resolution increases, up to about 10,000 feet. The ANUDEM method produced more accurate grids overall.

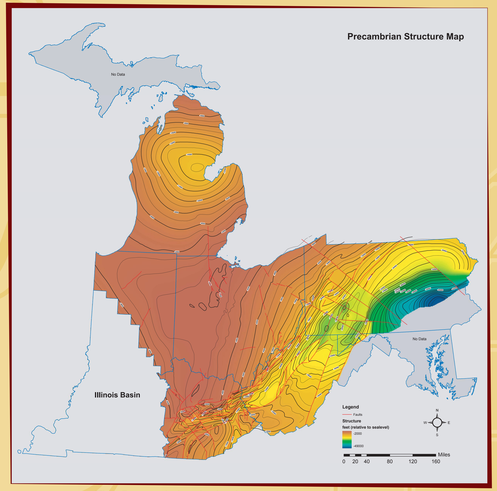
6. We needed a method to convert hand-edited contours back into grids for modeling. We looked at two approaches, ANUDEM, which uses localized splines to interpolate between contours, and the Triangular Integrated Networks (TIN) method.

We found the best results were obtained using ANUDEM.

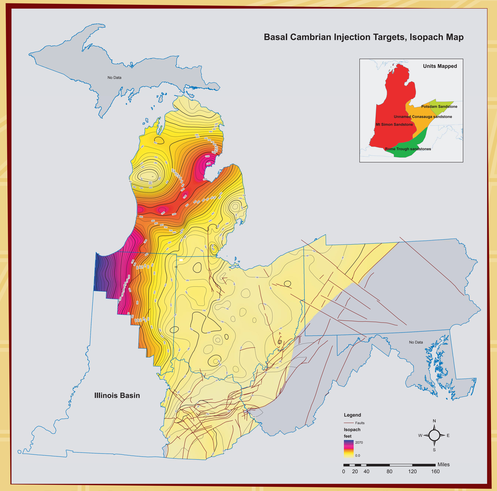


The biggest challenge to gridding is accurate representation in faulted regions. ANUDEM grids obey the well values better than TIN. ANUDEM also produces sharp breaks at the faults. Nevertheless, hand editing could further improve the fit of wells at faults.

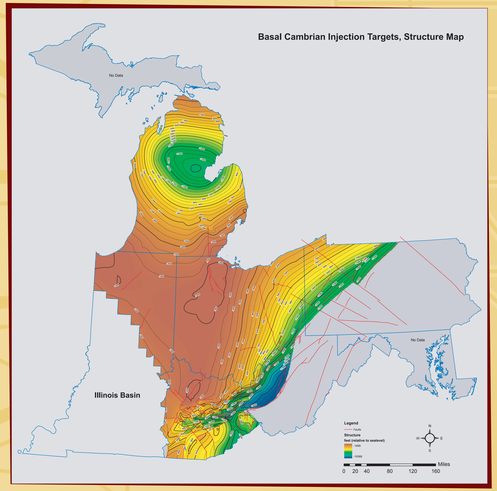
Example Geologic Maps



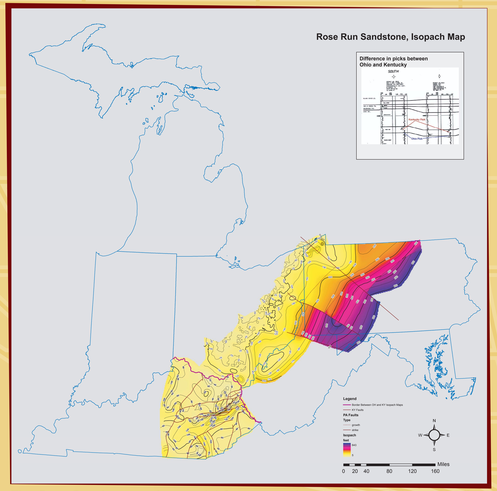
The Precambrian is the bottom-most confining layer



The Basal Cambrian injection targets represent a large saline aquifer.

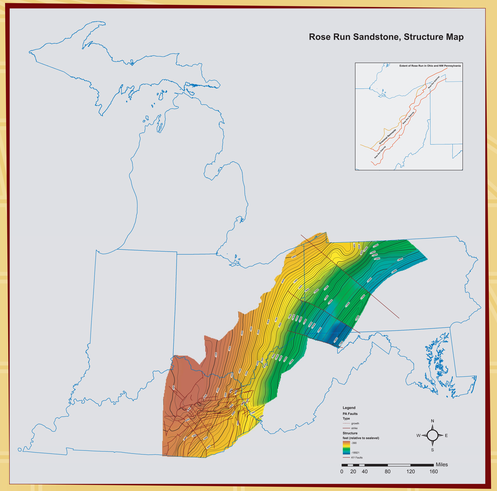


Much of the layer is at a depth appropriate for injection projects. An overburden of approximately 2,500 feet is needed to keep CO_2 in a supercritical state.

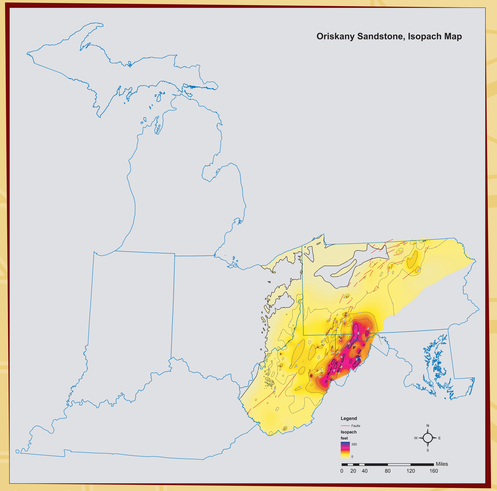


The Rose Run has good potential for storage in oil and gas fields, as well as EOR operations.

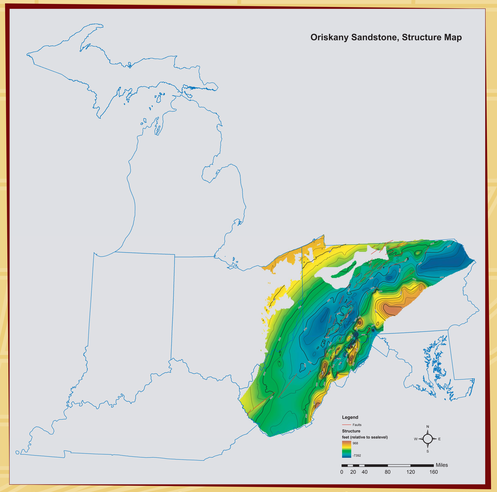
More Maps.....



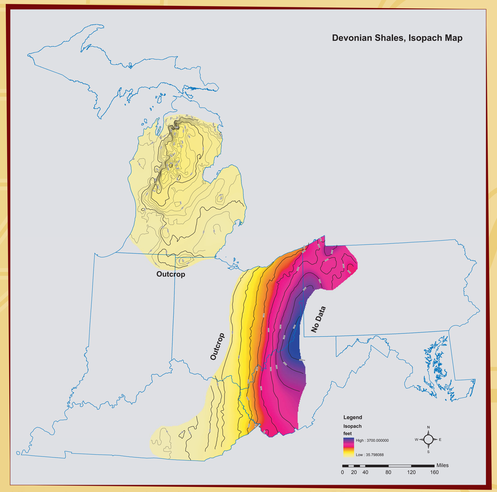
Maps in this project are both machine and hand contoured. For the Rose Run, the OH and WV portion were kriged, but PA and KY were contoured by hand.



Oriskany Sandstone has potential as both a saline aquifer and from depleted oil and gas fields.



Regional maps such as the Oriskany illustrate the need for detailed site studies. For example, faults can serve as reservoir traps or potential leakage pathways.

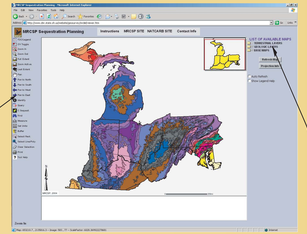


Like coals, organic rich shales can be used in CO_2 enhanced methane recovery—CO_2 storage projects.

How Will the Maps Be Used?

GIS-based Website for Map Viewing and Public Outreach

Opening page with USGS surface bedrock map

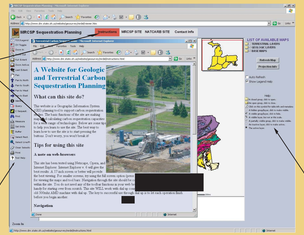


Tools for navigating page and maps

Table of Contents (TOC)

General instructions

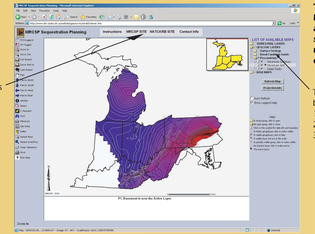
Tool help



Various help pages are provided to aid use by the general public

Links to websites with basic information about carbon sequestration and the MRCSP and NATCARB projects

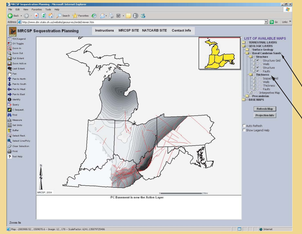
Table of contents help



The site is built to view and browse sequestration maps and data

TOC organized by type of map
1. Terrestrial
2. Geologic
3. Basemaps

Structure and isopach data points, isolines, faults and grids available

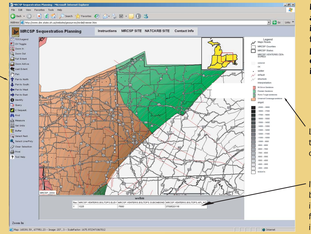


Target layer

For each layer, structure, thickness, and interpretive data are provided.

Any combination of layers can be turned on or off to produce custom maps.

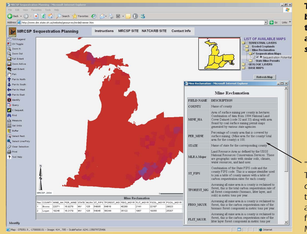
Zoom and navigation buttons to change area of interest



Navigation and identification functions provide detailed information

Legends can be toggled on or off

Identify tool can be used to get information from an individual well



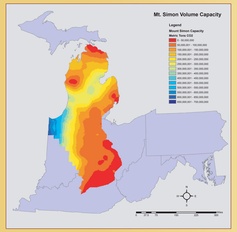
Terrestrial-based sequestration data is also presented

"i" button in TOC provides detailed info on tabular data and links to formal FGDC Metadata

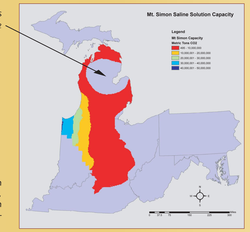
CO_2 Sequestration Capacity Calculations

1. We are calculating saline aquifer, oil-and-gas reservior, and coal bed/ organic shale capacities.
2. Calculations require many parameters, some of which have very limited data support.
   a. Porosity, thickness, overburden pressure, temperature, salinity, and pore-water fluids
   b. We will develop lithology maps for Phase II to improve spatial models of above parameters.
3. Example calculations for the Mt. Simon Sandstone (a saline aquifer) show enormous capacity.
   a. Volumetric and solution calculations use 14% average porosity (measured from injection wells in western Ohio)
   b. Assuming only 10% of total pore volume is available, calculation still yields 380 billion metric tons CO_2 capacity!
   c. Solution capacity with 10% available pore space is 14.6 billion metric tons.
4. Calculations are for regional assessment, detailed studies are required for specific sites.

Saline Solution vs. Volumetric Calculation Methods



Volumetric capacities are huge, but how much pore space is really available for injection? Volumetric calculations provide a maximum capacity estimate.

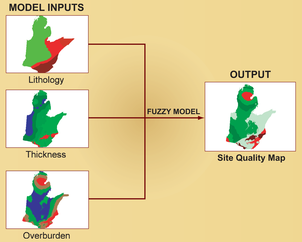


Salinity is too large in this region to permit CO_2 into solution.

Solution capacities are an order of magnitude less, still very large. Solution capacity provides a minimum estimate.

GIS Modeling for Site Discrimination

Expert systems approaches utilizing GIS technology are being explored to sythesize multiple geologic maps for stakeholders outside the earth sciences.



Making Interpretive Geologic Maps Using Fuzzy Techniques

- Combine lithology, thickness and overburden grids to make a single map of geologic quality for CO_2 injection.
- The fuzzy model and subsequent map summarizes the geologic information. The map can be combined with other economic/engineering factors for use in regional evaluations. A hypothetical example is provided (below and figure to left).

Fuzzy Modeling Procedure

1. Grid cells for each input layer are reclassified (values from 0.0-1.0) as to injection appropriateness (1 = very good, 0.5 = mediocre, 0.0 = unacceptable). In the diagram to the left, blues are excellent, greens are good, and reds are poor for injection.
2. The grid layers are combined using a fuzzy operator. For this example, we used the fuzzy AND operator. This operator returns the lowest value of the three layers at each grid cell.
3. The output map (grid) is created according to the rules of the operator. For this example, if we had grid cell values (thickness = 0.2, lithology = 0.5, overburden = 0.9), the value 0.2 would be returned. The map is conservative, as the presence of any low value will keep the area from getting a high score.