A Multi-Disciplinary Approach for Mapping Rock Units with Geologic Carbon Sequestration Potential

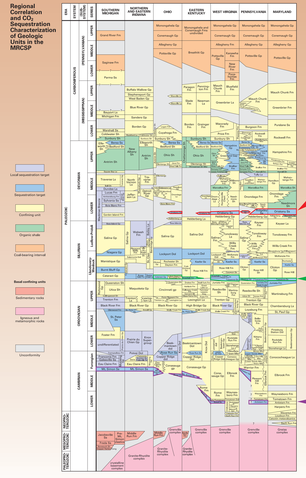
Kristin M. Carter, P.G.
Pennsylvania Department of Conservation and Natural Resources
Bureau of Topographic and Geologic Survey
Pittsburgh, PA
and
Erik R. Venteris
Ohio Division of Geological Survey
Columbus, OH

The Midwest Regional Carbon Sequestration Partnership (MRCSP) seeks to minimize atmospheric carbon dioxide (CO_2) levels while developing increased energy production capacity using fossil fuels. Geologic CO_2 sequestration is a key component of this approach.

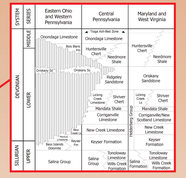
To this end, members of the MRCSP have collaborated to map the structure and thickness of several, discreet geologic packages with CO_2 sequestration potential. The partners used an unique, multi-disciplinary approach by compiling a wide range of legacy data and mapping it using a combination of computer and hand contouring.

Conversion of contour lines to vectorized grids (for evaluation of CO_2 sequestration potential) proved challenging due to complex geologic structures and occasional large data gaps. Three gridding approaches (BLOCK KRIGING, PETRA, and ANUDEM) were evaluated.

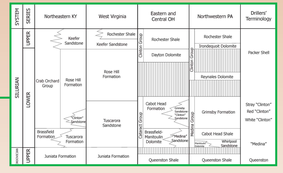
Stratigraphy of Geologic Units in the MRCSP Study Area



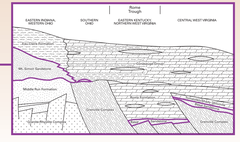
Regional Oriskany Sandstone Correlation Chart



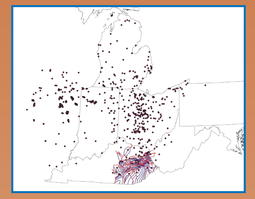
Regional Medina Group/ "Clinton" Sandstone Correlation Chart



Basal Cambrian Injection Targets Correlation Chart

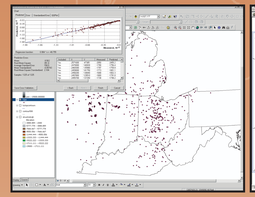


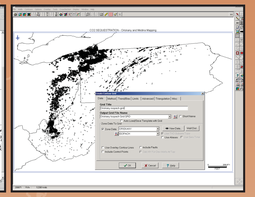
Mapping Workflow



Step 1. Data Gathering

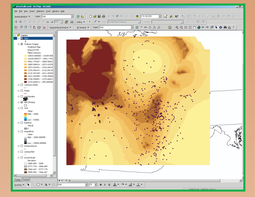
Point data were gathered from several sources, including digital oil and gas well databases, cores, outcrops, subcrops, and seismic lines. In addition, previously published reports and maps were identified for areas with sparse point data.

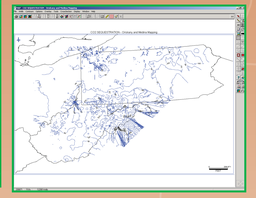




Step 2. Gridding Processes

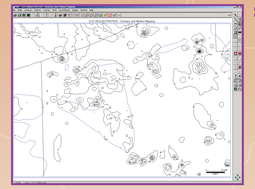
Data were gridded in different ways, depending upon the software used: Arc-GIS Geostatistical Analyst (ordinary kriging option; left) as well as PETRA (a simple least squares algorithm; right) were utilized. No grid size constraints or directional bias were employed in PETRA.





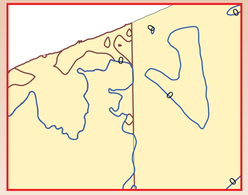
Step 3. Contouring Gridded Data

For the Arc-GIS approach, block kriging was conducted to produce grids. These grids were then contoured using Spatial Analyst. For the PETRA approach, manual revision of draft contours was preferred to ensure that data outliers could be considered individually and geologic interpretations could be directly applied to the contours.



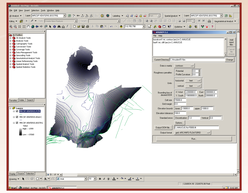
Step 4. Manual Editing of Digital Contour Maps

Draft contour lines were manually revised to reflect known depositional patterns and other relevant geologic history: here, the "Oriskany No-Sand Area" of northwestern Pennsylvania was evaluated by checking data associated with anomalous-looking draft contours (e.g., bullseyes, unusually thick sequences, etc., shown here with black lines) and revising them after reevaluation of existing drilling and geophysical log data (final contours shown using blue lines).



Step 5. Peer Review

Resolving Oriskany isopach contours near the Ohio-Pennsylvania boundary: subcrop data (brown lines) from previously published maps supplied by the Ohio Geological Survey were incorporated into isopach contours (blue lines) so that the final contour map was representative of both field mapping and subsurface drilling data.



Step 6. Final Contour Maps and Creation of Grids for Sequestration Calculations

We needed to convert edited contour maps back into grid format for GIS analysis. ANUDEM and PETRA were tested to accomplish this task.

Qualitative and Quantitative Comparison of Gridding Methods

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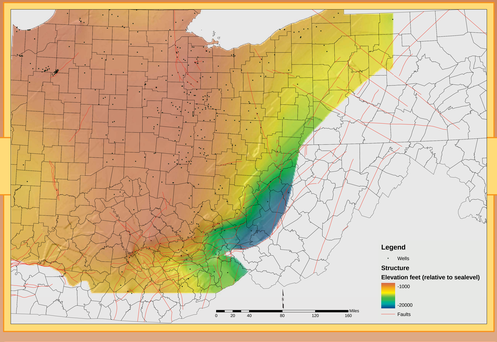
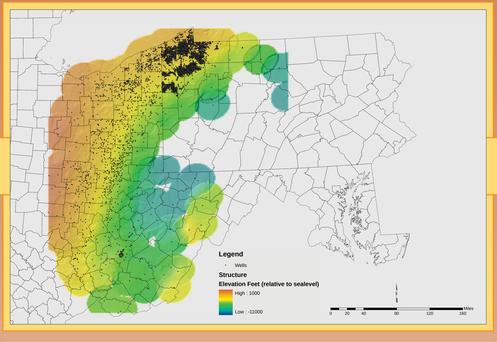
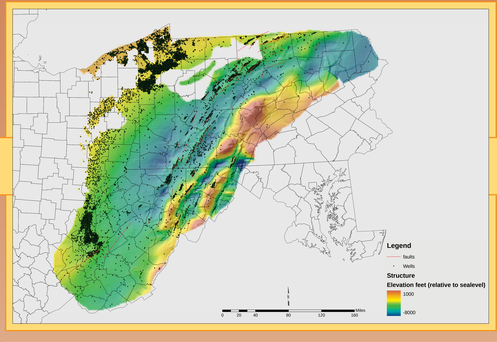
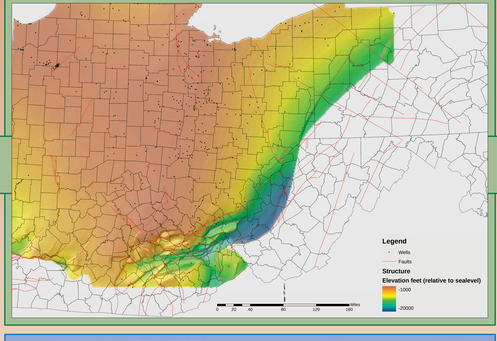
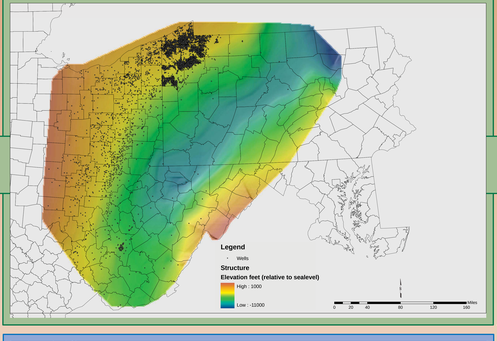
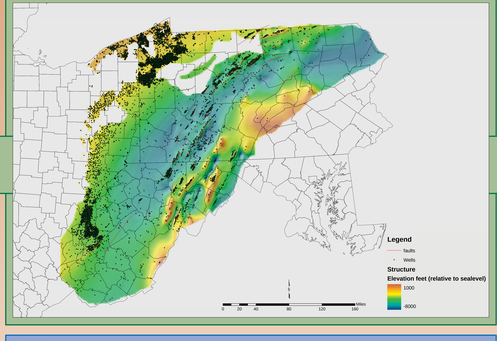
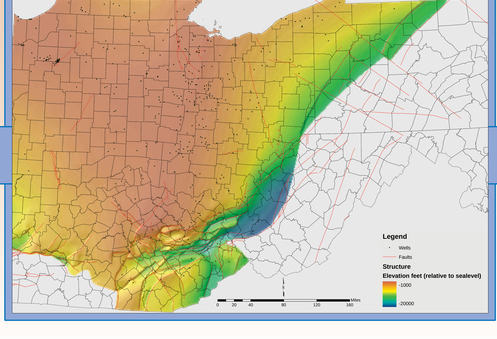
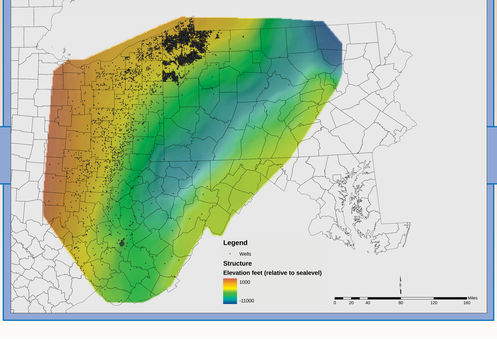
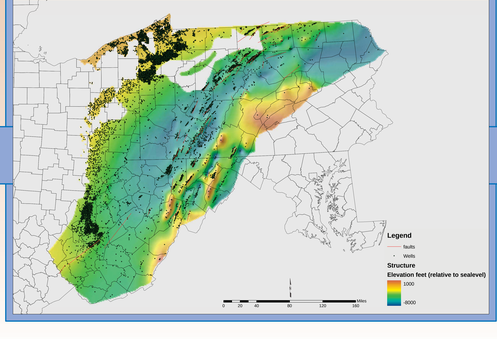
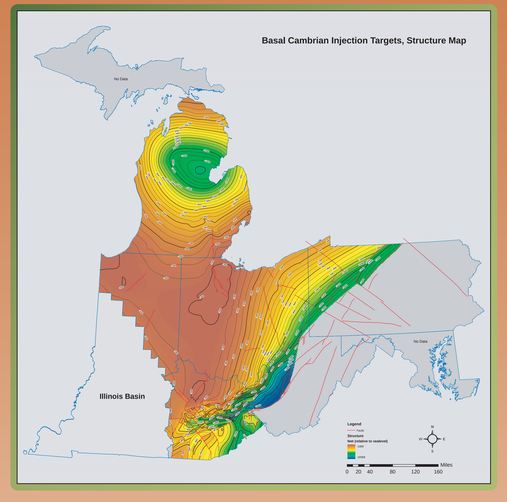
	Basal Cambrian Sands	Error Measure	Medina Group/ "Clinton" Sandstone	Error Measure	Oriskany Sandstone	Error Measure
BLOCK KRIGING		Cross Validation RMSE = 628 feet Grid Error RMSE = 112 feet		Cross Validation RMSE = 58 feet Grid Error RMSE = 37 feet		Cross Validation RMSE = 216 feet Grid Error RMSE = 155 feet
PETRA		Grid Error RMSE = 335 feet		Grid Error RMSE = 78 feet		Grid Error RMSE = 119 feet
ANUDEM		Grid Error RMSE = 361 feet		Grid Error RMSE = 68 feet		Grid Error RMSE = 154 feet

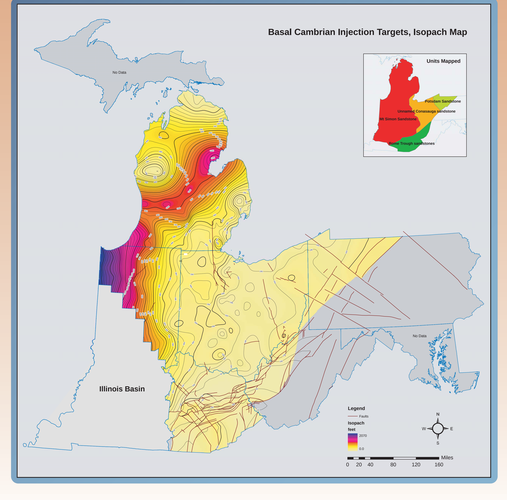
$$\text{Root Mean Squared Error, } RMSE = \sqrt{\left(\frac{1}{n}\right) \times \left(\sum_{i=1}^{n} \left(x_i - x_{observed}\right)^2\right)}$$

where:
x_i = the grid value
$x_{observed}$ = the well value
n = the total number of observed data values

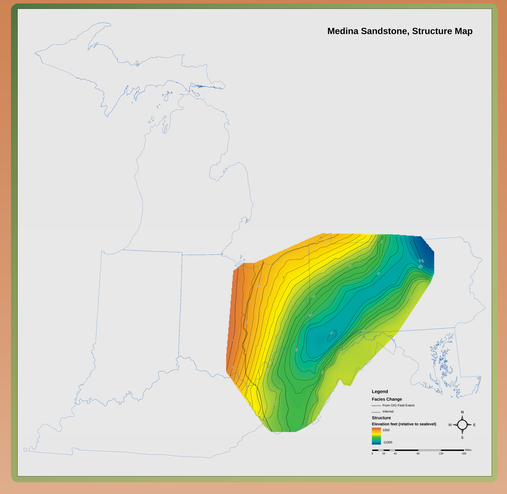
Completed Phase I Digital Geologic Maps

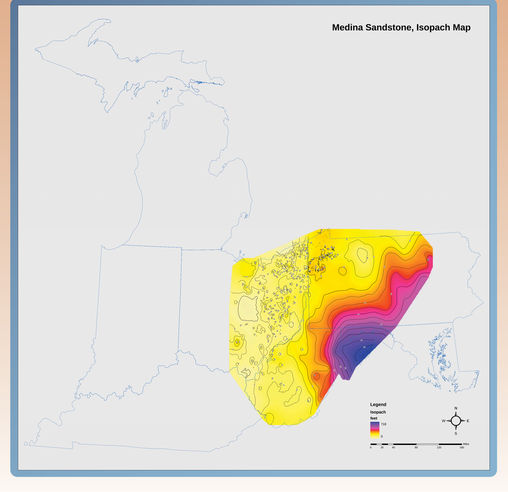
Basal Cambrian Sands



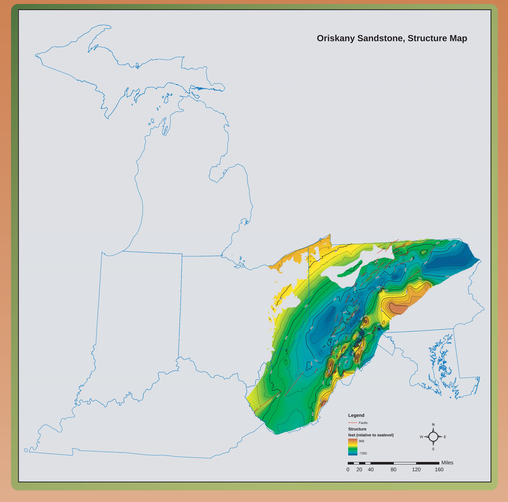


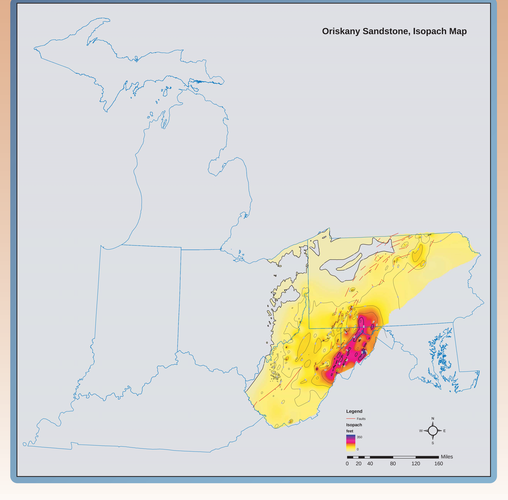
Medina Group/ "Clinton" Sandstone





Oriskany Sandstone





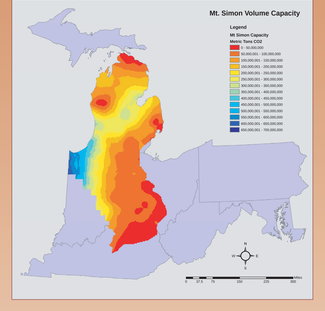
CO_2 Sequestration Capacity Calculations

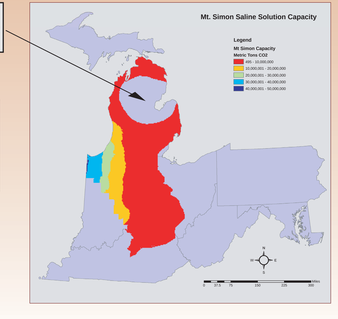
1. We are calculating saline aquifer, oil-and-gas reservior, and coal bed/ organic shale capacities.
2. Calculations require many parameters, some of which have very limited data support.
   a. Porosity, thickness, overburden pressure, temperature, salinity, and pore-water fluids
   b. We will develop 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, but still very large. Solution capacity provides a minimum estimate.