

Addressing Critical Issues in Geologic Storage Through Mountaineer and MRCSP Projects: Part 3 - MRCSP

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Please Note

- The full presentation by Dr. Gupta is divided into three parts. This is part three. Parts one and two are available online at: www.mrcsp.org
- The original slides presented at the briefing did not include as much text as is included in this version. New text slides have been added to make it easier for viewers of the slides to follow the main points.
- Frequently, the new text slides have been inserted in front of the original slides to offer more detailed explanation.

Overview of MRCSP Slides

- This section consists of 48 slides that address three main topics:

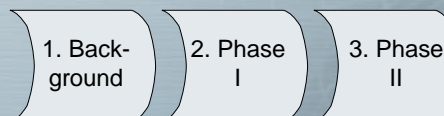
1. Background on the research project – Phase I and Phase II.

2. Phase I activities and findings

- Mapping
- Capture technology assessment
- Regulatory assessment.

3. Phase II Geologic Research

- Michigan Basin
- Appalachian Basin
- Cincinnati Arch.



The MRCSP Region: Vast CCS Potential

- The following two slides show the diverse geology of the region and a correlation of the deep geology across the states in the region.
- Based on this initial screening, the region appears to be a good potential area for carbon capture and storage (CCS).
- The seven Regional Carbon Sequestration Partnerships, including MRCSP, are completing detailed regional geologic characterization and also providing a critical “learning by doing” experience for researchers, regulators, local officials, industry partners and stakeholders.
- Phase I was completed in September 2005. Phase II started in October 2005 and will run through fall 2009.

MRCSP – Moving from Regional Mapping to Field Implementation

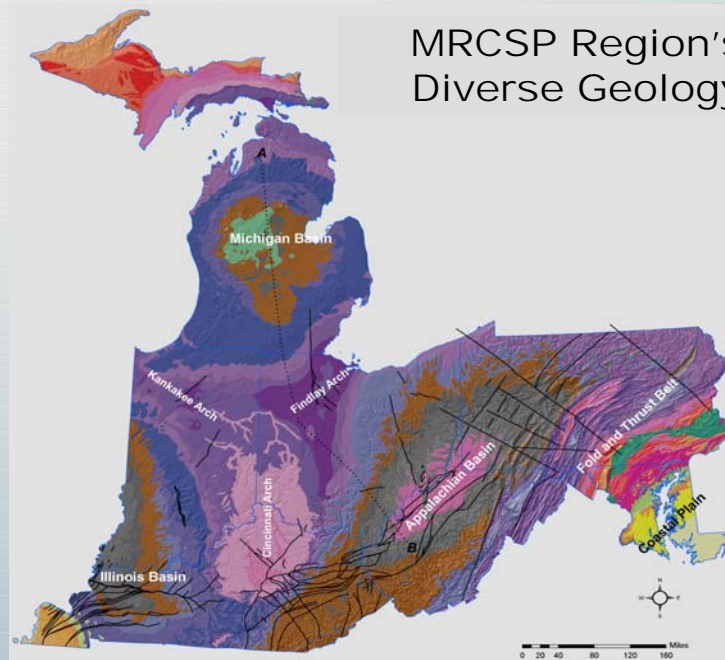
- MRCSP Phase I built a strong foundation for understanding the regional geological framework for storage and containment.
- During Phase II, the research team will validate the regional potential using a series of field characterization and injection demonstrations.
- The geologic tests will be led by Battelle in collaboration with regional geologic surveys.
- Maps presented in following slides were prepared by a team from the MRCSP states' geological surveys and Western Michigan University.



A partnership of regional expertise

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MRCSP Region's Diverse Geology



Modified from
King, et al, 1974

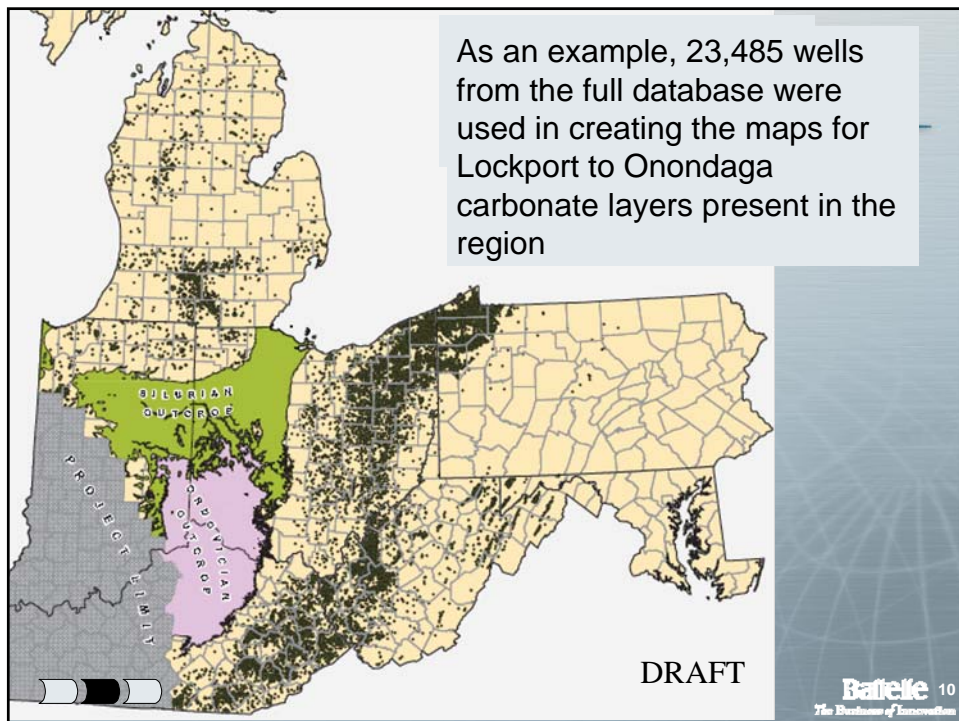
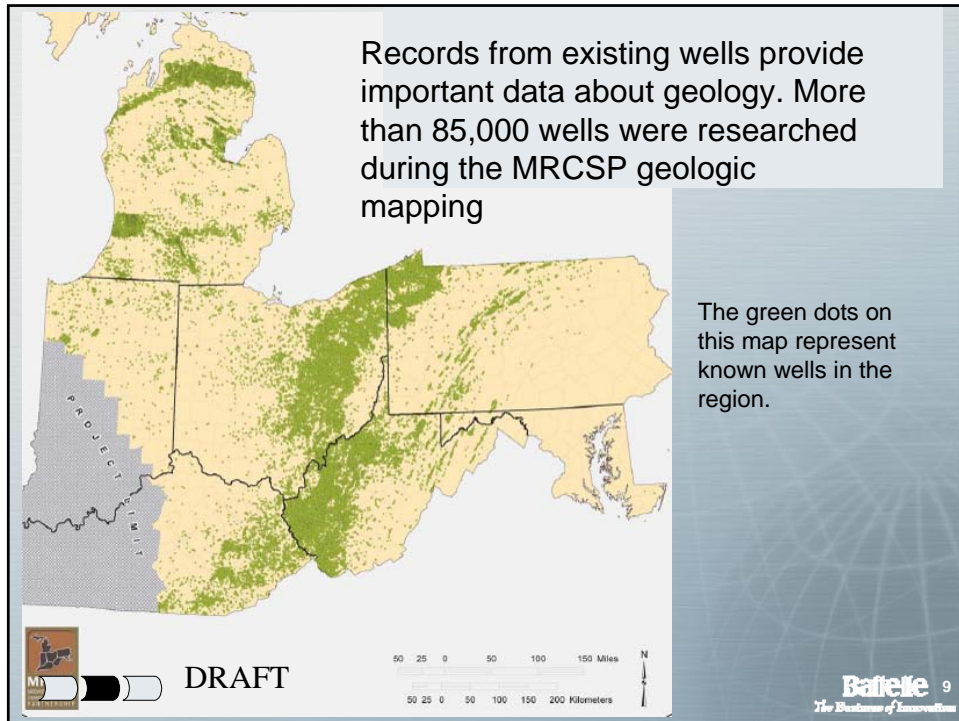
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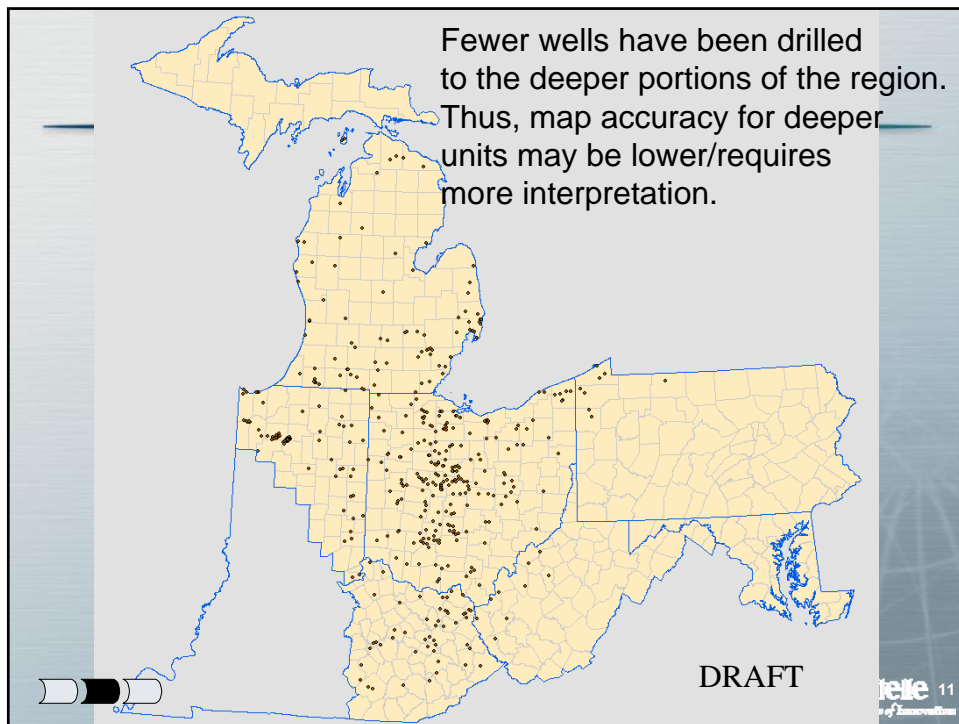
- Geologic Heterogeneity -



MRCSP Phase I Accomplishments: A Number of Firsts!

- First detailed regional mapping effort to combine this group of states. First such consortium to tackle more than one basin. Maps include:
 - Structure (depth) and thickness maps
 - Porosity, salinity, temperature data: grids
 - Oil and gas field locations, production data
 - Coal: Thickness, depth, and number of beds.
- First detailed regional oil and gas fields map, and it is digital!
- First-ever digital compilation at the state level for: PA, MI, WVA, MD.
- First-ever mapping of CO₂ sequestration potential in MI, MD, PA, WVA.
- First regional database compilation for mapping formations, salinity, geothermal gradient. 30 original depth and thickness maps, 9 regional thematic maps, and 14 derivative capacity maps.
- First time MD data put into digital format; first time that state has been included in regional mapping of subsurface units with the Midwestern states.



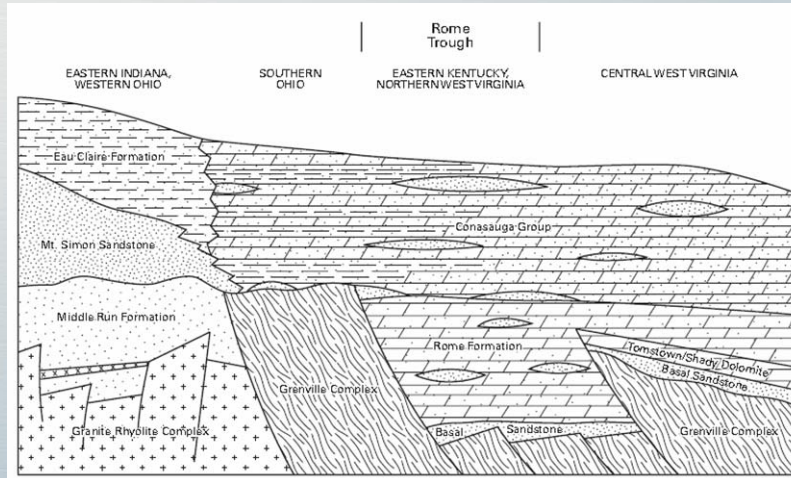


MRCSP Regional Mapping

- The region's geology is comprised of a number of different sedimentary layers.
- Precambrian crystalline rocks with no currently known injection potential underlie the layers of sedimentary formations in much of the region.
- On top of this lies a series of layers, some of which are sandstones, others are shales and still other types of rock are layered in. The following slide presents a graphic representation of this layering effect in the Appalachian Basin.



MRCSP: Cross-Sectional View of the Basal Precambrian Sands



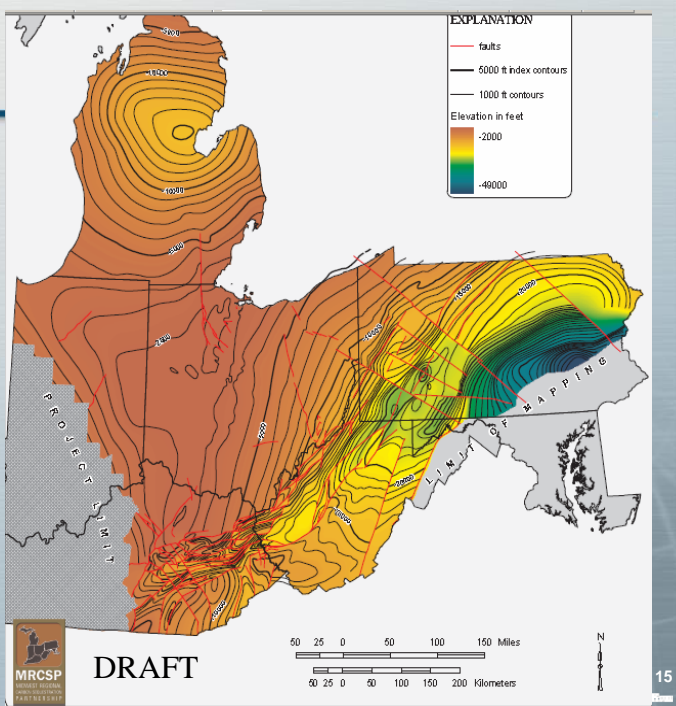
Developing a Model of the Regional Geology

- Geologists work to define the various rock layers by taking core samples and other data from previously dug wells and seismic tests.
- This information is used to “connect the dots” in order to construct virtual models or maps of the geology. The next series of slides illustrate maps of the thickness of different layers underneath the MRCSP region.



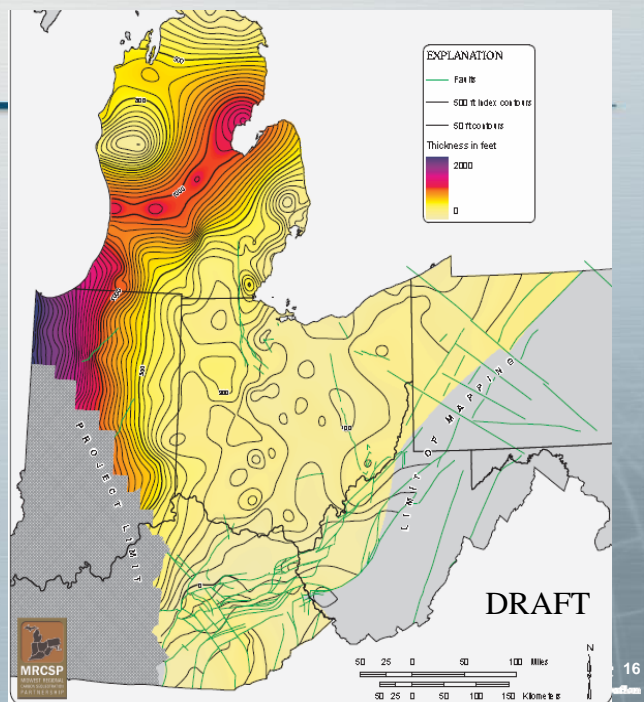
MRCSP Structural Maps

This map shows the structure of the geology overlying some of the deepest layers of rock. It is known as the Precambrian Unconformity.



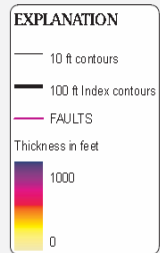
MRCSP Thickness Maps

This map shows the thickness of the basal Cambrian sands interval.

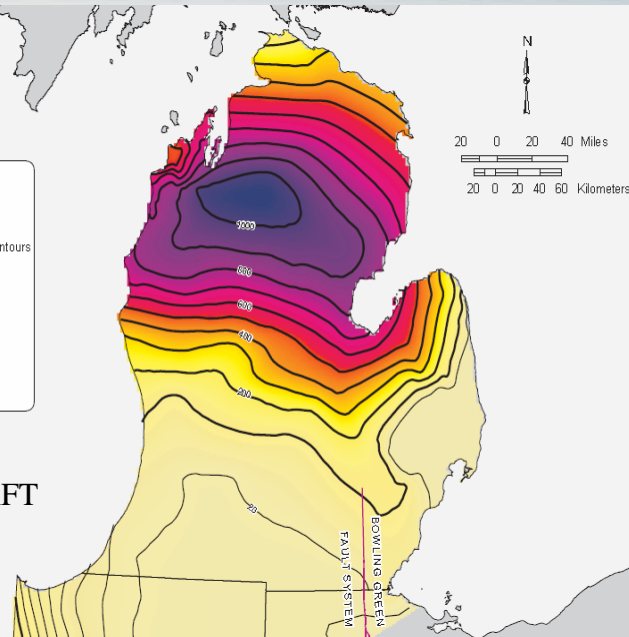


MRCSP Thickness Maps

Map showing the
thickness of the St.
Peter Sandstone.



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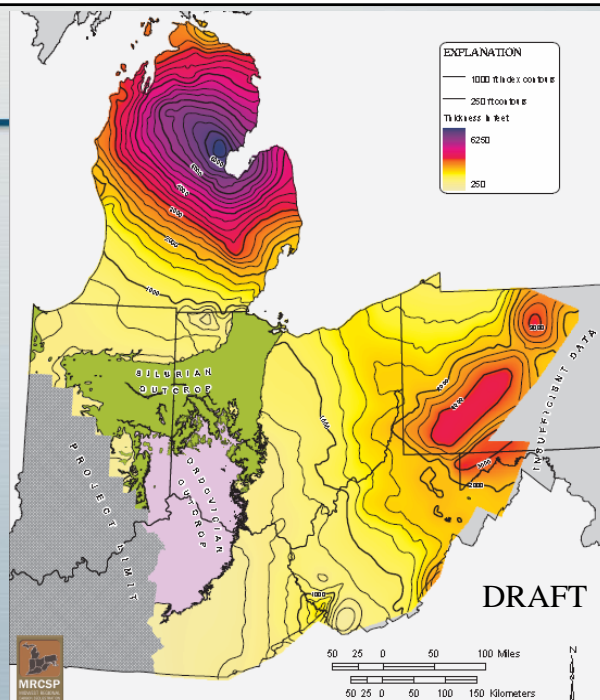
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MRCSP Thickness Maps

Map showing the
thickness of the
Niagaran to Onondaga
Limestone interval.



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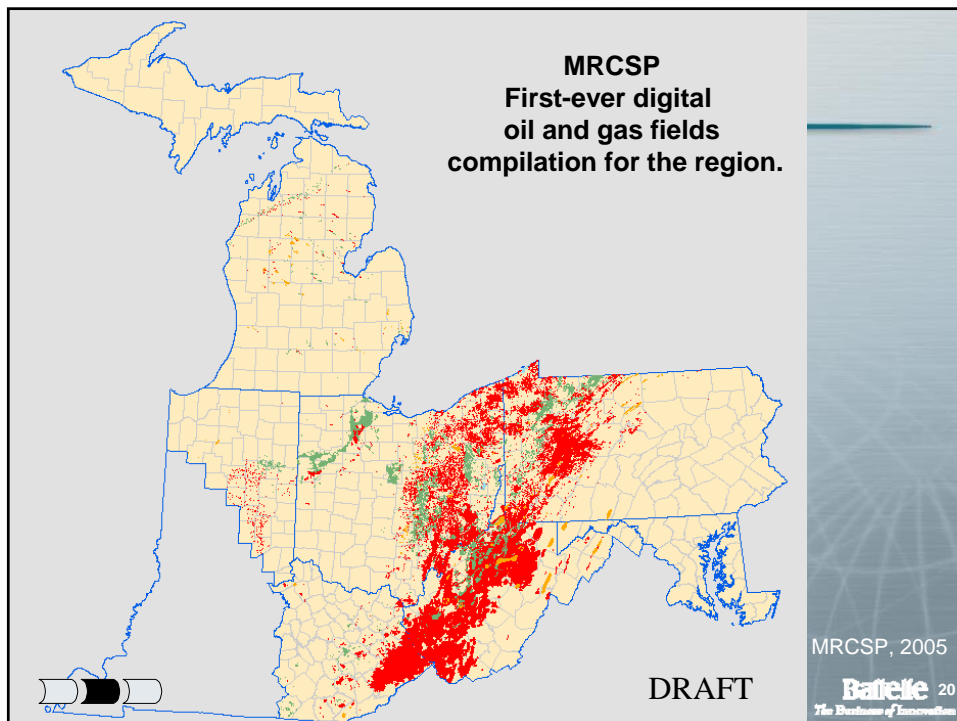
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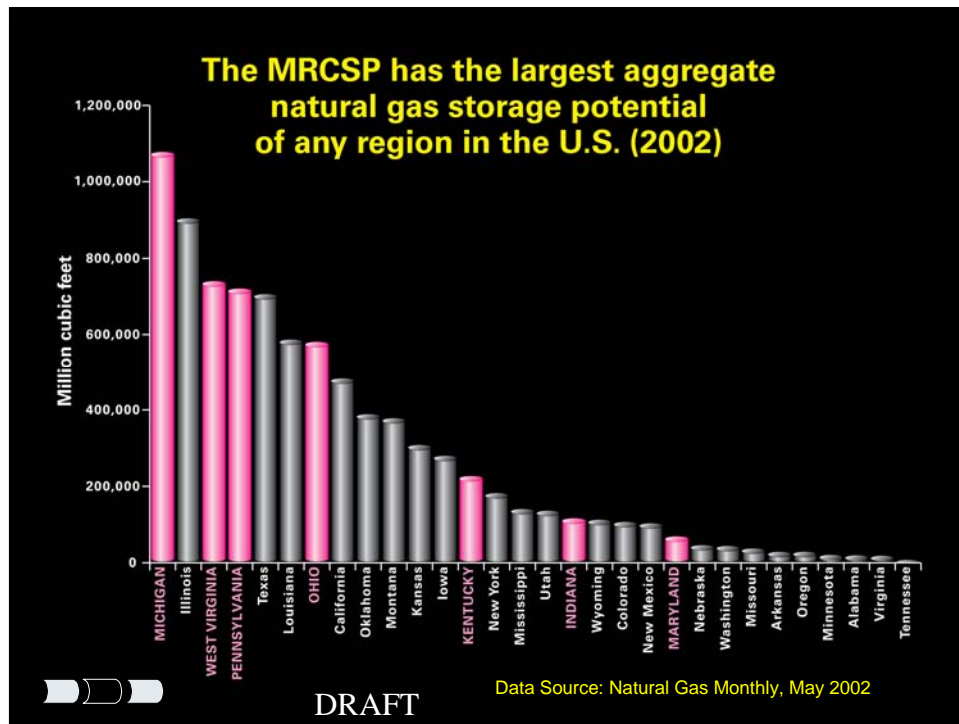
Oil, Gas and Coal Deposits Indicate Regional Storage Potential

The following two slides illustrate some of the oil and natural gas activities in the region. These fossil fuels were formed over millions of years and have remained stored in the geologic formations until we removed them during the last two centuries.



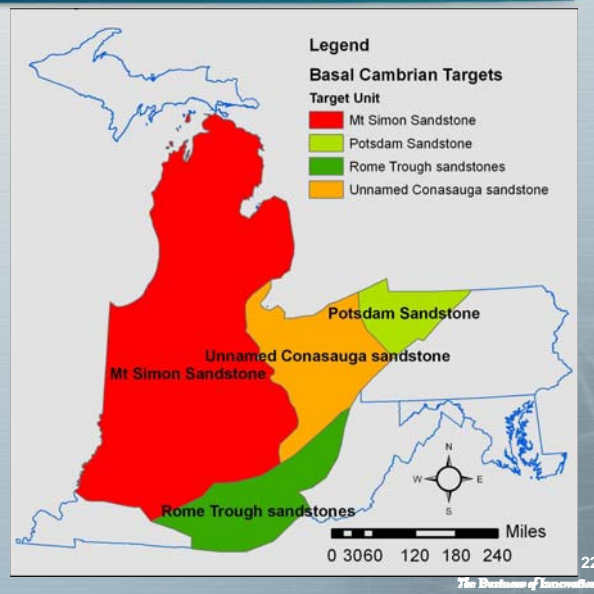
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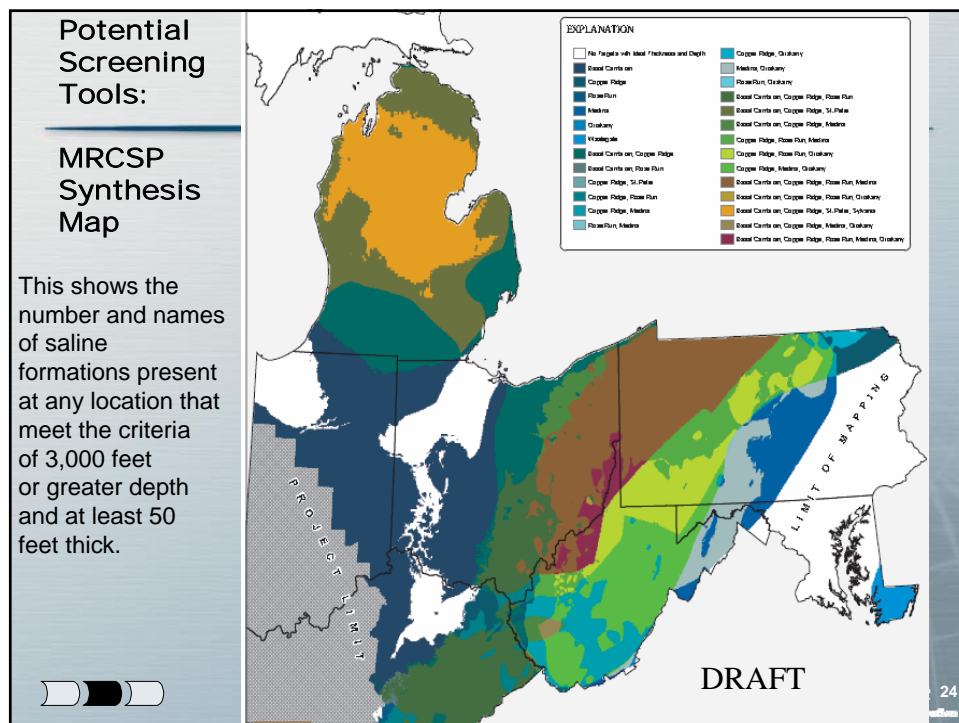
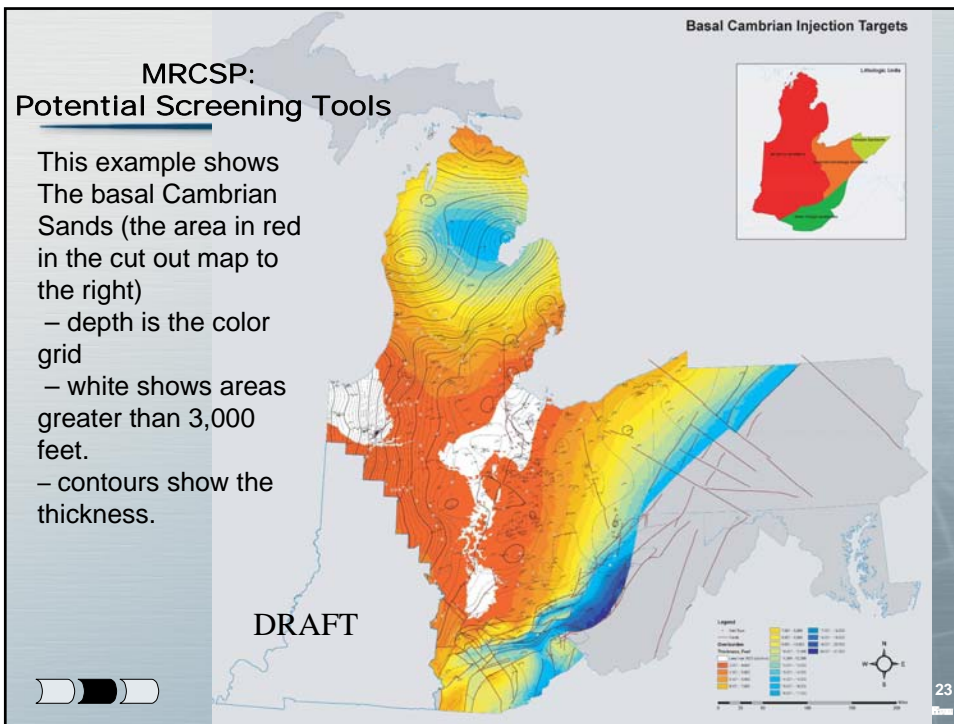




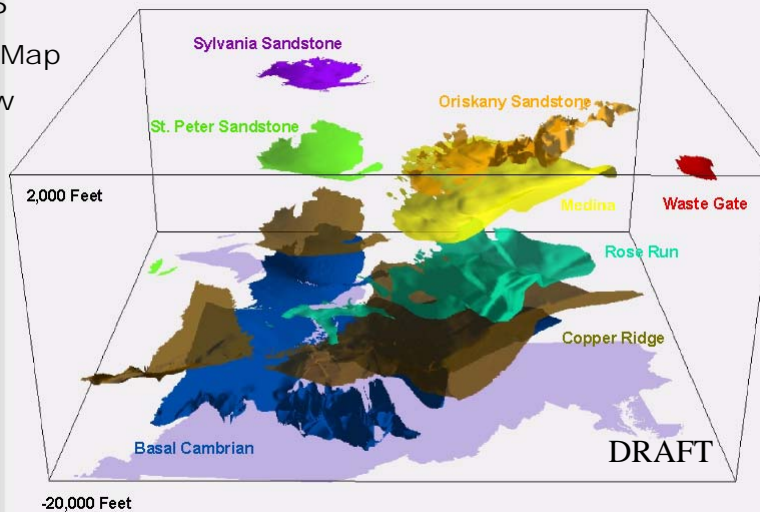
Identifying Potential Regional Storage Targets

- Once various map layers are created, they can be combined, using Geographic Information System (GIS) mapping tools to identify areas of potential interest.
- The following slides show some of the screening tools generated for exploring these areas in detail.





MRCSP
Synthesis Map
3D View



3-D View of the same synthesis map shown on the previous slide: Saline formations that meet the criteria of 3,000 feet or greater depth and at least 50 feet thick.



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CONSOL Has Completed a Detailed Analysis of Capture Technologies for MRCSP

The MRCSP also looked at viable options for capturing CO₂ from power plants.



An Amine Capture Plant on a Gas Processing Plant
Photo provided by CONSOL Energy

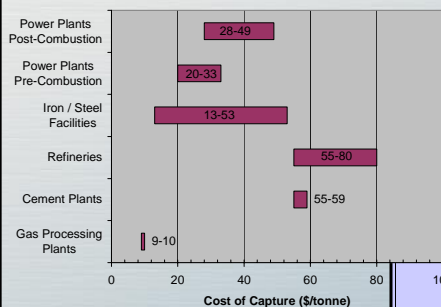
Technologies Considered

- Amine Scrubbing
- Alkaline Salt Scrubbing
- Ammonia Scrubbing
- Physical Absorption
- Gas Separation Membrane
- Gas Absorption Membrane
- Physical Adsorption
- Solid Chemical Absorption
- Cryogenic
- Hydrate Formation
- Electrochemical Separation
- Biochemical Separation
- Oxyfuel
- Chemical Looping Combustion



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CONSOL Capture Analysis



Cost of capture is in the range of \$20 to \$50 per tonne of CO₂ for most MRCSP sources

Capture technologies were ranked as:
 • "L" Likely,
 • "A" Attractive, and
 • "S" Speculative

Source Type	Point of Capture	Amines Scrubbing	Ammonia Scrubbing	Physical Absorption	Gas Separation Membrane	Gas Absorption Membrane	Oxyfuel + Drying/Compression	Simple Drying/Compression
Power Plants Post-Combustion	Flue Gas	L	A	--	A	A	A	--
Power Plants Pre-Combustion	Shifted Syngas	--	--	L	A	--	--	--
Iron / Steel Facilities	Blast Furnace Gas (~60-70% of total CO ₂)	L	--	L	A	S	--	--
Refineries	Heater/Boiler Flue Gas (~65-85% of total CO ₂)	L	S	--	A	S	A	--
Cement Plants	Kiln Flue Gas	L	S	--	S	S	S	--
Gas Processing Plants	Vented CO ₂	--	--	--	--	--	--	L

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Assessment of Regional Regulatory Infrastructure

- Contacts made in all states. Copies of pertinent regulations obtained and analyzed.
- Meetings held at state level
 - Public utility commissions, EPA, and other stakeholders.
- Analysis includes:
 - Regulations for fluid injection and analogues such as gas storage
 - Discussion of selected case law related to subsurface injection
 - Review of rights of way/mineral rights issues for subsurface reservoirs
 - Review of pipeline rights of way procedures and precedents
 - Assessment of eminent domain issues
 - Assessment of credit mechanisms for terrestrial storage
 - International accords related to carbon mitigation
 - Carbon trading status in the USA
 - Identification of regulatory jurisdiction in all seven states.

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Regional Regulatory Findings

- Geologic sequestration in the pilot stage
 - UIC program for drinking water will apply in the absence of other specific statutes
 - State regulators confirm that pilot projects will be permitted under the UIC.
- Need for interagency coordination over the long term
 - Dialogue between various state agencies on sequestration
 - Knowledge and awareness of sequestration technologies
 - Integrated siting and permitting process.



MRCSP Goals at the Outset of Phase II Proposal Planning

- Multiple (two or three) geological field projects
 - Inject CO₂ (at least 10,000 tonnes over the four years)
 - Multiple possible sources of CO₂. Cost is an issue.
- One or more terrestrial field projects.
- Further characterization of our region
 - Build upon Phase I characterization efforts
 - “Piggy Back” drilling a key element
 - Continue working with regulators as a complement to the permitting process carried out for the field projects.
- Intensified public outreach and education
 - Tailored to specific sites as field projects become clear.



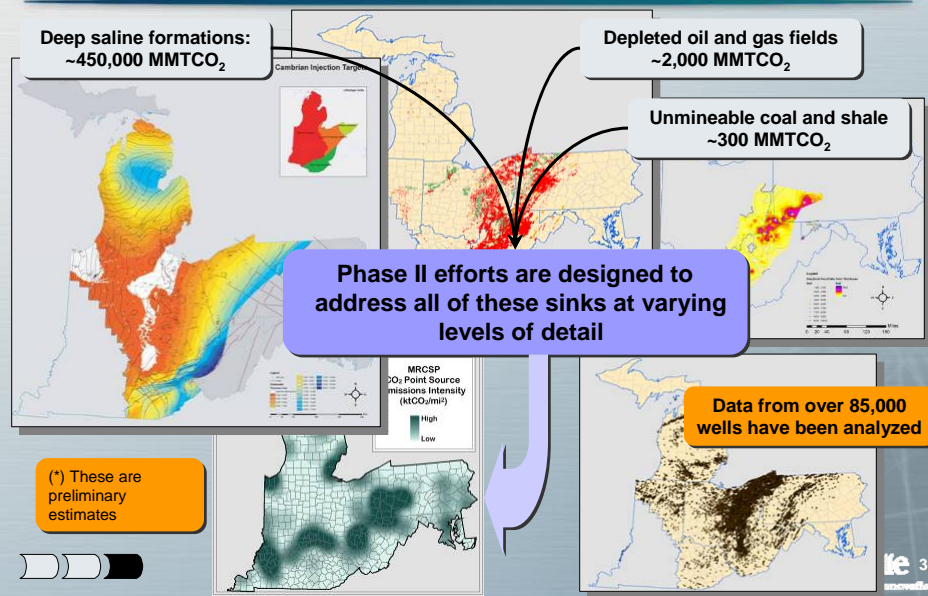
MRCSP Phase II Geologic Tests and Characterization

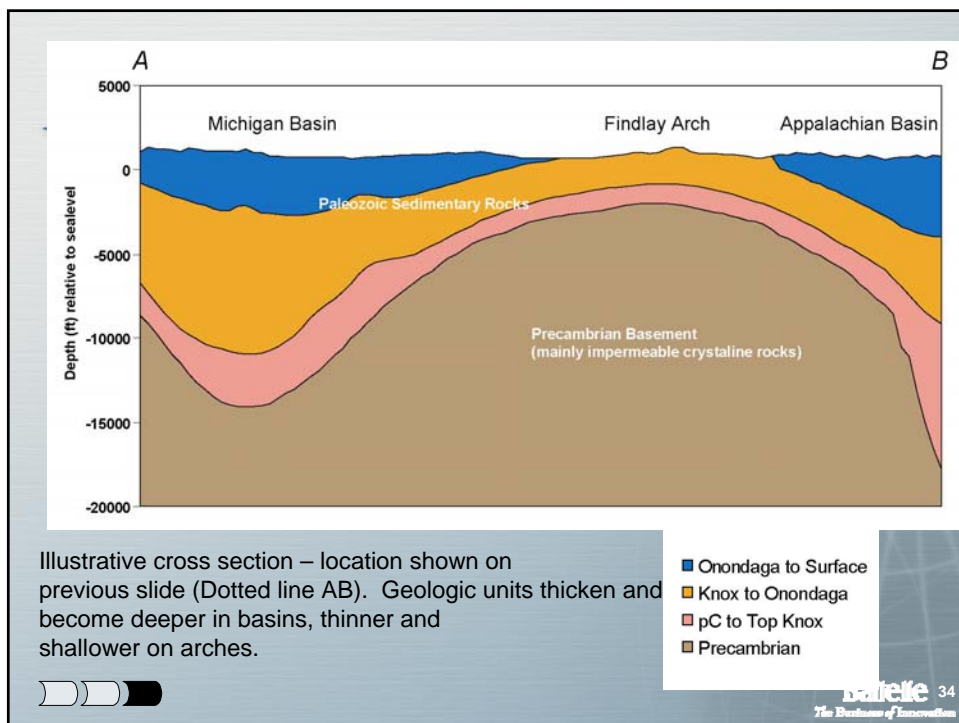
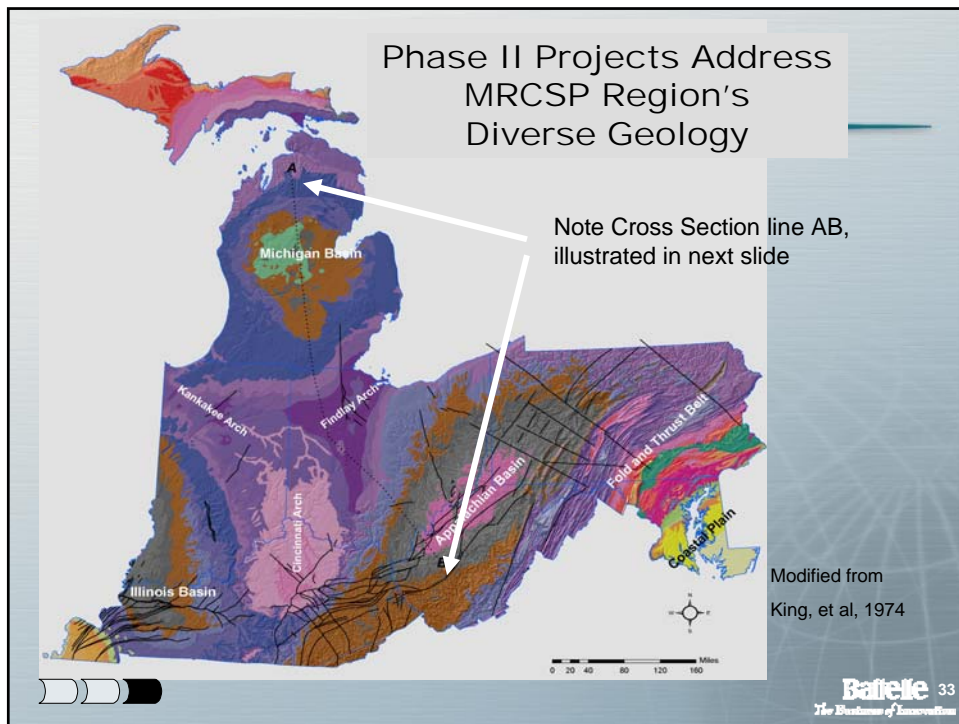
- Our geological team, headed by Larry Wickstrom of the Ohio Geological Survey and including all the state geological surveys in the region, plus Western Michigan University, have completed a first-ever mapping of the region's geologic resources. These resources are vast and represent literally hundreds of years of potential storage capacity.
- In Phase II, MRCSP is pursuing several projects designed to provide more detailed information about representative areas in the region.
- The next three slides show the diversity and present a cross-section of the geology.



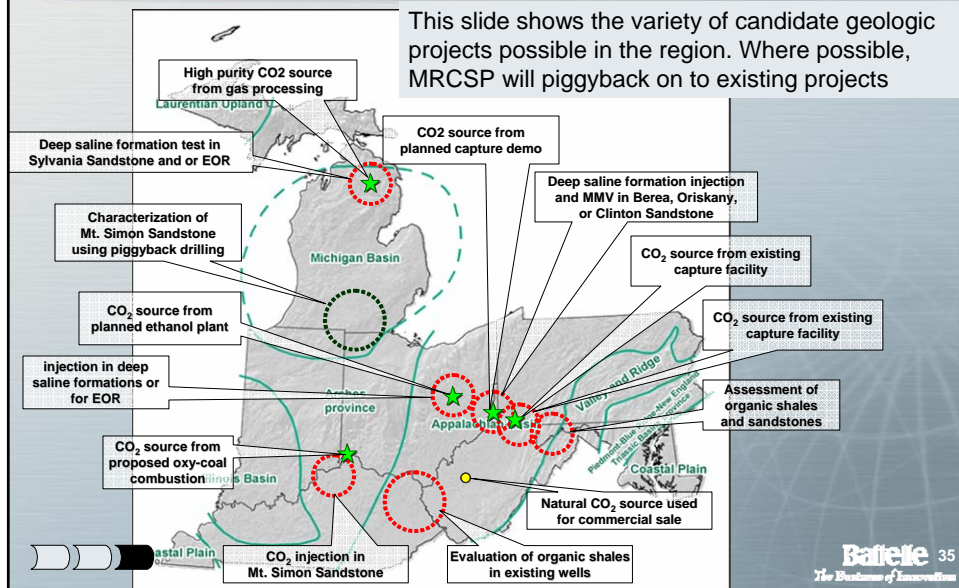
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The Geological Potential of the MRCSP Region is Vast and Well Positioned Relative to Sources*





MRCSP Geologic Field Project Overview



3 Potential Injection Tests

MRCSP is planning to conduct as many as three drilling and injection tests. Each is described on the following slides. MRCSP selected these tests by considering the following:

Evaluating Proposed Projects

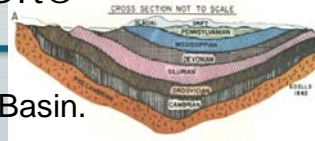
- Cost/benefit
- Cost share support available
- Innovativeness of research (is it helping to define the state of the art)
- Applicability to region (capability to address multiple reservoirs)
- Public stakeholder acceptance
- Degree of support from state and federal regulators
- Safety and risk assessment

Impact of Research Results on the Region

- Potential for sequestration deployment in the region
- Cost of commercial implementation
- Time to commercial implementation
- Will it help to attract and retain business or research to the region
- Degree to which project would help to define new science based regulations



Michigan Basin Candidate Site



- Located at the northern rim of Michigan Basin.
- Gas processing plants owned by DTE provide pure CO₂.
- Compression facility and ~8-mile long pipeline for active enhanced oil recovery (EOR) – possibility of longer-term injection test.
- Geology suitable for tests in multiple saline formations (Sylvania Sandstone, Mt. Simon, St. Peter) and/or EOR (Niagaran Reefs). MRCSP primary target is in saline formations.
- Available geologic data from existing wells.
- Potential for 4-D seismic or cross-well monitoring.
- EPA Region 5 permitting for all classes of wells in Michigan.



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Michigan Basin Candidate Site



CO₂ Capture Plant from Gas Processing



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Michigan Basin Candidate Site



CO₂ Capture, Compression, Pipeline in the Vicinity of Potential Injection Sites



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Michigan Basin Candidate Site



Active CO₂ EOR Flood with several additional wells present



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Appalachian Basin Candidate Site

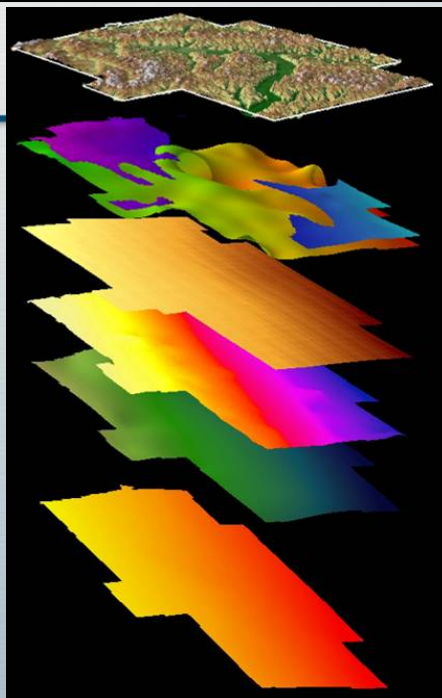
- Injection at or near coal-fired power plant in Eastern Ohio.
- CO₂ from planned extension of PowerSpan process for CO₂ capture, gas processing plants, or commercial sources depending on timing, cost, and composition requirements.
- Multiple but probably thin saline formations present in the area. Enhanced oil recovery (EOR) and enhanced coalbed methane (ECBM) also possible.
- Ohio has primacy for permitting.
- Seismic monitoring may be difficult in deeper layers but possible in intermediate formations.
- CO₂ from planned extension of ECO Process by PowerSpan process for CO₂ capture, gas processing plants, or commercial sources depending on timing, cost, and composition requirements.



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Appalachian Basin Candidate Site

Example from eastern Ohio - Maps/data within a GIS environment allows development of geologic framework



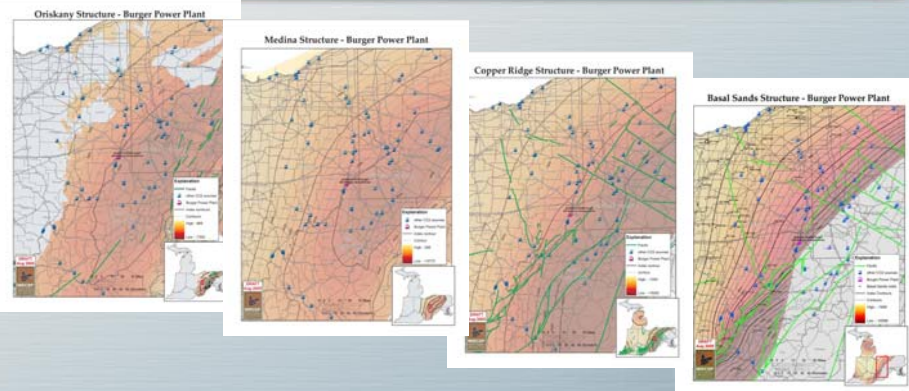
Surface Topography

Oriskany Sandstone
Bass Islands Dolomite
Clinton Sandstone (oil & gas)
Rose Run Sandstone
Copper Ridge Dolomite
Cambrian sands?



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Appalachian Basin Candidate Site



Use of Phase 1 maps for preliminary site assessment and to guide the site characterization efforts and monitoring, mitigation and verification



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Cincinnati Arch Candidate Site

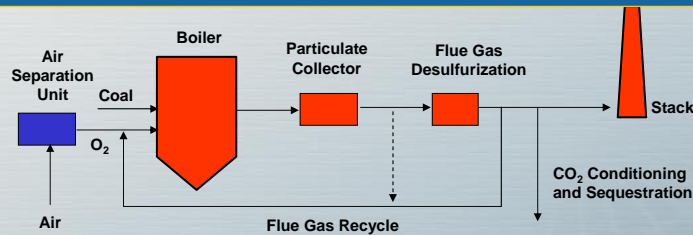
- Located at or near a power plant between Appalachian and Illinois basins.
- CO₂ from a planned oxy-fuel capture test in Cincinnati area or from commercial source depending on feasibility, cost, and timing.
- Mt. Simon sandstone is the primary storage candidate with good thickness and Eau Claire Shale as caprock. Potential storage in Knox Dolomite.
- Permitting by EPA Region 4 in Kentucky.
- Mt. Simon likely to have high injectivity and should be conducive to seismic monitoring compared to deeper sites.



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What is Oxy-combustion?

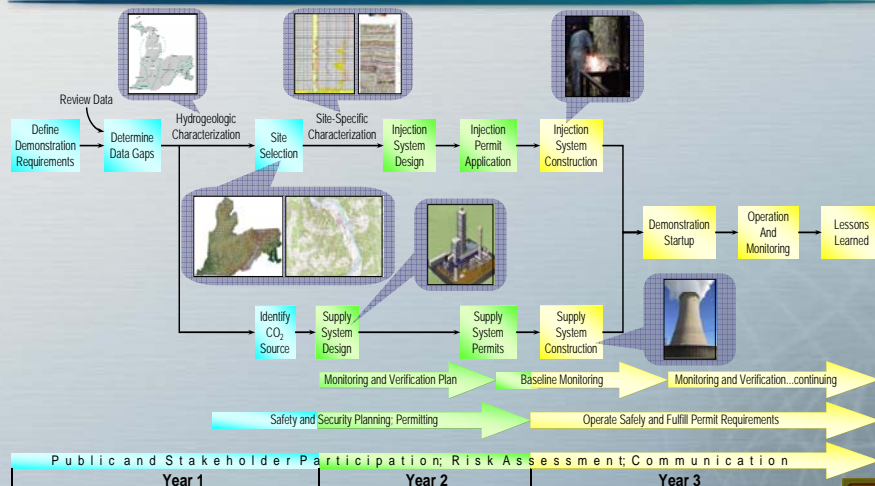
A CO₂ control option for coal-fired plants



- Project organization:
 - Phase 1 – Engineering assessments & plant design (already funded)
 - Phase 2 – Installation & demonstration of multiple environmental control technologies (to be proposed at the end of Phase 1).
- Host Site: 25 MWe, 1963 vintage, B&W Stirling Power Boiler at the Municipal Power Plant in the City of Hamilton, Ohio.
- Project Team: The Babcock & Wilcox Company, Air Liquide, MRCSP/Battelle.



Key Steps in Developing CO₂ Storage Demonstrations



Monitoring Plan Guiding Principles

- Monitoring for any injection test phase will need to address
 - Regulatory monitoring requirements for injection wells
 - Performance assessment or scientific monitoring to understand fate and transport of injected CO₂.
- Avoid setting costly precedents for the future full-scale sites.
- Site features/constraints for industrial settings
 - Active high-value asset – no interruptions to operations allowed
 - Surface features e.g. plant, power lines, ash ponds, railway lines
 - Local public/stakeholders must be kept informed.
- Monitoring, mitigation and verification (MMV) should have enough resolution relative to injected CO₂.
- Effort will be made to evaluate/demonstrate a range of MMV options but only a selected subset will be used for any site.



Improving Regional Sequestration Framework through Continued Geologic Characterization

- Improve capacity estimates - injectivity data, porosity, permeability are key. Map more heterogeneity.
- Analyze best candidate oil and gas fields to determine best approaches, challenges, economics.
- Gather data and map additional potential injection horizons.
- Piggyback drilling program to obtain data at low cost.
- Obtain coal samples in collaboration with CONSOL Energy to evaluate ECBM potential.
- Refine capacity calculations and maps.
- Create 1st pass injectivity maps.
- Continue efforts to create synthesis maps.
- Develop more robust GIS/IMS applications.

