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MIDWEST REGIONAL CARBON SEQUESTRATION PARTNERSHIP

"Managing Climate Change and Securing a Future for the Midwest's Industrial Base"

# Phase II Plans

DOE Annual Review Meeting
Pittsburgh, Pennsylvania
October 14, 2005

DOE Cooperative Agreement No. DE-FC26-03NT41981

# Outline

- Makeup of the MRCSP in Phase II
- General Approach to Phase II
- Terrestrial Field Project Plans (Rattan Lal)
- Geological Field Project Plans (Neeraj Gupta)
- Outreach
- Regulatory Analysis
- Project Organization
- Project Timeline

# MRCSP Phase II Partners

Constellation Energy Group

AEP

Department of Natural Resources Maryland Geological Survey

nrri National Regulatory Research Institute

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West Virginia University Where Greatness is Learned

Maryland Energy Administration

Consol Energy

The Keystone Center

Michigan Basin Core Research Laboratory Western Michigan University

bp

Soy Ohio Ohio Soybean Council

The Ohio State University

O.D.N.R. Geological Survey

Making Ohio Coal the Clean Choice

Pennsylvania Geological Survey Est. 1836

West Virginia Geological Survey

DTE Energy

Cinergy

AJW Inc.

CCX Chicago Climate Exchange

BAARD energy

Pacific Northwest National Laboratory Operated by Battelle for the U.S. Department of Energy

FirstEnergy

The Ohio Forestry Association, Inc.

Schlumberger

CEED Center for Energy and Economic Development

B&W

Indiana Geological Survey 1837 Indiana University

Ohio Environmental Council Keep Watch. Take Action. Make Change.

NETL

U.S. Department of Energy/NETL

American Corn Growers Association

AES Warrior Run

Kentucky Geological Survey University of Kentucky

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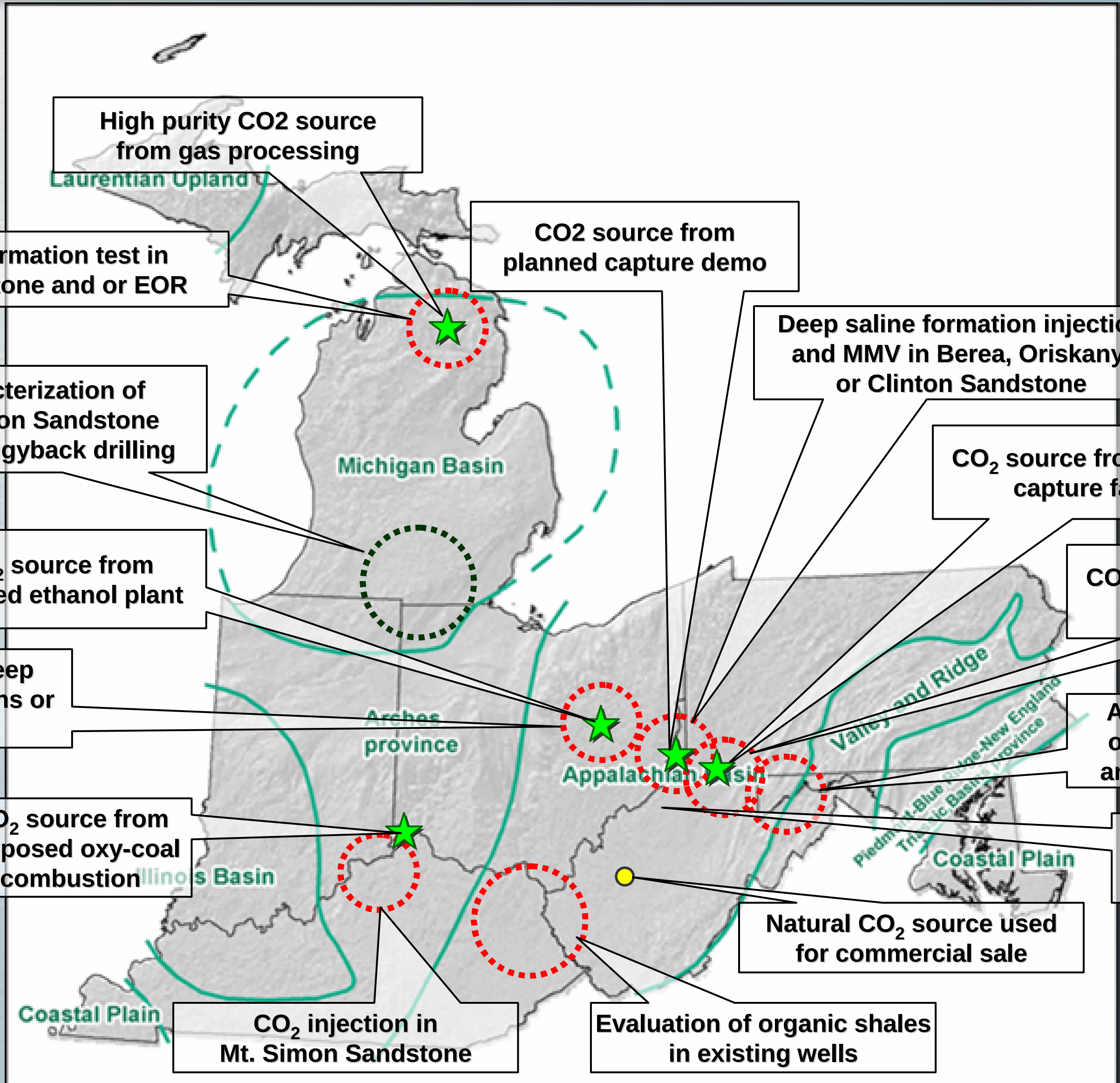
# Our goals at the outset of our Phase II proposal planning

- Multiple (at least two) geological field projects
  - Inject $CO_2$ (at least 10,000 tonnes over the four years)
    - Multiple possible sources of $CO_2$. 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.

# Candidate Field Demonstration Projects

- The MRCSP has identified, and is further assessing, the suitability of a number of candidate field projects representing geographic, land use, and geologic diversity in the region
- Appropriate monitoring methods and safeguards will be employed in carrying out the selected field projects
- MRCSP will work with government officials and other stakeholders to gain any necessary approvals before proceeding with implementation

# Candidate geologic field project overview

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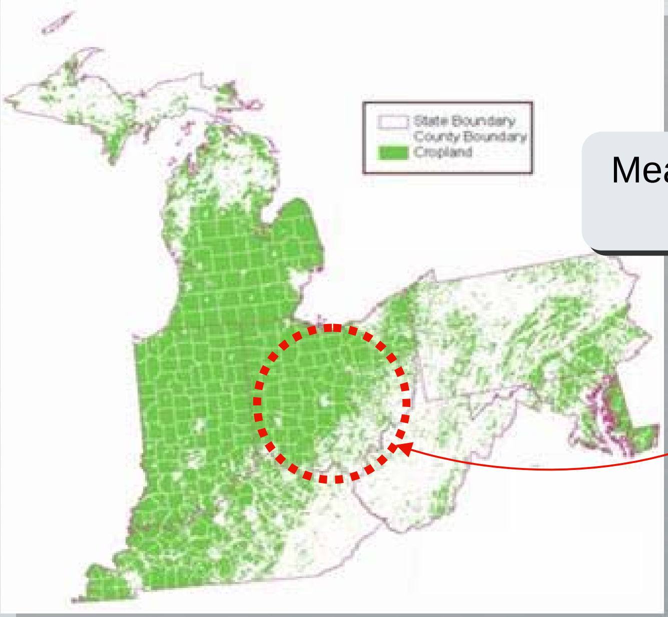
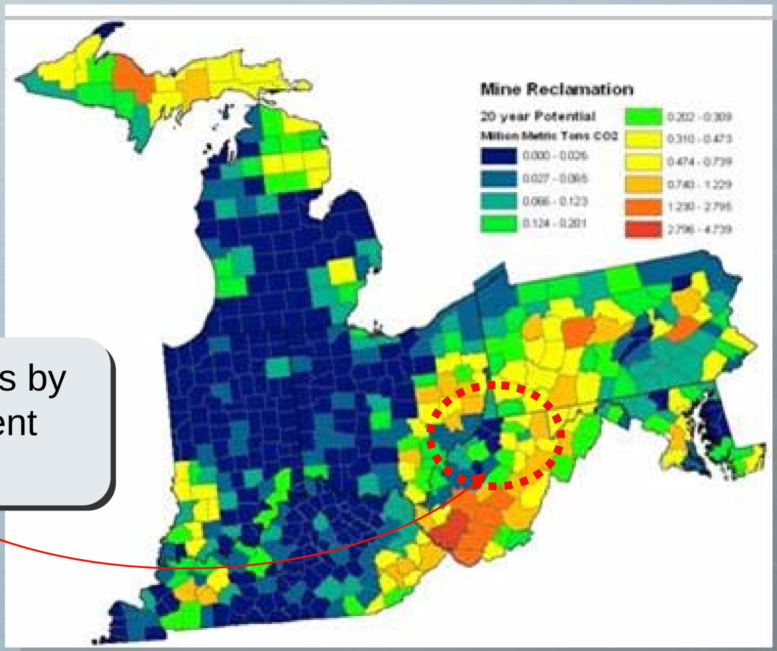
# Terrestrial field project overview




Measure sequestration on croplands under different conditions.




Characterize sequestration for minelands by comparing carbon uptake under different reclamation practices.

# Terrestrial field projects

***Rattan Lal***

***Carbon Management and Sequestration Center***

***The Ohio State University***
***Columbus, Ohio***

# Research Team

**Ohio State University (Rattan Lal)**

Cropland

**West Virginia University (Mark Sperow)**

Mineland

# Designing projects for terrestrial/soil carbon sequestration within the MRCSP

**The issues to be addressed:**

- Baseline (vegetation, soil, drainage, land use, reference point)
- Hidden C costs
- Verification of stock and fluxes
- Incentives or value of C credits (benefits)
- Transaction costs (costs of measuring C stock and fluxes)

# Working with stakeholders

- Corn Growers Association
- Soybean Growers Association
- CONSOL Energy (mining company)
- Farm Bureau
- USDA
- Agricultural Industry (Monsanto, John Deere, Firestone, etc.)

# Demonstration sites

- Farm with Recommended Management Practices (RMPs).
- Reference Farm and Baseline.

# RMPs for soil carbon sequestration

1. **No-till farming**
2. **Residue retention**
3. **Cover crops**
4. **Fertility management**
5. **Drainage**

# Conventional plow tillage

# Drainage

# Removing residue

# The amount of crop residue production in the U.S.

| Crop | 1991 | 2001 |
|---|---|---|
| | -------------million tons | ---------- |
| Cereals | 325 | 367 |
| Legumes | 58 | 82 |
| Oil crops | 17 | 20 |
| Sugar crops | 25 | 14 |
| Tuber | 5 | 5 |
| Total | 430 | 488 |

**This residue can be used for either carbon sequestration or biofuels ($H_2$, ethanol) but not for both**

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# Mining and reclamation process


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# Mining operation

# Mineland prepared for reclaiming


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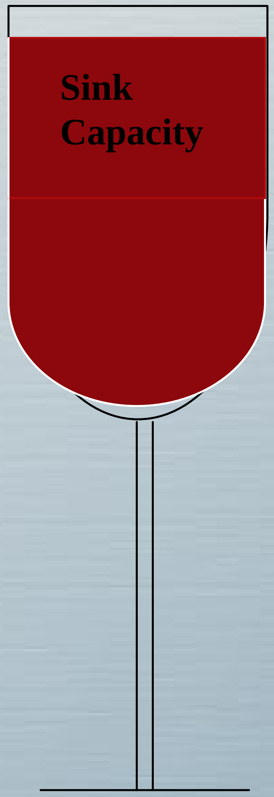
# What is the fluid capacity of the cup?




**Is the cup half full or half empty?**

# No till following a cover crop

# Pasture

# Water conservation and cover crop

# No till soil

# Indiscriminate dumping

**No more than 5 t/acre/yr indiscriminate dumping can cause environmental problems.**

# Deep rooted cover crop

# Balancing input and output for sustainability

# Residue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# Mineland reclaimed in pasture

# Mineland reclaimed in trees

# Coal in reclaimed mineland soil

# SOC pools quantification in reclaimed mined soils (RMS)

**Soil carbon in RMS comprises numerous materials:**

1. Inorganic C associated with carbonates.
2. Organic C associated with coal particles dispersed during mining and reclamation
3. Recent organic C resulting from decomposition of plant residues (humus).

**Accurate estimates of SOC pools are needed for understanding of the role of terrestrial sequestration.**

# Coal-Derived C and SOC in RMS

Due to high C content and its light weight, coal particles in small amount can introduce large errors in SOC measurements.

– Difficult to detect small increments of recent C pools in reclaimed mined soils.

– Leads to inaccurate estimation of C sequestration rates in mined land

# Evaluation of Chemi-Thermal methods

**This is a 3-step procedure**

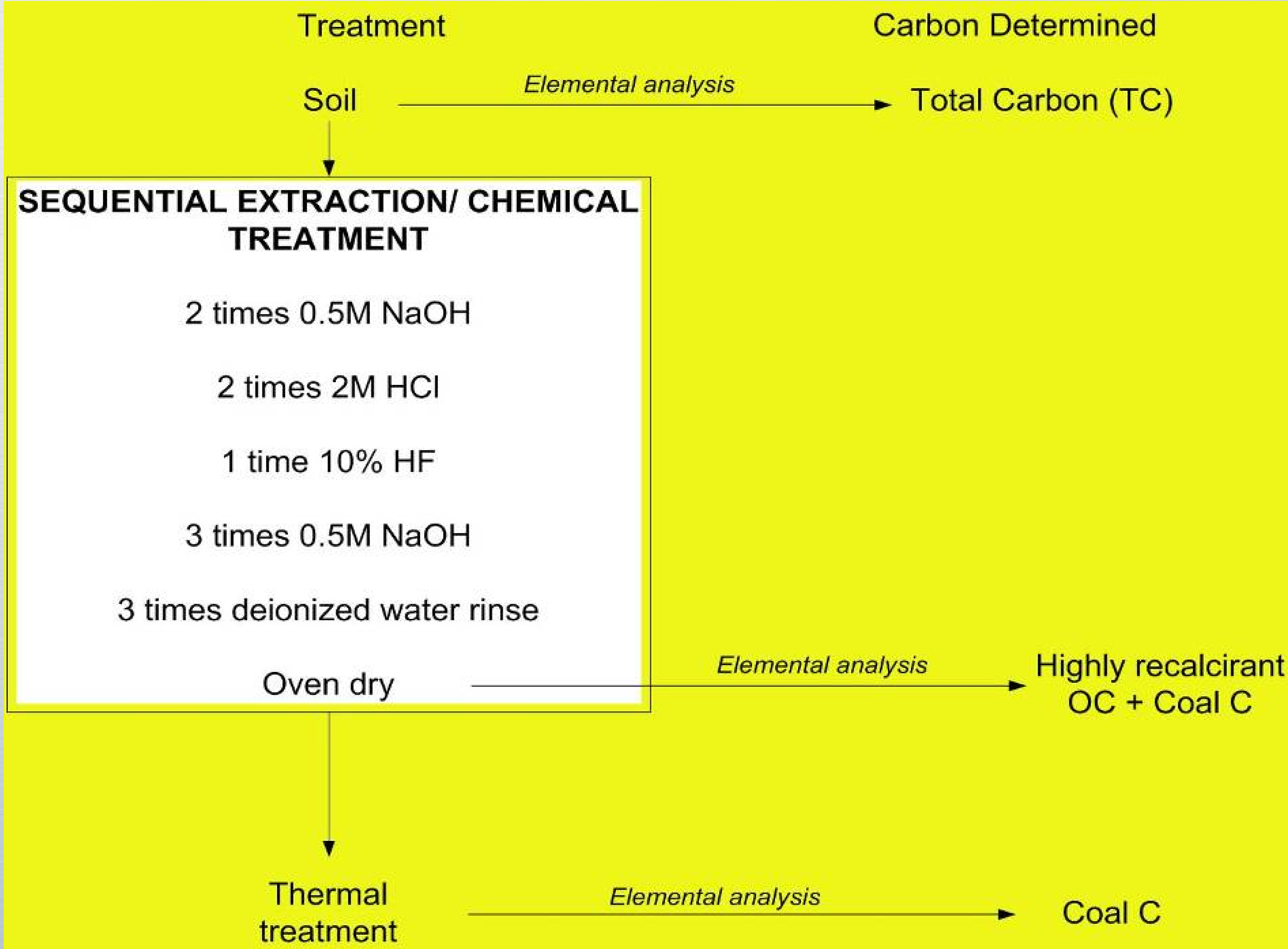
Pre treatments

- Sample grinding to 0.25 mm
- Removal of inorganic C by 1M HCl
- Demineralization and removal of silica by 10% HF

Selective extraction of recent C

- Removal of hydrolizable SOC by 6M HCl (labile)
- Removal of NaOH extractable SOC by 0.5M NaOH (intermediate)
- Thermal treatment to oxidize highly recalcitrant SOC

Determination of coal C by elemental analysis


Treatment
Carbon Determined
Soil
Elemental analysis
Total Carbon (TC)
SEQUENTIAL EXTRACTION/ CHEMICAL TREATMENT
2 times 0.5M NaOH
2 times 2M HCl
1 time 10% HF
3 times 0.5M NaOH
3 times deionized water rinse
Oven dry
Elemental analysis
Highly recalcirant OC + Coal C
Thermal treatment
Elemental analysis
Coal C

# Stable C Isotopic Ratio

- Natural abundance: $^{12}C$ = 98.89%

  $^{13}C$ = 1.11%
- $C_3$ (e.g., trees, shrubs) discriminate against $^{13}C$, while $C_4$ plants (e.g., corn) absorb indiscriminately
- Therefore $^{13}C/^{12}C$ ratio can be used to identify the source of OC in soils.

# Stable C Isotope Ratio Analysis

$\delta^{13}C$ (‰) = $(R_{sample} - R_{standard})/R_{standard}$

**Where $R_{sample}$ and $R_{standard}$ is $^{13}C/^{12}C$ ratio of sample and standard, respectively.**

# Testing and Evaluation of $\delta^{13}C$ Approach

- **Samples analyzed by isotope ratio mass spectrometer**
- **The fraction of C originating from coal ($F_c$) computed by using isotope mixing model**

$$F_c = \frac{\delta^{13}C_{mixture} - \delta^{13}C_{soil}}{\delta^{13}C_{coal} - \delta^{13}C_{soil}}$$

**(Bernoux et al. 1998**)

# Isotope ratio mass spectrometer setup in the lab

# Demonstration site collaborators

**<u>Cropland</u>: Corn and Soybean Growers Association**

**<u>Reclaimed Mineland</u>: CONSOL Energy**

# Criteria for site selection

1. Similarity of soils, bedrock, geology, slope and aspect.
2. Known history of land use and management on cropland, and date and methods of reclamation on minelands.
3. Information on cropping systems (rotations, fertilizer, pesticides, tillage), and forage/tree species on minelands.
4. Amenable to extrapolation to MRCSP region by scaling procedures.

# Demonstration practices

| Cropland | Mineland |
|---|---|
| • No-Till | • Restoration techniques |
| • Cover Crops | • Post-restorative land uses |
| • Manuring | • Forage/tree species |
| • Residue management | • Soil and environment quality |

# Baseline

- SOC and N concentrations, $\rho_b$, clay content, CEC, etc.
- Spatial variability in soil properties.

# Sampling protocol

1. **Soil samples will be obtained on a grid:**

- Cropland: 200 m x 100 m
- Mineland: 25 m x 50 m

2. **Depths of Sampling:**

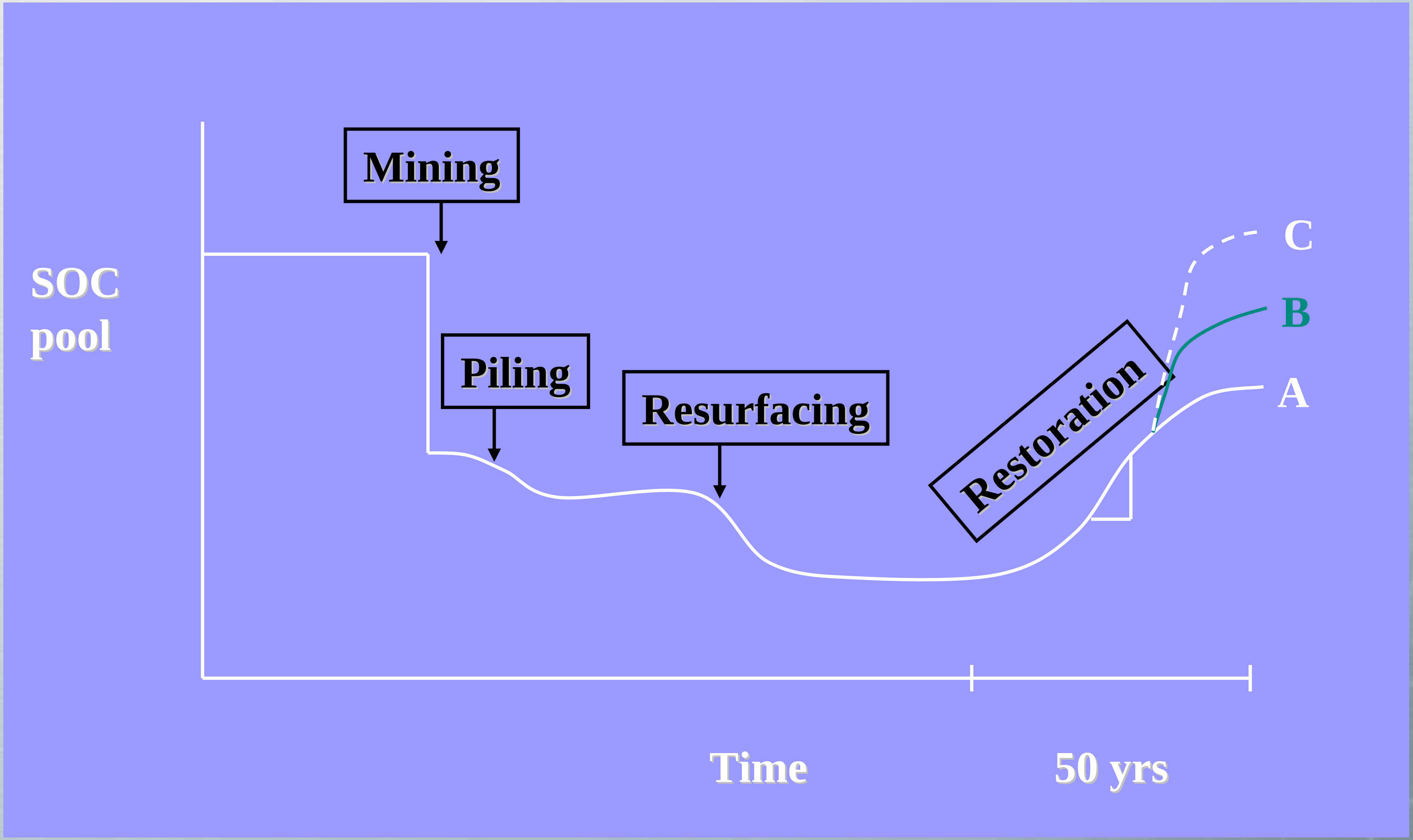
- Cropland: 0 - 10 cm, 10 - 30 cm, 30 - 60 cm, 60 - 100 cm
- Mineland: 10 cm depth increments to the spoil material or 50 cm depth for age-chronosequences (5, 10, 20 30 years since reclamation)

3. **All sites will be geo-referenced**

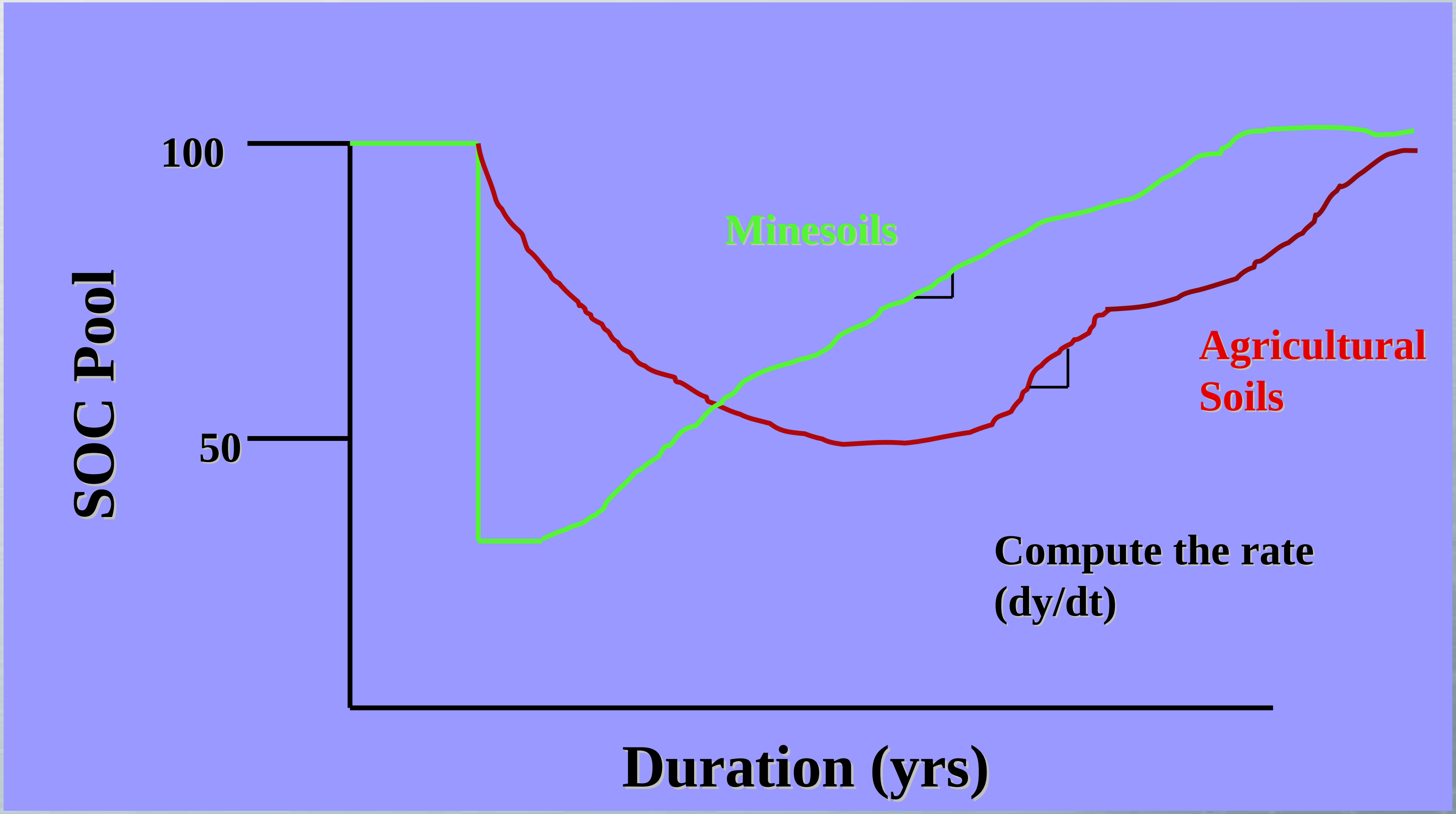
# Trading carbon credits

- Liaise with Chicago Climate Exchange.
- Work with industry (coal companies, utility companies) and farmers/forestry associations.

# SOC dynamics



# Carbon sequestration rates



# Geologic field project research coordinators

- Battelle
  - Neeraj Gupta, Phil Jagucki, Joel Sminchak
- Ohio Geological Survey
  - Larry Wickstrom
- Indiana Geological Survey
  - John Rupp
- Kentucky Geological Survey
  - Steve Greb
- Maryland Geological Survey
  - Jerry Baum
- Pennsylvania Geological Survey
  - John Harper
- West Virginia Geological Survey
  - Lee Avary, Michael Hohn
- Western Michigan University
  - Bill Harrison

# Geologic field project industry collaborators to date

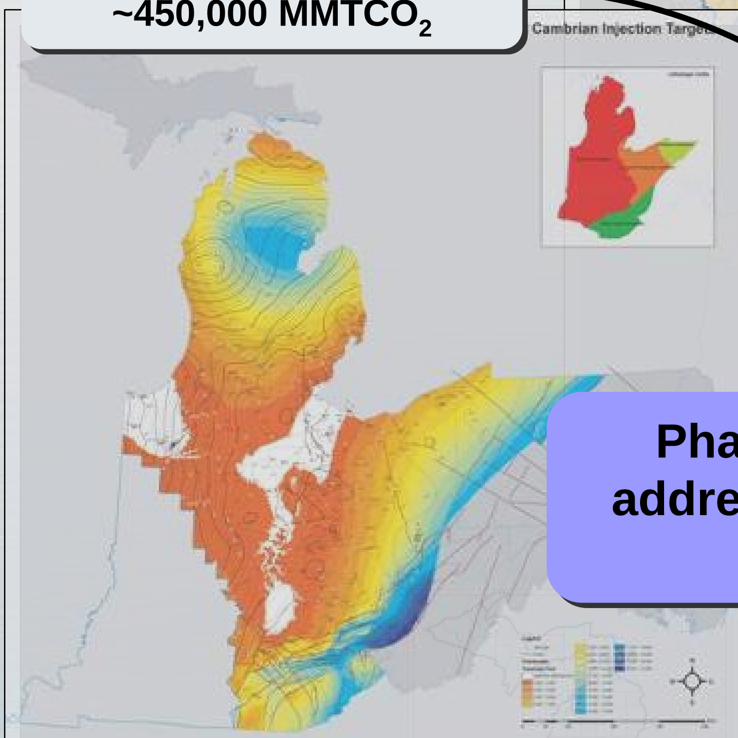
- Schlumberger
  - T.S. Ramakrishnan
- First Energy
  - Mike Williams
- DTE Energy
  - Abed Houssari, Becky Cook
- CONSOL Energy
  - Dick Winschel
- Cinergy
  - Eric Kuhn
- Baard
  - Steve Dopuch
- Babcock & Wilcox
  - Hamid Sarv
- Stanford University
  - Mark Zobak

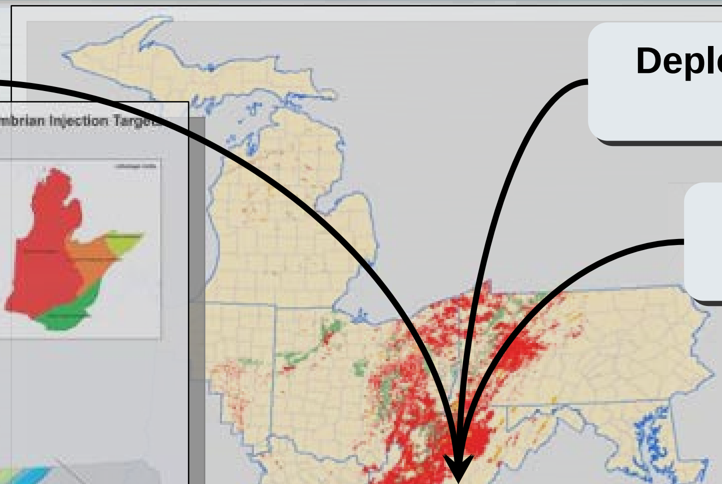
# Phase II candidate geologic field tests and characterization

- Candidate field project locations and $CO_2$ sources
- Typical field injection test plan
- Expanded geologic characterization efforts

# The geological potential of the region is vast and well positioned relative to sources*

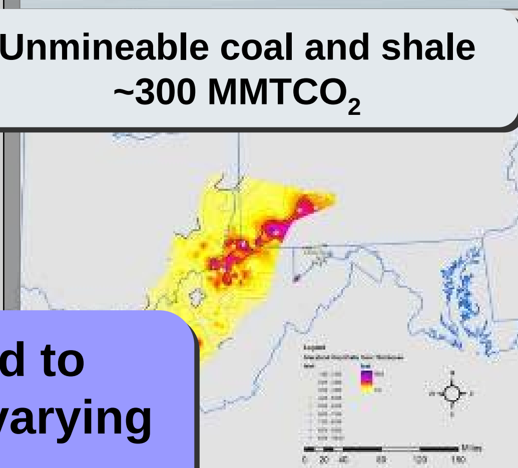
**Deep saline formations: ~450,000 MMT$CO_2$**



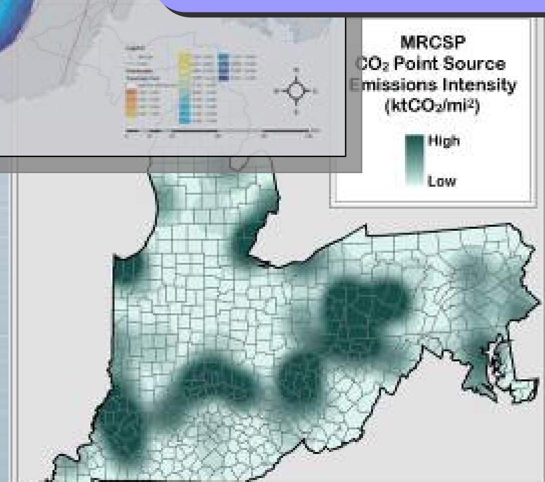



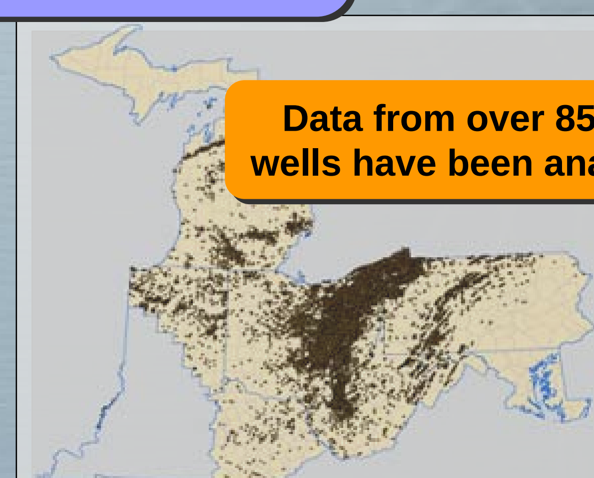
**Depleted oil and gas fields ~2,000 MMT$CO_2$**

**Unmineable coal and shale ~300 MMT$CO_2$**



**Phase II efforts are designed to address all of these sinks at varying levels of detail**



**Data from over 85,000 wells have been analyzed**

(*) These are preliminary estimates

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# Framework for evaluating candidate Phase II field projects

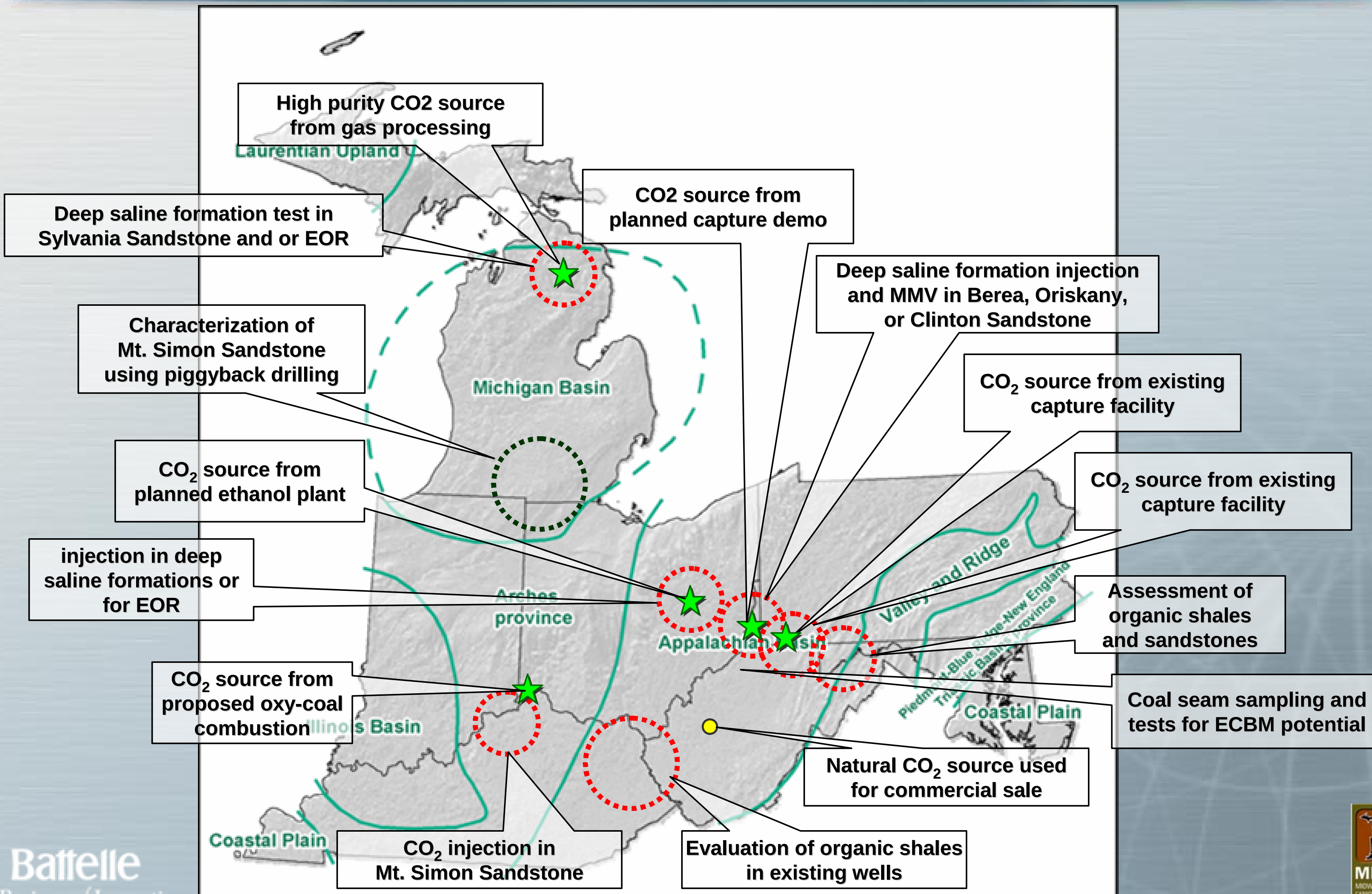
## Evaluating Proposed Projects

- 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

# Candidate geologic field project overview

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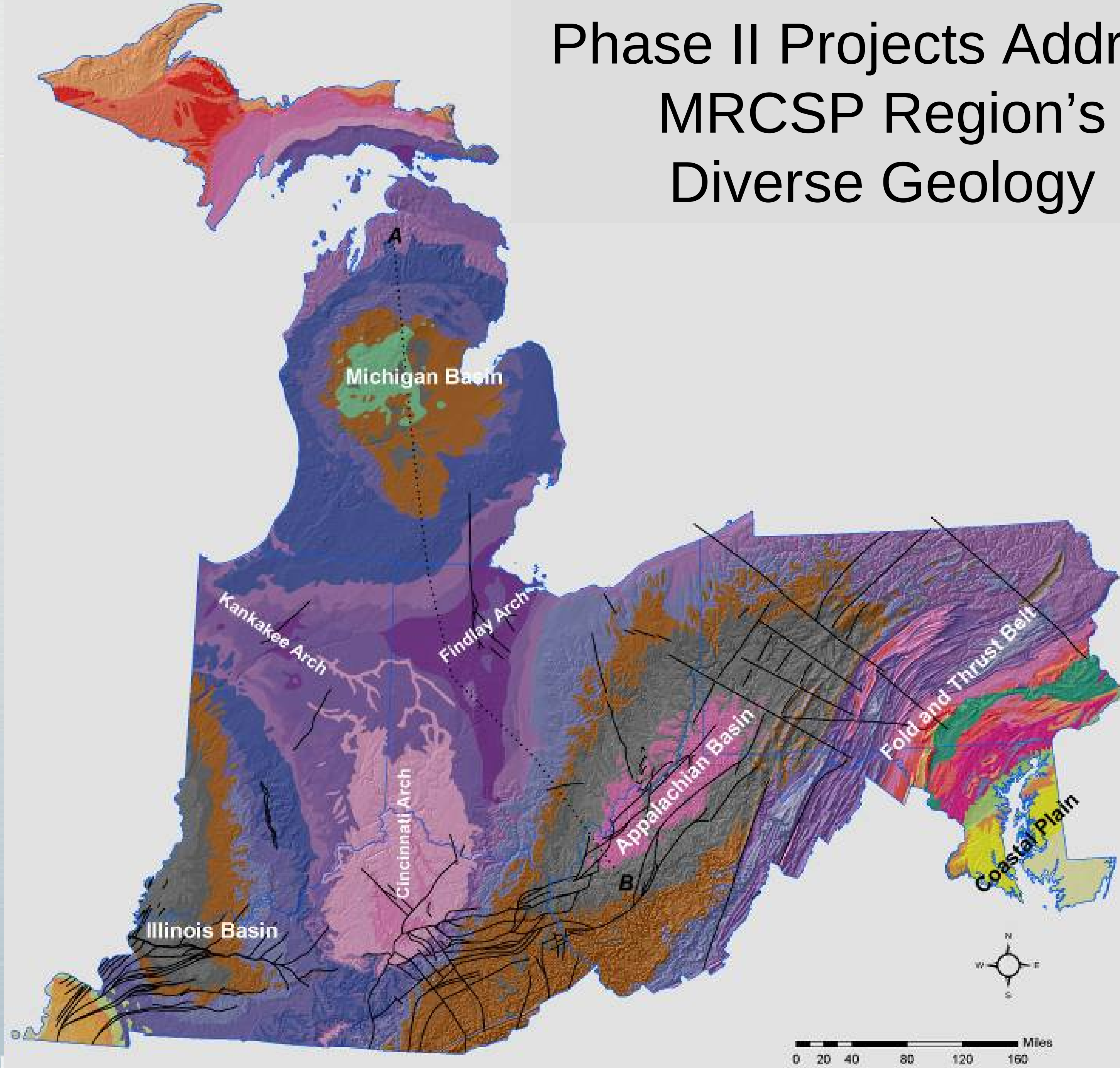
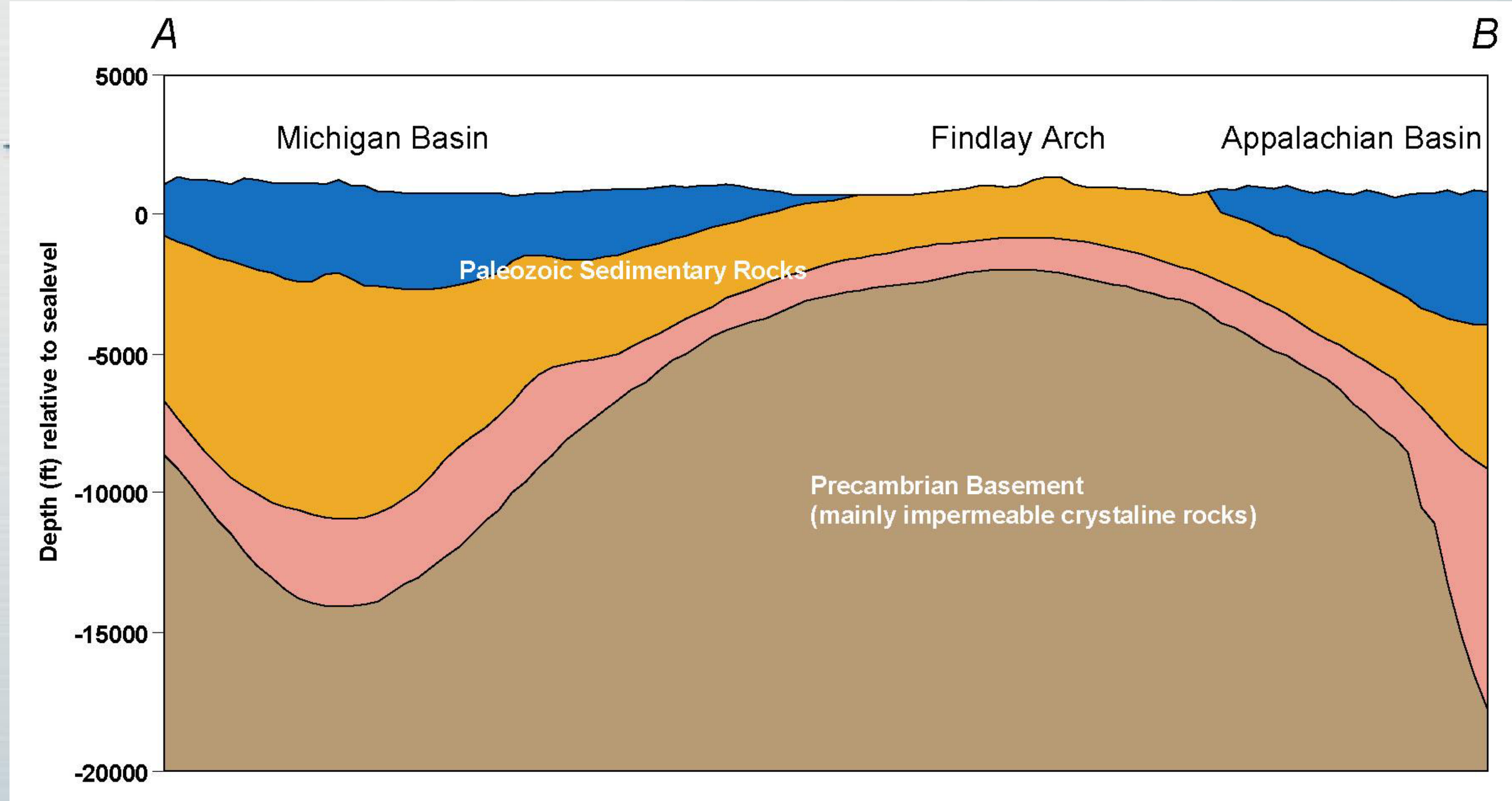
# Phase II Projects Address MRCSP Region's Diverse Geology




Modified from

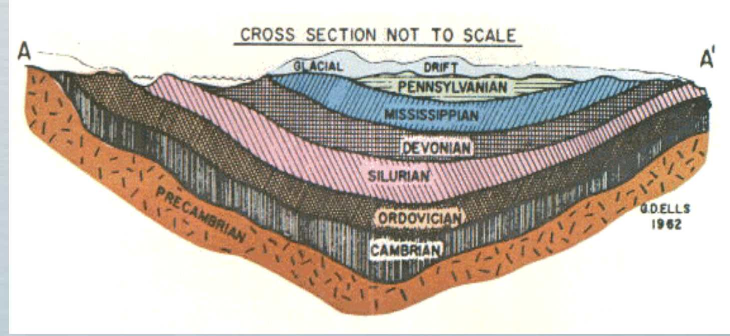
King, et al, 1974





Illustrative cross section – location shown on previous slide. Geologic units thicken and become deeper in basins, thinner and shallower on arches.

# Michigan basin candidate site




- Located at the northern rim of Michigan Basin
- Gas processing plants there provide a potential source of pure $CO_2$
- Compression facility and ~8-mile long pipeline for active 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).
- 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

# Michigan basin candidate site

$CO_2$ Capture Plant from Gas Processing

# Michigan basin candidate site

$CO_2$ Capture, Compression, Pipeline in the Vicinity of Potential Injection Sites

# Michigan basin candidate site

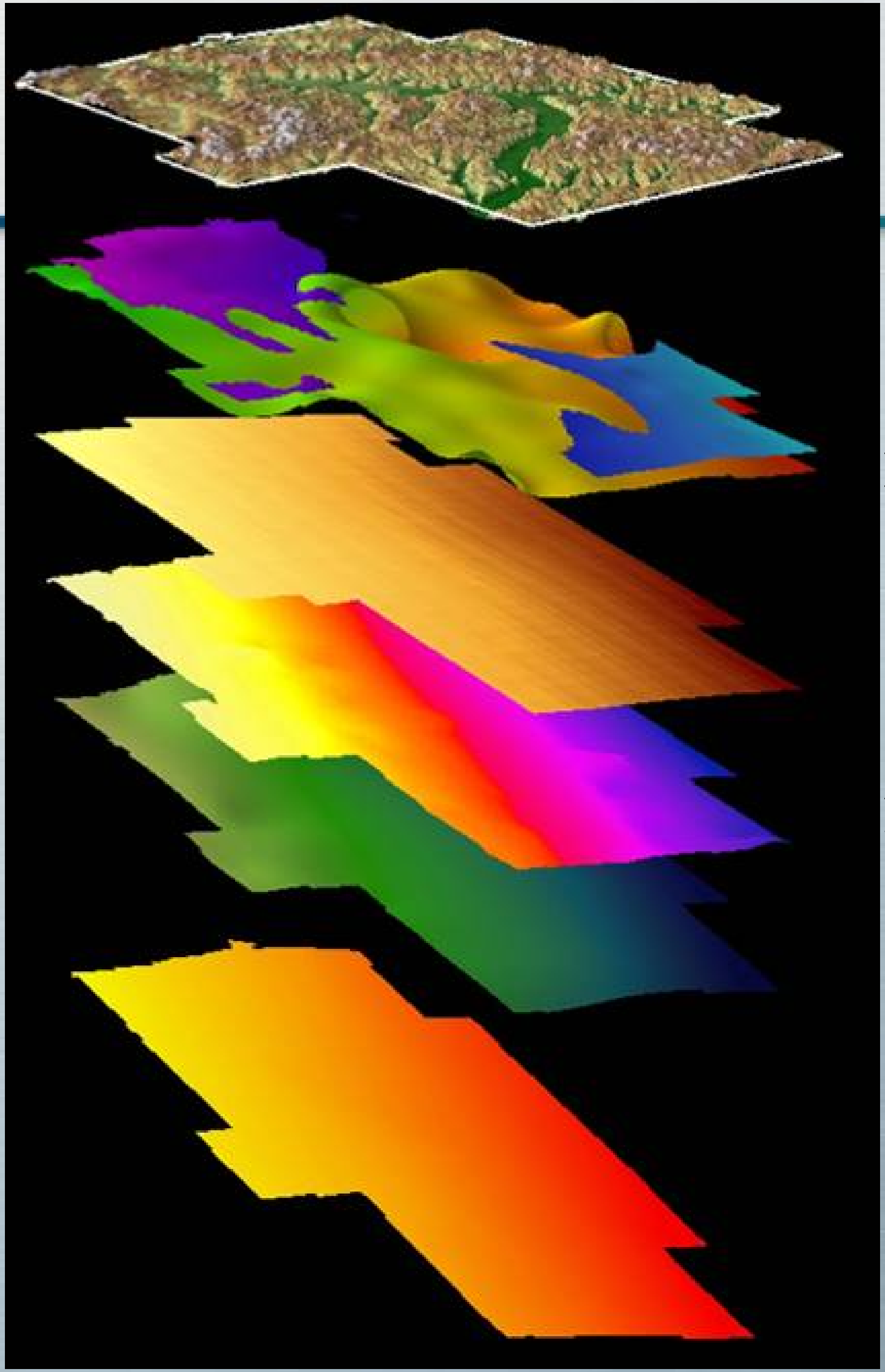
Active $CO_2$ EOR Flood with several additional wells present

# Appalachian basin candidate site

- Injection at or near a coal-fired power plant in Eastern Ohio
- $CO_2$ source possible from planned capture demonstration, gas processing plants, or commercial sources in the area
- Multiple, but probably thin saline formations present in the area.  EOR and ECBM are also possible
- Ohio and West Virginia have Primacy and Region 3 oversees permitting in Pennsylvania.
- Seismic monitoring may be difficult in deeper layers but possible in shallow formations

## 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

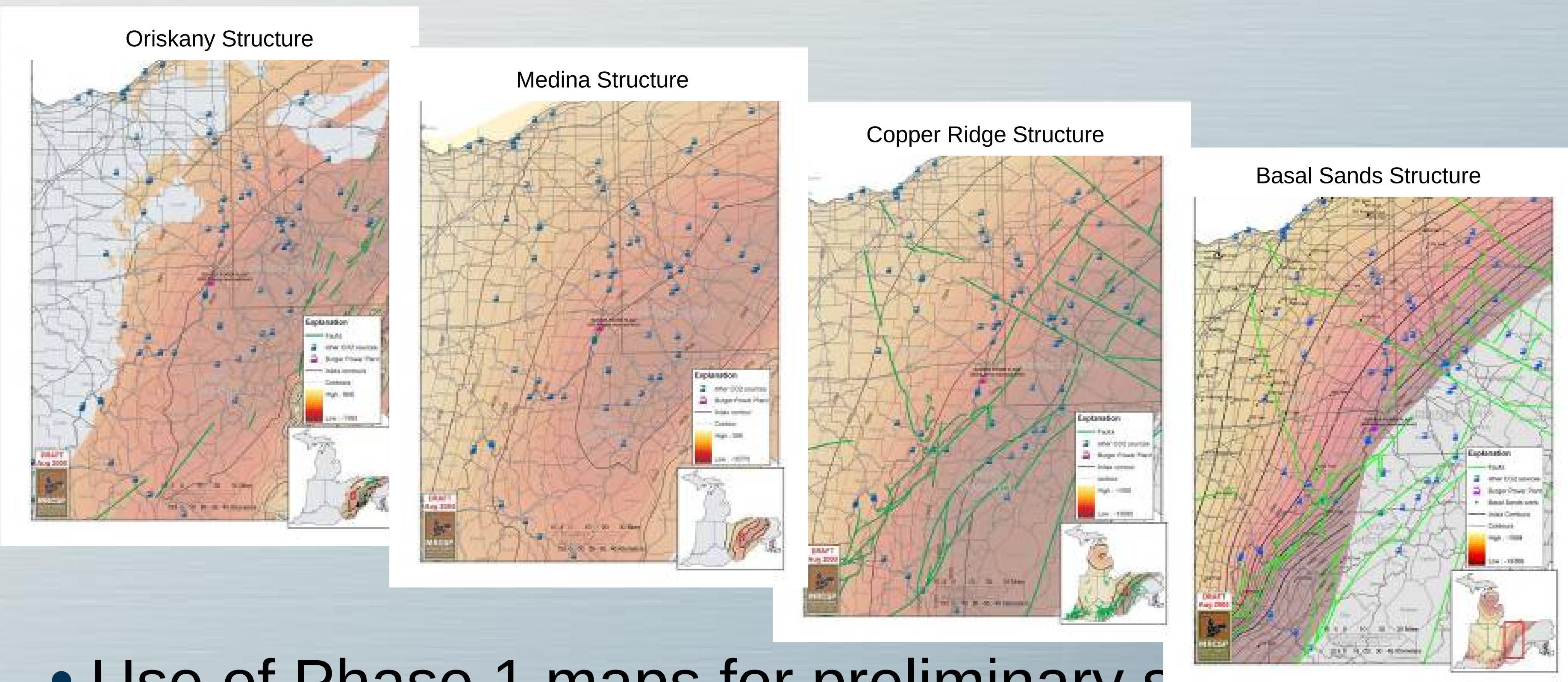
Clinton Sandstone (oil & gas)

Rose Run Sandstone

Copper Ridge Dolomit

Cambrian sands?

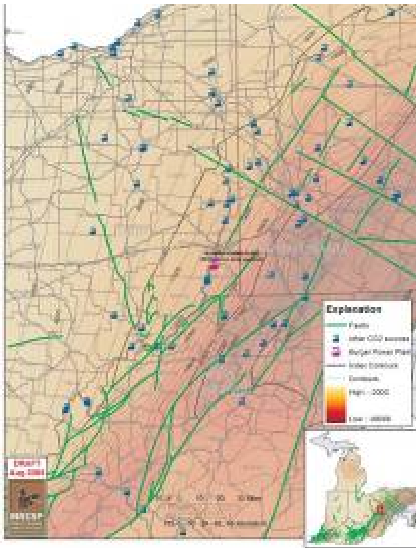
# Appalachian basin candidate site



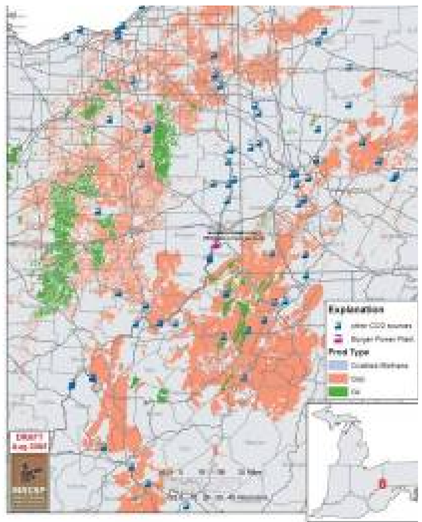

- Use of Phase 1 maps for preliminary site assessment and to guide the site characterization efforts and MMV

# Appalachian basin candidate site

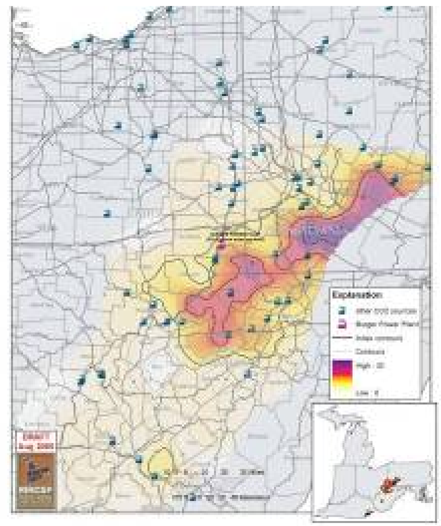
Pre Cambrian Structure



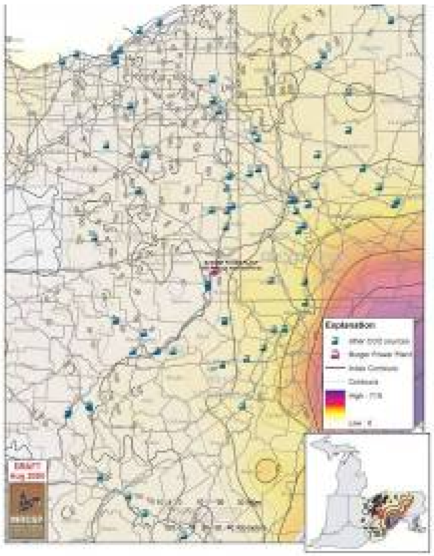
Oil and Gas Fields Greater than 2500 Feet Deep



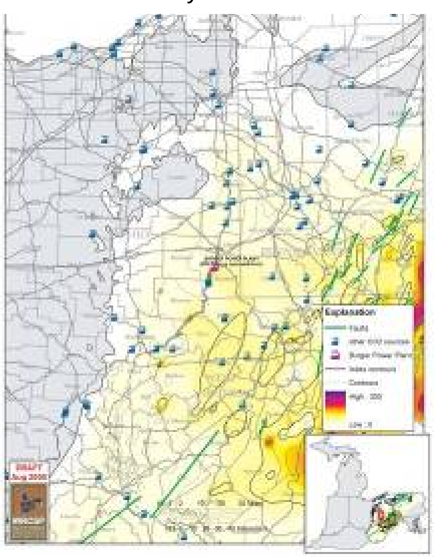
Total Coal Thickness Greater than 2500 Feet Deep



Medina Thickness



Oriskany Thickness



- Geologic structure, isopach maps, oil/gas, and deep coal seams

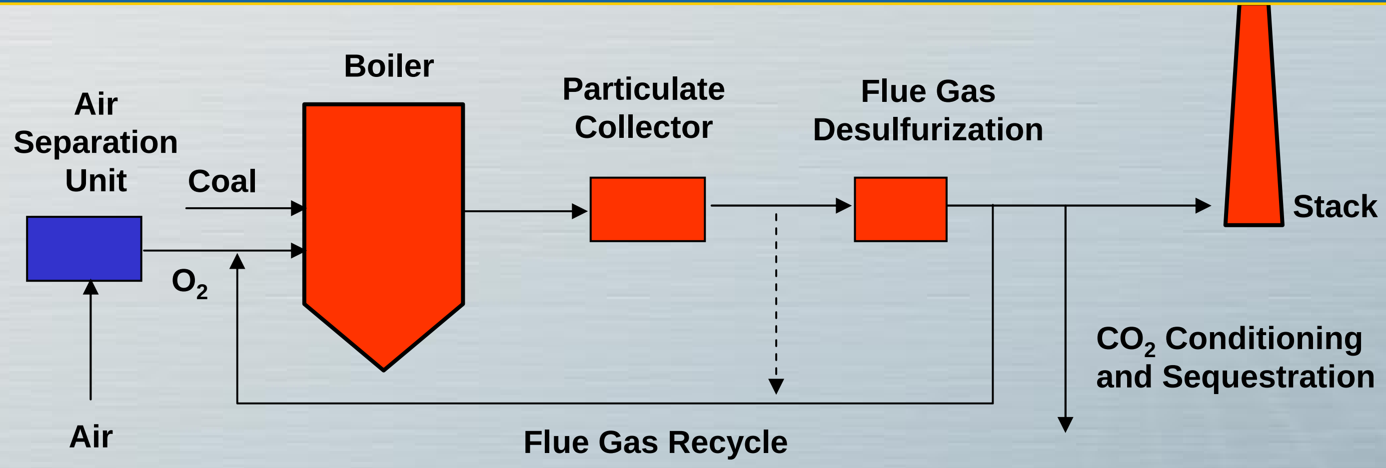
# Cincinnati arch candidate site

- Located on the Ohio River south of Cincinnati and between Appalachian and Illinois basins
- $CO_2$ from a planned oxy-fuel capture test in Cincinnati area or from commercial source
- 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, Region 5 in Indiana, and Primacy for Ohio
- Mt. Simon likely to have high injectivity and should be conducive to seismic monitoring compared to deeper sites

Cincinnati Arch Candidate Site

# *What is Oxy-combustion?*

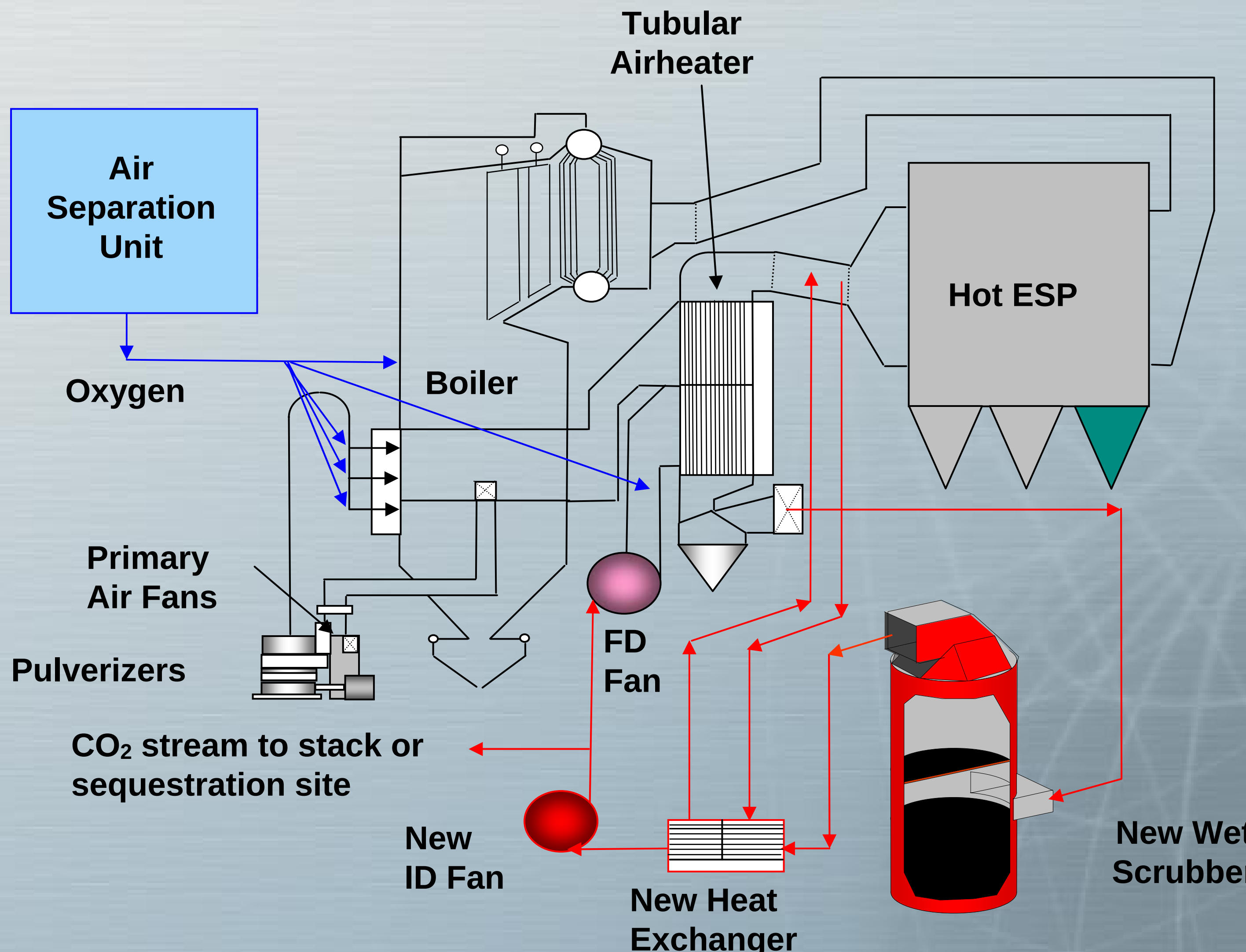
## A $CO_2$ control option for coal-fired plants



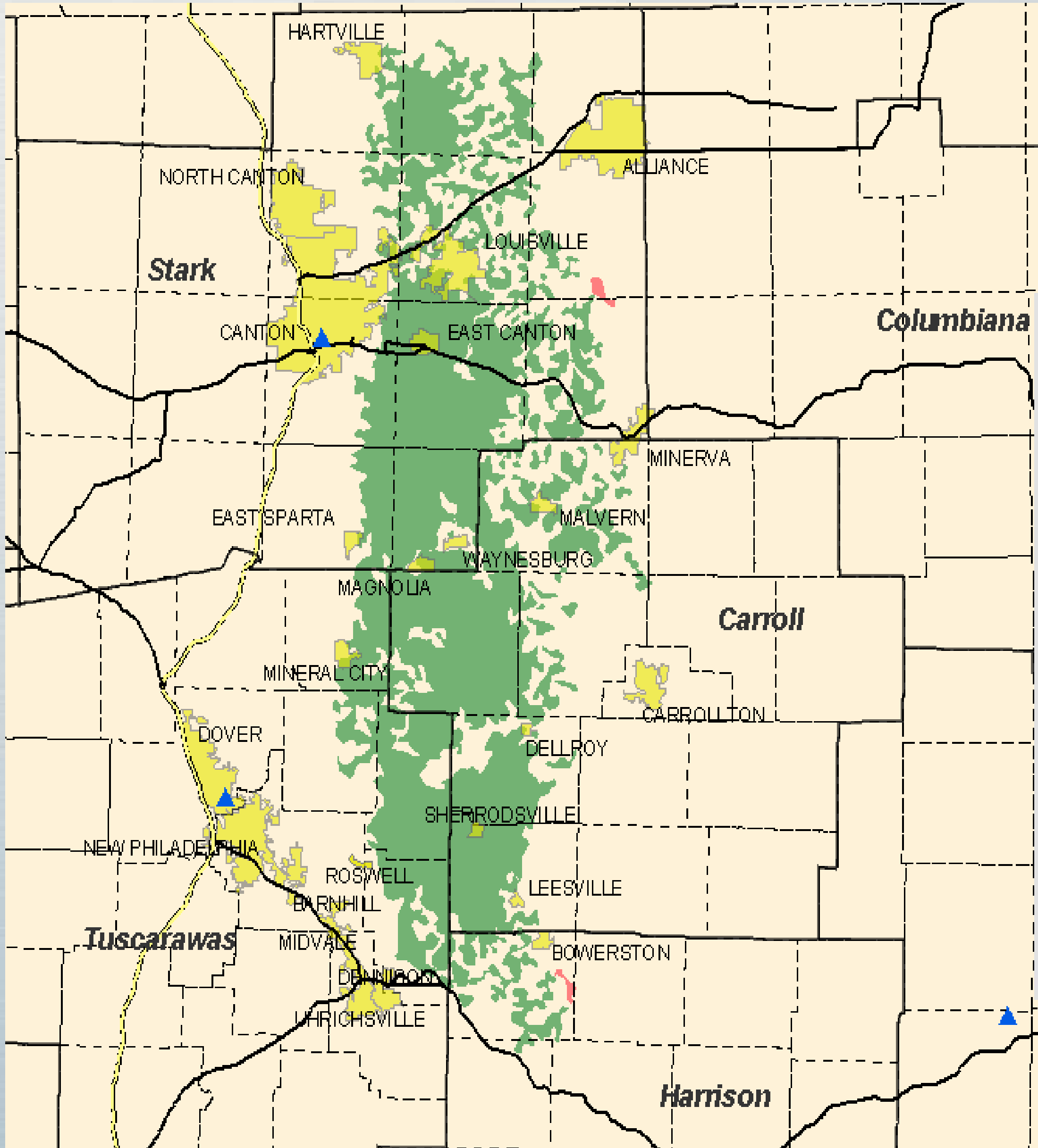

- Project organization:
  - Phase 1 – Engineering assessments & plant design (already funded)
  - Phase 2 – Installation & demonstration of multiple environmental control technologies (to be proposed at the end of Phase 1)
- Host Site: 25 MWe, 1963 vintage, B&W Stirling Power Boiler at the Municipal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

# Cincinnati arch candidate site

*Oxy-combustion Process*

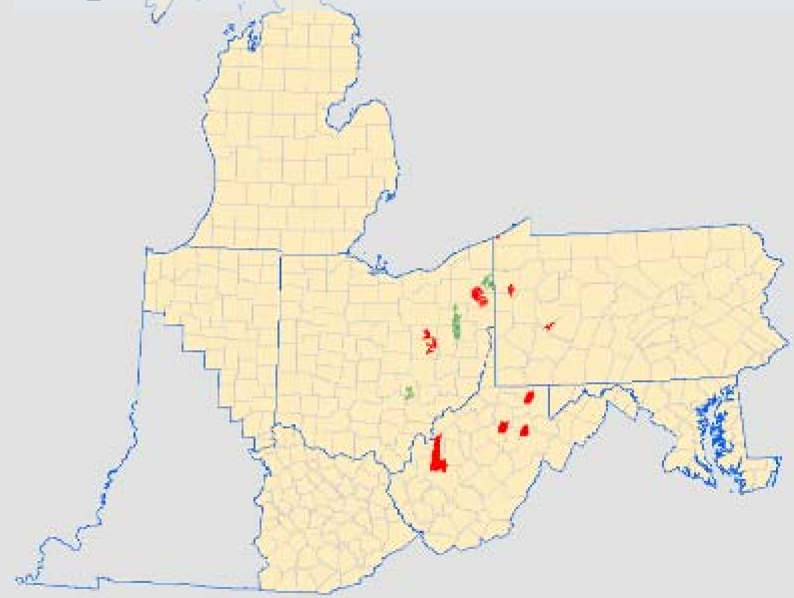


# Eastern Ohio EOR candidate site




Detailed map of the East Canton Field.

**Top 10 Oil & Gas Fields for $CO_2$ Capacity (>2,500' avg producing depth)**



# Eastern Ohio EOR candidate site

## EAST CANTON OIL FIELD

| | |
|---|---|
| ▪ 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 |

# Eastern Ohio EOR candidate site

## EAST CANTON OIL FIELD

“Clinton” Production Characteristics

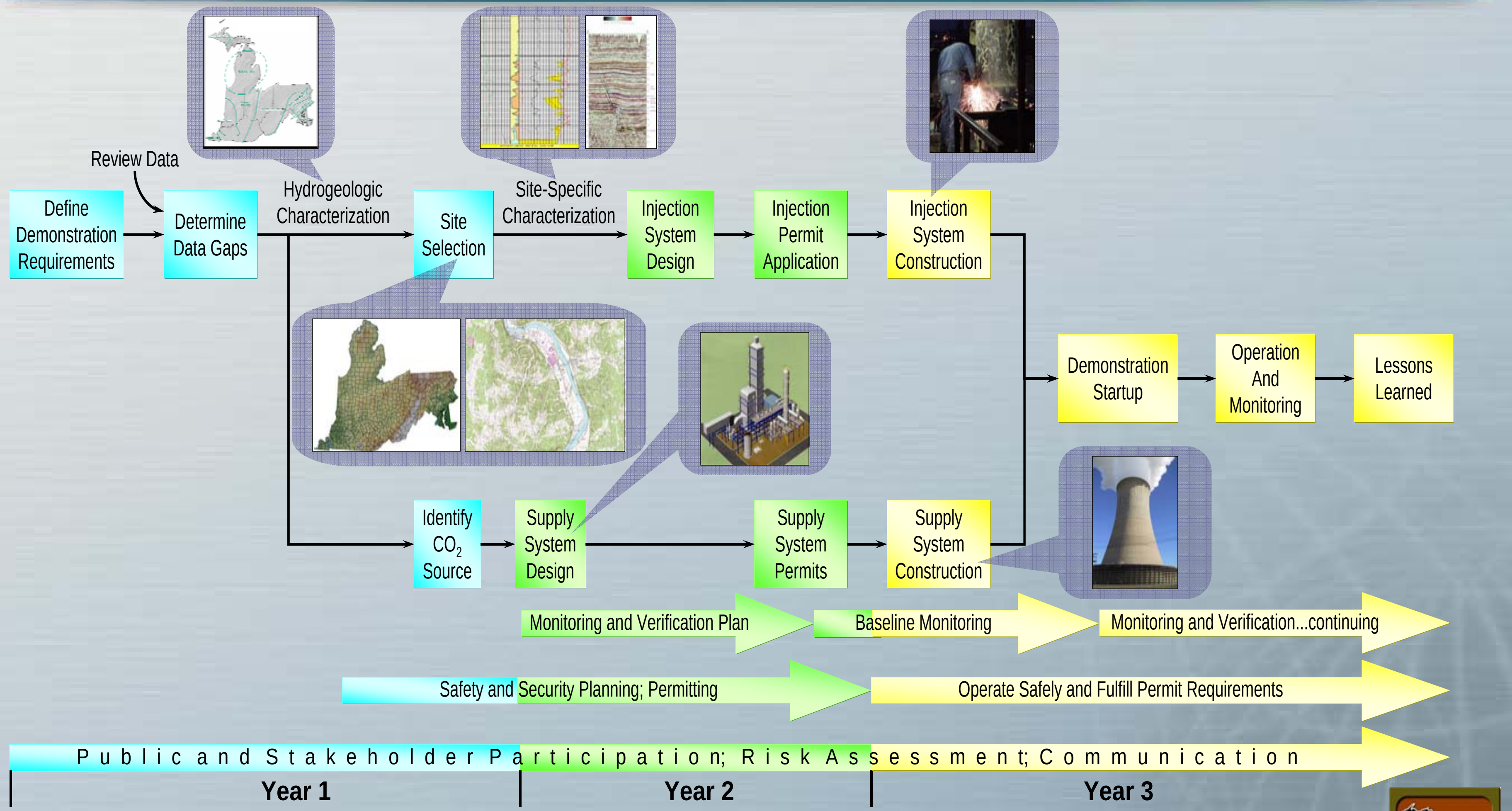
- Estimated Cum. Prod. — 90 MMBO
- Original Oil Reserves — 138 MMBO
- Remaining Oil Reserves — 48 MMBO
- Primary Recovery Factor — 9-10 %
- Original Oil In Place — 1.5 BBO

# Eastern Ohio EOR candidate site

## Why the "Clinton" at East Canton?

- "Clinton" reservoirs are widespread in Appalachian Basin – (KY, OH, PA, NY, ONT) – ~ 500 MMBO Produced
- East Canton has produced ~ 100 MMBO
- The field is largely controlled by two (cooperative) companies
- Depths are optimal for sequestration
- We have large knowledge base of this field to work from
  - Cores, logs, production histories, completion methods, etc.
- Potential $CO_2$ sources from ethanol plant, gas processing, or commercial suppliers

# Key Steps in Developing $CO_2$ Storage Demonstrations

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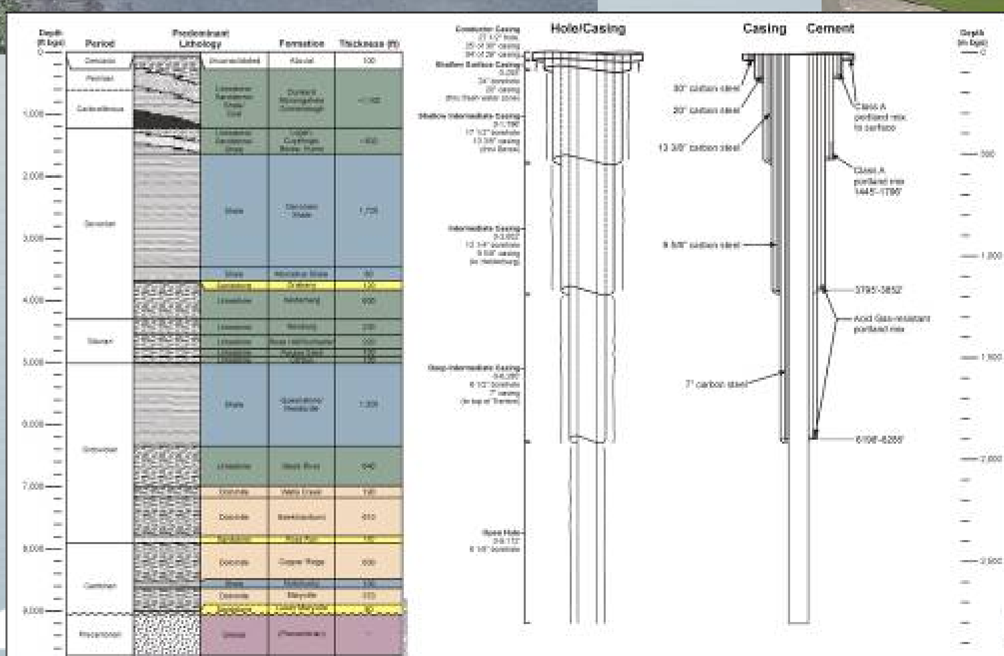
# Potential steps in conducting a geologic storage demonstration

- Preliminary site screening
- Review of regulatory and outreach requirements
- Determine $CO_2$ source and handling requirements
- Seismic Survey (2-D or 3-D)
- Drilling and testing a borehole
- Analysis of field samples and data
- Reservoir simulations and injection system design
- $CO_2$ supply and above-ground handling
- Pre-injection monitoring
- Injection and concurrent monitoring
- Post injection monitoring and data analysis
- Reporting and information dissemination
- Well plugging and Abandonment
- Project closeout

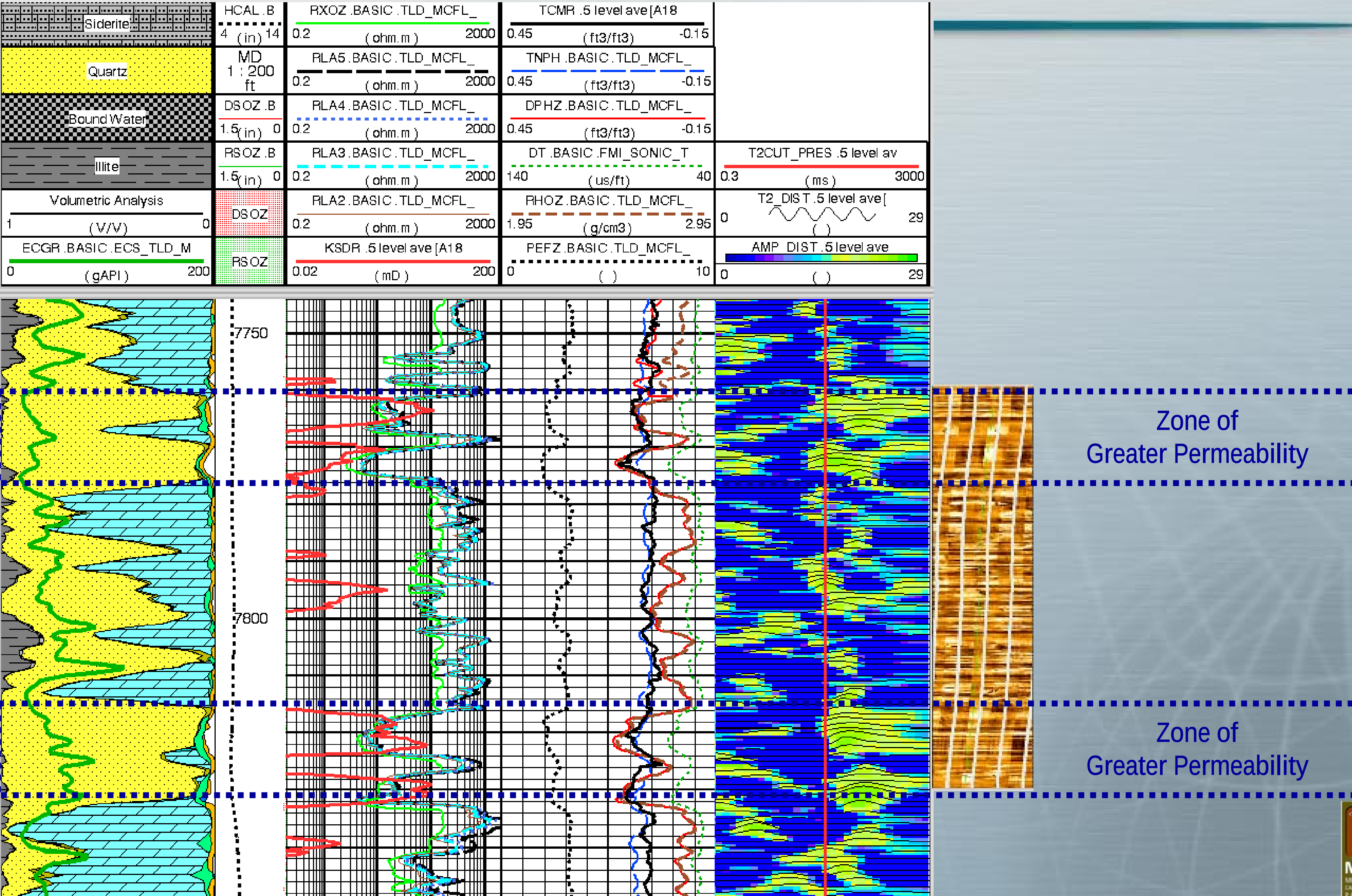
# Site logistics issues are very important

- ***Health, Safety, and Environmental Protection is the highest priority***
- Permitting and well ownership issues
- Projects involve a combination of Oil & Gas and Power Industry regulations, rules, and policies:
  - Disparate safety standards
  - Management of investigation-derived wastes
  - Industrial discharge to surface water
  - Stormwater Management
  - Wellhead Protection
  - Fuel and chemical storage
  - Site Access and security

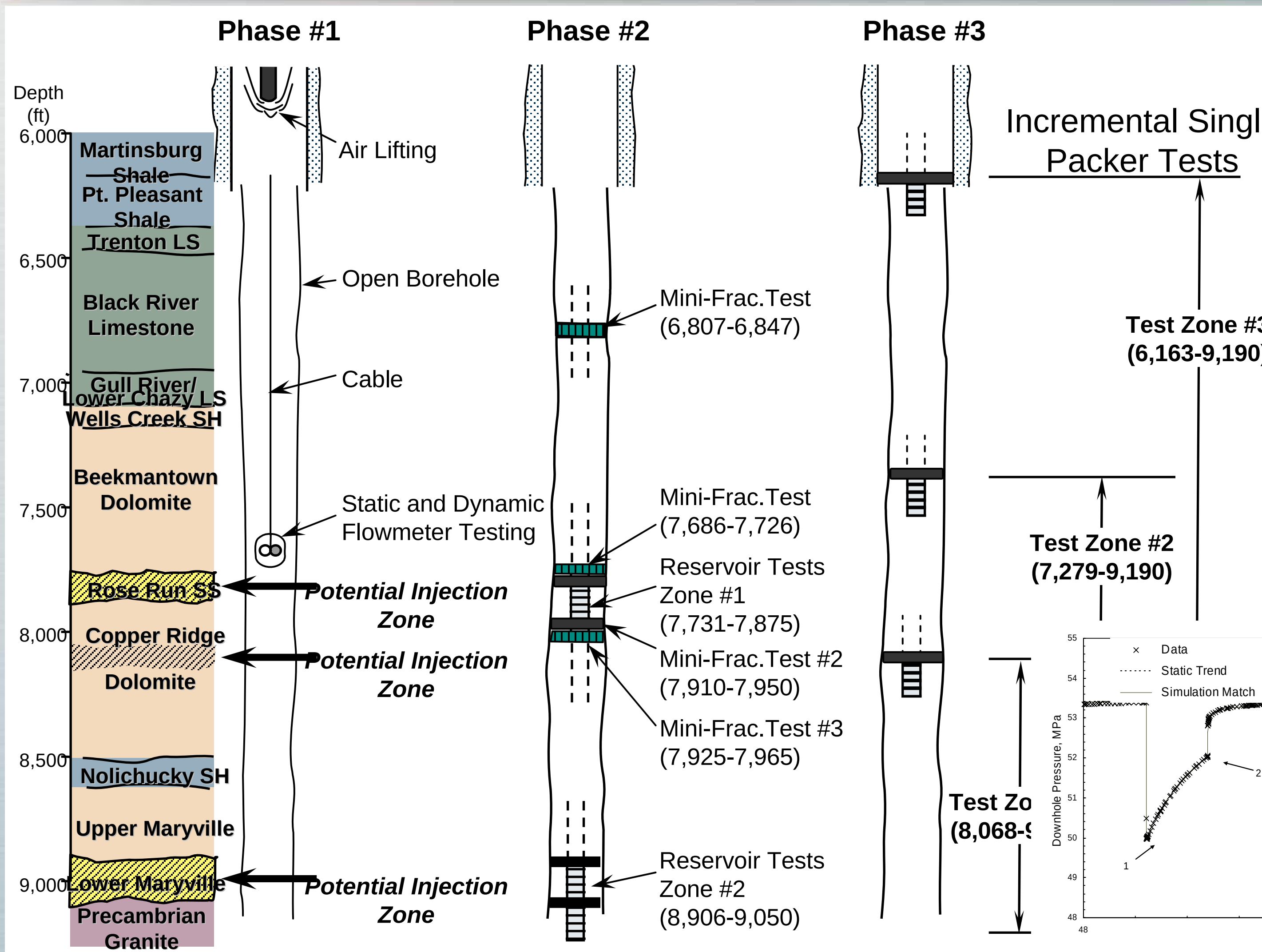
# Site characterization – seismic surveys and drilling

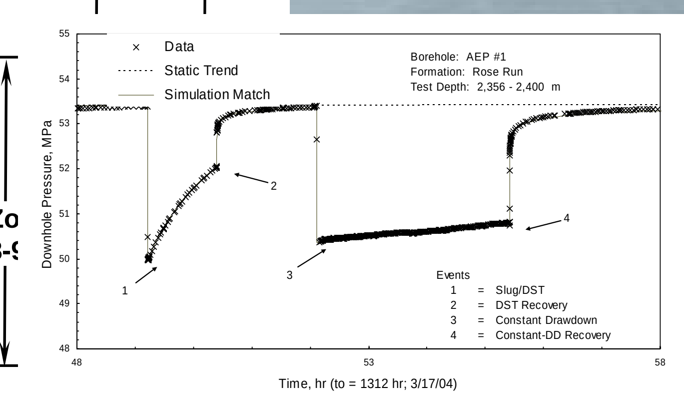


# Borehole Logging Example from Rose Run Sandstone showing high k zones at Mountaineer Site



# Reservoir tests can be used to evaluate injection zones

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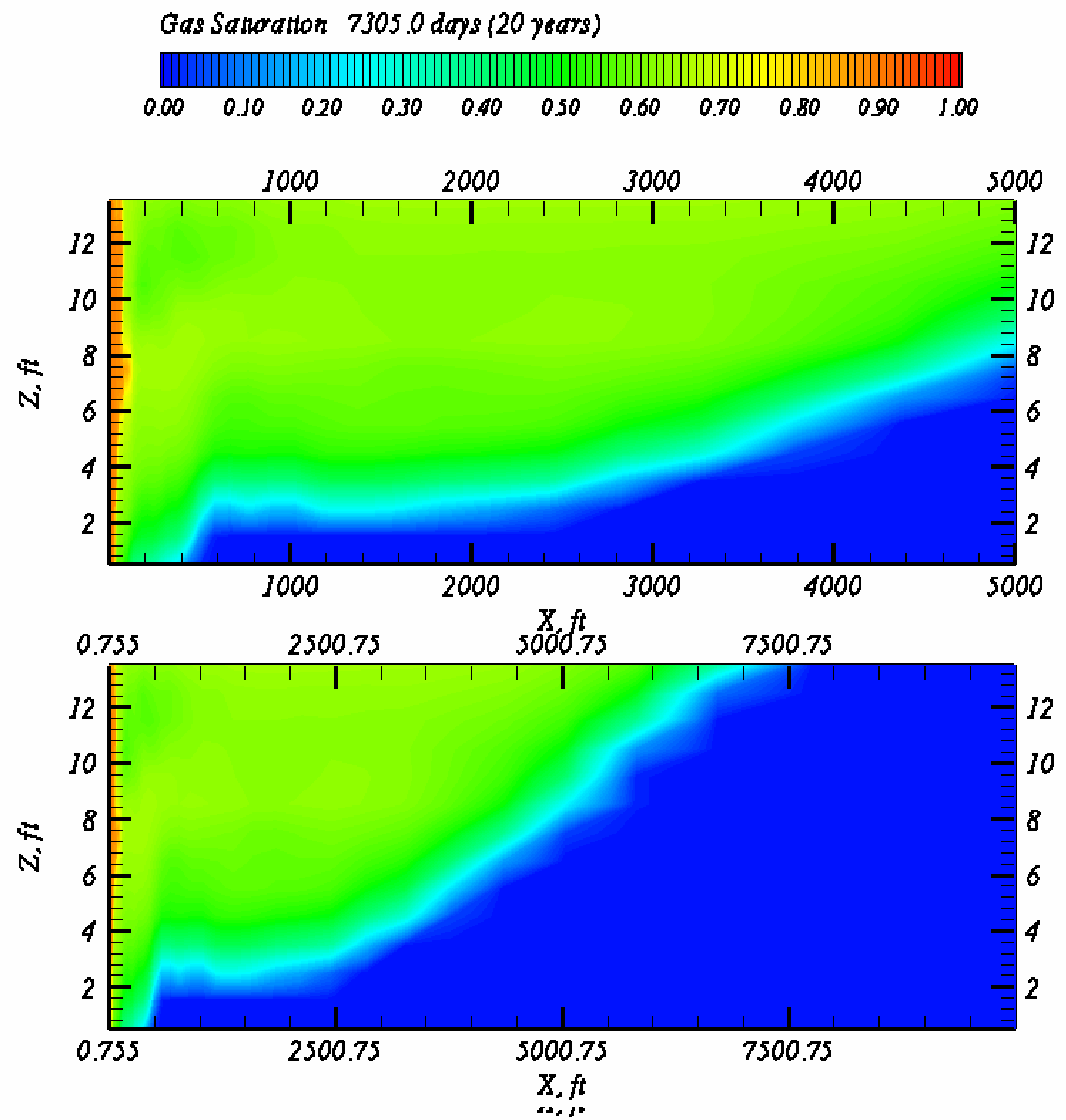
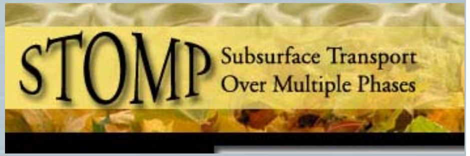
# Multiphase injection simulations to support design, MMV, and permitting

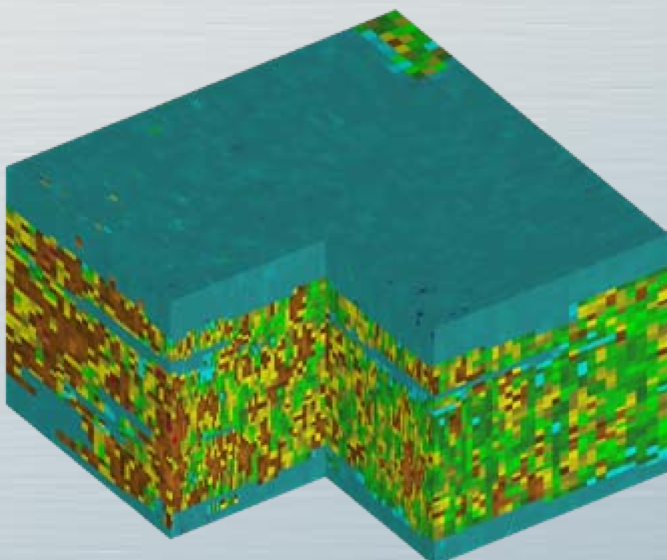
- STOMP-CO2 Code
- 14-ft Sandy zone in Rose Run
- Stochastic permeability based on field data
- 20 years of injection



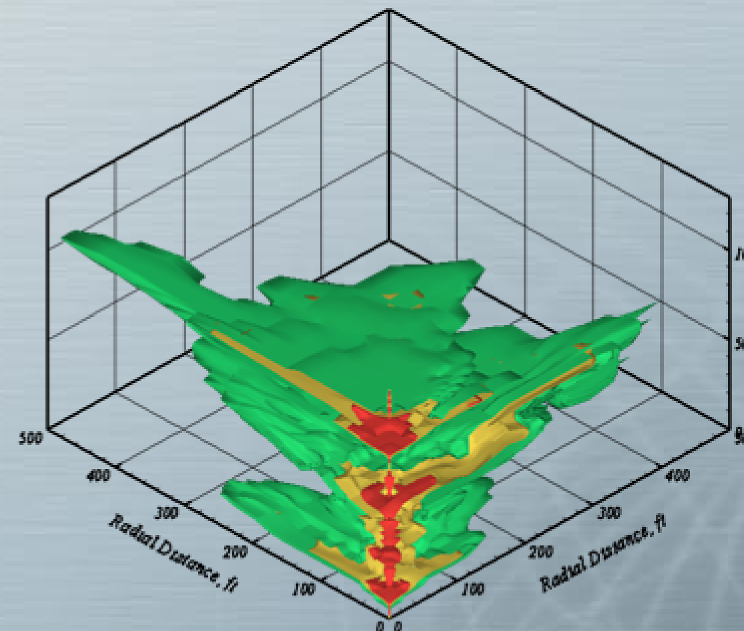



# 3-D Simulations using STOMP-$CO_2$ code

- More detailed scenarios with heterogeneity and subsurface processes will be simulated as needed.



3-Dimension Random Field- Realization of Intrinsic Permeability, ln(mD)




$CO_2$ Saturation Isosurfaces (0.01, 0.2, 0.3) @ 44 days (Saturation Range 0.0 - 0.81)

# Monitoring plan guiding principles

- Monitoring for any injection test phase will need to address
  - Regulatory monitoring requirements for injection wells
  - Performance assessment – scientific monitoring to understand fate and transport of injected $CO_2$
- 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 such as plant, power lines, ash ponds, railway lines affect monitoring
  - Local public/stakeholders must be kept informed
- MMV should have enough resolution relative to injected $CO_2$
- Effort will be made to evaluate/demonstrate a range of MMV options but only a selected subset will be used for any site

# $CO_2$ Monitoring Systematics

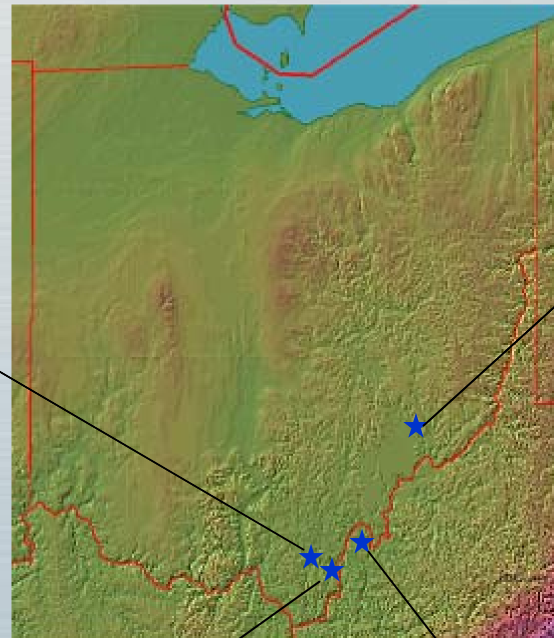
| System | Remote | Surface | Observation Well(s) |
| --- | --- | --- | --- |
| Injection Pressure | 4-D Seismic | Seismograph | Temperature/ Pressure |
| Flow Rate | Electromagnetic/ Seismic Crosswell | Soil Gas | Flow/ Density |
| Fluid Composition | Vertical Seismic Profile/Wireline | USDW Aquifer Sampling | Fluid Samples |
| Well Workovers | Tracers | Downhole Stressmeters | ERT |

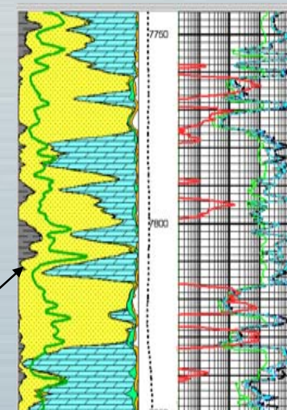
# Improving regional sequestration framework through continued geologic characterization

- 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 – e.g. – Bass Islands, Lockport.
- 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.

# Collaboration with oil and gas industry to build regional geologic framework

<u>Gallia County, Ohio</u>
- Extend borehole depth
- Collect wireline data
- Collect rock cores
- Establish regional continuity





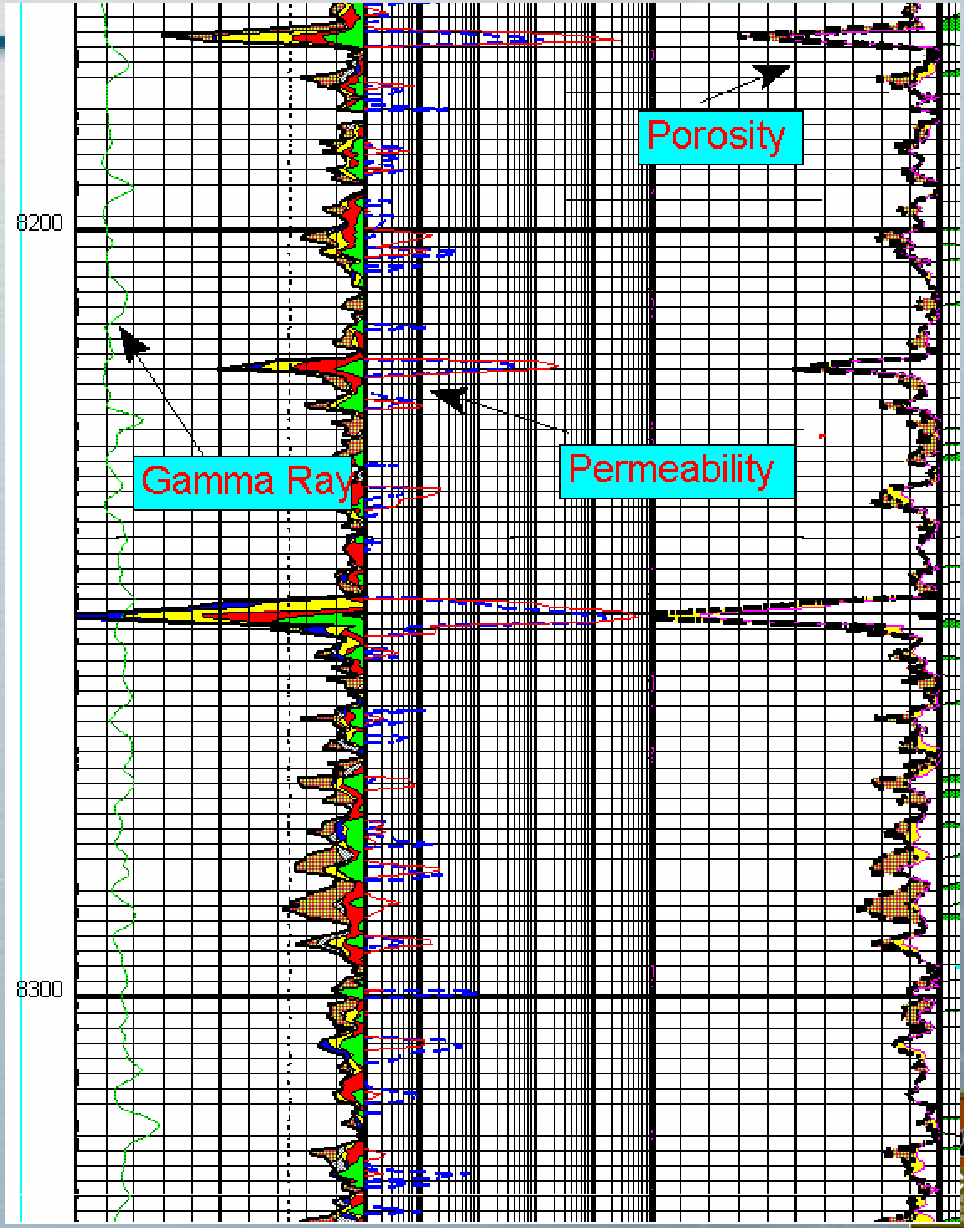
<u>Noble County, Ohio</u>
- Collect wireline data
- Collect rock core samples

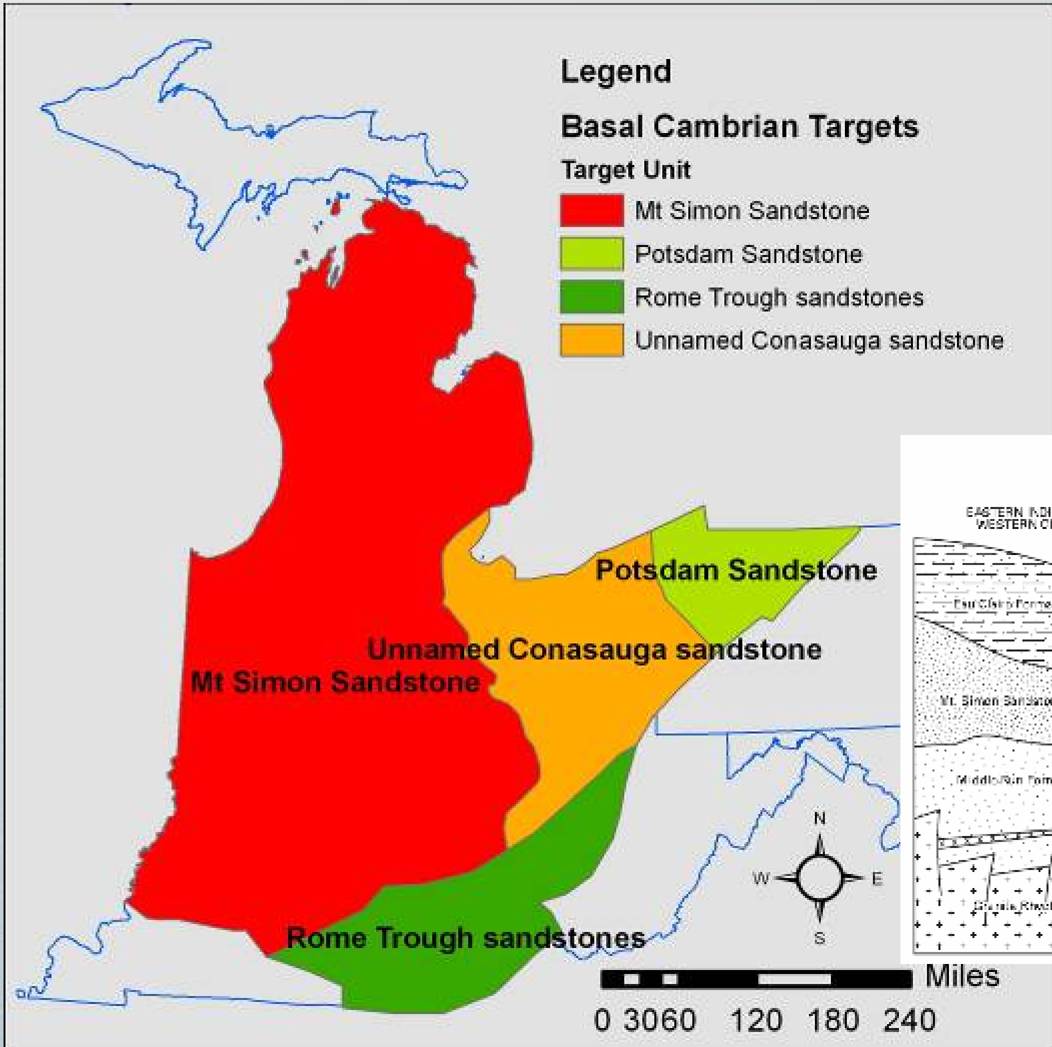
<u>Gallia County, Ohio</u>
- Drill, log, and core borehole to risk assessment
- Collaborative project with Japanese electric power institute

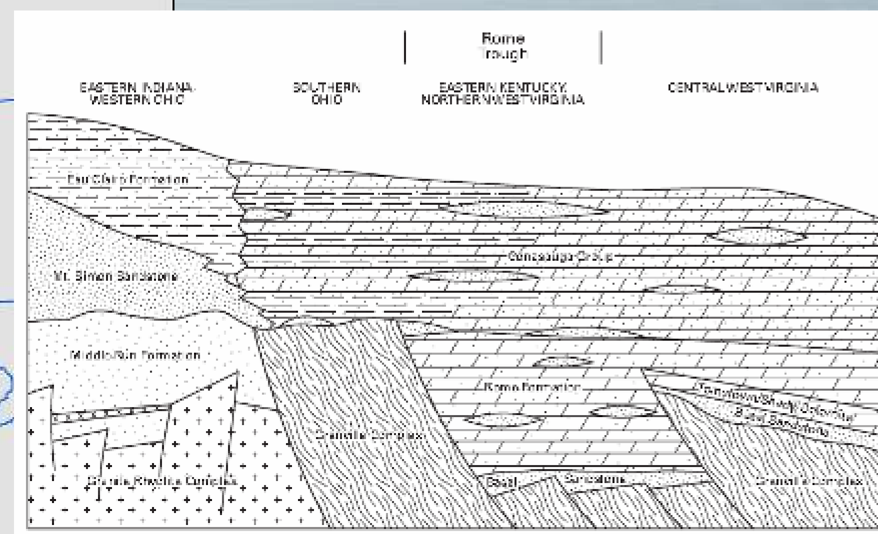
<u>Mountaineer Plant</u>
- Drill 9200 ft. test well
- Collect wireline data
- Collect brine and rock core samples

# Characterizing new sinks in the region?

- Cambrian carbonates in the MRCSP region generally dominated by dense dolomite layers.
- However, significant storage potential has been observed in part of Copper Ridge Dolomite (B-Zone) at Mountaineer and several other wells
- Based on packer tests, this zone can account for substantial flow potential in the boreholes
- This is promising for regional storage potential and needs further exploration



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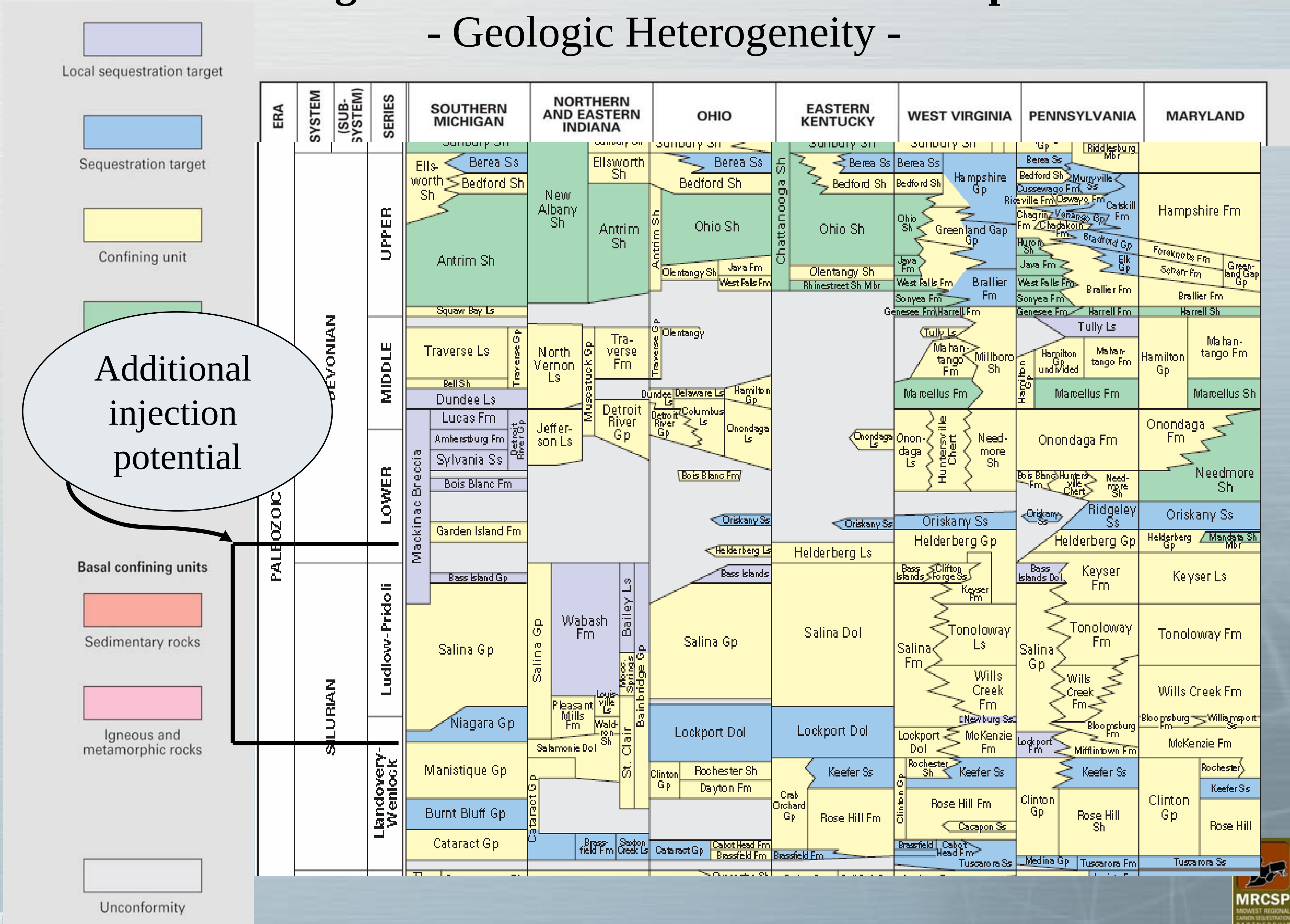
# MRCSP Regional Correlation Chart – Mid-depth Strata

## - Geologic Heterogeneity -



# Phase II pilot injection tests

Table 7.—Summary of estimated $CO_2$ storage capacity by geologic interval or reservoir type (in gigatonnes)

| *Sequestration Target* | *Porosity (%)* | *Density (g/cc)* | *Gas Content (scf/ton)* | *Area (mi²)* | *Total (GT)* | *10% of Total* |
|---|---|---|---|---|---|---|
| Oil and Gas Fields | | | | | 25.1 | 2.51 |
| Waste Gate Formation | 10 | | | 1,342 | 43.8 | 4.38 |
| Net Coal | | 1.32 | 100 | 25,578 | 2.5 | 0.25 |
| Antrim and Ohio shales | | 2.62 | 42.9 | 109,043 | 453 | 45.3 |
| Needmore Shale | | 2.62 | 42.9 | 850 | 0.5 | 0.05 |
| Sylvania Sandstone | 10 | | | 25,324 | 151.1 | 15.11 |
| Oriskany Sandstone | 10 | | | 57,313 | 194.3 | 19.43 |
| Medina/Tuscarora SS | 8 | | | 72,328 | 705.3 | 70.53 |
| St. Peter Sandstone | 10 | | | 41,796 | 881.3 | 88.13 |
| Rose Run sandstone | 8 | | | 57,493 | 492.7 | 49.27 |
| Potsdam Sandstone | 2 | | | 9,298 | 17.1 | 1.71 |
| Conasauga Formation | 2 | | | 24,973 | 42.5 | 4.25 |
| Rome trough sandstone | 1 | | | 18,452 | 12.3 | 1.23 |
| Mt. Simon Formation | 8 | | | 85,916 | 2,171.8 | 217.18 |
| Total | | | | | 5,193.5 | 519.35 |

To fully evaluate the region's potential pilots should be designed to test as many of the best candidate reservoirs as possible, over a broad area of the partnership.

# Public outreach

- Build on Phase I experience and contacts
- Move from “top down” to “bottom up” approach
  - Identify and interact with stakeholders at field sites
- Adapt lessons learned from Mountaineer Project
  - Work closely with industry partners to engage stakeholders
- Continue to update and use the interactive web site as a source of information and feedback
  - Reach broader regional groups
  - Complement the field site outreach activities

# Regulatory analysis

- Two-pronged effort
  - Complete regulatory process (e.g. permitting) for field projects
  - Capacity building at regional level (sharing of information)
- Develop a Regulatory Compliance Plan
  - Specifies how MRCSP will comply with NEPA requirements
- Hold a series of additional workshops with regulators at the state level
  - Further inform them about the MRCSP and sequestration technologies
  - Help them understand the need for and means of achieving interagency regulatory coordination
    - Draws upon the unique role played by NRRI in working with PUC and other regulatory bodies
- Coordinate with outreach groups and other partnerships

# Phase II project organization

**Industry Advisors**

**Project Management**
David Ball, Battelle

**Technical Integration and Deployment Strategy Development**
James Dooley, Battelle

**Terrestrial Characterization and Field Projects**
Rattan Lal, OSU

- West Virginia Univ.
  Mark Sperow

**Geological Characterization and GIS Integration**
Larry Wickstrom, OGS

- Indiana Geological Survey
  John Rupp
- Kentucky Geological Survey
  James Drahovzal
- Maryland Geological Survey
  Gerald Baum
- Pennsylvania Geological Survey.
  John Harper
- West Virginia Geological Survey
  Michael Hohn
- Western Michigan Univ.
  William Harrison III

**Geological Field Projects Management**
Neeraj Gupta, Battelle

- Field Operations and Logistics
  Phil Jagucki, Battelle
- Geological Survey Coordination
  Larry Wickstrom, ODGS
- Piggyback Opportunities
  Neeraj Gupta, Battelle
- $CO_2$ Sourcing & Transport
  Bruce Sass, Battelle
- NEPA
  Lucy Swartz, Battelle

**Technology Integration and Deployment Studies**
Bob Dahowski, Battelle

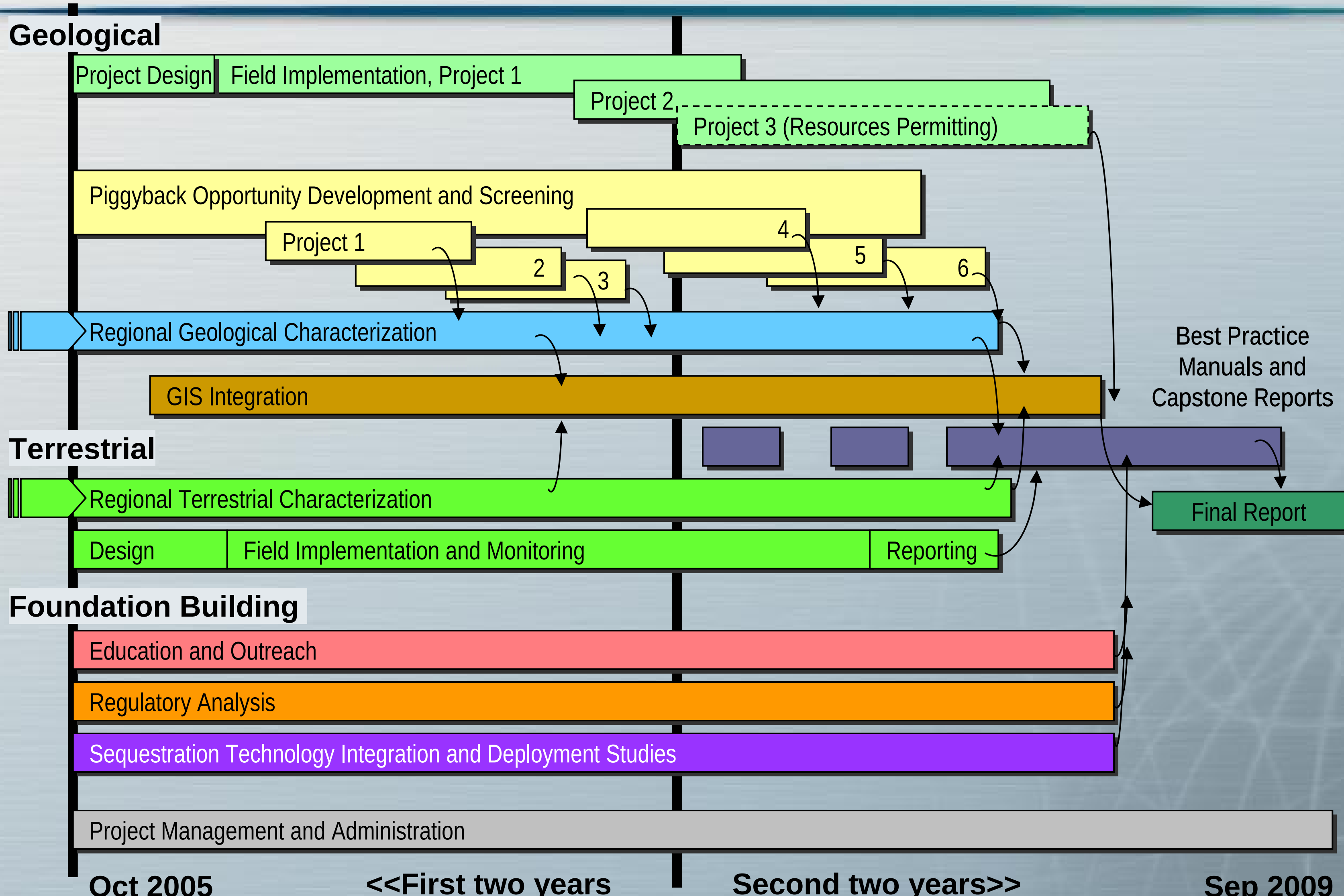
- Capture Technology Assessment
  Bruce Sass, Battelle

**Public Outreach & Education**
Judith Bradbury, Battelle

- Sarah Wade, AJW Group
  Jeremy Kranowitz, The Keystone Center

**Regulatory Analysis**
Bob Burns, NRRI

# Phase II work plan

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