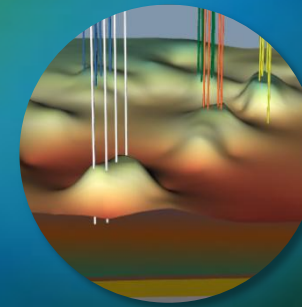
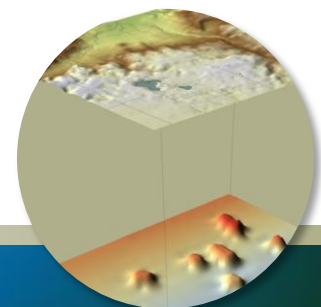


# CO<sub>2</sub>-Enhanced Oil Recovery and Geologic Storage in the Midwestern USA

McIlvaine Company Webinar  
August 29, 2013

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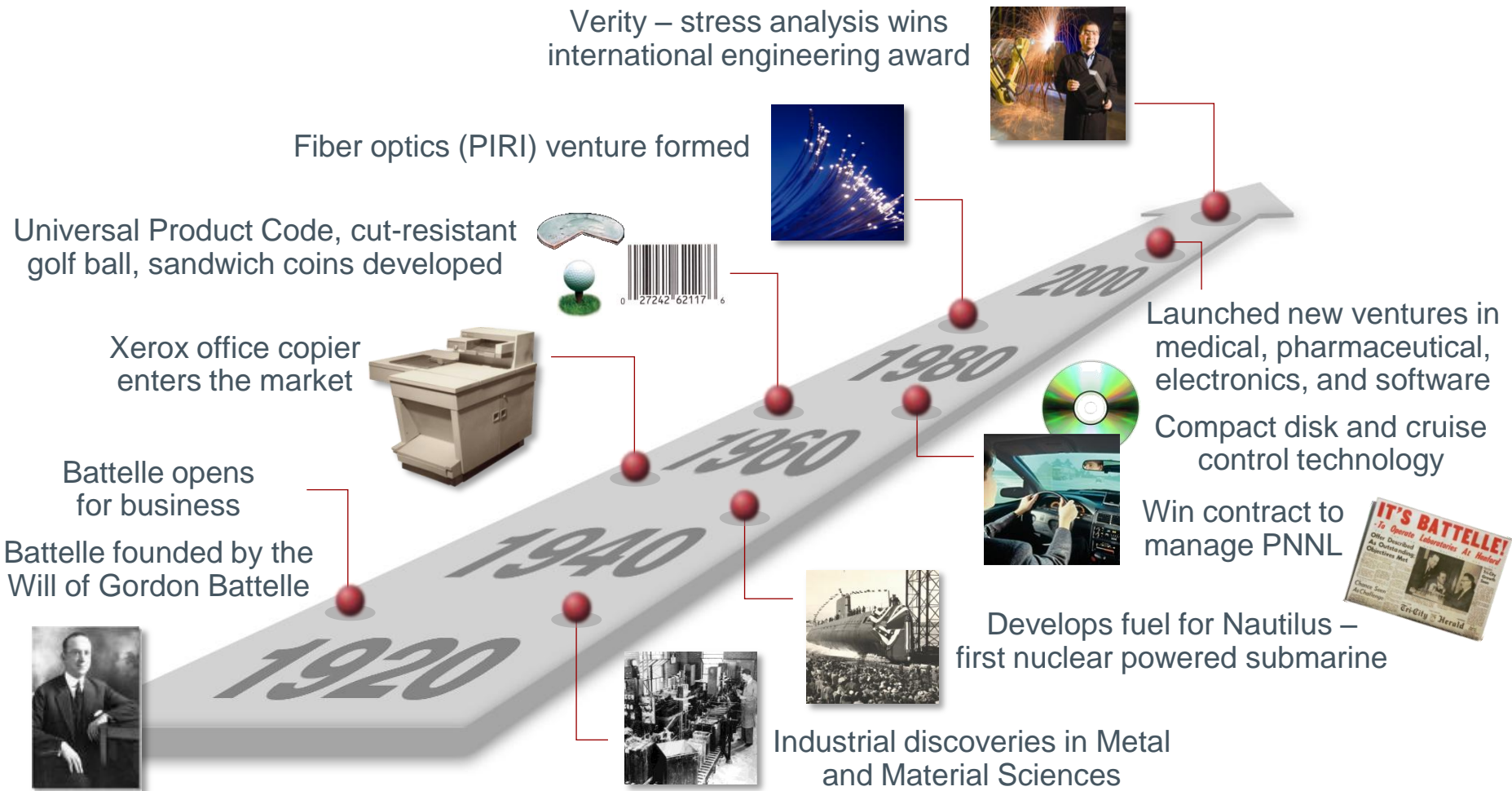


# Discussion Topics

- Introduction to Battelle
- Midwestern Regional Carbon Sequestration Partnership (MRCSP)
  - Large-scale CO<sub>2</sub>-Utilization test
- Related subsurface research and benefits
  - Large-scale deployment
  - Finding storage potential in the Ohio River Valley
  - Ensuring safety
  - Understanding brine disposal needs

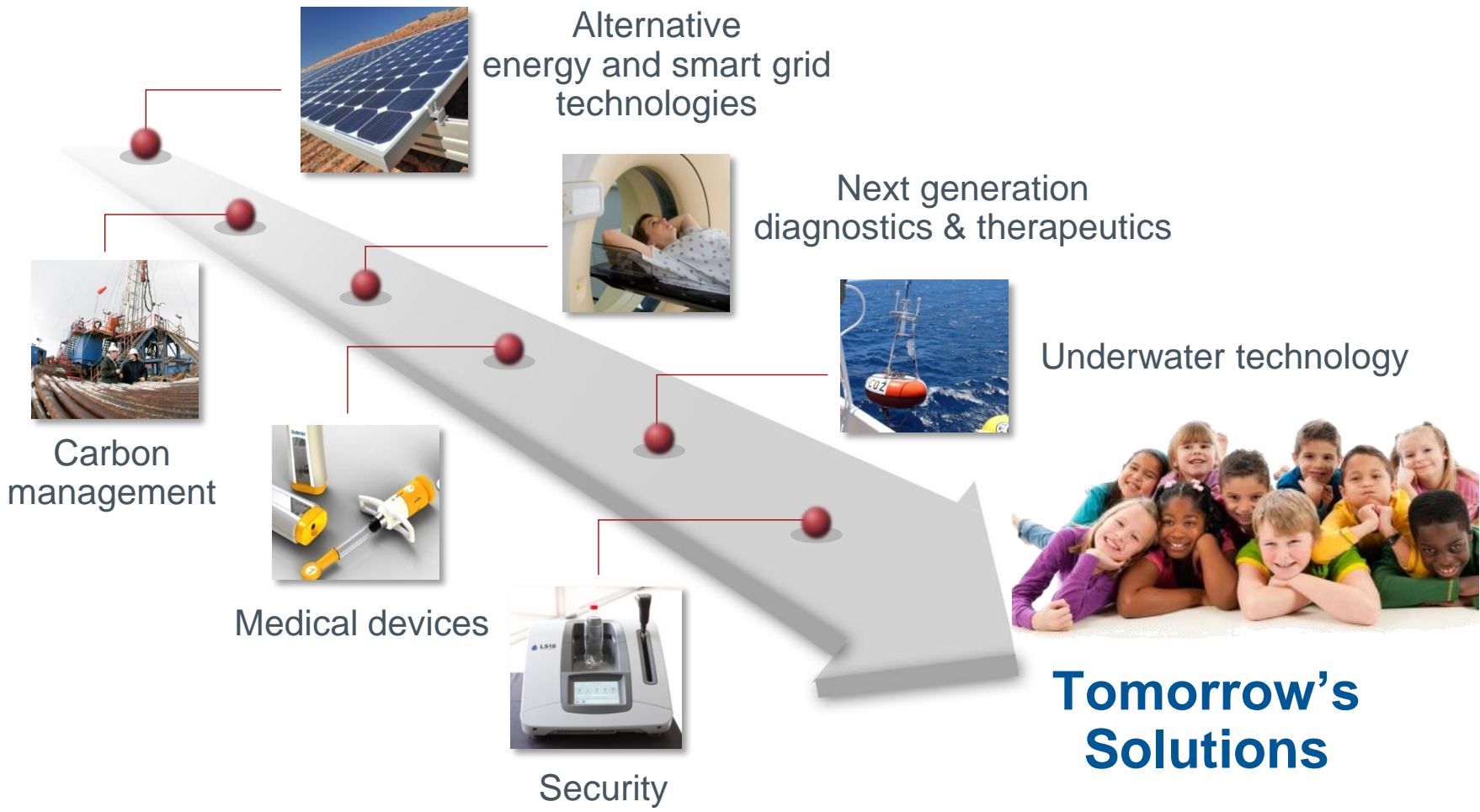
# A History of Innovation

*inspiring new industries; revolutionizing products*



# What Matters Most Tomorrow

*inspiring new industries; revolutionizing products*



# Battelle plays a key role in the national CO<sub>2</sub> storage program

## Case Studies of Success

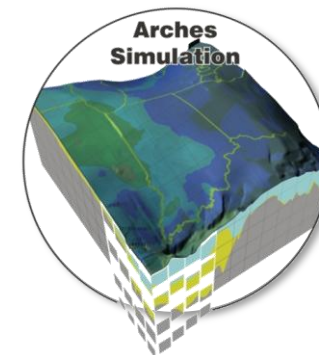
### AEP Mountaineer

- Site characterization, design
- Permitting, construction
- Operations
- Post-injection monitoring

### DOE Regional Partnerships

- Regional Mapping
- Policy & Regulation
- Small-Scale Tests
- Large-Scale Test
- Ohio River Valley Characterization

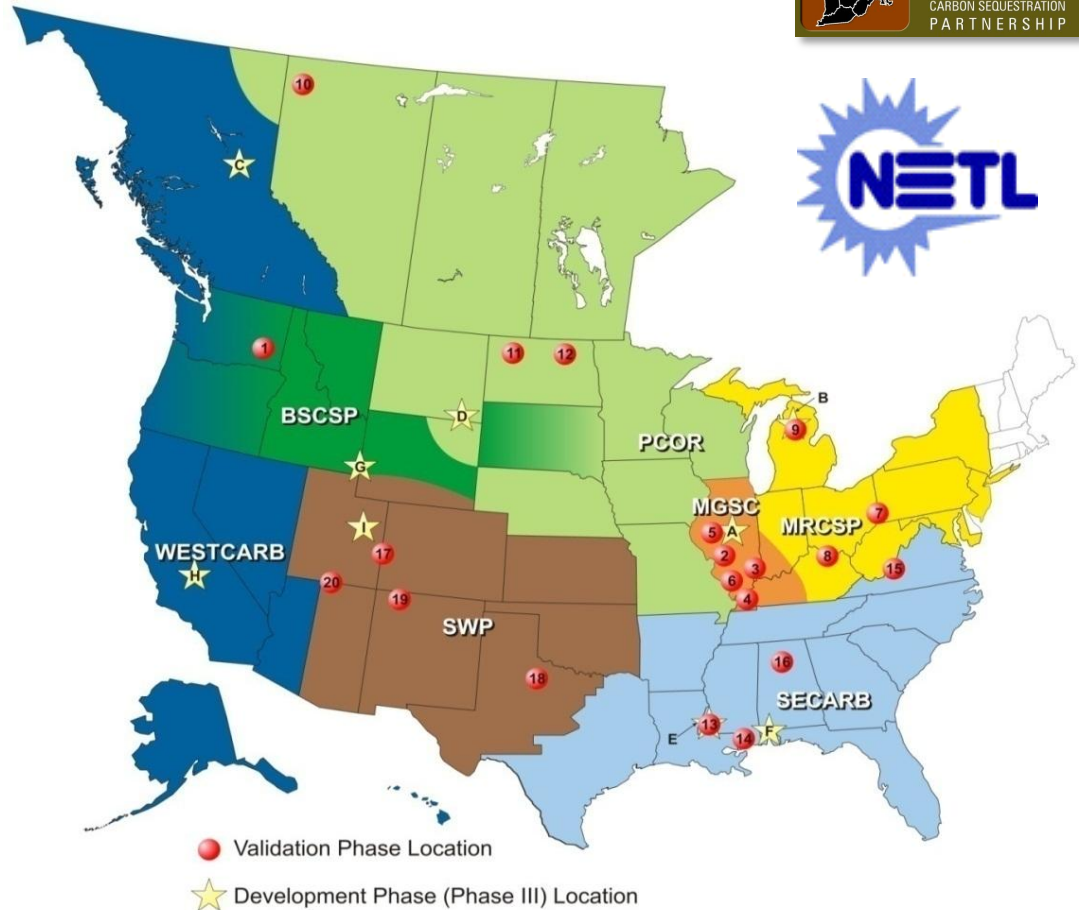
### Domestic and International Consulting





# The MRCSP assesses viability of carbon sequestration

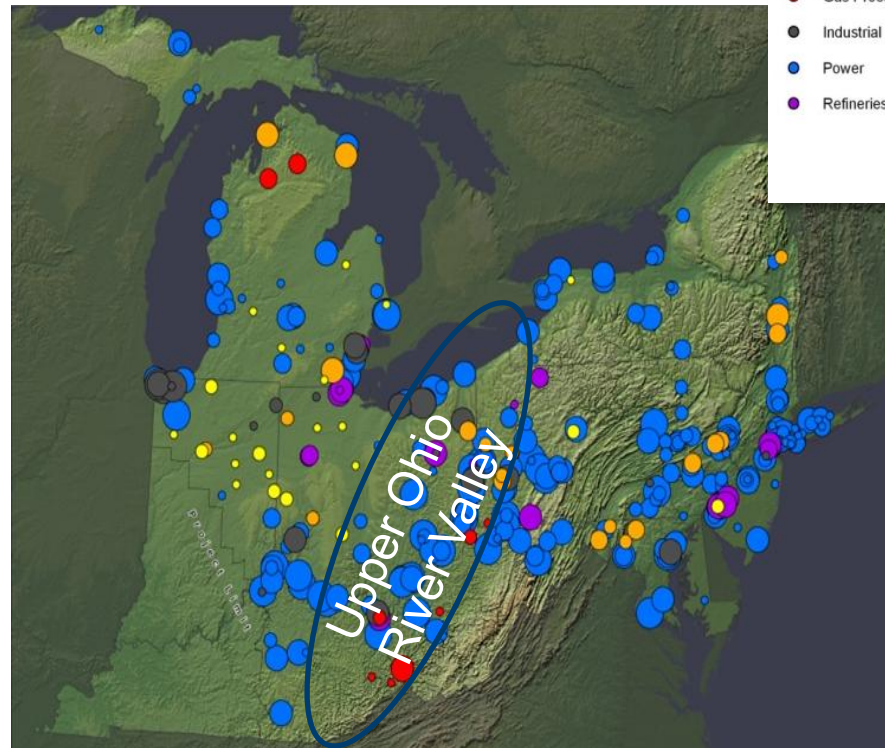
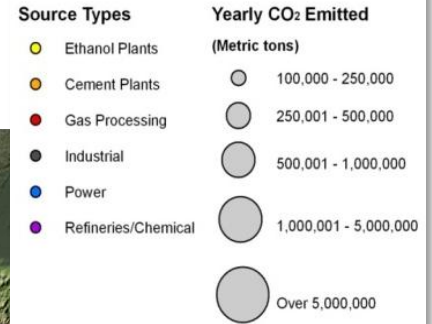
- Established in 2003 by Battelle with DOE-NETL funds – Currently in Phase III
- Led by Battelle, there are 40 organizations from non-profit, government, and commercial entities
- Mission – The premier resource for CO<sub>2</sub> storage and utilization expertise in the region



# MRCSP region: Many CO<sub>2</sub> emission sources with dependence on coal

- CO<sub>2</sub> storage/utilization technologies key to affordable energy supplies
- Environmental/climate issues and shale gas, are leading to energy supply transition
- Coal continues to be dominant fuel source

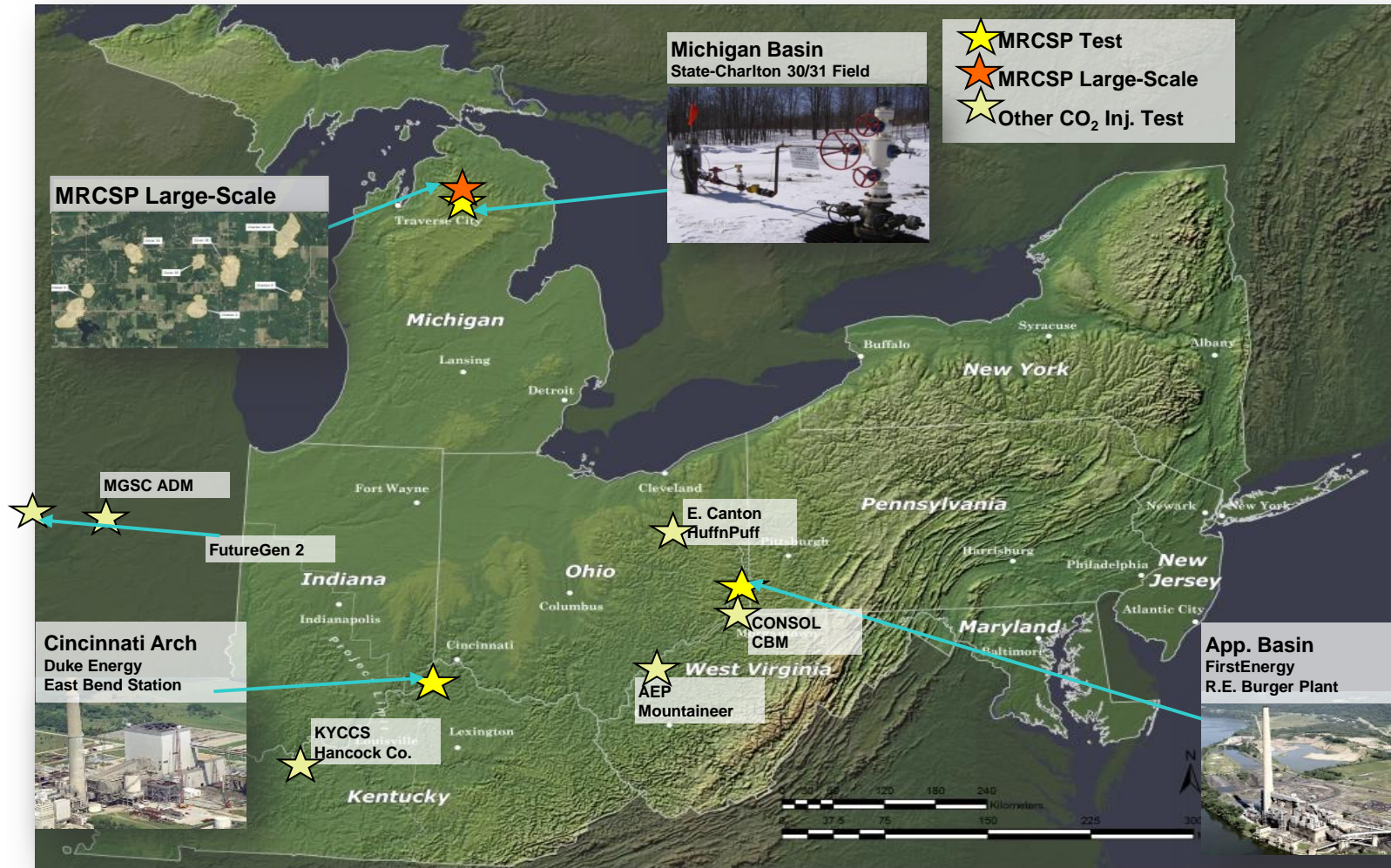
## MRCSP CO<sub>2</sub> Sources





# MRCSP region has large but uneven storage potential

Region is home to several field tests – but many more are needed

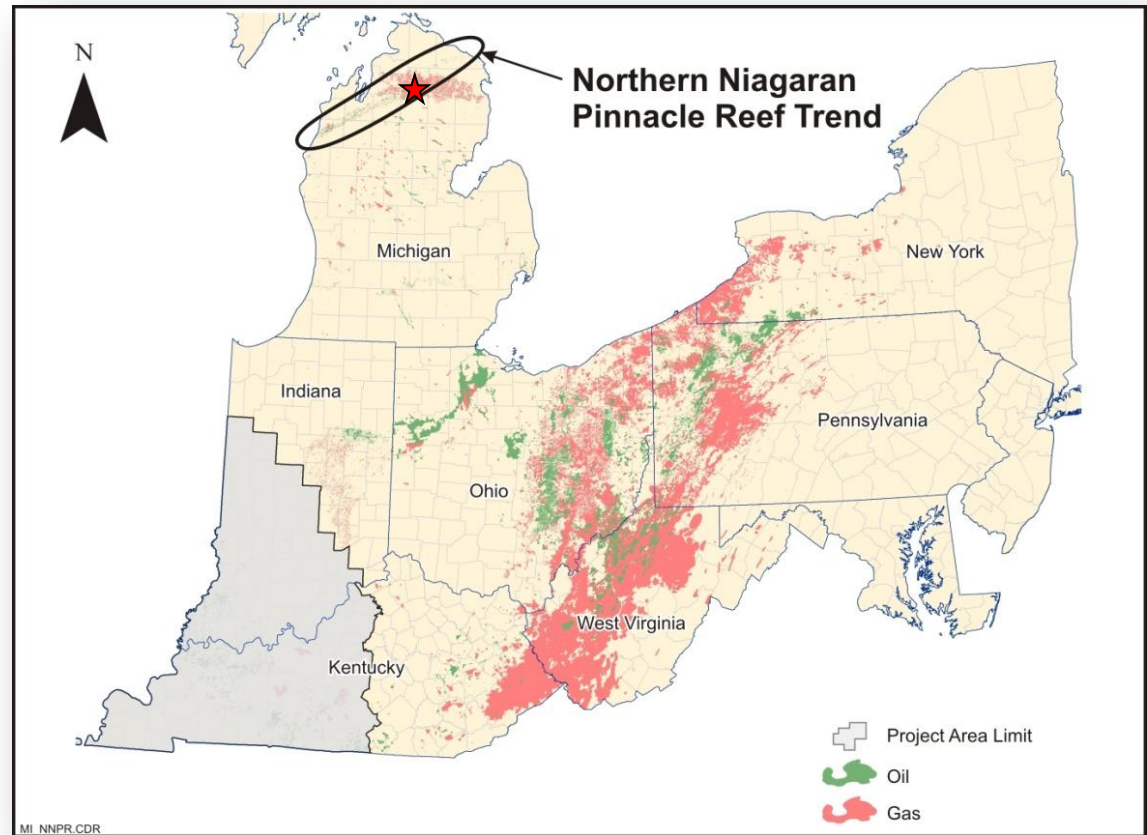




# MRCSP region has many large historic oil and gas producing areas

- ~ 8,500 million metric tons of CO<sub>2</sub> could be stored within depleted O&G fields (~10 years worth of regional emissions)\*
- Using CO<sub>2</sub> for EOR could lead to the production of an additional 1.2 billion barrels\* of oil
- However, EOR needs to be proven in the region

Oil and gas fields map for region\*



\* Source: Estimates developed by the Geological Surveys within the MRCSP

# MRCSP large-scale test site — only CO<sub>2</sub> – EOR site in the Midwest

## Location:

Otsego County, Michigan

## Host Company:

Core Energy LLC

## Reservoir Type:

Closely-spaced, highly compartmentalized oil & gas fields located in the Northern Michigan Niagaran Reef Trend

## Source of CO<sub>2</sub>:

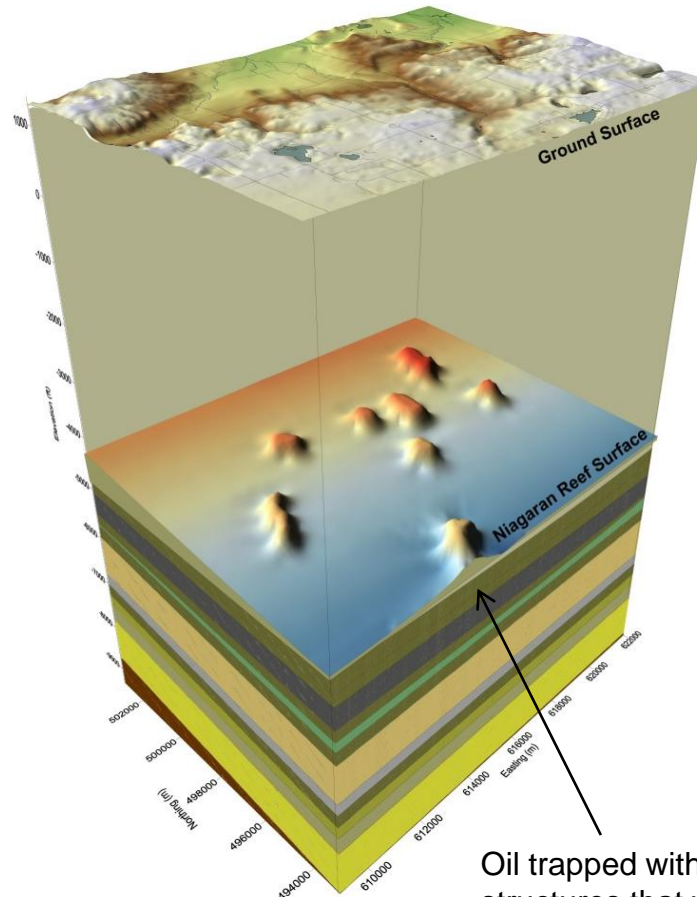
Natural Gas Processing Plant

## Injection Goal:

At least 1 million metric tons of CO<sub>2</sub> over ~four years

## Local Participants:

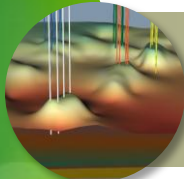
Western Michigan University



Oil trapped within ancient buried reef structures that were formed millions of years ago when oceans covered this part of the world.

# MRCSP Field test research objectives

Site  
Characterization



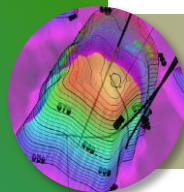
Assess the variability among adjacent reefs

Reservoir  
Models



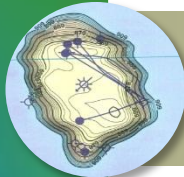
Validate using injection and production volumes

Operational  
Models



Predict CO<sub>2</sub> storage and oil production;  
suggest approaches to optimize both

Monitoring  
Techniques and  
Equipment



Identify cost effective and useful techniques  
and methods

Reef Capacity  
and Injectivity

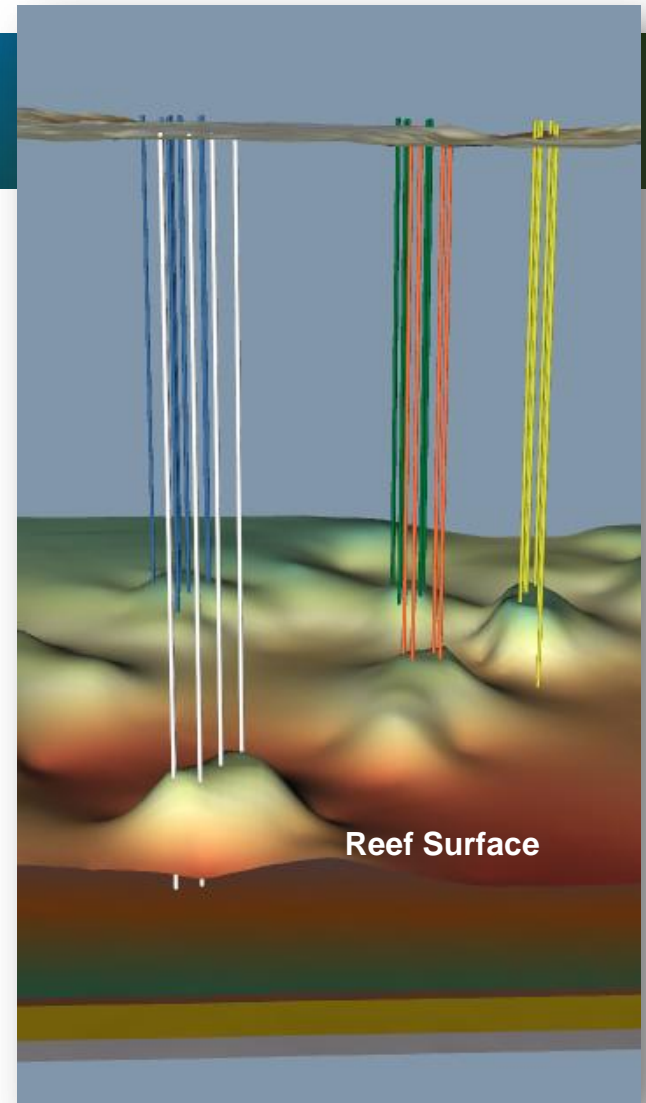


Identify key parameters and variability;  
address uncertainty

# MRCSP will evaluate reef capacity

## Oil fields are in various production life-cycle stages

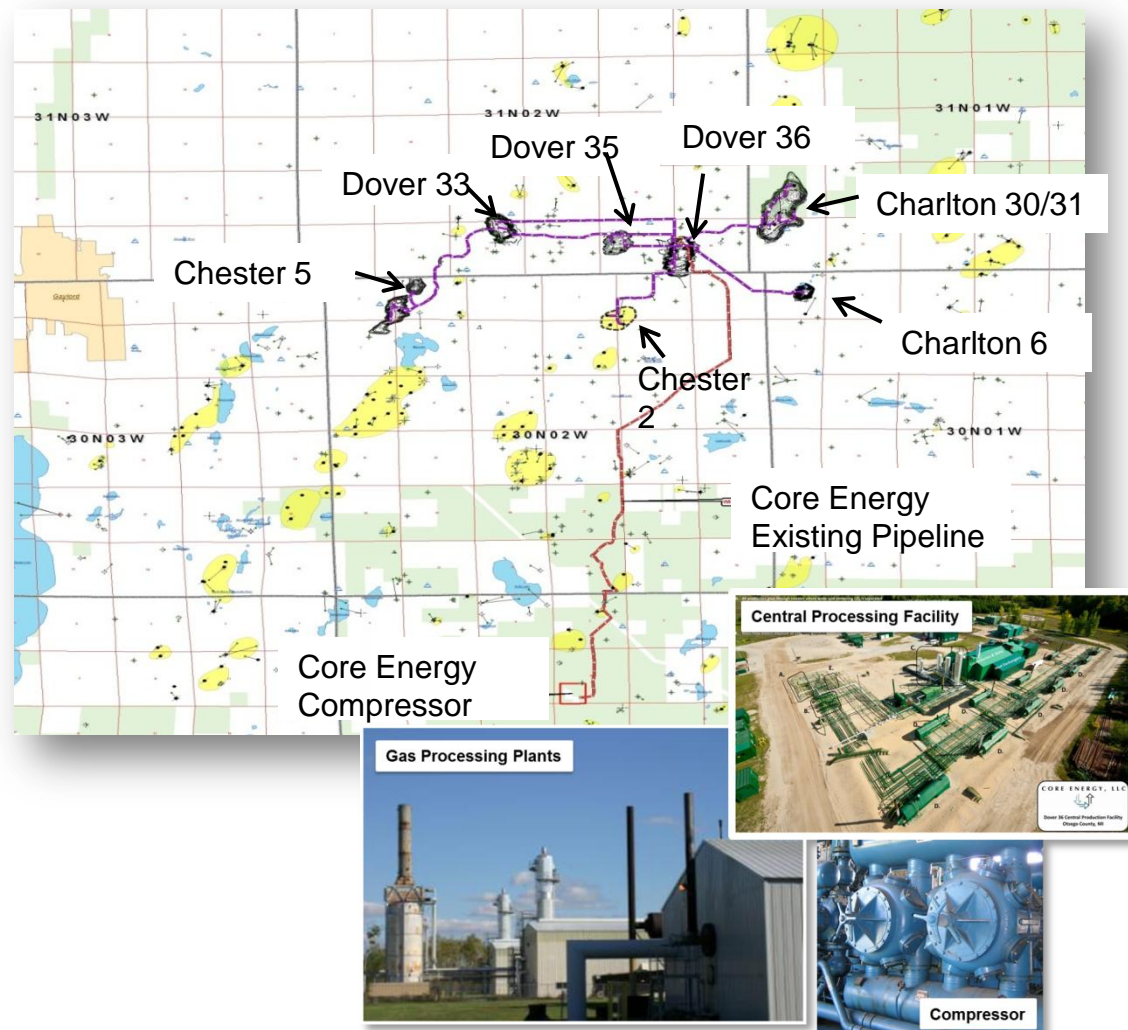
- **Pre-EOR Reefs** – New CO<sub>2</sub> EOR  
Undergone primary oil recovery but no CO<sub>2</sub>-EOR yet
- **Active EOR Reefs**  
Completed primary oil recovery and CO<sub>2</sub>-EOR is under way
- **Late-Stage EOR Reefs**  
Undergone extensive primary and CO<sub>2</sub>-EOR – highly depleted – potential future storage targets?





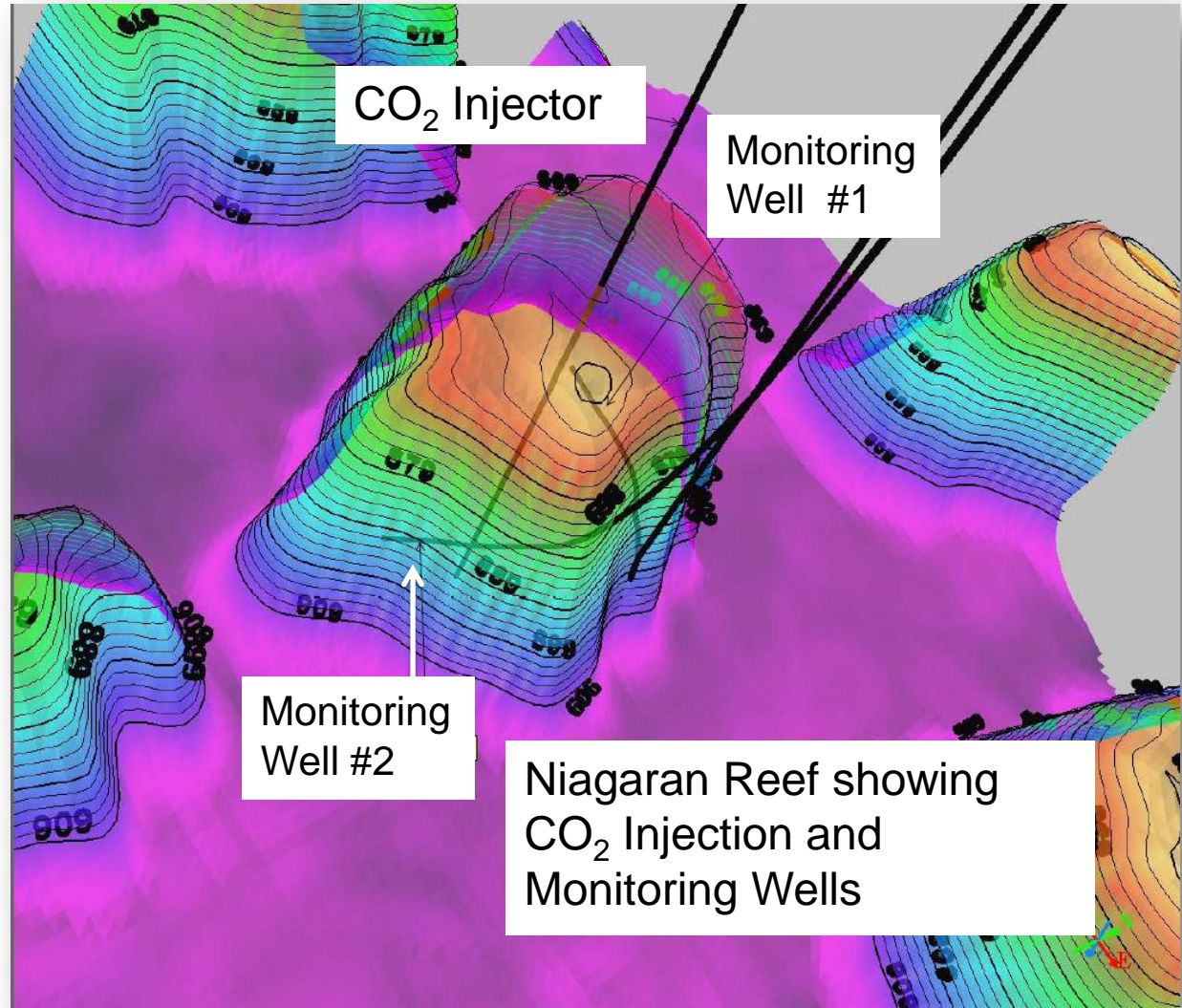
# Existing EOR infrastructure enables cost effective research for MRCSP tests

- MRCSP injection started in April 2013 at more than 1,000 t/day (~10% of 500 MW power plant)
- 7 CO<sub>2</sub>-EOR fields in varying life stages
- MRCSP goal – inject and monitor >1 MMT CO<sub>2</sub>
- Extensive monitoring and operational assessment underway

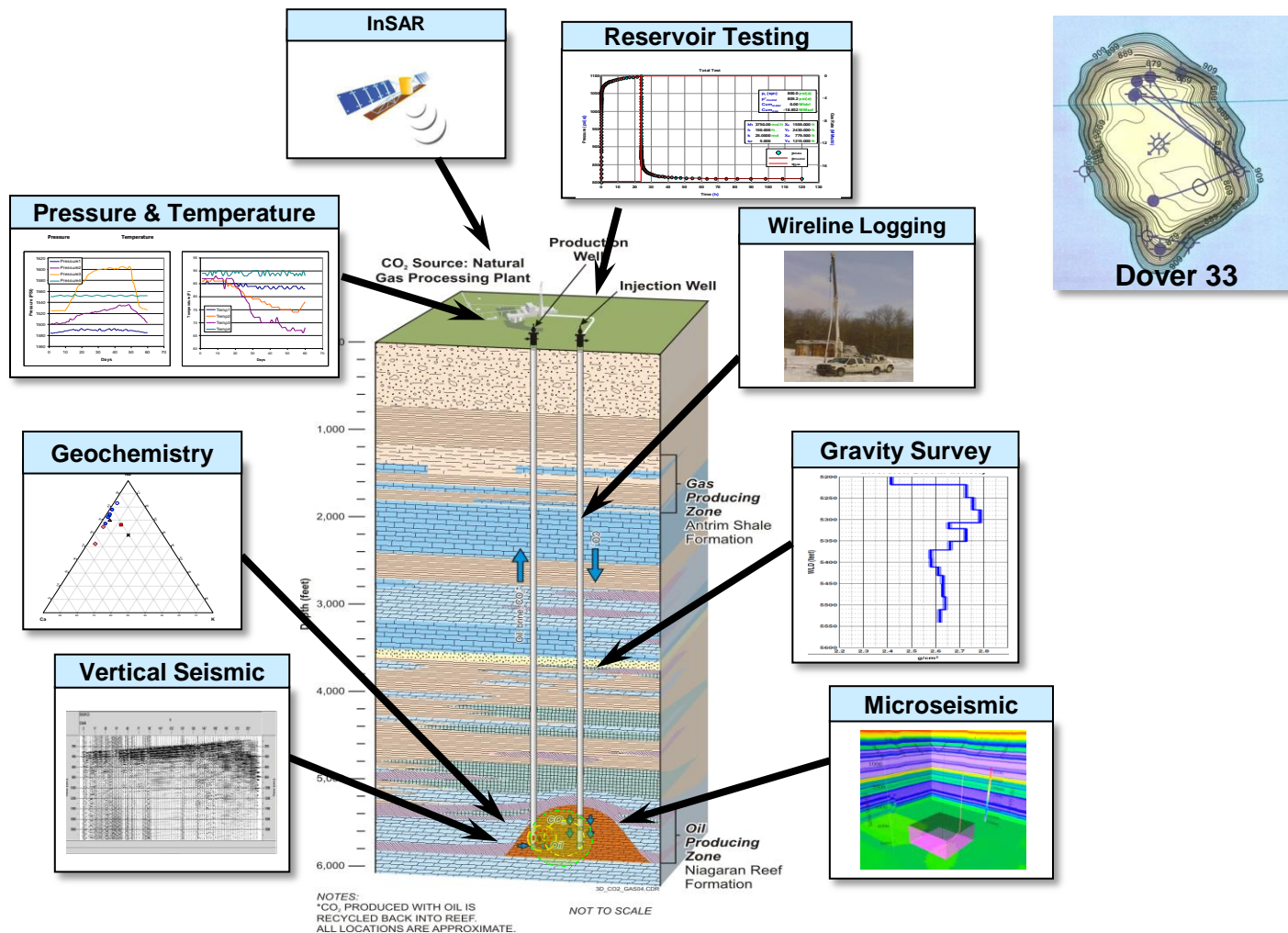


# 3D Seismic is a key tool for exploration

- Core Energy has 3D seismic on all project reefs
- Core also collected 38 sq miles of new 3D seismic in 2011
- 3D seismic essential for E&P in these areas
- Seismic technologies also useful for monitoring in some areas



# Highly depleted field provides a test bed for advanced monitoring technologies

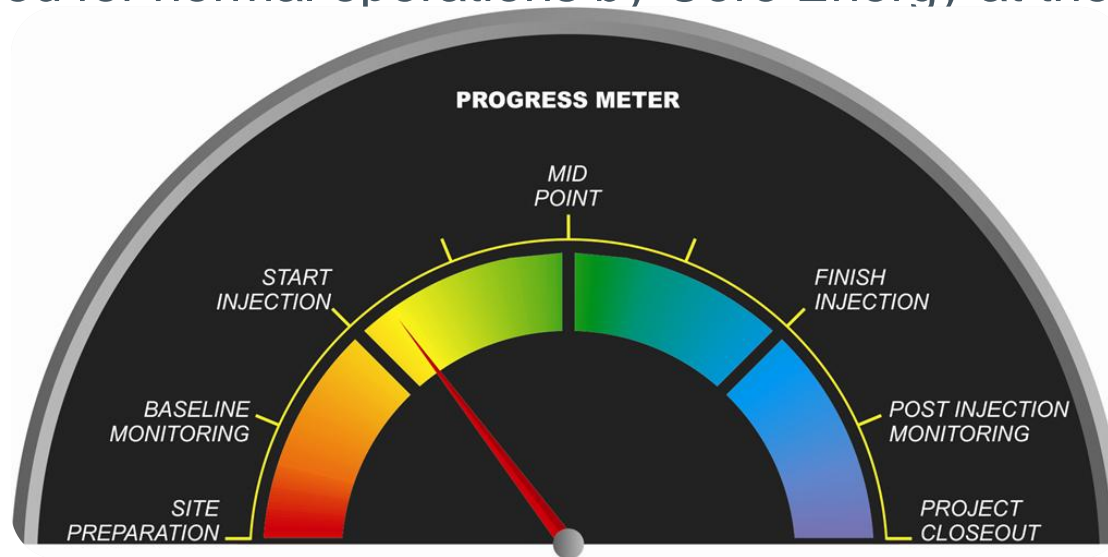


**Monitoring options under testing at Dover 33 field**



# MRCSP will continue to monitor reef after injection

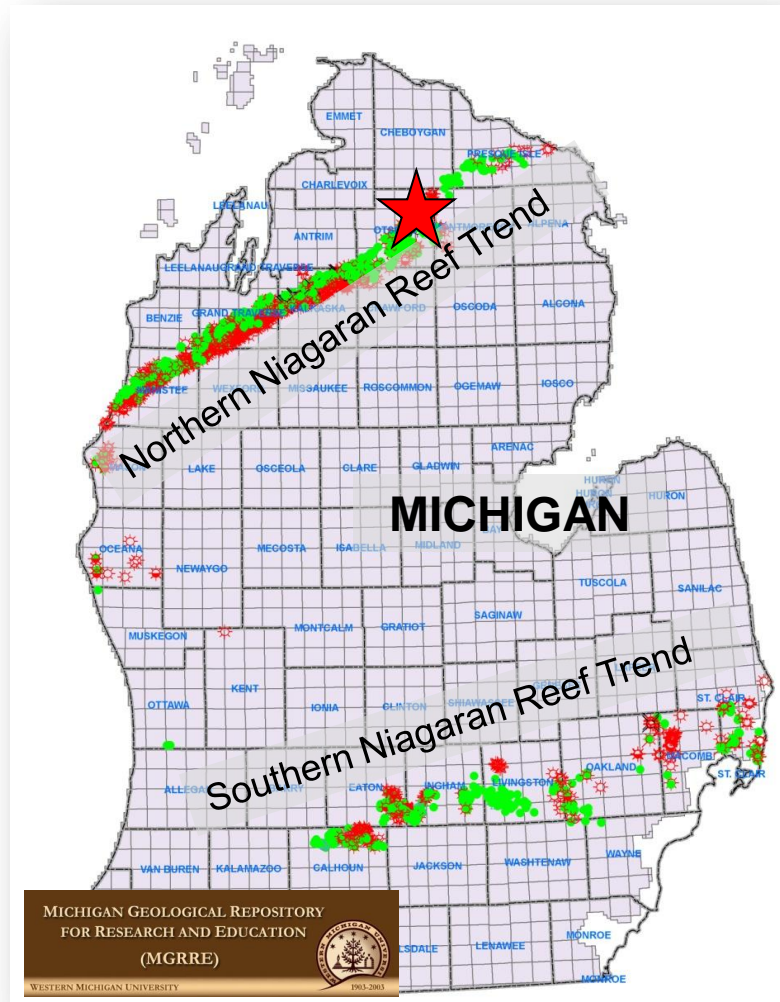
- Late-stage reef injection began April 2013 – ~100K tonnes to date
- Up to 500,000 tonnes of CO<sub>2</sub> over the next 2 to 3 years
- Additional fields will be selected for new CO<sub>2</sub>-EOR tests
- More than 125,000 tonnes injection/recycling monitored in active reefs by July 2013
- Wells returned for normal operations by Core Energy at the end





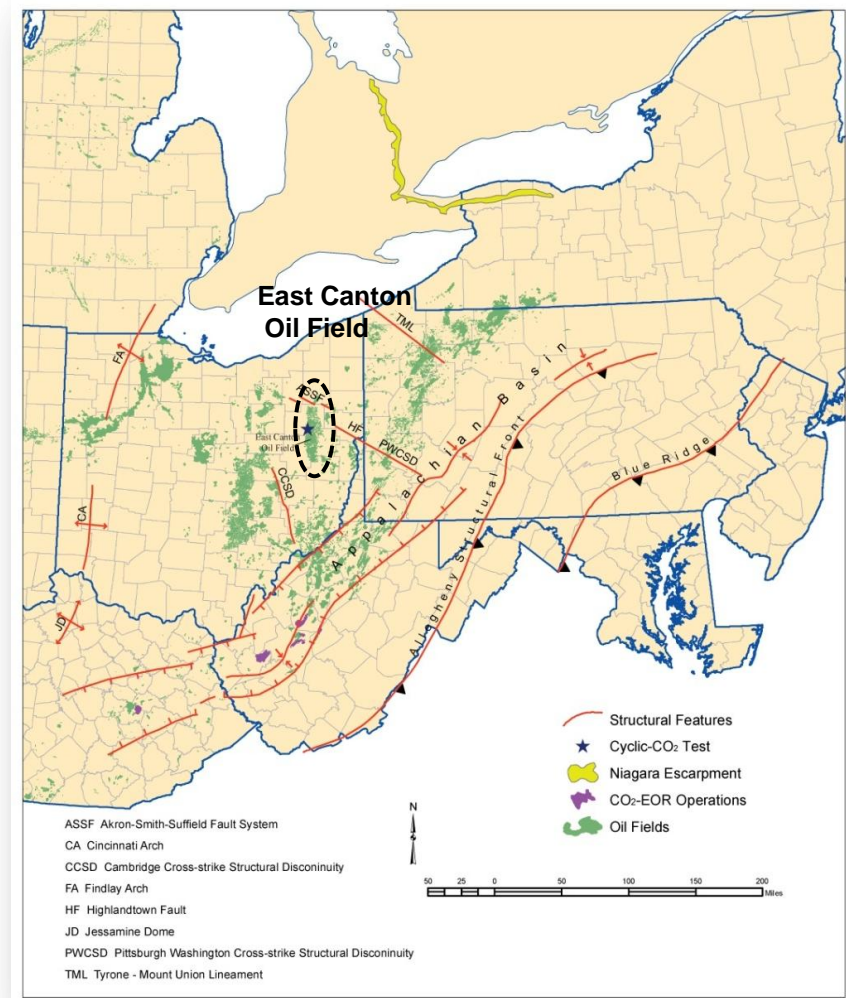
# Test results will be used to determine regional feasibility

- Extensive 3-D seismic and well data from project area, as well as data on over 700 reefs regionally
- Test modeling and monitoring will be used to estimate capacity, injectivity, economics, regulatory issues for storage
- Results useful for other carbonate reservoirs in region



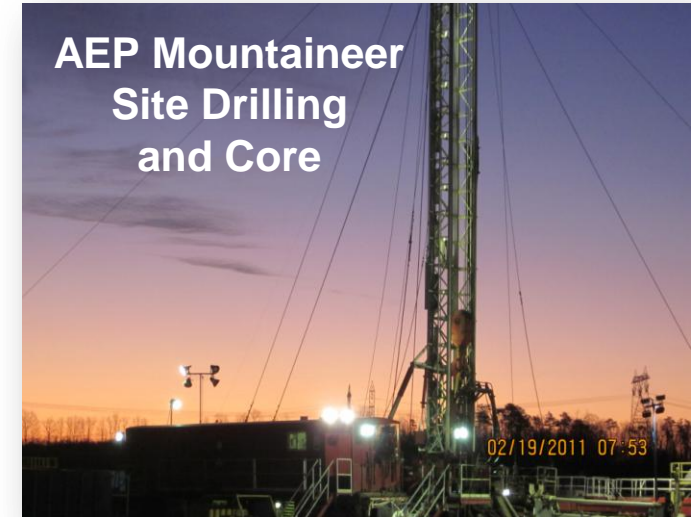
# Developing CO<sub>2</sub>-EOR/storage in Ohio's depleted oil fields

- Significant additional oil recovery and CO<sub>2</sub> utilization potential in Ohio
  - Example - East Canton oil field produced on ~95 MMbbl (<10%) of 1.5 billion barrels OOIP
  - Other plays include Beekmantown, Rose Run, Copper Ridge fields
- Additional testing is needed to determine CO<sub>2</sub> utilization viability in such fields
- CO<sub>2</sub> utilization may not occur without oil & coal collaboration – a key challenge



# Understanding injectivity in Appalachian Basin: extending knowledge from AEP Mountaineer tests

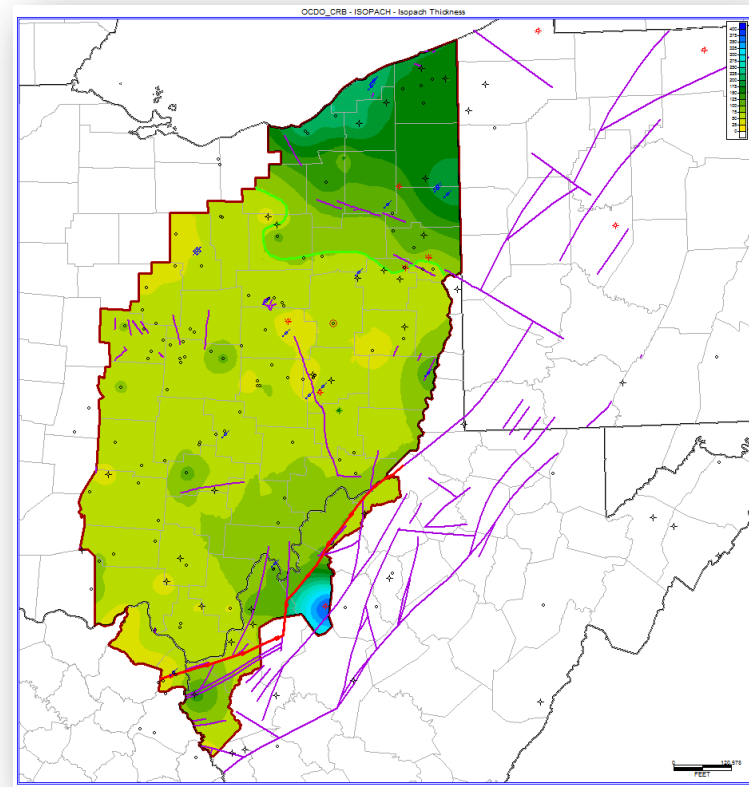
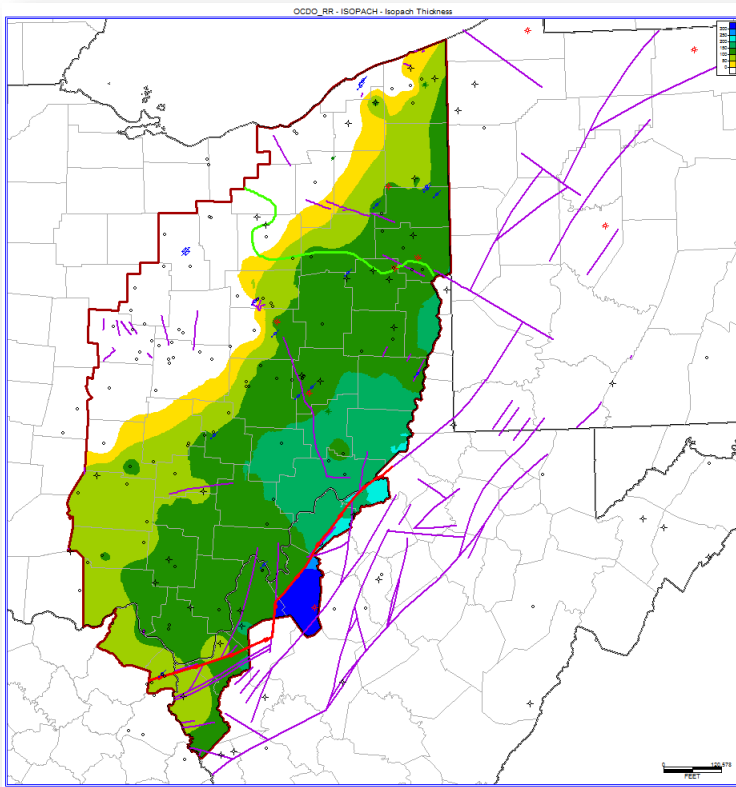
- Extensive work at AEP Mountaineer site over 11 years
  - Exploration and testing revealed thin but highly permeable zones with high injectivity
  - Exploration needed for commercial-scale storage
- Regional mapping essential to qualify this formation
  - Working with oil/gas/disposal well drilling to characterize the region
  - Significant cost leveraging



**Copper Ridge Dolomite Core 8370'**

# Developing CO<sub>2</sub> storage and utilization options in Appalachian Basin

- Developing maps using knowledge from Mountaineer Projects
- Conceiving new initiatives to map storage and CO<sub>2</sub>-EOR potential
- Research co-funded by Ohio Coal Development Office under MRCSP





# Battelle plays a key role in geologic storage development for FutureGen

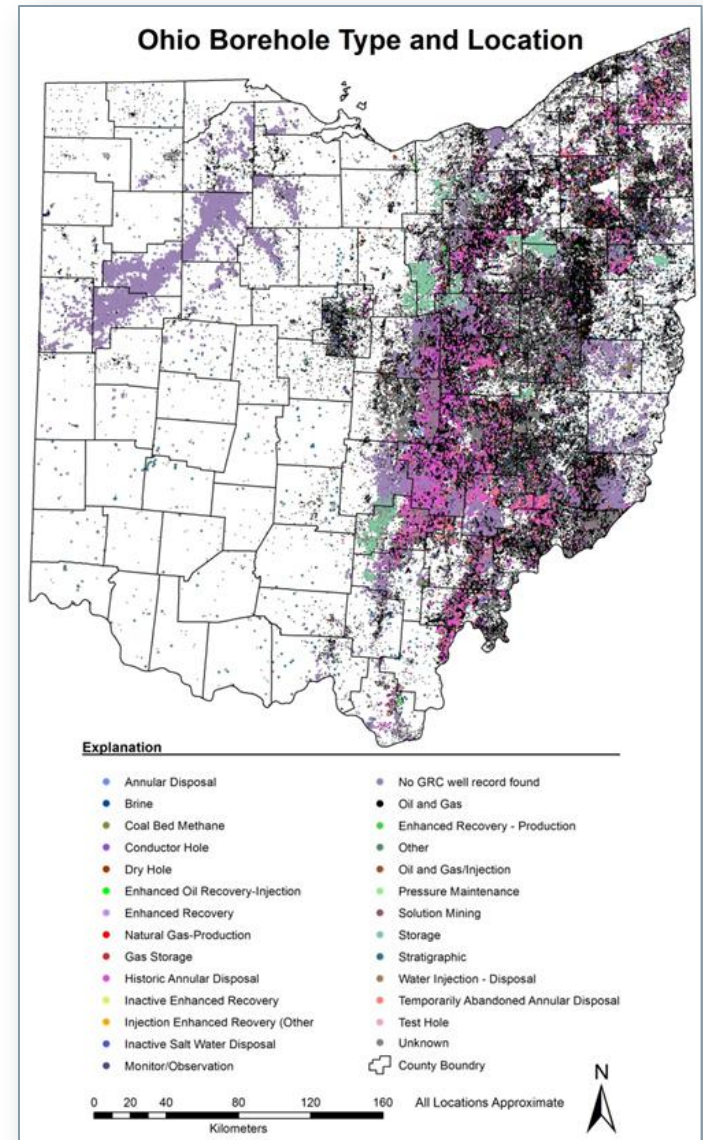
- Battelle involved since the inception
- Oxy-Combustion Repowering with pipeline transport to Morgan County, Illinois site
- Deep saline formation storage
- Battelle leading characterization, monitoring, design for the Alliance
- Storage in the Mt. Simon Sandstone up to 5000' depth
- Front-end engineering design underway (2013) with construction planned to start in 2014



***FutureGen 2.0 Test Well***  
*October 5, 2011*

# Understanding risk from old wellbores is important for safe storage

- Systematic assessment of wellbore integrity for CO<sub>2</sub> storage
- Areas in the Midwest have perceived risk for well integrity due to long drilling history
- However, many of the old wells may not present realistic risk for CCUS b/c they are shallow, depressurized, or properly plugged and abandoned



# Objective is to evaluate well status and specifications for CCS risk mitigation

1

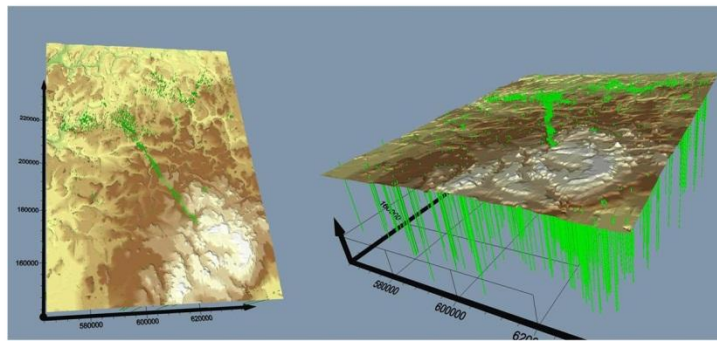
## Field Data



Compile well plugging and abandonment data

2

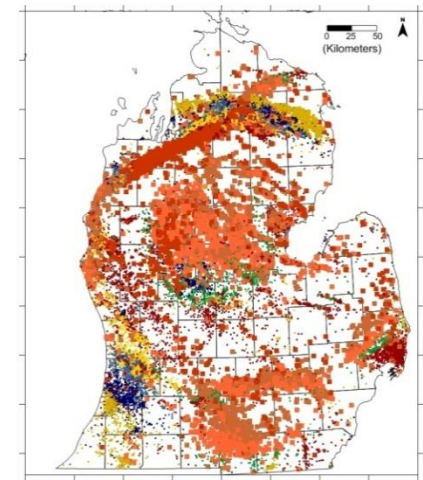
## Case Study Area



Compile cement bond logs

3

## Regional Datasets



Analyze data in terms of depth, age, formation, spatial distribution

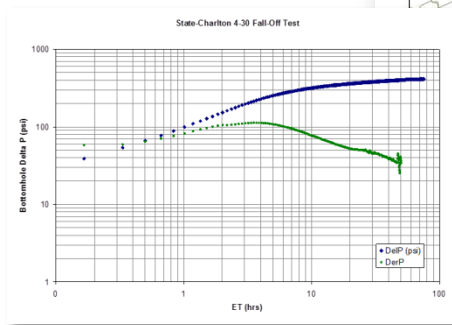
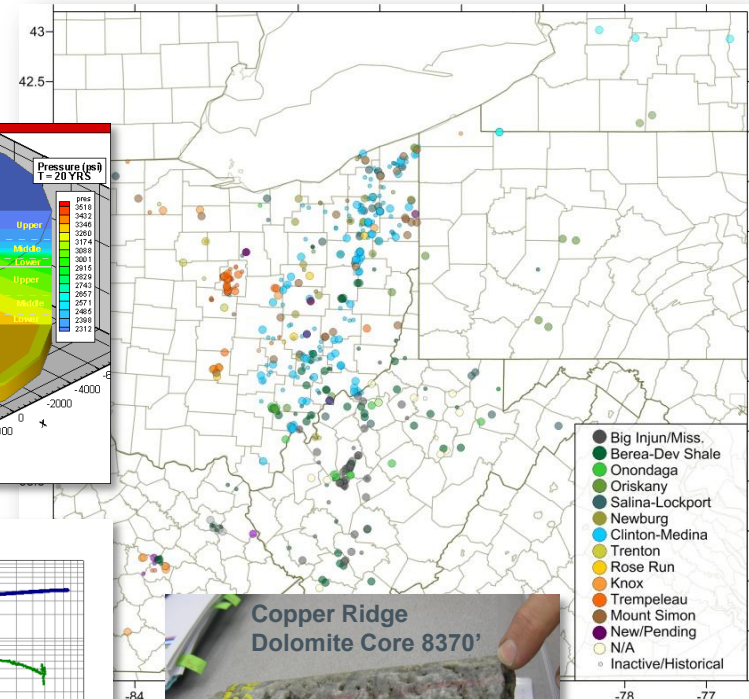
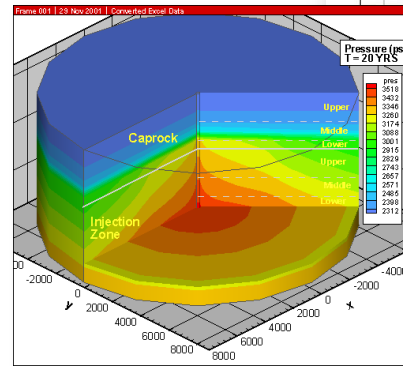
# Development of subsurface brine disposal framework in the Northern Appalachian Basin

- Applying MRCSP knowledge to shale gas environmental issues
- 2-year project funded by DOE through RPSEA
- Evaluate brine disposal capacity, protocols
- Assess safe injection pressure
- Economic issues
- Knowledge sharing with public

**Battelle**



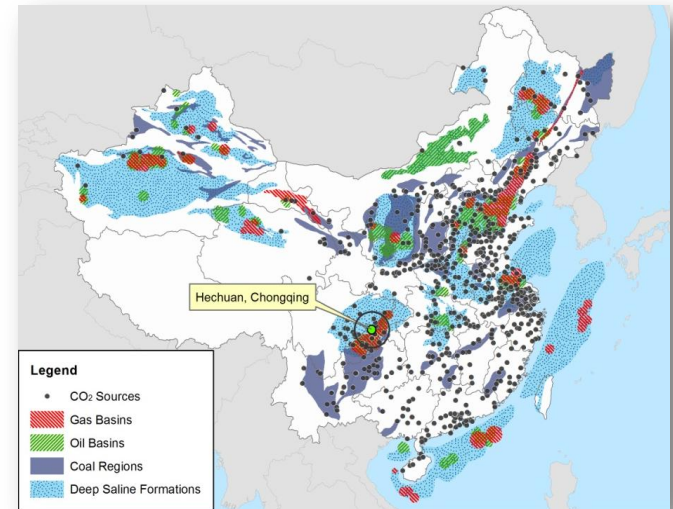
**Research  
Partnership to  
Secure Energy  
for America**





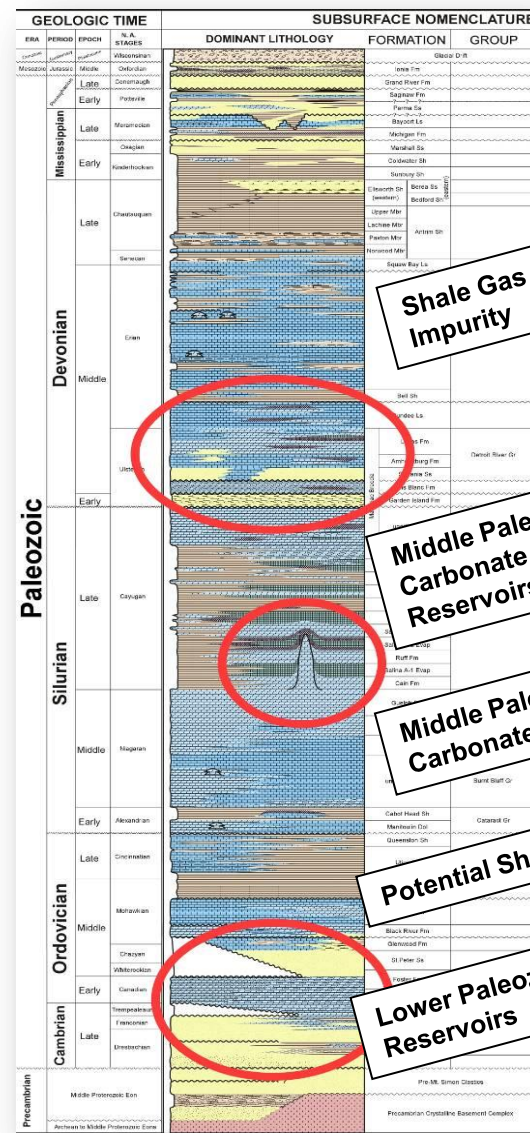
# Battelle selected by World Bank for geologic storage in Sichuan Basin

- Assess the suitability and select potential candidate storage sites near the plant
- Provide training at two capacity building workshops in China
- Facilitate international visits to CCUS sites in the USA
- Collaboration with China Geological Survey



# Future need: addressing multiple demands on subsurface resources

- Shale oil/gas production
- Produced brines disposal
- CO<sub>2</sub> utilization, and storage (CCUS) – mitigating greenhouse gas emissions
- Incremental oil recovery
- Conventional oil/gas production
- All these require integrated long-term management and clear policy on mineral rights, liability, and permitting



Example from Michigan Basin

# Battelle's work with MRCSP will deliver robust carbon emissions reduction strategies

- MRCSP has focused our efforts on carbon capture, utilization, and storage activities
- Novel modeling and MVA techniques will be further tested and validated using nearly depleted oil fields in Michigan
- Lessons learned will contribute to best practices and help to develop regional implementation plans



# Questions?

**Neeraj Gupta, Ph.D.**

Senior Research Leader, Battelle, Columbus, Ohio

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