A Retrospective Accounting of the Midwest Regional Carbon Sequestration Partnership's Technical Achievements and Contributions*

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Abstract

The Midwest Regional Carbon Sequestration Partnership (MRCSP) is a public/private consortium established by the U.S. Department of Energy that has worked to assess the technical potential, economic viability, and public acceptability of carbon utilization and storage within its region for nearly 20 years. The MRCSP region is comprised of three major physiographic regions covering ten states: the Atlantic Plain (Delaware, Maryland, and New Jersey), Appalachian Highlands (Kentucky, Maryland, New York, Ohio, Pennsylvania, and West Virginia) and Interior Plains (Indiana, Kentucky, Michigan, and Ohio). Sometimes referred to as the "boiler room" of the United States, this region generates 24 percent of the nation's electricity, half of which is derived from coal. In addition, the region is home to the modern oil, gas, and petrochemical industries and offers world-class unconventional shale reservoirs. This has uniquely positioned the MRCSP region to leverage industry support in the development of practical carbon management solutions.

In addition to the requisite work of planning and implementing its full-scale implementation project of more than 1,000,000 tonnes of CO_2 stored as part of a CO_2-enhanced oil recovery (EOR) operation in the Michigan Basin, MRCSP has built and maintained a strong coalition of state geological surveys and educational institutions. It is this group of "Geoteam" members with diverse skill sets and areas of expertise who have prepared assessments of regional subsurface geology, addressing stratigraphic correlations across geopolitical boundaries; refined methods for carbon storage resource estimates over time; developed granular data inventories and important data transforms to make the most of publicly available datasets; and provided important stakeholder outreach and engagement. MRCSP Geoteam members prepared the first-ever digital oil and gas fields map of the Appalachian Basin (2005); coordinated the completion and assessment of the first-ever state-funded CO_2 stratigraphic test well in Tuscarawas County, Ohio (2007); provided critical insight regarding CO_2-EOR opportunities in the Appalachian and Michigan basins (2010) even before this was considered a bona fide approach to mitigating carbon emissions; generated the first digital petroleum hydrocarbons geodatabase that spans the entire MRCSP region (2019); and is publishing regional geologic cross sections spanning multiple physiographic provinces to illustrate subsurface geologic, economic, and carbon storage resources to policymakers and the public at large (2019).

References Cited

Rine, M., J. Garrett, S. Kaczmarek, D. Barnes, and W. Harrison III, 2016, A New Model for Niagaran "Pinnacle" Reef Complexes of the Michigan Basin: AAPG 2016 Annual Convention and Exhibition, Calgary, Alberta, Canada, June 16-22, 2016, Search and Discovery Article #51319 (2016). Website accessed July 2020.

Suhaimi, A.A., 2016, Pore Characterizations and Distributions within Niagaran – Lower Salina Reef Complex Reservoirs in the Silurian Northern Niagaran Pinnacle Reef Trend, Michigan Basin: M.S. Thesis 710, Western Michigan University, Kalamazoo, MI.

A Retrospective Accounting of the Midwest Regional Carbon Sequestration Partnership's Technical Achievements and Contributions

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Neeraj Gupta, Battelle Memorial Institute

October 15, 2019

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  - Delaware - Mike Fulton, Mojisola KunleDare, Peter McLaughlin, David Wunsch
  - Indiana - Kevin Ellett, Cristian Medina, John Rupp
  - Kentucky - Stephen Greb, David Harris, Brandon Nuttall, Thomas Sparks
  - Maryland - David Andreasen, David Brezinski, William Junkin, Rebecca Kavage-Adams, Richard Ortt, Jr., Heather Quinn, Andrew Staley
  - Michigan - Dave Barnes, Andrew Caruthers, Jon Garrett, William Harrison, III, Matthew Rine, Jenny Trout
  - New Jersey - Alexandra Adams, Kim Baldwin, James Browning, Leslie Jordan, Christopher Lombardi, Kenneth Miller, Gregory Mountain, William Schmelz, Ying Fan Reinfelder
  - New York - Brian Slater
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  - Pennsylvania - Robin Anthony, Kristin Carter, Michele Cooney, Brian Dunst, John Harper (ret.) Katherine Schmid, Stephen Shank, Ion Simonides
  - West Virginia - Gary Daft, Philip Dinterman, Michael Hohn, J. Eric Lewis, Ronald McDowell, Jessica Moore, Susan Pool
- **Battelle project direction**: Neeraj Gupta, Lydia Cumming, Joel R. Sminchak, Autumn Haagsma
- **U.S. DOE NETL program management**: Andrea McNemar

DOE-NETL Cooperative Agreement DE-FC26-05NT42589

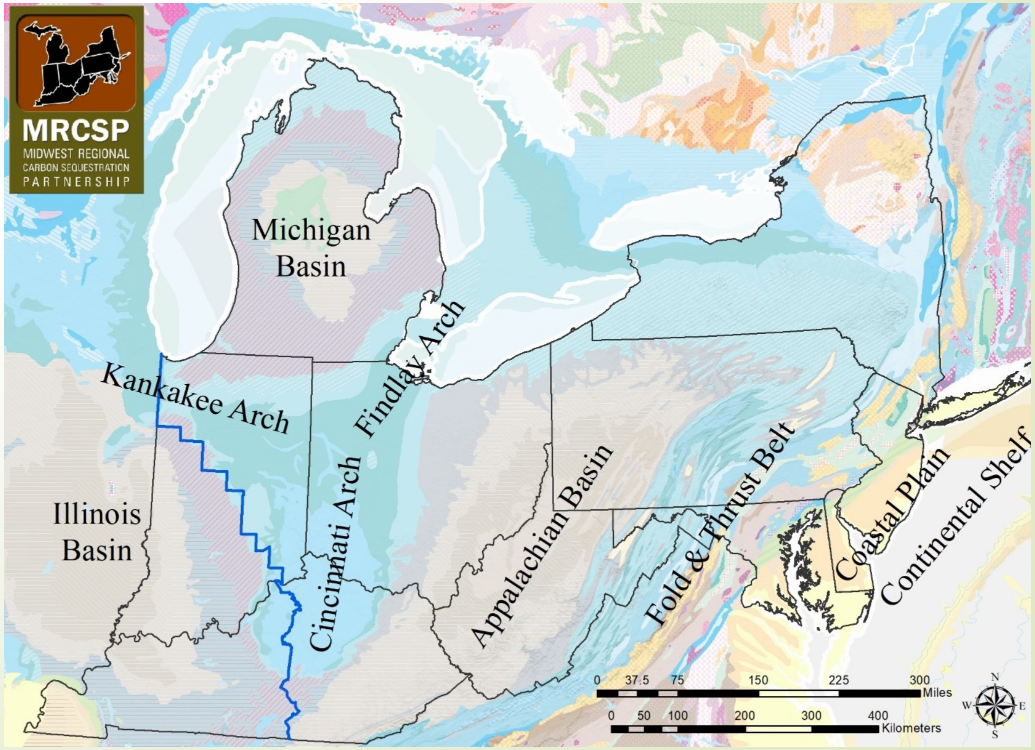
MRCSP
MIDWEST REGIONAL CARBON SEQUESTRATION PARTNERSHIP

Today's Focus

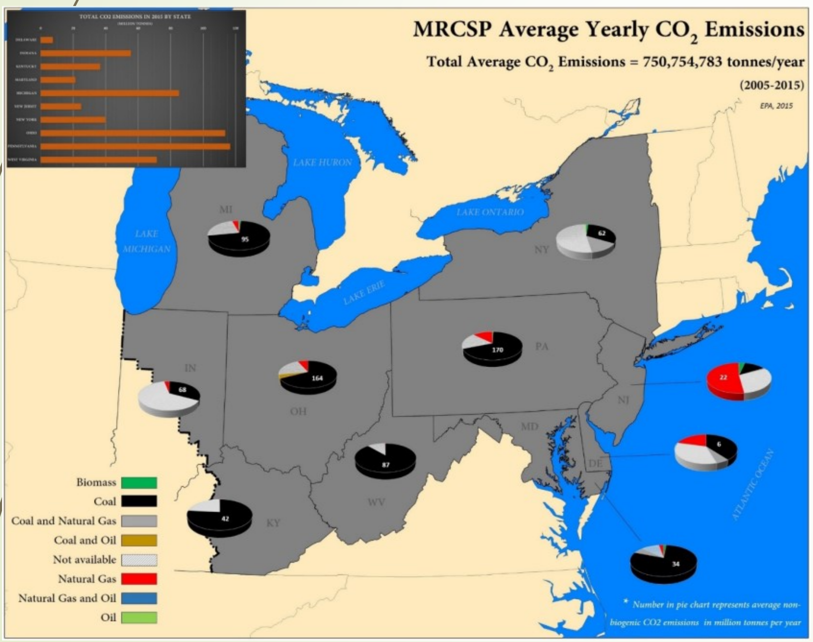
- MRCSP geographic footprint
- Geoteam history
- Successes and firsts
- CO_2-EOR
- Our future impact

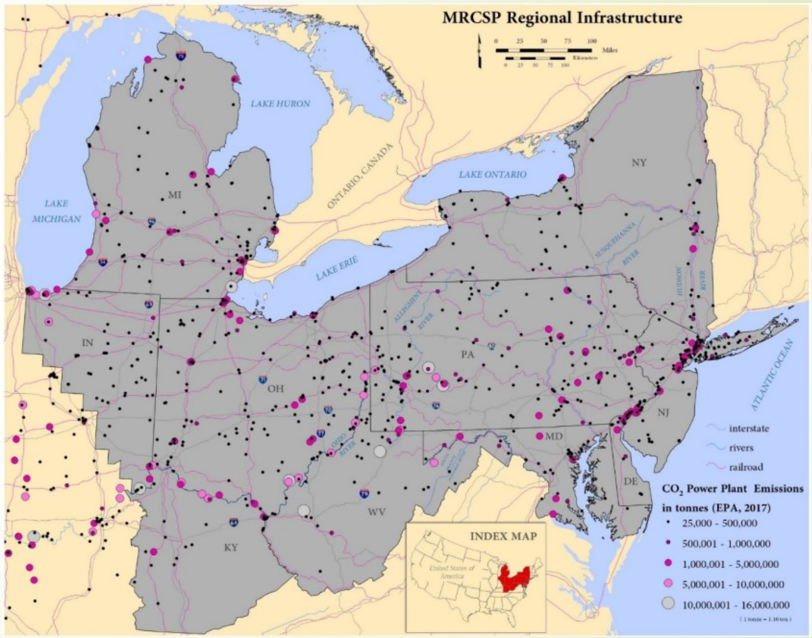
MRCSP Region

- Grown from 5 to 10 states over the past 16+ years
- Three physiographic regions: Atlantic Plain, Appalachian Highlands, Interior Plains
- Four subregions: Michigan Basin, Arches Province, Appalachian Basin, Coastal Plain and Mid-Atlantic U.S. Offshore



Regional Power Plant Emissions and Infrastructure





Historical Snapshot of MRCSP – 16+ Years of CCUS Innovation

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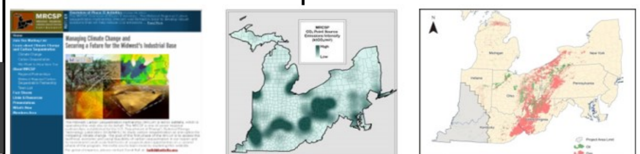
2003 | 2004 | 2005 | 2006 | 2007 | 2008 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 | 2018

Phase I
Characterization



Phase II
Small Scale Validation

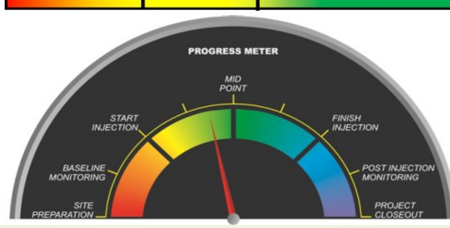
Phase III
Large Scale Development Project

Site Selection, Permitting, Site Characterization, Site Preparation, and Baseline Monitoring

OH Site | MI Saline | MI EOR Fields

MI Injection Operations (multiple fields)
- Late-stage EOR reef
- Operational EOR reef
- Newly targeted reef

Post Injection Monitoring



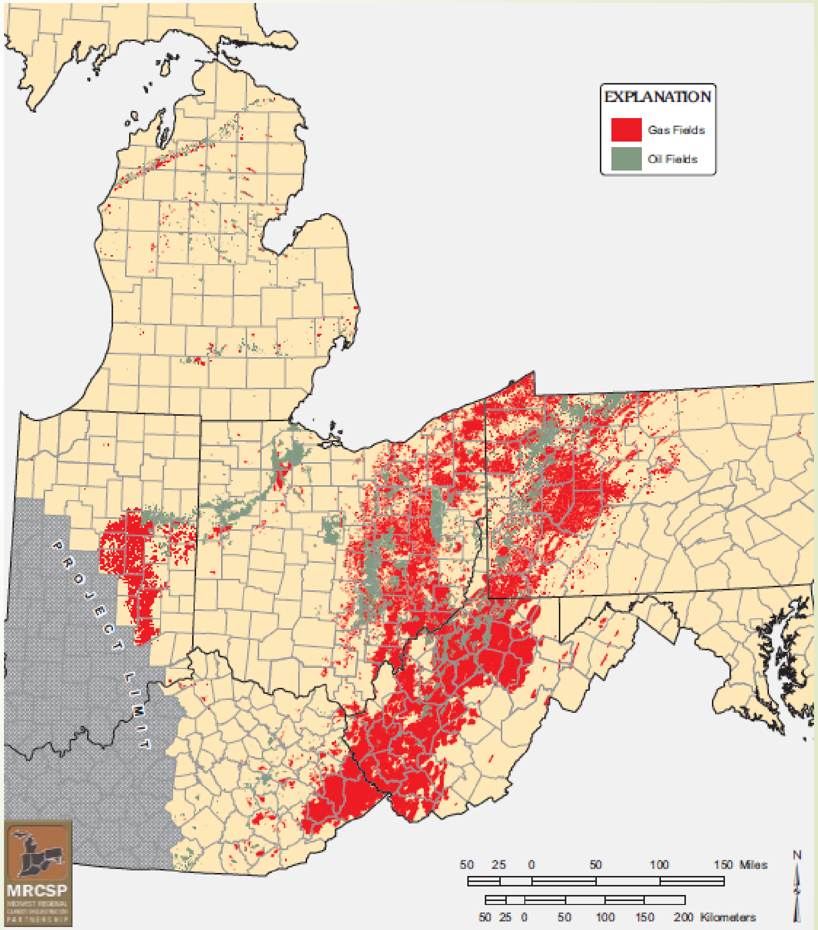
Project updates and results can be found at www.mrcsp.org

Phase I (2003-2005): A Series of Regional Firsts

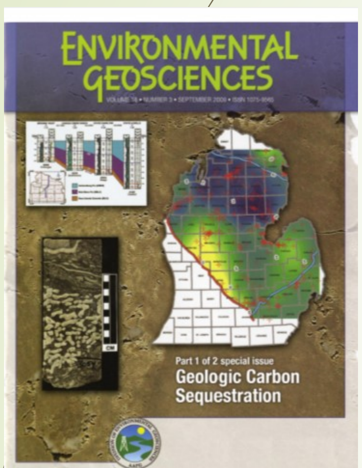
- Seven states working together for the first time, tackling mapping efforts for more than one basin
- Digital data compiled into consistent format, and the first such effort for Maryland, Michigan, Pennsylvania and West Virginia
- Comprehensive GIS database (>50 maps)
- First time that regional mapping had been conducted for some intervals (e.g., basal Cambrian sandstone)

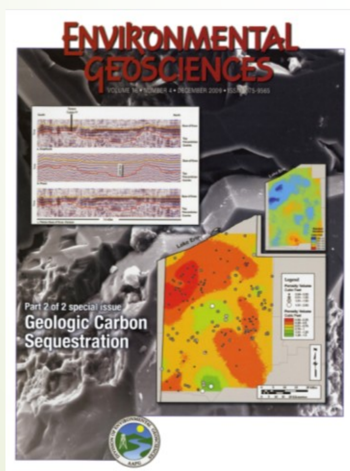
Appalachian Basin Oil and Gas Fields Map (2005)

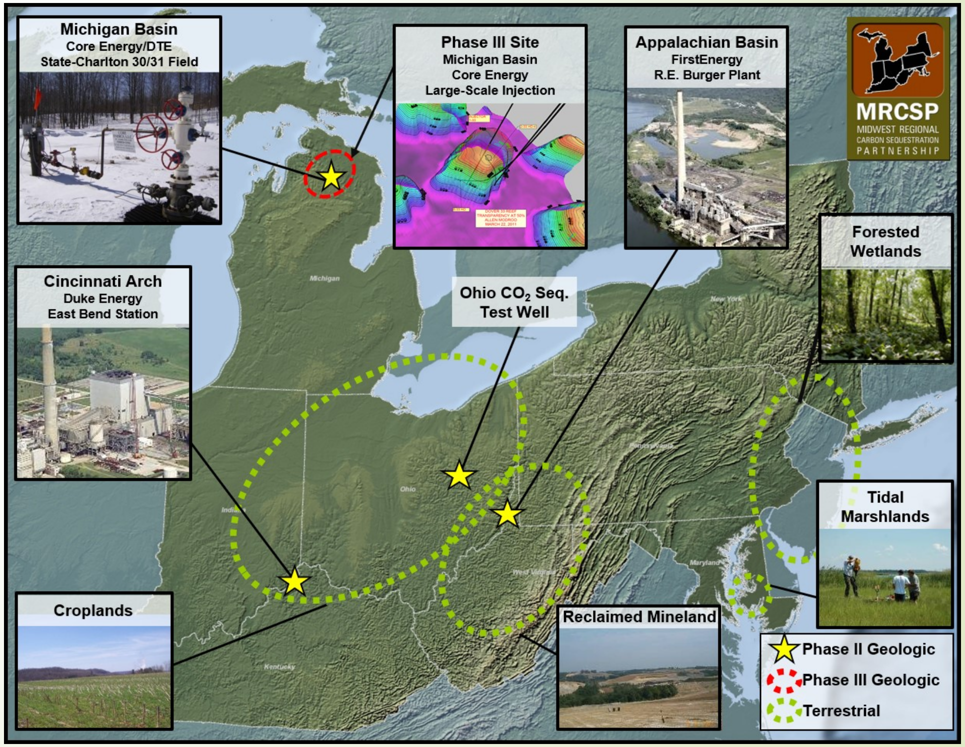
- Fields producing oil and/or gas
- First digital compilation of this type for some partner states
- Subsurface geology and reservoir activity crossing state lines
- Massive footprint compared to western portion of partnership area



Phase II (2005-2009): From Characterization to Validation

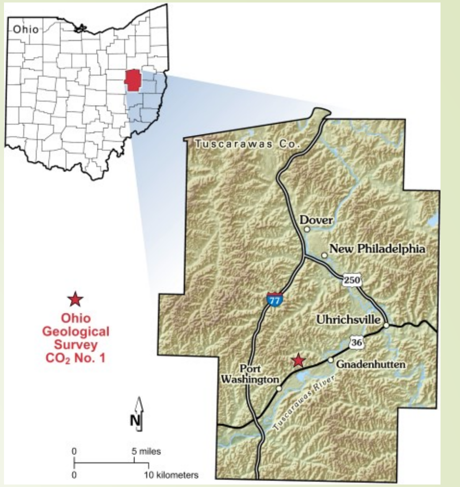


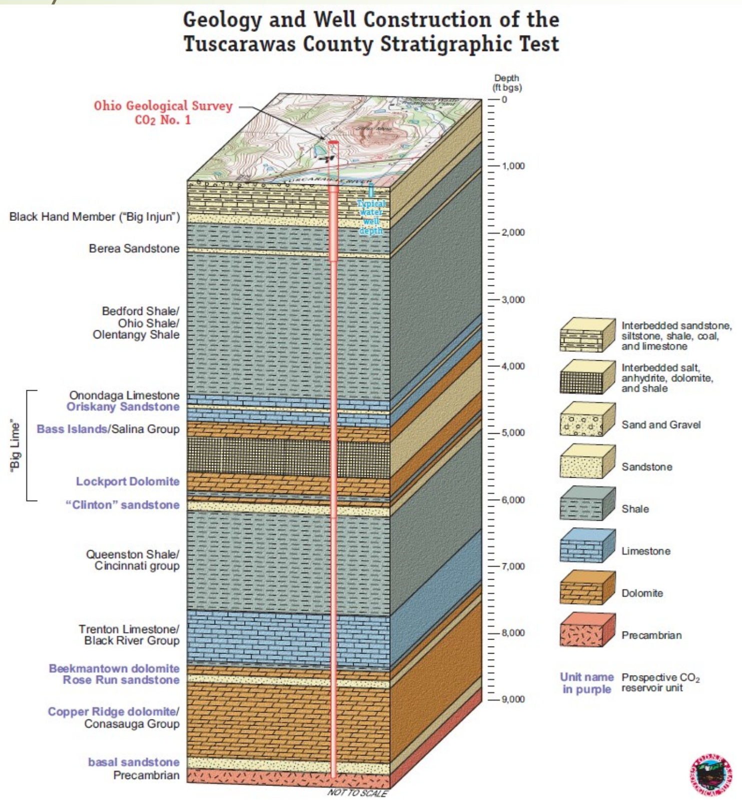




September and December 2009 issues

Tuscarawas County CO_2 Stratigraphic Test Well (2007)

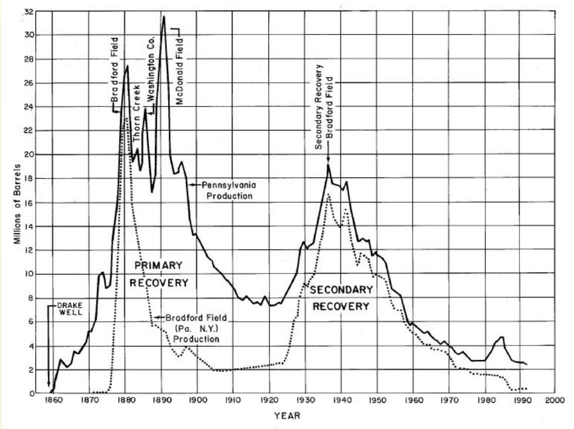


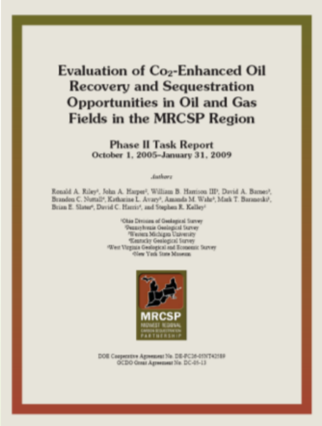


- Collaborative effort among the Ohio Division of Geological Survey, Ohio Air Quality Development Authority, MRCSP and Battelle
- Test well completed to the Precambrian (8695 ft)
- Geophysical logging and sidewall coring
- Injectivity testing and pressuring monitoring of Rose Run and basal Cambrian sandstone
- Rose Run avg ϕ 9.5%, K 1-26 mD
- Basal Cambrian sandstone avg ϕ 10%, max K 1.0 mD

CO_2-EOR Prospects for the Appalachian and Michigan Basins (2005-2010)

- Concerted effort to document enhanced recovery projects for the region
- Particularly helpful for the Appalachian basin, as EOR was born here and many projects have been completed since the mid 1800s





Evaluation of CO_2-Enhanced Oil Recovery and Sequestration Opportunities in Oil and Gas Fields in the MRCSP Region

Phase II Task Report
October 1, 2005–January 31, 2009

Authors

Ronald A. Riley, John A. Harper, William B. Harrison III, David A. Barnes, Brandon C. Nuttall, Katharine L. Avary, Amanda M. Wahr, Mark T. Baranoski, Brian E. Slater, David C. Harris, and Stephen R. Kelley

Ohio Division of Geological Survey
Pennsylvania Geological Survey
Western Michigan University
Kentucky Geological Survey
West Virginia Geological and Economic Survey
New York State Museum

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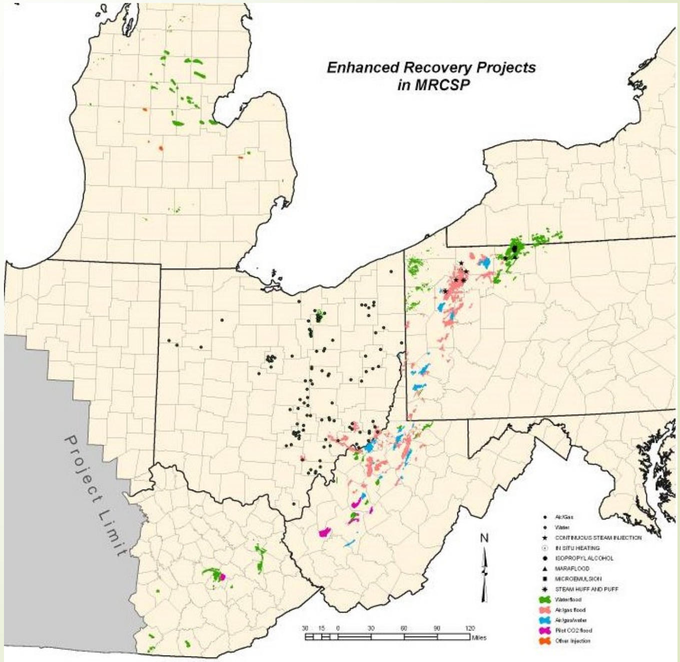
DOE Cooperative Agreement No. DE-FC26-05NT42589
OCDO Grant Agreement No. DC-05-13



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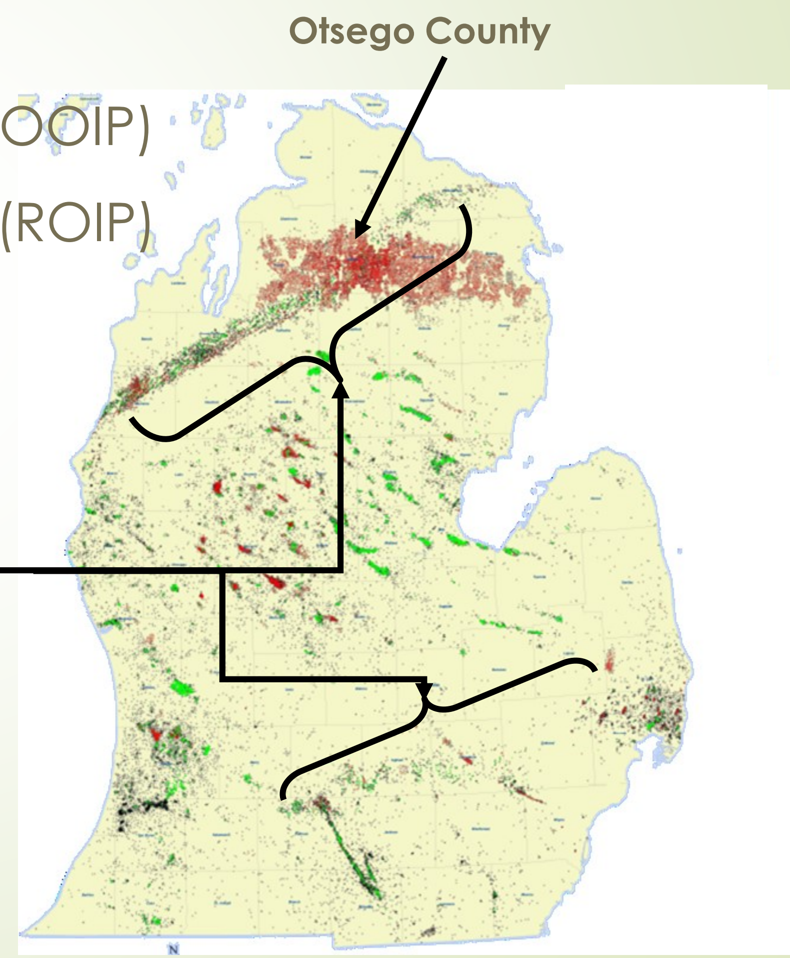
Michigan Basin EOR Prospects (ca 2006)

Michigan Oil Fields

~ 3.5 Billion Original Oil in Place (OOIP)

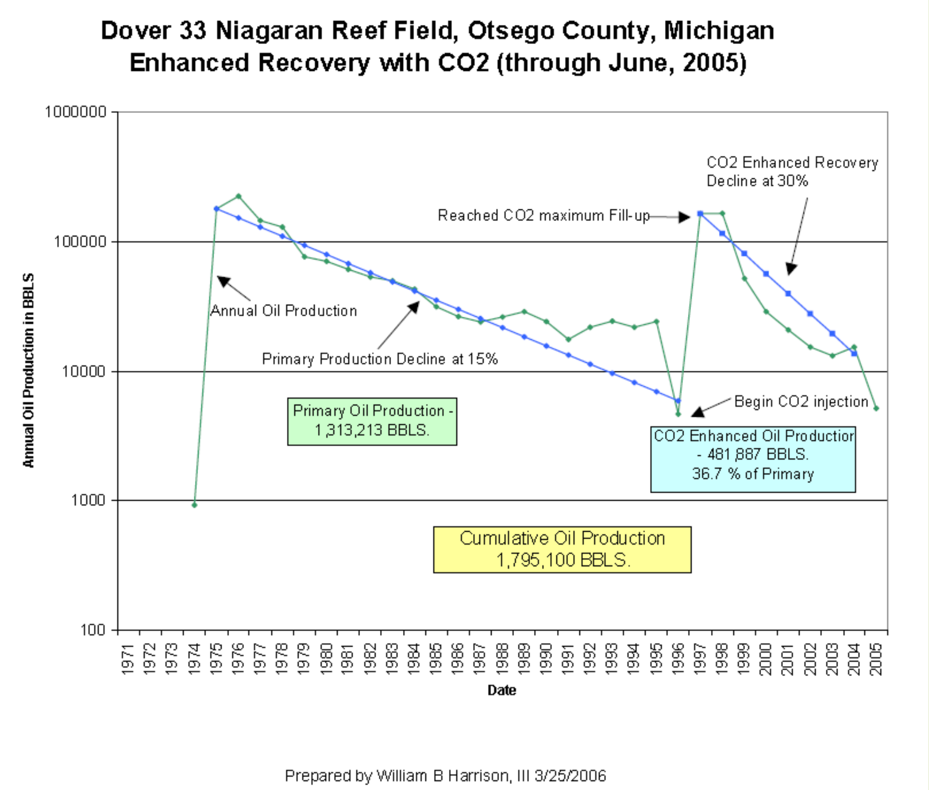
~ 2.3 Billion Residual Oil in Place (ROIP)



Niagaran Reefs
~1,200 pools
Cumulative production **~400 MMBO**
ROIP **~1.2 BBO**

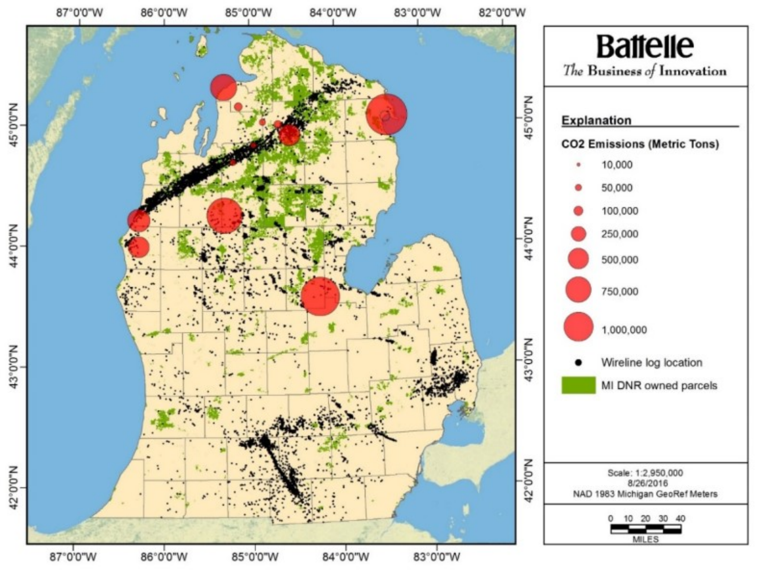
Michigan Basin Reef Characterization

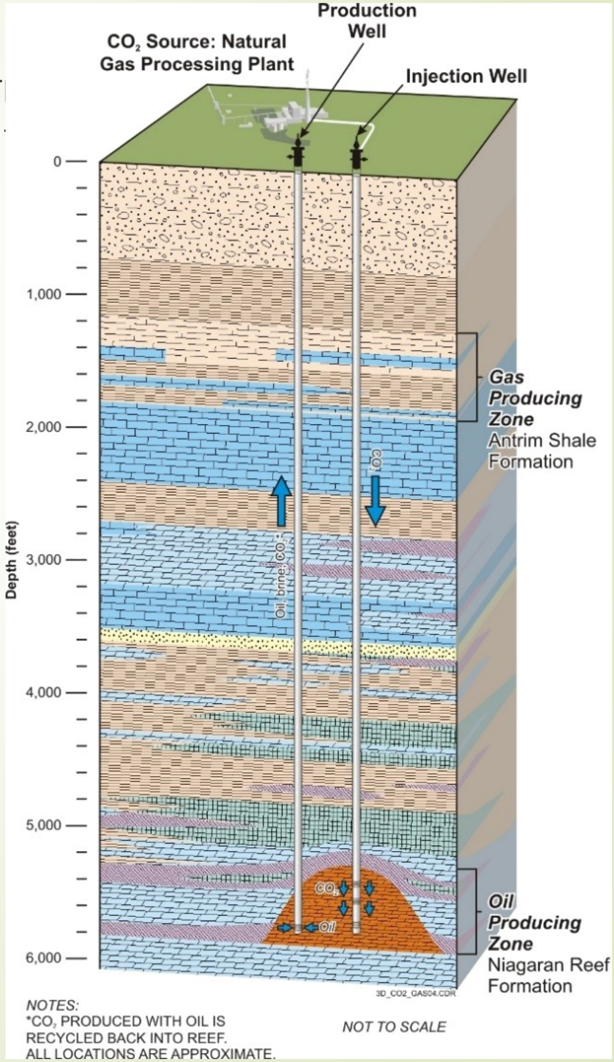
- Collaboration with Core Energy
- Ultimately selected the Northern Niagaran Pinnacle Reef Trend (NNPRT) for the partnership's full-scale implementation project



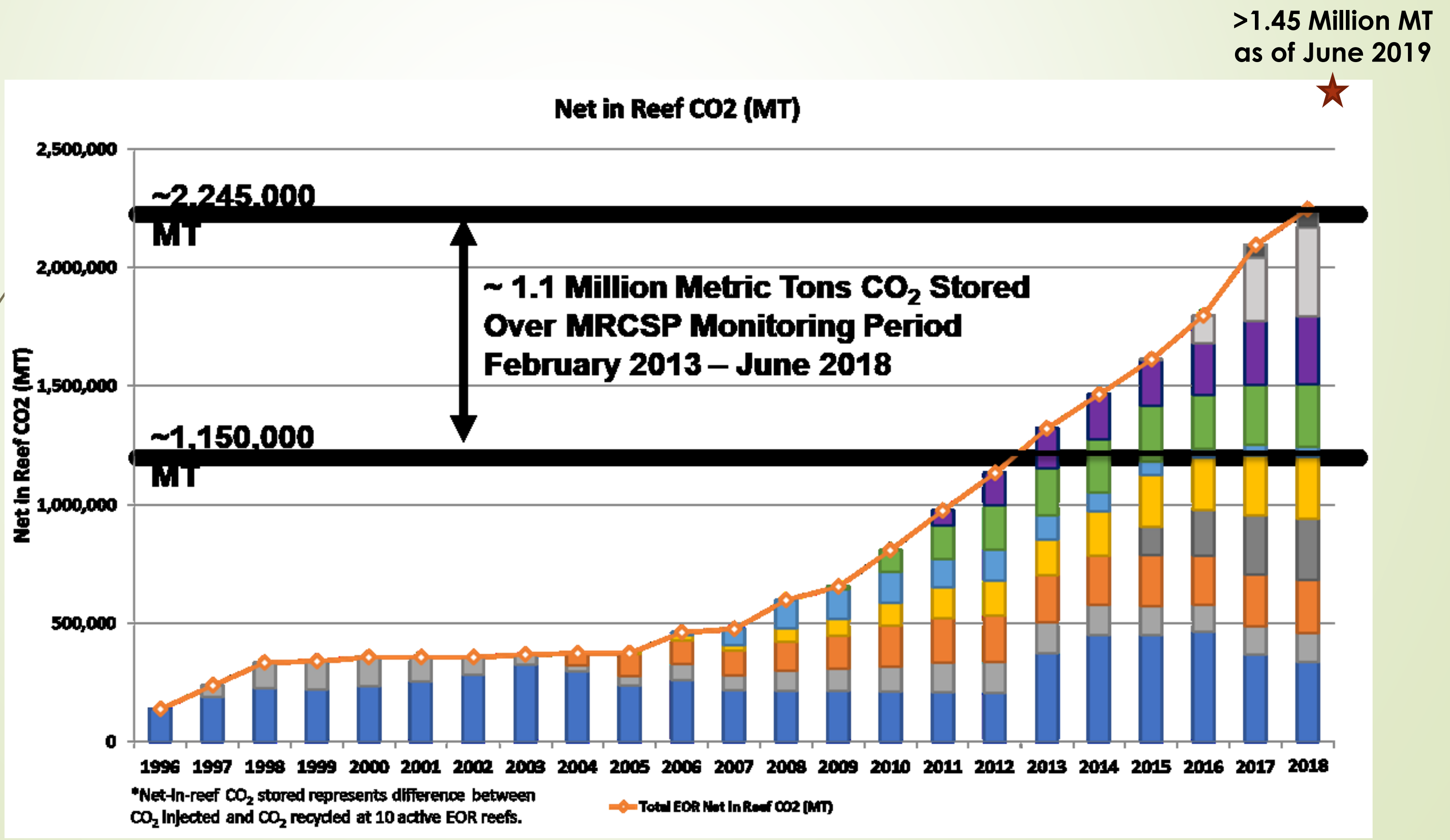
MRCSP Basin Large-Scale Injection

- Objective – Inject/monitor 1 million met of CO_2 in collaboration with EOR opera
- Evaluate CO_2 injectivity, migration, containment
- Evaluate regional storage resources
- Outreach and knowledge shared

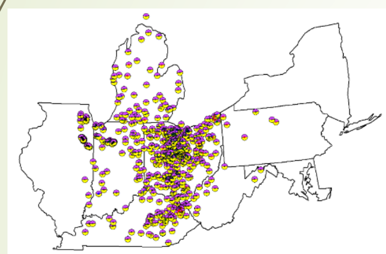




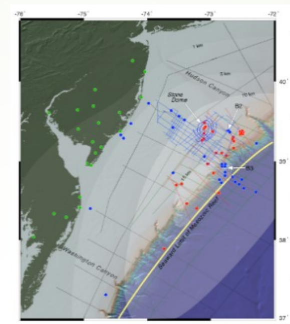
Net CO_2 Storage Exceeds 1 Million Metric Tons as of June 2018



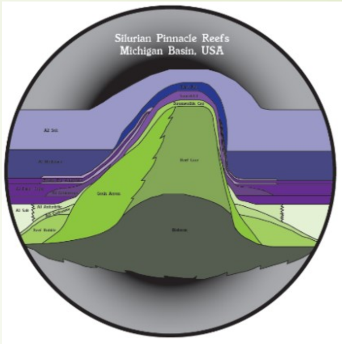
Phase III Regional Characterization: Topical Areas



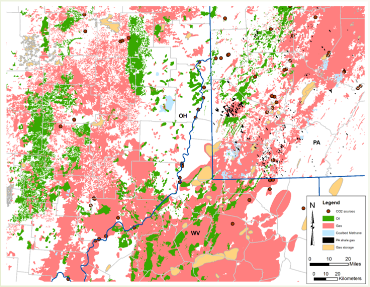
Cambro-Ordovician Storage Potential



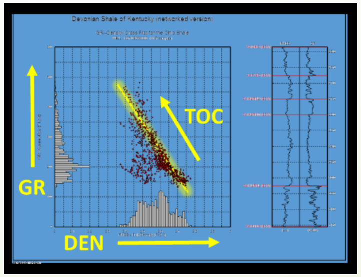
East Coast Offshore and Onshore Storage Targets



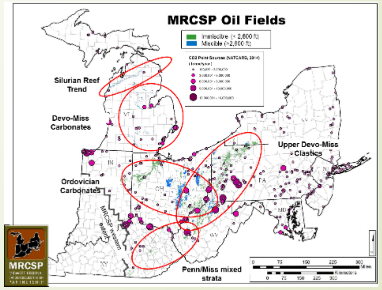
Silurian Pinnacle Reef Reservoirs



CCUS Opportunities in Appalachian Basin



Storage and Enhanced Gas Recovery for Organic-Rich Shale



Reservoirs for CO_2-EOR, EGR and Other Commercial Uses

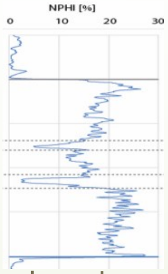
Regional Characterization Strategy

- **Goals**
  - To establish the fundamental geological factors needed to effectively contain large volumes of CO_2 in the subsurface of the Midwest Region
  - To qualify what volumes, where and how CO_2 can be stored
- **Objectives**
  - Assess potential reservoirs and seals in the region
  - Determine the type of storage (saline, EOR or EGR reservoirs)
  - Quantify potential storage resources in the region
  - Generate products essential for siting, performance modeling and monitoring, verification, accounting (MVA)

Cambro-Ordovician SRE Methods

Increasing sophistication/complexity of porosity data

Method 1	**Method 2**	**Method 3**	**Method 4**	**Method 5**	**Method 6**
Assumes ϕ = 10% Similar to DOE method	Uses average porosity from core analysis	Uses porosity from wireline logs	Uses a diagenetic model that assumes an exponential decrease of porosity as a function of depth	Uses MICP-data to define petrofacies models	SRE calculated using NETL's CO_2 Storage prospeCtive Resource Estimation Excel aNalysis (SCREEN)
Robust dataset	Limited data	Robust dataset	Robust dataset	Limited data	Robust dataset

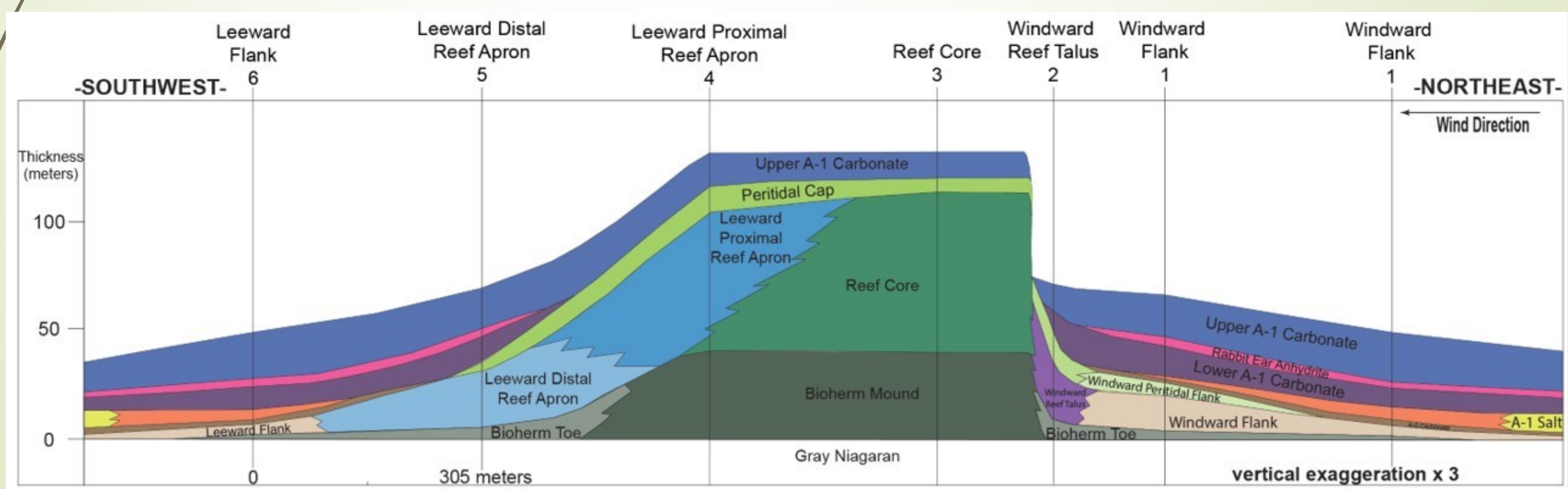


Silurian Pinnacle Reef Reservoirs

- **Approach**
  - Develop static geological reservoir model(s) based on field analogs that are data-rich, including abundant core and log data; define reservoir and non-reservoir facies
  - Apply model(s) to less data-rich fields that have some core or log data; estimate reservoir volume for each facies
  - Apply reservoir properties (porosity and permeability) to each facies to be derived from core and log analysis in analog fields; calculate total facies volume and potential reservoir pore volume
- **Results and Value**
  - Geological facies models constructed for multiple fields
  - Facies volume calculated for modeled fields

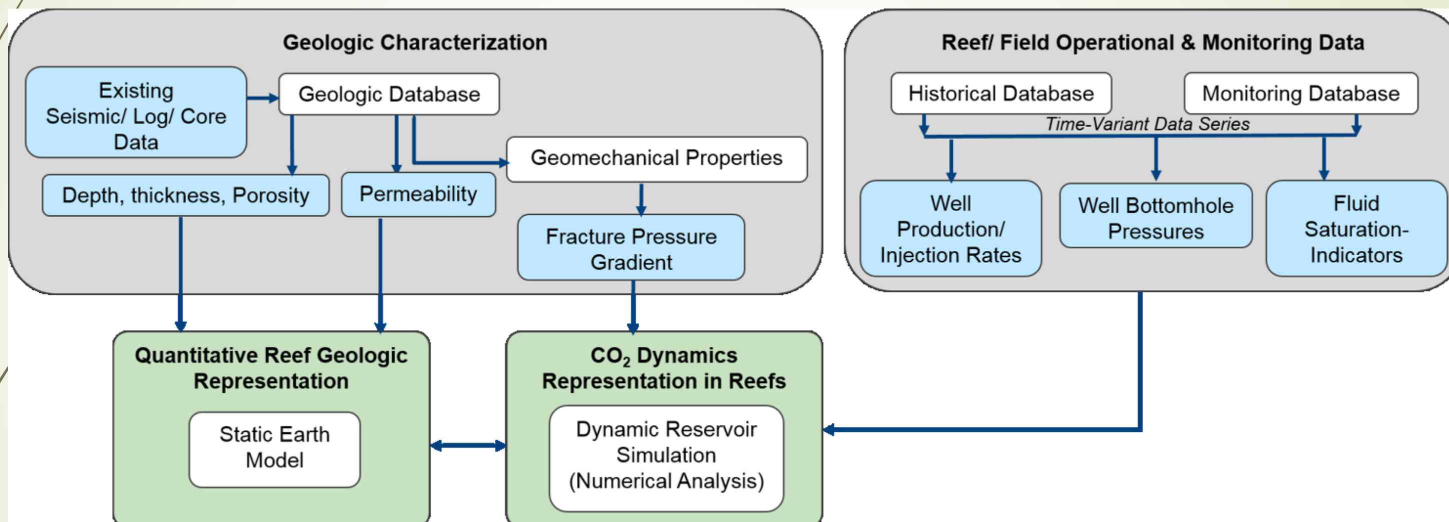
Geological Facies Models for Silurian Pinnacle Reef Reservoir Complexes

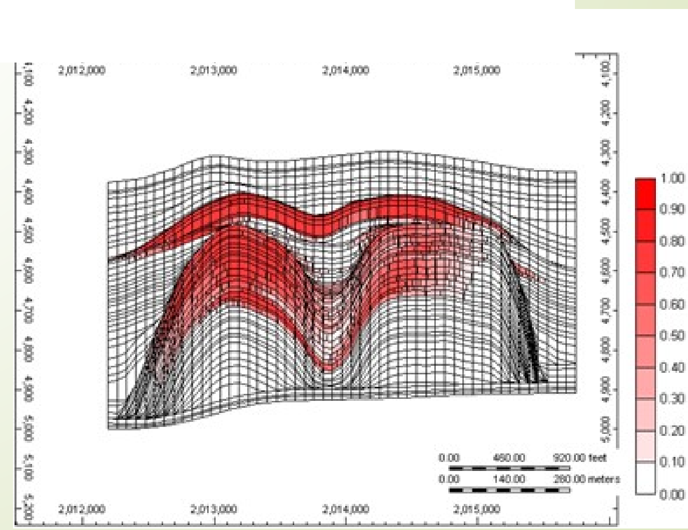
- WMU has identified these as **highly asymmetrical** in overall geometry (~15º leeward slopes, ~45º windward slopes)
- Reef complexes also display **windward-leeward internal facies architecture** – allows for **prediction of facies spatial distribution**
- Facies have distinctively different dominant pore-throats/sizes (Suhaim, 2016, M.S. thesis), and in turn distinct **porosity-permeability distributions**



Asymmetrical reef model (Rine et al. 2016)

Geologic Data Informs Modeling Efforts





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Improved Workflow for Static Earth Models

Polygons

Surfaces

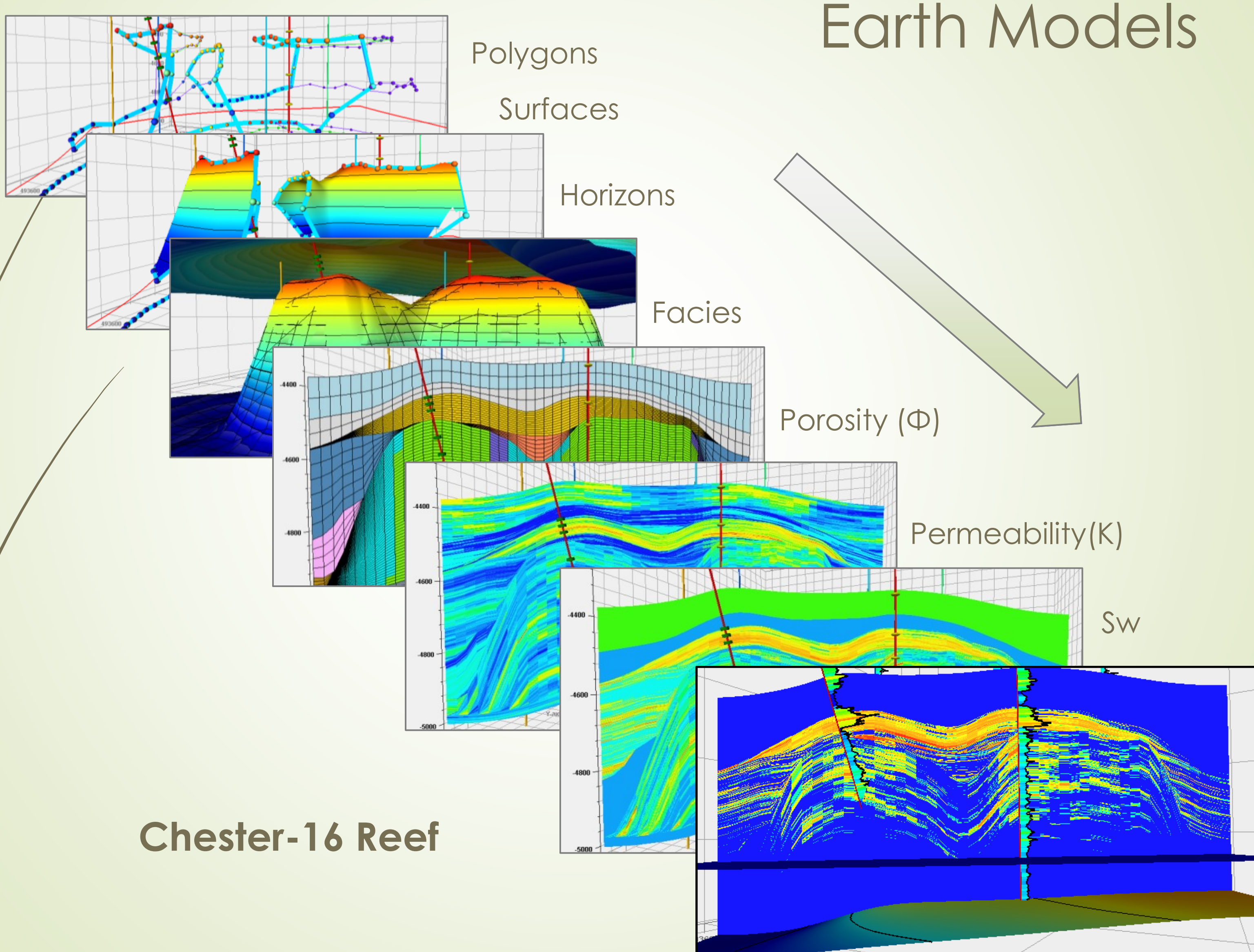
Horizons

Facies

Porosity (Φ)

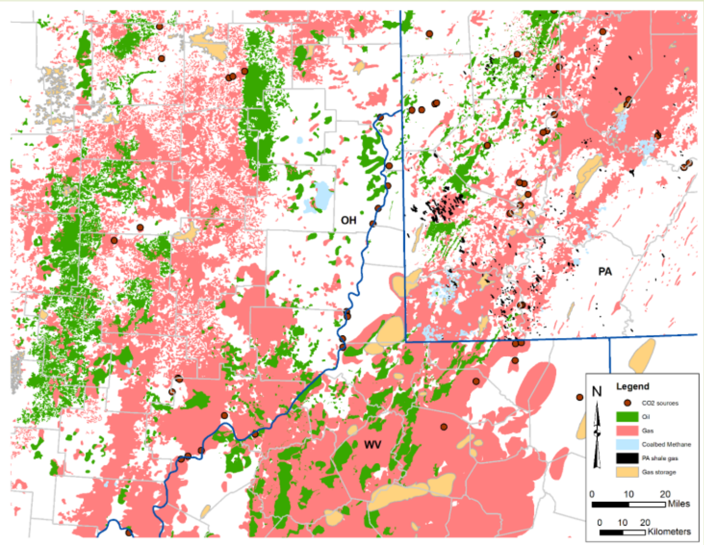
Permeability(K)

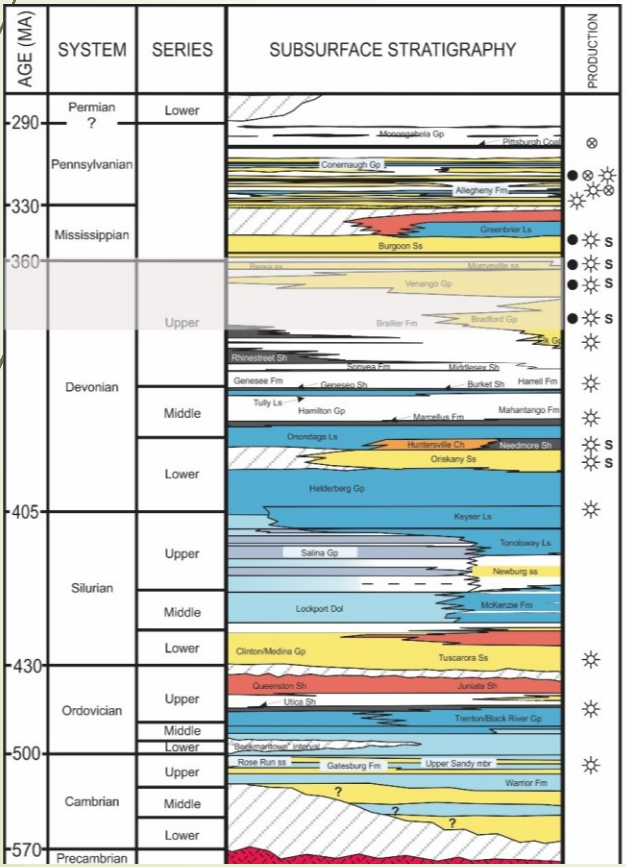
Sw



Chester-16 Reef

CCUS Opportunities in the Appalachian Basin

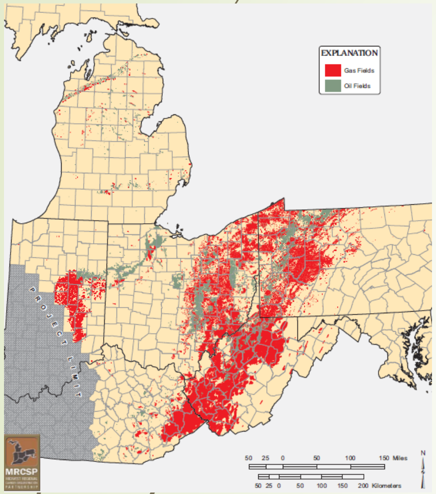


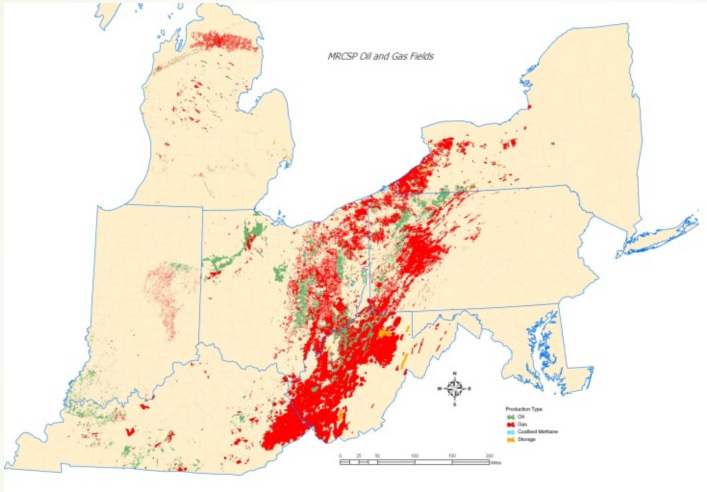


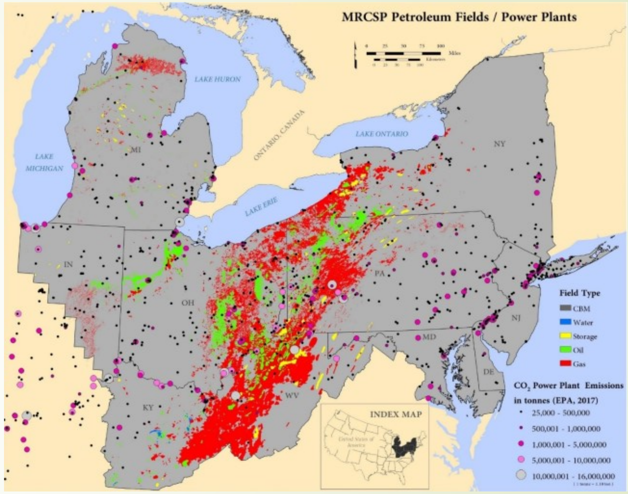
Immiscible/ miscible depth range

- ***Immiscible opportunities*** include shallow oil and gas reservoirs, as well as abandoned natural gas storage fields
- A majority of ***miscible opportunities*** are comprised of natural gas reservoirs, with a limited number of gas storage fields
- ***Stacked opportunities*** refer to two or more reservoirs layered on top of one another (at least in part) within the same geographic area

Evolution of the Petroleum Fields Database (2019)



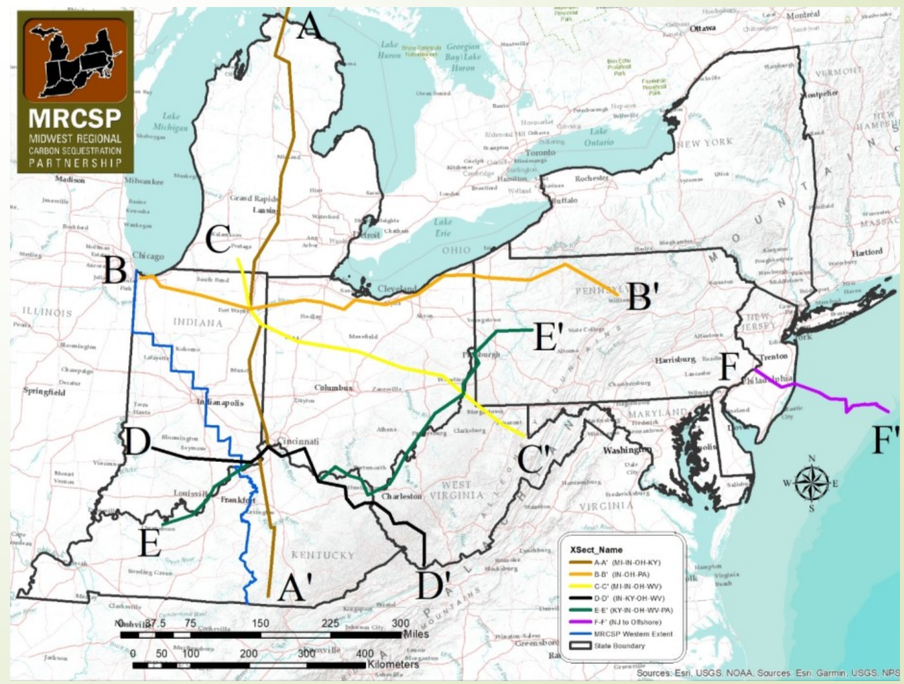




- 7 to 10 states
- More types of fields
- More current field accounting
- More granular field-level attributes

Regional Geologic Cross Sections

- Six cross sections spanning multiple physiographic provinces
- Depth, thickness and extent of subsurface geologic formations that may be used for carbon storage
- Meant for multiple audiences, including government, policymakers and public



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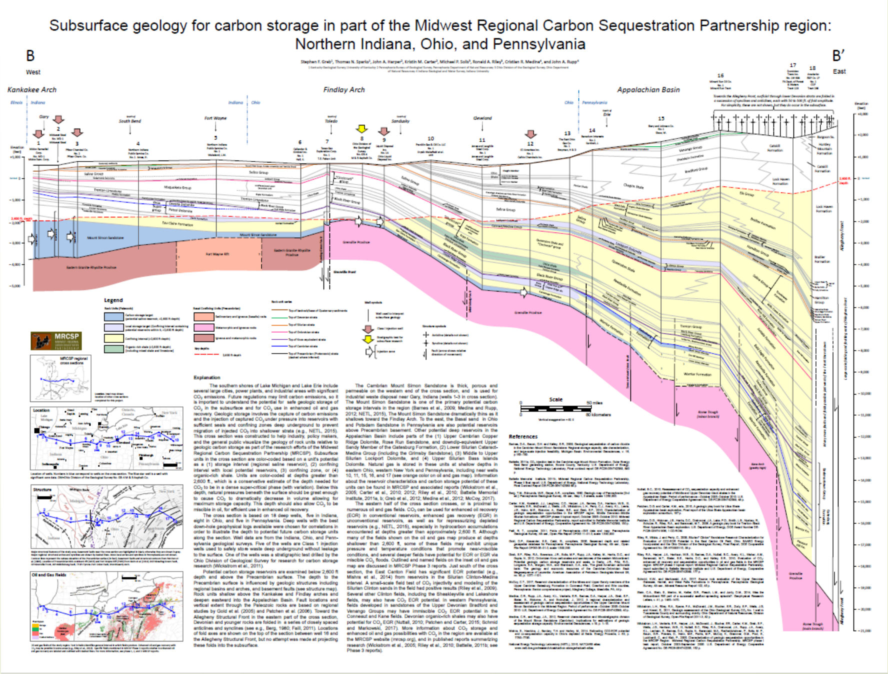
Northern Section – Northern Indiana, Ohio and Pennsylvania

- B – B' (west to east)
- Geology (exaggerated but to scale)
- Color-coded geologic intervals and bounding lines
- Multiple deep well control points
- Area inset maps (location, structure and oil and gas fields)
- Written explanation with references



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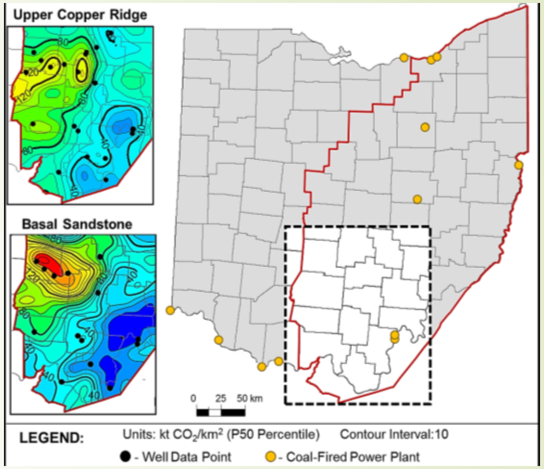
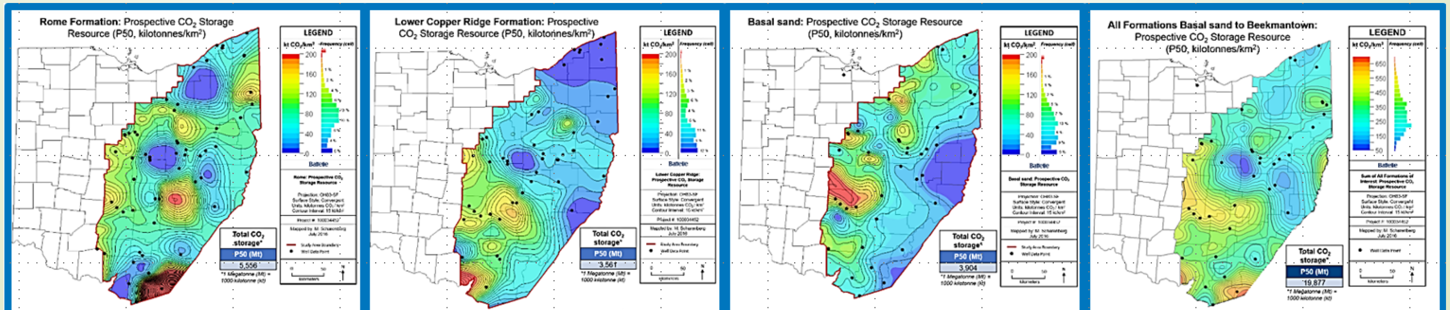
Associated Complementary Projects: Regional Assessment in Eastern Ohio – Calculation of Prospective Stacked CO_2 Storage Resource

- Static modeling exercises used to define geologic storage framework
- Calculation of CO_2 storage resource for two major deep saline formations shows suitable storage potential
- Storage resource maps show the spatial distribution and opportunities for stacked storage

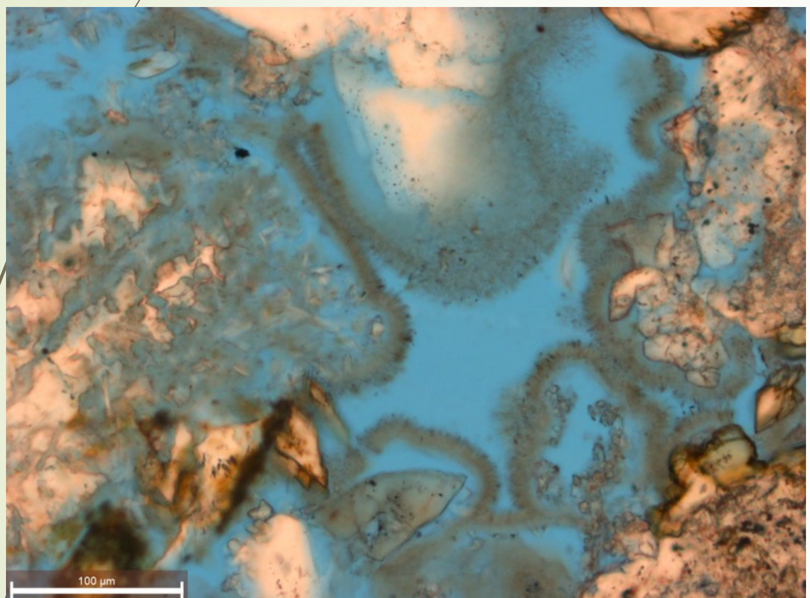




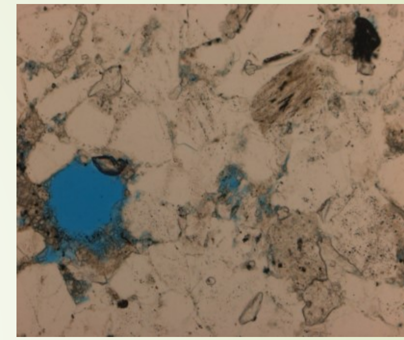
Rome Formation P50 Prospective Resource | Lower Copper Ridge Formation P50 Prospective Resource | Basal sand Formation P50 Prospective Resource | All Reservoirs in Study P50 Prospective Resource

Co-Funded by ODSA/OCDO Project D-13-22

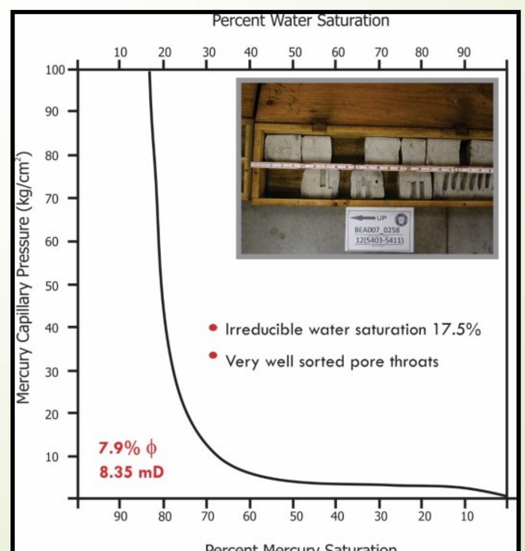
Associated Complementary Projects: Mid-Atlantic U.S. Offshore Carbon Storage Resource Assessment



Logan Canyon Sandstone (COST B-2)
~18% ϕ and 21 – 27 mD permeability



Oriskany Sandstone ~8% ϕ
(Wood County, WV)

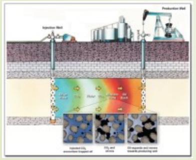


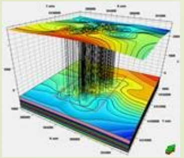
Oriskany Sandstone
Beaver County, PA

Our Future Impact

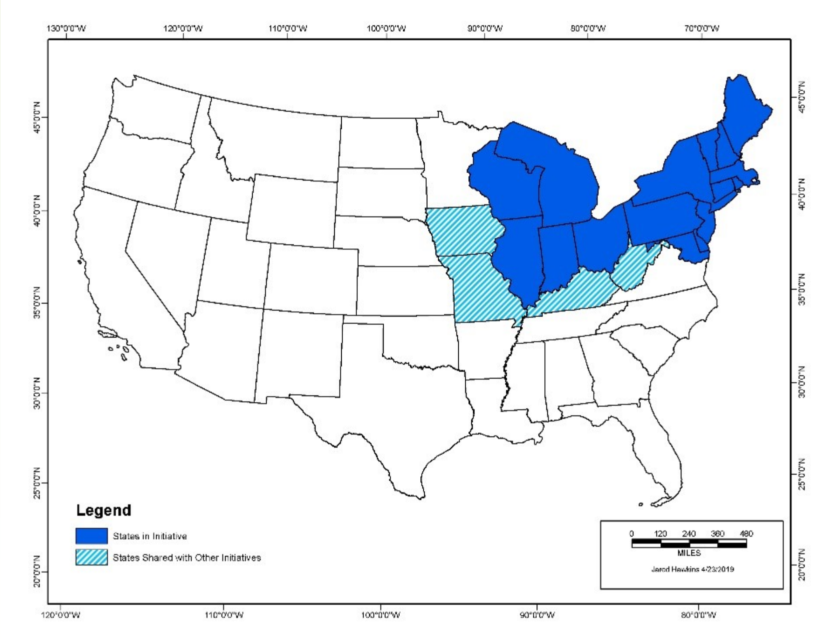

CARBON


CAPTURE


UTILIZATION


STORAGE

- Bigger geographic footprint
- Match source to sinks
- Responsible infrastructure placement and usage
- Stacked potential
- Utilization AND storage



Source Type	2017 Emissions (MMt)	% of Total
Power Plant	694	73%
Metals	72.5	8%
Minerals	44.4	5%
Chemicals	38.3	4%
Petroleum, Natural Gas, and Refineries	28.4	3%
Other	28.0	3%
Ethanol	16.9	2%
Pulp and Paper	10.7	1%
Waste	7.9	1%
Manufacturing	3.5	<1%
TOTAL	945	-

Questions?

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