Utilizing Midwest's Subsurface for Effective Mitigation of Greenhouse Gases, Produced Waters Disposal, and Enhancing Oil/Gas Production*

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Abstract

The last decade has seen revolutionary changes in the utilization of subsurface space and resources due to emphasis on use of pore-space for oilfield brine disposal, CO_2 storage for greenhouse gas mitigation, CO_2 utilization for enhanced oil recovery (EOR), and shale gas extraction from unconventional reservoirs. Such multi-purpose utilization of strata in the geologic column is sometimes occurring in the same area. For example, in northern Michigan, CO_2 produced as impurity in Antrim Shale has been used for CO_2 EOR in Niagaran Reefs and for testing of CO_2 storage in the Bass Island Dolomite zones; produced brine is injected into multiple intermediate zones; and exploration is underway for deep shale gas zones. Similar scenarios may evolve in northern Appalachian, especially in eastern Ohio, due to a growth in unconventional Utica Shale production, need for disposal of brines and flowback waters, possibility of CO_2 utilization in depleted oilfields like the East Canton Oil Fields, and possible CO_2 storage in deep saline formations in the Cambrian layers. This presentation summarizes Battelle's recent work in characterization of multiple zones in Eastern Ohio; it has a goal of identifying and quantifying geologic injection capacity and assessment of options for EOR. Synergistic characterization strategies that leverage ongoing drilling and testing are presented. For example, exploration for CO_2 sequestration horizons through flowmeter logging is being done in brine disposal wells in eastern Ohio. In addition, the regional seismic lines that are being acquired for shale gas exploration are also being used to determine geologic continuity of potential CO_2 injection zones. Data from several such wells and its implication for fluid injection or CO_2 storage wells are presented.

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Using Midwest's Subsurface for Effective Mitigation of Greenhouse Gases, Produced Water Disposal, and Enhancing Oil/Gas Production

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Eastern Section, AAPG, Cleveland, Ohio, September 25, 2012

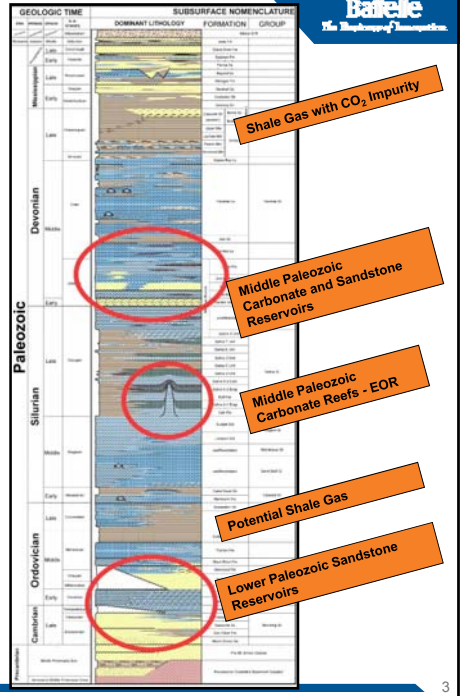
Multiple Demands on Subsurface Resources Utilization

- CO_2 capture, utilization, and storage (CCUS) – mitigating greenhouse gas emissions
- Shale oil/gas exploration/production
- Produced brines/flowback waters disposal
- Enhanced oil recovery using CO_2 or water Injection
- Conventional oil and gas production

- These increasing demands require stronger emphasis on geologic research

Multiple Demands on Subsurface Resources

- ~16,000 feet of sedimentary layers with multiple uses across geologic column
  - Conventional shale gas
  - Conventional oil
  - CO_2-EOR
  - Brine Disposal
  - Deep shale gas
  - Potential CO_2 storage
- A possible future analogue for Appalachian Basin
- Need to manage cross-cutting risks and enhance geologic characterization



Battelle Carbon Management – Involved in Major Public-Private and Other CCS Efforts

AEP Mountaineer – 3 Projects over 9 Years

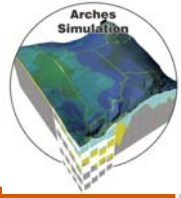
DOE Regional Partnerships Program

MRCSP
MIDWEST REGIONAL CARBON SEQUESTRATION PARTNERSHIP

BIGSKYCARBON SEQUESTRATION PARTNERSHIP
(Basalt Demonstration)

FutureGen and FutureGen 2.0

FutureGen™ ALLIANCE



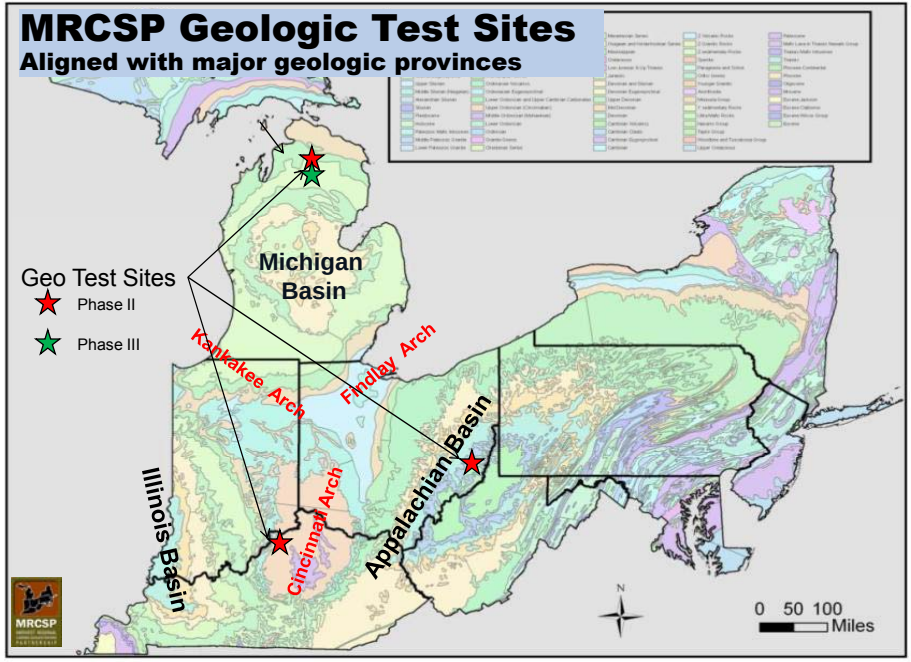
Regional Characterization and Basin-Scale Modeling

Direct Industry Projects Examples

- Consulting projects for domestic and international utilities, oil, gas, coal, steel, and infrastructure companies

MRCSP Geologic Test Sites

Aligned with major geologic provinces



Michigan Basin Phase II Injection Test

Leveraging Existing EOR Infrastructure

Gas processing plant, source of pure CO_2

600 T/d Compressor

5000 Foot Deep Test Well Drilled in November 2006

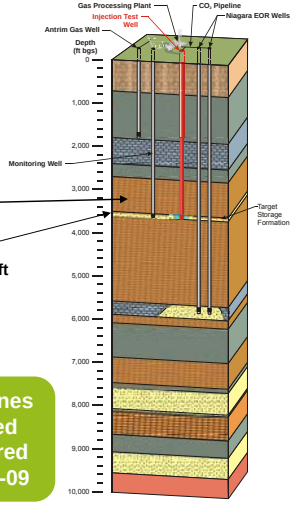
180 feet of core taken

Injection well head

Confining Layer: Amherstburg Limestone

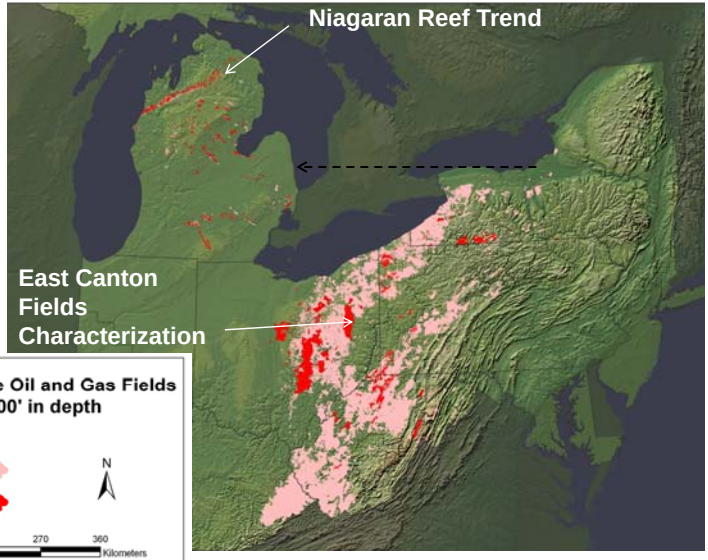
Injection Target: Bass Islands Dolomite 3500 ft

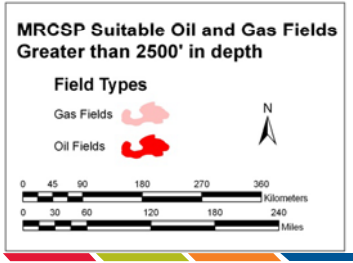
~60,000 Tonnes CO_2 injected and monitored during 2008-09



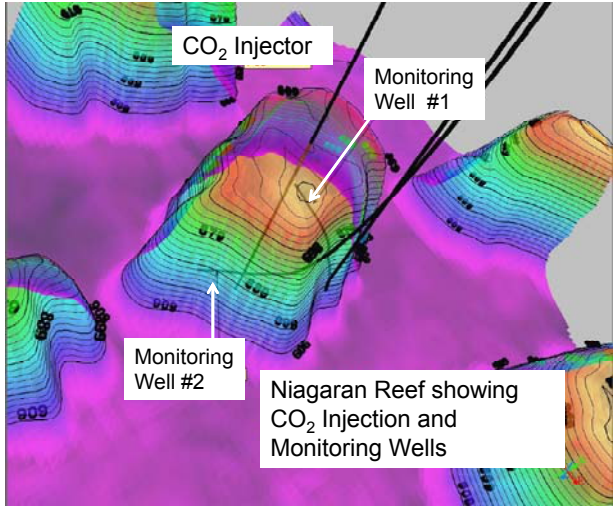
Well Column

MRCSP – Leveraging EOR Infrastructure in Oil Fields for CCS Research





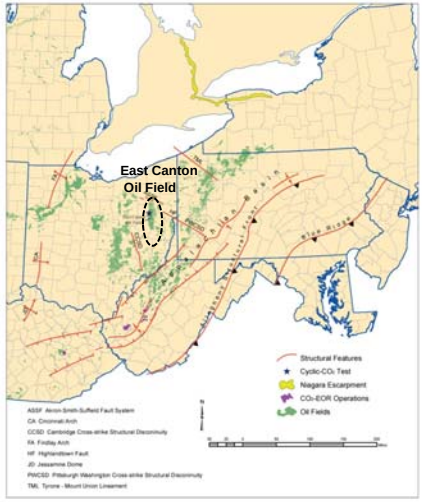
Niagaran Reefs – Testing Grounds for EOR



3D Seismic is a key technological tool for effective exploration, production, and monitoring

Potential Testing EOR/CO_2 Storage Potential in East Canton Oil Field Clinton Sandstone

- Discovered in 1947, the ECOF in northeastern Ohio has produced approximately 95 million barrels (MMbbl) of oil from the Silurian "Clinton" sandstone.
- Encompassing 175,000 reservoir acres with more than 3100 current or past producing wells, this is the most significant, actively producing oil field in Ohio.
- The original oil-in-place (OOIP) for this field is estimated to be approximately 1.5 billion bbl of oil.
- ***Additional testing is needed to determine EOR viability in such fields.***



CCS history of AEP at Mountaineer

Location: Mountaineer Power Plant, New Haven, West Virginia

- 1300 MW coal fired power plant.
- Operated by Appalachian Power Company (a subsidiary of AEP)

CCS Projects:

- 2003, Ohio River Valley Project.
- 2007, Product Validation Facility (PVF).
- 2010, Commercial Scale Project (CSP-2)

Site Selection

- Suitable Power Plant.
- Available Property.
- AEP's coal fired generation fleet in this region.

CO_2 Sequestration at Mountaineer Plant

~150,000 man-hours of safe drilling, completion, and workover operations. Extensive subsurface monitoring program

- Approximately 37,000 tonnes CO_2 injected, with majority of injection in the Copper Ridge zone, which showed very good injectivity

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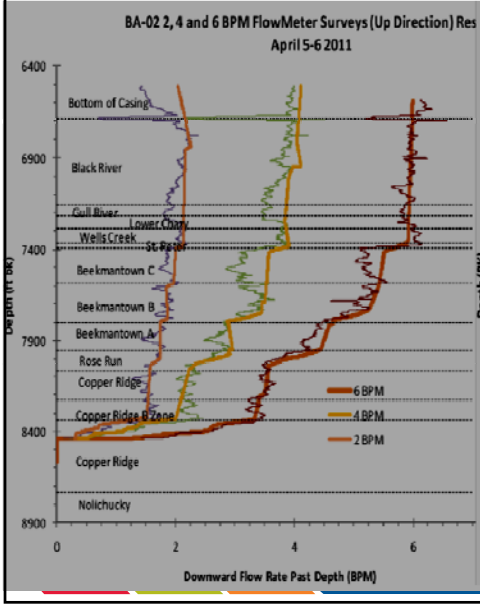
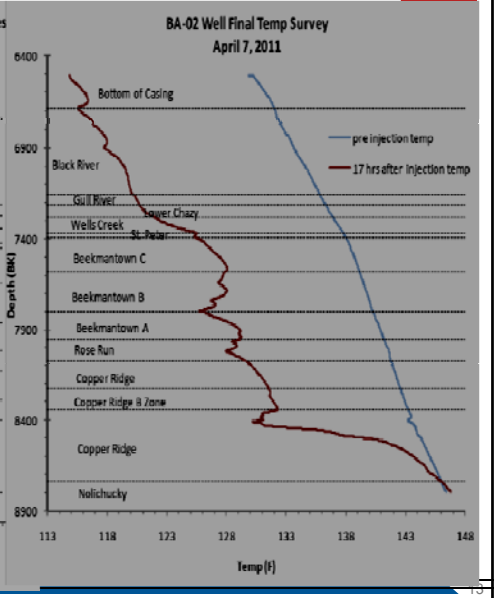
AEP Mountaineer Scale-up Assessment – Validating Payzones

- Test well drilled in 2011 to evaluate geologic continuity in the area
- Well logs, cores, and reservoir testing results consistent with PVF injection tests; however, more regional characterization is needed
- Preliminary design, monitoring program, costs, and schedule are developed for all phases
- Preliminary design estimates indicated that 2-3 wells in Copper Ridge Dolomite may be sufficient for CSPII scale injection project,

AEP CSP-II - Reservoir Testing: BA-02
Determining Fluid Intake Zones in Wells

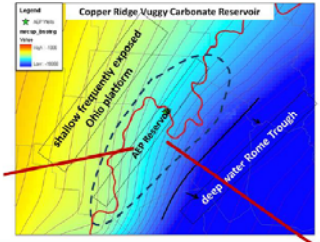


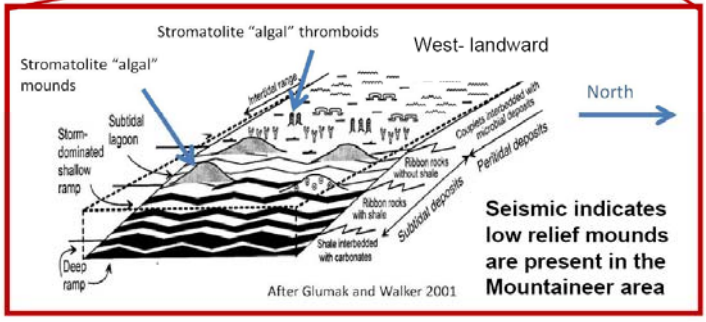


Mapping Vug Development in Appalachian Basin – Key to Injectivity?

Lower Copper Ridge Vuggy Carbonate Reservoir Model

- **Dolomite secondary dissolution porosity preferentially develops in grain-rich, higher energy, subtidal stromatolite facies**
- **Later greatly enhanced by hydrothermal overprint**



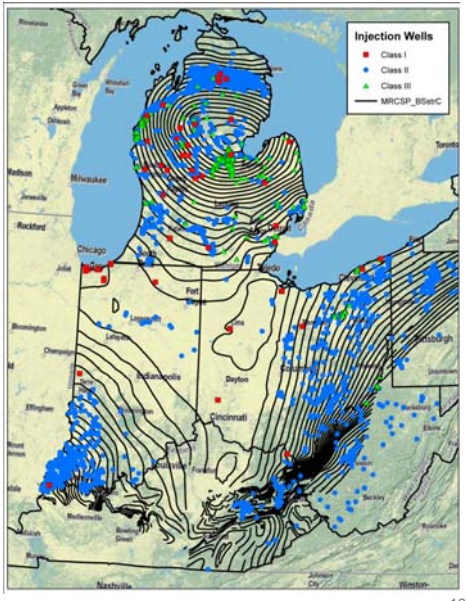


Produced Waters Disposal

- Growth in shale gas production and associated brine production causing increased demand for larger-scale Class II brine disposal wells
- Geologic/regulatory constraints in other states leading to commercial-scale facilities in western Appalachian basin, especially in eastern Ohio
- The geologic and reservoir parameters of injection zones poorly understood - planned assessment is required to meet long-term demand
- Concerns about potentially low injectivity, fracture pressure constraints, and induced seismicity.
- Battelle's regional geology/fluid injection in Midwest - a strong foundation for brine disposal study

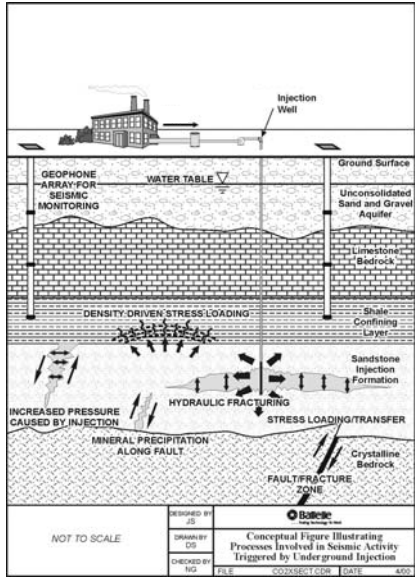
Appalachian Basin Brine Disposal Assessment

- Brine disposal needs in Appalachian Basin have increased as the result of shale gas development in the region.



Induced Seismicity

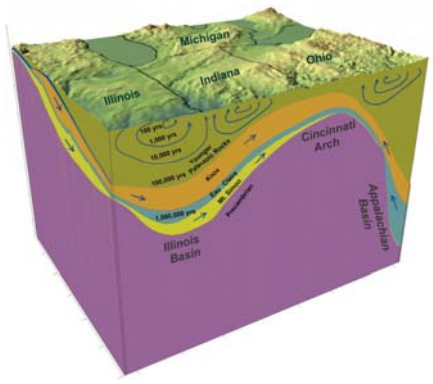
- Many processes may contribute to induced seismicity.
- Appropriate siting, construction, operation, and monitoring may reduce risk of induced seismic activity related to deep well injection.
- Regional and local characterization crucial for locating commercial-scale wells for brine/CO_2 injection

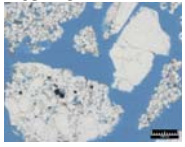


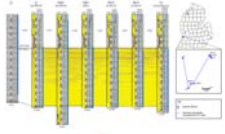
Mt. Simon Basin-Scale Modeling

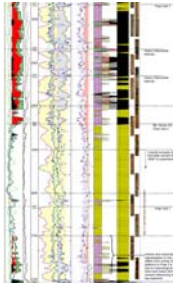
Funded by DOE, OCDO and others

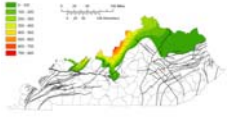
- Evaluate long-term regional-scale injection potential
- Geophysical porosity logs from 176 wells that penetrate Eau Claire or deeper were compiled into a 3D database.
- Database contains a total of ~960,000 data points from Knox, Eau Claire, Mt. Simon, and Precambrian interval.



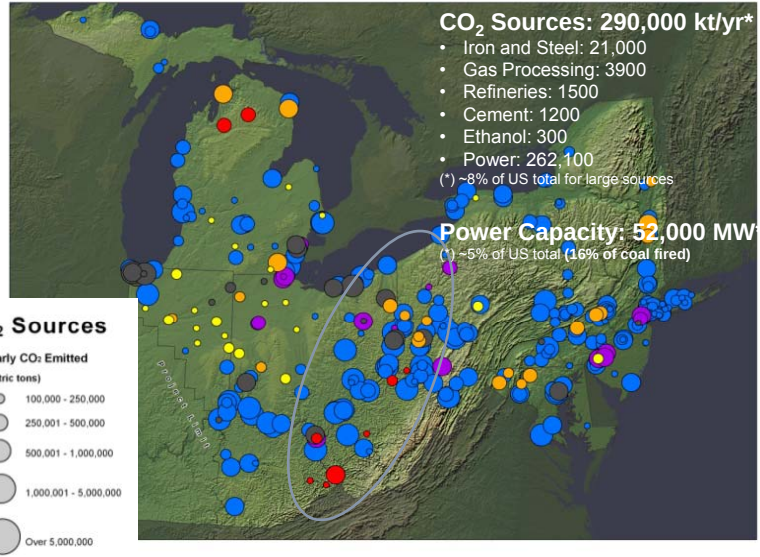






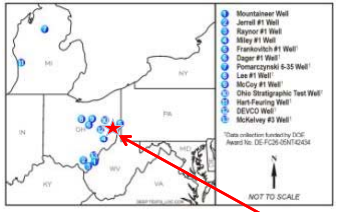


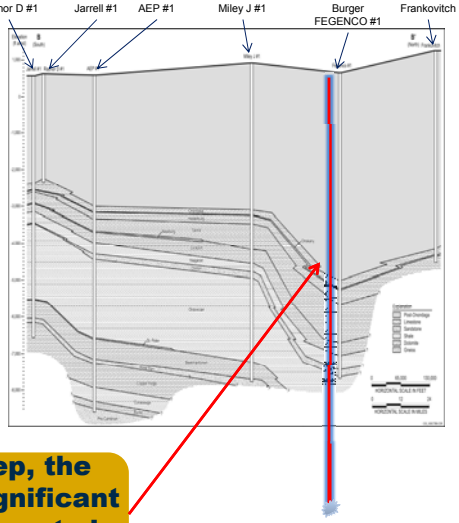
The UORV –Many Sources of CO_2 and a Growing Need for Brine Disposal



Upper Ohio Valley Characterization – Leveraging with Oil and Gas Activities

- Funded by Ohio Coal Development Office
- Jointly with ODGS
- Partnering with local oil/gas and brine-disposal company

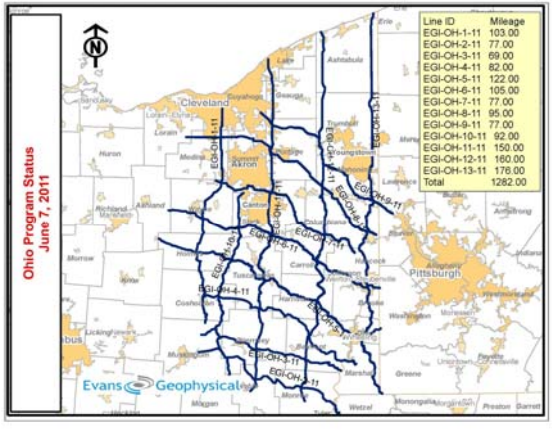


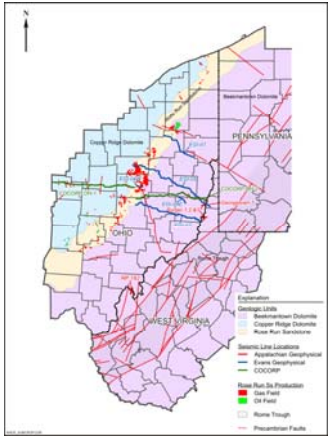


GM #1 is ~14,000 feet deep, the deepest in Ohio. It adds significant new data on the deep sediments in the Ohio Valley

New 2D Seismic Data in Appalachian Basin
Co-benefit from Gas Shale Boom

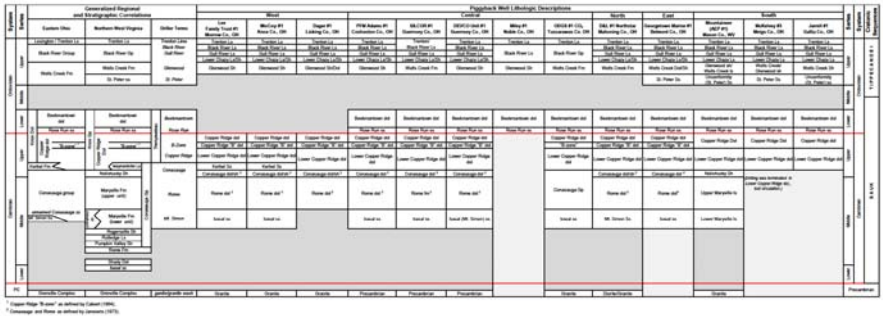
- More than 250 Miles of new 2D seismic data available to Battelle for regional mapping – Proprietary Data Only
- Integration of seismic, logs, cores, reservoir data underway





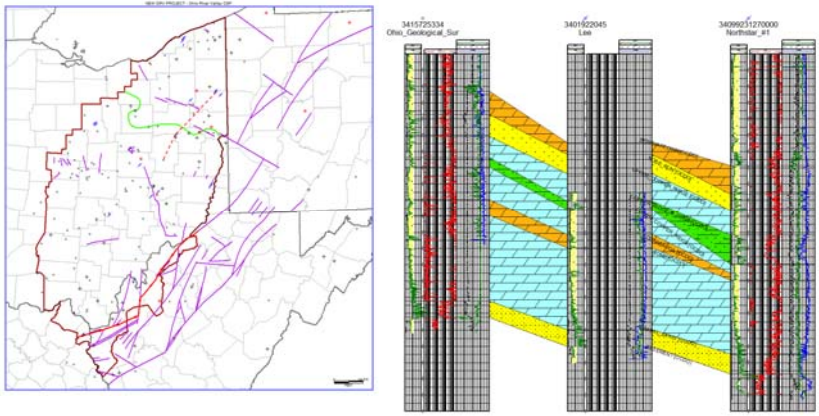
Detailed Well to Well Correlations

- Geologic Nomenclature still poorly understood



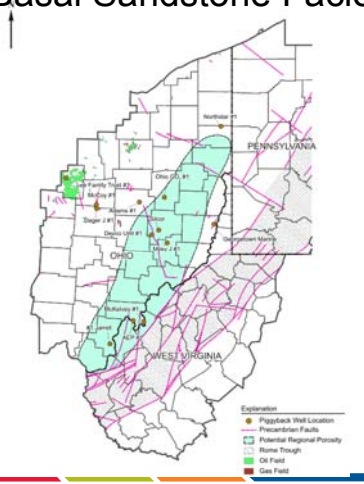
Facies Changes within Copper Ridge Provide Information on Porosity Development

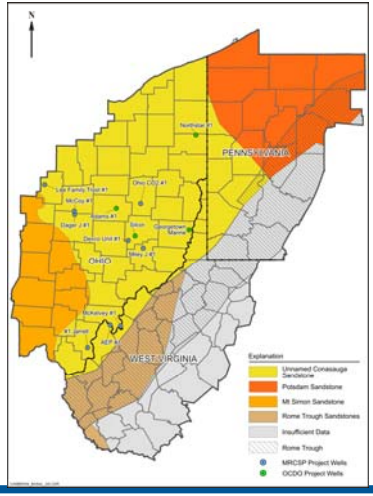
- Cross-section across northeast Ohio



Updated Maps Under Preparation for Cambrian Sections

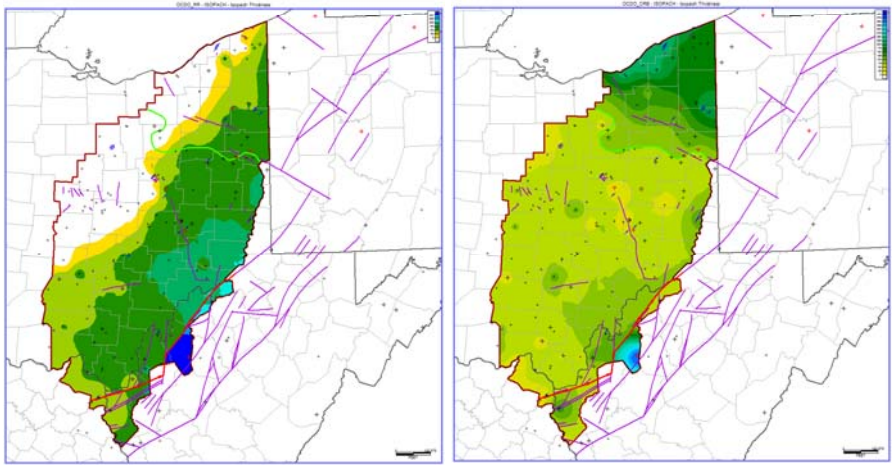
- Copper Ridge Porosity Zones?
- Basal Sandstone Facies





Updated Maps Under Preparation for Cambrian Sections

- Preliminary Copper Ridge “B” Zone and Rose Run Thickness



Shale Gas – RPSEA Proposals by Battelle

Unconventional Onshore Resources

Evaluation of Brine Injection in Northern Appalachian Basin
Project Manager = Joel Sminchak/Neeraj Gupta,
In-Kind Partners = OH, WV, PA, KY Geol. Surveys; Support from OOGA, ODNR
Industry Participants = Ohio Oil Gathering/Clearfield, NSI Tech.

Evaluation of Biocides for Hydraulic Fracturing
Project Manager = Olga Koper;
Industry Participants = BSWCMC, Dow, HTI, IST, MIOX (Schlumberger), Rex Energy, TDA

Environmentally Friendly Hydraulic Fracturing Fluids
Project Manager = Joel Elhard
Industry Participants = BSWCMC, Lord Chemicals

Barnett Shale Water Conservation and Management Committee (BSWCMC)
BP, Chesapeake Energy, Conoco Phillips, Devon, XTO Energy, Encana Natural Gas, Legend Natural Gas, Pioneer, Pitts Oil Company, EOG Resources, Quicksilver Resources

Liquid-Rich Shale Proposal
Utica/Point Pleasant Shales

- Reservoir Characterization and Development Optimization
  - Determination of geomechanical stresses
    - Better stimulation modeling
  - Analyze log and core data
    - Correlate core data with open hole log responses
  - Perform isotope analyses
    - Determine “producibility” of shale for maximum recovery
    - Determine pore pressure of formation
    - Determine permeability
  - Collect and analyze fluid samples
    - Determine “sweetspots” in formation
- Proposal submitted to DOE NETL with support from Bakerwells, Inc.

Acknowledgements

- Funding – DOE-NETL, Ohio Coal Development Office, AEP, MRCSP Sponsors, Battelle Research Funds
- Battelle Geosciences and Carbon Management Team – David Ball, J. Gerst, Charlotte Sullivan, Glen Larsen, Erica Howat, Mark Kelley, Matt Rine, and others
- MRCSP Geology Team
- Ohio Division of Geological Survey
- Larry Wickstrom