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**A Decade of Applied Research
on Geologic Sequestration in the
Midwestern USA – Lessons
Learned and Future Challenges**

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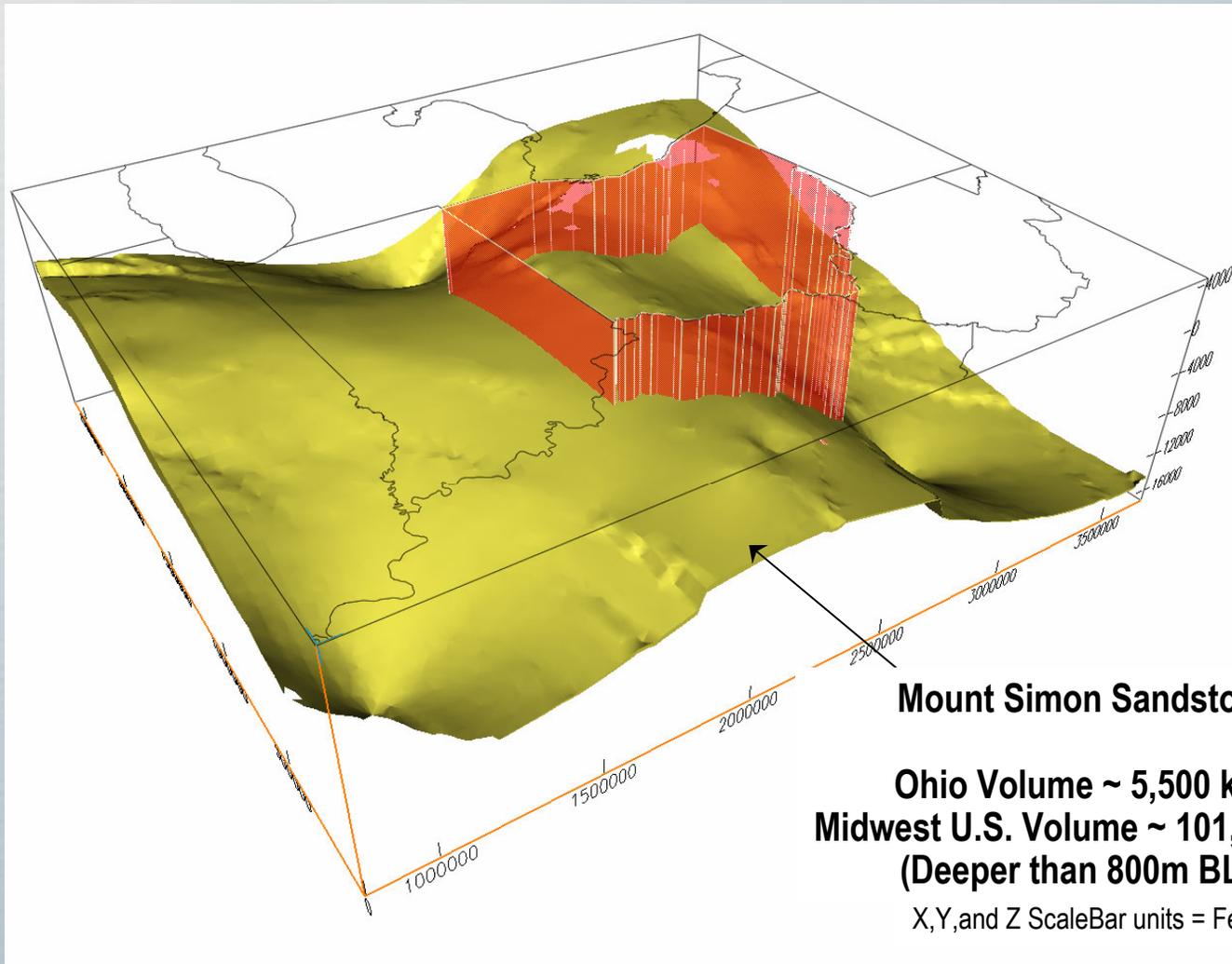
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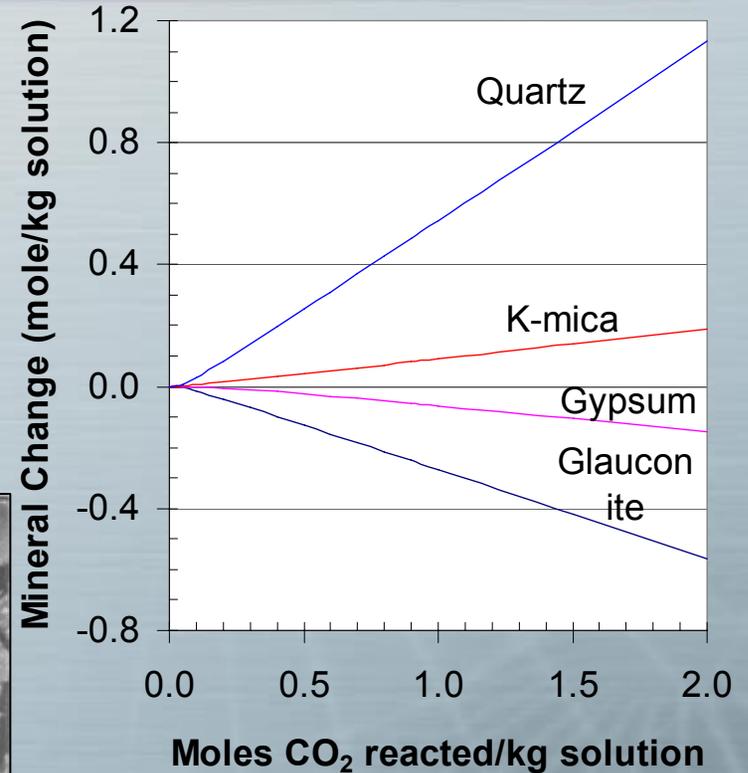
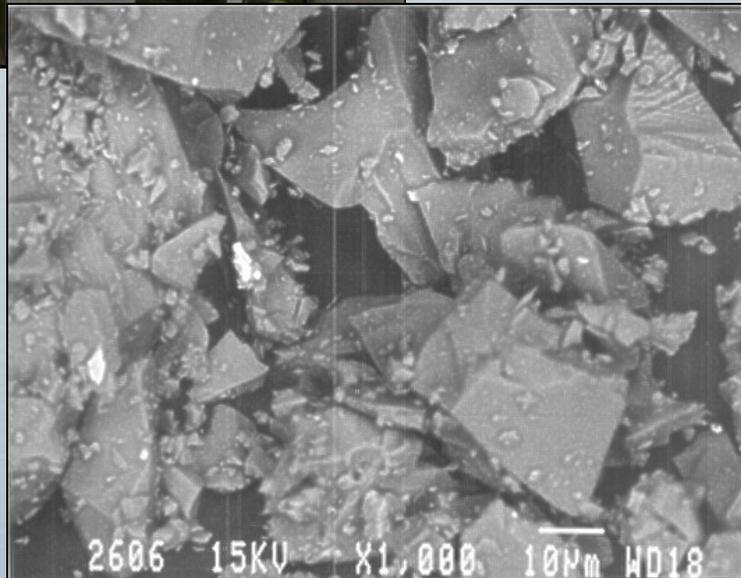
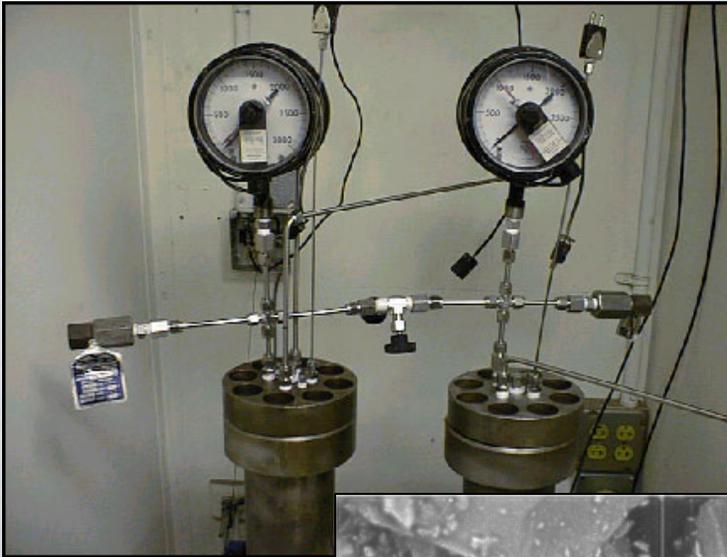
Background

- DOE NETL's CCS program is approaching 10 years
- Midwestern US has been a key area of evaluation under DOE and industry initiatives:
 - Started with small paper studies – literature reviews, modeling data from UIC wells, laboratory experiments
 - MIDCARB project – precursor to partnerships
 - AEP Mountaineer site assessment
 - MRCSP and MGSP Phases I, II, and III
 - FutureGen siting process (IL, KY, OH, WV)
 - Regional characterization, organic shales, ECBM studies
 - Capture studies, IGCC, oxy-fuel combustion etc.

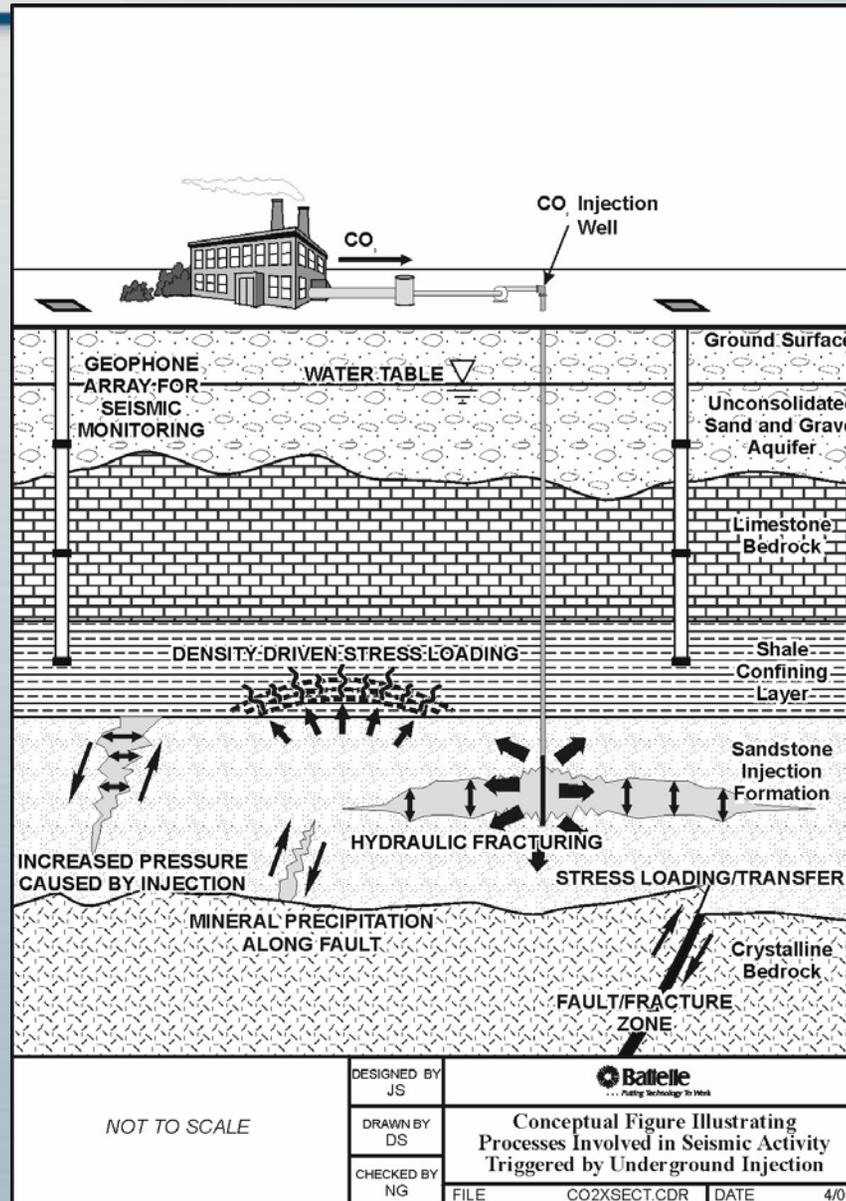
Early Efforts – Maps Used for Mt. Simon Sandstone Capacity Estimates (1997-98)



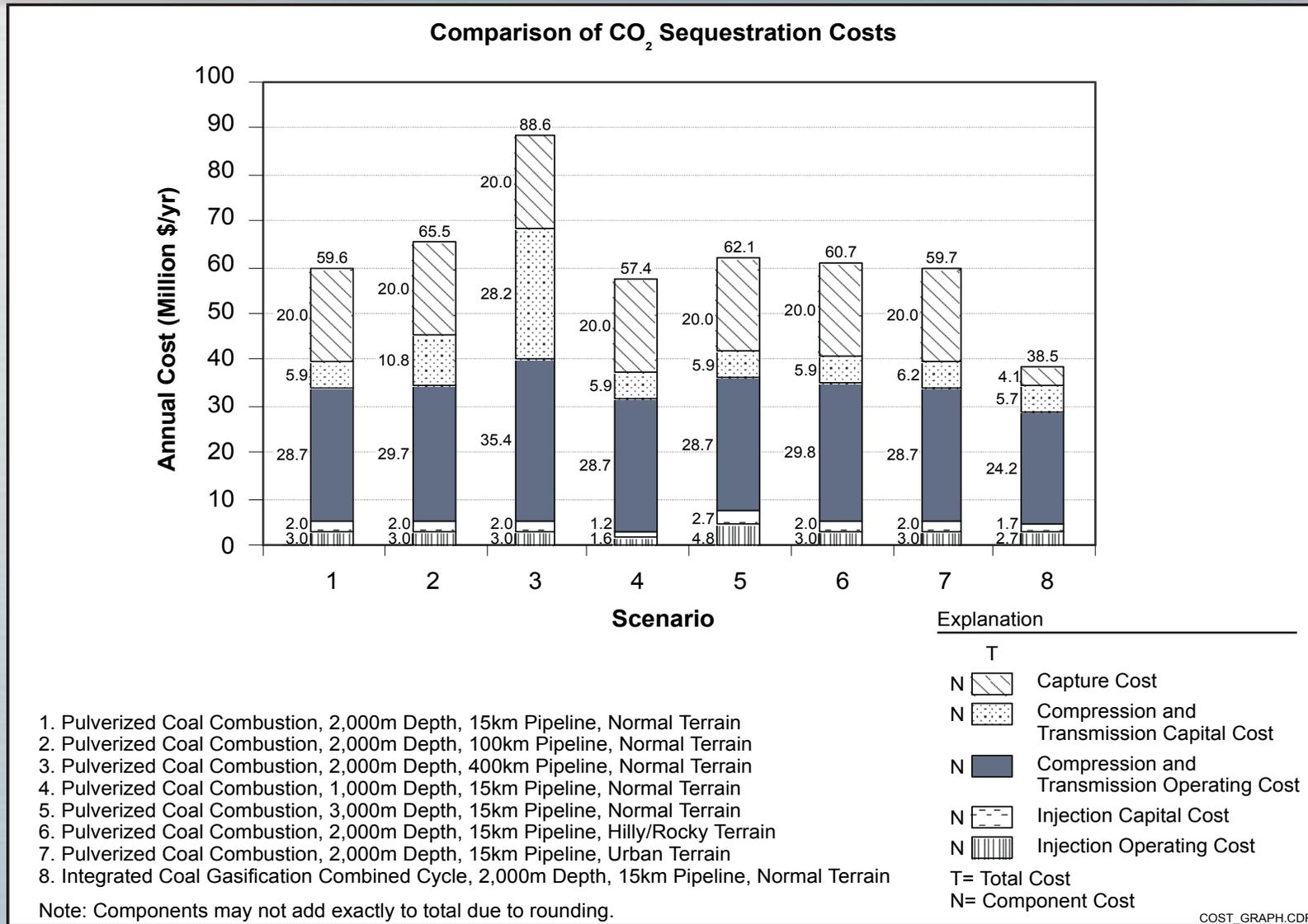
Early Efforts – Geochemical Assessments of Mount Simon and Caprocks (1997-2000)



Early Efforts - Induced Seismicity Assessment for Midwestern US (1999)



Early Efforts – Economic Assessment and a Framework for Field Implementation



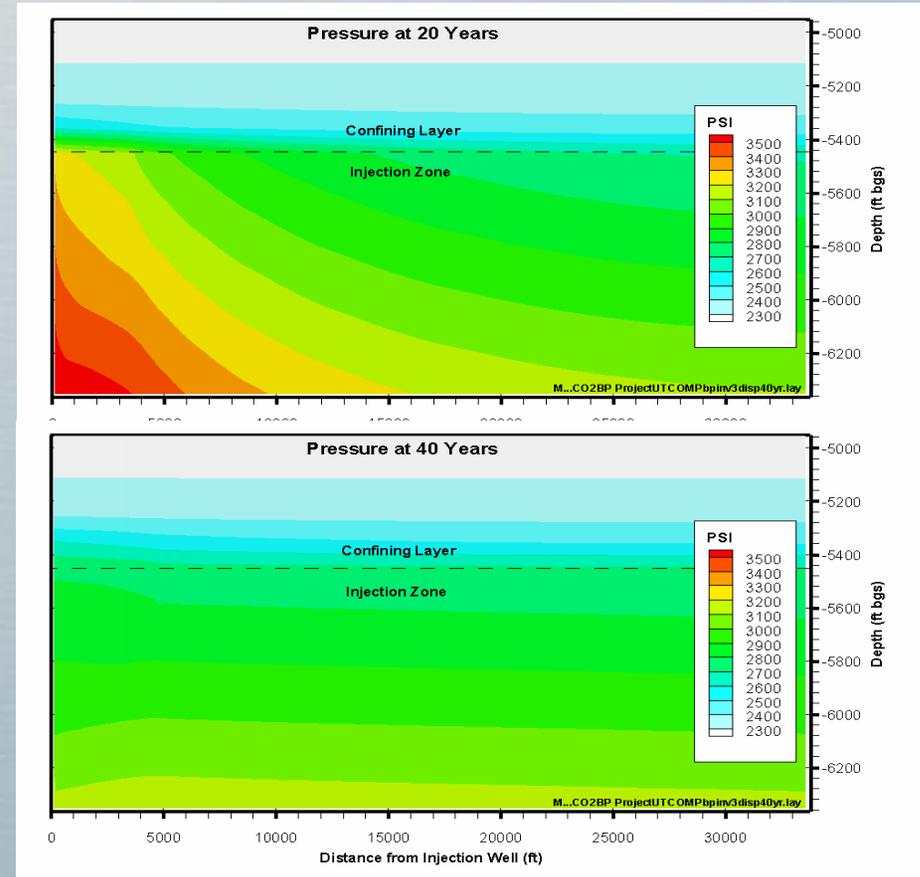
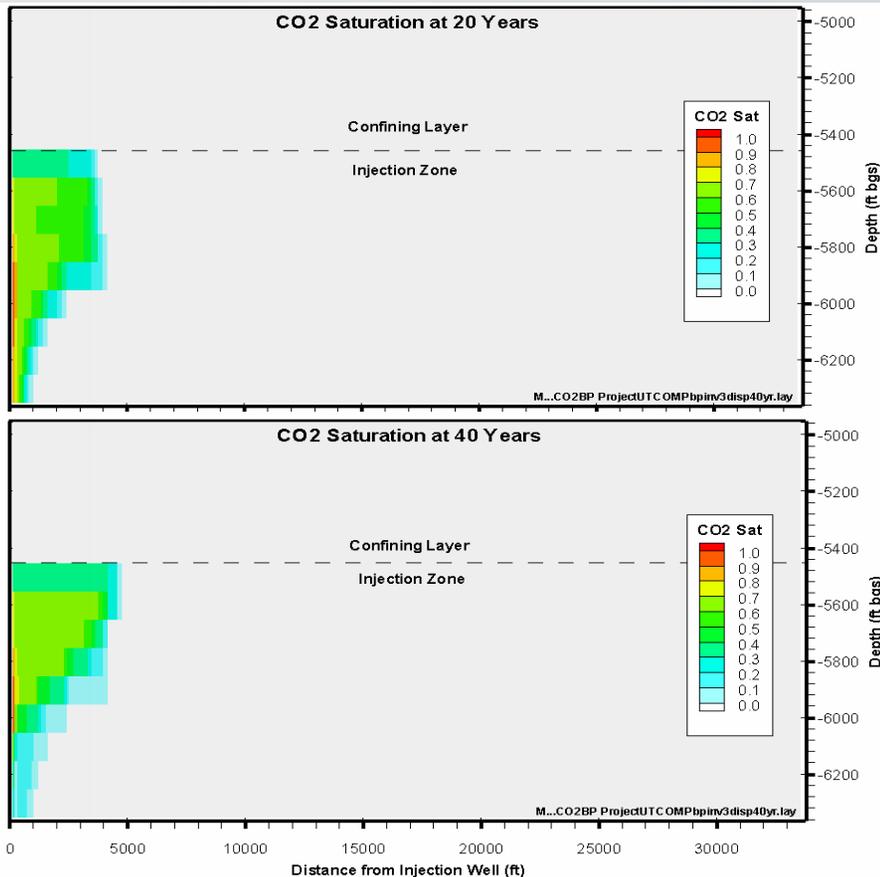
COST_GRAPH.CDR



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Early Efforts – Modeling of CO₂ injection in Mt. Simon Sandstone, W. Indiana,

1 mt/yr/well injection



Ongoing Initiatives – Progressing to Field Implementation and Deployment

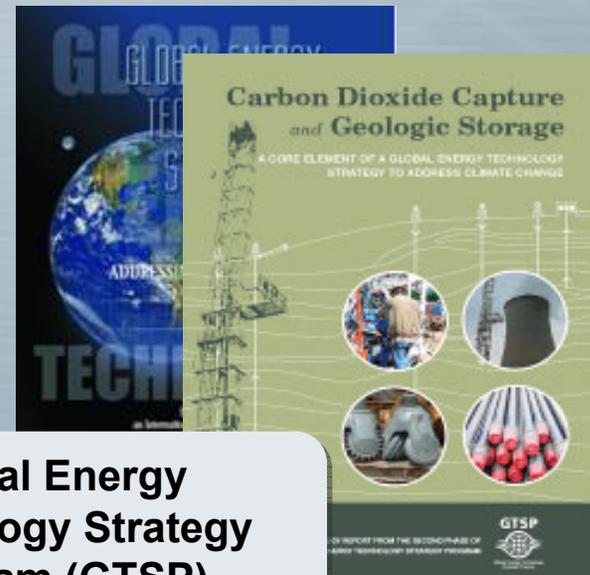
Mountaineer



FutureGen



Regional Reservoir Characterization
“Piggyback Drilling”

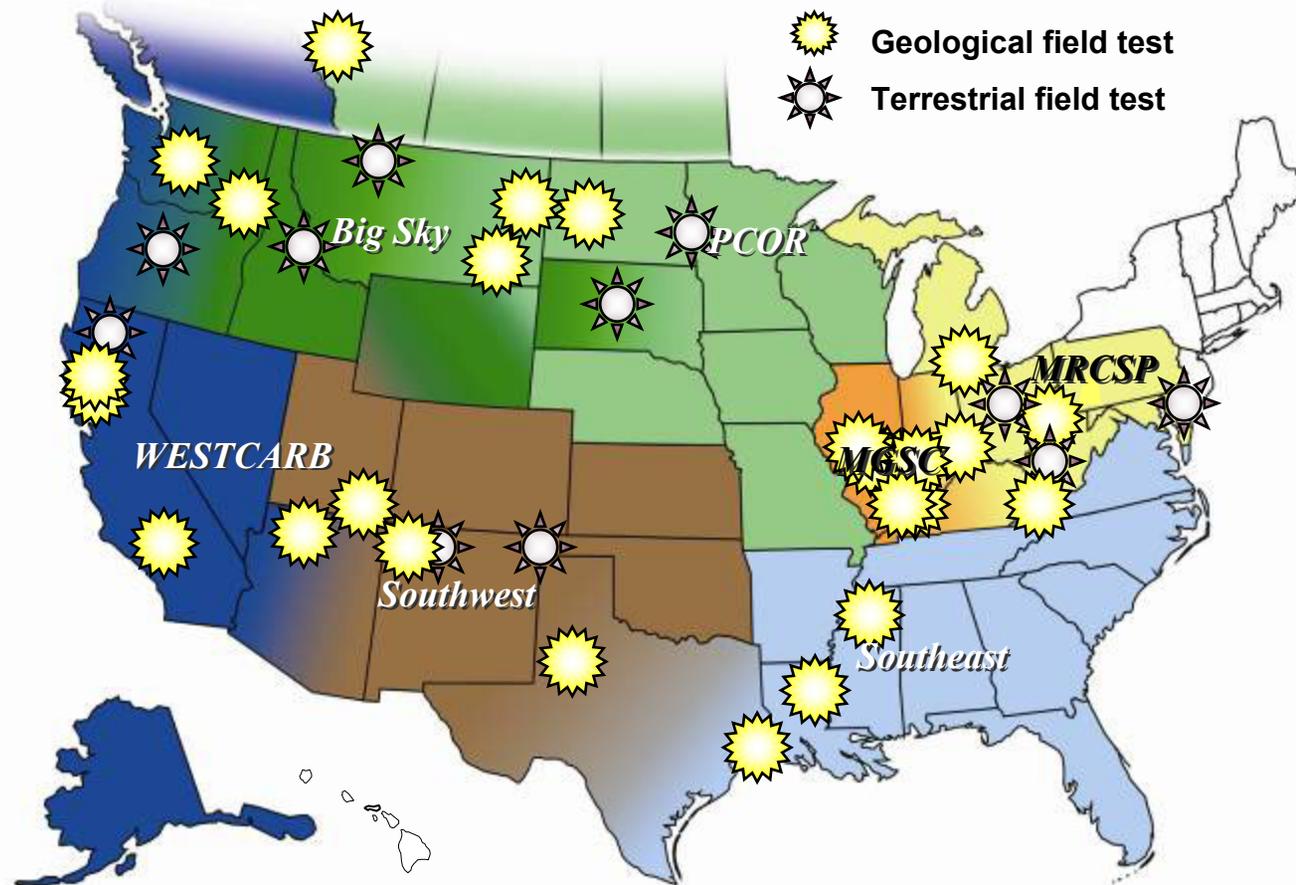


Global Energy
Technology Strategy
Program (GTSP)

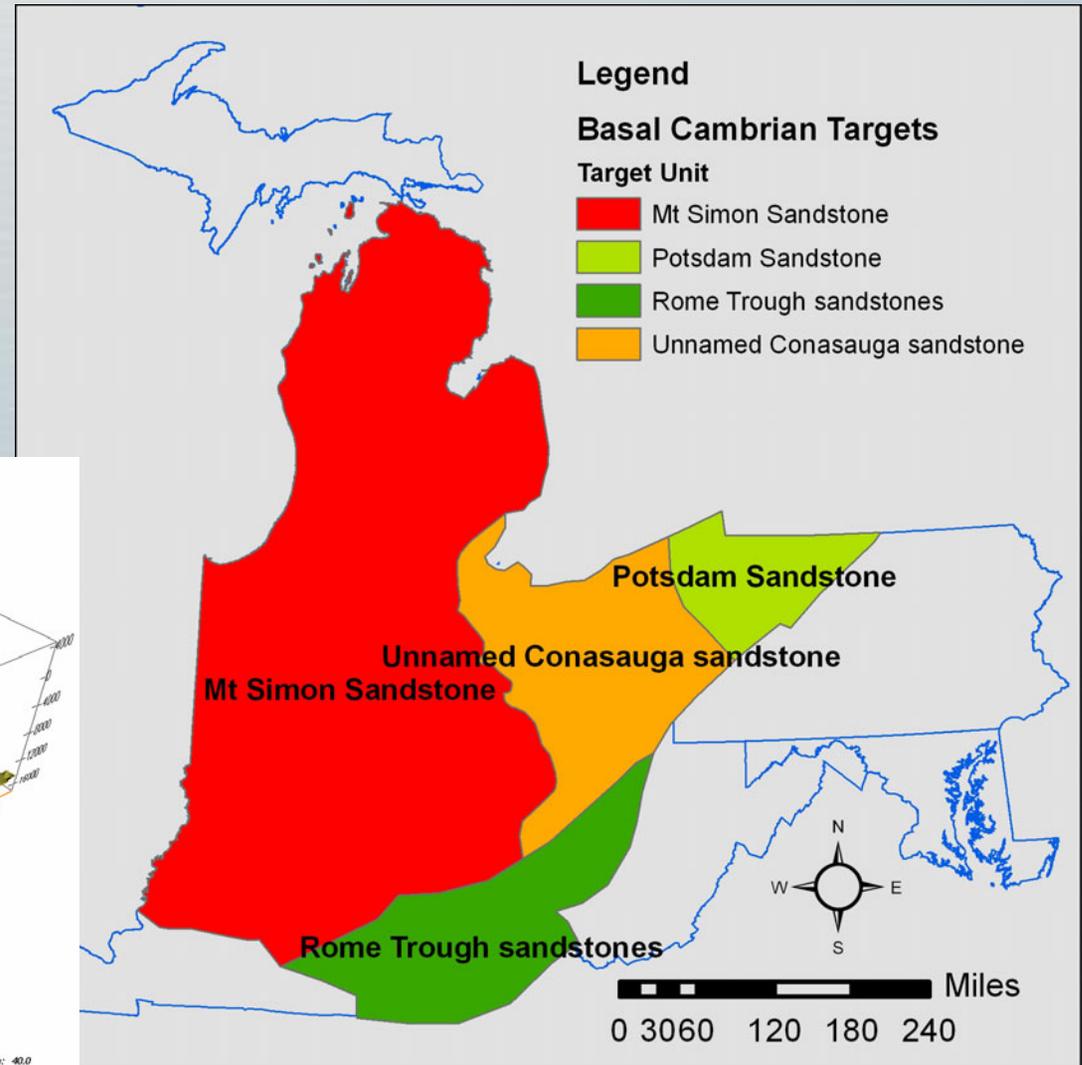
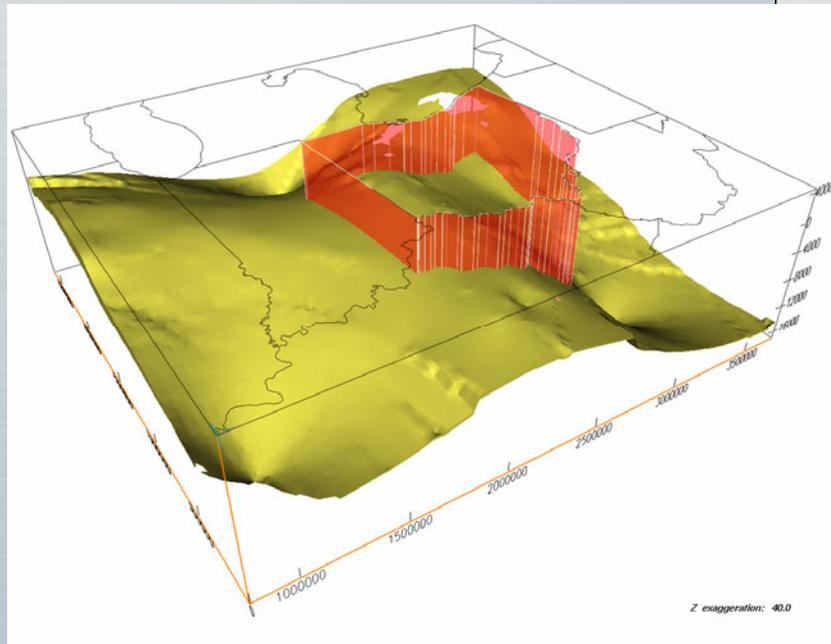
Ongoing Efforts - The MRCSP and MGSP Partnerships Address Regional Deployment Issues

35 field projects are underway across the nation as part of Phase II:

- 24 geologic and 11 terrestrial projects

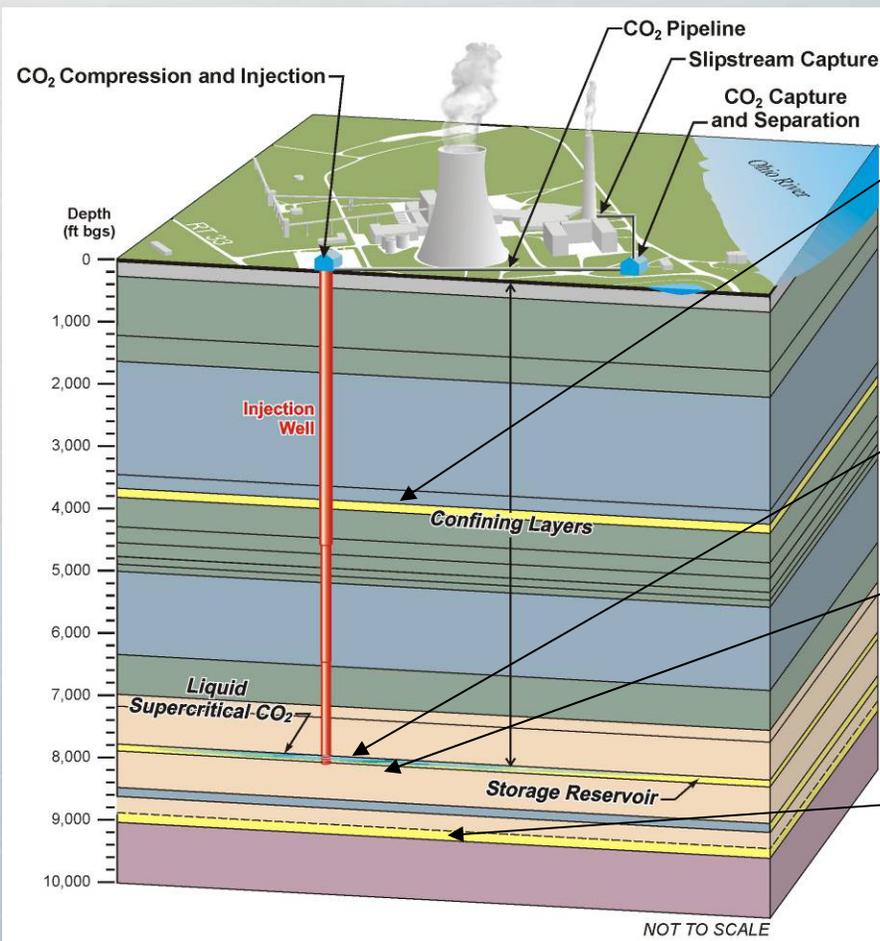


Trends – Regional Variability in Key Sinks Must be Understood



Trends – Detailed Site Assessment to Evaluate Known and Unknown Reservoirs

- A number of geologic formations have been evaluated for CO₂ storage potential in the Ohio River Valley region through Mountaineer project



CO₂ injection should also be possible in shallower sandstone and carbonate layers in the region

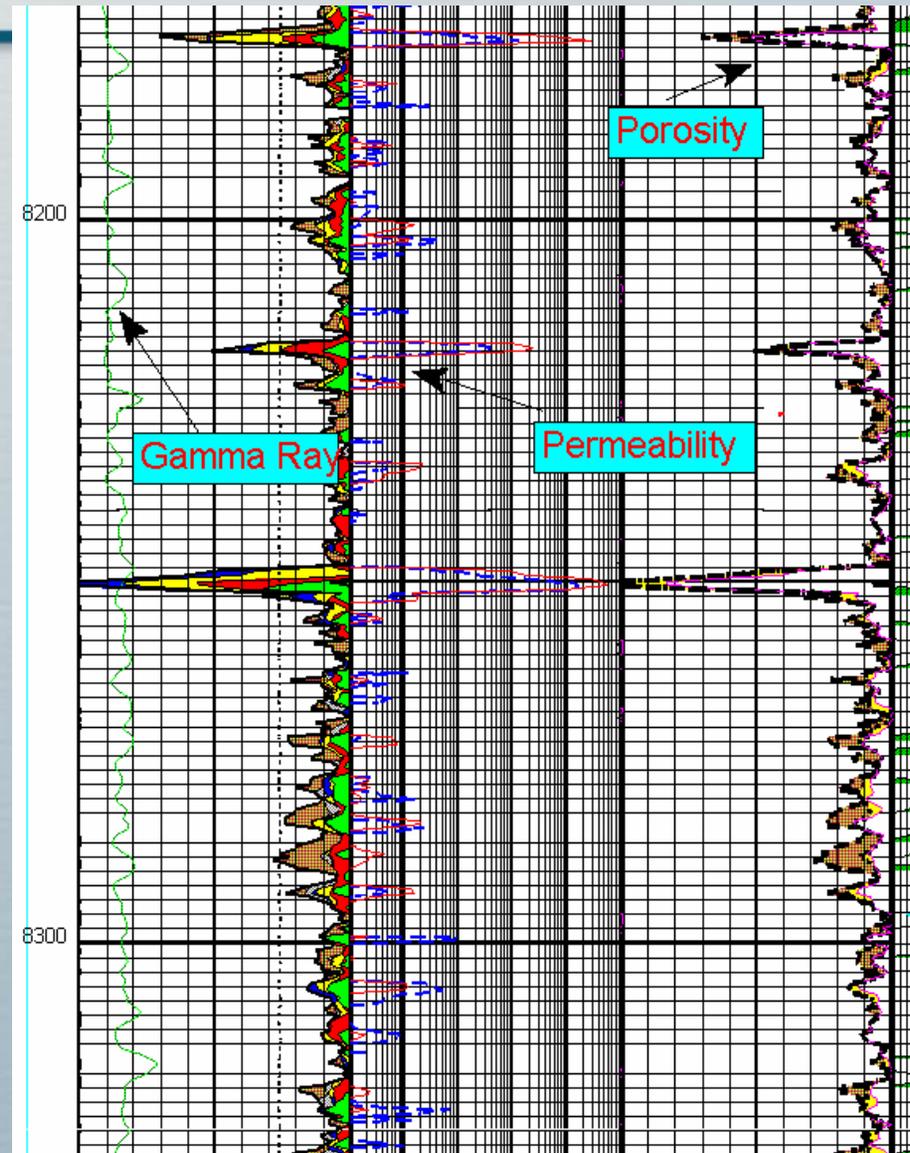
Rose Run Sandstone (~7800 feet) is a regional candidate zone in Appalachian Basin

A high permeability zone called the “B zone” within Copper Ridge Dolomite has been identified as a new injection zone in the region

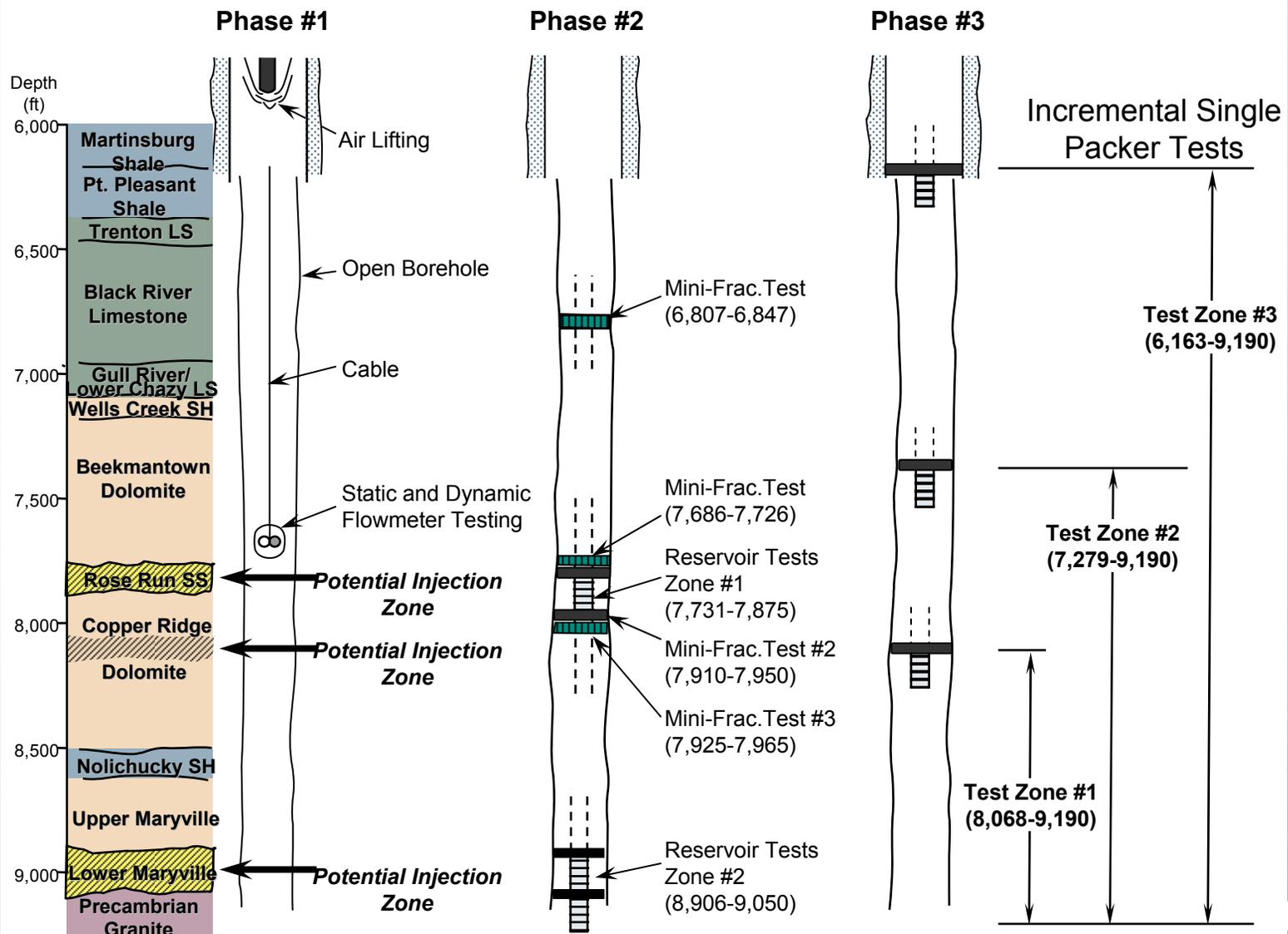
Mount Simon Sandstone/Basal Sand - the most prominent reservoir in most of the Midwest

Trends – Every Potential Storage Zone is Important in Deep Mature Basins

- Example – Mountaineer project storage potential was observed in part of Copper Ridge Dolomite (B-Zone at 8100-8300 ft depth) based on detailed NMR logging and reservoir testing
- Similar high permeability zone observed in several wells, including one near Gavin plant. This is promising for regional storage potential
- Lesson - We have learned a lot about characterization tools and feasibility in the region

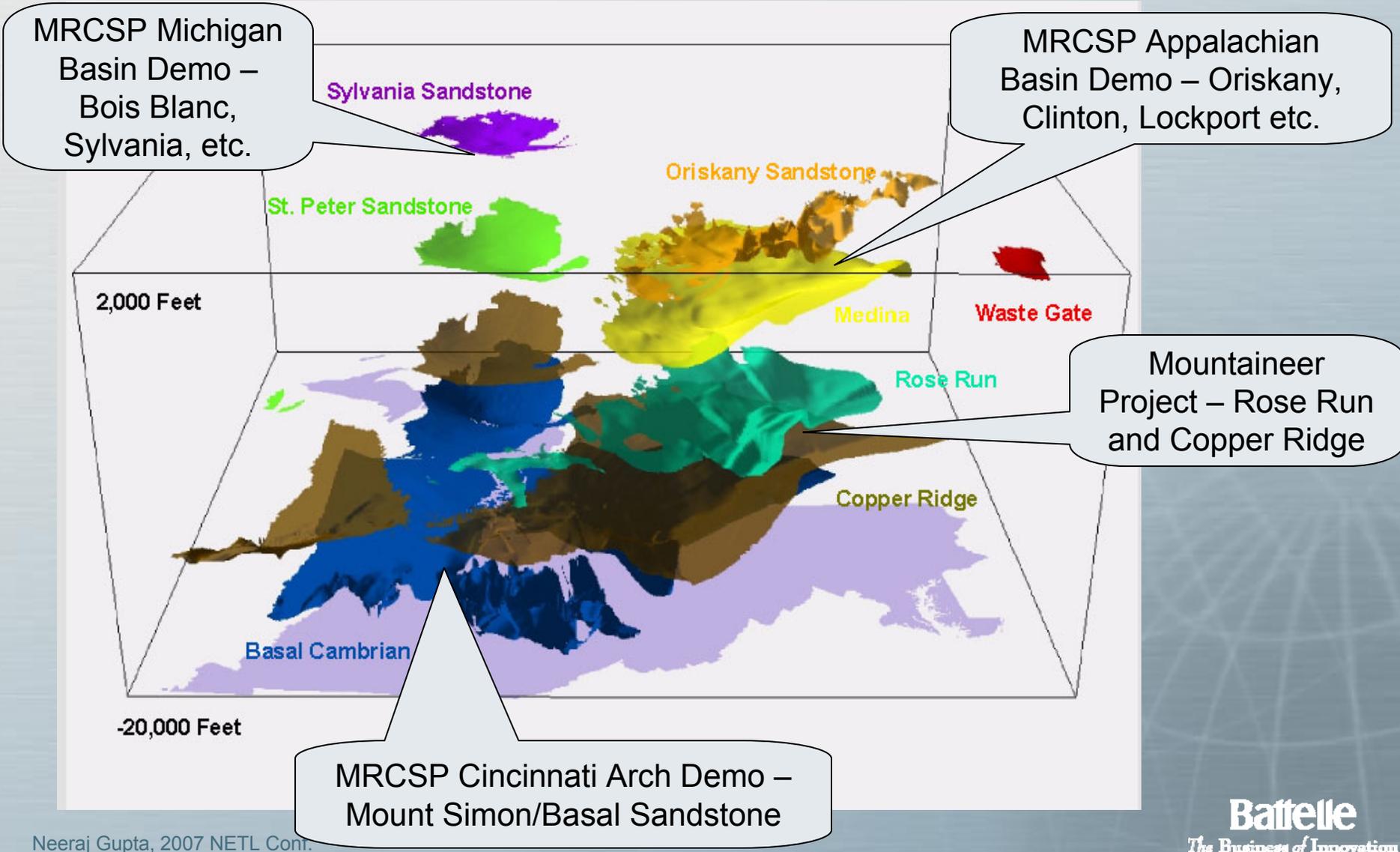


Trends – Reservoir Testing in Multiple Zones to Quantify Injectivity Across Region



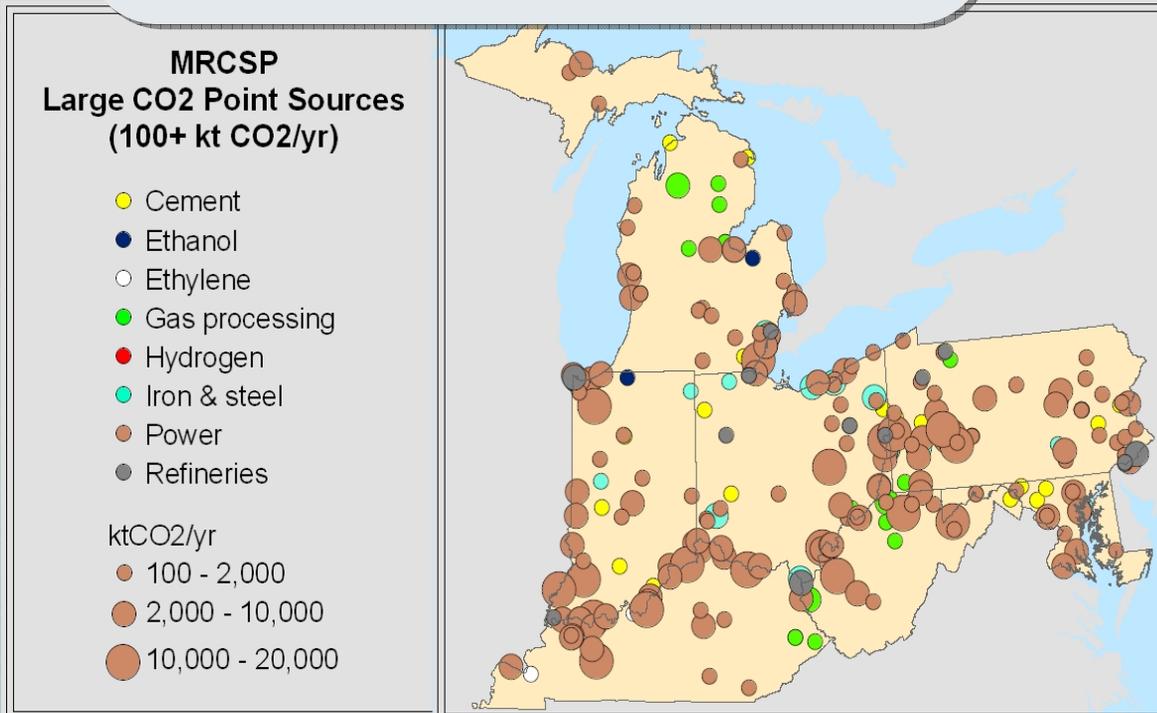
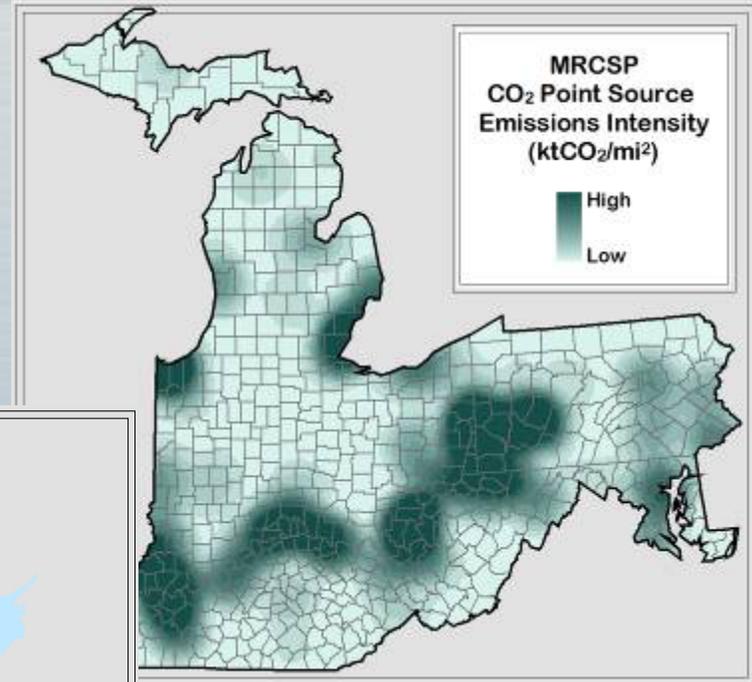
Trends - Major Regional Storage Zones

Even Small Tests Provide Tremendous Knowledge



Challenge – Will There be Competition for Storage Space?

- CO₂ sources clustered around rivers and in deeper basin settings
- Sink capacity is more distributed
- Strong need for regional storage and transport planning



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Trends – Characterization and Injection Demos Must Cover Many Geologic Provinces

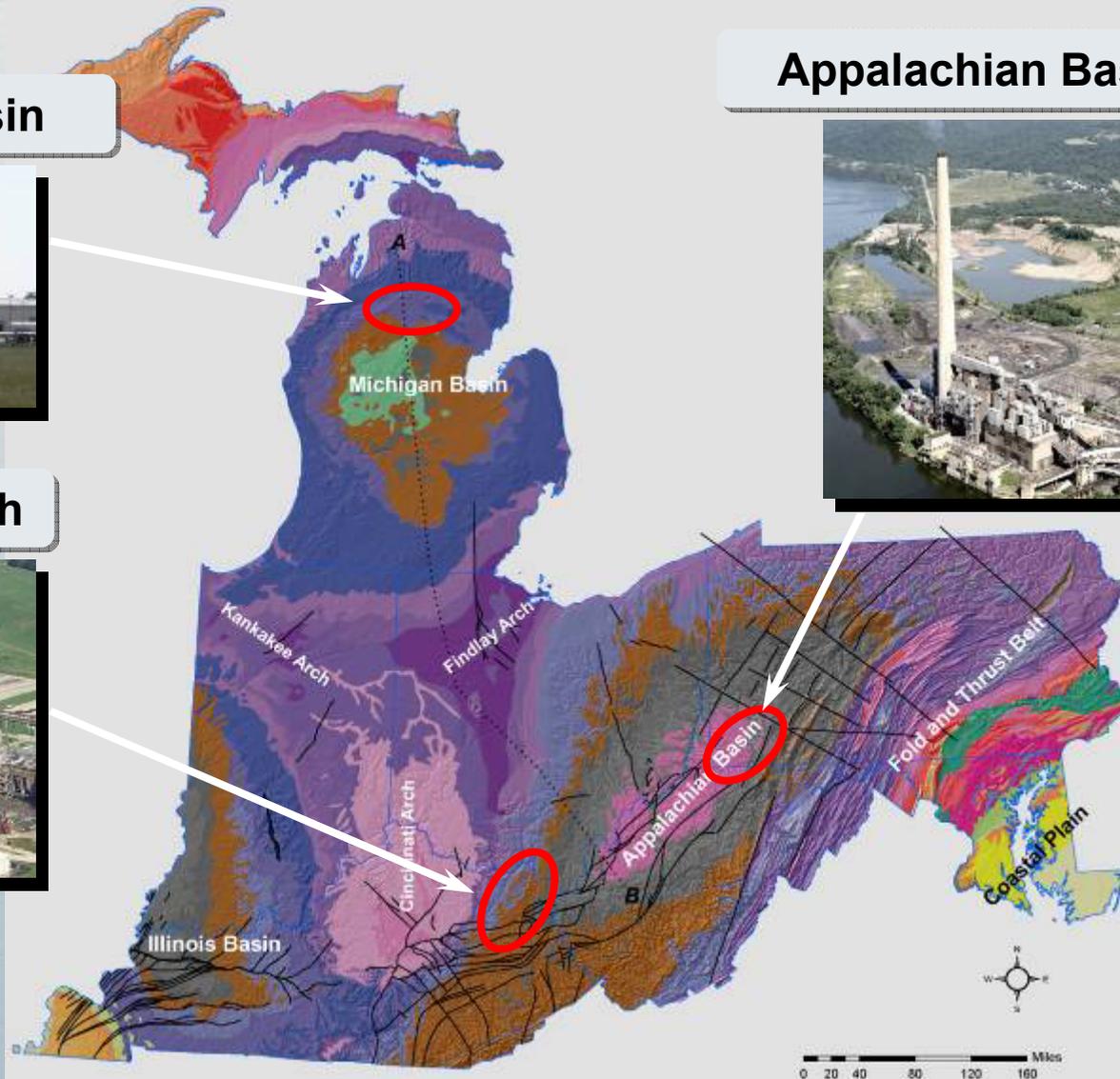
Michigan Basin



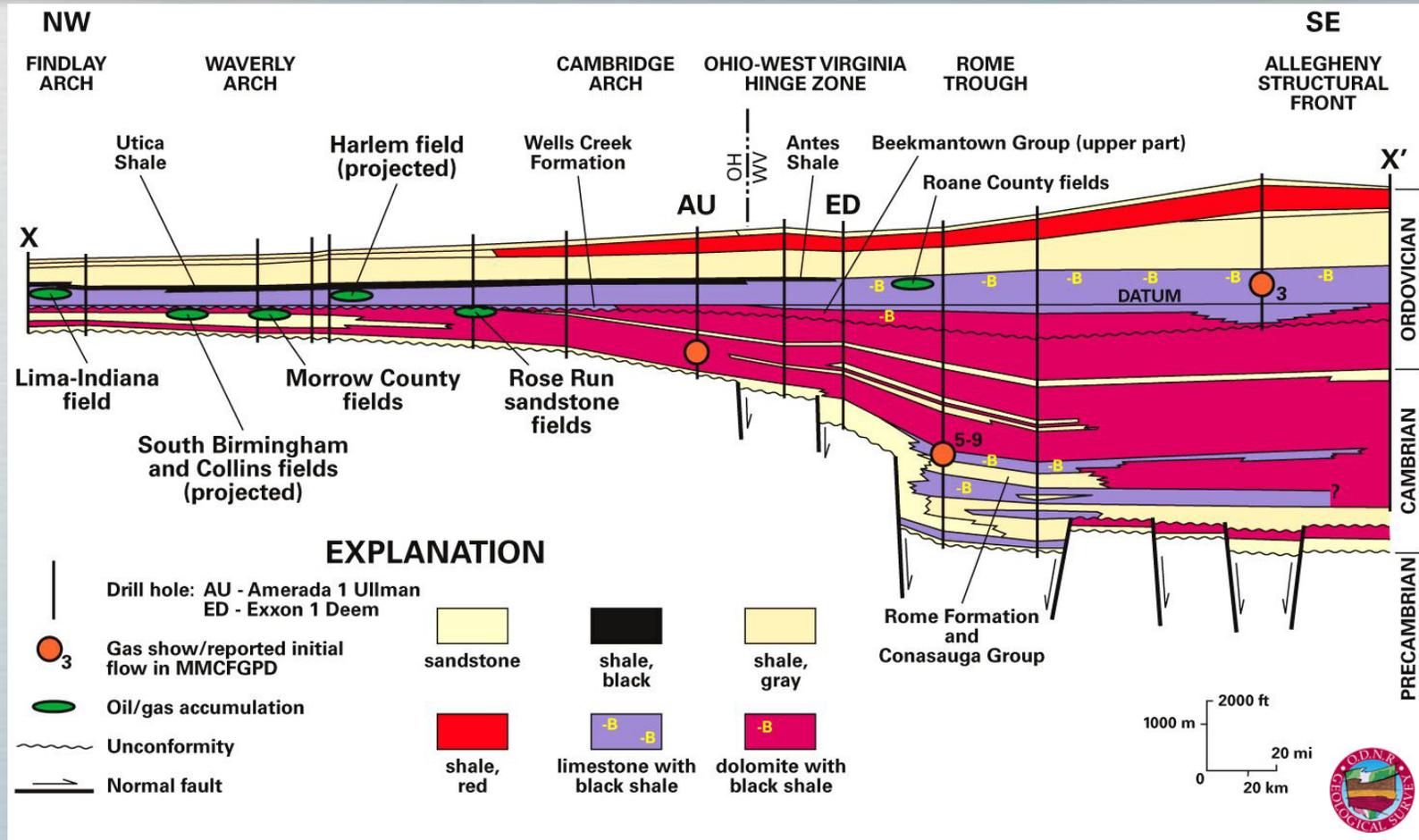
Appalachian Basin



Cincinnati Arch

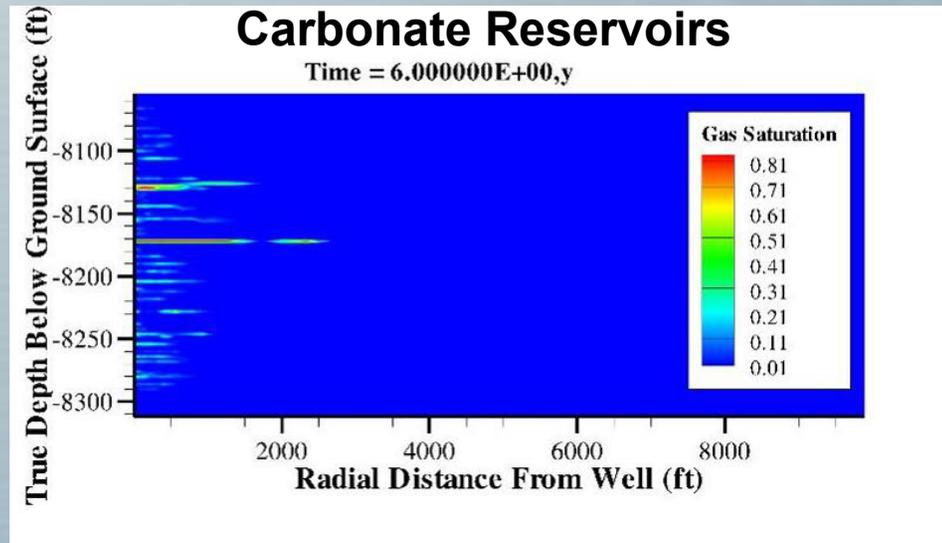
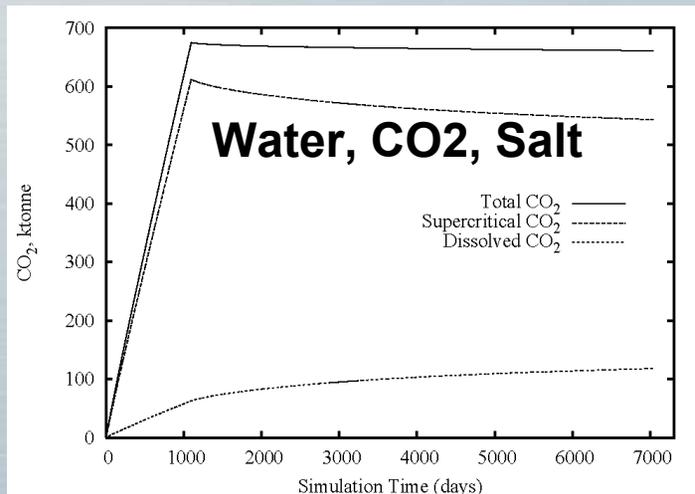
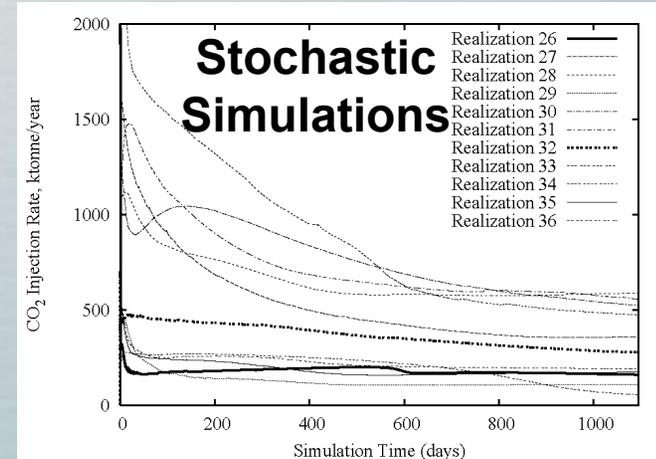
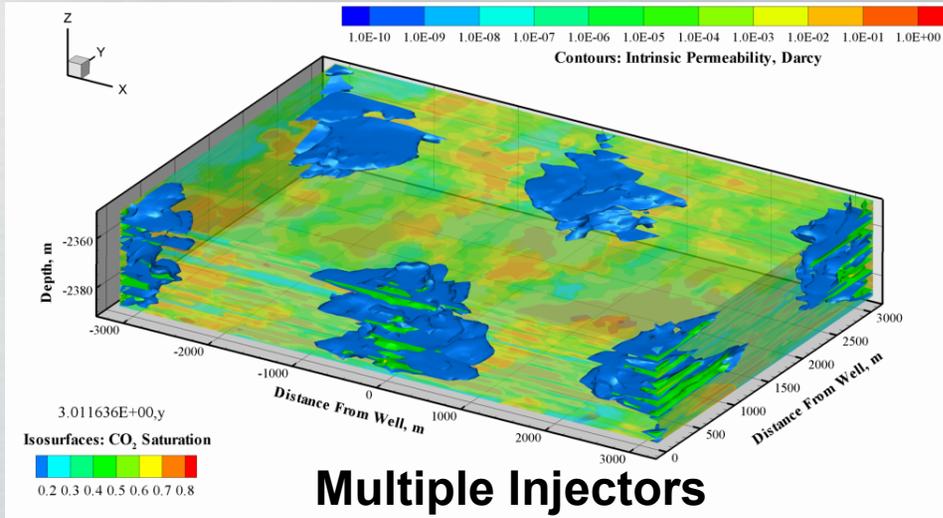


Challenge – Continued Regional Geology Mapping with Wellbore and Seismic Data



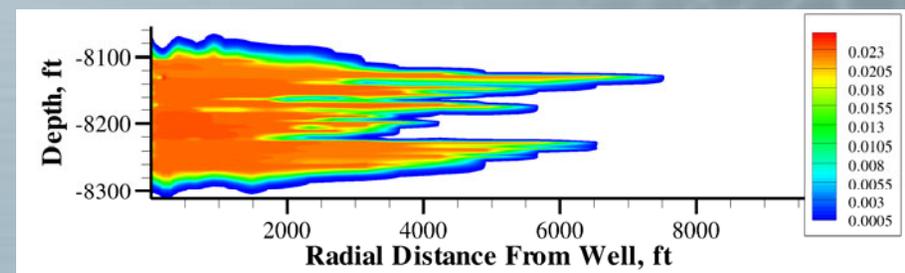
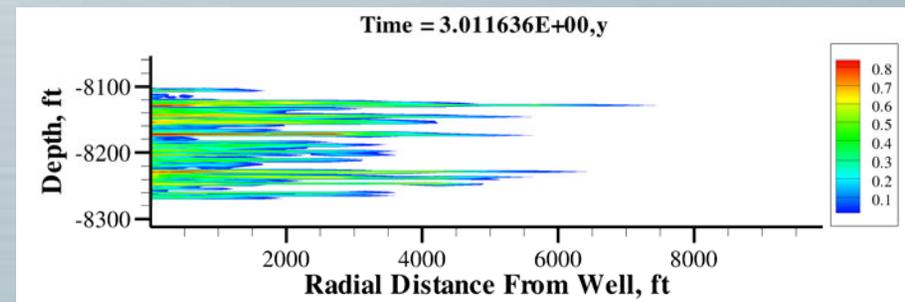
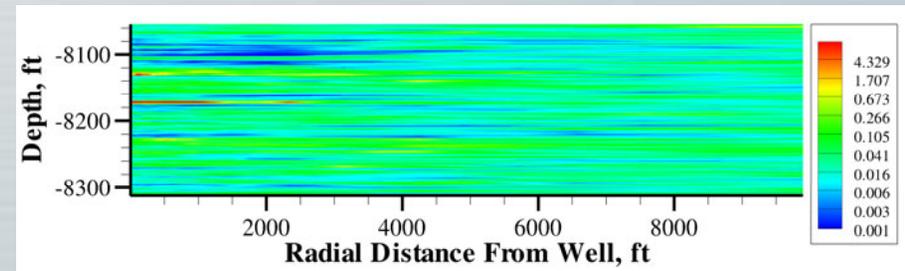
- Extremely geologic data in deeper Appalachian, Michigan, and Illinois Basin is a challenge

Trends – More Detailed Simulations to support permitting, outreach, MMV, and Facility Design are Underway

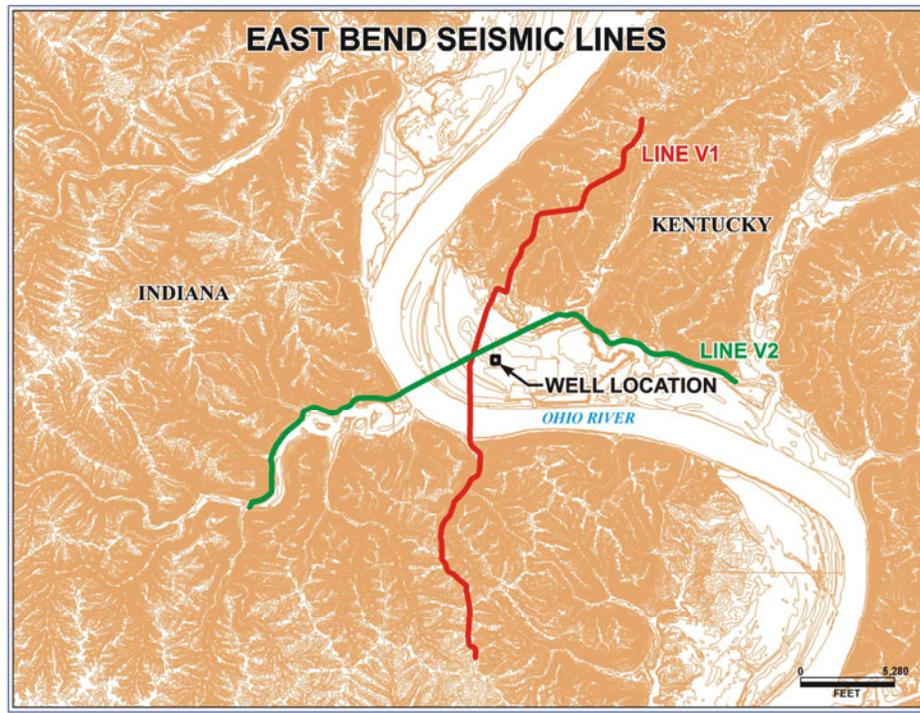


Challenge - Mapping and Modeling Storage in Carbonate Zones

- Example – Copper Ridge/Knox Dolomite at Mountaineer site
- Potentially thin but very high permeability zones in carbonates throughout the region
- Need to understand geologic continuity and geochemical behavior
- Estimating capacity in discontinuous carbonates can be difficult



Trends – Characterization 3D Seismic Surveys and Well Logging

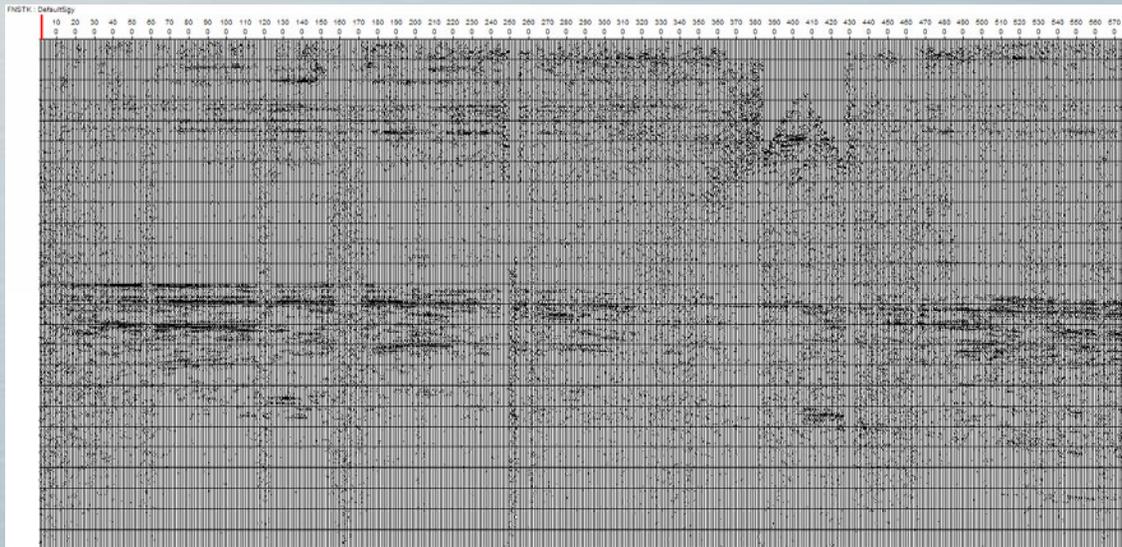
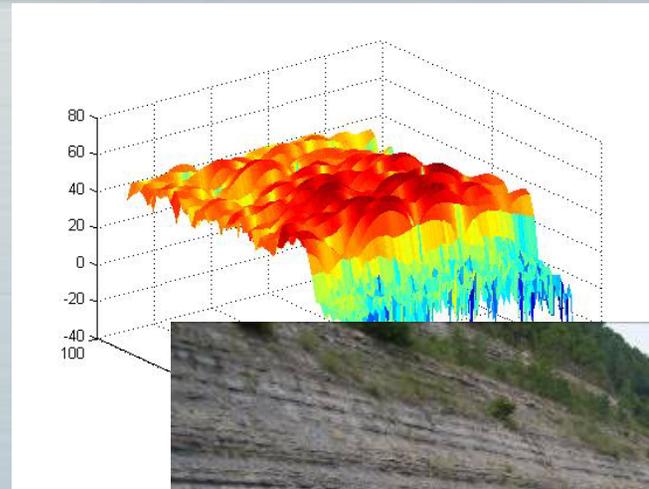


- 3D surveys in complex topography offers numerous challenges
 - Data loss across the river
 - Twisted survey lines offer significant processing challenges

- Possible solutions include:
 - Taking data at the bottom of the river using modified off shore techniques
 - Careful collaboration between acquisition and processing to try and straighten the lines as much as possible

Trends – Deriving Maximum Knowledge from Seismic Interpretations

- Examining the data in numerous ways can yield new information
 - Spectral Decomposition
 - AVO
 - Pre-migrated Stacks
 - Attribute Analysis (ie amplitude)

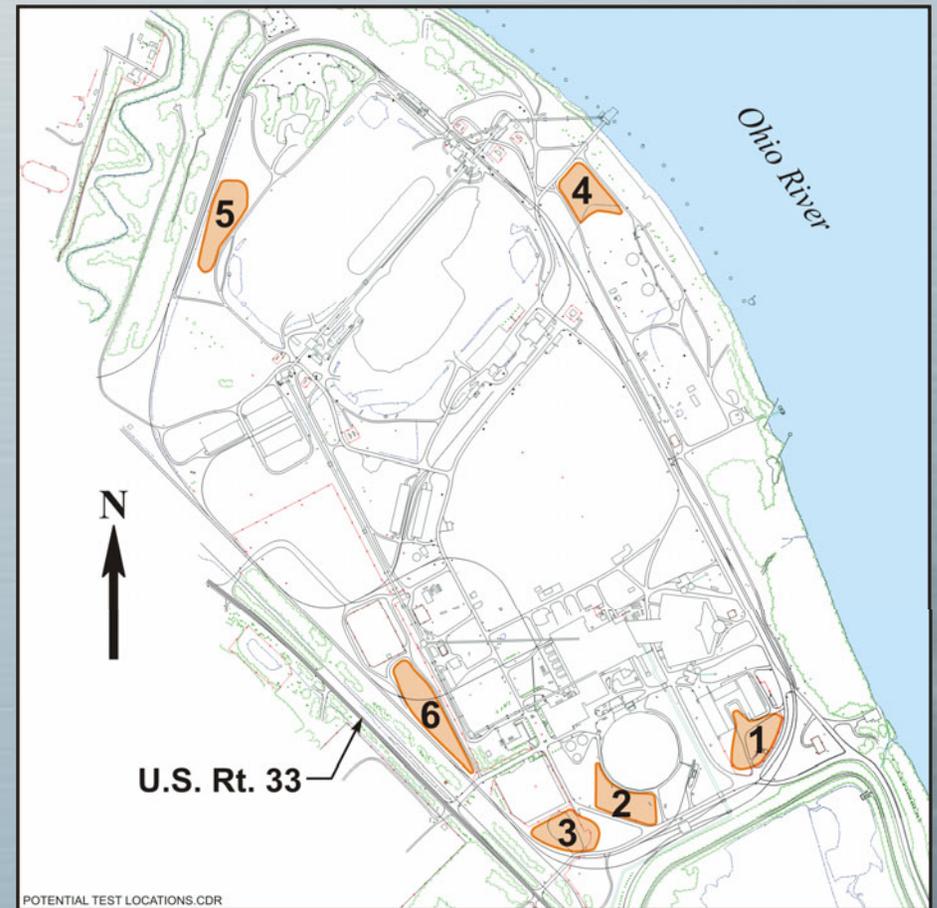


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Trends - Integration of CCS with Plant Operations and Site Logistics

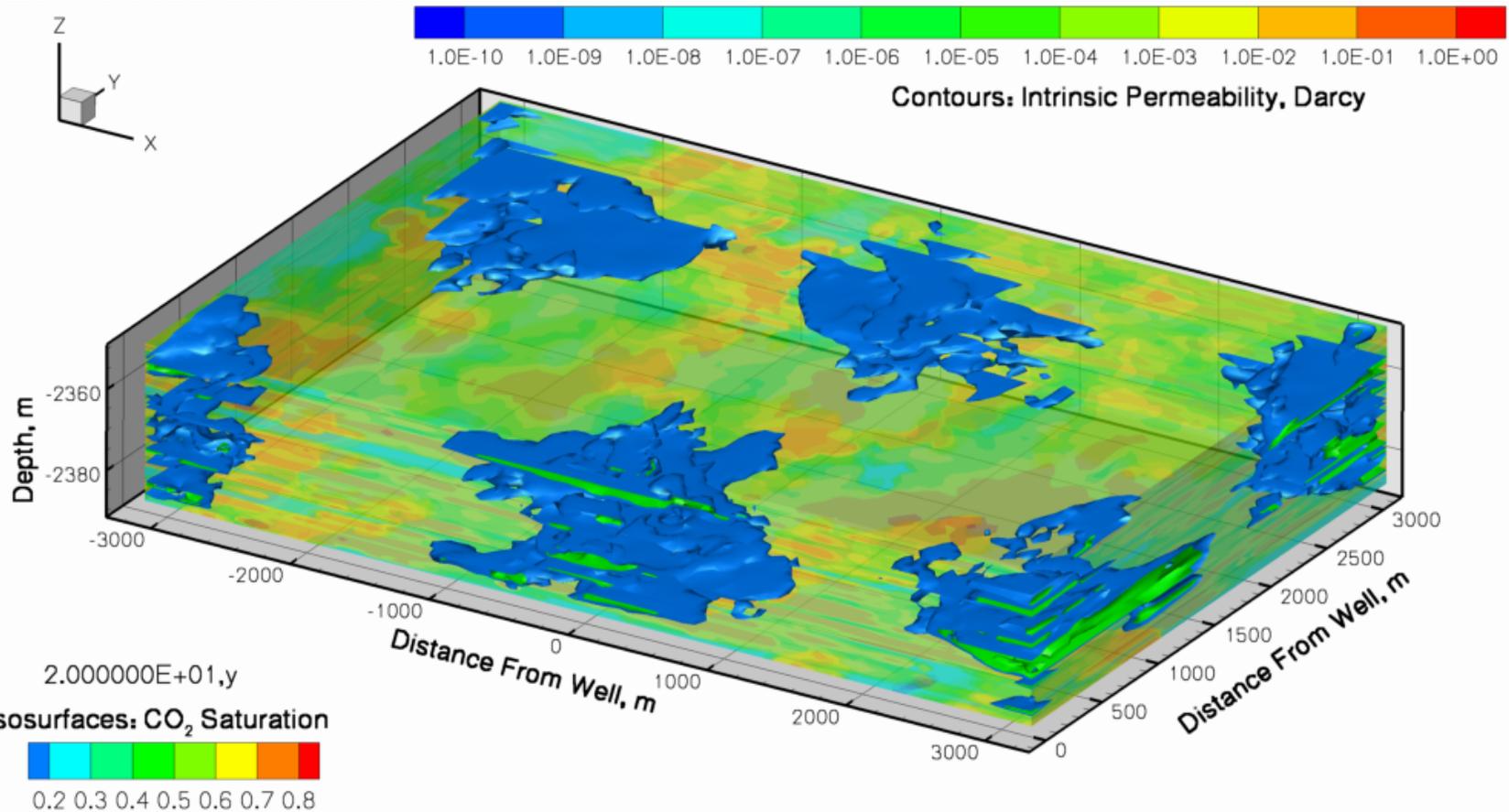


- Logistics of drilling and MMV at and near industrial facility are a major challenge



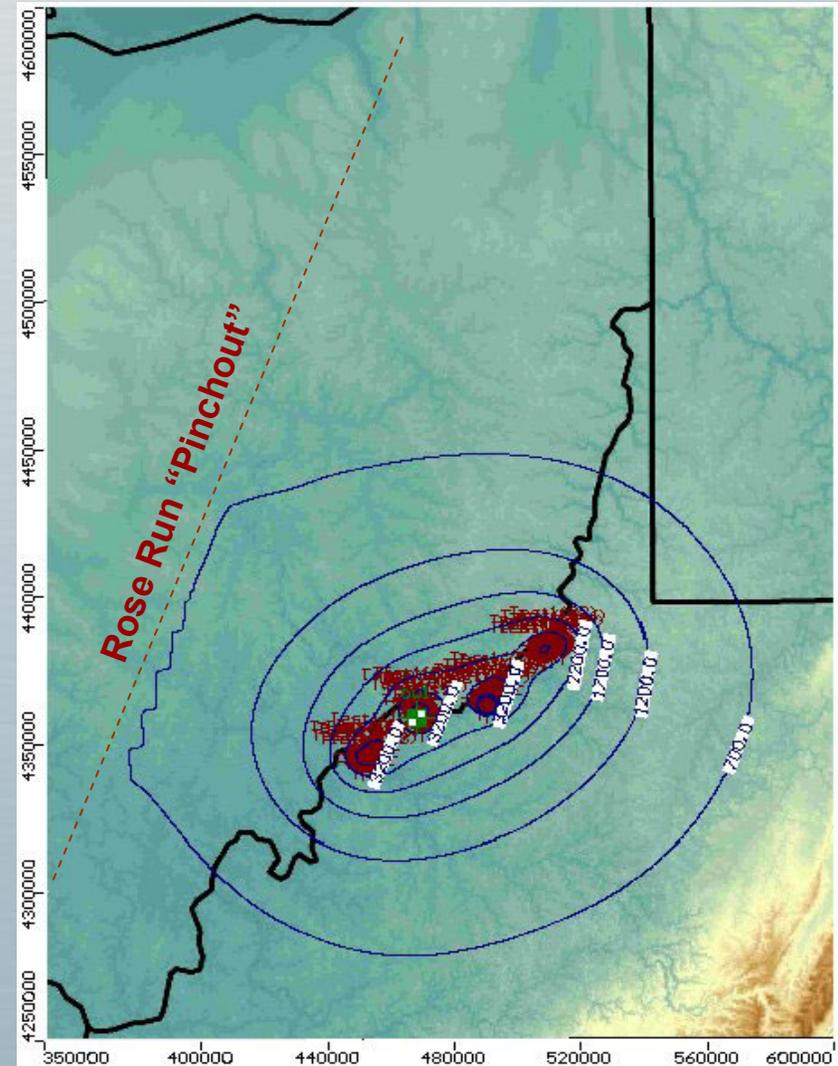
POTENTIAL TEST LOCATIONS.CDR

Challenge - Spacing of Wells Critical Issue for Site-Specific Feasibility



Trends – Developing Hydrogeologically Sound Regional Deployment Plans

- Important for evaluating regional capacity, pressure, geomechanical, and brine mobilization issues.
- Will be required for regional infrastructure planning – inter-facility spacing and transport network
- Example - Simulated pressure buildup @ 20 million tons/year for 20 years in 40 **water** injection wells in Rose Run Sandstone



Trends and Challenges - Institutional/Regulatory Aspects

- A regulatory framework is emerging for deep well injection through extensive interactions with federal and state authorities under ongoing projects
- Public utility commissions and policymakers are becoming increasingly aware of the technical and economic issues related to CCS. The CCS potential is discussed routinely in PUC deliberations
- Through FutureGen process several states have considered long-term liability and ownership issues
- There is a strong need for faster progress on these issues as we move towards large-scale testing

Summary of Trends – Key Lessons

- The last decade has seen tremendous progress in our knowledge of CCS potential in the Midwest
- Regional geologic framework is generally well understood and major sinks and caprocks have been identified
- There is enormous gross capacity in the region
- However, geologic mapping and capacity needs to be continually refined through characterization and data mining
- There is ample caprock in the deep basins, but the injectivity in reservoirs in the deeper basins must be further understood for large-scale deployment
- Major geologic features are well known, however, we need to use existing or new seismic and well data to delineate the nature and extent fault zones

Summary of Trends – We are Now in a Critical Phase for Future Success of CCS

- During last few years, CCS has attracted growing interest and support from regional industry and policymakers, this momentum must continue
- ***Despite our confidence in its potential we must not set unrealistic expectations about CCS***
- Emerging Issues:
 - Regional fluid mobilization
 - Inter-well and inter-facility spacing/regional infrastructure
 - Competing pore space demands at CO₂ source clusters
 - Developing suitable MMV framework for the region
 - Developing regulatory, policy, and risk management framework in parallel with large-scale testing
 - ***Building public acceptance as we proceed to deployment***