

**Presented to the
Greater St. Louis Section
AWMA
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**Missouri Carbon
Sequestration
Project**

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Missouri Carbon Sequestration Project**

Project Overview

- The Missouri Carbon Sequestration Project is a federally-funded research project to assess the feasibility of onsite carbon sequestration at Missouri power plant sites.



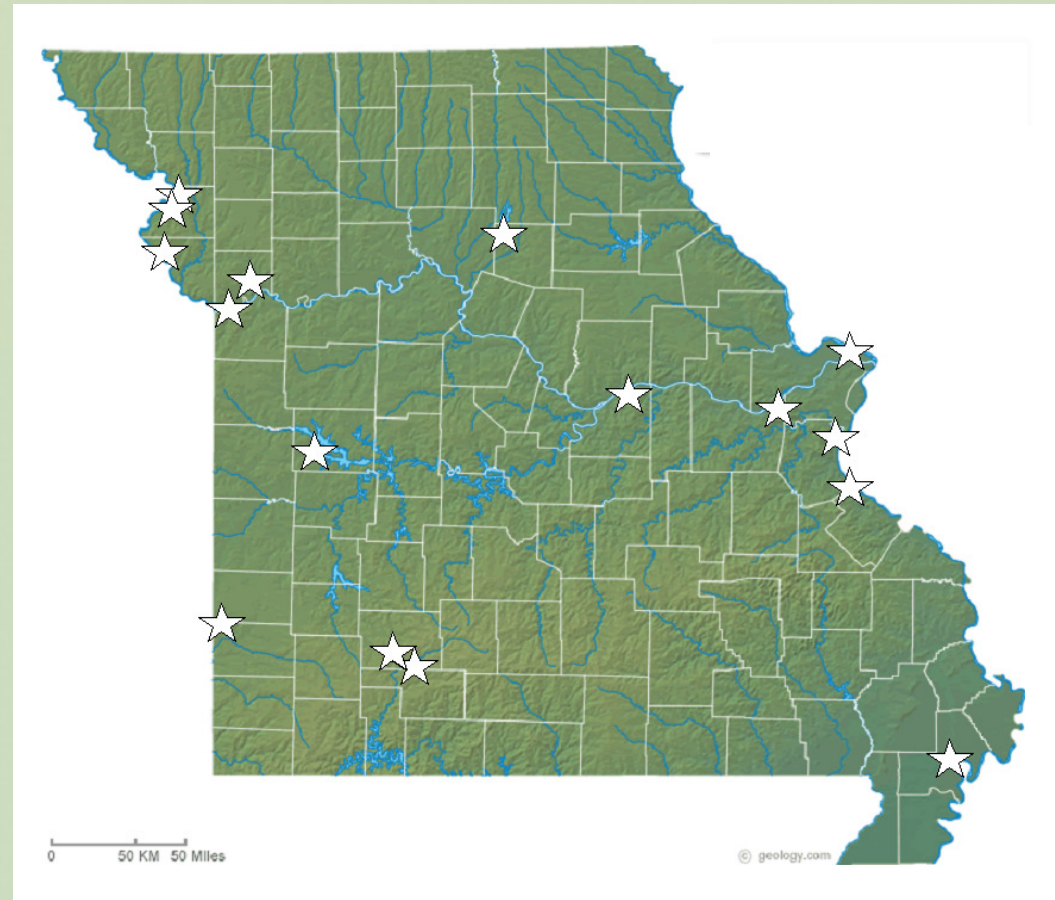
Project Funding

- Project funding totaling \$2.46M was included in the December 21, 2007 Omnibus Appropriations Bill.
- DOE is administering the funds. A total of **\$2,362,349** in federal funding is available.
- The utility partners, AmerenUE, AECI, City Utilities, KCP&L, and The Empire District Electric Company, are providing 20% matching funds totaling **\$590,587**.
- The total project budget is **\$2,952,936**.



Member Utility Coal-Fired Power Plants

- Missouri's electric utilities and Missouri's citizens have a large stake in the project.
- The five member utilities collectively provide electricity to 90% of Missouri's farms, families, and businesses.



Member Organizations and Supporters

- Research Members
 - City Utilities of Springfield
 - Missouri Department of Natural Resources
 - Missouri State University
 - Missouri University of Science & Technology
- Funding Members
 - AmerenUE
 - Associated Electric Cooperative, Inc.
 - City Utilities of Springfield
 - Kansas City Power & Light
 - The Empire District Electric Company
- Supporting Organizations
 - Missouri Energy Development Association
 - Missouri Public Service Commission
 - Missouri Public Utility Alliance
 - U.S. EPA Region VII



A Missouri Solution

- The Missouri Carbon Sequestration Project is a statewide effort involving a number of organizations across Missouri.
- The project has the support of key state and federal agencies.
- The organizations are collectively working toward a Missouri solution to a Missouri problem.

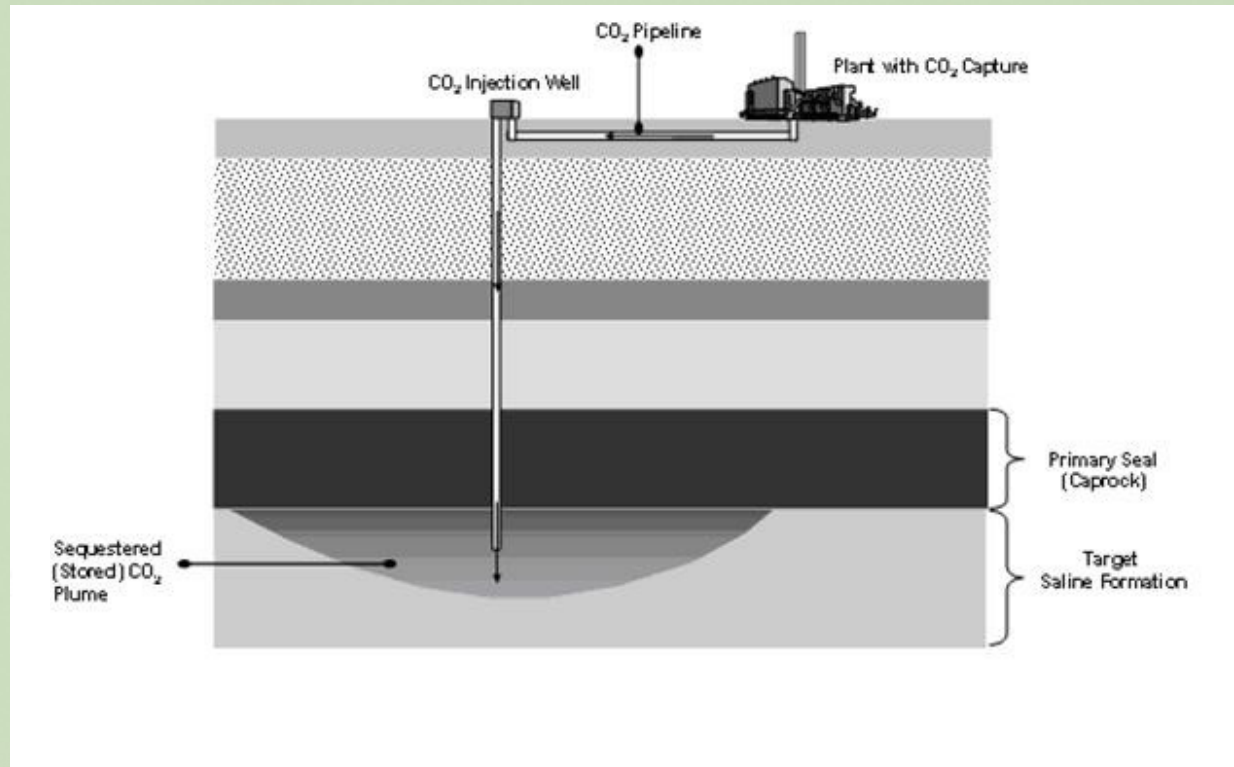


The Carbon Challenge

- Missouri utilities face a very stiff challenge in ***reducing carbon emissions*** in a safe, effective, and economical manner.
- The most promising means to reduce emissions appears to be **carbon capture and sequestration (CCS)**.
- The **capture** component of CCS is under development and could be commercially available for pulverized coal power plants within ten years.
- The **sequestration** component of CCS requires specific geological conditions and is the focus of the Missouri Carbon Sequestration Project.



How CCS Works



Alstom – Chilled Ammonia Process

AEP Mountaineer Plant, New Haven, WV



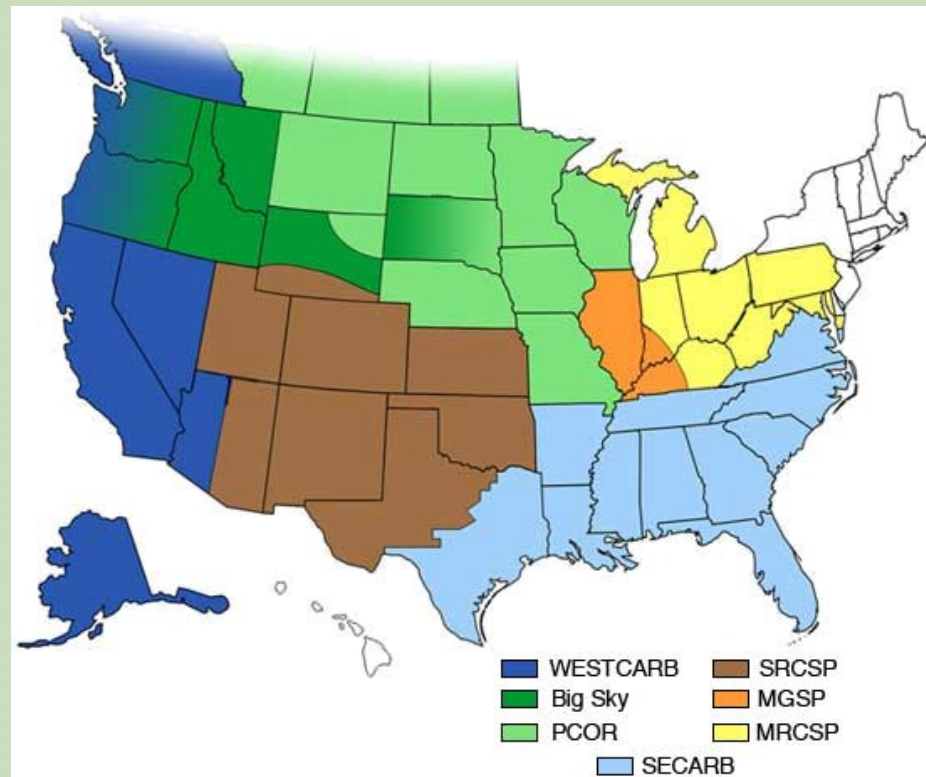
CCS In Perspective

- Flue gas from pulverized coal power plants generally contains 12-18% CO₂ by volume.
- Estimates of the energy requirements for CCS range from 25-50% of gross plant output.
- DOE estimates that CO₂ capture and compression using the aqueous amine process may increase electric costs by 84%.
- Implementation of CCS nationwide would have a tremendous impact on both electric rates and electric capacity.

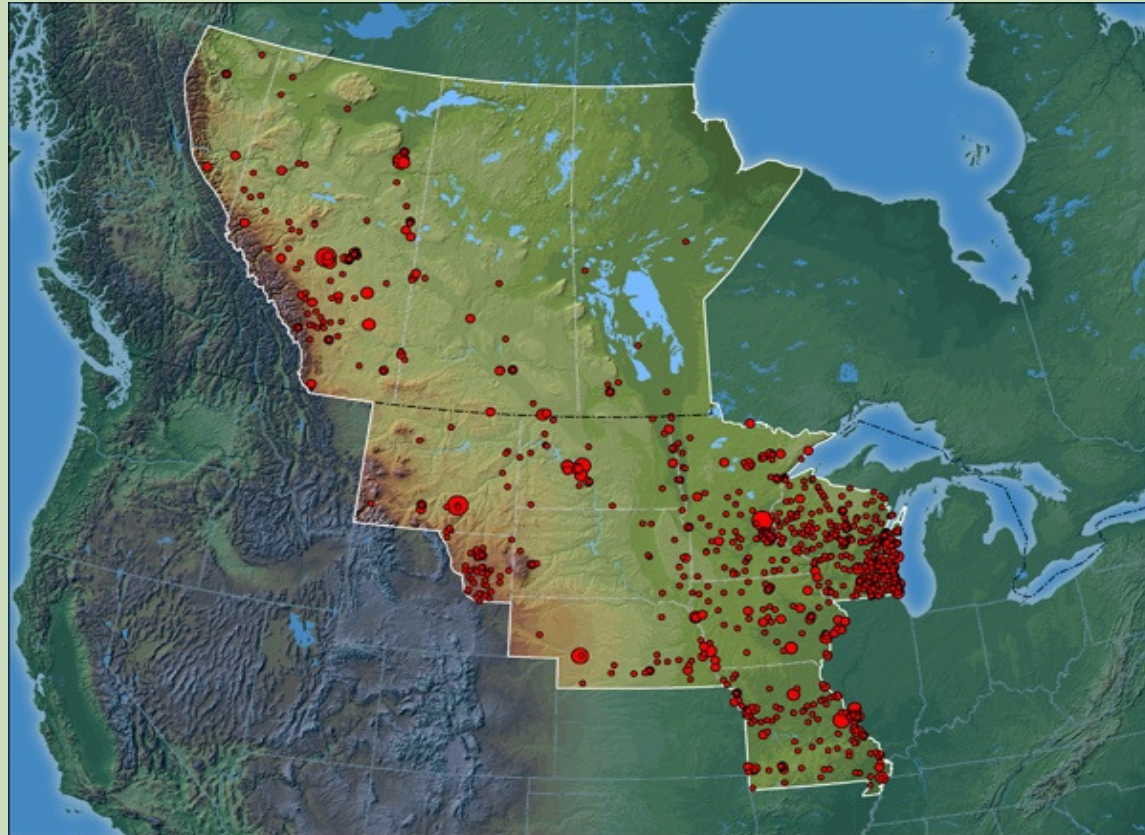


The National Carbon Strategy

- DOE has established 7 regional partnerships to address carbon sequestration.
- DOE research, to date, has focused on demonstration projects involving the deepest geological basins.



The Plains CO₂ Reduction (PCOR) Partnership



Geological Basins In The PCOR Region



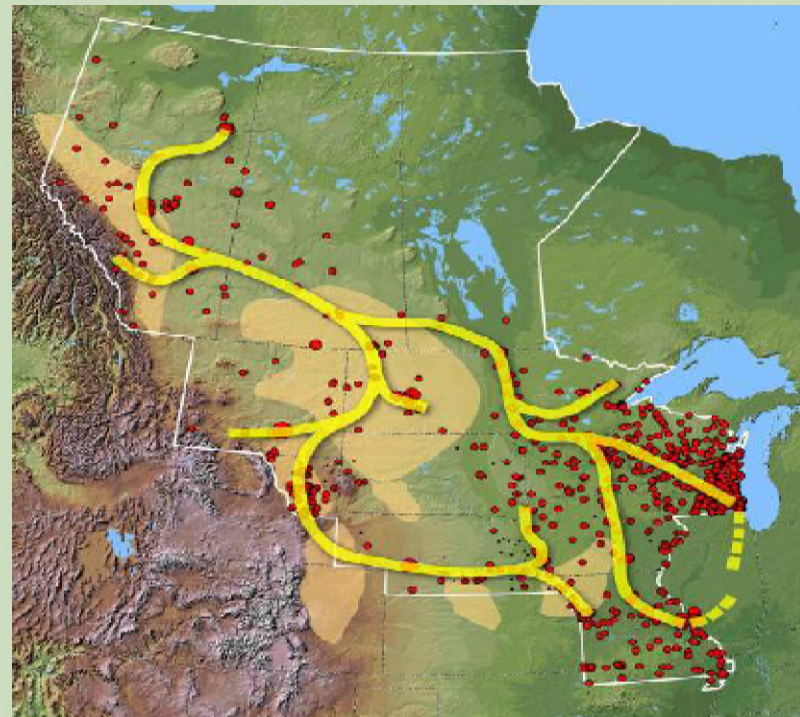
The National Carbon Strategy

- Although these deep geological basins are ideal sites for regional sequestration, they are located at such distances from Missouri power plants that transportation of CO₂ to the regional sites would be extraordinarily expensive.



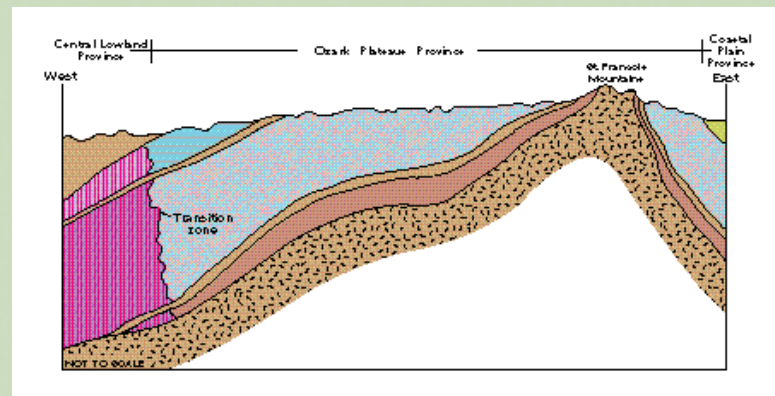
The National Carbon Strategy

- Regional carbon sequestration would require an extensive pipeline system for CO₂ collection, compression, and transmission.
- Permitting and construction of the pipeline system would take decades to complete.



A Missouri Solution

- Missouri's geology is similar to that of the regional sequestration sites.
- The Lamotte Sandstone is the deepest sedimentary strata in the state and serves as the primary sequestration target.
- The Reagan Sandstone lies above the Lamotte and serves as a secondary target.
- The Derby-Doerun/Davis confining layer lies above the Lamotte and Reagan Sandstones.

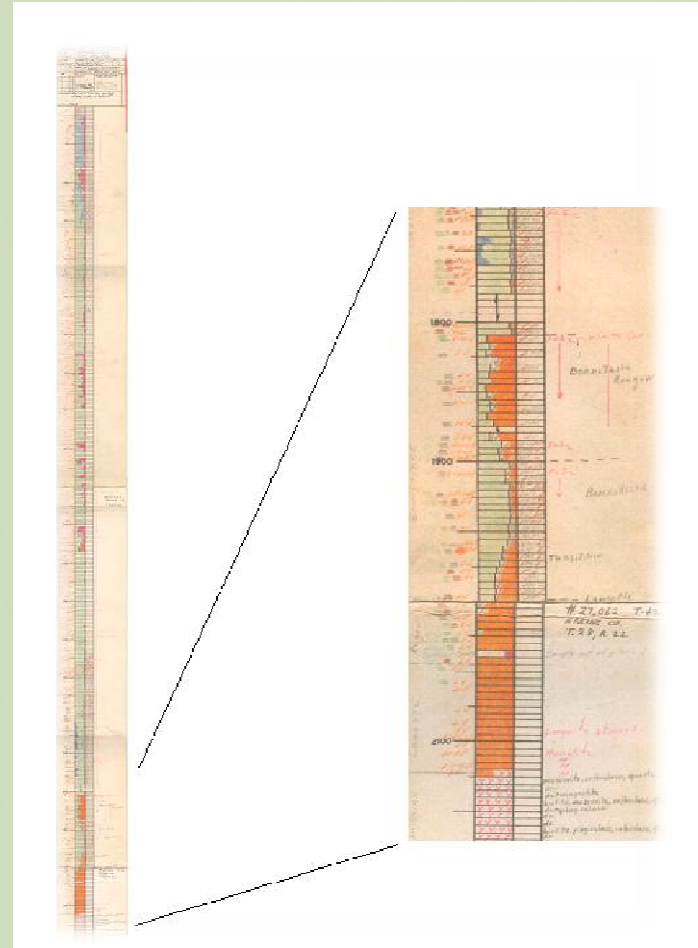


Lamotte – Reagan Target

Southwest Power Station

Missouri Well Log No. 27062

- Springfield Aquifer
(Surface to 275')
- Northview Confining Layer
(275' to 305')
- Ozark Aquifer
(305' to 1545')
- Derby-Doerun/Davis Confining Layer
(1545' to 1810')
- Lamotte-Reagan Target
(1810' to 2125")



Research Question

- *Is it possible to sequester CO₂ at individual power plant sites in Missouri?*
- *Yes, depending on . . .*
 - *Storage capacity of the receiving formation*
 - *Maximum sustainable injection rate*
 - *Competency of the confining layer*
 - *Rate, type and degree of trapping mechanisms*



CO₂ Trapping Mechanisms

- CO₂ injected into the subsurface may be held in place by the following mechanisms:
 - **Stratigraphic/Structural Trapping** - CO₂ can be held beneath a low-permeability layer.
 - **Solubility Trapping** - CO₂ can be dissolved into a liquid, such as water or oil.
 - **Mineral Trapping** - CO₂ can react with minerals, fluids, and organic matter in the formation to form stable compounds.
- CO₂ trapping mechanisms are a function of geology and are independent of depth.



Project Site

- The primary project site is City Utilities' Southwest Power Station in Springfield.
- Additional site characterization may be performed at other Missouri power plant sites in future phases.



Project Plan

- **Phase I – Initial Assessment:** Analysis of existing Lamotte sandstone core and preliminary site evaluation. Completed by UMR in 2006 and funded solely by City Utilities.
- **Phase II – Site Characterization:** Site drilling, coring, geophysical logging and seismic surveys. Pump testing to provide data for the hydrologic model and to validate the competency of the confining layer. Completion of boreholes as monitoring wells. Rock core samples will be prepared by the Missouri Department of Natural Resources and distributed to researchers.
- **Phase III – Sequestration Research:** Laboratory testing, reservoir analysis, and bench-scale reactor simulations at Missouri State University and Missouri University of Science & Technology, as well as core logging and development of structural, stratigraphic, and hydrologic models at the Missouri Department of Natural Resources.
- **Phase IV – Injection Test:** Injection well permitting and construction, followed by pilot scale injection of a limited quantity of “food grade” carbon dioxide at the demonstration site and long term site monitoring.
- **Phase V – Reporting:** Assimilation of all research findings into a comprehensive final report. DOE requires publication and presentation of research findings.



City Utilities' Role

- Community/Governmental/Media Relations
- Project Administration and Coordination
- Drilling and Coring Services
- Pump Testing Services
- Well Logging Services
- Injection Well Permitting and Construction
- CO₂ Injection
- Site Monitoring
- Report Preparation



Missouri Department of
Natural Resources
Division of Geology and Land Survey
Geological Survey Program

Shallow Carbon Sequestration Pilot
Demonstration



**DEPARTMENT OF
NATURAL RESOURCES**
Division of Geology and Land Survey

MDNR's Role in the Project

- Develop **geologic model**.
- Facilitate discussions with EPA concerning **UIC requirements** in Missouri.
- Participate in **public availability sessions, public hearings, and community information sessions** in conjunction with other participating entities.
- Establish and maintain a comprehensive and detailed **structural, stratigraphic, and hydrologic model** of the subsurface environment.
- Develop **digital maps and cross sections** for use by all project researchers.

MDNR's Role in the Project

- Prepare **geologic descriptions** of drill core and drill cuttings generated during the project.
- Inventory project drill core and drill cuttings into the **McCracken Core Library** for permanent storage.
- Prepare **Report of Findings**.



MDNR's Role in the Project

- Primacy has been given to MDNR by EPA to regulate the **UIC Program** in Missouri.
- Class V wells are regulated by the Water Protection Program of DEQ with consultation of the Geological Survey Program of DGLS.
- An application for a permit to construct an injection well and to inject must be filed with the Water Protection Program.



Shallow Carbon Sequestration Pilot Demonstration



**Missouri
State**
UNIVERSITY

Missouri State Team--Task 1

- ***Geochemical Analysis of Anticipated Receiving Formation (Lamotte Sandstone)***
 - Erwin Mantei, PhD
 - Thomas G. Plymate, PhD, RG
 - Mineral composition, texture and rock fabric, and pore fluid chemistry, based on samples and data from City Utilities and Missouri S&T.



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Missouri State Team--Task 2

- *Hydrogeologic Analysis of Receiving Unit Flow System*
 - Charles Rovey, II, PhD
 - Development of fluid flow model of the injection formation based on analysis of hydrogeologic testing data supplied by City Utilities.



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Missouri State Team--Task 3

- ***Numerical Geochemical Model of Formation Fluid Interactions***
 - Douglas Gouzie, PhD, RG
 - Melida Gutierrez, PhD
 - Model interactions between rock unit (MSU & MS&T data), formation fluid (CU and MSU data), and injection stream (CU data).
 - Compare formation-scale model with bench scale experimental data (MS&T).



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Shallow Carbon Sequestration Pilot Demonstration

**Global
Sustainability
for Future
Generations**



Carbon Dioxide Trapping Mechanisms

Hydrodynamic Trapping:

Dissolution of CO₂ into saline aquifer system as a soluble gas phase.

Stratigraphic/Structural Trapping:

Aqueous, gas, and/or supercritical CO₂ phase(s) trapped underground by confining properties of impermeable geologic strata.

Mineral Precipitation:

Sequestration of dissolved CO₂ into geologically stable mineral phase(s).

MS&T researchers will focus on determining properties of the Lamotte Formation through:

- Core Analysis
- Well Log Analysis
- Geomechanical Rock Properties
- Hydraulic Fracturing/Formation Integrity Analysis
- Simulated Laboratory Reactions: Water + CO₂ + Minerals

Core Analysis



A statistically valid number of samples from the Lamotte Formation will be analyzed to determine important parameters such as *porosity* and *permeability*.

Porosity is the empty space in the rock which determines its storage capacity. It will be measured in several ways and results compared.

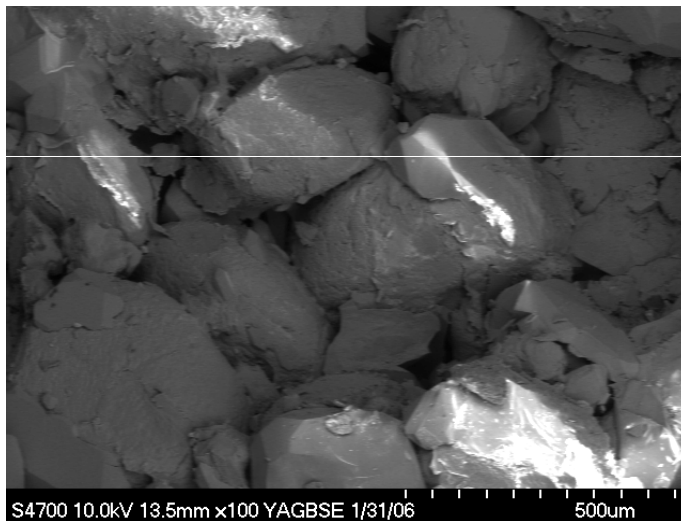
Permeability is a measure of the ease with which fluid and CO₂ can move into or out of the rock.

X-Ray Analysis

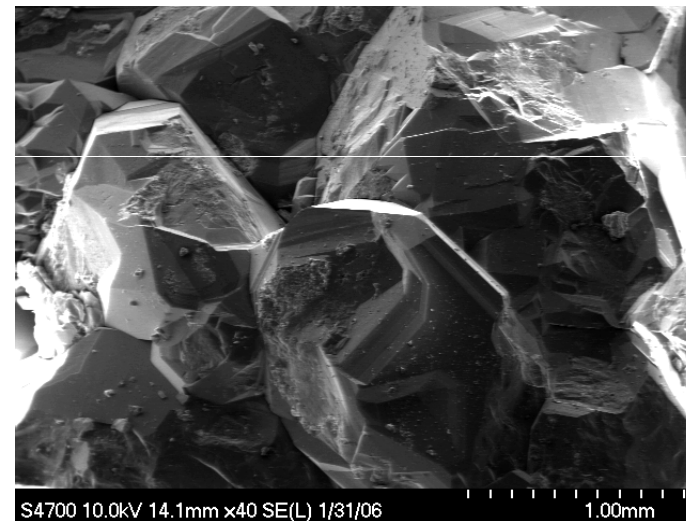
- **X-ray Diffraction (XRD) Analysis**
 - Used to characterize the crystalline structure and mineralogy. In this study XRD will be used to identify clay mineral types and other fine grained sediments.
- **X-ray Fluorescence Spectrometry (XRF)**
 - Used to determine precise chemical element analysis and quantitative determination for solids. In this study XRF will be used for identification of clay mineral composition and total percentage clay in each sedimentary unit.

Scanning Electron Microscopy (SEM)

SEM is a highly versatile tool for providing high-resolution image and semi-quantitative chemical analysis.

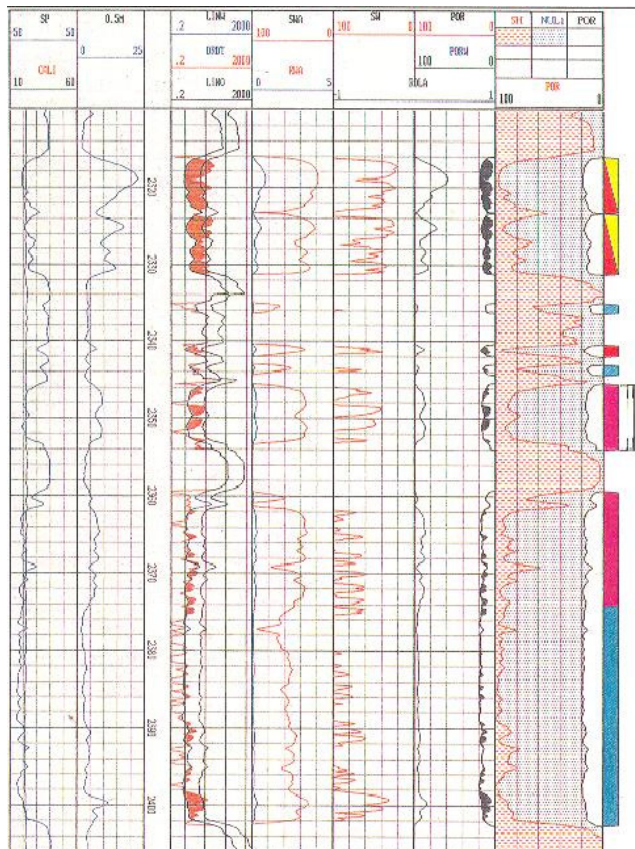


Lamotte sand grains and clay coatings. Pore spaces between grains.



Sand grains generally clear of clays, but with more limited pore space.

Well Log Analysis

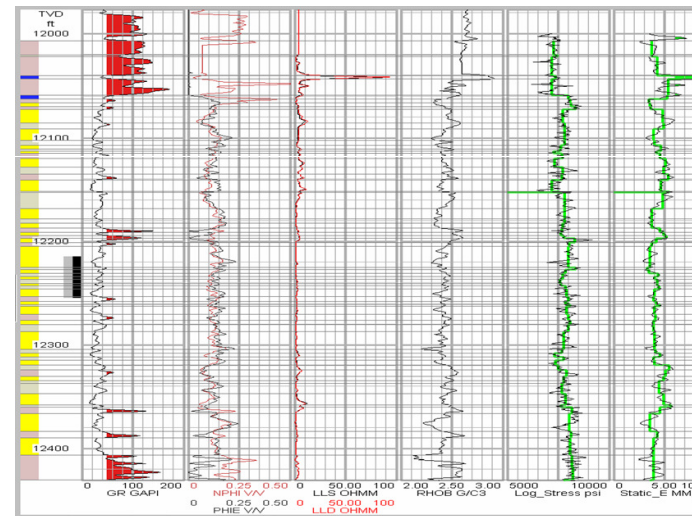


Well logs provide direct and continuous measurements of physical properties, such as formation density, resistivity, gamma radiation, acoustic properties, etc.

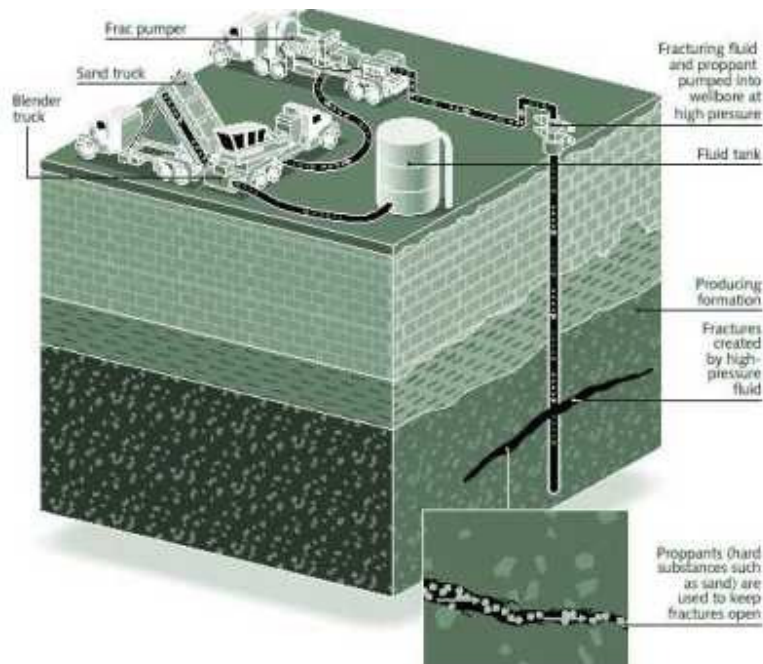
Provides indirect measurement of porosity and fluid saturations. Acoustic log information is used to build earth models which are 3-D projections of the subsurface stress fields.

Geomechanical Rock Properties

- **Geomechanical dataset refers to properties of rock strength. Properties are measured in static mode (in lab) using core samples.**
- **Geomechanical data properties are combined with well log data to identify different layers with variable compressive strengths. In the example shown here, shales are shaded with grey and sands or silts are shaded with yellow.**

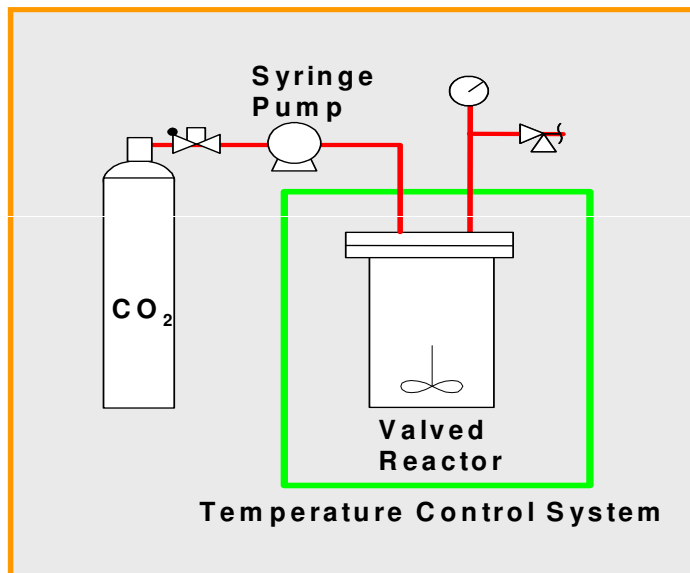


Hydraulic Fracturing Formation Integrity Assessment



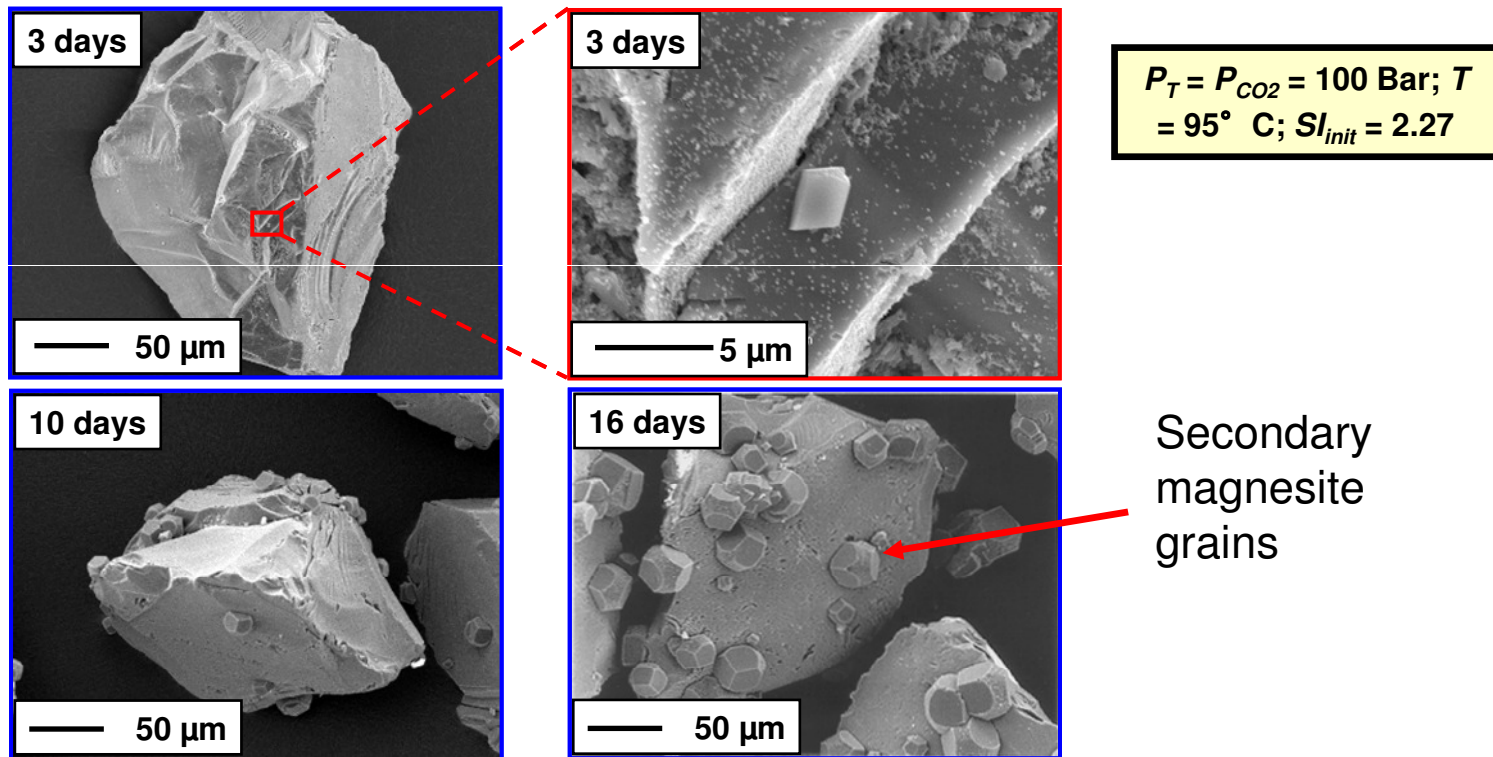
- Hydraulic fracturing creates a thin crack in a rock by pumping an incompressible fluid downhole at a pressure above the breakdown pressure for a rock layer.
- Fracturing may occur as a function of formation cooling rate or as a need to increase injection pressure as clay minerals move and 'plug' the pore space.
- In this project, formation breakdown and fracturing will be investigated with a pump-in, and pressure fall off analysis.
- Ideally, CO₂ would be injected without subsurface fracturing.

Research Approach: Investigation of Water-Rock-CO₂ Interactions



Laboratory investigations of reactions occurring at expected temperature-pressure conditions relevant to Lamotte Formation strata.

Reaction between Olivine (Mg_2SiO_4) + CO_2
Charged Water to Produce Magnesite ($MgCO_{3(s)}$)

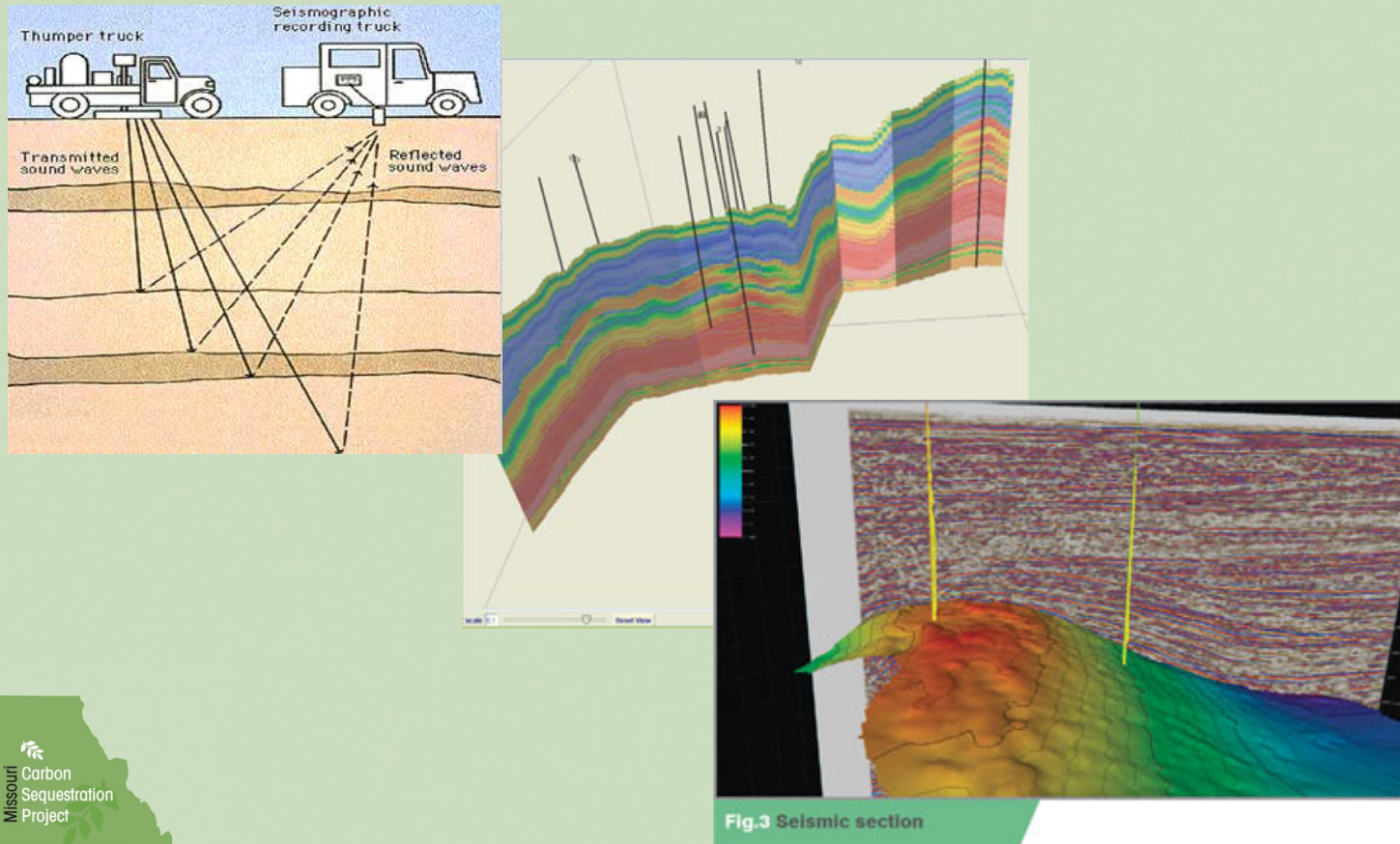


From: Giammar et al., 2005; *Chemical Geology*, v. 217, p. 257-276

Site Characterization

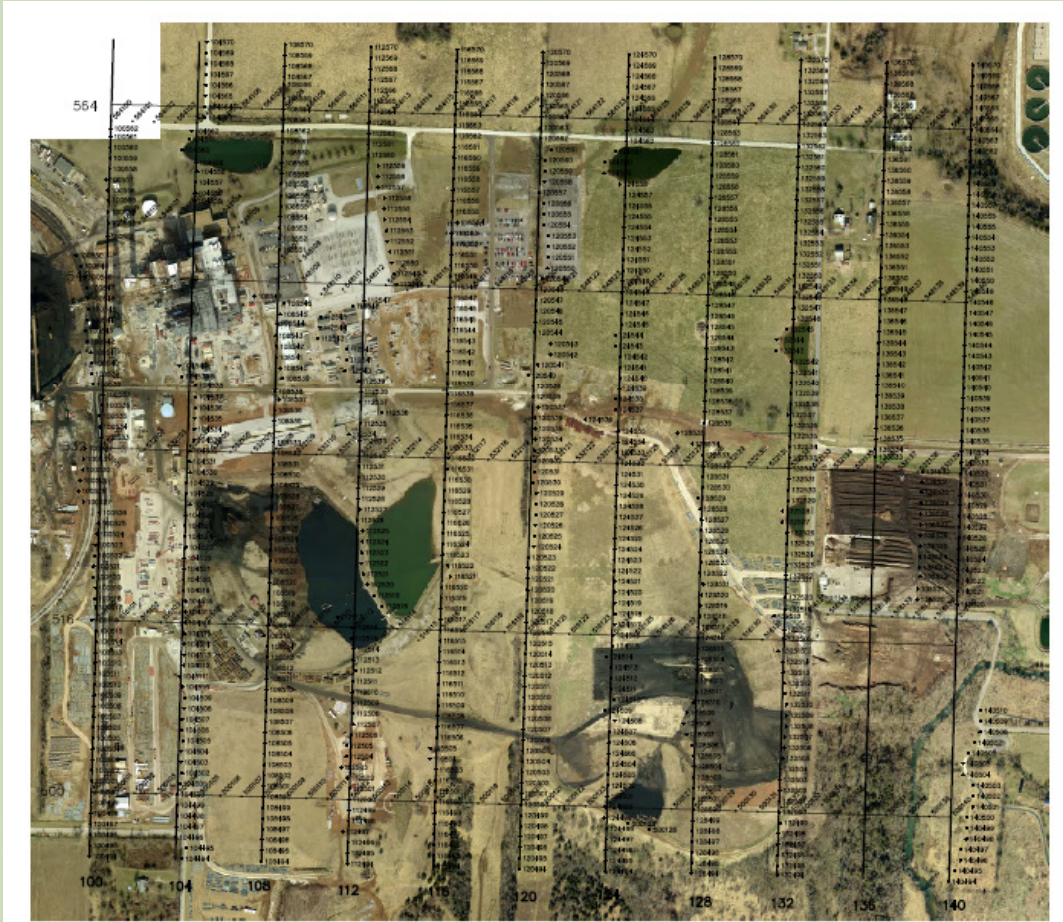


3D Seismic Reflection Survey



3D Seismic Reflection Survey

- Data Acquisition, Processing, and Interpretation
 - 200+ geophone locations.
 - 800+ thumper truck locations.
 - Seismic reflections recorded from a number of subsurface layers.
 - Thousands of data points allow generation of a three-dimensional model of the subsurface.



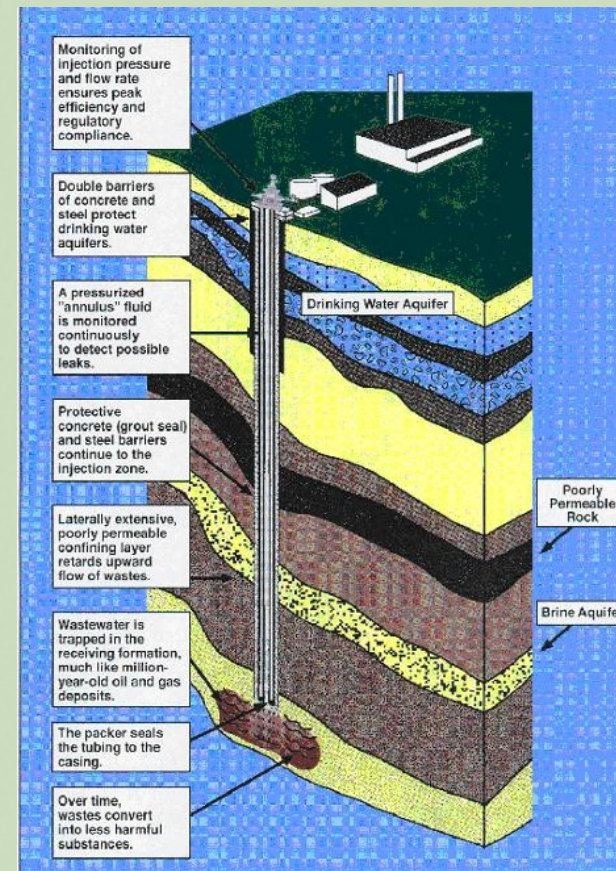
Exploratory Well Drilling & Completion

- Bid Opening held on November 16, 2009.
- Anticipated commencement of drilling in January 2010.



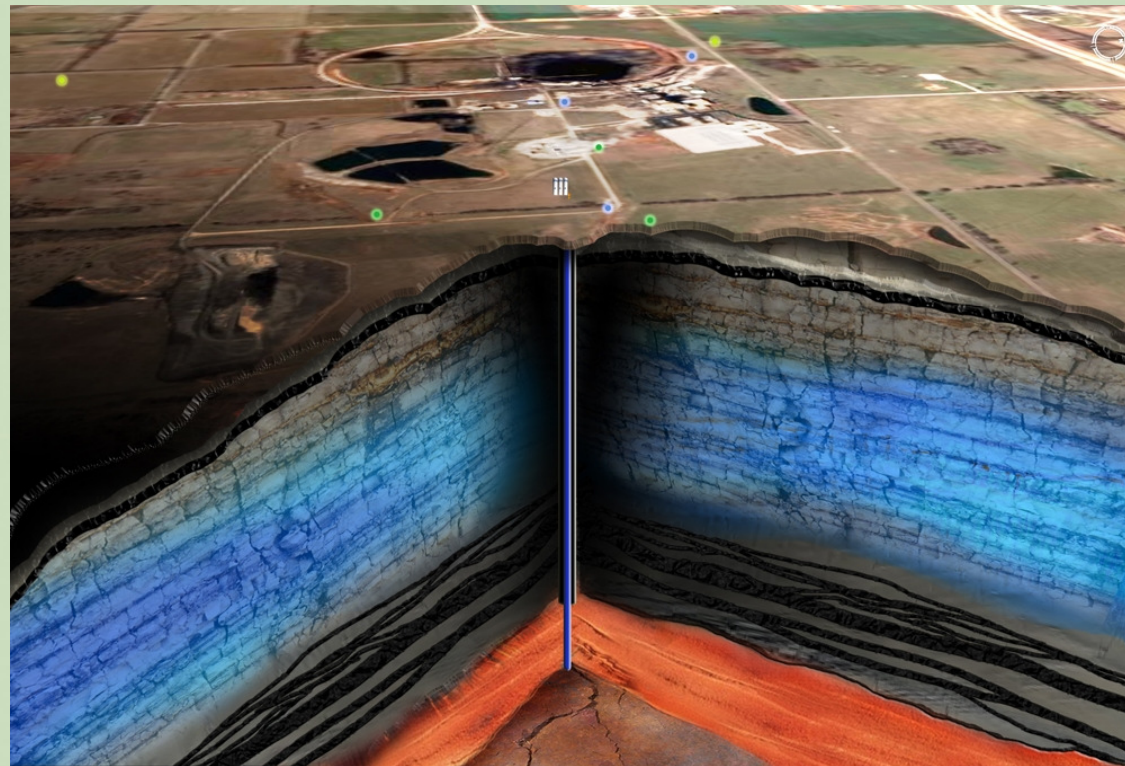
Injection Well Permitting & Construction

- Site characterization and injection well design data will be incorporated into permit application.
- Application will be submitted to MDNR in late 2010.
- Injection well construction will commence upon receipt of permit.
- EPA is in the process of formulating CO₂ injection well design criteria.



Injection Test

- Food grade CO₂ to be delivered in tanker trucks.
- Limited injection to confirm reservoir properties.
- Long term monitoring via monitoring wells and SWPS service water supply wells.



Summary

- The Missouri Carbon Sequestration Project is an important project that has broad state-wide interest and support.
- Missouri's energy future depends on the outcome of carbon cap & trade legislation and the viability of carbon capture and sequestration.



Summary

Missouri stands at a crossroads.

Carbon
Cap & Trade
(tax on coal)

Carbon
Capture &
Sequestration

Onsite Sequestration
At Missouri Power
Plant Sites

Transport to Regional
Sequestration Sites
in Other States



Questions?

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