Shallow Carbon Sequestration Demonstration Project

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U.S. Department of Energy

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Carbon Storage R&D Project Review Meeting
Developing the Technologies and
Infrastructure for CCS

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Presentation Outline

- Benefits to the Program
- Project Overview
- Project Organization
- Project Sites
  - John Twitty Energy Center
  - Thomas Hill Energy Center
  - Sioux Power Plant
  - Iatan Electric Generating Station

Presentation Outline

- Project Completion
- Accomplishments to Date
- Summary

Benefit to the Program

- Program goal being addressed.
  - Support industry's ability to predict CO_2 storage capacity in geologic formations to within ±30 percent.
- Project benefits statement.
  - The research team is assessing CO_2 storage capacity at four Missouri power plant sites. The research will determine the feasibility of carbon sequestration in Missouri and fill a gap in the Program's database.

Project Overview:
Goals and Objectives

- Project Goal: Determine the feasibility of carbon sequestration in Missouri.
- Project Objectives:
  - Characterize four Missouri power plant sites.
  - Drill a characterization well at each site to determine the reservoir properties of the target formation, competency of the confining layer, and storage mode.
  - Estimate the storage capacity and maximum sustainable injection rate of CO_2 into the target formation.

Project Organization

- **Research Members**
  - City Utilities of Springfield
  - Missouri Department of Natural Resources
  - Missouri University of Science & Technology
  - Missouri State University
- **Utility Members**
  - Ameren Missouri
  - Associated Electric Cooperative, Inc.
  - City Utilities of Springfield
  - Kansas City Power & Light
  - The Empire District Electric Company

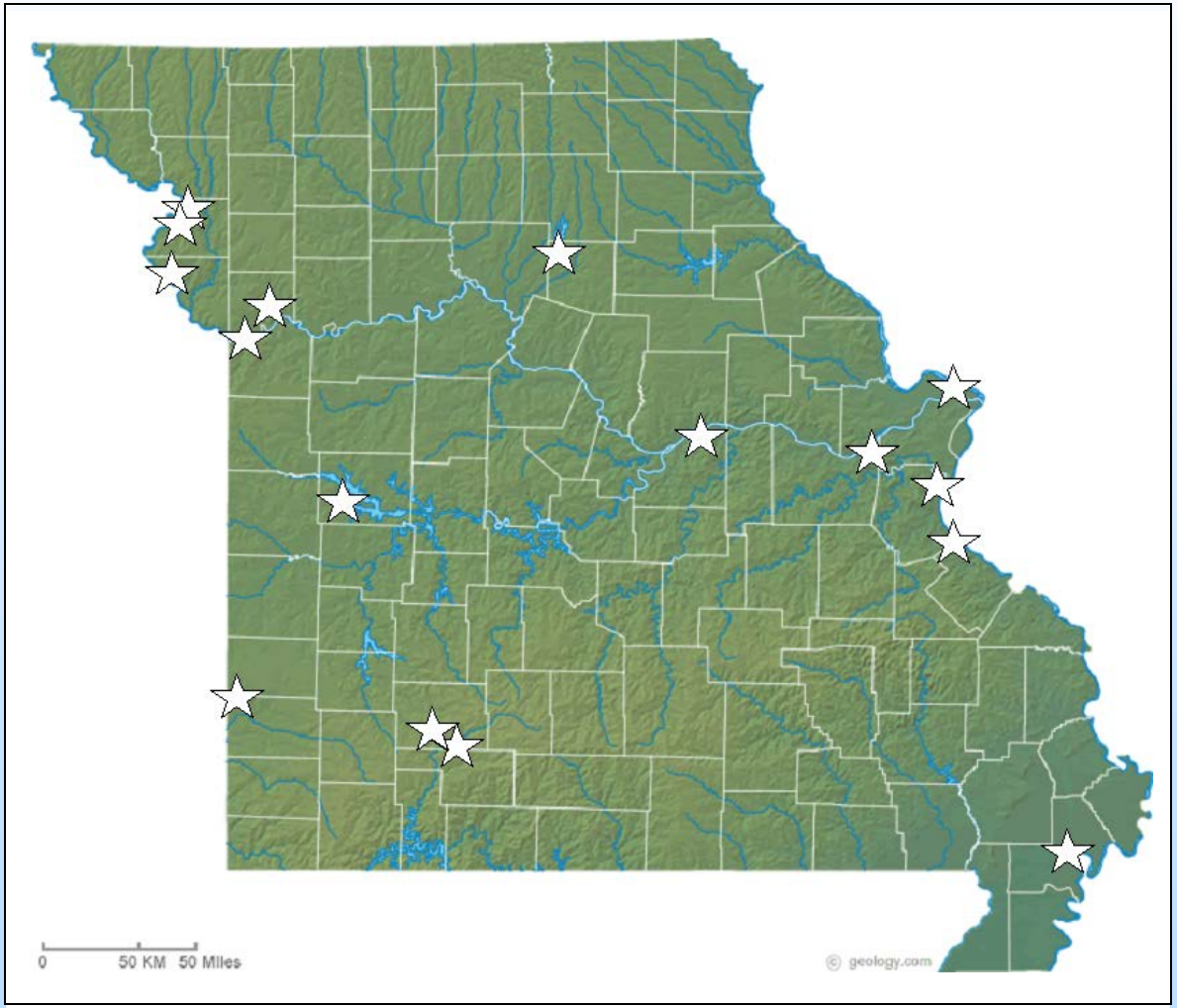
"Missouri Carbon Sequestration Project" adopted as the working project name

Project Responsibilities

- **Missouri State University**
  - Mineralogy, Hydrology
- **Missouri University of Science & Technology**
  - Reservoir Properties, Geomechanics
- **Missouri Department of Natural Resources**
  - Logging of Core/Cuttings, Geological Mapping
- **City Utilities**
  - Coordination of Research, Contracting/Management of Drilling Operations, Financial Management, Reporting
- **Utility Members**
  - Contribution of Matching Funds, Access for Drilling Operations

Value to Missouri

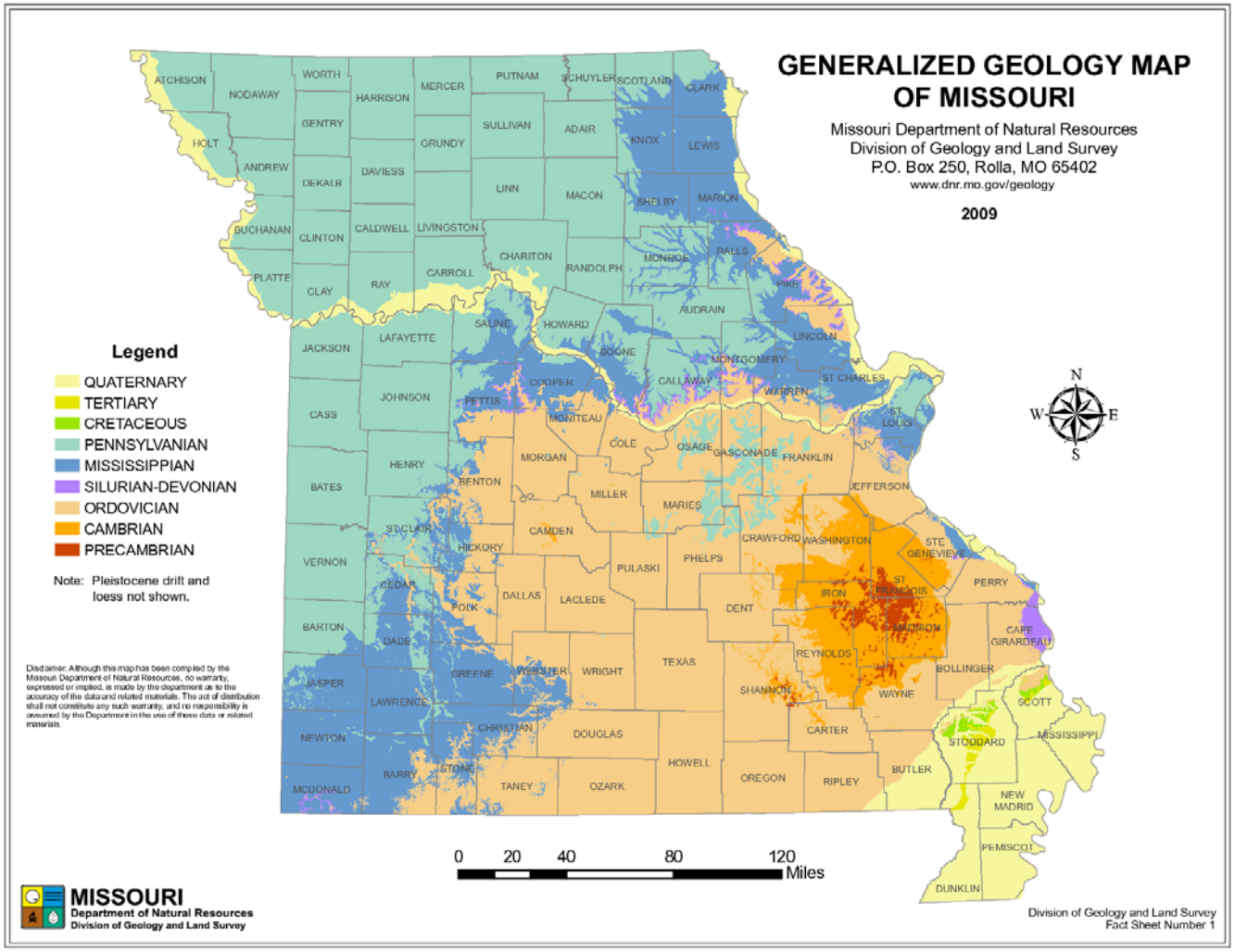
- Missouri's electric utilities and Missouri's citizens have a large stake in the project.
- The 5 member utilities operate 16 coal-fired power plants and collectively provide electricity to 90% of Missouri's farms, families and businesses.



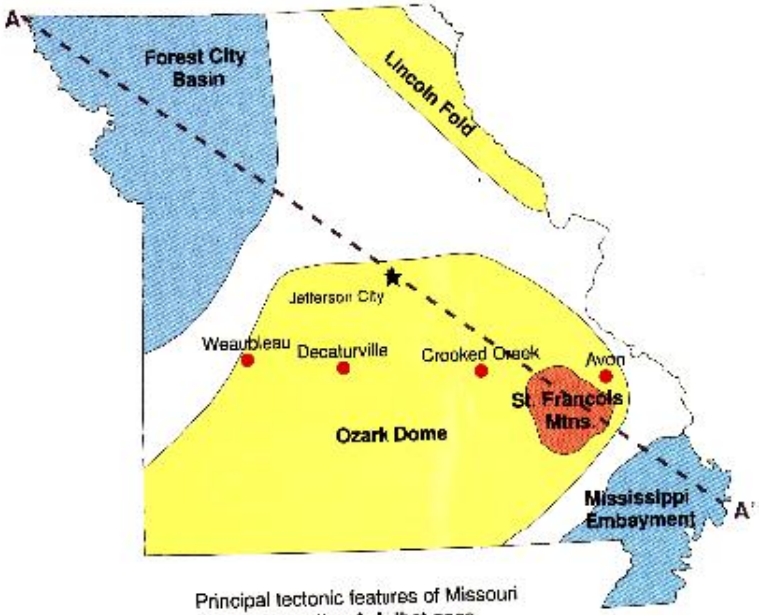
Project Sites

- The four project sites represent all five member utilities and provide good state-wide geographic and geologic distribution.
- The four boreholes provide a good characterization of carbon sequestration in Missouri, and fill an important Program data gap.

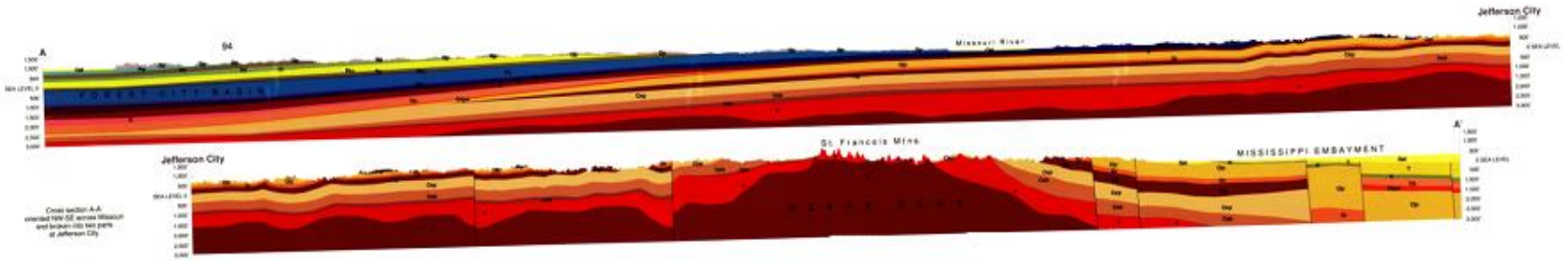
Missouri Geology



Missouri Geology

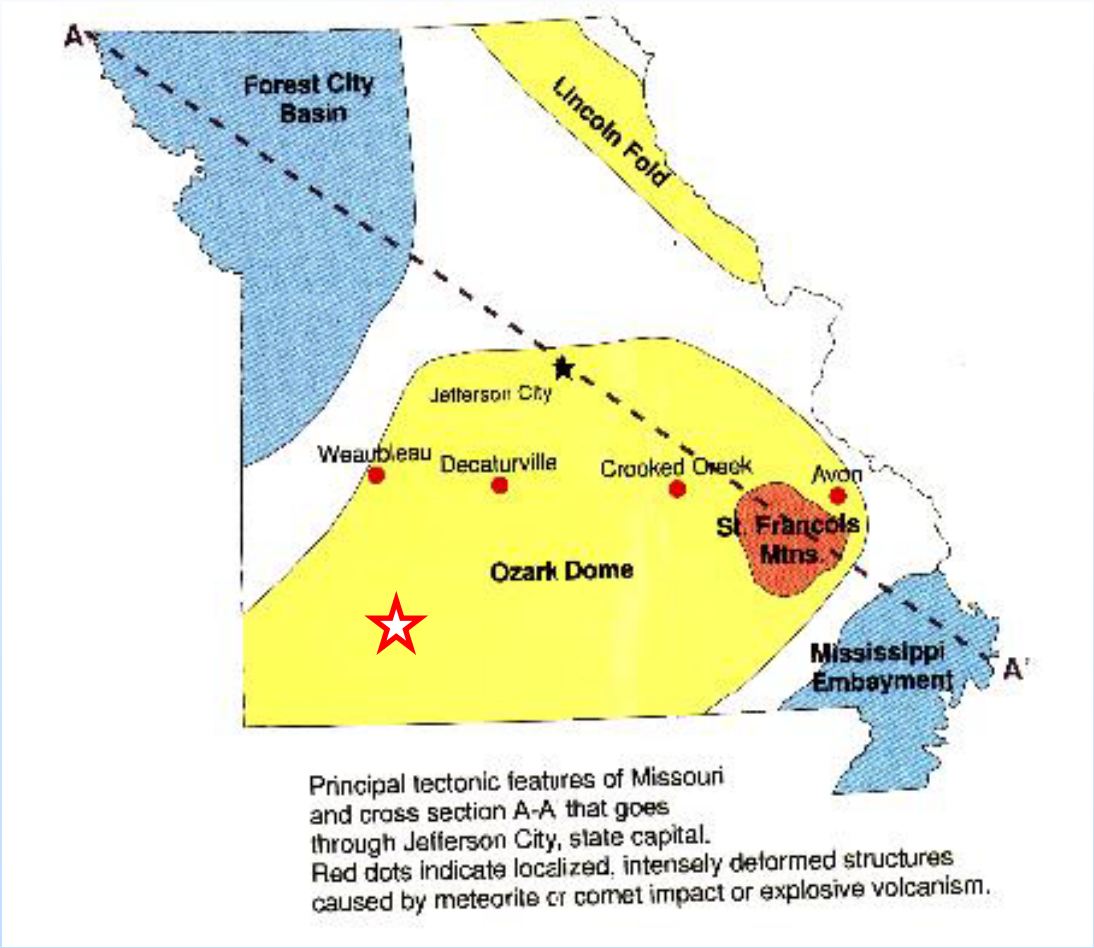


Principal tectonic features of Missouri and cross section A-A that goes through Jefferson City, state capital. Red dots indicate localized, intensely deformed structures caused by meteorite or comet impact or explosive volcanism.



Project Sites

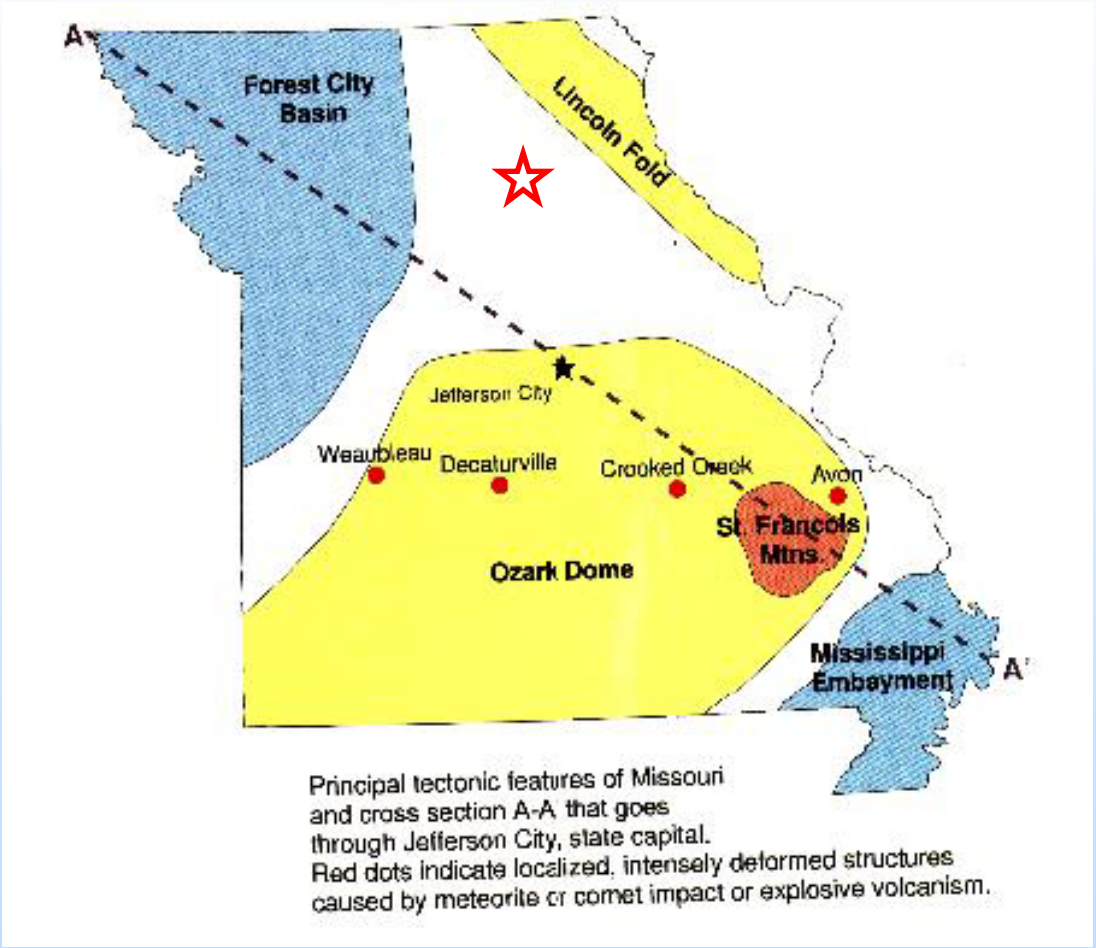
- Borehole #1, John Twitty Energy Center, 503 megawatt power plant, located on the western flank of the Ozark Dome on the Springfield Plateau.



Principal tectonic features of Missouri and cross section A-A that goes through Jefferson City, state capital. Red dots indicate localized, intensely deformed structures caused by meteorite or comet impact or explosive volcanism.

Project Sites

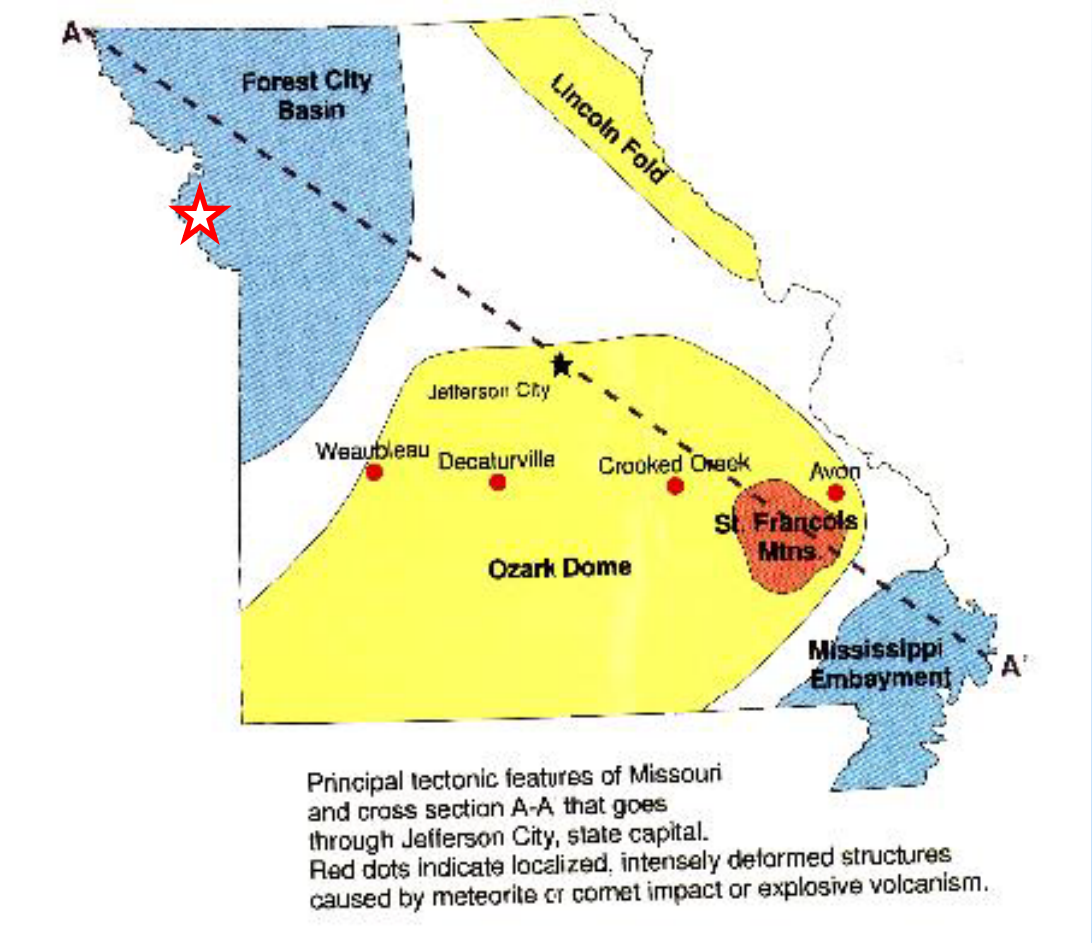
- Borehole #2, Thomas Hill Energy Center, 1,153 megawatt power plant, located on the northern flank of the Ozark Dome on a 30,000-acre mine-mouth site.



Principal tectonic features of Missouri and cross section A-A' that goes through Jefferson City, state capital. Red dots indicate localized, intensely deformed structures caused by meteorite or comet impact or explosive volcanism.

Project Sites

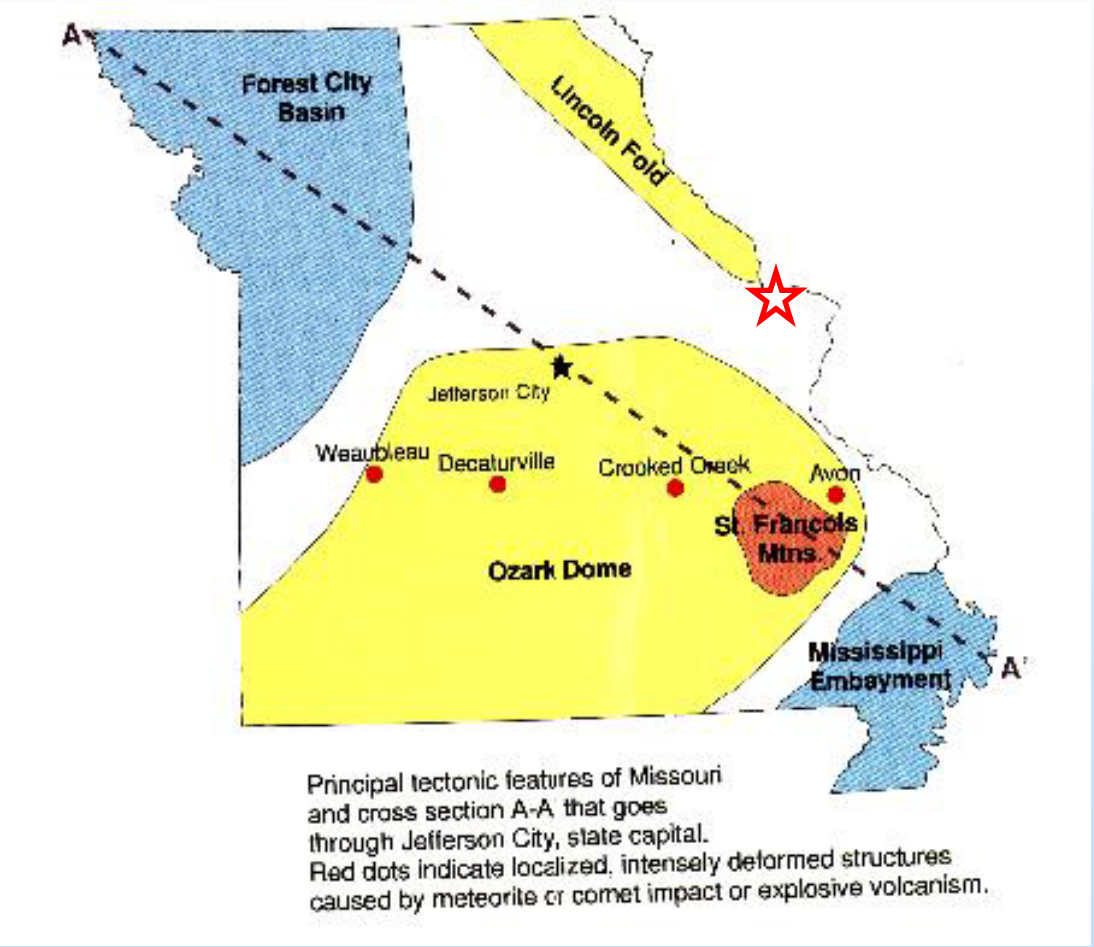
- Borehole #3, Iatan Electric Generating Station, 1,501 megawatt power plant, located within the Forest City Basin along the Missouri River.



Principal tectonic features of Missouri and cross section A-A that goes through Jefferson City, state capital. Red dots indicate localized, intensely deformed structures caused by meteorite or comet impact or explosive volcanism.

Project Sites

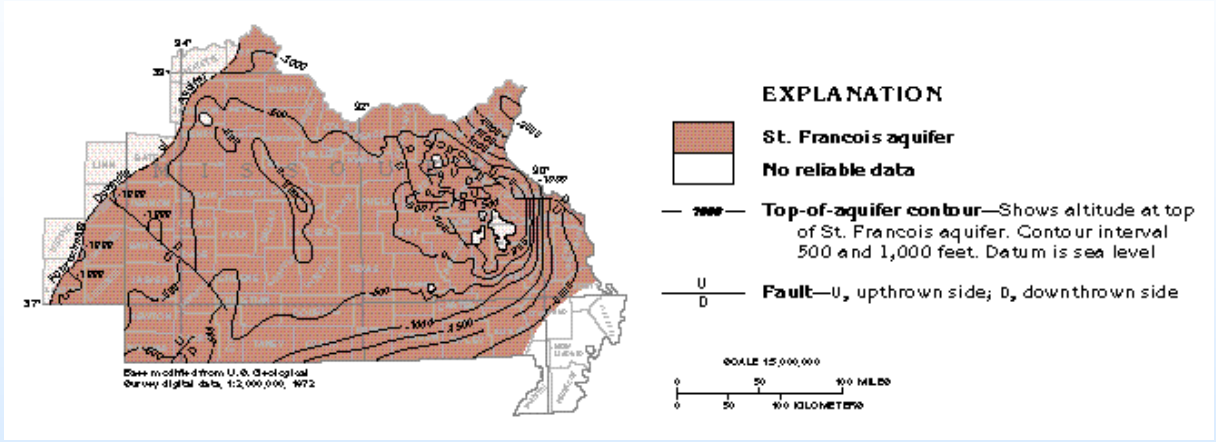
- Borehole #4, Sioux Power Plant, 986 megawatt power plant, located on the western flank of the Florissant Dome (the southern extension of the Lincoln Fold) along the Missouri River.

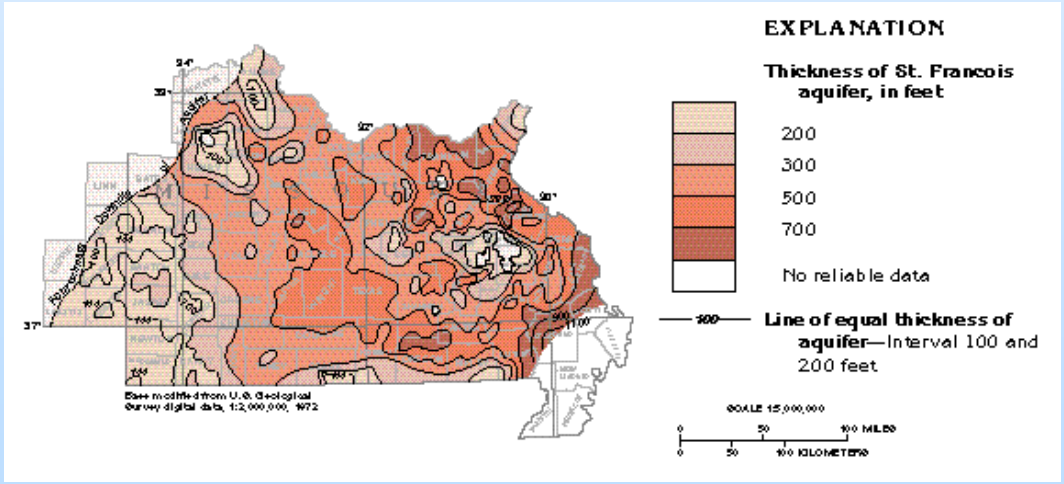


Principal tectonic features of Missouri and cross section A-A that goes through Jefferson City, state capital. Red dots indicate localized, intensely deformed structures caused by meteorite or comet impact or explosive volcanism.

Target Formation

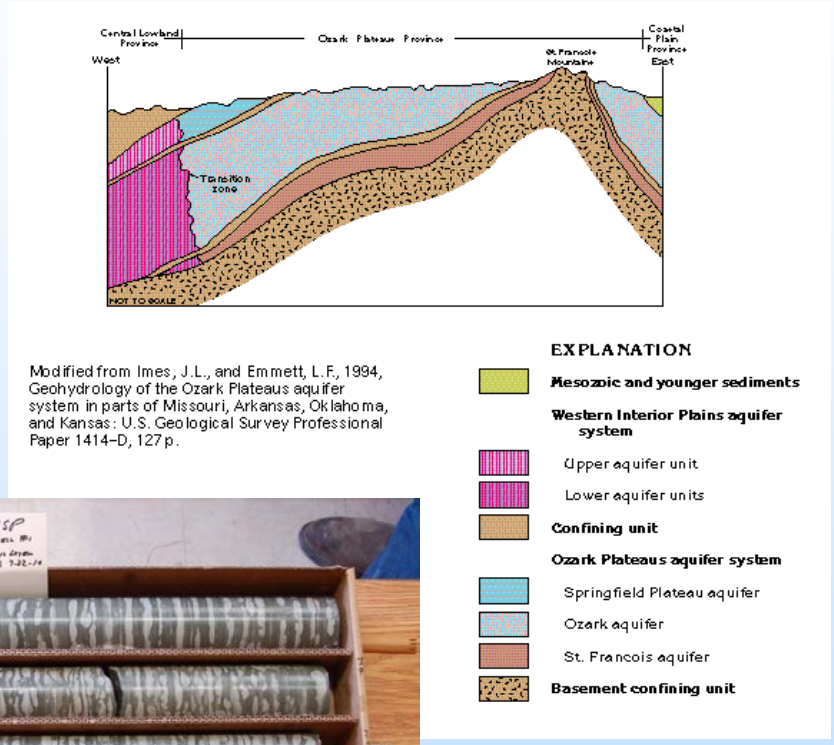
- St. Francois Aquifer comprised of basal Lamotte Sandstone and overlying Bonneterre Dolomite.
- Lamotte Sandstone is lateral equivalent of Mt. Simon.
- Thickness of St. Francois Aquifer varies greatly, but ranges up to 700 feet.
- St. Francois Aquifer underlies the entire state.



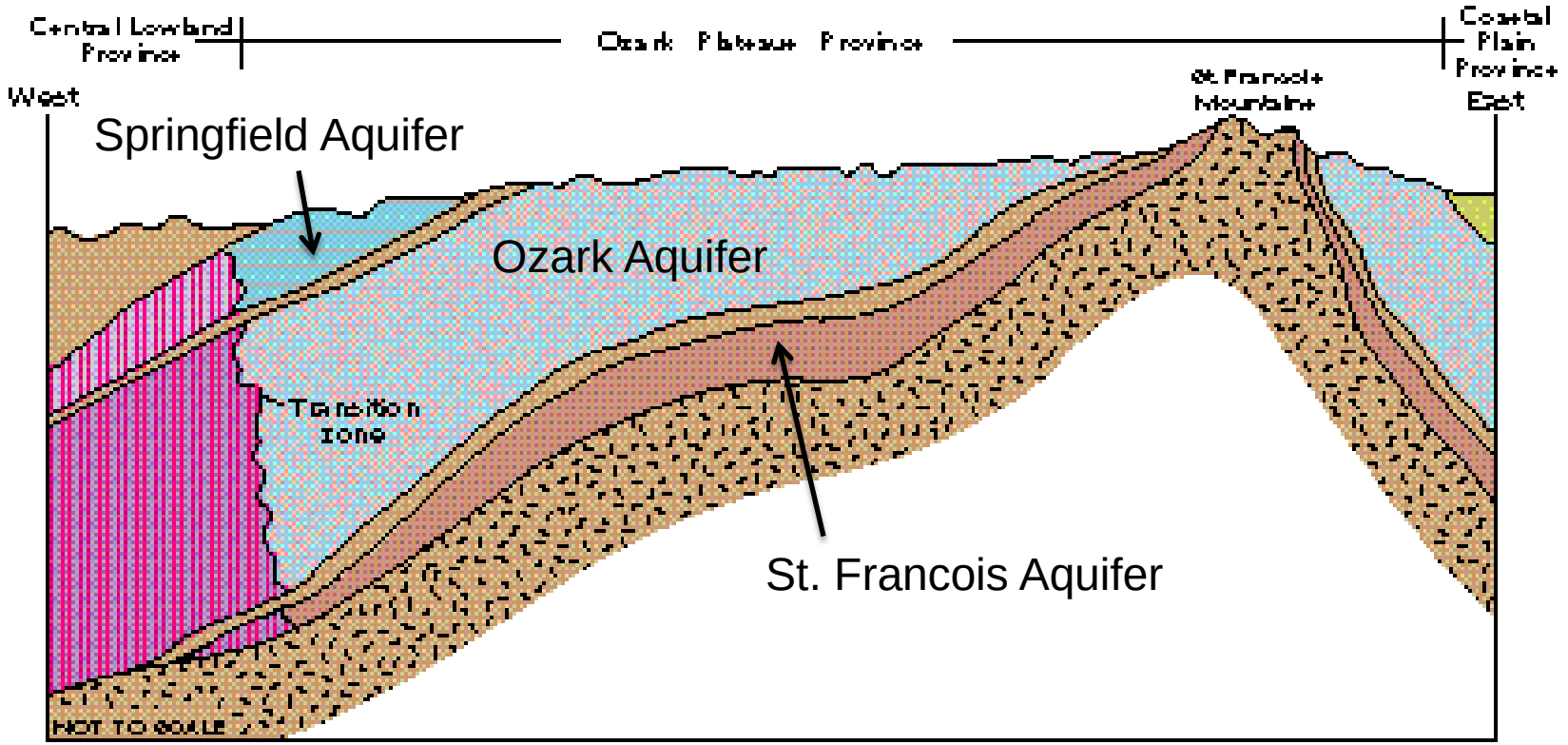


Confining Layer

- Derby-Doerun/Davis confining layer separates St. Francois Aquifer from overlying Ozark Aquifer.
- Davis consists of shale with discontinuous carbonate pebbles.
- Derby-Doerun/Davis confining layer underlies the entire state.



Aquifer Systems



Ozark Aquifer

- The Ozark Aquifer is a very prolific water source.
- Well penetrating the total thickness may yield 2,000 gallons per minute.
- The lower members of the Ozark Aquifer, the Eminence and Potosi Dolomites, are very fractured and karsted.
- Many of the large springs in Missouri surface from the Eminence and Potosi Dolomites.

John Twitty Energy Center

- Original project scope contemplated an injection test at the site.
- Borehole #1 completed to TD of 2,186 feet.
- 731 feet of core obtained from the confining layer and target formation.
- Water samples obtained from the Lamotte Sandstone yielded TDS concentrations of 152 mg/L and 208 mg/L.
- Plans for an injection test were abandoned and project re-scoped to provide characterization wells at the three additional power plant sites.

Initial Eminence/Potosi Problems

- A 3D seismic reflection survey was conducted at JTEC in an attempt to image the erosional surface of the Precambrian bedrock. However, the survey was generally unsuccessful because the Precambrian surface was masked by karst development in the Eminence and Potosi Formations.
- During drilling of Borehole #1, substantial voids were encountered and videotaped. Treatment with LCM was required.
- During cementing of casing, cement did not return above the void zone.

Redirection of Project

- Closeout of John Twitty Energy Center work.
- Selection of additional drilling sites.
- Preparation/submittal of revised budget and SOPO.
- Preparation/submittal of revised PMP.
- Preparation/submittal of NEPA questionnaires.
- Revision of MOU with utility members.
- Amendment of subcontracts with research team.
- Determination of need for temporary APCP permit.
- Preparation of bid documents for additional sites.
- Bidding and award of drilling contracts.

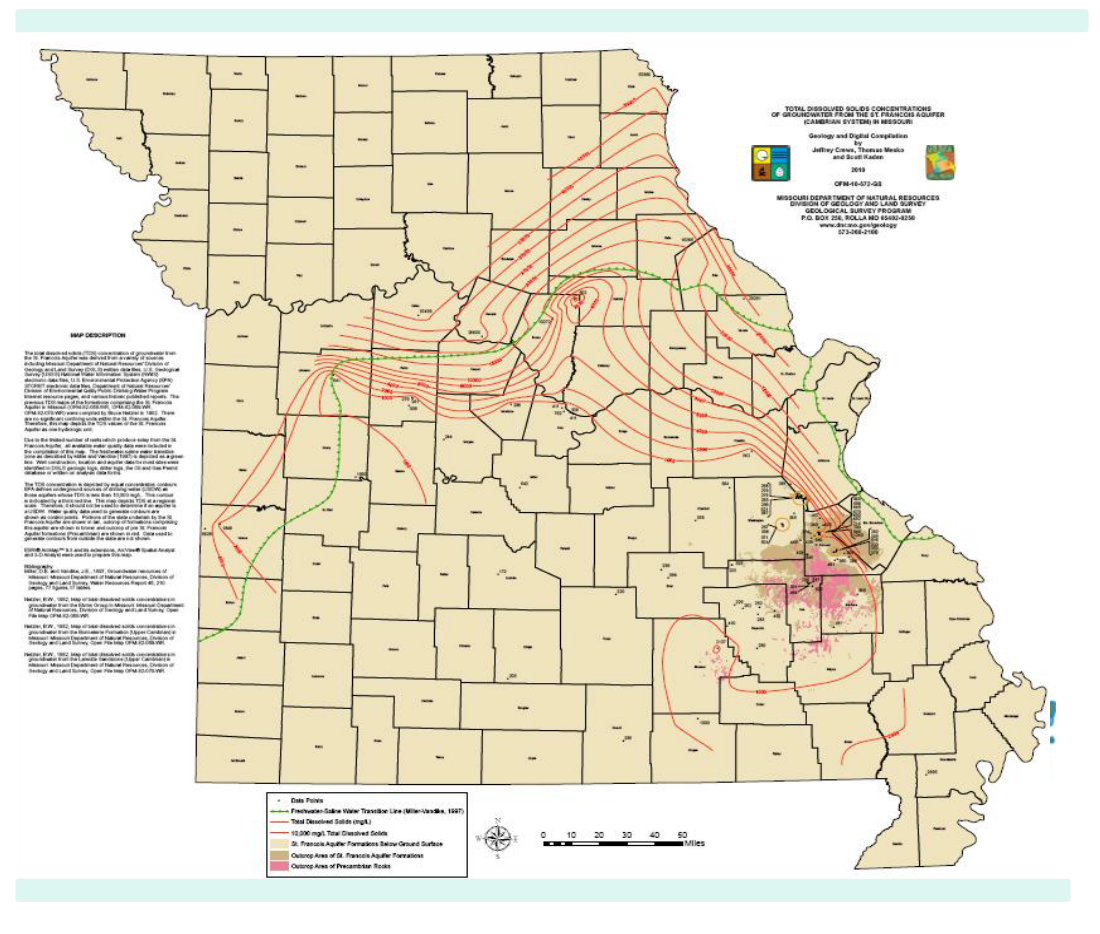
Revised Scope of Work

- Open 8-1/2” borehole to top of confining layer.
- Set 5-1/2” casing to conduct coring rods.
- Obtain HQ core through confining layer and target formation.
- Perform geophysical logging of confining layer and target formation.
- Perform hydrologic testing and collect water sample.
- Provide core samples to researchers.
- Conduct pressure testing/breakdown testing.
- Plug and abandon borehole.

Note: limited funding precluded multiple casing strings.

St. Francois Aquifer TDS

- Based on available data, TDS concentrations at the three additional drilling sites was expected to occur in the range of 20,000 to 45,000 mg/L.



Thomas Hill Energy Center

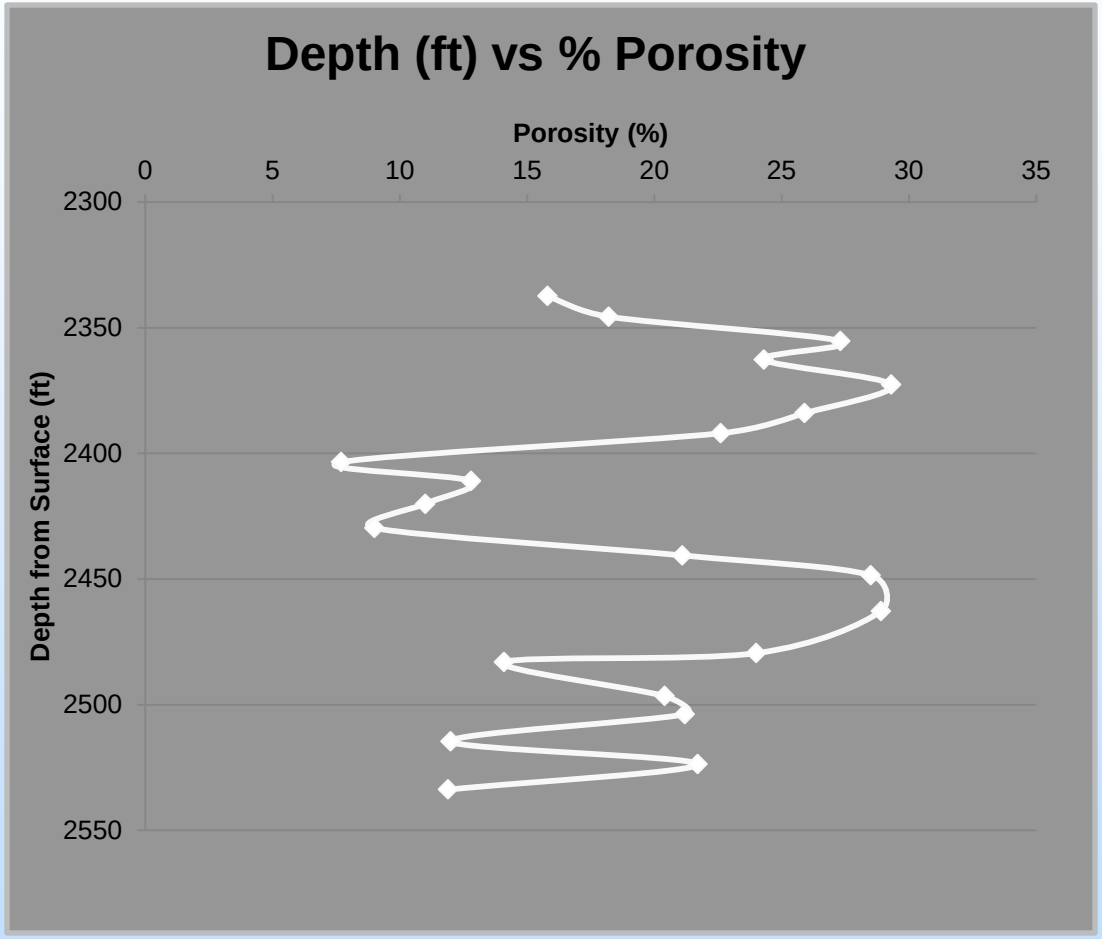
- Drilling at Thomas Hill commenced in February 2012.
- Top of confining layer encountered at 1,950 feet.
- Top of target formation encountered at 2,083 feet.
- Top of Pre-Cambrian basement rock encountered at 2,530 feet.
- Confining layer thickness found to be 133 feet.
- Target formation thickness found to be 447 feet.

Thomas Hill Energy Center

- Wireline logging completed.
- Preliminary results of target formation water sampling yielded TDS concentration (evaporation method) of 55,452 mg/kg.
- Rock core transferred to MO Division of Geology and Land Survey McCracken Core Library.
- MSU and MS&T researchers selected core intervals for testing on August 1, 2012.
- Lamotte core appears porous and permeable. Davis core appears very tight.
- Pressure testing and well closure on hold pending determination of remaining funds.

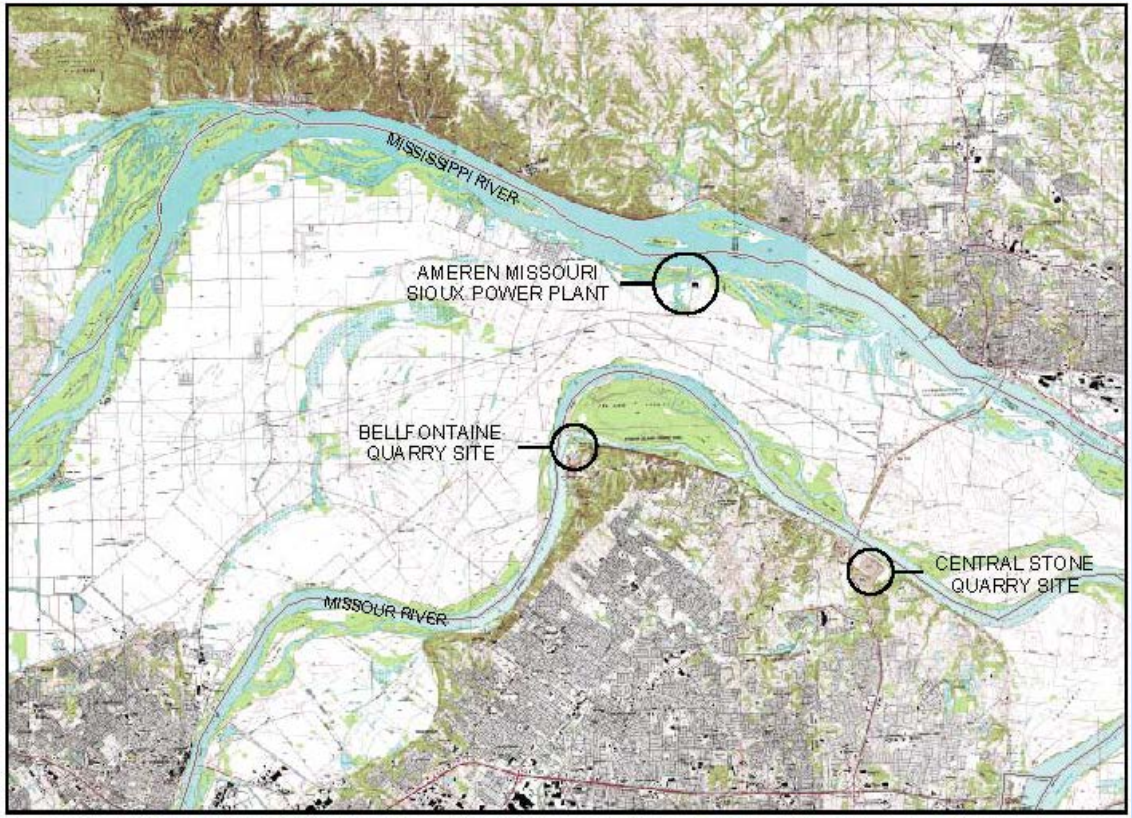
Thomas Hill Energy Center

- Analysis of Davis core samples indicated permeability as low as 0.0008 md.
- Lamotte Sandstone was found to have good porosity, ranging from 6 to 17% throughout the zone.
- Permeability of the Lamotte ranges from 2 to 306 md, with an average permeability of 47 md.
- Lamotte porosity values counted in thin sections shown at right.



Sioux Power Plant

- Sioux Power Plant is located in floodplain between Mississippi and Missouri Rivers.
- Drilling sites were evaluated and site secured at former Bellfontaine Quarry Site.



Sioux Power Plant

- Drilling of Exploratory Borehole # 4 at the Sioux Site began on October 3, 2012.
- At 988 feet, drilling operations were converted to mud rotary and a blowout preventer installed on the surface casing as a precaution due to proximity to the Laclede Gas Storage Facility.
- Experienced lost circulation at 2500 feet in the Eminence Formation. LCM unsuccessful. Terminated mud rotary operation and converted to coring.

Sioux Power Plant

- Depth and thickness of the Lamotte Sandstone was found to be much greater than anticipated.
- Coring was discontinued, in the Lamotte, when the Layne Christensen coring rig reached its functional limit at 3,624 feet.
- Pump testing and formation fluid sampling was conducted on Feb. 16-17, 2013.
- TDS values averaged 42,055 mg/kg for three separate water samples.

Iatan Electric Generating Station

- An “Advance Casing While Drilling Rig,” also known as a “Barber Rig,” was used to set 94 feet of 16 inch conductor pipe through the Missouri River alluvium.
- Drilling commenced at Iatan, but was plagued by sloughing of friable shale formations, which made removal of cuttings and further advancement of the borehole extremely difficult and expensive.
- Upon consultation with DOE, drilling was terminated at Iatan and remaining funds redirected toward pressure testing and geophysical logging at the Luecke and Thomas Hill Sites.
- Plugging and abandonment of the borehole was completed in April, 2013.

Pressure Testing - Sioux

- Field crews returned to the Sioux site in June, 2013 to conduct remaining geophysical logging and pressure testing.
- An obstruction was encountered at approximately 800 feet BGS. Downhole video indicated a highly fractured zone and a piece of rock bridging the hole. The decision was made to drill out the bridge and attempt to open the hole to TD for pressure testing.
- Layne drilled out the obstruction, but encountered additional difficulty farther downhole. A second downhole video found significant voids at 823 feet BGS and the hole bridged at 835 feet BGS.
- The decision was made to abandon plans for pressure testing of Borehole # 4 due to the risk of losing downhole equipment.
- The borehole has subsequently been plugged and abandoned.

Pressure Testing – Thomas Hill

- Field crews returned to the Thomas Hill site this week and began tripping in the packer assembly this morning.
- Pressure testing will be conducted in the Lamotte Sandstone, Bonneterre Dolomite, and Davis Shale, followed by breakdown testing in the Lamotte Sandstone.

Accomplishments to Date

- Teaming arrangements established with five major electric companies, two universities, and state DNR.
- Internal team established to manage technical, financial, and logistical aspects of the project, along with media, community, and governmental relations.
- Characterization of John Twitty Energy Center complete.
- Internal team successfully managed total re-scoping of the project.
- Drilling and coring of JTEC, Thomas Hill and Sioux Sites completed successfully.
- Research at MSU, MS&T and MDNR nearly complete.
- Project remains on schedule and within budget.

Summary

– Key Findings

- Geology/hydrology of southern Missouri is unacceptable for carbon sequestration.
- Geology/hydrology of northern Missouri much more favorable for carbon sequestration.
- Davis Shale appears to be a competent confining layer state-wide.
- Lamotte Sandstone is highly variable due to multiple facies. Suitability for carbon sequestration will be site-specific.

Summary

– Lessons Learned

- Several of the shallower formations present problems for deep drilling.
- Multiple casing strings should be employed to case out problematic zones.
- Creative thinking and ability to adapt are important.
- The structure, process and scope of the Missouri project are transferrable to other states interested in assessing the feasibility of carbon sequestration.

Summary

- Future Plans
  - Complete research and prepare final report.
  - Consider pursuing funding for complete site characterization at favorable sites.

Questions

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Appendix

– These slides will not be discussed during the presentation, but are mandatory

Organization Chart

- Describe project team, organization, and participants.
  - Link organizations, if more than one, to general project efforts (i.e. materials development, pilot unit operation, management, cost analysis, etc.).
- Please limit company specific information to that relevant to achieving project goals and objectives.

Gantt Chart

- Provide a simple Gantt chart showing project lifetime in years on the horizontal axis and major tasks along the vertical axis. Use symbols to indicate major and minor milestones. Use shaded lines or the like to indicate duration of each task and the amount of that work completed to date.

Bibliography

List peer reviewed publications generated from project per the format of the examples below

- Journal, one author:
  - Gaus, I., 2010, Role and impact of CO2-rock interactions during CO2 storage in sedimentary rocks: International Journal of Greenhouse Gas Control, v. 4, p. 73-89, available at: XXXXXXX.com.
- Journal, multiple authors:
  - MacQuarrie, K., and Mayer, K.U., 2005, Reactive transport modeling in fractured rock: A state-of-the-science review. Earth Science Reviews, v. 72, p. 189-227, available at: XXXXXXX.com.
- Publication:
  - Bethke, C.M., 1996, Geochemical reaction modeling, concepts and applications: New York, Oxford University Press, 397 p.