Western Kentucky Deep Saline Reservoir CO_2 Storage Test

Principal Investigators:

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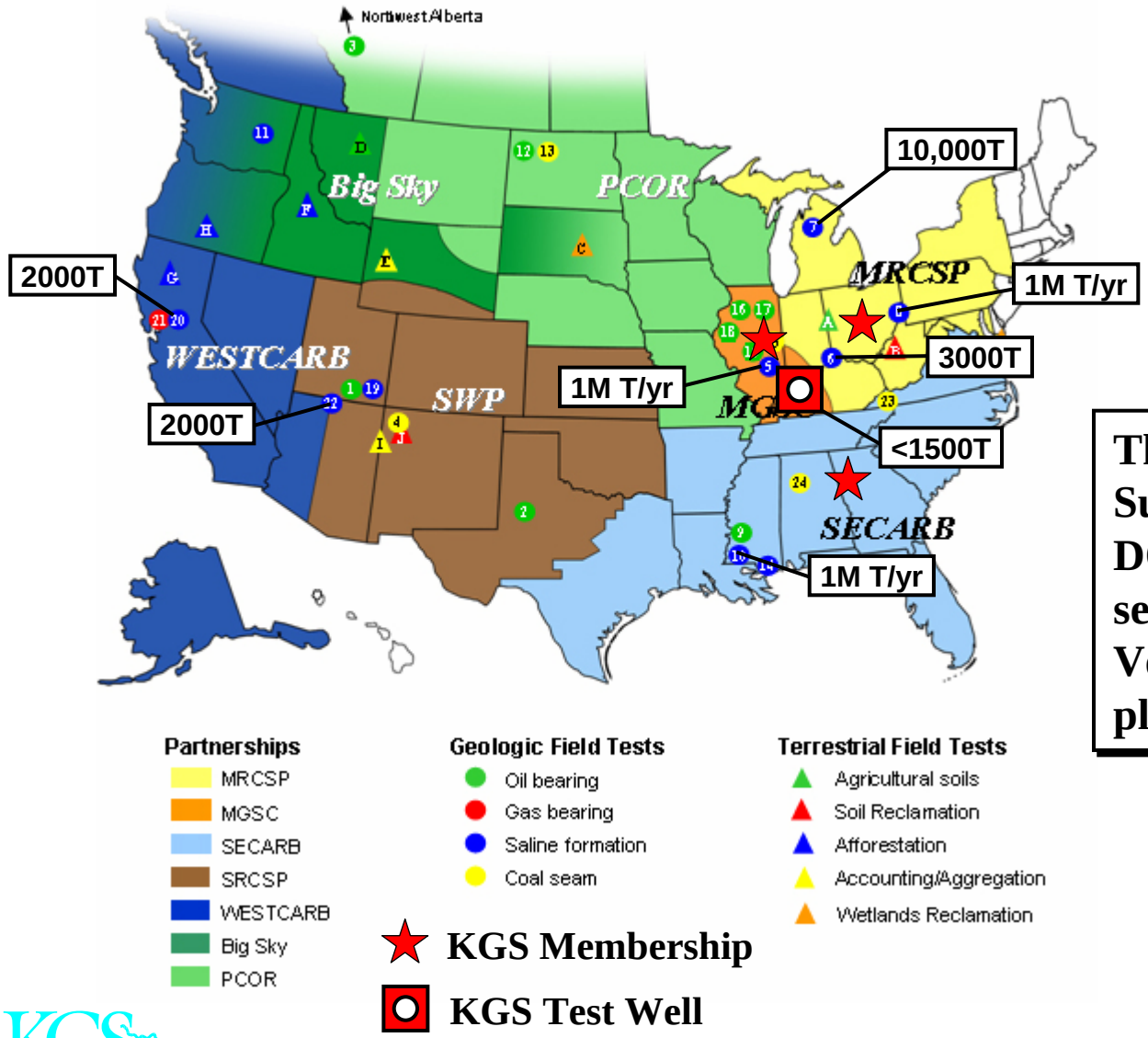
October 2, 2008


Electric power generating and industrial plants in western Kentucky discharge ~78 million metric tons of CO_2 to the atmosphere each year.
KGS
TVA Paradise Power Plant, Muhlenberg County

Regional Sequestration Partnerships

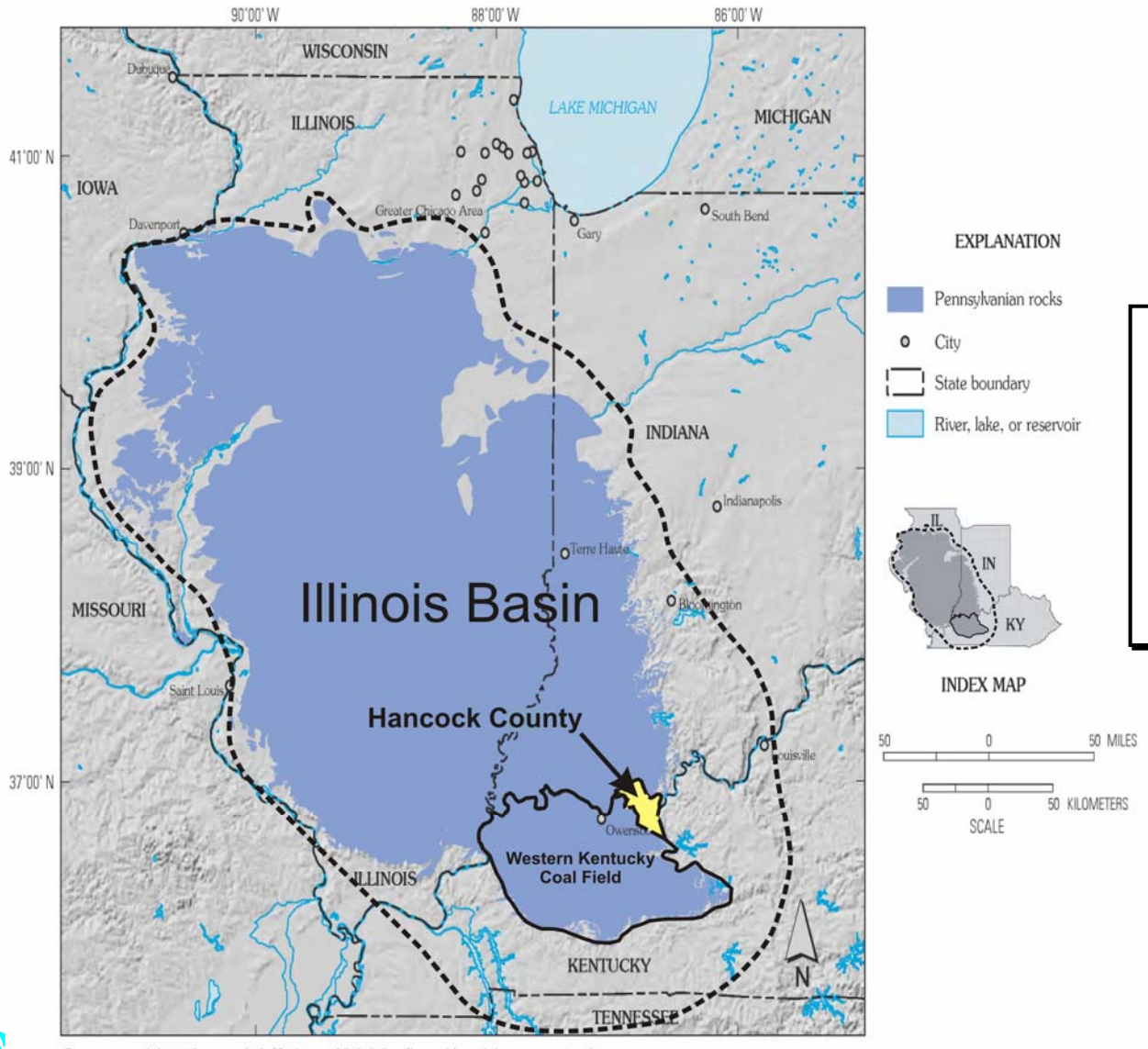


The Kentucky Geological Survey is a member of three DOE-sponsored regional sequestration partnerships. Volumes of CO_2 injected or planned noted.

Project Purpose

- Discharge of CO_2 to the atmosphere will be regulated within 10 years and its subsurface storage required for existing facilities and the financing and construction of new facilities.
- Kentucky House Bill 1, passed in a special legislature session and signed into law in August 2007, appropriated $5 million funding for KGS to research the storage and use of CO_2 throughout the Commonwealth.
- HB-1 mandates the drilling a CO_2 storage demonstration well in the Western Kentucky Coal Field.
- The Hancock County drillsite was chosen for its favorable geologic setting and accessibility.

Location of Hancock County, Kentucky



Source: Hatch and Affolter (2002, fig. 1) with annotations

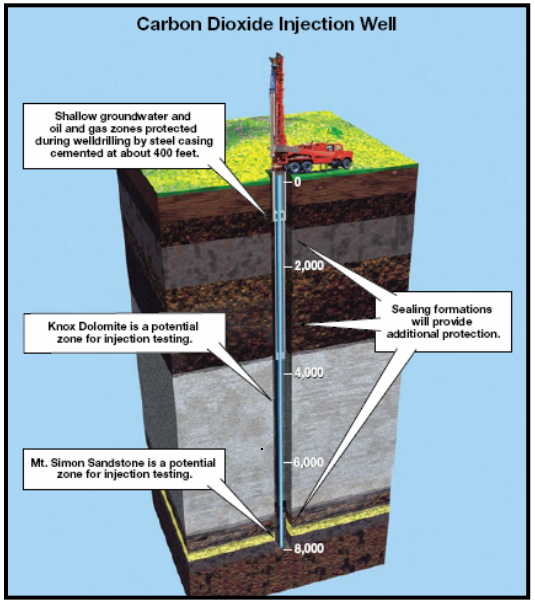
Hancock County lies in the southeastern Illinois Basin, on the northeastern margin of the Western Kentucky Coal Field

Project Goals

- Demonstrate CO_2 storage in deep saline reservoirs under the Western Kentucky Coal Field through the drilling and testing of an 8350 ft well in east-central Hancock County
- Demonstrate the integrity of reservoir sealing strata for long-term CO_2 storage in western Kentucky
- Demonstrate appropriate technologies for the evaluation of CO_2 storage in Kentucky deep saline reservoirs
- Publish the project results for use by government, industry, and the public in evaluating CO_2 storage in Kentucky
- Accomplish this project with consideration of the interests and concerns of the landowner, residents of Hancock County and western Kentucky, and the citizens of the Commonwealth

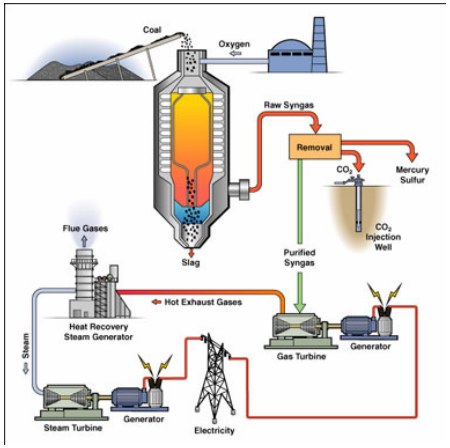
Project Stakeholders

Landowner, oil and gas leaseholder, and Hancock County residents



Western Kentucky coal mining industry

Electric power generators

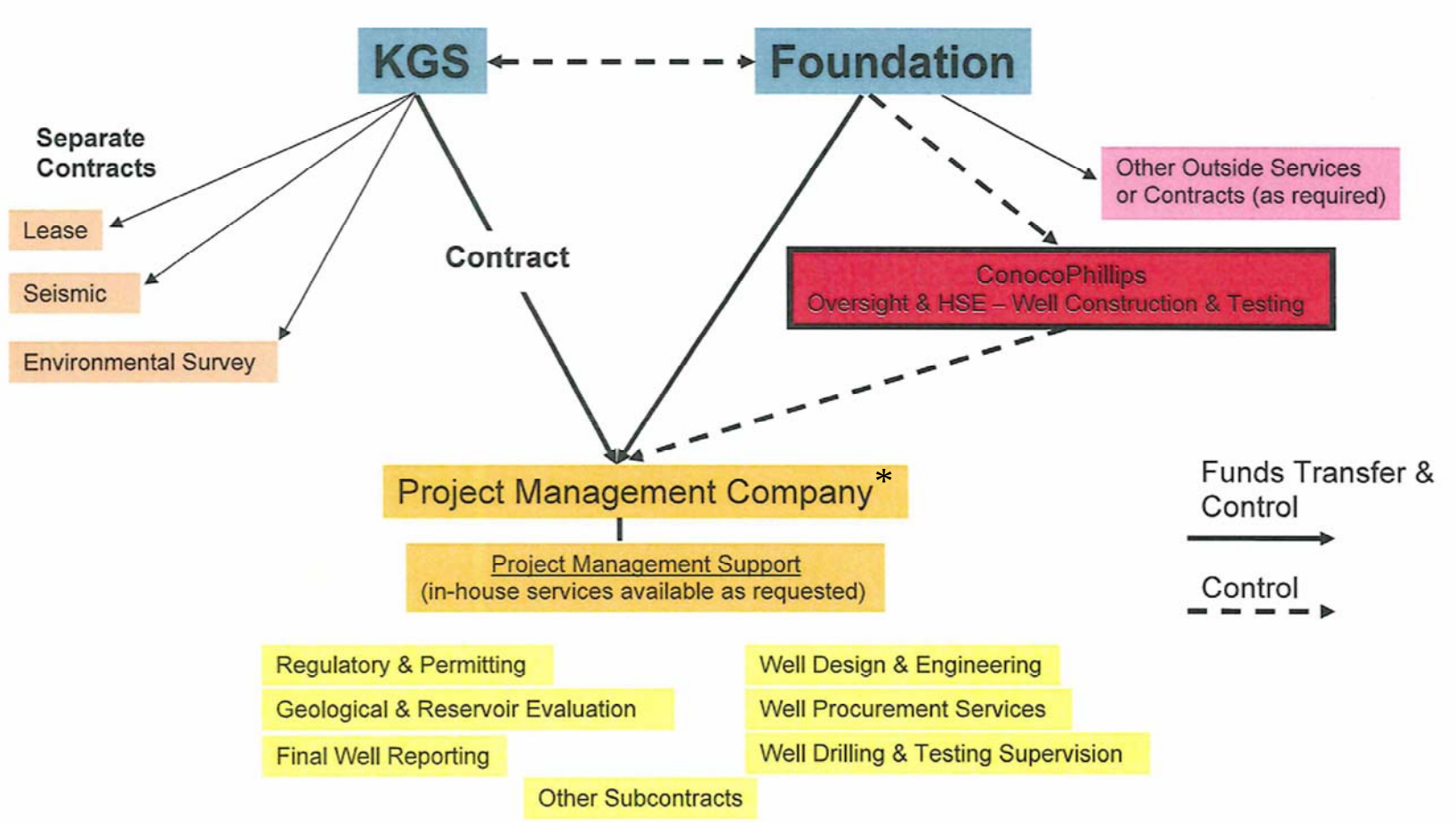


Clean coal syngas projects

Project Organization

- **Project management agreements in place**
  - 501(c)3 Western Kentucky Carbon Storage Foundation
  - MOA between KGS and the foundation
- **Project operations agreements**
  - Right of way and injection test well agreement with the landowners executed August 1, 2008
  - Easement and data sharing agreements with the oil and gas leaseholder executed October 1, 2008
- **Estimated project budget is ~$7.3 Million**
  - $1.35 million HB-1 funds
  - $250,000 pledged by the Illinois Geological Survey
  - $5.70 million committed by the foundation
- **Major services totaling ~$1.1 million have been contracted**

Project Management Structure

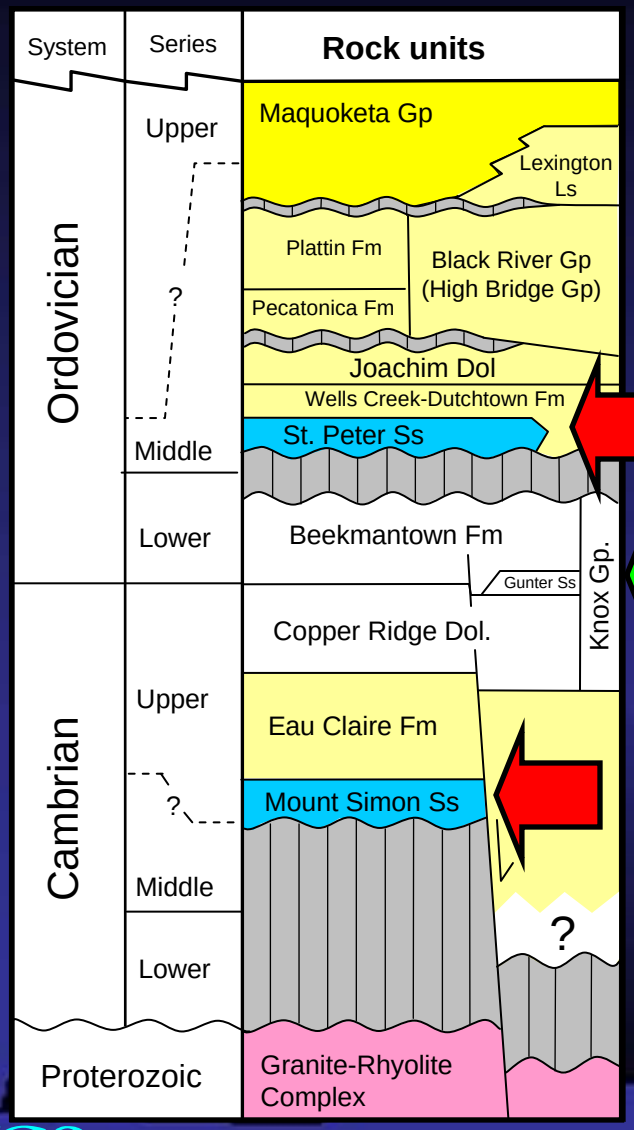


*Sandia Technologies, LLC

Project Geologic Requirements

- Effective storage of CO_2 in deep saline reservoirs requires its injection in a supercritical state to achieve a 250 times volume reduction.
- The temperature and pressure conditions in Kentucky deep saline reservoirs requires a minimum depth of ~2350 ft to be able to store CO_2 in its supercritical state.
  - Reservoir pressure > 1085 psi
  - Reservoir temperature > 88° F
- Reservoirs must have sufficient porosity and permeability for the injection of CO_2 as well as overlying sealing strata to ensure its long-term storage.

Deep Rock Units in Western Kentucky



Regional saline reservoirs:

- Mt. Simon Sandstone
- Knox Group dolomites
- St. Peter Sandstone

Potential CO_2 sinks/ reservoirs

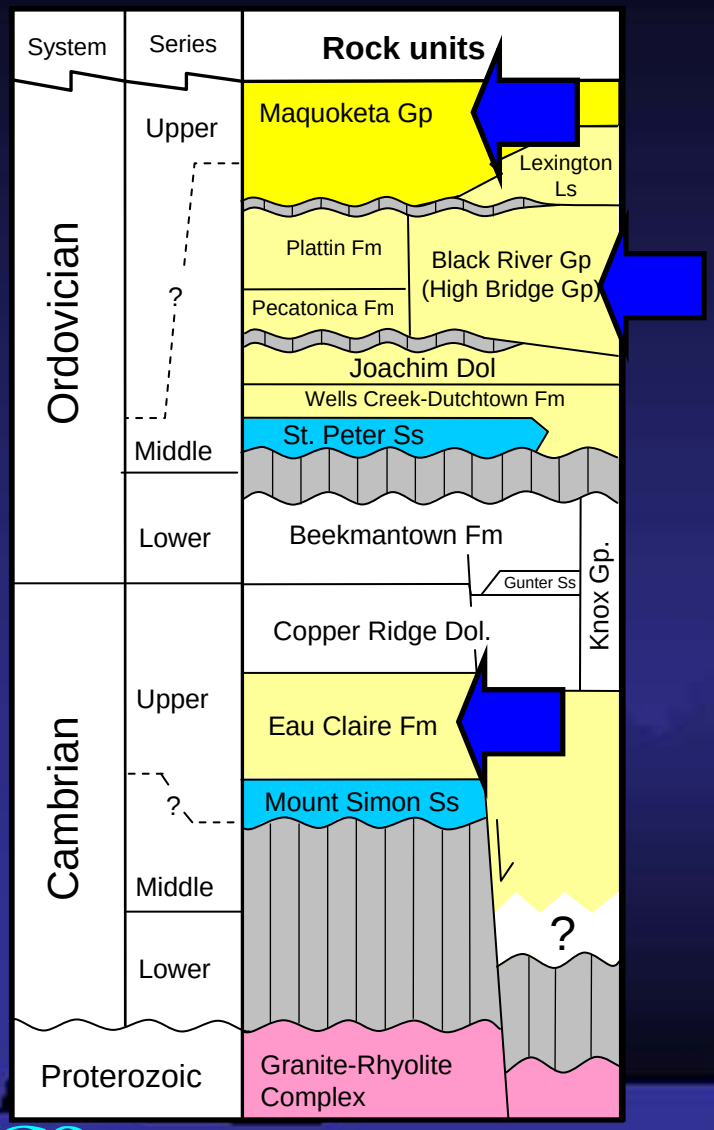
Sealing interval

Missing section

Sink or seal (*depends on location*)

Metamorphic and igneous rocks (*mostly seal*)

Deep Rock Units in Western Kentucky



Just as important in an injection project are the sealing units:

- **Eau Claire Formation**
- **Maquoketa Shale**
- **Ordovician carbonates**
- **Devonian Shales**

Potential CO_2 sinks/ reservoirs

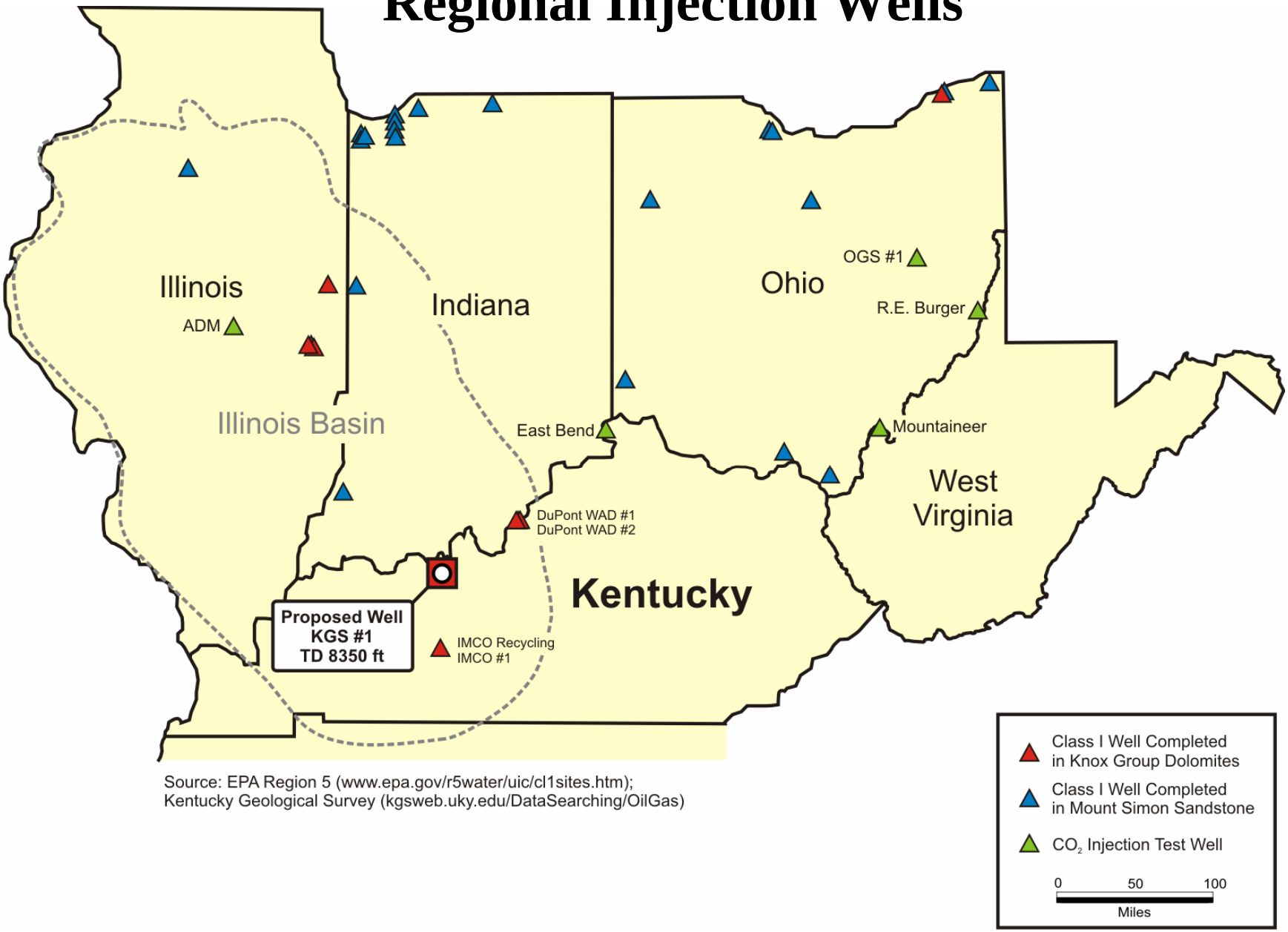
Sealing interval

Missing section

Sink or seal (*depends on location*)

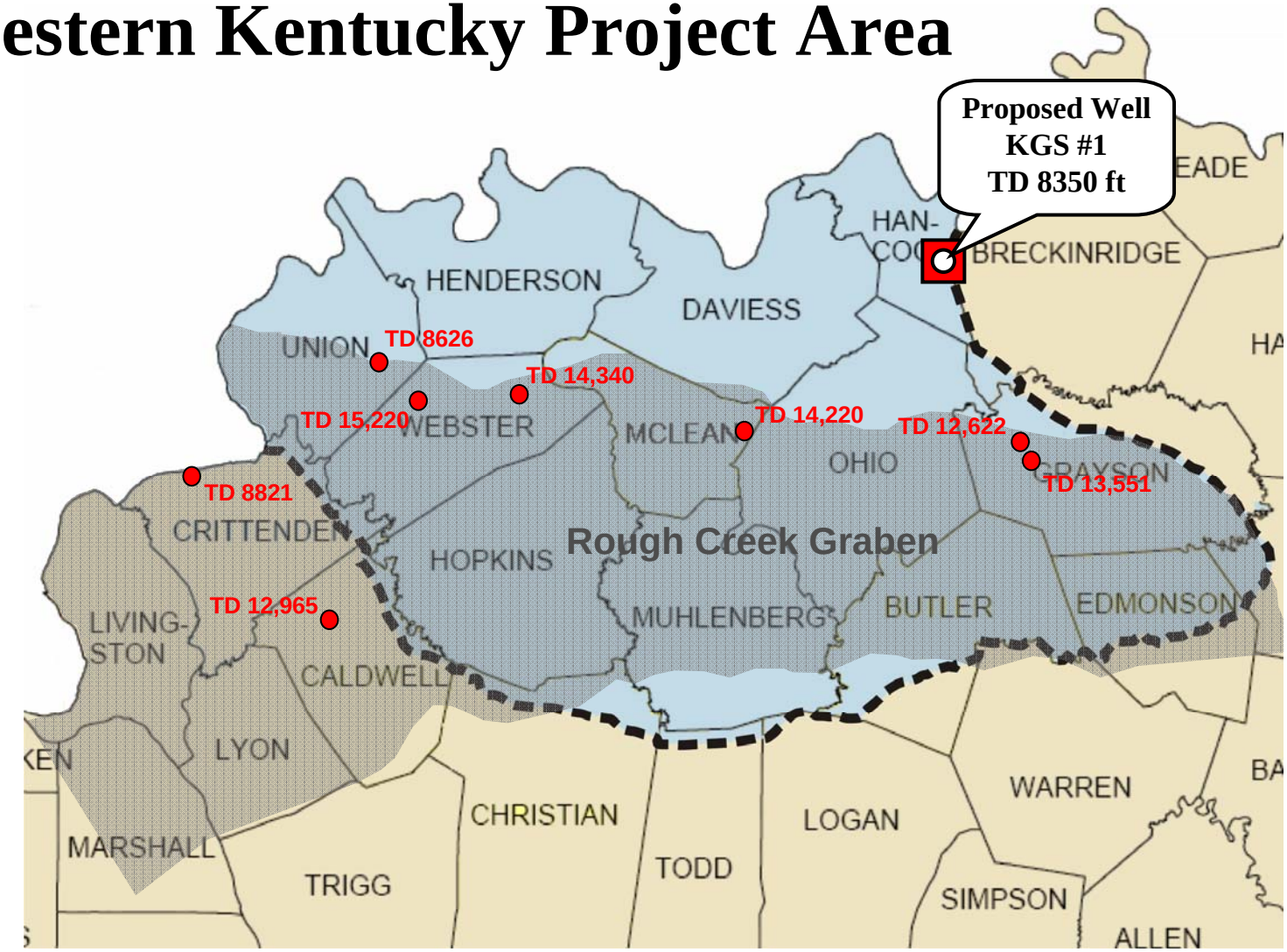
Metamorphic and igneous rocks (*mostly seal*)

Regional Injection Wells



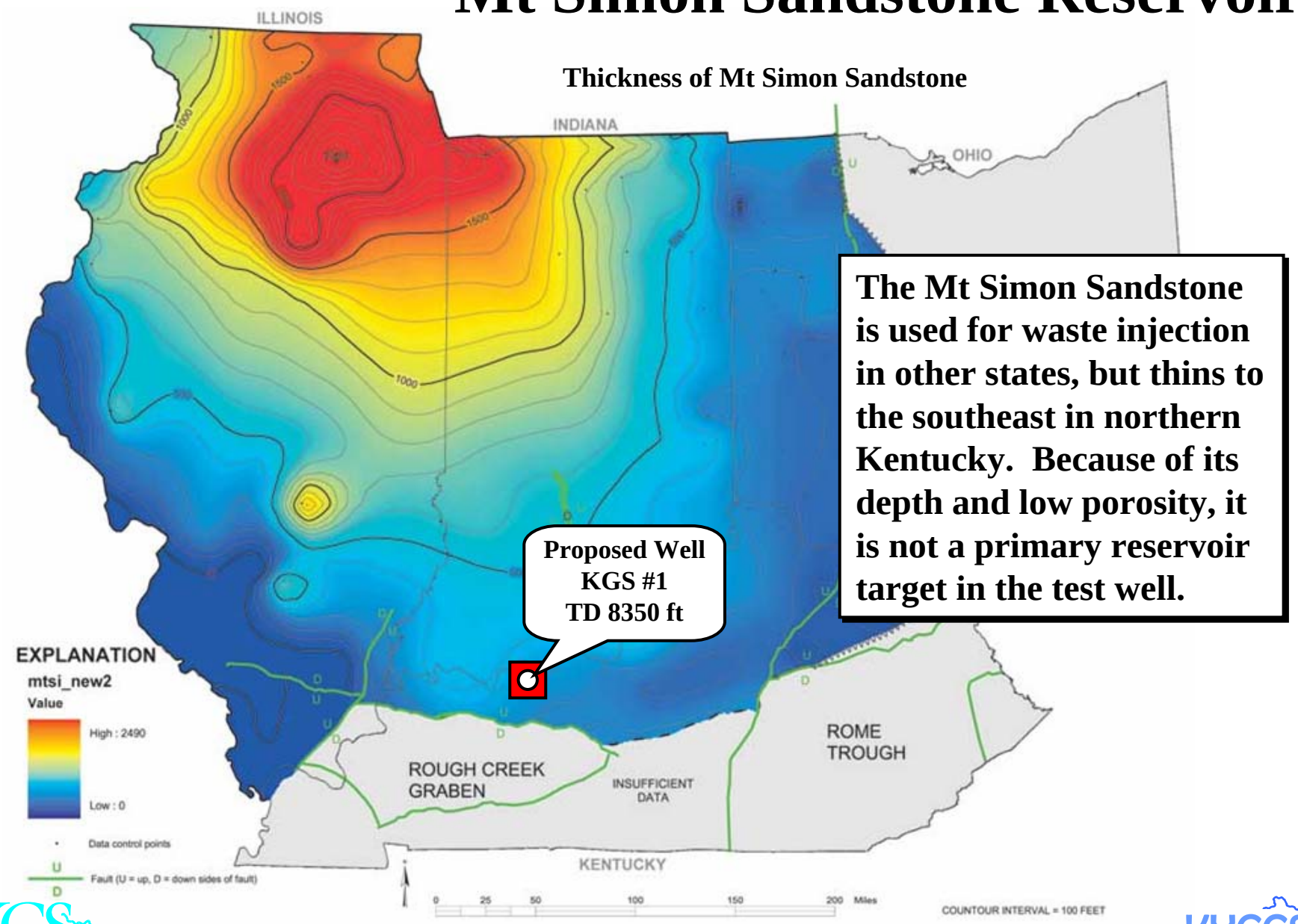
Source: EPA Region 5 (www.epa.gov/r5water/uic/cl1sites.htm);
Kentucky Geological Survey (kgsweb.uky.edu/DataSearching/OilGas)

Western Kentucky Project Area



Although the shallowest drill depth to reach the targeted reservoirs is in east-central Hancock County, the completed CO_2 storage test well will be among the deepest wells drilled in western Kentucky.

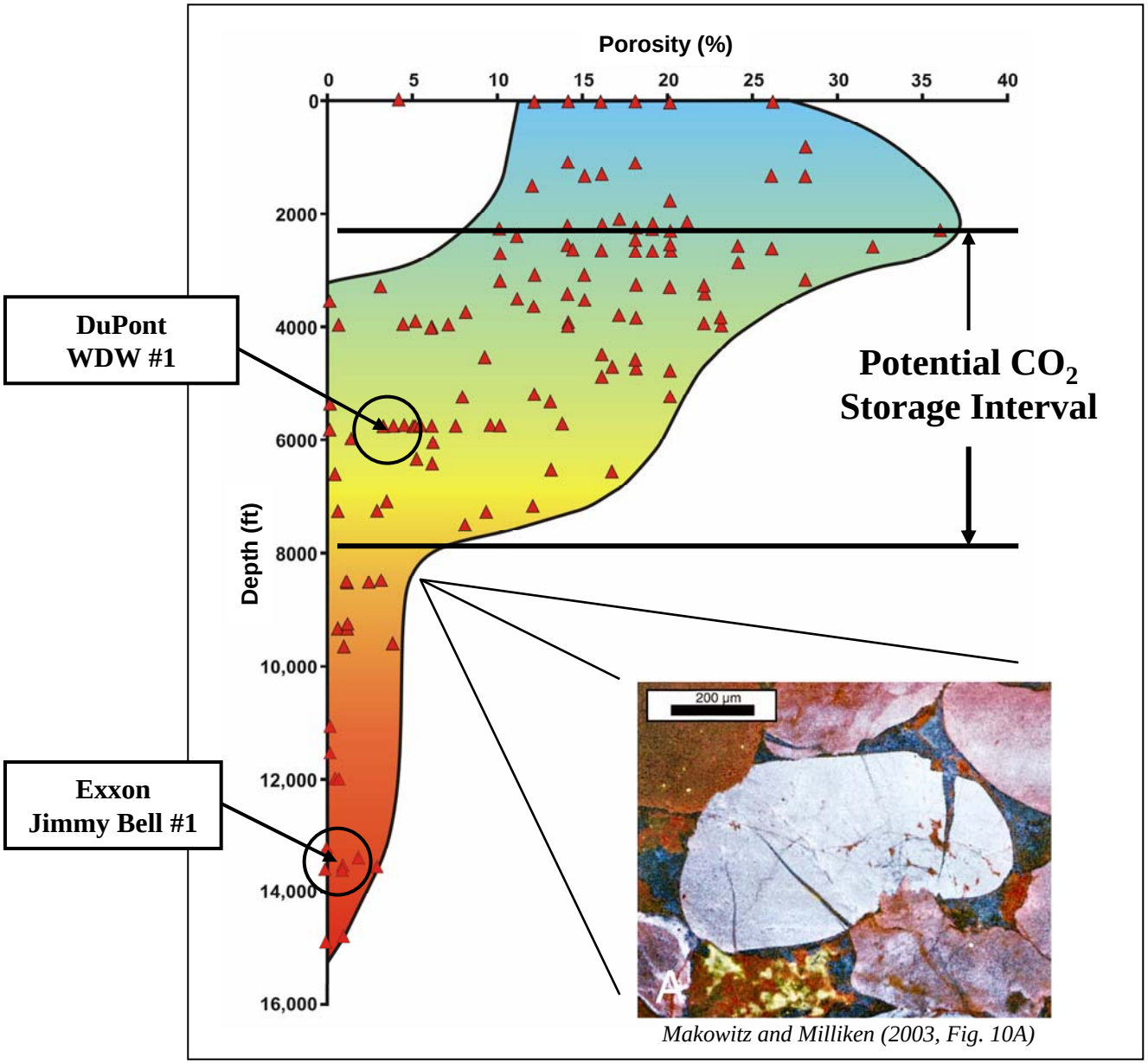
Mt Simon Sandstone Reservoir



The Mt Simon Sandstone is used for waste injection in other states, but thins to the southeast in northern Kentucky. Because of its depth and low porosity, it is not a primary reservoir target in the test well.

Hickman et al., *www.esri.com/mapmuseum/mapbook_gallery/volume19/environment3.html*

Mt Simon Sandstone Porosity

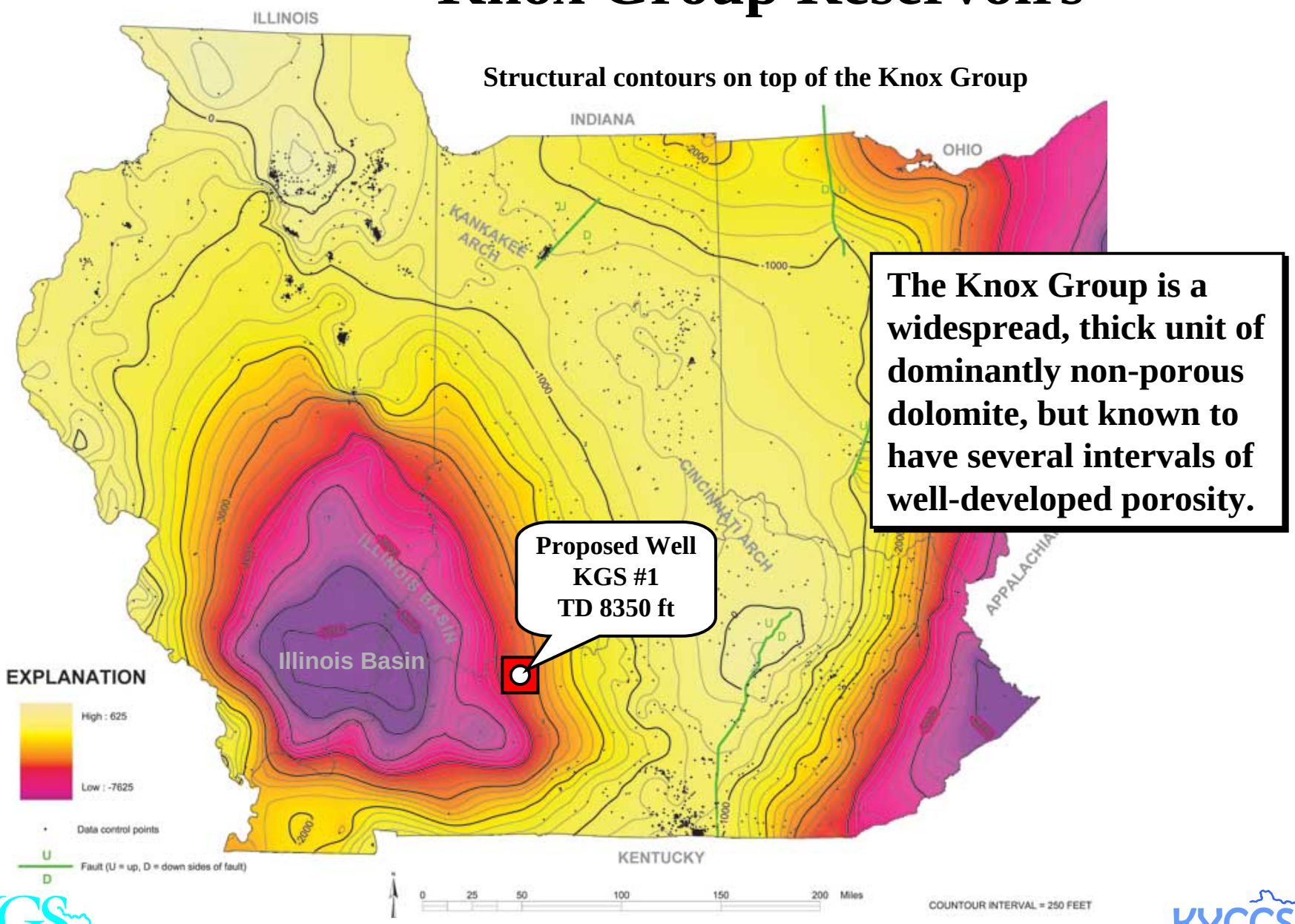


Makowitz and Milliken (2003, Fig. 10A)

Porosity in the Mount Simon Sandstone decreases with depth. At the depths it would be encountered in western Kentucky, below 7000 ft, it has low porosity.

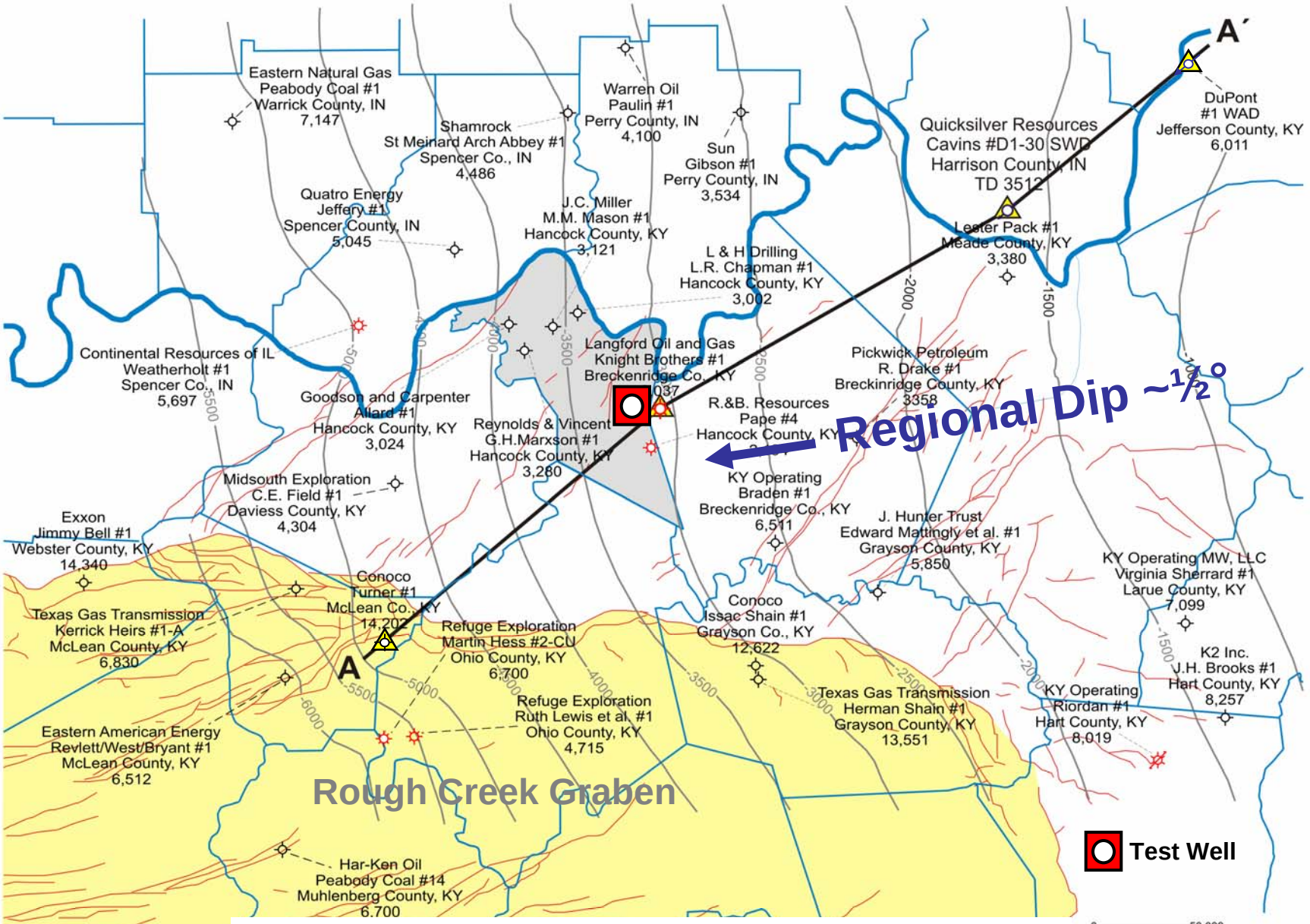
Data sources (828 samples):
Metarko (1980; 89 samples)
Shebl (1985; 9 samples)
Makowitz (2004; 27 samples)
Kunledare (2005; 690 samples)
DuPont #1 WDW (13 samples)

Knox Group Reservoirs

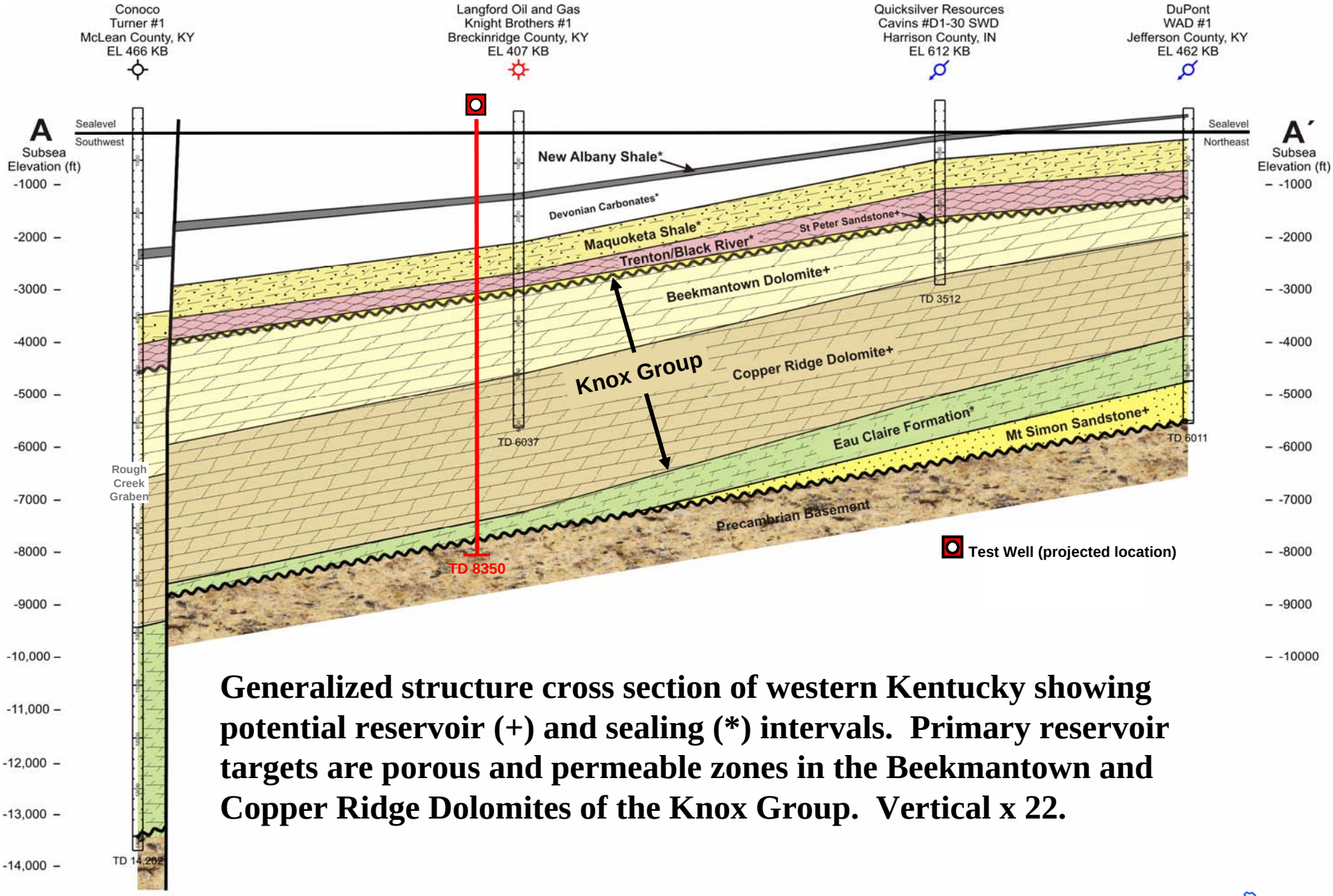


The Knox Group is a widespread, thick unit of dominantly non-porous dolomite, but known to have several intervals of well-developed porosity.

Hickman et al., *www.esri.com/mapmuseum/mapbook_gallery/volume19/environment3.html*

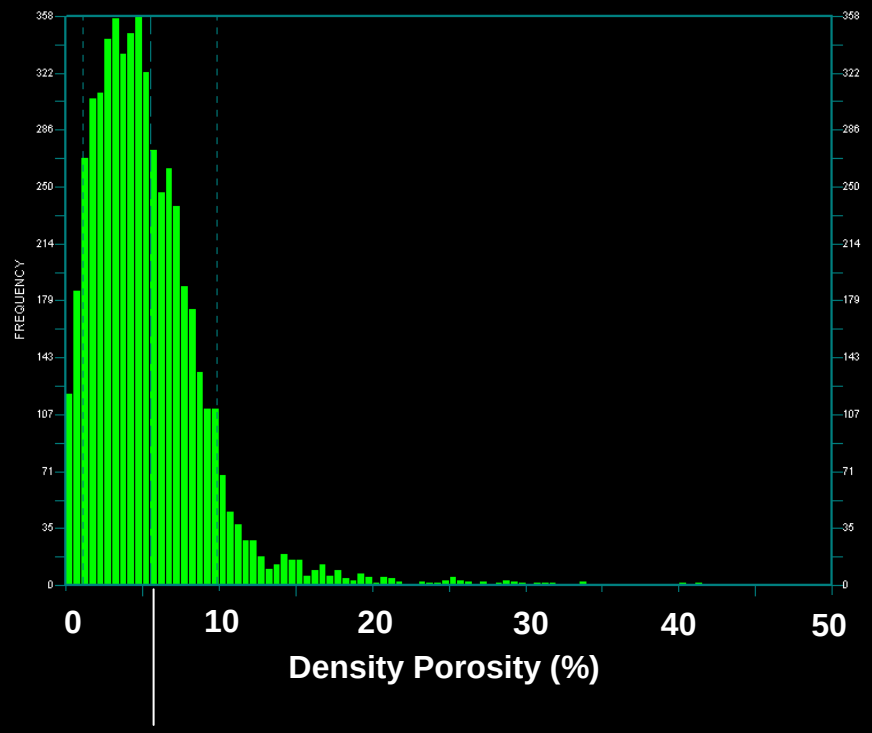


The Knox Group unconformity in western Kentucky shows a very shallow westerly dip

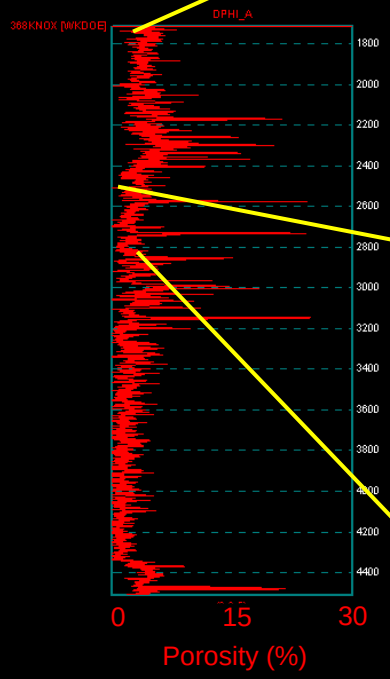


Generalized structure cross section of western Kentucky showing potential reservoir (+) and sealing (*) intervals. Primary reservoir targets are porous and permeable zones in the Beekmantown and Copper Ridge Dolomites of the Knox Group. Vertical x 22.

Porosity Development in Knox Group Dolomites, DuPont WAD #1



Mean porosity 5.5%



Intragranular Porosity

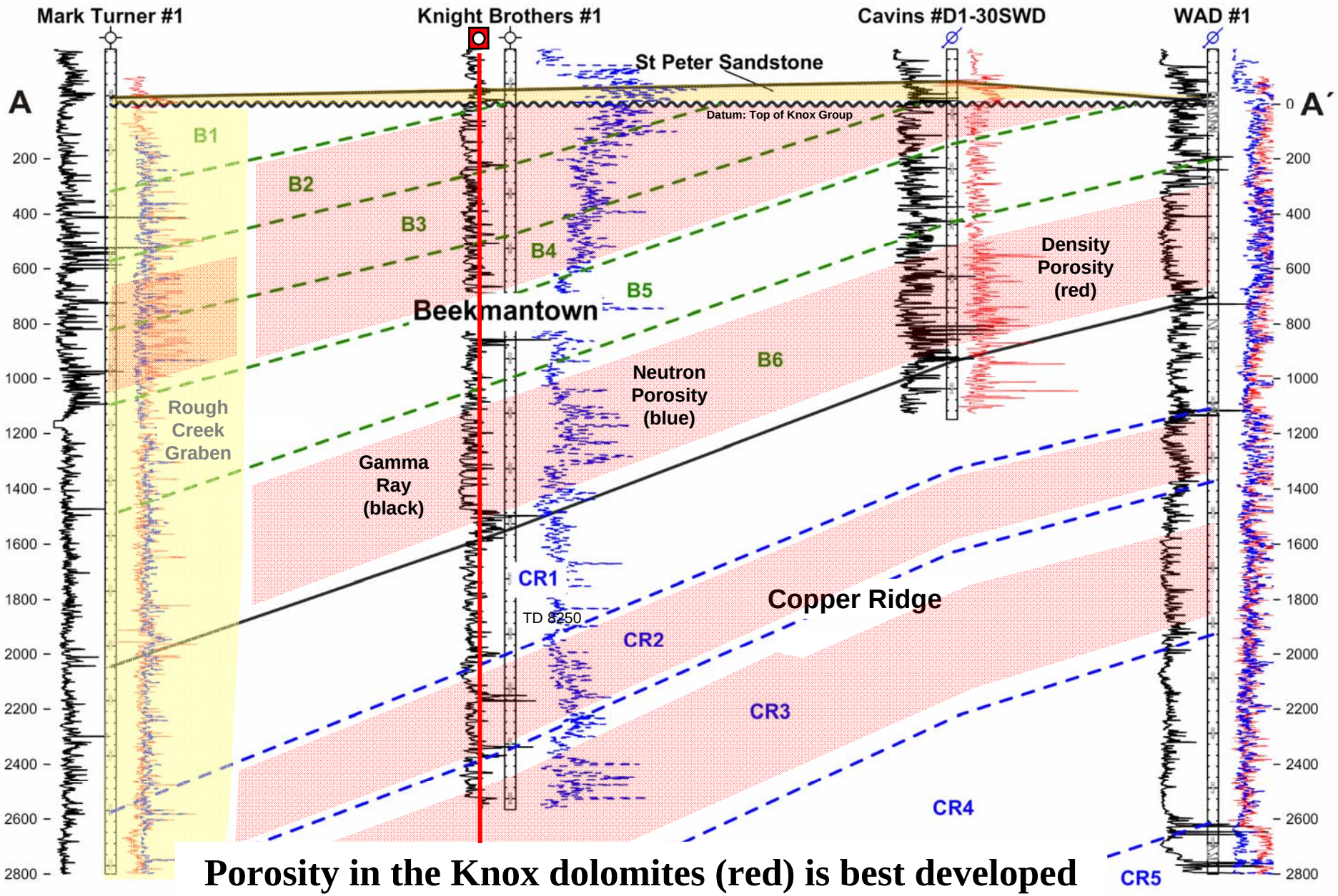
1718 ft

Intragranular Porosity

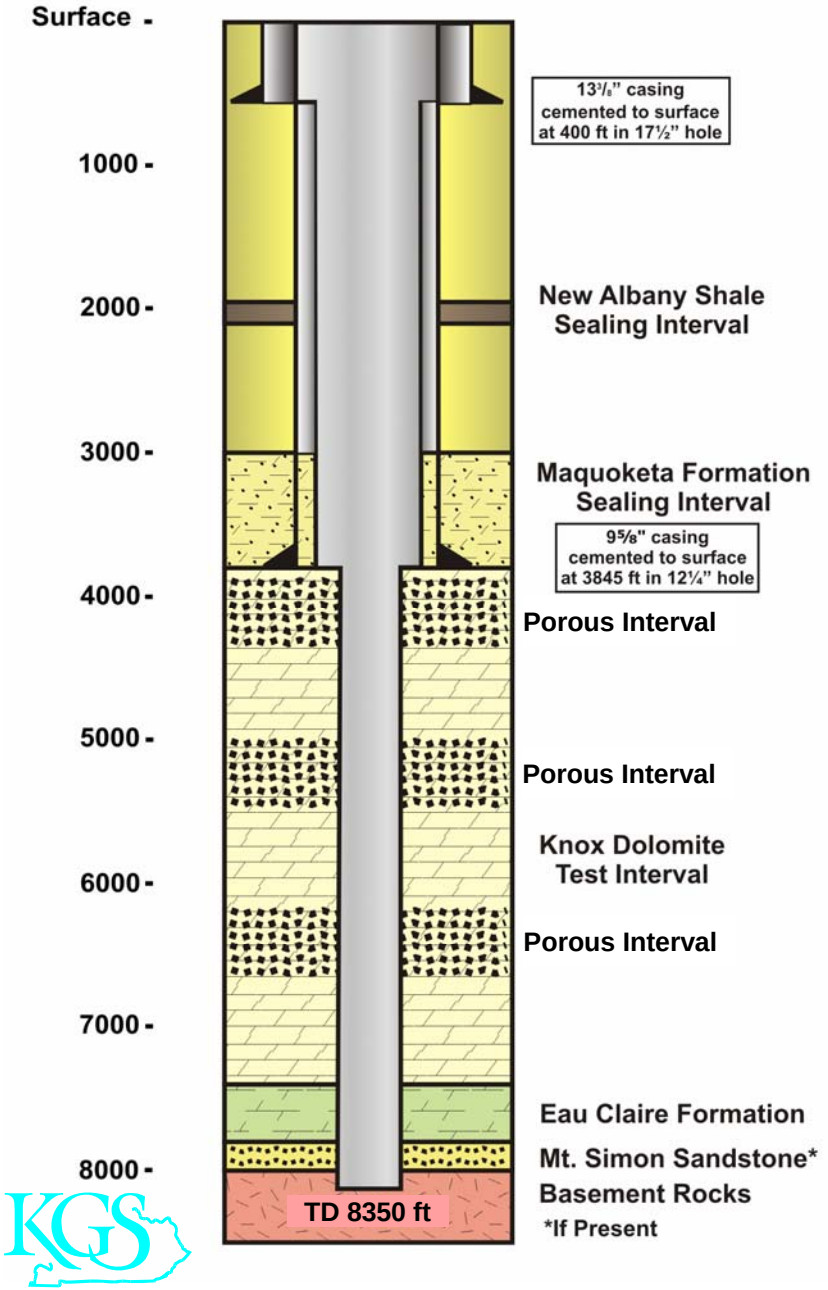
2521 ft

Vuggy Porosity

2815 ft

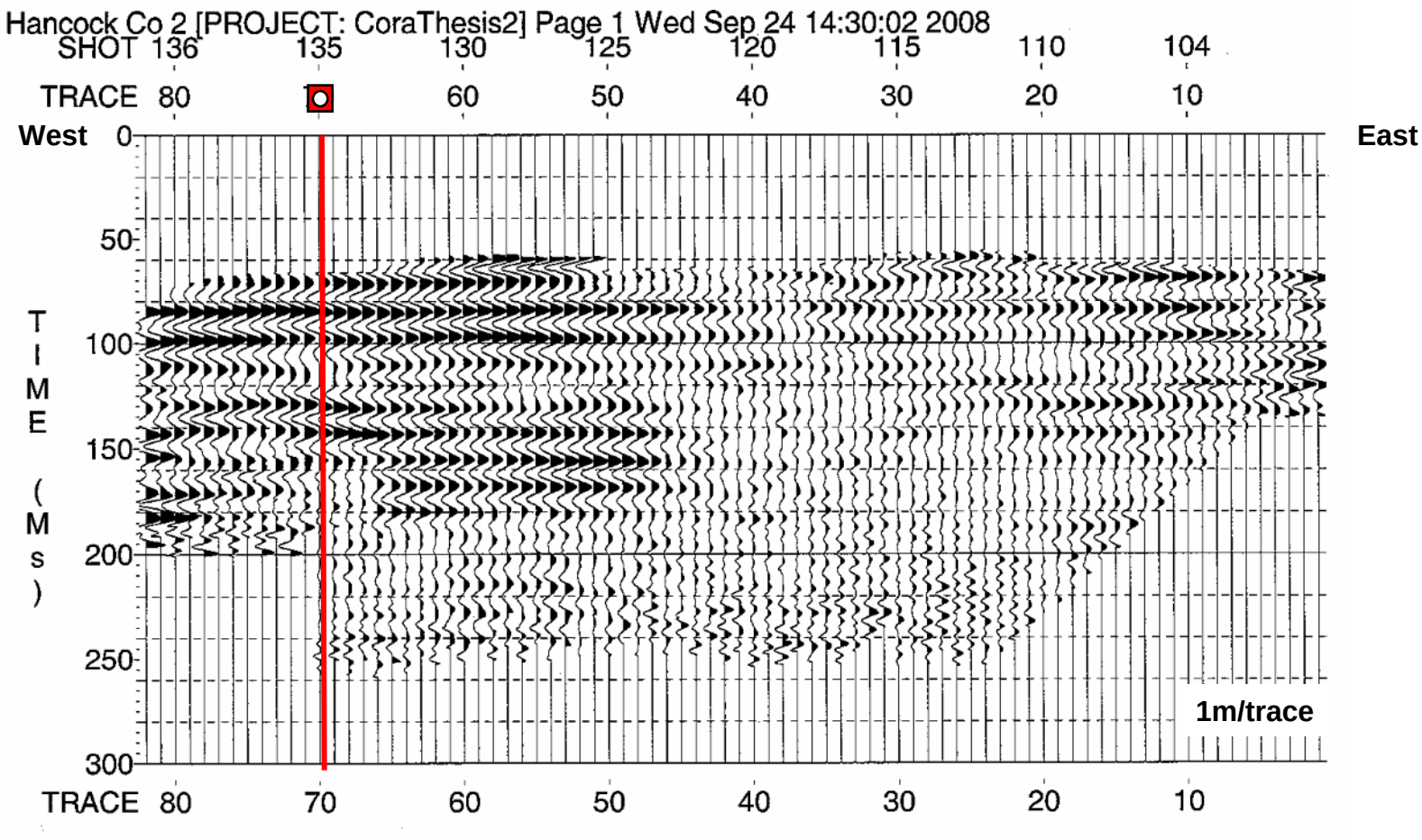


Porosity in the Knox dolomites (red) is best developed in the B2-B4, B6, CR2, and lower CR 3 members

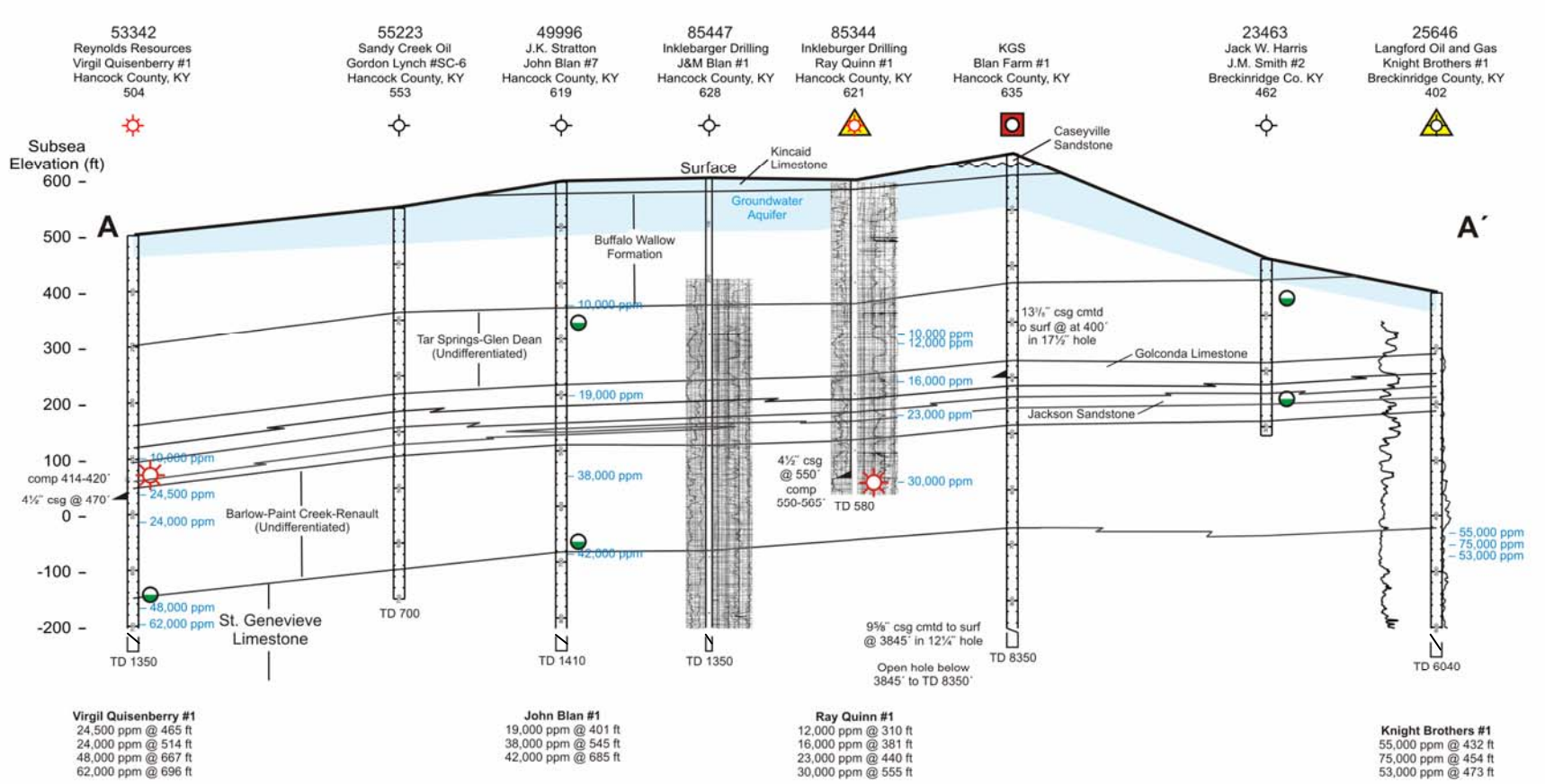


Drilling Program

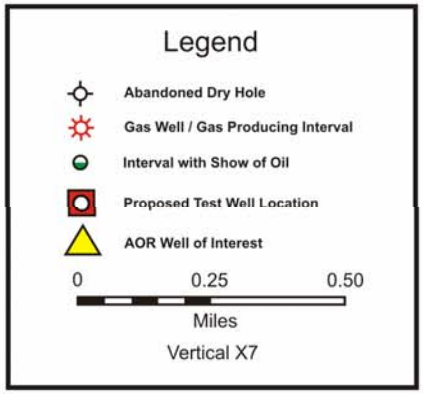
- **Drill to 400 ft and cement casing to isolate groundwater and any shallow oil and gas zones**
- **Drill to 3845 ft and cement casing to ensure against any possible leakage to the surface during testing**
- **Drill to 8350 ft to gather geological, geophysical, and geochemical data to identify and aid the design and evaluation of the intervals to be tested**

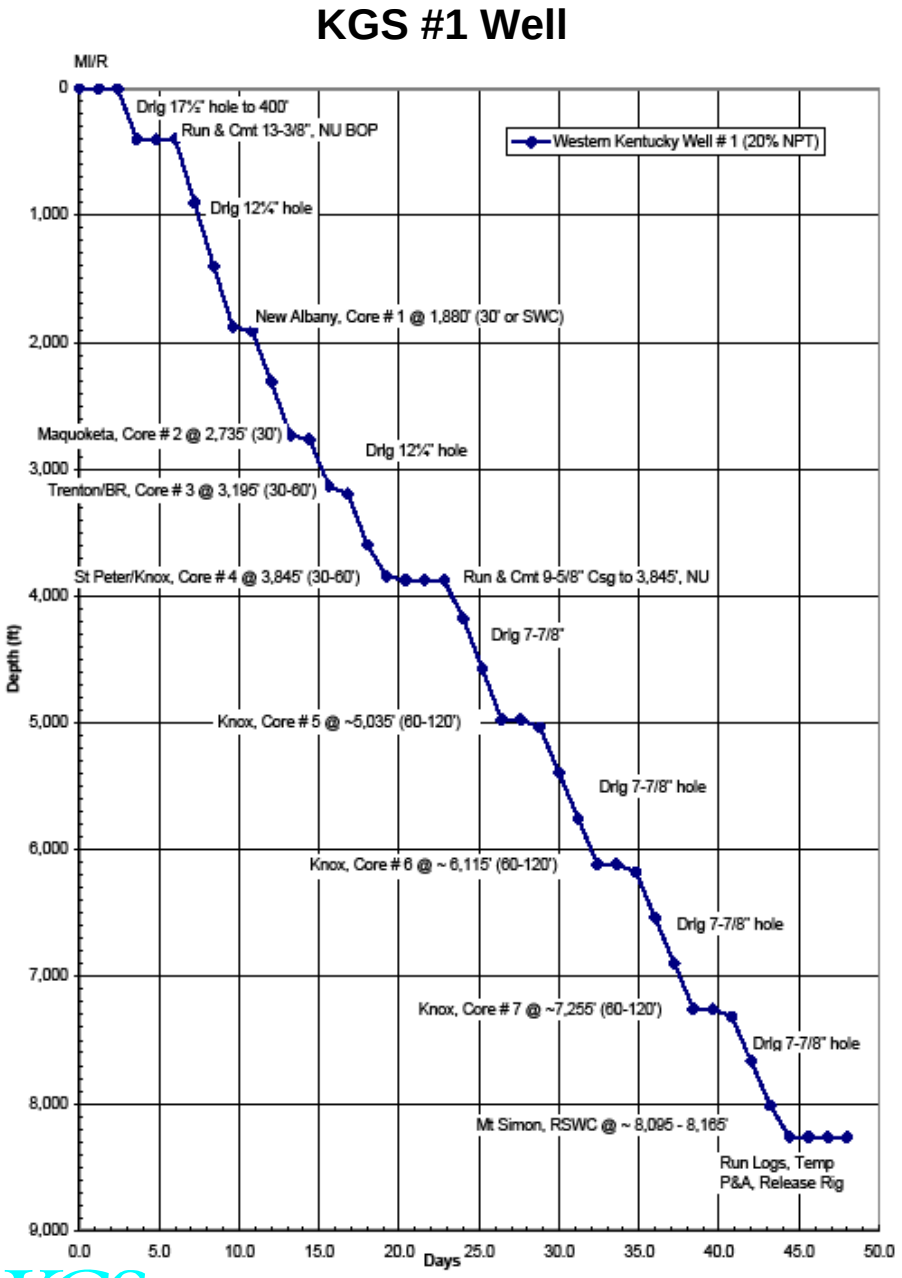


Shallow subsurface structure and stratigraphy are being evaluated before wellsite construction to determine the presence of any adverse conditions of karsting and faulting.



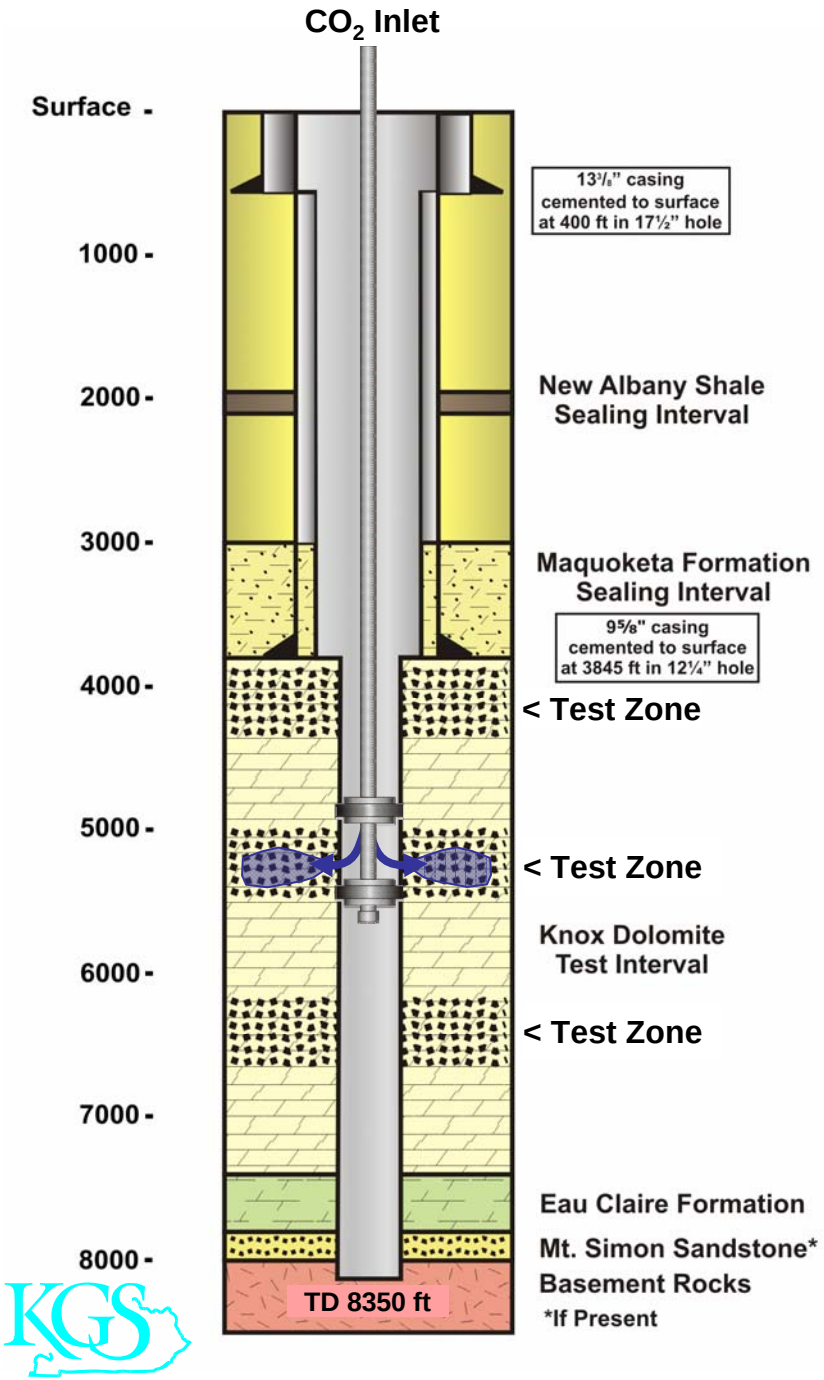
Domestic water wells near the proposed wellsite are generally >100 ft deep. The base of US Drinking Water, waters less than 10,000 ppm total dissolved solids, is at ~290 ft at the proposed wellsite. Shallow groundwater zones will be protected by casing cemented at 400 ft.





Drilling Program

- **Drilling to 8350 ft is expected to take ~45 days including time coring**
- **>300 ft of whole cores will be cut**
  - **New Albany Shale (30 ft)**
  - **Maquoketa Shale (30-60 ft)**
  - **Trenton/Black River (30-60 ft)**
  - **St Peter Sandstone/Knox Dolomite (60-120 ft)**
  - **Knox Dolomite (180-360 ft)**
- **Rotary sidewall cores will be cut in intervals without whole cores**
  - **New Albany Shale**
  - **Mt Simon Sandstone**
- **Extensive electric log program**

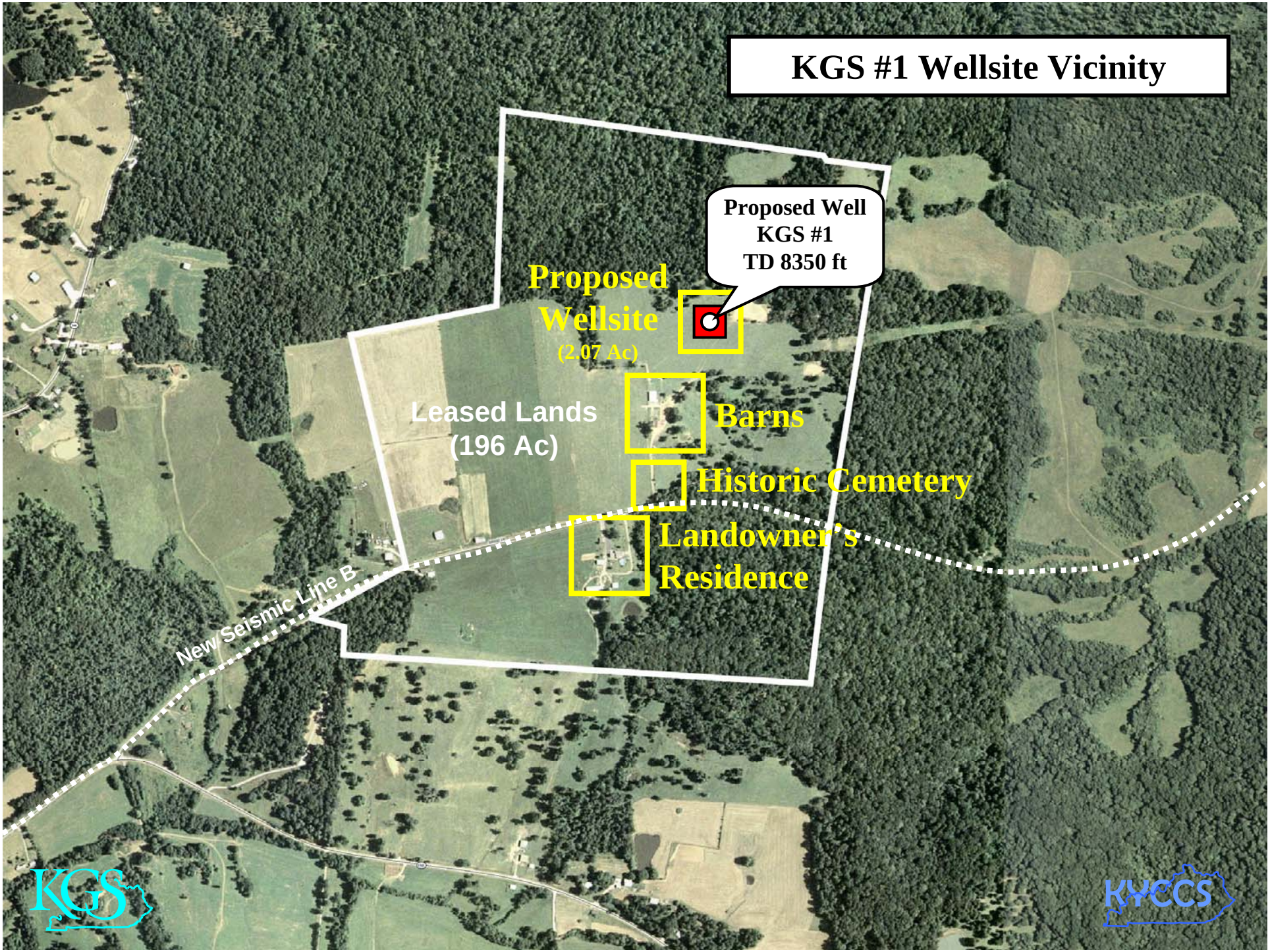


Testing Program

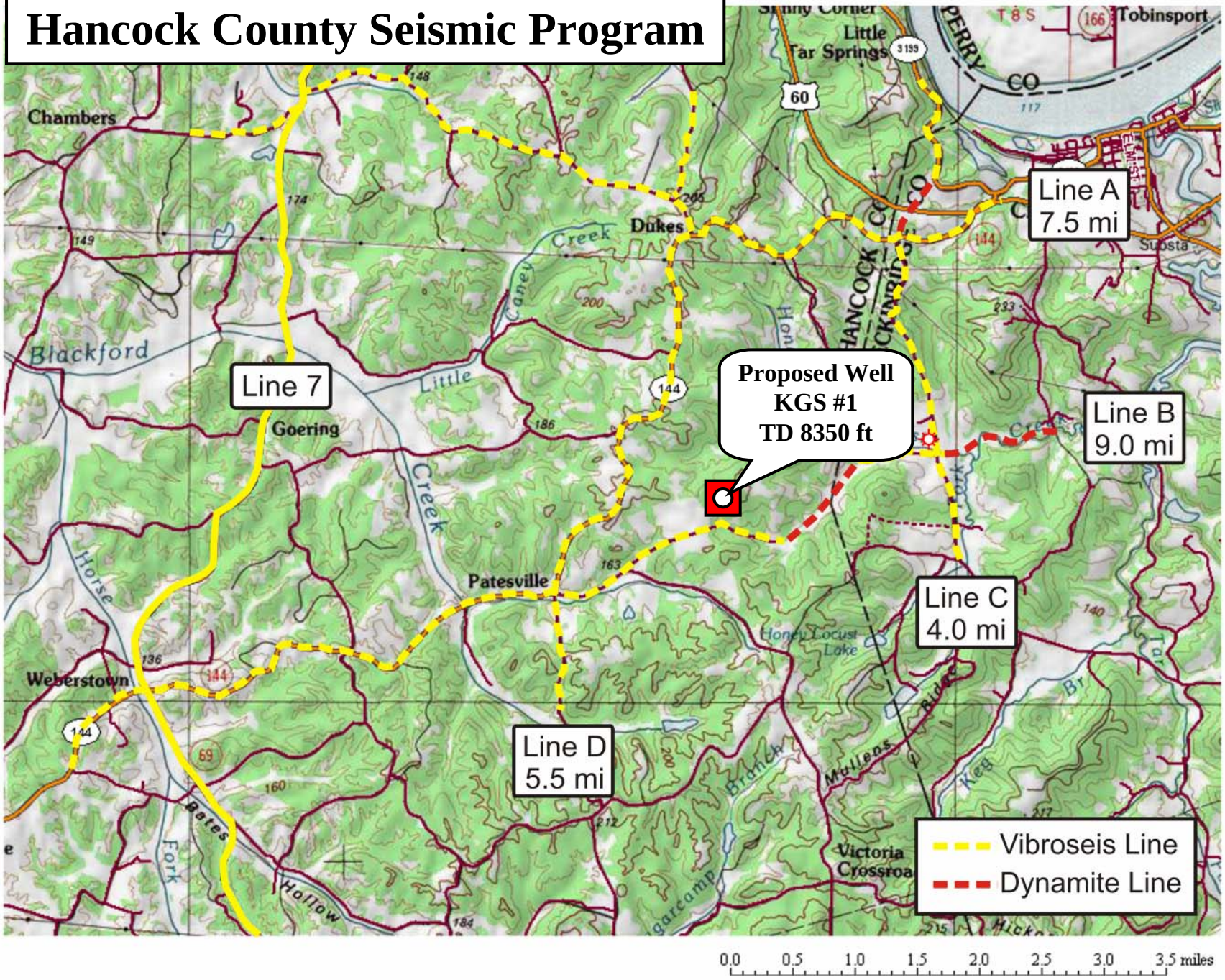
- Testing will proceed from the deepest interval to the shallowest below casing
- Test intervals will be isolated from deeper and shallower intervals
- All intervals will be first tested by injection of an artificial brine
- The most favorable interval will be tested by injection of a small volume of CO_2
- At the completion of testing the well will be plugged and abandoned to Kentucky and EPA standards

Project Status: Operations

- **Bids for services have been solicited, are under review, or have been awarded**
  - Title search (Paul L. Madden, Jr., Esq.)
  - Phase 1 environmental survey (GeoScience Consultants, Inc.)
  - Seismic acquisition (WesternGeco LLC)
  - Project manager (Sandia Technologies, LLC)
- **Well design and testing program is under review by ConocoPhillips engineering and drilling staff in consultation with KGS and Sandia Technologies**
- **Wellsite construction evaluation is in progress by ConocoPhillips drilling staff**


KGS #1 Wellsite Vicinity
Proposed Well
KGS #1
TD 8350 ft
Proposed
Wellsite
(2.07 Ac)
Leased Lands
(196 Ac)
Barns
Historic Cemetery
Landowner's
Residence
New Seismic Line B
KGS
KYCCS

Hancock County Seismic Program



Western Kentucky Project Timeline

- **Characterize the background surface conditions for follow-on environmental monitoring**
  - Shallow seismic program at the wellsite to define karsting
  - Soil gas surveys of the area surrounding the wellsite
- **Acquire ~26 mi of new seismic lines in east-central Hancock County to characterize the subsurface structure**
- **Permit the well for CO_2 injection with EPA Region IV**
- **Drill an 8350 ft well to Precambrian basement rocks**
  - Collect subsurface reservoir characterization data for Knox Group dolomites and other reservoirs
  - Complete an extensive reservoir evaluation program of geologic and geochemical testing and petrophysical, geomechanical, and reservoir engineering modeling
- **Conduct an extensive program of fluid injection and pressure testing including both brine and CO_2**
- **Conduct long-term surface environmental monitoring**

KGS

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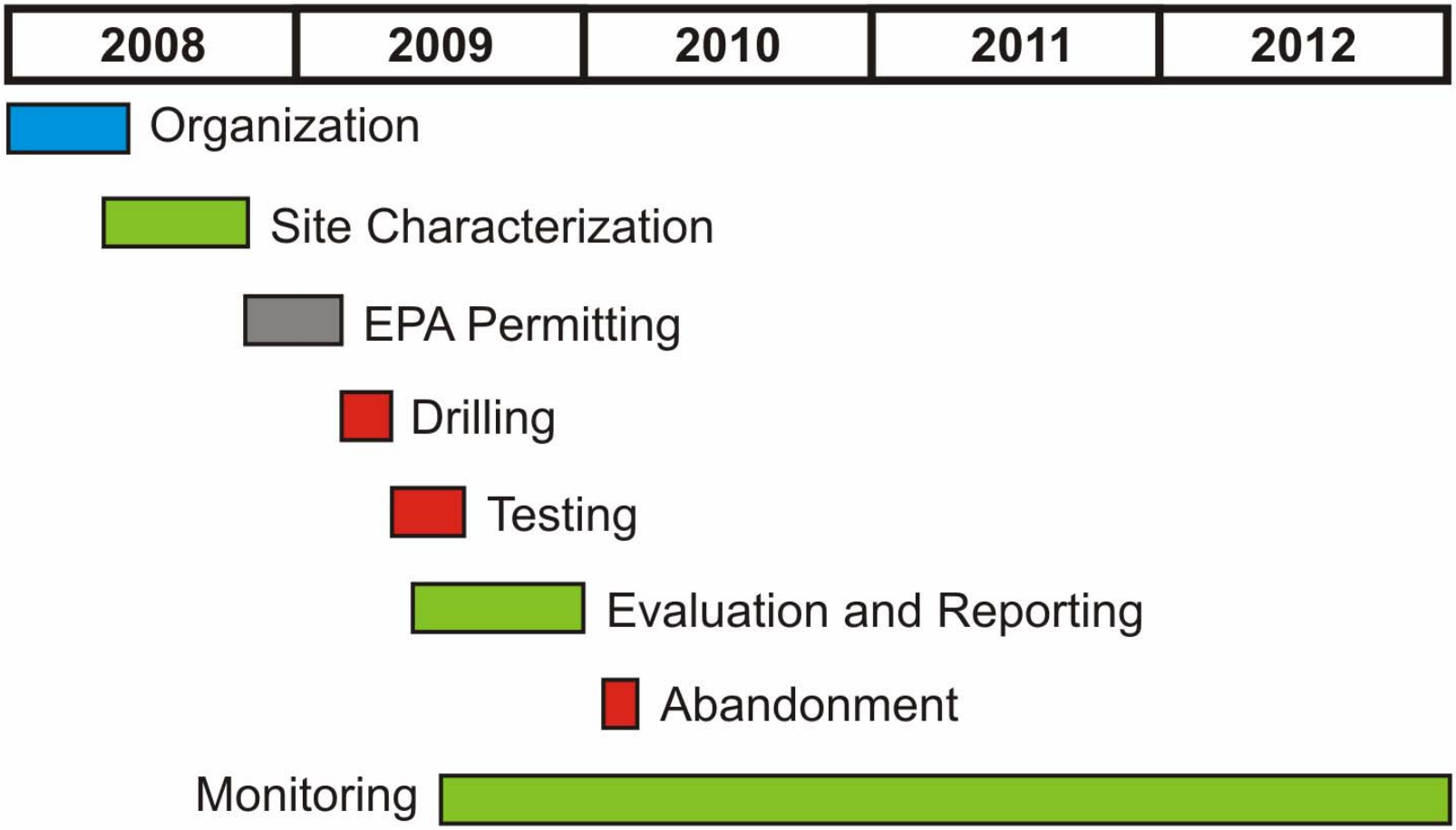
Western Kentucky Project Timeline



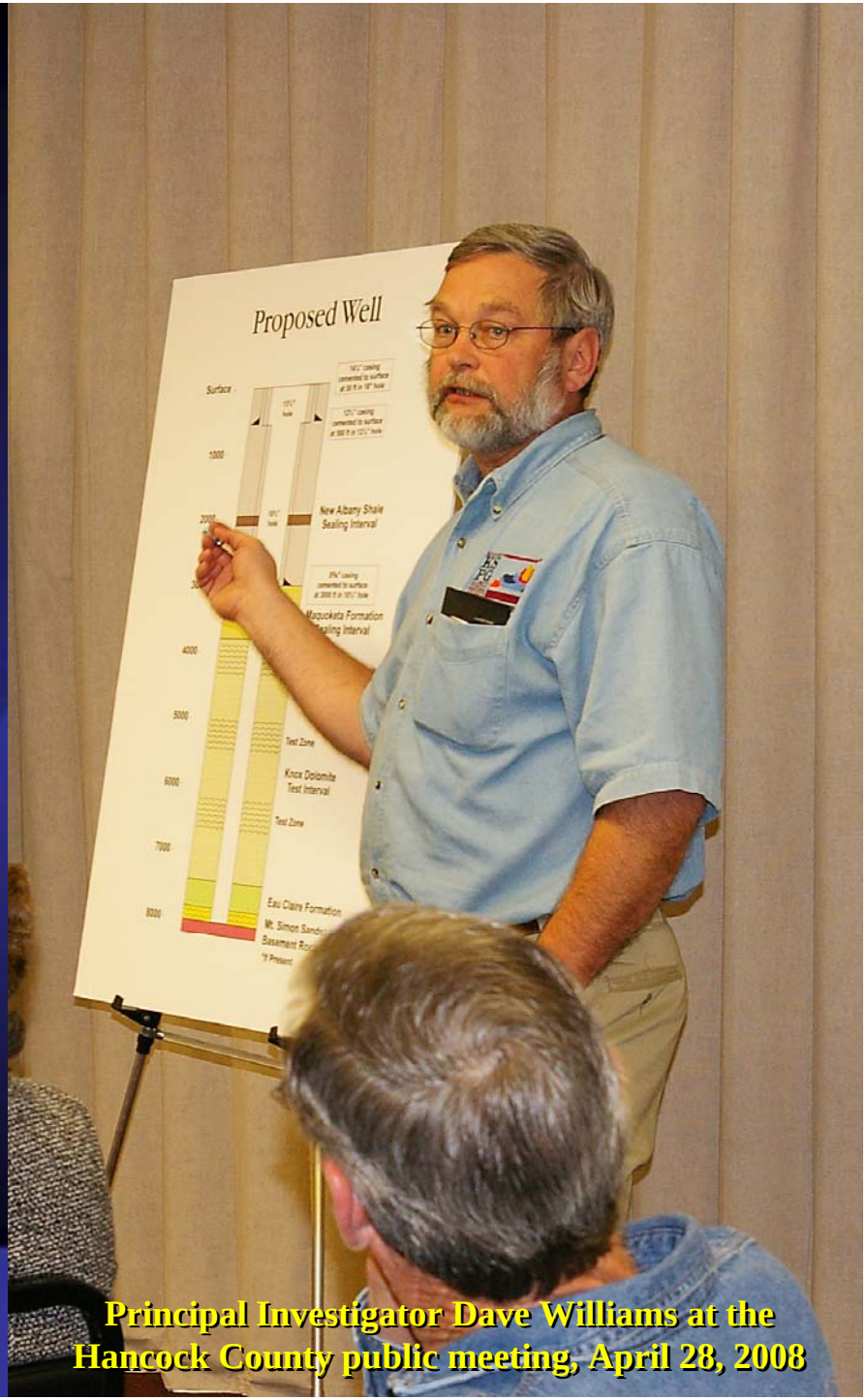
Public Outreach

Print Media Stories

- NETL *Carbon Sequestration Newsletter*, August 2008
- *Louisville Courier-Journal*, July 16, 2008
- *The Paducah Sun*, July 15, 2008
- News release by Governor Steve Beshear, June 30, 2008
- KGS *Kentucky Cross Section*, Winter/Spring 2008, Summer 2008

Public Presentations

- Kentucky Legislature, Special Subcommittee on Energy, July 18, 2008
- Kentucky Oil and Gas Association, July 1, 2008, Louisville, KY
- Platts Carbon Capture & Sequestration Conference, June 28, 2008, Houston, TX
- KGS Annual Seminar, May 23, 2008
- Hancock County Fiscal Court and public meeting, April 28, 2008, Hawesville, KY



Principal Investigator Dave Williams at the Hancock County public meeting, April 28, 2008

Project Status: Review

- **The western Kentucky CO_2 storage demonstration project has progressed quickly**
  - A consortium of KGS and energy industry partners has been organized
  - The project funding vehicle has been established
  - A drillsite has been identified and lease use terms negotiated with the landowner and oil and gas leaseholder
  - Initial contractor service bids are under review
  - Drillsite construction is being evaluated
- **Estimated commencement of operations is during the 1st Quarter of 2009 with well testing, reservoir evaluation, and final reports completed by yearend 2009**
- **Surface monitoring will continue through year-end 2012 until the abandonment of the well and dissolution of the consortium**

KGS

KY CCS

Acknowledgements

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Western Kentucky Carbon Storage Foundation
ConocoPhillips Company
Peabody Energy
E.ON US
TVA
R&B Resources LLC
GEO Consultants, LLC
Schlumberger Carbon Services
Smith Management Company
Wyatt, Tarrant & Combs, LLP


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