Carbon Sequestration Challenges in Kentucky*

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Abstract

The State legislature of Kentucky recently passed legislation to provide incentives for coal-to-liquids and coal-to-gas facilities in Kentucky. The incentives include funding for the drilling of a deep research test well in each of the two Kentucky coal fields located in the Appalachian and the Illinois Basins. The goal of the two drill holes will be to provide detailed data critical for assessing the potential of specific reservoirs that are deeper than 2,500 feet for long-term CO_2 sequestration. In addition to the study of large-scale, "permanent" reservoirs, the legislation also calls for specific data collection with regard to the enhanced oil and gas recovery potential of existing Kentucky oil and gas fields. The challenge of this drilling program will lie in the selection of two sites that represent the complex and varied deep geology of the state, with broad applicability to the proposed facilities. Because coal-to-fuels facilities have lifetimes up to 40 years and will generate as much as 5 million tonnes of CO_2 each year, massive reservoir capacities will be required. Although Kentucky has projected an estimated 7.2 billion tonnes of geologic capacity in deep saline aquifers and oil and gas fields, the details of reservoir- and seal-rock parameters, such as porosity, permeability, injectivity, capillary entry pressure, and degree of fracturing at depth, remain largely unknown. An additional 25 billion tonnes of storage may be available in organic-rich shales by means of adsorption of CO_2, but this is speculative and requires confirmation. Data collected from the drilling and analyses of the two wells will help to inform decision makers about the viability of future development of the proposed facilities in Kentucky. Such facilities are important to the future economy and use of coal in the Commonwealth, as well as to that of the Nation.

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Energy and Minerals
Kentucky Geological
Survey

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- **Partners**
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- **PIs for the Western Kentucky Deep Drilling Project**
  - David Williams
  - Rick Bowersox

Outline

- Kentucky House Bill 1 legislation that:
  - encourages development of coal-gasification facilities
  - provides Kentucky Geological Survey funding for geologic carbon-storage research
- Resulting KGS carbon storage projects
- Western Kentucky deep drilling project

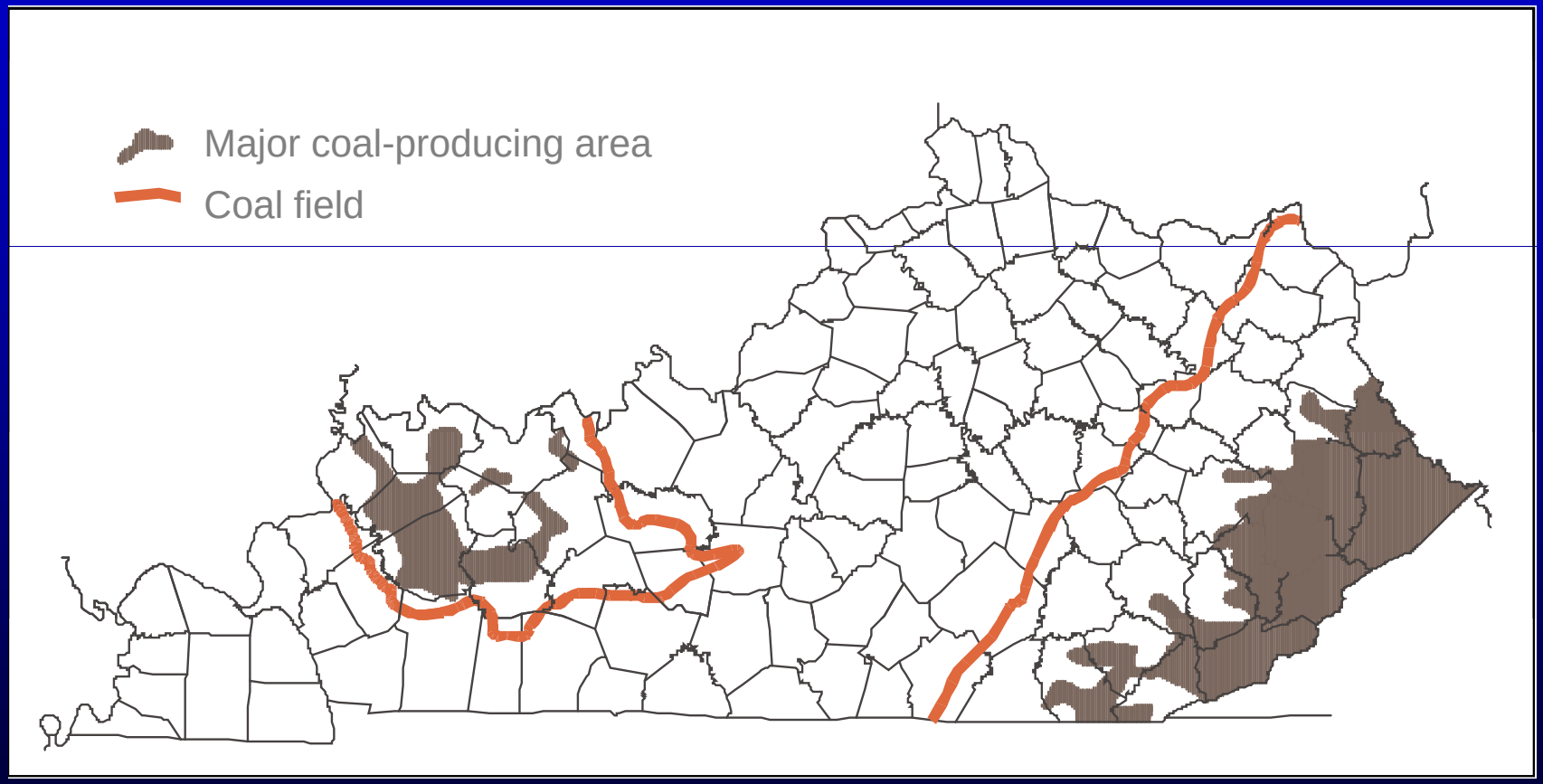
Background

- Kentucky HB 1 passed in August 2007
- Provides financial incentives for development of coal-gasification plants
  - In Kentucky
  - Use Kentucky coal
  - Carbon-capture ready
- Provides $5 million to KGS for geologic carbon storage research
- Encouraged to use the $5 million to match available federal and private funds

2007 HB 1 Directives

- Quantify the potential for:
  - CO_2 EOR
  - CO_2 EGR
- Test the organic-rich Devonian gas shales
  - CO_2 EGR
  - CO_2 storage potential
- Drill deep tests to estimate permanent storage potential
  - Eastern Coal Field
  - Western Coal Field

Deep Drilling in the two Kentucky Coal Fields



Organization of Partnership

- **KGS realizes that $5 million is not sufficient to accomplish all these goals**
  - **Developed and is still developing partnerships**
- **Created a joint industry–government consortium to carry out the directives**
  - **Kentucky Consortium for Carbon Storage (KYCCS) administered by KGS at the University of Kentucky**
  - **Web site: www.kyccs.org**

Five Subprojects

- CO_2 enhanced oil recovery
- CO_2 enhanced gas recovery/Devonian shale
- Western Kentucky deep CO_2 storage
- Eastern Kentucky deep CO_2 storage
- Public relations and technology transfer

Western Kentucky Deep Drilling Project

- Funding Partners
  - ConocoPhillips, E.ON U.S. LLC, Kentucky Syngas, LLC, Kentucky Geological Survey, University of Kentucky, Kentucky Governor's Office of Energy Policy, Smith Management Group, State of Illinois Office of Coal Development, Schlumberger Carbon Services
- Associate Partners
  - Big Rivers Electric Corp., GEO Consultants, LLC, Henderson County Riverport Authority, ICON Construction, Inc., Praxair Inc., Tennessee Valley Authority, Sunshine Oil and Gas, University of Kentucky Center for Applied Energy Research, URS Corp.
- Open to other participants

KGS

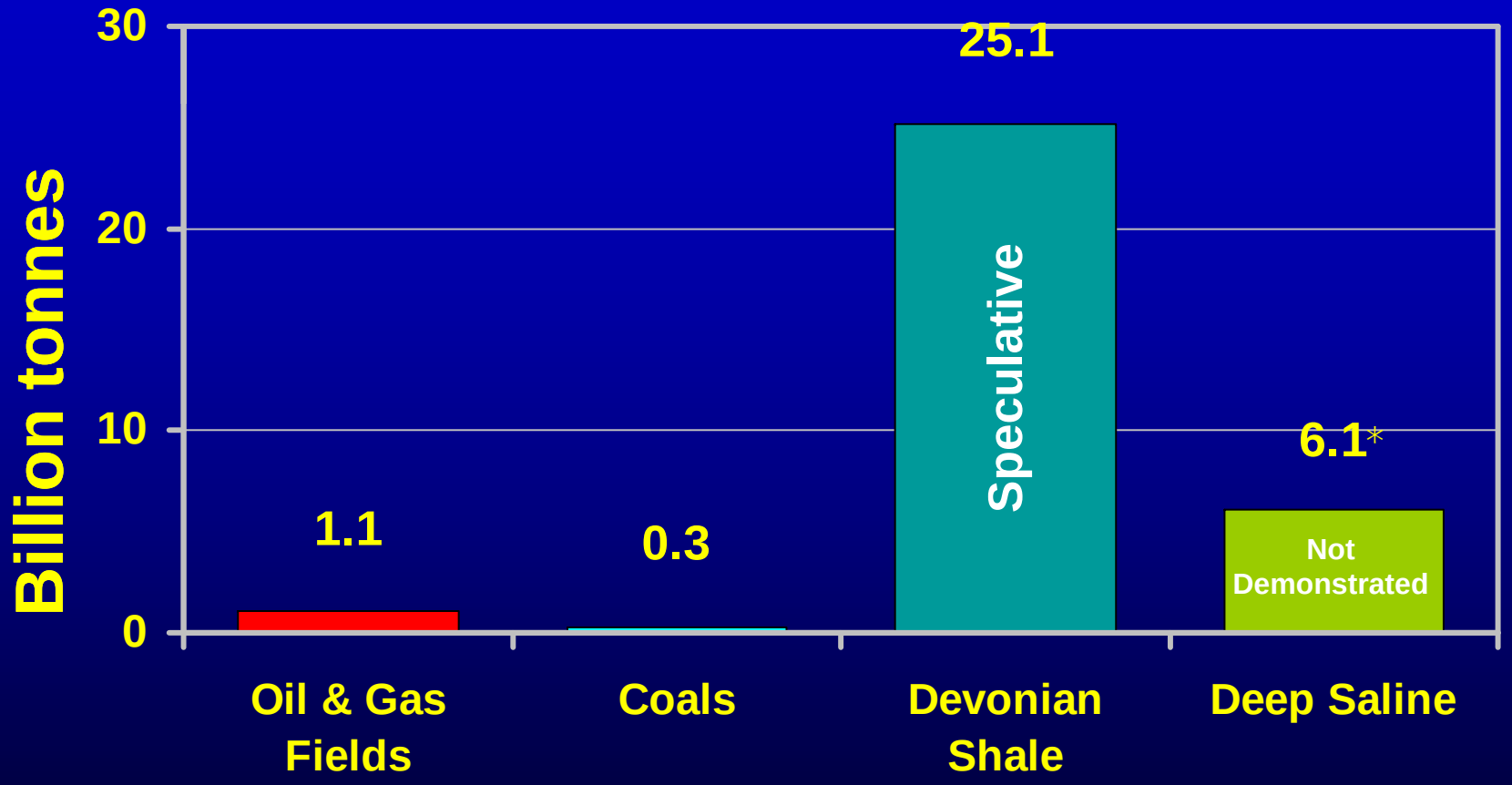
Partnership Roles

- Partners (utilities, energy companies, service companies, state agencies, U.S. DOE) are agreeing to:
  - contribute cash
  - provide in-kind services
  - provide well sites
  - share in the planning
- Not-for-profit organization: Western Kentucky Carbon Storage Foundation Inc.
- KGS selects projects and sites, and allocates funds
- All results are public

Project Schedule

- Project will require 3 to 4 years for completion
- Projects to run concurrently
- Deep drilling is the first priority due to lead time required in identifying partners, drilling rigs, and funding
- Western Kentucky deep-drilling project started
  - Drilling expected to commence within the year
  - Collecting seismic data in area of well before drilling
- Partners for the other projects currently being sought

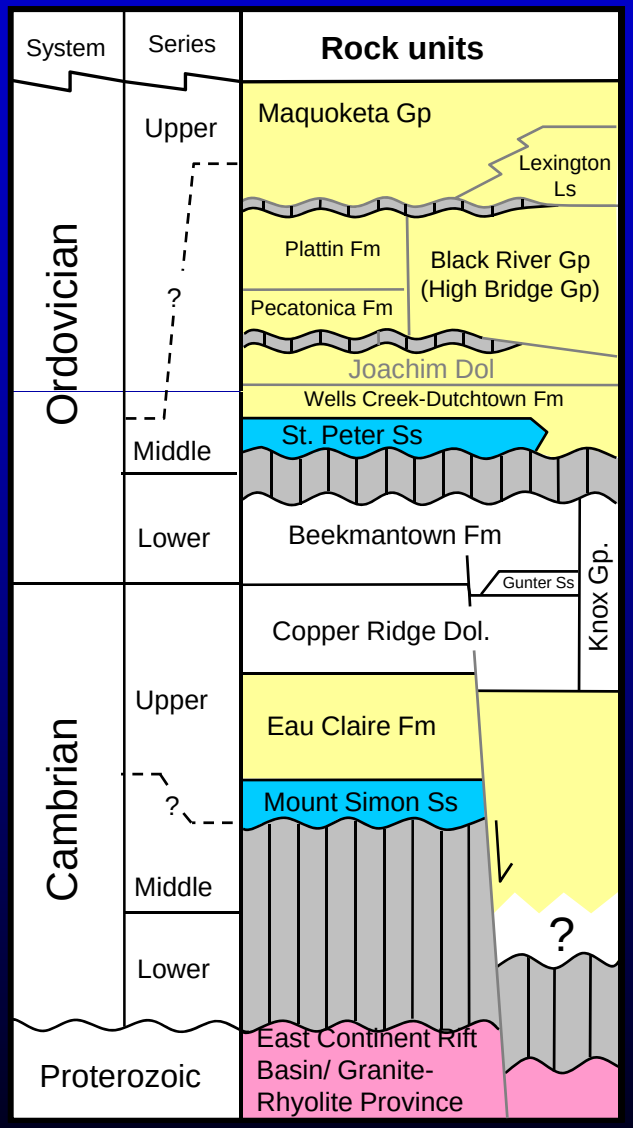
DOE Phase I CO_2 Storage Estimates



Total: 32.5 billion tonnes total (>300 years of Kentucky emissions)

*** Does not include the Knox Group and the Precambrian sandstones**

Western Kentucky Stratigraphic Units with CO_2 Storage Potential

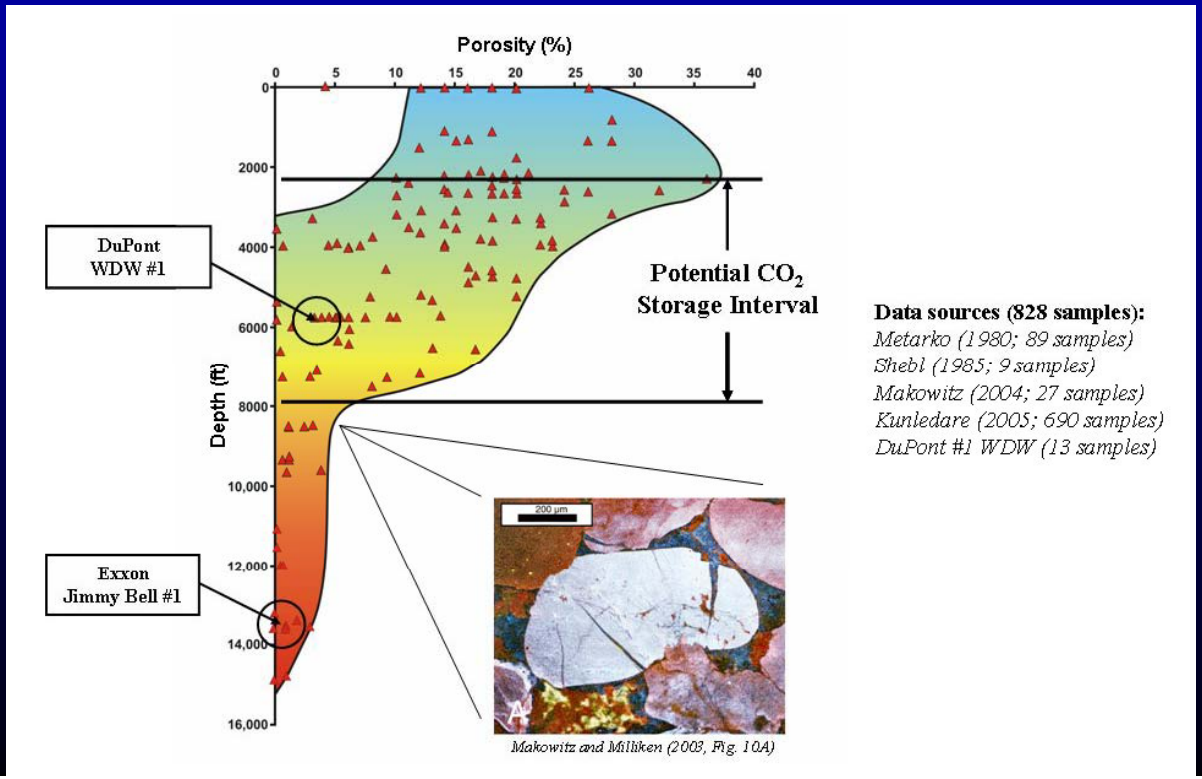


- Potential CO_2 sinks/ reservoirs
- Caprock- seal interval
- Unconformity
- Sink and seal (*depends on horizon)*
- Basement sedimentary and igneous rocks (*mostly seal; some sink*)

- Mt Simon considered a major sink in E Midcont.; tight in Ky
- Knox Group both sink and seal; greater sink potential in Ky
- Some units above this including:
  - Deeper Mississippian sands and carbonates
  - New Albany Shale
  - Silurian Dolomites

Western Kentucky Deep Drilling Project

- **Farthest along of the projects**
- **Drill-site selection criteria (primarily geologic)**
  - As representative of the regional geology as possible
  - Maximum depth 8,000 feet
    - Porosity of the Mt. Simon is higher at shallower depths



Western Kentucky Deep Drilling Project

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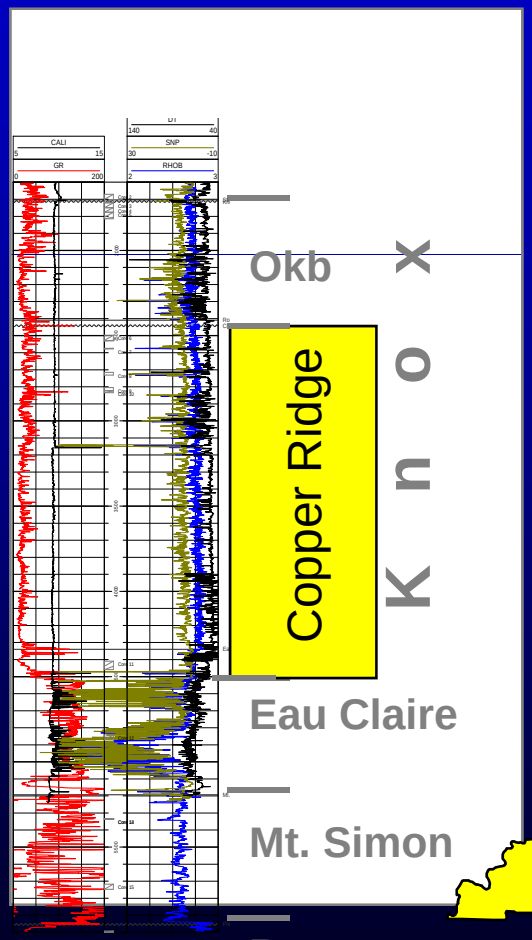
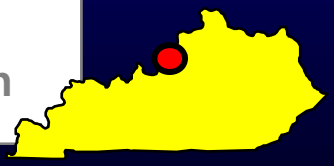
- **Drill-site selection criteria (primarily geologic)**
  - As representative of the regional geology as possible
  - Maximum depth 8,000 feet
    - Porosity of the Mt. Simon is higher at shallower depths
    - Drilling and testing cost considerations (up to $7 million)
  - Test the entire sedimentary section to basement for both sink and seal characteristics
  - Target reservoir zones below 2,500 feet depth
    - Knox Group: Primary target
    - Mt. Simon Sandstone: Secondary target
    - Other targets: New Albany Shale, Silurian dolomites, St. Peter Sandstone, Gunter Sandstone (Knox), Precambrian sandstones
  - Must be within the western coal producing area
- **Screening for location relied regional seismic data (only 7 basement test)**

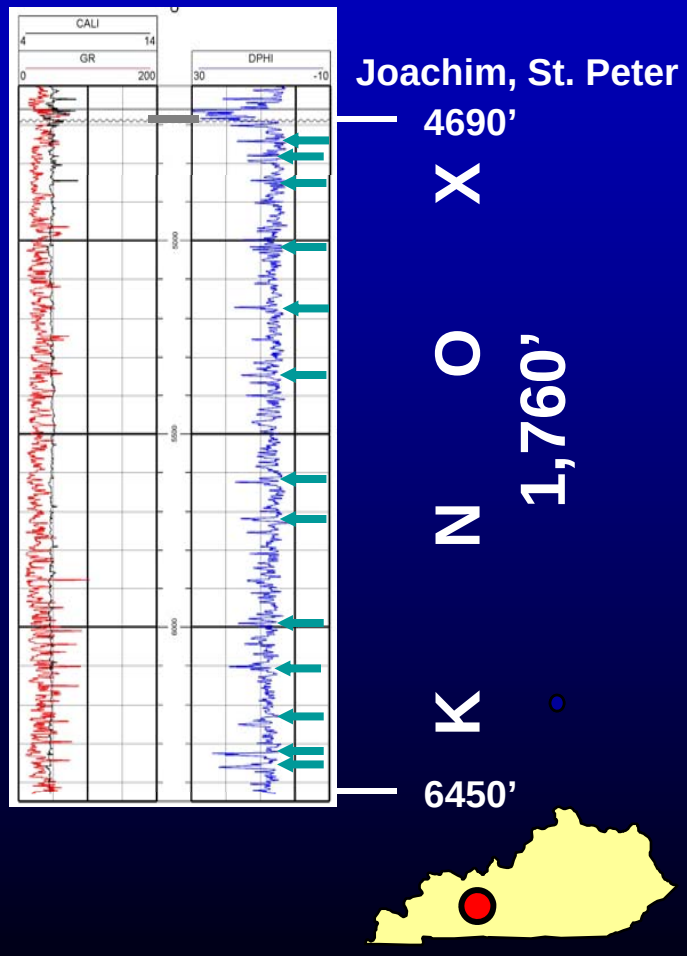
Storage Potential Greater in Knox than in Mt Simon





- DuPont Waste Injection Well, Louisville, KY
- 750 ft of Mt. Simon has low permeability (not used)
- Best permeability in 1870 ft. of Copper Ridge Group
  - Five thin zones of vuggy, fractured dolomite
  - 150 g/m @175 psi or 1/3 MMT CO_2 /yr)
  - Sink and Seal

Storage Potential of Knox Confirmed



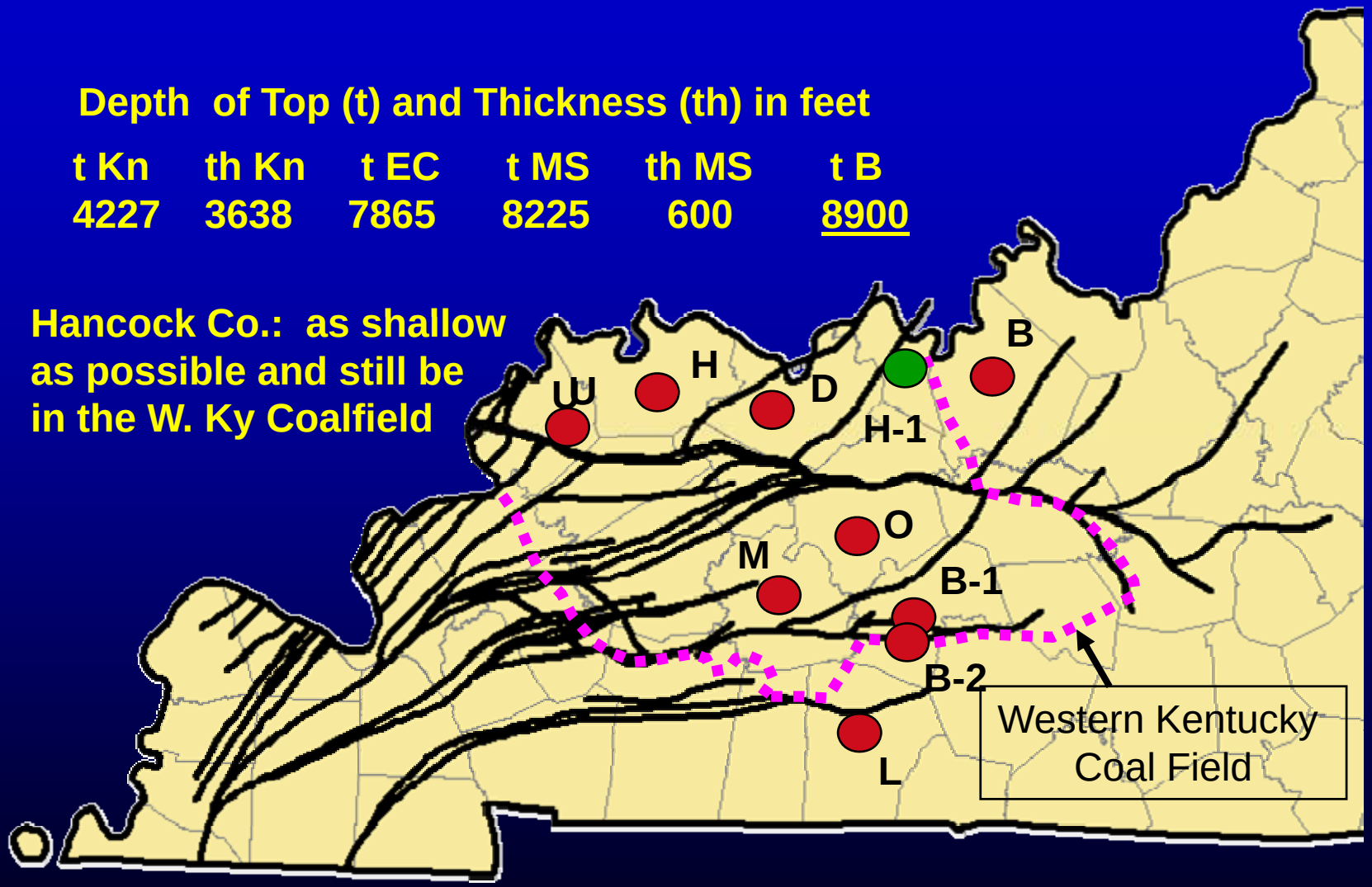
- Waste water injection well in Butler Co.
- 1,760 ft open hole
- Injection zones unknown, but note spikes on the density porosity log
- CO2 injection rates and storage capacity similar to the DuPont well
  - Injection rates not maximized in well

Screening for the Deep Well

Depth of Top (t) and Thickness (th) in feet

t Kn	th Kn	t EC	t MS	th MS	t B
4227	3638	7865	8225	600	8900

Hancock Co.: as shallow as possible and still be in the W. Ky Coalfield



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Based on proprietary seismic data

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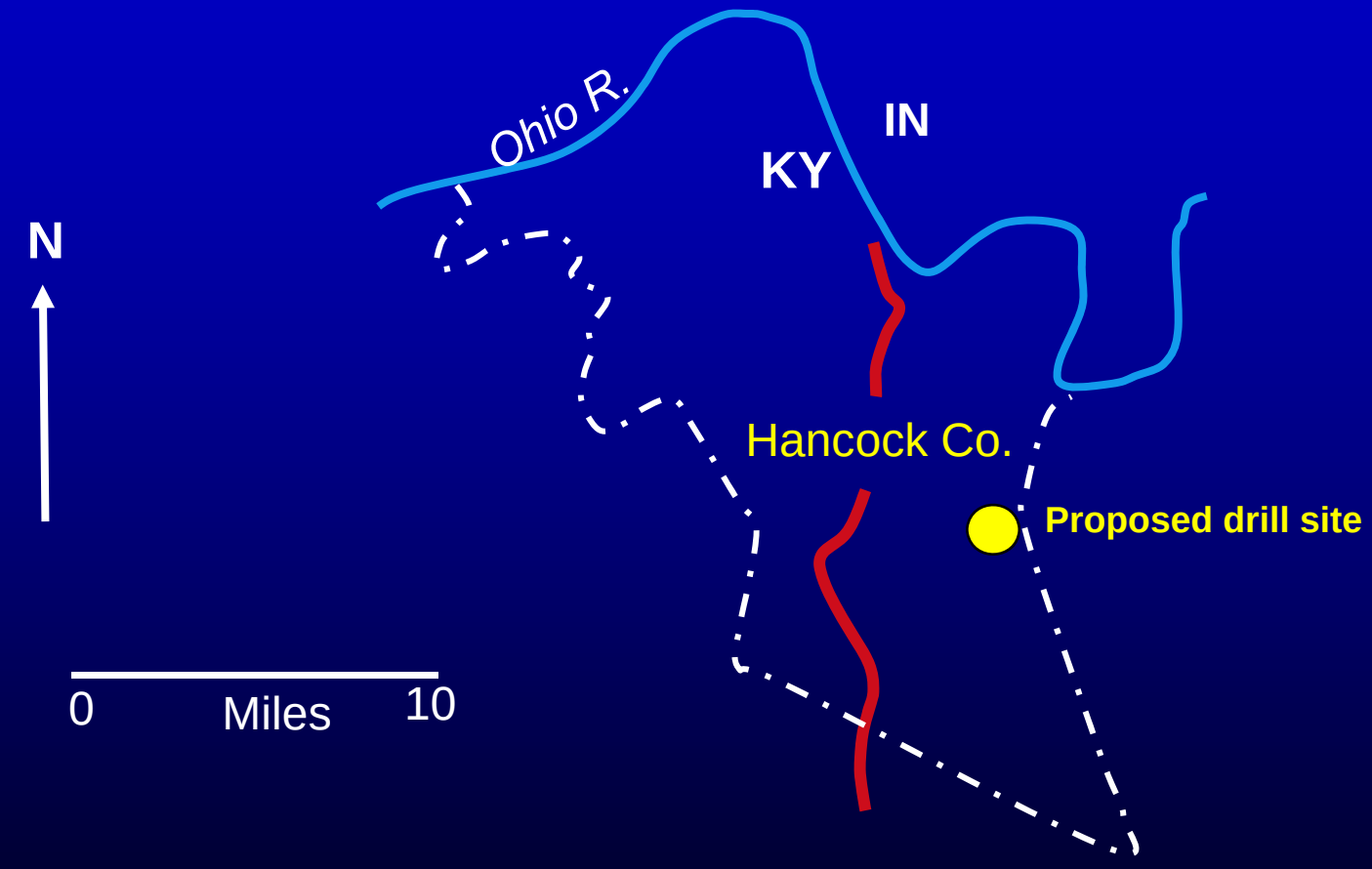
Seismic Line and Drill Location in Hancock Co., Kentucky



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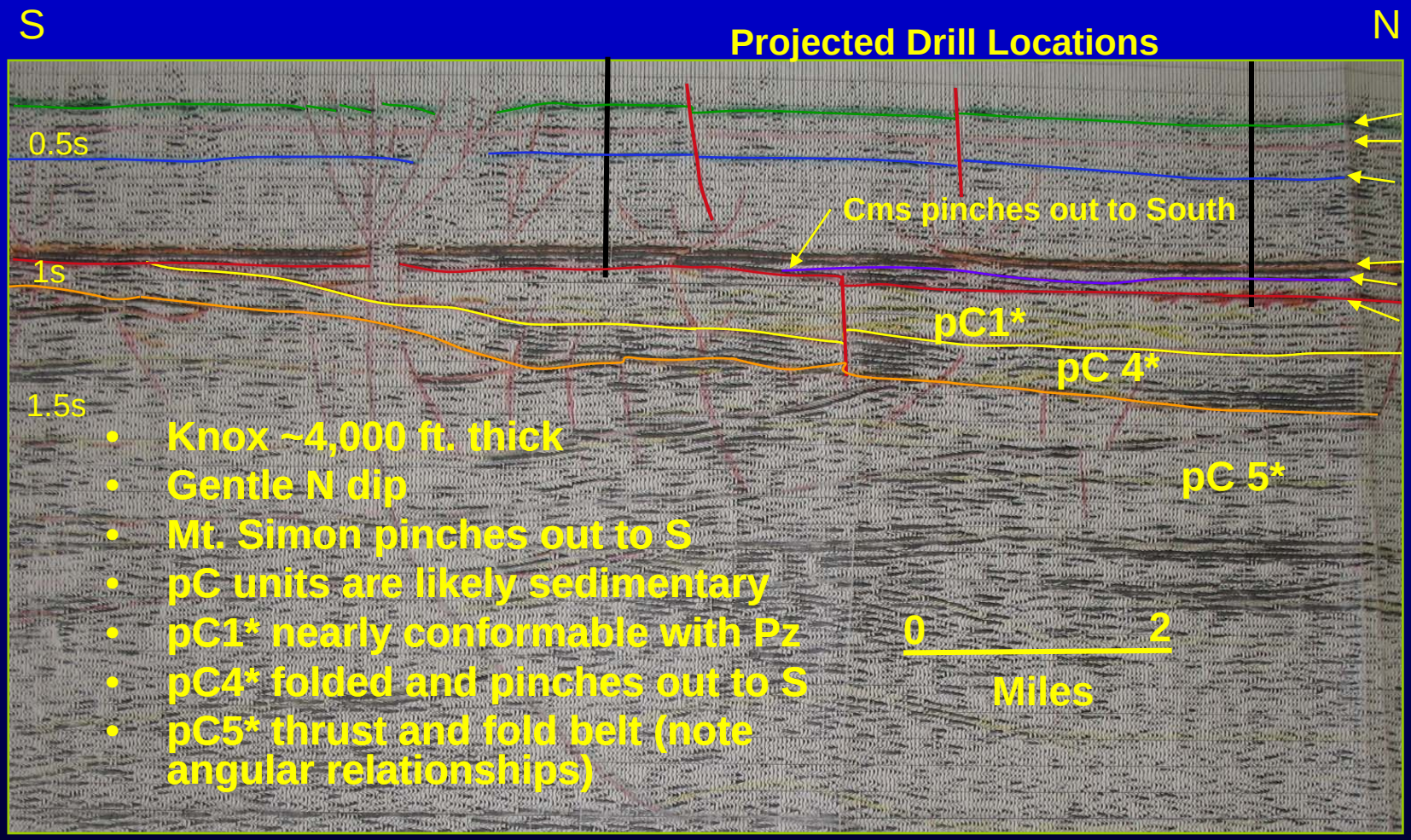
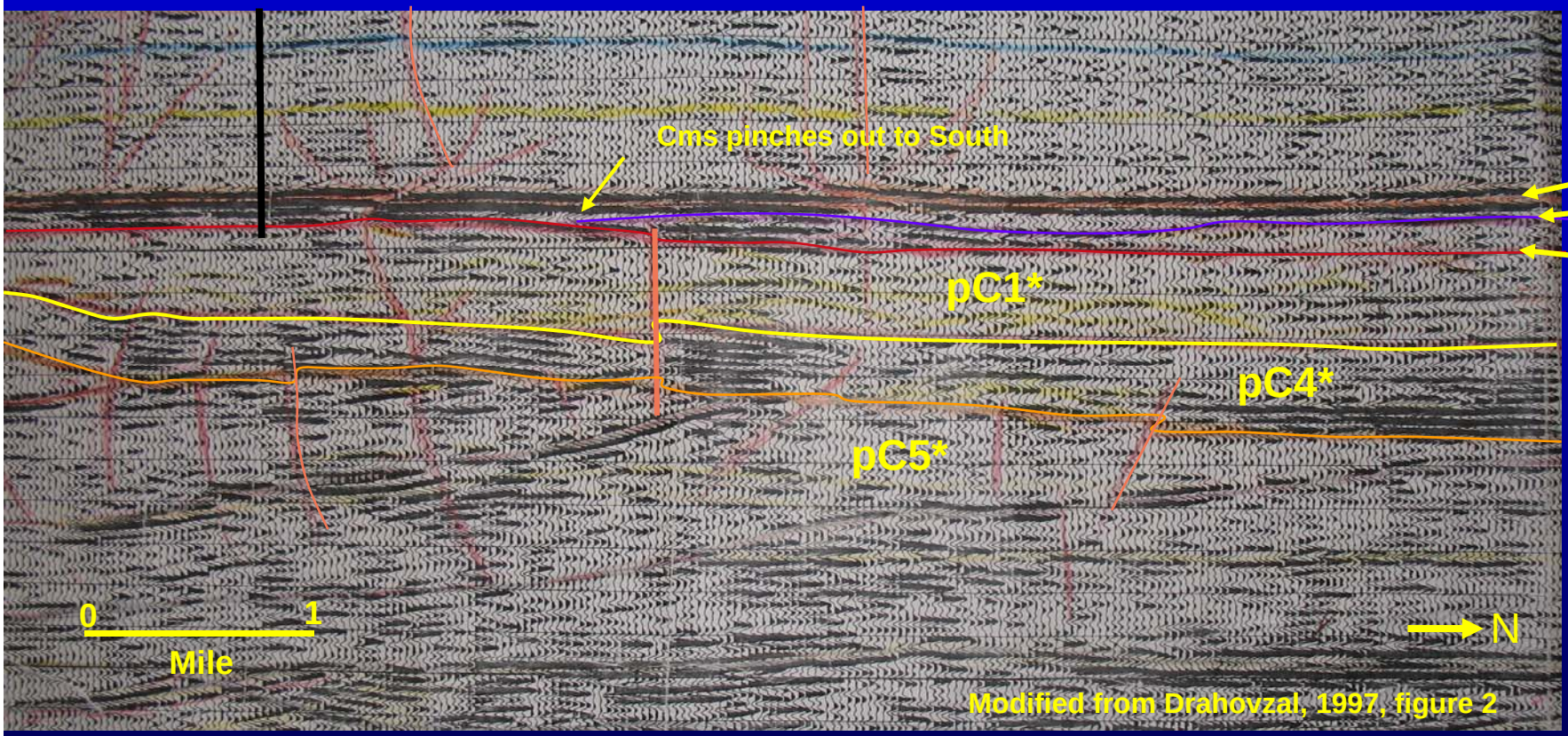
N-S Seismic Line in Hancock Co.



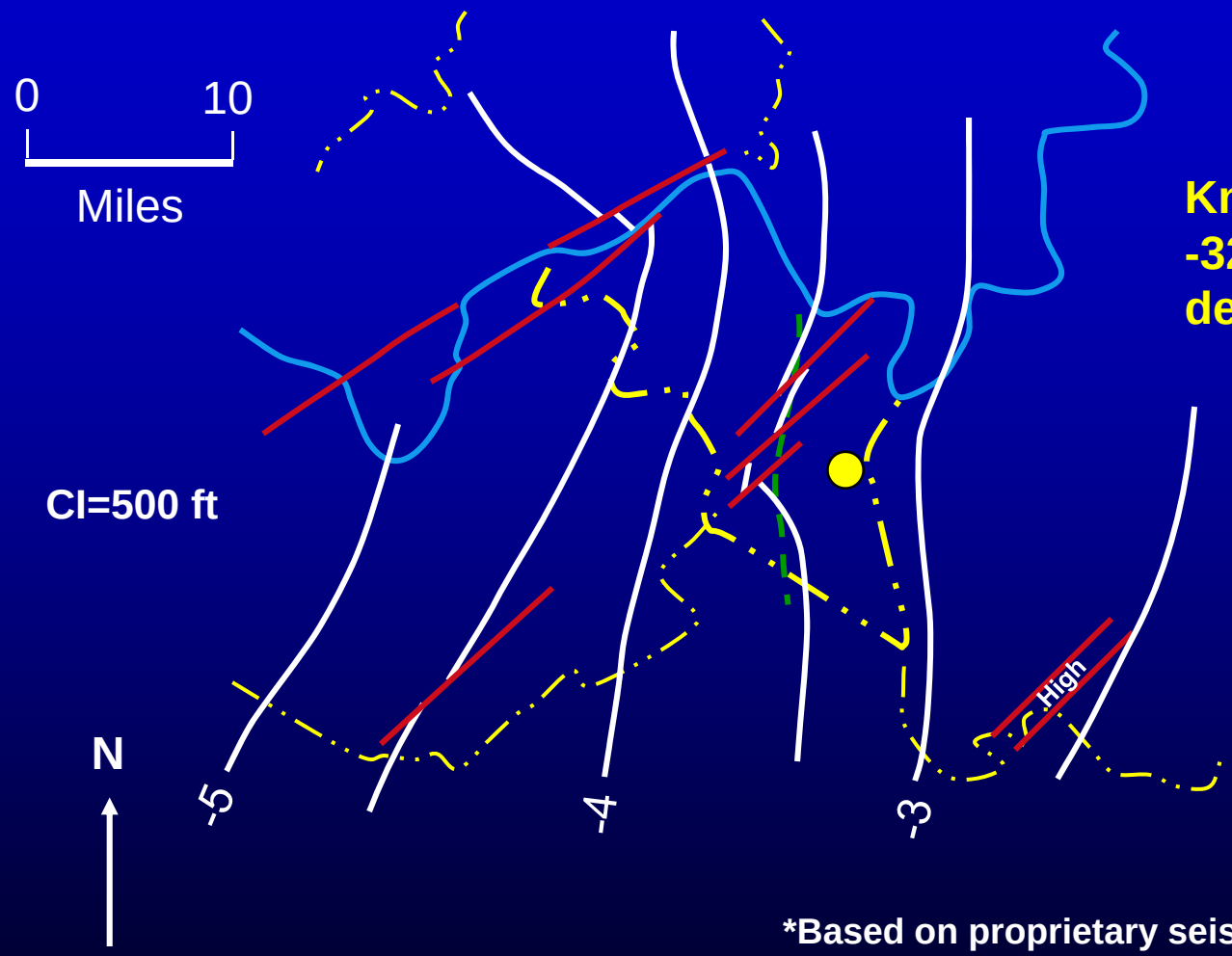
Modified from Drahovzal, 1997, figure 2

N-S Seismic Line in Hancock Co.



- Knox Group is up to about 4,000 ft. thick at drill site—primary target
- Mt. Simon is up to nearly 600 ft thick—likely thin (<100 ft?) to missing at drill site—secondary target (land acquisition problems prevented drilling farther N)
- Possible sand-rich facies below in pC1*-- could represent reservoir rock (not previously drilled)

Top of Knox Group in Hancock Co., Kentucky* (in thousands of feet sub sea)



Knox Group is at about -3200 ft sub sea or 3750 ft depth**.

*Based on proprietary seismic data in adjacent counties of northern Kentucky and southern Indiana

**Assuming ground elevation of 550 ft.

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Top of Eau Claire Formation in Hancock Co., Kentucky* (in thousands of feet sub sea)

Eau Claire Formation is at about -7200 ft sub sea or 7750 ft depth**.

*Based on proprietary seismic data in adjacent counties of northern Kentucky and southern Indiana

**Assuming ground elevation of 550 ft.

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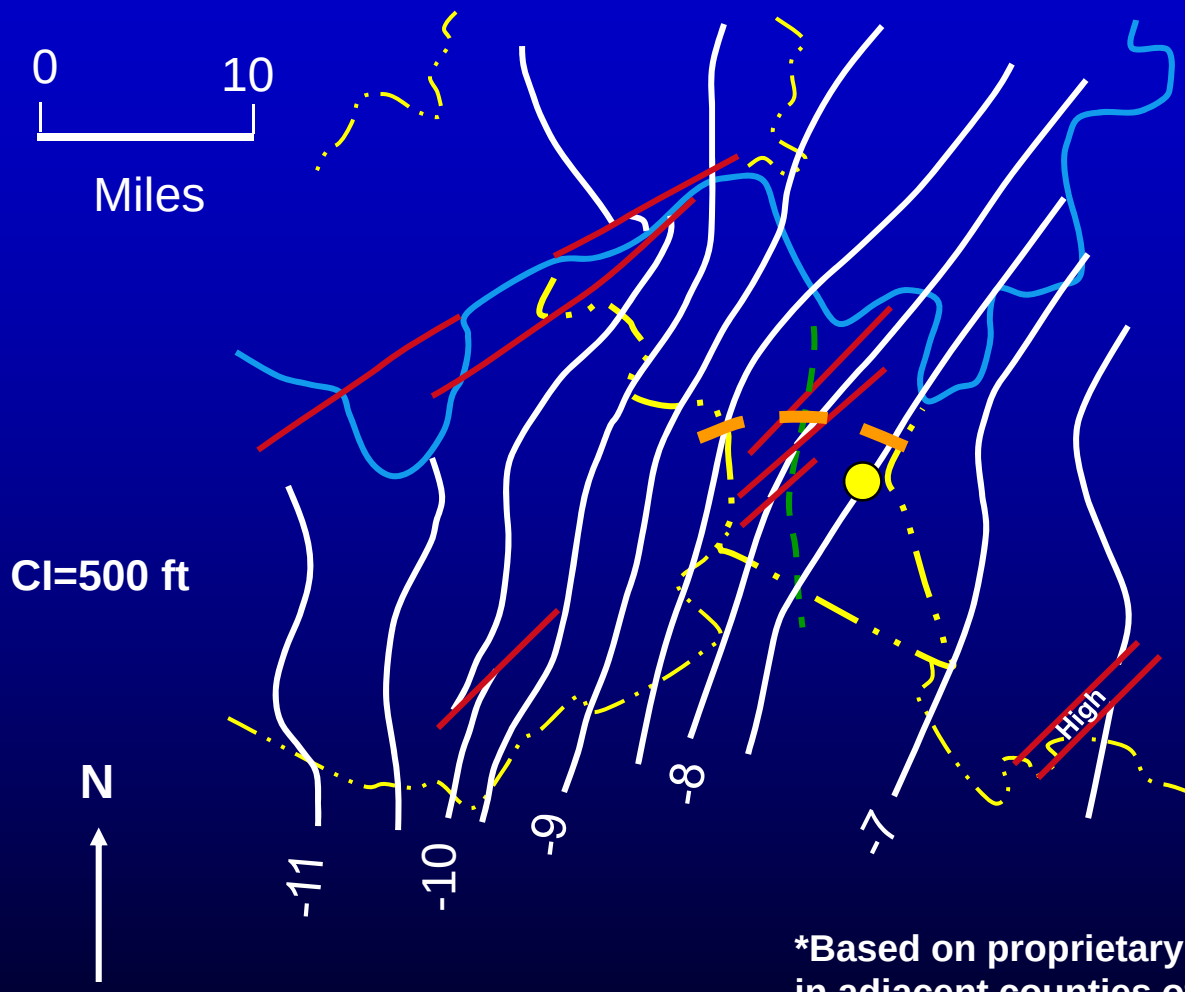
Top of Precambrian Basement in Hancock Co., Kentucky* (in thousands of feet sub sea)



Precambrian Basement is at about -7500 ft sub sea or 8050 feet depth. It is likely that Mt. Simon will be thin (<100ft) or missing.**

Approximate southern limit of Mt. Simon

***Based on proprietary seismic data in adjacent counties of northern Kentucky and southern Indiana**

****Assuming ground elevation of 550 ft.**

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Data to be Collected and Analyzed

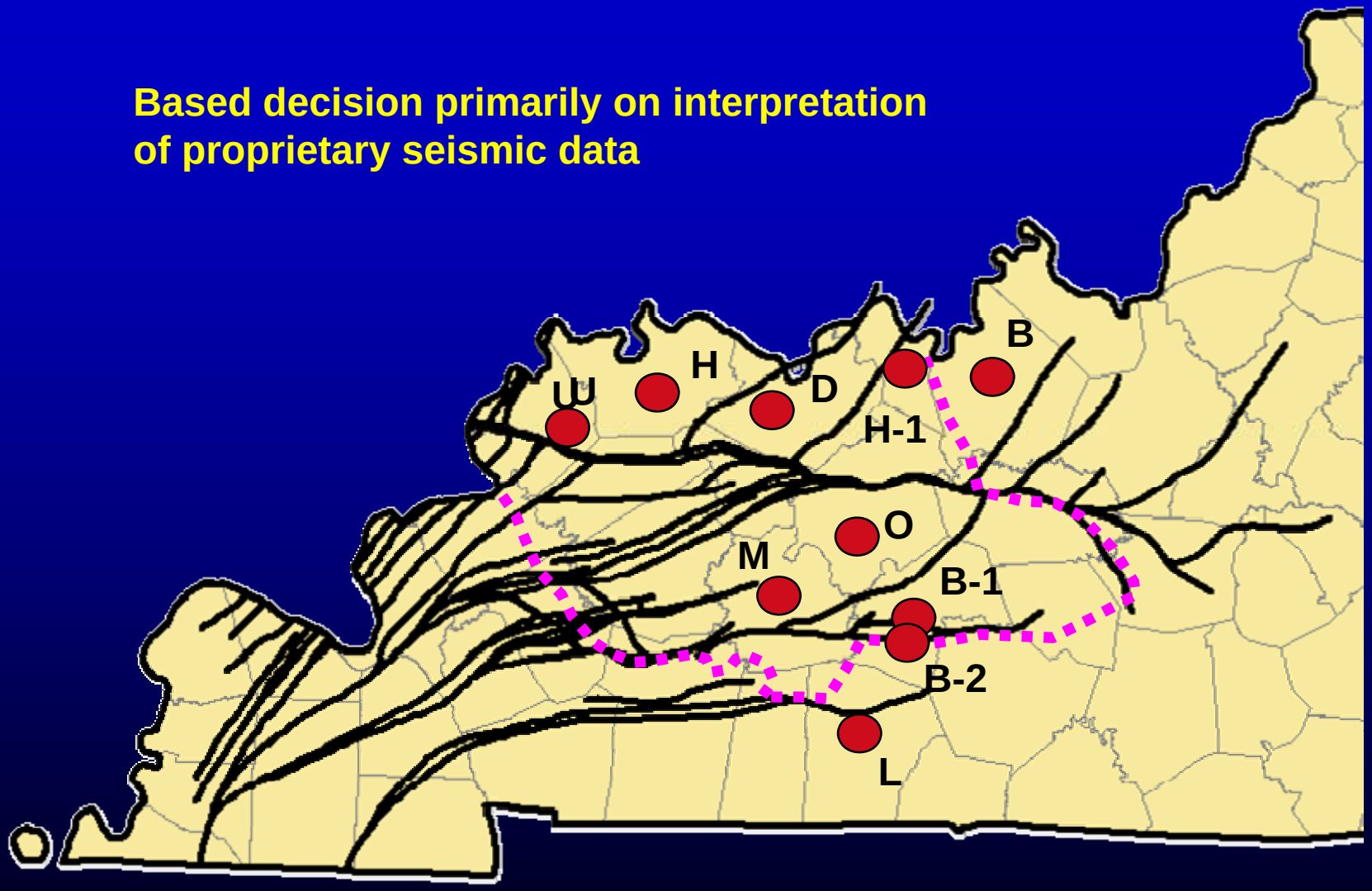
- Additional seismic data will be collected prior to drilling—will tell us if Mt Simon is at drill location
- Whole core and side-wall cores in reservoir and seal intervals
- Run and interpret extensive suite of well logs
- Collect fluid samples (brine, oil, gas) from target zones for geochemistry
- Analyze core samples for porosity, permeability, mineralogy, mechanical strength, and other physical properties
- Conduct injection tests using fluid, air, or CO_2

Conclusions

- HB-1 is an opportunity to assess geologic CO_2 enhanced recovery and permanent storage options in Kentucky with better data sets than in the past
- The deep drilling project in western Kentucky has progressed the farthest
- Updated results of this and the other projects will be reported at future meetings over the next 4-5 years
- Still looking for partners

Where to drill?

Based decision primarily on interpretation of proprietary seismic data



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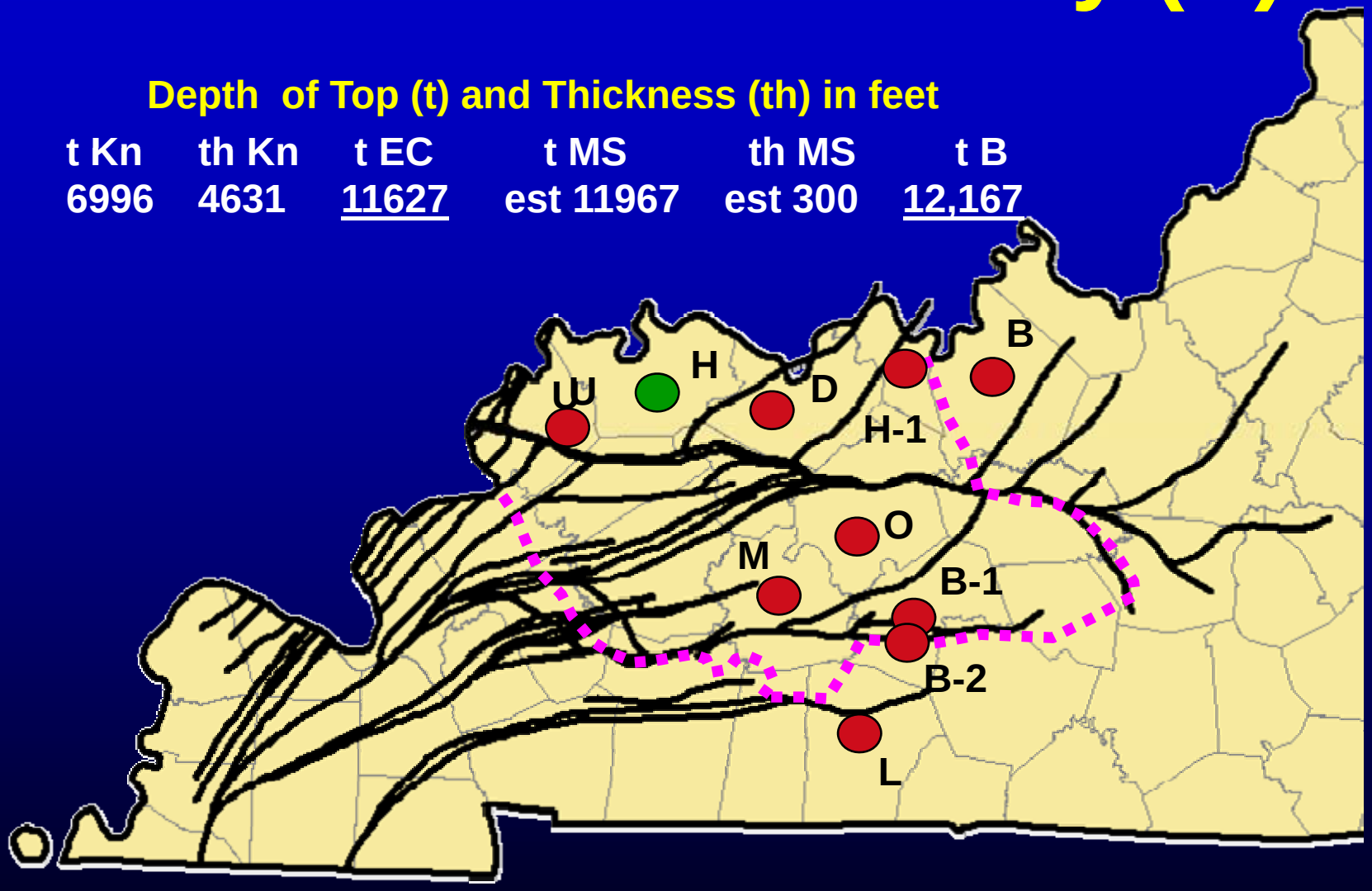
Henderson County (H)

Depth of Top (t) and Thickness (th) in feet

t Kn	th Kn	t EC	t MS	th MS	t B
6996	4631	11627	est 11967	est 300	12,167



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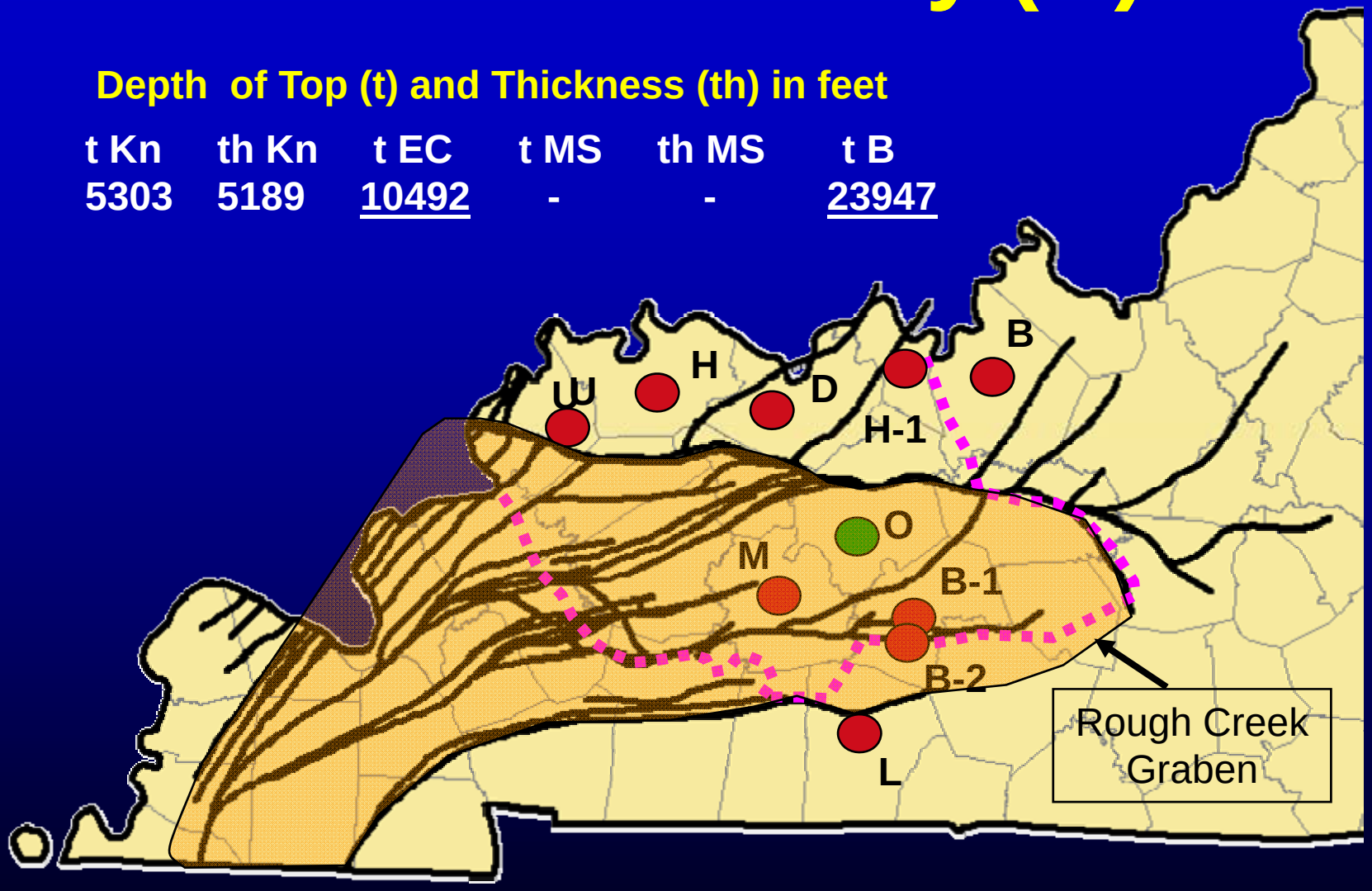
Based on proprietary seismic data

KGS

Ohio County (O)

Depth of Top (t) and Thickness (th) in feet

t Kn	th Kn	t EC	t MS	th MS	t B
5303	5189	10492	-	-	23947



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West Kentucky Coal Field Deep Drilling Project