Geologic Criteria for Eastern Kentucky Permanent CO_2 Storage

(Saline reservoir test)

Stephen Greb

Warren Anderson

Kentucky Geological Survey

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House Bill 1

$5 million appropriated to research use and storage of CO_2 in Kentucky

"…the research shall include the drilling of deep wells in both coal fields (Illinois and Appalachian) in Kentucky, and performing the analysis necessary to estimate the potential for enhanced oil and gas recovery, enhanced coalbed methane recovery, or permanent storage of sequestration of carbon dioxide."

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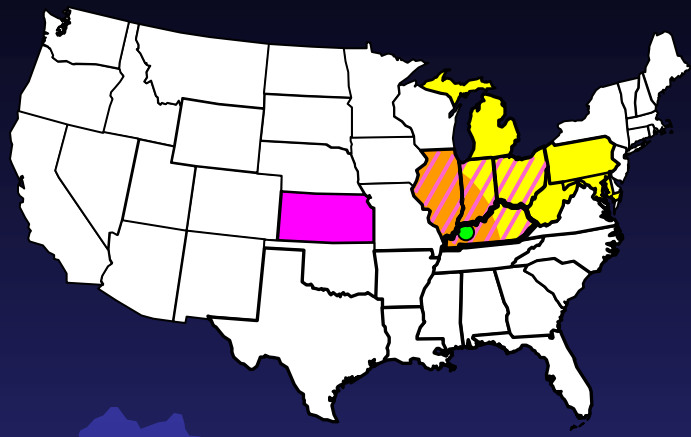
Storage (sequestration) research to build on



Past research

DOE-sponsored research in Kentucky

- **MIDCARB**
- **Phase 1- Midwest Regional Carbon Sequestration Partnership (MRCSP)**
- **Phase 1- Midwest (Illinois Basin) Geological Carbon Sequestration (MGCS) Consortium**

GOEP-sponsored research in Kentucky

- **Kentucky's FutureGen proposal**

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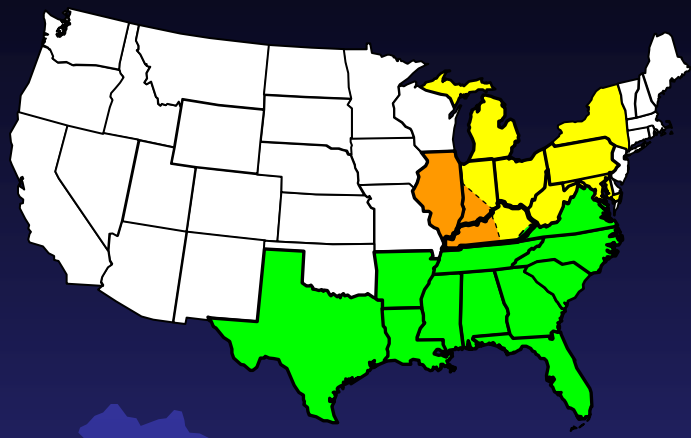
Storage (sequestration) research to build on



Past research

DOE-sponsored research in Kentucky

- Phase 2- Midwest Regional Carbon Sequestration Partnership (MRCSP)
- Phase 2- Midwest (Illinois Basin) Geological Carbon Sequestration (MGCS) Consortium
- Phase 2- Southeast Regional Carbon Sequestration Partnership (SECARB)

GOEP-sponsored research in Kentucky

- Kentucky's industrial plant site bank

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Storage (sequestration) research to build on

From this research we have gathered some geologic background to aid in planning a test for deep CO_2 storage in eastern Kentucky:

- **Minimum depths for miscible injection**
- **Principle reservoir targets and seals**
- **Other potentially limiting factors**
- **Wisdom from similar tests within the DOE-sponsored projects**

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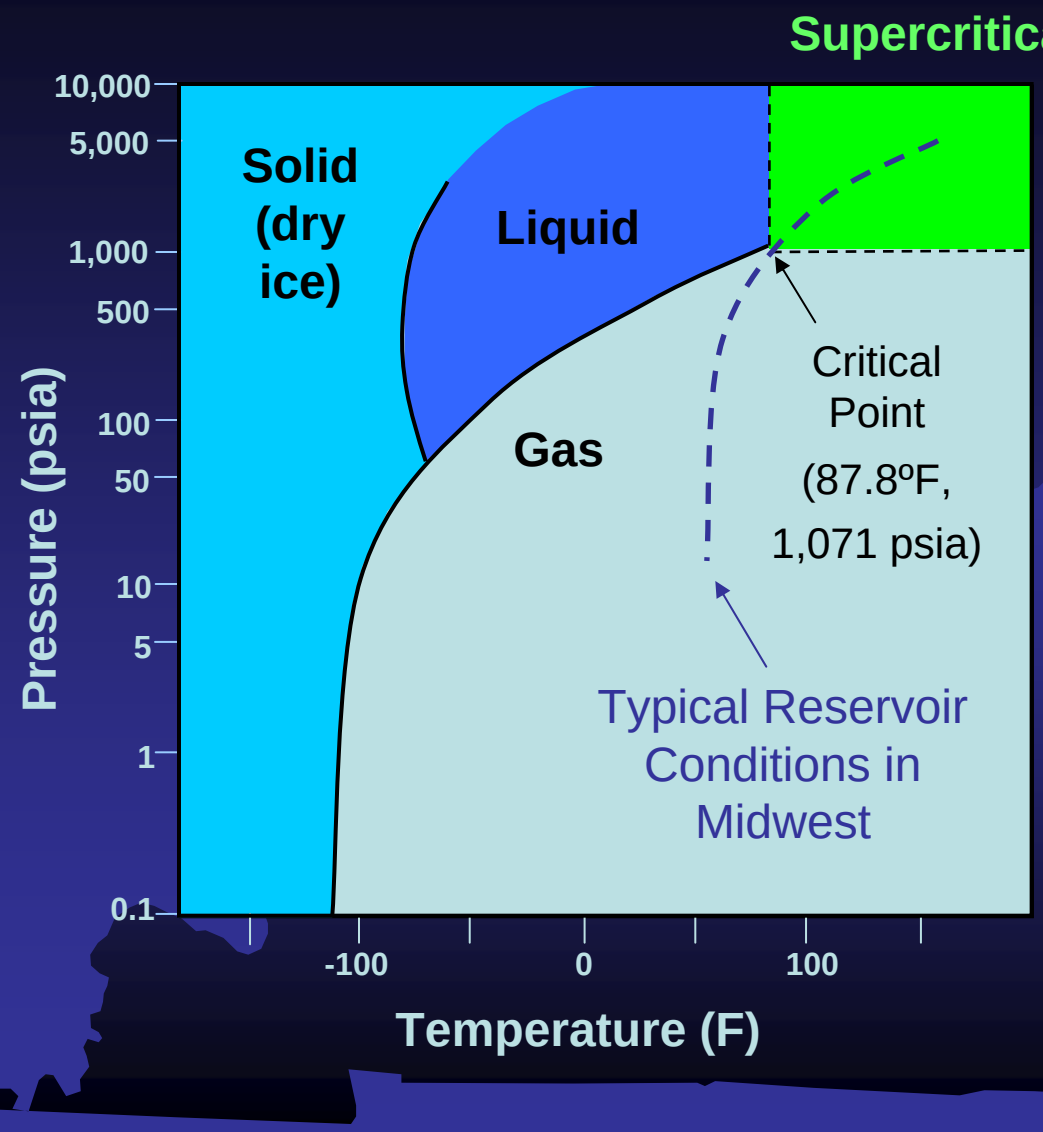
Minimum storage depths



At increased pressure and temperature, CO_2 behaves as a super-critical fluid (has properties of a liquid and gas) and is reduced in volume ~250 times.

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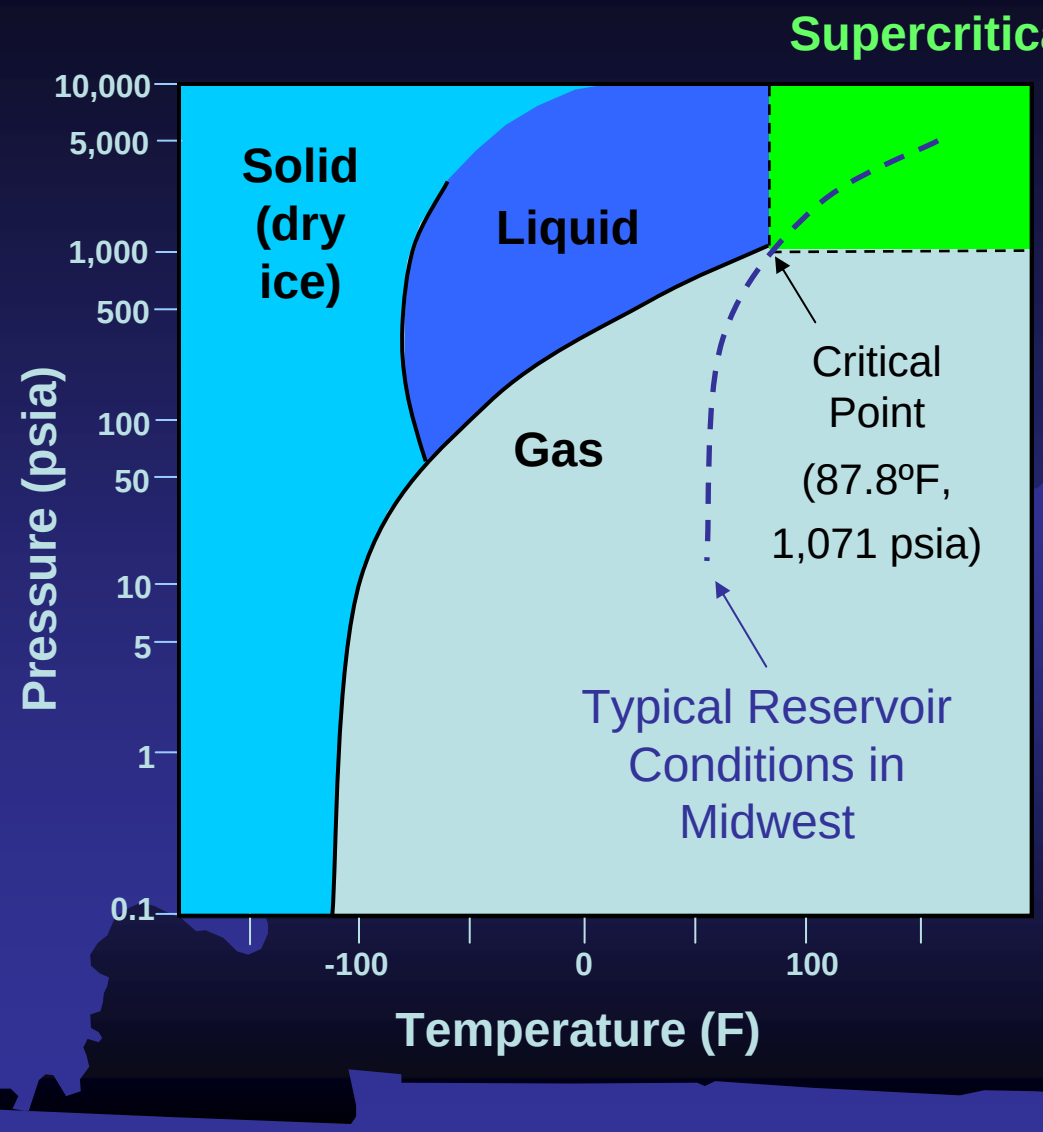
Minimum storage depths



Because future large-scale CO_2 storage will need supercritical conditions, our deep well needs to test reservoirs at depths where any injected CO_2 would be at supercritical conditions

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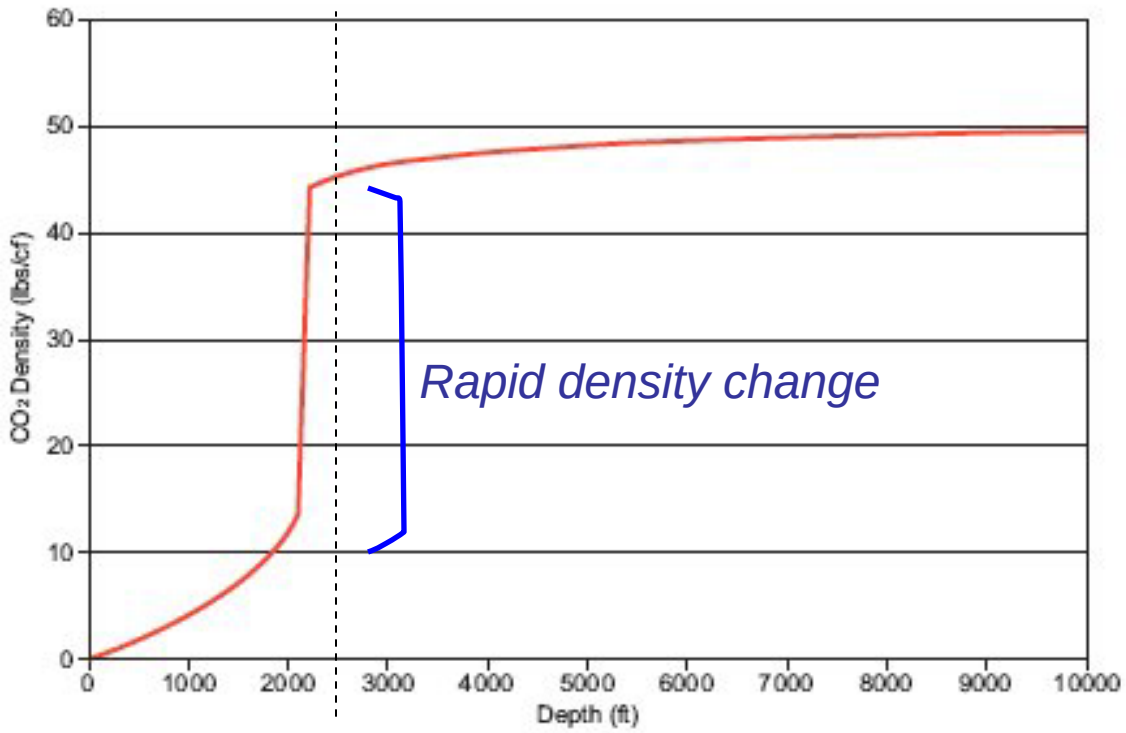
Minimum storage depths



From MRCSP Phase 1 Final Report (Wickstrom and others, 2004)

Figure 23.—Diagram showing CO_2 density with depth for a typical pressure gradient, surface temperature, and geothermal gradient in the MRCSP area. CO_2 density data is from Lemmon and others (2003).

Research by the MRCSP and MGCS indicate that the critical point for CO_2 in the Midwest and Kentucky should occur at a depth of ~2,500 ft

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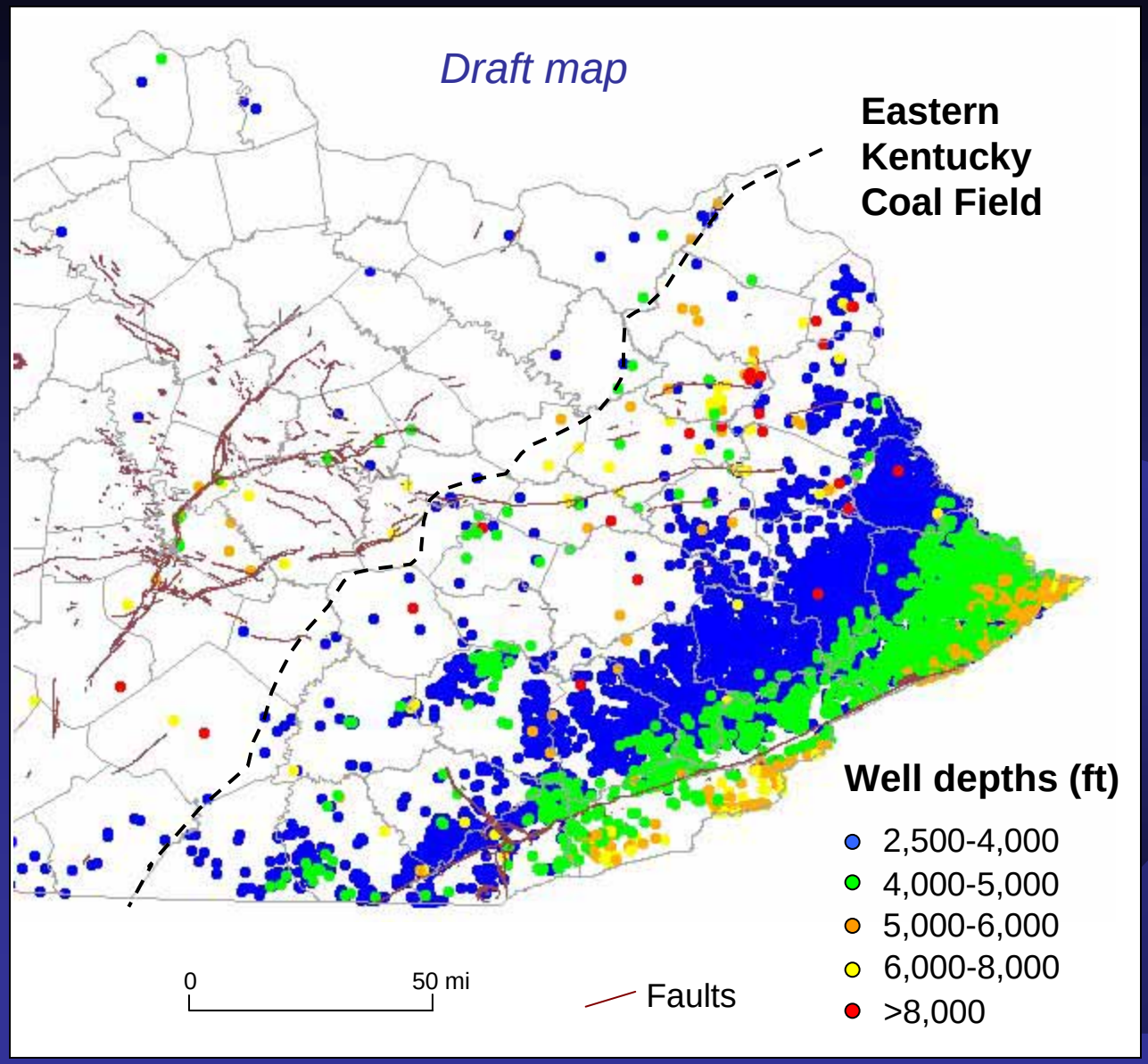
Kentucky data at minimum storage depths



Existing well data in eastern Kentucky at depths greater than 2,500 ft

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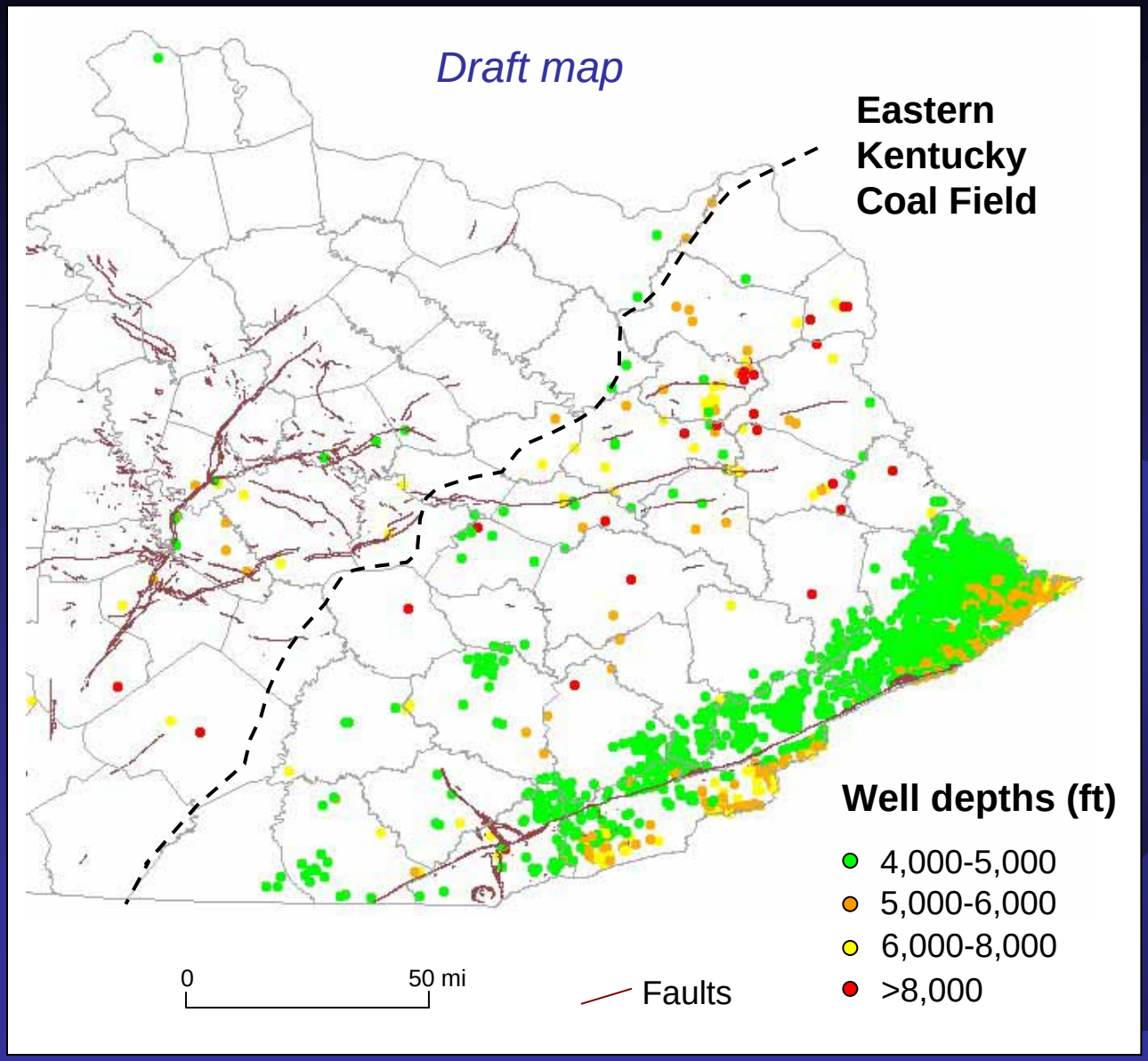
Kentucky data at minimum storage depths



Existing well data in eastern Kentucky at depths greater than 4,500 ft

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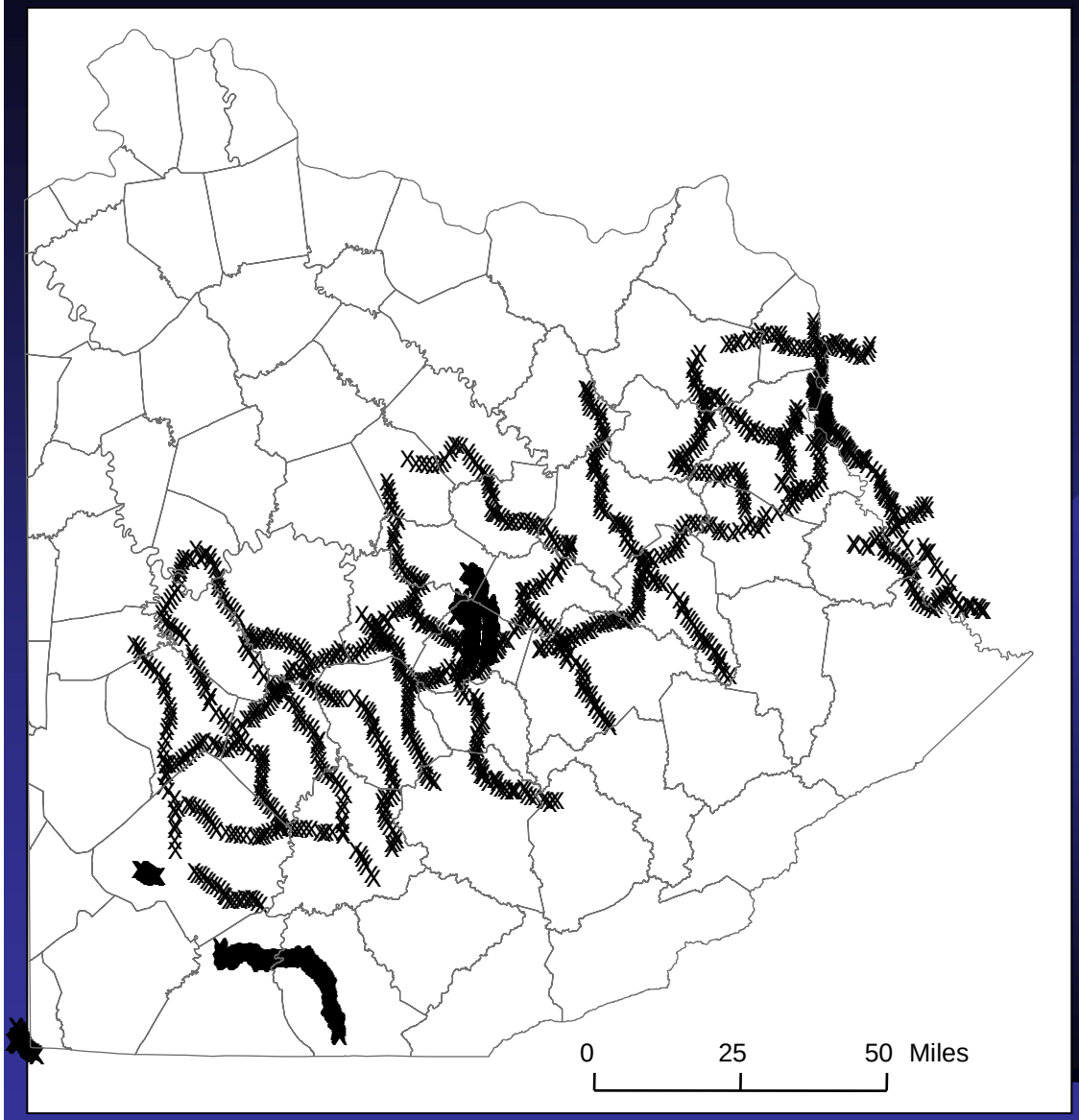
Kentucky data below minimum storage depths



KGS also has access to seismic data to aid in deep subsurface analyses

- **Seismic data will likely be needed prior to drilling a site in eastern Kentucky**

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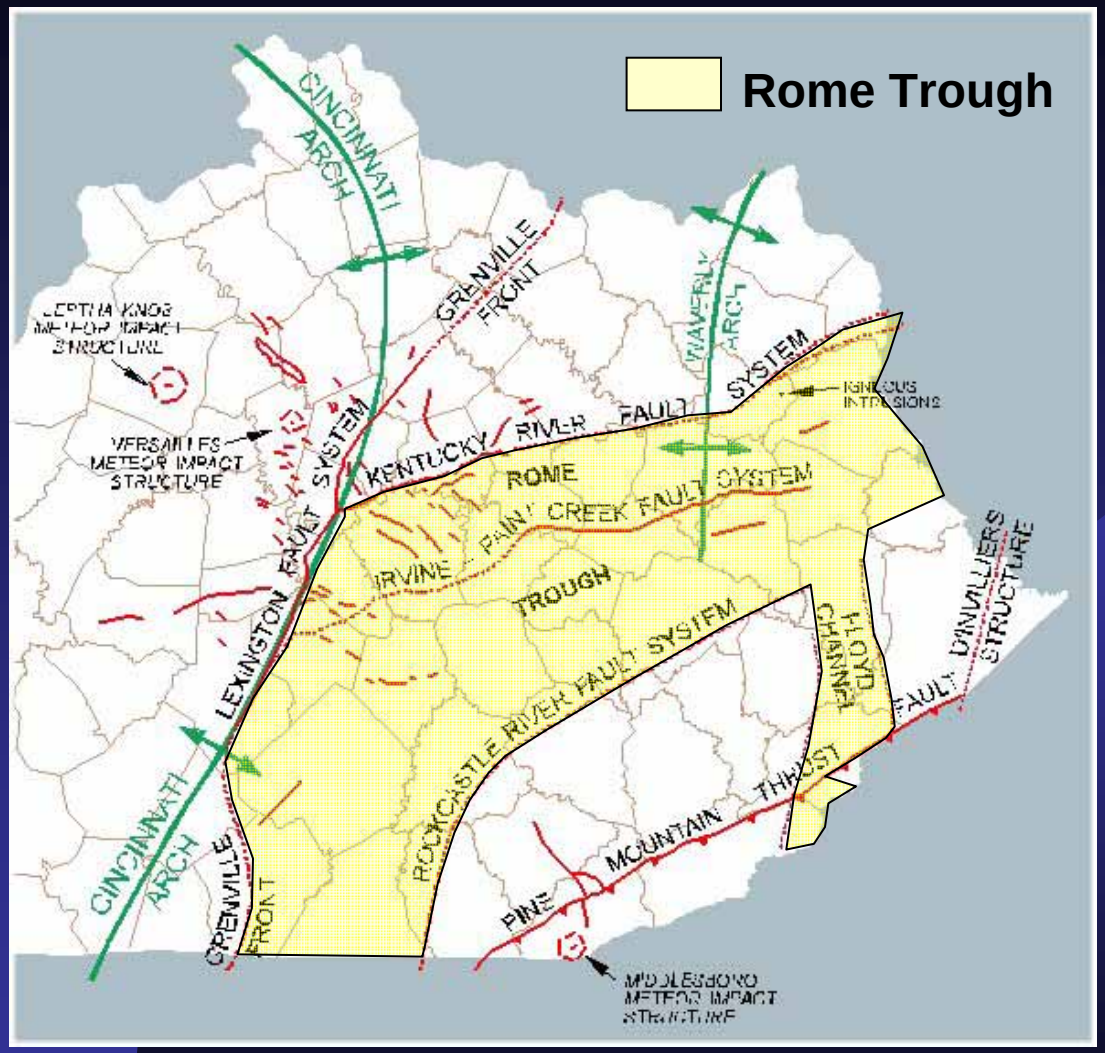
Eastern Kentucky structure



Our site evaluation needs to consider that there are several distinct geologic areas in the Eastern Kentucky Coal Field:

- **In and out of the Rome Trough**

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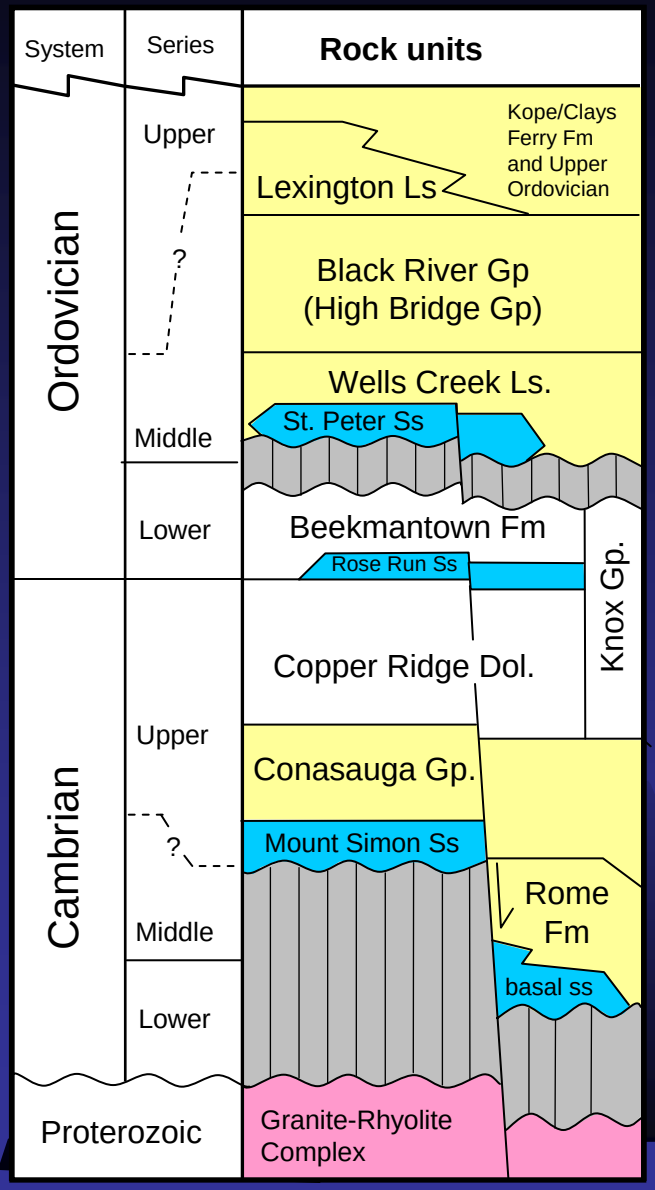
Deep rock units in eastern Kentucky



Previous research has established which rock units in the deep subsurface are possible saline reservoirs and which are possible sealing or containment intervals

- **Potential CO_2 sinks/ reservoirs**
- **Caprock-containment interval**
- **Unconformity**
- **Sink or seal (*depends on location*)**
- **Metamorphic and igneous rocks (*mostly seal*)**

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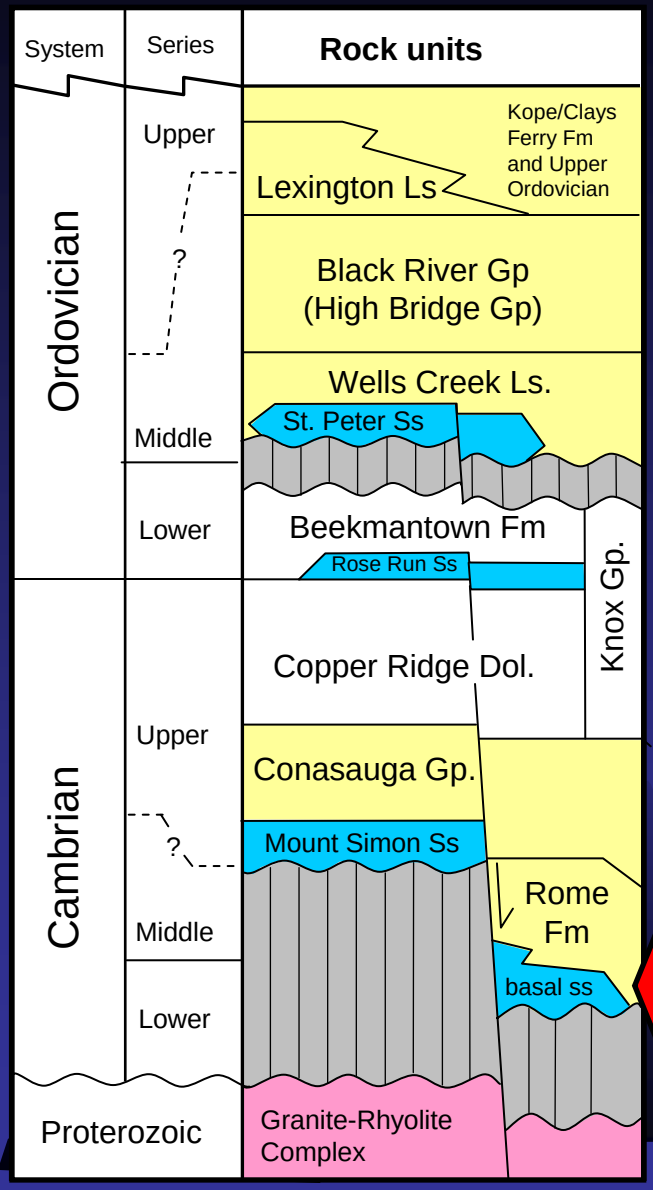
Deep rock units in eastern Kentucky



Known, deep saline reservoirs include:

- **Rome Fm. (basal sands)**

- **Potential CO_2 sinks/ reservoirs**
- **Caprock-containment interval**
- **Unconformity**
- **Sink or seal (*depends on location*)**
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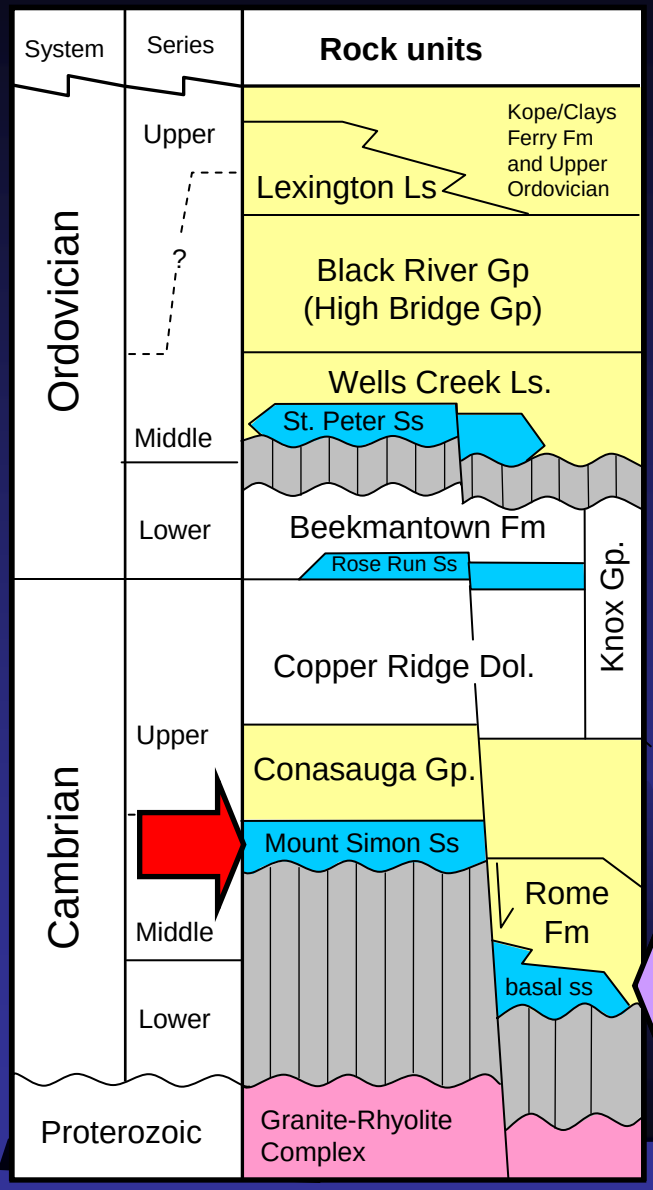
Deep rock units in eastern Kentucky



Known, deep saline reservoirs include:

- Rome Fm. (basal sands)
- Mt. Simon Ss.

- Potential CO_2 sinks/ reservoirs
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- Metamorphic and igneous rocks (*mostly seal*)

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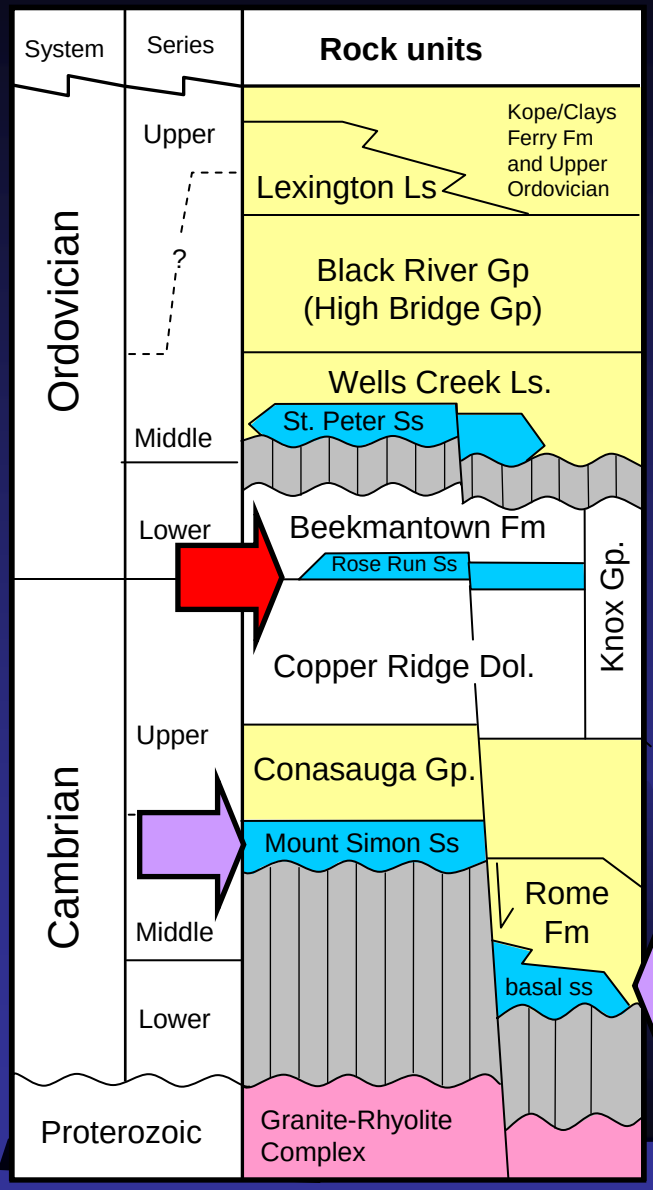
Deep rock units in eastern Kentucky



Known, deep saline reservoirs include:

- Rome Fm. (basal sands)
- Mt. Simon Ss.
- Rose Run Ss.

- Potential CO_2 sinks/ reservoirs
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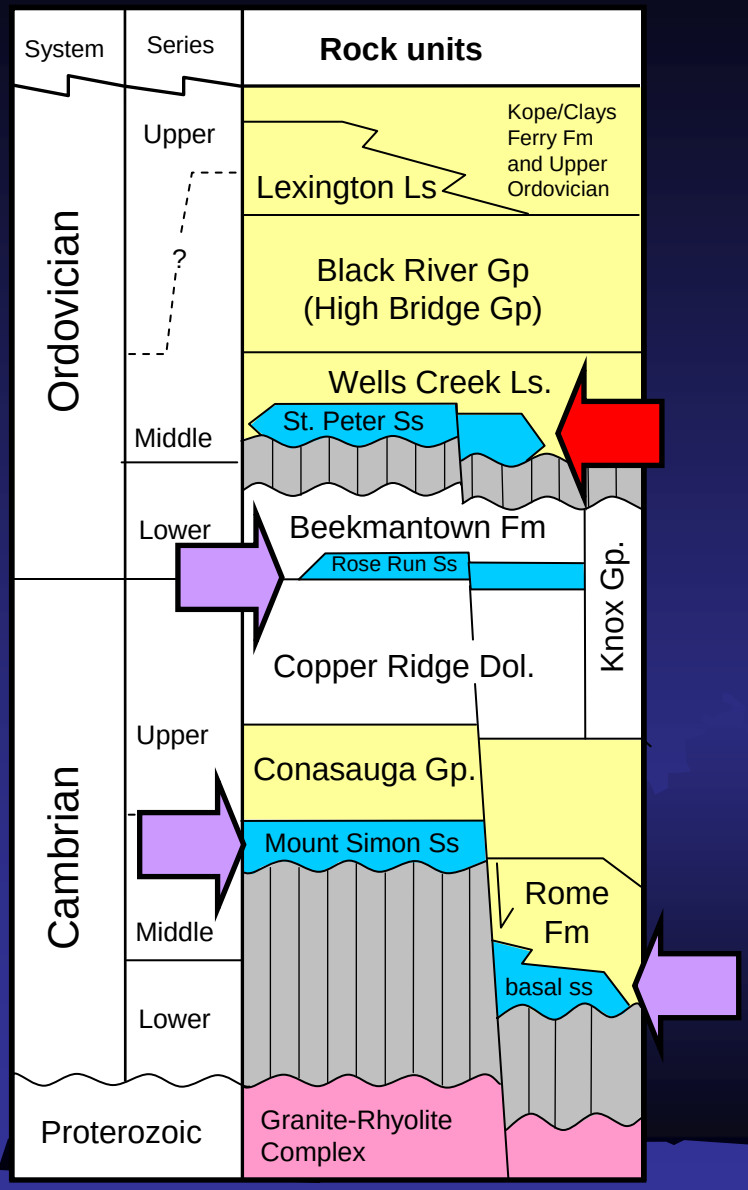
Deep rock units in eastern Kentucky



Known, deep saline reservoirs include:

- Rome Fm. (basal sands)
- Mt. Simon Ss.
- Rose Run Ss.
- St. Peter Ss.

- Potential CO_2 sinks/ reservoirs
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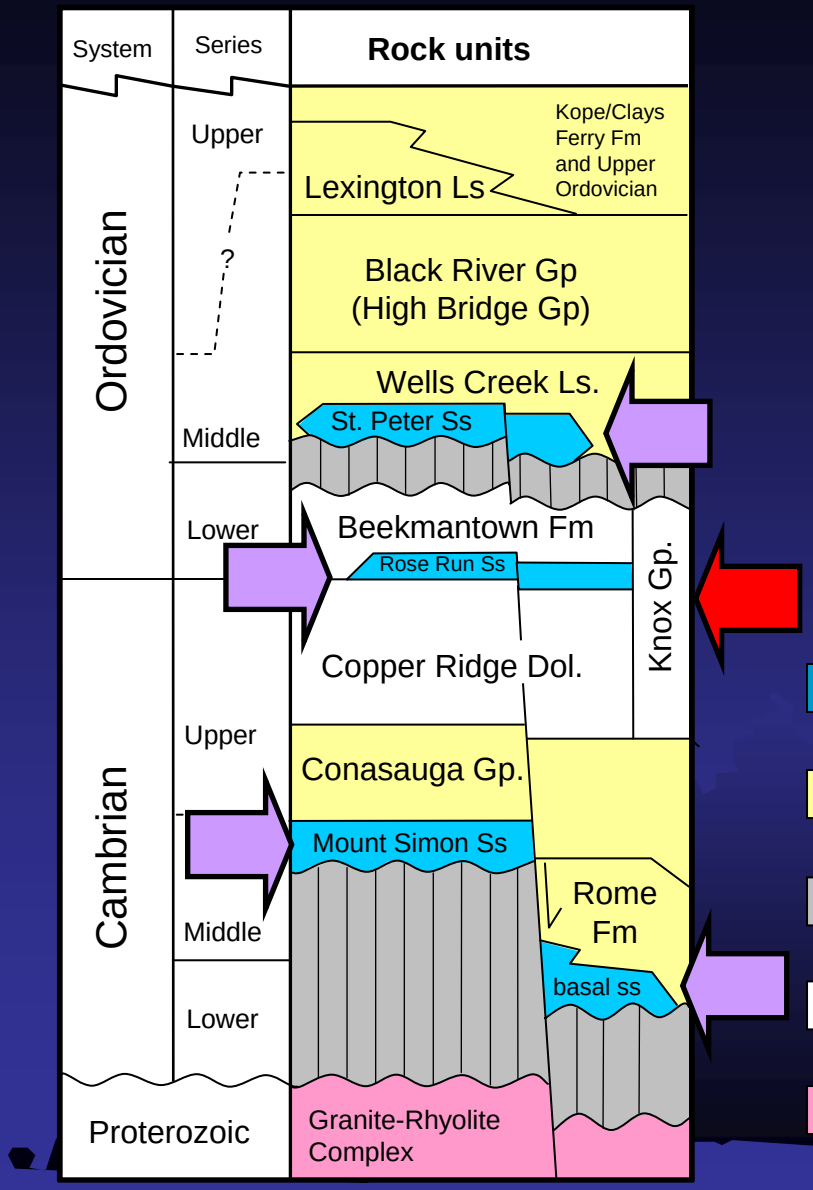
Deep rock units in eastern Kentucky



Also, some units may contain both sealing intervals and saline reservoirs:

- **Knox Gp.**

Other reservoirs may also occur and may need to be evaluated in different areas

Potential CO_2 sinks/ reservoirs

Caprock-containment interval

Unconformity

Sink or seal (*depends on location*)

Metamorphic and igneous rocks (*mostly seal*)

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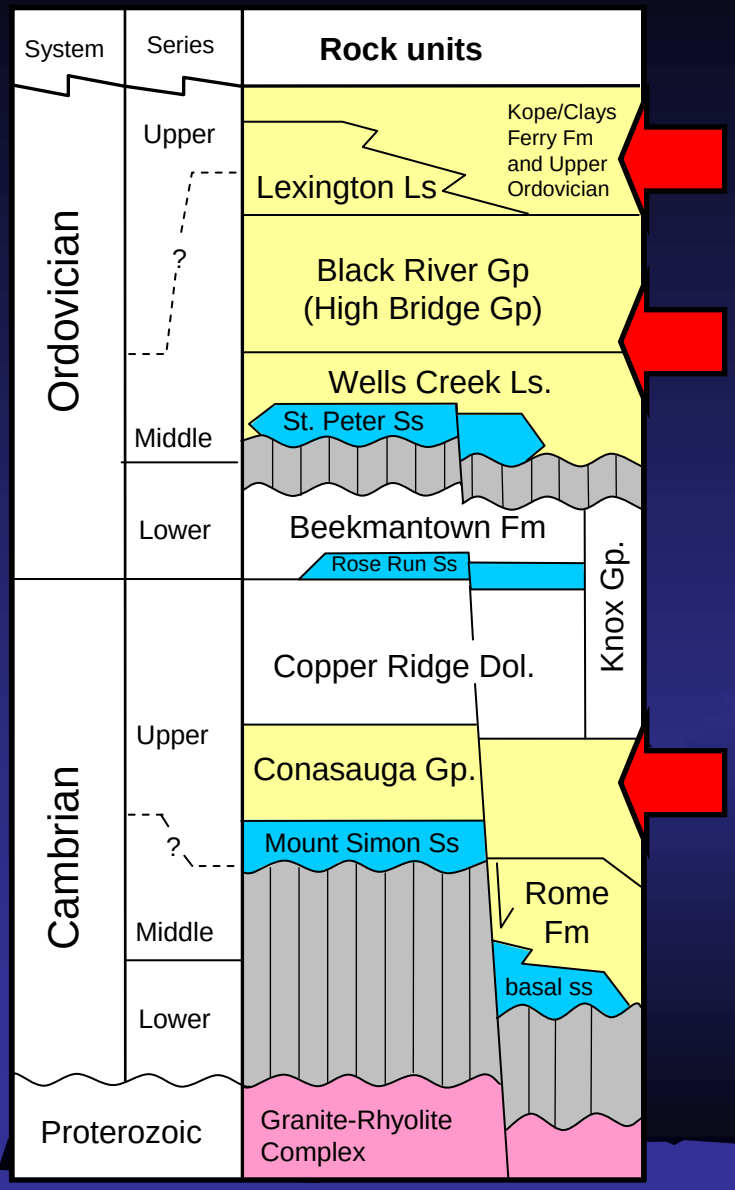
Deep rock units in eastern Kentucky



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

- **Conasauga Fm**
- **Wells Creek and High Bridge carbonates**
- **Kope Fm**
- **Devonian Shale (ultimate seal)**

- **Potential CO_2 sinks/ reservoirs**
- **Caprock-containment interval**
- **Unconformity**
- **Sink or seal (*depends on location*)**
- **Metamorphic and igneous rocks (*mostly seal*)**

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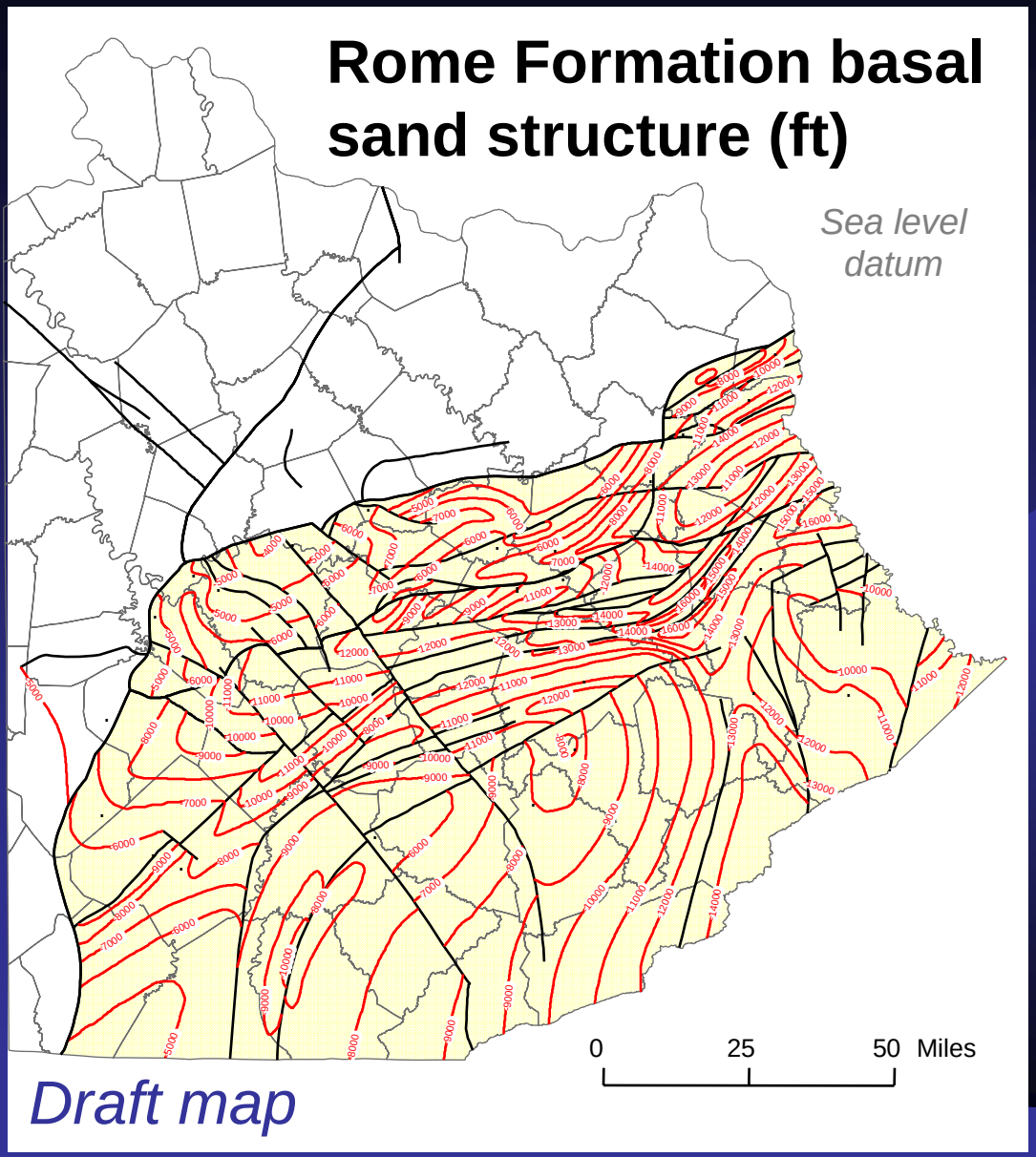
Potential reservoirs at depth: Rome basal sands



The basal sandstones of the Rome Formation are a saline-water bearing unit (saline reservoir)

- **Complex depth, thickness, and dip relations because of faulting**
- **Depths: 6,000 to more than 16,000 ft**

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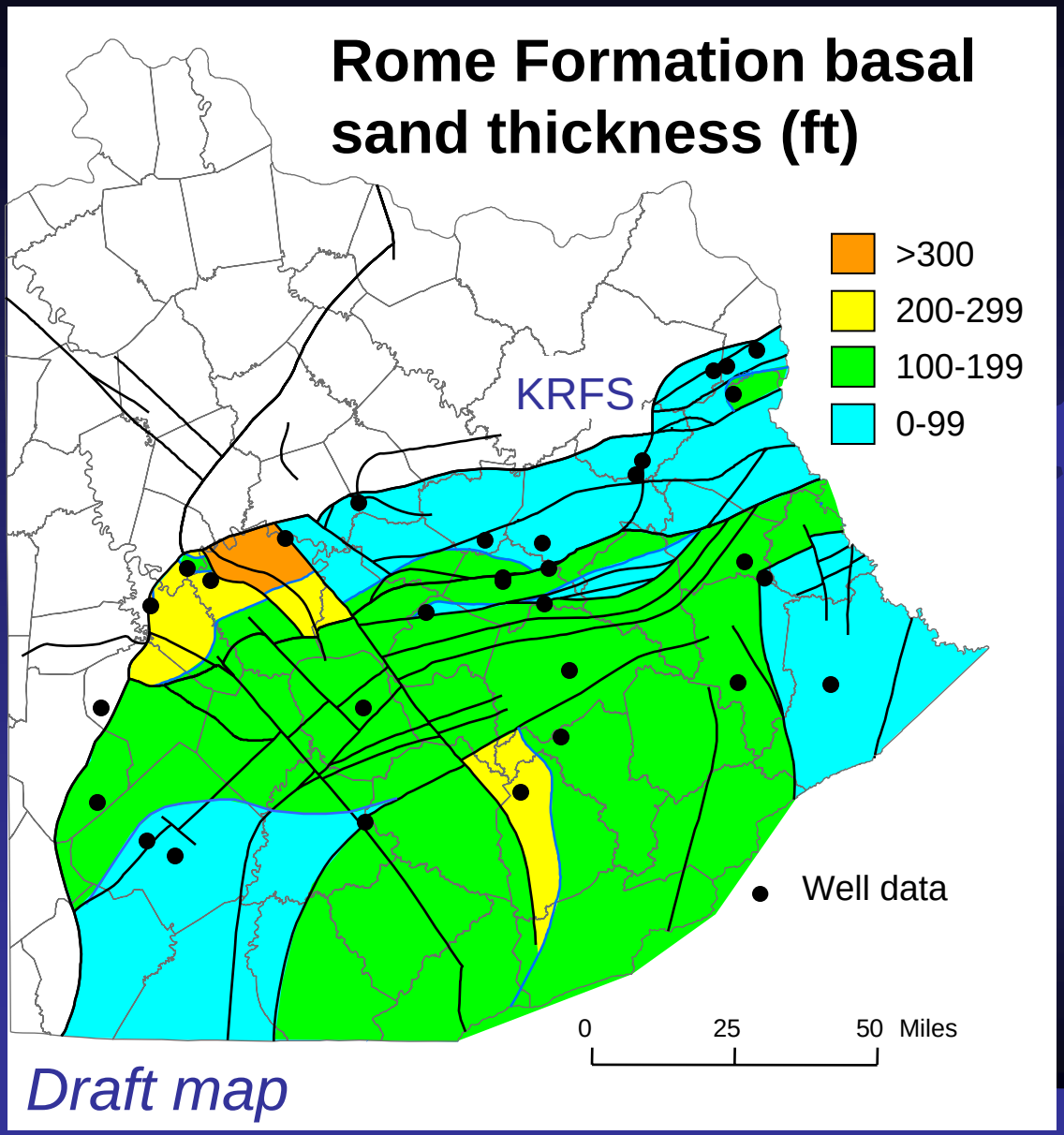
Potential reservoirs at depth: Rome basal sands



Sandstones are restricted to areas south of the Kentucky River Fault System (Rome Trough)

- **Basal sand thickness: 0 to >300 ft**
- **There can be several Rome sandstones in the Rome Trough in addition**

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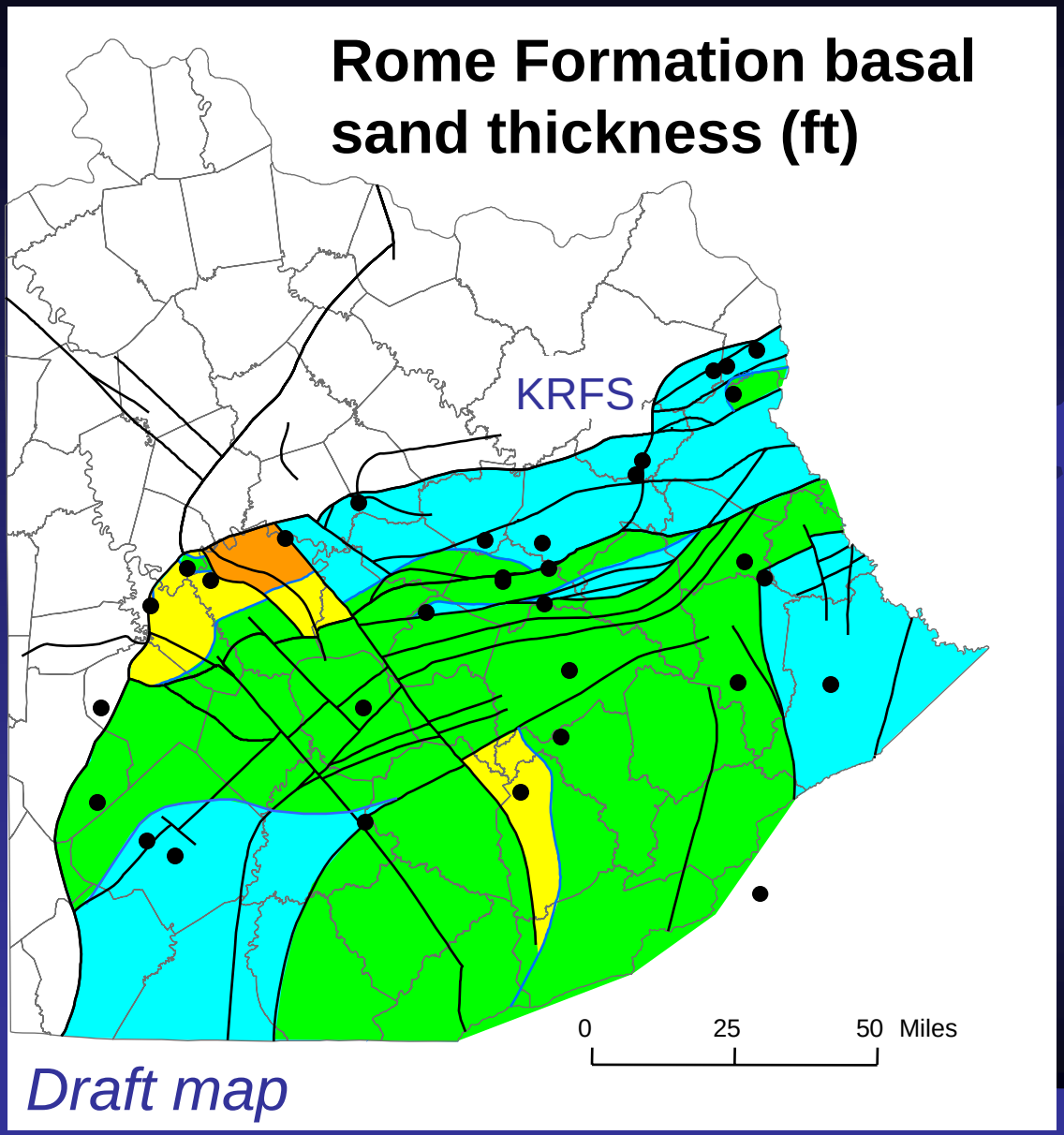
Potential reservoirs at depth: Rome basal sands



Sandstones are restricted to areas south of the Kentucky River Fault System (Rome Trough)

- **Thickness changes across some faults**

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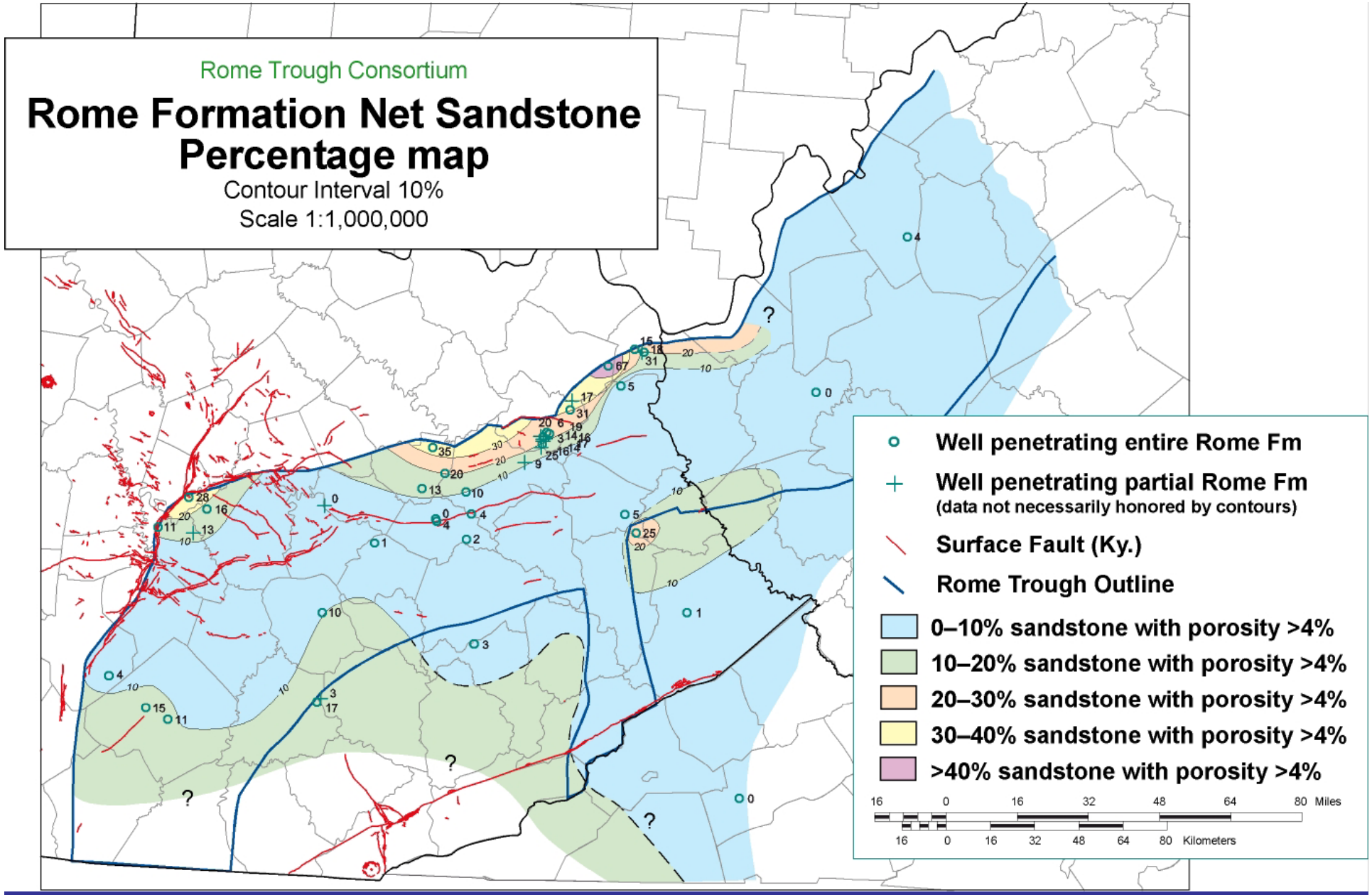

Porosity is documented in a series of sand wedges along the margin of the Rome Trough

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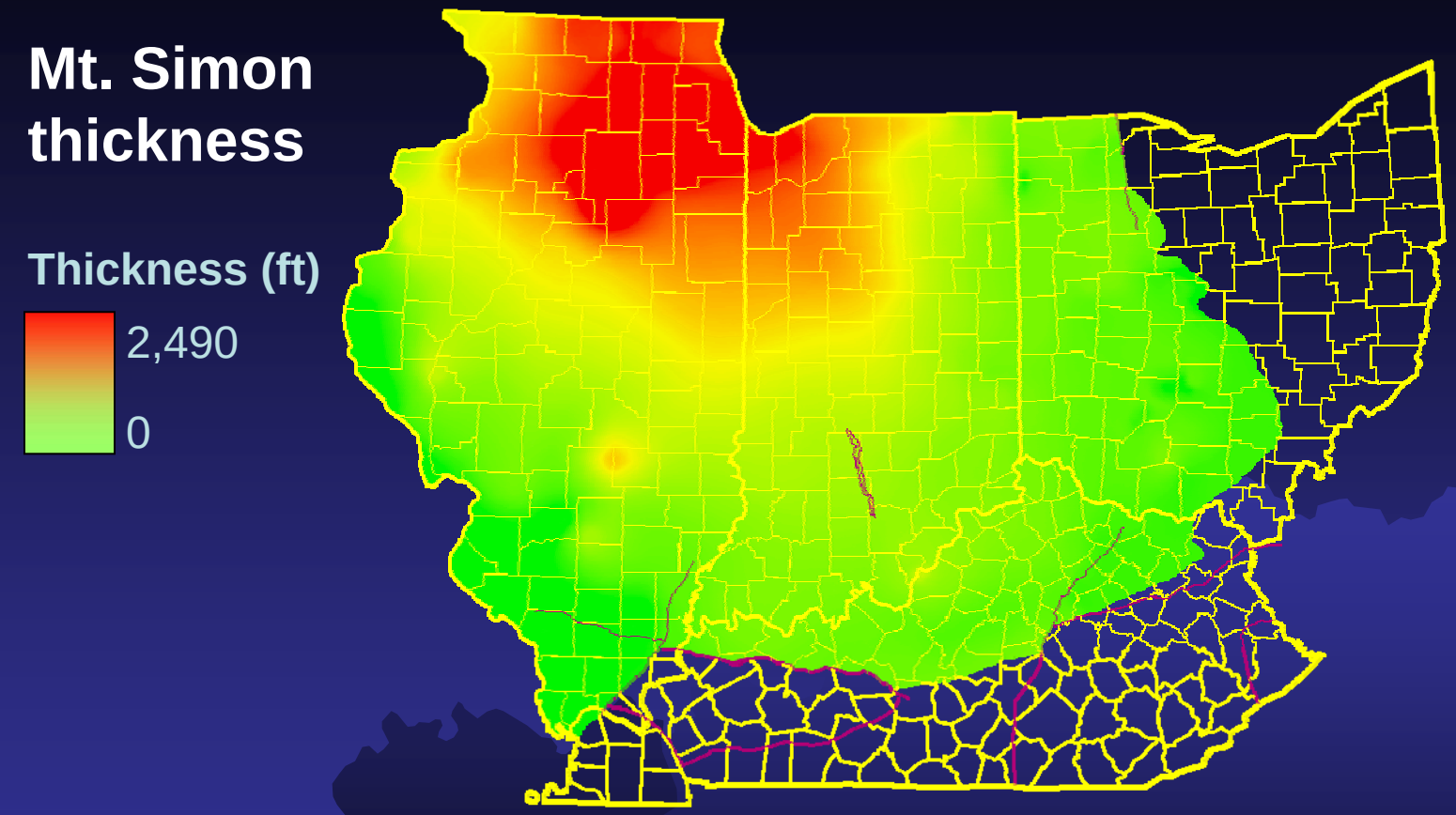
Potential reservoirs at depth: Mount Simon



The Mt. Simon Sandstone (basal sand) is the saline reservoir being targeted for CO_2 storage in much of the Midwest

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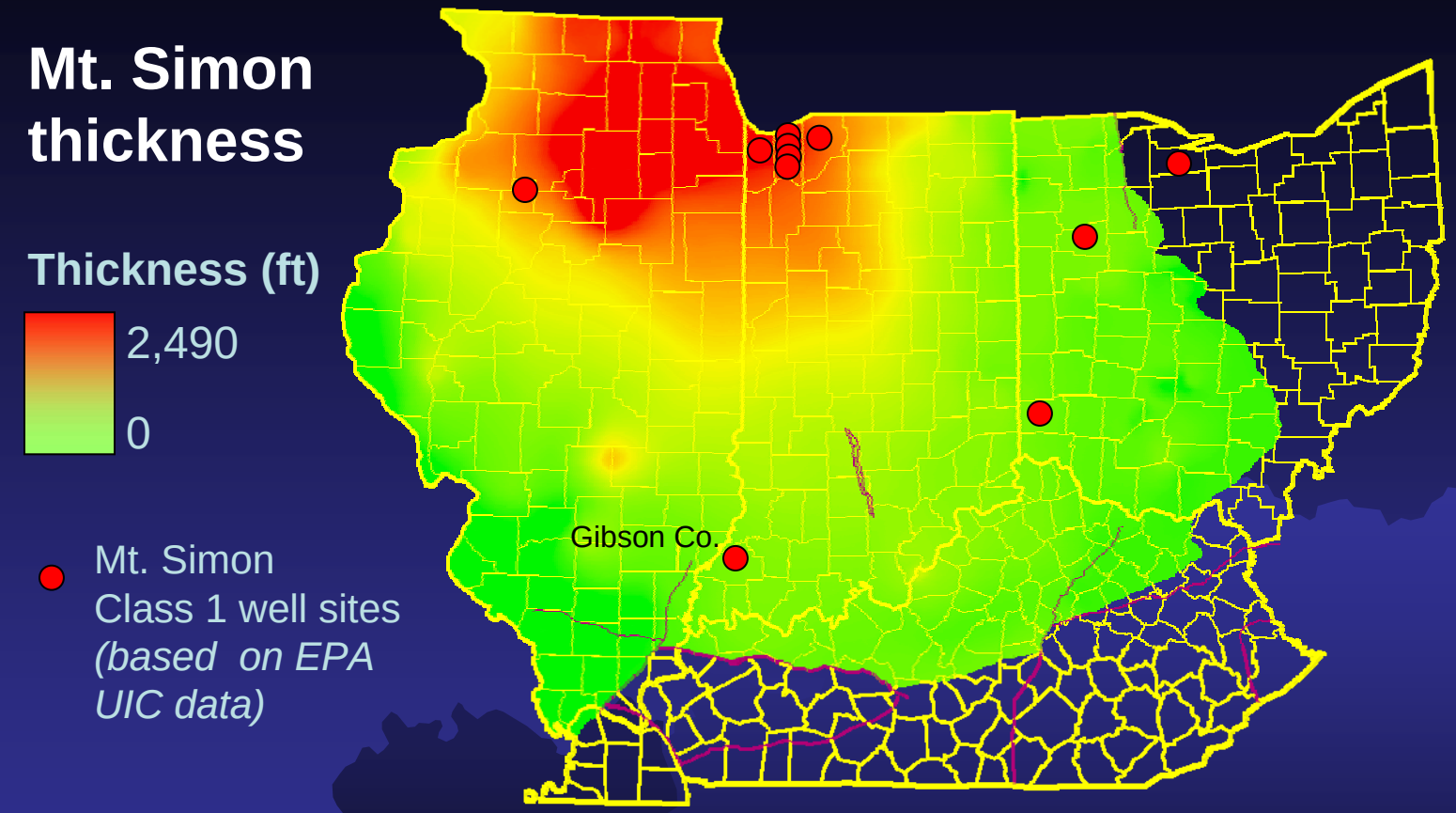
Map from MGCS data

Potential reservoirs at depth: Mount Simon



The Mt. Simon is already used for industrial waste injection in other states

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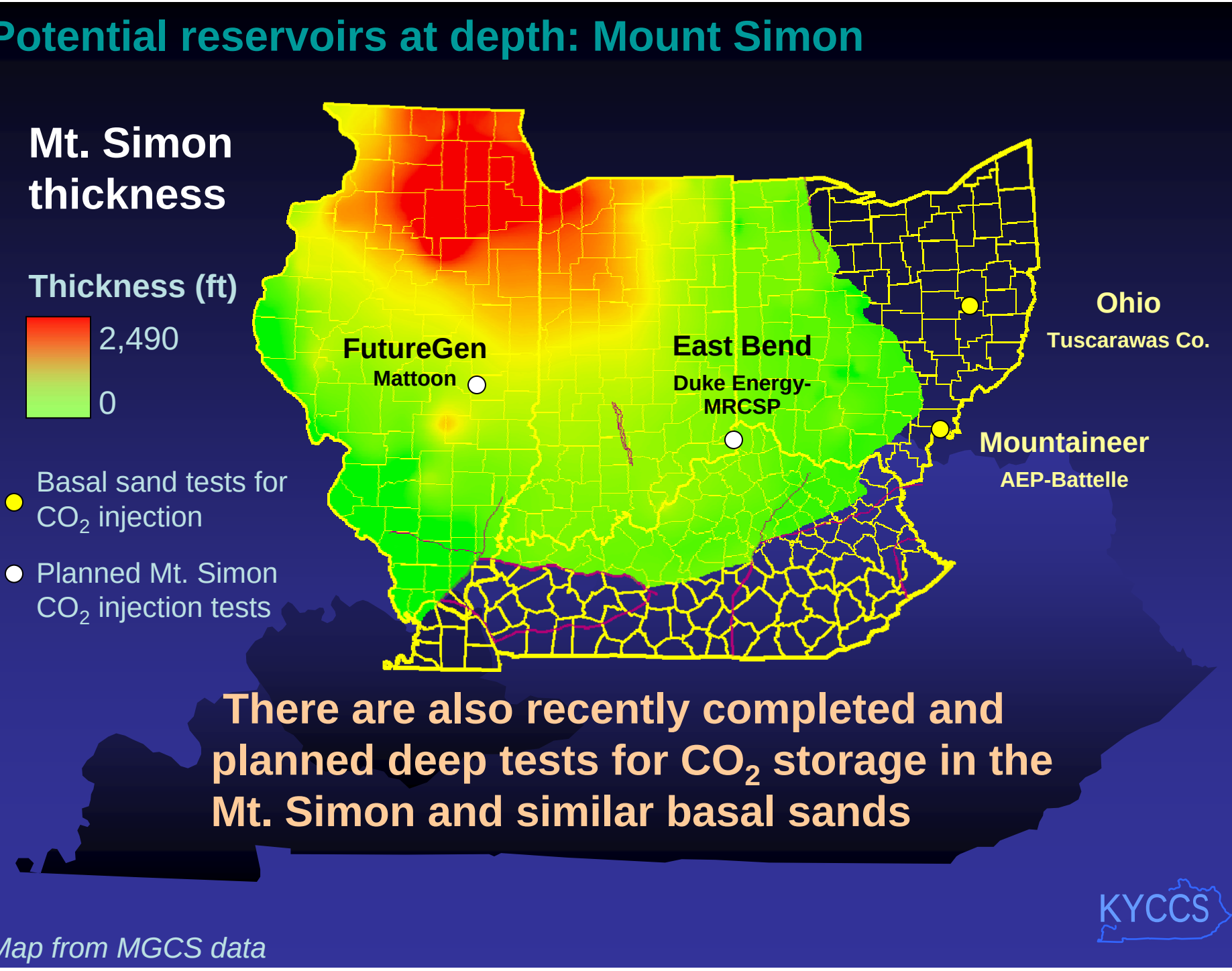
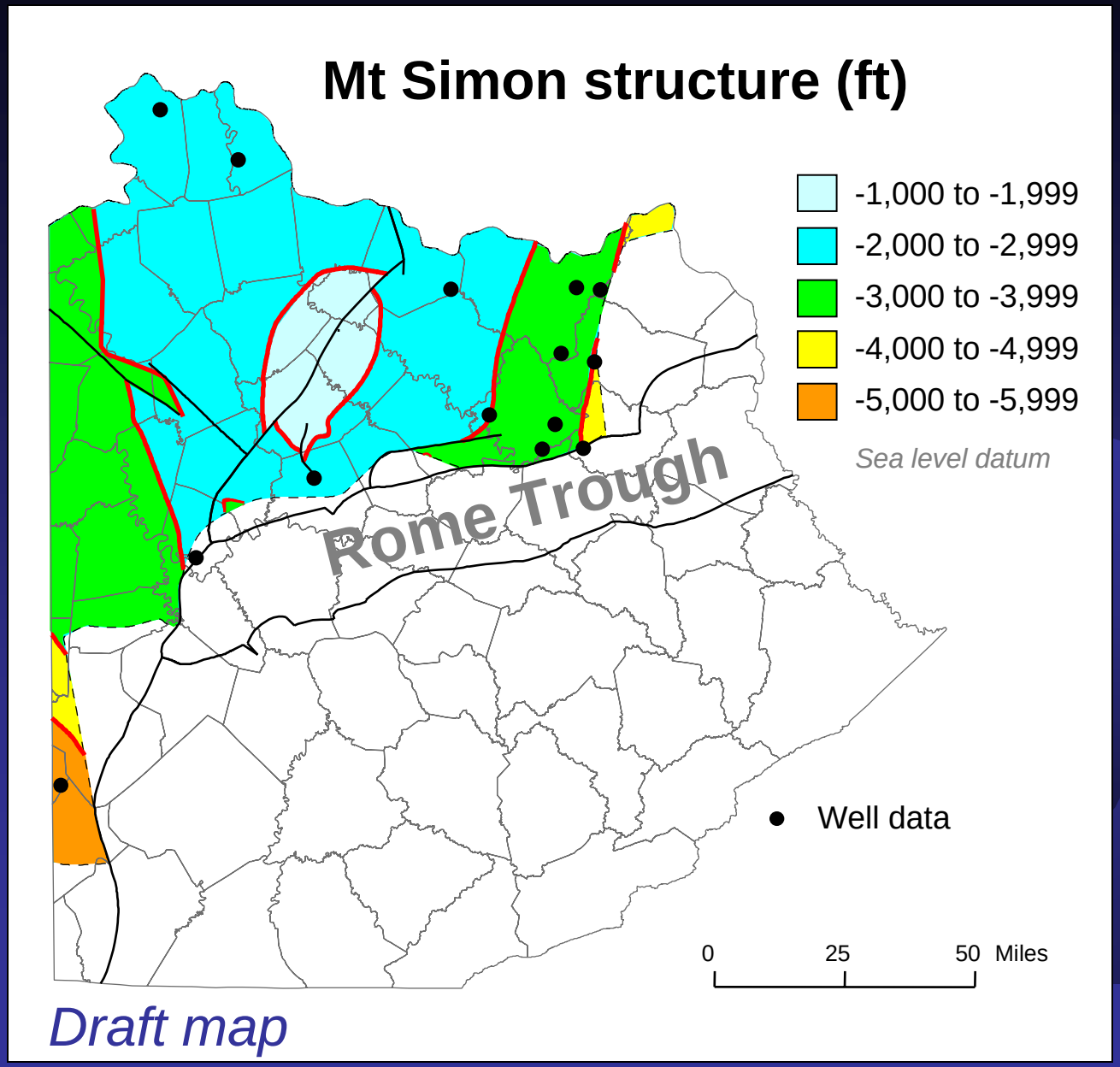
Map from MGCS data

Potential reservoirs at depth: Mount Simon



Potential reservoirs at depth: Mount Simon



The Mount Simon Sandstone is restricted to the area north of the Rome Trough in eastern Kentucky

- **Depths: -2,500 to -7,000 ft**

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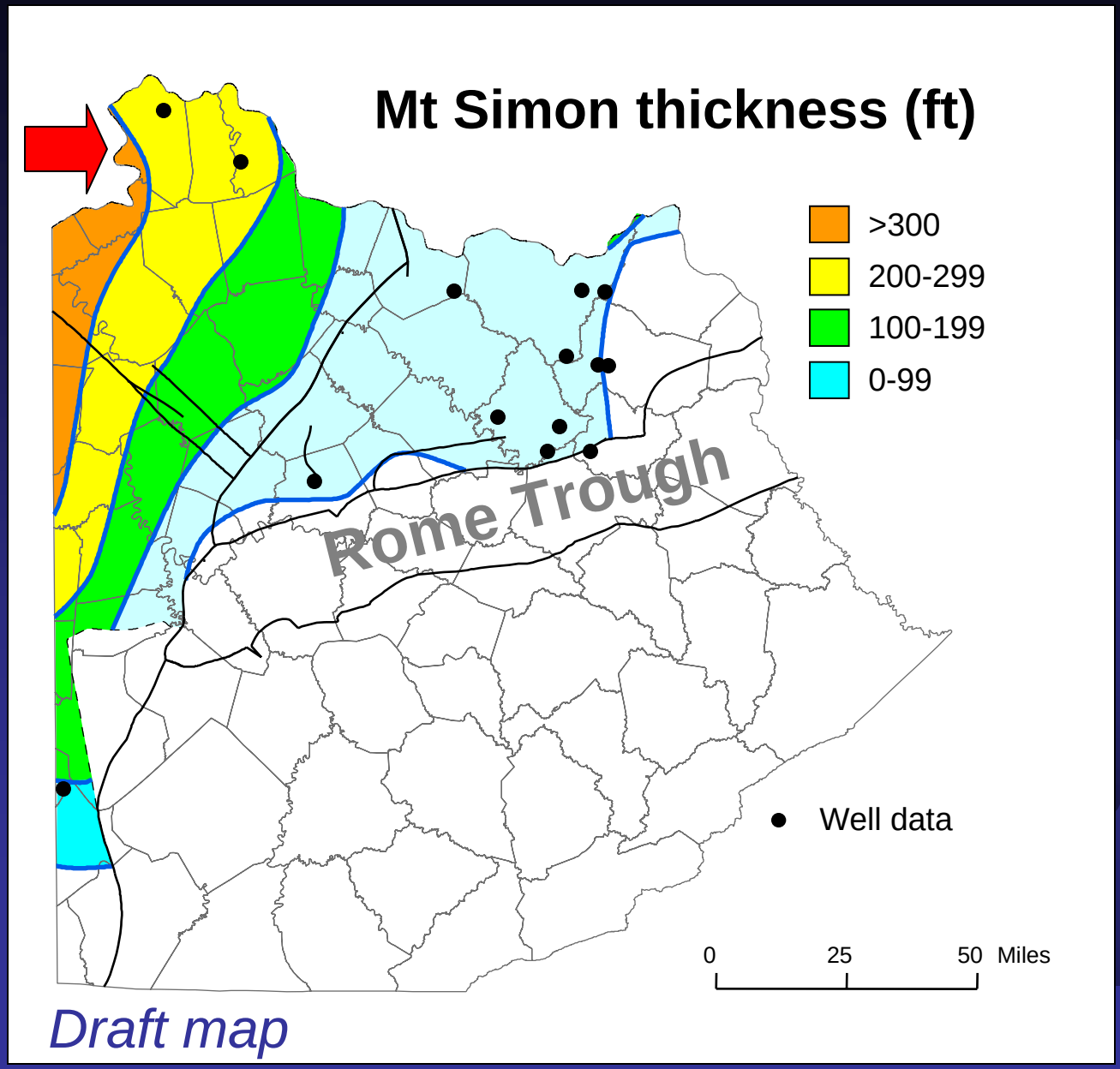
Potential reservoirs at depth: Mount Simon



Draft map

The Mount Simon is 0 to 300 ft thick in eastern Kentucky

- **It will be tested in north-central Kentucky at Duke Energy's East Bend plant as part of the MRCSP**

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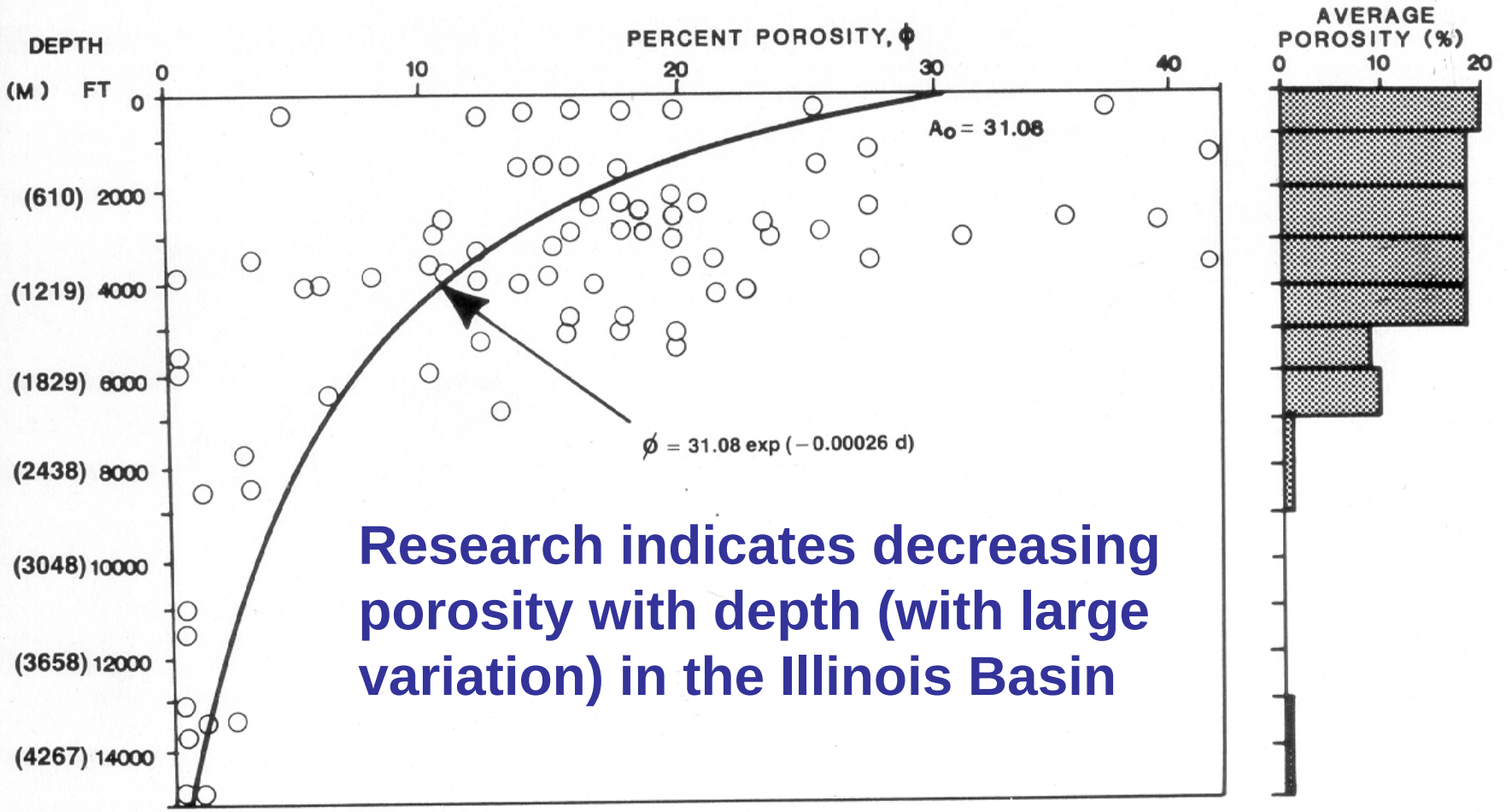
Potential reservoirs at depth: Mount Simon



Research indicates decreasing porosity with depth (with large variation) in the Illinois Basin

Figure 11—Porosity-depth relationships for 89 samples of Upper Cambrian Mount Simon Sandstone. Open circle = secondary porosity dominant.

From Hoholick and others, 1984, AAPG Bulletin

Data is mostly from Illinois and Indiana

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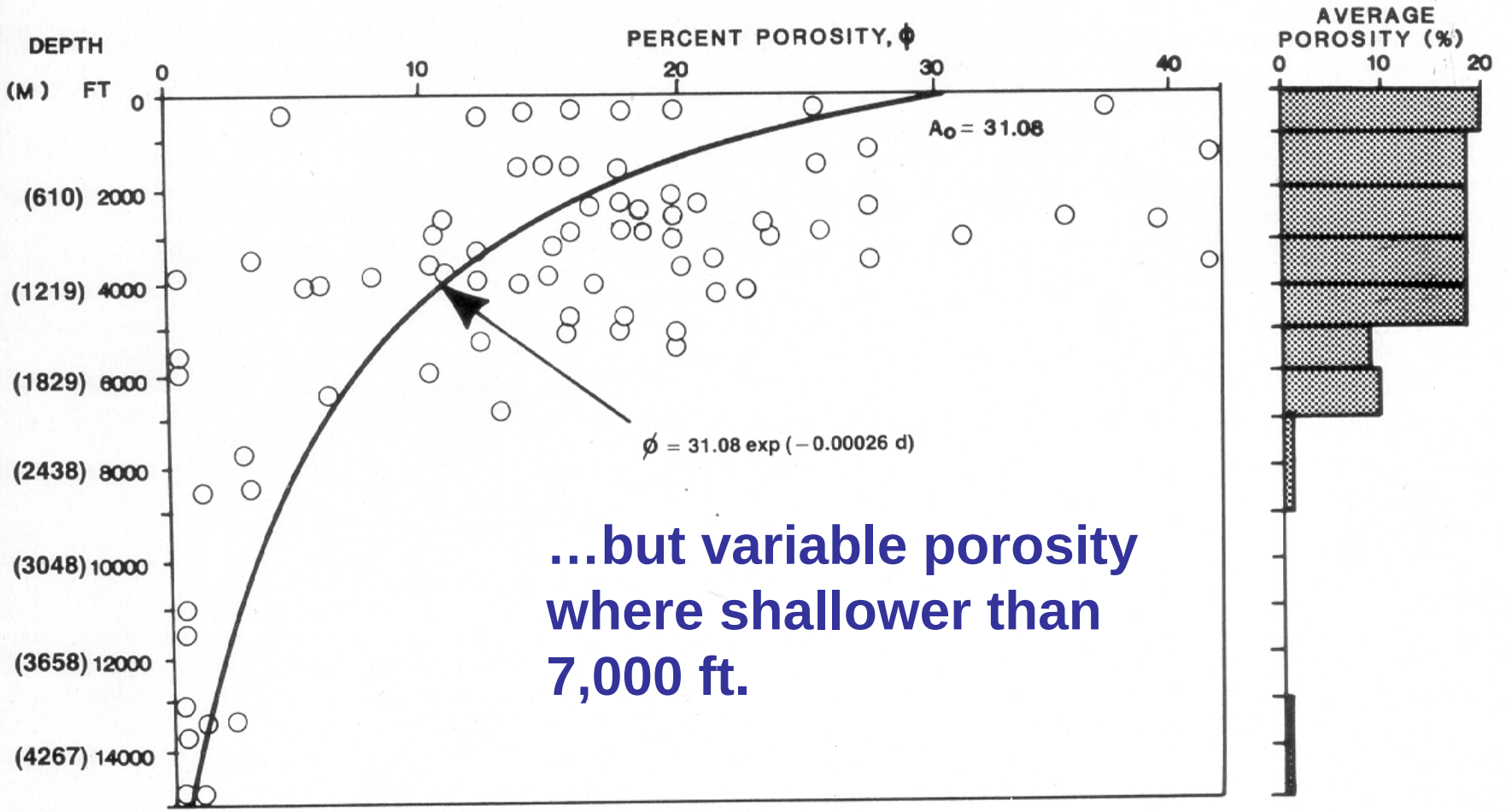
Potential reservoirs at depth: Mount Simon



…but variable porosity where shallower than 7,000 ft.

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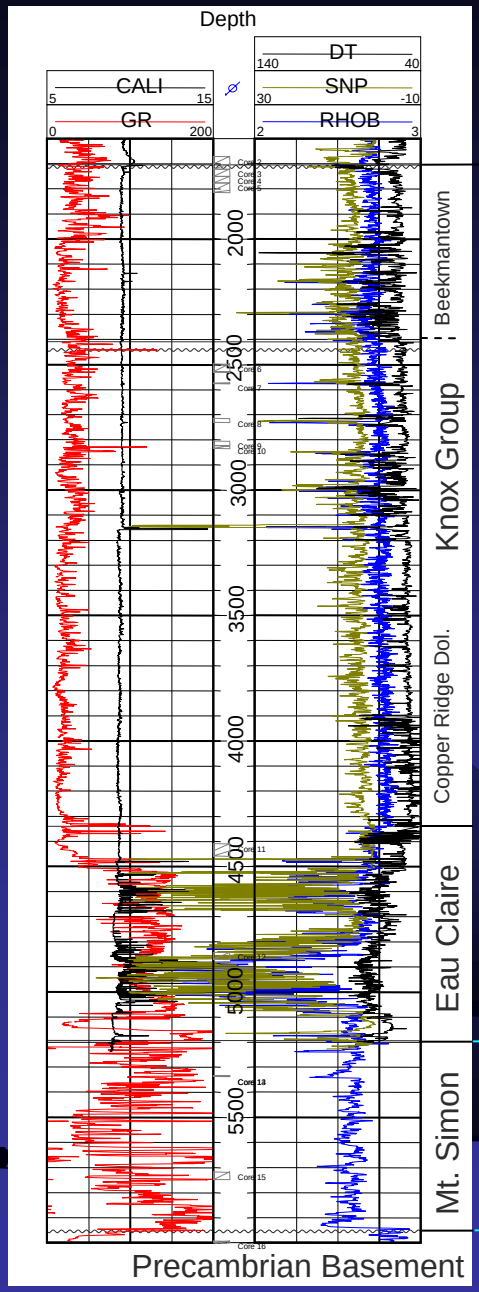
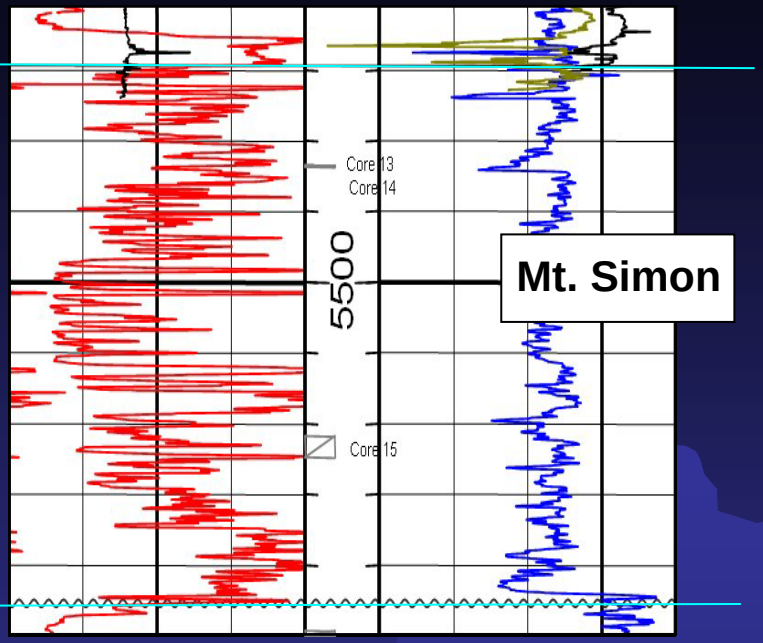
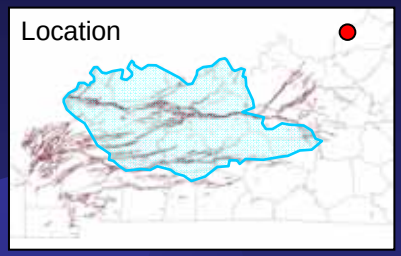




Case in Point:

Dupont No. 1WAD, Louisville KY



Initially targeted Mt. Simon for waste injection

- **Depth: 5,193 ft**
- **Thickness: 761 ft**

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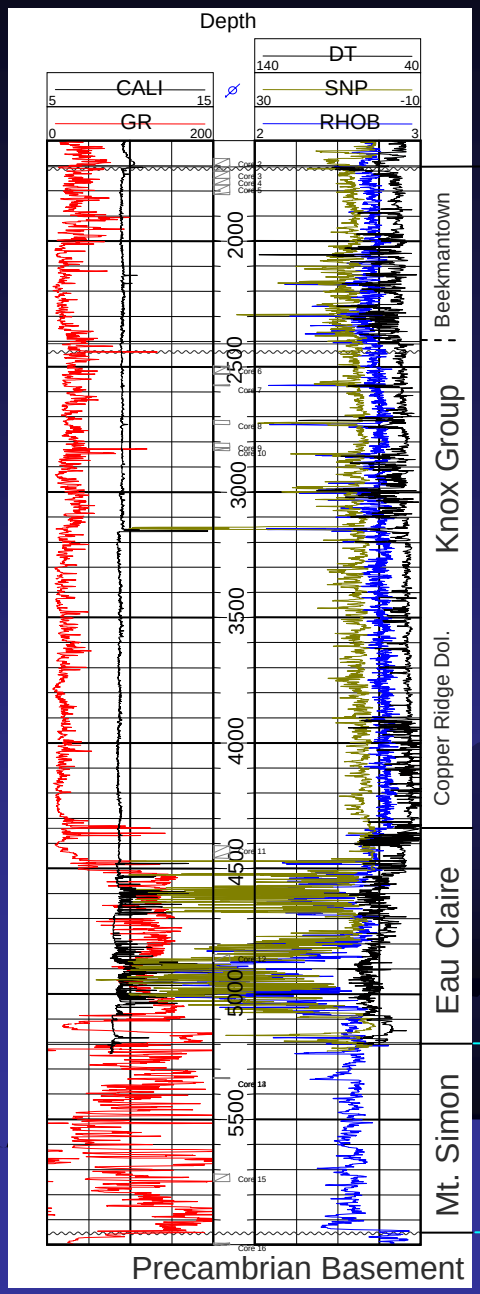
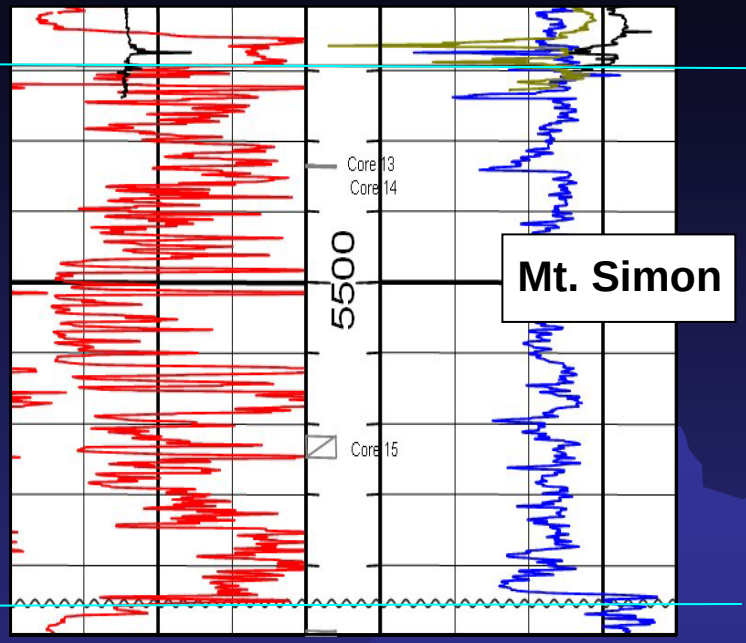
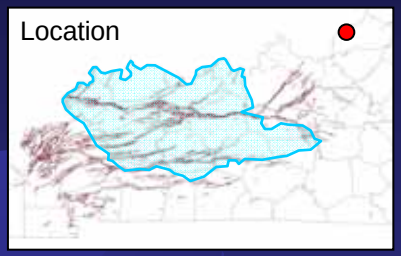
Potential reservoirs at depth: Mount Simon





Case in Point:

Dupont No. 1WAD, Louisville KY



Initially targeted Mt. Simon

- **Encountered tight sand, and came up the hole into the overlying Knox Formation**

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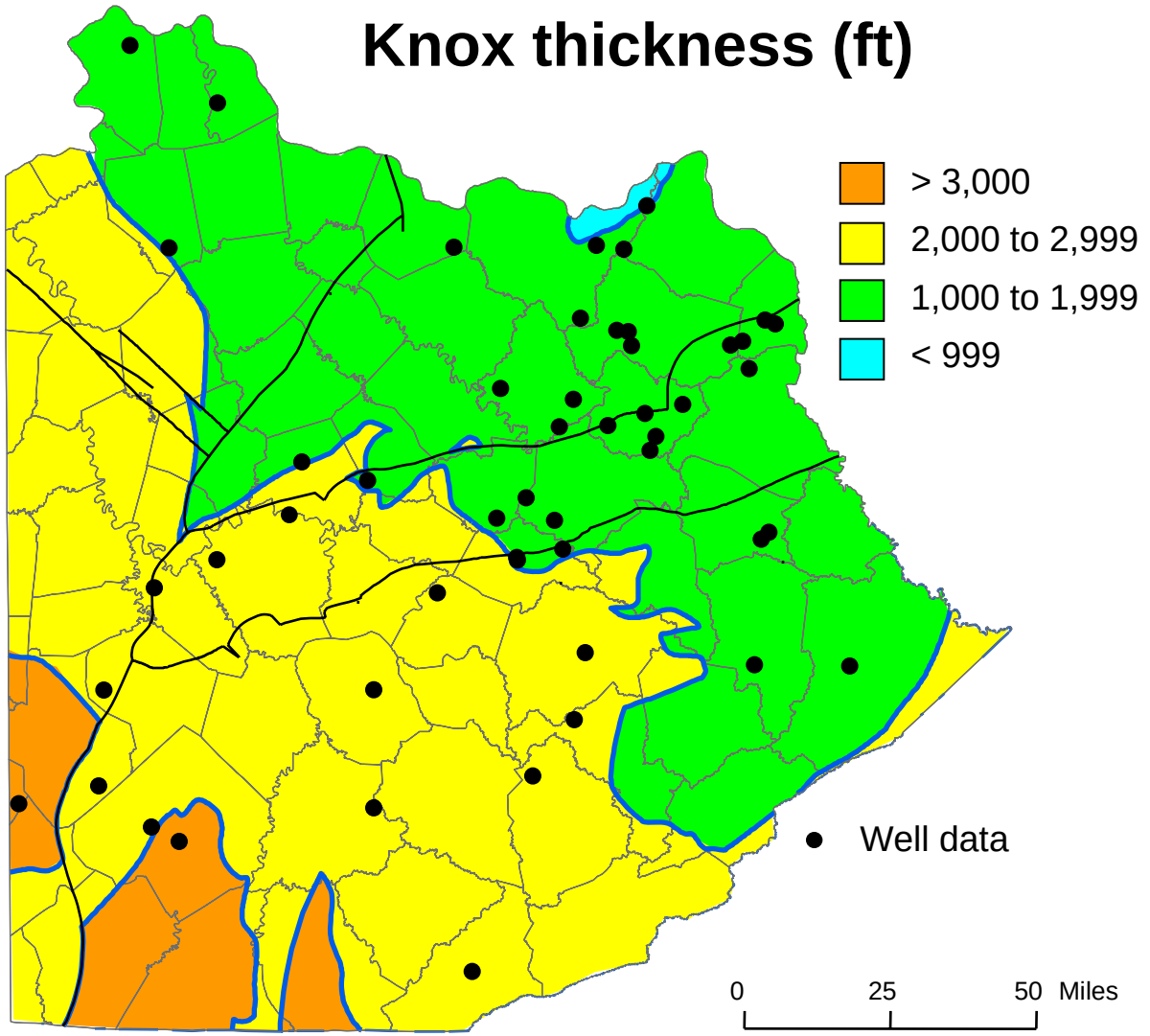
Potential reservoirs at depth: Knox



Draft map

The Knox is a widespread, thick, unit

- **Dominantly non-porous dolomite, but known to have several different porosity zones locally**

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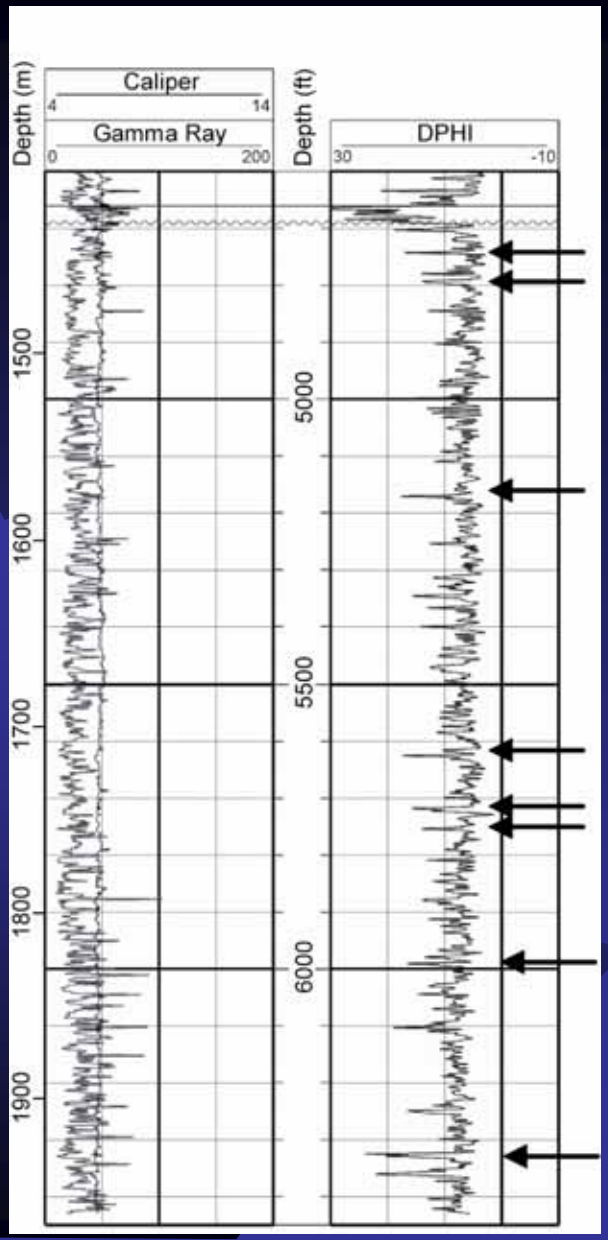
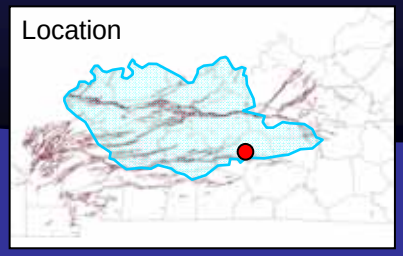
Potential reservoirs at depth: Knox

IMCO Recycling Waste Injection Site, Butler County, Kentucky

The only active waste injection site in Kentucky

- **Multiple, thin porosity intervals in the upper 1,760 ft of Knox**
- **Inject open hole through interval**
- **11 years, 3.5 million bbls injected**
- **No cores**





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Potential reservoirs at depth: Knox

Gas storage fields in central Kentucky

Several Knox gas (methane) storage fields at shallow (immiscible) depths in unconformity traps at the top of the Knox in north-central Kentucky

- **Numerous Knox oil fields associated with unconformity "highs" and fractures in south-central Kentucky**

- **Requires closely spaced data or seismic to detect unconformity traps**

- Knox gas storage County
- Knox oil field area

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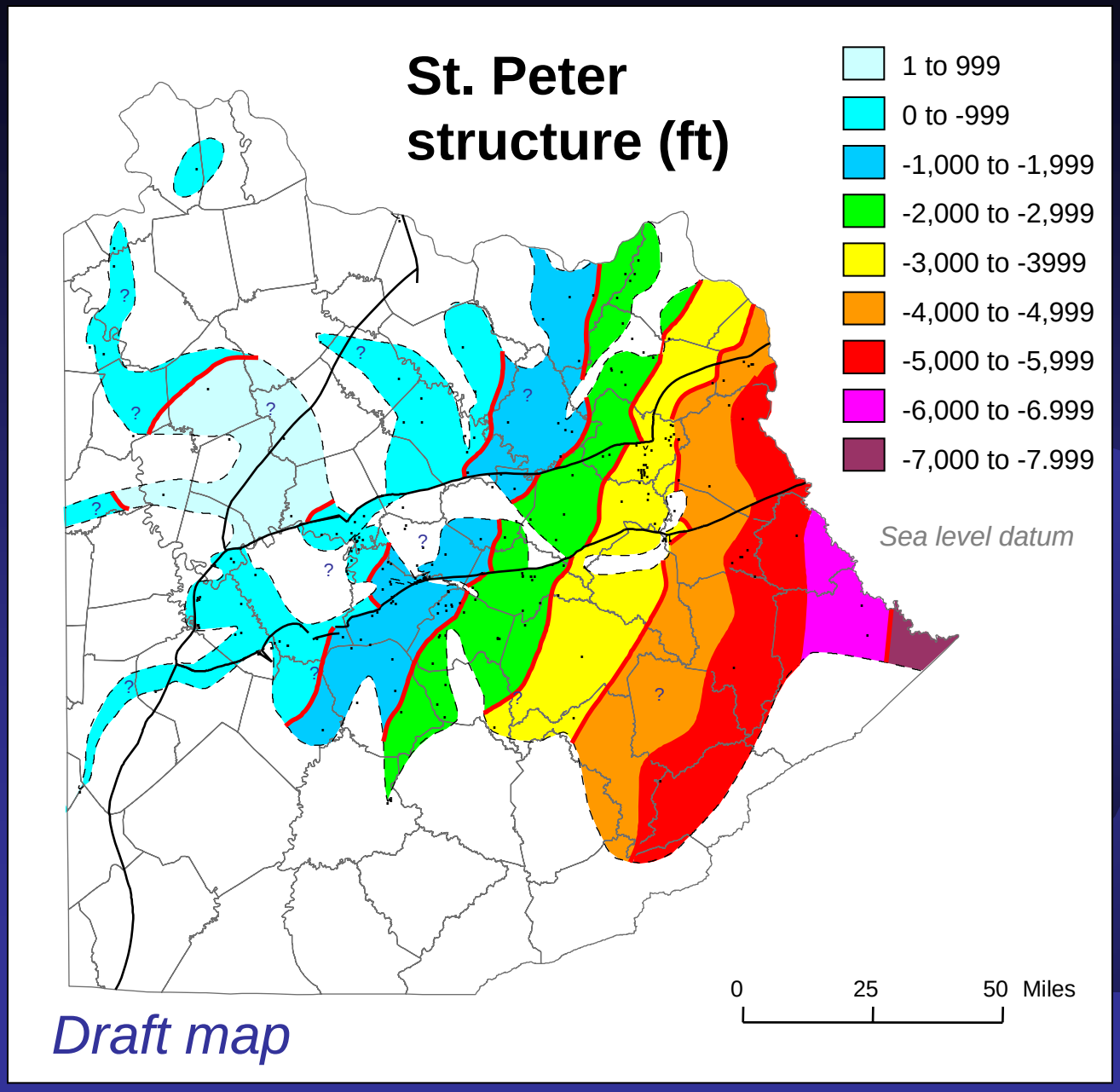
Potential reservoirs at depth: St. Peter



The St. Peter Sandstone overlies the Knox

- **It has an irregular distribution**

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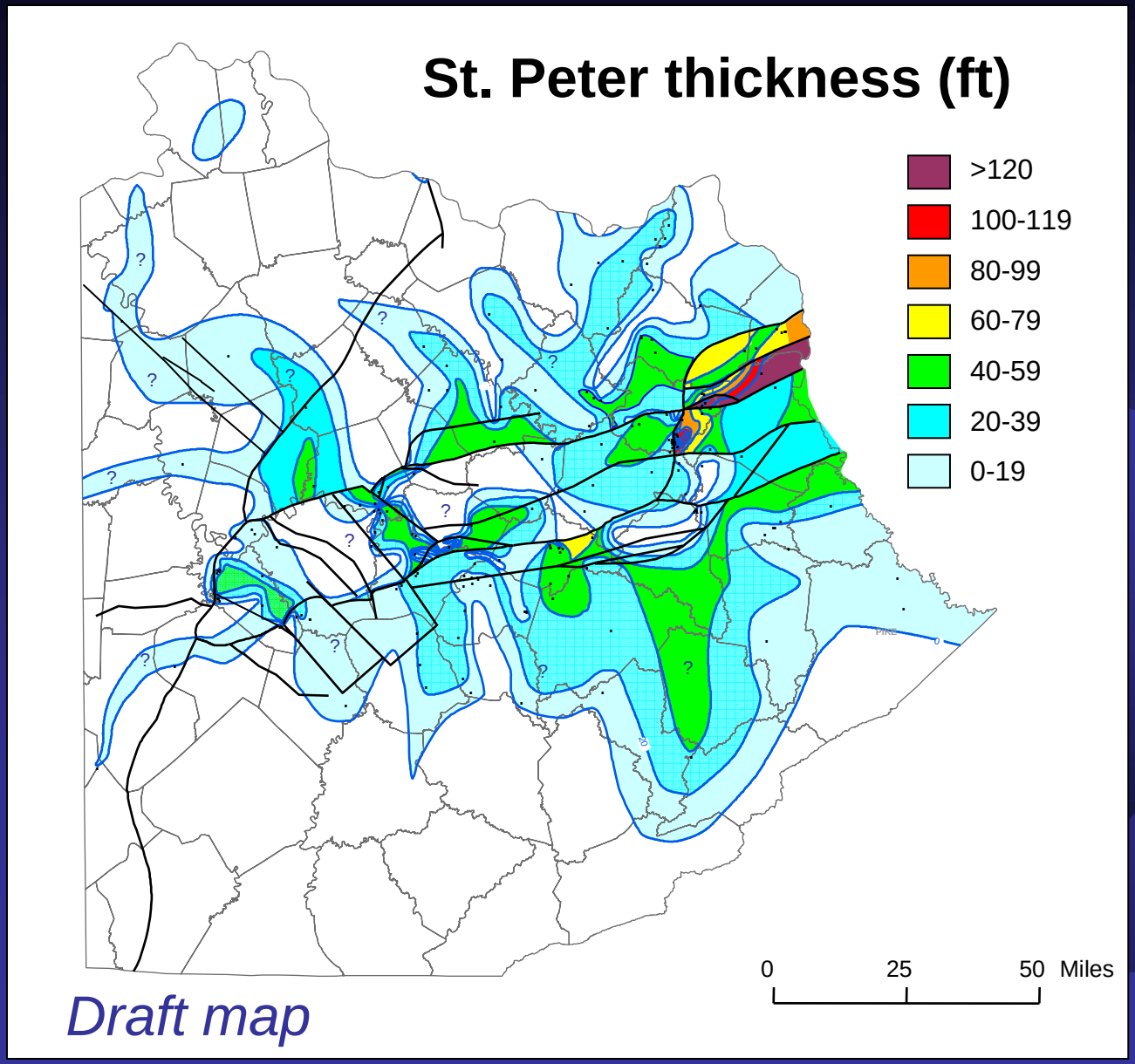
Potential reservoirs at depth: St. Peter



St. Peter thickness ranges from 0 to more than 120 ft

- **Thickness is influenced by faulting in the Rome Trough**

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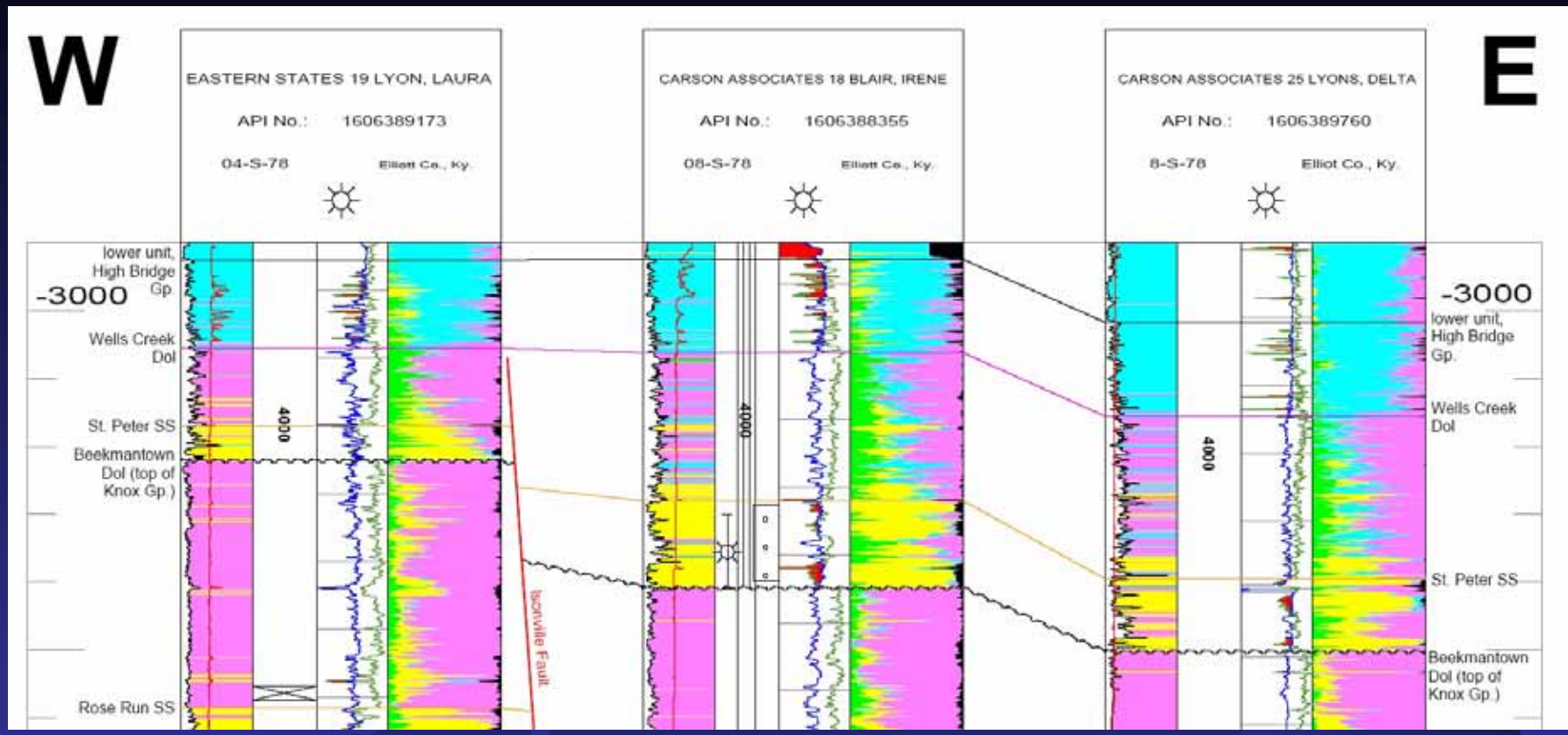
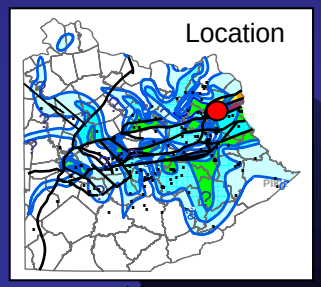
Potential reservoirs at depth: St. Peter





Thickness variation across faults in the Homer Field, Elliott County, Kentucky

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Potential reservoirs at depth: St. Peter

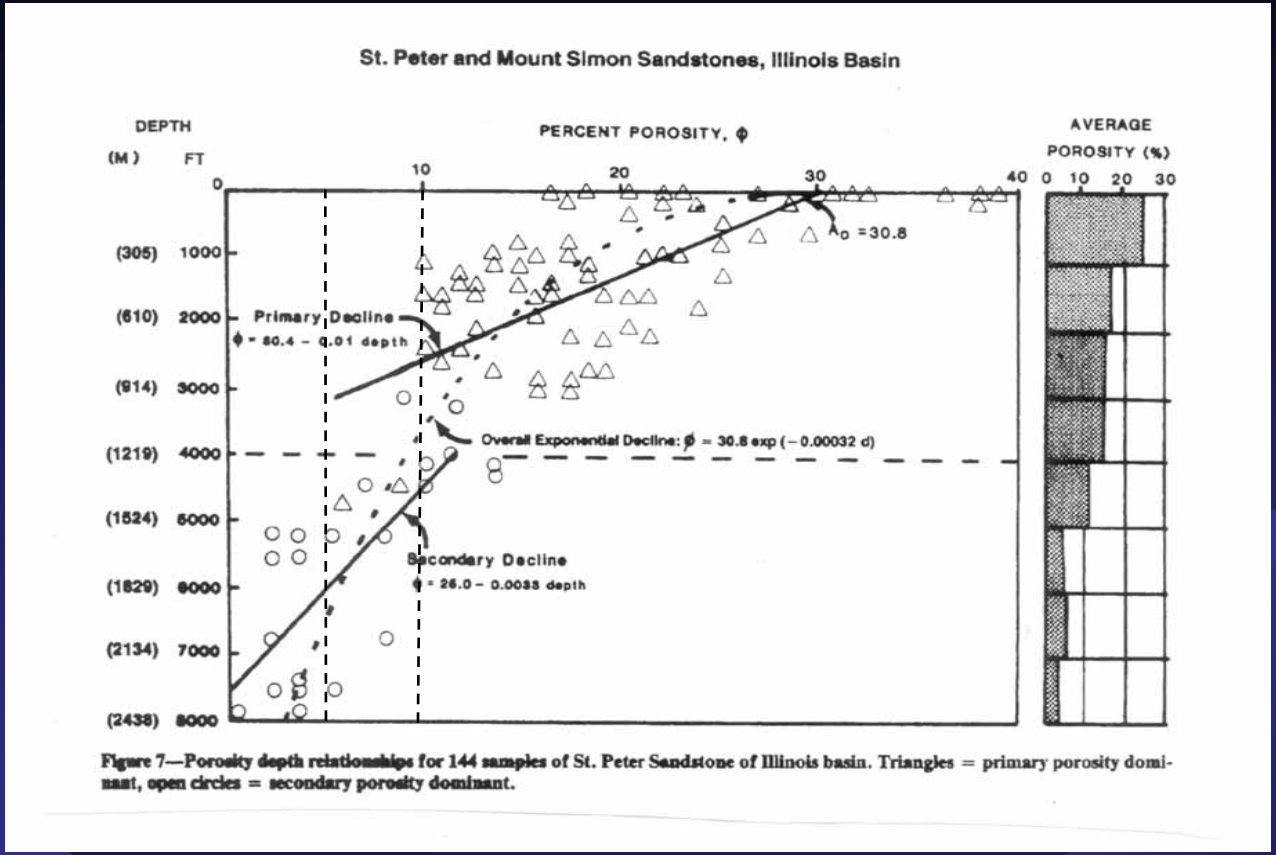

Figure 7—Porosity depth relationships for 144 samples of St. Peter Sandstone of Illinois basin. Triangles = primary porosity dominant, open circles = secondary porosity dominant.

In western Kentucky and Illinois basin there is decreasing porosity in the St. Peter with depth

…we need to see if eastern Kentucky is similar

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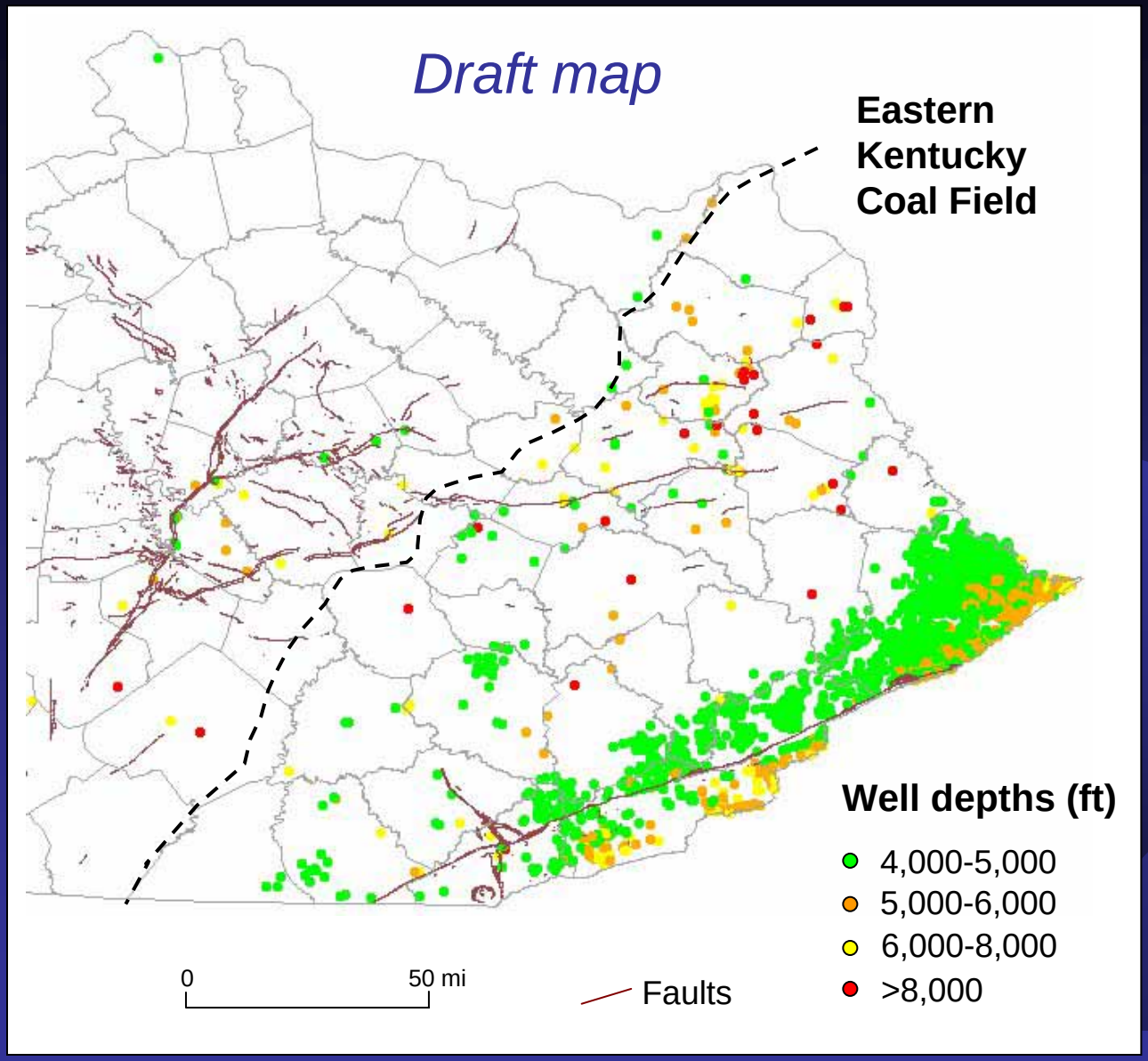
From Hoholick and others, 1984, AAPG Bulletin

Fault Leakage issues



Faults can act as both reservoir seals and pathways for leakage

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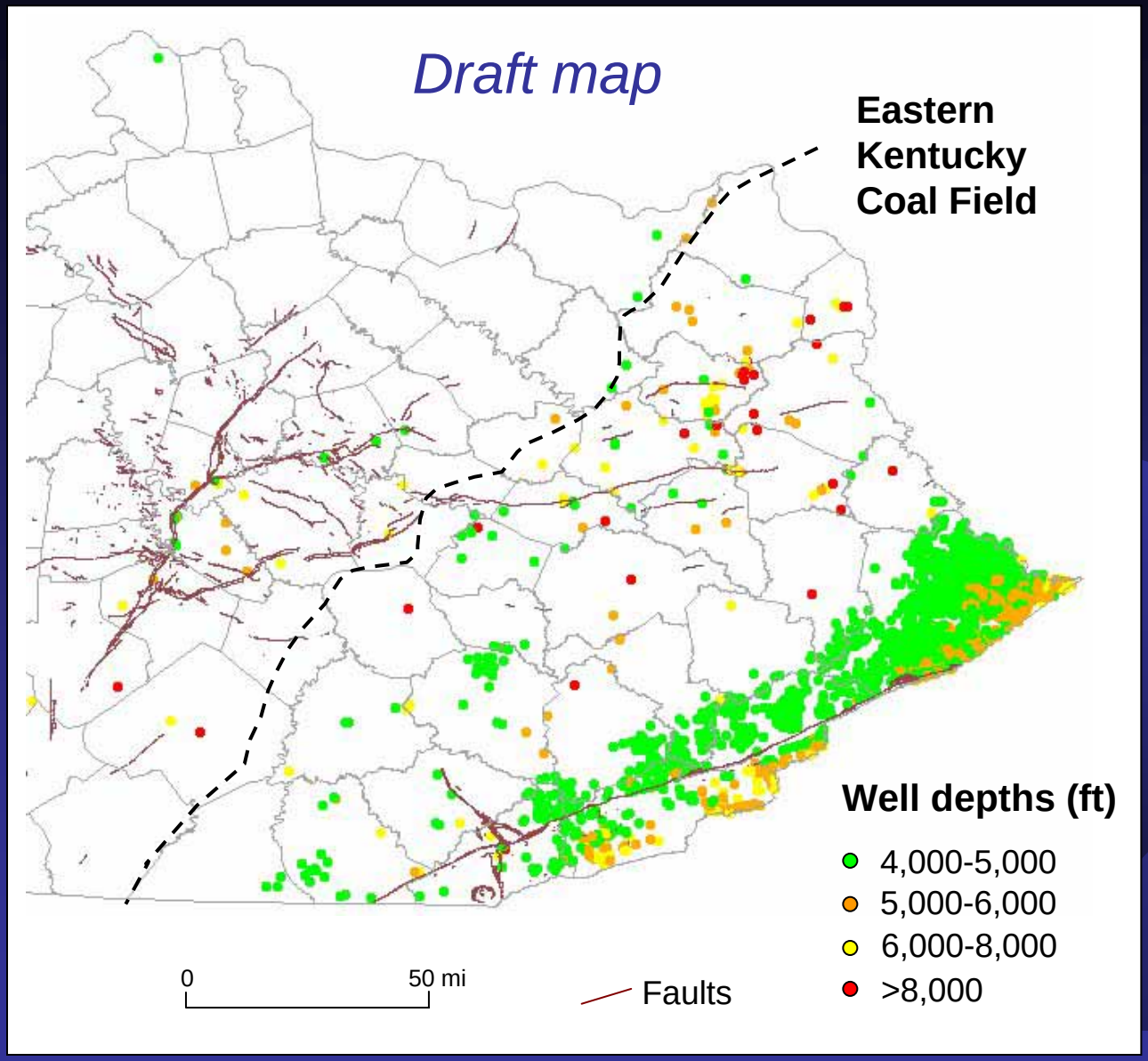
Fault Leakage issues



Faults can act as both reservoir seals and pathways for leakage

- **If storage-plume areas intersect faults, sealing properties will need to be determined**

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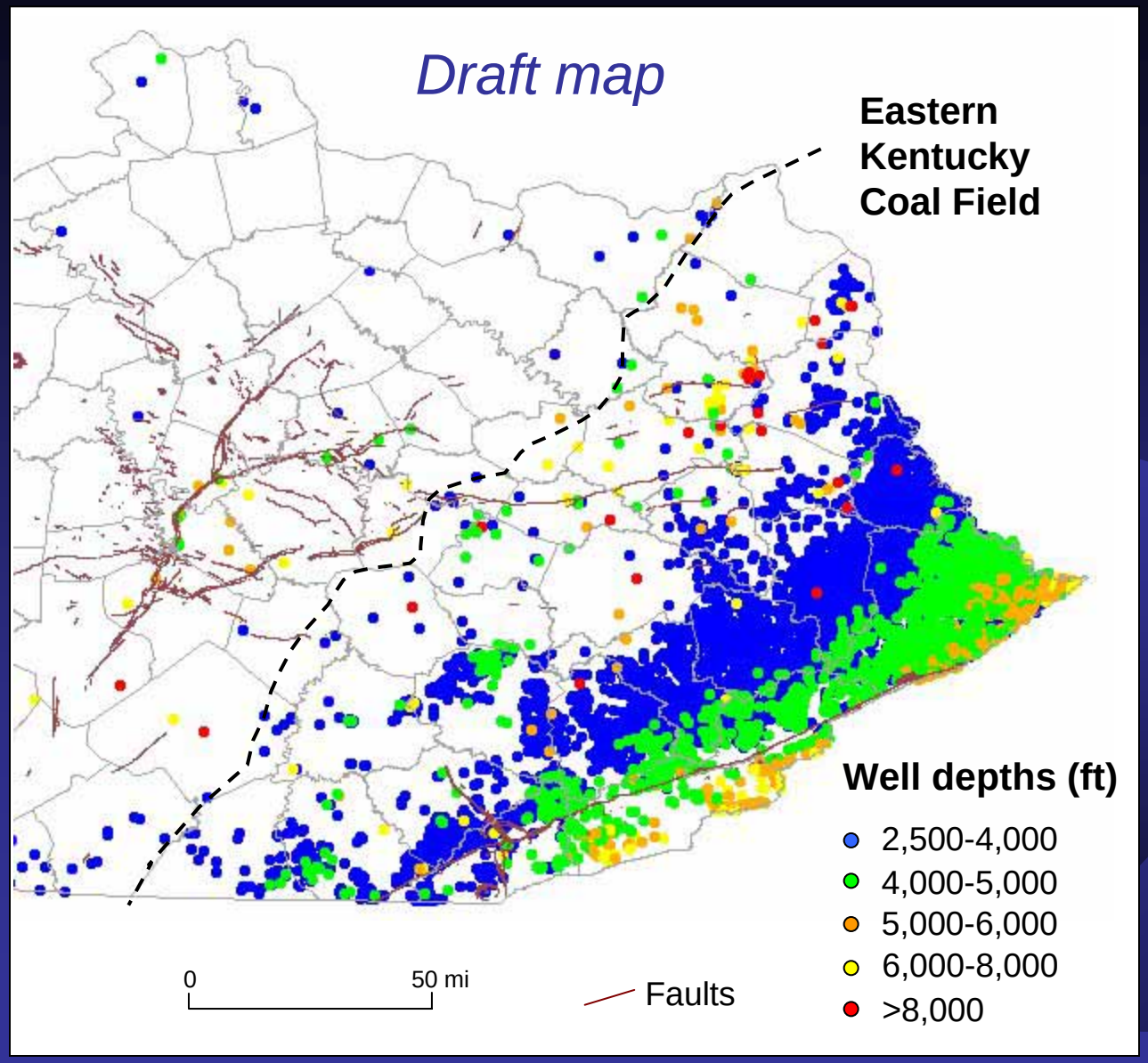
Old Well Bore Leakage Issues



Another potential leakage pathway is old well bores

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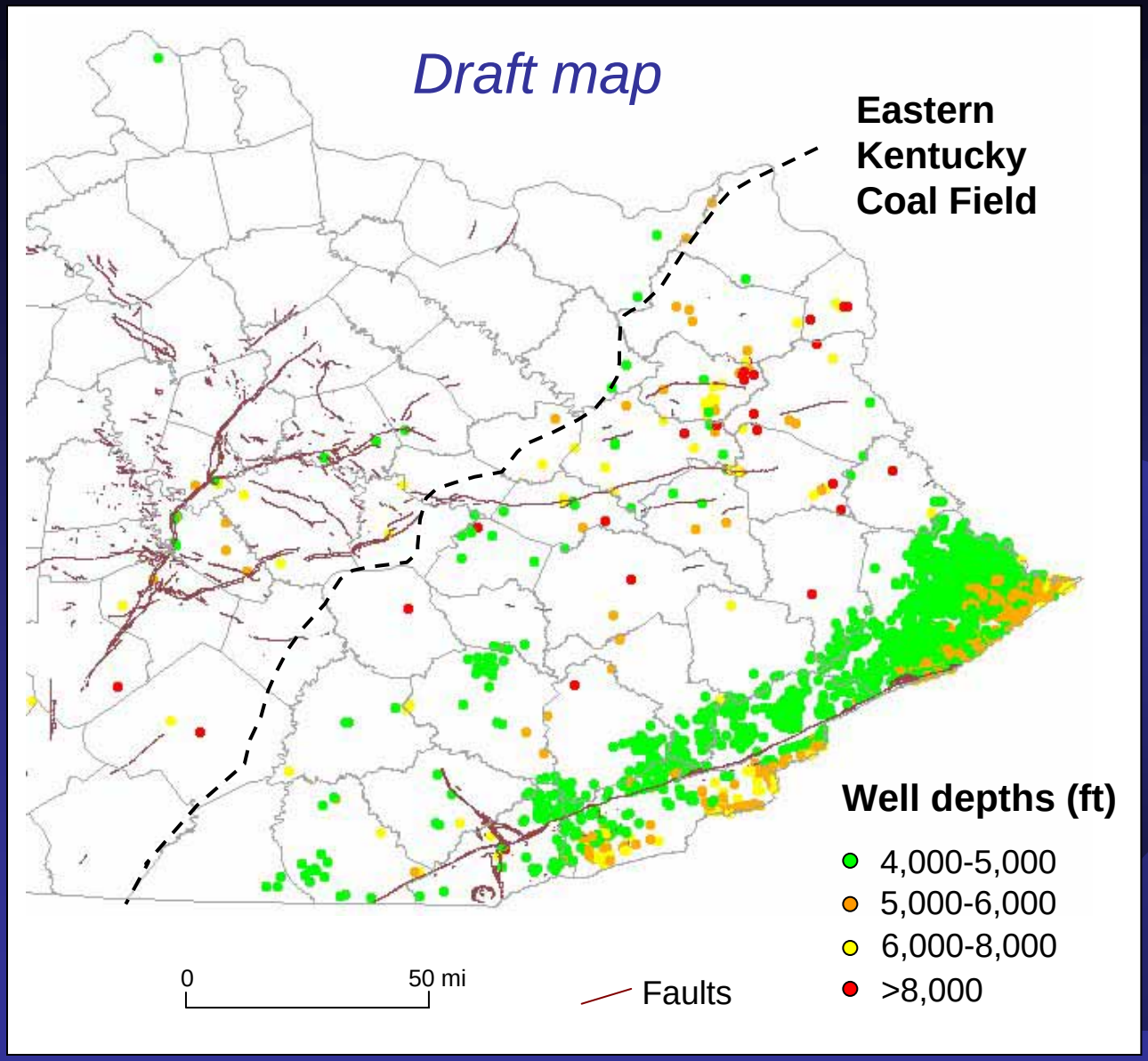
Old Well Bore Leakage Issues



- **Saline formations not penetrated by large numbers of wells are favorable to units that are widely penetrated**

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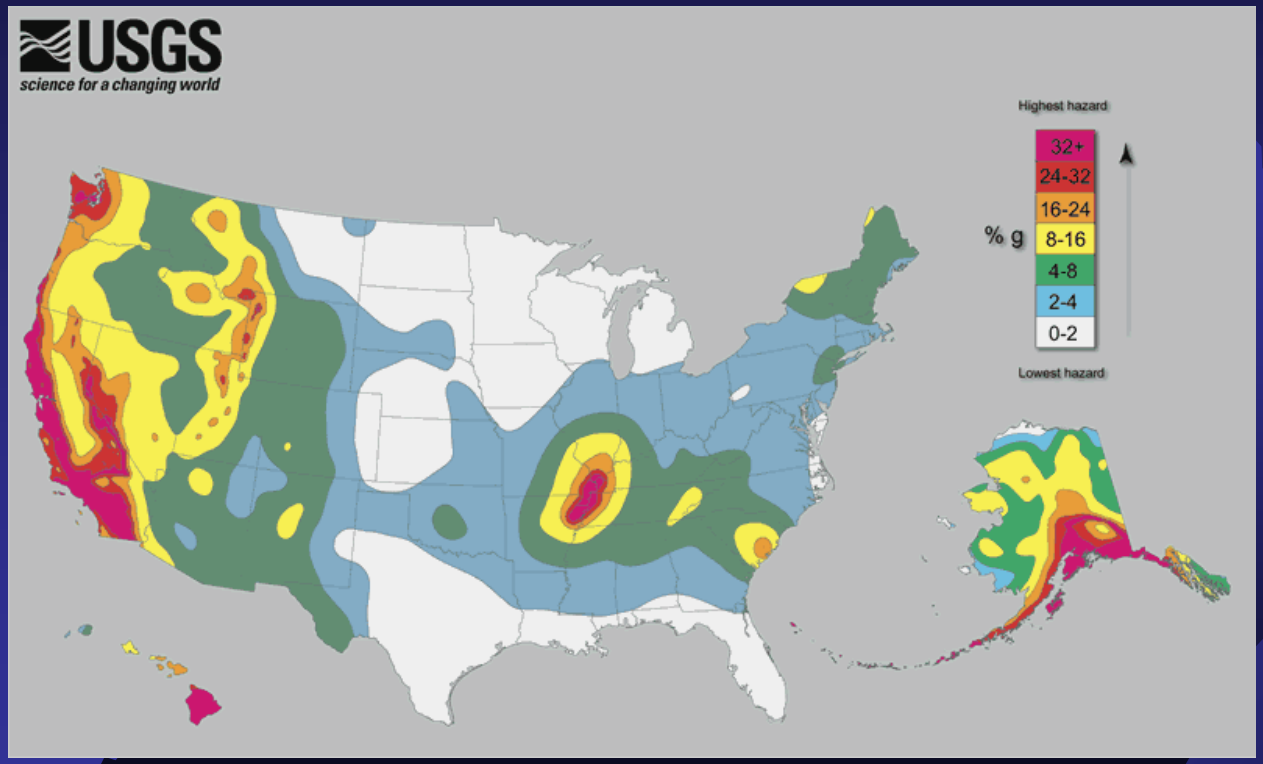
Seismic risk Issues

In the FutureGen proposals, seismic risk limits were set at peak acceleration of 0.3% g with 2% probability of exceedence in 50 years by the Federal government



- **Such a limit would not preclude any of eastern Kentucky**

http://earthquake.usgs.gov/research/hazmaps/products_data/images/nshm_us02.gif

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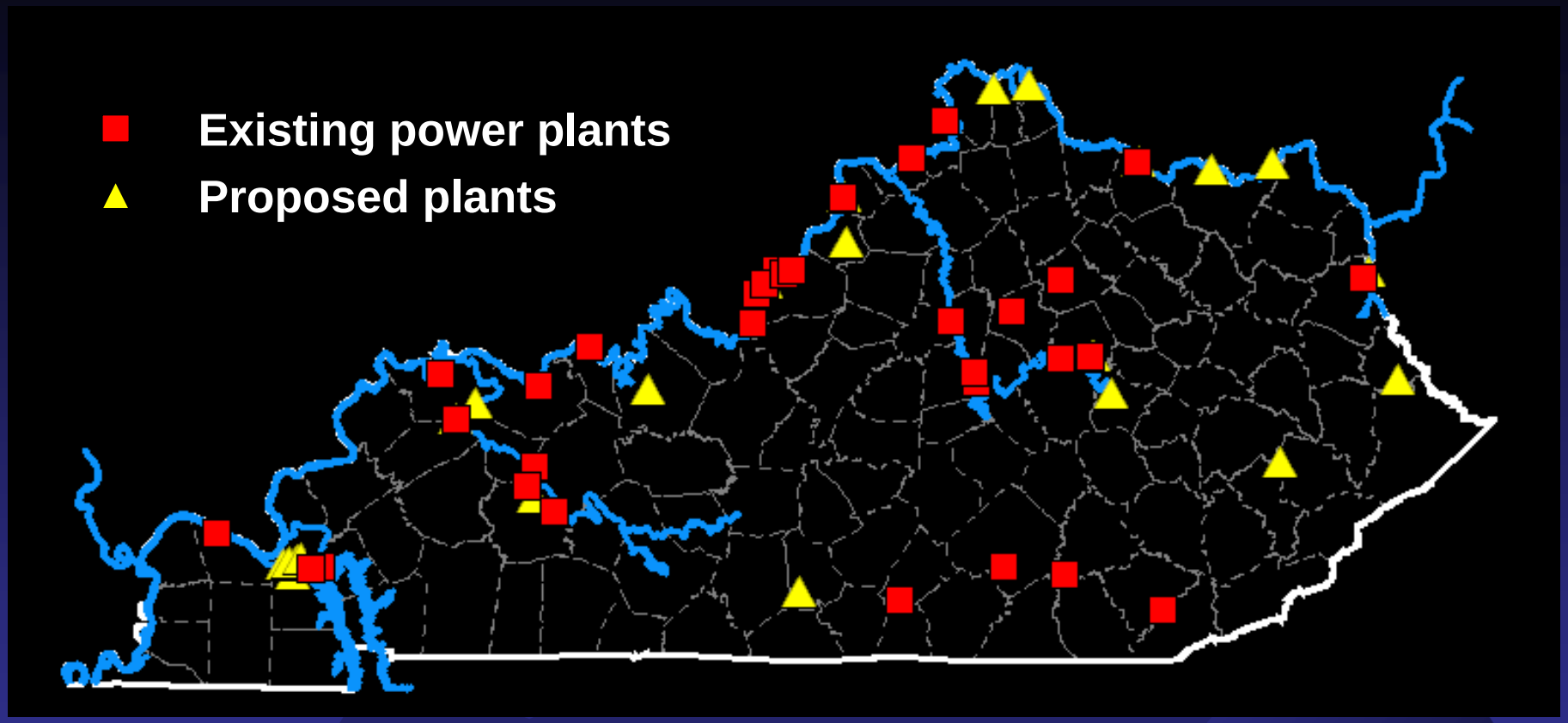
Water supply issues



Another issue for site criteria might be proximity to large water supplies

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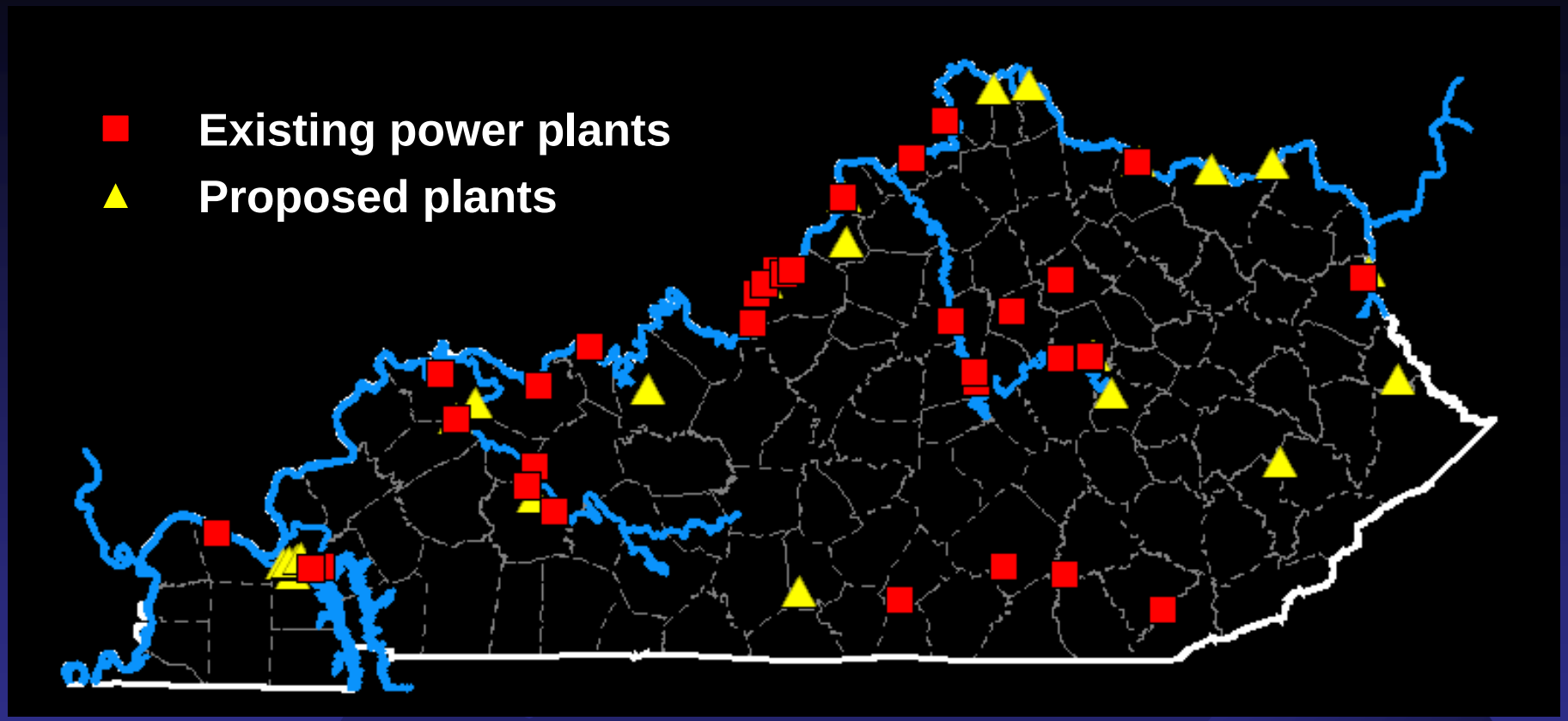
Water supply issues



Another issue for site criteria might be proximity to large water supplies

- **Power plants and potential coal-to-liquids plants that will need CO_2 storage also need large water supplies**

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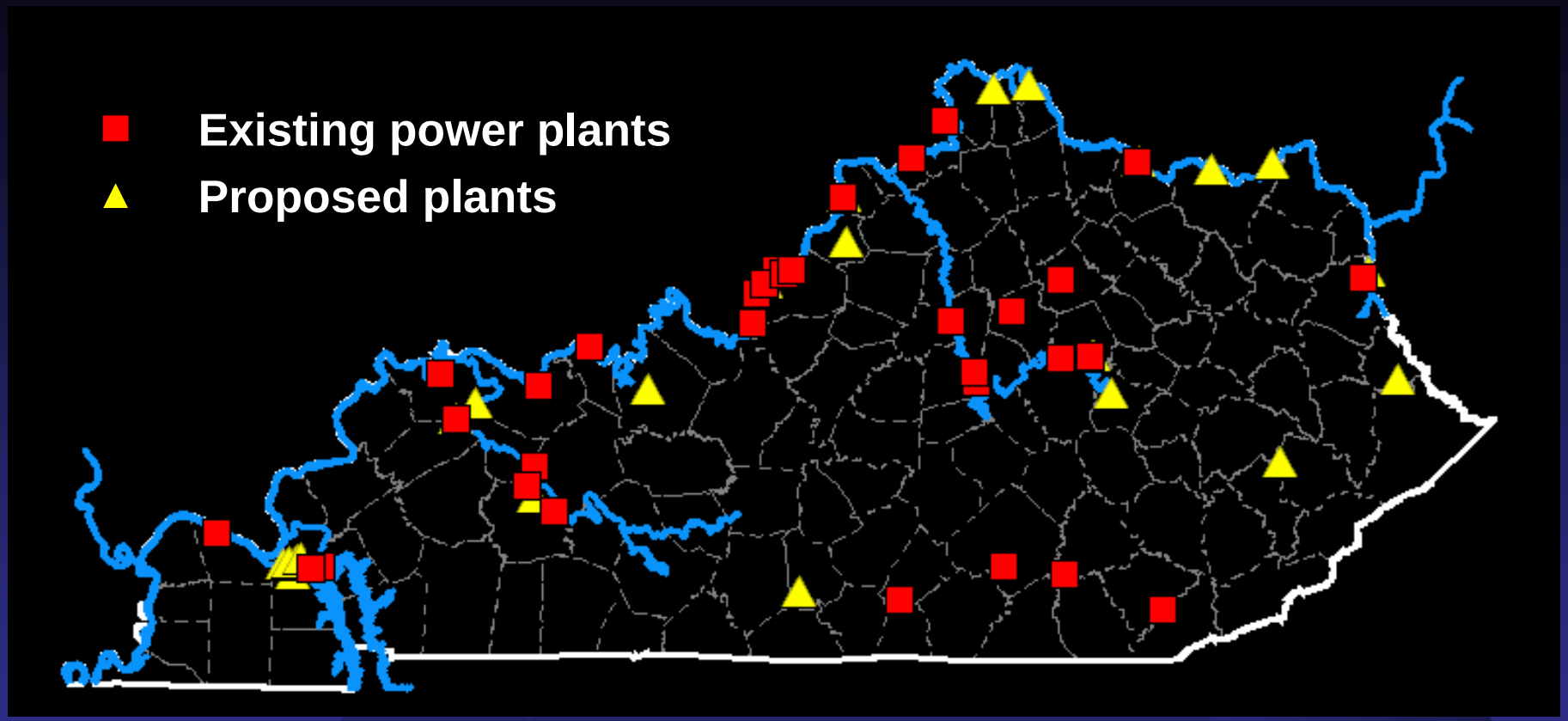
Water supply issues



Another issue for site criteria might be proximity to large water supplies

- Not needed for test hole, but may need to be considered when choosing sites

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Potential site selection method

We can use the existing site bank developed for commercial-scale CTL and CTG plants by the Governor's Office of Energy Policy or look for other available areas for drilling. Then we need to compare site characteristics through a series of weighted criteria

- Geologic and non-geologic criteria will have to be considered
  - ➢ The following shows how an initial geologic site selection might be done. It is not the final selection. It is only meant to show how a set of criteria might be used to help select an area. The actual criteria used have yet to be decided.

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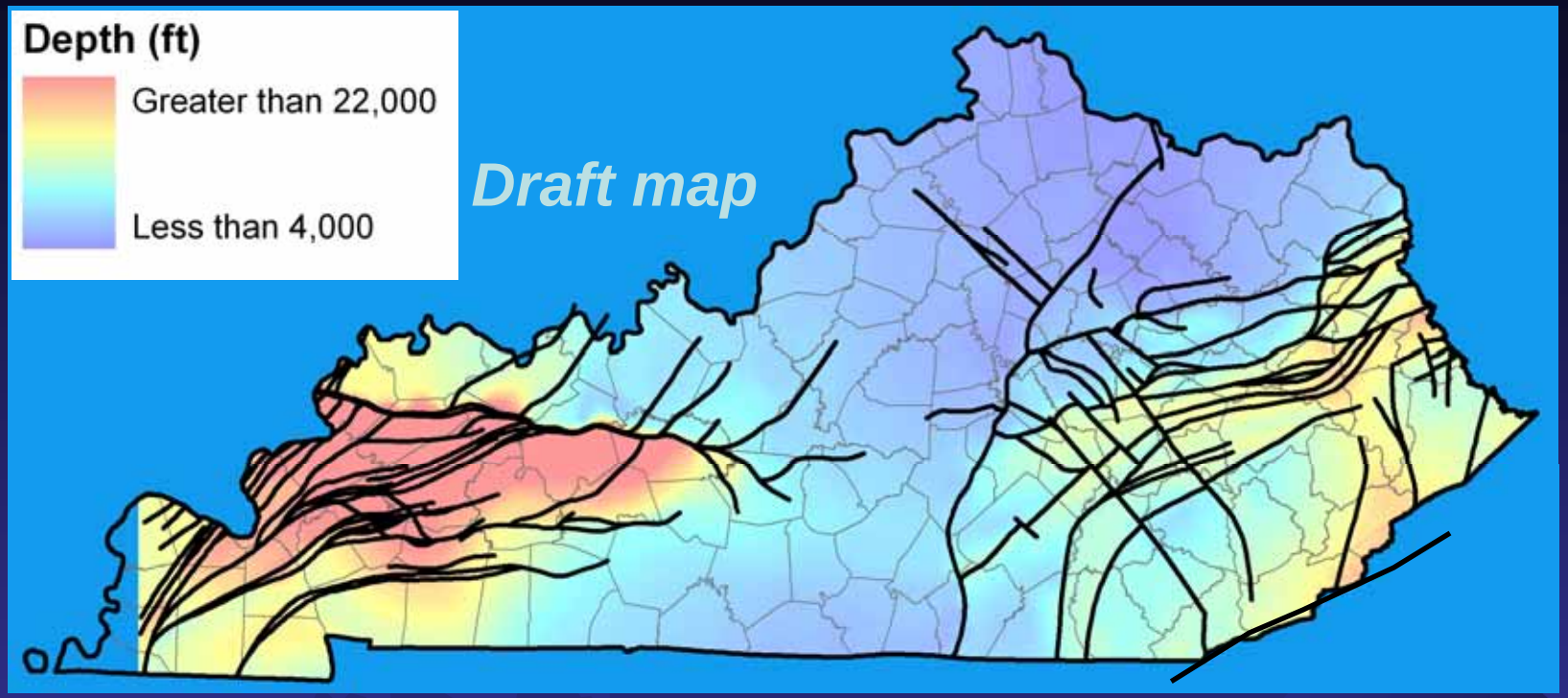
Potential site selection method to show how a set of criteria might be used to help screen sites



Depth to the Precambrian basement

For example, if we want to test the major regional saline reservoirs, including basal sands, but at depths not exceeding 8,000 ft. in order to maximize potential for porosity in deep sandstones (may not be as important in eastern KY), then….

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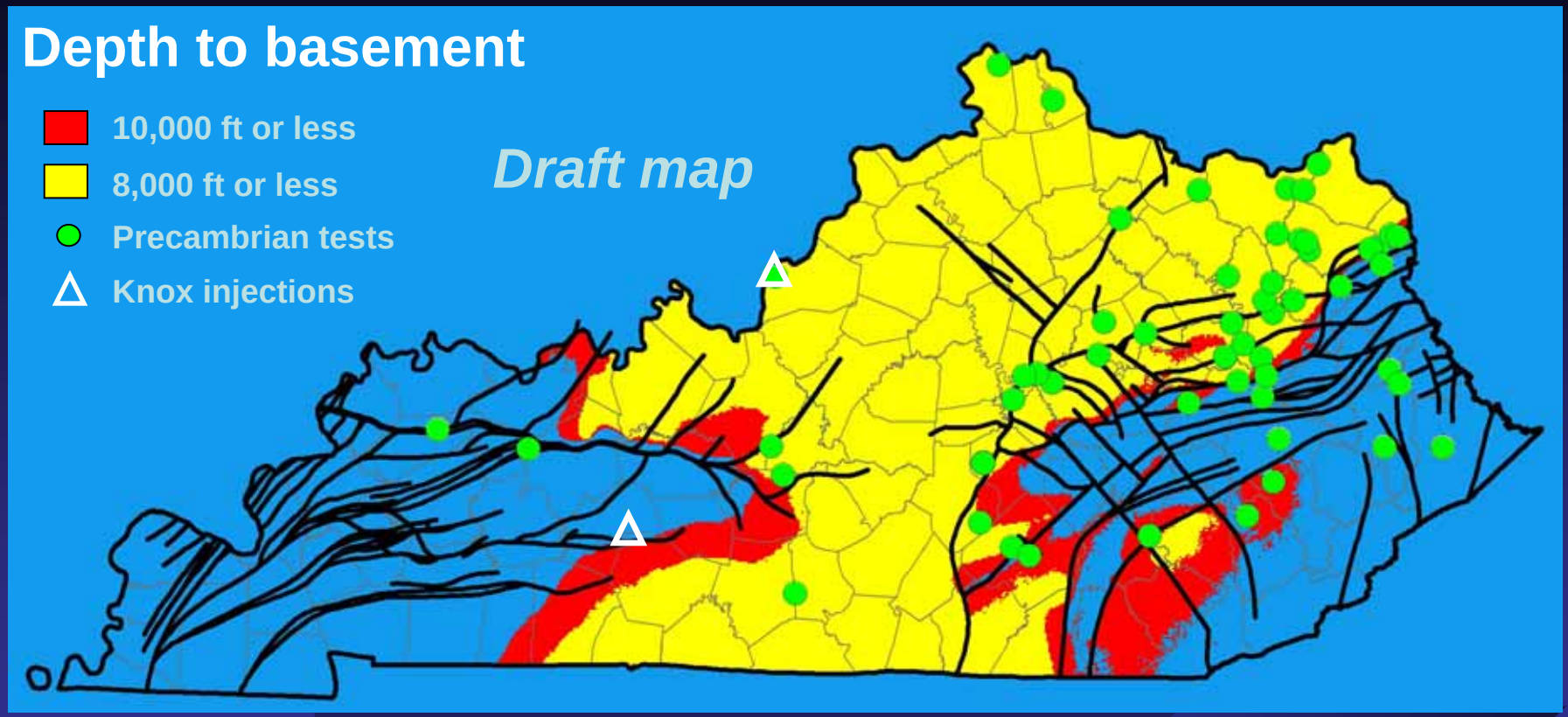
Potential site selection method to show how a set of criteria might be used to help screen sites



…this would result in site selection weighted toward the northern and western margin of the Eastern Kentucky Coal Field

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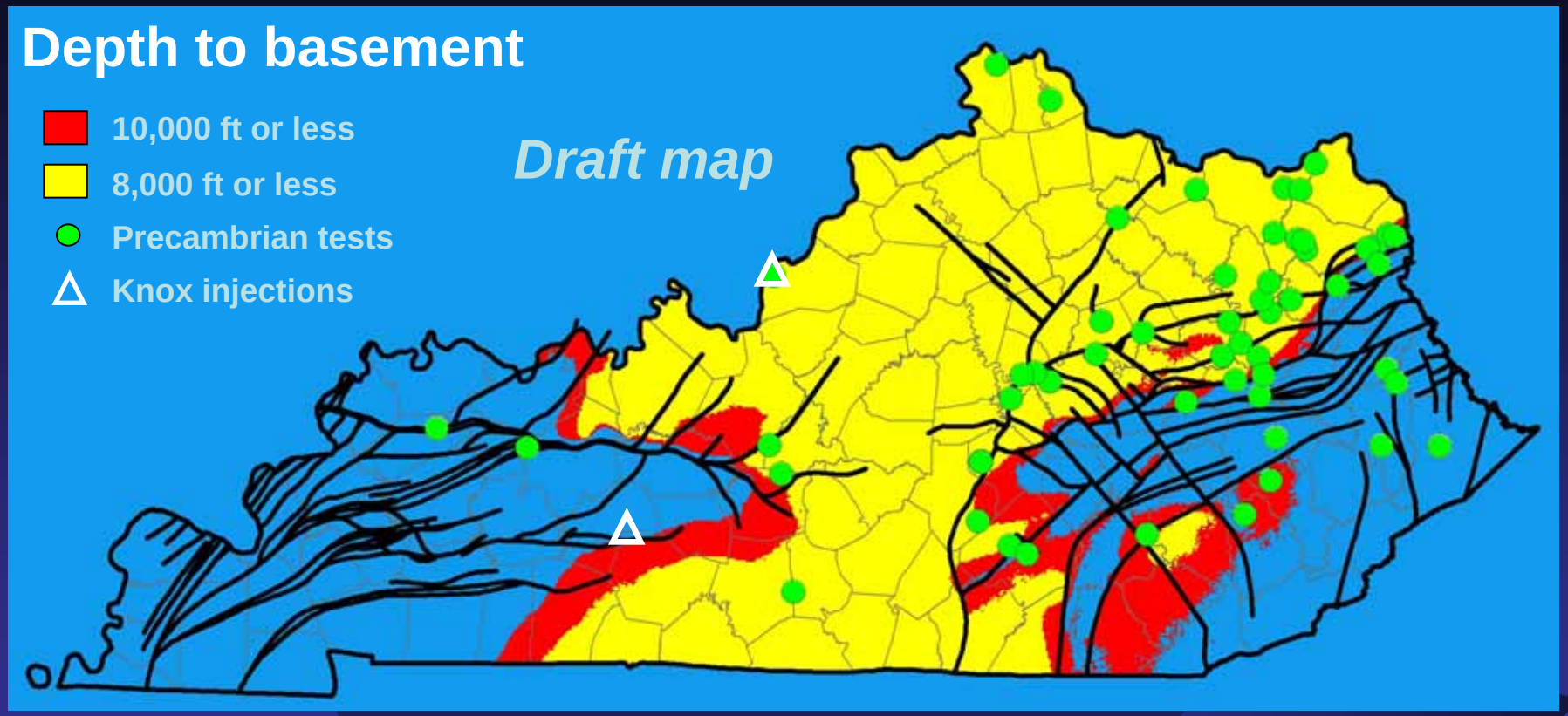
Potential site selection method to show how a set of criteria might be used to help screen sites



- Basal sands in the Rome Trough and to the southeast would require deeper and more expensive wells
- In those areas, shallower horizons would have to be evaluated

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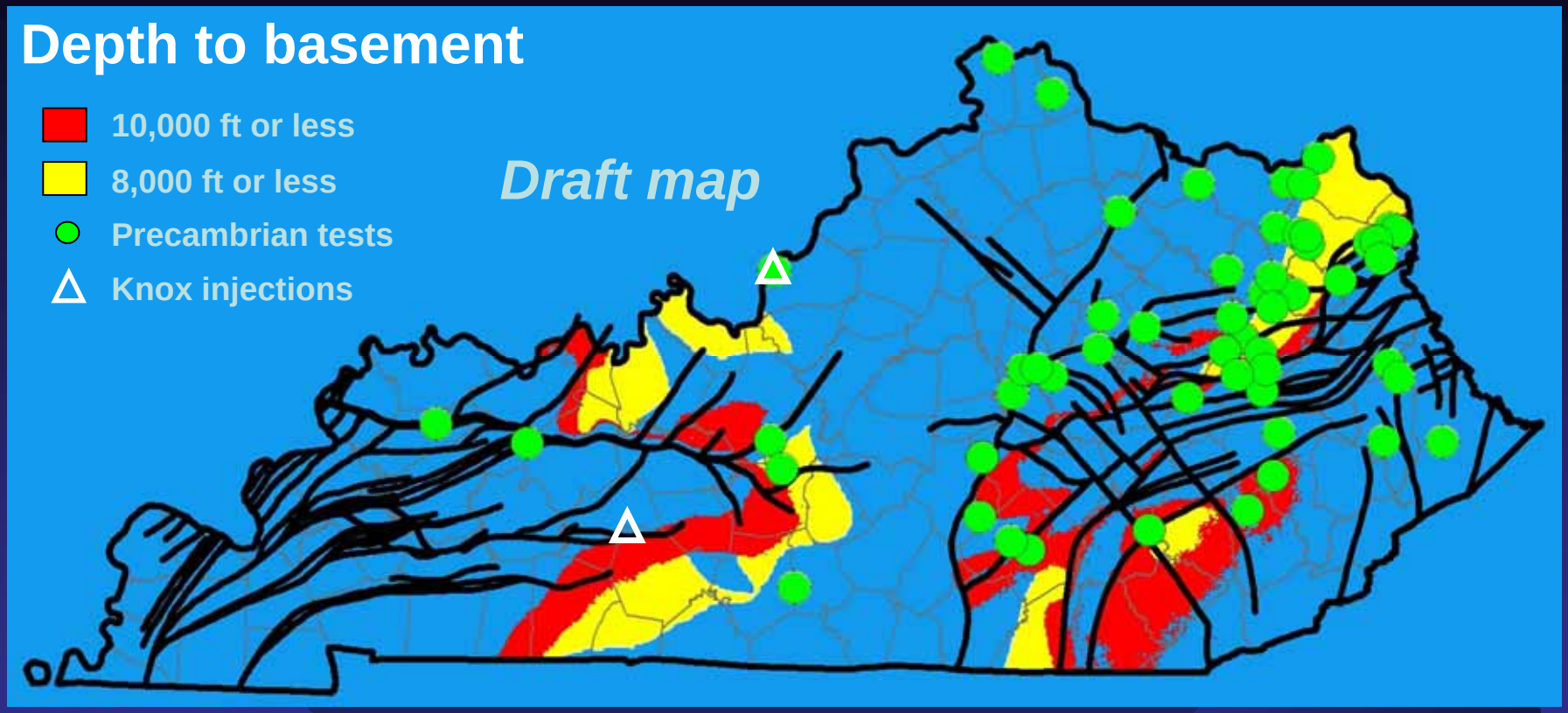
Potential site selection method to show how a set of criteria might be used to help screen sites



- If we further restrict area to where there is basal sands, Mt. Simon, St. Peter (or other deep sandstones including some Silurian sands) at depths between 8,000 to 2,500 ft, in order to intercept multiple horizons in this range, the area is more limited

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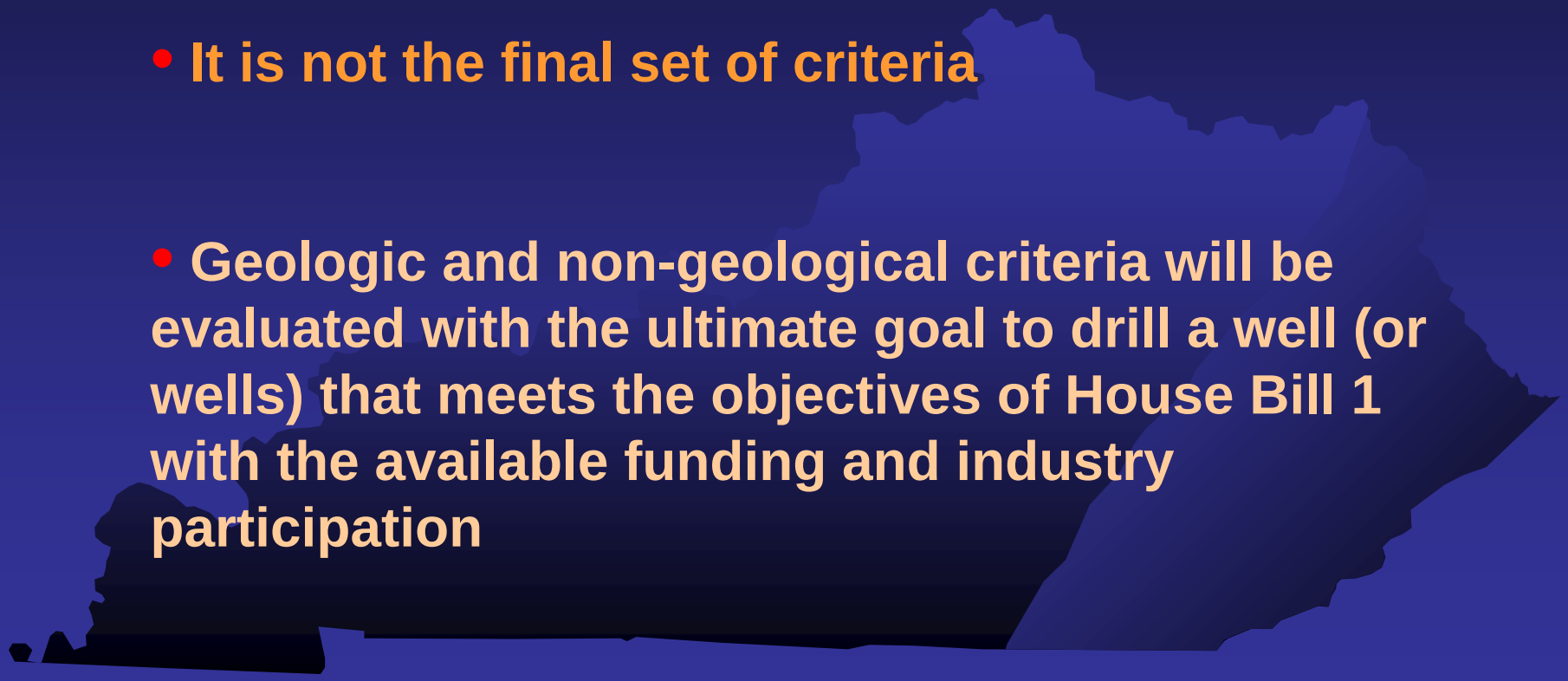
Potential site selection method to show how a set of criteria might be used to help screen sites

This example scenario shows how a set of criteria might be developed to aid in determining the area best suited for a test well

- **It is not the final set of criteria**

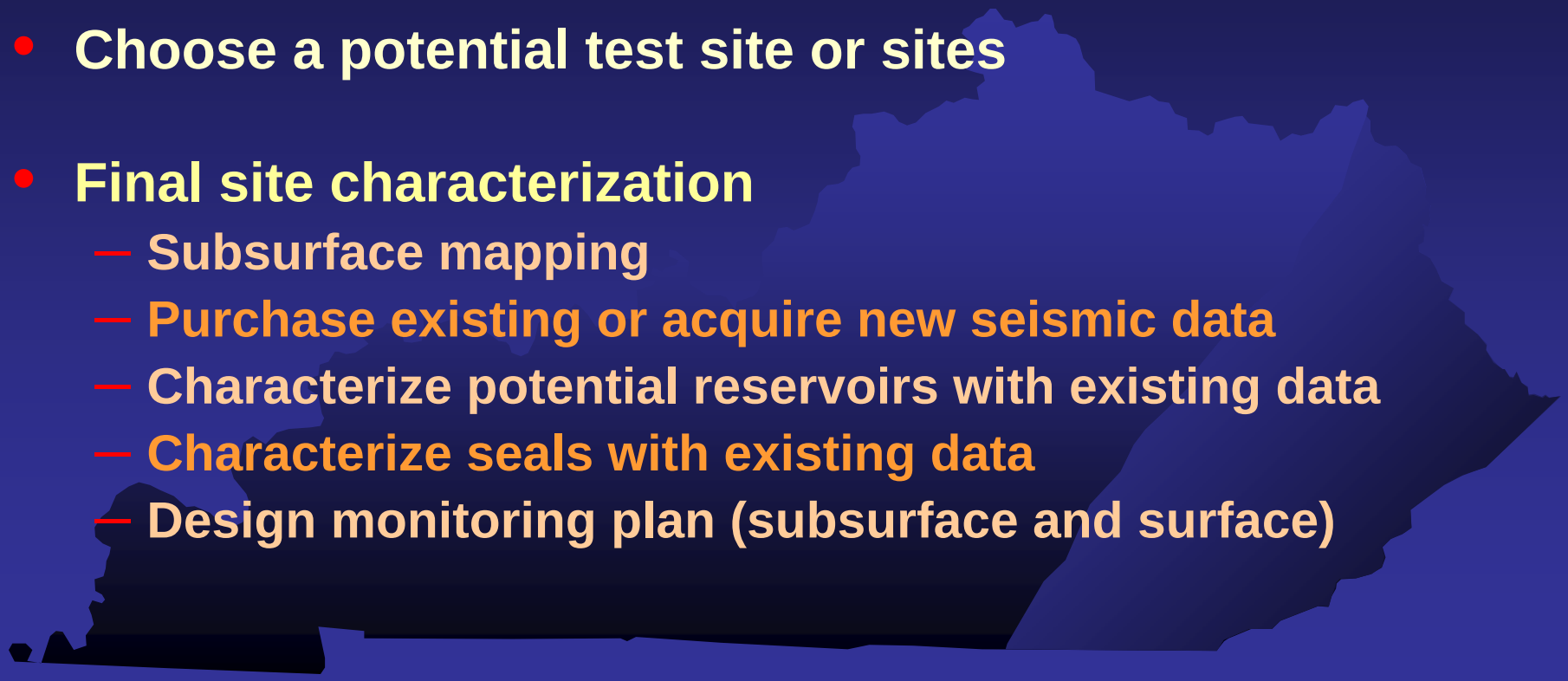
- **Geologic and non-geological criteria will be evaluated with the ultimate goal to drill a well (or wells) that meets the objectives of House Bill 1 with the available funding and industry participation**



Eastern Kentucky Deep Well Planning

A working committee that includes KGS and industry partners must work together to:

- **Finalize site screening criteria**
- **Choose a potential test site or sites**
- **Final site characterization**
  - **Subsurface mapping**
  - **Purchase existing or acquire new seismic data**
  - **Characterize potential reservoirs with existing data**
  - **Characterize seals with existing data**
  - **Design monitoring plan (subsurface and surface)**



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Eastern Kentucky Deep Well Planning

- Well design and engineering
- Permitting
- Drilling
  - Obtain whole core and side-wall cores in reservoir and seal intervals
  - Run and interpret extensive suite of well logs
  - Collect brine samples from target zones for geochemistry
  - Analyze core samples for porosity, permeability, mineralogy, cements, mechanical strength, and other physical properties
  - Conduct injection tests using fluid, air or CO_2
- Monitoring, verification, and closure
- Public education and outreach
- Reporting and technology transfer

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Thank you

Let’s open the floor for questions

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