Kentucky Geological Survey
Marvin Blan #1
Hancock County, Kentucky

Geologic Review

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Kentucky Geological Survey

KYCCS Western Kentucky Project Review
Lexington, Kentucky
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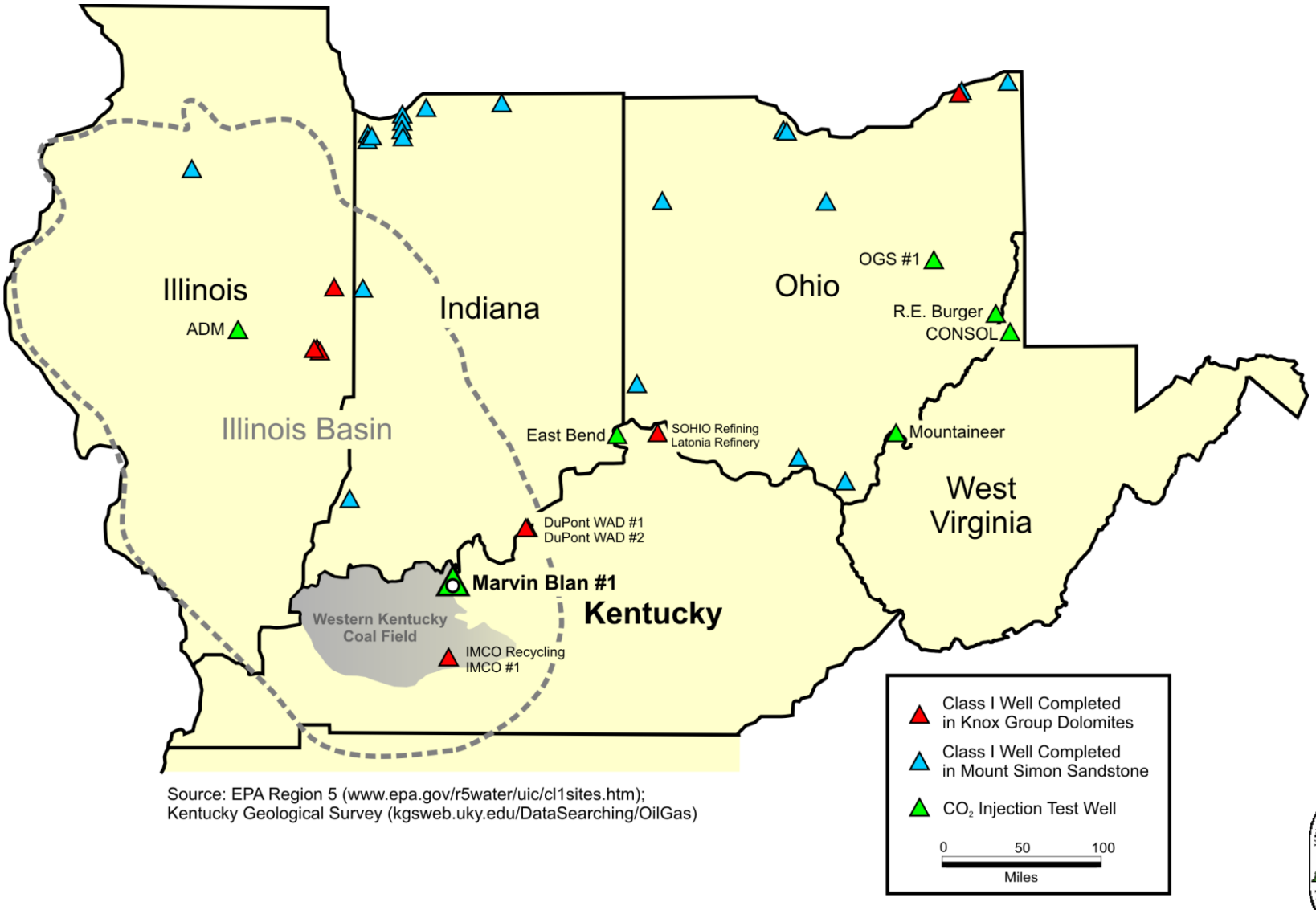
Regional Injection Wells

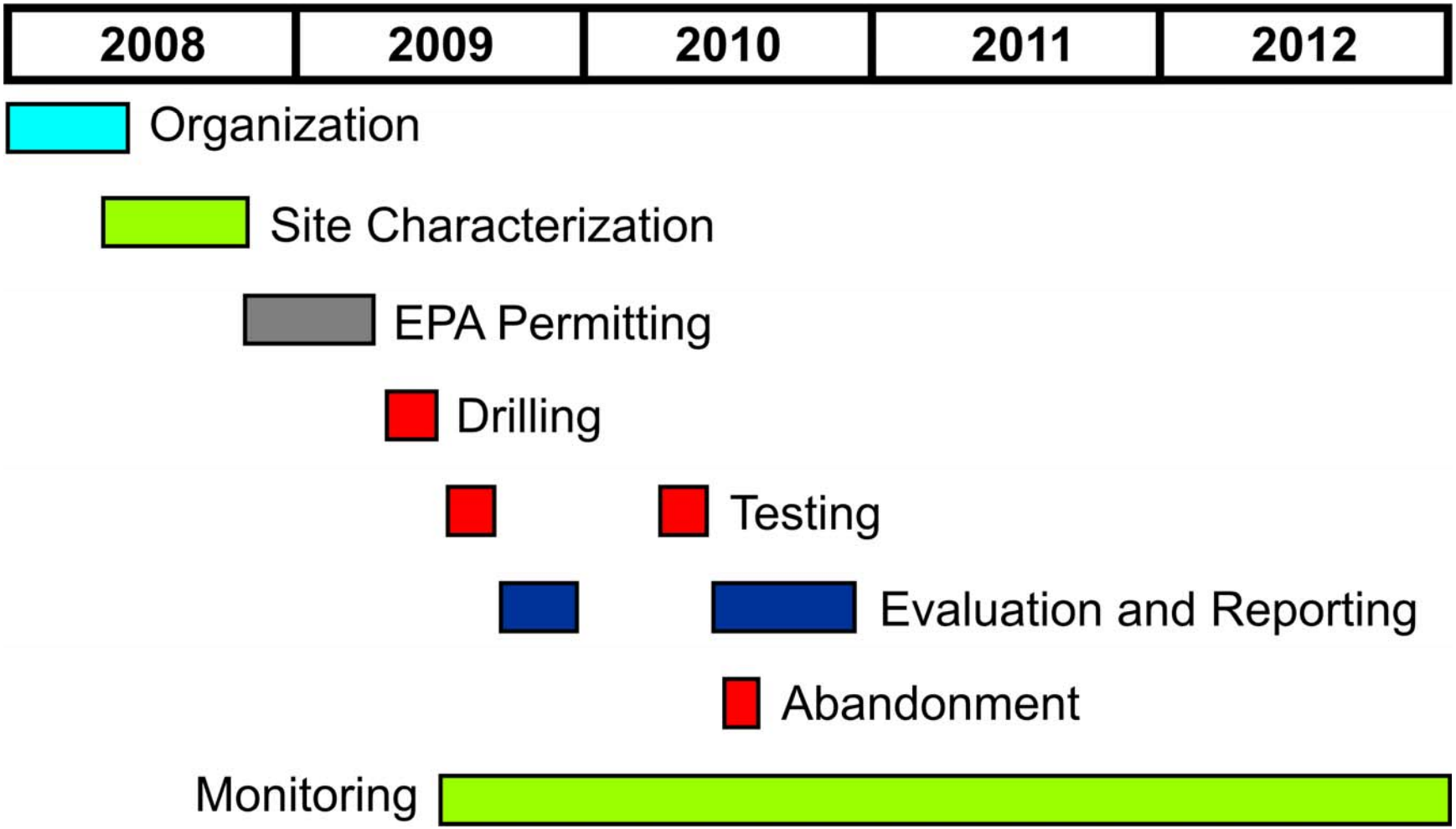


Source: EPA Region 5 (www.epa.gov/r5water/uic/cl1sites.htm);
Kentucky Geological Survey (kgsweb.uky.edu/DataSearching/OilGas)

Project Goals

- **Demonstrate and characterize the potential for the geologic storage of CO_2 in western Kentucky**
  - Target reservoir is the Knox Dolomite
    - Found 3617 ft of Knox Dolomite, including Gunter Sandstone
    - Average porosity 6.7% calculated from logs
    - Successfully injected 18,454 BW brine and 323 T CO_2
  - Evaluate St Peter and Mount Simon Sandstones, if present
  - Test the reservoir potential of the Precambrian Middle Run Sandstone
  - Characterize the reservoir sealing properties of the New Albany Shale, Maquoketa Shale, Black River Group, and non-reservoir intervals in the Knox

Western Kentucky Project Timeline

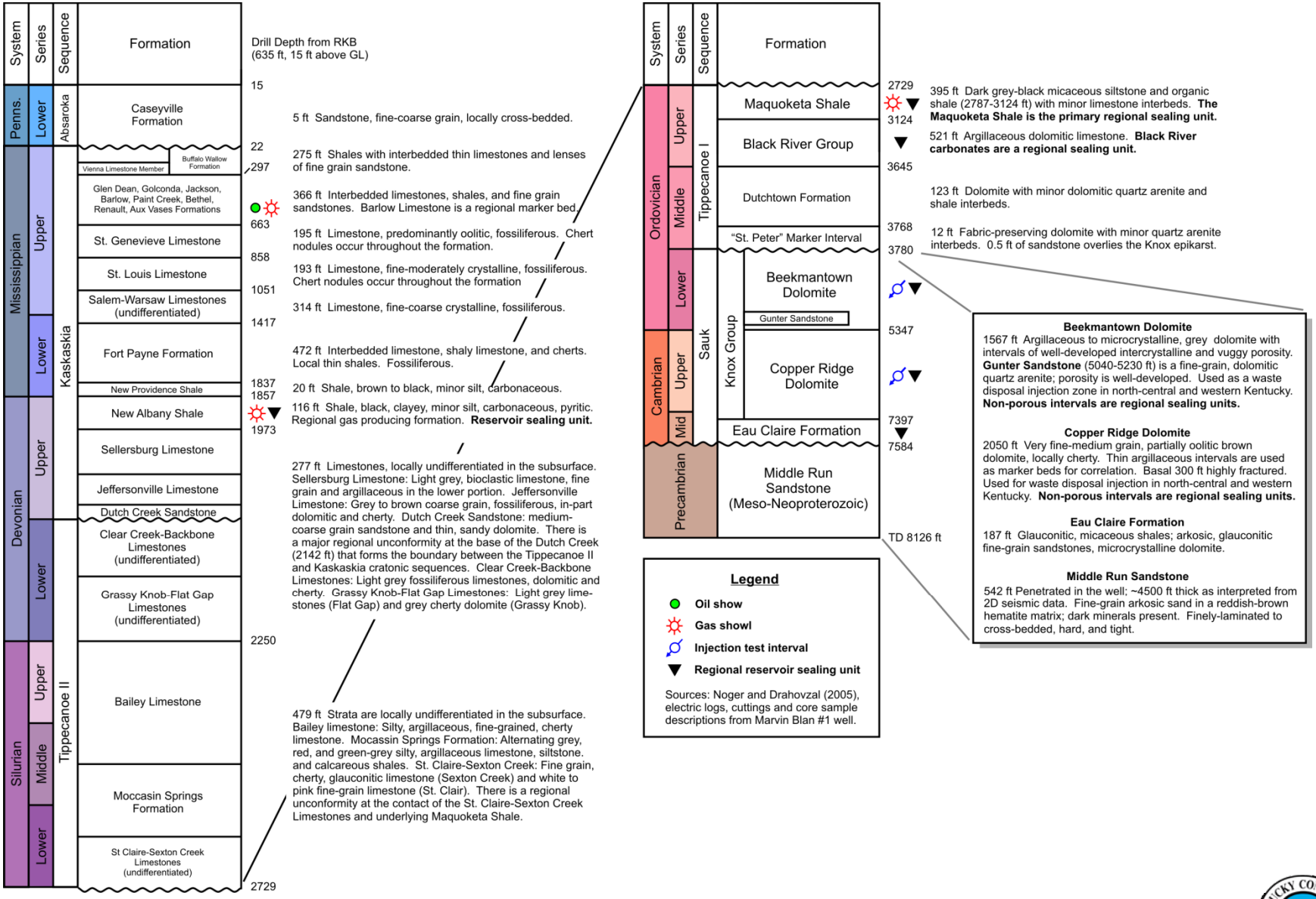


Drilling Marvin Blan #1

- **Drilling commenced on April 24, 2009**
  - Casing cemented at 3660 ft, open hole below to TD
  - Drilled through the Knox Group using $CaCO_3$-based mud to mitigate potential reservoir damage
- **Seven cores cut to test reservoir and seal properties**
  - **Reservoir seals**
    - New Albany Shale (30 ft)
    - Maquoketa Shale (31 ft)
    - Black River Limestone (61 ft)
  - **CO_2 storage reservoirs**
    - Knox Group (three cores, 243 ft total)
    - Precambrian Middle Run Sandstone (30 ft)
- **Reached TD at 8126 ft on June 14**

Drilling Results

- St Peter Sandstone effectively absent: only six inches of sand was present at the Knox unconformity
- The Knox Group was found 85 ft structurally higher than expected and 380 ft thinner
- Eau Claire was considerably thinner than expected, only 187 ft thick including a 61 ft dolomite bed
- Top of the Precambrian Middle Run Sandstone was found 420 ft higher than expected



Strata penetrated in the Marvin Blan #1.

Maquoketa Shale Core

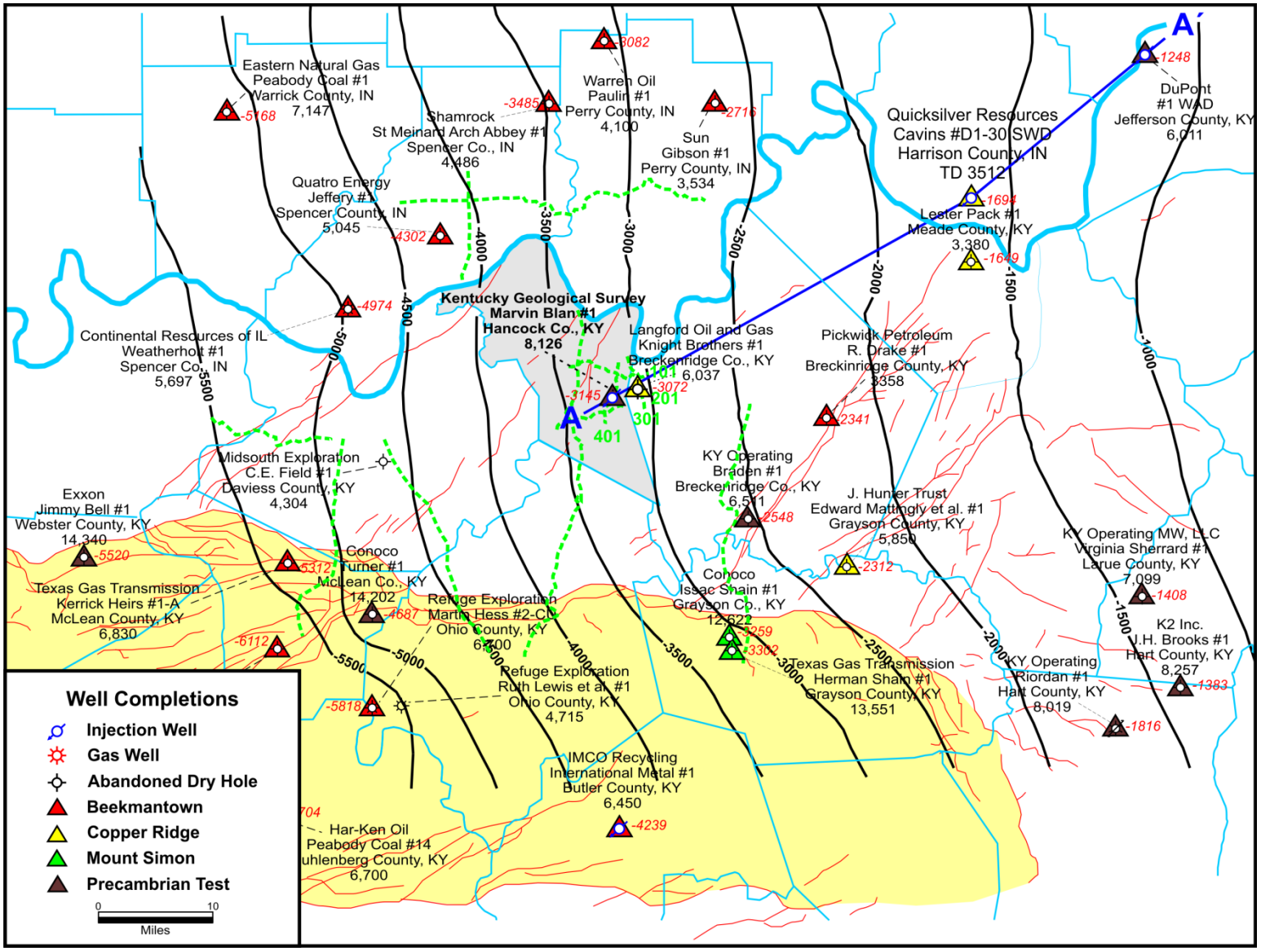
- **Maquoketa Shale was cored 2800-2831 ft to test its reservoir seal properties**
- **Analyses of seal properties**
  - Threshold entry pressure
  - XRD mineralogy
  - Thin section petrography
  - Mechanical properties

St. Peter Sandstone (6 inches)

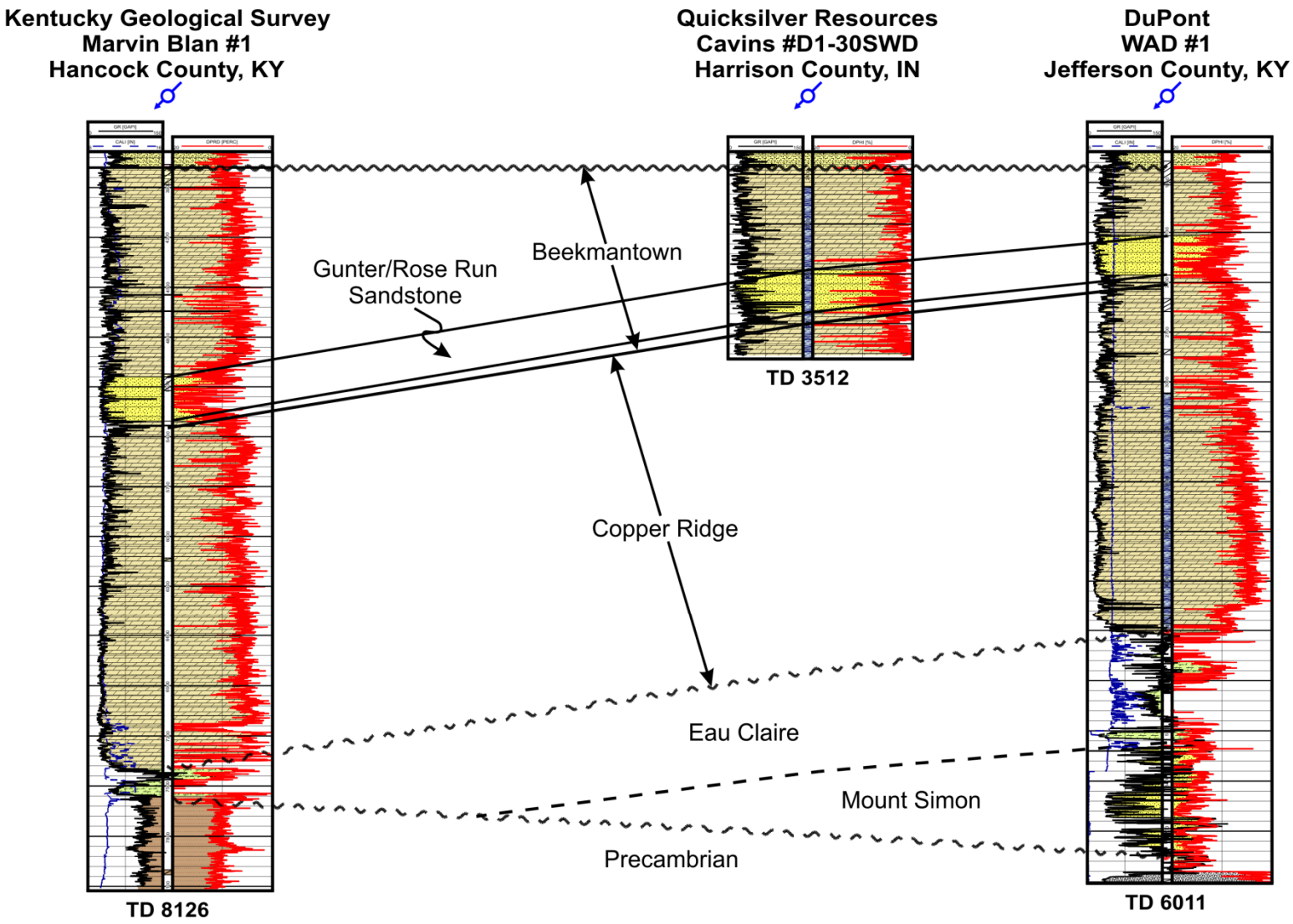
Epikarst infilled with sandstone (3 inches)

Unconformity

Knox Dolomite



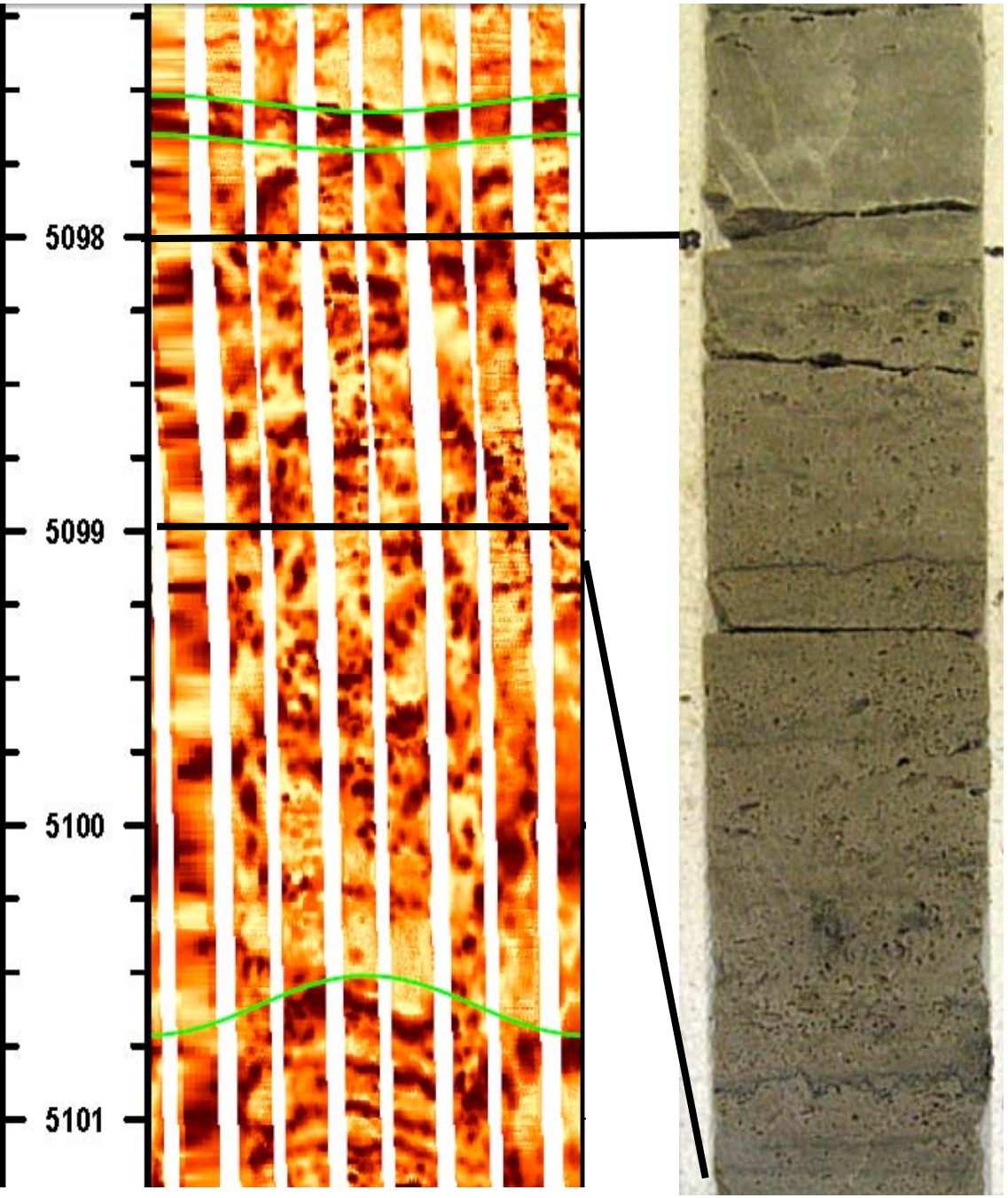
Structural contours on top of the Knox Group.



Stratigraphic correlation of the Knox Group and deeper strata.

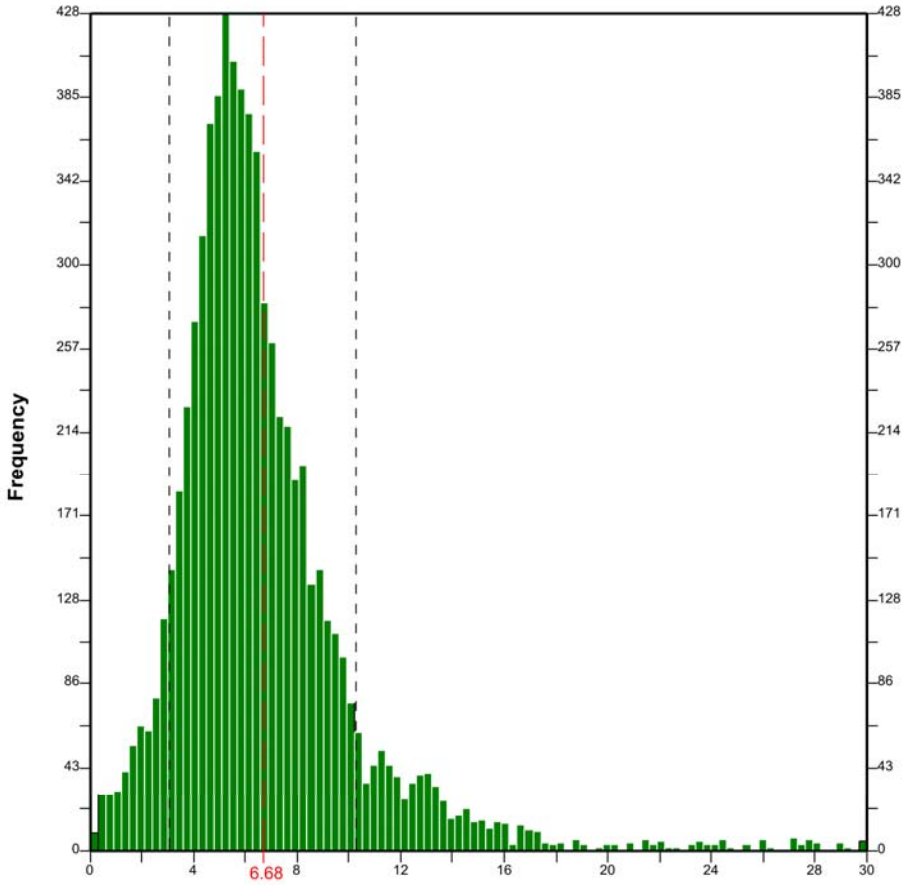
Knox Dolomite Cores

- **Knox Dolomite was cored in three intervals (total 243 ft) to test reservoir properties**
  - "St Peter"-Beekmantown (123 ft)
  - Beekmantown-Gunter (101 ft)
  - Copper Ridge (19 ft)
  - Found porosity system to be a complex of preserved fabric, primary dolomite porosity, vugs, and fractures
- **Extensive analysis program**
  - Routine core analysis
  - Mechanical properties
  - XRD mineralogy
  - CO_2 core flood
  - Thin section petrography
  - Threshold entry pressure

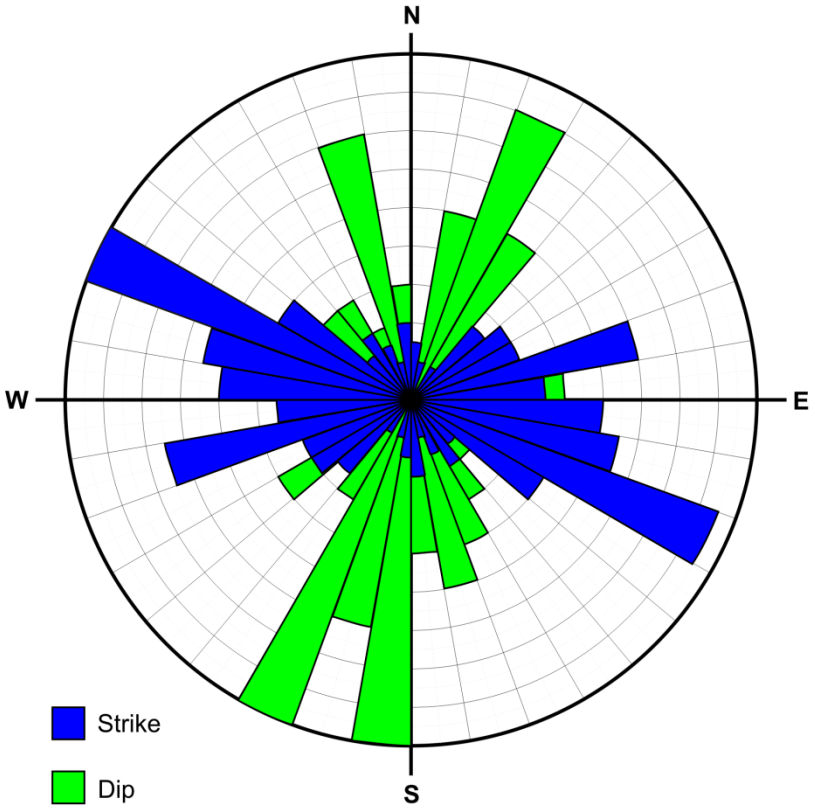


CMI log section and core showing vuggy porosity in the Beekmantown Dolomite

Knox Reservoir Properties

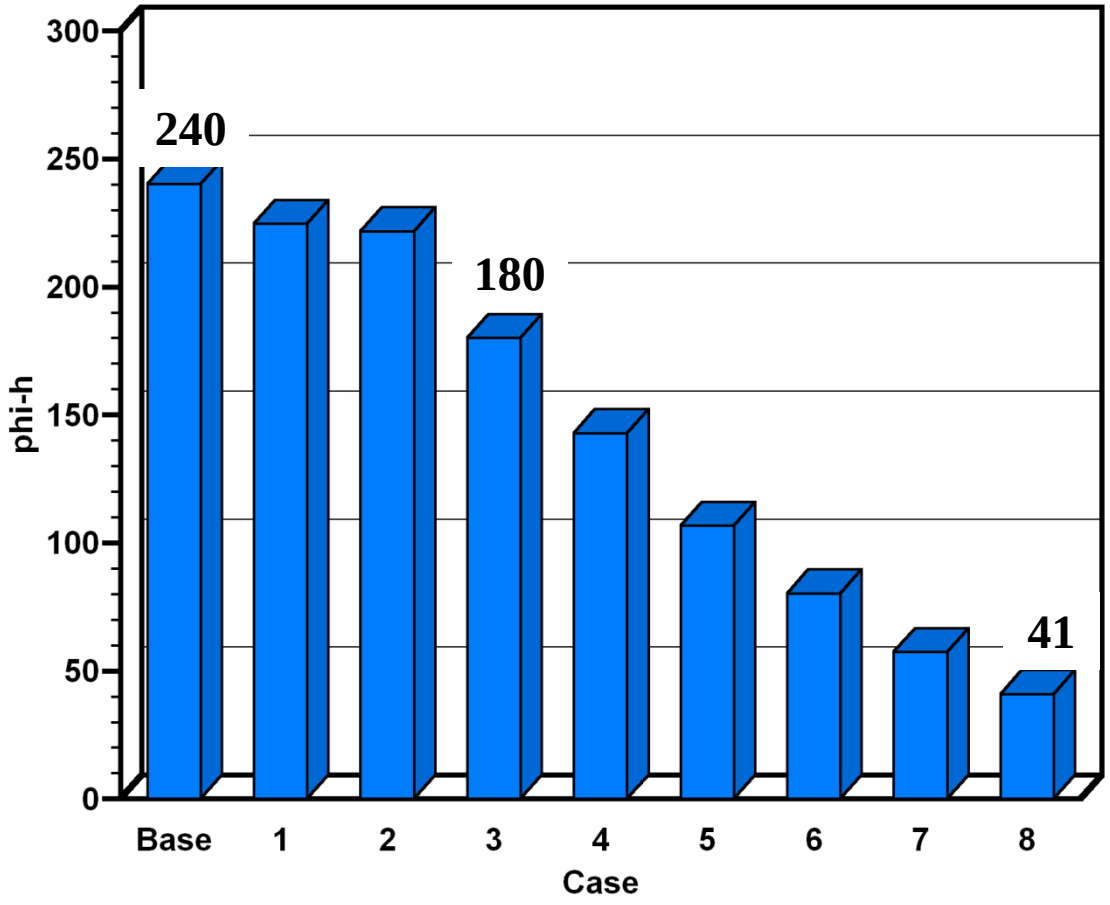


Average Porosity 6.7%

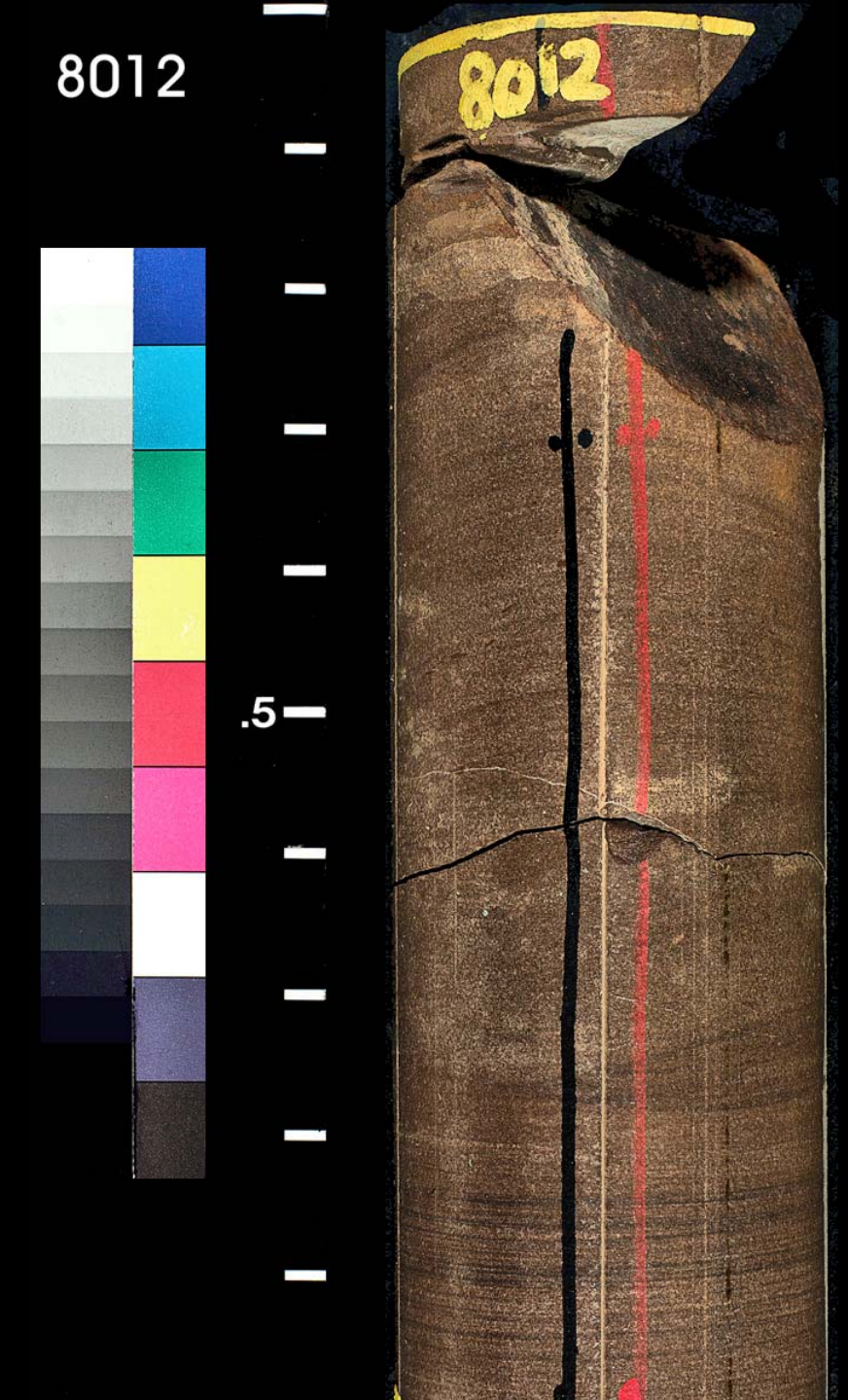


NNW Fracture Trend

Potential Reservoir Volume in the Knox



- Base: all data
- Cutoff cases:
  - 1. caliper > 10½ in.
  - 2. porosity > 20%
  - 3. porosity < 5%
  - 4. porosity < 6%
  - 5. porosity < 7%
  - 6. porosity <8%
  - 7. porosity < 9%
  - 8. porosity < 10%

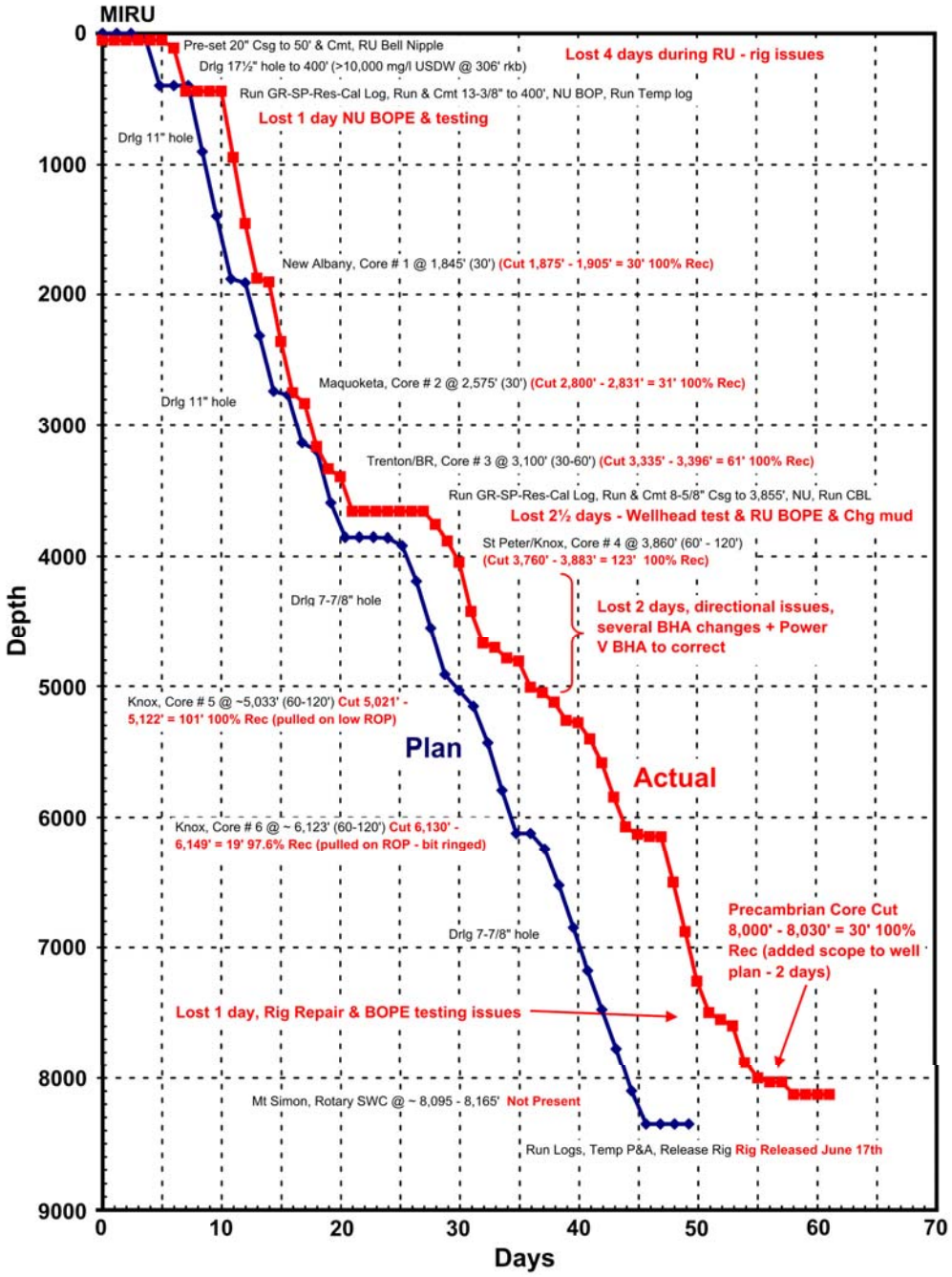


Middle Run Sandstone Core

- **Precambrian Middle Run Sandstone was cored 8000-8030 ft to evaluate its potential as a carbon storage reservoir**
  - DOE-NETL grant for coring and analysis
- **Analysis Program**
  - Routine core analysis
  - Fracture orientation
  - XRD mineralogy
  - Thin section petrography
  - Provenance
  - Zircon age dating
  - Mechanical properties

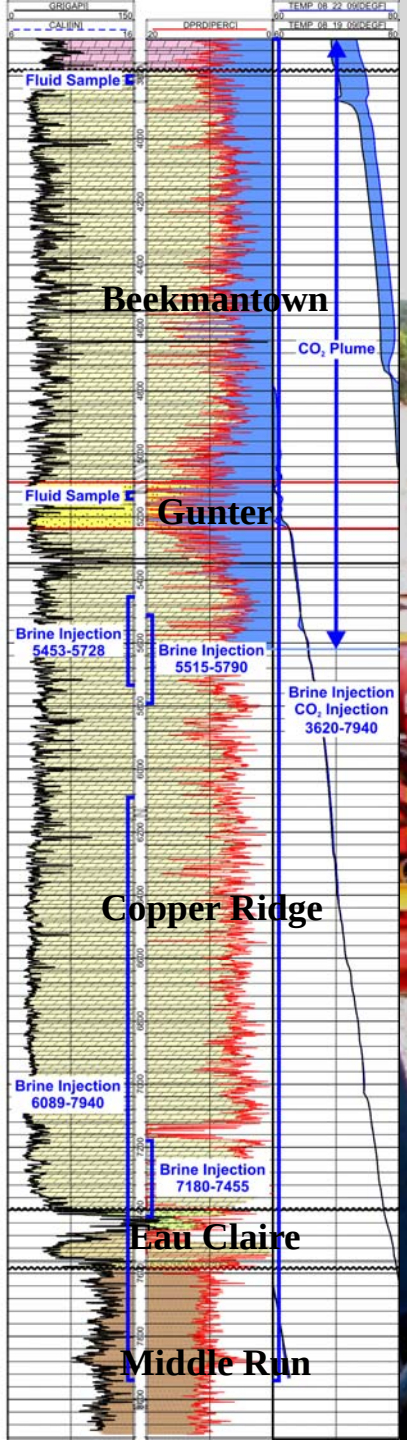
Drilling Challenges

- **Drilling rig and wellhead mechanical failures**
- **Lower than expected penetration rates**
- **Borehole deviation below 3000 ft**
  - Angle built to 5.75°
  - Used Schlumberger Vertical Seeking Power V System to bring borehole back to vertical
- **Lost circulation thief zone at 5581 ft**
  - Successfully controlled with LCM
- **Drilled ~250 ft deeper than necessary to achieve objectives due to missed formation tops**
  - Added two days to drilling



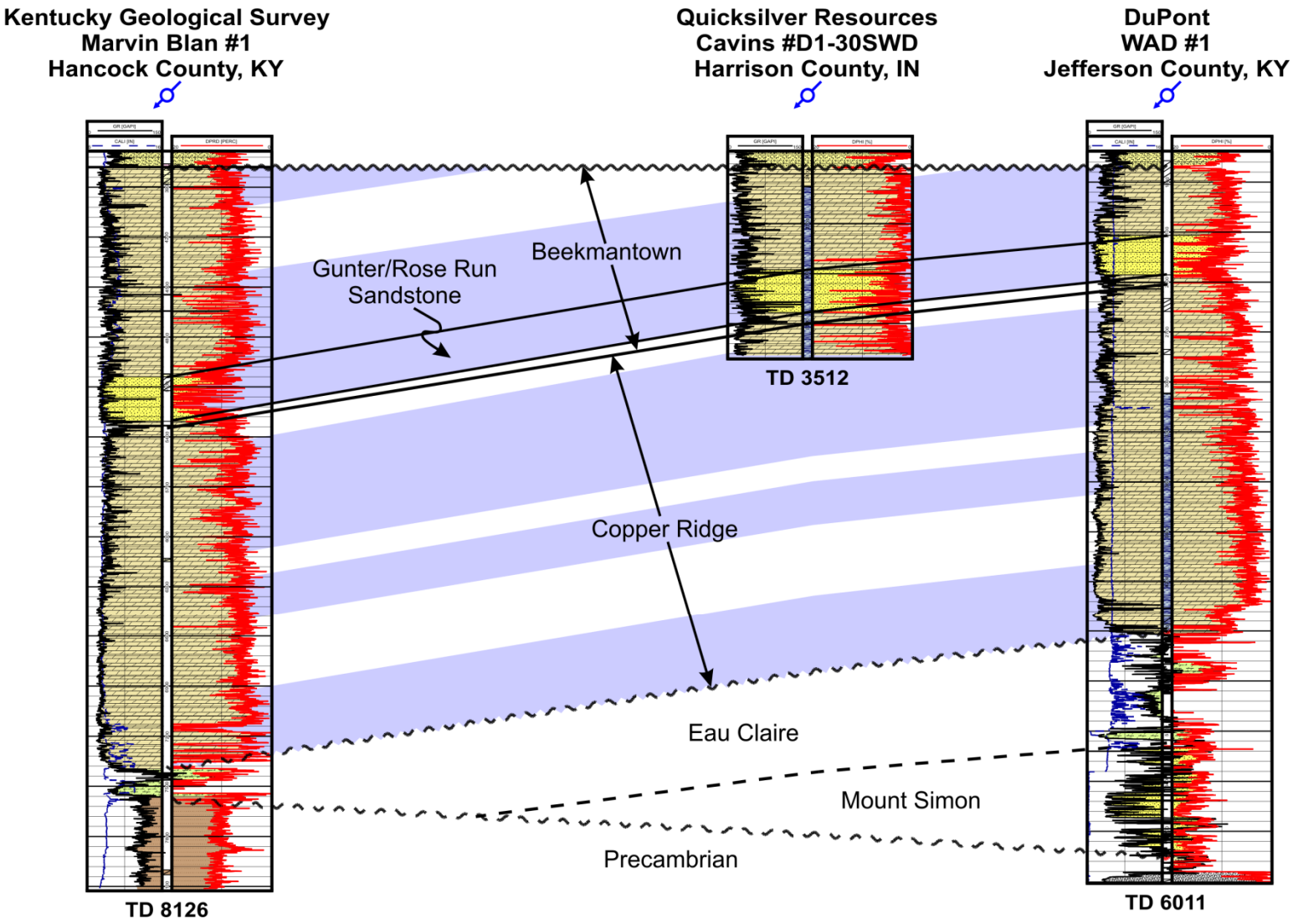
Marvin Blan #1 Depth vs. Days

Drilling took 62 days, 13 days longer than planned, despite a shallower than planned TD.



Injection Testing

- **Three tests with straddle packers**
  - basal Copper Ridge: 218.8 BW, broke down at 0.9 psi/ft gradient and took water on vacuum
  - upper Copper Ridge: two tests, total 5192.7 BW, lost seal due to communication through formation porosity system around packers
- **Two tests with single packer**
  - Copper Ridge below 6089 ft: 2190 BW brine,1212.1 BW with borax tracer
  - Full wellbore below 3620 ft: 7075.7 BW with borax tracer
  - Injection rates to 14 BPM at 285-500 psi wellhead pressure
- **Found 70% of water was injected above the Copper Ridge**



Regional correlation of Knox injection zones

CO_2 Injection

- Injected a total of 323 Tons of CO_2 (1765 bbl or 5646 mcfg) below a packer set in casing at 3603 ft
- Limited to 4.1 BPM rate due to pump limitations
- Wellhead pressure 936 psi, bottomhole pressure 1754 psi
- Post-injection flushed with 4568 BW brine
- Long-term downhole pressure gauge in place to monitor pressure fall-off pending re-entry for additional tests

Additional Work

- **Testing planned for 2010, funded by DOE research award of $1.6 million**
  - Additional brine, possibly additional CO_2 injection
  - 3D VSP to image injection plume
  - Knox reservoir evaluation
- **Plug and abandon the Marvin Blan #1 in compliance with State and EPA regulations**
- **Remediate drillsite**
- **Groundwater and soil gas monitoring through 2012**

Acknowledgements

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