A Pilot Study to Assess Baseline Groundwater Chemistry for the Berea Sandstone and Rogersville Shale Play Area, Eastern Kentucky

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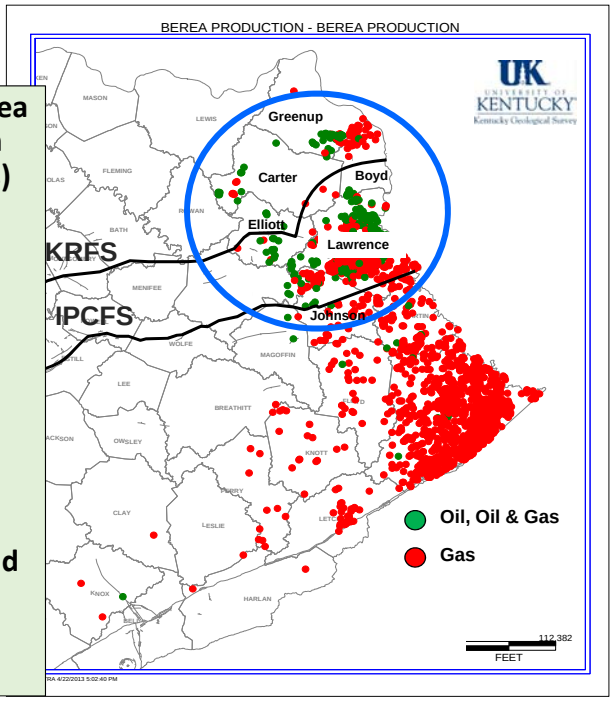
Berea Play

- **Historic Devonian Berea Sandstone production mostly gas (red circles)**
- **Since 2010 active oil play in Elliott, Carter, Greenup, Lawrence, Johnson, and Boyd Counties**
- **Approximately 70 horizontal oil wells completed (green circles)**
- **KGS Energy section and partners currently studying Berea petroleum system**



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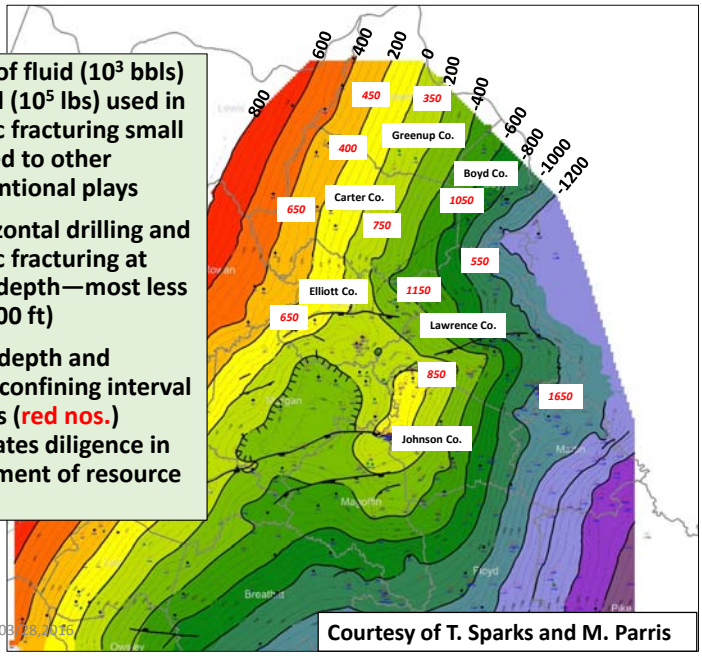
Berea Sandstone Structure

- Volume of fluid (10^3 bbls) and sand (10^5 lbs) used in hydraulic fracturing small compared to other unconventional plays
- But horizontal drilling and hydraulic fracturing at shallow depth—most less than 2,000 ft)
- Shallow depth and variable confining interval thickness (red nos.) necessitates diligence in development of resource



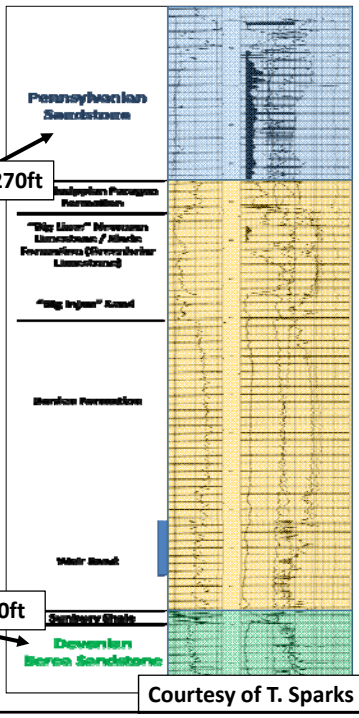
Courtesy of T. Sparks and M. Parris

Eastern Kentucky Mid-Upper Paleozoic Stratigraphy

Surface rocks and aquifers mostly in Pennsylvanian Sandstone

Confining interval (100s ft) includes interbedded Mississippian shale, mudstone, siltstone, and limestone

Oil reservoir is Upper Devonian Berea Sandstone



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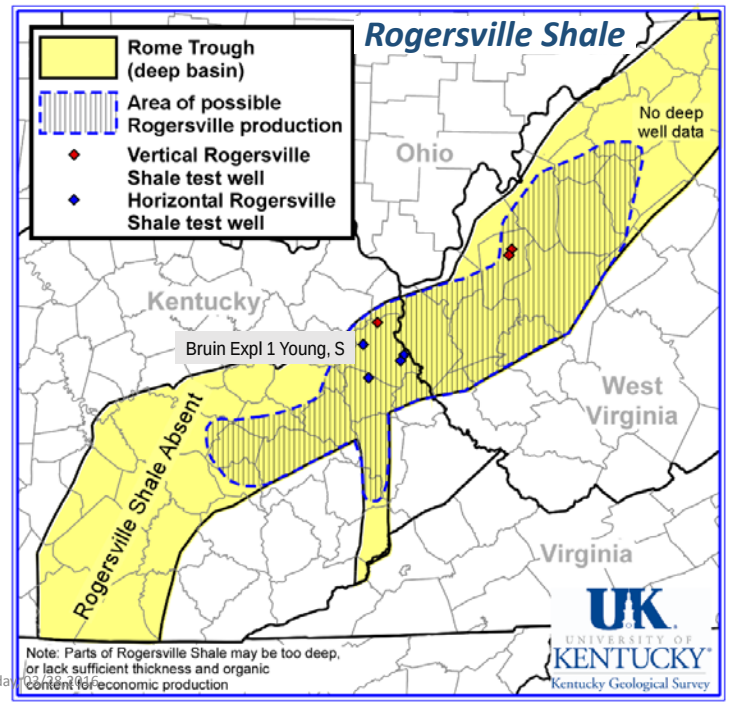

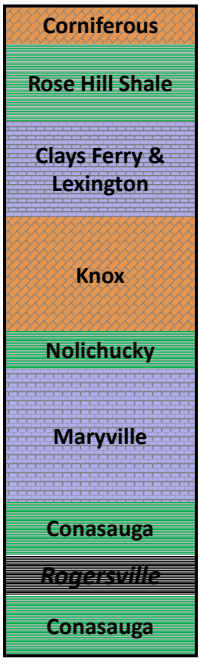

Bruin #1 Young Lawrence County

- First vertical well to test zone
- Slickwater frac (677,000 gal fluid, 600,000 lb sand)
- Tested 115 Mcf and 19 bo (5/6/2014)
- Shut-in 5/30/2014
- New permit for horizontal lateral

TD 11,967, Rome

Courtesy o D. Harris

Rogersville Shale Summary

- New deep unconventional reservoir is being explored in E. Kentucky and West Virginia
- Very early stage of development; economics uncertain in today's market
- 5,000 to 10,000 ft deep in eastern Kentucky
- 2–4.8% total organic carbon in parts, and has generated gas & condensate
- Up to 1,100 ft thick in Kentucky, but limited to deeper parts of Rome Trough- and not all is organic rich
- Opportunity to gather baseline ground-water prior to any large-scale development, employ best practices to ensure prudent development

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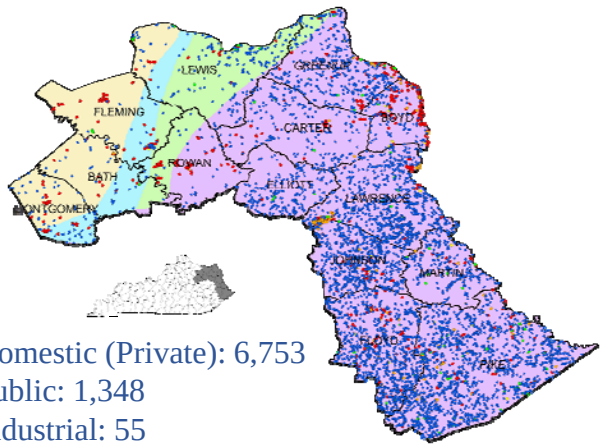
Courtesy of D. Harris

Existing water wells

Type of Well
- Domestic
- Public
- Industrial
- Monitoring
- Irrigation

Physiographic Region
- Eastern Coal Field
- Eastern Pennyroyal
- Knobs
- Outer Blue Grass



Domestic (Private): 6,753
Public: 1,348
Industrial: 55
Monitoring: 3,932
Agriculture (Irrigation or Livestock): 114

TOTAL: 12,202

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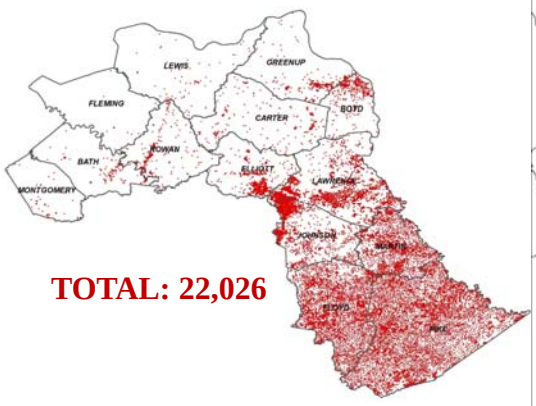
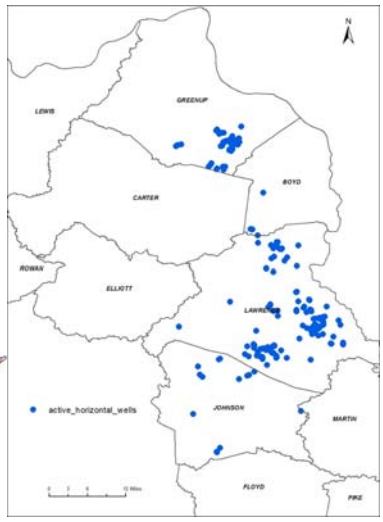
Existing vertical oil and gas wells



TOTAL: 22,026

Active horizontal wells



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Advanced Analytical Methods

RPSEA 11122-45

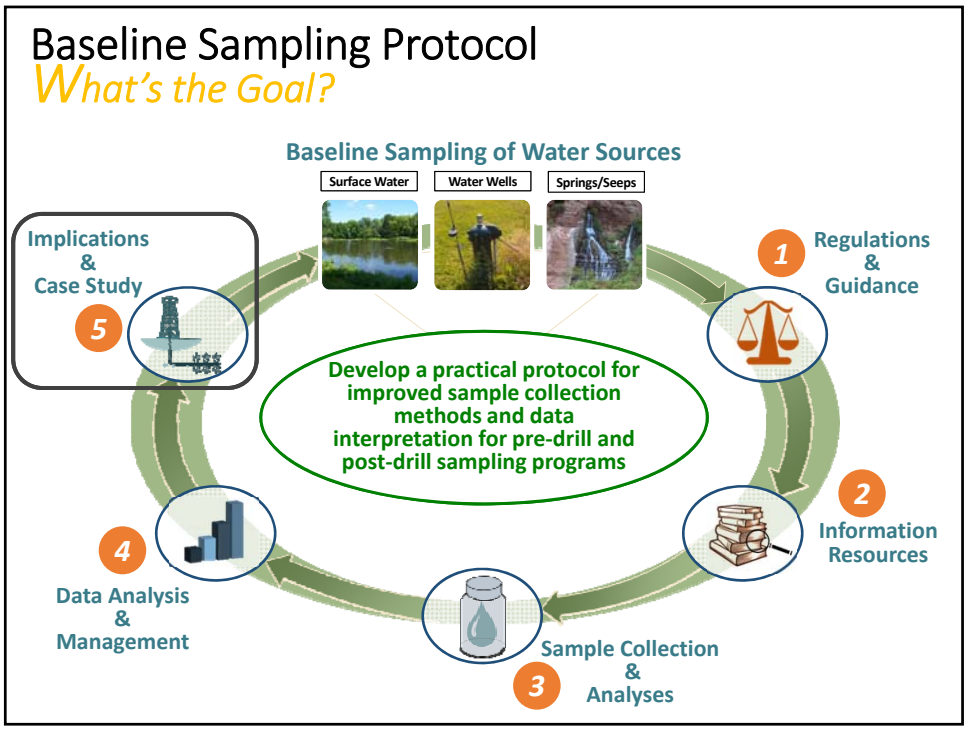
- 3-Year project in 2 phases (currently in Phase II)
- $3.5M from DOE/RPSEA, $900k in cost share

RESEARCH FOCUS ON THREE KEY ENVIRONMENTAL ISSUES:

Baseline Sampling and Stray Gas Investigation — GSI ENVIRONMENTAL

Advanced Analytics for Air Emissions — TEXAS A&M Institute of Renewable Natural Resources

Produced Water Characterization — TEES GLOBAL PETROLEUM RESEARCH INSTITUTE


Baseline Sampling Protocol
What's the Goal?
Baseline Sampling of Water Sources
Surface Water
Water Wells
Springs/Seeps
Implications & Case Study
5
1 Regulations & Guidance
Develop a practical protocol for improved sample collection methods and data interpretation for pre-drill and post-drill sampling programs
2 Information Resources
4 Data Analysis & Management
Sample Collection & Analyses
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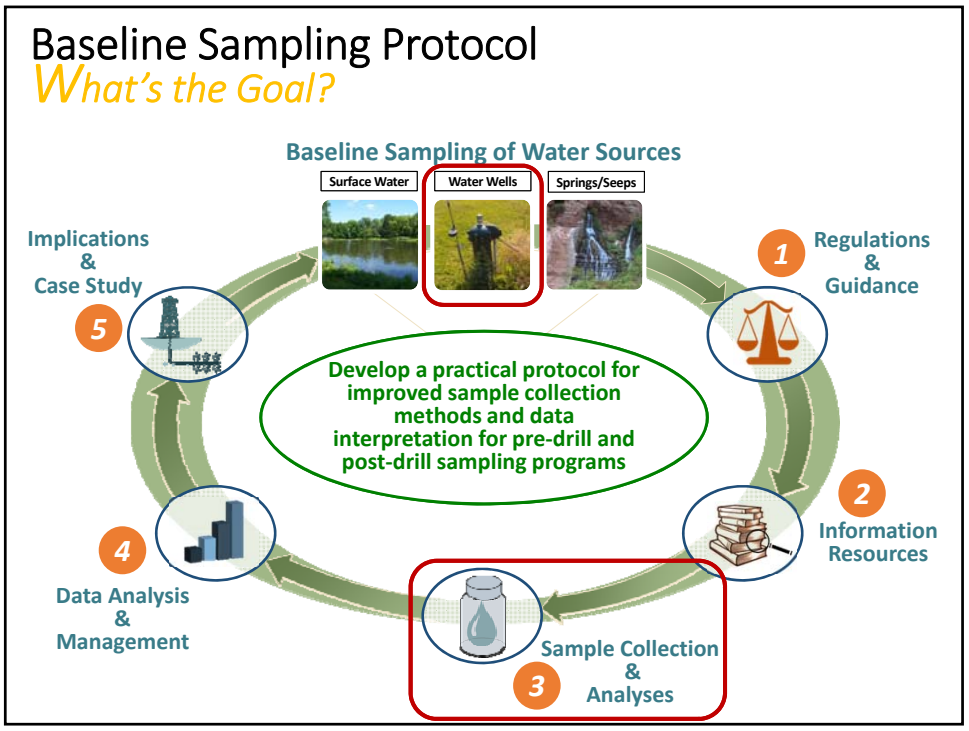
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Scope of Work:

1. **Select up to 50 water wells in the study area, including Greenup, Carter, Boyd, Lawrence, and Johnson Counties.**

2. **Follow the Baseline Sampling Protocol to collect water samples, which are analyzed for :**
   - Dissolved gases
   - Major cations, anions, and metals
   - General water quality parameters
   - Carbon and hydrogen Isotopes
   - BTEX/TPH

Scope of Work

3. **Analyze the resulting dataset for:**

   - Spatial variability in dissolved gases
   - Evaluate relationship between water quality parameters and methane occurrence
   - Identify origin of methane

Locating Water Wells

With help from UK Agricultural Cooperative Extension Office, contact well owners and to get permission to sample

Inspect well-sites

Photo by Bart Davidson

https://extension.ca.uky.edu/county

Field Sample

Collect well information

Purge

Collect water samples

Deliver water samples

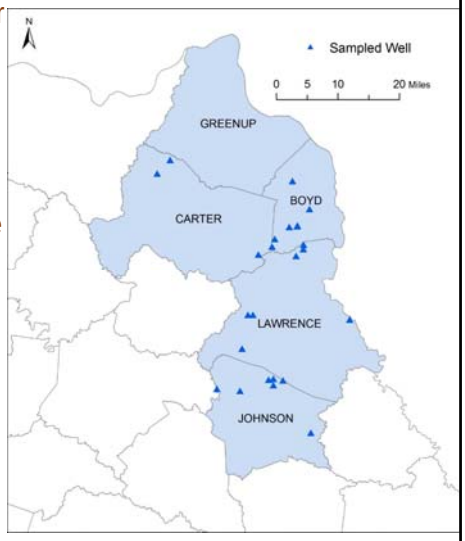
Progress…

Twenty seven wells sampled so far

Samples are sent to the KGS lab and Lancaster Laboratories for analysis.

Analysis results indicate half of the sampled wells from the first two weeks have methane concentration above 1 mg/L

Wells with methane > 1 mg/l samples are being sent to Isotech Laboratories for carbon and hydrogen isotope analysis.



Field sampling will continue for the next several weeks

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Acknowledgements

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We thank UK Agricultural Cooperative Extension Office for assistance in contacting well owners.

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ENVIRONMENTALLY FRIENDLY DRILLING providing unbiased science to address environmental issues

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