Update on the Berea Sandstone Oil Play in Kentucky

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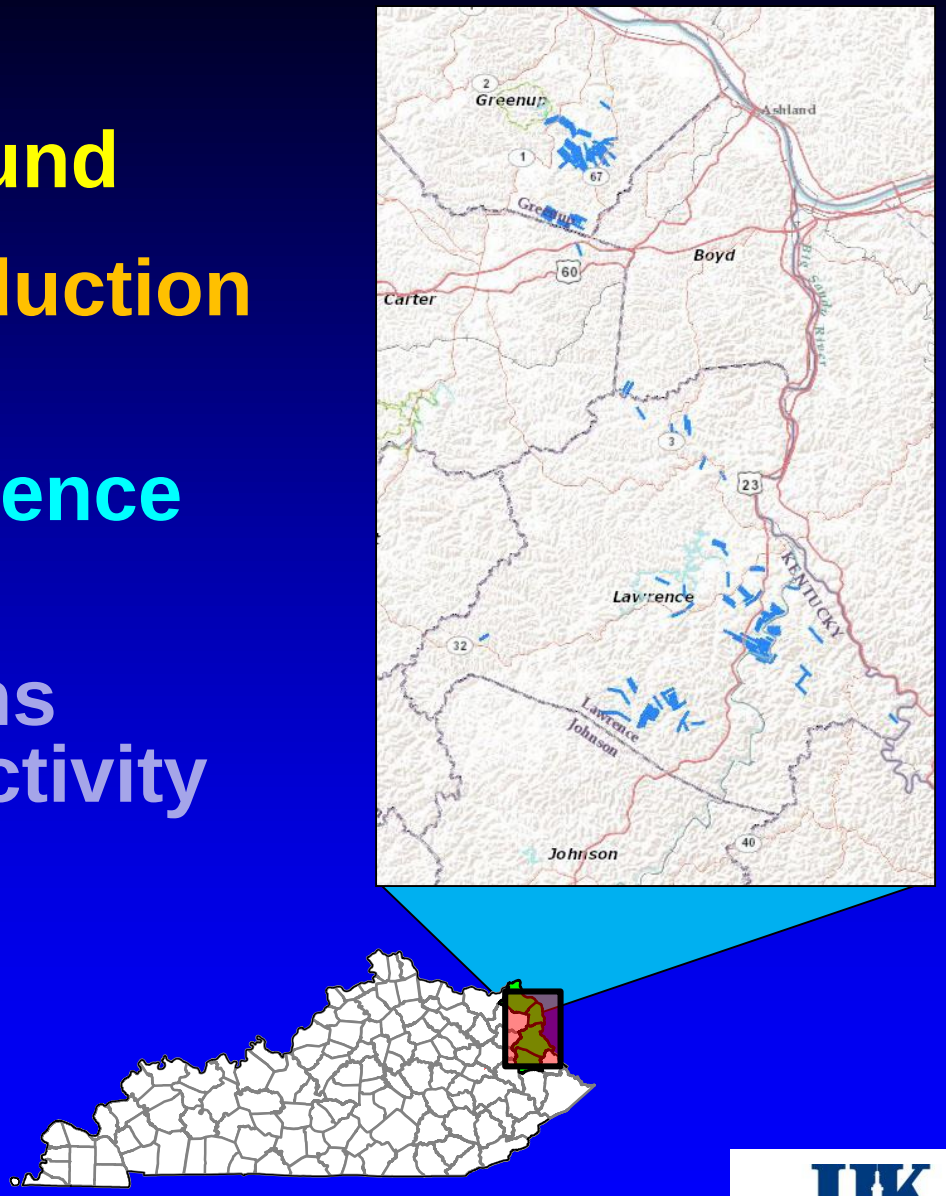
Update on the Berea Ss

- Berea Ss background
- Recent KY oil production trends
- Greenup and Lawrence County update
- Research questions raised by recent activity
- Berea Sandstone Consortium



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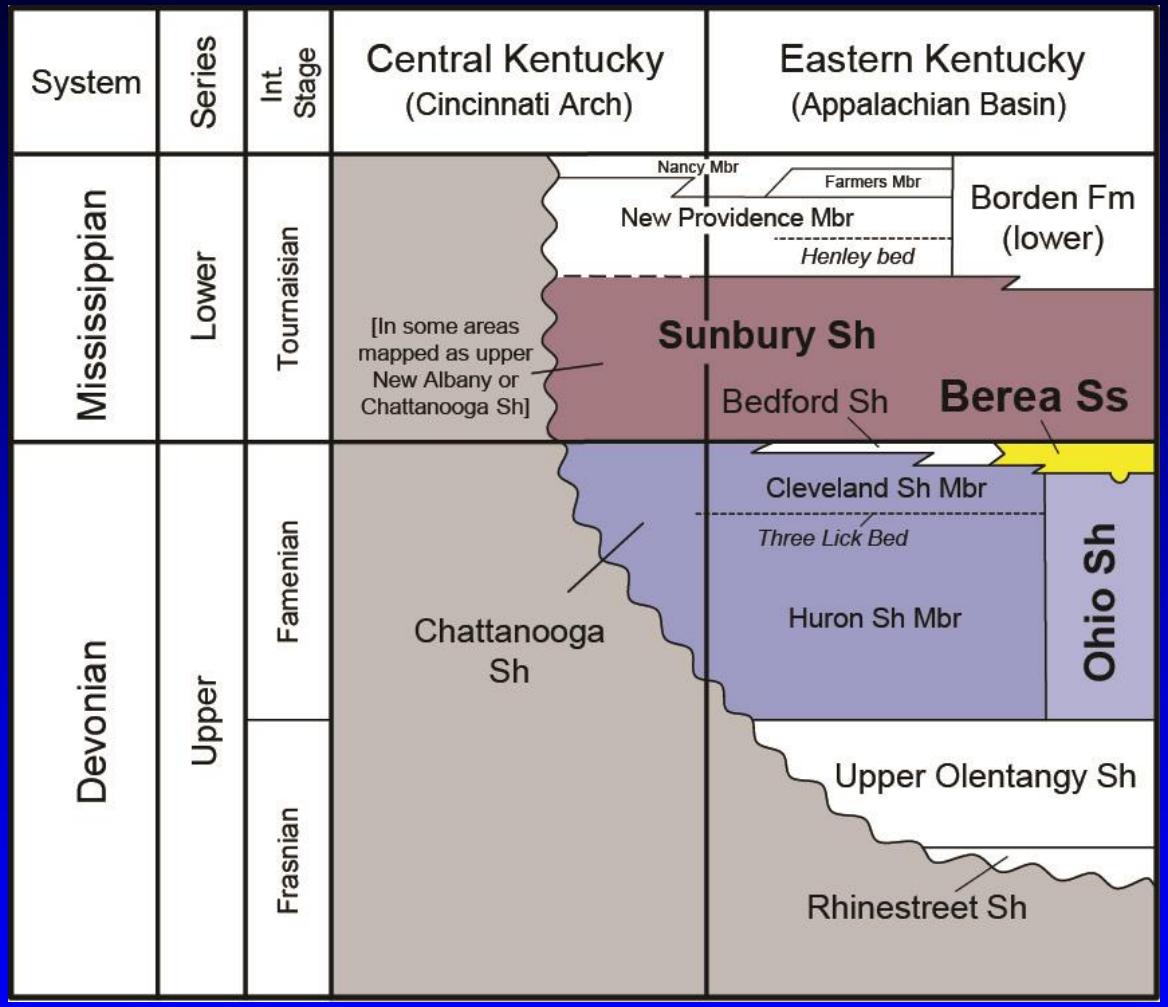
Background



The Berea Ss is an upper Devonian "tight sand" (siltstone across much of KY)

- **Interfingers with the Bedford Sh**
- **Overlain by the Sunbury Sh and underlain by the Ohio Sh (potential source rocks)**

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Background

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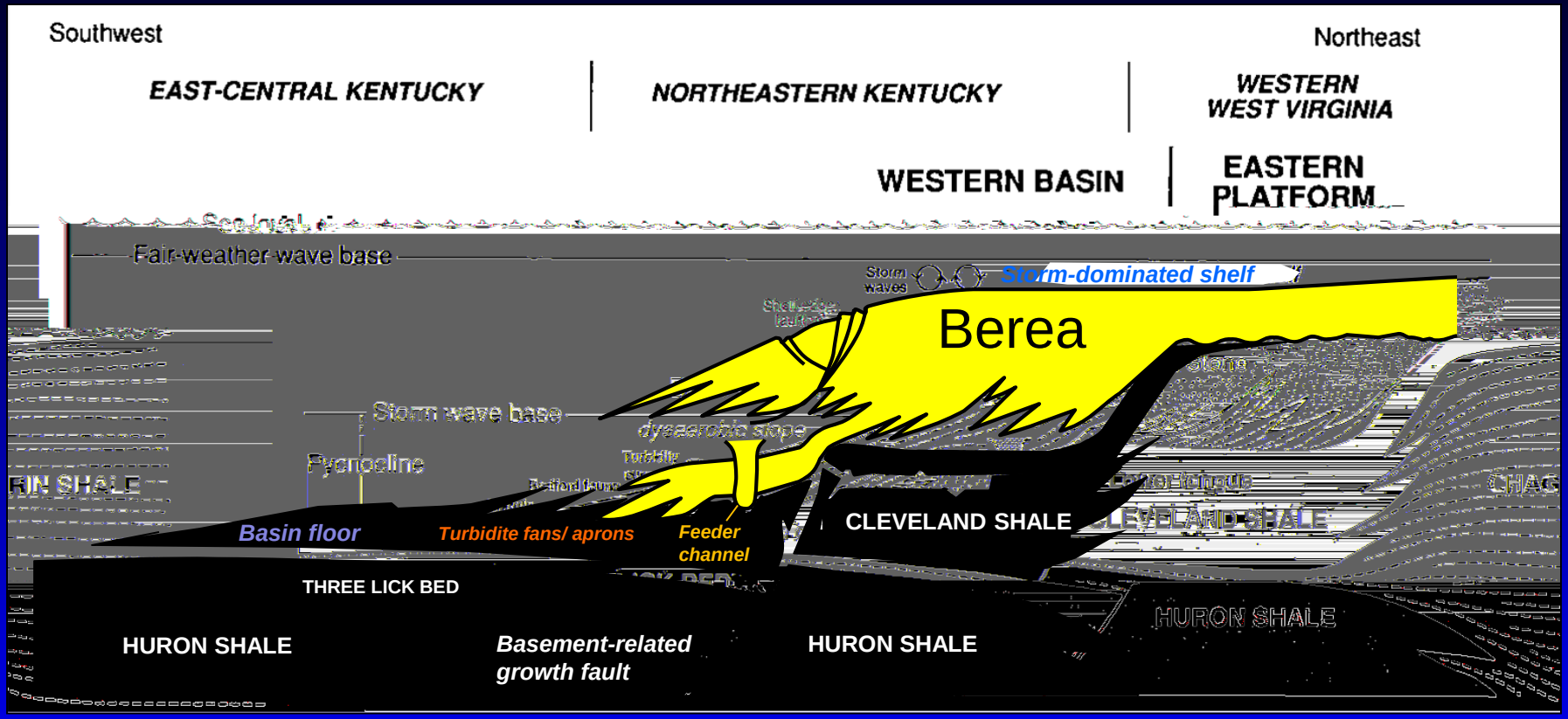

(from Pashin and Ettensohn, 1995)

Based on existing models (e.g., Pashin and Ettensohn, 1995), Ky reservoirs could be developed in storm shelf and slope facies including turbidite fans and channels.

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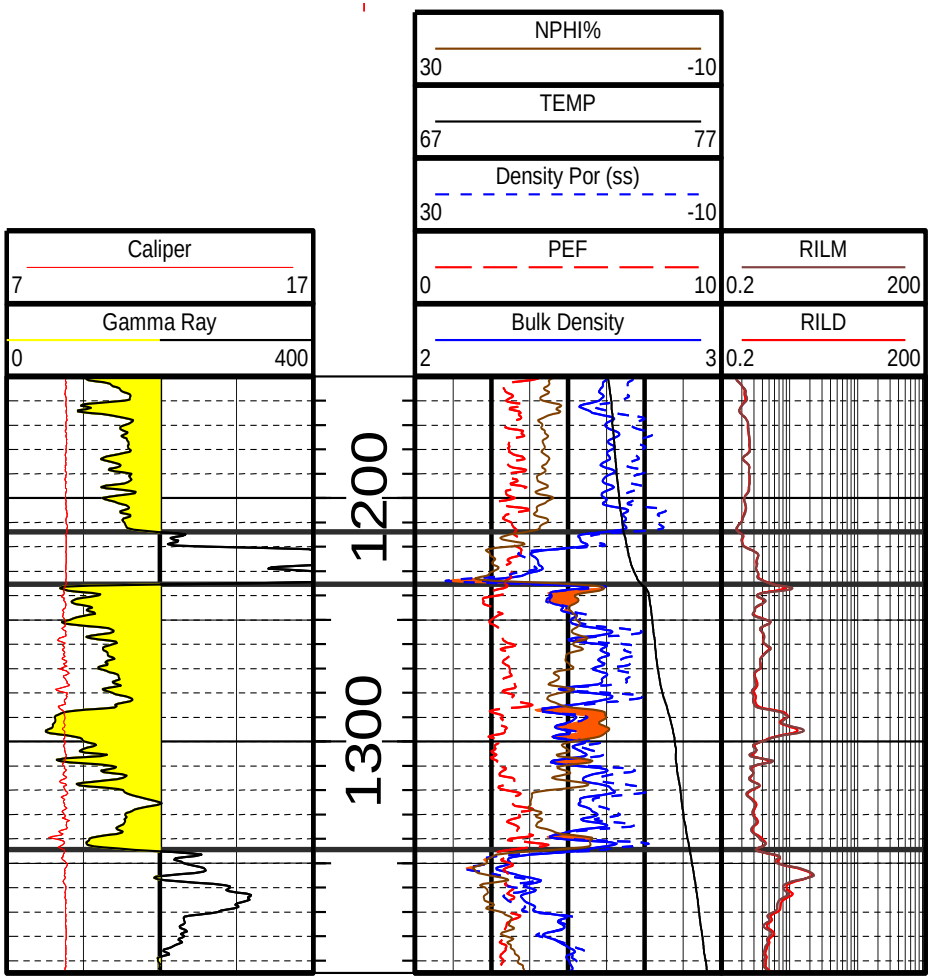
Background

Eastern KY type Log, Lawrence County

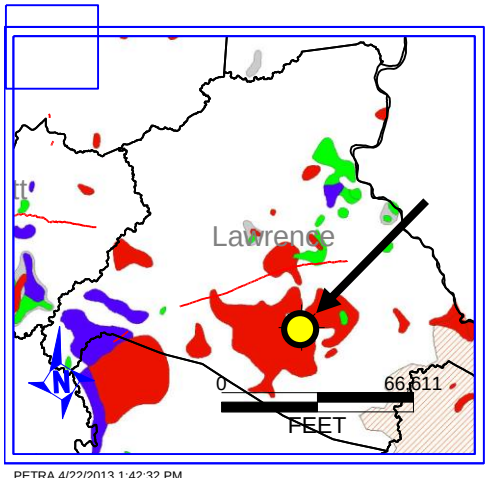


Sunbury Sh

Berea Ss/Bedford Sh

Ohio Sh

137383
APP ENERGY 1 MOORE, C
Lawrence
KY



Berea is a classic low-permeability reservoir

(perms are generally less than 2 md based on available core)

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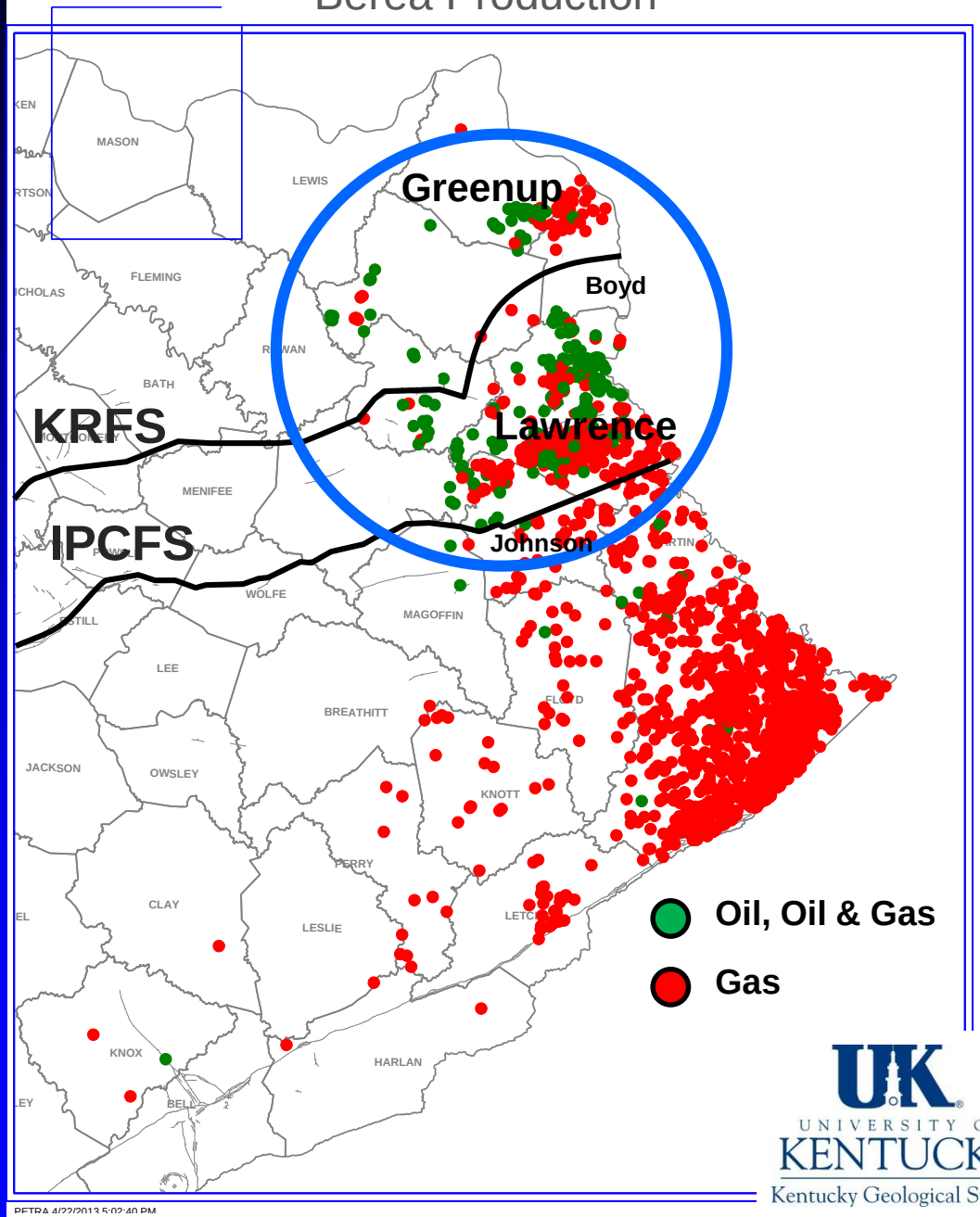
Background

Berea Hydrocarbon Distribution

- Oil production limited to NE KY
- Shallower part of basin (north of Rome Trough)
- 1,898 Berea completions (mostly verticals) in KGS database

➡ 58 horizontal oil completions since 2011

Berea Production



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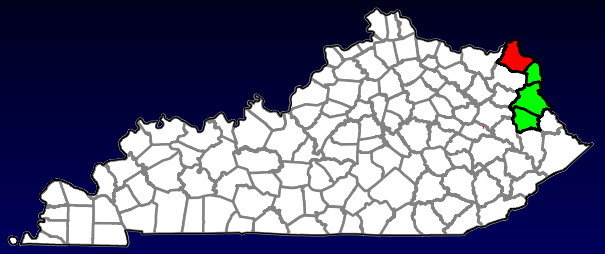
Recent Production Trends

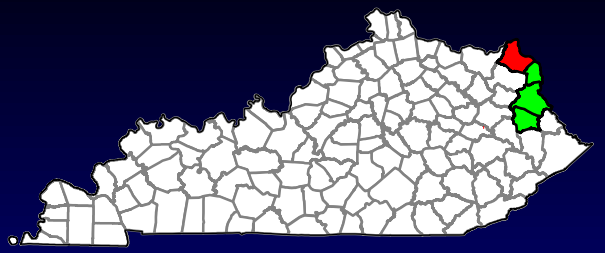
Greenup County



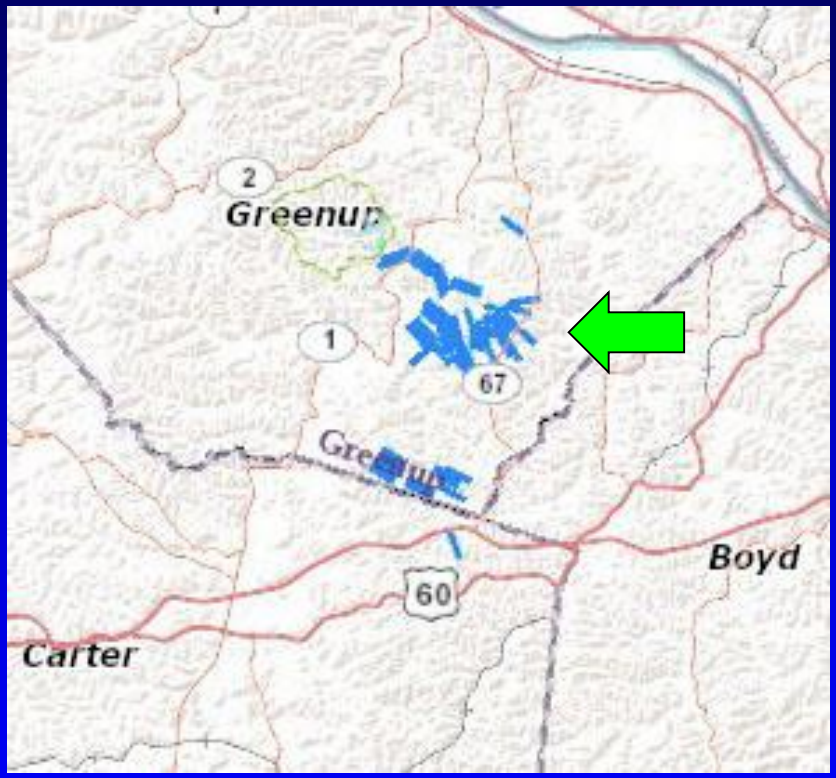
- **Operator: Nytis Exploration**
  - First completion in March, 2011
  - 51 horizontal wells permitted
  - Completion data submitted for 28 wells
- True vertical depths: 979-1362 ft (avg = 1132 ft)
- Stratigraphic traps
- Average lateral is 2,500 ft, oriented SE-NW (downdip)
- Multistage hydraulic fracture stimulation

Recent Production Trends

Greenup County



- 17 wells with IP's as of March, 2014
- Reported oil IP's:
  - 12-70 BOPD
  - 7-37 MCFGD
- Water IP:
  - 15-114 bbl/day
- WOR (water/oil):
  - 1.3-6.0 (avg = 3)



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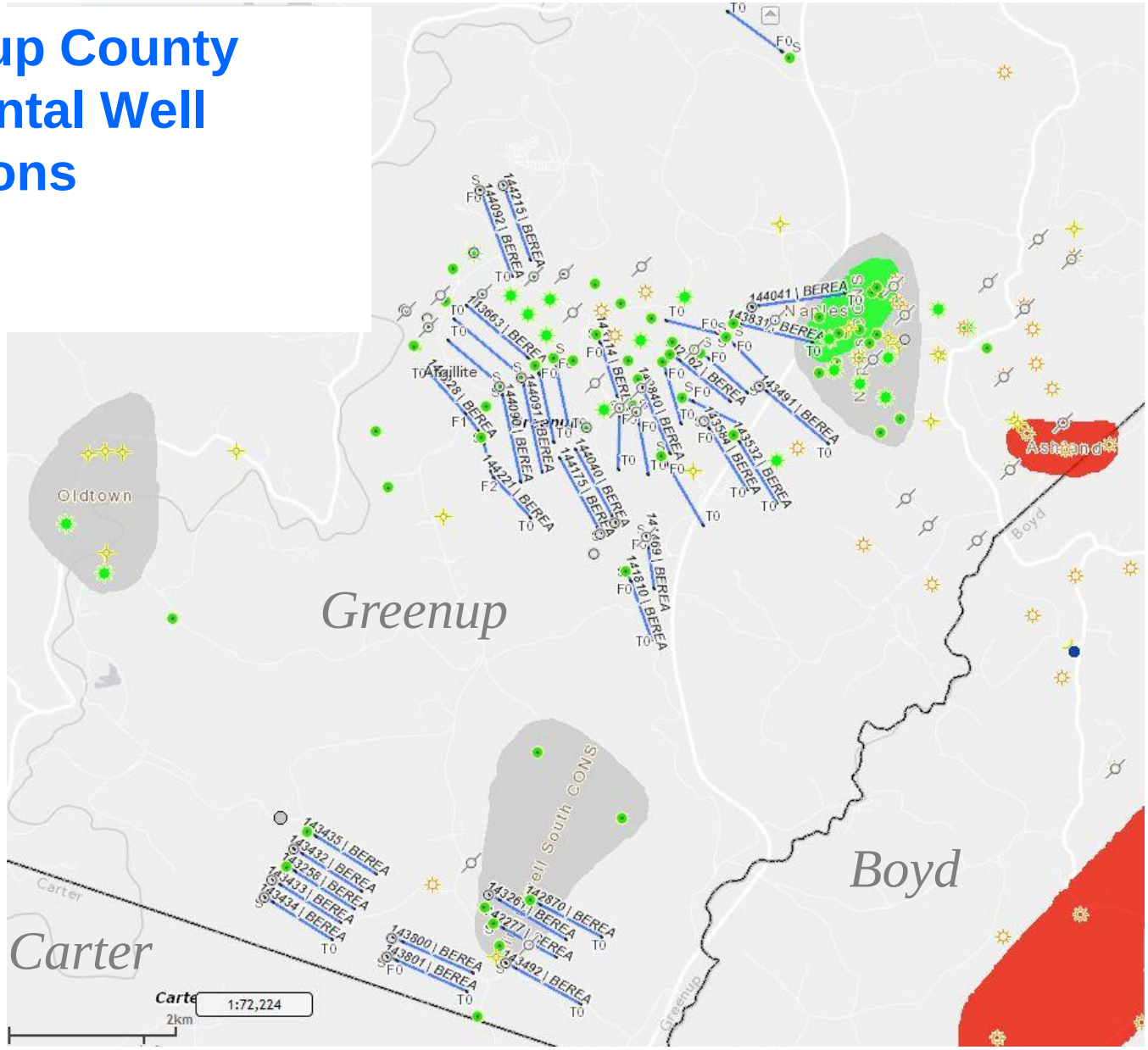
Recent Oil Production Trends

Greenup County Horizontal Well Locations

2014



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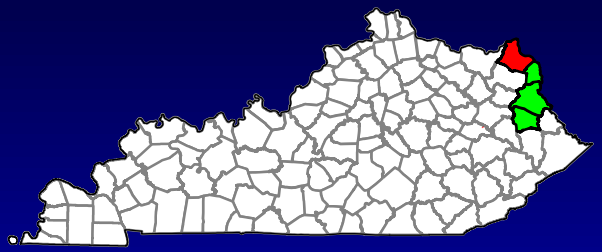
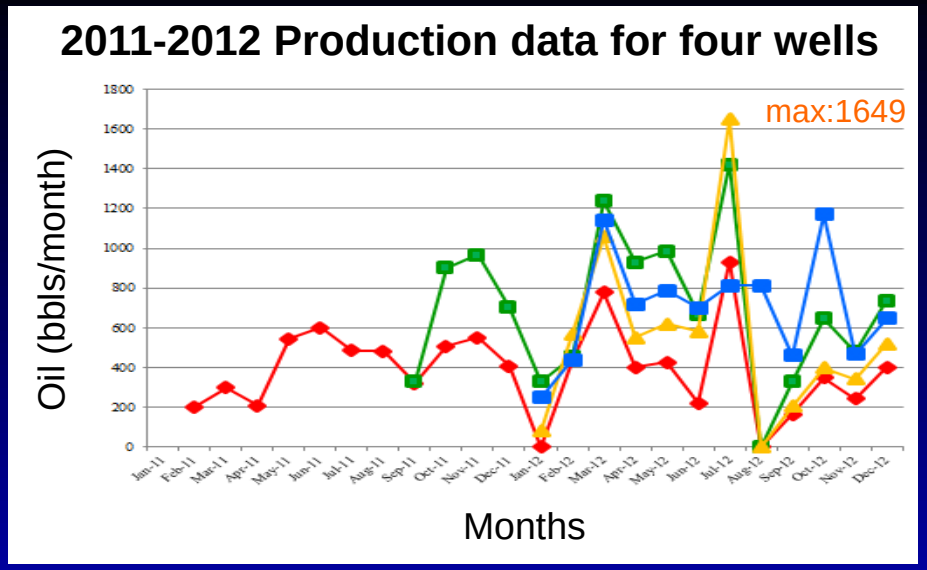
Recent Production Trends

Greenup County





Oil production data for four wells:

	Avg bbls/month	First 6 months bbls/month	Since bbls/month
Brice Sheperd 1	389	389	389
Emory Patton Heirs 2	695	614	744
Emory Patton Heirs 3	548	576	519
Brice Sheperd Heirs 3	701	673	729

Avg = 583 bbls/month

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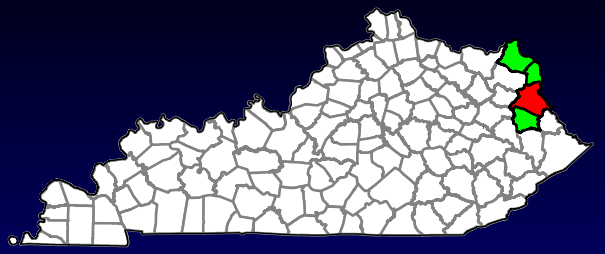
Recent Production Trends

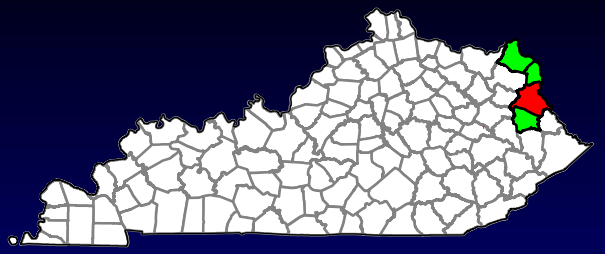


Lawrence County

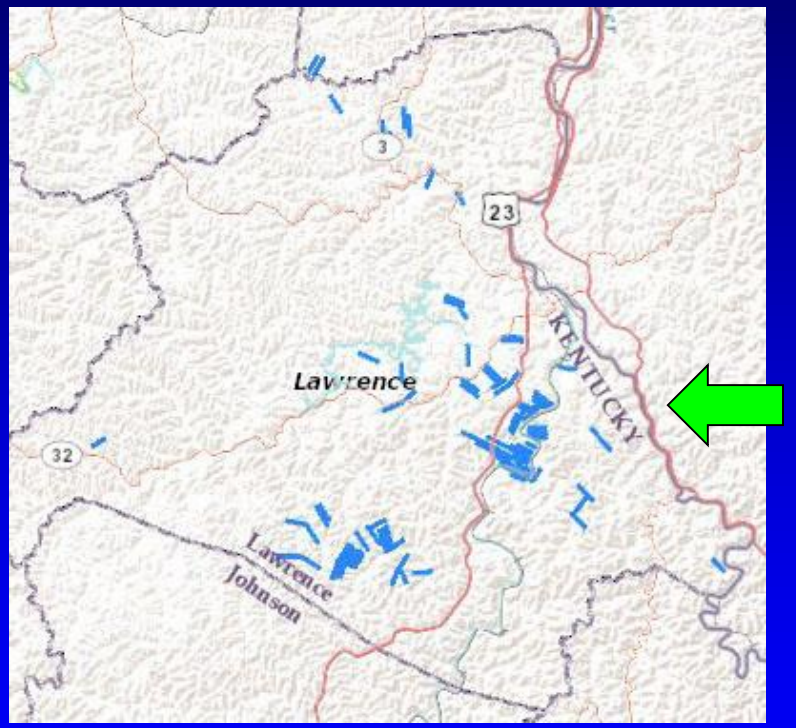
- **Operators: Eagle and others, Nytis Exploration, Hay Exploration, App Energy**
  - **First completion in October, 2012**
  - **98 horizontal wells permitted**
  - **Completion data submitted for 30 wells**
- **True vertical depths: 1115-1862 ft (avg = 1517 ft)**
- **Stratigraphic traps**
- **Average lateral is 2,600 ft., variable orientations**
- **Multistage hydraulic fracture stimulation**

Recent Production Trends

Lawrence County



- 25 wells with IP's as of 3/2014
- Reported oil IP's:
  - 8-44 BOPD, avg. = 25 BOPD
  - 12 MCFGD
- Water IP (for 1 well):
  - 10 bbl/day
- WOR (for 1 well)):
  - 0.33
- No public production data available yet



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Recent Production Trends

Lawrence County Horizontal Well Locations

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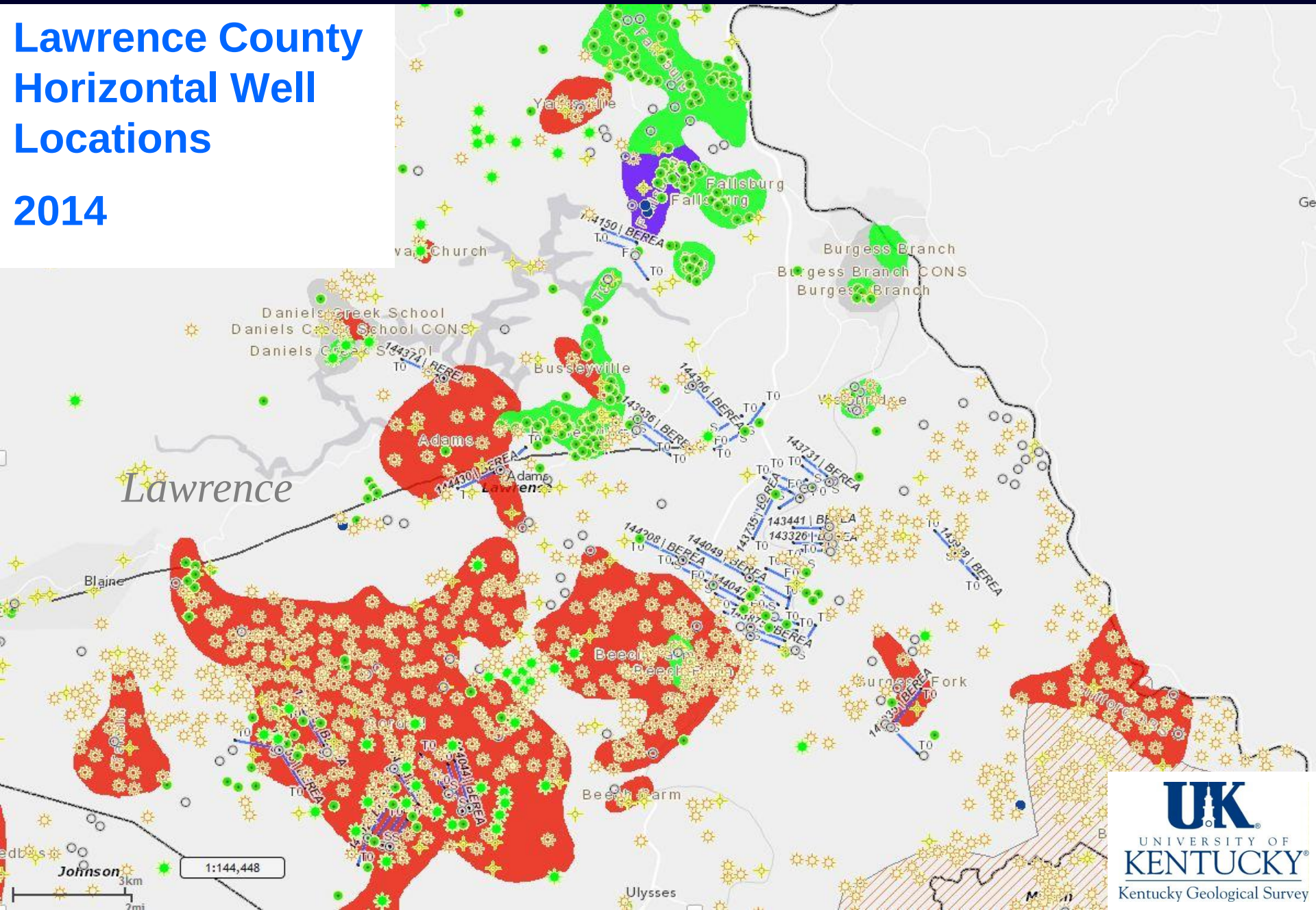
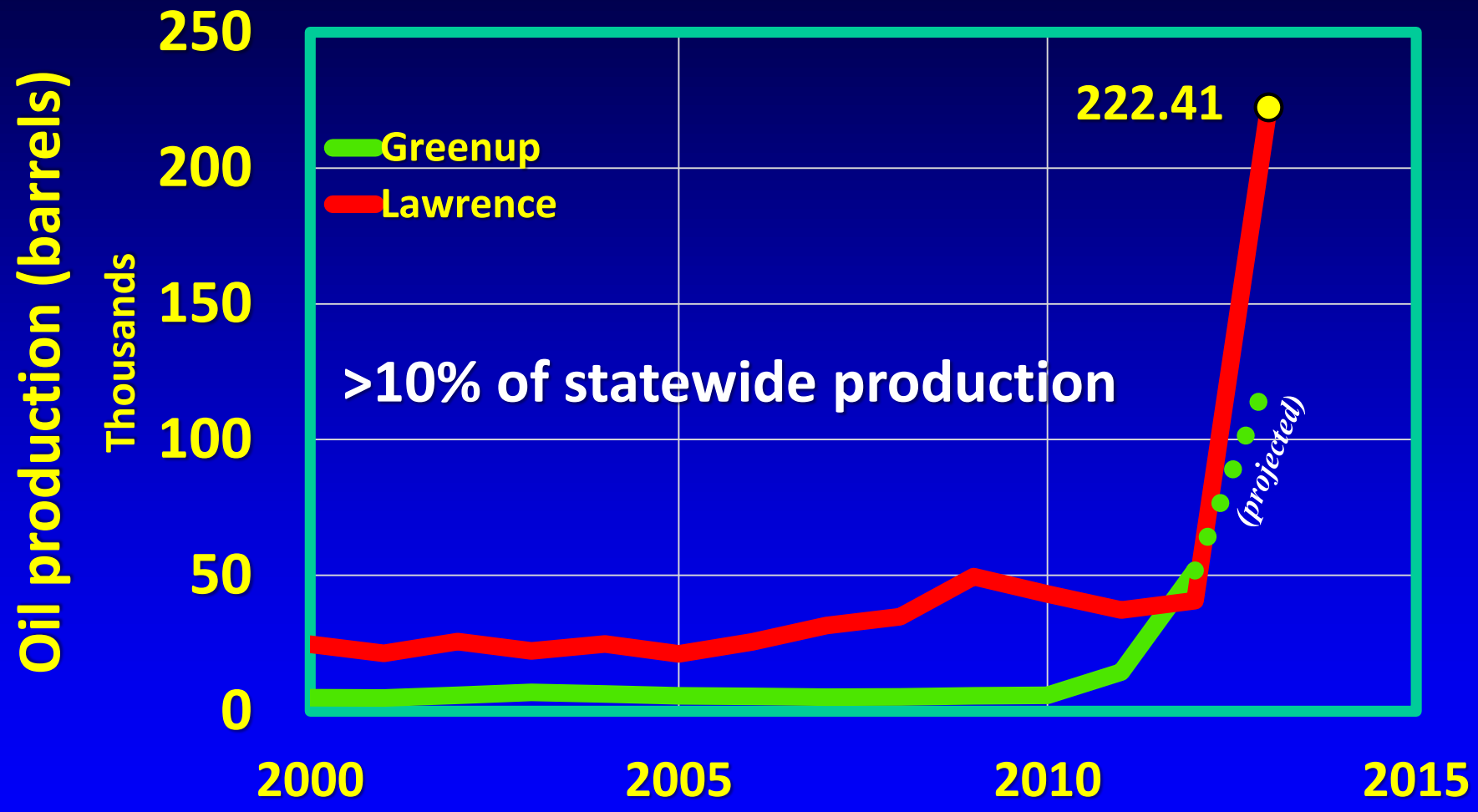


Recent Production Trends

Recent Berea Oil Production, East Kentucky



2013 production volume for Greenup County is confidential (3 or fewer respondents)

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Recent Production Trends

Summary

- **Initial data shows horizontal drilling has been a technical success in shallow tight Berea reservoirs**
  - **Horizontal drilling has dramatically increased Berea oil production in KY**
  - **Dramatic increases in Greenup and Lawrence County oil production (and for EKY as a whole)**
  - **Berea horizontal play spreading into neighboring Boyd and Johnson Counties**
  - **Shallow depths (lower costs) part of the interest**
  - **Determining economic success will require longer term production data**

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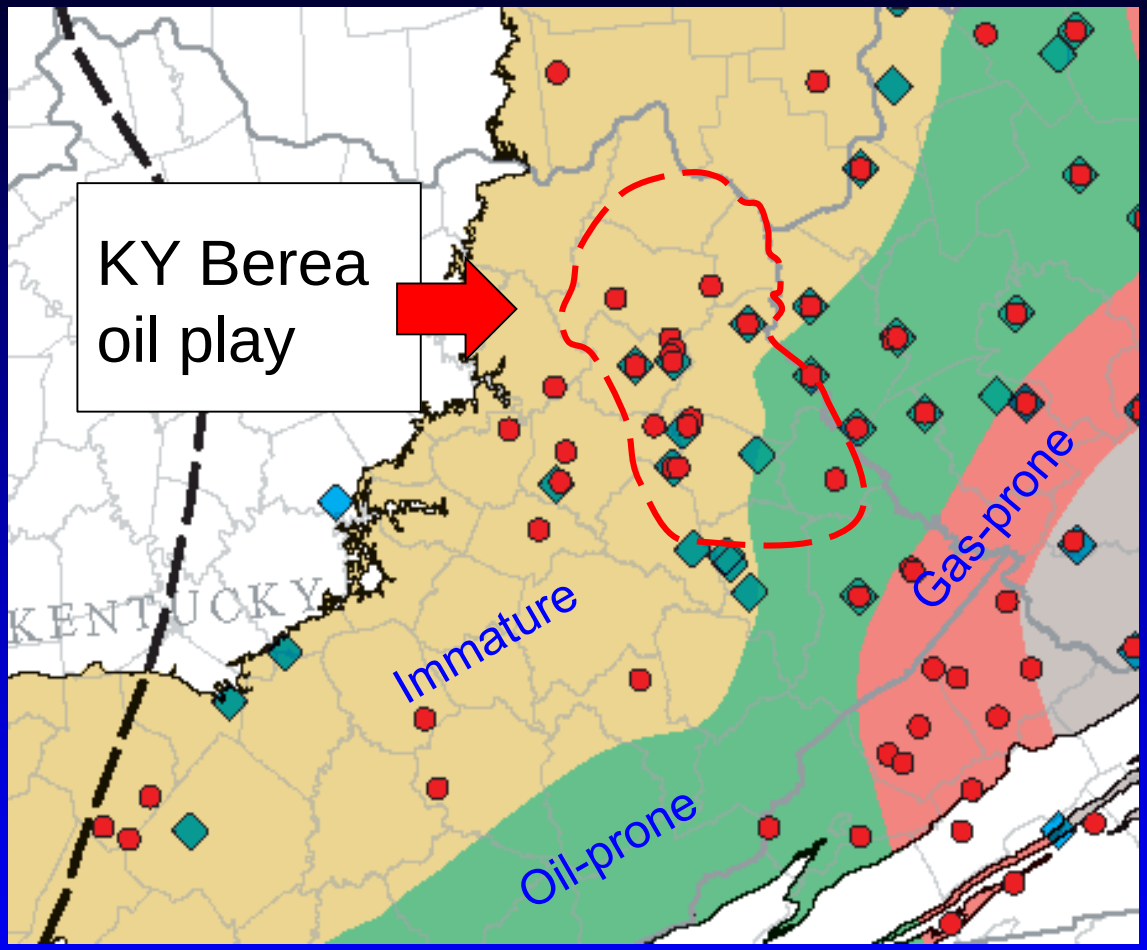
Research Questions



USGS Thermal Maturity Map
(East and others, SIM 3214, 2012)

1) Why does the Berea produce oil and gas in areas where the surrounding source rocks are interpreted as thermally immature ?

- Thermally immature (<0.6 % Ro)
- Prolific oil generation (0.6 to 1.1 % Ro)
- Thermal gas generation (>1.1 % Ro)

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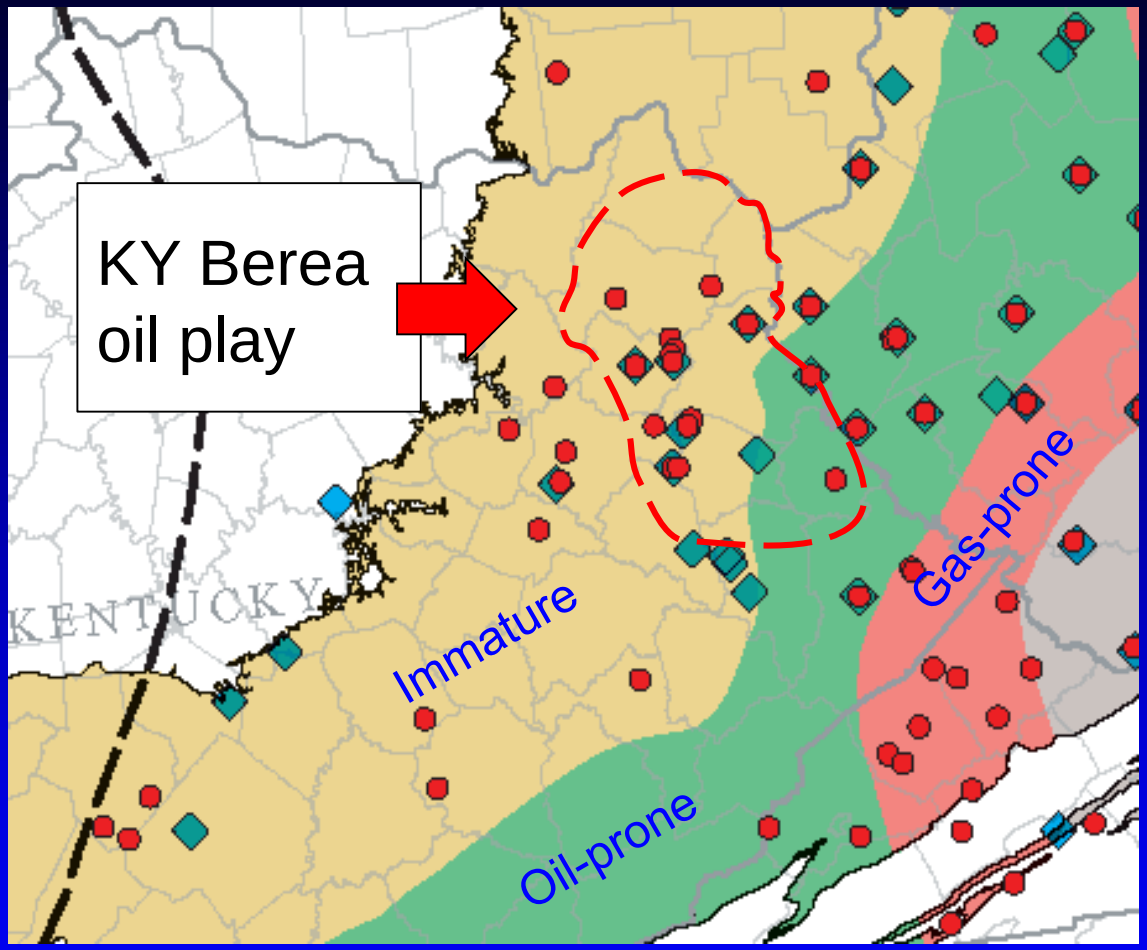
Research Questions



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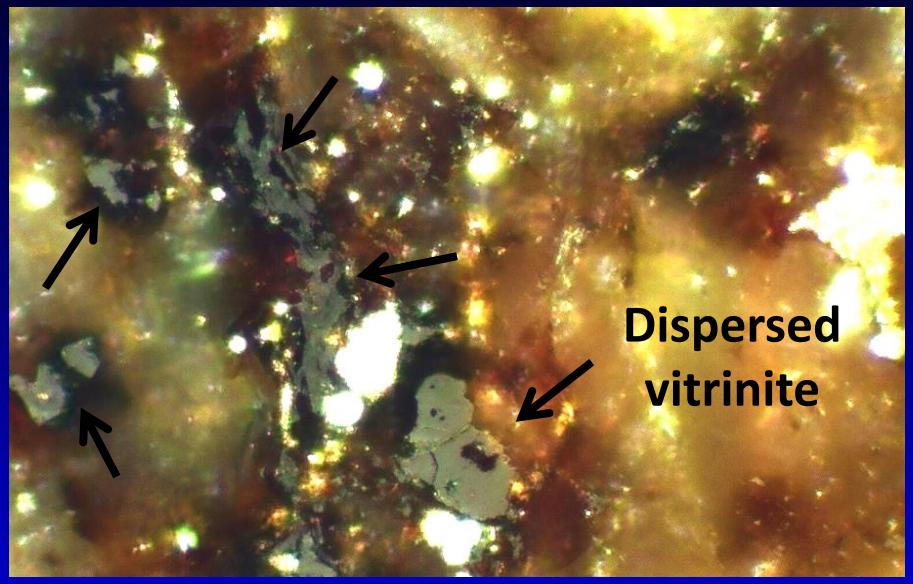
Research Questions

1a) Is vitrinite suppression responsible for the apparent source rock immaturity?

- **Or is some of the vitrinite from Devonian shales actually bitumen with a different R_o and different relationship to maturity?**



Petrographic slide of dispersed vitrinite from the Ohio Shale under white light

- **Can we use other geochemistry measurements (e.g. isotopes, biomarkers) in gas, oil, and extract samples to better understand thermal maturity in conjunction with vitrinite reflectance measurements.**

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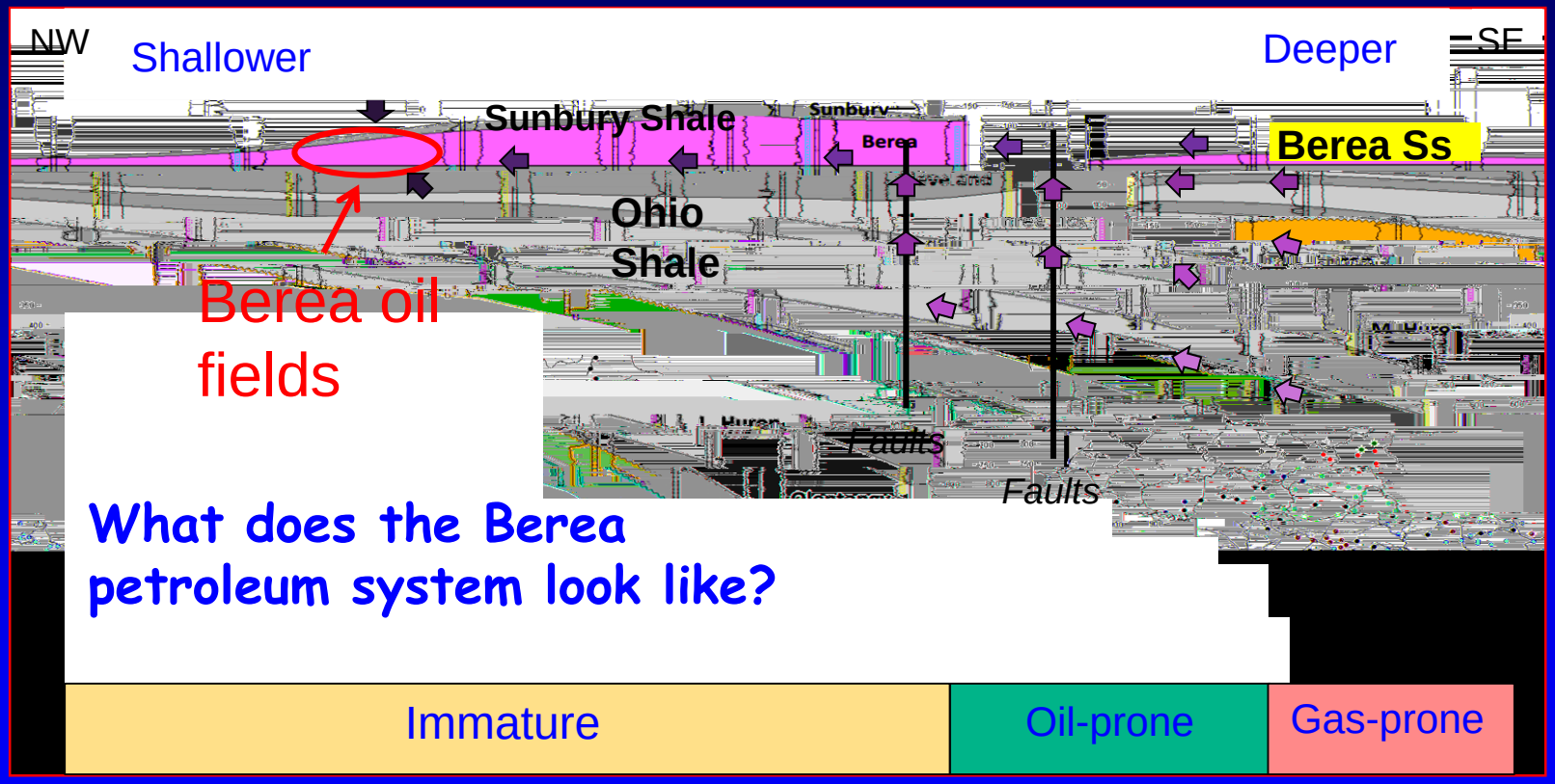
Research Questions

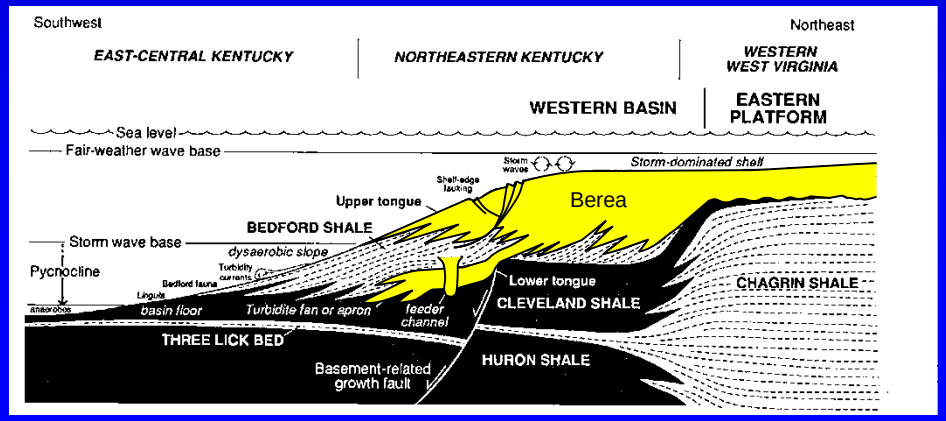
2) Are Berea hydrocarbons derived from the Sunbury or Ohio Shales and are the hydrocarbons generated locally or migrated from deeper (more mature) parts of the basin?



Research Questions

3) What are some of the controls on pay zones, porosity, and permeability in the Berea in Kentucky?

- **Regional trends in thickness?**
- **Sandstone architecture and facies in producing fields (lateral and vertical variability)?**
- **Any structural influences on facies?**
- **Any structural influences on oil/gas/water saturations?**



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Berea Sandstone Consortium Project

- KGS, USGS, OGS, R.J. Lee Group, and 7 industry partners
- 18-month study (07/2014- 12/2015) of the Berea petroleum system
- Analysis will be conducted along a NW-SE transect representing thermal maturity range in Ky
  - Generate regional cross sections, and updated isopach and structure maps of the Berea in KY
  - Compare geophysical logs, cores, and outcrops to better characterize the Berea petroleum system

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Berea Consortium Project

- Collect and analyze samples of source rocks for TOC, Rock-Eval pyrolysis, vitrinite reflectance, and spectral fluorescence to evaluate thermal maturity
- Collect and analyze (LC, GC, GCMS) samples of Berea oil and gas to geochemically understand provenance and distribution
  - Use GCMS and IRMS measurements of extracts and oils to analyze biomarker profiles and carbon isotope composition to interpret hydrocarbon source
- Results will be confidential for one year and then a public report will be published (~Dec. 2016)

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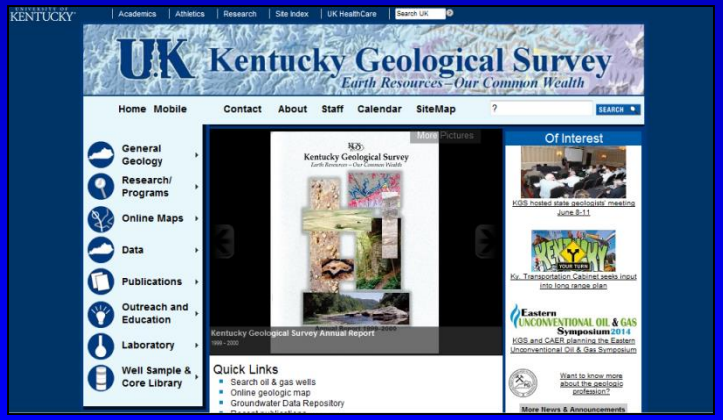
Thank you

KGS Berea Play Web Page:
www.uky.edu/KGS/emsweb/berea_ss/Upper_Devonian_Berea_SS.htm



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