Summary of Publicly Available Production Data for the Devonian Berea Sandstone Play, Eastern Kentucky*

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Abstract

The Devonian Berea “Sandstone” was discovered in Lawrence County in the late 1870's. Major Berea development occurred in the 1920's and in the late 1950's with the advent of waterflooding. In the 1980's, Section 29 tight formation tax credits temporarily made the Berea interesting again. Recently, horizontal drilling and slickwater fracture stimulations have led to a Berea renaissance with Lawrence County now the leading oil-producing county in the state. Berea wells completed since 1997 were selected that had enough periods of publicly available production data for analysis to characterize the initial performance of the wells.

The maximum reported monthly production rate, first year cumulative production volume, and production decline were modeled. For each well with sufficient data, the better fit of an exponential or hyperbolic decline curve was used to characterize production trends. A gas production index was defined as the ratio of gas production to the sum of oil and gas production on a barrels of oil equivalent basis and used to map regional trends in oil- and gas-prone production. Well performance was divided into three classes based on the first year cumulative production at the 25th and 75th percentiles. Typical oil and gas decline curves for each of these groups exhibit significant differences relative to predicted future performance.

Based on limited historic production data, Berea oil producers out-perform typical Kentucky wells. The Berea in Greenup and Lawrence counties is oil-prone while Pike County exhibits a significant wet gas-prone area with some wells reporting varying amounts of oil production.

References Cited

Fetkovich, M.J., E.J. Fetkovich, and M.D. Fetkovich, 1996, Useful Concepts for Decline-Curve Forecasting, Reserve Estimation, and Analysis: Society of Petroleum Engineers, Reservoir Engineering, SPE-28628-PA, February 1996, p. 13-22.

Nuttall, B.C., 2014, Review of Kentucky Oil and Gas Production, 2010: Lexington, Kentucky, Kentucky Geological Survey, Series XII, Information Circular 30, 16 p., http://kgs.uky.edu/kgsweb/olops/pub/kgs/IC30_12.pdf, Website accessed December 2016.

Nuttall, B.C., 2007, Decline Object: A Python Script to Find the Best Fit Hyperbolic or Exponential Decline Parameters: Lexington, Kentucky, Kentucky Geological Survey, http://www.uky.edu/KGS/emsweb/devsh/production/decline_obj.py, Website accessed December 2016.

Pilgrim, M., 2004, Dive into Python: New York, Apress Publishing Company, 413 p., http://www.diveintopython.net, Website accessed December 2016.

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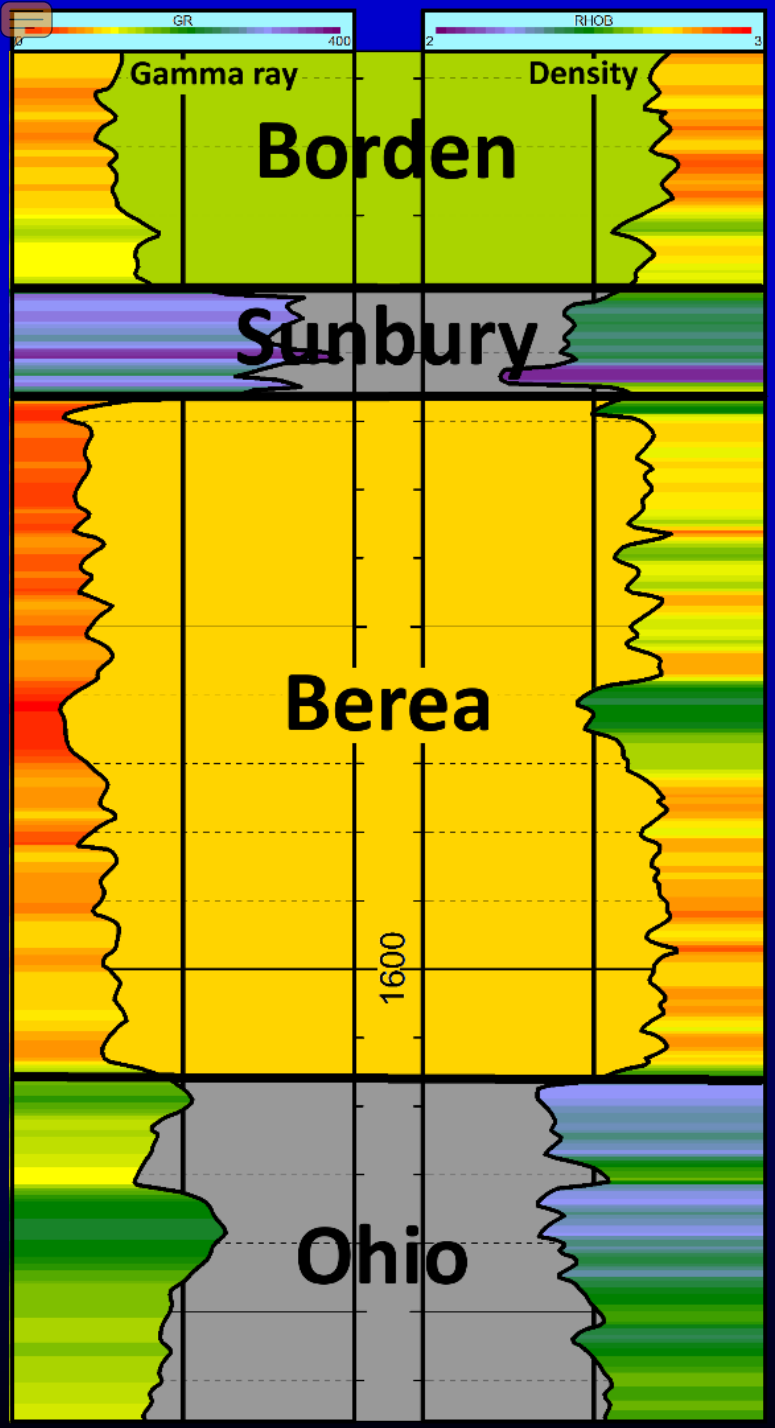
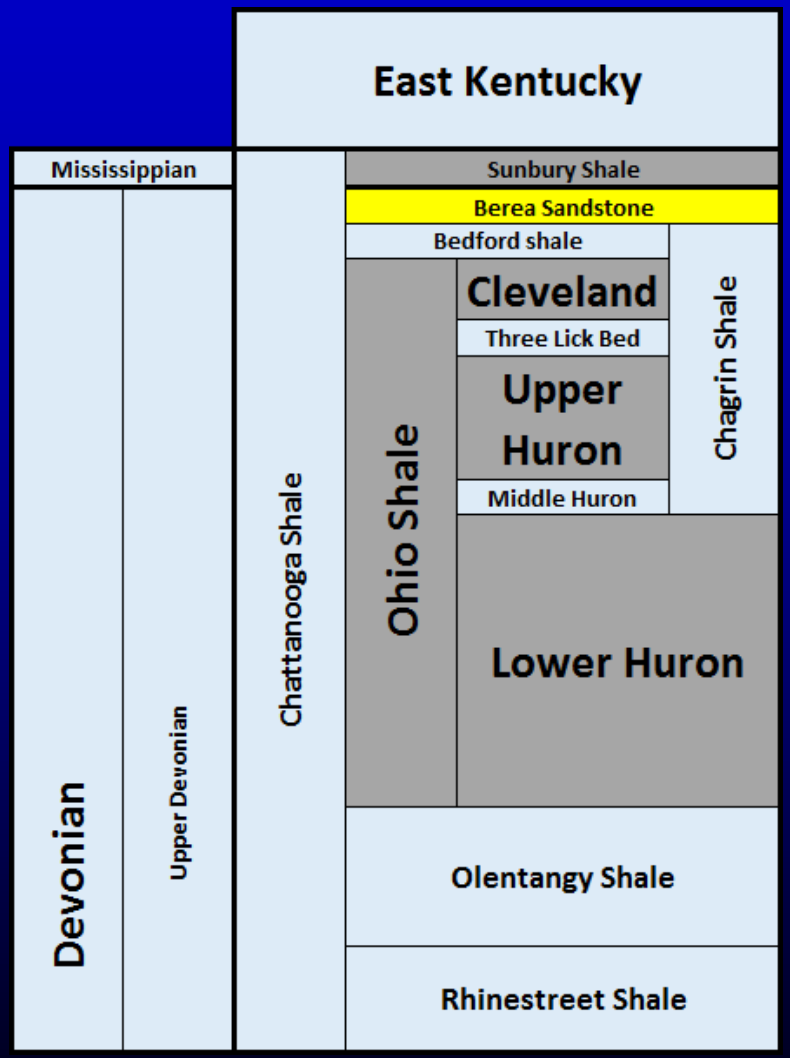
Kentucky Geological Survey

Eastern Section AAPG, Lexington, Kentucky, 26-Sep-2016

General Stratigraphy

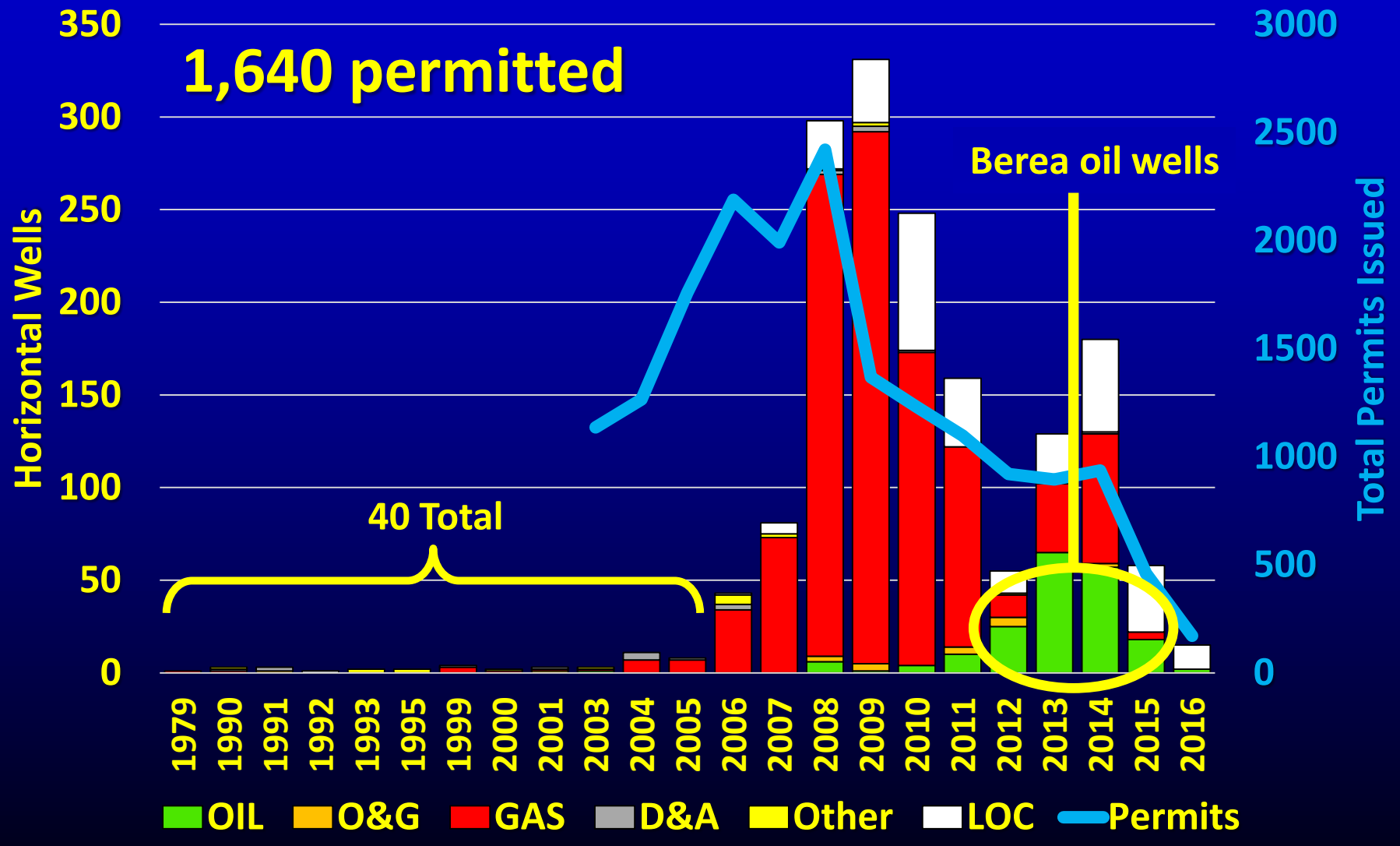




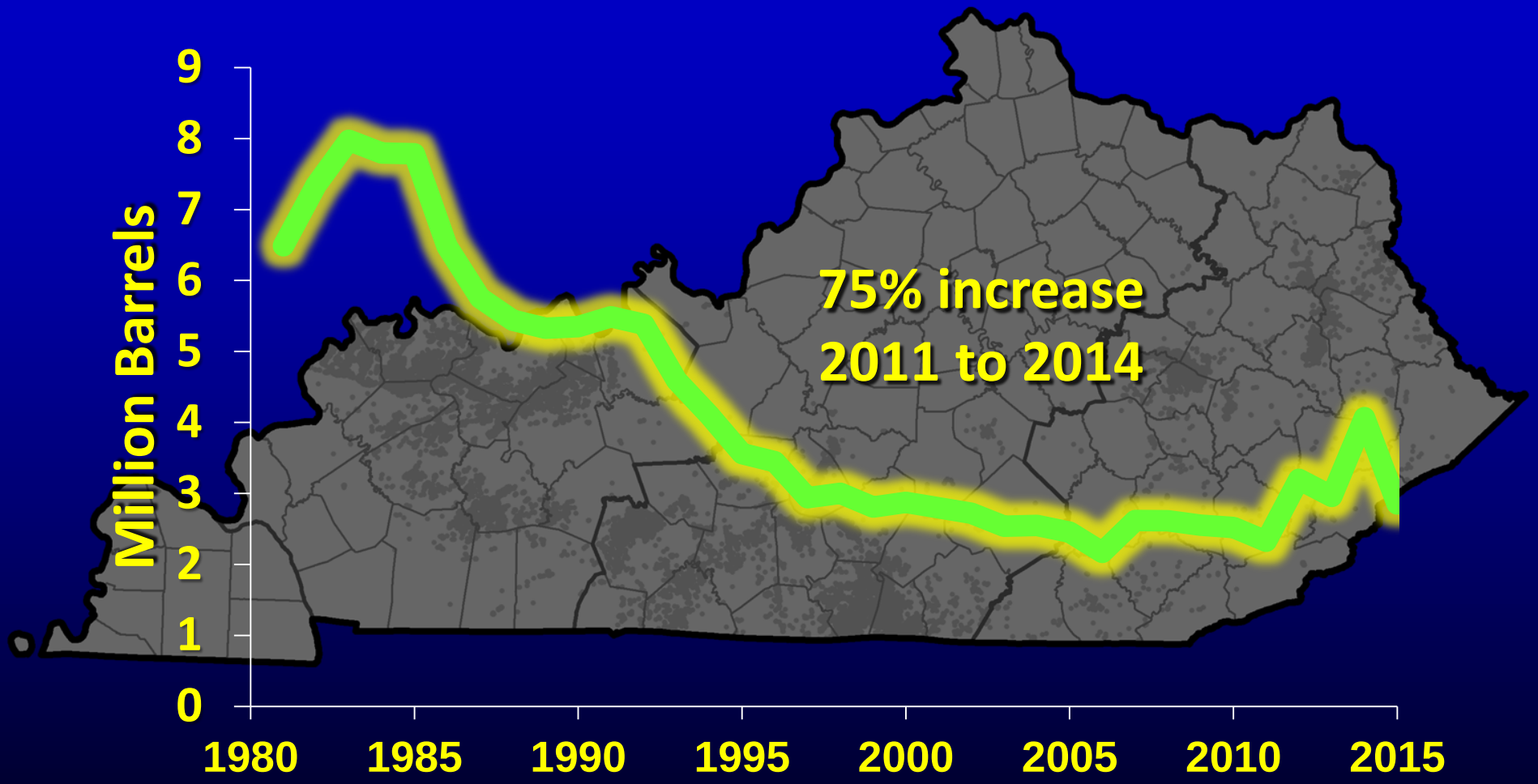
Heterogeneity and Soft Sediment

KY 10, near Garrison, Lewis County, Kentucky

Horizontal Wells by Year

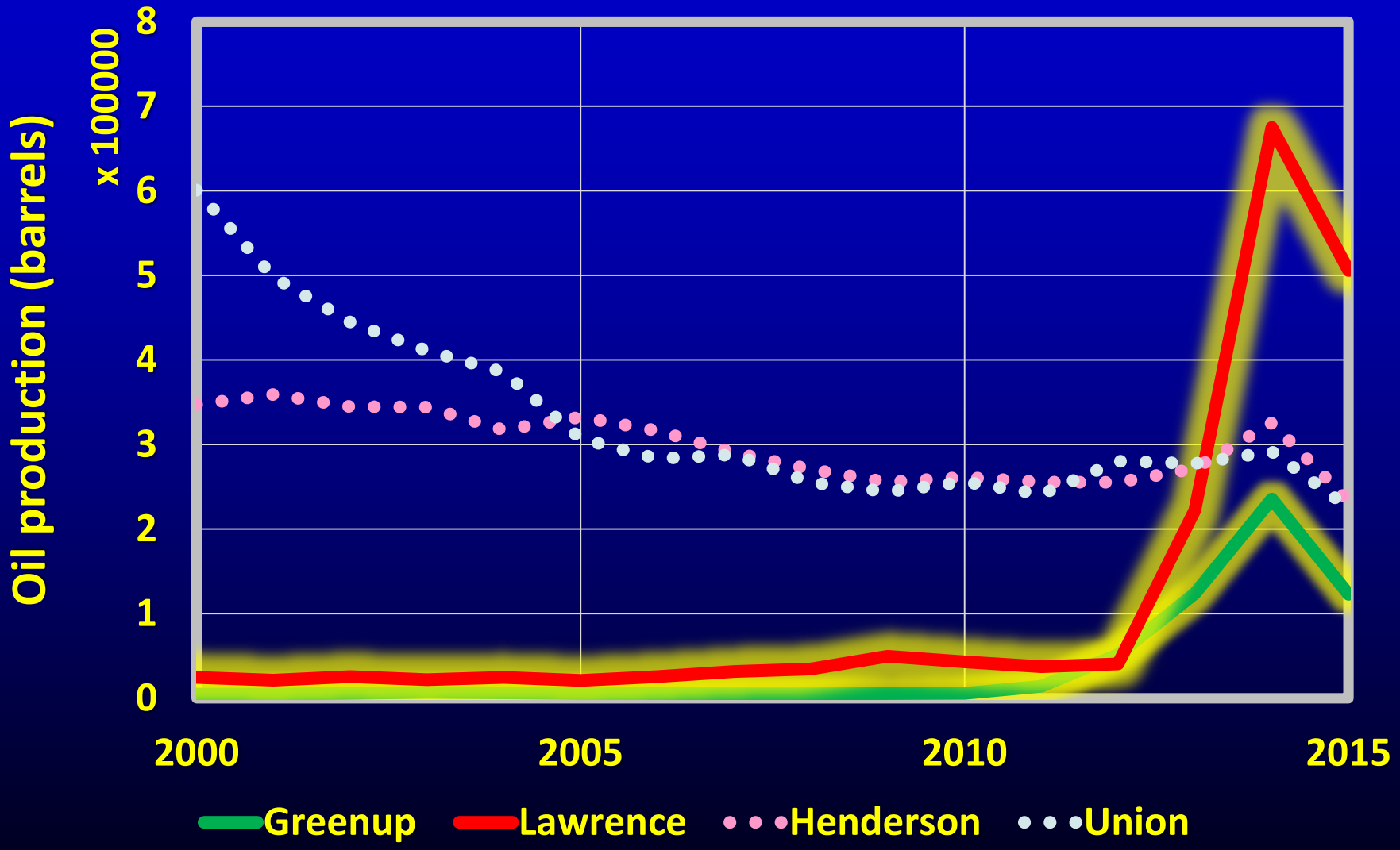


2015 Oil Production: 2.8 MMbo

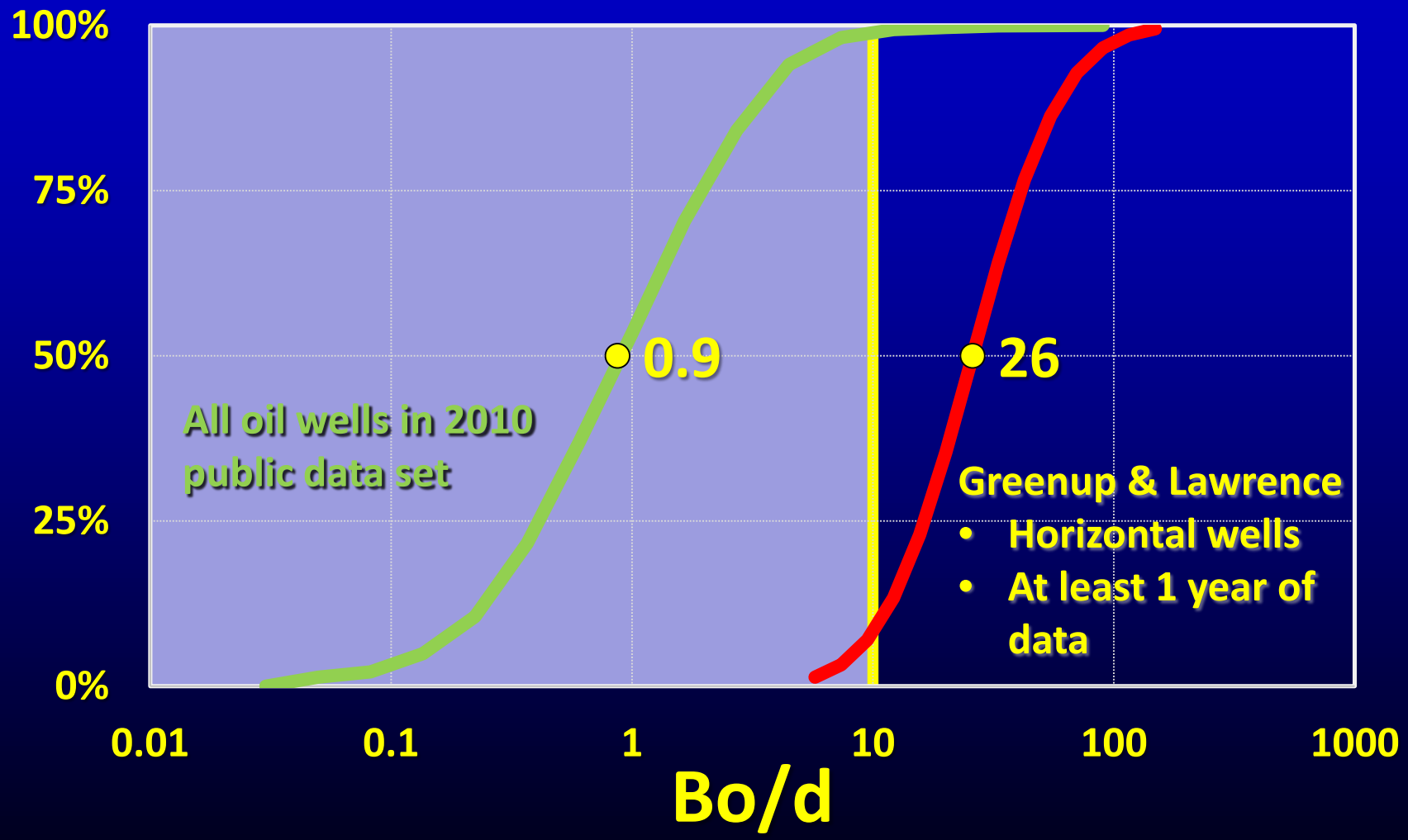


63 Kentucky counties, 58 percent from eastern Kentucky

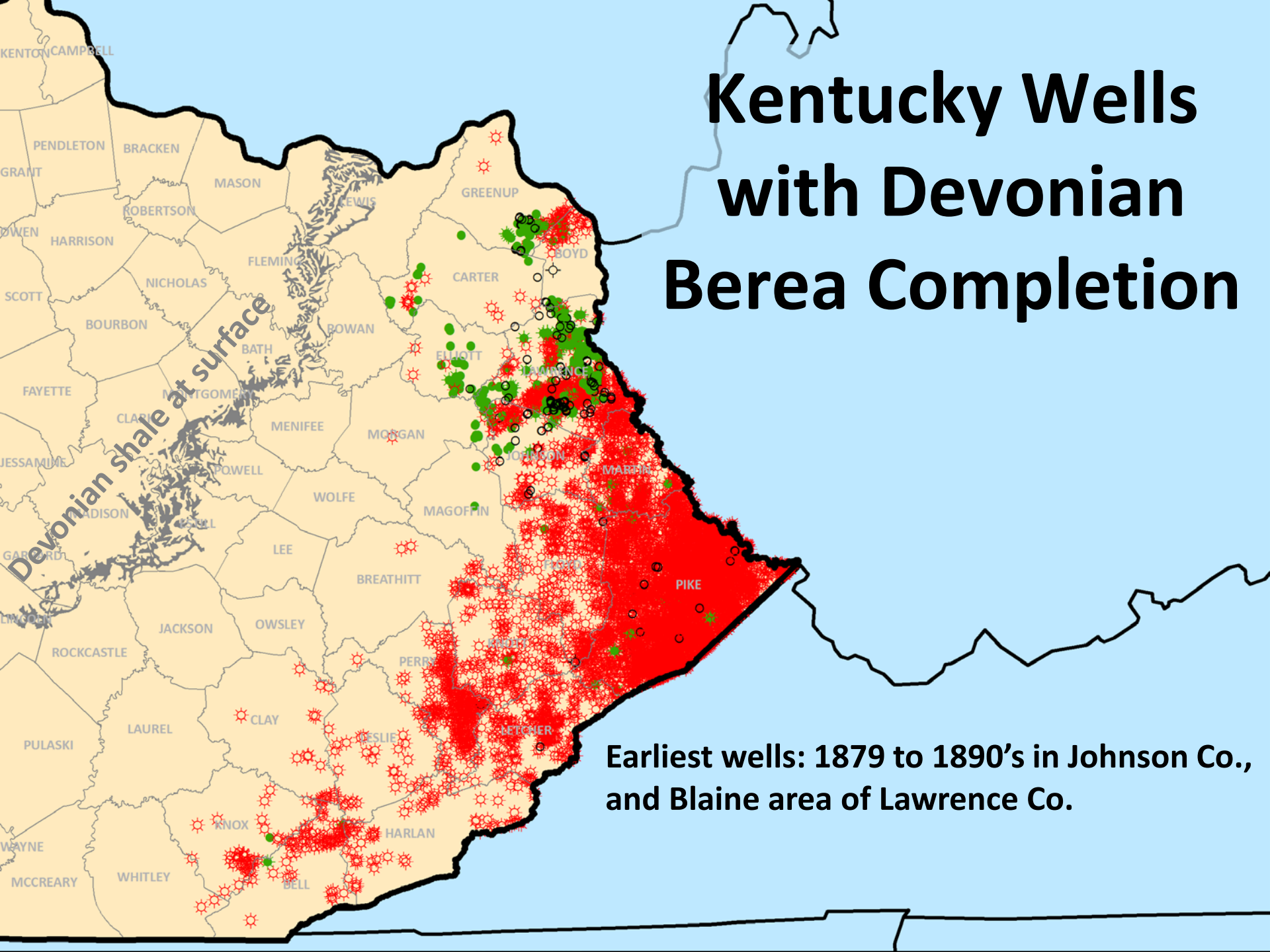
Significant Increase in Berea Production



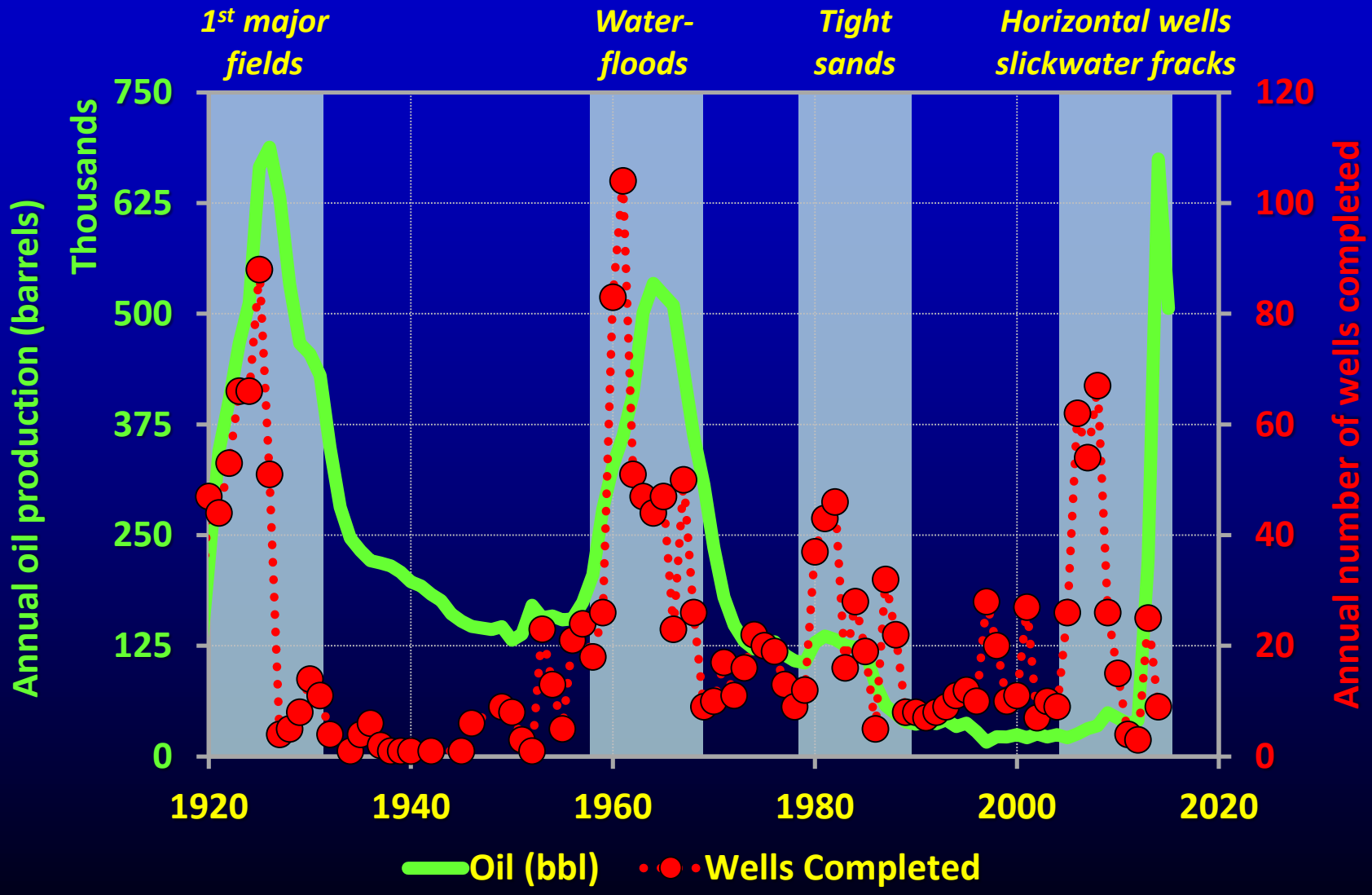
Daily Average vs 2010 Study

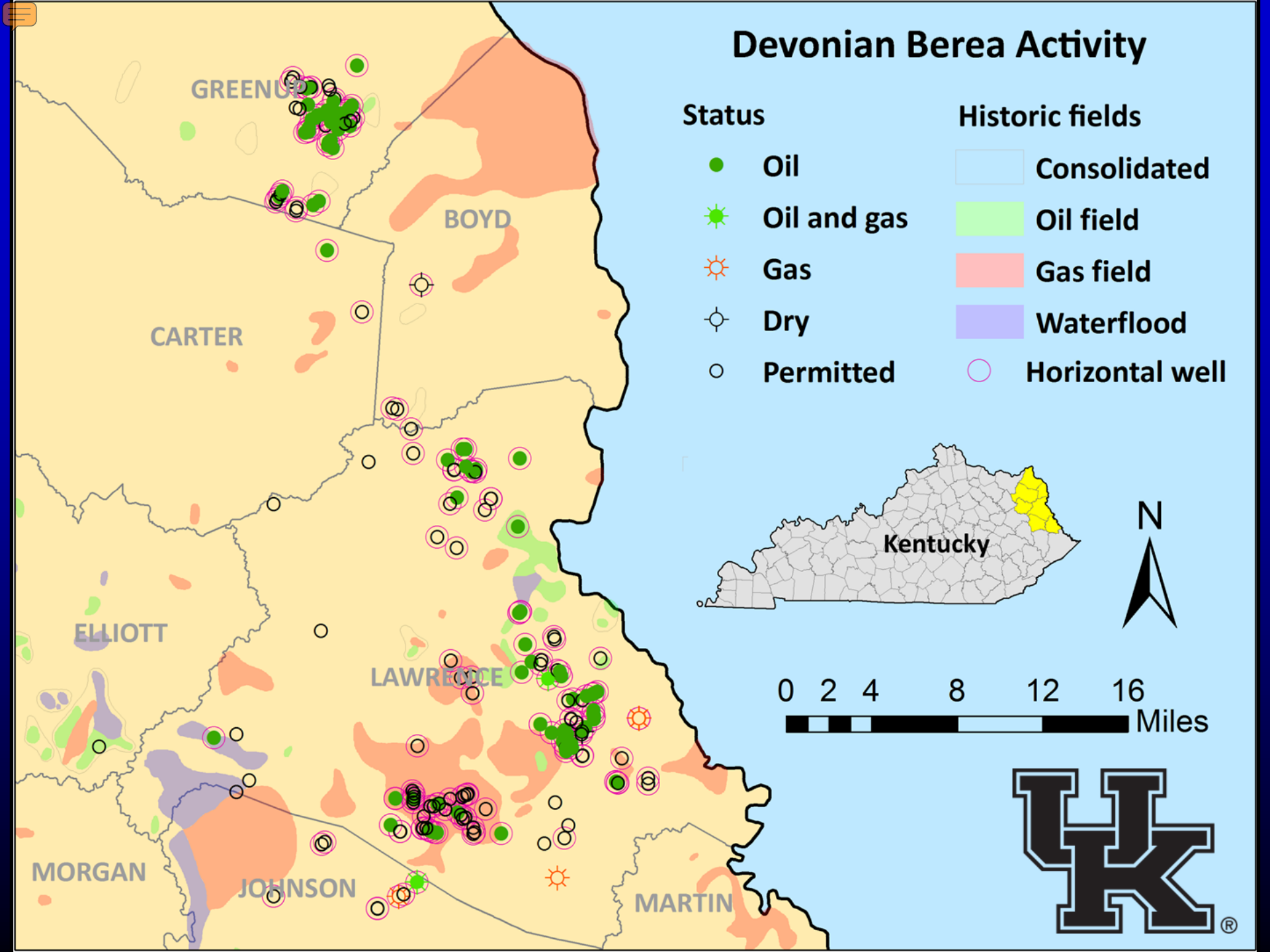


Nuttall, 2014, KGS Ser 12, IC 30


Kentucky Wells with Devonian Berea Completion
Devonian shale at surface
Earliest wells: 1879 to 1890's in Johnson Co., and Blaine area of Lawrence Co.
KENTON
CAMPBELL
PENDLETON
BRACKEN
GRANT
MASON
ROBERTSON
LEWIS
GREENUP
BOYD
OWEN
HARRISON
FLEMING
CARTER
SCOTT
NICHOLAS
BOURBON
BATH
ROWAN
ELLIOTT
FAYETTE
MONTGOMERY
CLARK
MENIFEE
MORGAN
JESSAMINE
POWELL
WOLFE
MADISON
MAGOFFIN
GARRARD
LEE
BREATHITT
PIKE
JACKSON
OWSLEY
ROCKCASTLE
PERRY
CLAY
LAUREL
LESLIE
LETCHER
PULASKI
KNOX
HARLAN
WAYNE
MCCREARY
WHITLEY
BELL

Lawrence County Development History

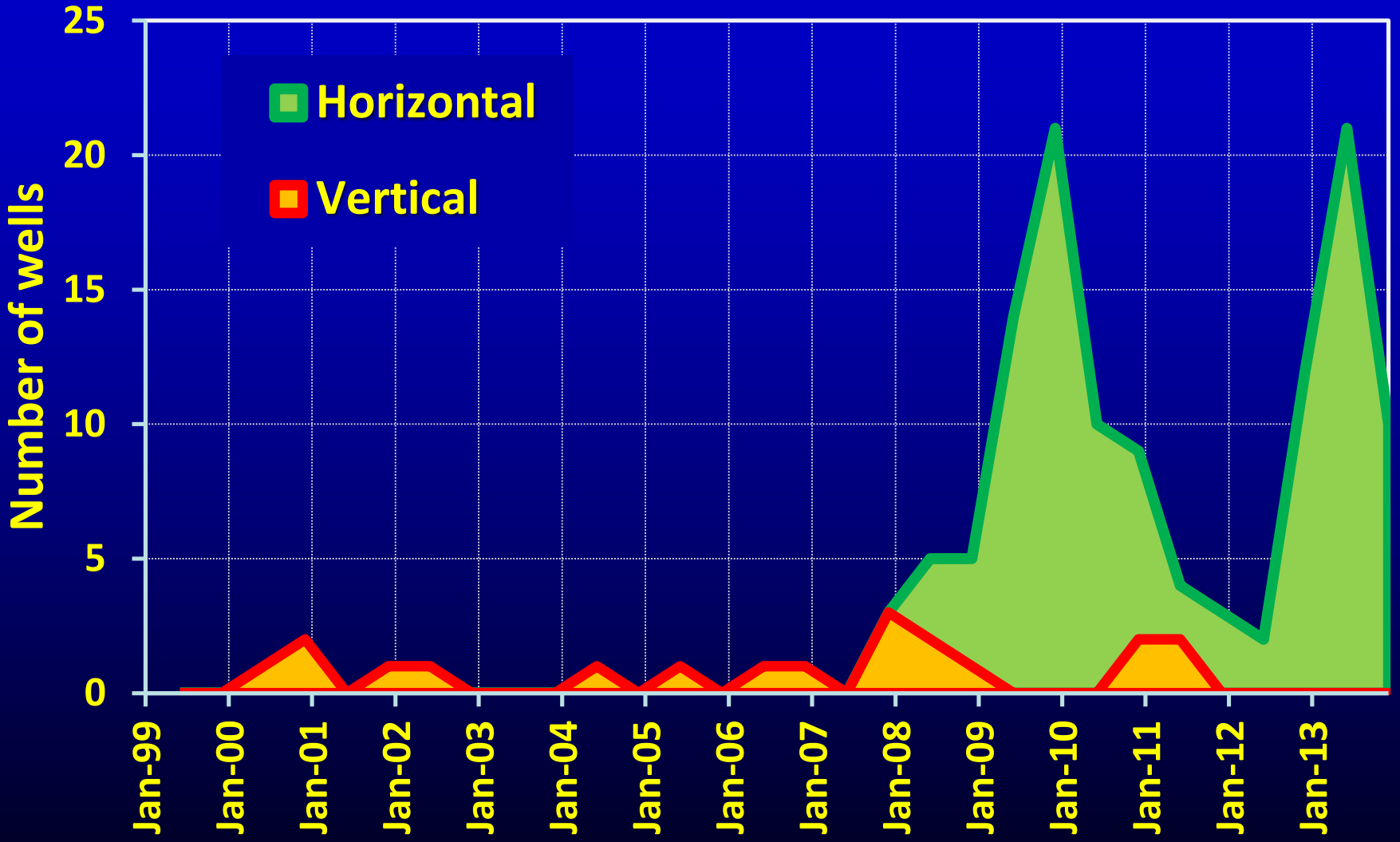



Devonian Berea Activity
Status
Oil
Oil and gas
Gas
Dry
Permitted
Historic fields
Consolidated
Oil field
Gas field
Waterflood
Horizontal well
GREENUP
BOYD
CARTER
ELLIOTT
LAWRENCE
MORGAN
JOHNSON
MARTIN
Kentucky
N
0 2 4 8 12 16
Miles

Public Data Selection Criteria

- Oilandgas.ky.gov
  - 805 KAR 1:180
- Well was completed
  - Berea only (no commingling)
  - After 1997 (early-time data available)
- Oil or gas production values
  - >0 for at least 1 month (no shut-in)

Well Types



Wells with production data

Decline Models

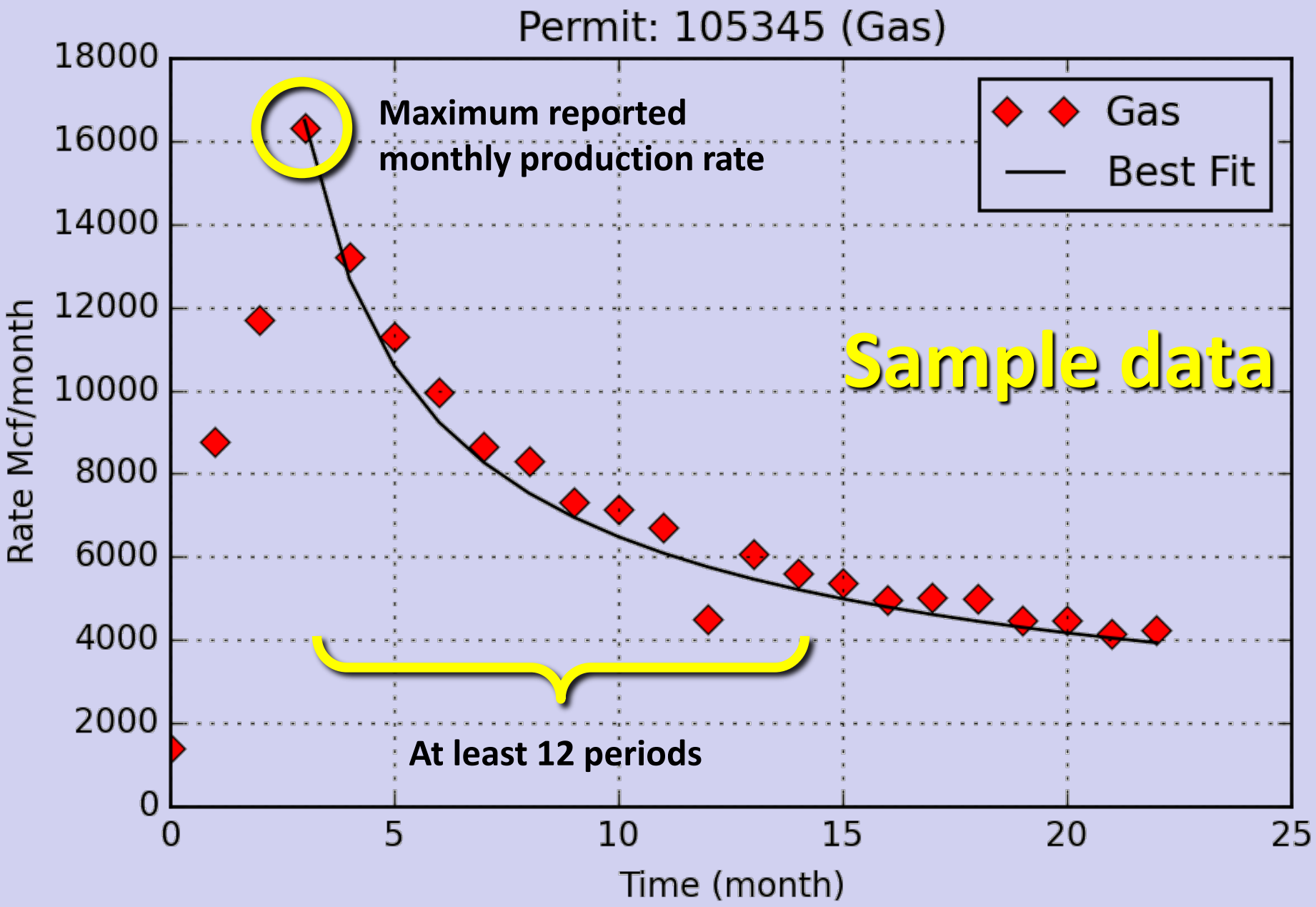
- Begin at period of maximum reported monthly production
- At least 11 months of data following
- Correlation coefficient, r^2, at least 0.47

Exponential

$$q_t = \frac{q_i}{e^{D_i t}}$$

Hyperbolic

$$q_t = \frac{q_i}{(1 - bD_i t)^{\frac{1}{b}}}$$


Permit: 105345 (Gas)
Rate Mcf/month
Time (month)
Gas
Best Fit
Maximum reported
monthly production rate
Sample data
At least 12 periods
0
2000
4000
6000
8000
10000
12000
14000
16000
18000
0
5
10
15
20
25

GOR & GPI

$$GOR = \frac{Gas_{Mcf}}{Oil_{bbl}}$$

- No oil then what?

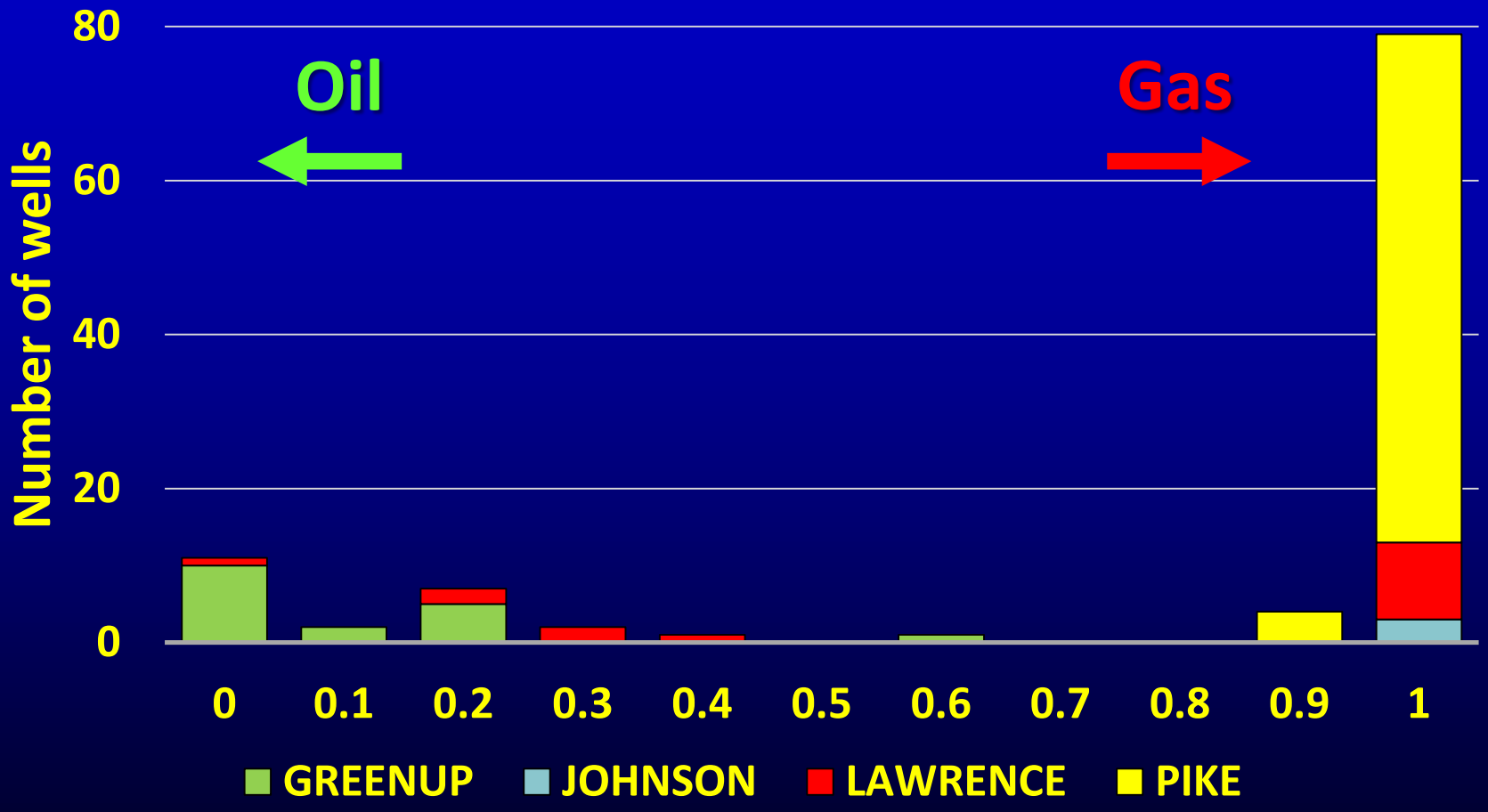
Gas Production Index

$$GPI = \frac{0.1724 * Gas_{Mcf}}{Oil_{bbl} + 0.1724 * Gas_{Mcf}}$$

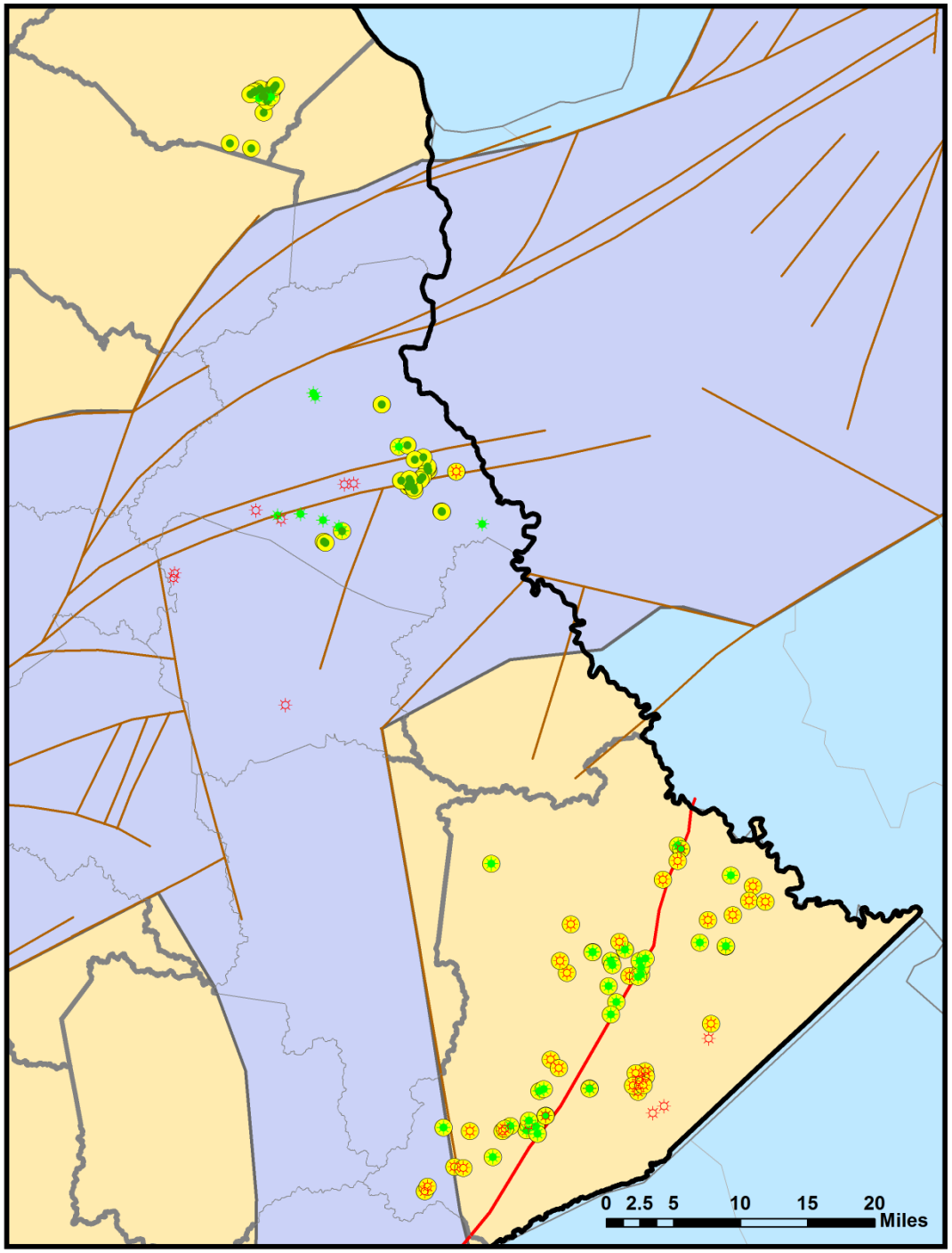
- Ratios on boeq basis
- Compare cumulative production data

- 0 to < 0.25 – oil well
  - <= 2Mcf/bbl (stripper gas)
- 0.945 to 1 – gas well
  - >= 100 Mcf/bbl

Gas Production Index



Regional Distribution of Production Data



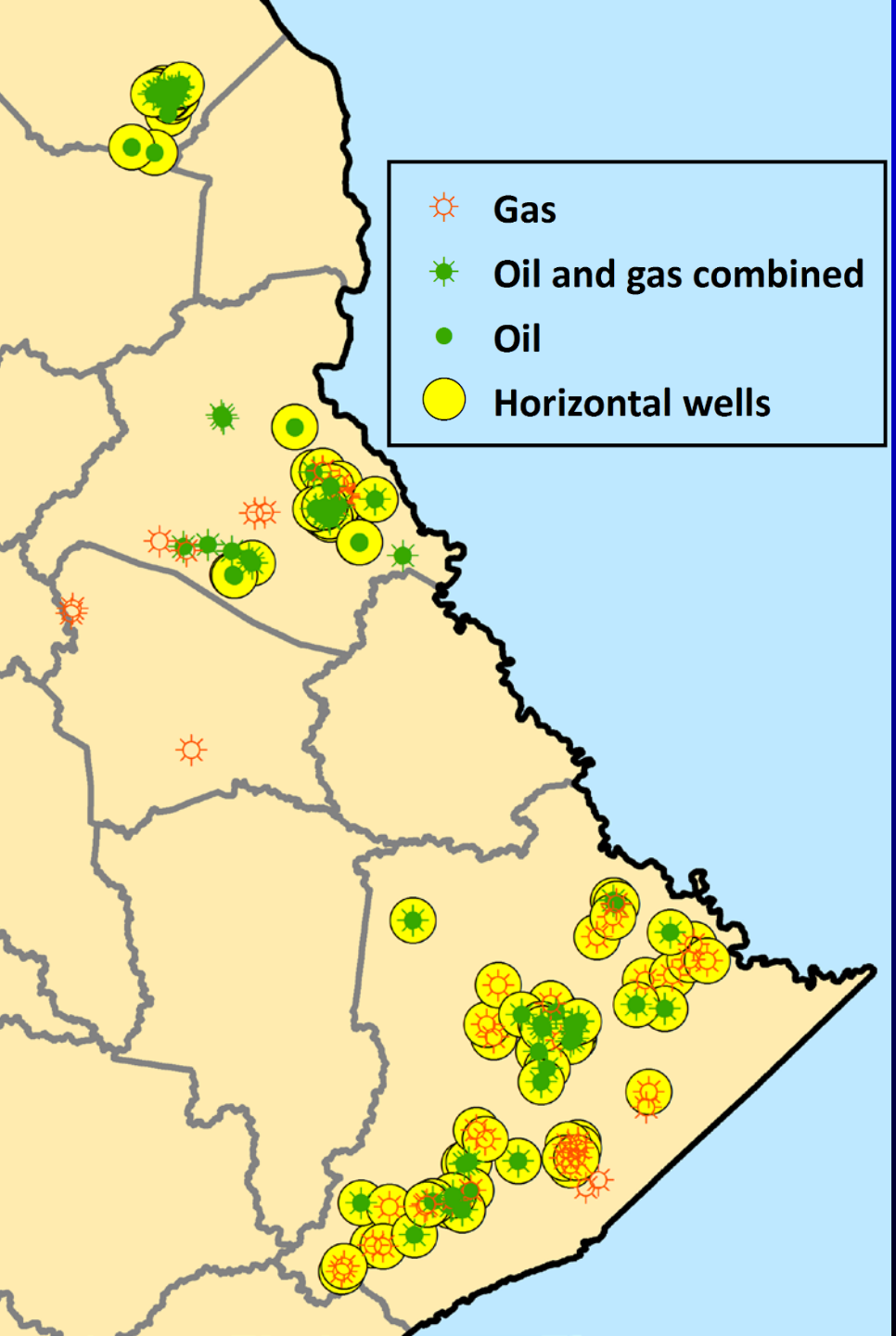
Legend

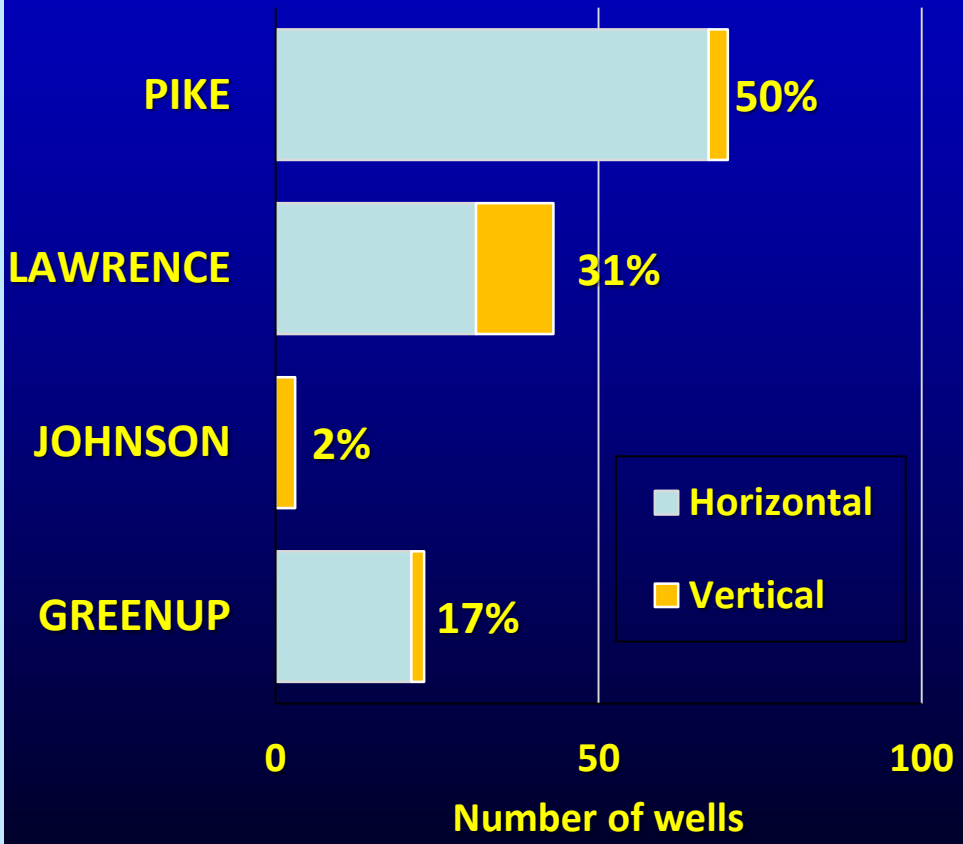
Completion types

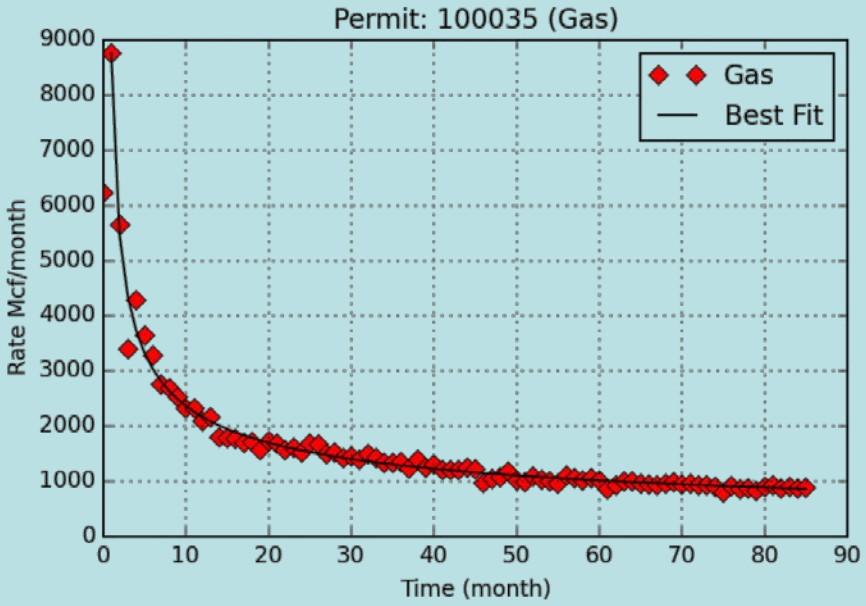
- Oil well
- Combined oil and gas well
- Gas well
- Horizontal wells
- D'Invilliers structure
- Basement faults
- Rome Trough

Production Data Set

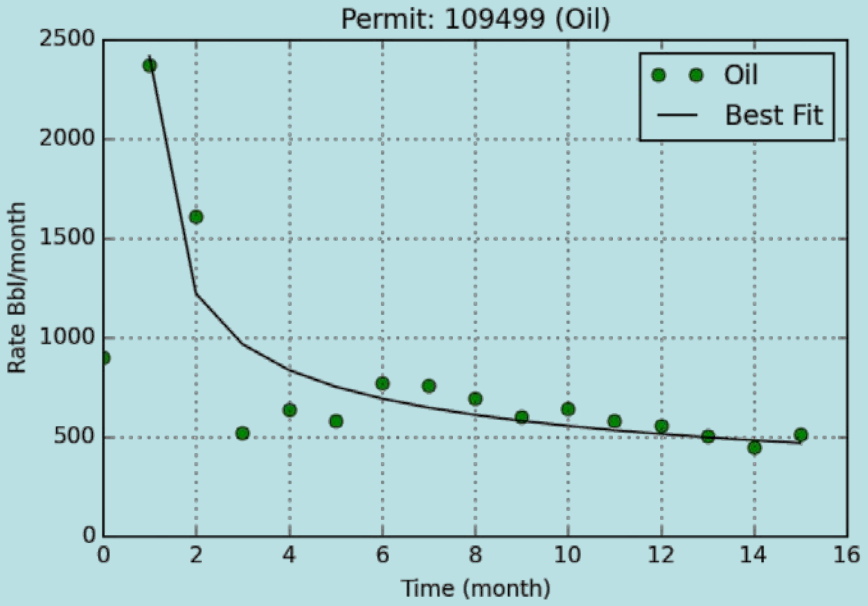
- 139 wells



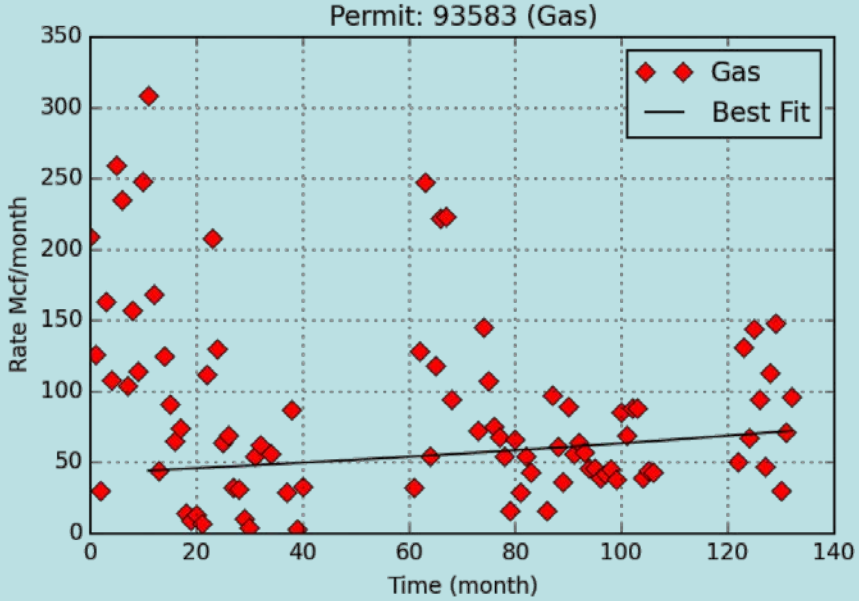




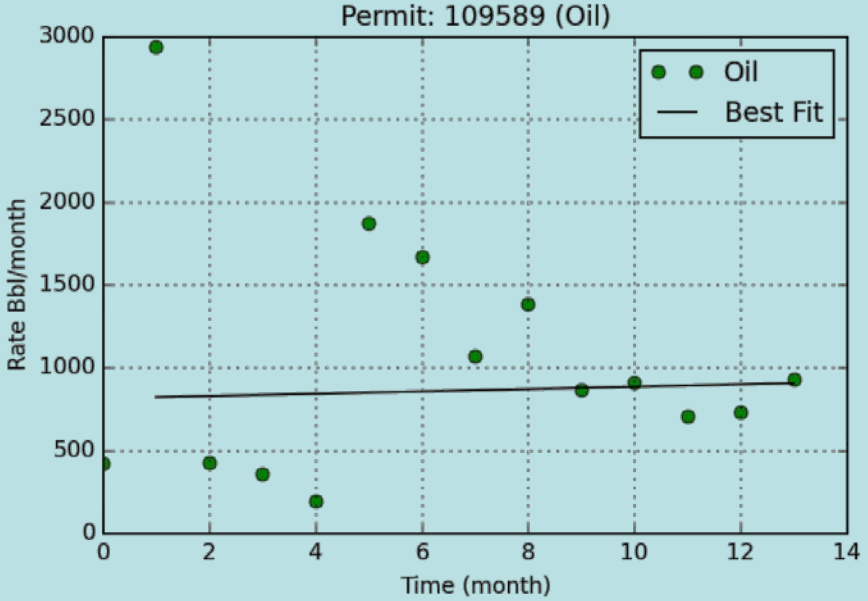
Pike Co. r^2=0.98



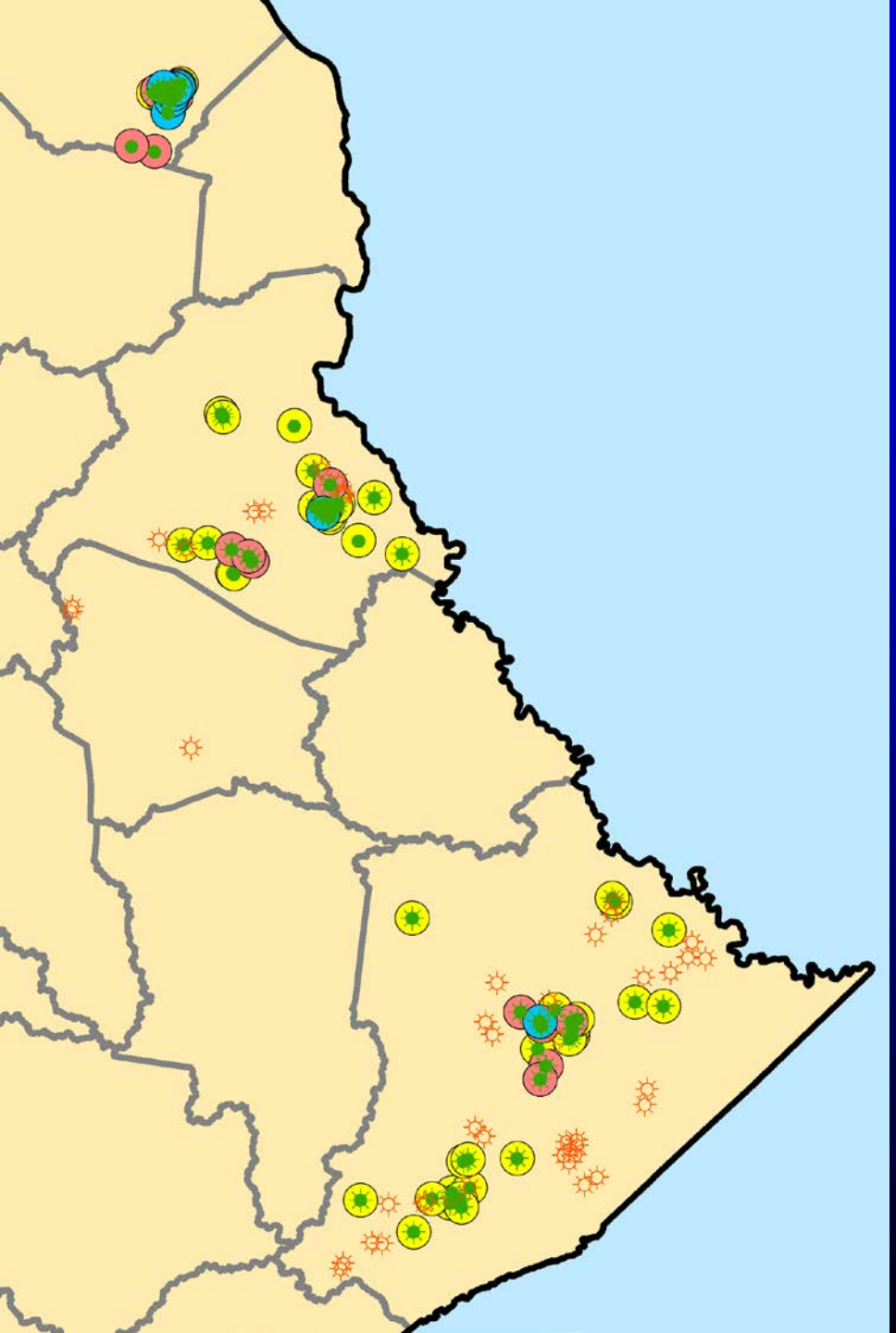
Greenup Co. r^2=0.87



Lawrence Co. r^2=0.03



Greenup Co. r^2=0.002



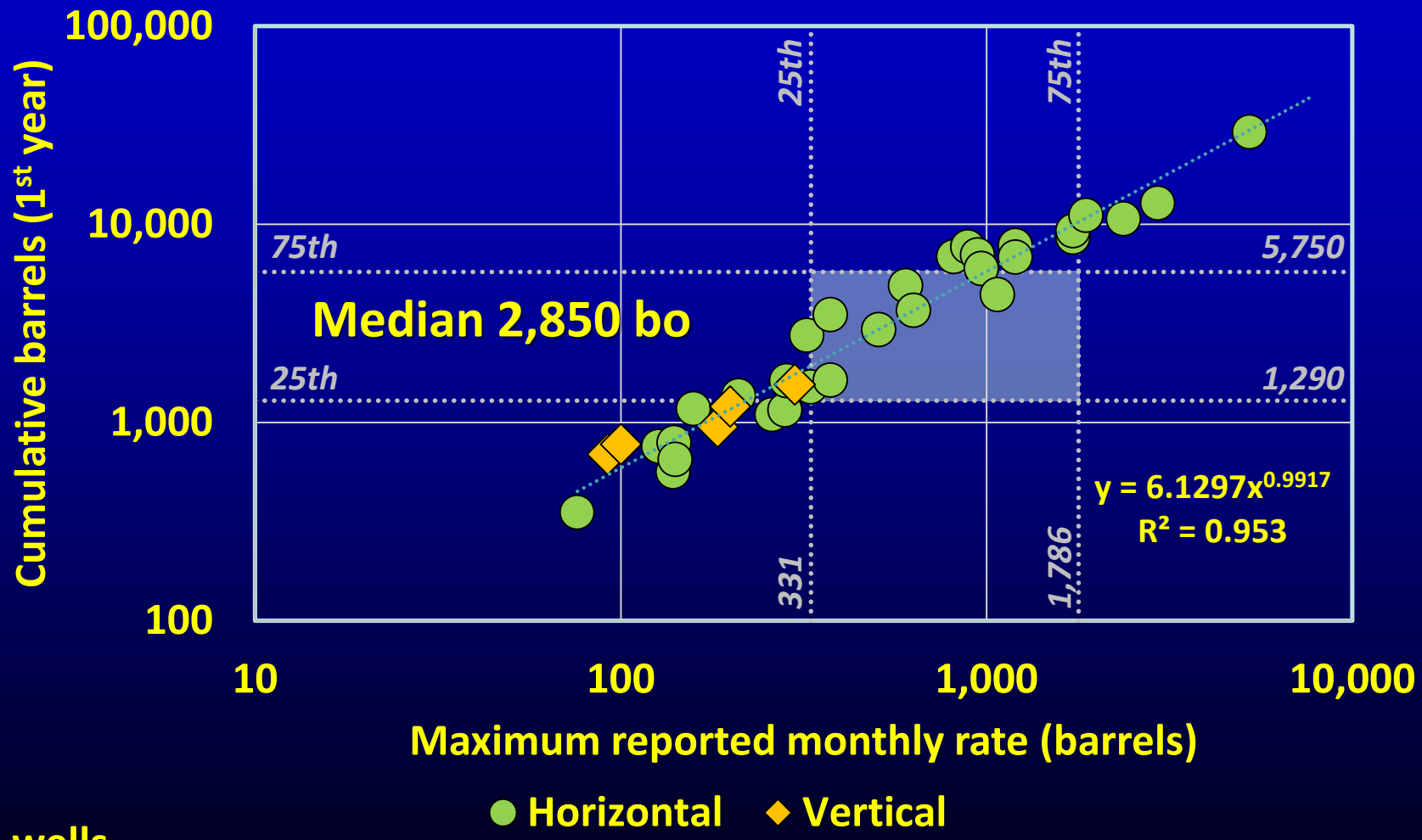
Oil Production

- **Production data**
  - 88 wells
- **At least 12 months**
  - 32 wells

  (Cumulative graph)
- **Decline significant ($r^2 > 0.47$)**
  - 10 wells

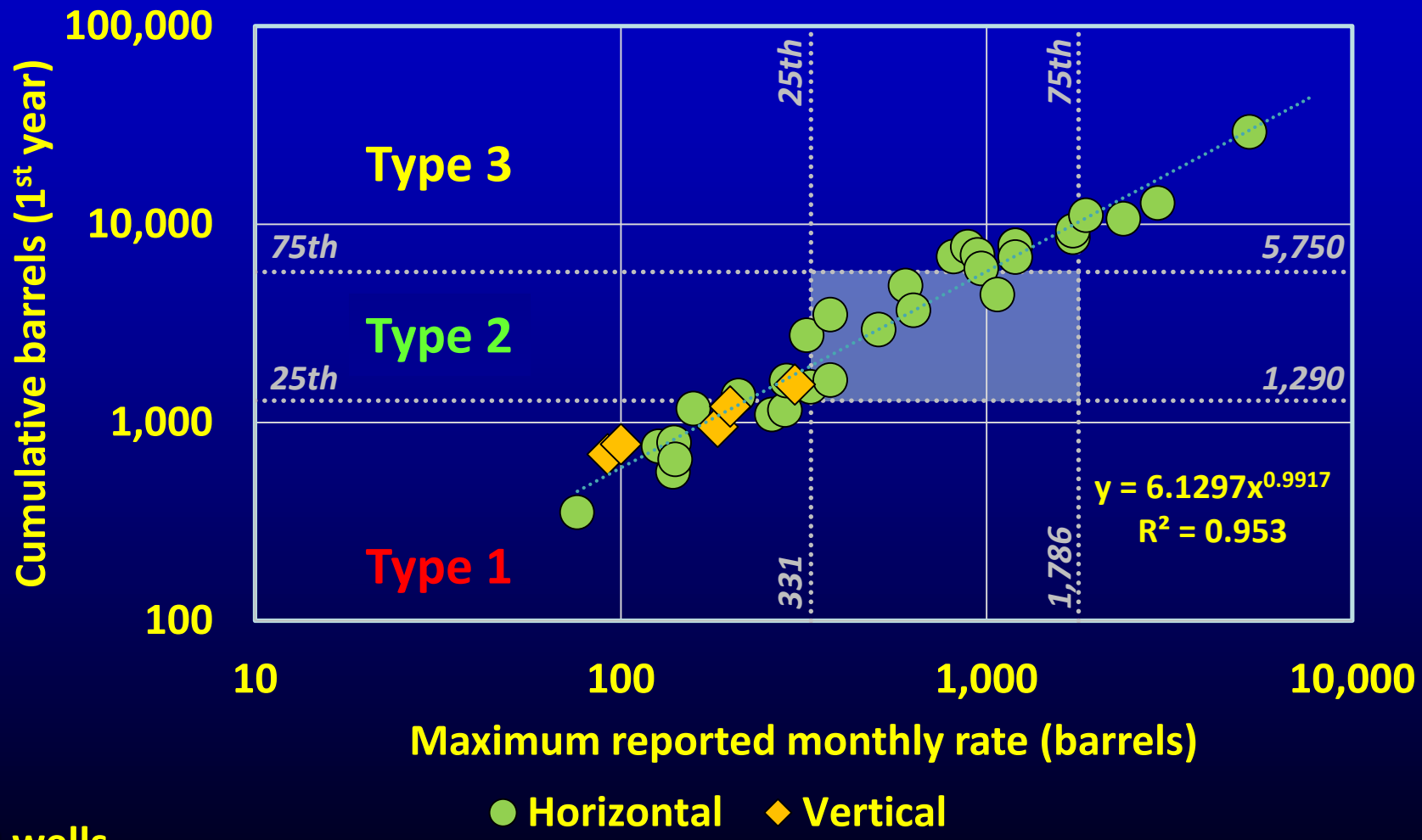
  (Type declines)

Short Term Oil Well Performance



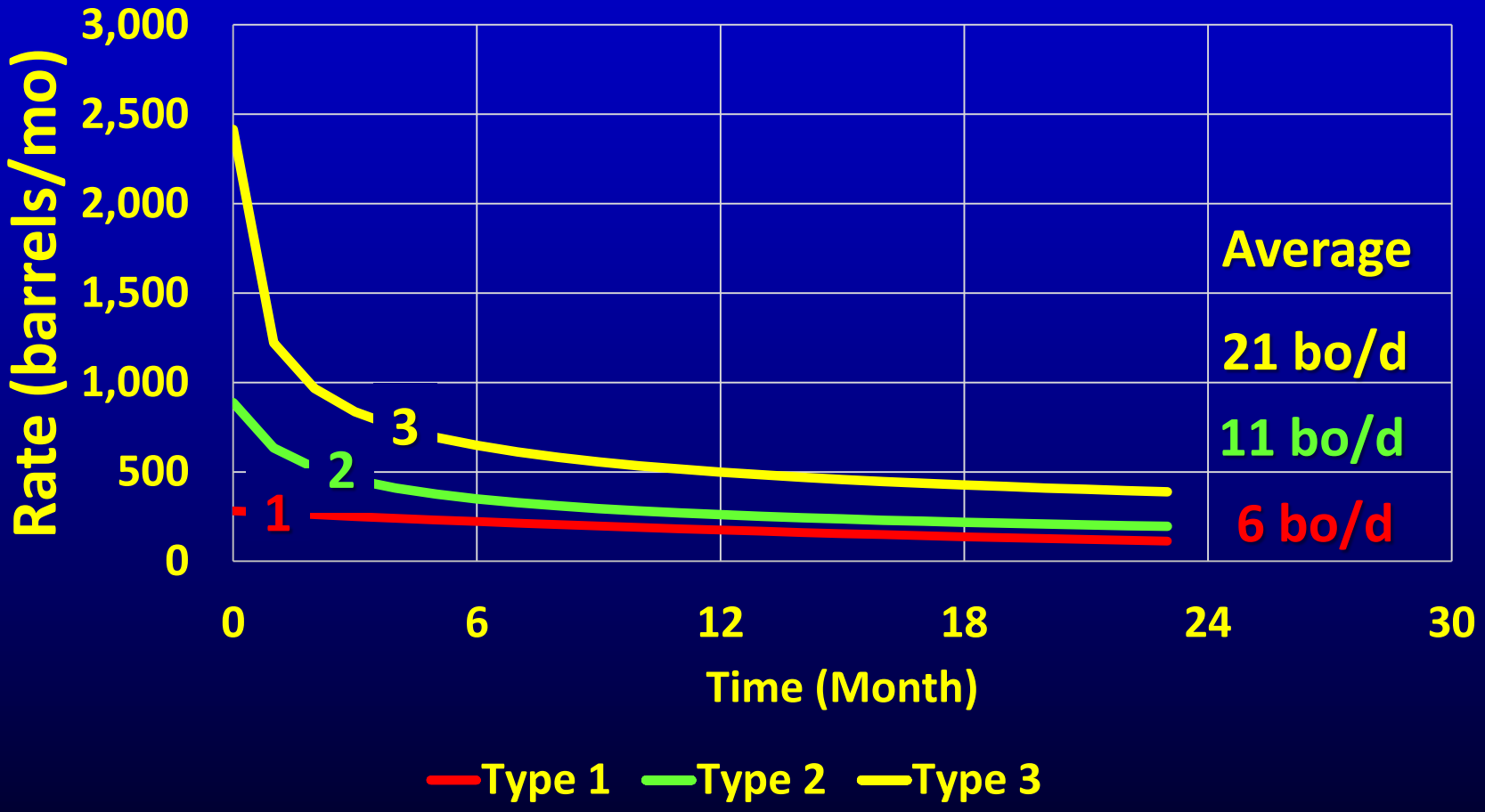
32 wells

Short Term Oil Well Performance



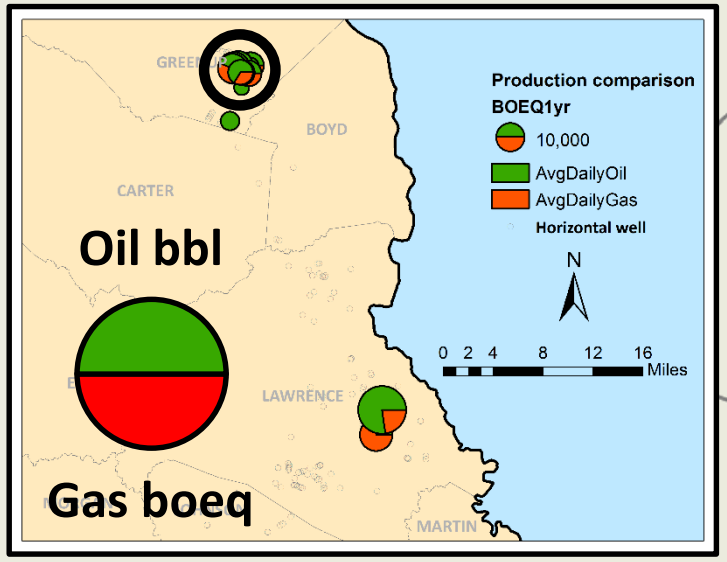
32 wells

Typical Oil Declines



Median decline within each type class

Greenup County Cumulative Production



10,902

8,8933,131

7,456

3,506

12,805

11,109

7,709

7,471

7,826

7,826

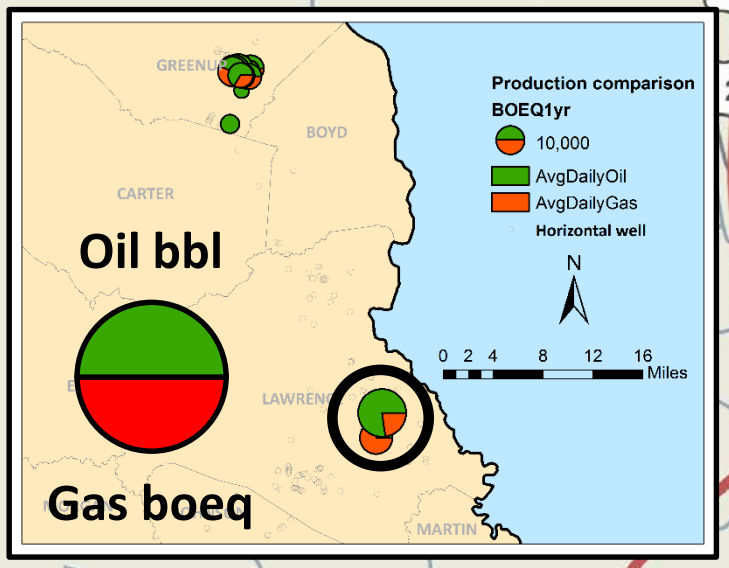
8,320

3,686

1st year oil and gas total (boeq)

Lawrence County Cumulative Production

1st year oil and gas total (boeq)



29,232

12,201

13,696

LAWRENCE

Torchlight

Chapman

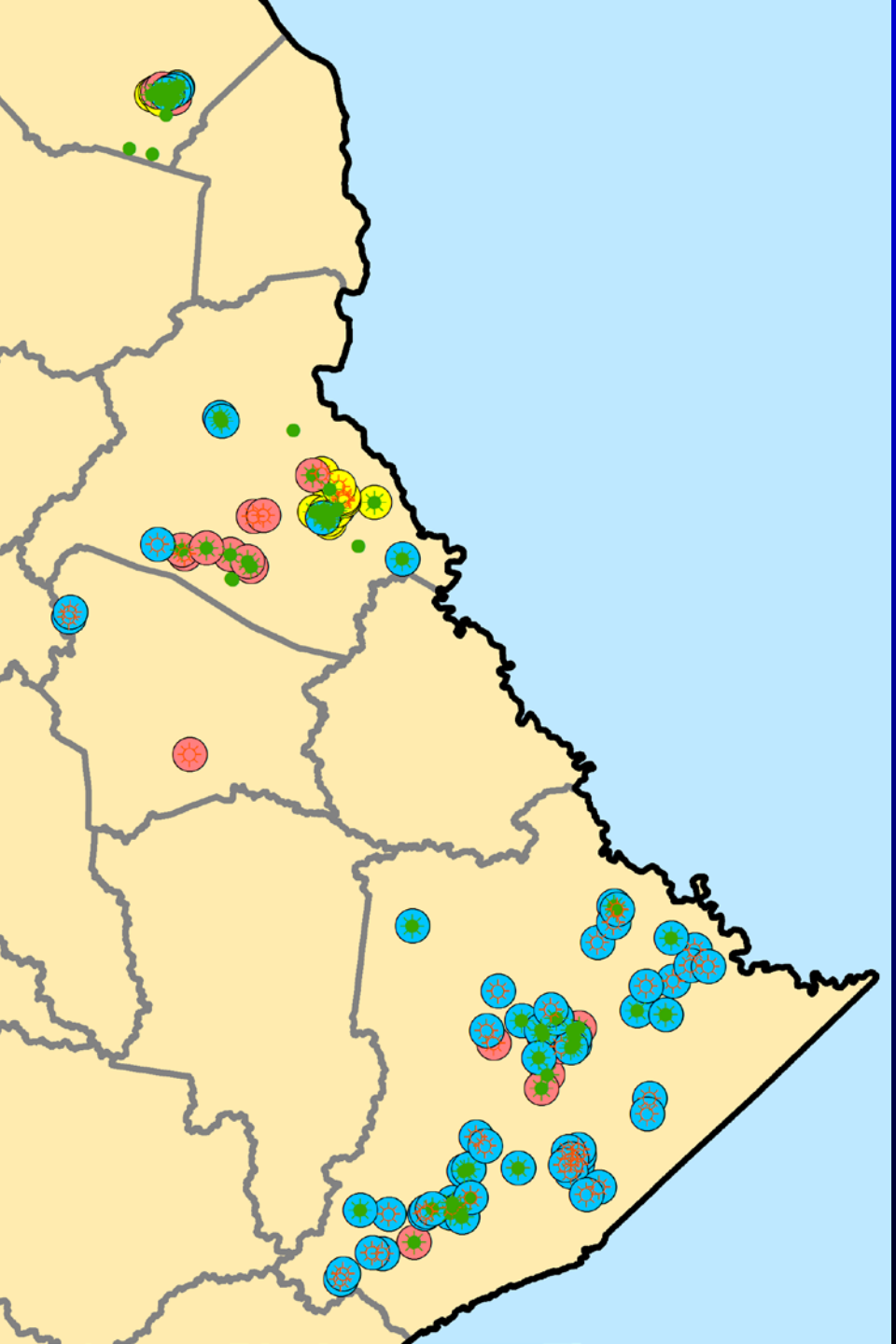
23

23

2037

2038

Kentucky Division of Geographic Information (DGI)



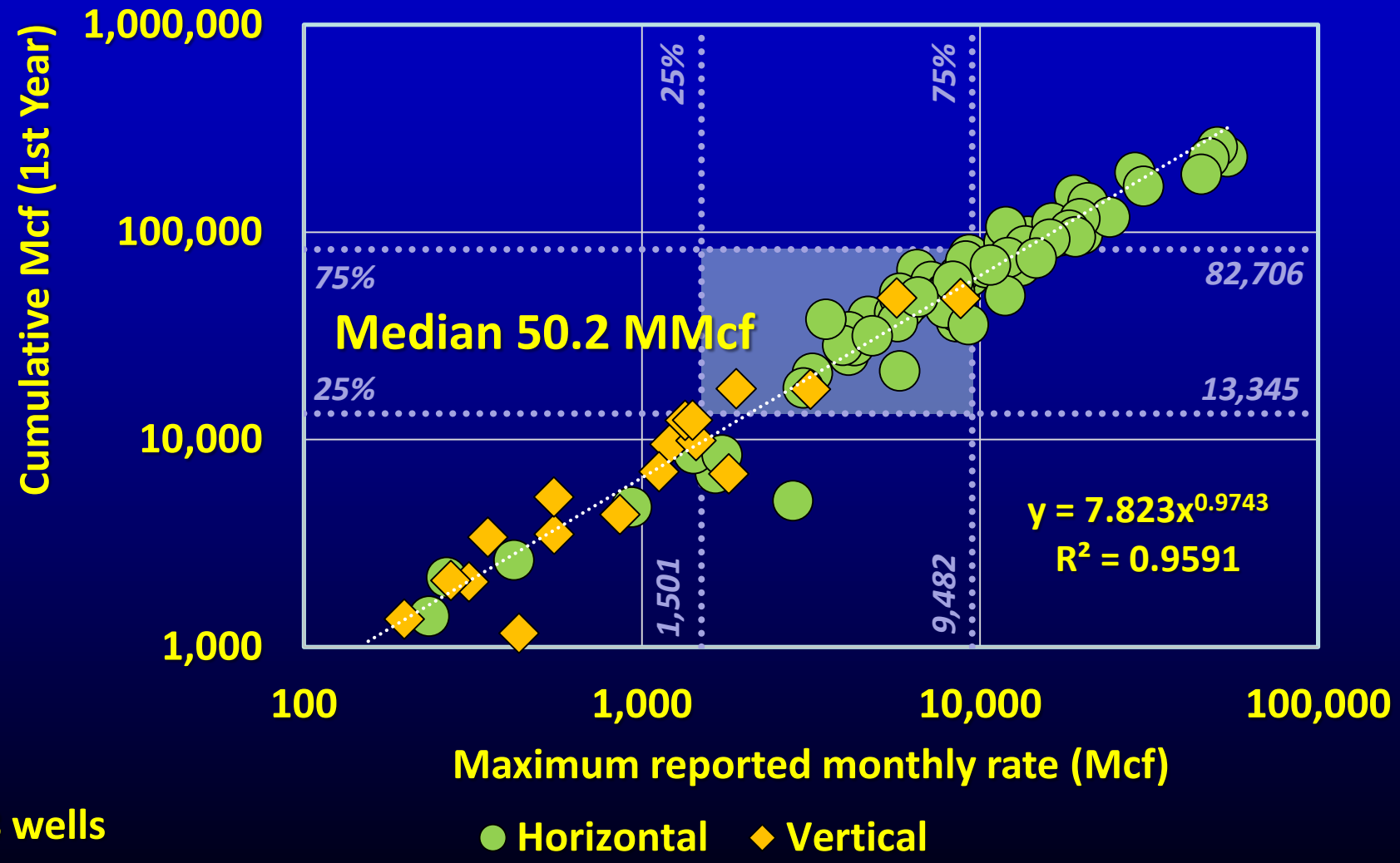
Gas Production

- **Production data**
  - 128 wells
- **At least 12 months**
  - 98 wells

  (Cumulative graph)
- **Decline significant ($r^2 > 0.47$)**
  - 74 wells

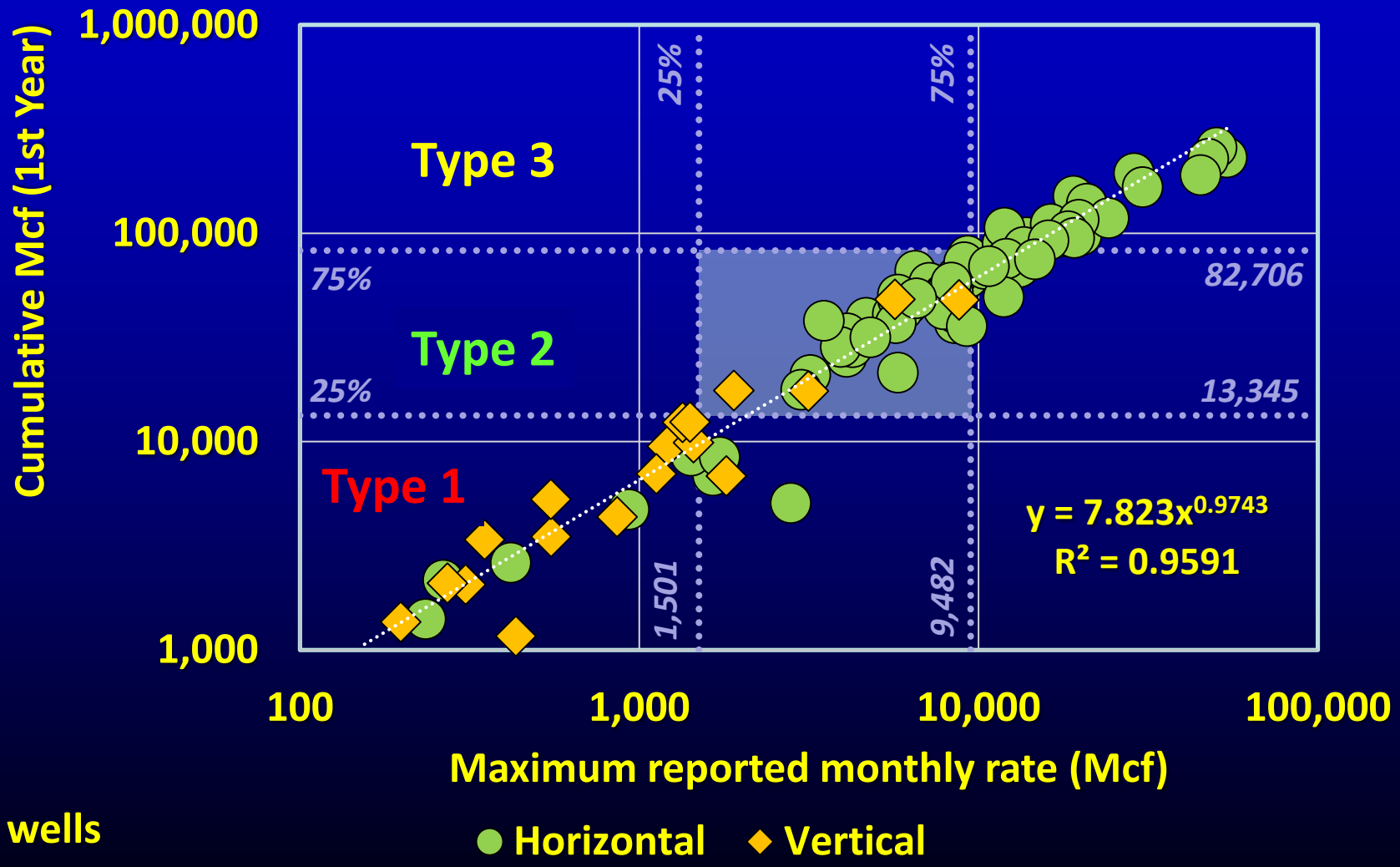
  (Type declines)

Short Term Gas Well Performance



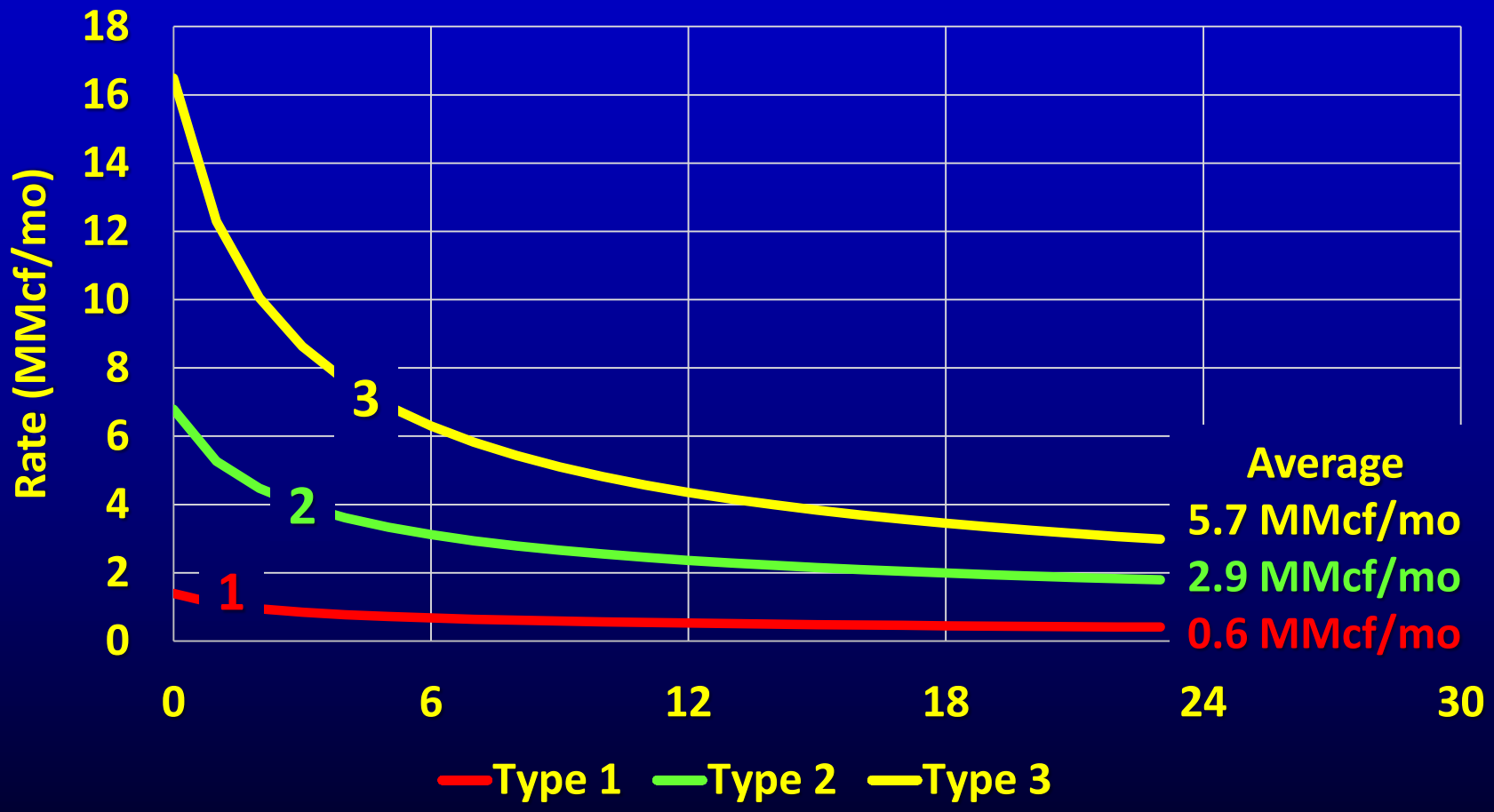
98 wells

Short Term Gas Well Performance



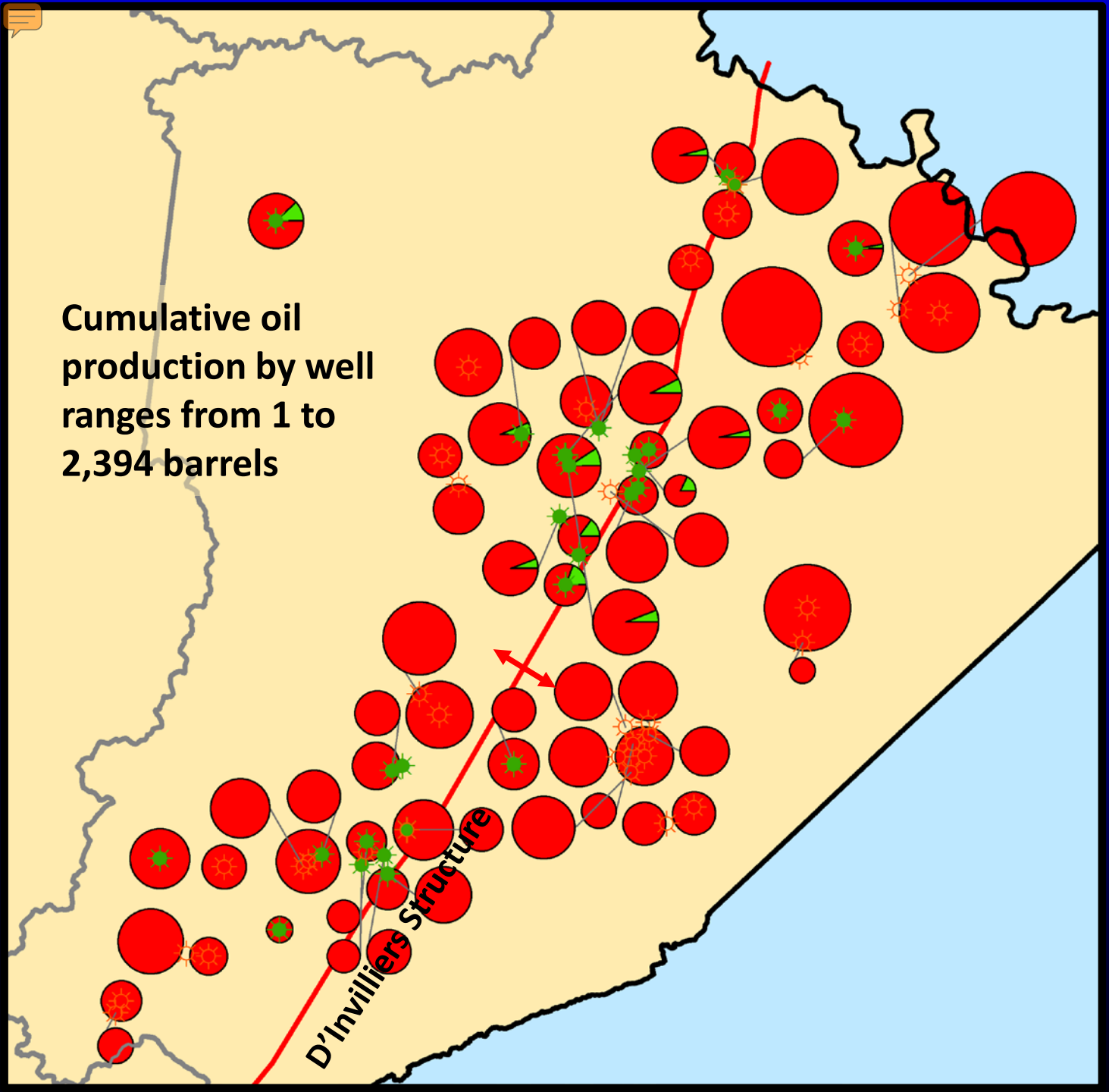
98 wells

Typical Gas Declines



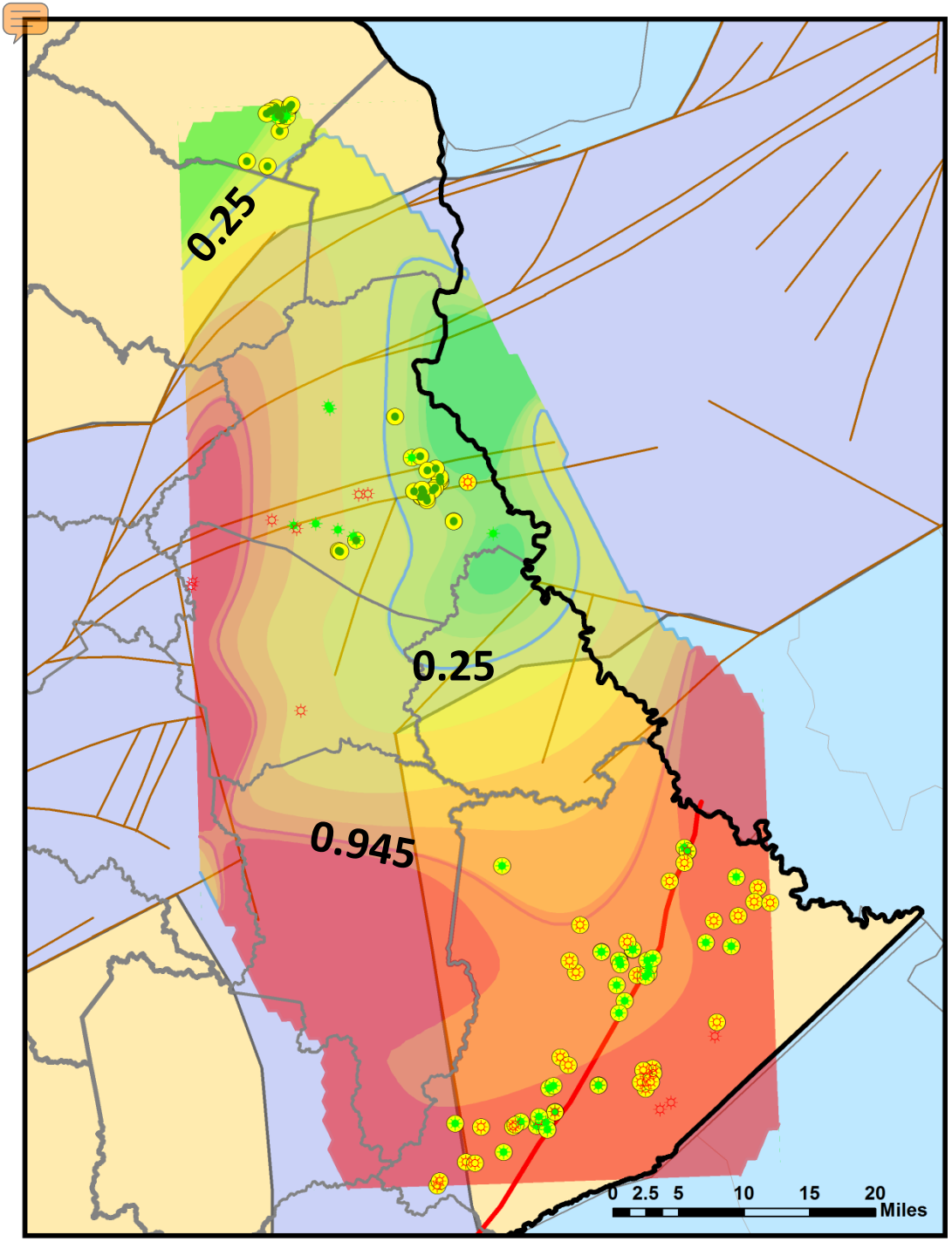
Median decline within each type class

Pike County



Oil bbl

Gas boeq



GPI

- Oil prone
  - Greenup
  - Lawrence
  - Martin ?
- Gas prone
  - Pike

Synthesis

- Limited historic production data
  - Most recent public data are 2 years old
  - Few oil wells with >12 months of data
- Berea oil producers out-perform typical Kentucky well
  - Horizontal, Greenup and Lawrence Counties
- Oil-prone areas: Greenup and Lawrence
- Gas-prone area: Pike County
  - Wet gas includes reported oil production

Implication

There may be additional areas with old, relatively shallow producing wells where horizontal drilling and modern completions could revive that production.

If the price is right…

Thanks

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www.uky.edu/kgs

Kentucky Geological Survey

References

Fetkovich, M.J., Fetkovich, E.J., and Fetkovich, M.D., 1996, Useful concepts for decline-curve forecasting, reserve estimation, and analysis: Society of Petroleum Engineers, Reservoir Engineering, SPE-28628-PA, February 1996, p. 13-22.

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