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


General Stratigraphy

East Kentucky

Mississippian
- Sunbury Shale
  - Berea Sandstone
    - Bedford Shale
      - Cleveland
        - Three Lick Bed
      - Upper Huron
        - Middle Huron
    - Olentangy Shale
      - Lower Huron
        - Olentangy Shale
        - Rhinestreet Shale

Devonian
- Upper Devonian
  - Chattanooga Shale

Ohio

Berea

Sunbury

Borden

Ohio
Heterogeneity and Soft Sediment

KY 10, near Garrison, Lewis County, Kentucky
Horizontal Wells by Year

1,640 permitted

- Berea oil wells
- 40 Total

Horizontal Wells

Total Permits Issued

- OIL
- O&G
- GAS
- D&A
- Other
- LOC
- Permits
2015 Oil Production: 2.8 MMbo

75% increase 2011 to 2014

63 Kentucky counties, 58 percent from eastern Kentucky
Significant Increase in Berea Production

Oil production (barrels) x 100000


Greenup  Lawrence  Henderson  Union
Daily Average vs 2010 Study

- All oil wells in 2010 public data set
- Greenup & Lawrence
  - Horizontal wells
  - At least 1 year of data

Bo/d

Nuttall, 2014, KGS Ser 12, IC 30
Kentucky Wells with Devonian Berea Completion

Earliest wells: 1879 to 1890’s in Johnson Co., and Blaine area of Lawrence Co.
Devonian Berea Activity

Status
- Oil
- Oil and gas
- Gas
- Dry
- Permitted

Historic fields
- Consolidated
- Oil field
- Gas field
- Waterflood
- Horizontal well

Kentucky

Miles
0 2 4 8 12 16

GREEN
BOYD CARTER ELLIOTT LAWRENCE MORGAN JOHNSON MARTIN
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

Number of wells

Horizontal

Vertical

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

$$q_t = \frac{q_i}{e^{D_it}}$$

Hyperbolic

$$q_t = \frac{q_i}{(1 - bD_it)^b}$$
Maximum reported monthly production rate

Sample data

At least 12 periods
GOR = \frac{Gas_{Mcf}}{Oil_{bbl}}

GOR & GPI

Gas Production Index

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

• No oil then what?

• 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
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

**Pie Charts:***
- **Pike:** 50% Horizontal, 0% Vertical
- **Lawrence:** 31% Horizontal, 2% Vertical
- **Johnson:** 17% Horizontal, 2% Vertical
- **Greenup:** 17% Horizontal, 2% Vertical

**Legend:**
- Sun: Gas
- Green: Oil and gas combined
- Green Circle: Oil
- Yellow: Horizontal 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
  - 10 wells
  (Type declines)
Short Term Oil Well Performance

Cumulative barrels (1st year)

Maximum reported monthly rate (barrels)

Median 2,850 bo

32 wells

y = 6.1297x^{0.9917}

R² = 0.953
Short Term Oil Well Performance

Cumulative barrels (1st year)

Maximum reported monthly rate (barrels)

y = 6.1297x^{0.9917}
R^2 = 0.953

Type 1
Type 2
Type 3

32 wells

Horizontal
Vertical
Typical Oil Declines

Median decline within each type class
Greenup County Cumulative Production

1st year oil and gas total (boeq)

<table>
<thead>
<tr>
<th>Oil bbl</th>
<th>Gas boeq</th>
</tr>
</thead>
<tbody>
<tr>
<td>11,109</td>
<td>7,709</td>
</tr>
<tr>
<td>12,805</td>
<td>7,826</td>
</tr>
<tr>
<td>10,902</td>
<td>7,826</td>
</tr>
<tr>
<td>10,000</td>
<td>3,506</td>
</tr>
<tr>
<td>3,686</td>
<td>7,456</td>
</tr>
<tr>
<td>8,320</td>
<td>8,8933,131</td>
</tr>
</tbody>
</table>

Production comparison BOEQ1yr

- Avg Daily Oil
- Avg Daily Gas
- Horizontal well

1st year oil and gas total (boeq)
Gas Production

- Production data
  - 128 wells

- At least 12 months
  - 98 wells
  (Cumulative graph)

- Decline significant
  - 74 wells
  (Type declines)

- Cumulative graph
- Type declines

- Production data
- At least 12 months
- Decline significant

- 128 wells
- 98 wells
- 74 wells

- (Cumulative graph)
- (Type declines)
Short Term Gas Well Performance

Median 50.2 MMcf

\[ y = 7.823 \times 0.9743^{\,x} \]

\[ R^2 = 0.9591 \]

Cumulative Mcf (1st Year)

Maximum reported monthly rate (Mcf)

98 wells

98 wells

Horizontal

Vertical

25%

75%

25%

75%

9,482

13,345

1,501

82,706

1,000

100,000

1,000,000

100

1,000

10,000

100,000
Short Term Gas Well Performance

Cumulative Mcf (1st Year)

1,000,000
100,000
10,000
1,000

Maximum reported monthly rate (Mcf)

100
1,000
10,000
100,000
1,000,000

Type 1
Type 2
Type 3

y = 7.823x^{0.9743}
R^2 = 0.9591

98 wells

25%
75%

25%

75%

1,501
9,482
13,345
82,706

Horizontal
Vertical
Typical Gas Declines

Median decline within each type class
Cumulative oil production by well ranges from 1 to 2,394 barrels.
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

