Update on the Berea Sandstone Oil Play in Kentucky

Stephen F. Greb, David C. Harris, Thomas M. (Marty) Parris, and Cortland F. Eble

Kentucky Geological Survey, University of Kentucky
Update on the Berea Ss

- Berea Ss background
- Recent KY production trends
- Greenup and Lawrence County activity
- Research questions raised by recent activity
- Berea Sandstone Consortium
The Berea Ss is an upper Devonian “tight sand” (siltstone across much of KY)

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

Berea outcrops in NE KY
Ky reservoirs are likely developed in storm shelf and slope deposits based on regional models (e.g., Pashin and Ettensohn, 1995)
Background

Eastern KY type Log, Lawrence County

Berea is a classic low-permeability reservoir

Sunbury Sh
Berea Ss/Bedford Sh

Ohio Sh

Caliper

Gamma Ray

NPHI%

TEMP

Density Por (ss)

PEF

Bulk Density

RILM

RILD

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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
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)
Recent Production Trends

Greenup County
Horizontal Well Locations

2014
Recent Production Trends

Greenup County

Production data available for two wells:

<table>
<thead>
<tr>
<th>Well</th>
<th>Mean bbls/month</th>
<th>First 6 months bbls/month</th>
<th>Since bbls/month</th>
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<tr>
<td>Brice Sheperd 1</td>
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<tr>
<td>Emory Patton Heirs 2</td>
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<td>744</td>
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</table>

Avg = 542 bbls/month
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 March, 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
Recent Production Trends

Lawrence County
Horizontal Well Locations
2014
Recent Production Trends

Recent Berea Oil Production, East Kentucky

Oil production (barrels) in Thousands:
- Greenup
- Lawrence

>10% of statewide production

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

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

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

- Can we examine possible Berea sources using different laboratory techniques to better understand $R_o$ and thermal maturity in the basin?
2) Is the Berea hydrocarbon source local, or has it migrated from the 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?
Berea Sandstone Consortium Project

- KGS, USGS, OGS, and 7 industry partners
- 18-month study of the Berea petroleum system

- Collect and analyze samples of source rocks for TOC, Rock-Eval pyrolysis, and reflectance to evaluate thermal maturity

- Collect and analyze samples of Berea oil and gas to geochemically tie the produced hydrocarbons to their source
  - Advance geochemical analyses including liquid and gas chromatography-mass spectroscopy of bitumen for biomarker analyses and stable carbon isotope composition
Berea Consortium Project

- KGS, USGS, OGS, and 7 industry partners
- 18-month study of the Berea petroleum system

- Generate cross sections, and detailed stratigraphic and structure maps of the Berea in KY

- Compare geophysical logs, cores, and outcrops to better characterize the Berea petroleum system

- Project updates will be posted on the KGS website and a report will be published 1 year after the project is completed
Thank you

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