Oil Production From Low-Maturity Organic-Rich Shale: An Example from the Devonian New Albany Shale in the Illinois Basin, Breckinridge County, Kentucky *

Brandon C. Nuttall¹, Thomas M. Parris¹, Glynn Beck¹, Donna C. Willette², Maria Mastalerz³, and Joan Crockett²

Search and Discovery Article #51196 (2015)**
Posted November 30, 2015

*Adapted from oral presentation given at AAPG Eastern Section 44th Annual Meeting, Indianapolis, Indiana, September 20-22, 2015
**Datapages © 2015 Serial rights given by author. For all other rights contact author directly.

¹Kentucky Geological Survey, Lexington, KY, USA (bnuuttall@uky.edu)
²Illinois State Geological Survey, Champaign, IL, USA
³Indiana Geological Survey, Bloomington, IN USA

Abstract

The Devonian New Albany Shale is recognized as the primary source rock for Illinois Basin oil and gas production. As a shale reservoir, the New Albany is historically a gas producer. In 2011, Endeavor Energy Resources LP drilled and completed four natural gas producers in the Grassy Creek Member at the top of the shale in Breckinridge County, Kentucky. In 2012, Endeavor filed new completion reports indicating these wells had transitioned to combined oil and natural gas producers. In 2013, Hard Rock Drilling completed two oil producers to the northwest of the Endeavor wells. In approximately 18 months, these six wells have produced 23,649 barrels of oil and 246 MMcf of gas.

Oil, gas, and well cutting samples were acquired from two Endeavor wells and the Kentucky Geological Survey No. 1 Blan well. Rock-Eval, isotopic, and chromatographic analysis indicates the New Albany is a good, early mature source rock with Type I and Type II oil-prone marine kerogen that was thermogenically altered to natural gas and oil. Low reservoir pressures and geochemical fingerprinting suggest that the hydrocarbons were generated in place or very locally with minimal migration. The low Tmax and high hydrogen index (from Rock-Eval), presence of wet gas, and a large fraction of light gasolines in the produced oils are not consistent with classic measures of thermal maturity, however. Additional study is needed to develop a better understanding of this production and realistically assess the oil and gas potential of the New Albany Shale.

Selected References


Oil Production from Low-maturity Organic-rich shale: an Example from the Devonian New Albany Shale in the Illinois Basin, Breckinridge County, Kentucky

Brandon C. Nuttall¹, Marty Parris¹, Glynn Beck¹, Donna Willette², Maria Mastalez³, Joan Crockett²

Eastern Section AAPG, Indianapolis, IN 21-Sep-2015
Kentucky is Underlain by Gas Shale

At least 100’ thick and 1,000’ deep
### General Stratigraphy

#### Kentucky shale gas producer

**Minor producer**

**Correlations in this chart from West Kentucky to Pennsylvania are relative and not formal.**
Kentucky Shale Gas Wells

2014: 257 Bcf

99%
Endeavor Wells in Breckinridge Co.

- 2011 – drilled, gas
- 2012 – new report, oil

Initial GOR from 1.8 to 4
Historic Shale Wells with Oil

Gas wells with small amounts of oil (4 to 450 bbls)

Study Area

RCFZ
Fort Payne
New Albany
Completion

Grassy Creek Mbr
New Albany

Endeavor 5
Endeavor 4

3.25 miles

Total Depth

Completion
- Fort Payne
- New Albany
Endeavor 5 Whitfill

- 200 Mcf (IOF, 2011)
- 33 Bo/d & 60 Mcf (2012)
Endeavor #5 Whitfill

During visit:
- Estimated
- 10-12 bo/d
- 20 Mcf/d
- 400 psi backpressure
- Paraffin
- AT 60 bo/d
- Declines to 5 bo/d
Preparing to Sample Fluids
## Analyses & Data Sets

<table>
<thead>
<tr>
<th></th>
<th>Endeavor 4</th>
<th>Endeavor 5</th>
<th>KGS 1 Blan</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Natural gas</strong></td>
<td><img src="checkmark.png" alt="Checkmark" /></td>
<td><img src="checkmark.png" alt="Checkmark" /></td>
<td>Other data see Nuttall (2013) KGS RI 17</td>
</tr>
<tr>
<td>Composition</td>
<td><img src="checkmark.png" alt="Checkmark" /></td>
<td><img src="checkmark.png" alt="Checkmark" /></td>
<td></td>
</tr>
<tr>
<td>Isotopes</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Oil</strong></td>
<td><img src="checkmark.png" alt="Checkmark" /></td>
<td><img src="checkmark.png" alt="Checkmark" /></td>
<td><img src="checkmark.png" alt="Checkmark" /></td>
</tr>
<tr>
<td>Whole oil GC</td>
<td><img src="checkmark.png" alt="Checkmark" /></td>
<td><img src="checkmark.png" alt="Checkmark" /></td>
<td></td>
</tr>
<tr>
<td>Isotopes</td>
<td><img src="checkmark.png" alt="Checkmark" /></td>
<td><img src="checkmark.png" alt="Checkmark" /></td>
<td></td>
</tr>
<tr>
<td>MPLC</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Cuttings/Core</strong></td>
<td><img src="checkmark.png" alt="Checkmark" /></td>
<td><img src="checkmark.png" alt="Checkmark" /></td>
<td><img src="checkmark.png" alt="Checkmark" /></td>
</tr>
<tr>
<td>Extract GC</td>
<td><img src="checkmark.png" alt="Checkmark" /></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Aromatic GCMS</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Saturate GCMS</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>MPLC</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Gas Chromatograms of Whole Oil

Endeavor # 4
Depth 1858’
API 42  GOR 3.8

Unusually large \(<nC7\) gasoline component

Endeavor # 5
Depth 1998’
API 42  GOR 1.8

Unusually large \(<nC7\) gasoline component
Oil & Extract Gas Chromatographs

Phytane/n-C18 vs. Pristane/n-C17

Data:
- Burgess, Humble Geochemical
- Burruss, USGS
- Reynolds (unpublished, WKY)
- Chou, IP136

Modified from Hamilton-Smith (KGS unpublished)
Hunt (1995)
Biomarkers: Sterane Distributions (GCMS)

Cuttings Extracts

Endeavor 4

Oil

KY0014
Geomark

(U. Devonian, distal marine shale, moderate maturity)
Clustering indicates oil and source are related (statistically significant).
Mastalerz and others, 2013, AAPG v. 97 n. 10
Endeavor #4 Pyrogram

- Organic-rich, early mature source rock
- Broad S2 indicates large capacity to generate hydrocarbons
$T_{\text{max}} \ (°C) - \text{Max. Rate S2 Conversion}$

After Cole et al (1994)
Data from Endeavor 4, Blan, IP136, RPSEA
Methane Isotopes

Whiticar (1999)
Rock-Eval

- Early mature
- Type I & II
- Oil prone
- Marine

Blan: Nuttall (2013) KGS Ser 12, RI 17
IP136: Chou and others, (1991)
RPSEA: Salehi and others, (2010) contract 07122-6
# Key Data Summary

<table>
<thead>
<tr>
<th></th>
<th>Endeavor 4</th>
<th>Endeavor 5</th>
<th>Blan 1</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Depth (ft)</strong></td>
<td>1,858</td>
<td>1,998</td>
<td>1,876.5</td>
</tr>
<tr>
<td><strong>TOC (%)</strong></td>
<td>9.93</td>
<td>7.93</td>
<td></td>
</tr>
<tr>
<td><strong>HI</strong></td>
<td>756</td>
<td>896</td>
<td></td>
</tr>
<tr>
<td><strong>S1</strong></td>
<td>4.73</td>
<td></td>
<td>6.16</td>
</tr>
<tr>
<td><strong>%Saturates (Oils)</strong></td>
<td>61.69</td>
<td>62.95</td>
<td></td>
</tr>
<tr>
<td><strong>%Aromatics (Oils)</strong></td>
<td>28.43</td>
<td>26.84</td>
<td></td>
</tr>
<tr>
<td><strong>Sat. $^{13}$C</strong></td>
<td>* -30.9</td>
<td>* -30.8</td>
<td></td>
</tr>
<tr>
<td><strong>Arom. $^{13}$C</strong></td>
<td>* -29.8</td>
<td>* -29.8</td>
<td></td>
</tr>
<tr>
<td><strong>%Saturates (Ext)</strong></td>
<td>21.37</td>
<td></td>
<td>31.68</td>
</tr>
<tr>
<td><strong>%Aromatics (Ext)</strong></td>
<td>17.57</td>
<td></td>
<td>19.72</td>
</tr>
<tr>
<td><strong>Sat. $^{13}$C</strong></td>
<td>* -29.2</td>
<td></td>
<td>* -29</td>
</tr>
<tr>
<td><strong>Arom. $^{13}$C</strong></td>
<td>* -29.1</td>
<td></td>
<td>* -29.1</td>
</tr>
</tbody>
</table>

Consistent with having been generated in place
HI – Kerogen Conversion

New Albany Shale Petroleum System

Smaller HI indicates more conversion

$R_o$ Calculated from Biomarkers

Median 0.48

Count

$R_o$

Extracts

Oils
### Maturity Summary

- **Good source rock**
- **Early mature**
- **Type I & II**
- **Oil prone**
- **Marine**
- **Thermogenic**

---

<table>
<thead>
<tr>
<th>Pre-metamorphic zones</th>
<th>Coal rank</th>
<th>( R_0 ) %</th>
<th>Organic diagenesis phases</th>
<th>Hydrocarbon generation from source rocks containing kerogens type-I and type-II</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>Maturity</td>
<td>Types</td>
</tr>
<tr>
<td><strong>diagenesis</strong></td>
<td>peat</td>
<td>0.2</td>
<td>immature</td>
<td>early dry gas</td>
</tr>
<tr>
<td></td>
<td>lignite</td>
<td>0.3</td>
<td>immature</td>
<td>early dry gas</td>
</tr>
<tr>
<td></td>
<td>sub-bit.</td>
<td>0.38</td>
<td>immature</td>
<td>early dry gas</td>
</tr>
<tr>
<td></td>
<td>B</td>
<td>0.4</td>
<td>mature</td>
<td>oil</td>
</tr>
<tr>
<td></td>
<td>C</td>
<td>0.5</td>
<td>mature</td>
<td>oil</td>
</tr>
<tr>
<td></td>
<td>A</td>
<td>0.6</td>
<td>mature</td>
<td>oil</td>
</tr>
<tr>
<td></td>
<td>high vol. bit.</td>
<td>0.7</td>
<td>mature</td>
<td>oil</td>
</tr>
<tr>
<td></td>
<td>B</td>
<td>0.8</td>
<td>mature</td>
<td>oil</td>
</tr>
<tr>
<td></td>
<td>A</td>
<td>0.9</td>
<td>mature</td>
<td>oil</td>
</tr>
<tr>
<td></td>
<td>medium vol. bit.</td>
<td>1.2</td>
<td>mature</td>
<td>oil</td>
</tr>
<tr>
<td></td>
<td>low vol. bit.</td>
<td>1.5</td>
<td>mature</td>
<td>oil</td>
</tr>
<tr>
<td><strong>catagenesis</strong></td>
<td>semi-anthrac.</td>
<td>1.35</td>
<td>mature</td>
<td>condensate and wet gas</td>
</tr>
<tr>
<td></td>
<td>anthracite</td>
<td>1.5</td>
<td>mature</td>
<td>condensate and wet gas</td>
</tr>
<tr>
<td></td>
<td>meta-anthrac.</td>
<td>2.0</td>
<td>over-mature</td>
<td>thermogenic dry gas</td>
</tr>
<tr>
<td></td>
<td></td>
<td>2.5</td>
<td>over-mature</td>
<td>thermogenic dry gas</td>
</tr>
<tr>
<td></td>
<td></td>
<td>3.0</td>
<td>over-mature</td>
<td>thermogenic dry gas</td>
</tr>
<tr>
<td></td>
<td></td>
<td>4.0</td>
<td>over-mature</td>
<td>thermogenic dry gas</td>
</tr>
<tr>
<td></td>
<td></td>
<td>5.0</td>
<td>over-mature</td>
<td>thermogenic dry gas</td>
</tr>
</tbody>
</table>

---

Modified from Mastalerz and others (2013) AAPG v. 97, n. 10
Cumulative Total: 23,649 bo, 246 MMcf

Hard Rock

#5 Whitfill

#4 Burton-Whitfill

General location
Breckinridge County Activity

- Endeavor and Hardrock
- Old wells with oil

Permits since 1/1/2013:
- OIL
- O&G
- GAS
- DRY
- Location
- Expired or cancelled

CountryMark
Conclusions

- Early mature source rock (in oil window)
- Consistent with generation in New Albany
- Not consistent with classic measures of thermal maturity ($T_{\text{max}}$, $\%R_o$)
  - Wet gas
  - Higher than expected light gasoline fractions
- What does $\%R_o$ mean in a marine shale?
• Extremely limited data set
  – 4 data points with geochemistry does not make a play

• Potential for oil and NGLs
  – Down dip?
  – West of Locust Hill-Cave Spring Fault?
  – North of the Rough Creek Fault?
  – More mature in Rough Creek Graben?
Takeaway

• Extremely limited data set
  — 2 data points does not make a play
• Potential for oil and NGLs
  — Down dip?
  — West of Locust Hill-Cave Spring Fault?
  — North of the Rough Creek Fault?
  — More mature in Rough Creek Graben?

The current wellhead price of oil and gas!
Acknowledgments

Ray Henning
Wally Dow
John Zumbarge
Thanks

Brandon C. Nuttall
Kentucky Geological Survey
www.uky.edu/KGS
bnuttall@uky.edu
(859) 323-0544
Detailed geochemical and geomechanical assessment of selected wells in Indiana and Kentucky

• www.rpsea.org
• www.gastechnology.org
• www.isgs.Illinois.edu
Rock-Eval pyrolysis and oil fingerprinting data for wells in Illinois, Indiana, and Kentucky (includes data other than New Albany Shale)
KGS #1 Blan Publication

- TOC – 4.75% to 9.74%
- Oil to wet gas
  - TAI – 2 to 2.3
  - $R_{\text{max}}$ – 0.45% to 0.55%
  - $T_{\text{max}}$ – 431°C to 440°C
- $k$ – 9.48x10^{-5} md

www.uky.edu/KGS to download PDF

RI 17, 2013