Evidence of Oil Generation in Early Mature Shale, Devonian New Albany Shale, Breckinridge County, Kentucky

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¹Kentucky Geological Survey
²Cimarex (Retired)

Kentucky Section AIPG, Lexington, KY 17-Apr-2015
Kentucky is Underlain by Gas Shale

At least 100’ thick and 1,000’ deep
Kentucky Shale Gas Wells

2014: 257 Bcf

RCFZ
Flaherty
Shrewsbury
Apex

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)
Oil Production from New Albany

- **Endeavor Energy**
  - #1 Baum (107321)
  - #3 Burton-Whitfill (107322)
  - #4 Burton Whitfill (107296)
  - #5 Whitfill (107651)
- **Hard Rock #1 Pullen (110407)

Thanks to Dave Harris for digging these out
Endeavor 5 Whitfill

- 200 Mcf (IOF, 2011)
- 33 Bo/d & 60 Mcf (2012)
Initial Completions

• **Endeavor wells**
  - Vertical wellbore
  - Cased hole
  - High GR in Grassy Creek
  - 7’ to 8’ interval
  - Water: 376 to 390 bbl
  - Sand: ≈45,000 lb
  - IOF 150 to 200 Mcf/d
    • Oil after 1 yr +/-

• **Previous wells**
  - Vertical wellbore
  - Cased hole
  - Entire New Albany
  - 113’ to 160’ interval
  - N₂ or N₂-foam frac
  - Sand: ≈60,000 lb
  - IOF 20 to 500 Mcf/d
    • Some production data indicate possible oil

• Oil after 1 yr +/-
Oil & Gas Production through 2013

Hard Rock 1 Pullen
- 3,538 bo

5 Whitfill
- 9,548 bo, 35.8 MMcf

3 Whitfill-Burton
- (449 bo, 152 MMcf)
- 720 bo, 2.4 MMcf

4 Burton-Whitfill
- 1,696 bo, 10 MMcf

1 Baum
- 2,303 bo, 41.8 MMcf

Cumulative total: 17,805 bo, 90 MMcf
Isopach of New Albany
Structure on Top of New Albany

- No significant closure
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
Sampling

- Medium olive, 42° API oil
- All sampling done in closed systems
# Analyses & Data Sets

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<thead>
<tr>
<th></th>
<th>Endeavor 4</th>
<th>Endeavor 5</th>
<th>KGS 1 Blan</th>
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<tbody>
<tr>
<td><strong>Natural gas</strong></td>
<td>![Checkmark]</td>
<td>![Checkmark]</td>
<td>Other data see Nuttall (2013) KGS RI 17</td>
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<td>Composition</td>
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<td><strong>Cuttings/Core</strong></td>
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<td>Extract GC</td>
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<td>Aromatic GCMS</td>
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<td>Saturate GCMS</td>
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<td>MPLC</td>
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### Gas Analysis

<table>
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<th>Well</th>
<th>BTU</th>
<th>GPM</th>
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<tbody>
<tr>
<td>Endeavor 4</td>
<td>1,126</td>
<td>5.02</td>
</tr>
<tr>
<td>Endeavor 5</td>
<td>1,182</td>
<td>5.74</td>
</tr>
</tbody>
</table>

![Bar chart showing mole percent of various components for Endeavor 4 and 5 wells.](chart.png)

**Endeavor 4**
- BTU: 1,126
- GPM: 5.02

**Endeavor 5**
- BTU: 1,182
- GPM: 5.74
Gas Chromatograms of Whole Oil

Endeavor # 4
Depth 1858'
API 42  GOR 3.8

Endeavor # 5
Depth 1998'
API 42  GOR 1.8

Unusually large \(<nC7\) gasoline component

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

Phytane/n-c18 vs. Pristane/n-C17

- Ordovician
- Cincinnati Arch
- West Kentucky
- Extracts
- Oils

Maturity

Data:
Burgess, Humble Geochemical
Burruss, USGS
Reynolds (WKY)

Modified from Hamilton-Smith (KGS unpublished)
Hunt (1995)
Not a Geochemist
Rock-Eval Definitions

- **S1** – free oil content
- **S2** – remaining hydrocarbon potential
- **$T_{\text{max}}$** – temperature of maximum rate of evolution of S2 hydrocarbons, thermal maturity
  - \[\%R_o = 0.018 \times T_{\text{max}} - 7.16\] (Jarvie, 2001)
- **Kerogen types:**
  - **HI** – normalized hydrogen content
  - **OI** – normalized oxygen content
Endeavor #4 Pyrogram

- Organic-rich, early mature source rock
- Broad S2 indicates large capacity to generate hydrocarbons
Observations

T_{\text{max}} (°C) – Max. Rate S2 Conversion

After Cole et al (1994)
Data from Endeavor 4, Blan, IP136, RPSEA
Mastalerz and others, 2013, AAPG v. 97 n. 10
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
HI – Kerogen Conversion

New Albany Shale Petroleum System

Smaller HI indicates more conversion

Methane Isotopes

Whiticar (1999)
Biomarkers: Early Mature

- **22S/(22S+22R)**: At or above early oil generation
- **Ts/Ts+Tm**: Early to peak oil generation
- **C_{29}αββ/(αββ+ααα)**: Early to peak oil generation
- **C_{28}αββ/(αββ+ααα)**: Early to peak oil generation
- **C_{29}20S/(20S+20R)**: At or above peak oil generation
- **C_{28}20S/(20S+20R)**: Early to peak oil generation
- **C_{27}20S/(20S+20R)**: At or above peak oil generation

**Biomarkers:** Early Mature
## Key Data Summary

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

Consistent with having been generated in place
Biomarkers: Sterane Distributions (GCMS)

Cuttings Extracts

Endeavor 4

KY0014
Geomark

(U. Devonian, distal marine shale, moderate maturity)
Endeavor 4 Saturates (Steranes)

GCMS ratios (on area)

- %C27 abbS (218)
- %C28 abbS (218)
- %C29 abbS (218)
- %C27 aaaR (217)
- %C28 aaaR (217)
- %C29 aaaR (217)

Oil
Extract

Drawn from same population ($X^2 @ 95\%$ confidence)
Oils and Extracts

Clustering indicates oil and source are related (statistically significant)

Some data courtesy of Geomark
47 Permits issued since 1/1/13

IP 45 bo/d

5,363 bo

IP 36 bo/d, 50 Mcf/d

Permitted location

Not completed in New Albany Shale

Reported completed, but no completion or production available
### 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>Organic diagenesis phases</th>
<th>Hydrocarbon generation from source rocks containing kerogens type-I and type-II</th>
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<td>Maturity</td>
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<td>peat</td>
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<td>early dry gas</td>
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<td></td>
<td>C</td>
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<td></td>
<td>B</td>
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<td>A</td>
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<tr>
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<td>medium vol. bit.</td>
<td>catagenesis</td>
<td>mature</td>
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<td>low vol. bit.</td>
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<td>overmature</td>
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Modified from Mastalerz and others (2013) AAPG v. 97, n. 10
Conclusions

• Early mature source rock
• Consistent with generation in New Albany
• Not consistent with classic measures of thermal maturity
  – Wet gas
  – Higher than expected light gasoline fractions
Takeaway

• Extremely limited data set
  – 2 data points do 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?
  – South of the Rough Creek Fault?
  – More mature in Rough Creek Graben?

The current wellhead price of oil and gas!
Acknowledgments

Glynn Beck
Marty Parris
Dave Harris
Ray Henning
Wally Dow
John Zumberge
Thanks

Brandon C. Nuttall
Kentucky Geological Survey
www.uky.edu/KGS
bnuttall@uky.edu
(859) 323-0544
RPSEA Contract 07122-16

RPSEA/GTI, 2010

Detailed geochemical and geomechanical assessment of selected wells in Indiana and Kentucky

- www.rpsea.org
- www.gastechnology.org
- www.isgs.Illinois.edu

New Albany Shale Gas Project
07122-16

November 23, 2010

Iraj Salehi
Manager, Shale Gas Research

Gas Technology Institute
1700 South Mount Prospect Road
Des Plaines IL, 60018
HYDROCARBON SOURCE POTENTIAL AND ORGANIC GEOCHEMICAL NATURE OF SOURCE ROCKS AND CRUDE OILS IN THE ILLINOIS BASIN

Mei-In M. Chou, Donald R. Dickerson, Sheng-Fu J. Chou, and Michael L. Sargent

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