Abstract

Activity associated with the Ordovician Utica Shale-Point Pleasant Formation play continues to ramp up, and Ohio continues to be the primary focus of activity within this continuous reservoir system. This focus is mostly due to the drilling depths and the presence of natural gas liquids and oil within Ohio. The first horizontal exploration wells were drilled and completed in the Utica-Point Pleasant interval in early 2011. By the end of 2011, over 150 horizontal permits had been issued and 30 wells drilled. As of early January 2013 500 permits had been issued and 210 wells drilled. However, it still is early within this play and much remains to be defined.

Within Ohio, the Point Pleasant Formation lies directly above the Trenton Limestone and is, at least in part, equivalent with the thick deposits of the Trenton carbonate platform of northwestern Ohio, famous for the Lima-Indiana oil-and-gas trend, which was the first true giant field produced in North America, starting in 1884. As the carbonate-platform deposits of the Trenton thin, the interbedded, organic-rich carbonates and shales of the Point Pleasant thicken. The deposition of Trenton platform carbonates and contemporaneous interplatform shales represents major sedimentological and structural changes to the region as a direct result of the ensuing Taconic Orogeny. As the orogenic activity increased and the foreland basin deepened, the organic-rich Utica Shale transgressed the area overwhelming and drowning the carbonate environments. Thus in the deeper portions of the present-day basin, the Utica (and Antes) is, in part, laterally equivalent and overlies the Point Pleasant.

Even though most refer to this as the Utica Play, the Point Pleasant Formation is the primary target and producing interval. The Point Pleasant consists of interbedded light gray to black limestones, brown to black organic-rich calcareous shales, and, quite often, brachiopod coquina layers. The overlying Utica Shale is mostly light gray to black calcareous shales with few limestone layers and is, in general, more massive and denser than the Point Pleasant. In most wells analyzed, the Point Pleasant shales have higher source-rock potential than within the Utica. Clay
content of the Point Pleasant is fairly low (5-20%), while in the overlying Utica it can be 30-40%. Low water saturation is also prevalent (5-20%) and post-frac “soaking” periods appear to be working quite well.

**Selected References**


Websites


Geology and Activity of the Utica-Point Pleasant of Ohio

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Tulsa Geological Society
March 5, 2013
Overview

- Geology of the Point Pleasant Play
- Source Rock Geochemistry
  - Analyses and Pitfalls
- Activity Update
- Summary
Ohio Oil & Gas Fields

- Ohio currently has in excess of 63,000 producing oil & gas wells
- Historically, over 250,000 wells have been drilled
- Production has been established in 66 of our 88 Counties.
- The Lima-Indiana Trend of NW Ohio was one of the first true giant fields produced in the U.S. (1884-1934)
- Thus, oil & gas is not new to Ohio, especially in eastern half of state
Drilling and producing from organic-rich shales represents a large paradigm shift for the oil and gas industry.

Prior to the late 1990s these shales were thought of principally as the source of oil and gas that would then migrate slowly over time into “conventional” reservoirs.
Facies map of Trenton/Point Pleasant Time

- **Collingwood Sub-Basin**
  - Clean carbonate grainstones, packstones, and wackestones with sharp upper contact

- **Michigan Basin**
  - Argillaceous carbonate grainstones, packstones, and wackestones with sharp upper contact

- **Trenton Platform**
  - Argillaceous carbonate grainstones, packstones, and wackestones with gradational upper contact

- **Utica/Point Pleasant Sub-Basin**
  - Shale

- **Central Appalachian Basin**
  - Calcareous shale and interbedded limestone

- **Lexington Platform**

- **Taconic Foredeep**

- **15° south Paleo latitude**
INTERVAL-THICKNESS MAP OF THE UTICA
(top of Trenton to top of Utica; includes the Point Pleasant and Antes Shale.)
The extent of the Utica and the Point Pleasant are also shown.

Recommended bibliographic citation:


Map modified by Powers, D.M. and Martin, D.R.

EXPLANATION

- Trenton-Black River outcrop area
- Fault
- Utica extent
- Point Pleasant extent
- Data point (oil and gas well)
- Data points not corrected for structural dip

Thicknes in feet

- 250-ft index contour
- 50-ft contour; 700
- 705

Legend:

- Gray: Trenton-Black River outcrop area
- Black: Fault
- Orange: Utica extent
- Light blue: Point Pleasant extent
- Red: 250-ft index contour
- Red: 50-ft contour; 700
- Red: 705
- Black: Data point (oil and gas well)
- Blue: Data points not corrected for structural dip

Scale:

- 50 Miles
- 50 Kilometers
The presence, thickness, fracability, and source-rock richness, of the Point Pleasant Formation in Ohio are what make this state the center of this play.

- Low-density shale
- AVG TOC = 2.78
- High TOC = 7.3
- High carbonate %
- Responds to HCL
- Interbedded limestone and black shale

FRACABILITY
COSHOCTON COUNTY BARTH #3

J. Wicks, 2011
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<th>SYSTEM TYPE</th>
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<th>POROSITY AND PERMEABILITY COMPONENTS</th>
<th>EXAMPLES</th>
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<td>Porous Mudstone</td>
<td>Source rocks with significant inter/intra-grain porosity at oil to gas/condensate level of maturity</td>
<td>Minimal</td>
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<td>Eagle Ford; Haynesville; Wolfcamp; Woodford; Niobrara</td>
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<td>Fractured Mudstone</td>
<td>Mature source rocks with significant fracture porosity</td>
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<td>Monterey; Woodford; Mowry; Barnett; Marcellus; Utica</td>
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Gas-prone areas of Utica Shale will be in the deeper portion of the basin. Much of Ohio may contain appreciable amounts of oil and natural gas liquids within Utica wells as illustrated by this NW–SE-oriented schematic cross section by Bob Ryder illustrating the results of geochemical analyses of well samples.
Source Rock Geochemistry

Petroleum Formation: Reactions and Processes

- **Kerogen**: Insoluble organic solid
  - **Immature**
  - **Bitumen**: Soluble organic tar
    - **Mature**
    - **Crude Oil**: Hydrocarbon-rich liquid
      - **Natural Gas**: Hydrocarbon-rich gas
      - **Char/Pyrobitumen**: Insoluble organic solid
        - **Over mature**
        - **Hydrogen Sulfide**: Non-hydrocarbon-rich gas

Courtesy Michael Lewan, USGS
A Utica-Point Pleasant Type Log for Eastern Ohio

Ohio Geological Survey CO2 #1
Belden Brick Unit, Tuscarawas Co.

Source Rock Analyses

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**Total Organic Carbon (TOC)** is a measurement in weight percent of the quantity of organic carbon preserved in a rock sample and includes both kerogen and bitumen (Peters and Casa, 1994). A TOC of 0.5 percent is generally regarded as the minimum for defining a petroleum source rock, but most geochemists consider a TOC of greater than 1.0 percent as a good source rock for generating petroleum potential.

$S_1$ is a measurement (mg HC/g of rock) of the free hydrocarbons already generated that are volatilized out of the rock without cracking the kerogen. An $S_1$ of greater than 1 is considered to be a good source rock.

$S_2$ is a measurement (mg HC/g of rock) of the amount of hydrocarbons generated through thermal cracking of kerogen and heavy hydrocarbons. It represents the existing potential of a rock to generate hydrocarbons and is a more realistic measure of source rock potential than TOC, which includes “dead carbon” incapable of generating hydrocarbons. An $S_2$ of greater than 5 is considered to have good source rock generative potential.
Diagrammatic Illustration of TOC for a given kerogen type, e.g., Type II

- Oil/Bitumen-Free TOC (wt.%)
  - Generative Organic Carbon (wt.%): Responsible for generation of hydrocarbons, Accounts for development of organic porosity
  - Non-Generative Organic Carbon (wt.%): Does not generate any appreciable amount of petroleum, Does account for storage by adsorption

After: Jarvie et al., 2012
Figure 8. Graph of subsurface processes, depths, temperatures, and vitrinite reflectance values associated with the conversion of organic matter to hydrocarbons in petroleum source rocks. Modified from Tissot and Welte (1984).

Source: Pennsylvania Geology, Spring 2010
Maximum TOC Value per Well of the Upper Ordovician Shale Interval* in Ohio

EXPLANATION
TOC data source
- Core
- Cuttings
- Sidewall core/cuttings

TOC contours - weight %
- 4
- 2
- 1
- 0.5

TOC maximum - weight %
- Excellent >4
- Very Good 2-4
- Good 1-2
- Fair 0.5-1
- Poor 0-0.5

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Division of Geological Survey
11/23/2012
www.ohiogeology.com
Why is TOC important?
Porosity Increase due to Organic Carbon Decomposition

TOC is 7 weight percent

which is about 14 volume percent

After: Jarvie et al., 2012
Formation of Organic Porosity from Generative Organic Carbon

Assumptions:

- 80% conversion of kerogen: 3.92%
- 100% conversion of kerogen: 4.90%

- Assumptions:
  - 7.00 wt.% TOC₀
  - 14.00 vol.% TOC₀
  - TOC₀ is 37% GOC
  - Kerogen density is:
    - 1.1 g/cc GOC
    - 1.4 g/cc NGOC

After: Jarvie et al., 2012
Point Pleasant Organic Porosity Examples

After: Laughrey et al., 2012
Shale Matrix Porosity
Extensive organic porosity development in Pt Pleasant fm.
Maximum $S_1$ Value per Well of the Upper Ordovician Shale Interval* in Ohio

EXPLANATION

$S_1$ data source
- Core
- Cuttings
- Sidewall core/cuttings

$S_1$ contours - generative potential
- mg HC/g of rock
  - 4
  - 2
  - 1
  - 0.5

$S_1$ maximum - generative potential
- mg HC/g of rock
  - Excellent >4
  - Very Good 2–4
  - Good 1–2
  - Fair 0.5–1
  - Poor 0–0.5

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Division of Geological Survey
11/23/2012
www.ohiogeology.com
Maximum S₂ Value per Well of the Upper Ordovician Shale Interval* in Ohio
Basic Source-Rock Potential Definitions

- **Vitrinite Reflectance (Ro)** is a key diagnostic tool for assessing thermal maturity and is based on measuring the reflectivity ($R$) of vitrinite through a microscope. Vitrinite is a maceral (plant and animal remains) found in many kerogens. As temperature increases, vitrinite undergoes complex alterations that increase the reflectance. Reflectance measurements represent the percent of light reflected in oil, designated as $Ro$. The oil window generally falls within an $Ro$ ranging from 0.6 to 1.4. Because vitrinite is only present in sediments with plants, and there was no plant life yet in the Ordovician, calculations and plots using Tmax and Hydrogen Index (HI), or other means of calibrating a given rock’s $Ro$, are used. Conodont alteration indexing is perhaps the most reliable, but also the most difficult means of estimating maturity of these older sediments.
THERMAL MATURATION OF ORDOVICIAN SOURCE ROCKS BASED ON COMBINED CAI TO Ro REGRESSION EQUATION

From Repetski and others (2008); map prepared by John Harper, Pennsylvania Geological Survey
Equivalent Ro Max Map Overlain with Cambrian Thru Silurian Oil and Gas Fields
## UTICA - POINT PLEASANT SOURCED CONVENTIONAL PRODUCTION IN OHIO

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<th>RESERVOIR</th>
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<td><strong>TOTAL</strong></td>
<td><strong>610</strong></td>
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<td><strong>1,669</strong></td>
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J. Wicks, 2011
PITFALLS: Underestimation of Present Day TOC: Sample Dilution

From: Laughrey et al., 2012
Change in Various Geochemical Measurements due to age, sample type
(data from 1980s well and new offset well)

Jarvie, 2012
Underestimation of Present Day TOC

TOC = 1.80

TOC = 3.44
PITFALLS: Underestimation of S1, inflation of S2 & inaccurate Tmax

S1 Carry over: Inflates S2 value

Note “shoulder” on front side of S2

2009 Weatherford Laboratories
Oil Content in Rock Sample as measured by thermal extraction

Measured →

S1 (oil) → S2 (kerogen)

Reality →

Evap. Loss of oil → S1 (oil) → S2 extracted rock
S1’ (oil in S2)

Overlap of free oil and oil carried over into S2
This is a function of oil type and isolated organic pores

Total Oil = (S1 \text{WR} - S1 \text{extracted rock}) + (S2 \text{whole rock} - S2 \text{extracted rock}) + E.L.

Evaporative Losses = S1 \times (\text{GC Fingerprint produced oil} / \text{GC Fingerprint of extracted oil})
This technique also allows prediction of GOR on shale (rock) samples.

After: Jarvie et al., 2012
A Respected Group of Geochemists Summarize the Source Rock Potential:

**Utica-Point Pleasant**

- Organic content in eastern Ohio is very high
- Organic matter is very rich and oil-prone
- The maturity ranges from dry gas in the east to early oil (westward) in the central part of the state over about 100-mile distance
- Significant hydrocarbon generation has occurred across the area and the hydrocarbon content is quite high
- The majority of the hydrocarbons are being generated in the Point Pleasant, but the overlying Utica is also prospective
- The high carbonate content of the entire section suggests fracing could be very effective for production

From: Reed, Brown, and Zumberge: DUG East, November 2011
UTICA HORIZONTAL WELL STATUS THROUGH 3/2/2013

- PERMITTED OR NOT DRILLED (286)
- PRODUCING (73)
- DRILLED, DRILLING OR INACTIVE (173)
- PLUGGED (11)

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TOTALS: 73 278 16 154 11 3 8 543

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<td>PERMITTED</td>
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<tr>
<td>PROD</td>
<td>PRODUCING</td>
</tr>
</tbody>
</table>

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# Utica Shale – Summary of Wells Tested

<table>
<thead>
<tr>
<th>Well Name</th>
<th>County</th>
<th>Completion Date</th>
<th>Length of Lateral (feet)</th>
<th>Frac Stages</th>
<th>Peak IP Test (Boe/d) (^{[1]})</th>
<th>Oil</th>
<th>Gas</th>
<th>NGLs</th>
<th>Shrink Factor (^{[1]})</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wagner 1-28H</td>
<td>Harrison</td>
<td>5/28/12</td>
<td>8,143</td>
<td>28</td>
<td>4,650</td>
<td>9%</td>
<td>50%</td>
<td>40%</td>
<td>18%</td>
</tr>
<tr>
<td>Boy Scout 1-33H</td>
<td>Harrison</td>
<td>6/13/2012</td>
<td>7,974</td>
<td>22</td>
<td>3,456</td>
<td>45%</td>
<td>26%</td>
<td>29%</td>
<td>25%</td>
</tr>
<tr>
<td>Groh 1-12H</td>
<td>Guernsey</td>
<td>7/7/2012</td>
<td>5,414</td>
<td>16</td>
<td>1,935</td>
<td>61%</td>
<td>20%</td>
<td>19%</td>
<td>18%</td>
</tr>
<tr>
<td>Shugert 1-1H</td>
<td>Belmont</td>
<td>7/27/2012</td>
<td>5,758</td>
<td>16</td>
<td>4,911</td>
<td>3%</td>
<td>56%</td>
<td>41%</td>
<td>17%</td>
</tr>
<tr>
<td>Ryser 1-25H</td>
<td>Harrison</td>
<td>8/11/2012</td>
<td>8,291</td>
<td>23</td>
<td>2,914</td>
<td>51%</td>
<td>27%</td>
<td>22%</td>
<td>21%</td>
</tr>
<tr>
<td>BK Stephens 1-14H (^{[2]})</td>
<td>Harrison</td>
<td>9/19/2012</td>
<td>5,276</td>
<td>19</td>
<td>3,007</td>
<td>41%</td>
<td>34%</td>
<td>25%</td>
<td>11%</td>
</tr>
</tbody>
</table>

- First six wells averaged a peak rate of 1,006 barrels of condensate per day, 8.17 MMCF of natural gas per day and 1,111 barrels of NGLs, or 3,479 BOEPD \(^{[1]}\)
  - Production mix of included approximately 29% condensate, 39% natural gas, and 32% natural gas liquids

\(^{[1]}\) Assumes full ethane recovery

Source: Company filings
Infrastructure
Summary

- Organic-rich mixed-carbonate/siliciclastic mudstones in the Upper Ordovician Utica, Point Pleasant, and Trenton formations are important source rocks in the northern Appalachian basin and are the target of tight-oil and shale-gas exploration and development, particularly in eastern Ohio.

- This activity is dictated by geology, and by geochemical screening parameters routinely employed to map and constrain the generative potential, kerogen type/expelled product, and thermal maturation of source rocks.
Summary

- Careful scrutiny of data derived from these screening methods, and comparisons with data from more advanced geochemical tools, such as stable isotope, light hydrocarbon, and biomarker analyses, reveal potential pitfalls in interpreting the geochemistry of these rocks. Caution must be applied when interpreting source rock data.

From: Laughrey et al., 2012
Summary

- Permitting and drilling activity remain fairly high, but completions and production are lagging, due largely to inadequate infrastructure.

- Many pipeline and processing plant projects are underway or being planned. Between 1st QTR 2013 and 1st QTR 2014 we should see a number of these projects completed – if economics stay favorable...
Acknowledgments

- Many of the maps and slides were obtained from the Ohio Geological Survey and I thank them for their continued good work.
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- Air photos courtesy of Tim Cox.