Update on the Regional Assessment of Gas Potential in the Devonian Marcellus and Ordovician Utica Shales in New York

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Assessing unconventional shale gas plays in New York

- Identify high gas potential fairways using same geochemical methods applied to the Barnett and other successful shale gas plays
- These include TOC, vitrinite reflectance, hydrogen index and transformation ratios
- Create new structure and isopach maps of shale formations and potential gas producing intervals
Two Similar Black Shales: Devonian Marcellus and Ordovician Utica

- Deposition of both shales followed lithospheric downwarping associated with tectonic loading
- Both shales terminated by shallow shelf carbonates
- Both shales thicken to the east
The Ordovician Utica Shale

Trenton Limestone in blue colors is time-equivalent to Utica Shale in brown colors: Primarily interested in Flat Creek and to a lesser extent the Dolgeville Member.

(Goldman, et al 1994)
Trenton-Utica Subsurface Stratigraphy

Indian Castle Mbr (0-0.5% TOC)

Stueben Lst Mbr  Dolgeville Mbr (0.5-1.5% TOC)

Flat Creek Mbr (1.5-3% TOC)

Black River

NW SE

Trenton

Utica

Black River

Trenton

Utica
Utica Structure Contour Map

Utica gets deeper to the south
Utica Isopach Map

Utica formation thickens to the east
Utica Flat Creek Member

- Lowermost member of the Utica Formation
- K-bentonites and graptolites used to match key successions (Goldman, et al., 1994)
- Dark gray to black, variably calcareous shale with minor thin beds of argillaceous micrite and biomicrite (Lehmann, et al. 1995)
- Bounded by Dolgeville member on top
Utica - Flat Creek Member

Vertical calcite filled veins cutting Flat Creek Member in Chuctanunda Creek, Florida, NY
Utica Flat Creek member thickens to the southeast –
In the end, this is likely to be the Utica Fairway map
Utica - Dolgeville Member

- Interpreted as a slope facies peripheral to the Trenton platform
- Tabular ribbon limestones and dark gray to black shale beds
- Several geochemically correlated K-bentonites
- Bounded on top by Thruway unconformity
- Slump folds occur immediately below the unconformity
- Folds are dominantly asymmetrical with a westward vergence
Utica – Dolgeville Member

Asymmetrical slump fold in Dolgeville
Utica Dolgeville Isopach Map

Dolgeville thickens to southeast
Utica - Indian Castle Member

• Uppermost member of the Utica Formation blankets all of western NY
• Thin layers of fossil debris, phosphatic debris and quartz
• Condensed beds
• K-bentonites used to match key successions
• Sharp contact with underlying Steuben limestone, more subtle contact where it overlies Dolgeville
• Divided into the lower and upper sections

(Baird and Brett, 2002)
Utica - Lower Indian Castle Member

Characteristically hard, blocky shale with interbedded, tabular, impure limestone
Utica Upper Indian Castle

Monotonous fissile, black shale and silty black shale
Geochemical Study

- Using geochemistry in an attempt to define general fairways for exploration in Utica and Marcellus
- Using the same Rock-Eval approach Jarvie et al used for the Barnett Shale

Used cuttings from 31 wells, and samples from 12 cores, 5 outcrops
Gas Production from Shales

- Gas production from tight shales requires maturation and cracking of oil that has been generated from live organic matter - need to have at least 2 percent TOC to begin with
- With increasing maturation carbon and hydrogen are lost from shale due to hydrocarbon generation
- Increasing thermal maturity therefore leads to decrease in TOC and hydrogen values
- Want shales with decent original TOC, with evidence that significant amounts of gas has formed from that TOC during thermal maturation
Geochemical Measurements

- TOC = Total organic carbon (\%)
- Live carbon including $S_1$ (oil and gas present in shale) and $S_2$ (remaining kerogen)
- $T_{\text{max}}$ = The temperature at peak evolution of $S_2$ hydrocarbons from Rock Eval
- $R_o$ \% = Vitrinite Reflectance (calculated from $T_{\text{max}}$)
- HI = Hydrogen Index ($S_2 \times 100$)/ TOC
- $TR$ = Transformation or conversion ratio calculated from hydrogen index (HI)
Geochemical TOC Data

- Indian Castle < .5%
- Dolgeville .5 - 1.5%
- Flat Creek 1.5 - 3%

In Jarvie, et al., 2005 study TOC from cuttings were 2.36 times lower than samples from core; therefore this same dilution effect would be seen on other geochemical parameters.

Productive shales are generally >2% TOC
TOC increases to the SE as Utica (Flat Creek and Dolgeville members) also thickens in that direction
TOC increases in Dolgeville and increases more in the Flat Creek member.
Dispersed Organic Matter: the “source” of oil + assoc. gas

<table>
<thead>
<tr>
<th>Total Organic Carbon (T.O.C.)</th>
<th>Dead Carbon</th>
</tr>
</thead>
<tbody>
<tr>
<td>Live Carbon</td>
<td></td>
</tr>
<tr>
<td>Organic Matter (Kerogen)</td>
<td>Dead Carbon</td>
</tr>
</tbody>
</table>

Rock-Eval Terminology

Jarvie, 1991
If $S_1$ and $S_2$ are very low, this means that almost all remaining carbon is dead carbon – the rock cannot and will not generate any more hydrocarbons.
• $S_1$ = Free volatile hydrocarbons thermally flushed from a rock sample at 300°C
• $S_2$ = Products that crack during standard Rock-Eval pyrolysis temperatures 300°C-600°C
In order to get a reliable Tmax, it is necessary that $S_2 > S_1$ and the value of $S_2 > 0.2$ - If $S_1 > S_2$ or $S_2$ has very low values ($< 0.2$) that means that there is very little remaining live carbon (kerogen or oil and gas).
Experimental Conversion of Barnett Shale

<table>
<thead>
<tr>
<th>Tmax</th>
<th>TOC</th>
<th>S2</th>
<th>HI</th>
</tr>
</thead>
<tbody>
<tr>
<td>432</td>
<td>5.21</td>
<td>19.80</td>
<td>380</td>
</tr>
<tr>
<td>435</td>
<td>4.53</td>
<td>13.45</td>
<td>297</td>
</tr>
<tr>
<td>437</td>
<td>4.11</td>
<td>10.27</td>
<td>250</td>
</tr>
<tr>
<td>443</td>
<td>3.77</td>
<td>5.88</td>
<td>156</td>
</tr>
<tr>
<td>455</td>
<td>3.41</td>
<td>1.81</td>
<td>53</td>
</tr>
<tr>
<td>470</td>
<td>3.32</td>
<td>1.36</td>
<td>41</td>
</tr>
<tr>
<td>?</td>
<td>2.3</td>
<td>&lt;0.2</td>
<td>&lt;10</td>
</tr>
</tbody>
</table>

36%↓TOC 89%↓HI

Values so low it is hard to pick Tmax

Remaining potential decreases

INCREASING THERMAL MATURITY

CONVERSION TO OIL and GAS

Tmax increases
Maturation of Organic Matter – modified from Jarvie

Utica Shale – almost all TOC dead carbon

Increased Maturation
Barnett Shale has samples with range of maturation values.
Utica Samples

Kerogen Quality

- Type I Oil Prone (usu. lacustrine)
- Type II Oil Prone (usu. marine)
- Mixed Type II / II Oil / Gas Prone
- Type III Gas Prone
- Organic Lean
- Dry

REMAINING HYDROCARBON POTENTIAL (mg HC/g Rock)

TOTAL ORGANIC CARBON (TOC, wt.%)
Utica $T_{\text{max}}$ and Vitrinite Reflectance ($R_o$)

- $T_{\text{max}}$ is the temperature where $S_2$ peaks
- Because $>95\%$ of the $S_2$ values in the Utica are too low and/or $<S_1$, the $T_{\text{max}}$ values are unreliable in the Utica Shale
- $T_{\text{max}}$ can be used in some cases to obtain a calculated value for vitrinite reflectance ($R_o$) by the formula $R_o=0.0180*{T_{\text{max}}}-7.16$
- Because $T_{\text{max}}$ is unreliable in the Utica, it is not possible to calculate reliable values for $R_o$
Hydrogen Index

• Hydrogen Index (HI) is a calculation to determine the amount of hydrogen remaining in the shale
• HI = (S₂*100)/TOC
• HI decreases as thermal maturity increases because S₂ goes down
• Again, S₂ is uniformly very, very low in Utica so the HI values largely driven by TOC –
• Lower values are generally thought to be better in Utica as they represent higher original TOC
Lowest values occur where TOC was highest in Flat Creek and Dolgeville.
Transformation Ratio

- Evaluates the conversion directly by measuring changes in the kerogen (organic matter) yields
- In order to calculate this ratio, you need the present day Hydrogen index ($\text{HI}_{\text{pd}}$) and original Hydrogen index ($\text{HI}_{\text{o}}$) (see Jarvie, et al., 2007 for formula)
- Areas with highest potential for production have values approaching 1, lower values = lower potential
Best TR values occur where the Flat Creek and Dolgeville occur – all of these values driven by higher TOC in those members
Wells with good Utica shows and TR Map

Inside the blue lines as defined by the transformation ratio might be a productive fairway for Utica Flat Creek prospects
New Utica wells and TR map

Inside the blue lines as defined by the transformation ratio are the newly drilled wells – awaiting results.
Utica Flat Creek Isopach Map

The Utica Fairway is probably best defined by the Flat Creek Mbr isopach map – All of the Utica is supermature; the Flat Creek had the highest original TOC which drives HI and TR maps.
The Devonian Marcellus Shale

Primarily interested in Union Springs and Lowermost Oakta Creek Members
Marcellus Union Springs

- Organic rich thinly bedded blackish grey to black shale with thin silt bands
- The member is between the Cherry Valley and Onondaga Limestone
- Characterized as pyritiferous; farther east the Union Springs becomes the Bakoven member that becomes darker, less organic and has few limestone members
- Lenses in and out in localities in far Western New York
Marcellus Union Springs

Union Springs with vertical calcite filled fractures in the Onesquethaw Creek, Albany County, NY
Marcellus Cherry Valley

- Consists of skeletal limestones and shaly intervals
- Westward thinning of the Marcellus Formation in western and central New York leads to the condensation and union of the Cherry Valley limestones with limestones in the upper part of the Union Springs
Marcellus Cherry Valley

Cherry Valley dark shaly interval and limestone near Cherry Valley, NY
Marcellus Oatka Creek

- Upper member of the Marcellus Formation in Western and central New York
- Becomes Cardiff and Chittenango members in Central and Eastern New York
- Is confined in Western New York by Stafford and Onondaga limestones
- Farther east it is between the Stafford and Cherry Valley limestones where it is present
- Dark grey to black organic rich shale
Marcellus Oatka Creek

Oatka Creek shale in Oatka Creek, LeRoy, NY
Marcellus thickens to the east
Marcellus Structure Contour Map

Marcellus has a general east-west strike is gently dipping south
Map of Marcellus Geochemical Locations

33 wells, 2 cores, 9 outcrops
TOC much higher in Marcellus than in Utica (up to 12%)
TOC values are highest in central part of state and decrease to east
TOC in the Union Springs increases from the western part of NY to the central eastern side of NY.
TOC increases in the Oatka Creek to the northeast and west-northwest
TOC Marcellus Cross Section

TOC increases in Oatka Creek and the Union Springs member
About half of the $S_2$ values in the Marcellus can be trusted for $T_{\text{max}}$ values – using these, $T_{\text{max}}$ increases to east as would be expected.
Vitrinite Reflectance Calculation

• Vitrinite reflectance ($R_o$) is a measure of thermal maturity that can be done directly on plant matter.
• $R_o$ can be estimated from reliable $T_{max}$ data using the following calculation:
  $$R_o (\%) = (0.0180 \times T_{max}) - 7.16$$
• The $T_{max}$ data in the Marcellus is much better than the Utica – about half the points have usable $S_2$ values.
# Vitrinite Reflectance (Ro%)

<table>
<thead>
<tr>
<th>Well Cuttings</th>
<th>Core</th>
</tr>
</thead>
<tbody>
<tr>
<td>Low maturity source rocks 0.0 – 0.55%</td>
<td>Low maturity source rocks 0.0 - 0.55%</td>
</tr>
<tr>
<td>Oil window 0.55% - 1.0%</td>
<td>Oil window 0.55% - 1.15%</td>
</tr>
<tr>
<td>Condensate - wet gas window 1.0% - 1.40%</td>
<td>Condensate – wet gas window 1.15% - 1.40%</td>
</tr>
<tr>
<td>Dry gas window &gt; 1.40%</td>
<td>Dry gas window &gt; 1.40 %</td>
</tr>
</tbody>
</table>

Based on Jarvie, et al, 2005
Optimum Ro% for Marcellus Union Springs is in the central and eastern New York.
Optimum Ro% for Oatka Creek is in eastern side of basin – based on this it is best to avoid western half of state
Marcellus Union Springs HI Map

Union Springs HI decreases to the east
Oatka Creek HI decreases from west to east
Marcellus Union Springs Transformation Ratio Map
The geochemistry work that we have done suggest that the shales in this area are favorable - some wells drilled here have not produced
Marcellus

• Some wells, such as the Beaver Meadows well, were drilled in what is the geochemical fairway for Marcellus but were not completed and are assumed to be dry holes. Why?
• Other aspects may be equally important
  – completion/frac practices need to be refined
  – may need certain silica content
  – too much TOC?
  – Overcooked?
• More work is needed
Utica and Marcellus fairways

They overlap in eastern side of basin
Future Work

• Calculate and make maps of original TOC, S2 and HI
• Get analysis of gas samples from newer wells whenever possible
• Get mineralogy data for shales
• Resample areas where data is questionable or missing and test conclusions with new samples in fairways
• See what happens with newer wells in fairways that have new drilling/completion/frac concepts
Conclusions

• The Marcellus and Utica Shales both contain fairways that are favorable to gas exploration based on geochemical data.
• Both fairways occur in overlapping areas in the eastern Southern Tier of the State where there are not many wells drilled to date.
• Wells with good shows occur in predicted fairways.
• Within the Utica Shale, the Flat Creek and to a lesser extent the Dolgeville Members, which both thicken to the east and pinch out to the west have the best potential.
• In the Marcellus Shale, the Oatka Creek and Union Springs Members have the best potential.
• The Marcellus is organically richer than the Utica.
Acknowledgements

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