Cana Woodford Shale Play, Anadarko Basin: The Effects of Mudrock Lithologies and Mechanical Stratigraphy on Completion and Production

Craig D. Caldwell
Cimarex Energy Co., Tulsa, OK

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• Introduction/Acknowledgements
• Regional Maps- Overview
  • Geologic Provinces of Oklahoma
  • Woodford Isopach
  • Woodford Structure
• Mechanical/lithostratigraphic model, mudrock lithologies, and their relation to completion
• Regional variations in stratigraphy and lithology
• Conclusions
• Rock stuff
Is there a relationship between Woodford rock types, mechanical/lithostratigraphy, completion, and production?
STRAT COLUMN AND MAJOR GEOLOGIC PROVINCES OF OKLAHOMA

High Resolution Image
Type Log from Core Area Showing Lithostratigraphy and % Clay for Middle & Upper Woodford
## Woodford Rock Types

### Anadarko Basin Woodford Play

<table>
<thead>
<tr>
<th>ROCK TYPE</th>
<th>% QUARTZ</th>
<th>% CLAY</th>
<th>% TOC</th>
<th>% GAS-FILLED POROSITY</th>
<th>PRv</th>
<th>Britteness Index*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Siliceous mudrock</td>
<td>75.2</td>
<td>14.5</td>
<td>4.86</td>
<td>5.4</td>
<td>0.155</td>
<td>0.75</td>
</tr>
<tr>
<td>Clayey, siliceous mudrock</td>
<td>54.8</td>
<td>27.4</td>
<td>6.43</td>
<td>6.8</td>
<td>0.164</td>
<td>0.55</td>
</tr>
<tr>
<td>Clayey mudrock</td>
<td>40.6</td>
<td>38</td>
<td>5.97</td>
<td>5.6</td>
<td>0.192</td>
<td>0.41</td>
</tr>
<tr>
<td>Organic-poor, clayey mudrock</td>
<td>27.3</td>
<td>52.4</td>
<td>0.6</td>
<td>1.8</td>
<td>0.25</td>
<td>0.27</td>
</tr>
</tbody>
</table>

*B.I. = Quartz/Qtz+Carbonates+Clay

(Sondergeld et. al., 2010)
Anadarko Woodford Mineralogy (XRD) and Rock Types

- Siliceous mudrock
- Clayey mudrock
- Clayey, siliceous mudrock
- Organic-poor, clayey mudrock

QUARTZ (and feldspar)

- Upper WDFD
- Middle & Lower WDFD
- Basal WDFD

DOLOMITE and PYRITE
Anadarko Woodford Mineralogy (XRD) and Rock Types

Siliceous mudrock

Clayey mudrock

Clayey, siliceous mudrock

Organic-poor, clayey mudrock

Upper WDFD

Middle & Lower WDFD

Basal WDFD

BARNETT SHALE

EAGLE FORD SHALE

CARBONATE

CLAY

Barnett and Eagle Ford Mineralogy from Q. R. Passey Et. Al. 2010
Middle and Upper Woodford Lithostratigraphy, Anadarko Woodford Play – Core Area

- **Siliceous mudrock**
- **Clayey, siliceous mudrock**
- **Clayey mudrock**

**Quartz/Clay**
- MISS
- UW3
- UW2
- UW1
- MW4
- MW2
- MW1C
- MW1B
- MW1A
- LW3

**Depth**
- 12600
- 12700

**Areas**
- 75/14
- 41/38
- 55/27
Basal, Lower, & Middle Woodford Lithostratigraphy,
Anadarko Woodford Play – Core Area

Clayey, siliceous mudrock

Clayey mudrock

Organic-poor clayey mudrock

Quartz/Clay

MW

MW1B

MW1A

LW3

LW2

LW1C

LW1B

LW1A

LW1

LW0

LW

BW

HNTN

27/52

55/27

41/38
Woodford Lithostratigraphy
Anadarko Basin
Woodford Play
Core Area

Siliceous mudrock
Clayey, siliceous mudrock
Clayey mudrock
Organic-poor clayey mudrock

WDFD Thk. 290’
<table>
<thead>
<tr>
<th>ROCK TYPE</th>
<th>% QUARTZ</th>
<th>% CLAY</th>
<th>% SUCCESS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Siliceous mudrock</td>
<td>75.2</td>
<td>14.5</td>
<td>100</td>
</tr>
<tr>
<td>Clayey, siliceous mudrock</td>
<td>54.8</td>
<td>27.4</td>
<td>86</td>
</tr>
<tr>
<td>Clayey mudrock</td>
<td>40.6</td>
<td>38</td>
<td>53</td>
</tr>
</tbody>
</table>

Successful frac' defined as one in which >75% of planned proppant amount was placed.
<table>
<thead>
<tr>
<th>ROCK TYPE</th>
<th>% QUARTZ</th>
<th>% CLAY</th>
<th>% DOLOMITE</th>
<th>% Success, Pre-HF</th>
<th>% Success, w/ HF</th>
</tr>
</thead>
<tbody>
<tr>
<td>Siliceous mudrock</td>
<td>75.2</td>
<td>14.5</td>
<td>2.8</td>
<td>100</td>
<td>100</td>
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<tr>
<td>Clayey, siliceous</td>
<td>54.8</td>
<td>27.4</td>
<td>3.6</td>
<td>86</td>
<td>94</td>
</tr>
<tr>
<td>mudrock</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Clayey mudrock</td>
<td>40.6</td>
<td>38</td>
<td>5.0</td>
<td>53</td>
<td>80</td>
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</tbody>
</table>

Successful frac' defined as one in which >75% of planned proppant amount was placed. Table drawn from 906 frac stages.
Well Path Showing Woodford Lithostratigraphy and Lateral Placement
Fracture Conductivity versus increasing Closure Stress – 40/70 PRC Proppant
Woodford Lithostratigraphy Anadarko Basin
Woodford Play - SE Area

Clayey, siliceous mudrock

Clayey mudrock

WDFD Thk. 110’
Woodford Lithostratigraphy
Anadarko Basin
Woodford Play
Core Area

Siliceous mudrock
Clayey, siliceous mudrock
Clayey mudrock
Organic-poor clayey mudrock

WDFD Thk. 290'
Lateral Placement and EUR- CANA SW
CONCLUSIONS:

Seven mudrock lithologies are defined, primarily on mineral content and percent TOC, and a mechanical/lithostratigraphic model is established for the central part of the Anadarko Woodford Play.

Core and frac' data indicate that quartz-rich mudrocks and clay-rich mudrocks have distinctively different mechanical properties. Clay-rich mudrocks commonly treat at higher pressures and proppant placement can be challenging.

Embedment studies demonstrate lower fracture conductivity in more clay-rich lithologies compared to those observed in more silica-rich rock.

Regional work shows that in the SE Cana area decreased Woodford thickness and an overall increase in percent of clay-rich lithologies is associated with decreased well performance.

In the SW Cana area a relationship appears to exist between lateral placement and EURs.

An important part of any Woodford completion program should be the discussion of lateral placement.
Rock Stuff
Thin Section Photomicrographs of Woodford Rock Types

**UW1 sample showing silicified Tasmanites; sample is 64% quartz and 21% clay.** Siliceous mudrock lithology.

**MW1B sample showing detrital silt; sample is 34% quartz and 38% clay.** Clayey mudrock lithology.
SEM Photomicrographs of Woodford Microfabrics

UW2 sample showing microcrystalline silica with intercrystalline porosity; sample is 76% quartz and 18% clay. Siliceous mudrock lithology.

MW4 sample showing parallel alignment of illite clay; sample is 26% quartz and 44% clay. Clayey mudrock lithology.
Bed-limited dolomite-cemented fractures in thin silicic layers Siliceous mudrock lithology
Silicic laminae with dolomite-cemented fracture
Siliceous mudrock lithology
Porosity in organic laminae
Clayey siliceous mudrock
Parallel lamination in Clayey mudrock lithofacies
Bioturbated bed
Clayey mudrock
lithofacies
Woodford Lithostratigraphy With Sonic Scanner Data
Woodford Lithofacies

BIOGENIC SILICA

DETRITAL CLAY AND SILT

Upper Woodford
Middle/Lower Woodford
Basal Woodford

Distal (?)
Proximal (?)

“GOOD” MECHANICAL PROPERTIES

“POOR” MECHANICAL PROPERTIES
An Incomplete List of Things That Could Impact Cana Woodford Production

<table>
<thead>
<tr>
<th>The Rocks</th>
<th>The Completion</th>
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<tbody>
<tr>
<td>Thickness</td>
<td>Lateral Length</td>
</tr>
<tr>
<td>Brittleness</td>
<td>Amount &amp; Type Proppant</td>
</tr>
<tr>
<td>Porosity/Perm</td>
<td>Amount &amp; Type Fluid</td>
</tr>
<tr>
<td>Natural Fractures</td>
<td>Number Stages</td>
</tr>
<tr>
<td>Maturity</td>
<td>Cluster Spacing</td>
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<tr>
<td></td>
<td>Pump Rate</td>
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<td></td>
<td>Lateral Configuration</td>
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<tr>
<td></td>
<td>Lateral Placement</td>
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</tbody>
</table>
Siliceous mudrock

Clayey, siliceous mudrock

Clayey mudrock

Dolomitic, clayey mudrock

Organic-poor clayey mudrock

Organic-poor clayey mudrock II

Regional Stratigraphic Variability Anadarko Woodford Play
Average Treating Pressure of Woodford Stages, Dixie 1-4H

<table>
<thead>
<tr>
<th>Stage</th>
<th>MW1C Stages</th>
<th>Average Treating Pressure of Woodford Stages, Dixie 1-4H</th>
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</thead>
<tbody>
<tr>
<td>1</td>
<td>8000-11000</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>8000-11000</td>
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<td>3</td>
<td>8000-11000</td>
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<td>5</td>
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<td>8</td>
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<td></td>
</tr>
<tr>
<td>9</td>
<td>8000-11000</td>
<td></td>
</tr>
</tbody>
</table>
WELL 1-4H
EUR 6.4 BCF

52% Clay-rich mudrock

48% Silica-rich mudrock

187 MB SW
1.5 MM#
4128’/9 stgs

~2200’

WELL 1-3H
EUR 8.83 BCF

5%

95% Silica-rich mudrock

186 MB SW
1.5 MM#
4087’/9 stgs