Devonian-Mississippian Petroleum Systems of Southern Laurasia: What Makes the STACK-Merge-SCOOP Play in Oklahoma so Special*

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Abstract

Devonian-Mississippian unconventional plays and reservoirs of the greater Mid-Continent encompass the full range of unconventional tight reservoirs and play types. From shelf to basin, the Mississippian Lime, STACK, Merge, SCOOP, and Barnett Shale plays comprise a petroleum megasystem that records a change in source rock depositional environments. Devonian siliceous mudrocks of the Woodford Formation were deposited on locally incised shallow marine platforms, whereas Early Mississippian (Lower Carboniferous) siliceous source rocks were deposited in a foreland basin created by continental collision of Gondwana with Laurasia during closure of the southern Iapetus Ocean. This article explores the question of why the Meramec siltstones and correlative lithofacies in the STACK, Merge, and SCOOP are so prolific relative to other Devonian-Mississippian basins and embayments of southern Laurasia that share lithostatigraphic characteristics: Rancheria Formation (New Mexico), Barnett Shale (Permian Basin), Moorefield Shale (Arkansas), and Borden Siltstone (Illinois Basin).

References Cited


Devonossippian Petroleum Systems of Southern Laurasia: What Makes the STACK-MERGE-SCOOP in Oklahoma so Special?

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Special Thanks
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AAPG for the quite unexpected invitation to speak.
• STACK-SCOOP Regional Setting
• Stratigraphic Considerations & Correlations
• Reservoir Characterizations
• Charge-Maturity-Migration Considerations
• Overpressures
• How the Midcontinent Mega-Systems works.
• Southern Laurasia Devonian-Mississippian systems.
• Play Analysis: Why the STACK is special.
• Conclusions
GEOLOGICAL OVERVIEW ANADARKO BASIN (OK & KS)

Classical example of the Wilson Cycle

- Failed arm of Cambrian rift during opening of Iapetus Sea
- Carboniferous inversion - Iapetus closure assembly of Pangea
- Triassic-Jurassic rifting in Gulf of Mexico

STACK SCOOP

Carboniferous Source Rocks

STACK SCOOP

Carboniferous Source Rocks

WHEELER DIAGRAM

> 40,000ft of sediment
> 15 billion boe produced
RESERVOIRS
Cambrian to Permian
SOURCE ROCKS
Ord. Miss. Penn.
MULTIPLE HORIZONTAL PLAYS IN THE ANADARKO BASIN

28,000 horizontal wells. Vertical wells are now the exception.

OKLAHOMA’S PRINCIPAL HORIZONTAL PLAYS

4 Horizontal Play Types (nearly all worked vertically somewhere)

1. Source-rock shales (Woodford and Springer shales)
2. Tight reservoirs adjacent to source rocks (Meramec, Granite Wash)
3. Tight reservoirs with long distance migration (Miss Lime)
4. Dewatering of dual porosity carbonates

Mississippian Plays
- MISS LIME
- STACK
- NW STACK – WMD
- SCORE
- SCOOP
STACK & SCOOP: MULTIPLE STACKED HORIZONTAL TARGETS

STACK
Woodford was the initial basal target
Current focus is on the Meramec.
Osage productive & being appraised

SCOOP
Woodford original target- active drilling.
Springer discovered later – active drilling
Sycamore productive & being appraised
Siltstone
Argillaceous
Calcareous

- Well-sorted, sub-angular silt-sized quartz grains
- Pink grains are carbonate skeletal fragments.
- Light blue is epoxy filled porosity.
- Violet rhombs Fe-dolomite
MERAMEC IS A CLASTIC RESERVOIR

- Local carbonate factory mixed with transported silt-sized quartz
- Predominantly angular silt-sized quartz and plagioclase grains
- Intergranular pores is occluded by calcite and Fe-dolomite cement
- Accessory minerals: mica, pyrites, zircon?

Calcareous Siltstone

- GS 9821.5ft

![Image of Calcareous Siltstone](image_url)

- Calcite Cement
- Plagioclase
- Mica

Silt < 60 μm = .06 mm
MERAMEC RESERVOIR: Good correlation of phi-k

Shaffer - Rohling
Porosity versus Permeability

4%-6% range
10 to 100 micro-darcies

4%-6% porosity zones present on logs but not sampled

DATA FROM OPIC REPOSITORY
The Meramec formation: siltstones deposited as clinoforms & small fan lobes on a low angle (<0.2°) ramp outboard of the Osage shelf.

Meramec Thickness Map

Wave / current influenced traction deposition
Increase in average gamma ray correlates with decrease thickness of sand & carbonate
MERAMEC to CANEY XRD facies down-dip change

- Increasing clay % at expense of carbonate, much lower chlorite
- Increasing % TOC basinward

### Whole Rock Mineralogy (Weight %)

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<thead>
<tr>
<th>Component</th>
<th>AVG</th>
<th>SD</th>
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<tr>
<td>Quartz</td>
<td>37.71</td>
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<tr>
<td>K-Feldspar</td>
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<tr>
<td>Plagioclase</td>
<td>6.67</td>
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<tr>
<td>Calcite</td>
<td>37.82</td>
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<td>Ankerite</td>
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<tr>
<td>Fe-Dolomite</td>
<td>3.51</td>
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<tr>
<td>Pyrite</td>
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<td>Apatite</td>
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<td>1.17</td>
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<tr>
<td>Phyllosilicates</td>
<td>11.19</td>
<td>6.96</td>
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</table>

<table>
<thead>
<tr>
<th>Phyllosilicates AVG</th>
<th>SD</th>
</tr>
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<tbody>
<tr>
<td>ML I/S</td>
<td>13.03</td>
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</tbody>
</table>

% detrital?

- Illite & Mica: 56.52, 11.84

Fresh water mixing OR altered mafic igneous rock fragments?
MERAMEC OIL-SOURCE ROCK CORRELATION

- Good source rocks present but discreet beds are not common.
- Thinner laminae and dispersed organic matter are common.
- Meramec is partly self sourced – imprints Woodford + Caney

**MERAMEC OIL -STACK BLURTON 6-7 16N 10W**

Rock extract from core

Blurton MRMC oil is like many of the others from that area. It is not a mixture, there is no cracked oil mixed in with it. The rock extract had low yield. The 191 plot for the terpanes were similar to the oil, but had small very subtle differences. There are some compounds in this chromatogram not in the oil. This oil does not have a Woodford contribution.

**TOC** 6.36%
**Tmax** 444 °C
**HI** 323

<table>
<thead>
<tr>
<th>Play</th>
<th>TOC (%)</th>
<th>Ro</th>
<th>HI</th>
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<tbody>
<tr>
<td>Caney</td>
<td>1.2-9</td>
<td>0.8-2.0</td>
<td>20-180</td>
</tr>
<tr>
<td>Woodford</td>
<td>3-10</td>
<td>0.7-1.5</td>
<td>50-200</td>
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</table>
OVERPRESSURE SANDWICH BETWEEN 2 OVERPRESSURE SYSTEMS

Mississippian Shelf

WTC Morrow Overpressured

NEMAH WA RIDGE

MRMC > 300ft
STACK: MERAMEC+WOODFORD - EUR 10,000 MMBOE
Osage NOT included

STOCK TANK OIL and GAS IN PLACE

Continental, Devon, Newfield down-spacing units.
6 to 10 wells 800-1,200 mboe per well 40%-60% liquids.

High-NGL to dry gas window with wells up to ~20bcfg EUR
SCOOP: WOODFORD + SPRINGER PRIMARY TARGETS

SCOOP - Woodford western extension of Arkoma shale play. Springer discovered later prolific legacy vertical production in the Golden Trend and Carter-Knox. Woodford shale thick enough to support stacked completions with 12 well down-spacing.

Springer restricted deposition only locally overlies Woodford.

SCOOP Woodford play EUR: 976mmbo and 28tcfg.
In addition to the Woodford, excellent regional Mississippian age source rocks in Oklahoma, Texas, and Arkansas.

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<tr>
<td>388</td>
<td>Woodford 359</td>
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From a global perspective development of Barnett, Fayetteville, Moorefield, Caney, and Meramec source rocks is anomalous.

World-wide only 0.4% of generated HC are from Mississippian source rocks.

Percentage of generated crude oil equivalent gas by source rock.
REGIONAL CONSIDERATIONS: CHARGE & TRAP

- STACK-SCORE is essentially a mega-stratigraphic trap

Miss Lime charged via Osage?

Super-charged tight rock. Close to Sw irr?

Rapid Burial 300-250 Ma
Peak generation & expulsion

OVERPRESSURED MORROW

OVERPRESSURED WOODFORD

FORELAND BASIN
Penn sands OP disequilibrium compaction
PLAYMAKER CONSIDERATIONS: WHERE TO GO TO FIND ANOTHER ONE?
• SOURCE ROCKS – restricted circulation in peripheral foreland basins
The Borden Silt in Illinois is a slightly calcareous, glauconitic, fine-grained siltstone. Some fine sandstone and siltstones near the base of the Borden contain oil (Stevenson, 1964).

IL State students presented Borden Silt detrital zircon data at GSA-2016. Rather than a transition from continental to Appalachian derived sediment, the Borden has a unique northerly provenance and was likely transported by wind rather than water.
ARKOMA BASIN: The Moorefield shale is an emerging play.
PERMIAN BASIN: Could Barnett siltstones represent an exploration target?
ILLINOIS BASIN: Could BORDEN SILT represent an exploration target? Charge from New Albany / Woodford equivalent.

Map of vitrinite reflectance ($R_o$) of the New Albany Shale

- Immature: <0.60
- Early mature: 0.60-0.65
- Peak mature: 0.65-0.90
- Late mature: 0.90-1.35
- Post-mature: >1.35

$R_o$ range: 0.35-1.50%

Higley et al. 2003

Should we reconsider the onset of oil window? What is the effect of vitrinite suppression?
Devonossippian Petroleum Systems of Southern Laurasia:
What Makes the STACK-MERGE-SCOOP in Oklahoma so Special

- SUPER CHARGED FROM MULTIPLE SOURCE ROCKS
- HIGH GOR = STRONG DEPLETION DRIVE
- HIGH API GRAVITY = LOW VISCOSITY
- THICK SILTSTONE RESERVOIR (200-600ft)
- PERMEABILITY IN THE MICRO-DARCY RANGE
- OVERPRESSURE SANDWICH
SOME FINAL PLAYMAKER THOUGHTS

• BUILD YOUR PLAYS FROM THE BOTTOM UP

• BE HONEST ABOUT YOUR CONFIDENCE & RISKS

• APPLY RISK SEGMENT MAPPING TO HIGH GRADE

"You've got the play the game with fear and arrogance"  
Crash Davis

Don't forget to learn your clichés.
Klias Peninsula NW Borneo: Padas River debouching mud and silt into Brunei Bay