Data Driven Woodford Shale Risk Characterization

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• Mission and Motivation

• Woodford Shale Overview

• Developing a Woodford Play Fairway

• Conclusions

• Acknowledgments
**Mission and Motivation**

- **Quickly** provide a **predictive** production risk map using reservoir attributes that demonstrate a **tangible impact on hydrocarbon production**. Map is used to **direct rig placement**.

**Step 1**
- Map Woodford geological / petrophysical data
- Compile HRZ Woodford production data
- Assign mapped geological / petrophysical data to wells with HRZ production data

**Step 2**
- Generate multivariate linear (MVL) models
- Identify best statistically valid MVL model and key attribute(s)
- Generate risk maps using key attribute(s) and validate model

**Step 3**
- Deliver map to Operation team and implement

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[Marathon Oil Logo]
Woodford Shale Overview

- **Woodford Shale:**
  - Late Devonian – Early Mississippian
  - Thinly bedded black marine shale
  - 50’-500’ thick
  - Rich in silica
  - Organic (2%-8% TOC)

Modified from:
Northcutt and Campbell, 1995
Johnson and Luza, 2008
Oklahoma Geological Survey Publication EF 9
Woodford Shale Overview

- Three cores collected by MRO
- From basinal to upper slope environment of deposition
- WDFD is subdivided into three members:
  - Upper
  - Middle
  - Lower
- Variation in lithofacies and fabric type reflected in log character
Developing a Woodford Play Fairway

• Play Fairway map was needed
  • Prioritize future drill locations and leasing (re-leasing) opportunities

• Needed early on in the Woodford appraisal process
  • Prior to creation of a large resource database

• Mapped attributes required
  • Extend trends beyond well locations

• Quick turnaround requested
Developing a Woodford Play Fairway

Step 1: Map Woodford geological / petrophysical data
   • Un-shrunk
   • Not normalized

Step 2: Generate multivariate linear models
   Assign mapped geological / petrophysical data to wells with HRZ production data

Step 3: Generate risk maps using key attribute(s) and validate model
   Deliver map to Operation team and implement

- Map geological / petrophysical attributes
  - Gross thickness, OGIP, Neutron/Density Convergence thickness, PHIT, RHOB, etc.
- Compile primary phase gas EUR data
  - Un-shrunk
  - Not normalized
Developing a Woodford Play Fairway

- 1,000s of model permutations
  - Use geo and petro attributes to model EUR
- Results of the analysis
  - Identify the key geologic and petrologic attributes
  - Provide a linear regression equation to model EUR

Three Key Geological / Petrophysical Attributes:

- Gross Thickness
- OGIP
- N/D Convergence Thickness

Plug data into software to generate multivariate linear models
Developing a Woodford Play Fairway

• Three key attributes
  1. Woodford Gross Thickness
Developing a Woodford Play Fairway

**Three key attributes**

1. Woodford Gross Thickness
2. N/D Convergence Thickness
Developing a Woodford Play Fairway

Three key attributes
1. Woodford Gross Thickness
2. Convergence Thickness
3. OGIP
Developing a Woodford Play Fairway

- Generate fairway risk maps for each key attribute
- Low, Moderate, High Risk cutoffs based on qualitative production / key attribute observations

Gross Thickness Play Fairway Risk Map

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Developing a Woodford Play Fairway

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N/D Convergence Thickness
Play Fairway Risk Map

- Step 1: Map Woodford geological / petrophysical data
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Low Risk
Moderate Risk
High Risk

High EUR
Low EUR
Developing a Woodford Play Fairway

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  • Low, Moderate, High Risk cutoffs based on qualitative production / key attribute observations

OGIP Play Fairway Risk Map

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Composite Play Fairway Risk Map

- Combination of all three risk maps
Developing a Woodford Play Fairway

- Resulting predictive multivariate linear model for EUR using:
  - Gross Thickness
  - N/D Convergence Thickness
  - OGIP
Developing a Woodford Play Fairway

Well performance indicates based on location in fairway:

- Low Risk outperform Moderate Risk
- Moderate Risk outperform High Risk

EUR ranked probability curves
- Grouped by fairway risk designation

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Developing a Woodford Play Fairway

- EUR bar graph
  - Grouped by fairway risk designation

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Low Risk Locations

Composite Play Fairway Risk Map

Marathon Oil Company
Woodford Shale Composite Play Fairway
Conclusions

• The Woodford Play Fairway concept:
  • Quick and practical method to predict economic risk early on in unconventional play
  • Assumption is that key reservoir attributes impact Woodford production

Gross Thickness
- Relationship to EoD
- OM content deposition / preservation

OGIP
- Incorporates organic richness, PHI, Sw
- Determine overall gas potential of reservoir

N/D Convergence Thickness
- Relationship to shale petrology and mineralogical properties
- Siliceous/cherty sub-facies
- Predominately brittle (ideal target)
- Typically fractured with elevated K and PHI
Conclusions

• Future Work

• To provide a high resolution assessment of fairway risk, additional multivariate work is needed that includes a more robust set of attributes that *may* impact production
  • Completion style and success
  • Wellbore targeting / orientation
  • Seismic attributes (tectonic stress / faulting / fracturing)
  • Petrophysical character and quality
  • Wellbore parent / sister relationship
  • Normalized EUR dataset (by effective lateral length)
  • The list goes on...

Fractures confined to the more competent, chert sub-facies of Woodford Shale
Thank you!

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Questions?