

Data Driven Woodford Shale Risk Characterization

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Oil Company



Outline

- Mission and Motivation
- Woodford Shale Overview
- Developing a Woodford Play Fairway
- Conclusions
- Acknowledgments



MRO Woodford
Cana Infill

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

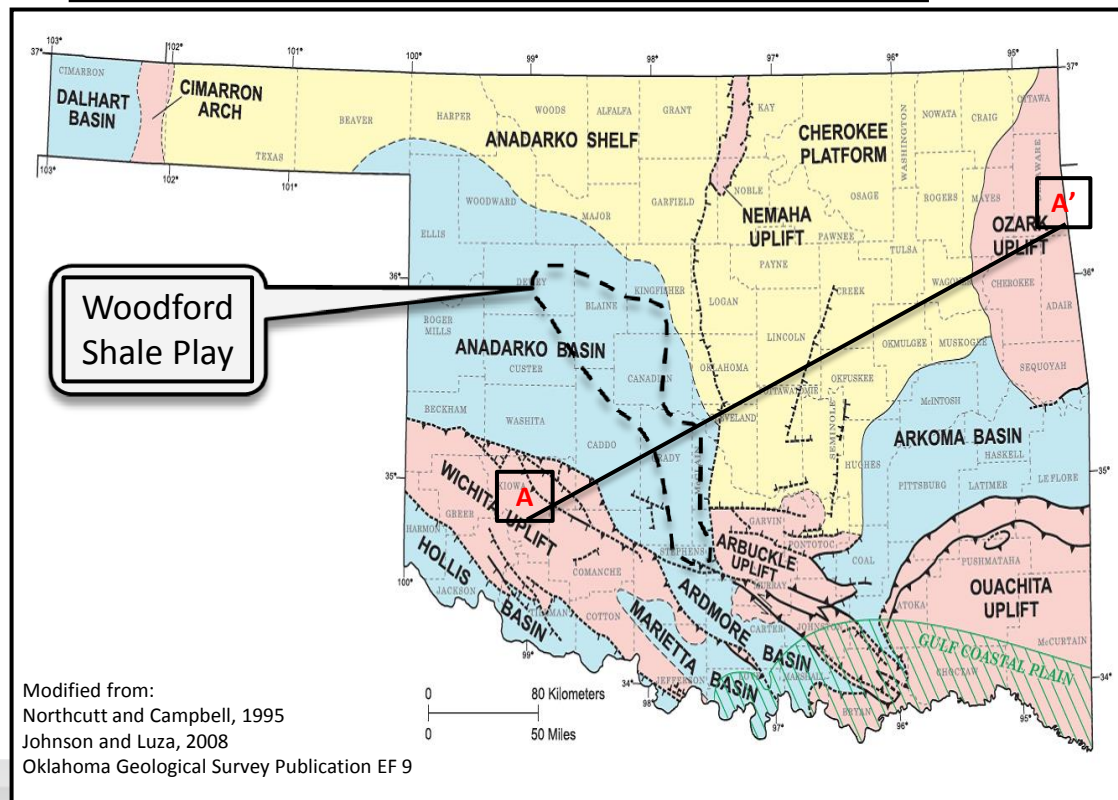
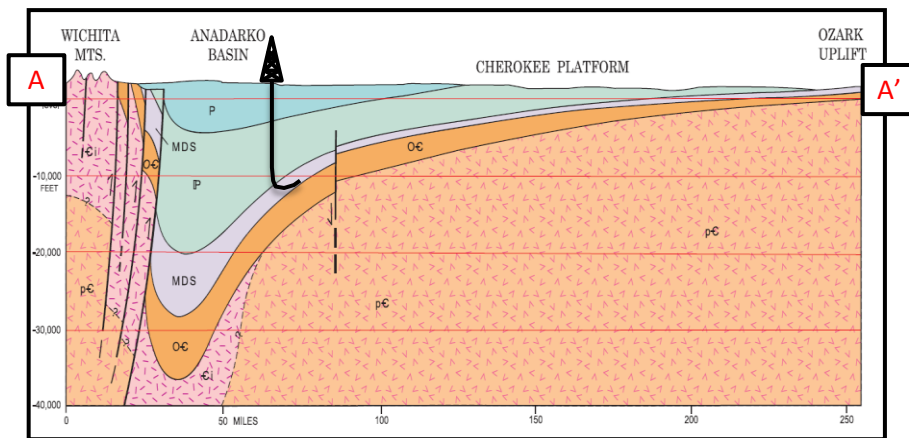
Identify best statistically valid MVL model and key attribute(s)

Generate risk maps using key attribute(s) and validate model

Step 3

Deliver map to Operation team and implement

Woodford Shale Overview

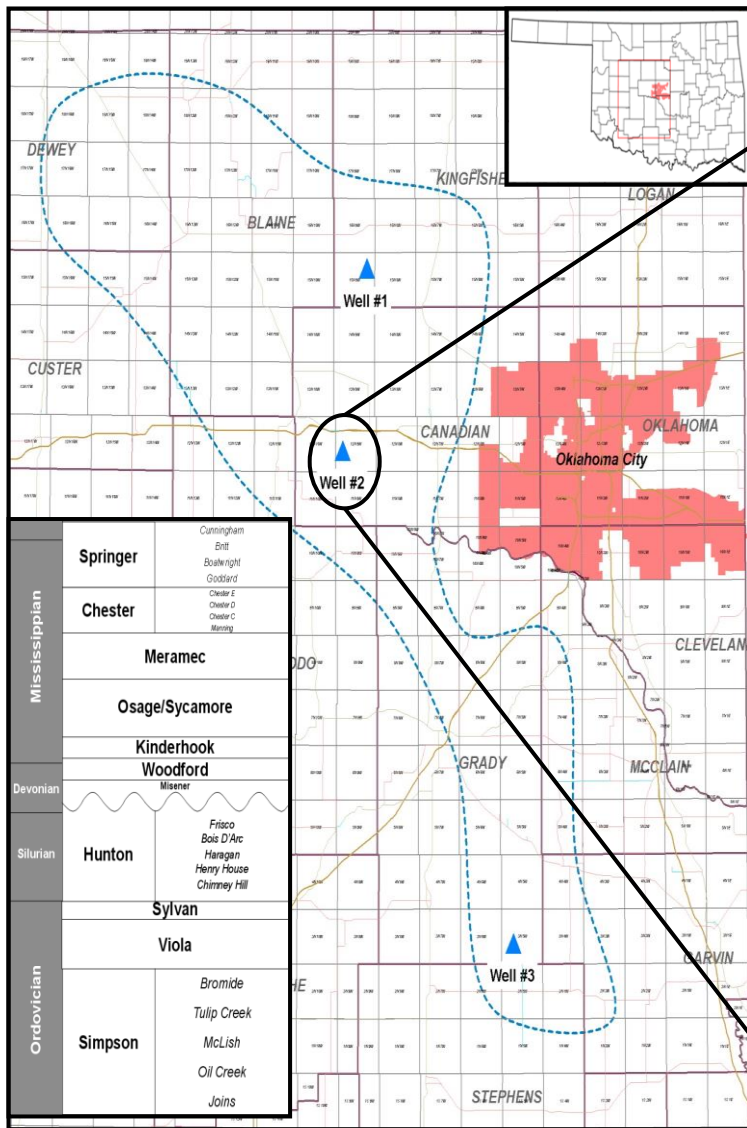


• Woodford Shale:

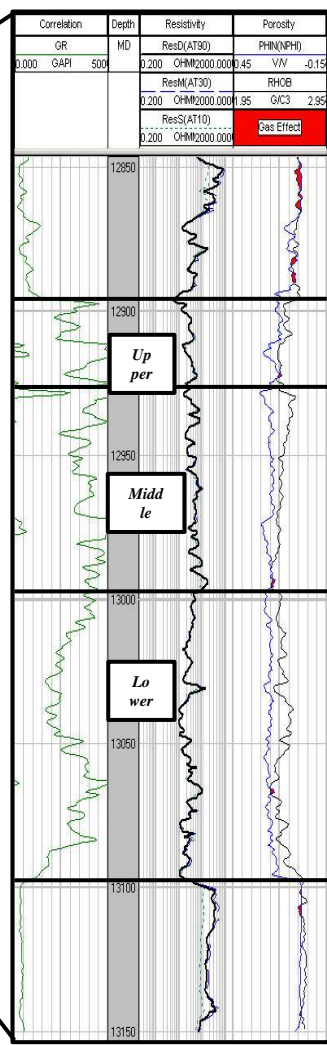
- Late Devonian – Early Mississippian
- Thinly bedded black marine shale
- 50'-500' thick
- Rich in silica
- Organic (2%-8% TOC)

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

Woodford Shale Overview

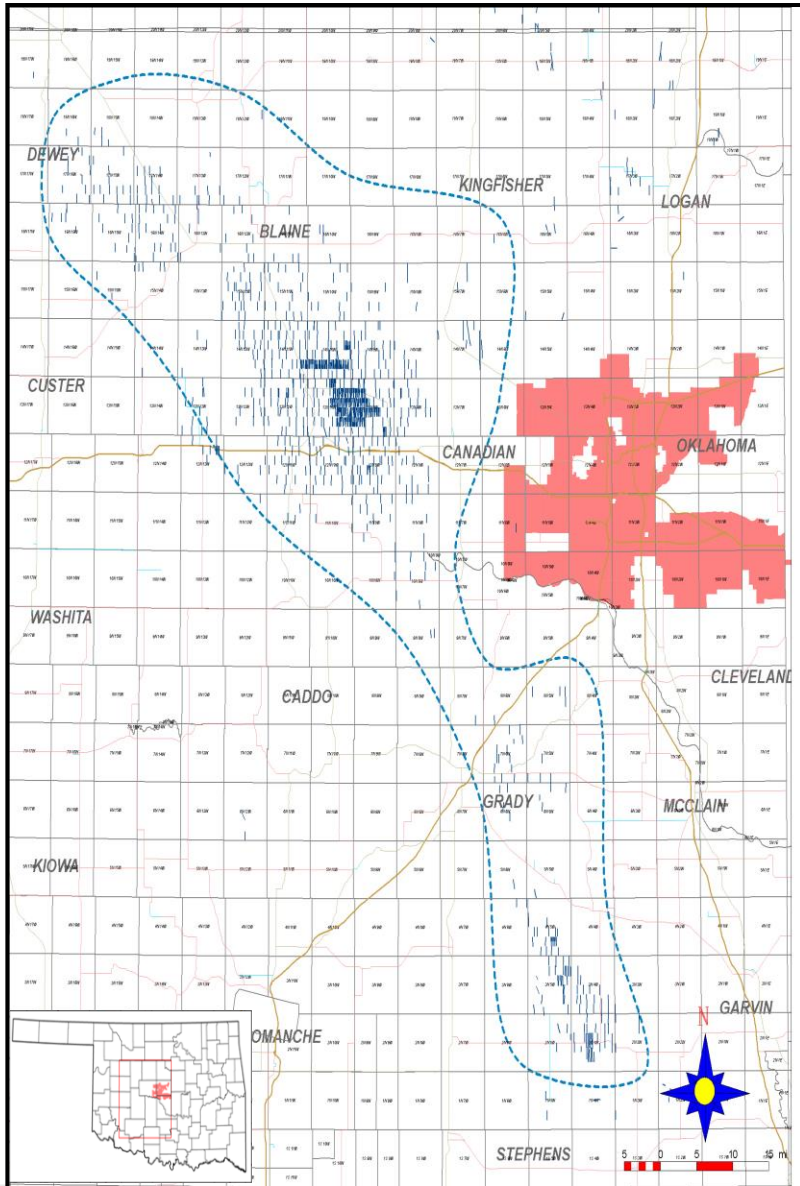


Well #2
12N-9W, Sec. 20
Canadian County, OK



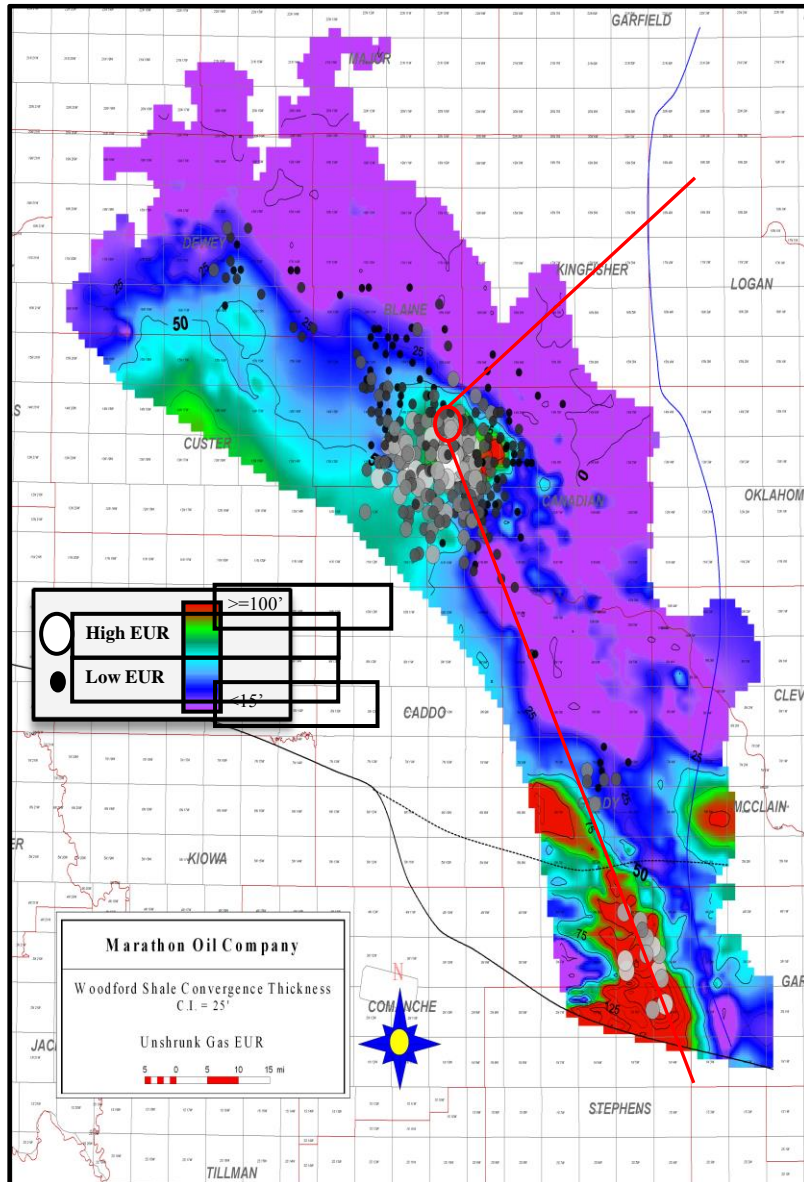
- Three cores collected by MRO
- From basinal to upper slope environment of deposition
- WDFD is subdivided into three members:
 - Upper
 - Middle
 - Lower
- Variation in lithofacies and fabric type reflected in log character

Developing a Woodford Play Fairway

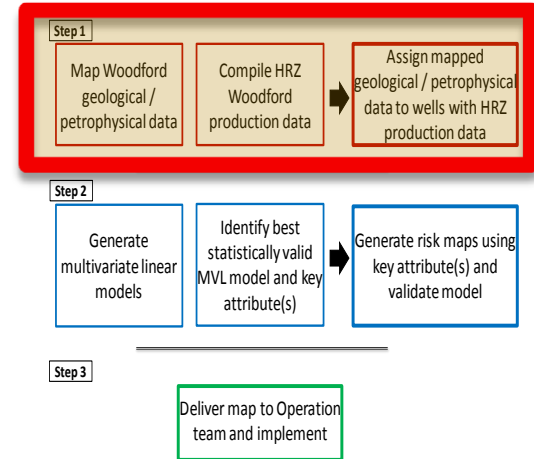
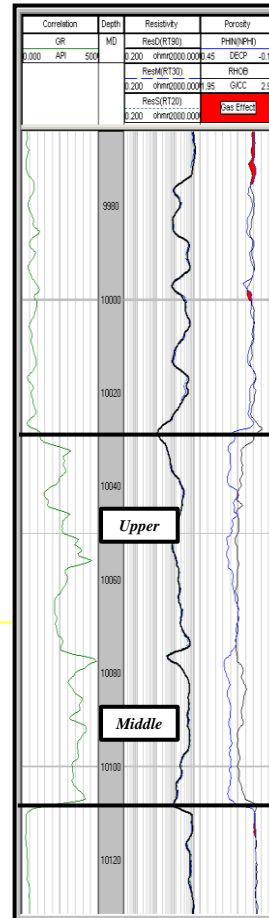


- Play Fairway map was needed
 - Prioritize future drill locations and leasing (re-leasing) opportunities
- Needed early on in the Woodford appraisal process
 - Prior to creation of a large resource database
- Mapped attributes required
 - Extend trends beyond well locations
- Quick turnaround requested

Developing a Woodford Play Fairway

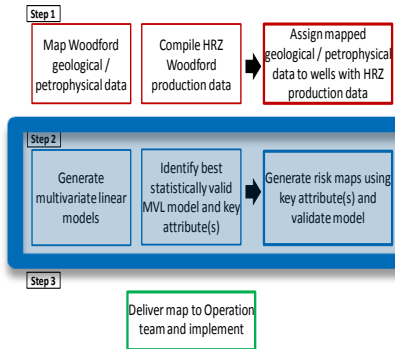


Well #1
15N-9W, Sec. 14
Kingfisher County,
OK



- 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



Plug data into software to generate multivariate linear models

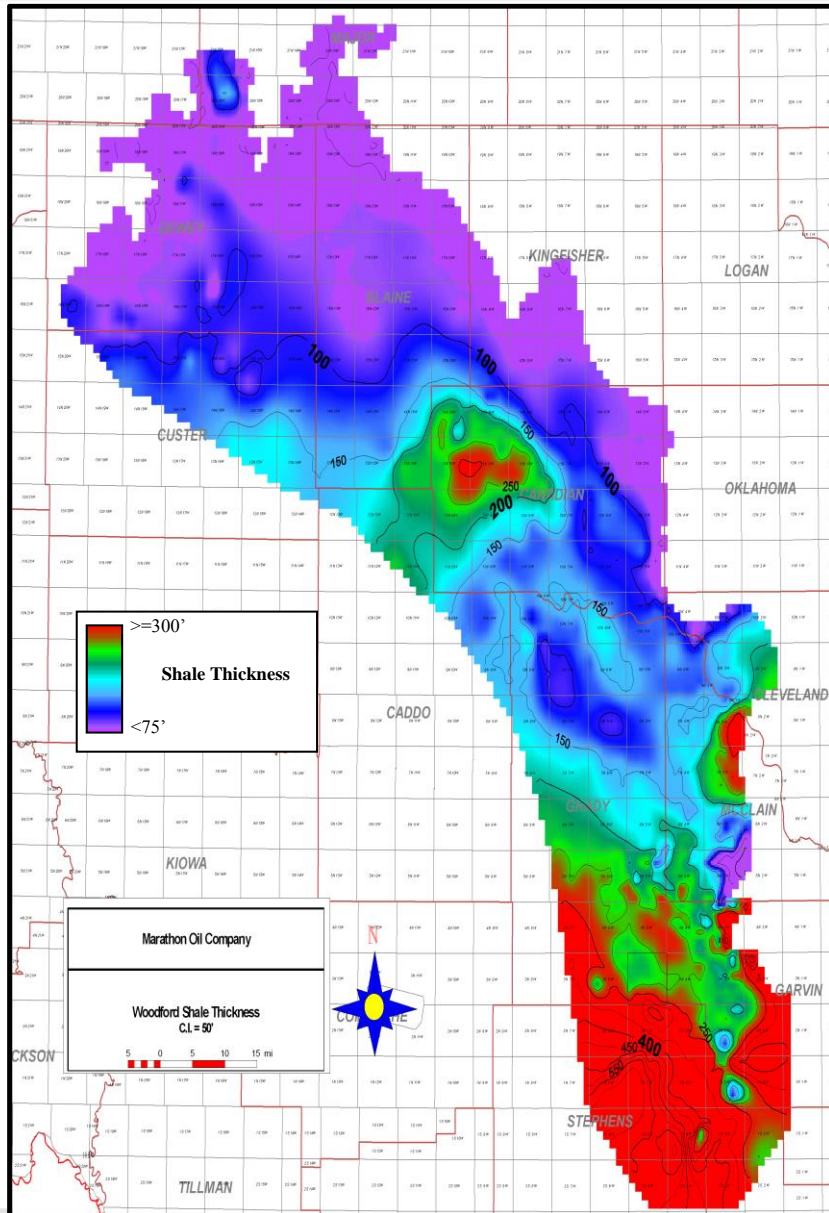
Three Key Geological / Petrophysical Attributes:

Gross Thickness

OGIP

**N/D Convergence
Thickness**

Developing a Woodford Play Fairway



Step 1

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Step 2

Generate multivariate linear models

Identify best statistically valid MVL model and key attribute(s)

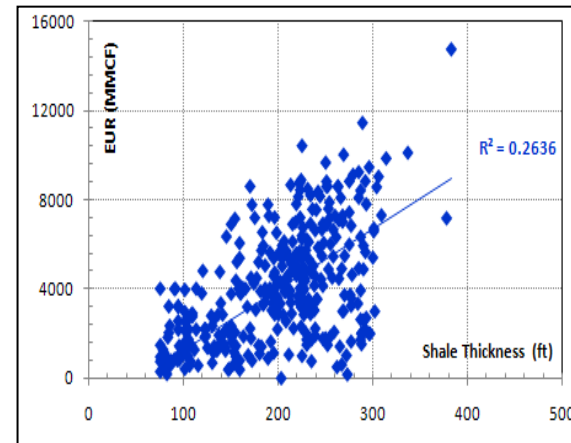
Generate risk maps using key attribute(s) and validate model

Step 3

Deliver map to Operation team and implement

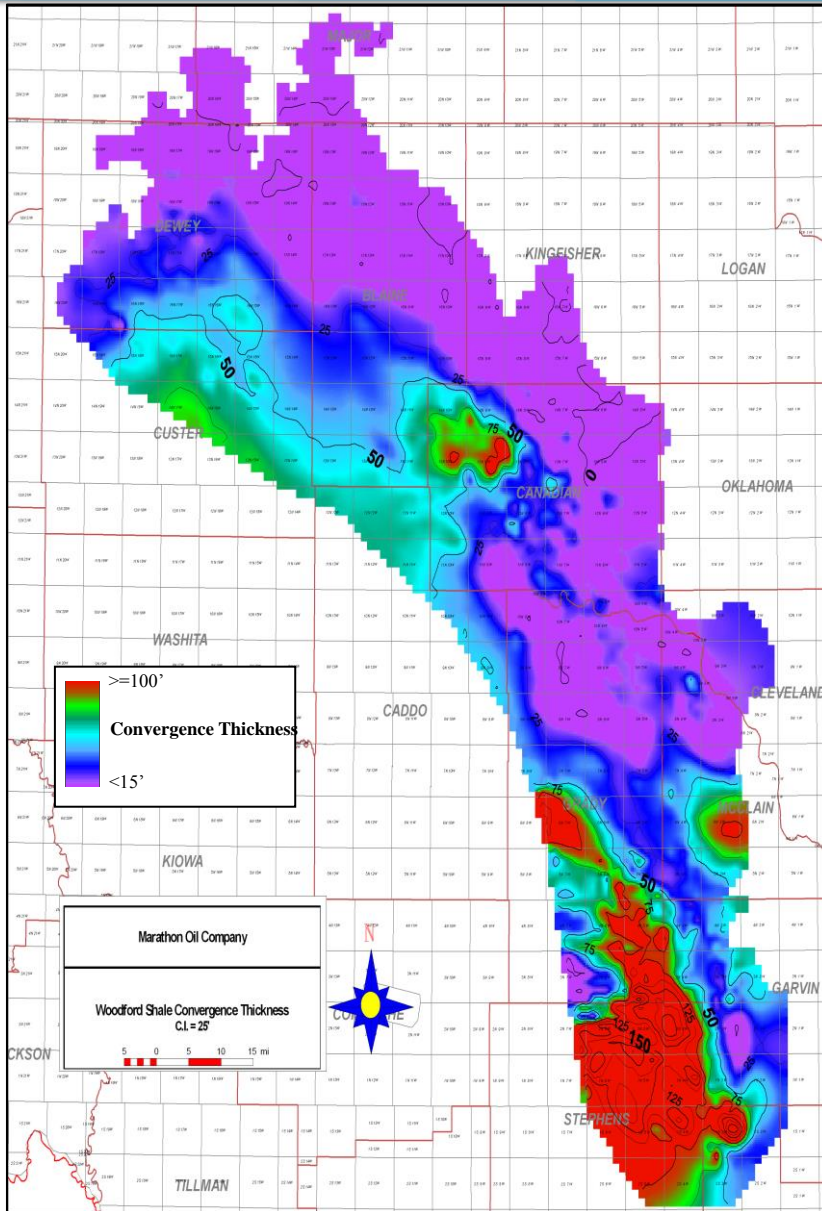
• Three key attributes

1. Woodford Gross Thickness



Marathon Oil®

Developing a Woodford Play Fairway



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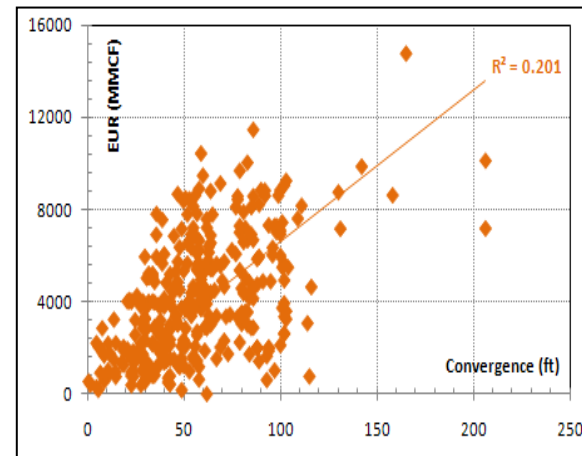
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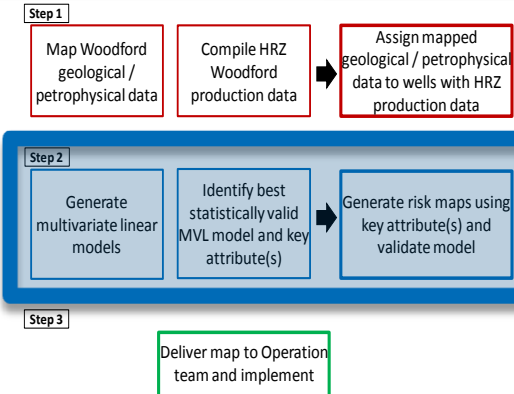
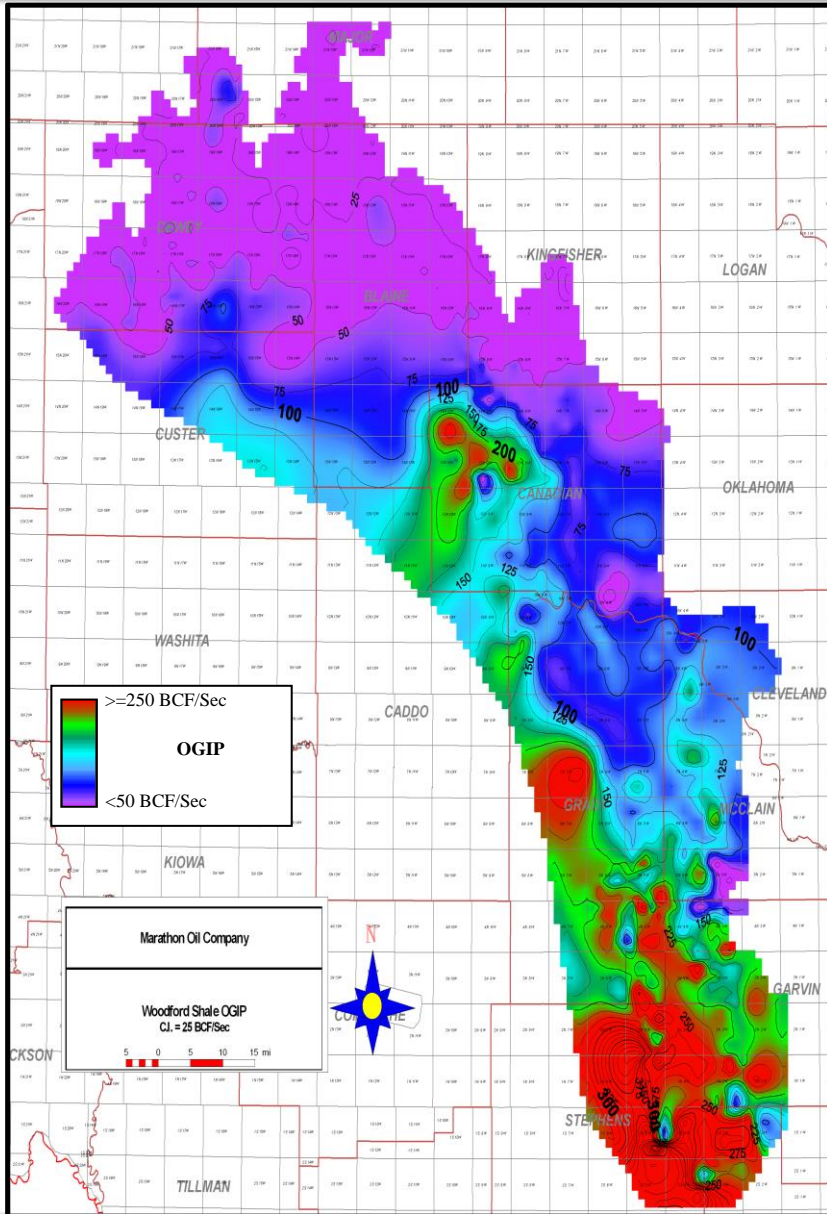
• Three key attributes

1. Woodford Gross Thickness
2. N/D Convergence Thickness



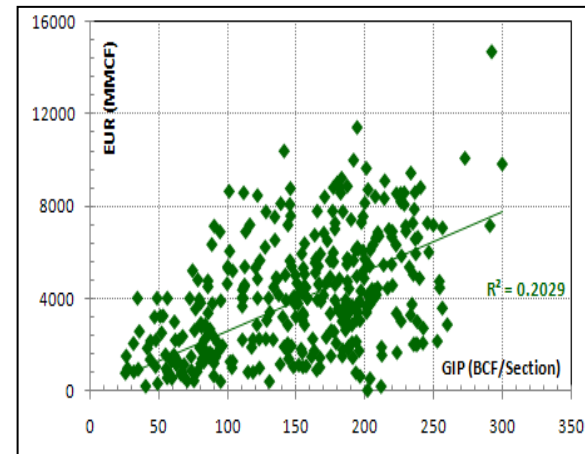
Marathon Oil®

Developing a Woodford Play Fairway

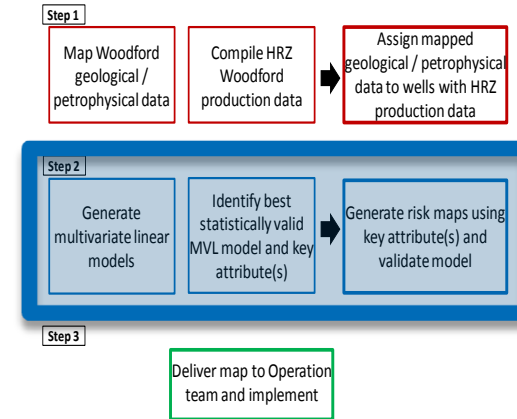
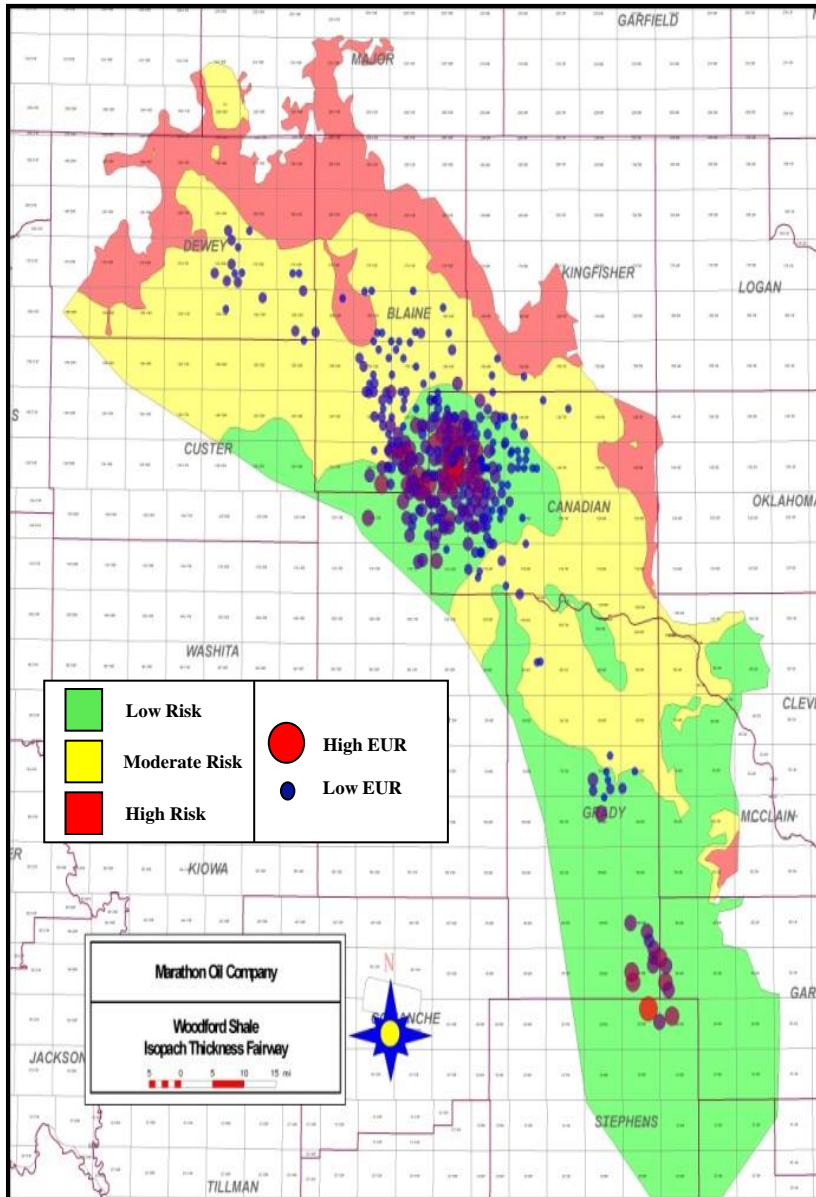


• Three key attributes

1. Woodford Gross Thickness
2. Convergence Thickness
3. OGIP



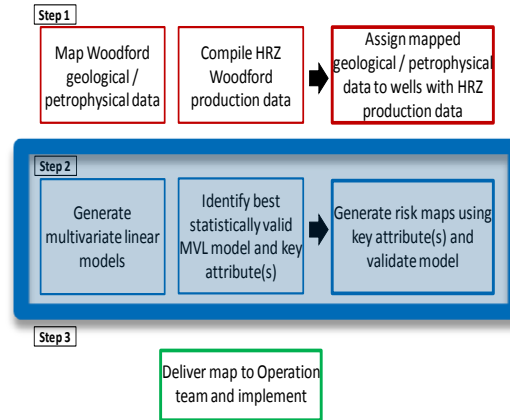
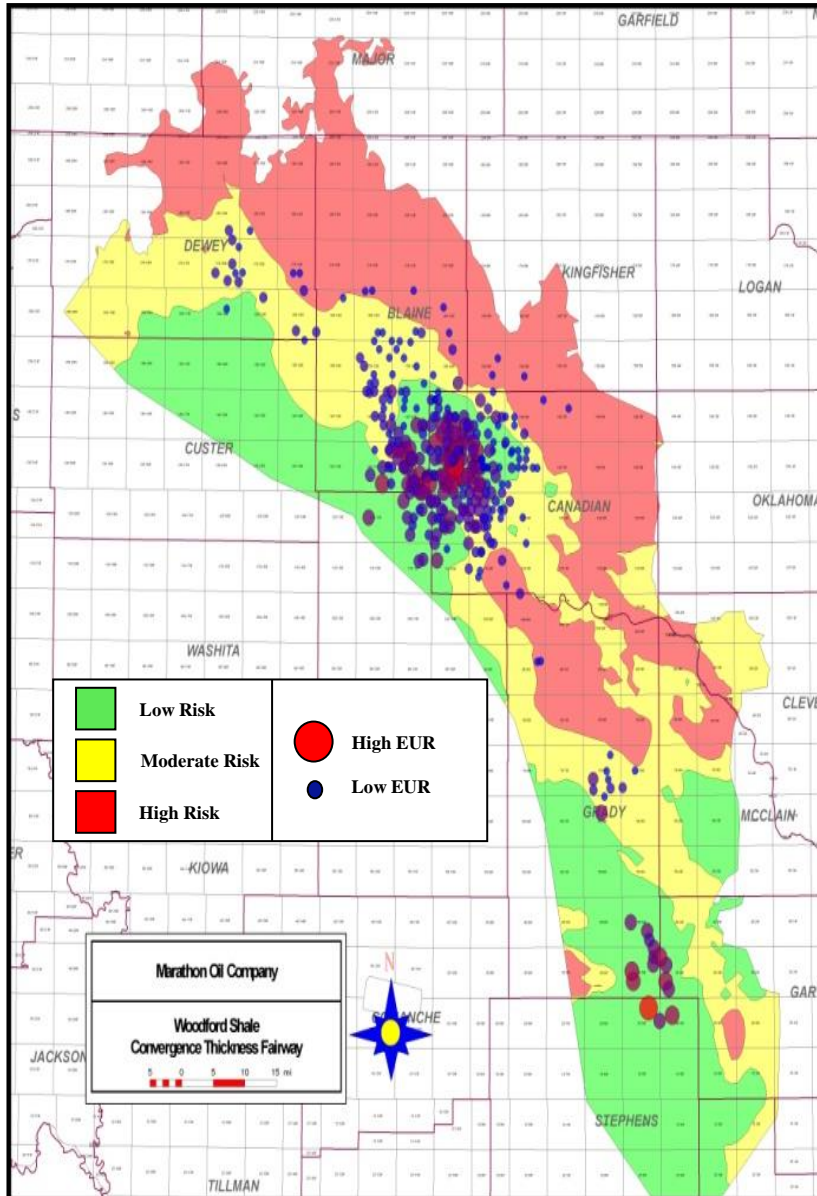
Developing a Woodford Play Fairway



Gross Thickness Play Fairway Risk Map

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

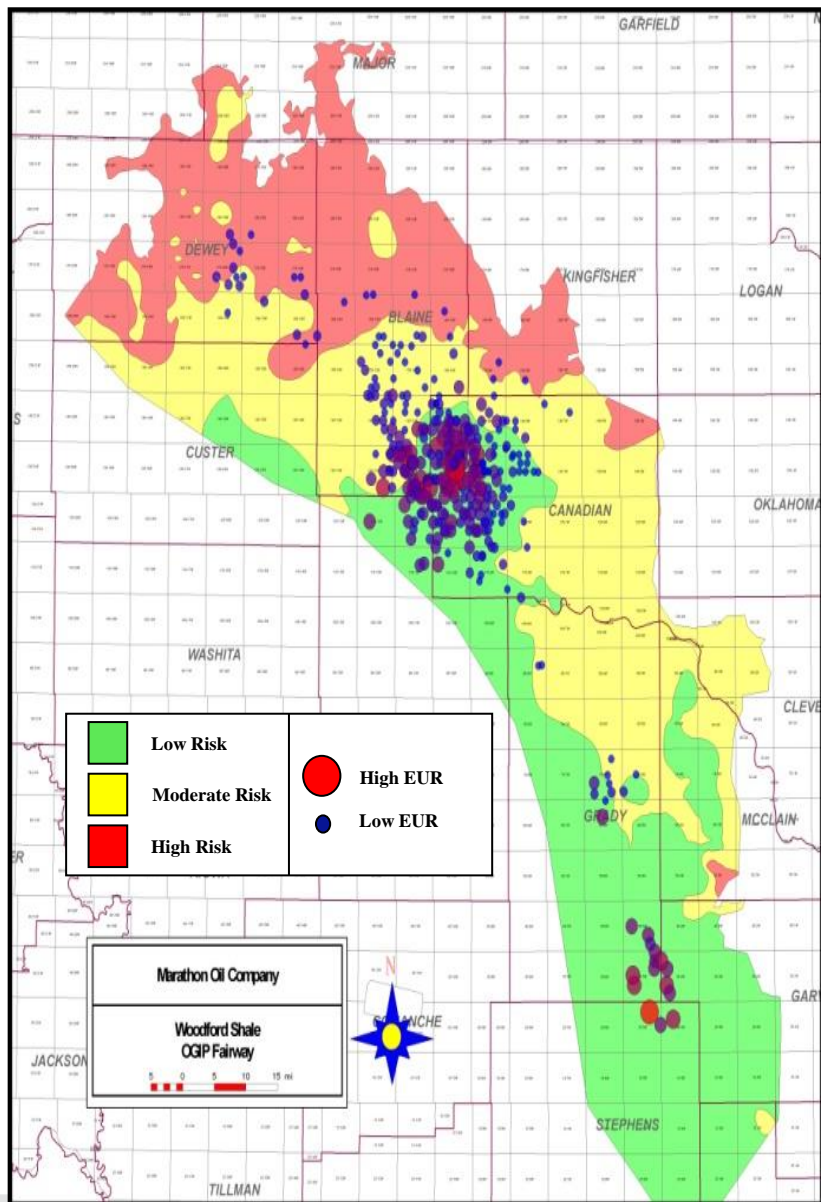
Developing a Woodford Play Fairway



N/D Convergence Thickness Play Fairway Risk Map

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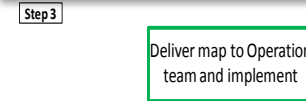
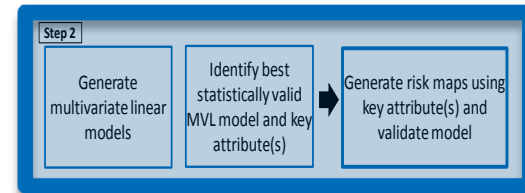
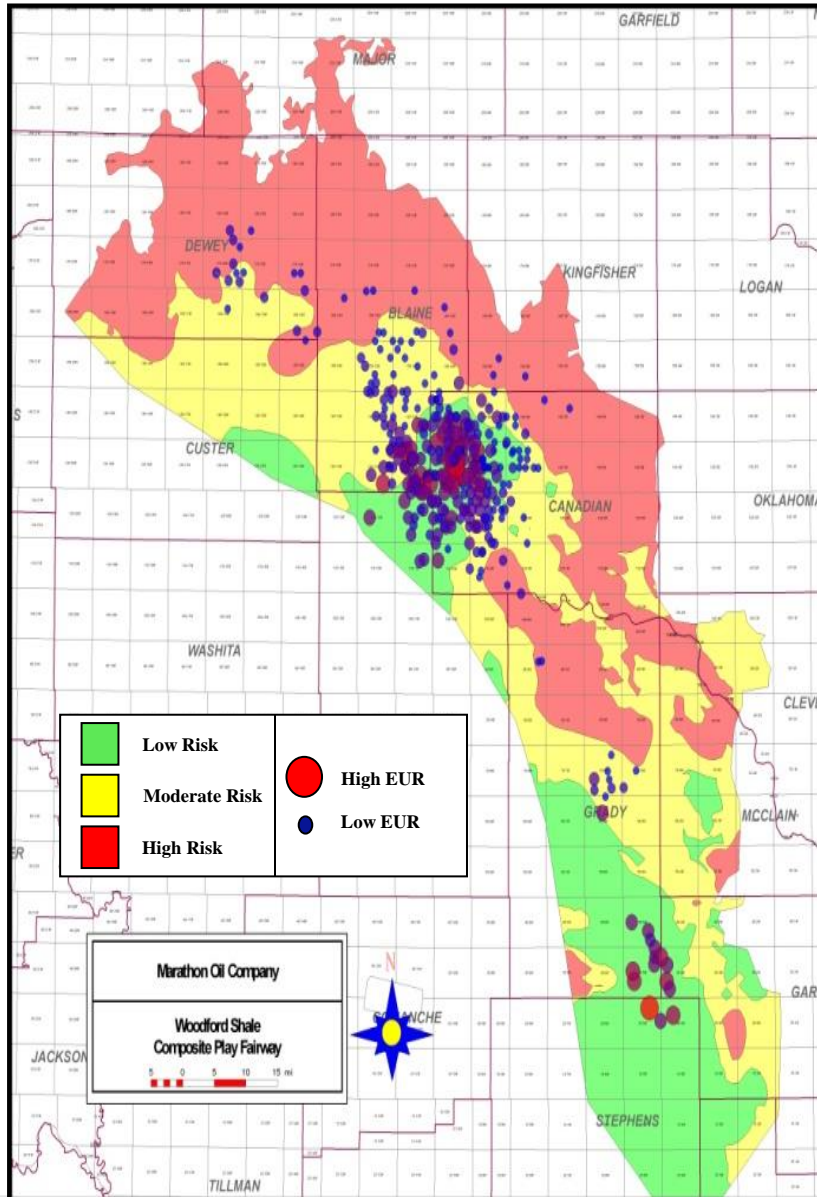
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OGIP Play Fairway Risk Map

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

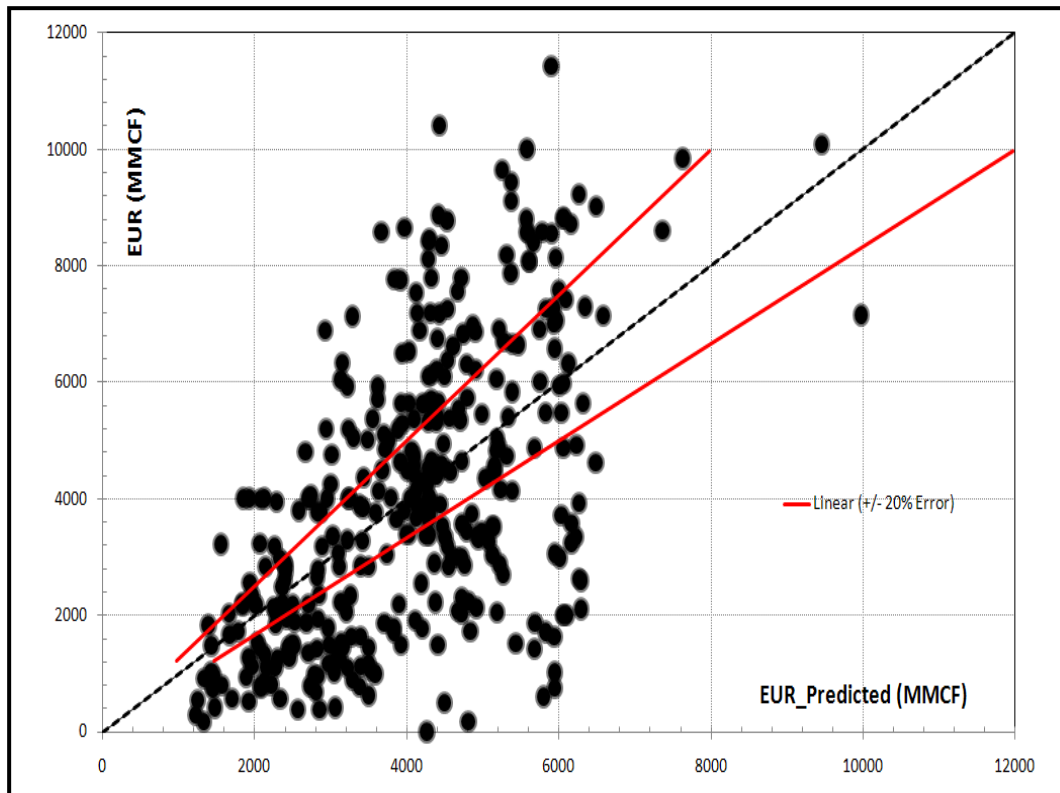
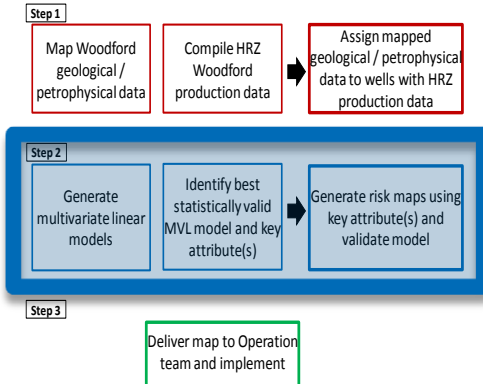
Developing a Woodford Play Fairway



Composite Play Fairway Risk Map

- Combination of all three risk maps

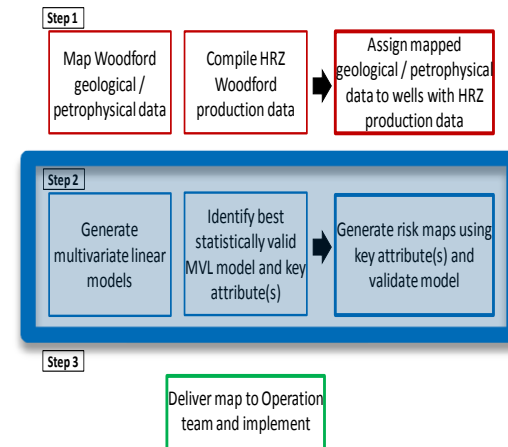
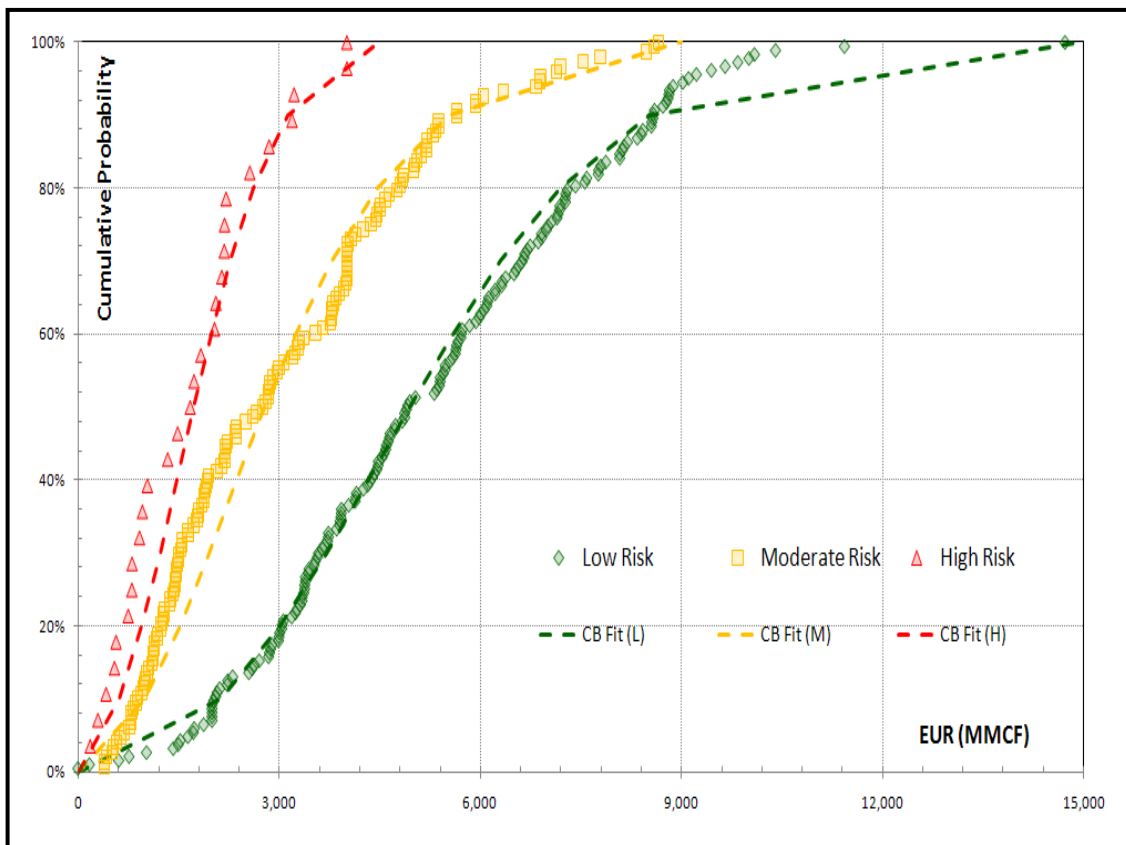
Developing a Woodford Play Fairway



•Resulting predictive multivariate linear model for EUR using:

- Gross Thickness
- N/D Convergence Thickness
- OGIP

Developing a Woodford Play Fairway

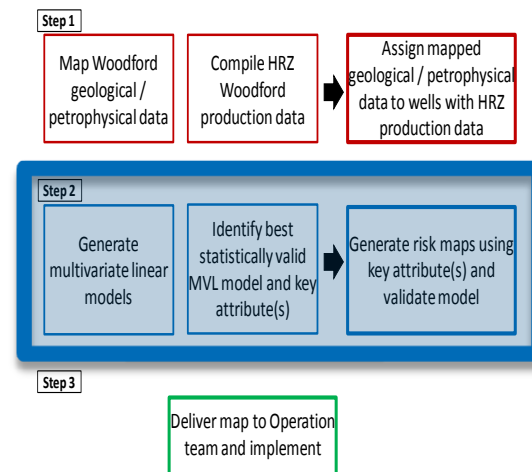
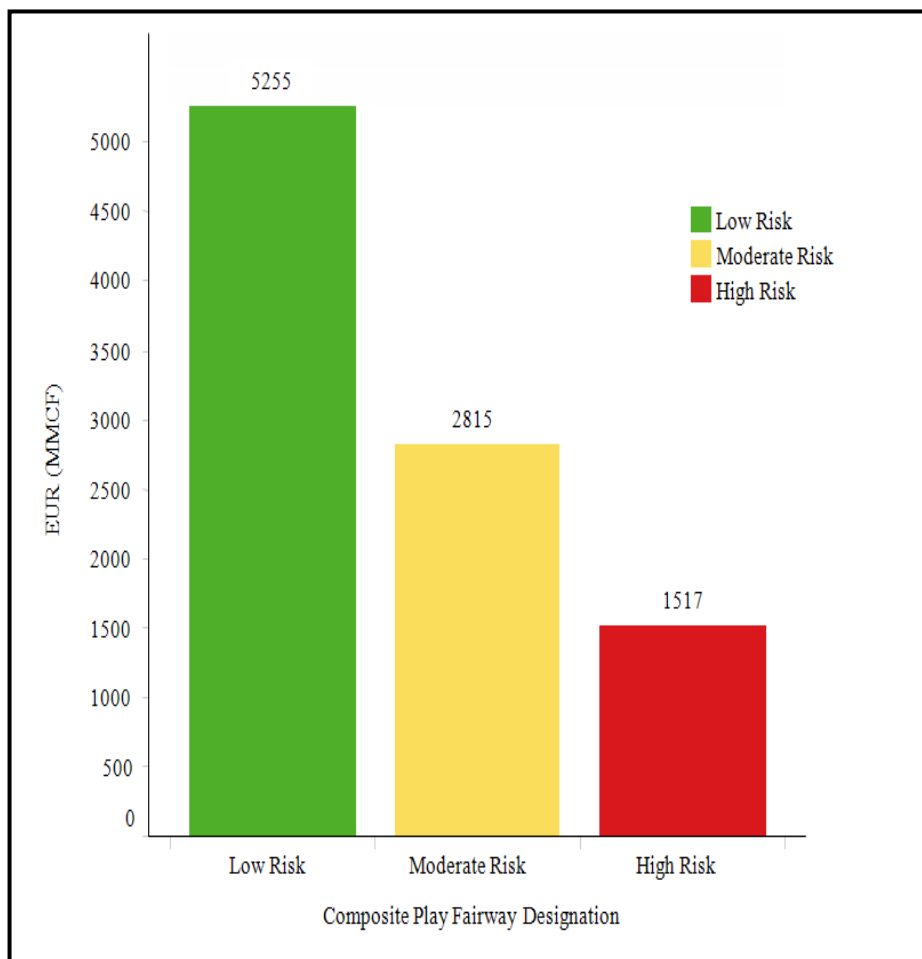


- EUR ranked probability curves
- Grouped by fairway risk designation

Well performance indicates based on location in fairway:

Low Risk outperform Moderate Risk Moderate Risk outperform High Risk

Developing a Woodford Play Fairway

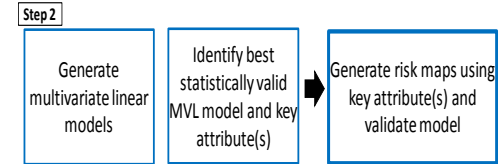
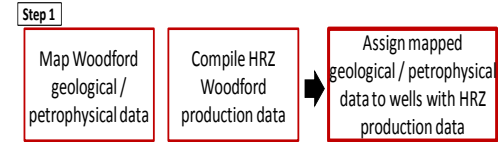
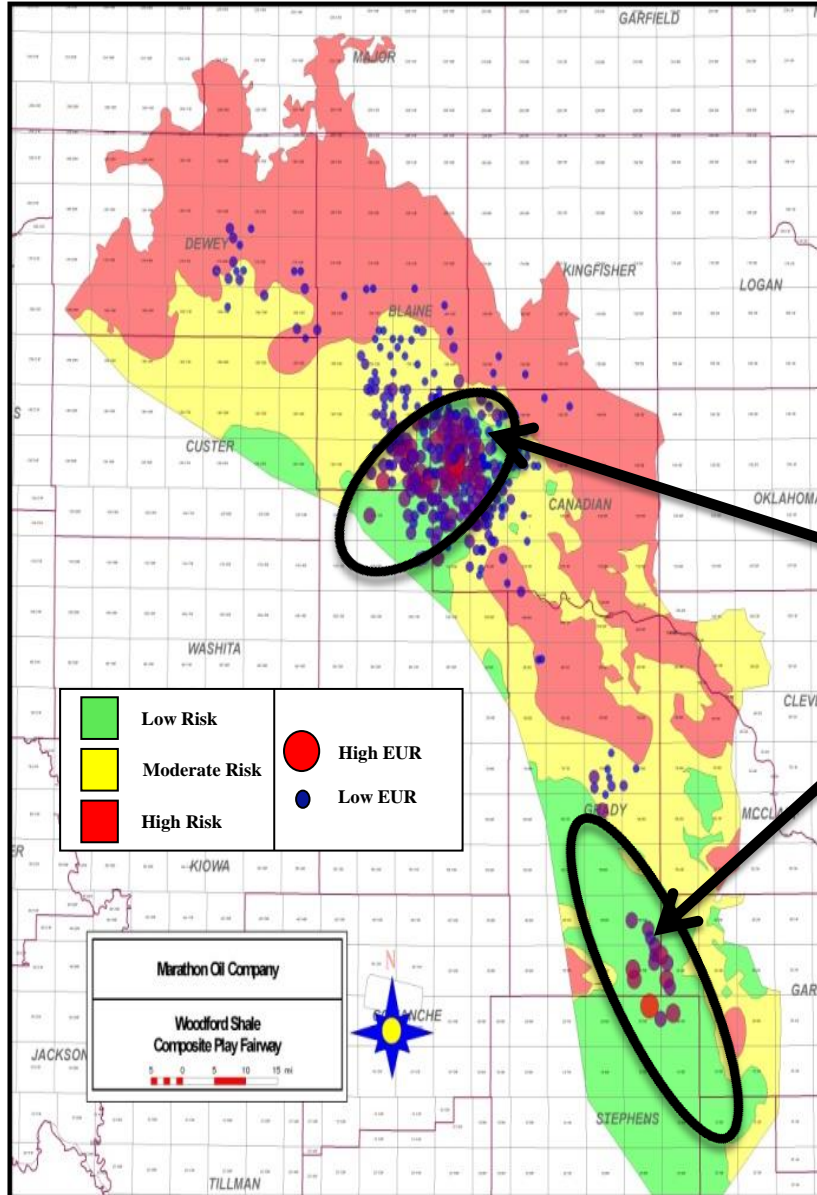


- EUR bar graph
 - Grouped by fairway risk designation

Well performance indicates based on location in fairway:

Low Risk outperform Moderate Risk Moderate Risk outperform High Risk

Developing a Woodford Play Fairway



Low Risk Locations

Composite Play Fairway Risk Map

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?

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