Permian Stacked-Pay Potential Assessment Using Multi-Disciplinary Analytics*

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Abstract

Nearly 100 years after the original discovery wells, the Permian Basin continues to challenge “conventional thinking” and provide opportunities for new understandings and economic opportunities. In this current phase of unconventional Permian development (i.e. hydraulically fractured horizontal wells), a significant case-in-point is the Alpine High focus upon deeper Pennsylvanian, Woodford, and Barnett reservoirs. A comprehensive understanding of the Permian Basin: spanning the Delaware, Central Platform, and Midland Sub-basins specifically; requires an evolving understanding of the interplay of thousands of feet and hundreds of million years of deposition.

Accessing regional interpretations of over 100,000 vertical wells, a time-equivalent framework of major Paleozoic sequence depths and thicknesses is introduced. Using a database of well over 10,000 horizontal wells: drilling, completions, and production data are used in tandem with geologic framework data to develop analytic models to isolate regional trends of major reservoirs. Engineering variations in well lengths (and paths), proppant intensity, frac type, and more, are modeled from statistically significant sampling of horizontal wells using multi-variate analytics techniques. Practically, this workflow “normalizes” the impact of different engineering decisions to isolate the impact of geology on well performance.

What is clear is the significance of hydrocarbon maturity and depth (i.e. reservoir pressures) in the understanding of oil and gas prospects across the Permian. While the core of the Delaware or Midland sub-basins may have 10 or more distinct landing zone targets (spanning the Bone Springs/Wolfcamp and Spraberry/Wolfcamp benches respectively); the Permian Basin fringes may offer a half dozen or more targets (spanning Wolfcamp/Pennsylvanian/Woodford/Barnett). What is clearly illustrated is that thousands of feet of potential play exist across very large extents of the Permian, requiring increasingly more in-depth understanding of depositional patterns, lithology, mineralogy, geomechanics, and more.

Using basic drilling and completions cost estimates, “penalty weightings” are estimated to better understand the relative economic viability of multi-zone development across the play. As the “modern Permian” moves into more mature stages of unconventional field development, it is critical to deploy optimized pad drilling and lateral/vertical spacing strategies, driven by grounded geologic input.
References Cited


PERMIAN STACKED-PAY POTENTIAL ASSESSMENT USING MULTI-DISCIPLINARY ANALYTICS

An Adventure in Bracketology....
Bracketology (according to IBM Watson…)

With “Big Data Analytics” do we even have to play the games anymore……?
Delaware versus Midland
Permian Basin Formations

**Delaware versus Midland**

Leonardian versus Wolfcampian

### Delaware Basin Stratigraphic Formations

<table>
<thead>
<tr>
<th>Period</th>
<th>Series</th>
<th>Formations</th>
</tr>
</thead>
<tbody>
<tr>
<td>Guadalupian</td>
<td>Delaware Group</td>
<td>Lamar Bell Canyon, Cherry Canyon, Brushy Canyon</td>
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<tr>
<td>Leonardian</td>
<td></td>
<td>Upper Avalon Shale, Lower Avalon Shale, 1st Bone Spring, 2nd Bone Spring, 3rd Bone Spring</td>
</tr>
<tr>
<td>Wolfcampian</td>
<td></td>
<td>Wolfcamp</td>
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<tr>
<td>Pennsylvanian</td>
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<td>Pennsylvanian</td>
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</tbody>
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### Central Basin Platform Stratigraphy

<table>
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<tbody>
<tr>
<td>Guadalupian</td>
<td>White Horse</td>
<td>Tansil, Yates, Seven Rivers, Queen, Grayburg</td>
</tr>
<tr>
<td>Leonardian</td>
<td>Yeso</td>
<td>Paddock, Blinney, Tubb, Drinkard</td>
</tr>
<tr>
<td>Wolfcampian</td>
<td></td>
<td>Ward, San Andreas, Glorietta</td>
</tr>
<tr>
<td>Pennsylvanian</td>
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<td></td>
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</tbody>
</table>

### Midland Basin Stratigraphic Formations

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<tr>
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<tr>
<td>Pennsylvanian</td>
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</tbody>
</table>
Basin Assignment

After Breton and Dutton
Basin Assignment

~450,000 Vertical Wells
~17,000 Horizontal Wells
KB QC and Editing

½ mile by ½ mile grid
319 by 293 miles
39,467 sq miles
Wolfcamp bench performance varies throughout basin
20 Grids created across the Permian
Top Wolfcamp Geologic Tops ~140,000
Wolfcamp Benches in 3D with Horizontal Wellbores
Wolfcamp Benches in 3D with Horizontal Wellbores
Wolfcamp Benches in 3D with Horizontal Wellbores
Wolfcamp Benches in 3D with Horizontal Wellbores
Wolfcamp Benches in 3D with Horizontal Wellbores
Landing Zone Assignments
“Sweet Sixteen” Well Liquid Production
“Sweet Sixteen” Liquid Production per foot
Horizontal Wellbore Lengths by Formation
“Sweet Sixteen” BOE Production per foot
Liquid Production per foot – go deep/big
Cum Liquid Curves out to 6 Months
“Final Four” Liquid Production per foot
“Final Four” Liquid Production per foot
Permian Basin “Final Four”

**DELAWARE**

- Upper/Lower Avalon
- 1st Bone Springs
- 2nd Bone Springs
- 3rd Bone Springs

- Wolfcamp A
- Wolfcamp B
- Wolfcamp C
- Wolfcamp D

**MIDLAND**

- Leonardian
- Lower Spraberry

- Clear Fork
  - Upper Spraberry
  - Lower Spraberry
  - Dean
  - Wolfcamp A
  - Wolfcamp B
  - Wolfcamp C
  - Wolfcamp D

**Wolfcampian**

- 2nd Bone Springs
Permian Basin “Final Four” – Penalty Weight by TVD/Fluid per foot
Delaware 2\textsuperscript{nd} Bone Springs Sweetspot
Outlier Analysis

Analyze and remove possible data outliers using a non-parametric approach based upon distribution smoothing and degree of rejection (alpha).

Outlier alpha (usually < 0.01) 0.002
PDF Smoother Length

Select attributes to be analyzed

Outliers found

Horizontal Section - Depth - Isachev 1541 60:0.00194
Horizontal Section - Depth - Isachev 1535.04:0.00146
Horizontal Section - Depth - Isachev 1524:0.00156
Horizontal Section - Wellbore Horizontal Len 1104.94:0.00133
Well - Unknown - API Gravity 61.0:0.00118
Well - Unknown - Cum 6 Month Liquid (bbl) 194616.701294
Well - Unknown - Frac Fluid per Length 2606.75:0.00109
Well - Unknown - Frac Fluid per Length 2542.07:0.00123
Well - Unknown - Frac Fluid to Proppant Rati 6.621818.873583
Well - Unknown - Frac Fluid to Proppant Rati 5.348081.404082
Well - Unknown - Proppant per Length 2549.17:0.00110

Horizontal Section - Depth - SB5G (GDS) - 4 Nearest Points Mean (ft)

Analyze | Remove | Dismiss
Predicted versus Measured 6-mo Liquid
Predicted versus Measured 6-mo Liquid
Optimization Plots for Production Predictors
FUTURE WORK
Workflow Highlights

Identify and Classify features for Multi-Variate Analytics

Fault/Debris Flow/Channel Features
Big thanks to IHS Markit and John Roberts/Dean Williams for access to GDS geologic tops database