Abstract

Description:

A comprehensive interpretation of nearly 2 million geologic tops is used to build a structural framework spanning the: Delaware Basin, Central Basin Platform, and Midland Basin. Digital well logs are extracted over mapped Leonardian and Wolfcampian geologic zones and are gridded into regional trends. Fluid information, gathered during production testing and historical production, are similarly gridded for corresponding well target zones – to create maps of: GOR, water-cut, gas-cut, and more. Full 3D models are constructed for key petrophysical and fluid properties, which in turn are extracted to average values along intersecting horizontal wellbores.

Model-based analytics are then used to correlate extracted properties and engineering data (horizontal length, etc.) to build a well production prediction model. Finally, the analytics model is normalized for engineering variability (i.e. engineering parameters are set to nominal values) and is applied to the 3D property models of gamma-ray, porosity, pressure, water-cut, etc. – creating a 3D sweetspot volume. Incorporating vertical and horizontal well spacing data into the analytics model updates provides a way to estimate well production depletion effects on the sweetspot model.

Application:

The original and depleted Permian 3D sweetspot models provide insight into existing well pattern effectiveness and metrics for design of future multi-bench development. Well-to-well frac interference and production contention effects are highlighted, providing guidance into not just horizontal well placement – but also timing of infill and extension development. The analytics model can also be used to predict planned well performance, through specification of intended target location, well length, frac intensity, and stage spacing.

Results and Conclusions:
Contrary to previous published studies that focus on the importance of high-energy fracs, we find that frac intensity, and other engineering parameters, need to be tuned to rock and fluid properties of targeted reservoirs. Specifically, for the Permian: water-cut, reservoir pressure, potential frac barriers, and relative lithology and porosity need to be factored into any engineering optimization workflow.

**Technical Contributions:**

Regional 3D property models of the Permian Basin. Creation of corresponding original and production-depleted 3D sweetspot models. Evergreen model of optimizing engineering designs for specific target reservoirs.

**Selected References**


OPTIMIZING ENGINEERING FOR PERMIAN GEOLOGY/FLUID USING MODEL-BASED ANALYTICS

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Permian Basin unconventional oil prospectivity is primarily driven by oil/gas/water mix and reservoir pressure.

Poor well performance, often in the form of early gas bubble-point effects, can occur in certain areas or result from over-engineering geologic sweetspots.

Using measured engineering data, and gridded fluid and geologic data, we construct layer-based analytics models to predict well performance response to horizontal well locations, and drilling and completions parameters.
Good wells going bad across the Permian

- Wells in Andrews, Martin, Midland and Upton Counties have the highest and most consistent oil cuts.
- Wells in Irion, Crockett and Schleicher Counties start with lower oil cuts and rapidly transition to gas well.
- Wells in Glasscock and Reagan Counties start with high oil cuts, but become very gassy.
What is causing **good** wells to go **bad** across the Permian?

How much Geology?

Fluid Type  
Lateral Length  
Thickness  
Mesh Size  
Natural Fractures  
Choke Size  
Mineralogy  
Fluid Intensity  
Wellbore Azimuth

Pressure  
TVD  
Porosity  
GOR  
Date

Water Cut  
Stages/Perfs  
Well Spacing  
Fluid/Proppant  
Frac Type  
Oil API  
Wellbore Path  
Proppant Intensity  
TOC  
Brittleness

Stress  
Tmax

How much Engineering?
Project Data and Work Flow

Model-Driven Analytics

Model impact of individual geologic and engineering parameters on horizontal well performance

Data Cleaning, Enhancement and Integration

FracFocus+
FracFocus and State frac ingredient details

Enerdeq™
Well, survey, well log, engineering and production data

GDS™
Geologic tops

Decision-Ready Data

Spotfire™ Dashboard

Data Quality Control and Basic Analysis
Data Cleaning, Enhancement and Integration

Correct/Infill Bad/Missing Data
- KB Correction
- Survey Estimation

Complete the Dataset
- Present Day Spacing
- Well Spacing
- Geologic Data

Reconcile Misleading Data
- Raw Enerdeq
- GTC Corrected

Integrate Data

Correct/Infill data
- KB errors (DEM)
- Missing surveys
- Remove data outliers

Complete the datasets
- Grid structural surfaces
- Grid oil/gas/water cuts
- Grid gamma-ray data
- Calculate isochore grids
- Landing zones/%
- Time-based vertical and lateral well spacing

Reconcile misleading data
- Production stub months,
- Normalize production

Integrate data
- Extract geology/fluid grid data along wellbores
Gridding Geologic Tops across the Midland Basin
Gridding Midland Basin Oil, Gas and Water Cut

3-6 month averaged gas and oil cut (production bubbles on left) for all 1239 Wolfcamp B wells used as control points for creating oil/gas-cut grids (right).

Contours for top Wolfcamp depth from surface are overlain.
Midland Basin Oil and Gas Cut delta over 2 years

Year 2 Q4 averaged oil/gas cut (21-to-24 months) (left)

Year 2 Q4 averaged oil/gas cut minus Year 1 Q1 oil/gas cut (1-3 months) (right)

Red areas = greatest increase in gas cut, orange less and yellow effectively no change, over 2 years.

BEG faults (blue).
Midland Basin Cum Oil versus Gas Cut over 2.5 years

Two-and-a-half-year normalized cumulative oil (vertical axis) versus monthly gas-cut percentage (horizontal axis) – averaged for Midland Basin Wolfcamp B wells over depths

Every dot along a curve is a month
Every large dot along a curve is a year
6-mo Cum Oil versus Depth and Proppant

This is the highest geologic correlation with production
(0.20 $R^2$ | 0.45 $R$)

Six-month cumulative oil (vertical axis) versus true vertical depth (horizontal axis) colored by total proppant, left.

This is the highest engineering correlation with production
(0.26 $R^2$ | 0.52 $R$)

Six-month cumulative oil (vertical axis) versus total proppant (horizontal axis) colored by true vertical depth, right.
Cum Oil and Oil Cut - Depth versus Proppant Intensity

Depth (vertical axis) versus Proppant Intensity (horizontal axis) crossplots and heat maps.

6-month cum oil (normalized to 7500’ lengths) on left.

22-24 month oil cut on right.

Best Oil Production

Best Oil Cut

~1200 lb/ft
Create simple “Oil Prospectivity Sweet-spot Map”

Divide well production by total proppant pumped, to highlight non-engineering trends (i.e. normalize production by well length and frac intensity)

This is a crude geologic/fluid sweetspot map...

Want to explain why production dives at the deepest (and highest pressure) part of the Midland Basin (to the northwest) and at the shallowest (and lowest pressure) part of the Midland Basin (to the southeast)
Midland Wolfcamp B - 4-6 month Water and Gas Cut

Normalized 6-month Cum Oil
(Oil bbls/MM lbs proppant)

4-6-month water cut (water/oil+water+gas)

4-6-month gas cut (gas/oil+gas BOE)

Lower production due to higher water cut, lower gas cut (and API oil gravity), thinner zone and higher clay (GR)?

Lower production due to higher gas cut, lower pressure (shallower) and higher clay (GR)?
Midland Gamma-Ray Trends

Distance along transect North-South traverse on West side of Midland (ft)

Distance along transect WEST-EAST from Odessa to Eastern Shelf (ft)
Midland Gamma-Ray Trends – Flattened on USBY
Lower production due to higher water cut, lower gas cut (and API oil gravity), thinner zone and higher clay (GR)?

Lower production due to higher gas cut, lower pressure (shallower) and higher clay (GR)?
Model-Driven Analytics Optimization Plots

- 3-mile wellbores OK
- 1500 lbs/ft proppant
- Slickwater frac
- Simplest wellbore path
- Modern frac techniques
- Strong well-to-well interference at < 750'
- Optimal depth 6000' SS (~9500' TVD)
- Regionalial Gas Cut <20%
- Low water cut ~20%
- GR ~ 75 API
- Parent Wells
- Wolfcamp B & C
Midland Wolfcamp B Oil Prediction Maps

Normalized 6-month Cum Oil
(Oil bbls/MM lbs proppant)

6-month Cum Oil Prediction
(normalizing for all Engineering)

6-month Cum Oil Prediction
(with well depletion estimates)
Multi-layer Wolfcamp Production Prediction Model

Transparency view of 4-layer Wolfcamp B oil production prediction model (left)

Horizontal wellbores landing above the Wolfcamp B structural surface, colored by oil production prediction model (right)
Multi-layer Wolfcamp Production Prediction Model

Wolfcamp A oil production prediction model updated for well production (left)

Wolfcamp B oil production prediction model updated for well production (right)
Production Prediction Model Quality

- Total wells in prediction model
- Wells predicted from previous year’s model
- Average prediction error for future wells
- Average correlation of predictions for included wells
- Average correlation of predictions for future wells
Results and Conclusions

- Model-driven analytics identify optimal Midland Basin oil production sweetspot characteristics:
  - Wolfcamp B & C at 6000 foot subsea depths (~9500 TVD)
  - Low initial gas cut, relative to oil and gas BOE, of 20%
  - Low initial water cut, relative to oil, gas and water BOE, of 20%
  - Gamma-ray lithologies of ~75 API

- Contrary to previous published studies, focusing on the importance of high-energy fracs, we find that frac intensity, and other engineering parameters, need to be tuned to rock and fluid properties of targeted reservoirs.
  - Simply drilled horizontal wellbore paths of ~3 miles, that are parent wells >750’ from other wells
  - Modern slickwater fracs (water (gal) ~ proppant mass (lb)), with 1500 lb/ft proppant intensity

- 2D sweetspot grids and 3D sweetspot volumes, updated for dynamic well spacing production, highlight remaining well targets in the Midland Basin Wolfcamp reservoirs – to support full-field development
References


• Scott Lapierre; *Bubble-Point-Death and the PXD Oil Mix Challenge: Part 2*; (https://www.linkedin.com/pulse/bubble-point-death-pxd-oil-mix-challenge-part-2-scott-lapierre); October 16, 2017


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