Optimizing Engineering for Permian Geology/Fluid Using Model-Based Analytics*

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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.

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

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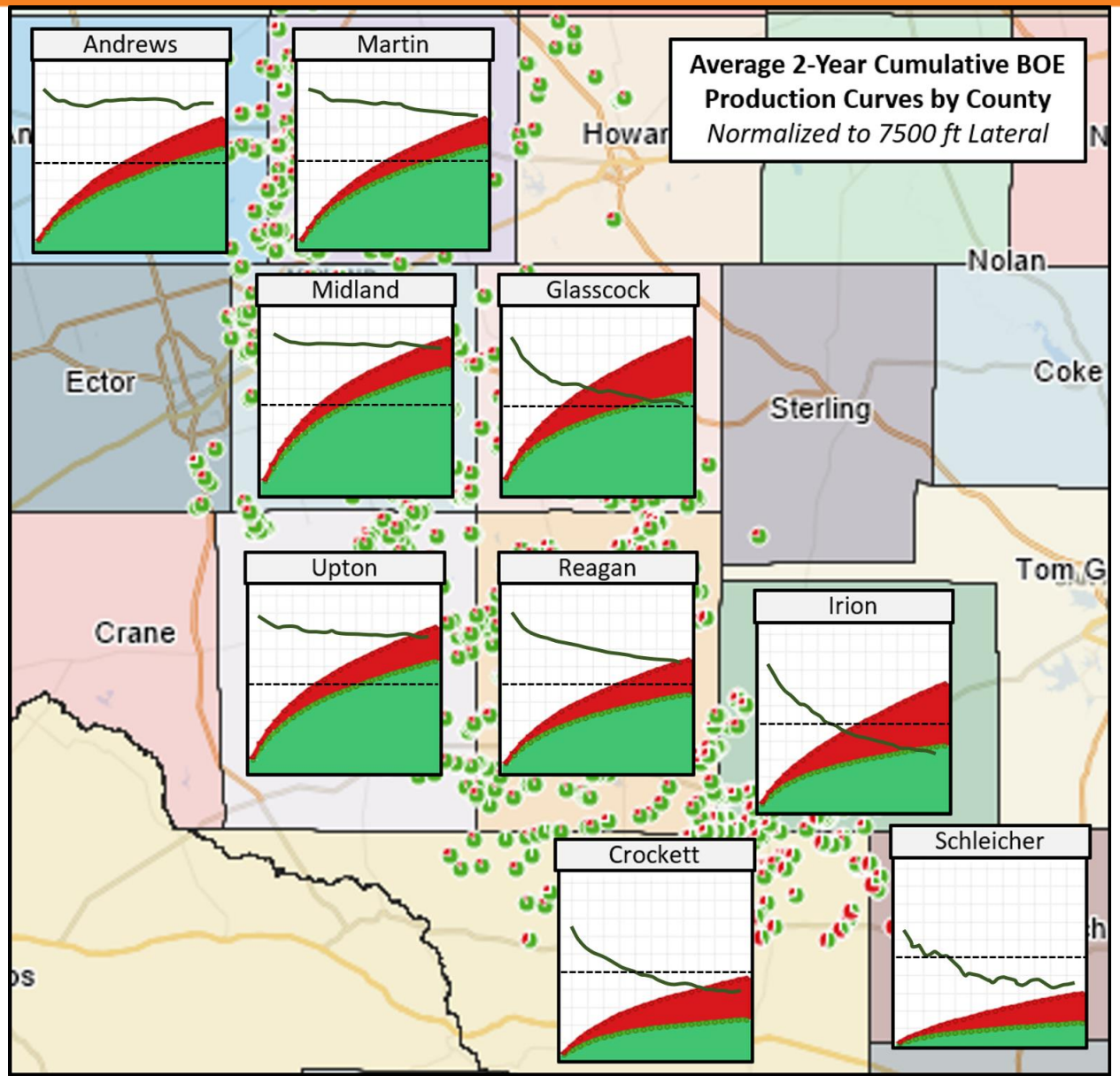
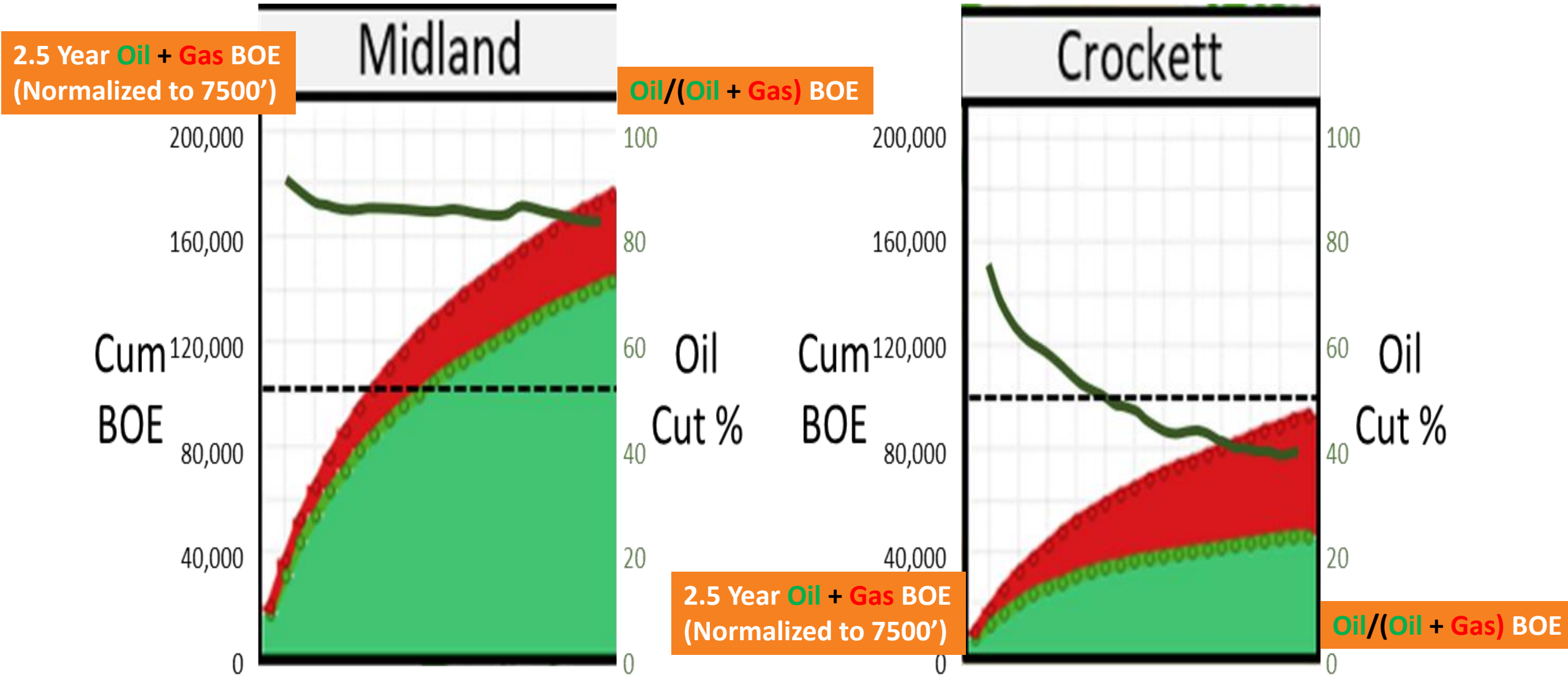
Optimizing Engineering for Permian Geology/Fluid Using Model-Based Analytics

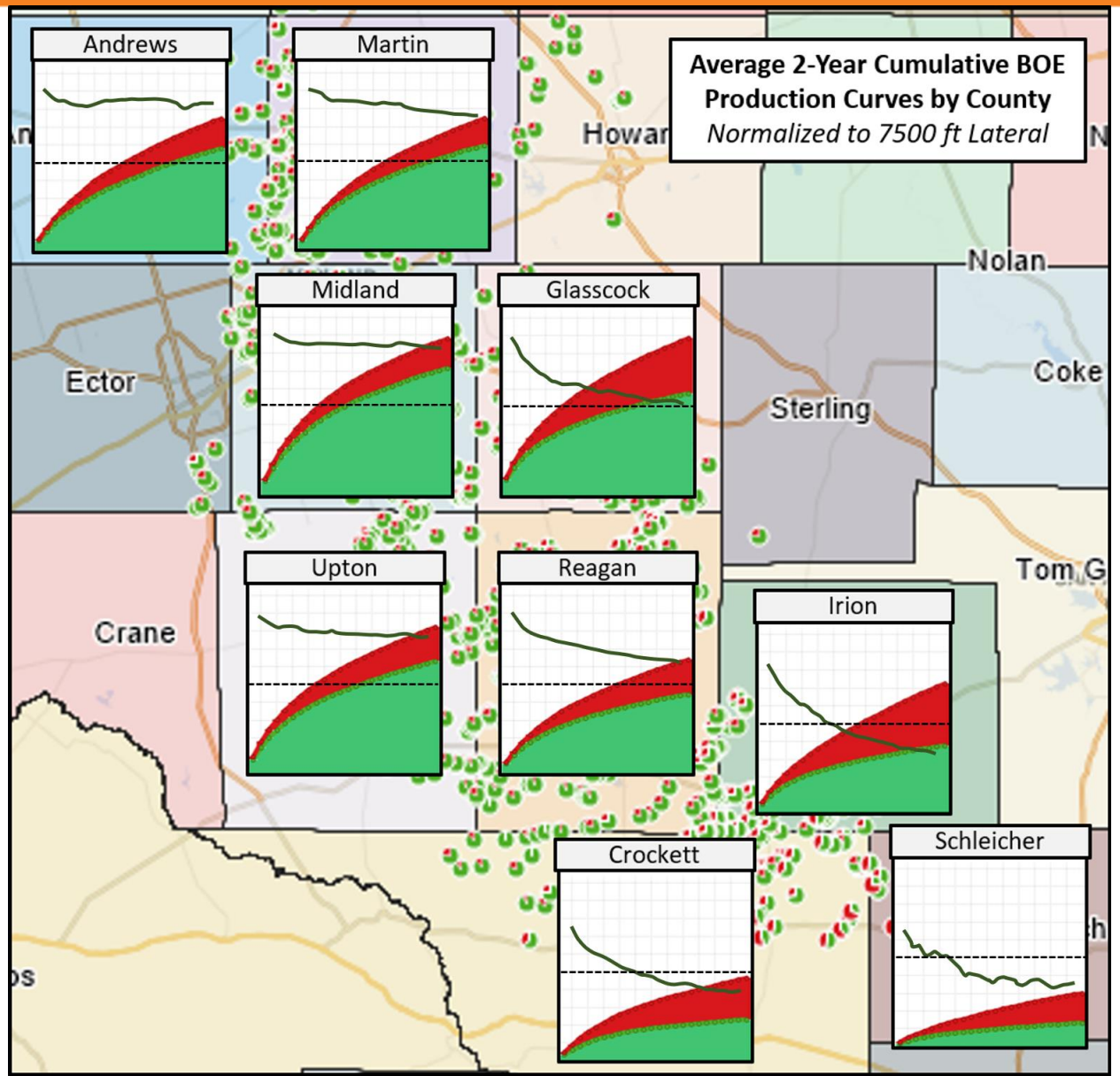


- Permian Basin unconventional **oil prospectivity** is primarily driven by **oil/gas/water mix and reservoir pressure.**
- **Poor well performance**, often in the form of early **gas bubble-point effects**, can occur in **certain areas or result from over-engineering geologic sweetspots**.
- Using measured 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**

Stacked Cum Oil/Gas and Oil Cut Trends



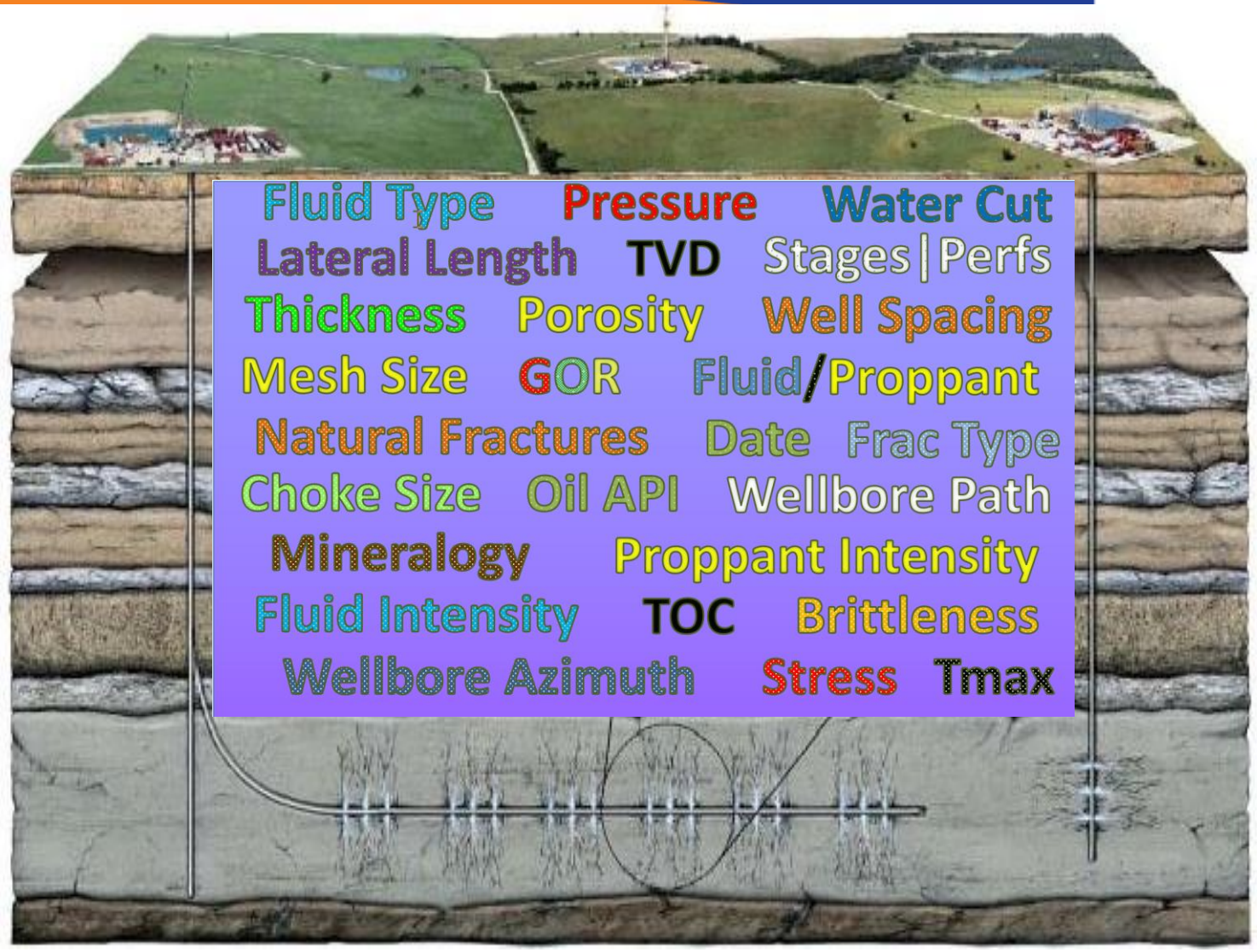
Good wells going bad across the Permian



- 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**

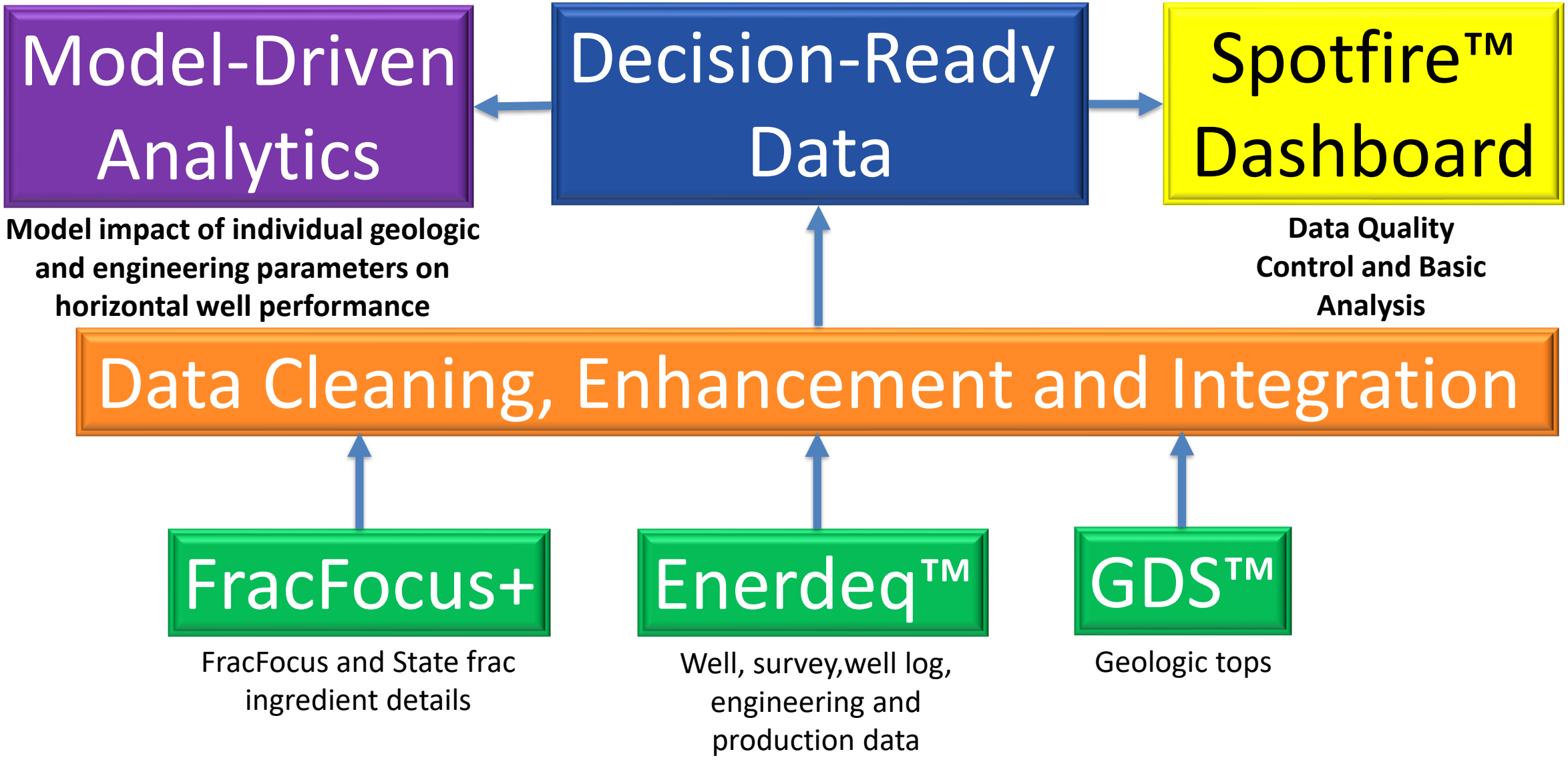
What is causing good wells to go bad across the Permian?

How much Geology?



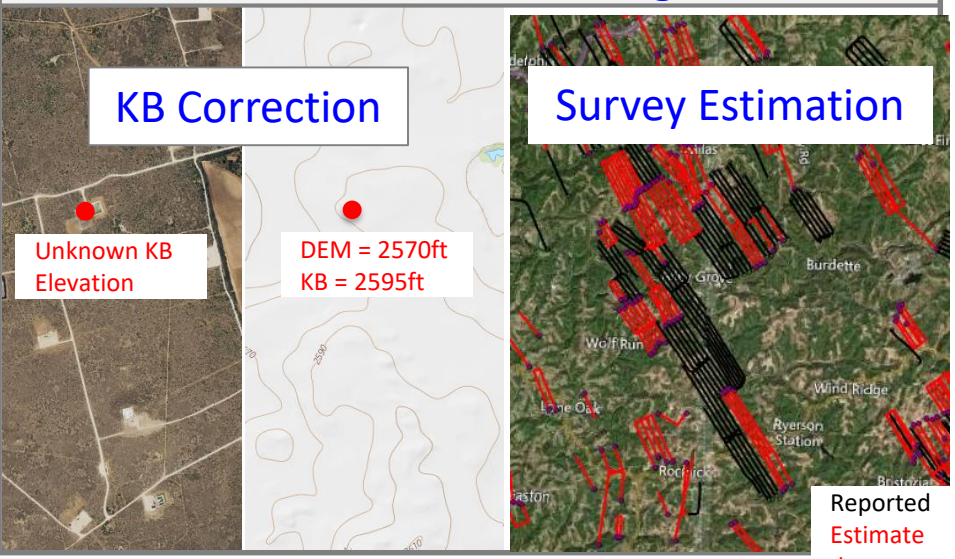
How much Engineering?

Project Data and Work Flow

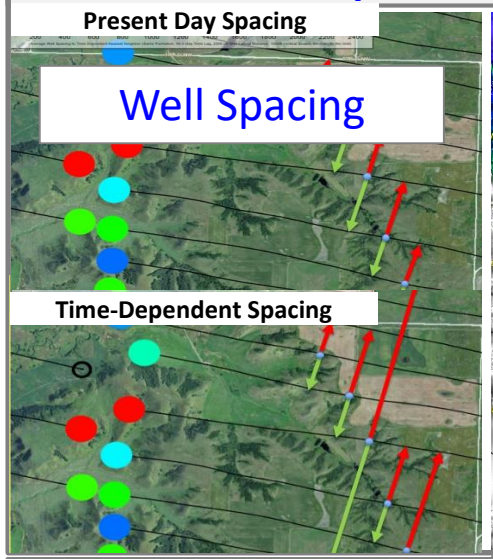


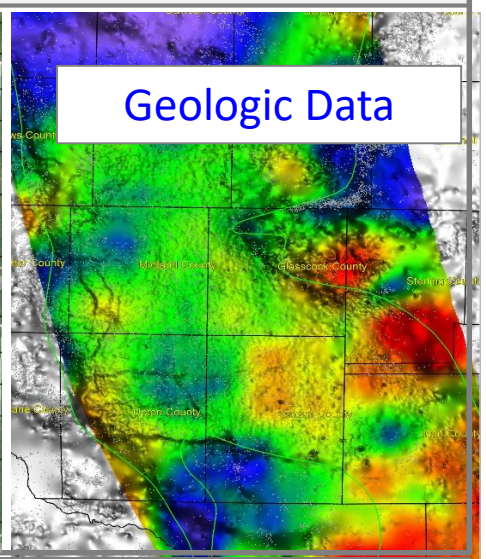
Data Cleaning, Enhancement and Integration

Correct/Infill Bad/Missing Data

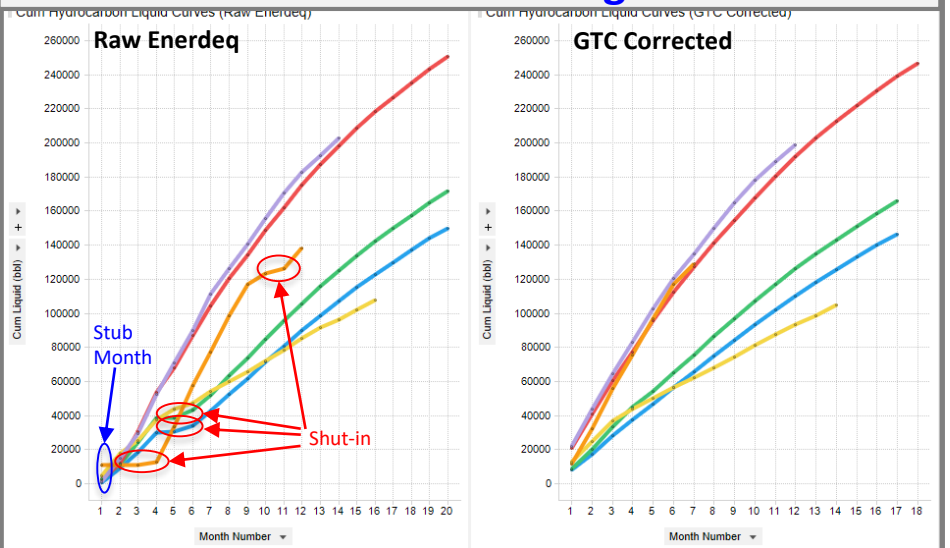


Complete the Dataset

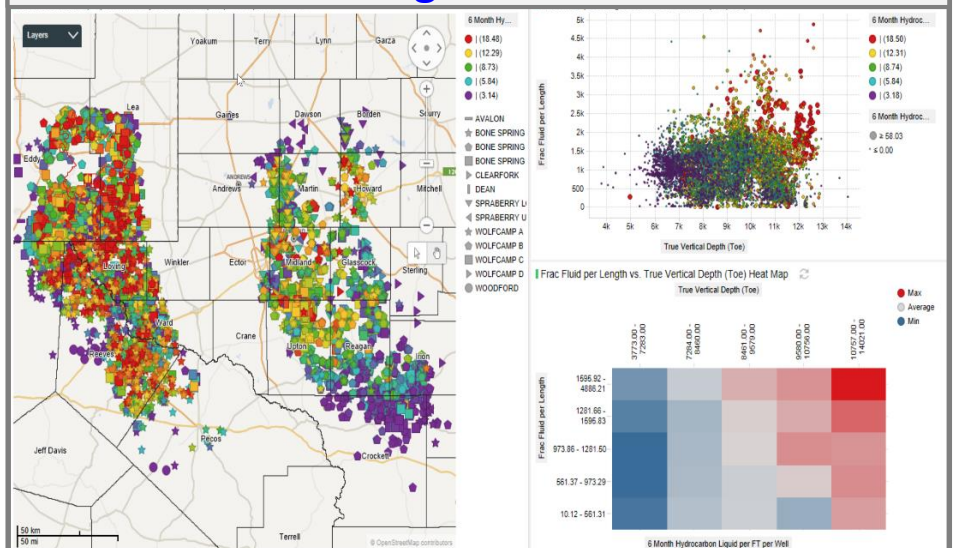




Reconcile Misleading Data



Integrate Data



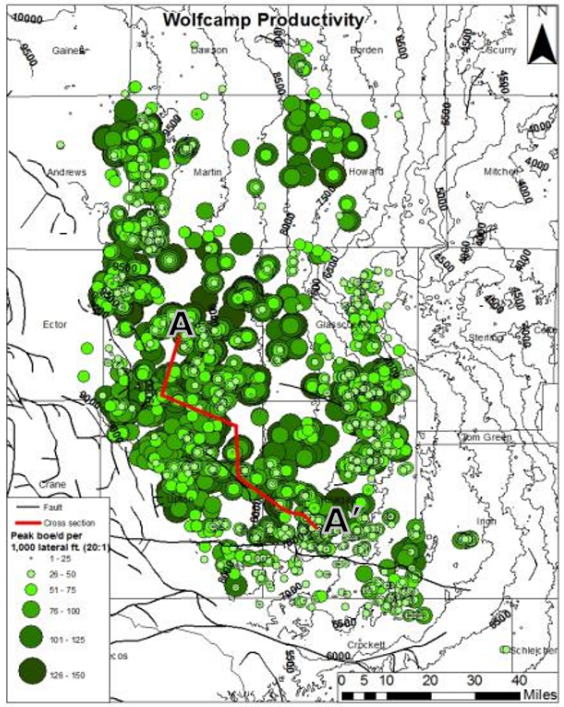
Correct/Infill data
- KB errors (DEM)
- Missing surveys
- Remove data outliers

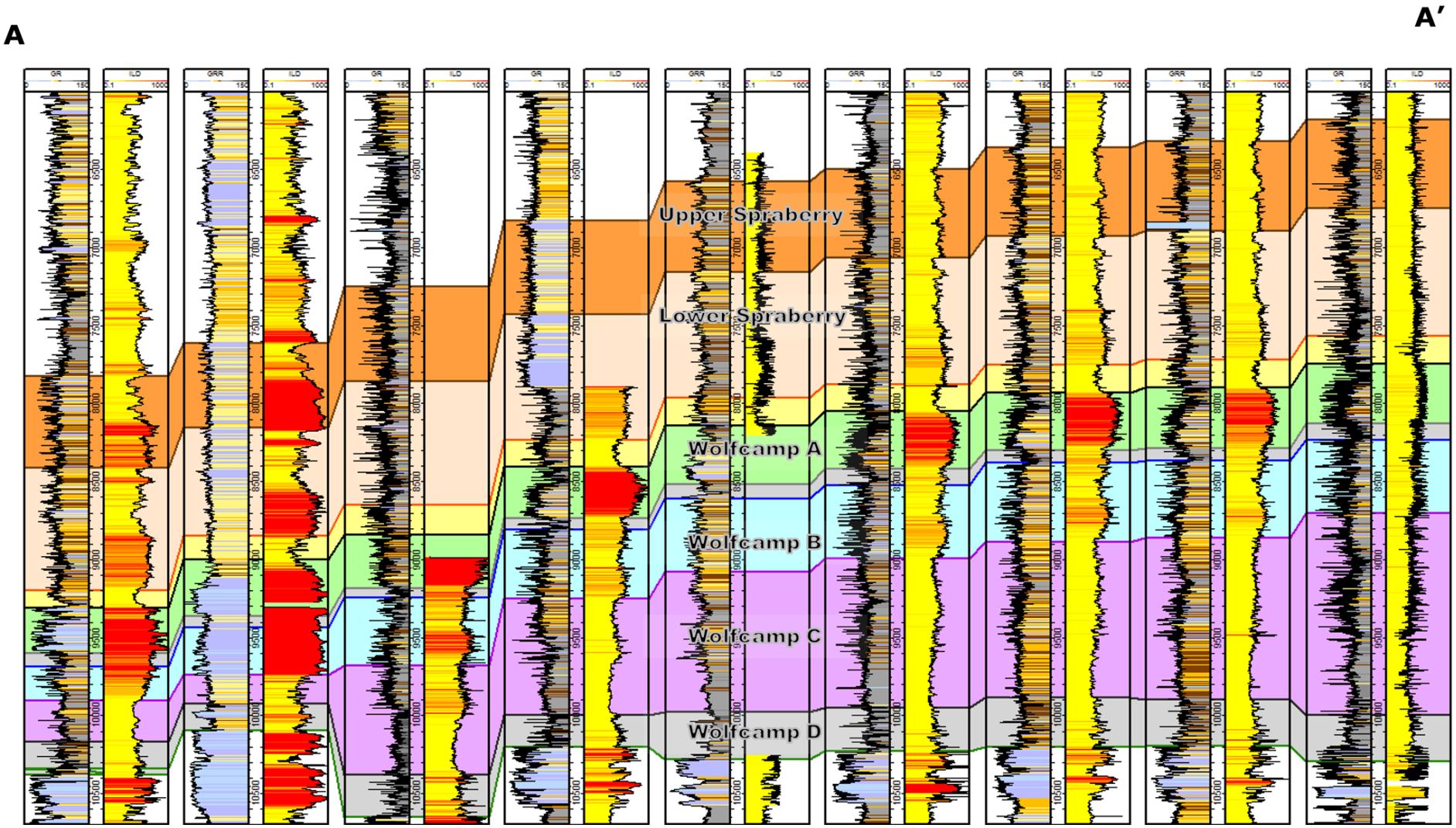
Complete the datasets
- Grid structural surfaces
- Grid oil/gas/water cuts
- Grid gamma-ray data
- Calculate isochore grids
- Landing zones/%
- Time-based vertical and lateral well spacing

Reconcile misleading data
- Production stub months,
- Normalize production

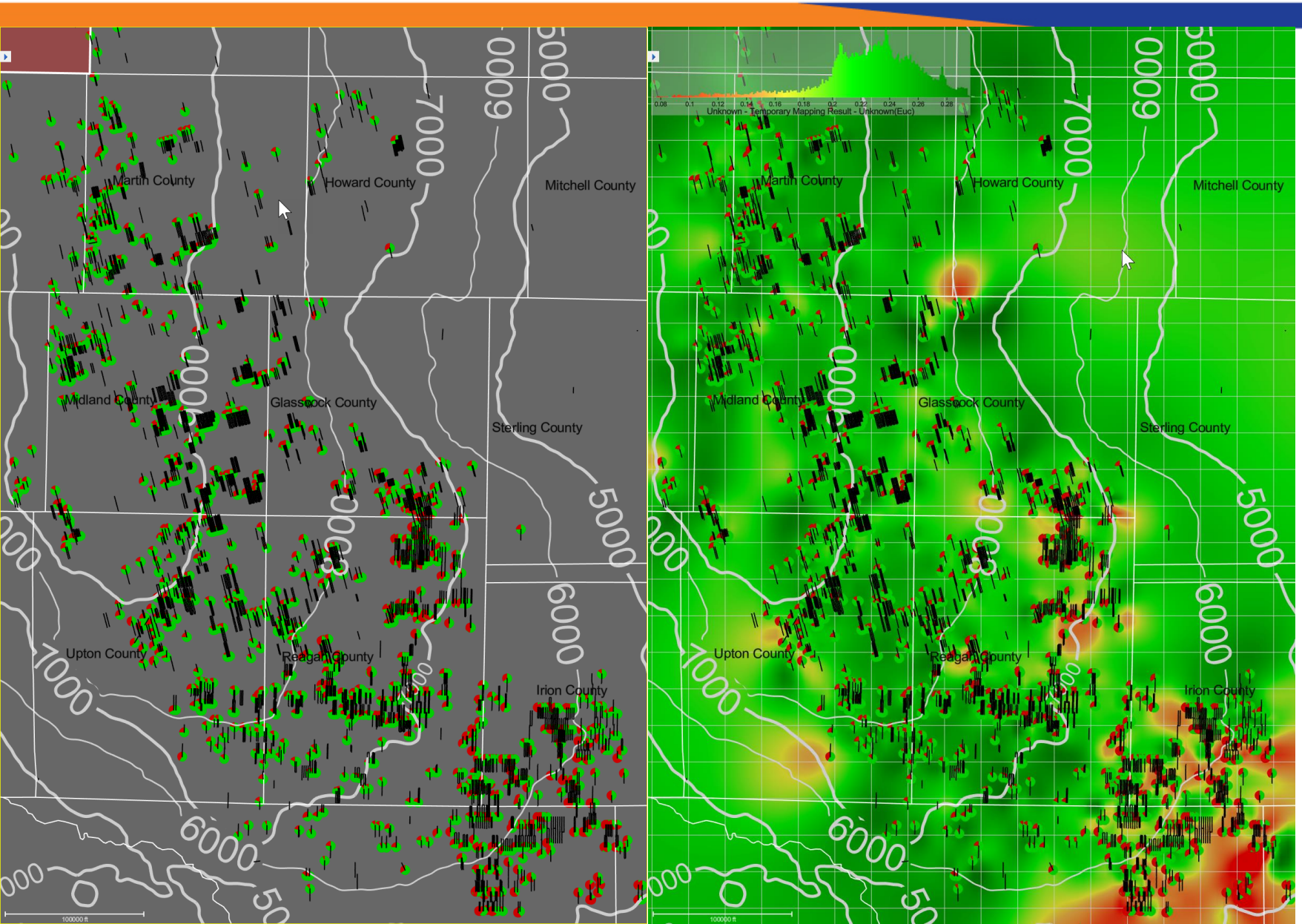
Integrate data
- Extract geology/fluid grid data along wellbores

Gridding Geologic Tops across the Midland Basin





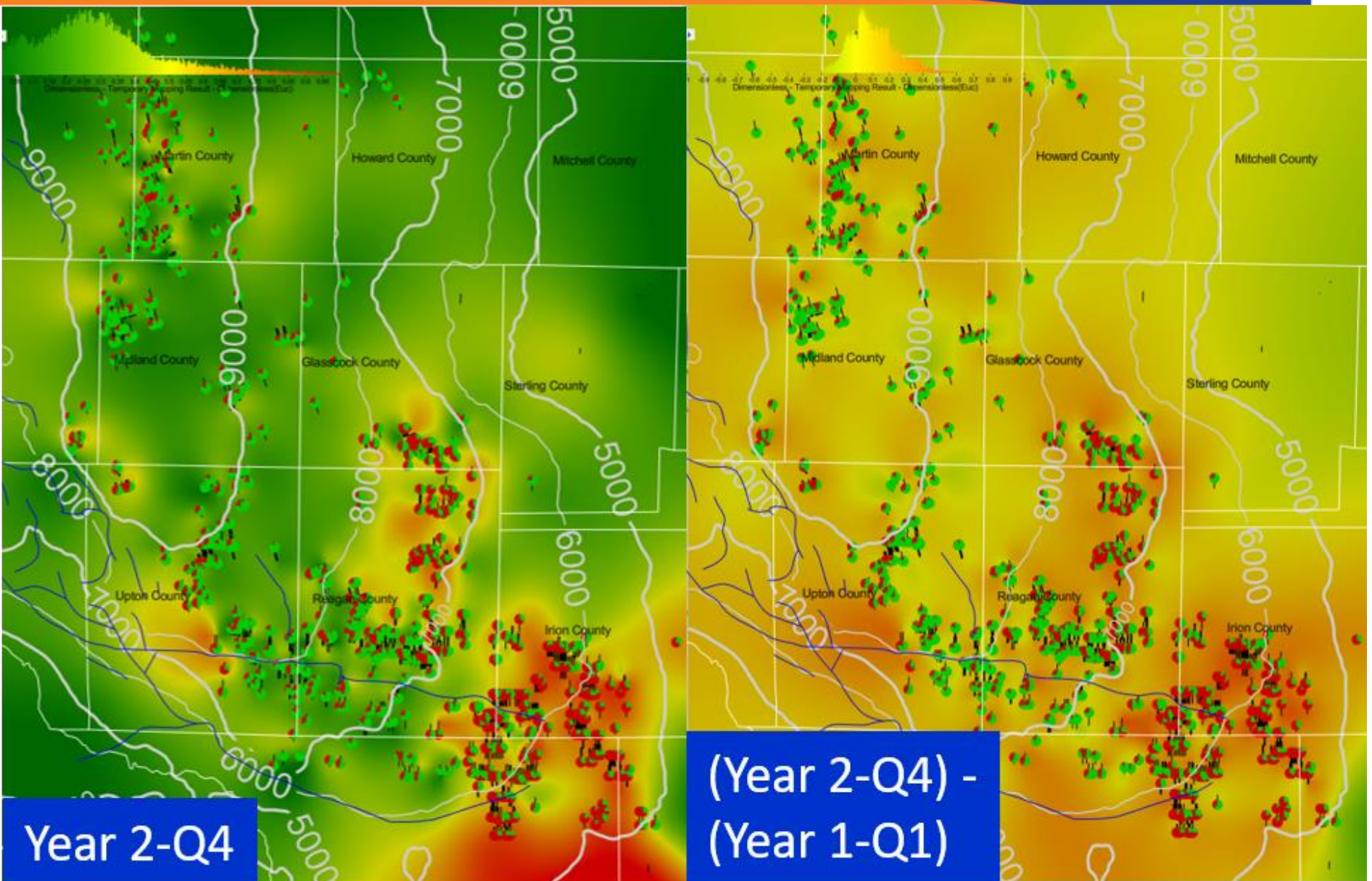
Gridding Midland Basin Oil, Gas and Water Cut



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



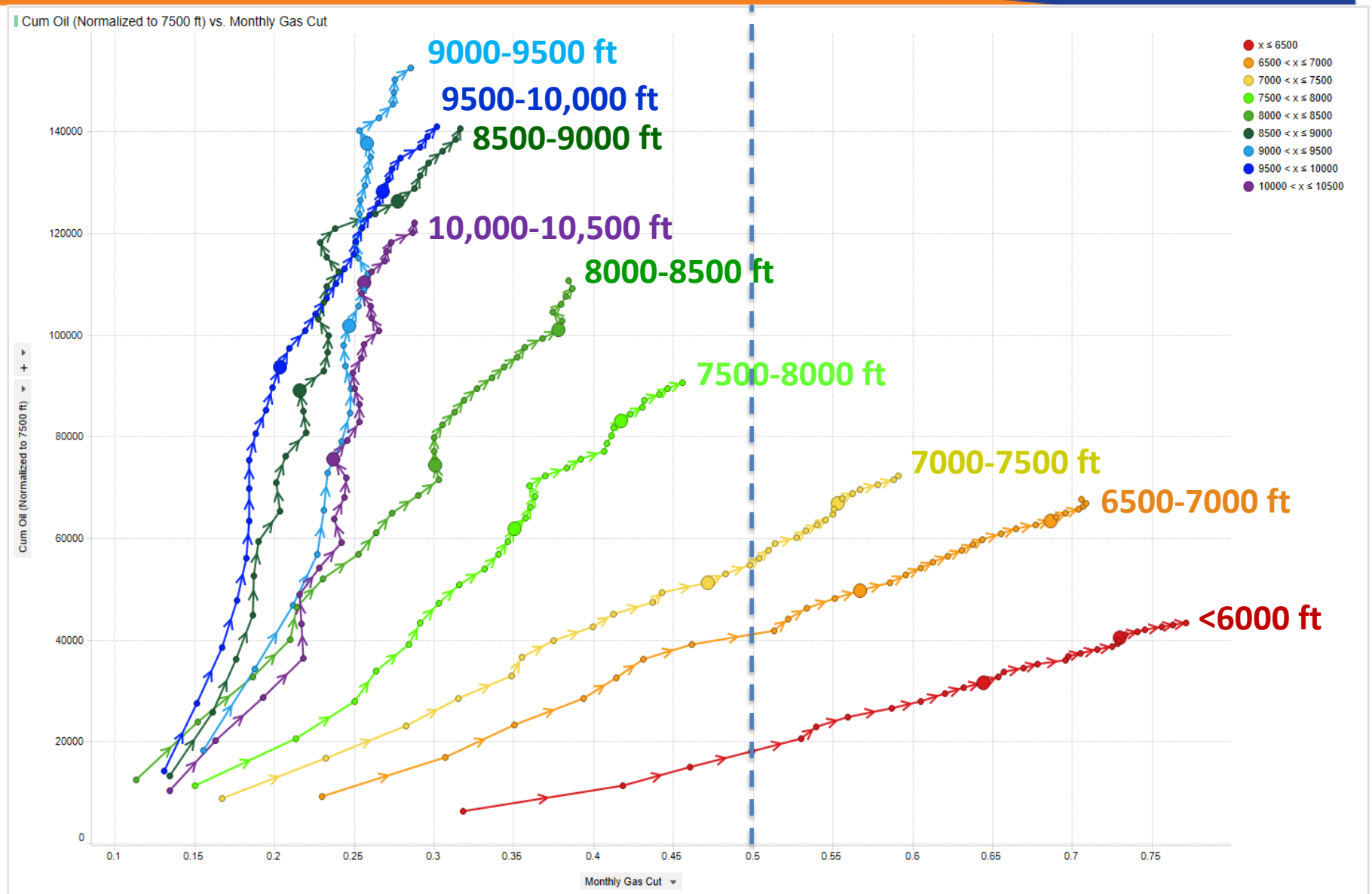
Year 2 Q4 averaged oil/gas cut (21-to-24 months) (left)

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

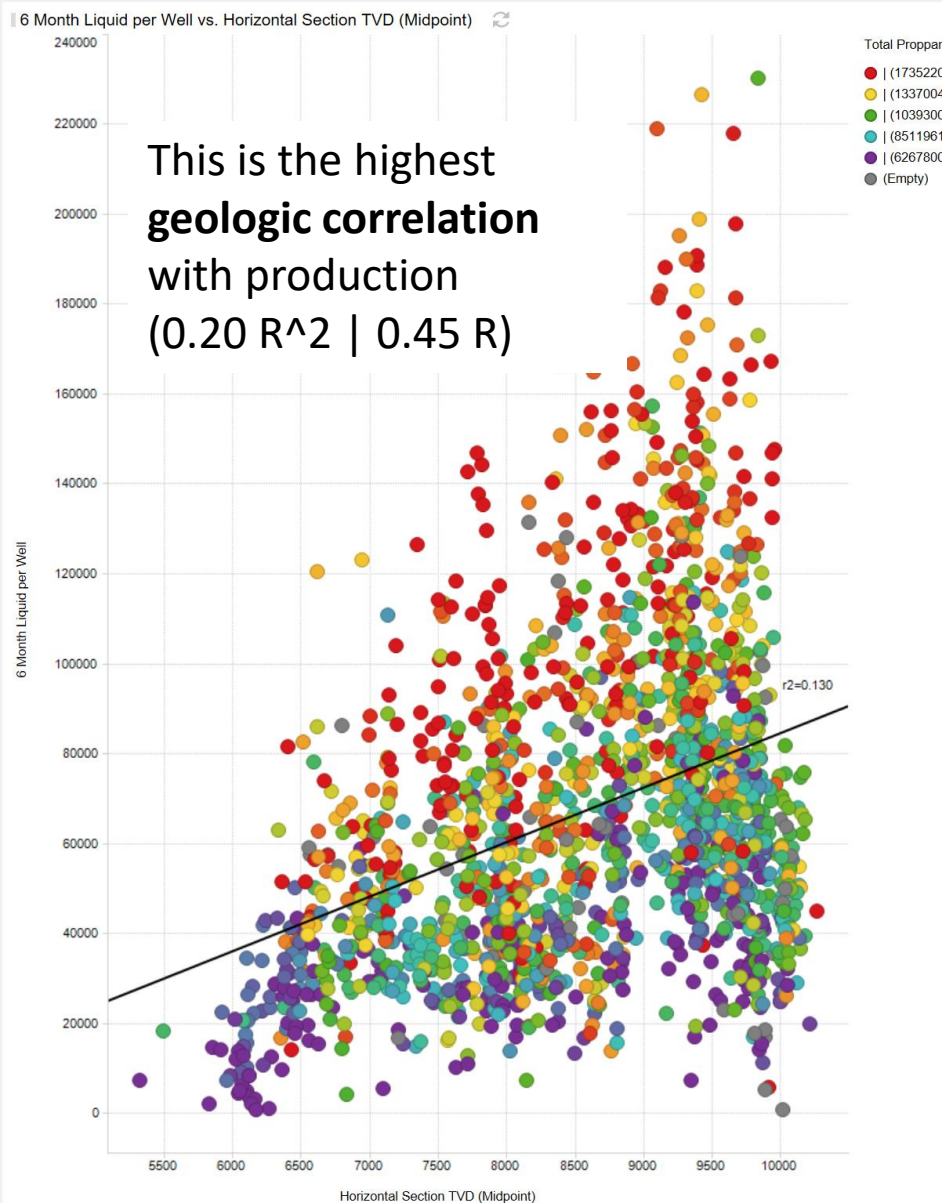


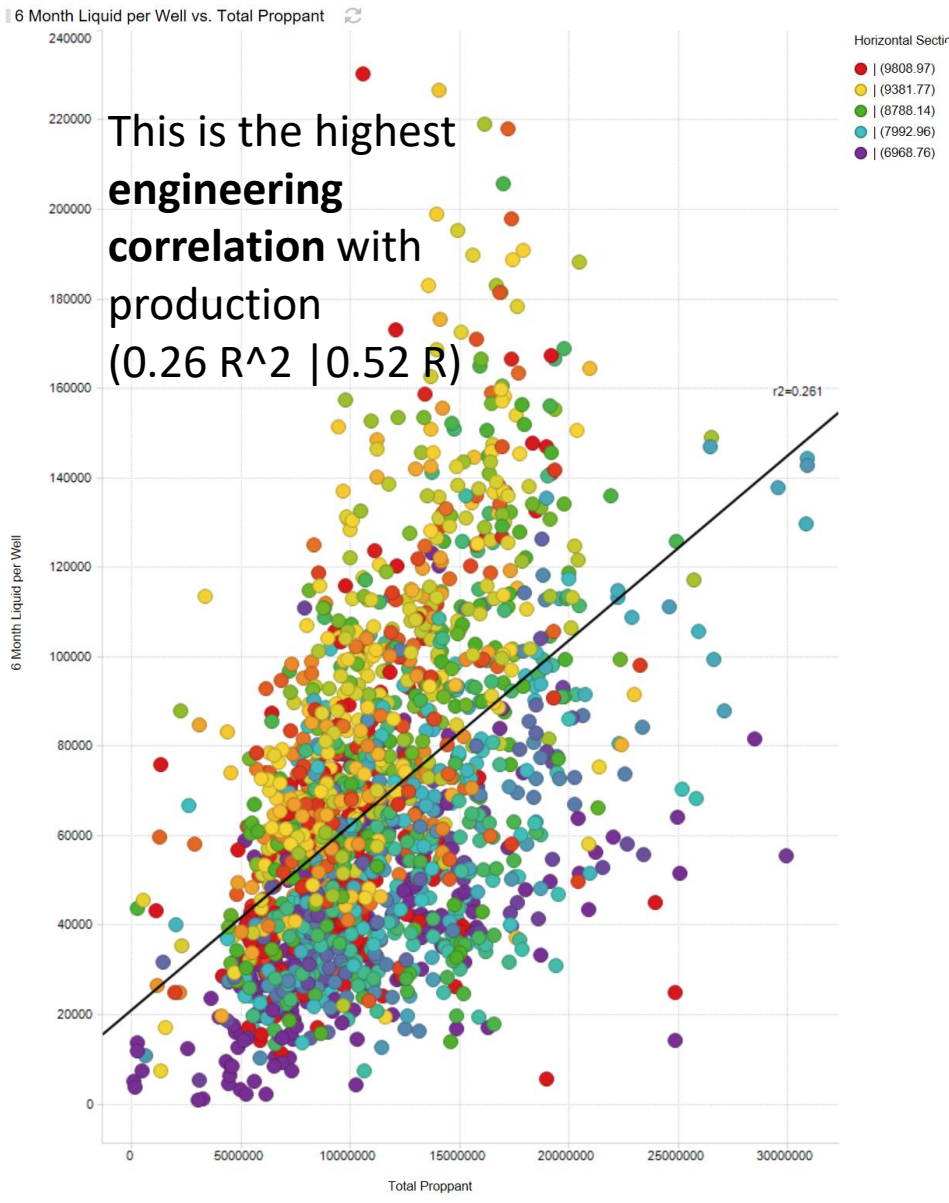
Two-and-a-half-year normalized cumulative oil (vertical axis) versus monthly gas-cut percentage (horizontal axis) – averaged for Midland Basin Wolfcamp B wells over depths

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

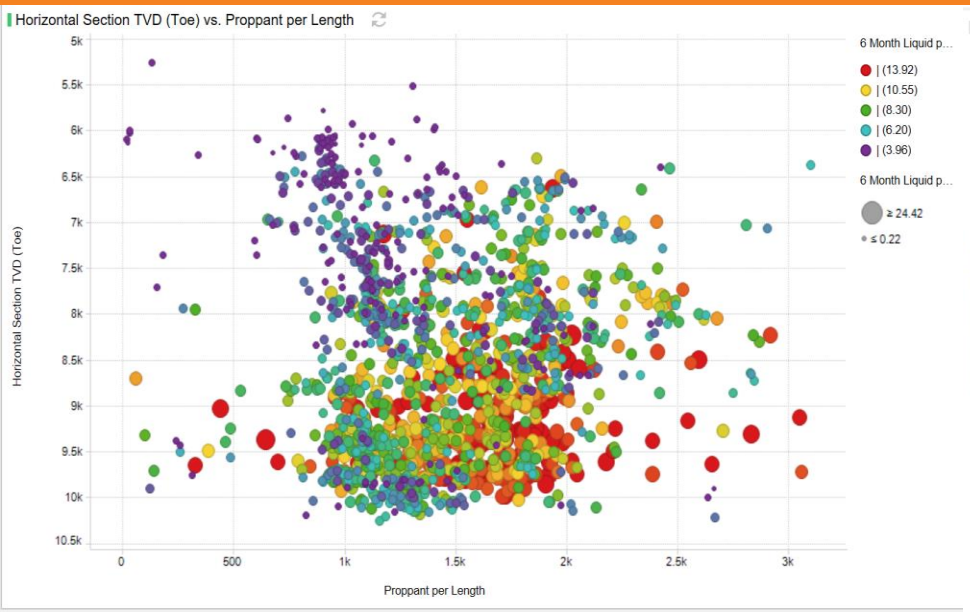


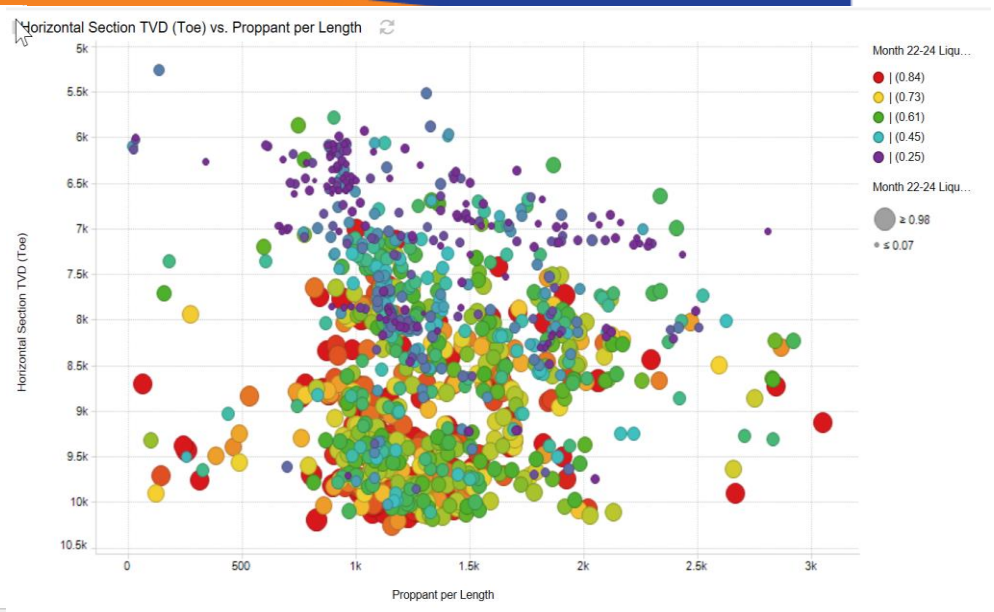


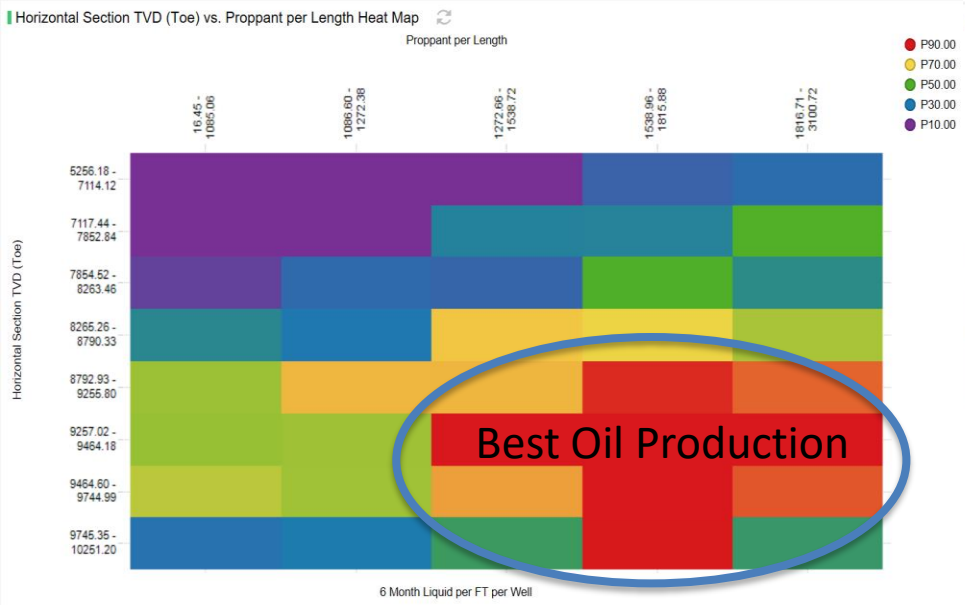
Six-month cumulative oil (vertical axis) versus true vertical depth (horizontal axis) colored by total proppant, left.

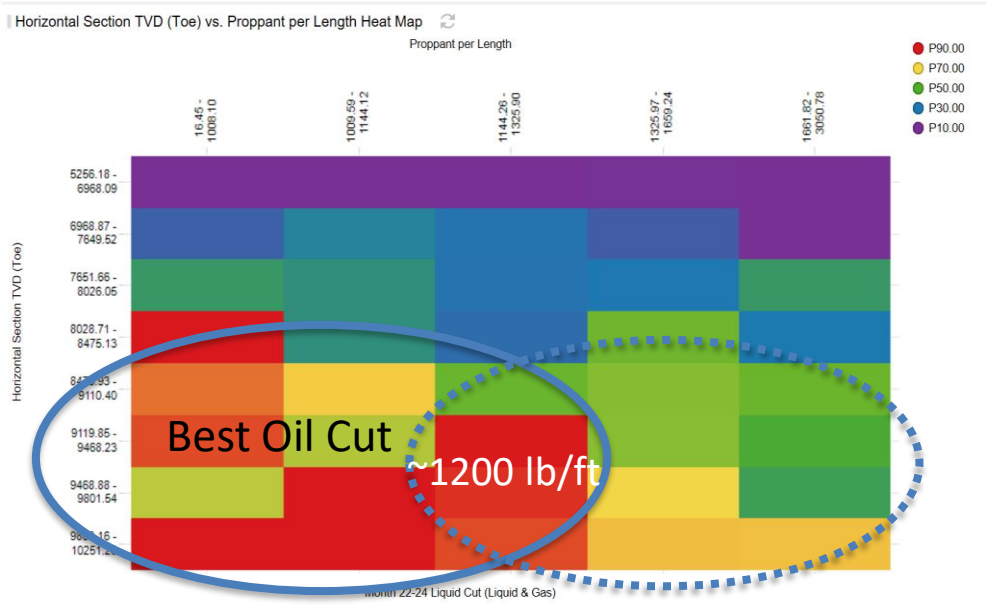
Six-month cumulative oil (vertical axis) versus total proppant (horizontal axis) colored by true vertical depth, right.

Cum Oil and Oil Cut - Depth versus Proppant Intensity









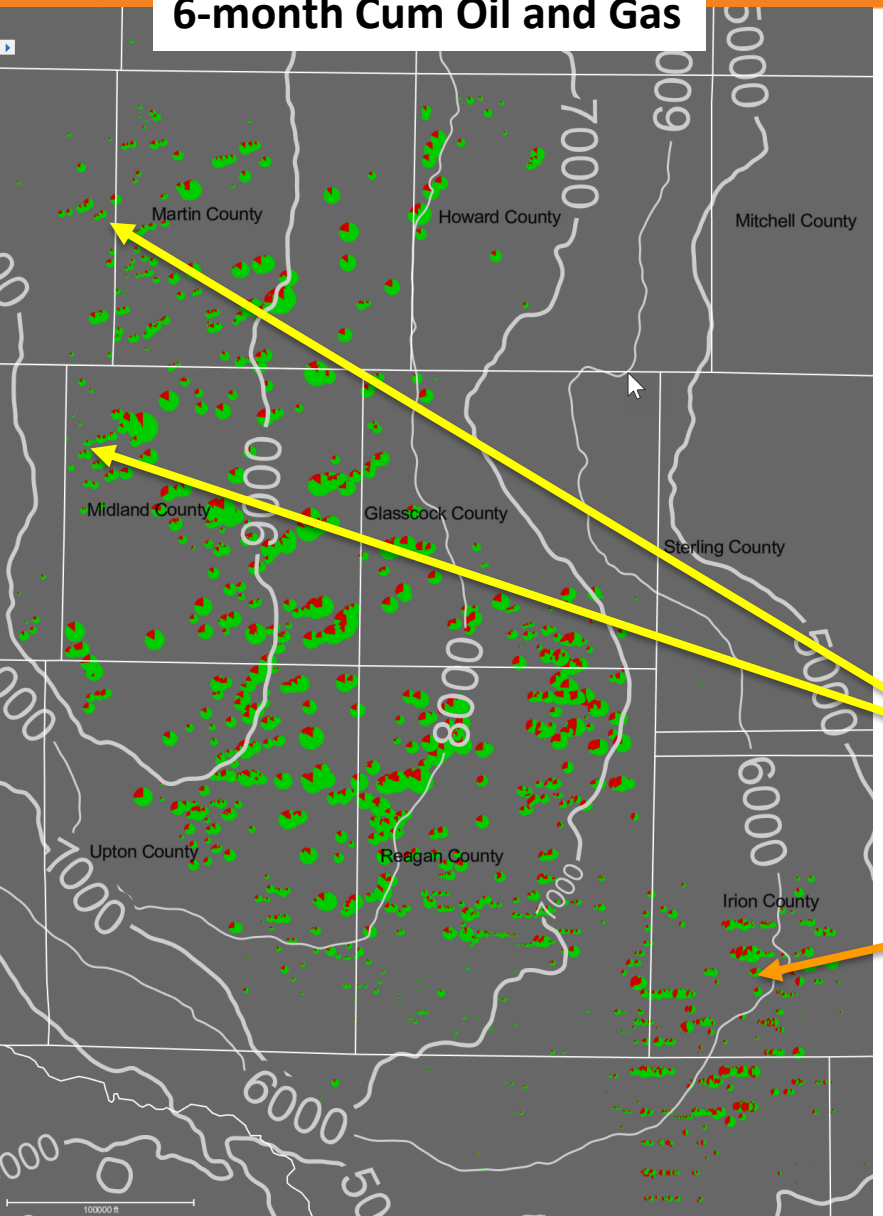
Depth (vertical axis) versus Proppant Intensity (horizontal axis) crossplots and heat maps.

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

22-24 month oil cut on right.

Create simple "Oil Prospectivity Sweet-spot Map"

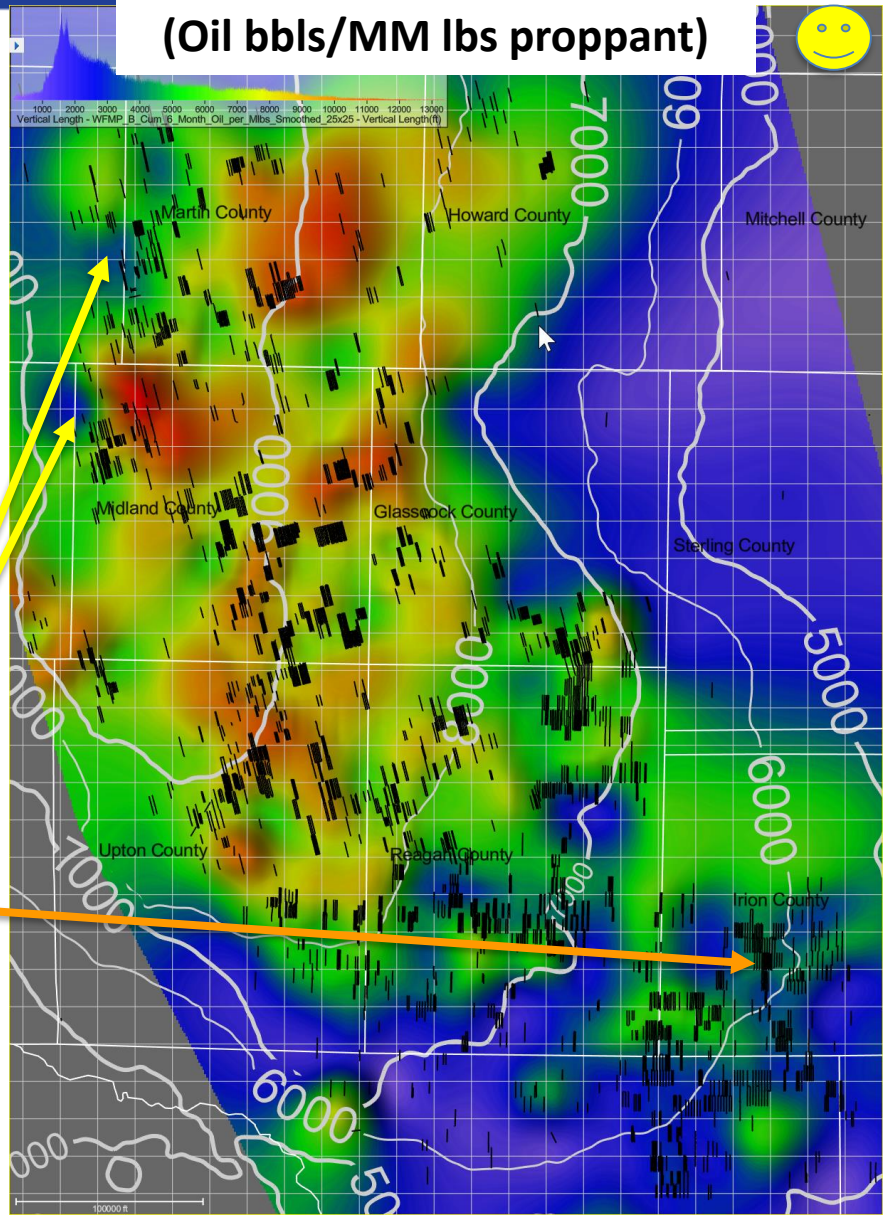
6-month Cum Oil and Gas



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)

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

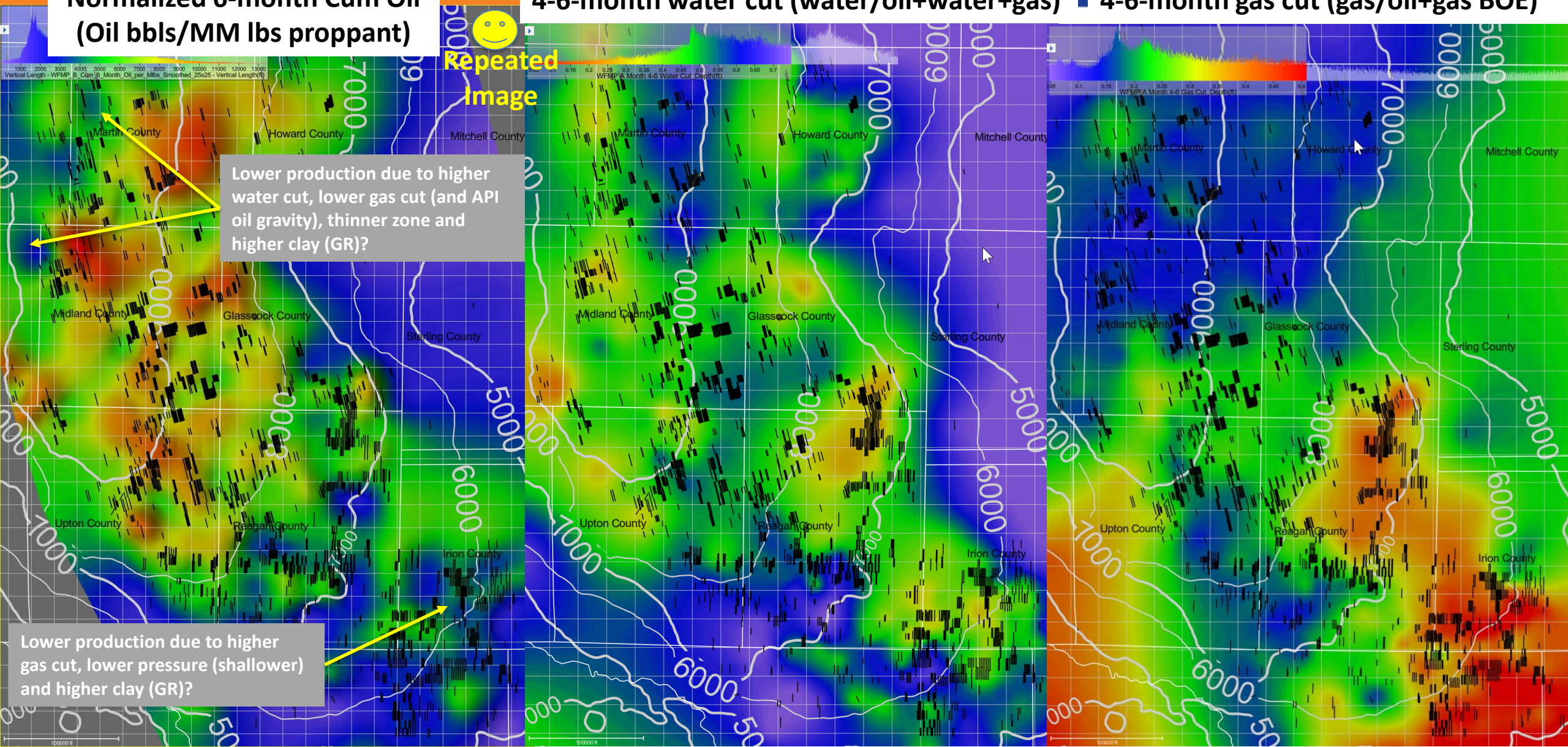


Midland Wolfcamp B - 4-6 month Water and Gas Cut

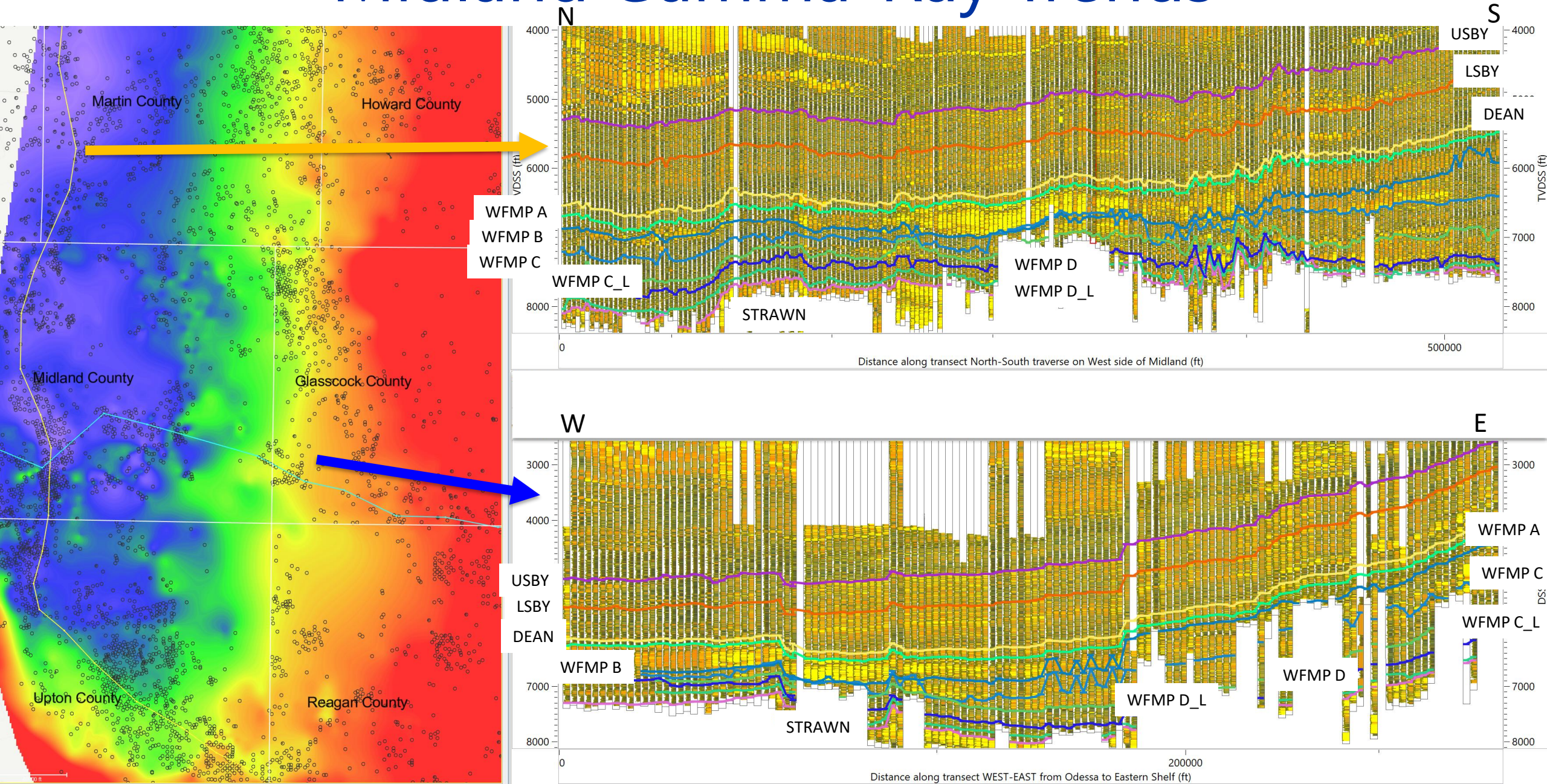
Normalized 6-month Cum Oil (Oil bbls/MM lbs proppant)

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

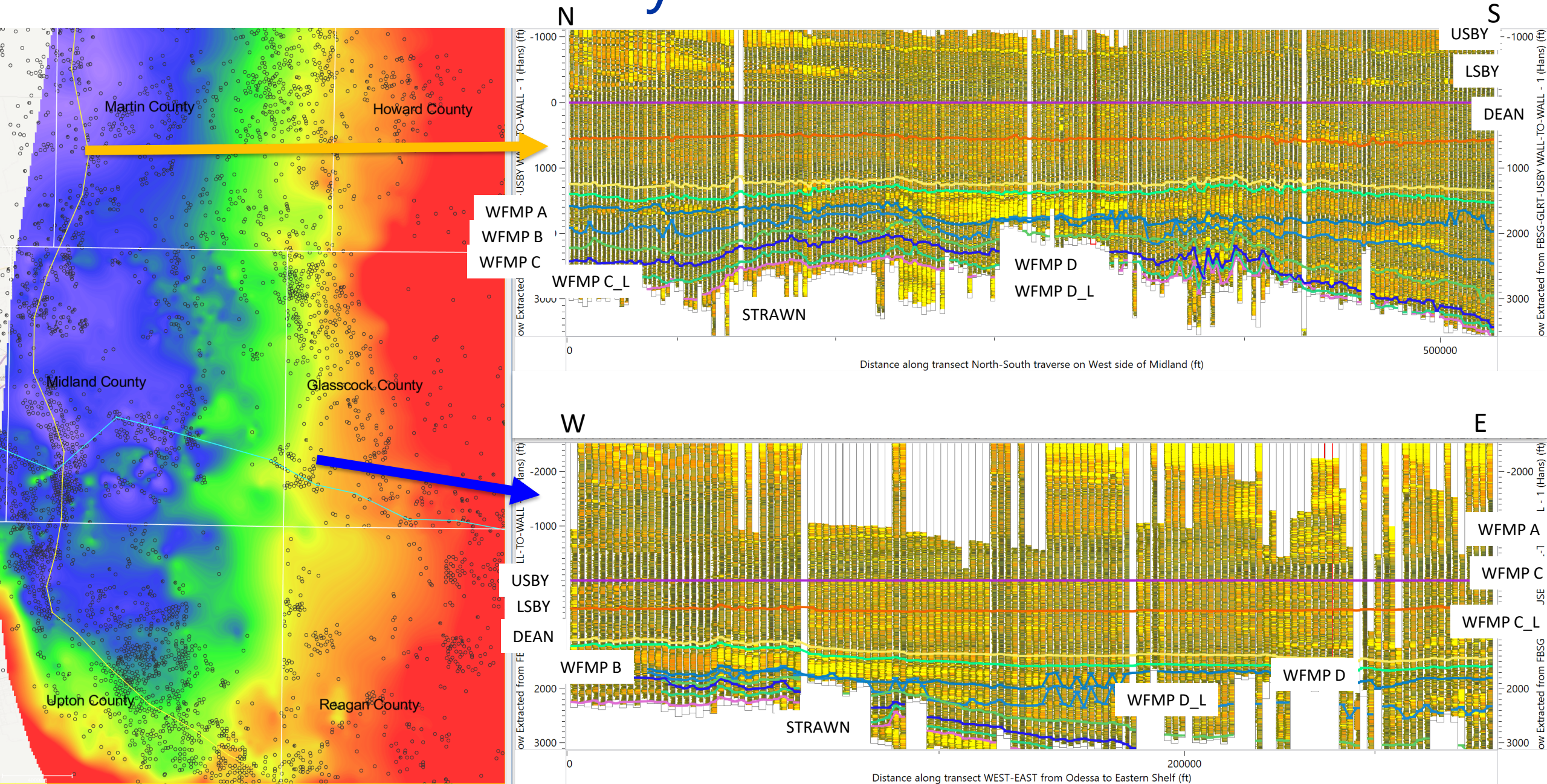
4-6-month gas cut (gas/oil+gas BOE)



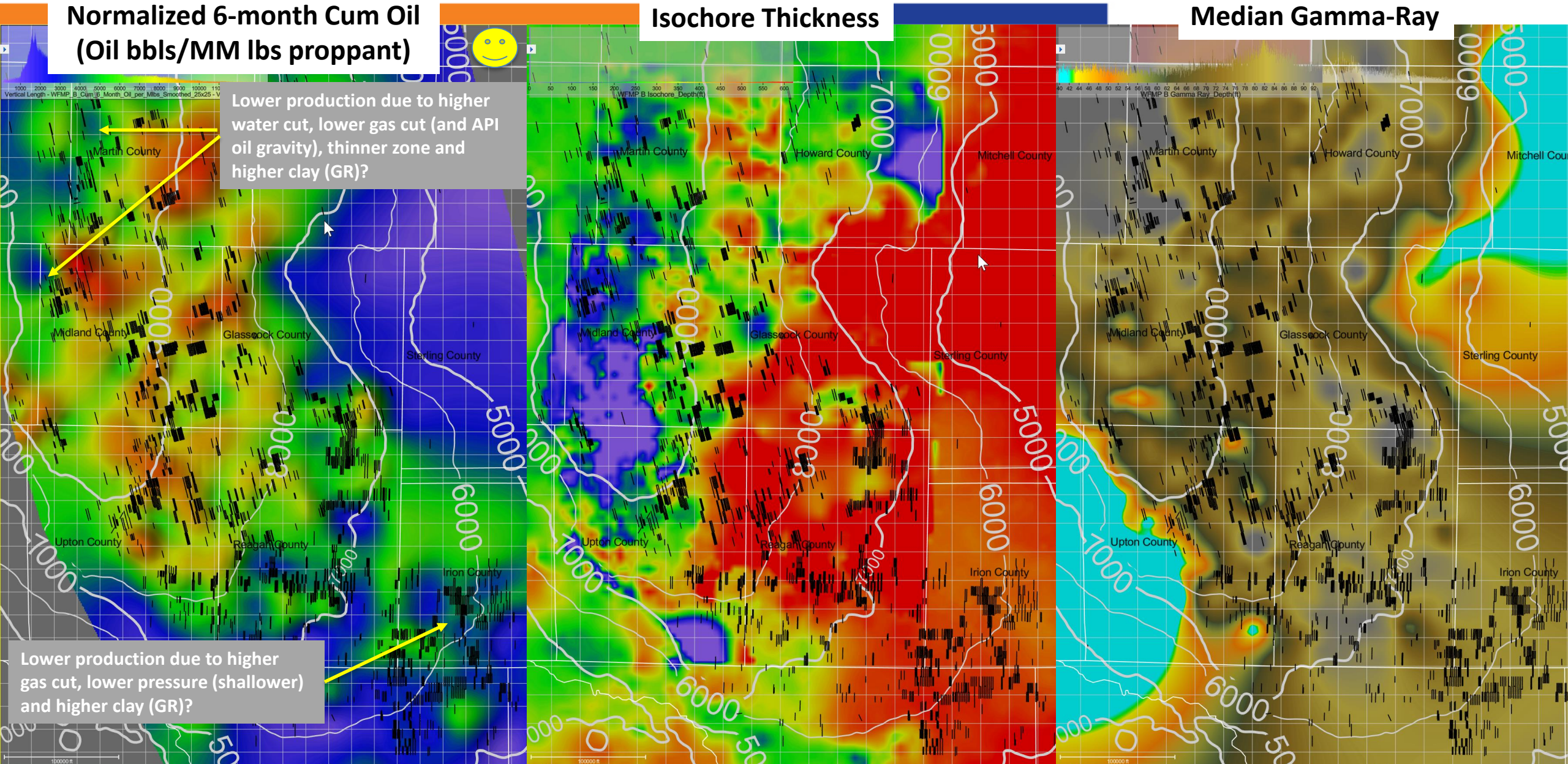
Midland Gamma-Ray Trends



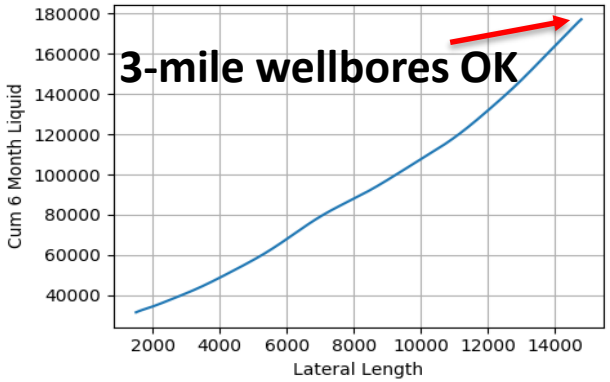
Midland Gamma-Ray Trends – Flattened on USBY

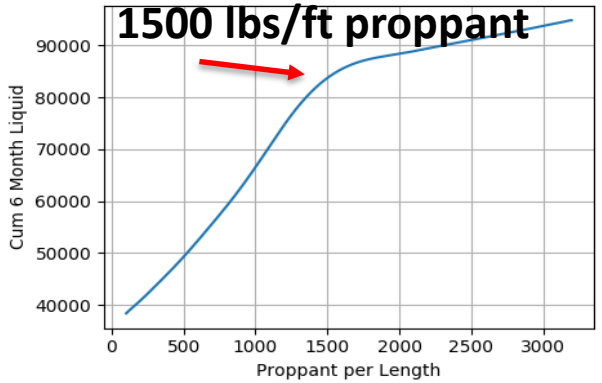


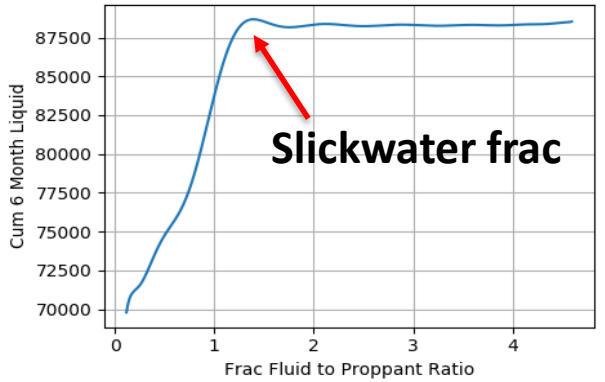
Midland Wolfcamp B – Isochore Thickness and Gamma Ray

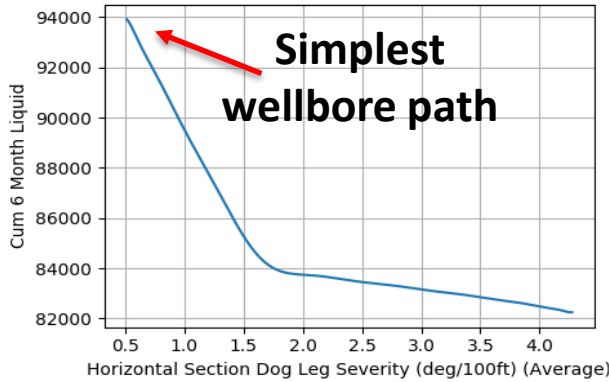


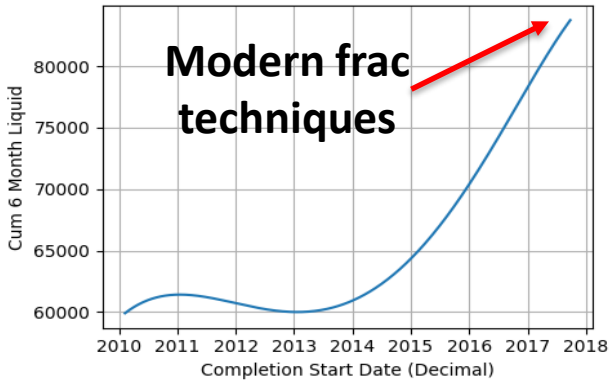
Model-Driven Analytics Optimization Plots

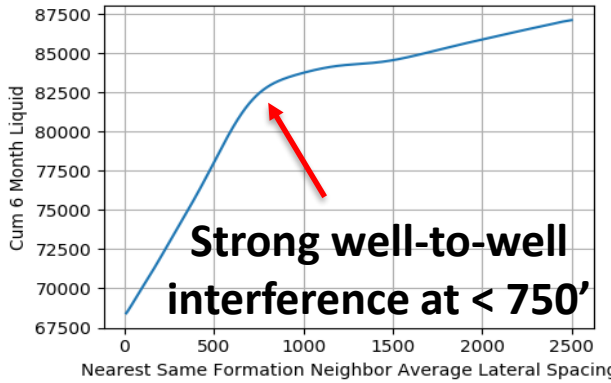


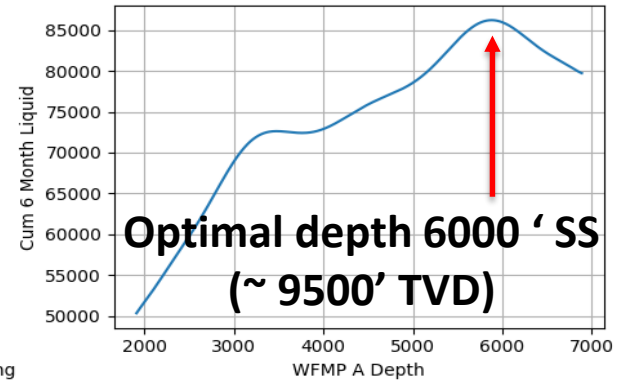


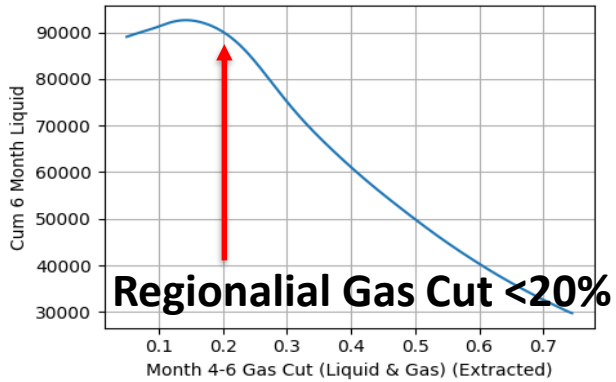


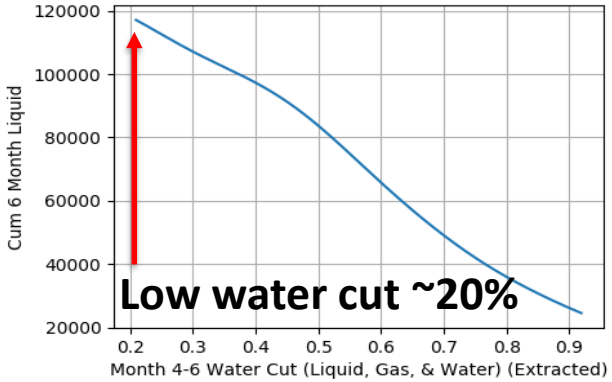


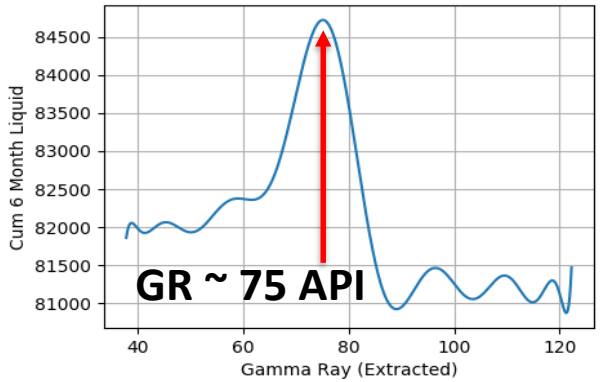


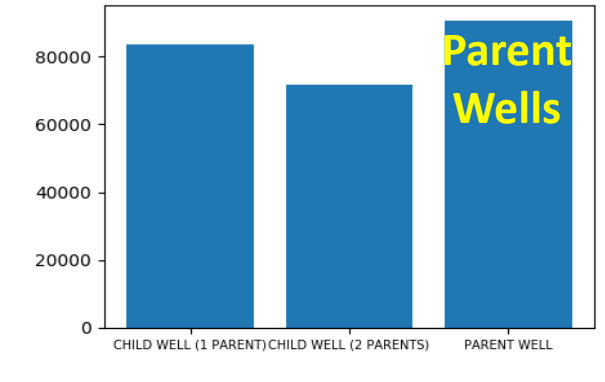


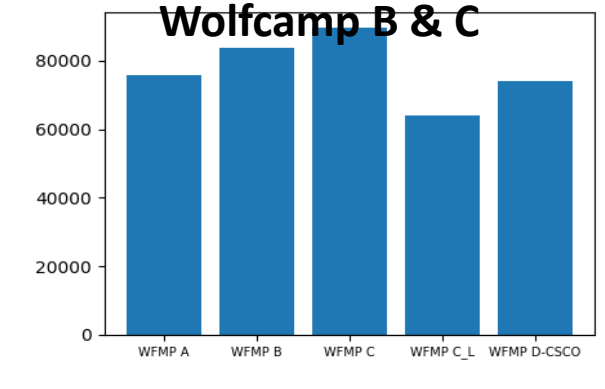










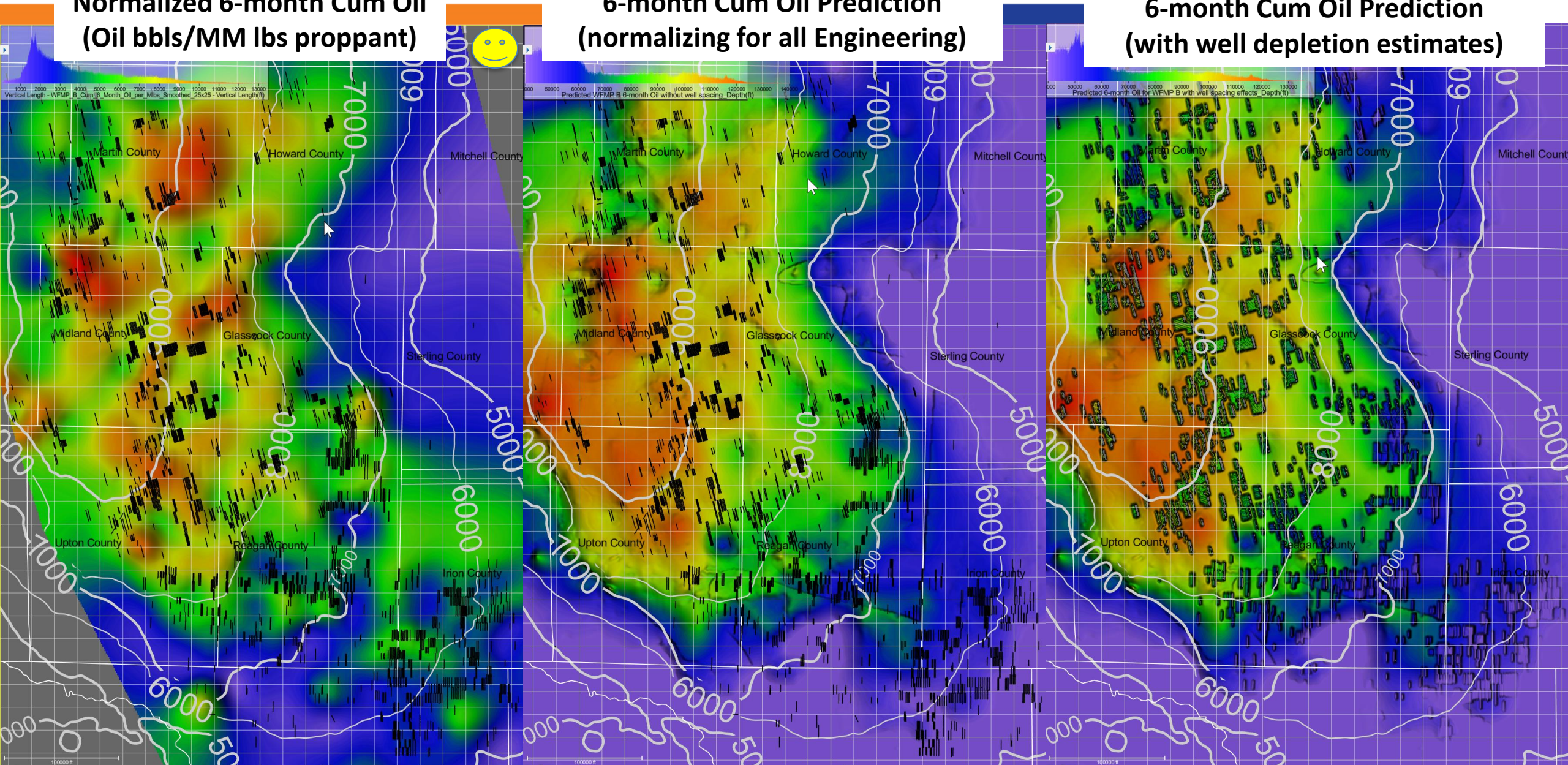


Midland Wolfcamp B Oil Prediction Maps

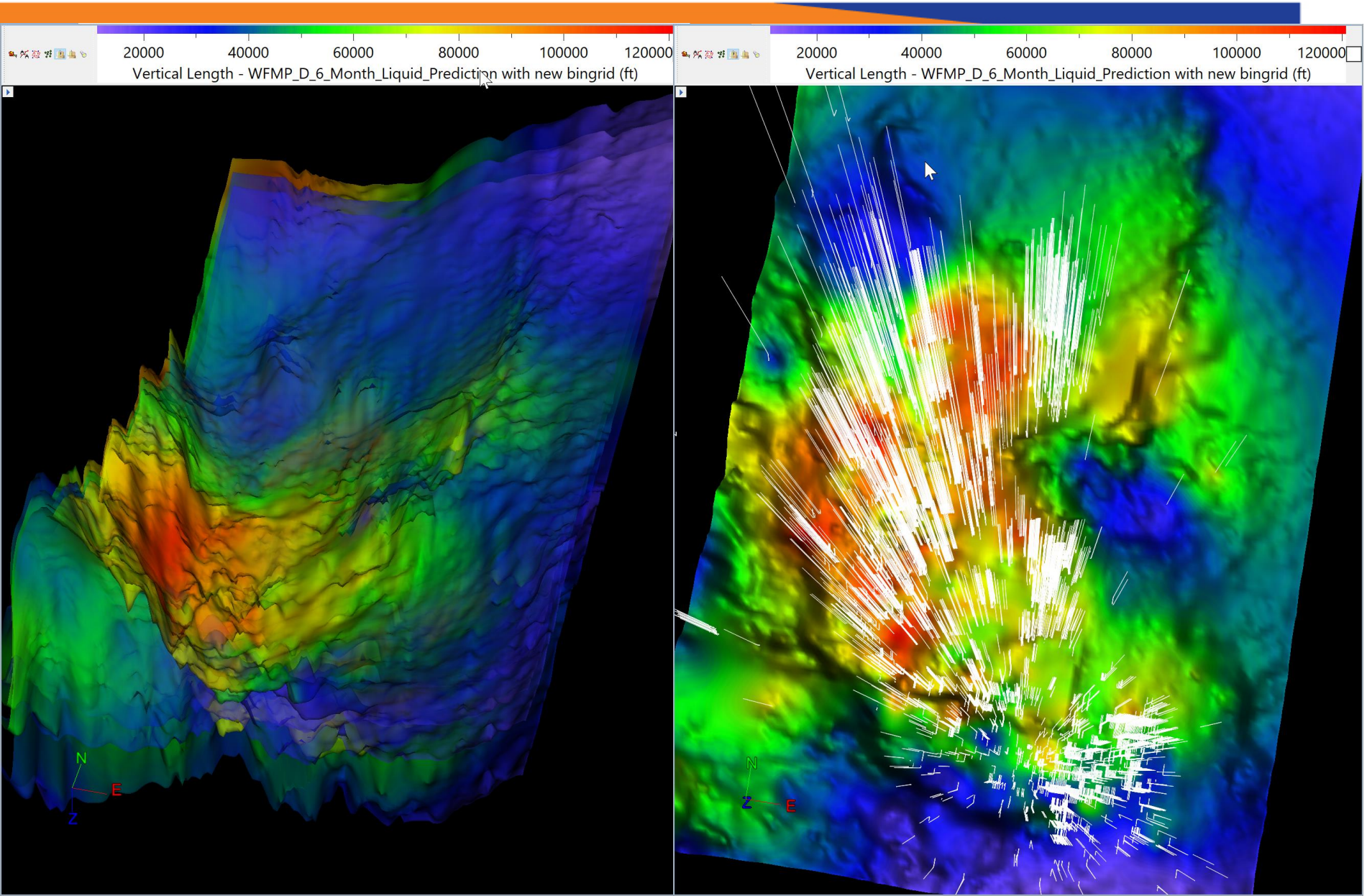
Normalized 6-month Cum Oil (Oil bbls/MM lbs proppant)

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

6-month Cum Oil Prediction (with well depletion estimates)



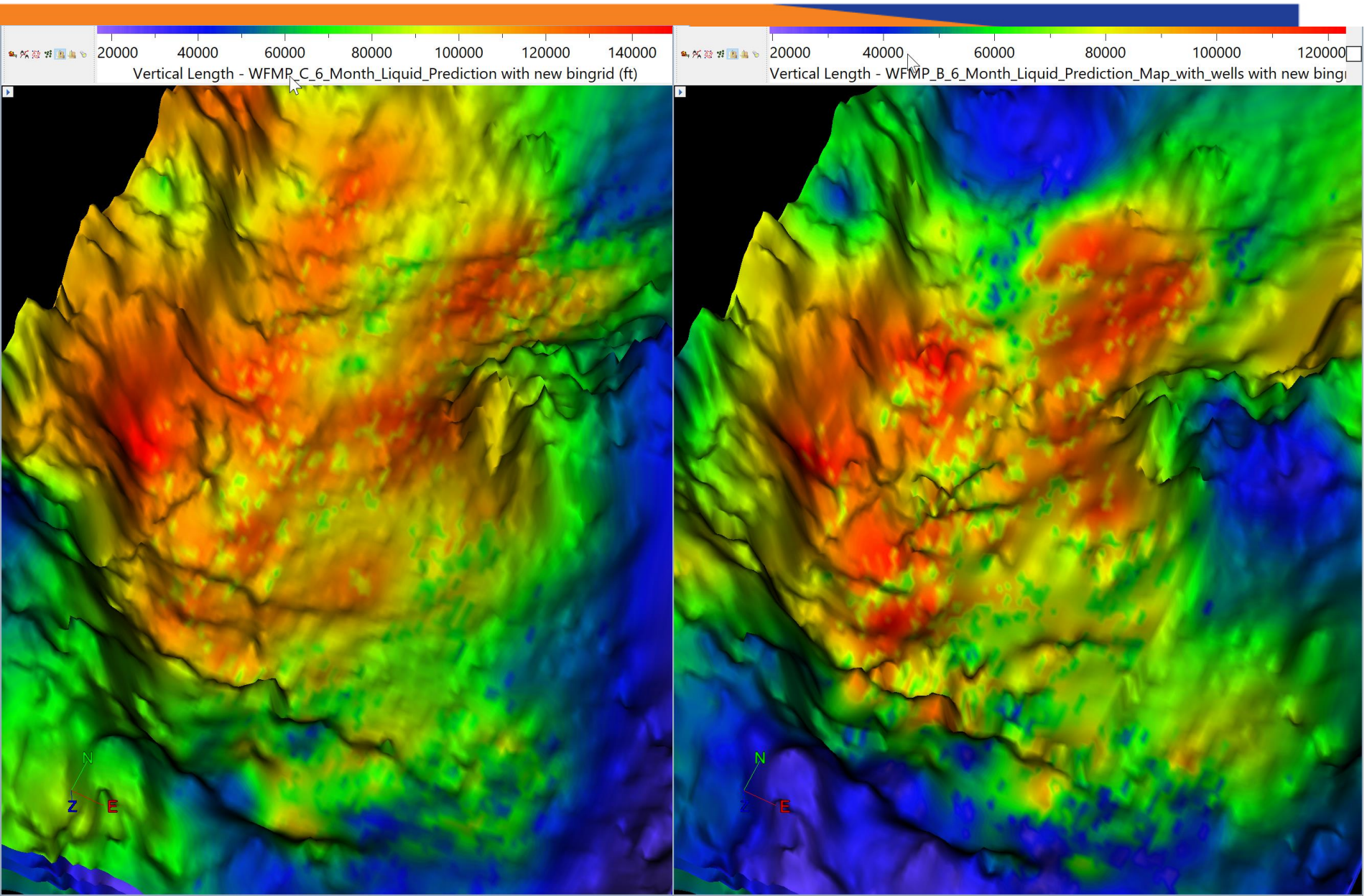
Multi-layer Wolfcamp Production Prediction Model



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)

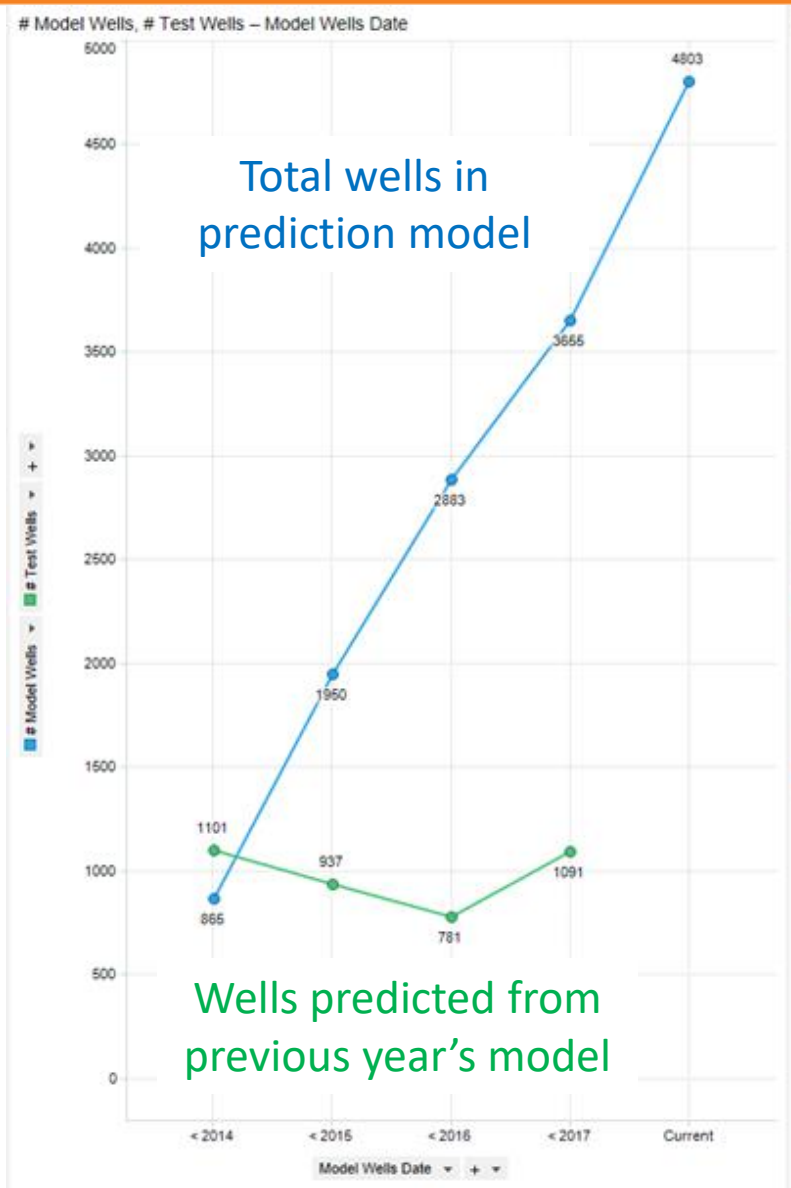
Multi-layer Wolfcamp Production Prediction Model

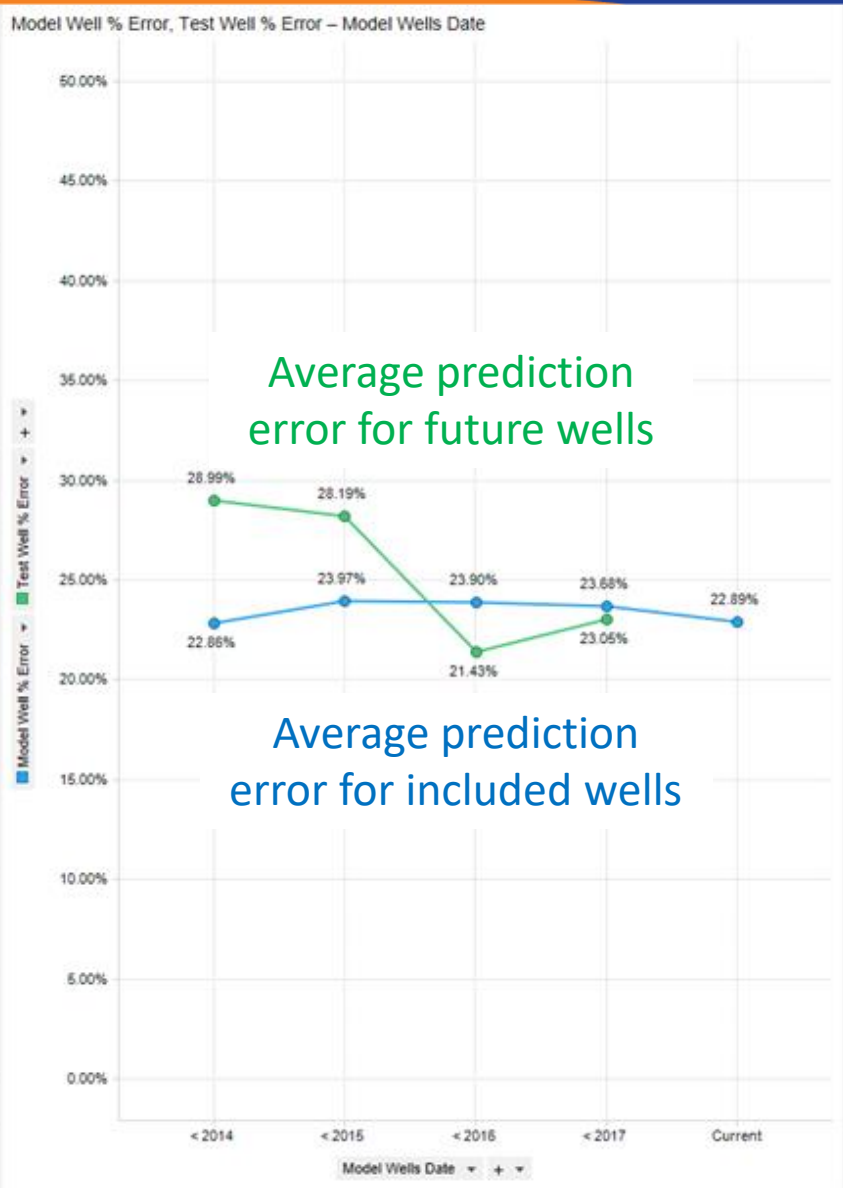


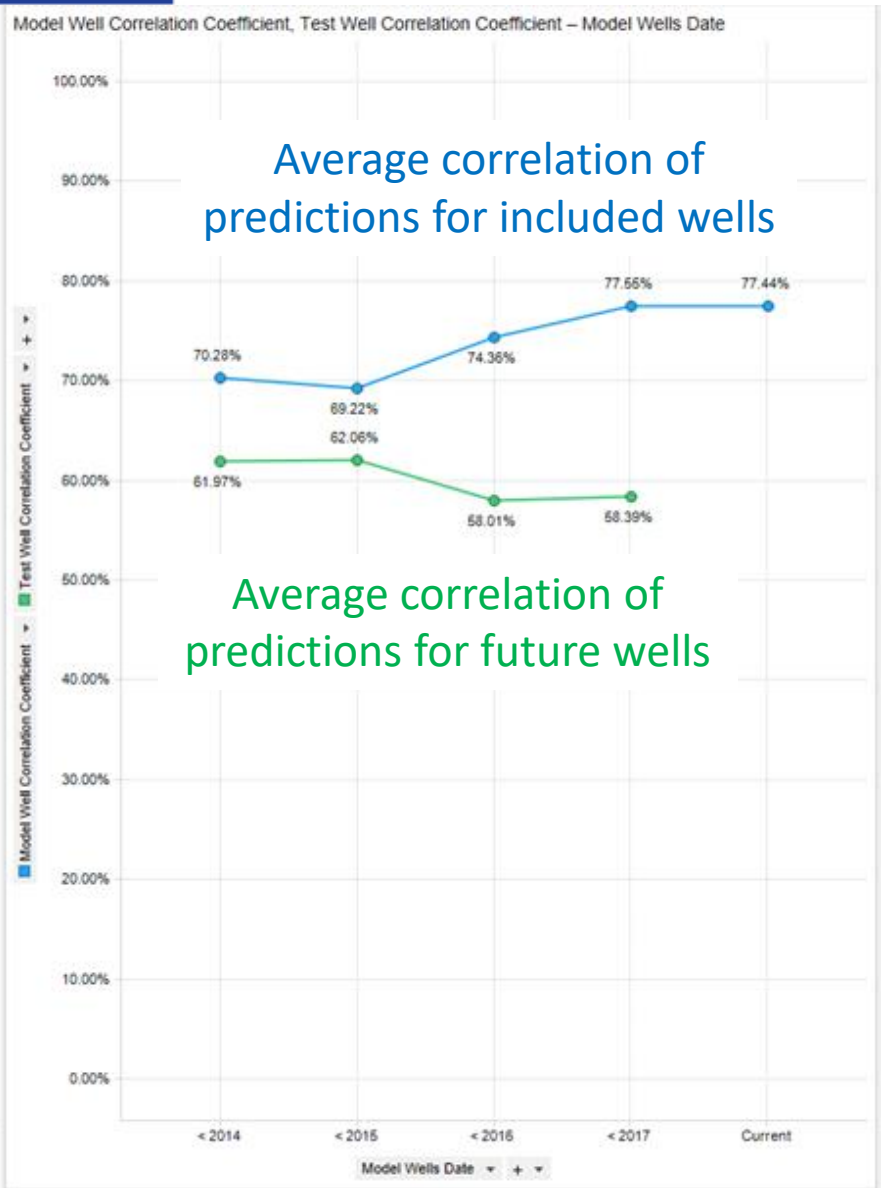
Wolfcamp A oil production prediction model updated for well production (left)

Wolfcamp B oil production prediction model updated for well production (right)

Production Prediction Model Quality







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 by 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**

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