Identifying new drilling areas in Midland basin integrating geological mapping, predictive analytics and GIS technology

Camilo Rodriguez, IHS Markit

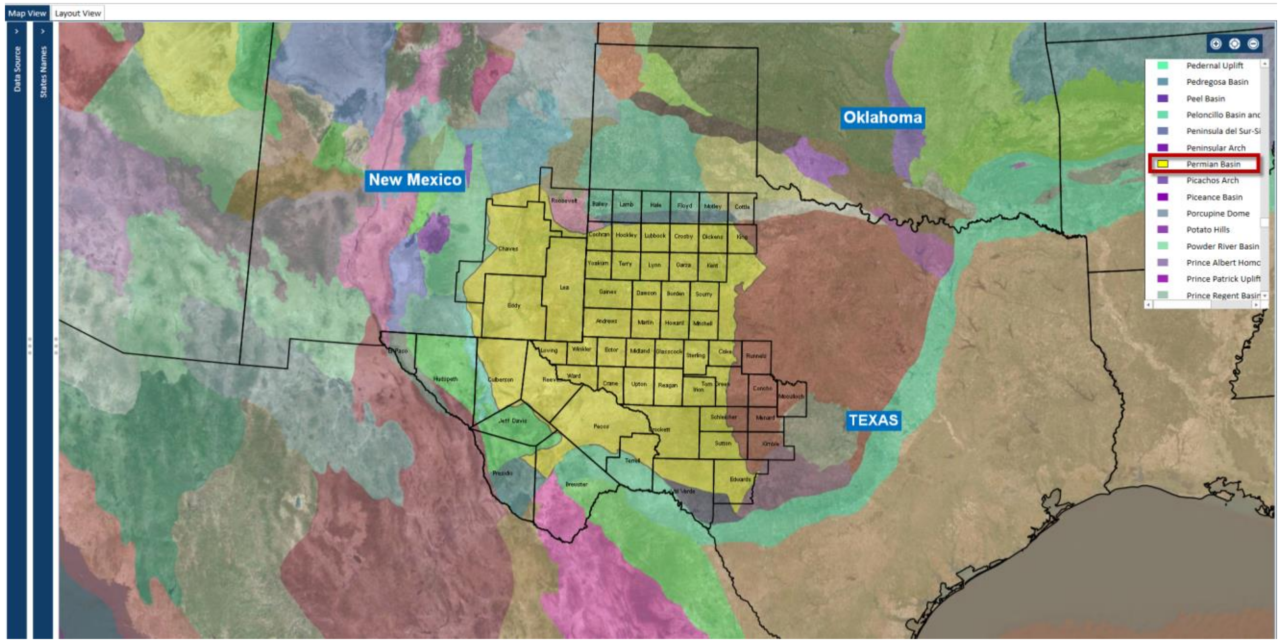
Camilo is a geologist from Colombia National University with 17 years of experience in the Oil and Gas industry including consulting projects in seismic interpretation, geological interpretation, mapping, and multi-variate analytics. Currently he is an Associate Director of Product Management at IHS Markit responsible for Kingdom development.

Applied Geoscience Conference

Identifying new drilling areas in Midland basin integrating geological mapping, predictive analytics and GIS technology

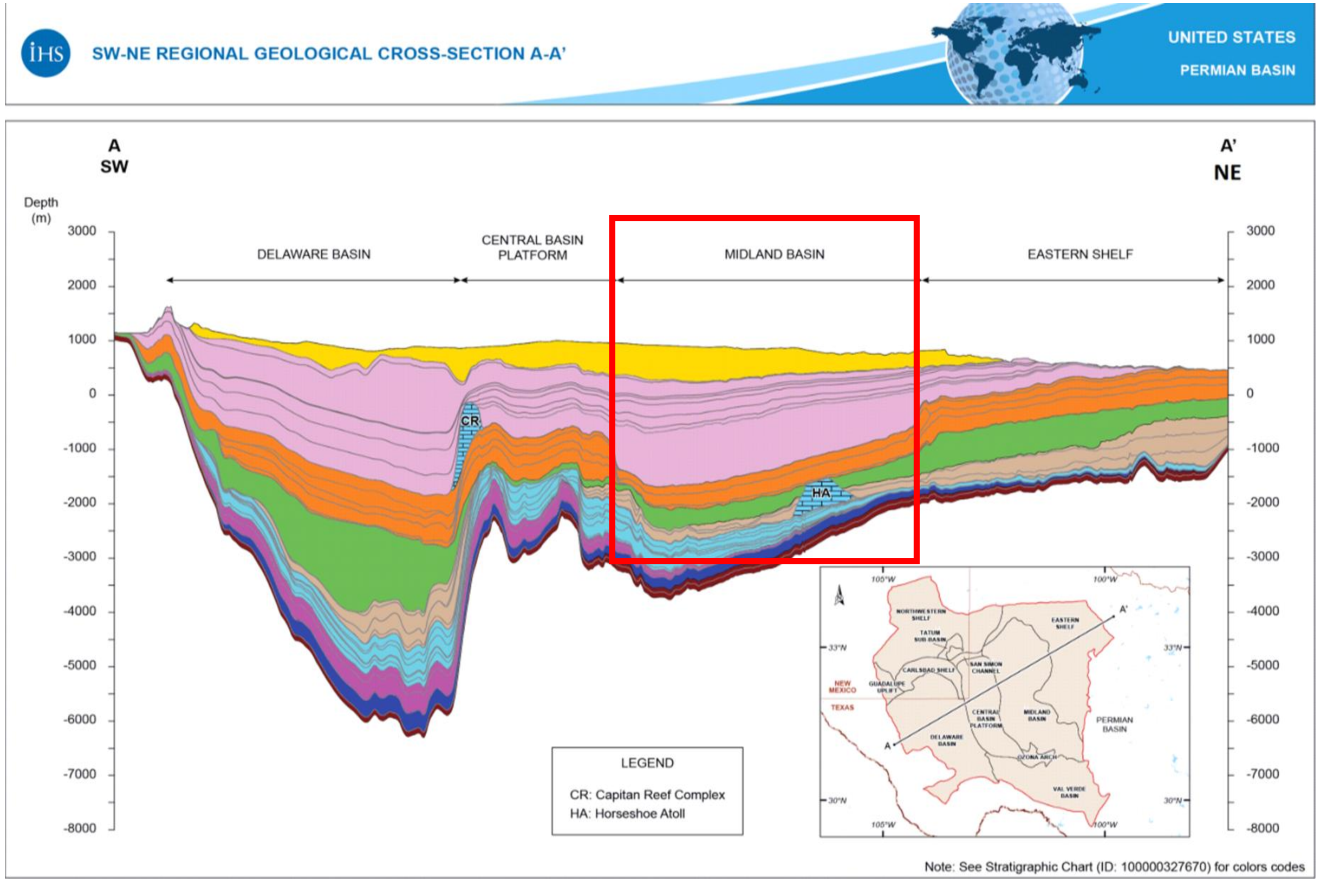
Camilo Rodriguez
Associate Director, Product Management
IHS Markit

Introduction



- The Permian basin has been producing oil and gas for almost a century.
- The decline curve turned around due to advances in unconventional reservoirs technologies.
- In 2012, horizontal well development began to surpass vertical well development, Today vertical wells comprise only 5% of the play while 8,000-10,000 ft horizontal wells dominate the rest.
- With about one million wells, the basin provides enough information that can be analyzed with different disciplines to find drilling areas.
- **Due to the high density of wells and state regulations, it is necessary to include GIS techniques along with geoscience and engineering studies to find the next sweet spot area.**
- **This presentation will demonstrate an approach of how machine learning algorithms and in general predictive analytics can be embedded in all the asset evaluation process. The methodology will be highlighted in one of the Wolfcamp benches (B Upper) in the Midland basin.**

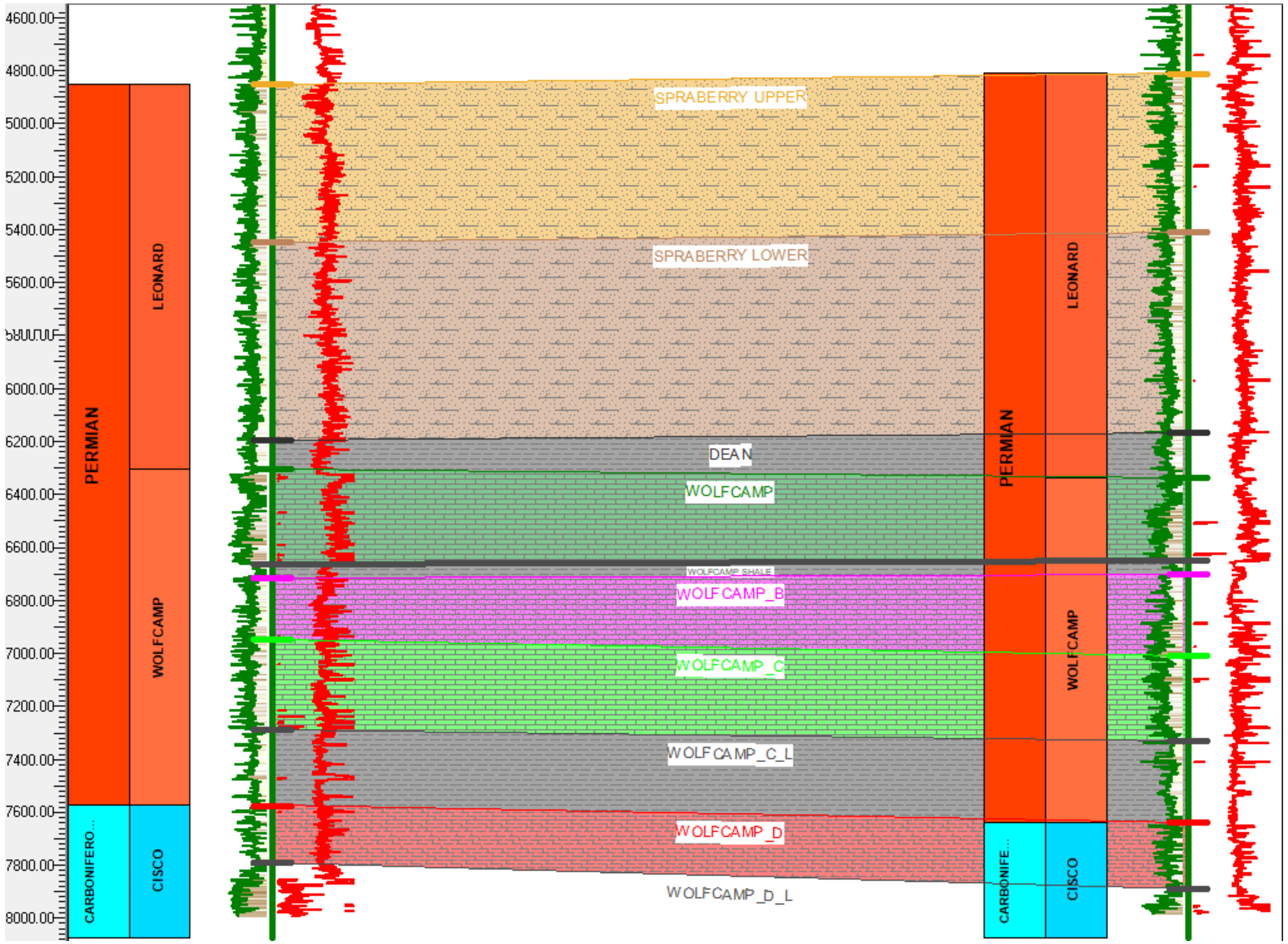
Midland Basin Location

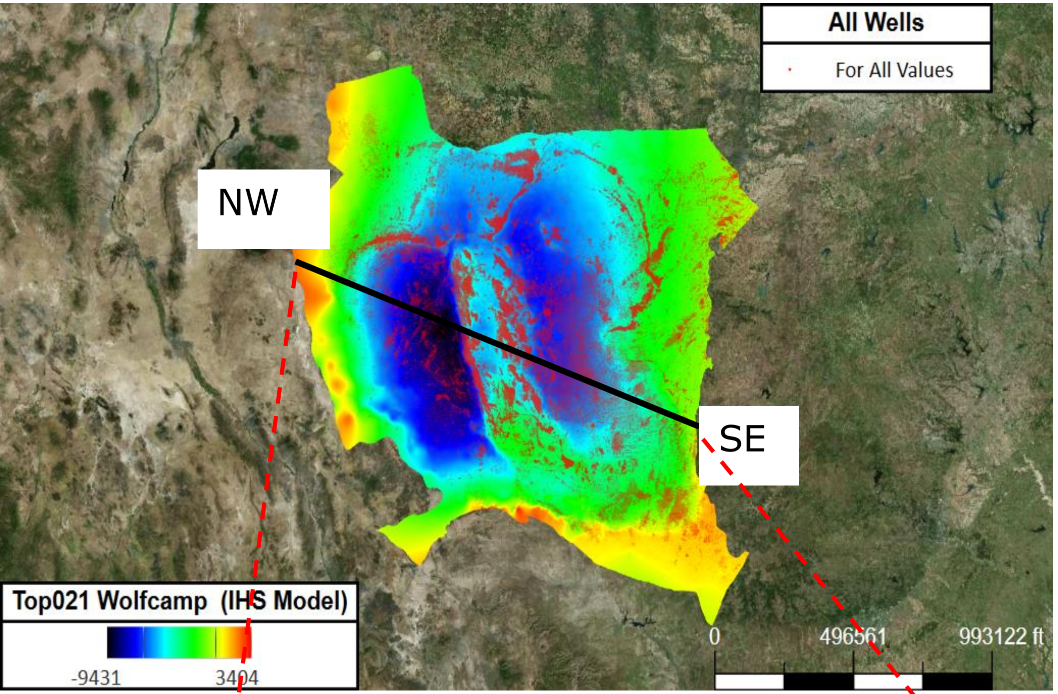


- The Permian Basin is a foreland basin divided into two main subbasins: the steeply dipping Delaware Basin to the west and the shallow-dipping Midland Basin to the east.
- The Permian-age Wolfcamp Formation exists throughout the Delaware and Midland basin.
- The Wolfcamp Midland play is one of the recent major Permian Basin “stacked pay” plays that continues to grow despite persistently low oil prices. The phrase “stacked pay” refers to multiple benches, or target intervals, that are relatively close stratigraphically. The Wolfcamp Midland play consists of six major benches within the Wolfcamp and Spraberry formations, many of which are widespread across the Midland Basin core

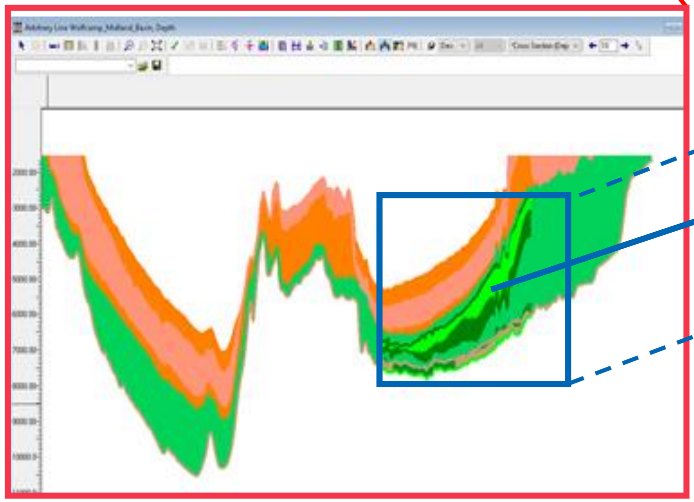
Stratigraphy

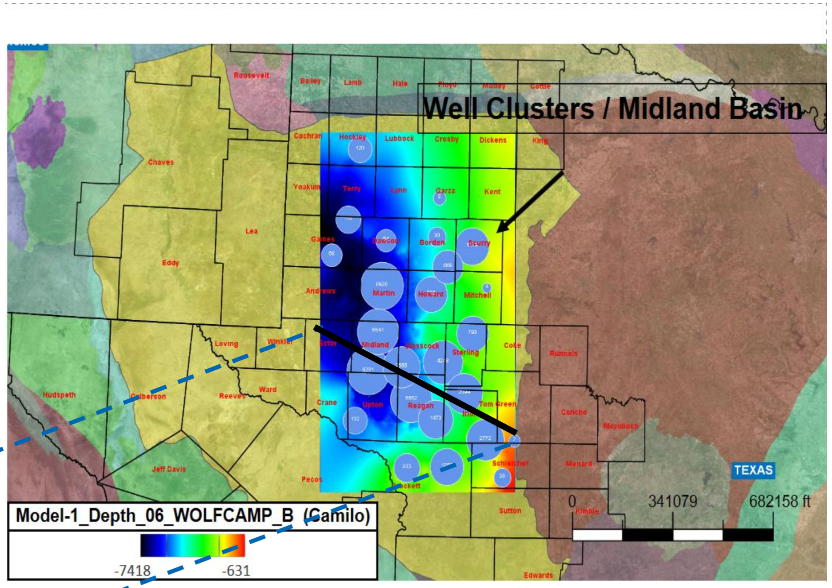
- The Wolfcamp Formation is composed of predominantly organic-rich shales, interbedded with carbonate debrites, and clastic turbidites with porosities of 4 to 10%. Organic-rich shale intervals contain total organic carbon (TOC) contents of 2.0-8.8%. The formation is in the oil window with a vitrinite reflectance (%Ro) of 0.85-0.9%.
- IHS Markit has defined five members of the Wolfcamp Formation: Wolfcamp A-D and the Wolfcamp Shale. Wolfcamp A is so far the best producer bench, but some companies are starting to focus on Wolfcamp B, which is producing in average between 60 to 70 boe/d per 1000 ft lateral feet. (***Droege L, & Olmestead R, IHS Markit, 2017***).
- **The focus of this presentation will be Wolfcamp B.**





Structure Map Wolfcamp Formation – Permian Basin

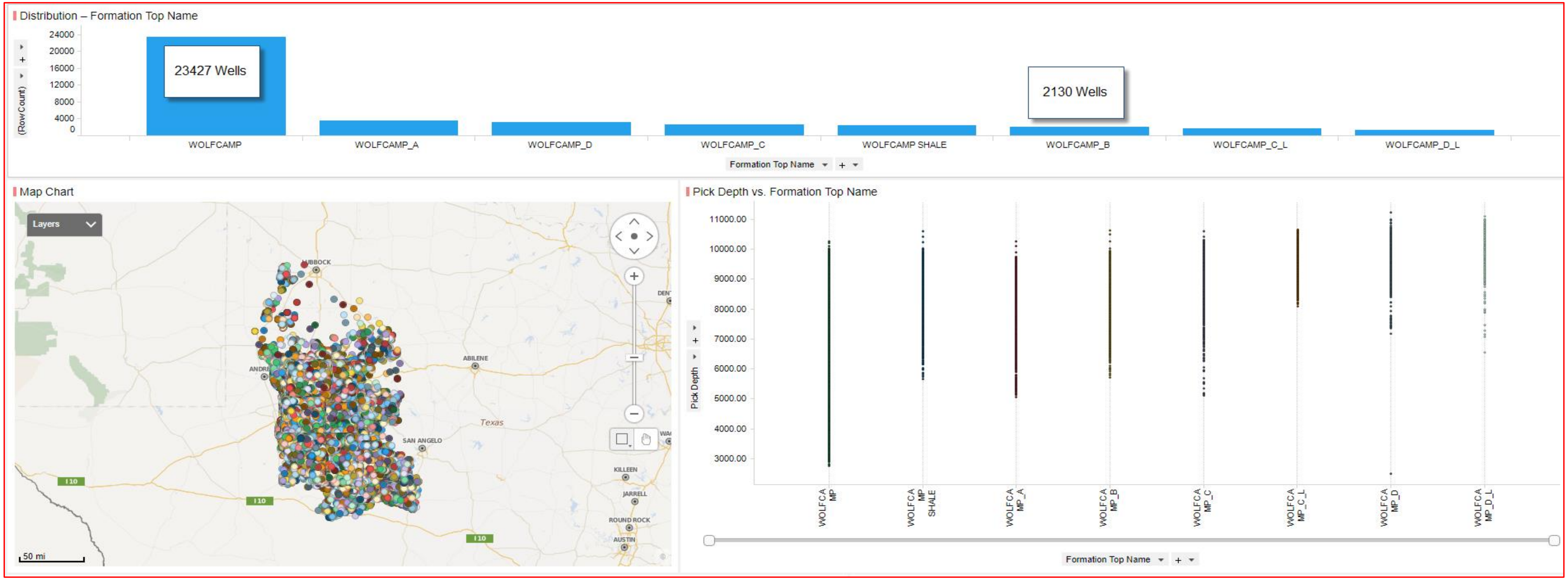




Wolfcamp B

Structure Map Wolfcamp B Formation (Case study) - Midland Basin

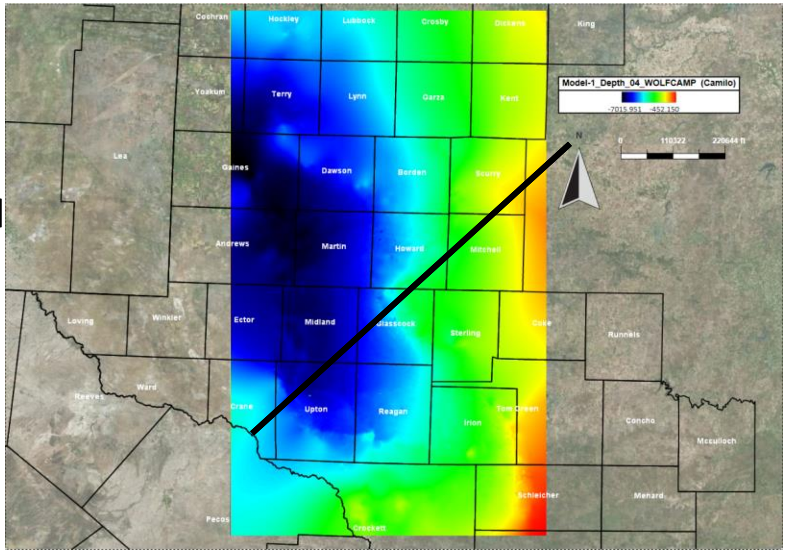
Structural Mapping in the Midland Basin



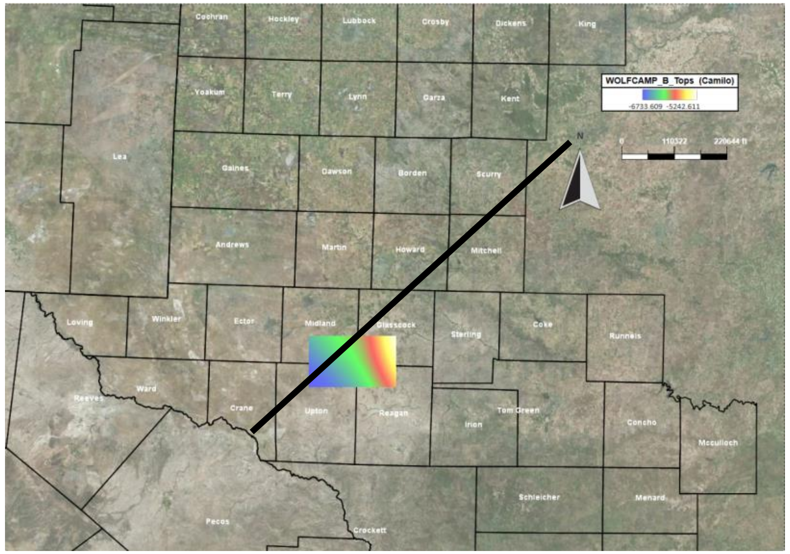
In the Midland Basin, IHS Markit currently has 23427 wells interpreted for the Wolfcamp formation. The other benches are interpreted with much less wells. Wolfcamp B, for example is interpreted in 2130 wells for the same area. Advance mapping techniques with geological rules is necessary to properly model the Wolfcamp B structure.

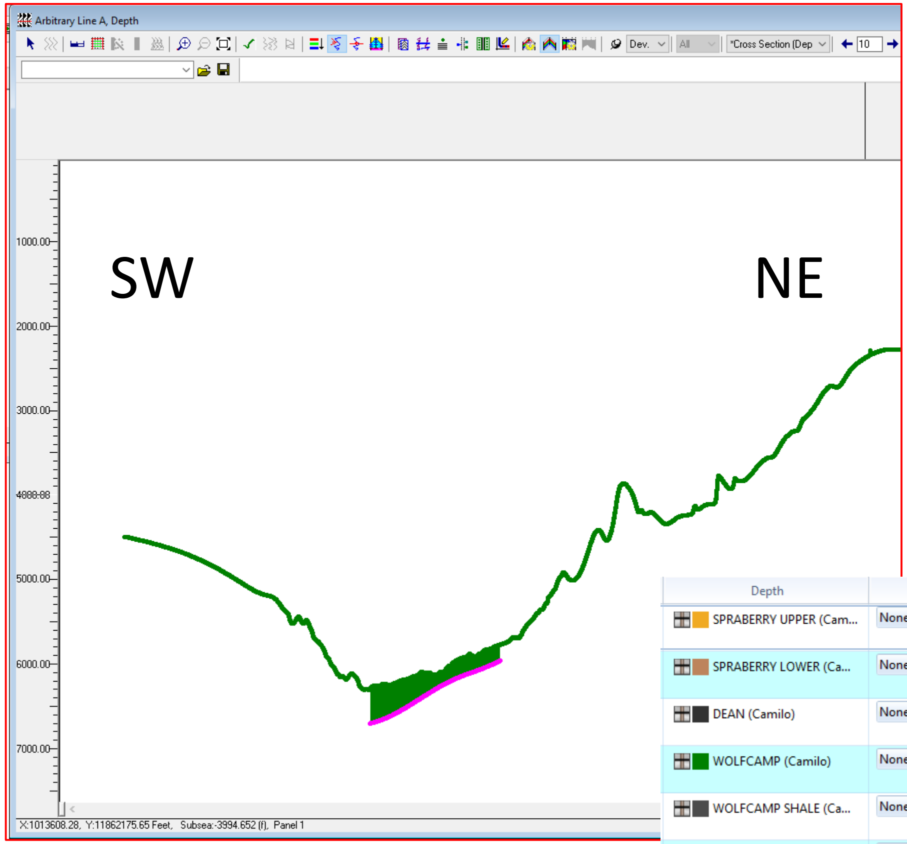
Defining Wolfcamp B Structure and Thickness

Structure Map - Top Wolfcamp Formation based on 23427 wells



Structure Map - Top Wolfcamp B based on 2130 wells

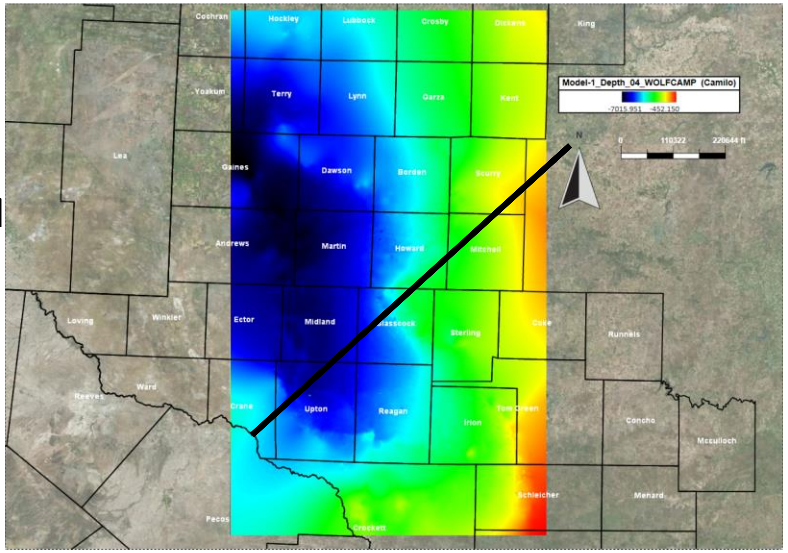




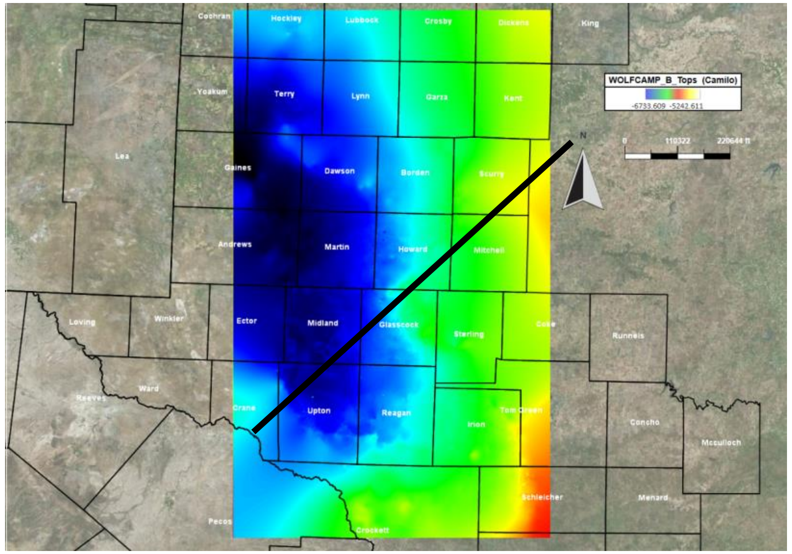
Depth	Fault Polygon	Framework Rules
SPRABERRY UPPER (Cam...	None	Non-Conformable
SPRABERRY LOWER (Ca...	None	Conform to surface above
DEAN (Camilo)	None	Conform to surface above
WOLFCAMP (Camilo)	None	Conform to surface above
WOLFCAMP SHALE (Ca...	None	Conform to surface above
WOLFCAMP_B (Camilo)	None	Conform to surface above
WOLFCAMP_C (Camilo)	None	Conform to surface above
WOLFCAMP_C_L (Camilo)	None	Conform to surface above
WOLFCAMP_D (Camilo)	None	Conform to surface above
WOLFCAMP_D_L (Camilo)	None	Conform to surface above
No items selected.	None	Conform to surface above

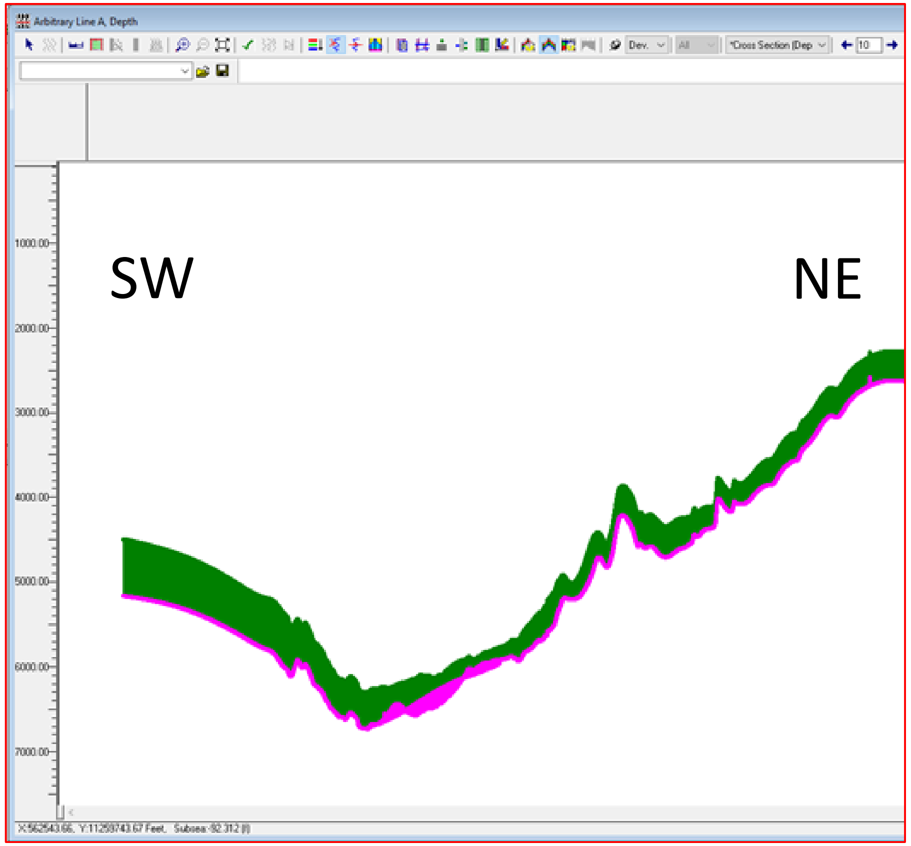
Defining Wolfcamp B Structure and Thickness

Structure Map - Top Wolfcamp Formation based on 23427 wells



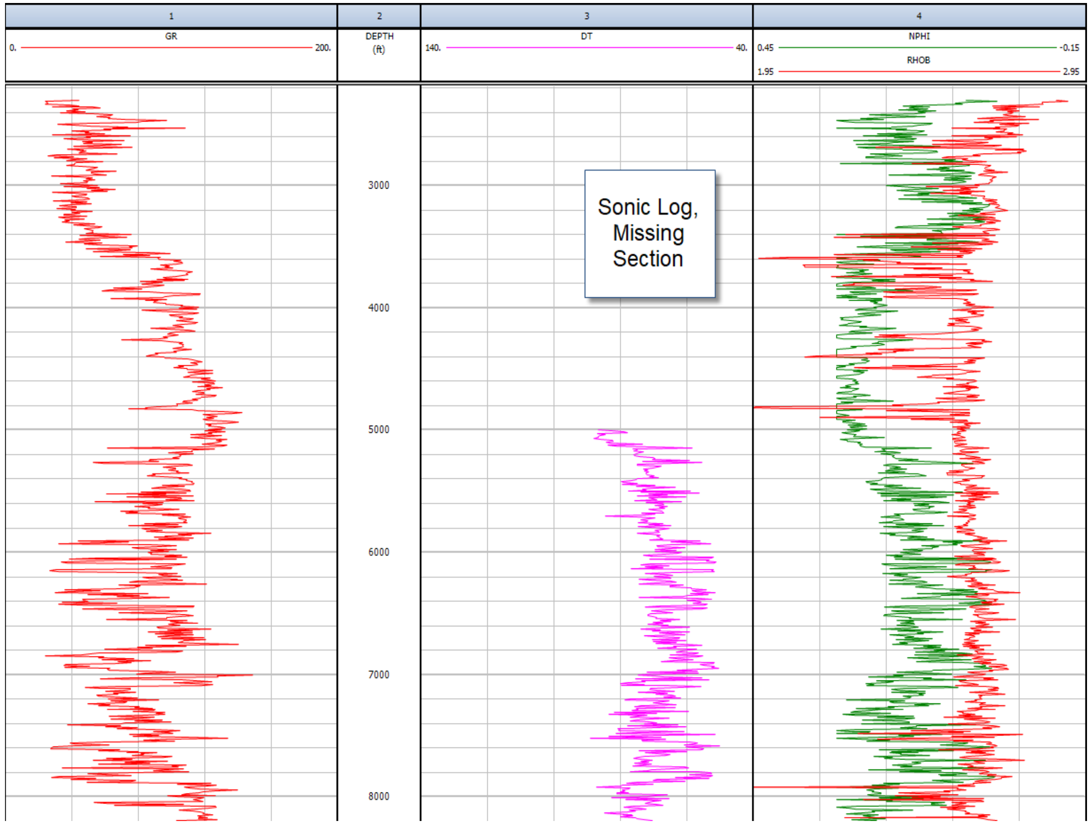
Structure Map - Top Wolfcamp B based on 2130 wells

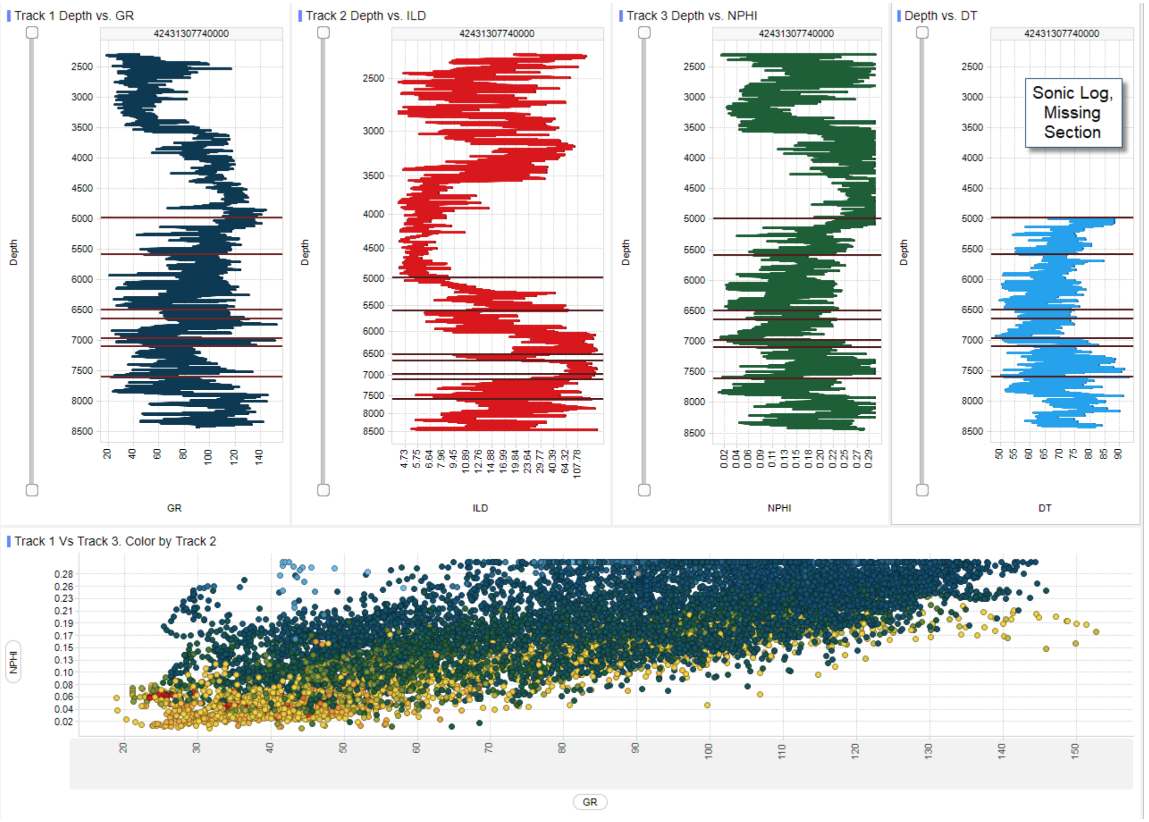




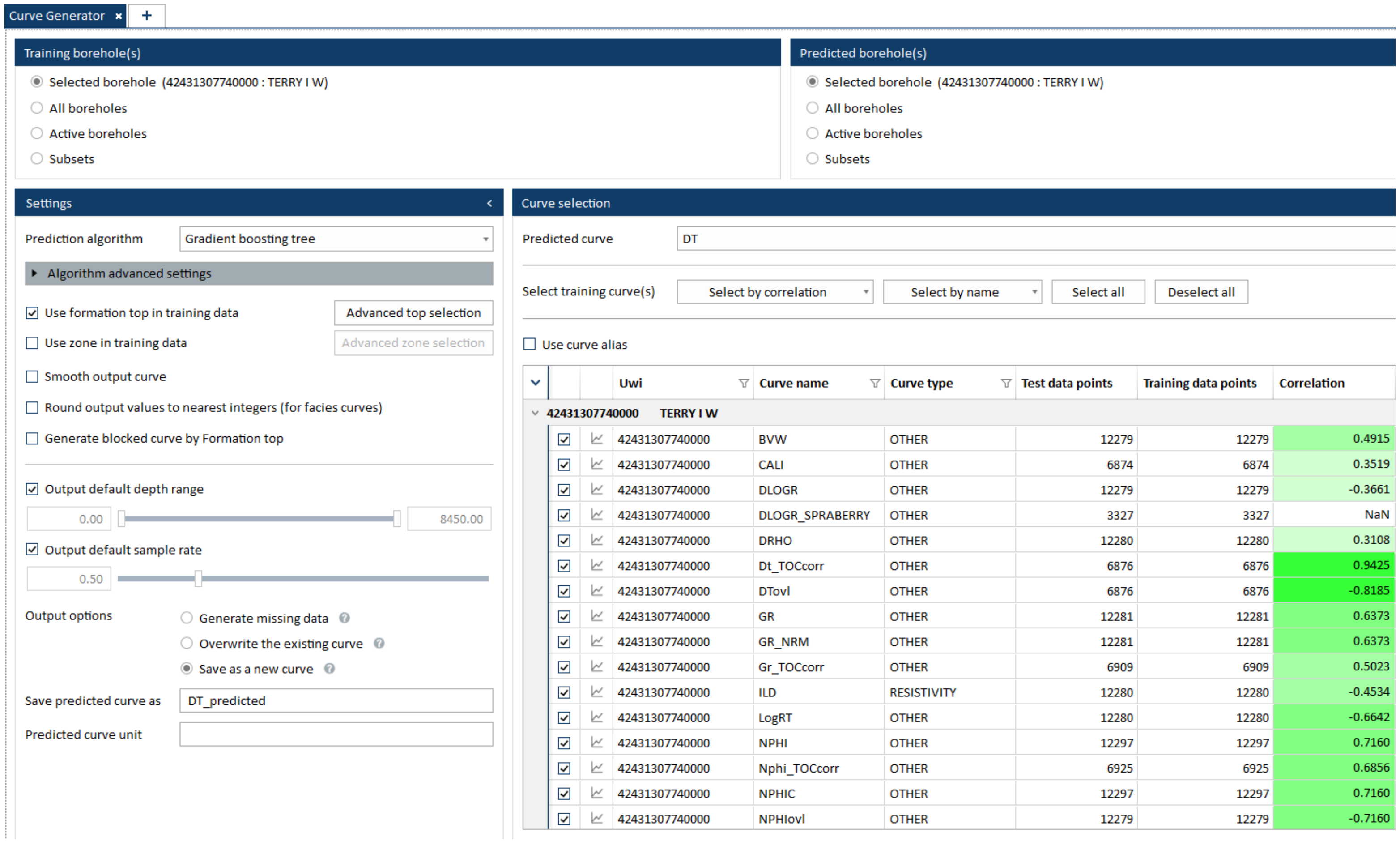
Structure Map and cross section profile. Top Wolfcamp B after applying conformable geological rules

Machine Learning to Predict missing data



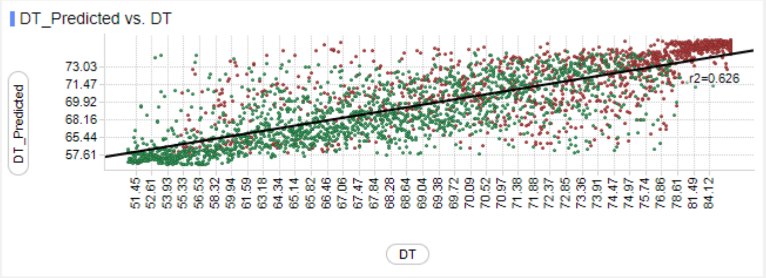


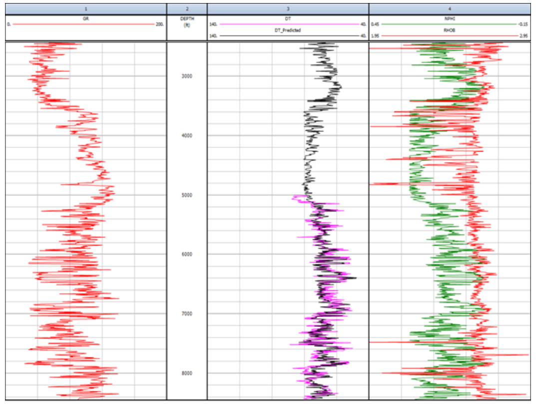
Machine Learning to Predict missing data

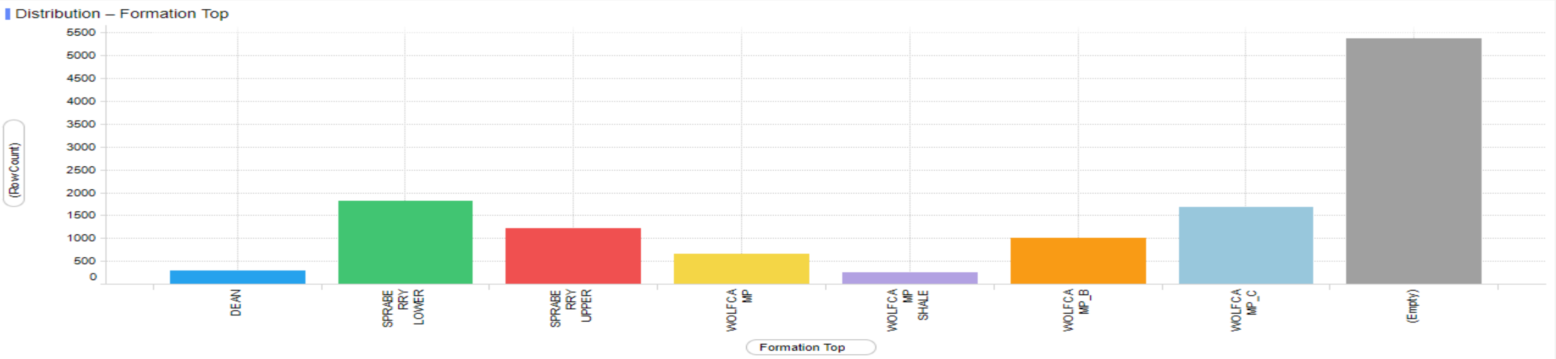


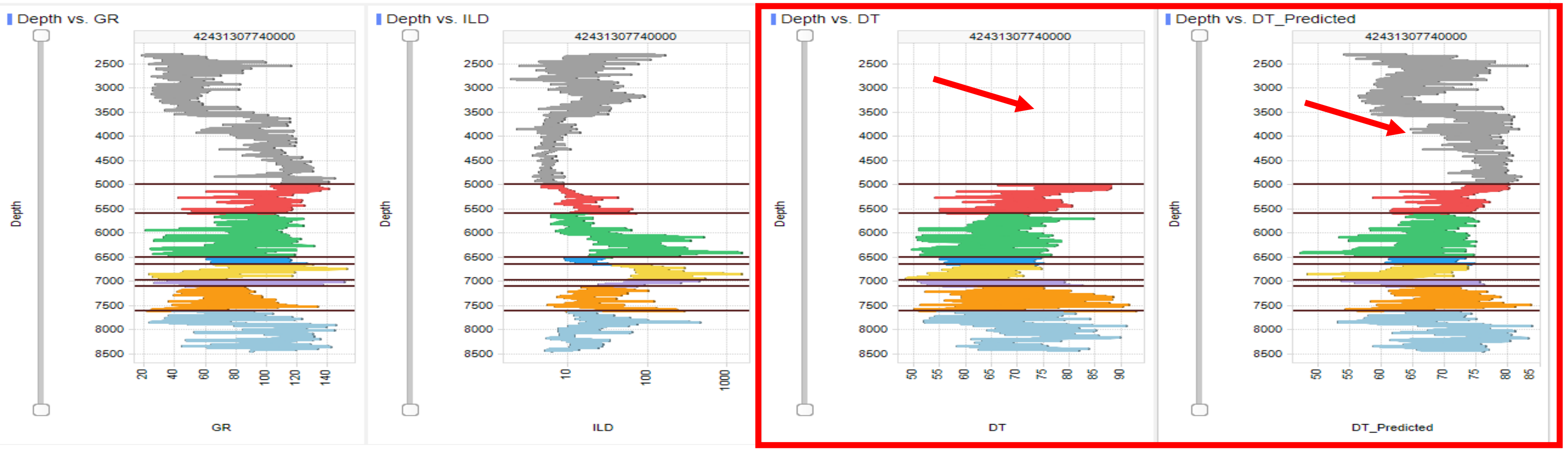
Uwi	Curve name	Curve type	Test data points	Training data points	Correlation
42431307740000	BVW	OTHER	12279	12279	0.4915
42431307740000	CALI	OTHER	6874	6874	0.3519
42431307740000	DLOGR	OTHER	12279	12279	-0.3661
42431307740000	DLOGR_SPRABERRY	OTHER	3327	3327	NaN
42431307740000	DRHO	OTHER	12280	12280	0.3108
42431307740000	Dt_TOCcorr	OTHER	6876	6876	0.9425
42431307740000	DTovl	OTHER	6876	6876	-0.8185
42431307740000	GR	OTHER	12281	12281	0.6373
42431307740000	GR_NRM	OTHER	12281	12281	0.6373
42431307740000	Gr_TOCcorr	OTHER	6909	6909	0.5023
42431307740000	ILD	RESISTIVITY	12280	12280	-0.4534
42431307740000	LogRT	OTHER	12280	12280	-0.6642
42431307740000	NPHI	OTHER	12297	12297	0.7160
42431307740000	Nphi_TOCcorr	OTHER	6925	6925	0.6856
42431307740000	NPHIC	OTHER	12297	12297	0.7160
42431307740000	NPHIovl	OTHER	12279	12279	-0.7160

Machine Learning to Predict missing data

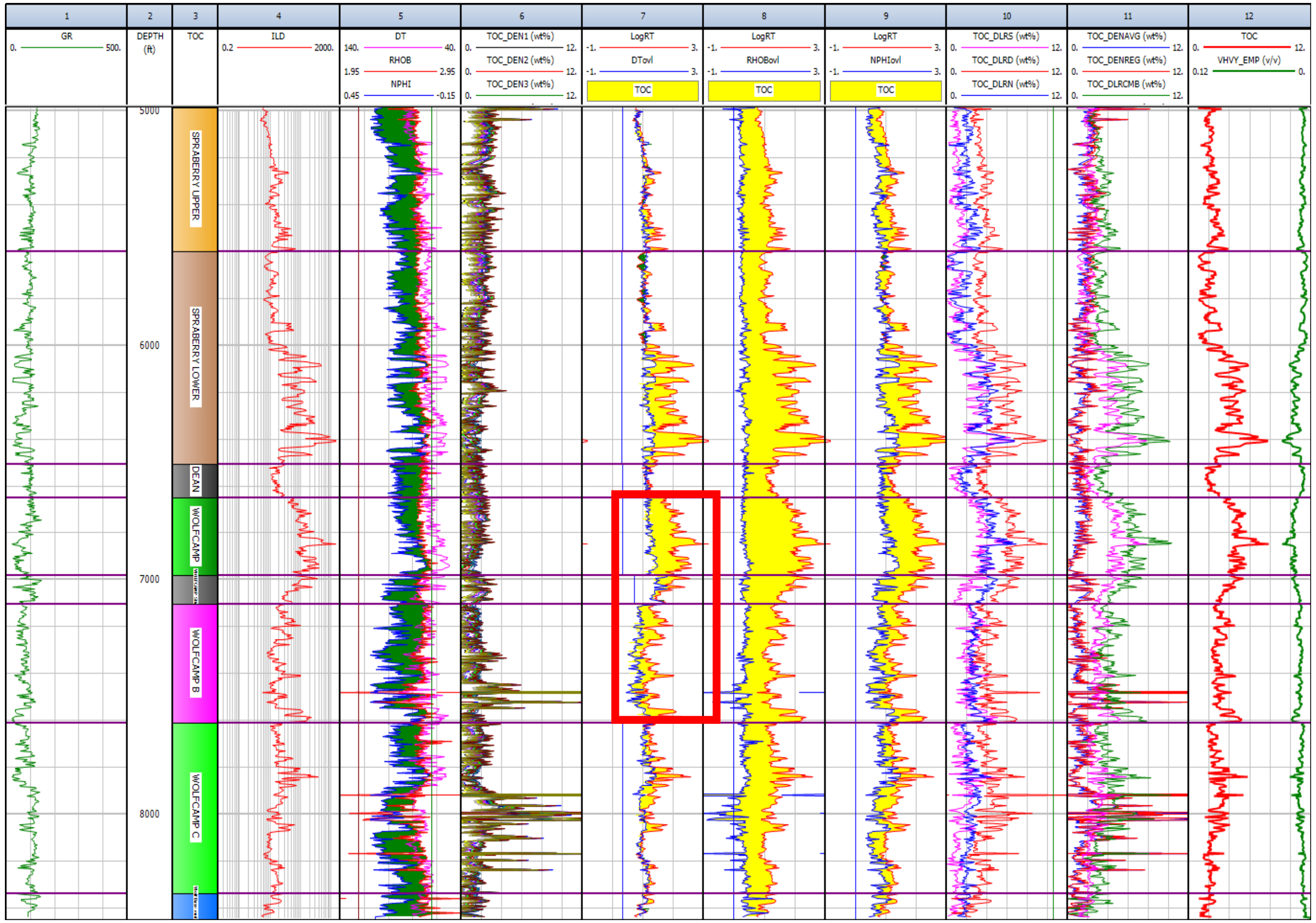






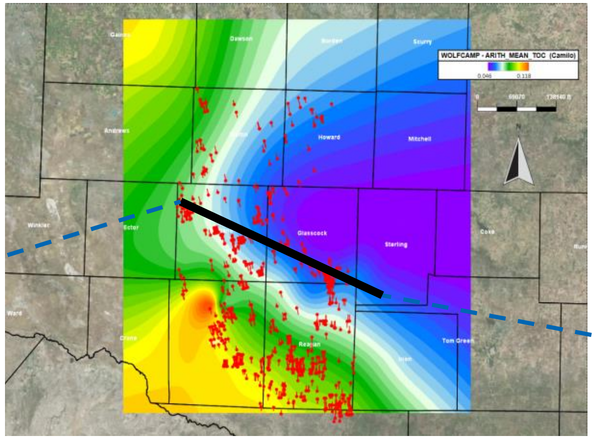


Defining Wolfcamp B Petrophysical Properties – Total Organic Carbon Content

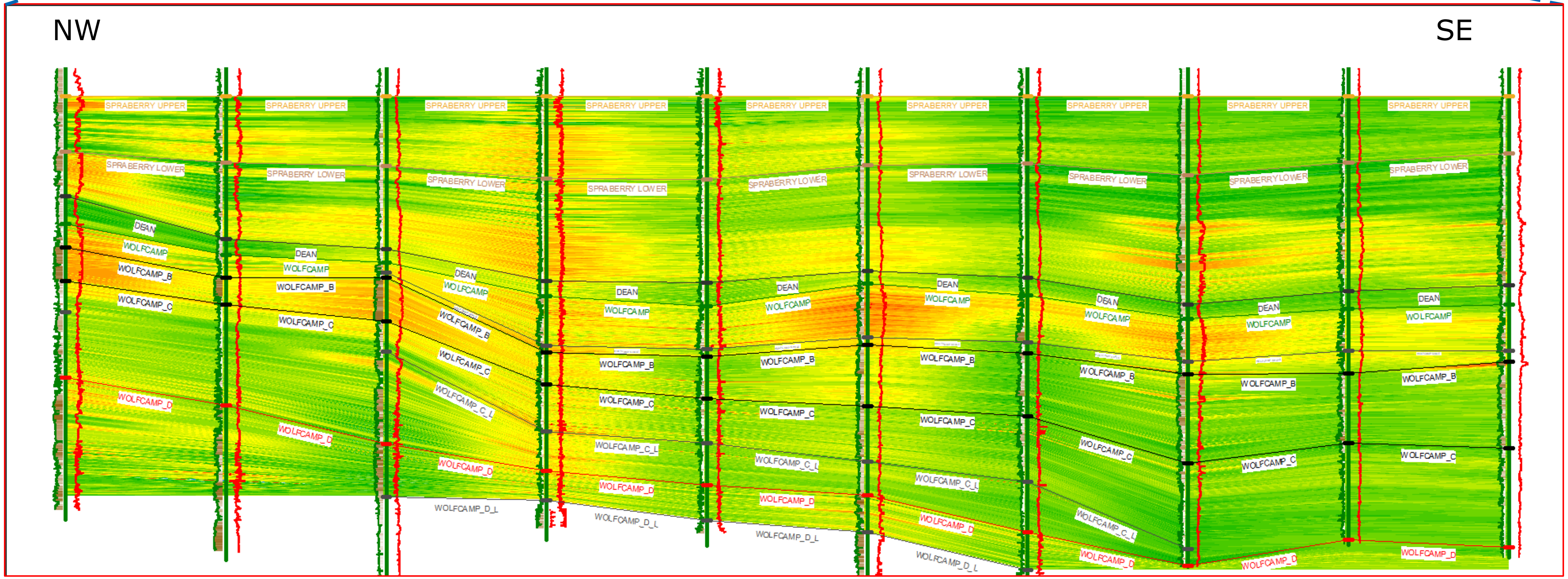


- Most of the wells in the study area have GR logs, those logs were properly normalized and then used for clay volume calculations and to identify the zones to calibrate Sonic and Resistivity logs for TOC calculation per Passey's methodology. (**Passey, et. al., 1994**)
- For TOC calculations, the sonic log and resistivity logs were calibrated in water saturated organic rocks (Upper part Spraberry lower formation and Dean formation)
- After the calibration, Sonic log and resistivity log separate from each other in Wolfcamp A and B benches due to the presence of low density/low velocity kerogen and the presence of fluids, more likely hydrocarbons.

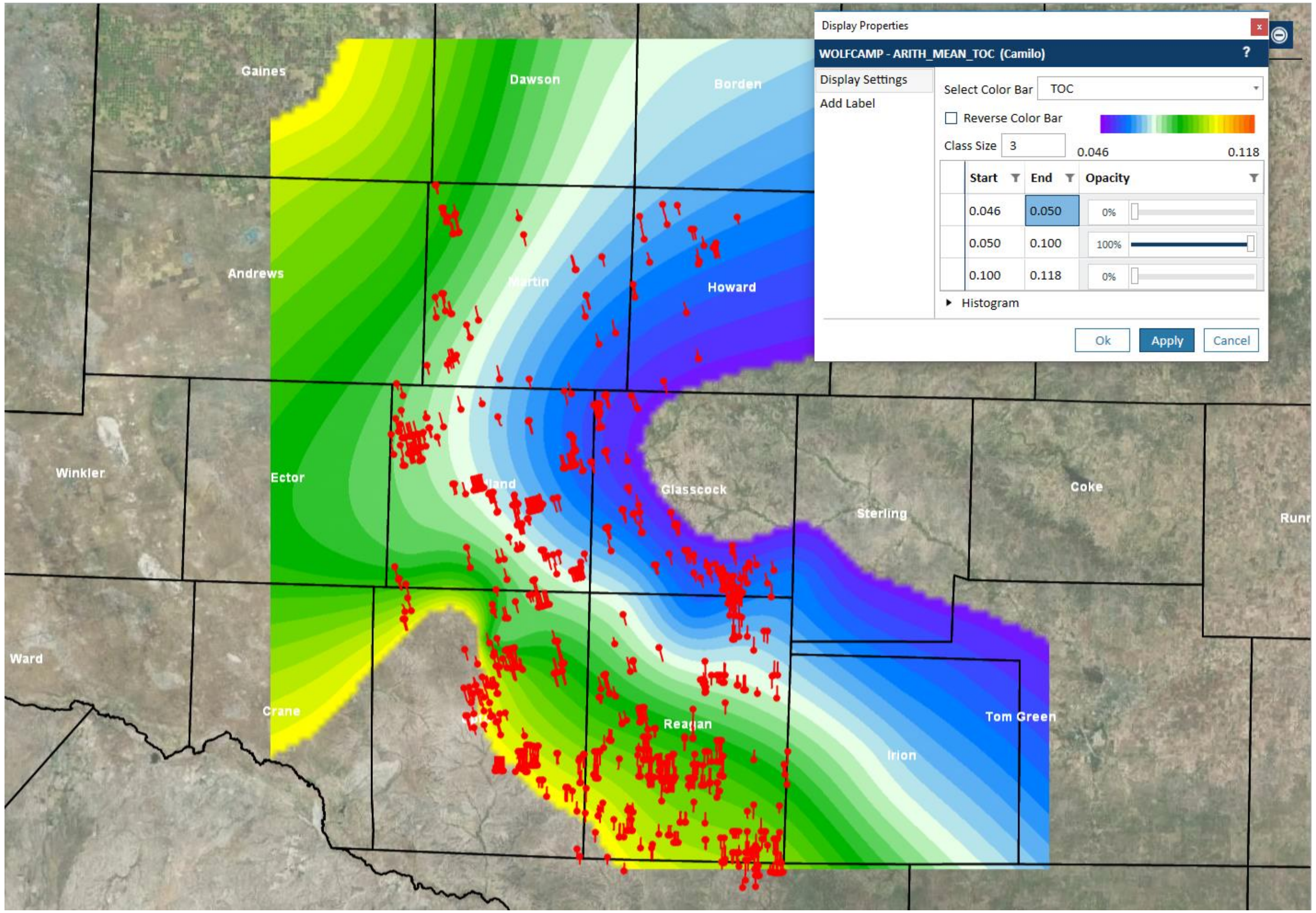
Wolfcamp B Upper TOC Map



- In the type log and in the cross section, one can see that the best TOC distribution happens at Wolfcamp A bench. This is why it is the most prolific and exploited bench. Wolfcamp B shows important TOC accumulations and it has also been proved to be profitable.

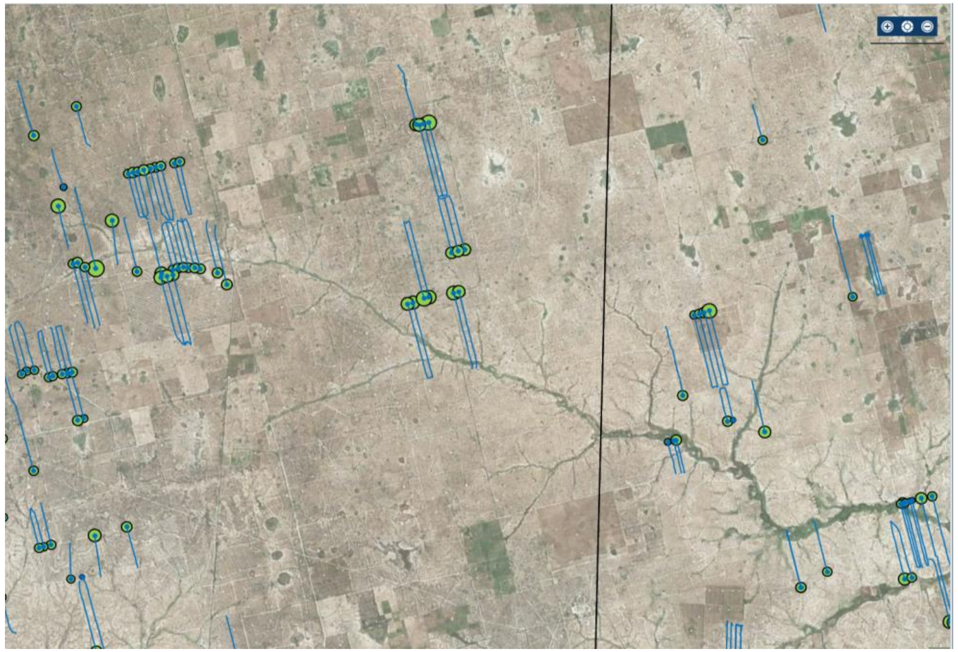


Wolfcamp B TOC Map with opacity control

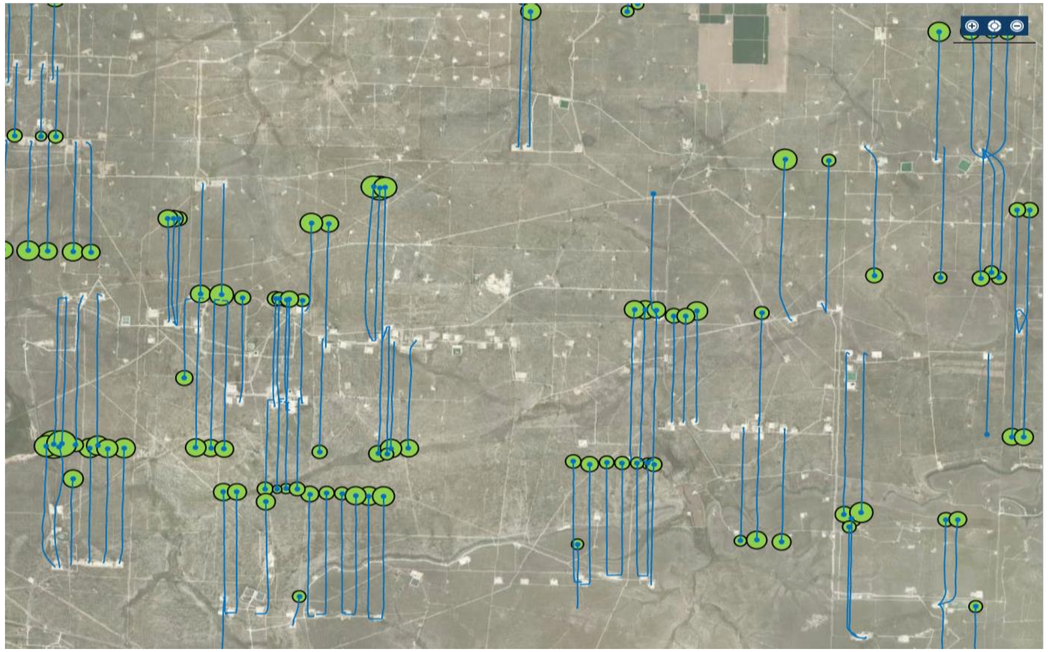


- In this map, one can see in red all the Oil producing wells from Wolfcamp B bench. In the TOC map we have applied opacity control to hide to lowest TOC values. Notice that the distribution of the producing wells follows a TOC pattern. This picture shows that the productive TOC percentage in Wolfcamp B is between 5% and 10%.

But, what’s is controlling production in Wolfcamp B?

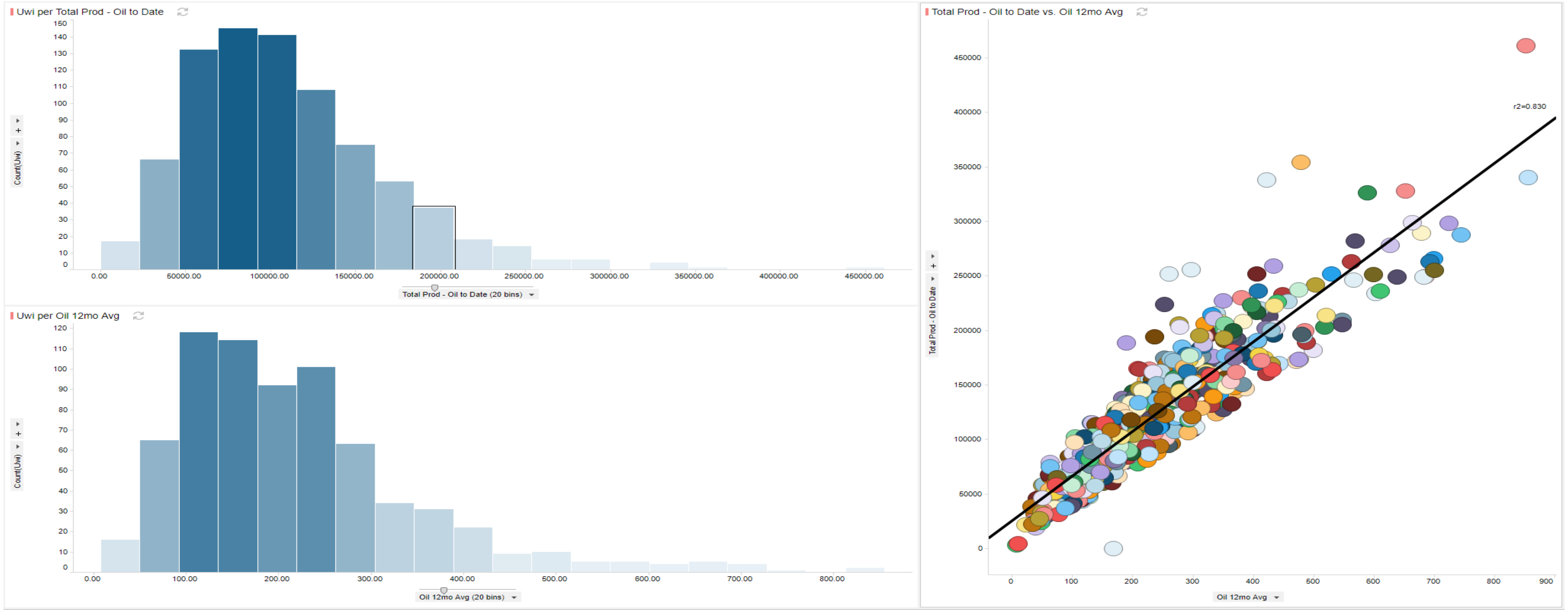


Production variability Midland County

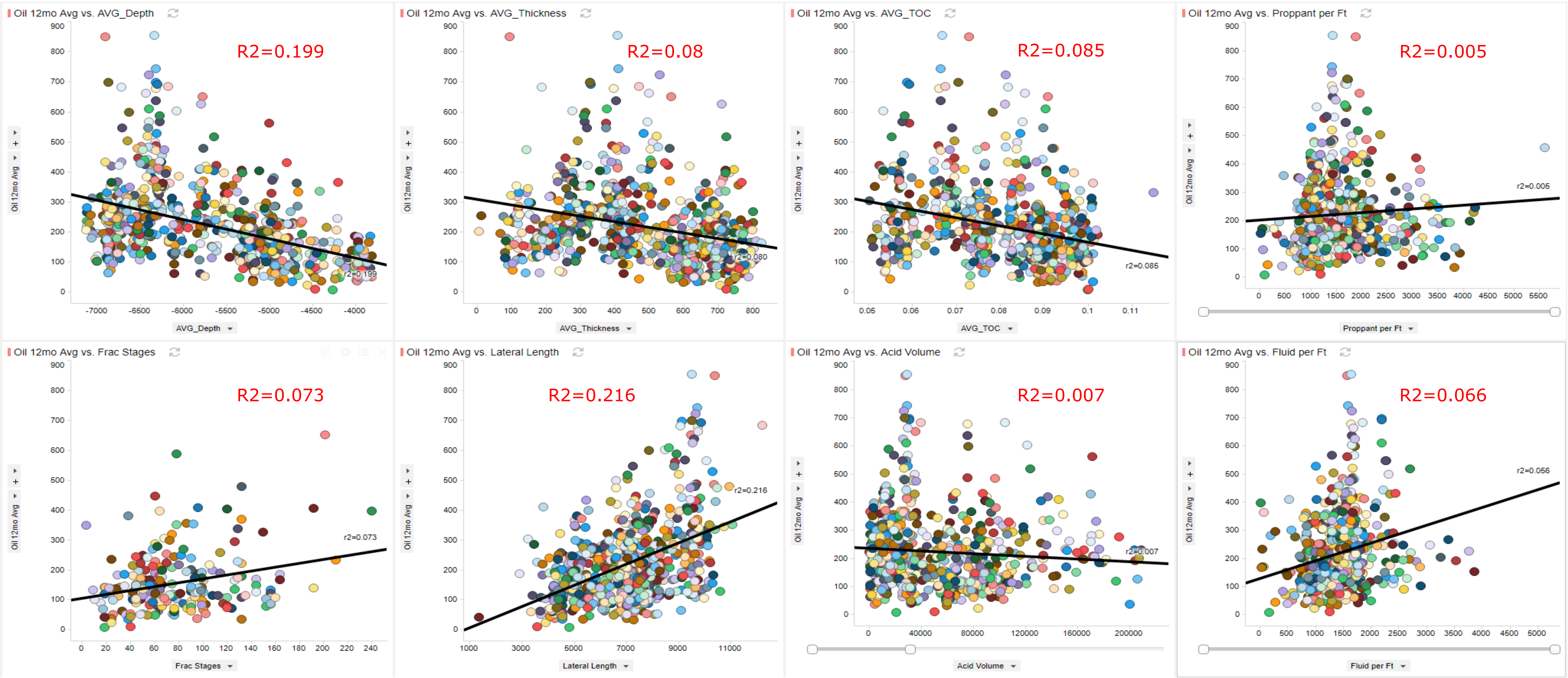


Production variability Reagan County

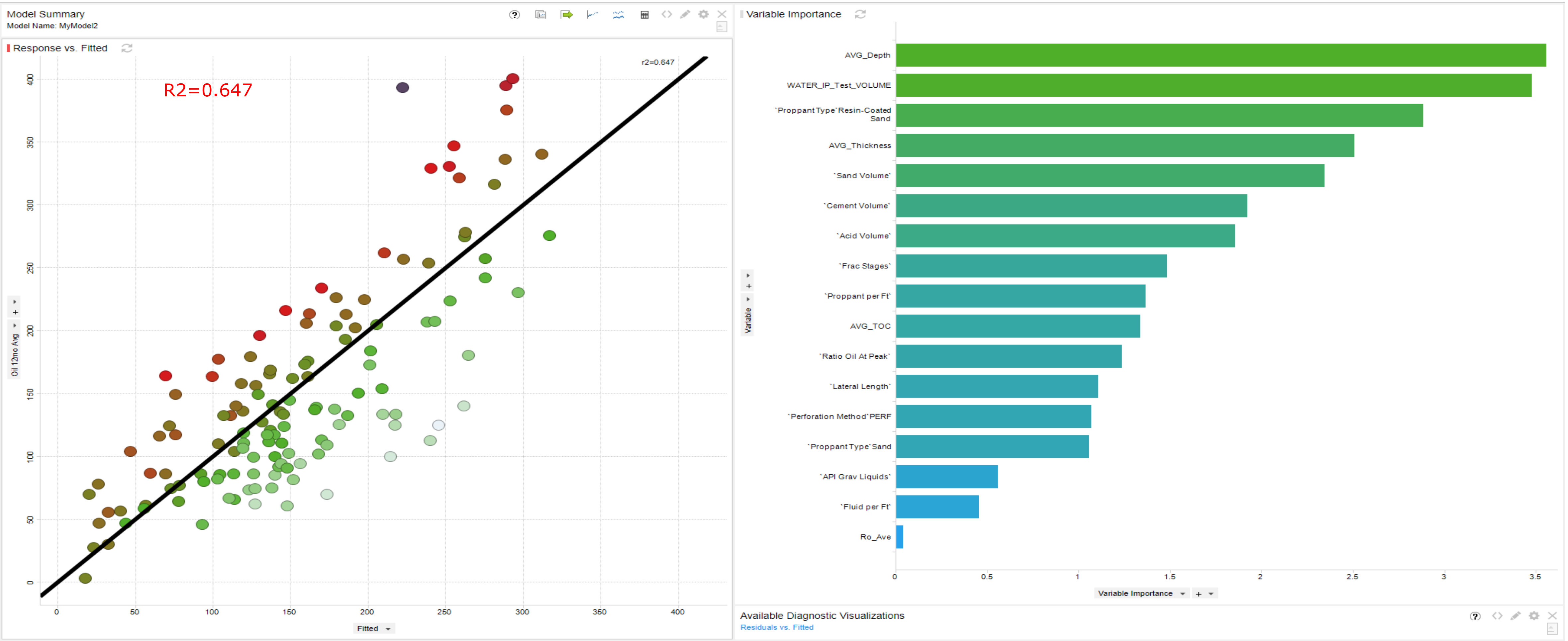
Geological properties seem to match the producing wells, but why do we have a lot of variability in wells that are close by and in the same geological area with apparent same properties? Next we have to include in the analysis engineering data, understand how the wells are being completed, and create a production prediction map assuming equal conditions for all the wells.



To normalize the wells and their production, we selected average oil production of the first 12 months of every well. The graphs show that it will be a good indicator to predict production. Comparing the histogram of total oil production (above) vs first 12 month production (below), with the cross-plot between both variables shows a high correlation coefficient of 0,830.



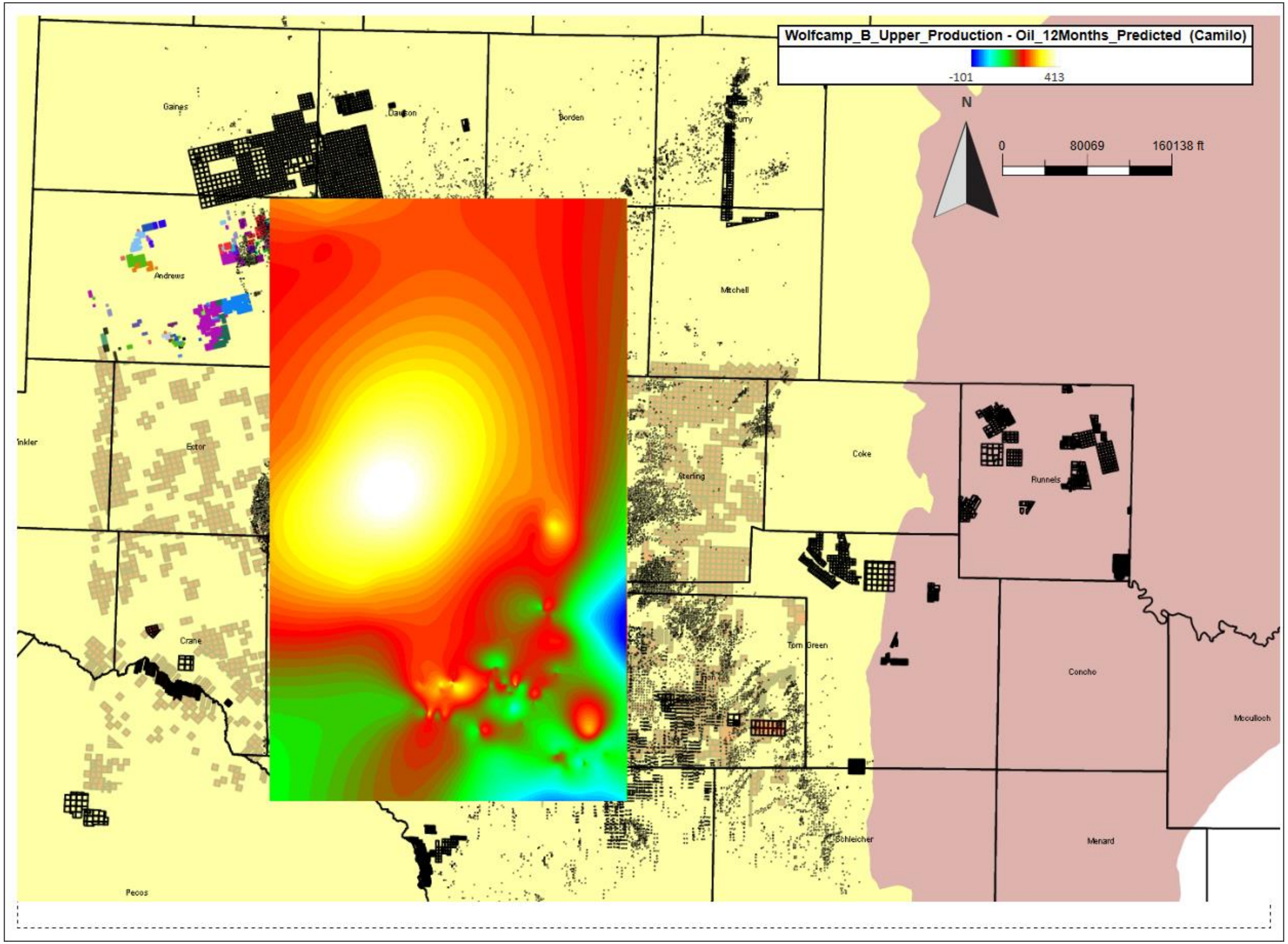
Above are crossplots highlighting average production of the first 12 months versus different geological and engineering properties. Notice that by itself, none of the variables correlates high with production



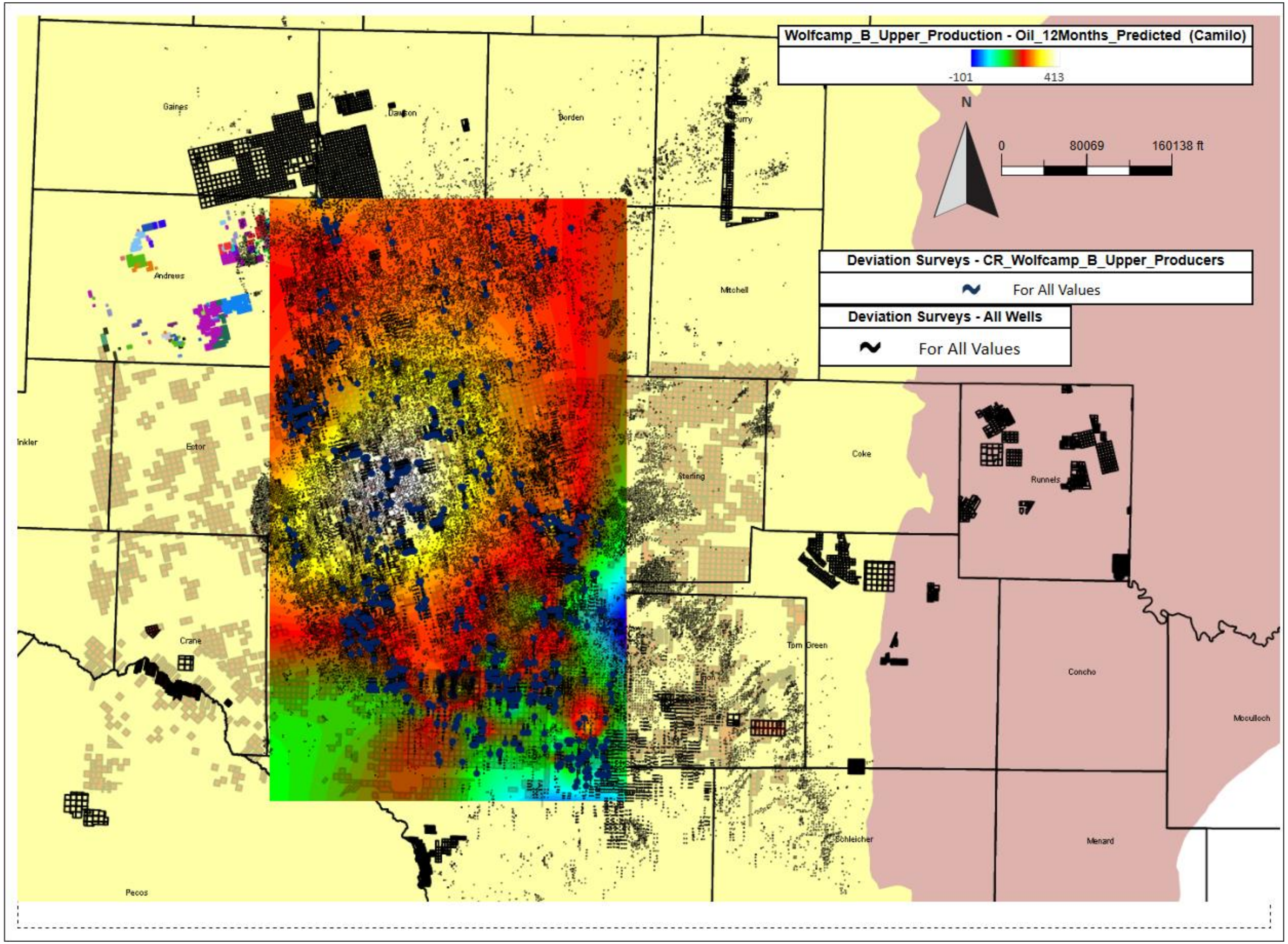
In this study, we run a lineal regression modeling technique to combine every variable to predict production. The results shows a correlation coefficient of 0.647 between predicted first 12 month production versus 12 months production (left). On the right one can see the variable importance for the model in decreasing order, and thus their weight or contribution on the final model

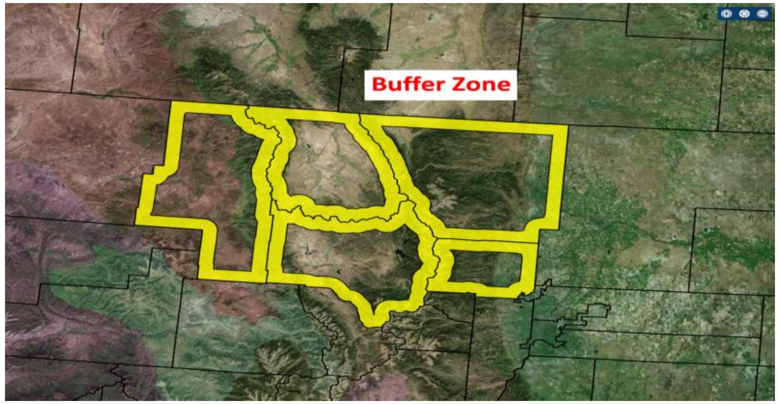
First 12 months average production prediction map.

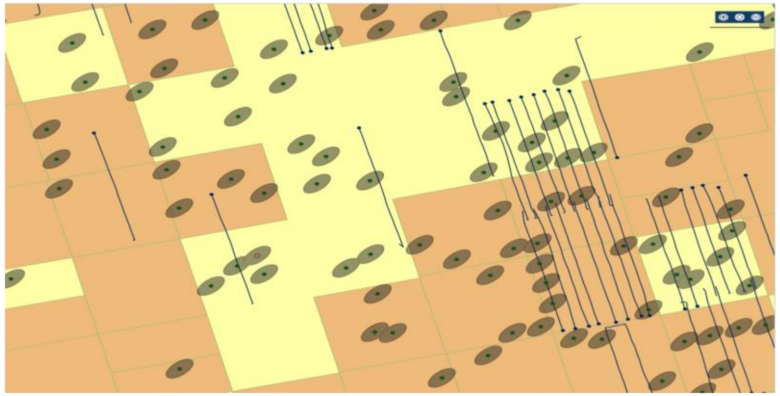
This predicted map assumes that all the wells in the area were drilled with same engineering parameters (horizontal length, frac stages, fluids volumes, etc.). The variables were normalized to their optimum predicted values.

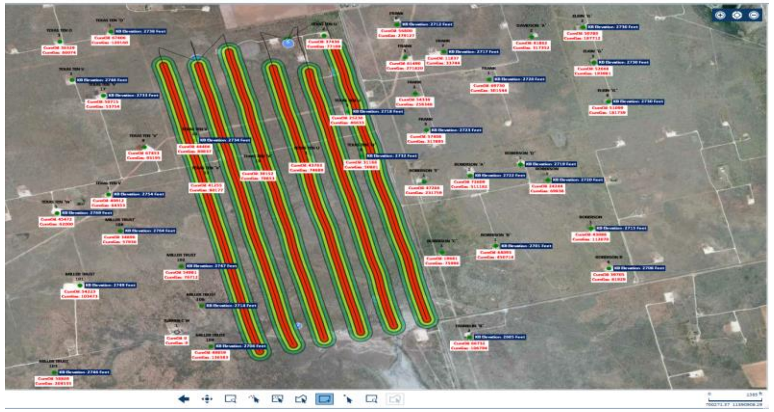


First 12 months average production prediction map. Over posting are: Wolfcamp B producers wells in blue (all of them are horizontals), in black all the other wells in the Midland basin producing from other formations, and underneath the map and wells, one can see the leases. GIS Buffering technology is imperative to eliminate the influence of current drainage areas, geohazards and lease regulations.



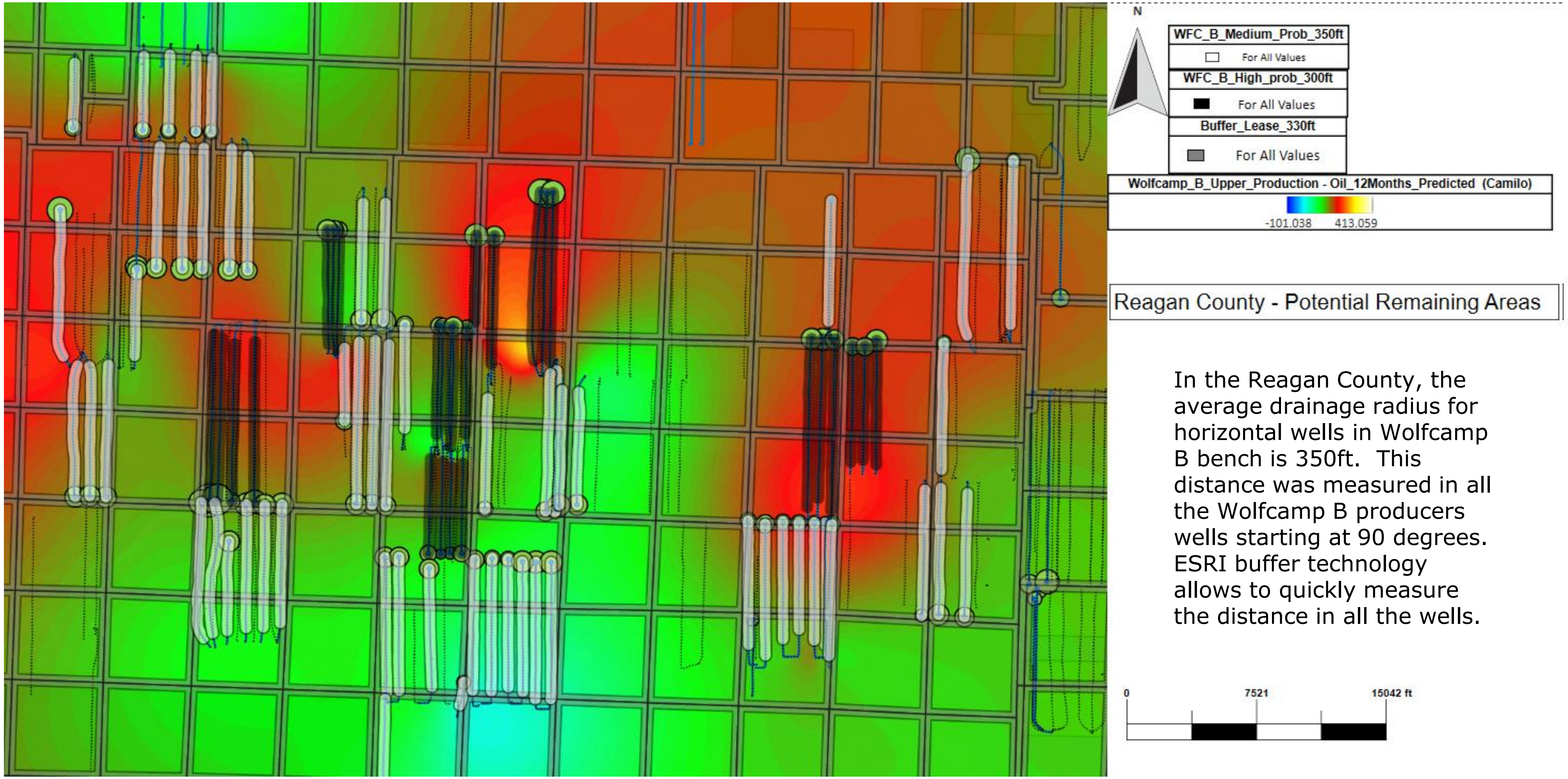






The data sources for buffering calculations are different depending on the target layer to be analyzed. Because the huge amount of data, the automation in the measurements is essential:

1. Cultural Data: Simple scenario, just measurement along the target entity.
2. Vertical Wells: Drainage is given in area units oriented along the preferred fracture direction (Production and Zones tables)
3. Horizontal wells: Drainage area has to be calculated along the completion stages and then normalized to the entire lateral length. (Production, Zone Tables, Completion, and Survey tables).



Reagan County - Potential Remaining Areas

In the Reagan County, the average drainage radius for horizontal wells in Wolfcamp B bench is 350ft. This distance was measured in all the Wolfcamp B producers wells starting at 90 degrees. ESRI buffer technology allows to quickly measure the distance in all the wells.

Proposed drill areas

N

WFC_B_Medium_Prob_350ft
For All Values
WFC_B_High_prob_300ft
For All Values
Buffer_Lease_330ft
For All Values
Wolfcamp_B_Upper_Production - Oil_12Months_Predicted (Camilo)
-101.038 413.059

Reagan County - Potential Remaining Areas

Leases regulations- Buffer distance are very variable even in the same state, but typically for Permian Basin this distance is 330ft (gray polygons). In black we are accounting for the influence of other wells in the area (Non-Wolfcamp B Producers) – 250ft

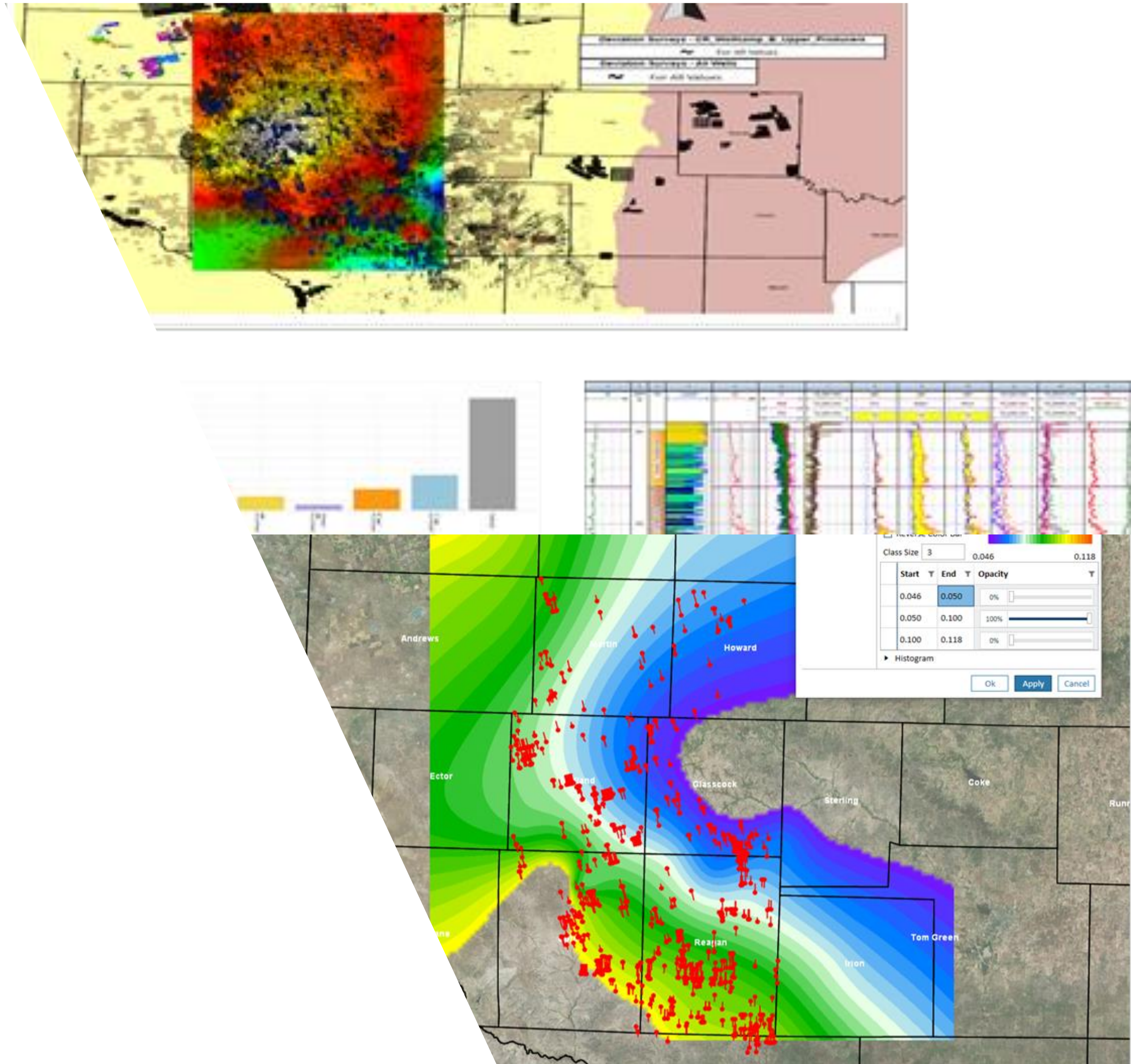
0 7521 15042 ft

Conclusions

- Predictive analytics can be applied at any stage during the interpretation process: in this project, multi-lineal regression was use to get one production map including multiple attributes. Also, Gradient boosting tree was used to complete missing log data, which enabled petrophysical interpretation.

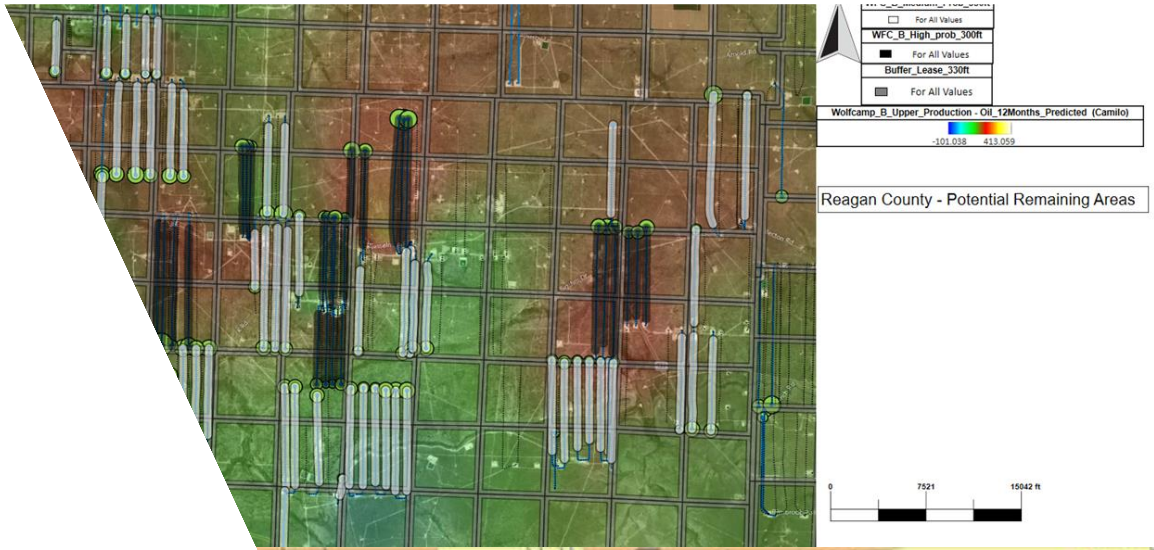
- Multiple machine learning algorithms should be run for classification and predictive models. This will help to validate results and will allow to select the best model.

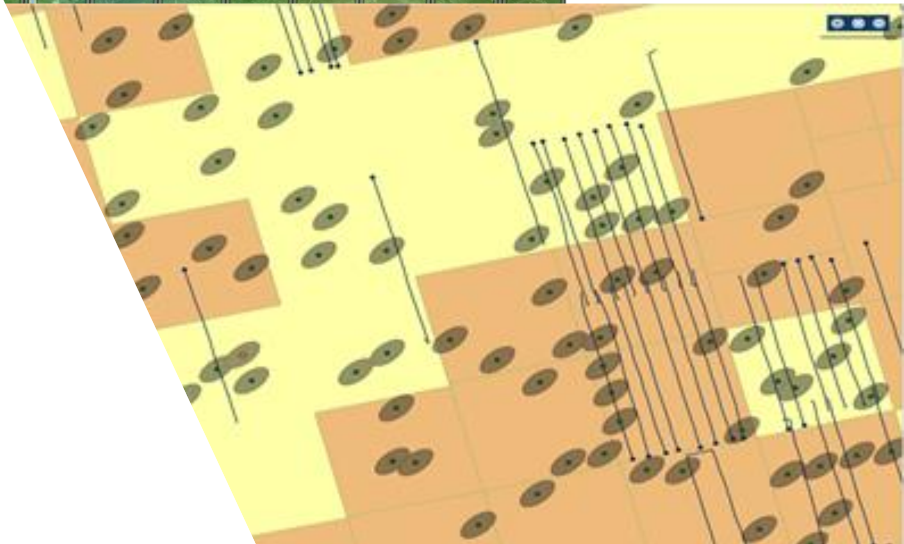
- Geological mapping is advancing in the direction of data analytics. In unconventional reservoirs, the optimum drilling areas are not longer a function of key geological, geophysical or petrophysical properties; it is now function of all of the above combined with rock mechanics, geochemistry, drilling and completions parameters. Advance multivariate analytics techniques are used get fewer maps that include all the information available.



Conclusions

- In highly well populated areas, the final maps have to be combined with advance buffering technology to quickly detect and account for the influence of drainage areas in existing wells (vertical or horizontal), keep reasonable distance from other wells targeting other producing formations, lease regulations, pipelines, and geohazards (rivers, roads, protected areas), etc. This buffering measurements in combination with geological mapping and pad planning is the new foundation for field planning.
- In Midland basin, Reagan county, the best producers wells for Wolfcamp B bench are mainly related to geological position (deeper and thicker areas) and the amount of proppant and sand quality to keep the fractures open.
- Other analytical techniques (like classification trees) can be used to determine the recommended drilling ranges parameters (it was not part of this job)





Thank you!!

Camilo Rodriguez
Associate Director, Product Management