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

Breton, C.L., S.P. Dutton, and R.F. Broadhead, 2008, Digital Oil-Play Maps of the Permian Basin: AAPG Annual Convention, San Antonio, Texas, April 20-23, 2008, Search and Discovery Article #40333 (2008). Website accessed October 2018.

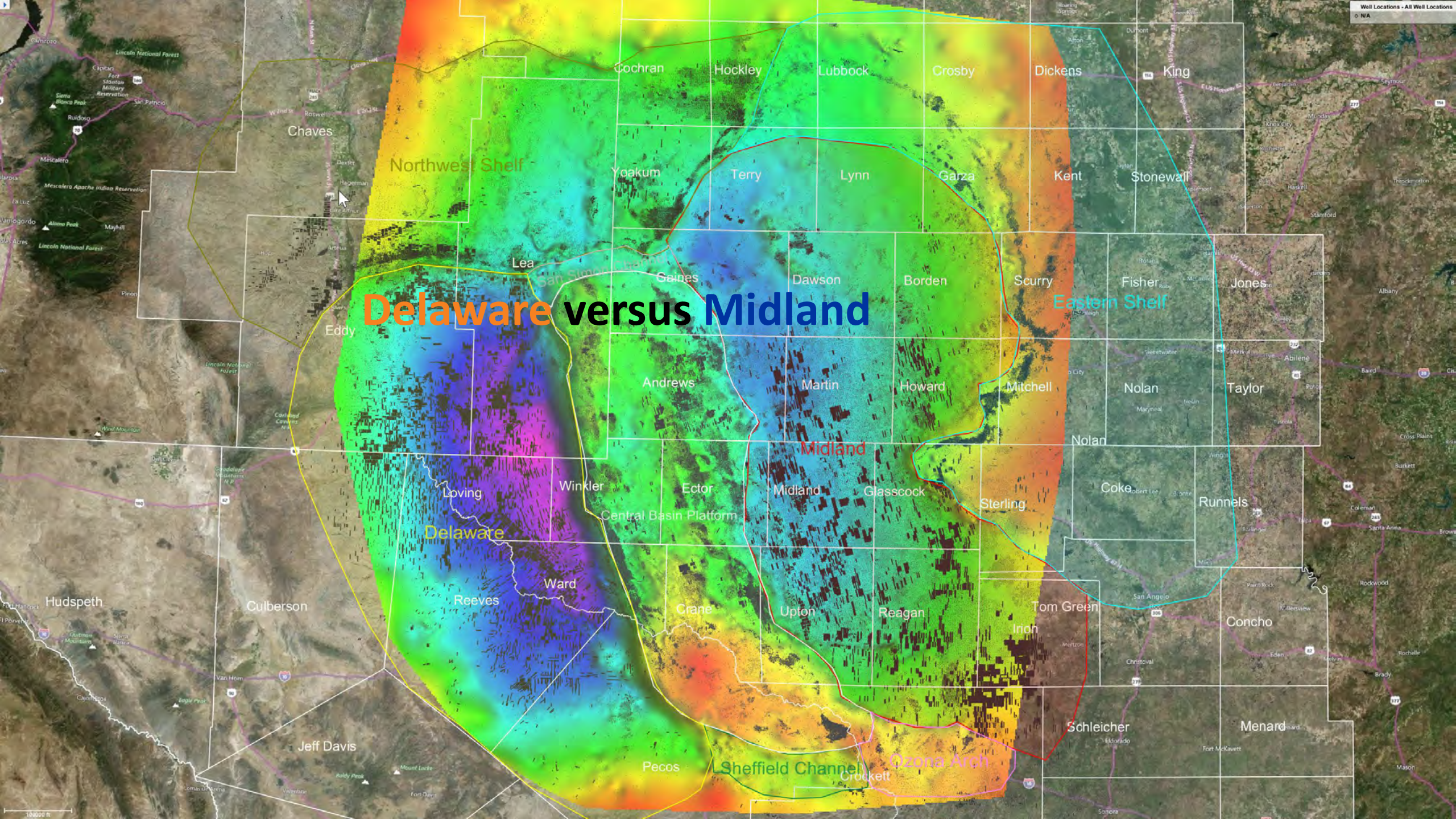
Handford, C.P. 1981, Sedimentology and Genetic Stratigraphy of Dean and Spraberry Formations (Permian), Midland Basin, Texas: American Association of Petroleum Geologists Bulletin, 65/9, p. 1602-1616. doi:10.1306/03B5962A-16D1-11D7-8645000102C1865D

PERMIAN STACKED-PAY POTENTIAL ASSESSMENT USING MULTI-DISCIPLINARY ANALYTICS

GROUND TRUTH

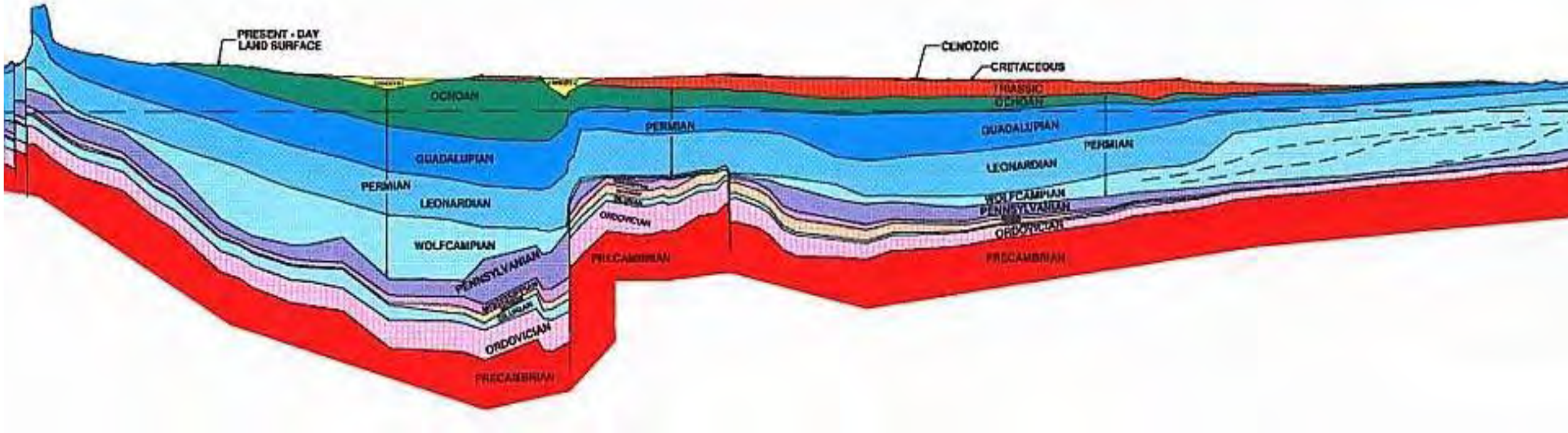
Bracketology (according to IBM Watson…)

With "Big Data Analytics" do we even have to play the games anymore…….?


Delaware versus Midland
Northwest Shelf
Eastern Shelf
Central Basin Platform
Delaware
Midland
Sheffield Channel
Ozona Arch
Cochran
Hockley
Lubbock
Crosby
Dickens
King
Chaves
Yoakum
Terry
Lynn
Garza
Kent
Stonewall
Lea
Gaines
Dawson
Borden
Scurry
Fisher
Jones
Eddy
Andrews
Martin
Howard
Mitchell
Nolan
Taylor
Abilene
Loving
Winkler
Ector
Midland
Glasscock
Sterling
Coke
Runnels
Ward
Reeves
Crane
Upton
Reagan
Irion
Tom Green
Concho
Hudspeth
Culberson
Jeff Davis
Pecos
Crockett
Schleicher
Menard

Gross Permian Basin Cross-Section

Delaware versus Midland



UTPB Website 2017

Permian Basin Formations

Delaware versus Midland

Leonardian versus Wolfcampian

Delaware Basin Stratigraphic Formations

Period	Series	Formations
Guadalupian (271-260 mya)	Delaware Group	Lamar Bell Canyon Cherry Canyon Brushy Canyon
Leonardian (280-271 mya)	Upper Avalon Shale Lower Avalon Shale 1st Bone Spring 2nd Bone Spring 3rd Bone Spring	
Wolfcampian (299-280 mya)	Wolfcamp	
Pennsylvanian (323-299 mya)	Pennsylvanian	

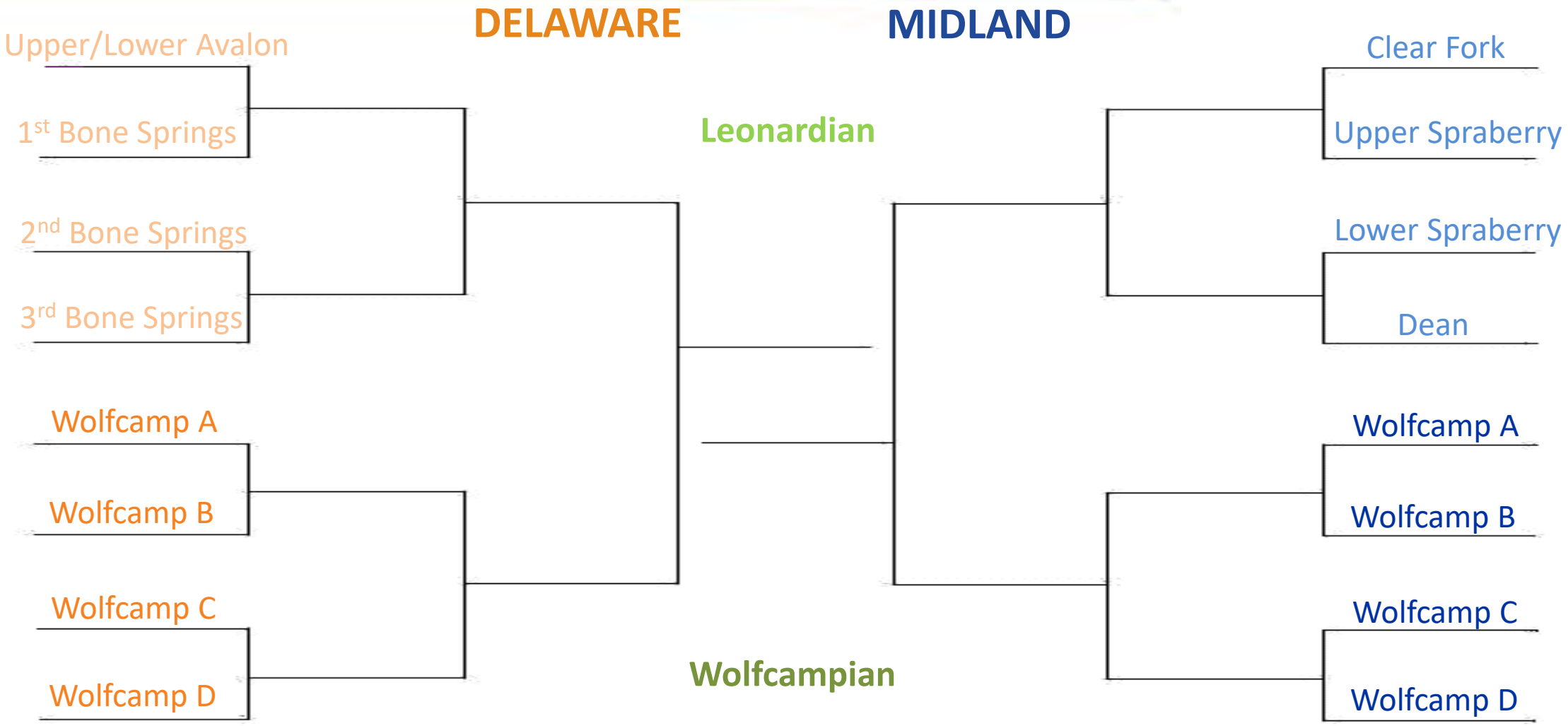
Central Basin Platform Stratigraphy

Period	Series	Formations
Guadalupian (271-260 mya)	White Horse	Tansil Yates Seven Rivers Queen Grayburg
	Ward	San Andreas Glorietta
Leonardian (280 -271 mya)	Yeso	Paddock Blinebry Tubb Drinkard
	Abo	
Wolfcampian (299-280 mya)	Wolfcamp	
Pennsylvanian (323-299 mya)	Pennsylvanian	

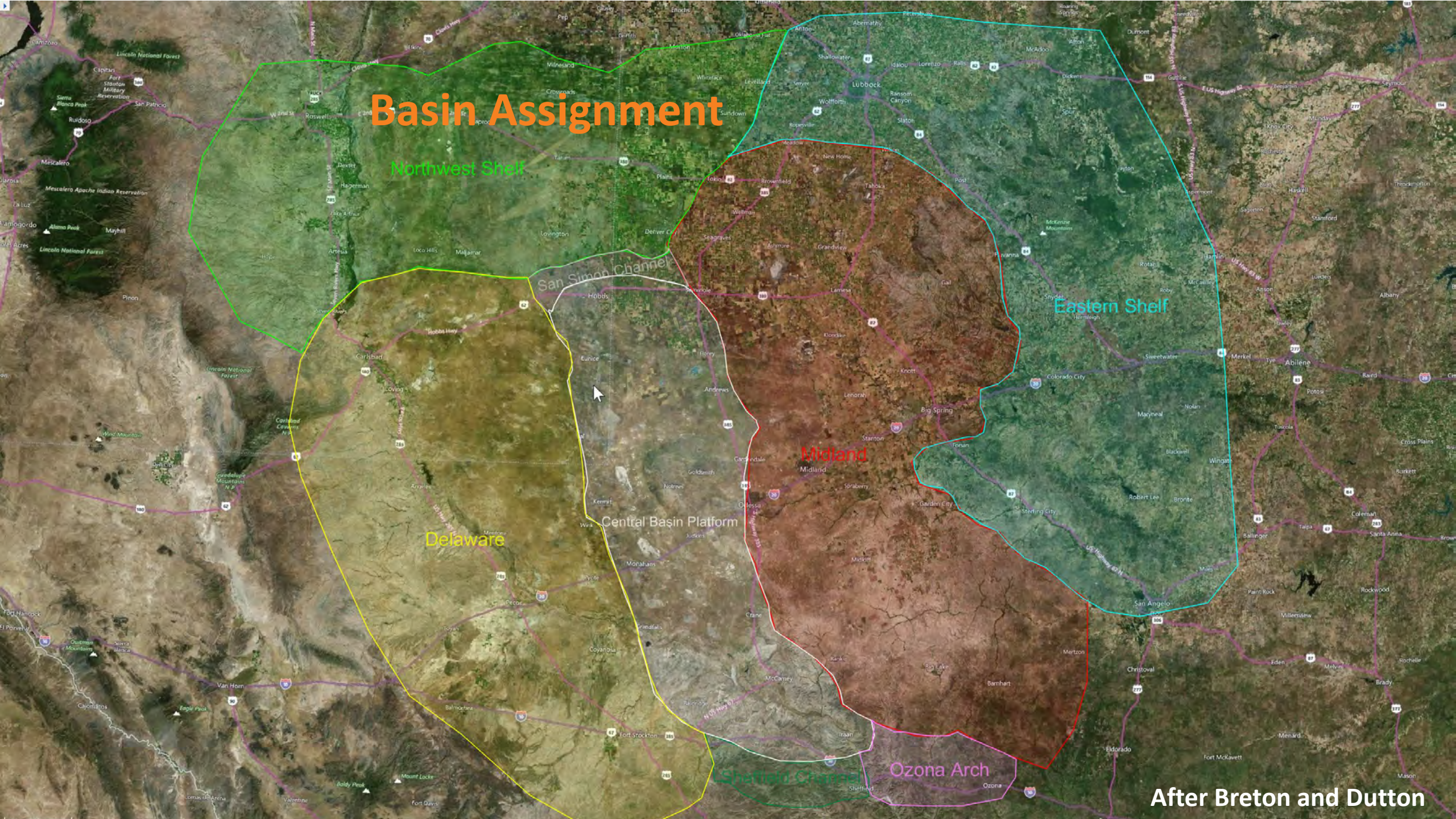
Midland Basin Stratigraphic Formations

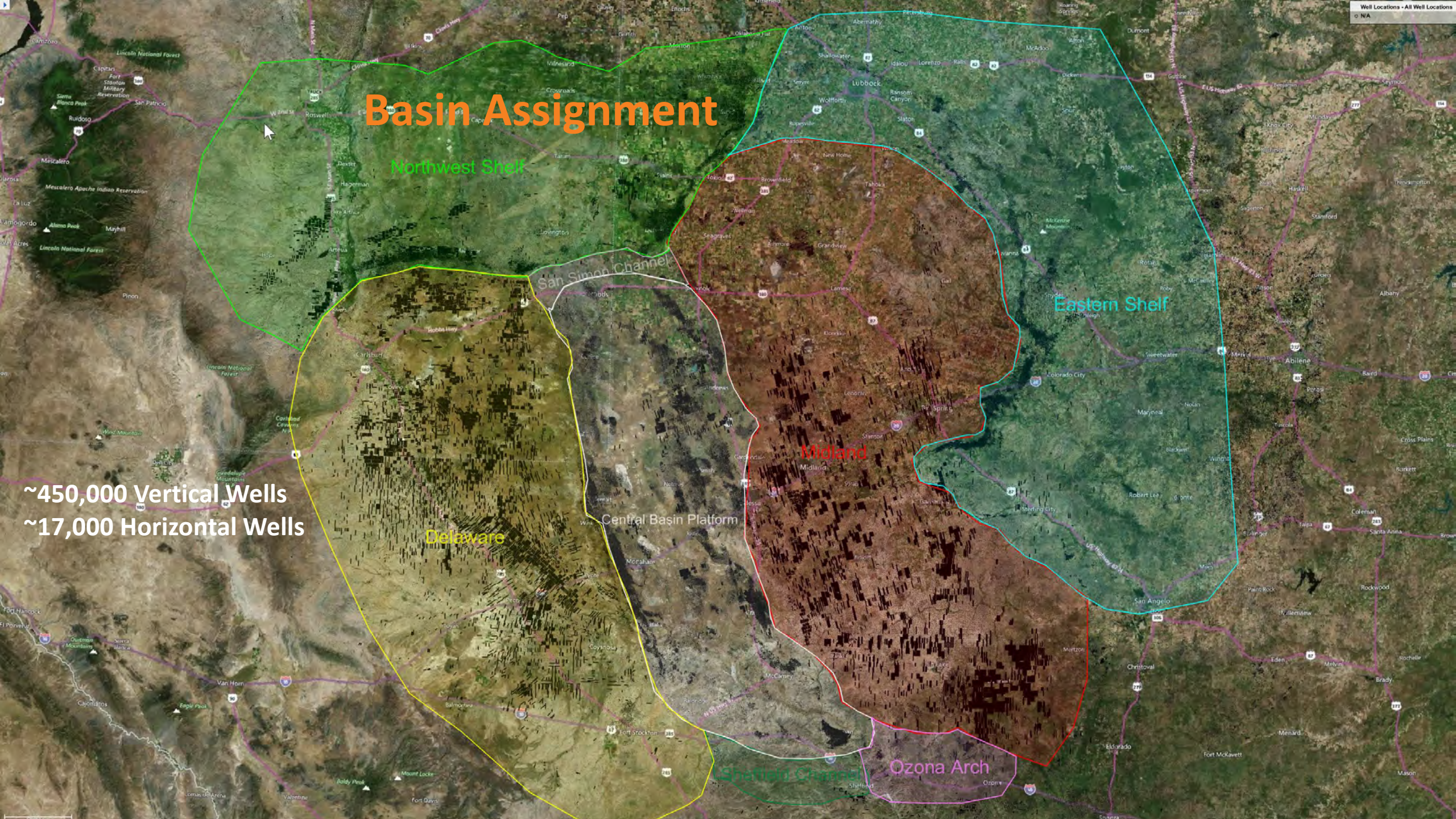
Period	Series	Formations
Guadalupian (271-260 mya)	White Horse	Yansil Yates Seven Rivers Queen Grayburg
	Ward	San Andreas Glorietta
Leonardian (280-271 mya)	Clear Fork	Upper Leonard
	Upper Spraberry	
	Lower Spraberry	
	Dean	
Wolfcampian (299-280 mya)	Wolfcamp	
Pennsylvanian (323-299 mya)	Pennsylvanian	

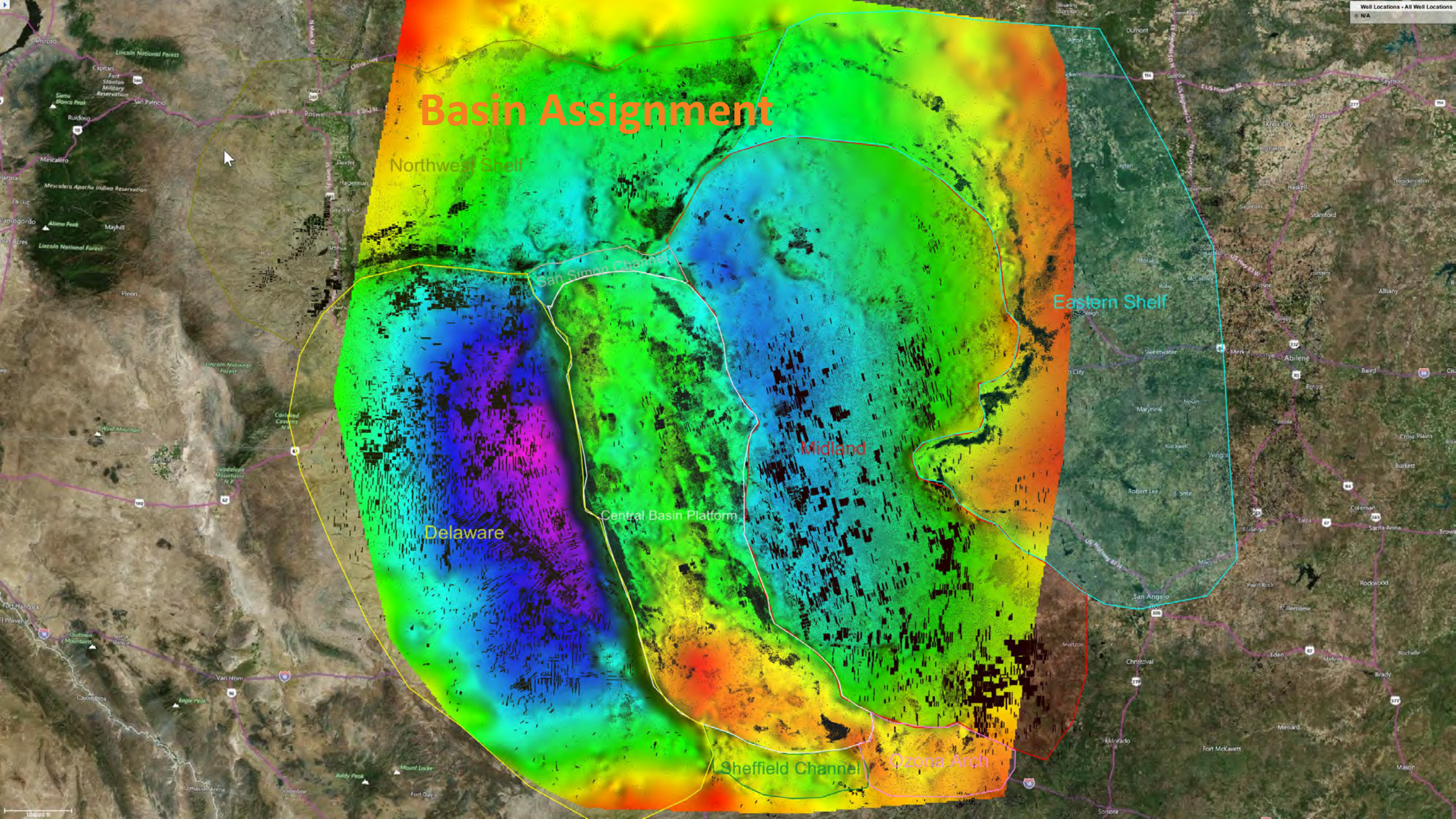
Permian Basin "Sweet Sixteen"

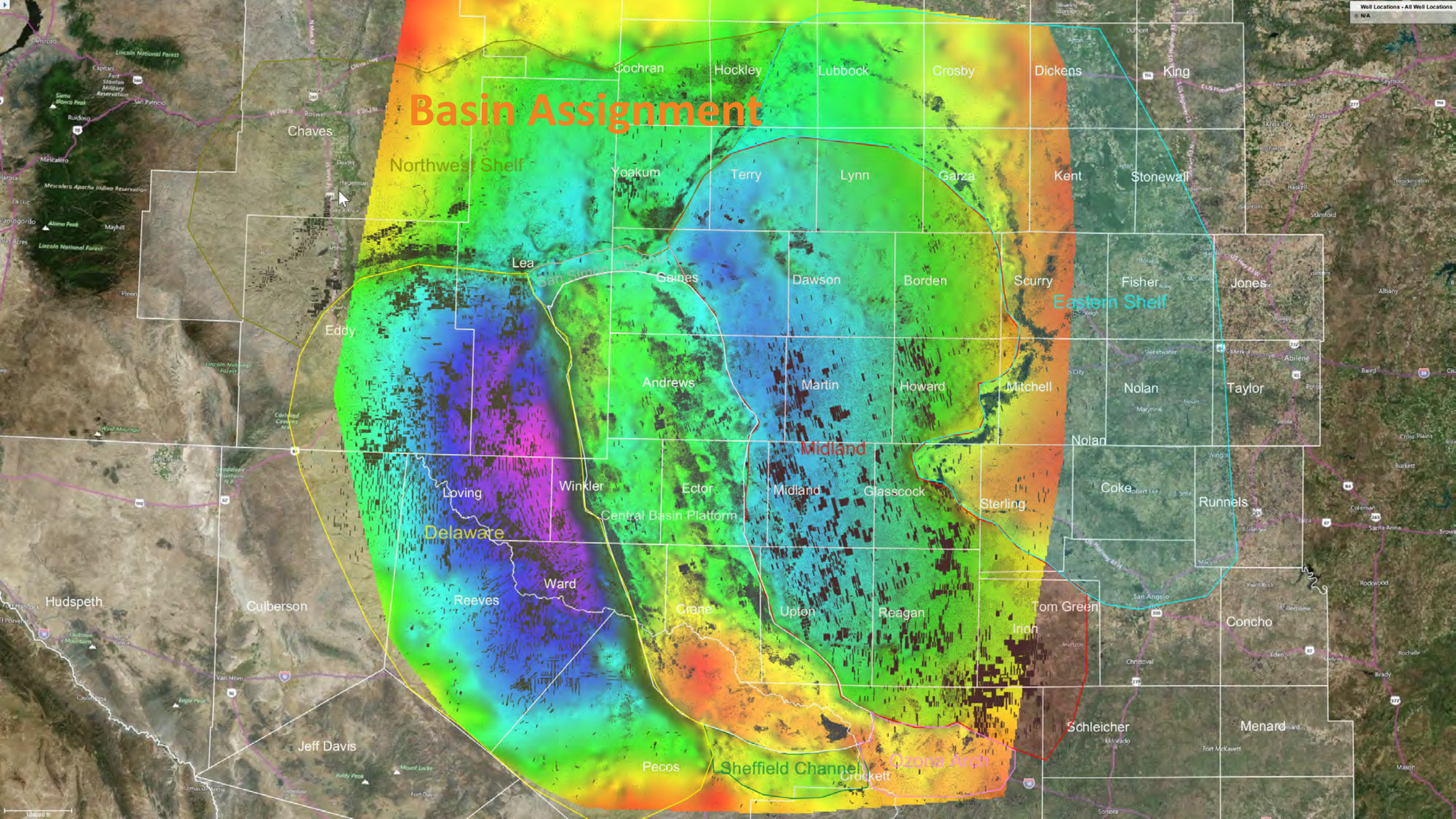


BACKGROUND


Basin Assignment
Northwest Shelf
San Simon Channel
Eastern Shelf
Midland
Central Basin Platform
Delaware
Sheffield Channel
Ozona Arch
After Breton and Dutton


Basin Assignment
Northwest Shelf
Eastern Shelf
Midland
Delaware
Central Basin Platform
San Simon Channel
Sheffield Channel
Ozona Arch
~450,000 Vertical Wells
~17,000 Horizontal Wells


Basin Assignment
Northwest Shelf
San Simon Channel
Eastern Shelf
Midland
Central Basin Platform
Delaware
Sheffield Channel
Ozona Arch
Well Locations - All Well Locations
N/A


Basin Assignment
Northwest Shelf
Eastern Shelf
Central Basin Platform
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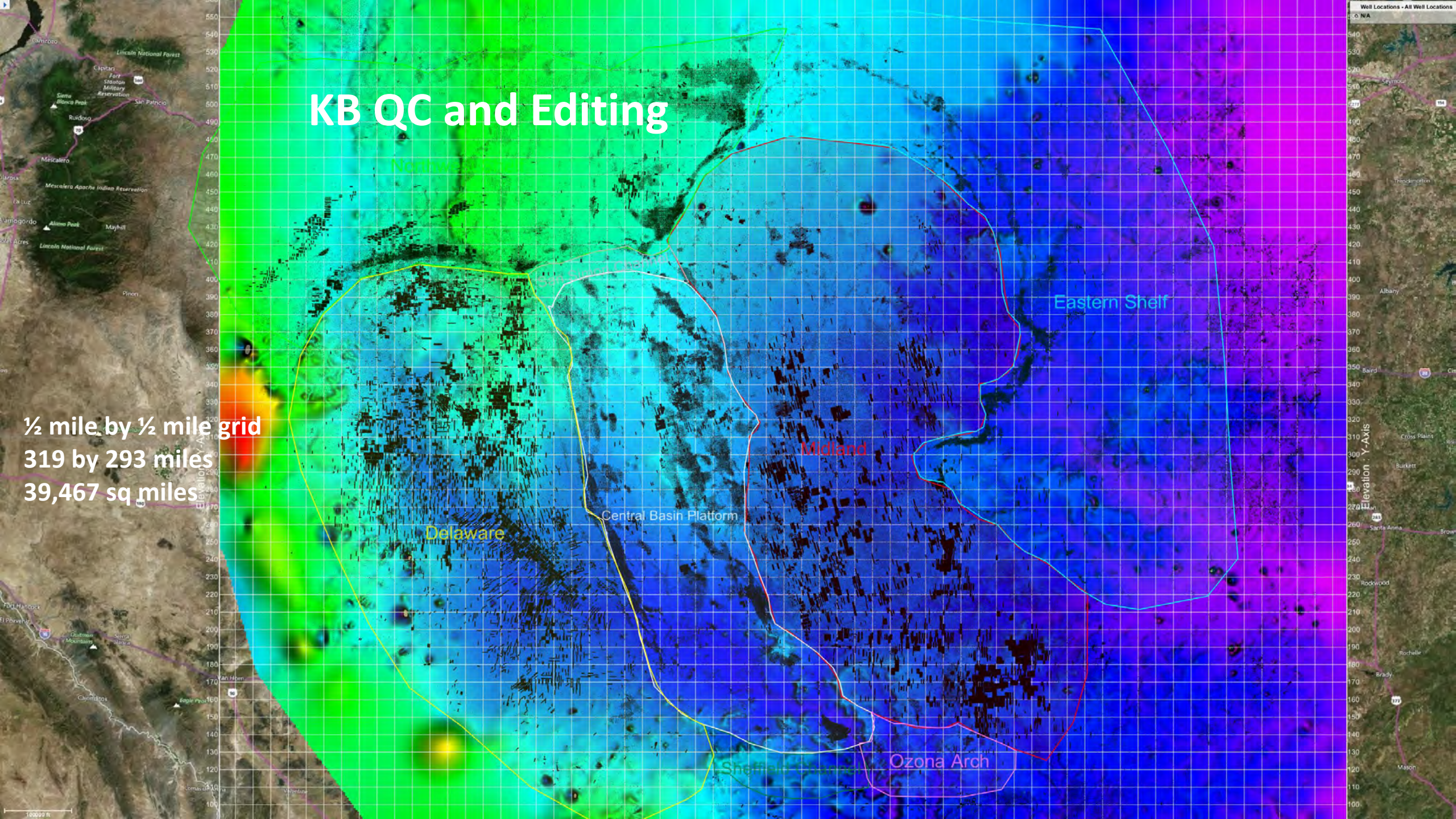
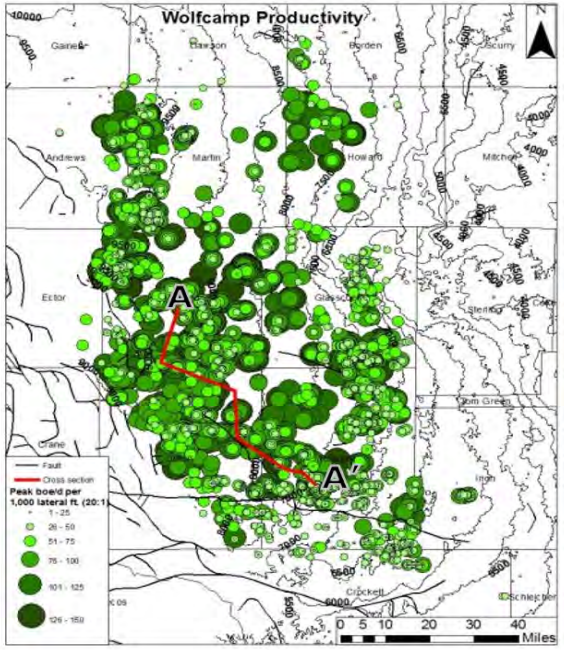
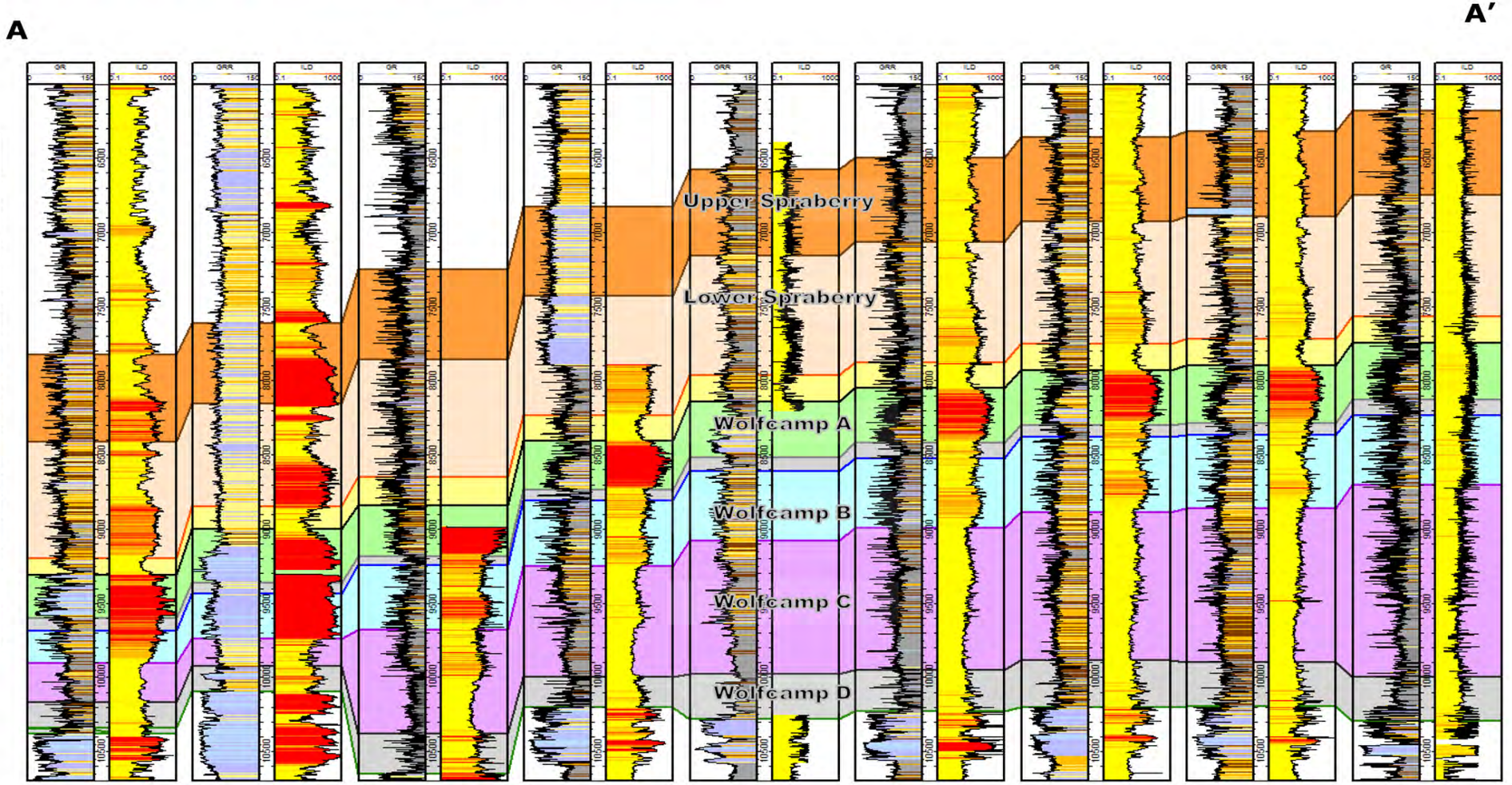
Midland
Sheffield Channel
Ozona Arch
Cochran
Hockley
Lubbock
Crosby
Dickens
King
Chaves
Yoakum
Terry
Lynn
Garza
Kent
Stonewall
Lea
Gaines
Dawson
Borden
Scurry
Fisher
Jones
Eddy
Andrews
Martin
Howard
Mitchell
Nolan
Taylor
Abilene
Loving
Winkler
Ector
Midland
Glasscock
Sterling
Coke
Runnels
Ward
Reeves
Crane
Upton
Reagan
Irion
Tom Green
Concho
Hudspeth
Culberson
Jeff Davis
Pecos
Crockett
Schleicher
Menard


KB QC and Editing
½ mile by ½ mile grid
319 by 293 miles
39,467 sq miles
Northwest Shelf
Eastern Shelf
Midland
Central Basin Platform
Delaware
Ozona Arch
Elevation - Y-Axis
Well Locations - All Well Locations

Used IHS GDS Geologic Tops

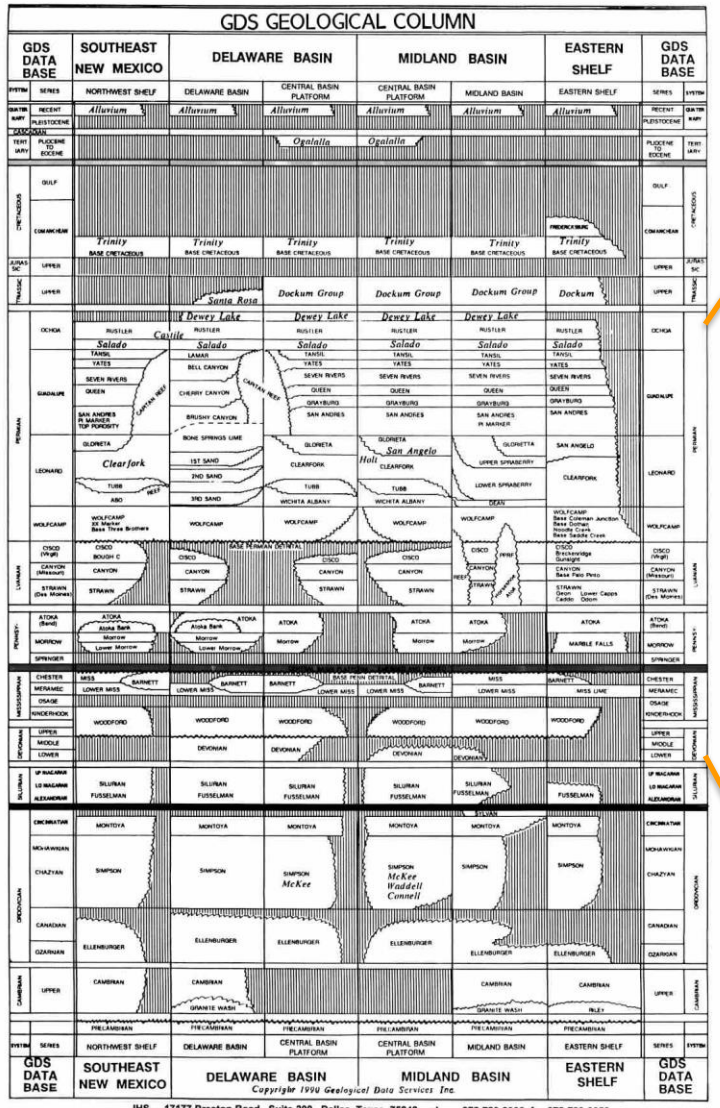
Wolfcamp bench performance varies throughout basin

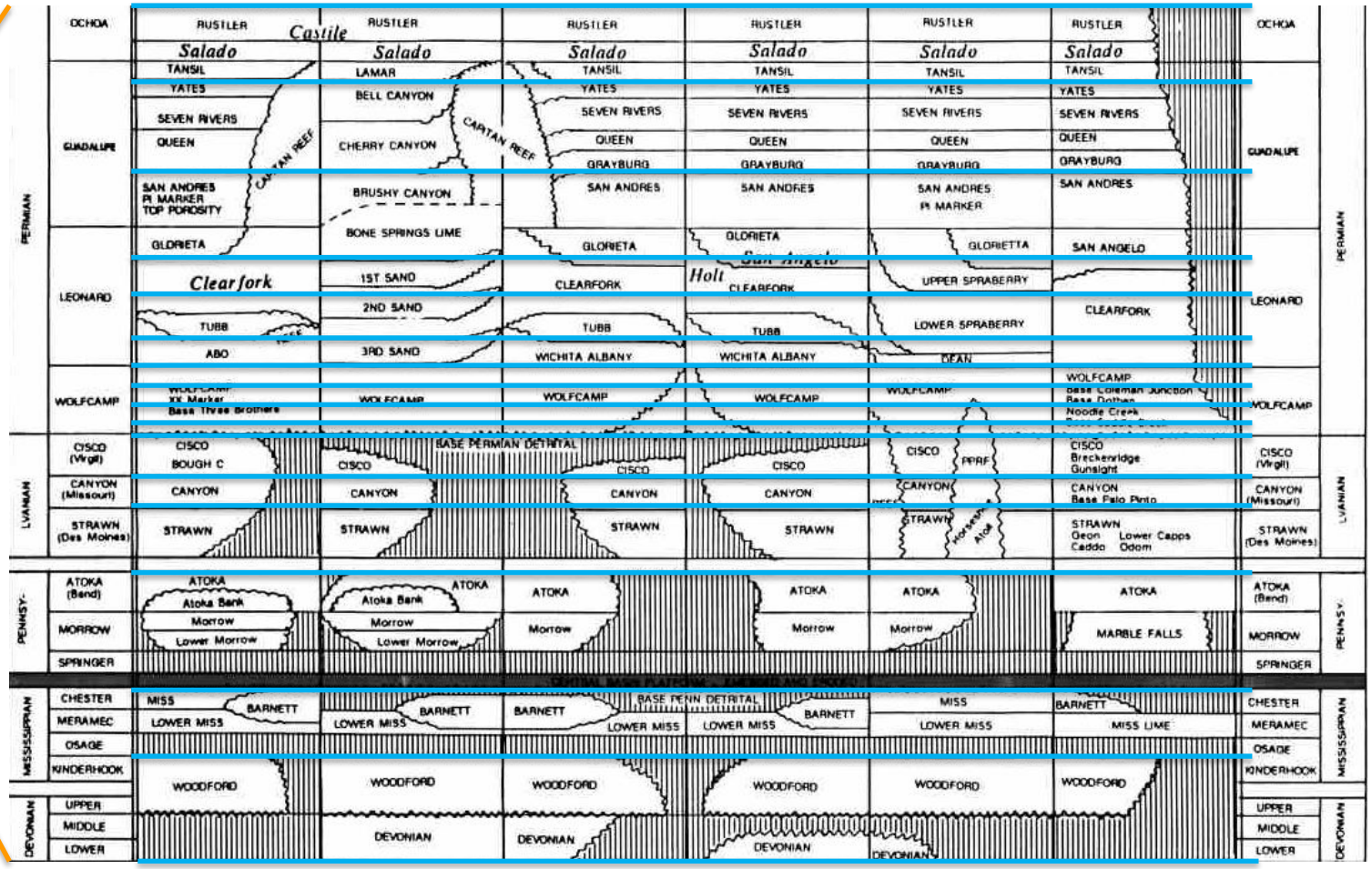




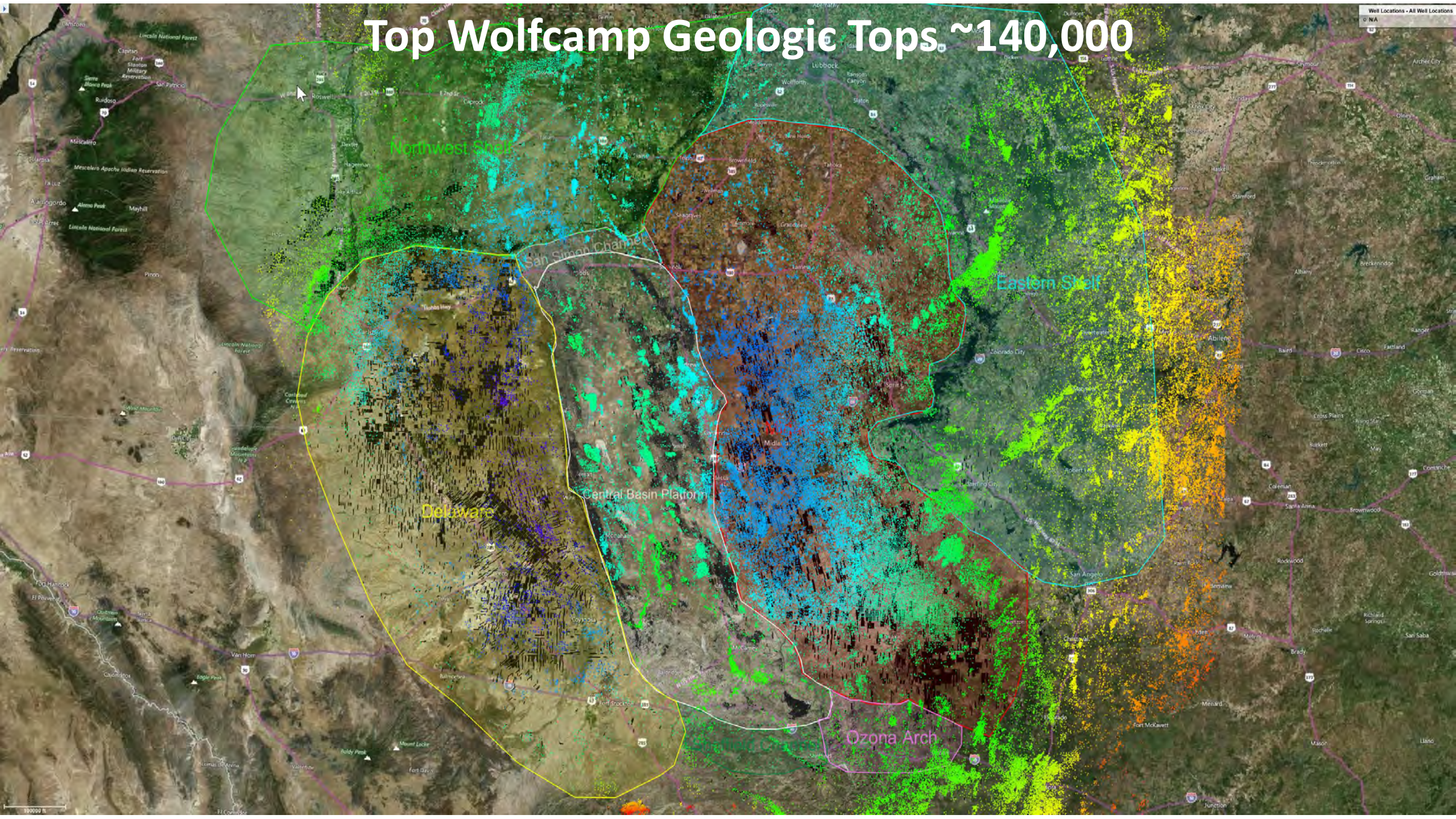
Courtesy Lauren Droege and Emilie Gubian, IHS Markit

20 Grids created across the Permian

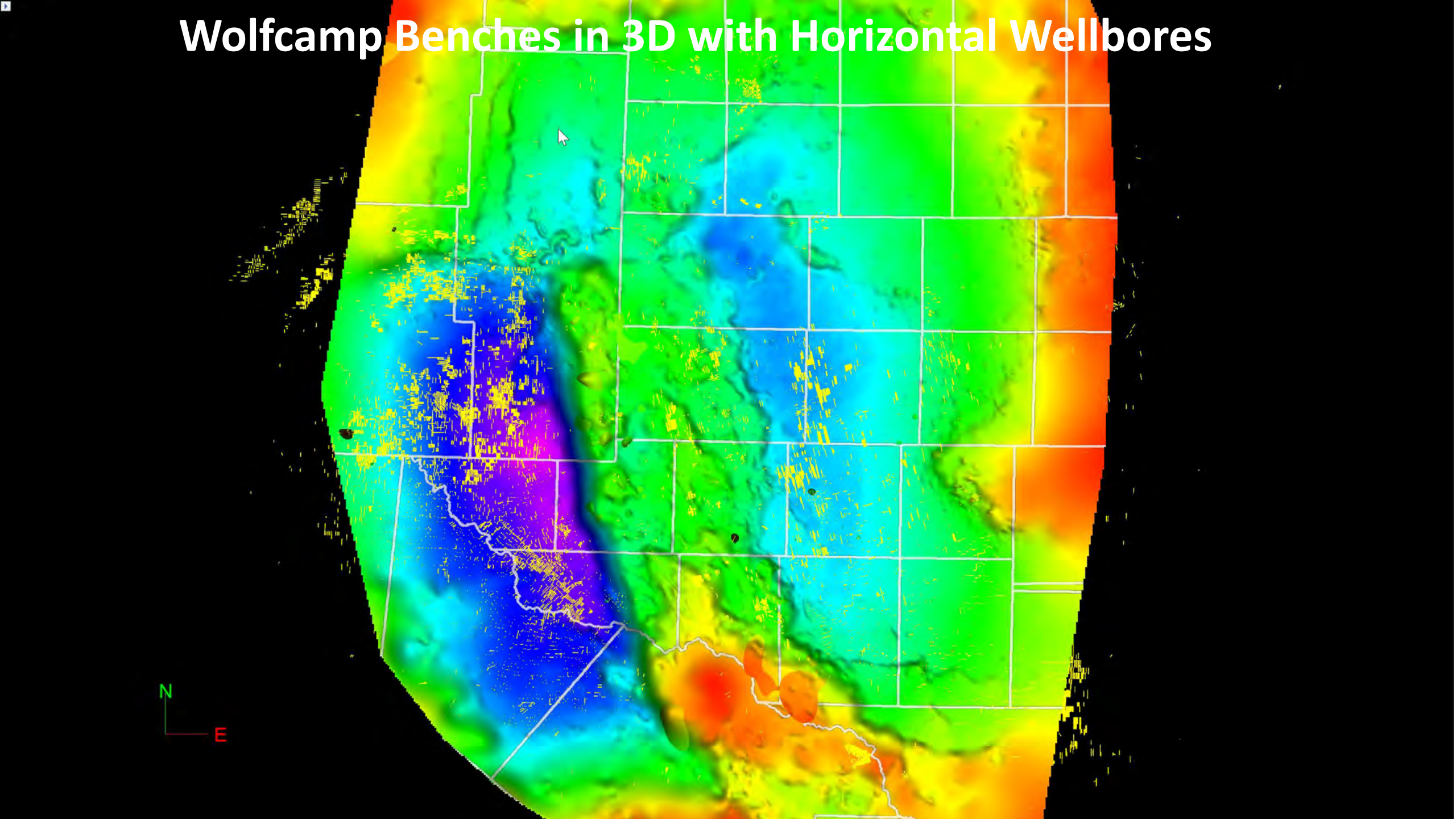




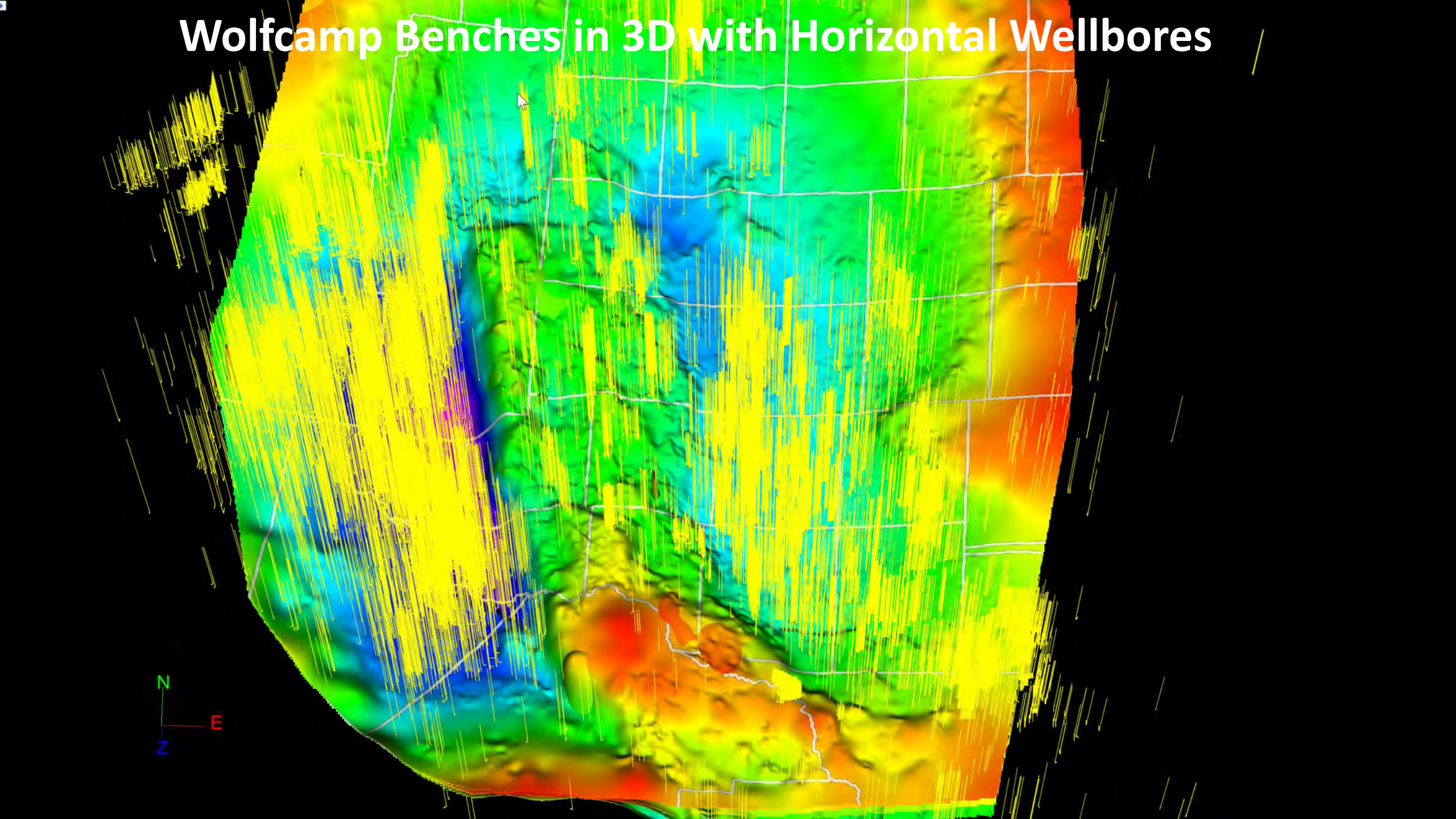
Top Wolfcamp Geologic Tops ~140,000



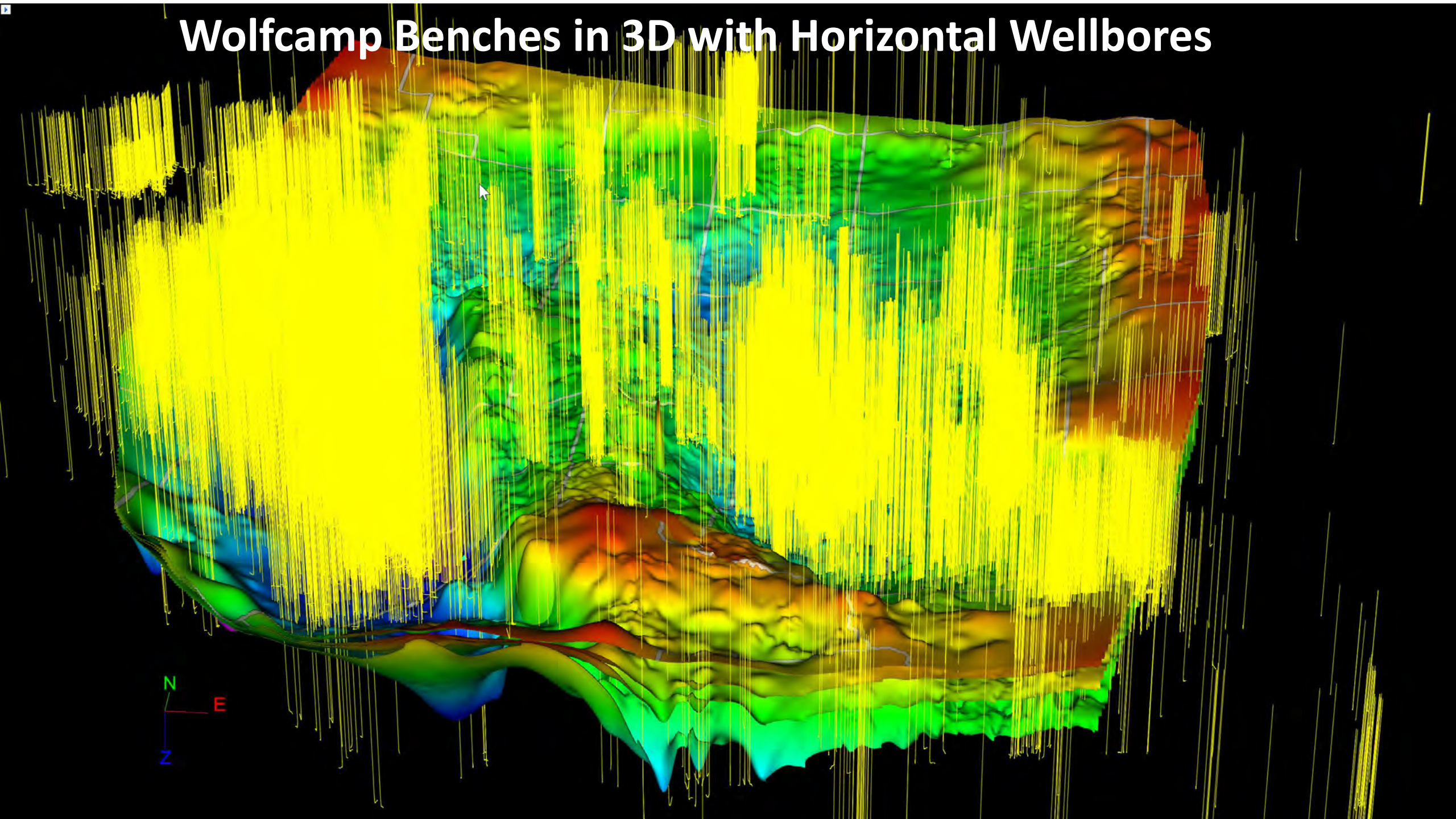
Wolfcamp Benches in 3D with Horizontal Wellbores



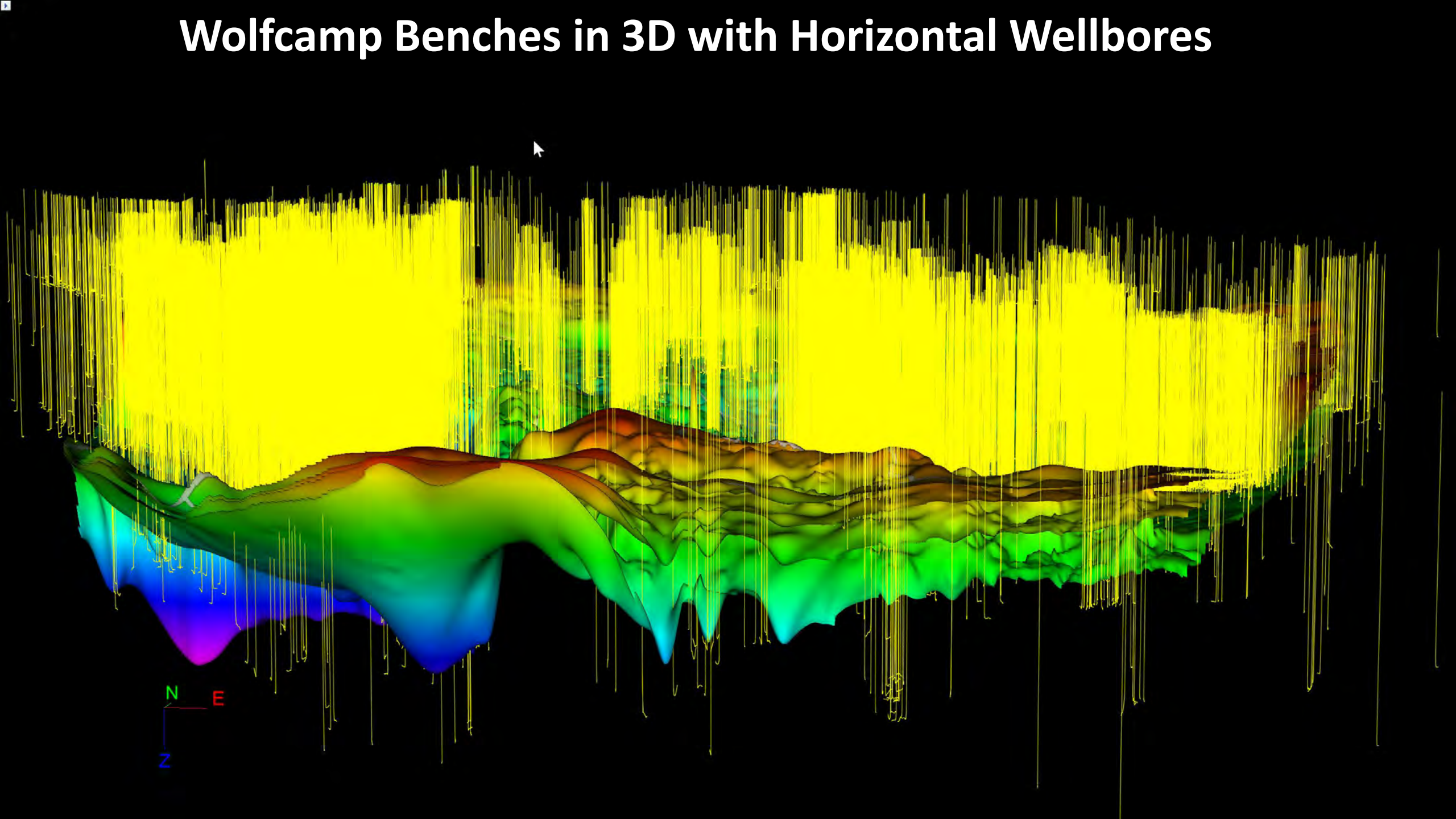
Wolfcamp Benches in 3D with Horizontal Wellbores



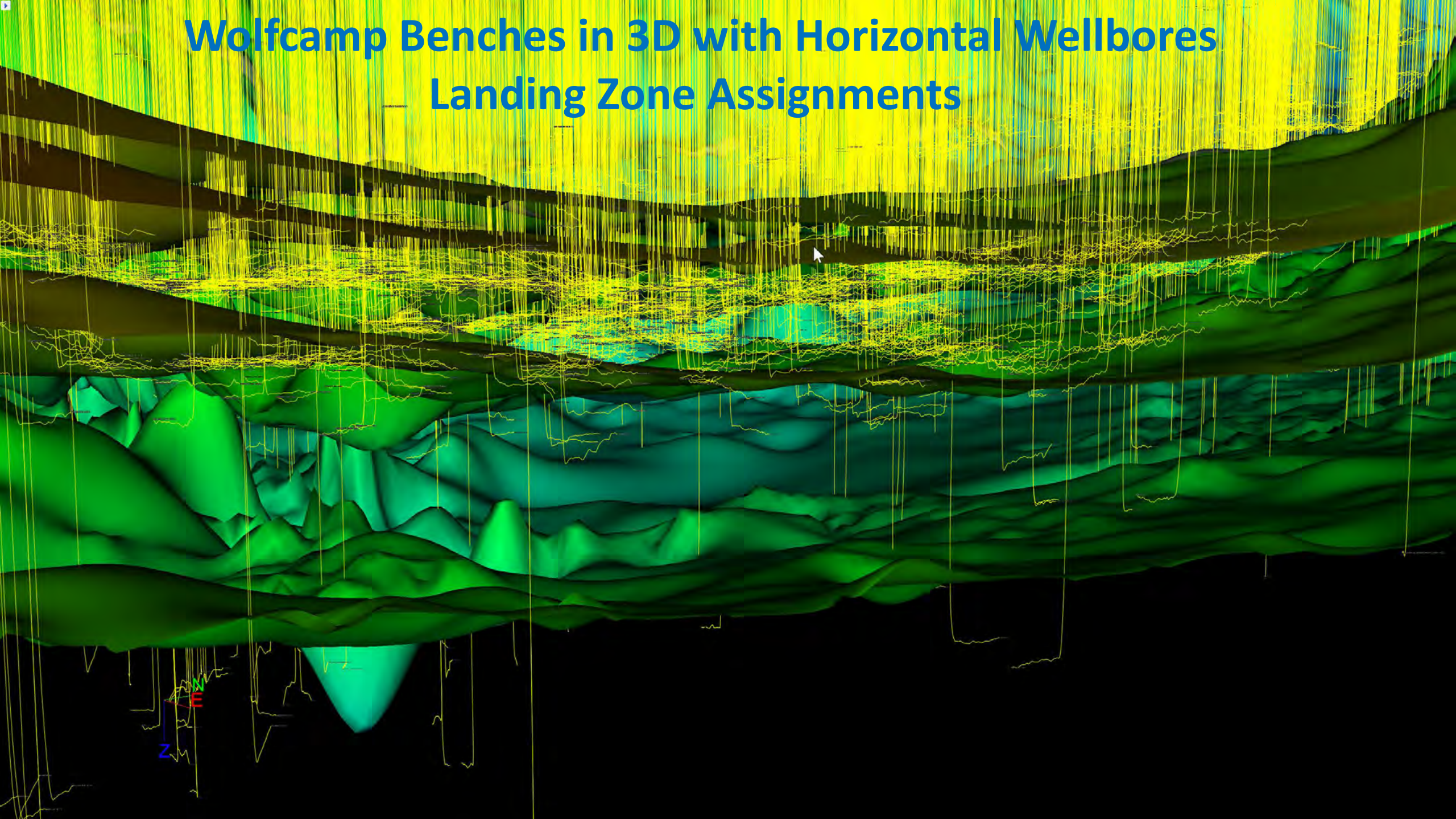
Wolfcamp Benches in 3D with Horizontal Wellbores



Wolfcamp Benches in 3D with Horizontal Wellbores

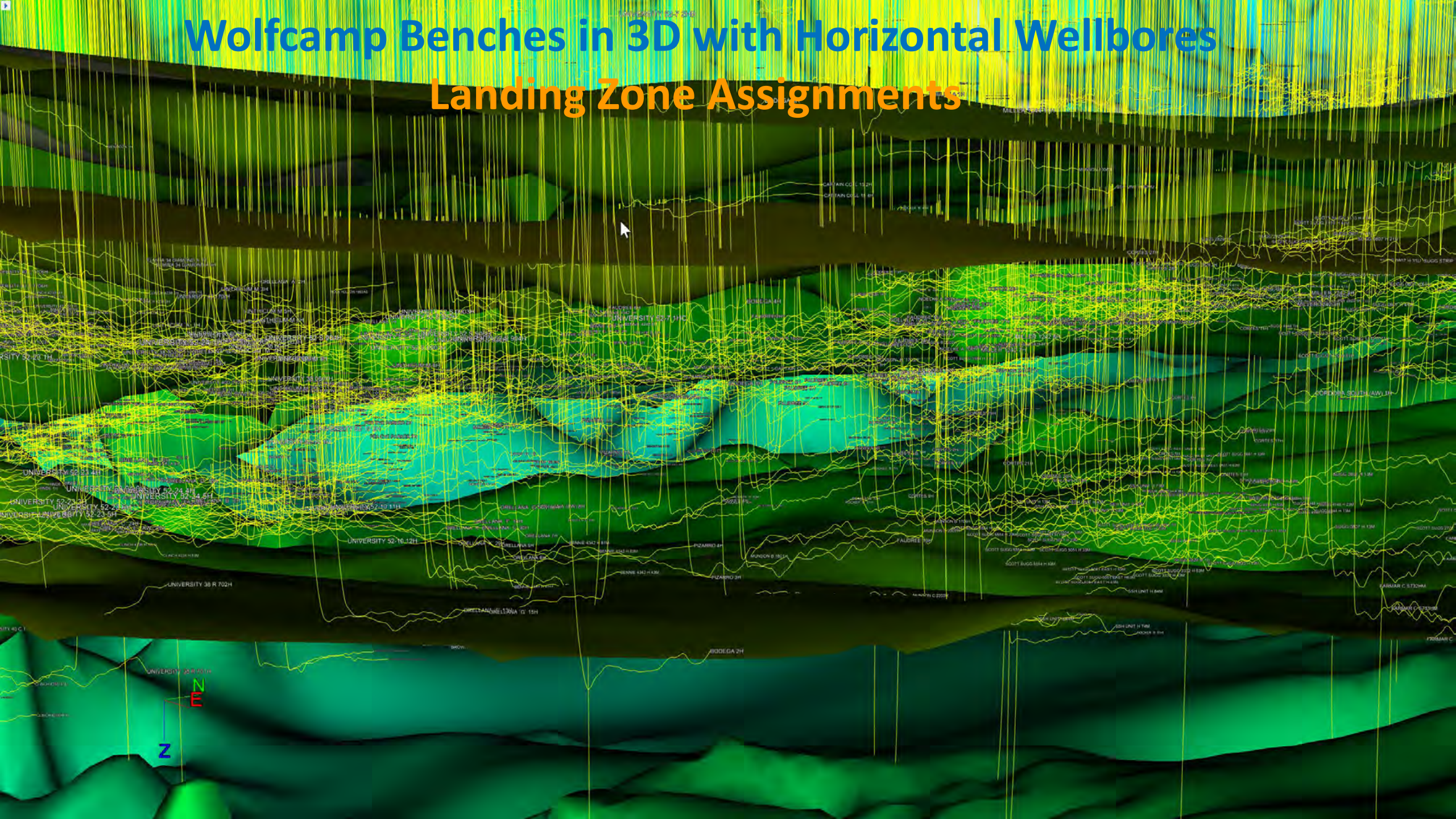


Wolfcamp Benches in 3D with Horizontal Wellbores
Landing Zone Assignments



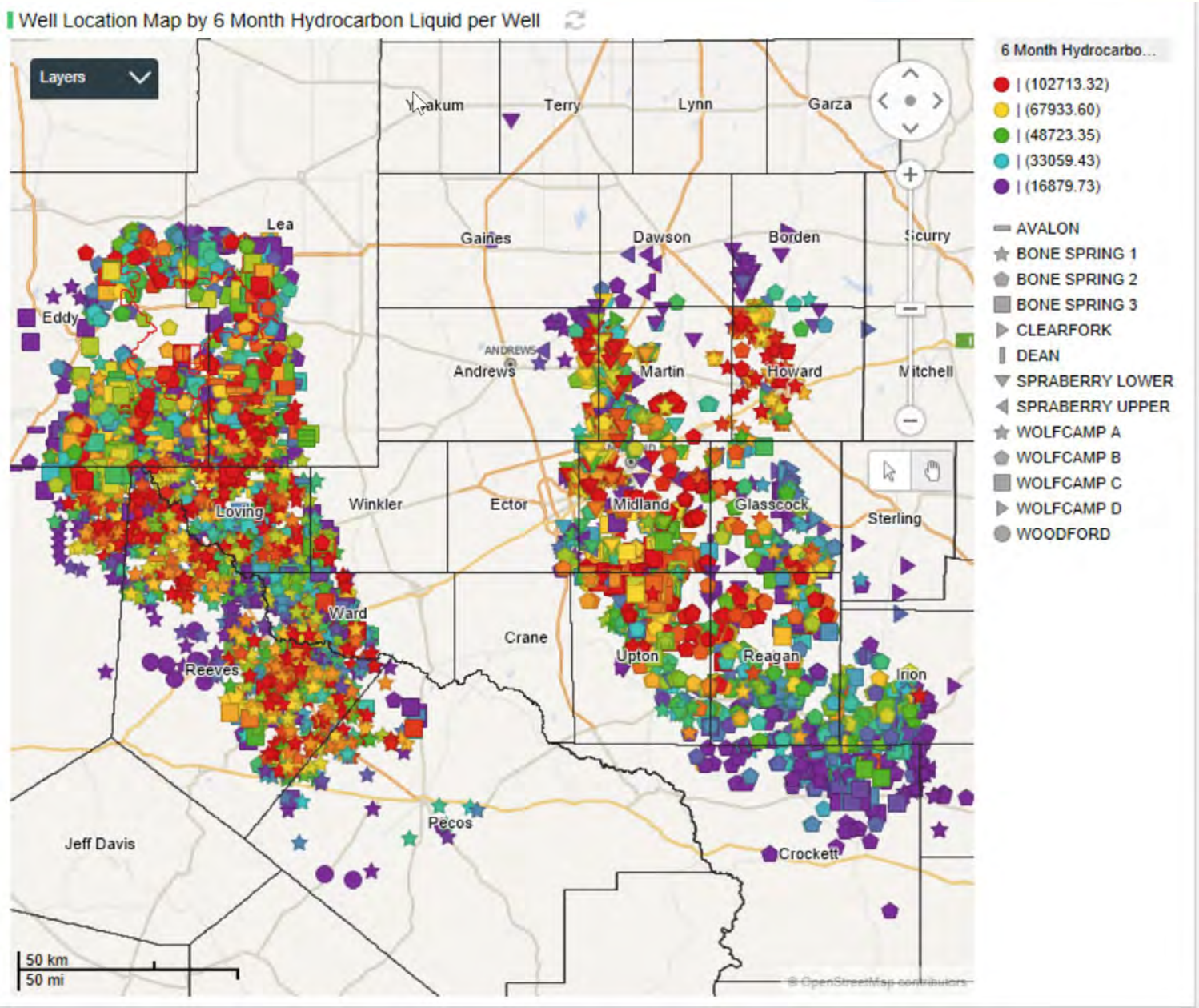
Wolfcamp Benches in 3D with Horizontal Wellbores

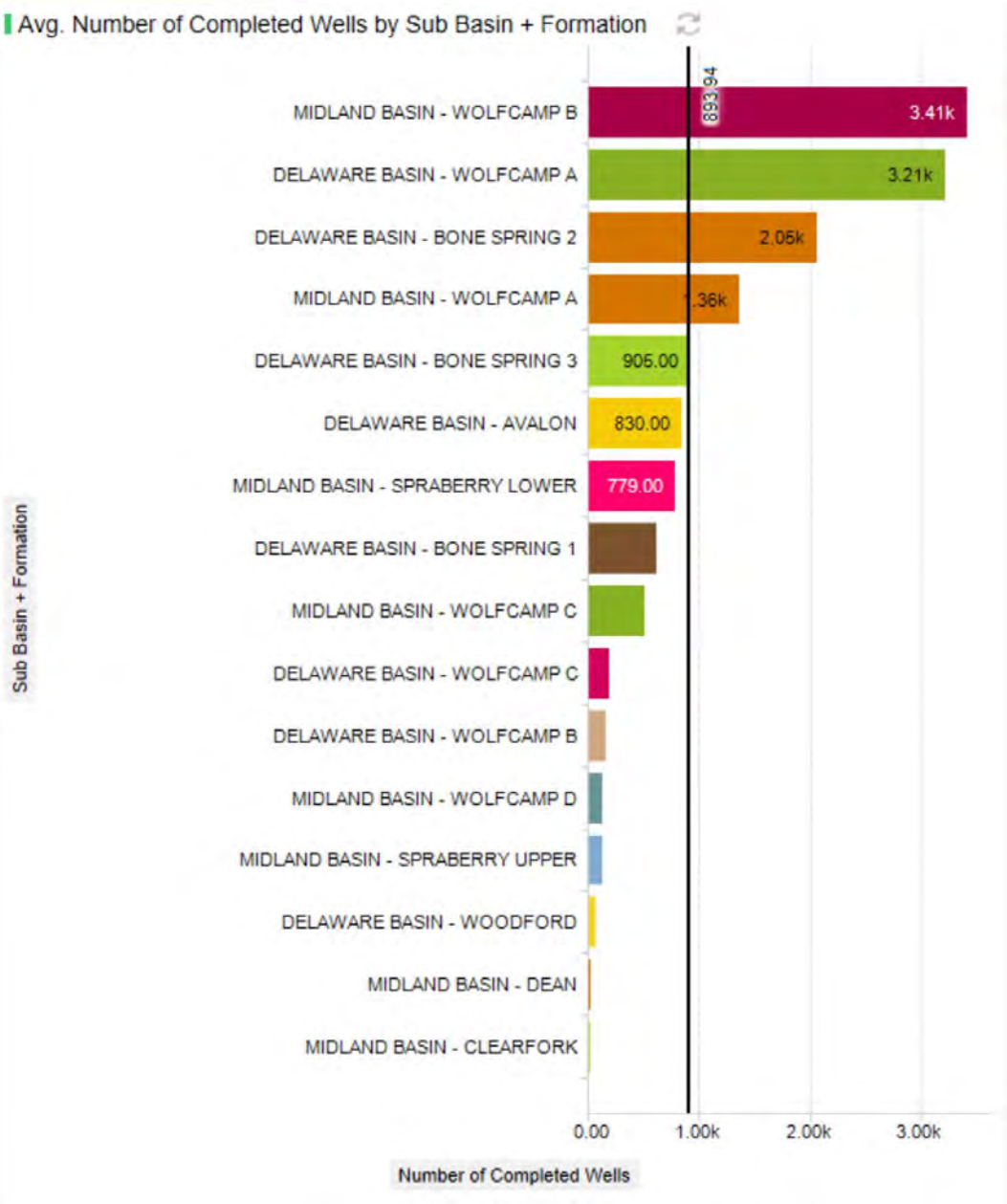
Landing Zone Assignments



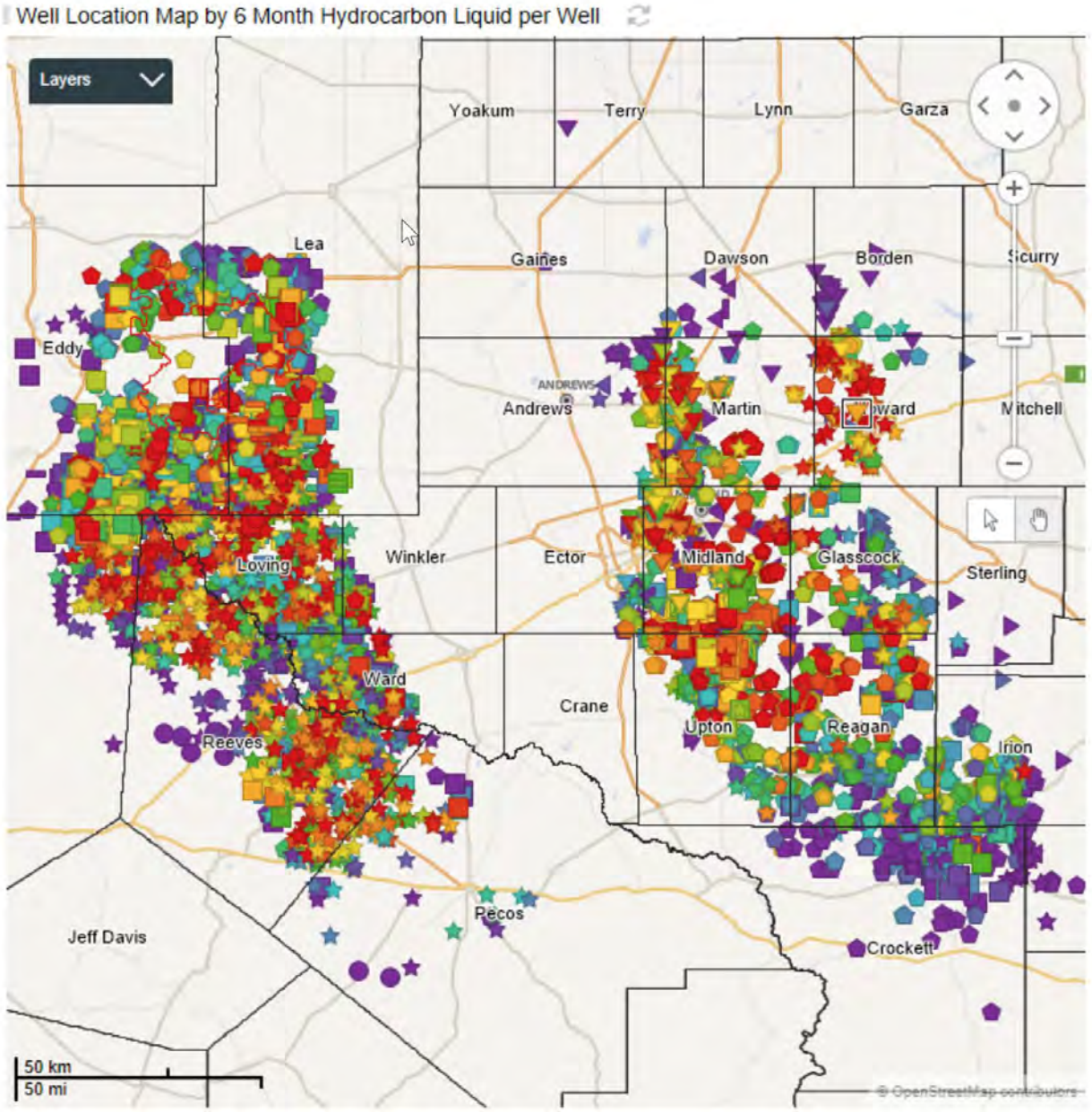
CROSSPLOT ANALYTICS

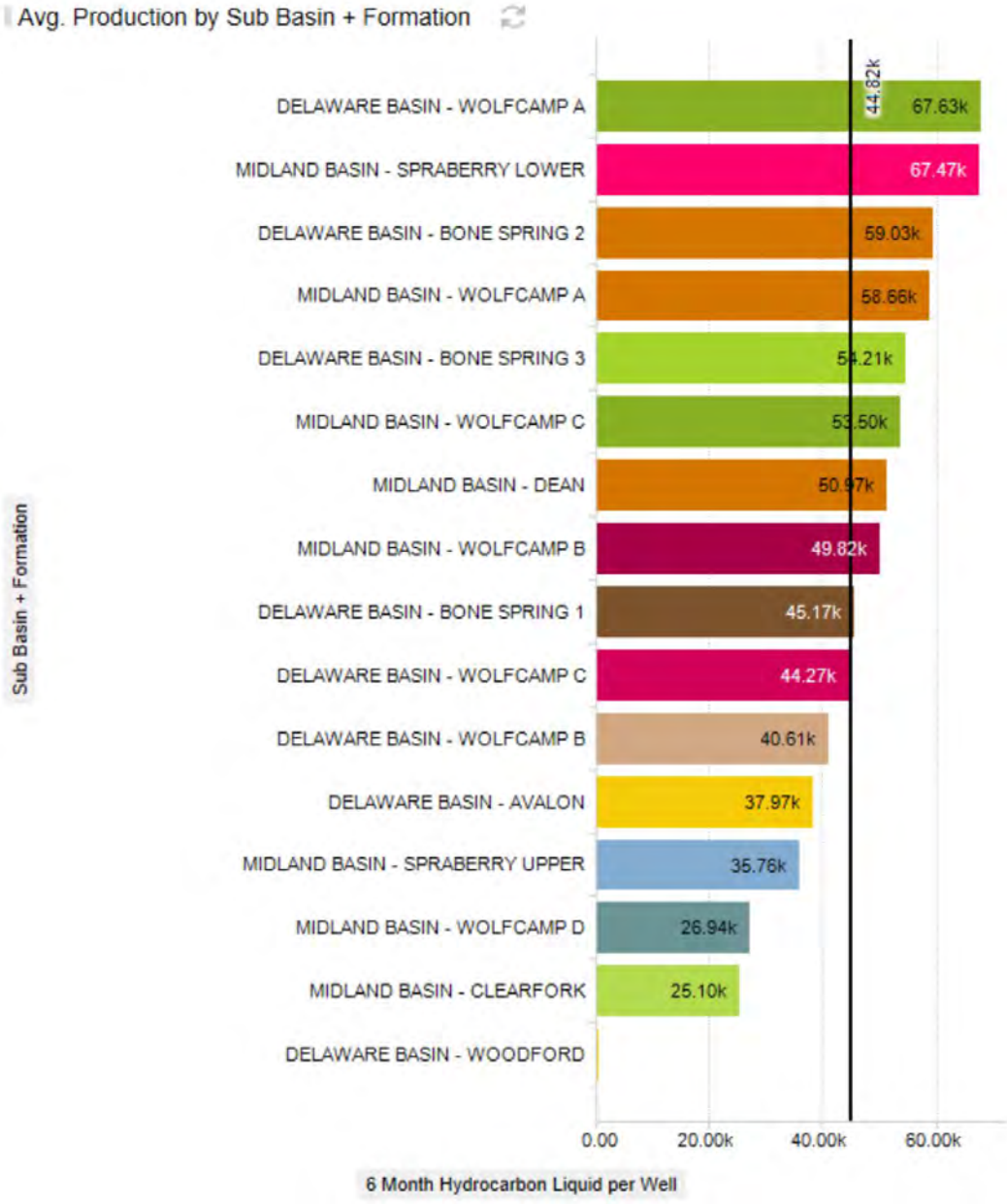
“Sweet Sixteen” Well Liquid Production and Number



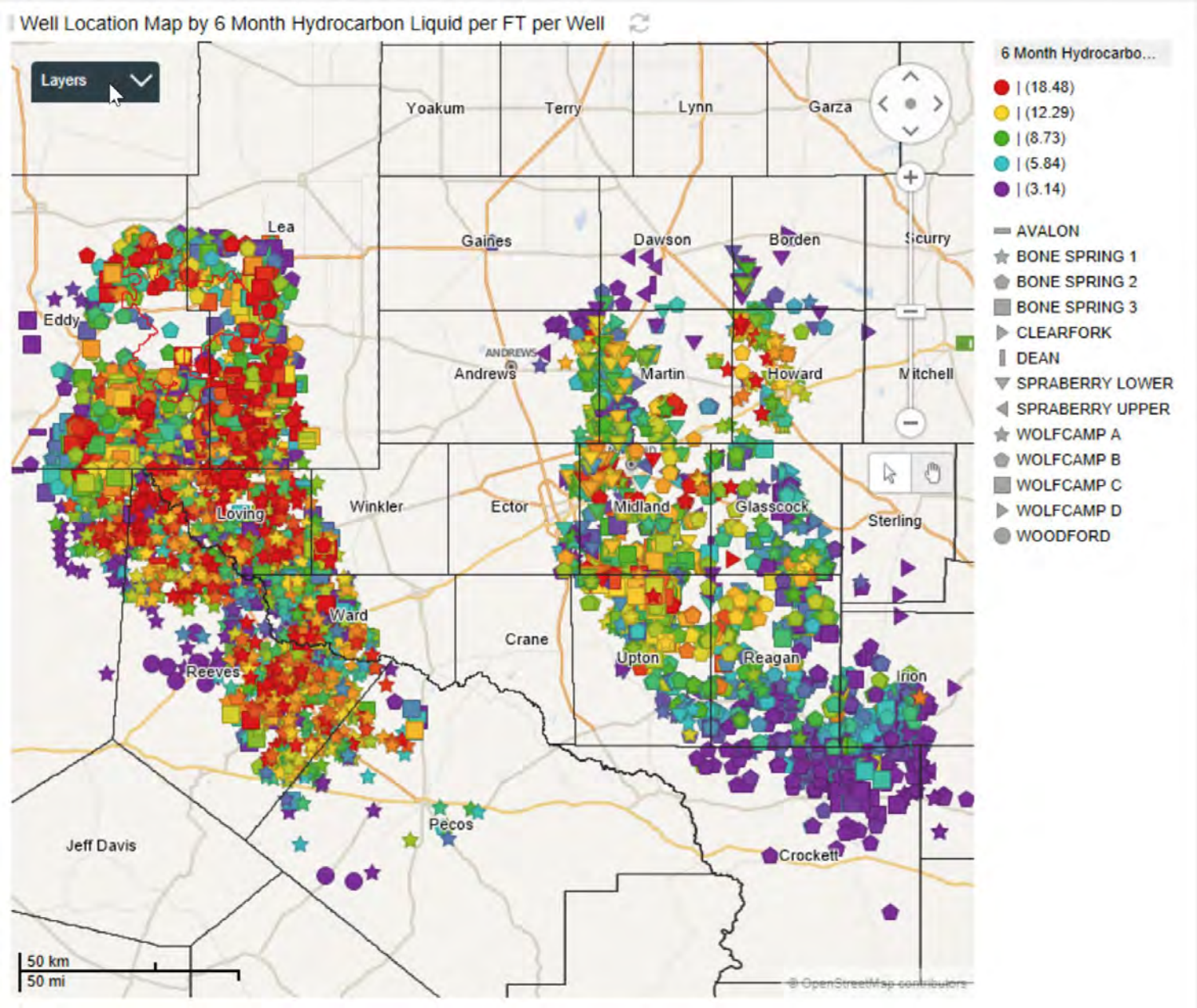


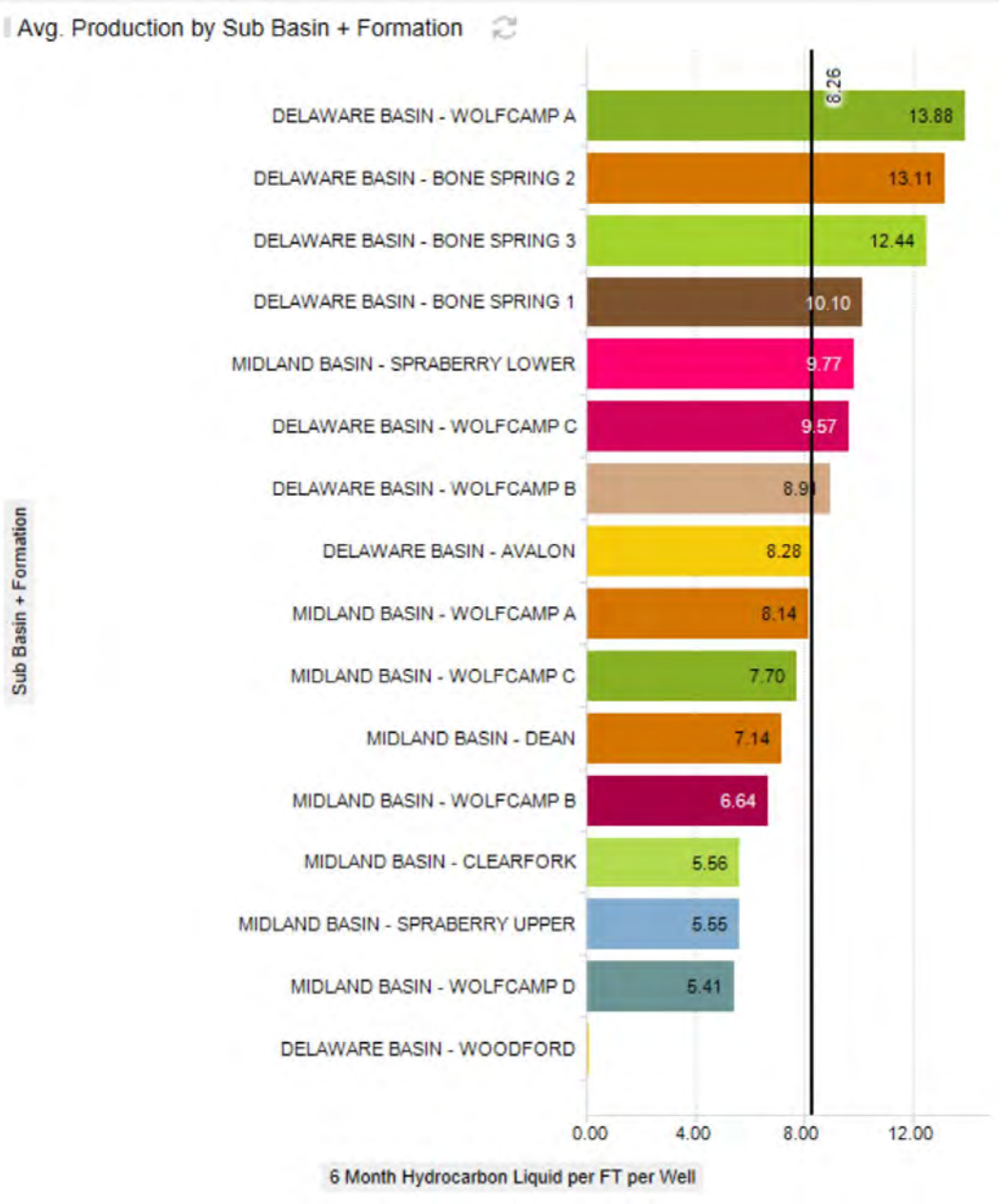
“Sweet Sixteen” Well Liquid Production



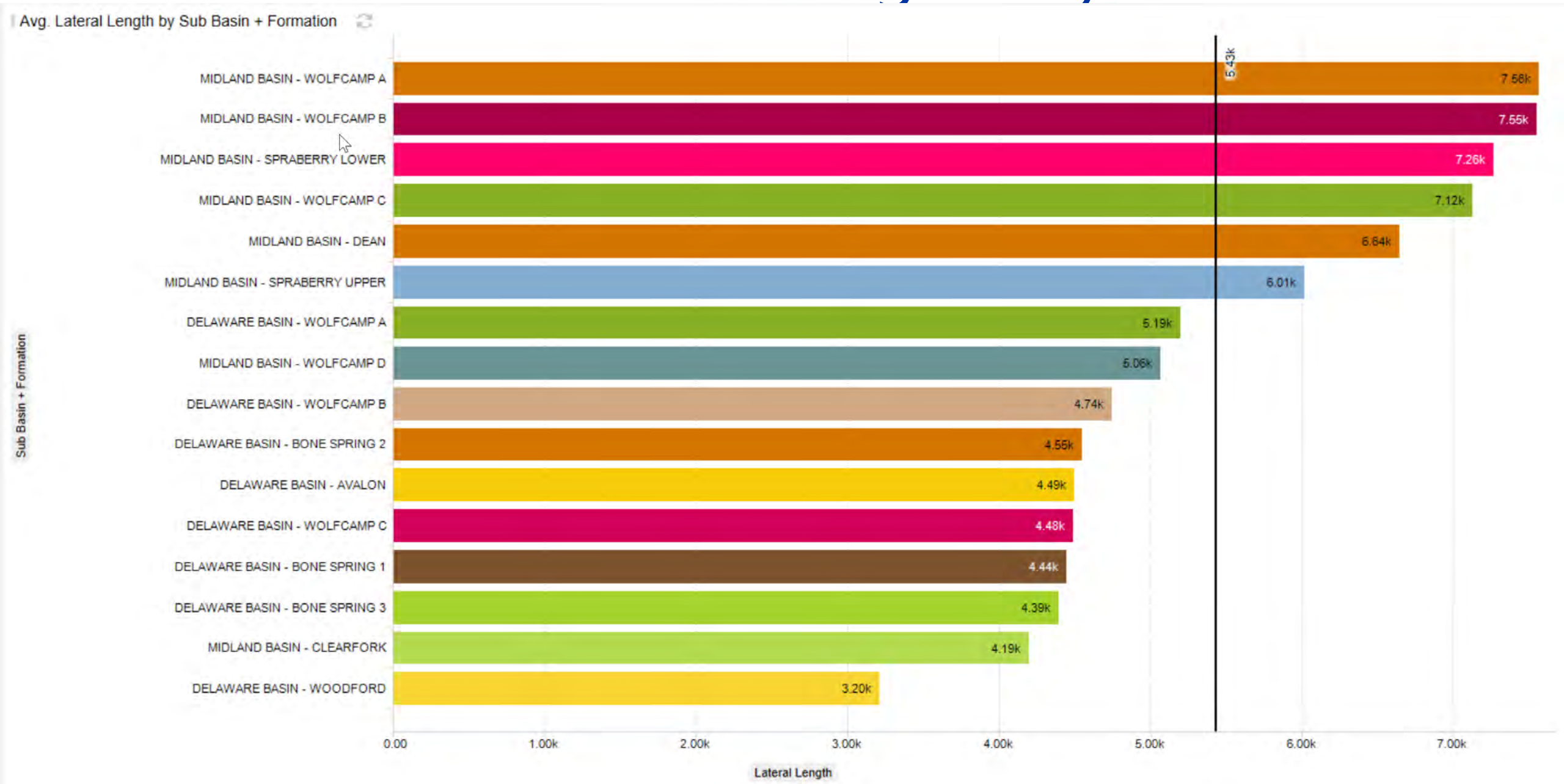


“Sweet Sixteen” Liquid Production per foot

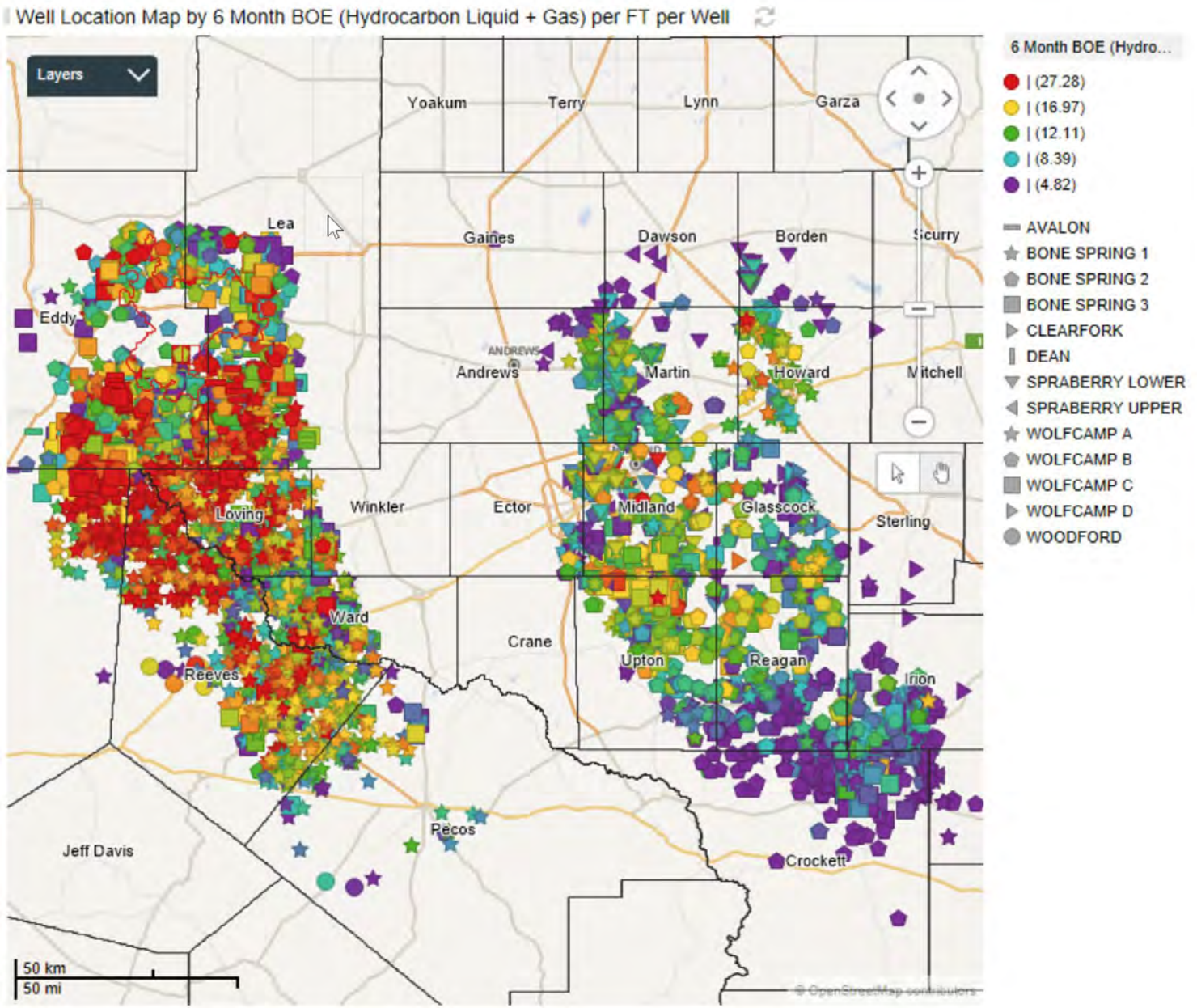


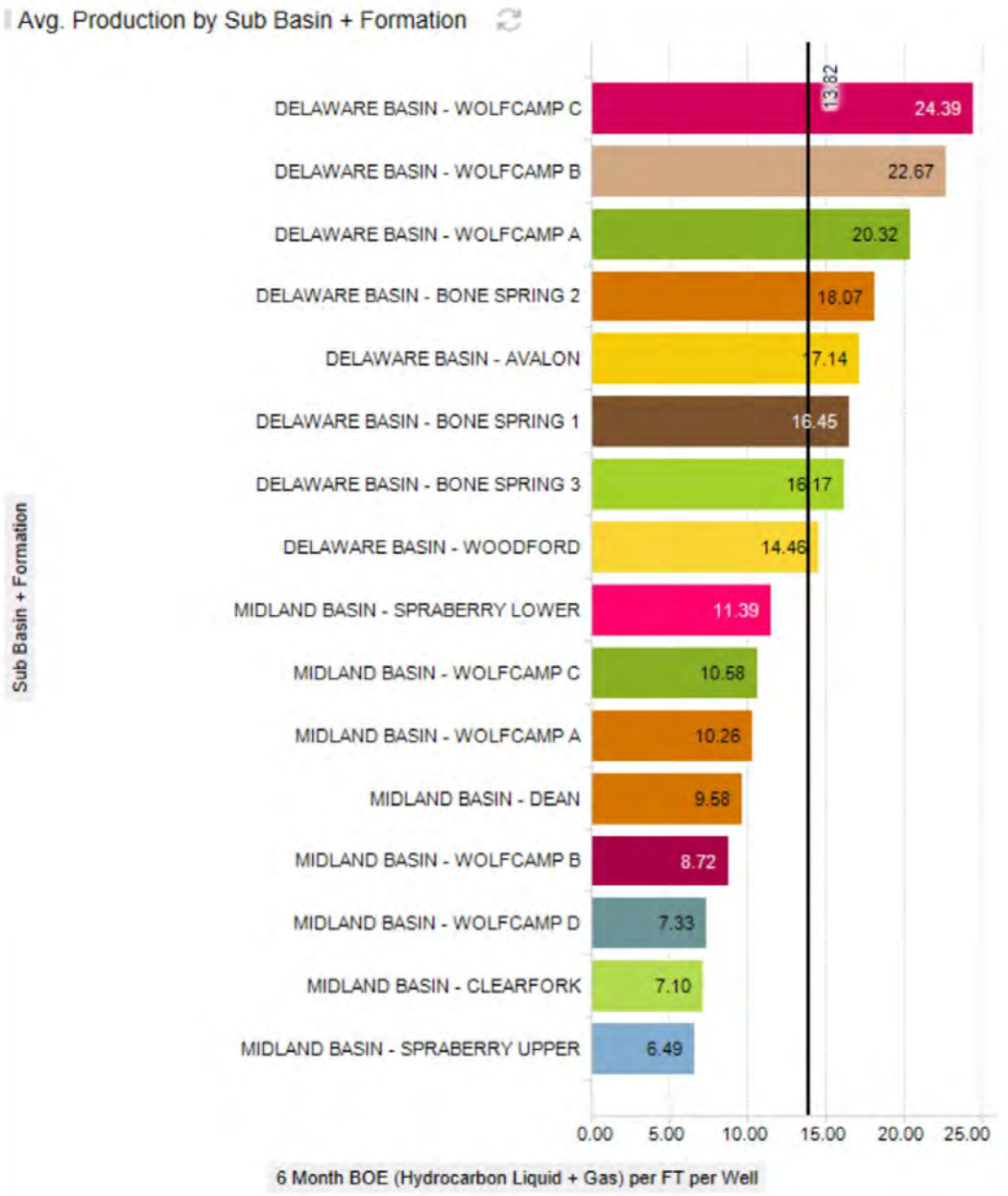


Horizontal Wellbore Lengths by Formation

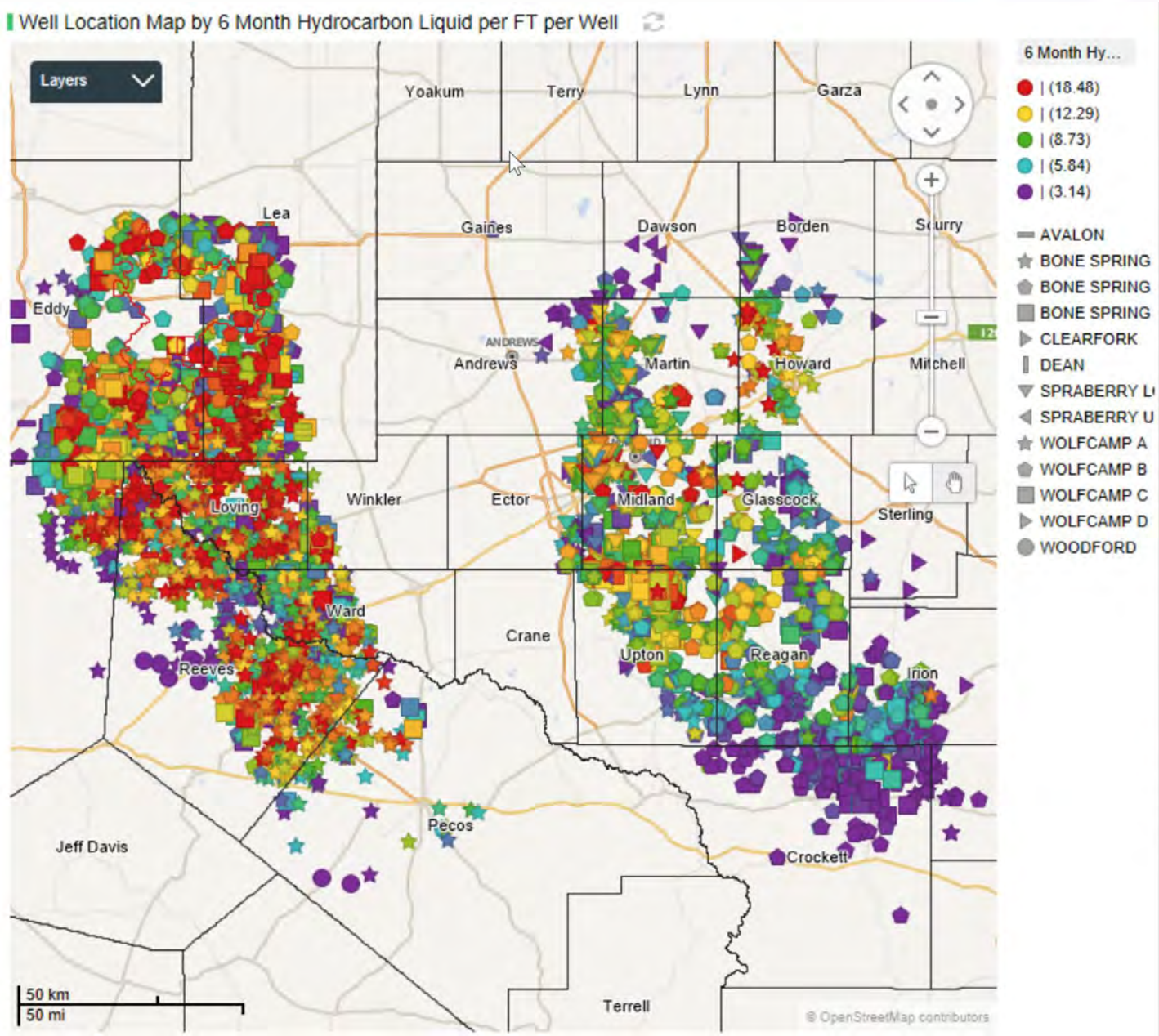


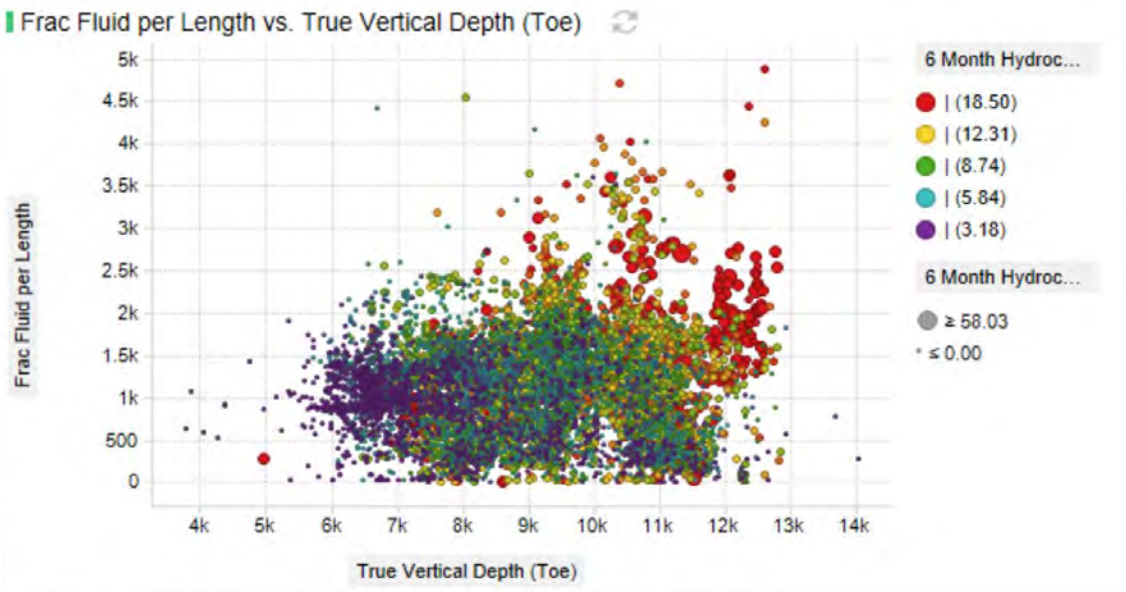
“Sweet Sixteen” BOE Production per foot

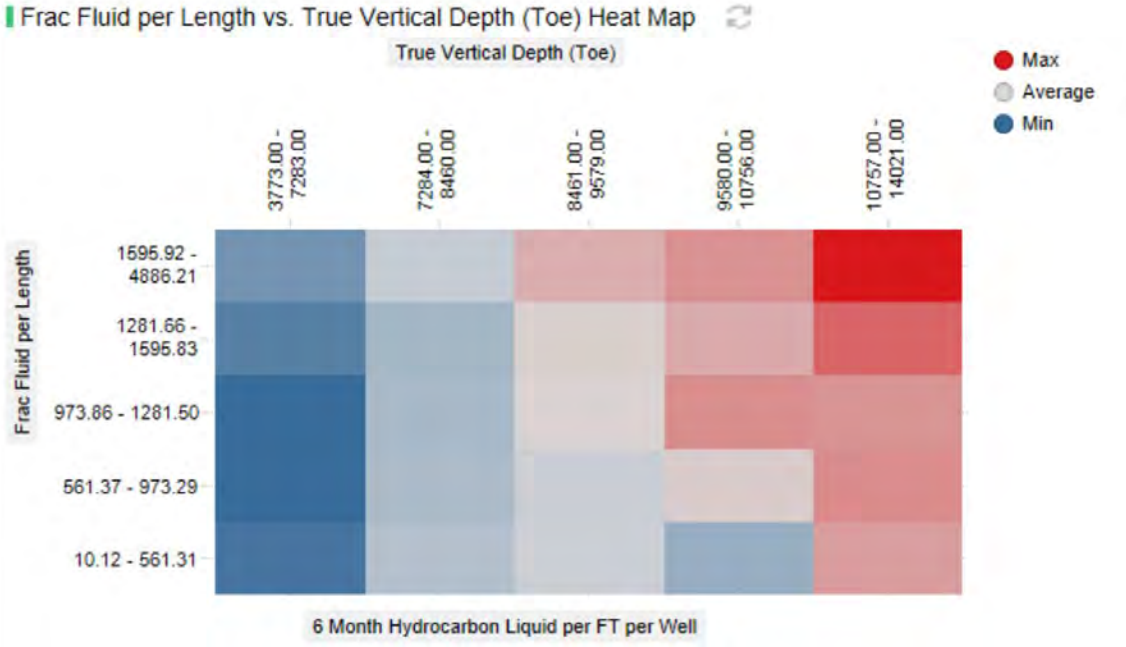




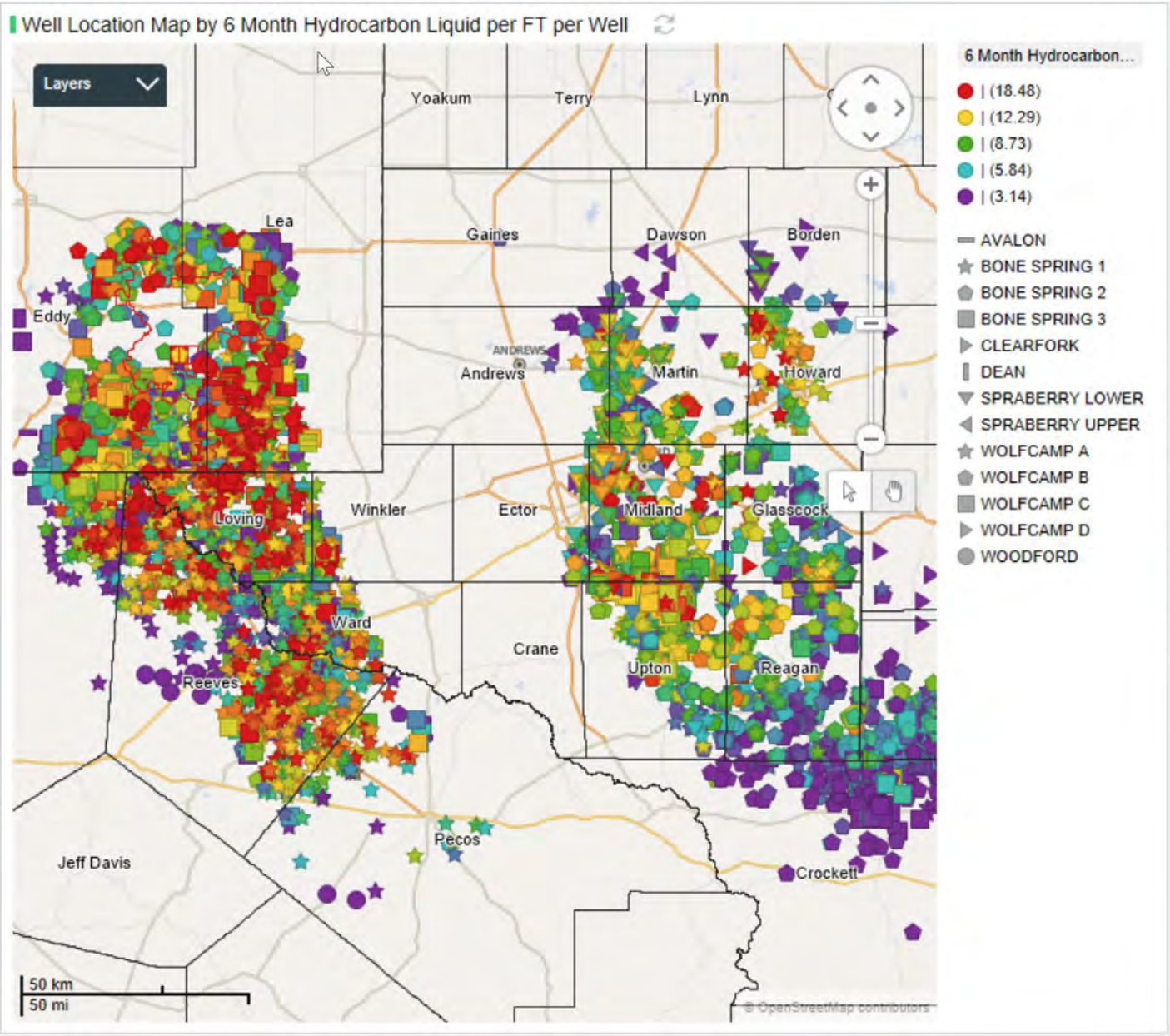
Liquid Production per foot – go deep/big

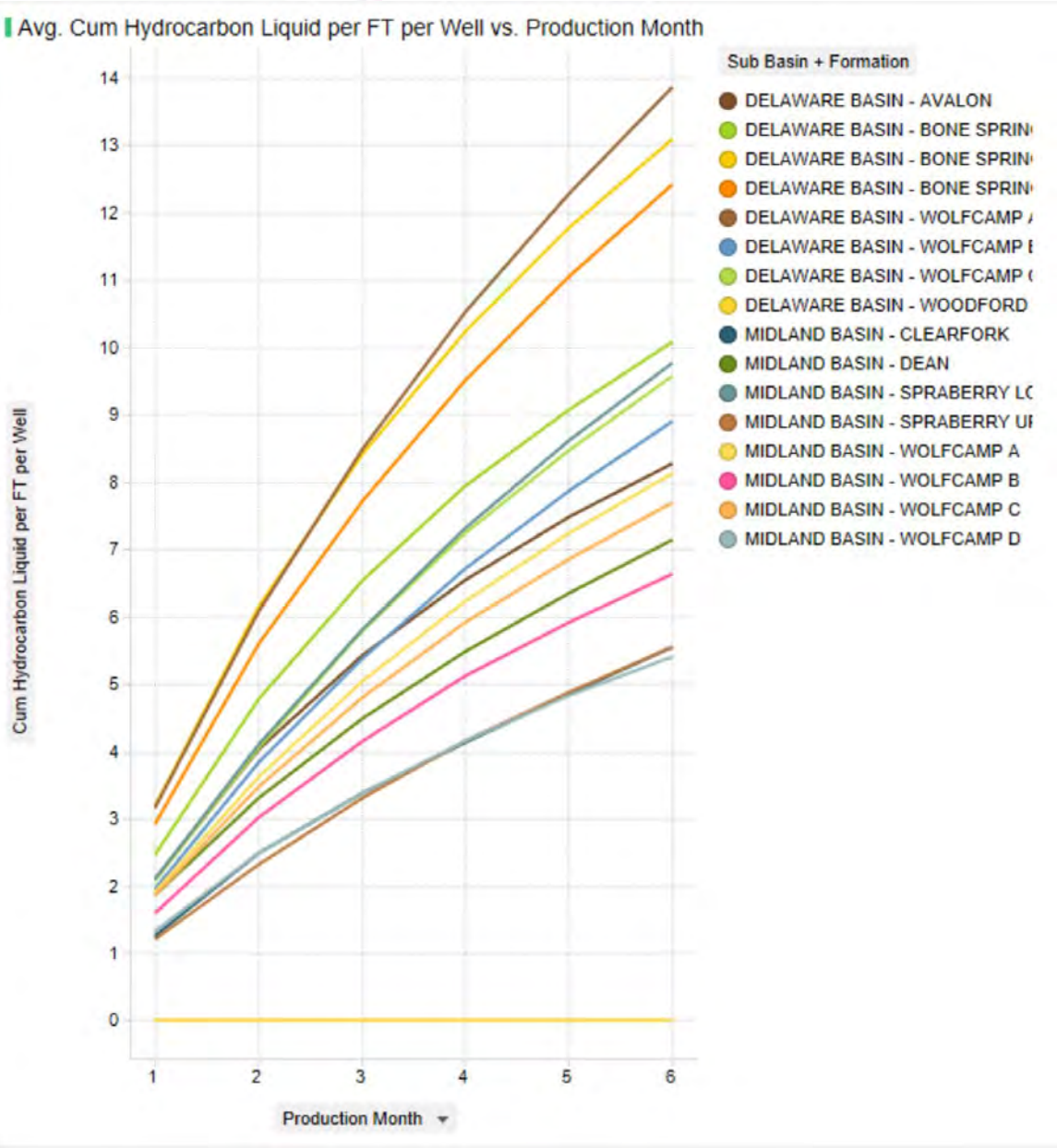




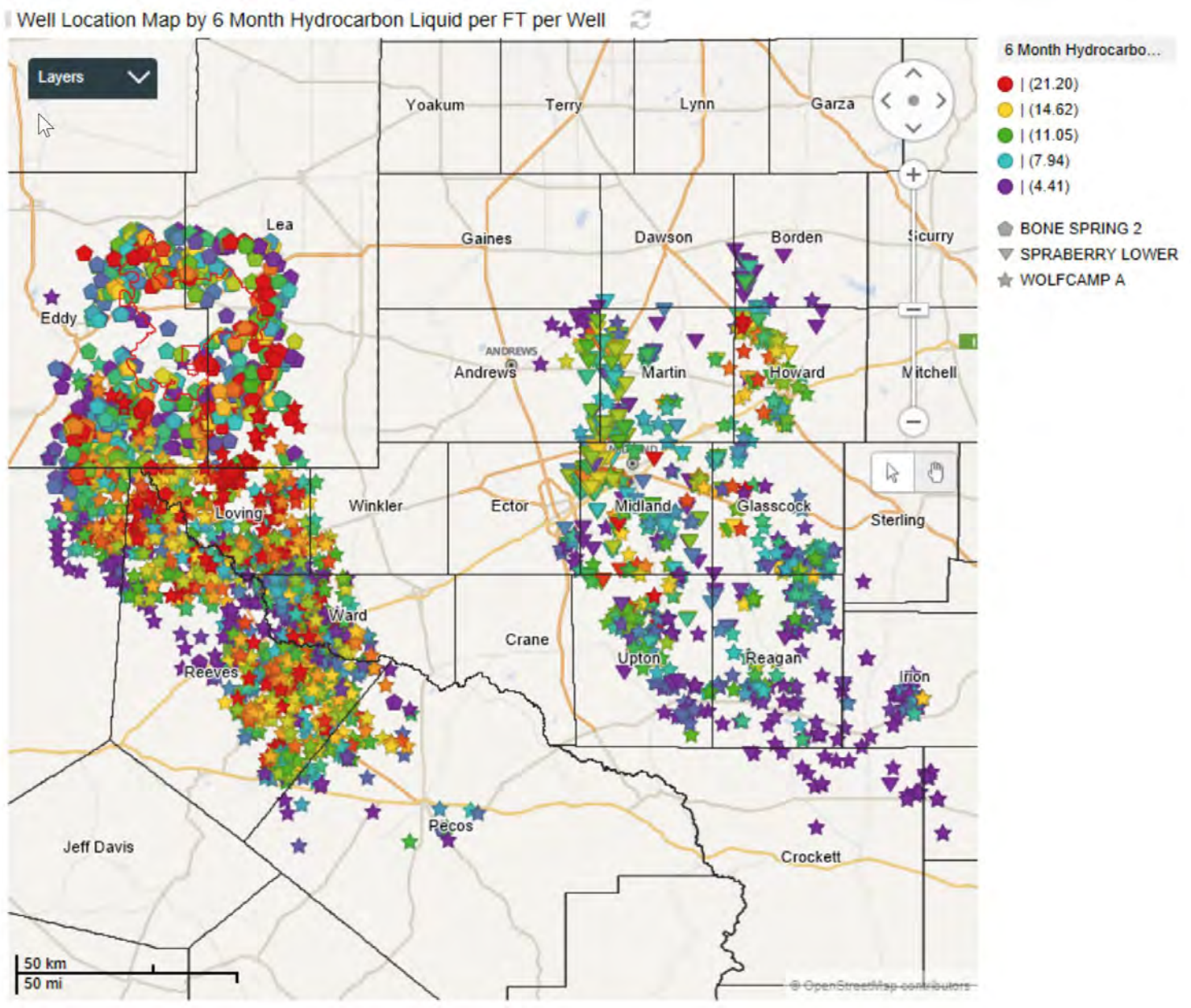


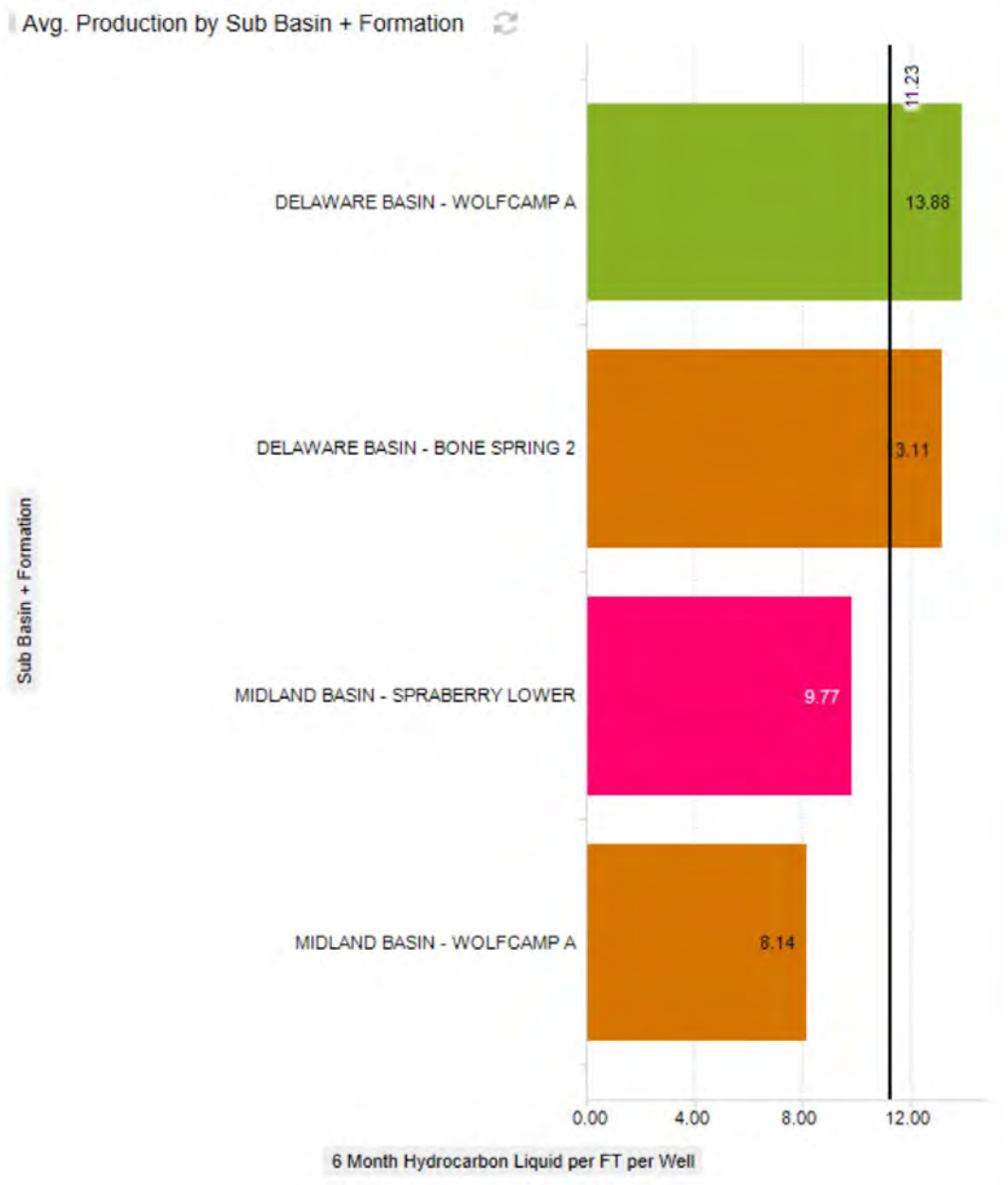
Cum Liquid Curves out to 6 Months



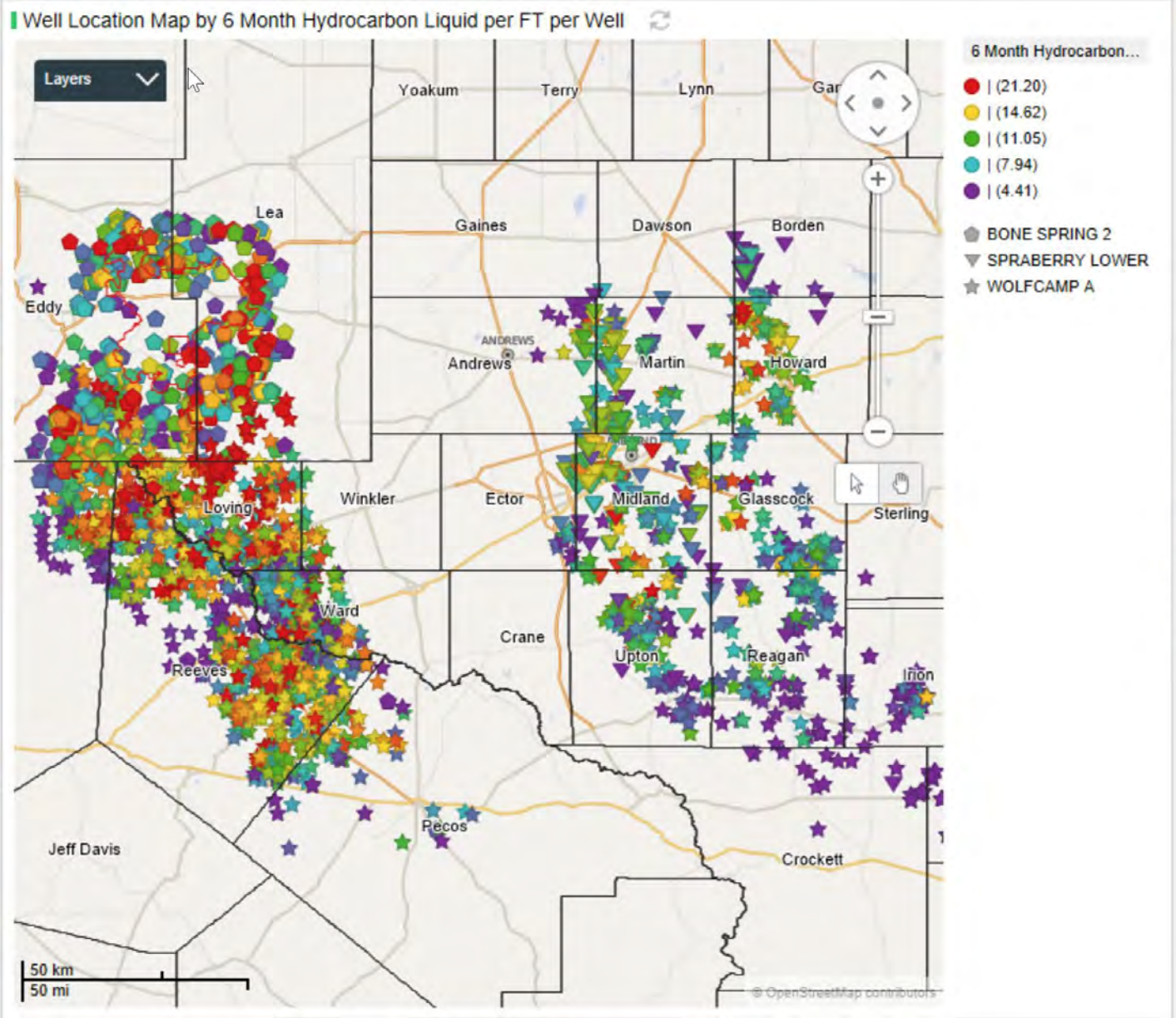


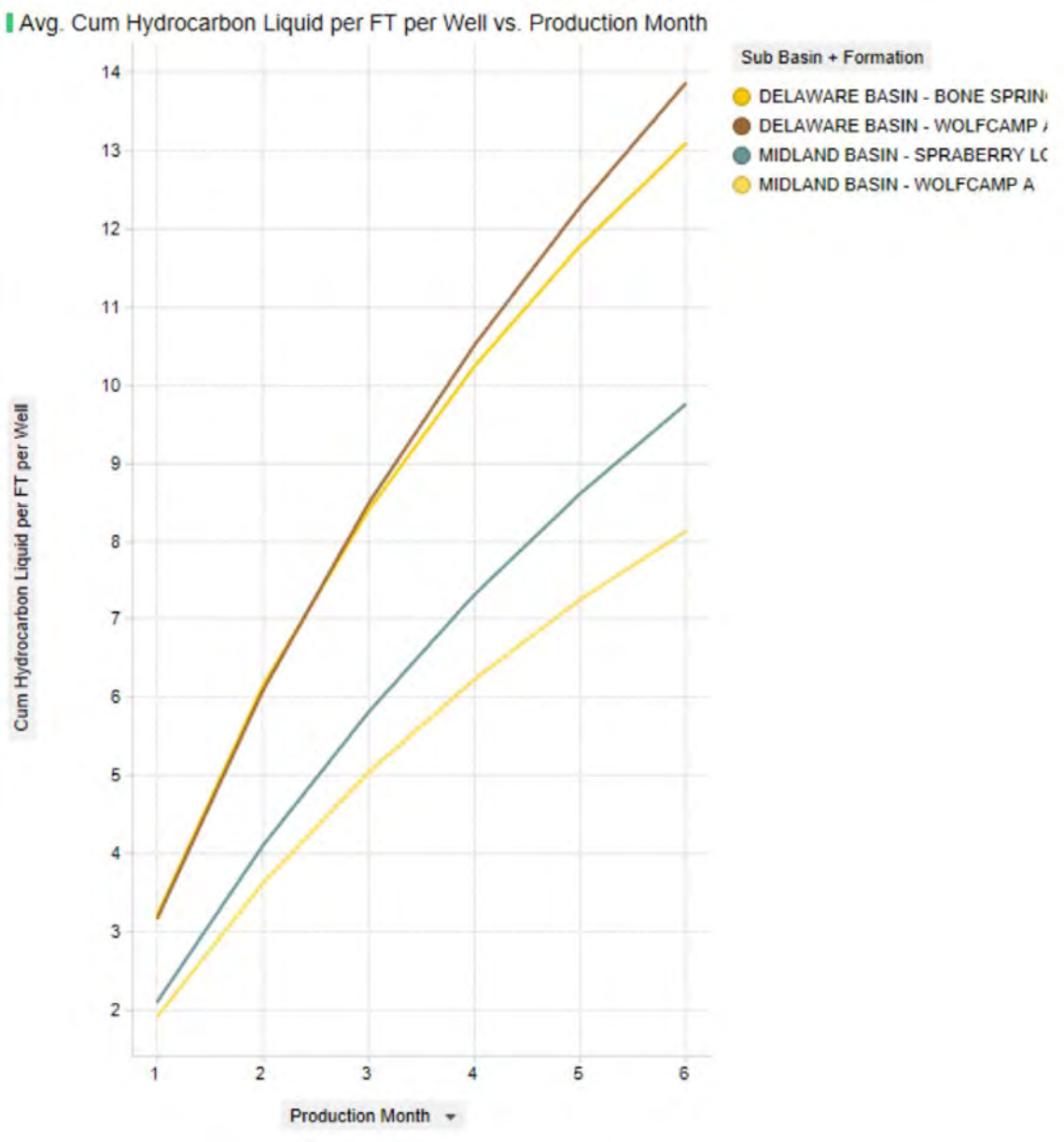
“Final Four” Liquid Production per foot



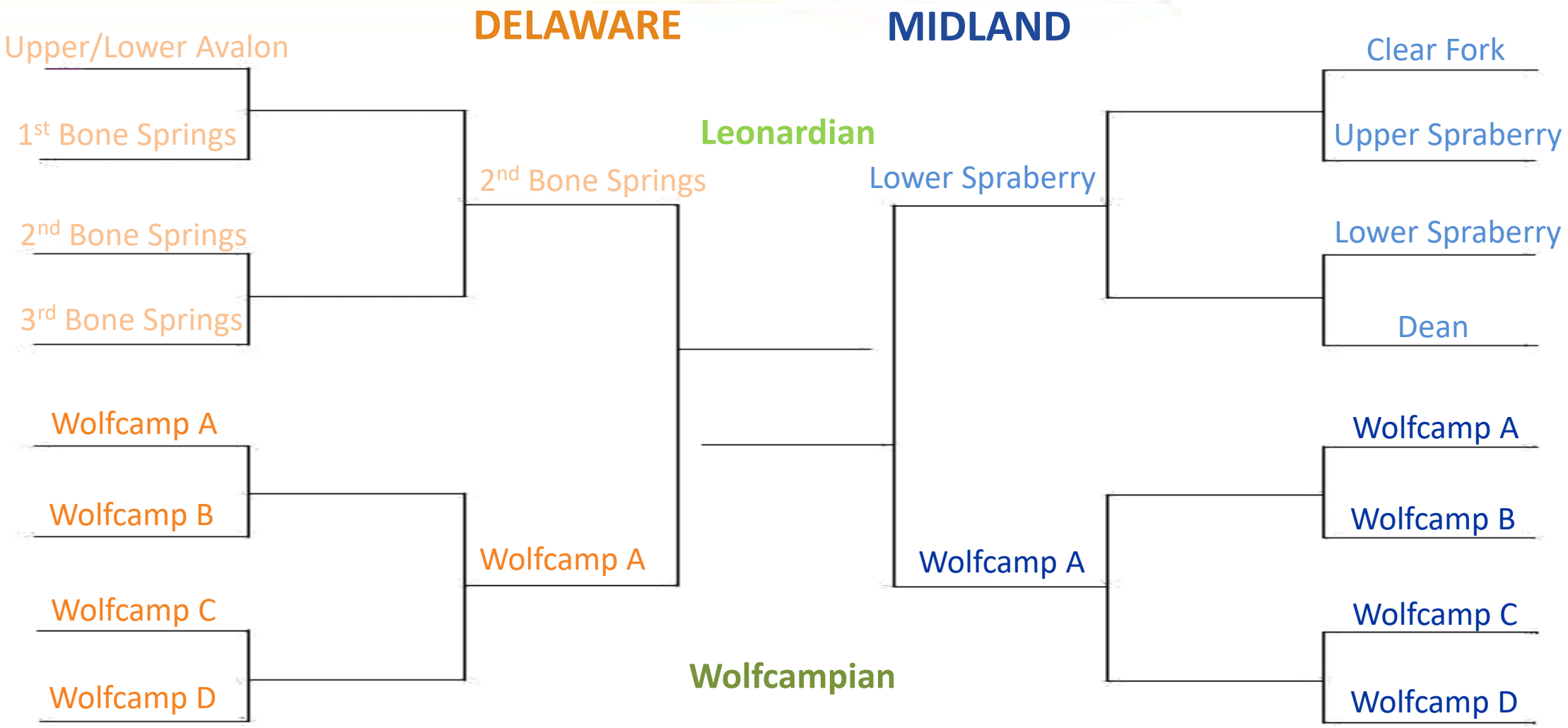


“Final Four” Liquid Production per foot

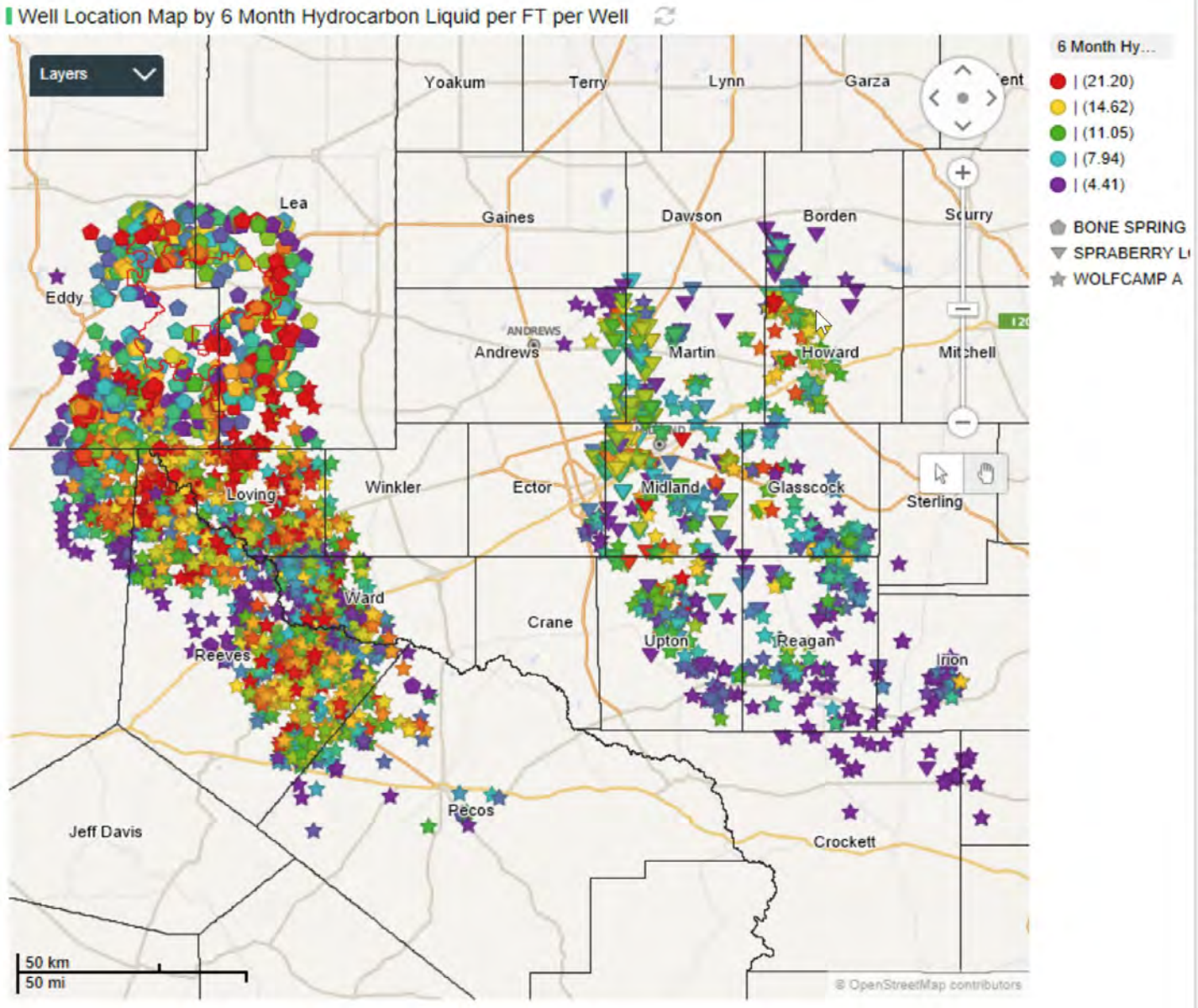


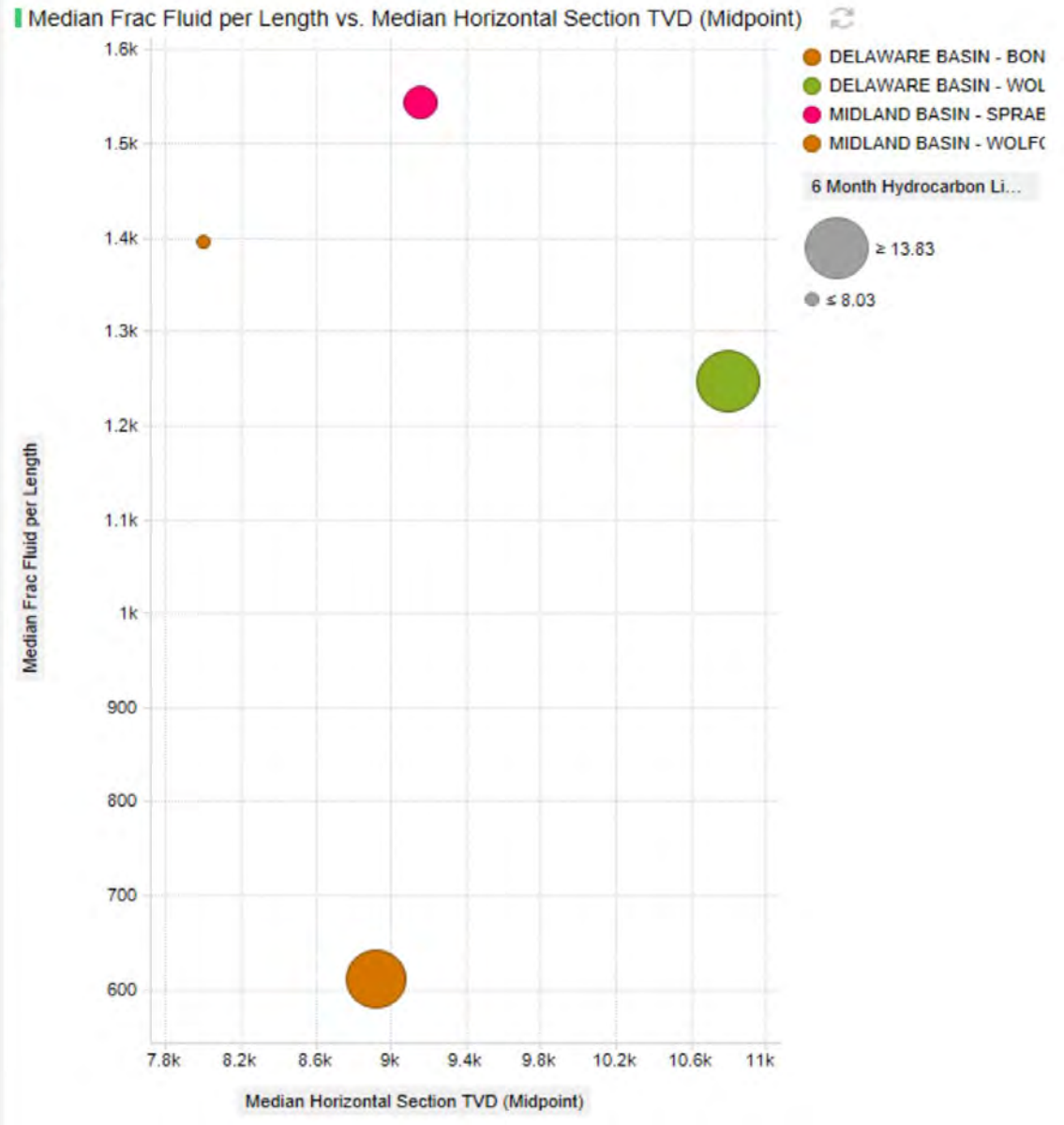


Permian Basin "Final Four"

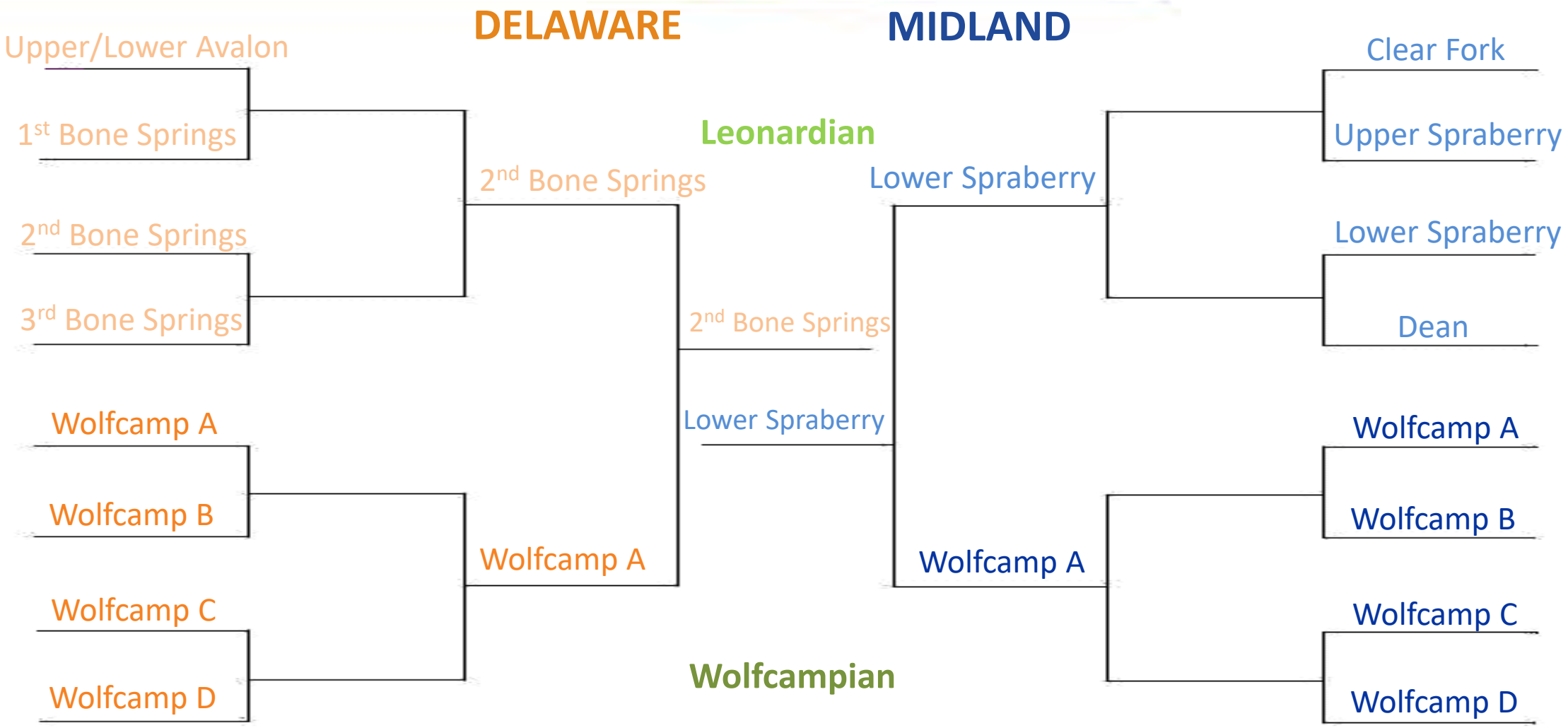


Permian Basin "Final Four" – Penalty Weight by TVD/Fluid per foot

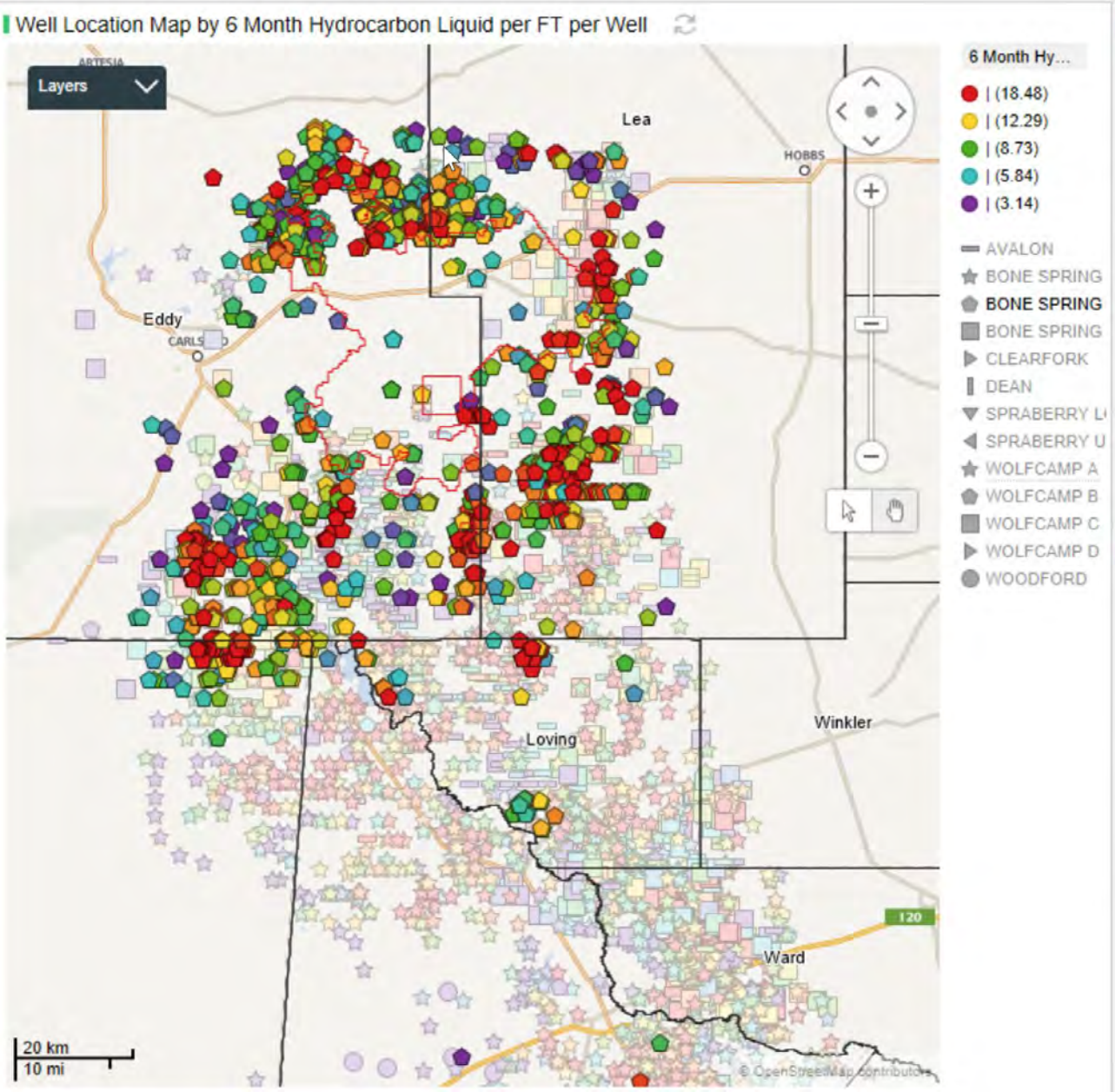


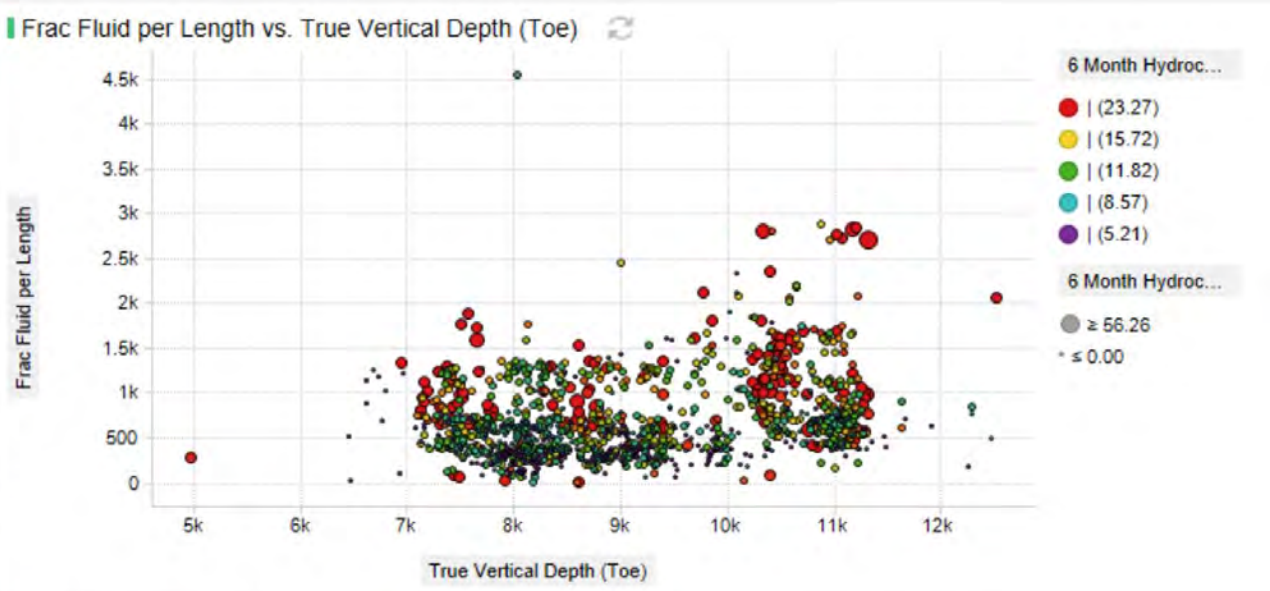


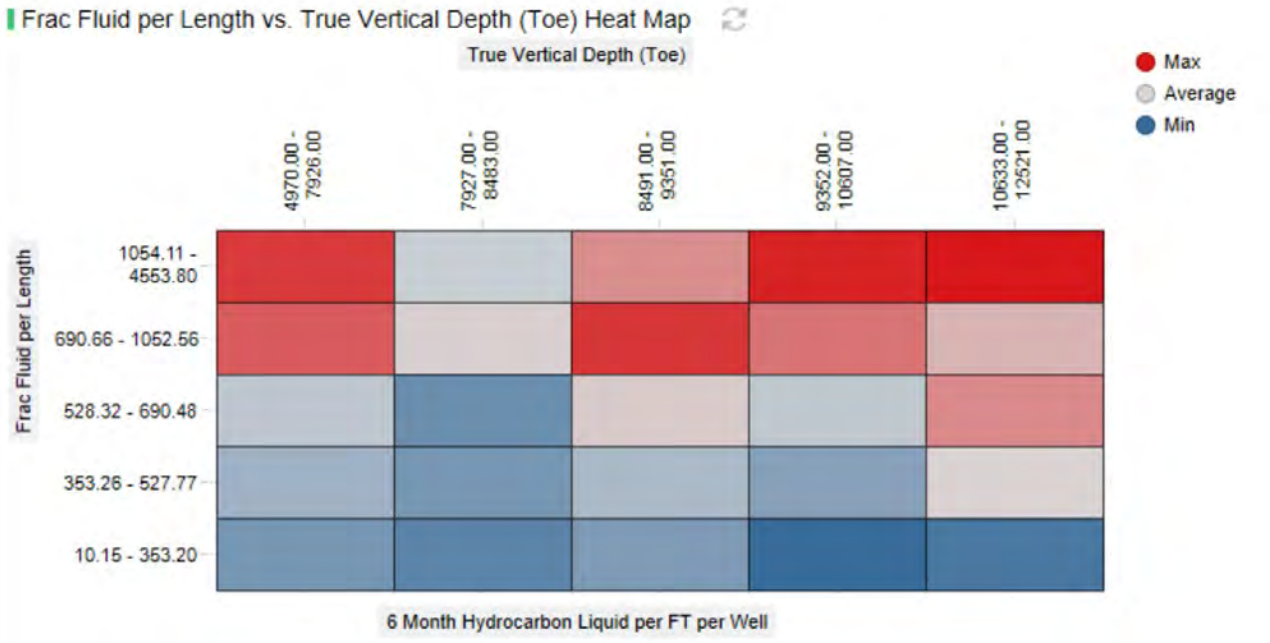
Permian Basin "Final Four"



Delaware 2nd Bone Springs Sweetspot

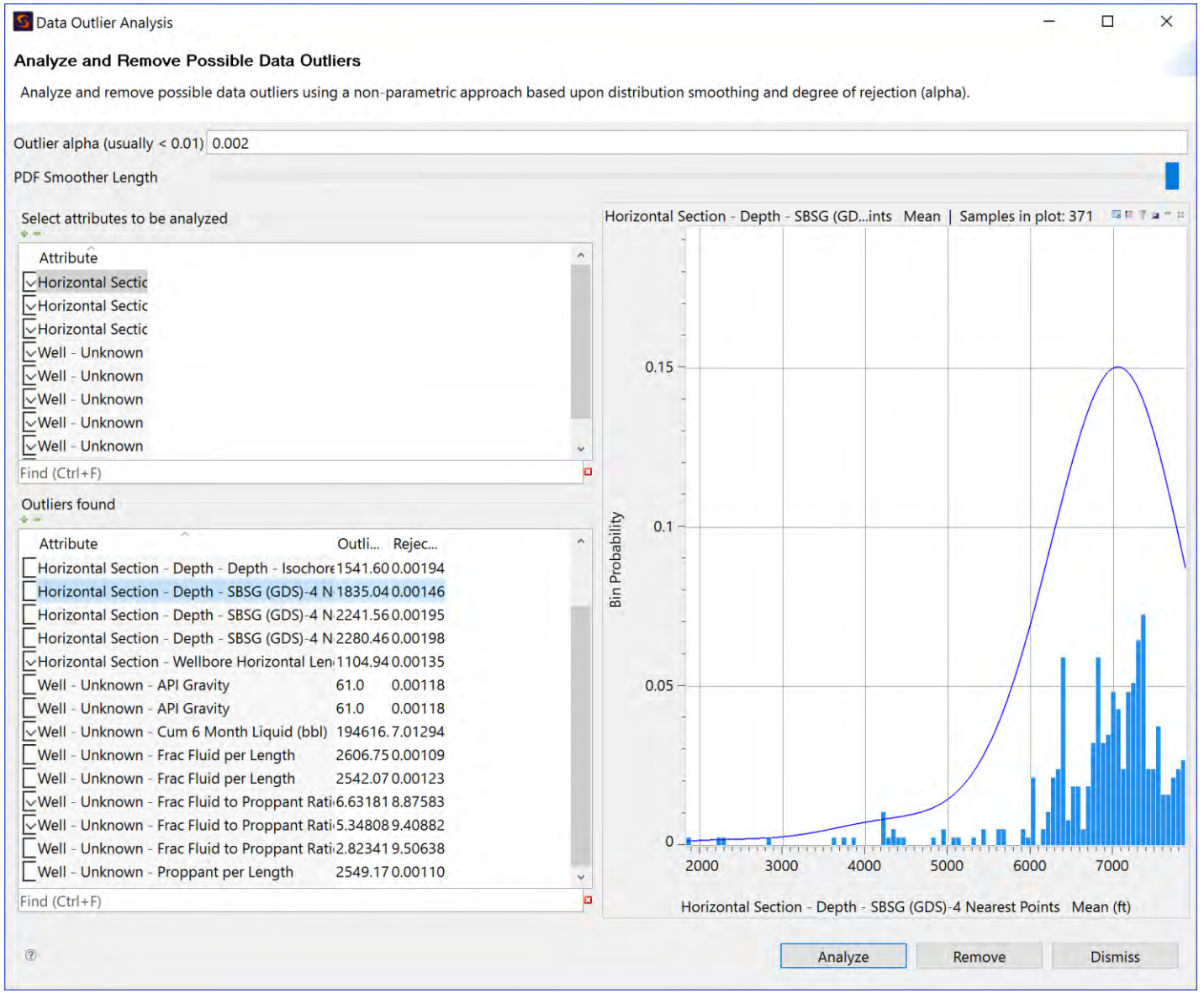




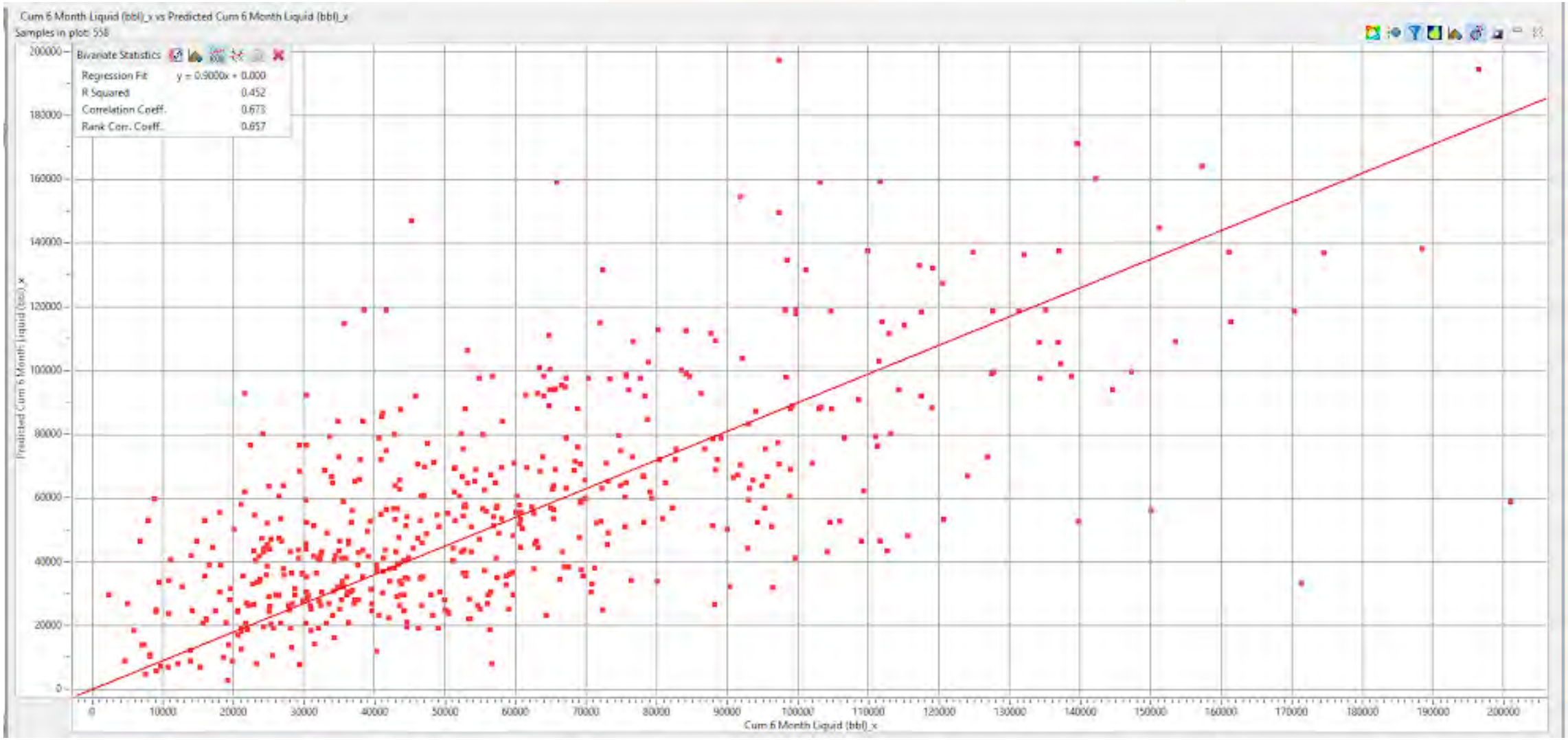


MULTIVARIATE ANALYTICS

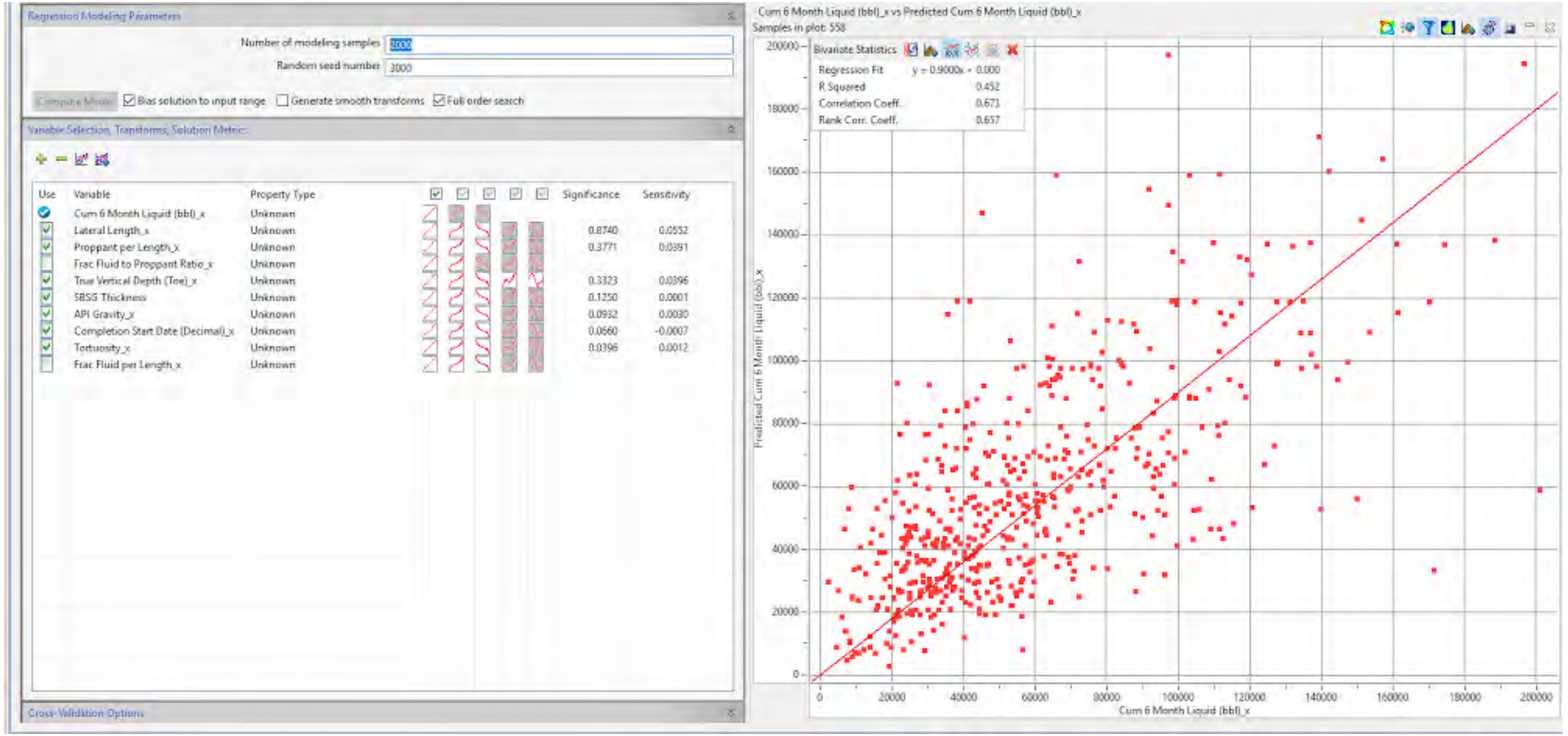
Outlier Analysis



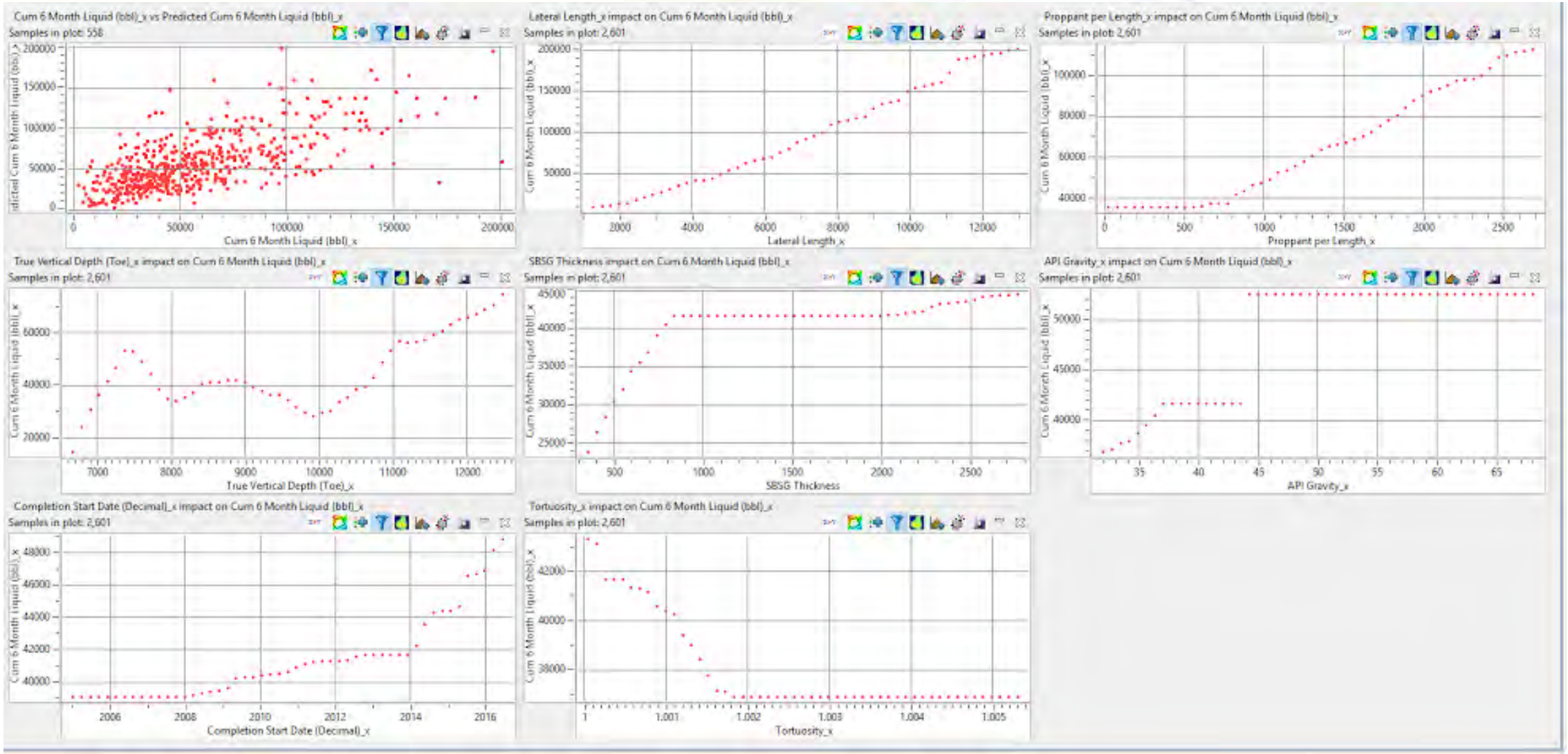
Predicted versus Measured 6-mo Liquid



Predicted versus Measured 6-mo Liquid



Optimization Plots for Production Predictors



FUTURE WORK

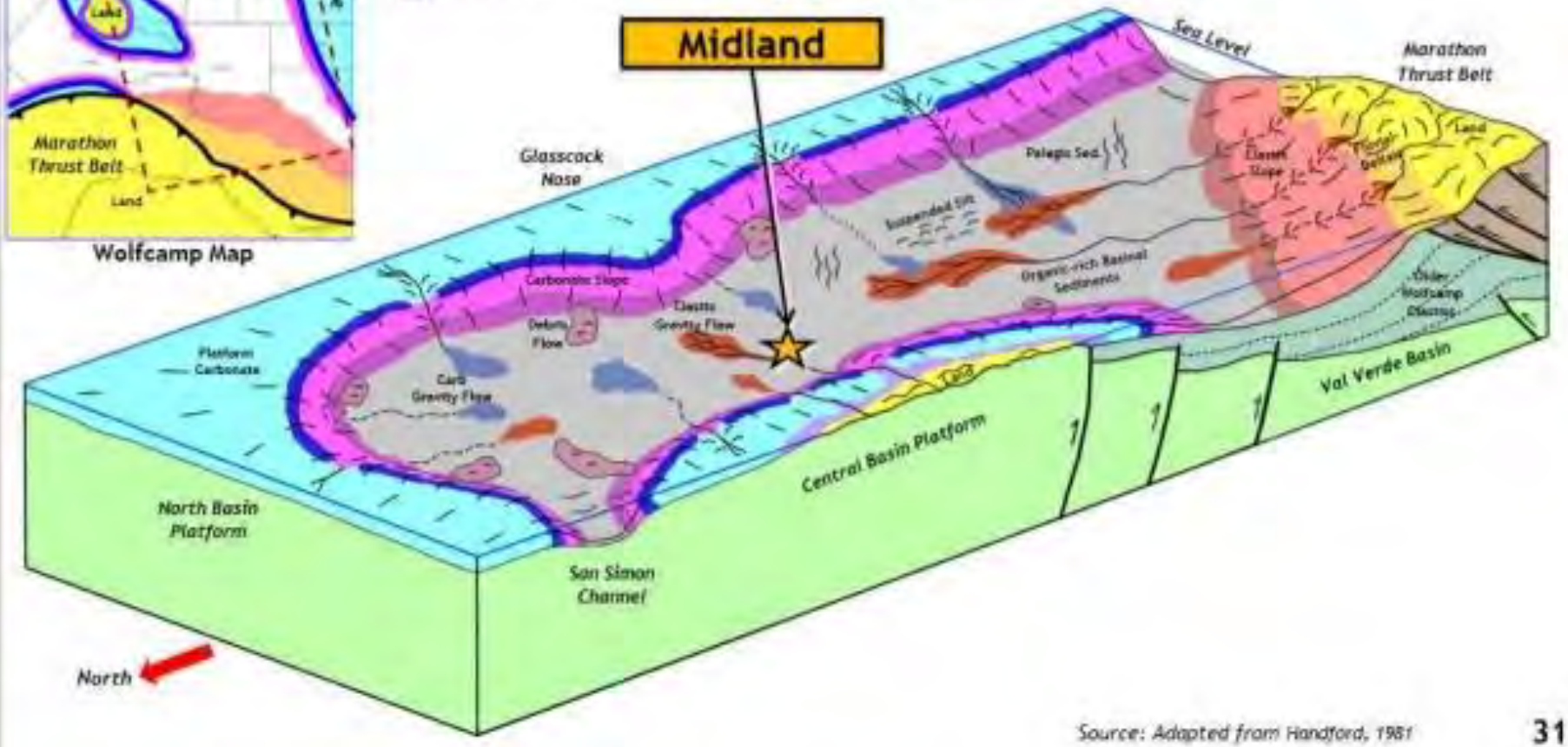
Pioneer Midland basin Wolfcamp depostion

Wolfcamp Depositional Model - Midland Basin

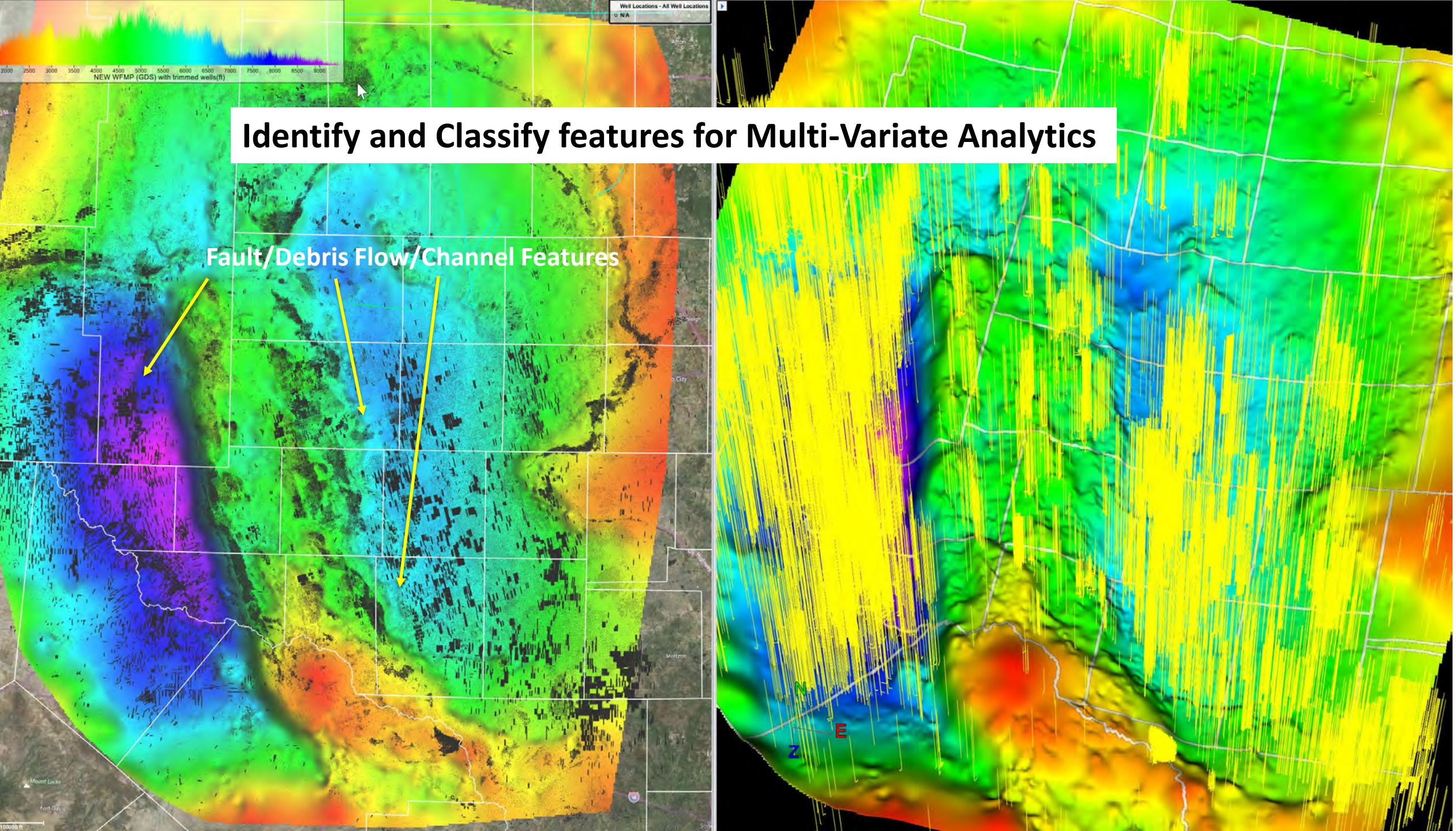
PIONEER NATURAL RESOURCES

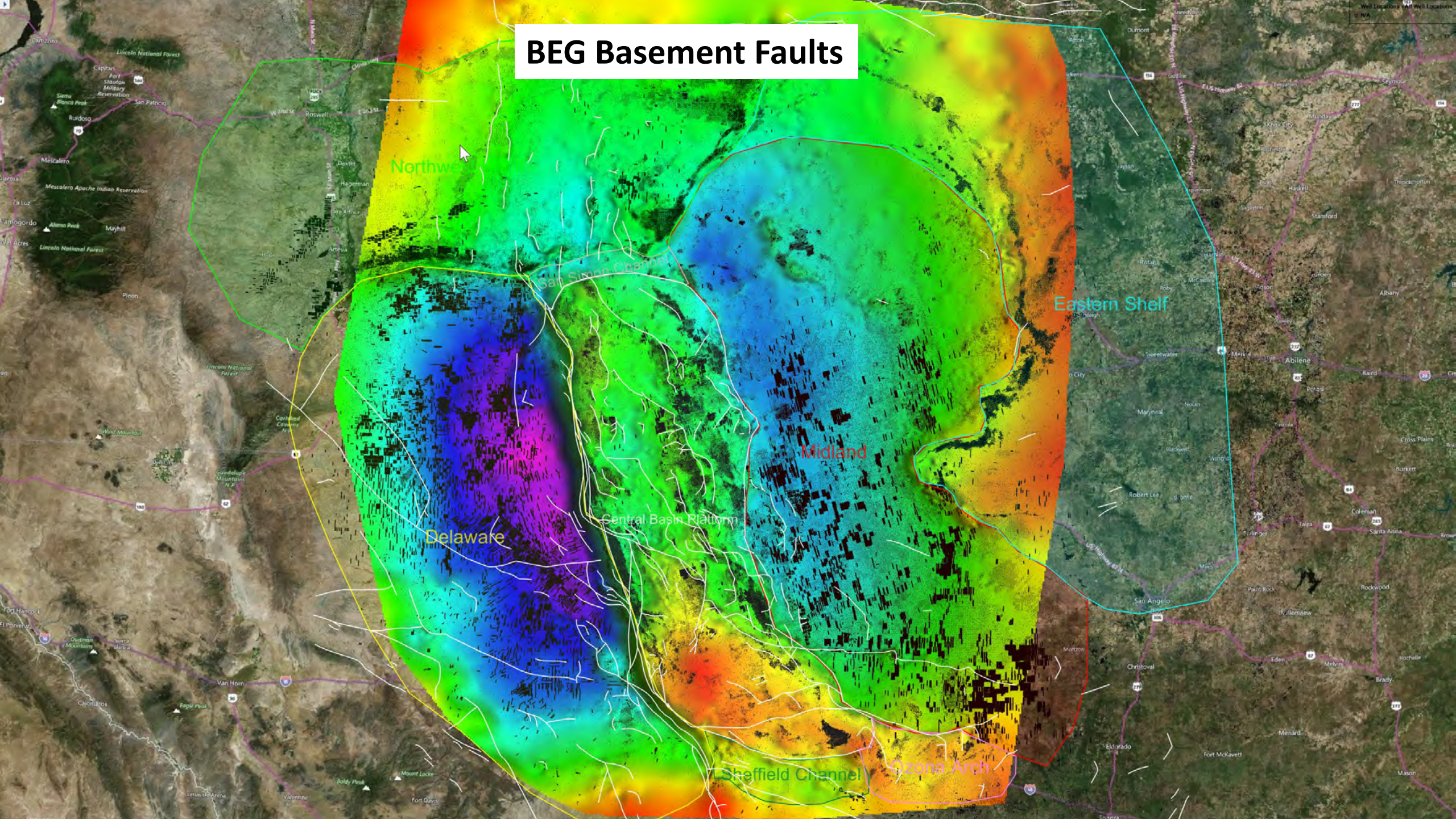
Wolfcamp Map

- Platform Carbonate
- Shelf Edge Carbonate
- Slope Sediments & Reef Talus
- Carbonate Debris Flows
- Carbonate Gravity Flows
- Basinal Sediments
- Land
- Clastic Detrital
- Fluvial - Deltaic
- Delta
- Clastic Slope Sediments
- Clastic Gravity Flows
- Pelagic Sediments
- Silt Cloud in Suspension
- Anaerobic Zone (Organic-rich Sediments)



Source: Adapted from Handford, 1981


NEW WFMP (GDS) with trimmed wells(ft)
Well Locations - All Well Locations
N/A
Identify and Classify features for Multi-Variate Analytics
Fault/Debris Flow/Channel Features
N
E
Z


BEG Basement Faults
Northwest
Salt Simon Channel
Eastern Shelf
Midland
Central Basin Platform
Delaware
Sheffield Channel
Ozona Arch

ACKNOWLEDGEMENTS

Big thanks to IHS Markit and John Roberts/Dean Williams for access to GDS geologic tops database