Reconstructing the Permian Basin for Wolfberry and Wolfbone Unconventional Assessment

Bill Fairhurst[1,2], Svetlana Ikonnikova[1], Robin Dommisse[1], Scott Hamlin[1], Dave Carr[1], Amin Gherabati[1], Frank Male[1], and Inessa Yurchenko[1]

[1] Bureau of Economic Geology, Jackson School of Geosciences, University of Texas – Austin
[2] Riverford Exploration, LLC

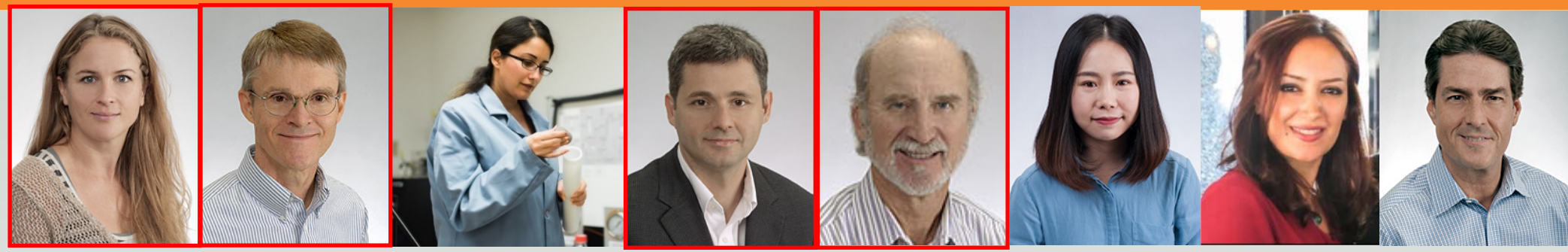
AAPG GLOBAL SUPER BASINS 2019
22-24 January 2019 • Sugar Land, Texas
Sugar Land Marriott Town Square
The Permian

TORA TIGHT OIL RESOURCE ASSESSMENT

BUREAU OF ECONOMIC GEOLOGY

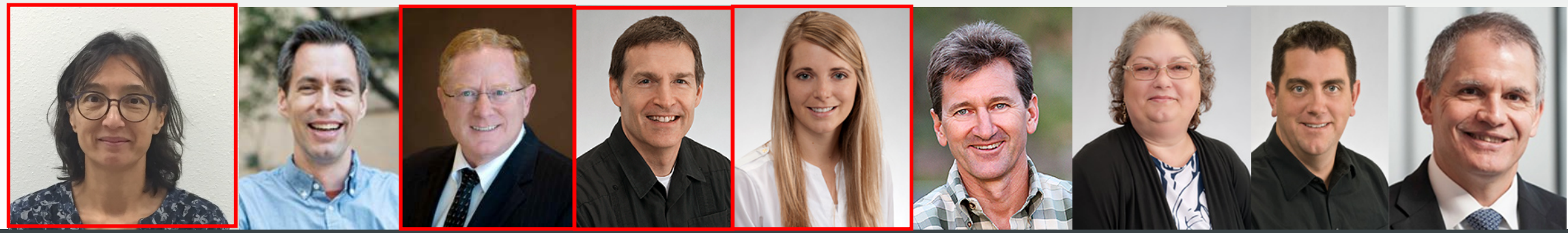
TEXAS Geosciences
Bureau of Economic Geology
Jackson School of Geosciences
The University of Texas at Austin

Left to Right:
Guin McDaid
Scott Hamlin
Zoya Heidari
Gurcan Gulen
Ray Eastwood
Qian Yang
Ameneh Rostami
Mark Blount



Left to Right:
Robin Dommisse
Inessa Yurchenko
Victor Del Carpio Neyra
Bridget Scanlon
Amin Gherabati
Svetlana Ikonnikova, co-PI
Harold Rogers
Xavier Janson
Sammy Jacobo

Left to Right:
Isabelle Pelletier
Michael Pyrcz
Bill Fairhurst
Dave Carr
Katie Smye
Scott Tinker
Dena Miller
Chris Zahm
Mark Schuster
Reinaldo Sabbagh
no picture



TORA
TIGHT OIL RESOURCE ASSESSMENT

Bureau of Economic Geology

Red outline are Core TORA team members, all others are collaborators.

State of Texas Advanced Oil and Gas Resource Recovery (STARR) $350,000 per year

Industry Consortium Sponsors

$50,000/year per member contribution

TOTAL

Apache CORPORATION

Sequitur ENERGY RESOURCES LLC

CONCHO

PIONEER NATURAL RESOURCES

ENERGEN

SM ENERGY

PARSLEY ENERGY

BMO Capital Markets

ikon Science

UNIVERSITY LANDS
FUNDING THE UNIVERSITY OF TEXAS AND TEXAS A&M UNIVERSITY SYSTEMS SINCE 1839

ExxonMobil

QUANTUM ENERGY PARTNERS

Schlumberger

fairfield GEOTECHNOLOGIES

COVIA

AMEREDEV

equinor

INPEX
INPEX CORPORATION

TORA
TIGHT OIL RESOURCE ASSESSMENT

Bureau of Economic Geology

TEXAS Geosciences
Bureau of Economic Geology
Jackson School of Geosciences
The University of Texas at Austin

Study Questions
TORA – Tight Oil (and Gas) Resource Assessment Industrial Consortium, Bureau of Economic Geology

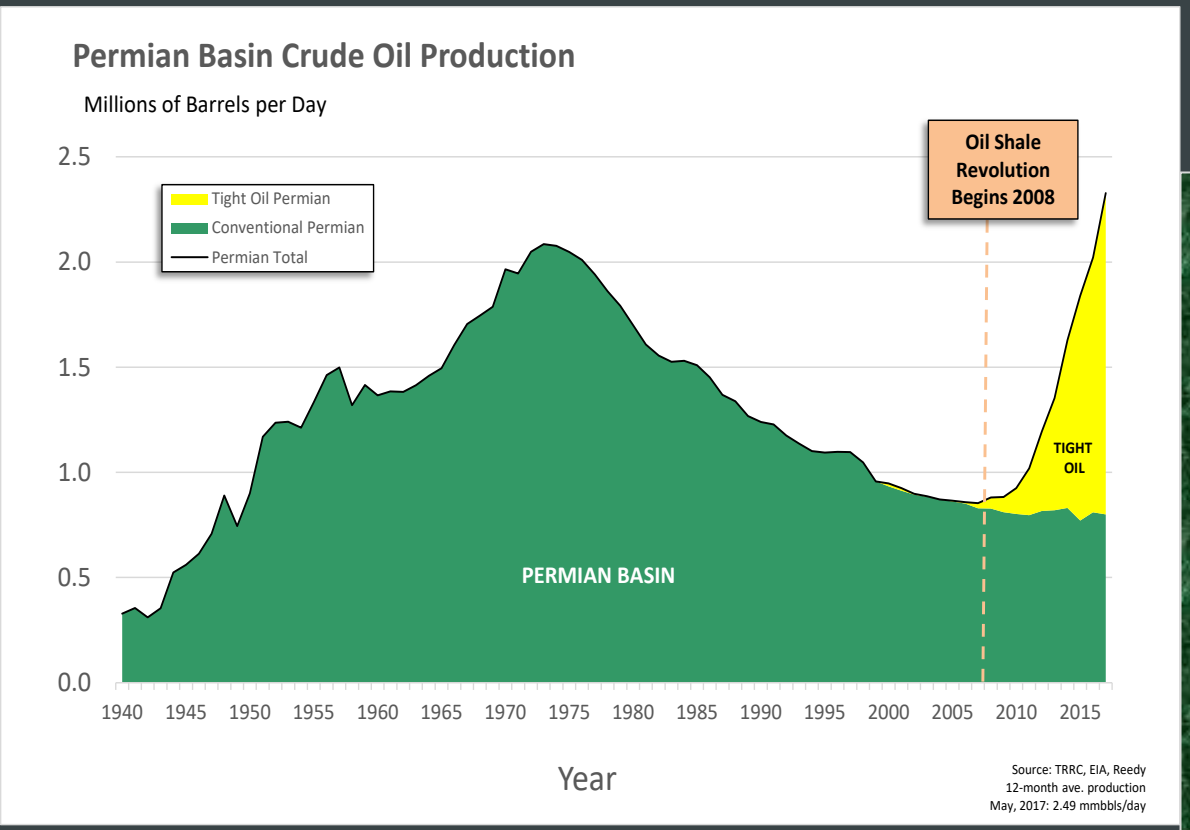
- What is the original resource in place (OGIP, OOIP)?
- What portion of the resource is technically recoverable

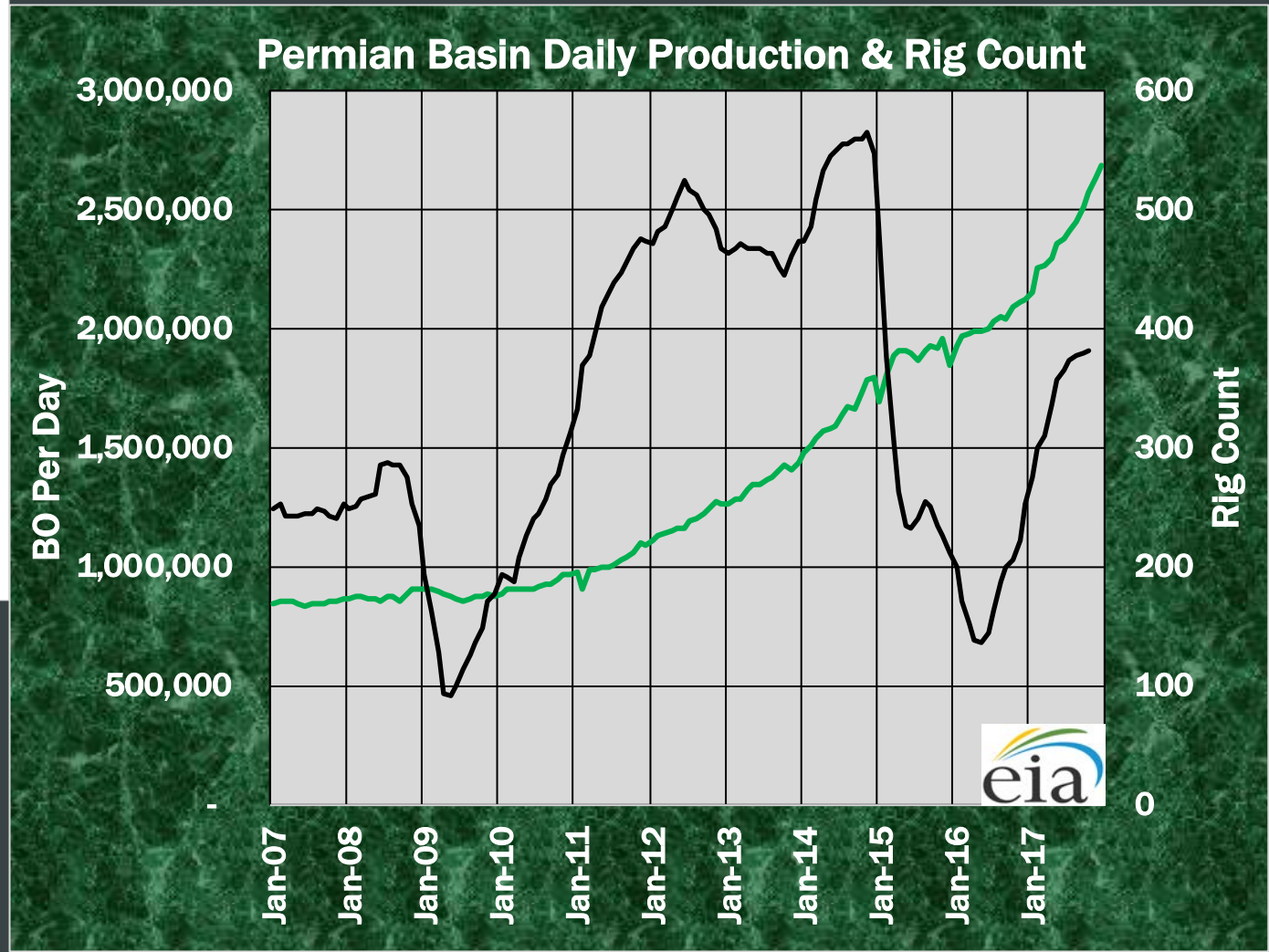
  past, present and future ?
- What portion of the resource is economically recoverable

  given technical and economic assumptions ?
- What are the long-term production outlook scenarios

  various energy prices, costs, technology, regulations ?

Permian Basin Rebirth

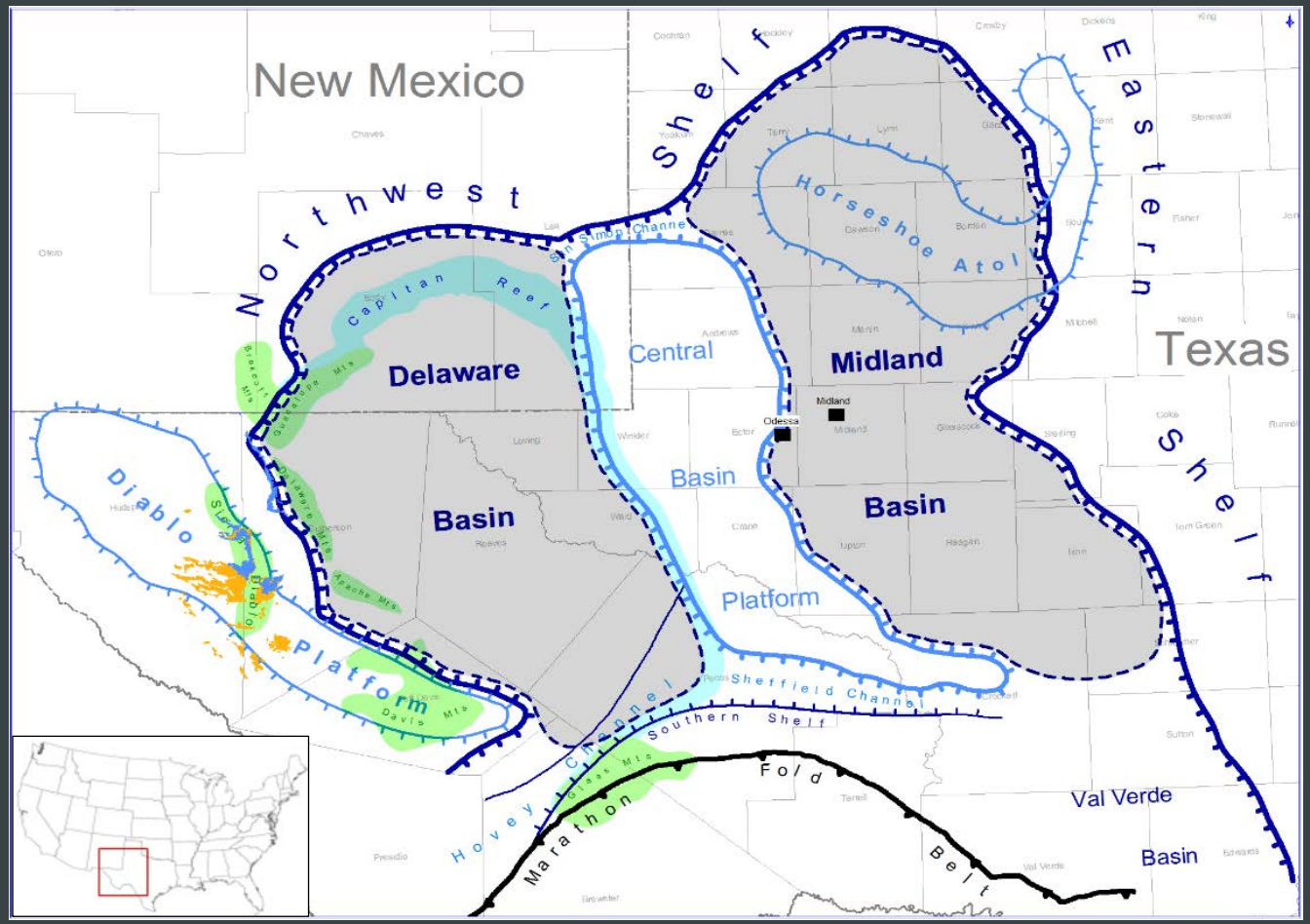




Bureau of Economic Geology

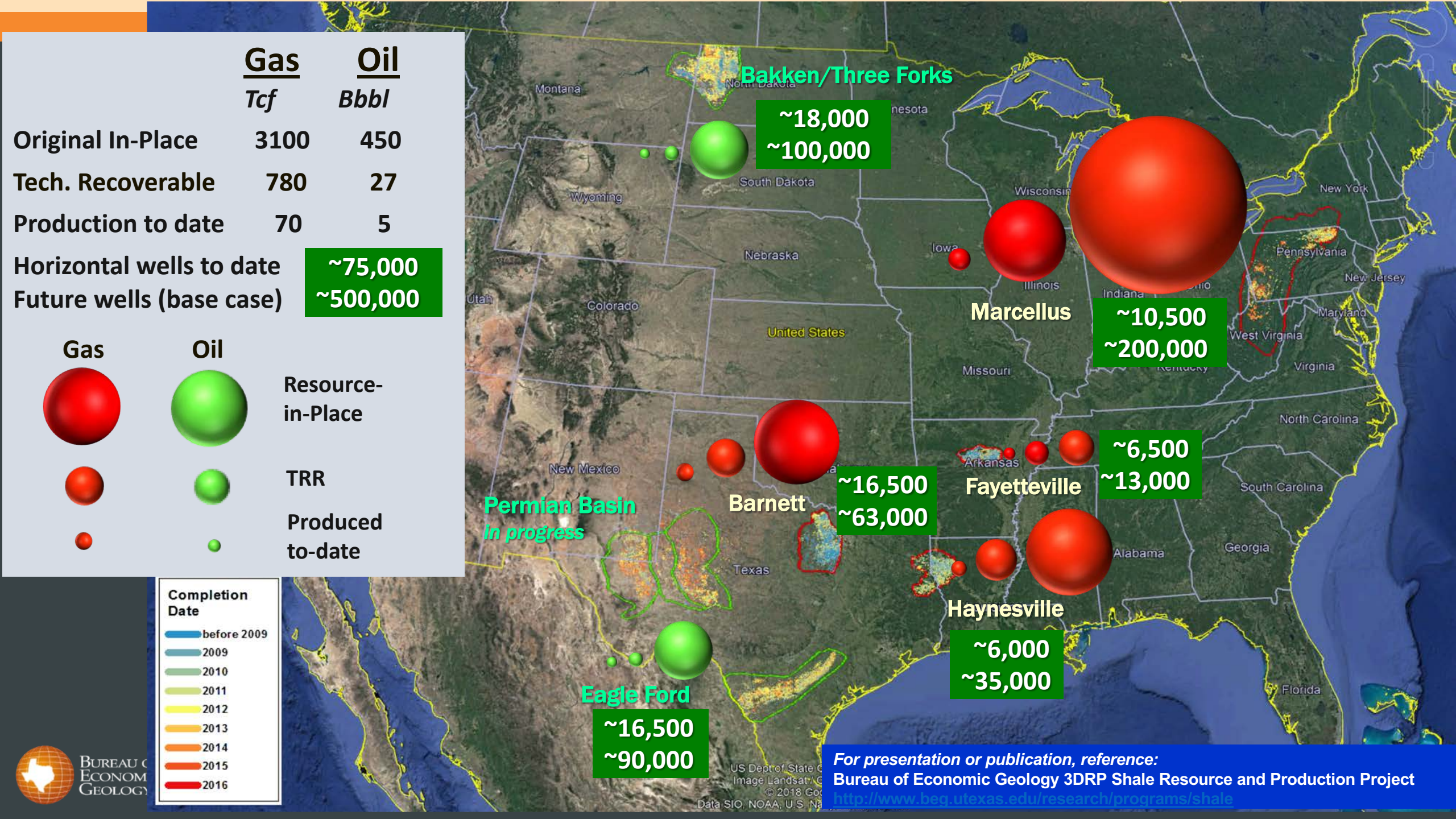
TORA Purpose

- Assess economically recoverable resources from tight, shale-resource reservoirs onshore United States using technical, statistical and economic modeling (e.g. Midland and Delaware, Permian Basin).



Bureau of Economic Geology

TORA
TIGHT OIL RESOURCE ASSESSMENT


Gas
Tcf
Oil
Bbbl
Original In-Place 3100 450
Tech. Recoverable 780 27
Production to date 70 5
Horizontal wells to date ~75,000
Future wells (base case) ~500,000
Gas
Oil
Resource-in-Place
TRR
Produced to-date
Completion Date
before 2009
2009
2010
2011
2012
2013
2014
2015
2016
Bakken/Three Forks
~18,000
~100,000
Marcellus
~10,500
~200,000
Barnett
~16,500
~63,000
Fayetteville
~6,500
~13,000
Permian Basin
in progress
Haynesville
~6,000
~35,000
Eagle Ford
~16,500
~90,000
Montana
South Dakota
Wyoming
Nebraska
Colorado
Utah
New Mexico
Texas
Missouri
Arkansas
Illinois
Indiana
Wisconsin
Iowa
New York
Pennsylvania
New Jersey
Maryland
West Virginia
Virginia
North Carolina
South Carolina
Georgia
Alabama
Florida
United States
For presentation or publication, reference:
Bureau of Economic Geology 3DRP Shale Resource and Production Project
http://www.beg.utexas.edu/research/programs/shale

Integrated Study Workflow

Geologic Analysis

- **Reservoir characterization**
- **Original-Resource-in-Place mapping**

Well Decline Analysis

- **Production and its decline for gas/oil/water**
- **Stimulated/drained rock volume**

Recovery and Productivity Statistical Analysis

Expected production *as a function of*

- **Well productivity drivers**
- **Location and Completion**
- **Inventory of future wells**
- **Technically Recoverable Resources**

Well Economics

Expected well profitability

as a function of

- **well production profile**
- **operational**
- **market and regulatory parameters**

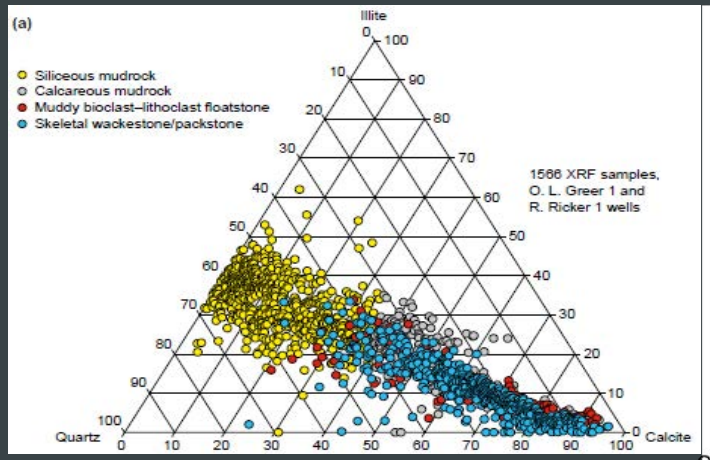
Production Outlook

- **Pace of drilling** *by year and area,*
- **Expected gas/oil/water production** *depending on* **economics, technology, regulation**

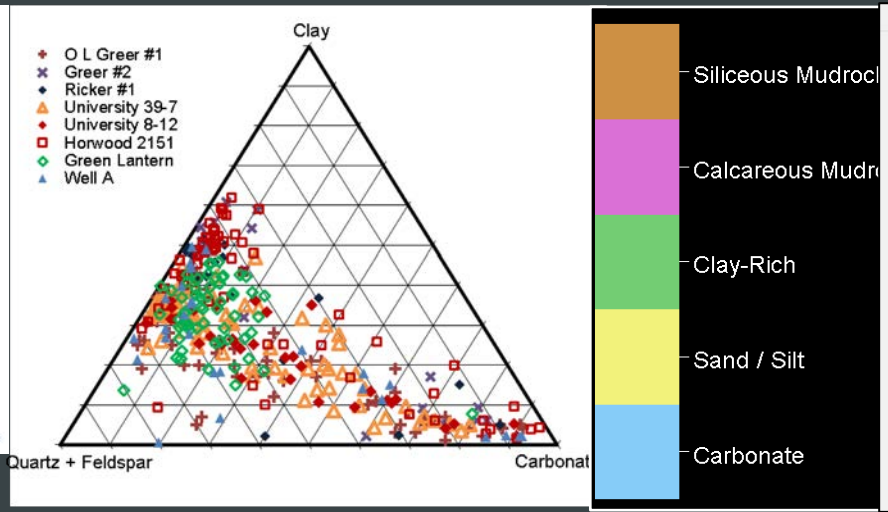
Bureau of Economic Geology

Example Products

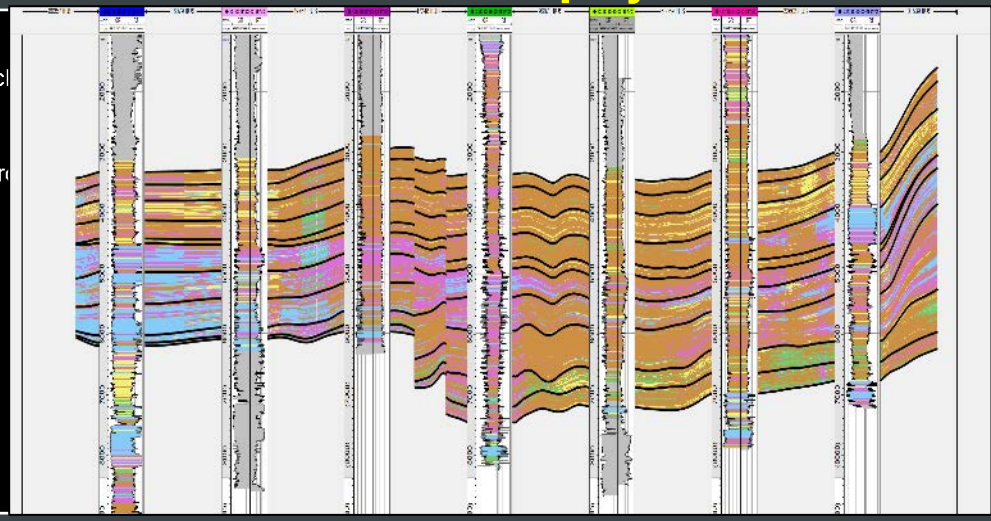
Geology



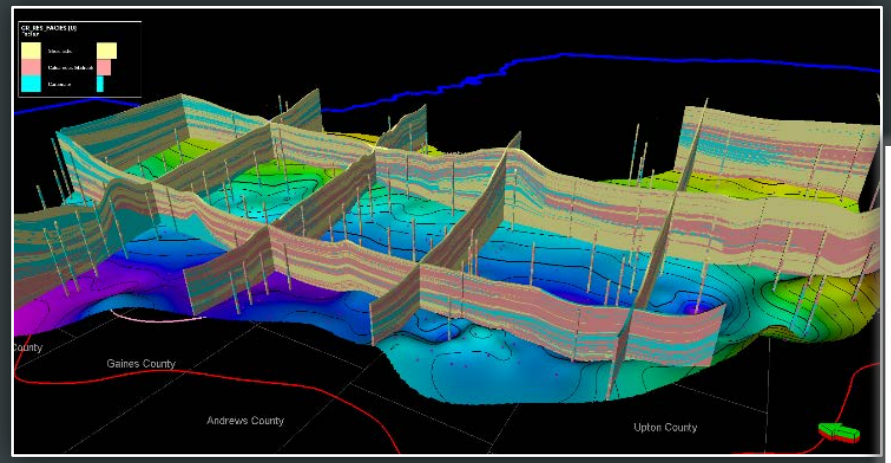
(from Baumgardner, Hamlin and Rowe, 2016; computed from XRF data)



Stratigraphic Framework Petrophysics

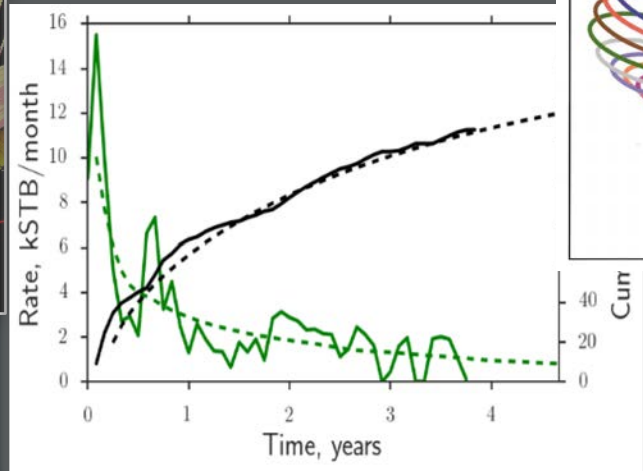


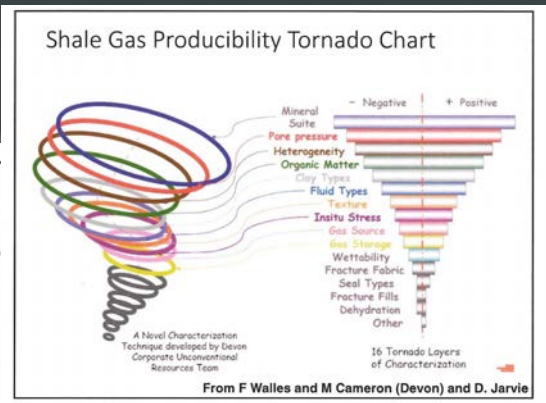
3D Models



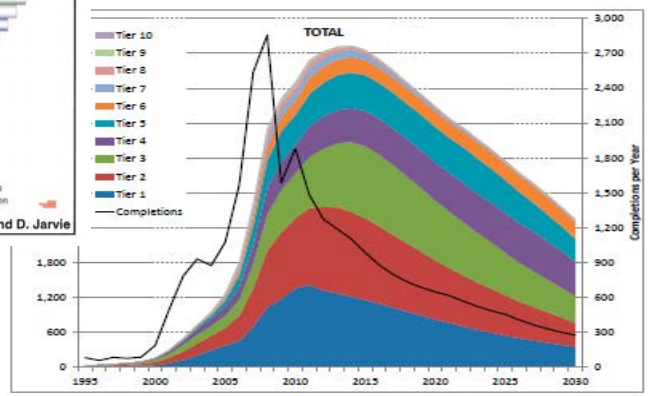
Statistical Modeling

History Matching





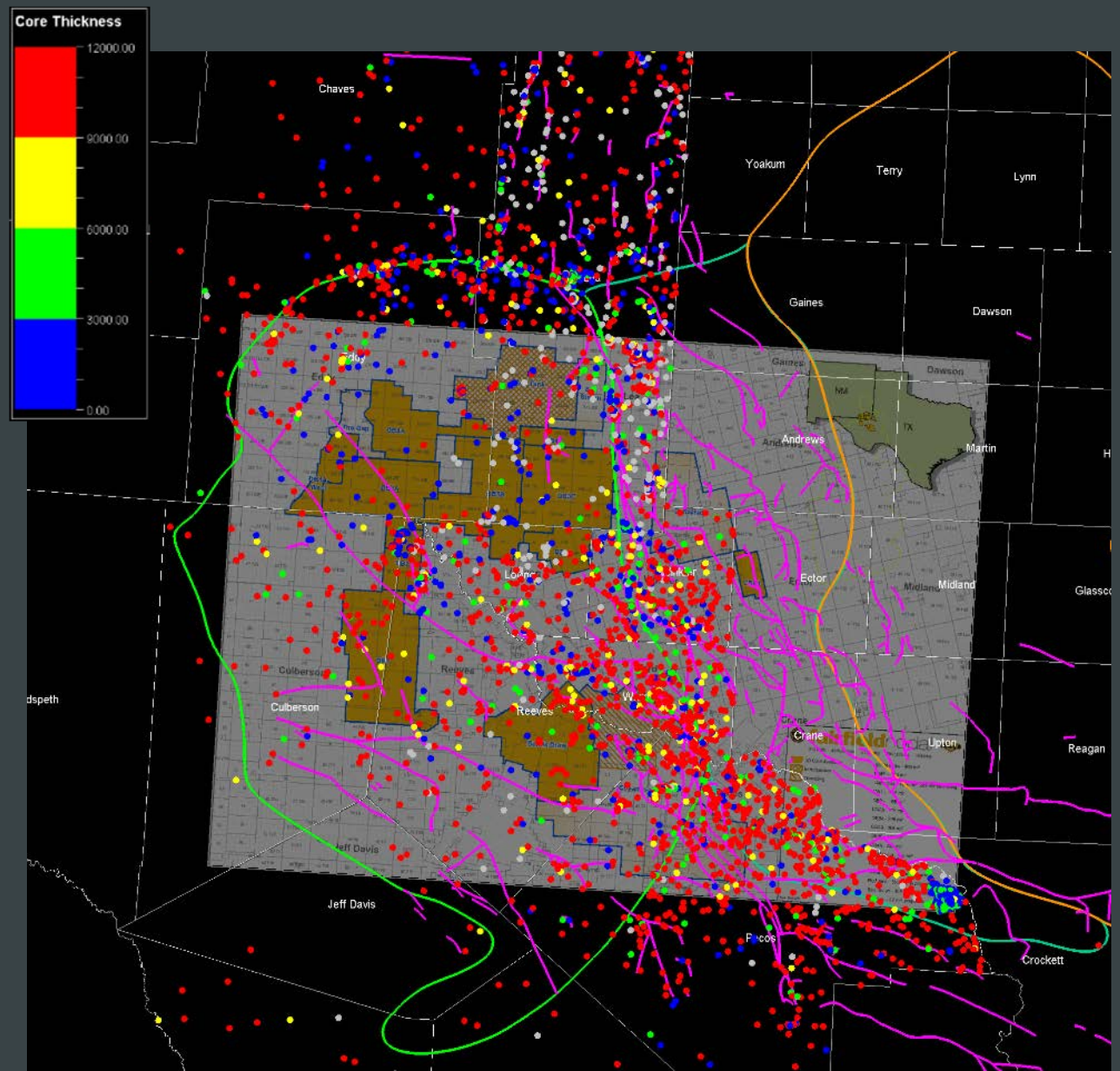
Production Outlook



A schematic illustrating production outlook for a specific price case.

Bureau of Economic Geology

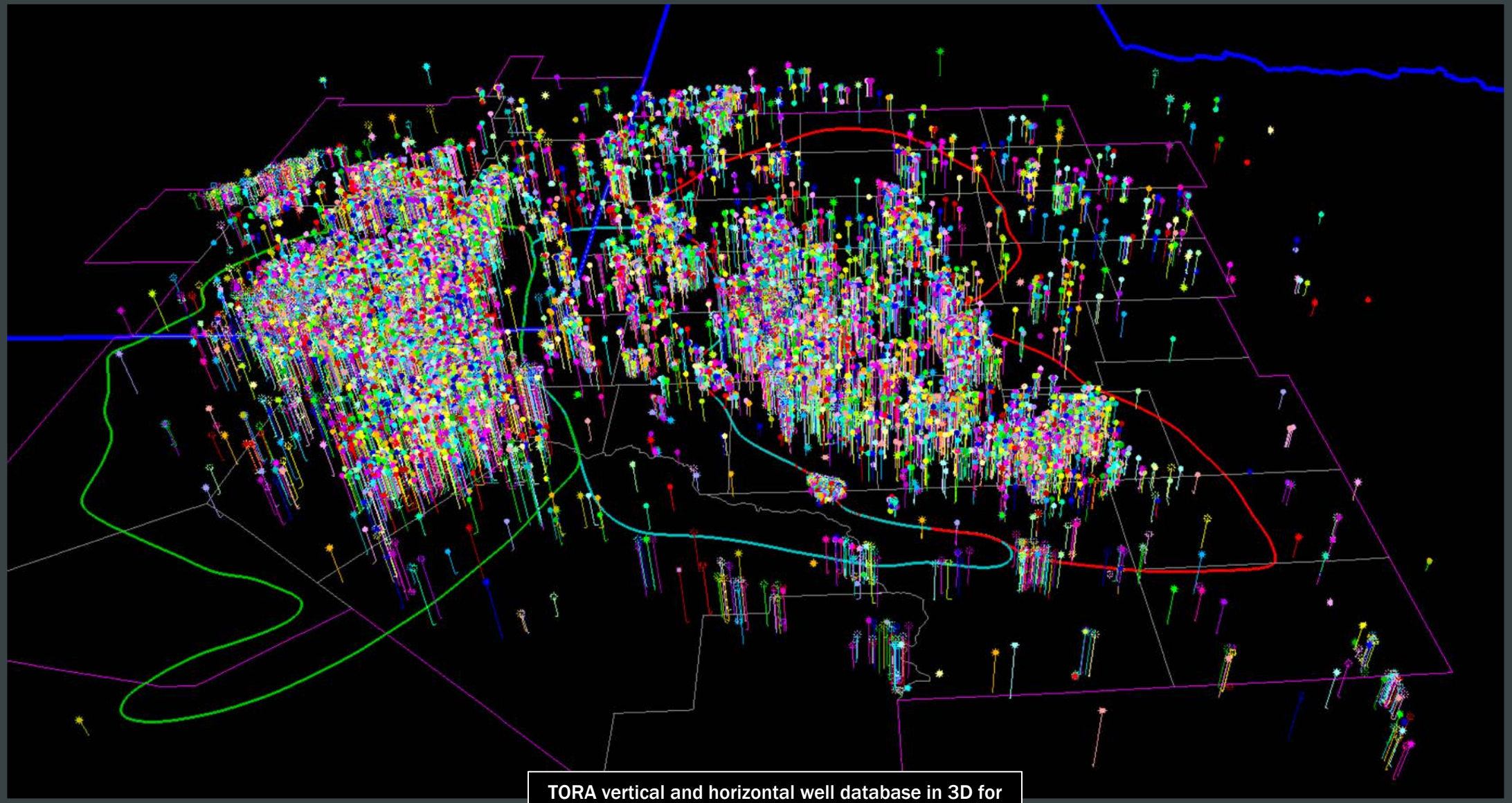
BEG Core Data Availability in Delaware Basin counties



- Wells with BEG Core data
- Faults

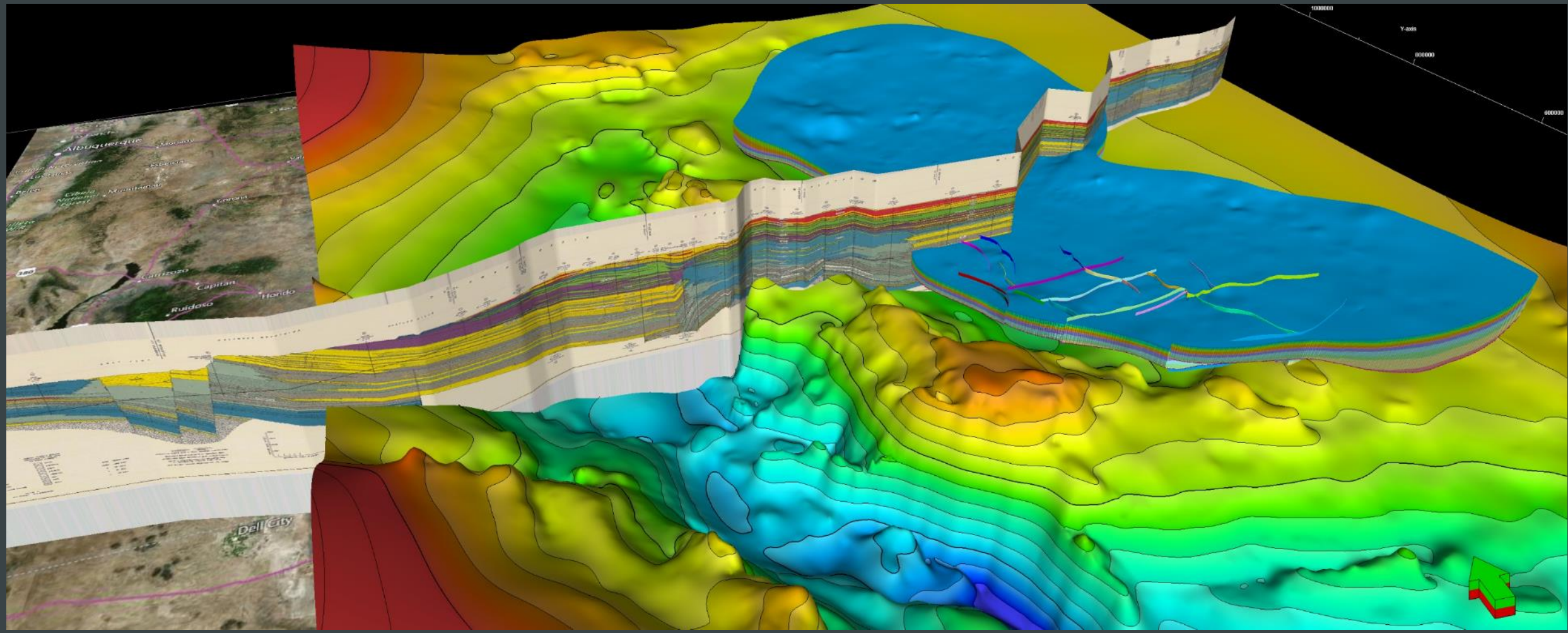
Bureau of Economic Geology

TORA 3D Model Well Distribution in 3D

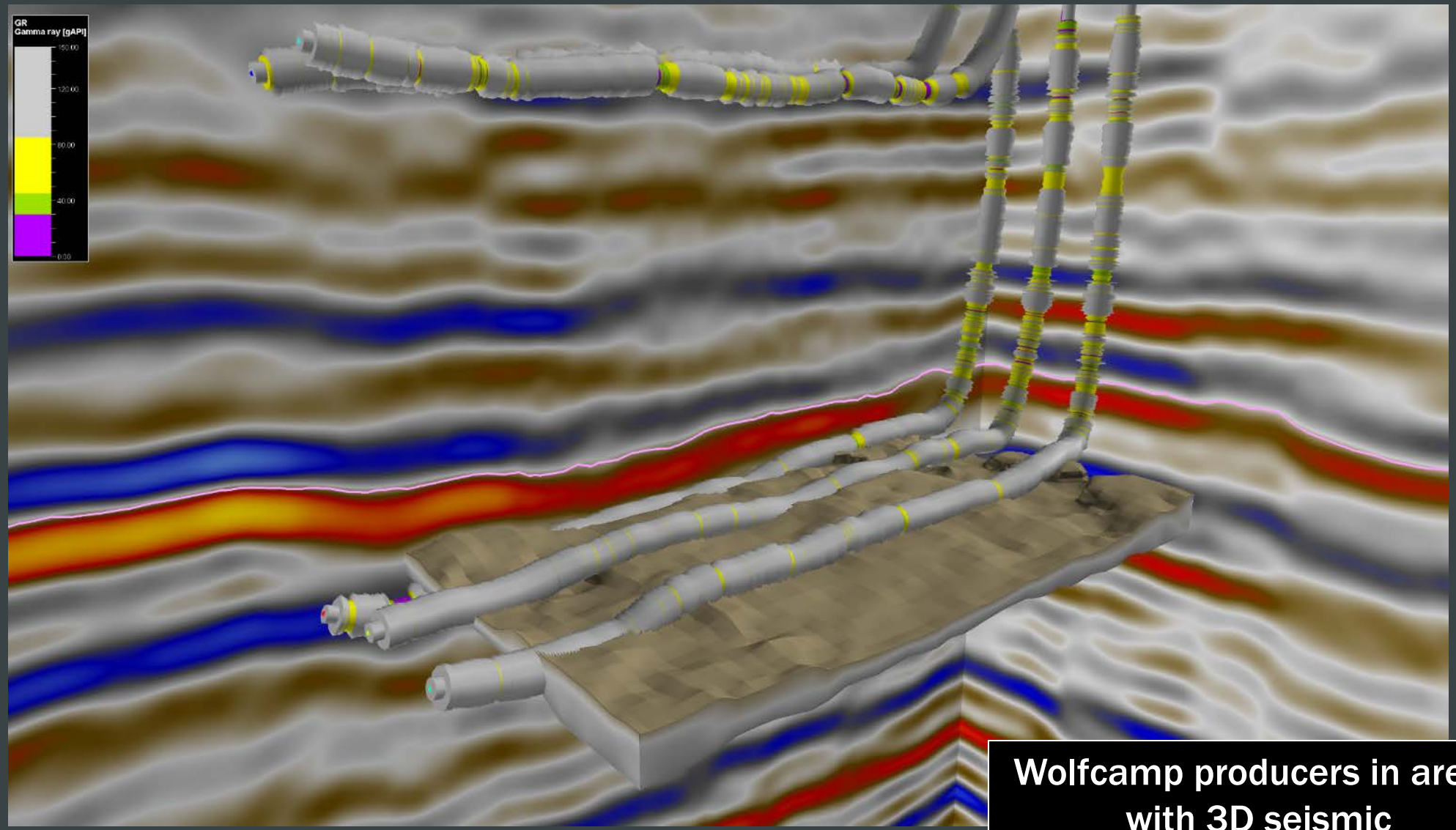


TORA vertical and horizontal well database in 3D for Delaware and Midland Basin

Regional Setting of Midland Basin Study

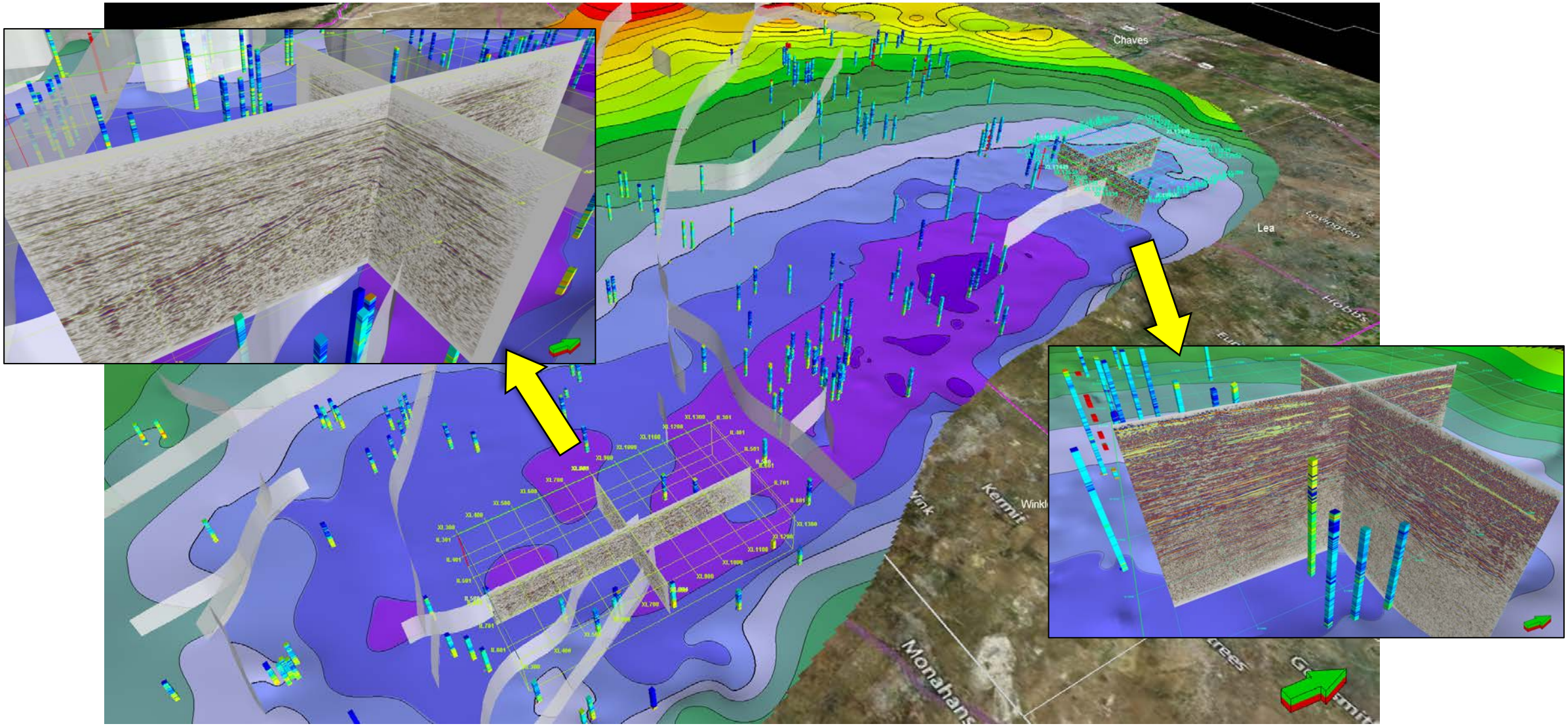


Bureau of Economic Geology

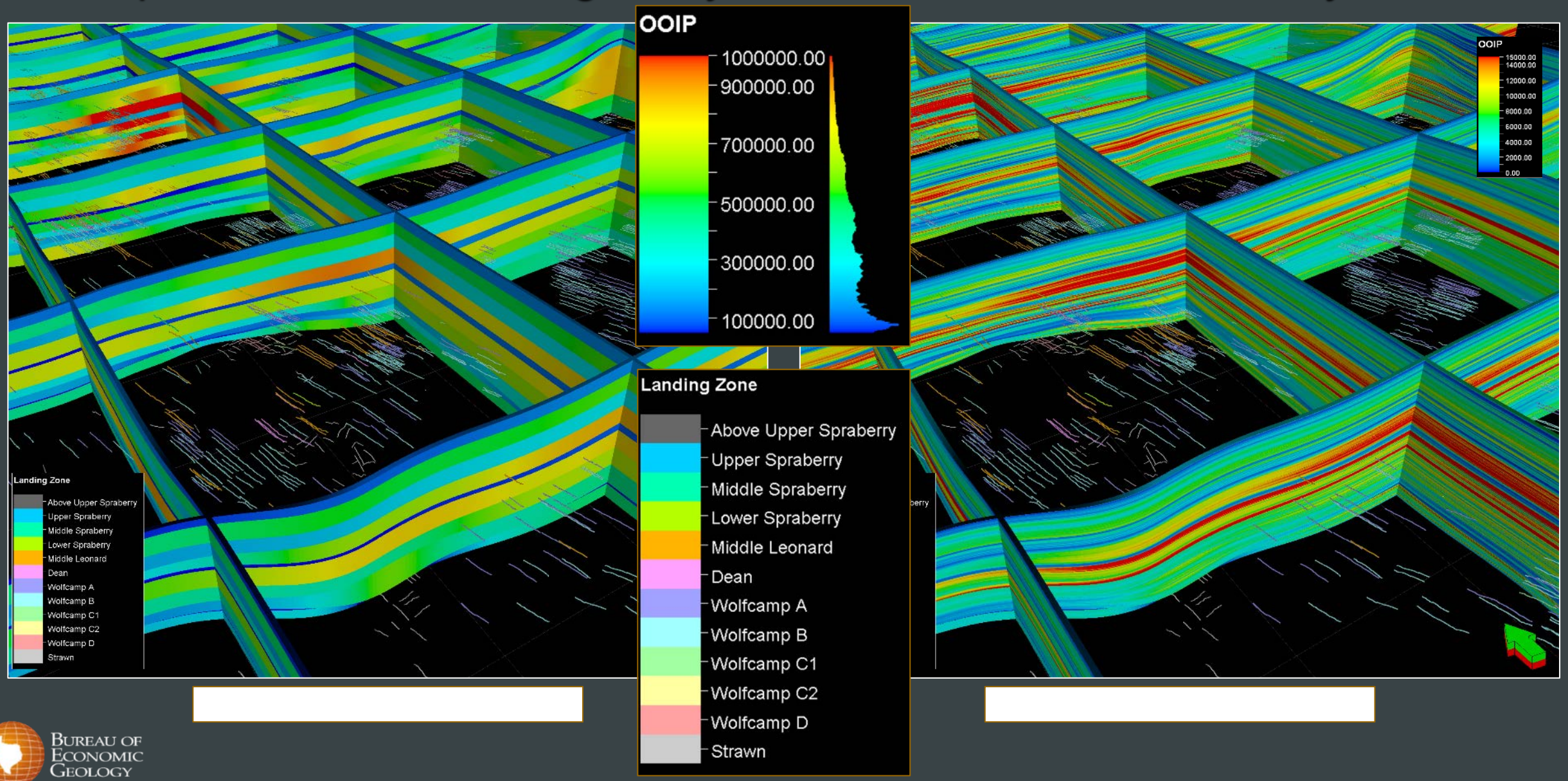


Wolfcamp producers in areas with 3D seismic

Two Available 3D seismic surveys: Red Tank & Waha-Lockridge



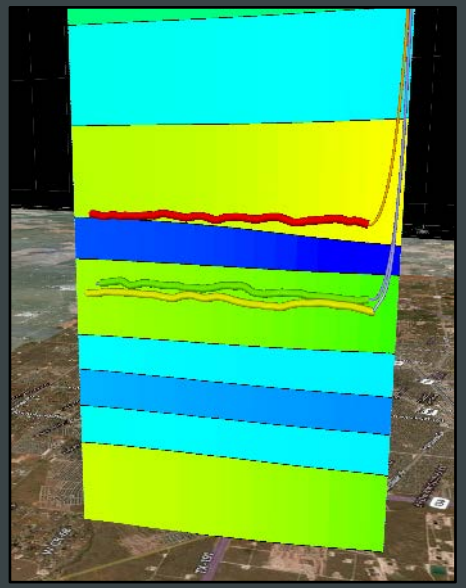
Comparison between Single Layer Model and 5-foot thick Layer Model

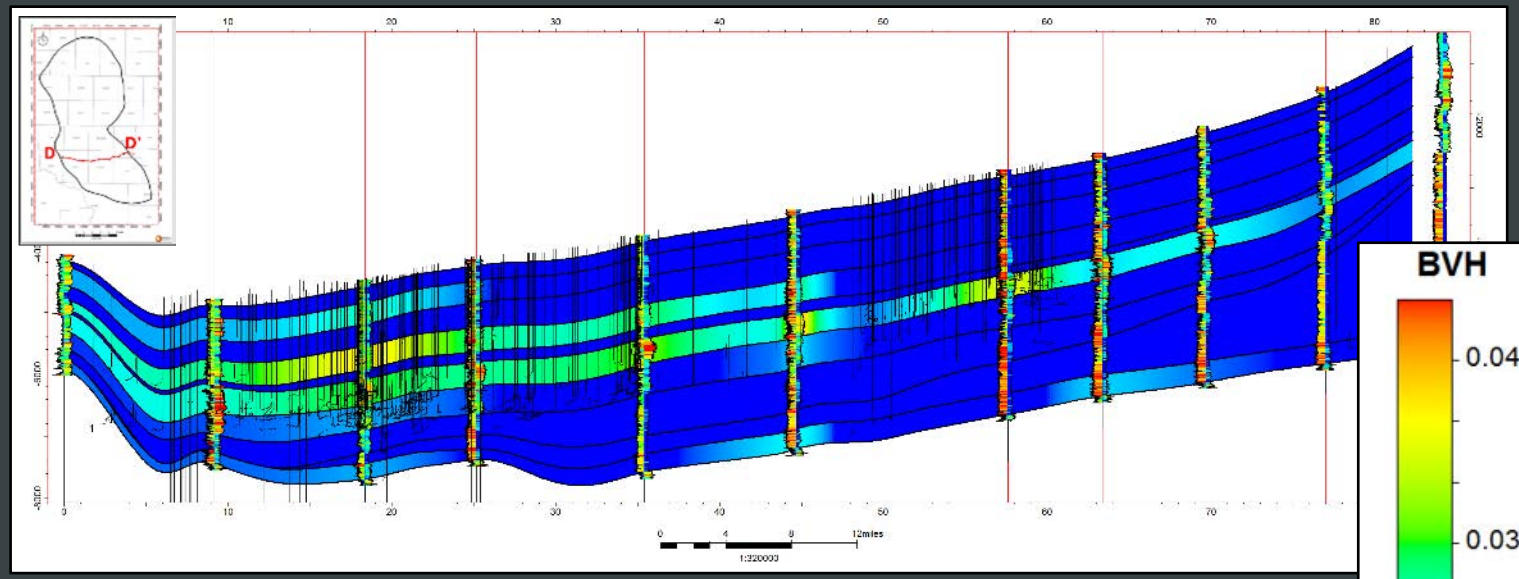


Bureau of Economic Geology

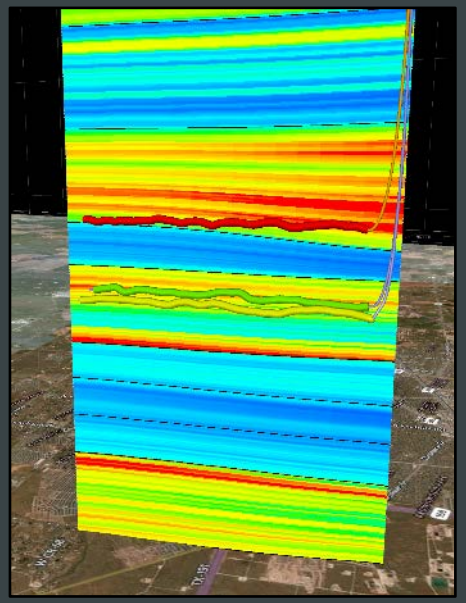
Comparison between Single Layer Model and 5-foot thick Layer Model

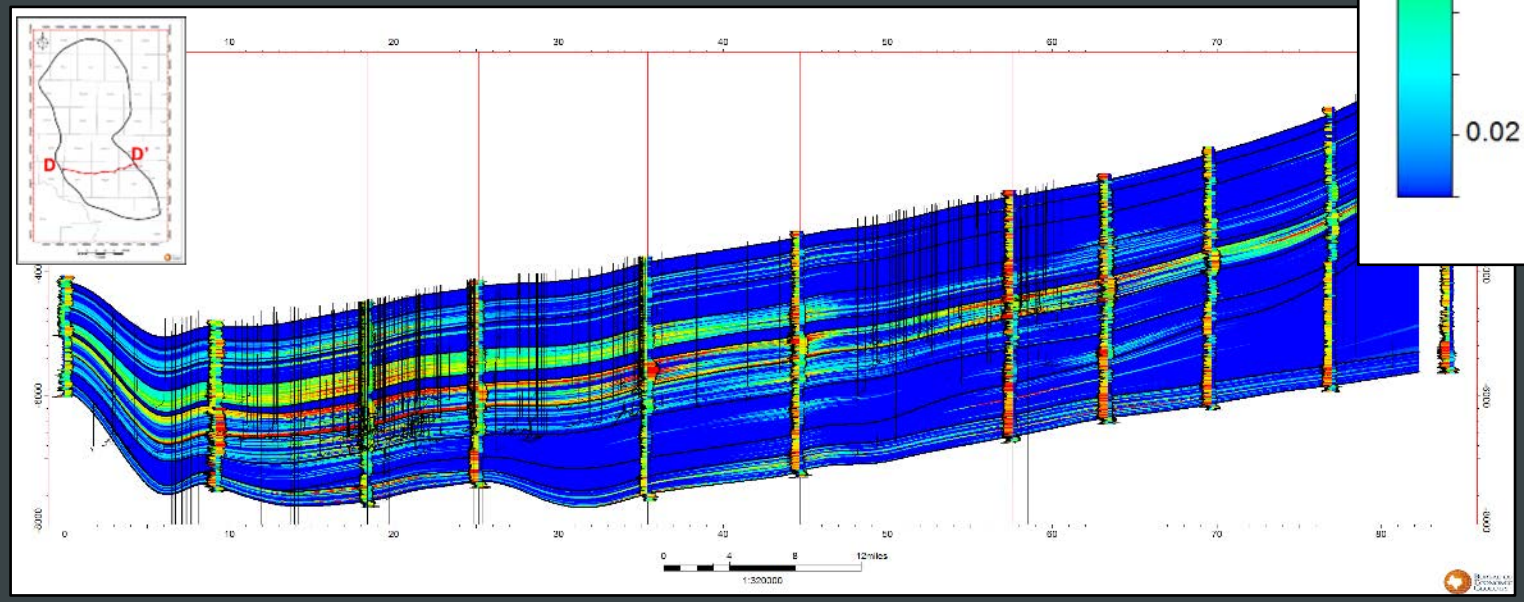
- 945 x 1408 x 12 3D Grid
- 750ft x 750ft x Variable Thickness Cells
- **16 million cells**
- 12 zones
- 12 layers
- **OOIP = 3.31T STB**





- 945 x 1408 x 682 3D Grid
- 750ft x 750ft x 5ft Cells
- **907 million cells**
- 13 zones
- 682 layers
- **OOIP = 2.83T STB**

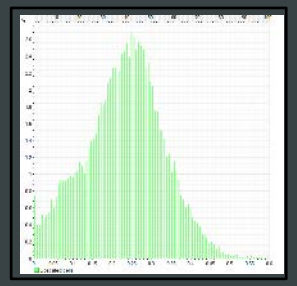




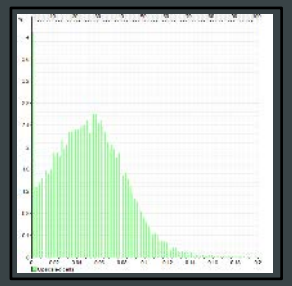
Single layer has **17%** OOIP increase

Bureau of Economic Geology

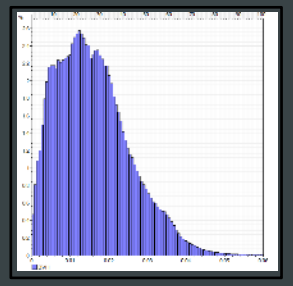
OOIP with Cutoffs



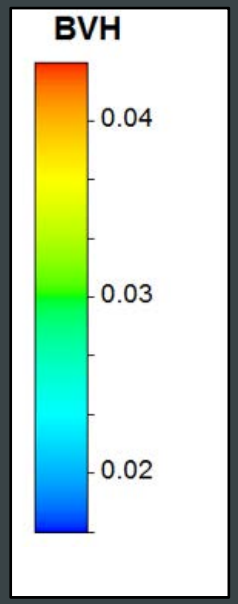
Vclay Histogram (0–0.6)

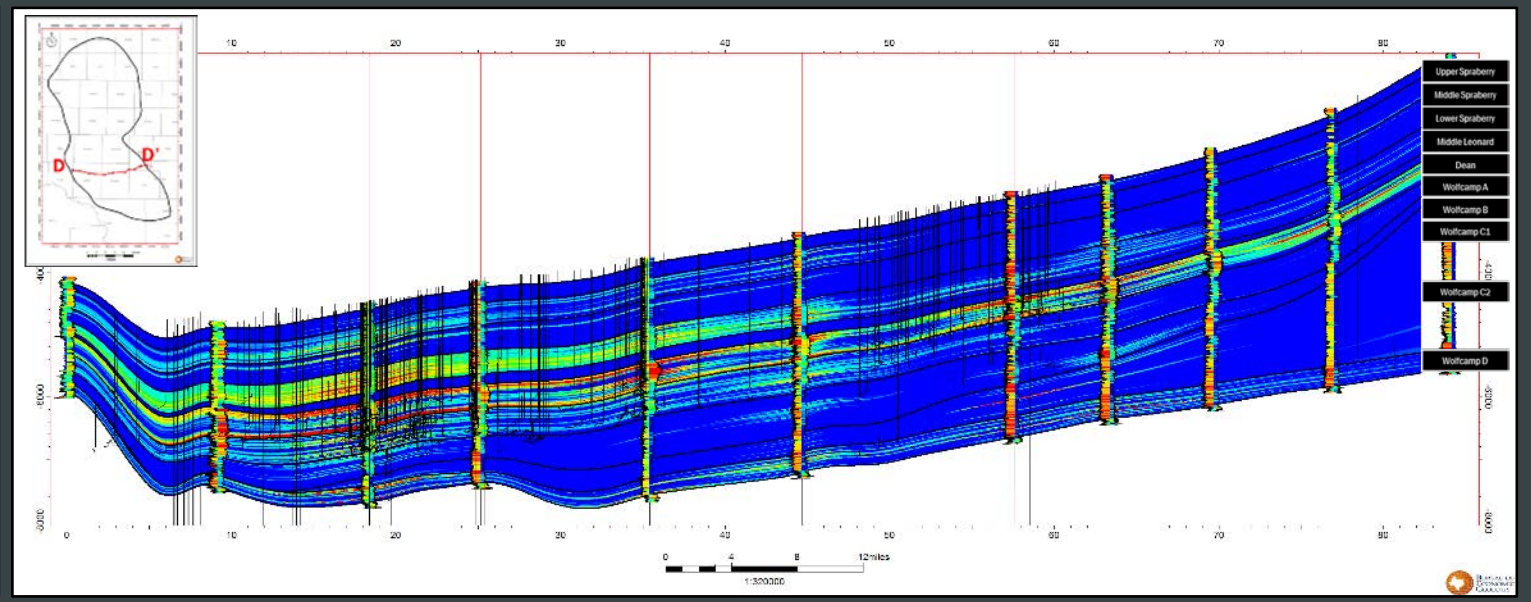


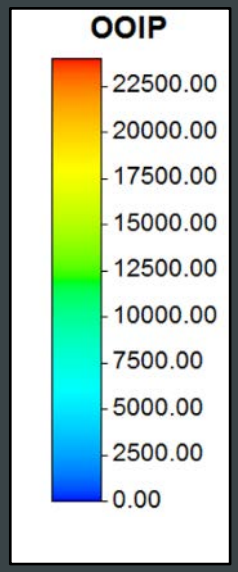
Vker Histogram (0–0.2)

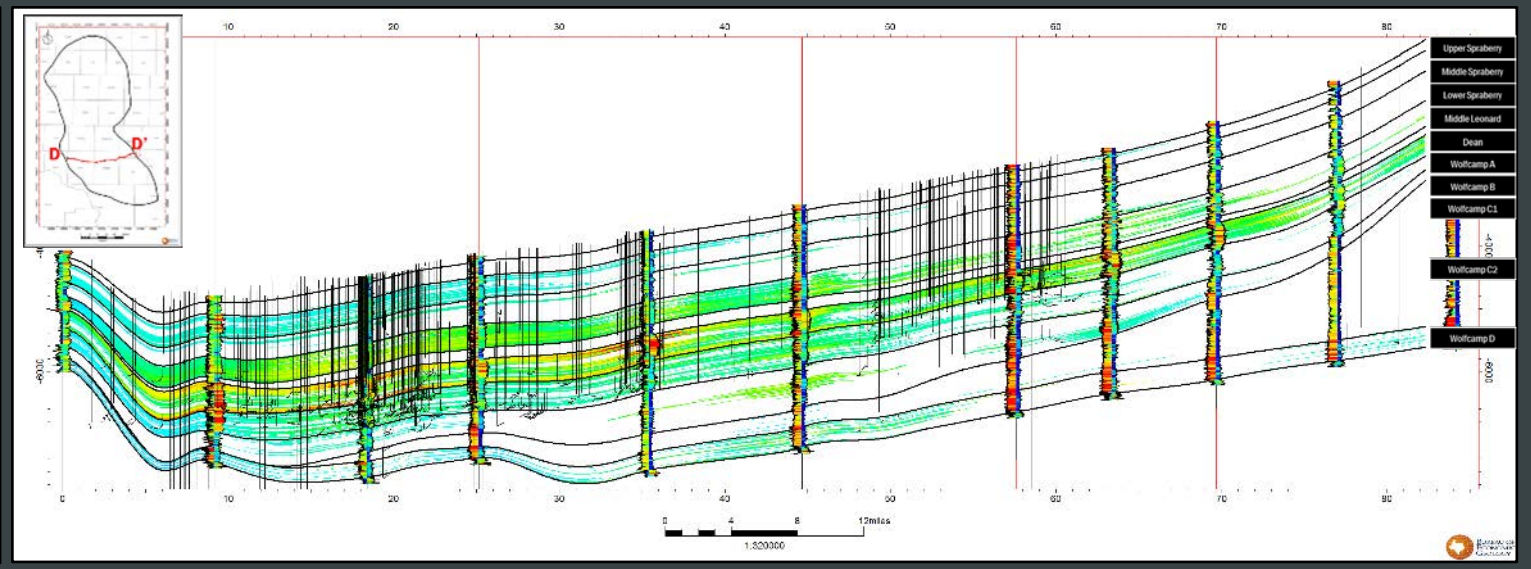


BVH Histogram (0–0.06)







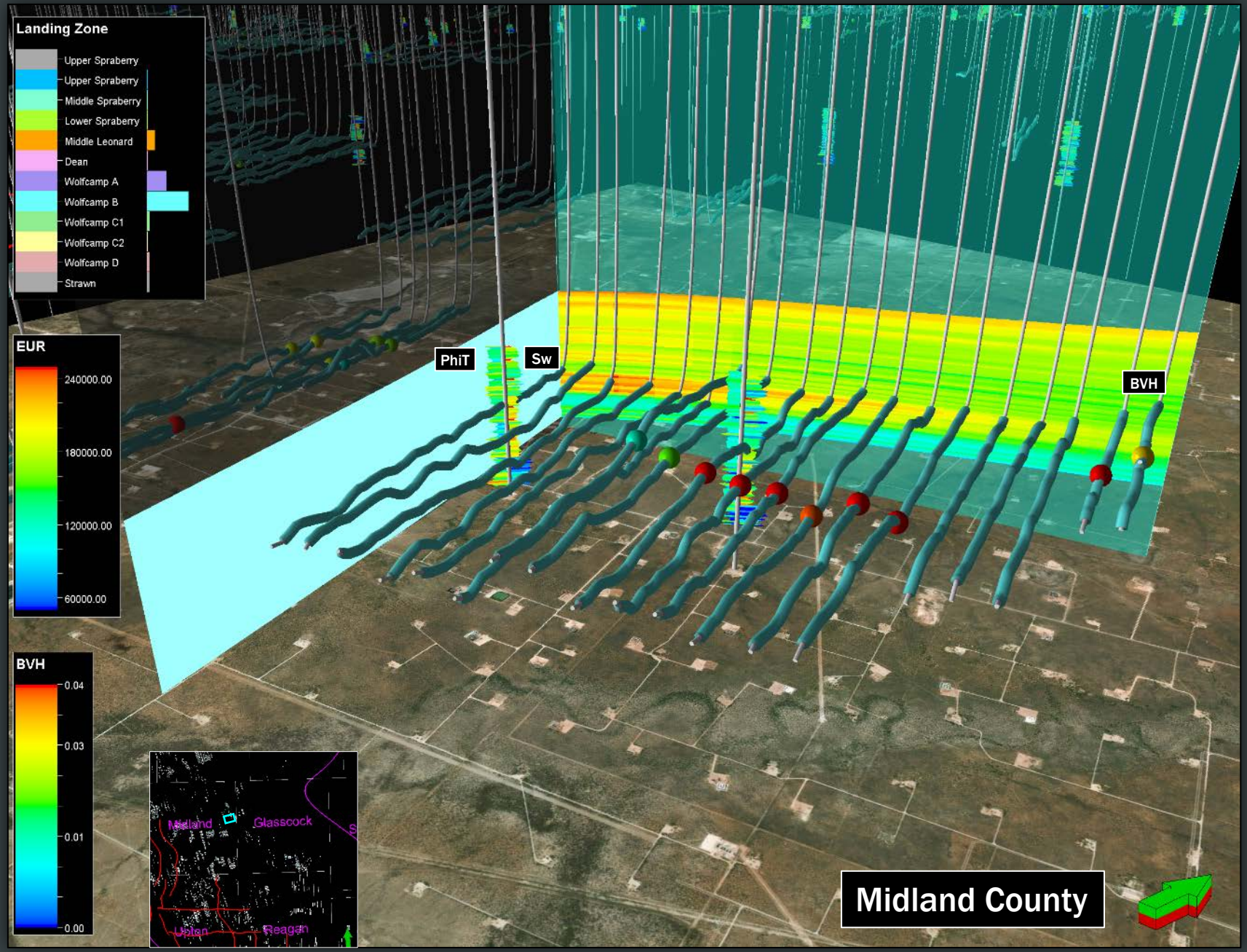


Cutoffs:

- Volume Clay (Vclay) < 30%
- Volume Kerogen (Vker) > 2%
- Bulk Volume Hydrocarbon (BVH) > 2%

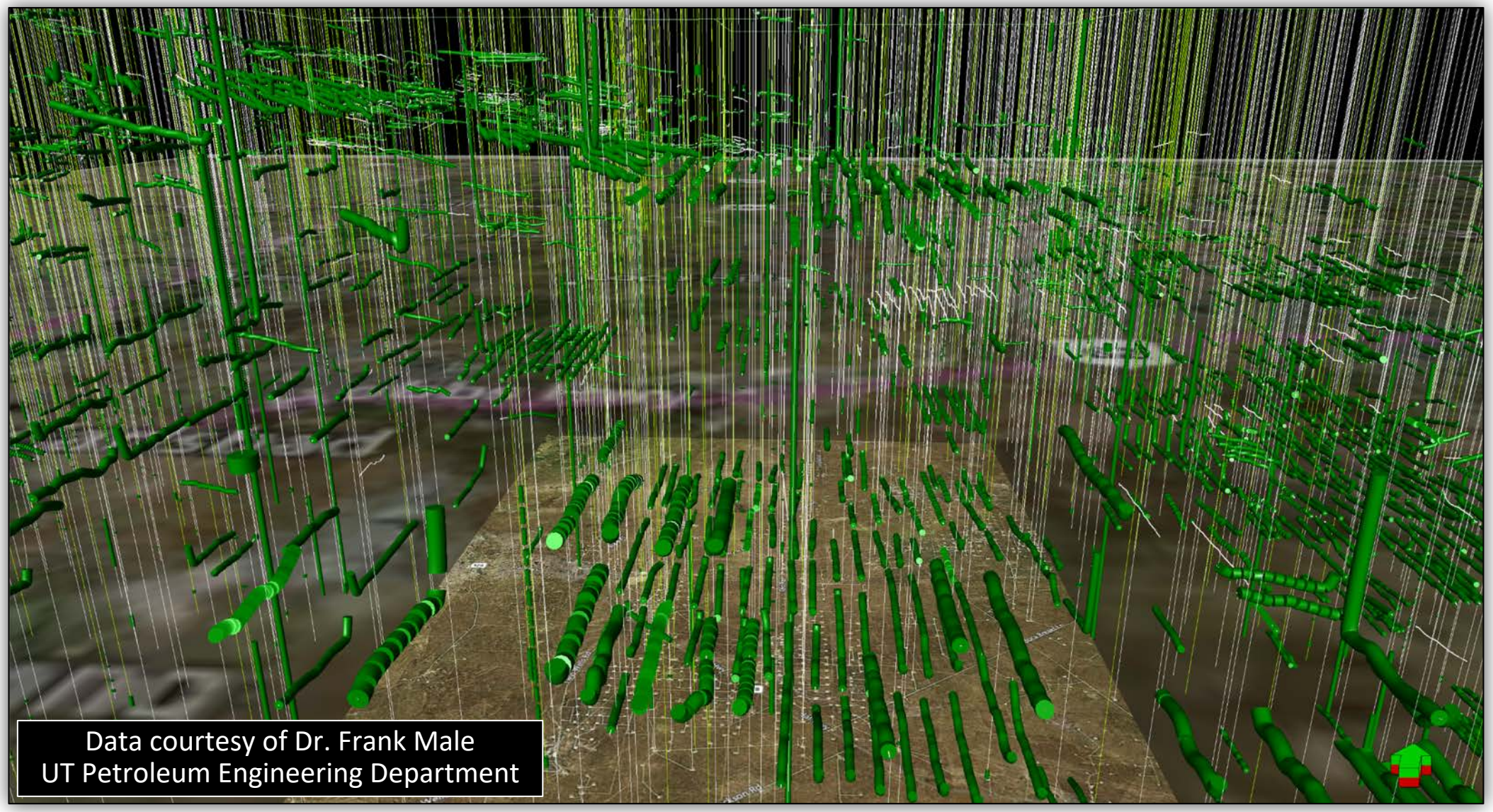
OOIP with cutoffs = **1.03T STB**

Bureau of Economic Geology



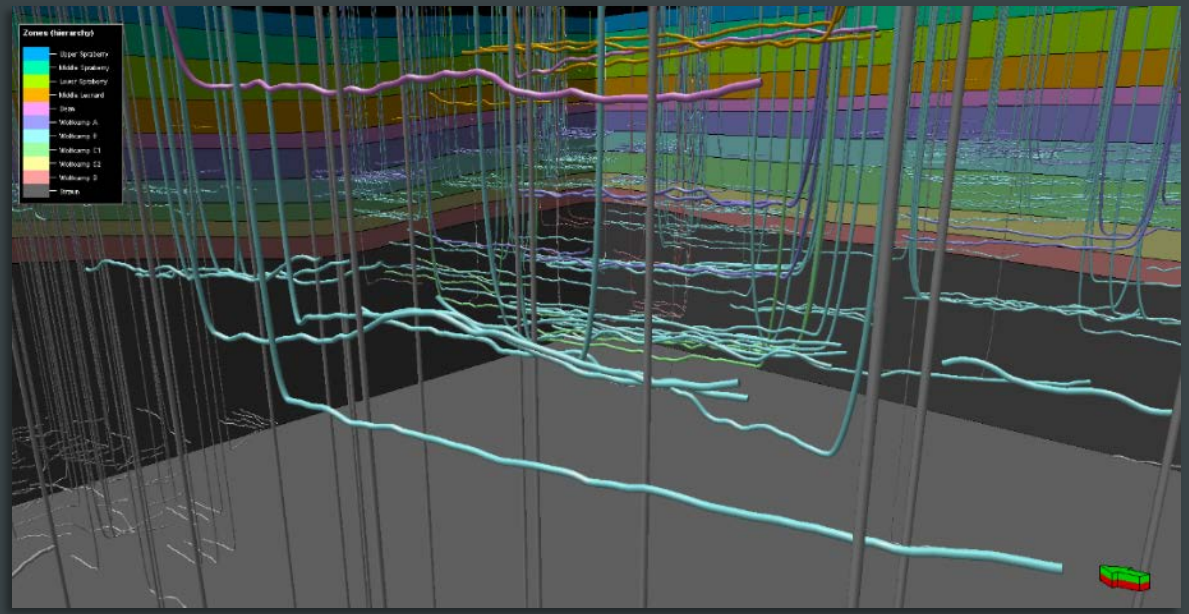
Bureau of Economic Geology

Operator Completion Data



3D Geomodeling

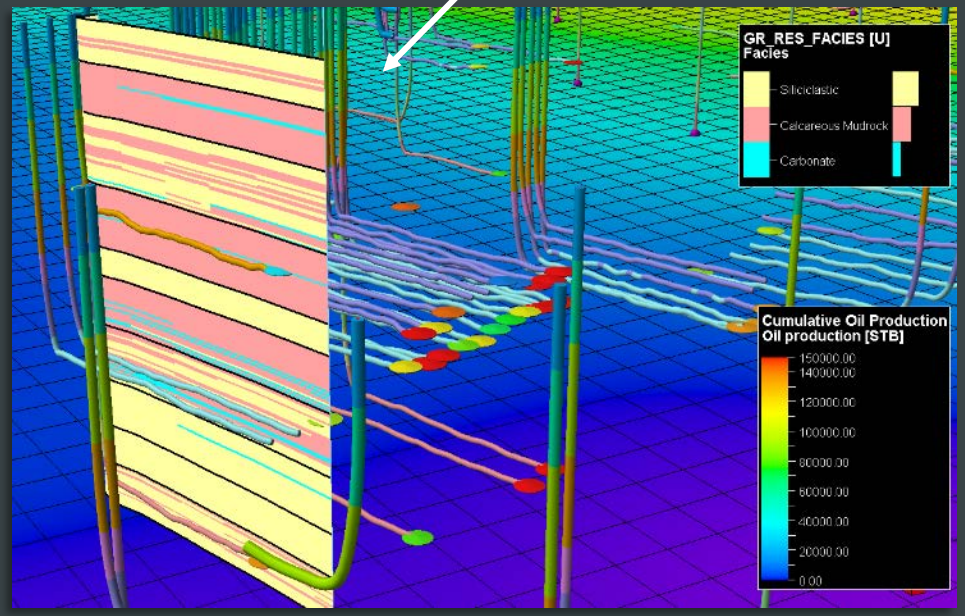
Landing Zones



Midland Basin well trajectories color coded by landing formation
(e.g., WC B is blue)

Lithofacies Descriptions

Formations

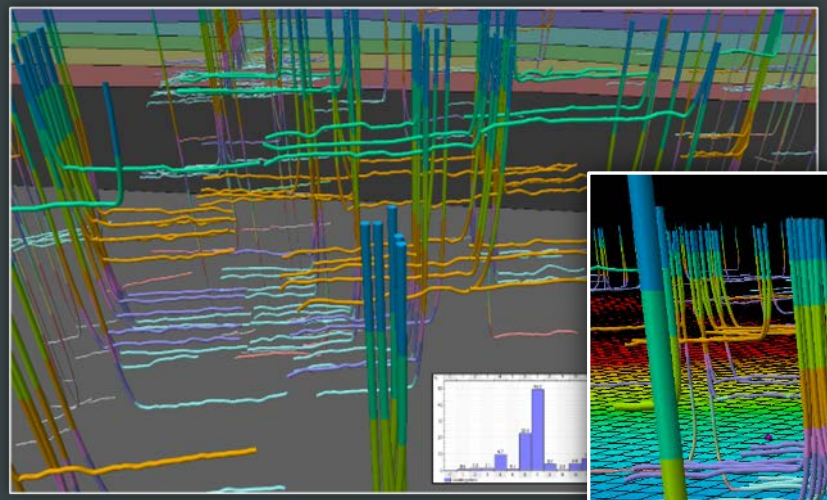


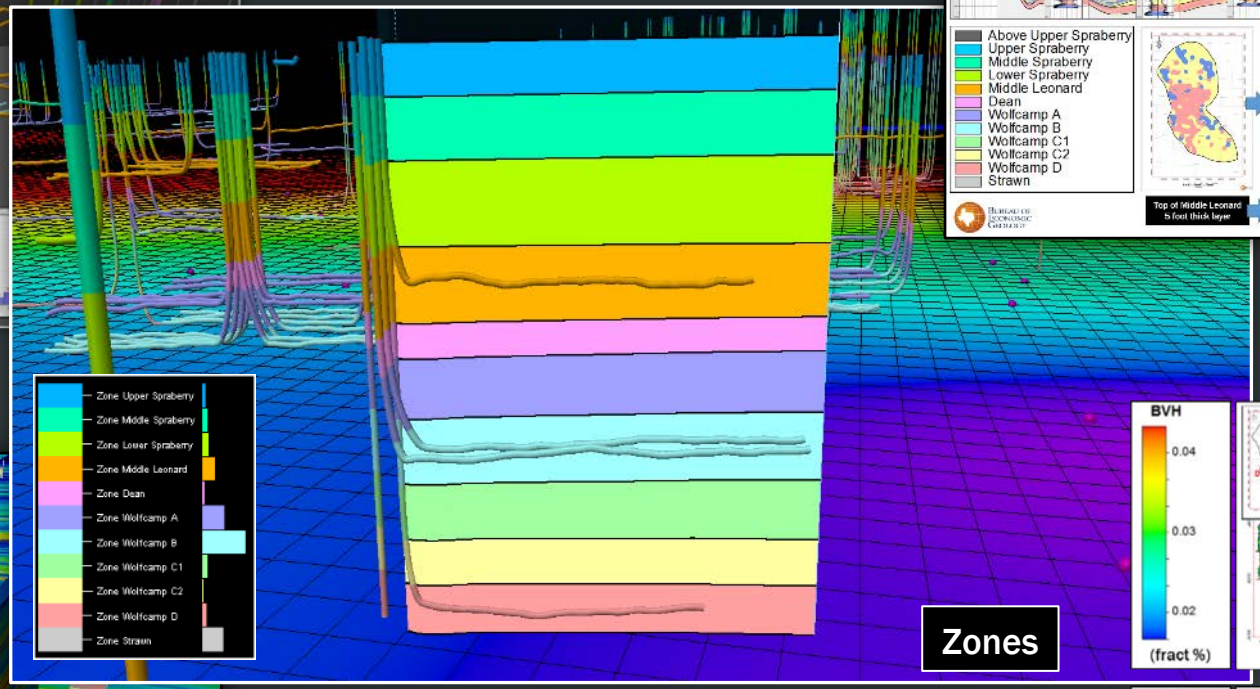
Lithofacies Groups

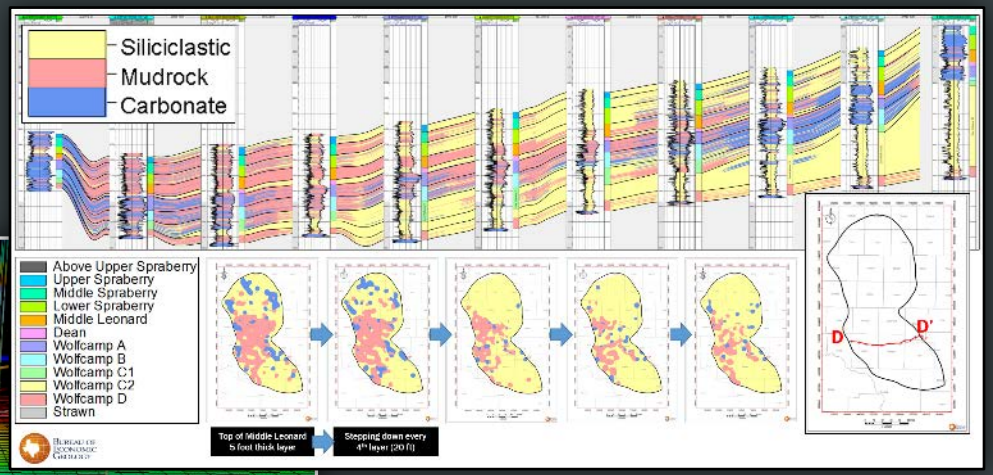
- *Siliciclastics*
- *OM Mudrock*
- *Carbonate*

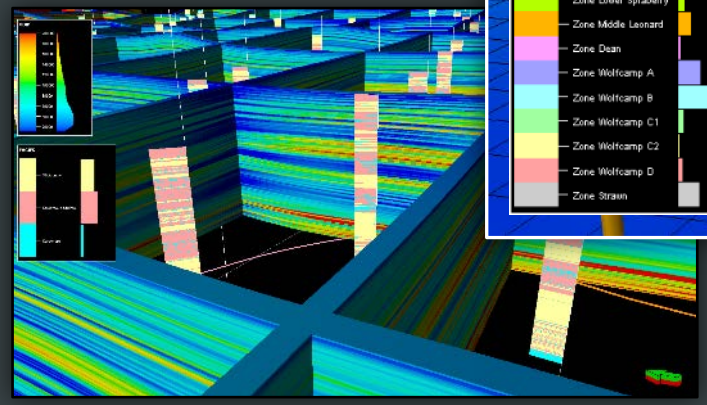
Lithofacies content of formations
(e.g., WC B dominated by siliciclastics and organic-rich mudrocks with minor carbonate)

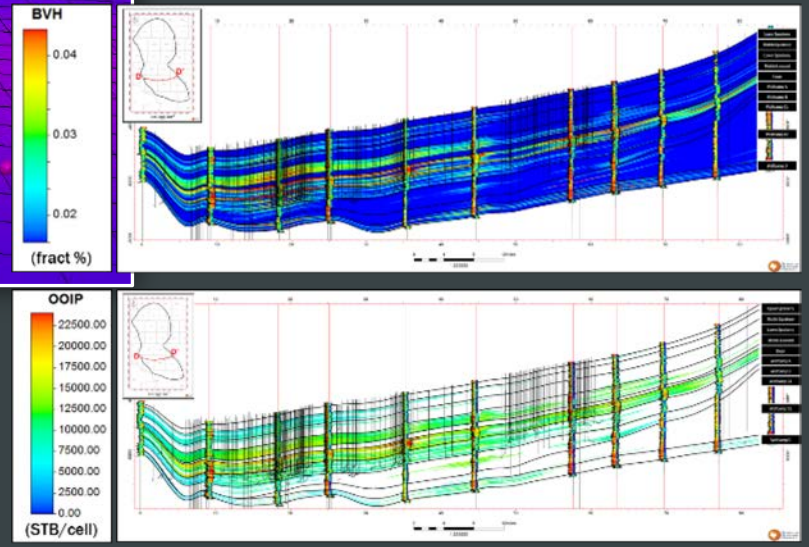
Midland Basin





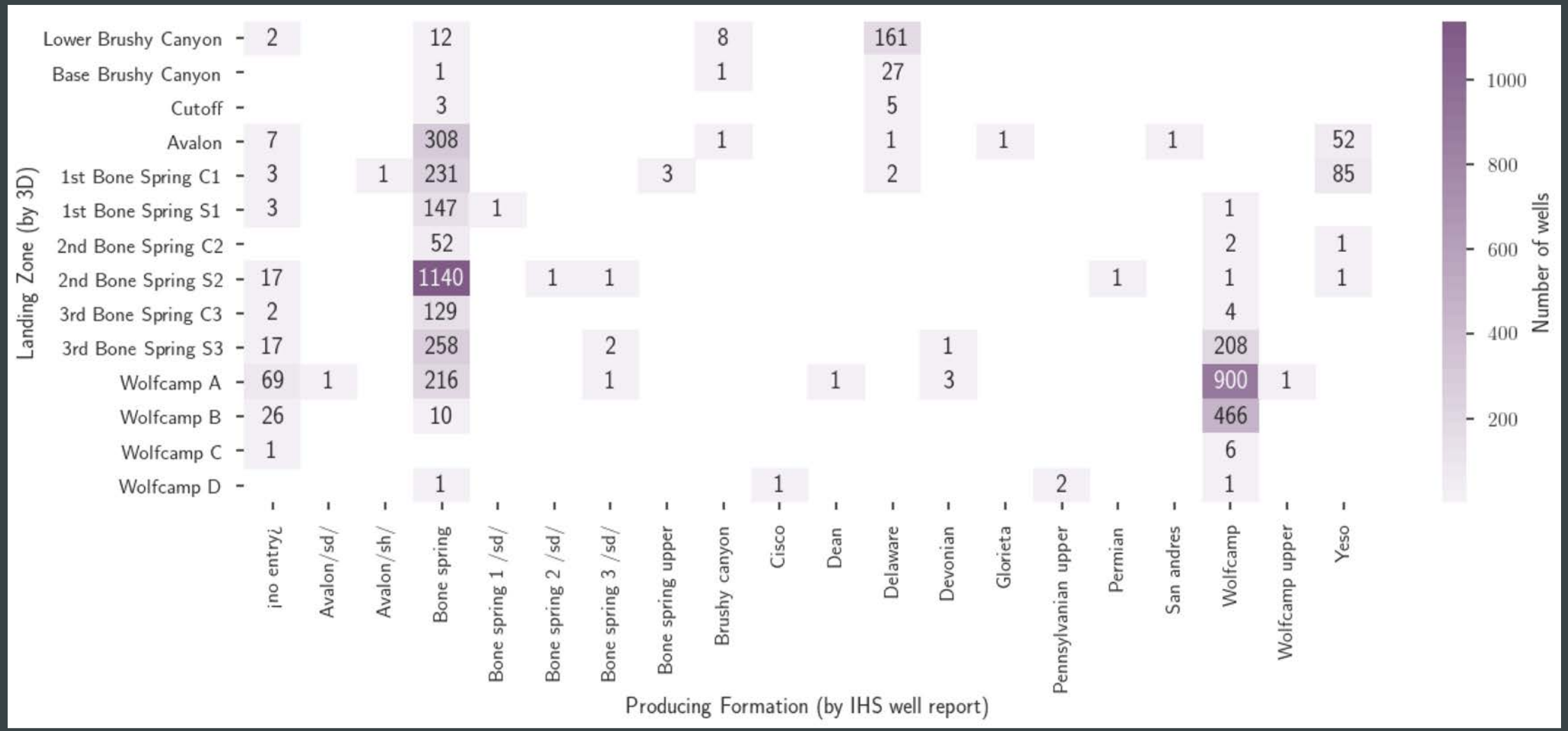






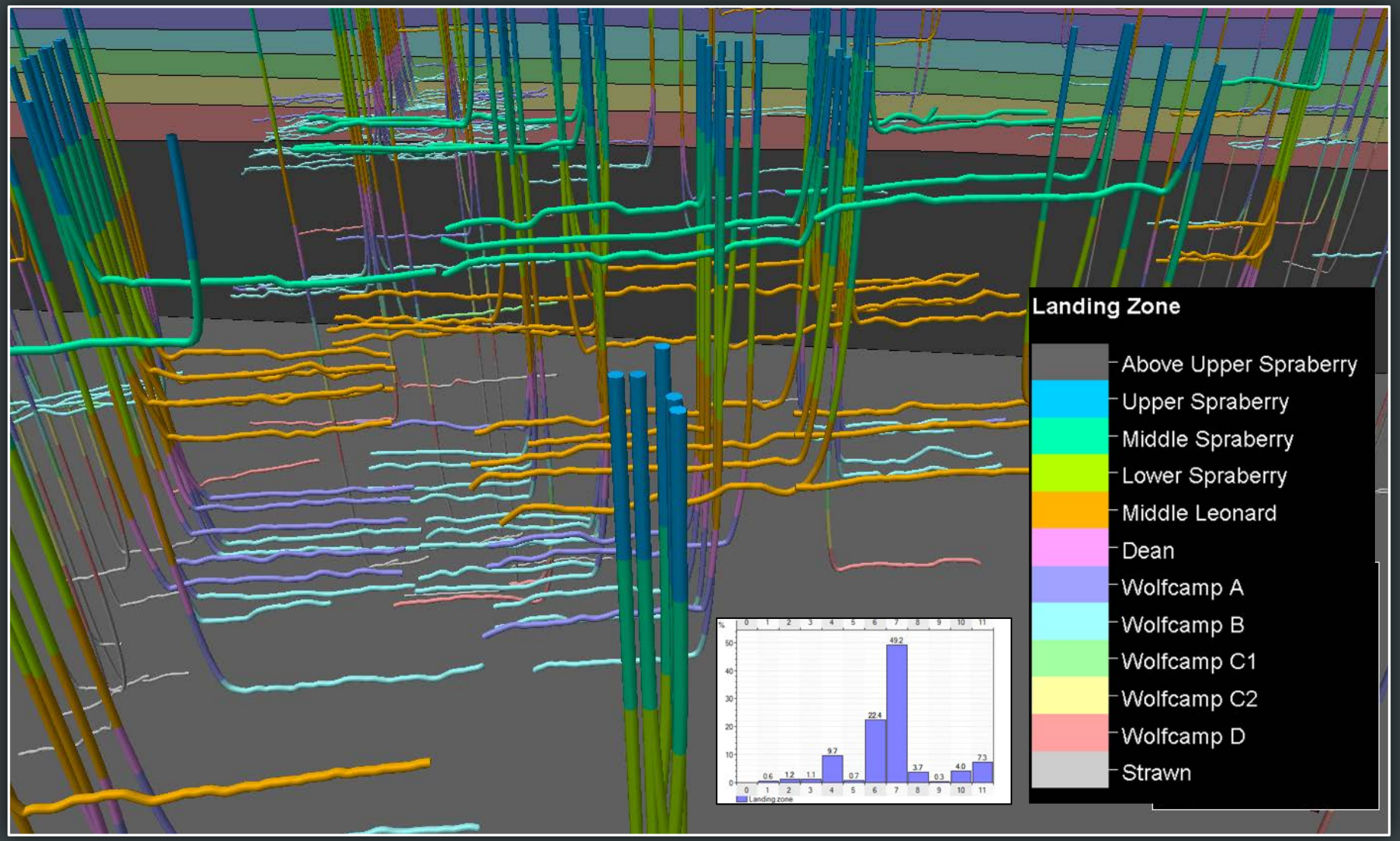
Bureau of Economic Geology

Comparison of IHS & 3D Model Landing Zones



Bureau of Economic Geology

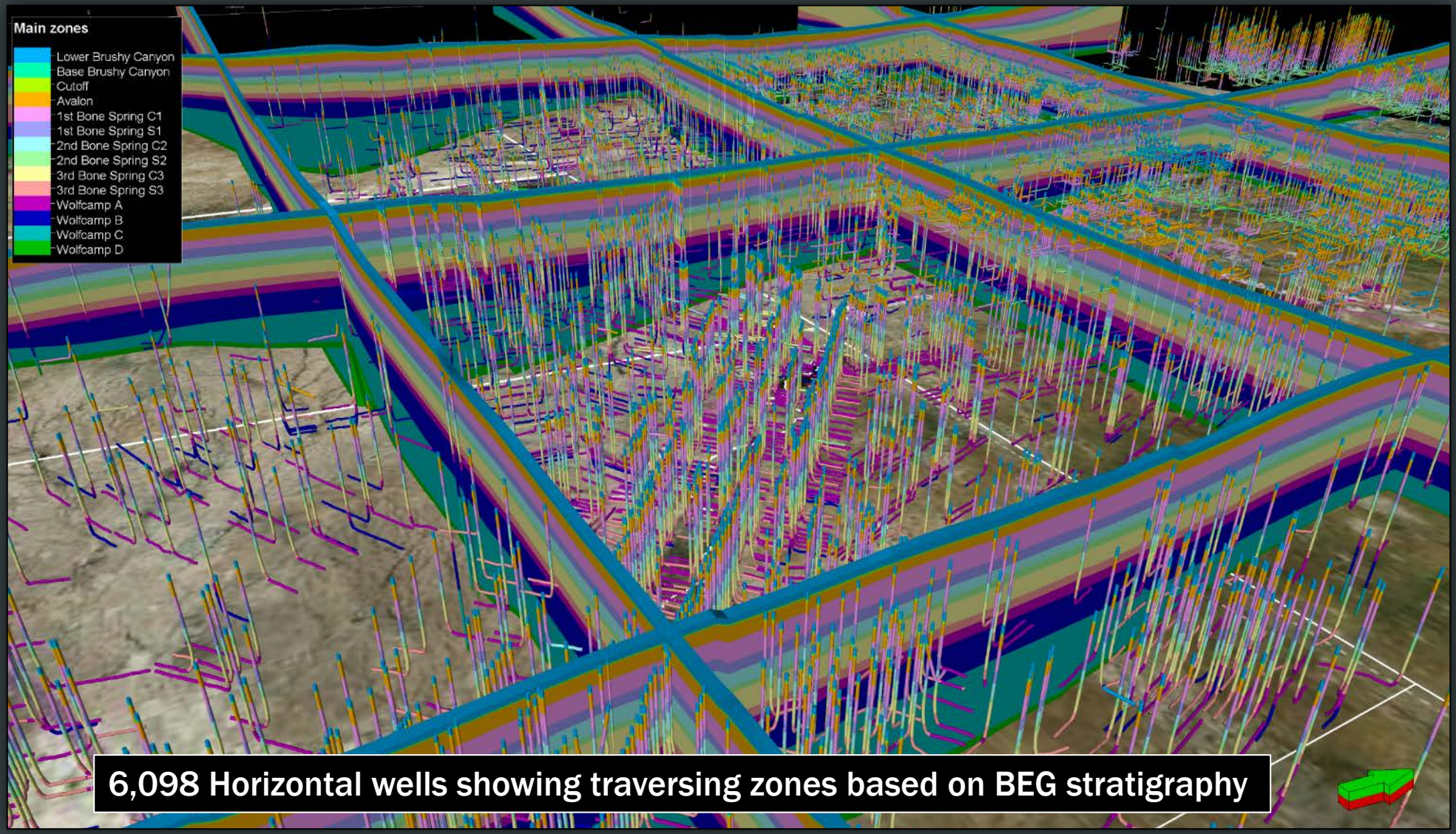
TORA Midland Basin wells – Landing Zones



Stratigraphic Zone	Horizontal Wells Landed
Upper Spraberry	32
Middle Spraberry	64
Lower Spraberry	58
Middle Leonard	529
Dean	36
Wolfcamp A	1,226
Wolfcamp B	2,695
Wolfcamp C1	202
Wolfcamp C2	18
Wolfcamp D	221
Strawn & below	399
Total Wells landed	5,480

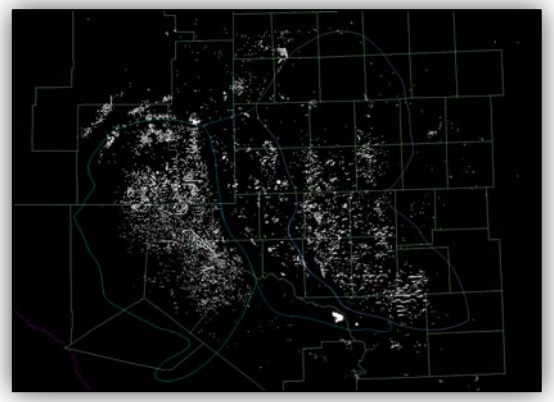
Bureau of Economic Geology

Delaware Basin Landing Zones

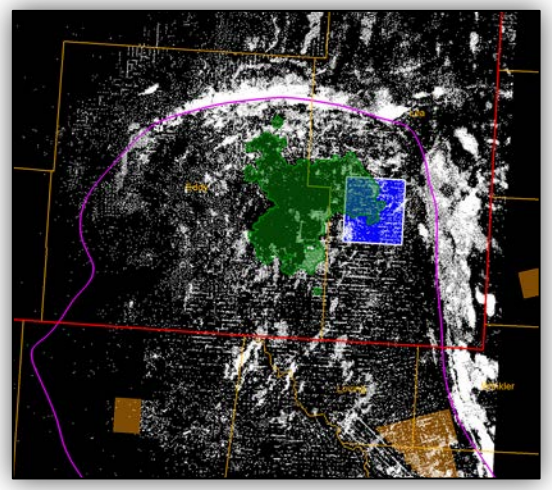


6,098 Horizontal wells showing traversing zones based on BEG stratigraphy

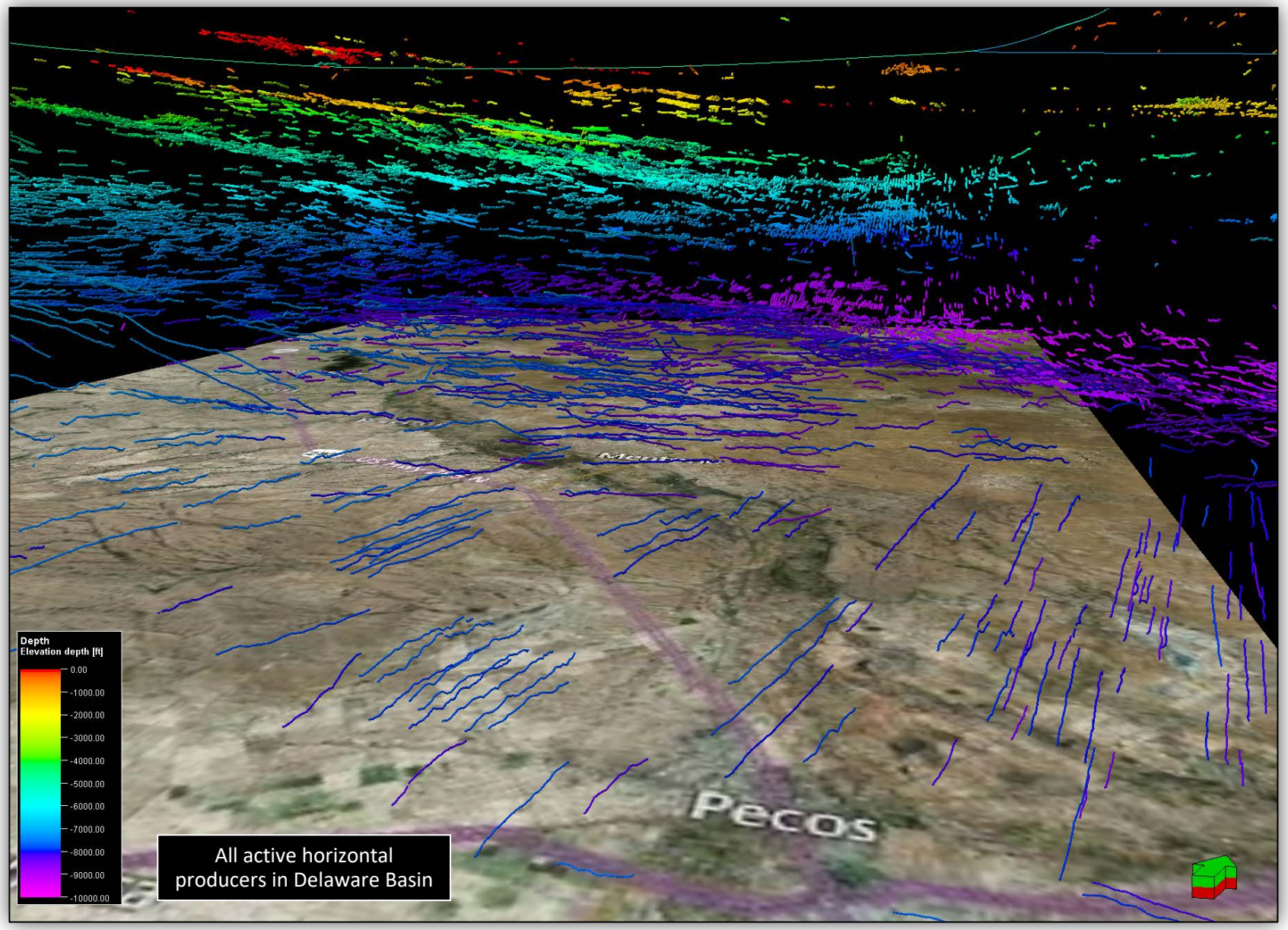
Latest Update of Horizontal Producers in Delaware Basin



All horizontal wells in Permian Basin



All wells in northern Delaware Basin

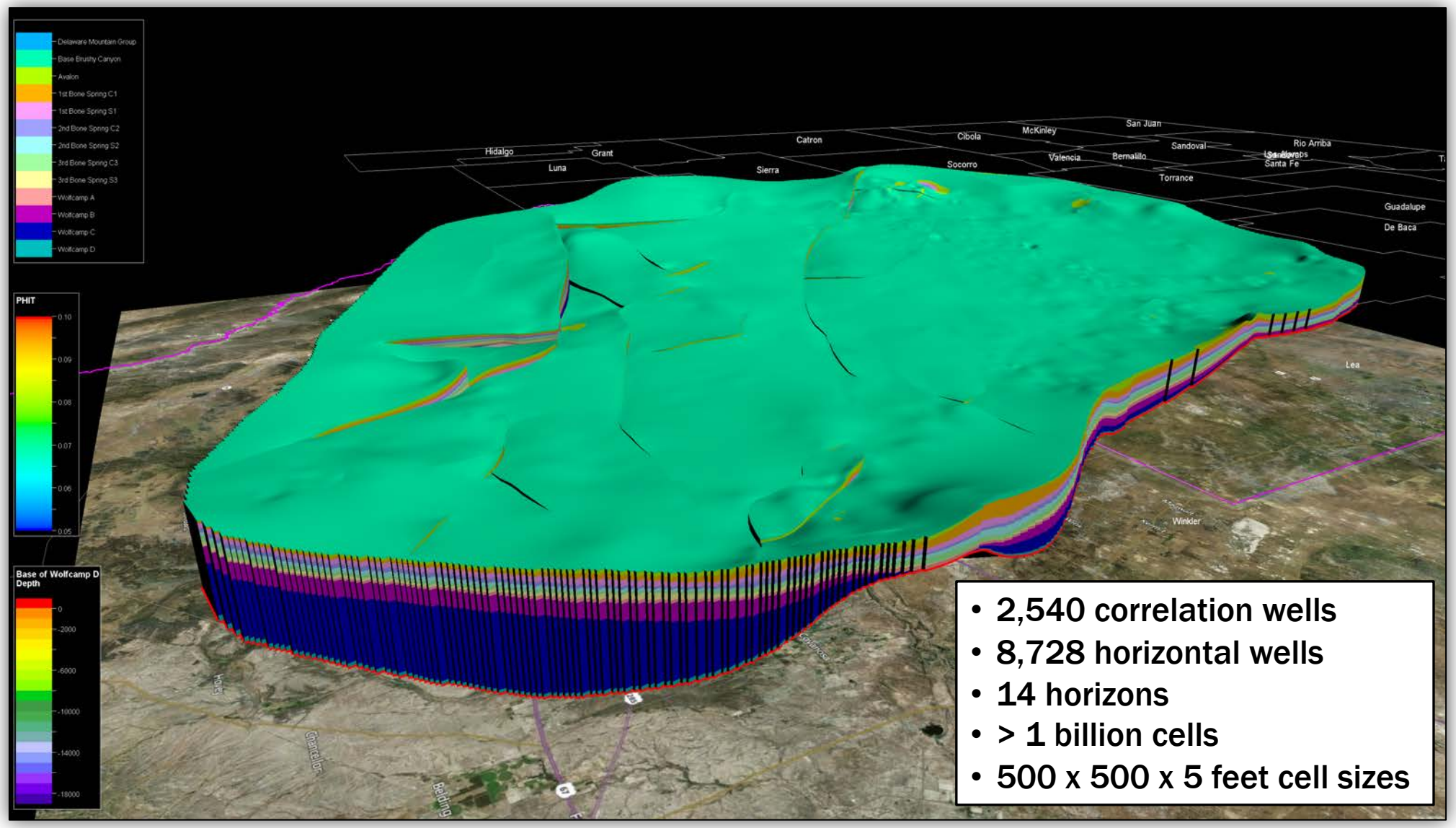


All active horizontal producers in Delaware Basin

Bureau of Economic Geology

TORA TIGHT OIL RESOURCE ASSESSMENT

Delaware Basin Regional 3D Geocellular Model

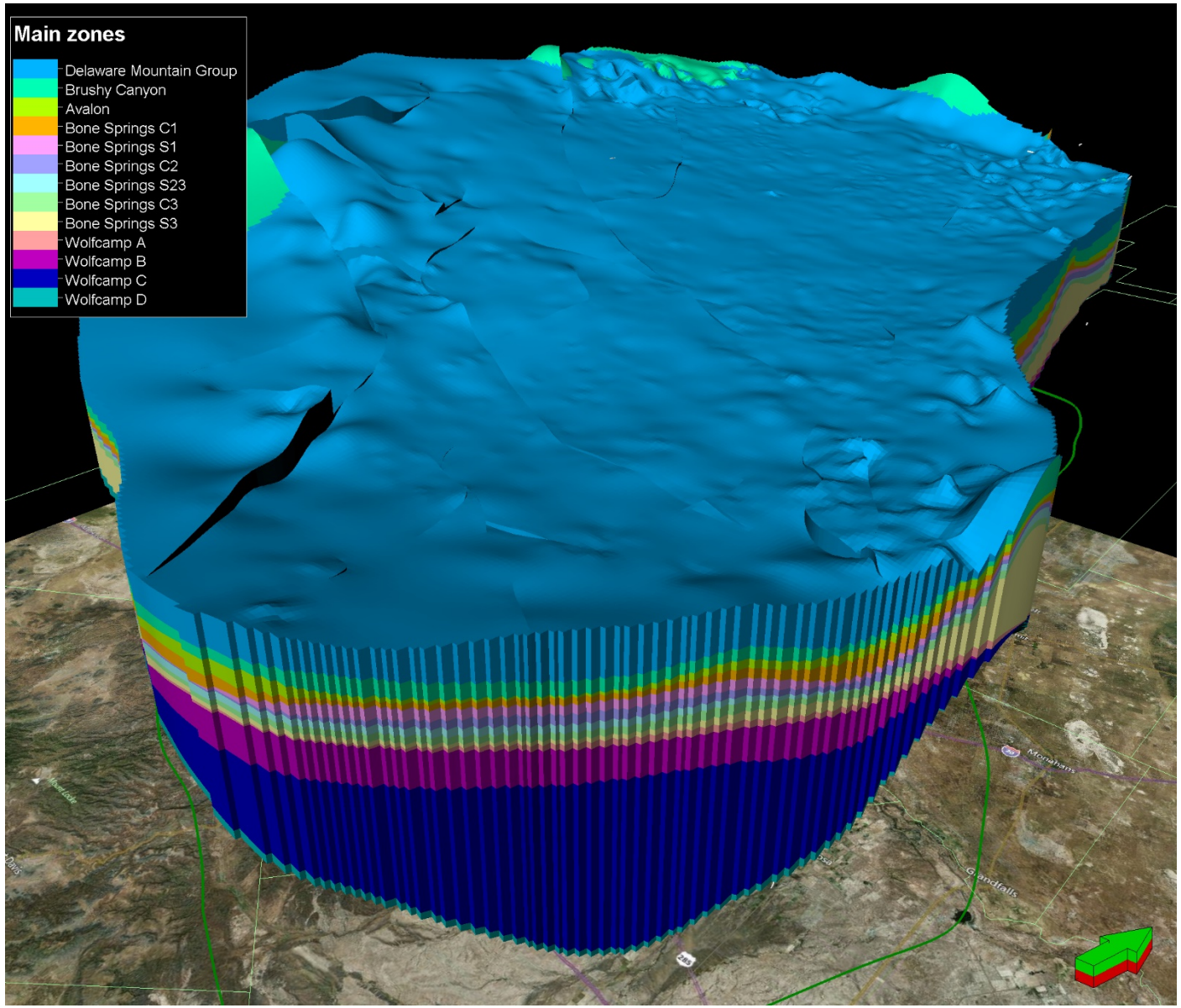


- 2,540 correlation wells
- 8,728 horizontal wells
- 14 horizons
- > 1 billion cells
- 500 x 500 x 5 feet cell sizes

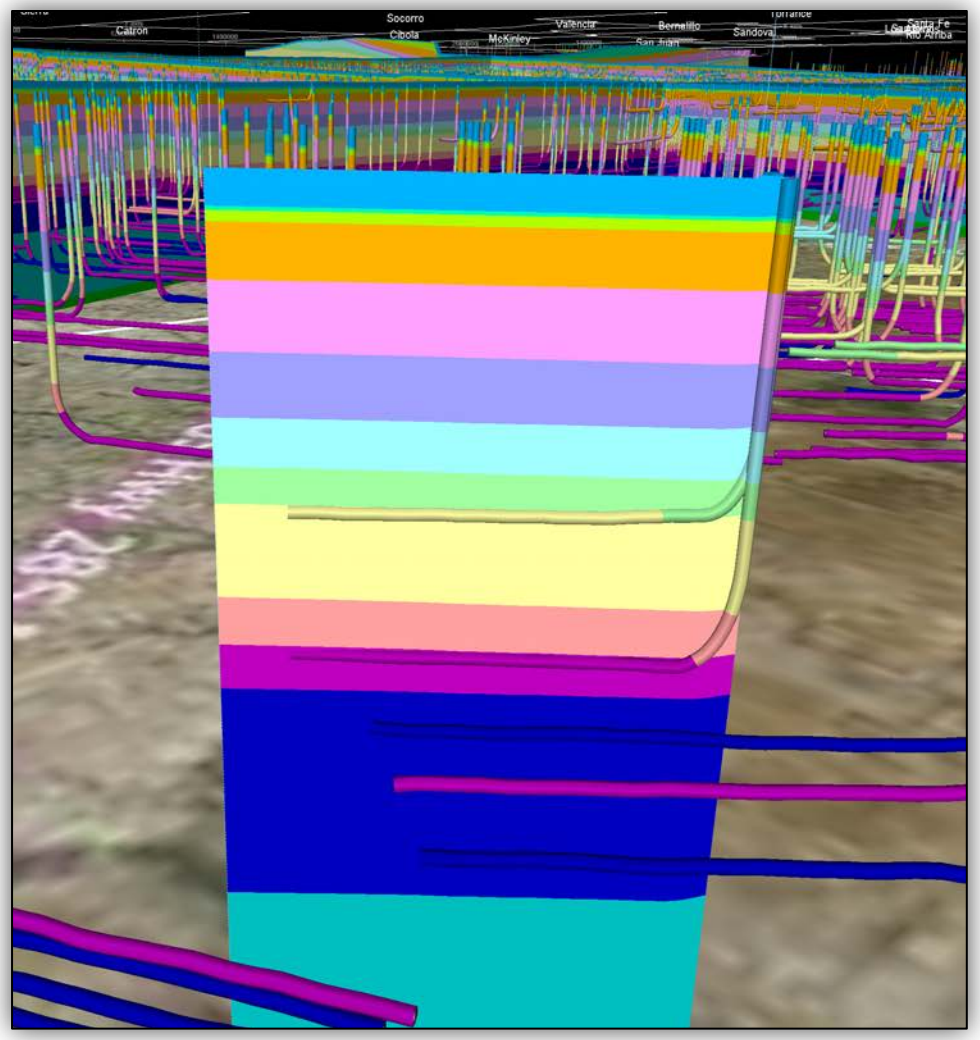
Bureau of Economic Geology

TORA
TIGHT OIL RESOURCE ASSESSMENT

Basin Fill History

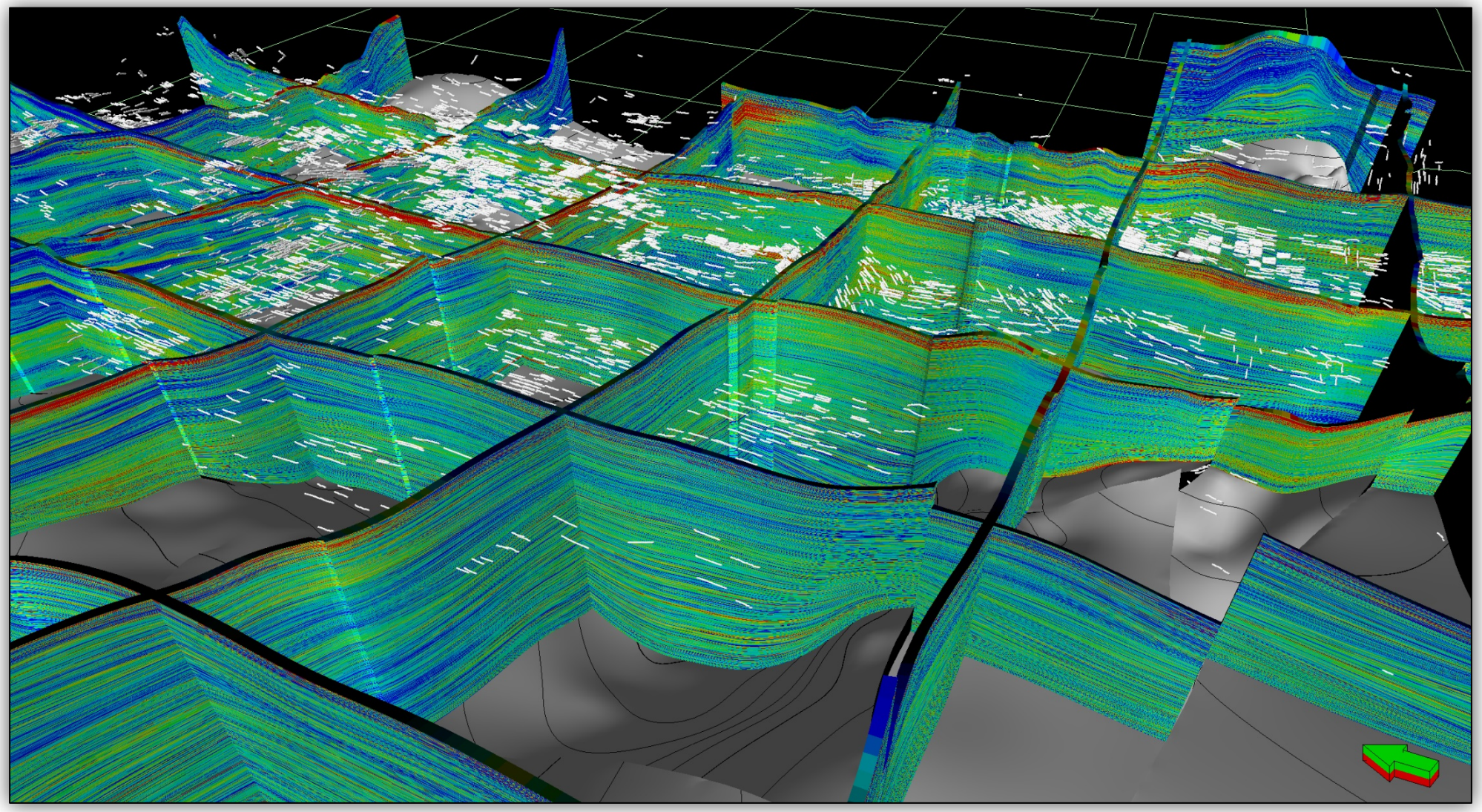


Delaware Basin Landing Zone Metrics

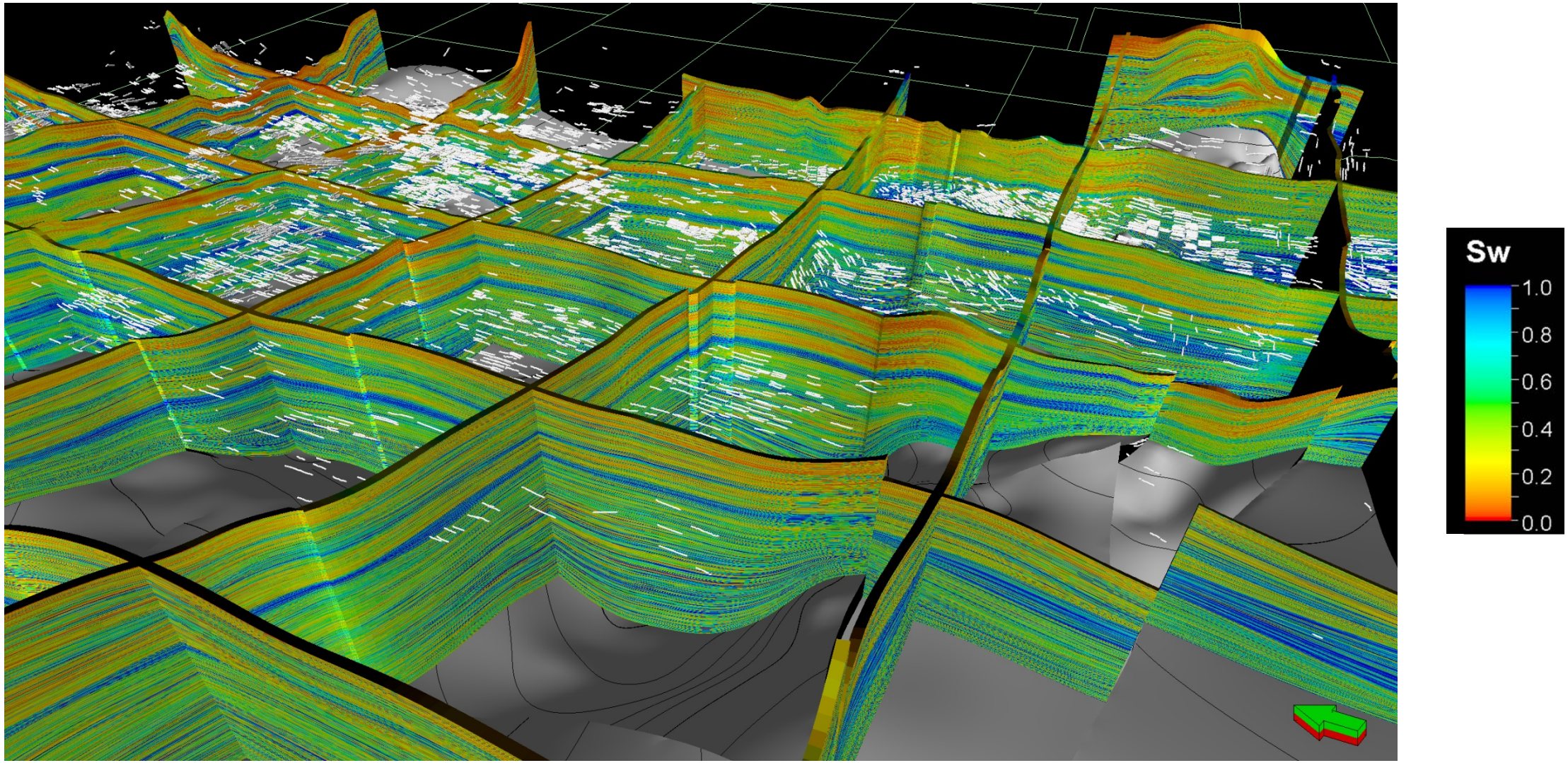


Stratigraphic Zone	2017	2018
1st Bone Spring C1	412	338
1st Bone Spring S1	231	273
1st Bone Spring C2	72	139
1st Bone Spring S2	1,377	1,539
1st Bone Spring C3	179	234
1st Bone Spring S3	747	803
Wolfcamp A	2,135	3,086
Wolfcamp B	882	972
Wolfcamp C	52	57
Wolfcamp D	11	16
Total Wells landed	**6,098**	**6,654**

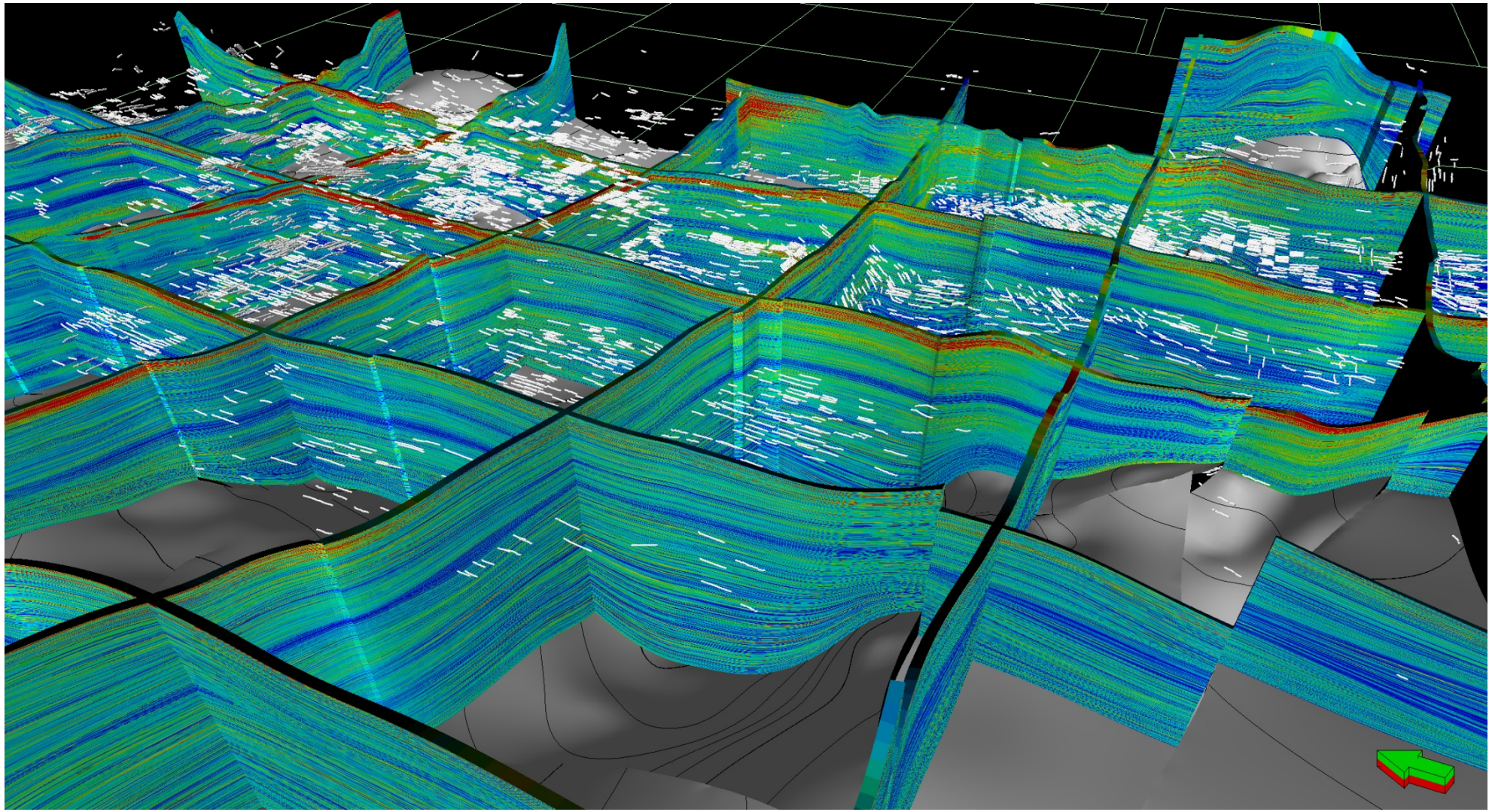
Porosity Distribution – Sequential Gaussian Simulation



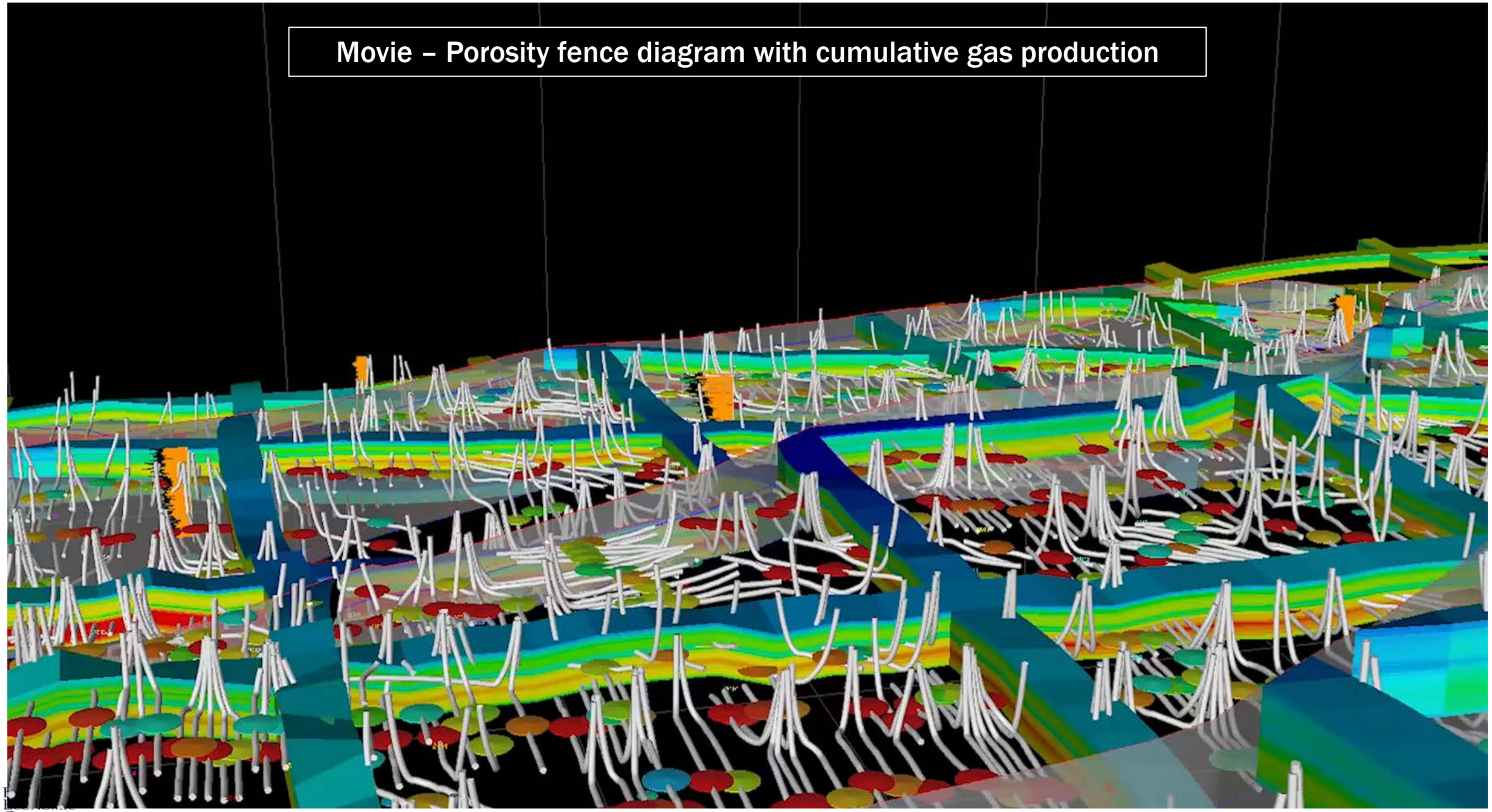
Water Saturation Distribution – Sequential Gaussian Simulation



Bulk Volume Hydrocarbons Calculation

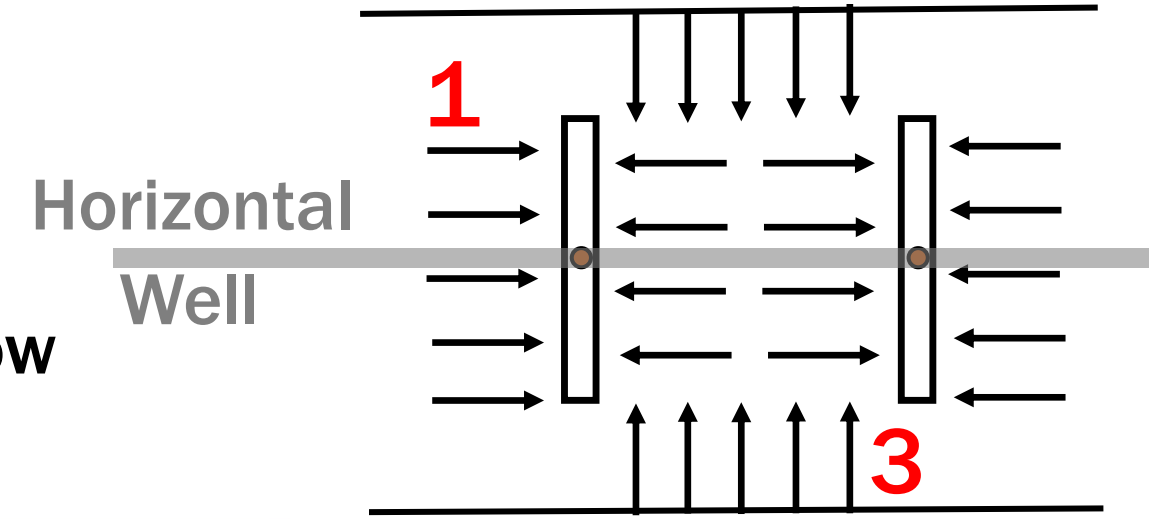


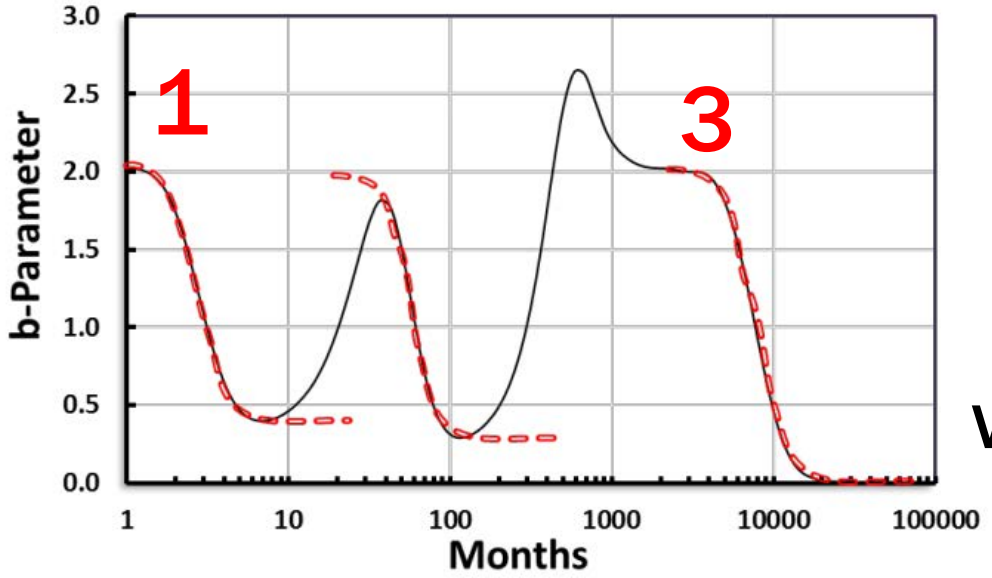
Movie – Porosity fence diagram with cumulative gas production



Hyperbolic b-parameter changes as flow regime changes over time

1. linear flow
2. Transition to compound linear flow
3. Compound linear flow
4. Transition to boundary-dominated flow
5. Boundary-dominated flow





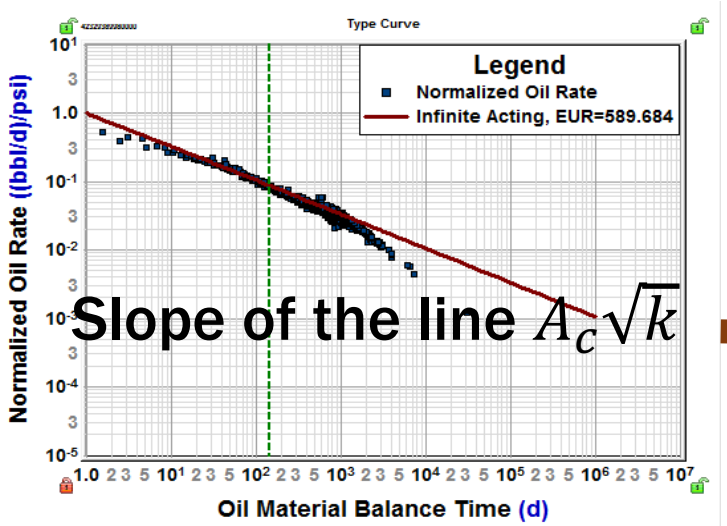
Verma et al. 2018

Bureau of Economic Geology

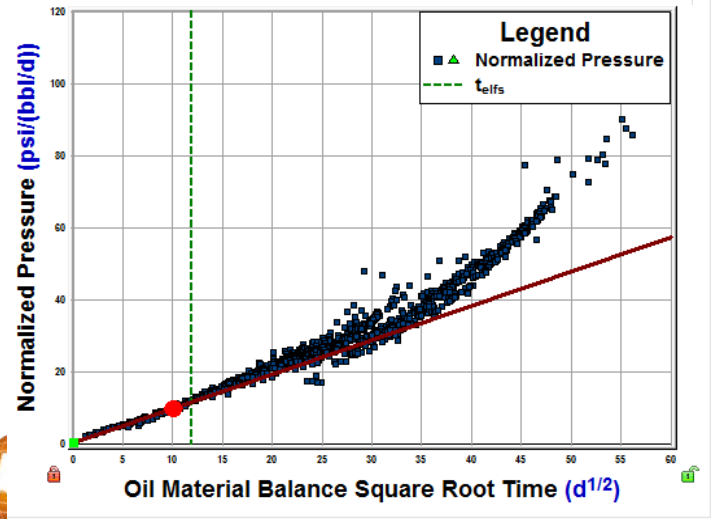
TORA
TIGHT OIL RESOURCE ASSESSMENT

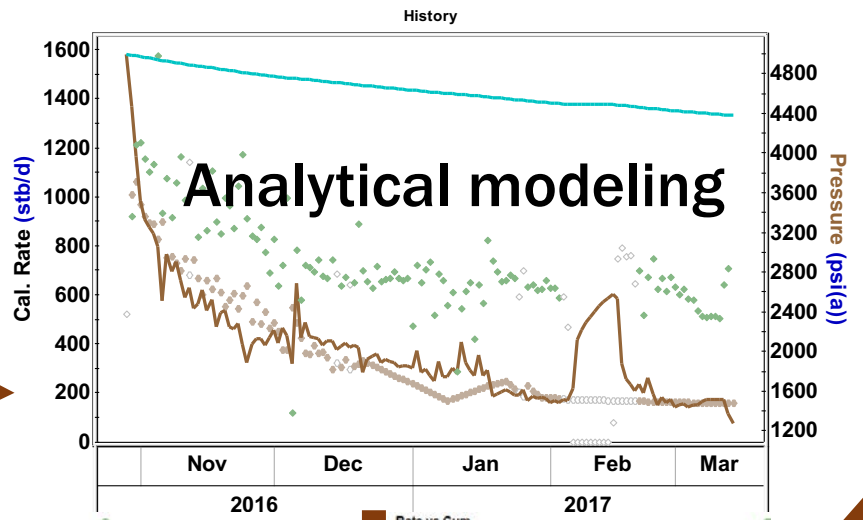
Workflow

Flow regime identification

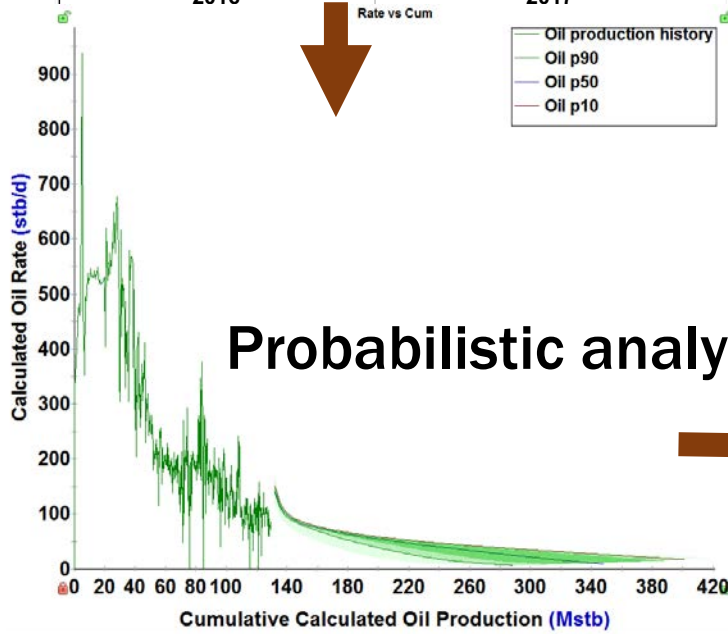


Slope of the line $A_c\sqrt{k}$



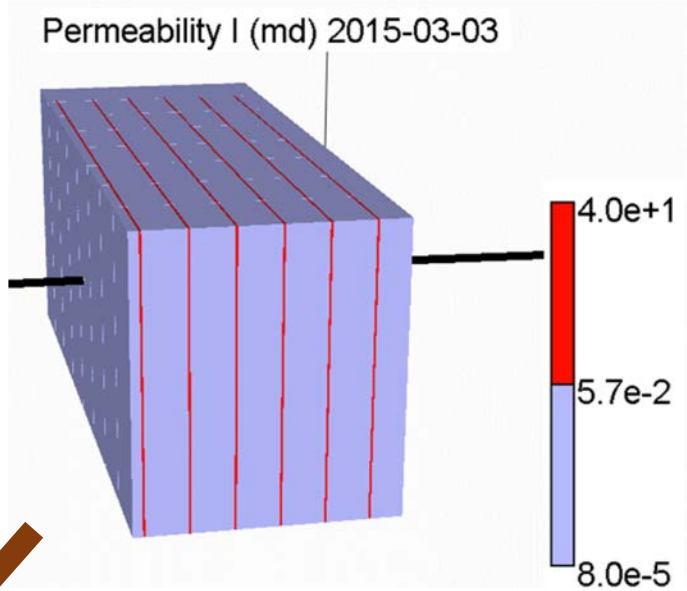


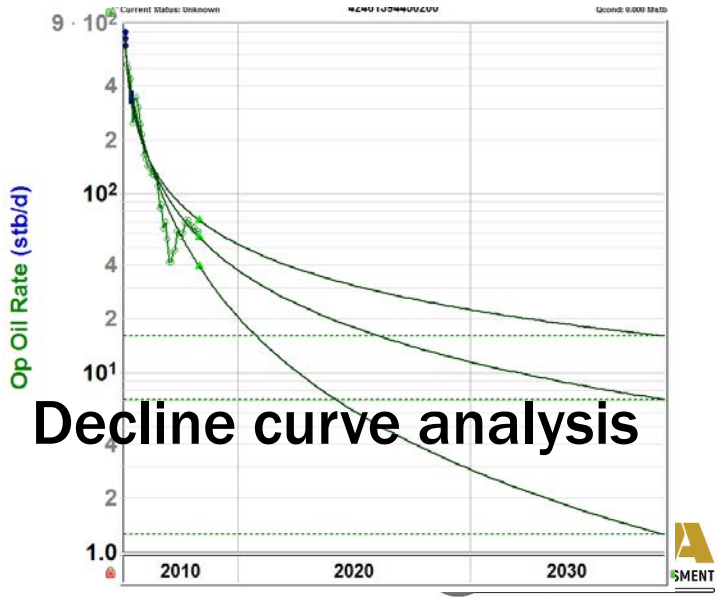
Analytical modeling



Probabilistic analysis

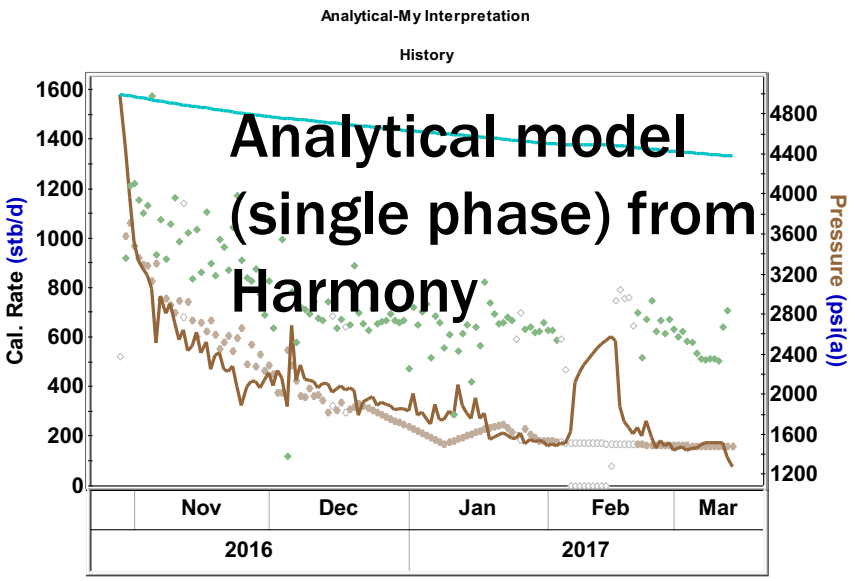
Numerical Modeling





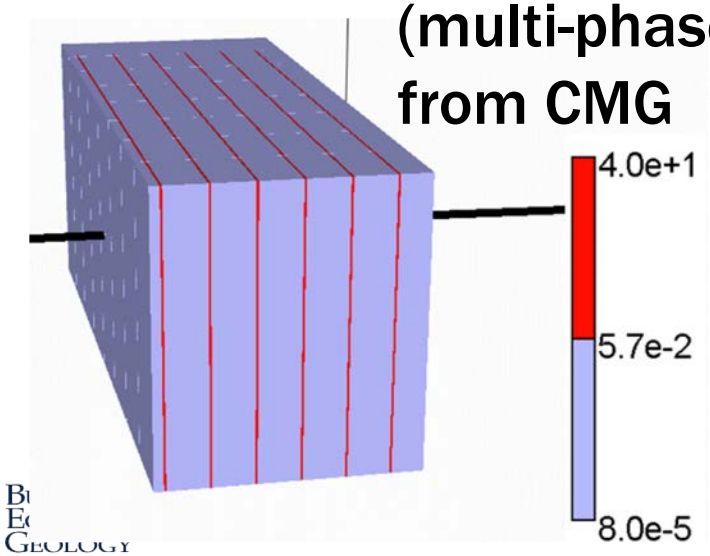
Decline curve analysis

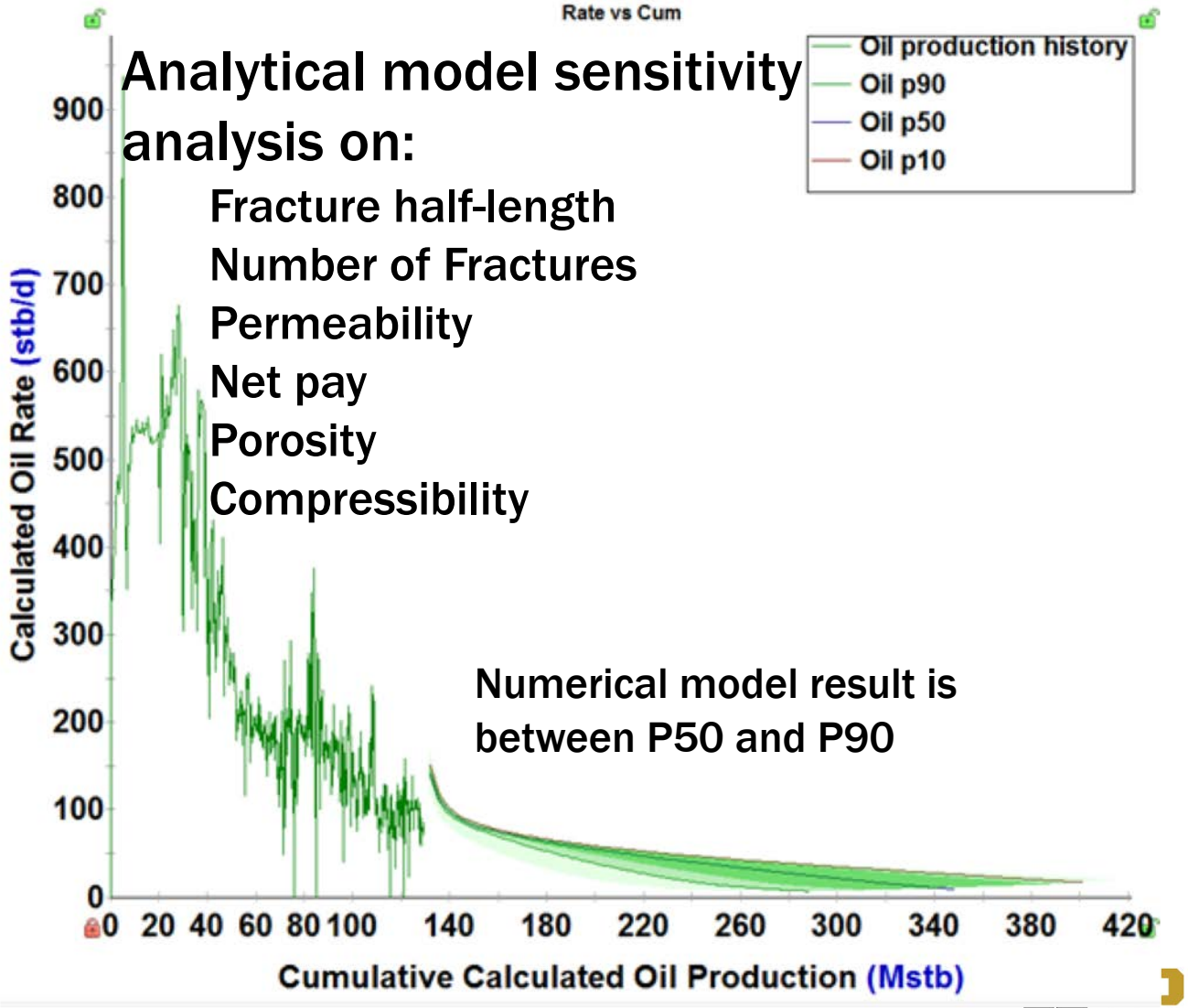
Probabilistic EUR analysis



Analytical model (single phase) from Harmony

Numerical model (multi-phase) from CMG



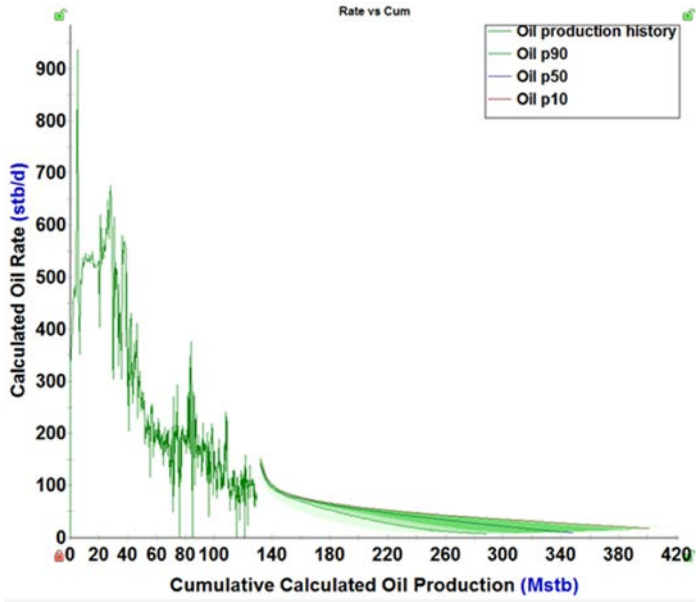


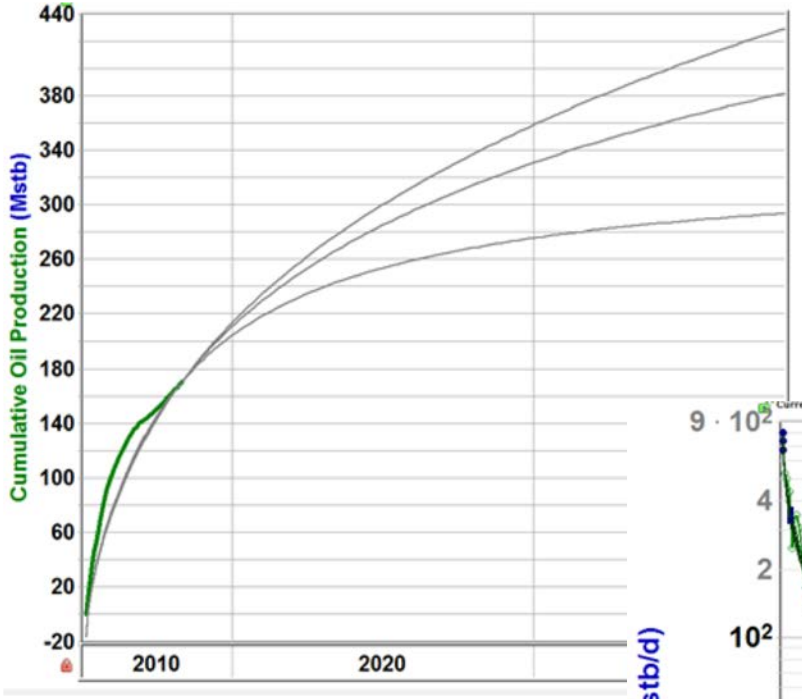
Analytical model sensitivity analysis on:

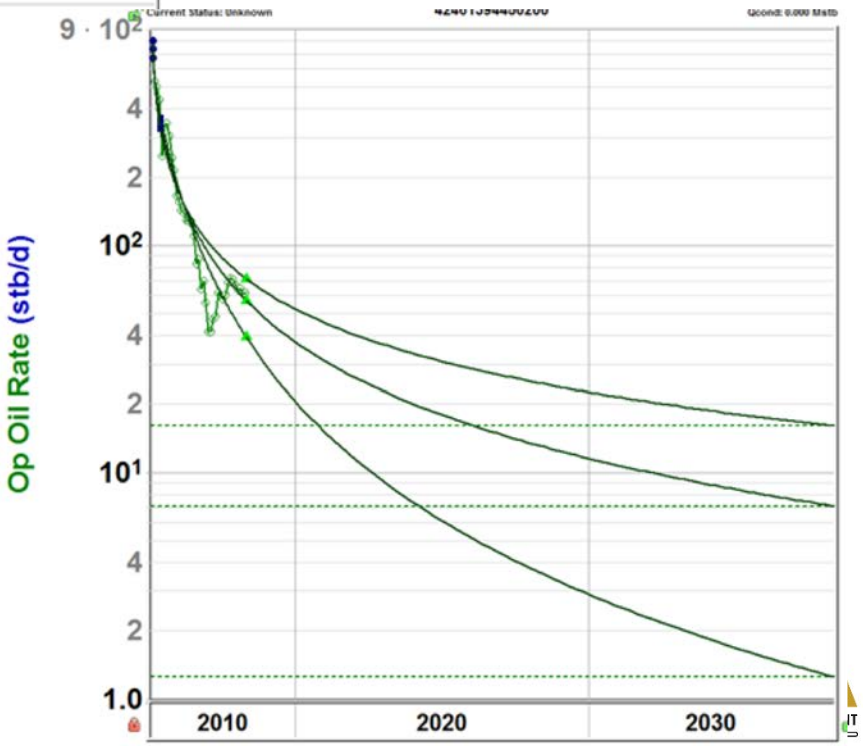
- Fracture half-length
- Number of Fractures
- Permeability
- Net pay
- Porosity
- Compressibility

Numerical model result is between P50 and P90

Probabilistic EUR analysis



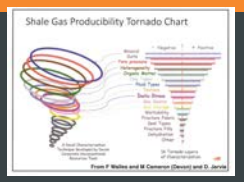


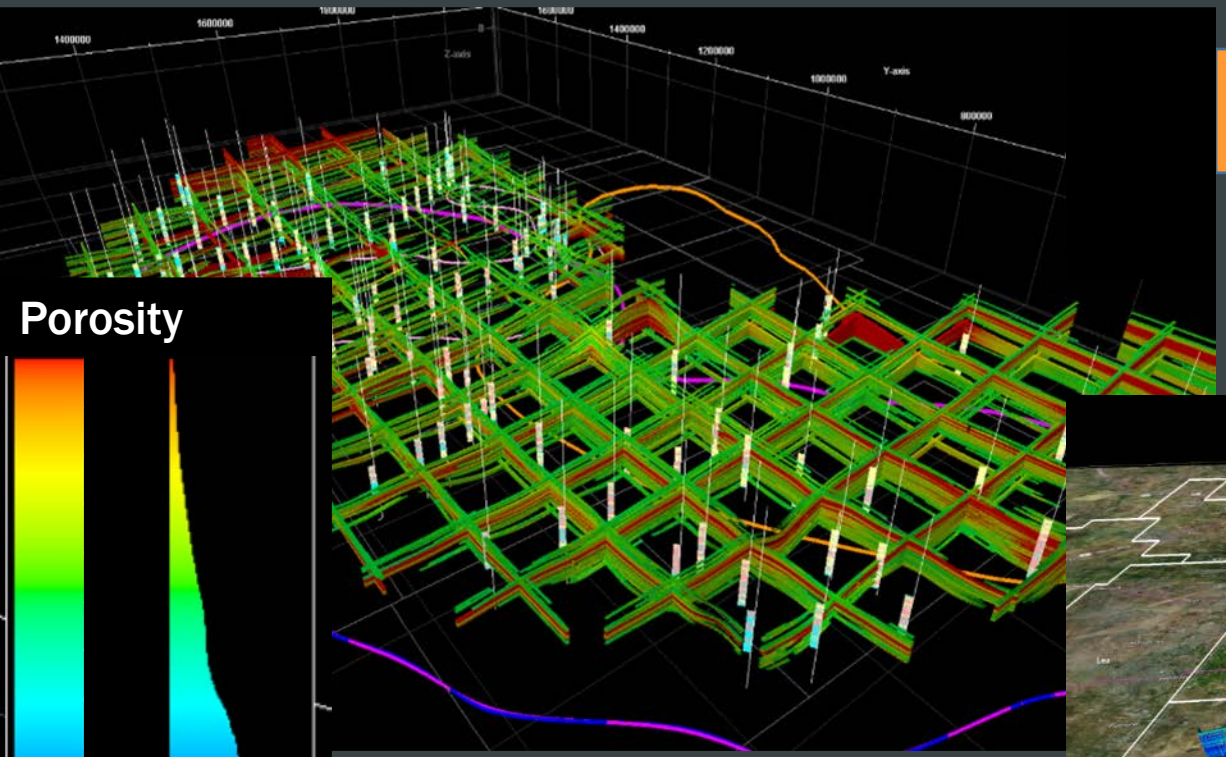


What range of multi-segment Arps parameters generates the probabilistic (P10, P50 and P90) EUR?

First hyperbolic segment,	$b - parameter = 2$
Final segment	$b - parameter\ 0.5, 0.9, 1.3$
Length of transition flow	$3, 6\ and\ 12\ months$

3D Geomodeling

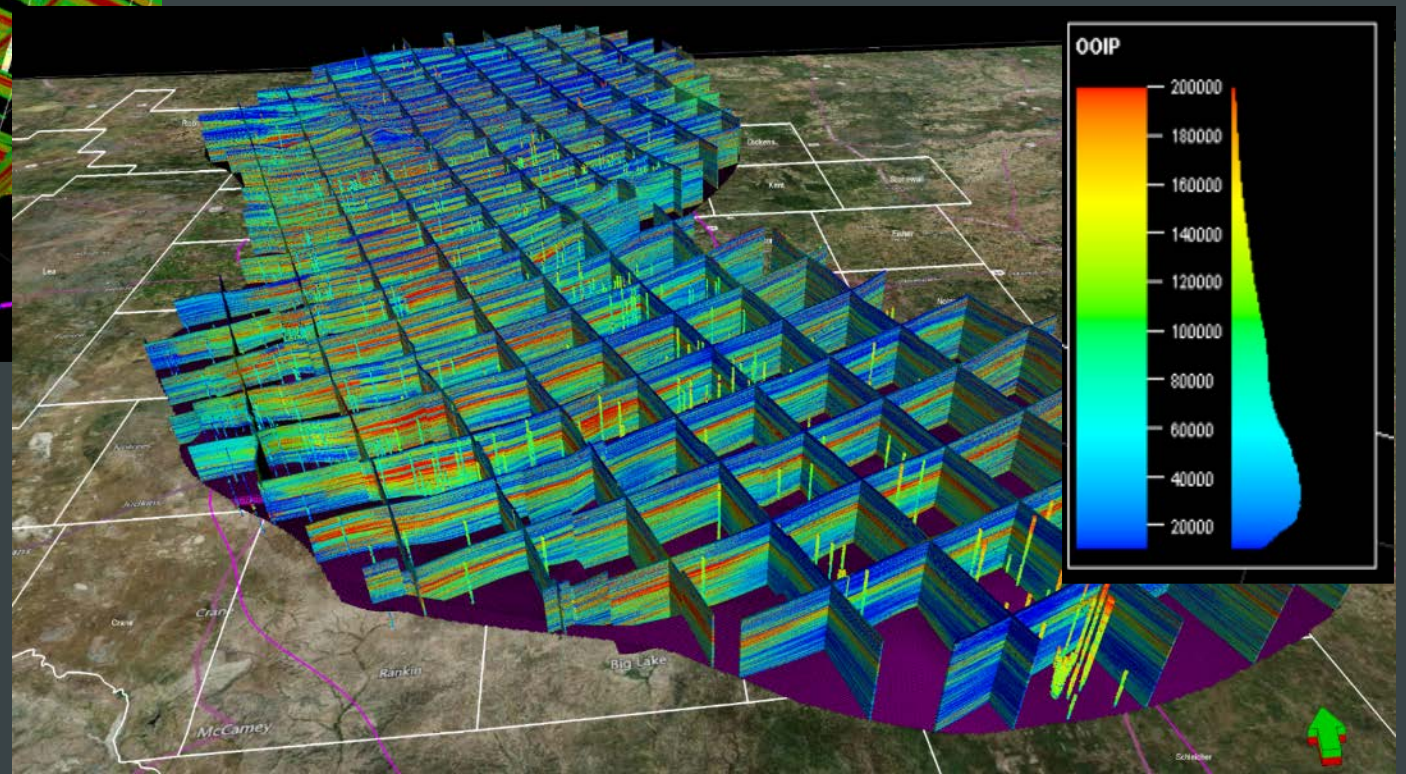




136 GB file
907M cells

Custom Research Products and Proprietary Data Analysis (e.g. Python script)

OOIP description, plots, and analysis

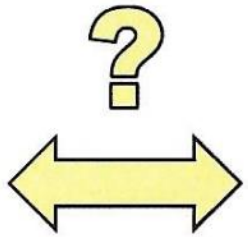


BVH Fence Diagram

Bureau of Economic Geology

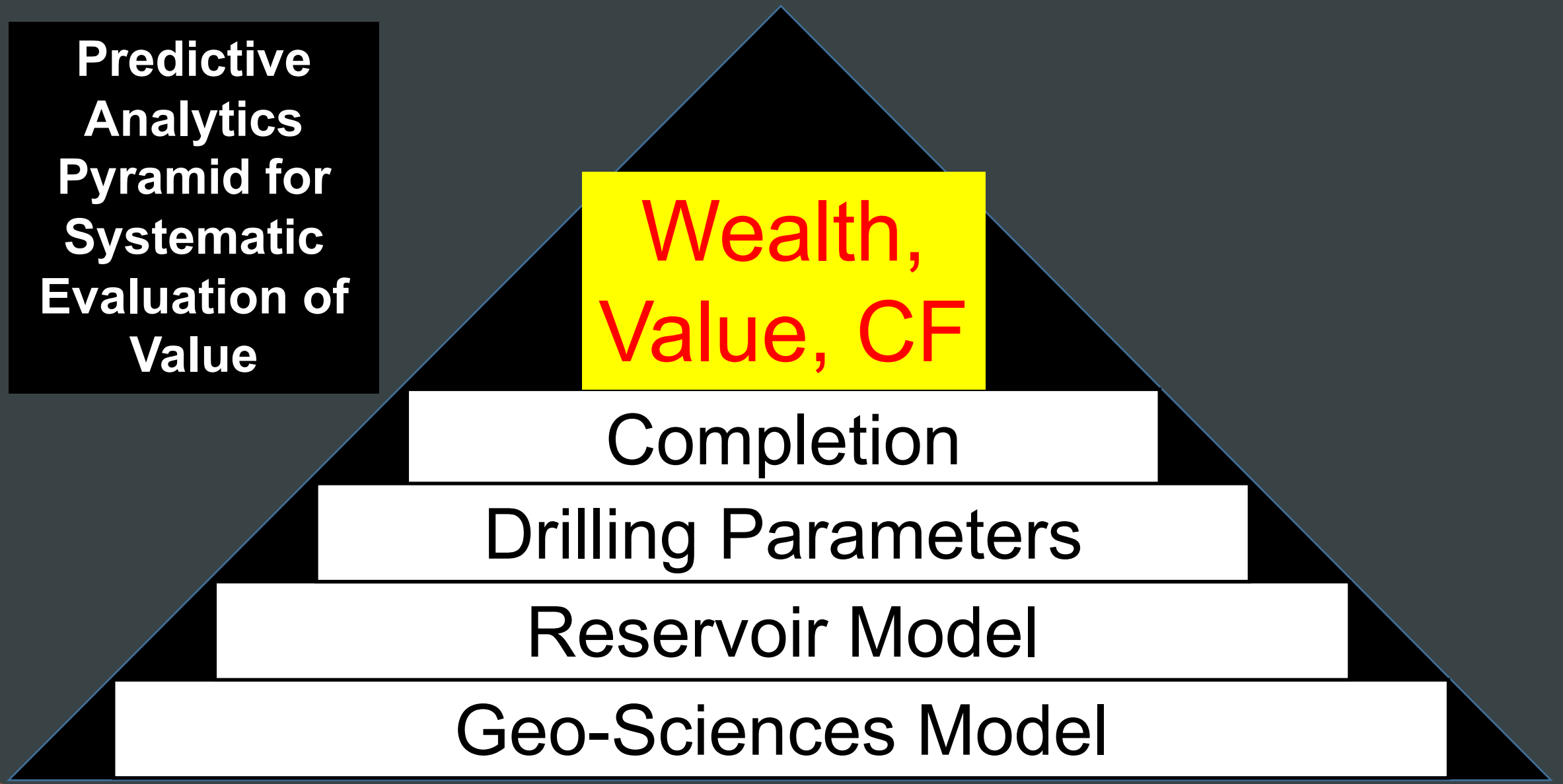
What factors influence productivity?

GEOLOGY	TECHNOLOGY
• Reservoir quality	• Well type
• Reservoir thickness	• Lateral length
• Oil & water saturations	• No. of hyd. fracturing stages
• HC generation potential	• Proppant volume & type
• Maturity	• Proppant loading
• Overpressure	• Fluid volume & type
• Structure and lineaments	• Fluid / proppant ratio
• Regional stress regime	• Injection rate
• Mechanical stratigraphy	• Treatment pressure
• Natural fractures	• Choke size
• Migration	• Plug & perf; sliding sleeves
• Traps	• Well spacing

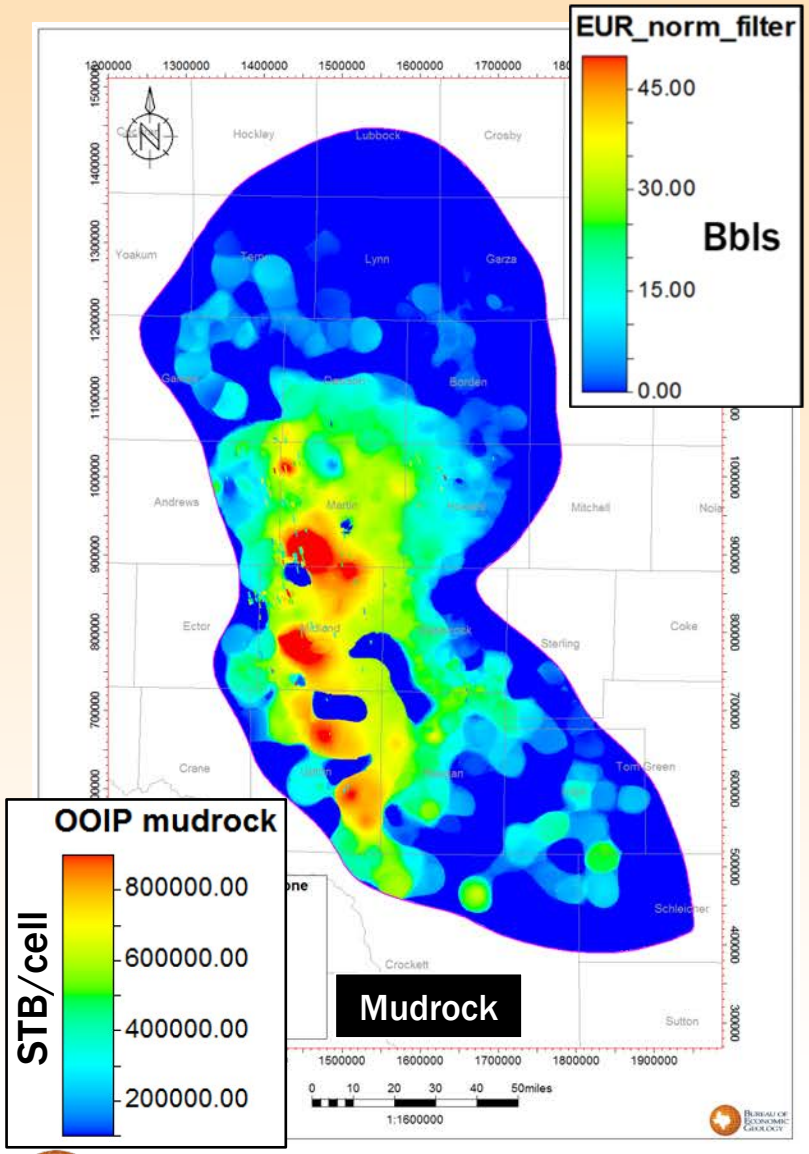


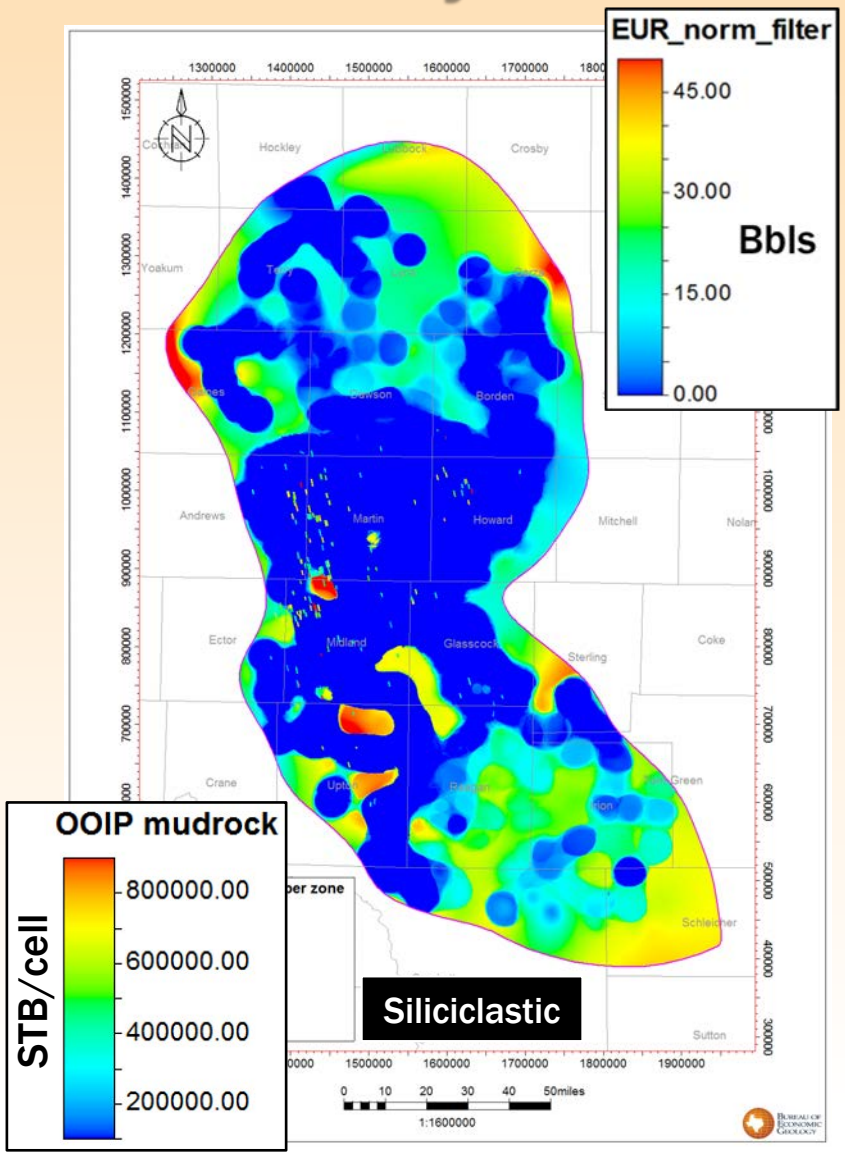
Theloy, 2013

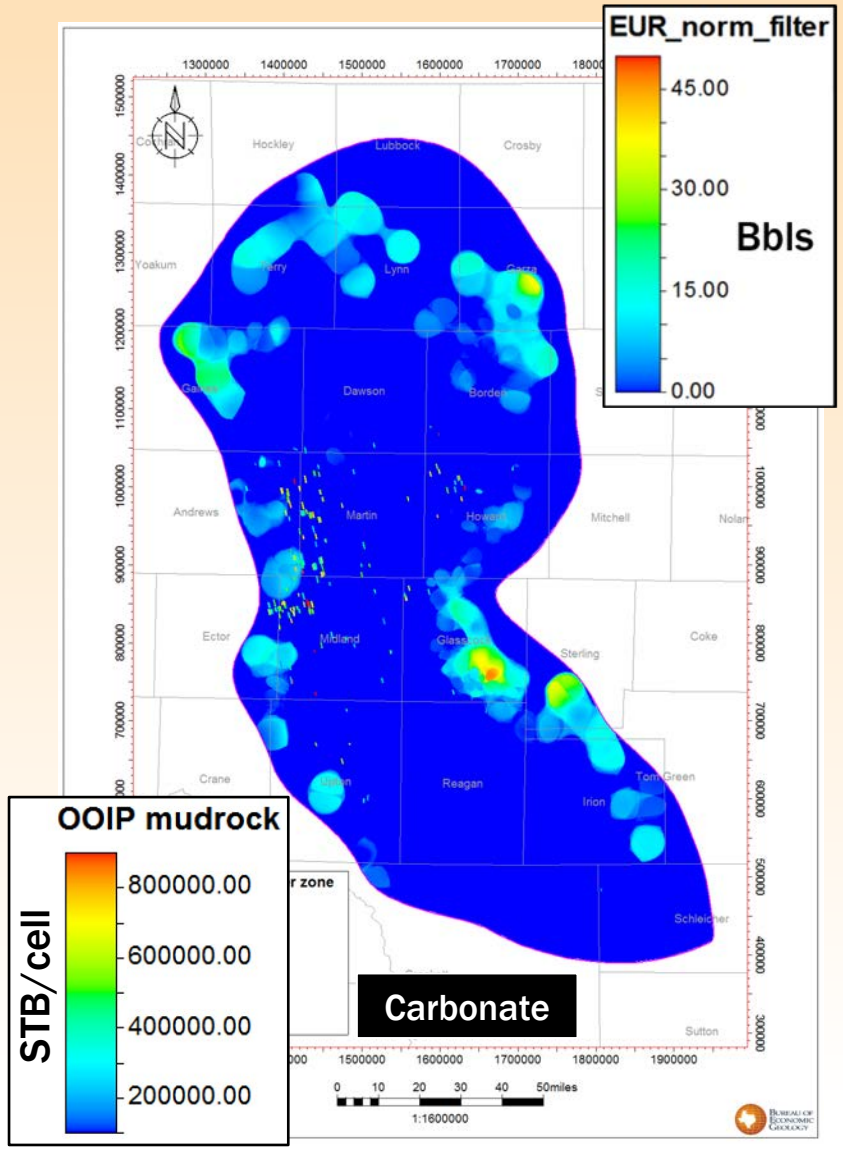
Predictive Analytics Pyramid for Systematic Evaluation of Value



Middle Leonard OOIP by Facies with EUR wells

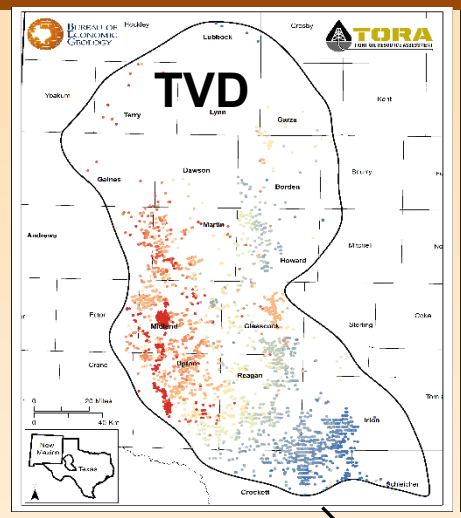


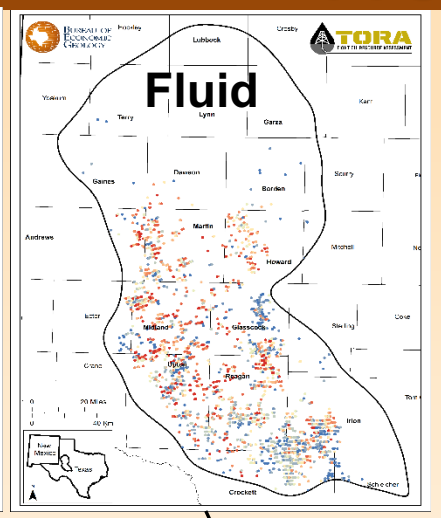


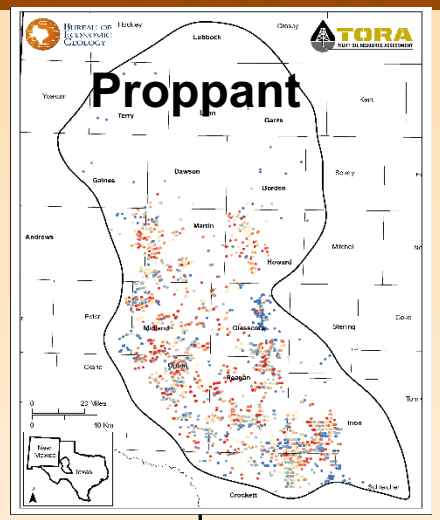


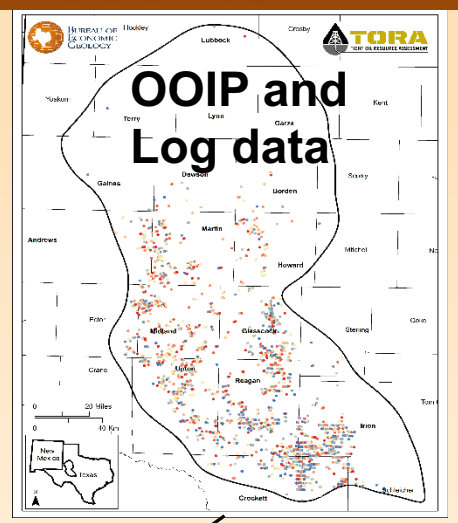
Bureau of Economic Geology

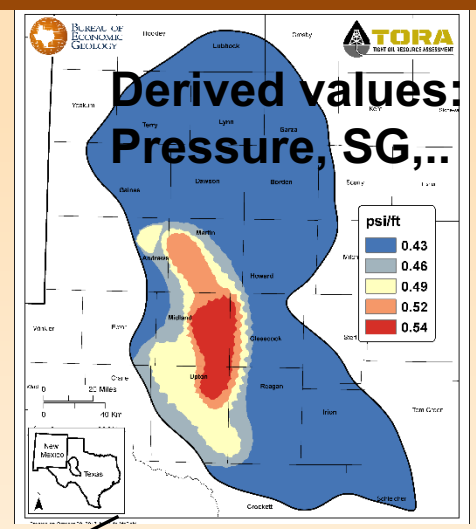
From Data to Results



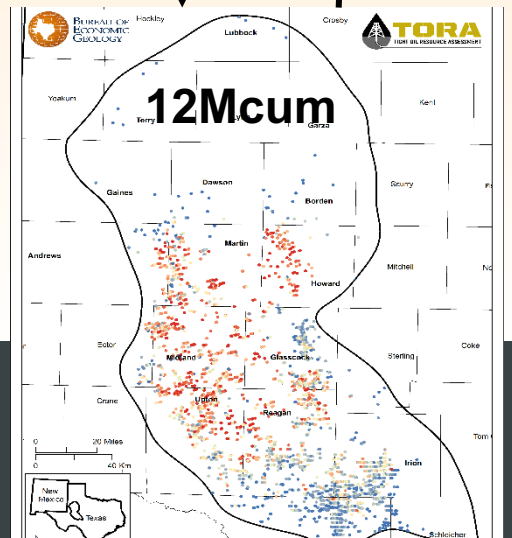






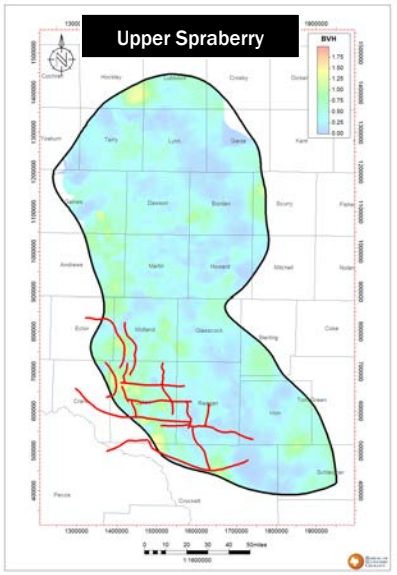


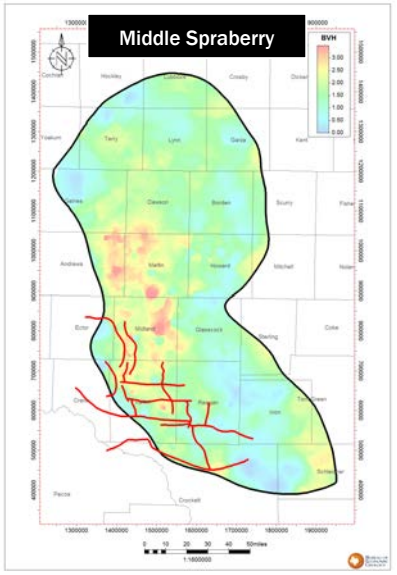
Model: Explain & Predict per layer per location per completion

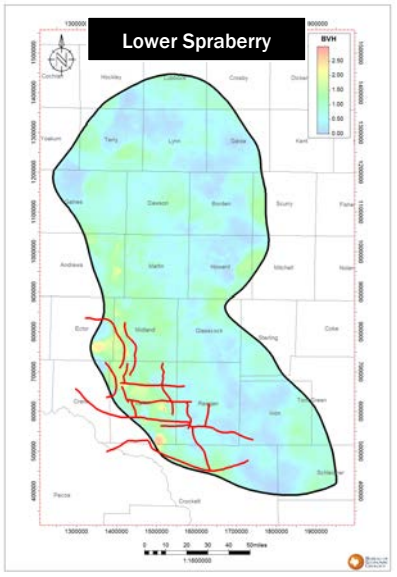


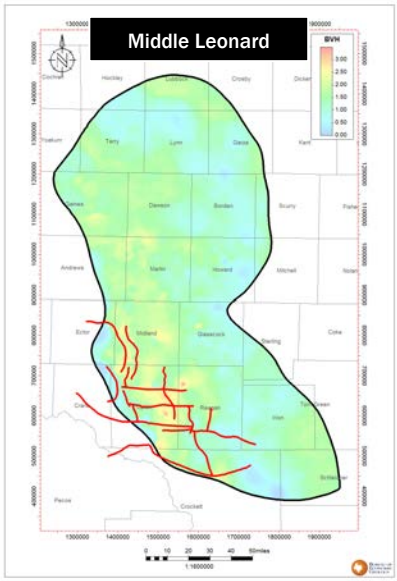
TORA
TIGHT OIL RESOURCE ASSESSMENT

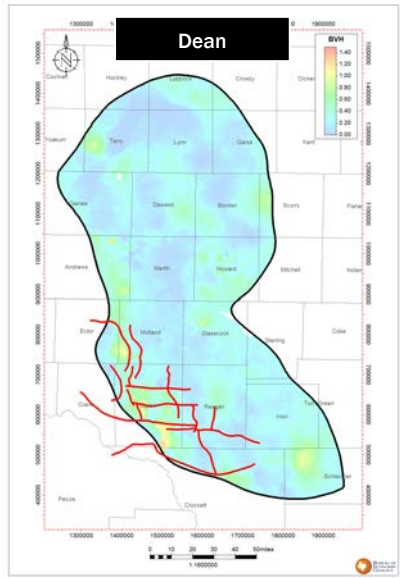
BVH By Zone

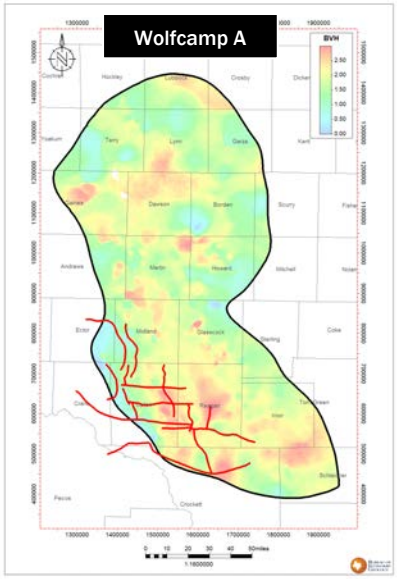


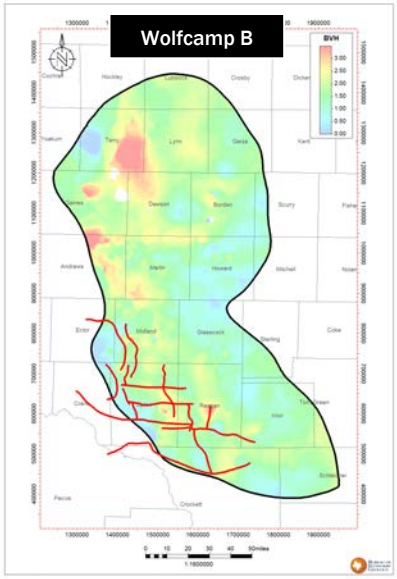


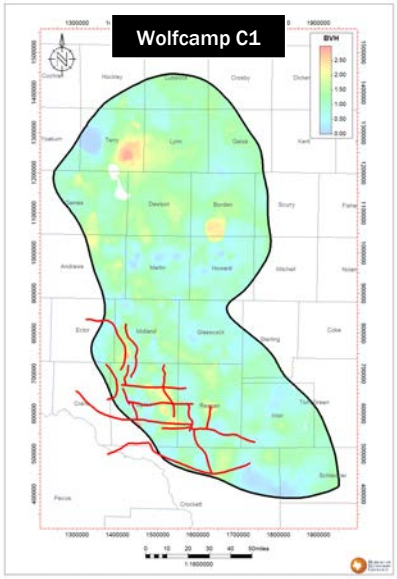


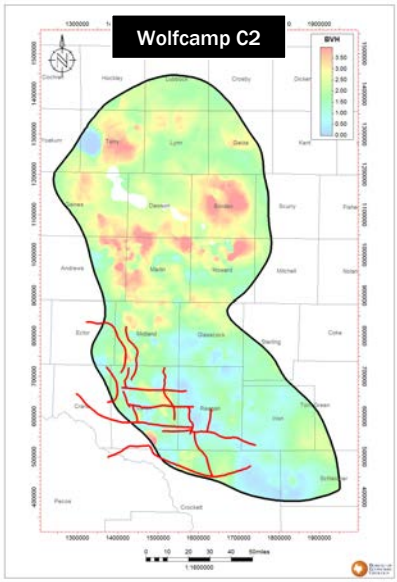


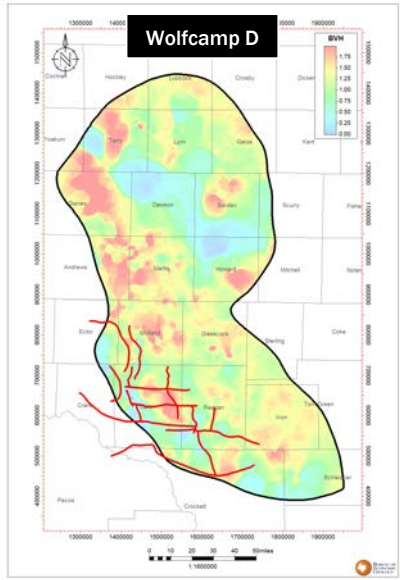








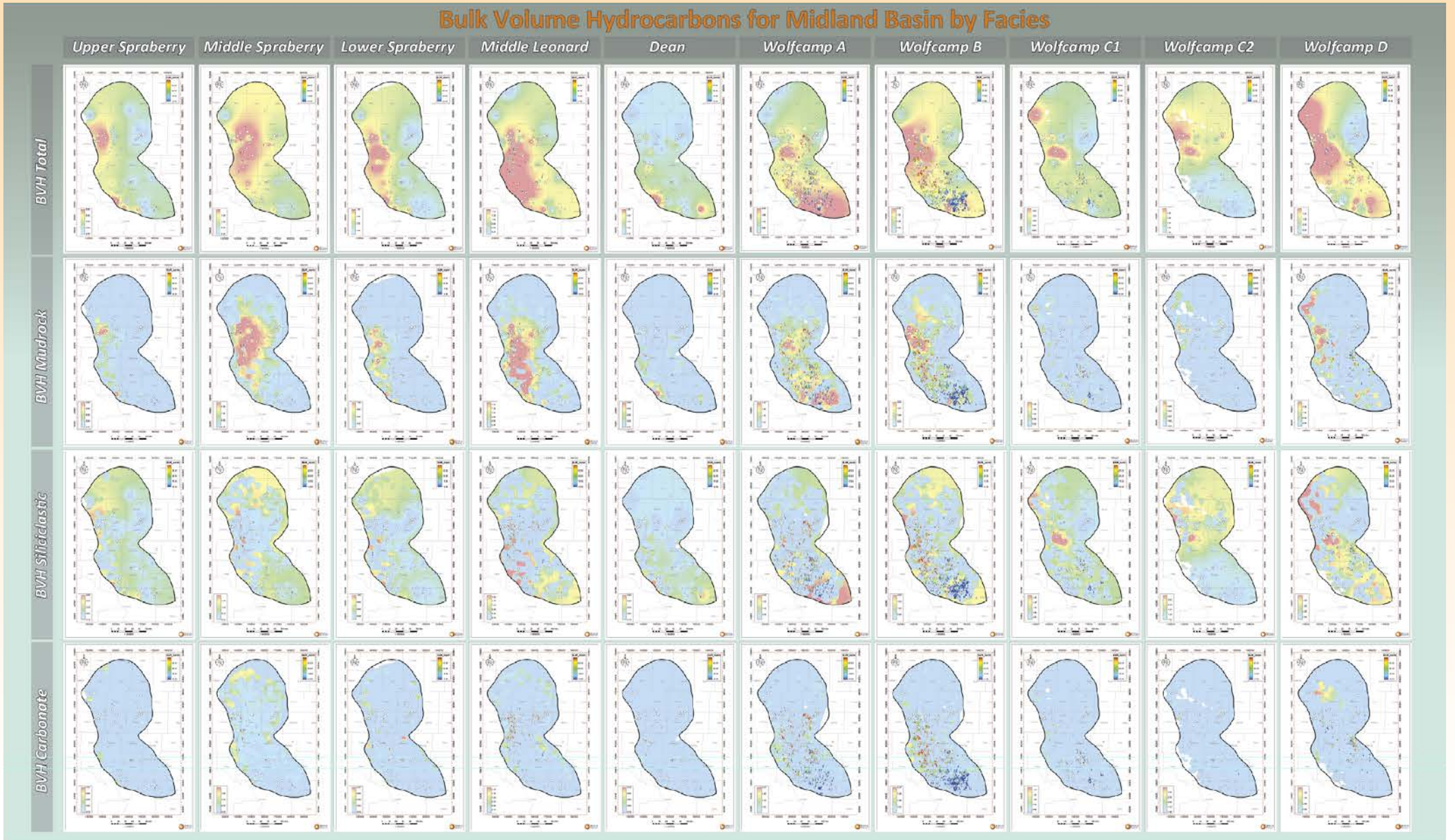




Bureau of Economic Geology

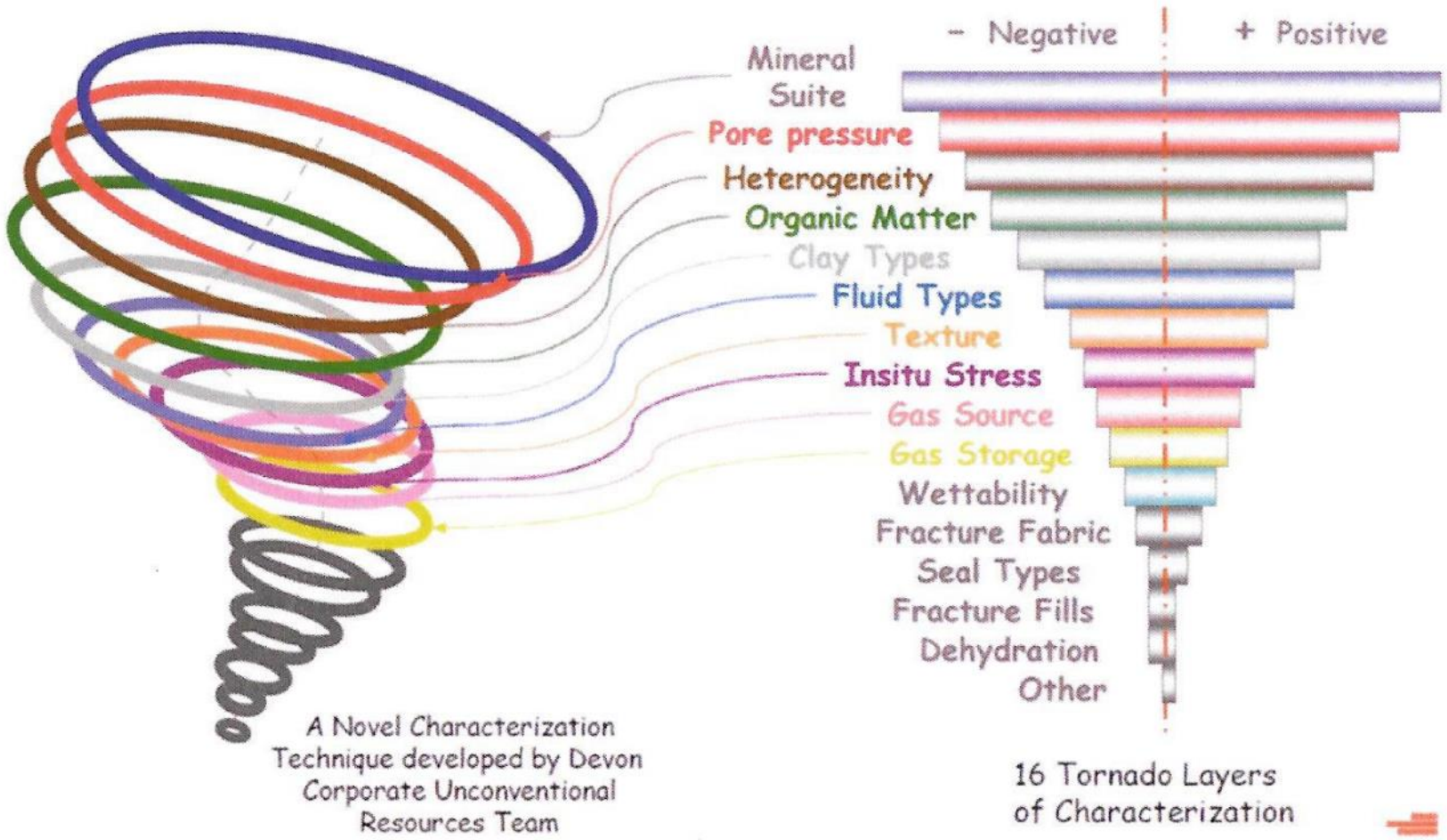
TORA
TIGHT OIL RESOURCE ASSESSMENT

Bulk Volume Hydrocarbons for Midland Basin by Facies



Bureau of Economic Geology

Shale Gas Producibility Tornado Chart

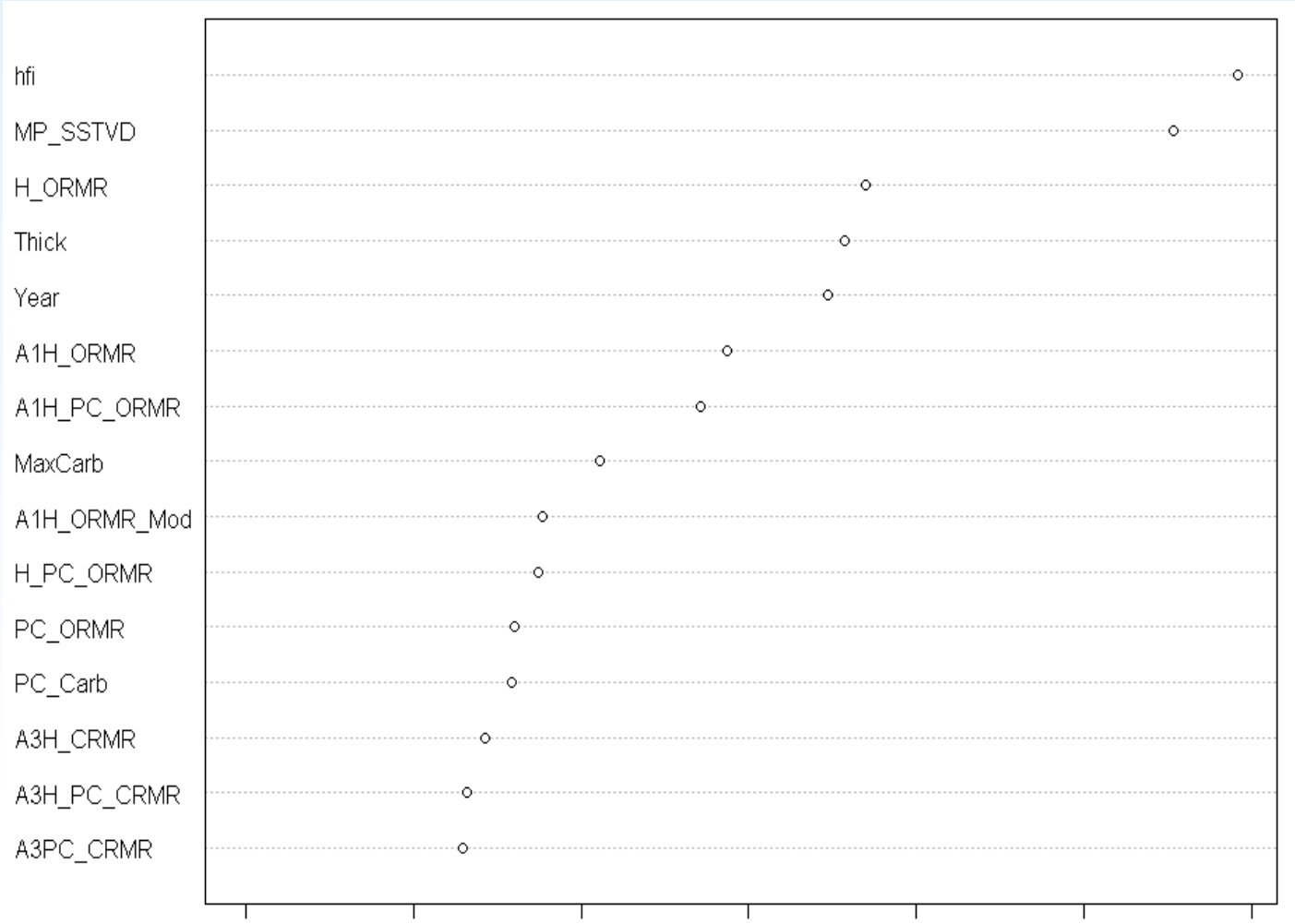


From F Walles and M Cameron (Devon) and D. Jarvie

What Explains WCA Wells Performance

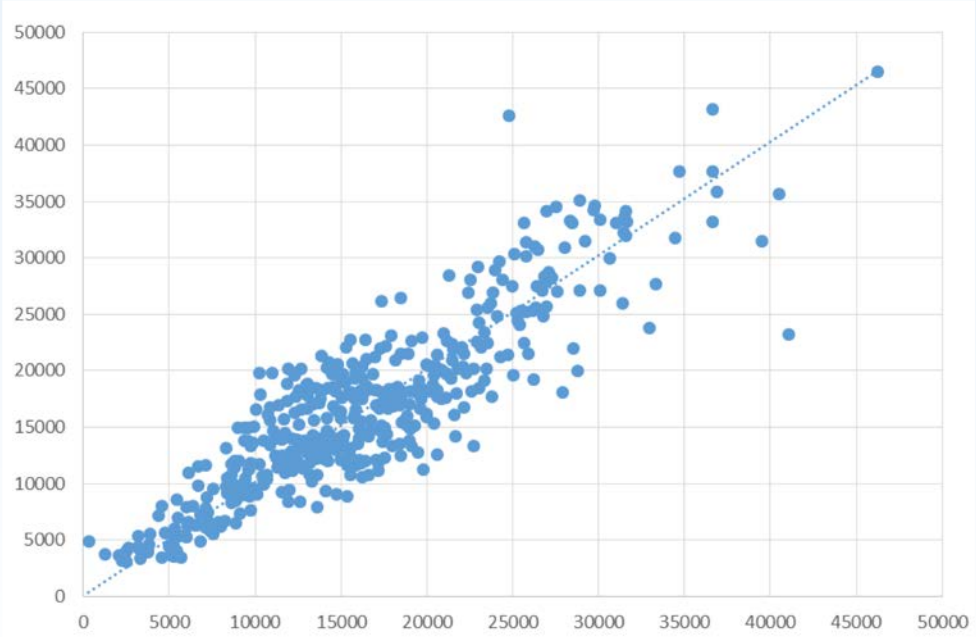
- HF fluid and pressure have the greatest positive impact on Q6m
- Next is H of Organic Rich facies
- Thickness of WCA has aerially positive and negative effect
- Properties of lower sublayer matter though less

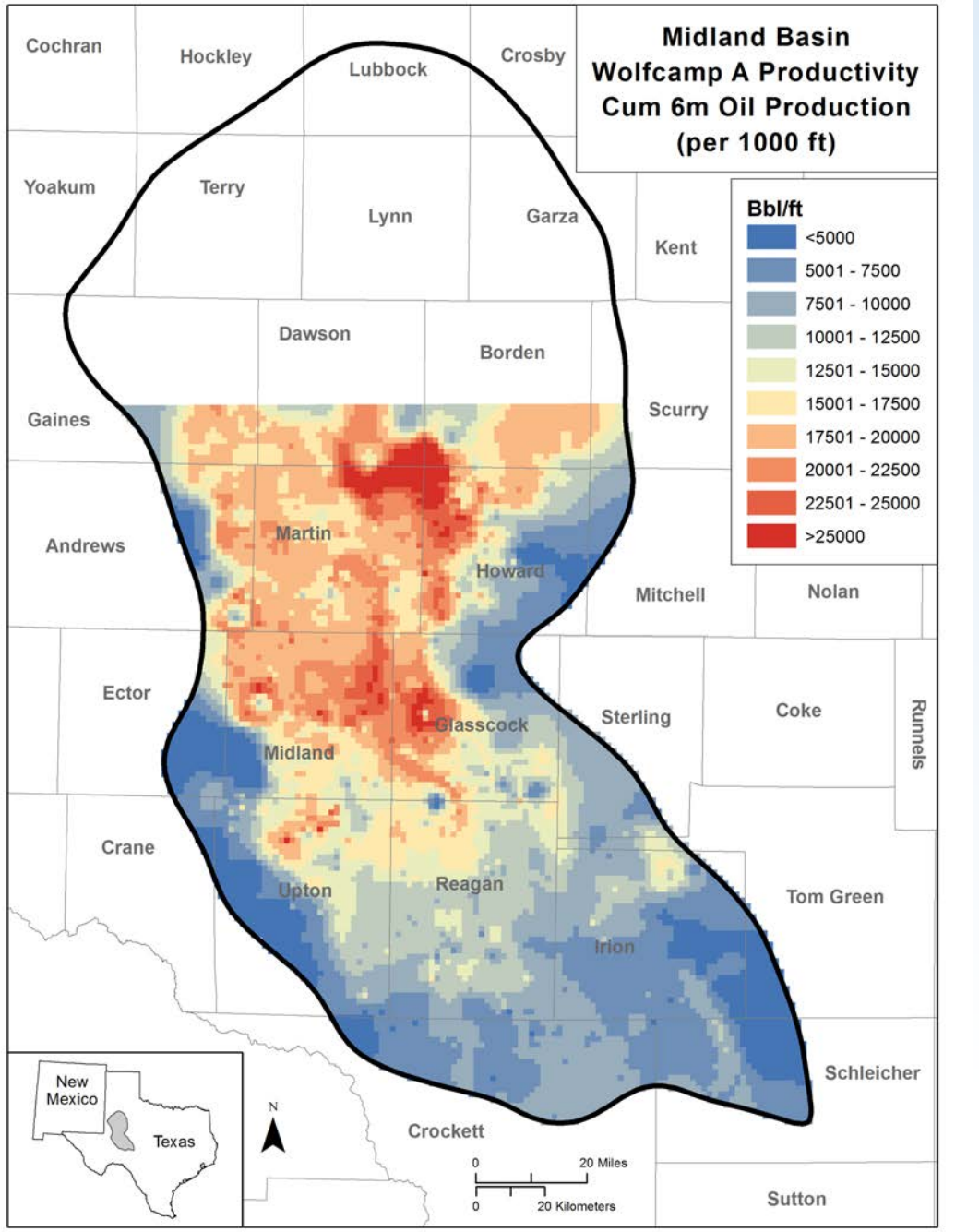
Variable Importance plot: From the most valuable to the least



Mapping WCA Results

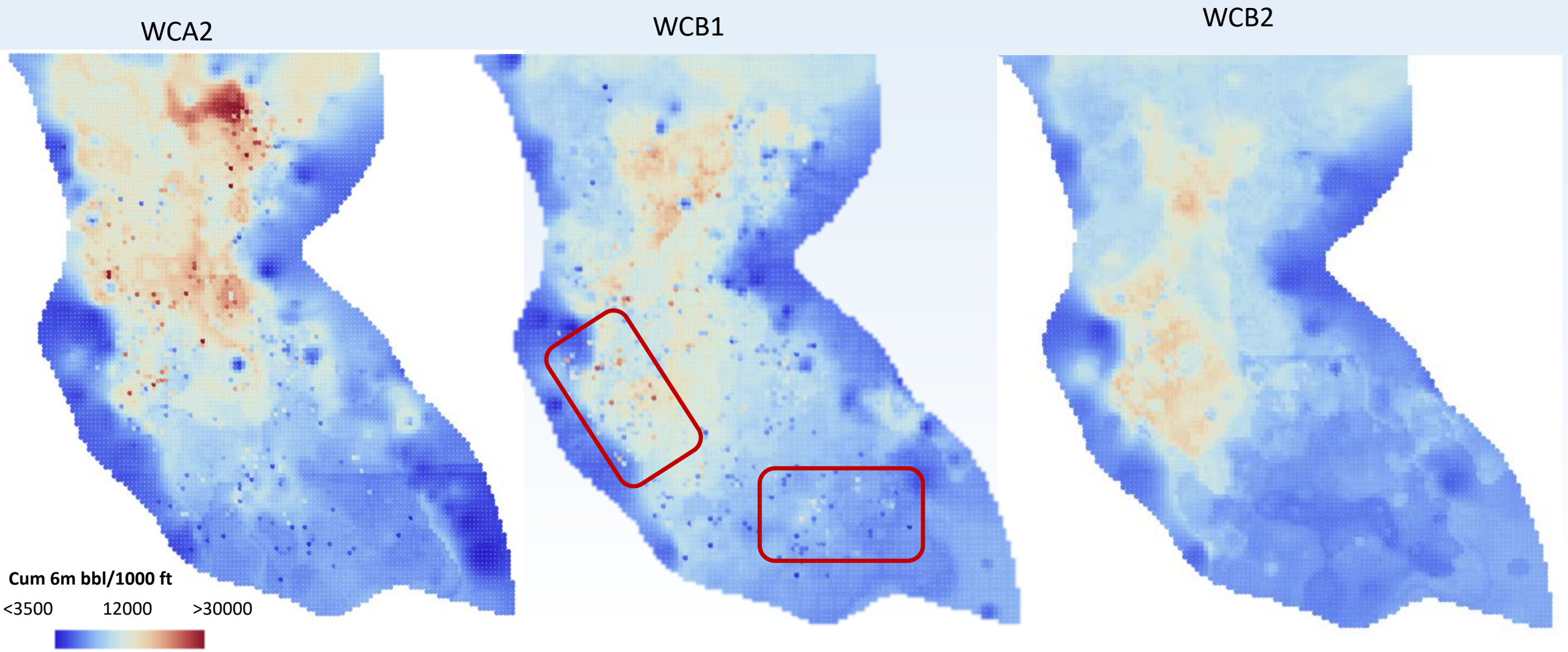
Distribution of errors for 2017





Bureau of Economic Geology

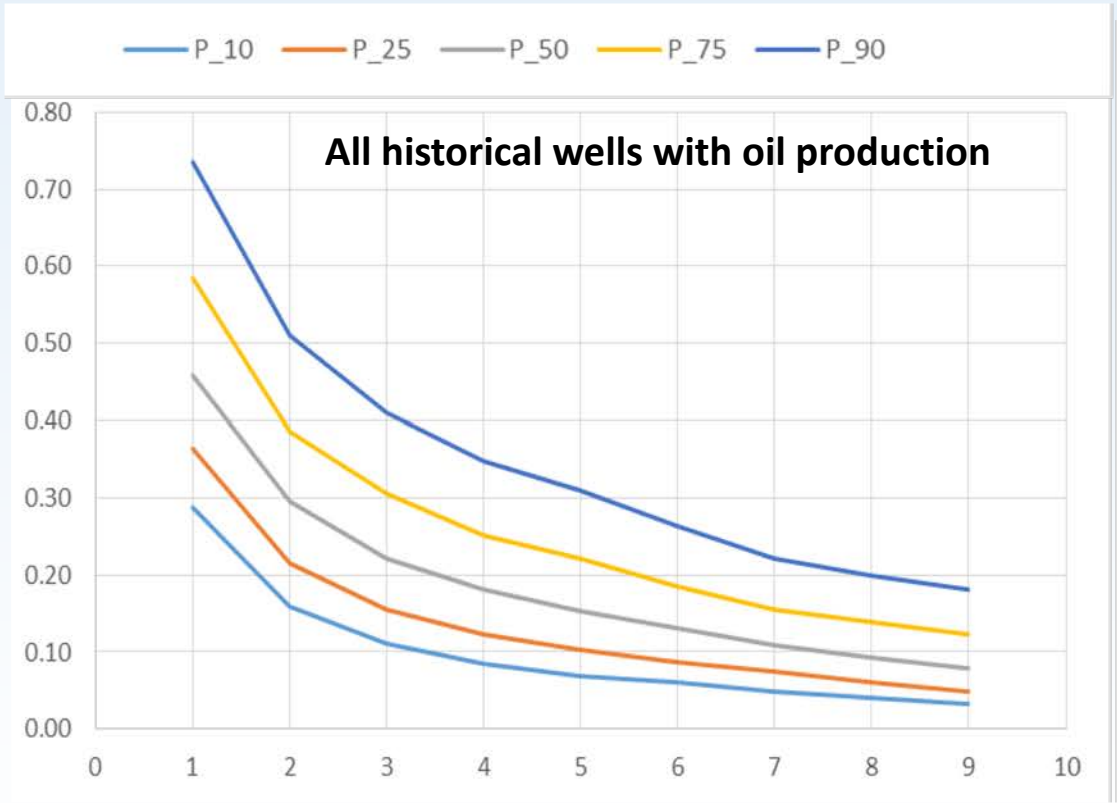
Productivity Across the Layers

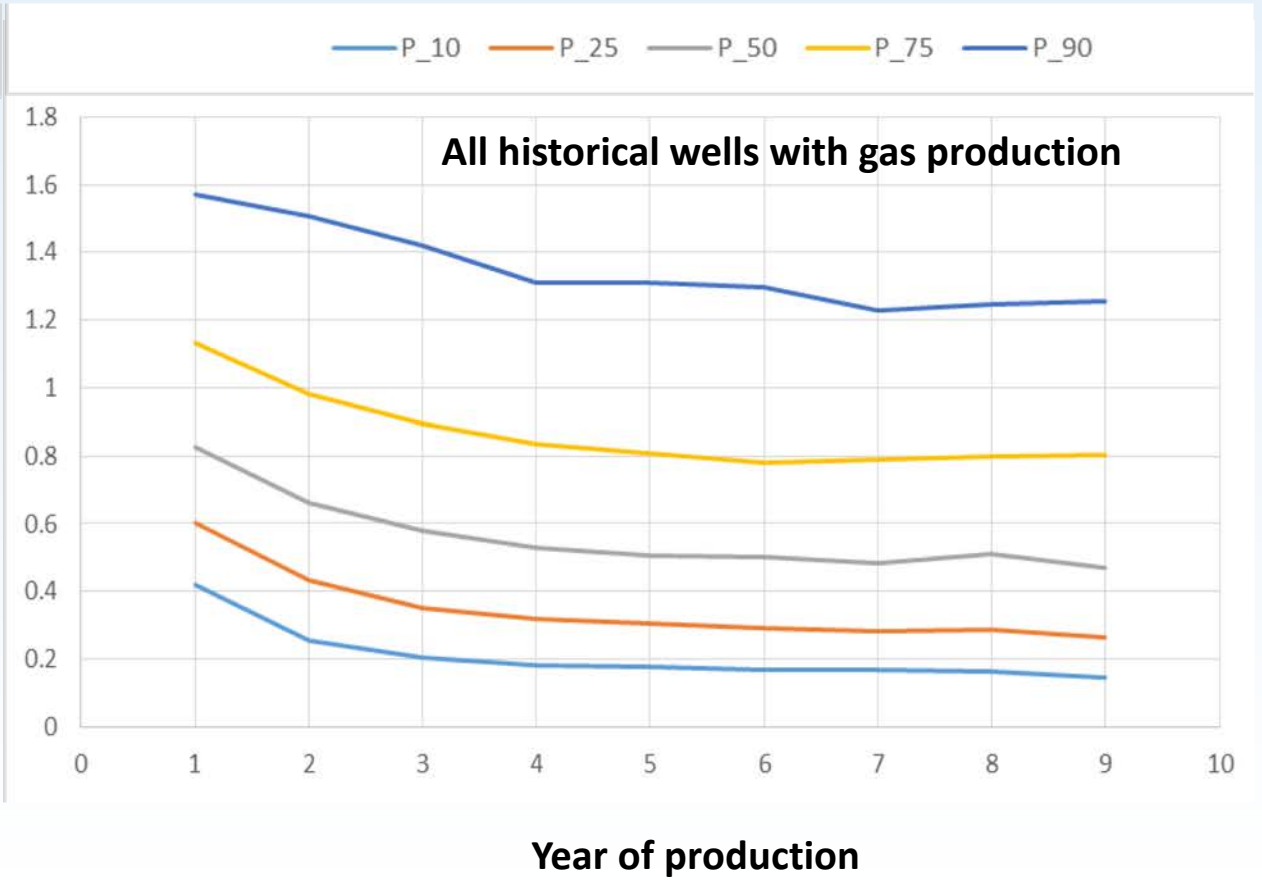


Bureau of Economic Geology

We identify a set of locations with higher variance for further detailed analysis

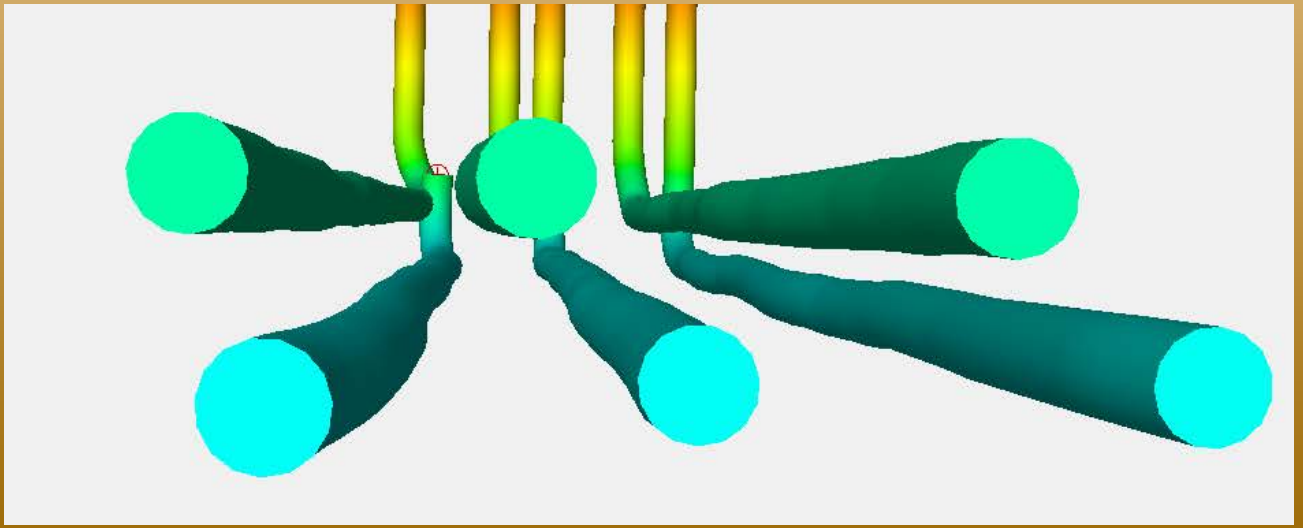
Percentiles of declines for sensitivity analysis



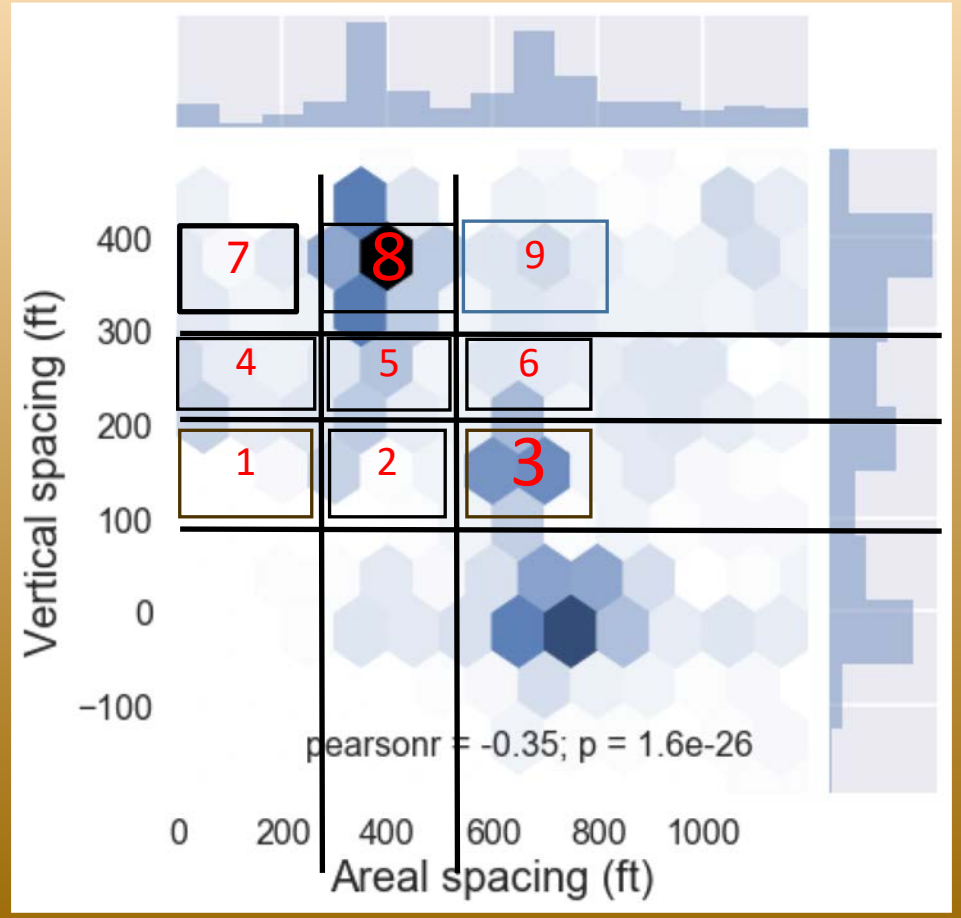


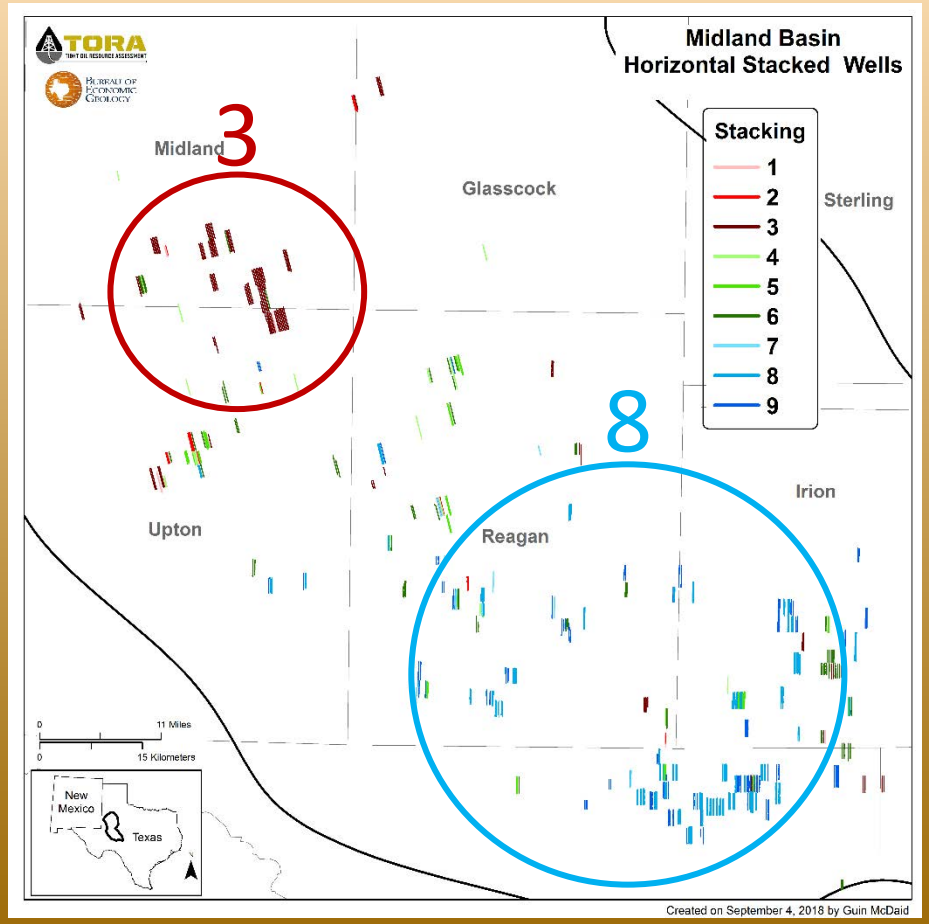
The need for reliable well spacing measurement:

- Production performance evaluation
  - Tight well spacing causes overlapping stimulated volume
- Field development planning and incremental wells estimation

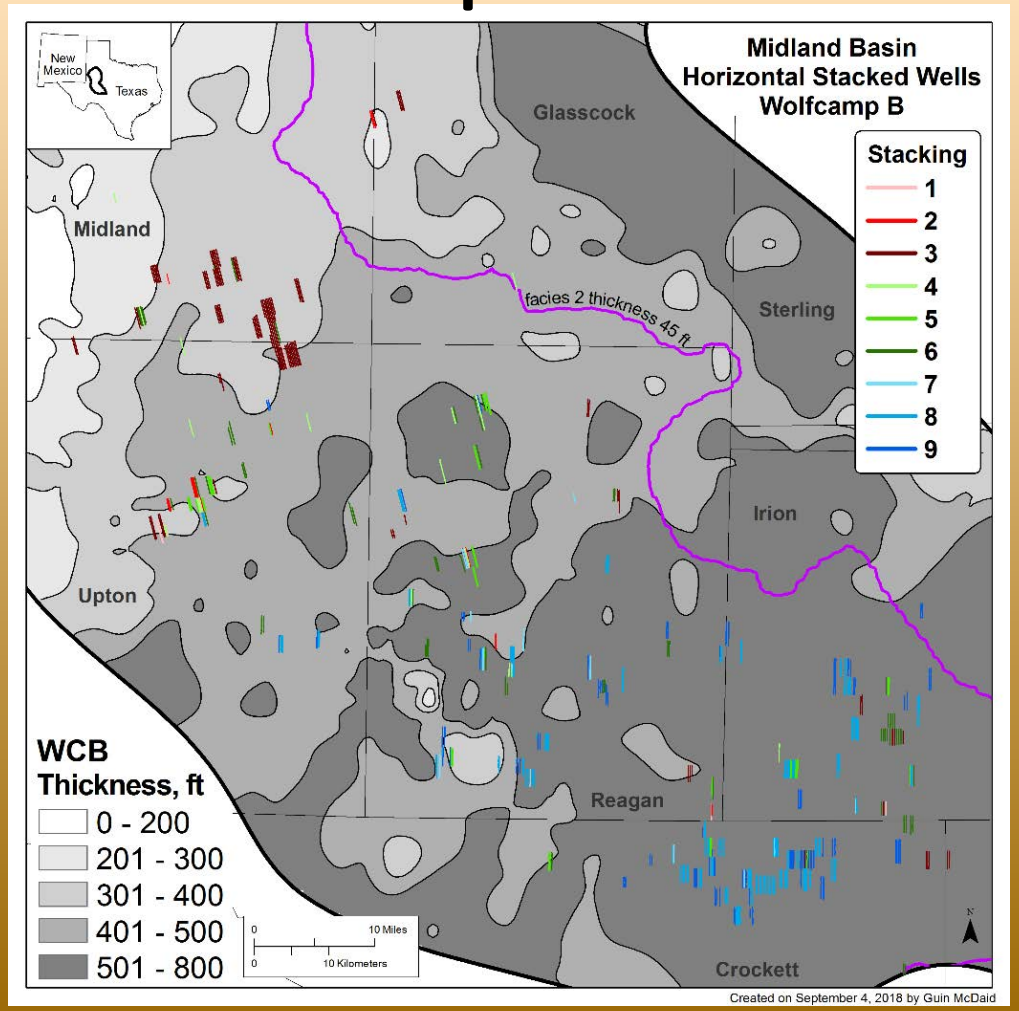


Where the stacked wells are located?

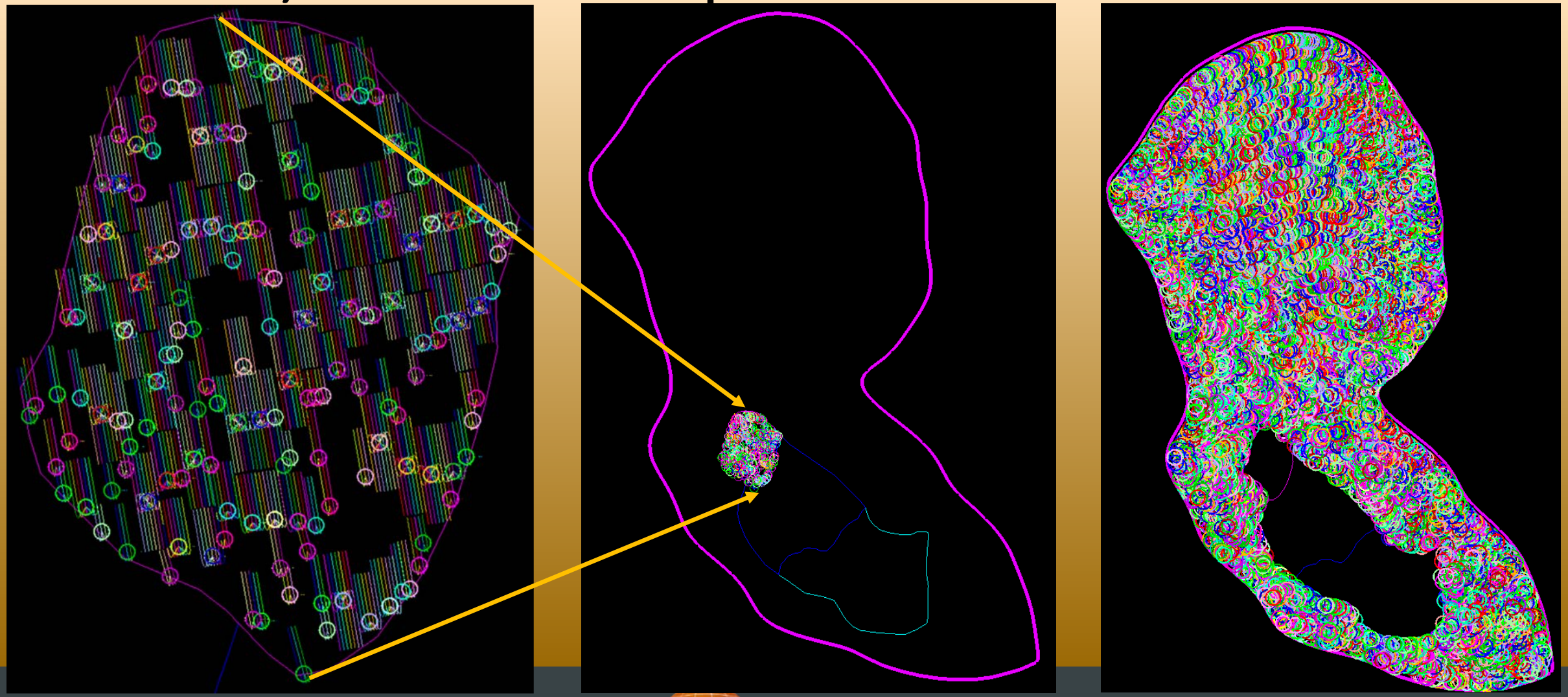




Stacked wells are not placed in thin pay zones



72,000 Wolfcamp B incremental wells



TORA
TIGHT OIL RESOURCE ASSESSMENT

Bureau of Economic Geology

TEXAS Geosciences
Bureau of Economic Geology
Jackson School of Geosciences
The University of Texas at Austin

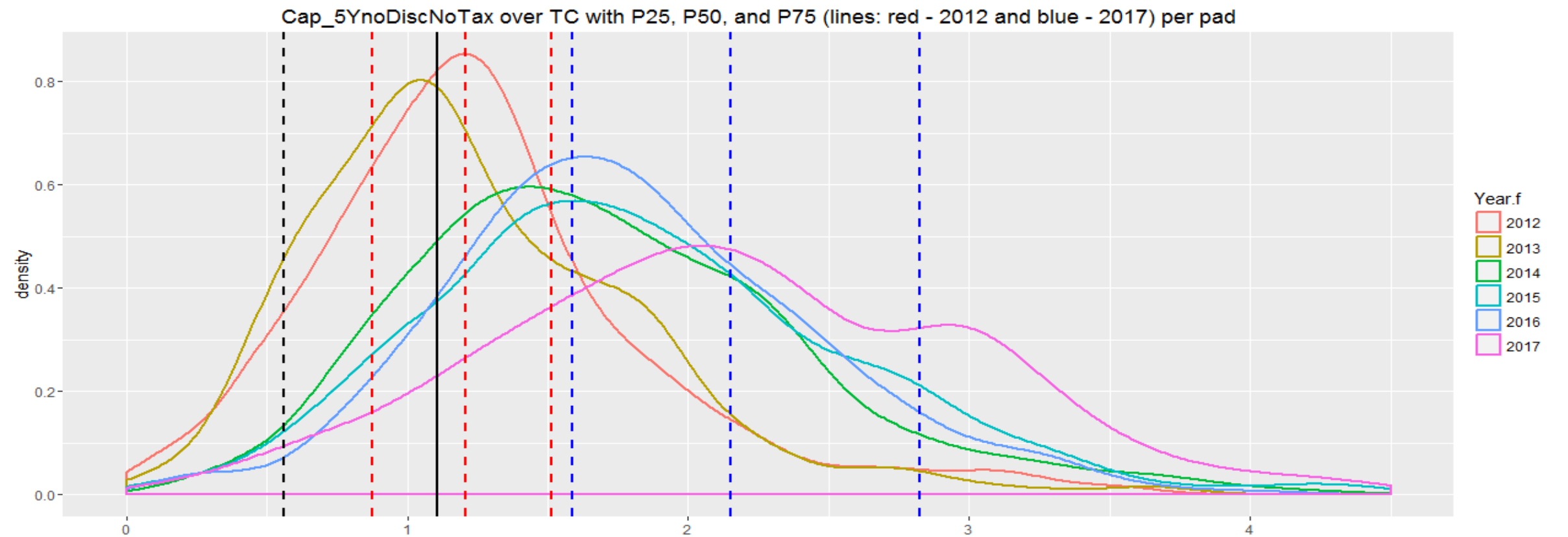
Technically Recoverable Resources

- Assuming the current trends in 2 and 3 layer stacked drilling continue, we estimate ~100,000 wells can still be drilled:
  - Future LL ~ 9,300 ft and average HFI <=3,000 gal/ft
  - No wells right next to the margins with high contiguous carbonate sections
  - Excluding northern part of the play (as shown on the map)
- With current production:
  - in A max -> 30,000bbl/1000ft, with average still <13,000bbl/ft
  - In B max -> 18,000bbl/1000ft, with average still <9,000bbl/ft
- With decline suggesting that in 15y production ~4* the first 6 month

TRR of WCA & WCB is in a range of 35 to 52 Bbbl or <7% of recovery

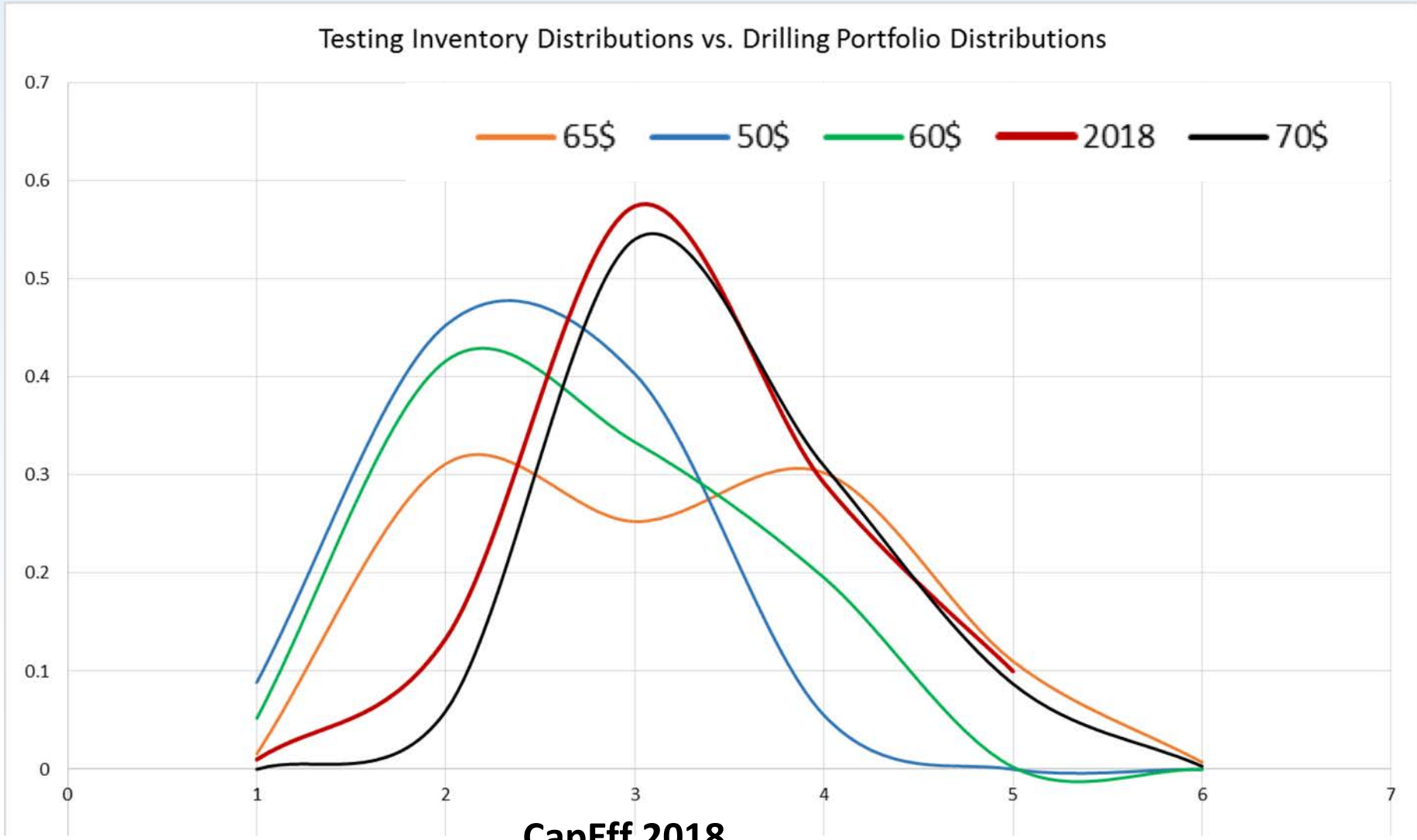
TRR of natural gas production suggests ~80 Tcf *(non-classified)*

In the Future Attractiveness of Pad Drilling Increases



Bureau of Economic Geology

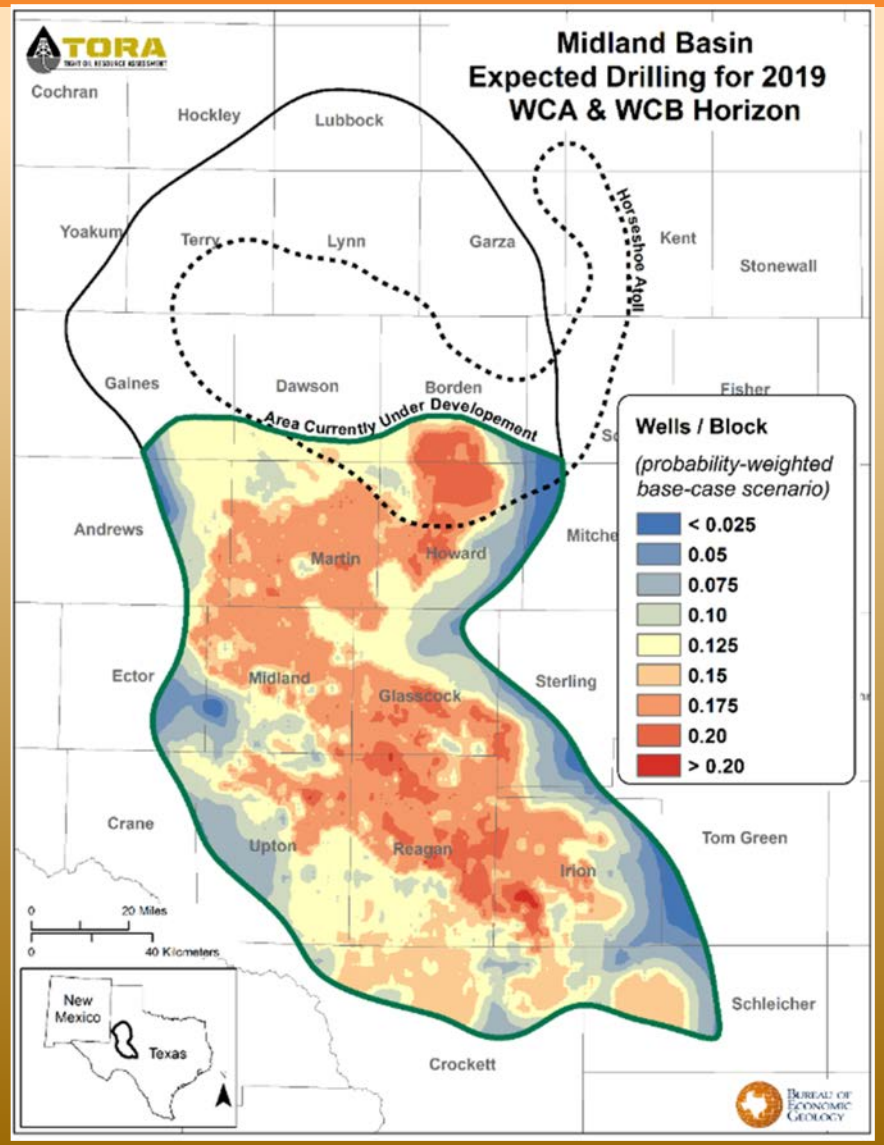
Role of Price Expectations: Explaining & Predicting Drilling Portfolio



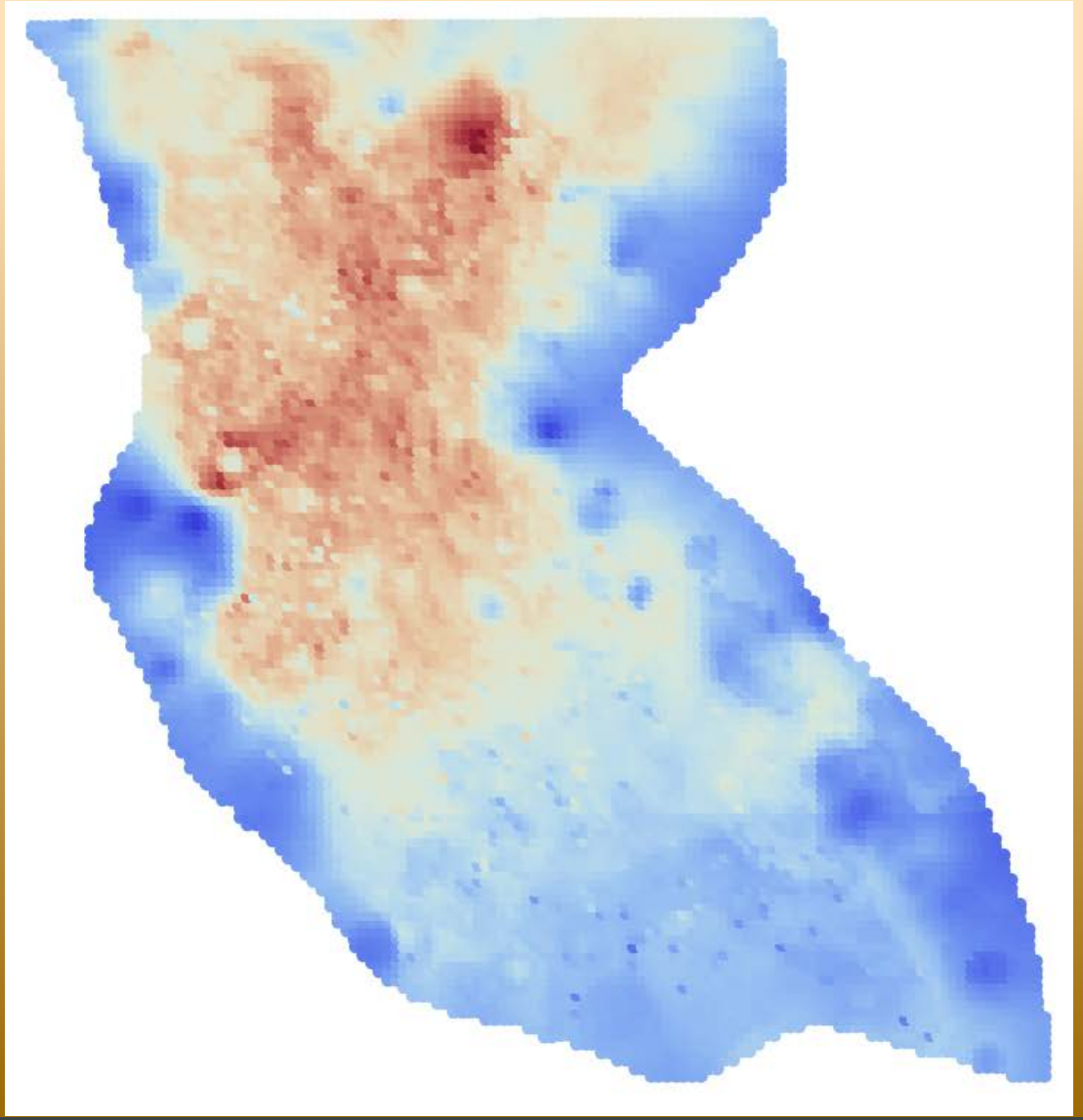
Bureau of Economic Geology

CapEff 2018

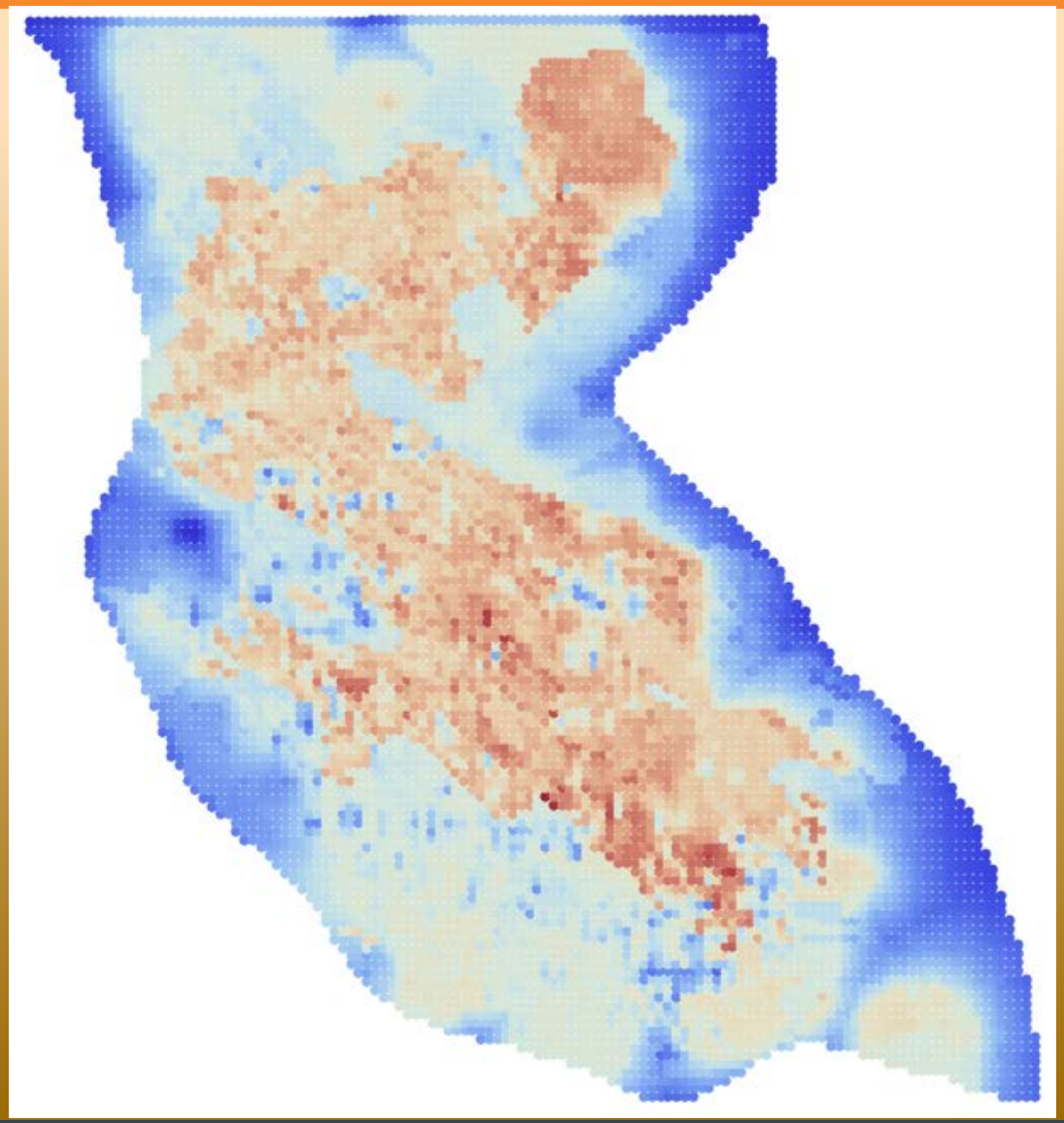
Expected Drilling (higher probability locations in red)



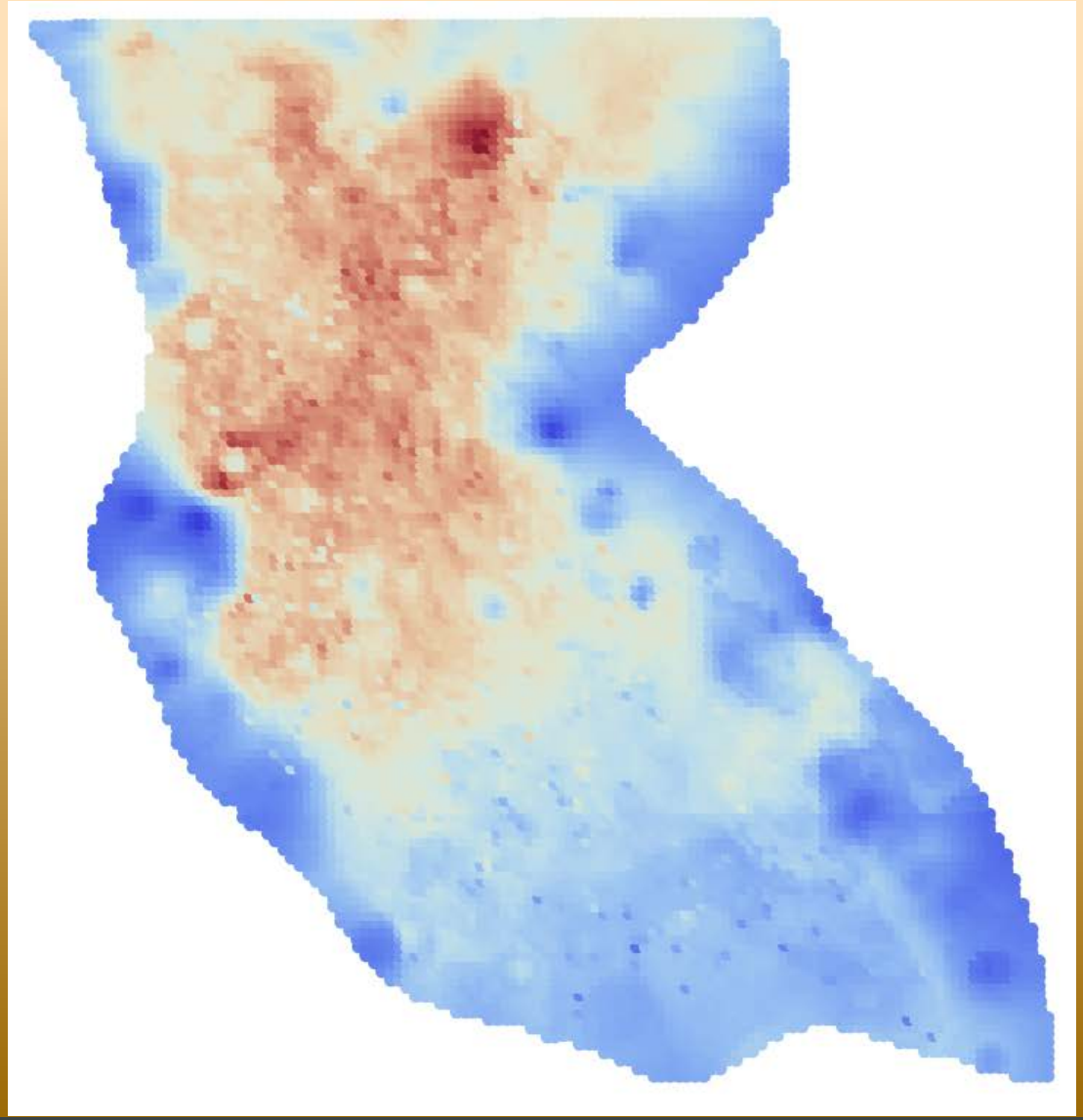
Pad Capital Efficiency 2019 ($70/bbl)



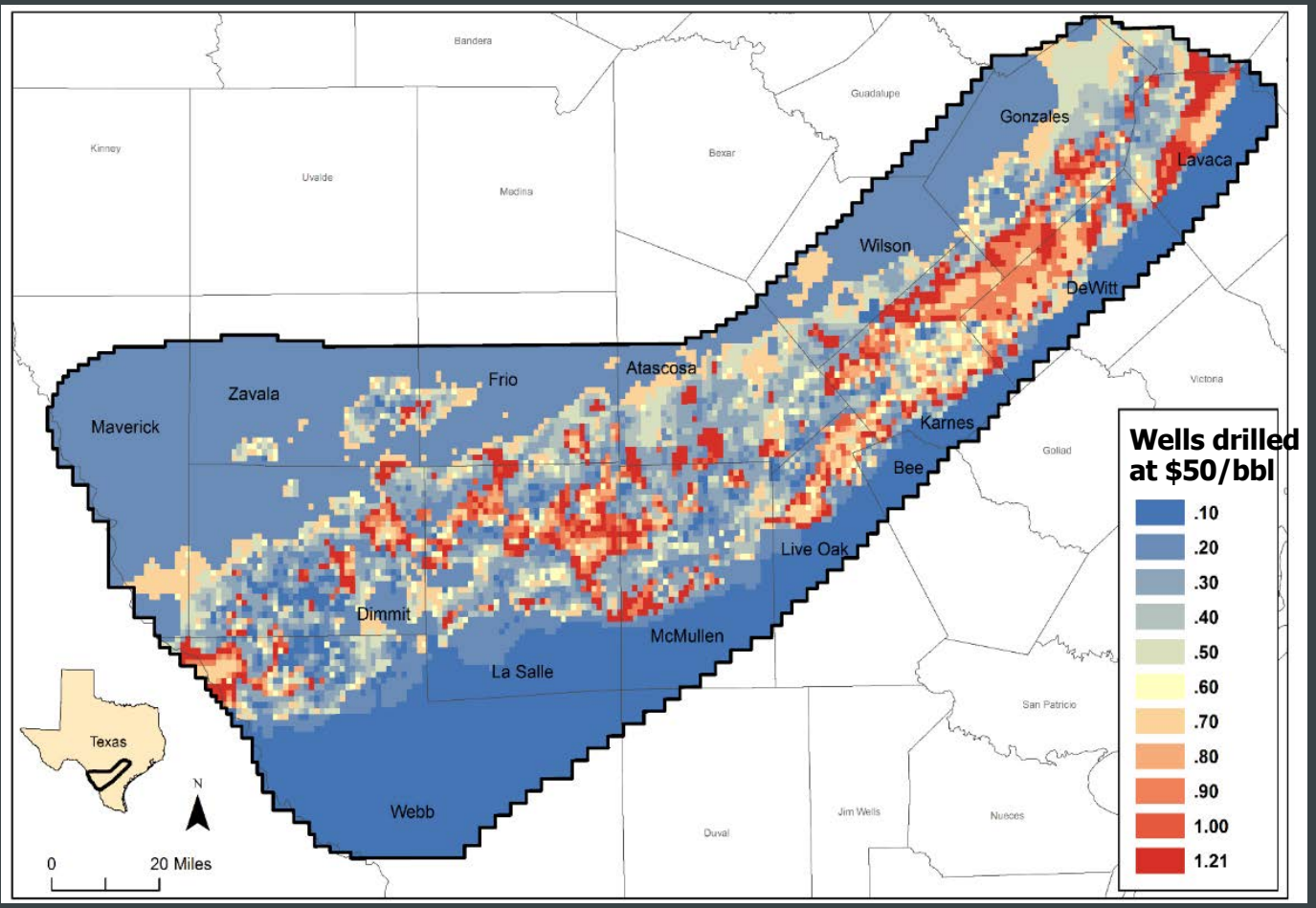
Expected Drilling (higher probability locations in red)



Pad Capital Efficiency 2019 ($70/bbl)



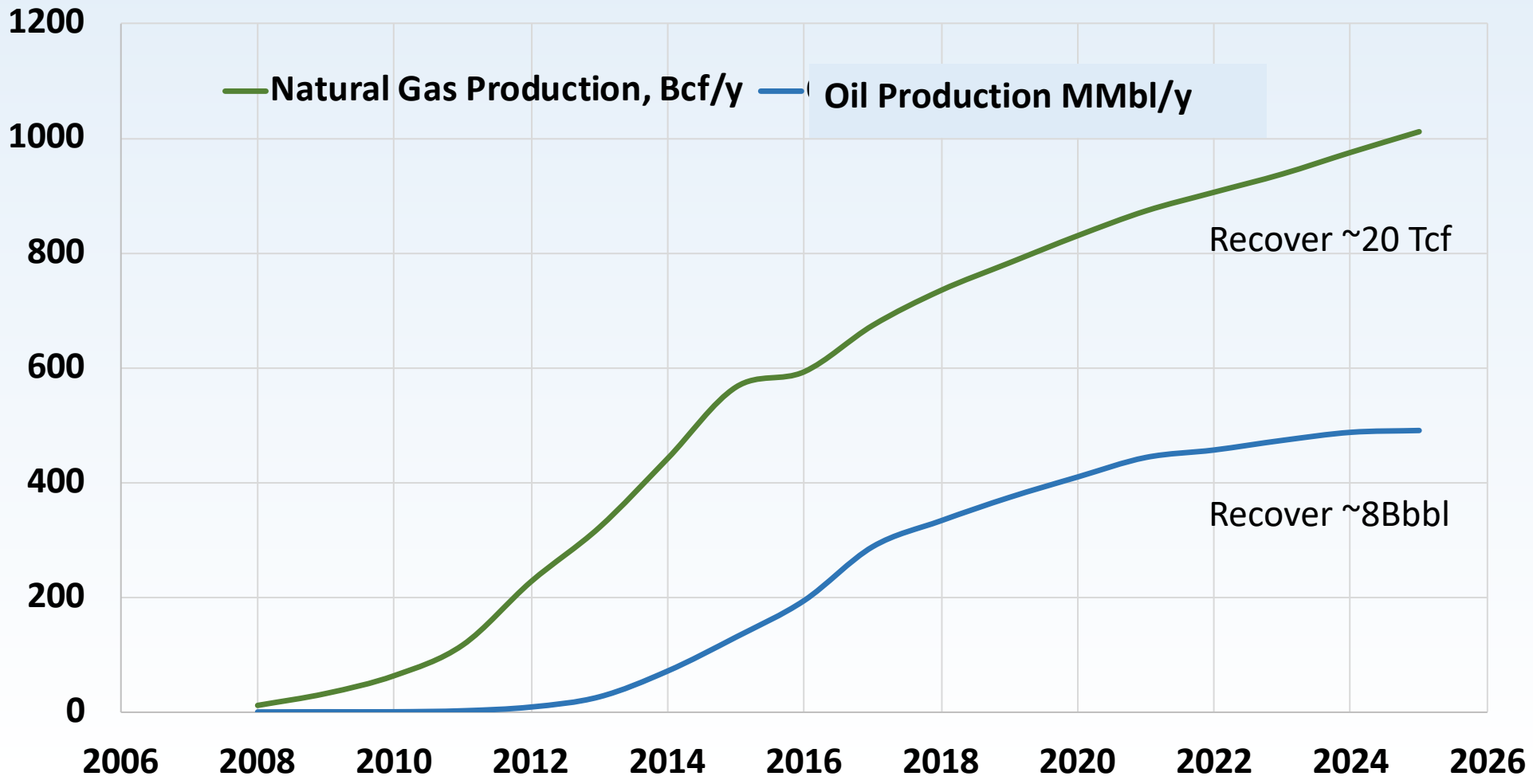
Expected Drilling



Profitability and well inventory maps are used to create expected drilling maps:

1. Depending on previous year's drilling and expected prices & costs we derive a **projection for the drilling portfolio**
2. Profitability map reveals which **locations are likely to be drilled**
3. **Probability of drilling** is assigned based on the inventory of wells available and drilling expected according to the portfolio.

Natural Gas Surpasses Oil and May Choke Production



Bureau of Economic Geology

Acknowledgments

We would like to thank all TORA Industrial Associate sponsors:

TORA TIGHT OIL RESOURCE ASSESSMENT

Apache · CONCHO · ENERGEN · PARSLEY ENERGY · PIONEER NATURAL RESOURCES · Sequitur ENERGY RESOURCES LLC · Shell · SM ENERGY · TOTAL · UNIVERSITY LANDS · AMEREDEV · QUANTUM ENERGY PARTNERS · ExxonMobil · INPEX INPEX CORPORATION · equinor · Schlumberger · COVIA · ikon Science · fairfield GEOTECHNOLOGIES · BMO Capital Markets

Software and Data resources provided by

- IHS Markit for access to well data via its Enerdeq platform.
- Schlumberger for the donation of Petrel® 3D modeling software tools.

IHS Markit

Schlumberger

Reconstructing the Permian Basin for Wolfberry and Wolfbone Unconventional Assessment

Bill Fairhurst[1,2], Svetlana Ikonnikova[1], Robin Dommisse[1], Scott Hamlin[1], Dave Carr[1], Amin Gherabati[1], Frank Male[1], and Inessa Yurchenko[1]

[1] Bureau of Economic Geology, Jackson School of Geosciences, University of Texas – Austin
[2] Riverford Exploration, LLC

AAPG GLOBAL SUPER BASINS 2019
22-24 January 2019 • Sugar Land, Texas
Sugar Land Marriott Town Square
The Permian

TORA TIGHT OIL RESOURCE ASSESSMENT

BUREAU OF ECONOMIC GEOLOGY

TEXAS Geosciences
Bureau of Economic Geology
Jackson School of Geosciences
The University of Texas at Austin