Inter-Disciplinary Work Flow Process to Achieve Profitable Results in Delaware Basin Resource Plays*

John Polasek[1]

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Abstract

For Permian resource plays, Oxy has deployed a strong inter-disciplined linkage or team co-dependency because of the numerous reservoir properties that are required and shared to help build and develop the most profitable inventory for the current oil price environment. The evaluation involves a major integrated effort between Geologists, Geophysicists, Petrophysicists, Basin Modelers, Reservoir, Completion and Drilling Engineers as well as Data Analytics. This process has helped improve well performance and capex focus particularly in Oxy's Delaware Basin properties. Several examples of this integrated workflow will be shown with the premise of profitable production growth through technical and execution excellence.

Occidental Petroleum

Inter-Disciplinary Work Flow Process to Achieve Profitable Results in Delaware Basin Resource Plays

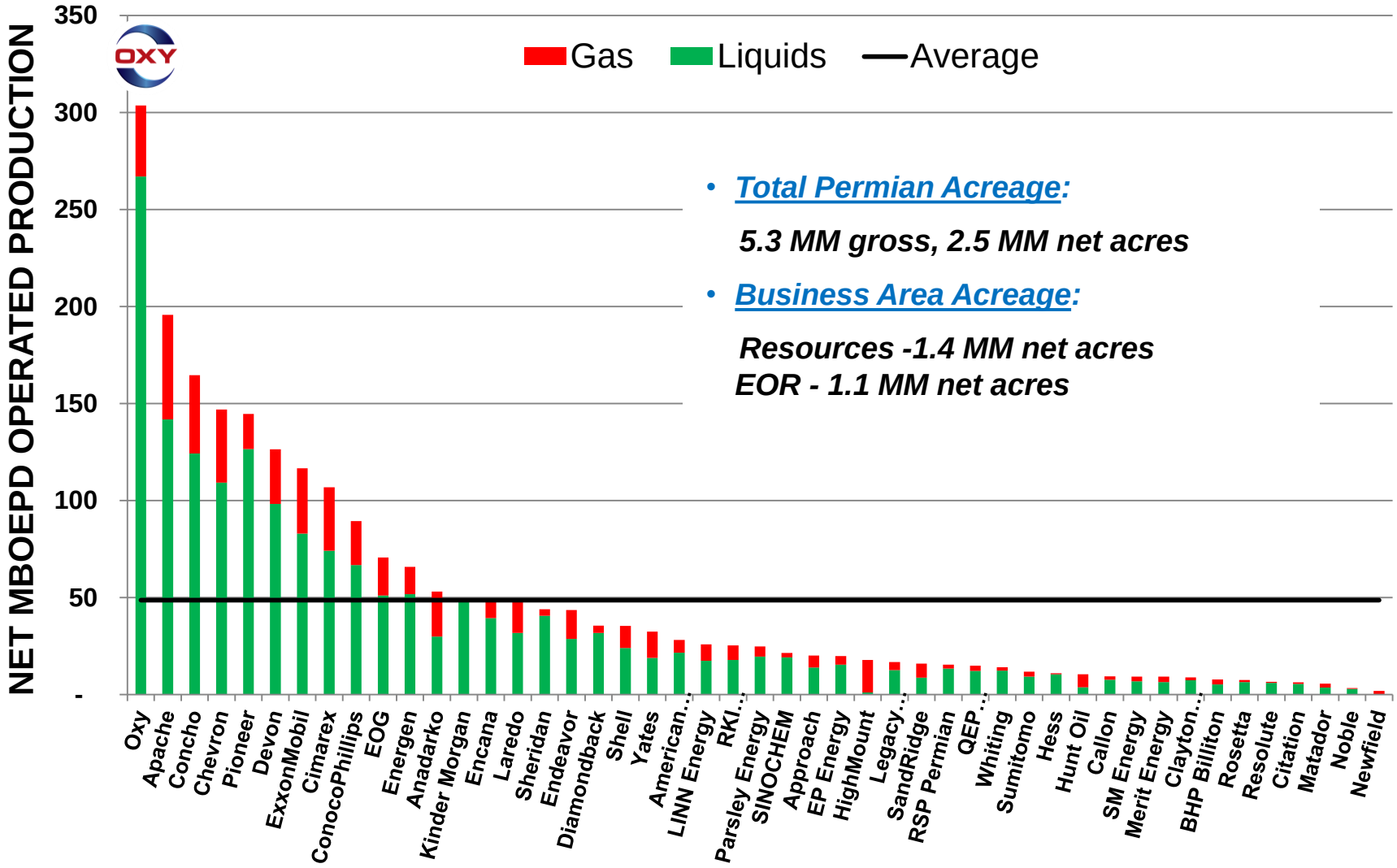
John Polasek -*VP Subsurface Characterization Group*

AAPG-DPA - Delaware Basin Playmaker Forum

Midland, Texas

February 22, 2017

The Largest Operator, Producer & Acreage Holder in Permian



- ***Total Permian Acreage:***

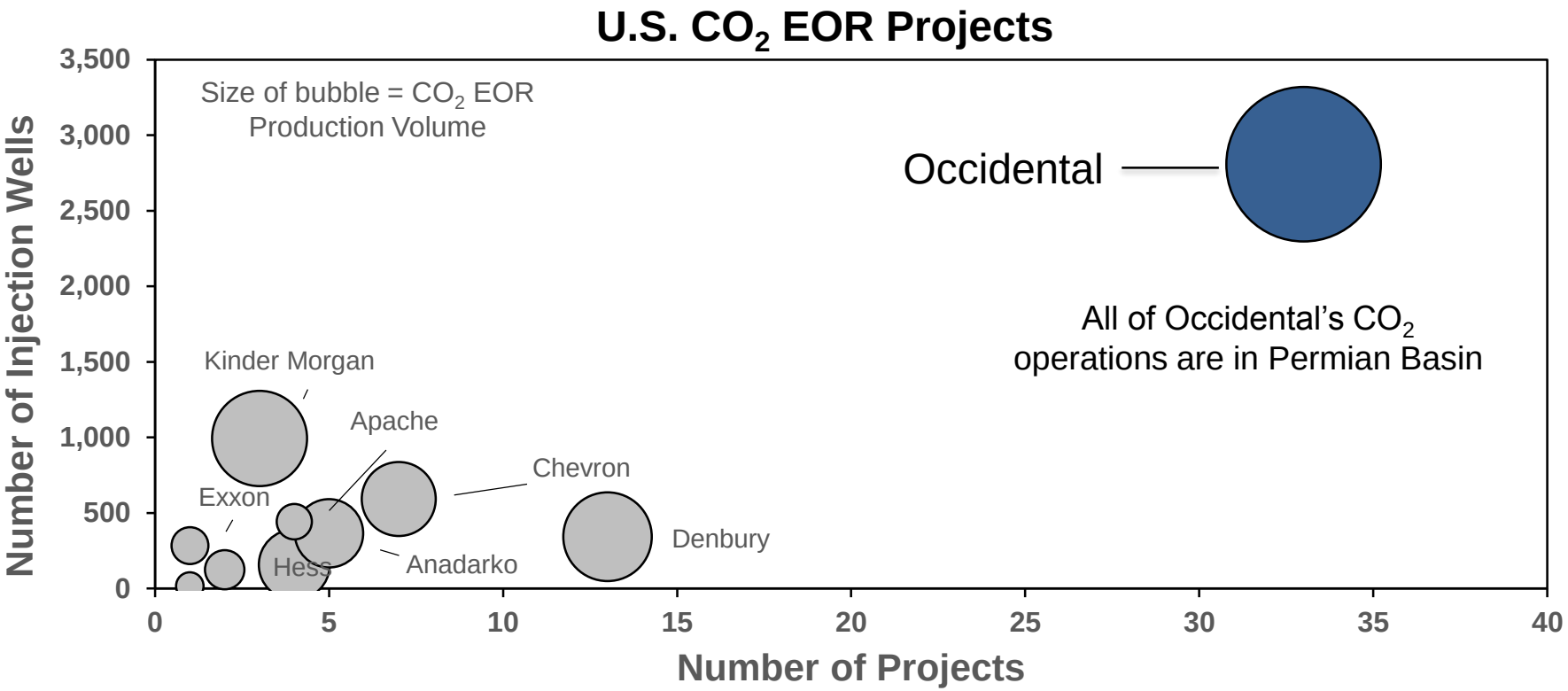
  5.3 MM gross, 2.5 MM net acres

- ***Business Area Acreage:***

  Resources -1.4 MM net acres
  EOR - 1.1 MM net acres

Source: Wood Mackenzie, 9/23/15, Company Net Working Interest Production Rates

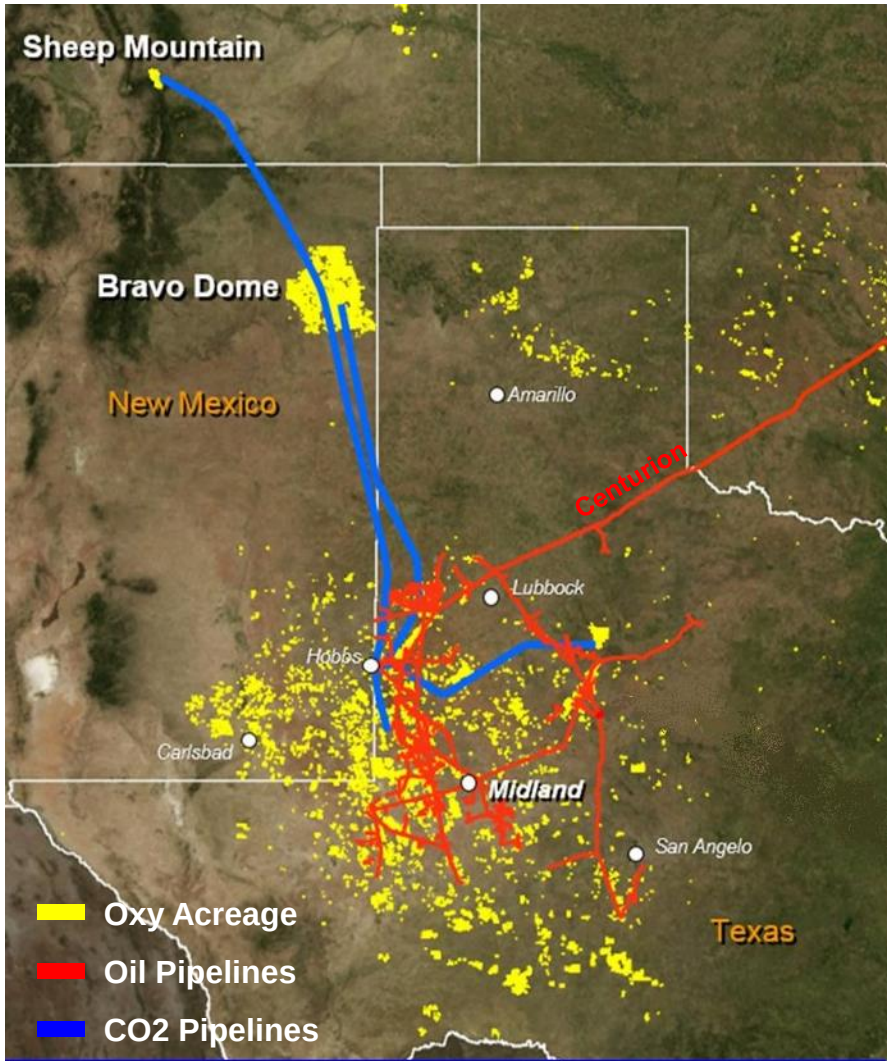
Oxy – Permian and World Leader in CO_2 EOR



- **Inject 1.9 billion cubic feet of CO_2 per day**
- **Operate 31 CO_2 EOR projects (74% of EOR production employs CO_2 technology)**
- **Half of Permian CO_2 floods are operated by Oxy**

Source: Oil & Gas Journal 2014 Biennial EOR Survey, Oxy 2016 update

Permian Basin is Oxy's Core Domestic Asset



EOR Business

- 2016 YE Net Production - 144 MBOEPD
- 1.1 million net acres
- 1.9 Billion BOE remaining in reserves and resources

Midstream

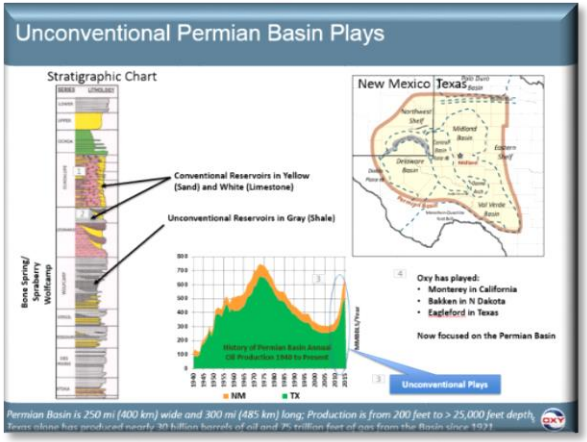
- 14 processing plants
- ~3,000 miles of pipeline
  - CO_2 pipelines
  - Oil infrastructure and pipelines
  - Marketing business

Resource Business

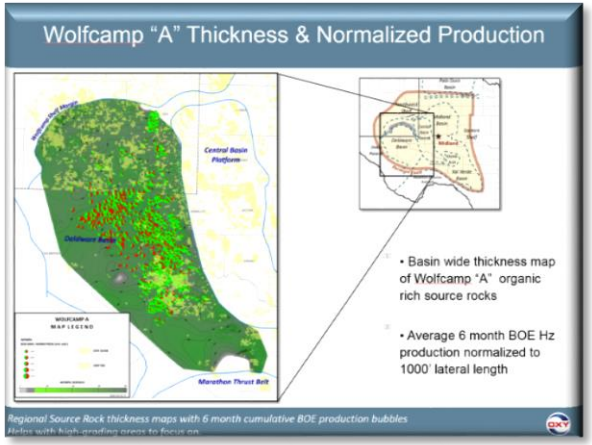
- 2016 YE Net Production – 124 MBOEPD
- 1.4 MM net acres in Resource Plays
- 0.3 MM net acres associated with 11,650 drilling locations
- >20% of current inventory BE at < $50 oil

** Based on 4Q16 metrics*

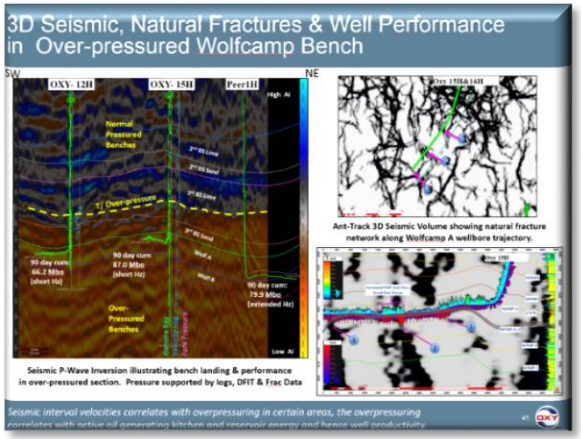
Basic Workflow to Evaluate Unconventional Plays



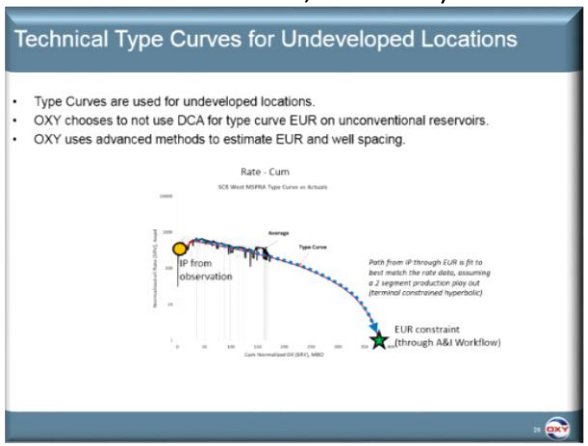
Geological Understanding: Review Basin Geology to Identify Unconventional Targets to focus on and pursue



Basin Analysis: Integrate Geochemistry to Determine best source rocks (Thick, High TOC, Thermally Mature, High Pressure, Oil Prone)



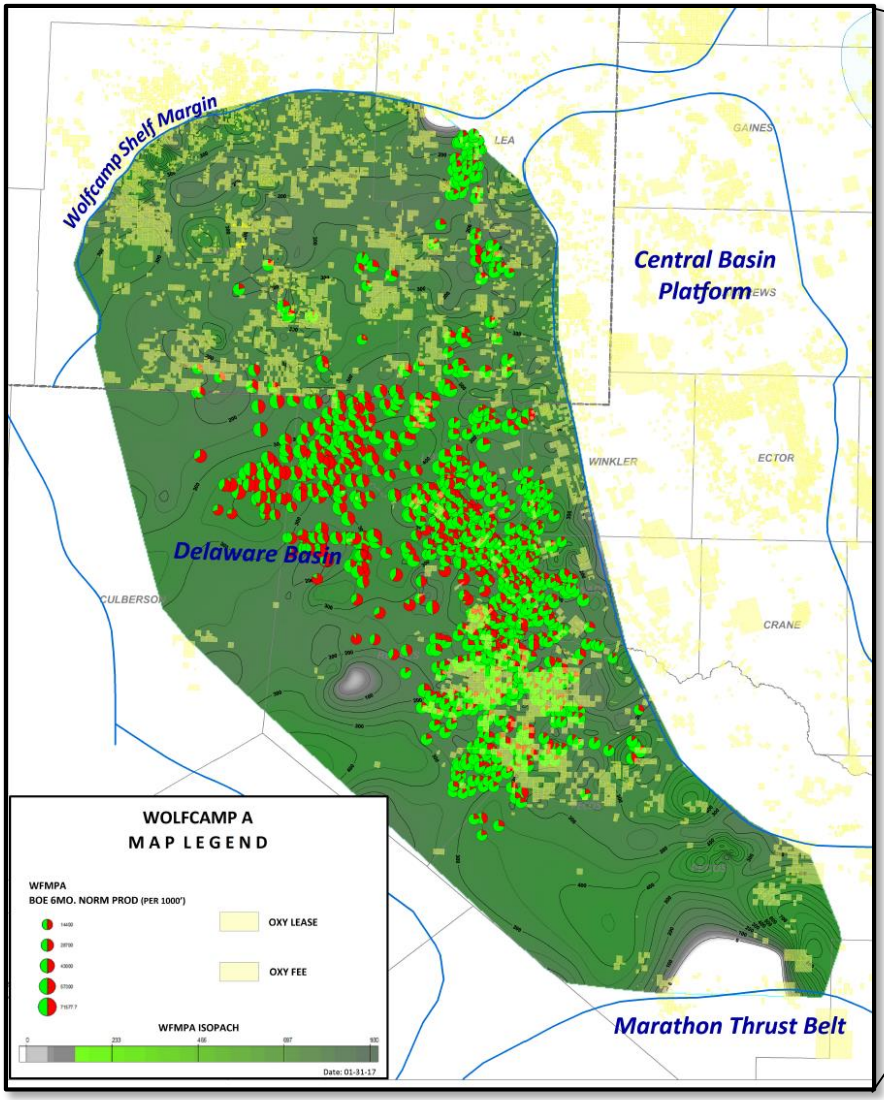
Appraisal: Integrate Petrophysics, G&G, RE to Accelerate Learnings (Good Porosity, low clay, High Oil Saturation, Fracabile, Source Rocks)

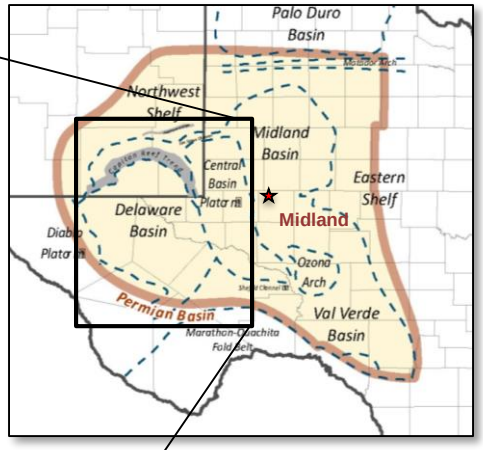


Development: Integrate Reservoir, Completion and Production Engineering for commercial development of play (Fracture Holding, High OOIP, High EUR per well, repeatable benches)

Unconventional Play Evaluation involves a major integrated team effort between Geologists, Petrophysicists, Geophysicists, Reservoir Engineers, Completion & Production Engineers.

Build Regional Source Rock Understanding from Bone Spring through Wolfcamp Intervals



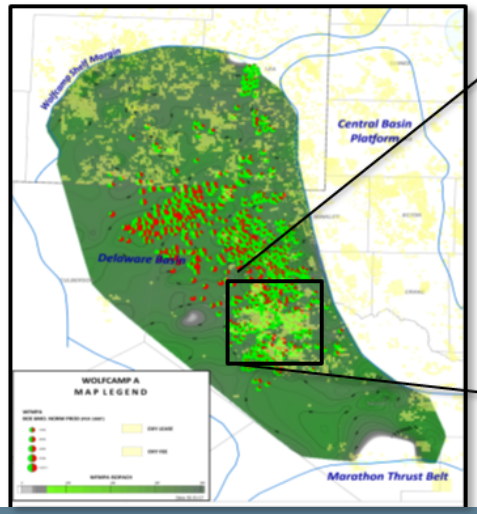


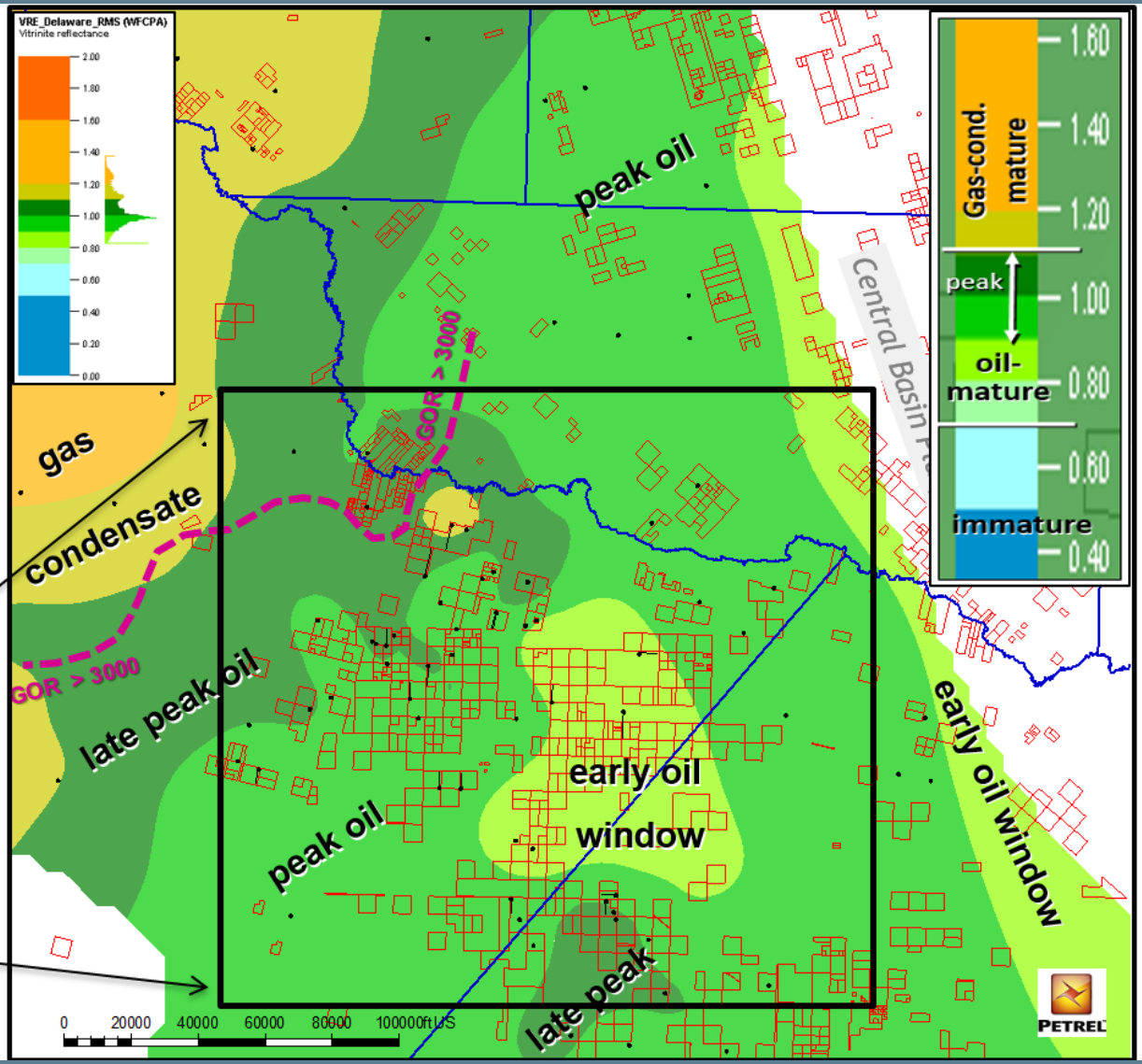
- **Basin wide thickness map of Wolfcamp "A" organic rich, source rock interval**
- **Average 6 month Hz production BOE's normalized to 1000' lateral length**

Basin-wide Source Rock understanding of all organic mudstone benches, what works, what doesn't, what's critical, how to map, all help Oxy with high-grading their vast acreage position.

Source Rock Thermal Maturity and Production Performance

- **Thermal Maturity calculated from pyrolysis, Tmax, confirmed with VRE**
- **"Peak-oil" maturity window is (0.9 to 1.1 VRE)**
- **Increasing GOR's (six month production) is consistent with increasing source rock maturity**



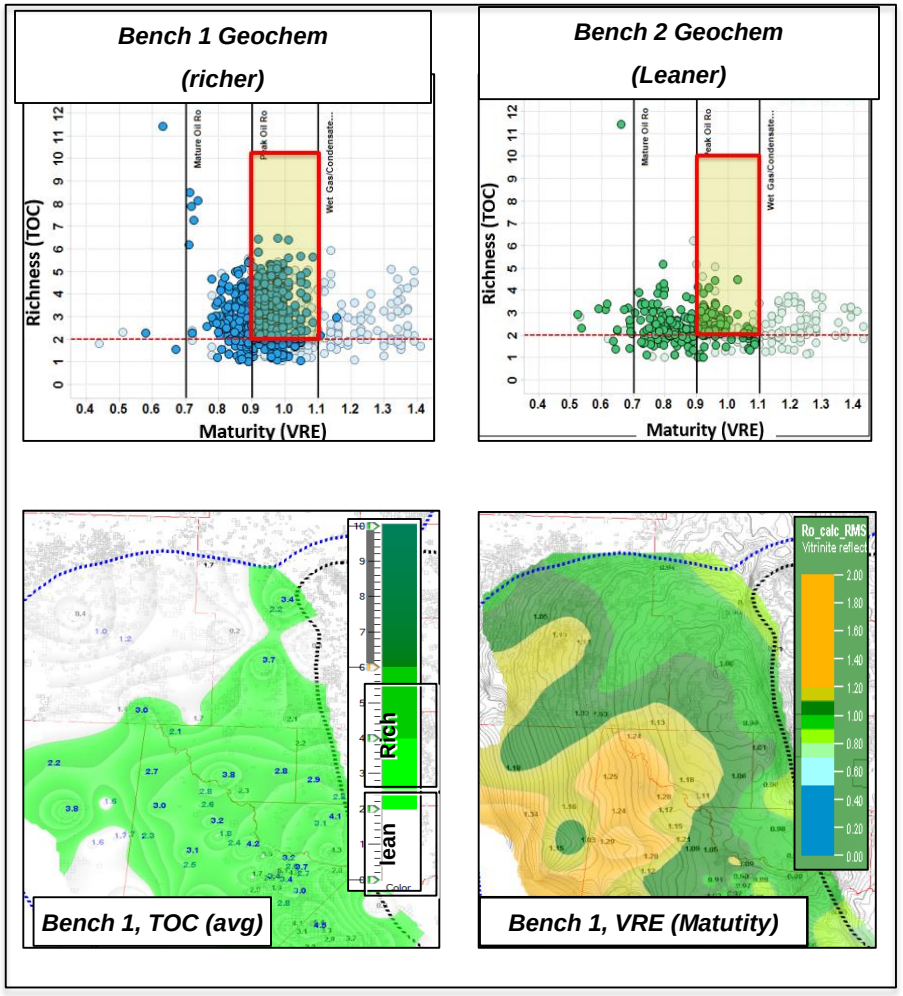


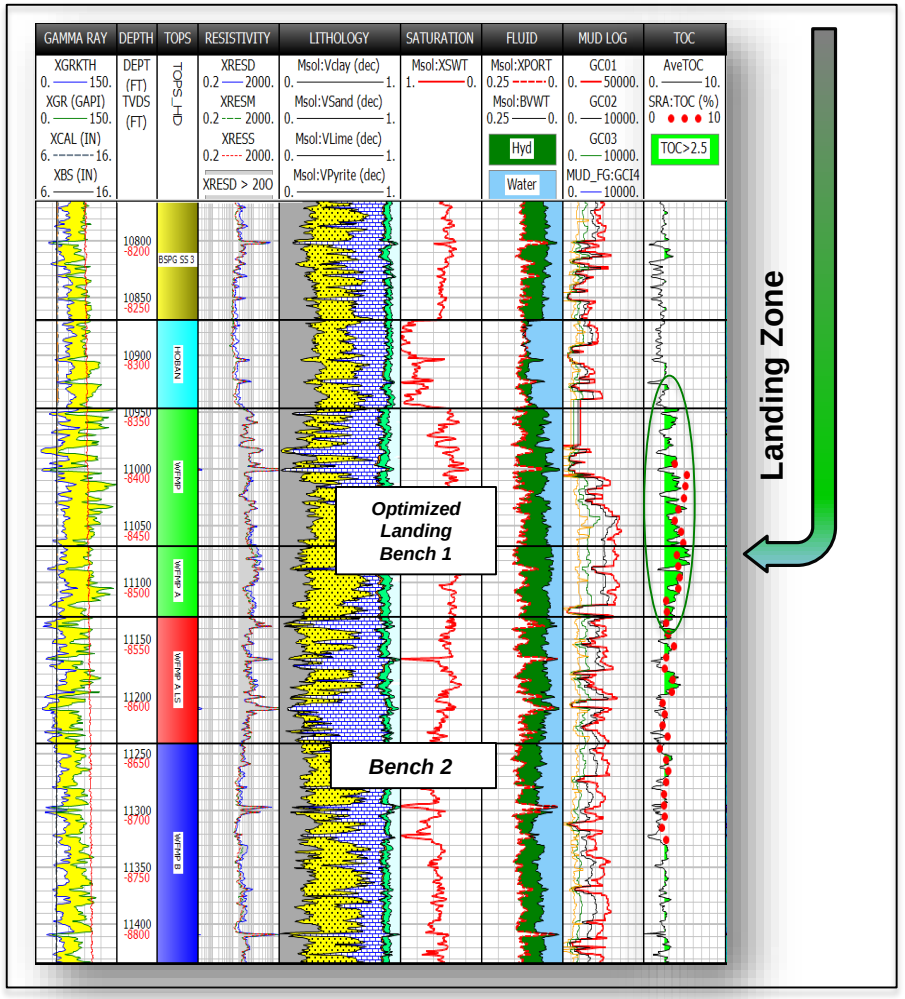
Organic richness, maturity and storage capacity are key elements to understanding Oxy acreage and a focused strategy towards economic development of this acreage,

Integrating Source Rock Understandings into Petrophysics

Source Rock Richness & Maturity Maps

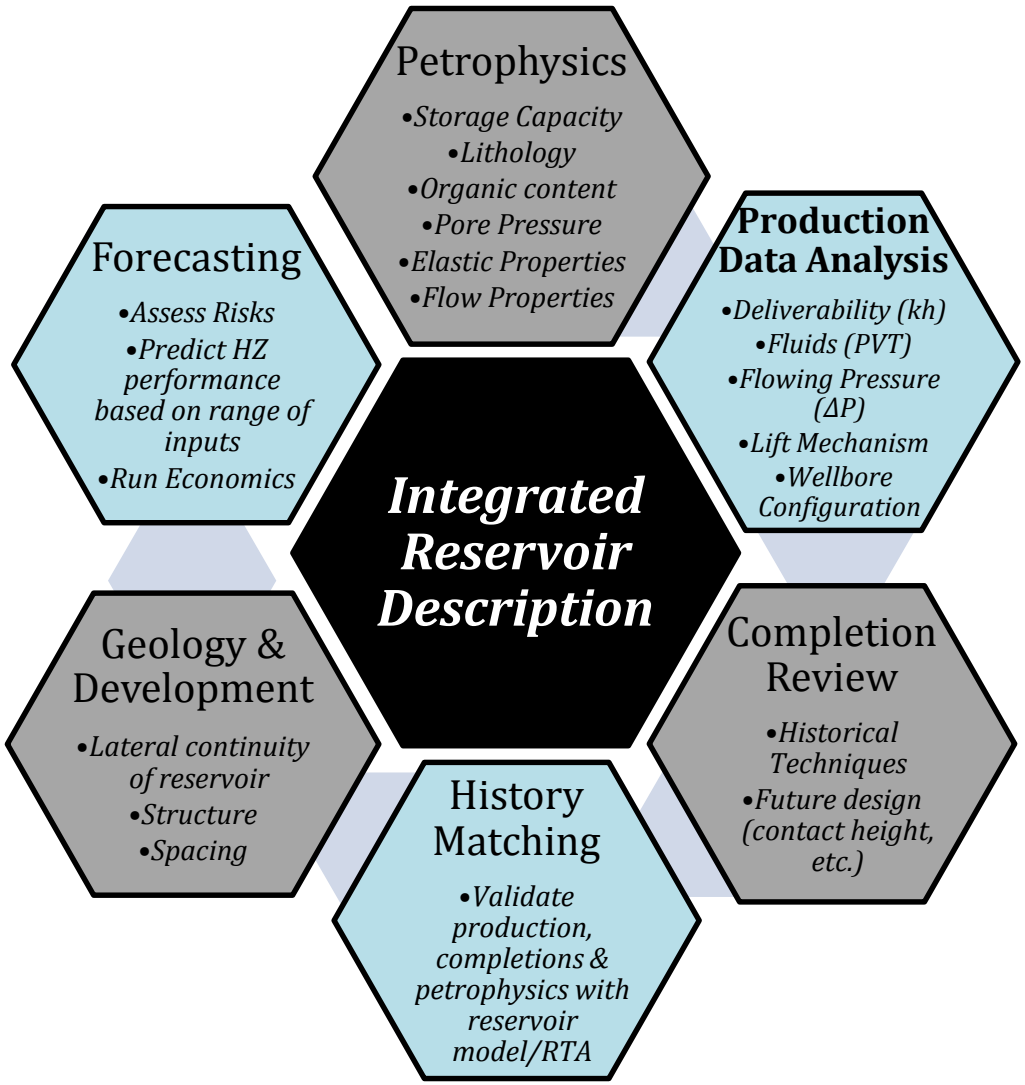
Petrophysics, Ranking & Landing





Source rock geochem from rock data is integrated into the petrophysical analyses of well log data to confirm prospective benches and help in choosing landing zones.

Unconventional Resources(UCR) – Petrophysics



Primary Data - In

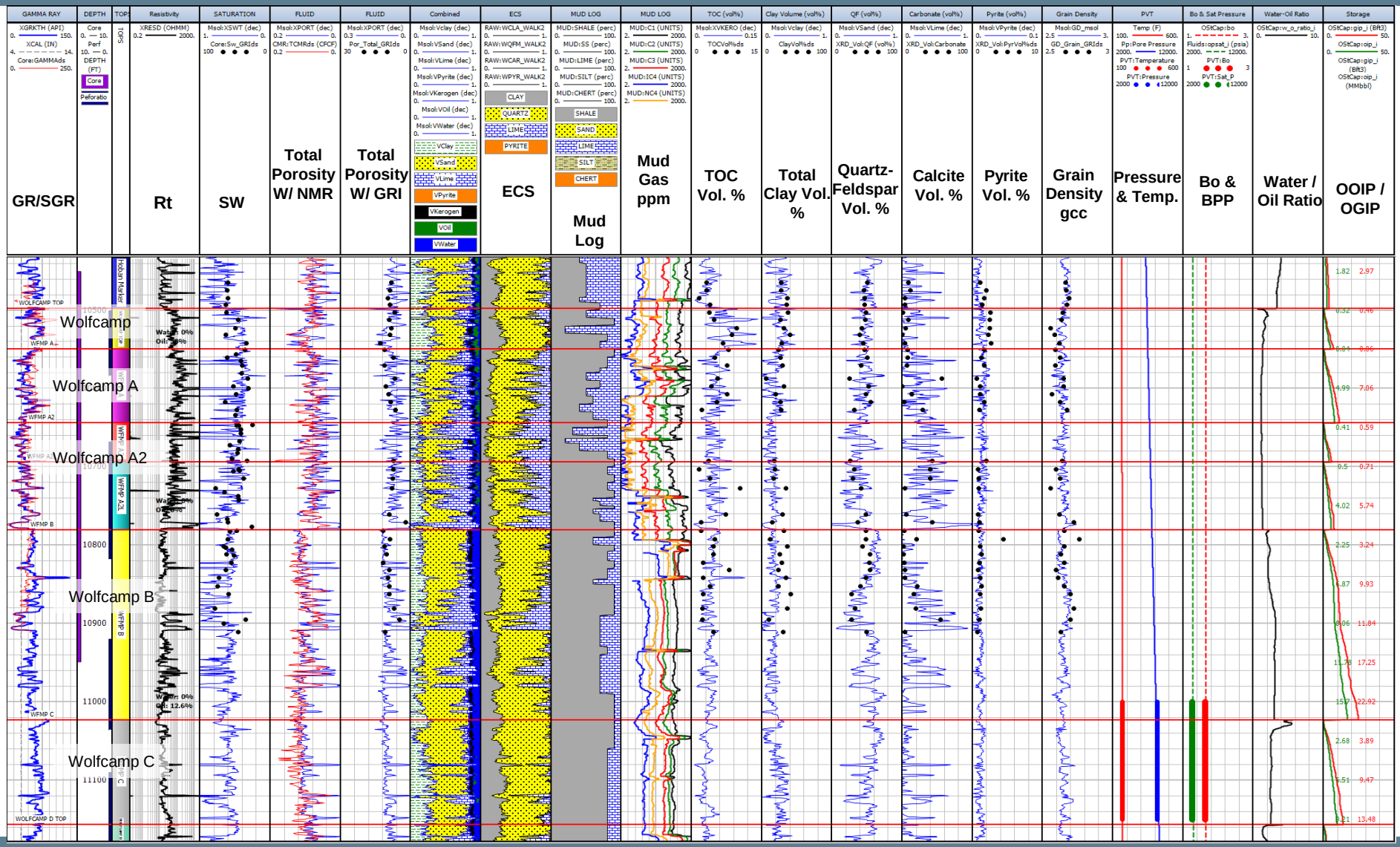
- **Rock Properties - Composition**
- **Organic content, type and maturity**
- **Storage properties**
- **Fluid Distributions & Properties**
- **Pore Pressure Profiles**
- **Elastic properties / Geomechanics**
- **Pore body (and pore throat) connection**
- **Flow properties**

Primary Impact - Out

- **Improved bench appraisal and ranking**
- **Improved HIP (more consistent RE)**
- **Hydrocarbon fractionation (mobile vs. residual oil)**
- **Water source determination (intra vs. inter – formational)**

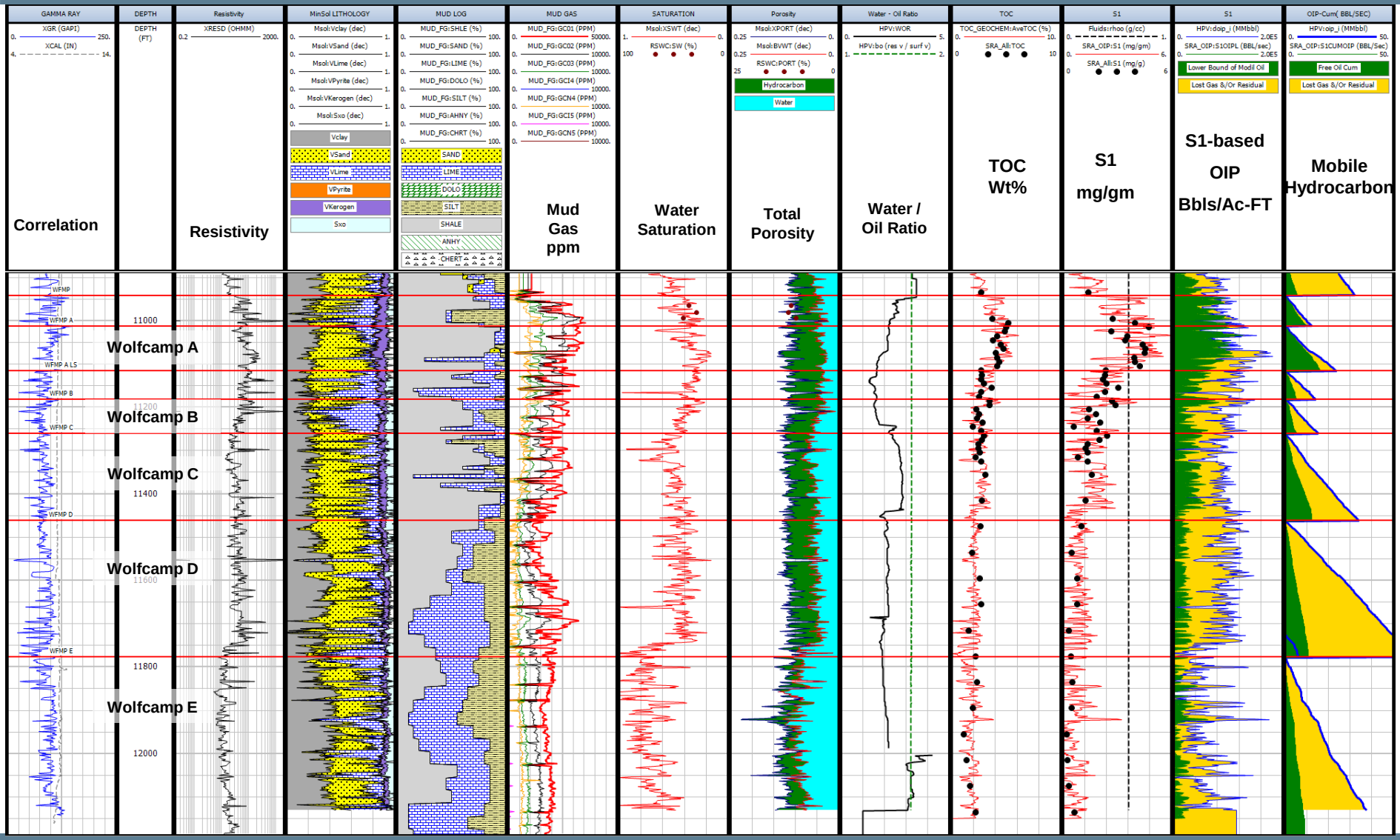
There is a strong inter-discipline linkage as there are numerous reservoir parameters that are gathered, calculated & shared for overall decisions on on capital commitment.

UCR Petrophysics – Putting it All Together: Core, Cuttings, NMR, ECS, Fluid Properties, Pressure etc. to predict OOIP/OGIP



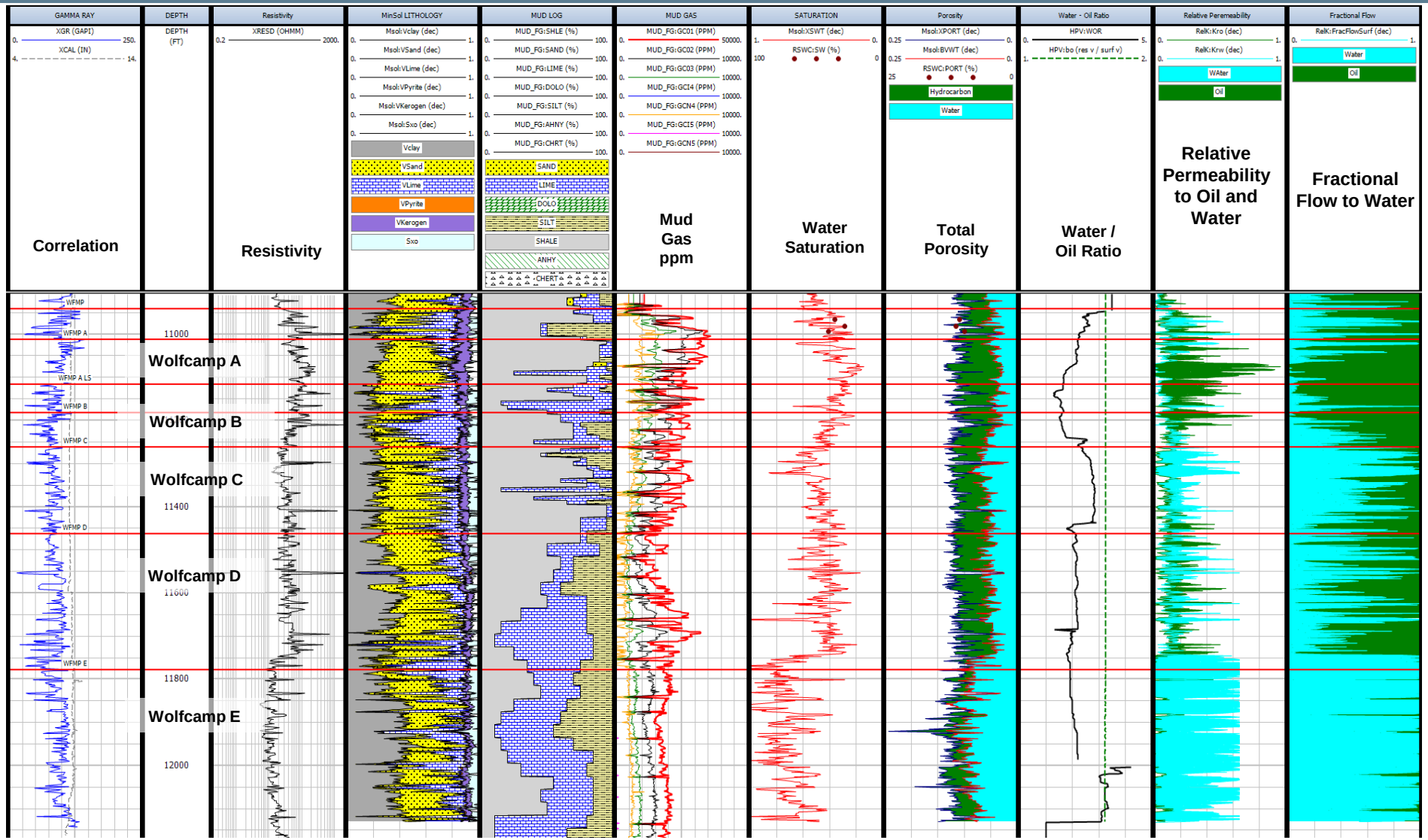
Black dots are cuttings or core measurements that show proper calibration with the petrophysical analysis. Fluid calibration shown by the Pressure, Temperature, Bo & Bubble Pt. (PVT) help to calculate OOIP / OGIP per bench

UCR Petrophysics – Fractionation of Bulk Hydrocarbon to Determine Oil Mobility & Bench Contribution



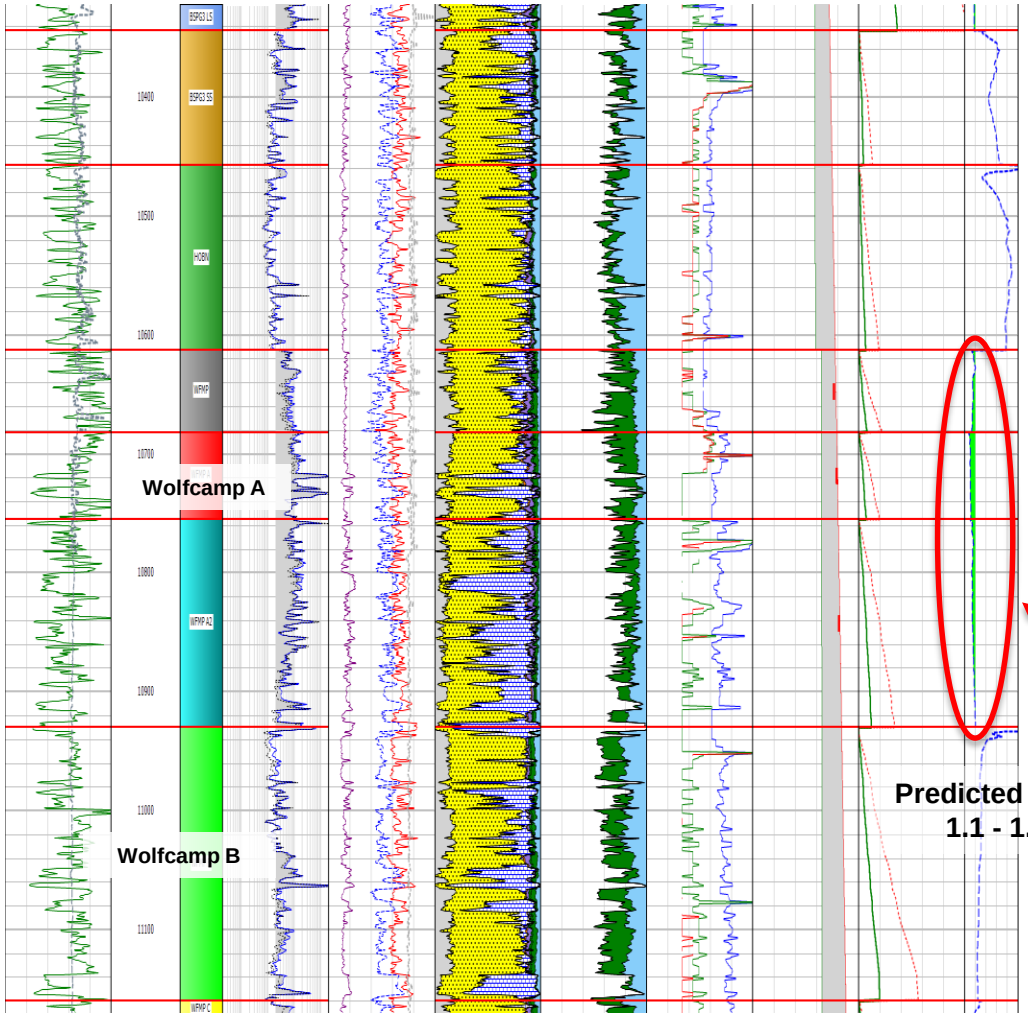
Fractionation of Bulk Hydrocarbon via Downey Method determining OOIP from Pyrolysis (S1) Data (Search and Discovery Article #40764, 2011)

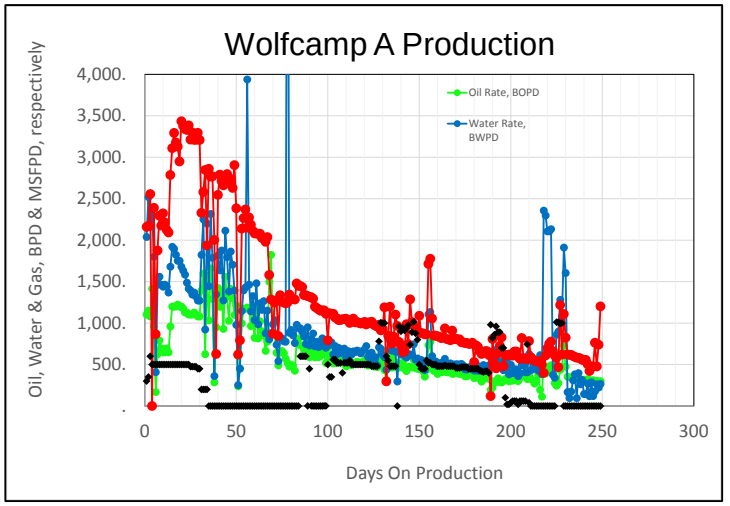
UNC Petrophysics – Determine Relative Permeability & Fractional Flow to Wolfcamp Benches

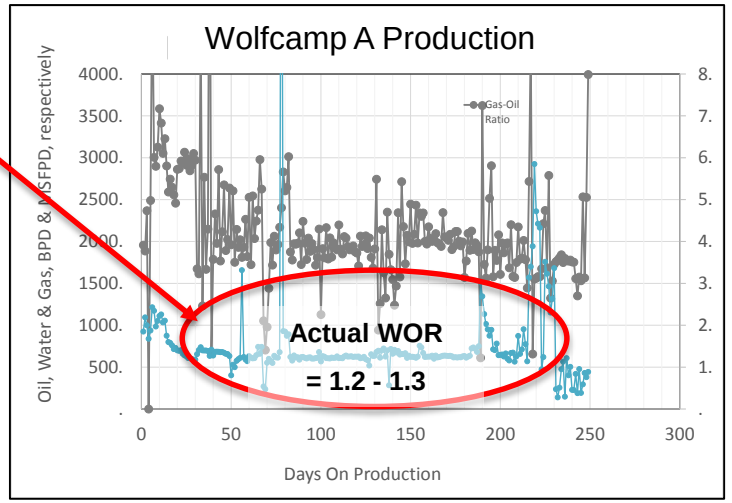


Corey Method (cap press & Rel perms)history match at reservoir conditions to help determine source of water production which is difficult to measure in mudstones

UNC Petrophysics – Calculated WOR Matches Produced Wolfcamp Fluid Production

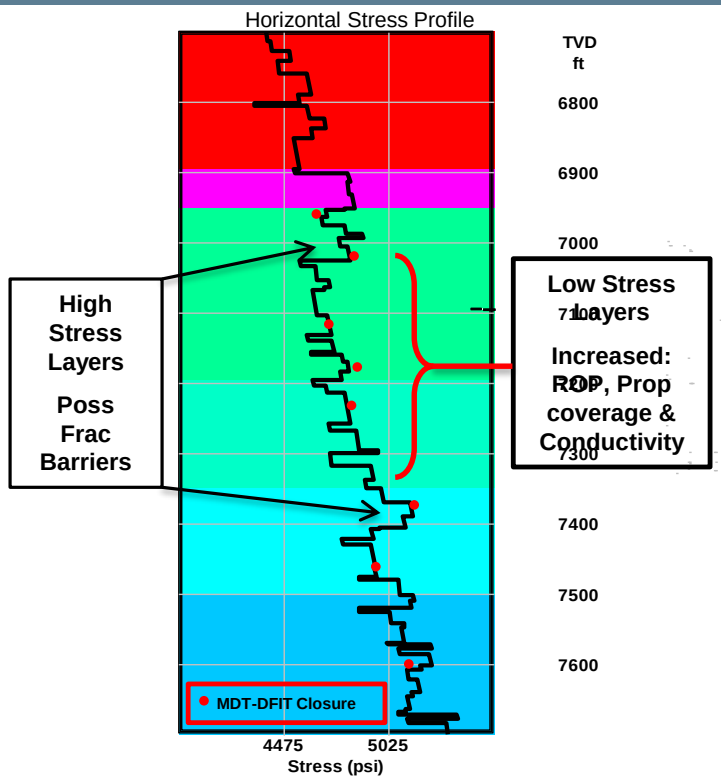


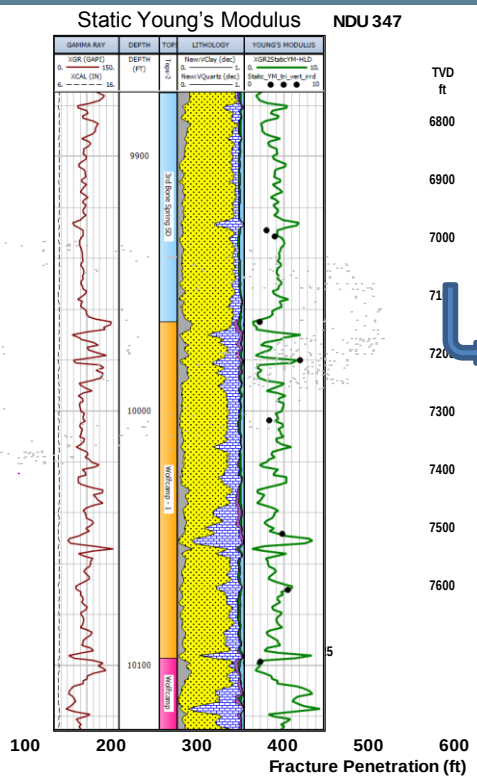


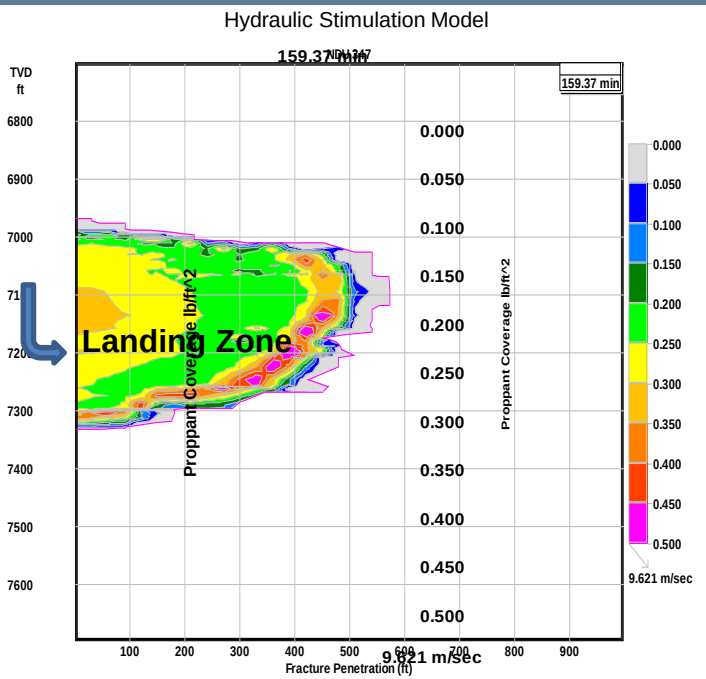


Actual Wolfcamp A water production is close to predicted from Corey Method is another cross check to calculated storage properties from the Petrophysical Analyses

UNC Petrophysics - Input to run Advanced Hydraulic Fracturing Model







Stress Profile Inputs:

- Dipole Sonic Logs
- Overburden
- Pore Pressure
- Strain (Poisson's Ratio)
- Poroelastic & anisotropy effects

Static Young's Modulus Input:

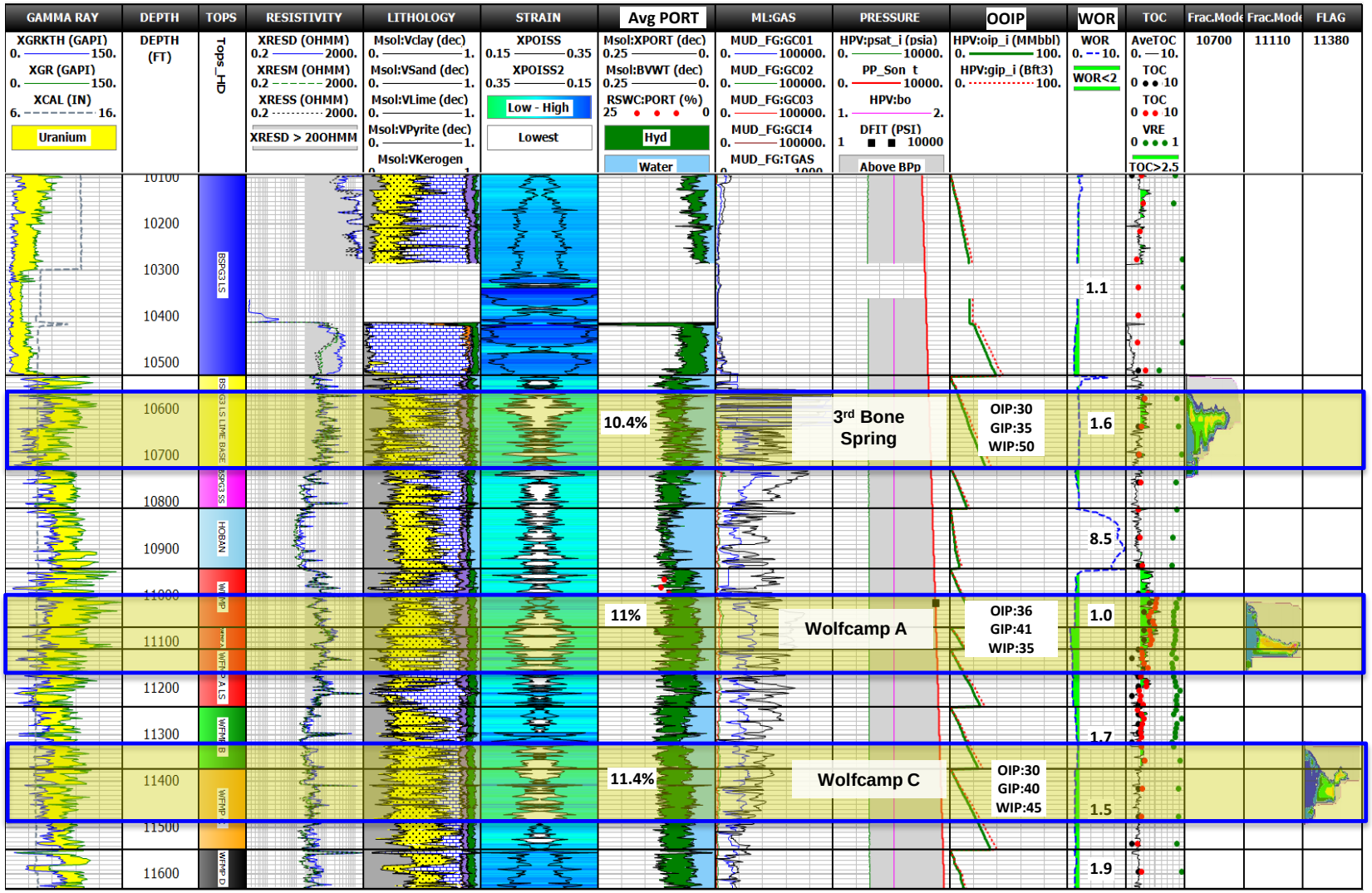
- Dipole Sonic Logs
- Impact hammer hardness
- Triaxial compression tests

Model Outputs:

- Hydraulic frac geometry (half frac length and stimulated height) for well spacing and production history modeling
- Proppant coverage and concentration
- Fracture conductivity

By calibrating closure stress (DFIT's, MDT 's) & static Young's Modulus (Geomechanics) results in frac model improvements to height, half length, conductivity and proppant placement.

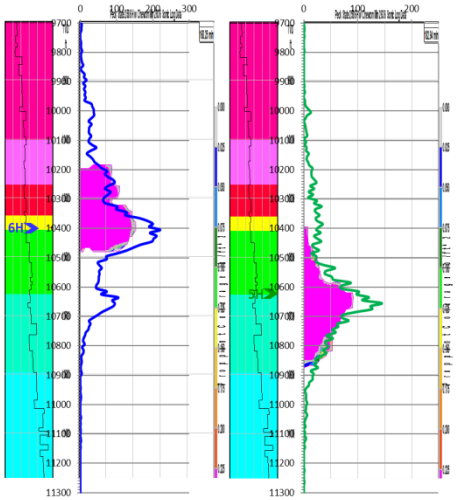
UNC Petrophysics & Frac Modeling for Bench Selection and Ranking



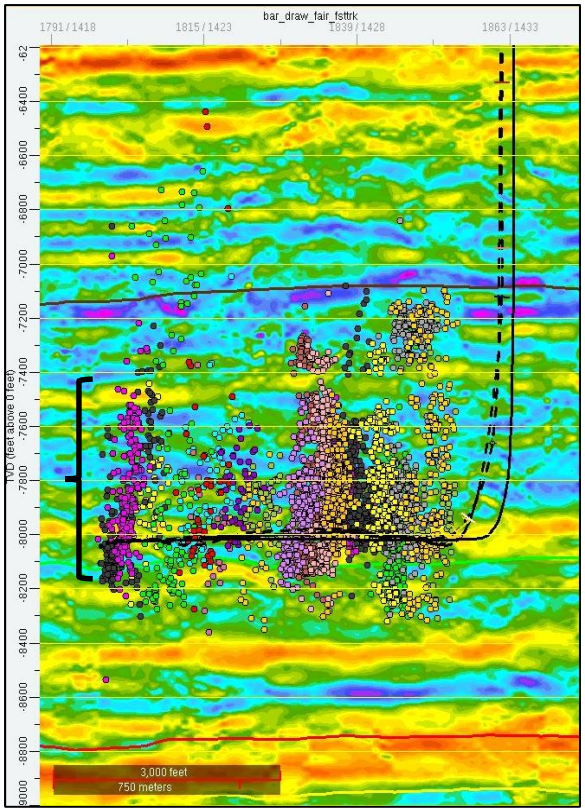
Bench ranking based on combined Petrophysics , Frac model geometry, OOIP calculations, Reservoir parameters etc, we can reasonably rank benches

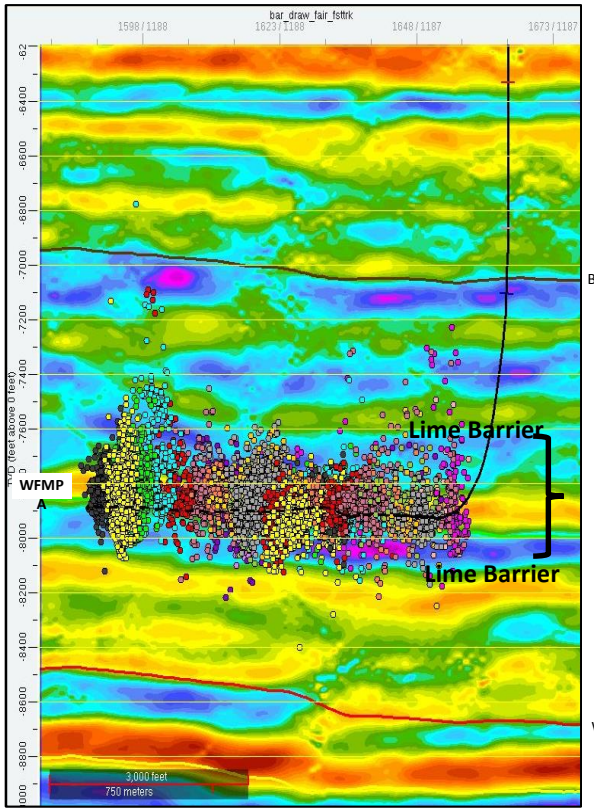
Seismic Inversion Derived Lithology & its Influence along Hz wellbore trajectory

Calibrate Stimplan Model to microseismic events



Less Constrained Frac Height (~600') w/ poss. natural fracture influence





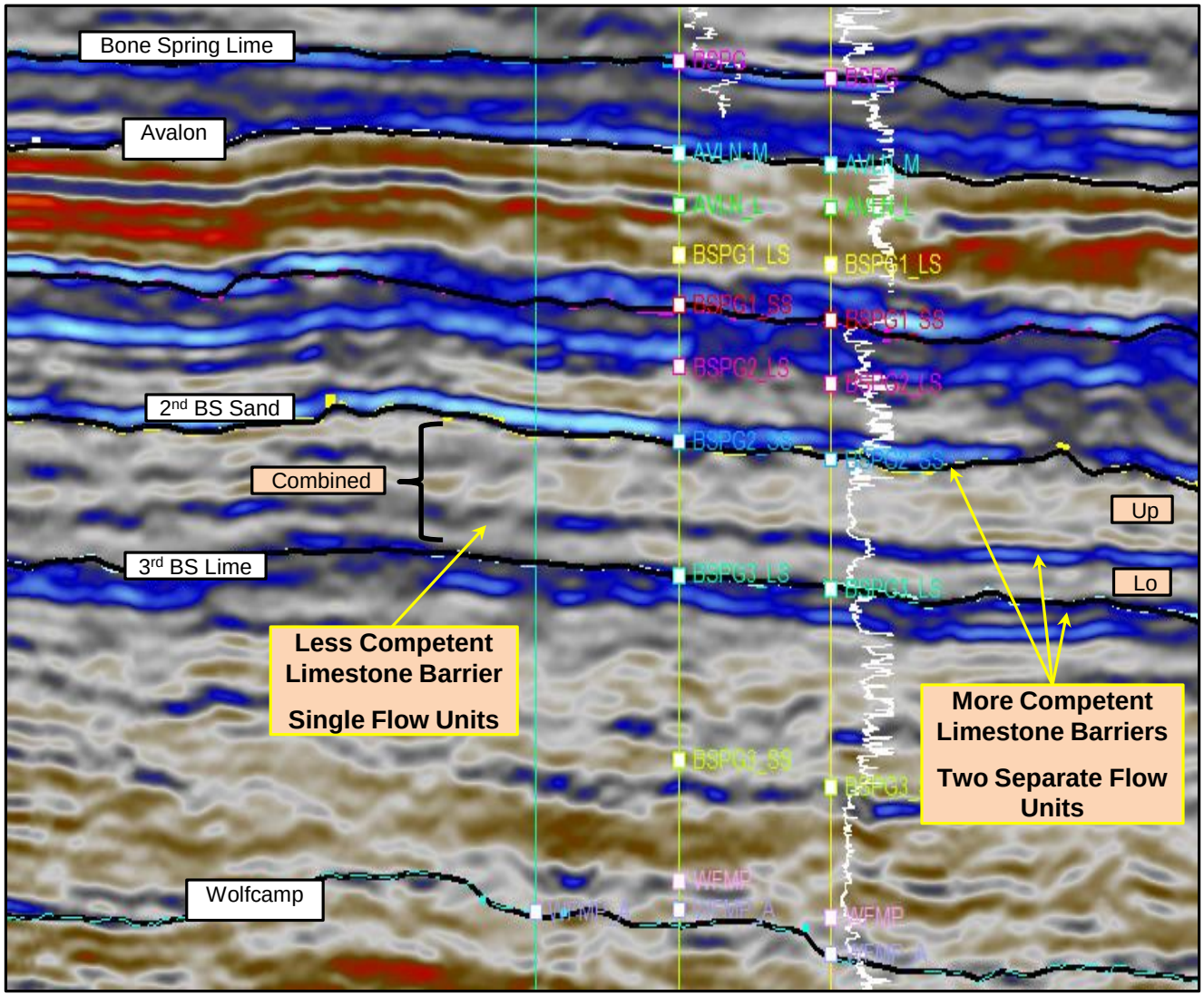
High Stress Layers More Constrained Frac Height (~350')

High AI

Low AI

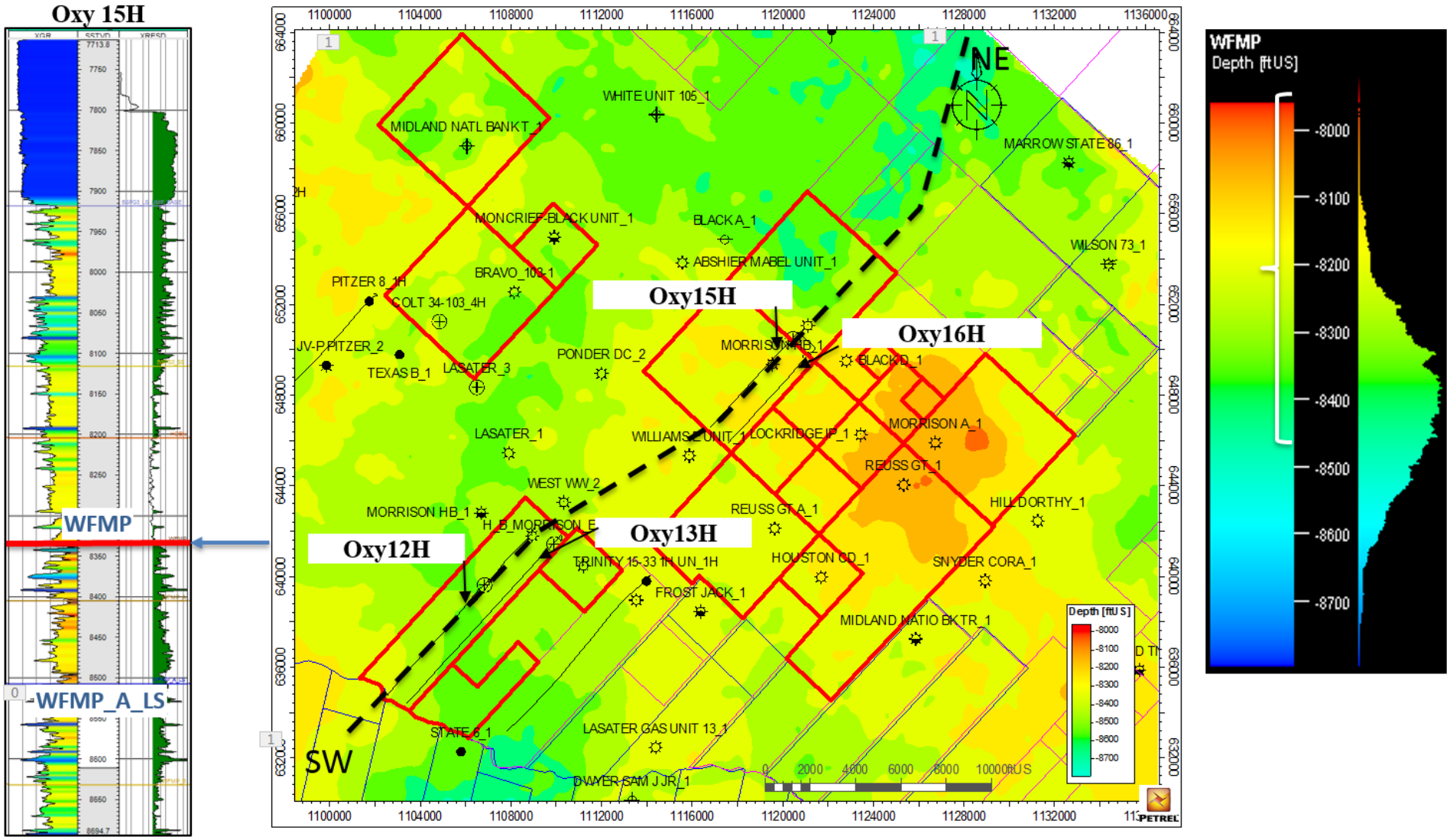
AI Inversion derived Lithology, with microseismic and well path. Lithology understanding & possible natural fractures may influence frac height growth, SRV and total fluid production

Seismic Inversion for Reservoir Mapping and Field Development Planning

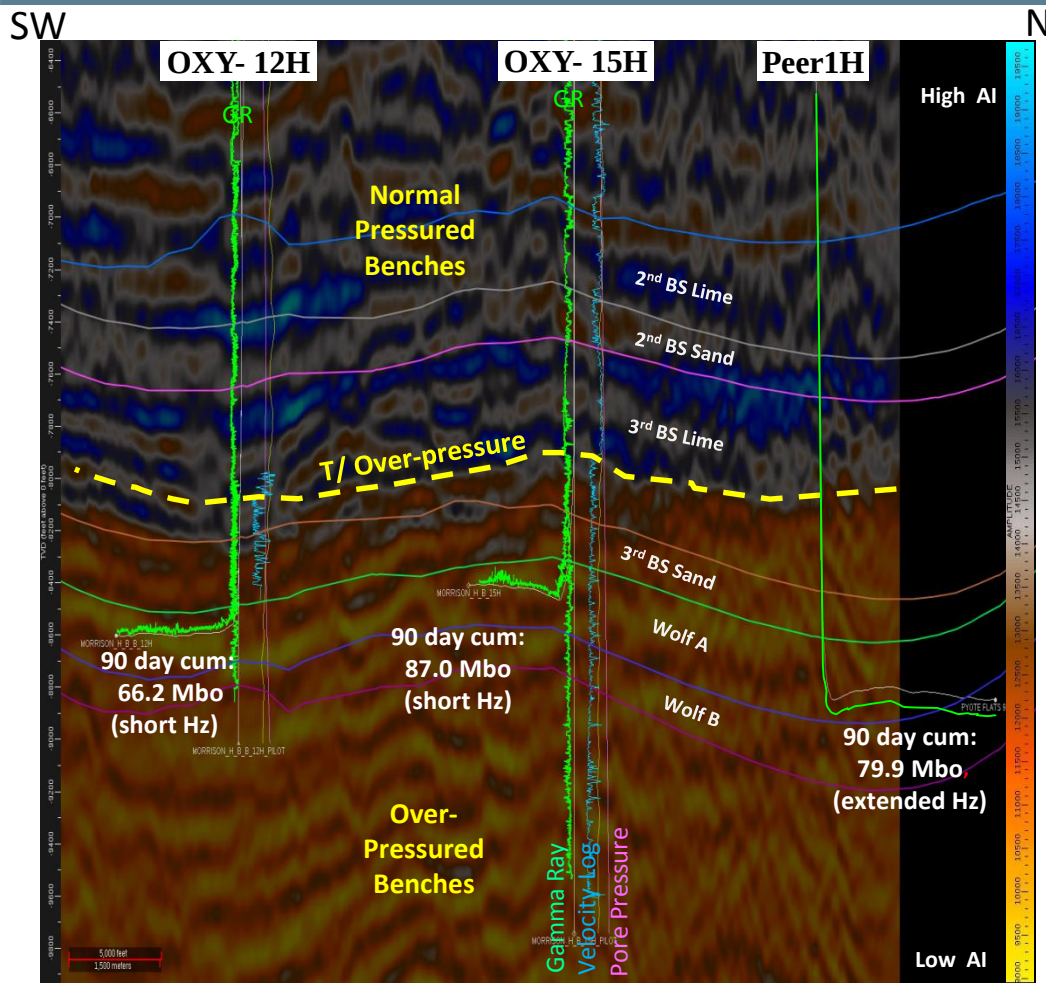


Seismic Inversion, Frac model h x w, reservoir flow unit understanding & mapping help drive FDP

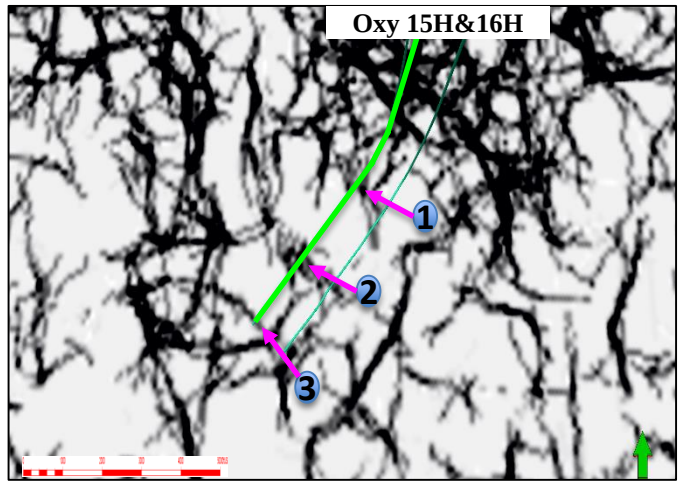
Appraisal - Wolfcamp “ A” Bench TX Delaware Basin



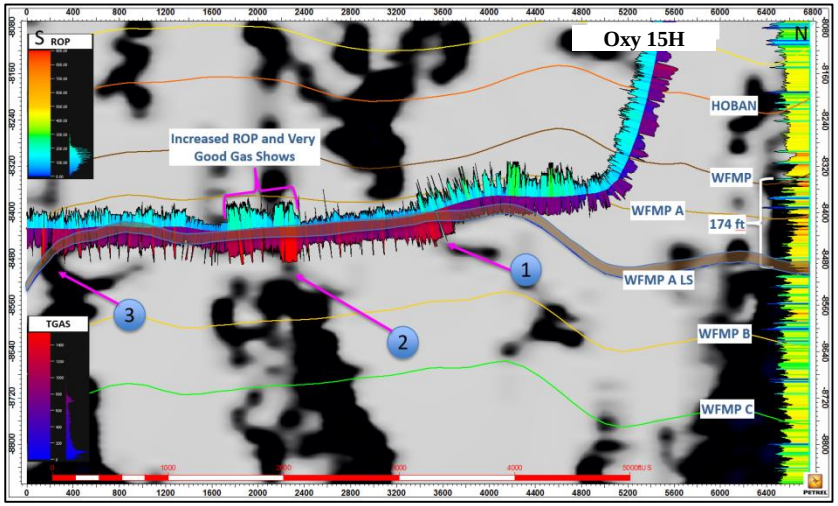
3D Seismic, Natural Fractures & Well Performance in Over-pressured Wolfcamp Bench



Seismic AI iversion illustrating bench landing & performance in over-pressured section. Pressure supported by logs, DFIT & Frac Data

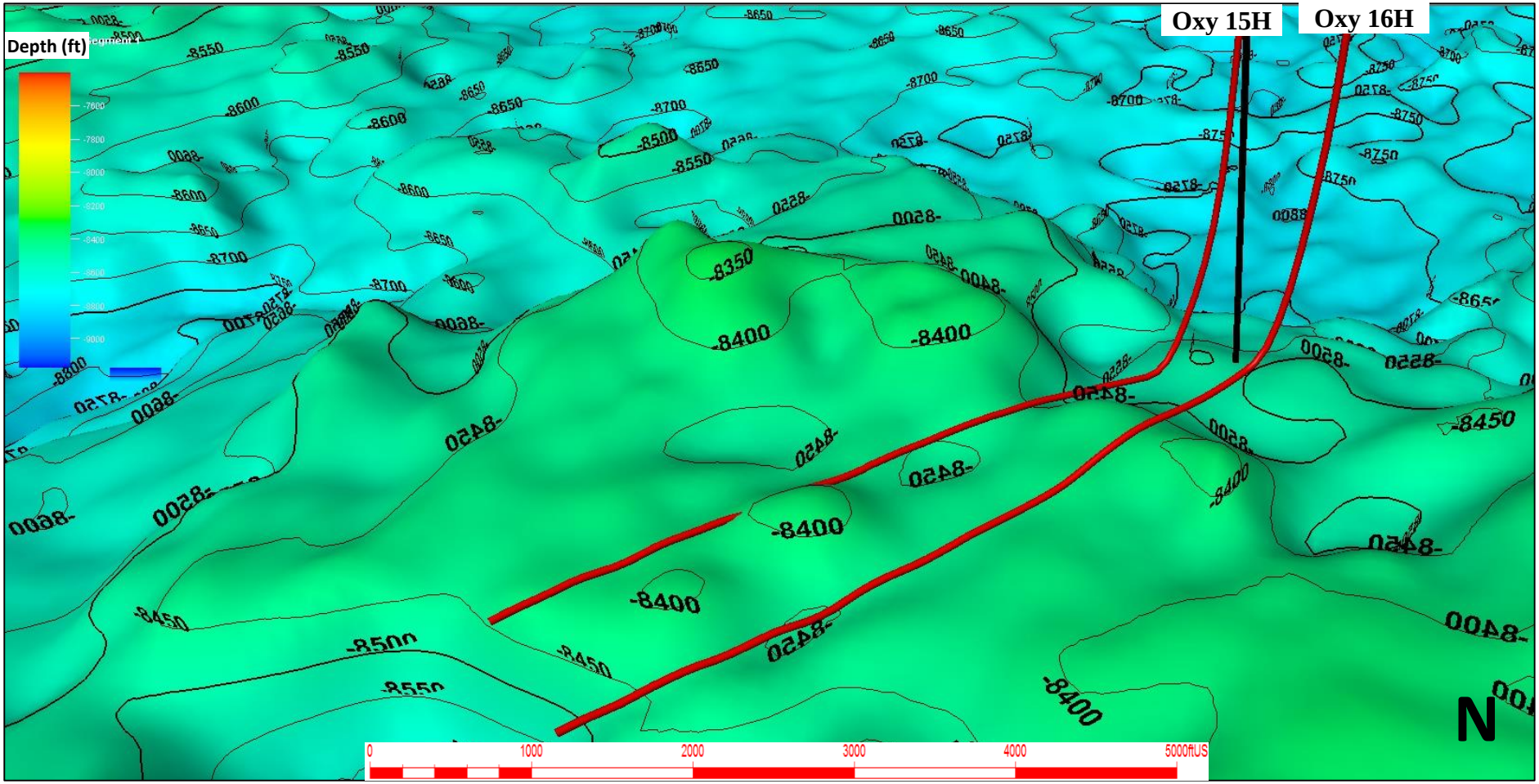


Ant-Track 3D Seismic Volume showing natural fracture network along Wolfcamp A wellbore trajectory.



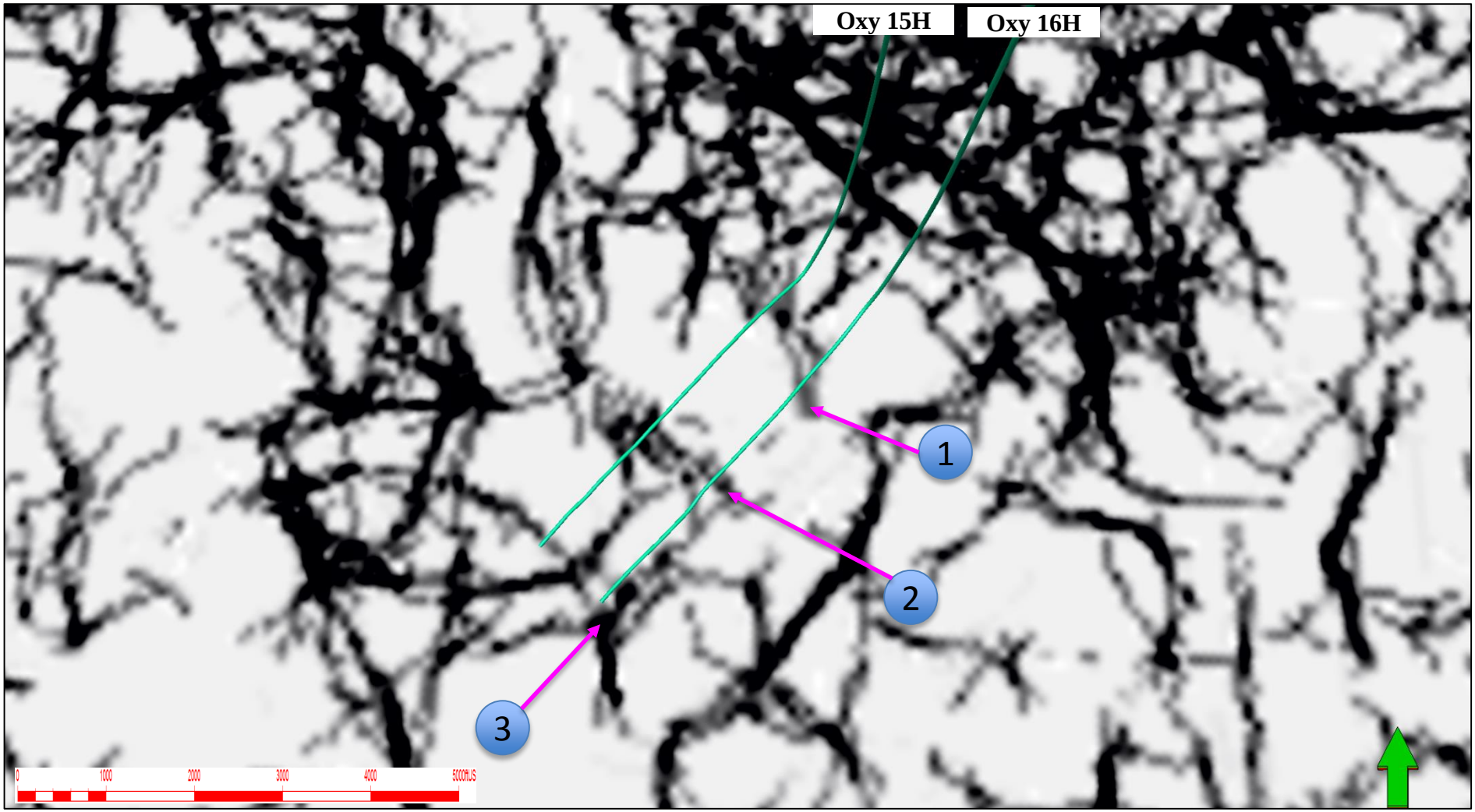
Seismic interval velocities correlates with overpressure in certain areas, the overpressuring correlates with active oil generating kitchen and reservoir energy and enhanced well productivity.

Structure Map along two Wolfcamp “A “ NE-SW Laterals



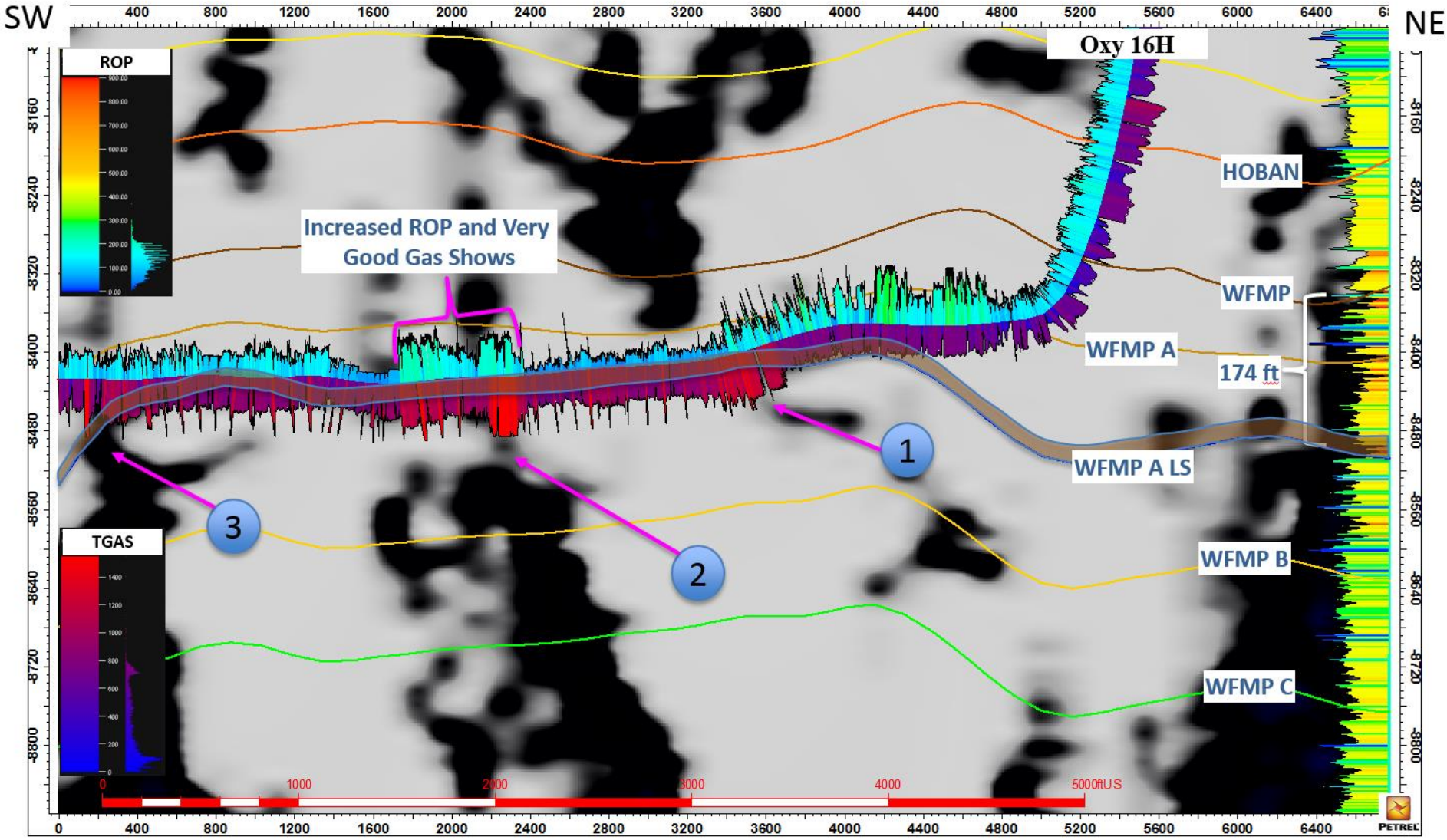
Seismic helps with mapping landing zone structural mapping to confirm lateral placement.

Seismic Ant-Tracks along Wolfcamp Wellbore Trajectory



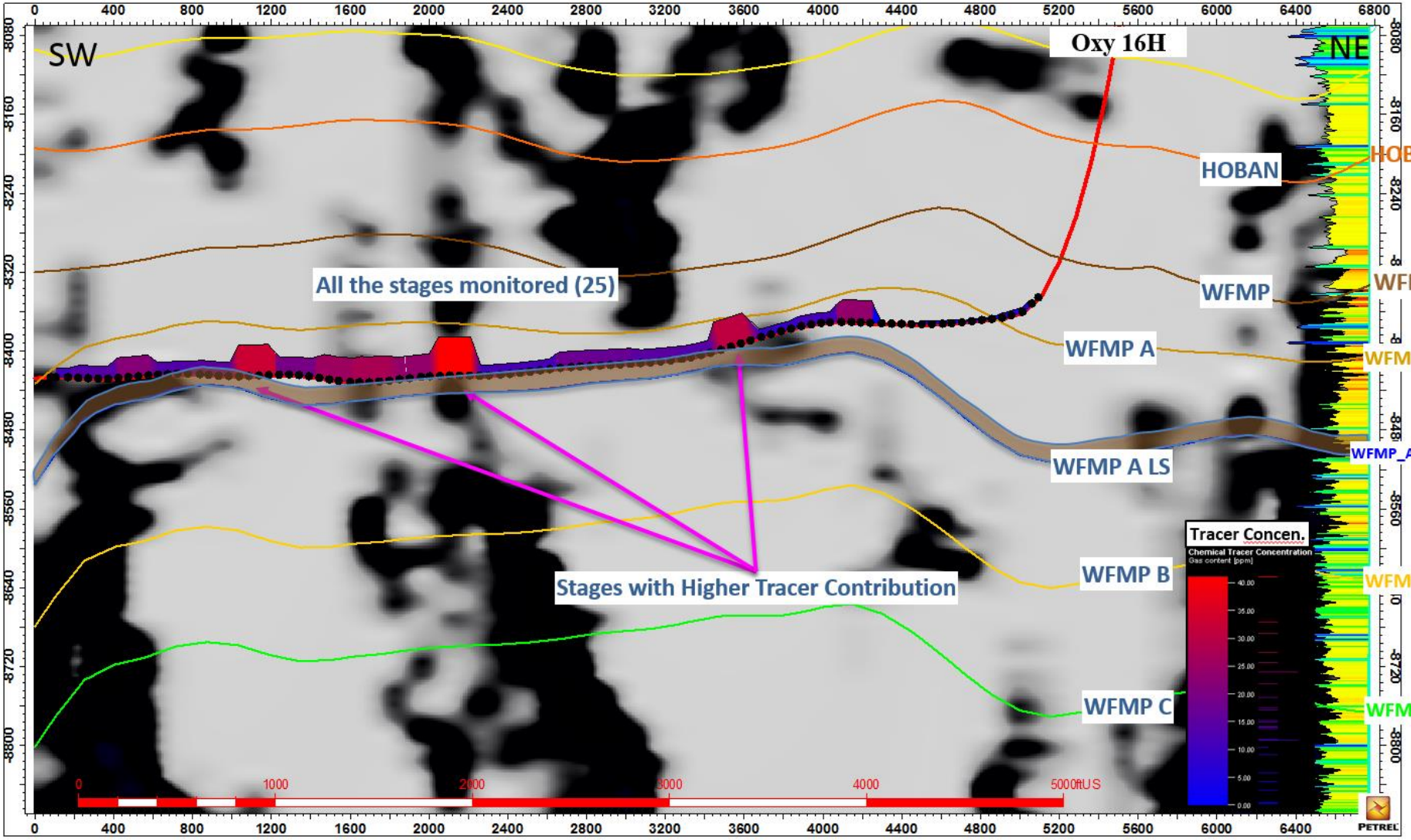
Seismic Ant-Tracks correlate with fracture zones in certain areas, the fracture zones correlate with hydrocarbon migration pathways.

Wellbore trajectory with 3D Seismic Ant-Tracks



Seismic Ant-Tracks correlate with fracture zones in certain areas, the fracture zones correlate with hydrocarbon migration pathways.

Oxy16H Well Trajectory with Ant-Tracks, Frac Stages and Tracers

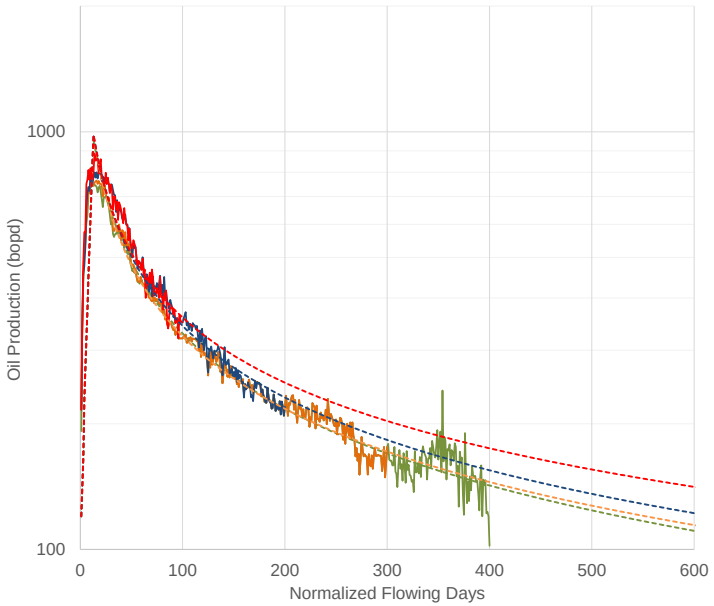


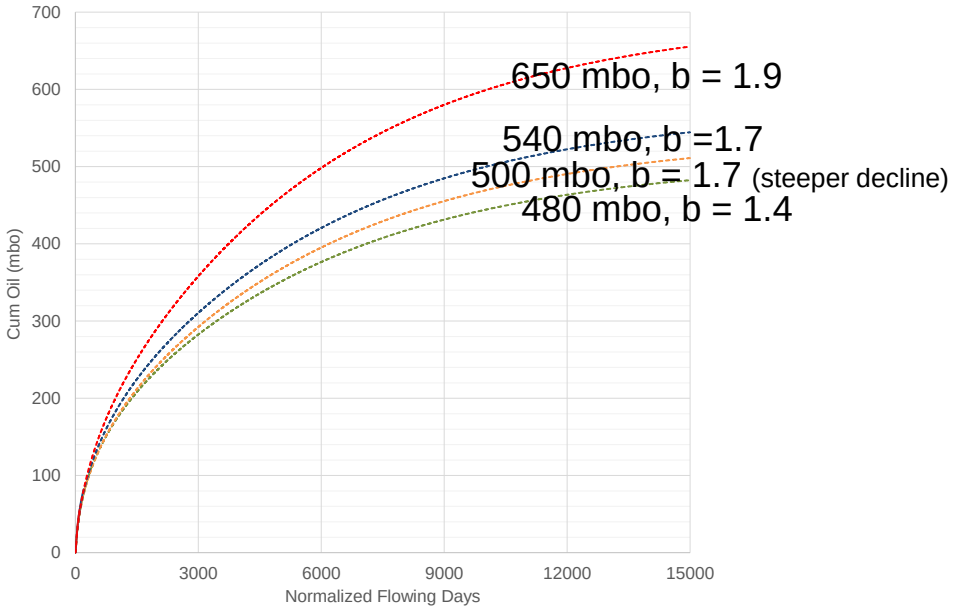
Seismic Ant-Tracks correlate with fracture zones in certain areas, the fracture zones correlate with hydrocarbon migration pathways.

EUR Through Time Using Decline Curve Analysis (DCA)

- Oldest stand alone wells fit with high B-Factor
- Production quickly fell below expectations
- Continued decline shows high b factors unrealistic
- Wells approaching minimum flowing bottom pressure
- The appropriate B-Factor can only be resolved with production time

DCA does not use physics of unconventional reservoirs, therefore, there can be low confidence in the EUR

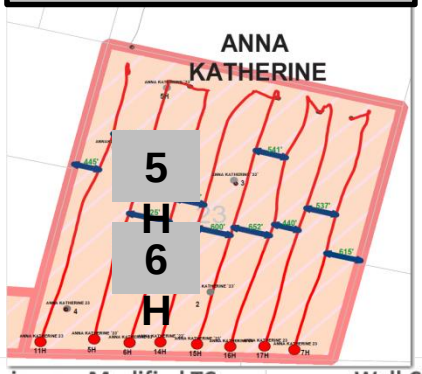




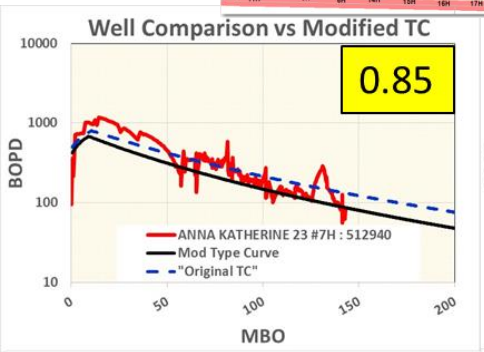
DCA is first step, advanced analyses Including RTA, PVT, Petrophysical, frac and numerical simulation models all help construct a "technical type curve" which representing the average field performance for bench development

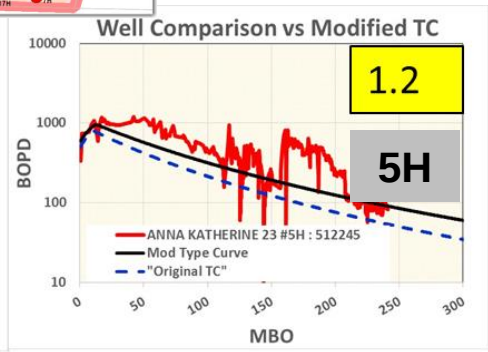
Standalone Wells vs. Infill Effects and Well Spacing

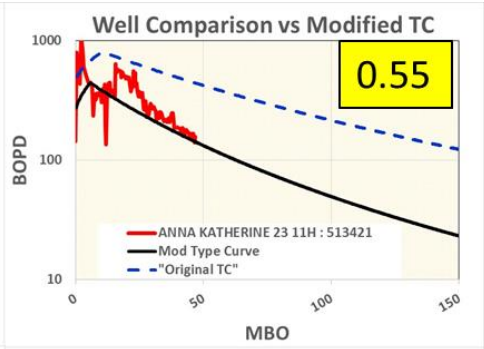
8 wells/section

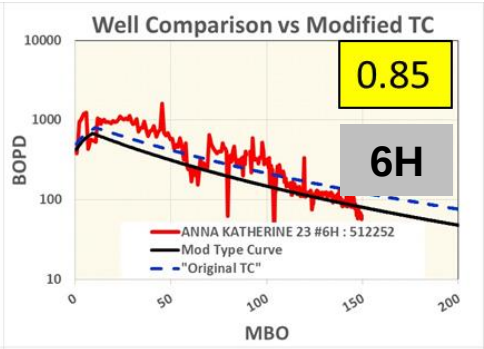


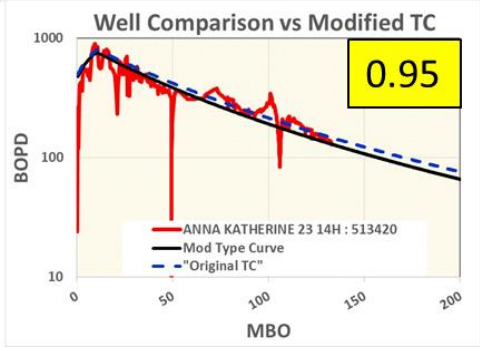
- Original Type Curve
- Actual Performance
- Modified Technical Type Curve
- Ratio of Original type curve to fit actual performance

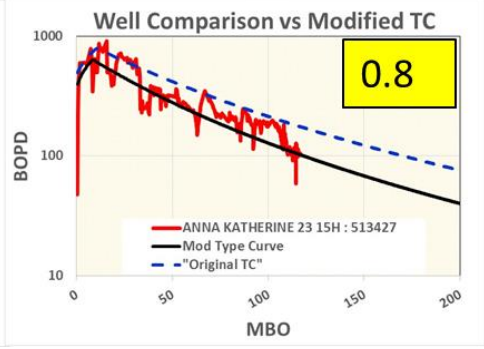


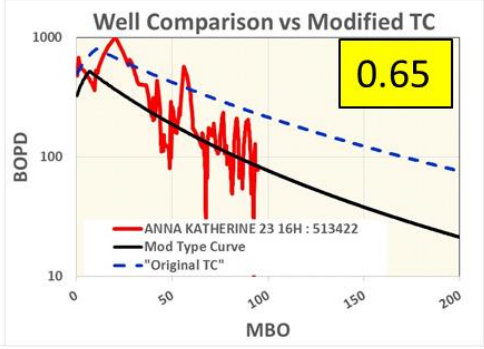


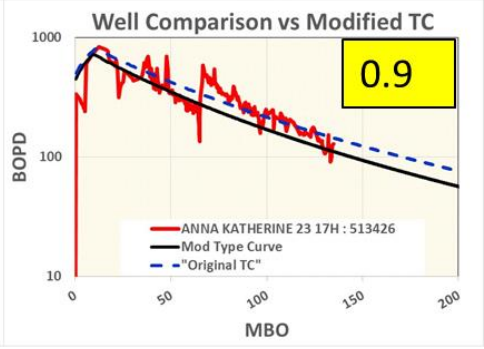






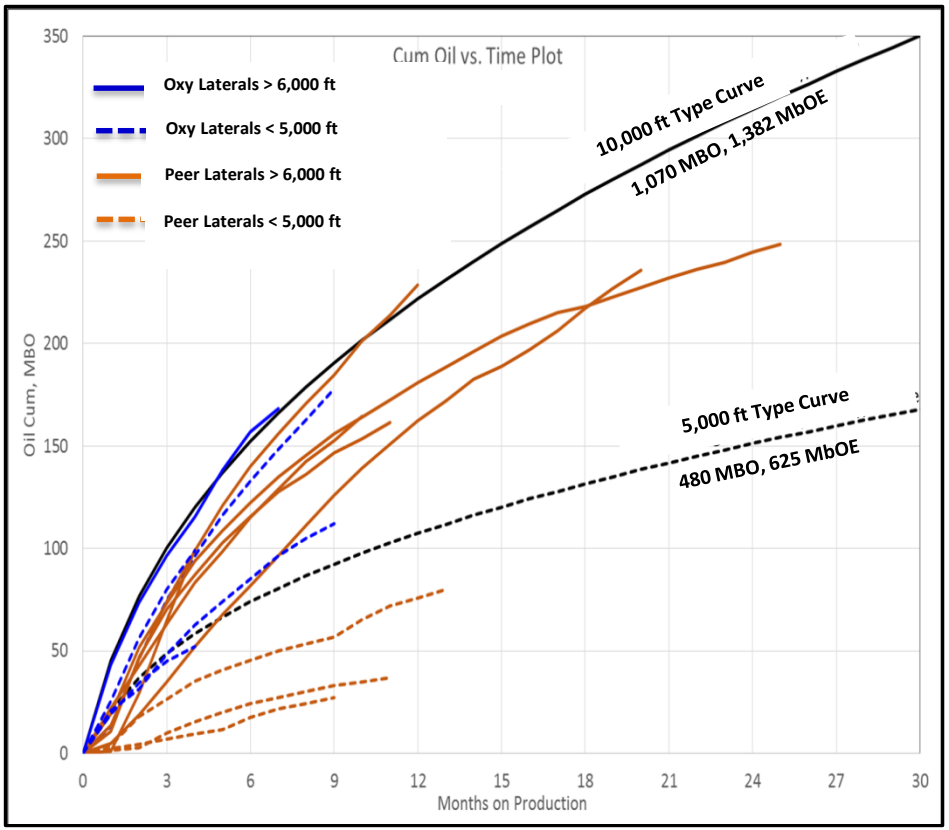


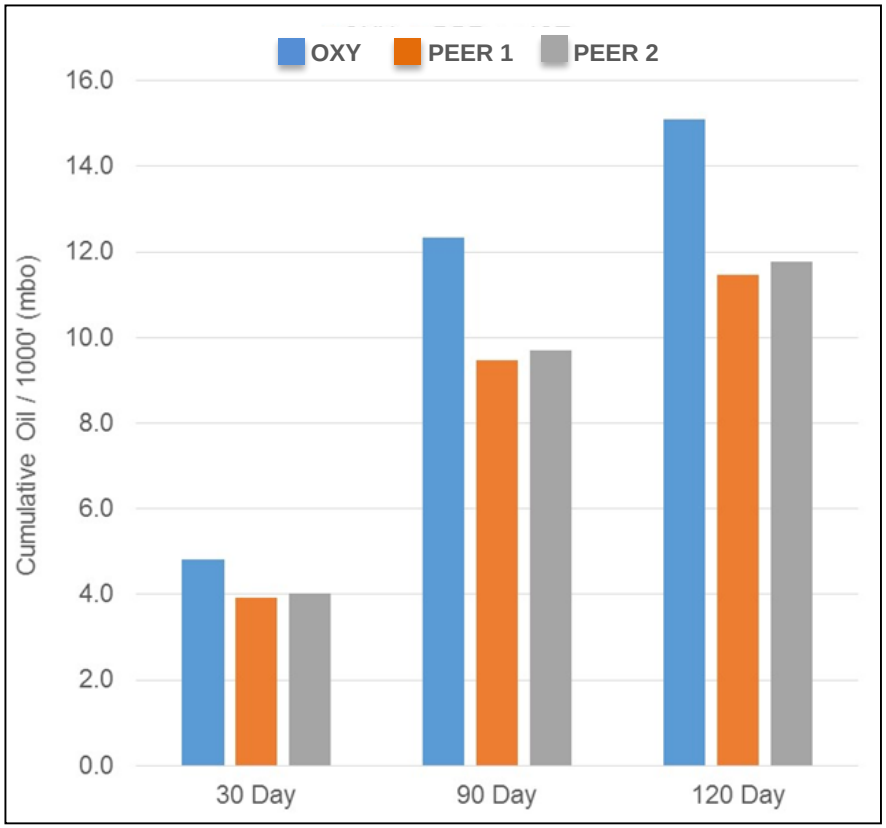




The "Technical" Type curve represents the average field performance (P50) for that particular bench, for that particular area and includes total stand alone and development wells.

Optimized Results from Oxy's Integrated Efforts

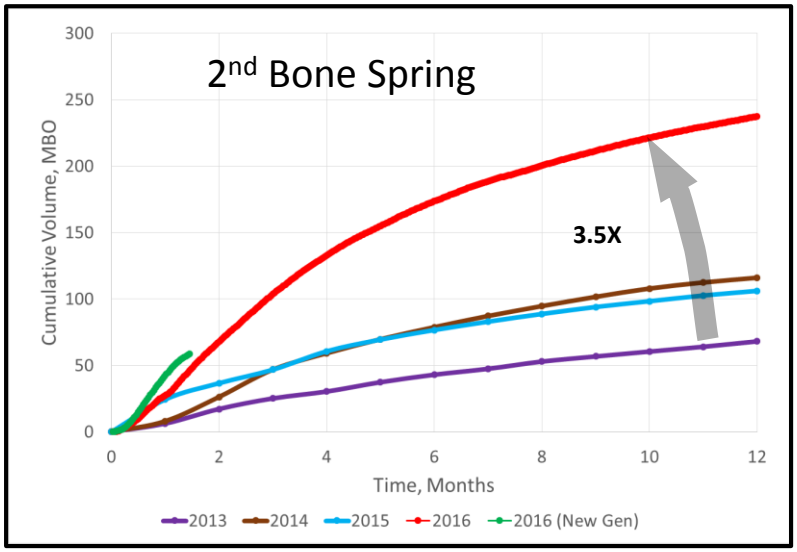


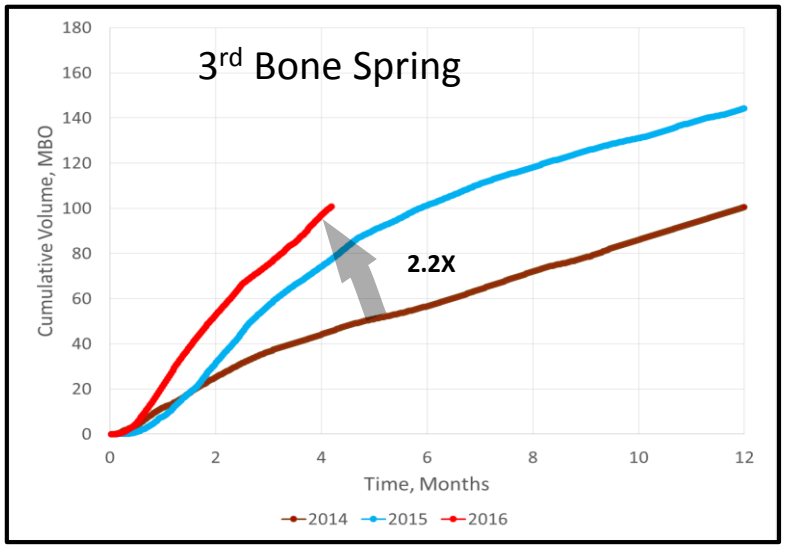


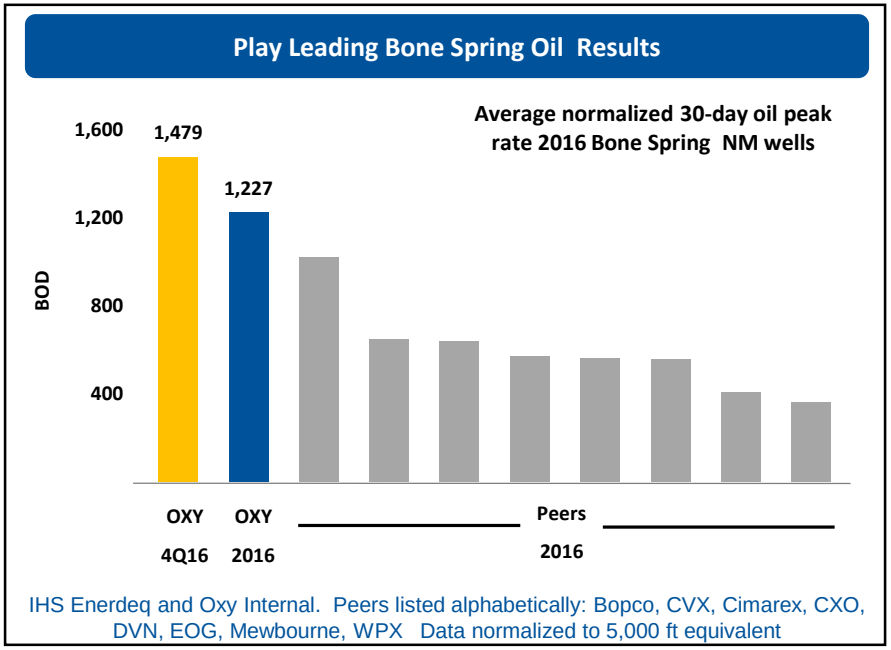
Oxy's South Delaware long and short laterals are both consistently outperforming peer wells and meeting or exceeding type curve predictions.

Multi-disciplined efforts also include Data Analytics as a predictive tool towards profitable growth

Optimized Results from Oxy's Integrated Efforts







Well performance has improved over time

- Improved landing zone
- Focusing on hi-graded acreage
- Optimized frac design
- Increased SRV
- Enhanced flowback practices

Only through dedicated integrated efforts that Oxy continues to improve well performance over time across several resource plays, particularly in New Mexico

Many thanks to the following Oxy teams:

- Reservoir Characterization
- Unconventional Petrophysics
- Appraisal & Subsurface Specialties
- Unconventional Stimulation Design
- Reservoir Engineering, Analysis & Interpretation
- Data Analytics
- Delaware Business Units

Thank You