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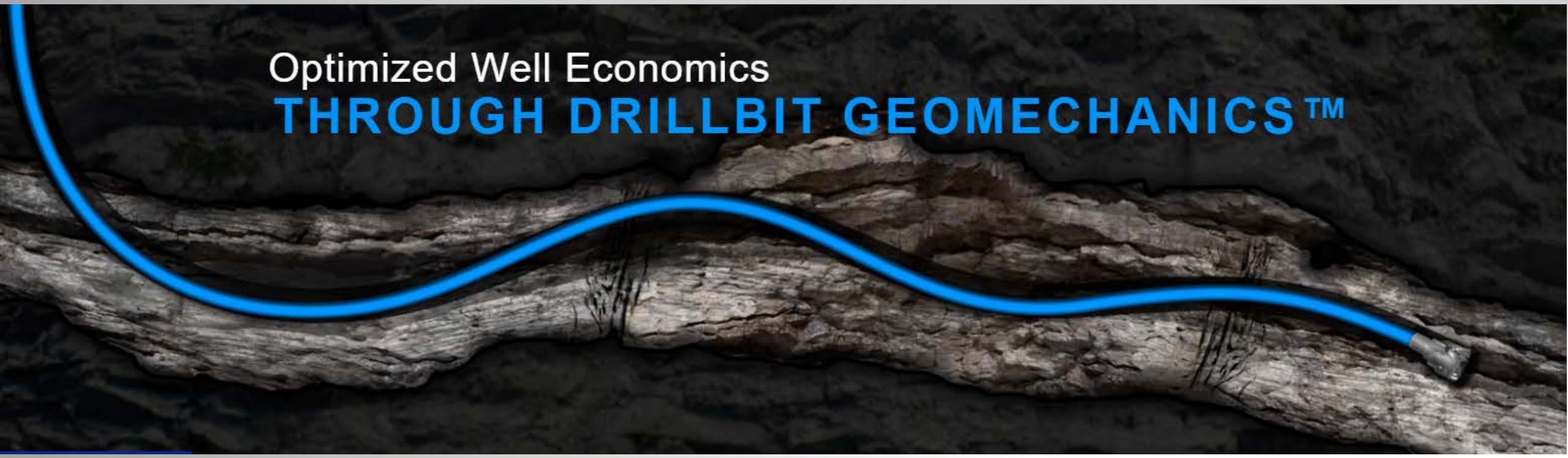
Fracture ID



Value Proposition of Drillbit Geomechanics™

Fracture ID will deliver the following

- Rock mechanical properties along the well
  - Poisson's ratio and Young's modulus
- Fracture and bedding identification along the well
- Pricing based on day rate and footage

Operators will use this to

- **Accurate, High Resolution Reservoir Characterization** –
  Development of 4D earth models to identify ideal landing zones, previously undetectable frac barriers and regional sweet spots.
- **Completions Optimization** –
  Detailed knowledge of rock properties along the well and fracture presence to guide completions design.
- **Understanding the Impact of Natural Fracture Systems** –
  For the first time, allowing detailed fracture analysis on every well. Correlation of natural fractures across formations to understand their impacts on drilling, completions and production.
- **Optimized Well Spacing** –
  Improved understanding of interaction between parent and child wells through high resolution, 3D depletion mapping.
- **Reduced Drilling Dysfunction** –
  Using the same data collected for Drillbit Geomechanics, NOV can help to reduce drilling days and unnecessary wear on downhole equipment through drilling dysfunction analysis.

Fracture ID will get this data while

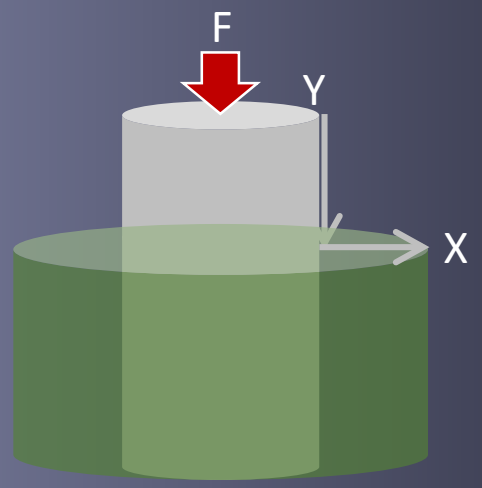
- Costing zero rig time
- Reducing open hole risk

Fracture ID Technology Review

Fracture ID Basic Methodology:

- Rock failure mechanics induced by drilling are comparable to seismically-induced failure
- Downhole accelerometers record failure events while drilling as a function of time
- Earthquake seismology models provide three component stress-strain relationships

Fracture ID solves stress-strain models for mechanical properties:



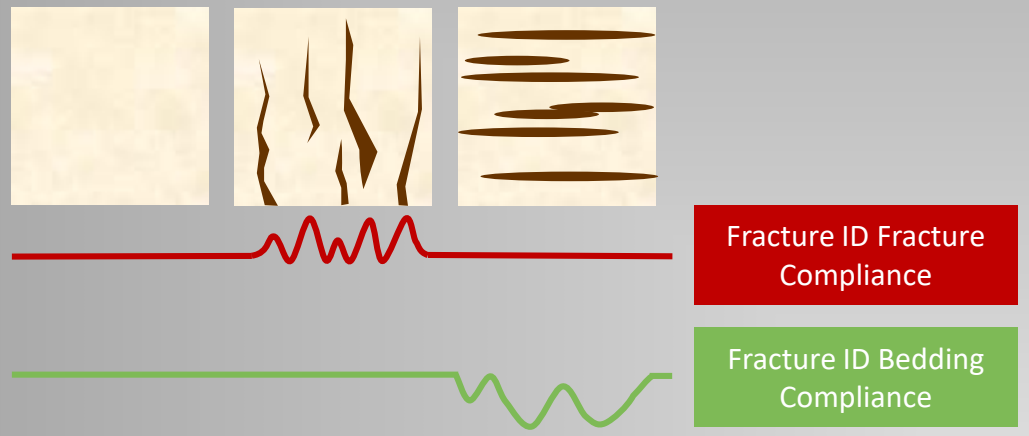
Young's Modulus (YM)
The amount of force (F) required to compress a material elastically by distance Y.

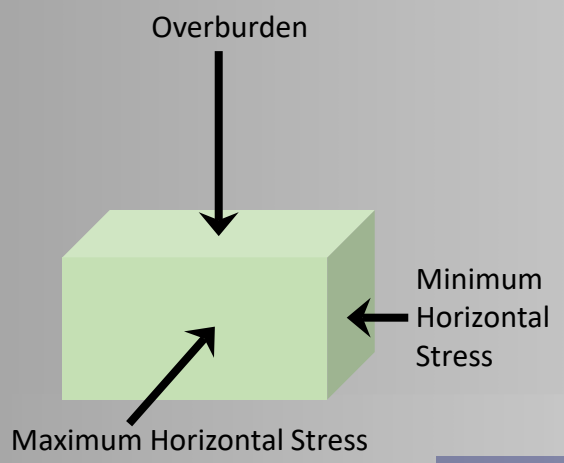
Poisson's Ratio (PR)
The amount an object increases in width (X) compared to how much shorter it gets (Y) when elastically compressed.

Assumptions & Inputs

Sedimentary rocks fit one of three models

- An isometric medium
- A vertically fractured medium
- A horizontally layered medium

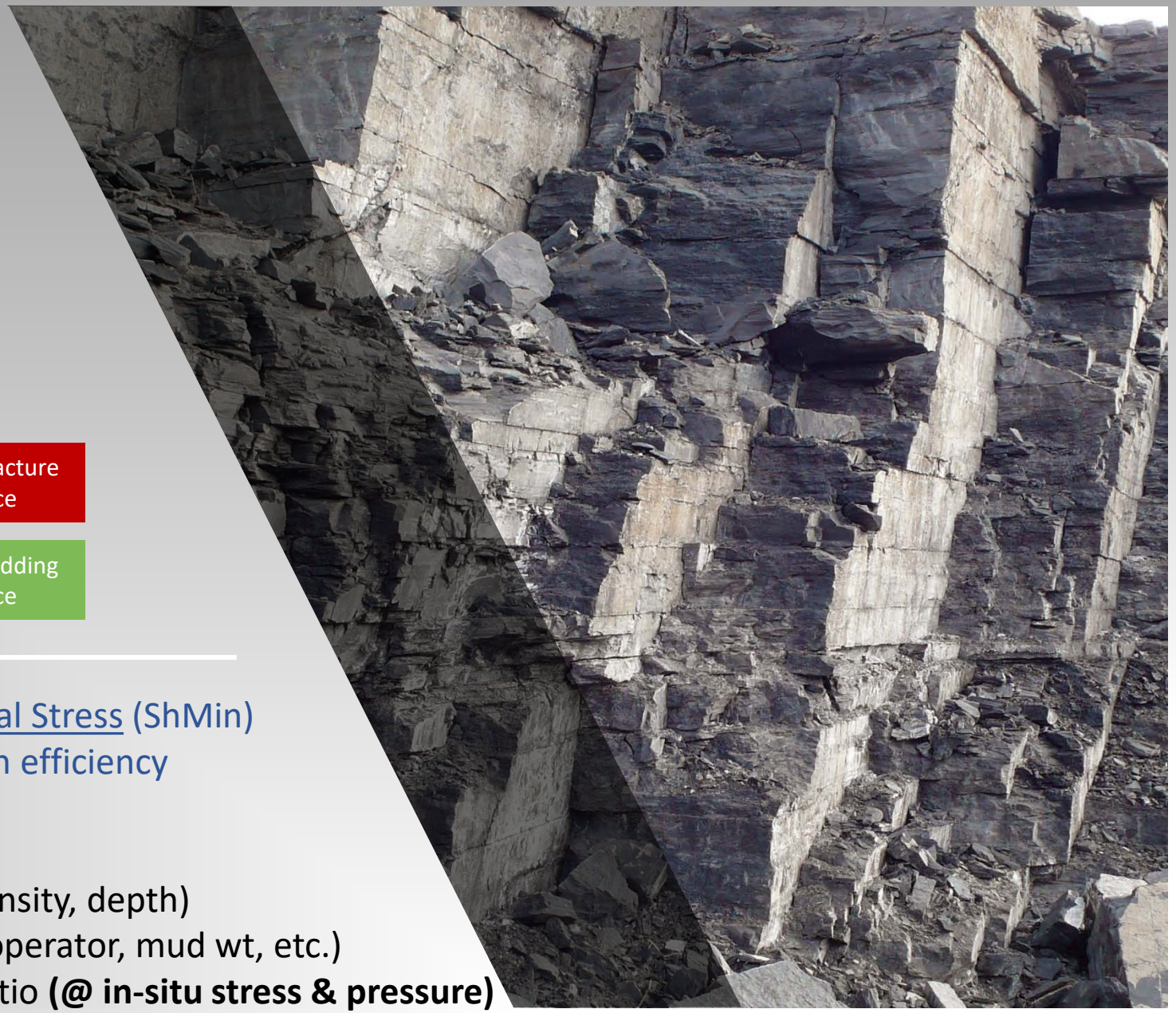




Minimum Horizontal Stress (ShMin) controls stimulation efficiency

Inputs:

- Overburden (density, depth)
- Pore pressure (operator, mud wt, etc.)
- FID Poisson's Ratio **(@ in-situ stress & pressure)**



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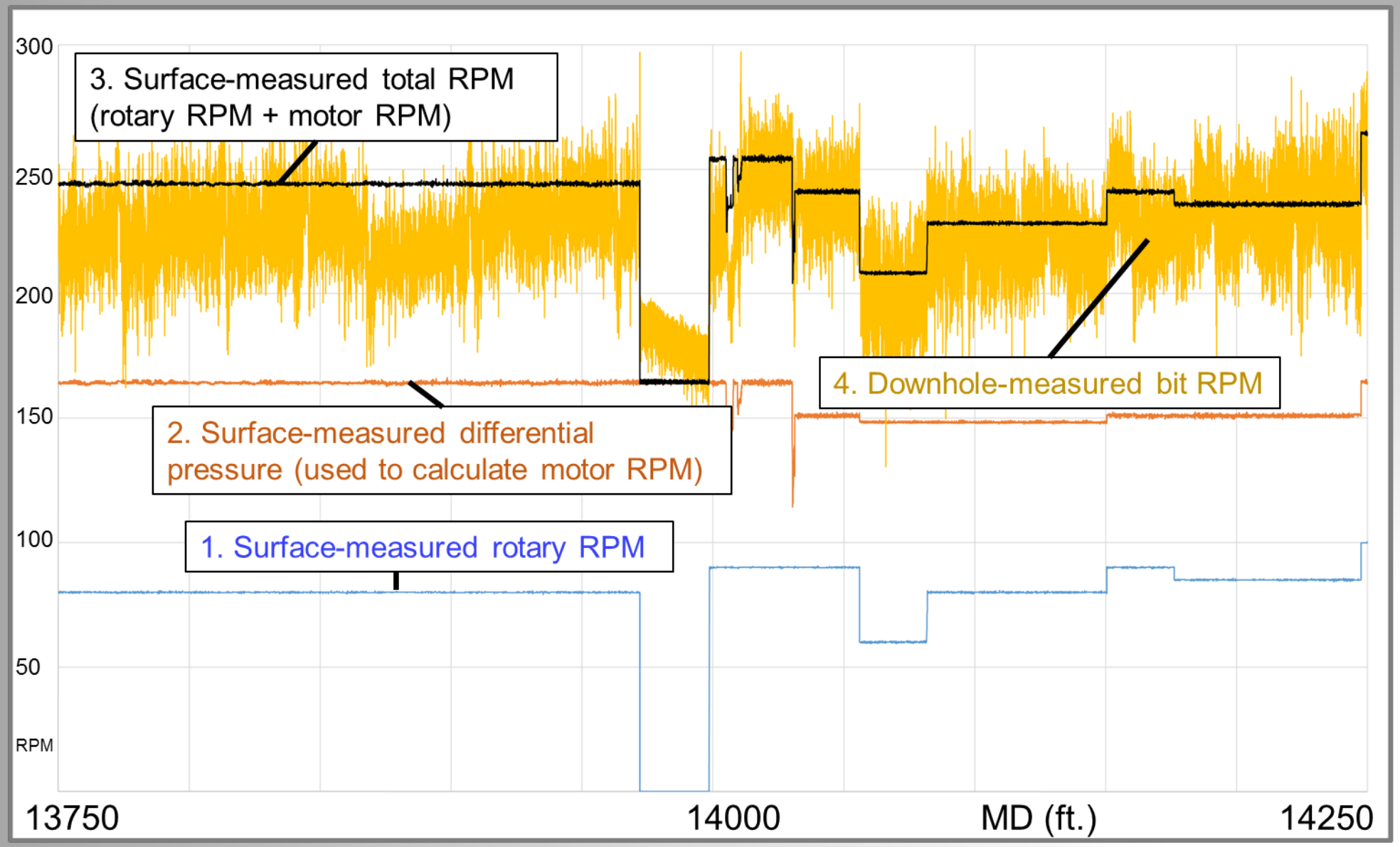
Downhole Data Must Be Used for High Resolution Results



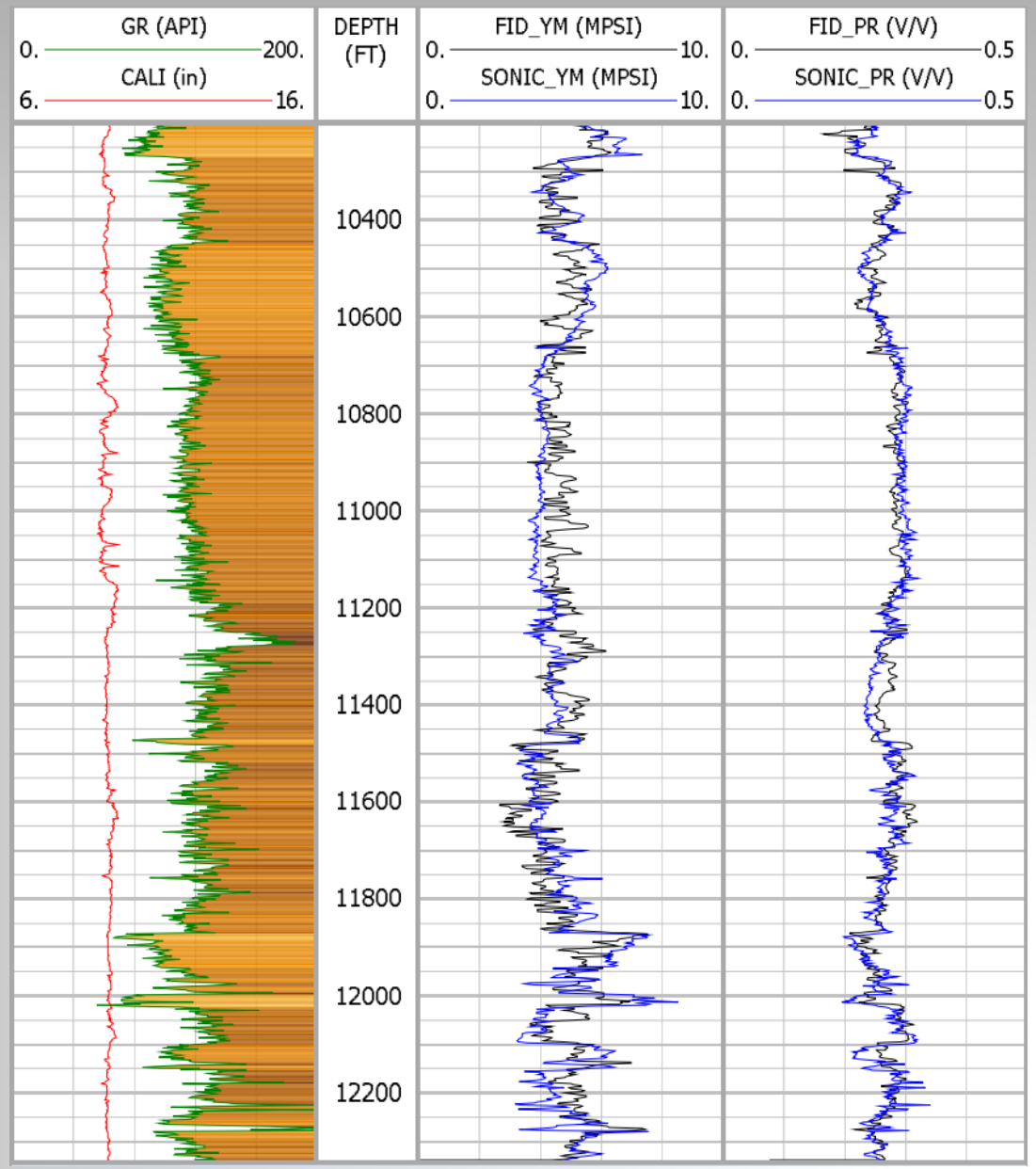
Traditionally surface-measured rotary RPM (1) and surface-measured differential pressure (2) have been combined to give an estimate of downhole total RPM (3).

True downhole RPM measurement (4) has a significantly different character to that of the traditional estimate.

Fracture ID uses at-the-bit measurements to derive rock mechanics and fracture presence rather than any measurements made at surface.

Fracture ID's Drillbit Geomechanics™ Solution: Vertical Well

To the right you can see a comparison between Fracture ID's rock properties (black) and wireline dipole (blue).



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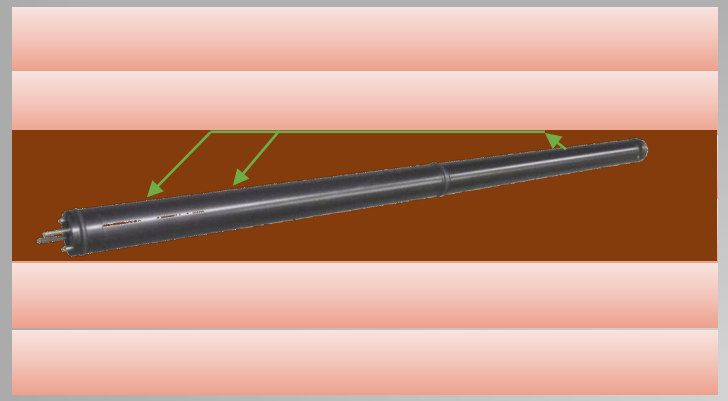
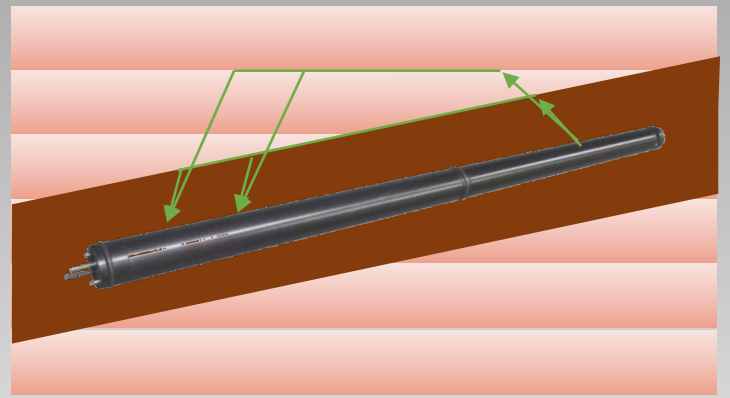
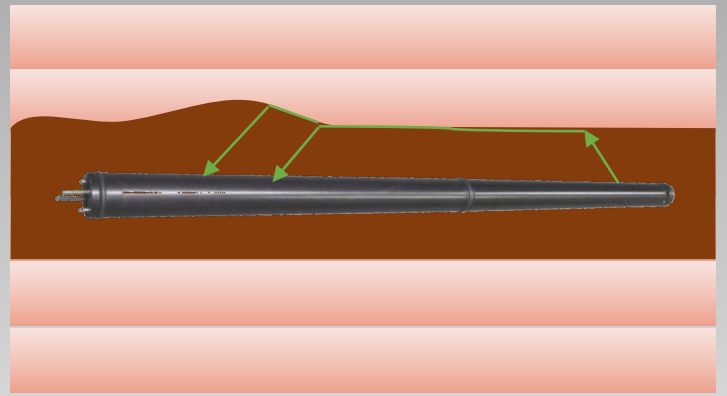
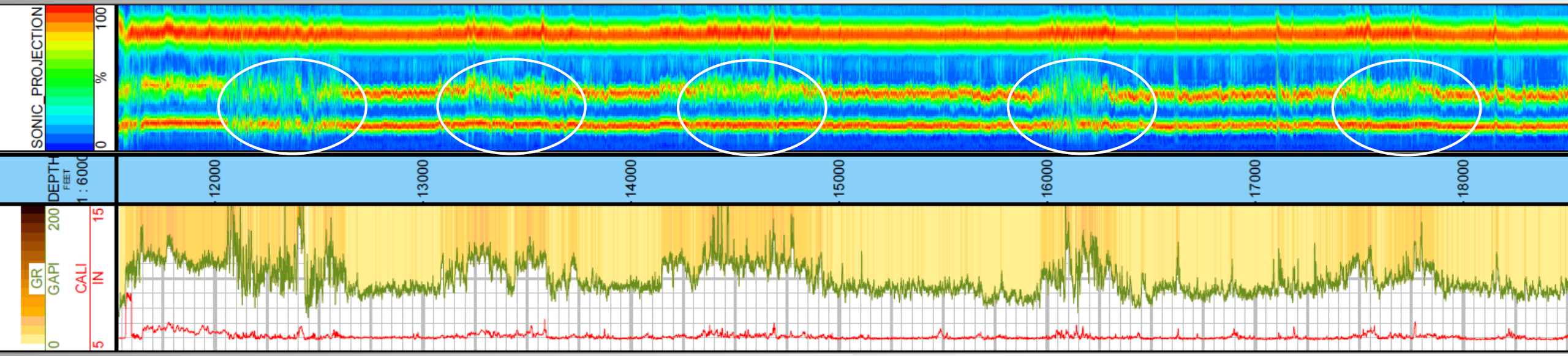
Traditional Technology







Traditionally sonic tools were deployed to collect data in vertical wells, while in recent years they have been deployed more and more in horizontal wells. Often they do run correctly, but in the horizontal environment they are susceptible to tool deviation, near by bedding and washouts (pictured above) which can affect the coherence of the signal received (white ovals below).



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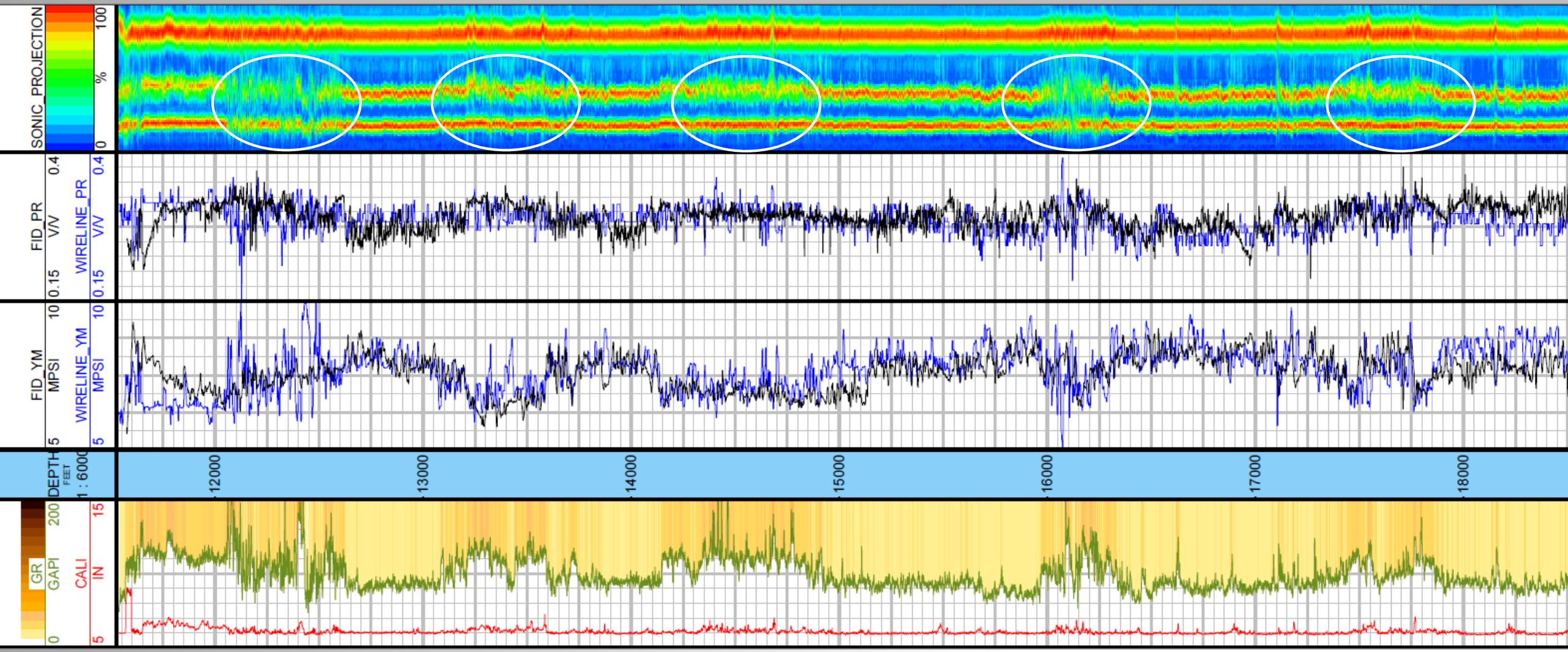
Drillbit Geomechanics Solution

Below you can see a comparison between Fracture ID's rock properties (black) and wireline dipole (blue). Note that the areas of non-agreement are associated with areas of low coherence in the sonic signal (white ovals).



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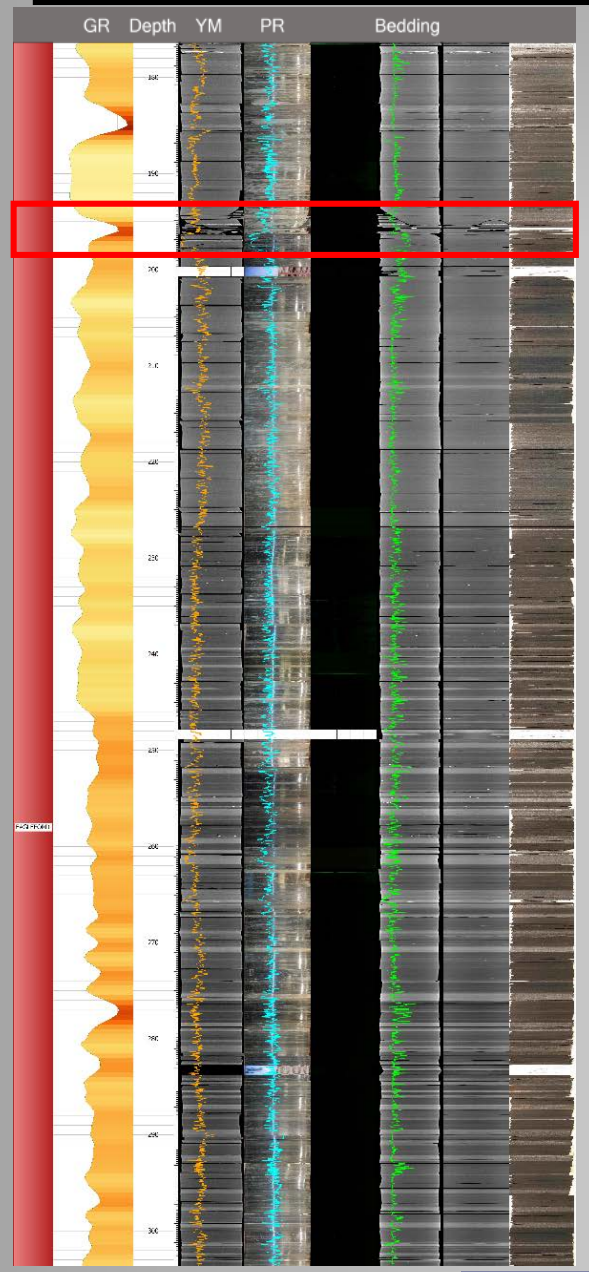
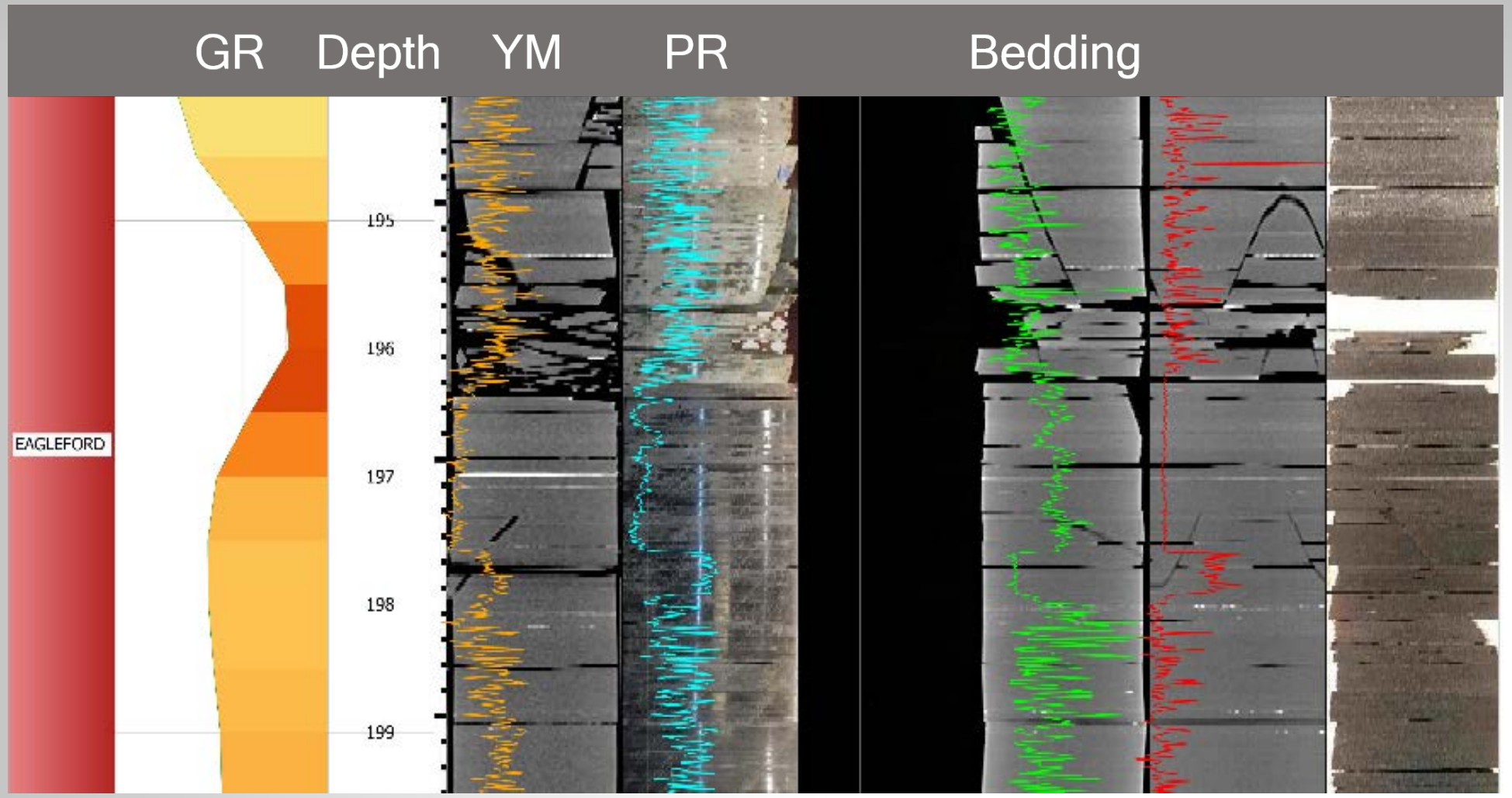
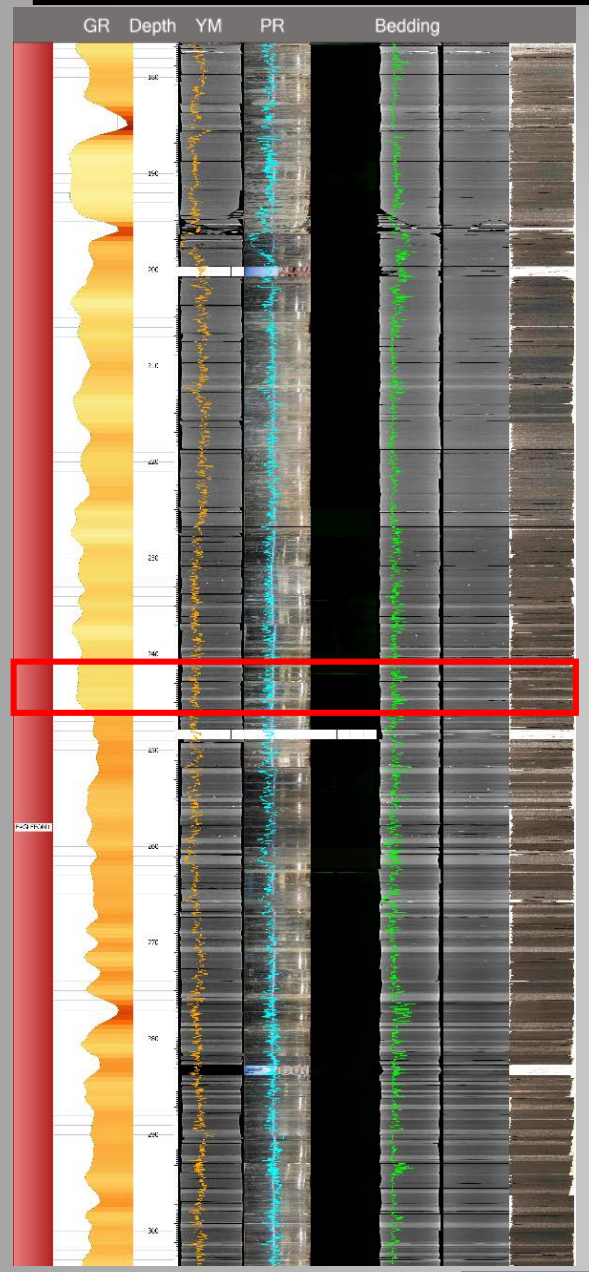
Drillbit Geomechanics Solution



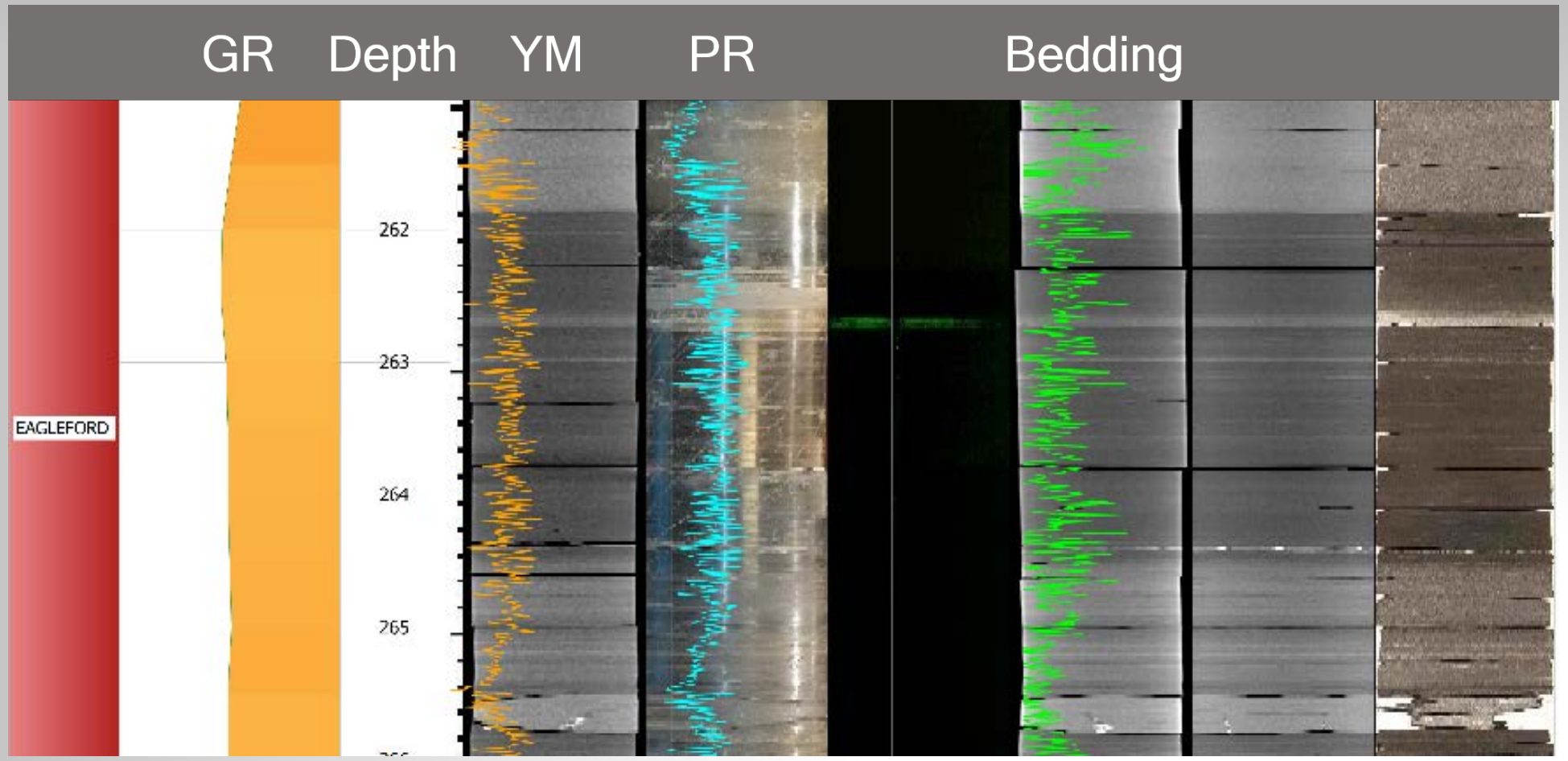
Below you can see a comparison between Fracture ID's rock properties (all increasing to the right) and the actual core images. In this example Fracture ID data was collected while coring took place. Fractures can be seen at 196 and 198 ft.



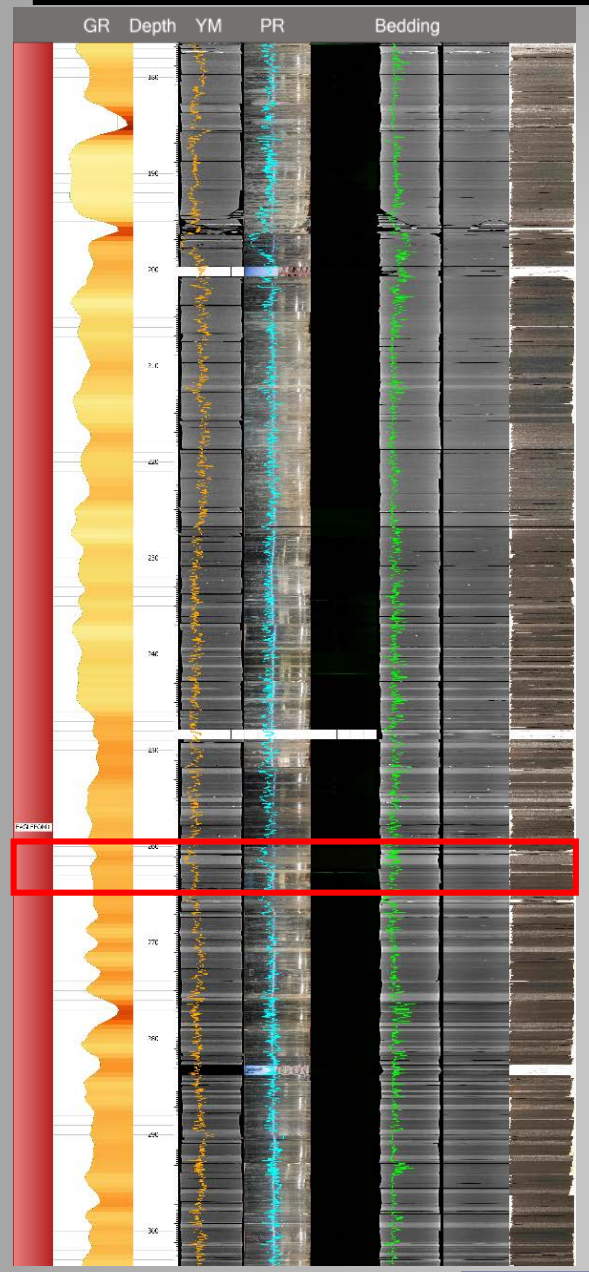
Drillbit Geomechanics Solution



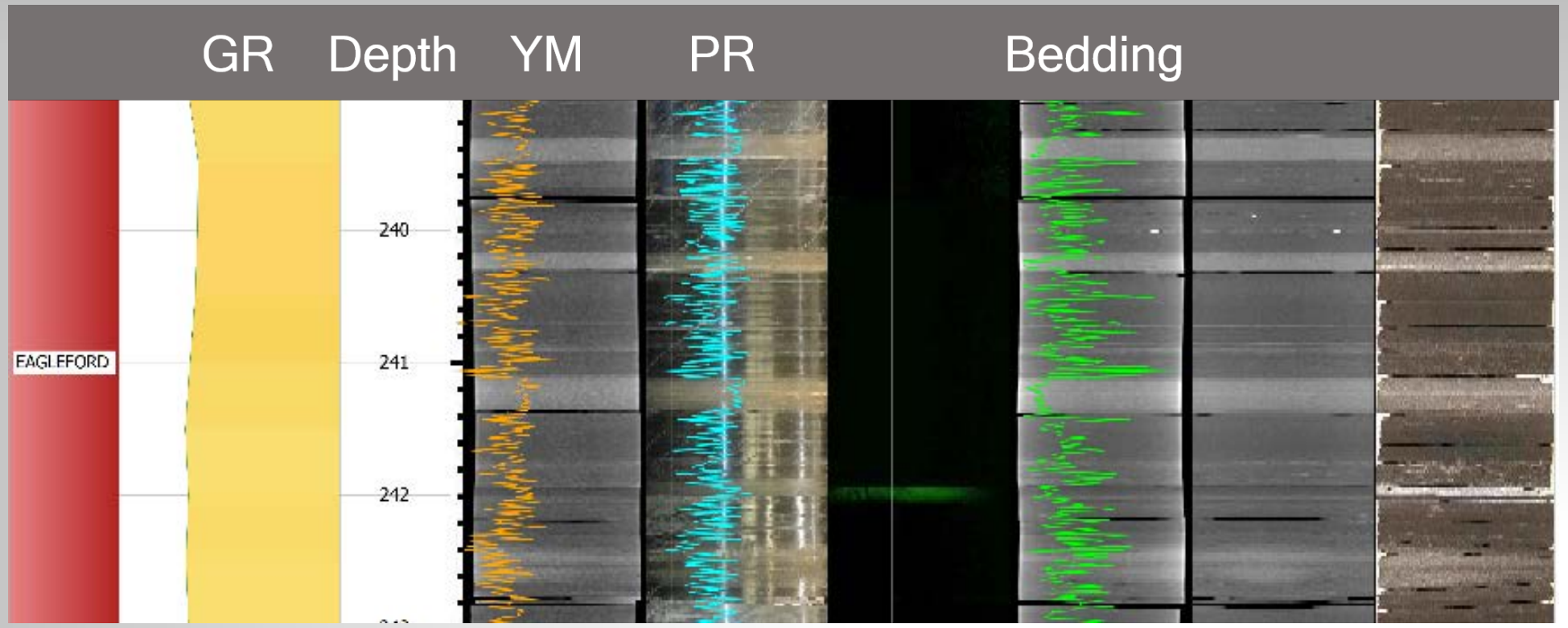
Below you can see a comparison between Fracture ID's rock properties (all increasing to the right) and the actual core images. In this example Fracture ID data was collected while coring took place. A 3.5 ft parasequence can be seen from 262 to 265.5 ft.



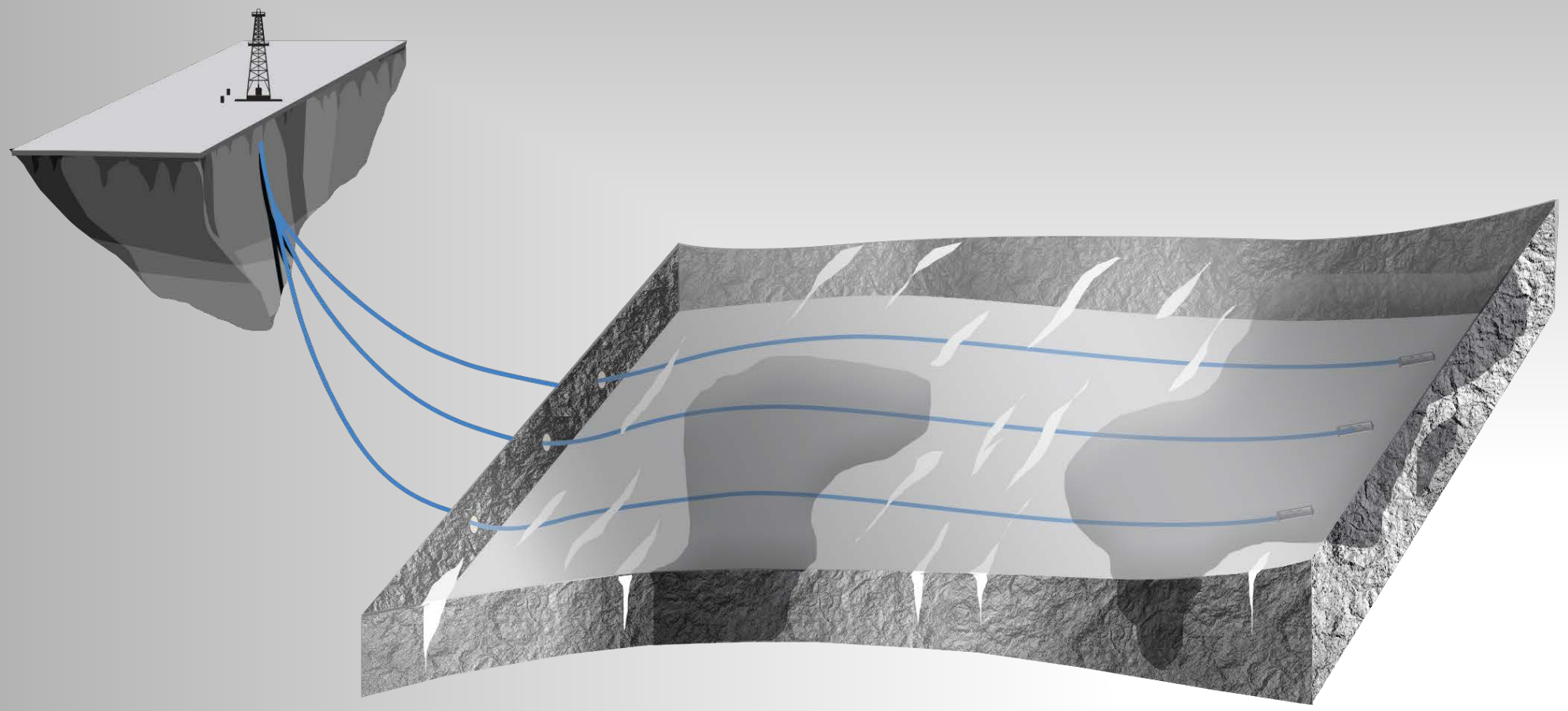
Drillbit Geomechanics Solution



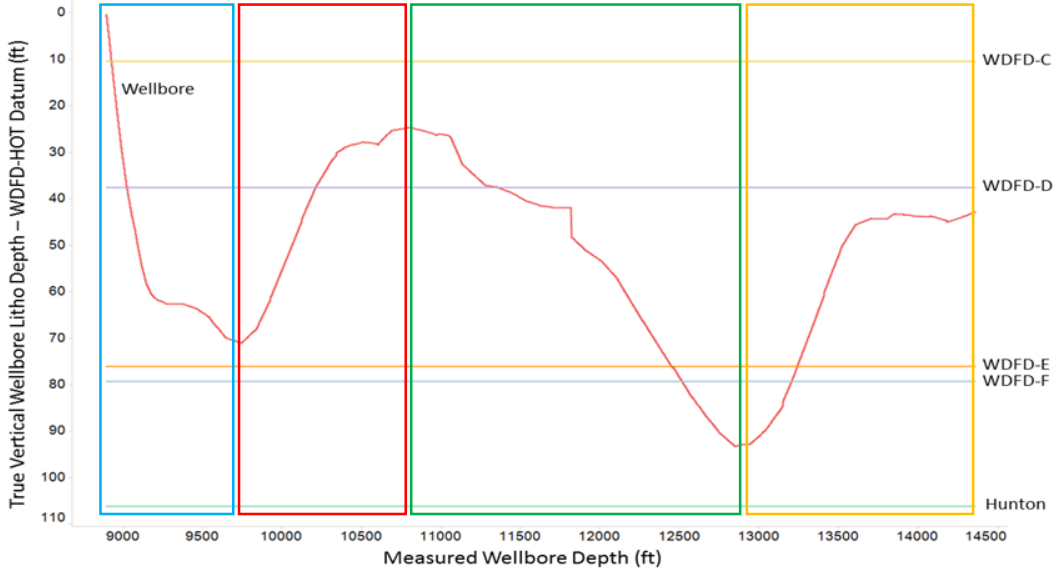
Below you can see a comparison between Fracture ID's rock properties (all increasing to the right) and the actual core images. In this example Fracture ID data was collected while coring took place. Thin beds can be seen throughout.



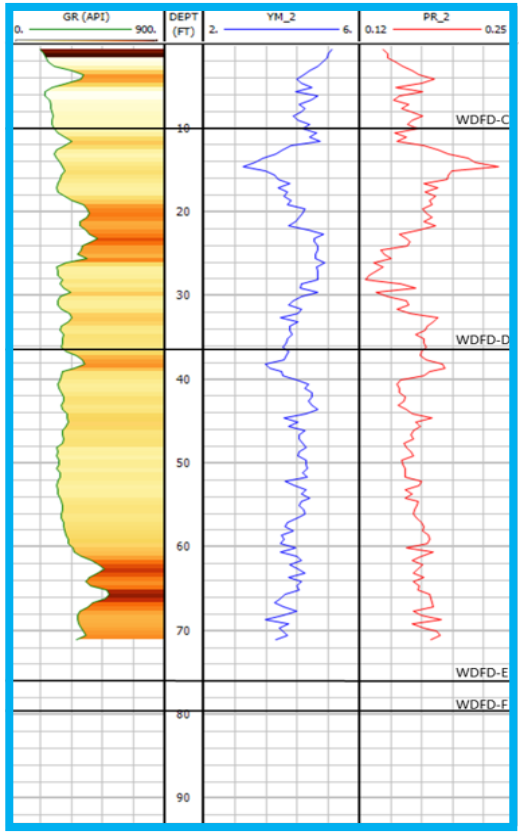
Fracture ID Illuminated Earth Model Allows Operators to Map Heterogeneity

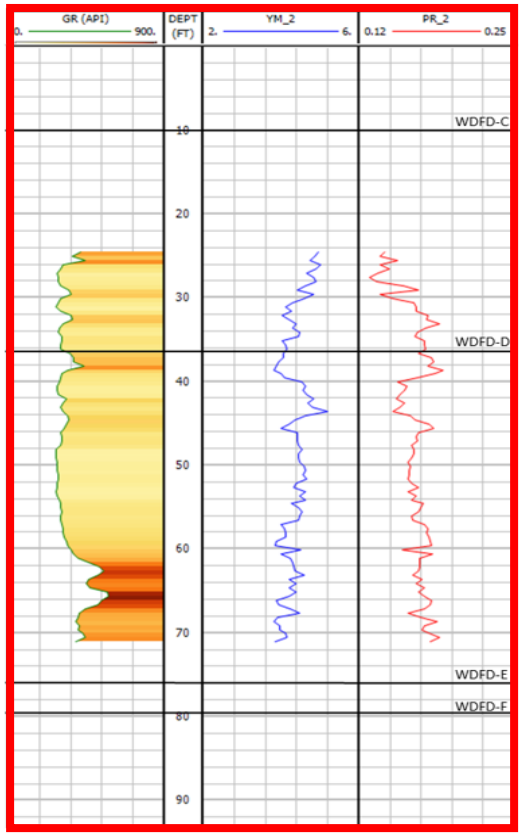


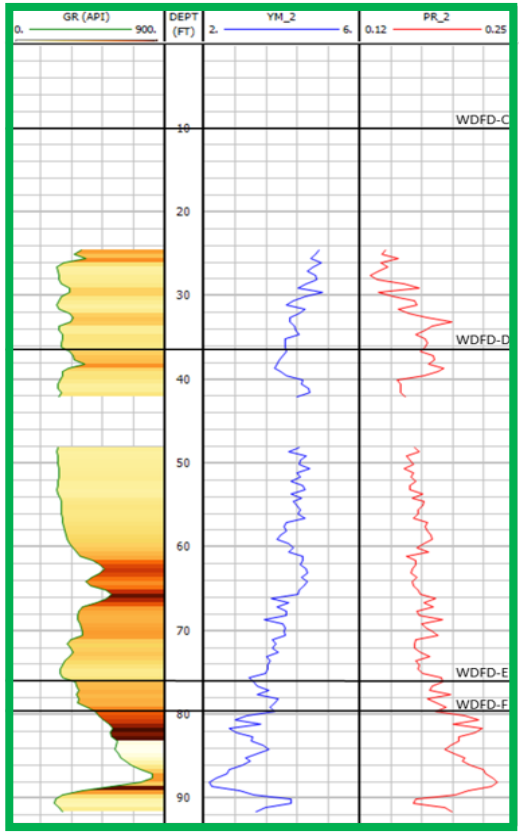
Woodford Arkoma – Pseudo Verticals and their Application

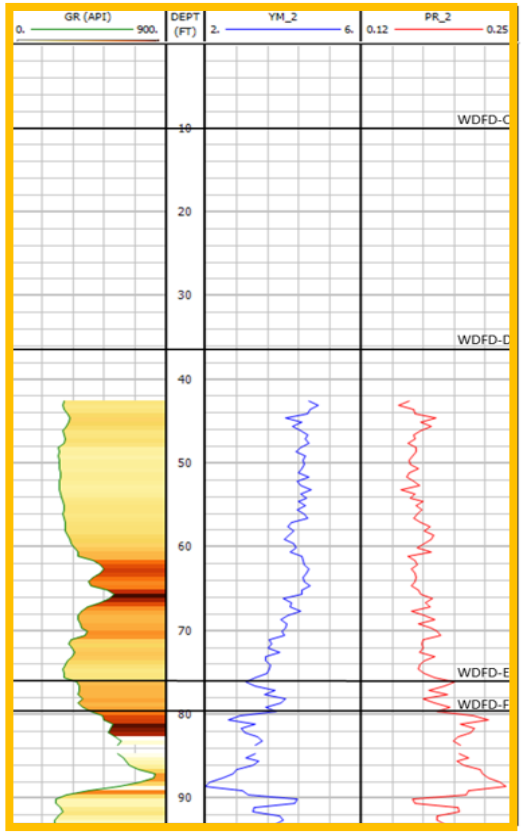


Different sections of the lateral well crossing geology are stacked into pseudo verticals along the lateral. Here you can see 4 pseudo verticals showing lateral variation. The colors represent the section of well used to create each pseudo vertical.









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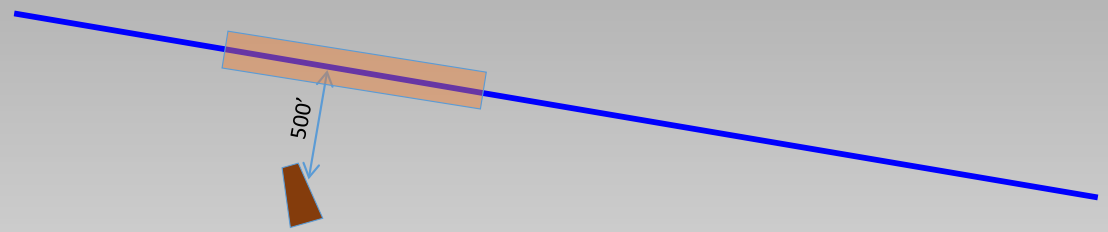
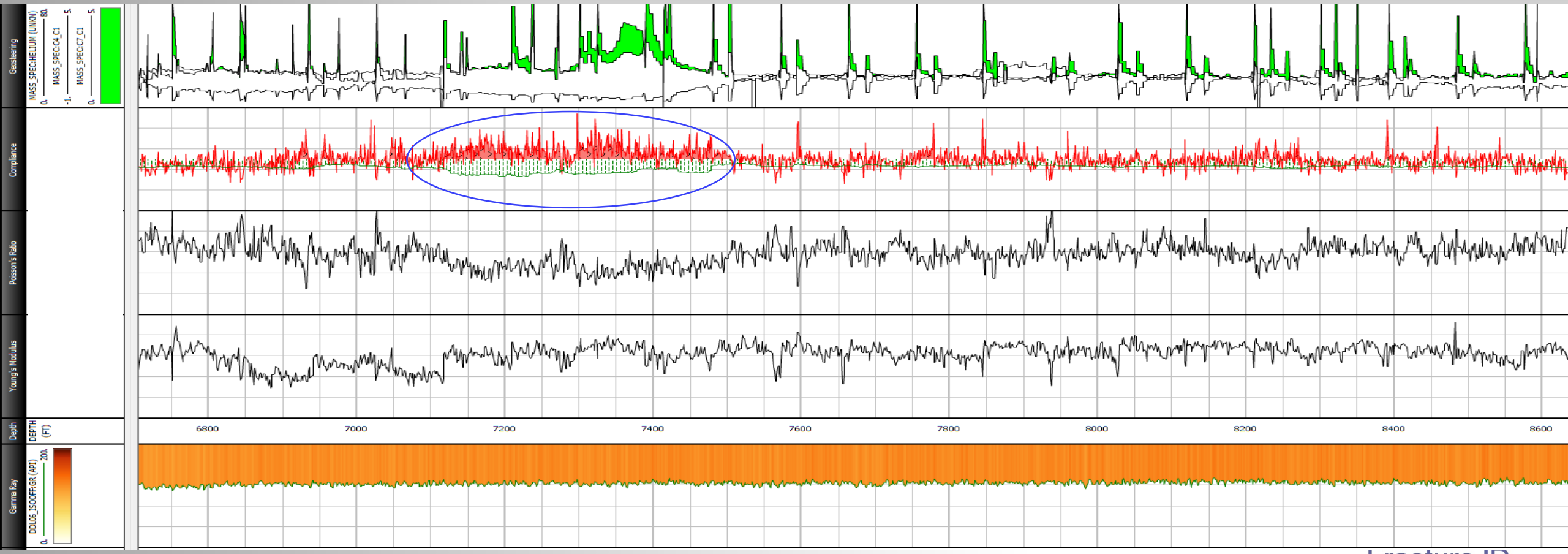
Understanding the Impact of Fracture Systems

A horizontal well was drilled in the neighborhood of a producing vertical well.

Well-normalized curves from mass spectrometer showing relative ratios of heavy to light gas species vary with the presence of downhole fractures, indicating communication between wells (blue oval). As the red curve increases this indicates increased fracture presence. Ain this area the Poisson's Ratio also drops, indicating depletion.

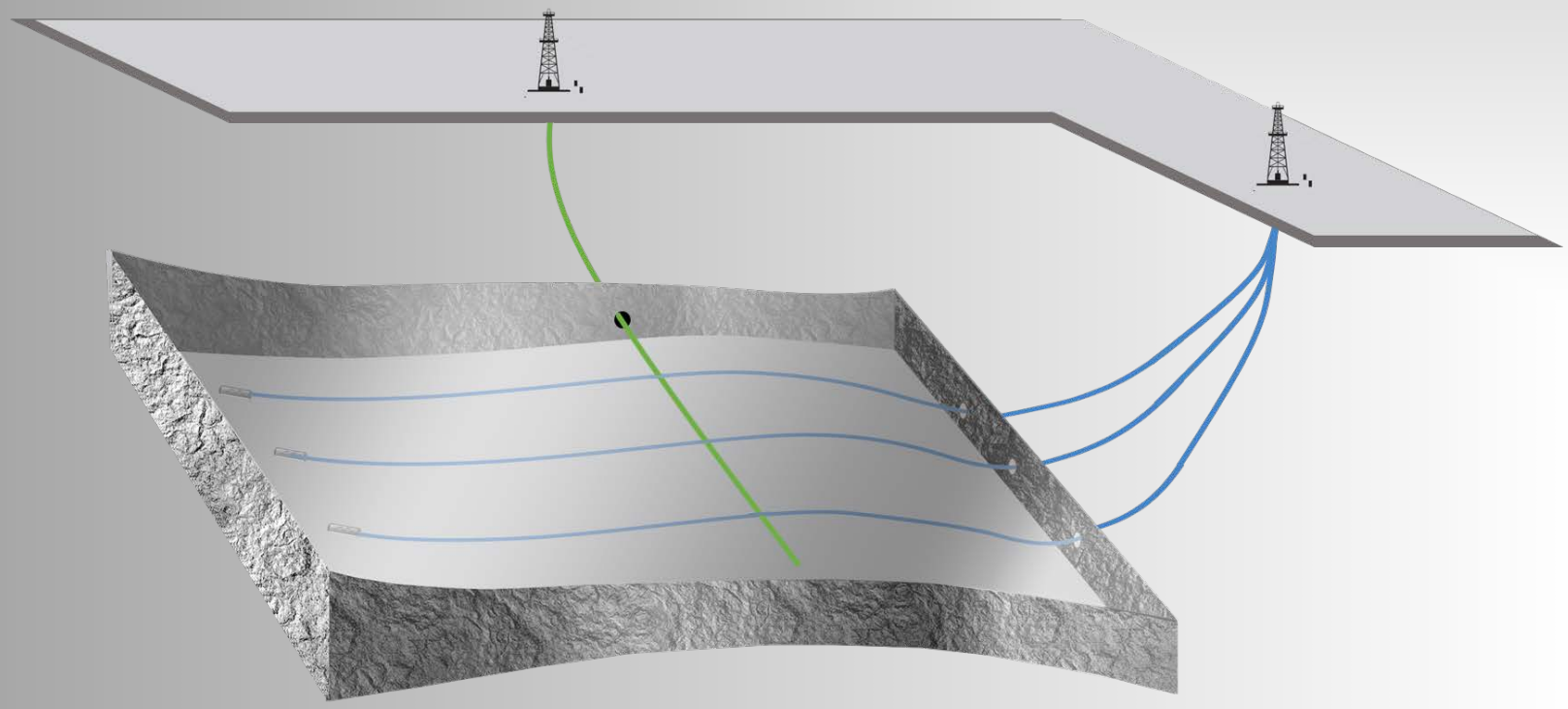


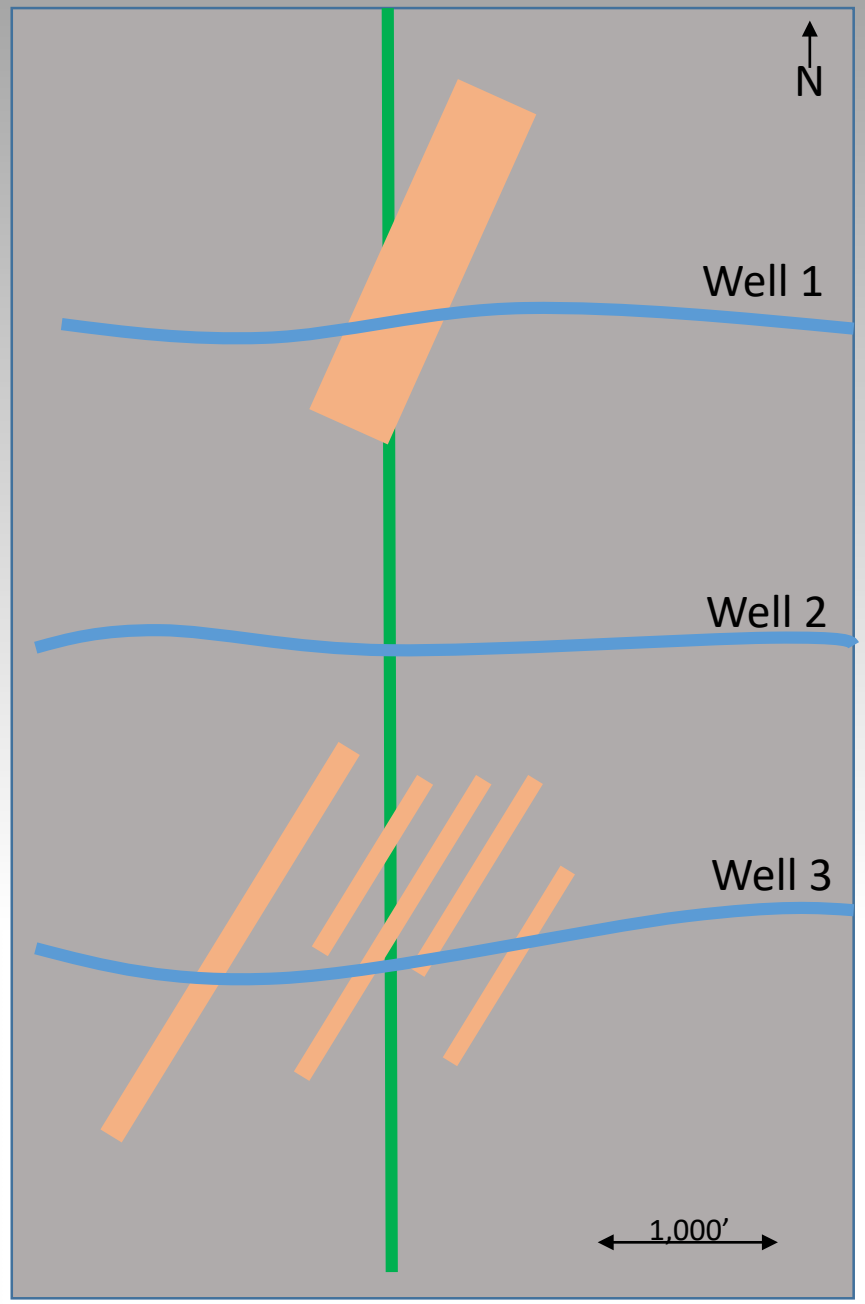


Reservoir Characterization: Middle Bakken Depletion

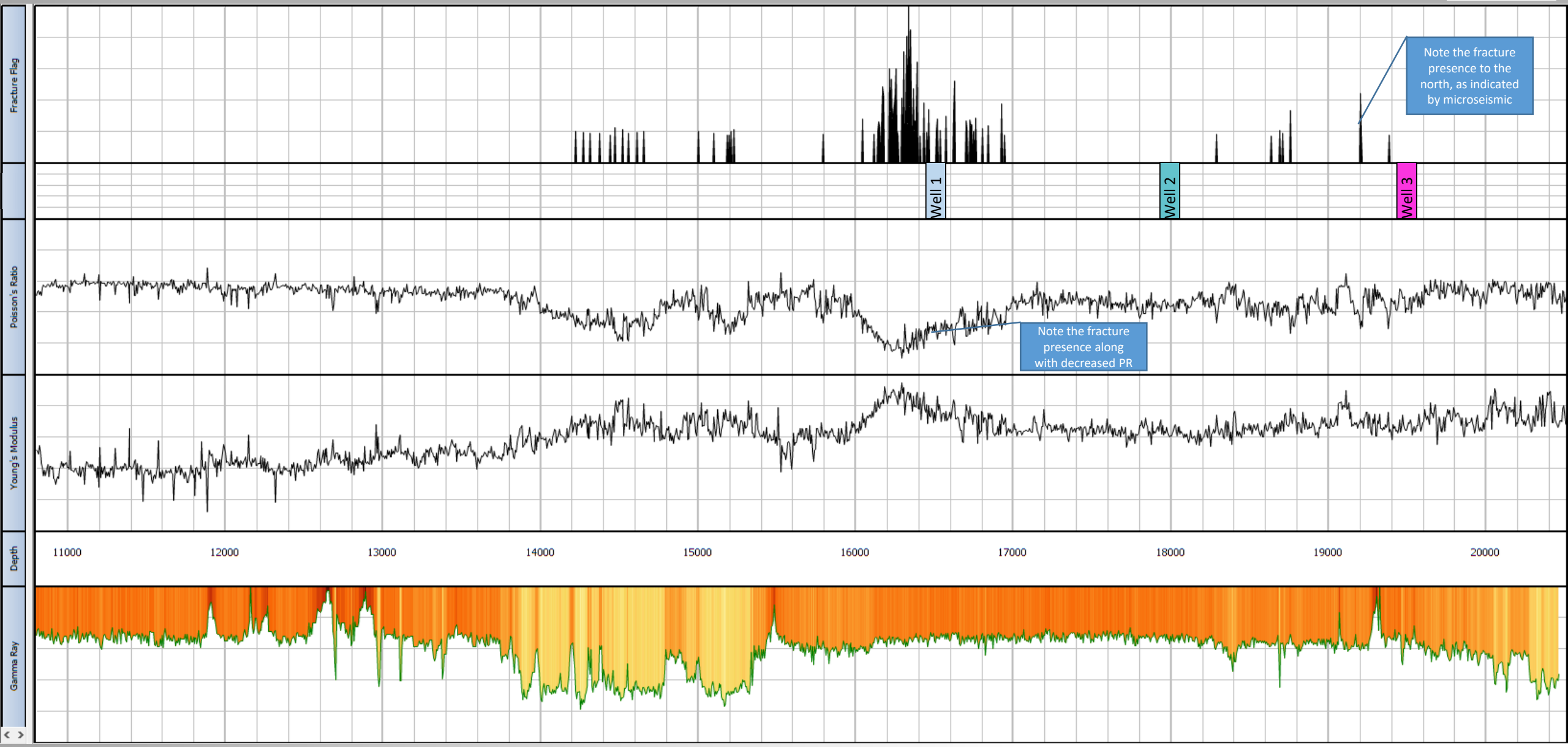
A decade ago the blue wells were drilled and completed (Well 2 was a monitor well), the orange rectangles represent where microseismic energy was recorded.

Liberty Resources drilled the green well this year 15 ft below the blue wells to investigate depletion in this area.



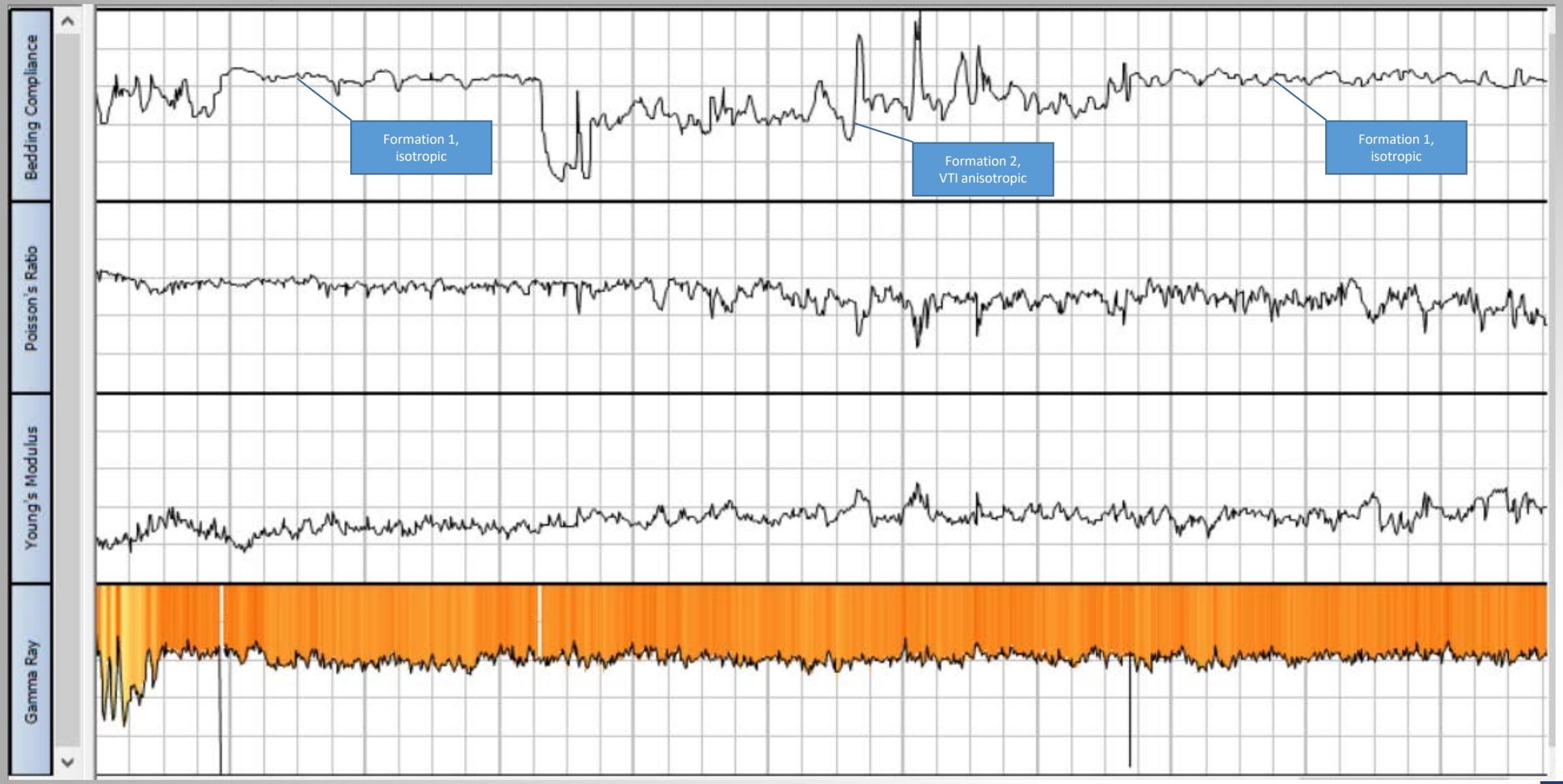


Reservoir Characterization: Depletion



Reservoir Characterization: Lithology and Bedding

Powder River Example – Two formations discriminated by lamination



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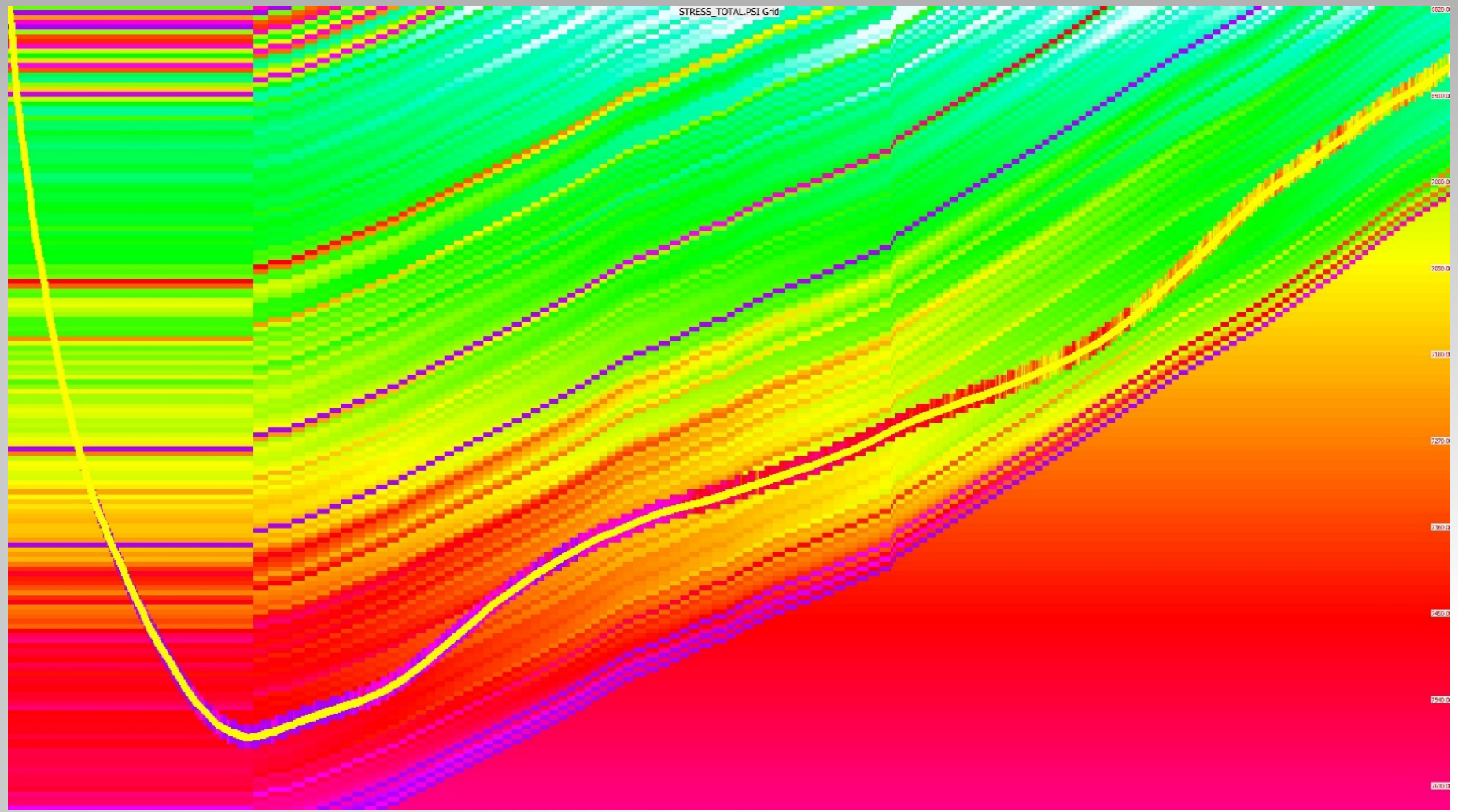
High Resolution, Entire Well Completion Modeling in Gohfer

High resolution data is loaded along the lateral with all geologic structure and geosteering incorporated.

Data is loaded into bins 1x2 ft.

This allows for:

- Improved perf placement (similarly stressed rock)
- Improved stage placement (reduced stress variance over stage)
- Estimate of impact of induced stress along well bore



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Perforation Treatment Efficiency Study

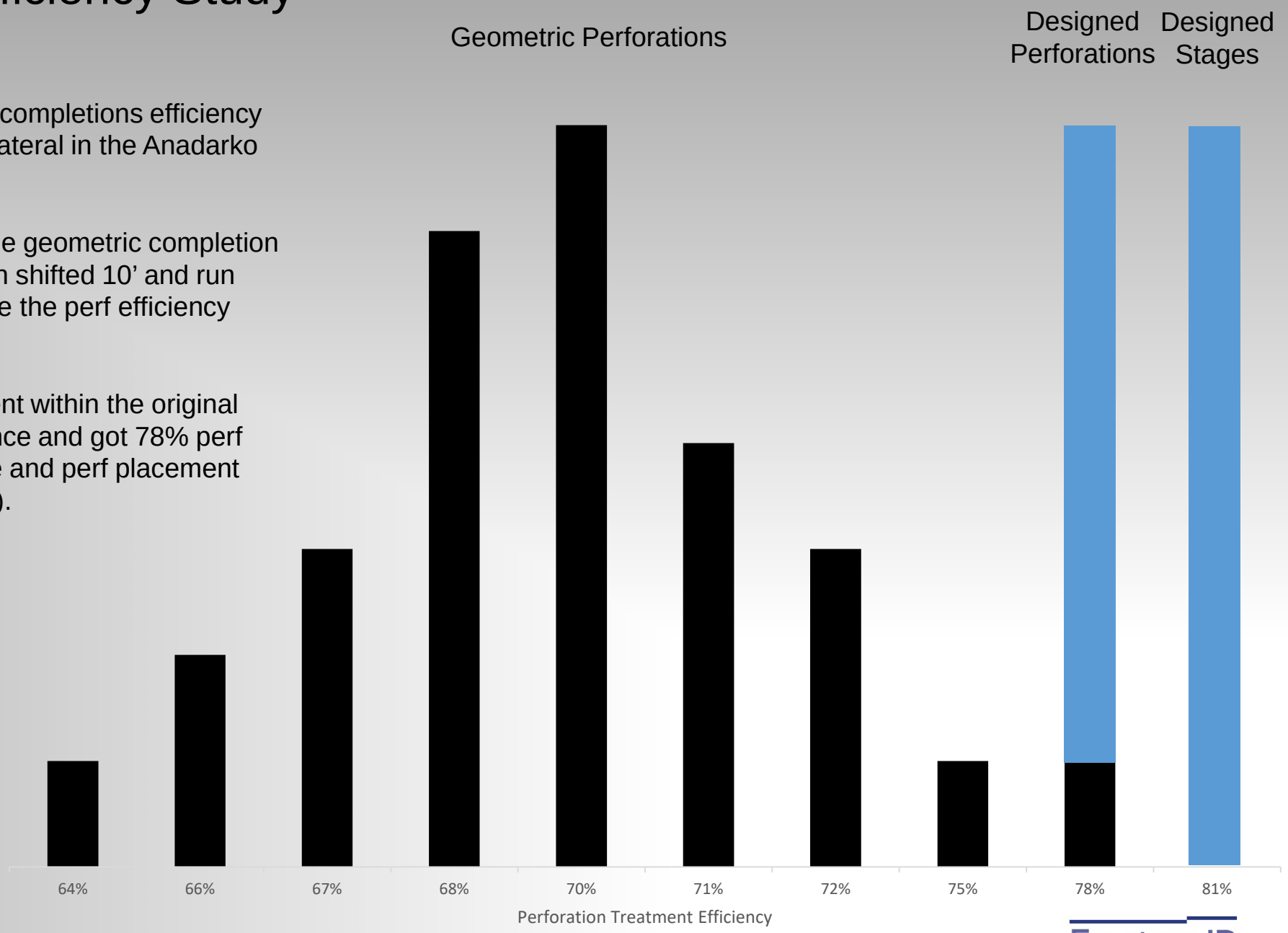
As an experiment measuring geometric completions efficiency Fracture ID data was collected along a lateral in the Anadarko Basin.

This data was loaded into Gofher and the geometric completion was modeled. This completion was then shifted 10' and run again. This was done 28 times and gave the perf efficiency distribution to the right (black).

Next the modeler adjusted perf placement within the original stage placements to optimize performance and got 78% perf efficiency (blue). Next a complete stage and perf placement variation was modeled to get 81% (blue).

The take away:

- A geometric completion offered between 64 and 78% efficiency.
- Just by moving perfs around, a 78% perf efficiency was gained.
- Even more gains and reduced costs were experienced by adjusting stage and perf locations based on Fracture ID data.

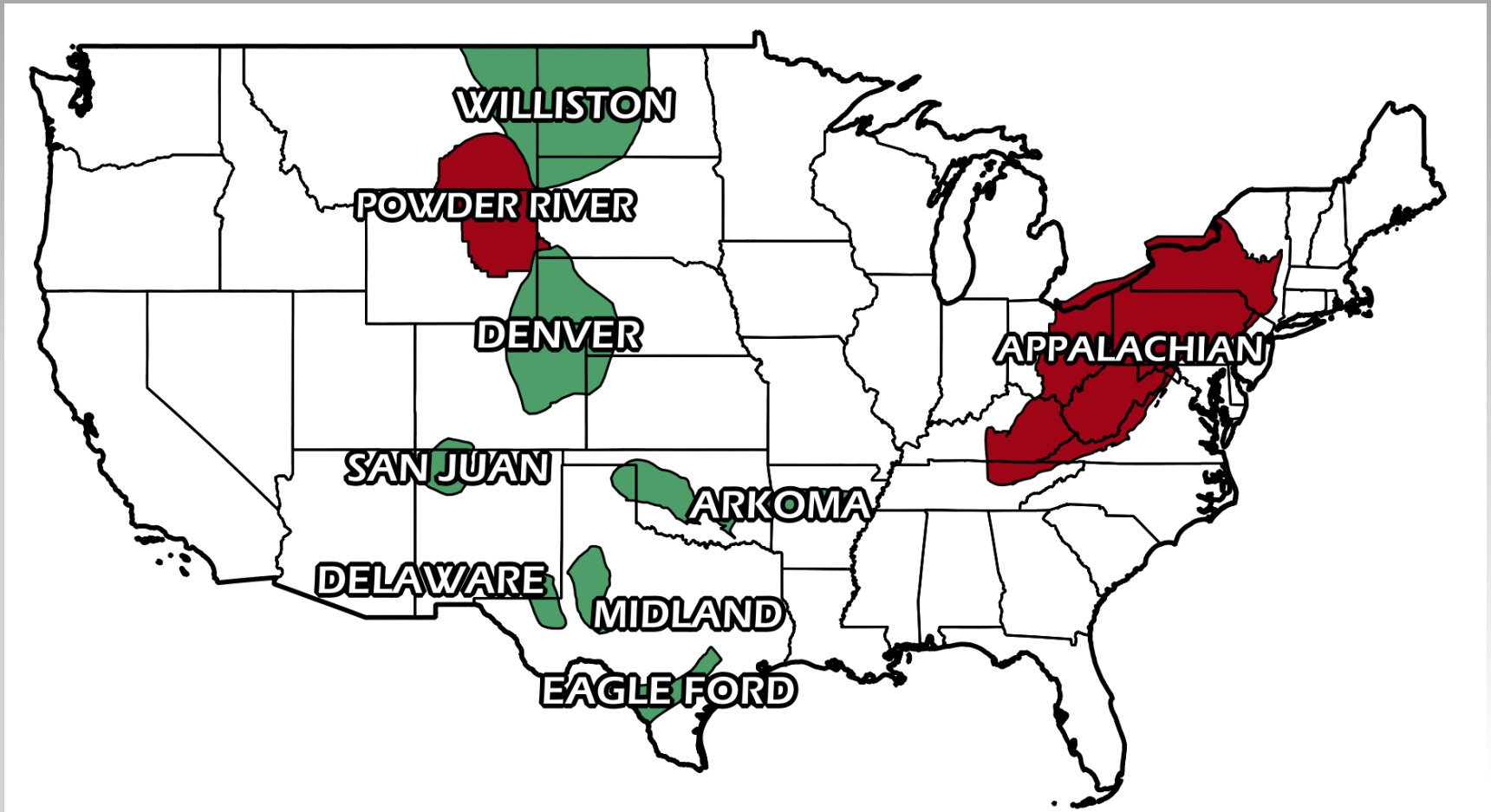


Fracture ID

Current Business

Basins

- Delaware
- Midland
- Anadarko
- San Juan
- Eagle Ford
- Williston
- DJ
- Powder River
- Appalachian
- Arkoma



37 Clients to date including:

Devon Energy	Cimarex Energy	Hess Corp	Lario O&G
Continental Resources	East Management	FourPoint Energy	Encana Corp
Liberty Resources	Noble Energy	WPX Energy	Anschutz Corp
Unit Petroleum	Rock Oil Company	Bravo	

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