Production-Focused Seismic: Applying 3D Seismic to Well Productivity Analysis and Completion Optimization, Examples from the Eagle Ford and Wolfcamp*

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Search and Discovery Article #80538 (2016)**
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*Adapted from oral presentation given at AAPG Geosciences Technology Workshop, International Shale Plays Houston, Texas, April 28-29, 2015. Please see closely related article, "Integrating Seismic, Microseismic and Engineering Data to Optimize Lateral Placement and Completion Design in the Eagle Ford", Search and Discovery article #80251.

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Abstract

Seismic is often considered a luxury or a "nice-to-have" item. For its cost, customers often feel that they do not get full value or "bang-for-the buck". In Unconventional plays, which are driven by fast and dense drilling and completion engineering, this can be especially true. However, with advanced processing and analysis, a few innovative work-flows, and some creative-thinking, 3D Seismic and Microseismic can be applied to everyday well performance and asset development issues. In this article we will present examples from the Eagle Ford and Wolfcamp in which 3D Seismic and Microseismic provide practical insights into:

• the effect of faults and fractures on well performance
• the cumulative effect of the subtle interplay of static and dynamic reservoir characteristics
• understanding and predicting unwanted water production
• the effective vertical placement of horizontal wells
• the placement and spacing of wells and hydraulic fracture stages

It is important for geoscientists to remember that while important reservoir characteristics (both static and dynamic) can be derived from seismic and microseismic attributes, this information and understanding is only truly useful if it can be integrated and calibrated with engineering and production data. In fact, to be truly practical, seismic and microseismic must provide predictive information, in a 3D earth model, which can then be proactively applied by engineers to their development plans, well plans, and completion designs.

Reference Cited

Donovan, A.D., T.S. Staerker, L. Weiguo, A. Pramudito., J. Evenick, T. McClain, A. Agrawal, L. Banfield,, S. Land, M.J. Corbett., C.M. Lowery, and A. Miceli Romero, eds., 2011, Field guide to the Eagle Ford (Boquillas) Formation: West Texas: AAPG Field Seminar Guide Book, Terrell County, TX, April 2011.

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Examples from the Eagle Ford and Wolfcamp

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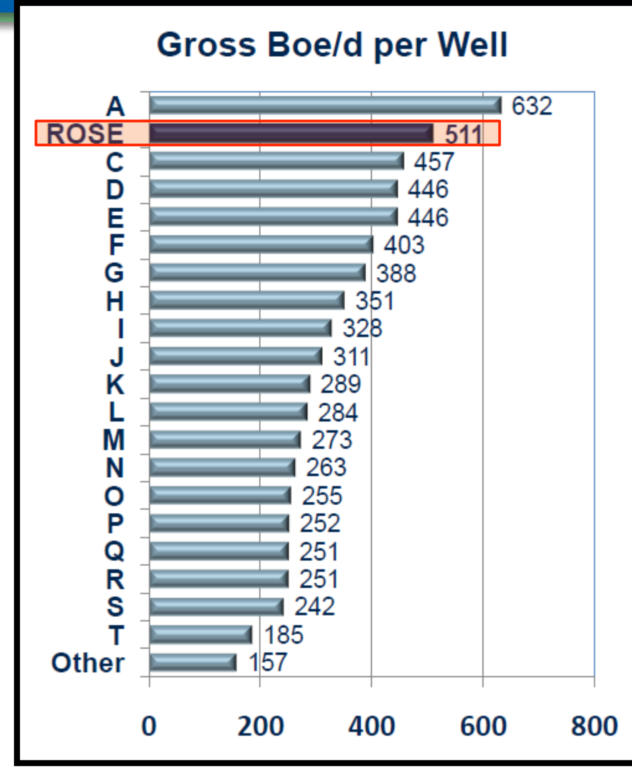
International Shale Plays
28-29 April 2015
Houston, Texas

Gates Ranch
100 acre spacing
Now 55 acre

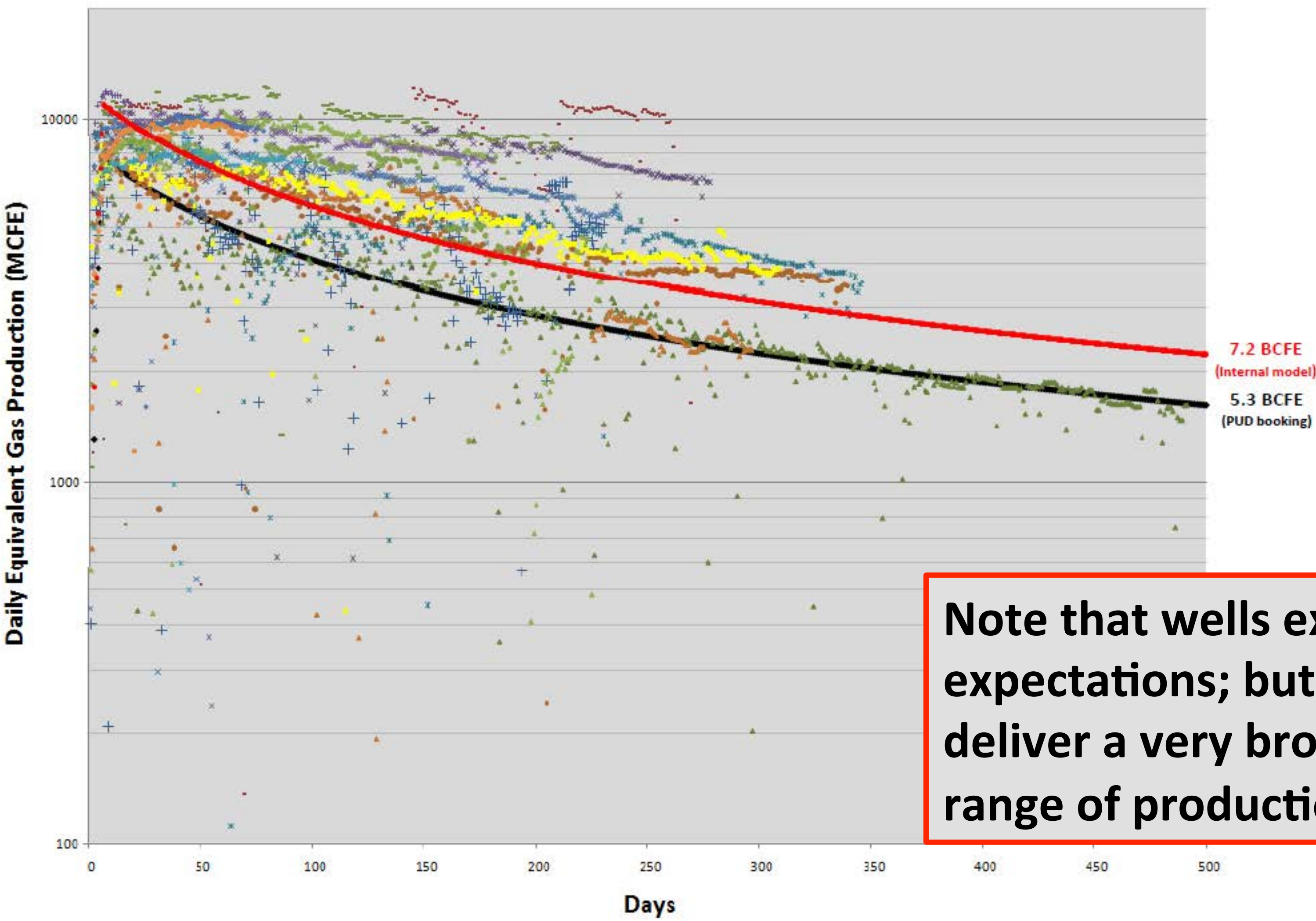


Note that development plan is based on geometric spacing to maximize acreage coverage – well azimuth is perpendicular to regional stress direction

Source: Rosetta Resources Investor Presentation, Feb 2014

Gates Ranch Proper – Individual Well Performance

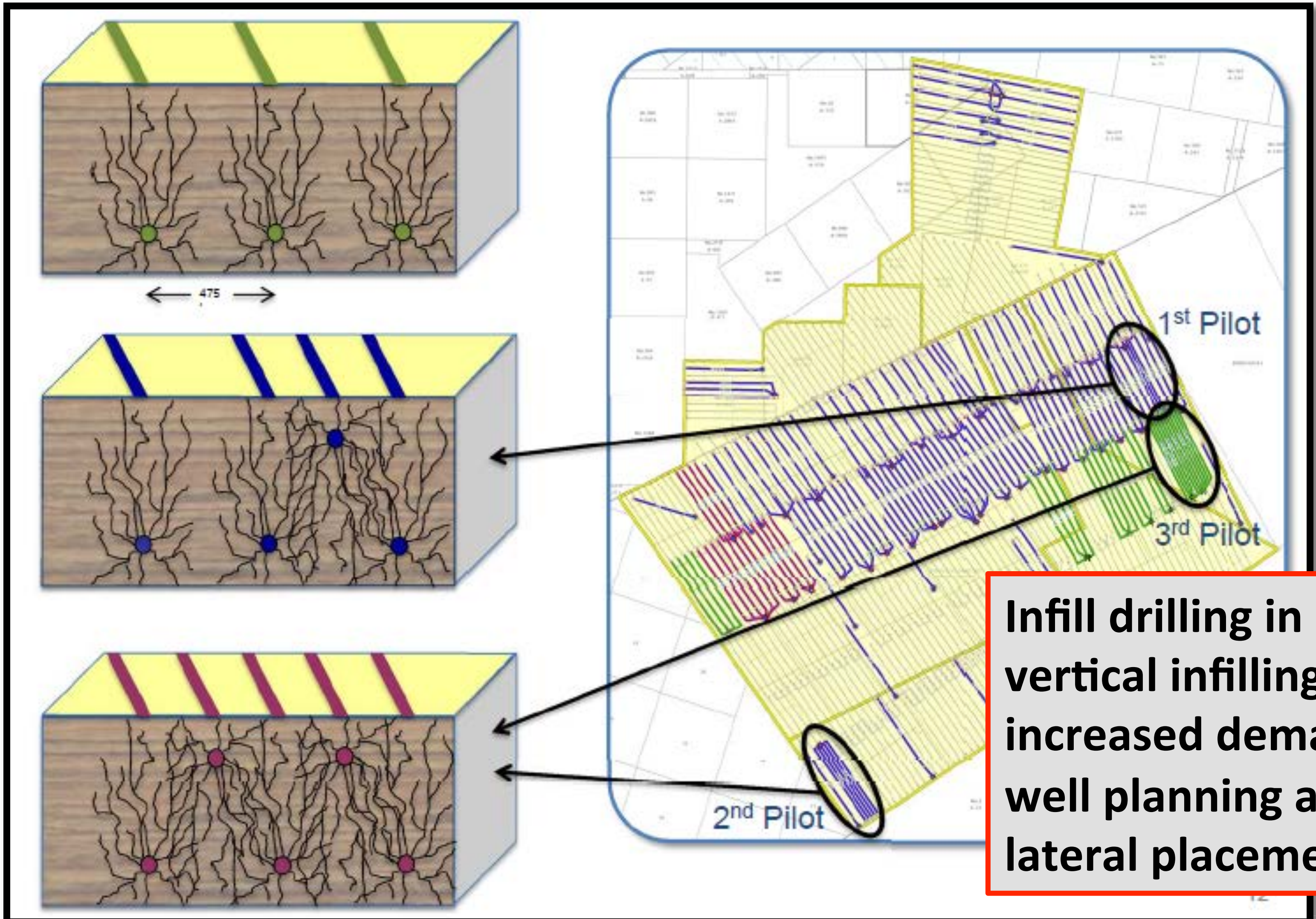
Normalized actual results versus internal 7.2 Bcfe P50 curve and P90 PUD booking curve



Note that wells exceed expectations; but, also deliver a very broad range of production

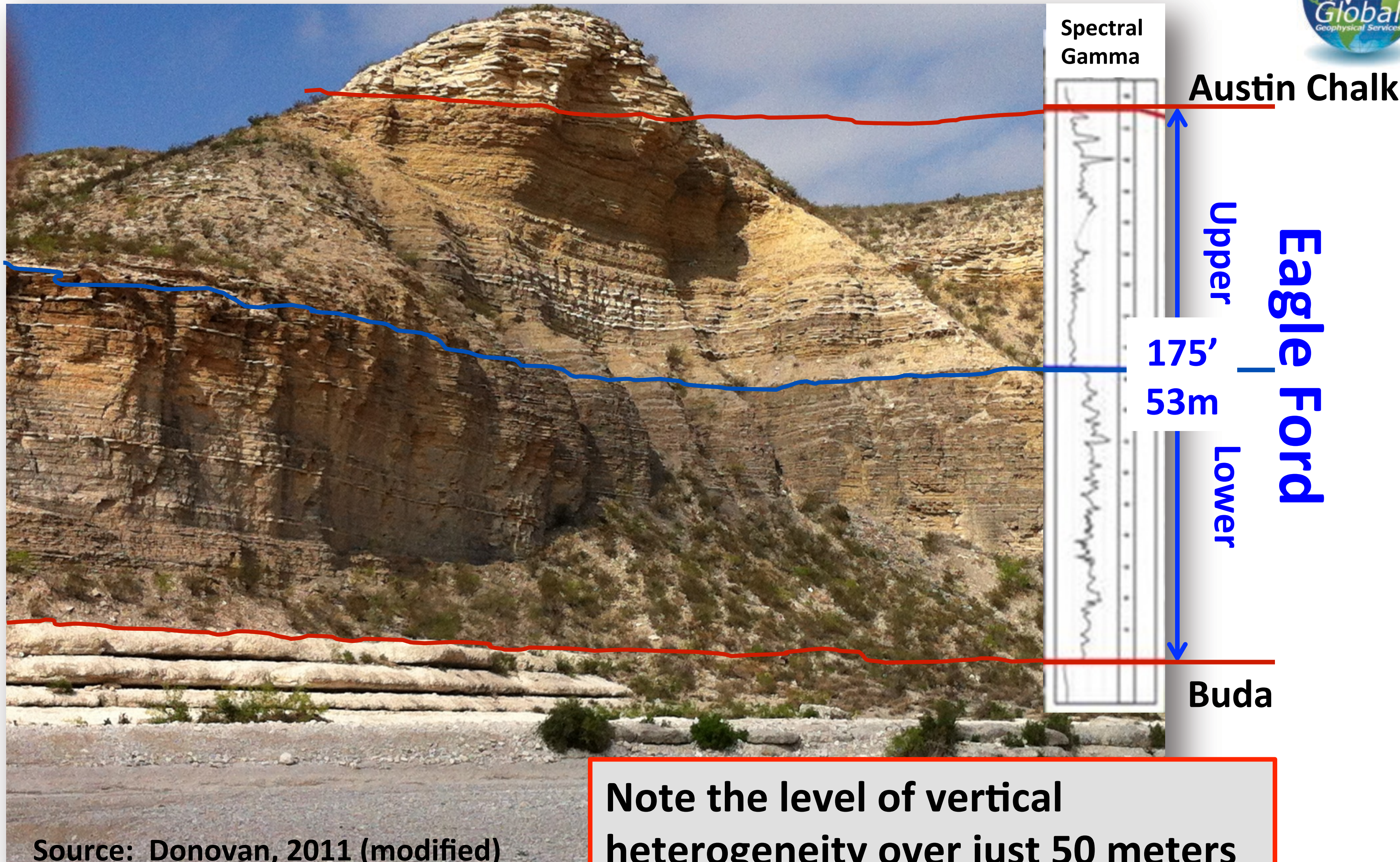
Source: Rosetta Resources
IPAA OGIS Conference, 11 April 2011

Rosetta Resources - Gates Ranch



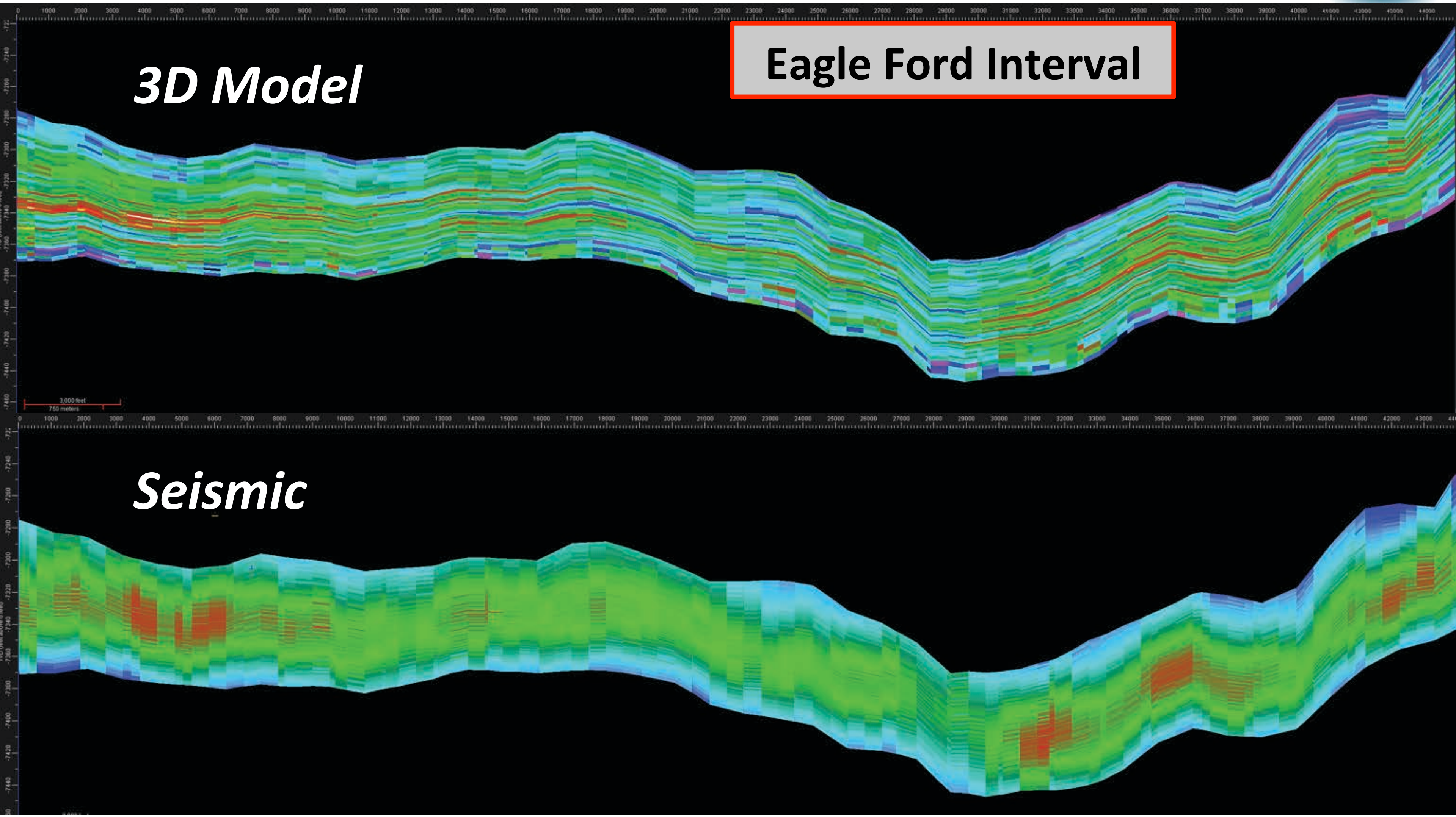
Source: Rosetta Resources Investor Presentation, Feb 2014

Eagle Ford - Outcrop - Lozier Canyon, South Texas



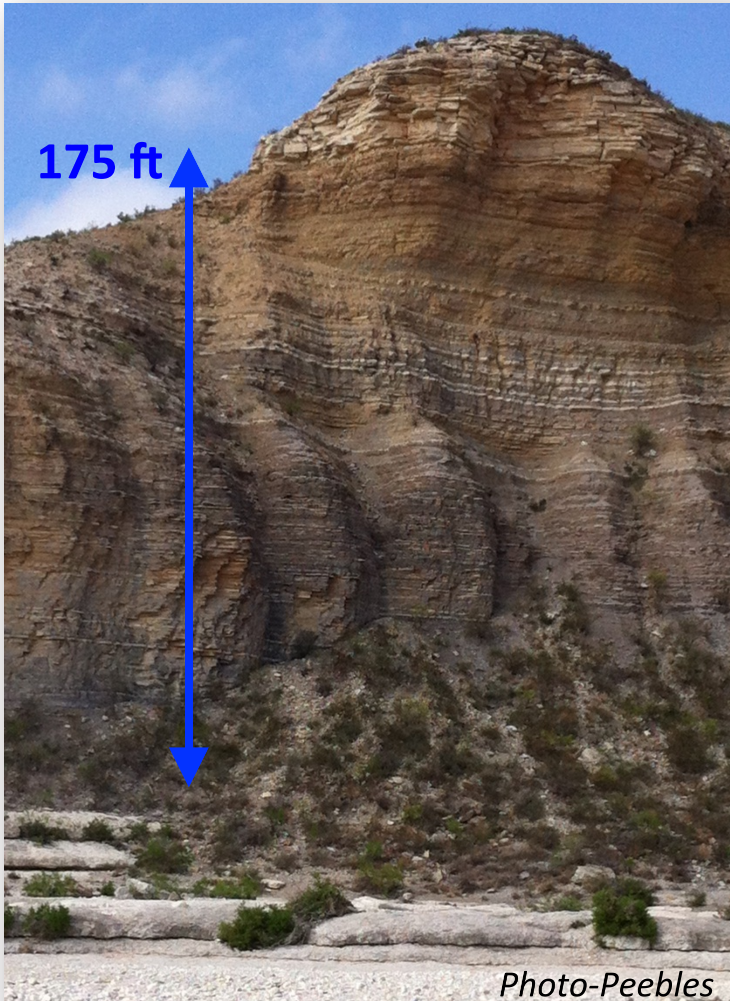
Note the level of vertical heterogeneity over just 50 meters (175 ft) of the zone of interest

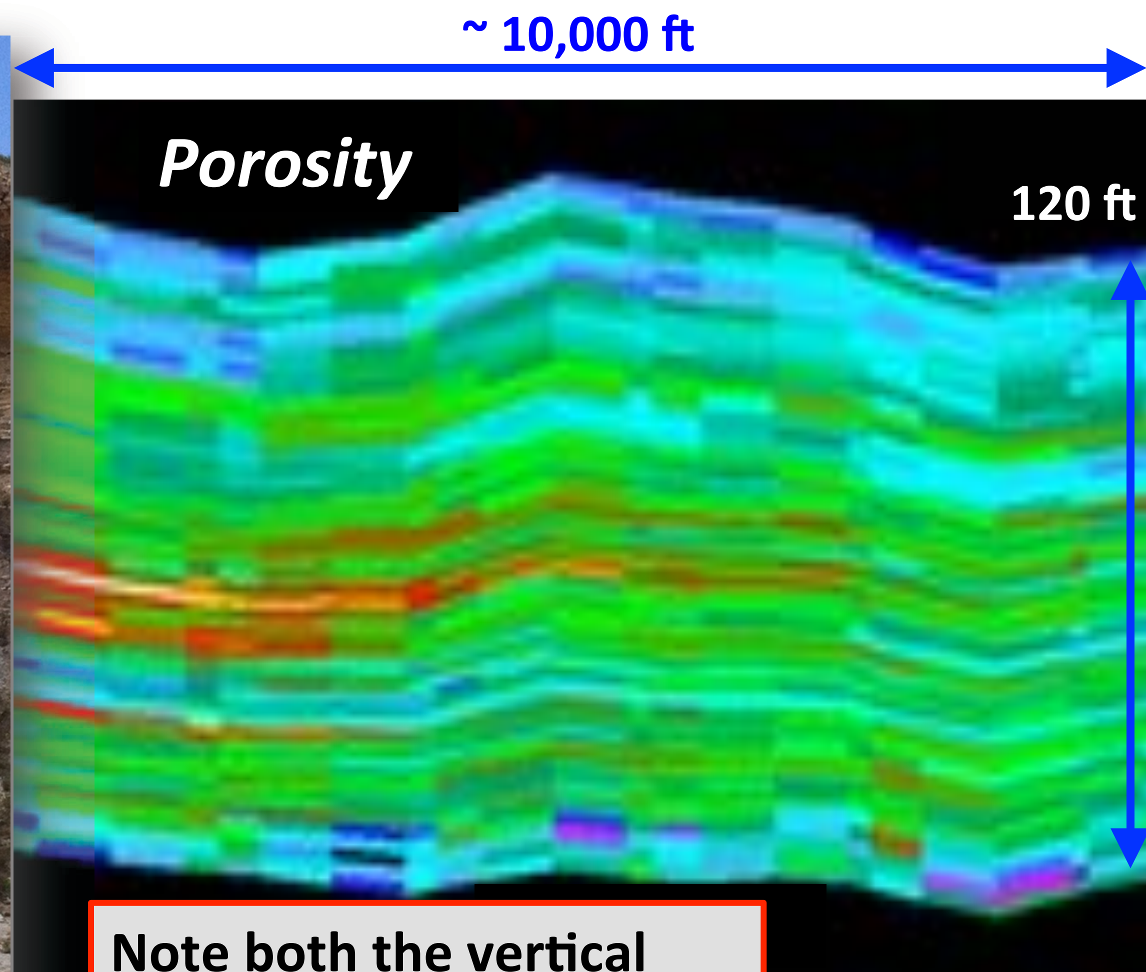
Vertical Resolution - Effective Lateral Placement



3D Geomodel for Lateral Placement

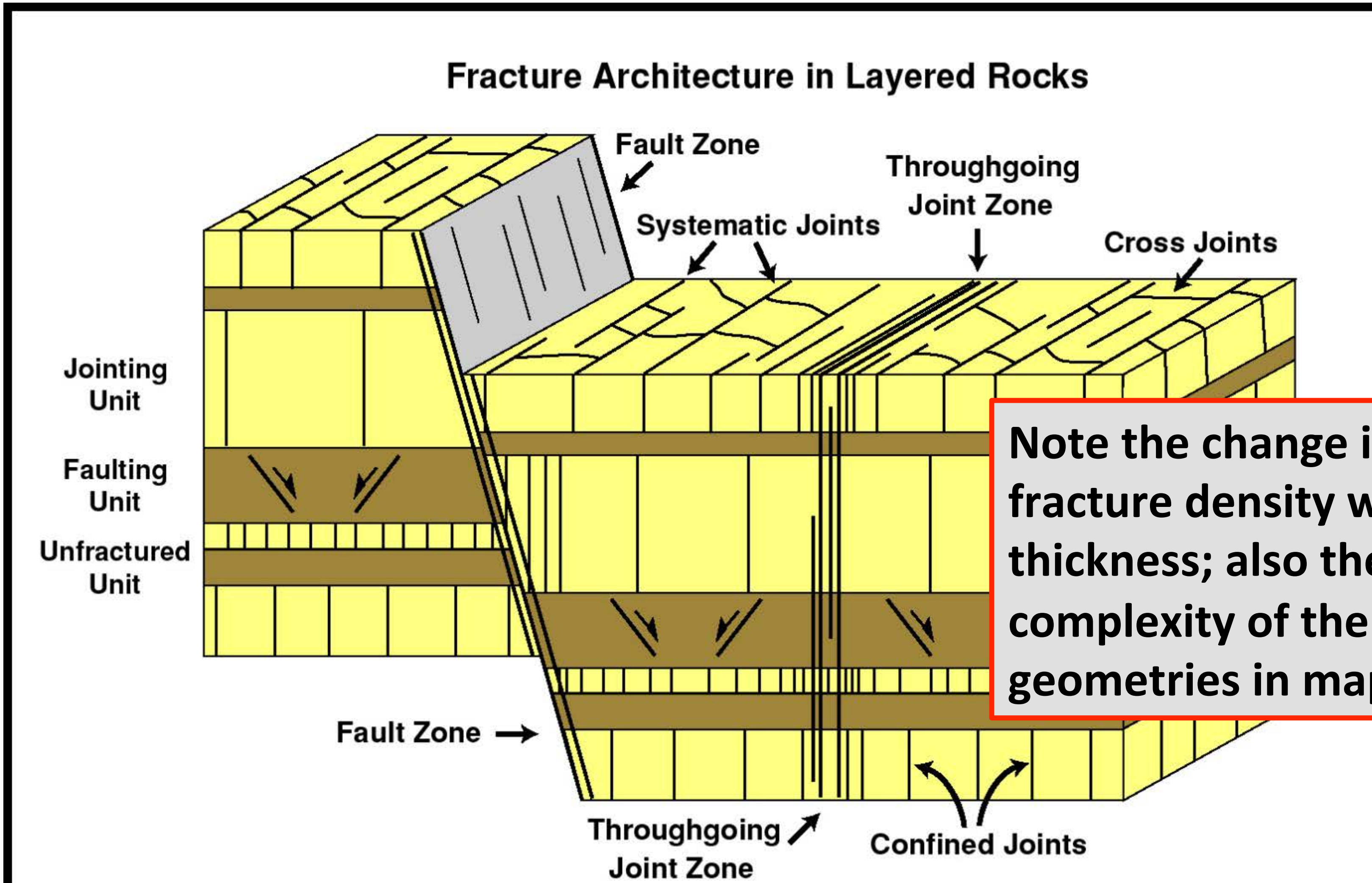
Eagle Ford - Lozier Canyon





Note both the vertical and lateral heterogeneity

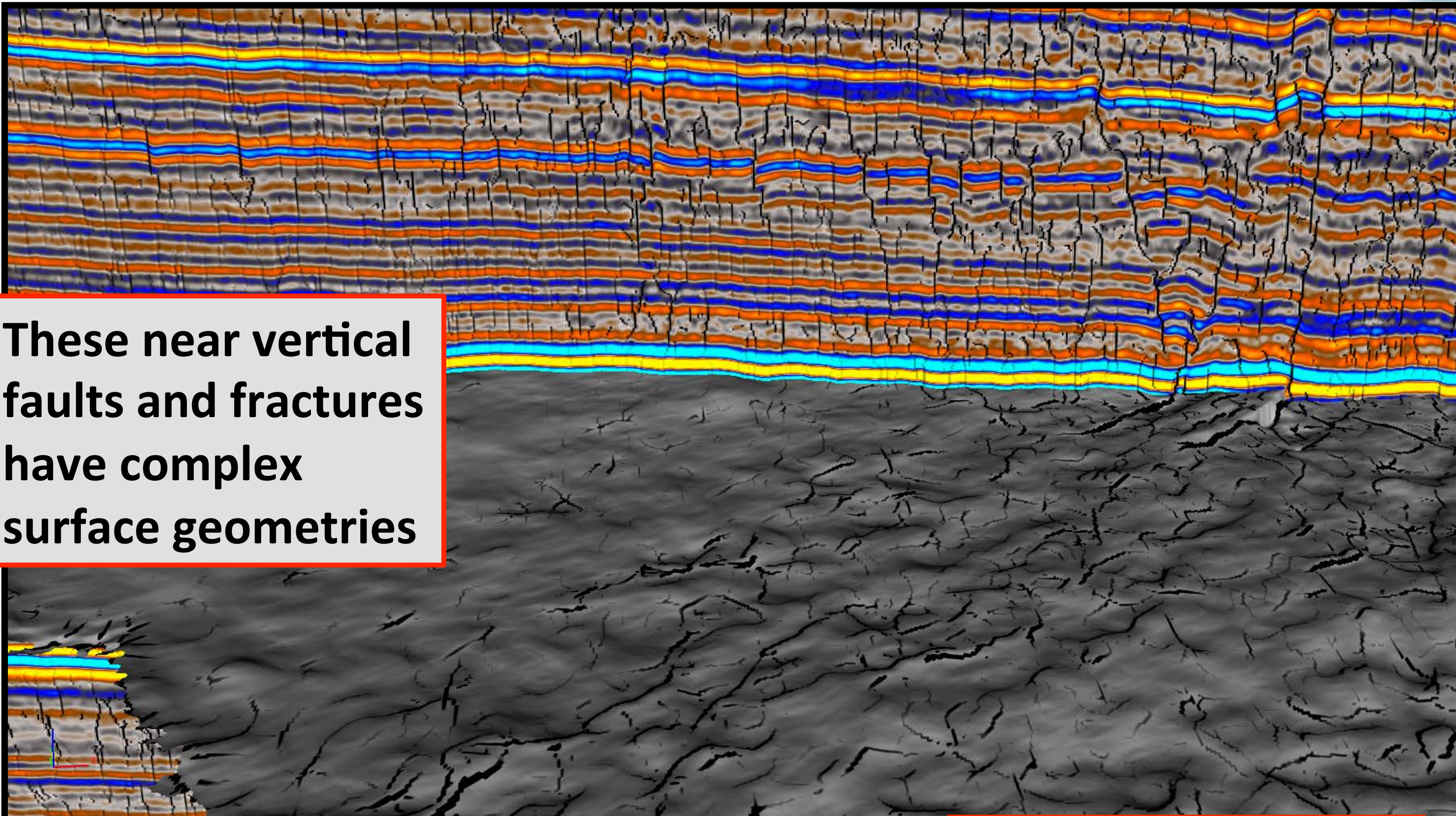
Fault & Fractures – 1st Order Impact on Productivity



Gross, 2013, HGS Mudrocks Conference

Note the change in fracture density with bed thickness; also the complexity of the fracture geometries in map view

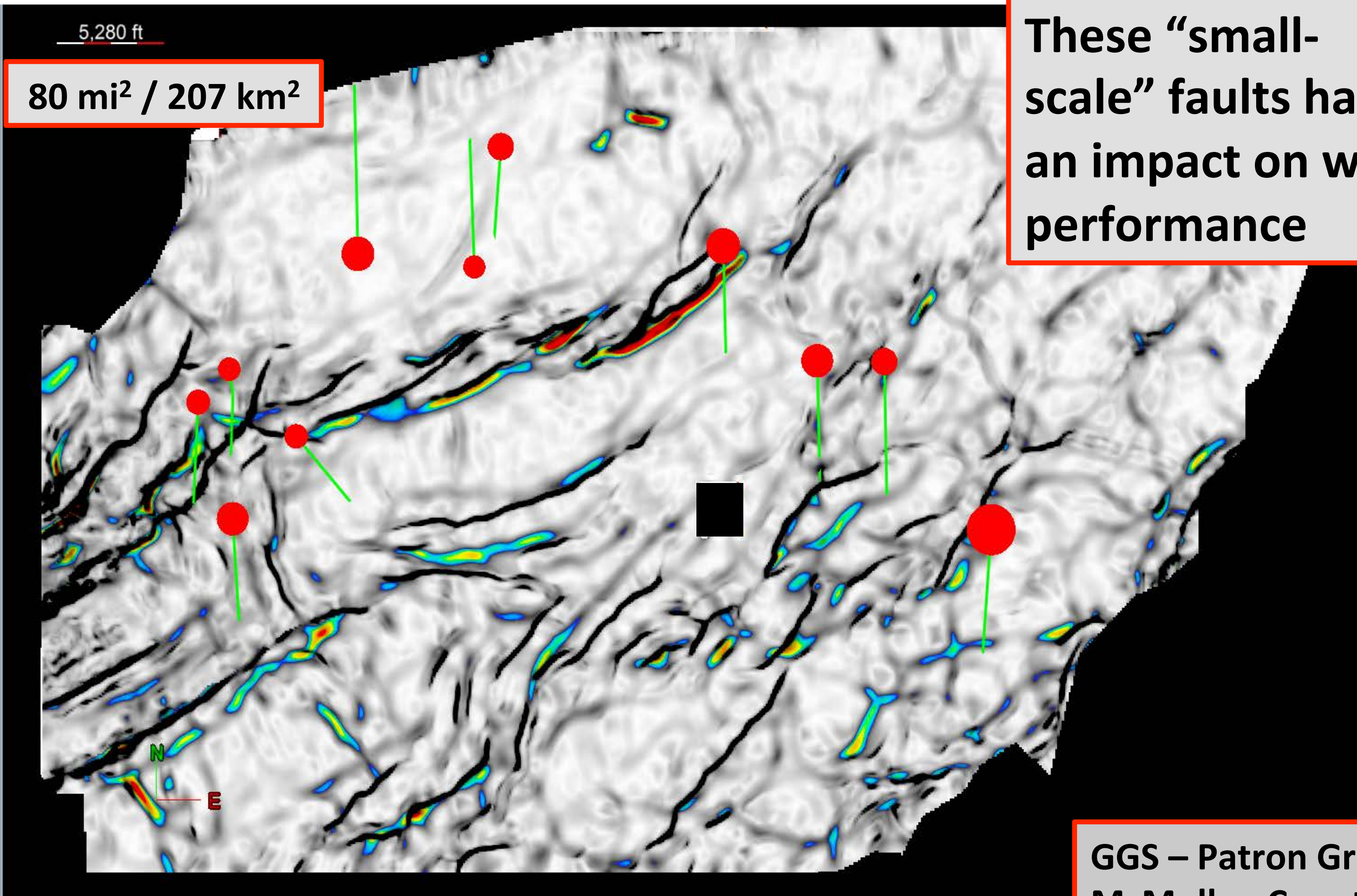
Fault Probability Attribute – South Texas
(derived from incoherence)



These near vertical faults and fractures have complex surface geometries

GGS – Multi-client Data

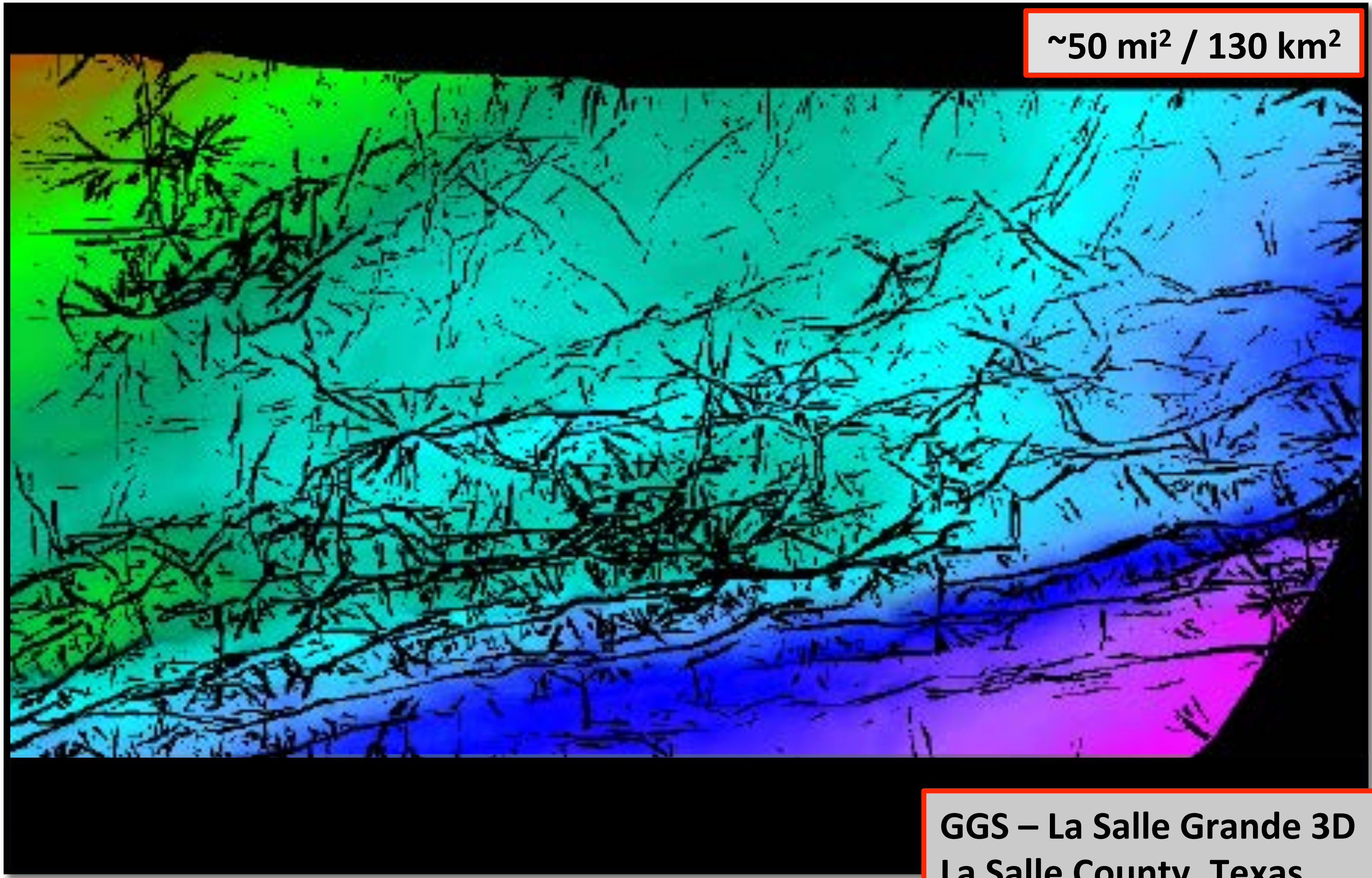
Incoherence & Max Curvature co-rendered with Max Monthly Gas Production



These “small-scale” faults have an impact on well performance

GGS – Patron Grande 3D
McMullen County

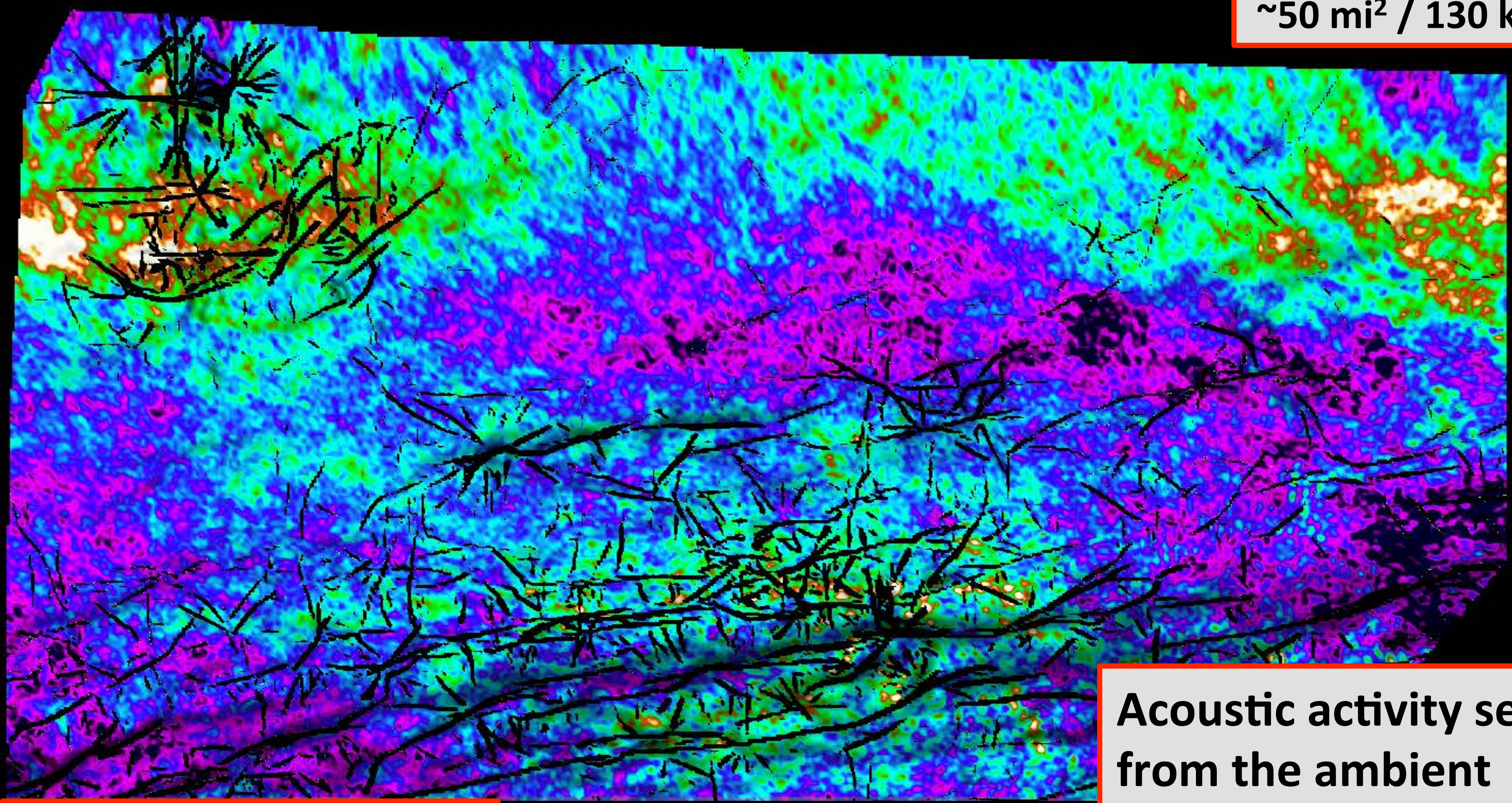
Eagle Ford with Fault Probability Attribute



GGS – La Salle Grande 3D
La Salle County, Texas

Ambient Seismic (Semblance) co-rendered with 3D Seismic (Fault Probability) - Eagle Ford

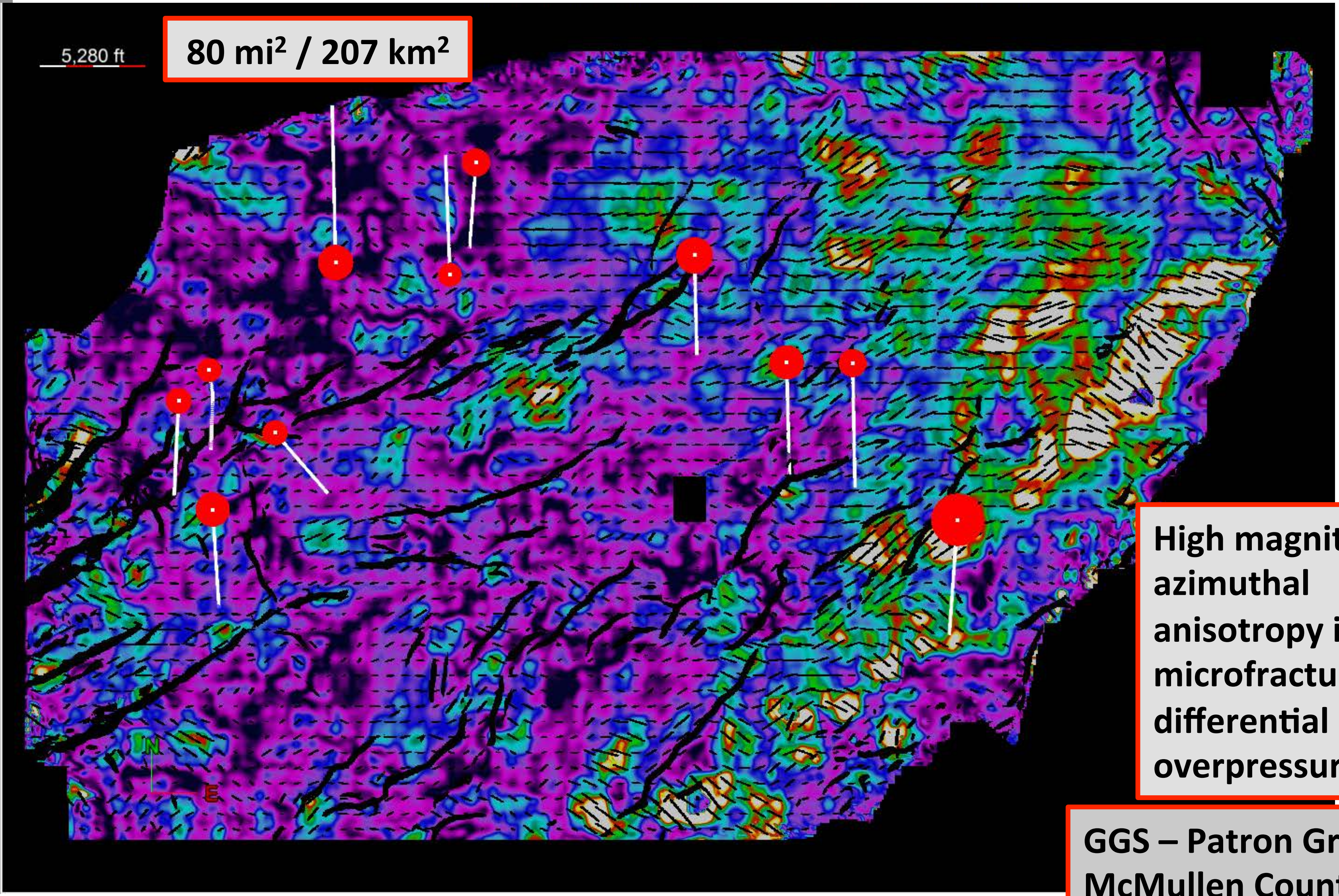
~50 mi² / 130 km²



GGS – La Salle Grande 3D
La Salle County, Texas

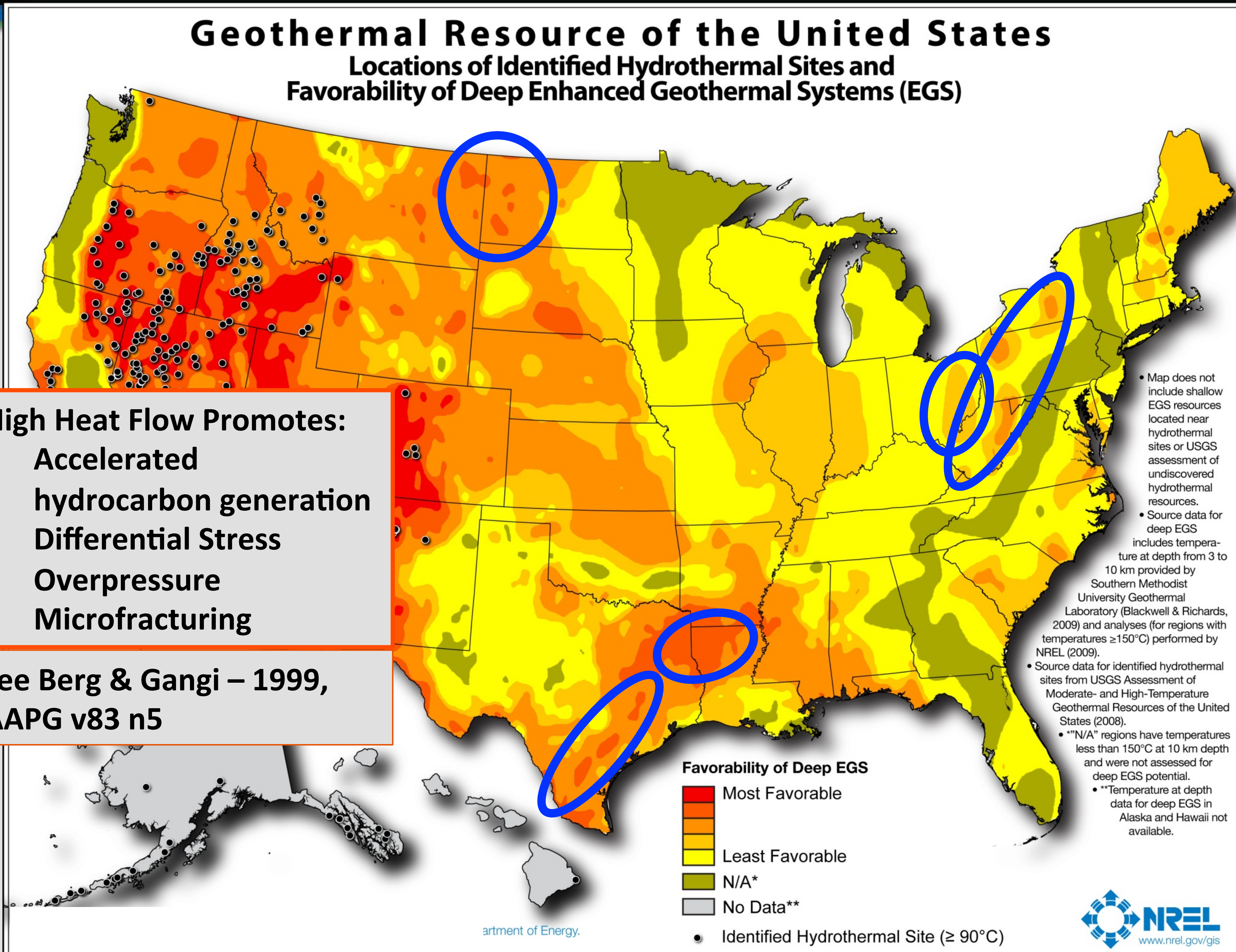
Acoustic activity seen from the ambient seismic highlights active fractures

Azimuthal Anisotropy with Max Monthly Gas Production – Eagle Ford



High magnitude azimuthal anisotropy identifies microfractures, differential stress, overpressure

GGS – Patron Grande 3D McMullen County



High Heat Flow Promotes:

- **Accelerated hydrocarbon generation**
- **Differential Stress**
- **Overpressure**
- **Microfracturing**

see Berg & Gangi – 1999, AAPG v83 n5

Resource / Reservoir Characteristics that drive productivity

- TOC
- Porosity
- Thickness
- Facies
- Brittle/Ductile Quality
- Differential Stress
- Stress Field Orientation
- Faults & Natural Fractures
- Oil & Water Saturation
- Pressure

Static & Dynamic Proxies for Producibility

Can we find proxies for these in seismic attributes?

How do we include engineering data?

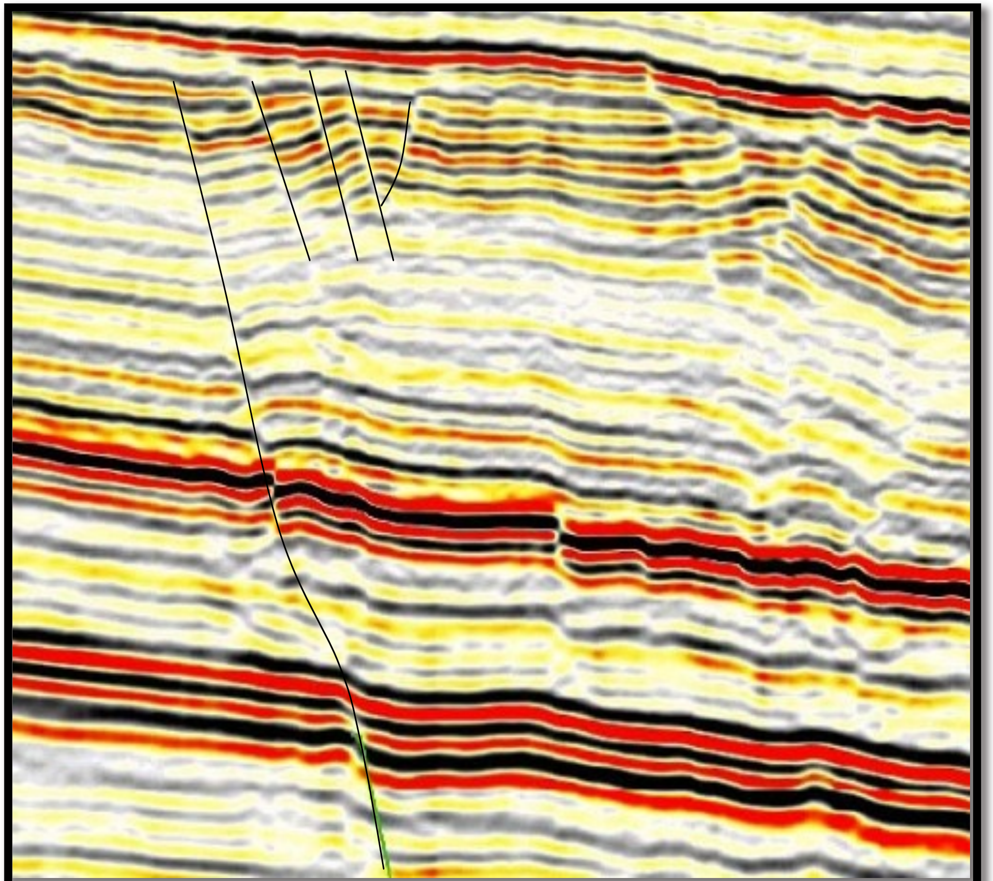
How do we capture the cumulative effect?

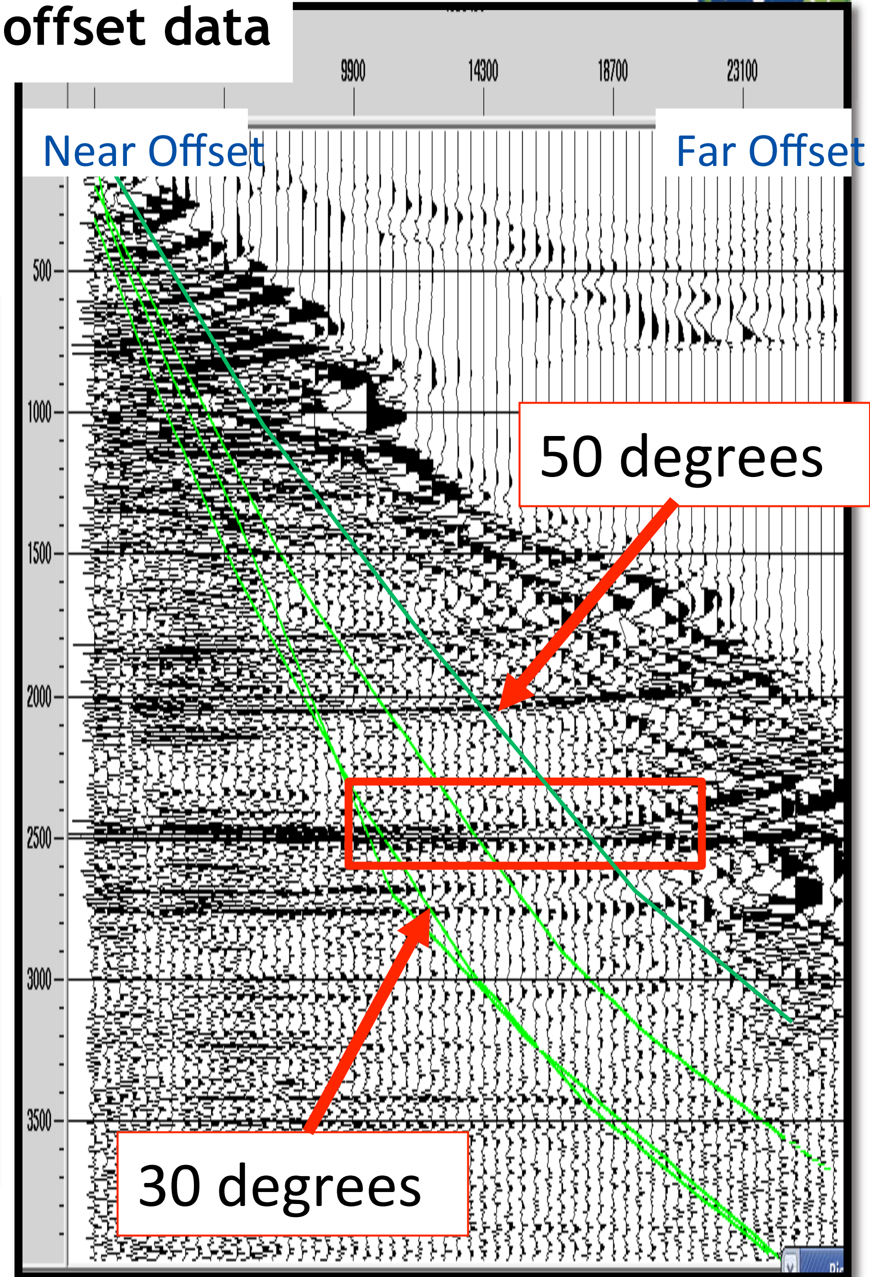
Seismic for Unconventionals

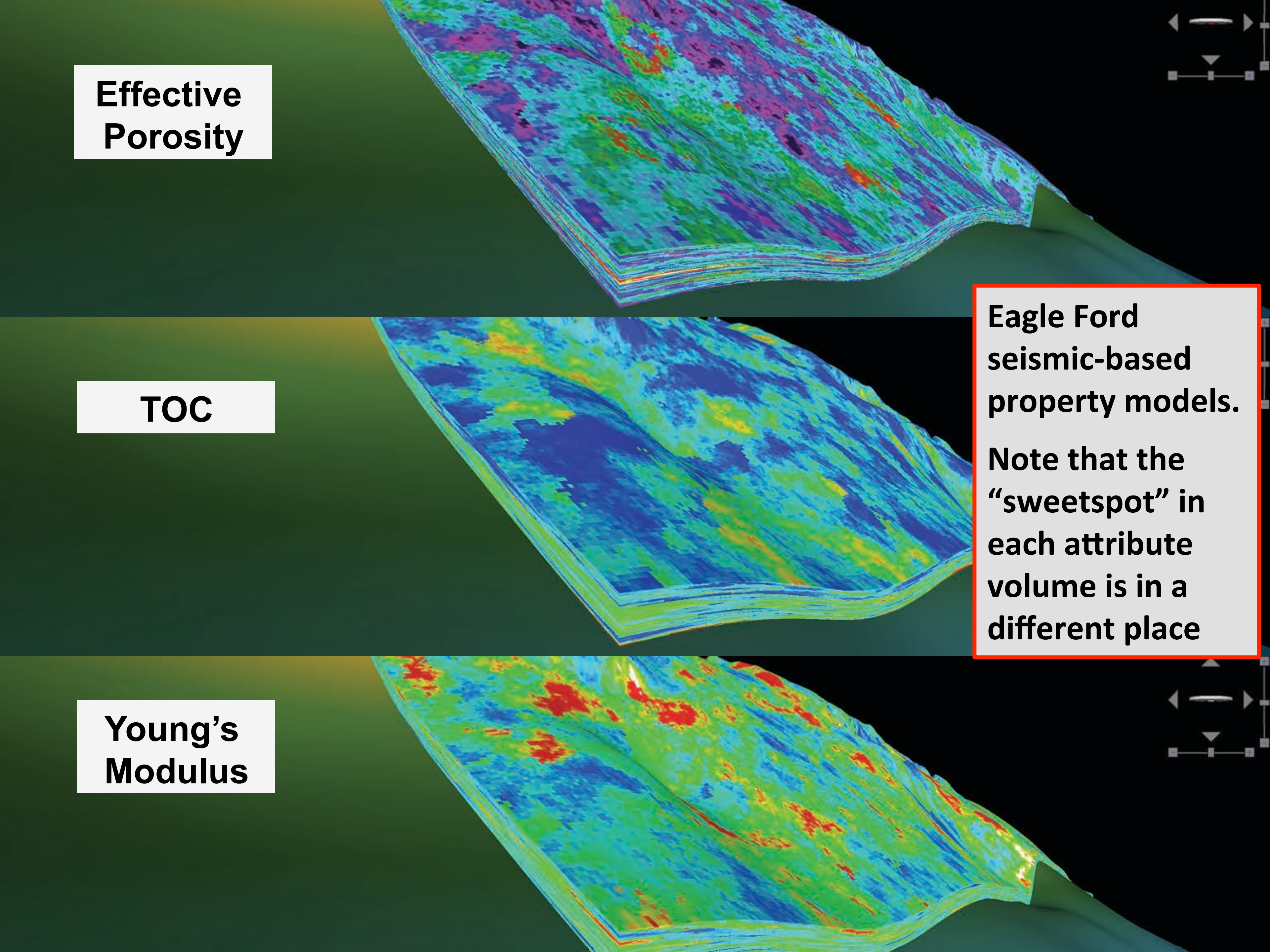
High channel count, full azimuth, long offset data

Crisp imaging of faults, fractures and layers

Analysis of anisotropy, rock properties etc…



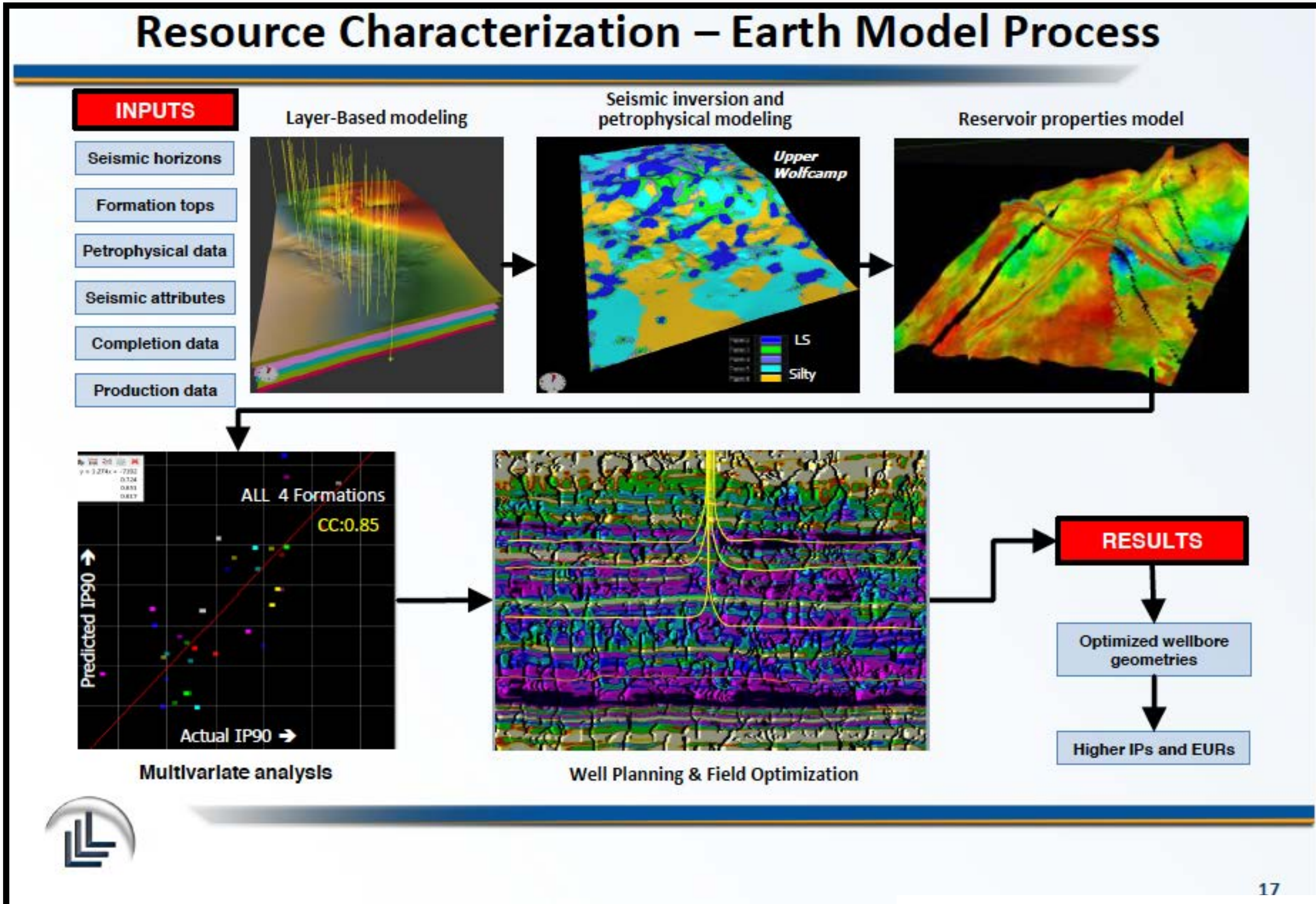




Eagle Ford seismic-based property models.

Note that the "sweetspot" in each attribute volume is in a different place

Workflow Example - Permian Basin - Wolfcamp



Source: Laredo Petroleum Investor Presentation, Apr 2015

3D Seismic Attributes

Amplitude and Structural Attributes

1) Amplitude
2) Relative Amp Change
3) Isochore
4) Depth
5) Envelope
6) Phase
7) Incoherence
8) Fault Probability
9) Distance to faults
10) Kshape
11) Kmaxmag Azimuth
12) Dip Azimuth
13) Time Dip
14) Kmax Curvature
15) Kmaxmag Curvature
16) Kmean Curvature
17) Kmin Curvature
18) Kneg Curvature
19) Kpos Curvature
20) Krms Curvature
21) Kgauss Curvature
22) Kstrike Curvature
23) Planarity
24) Linearity

Frequency Attributes

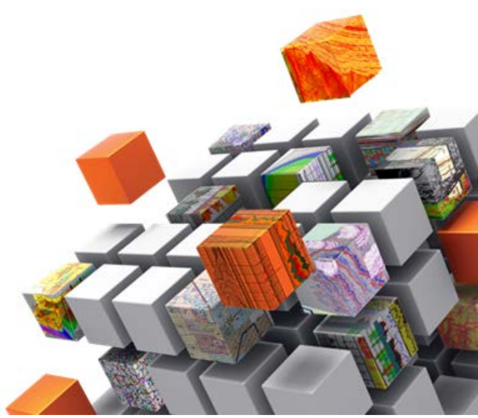
25) Spectral Decomposition 10Hz
26) Spectral Decomposition 12Hz
27) Spectral Decomposition 14Hz
28) Spectral Decomposition 16Hz
29) Spectral Decomposition 18Hz
30) Spectral Decomposition 20Hz
31) Spectral Decomposition 24Hz
32) Spectral Decomposition 28Hz
33) Spectral Decomposition 32Hz
34) Spectral Decomposition 36Hz
35) Spectral Decomposition 40Hz
36) Spectral Decomposition 45Hz
37) Spectral Decomposition 50Hz
38) Spectral Decomposition 55Hz
39) Spectral Decomposition 60Hz
40) Spectral Decomposition 60Hz
41) Dominant Frequency
42) Instantaneous Q
43) Average Frequency
44) Sweetness
46) Thin Bed Indicator
47) Interval Velocity

Rock Mechanical Properties

48) P Impedance
49) Shear Impedance
50) P-Wave Velocity
51) S-Wave Velocity
52) Density
53) Bulk Modulus
54) Shear Modulus
55) Vp/Vs
56) Poisson's Ratio
57) Young's Modulus
58) Lambda
59) Lambda Rho
60) Mu
61) Mu Rho
62) Relative Zp
63) Relative Zs
64) Relative Density
65) Frac Factor™

Anisotropy & Additional Attributes

66) HTI Magnitude
67) HTI Vfast Azimuth
68) VTI Eta Field
69) WOR Models

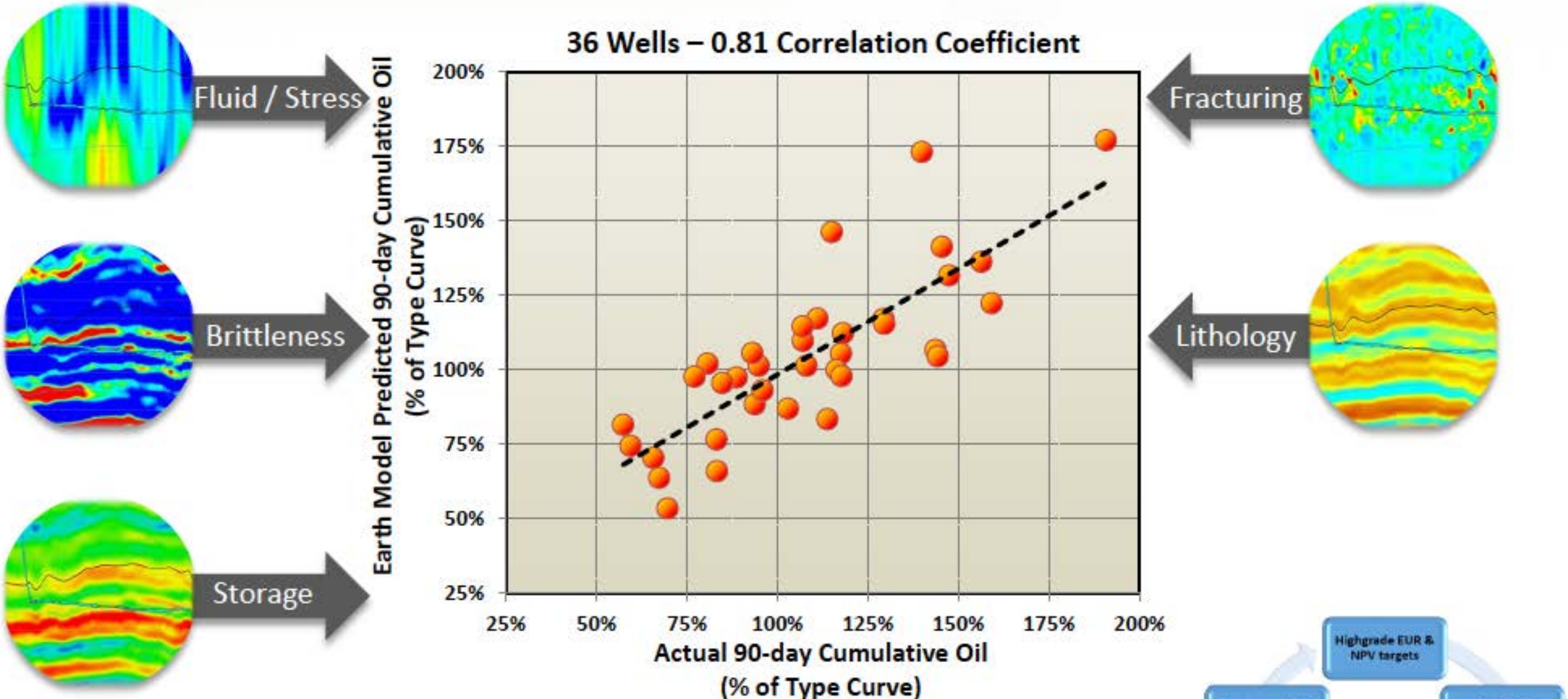


Engineering Attributes & Production Metrics

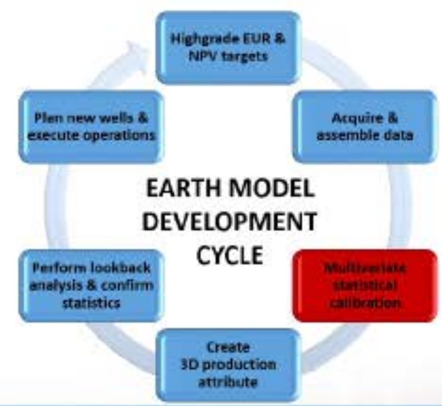
	Completion Variables
1	Time On Stream (months)
2	**Completion length (ft)**
3	Avg. Stage length (ft)
4	Number of stages
5	**Fracture gradient (psi/ft)**
6	Breakdown Pressure (psi)
7	ISIP (psi)
8	Slurry volume pumped (bbl/stage)
9	Clean Fluid pumped (bbl/stage)
10	Acid pumped (gals/stage)
11	**Avg. Injection Rate (bbl/min)**
12	Clean Fluid rate (bpm/stage)
13	Total Proppant pumped (lb/stage)
14	Gas rate (bpm/stage)

	Production Metrics
1	Min Daily Avg. (MCF)
2	Mean Daily Avg. (MCF)
3	Max Daily Avg (MCF)
4	**Max 30 Day (MCF)**
5	**3-month Cum Production (MCF)**
6	**6-month Cum Production (MCF)**
7	EUR (MCF)
8	Scaled Max 30 Day (MCF/ft)
9	Scaled Max Daily Average (MCF/ft)
10	Cum/time (MCF/month)

Step 2: Define Multivariate Relationships & Relate to IP



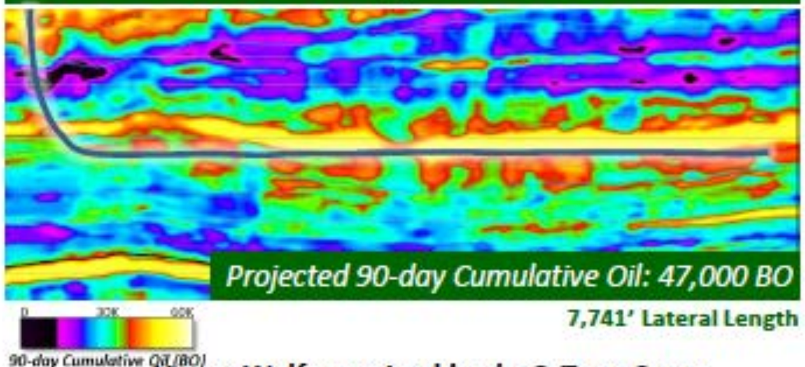
Earth Model achieves 0.81 correlation coefficient between 90-day cumulative oil and Earth Model attributes using multivariate statistics



Source: Laredo Petroleum Investor Presentation, Apr 2015

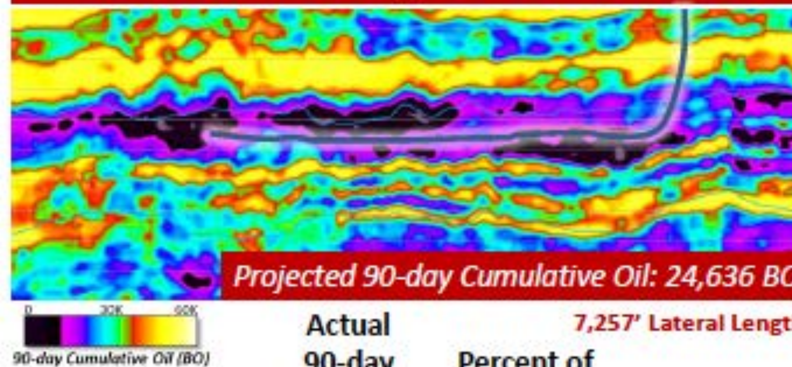
Contrasting Upper Wolfcamp Lookback Examples

Above Type Curve

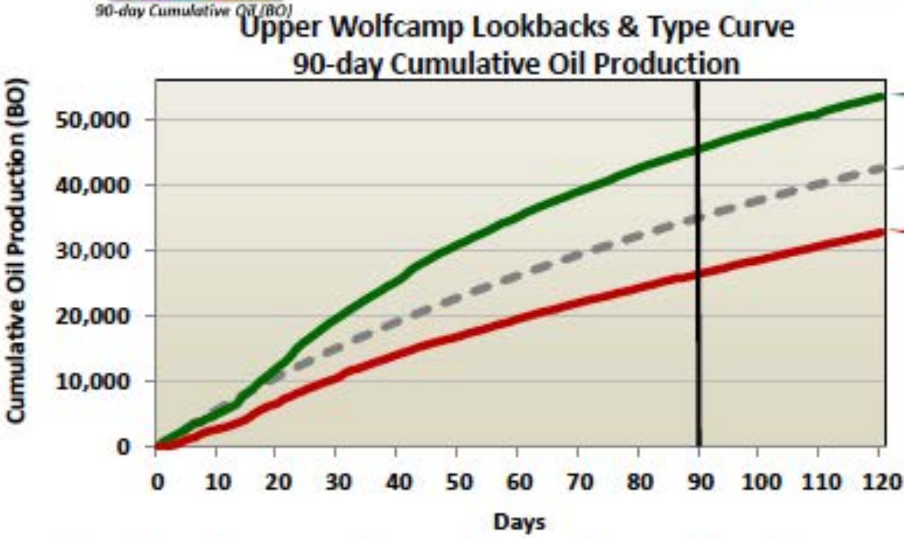


7,741' Lateral Length

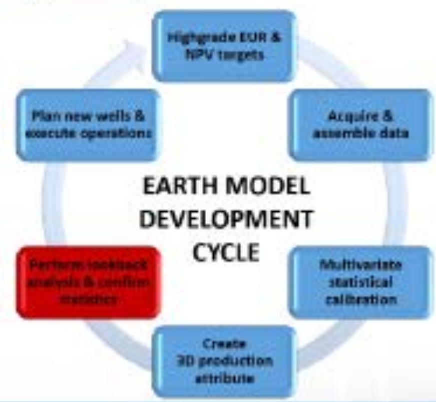
Below Type Curve



7,257' Lateral Length



	Actual 90-day Production [1]	Percent of Type Curve
Above Type Curve	45,517 BO	130%
Type Curve	35,075 BO	100%
Below Type Curve	26,233 BO	75%



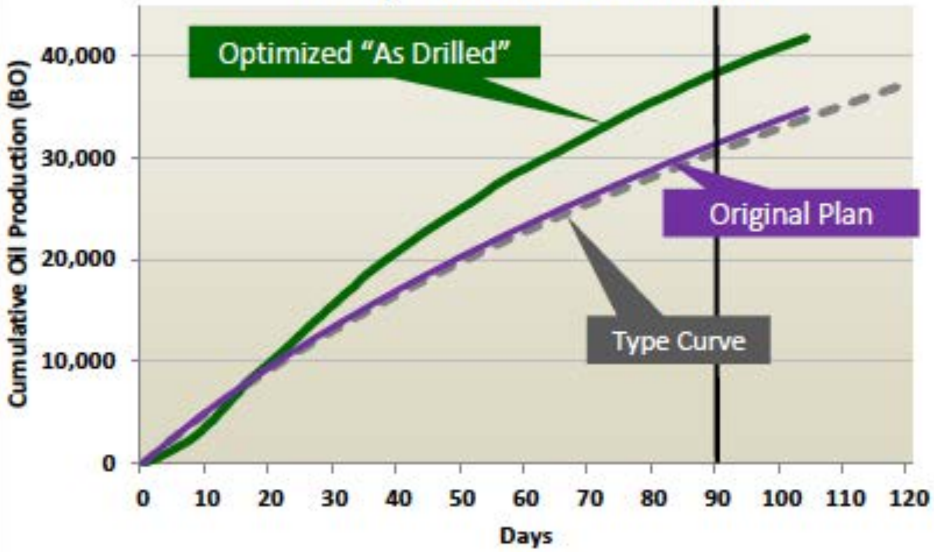
Production attribute is a vibrant indicator of 90-day cumulative oil production

[1] Cumulative oil production from Upper Wolfcamp lookback examples normalized to 7,500' type curve

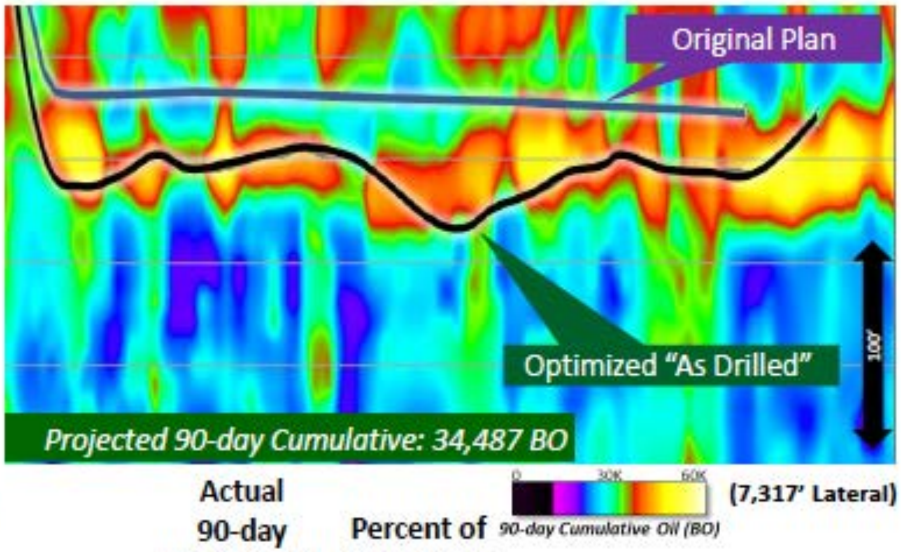
Source: Laredo Petroleum Investor Presentation, Apr 2015

Middle Wolfcamp Targeting Uplift Example

Middle Wolfcamp Lookback & Type Curve
90-day Cumulative Oil Production

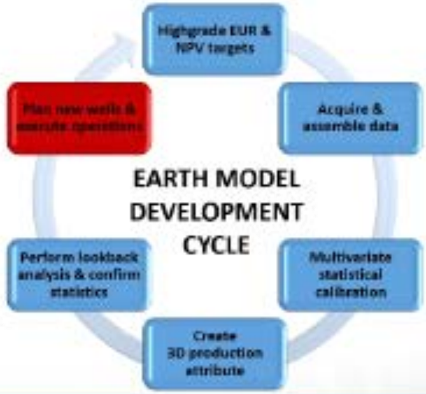


Middle Wolfcamp Targeting Example



Actual 90-day Production[1]	Percent of Type Curve
Actual: 38,430 BO	125%
Original: 31,453 BO	103%
Type Curve: 30,655 BO	100%

Optimized "as drilled" targeting results demonstrate 25% improvement in 90-day cumulative oil from type curve



Predicted Production = 34,487; Actual production = 38,430

[1] Cumulative oil production from Middle Wolfcamp lookback examples normalized to 7,500' type curve

Source: Laredo Petroleum Investor Presentation, Apr 2015

Summary

- Unconventional Well Productivity is a function of the interplay of many static and dynamic characteristics **requiring an integrated, multivariable solution**
- Seismic attributes can be **proxies** for these characteristics
- You can use seismic & engineering attributes to generate **predictive 3D models of reservoir properties and production**
- These models allow you to ***localize*** or ***customize*** well and completion design
- Recent **innovations in ambient seismic** processing allow you to characterize active natural fractures.

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Select References - Unconventionals

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