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Role of Integrated Reservoir Petrophysics in Horizontal Well Evaluations to Increase Production in Organic Rich Shales

Kevin Fisher
Schlumberger

Society of Petroleum Engineers
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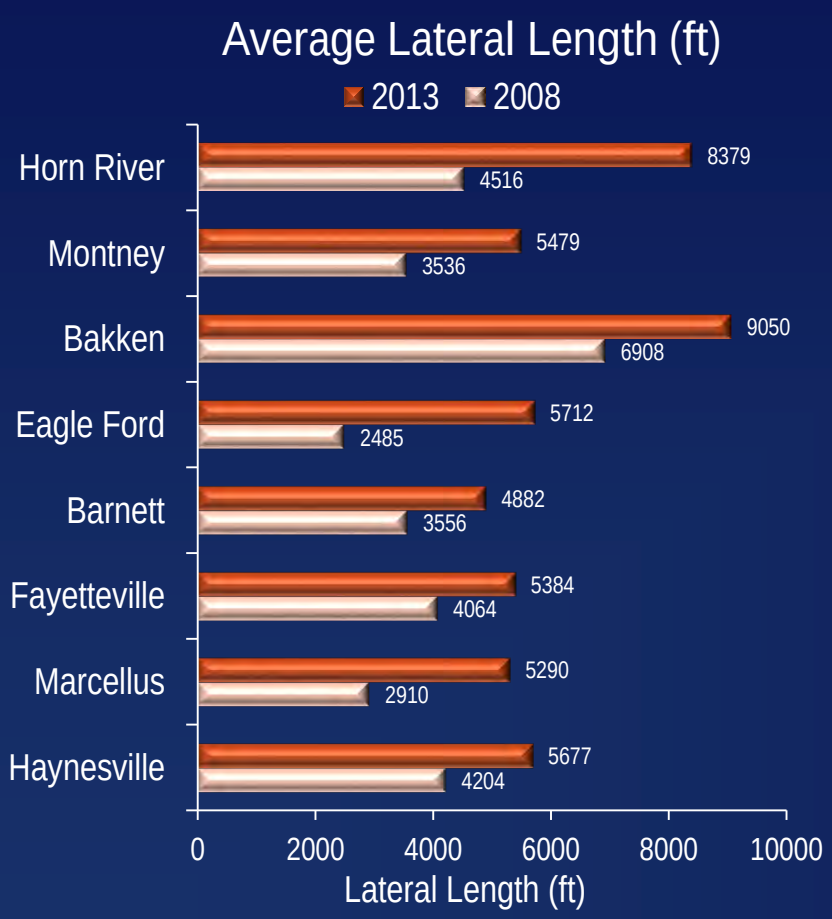
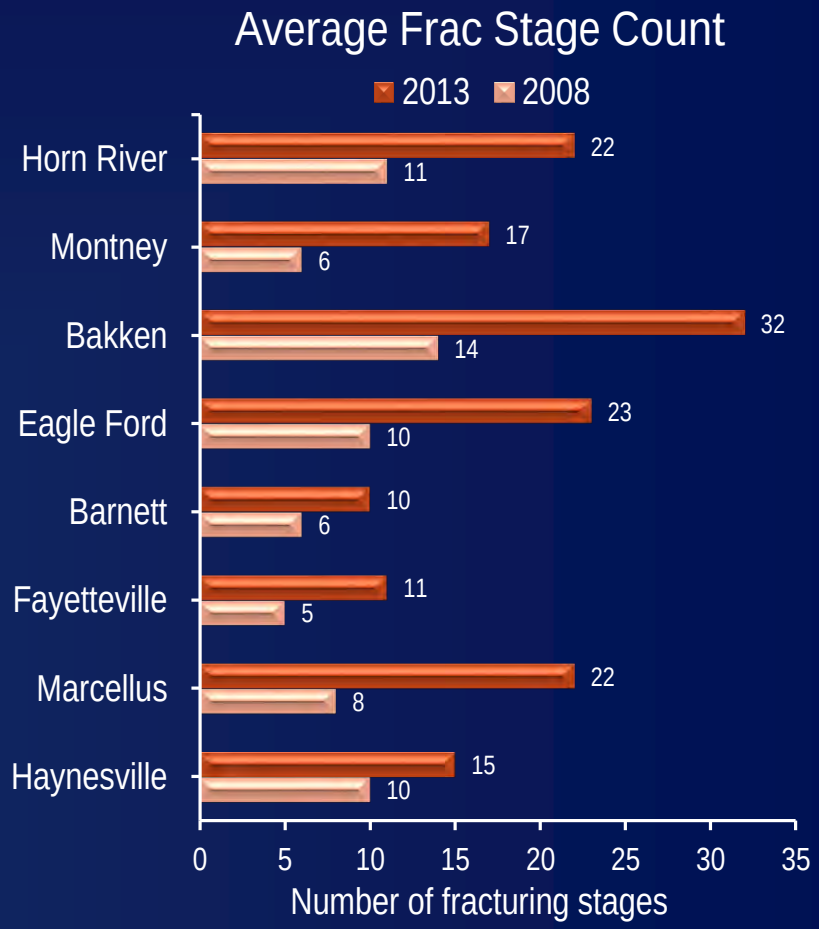
Agenda

- Reality
- Workflow: Integration
  - Geology Quality: GQ
  - Reservoir Quality: RQ
  - Completion Quality: CQ
- Results (multiple basins)
- Lessons learned

Reality – Lateral Lengths





Reality – Production

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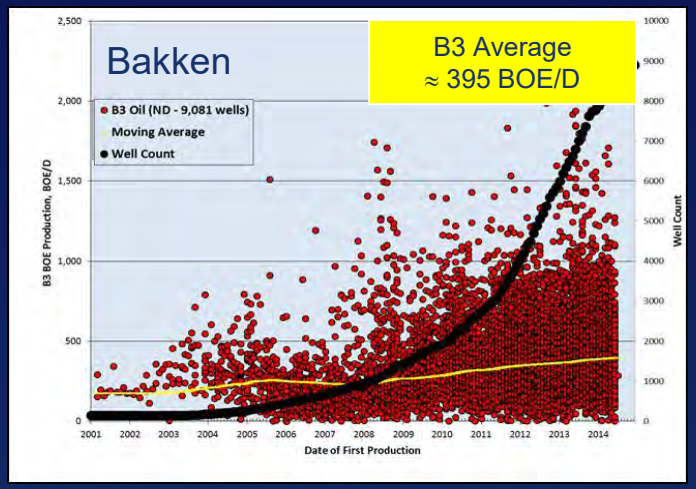
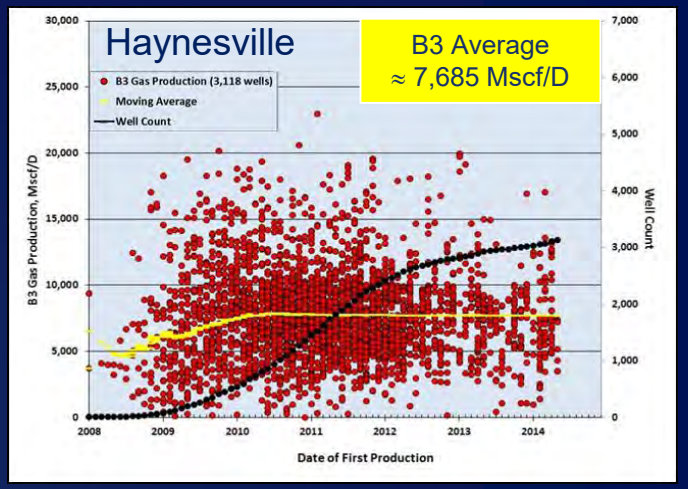
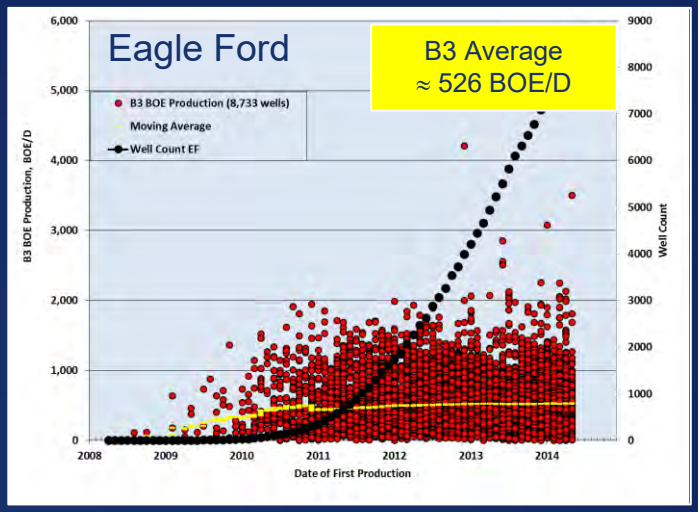
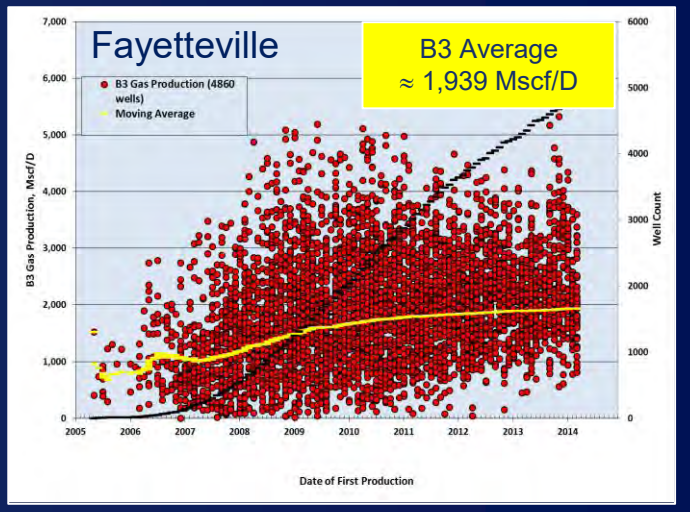




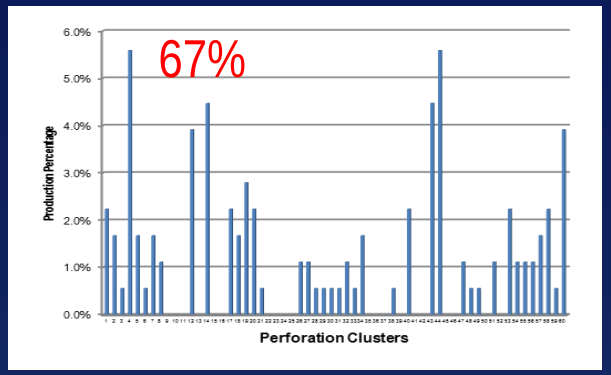


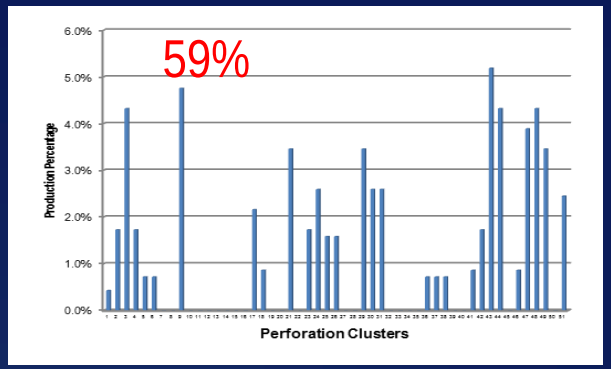


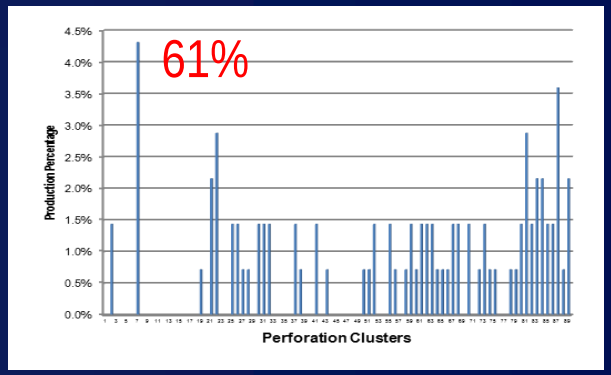
Source: IHS

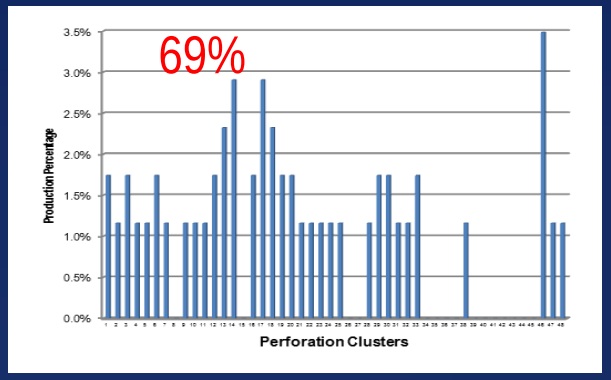
B3 = Best 3 months production

Production is Not Uniform



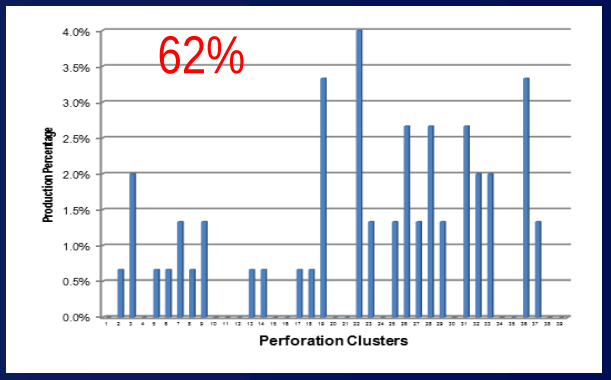






Production Log Examples

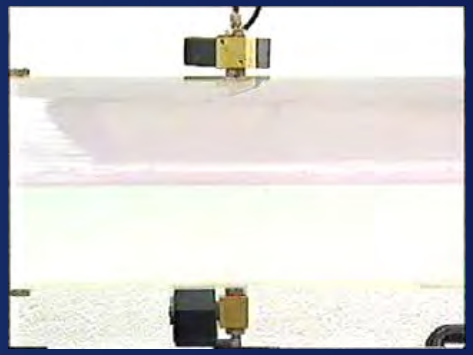
- Only 64% of the Perforation Clusters are contributing
- All wells were completed Geometrically



Horizontal Production Log

- Evaluation of Production Log Data from Horizontal wells Drilled in Organic Shales
  - Miller-SPE-144326-MS-P-2011
- Designed specifically for horizontal wells

88 degrees



90 degrees

92 degrees

Case Study: Eagle Ford Consortium

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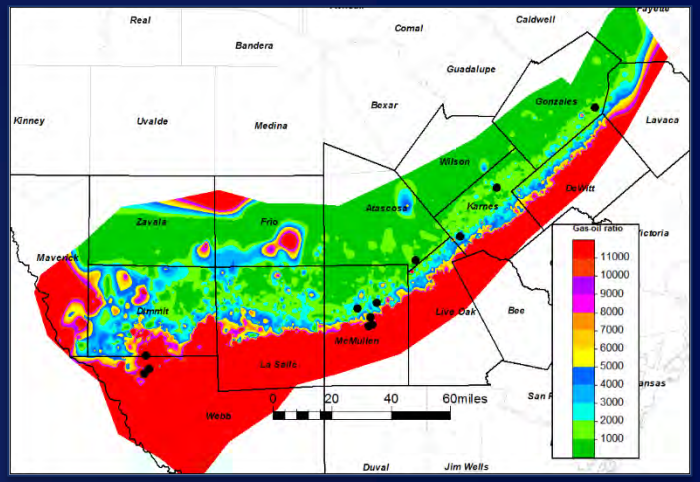
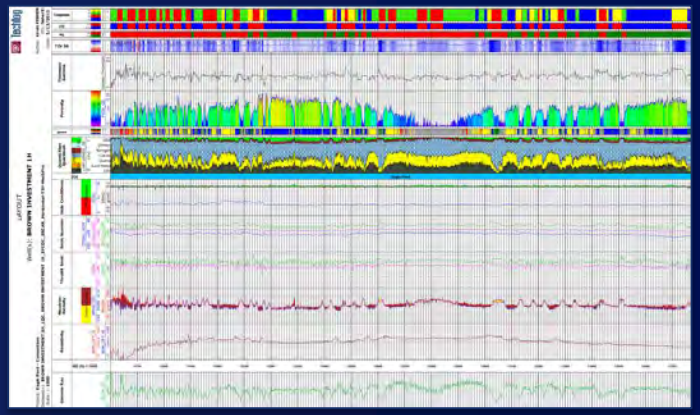
Original Hypothesis:

1. *"In a horizontal well placed in good Reservoir Quality rock with lateral variation in stress, a more effective stimulation can be achieved by **<u>grouping similarly</u>** stressed rock for treatment."*
2. *"This will be characterized by a reduced number of perforation clusters showing no productivity, leading to better overall recovery and drainage"*





Slocombe, et al, SPE 13ATCE-P-166242 2013

Unconventional Reservoir Optimized Completion (U-ROC)

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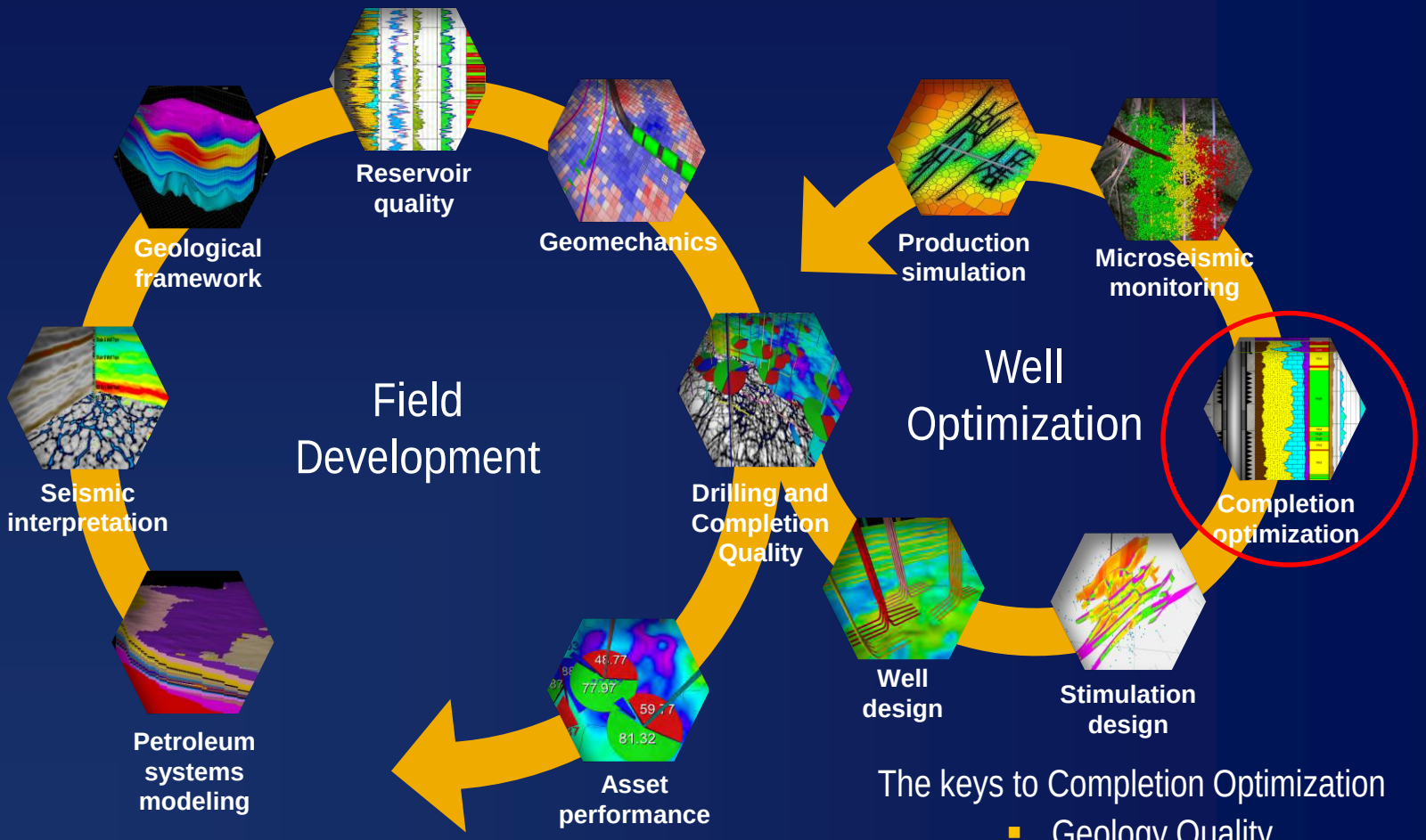


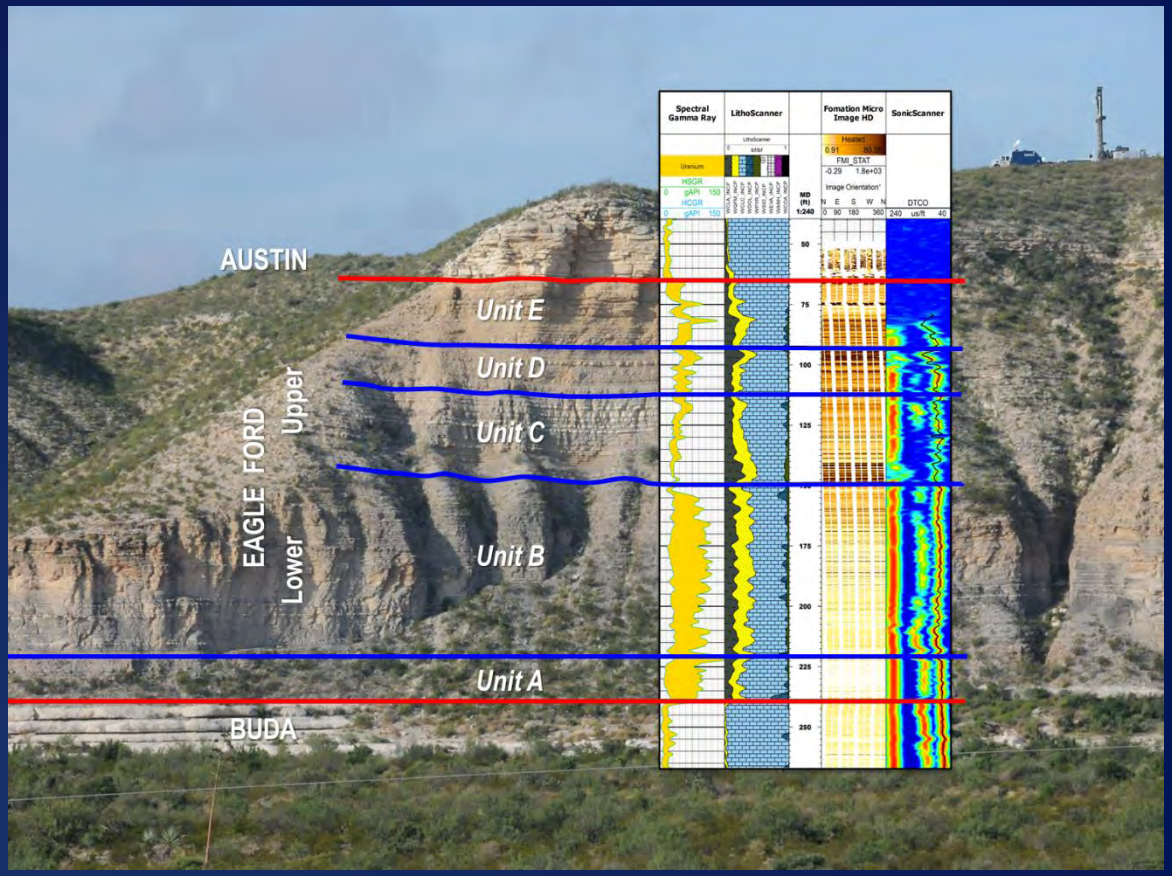
The keys to Completion Optimization

- Geology Quality
- Reservoir Quality
- Completion Quality

Geology Quality: GQ

- Analog – Outcrop
- Landing Point
- “Like Rock”
- Pilot to Lateral correlations

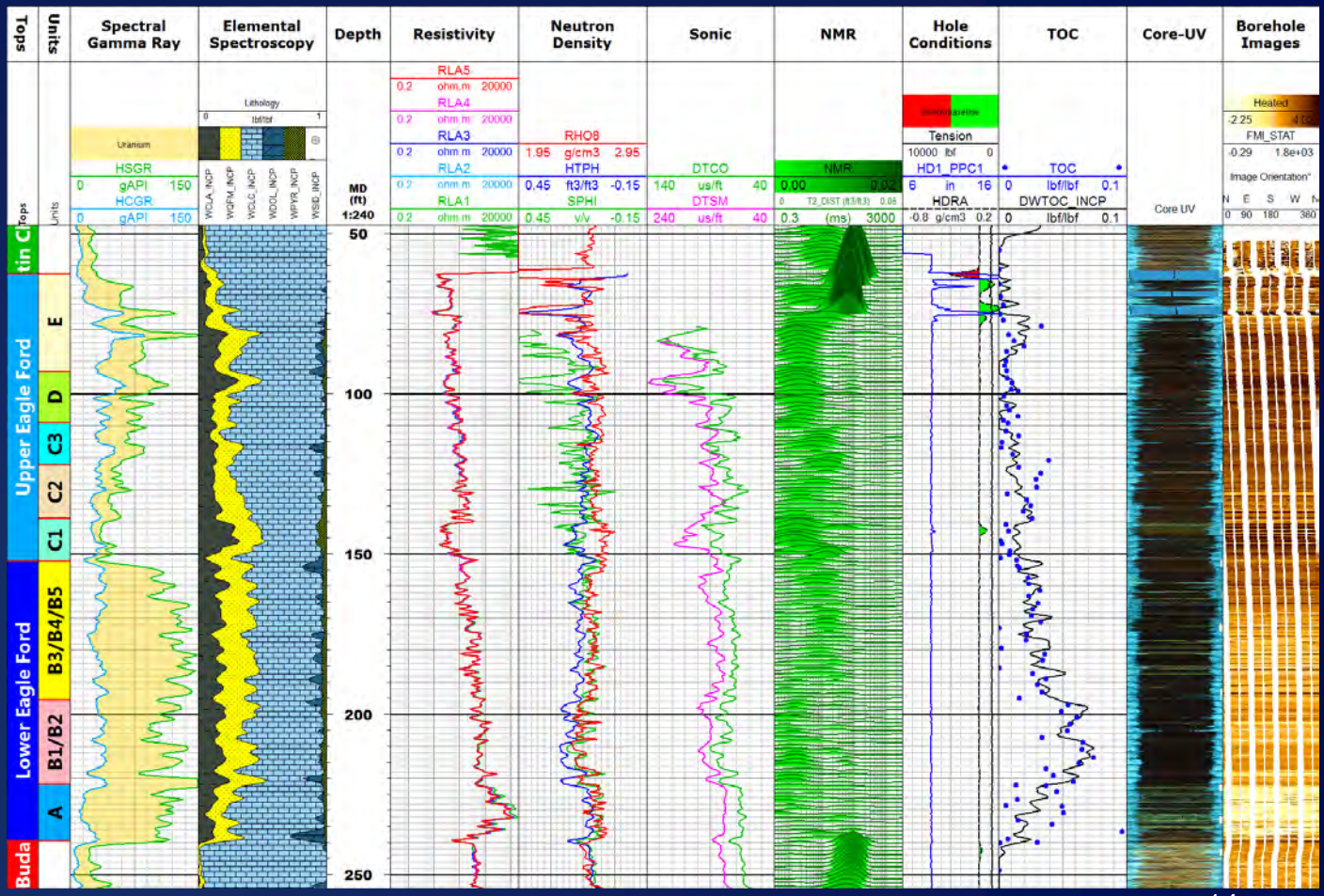
Analog – Outcrop
Eagle Ford example



Donovan, URTeC 1580954, 2013

Know your Geology

- Members
- Units
- Issues
  - Clay
  - Ash beds
  - Fractures
  - Faults
- Identify on logs



UV Core Photos - B3/B4/B5

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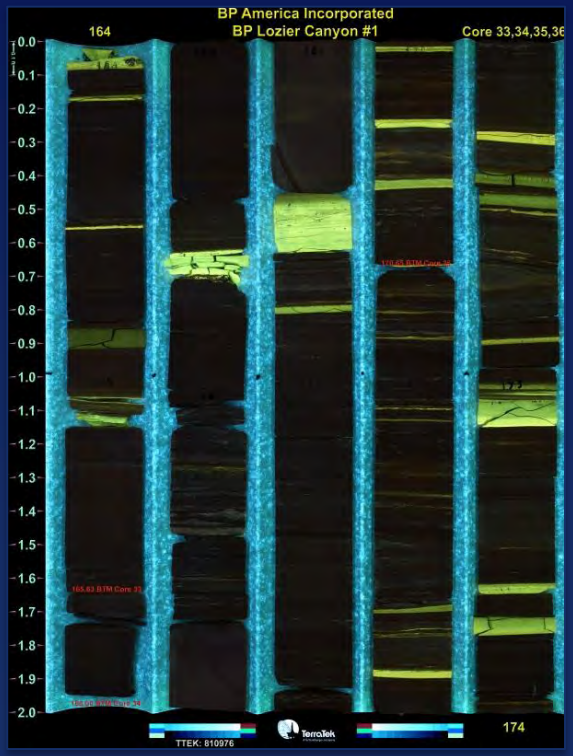
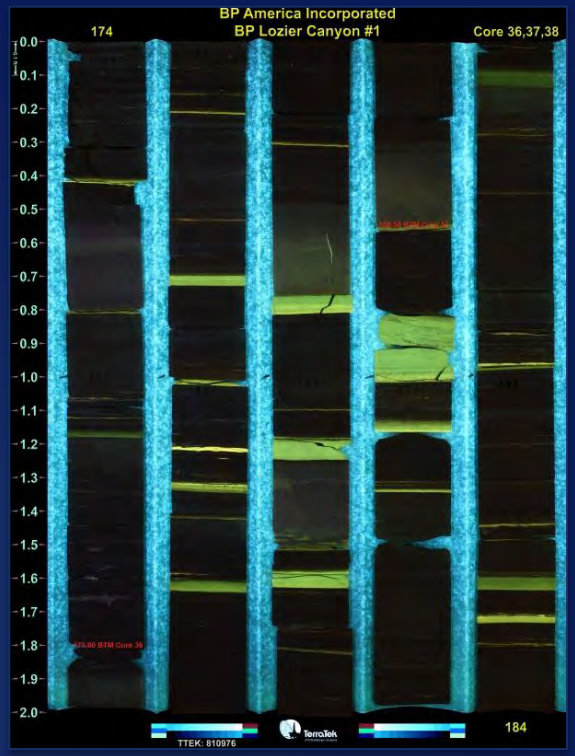
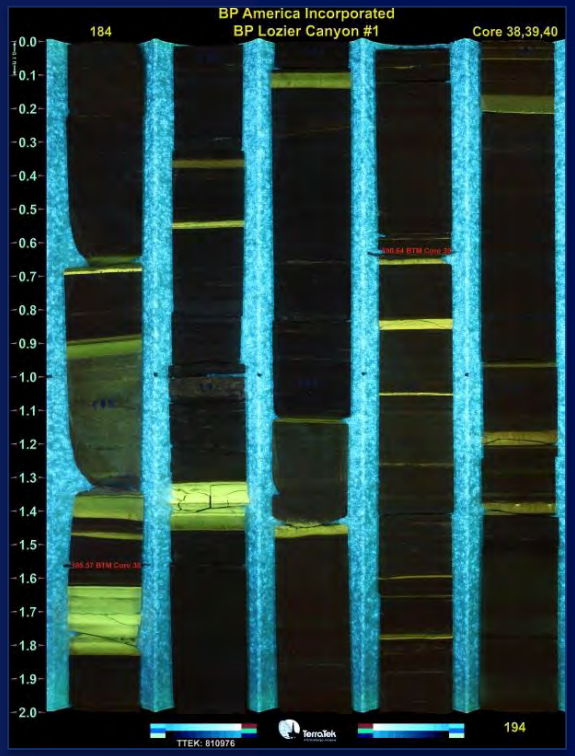
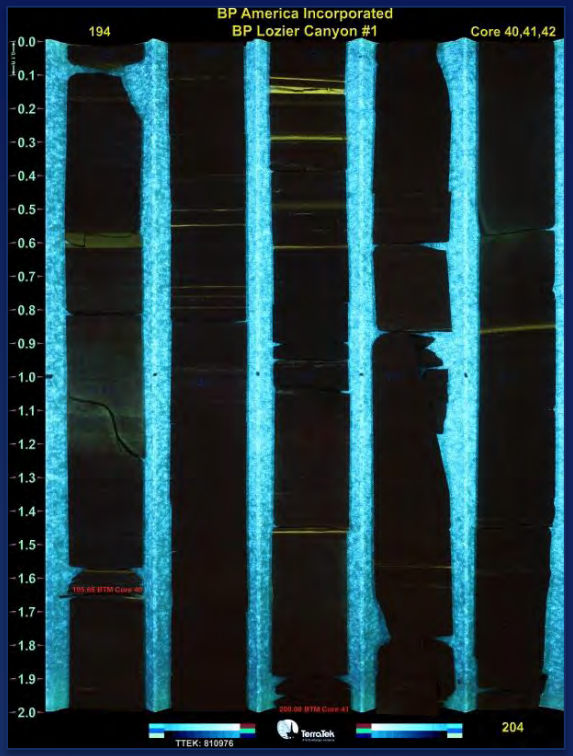


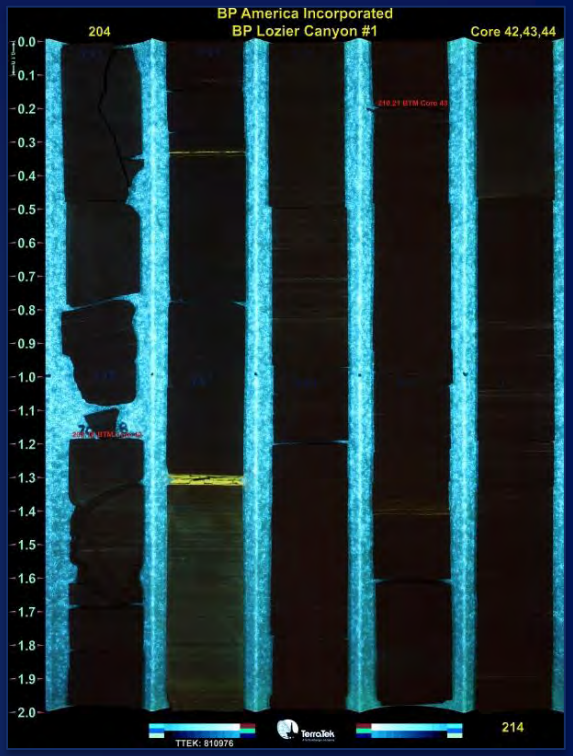




(Ash Beds are fluorescent)

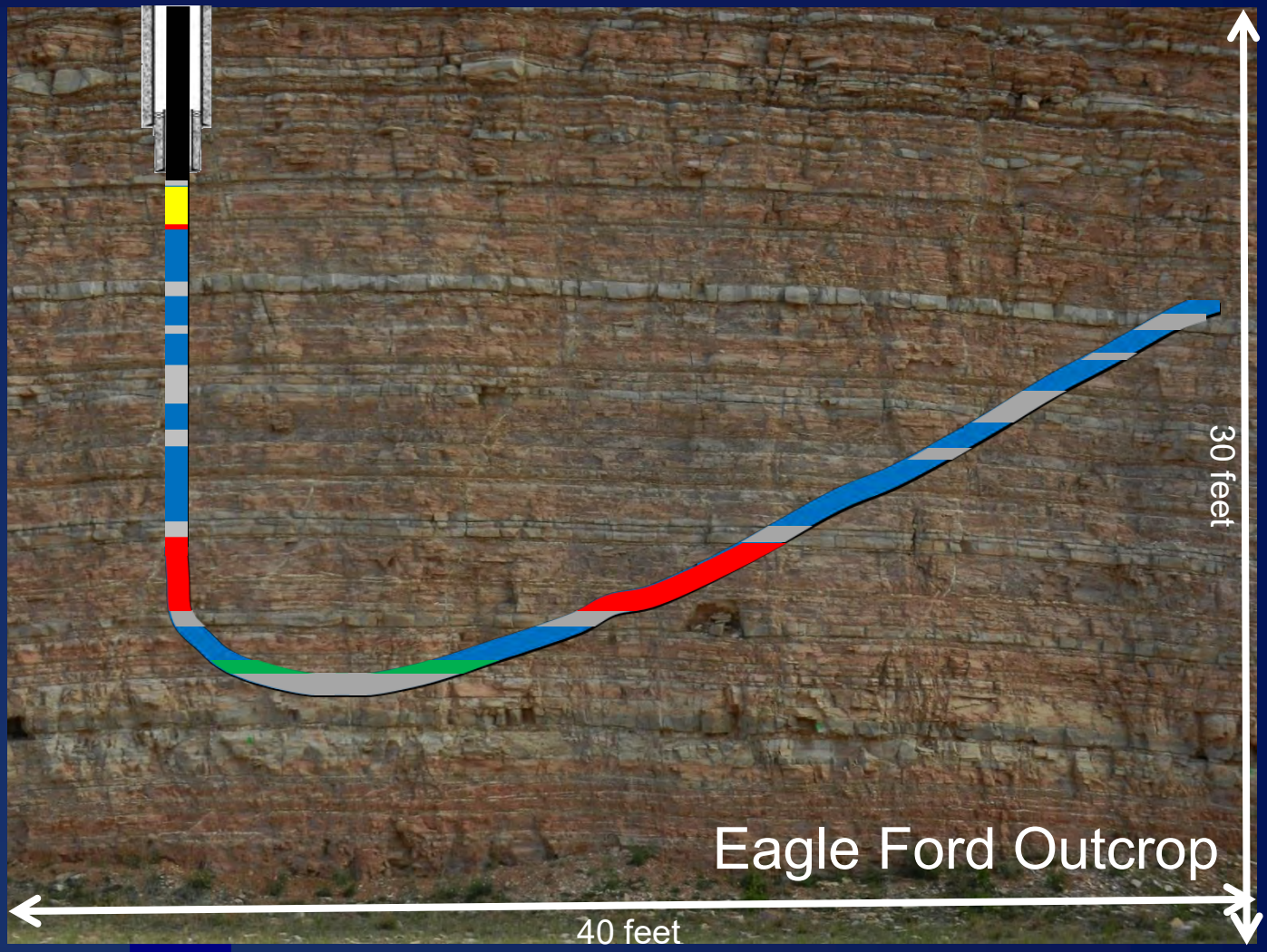
UV Core Photos - B1/B2





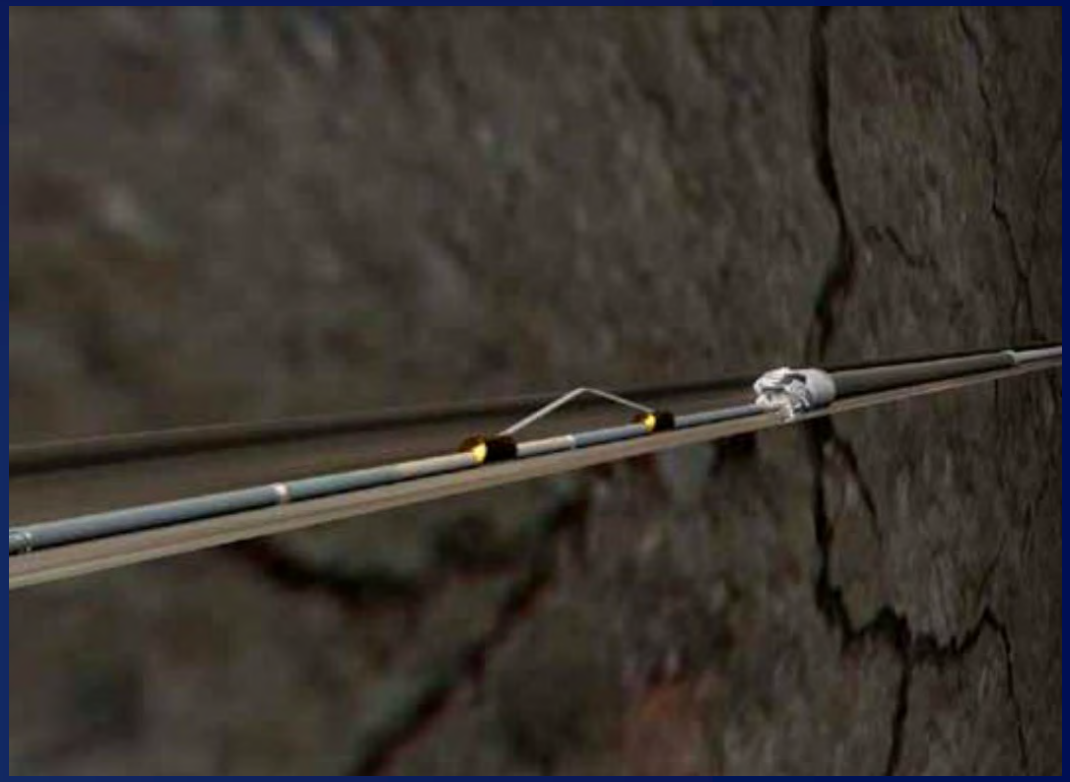
(Ash Beds are fluorescent)

Correlating Science Pilot well to Lateral with “like rock” types



Lateral Measurements and Deployment

- Openhole
- Casedhole
- LWD
- Cuttings



Reischman, R., SPE-143963-MS, 2011

Reservoir Quality: RQ "Like Rock" Workflow

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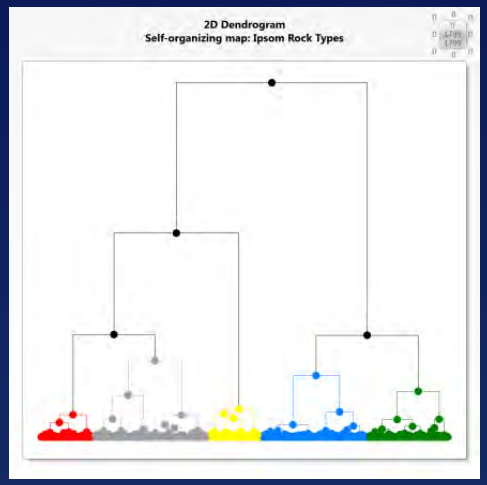
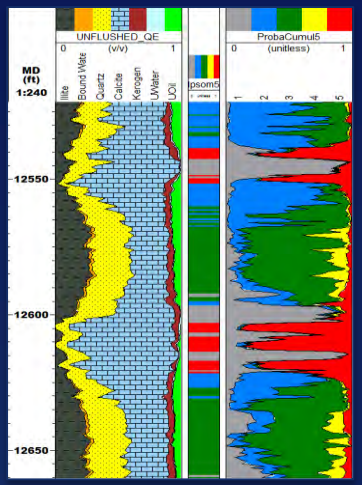
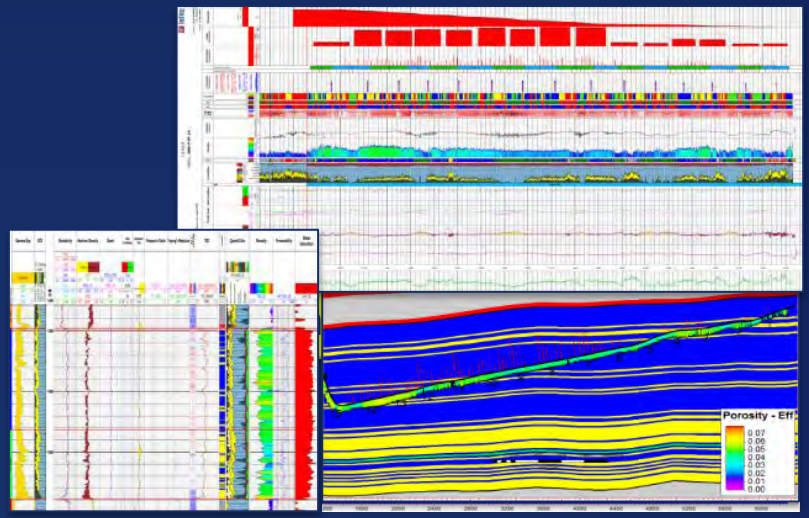




Grouping "like rock"

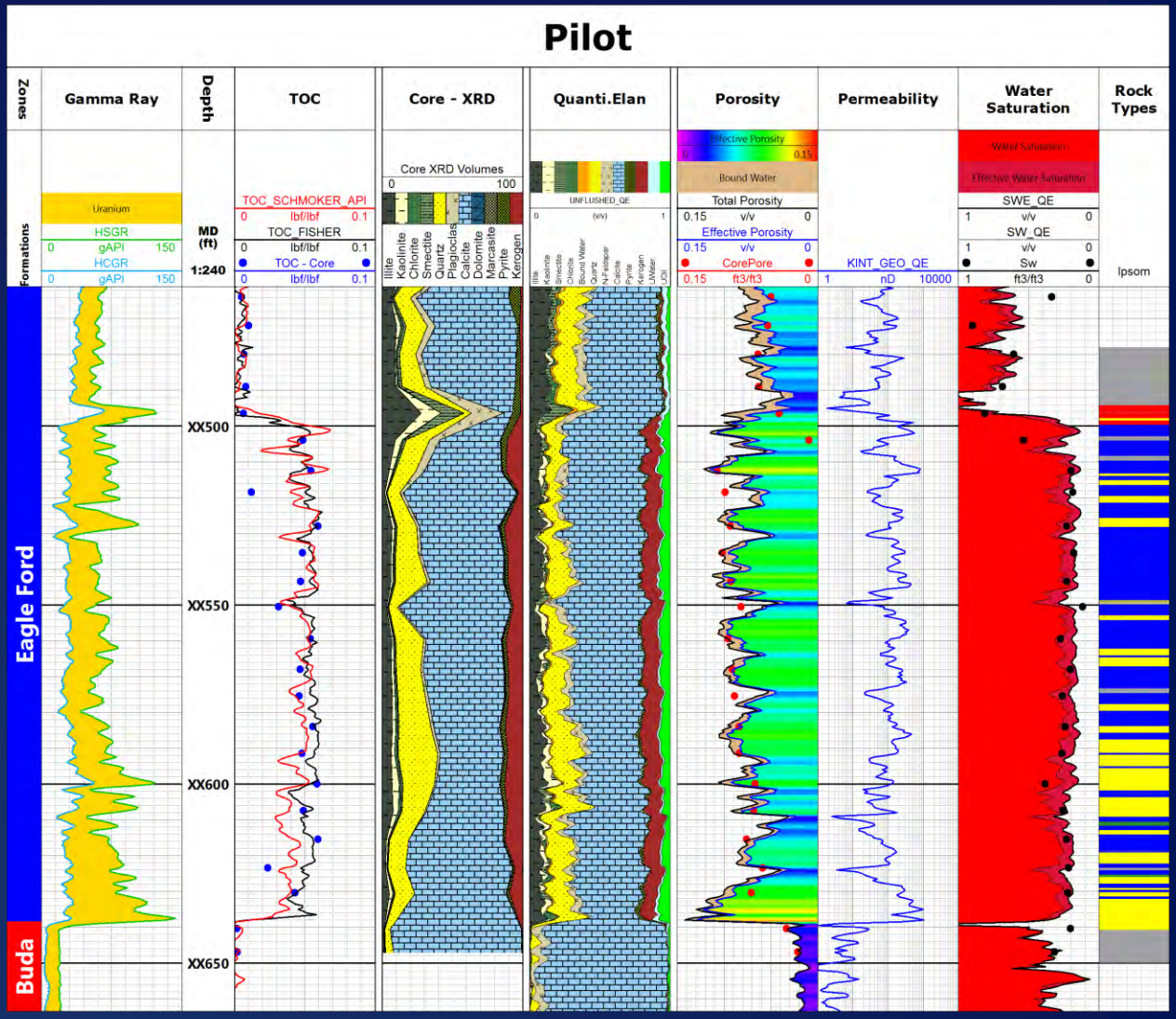
Color/Rock Type					
Clay Volume Fraction (v/v)	0.134	0.294	0.434	0.055	0.21
Effective Porosity (v/v)	0.074	0.068	0.034	0.039	0.016
Permeability (nD)	245	133	23	24	10
Total Organic Carbon (weight %)	4.90%	4.30%	2.20%	3.00%	1.90%
Thermal Neutron Porosity (v/v)	0.162	0.208	0.212	0.086	0.102
Bulk Density (g/cc)	2.422	2.449	2.565	2.519	2.579
Gamma Ray (gAPI)	67.9	87	99.4	49.9	69.6

IPSOM	Rock Quality
1	High TOC marl
2	High TOC marl
3	Low TOC argillaceous shale
4	Limestone
5	Low TOC marl

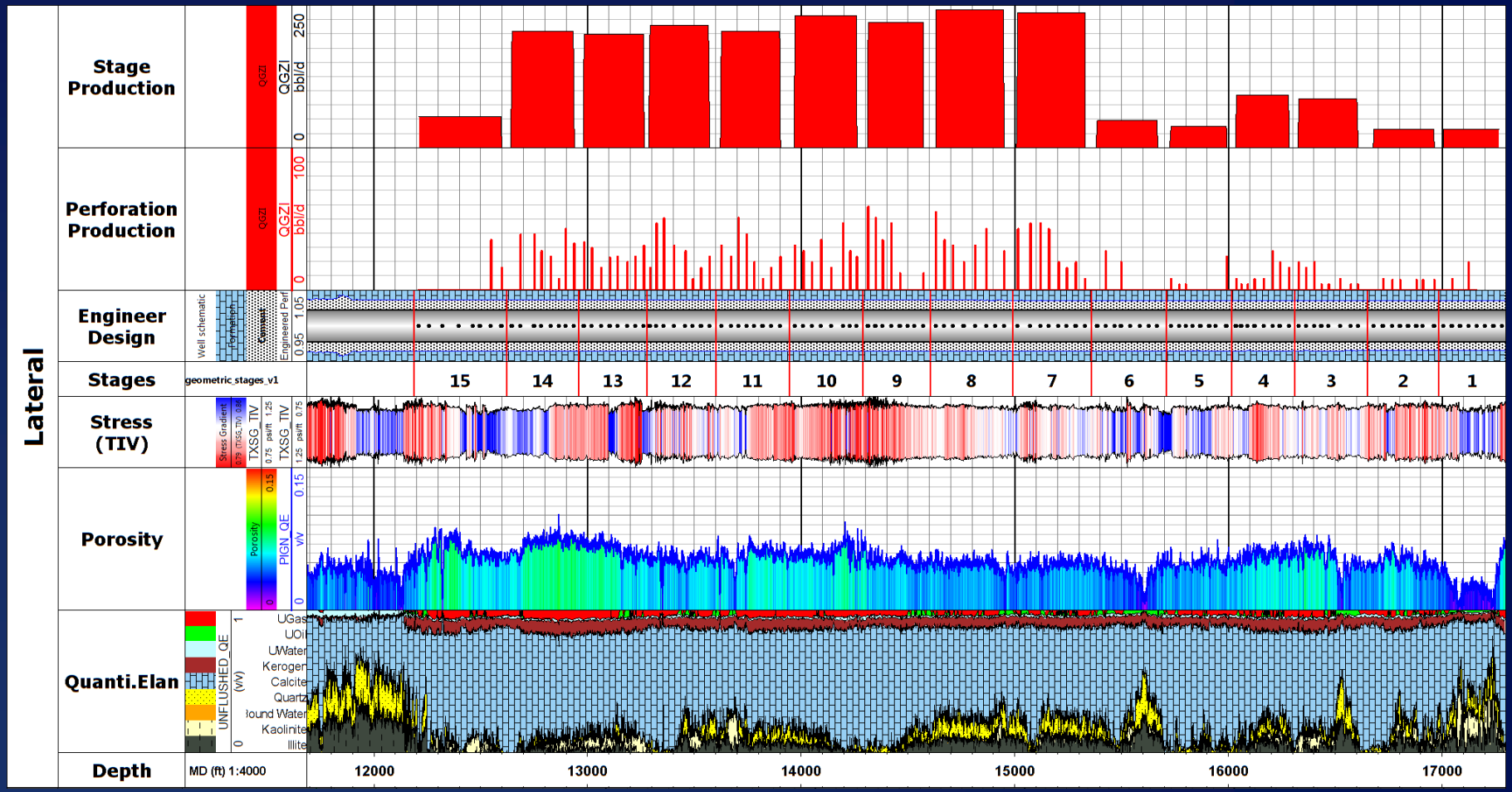


Pilot

SPE DISTINGUISHED LECTURER



Lateral


Lateral
Stage Production
QGZI
bbl/d
250
0
Perforation Production
100
Engineer Design
Well schematic
Formation
Engineered Perf
0.95
1.05
Stages
geometric_stages_v1
15
14
13
12
11
10
9
8
7
6
5
4
3
2
1
Stress (TIV)
Stress Gradient
TXSG_TIV
0.75
1.25
psi/ft
Porosity
PIGN_QE
0.15
v/v
Quanti.Elan
UNFLUSHED_QE
(v/v)
UGas
UOil
UWater
Kerogen
Calcite
Quartz
Bound Water
Kaolinite
Illite
Depth
MD (ft) 1:4000
12000
13000
14000
15000
16000
17000

Pilot and Lateral Integration

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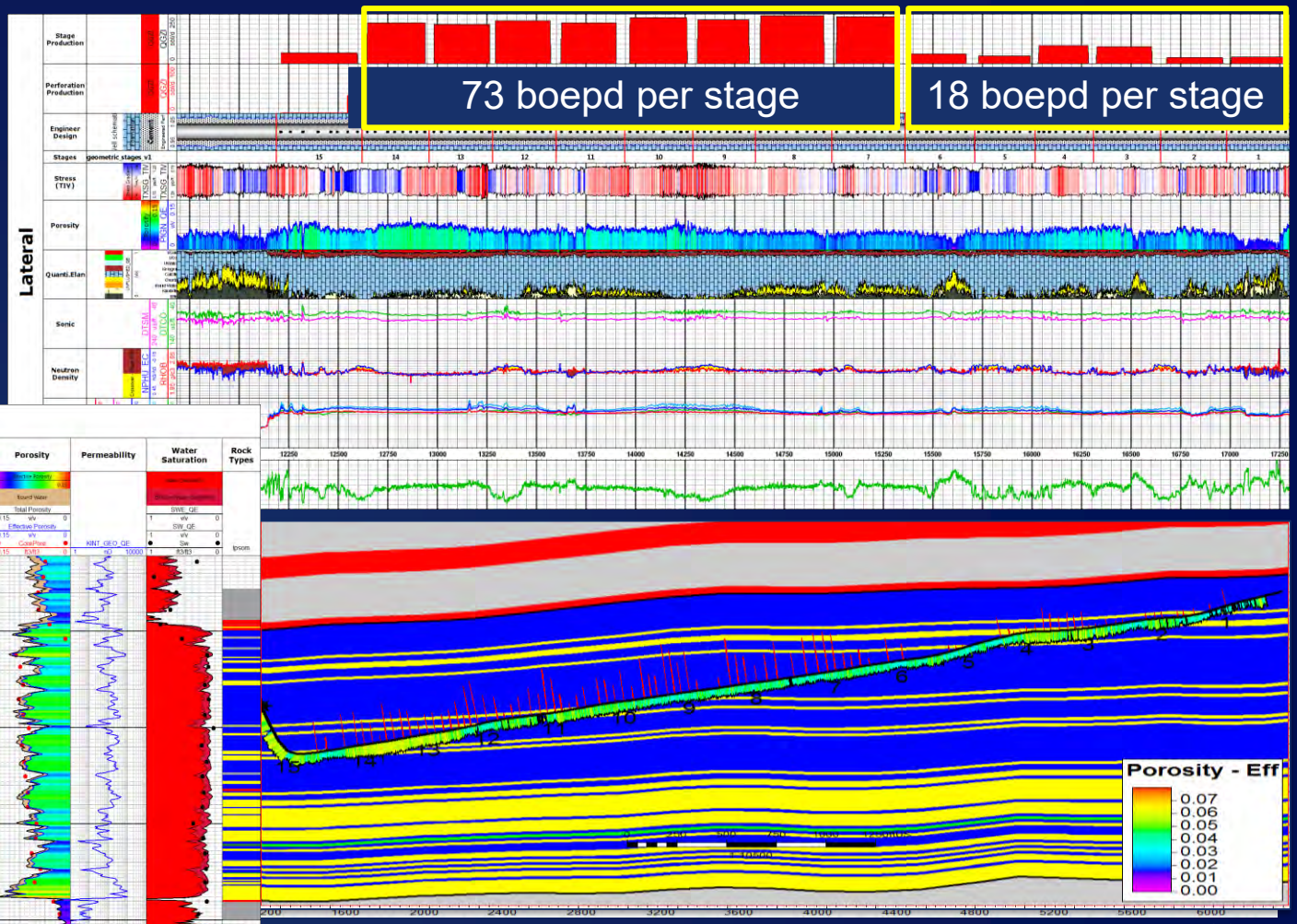

Case Study:
RQ vs. Rock Groups

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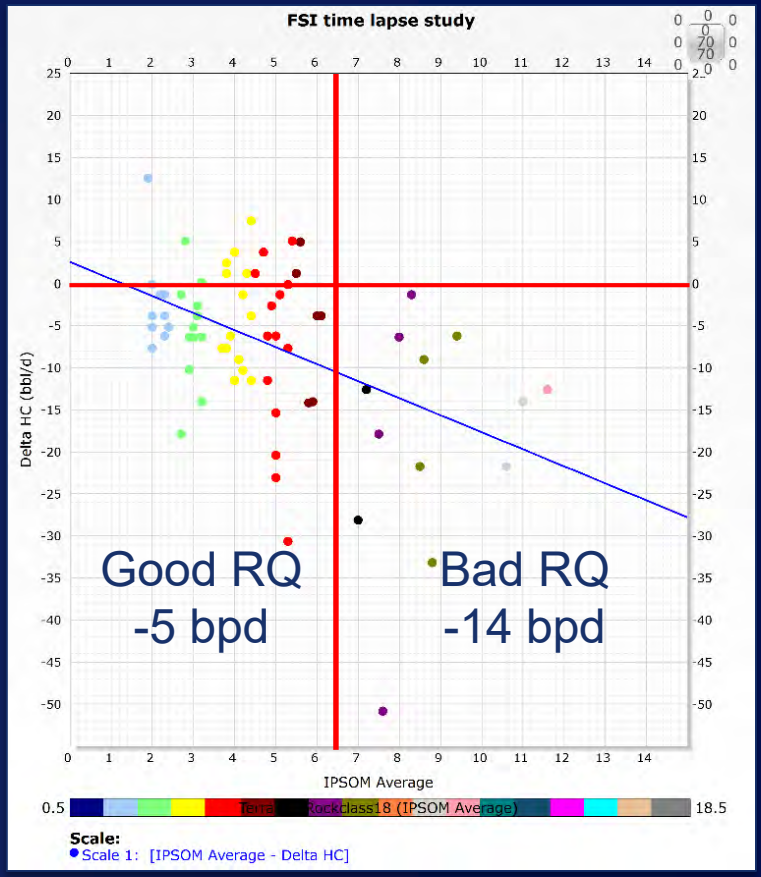
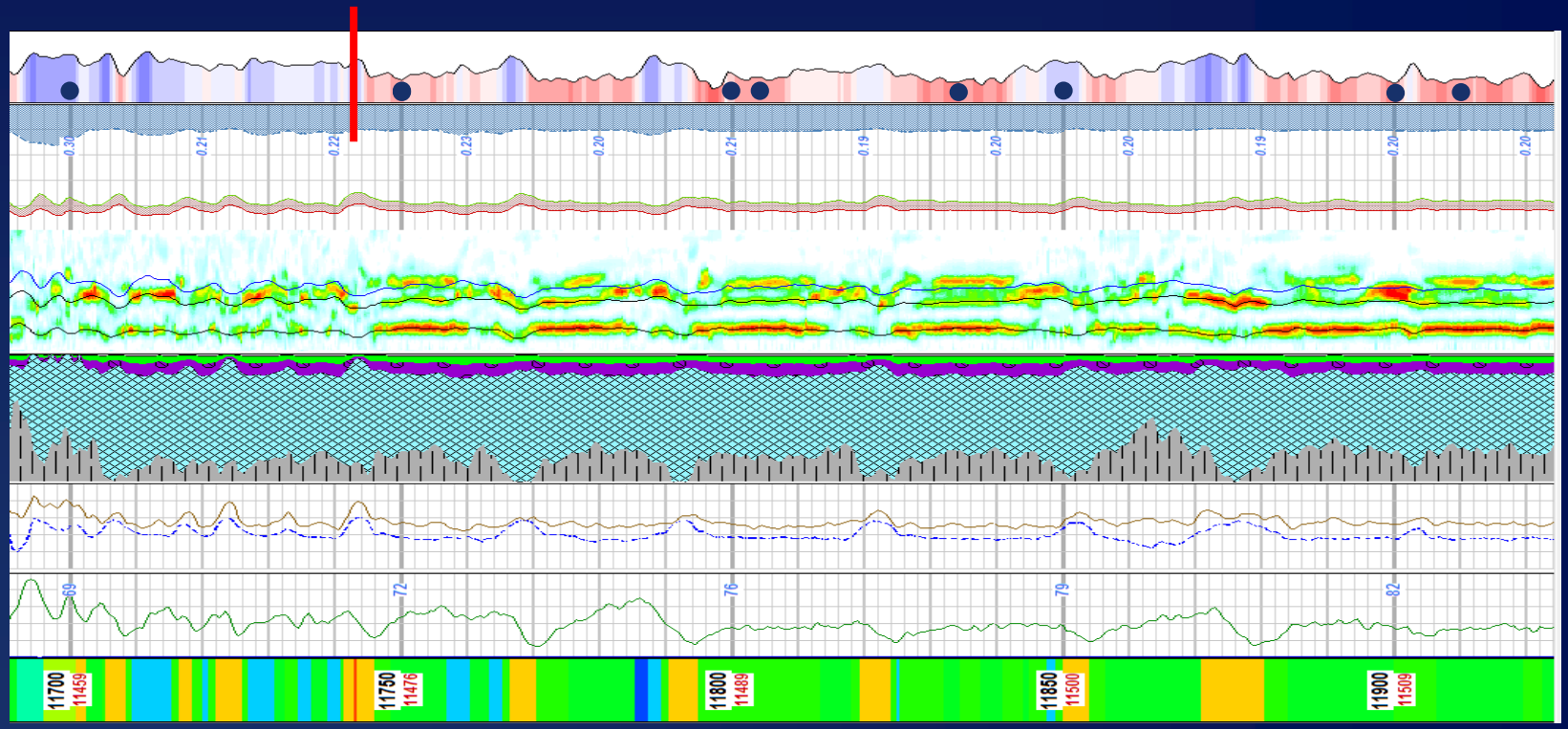
Time Lapse Production Log

- 2 production logs run 6 weeks apart
- Delta Hydrocarbon



Completion Quality: CQ



Optimizing Completion integrating RQ and CQ

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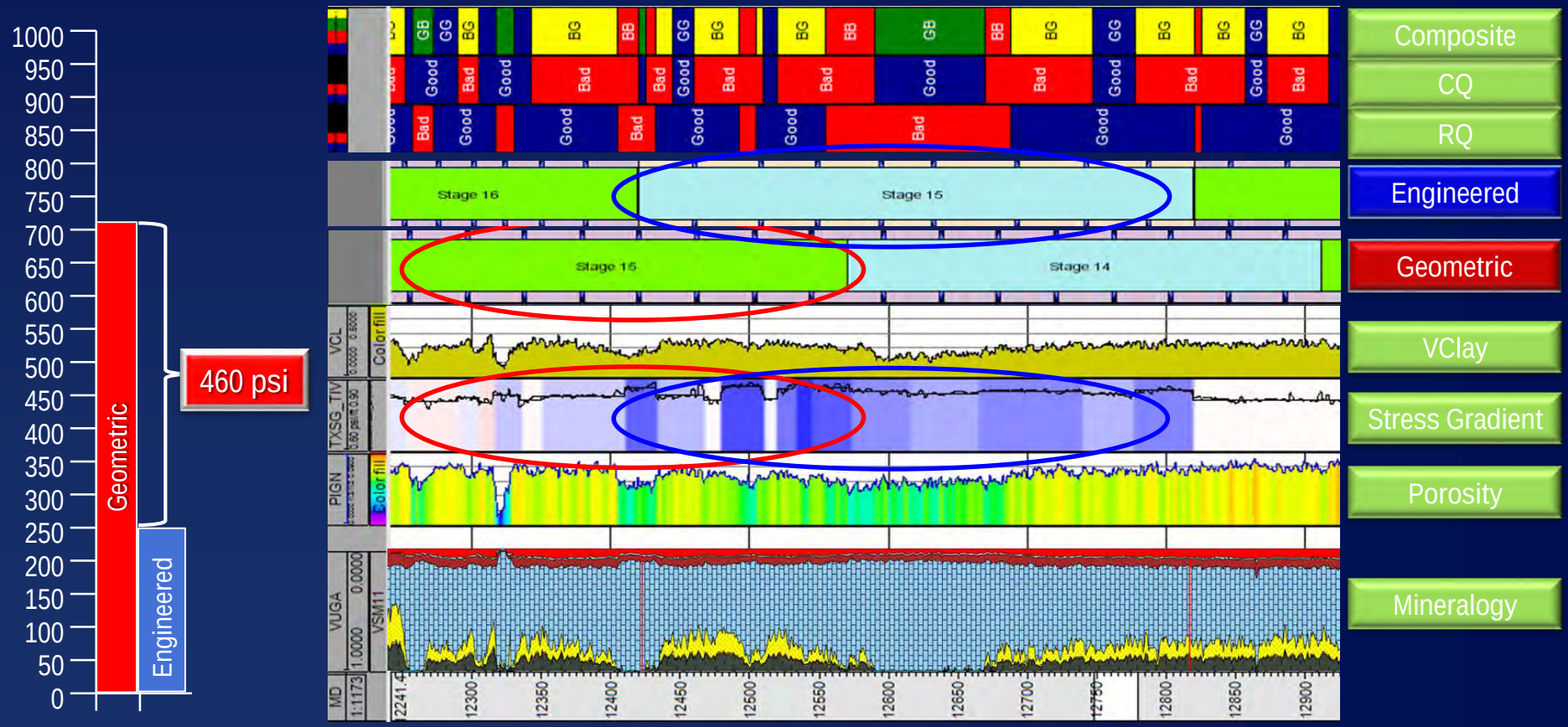
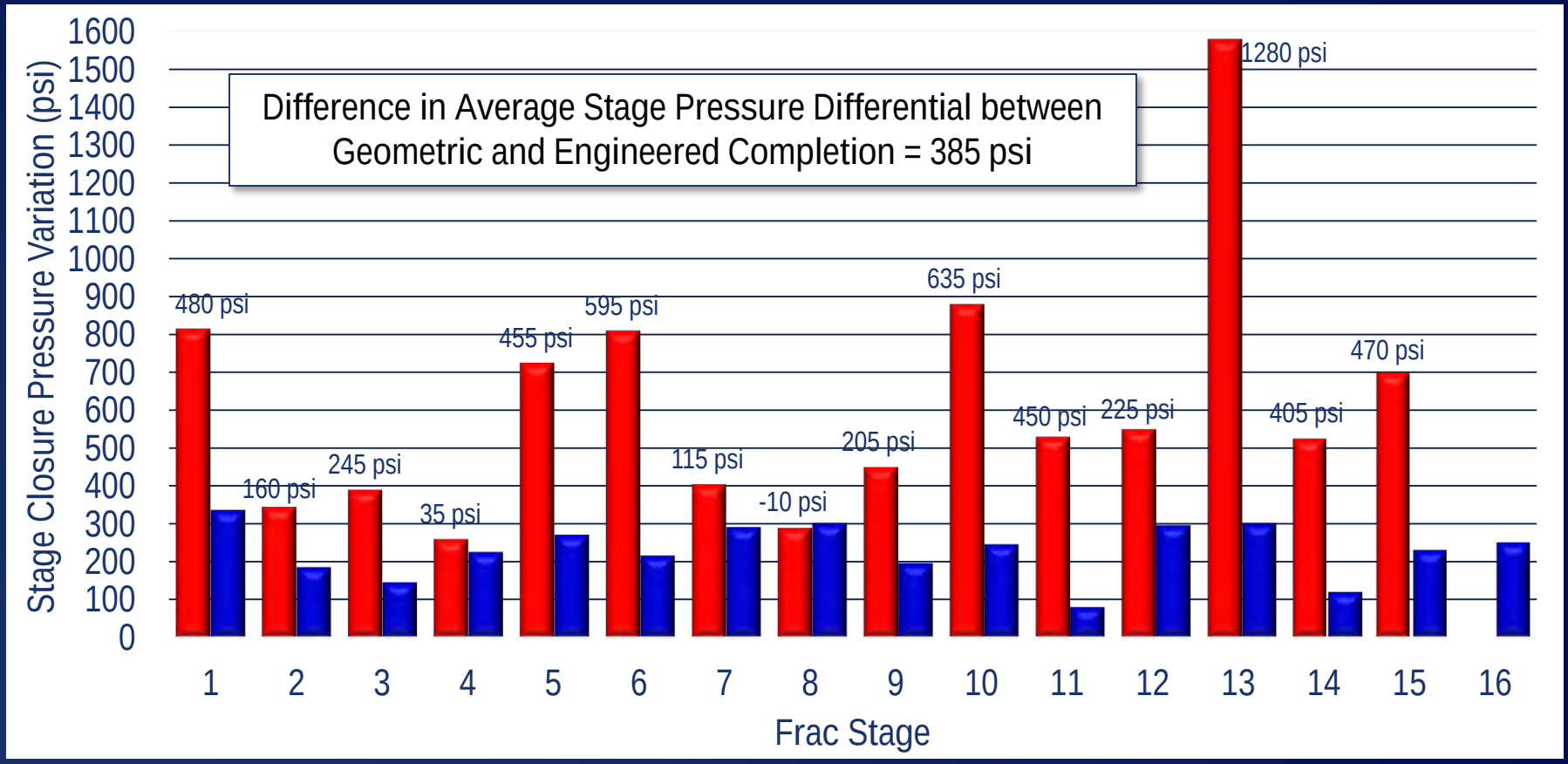


Frac Stage Pressure Differential



Engineered Completion Results: 940 bopd / 375 bwpd

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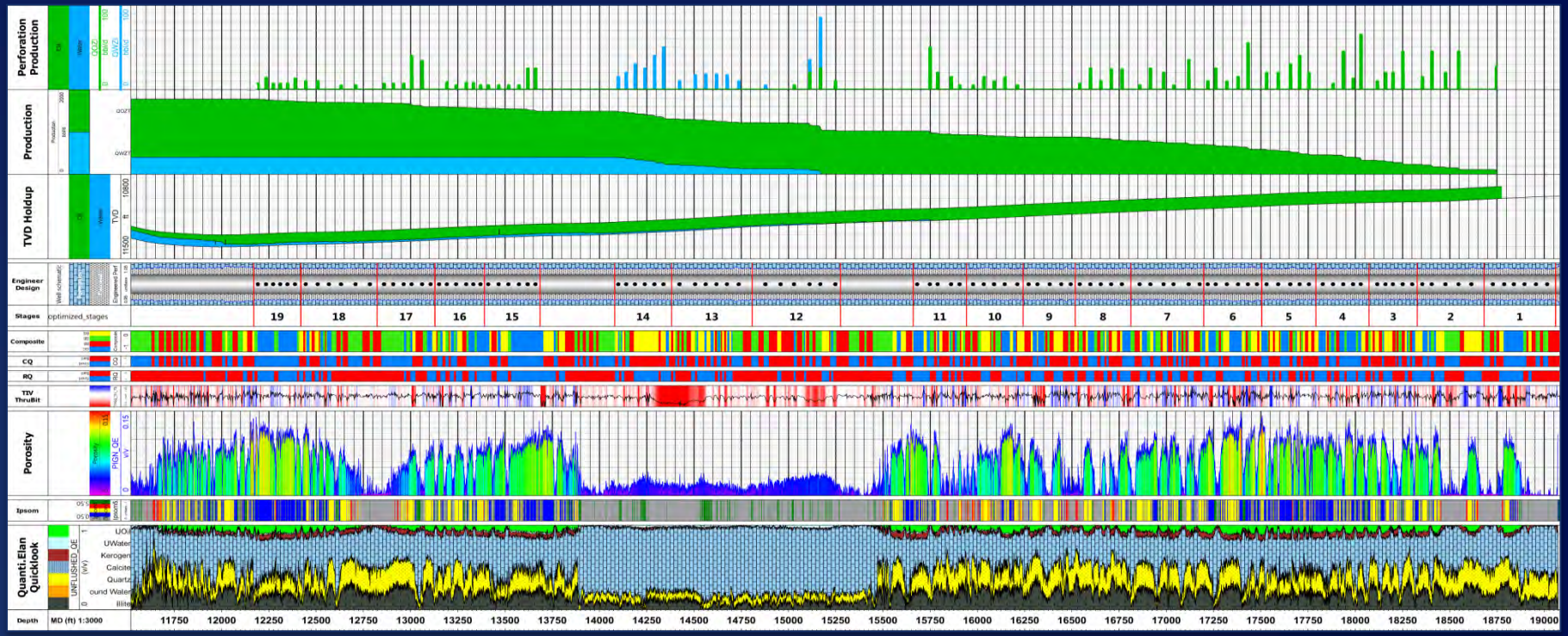
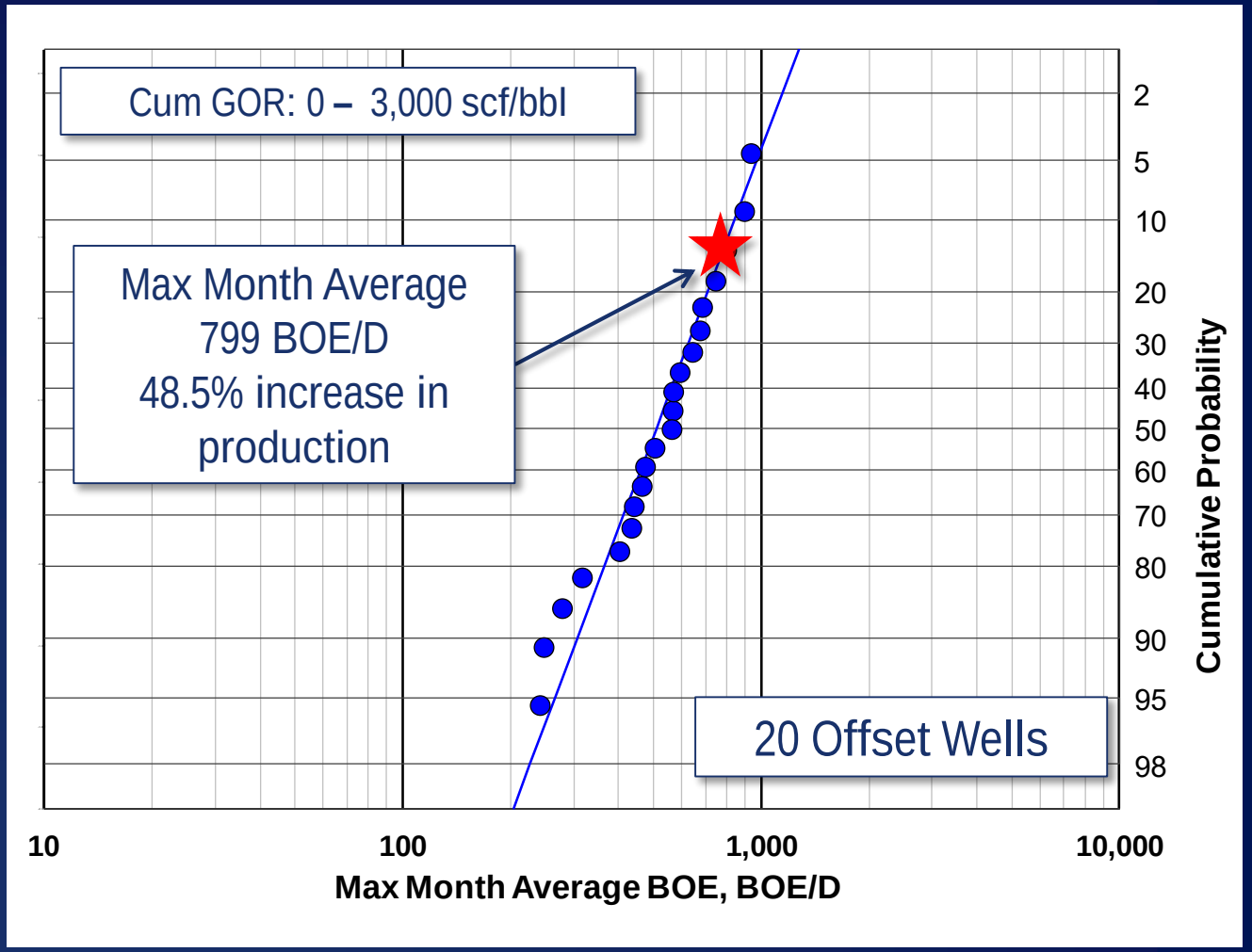
85.3% Perforation Efficiency



64% Average Perforation Efficiency for Geometric Designs

Production Comparison



Increased Production – Engineered vs. Geometric

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Well	Best 1 month bpd	P50 of Offsets bpd	% Production Increase
Well A	799	538	48.50%
Well B	1258	499	152.10%
Well G	950	798	19.00%
Well H	560	392	42.90%
Well I*	730	789	-7.50%
Well J	1100	392	180.60%
Well K	771	495	55.80%
Average	**881**	**558**	**58.0%**

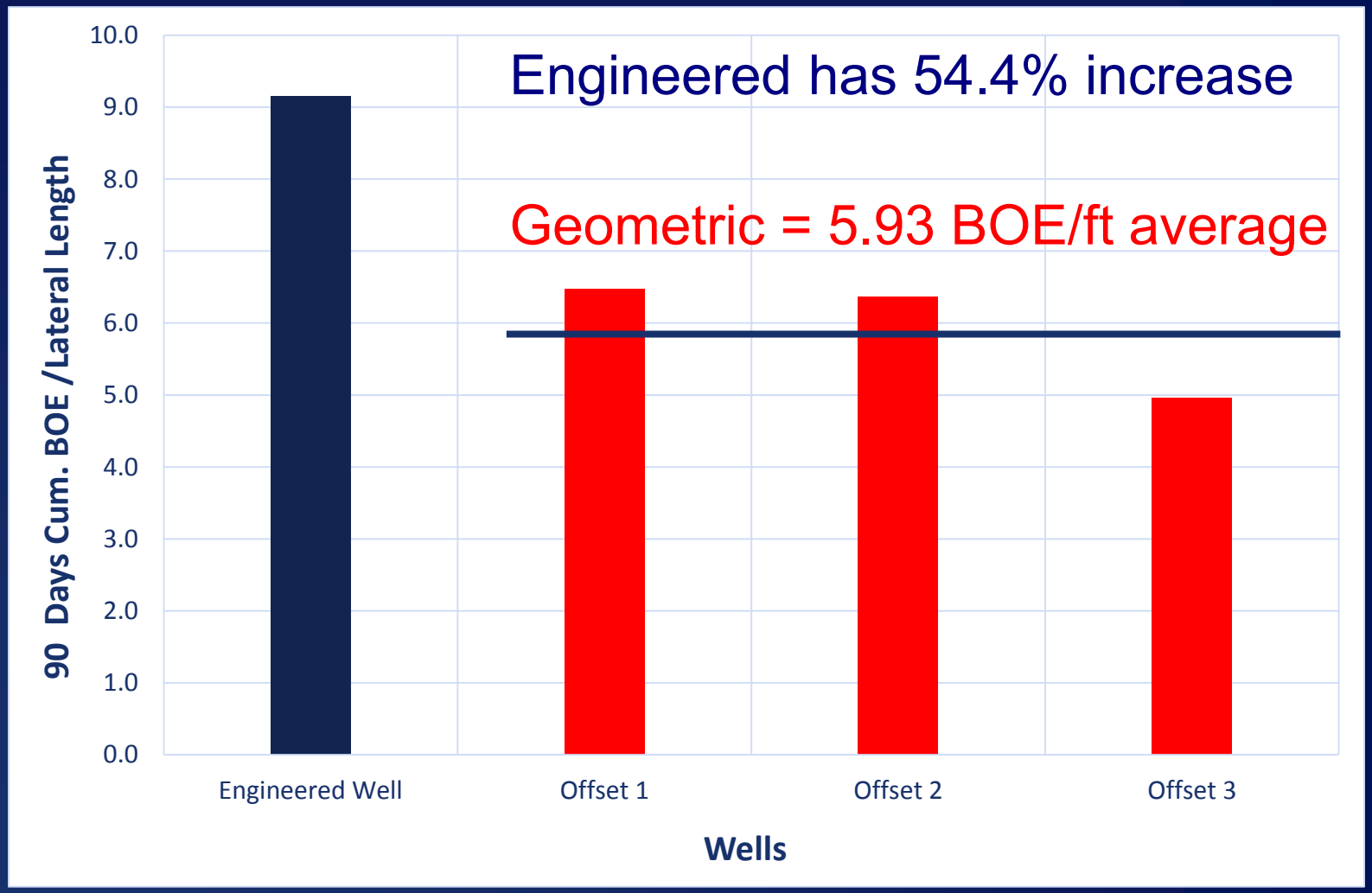
*** 1/3 of lateral out of zone**

Eagle Ford Results

- Increased perforation efficiency from 64% to 82% (28% increase in lateral contribution)
- Increased well performance by an average of 58% vs. average offsets
- 28% increase in lateral contribution yields a 58% increase production (Not Linear)

Slocombe, et al, SPE 13ATCE-P-166242 2013

Permian Wolfcamp Results (Clean out issues)



Niobrara Results

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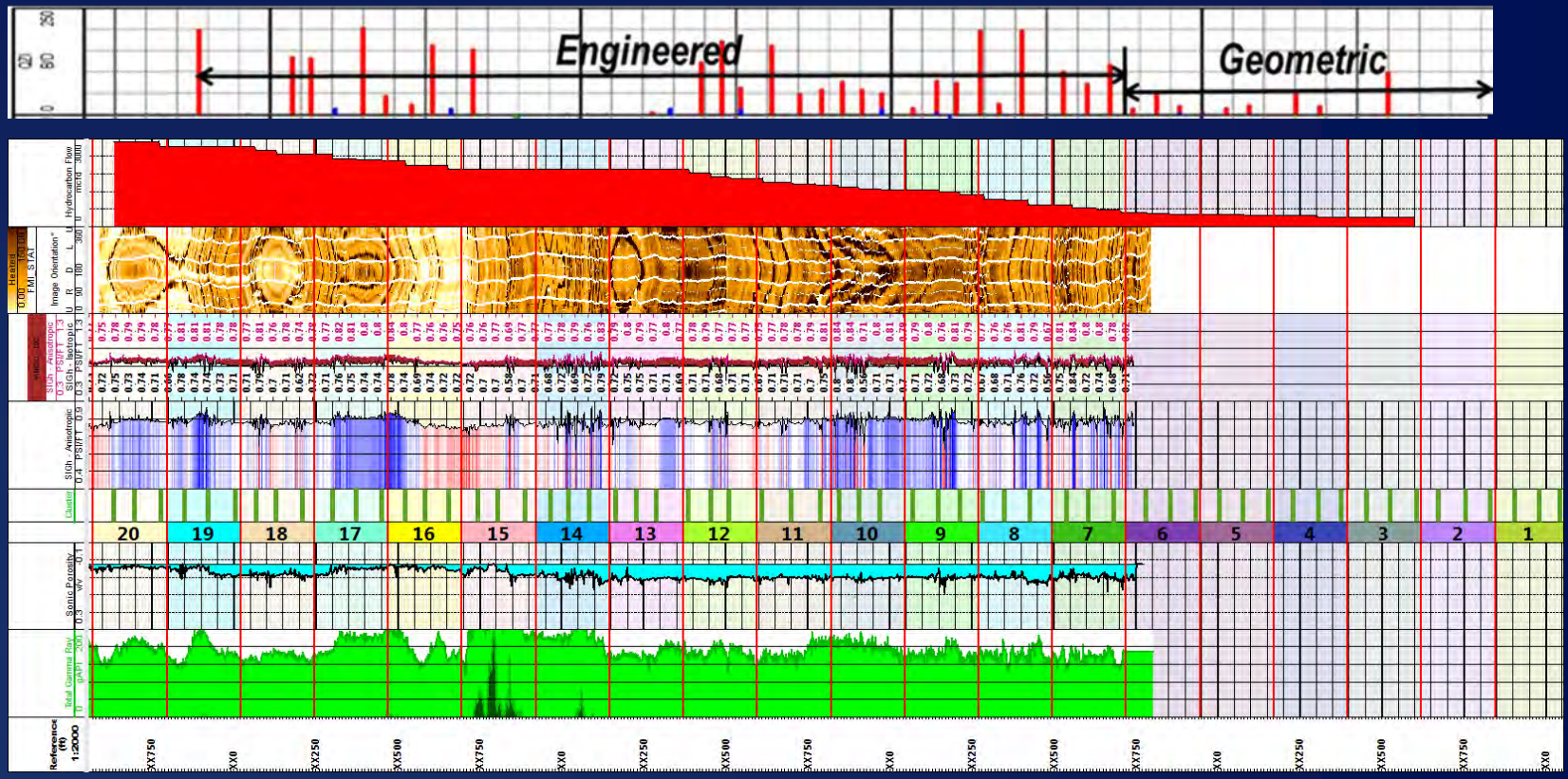
Engineered stages outperformed geometric stages by 2 – 3 times



Pirie, et al, URTeC: 2154958, 2015

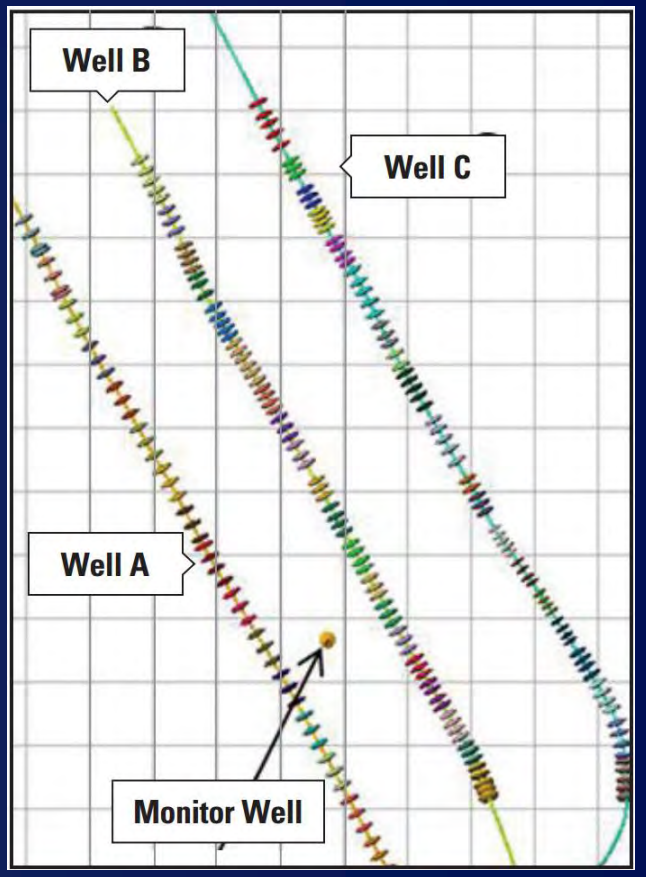
Marcellus Results

Engineered outperformed geometric by 33% & 40% on initial production

Well A – Geometric

Well B – Engineered

Well C – Engineered



Lessons Learned

- Geology Quality (GQ)
  - Layers and landing point is critical to production.
- Reservoir Quality (RQ)
  - Near wellbore has influence in the over flushed stimulated fracture zone.
- Completion Quality (CQ)
  - Perforations in similar stress rock initiate simultaneously.
  - Fracture modeling

Conclusion

Integrating Geology Quality (GQ), Reservoir Quality (RQ) and Completion Quality (CQ) in the engineered designed completion leads to increased production when compared to peer wells with geometric designed completions.

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Thank You For Attending!

Question & Answer Session

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