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Increasing Production with Better Well Placement in Unconventional Shale Reservoirs – Challenges and Solutions

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Director, CamShale

Cameron

Society of Petroleum Engineers
Distinguished Lecturer Program
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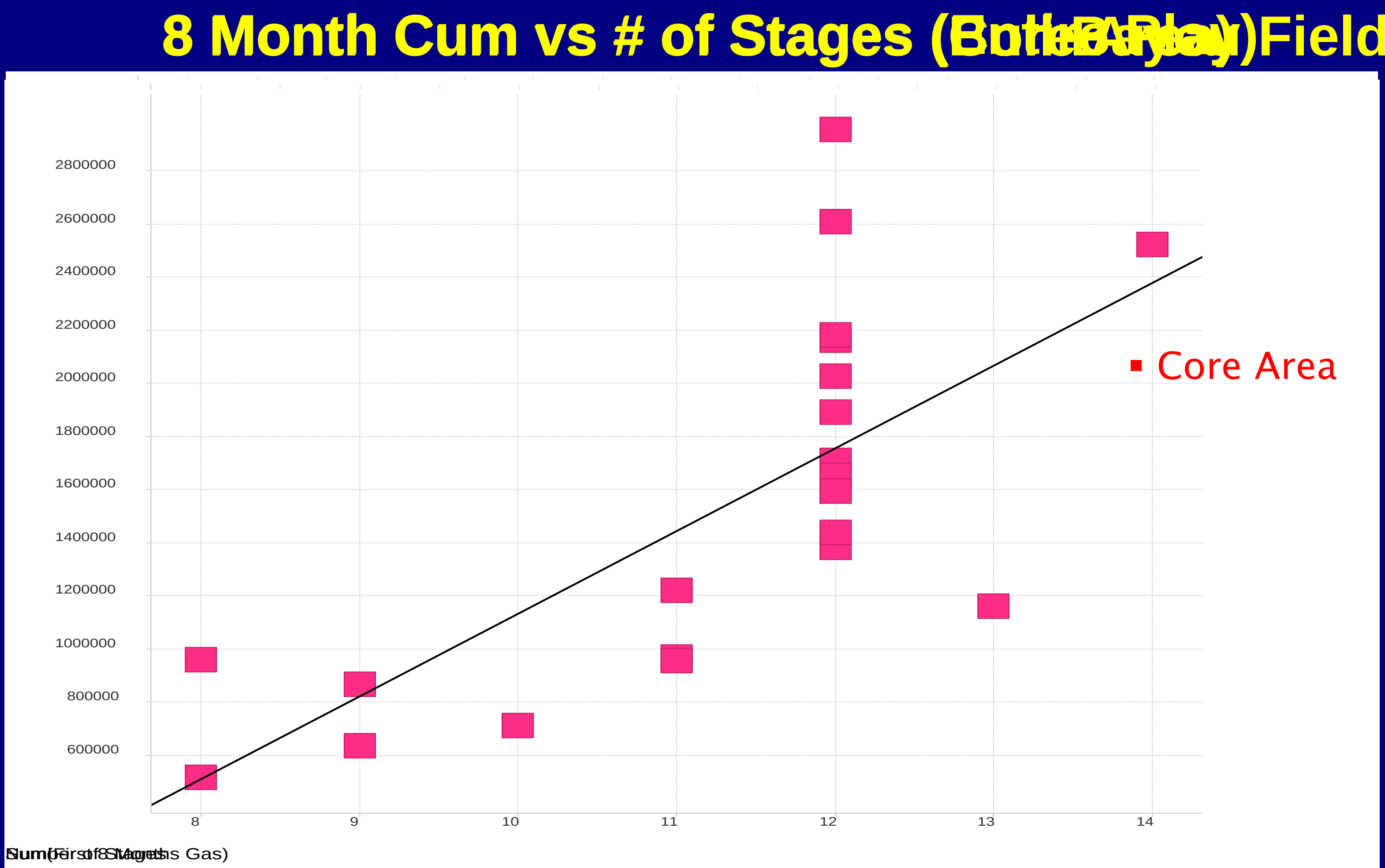
Presentation Outline

- What happens when you assume the “frac will get it”
- Current Best Practice in North America
- Geomechnical Properties that affect Production
- Using Data through the Life Cycle
  - Drilling
  - Completion
  - Stimulation
  - Production
- Summary and conclusion

What happens when you assume the "frac will get it"



Modeland, N., Buller, D. and Chong, K.K. 2011. Statistical Analysis of Completion Methodology on Production in the Haynesville Shale. Paper SPE 144120 presented at the SPE North American Unconventional Gas Conference and Exhibition, The Woodlands, Texas, 14-16 June

Old Problem
Old Solution

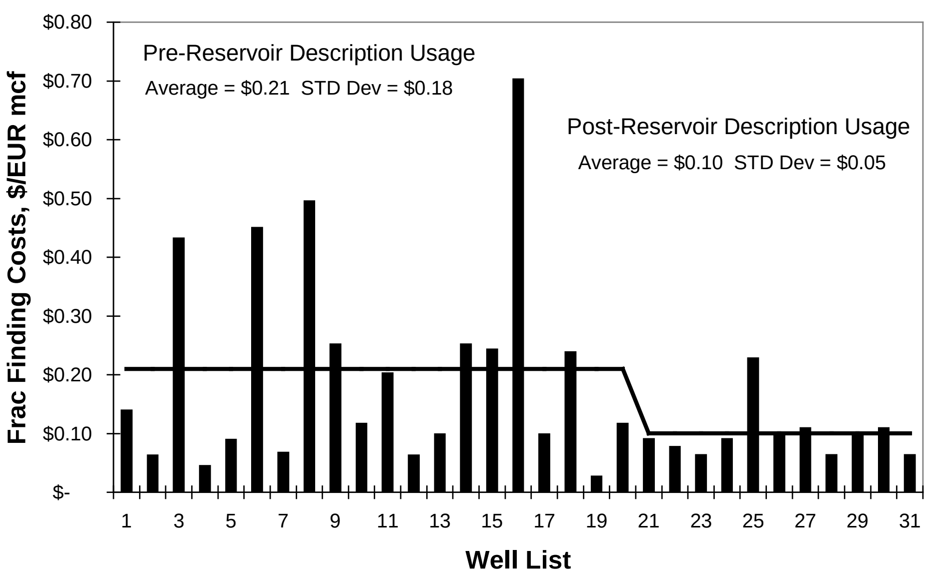


Fig. 10 - Frac Finding Costs for Project Wells

1998

SPE 39918

Reservoir Description Techniques Improves Completion Economics in Piceance Basin Mesaverde Project

S.K. Schubarth, SPE, M.J. Mullen, SPE, and C.A. Seal, SPE, Halliburton Energy Services, and R.S. Woodall, SPE, Snyder Oil Company

This paper was prepared for presentation at the 1998 Rocky Mountain Regional/Low-Permeability Reservoirs Symposium held in Denver, Colorado, 5-8 April 1998.

Abstract

The Mesaverde formation in the Piceance Basin of western Colorado is a series of tight gas sands contained in a complex geological environment. Pay selection and completion techniques have varied greatly during the development of this formation. Production response varies greatly from well to well, and decisions on where and how to optimize completion economics are difficult. Consistent treatment sizes and designs are usually used even though some treatments may be over-designed while others are under-designed. Knowing where to spend completion dollars and where to save them can substantially impact the economics of a development project in this Basin.

This paper will present a reservoir description technique that uses standard openhole well logs and helps operators to predict reservoir quality for individual sands. This prediction allows the operator to optimize the completion design and therefore maximize his economics. This technique has been applied to many wells, and the accuracy is documented through production analysis. Both total well production and individual sand production, determined with production logs, have been predicted through the use of this technique. This paper also examines the economic benefit of using this analysis technique will be presented. The authors believe that the methodology used can be applied to similar reservoirs to achieve similar results.

References at the end of the paper

Introduction

The Williams Fork formation of the Mesaverde Group in the Piceance Basin is a series of point bar sandstones with interbedded silts, shales, and mudstones.[1] The Cameo formation in the lower portion also contains several coal intervals. Much of the geology of the Mesaverde has been described from the data gathered at the Multiwell Experiment Site (MWX).[2,3] This work indicates that the fluvial point bar deposits are the source of gas produced from these wells and that these point bar systems are relatively small. The average point bar size has between 5 and 17 acres of aerial extent. However, a meander belt complex, comprised of vertically and horizontally stacked point bars, can be 37 to 68 acres at an average thickness of 20 ft. The nature of the deposition of these sands results in highly compartmentalized, poorly correlated reservoirs. Drainage area sizes, therefore, are small.

The purpose of the authors' work presented here was to attempt to model the behavior of the Mesaverde formation with a predictive reservoir model by using conventional log analysis as the primary input parameter. The model created relies on relationships between properties that we can measure (porosity, lithology, water saturation, sand thickness, treatment size, number of intervals perforated, etc.) and properties we need for designing optimal stimulation treatments (permeability, gas-in-place, fracture half-length, etc.). Fortunately, some relationships exist that will allow us to build this predictive model.

Relationships—Drainage Area. Relationships between the thickness of the point bar sands and their aerial extent has been presented by Lorenz, etal. This work presents an equation which relates the thickness of a point bar sand to the width of the bar. Simply stated, the thicker the sand the greater the aerial extent. **Fig. 1 (Page 2)** demonstrates an example of this relationship used in building the model.

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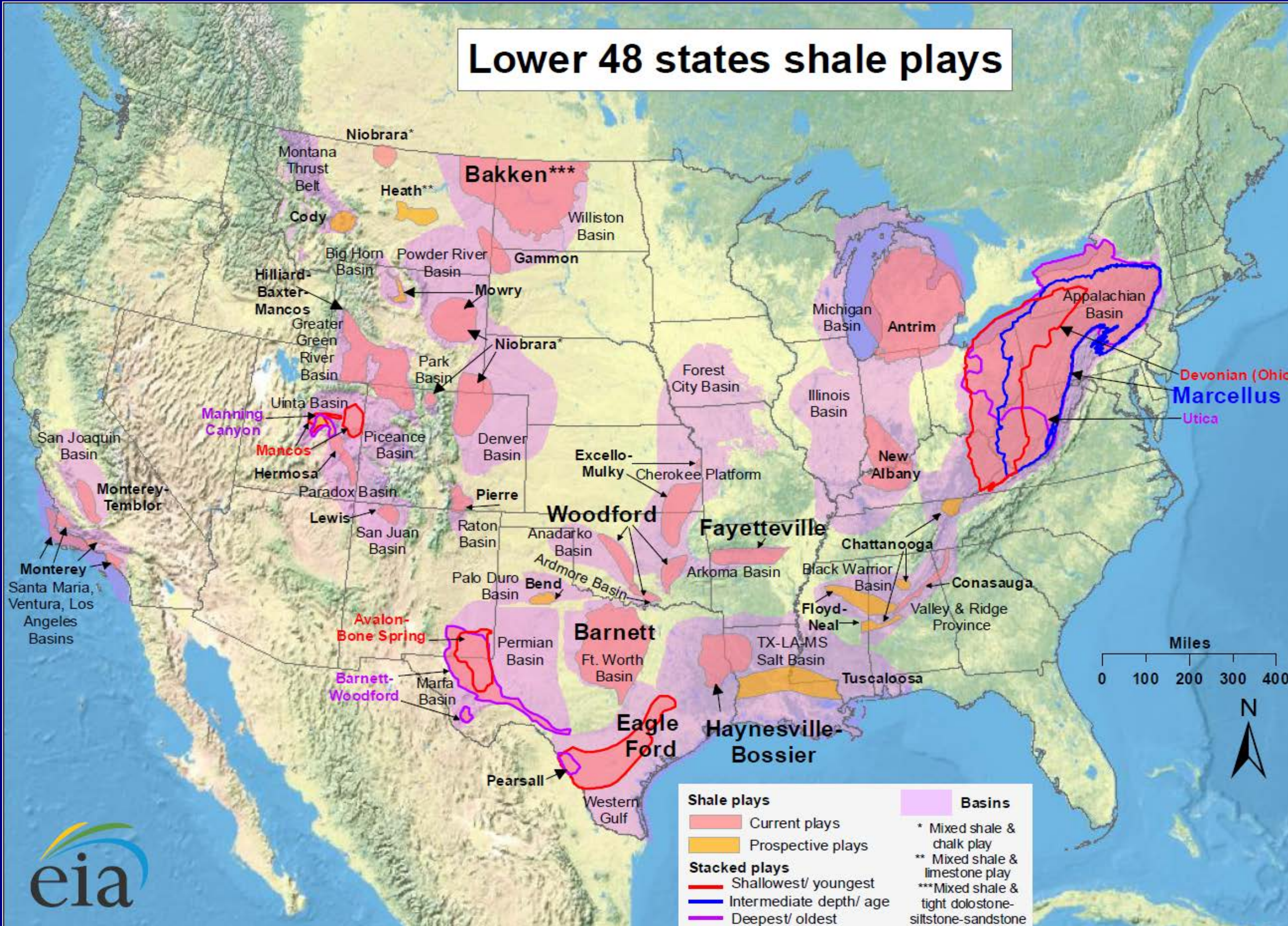
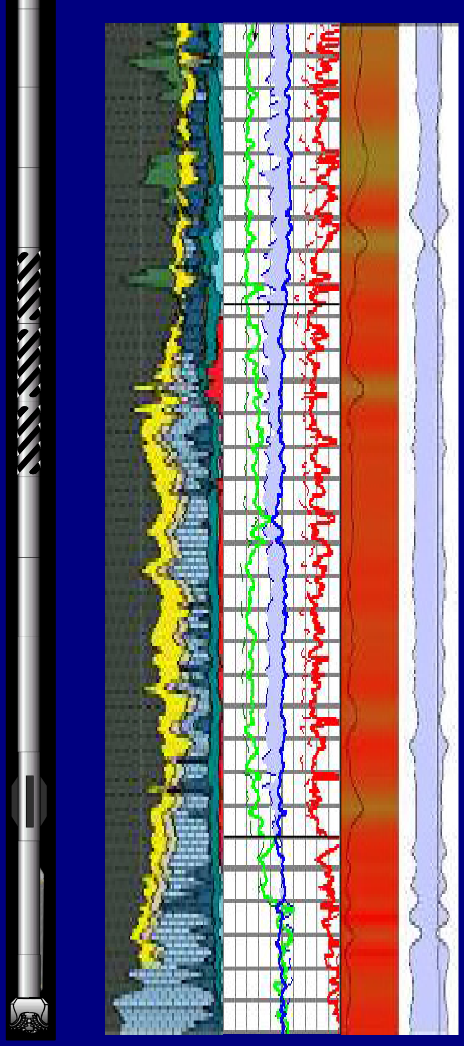
Lower 48 states shale plays



Source: Energy Information Administration based on data from various published studies.
Updated: May 9, 2011

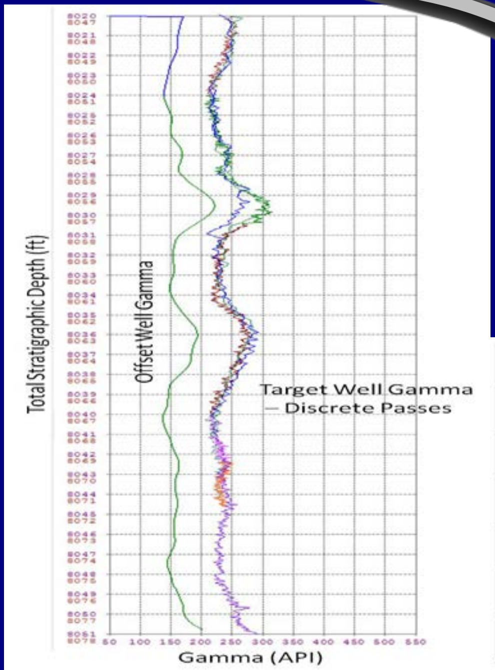


Drill an Evaluation Well

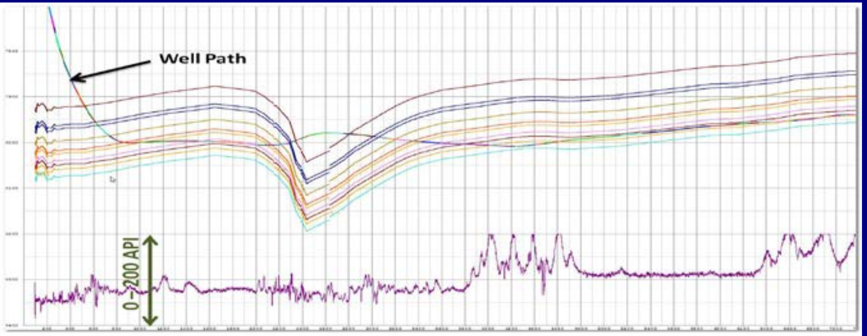
- Open Hole Logging
- Coring
  - Characterize the Reservoir
  - Define the Target
- Dfit or MiniFrac

Drill a Horizontal / High Angle Well

- LWD consists of Gamma Ray
- Well is geosteered to stratigraphy
- Pattern match gamma response to offset logs

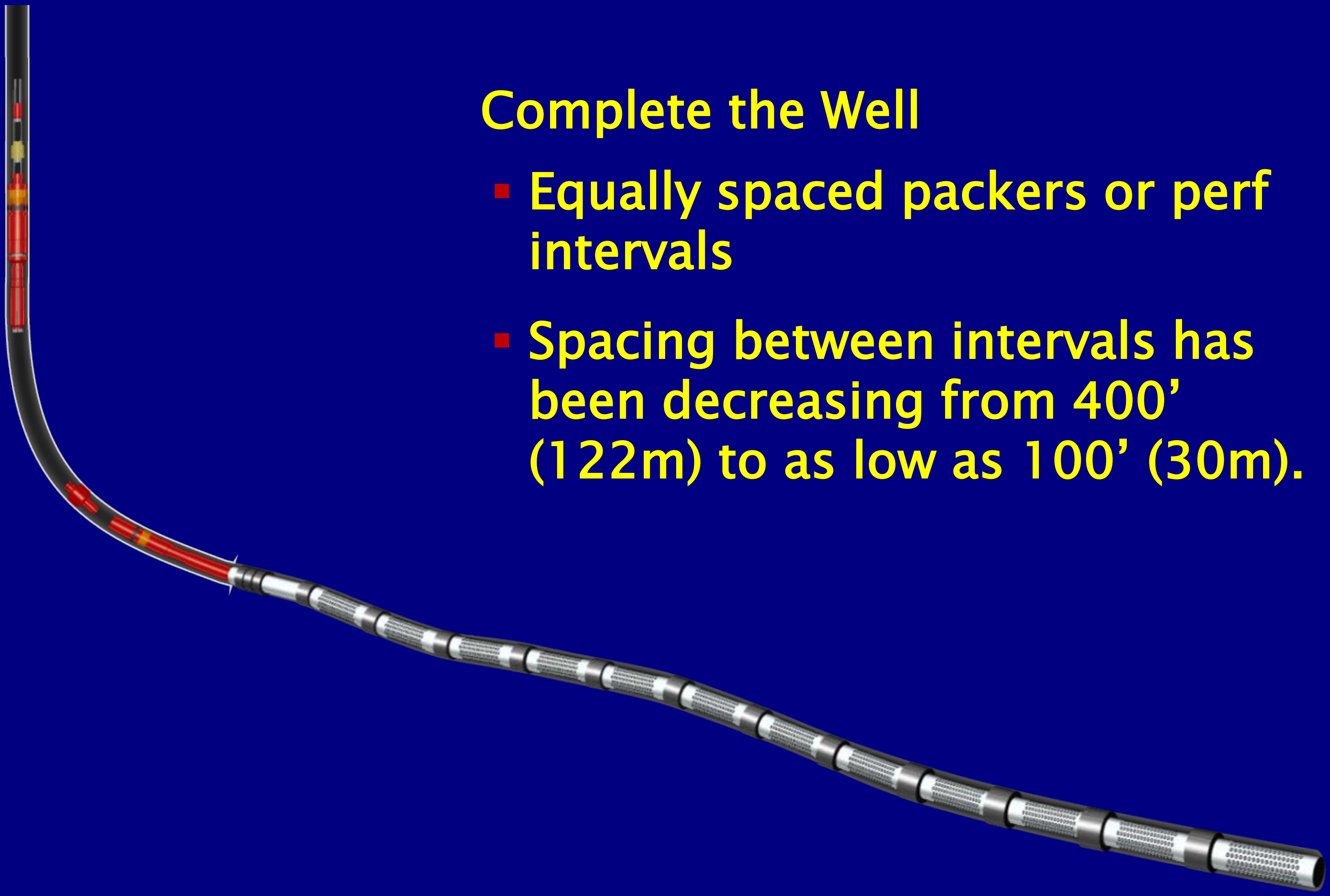


SPE 152580



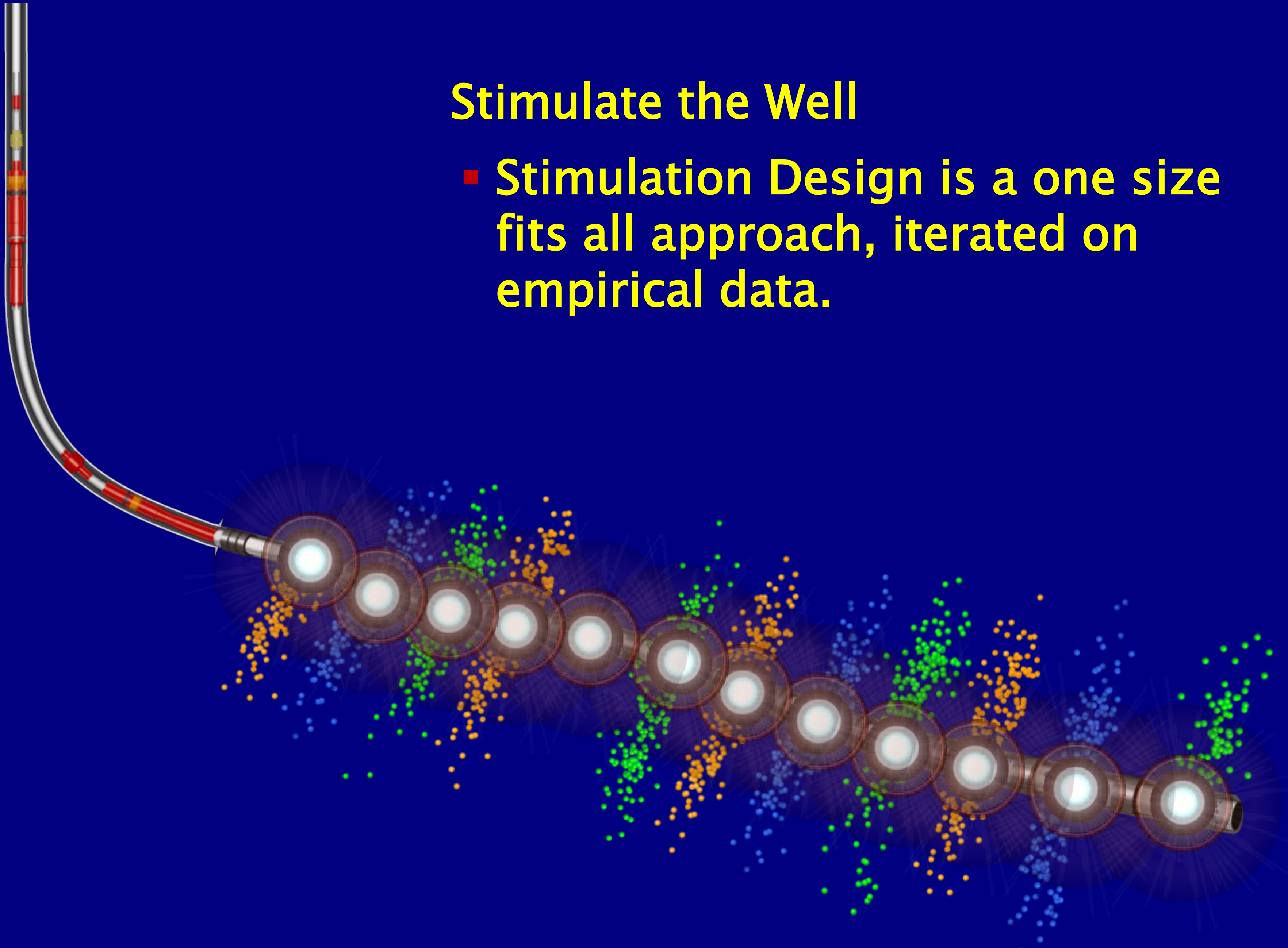
Complete the Well

- Equally spaced packers or perf intervals
- Spacing between intervals has been decreasing from 400’ (122m) to as low as 100’ (30m).



Stimulate the Well

- Stimulation Design is a one size fits all approach, iterated on empirical data.



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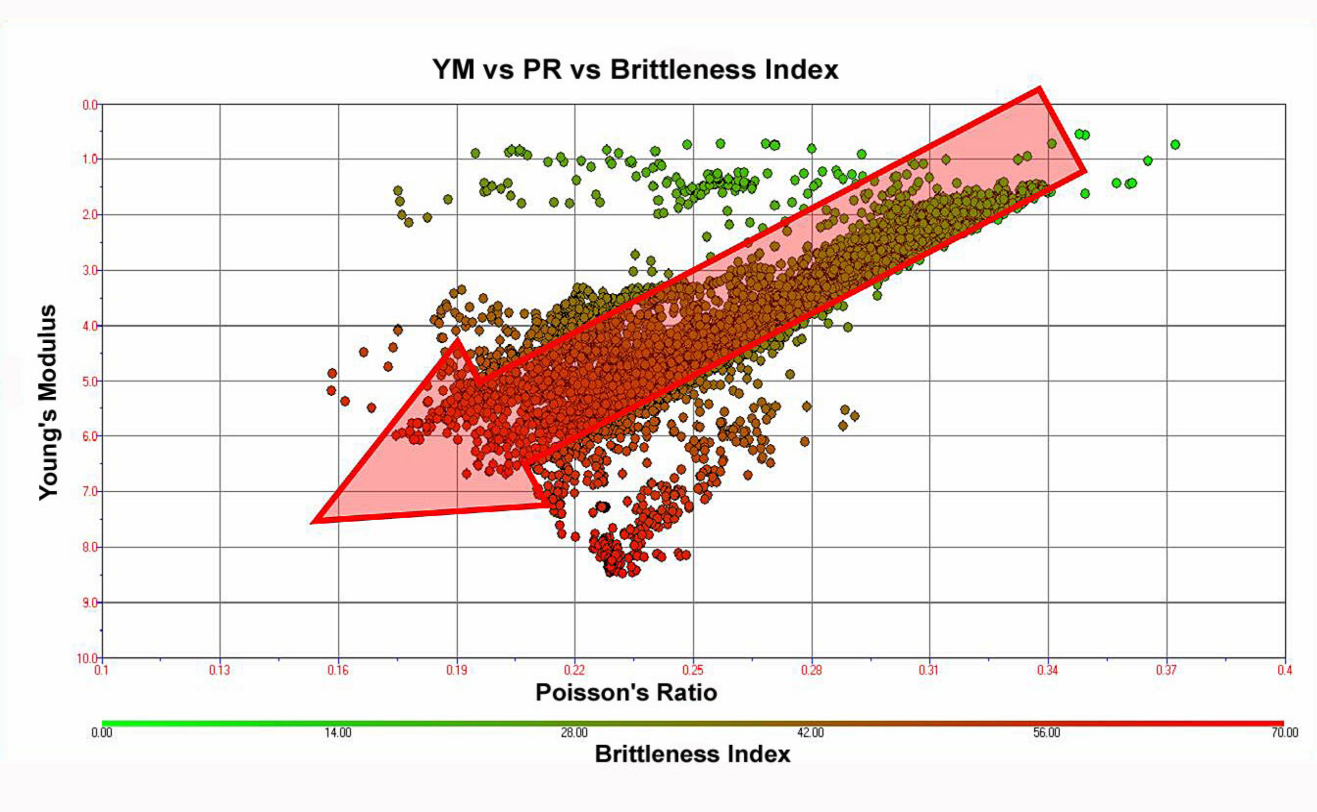
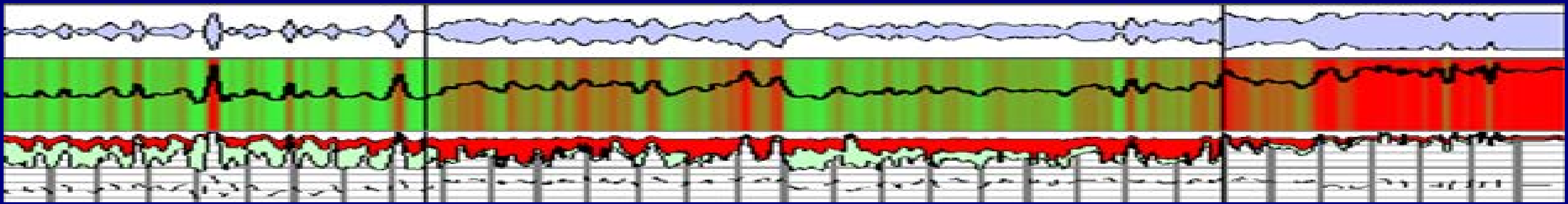
Shale Brittleness Index





Rickman et al. Paper SPE 115258

Rock Mechanics from Sonic

Dynamic Young's modulus

$$E_D = \rho \frac{(4 - 3\frac{\Delta t_s^2}{\Delta t_c^2})}{\Delta t_s^2 (1 - \frac{\Delta t_s^2}{\Delta t_c^2})}$$

Mullen et al. SPE 108139

Poisson's ratio

$$\mu = \frac{2 - \Delta t_s^2 / \Delta t_c^2}{2 * (1 - \frac{\Delta t_s^2}{\Delta t_c^2})}$$

Convert to Static:

$$E_s = E_D * (0.8 - \Phi_{\mathrm{Total}})$$

Brittleness Index:

$$\boldsymbol{BRIT} = \frac{\mathrm{E\_s\ (brit))} + \mu(brit)}{2}$$ *

Rickman et al. SPE 115258

For Anisotropic Media:

$$BRIT = \left[\frac{100(E_v - E_{v\_min})}{(E_{v\_max} - E_{v\_min})} + \frac{100(\mu_v - \mu_{v\_max})}{(\mu_{v\_min} - \mu_{v\_max})}\right] / 2$$

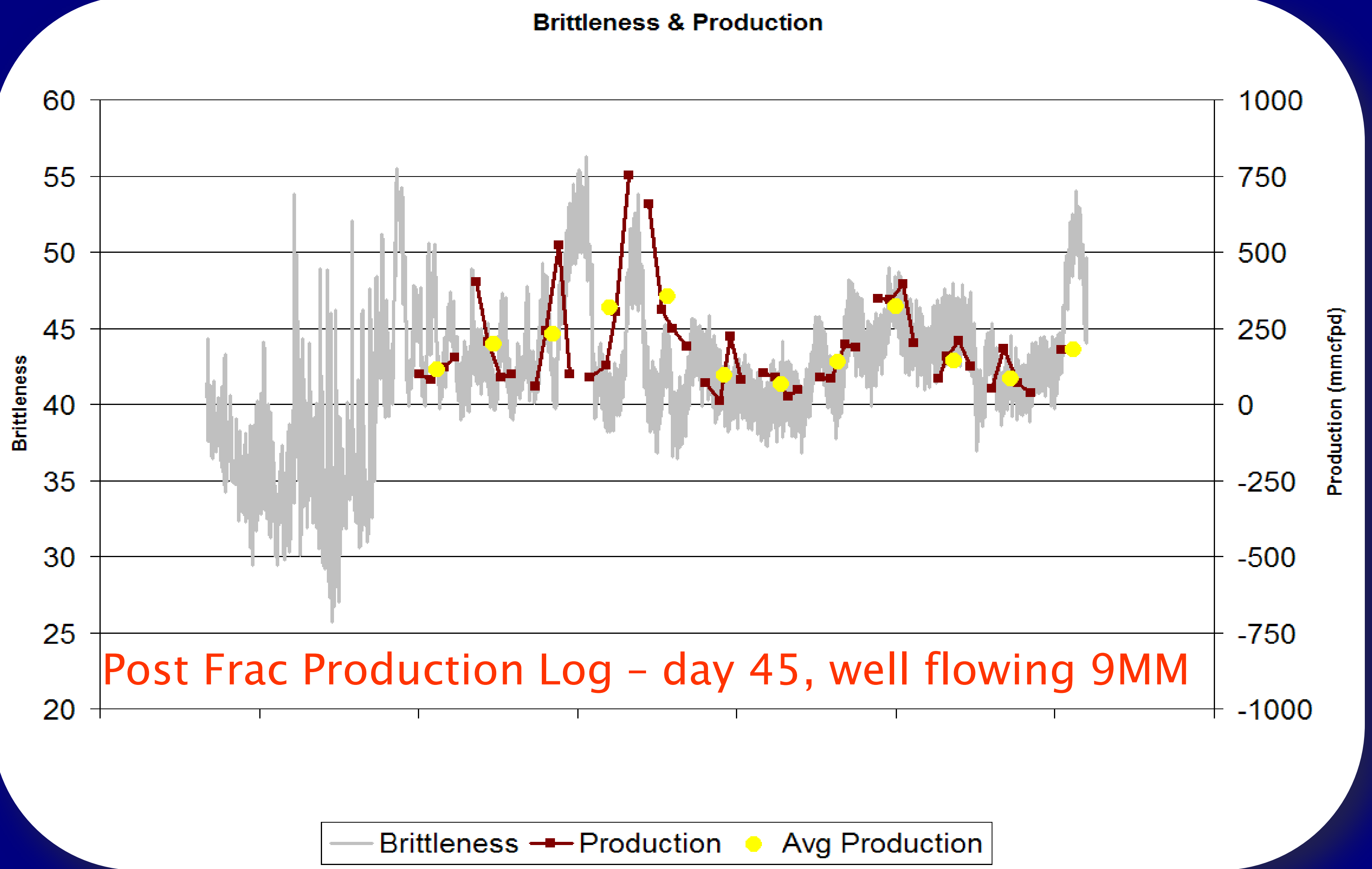
Mavko, G. et al. The Rock Physics Handbook 2009

$$TIV_{ratio} = \frac{DTS_{slow}}{DTS_{fast}}$$

$$Frac_{index} = BRIT_{index} / TIV_{ratio}$$

Buller, D. et al. 2010 SPE 132990
Petrophysical Evaluation for Enhancing Hydraulic Stimulation in Horizontal Shale Gas Wells

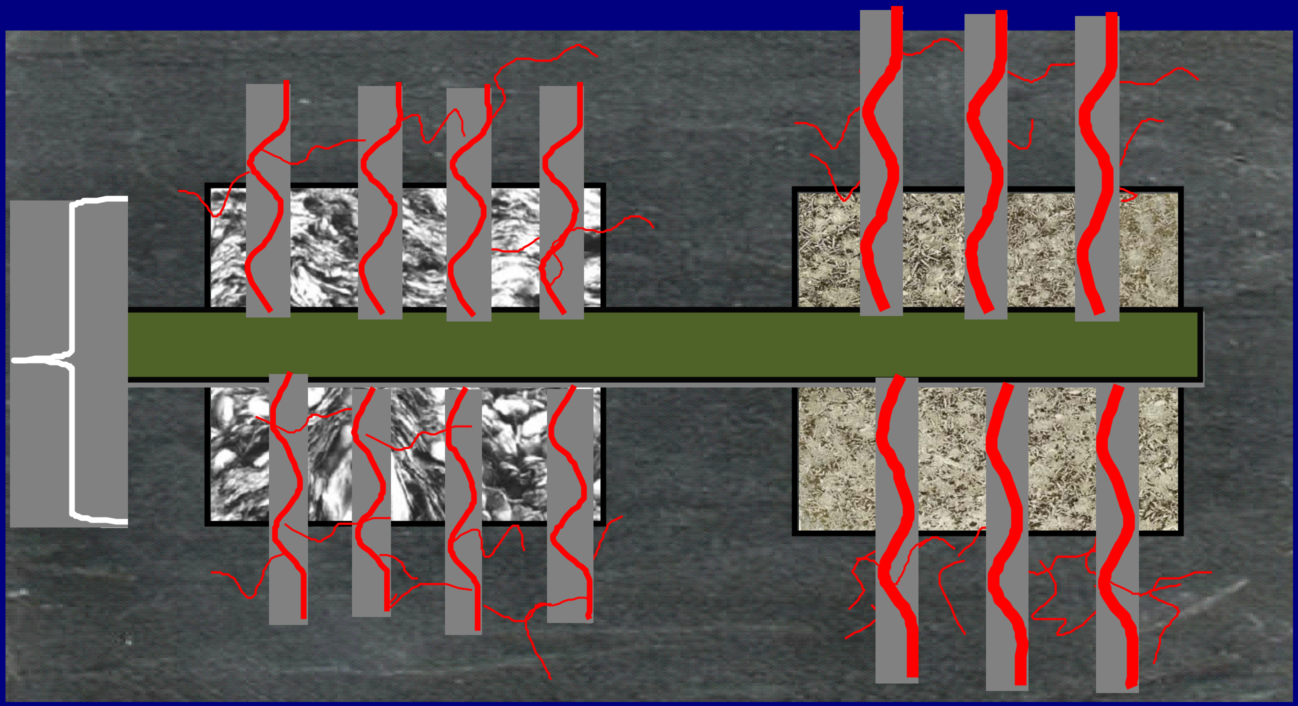
Brittleness Index vs Gas Production



Buller, D., Suparman, F., Kwong, S., Spain, D. and Miller, M. 2010. A Novel Approach to Shale-Gas Evaluation Using a Cased-Hole Pulsed Neutron Tool.

Frac Results

Near WellBore Region
3’ (1m)



Higher Clay Interval

Lower Clay Interval

Buller, D. et al. 2010 SPE 132990
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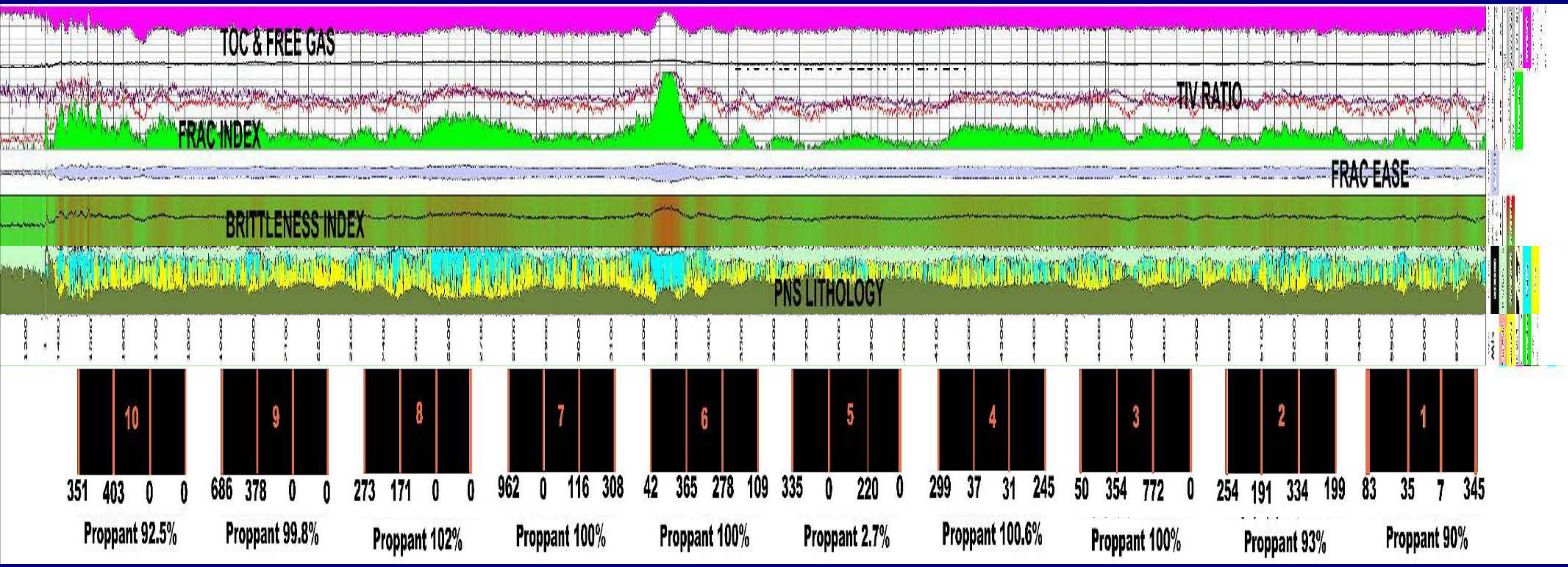
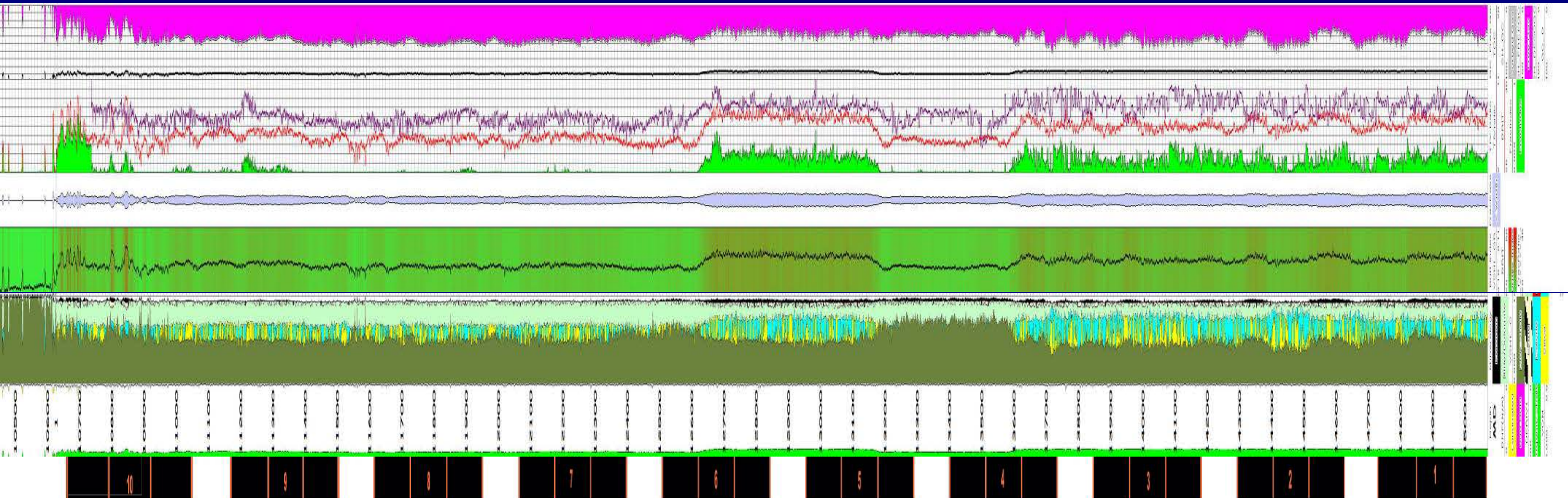
Haynesville #1



Buller, D. et al. 2010 SPE 132990
Petrophysical Evaluation for Enhancing Hydraulic Stimulation in Horizontal Shale Gas Wells

Haynesville #2



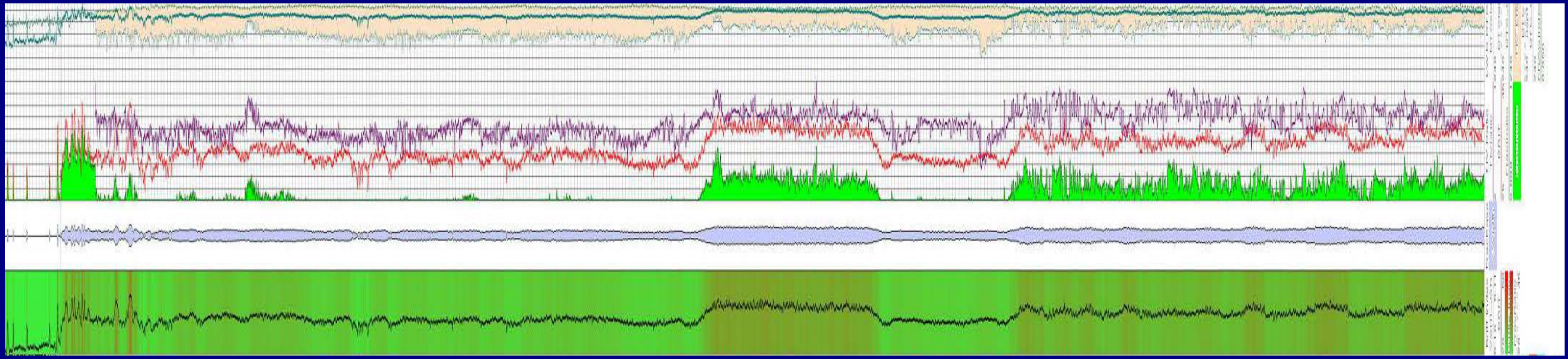
768 376 0 0 1 162 0 0 15 379 64 137 0 0 298 0 0 0 0 0 100 408 0 0 0 0 0 301 0 214 67 1 137 0 0 0 768 266 0 7

Prop 62.2% | Prop 85.3% | Prop 79% | Prop 29.5% | Prop 2.6% | Prop 89.5% | Prop 100% | Prop 3% | Prop 55.4% | Prop 35%

Buller, D. et al. 2010 SPE 132990
Petrophysical Evaluation for Enhancing Hydraulic Stimulation in Horizontal Shale Gas Wells

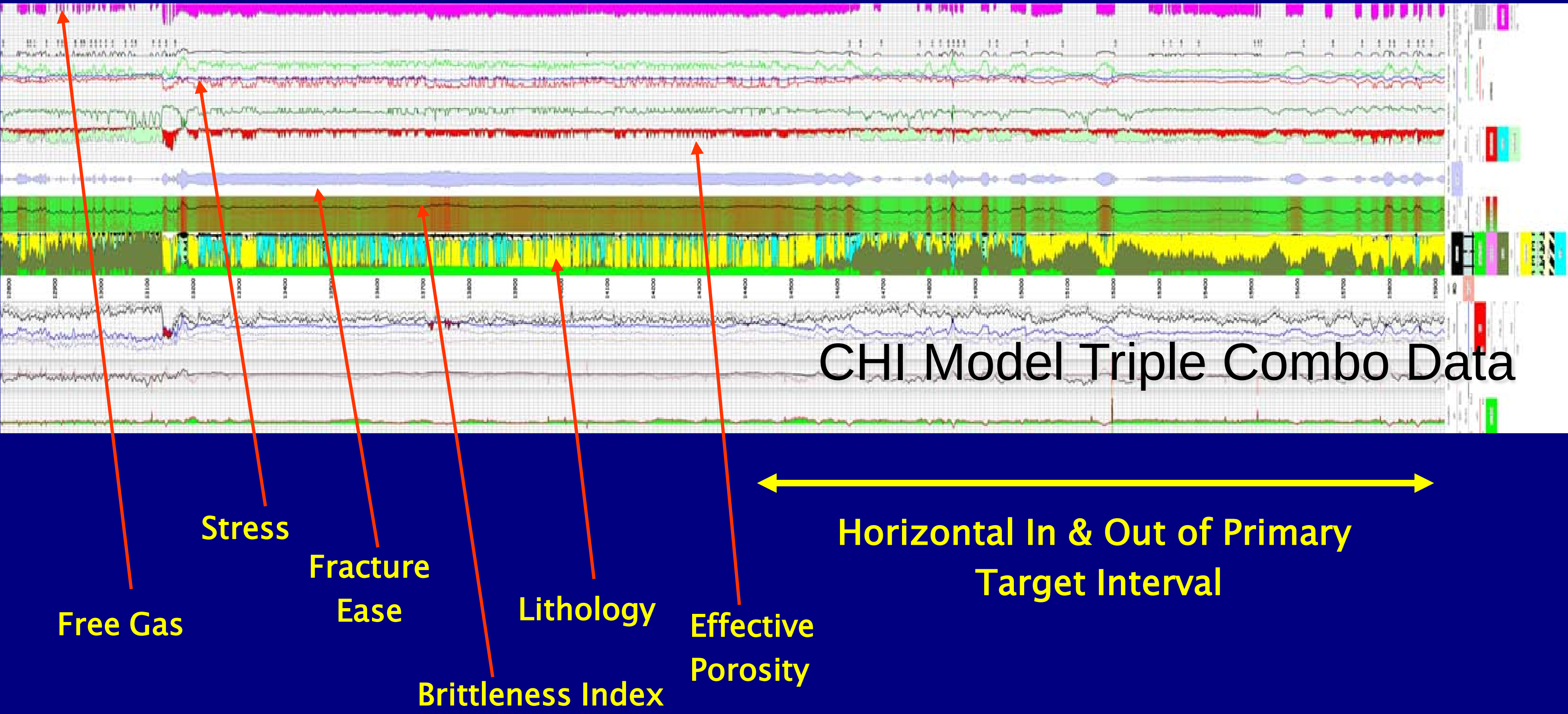
Haynesville #1 – 9 of 10 Water Fracs Placed – PL rate 8.2 MMCF/D

Haynesville #2 – 6 of 10 Fracs Placed > 50% – PL rate 4.5 MMCF/D

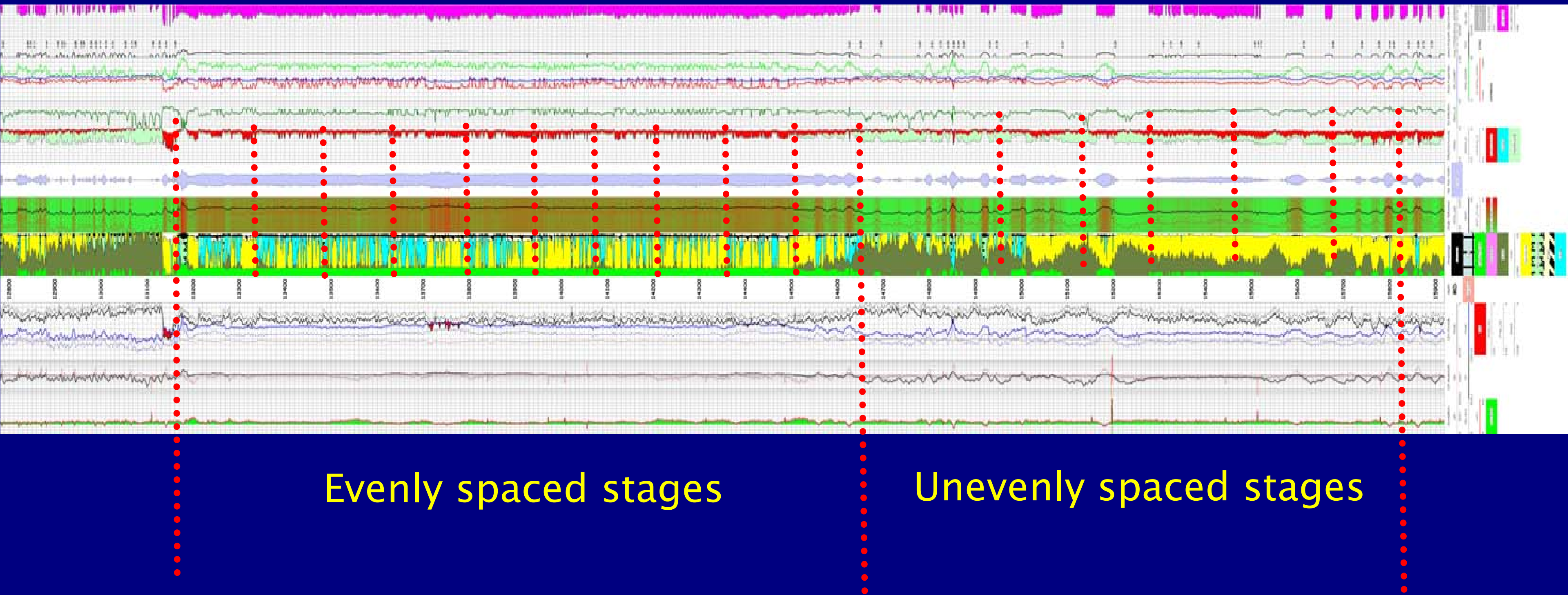


Horizontal Cased Hole Pulsed Neutron Log – Haynesville Shale

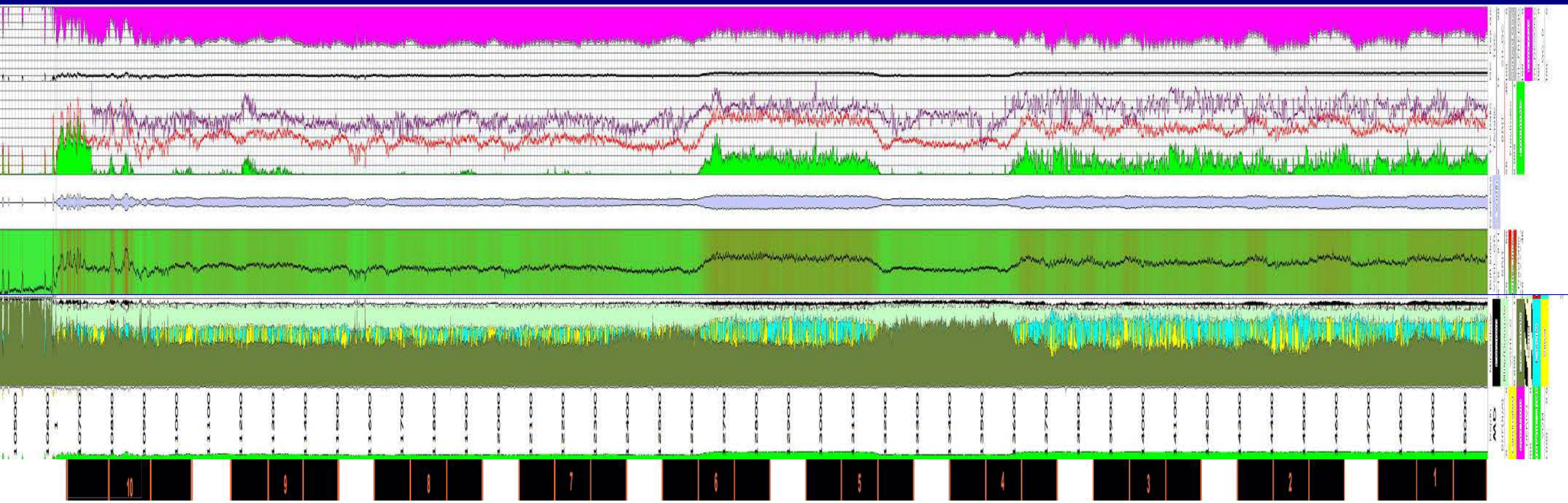
Brittleness Index, Fracture Ease, Effective Porosity, Free Gas, & TOC



Horizontal Cased Hole Pulsed Neutron Log – Haynesville Shale



Haynesville #2



768 376 0 0 1 162 0 0 15 379 64 137 0 0 298 0 0 0 0 0 100 408 0 0 0 0 0 301 0 214 67 1 137 0 0 0 768 266 0 7

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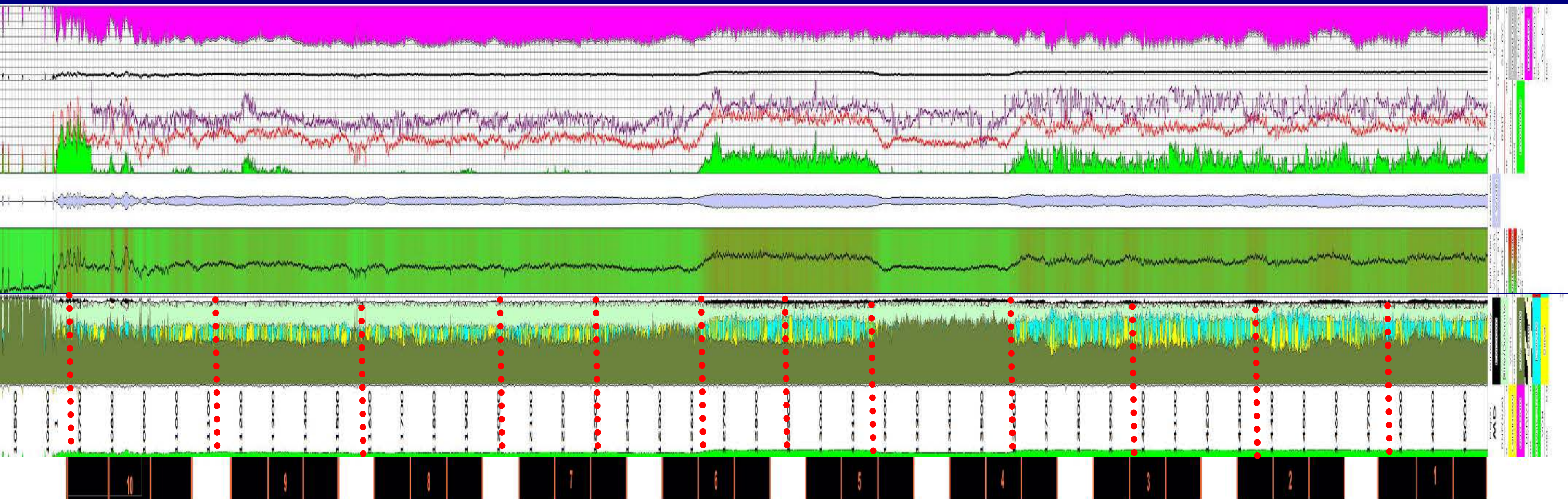
Haynesville #2



768 376 0 0 1 162 0 0 15 379 64 137 0 0 298 0 0 0 0 0 100 408 0 0 0 0 0 301 0 214 67 1 137 0 0 0 768 266 0 7

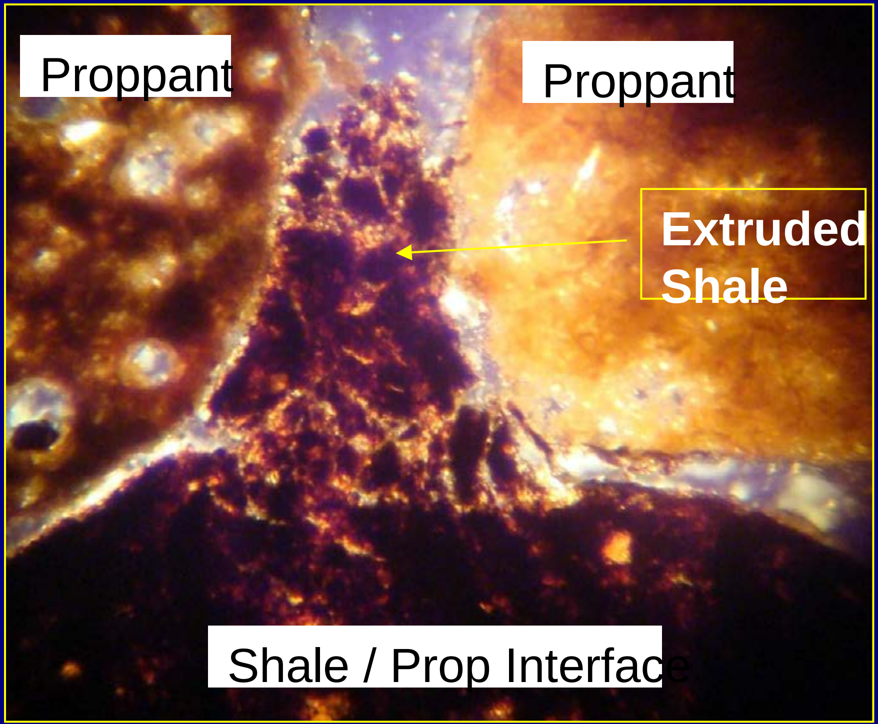
Prop 62.2%	Prop 85.3%	Prop 79%	Prop 29.5%	Prop 2.6%	Prop 89.5%	Prop 100%	Prop 3%	Prop 55.4%	Prop 35%

Shale Completion Strategy: Based on Formation Brittleness Index

Youngs Modulus	Brittleness	Fluid System	Proppant Concentration		Fluid Volume	Proppant Volume
7 E 6	70%	Slick Water	Low	Barnett	High	Low
6 E 6	60%	Slick Water				
5 E 6	50%	Hybrid		Marcellus		
4 E 6	40%	Hybrid				
3 E 6	30%	X-Linked		Eagleford		
2 E 6	20%	X-Linked		Haynesville		
1 E 6	10%	X-Linked	High		Low	High

SPE 115258

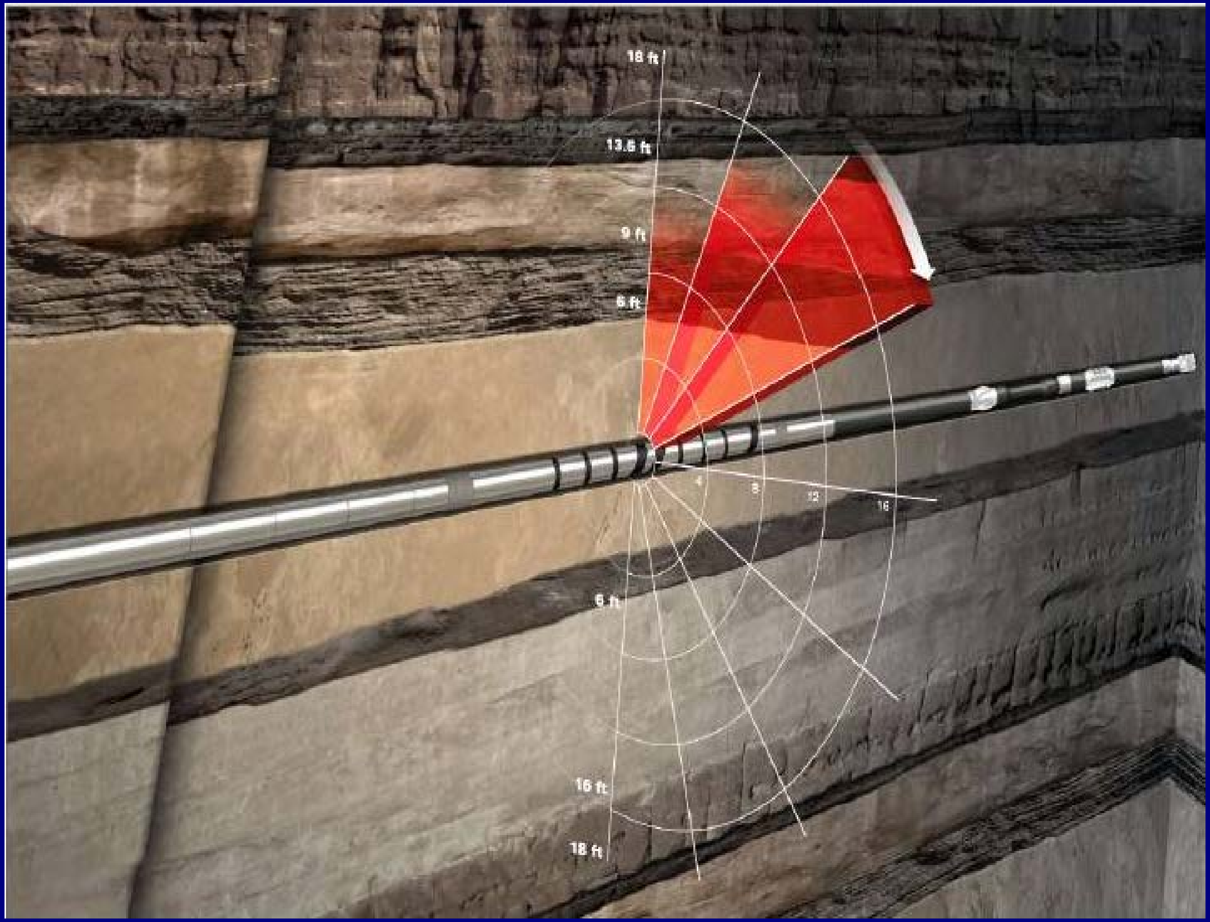
Shale Stimulation Strategy



Pitcher, J. and Buller, D., 2011 Shale Assets: Applying the Right Technology for Improving Results. Paper presented at the AAPG International Convention and Exhibition, Milan, Italy, 23-26 October.

Summary and Conclusion

- Shale reservoirs are statistical plays
  - ✓ Current Practice has limitations
- Well placement strategy dictated by geomechanics
- Geosteering enhances production by maximizing fracable reservoir contact
- Data acquired while drilling has a long shelf life
  - ✓ Data used in completion and stimulation optimization



Thank You

Спасибо

Gracias

Merci

谢谢你

Grazie

Takk

شكراً جزيلاً

Sağol

ありがとう

Obrigado

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