Evaluating Horizontal Cased Wells for Completion Design

Dallas SPE

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Evaluating Horizontal Cased Wells for Completion Design

- Introduction – why log horizontal wells ?
- Conveyance methods
- Performance Indicators
- Cased Hole Logs – Spectral Pulsed Neutron & Sonic
- Completion Design Workflow using logs
- Examples
- Conclusions

Objectives:

Lower Cost/BBL by:

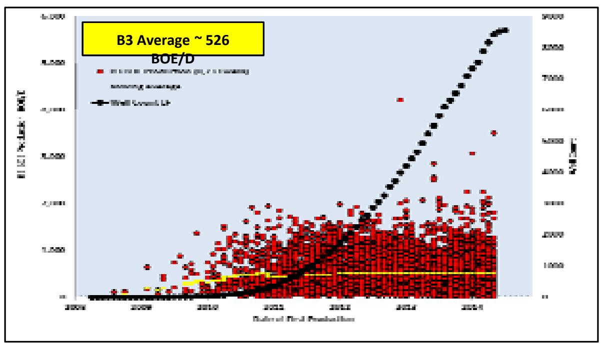
- Maximizing stimulation volume and Production
- Reduce the probability of screen outs.
- Lower completion costs.

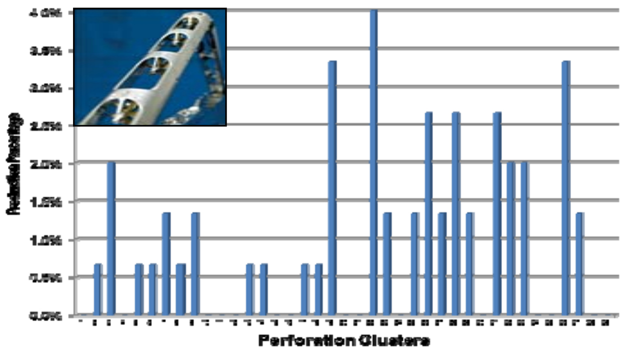
Strategy:

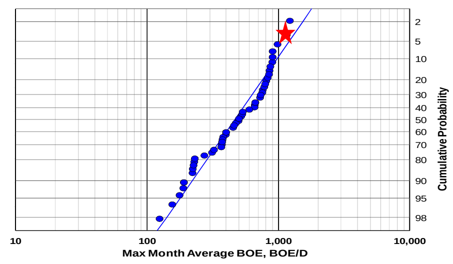
- Acquire log data in cased horizontal wells.
  1) Use the processed results to optimally position the stages and perfs, thereby ensuring a more uniform stimulation targeting the highest quality reservoir rock.
  2) Use the data as input to more comprehensive 3D frac models
     - ➢Enabling prediction of detailed fracture geometry
     - ➢Implications for well spacing and further optimization

Compelling Reasons to Consider Running Logs in the Lateral

- Despite the steady progression of drilling longer laterals and fracing more stages, production has leveled off in most US shale plays over the past 7 years.
- Production log studies show that 30-40% of stimulated perf clusters are not flowing in geometrically completed wells.
- Documented successes of logs being used for completion designs with increased production.
- Successful Re-Frac campaigns proving that many wells were not completely stimulated initially.
- Many operators moving towards more stages with tighter spacing > increased costs

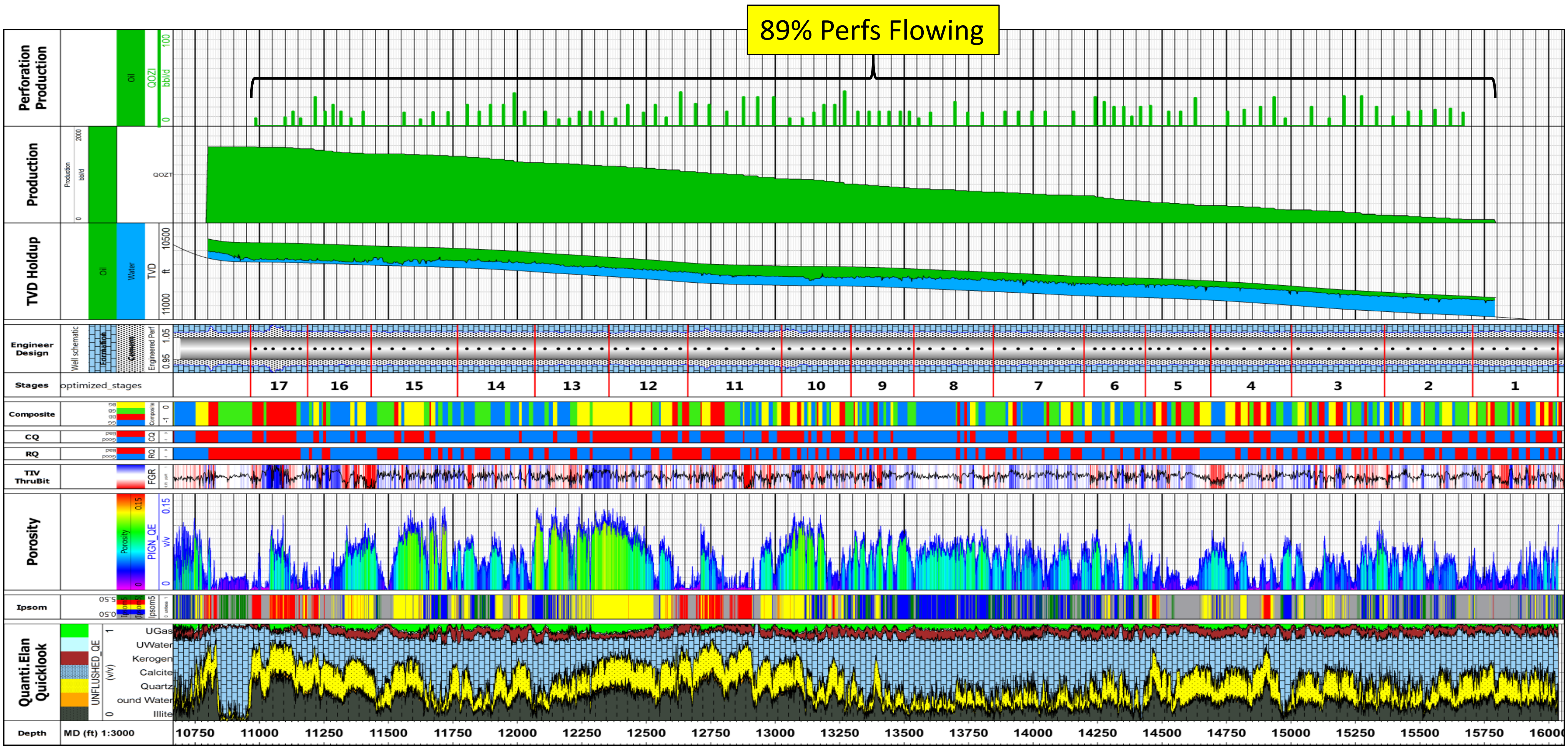






SPE Paper: 166242 (2013)

Completion Placement Guided by Logs Increases Flowing Efficiency



Open and Cased Hole logs used in Completion Design Success in most Major US Basins

References:

Eagle Ford	**SPE 166242 (2013)**
Wolfcamp	**SPE 170718 (2014)**
Marcellus	**SPE 159666 (2012), SPE 159681 (2012)**
Niobrara	**URTeC 2154958 (2015)**

Logging Conveyance Methods in Cased Horizontal Wells

Tractor:

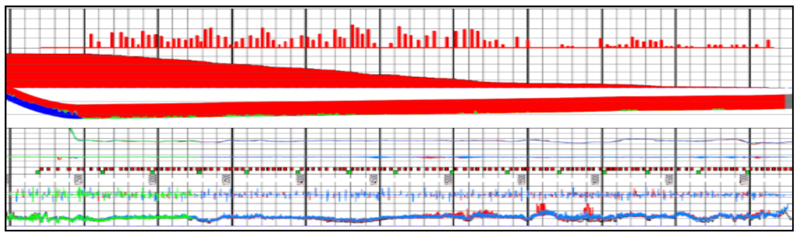
- Can run any WL tool that will fit in the casing
- Data can be monitored in real time (PL)
- Requires casing to be free of debris - scraper run
- Can sometimes have difficulty reaching the toe

Pumpdown:

- Simple and Cheap
- Must have holes in the casing – usually after toe perfs
- Data can be monitored in real time
- Greatest success in reaching the toe

Coiled Tubing:

- Most common for running Production Logs
- Can sometimes have difficulty reaching the toe
- With or without cable (Real Time vs Memory)
  Mostly memory logging now



Performance Indicators

Flags		Composite
CQ	RQ	RCQ
Good	Good	GG
Good	Bad	GB
Bad	Good	BG
Bad	Bad	BB

Frac: (CQ)

- Rock Strength
  (PR, YM, Stress,….)
- Clay volume/Lithology
- Natural fractures/Faults

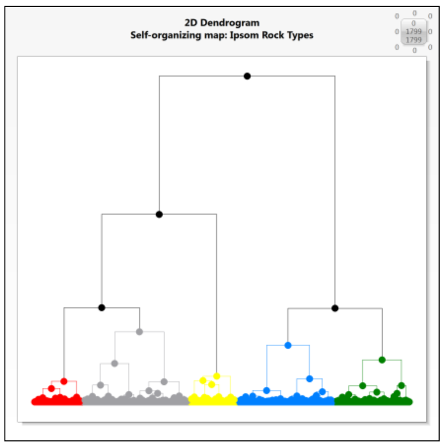
A more uniform stimulation will occur if perfs are placed in similarly stressed rock within each stage.

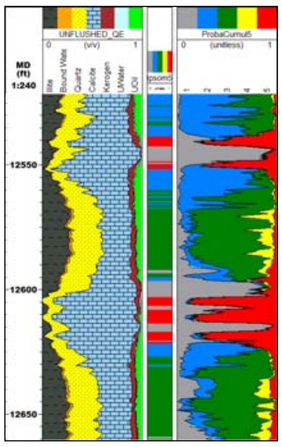
Reservoir: (RQ)

- Effective Porosity
- Clay volume/Lithology
- TOC/Kerogen
- HC Saturation
- Natural fractures

Perfs located in higher RQ will flow longer and produce better than those located in poor RQ.

Reservoir Quality – Cluster Analysis Workflow



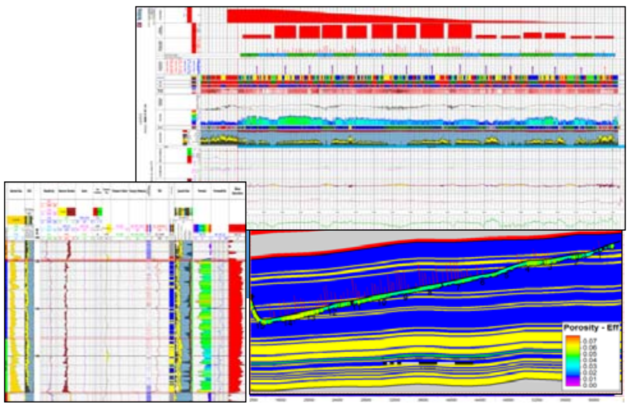


Grouping “like rock”

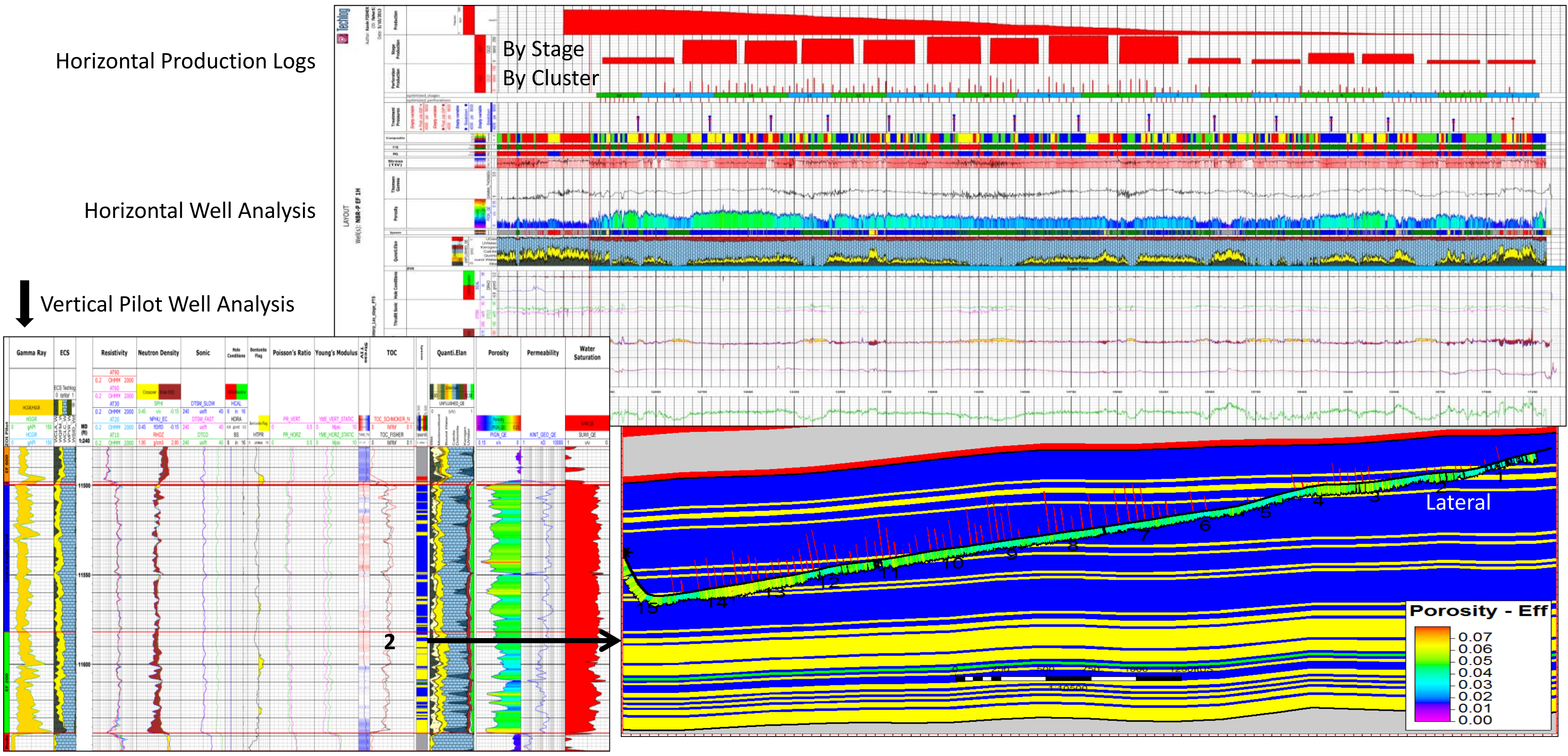
Color/Rock Type	Blue	Green	Yellow	Red	Gray
Clay Volume Fraction (v/v)	0.134	0.294	0.434	0.055	0.210
Effective Porosity (v/v)	0.074	0.068	0.034	0.039	0.016
Permeability (nD)	245	133	23	24	10
Total Organic Carbon (weight %)	4.9%	4.3%	2.2%	3.0%	1.9%
Thermal Neutron Porosity (v/v)	0.162	0.208	0.212	0.086	0.102
Bulk Density (g/cc)	2.422	2.449	2.565	2.519	2.579
Gamma Ray (gAPI)	67.9	87.0	99.4	49.9	69.6

“RQ-Good” “RQ-Bad”

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



Reservoir Quality does matter



Perforation Performance in Argillaceous Shales

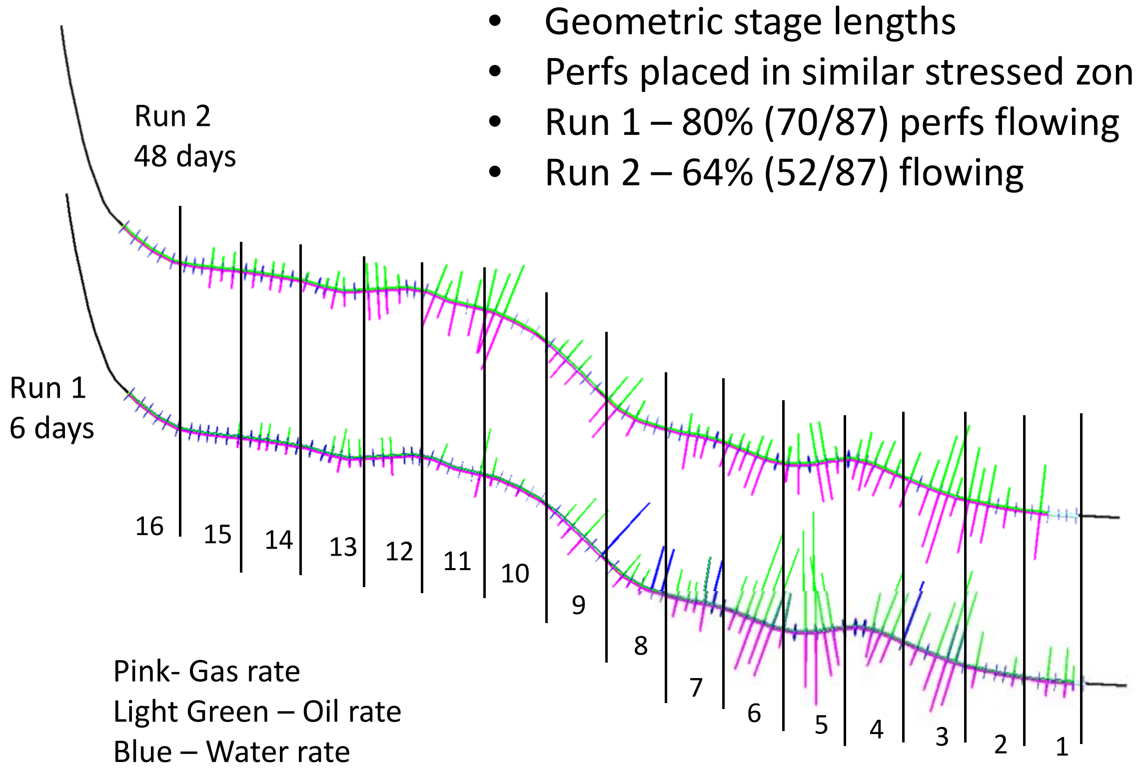
- Whole core from Mancos shale
- Single shot into core perpendicular to bedding

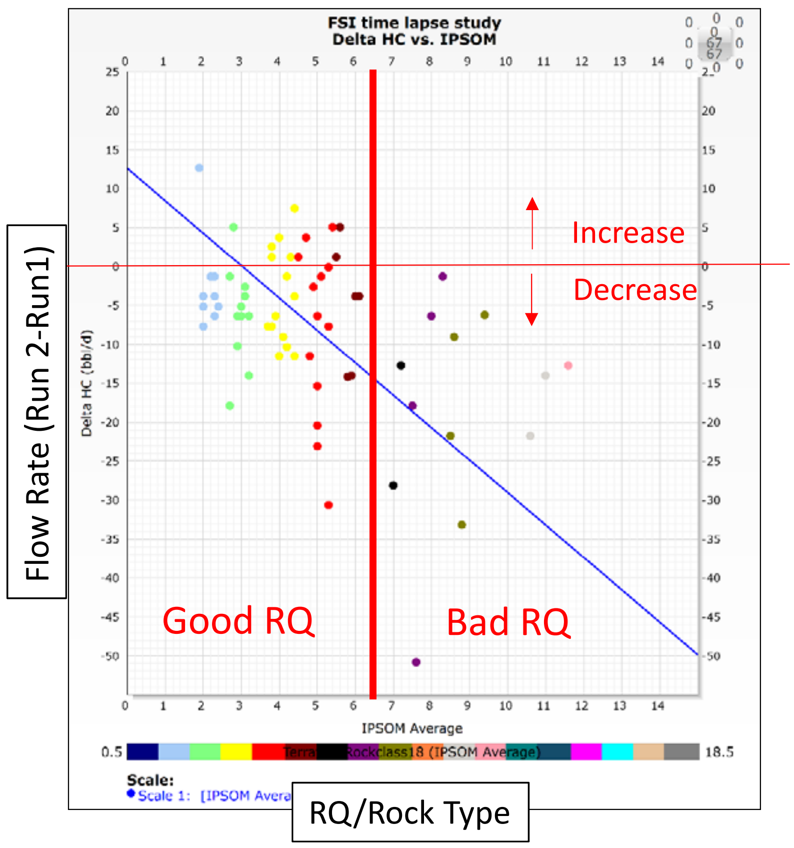
Narrow hole full of loose material after perforating, but the fill is more solid when left stressed for 24 hrs

Perf

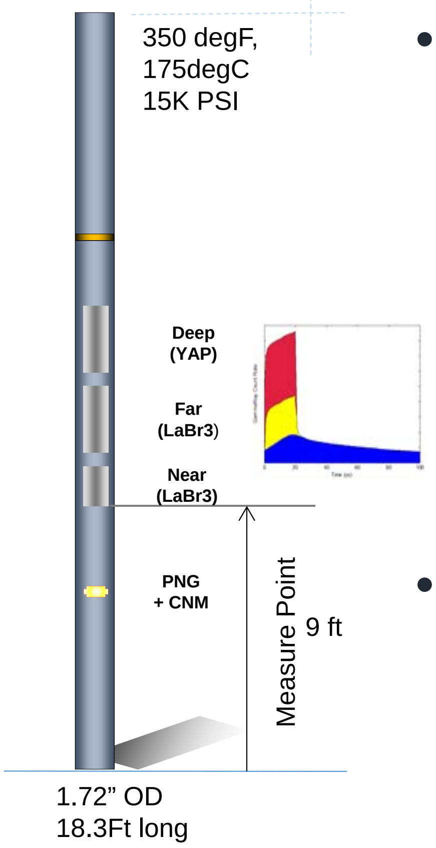
Time Lapse Production Logging – Eagle Ford Shale

- OH Logs for design
- Geometric stage lengths
- Perfs placed in similar stressed zones
- Run 1 – 80% (70/87) perfs flowing
- Run 2 – 64% (52/87) flowing

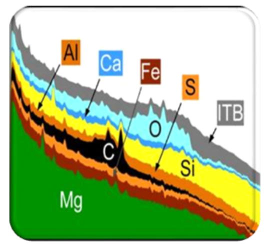




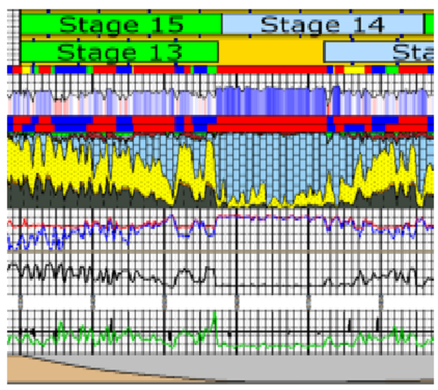
NEW - Slim Spectral Pulsed Neutron Tool



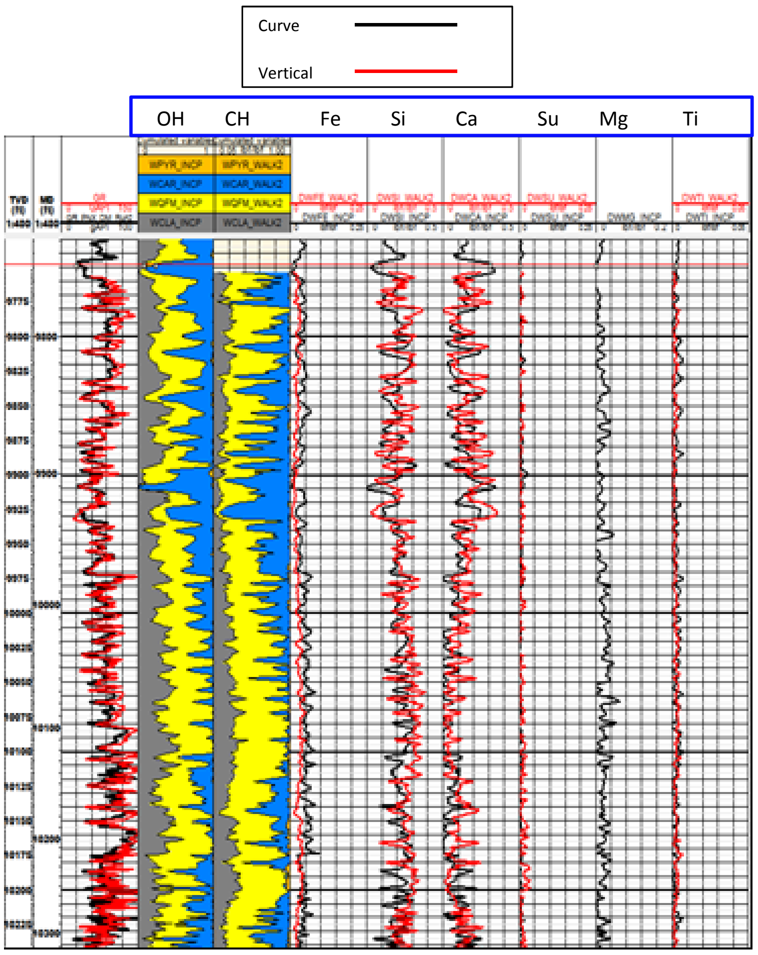
- 1.72" tool
  - Enhanced source and detector design
  - 3 detectors + CNM for better resolution
  - New & Improved Measurement Characterizations
  - Replicates OH neutron porosity (TNPH)
  - Fast neutron Cross-section for improved Gas Detection and Quantification
  - Simultaneous Advanced Spectroscopy with Traditional PNL measurements and in a single pass with greater precision and faster logging speeds (900 fph)



- Improved measurements in complex cased hole environments
  - Conventional & Unconventional Reservoirs
  - Enhanced Oil Recovery
  - Vertical and Horizontal wells
  - Gravity, Pump-down or Tractor Conveyance

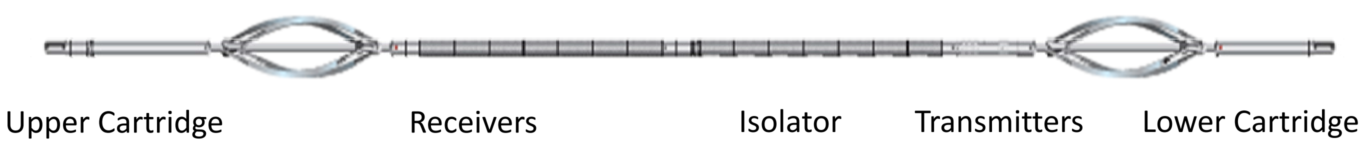


Comparison OH & CH Lithology from Neutron Spectroscopy



- Two separate wellbores
- Vertical Data is from OH pilot well Neutron Spectroscopy
- CH spectroscopy from New Slim Spectral Pulsed Neutron in the curve of Hz well – equivalent strat section
- Good agreement of OH-CH spectral elemental yields & lithology

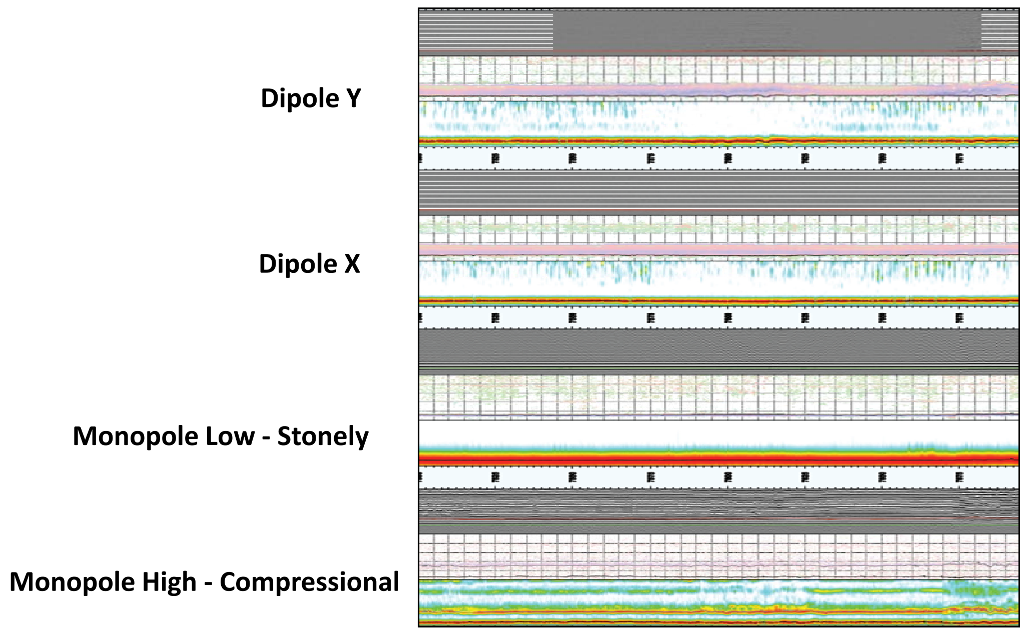
Slim Dipole Sonic



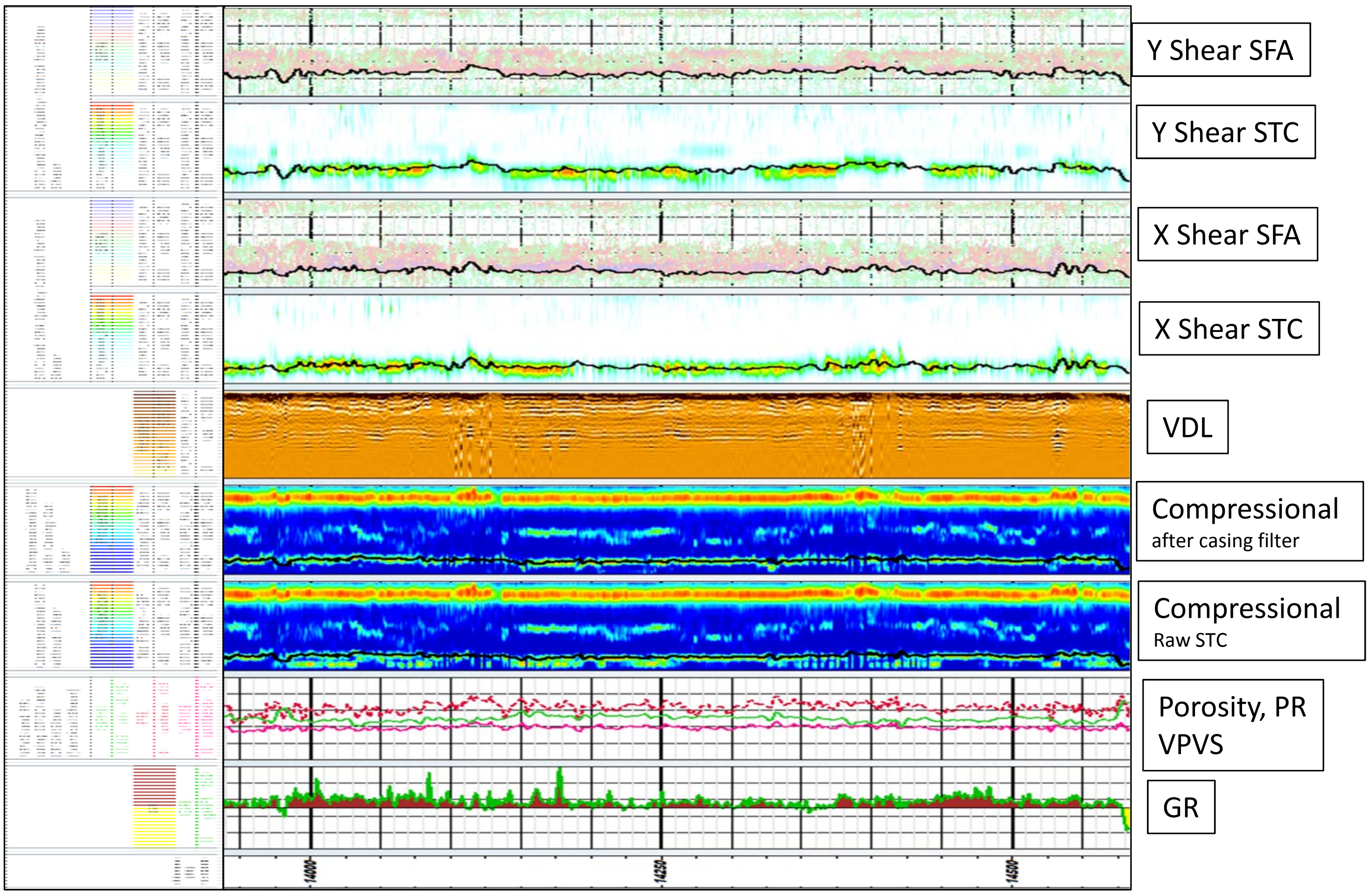
<u>OPEN or CASED hole</u>

Horizontal or Vertical wells

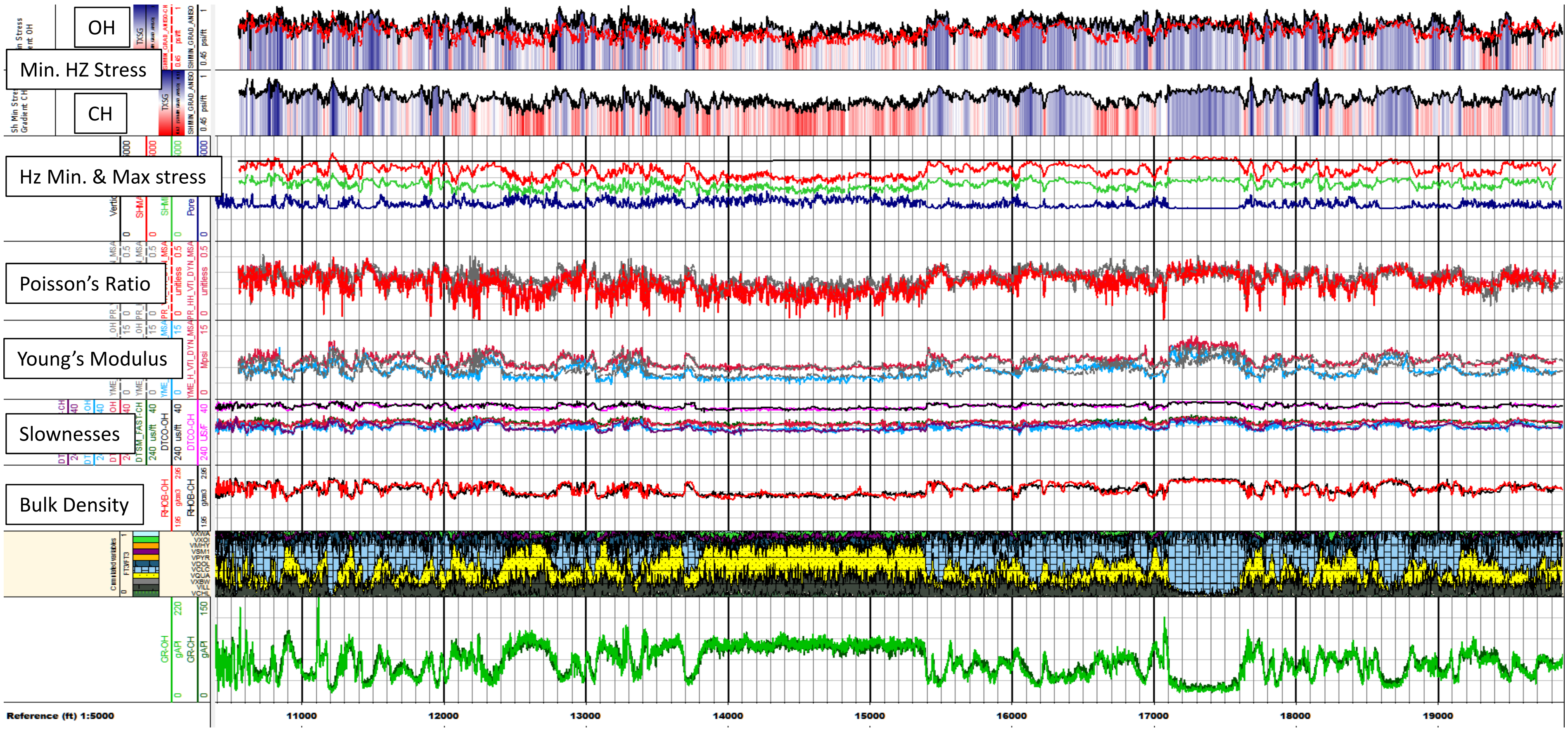
Fully Combinable with other tools	
Max Tool OD	2 1/8”
Maximum Hole Size Optimal readings	8.75”
Length	29.1’
Temperature	300°F
12 Receivers/4 azimuths	48 total
Receiver spacing	4”
Multiple Frequencies	
Monopole High and Low Freq. (Compressional & Stonely)	
Dipole Shear X & Y	
Maximum Shear - Optimal	200 us/ft
Accuracy	2 us/ft or 2%
Vertical Resolution	<44”



Slim Dipole Sonic in 4.5” casing



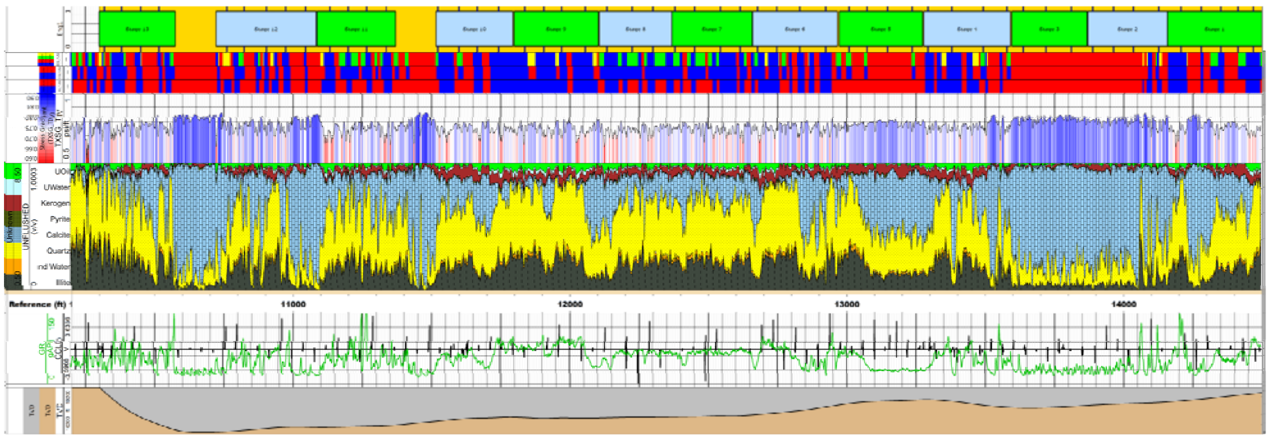
Mechanical Properties and Stress Gradient OH vs CH

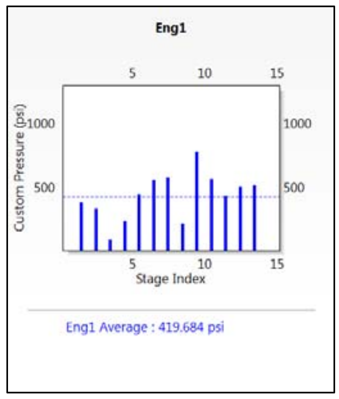


Wolfcamp Horizontal well Logged with Open and Cased Hole Sonics

Cased Hole Log Completion Design Workflow

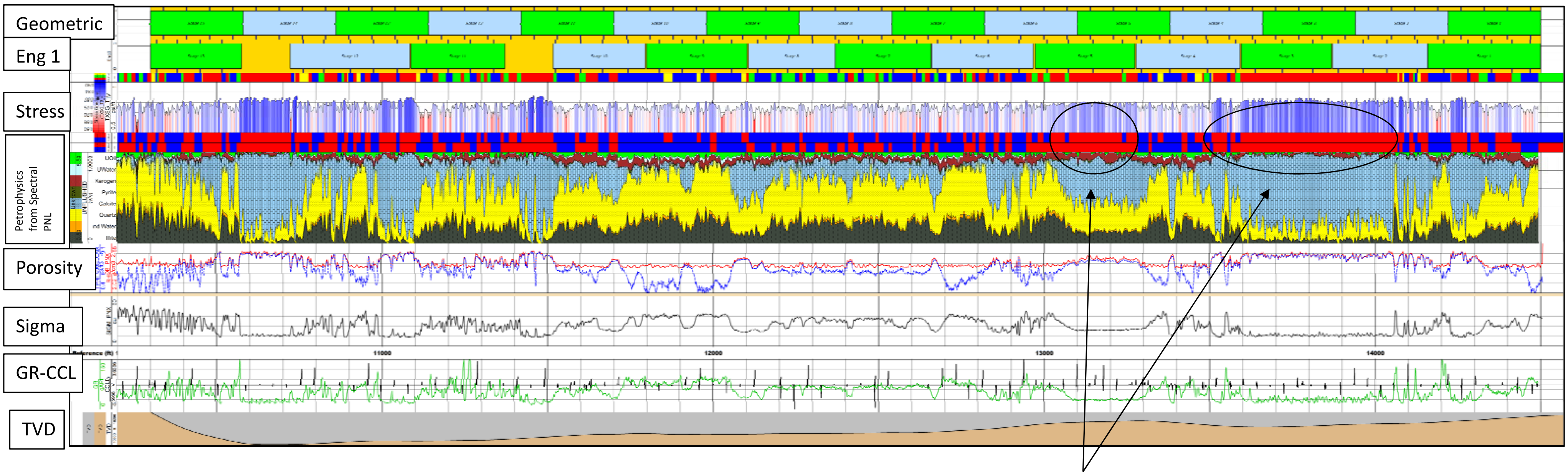
1) Petrophysical Analysis from Spectral Pulsed Neutron
2) Rock Strength from processed dipole sonic
3) Compute Performance Indicators from 1) & 2)
4) Software tool to use Indicators (RQ/CQ) and manual interactions to place stages.
5) Software tool to place perfs in similar stress areas within each stage while targeting the best RQ.





Wolfcamp Oil Example

Completion Design using CH logs (Slim Spectral PNL-Dipole Sonic)

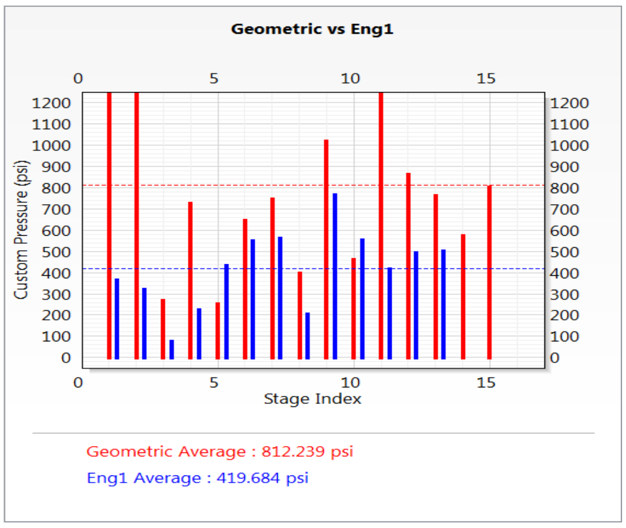


Horizontal well: Logs pumped down in 5.1" 18# casing

Difficulty fracing these areas

Wolfcamp Oil Example

Completion Design Summary



Flags		Composite
CQ	RQ	RCQ
Good	Good	GG
Good	Bad	GB
Bad	Good	BG
Bad	Bad	BB

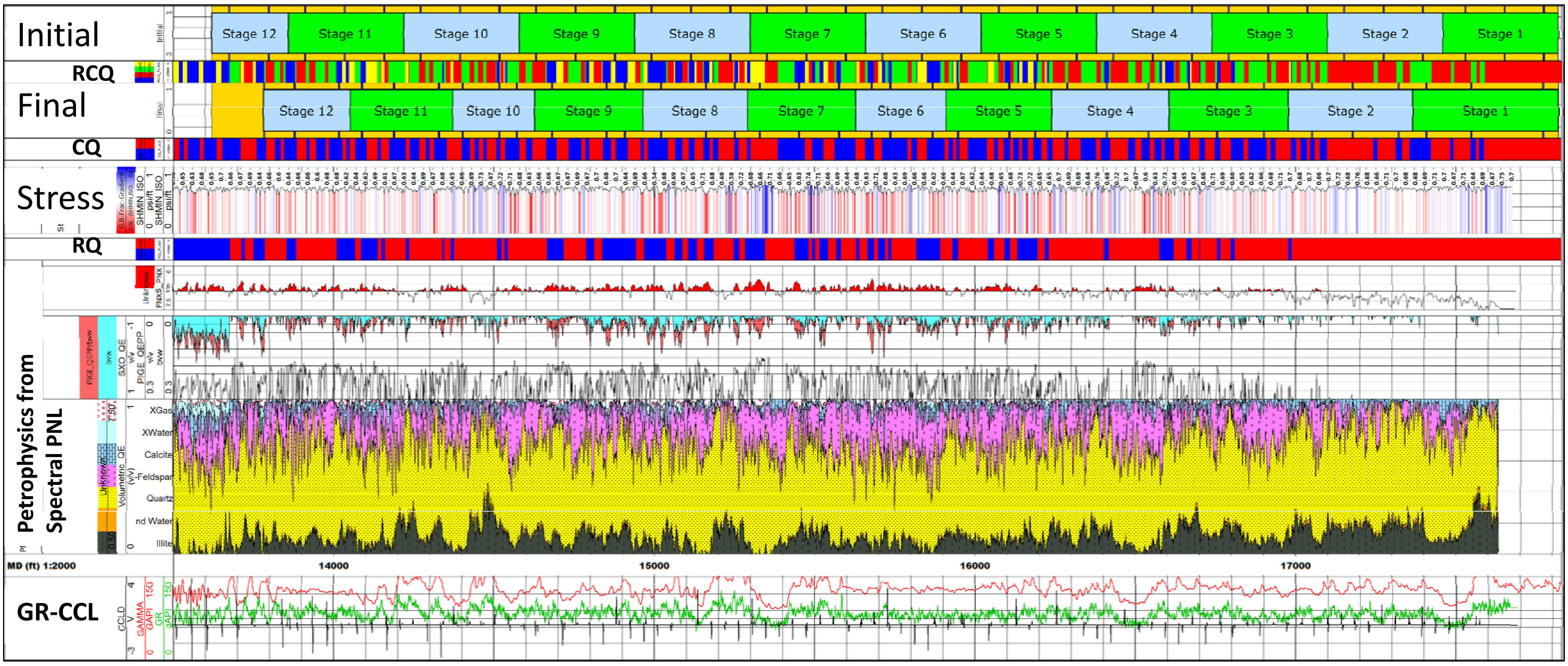
85% of perfs placed in the best rock vs 51% on the Geometric case

48% Decrease in Average Differential pressures

		% Perfs Placed	
RQ/CQ Summary:		**Eng1**	**Geometric**
GG		**62%**	**33%**
GB		**23%**	**18%**
BG		**2%**	**7%**
BB		**13%**	**42%**
Perf Spacing Summary:			
Min		**55**	**70**
Max		**245**	**70**
Avg		**81**	**70**
Stage Spacing Summary:			
Min		**205**	**280**
Max		**362**	**280**
Avg		**292**	**280**
# Stages		**13**	**15**
# Perfs		**52**	**60**
Min Clusters		**3**	**4**
Max Clusters		**5**	**4**
Avg. Differential Pressures - all stages		**420**	**812**

Granite Wash Gas Example

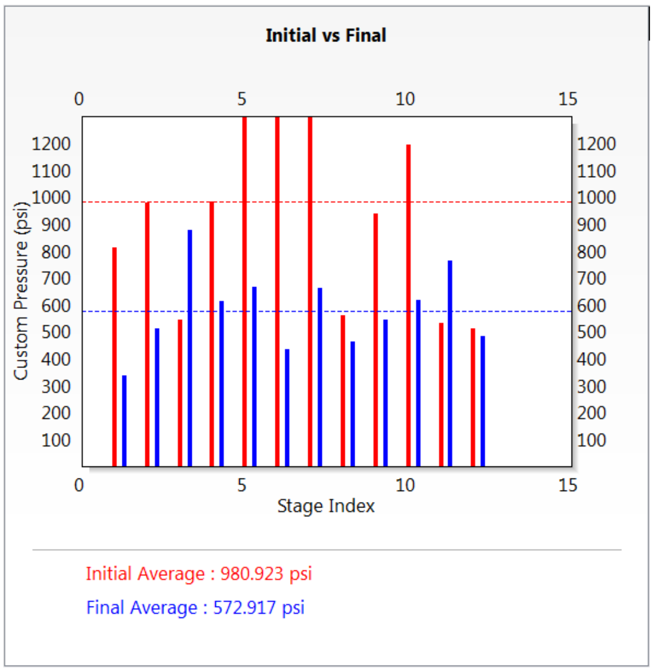
Completion Design using CH logs (Slim Spectral PNL-Dipole Sonic)



Horizontal well: Logs pumped down in 5.5” 20# casing

Granite Wash Gas Example

Completion Design Summary



Flags			Composite
CQ	RQ		RCQ
Good	Good		GG
Good	Bad		GB
Bad	Good		BG
Bad	Bad		BB

- 88% vs 26% perfs placed in the best rock
- 42% Decrease in average differential pressure

IP=1.0 MMCF/Day with water

as anticipated from petrophysics

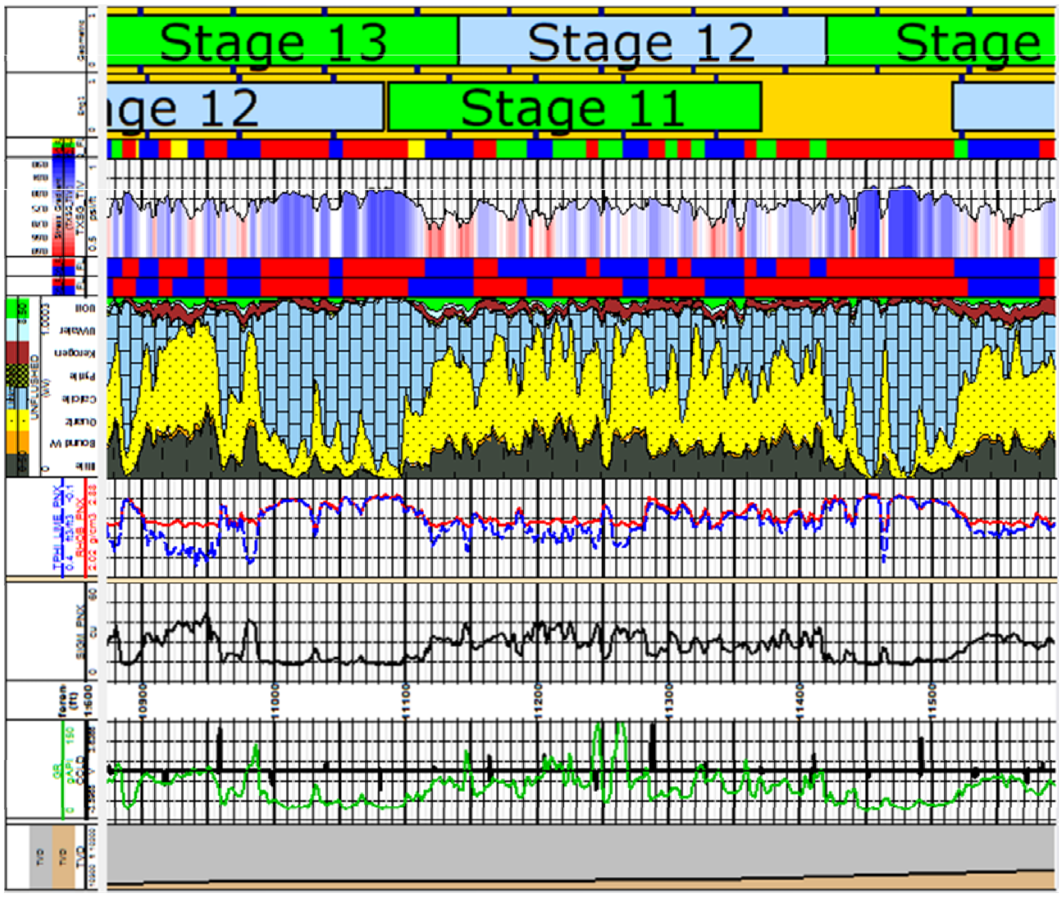
	% Perfs Placed	
RQ/CQ Summary:	**Final**	**Initial**
GG	**58%**	**17%**
GB	**33%**	**9%**
BG	**3%**	**14%**
BB	**6%**	**60%**
Perf Spacing Summary:		
Min	**55**	**114**
Max	**223**	**133**
Avg	**114**	**121**
Stage Spacing Summary:		
Min	**255**	**239**
Max	**454**	**360**
Avg	**337**	**350**
# Stages	**12**	**12**
# Perfs	**36**	**35**
Min Clusters	**3**	**2**
Max Clusters	**3**	**3**
Avg. Differential Pressures - all stages	**573**	**980**

Evaluating Horizontal Cased Wells for Completion Design

Summary - Conclusions

- Logging tools can be successfully run in cased Hz wells using tractors or by pumping down, thus saving the rig costs compared OH logging.
- New technology has made log data quality in cased hole comparable to open hole and acceptable for use in completion design. Some measurements, such as imaging, are not available in CH.
- The importance of Reservoir Quality in completion placement should not be discounted. It has been shown with production logs to have a direct influence on productivity.
- Using logs to adjust the stimulation intervals and perforation placement will lead to more effective stimulation and enhance productivity.
- The use of Lateral Measurements in completion design can significantly reduce completion costs by:
    1) Minimizing screen outs and their associated remediation costs.
    2) Possible reduction in stages needed for an effective stimulation.
- Engineered Completions result in accelerated Early production which results in faster payout and lower finding cost/barrel.

Questions



Abstract

Since the downturn of factory drilling, there remains an inventory of wells that have been drilled and cased, but are still uncompleted. In the current slower paced environment these uncompleted wells present an opportunity to use the latest technology to improve production potential while keeping the completion costs to a minimum. Since 2012 there have been a number of documented successes involving the use of logs run in horizontal wells to better understand well placement, reservoir quality and provide the data necessary to improve completion planning. While most of this early success using data to improve completions was with open hole logs, the current economics have forced more of the logging be done in cased hole in an effort to reduce the associated rig costs. In cased wells, logging tools can either be conveyed by tractor or pumped down to the toe of the well depending on the configuration and measurements needed.

A new generation pulsed neutron spectroscopy tool has been developed that acquires simultaneous lithology evaluation and improved gas quantification in addition to the traditional pulsed neutron data in a single pass. This new tool can be combined with a slim dipole sonic which obtains mechanical properties data through casing. The processed results from this suite of tools provides very similar results compared to open hole evaluation and can easily fit into existing workflows. An overview of these tools will be presented along with case histories showing their application in completion design.

Speaker Bio

Rick Reischman is a Domain Champion for Lateral Measurements in Unconventional plays with Schlumberger in Houston, Texas. He specializes in the use of horizontal logs in completion design. Rick’s past work experience includes 37 years most of which were with Schlumberger Wireline in various assignments, and three years with ThruBit as a petrophysical advisor before its acquisition by Schlumberger in 2012. Rick received a Bachelor’s of Science in Mechanical Engineering from the University of Texas at Austin and his professional affiliations include SPE, AAPG and SPWLA.