Focusing Stimulation Efforts on Sweet Spots in Shale Reservoirs for Enhanced Productivity*

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Abstract

As the quest for shale oil and gas spreads to South America, Europe, Asia and Australia, inevitably the operating practices of North America tend to serve as the template for the new, frontier areas. With either a sparse evaluation from logs, cores and cuttings or none at all, the ubiquitous approach for selection of zones for hydraulic fracturing in the long laterals in North America is to place 20 to 30 frac stages, more or less evenly spaced along the lateral, often without regard to variations in the reservoir properties. In many cases, especially in early stage frontier regions, a more comprehensive alternative approach that includes geological data integration to selectively optimize completion and stimulation intervals could be advantageous.

Specific field examples presented here show how each of the following can serve, in varying degrees, to delineate zones with better reservoir properties from those with poor reservoir characteristics: (i) Near real time measurements of XRF, XRD and pyrolisis on cuttings at the well site, (ii) a superior approach to monitoring the real-time hydrocarbon (C1-C8, benzene, toluene) and non-hydrocarbon gases (CO_2, N_2) dissolved in the drilling fluid in the mud stream, (iii) LWD spectral gamma ray and density measurements, (iv) LWD Shock wave acoustics, and (v) suites of openhole well logs obtained in horizontal shale gas wells. This enables the operator to concentrate frac dollars in zones that are more productive and at the same time avoid intervals that are not likely to be good producers. A relatively small investment in such surveys to delineate sweet spots could yield major dividends in enhanced productivity and improved utilization of frac dollars.

References

Basu, N., G. Barzola, H. Bello, P. Clarke, and O. Viloria, 2012, Eagle Ford Reservoir Characterization from Multisource Data Integration: Search and Discovery Article #80234, 58 p. Web accessed 20 November 2012.

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Pope, C., T. Palisch, and P. Saldungaray, 2012, Improving completion and stimulation effectiveness in unconventional reservoirs – Field results in the Eagle Ford Shale of North America: SPE 152839-MS, 1 pg.

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September 15th – 19th 2012

* Since Retired

Thank You

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- Alan Morrison
- Frank Walles *
- Don Hall**

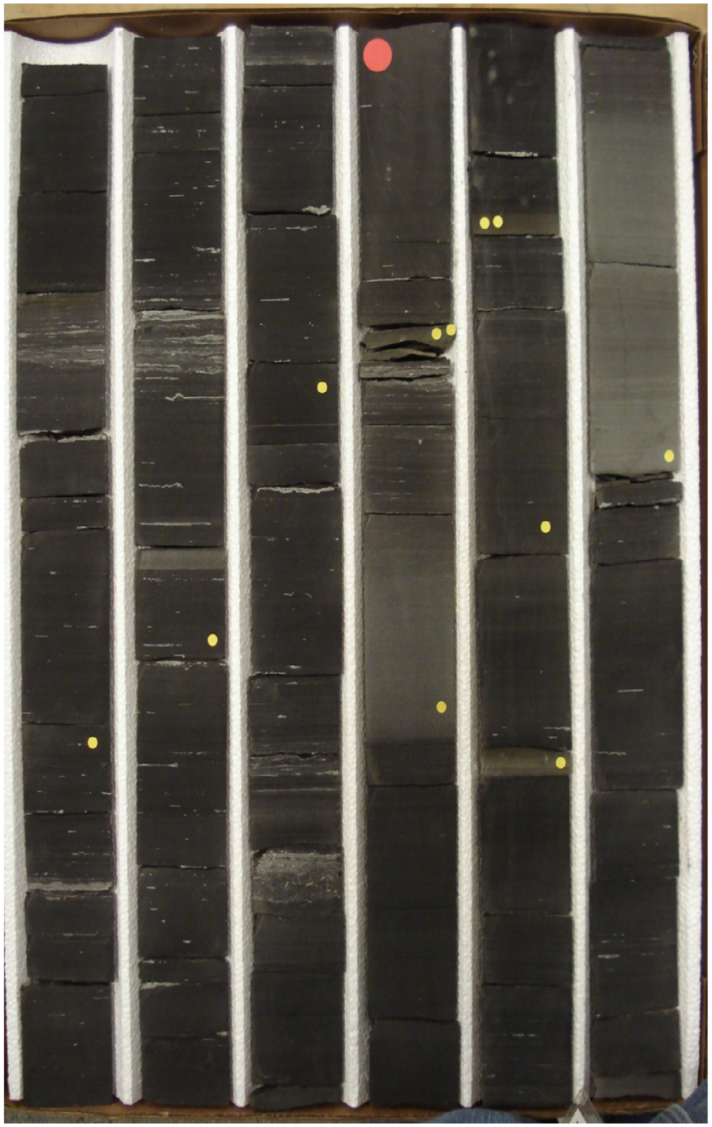
- Simon Hughes
- Mike Dix
- Nicolo Casarta
- Ryan King
- Tim Ruble
- Mark McCaffrey
- Rob Fulks
- Pat Jacobs
- Henderson Watkins

Weatherford

* Talisman Energy, ** Pioneer Natural Resources

Definition -"The Sweet Spot"

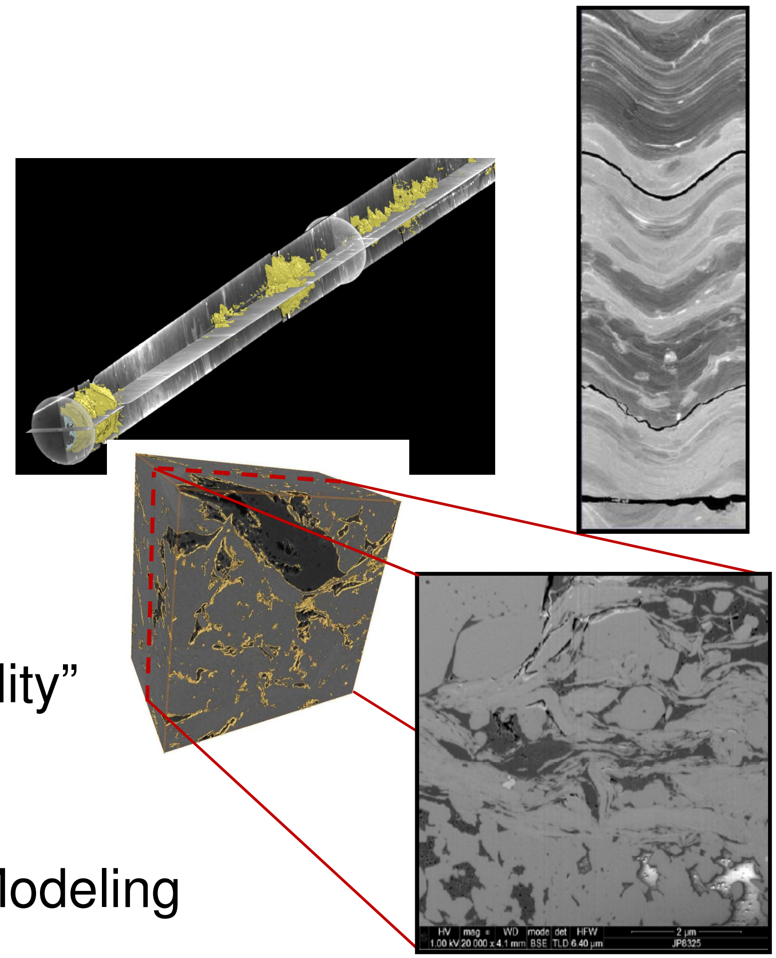
- High TOC
- Rel. High Brittleness
- Rel. High Φ, K, S Hy
- Low Clay Content
- Mineral Filled Natural Fractures
- Optimal Stress Regime



First Start with Core

Primary Core Evaluation Goals – Empirically Determine Key Shale Reservoir Properties

- Bulk Rock Properties
- Gas-in-Place Volume
- Oil-in-Place Volume
- Permeability to Gas and Oil
- Rock Mechanical Properties – "Fracability"
- Core-to-log Calibration
- Accurate Variable Input for Reservoir Modeling



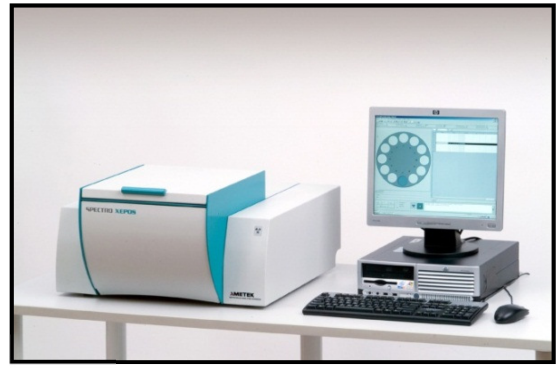
Sweet Spot: Identification Methods

- In Verticals and Laterals Mud gas and Cuttings are a by-product of the drilling operation.
- Advanced Mud Gas Extraction/Detection
- Cuttings analysis
  - XRF, XRD, & Pyrolysis on Cuttings
    1. In Pilot Holes
    2. In Laterals
- Logging While Drilling
- Wireline Logging

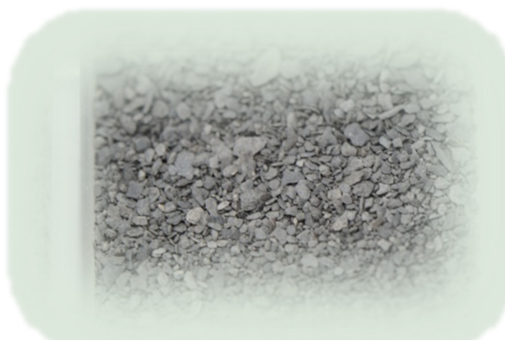
Wellsite Geoscience – Cuttings Analysis

SRA & XRD

XRF



Sample Prep & Fume Hood

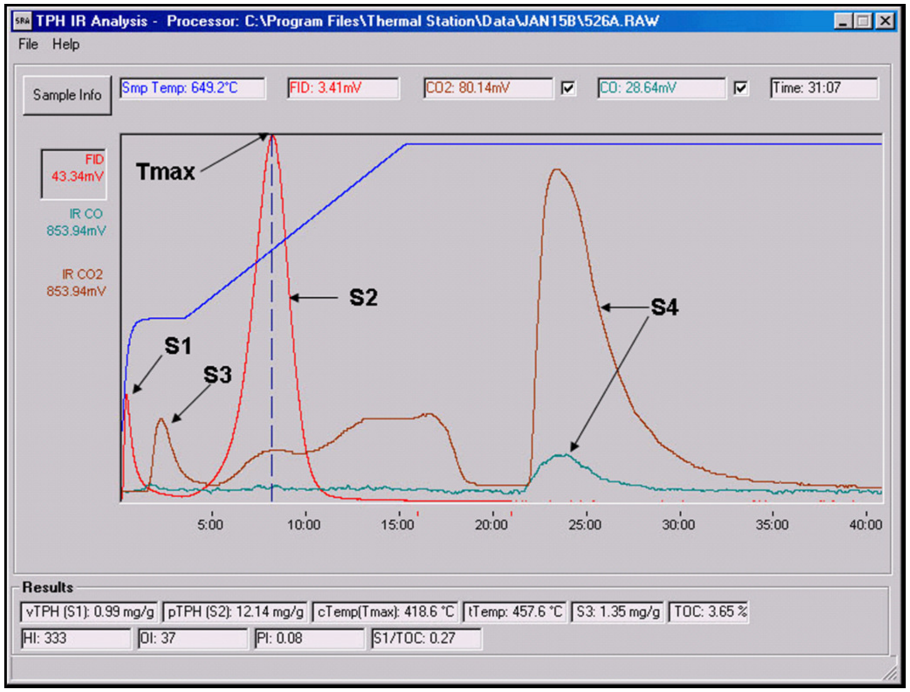


Data Analysis Center

Programmed Pyrolysis

SRA Portable Pyrolysis Instrument provides:

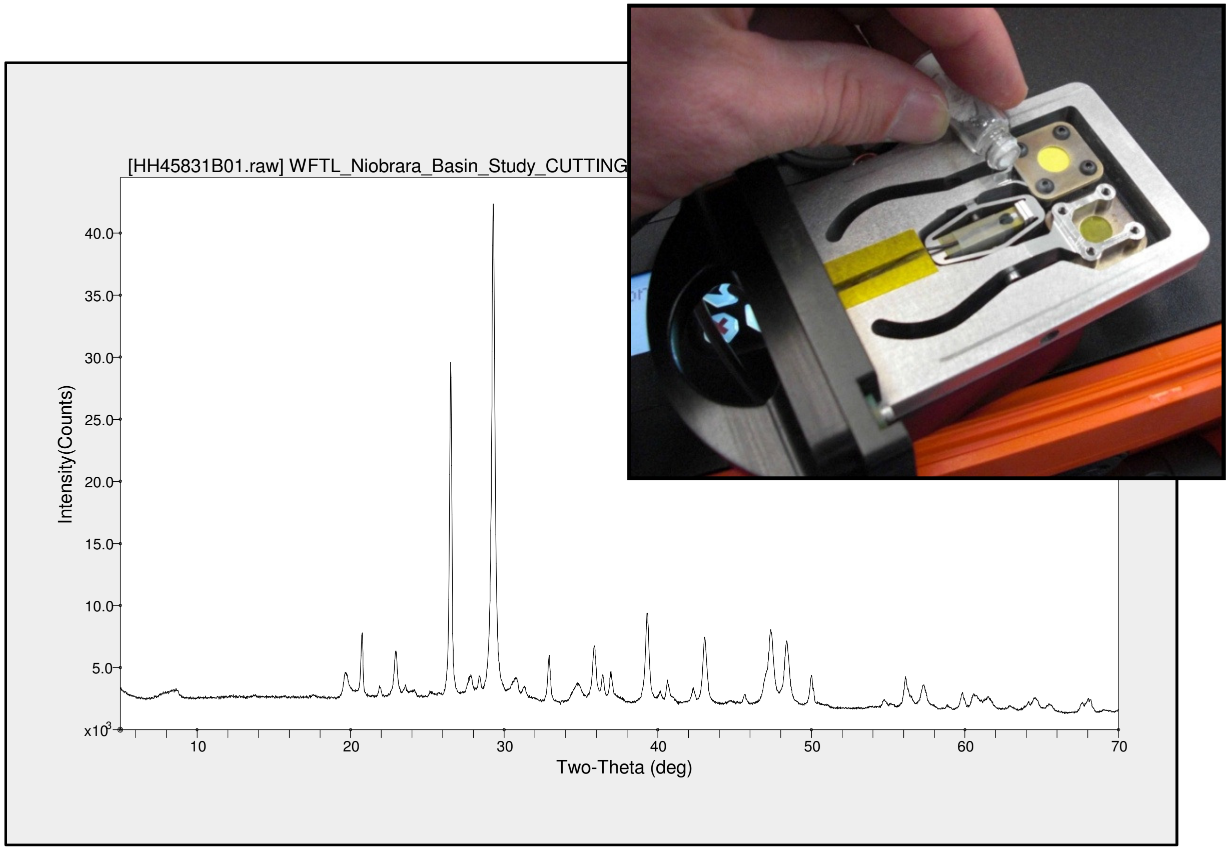
- Free Hydrocarbon (Gas/Oil) Content – S_1
- Remaining Hydrocarbon Generation Potential – S_2
- Organic richness – TOC
- Thermal Maturity – T_{max}



XRD Data – Mineralogy at Wellsite

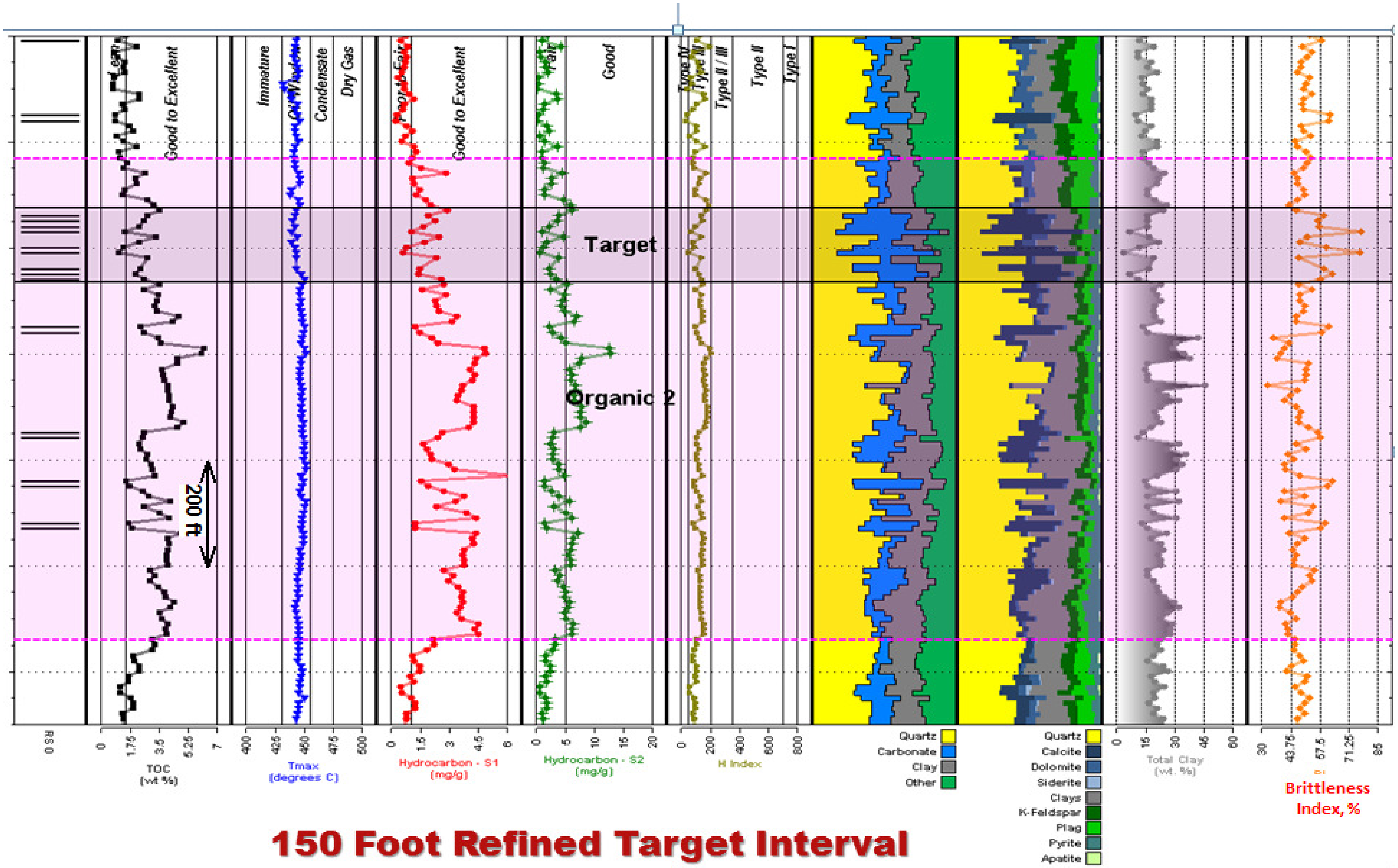
Direct Measurement of All Major Minerals

- Quartz
- K-Feldspar
- Plagioclase
- **Total Clay**
- Calcite
- Dolomite
- Siderite
- Pyrite
- Anhydrite



Procedures developed from laboratory bulk XRD analysis

XRD/PYROLYSIS DATA DEFINE TARGET ZONE



150 Foot Refined Target Interval

XRF Elemental Composition at Wellsite

Benchtop when compared to hand held device provided greater range of elements and superior accuracy and precision

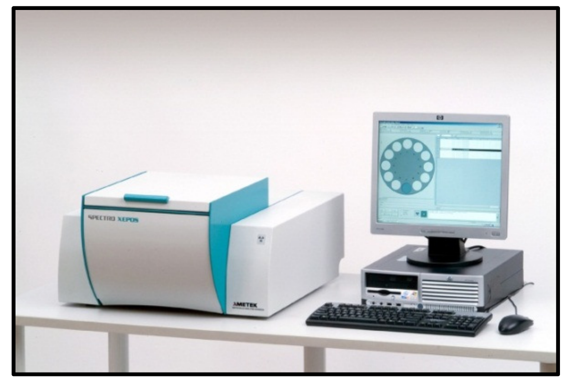
- XRF measures 10-12 Major Elements (oxide wt%)

  SiO_2 TiO_2 Al_2O_3 Fe_2O_3 MnO MgO CaO Na_2O K_2O P_2O_5 (plus S and Cl for most lithologies)

- XRF measures 18 Trace Elements (ppm)

  V Cr Co Ni Zn Ga As Br Rb Sr Y Zr Nb Mo Ba Hf Th U

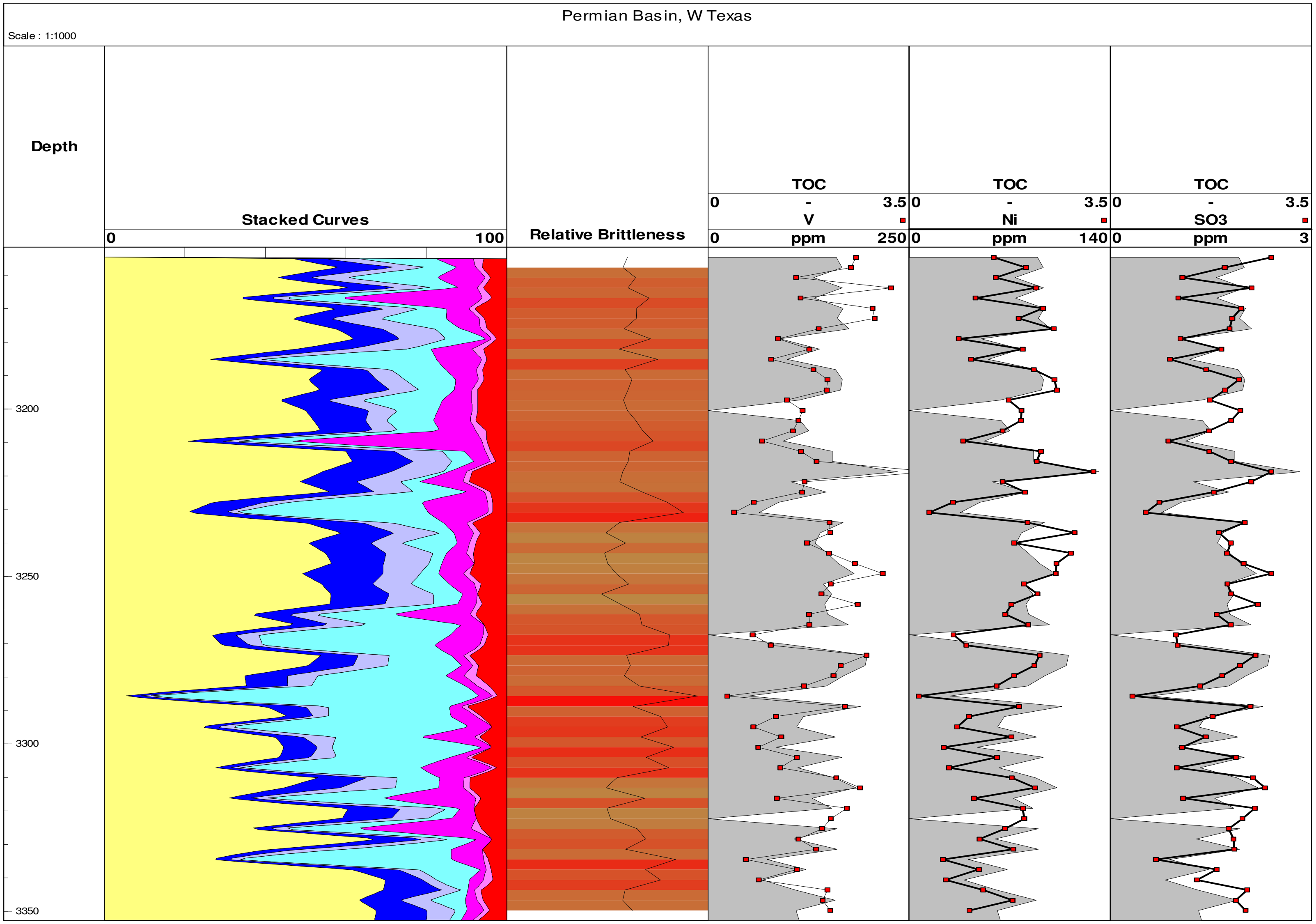
- Many minerals show considerable variability in their elemental composition, particularly with regard to trace elements.



Wellsite Cutting Analysis Work Flow

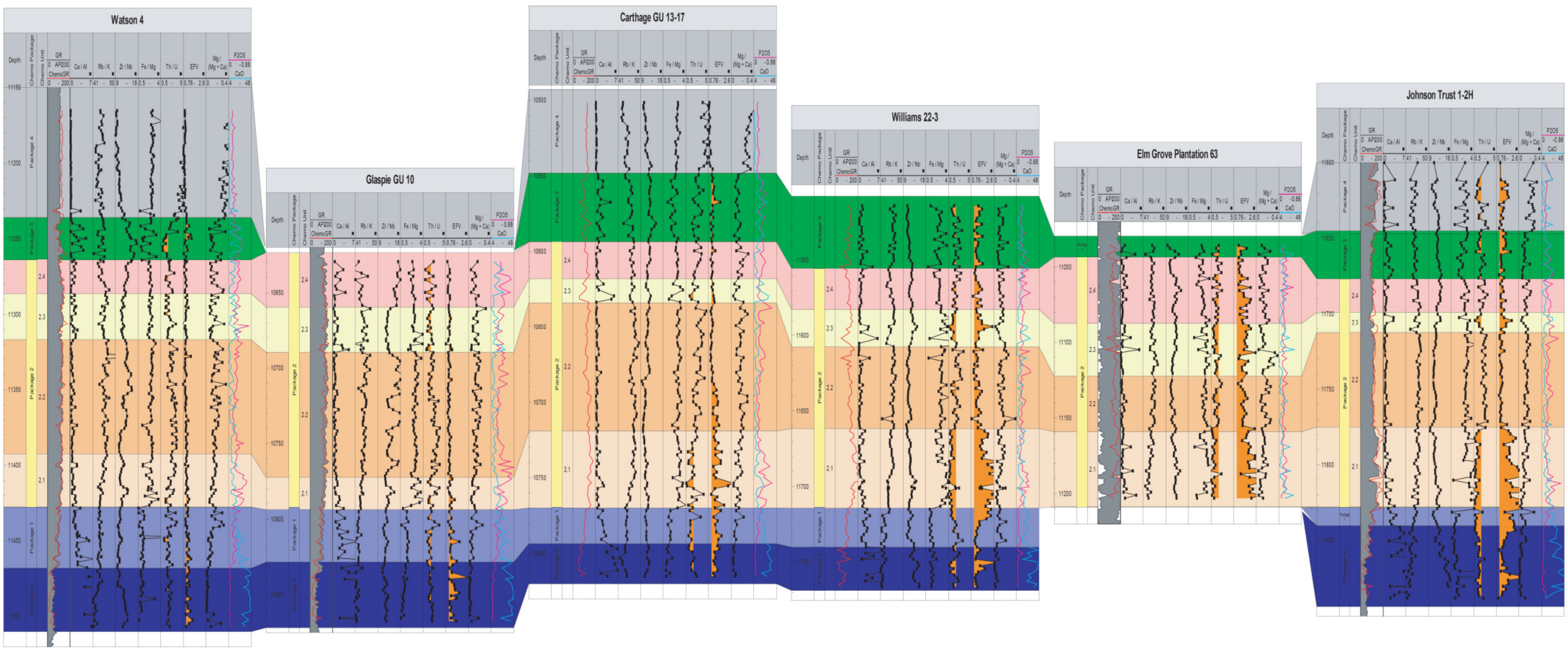
1. Commence with XRD/XRF and Pyrolysis on Pilot vertical holes and laterals.
2. Establish proxies for TOC with Trace Elements.
3. Resolve Mineralogy from the elemental data set.
4. As uncertainty is reduced move to XRF only.

Correlation of Pyrolysis TOC with Trace Metals



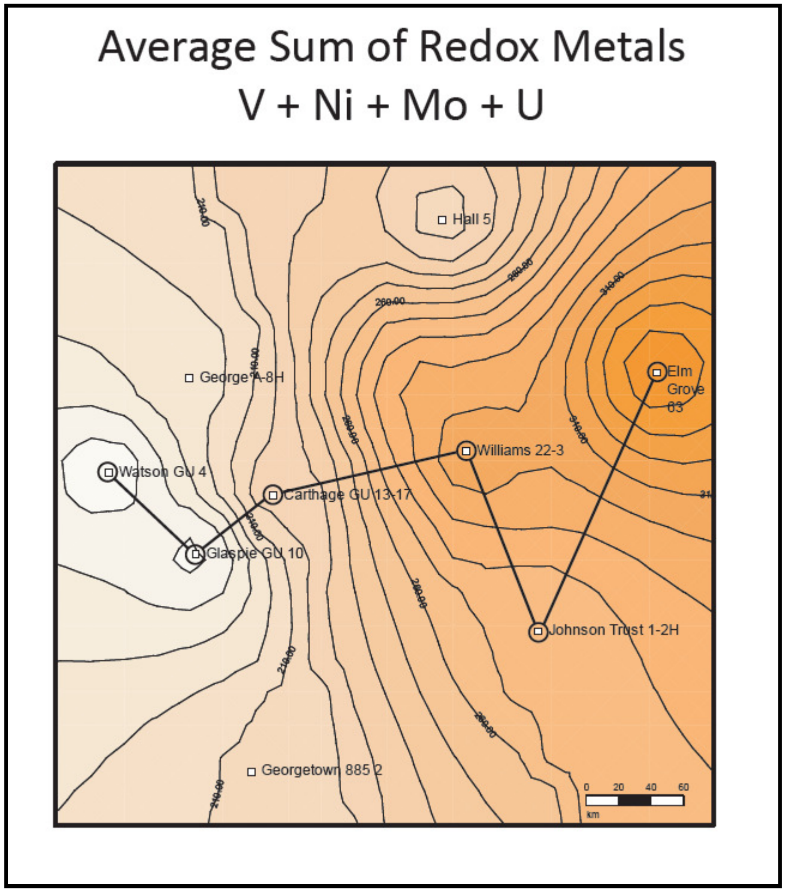
Chemostratigraphic Correlation

Haynesville Formation (Late Jurassic)
Texas - Louisiana

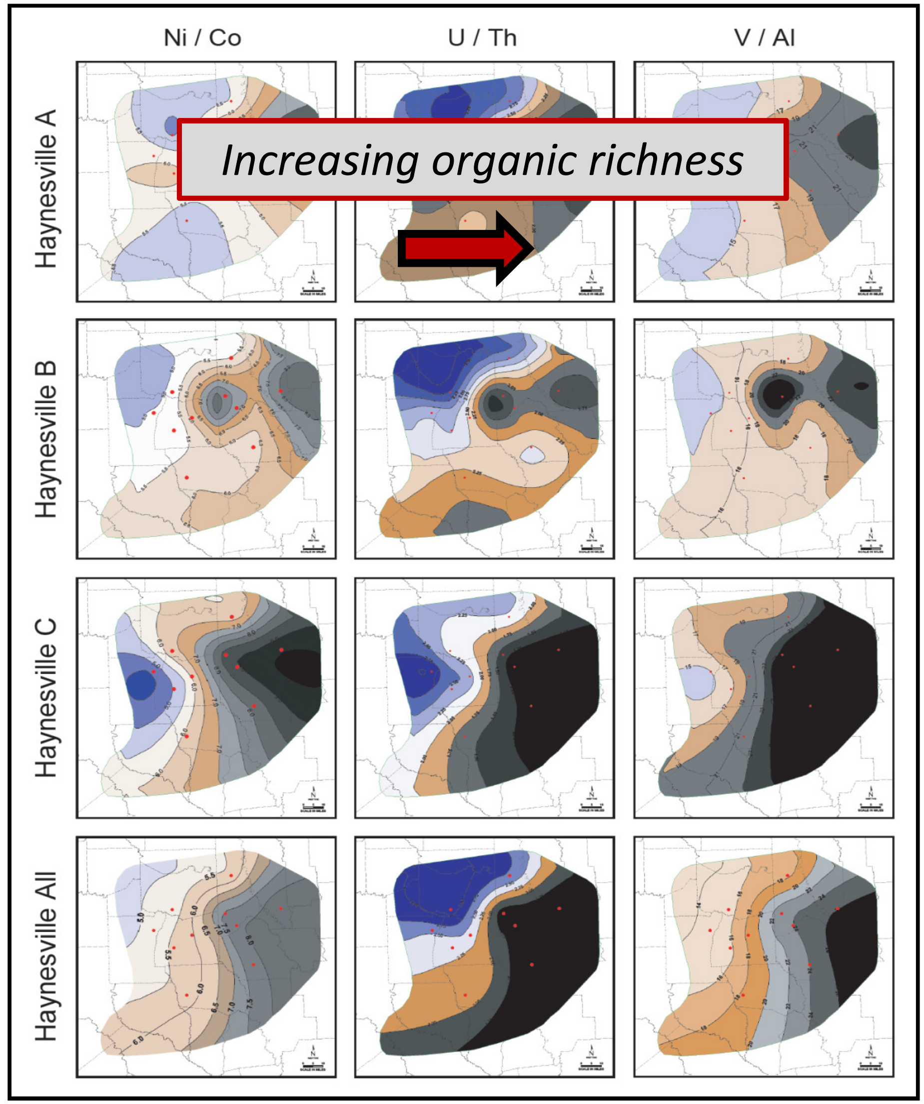


From Dix et al. (2010)

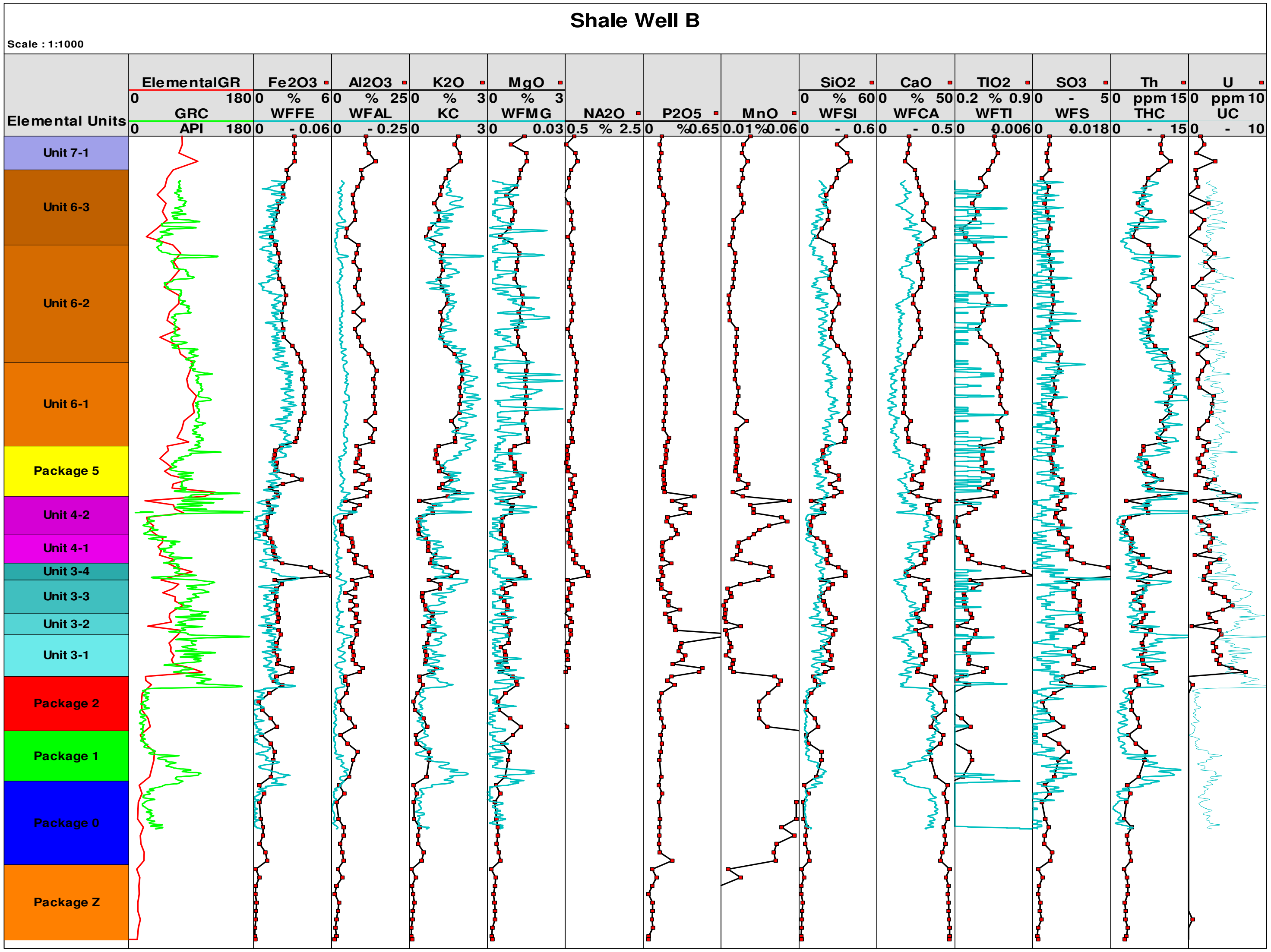
Chemosedimentology for Gas Shales



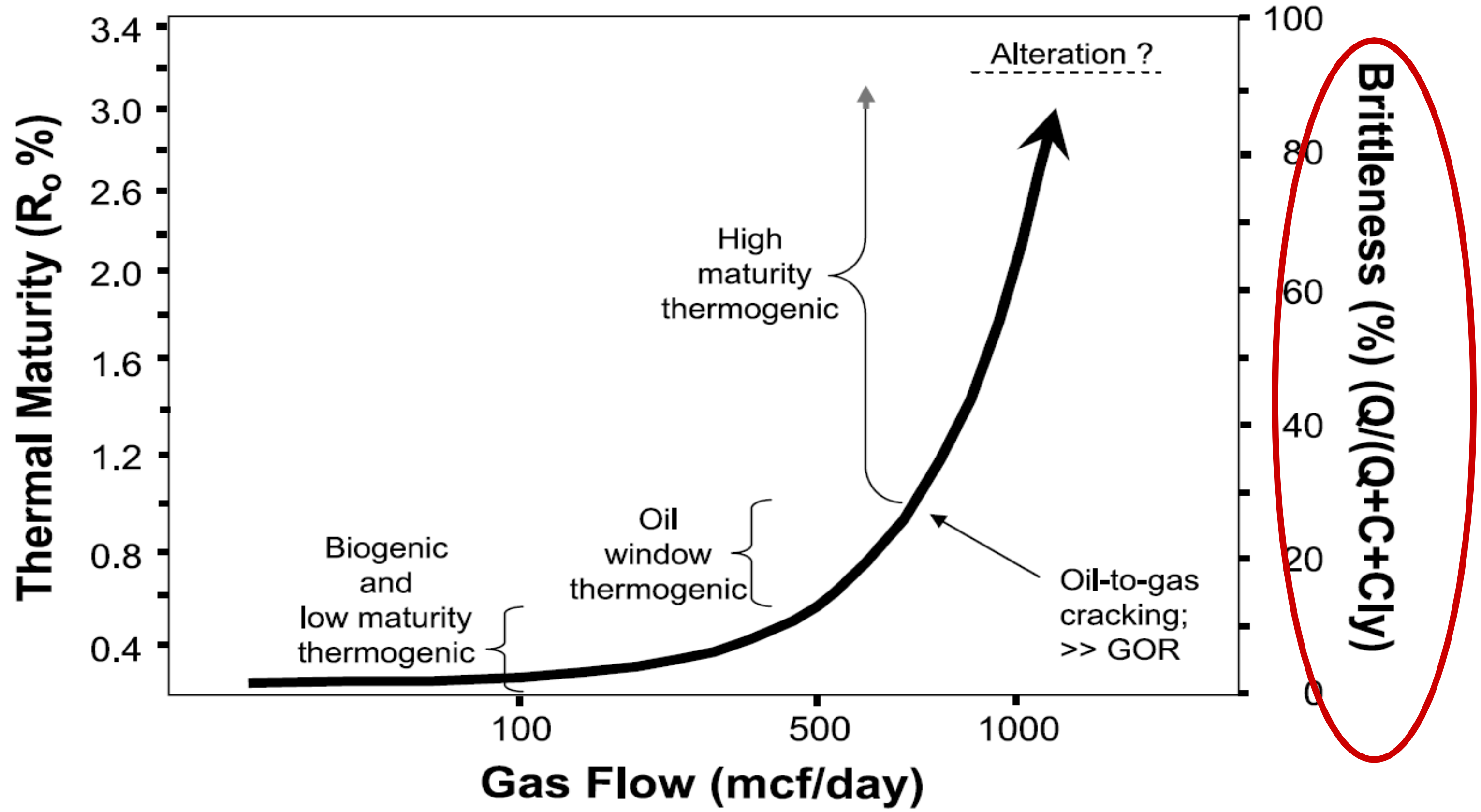
Redox-sensitive metals are excellent proxy for organic richness
From Dix et al. (2010)



XRF On Cuttings Compared To Elemental Capture Tool on Wireline

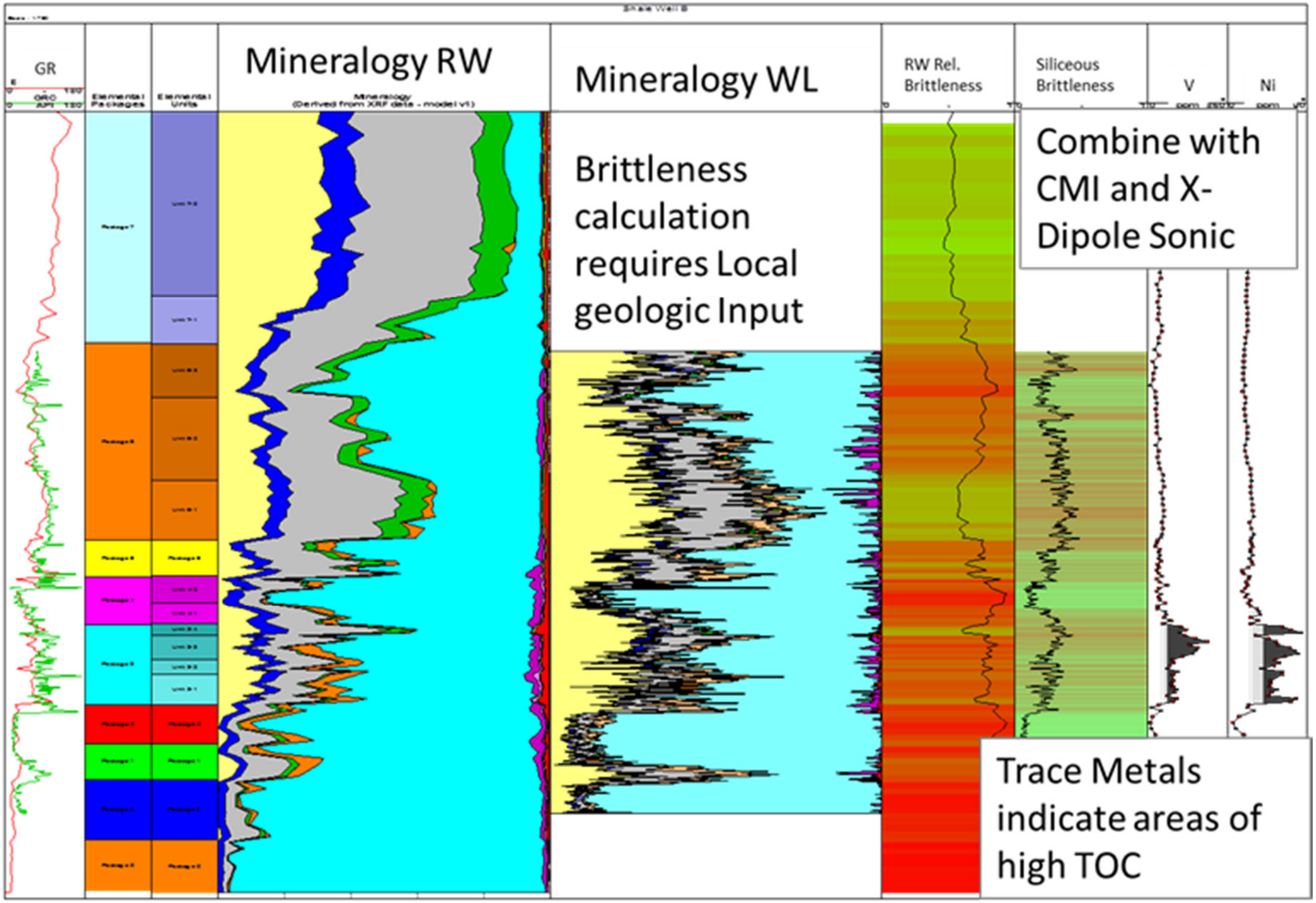


Jarvie et al. (2007) Brittleness Formula

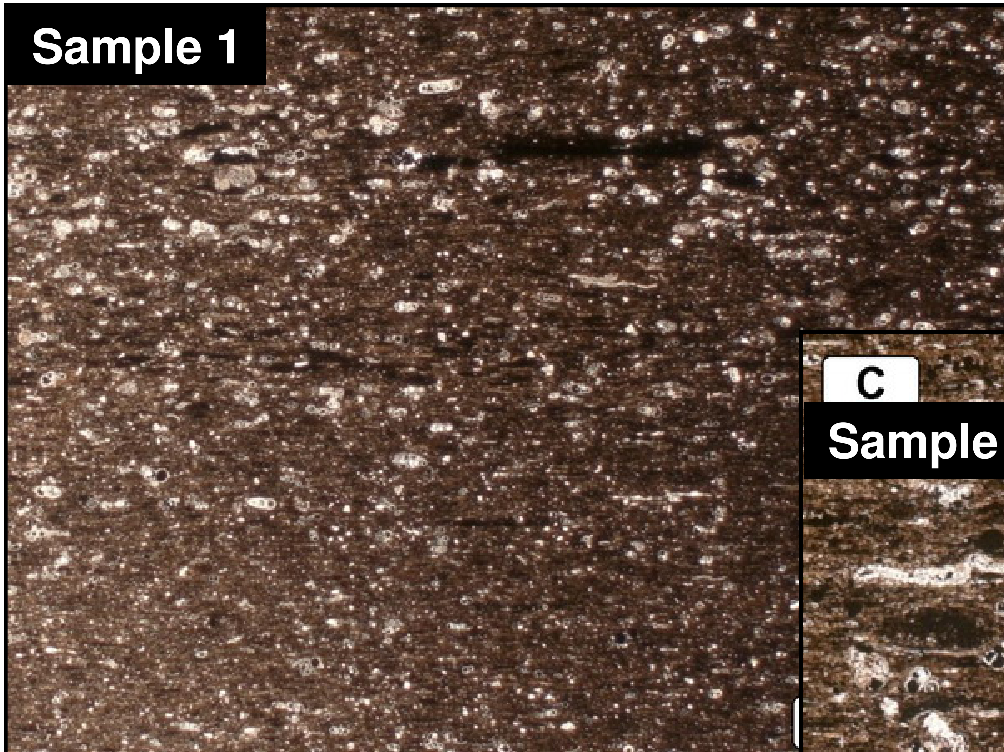


- ***Calculated for Barnett Shale – good first approximation***
- ***In reality, formula must be customized to each shale formation***

Brittleness Calculation Requires Local Geologic Input

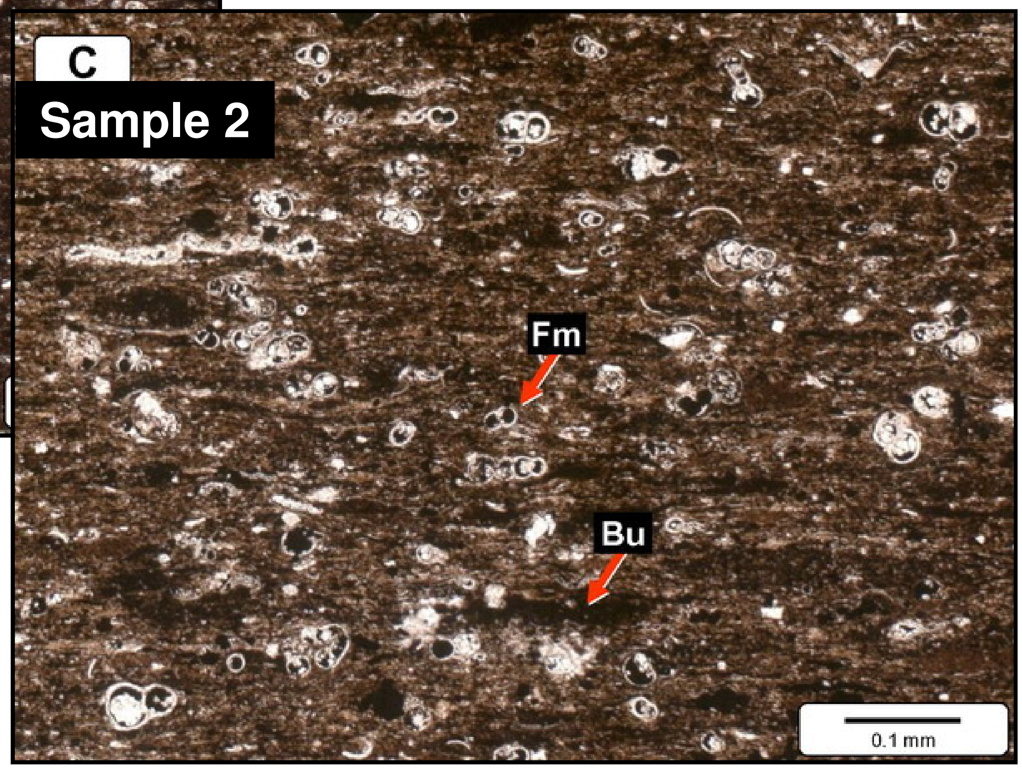


Eagle Ford Shale is Calcite-Dominated

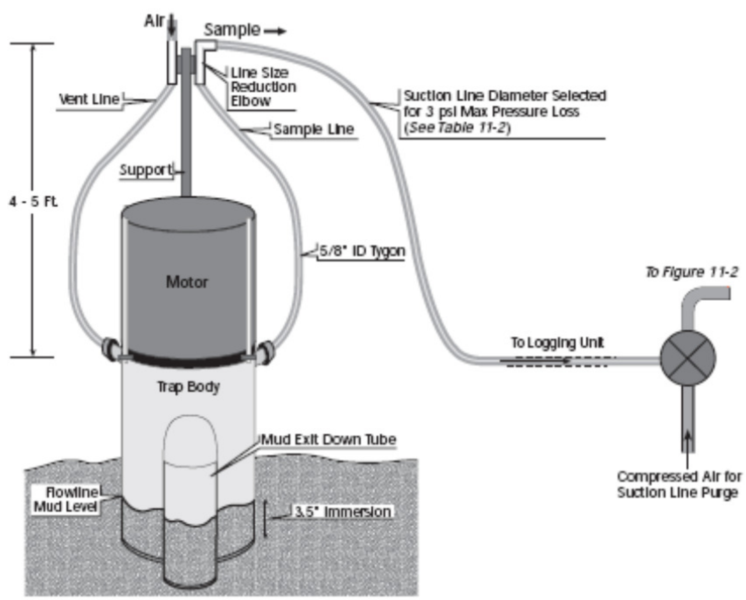


42% Calcite by XRD

60% Calcite by XRD



Mud Gas Extraction

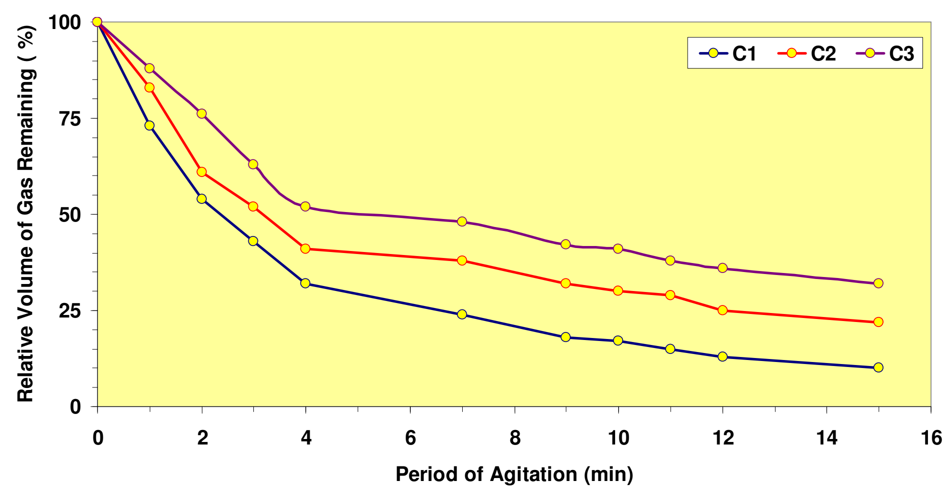


Traditional agitator-based methods of extraction are inefficient and preferentially extract light-end alkanes.

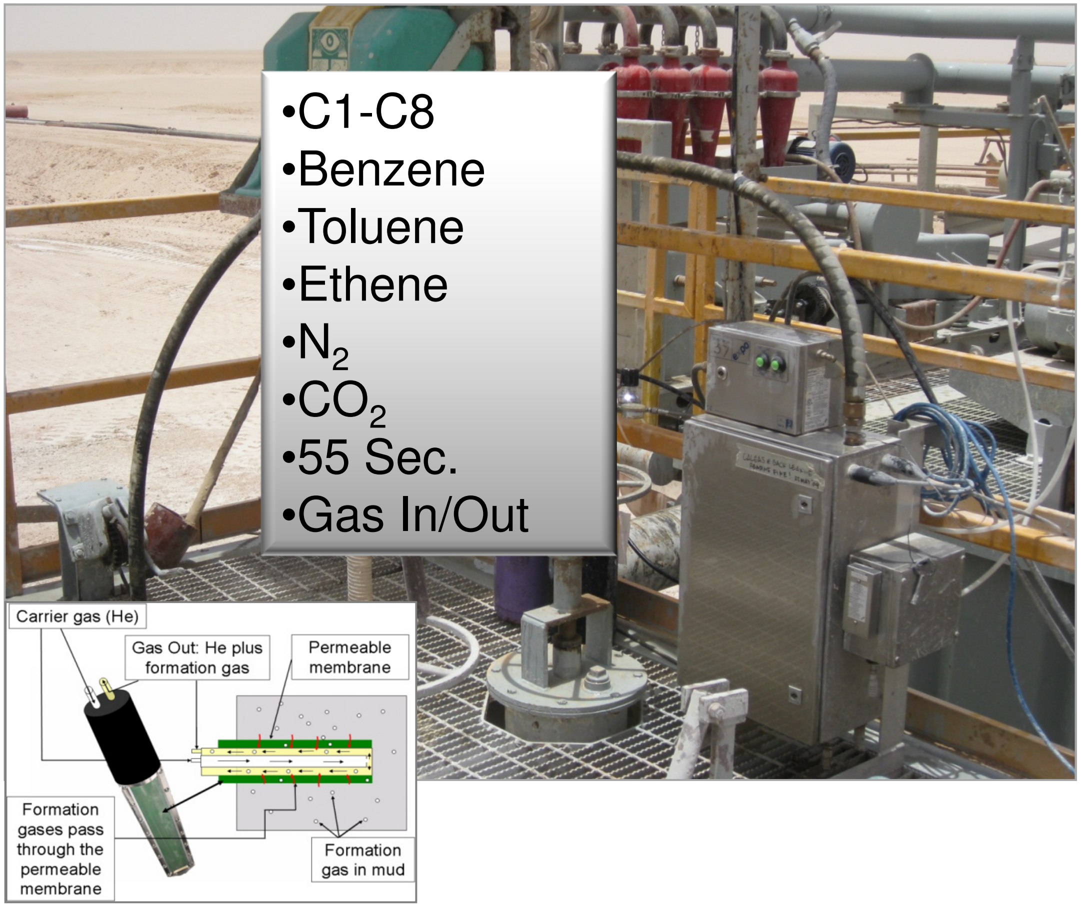
Elder, S.S, Delaune,P, Williams, Hawker, Brumboi, Law

Traditional Gas Traps Not Efficient

After 1 minute of agitation only 25% of methane is extracted from the mud. After 7 minutes there is still 25% of methane kept in the mud. It takes 15 minutes of agitation to remove 90% of methane from the mud.



Advanced Mud Gas Measurement



Delineates top and bottom of the reservoir

Identifies changes in fluid type

Can optimize downhole fluid sampling

- Critical fluid properties can be predicted directly from mud gas sample
- Need good calibration data set and good mathematical models

Reducing uncertainty of recycled gas effects

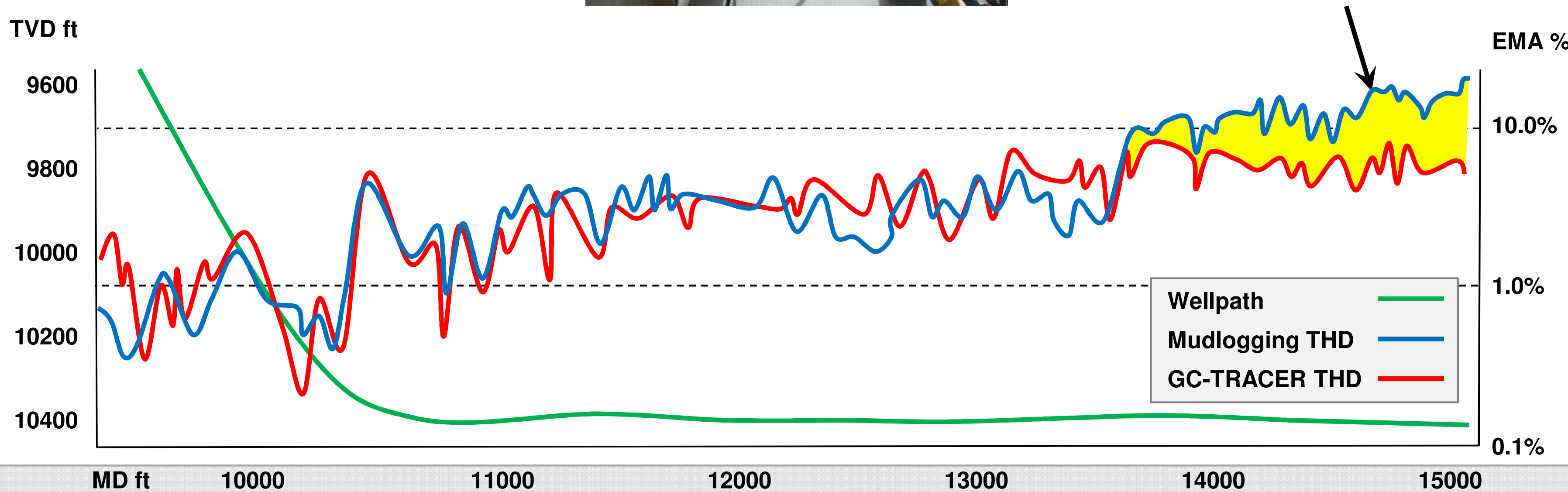
Delta Gas Measurement System

Active Mud Pit (in)

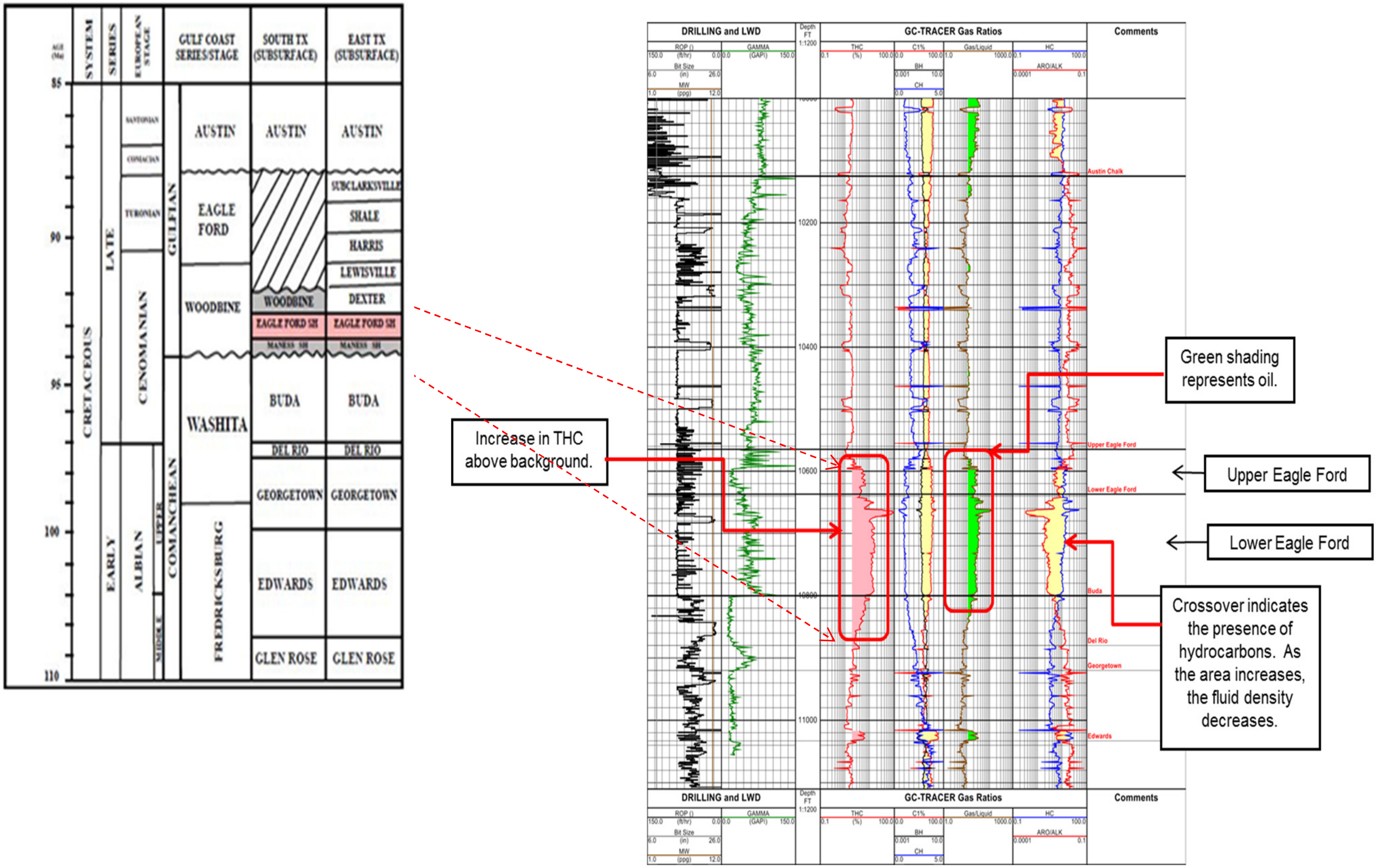
Flow Line/Possum Belly (out)

Using a delta system allows us to remove the effects of recycled gas, giving a more representative data set

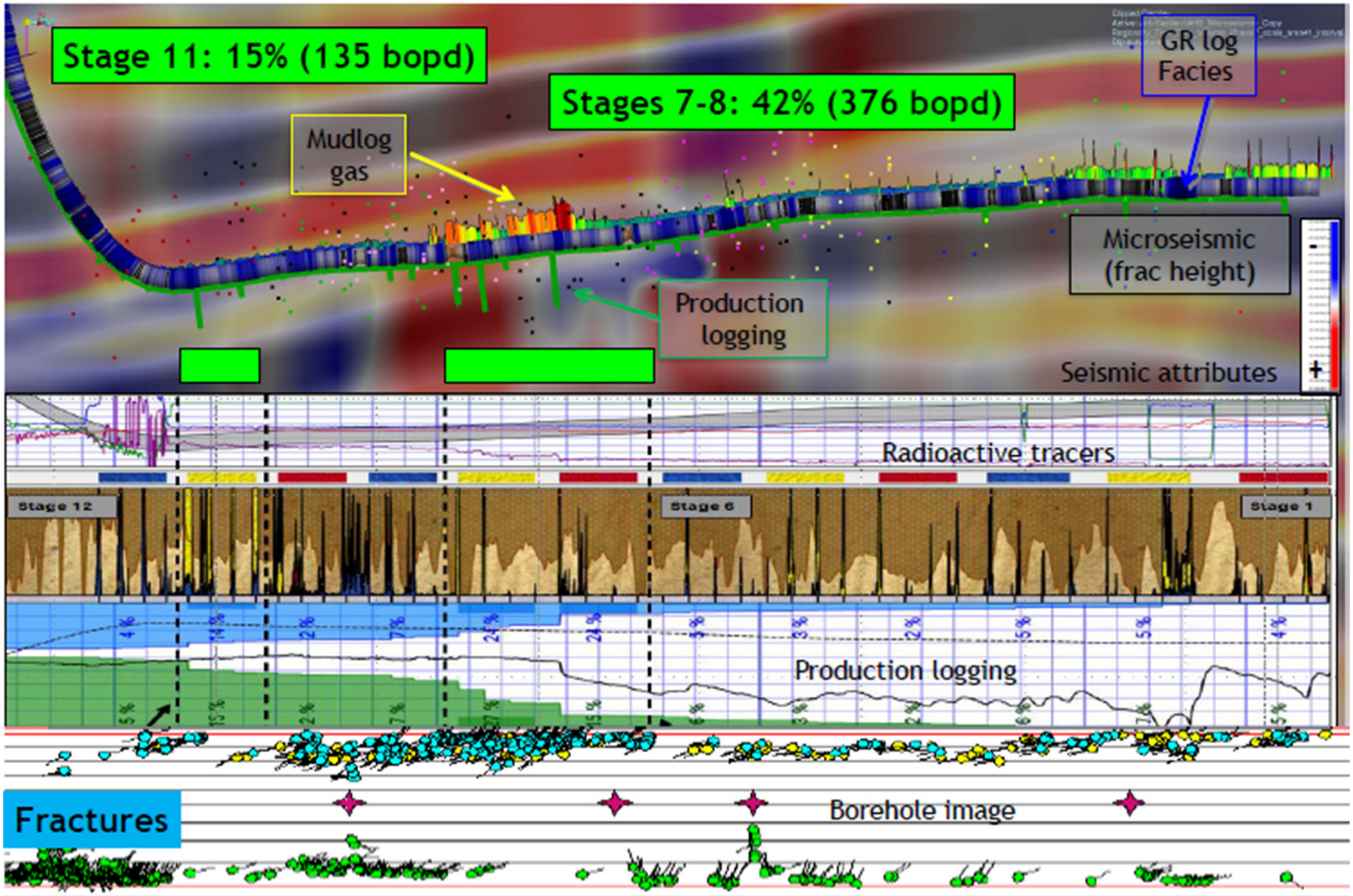
Increasing gas levels due to recycled gas in the system suggest false sweet spots



Identify Hydrocarbon Zones with Advanced Gas Detection

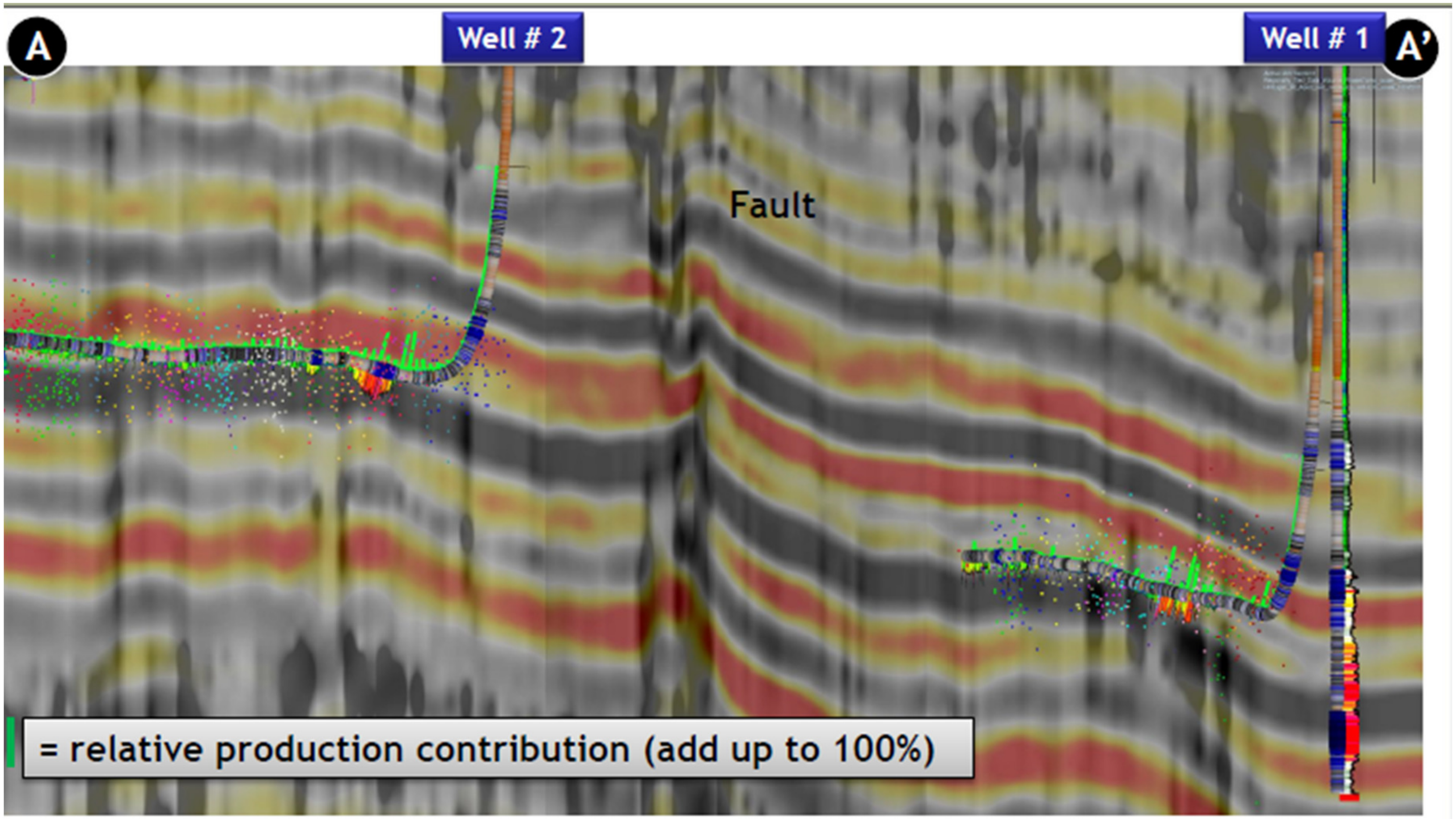


Mudgas Data in Lateral Indicates Productive Zone



Eagle Ford Reservoir Characterization from Multisource Data Integration*N. Basu1, G. Barzola1, H. Bello1, P. Clarke1 and O. Viloria1 Search and Discovery Article #80234 (2012)

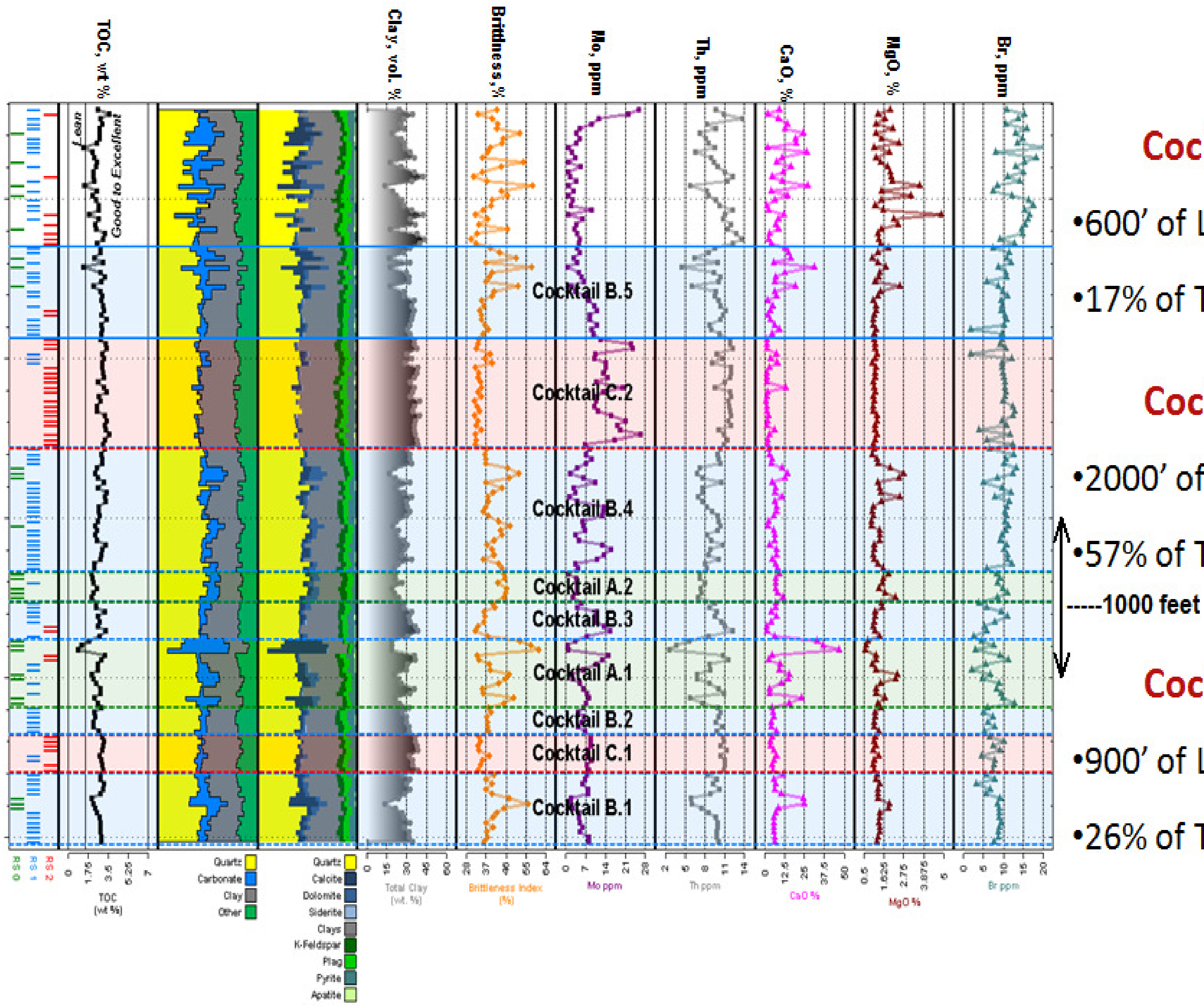
Mudgas and Oil Production



Max Tgas from mudlogs and initial oil production is related mainly to presence of faults and associated fractures (high-order geometries); high-resolution coherency is detecting mainly high-angle faults.

Eagle Ford Reservoir Characterization from Multisource Data Integration*N. Basu1, G. Barzola1, H. Bello1, P. Clarke1 and O. Viloria1 Search and Discovery Article #80234 (2012)

CUSTOMIZED FRAC TREATMENTS FOR SPECIFIC ROCK TYPES



Cocktail A

- 600' of Lateral
- 17% of The Lateral

Cocktail B

- 2000' of Lateral
- 57% of The Lateral

Cocktail C

- 900' of Lateral
- 26% of The Lateral

- WHTP
- Type of Proppants
- Amount Of Proppants

Fluid Selection

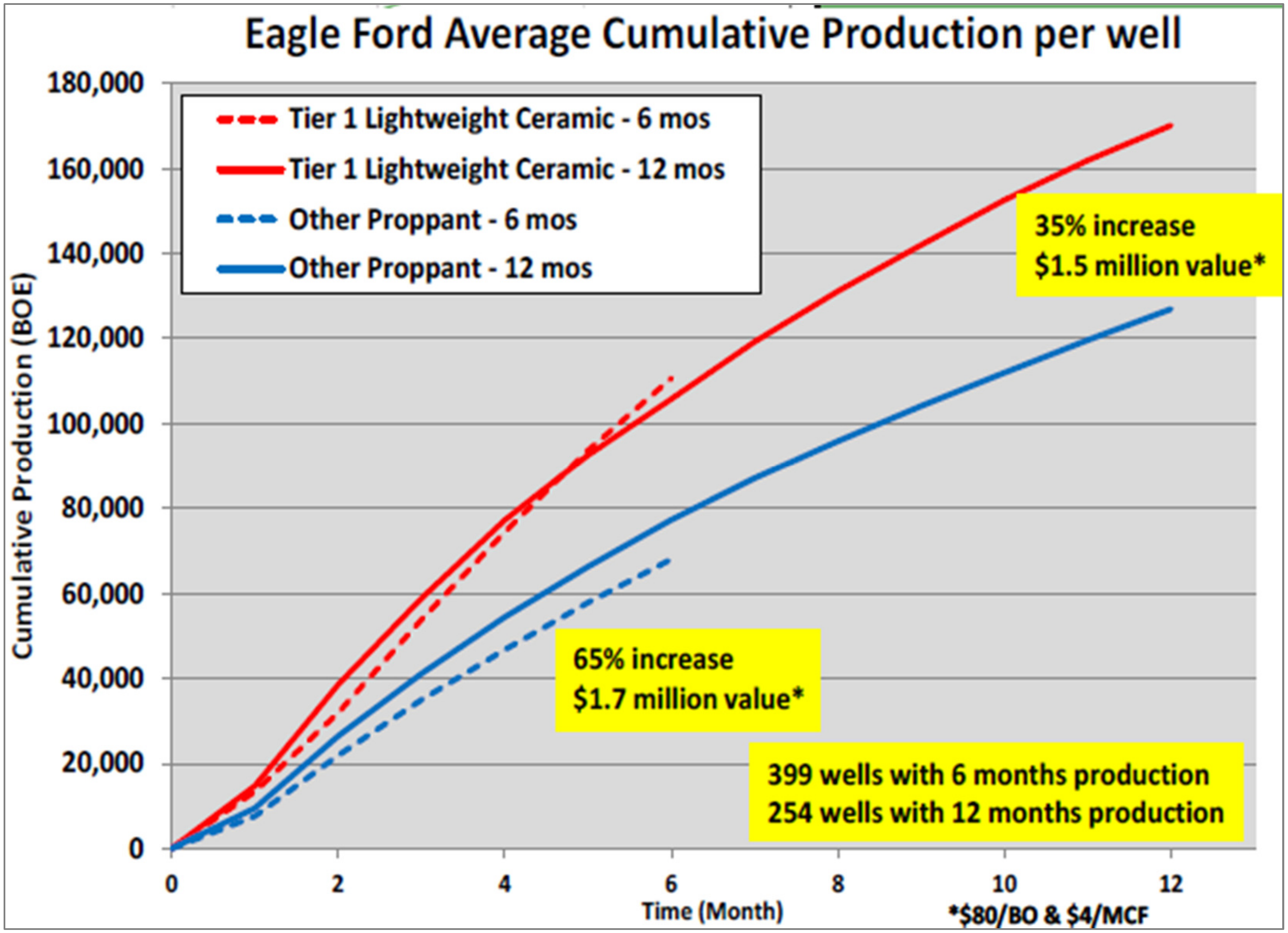
Oil/Condensate
Gels
Cross Linked Gels

Gas Window Slick
Water or Linear Gel for entire job

Fluid Determines Proppant Size

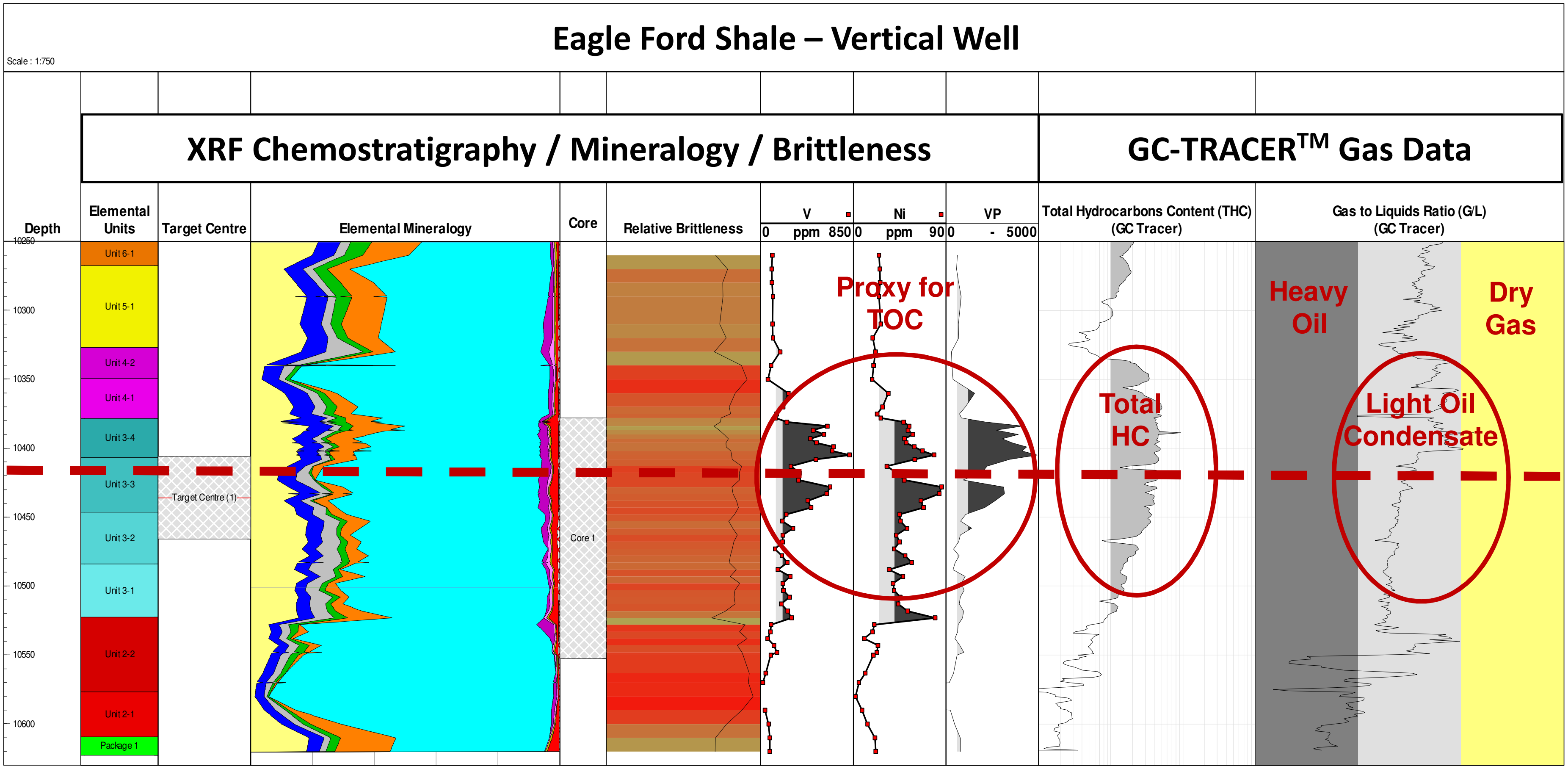
Conductivity requirements in liquids rich area Larger proppant Mesh sizes (30/50 and 20/40)

Effect of Proppant on Productivity



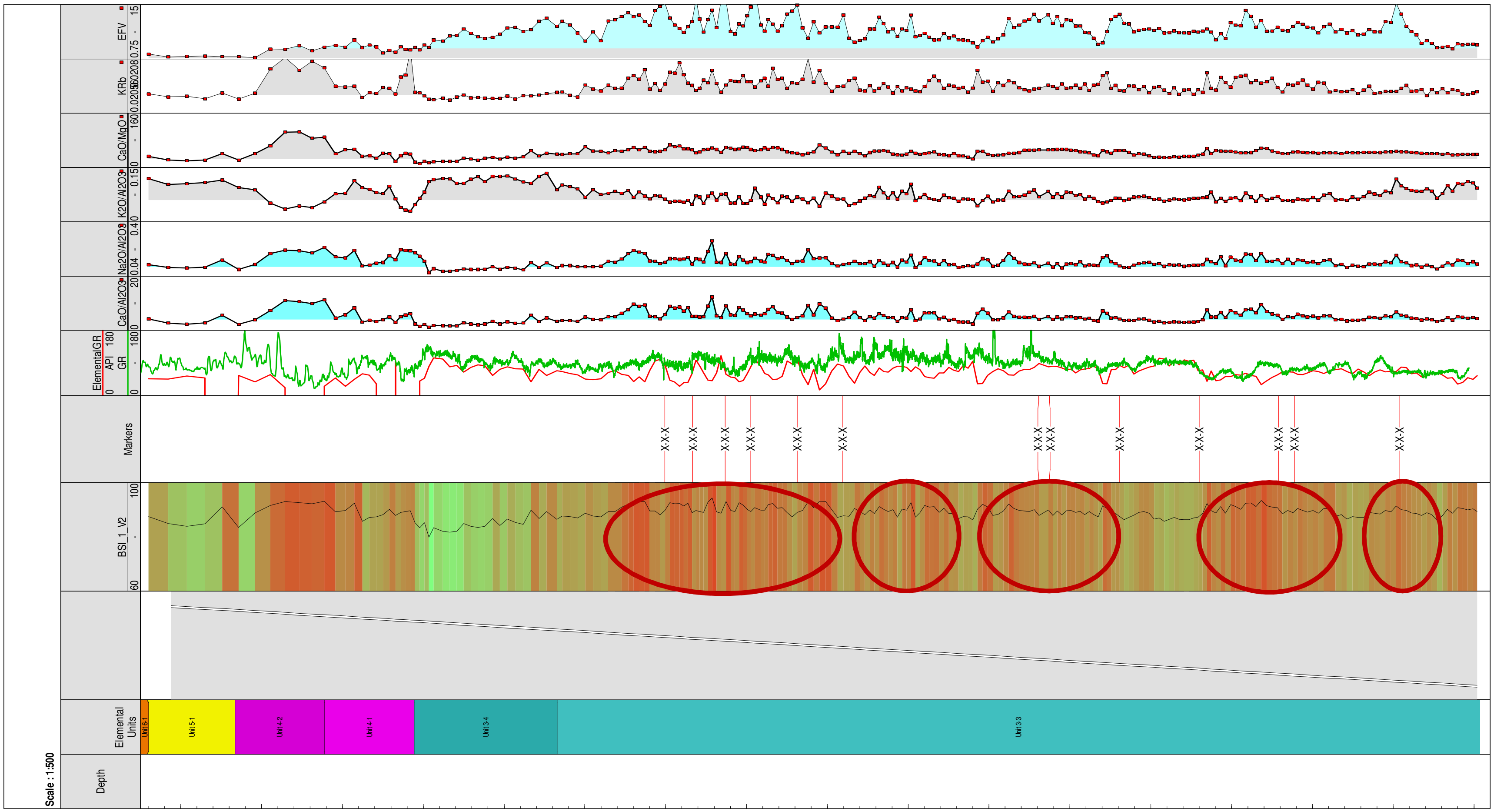
SPE Eagleford Workshop, 21-23 August 2012 , San Antonio, Texas, Charles Pope, Complete Shale

XRF and Enhanced Gas Measurements Identify the "Sweet Spot"



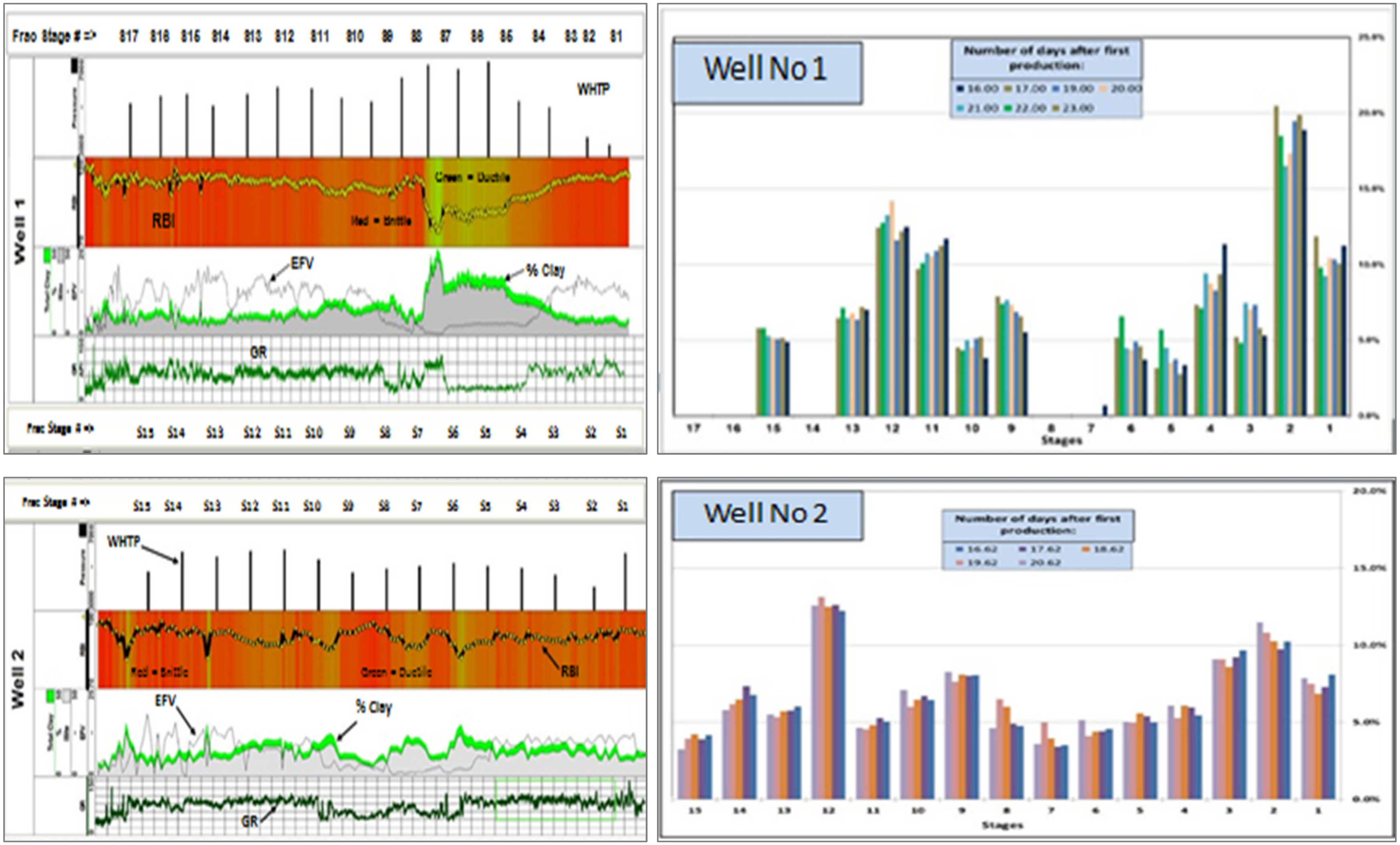
- **Good agreement between element-derived TOC and gas-derived total hydrocarbons**

Wellbore Containment



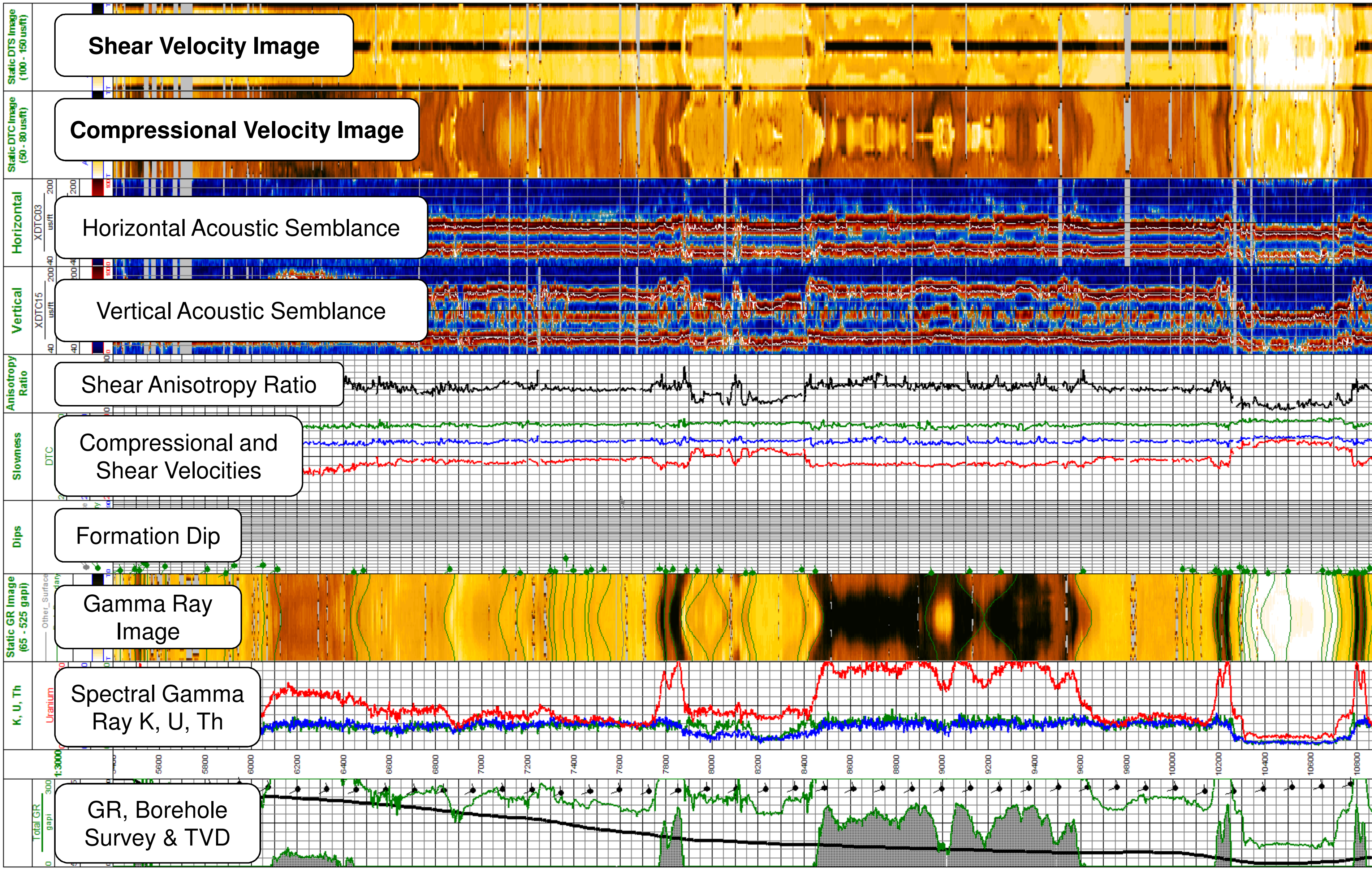
- *Wellbore maintained within +/- 10 feet of key brittle bed*

EagleFord Completions
Production Oil Tracers (Pseudo Production Log)

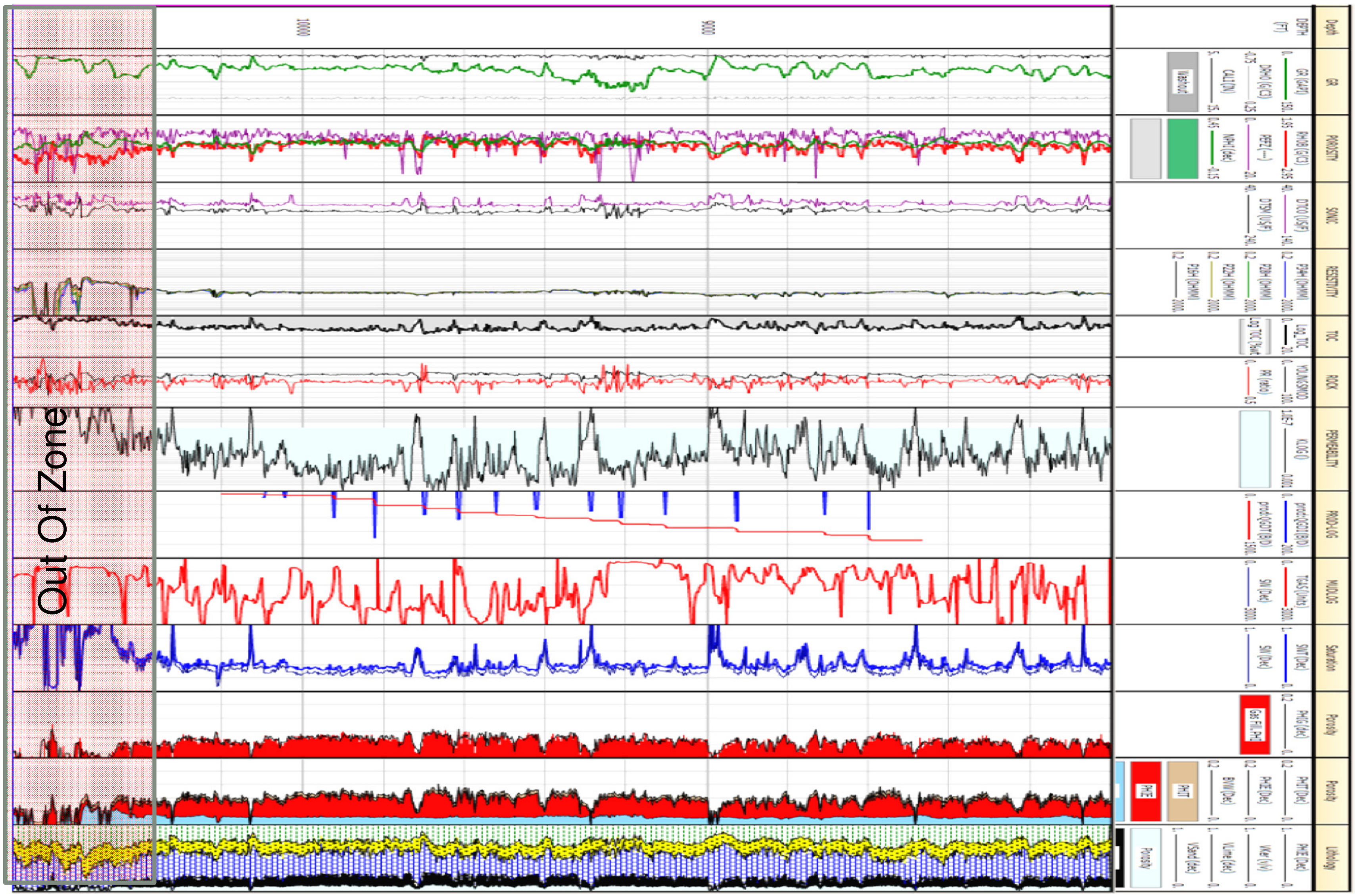


Eagle Ford Shale Workshop San Antonio, Texas , Rick Tompkins, EF Energy

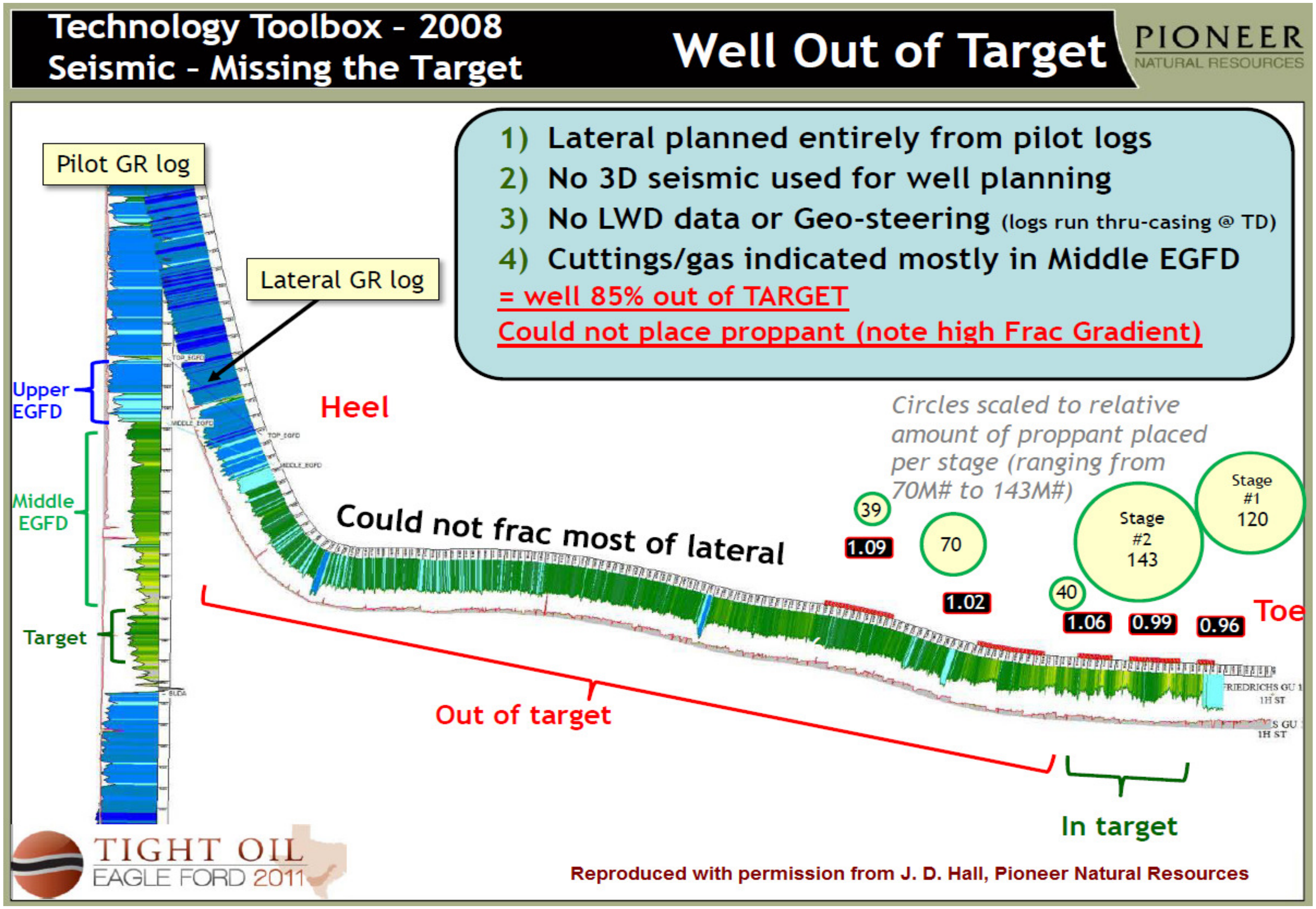
Characterization of Lateral With LWD



Wireline Identifies Sweet Spot

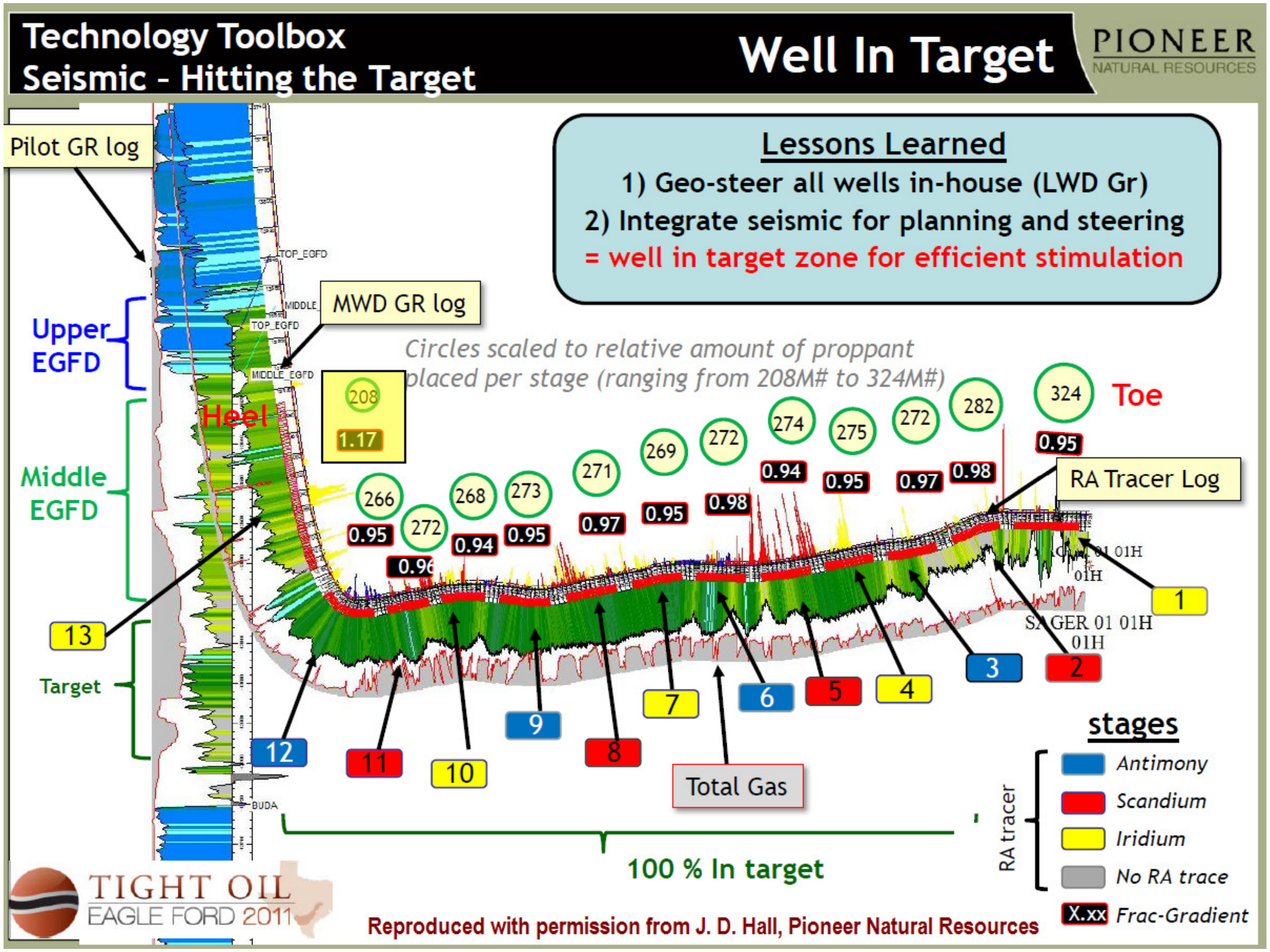


Case Study



Technology Toolbox - 2008
Seismic - Missing the Target
Well Out of Target
PIONEER
NATURAL RESOURCES
1) Lateral planned entirely from pilot logs
2) No 3D seismic used for well planning
3) No LWD data or Geo-steering (logs run thru-casing @ TD)
4) Cuttings/gas indicated mostly in Middle EGFD
= well 85% out of TARGET
Could not place proppant (note high Frac Gradient)
Pilot GR log
Lateral GR log
Upper EGFD
Middle EGFD
Target
Heel
Could not frac most of lateral
Circles scaled to relative amount of proppant placed per stage (ranging from 70M# to 143M#)
39
1.09
70
1.02
40
1.06
Stage #2 143
0.99
Stage #1 120
0.96
Toe
Out of target
In target
TIGHT OIL
EAGLE FORD 2011
Reproduced with permission from J. D. Hall, Pioneer Natural Resources

Optimal Well Placement and Completion



CONCLUSIONS

- XRF/XRD/Pyrolysis on cuttings offer a rapid, near real time approach to quantify mineralogy, elements and TOC in both vertical and lateral holes.
- Advanced Mud Gas extraction/detection provide real time, high resolution data for fluid typing and fracture identification in both vertical and lateral holes.
- LWD Spectral GR provides real time data on Kerogen content.
- LWD/Wireline Logs provide detailed petrophysical characterization of the lateral.

CONCLUSIONS

- These data sets can be used to;
  - Improve wellbore placement and containment
  - Reduce fracing in poor reservoir intervals
  - Focus completions in quality reservoir intervals
  - Assist with design of appropriate frac parameters
  - Assist with design of optimal frac placement

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