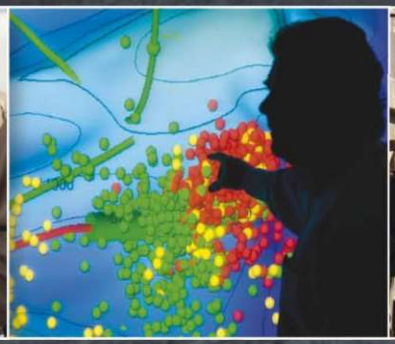
Unconventional Resources



Unconventional Well Evaluation for Completion and Field Development Optimization

Schlumberger

Egypt Vision 2030

EGYPT OIL&GAS

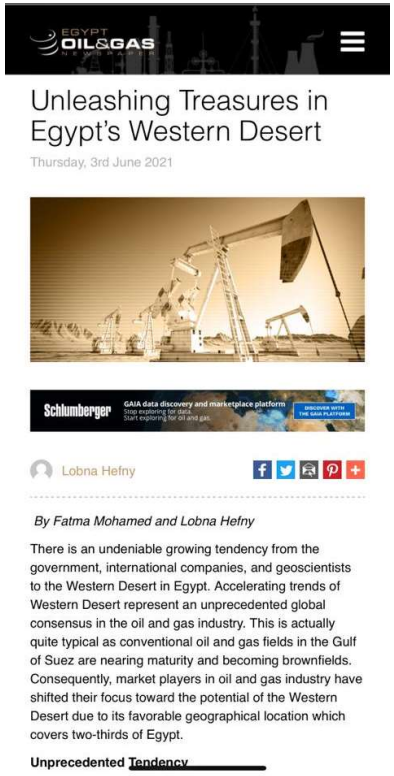
World Bank Supports Egypt's Push to Be Regional Energy Hub

Tuesday, 9th November 2021

In a meeting with two delegations from the World Bank, Minister of Petroleum and Mineral Resources Tarek El Molla stated that the World Bank's participation in the East Mediterranean Gas Forum (EMGF) as an observer is instrumental in pushing Egypt towards being a regional hub for energy.

During the meeting, he further elaborated that the World

https://egyptoil-gas.com/news/world-bank-supports-egypts-push-to-be-regional-energy-hub/



EGYPT OIL&GAS

Unleashing Treasures in Egypt's Western Desert

Thursday, 3rd June 2021

Lobna Hefny

By Fatma Mohamed and Lobna Hefny

There is an undeniable growing tendency from the government, international companies, and geoscientists to the Western Desert in Egypt. Accelerating trends of Western Desert represent an unprecedented global consensus in the oil and gas industry. This is actually quite typical as conventional oil and gas fields in the Gulf of Suez are nearing maturity and becoming brownfields. Consequently, market players in oil and gas industry have shifted their focus toward the potential of the Western Desert due to its favorable geographical location which covers two-thirds of Egypt.

Unprecedented Tendency

https://egyptoil-gas.com/features/unleashing-treasures-in-egypts-western-desert/

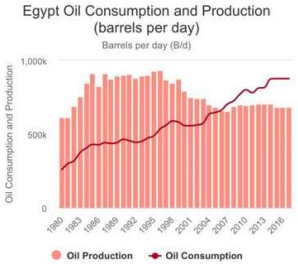
Oil Production in Egypt

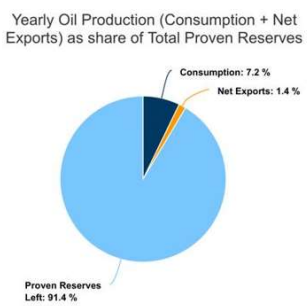
See also: List of countries by Oil Production

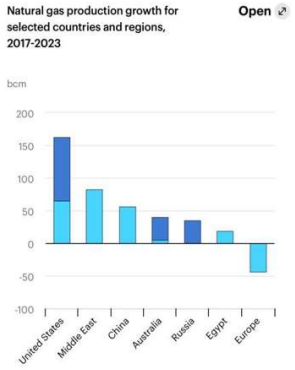
- Egypt **produces 682,904.14 barrels per day** of oil (as of 2016) ranking 27th in the world.
- Egypt produces every year an amount equivalent to **5.7% of its total proven reserves** (as of 2016).

Oil Exports

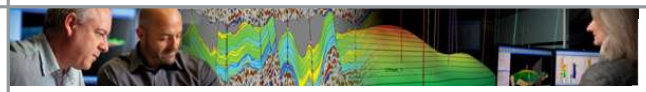
- Egypt **exports 25% of its oil production** (169,884 barrels per day in 2016).







https://www.worldometers.info/



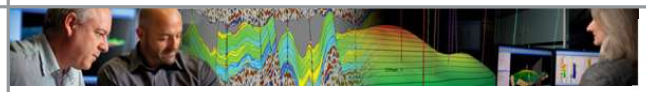
Unconventional Reservoir – Definition…s

[…] the **unconventional reservoir** is the one that cannot be produced at economic flow rates or that does not produce economic volumes of oil and gas without the assistance of massive stimulation treatments or special recovery processes and technologies.

https://petrowiki.spe.org/Unconventional_resources_of_oil_and_gas_from_a_geologic_perspective#:~:text=On%20the%20other%20hand%2C%20the%20unconventional%20reservoir%20is,stimulation%20treatments%20or%20special%20recovery%20processes%20and%20technologies.

The difference between a conventional and unconventional reservoir is migration. The unconventional reservoir has **hydrocarbons that were formed within the rock and never migrated.** The conventional reservoir is a porous rock formation that contains hydrocarbons that have migrated from a source rock (unconventional reservoir).

https://wiki.seg.org/wiki/Unconventional_reservoir



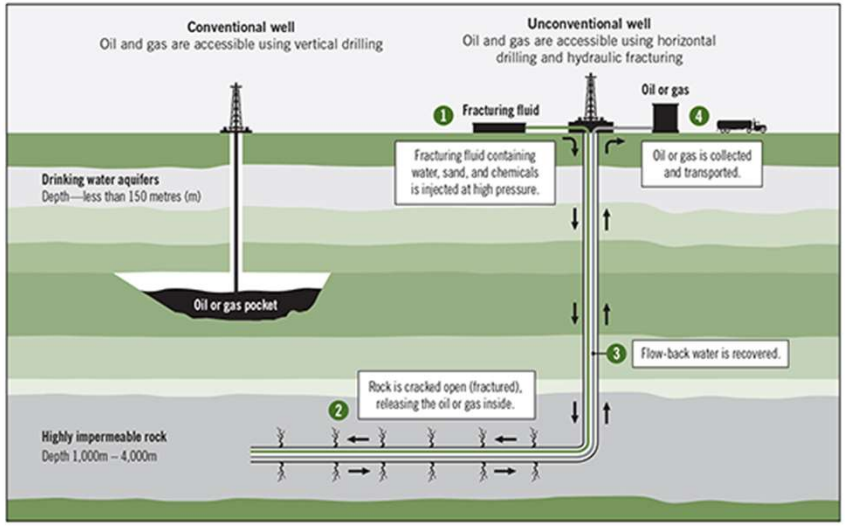
Unconventional Reservoir - Definition

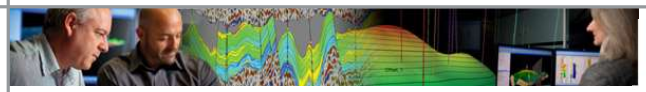
[…] the **unconventional reservoir** is the one that cannot be produced at economic flow rates or that does not produce economic volumes of oil and gas without the assistance of massive stimulation treatments or special recovery processes and technologies.

https://petrowiki.spe.org/Unconventional_resources_of_oil_and_gas_from_a_geologic_perspective#:~:text=On%20the%20other%20hand%2C%20the%20unconventional%20reservoir%20is,stimulation%20treatments%20or%20special%20recovery%20processes%20and%20technologies.

The difference between a conventional and unconventional reservoir is migration. The unconventional reservoir has **hydrocarbons that were formed within the rock and never migrated.** The conventional reservoir is a porous rock formation that contains hydrocarbons that have migrated from a source rock (unconventional reservoir).

https://wiki.seg.org/wiki/Unconventional_reservoir

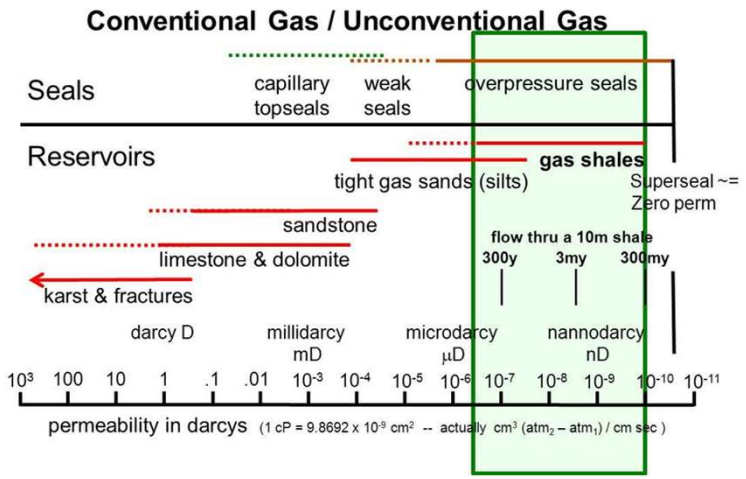


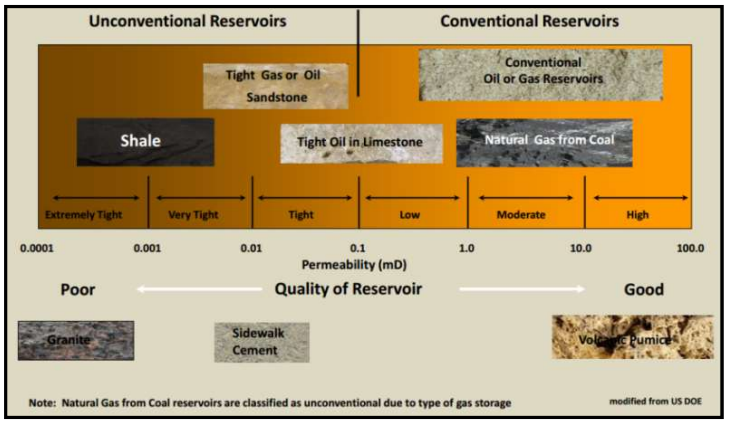


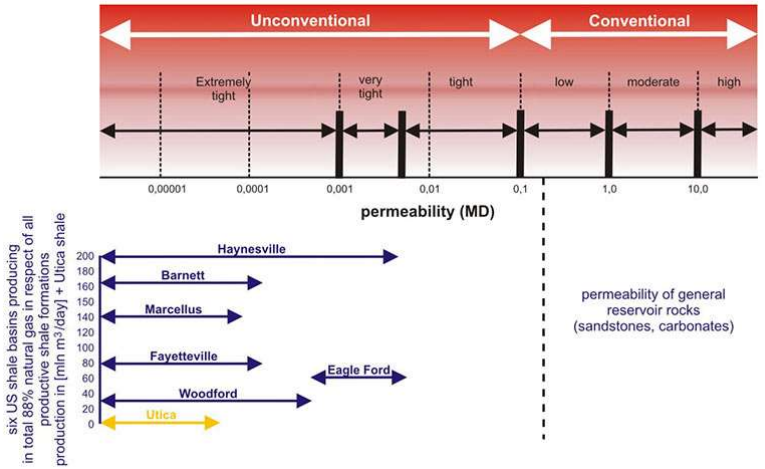
PetroTechnical Services
Global Expertise

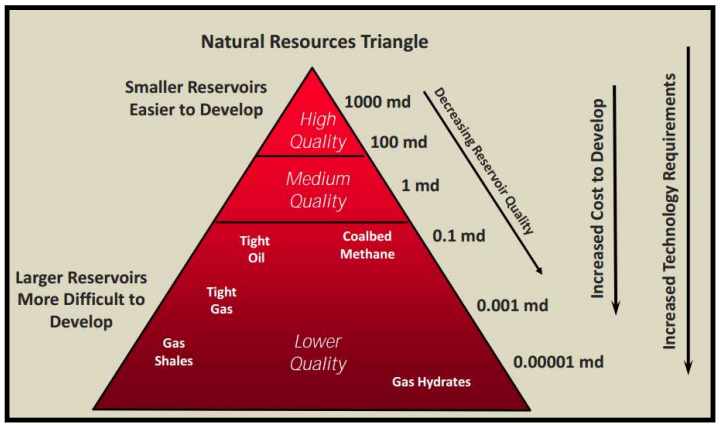
Schlumberger

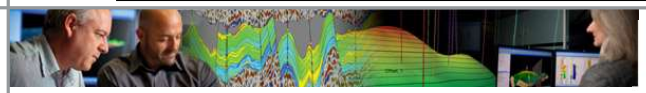
Unconventional: Permeability, Porosity – a few numbers



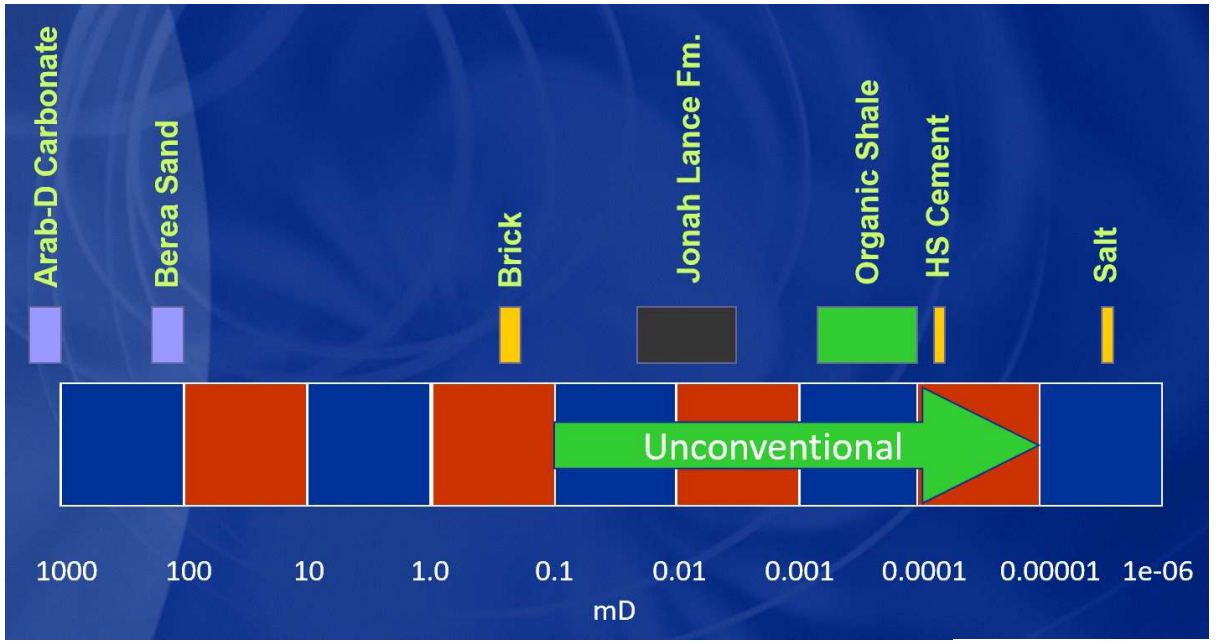


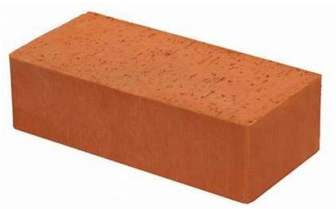


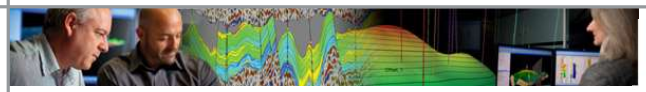




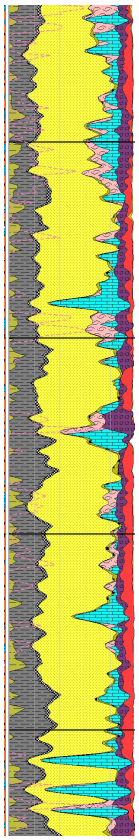
Unconventional: Permeability, Porosity – a few numbers







Key Parameters vs. Measure of Success



Geology

Organic richness

Mineral quantification

Gas in place

Permeability

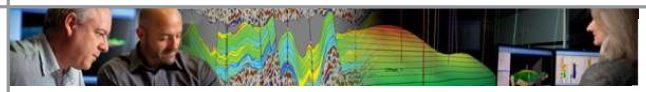
Thermal maturity

Adjacent water bearing formations

Reservoir pressure

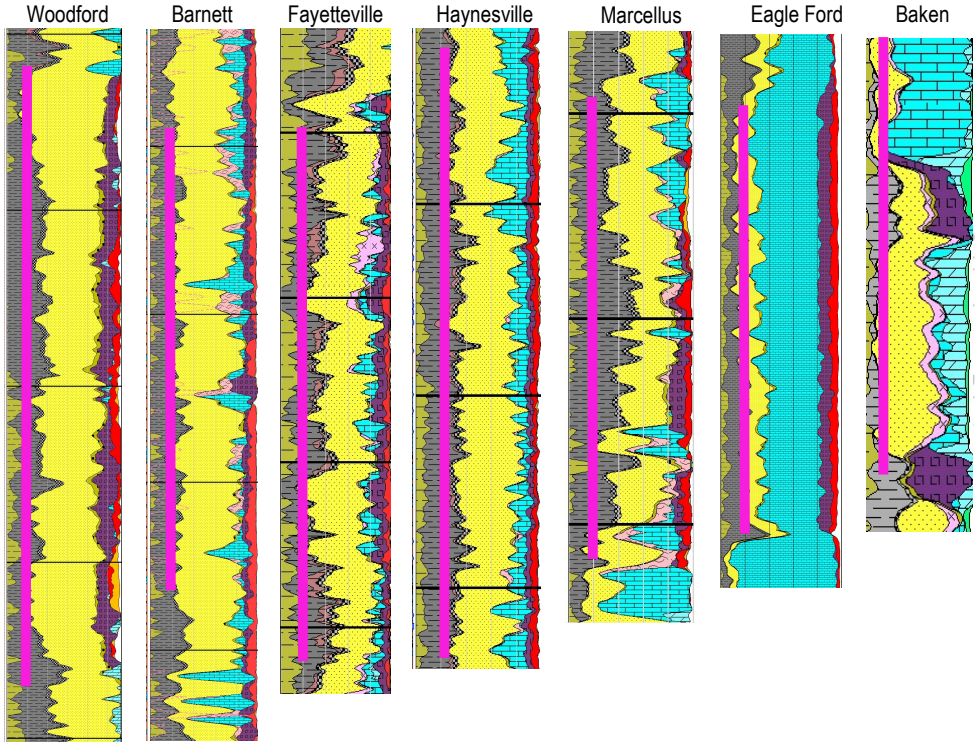
Engineering

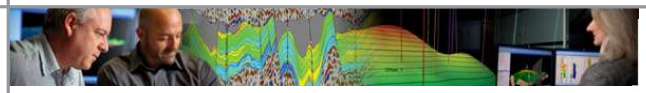
- Frac containment
- Frac conductivity
- Fluid compatibility



Different Lithologies

Challenges						
Low Porosity	Low Permeability	Heterogeneity	Fractured	Tight Reservoir	High Porosity	
	Yes			Yes		Carbonate
	Yes			Yes		Carbonate
	Yes	Yes				Carbonate
Yes	Yes	Yes				Carbonate
Yes	Yes			Yes		Carbonate
	Yes				Yes	Shale
Yes			Yes			Igneous
	Yes				Yes	Carbonate

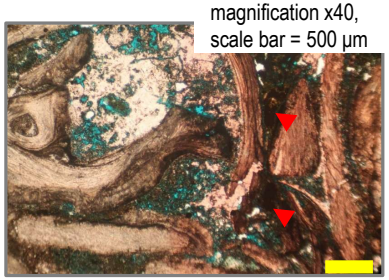




Carbonate Reservoir Challenges

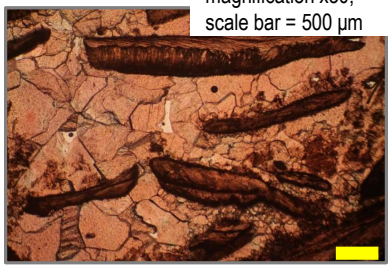
magnification x5,
scale bar = 5 mm

Rock type RT-1: no clay, no micrite, developed intergranular porosity



magnification x40,
scale bar = 500 µm

Rock type RT-2: moderate clay and micrite fractions, presence of mouldic porosity and reduced intergranular porosity



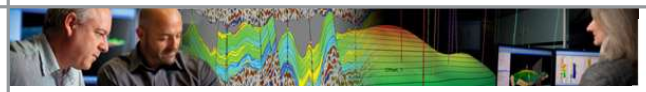
magnification x30,
scale bar = 500 µm

Rock type RT-3: no clay, prevalent micrite and calcite cementation, no intergranular porosity

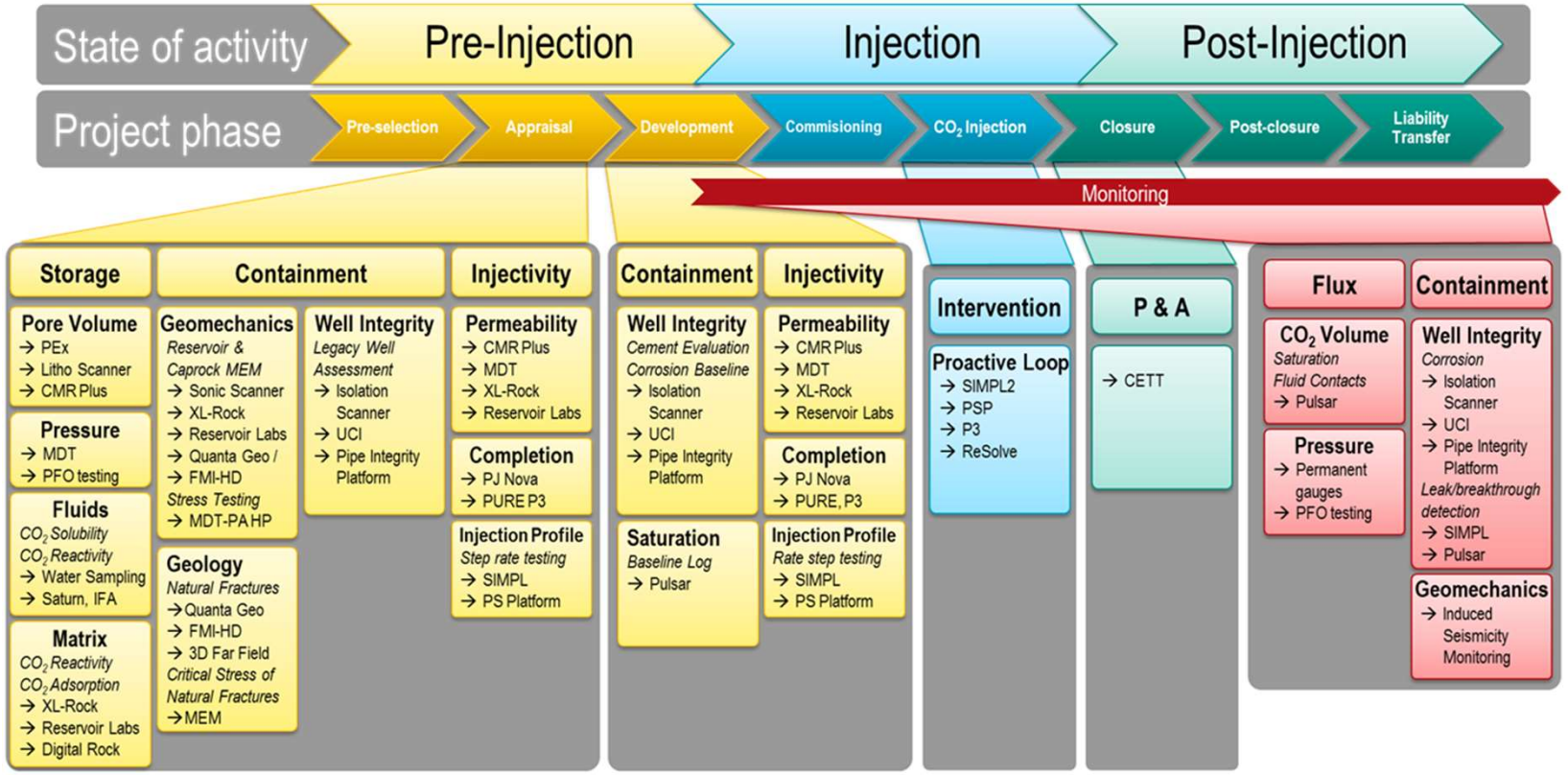
Tight rock properties

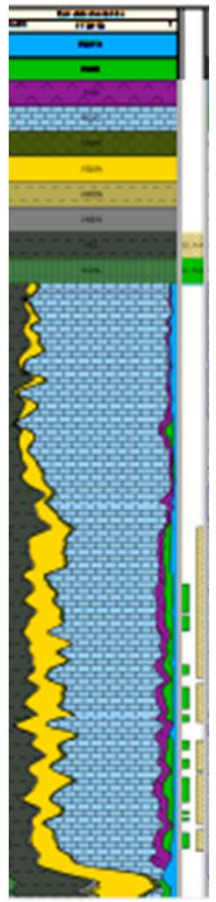
- low porosity (ρ_{matrix}?) → *mineralogy*
- low permeability (small pores / pore throats) → *texture*
- heterogeneous → *mineralogy & texture*

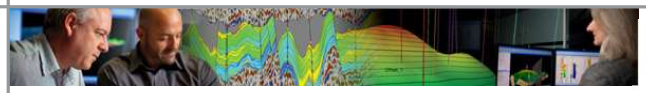
- Complex rock texture and pore network resulting from depositional facies and later diagenesis
  - Impacts determination of oil in place
- Carbonate rock surface has more affinity for oil than for water
  - Impacts determination of oil in place
  - Impacts ultimate oil recovery in waterflood processes
- Carbonate rock are brittle and fracture under tectonic loads
  - Detection and evaluation
  - Fractures either conductive to flow or sealed.
  - Major impact on well productivity / water flood management
- Heterogeneity at different scales
  - Texture variations; wettability
  - Flow barriers (stylolites, dense zones, anhydrite, tar mats)
  - Flow conduits (High permeability streaks, Fracture swarms)
    - Impacts reservoir description and management
    - Impacts water flood management



Formation Evaluation – Reservoir Characterization







Requirements for Carbonate Evaluation

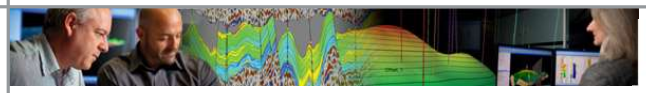
Petrophysical parameters

- Basic
  - Mineralogy and porosity
  - Saturations
  - Permeability
- Advanced
  - Rock and fluid types
  - Capillary pressure curves
  - Relative permeability

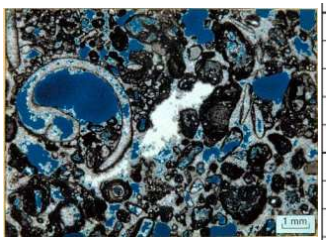
Rapid and accurate evaluation

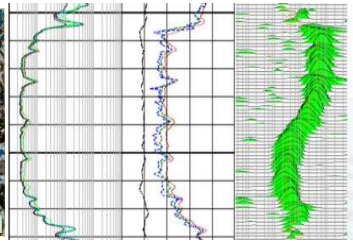
- Multiple decisions
  - Testing and Sampling decisions
  - Completion decisions
  - Reserves evaluation decisions

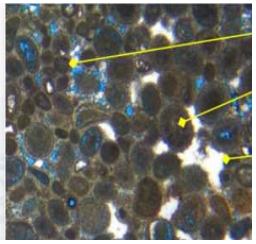
Must consider both static and dynamic petrophysical properties leading to successful stimulation plan



Recommended Technologies



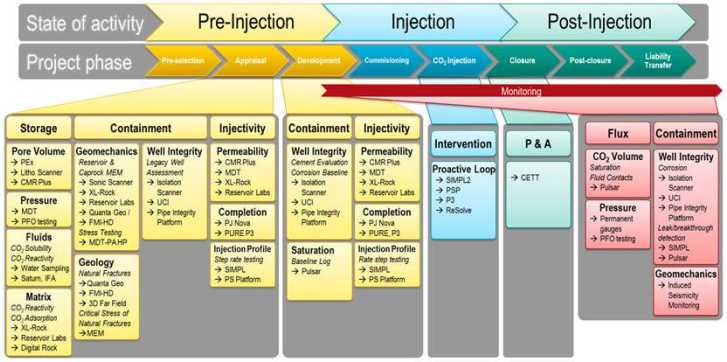




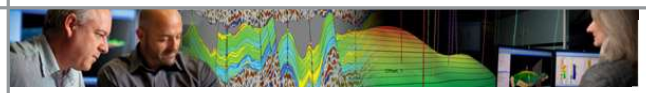
Porosity

Dolomite

Anhydrite



Formation property	Evaluation challenge	Technology	Applications
Mineralogy	Complex porosity system, carbonate typing	**Litho Scanner**	Mineralogy and matrix properties
Hydrocarbon volumes	Non-Archie rock, low resistivity contrast	**Litho Scanner, MR Scanner (if porosity)**	Direct hydrocarbon volume from organic carbon content; direct fluid frcations and volumes from D-T1-T2
Texture	Microporosity	**CMR, MR Scanner, Dielectric Scanner**	Pore size distribution, porosity bin partitioning for pore size distribution; textural parameters
	Permeability	**CMR /MR Scanner**	Correlation to pore sizes (Macro)
Wettability		**CMR, Dielectric Scanner**	Wettability index from T2 distribution and mn textural parameters from dielectric
Fracture and stresses	Complex fracture networing, connectivity	**Sonic Scanner**	Anisotropy analysis, Stoneley inversion
Mechanical properties	Stress and rock strenght	**Sonic Scanner**	Anisotropy analysis and radial profiling to map variation in elastic properties and fractures

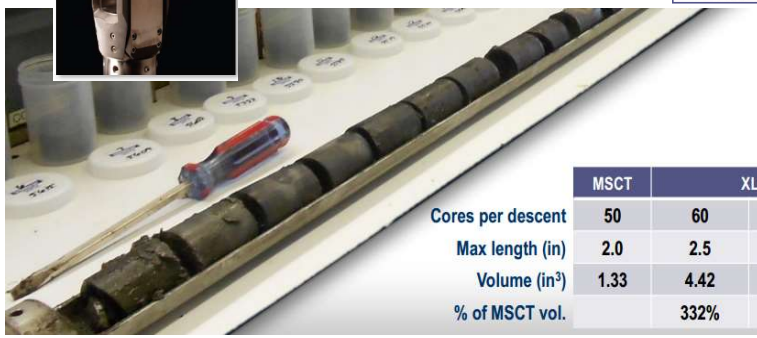


Sidewall Core – Heterogeneous Reservoir calls for Core Analysis

XL-Rock Large Volume Sidewall Coring

Large-volume rotary sidewall cores

- Adjustable weight on bit
- Realtime core detection
- Coring advisor

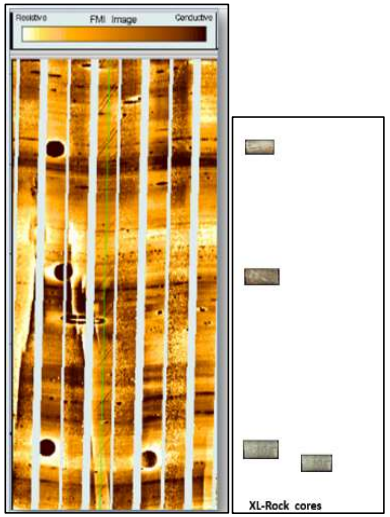


	MSCT	XL-Rock Options		
Cores per descent	50	60	50	43*
Max length (in)	2.0	2.5	3.0	3.5*
Volume (in³)	1.33	4.42	5.3	6.19
% of MSCT vol.		332%	399%	465%

	MSCT	XL-Rock
Storage Capacity	GOOD	V. GOOD
Flow Capacity	GOOD	V. GOOD
Grain Density	GOOD	V. GOOD
Evaluate productive potential (saturation)	GOOD	V. GOOD
Capillary pressure characteristics	GOOD	V. GOOD
Electrical properties	FAIR	GOOD
Acoustic velocity characteristics	FAIR	GOOD
NMR T2 and T2 critical	FAIR	GOOD
Mechanical Properties	FAIR	GOOD
Pore Volume Compressibility	FAIR	GOOD
End Point Relative Permeability	FAIR	GOOD
Core Wettability	FAIR	GOOD
Water Sensitivity, Critical Velocity	FAIR	GOOD
Mineralogical Information, XRD, SEM, Isotope	V. GOOD	V. GOOD
Petrographic Description	V. GOOD	V. GOOD
Environment of Deposition	FAIR	GOOD
Seal Studies and Breakthrough Pressure	FAIR	GOOD
Fracture Analysis	POOR	FAIR
Determination of Contacts	FAIR	GOOD
Source Rock and Oil Characterization	GOOD	V. GOOD
Biostratigraphic Correlation	FAIR	GOOD
Grain Size Analysis	GOOD	V. GOOD

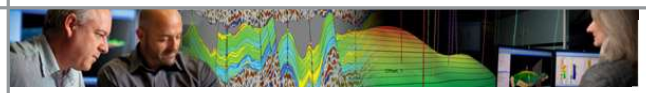
Micro-Imaging Benefits :

1. Continuous & In-situ description of structure and fabrics
2. Oriented measurements with azimuthal coverage
3. Convenient for upscaling & matching with other data



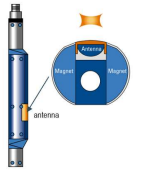
Sidewall Core (SWC) Benefits :

1. Efficient and cost-effective recovery of high quality rock samples
2. Multiple attempts / options to obtain required samples
3. Selective core sampling based on previous log measurements



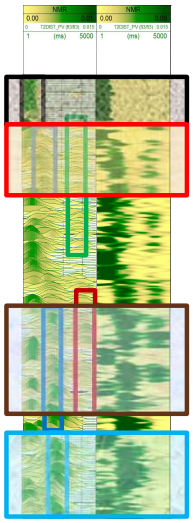
NMR – Free vs. Bound fluid & Quantification vs Fluid Typing

CMR-MagniPHI New Generation Nuclear Magnetic Resonance



- Modern electronics and firmware enable measurement of T1 down to 1 ms
- Continuous T1-T2 logging capability
- New pulse sequences for accurate resolution of short T1 and T2 components
- Sensitivity to T1-T2 fluid contrasts for enhances the ability to resolve fluid types (HC & water)
- Reduces porosity uncertainty (T1/T2 ratio important for accurate porosity and signal distribution)
- Retains all functionalities of the previous generation tool:
  - Sonde and magnet design: 2MHz, high SNR
  - Shortest echo spacing (0.2ms)
  - Temperature/salinity/pressure ratings
  - All depth log capabilities of CMR+; Station logs, including MRF DE

Acquired and inverted NMR T_2 distribution at a single depth level – Linear combination of volumetric contributions of the underlying Poro-Fluid Constituents' T2 distributions for refined cutoffs, rock facies and fluids, rock quality, link to other Petrophysics and domains.



Single T2 Distribution can not be decomposed uniquely!

Need to add more information … but how?

Parallel Analysis and Factor Analysis

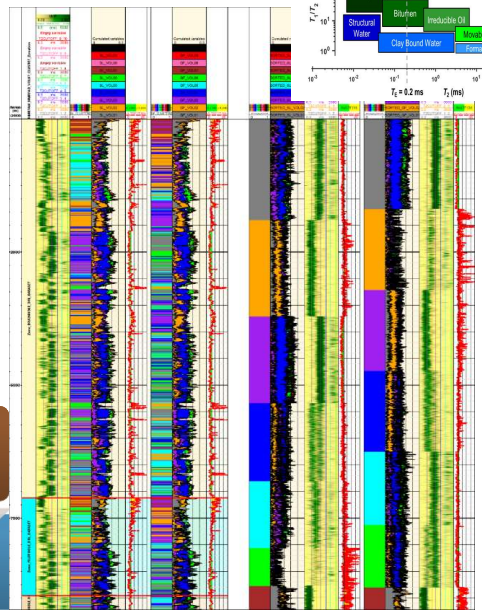
One way is to look for common peaks/modes over an interval. Interpret them into known "poro-fluid constituents".

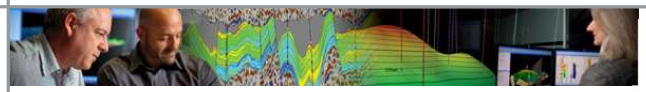
Near-Idempotent Clustering

Recognize pattern of poro-fluid constituent signatures appearing together -> "poro-fluid facies".

Known Industry NMR Transforms

Characterize each facie by its mean T2 distribution, pseudo-capillary and saturation height functions.

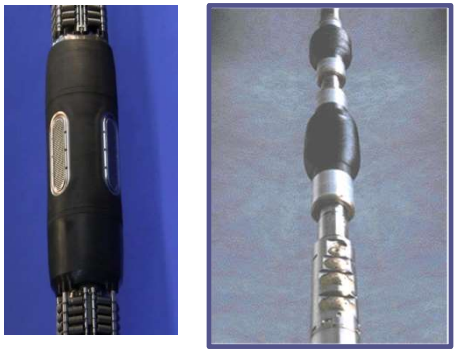


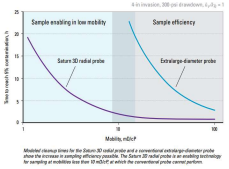


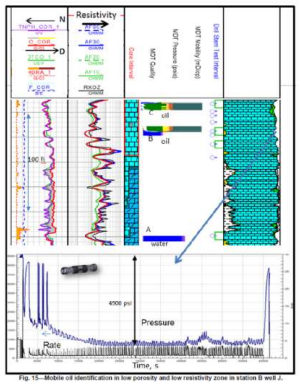
Live Fluid Analysis - Heterogeneous Reservoir calls for Fluid Identification and Sampling

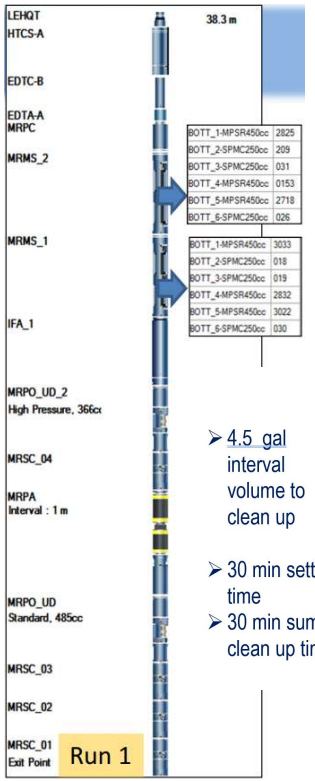
- Fractured / Vuggy Formations
- Unconsolidated Formations*
- Tight / Super Charged Formations
- Other applications:
  - Mini-Frac /Stress Testing; Mini-DST
  - Vertical Interference Test

Max DD	LD Probe	XLD Probe	Saturn	Dual Packer
	Equivalent Radius: 0.52"	*Equivalent Radius: 0.82"*	*Equivalent Radius: 7.375"*	*Packer Interval Height: 3.2ft*
Viscosity 20 cP	**4786 psi**	**2999 psi**	**201.6 psi**	**52.9 psi**
Viscosity 10 cP	**2393 psi**	**1499.5 psi**	**100.9 psi**	**26.5 psi**





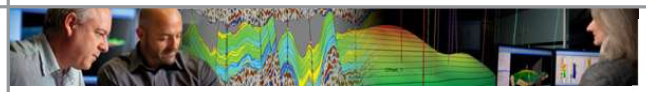




- 4.5 gal interval volume to clean up
- 30 min setting time
- 30 min sump clean up time

8.5 inch Hole Size

- Zero interval volume. Faster clean up
- 10 min setting time
- 1450 lbs retract force through spring loaded mechanism



Scaling Effect on Knowledge Needed

• Physical properties of interest have characteristic length and time scales

• Dictate use of different tools to perform measurements

• Crystal structure is small scale

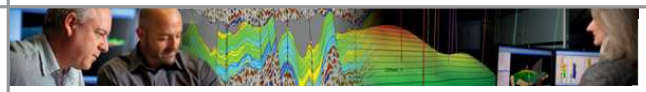
- Core testing
- Thin sections
- Geologically oriented

•Well logs are intermediate scale

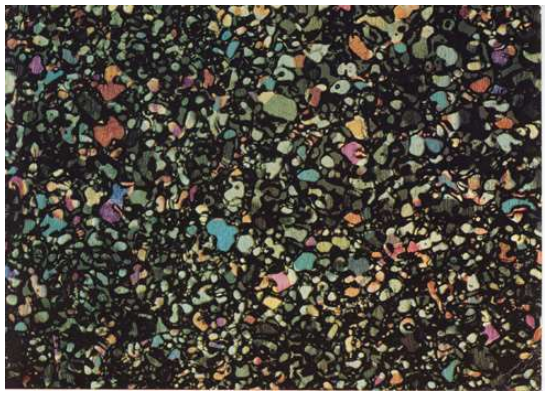
- Petrophysical measurements
- Borehole seismic
- Interplay of geology and geophysics

• Fields are large scale

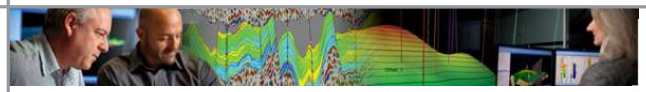
- Geophysics
  - ✓ Surface seismic
  - ✓ Potential field methods
- Geology
  - ✓ Well correlation
  - ✓ Depositional patterns



Scaling Effect on Knowledge Needed

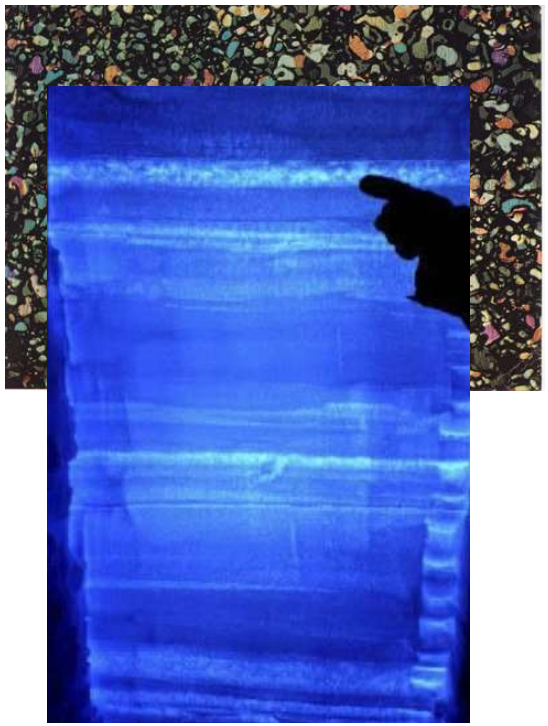


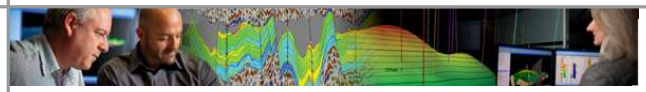
- Physical properties of interest have characteristic length and time scales
- Dictate use of different tools to perform measurements
- Crystal structure is small scale
  - Core testing
  - Thin sections
  - Geologically oriented
- Well logs are intermediate scale
  - Petrophysical measurements
  - Borehole seismic
  - Interplay of geology and geophysics
- Fields are large scale
  - Geophysics
    - ✓ Surface seismic
    - ✓ Potential field methods
  - Geology
    - ✓ Well correlation
    - ✓ Depositional patterns



Scaling Effect on Knowledge Needed

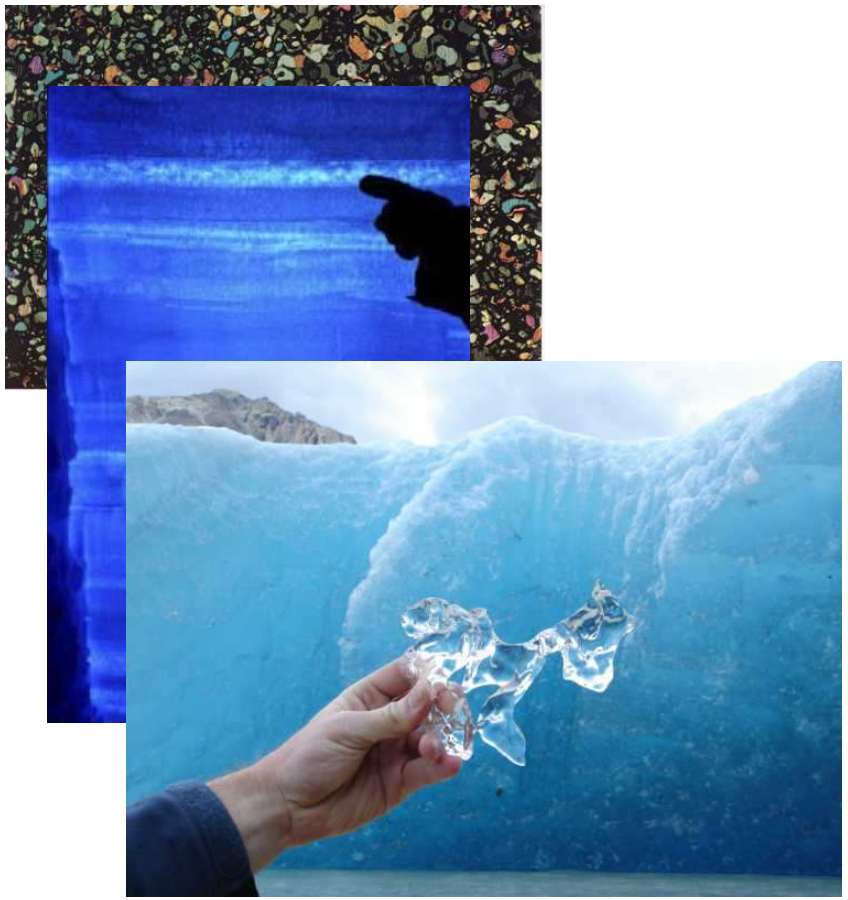
- Physical properties of interest have characteristic length and time scales
- Dictate use of different tools to perform measurements
- Crystal structure is small scale
  - Core testing
  - Thin sections
  - Geologically oriented
- Well logs are intermediate scale
  - Petrophysical measurements
  - Borehole seismic
  - Interplay of geology and geophysics
- Fields are large scale
  - Geophysics
    - ✓ Surface seismic
    - ✓ Potential field methods
  - Geology
    - ✓ Well correlation
    - ✓ Depositional patterns

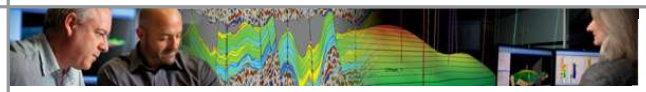




Scaling Effect on Knowledge Needed

- Physical properties of interest have characteristic length and time scales
- Dictate use of different tools to perform measurements
- Crystal structure is small scale
  - Core testing
  - Thin sections
  - Geologically oriented
- Well logs are intermediate scale
  - Petrophysical measurements
  - Borehole seismic
  - Interplay of geology and geophysics
- Fields are large scale
  - Geophysics
    - ✓ Surface seismic
    - ✓ Potential field methods
  - Geology
    - ✓ Well correlation
    - ✓ Depositional patterns



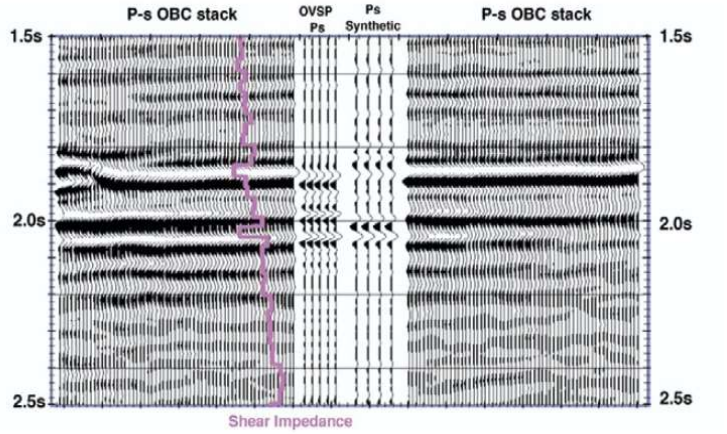


Scaling Effect on Measurement

- Sonic logging/synthetic seismograms
  - Want to see detailed velocity structure at well
  - Requires large bandwidth (several kHz)
  - Requires small source receiver spacing (2-11 ft)
  - Microsecond time scales
  - Waves make one-way trip
    - Dominant concern is borehole conditions

- VSP/borehole seismic
  - Want to see a bigger picture around the well
  - Small bandwidth
    - Spans approximately 10-100 Hz
    - Requires large source-receiver offsets
  - Millisecond time scales
  - Waves make one-way trip
    - Signal attenuation an issue but not dominant
    - Scattering and absorption not as important since waves travel one way

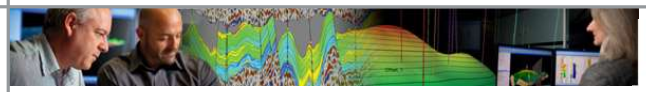
- Surface seismic
  - Want to see the whole field
  - Small bandwidth
    - Spans approximately 10-500 Hz
  - Large source-receiver offsets
  - Millisecond time scales
  - Waves make two-way trip
    - Scattering, attenuation, transmission losses become major concerns



Leaney et al., Borehole-integrated anisotropic processing of converted modes, The Leading Edge (20), 996-1007, September 2001

Agreement between different types of data sets increases confidence in interpretation

- Processing workflows different
- Assumptions about physical processes different
- Artifacts different



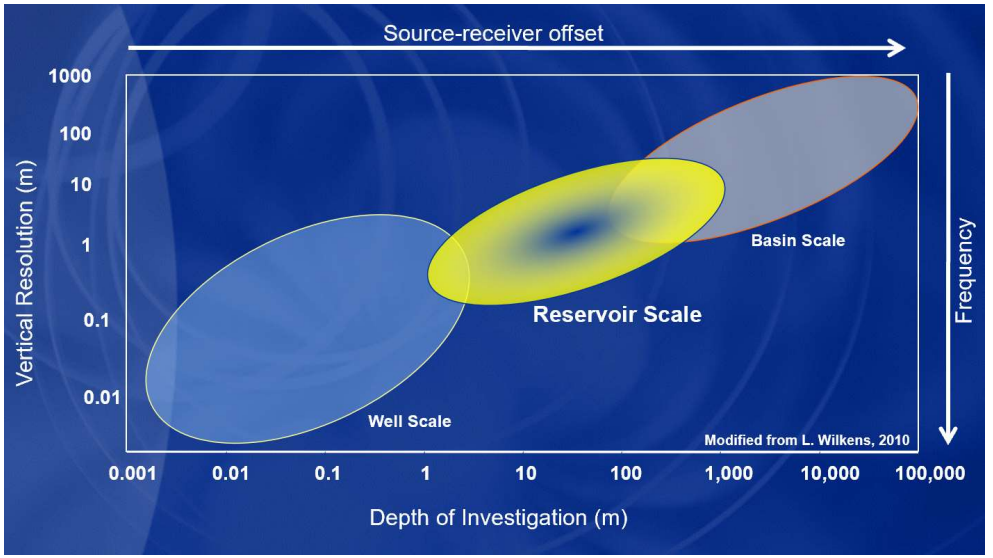
Scaling Effect on Measurement

- Sonic logging/synthetic seismograms
  - Want to see detailed velocity structure at well
  - Requires large bandwidth (several kHz)
  - Requires small source receiver spacing (2-11 ft)
  - Microsecond time scales
  - Waves make one-way trip
    - Dominant concern is borehole conditions

- VSP/borehole seismic
  - Want to see a bigger picture around the well
  - Small bandwidth
    - Spans approximately 10-100 Hz
    - Requires large source-receiver offsets
  - Millisecond time scales
  - Waves make one-way trip
    - Signal attenuation an issue but not dominant
    - Scattering and absorption not as important since waves travel one way

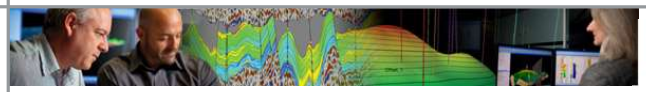
- Surface seismic
  - Want to see the whole field
  - Small bandwidth
    - Spans approximately 10-500 Hz
  - Large source-receiver offsets
  - Millisecond time scales
  - Waves make two-way trip
    - Scattering, attenuation, transmission losses become major concerns

Multi-scale investigation

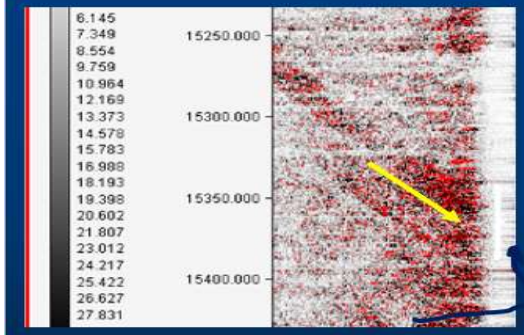


Agreement between different types of data sets increases confidence in interpretation

- Processing workflows different
- Assumptions about physical processes different
- Artifacts different

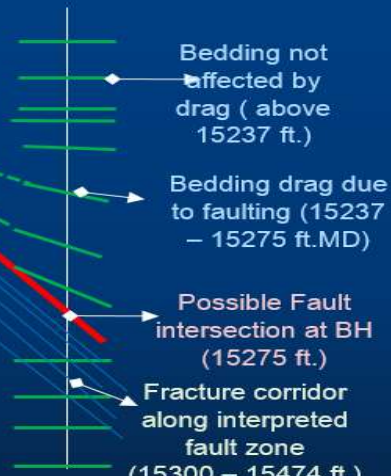


Imaging Natural Fractures



Fault / Fracture Corridor

Sonic Reflection Processed Images showing possible Fault Zone 15237 – 15450 ft. MD.



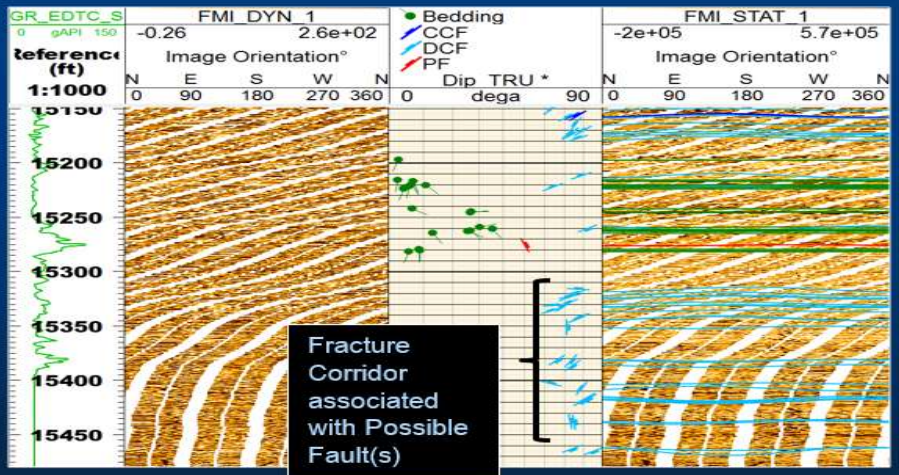
Bedding not affected by drag (above 15237 ft.)

Bedding drag due to faulting (15237 – 15275 ft.MD)

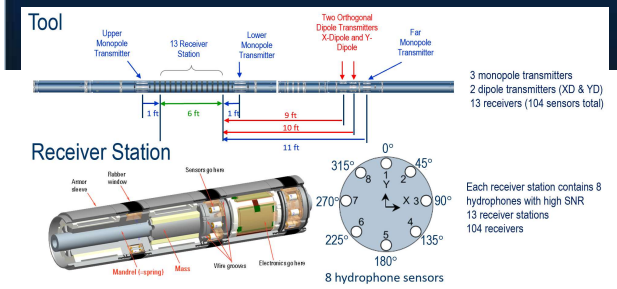
Possible Fault intersection at BH (15275 ft.)

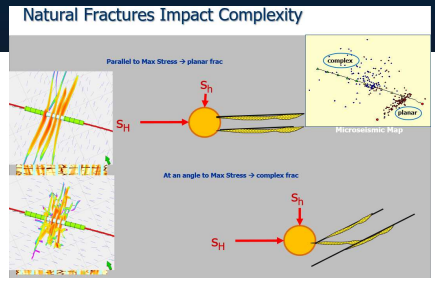
Fracture corridor along interpreted fault zone (15300 – 15474 ft.)

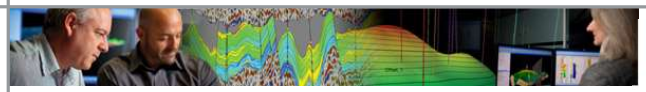
Conceptual model for faulting event in this well-section



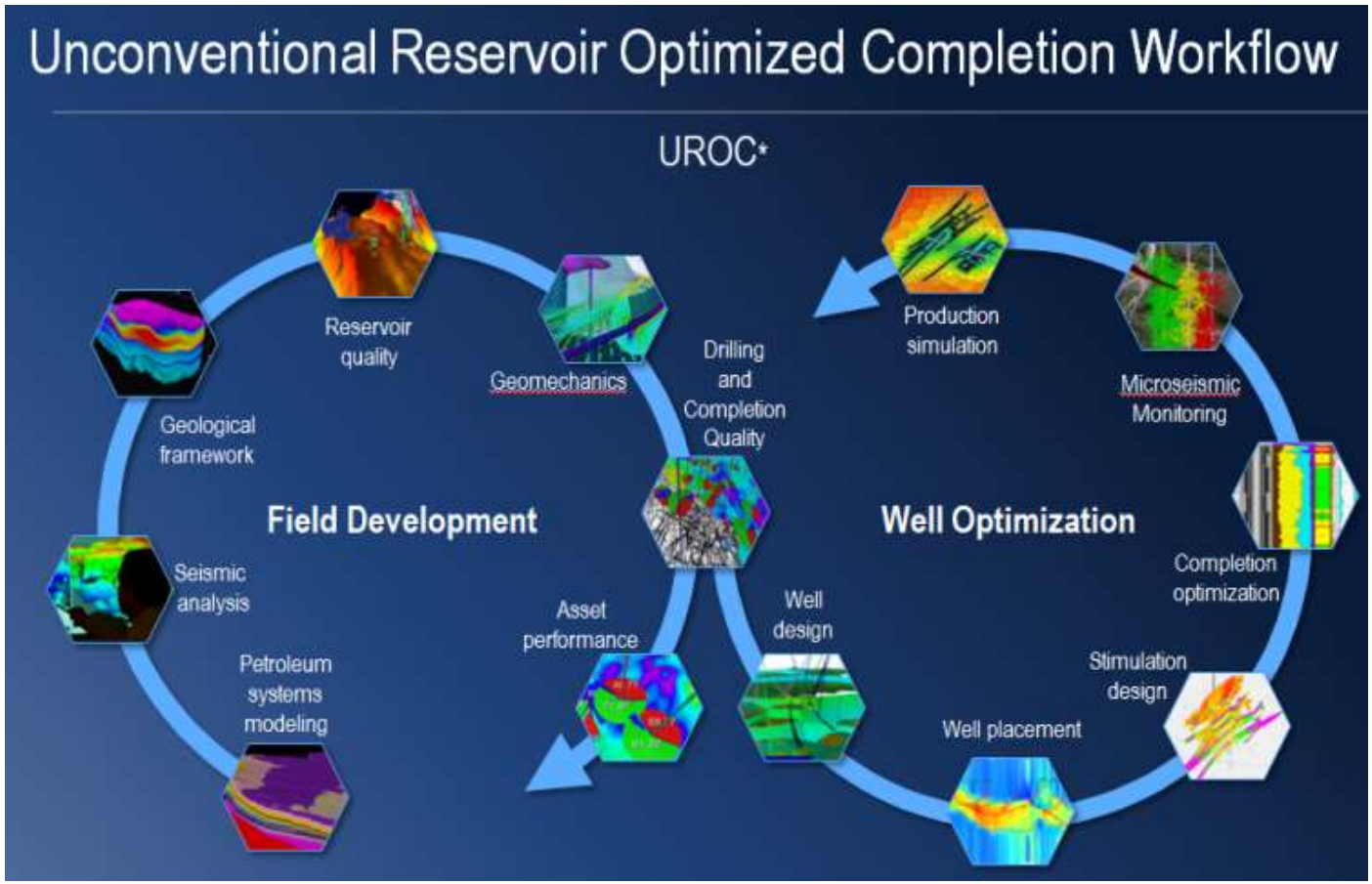
FMI Key Fractures Interpretation Summary





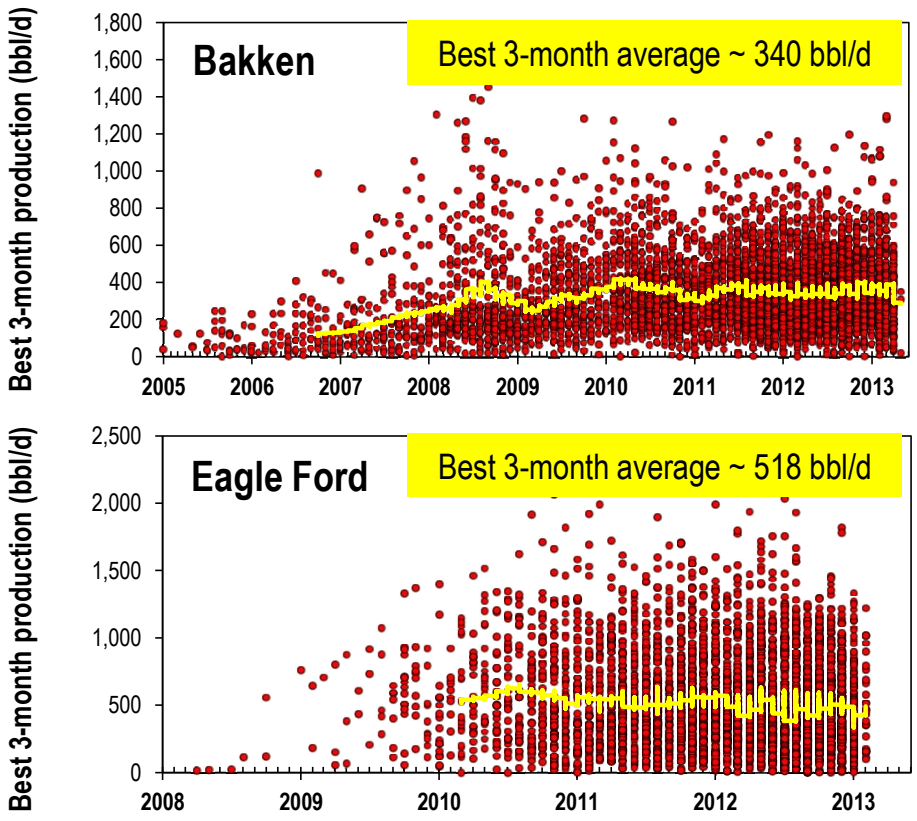


Unconventional Resources - Optimization Strategy

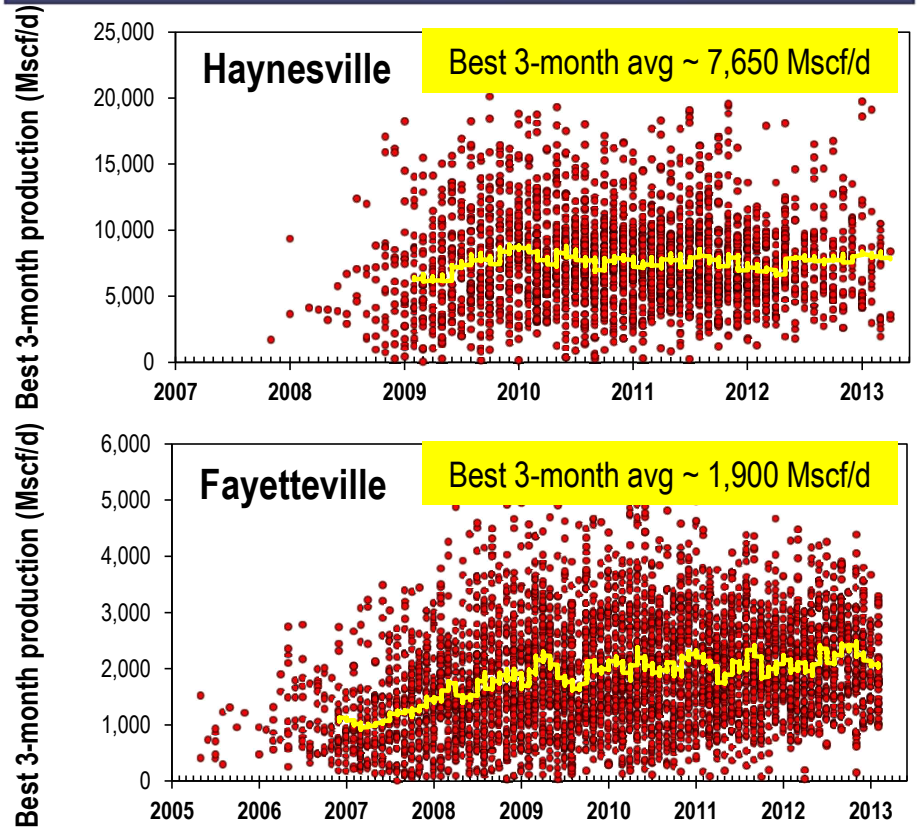


Introduction

Unconventional Liquid Plays



Unconventional Gas Plays

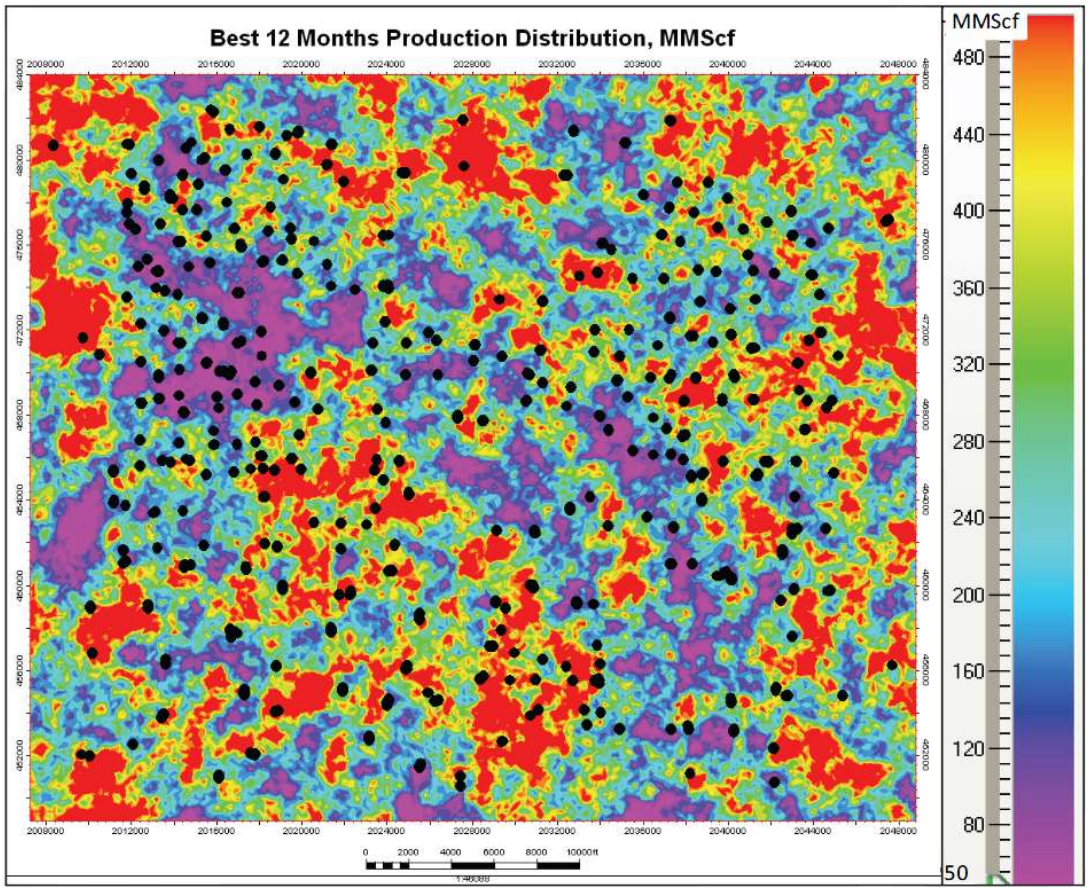


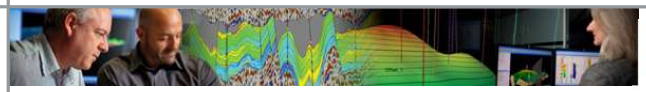
SOURCE: PFC Report; IHS Data

Root Cause 1: Field Scale Lateral Heterogeneity

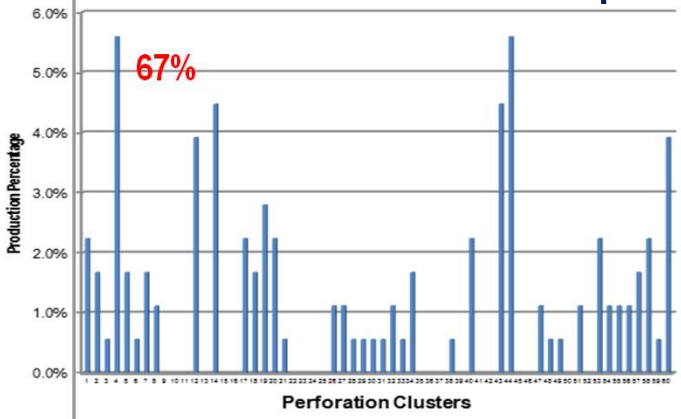
High degree of production variability across 50 sq. mi area.

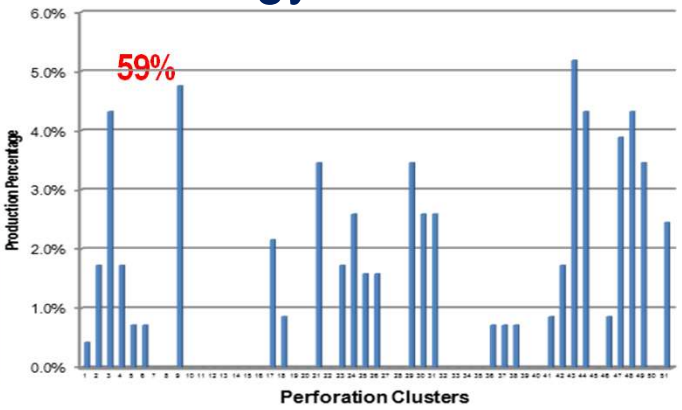
SPE 138427

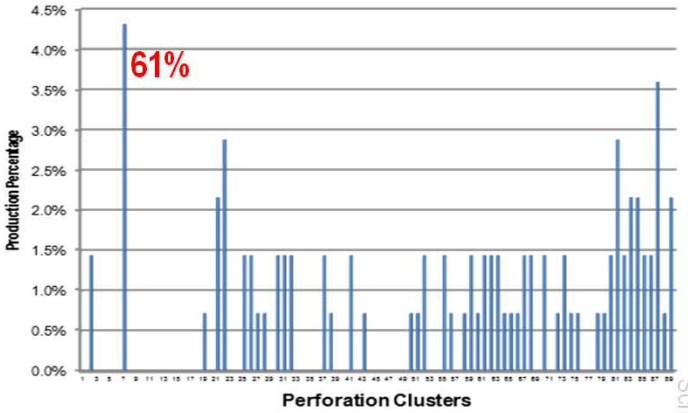


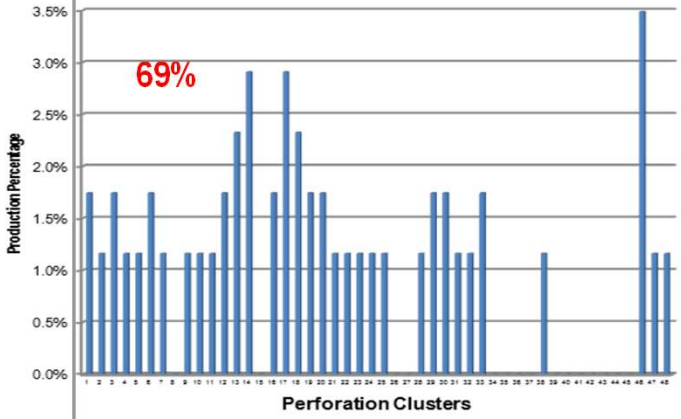


Root Cause 2: Completion Strategy



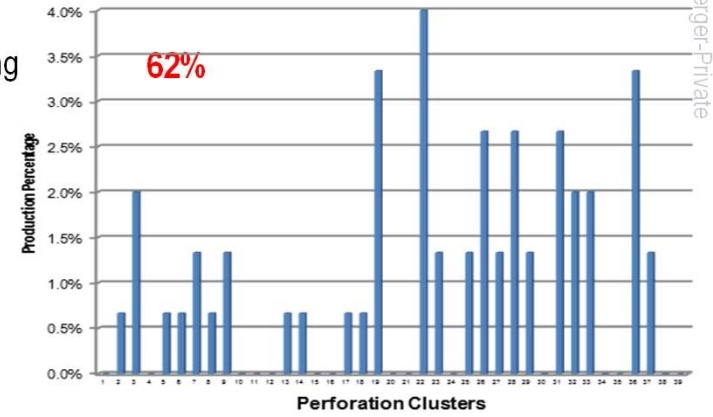


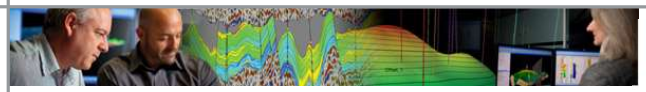




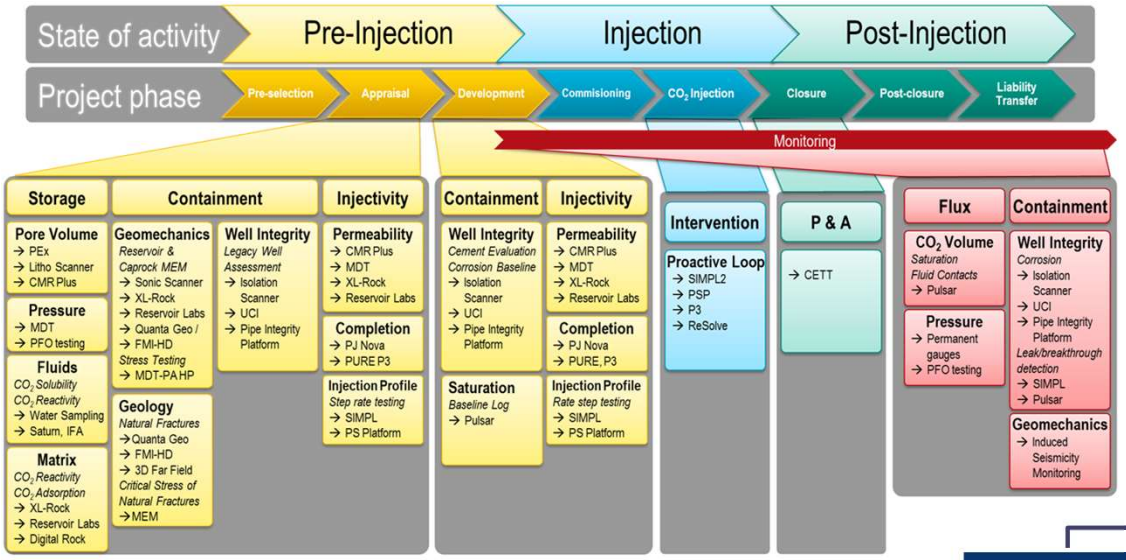
Eagle Ford Production Log Examples

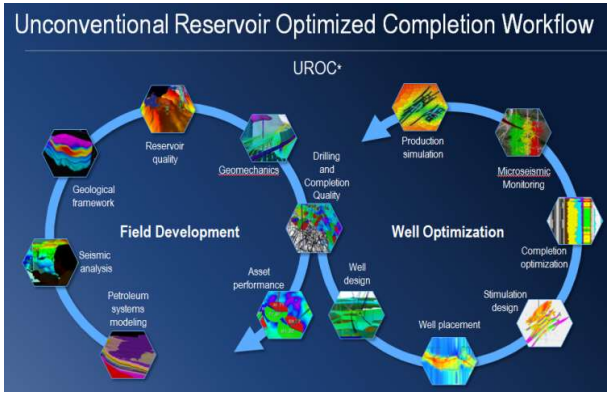
- Only 64% of the Perforation Clusters contributing
- All wells were completed Geometrically

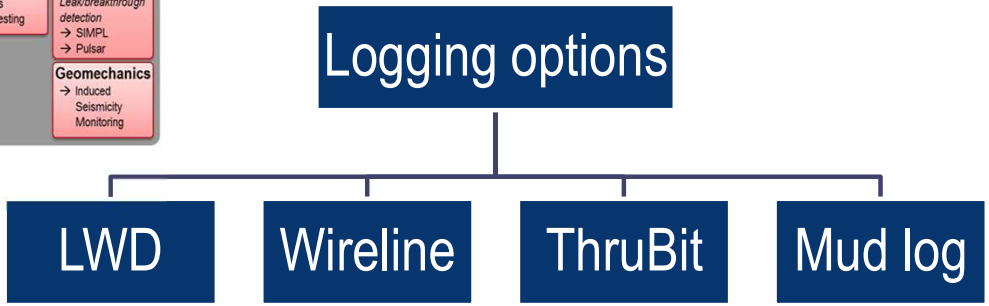




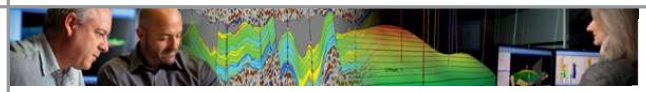
Measurements and Evaluations



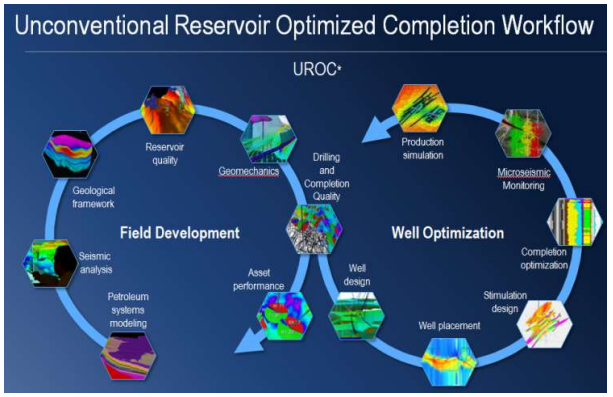




Measurement is the key to integrated evaluation



Measurements and Evaluations



Geology Geophysics

Petrophysical

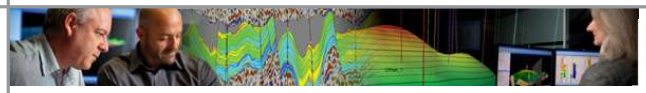
Reservoir Characterization

Well Placement

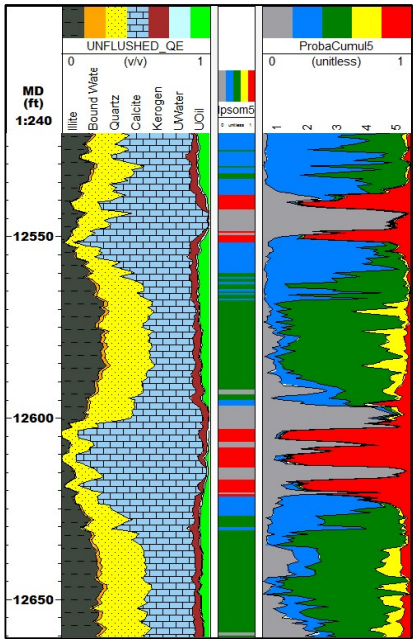
Reservoir Quality + Completion Quality

Acoustic

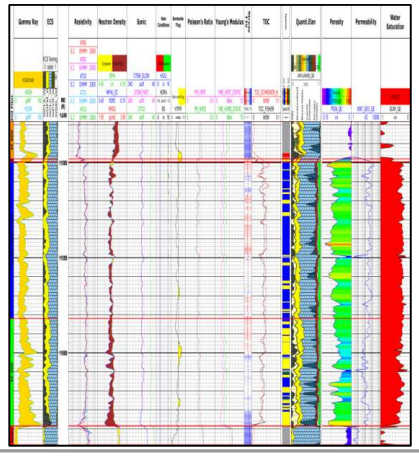
Mud data

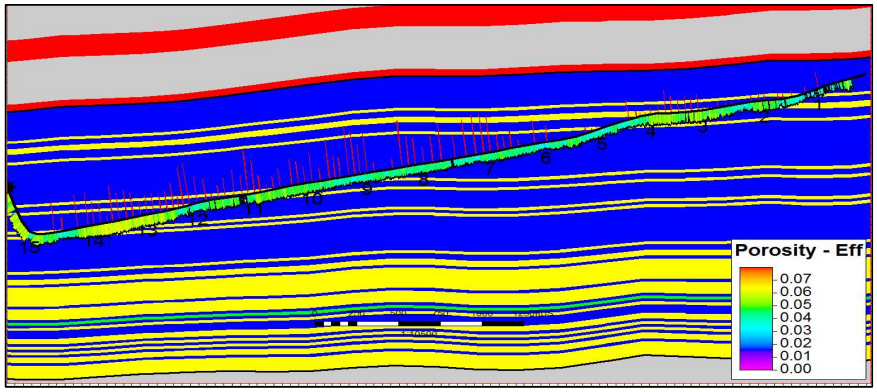


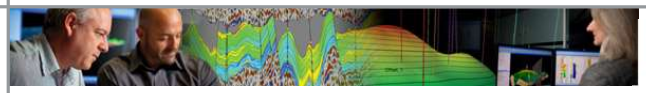
Horizontal Well Evaluation Rock Quality Workflow



Color/Rock Type					
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"		



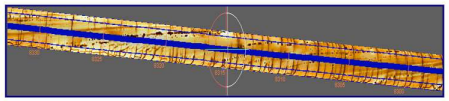




Fracture Evaluation

Objective

Better Understand the Geological Drivers for Completion Quality



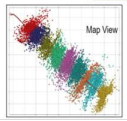
Mineralogy impacts hydraulic fracture initiation

Fracture analysis

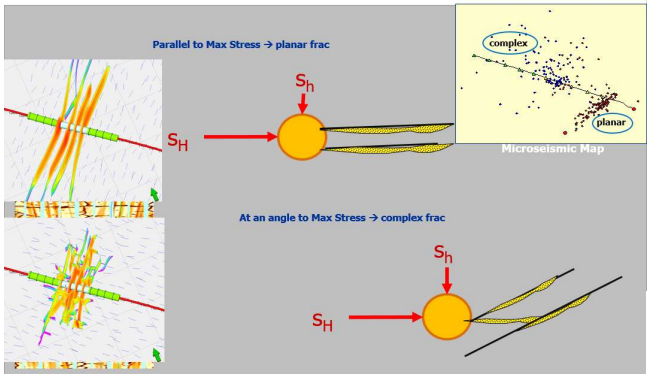
- drilling fractures – local stresses
- natural fractures – weak planes

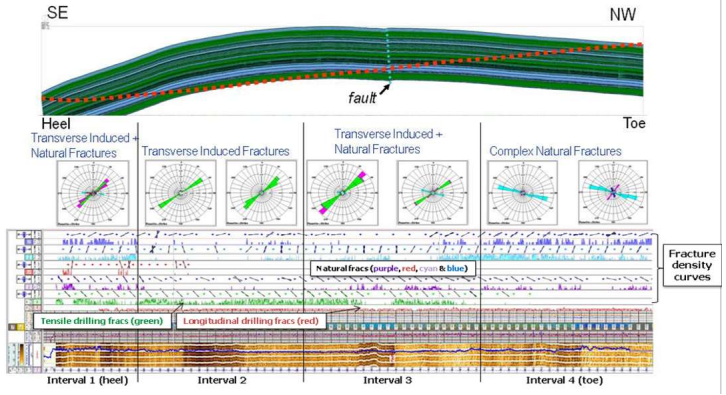
→ Hydraulic Fracture Complexity

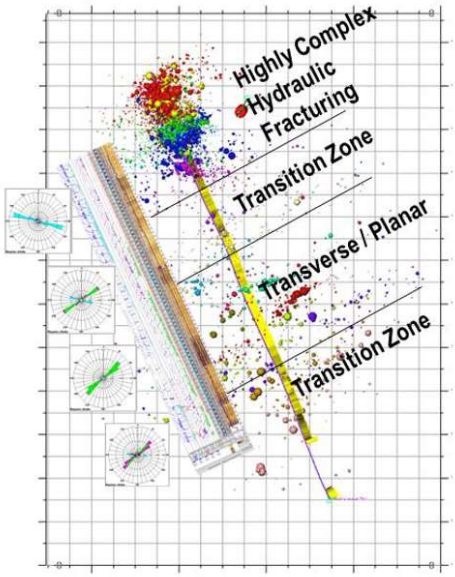
Maximize Reservoir Contact

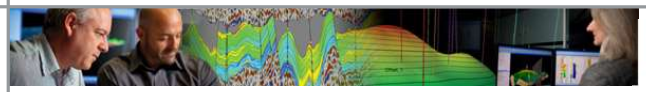


Natural Fractures Impact Complexity

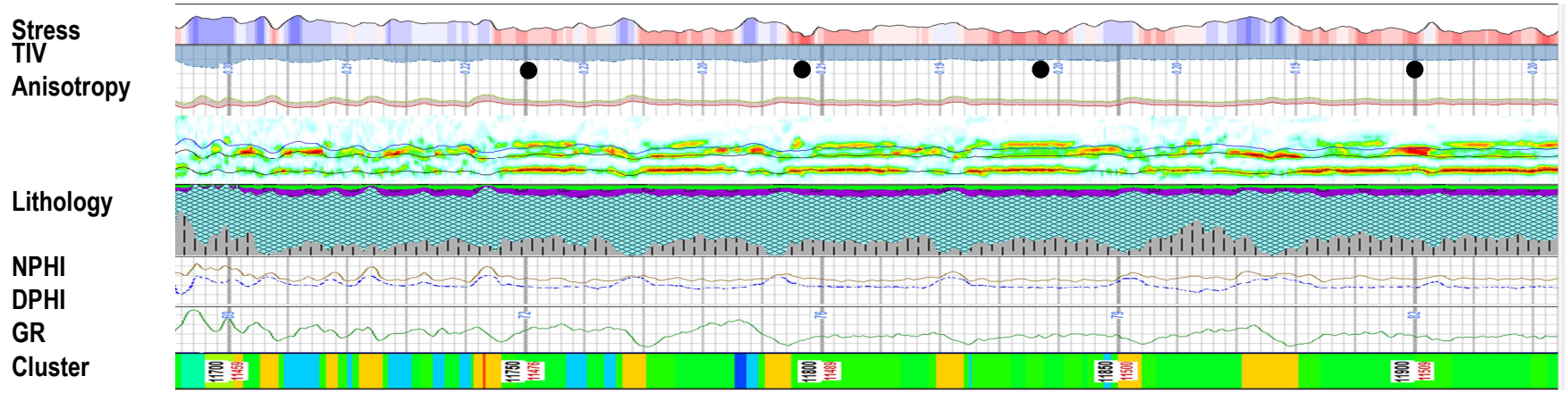




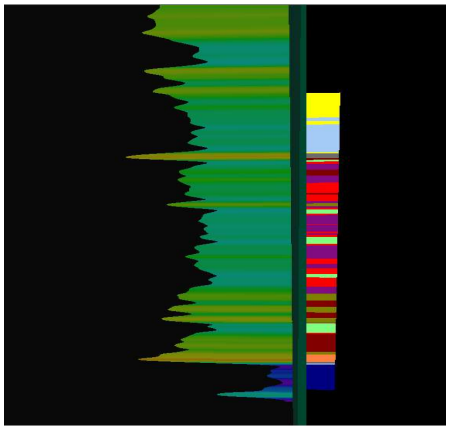




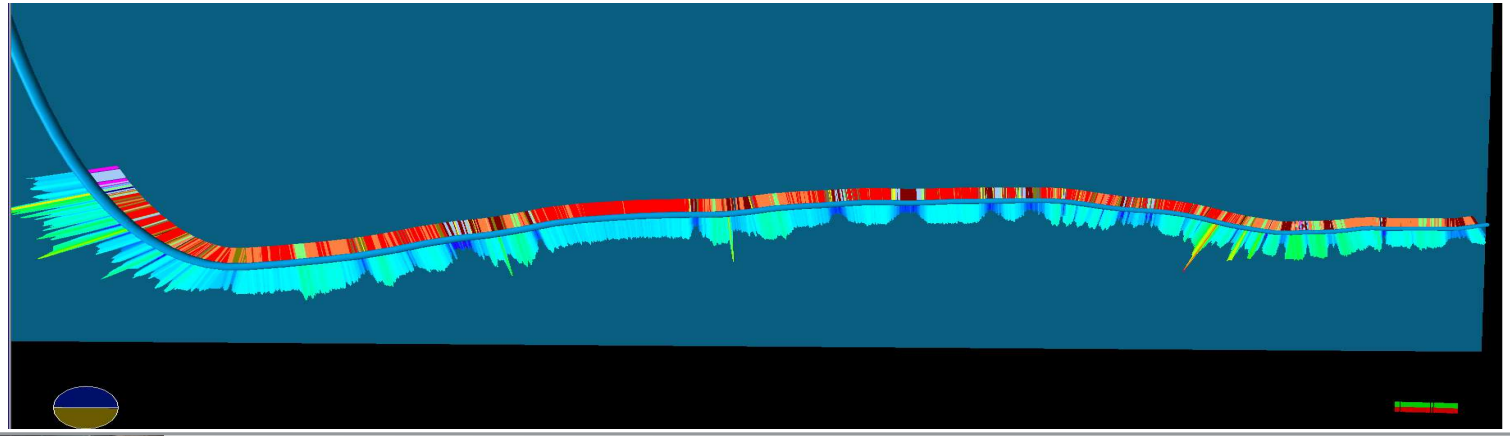
Completion Quality - CQ

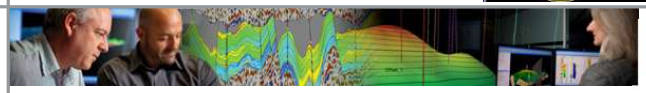


Pilot Well Measurements



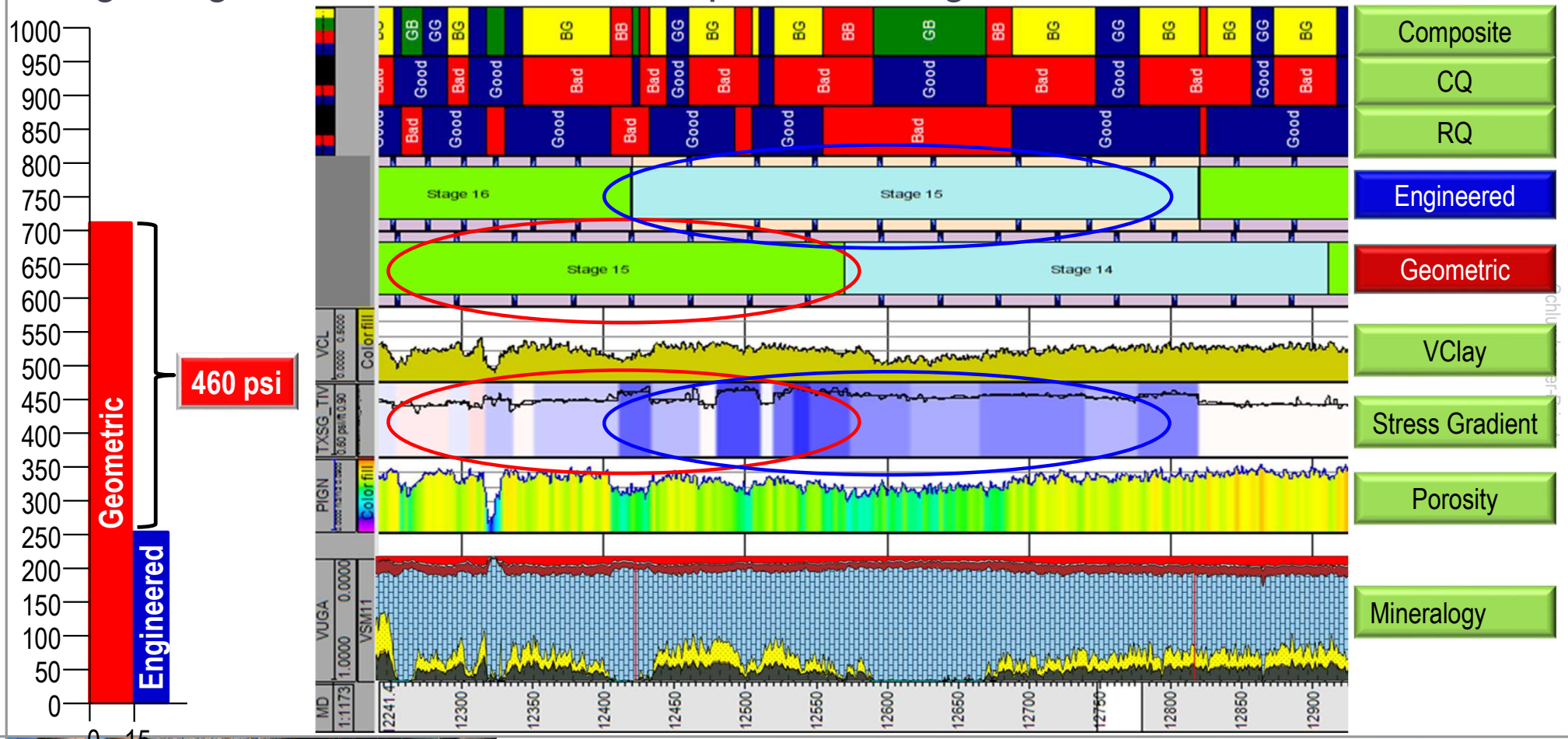
Lateral Well Measurements

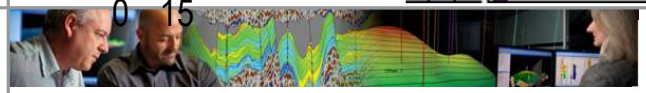




Integrating RQ and CQ in the Completion Design

Kinetix Completion Advisor





PetroTechnical Services
Global Expertise

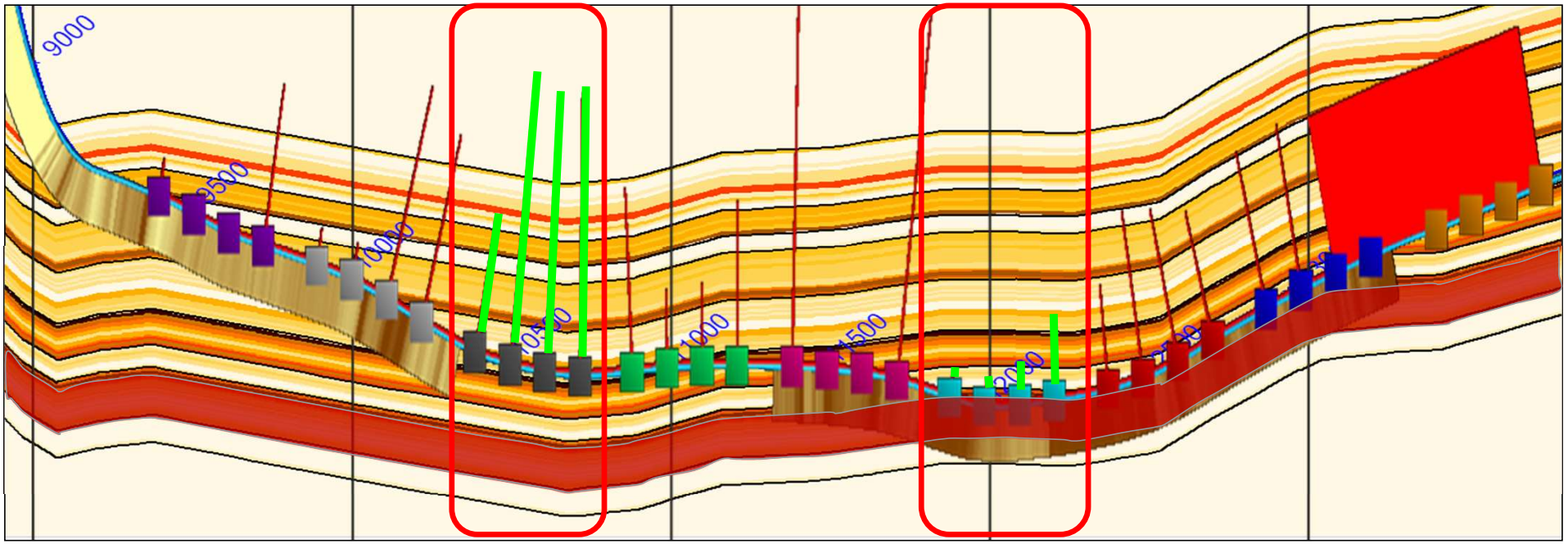
Schlumberger-Private

Schlumberger

Well Placement Matters

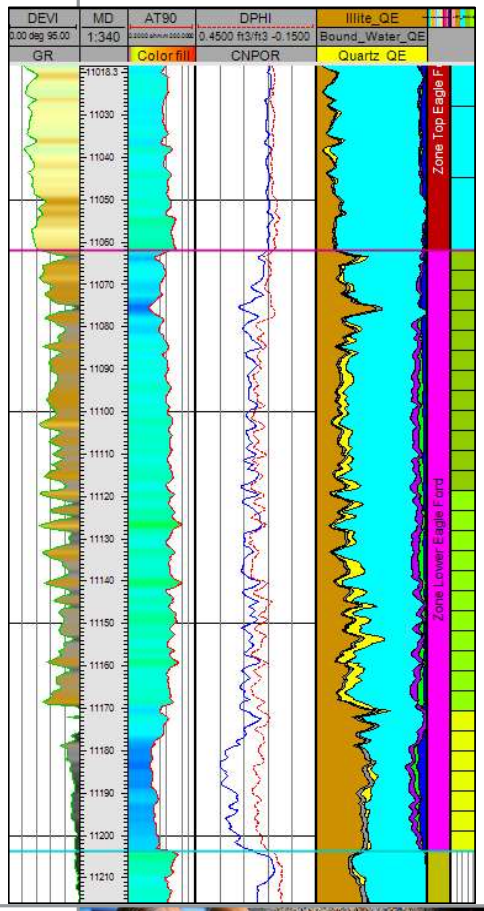
19% of Total Well Production

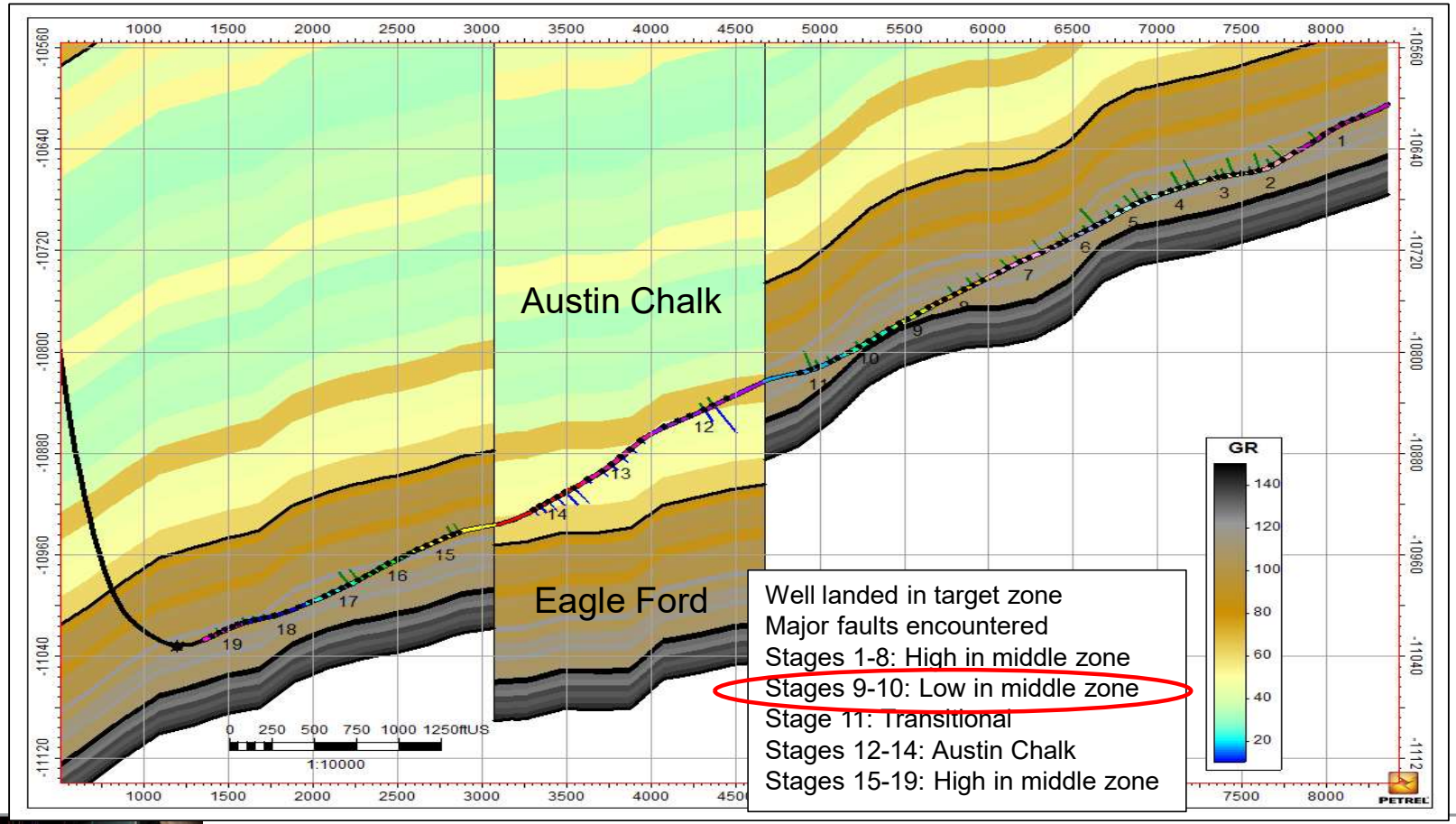
3% of Total Well Production



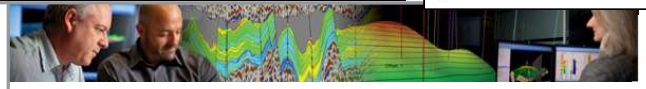
Optimization will require Well Placement and Engineered Completion

Well Placement Matters





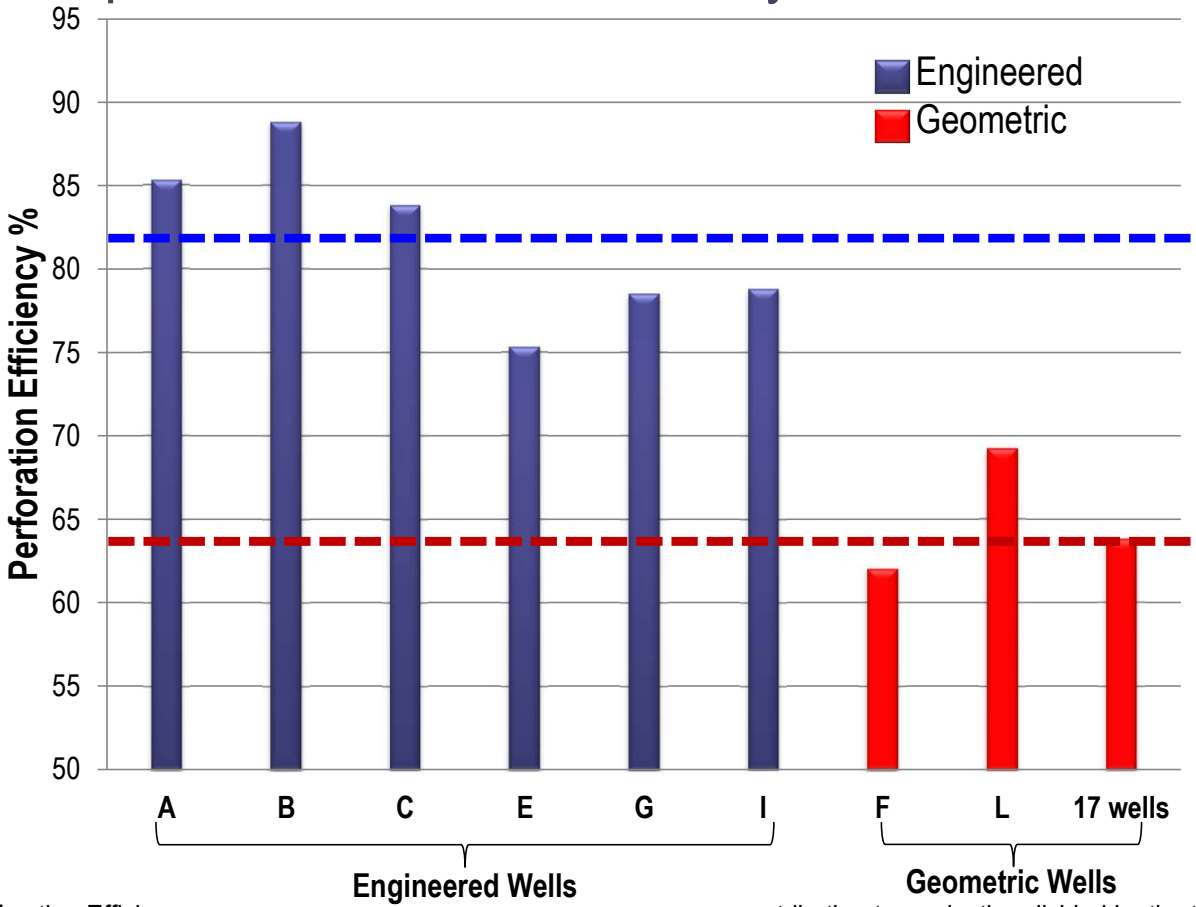
Well landed in target zone
Major faults encountered
Stages 1-8: High in middle zone
Stages 9-10: Low in middle zone
Stage 11: Transitional
Stages 12-14: Austin Chalk
Stages 15-19: High in middle zone



PetroTechnical Services
Global Expertise

Schlumberger

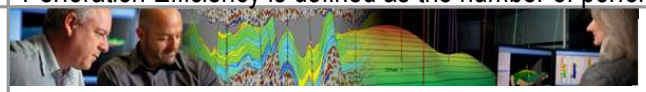
Example - Perforation Efficiency Increase



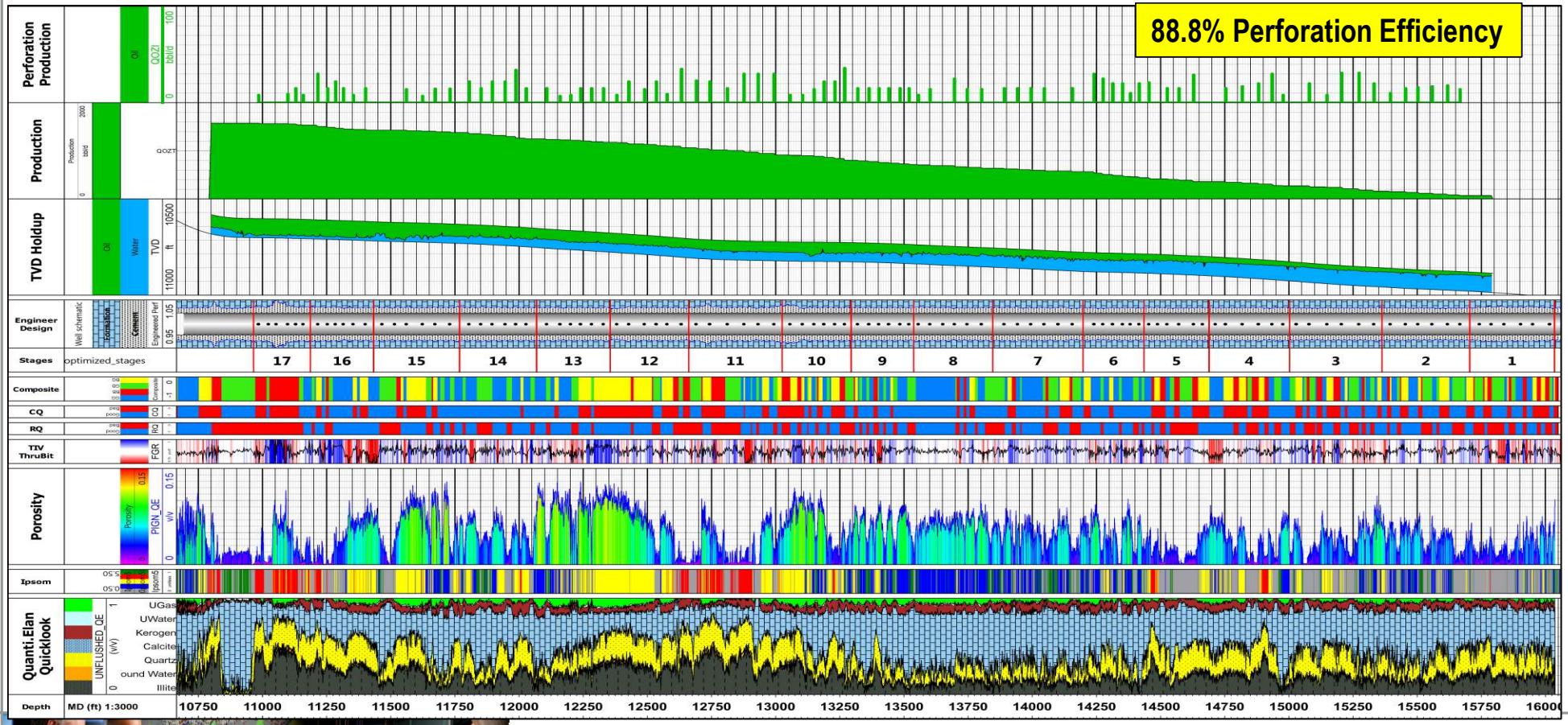
82 %
Engineered
Completion
Eagle Ford
Consortium
6 Well Avg

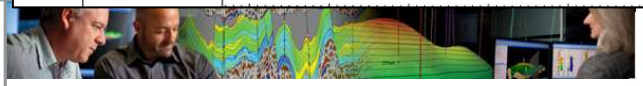
64 %
Geometric
Completion
Eagle Ford
17 Well Avg

* Perforation Efficiency is defined as the number of perforation clusters contributing to production divided by the total number of perforation clusters.



Example - Perforation Efficiency Increase





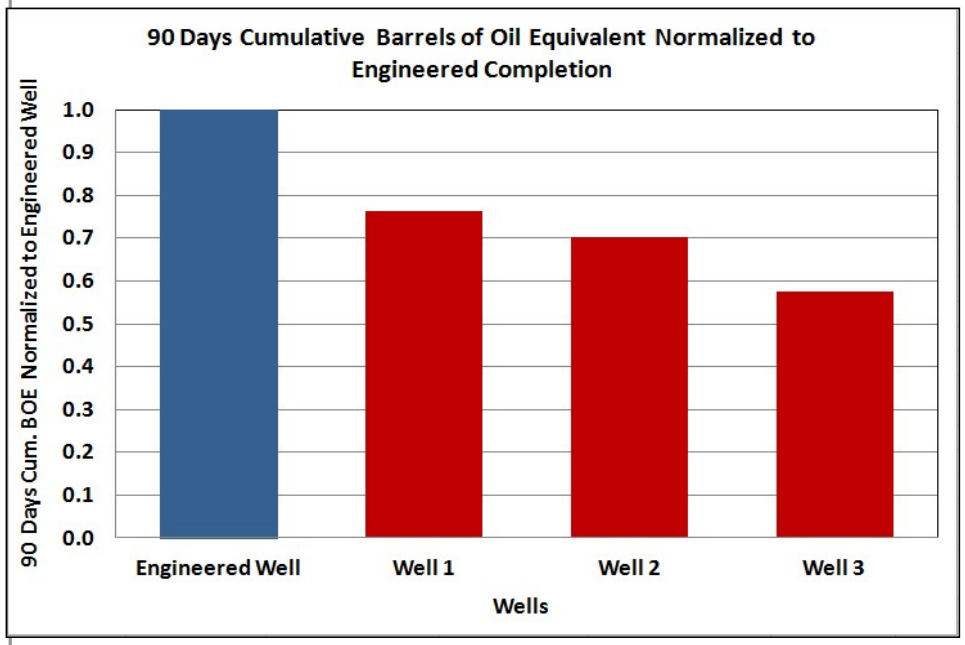
PetroTechnical Services
Global Expertise

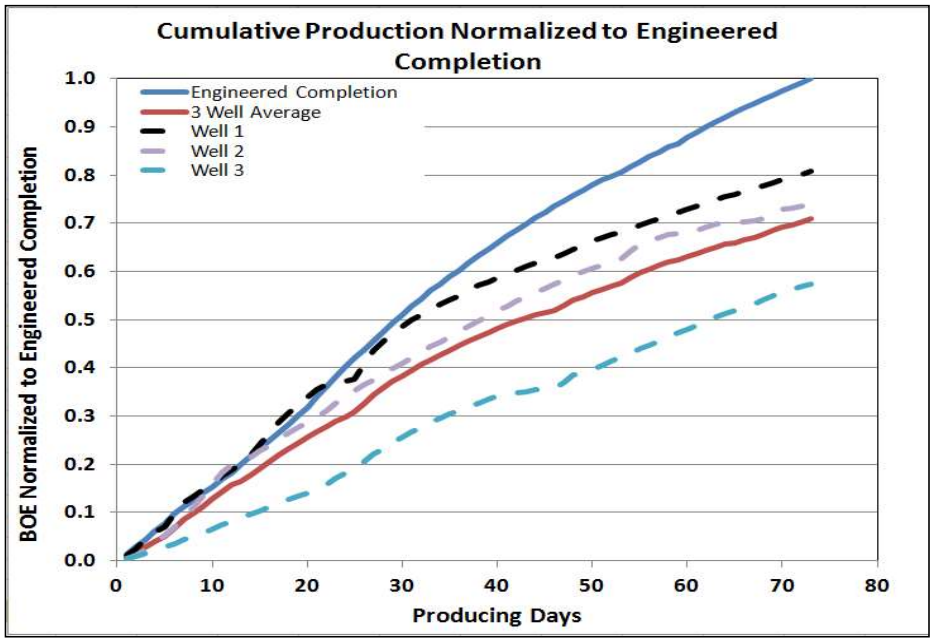
Schlumberger

Schlumberger-Private

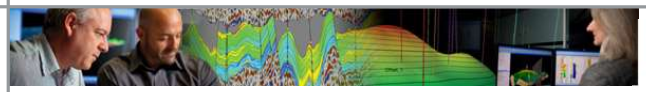
Example - Production Increase

39% increase in 90 days cumulative oil production on engineered well compared to best offset well.

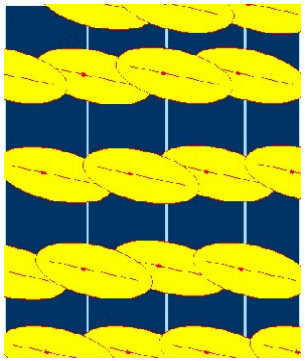




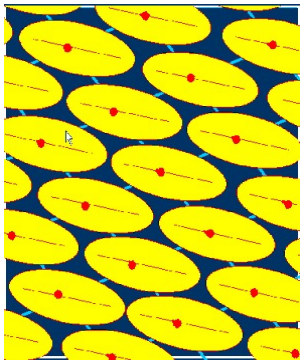
Clayton Williams - Wolfcamp



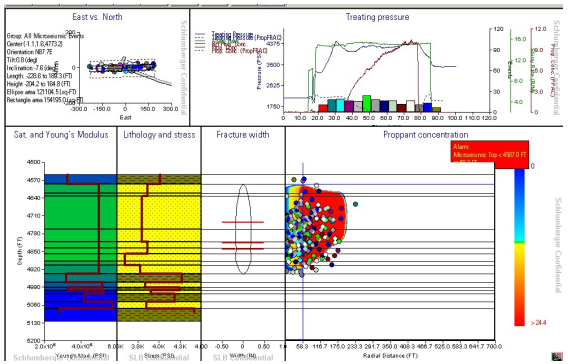
Monitoring Injection Efficiency



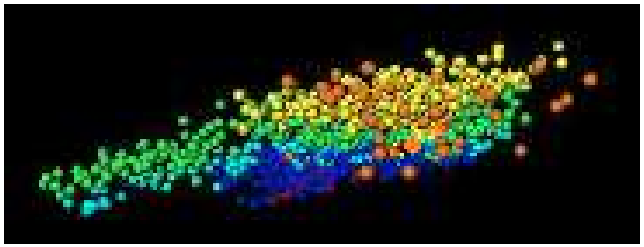
Well placement without fracture detection



Well placement with HFM fracture geometry

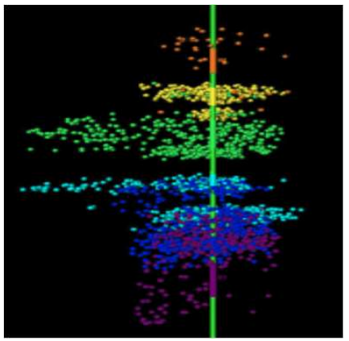


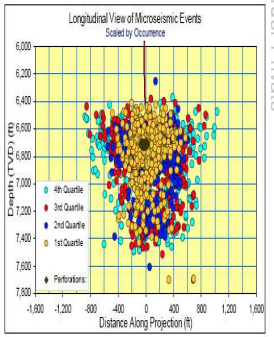
Integration of reservoir properties, fracture modeling and micro seismic detection aid in reservoir optimization (SPE 102493)

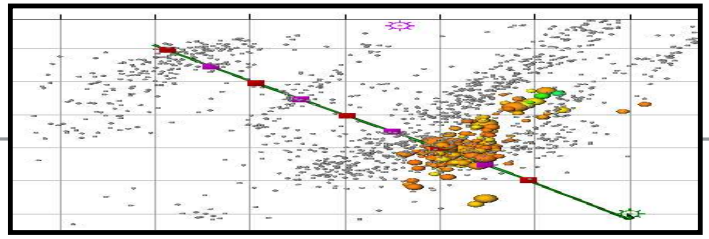


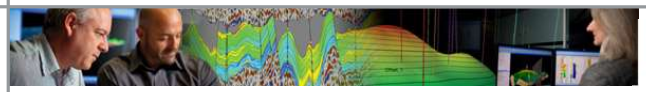
Actual microseismic map of a 6 stage completion

- Coverage
  - Zonal: is the pay zone targeted covered?
  - Lateral: is the opened zone properly stimulated?
- Vertical Fracture Growth
- Fracture (System) Half-Length
- Complex Fracture Network and/or Multiple Fractures
- Zonal Isolation (i.e., toe vs. heel)
- Structures (i.e., fault, pinch-out) identification





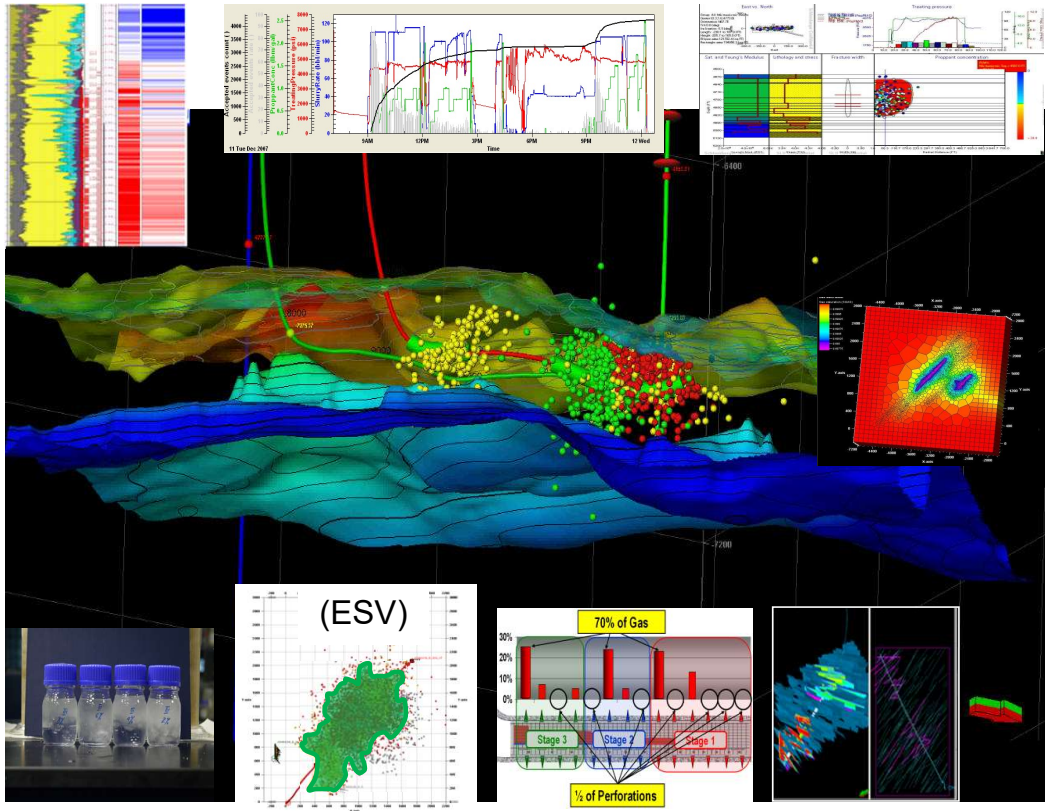


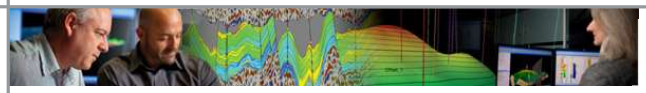


PetroTechnical Services
Global Expertise

Summary

- Reservoir characterization is essential for effective completion.
- Measurements is the key.
- Proper well placement maximizes production.
- Data integration is critical.



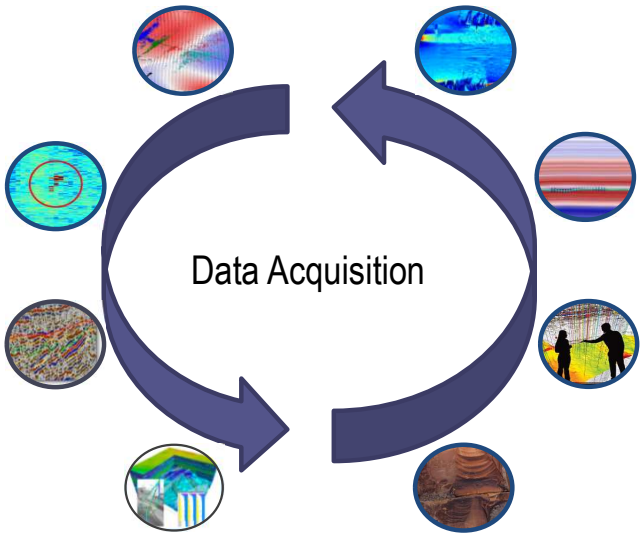


Post-Injection

Injection

Pre-Injection

State of activity



Monitoring

Injectivity
- **Permeability**: CMR Plus, MDT, XL-Rock, Labs
- **Completion:** PJ Nova, PURE P3
- **Injection Profile:** SIMPL, PS Platform

Containment
- **Geomechanics** (Caprock/MEM): Sonic Scanner, XL-Rock, Lab, Quanta Geo, FMI, MDT-PA HP
- **Geology** (i) Natural Fractures (Quanta Geo, FMI HD, 3D FFS (ii) Critical Stress (MEM)
- **Well Integrity Legacy Well Assessment** (USI, UCI, Pipe Integrity Platform, PMIT Caliper Log, Isolation Scanner, SCMT Cement Log)
- **Geophysics**: MS, ISM, BHS
- **Fiber monitoring**: DTS, DVS, Strain/Strain rate
- **Petrophysics** Permeability (CMR Plus, XL-Rock, Labs)
- **Completion** (PJ Nova, PURE3)
- **Injection Profile** (Step Rate Testing with SIMPL and PS Platform

Storage
- **Pore Volume**: PEx/LithoScanner/CMR Plus
- **Pressure:** MDT/PFO Testing
- **Fluids:** CO2 Solubility, Reactivity (Water Sampling, Saturn, IFA)
- **Matrix:** CO2 Reactivity, Adsorption (XL-Rock, Lab, iRock)

Automated monitoring

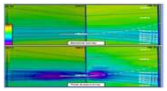
Regulated Safety Inspection

Project Verification

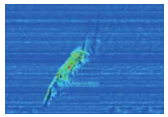
Injection Safety Monitoring

Pre-injection safety check

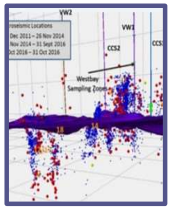
Site Appraisal



Passive Seismic Reservoir Monitoring
- Induced Seismic Monitoring (3C / Fiber) – Pseudo-automated
- 4D Surveys (VSP, Crosswell Seismic)

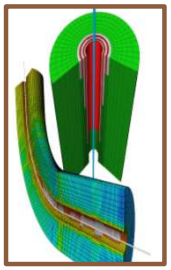


Passive Well Integrity Monitoring
- Distributed Strain – Pseudo-automated
- Distributed Temperature – Pseudo-automated
- Distributed Acoustic – Pseudo-automated



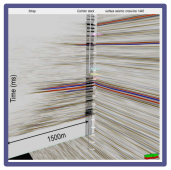
Post-Injection Well Integrity/Corrosion Check
- Wellbore Integrity
- Casing/Cement Integrity
- Temperature Monitoring
- Strain Monitoring

Post-Injection Caprock Integrity Check
- Microseismic Monitoring
- Induced Seismic Monitoring
- 3D Seismic, VSP, Crosswell
- Post-injection DTS/Strain
- Offset well monitoring



Caprock Integrity Monitoring / Plume Migration Monitoring
- Real-time Microseismic/Induced Seismic Monitoring
- Real-time Strain Monitoring
- Pseudo-real time VSP

Well Integrity Monitoring
- Real-time Wellbore Integrity
- Real-time Casing/Cement Integrity
- Real-time Temperature Monitoring
- Rea-time Strain Monitoring



Well Integrity Check
- Wellbore Integrity
- Casing/Cement Integrity

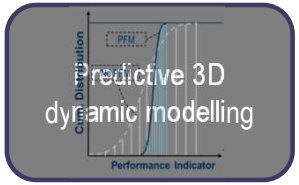
Caprock Integrity Check
- 3D Seismic, VSP, MS, ISM
- Injection testing

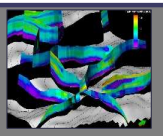
Well Placement Analysis
- Fault/Seal Integrity
- Storage Optimization

Predictive Plume Modeling
- Reservoir Modeling
- Petrochemical Analysis

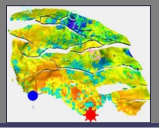
Storage Capacity Evaluation
- Geological Structure Mapping
- Seismic Volume Rendering
- Natural Fracture Characterization

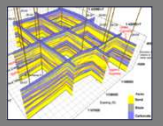
Site Safety Appraisal
- Fault/Seal Integrity
- Injection Sensitivity Testing
- Seismicity Analysis



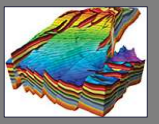


Update 3D model with Injection Data

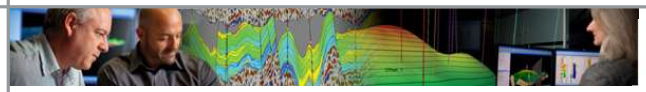




3D Geological Modelling



Roadblock to Successful Production from Unconventional Formations: Is Proppant Too Big?



Successful Production from Unconventional Formations Is About Applying the Right Combination of Technologies