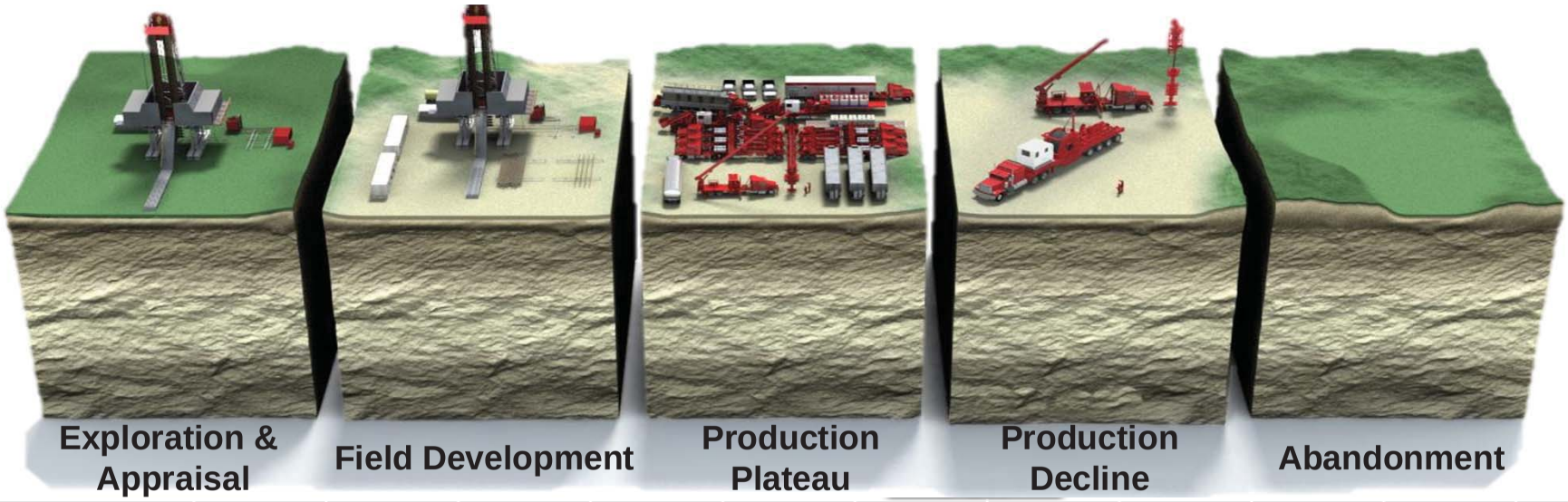

	FM. Evaluation	Reservoir Architecture	Well Placement	Completion	Pressure Management	FDP	Acid / Frac. Stimulation	Bypassed	EOR / IOR	Well Integrity	P&A
Seismic Attributes	■	■	■		■	■					
Geological Attributes	■	■	■		■	■	■				
Fracture Characterization	■		■	■	■	■	■		■		
Petrophysical Attributes	■		■	■	■	■	■	■	■		
Fluids Characterization	■		■	■	■	■	■	■	■		
Reservoir Attributes	■					■	■	■	■		
Reservoir Monitoring					■	■	■	■	■		
Geo-mechanical Analysis			■		■	■	■				
Production Evaluation						■	■	■	■	■	
Cement Integrity						■	■		■	■	■
Completion Integrity						■	■		■	■	■

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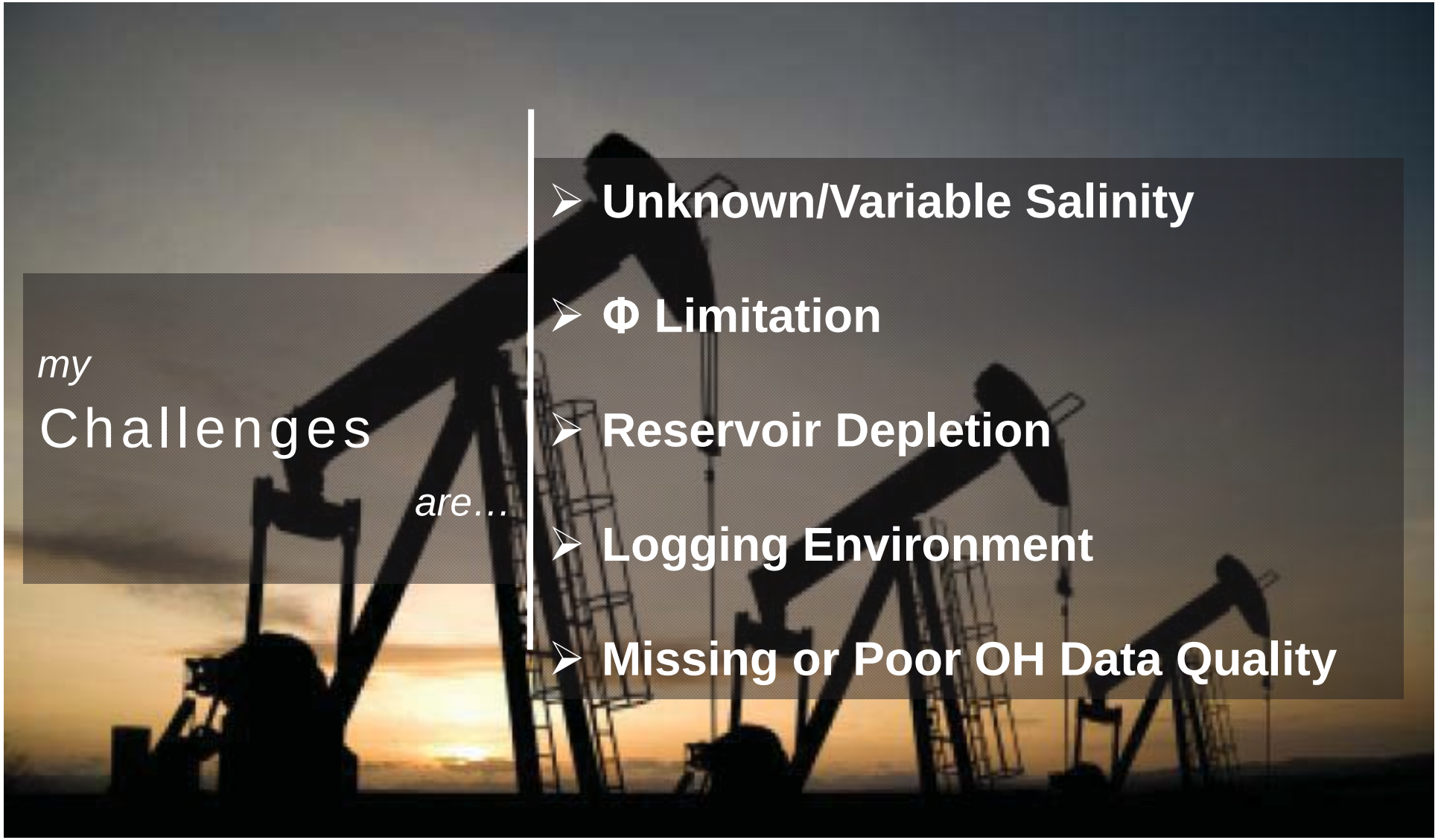
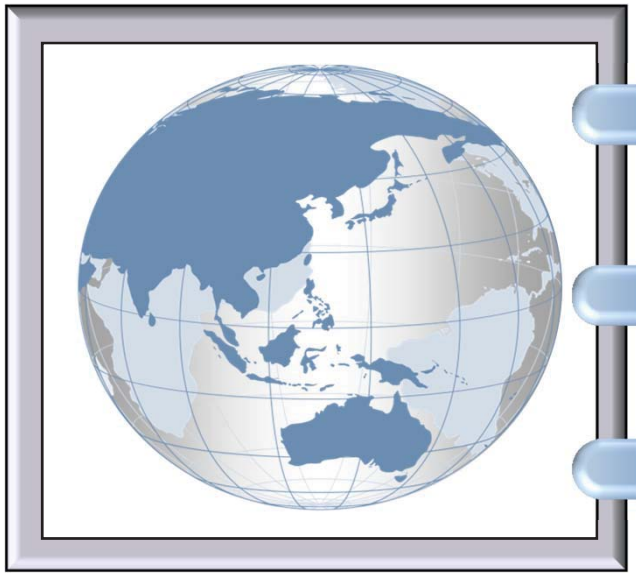


Outlines



Technique We Use

Technology We Use

Local **Examples**

Meeting Cased Hole Formation Evaluation Using Multi-Detector Pulsed Neutron Technology

FESM Meeting

June 16th, 2015

By: Ehab Najm

FRS Region Manager - AP

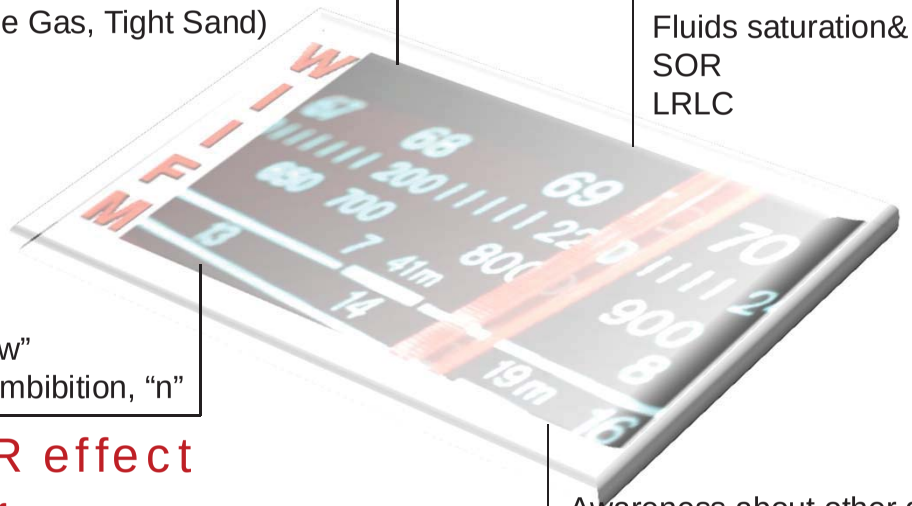
Solving challenges.™

Processing old wells

Missing or poor quality data
Clay typing
UC Gas(Shale Gas, Tight Sand)

Finding new/remaining pay zone

Fluids saturation& contact
SOR
LRLC



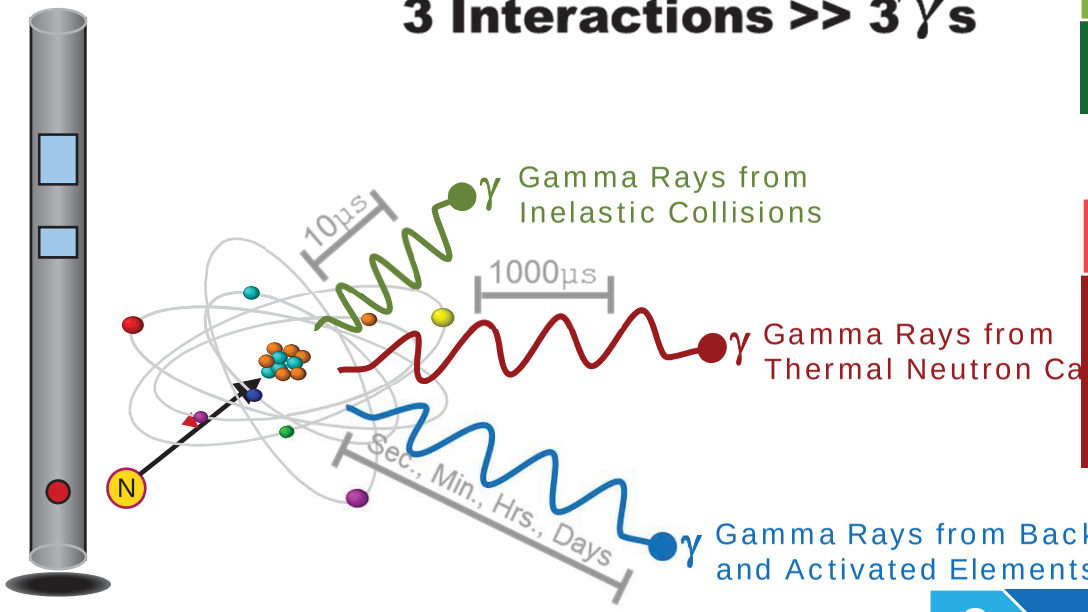
Formation water salinity “Rw”
Saturation exponent du to imbibition, “n”

Nearby EOR/IOR effect on my reservoir

Awareness about other disciplines
Planning future logging program

Asset Team

Pulsed-Neutron Technology



1 Inelastic

Fast and High Energy interaction, Si, Ca, C and O Spectrum are measured. Windows algorithm for C/O and Ca/Si ratios

2 Capture

Very slow and Low Energy Interaction, H, Si, Ca, Cl and Fe Spectrum are measured. Count rate measured; decay rate give Sigma and ratios of counts porosity

3 Elements Activation

Silicon and Oxygen Activation

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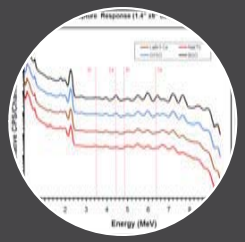
Pulsed Neutron Applications



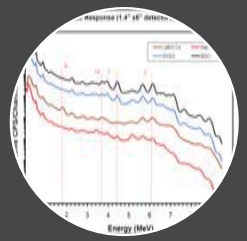
Capture Application

∑ logging
-Reservoir monitoring in **saline formation water**
-Water saturation, Sw

Capture Porosity
Neutron Phi

Spectroscopy Logging
Lithology identification

Reservoir & BH Fluids contacts

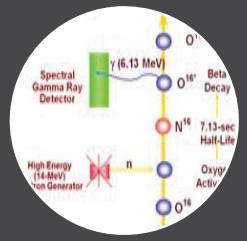


Inelastic Application

C/O Logging
-Reservoir monitoring in **fresh, mixed or unknown water salinity**
-Oil saturation, So

Inelastic porosity
-Density type Phi

Spectroscopy Logging
-Lithology identification

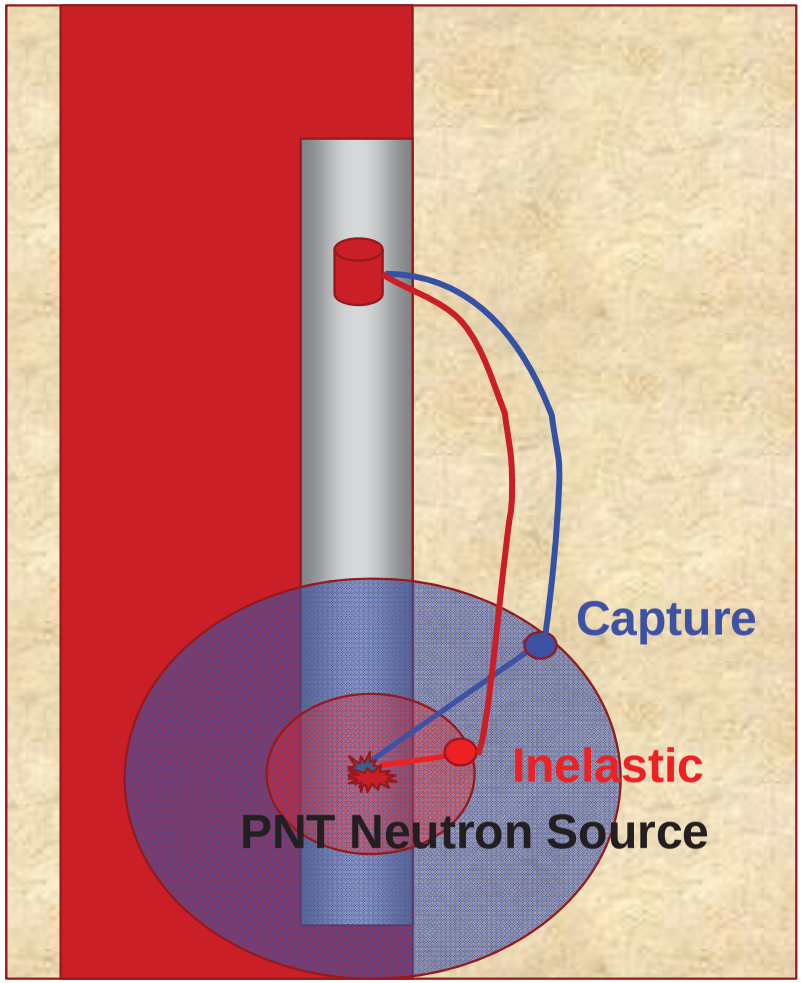


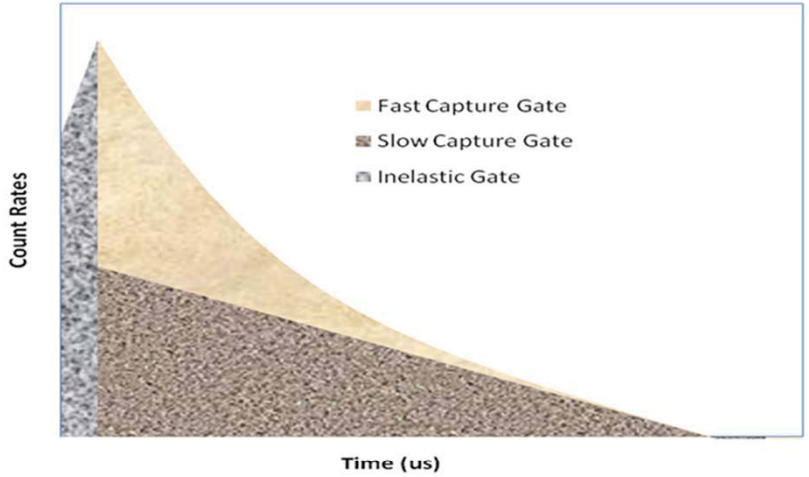
Activation Application

Oxygen Activation Logging
-Water Flow Logs

Silicon Activation Logging
-Gravel Pack evaluation
-Lithology identification of Clastics vs. Carbonates

TMD-3D Tool Physics

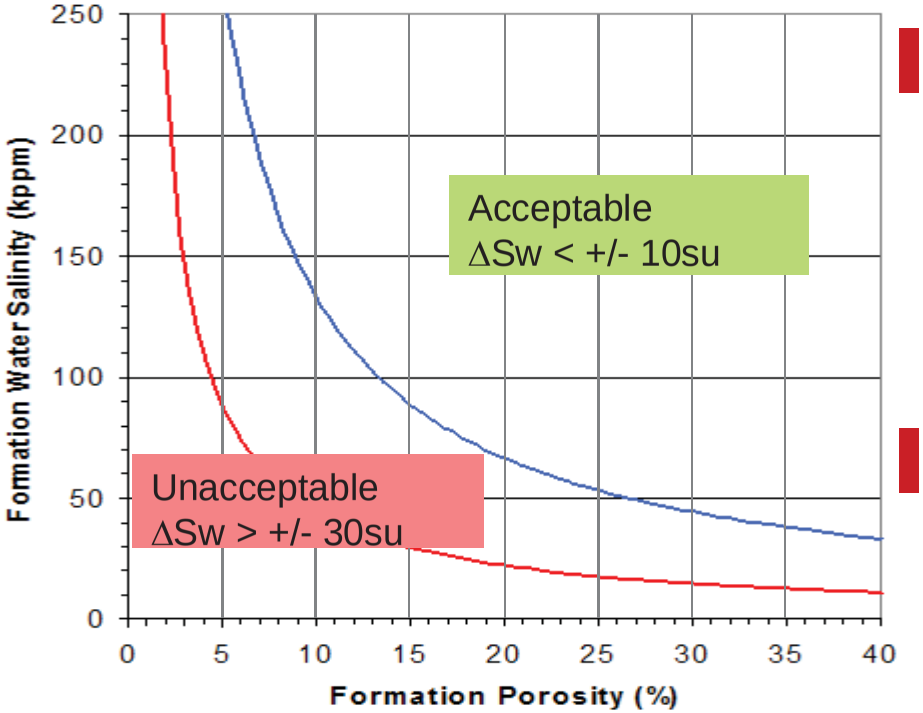




	Ninel/N(Total Cap)	Ninel/NSlow Cap)
33 pu FW Sand	1.72	1.11
33 pu SW Sand	3.11	1.12

$$SATG = \frac{\text{inelastic gate Counts}}{\text{Slow capture gate counts}}$$

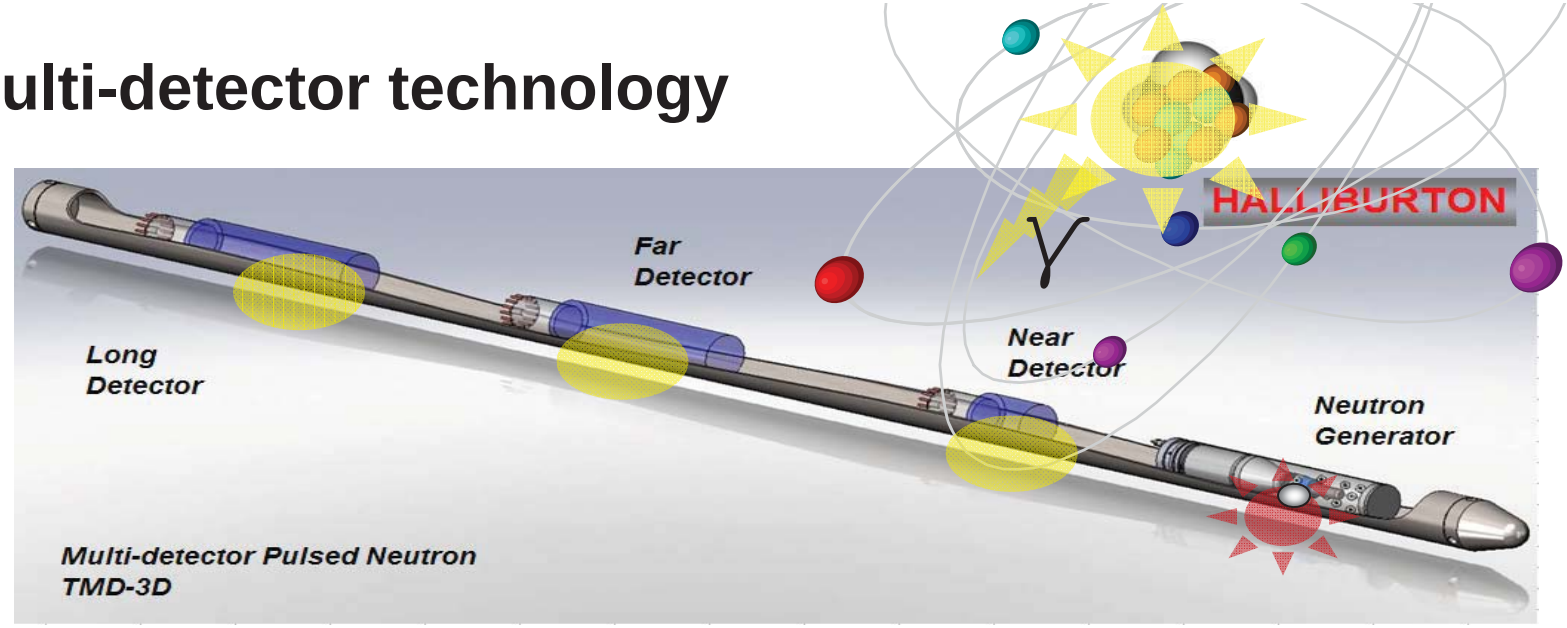
Sigma Limitations for Low Porosity & Salinity Environments

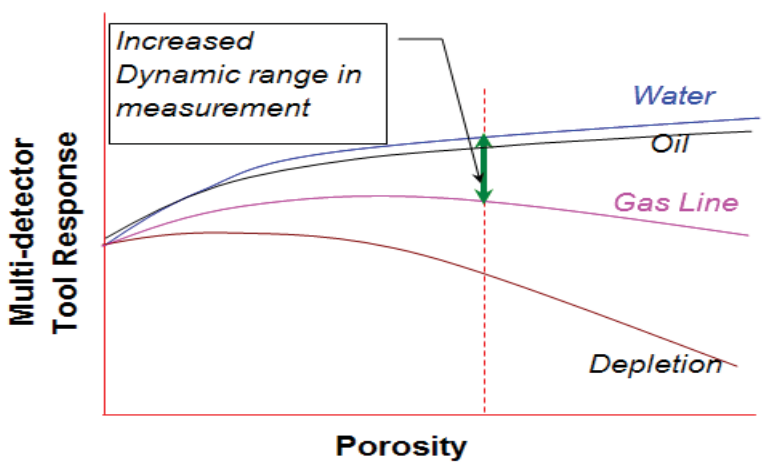


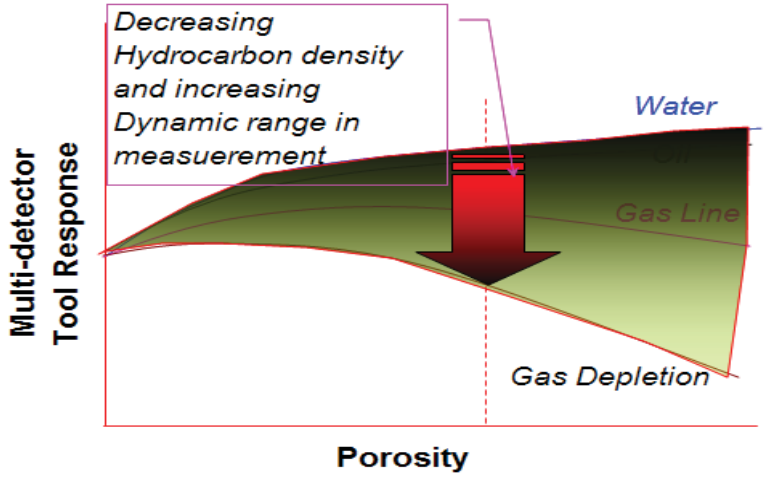
- Method 1 Standard Go-No-Go chart for Saturation evaluation in Oil reservoirs
- Method 2 Rule of Thumb for Saturation evaluation in Gas reservoirs

$$\phi_{effective}\ (deci) \times \left(\sum_{water} - \sum_{HC}\right) > 3_{\substack{Acceptable \\ Saturation}\ -Eval}$$

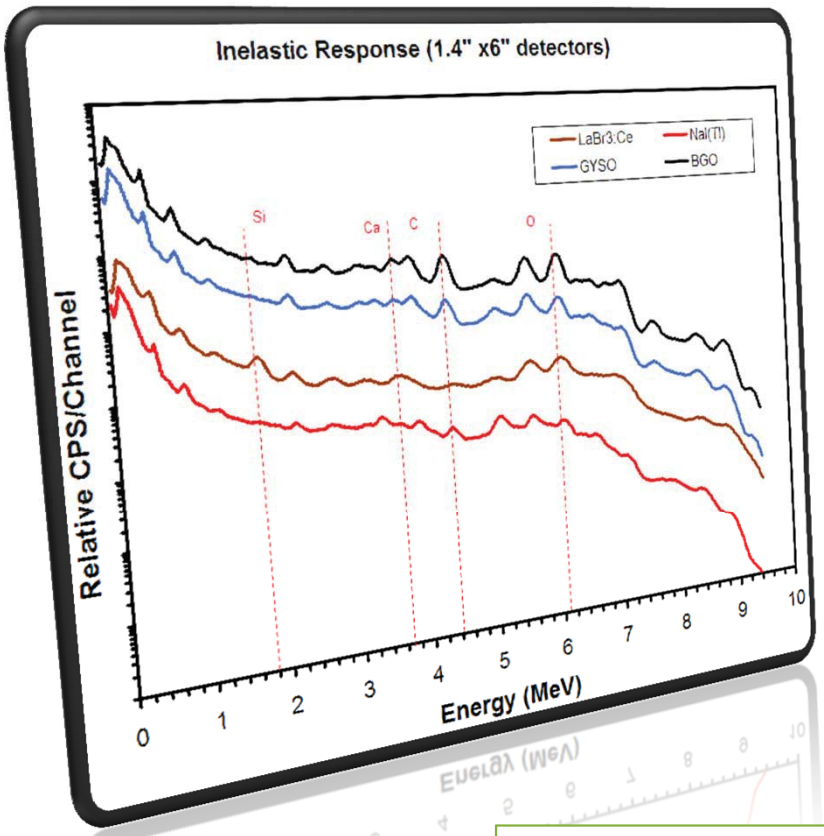
Multi-detector technology

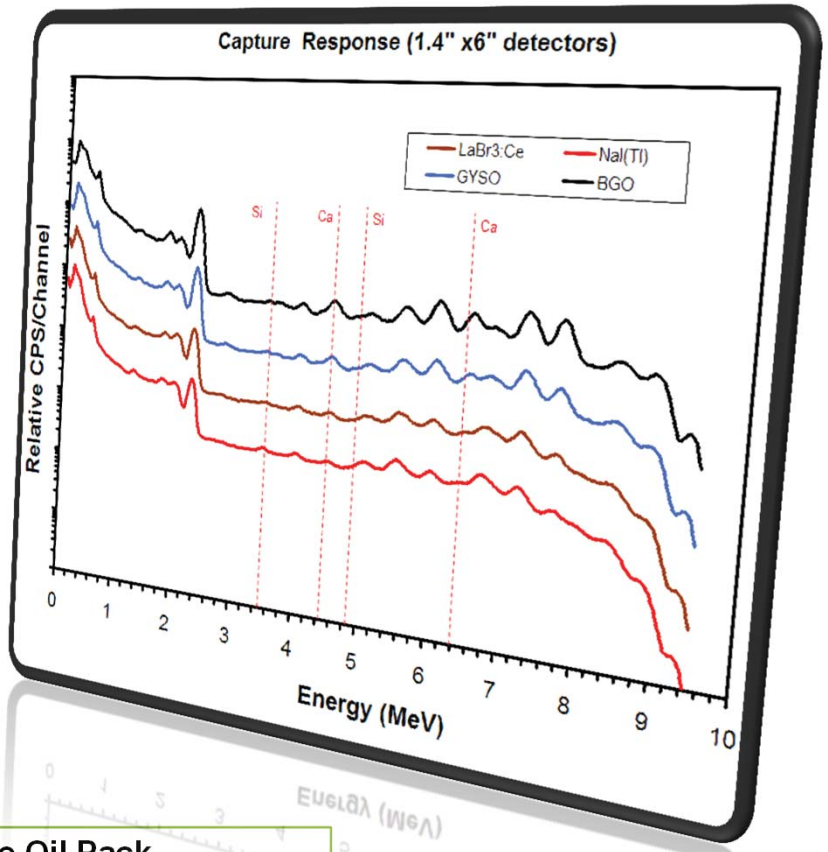






Detector Comparison (Spectral Quality)





43.5 p.u. TRAC Lab Marble Oil Pack
8-in. Freshwater-filled borehole
All detectors simulated at 10% 662 KeV resolution
RMT MCNP Model

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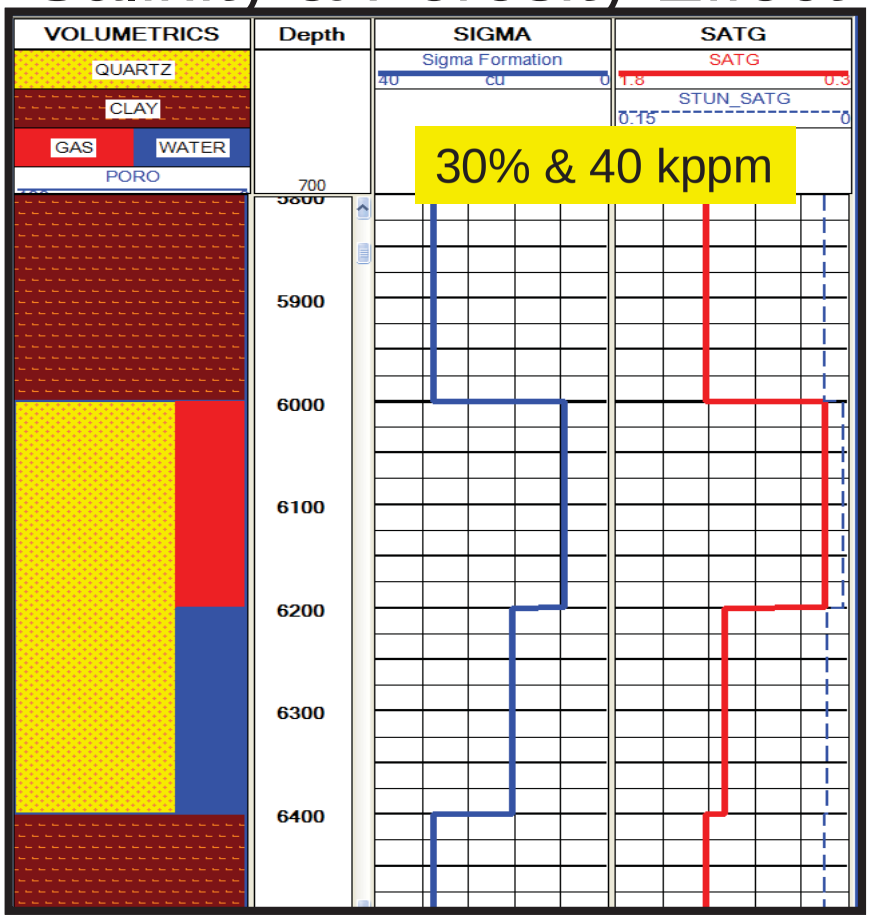
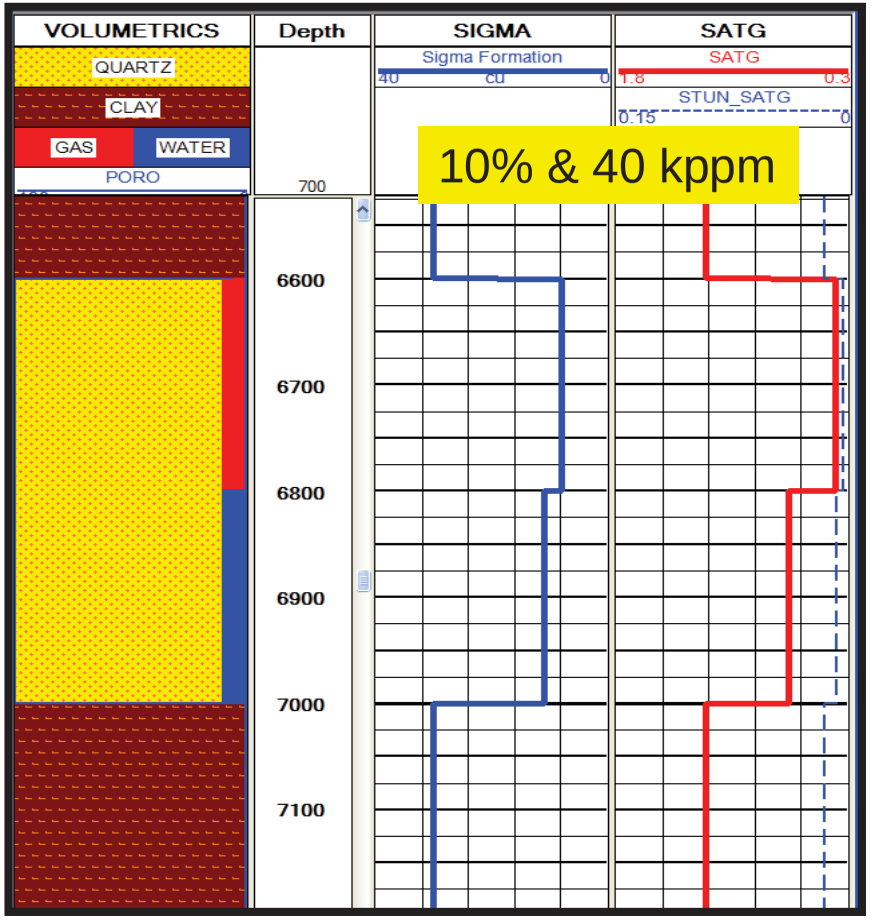
Salinity & Porosity Effect





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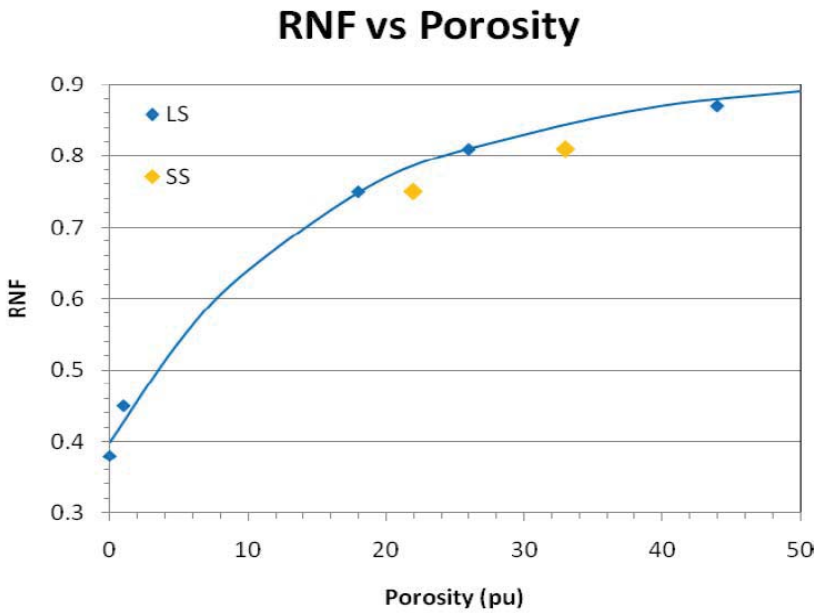
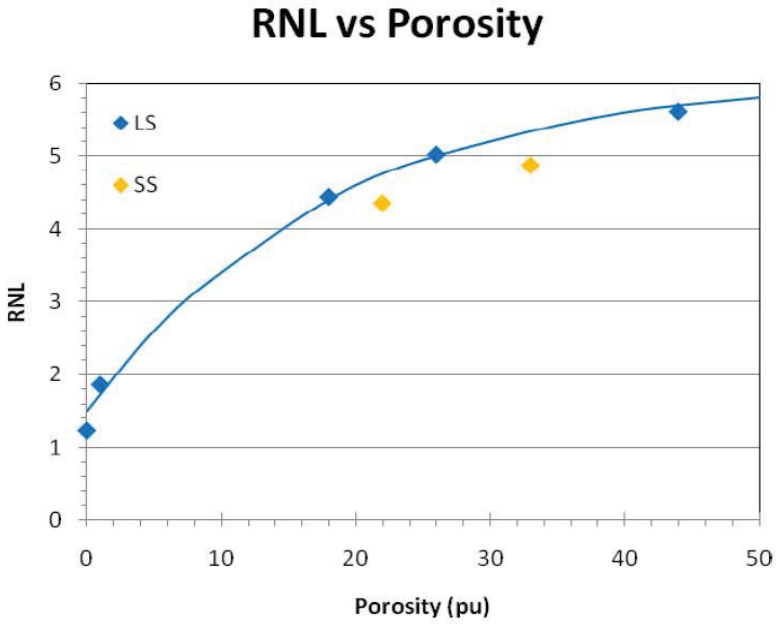
Cased hole Porosity

SPWLA 51st Annual Logging Symposium, June 19-23, 2010 , Wen Jun etc



The dynamic range of the near-to-far ratio from 0 to 40 pu is 2.2



The dynamic range of the near-to-long ratio from 0 to 40 pu is 3.7

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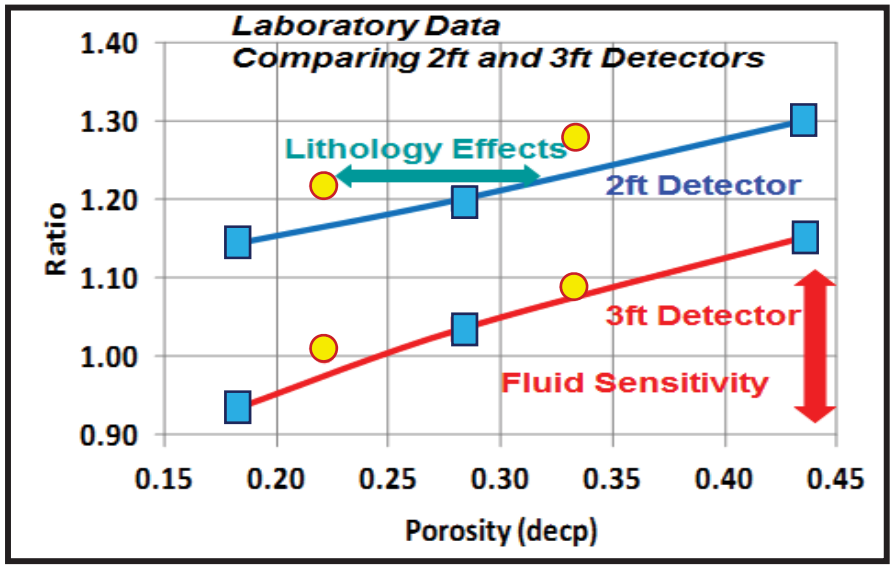
TMD3D SATG Measurement Response



- Single detector Inelastic and Slow Capture measurements SATG
- Increased fluid Sensitivity (40% of 2ft)
- Reduced Lithology Effect
- Reduced salinity effect
- Improved DOI

(ref: SPWLA 2010_JJ and 2012_RRR)

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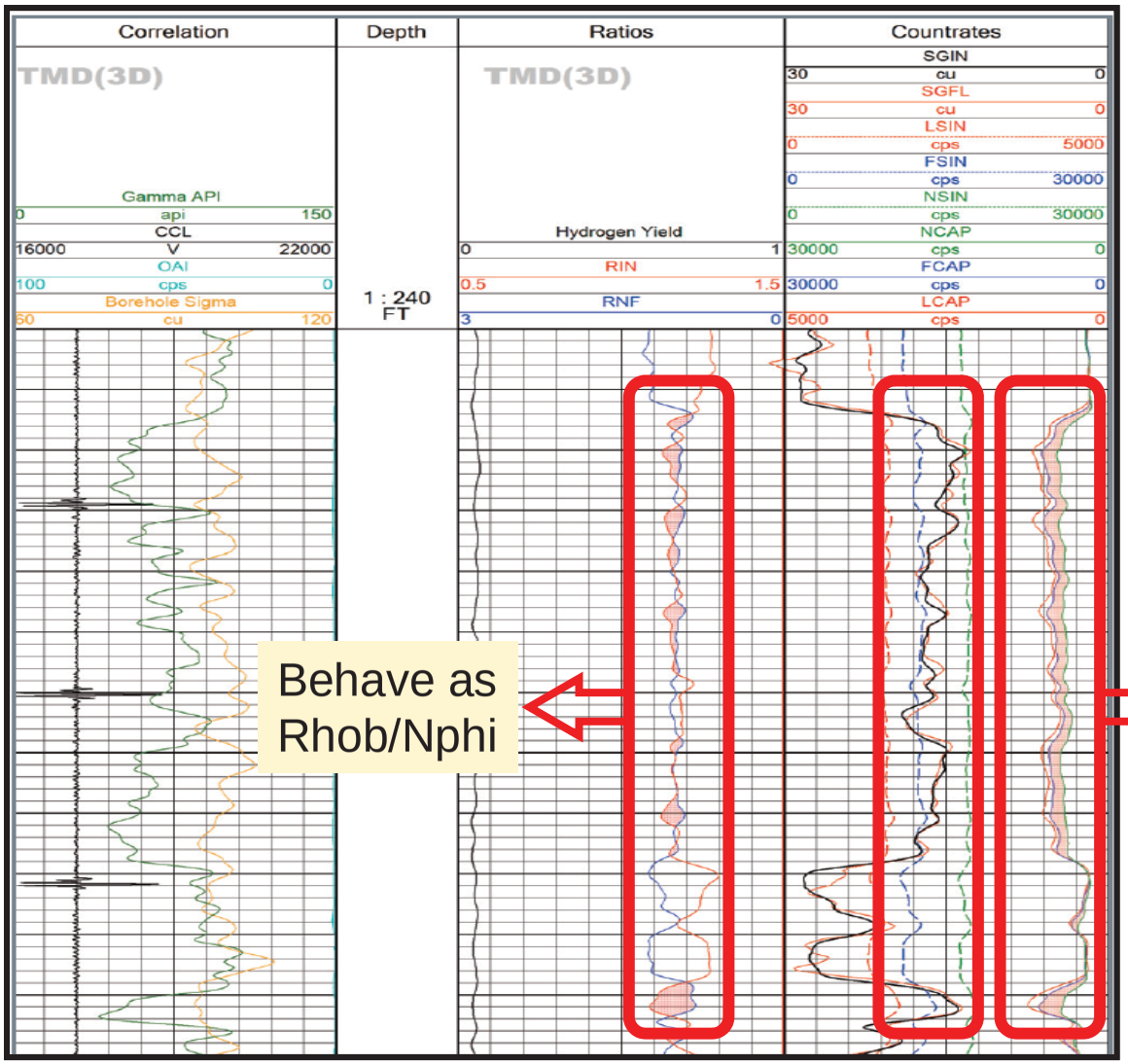
Raw Data Example



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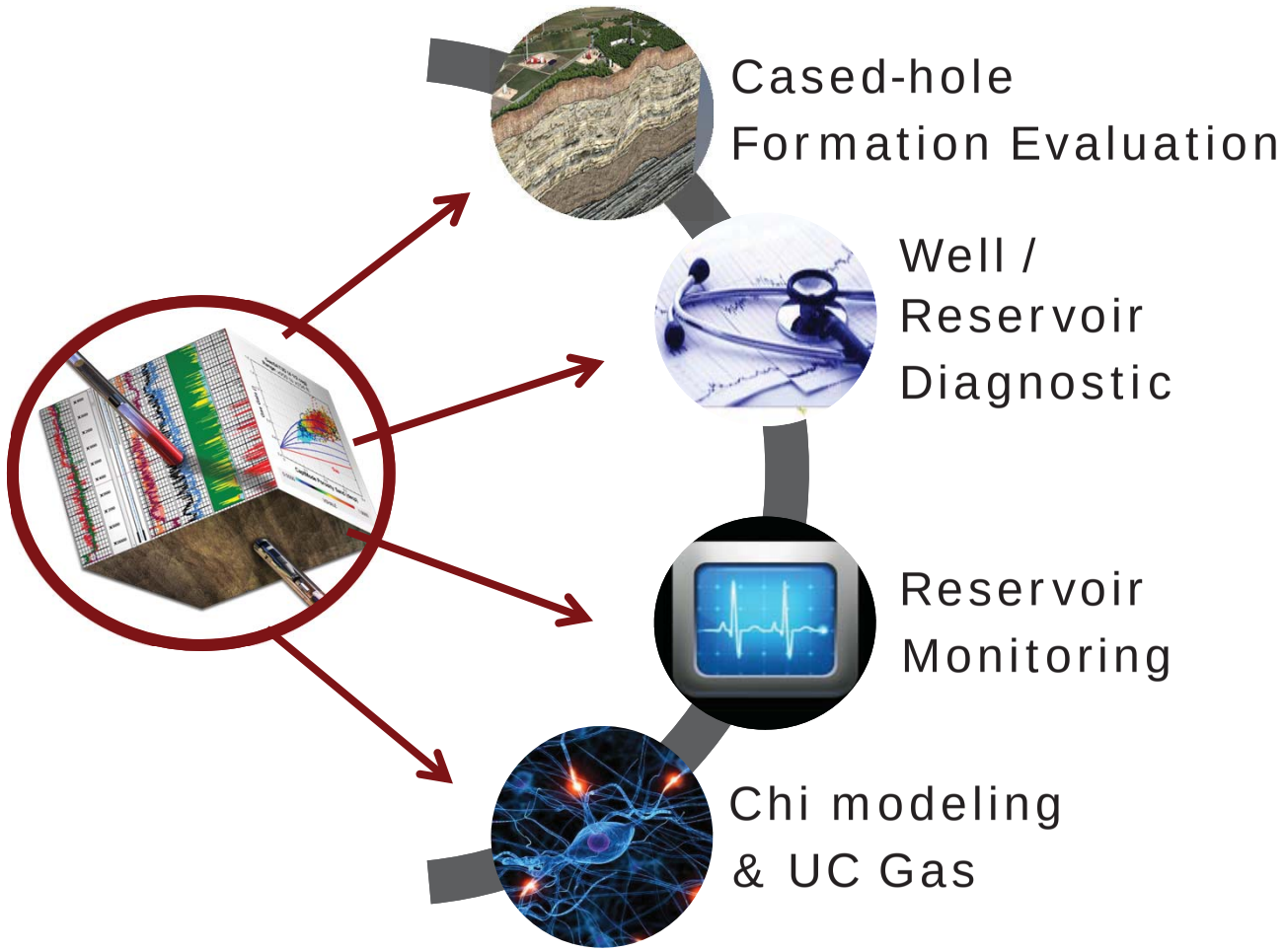
Pulsed Neutron -3D Applications



1 Minerals
Porosity
Fluids

2 Coning
Leak
Gravel Pack

3 Wtr/Gas Inj
Steam-CO2
Frac. Extent

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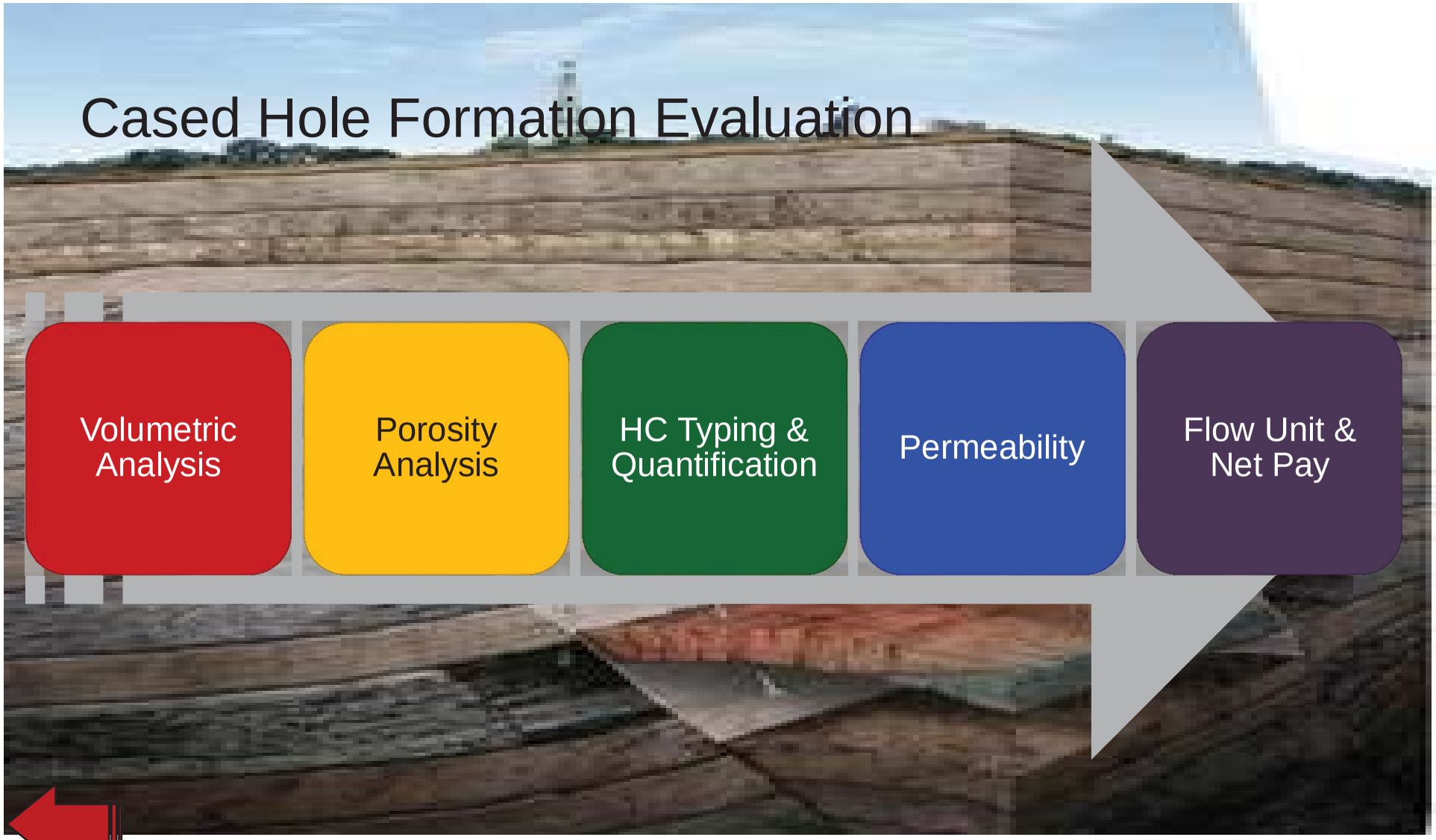
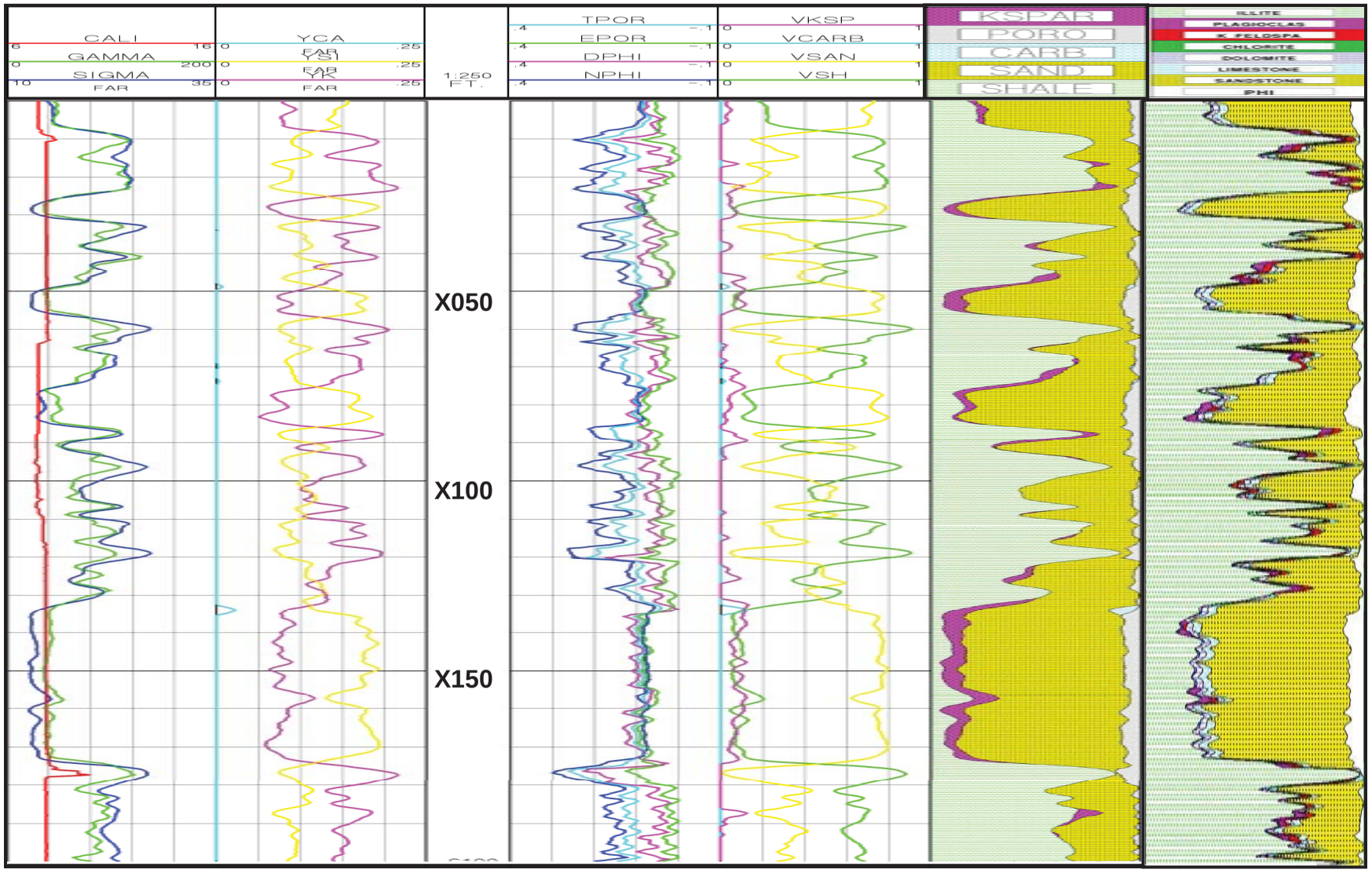
Cased Hole Formation Evaluation





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Pulsed Neutron – Spectral Gamma (KUTh)

1 Acquisition

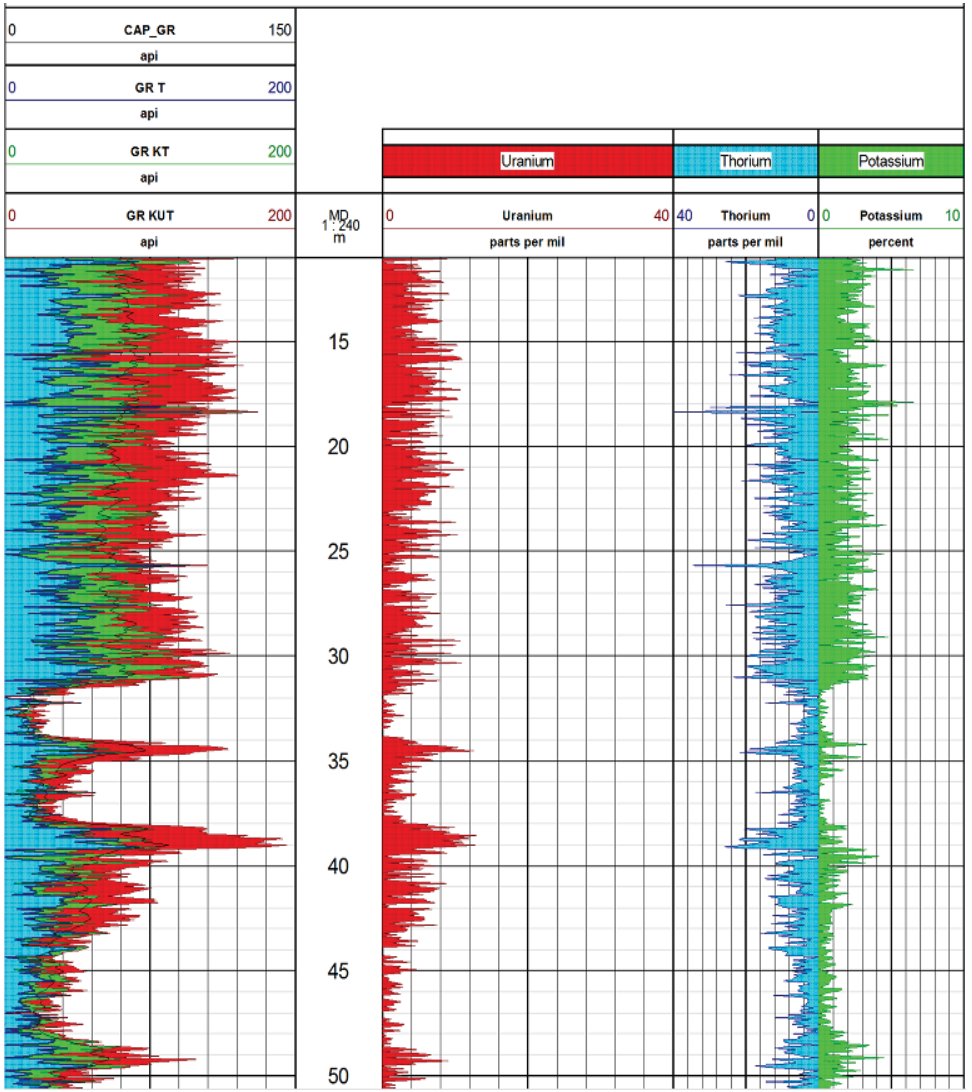
- One single pass with the Generator off

2 Deliverables

- K, Th, U and GRs
- Far and Long Detector
- 2x data quality

3 Applications

- Correlation
- Mineralogical analysis
- Clay typing
- Shale Gas id
- Sedimentological analysis
- Water Production/Entry
- Scaling within Reservoir



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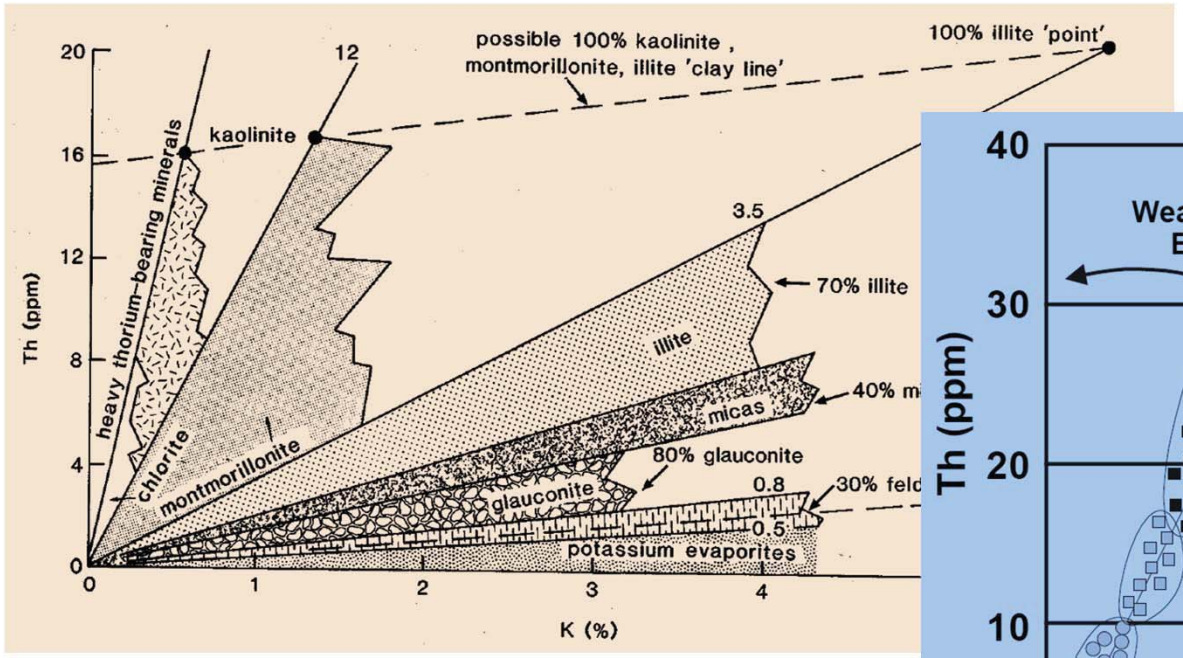
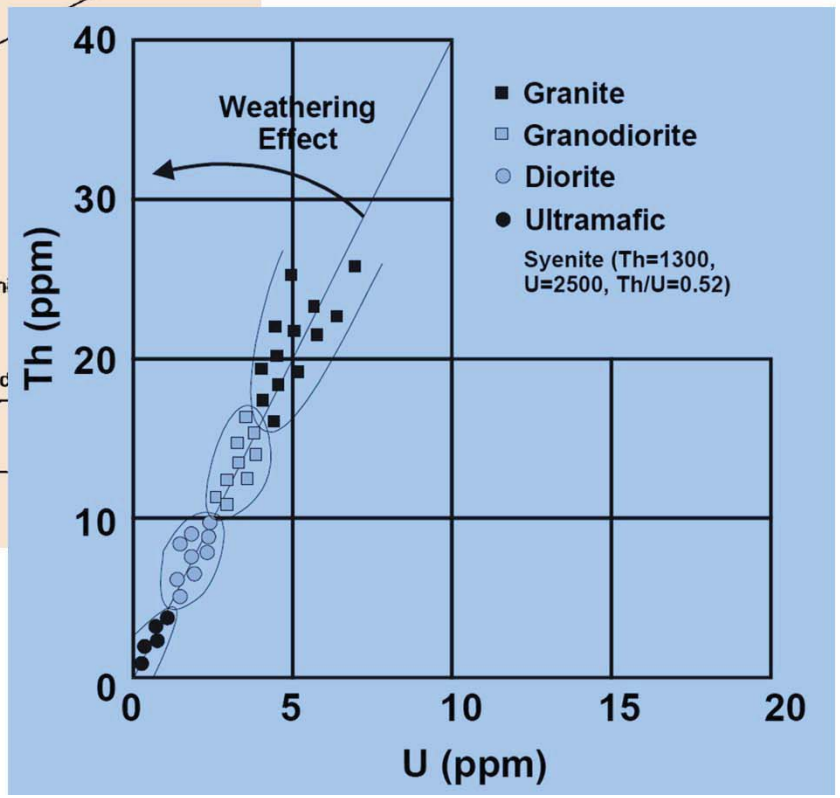
Mineralogical ID





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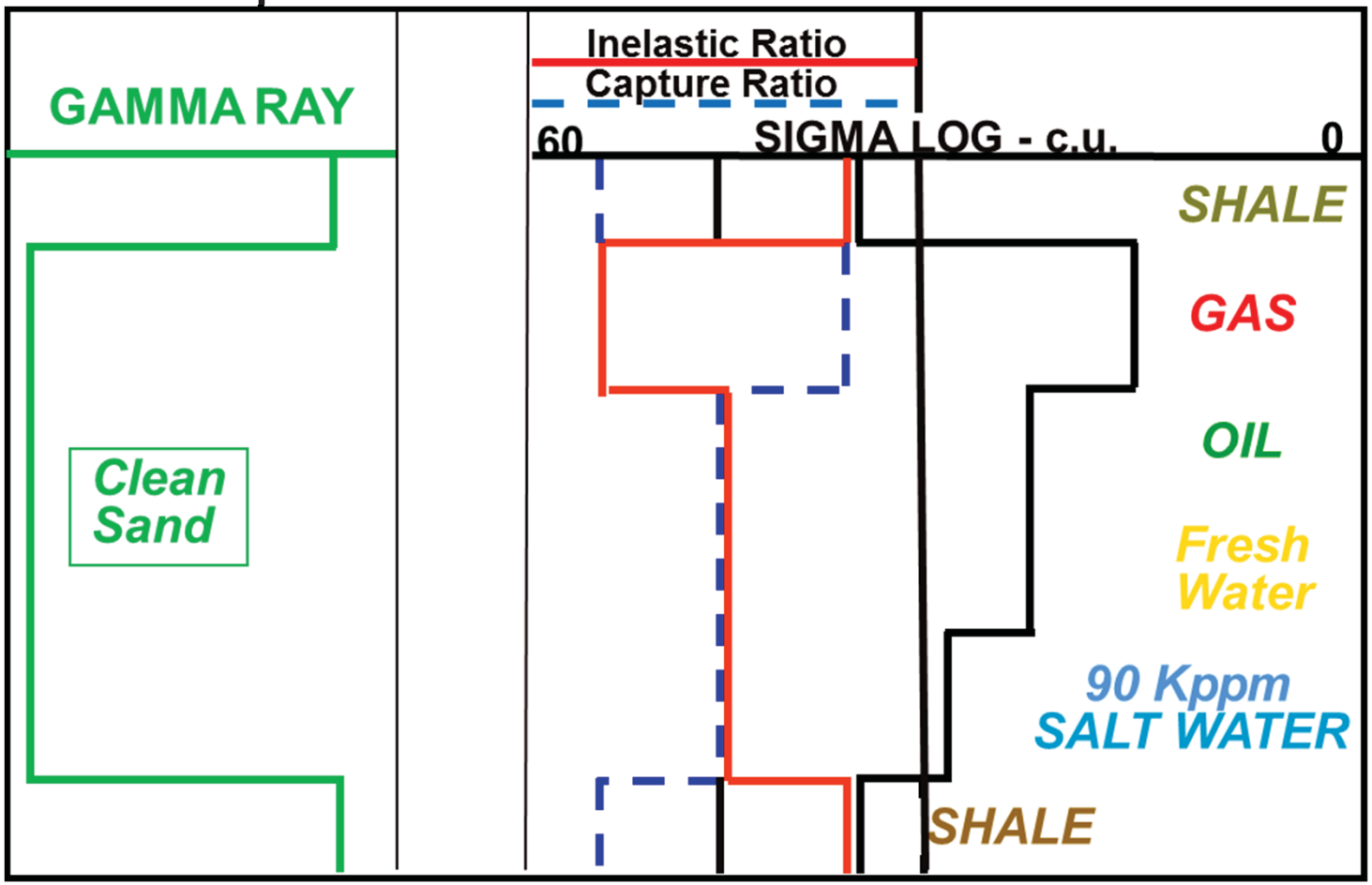
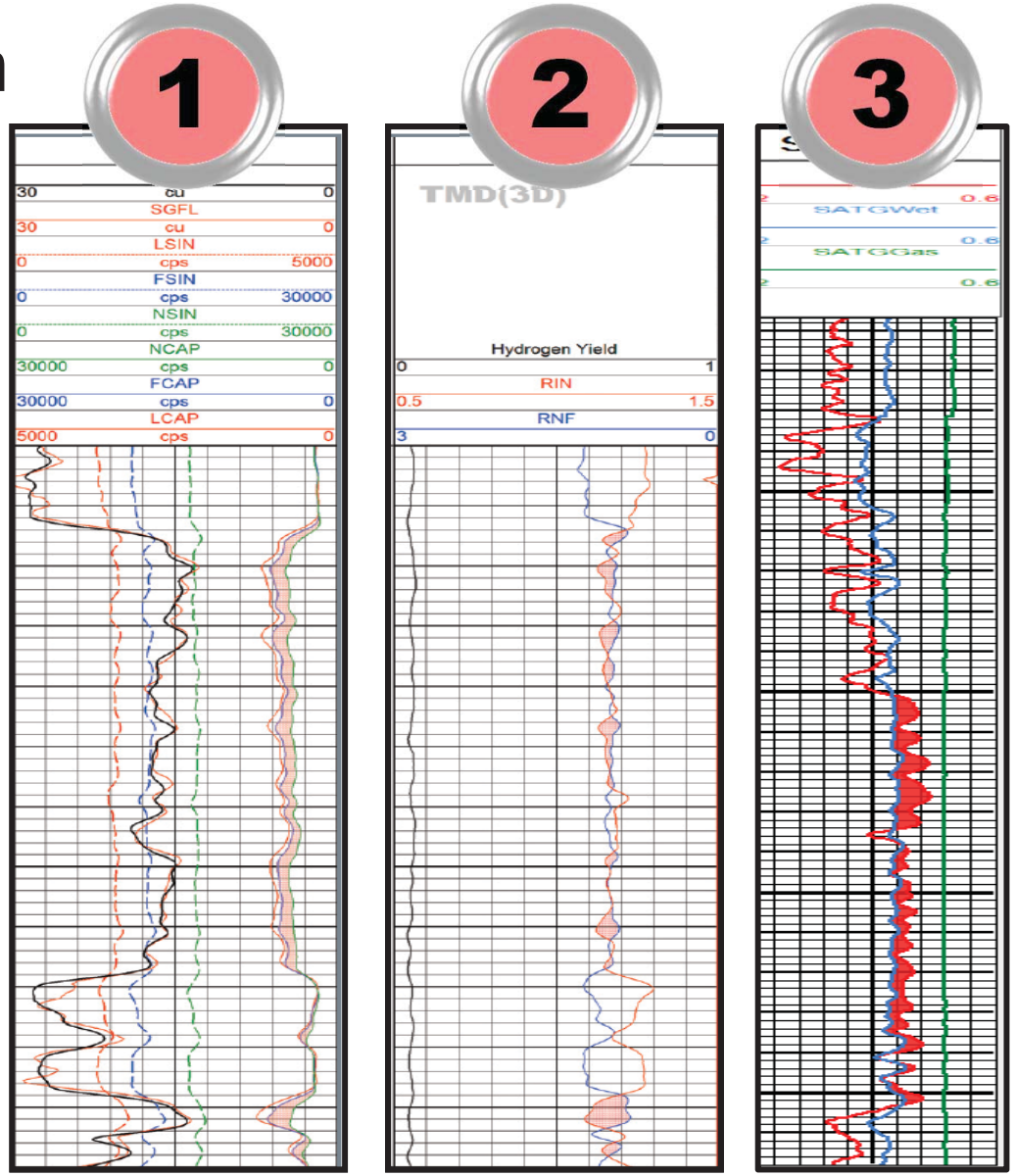
Typical Response Curves



Hydrocarbon Typing

1. N/F Count Rate
2. RIN & RNF
3. SATG



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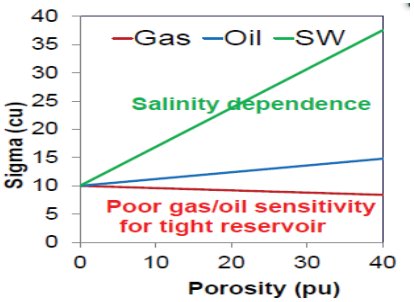
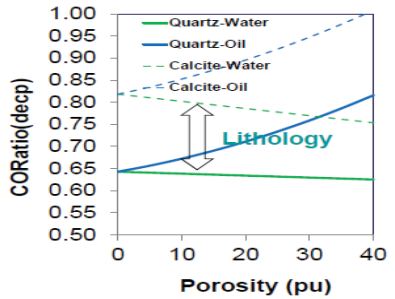
Fluids Saturation Models



Sigma Decay Saturation

1

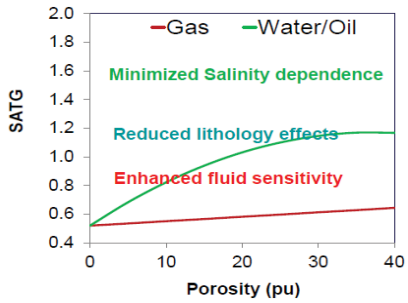
- High salinity dependency
- Low matrix dependency
  - Oil vs water saturation
  - Gas vs water saturation



Carbon-Oxygen Saturation

2

- Low salinity dependency
- High matrix dependency
- Oil vs water saturation



SATG Gas Saturation

3

- Low salinity dependency
- Low matrix dependency
- Gas vs fluid saturation

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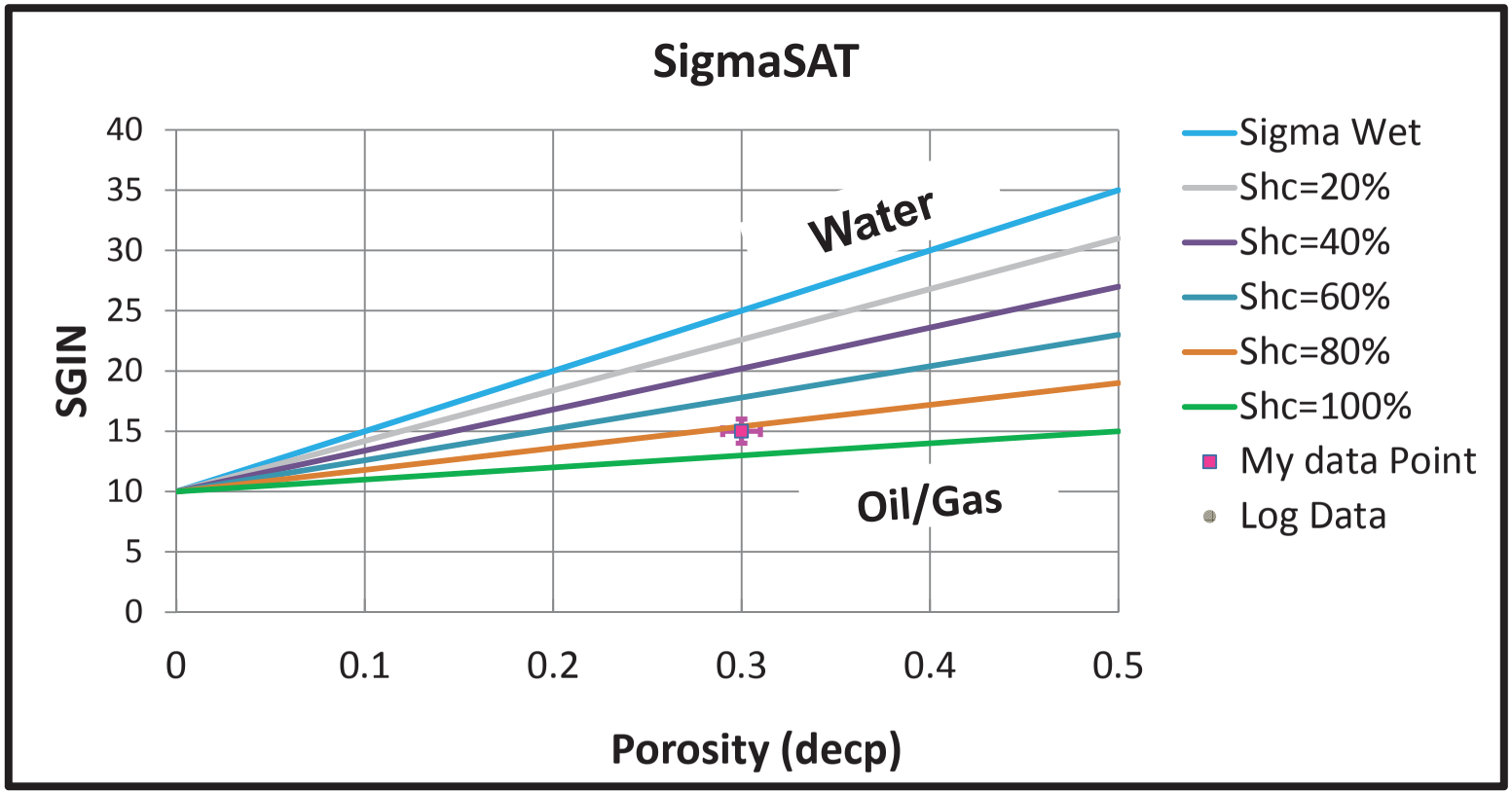
Sigma Decay Saturation



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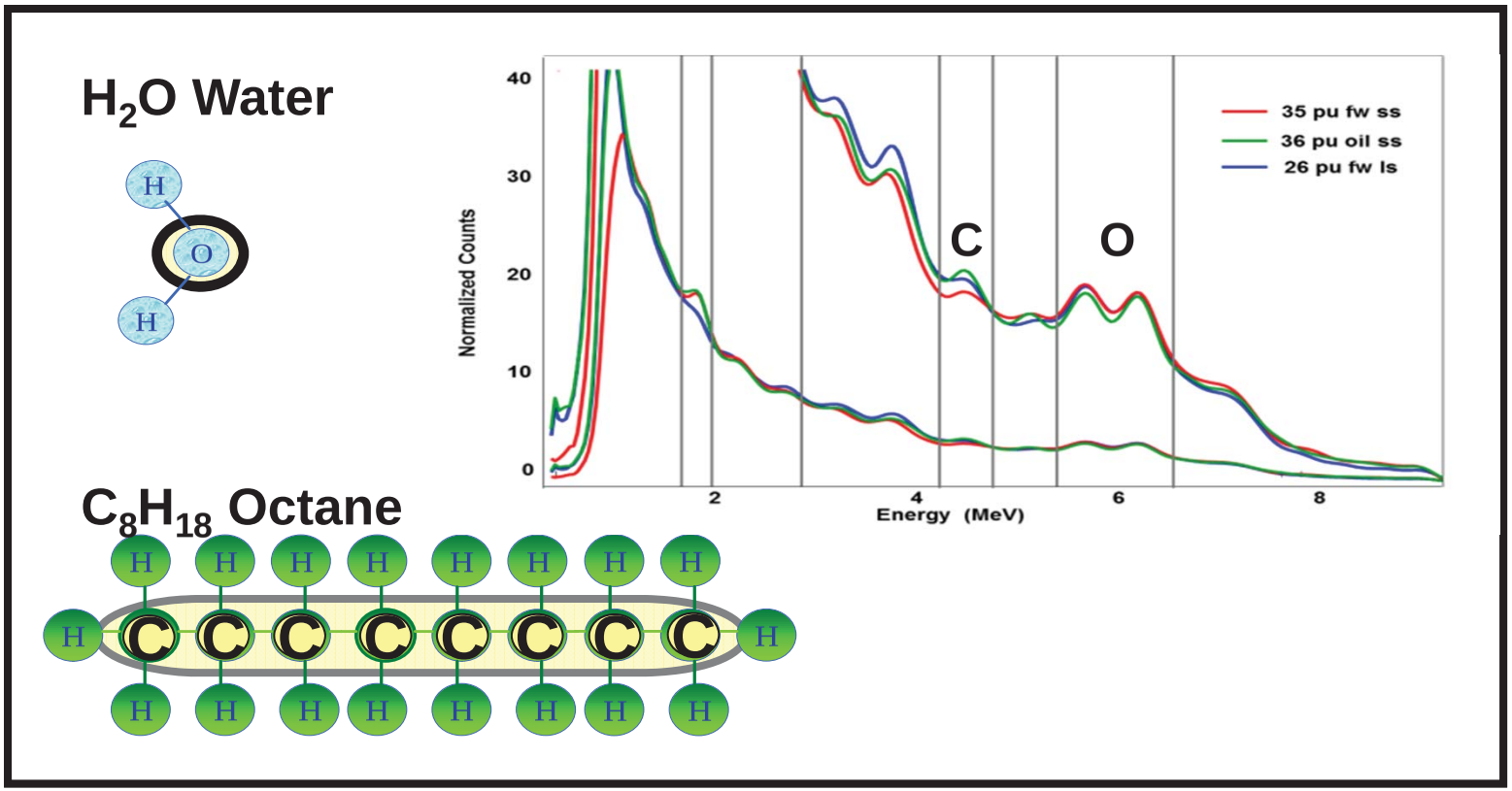
Carbon-Oxygen Saturation



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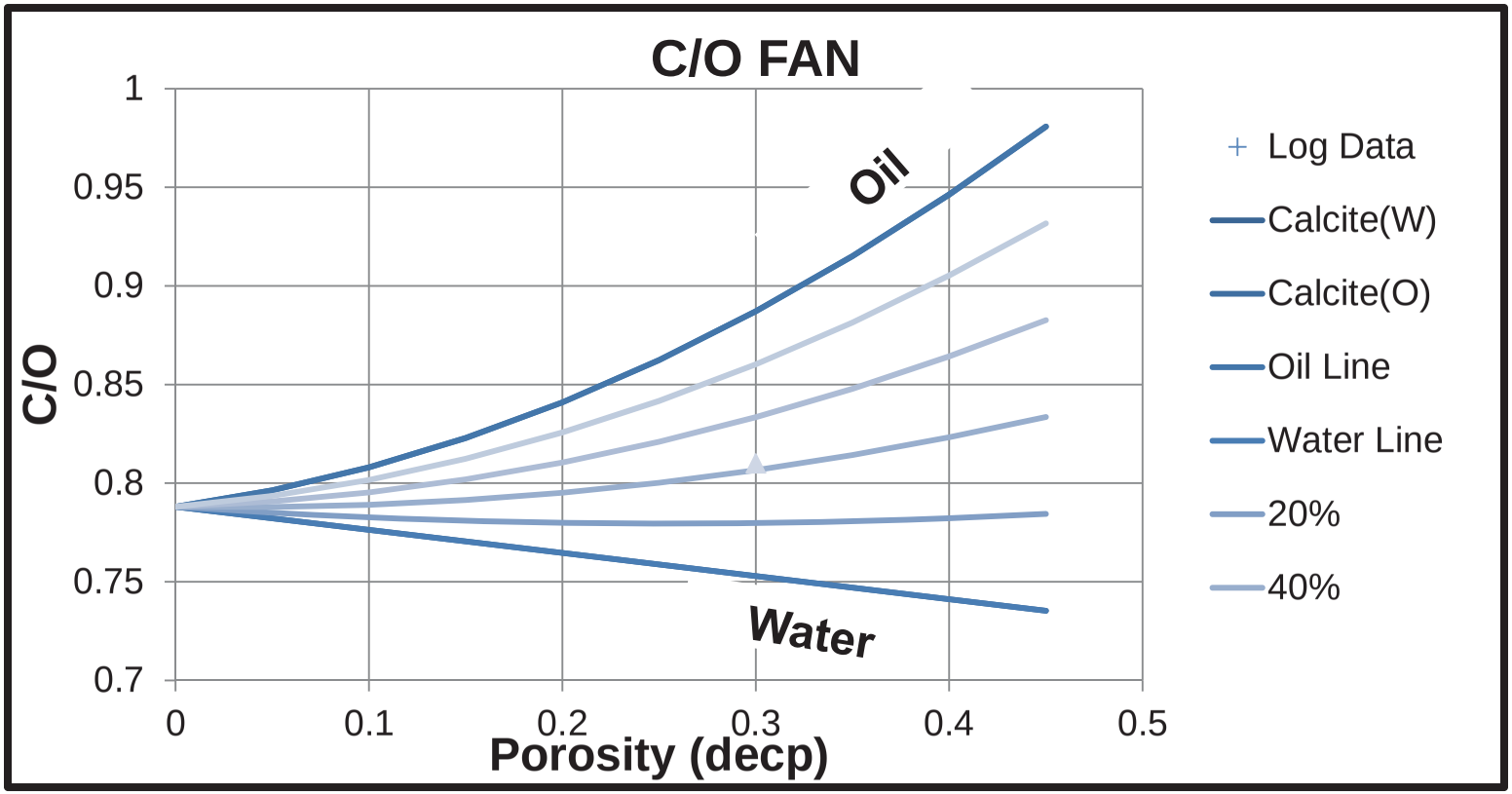
Carbon-Oxygen Saturation



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TripleSat (3 Phase) Evaluation

Correct, Merge, Depth Shiftes, Averaged (Stacked), and Recomputed C/O & Sigma

Basic 2 Phase HC/Water Fresh Water (or Unknown Water Salinity)
CarboxSat (C/O)

Basic 2 Phase HC/Water Saline Water
SigmaSat (Sigma)

TripleSat 3Phase Evaluation
> Expand C/O to 3 Phase Response Equation
> Exapnd Sigma to 3 Phase Response Equation
> Solve Simulataneously (Iterative Technique)
> Materail Balance ∑V=1

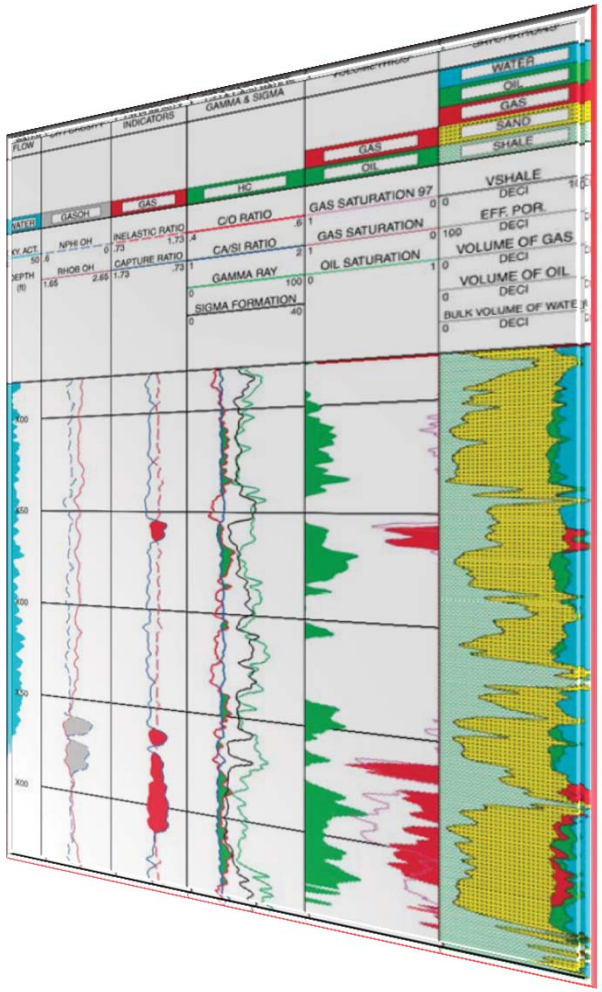
KernSat 3Phase
Dead Oil, Fresh Water and Steam
Assumptions
∑oil=∑water=22CU

WestTexSat 3Phase
Oil, Water and CO2

PaupauSat 3Phase
Light oil, saltwater, gas (induced or flood or original)

MarsSat 3Phase (ShalySand)
Oil, and 2 Different Salinity Waters (Connate and Flood (injected sea water))

RumailaSat 3Phase (Carbonate-Silicate)
Oil, and 2 Different Salinity Waters (Connate and Flood (injected))



~Flooded Environments

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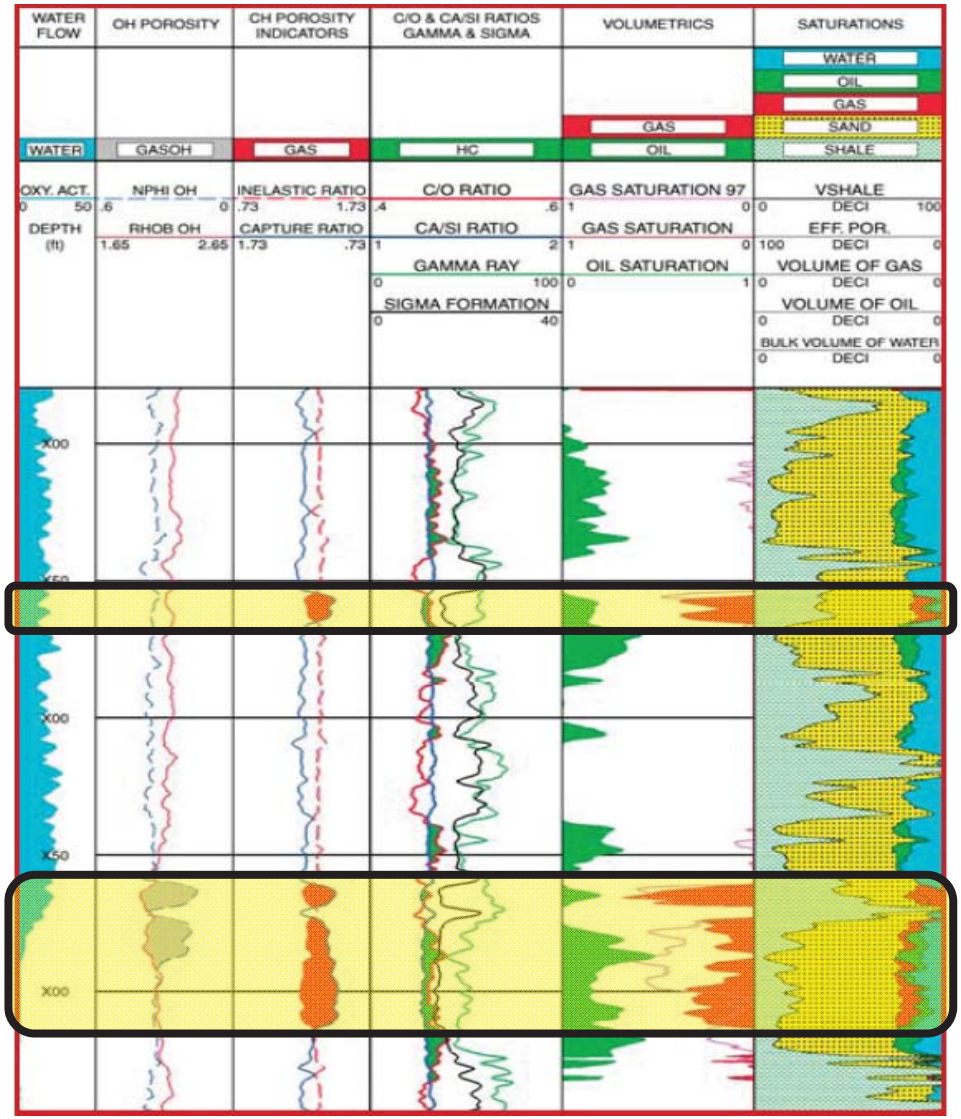
TripleSat Example

3 Phases
Gas – Oil – Water

Gas

Water entry
Gas



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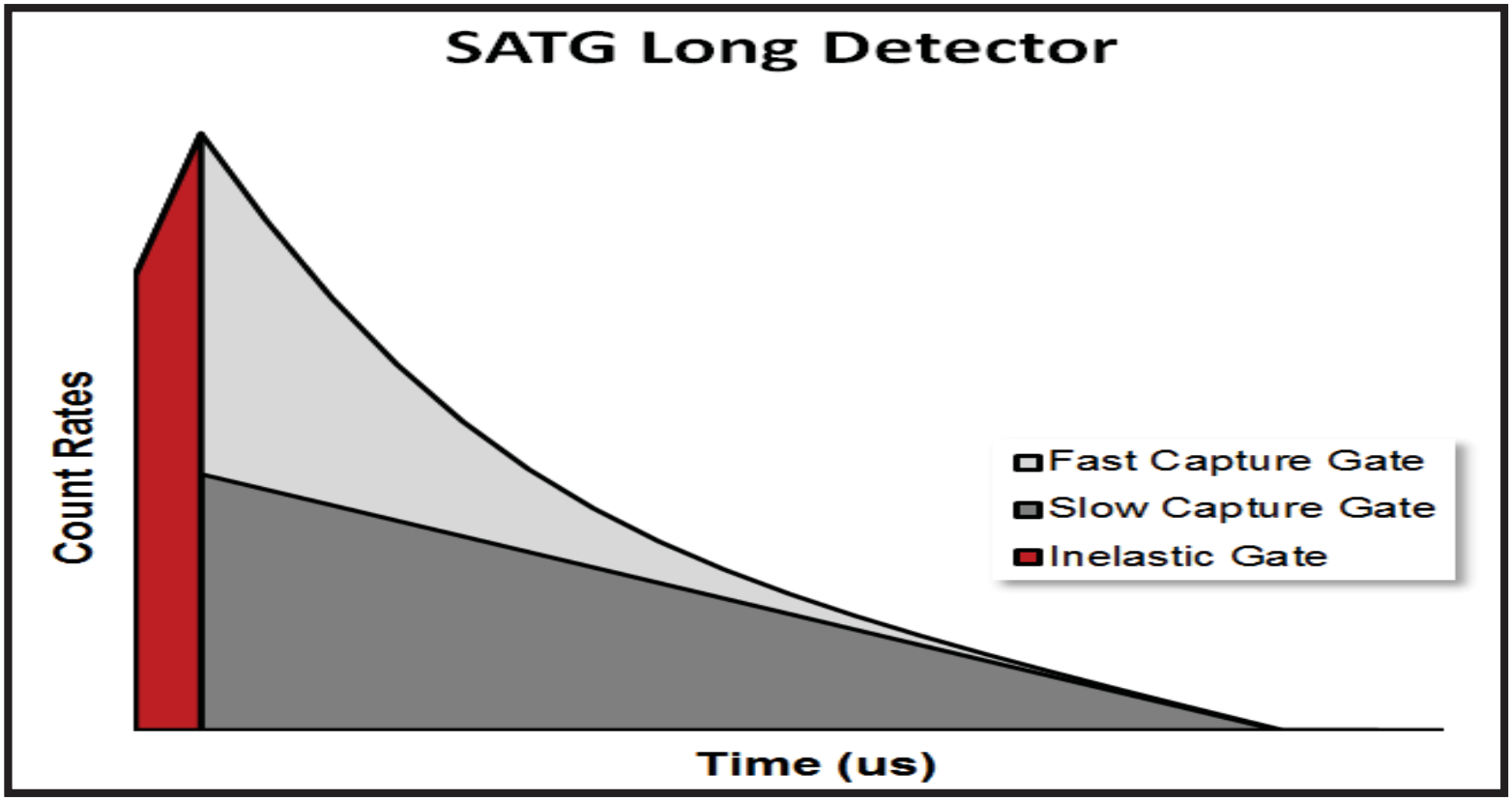
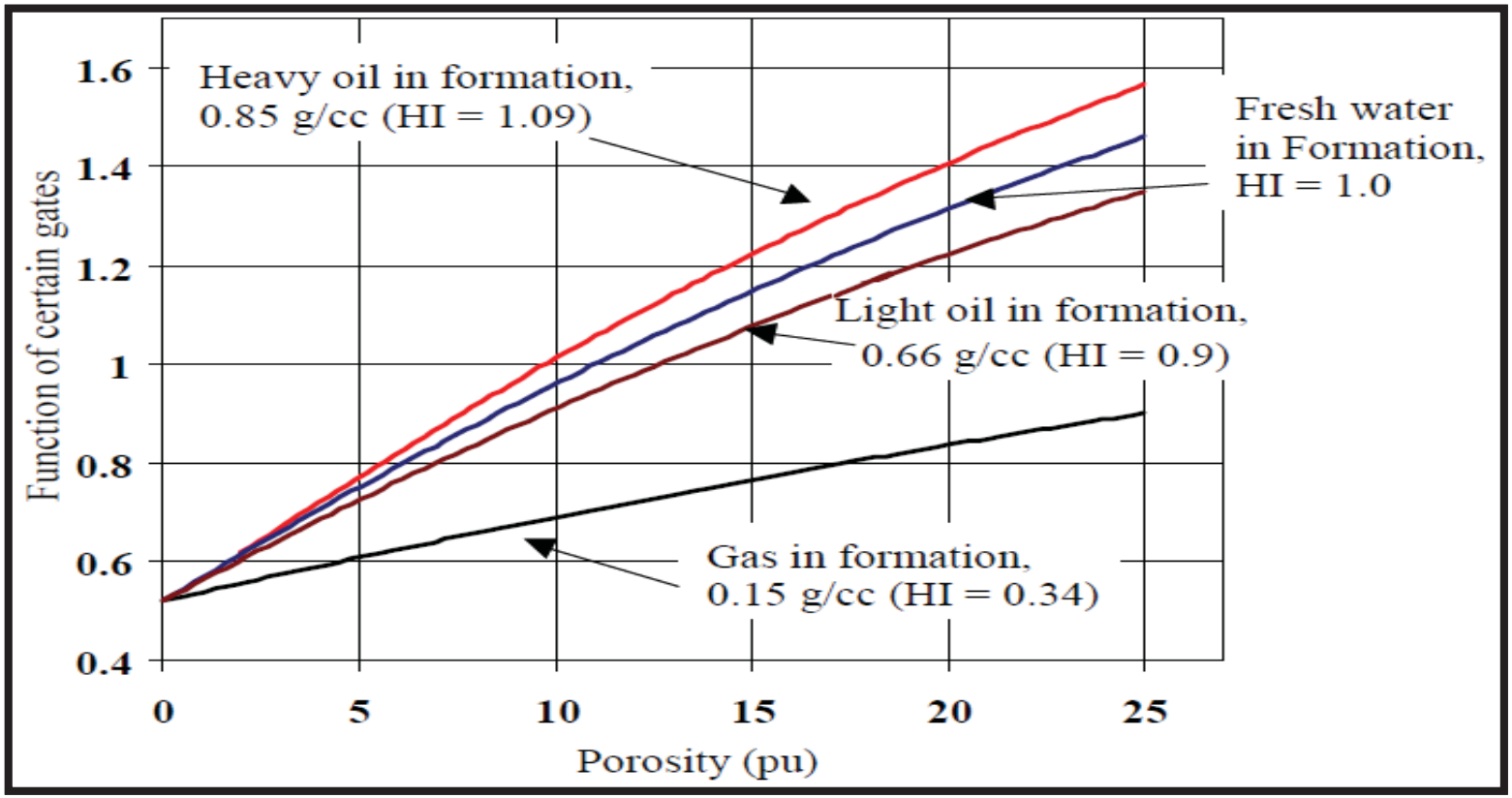
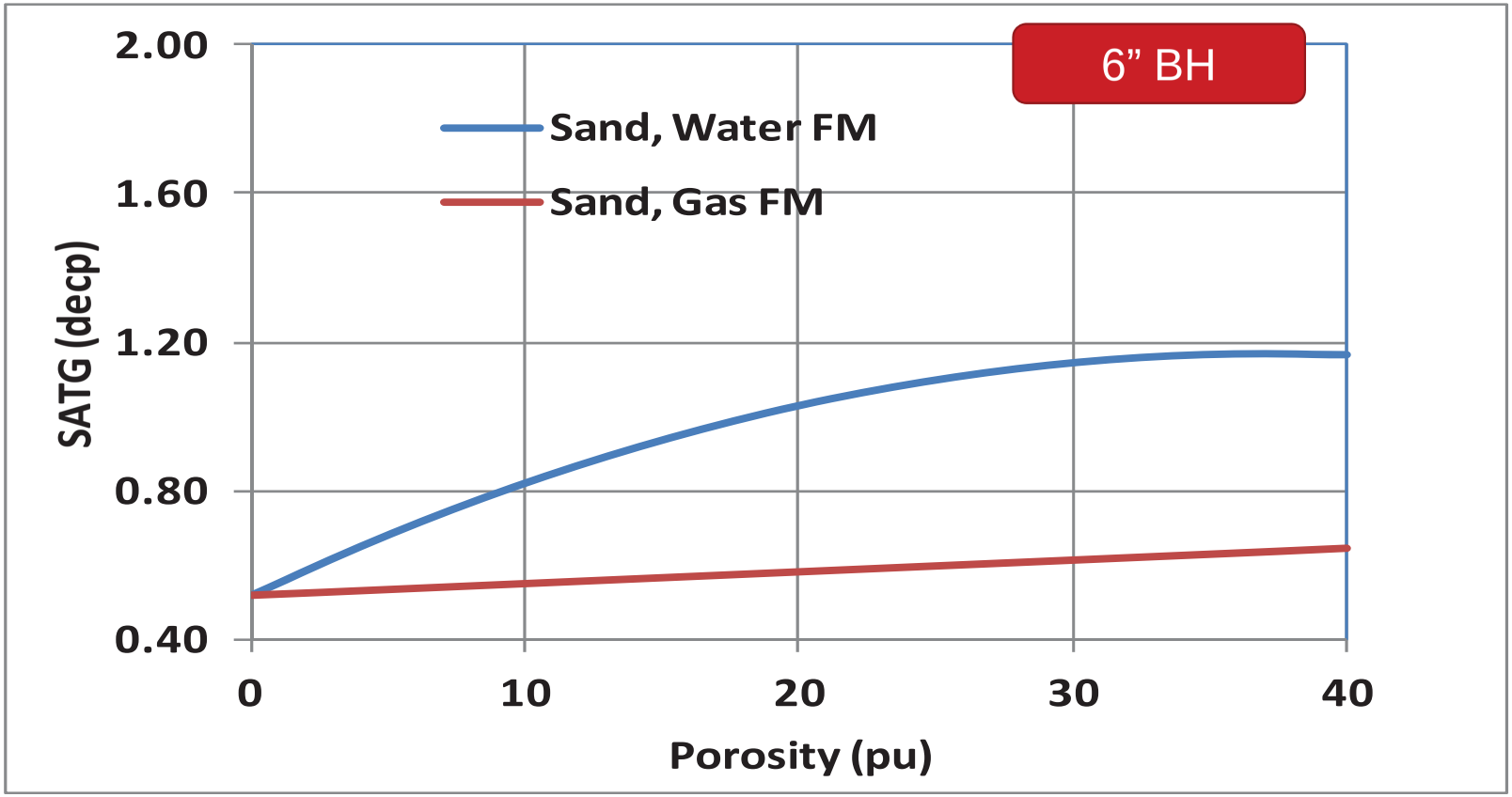
SATG ™ Gas Saturation



SATG ™ Gas Saturation



GasSat3D FAN Example



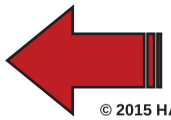
Well Diagnostics

Water Flow Detection

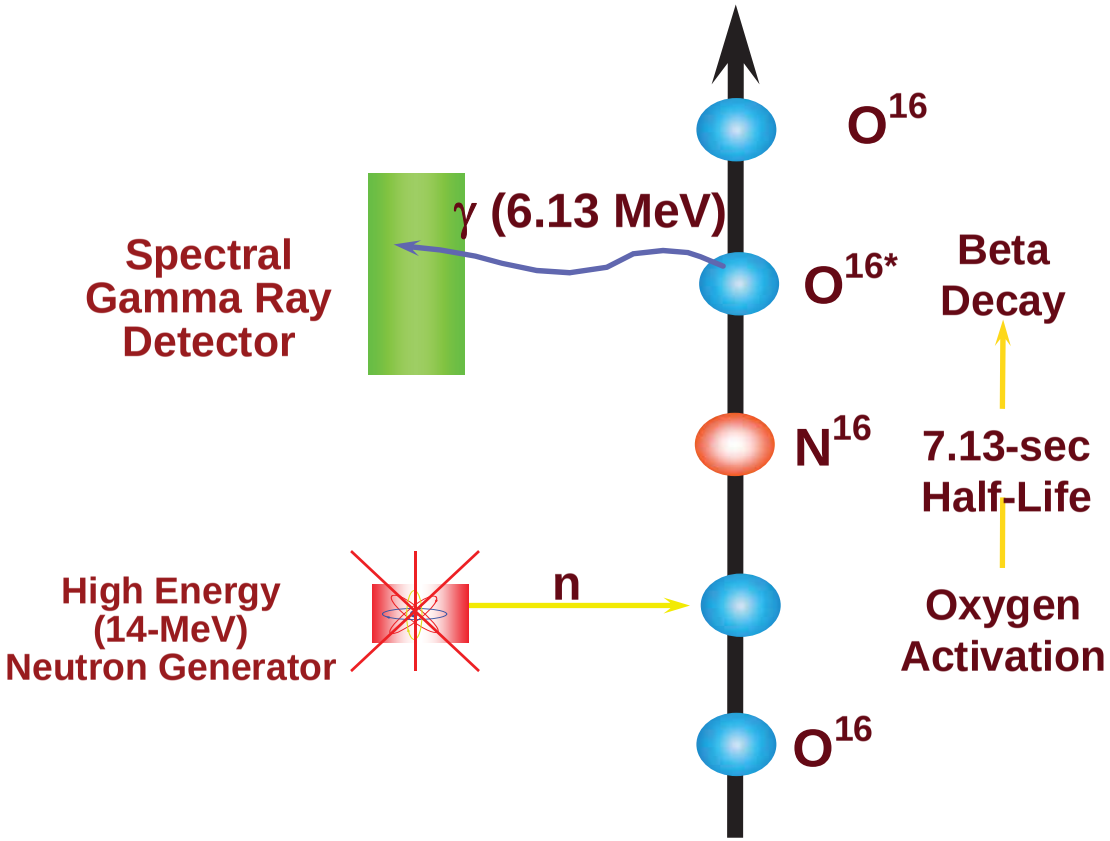
Oxygen Activation

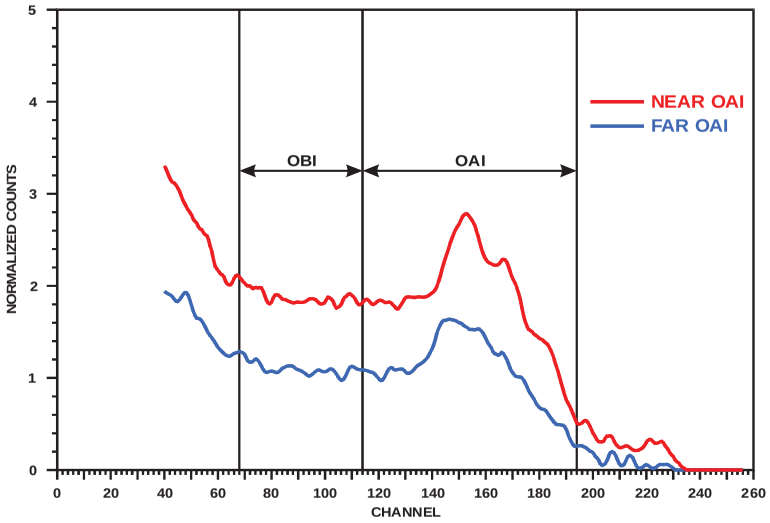
Gravel Pack Evaluation

Silicon Activation



Oxygen Activation – Measuring Water Flow





CRAT=OAI/OBI

Tool	CRAT Value inside pipe	CRAT value outside pipe
SPFL	>1.5	<1.5
TMDL	>1.5	<1.5
RMT	>1.8	<1.8

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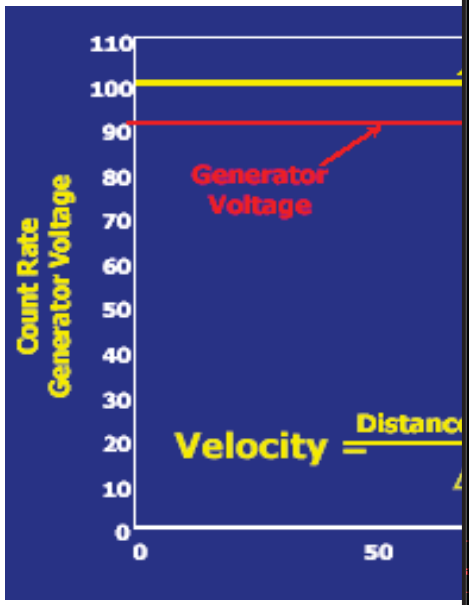
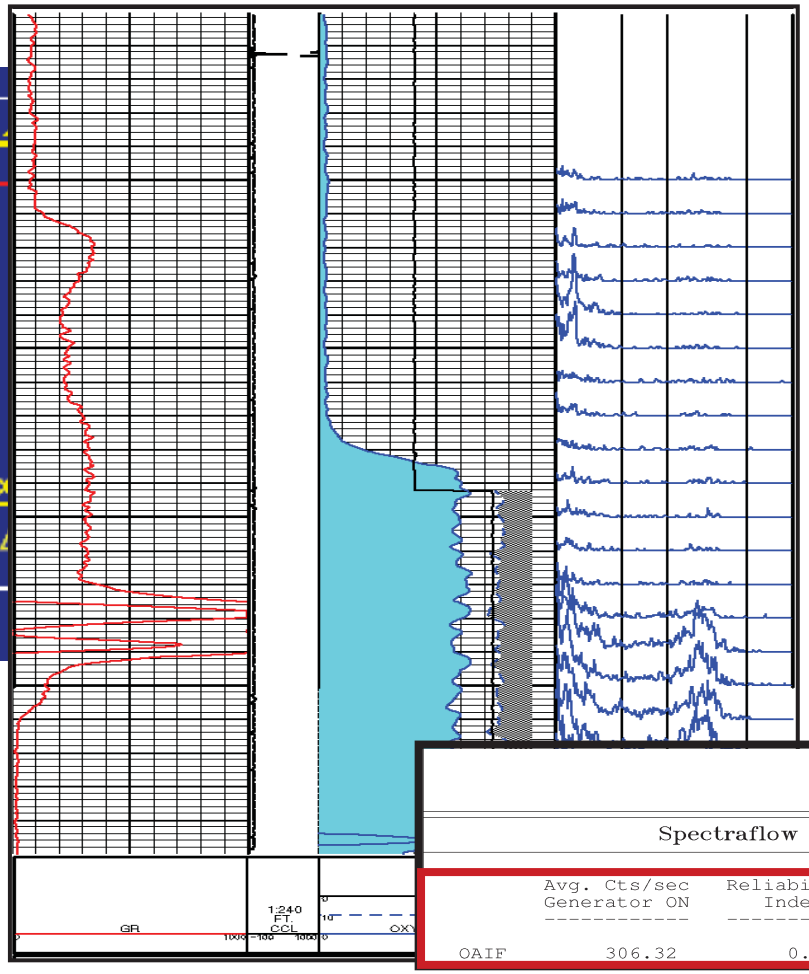
Stationary Impulse Timing Sequence (SpFL, TMDL, RMTE)





EXCELL–2000 Tool Report
Date: 17–May–2001 01:04

Spectraflow Impulse Test Tool Depth: 816.833 Test

	Avg. Cts/sec Generator ON	Reliability Index	Fluid Vel. Feet/Min	Flow Dir	Flow rate bbl/day
OAIF	306.32	0.95	10.51	UP	286.7

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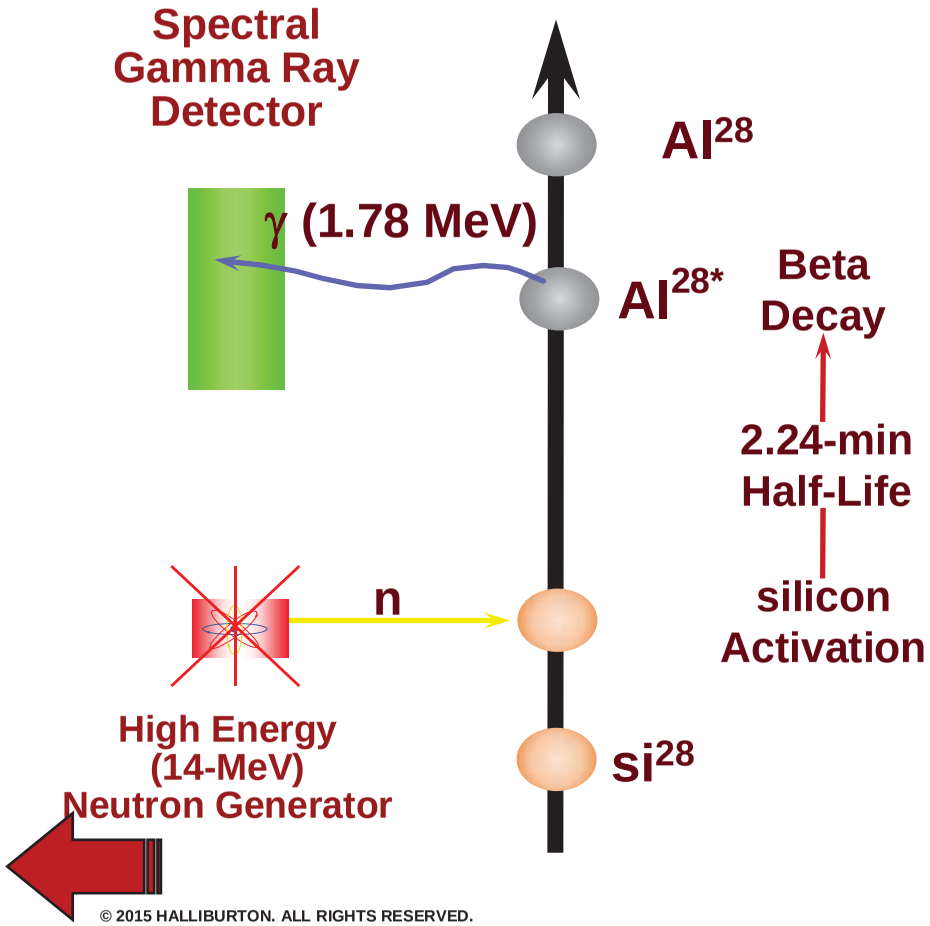
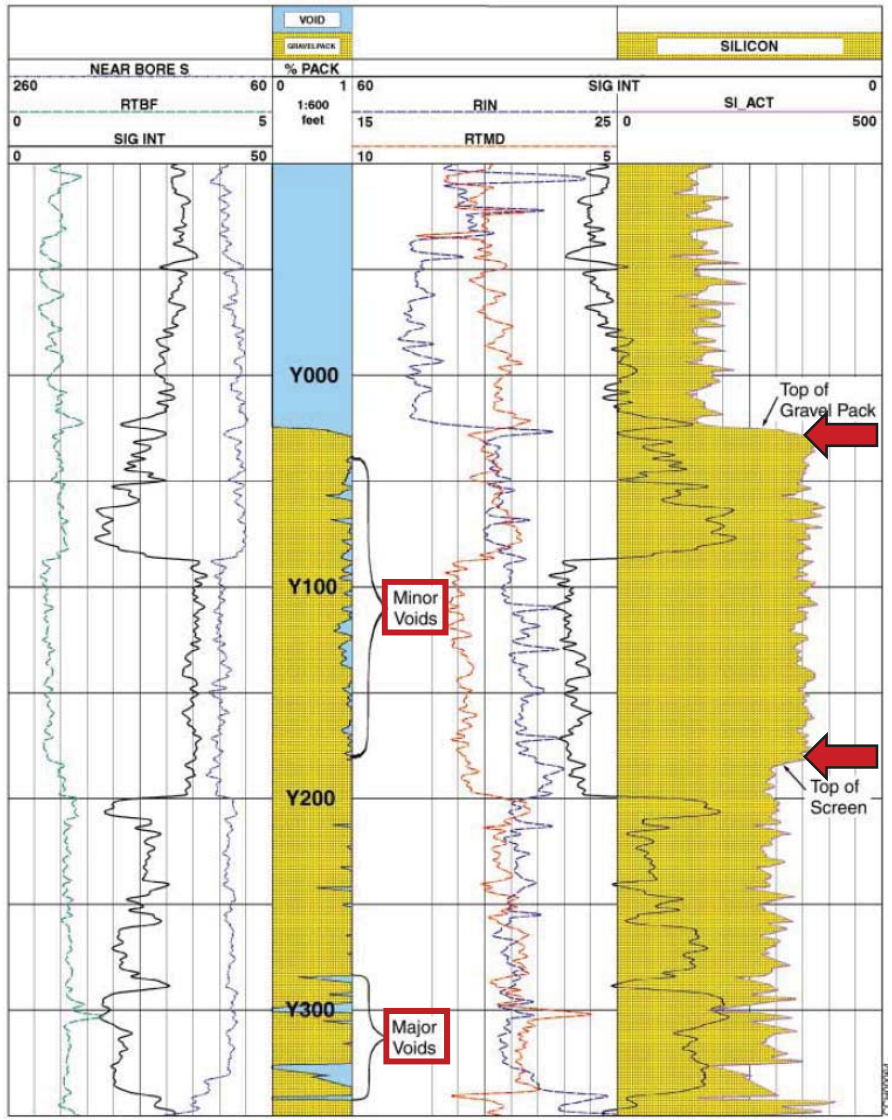
Silicon Activation





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Enhanced Recovery and Reservoir Monitoring

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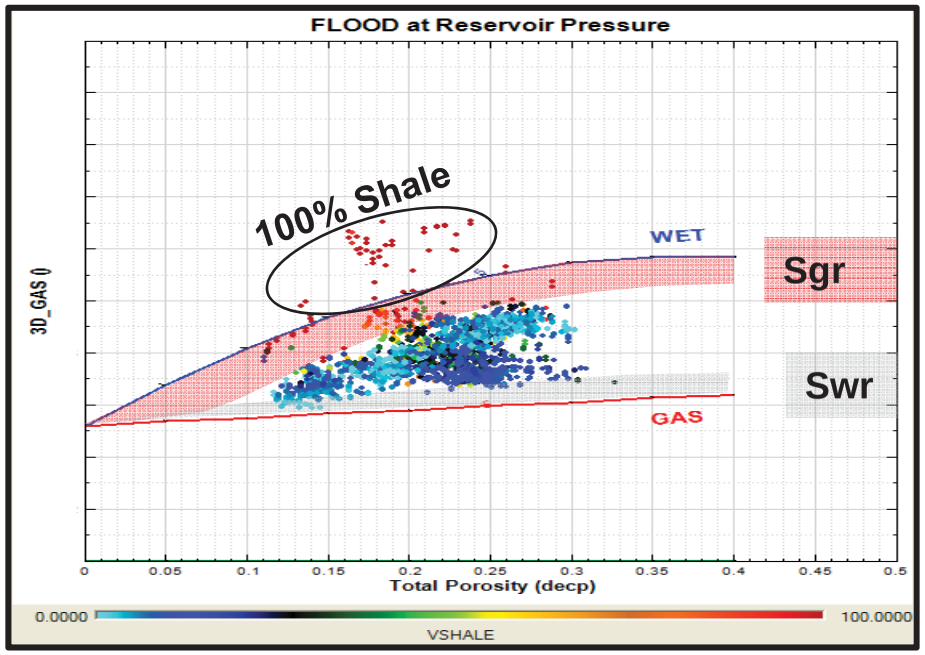
Example: Flooded Reservoir



Application and Solutions

Challenges

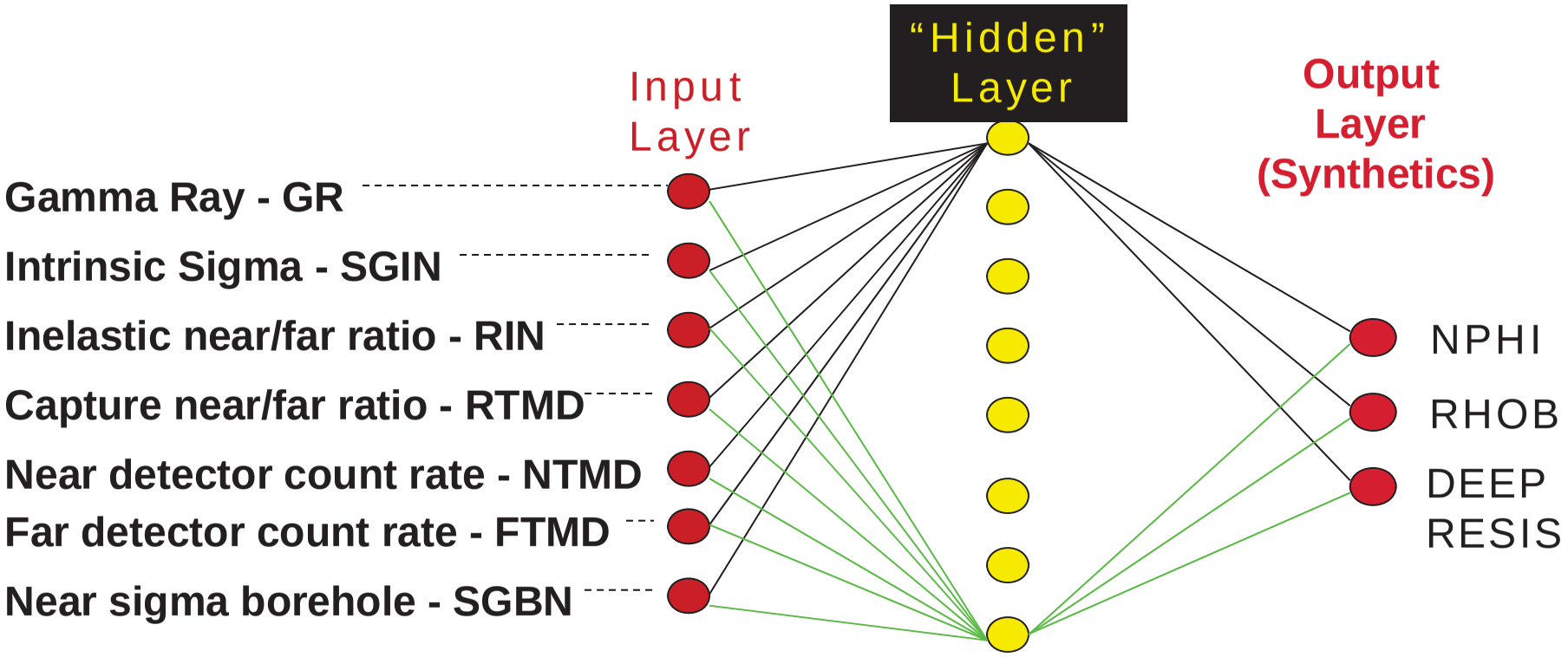
- Irreducible Saturation
  - Gas/hydrocarbon
  - Water
- Gas and Fluid Contact
- Complex Completions
  - Dual String
  - Multiple Casings
  - Multiple borehole fluids

3D Method and Solution

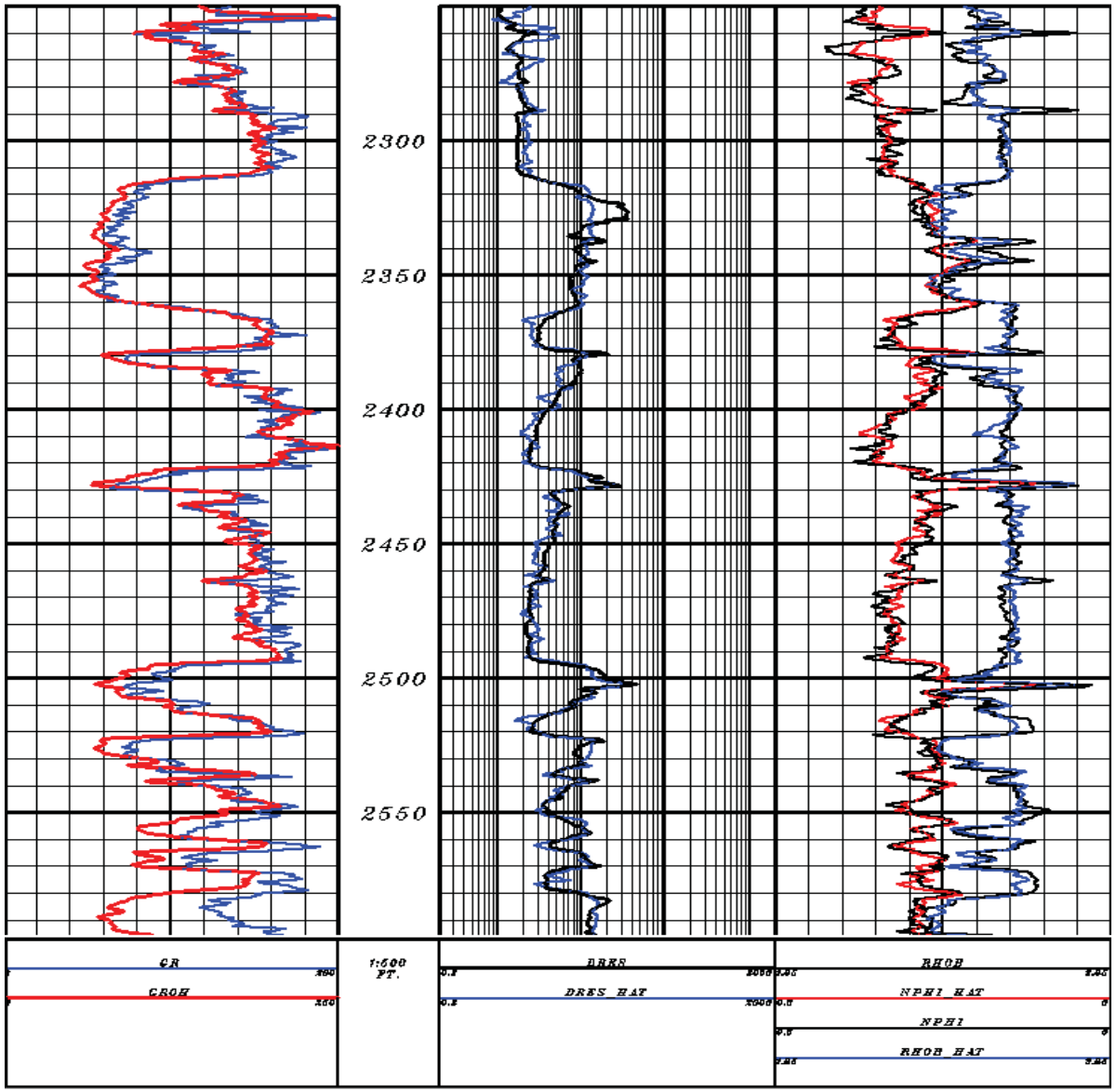
- Deeper depth of investigation
- Reduced borehole effects
- Large measurement dynamic range and accurate Saturation in complex completion geometries

CHI™ MODELING

Chi Modeling[SM]



Chi Modeling Example



Unconventional Reservoirs

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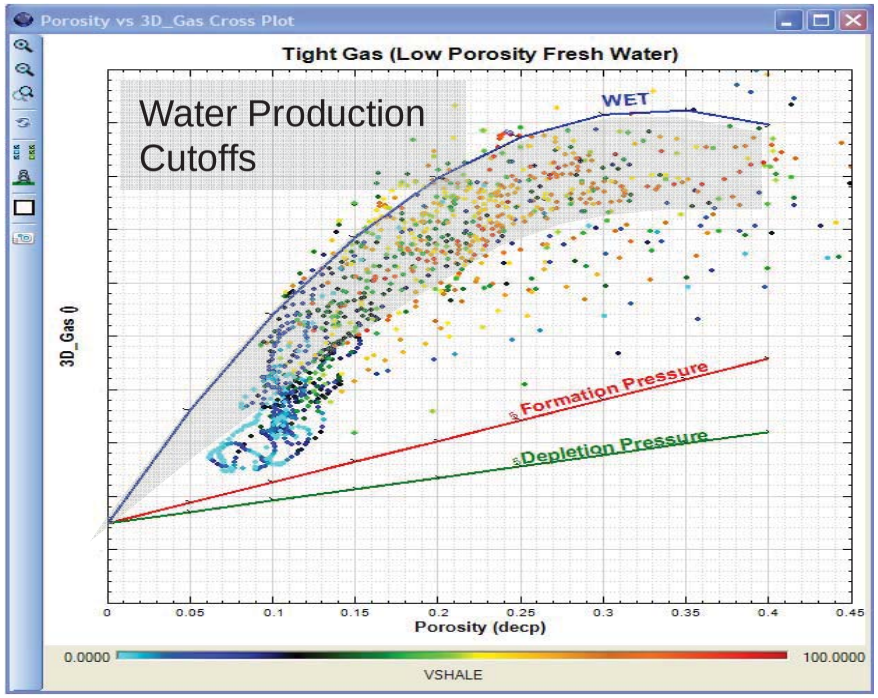
Example: Tight Gas Reservoirs



Application and Solutions

- Challenges
  - Low porosity and salinity
  - Complex matrix
  - Open hole replacement and porosity
  - Water Production
    - Permeability changes through hydraulic stimulation
    - Pressure and Relative permeability of the produced fluids
- 3D Solution
  - Large measurement dynamic range and accurate Gas Saturation
  - Pressure Depletion evaluation

~low Salinity and low Porosity

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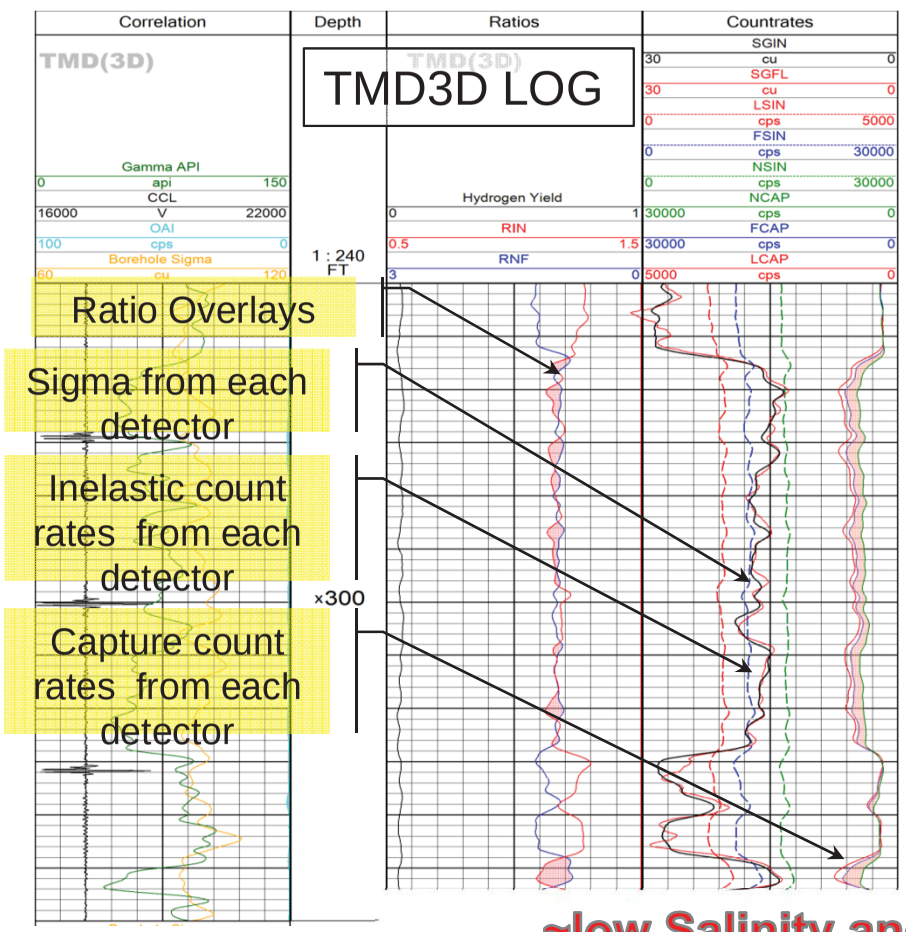
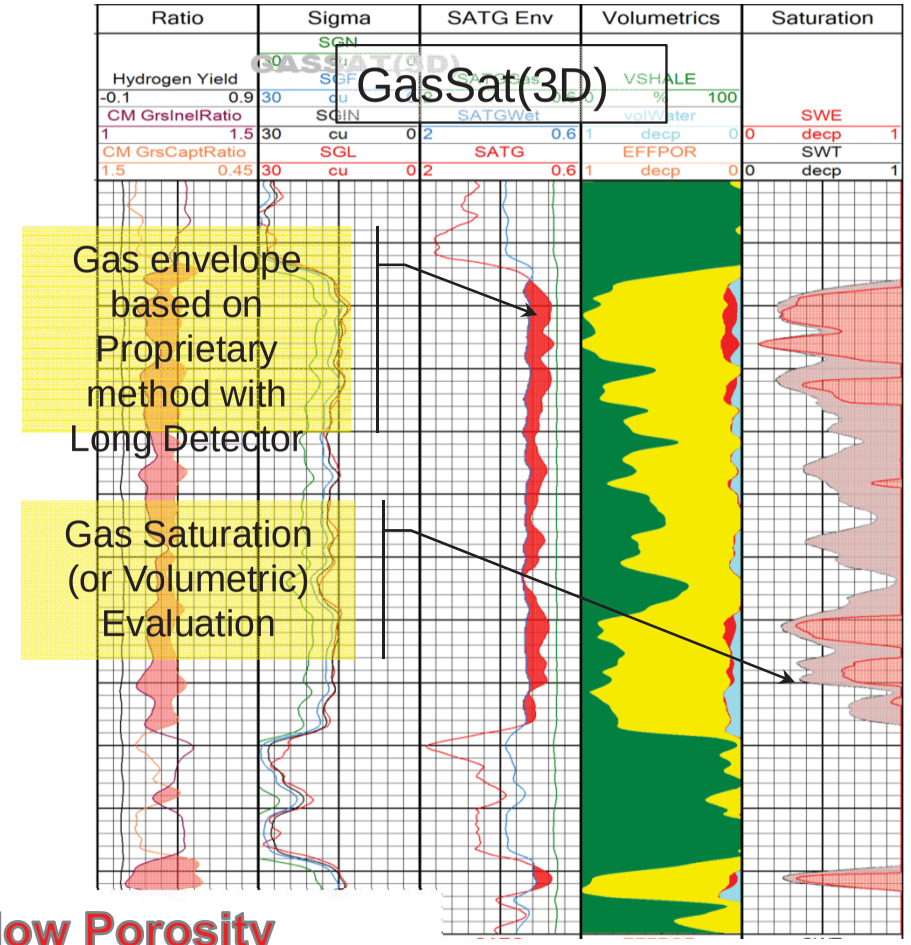
Example: Tight Gas Reservoir (Openhole Replacement)





~low Salinity and low Porosity

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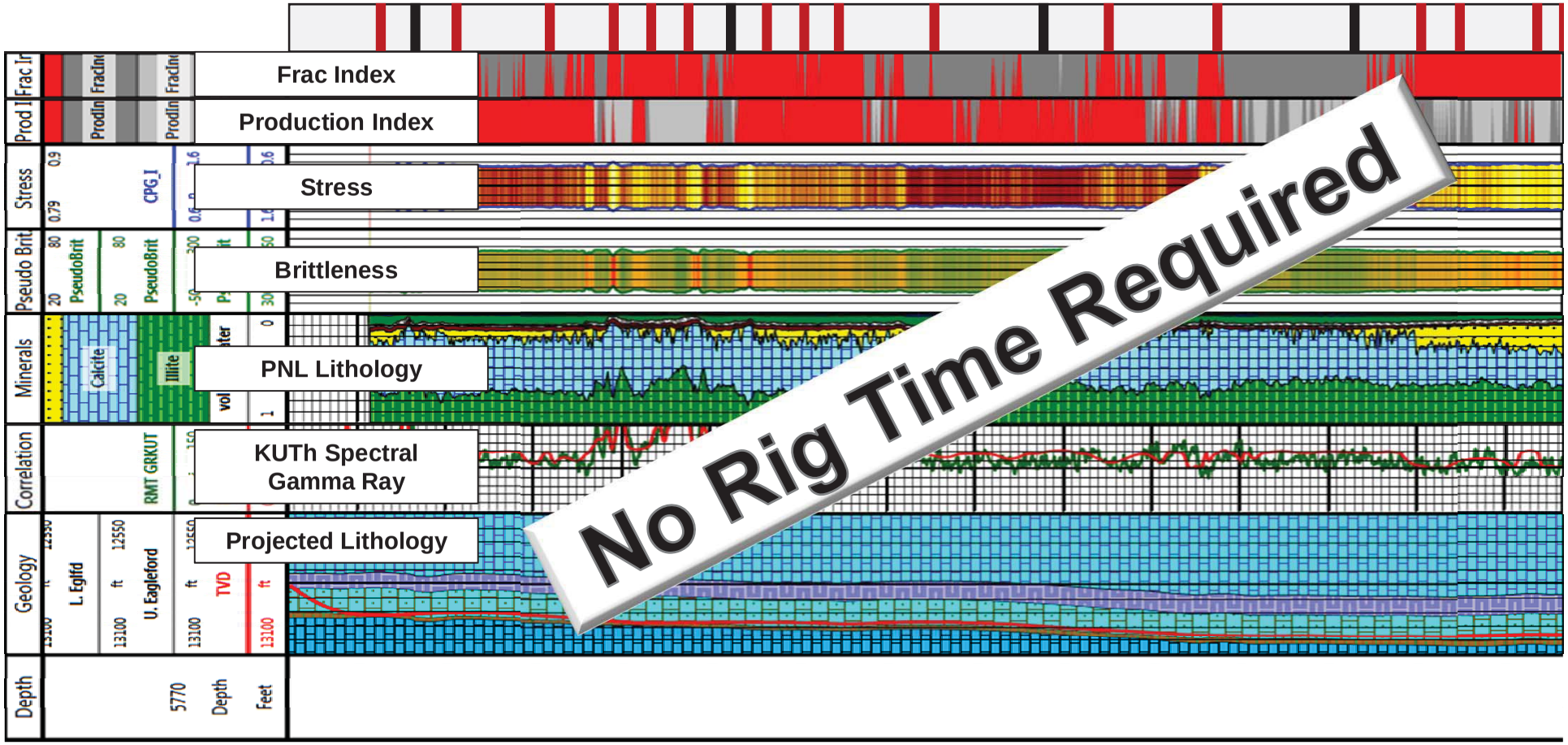
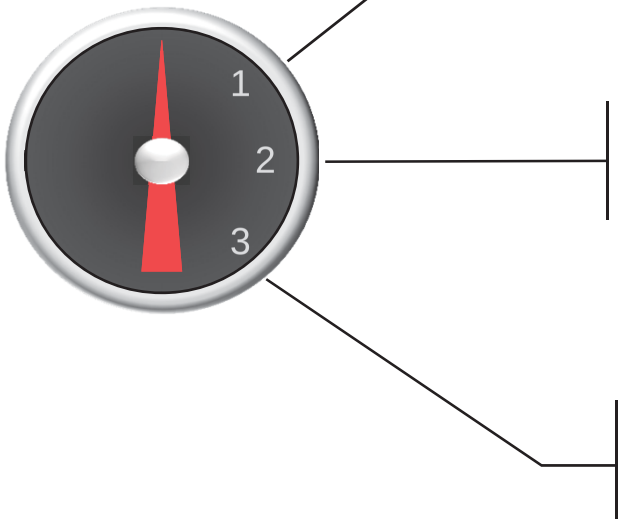
FracInsight™ ReFrac Service

Existing Geometric Perforation

New FracInsight Refrac Perforations



Conclusions



Salinity independent technique for fluids saturation analysis

Minimizes lithology and porosity effects

Better quality and **deeper** depth of investigation


THANK YOU