Pulsed Neutron Technology: Applications for Tight Gas Reservoirs*

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Abstract

As the oil and gas industry is moving forward with the optimization of costs, some reservoir challenges in tight gas reservoirs remain critical to increasing productivity. The evaluation of the gas-oil ratio is a key component of the reservoir modeling for field development. A new generation of pulsed-neutron technology enhances the cased-hole petrophysical applications. The technology design, advanced modeling, applications, and interpretation models are demonstrated in this case study.

Pulsed Neutron Technology

Applications for Tight Gas Reservoirs

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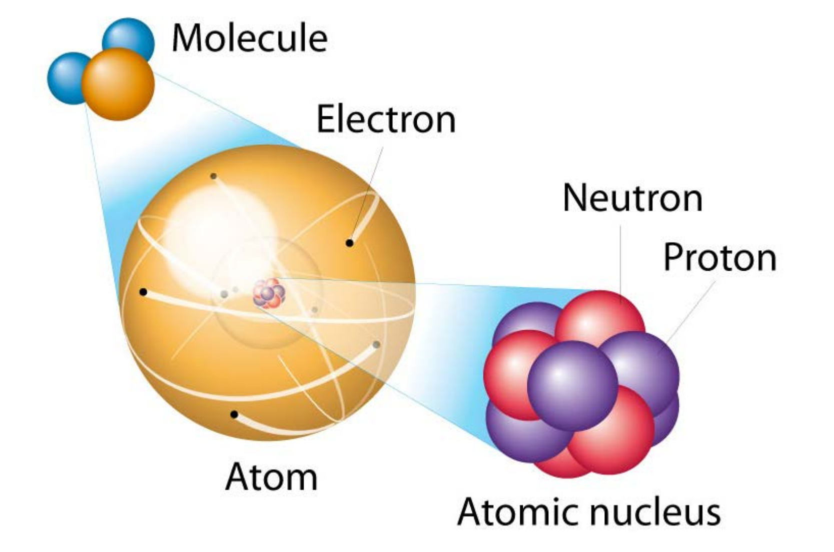
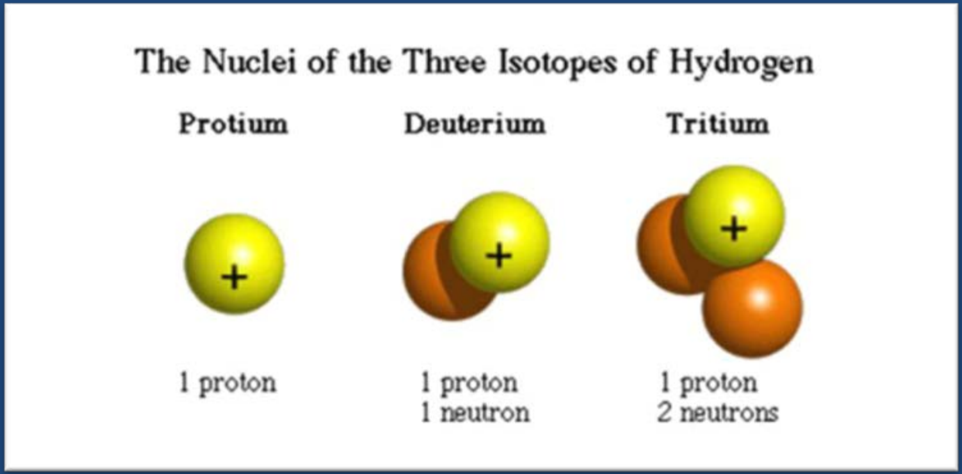
Neutrons

- What is a neutron?
  - Heavy particle without charge emitted from nucleus by fission or bombardment by external particles
  - No naturally occurring radioisotopes are direct neutron emitters
  - Mass about equal to proton
  - Highly penetrating



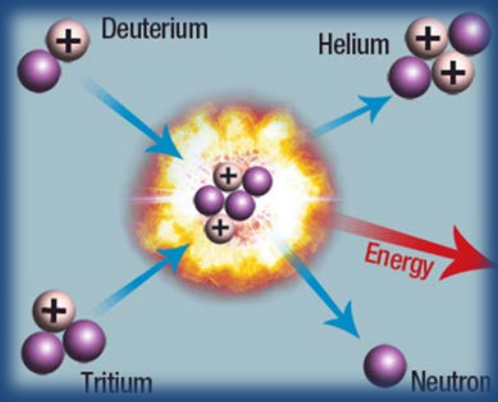
PNG

- What is a neutron generator?
  - Also called Deuterium-Tritium or D-T accelerators
  - Isotopes of hydrogen



Pulse Neutron – Basic Theory

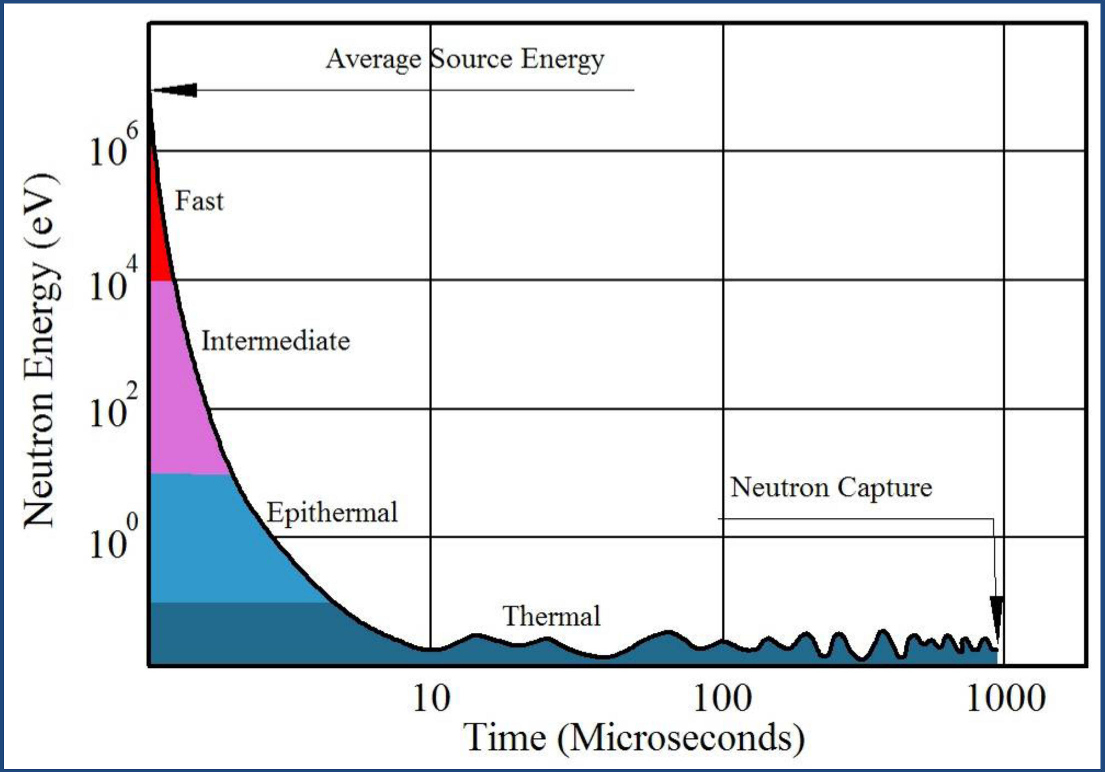
- What is a neutron generator?
  - Deuterium is accelerated into the tritium
  - High-energy neutrons that travel at 52,000 km/sec, 17.3% speed of light
  - 100,000,000 neutrons/sec output



3.5 MeV

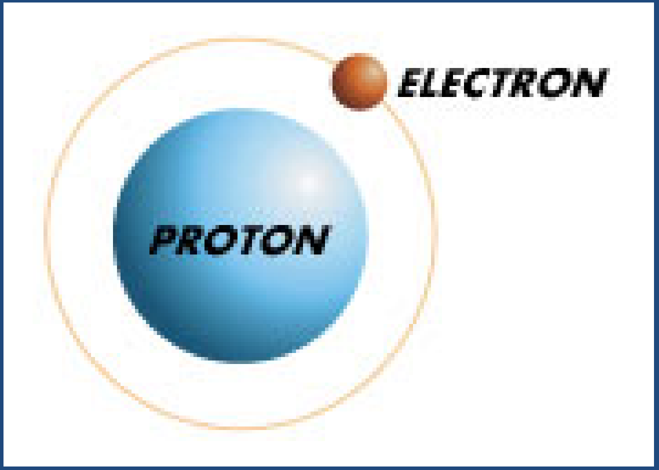
14.1 MeV

Neutron Energy vs. Time



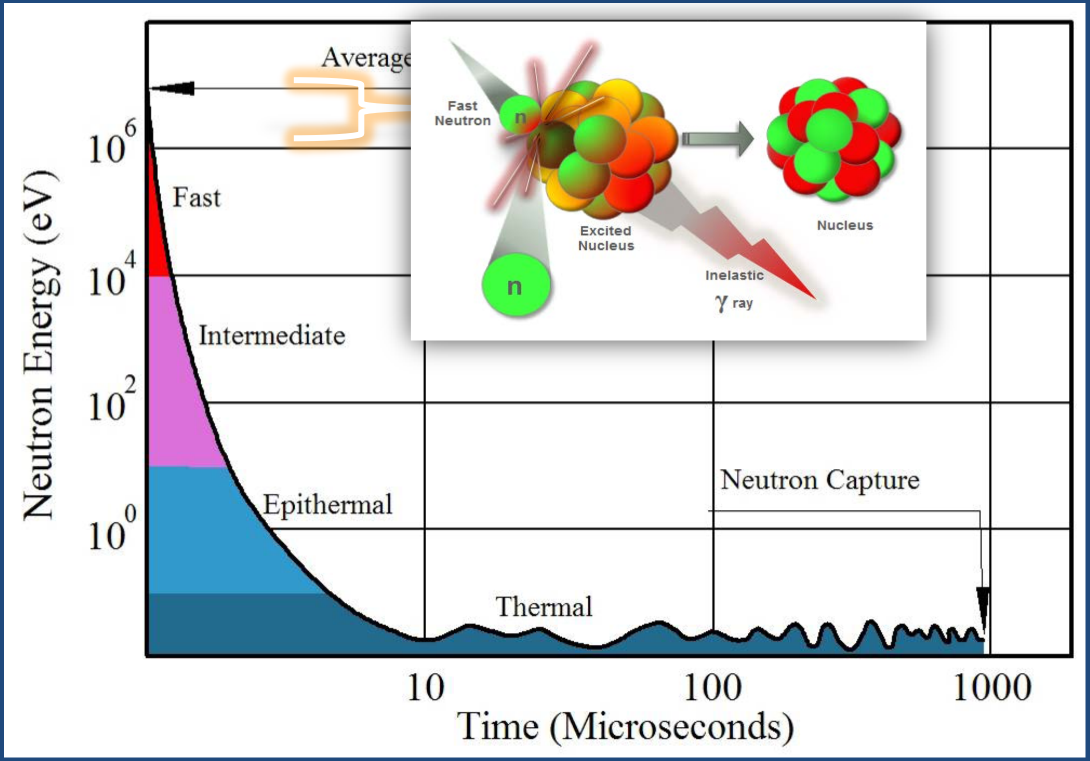
Neutron Interactions

- Inelastic interactions
  - Fast and high energy
- Elastic interactions
  - Intermediate Energy
- Capture
  - Slow energy (thermalized)
- Activation events



Pulse Neutron – Visualization

- Neutron interactions
  - **Neutron interacts basically with nuclei of atom**

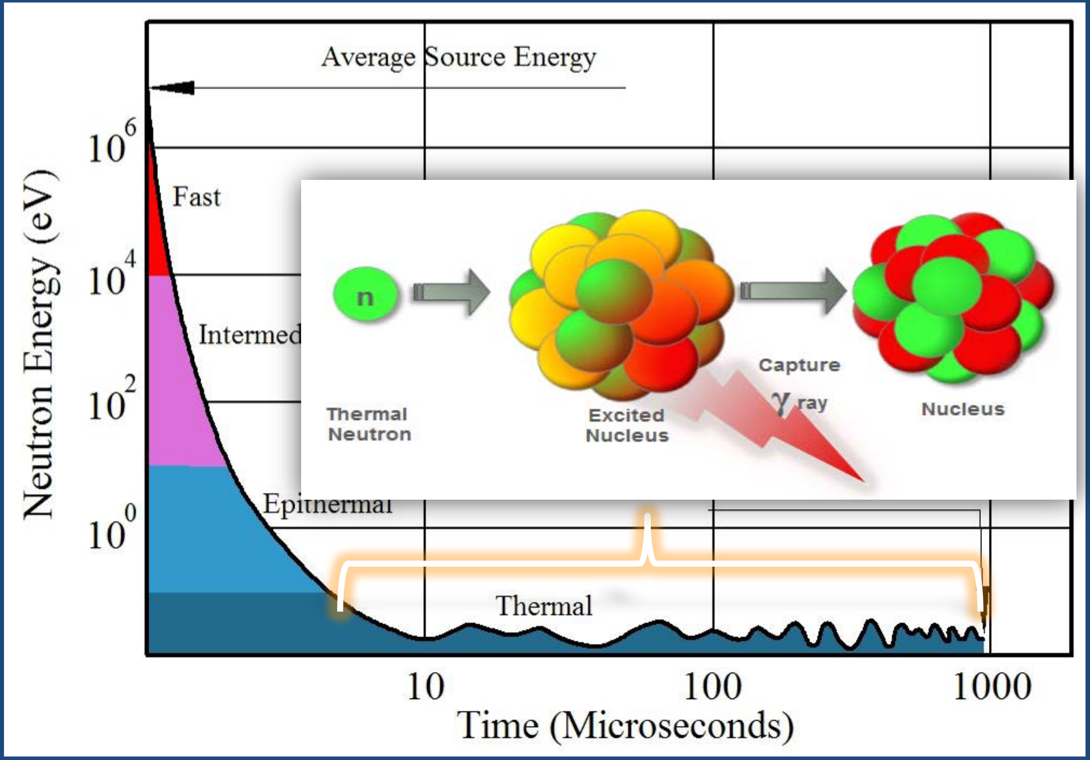


Inelastic Scattering

- High-energy neutrons >2MeV / >20.000 km/sec
- Nucleus gets excited
- Disturbed nucleus returns to normal state giving off a gamma ray
- Characteristic γ- ray from the isotope with energy between 2 to 7 MeV – Yield ratio for C/O computation
- Neutron bounces off and loses energy
- Occurs only during the burst and sometimes a few μsec after.

Pulse Neutron – Visualization

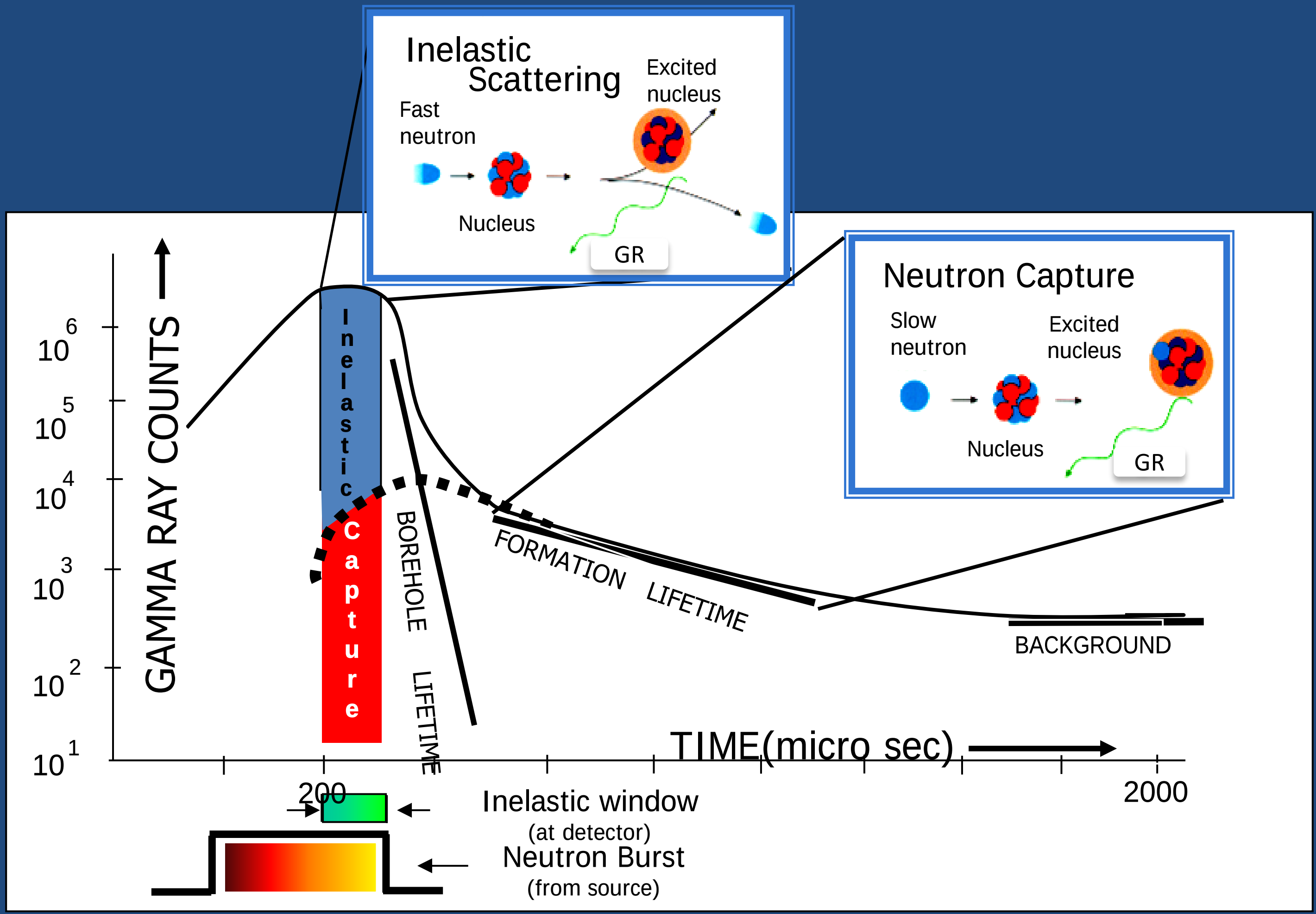
- Neutron interactions
  - **Neutron interacts basically with nuclei of atom**



Absorption

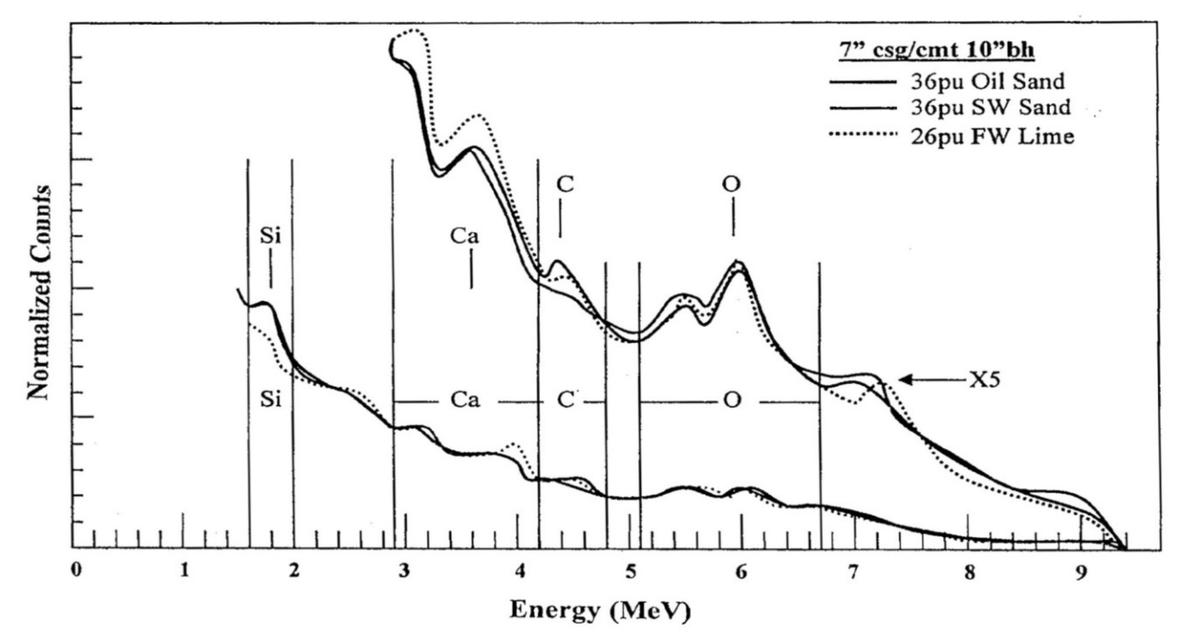
- Neutron energy at thermal equilibrium 0.025 eV□2.200 km/sec.
- When capture occurs, a characteristic gamma ray of the element is emitted.
- The thermalization time is measured and is the base for the SIGMA computation
- Cl-Chlorine is 100 times more efficient at capturing thermal neutron than any other element present on the wellbore.
- Occurs several hundreds of μsec after burst.

Inelastic vs. Capture Gamma Ray Window



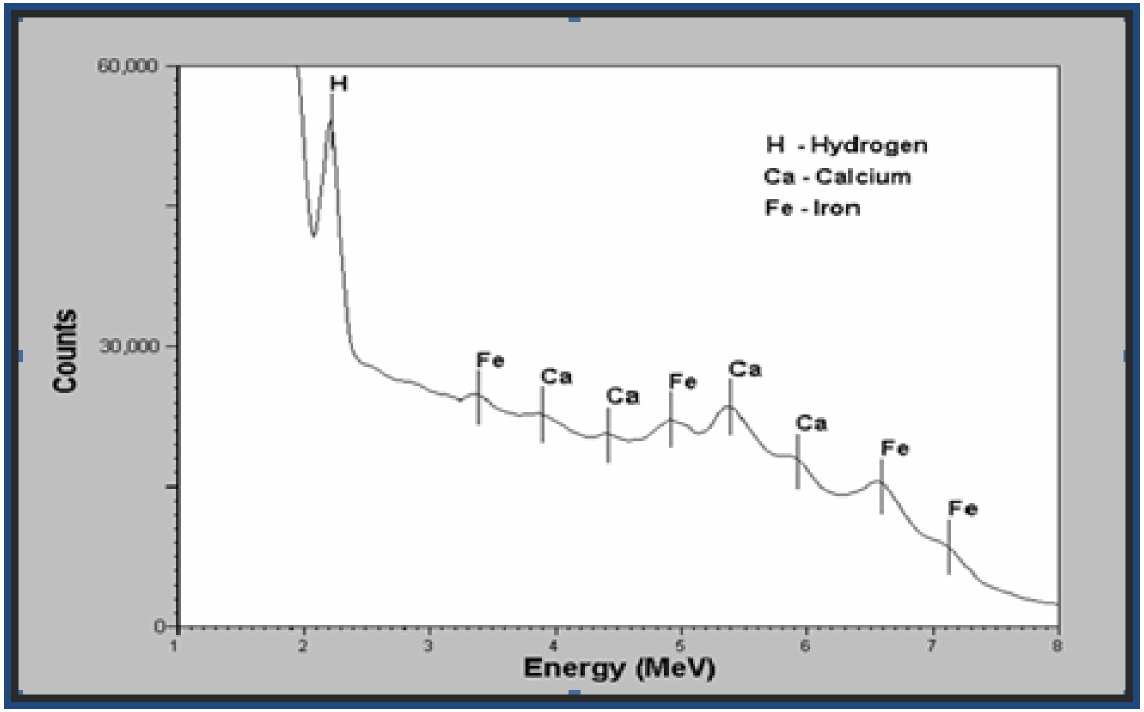
Inelastic Spectrum of Common Formation Elements

- Identify common elements downhole
  - Silicone
  - Calcium
  - Carbon
  - Oxygen

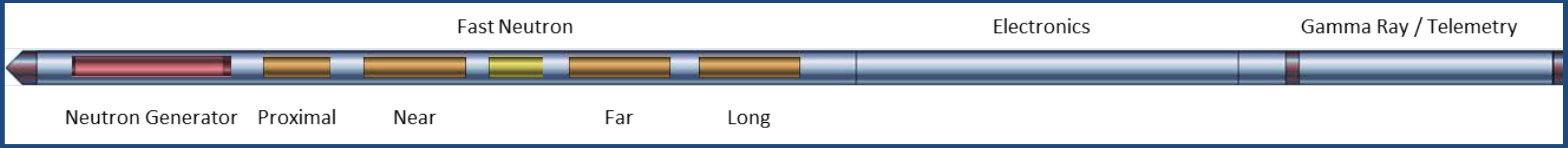


Capture Spectrum of Common Formation Elements

- Identify common elements downhole
  - Calcium
  - Iron
  - Hydrogen

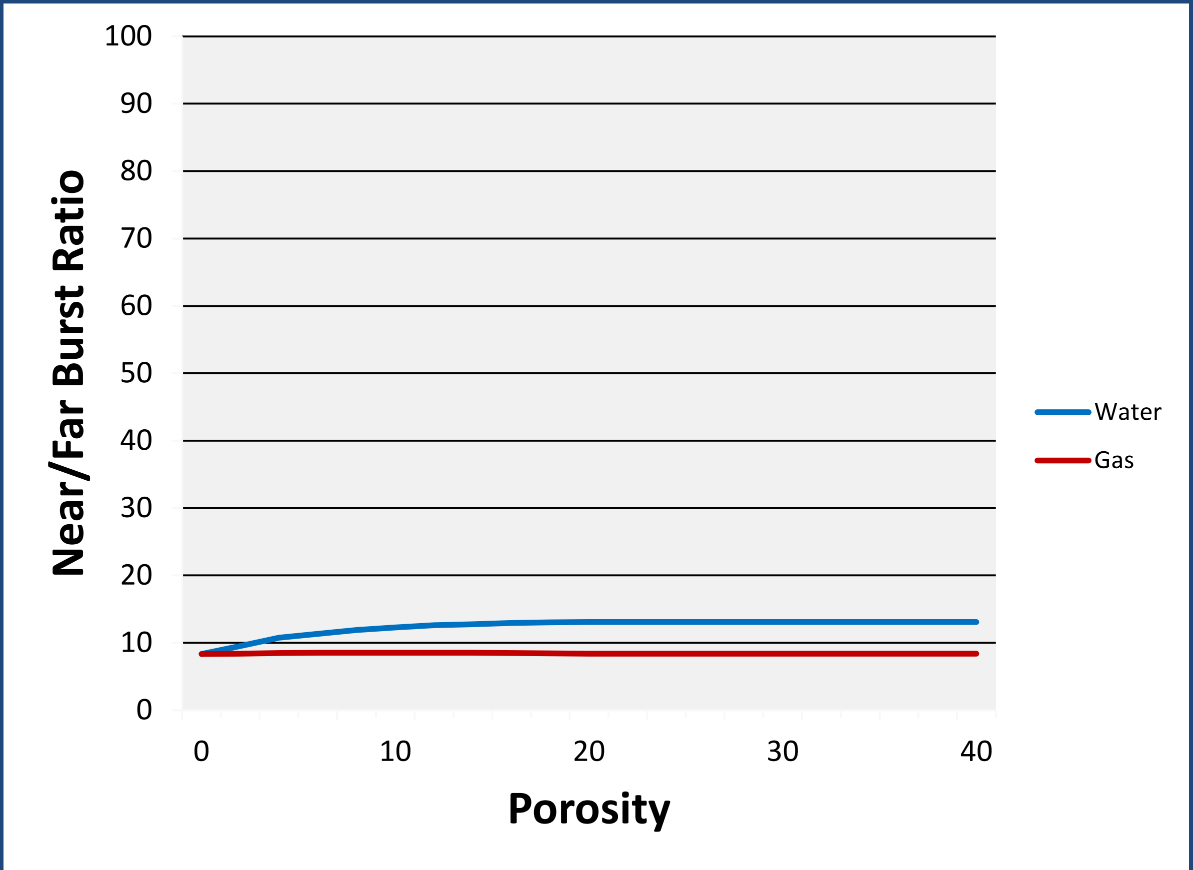


How do we detect interactions?

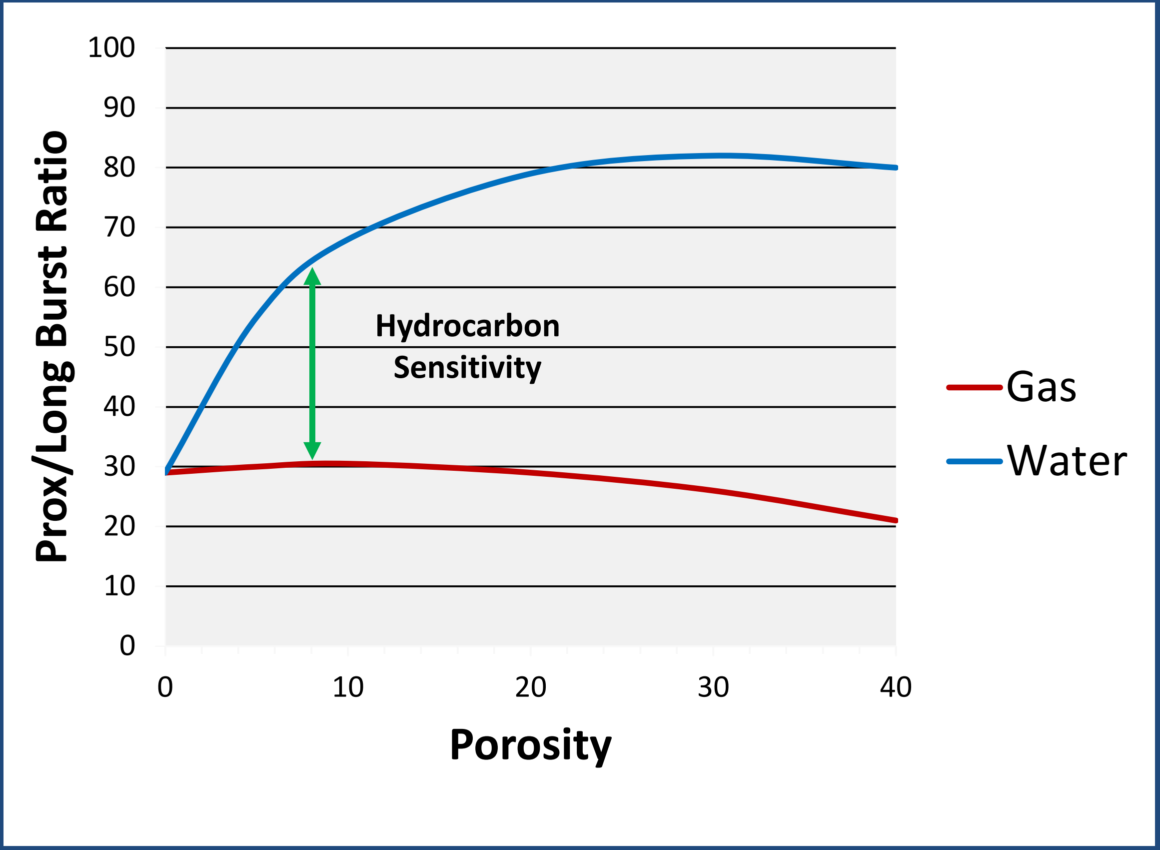


- Larger detector array
  - Senses more formation volume
- Detector type: $LaBr_3$(Ce)
  - Fastest detector in the industry
  - High count rates, faster logging
  - Brightest detector type – more signal, less noise
  - Full spectroscopic capability

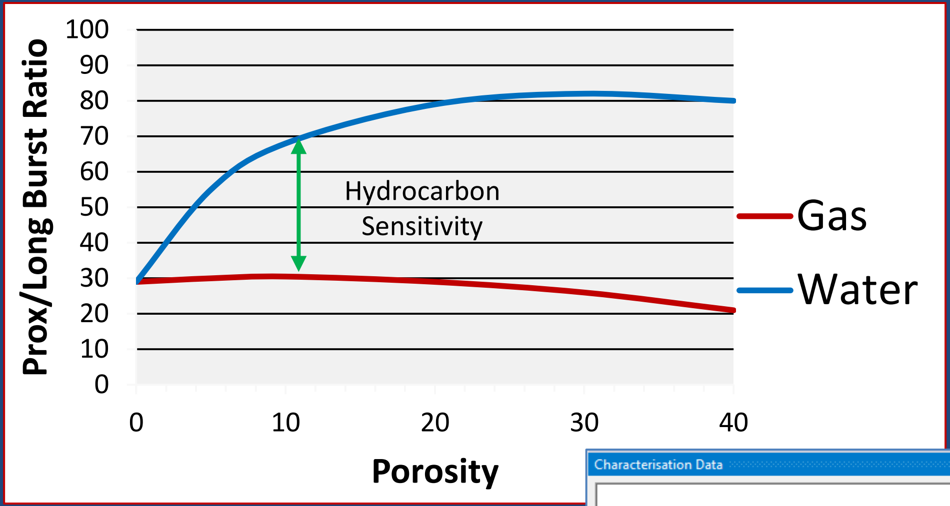
Why Four Detectors?

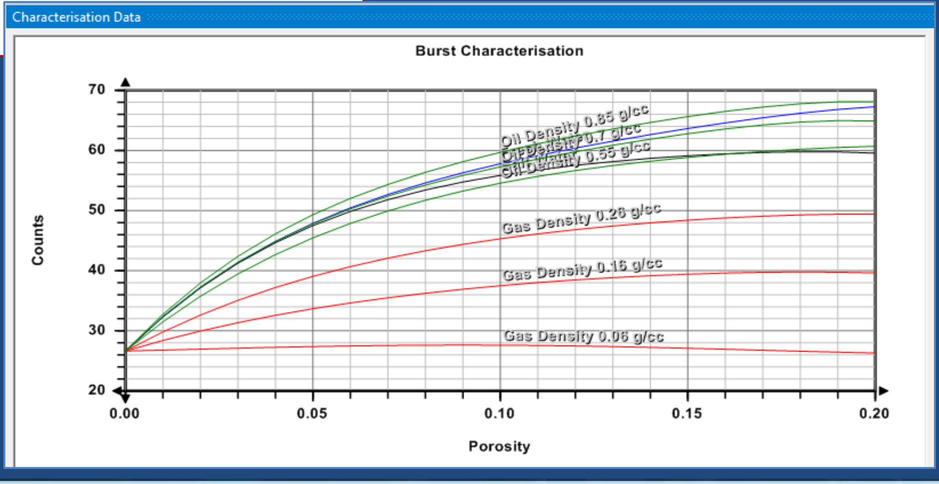


Why Four Detectors?



How do we use these interactions?





- 8.5 in borehole
- 5.5 in 17# casing

Case Studies

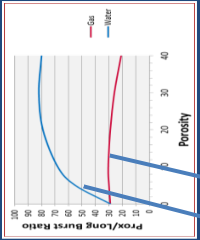
Geologic Considerations

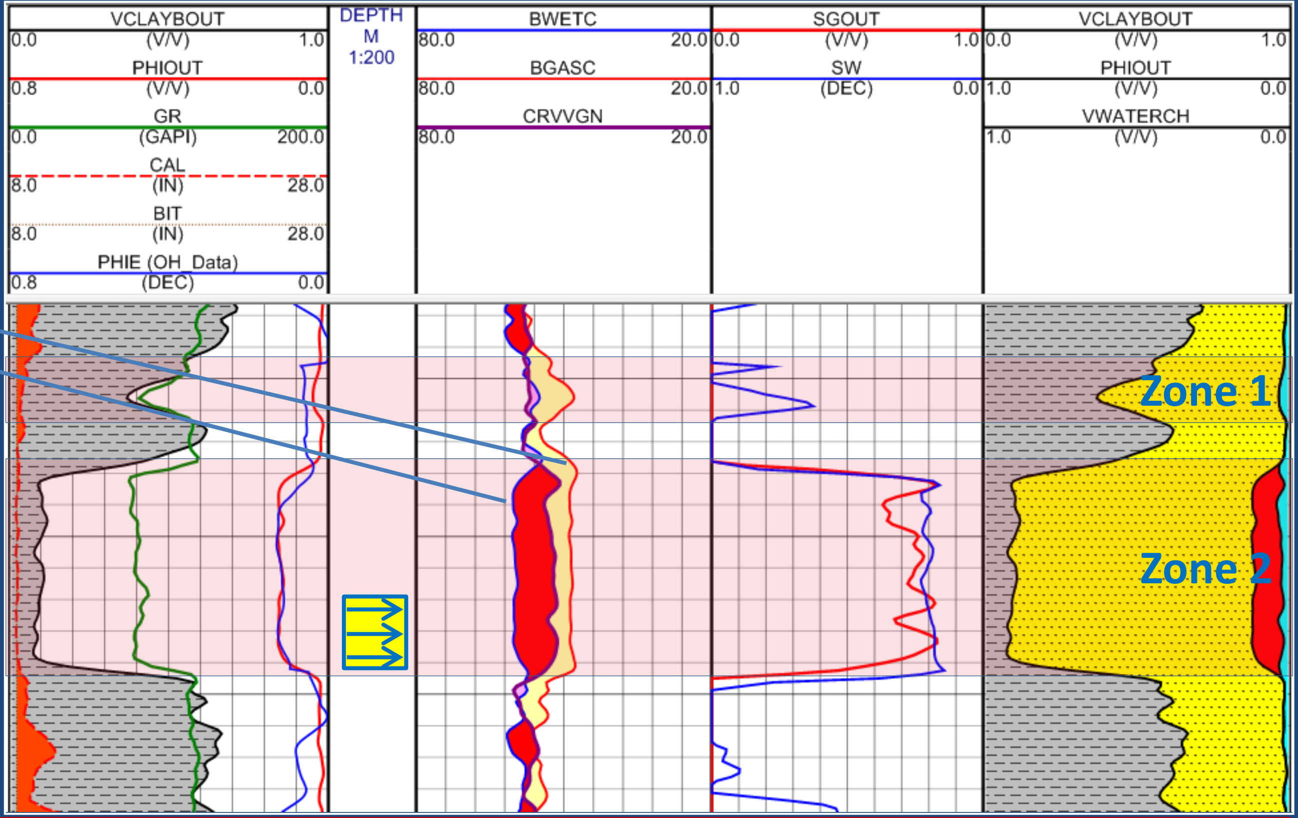
- Thorough understanding of the geologic characteristics of the formation:
  - The structural and tectonic regime
  - The regional thermal gradients
  - The regional pressure gradients

- Stratigraphy in a basin can affect:
  - Drilling
  - Evaluation
  - Completion
  - Stimulation

- Important geologic parameters:
  - Depositional system
  - Genetic facies
  - Textural maturity
  - Mineralogy
  - Diagenetic processes
  - Cements
  - Reservoir dimensions
  - Presence of natural fractures

Evaluations in the Neuquén Basin





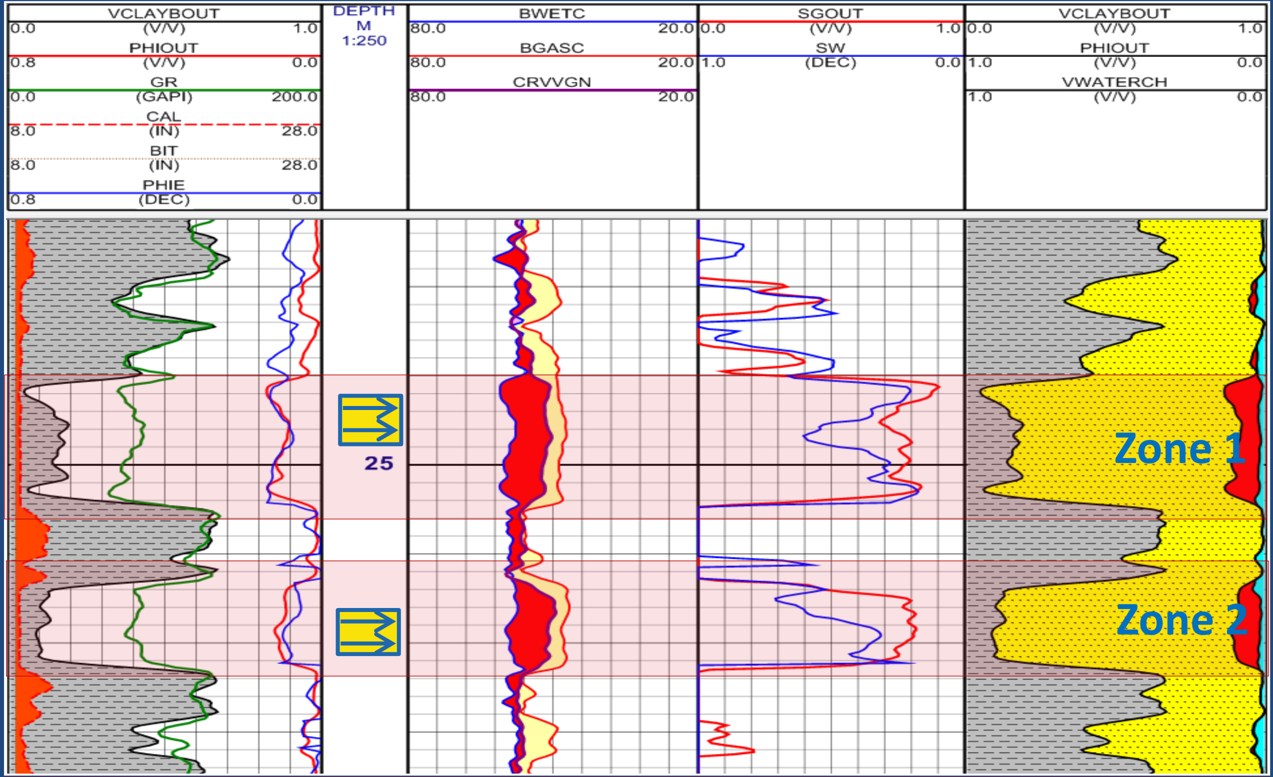
Track 1: Caliper, Vclay, GR , OH PHIE (blue) & Cased Hole PHIE (red). Track 2: perforations. Track 3: Saturation Envelope. Track 4: Openhole Sw (Blue), Cased-hole saturation (Red). Track 5: Volumetrics.

Pay zone evaluated by open hole and cased-hole data.

***Zone 1**: cased-hole PHIE pessimistic compared to openhole, PN tool is not seeing any Gas.*

***Zone 2**: there is a match between openhole and cased-hole PHIE; also saturations are similar.*

Evaluations in the Neuquén Basin



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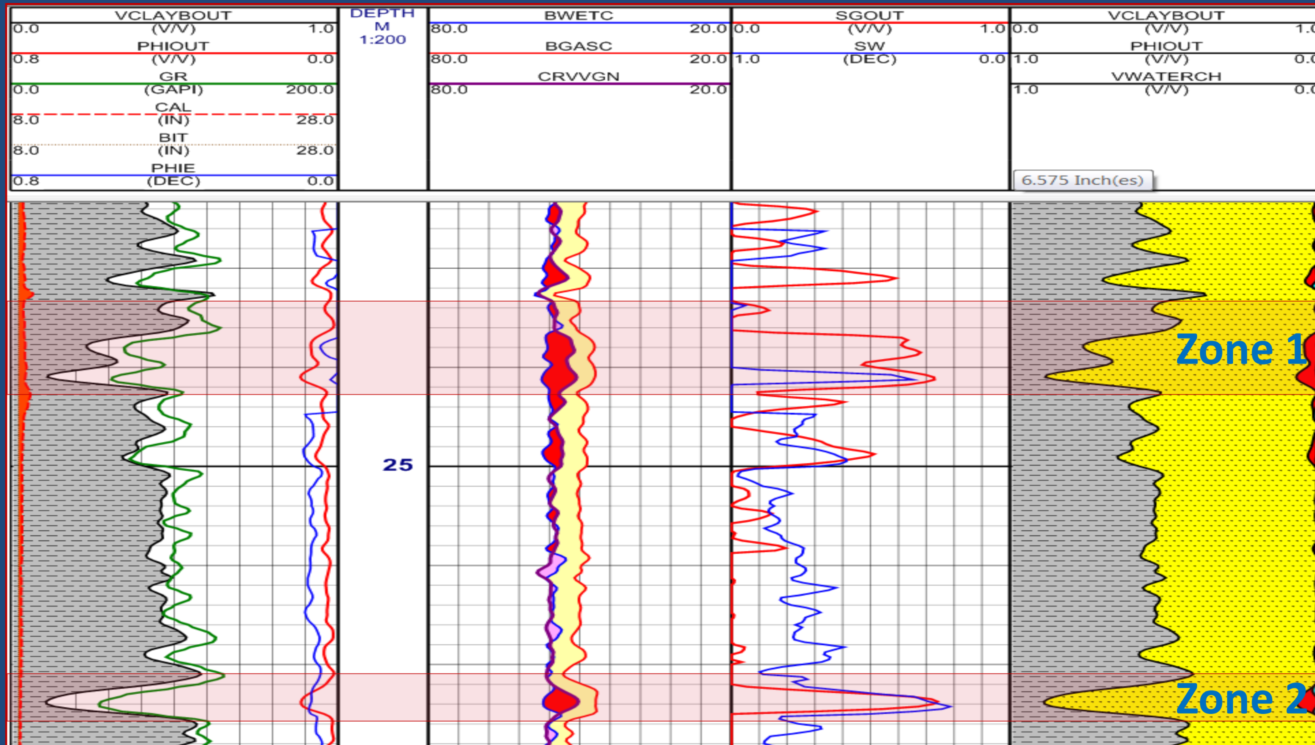
Pay zone evaluated by openhole and cased-hole data.

***Zone 1**: There is a match between cased-hole and openhole PHIE; saturations are close.*

***Zone 2**: Cased-hole PHIE is more optimistic; therefore, saturation is also optimistic compared to that of the open hole.*

Evaluations in the Neuquén Basin



Track 1: Caliper, Vclay, GR , openhole PHIE (blue) and cased-hole PHIE (red). Track 3: Saturation envelope. Track 4: Openhole Sw (Blue), cased-hole saturation (Red). Track 5: Volumetrics.

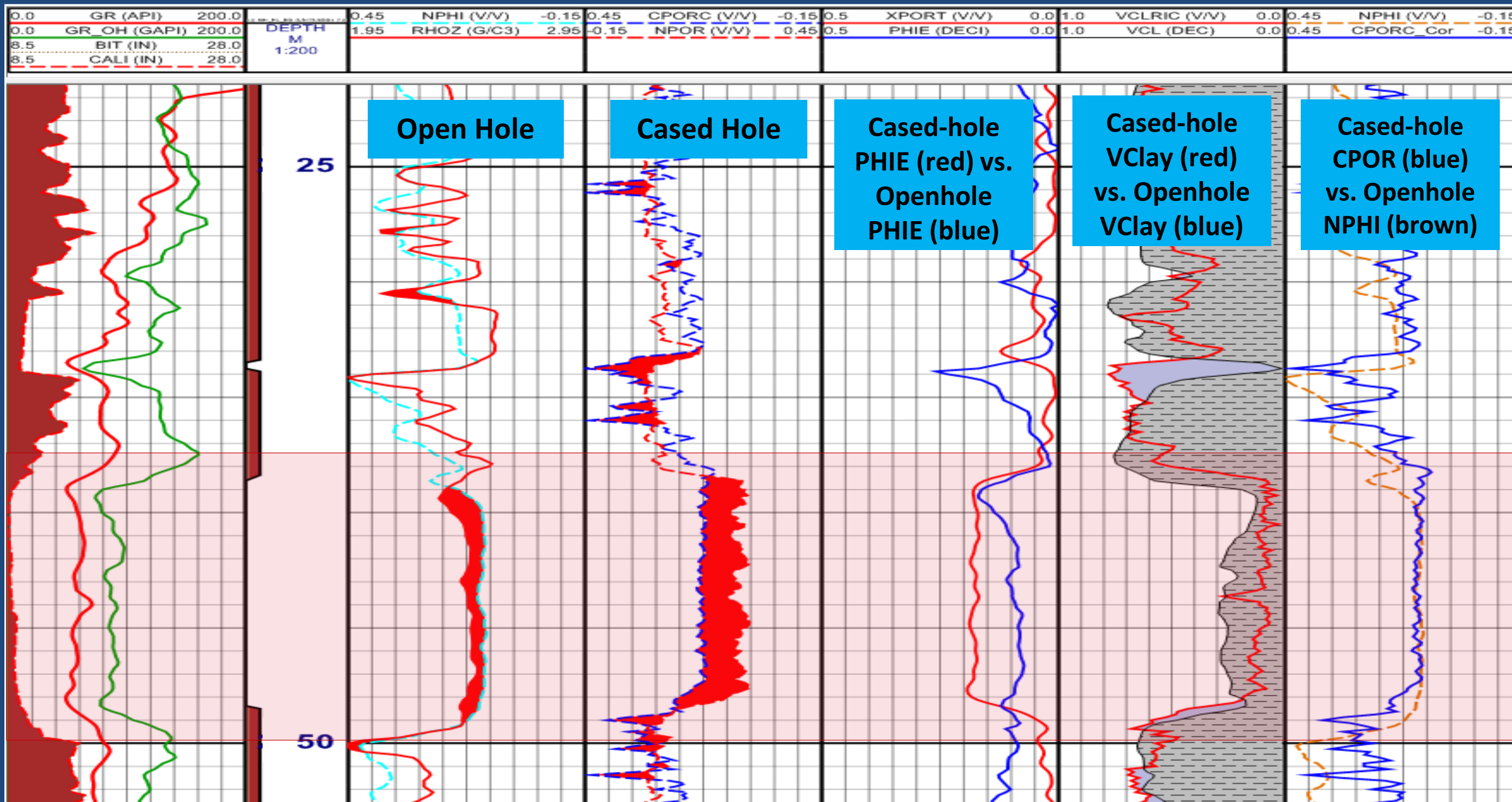
Pay zone evaluated by openhole and cased-hole data. There is a general miss match between openhole and cased-hole PHIE in shaly zones. This difference can be explained by clay-bound water effect in openhole data, generating an optimistic calculation in PHIE. Pulsed neutron tool seems to be unaffected by this matter when calculating PHIE.

***Zone 1**: Cased-hole PHIE optimistic compared to openhole PHIE, PN tool sees more gas.*

***Zone 2**: There is a better match between openhole and cased-hole PHIE; also saturations are close.*

Other Applications

Cased-hole PHIE vs. Openhole PHIE

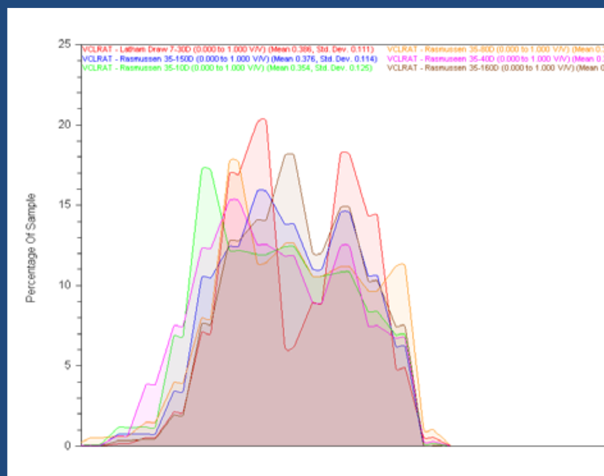


*Openhole data vs. cased-hole data. In tracks 5, 6 & 7 PHIE, Vshale, and NPHI compared to **XPORT** (gas-corrected PHI), **VClay** from inelastic/capture ratio and **CPORC** (characterized neutron porosity). Differences between cased-hole and openhole PHIE are explained by the differences on VClay estimations.*

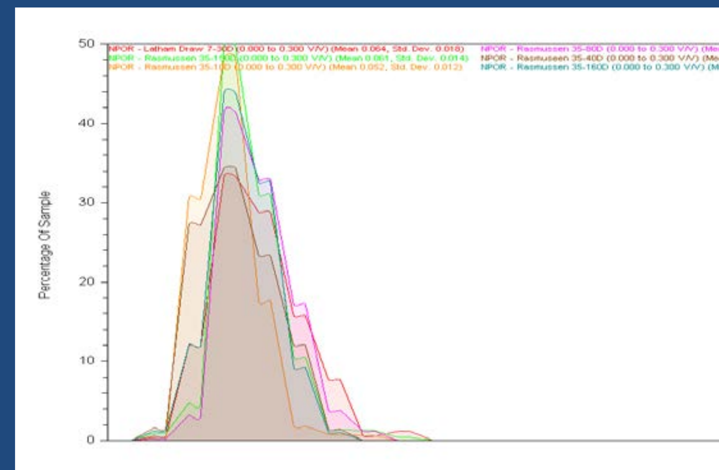
Other Applications

Field Petrophysical Model

VClay



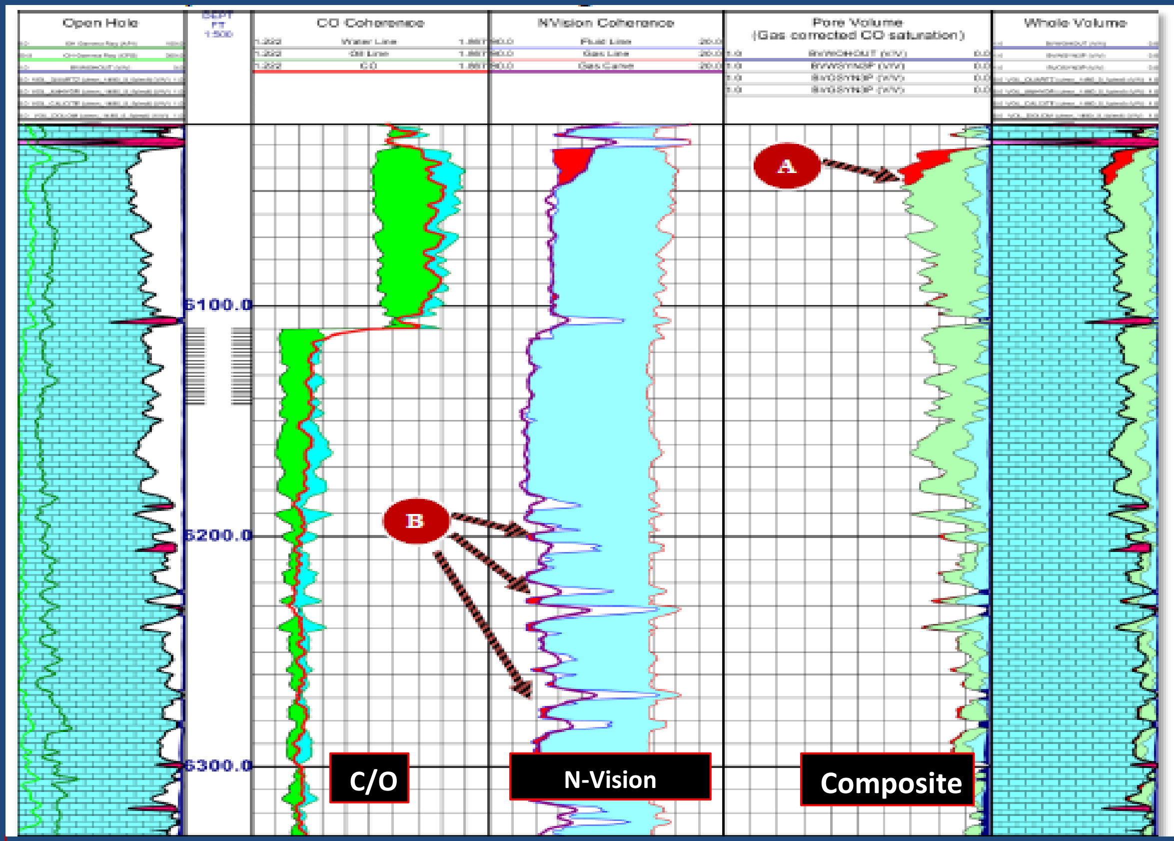
Porosity



Once curves are normalized with openhole data, petro-physical model can be propagated to other wells in the field without openhole information.

Other Applications

3-Phase identification



Carbonate reservoir where gas cap was developed in an oil reservoir. Contact was identified allowing client to adjust production strategy.

Conclusion

Data integration is fundamental for tight gas evaluations .
Five-detector tool has the most comprehensive detector array in the industry, with four spectroscopy detectors and one fast neutron detector. This array probes the neutron-gamma transport field over a larger volume than any other tool in the industry and as a consequence has more sensitivity than any other tool for Tight Gas reservoirs. This technology differentiator and the data interpretation method developed by Weatherford provide a significant input during the reservoir performance evaluation.

Acknowledgment

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THANKS!

QUESTIONS?