HWLAC

Ashbaugh ENERGY

pnnPlus

Well Logging Equipment

Innovations in Reservoir Saturation Measurement: PNNplus Technology including Oxygen Activation and PNN Ultra high-temperature tool

ISO 9001 14001 18001 REGISTERED

CO 3156

Outline

- Introduction
- PNN/PNN UHT/PNN Plus Tool Description
- Logging Requirements
- Tool Background Physics
- Sigma Processing
- Processing Curves and Meaning
- Niger-Delta Case Studies
- Benefits and Applications
- Summary

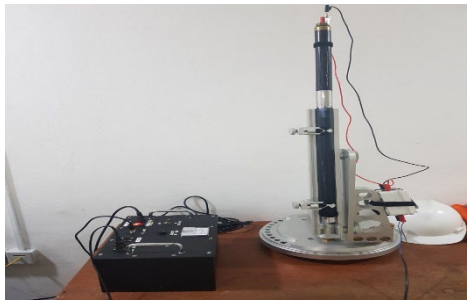
Introduction: Our Services

Ashboard ENERGY

Well Logging Equipment

- ✓ E-line
- ✓ Slickline
- ✓ North Seeking Gyro Services
- ✓ Well Testing (Surface Testing, DST, TCP, EPF)
- ✓ NDT (Inspection Service)
- ✓ Valves Supply, Repair and Maintenance
- ✓ Facility/Asset Maintenance
- ✓ Piping & Pipeline Support
- ✓ Drilling rig services
- ✓ Manpower Supply
- ✓ Procurement Solutions






Introduction

HWLAC Ashbard ENERGY pnnPlus
Well Logging Equipment

- Indigenous company incorporated in 2004 (Ashbard)
- Partnership with pnnPlus (formerly called **Hotwell**) located in Vienna, Austria
- HWLAC Interpretation Centre, Austria
- Provides Open & Cased Hole Well Logging Services
- Over 30 wells logged in the Niger-delta
- Dedicated to
  - Efficient product service delivery
  - Customer's satisfaction &
  - Continuous improvement.

Introduction

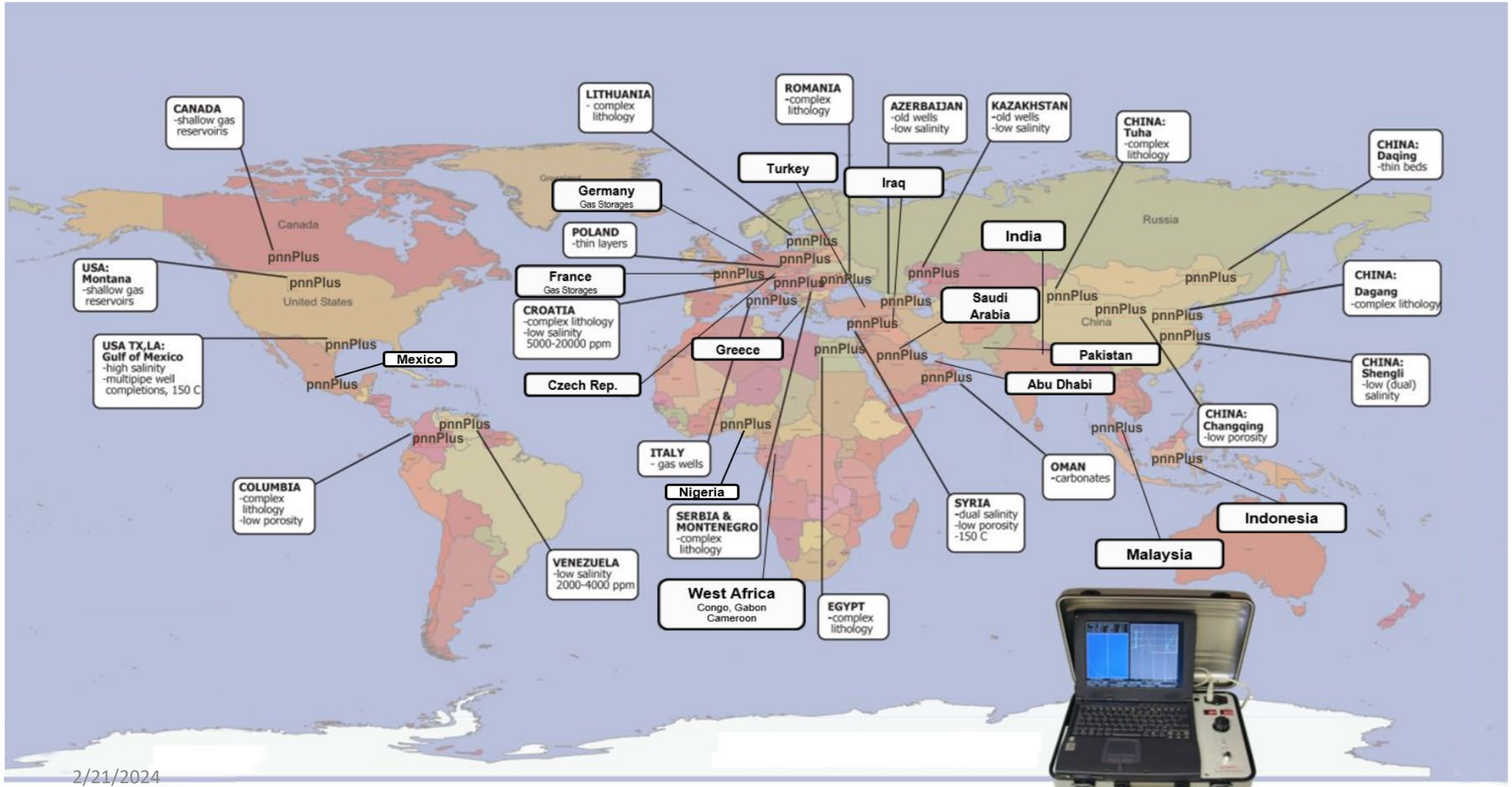
Well Logging Equipment

PNN Tool History:

- 1997 - Start
- 1998 -1999 Start Field Characterization
- 2000 – Present Worldwide Usage **18 Years**
  - **logged and analyzed more than 6500 wells throughout the whole world. There is about 3000-4000 more wells logged and analyzed by the customers themselves which makes it about >10000 wells in total.**
  - **PNN was logged for more than 480 oil companies and in a cooperation with > 65 service companies throughout the world.**
  - **built over 170 PNN tool strings and used more than 380 neutron generators.**

Introduction

HWLAC Ashland ENERGY pnnPlus
Well Logging Equipment



Standard PNN Tool:

HWLAC Ashbard ENERGY pnnPlus
Well Logging Equipment

COMMUNICATION SECTION

GAMMA RAY DETECTOR SECTION

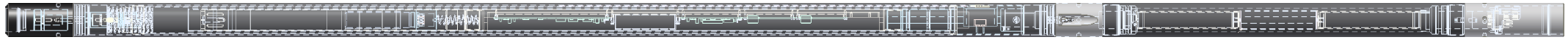
NEUTRON DETECTOR SECTION

NEUTRON GENERATOR SECTION

PNN Plus Tool 1400.0000:

Well Logging Equipment

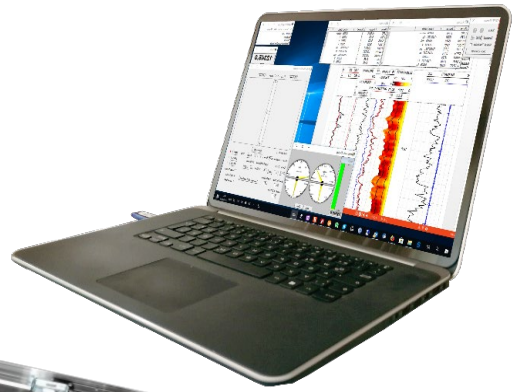
COMMUNICATION SECTION - P/N 1346.0000



NEUTRON DETECTOR SECTION - P/N 1197.1000

NEUTRON GENERATOR SECTION - P/N 1355.1000

DUAL GAMMA RAY SECTION - P/N 1356.0000



MAX TEMPERATURE:	175°C / 150 °C
MAX PRESSURE:	103MPA (15000PSI)
LENGTH:	5110MM (201,18")
TOOL OD:	43MM (1-11 / 16")
LOGGING SPEED:	3.5 M/MIN (11.5 FT/MIN)
NEUTRON FLUX:	2 X 10 N/S
NEUTRON ENERGY:	14.1 MEV
NETRON PULSE DURATION:	1 TO 3μS, REPEAT 75MS

PNN UHT 1500.0000:

HWLAC Ashbard ENERGY pnnPlus
Well Logging Equipment

HARDWARE

1500.0000 Ultra high-temperature pulsed neutron

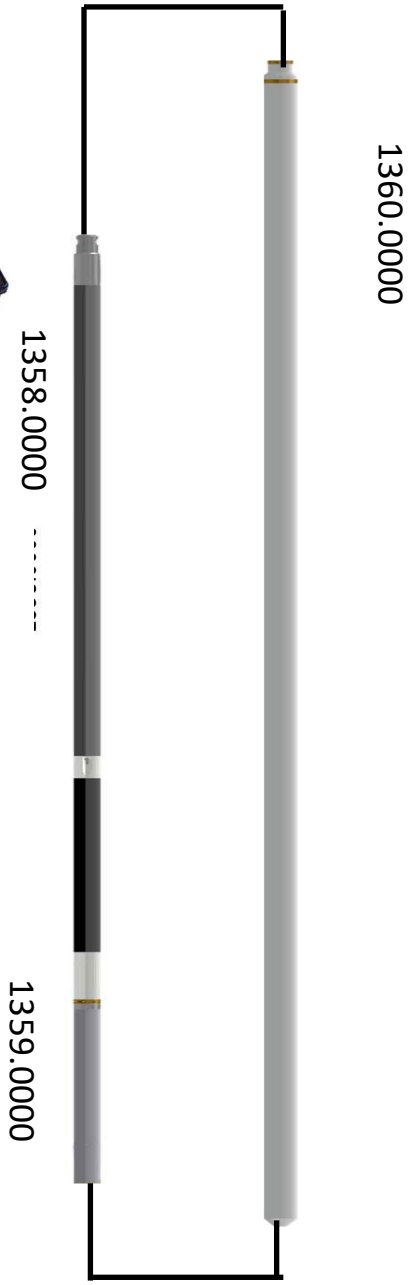
1358.0000 HT Telemetry Section

1359.0000 HT Connector Sub

1360.0000 HT Generator-Detector Section

3038.2000 Portable Surface Panel

PnnPlus HT Acquisition Logging software



MEASUREMENT SPECIFICATIONS

Logging speed: 2.5- 4m/min [8.2-13ft/min]
Range of measurement: 0 to 60 cu
Vertical resolution: 0.76m [2.5ft]
Depth of investigation 330 – 380mm [13"- 15"]

MECHANICAL SPECIFICATIONS

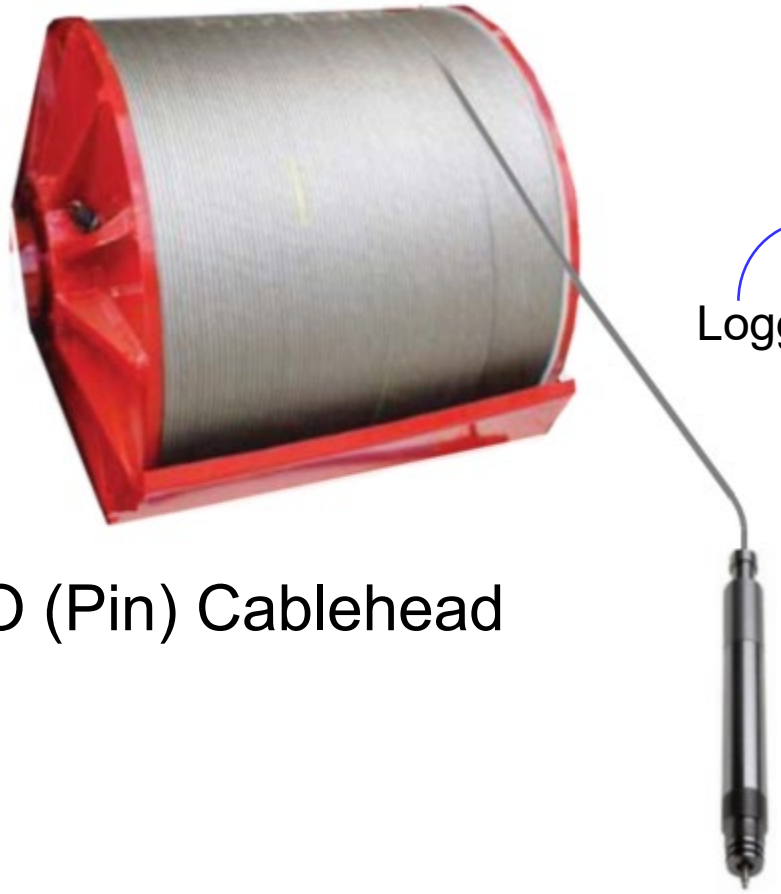
Temperature rating: 6h @ 200°C [392°F] and above
Pressure rating: 15000 psi [103 MPa]
Length: 7150mm [281.5”]
OD: 57mm [2-1/4”]
Weight: 90kg [100lb]

Logging Requirements:

Well Logging Equipment

Warrior Logging System

Mono-conductor Cable



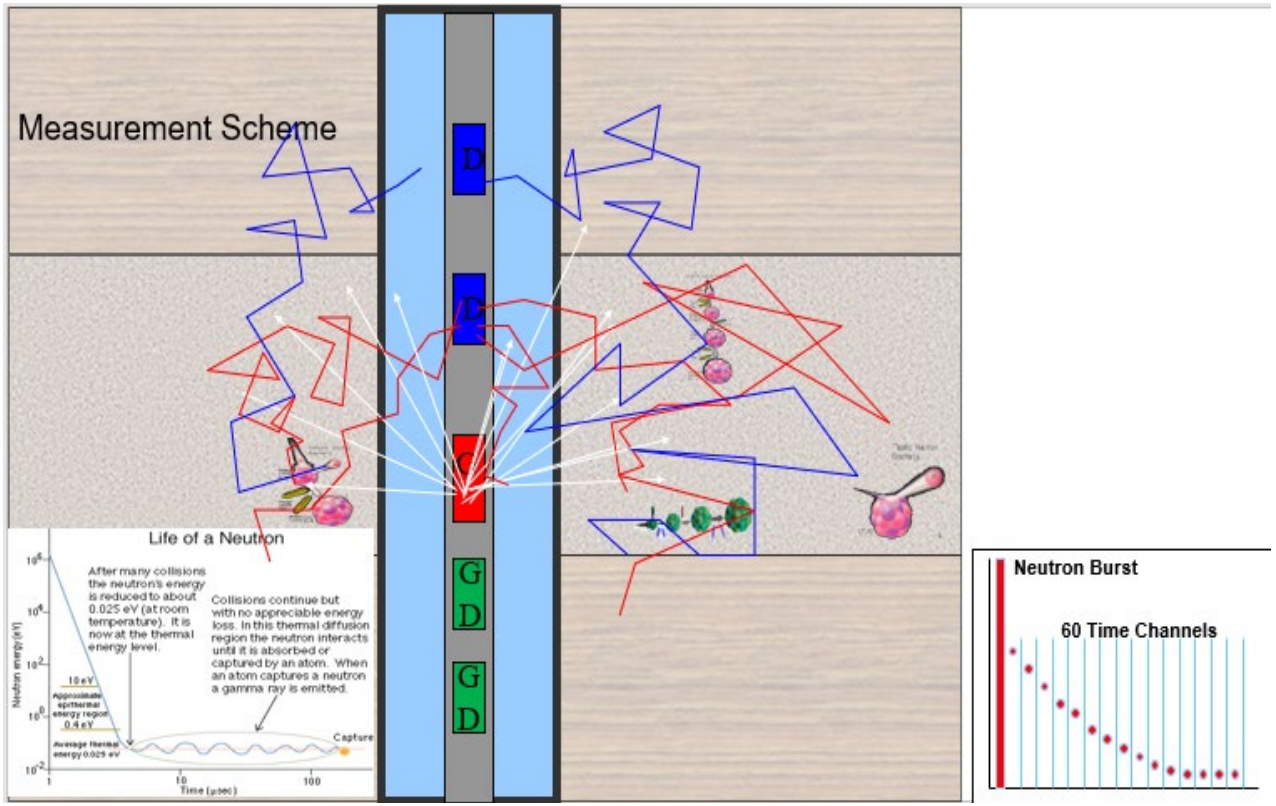
GO (Pin) Cablehead

Encoder Pulses

Logging Line

Portable Surface Panel

Tool Background Physics

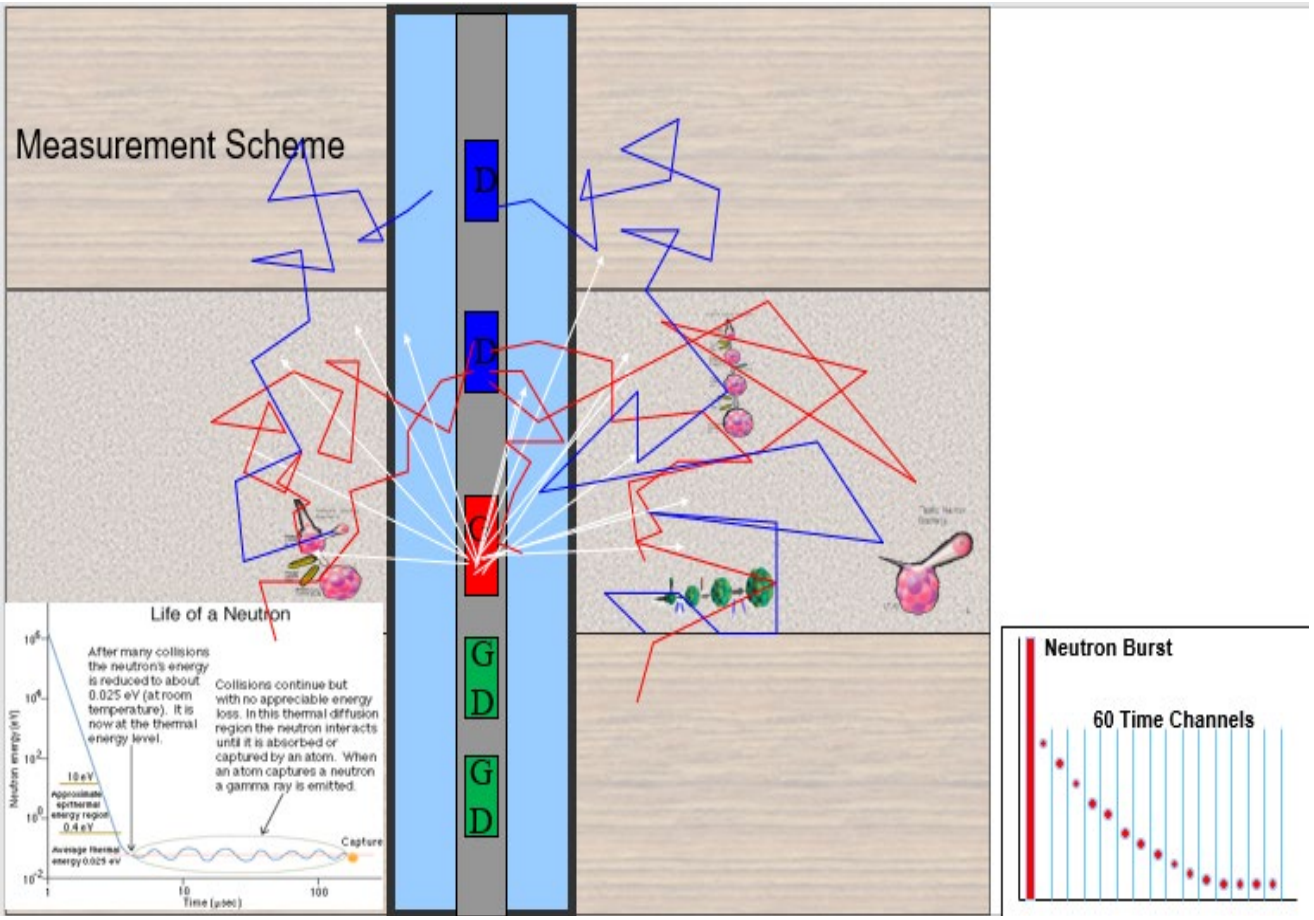


PNN tool bombards the formation with high-energy neutrons, 14.1 Mev, and these high-energy neutron undergoes elastic, inelastic collisions. When the neutrons lose kinetic energy they become thermalized. When neutrons reach the thermalized stage, they can be captured (killed, eaten up). Hydrogen has the highest neutron slowing down power while chlorine has the highest sigma(absorption cross-section, ability to capture thermal neutrons) within the formation. During inelastic collision and capture of thermal neutrons, gamma rays are emitted

The sigma of the reservoir can be computed, either by using the emitted gamma ray from thermal neutron capture, or by using the remaining count of thermal neutrons.

PNN tool uses the remaining count of thermal neutrons to compute reservoir sigma, hence has greater statistics in measurement and interpretation to delineate perfectly oil and water even in a low salinity environment even as low as 2000ppm

Tool Background Physics

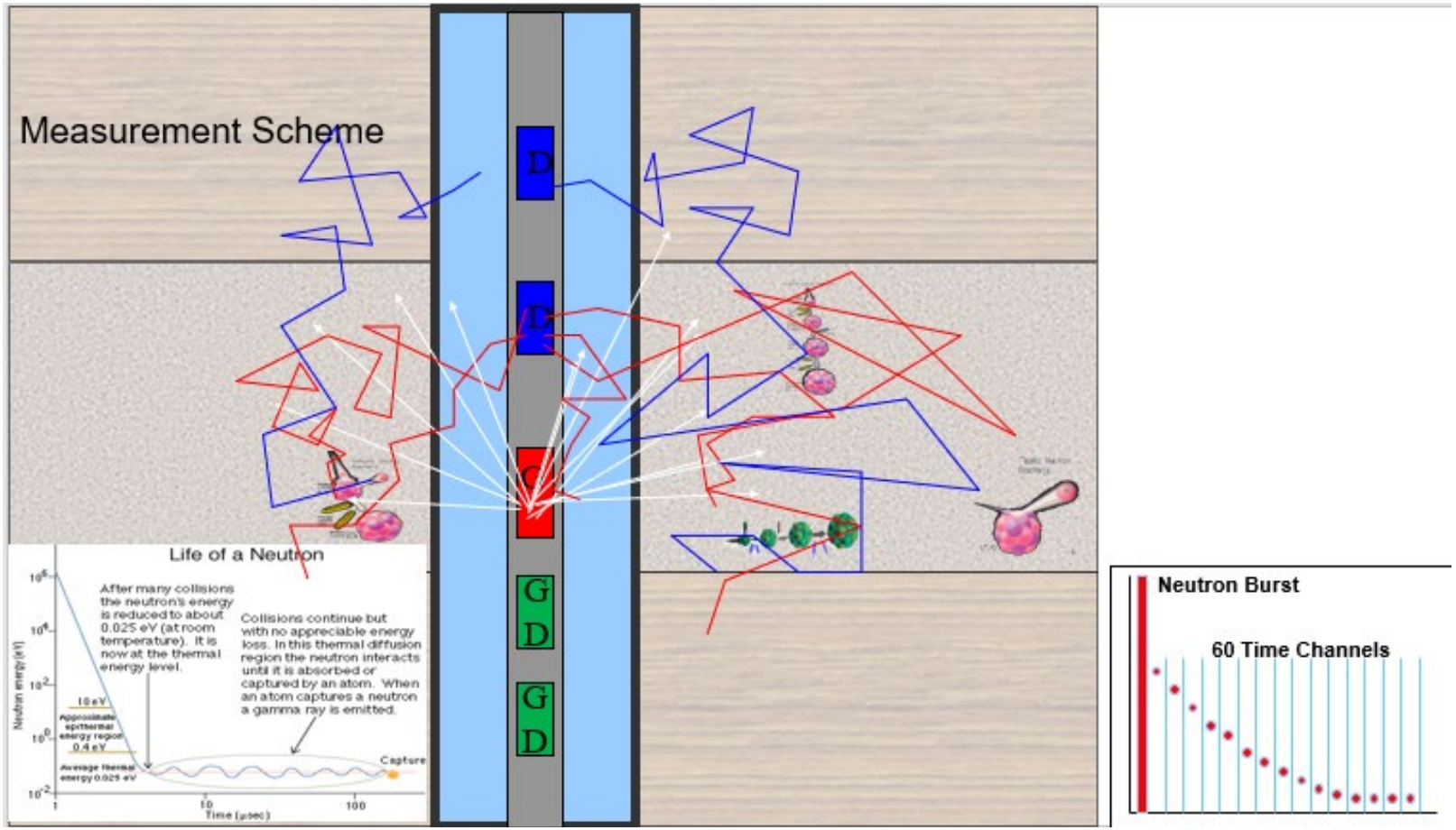


Basically, the PNNplus tool has 4 detectors to measure.

1. Long and short thermal neutron counts
2. Far and near gamma-ray activation counts

Note: Neutron has the ability to activate atoms within the formation, when the atoms are activated, they tend to return to a stable state by emitting a characteristic gamma ray. Pnnplus measures activation gamma rays from oxygen and other atoms within the formation.

Tool Background Physics



Curves from measurement are

1. LSS. Long-spaced detector thermal neutron count

2. SSN : Short_spaced detector thermal neutron count

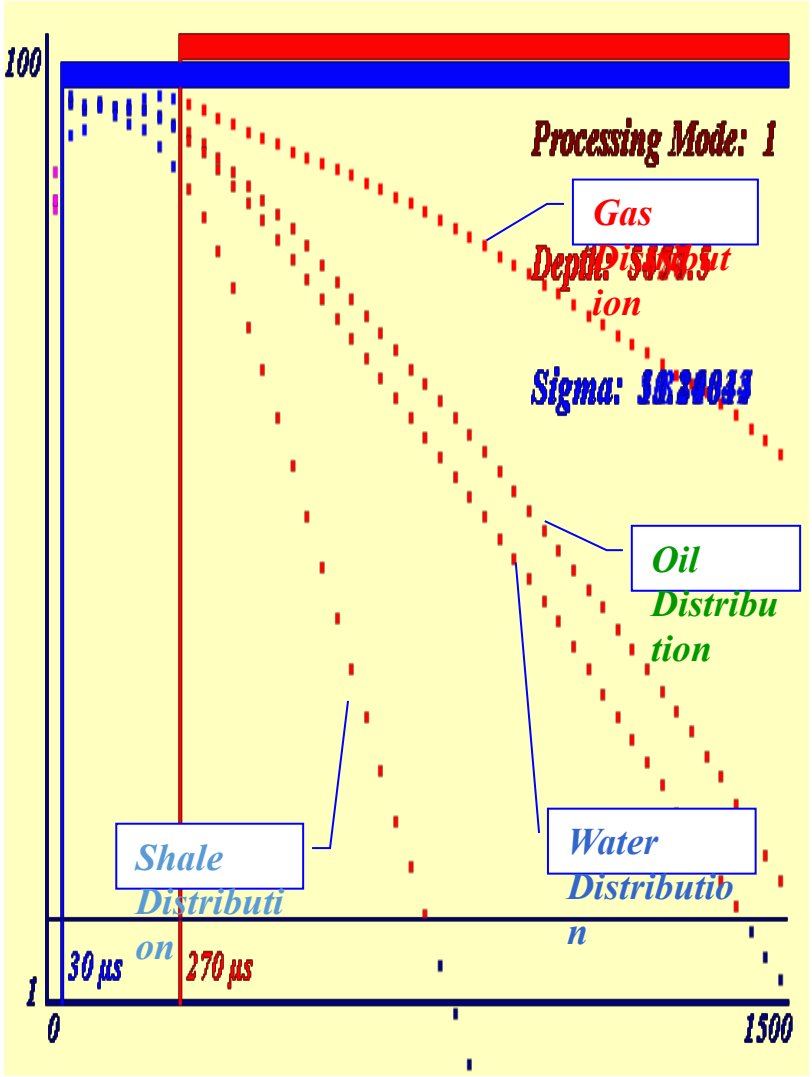
3. GRANLE : gamma-ray activation near detector low energy

4. GRANHE : gamma-ray activation near detector high energy

5. GRAFLE: gamma-ray activation far detector low energy

6. GRAFHE: gamma-ray activation far detector high energy

Sigma Processing



It is important to note that sigma computed is from the remaining counts of the thermalized neutrons, this is approach is different from sigma computed from induced gamma rays (highly influenced by salinity and might be difficult to delineate fresh water from oil).

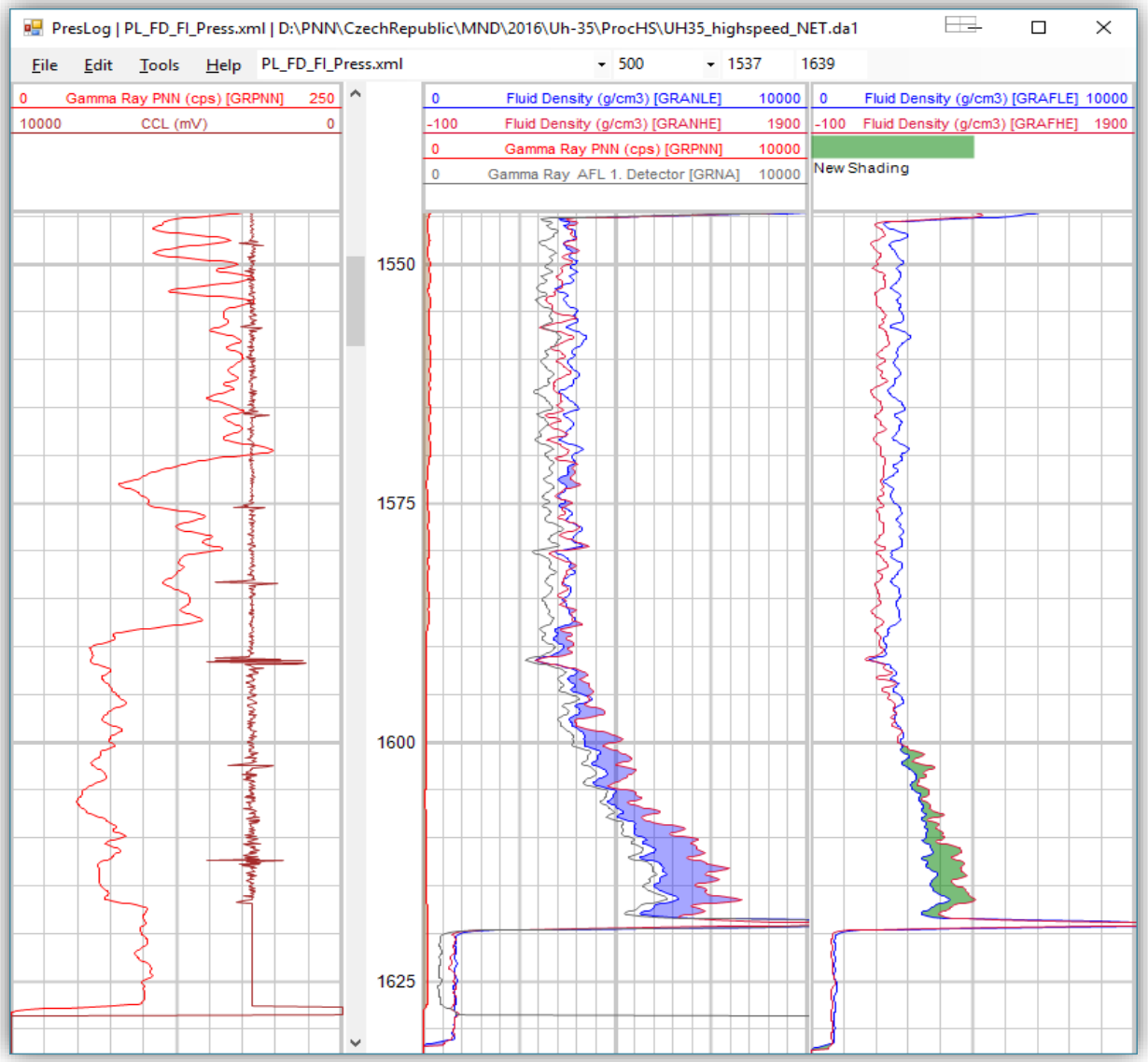
The approach of computing sigma from remaining thermalized neutron counts gives better resolution even in a low salinity environment as low as 2000ppm without needing a CO run. There are case studies in Niger-delta and abroad with accurate measurement and interpretation done with this approach using the PNN tool.
If sufficient statistics even small differences in water and oil-saturated zones can
Be interpreted with sufficient confidence.
Of course in such cases after Quantitative interpretation, these results should be judged qualitatively.

PNN Plus Description

Well Logging Equipment

GR Detectors:

- Short Spaced
  - Low Energy
  - High Energy
- Long Spaced
  - Low Energy
  - High Energy

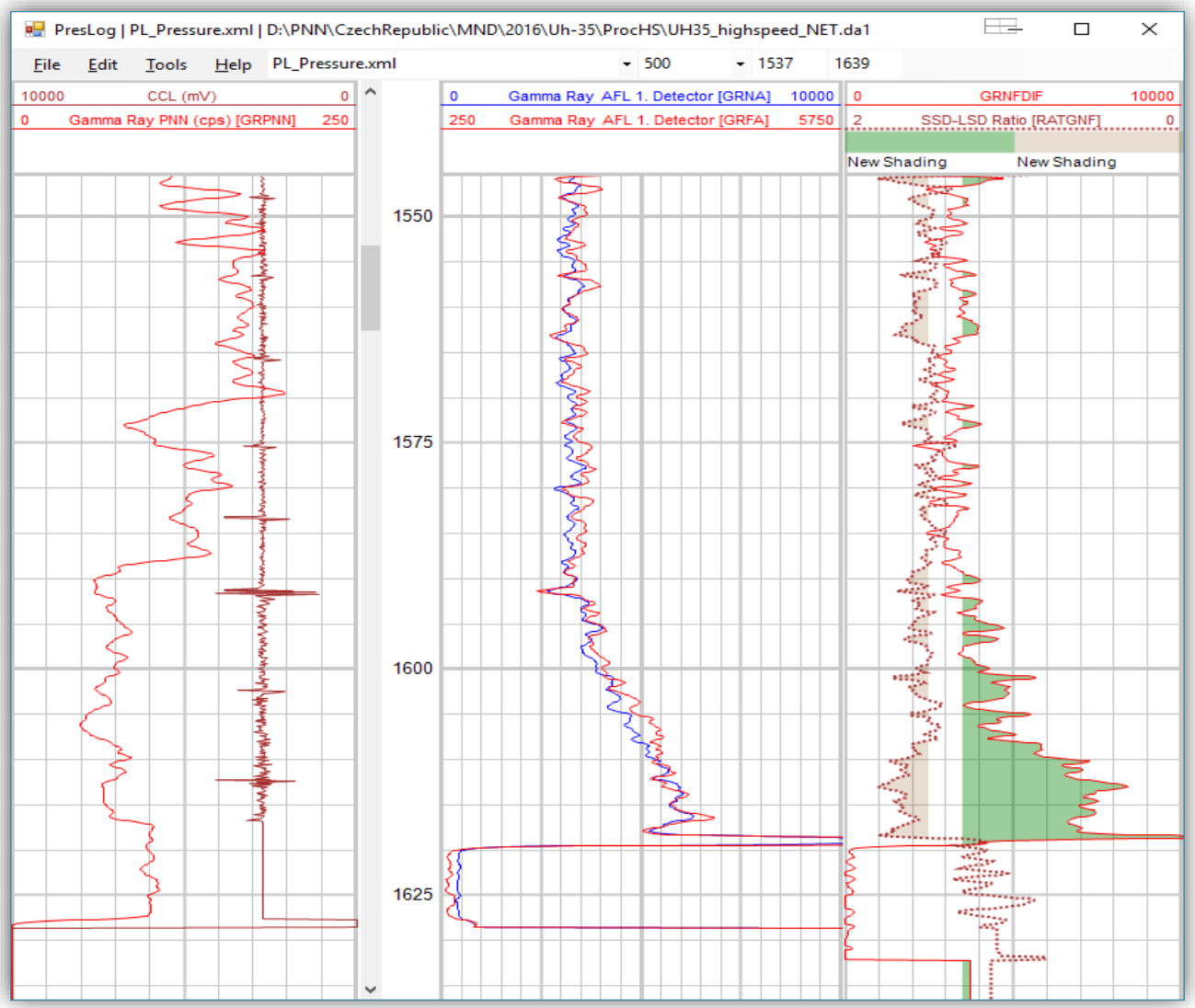


PNN Plus Description

Well Logging Equipment

GR Processing:

- Cleaning for background
  - SSG (GRNA)
  - LSG (GRFA)
- Calculating
  - Difference (GRNFDIFF)
- Ratio (RATGNF)
  - Near/Far Low Energy
  - Near/Far High Energy
  - Near Low/High Energy
  - Far Low/High Energy

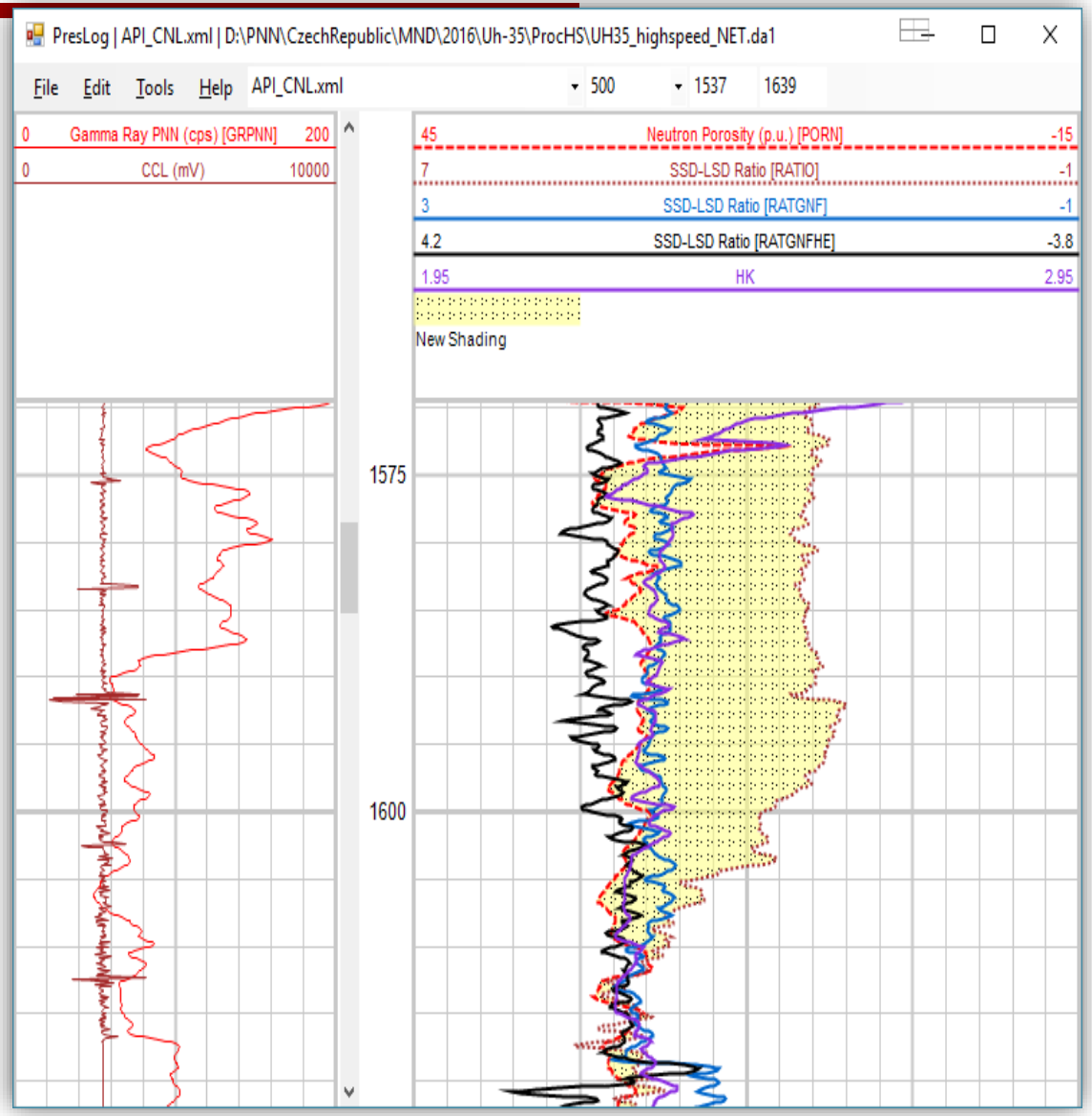


PNN Plus Description

HWLAC Ashbard ENERGY pnnPlus
Well Logging Equipment

Improved Porosity Measurement:

- PNN Porosity
  - SSN/LSN Ratio
  - RATPOR – compensated neutron porosity
- PNN Plus Porosity
  - SSN/LSN Ratio
  - RATPOR – compensated neutron porosity
  - SSG/LSG Ratio – Captured Gamma Porosity

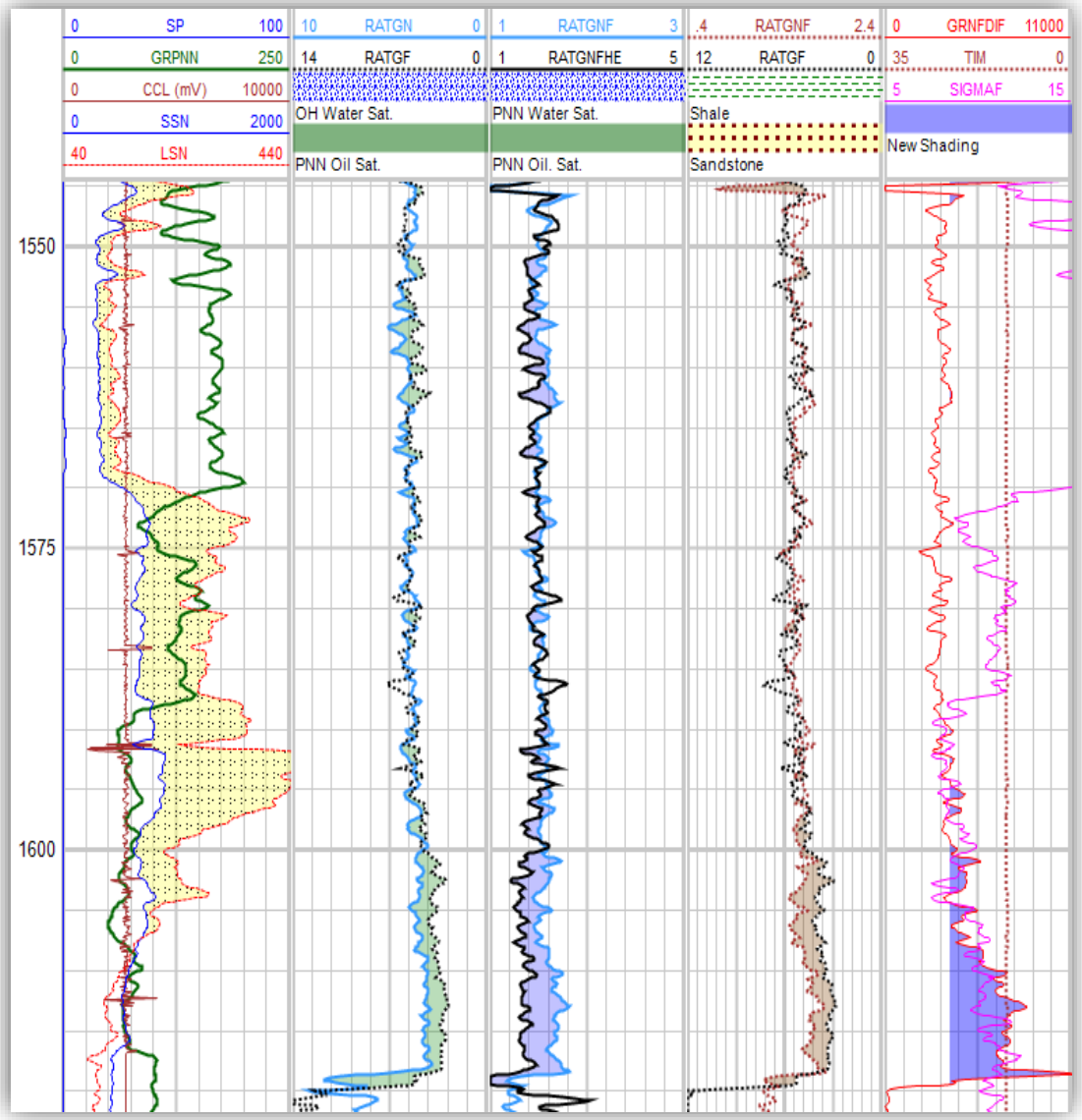


PNN Plus Description

HWLAC Ashbard ENERGY pnnPlus
Well Logging Equipment

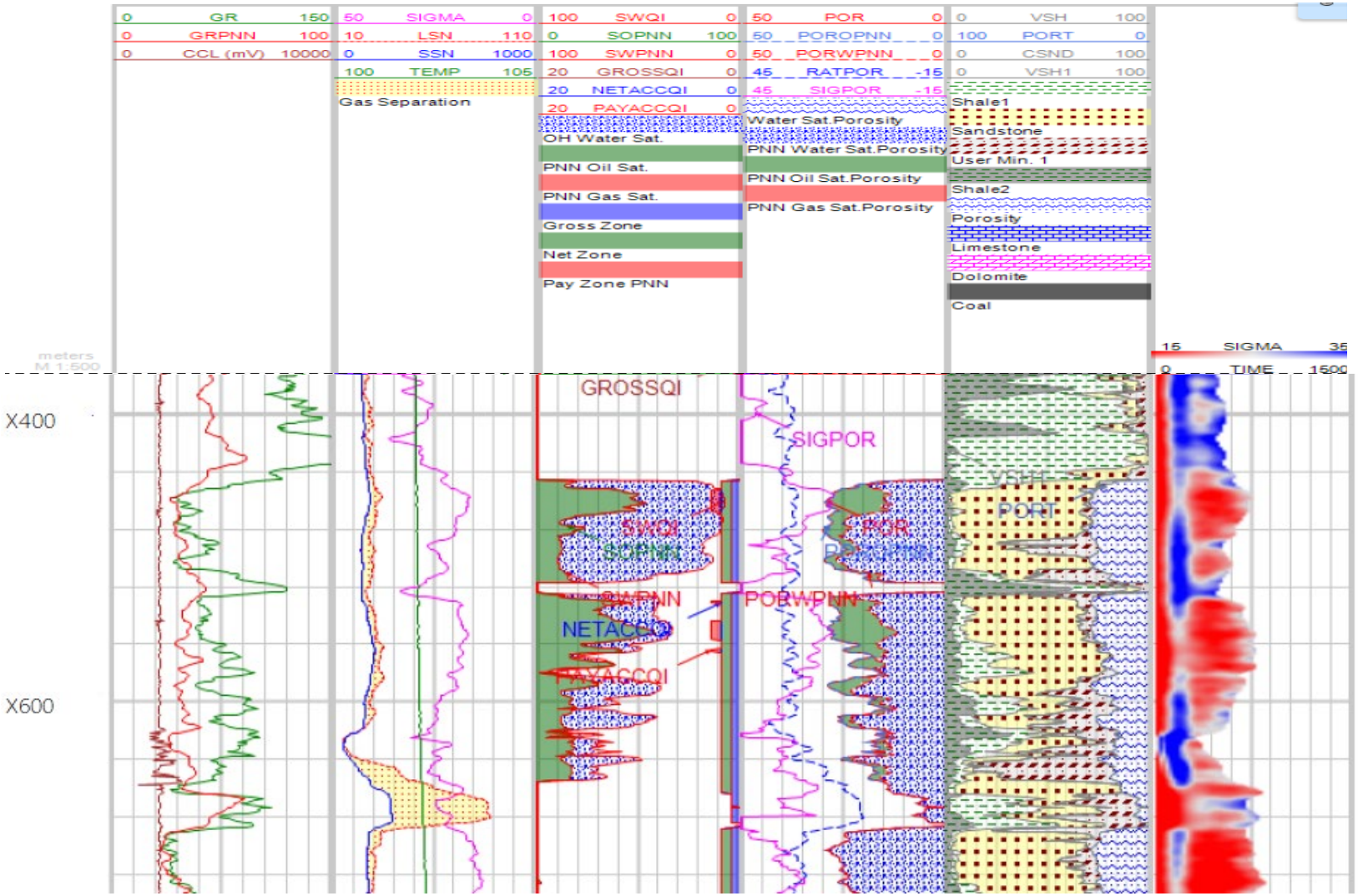
Improved Lithology Interpretation:

- Matrix Lithology
  - Si/Ca Ratio is measure of matrix lithology
  - Clear The Differences in lithology making more correct input for saturation interpretation
  - Other material as Al



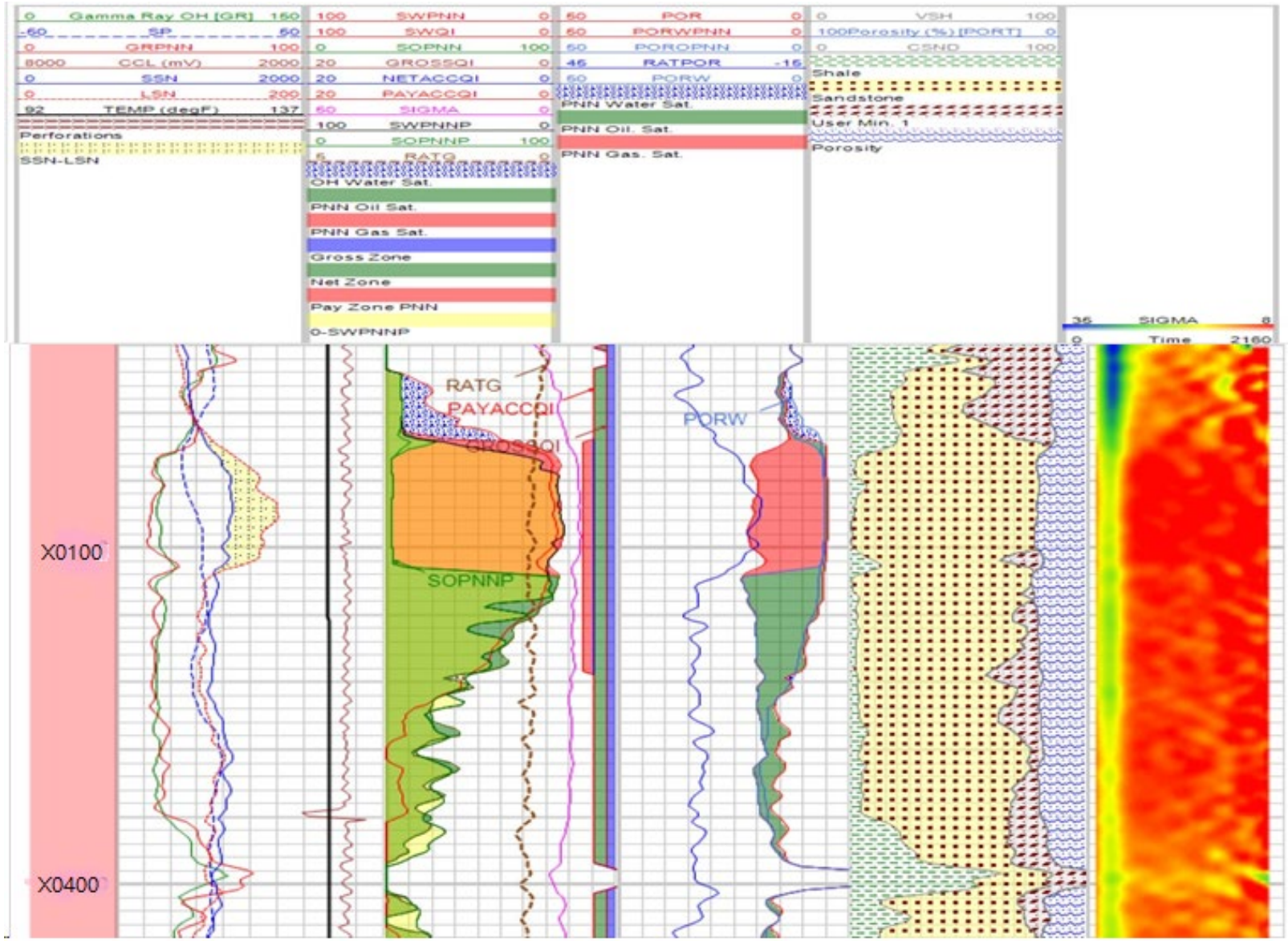
Standard PNN Example Niger-delta

Well Logging Equipment



PNNplus Example Niger-delta

HWLAC Ashbard ENERGY pnnPlus
Well Logging Equipment



Benefits and Applications

HWLAC Ashland ENERGY pnnPlus Well Logging Equipment

- Ultimate results in low, high, mixed and unknown salinity environment (no need for a separate C/O pass)
- Gravel pack analysis
- Substitute to open-hole triple combo
- Requires only Two Passes (Main and repeat)
- Water flowability behind pipe
- Excellent gas indicator and compensated neutron porosity analysis
- Stop check measurements
- Interpretation results within 12- 24 hours
- Experience knowledge database of more than 10,000 interpreted wells
- Small Diameter (1-11/16”) – can pass through the tubing
- Not dependent on the equipment or the fluid in the borehole
- Cost effective service solution

Summary

Huge amount of work already done

- Many real well examples in known and unknown conditions
- PNNPlus Services from PNNPlus company almost completely replaced standard PNN measurement.
- TOTAL test facility – Poe (France)

- Continuing to improve
  - Field characterization
  - Processing and interpretation models

THANK YOU

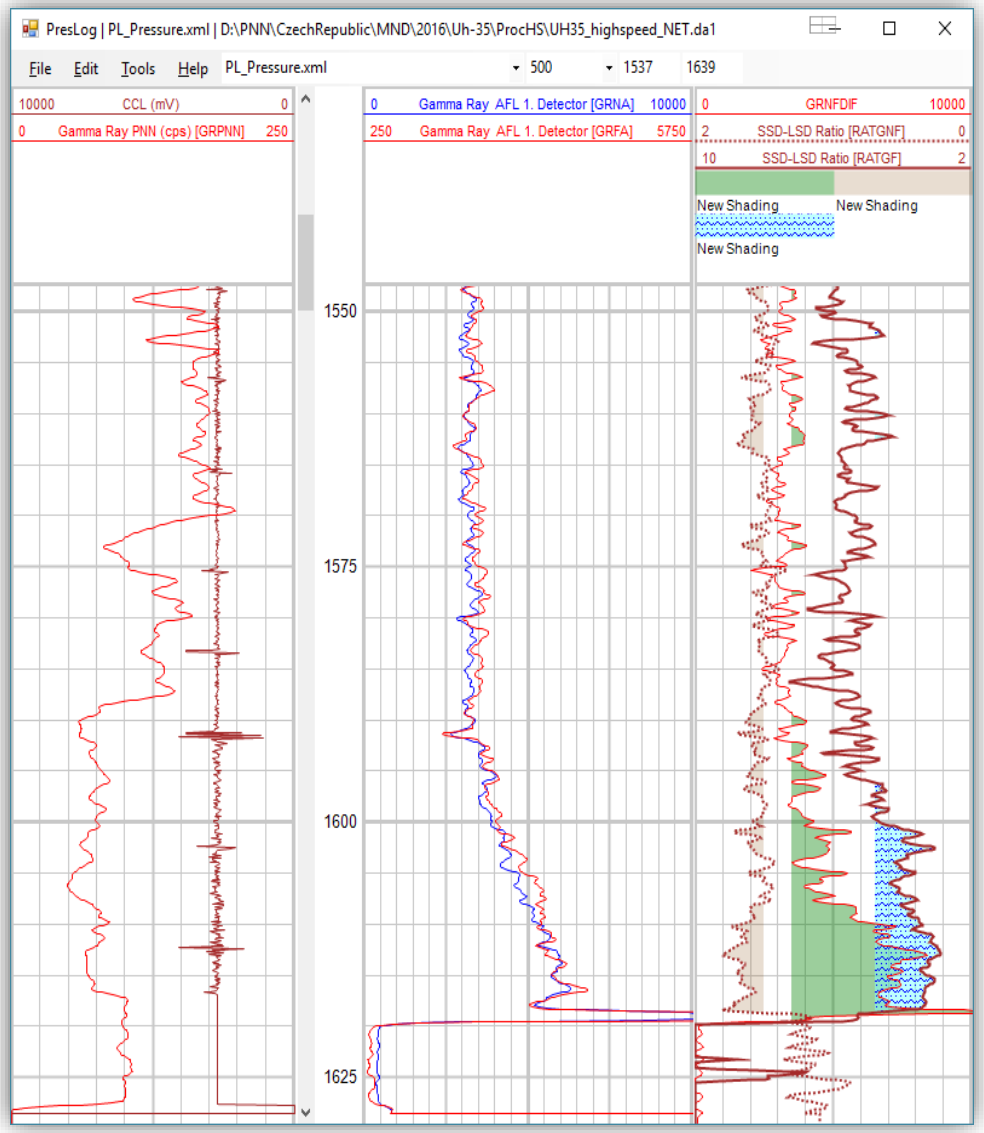
? QUESTIONS

PNN Plus Description

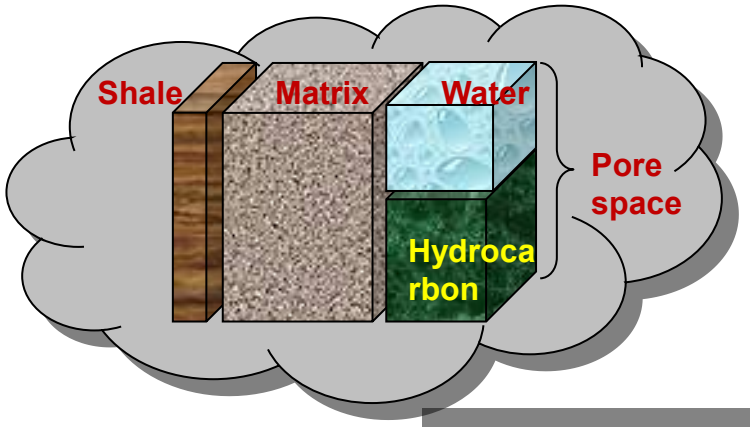
HWLAC Ashbard ENERGY pnnPlus
Well Logging Equipment

Improved Saturation Interpretation:

- Ratios can additionally improve and define points of high oxygen activation in reservoir indicating possible higher water saturation. Improving water saturation calculation in unknown water salinity zones
  - Near/Far Low Energy
  - Near/Far High Energy
  - Near Low/High Energy
  - Far Low/High Energy



Standard Approach For Quantitative Sw Interpretation From Sigma Curve



Rock Matrix

Shale

$$\Sigma_{Log} = (1 - V_{sh} - \varphi)\Sigma_{ma} + V_{sh}\Sigma_{sh}$$

Hydrocarbon

Water

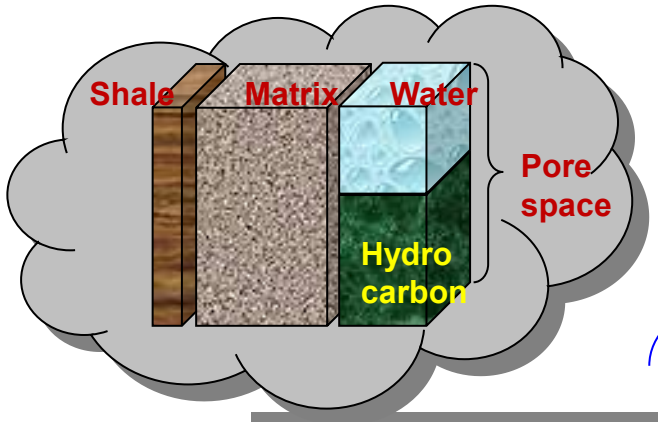
$$+\varphi(1 - S_w)\Sigma_h + \varphi S_w \Sigma_w$$

After Solving Previous Equation

$$S_w = \frac{(\Sigma_{Log} - \Sigma_{ma}) - \varphi\ (\Sigma_h - \Sigma_{ma})}{\varphi\ (\Sigma_w - \Sigma_h)}$$

$$- \quad \frac{V_{sh}(\Sigma_{sh} - \Sigma_{ma})}{\varphi\ (\Sigma_w - \Sigma_h)}$$

Standard Approach For Quantitative Sw Interpretation From Sigma Curve



Rock Matrix

Shale

$$R_{Log} = (1 - V_{sh} - \varphi)R_{ma} + V_{sh}R_{sh}$$

Hydrocarbon

Water

$$+\varphi(1 - S_w)R_h + \varphi S_w R_w$$

After Solving Previous Equation

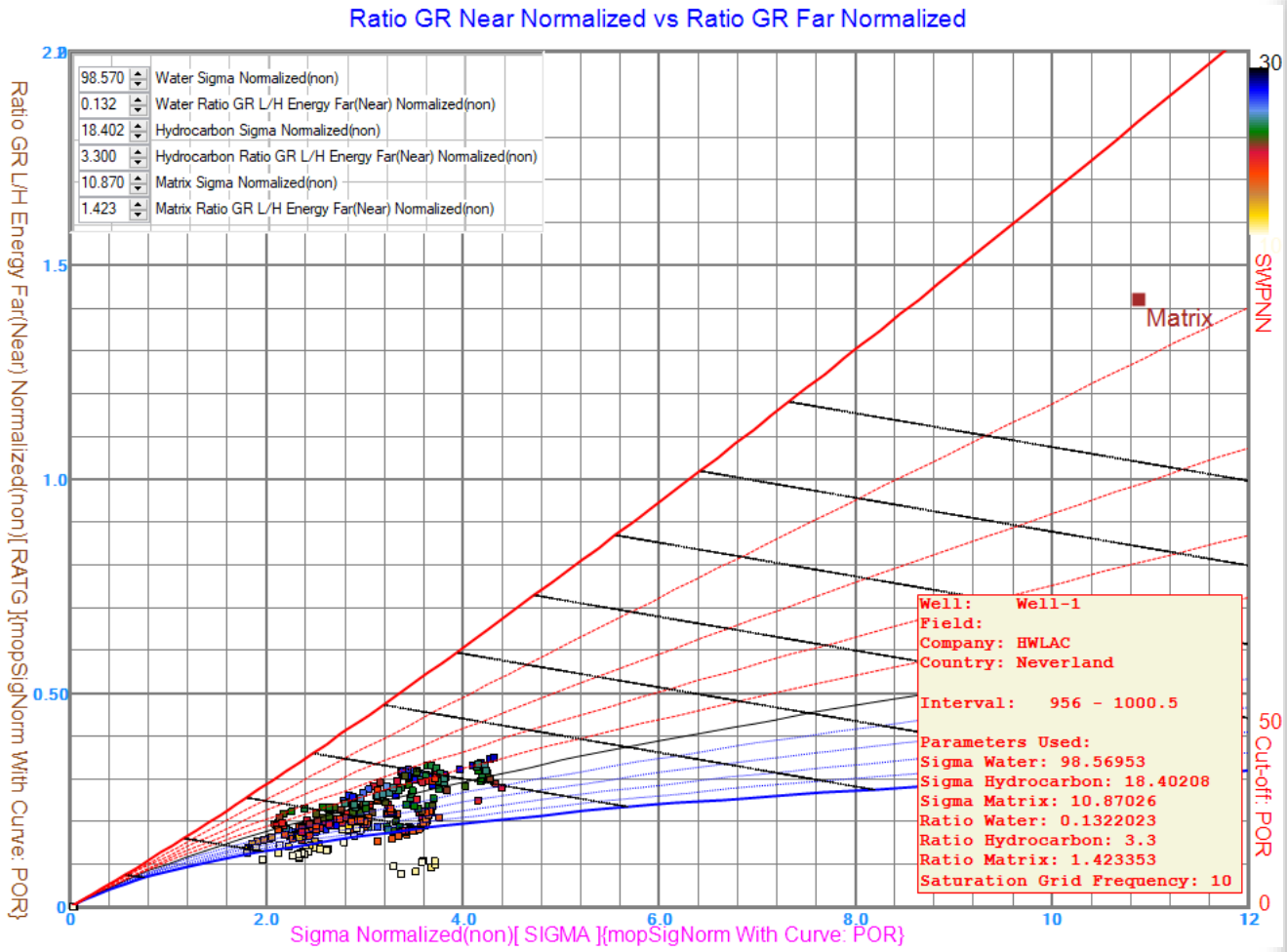
Well Logging Equipment

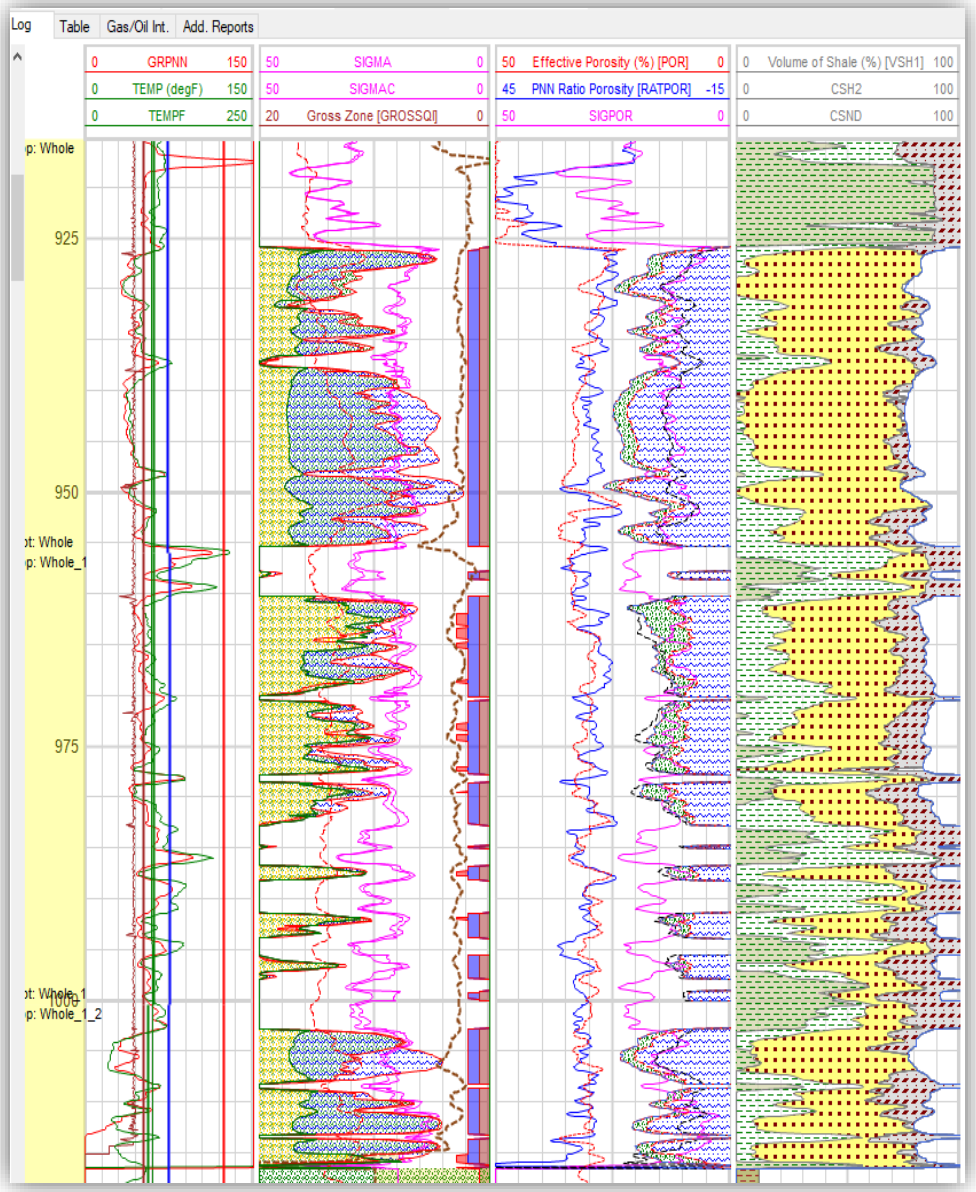
$$S_w = \frac{(R_{Log} - R_{ma}) - \varphi\ (R_h - R_{ma})}{\varphi\ (R_w - R_h)}$$

$$- \frac{V_{sh}(R_{sh} - R_{ma})}{\varphi\ (R_w - R_h)}$$

Graphical Interpretation Model

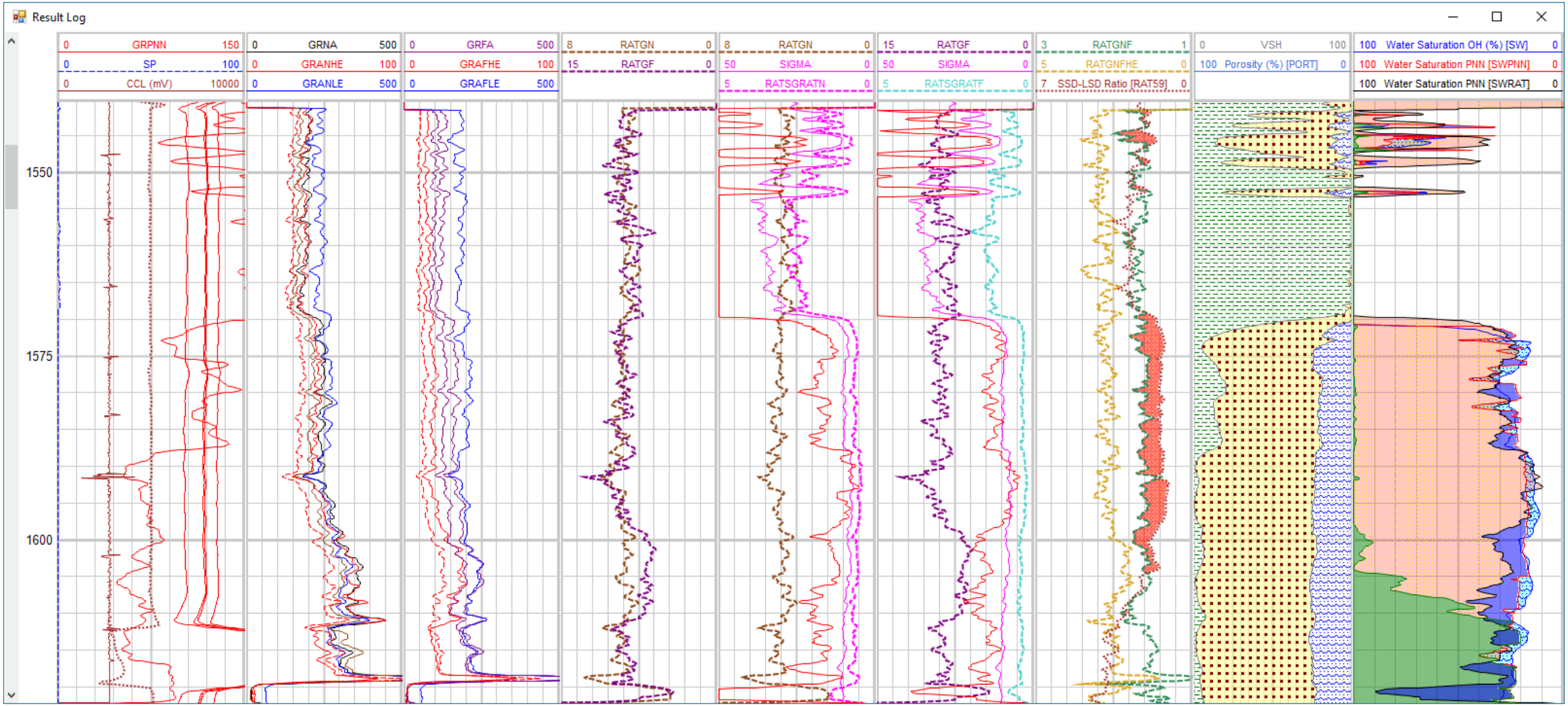
HWLAC Ashland ENERGY pnnPlus
Well Logging Equipment





Example

Well Logging Equipment



Example PNNplus

HWLAC Ashland ENERGY pnnPlus
Well Logging Equipment