Advanced Chromatography, Cuttings Analysis and Well Logging Integration: An Optimized Petrophysical Approach*

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Abstract

The characterization and petrophysical evaluation from conventional electric logs has become a real challenge when interpreting unconventional reservoirs or reservoirs characterized by the presence of fresh water and/or heavy oil fluids. The use of surface logging tools such as quantitative gas detectors in combination with the geochemical analysis of rock cuttings, utilizing XRD, XRF and Pyrolysis (TOC) instruments, has greatly aided the identification and characterization of hydrocarbon zones. In addition, it allows identification of the water content, which is obtained from Pixler ratios and aromatic hydrocarbon content. Another important consideration in evaluating the reservoir is a need to consider the effects of salinity, clay content, and laminations. The use of the advanced gas/geochemical analysis and its interpretation has solved models for hydrocarbon saturation in areas where high uncertainty exists or where, for economic or other reasons, it was not possible to acquire full sets of electric logs. This combination of surface logging techniques and interpretation method provides a reliable characterization solution.
Advanced Chromatography, Cuttings analysis and Well Logging integration

An Optimized Petrophysical approach

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Weatherford LTD Colombia.

Rio de Janeiro | 18-19 May 2016
General Overview

- Diversity on structural, stratigraphic and Petrophysic characteristics

Characterization Sources

- LWD / Wireline
- Core
- Cuttings

Byproduct of drilling (free)
Ideal Scenario

- **Porosity Lithology Textural**: Triple Combo - Spectral GR - SP + Dipolar Sonic + Image + Mineralogy
- **Porosity Distribution Geomechanic**: Image + Dipolar Sonic + NMR
- **Permeability Index**: NMR+ Pressure Points
- **Saturations**: Saturation Tools/Dielectric Tools
- **Fluid Properties**: NMR

Validated against RCA, SCA, PVT
Ideal Scenario
Petroleum Industry Reality

➢ Economic CHALLENGES
  ✓ Keep Developing Reservoirs in a OIL LOW PRICE SCENARIO

➢ Operational CHALLENGES
  ✓ Trip Time Savings/ Closing Wells.
  ✓ Avoid Risk on OH Logging, Mainly Special Services

➢ Characterization CHALLENGES
  ✓ Complex Lithology
  ✓ Fluid Reservoir Characterization
  ✓ Unconventional Reservoir
  ✓ Others.
Optimized Data Acquisition

- LWD/WL
- X Rays Fluorescence
- X Rays Diffraction
- Pyrolysis Advanced Chromatography

- Triple Combo/Quad Combo
- Lithology, Rock Properties
- Total Hydrocarbon, Fluid Quality

> Interest Zones Identification (Real Time or Not)
> More Accurate Evaluation of Production Scenarios
> Reliable Solution for Reservoir Characterization
Geochemical Analysis

X Rays Fluorescence

X Rays Diffraction

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

Pyrolysis Equipment

- Free Hydrocarbon Content (Gas/Oil) – $S_1$
- Remaining Generative Potential – $S_2$
- Organic Richness – TOC
- Thermal Maturity – $T_{max}$
Advanced Chromatography

Delta System

\[
\text{Gas Out} = \text{(Formation Gas)} + \text{Recycling gas} + \text{Mud additives}
\]
Advanced Chromatography

- Total Hydrocarbons Content: THC
- Index Fluid Mobility: FM
- Index Fluid Saturation: FS
- Aromatics/Alkanes Ratio
- C1/C2 Ratio
- C6/C7 Ratio
- C1% Ratio
- Liquids Ratio
- Gas/Liquids ratio

- Delimitation of Interest Zones
- Fluid Typification
- Change in Fluid Typing
- Connectivity or compartmentalization
- Correlation
- Geosteering
<table>
<thead>
<tr>
<th>Analysis</th>
<th>Min sample (g)</th>
<th>Destructive?</th>
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<tbody>
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<td>Photography</td>
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<td>Thin Section</td>
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<tr>
<td>Cap Pressure</td>
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<tr>
<td>CST</td>
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### Cuttings Lab analysis

<table>
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<th>Analysis</th>
<th>Min sample (g)</th>
<th>Destructive?</th>
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</thead>
<tbody>
<tr>
<td>Gas Comp</td>
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<td>TOC by LECO</td>
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<td>Pyrolysis</td>
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<tr>
<td>Vitrinite Reflectance</td>
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<td>Y</td>
</tr>
</tbody>
</table>

![Graph showing analysis results]
Elemental GR Calculated from K, Th, U

- Calculated from K, Th, and U measured by XRF
- Used to perform quality control on cuttings depth and as backup to LWD gamma
- Can be paired with LWD spectral gamma
Real Cases
Fitting Solutions to Challenges

**OPERATIONAL**

- **Saving Operational Times**
  - Minimize Rig Time
  - Minimize Operational Risk (Tight Hole & Open Hole Logging Hold ups)

**CHARACTERIZATION**

- **Assuring a Complete set of Information**
  - Reservoir Characterization
  - Stimulation Jobs
  - Completions
  - Others.
Making More of Existing Data

<table>
<thead>
<tr>
<th>Porosity Lithology Textural</th>
<th>Triple/Quad Combo + XRD + XRF</th>
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</thead>
<tbody>
<tr>
<td>Permeability Index</td>
<td>Advanced Chromatography</td>
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<tr>
<td>Saturations</td>
<td>Triple/Quad+ Advanced Chromatography</td>
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<tr>
<td>Fluid Properties</td>
<td>Advanced Chromatography</td>
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</tbody>
</table>

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