Petrophysics and Well Log preparation service

‘QI Prep Service’
So your company has just acquired some new acreage and is looking at exploring a different part of the basin?

You have been given well log data and seismic data from the partner company in the block and you need to make your own interpretation.

However there is a problem ... the data needs careful review to consider its suitability for future possible Rock Physics & QI work ....
Potential issues with the data …

• The data could be inconsistent, poor quality or just unfamiliar ….

• The Petrophysics for different wells may have been performed by different Petrophysicists over the years and a level of consistency needs to be achieved.

• Several of the wells may be affected by washed-out hole in Shale sections, missing shear log data and gaps in the log coverage over important intervals.

• The area is also unfamiliar and you need to know if you are looking at hard Sands or soft Sands, the Shale properties and the expected response on the seismic for hydrocarbons ….
• Interpreters looking at data associated with a new area might wish to know the basic Rock Physics at the wells before beginning interpretation across the survey area.

• A Rock Physics study usually includes;
  • Examine the well log data available (with Petrophysics curves present)
  • Well logs conditioned to fill missing sections of log data
  • Understand elastic properties of the different fluid cases (Brine, Oil and Gas) modelled through Gassmann fluid substitution
  • Understand the AVO signatures from either blocky models or synthetic gathers
  • Examine multi-well trends and Porosity-depth trends to understand the geology of the area across different stratigraphic intervals.
  • Tuning wedge models from the main reservoir sand and shale properties
How can I solve these issues ...

- Don’t battle with the data yourself - get an early insight into the suitability of the data for potential QI and Inversion project work at the outset and feel confident in your initial decision making and project evaluation.

- BlackRockQI can offer an early stage Petrophysics and Well Log Preparation service and guide your interpretation of the Seismic using QI models from the well log data.

- The deliverables are consistent Petrophysical curves, a full suite of complete Vp, Vs and RHOB logs for a range of different hydrocarbon fluid cases (with any gaps modelled from locally calibrated trends), cross-plots to highlight the optimum elastic properties for fluid/lithology discrimination and AVO models at each reservoir interval.

- Particularly beneficial in regional studies to guide an interpretation and provides value to the clients in prospect identification

- Firstly let’s look through the Petrophysics stage of the workflow in the following slides ...
Petrophysics workflow used for QI

A. **Data preparation.**

After checking and making an inventory of all data available the following steps are performed:

- Well data load. LAS/LIS, Core data, Formation tops and Deviation surveys data are loaded onto the project.

- Composite & Depth shift curves (if needed)

- Environmental/Matrix corrections (if needed)

- Standardize curve names. A Schlumberger naming convention is preferred.
Petrophysics workflow used for QI

B. Generate Well parameters

After checking all corrections & editing has been done, the following further analysis is performed:

- Estimate other curves. i.e. Formation temperature, Rw and Salinity
- Curve editing (if needed). In case of data been affected by washouts and rugose boreholes.
- Create VP & VS (in needed). This is done from Compressional and Shear sonic.
- Create other Elastic curves such as Acoustic Impedance and Poisson’s ratio.
C. Petrophysical Interpretation.
   After all the relevant curves has been edited and corrected, an interpretation is made:

- **Calculate Mineralogy.** Includes composite and mud logs, volumes of quartz, calcite, Dolomite, Coal, Salt etc.. are created.

- **Estimate Porosity.** Uses core data, if available and density, neutron and sonic methods.

- **Determine Water Saturation.** Archie-type formulae and Pickett plots for determining salinities.

- **Calculate TOC.** By using Passey’s method which uses resistivity and sonic curves.
Petrophysics workflow steps used for QI

1. Clay volume determination
2. Porosity estimation
3. Water saturation calculation
4. Petrophysical Interpretation
What about the Rock Physics? ...

- The Petrophysics workflow is carried out by an experienced Petrophysicist and this workflow will ensure consistency across all Petrophysical curves in the area.

- With a full set of Petrophysical curves now available at each well, why not consider carrying out some Rock Physics work?

  Rock Physics provides the key link between well log data and seismic data.

- BlackRockQI offer a Well Log preparation service and a consistent workflow and log naming convention is used on all of our projects.

- BlackRockQI offer a Rock Physics workflow to guide interpretation of the Seismic and is applied consistently for each well. This workflow comprises of three parts and is detailed on the following slide ...
More details (Rock Physics) …

**Single Well Rock Physics – Part 1**

Single Well Rock Physics - Part 1 is the name given to the section of the workflow containing the initial set up work for the Rock Physics project.

The aim of this section is work to output conditioned well logs at 100% Brine conditions for trend analysis in the multi-well analysis section.

The following steps are typically carried out:
- Data loading (logs, tops, deviation surveys, check-shots)
- Visual overview at each well
- QC cross-plots of Vp-Vs and Vp-Rho log data
- Log edits of erroneous log data
- Deriving fluid properties using FLAG fluid calculator
- Deriving elastic properties (bulk modulus, shear modulus) for clean shale points
- Gassmann fluid substitution from INSITU conditions to ensure that all log data is at 100% Brine conditions.

**Single Well Rock Physics – Part 2**

Single Well Rock Physics - Part 2 is the name given to the section of the workflow containing the results for the Rock Physics project and end of the core workflow.

The aim of this section is work to ensure that each well has a full suite of Vp, Vs and RHOB logs and examine how the elastic properties will change for each fluid case in the reservoir intervals. These results are used to guide Inversion work or any other more advanced Rock Physics modelling.

The following steps are typically carried out:
- Modelling missing sections of log data with derived trends from the Multi-well analysis
- Carrying out Gassmann fluid substitution to ensure that all remaining log data was at 100% Brine conditions
- Carrying out Gassmann fluid substitution to model the log response to 80% Oil and 90% Gas conditions
- Generating elastic logs to observe the elastic response at each fluid case as an overview at each well
- Constructing simple Blocky AVO models using average properties of clean sand points
- Generating Synthetic Gathers with a simple Ricker wavelet
- Generating Ai-PR and LR-MR cross-plots to guide the Inversion stage of the project

**Multi-well analysis**

- The multi-well analysis section of the project compares well log data from the project to established Rock Physics models. Only data at 100% Brine conditions is used in this analysis and if Gassmann Fluid Substitution is not possible in Single Well Rock Physics - Part 1 due to missing log data then saturation cut-offs will exclude hydrocarbon zones.
- The cross-plots of Vp-Rho and Vp-Vs will be made using data from every well in the following Intervals Palaeocene, Forties (including Forties and Base Forties), Balmoral and Andrew Sands Fm and these will be for clean lithology points of clean shale (VSh=0.8) and clean sand (V含_Sand=0.8).
- The trends derived from these cross-plots will be used to accurately model missing log data and derive a full suite of Vp, Vs and Rho logs over the interval of interest.

<table>
<thead>
<tr>
<th></th>
<th>Vp-Rho (Shale)</th>
<th>Vp-Rho (Sand)</th>
<th>Vp-Vs (Shale)</th>
<th>Vp-Vs (Sand)</th>
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</thead>
<tbody>
<tr>
<td>Palaeocene</td>
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<td></td>
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<td>Balmoral</td>
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<tr>
<td>Andrew</td>
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Any missing log data outside the interval of interest will be modelled using default Greenberg-Castagna and Gardner coefficients.
Initial well log panel identifies potential wash-out zones by comparing caliper log with bit size log. A general overview is also carried out of log data quality and erroneous areas are noted for further investigation.
Poor quality data is identified on initial QC cross-plots and removed from the Rock Physics study.
Fluid properties and shale mineral values are calculated in this section and used as input to Gassmann Fluid Substitution. Gassmann Fluid Substitution is carried out from INSITU to 100% Brine conditions.

The results show that the hydrocarbons in the Balmoral Fm have been substituted to 100% Brine conditions. The Vp and density logs both increase as brine is denser than the hydrocarbons whereas the Vs log shows a slight decrease.

The increase in the density log is more pronounced over the gas leg of the reservoir.

No hydrocarbons are present in the Andrew Fm (100% Brine conditions) and no fluid substitution is needed in this zone.
Examples ...

Multi-well analysis

Vp-Rho and Vp-Vs cross-plots using all the available well log data are analyzed to find the most suitable trends for the project area.
Examples ...

Multi-well analysis

A point density plot is used to find the best fitting trend to the data.
Log modelling with trends derived from the multi-well analysis ensures that a full suite of Vp, Vs and RHOB logs are available at 100% Brine conditions.
The full suite of Vp, Vs and RHOB logs available at 100% Brine conditions are now Gassmann fluid substituted to 80% Oil and 90% Gas conditions.
Elastic logs are generated for each fluid case and show the most promising attributes for separating hydrocarbon sand and brine sand.
Clean sand values can be found from Gassmann fluid substituted data and these can be compared to the Shale mineral values to form Blocky AVO plots.
Black Rock QI provide a Rock Property spreadsheet to summarize the findings of the study.

All tops are given in MD (ft)

<table>
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A study with BlackRockQI can add value by improving consistency and organization of the Well Log data in the early stages of the exploration cycle.

Initial models can be created with the Well Log data and can be used to enhance Seismic Interpretation of a new area for an interpreter.

A Rock Property spreadsheet is a quick look tool for understanding the Rock Properties of the area.

The project work can be revisited later in the exploration cycle and specific questions investigated in the Seismic Interpretation, providing a fuller knowledge of the prospect from an early stage of the project.