Submission code: 7QRKY5VJAW

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Well Log Correction with Rock Physics Modelling in the Volve Field

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Abstract Summary

We employ an iterative petrophysics and rock physics workflow to improve the quality of the well log data available in a subset of the Volve dataset. We started with raw logs, performed basic petrophysics corrections, determined the mineralogy with a stochastic approach and used this data to calibrate the rock physics model. We highlight the differences between measured and modelled elastic logs to identify the sources of mismatches and understand the causes of problems with the well logs. We determined the sources of the differences between measured and modelled logs to a series of issues with the original well logs, such as spikes in the compressional sonic log and zones with mud infiltration. The connection between issues and differences in elastic crossplots results in a demonstration of the improvements that rock physic models bring to well log data.

Introduction

Well log data are subject to various sources of errors, for example, due to sticking tools, poor borehole conditions and noisy data (Cannon, 2016). Rock physics modelling is a valuable tool for correcting well log data. Saberi (2018), among others, shows the impact of rock physics modelling on seismic well tie, which impacts subsequent steps in reservoir characterization. In recent developments, Santiago et al. (2023) used rock physics modelling as a basis for delivering geostatistical inversion results to numerical simulation.

In this work, we implement a petrophysics and rock physics approach to obtain modelled elastic logs in a subset of the Volve dataset (Equinor, 2018). We perform basic petrophysics corrections and stochastic determination of the mineralogy content of the formations (Mitchell and Nelson, 1991). Then, we calibrate a rock physics model for clastic reservoirs (Keys and Xu, 2002) to obtain modelled elastic logs from the mineralogy determination, and mineral and fluid elastic properties. The result of this process is a synchronized petrophysical and rock physics interpretation that derives robust results. Comparison between measured and modelled data allowed us to identify issues in the raw data and the benefits of the workflow.

Method

We employed an iterative petrophysics and rock physics workflow to obtain consistent petrophysics and modelled elastic logs. The steps of the workflow are: 1) gamma ray logs normalization, 2) well logs depth shift, to match their correct position, 3) stochastic determination of volume of quartz, clay and calcite minerals and to solve for porosity and fluid volumes, and 4) Rock physics model calibration for clastic reservoirs to obtain modelled logs from the mineralogy determination, and mineral and fluid elastic properties.

With an integral scope in mind, we aimed for consistency between the petrophysical determination and the rock physics model. To this end, we employed the same density values for the different minerals and fluids in both cases, deriving in an iterative process where porosities and mineral content determined in the petrophysics module are input in the rock physics module. Then, the fluid properties are determined in the rock physics module to be employed in posterior petrophysical volumes determinations. Existing sonic logs were used to calibrate the mineral moduli to obtain the best possible match to the measured logs across all wells. All the wells were modelled together using the same mineral properties and there was no need to further refine the model to match individual wells. Finally, we compared measured and modelled data in crossplots and were able to identify trends and outliers. Later, these outliers were identified in each well to analyse their causes.

Results

We performed an iterative petrophysics and rock physics analysis on five wells available within the Volve dataset (Equinor, 2018). These wells penetrate the Hugin Formation (Pelemo-Daniels and Stewart, 2024) and have the required logs for implementing the workflow. In this case, this consisted of Gamma Ray, Neutron Porosity, Density, and Resistivity for petrophysics, and, for the posterior calibration of the rock physics model, compressional and shear sonic logs.

Figure 1 shows the crossplot of the measured and modelled well logs in a P-impedance (Zp) and P-wave velocity and S-wave velocity (Vp/Vs) ratio. Well logs for all wells are shown in this figure and are indicated in the legend. Figure 1a shows the measured data and Figure 1b shows the modelled data. Figure 1c shows the raw (in red) and modelled (in blue) well logs overlaid. The comparison shows that there are certain trends present in the measured data that are not replicated by the modelled data. These mismatches can be caused by mud filtrate invasion, washouts, cycle skipping or other sources of bad readings, etc. We highlighted four sections of measured data that are not properly reproduced by the rock physics model. The zones are highlighted in blue, green, red and orange, respectively, with different causes for their mismatches.

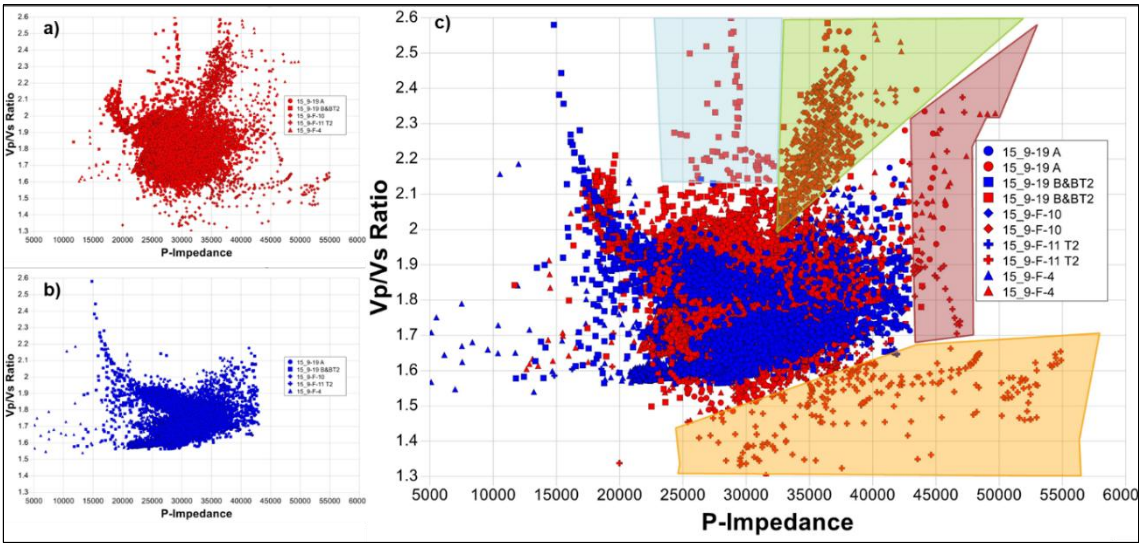

Figure 1: P-impedance vs Vp/Vs crossplots. a) Measured logs, b) rock physics modelled logs, and c) measured (in red) and modelled (in blue) logs superimposed, the highlighted zones identify the mismatch between measured and modelled logs.

Figure 2 shows the well 15_9-F-10, the tracks show the mineral volumes and effective porosity, water saturation, density, Zp and Vp/Vs logs, respectively. The raw logs are in red, and the modelled logs are in blue. The section highlighted in green in Figure 1c is shown in this plot and corresponds to the entirety of the reservoir zone in the Hugin Formation. The unusual values of Vp/Vs are due to artificial values resulting from the mud filtrate invasion, increasing P-velocity values (not shown) and, consequently, Zp and Vp/Vs.

Figure 3 shows well 15_9-F-11 T2, the tracks show the mineral volumes and effective porosity, water saturation, density, Zp and Vp/Vs logs, respectively. The raw logs are in red, and the modelled logs are in blue. The section highlighted in orange in Figure 1c is shown in this plot. The high Zp and low Vp/VS values are due to irregular sonic measurements in both compressional and shear sonic logs (not shown).

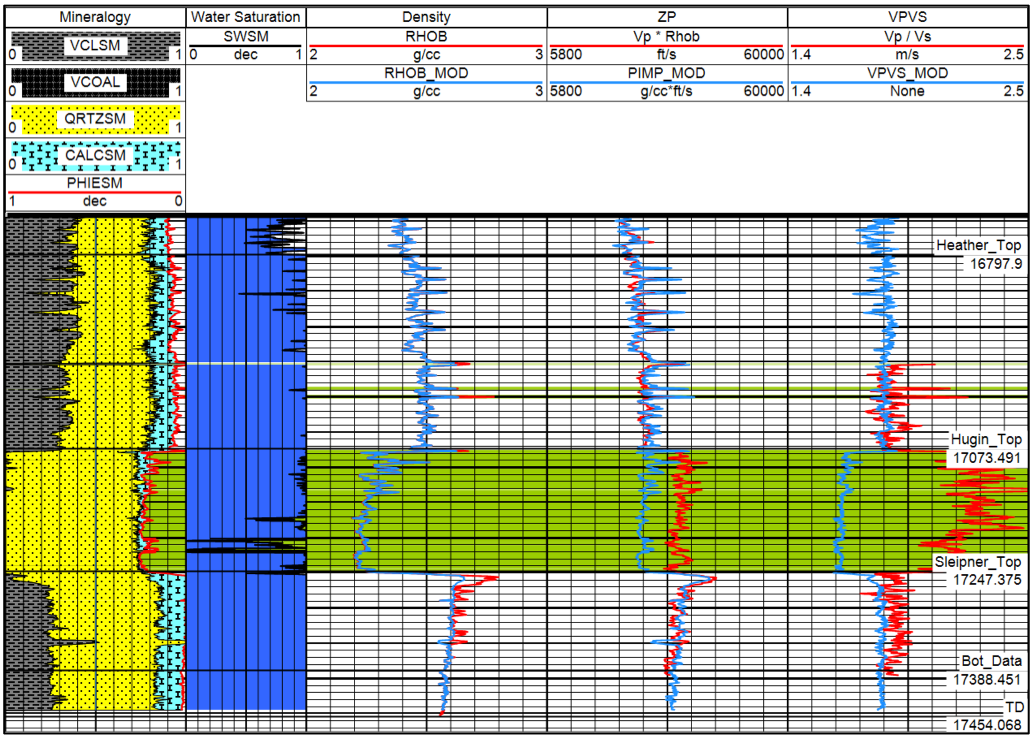

Figure 2: Well logs for well 15_9-F-10, from left to right, mineralogy content with effective porosity, water saturation, density, Zp and Vp/Vs. The measured logs are in red, and the modelled logs are in blue. The zone highlighted in green corresponds to the section highlighted in Figure 1c.

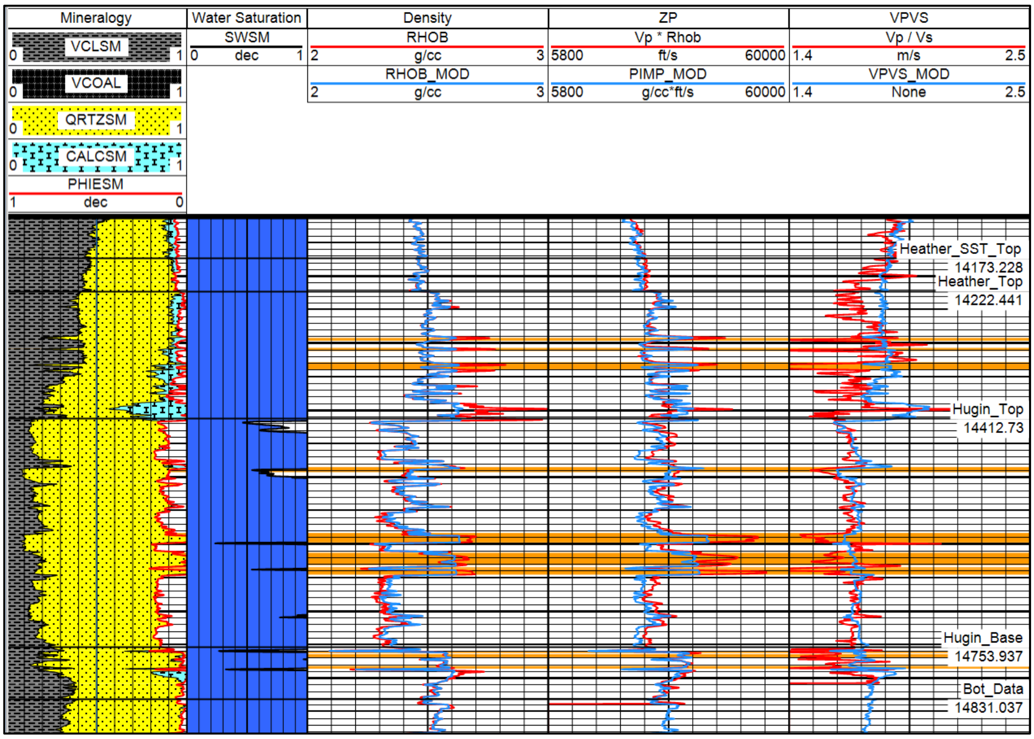

Figure 3: Well logs for well 15_9-F-11 T2, from left to right, mineralogy content with effective porosity, water saturation, measured (red) and modelled (blue) elastic logs: Density, P-impedance and Vp/Vs ratio. The zone highlighted in orange corresponds to the section highlighted in Figure 1c.

The section highlighted in blue in Figure 1c corresponds to a sparse set of data points located in well 15_9-19 B&BT2 (not shown). Their unusually high Vp/Vs values are due to low-value outliers in the shear sonic log in that well, probably due to cycle-skipping. The section highlighted in red in Figure 1c corresponds to sparse points with higher than regular P-impedance values mostly. These occurrences are distributed among several wells and correspond to occasional spikes in compressional sonic logs (not shown).

Conclusions

In this work we implemented an iterative petrophysics and rock physics workflow to improve the quality of the elastic logs in a set of five wells. Comparison between raw and modelled logs shows trends or zones in a P-impedance vs Vp/Vs ratio crossplot that are not represented in the modelled logs. These mismatches are attributed to a series of problems with the original logs, including invasion, cycle skipping and spikes in the sonic logs, which the modelled logs do not replicate, generating instead elastic logs with the expected properties for the formations according to their mineralogy and fluid composition. All the wells were modelled using the same mineral properties and there was no need to further refine the model to match individual wells. This work allowed us to demonstrate how rock physic modelling significantly improves the quality of well logs and avoids common pitfalls present in well data.

Acknowledgements

The authors wish to thank Equinor and the former Volve license partners for providing access to their publicly available data. We also wish to thank GeoSoftware for the opportunity to work on this dataset.

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