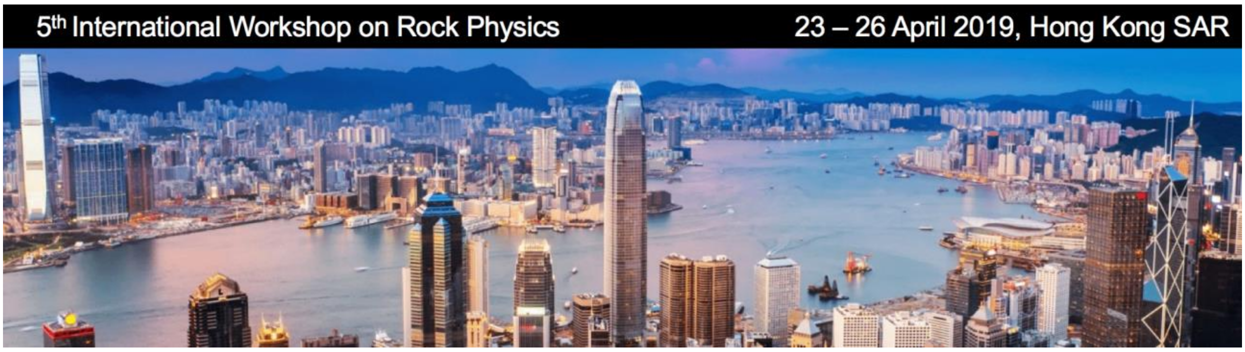

Data-driven and facies-guided rock-physics feasibility study in the Alvheim area, North Sea.

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Introduction

Paleocene sandstones in the North Sea are prolific hydrocarbon reservoirs that normally can be detected from AVO analysis. Reliable AVO analysis depends on a good rock-physics understanding of the cap-rock shales and reservoir sandstones. Contact theory models (Dvorkin and Nur, 1996) are known to be suitable for rock physics characterization of North Sea Paleocene sandstones (e.g. Avseth, 2000). However, these models need to be parameterized with input parameters that are often not well known by practitioners. In areas with abundant well log data, local rock-physics relations can be extracted from the data, using multi-linear regression analysis, where input parameters are normally well known by interpreters. In this study, we investigate data from tens of wells in the Alvheim area, North Sea, and extract local rock-physics relationships from the data constrained by pre-defined facies.

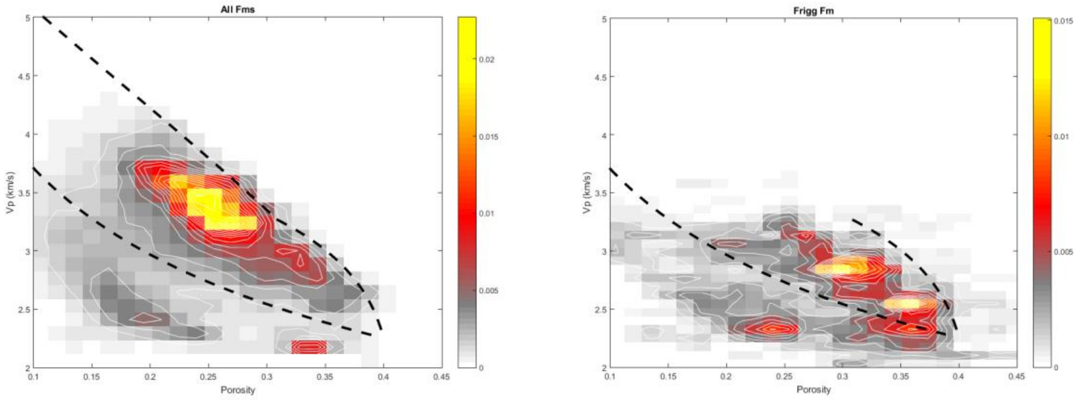

Figure 1: Vp versus porosity for Paleocene sandstones. Left: All formations, several wells. Right: Frigg Fm. The colours represent probability distributions.

Methodology

The first step is to do cleaning and sorting of the well log data. Elastic bounds are used to investigate if data comply with physics. If data fall outside these bounds, they are excluded from the analysis. We group data into files for different lithological formations. The second step is to perform facies classification using Mahalanobis distance method, where training data are defined from elastic properties. Five different sub-facies are defined for the Paleocene sandstones (Facies 1 = injectite sands, Facies 2 = unconsolidated, well-sorted sands, Facies 3 = cemented, well-sorted sandstones. Facies 4 = cemented, poorly-sorted or well-packed sandstones, Facies 5 = heterolithic, shaly sandstones). Regression analysis is performed for both separate formations and for given facies. The final products are rock physics models of Vp and Vs as a function of porosity, shale volume and burial depth.

Results

After cleaning and sorting of data, we screen the data in rock-physics cross-plot domains. Figure 1 shows the probability density function of Vp versus porosity for all Paleocene sandstones in tens of wells in the Alvheim area. We see that most data fall within the elastic bounds of clean sandstones. However, some of the data fall outside. These can either be heterolithics or shaly sands, or noisy data points. By investigating formation by formation, we can observe more detailed patterns and trends in the sandstone data. Primarily, we observe depth dependent trends caused by increasing quartz cementation. However, we also observe sorting and/or packing trends within each sandstone formation. In particular, we are able to discriminate undercompacted injectite facies from normally compacted motherbed sandstones using rock physics diagnostics. We also demonstrate the transition from smectite-rich to illite-rich shales from the data screening.

Pie-chart maps (Figure 2) are derived from the classification of the well log data and these are useful to assess the distribution of elastic facies geographically in the Alvheim area. These maps are compared with seismic amplitude maps and can aid in the interpretation of seismic facies.

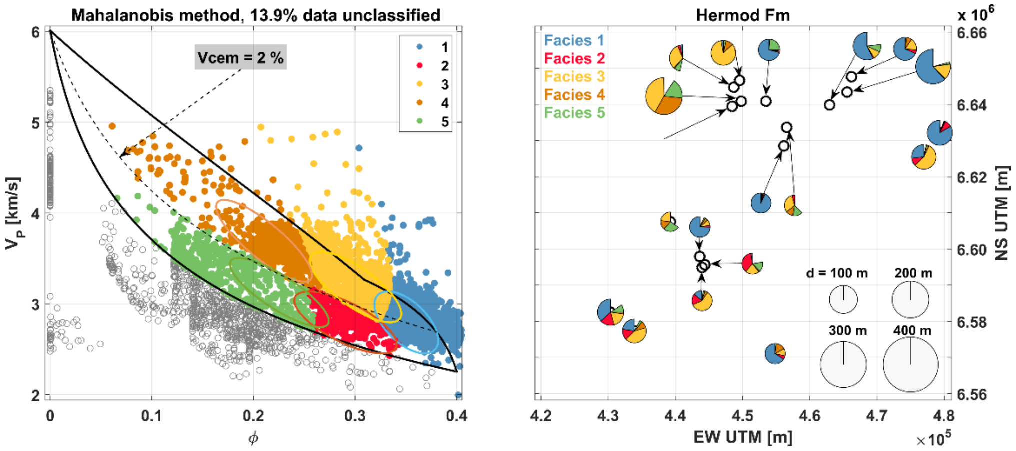

Figure 2: Elastic facies classification results for Hermod Fm sandstones in several wells. Left: Cross-plot of Vp versus porosity with superimposed elastic bounds. Right: Pie-chart map of facies distribution. The size of the pies represents the thickness of the Hermod Fm in each well. Note the abundance of injectites (Facies 1, blue).

Conclusions

We have demonstrated an approach for data-driven rock physics analysis, where we first do facies classification using elastic well log data from several wells, followed by facies-constrained regression analysis to establish local rock-physics relations for prediction of Vp and Vs from geological input parameters. We show that the locally-derived rock physics relations give better prediction results than using more universal rock-physics models, even when the latter are locally calibrated. The local rock physics relations can furthermore be used to create training-data for AVO classification.

References

Avseth, P., 2000: Combining rock physics and sedimentology for seismic reservoir characterization of North Sea turbidite systems; Unpublished PhD thesis, Stanford University.

Dvorkin, J., and Nur, A., 1996: Elasticity of high-porosity sandstones: Theory for two North Sea data sets; Geophysics, 61, 1363-1370.