Probabilistic prediction of lithology-fluid-classes from seismic - A North Sea case study

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Introduction

Interpretation of lithology and pore fluid properties from seismic and well data is an important step in the oil and gas exploration workflow. Lithology and pore fluid properties (in the following referred to as lithology-fluid-classes, LFCs) are often deduced from seismic inversion for elastic properties and correlations with rock physics relations. Here we present a study based on the alternative approach described in Buland et al. (2008), where a Bayesian AVO inversion scheme is used to invert directly to LFC probabilities. A key issue is the use of well logs to define LFCs and the stochastic distribution of elastic parameters for each class. The study is performed an a large area centred on the Volund field and covered by 3D seismic data and several exploration wells.

Methods and result

From logs, formation tops and petrophysical well analysis of 10 wells surrounding the Volund field we model a set of possible LFCs that may be present in the area. Each LFC is characterized by Gaussian distributions of P-wave velocity, S-wave velocity, and density (i.e. the elastic parameters). Their mean, standard deviation, and covariance are estimated from their corresponding acoustic and density logs. We try to avoid synthetic logs and data that are affected by irregular borehole shape when estimating the distributions.

The Bayesian inversion algorithm estimates the posterior probability of the different LFCs given the seismic data, the distributions of elastic parameters and a probabilistic background model of lithology and fluid. The algorithm combines the LFC elastic distributions with Bayesian inversion from seismic to elastic parameters using a linearized weak contrast approximation of the Zoeppritz equation (Buland and Omre, 2003).

We find that the study area can be characterized by nine different LFCs covering shale, sand and chalk. The effect of oil and gas is taken into account by using Gassmann's equation for fluid substitution on the elastic parameters. An observed depth trend in shale and sand is modelled by subdividing the classes depending on depth and formation. A result of an inversion around well 24/9-6 at the Volund field is shown in Figure 1. The upper right panel shows the probability map for hydrocarbons. The outline of the Volund field is clearly visible and similar to the map of gross oil in

Schwab et al., 2015. The lower panel shows a zoomed in 2D section of the most likely LFCs close to well 24/9-6. A hydrocarbon filled sand injectite is evident to the left and consistent with the geology and well data in the area (Schwab et al., 2015). A cross plot of Vp/Vs versus acoustic impedance (AI) of the modelled elastic distributions of the LFCs is shown to the upper right. The LFCs are colour coded according to fluid content and lithology.

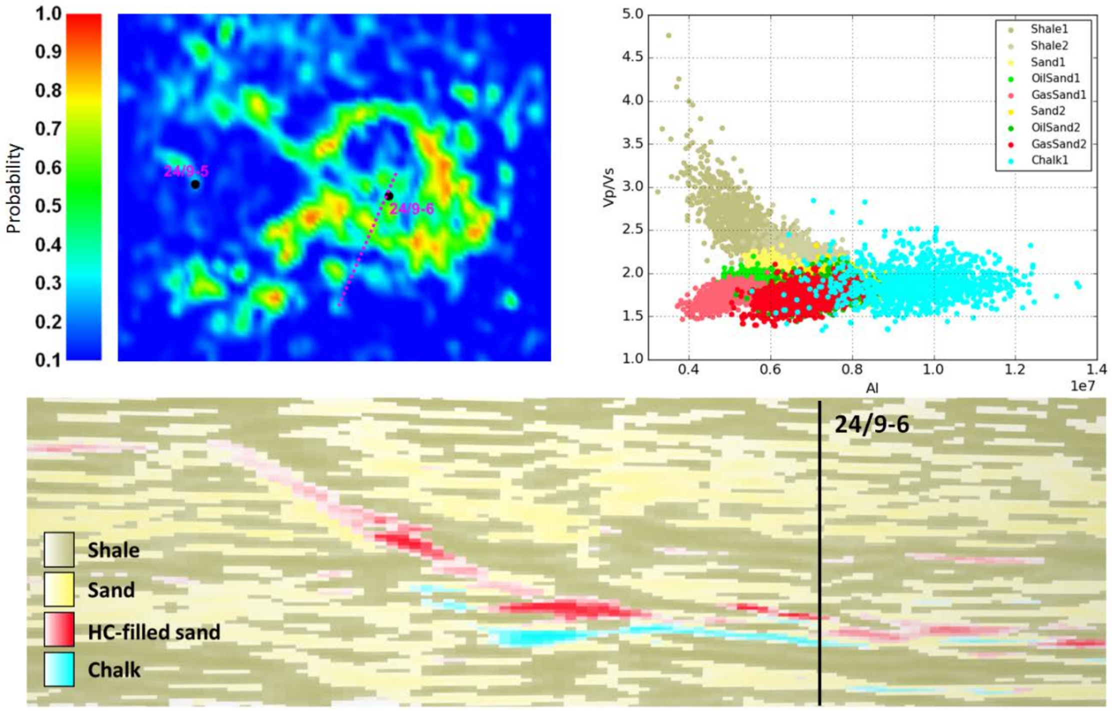

Figure 1: Upper left: Probability map for hydrocarbons; Upper right: Distribution of LFC elastic distributions in Vp/Vs vs AI cross plot; Bottom: A zoomed in 2D section showing sand injectite around well 24/9-6. The 2D section corresponds to the pink dashed line in the probability map.

Conclusions

We have applied Bayesian lithology-fluid-class (LFC) inversion of seismic data from the Volund field in the North Sea. The area can be characterized by nine LFCs giving a reasonably detailed background model based on well log interpretations and geologic knowledge of the area. The inversion quantifies the probability for different lithologies and fluids and detects hydrocarbon filled structures (e.g. injectites) that are consistent with the geology and well data in the area.

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References

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