

Reducing uncertainty in quantitative reservoir characterization using a multi-physics approach

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A robust characterization of rock and fluid properties is required to drive exploration and exploitation decision making. Surface measurements such as seismic and controlled source electromagnetic (CSEM) data are commonly used to estimate such reservoir properties. However neither, taken alone, can provide an unambiguous characterization of rock and fluid properties, and the resulting uncertainties increase the risk of poor well results or sub-optimal exploitation plans. Seismic data provide an excellent image of structure and stratigraphy, and can be inverted to provide a quantitative interpretation of porosity, lithology and similar attributes. However fluid saturation and properties, key parameters when evaluating a prospect or appraising a discovery, are often poorly constrained. The CSEM method provides a surface measurement of electrical resistivity, which is an integral part of a petrophysical interpretation; however, the structural resolution is limited. Seismic and CSEM data must be tightly integrated with available well log information in order to provide a robust interpretation.

The Wisting area in the Barents Sea provides a setting to illustrate this idea. Oil-bearing sands were encountered in the Realgrunnen interval at well 7324/8-1 (Wisting Central). Nearby well 7324/7-1S (Wisting Alternative) targeted the deeper Kobbe and Snadd intervals, but was wet in the Realgrunnen interval. Two additional wells have been drilled in the vicinity: 7324/7-2 (Hanssen), and 7324/8-2 (Bjaaland). These are used as a blind test. A dataset consisting of nine lines of 2D GeoStreamer seismic and towed streamer CSEM data (695km total) were acquired concurrently in 2015 by PGS over the Wisting area, and form the basis of the study.

Fast track processed pre-stack seismic data were conditioned carefully to be optimal for inversion, and then inverted using a simultaneous elastic impedance inversion to derive P- and S- impedance values. Rock property estimation from seismic data was carried out by applying a carefully tailored workflow based on RSI's multi-attribute rotation scheme (MARS) described by Alvarez et al (2015). This method is a hybrid rock physics/statistical approach designed to yield the optimum seismic inversion attribute correlation to target reservoir properties. For this case study, MARS was used to estimate total porosity, clay content and litho-fluid facies volumes.

A cross-section of the resultant volume of litho-fluid facies along the Wisting Central and Alternative wells, with their V_{clay} (left) and S_w (right) curves, are shown in **Figure 1** (top). The seismic results correctly identify the discovery at Wisting Central, and the dry well at Wisting Alternative. Based on the seismic data alone both the prospects at Hanssen and Bjaaland appear positive. However, the green-coloured facies may be related to clean oil sand, or fizz gas sand – the seismic data alone cannot distinguish between commercial and non-commercial hydrocarbon saturations leaving a significant ambiguity in the prospect evaluation with potentially significant commercial consequences. The ambiguity can be reduced significantly if CSEM data are incorporated into the analysis.

A significant response to the Wisting Central accumulation can be clearly seen in the CSEM data in a wide range of frequencies. The CSEM data for six frequencies were inverted to derive anisotropic resistivity models. Appropriate seismic structural constraints were applied to help enhance the resolution of the CSEM results and allow the interpretation to be focused in the zone of interest.

The final stage in the analysis is to invert the seismic and CSEM derived properties within a rock physics framework to derive a measure of saturation in the reservoir interval. The inclusion of the CSEM resistivity information within the inversion approach allows for the separation of the two possible scenarios at the prospect locations: oil sand or fizz gas sand. The integration of seismic, CSEM, and well data predicts very high hydrocarbon saturations at Wisting Central, and water wet sands at Wisting Alternative, consistent with the findings of the wells. At Hanssen, results show that the reservoir is oil saturated, correctly predicting the outcome of the well. At Bjaaland, although the seismic indications are good (upper plot in **figure 1**), the integrated interpretation result predicts correctly that this well was unsuccessful.

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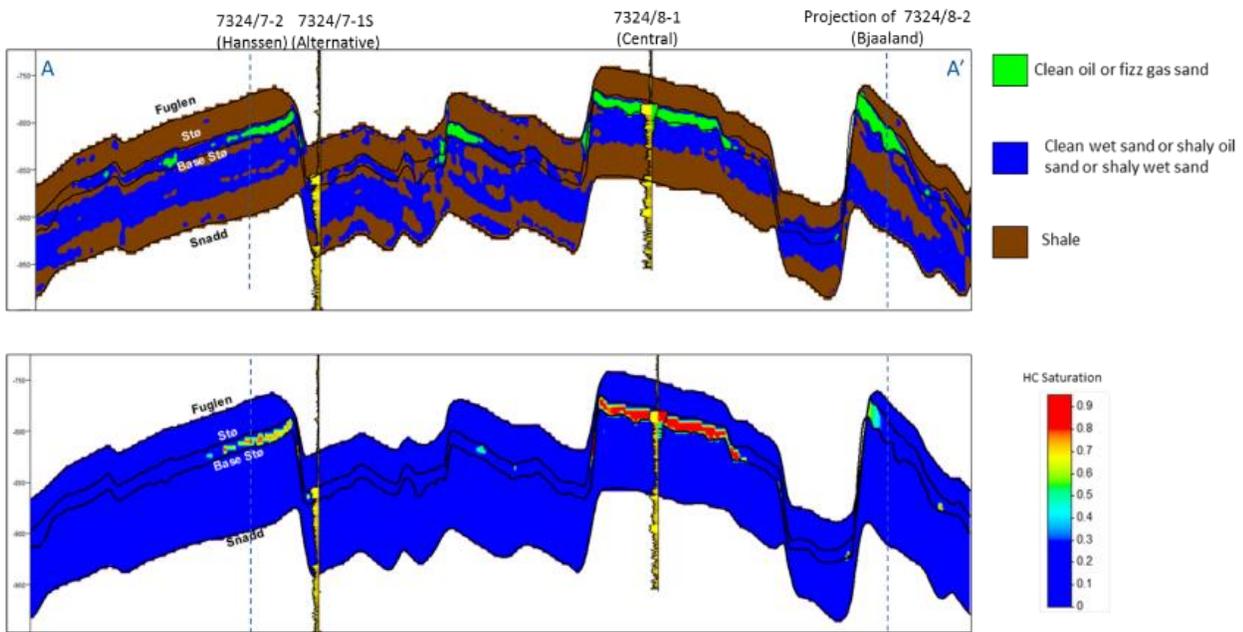


Figure 1: (Top) A cross-section of the resultant volume of litho-fluid facies obtained from seismic and well log data along a 2D line covering wells 7324/7-1S and 7324/8-1, with V_{clay} (left) and S_w (right) curves overlaid. (Bottom) A cross-section of the resultant volume of S_w obtained from a joint interpretation of CSEM, seismic and well log data, with S_w curves from wells 7324/7-1S and 7324/8-1.

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References

Alvarez, P., Bolivar, F., Di Luca, M. & Salinas, T., 2015, Multi-attribute rotation scheme: A tool for reservoir property prediction from seismic inversion attributes, *Interpretation*, **3**, SAE9-SAAE18