# Rock physics, broadband seismic and facies based seismic inversion

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## Introduction

De-risking via objective quantitative interpretation (QI) is an essential part of successful hydrocarbon exploration and appraisal. Given suitable subsurface scenarios QI using AVO inversion can be used to identify lithologies, indicate pore fluid fill and determine net rock volume. However, the detail that can be extracted from a conventional AVO inversion workflow is limited by the averaging effects of not taking into account facies variations and adopting a simplified, rigid low frequency model input to supplement band limited seismic input. An alternative emerging technology, joint-impedance facies inversion, is presented here and provides rock physics models for each individual facies, whilst simultaneously updating the low frequency model; thereby removing one of the main sources of error in conventional AVO inversion routines.

The case study shown in this paper centres on a Paleocene discovery, known as Avalon, in block 21/6b of the UK Central North Sea located at the north-western edge of the Central Graben, just south of the Buchan Field. The discovery was initially made using conventional simultaneous pre-stack inversion followed by a discovery well that successfully drilled an 85 ft column of oil in good quality sands. The reservoir sands lie within the proximal part of the prolific northwest to southeast late Paleocene Forties and Cromarty depositional trend. This fairway includes the giant Forties Field.

## Methods

This paper demonstrates a workflow using a novel facies based Bayesian seismic inversion technique to analyse the distribution of reservoir bodies through a range of facies based sensitivities. Facies based seismic inversion was introduced by Kemper and Gunning (2014) in which the low frequency model is a product of the inversion process itself, constrained by per-facies input trends, the resultant facies distribution and the match to the seismic. So the inversion benefits from a rock physics model (and therefore a low frequency model) per-facies to optimize the inversion. This new Bayesian inversion system simultaneously inverts for facies and elastic properties. QI workflows also often consist of rock physics analysis, fluid substitution, synthetic modeling, followed by well tying before inversion to elastic properties and facies. The problem of wavelet estimation for broadband seismic data, however, arises during the well tie process when the length (in time) of the well-logs is often seriously inadequate to provide sufficient constraints on the low frequency content of the resulting wavelet. In this study we use one of the three methods proposed in Zabihi Naeini et al. (2016), namely the “parametric constant phase” method to estimate the wavelet for inversion.

## Results

The most critical step for the joint impedance and facies based inversion technique was to derive impedance depth trends for each facies. From these per-facies depth trends equivalent low frequency models are generated, an essential input to the algorithm. The depth trends were obtained for five classified facies: Overburden hard shale, overburden soft shale, intra-reservoir shale, oil sand and brine sand. Separating the various shales into different facies types was a critical factor to improve the inversion accuracy. The end result is optimised facies (Figure 1) and impedance volumes generated without the influence of input low frequency model error.

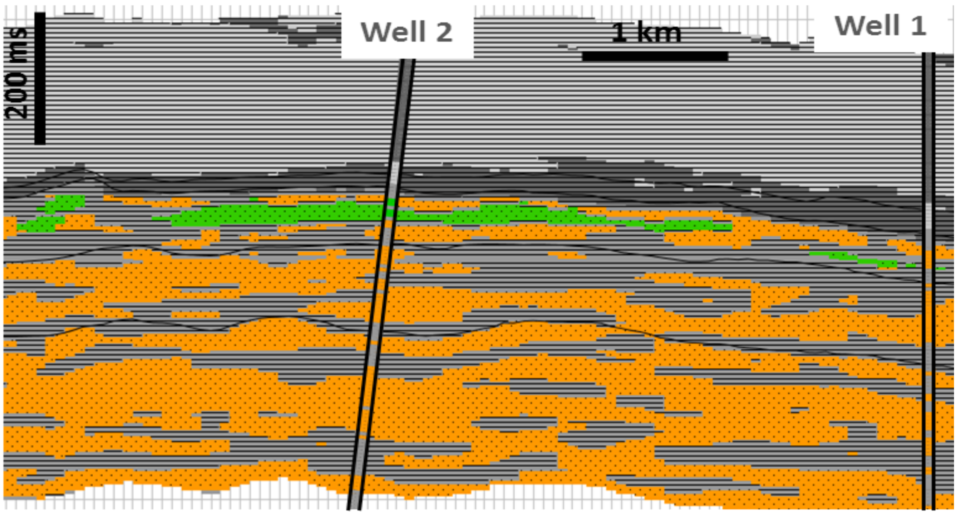


*Figure 1: Inverted facies section shows a good match at wells.*

## Conclusions

Facies based seismic inversion has been demonstrated, via a North Sea working case study, to provide significant advantages over more conventional impedance inversion techniques. When facies based inversion is combined with broadband data and appropriate broadband well tie techniques the resulting classified facies output provides a result ideally suited for geological interpretation and the generation of static and dynamic reservoir models. The joint impedance facies inversion technique successfully:

- Provides a better facies correlation with calibration wells.
- Inverts for an optimum low frequency model – thereby removing one of the most significant sources of error in more conventional simultaneous inversion techniques, where a low frequency model is an input, not an output.
- Reduces interpretation burden by producing facies based output akin to a geo-cellular model.
- Allows a full range of potential sensitivities to be explored therefore exploring the implications of inversion error.

## Acknowledgements

The authors would like to thank Summit Exploration & Production Ltd for permission to publish.

## References

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