Rock Physics as a Constraint on Seismic Inversion: a Carbonate case study

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Introduction

Seismic reservoir characterisation of the Miocene carbonates of SE Asia faces a number of challenges: the heterogeneous nature of the carbonates at many scales, the relatively low elastic property sensitivity of carbonate rocks to fluids and the limitations of the seismic data in terms of bandwidth, angle range and signal to noise. A recent well drilled into a carbonate reef in the Nam Con Son Basin offshore Vietnam provides a useful case study to assess these challenges.

Method

A seismic reservoir characterisation workflow has been followed. The well data are processed through a seismic petrophysics analysis. The petrophysics is calibrated to core and indicates complete dolomitisation of the reservoir interval; little terrigenous input; a very broad range of porosities (approximately 10-50pu); and very high gas saturations (>95%). The elastic properties can be adequately modelled with a simple inclusion based rock physics model using bimodal aspect ratios for the carbonate porosities. Examination of the elastic properties indicates that the seismic amplitudes will be dominated by the porosity variations of the carbonate rocks. In general, fluid effects will be subtle and require an accurate estimation of Vp/Vs for prediction from seismic data. The limited bandwidth and limited angle range of the actual seismic data suggest that sufficient accuracy of the Vp/Vs estimates from seismic for fluid discrimination is unlikely without additional constraints. Three methods of seismic inversion have been applied: elastic impedance of the near- and far-stack to relative elastic impedance; simultaneous inversion of partial angle stack data using a low frequency model based on a first pass interpretation of the top carbonate and GWC; a facies based inversion (Kemper and Gunning, 2014) solving simultaneously for elastic properties and the distribution of lithologies and fluids, where the same first pass interpretation is used to set prior probabilities.

Results

The results of the three inversions are compared in Figure 1. The elastic impedance inversion results have been interpreted as best as possible in terms of overburden, gas and brine carbonates from the elastic properties alone, that is without any geological or geophysical context. The predictions highlight the limitations of the information that resides in the seismic data. Context is provided in the standard simultaneous inversion through the low frequency model that introduces prior expectations.

The low frequency model, however, does not provide sufficient information or constraints to generate an accurate reservoir model, but in fact introduces significant bias. Note that the inverted elastic properties may not represent any actual rock or fluid type present. The facies based inversion generates more realistic models as the output is required to honour the rock physics relationships for the various lithologies and fluids modelled as well as the seismic data. The prior probabilities are adjusted to maximise the information from the seismic data in determining the lithology and fluid distribution. The accuracy of the top carbonate prediction is improved and the internal architecture of the carbonate better resolved.

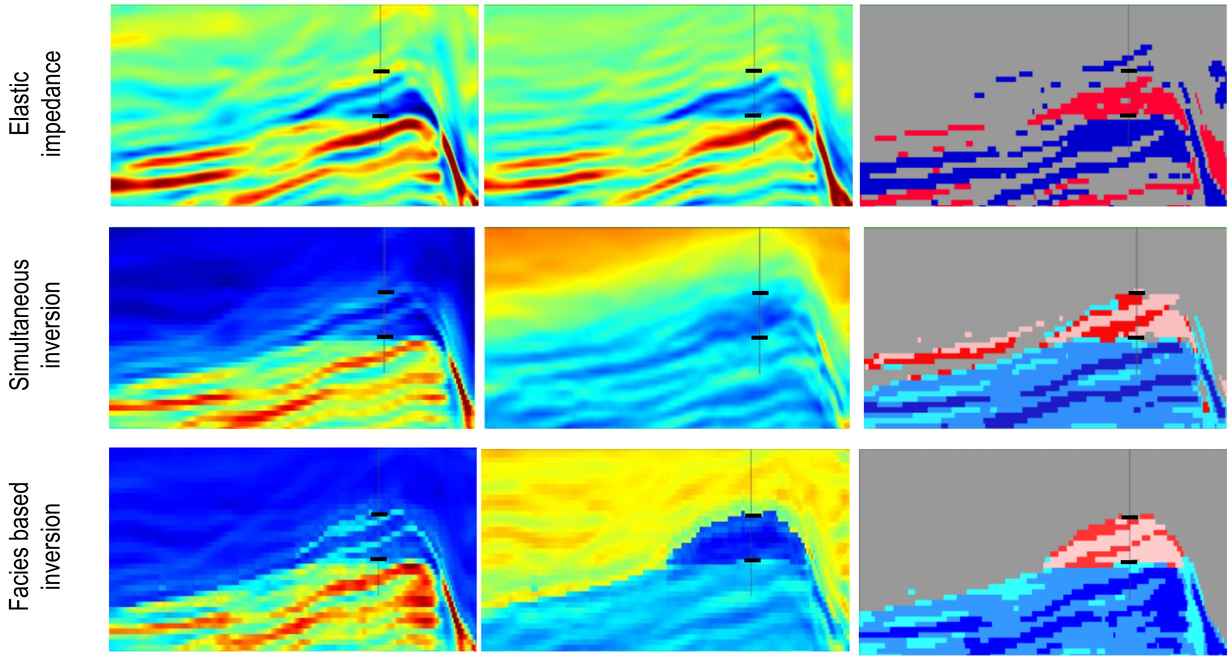

Figure 1: Inversion results and interpretation of a carbonate reef: elastic impedance inversion of near and far stack plus interpretation (top row); standard simultaneous inversion AI, Vp/Vs and interpretation (middle row); facies based inversion AI, Vp/Vs and facies (bottom row).Interpretations show grey for shale red for gas carbonate and blue for brine carbonate. Darker colours represent lower porosity for the carbonates where available.

Conclusions

Seismic data often do not contain enough information to enable the generation of realistic models of carbonate reservoirs from seismic inversion without additional information or constraints. Facies based inversion introduces rock physics constraints that supplement the seismic data to provide realistic reservoir models in a way that minimises the bias of the prior information.

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References

Kemper M. and Gunning J. (2014) Joint impedance and facies inversion – Seismic inversion redefined. First Break, 32, 89–95.