Calibration of frequency decomposition colour blends using forward modelling. Examples from the Scarborough Gas field, Offshore West Australia.

Introduction

This study investigates using a combination of seismic forward modelling with frequency decomposition (FD) and colour blending analysis with the aim of better understanding what the major controlling factors on the frequency response are and how this impacts the spectral interference colour patterns observed in FD colour blends. Forward modelling of reflectivity is common practise in the oil and gas industry, generally used to provide information on amplitude and phase changes which may occur in response to changes in a model. By incorporating frequency decomposition and red-green-blue (RGB) colour blending into the workflow there may be potential to detect subtle changes within the data since the interplay between three band-restricted frequency volumes produces a colour blend which is extremely sensitive to frequency change and can often highlight features or trends not seen in full frequency or bandpass volumes. Previous work carried out by McArdle et al. (2012) and Cooke et al. (2014) has shown the potential for increasing understanding of FD colour blends, which may aid in supporting or disproving interpretations made using other lines of evidence. Frequency is a non-unique seismic property in the sense that it is the result of multiple contributing factors for example; bed thickness, the seismic wavelet, lithology type, sequence of lithologies, and fluids in place. By using FD forward modelling it may be possible to better understand which factors are the dominant controlling influencers by isolating each of the contributing factors on a case by case basis. Understanding the FD blends in a more quantitative manner may allow additional geological insights to be made, such as potentially increased ability to identify or map facies, fluids, thicknesses and other changes in reservoir characteristics based on frequency response.

Scarborough Gas Field

This case study focuses on the Scarborough giant gas accumulation located on the Exmouth Plateau, in the Carnavon Basin, offshore Western Australia. The reservoir is a large sub-marine fan comprising of high quality sandstones within a large, low relief anticline structure (Fig. 1). The reservoir contains significant proven gas reserves and is currently being assessed for development by stakeholders Woodside, BHP Billiton and ExxonMobil. Economic development is complicated due to remote location and water depth in excess of 900m.

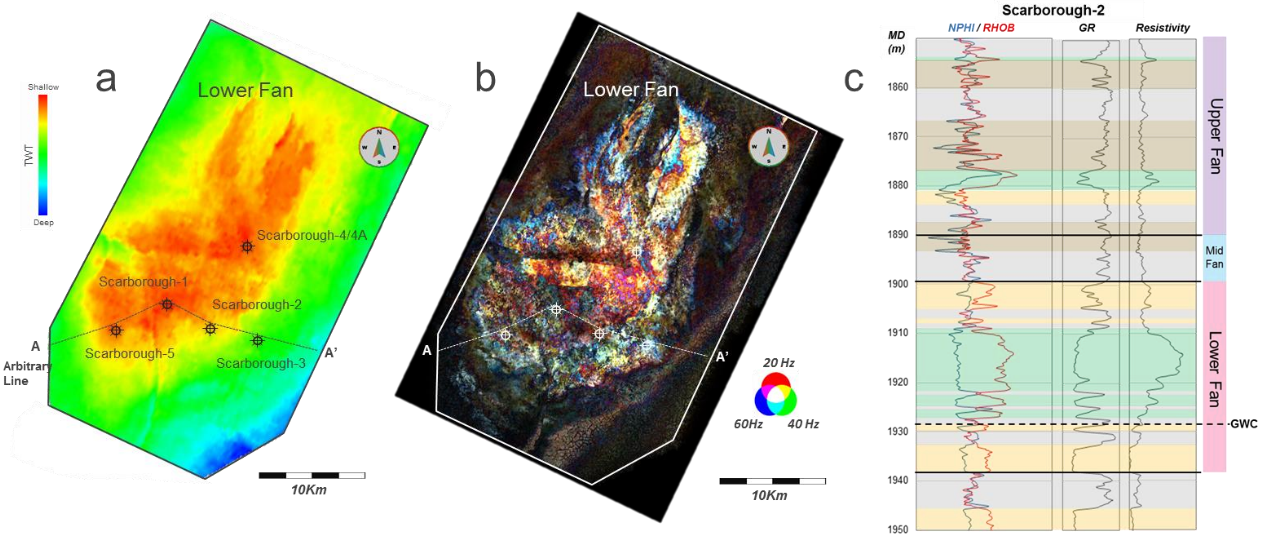


Figure 1 a) *TWT structure map near Top Lower Fan showing general anticlinal structure of field and well locations.* ***b)*** *Frequency Decomposition colour blend displayed on near Top Lower Fan horizon. Frequency variation of the data across the field is highlighted as changes in colour.* ***c)*** *Scarborough-2 well logs and quick look interpretation.*

The dataset used for this project comprised the full stack data from the ‘Scarborough 3D, HEX03A’ seismic survey, acquired in 2004. The survey was acquired with specific focus on the main floor fan reservoir at target interval ~2.1 seconds and has good frequency content at this interval of ~55Hz. (O’Halloran & Whittam, 2006). In addition well data was utilised for determination of petrophysical properties to use in the forward modelling. All data has been released to the public domain by Geoscience Australia. The stratigraphic architecture of the Lower Cretaceous reservoir fan complex is defined as 3 main successions; Upper Fan, Middle Fan and Lower Fan (Fig 1c). The main sand intervals, of excellent reservoir quality, occur within the Lower fan thick turbiditic sequence. The upper fan also contains reservoir quality sandstones but these are more restricted and generally thinner with variable quality. Gas sands typically exhibit high negative impedances and a prominent flat-spot is observed across the field which correlates with the GWC in wells (O’Halloran & Whittam, 2006).

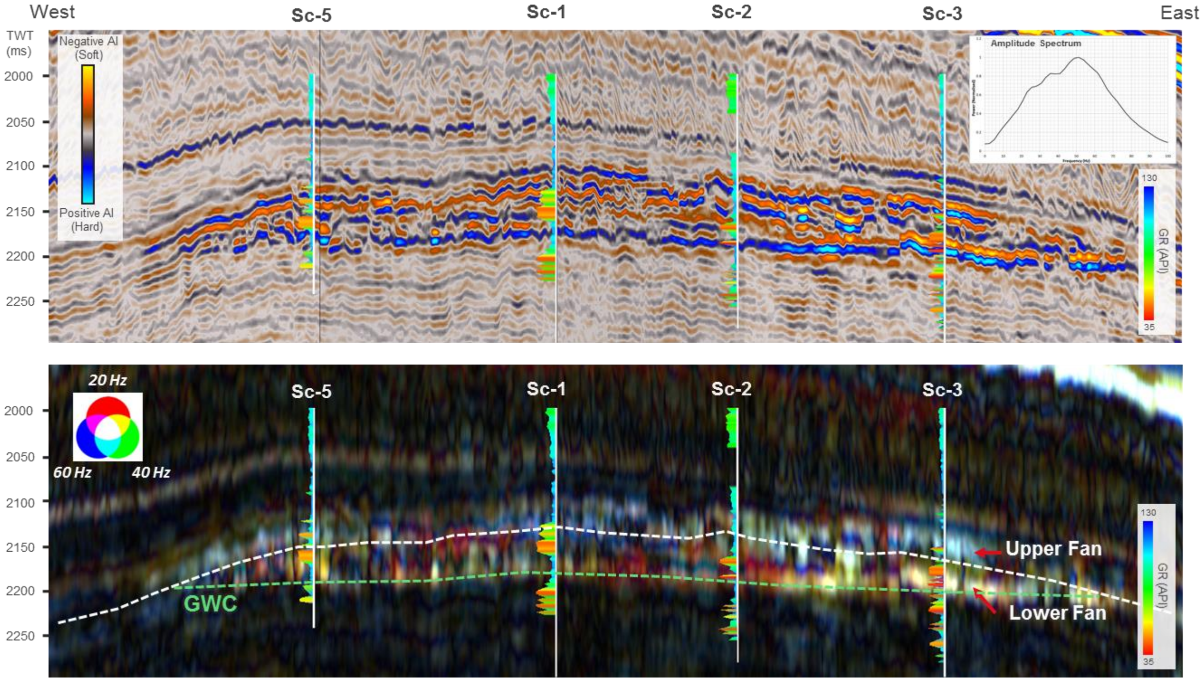


***Figure 2** Cross sections through arbitrary line A-A’. Top: Full Stack data, with amplitude spectra plot for reservoir interval. Below: High definition frequency decomposition colour blend with interpretation of fan elements and GWC.*

The main project objectives were to use forward modelling combined with frequency decomposition to calibrate and better understand the colours which are produced from the real world data. Of particular interest was to gain insight into how different geological scenarios may impact the response and whether it could help to characterise the reservoir in terms of reservoir quality, thickness and hydrocarbon saturation based on the seismic response.

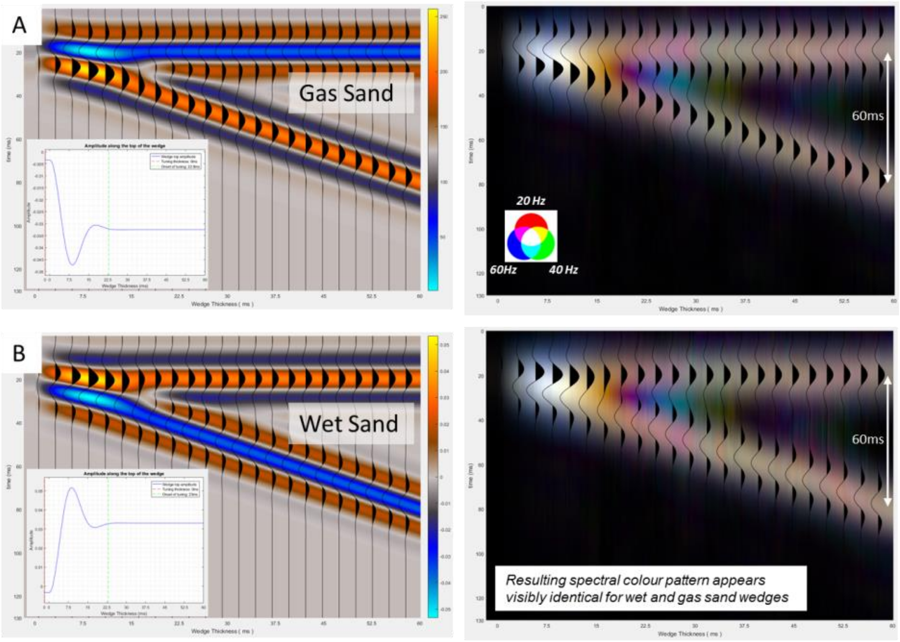
Frequency decomposition colour blending produced a detailed image of the fan structure which allowed initial qualitative interpretations to be formed based on the geometries and colours observed (Fig. 2). In very general terms the upper fan appears to show a tendency to higher frequency as indicated by a dominant blue colour in the blend corresponding to the 60Hz band restricted input volume. The middle and lower fans show a tendency towards lower frequency indicated by a dominance of red colours, corresponding to the 20Hz band restricted input volume. The initial interpretation is that these general frequency trends are due to the upper fan having a relatively thin interbedded mudstone and debris flow sand sequence in most areas with restricted zones of high N:G; whilst the lower fan showed more extensive homogeneous, thick sand of greater reservoir quality.

Methodology

An initial conventional seismic interpretation of the dataset was carried out to gain an understanding of the geological and geophysical characteristics of the reservoir. This consisted of; post stack data conditioning, well log interpretation and rock characterisation from logs, seismic to well ties, horizon interpretation. The forward modelling workflow was then carried out which involved firstly producing a FD colour blend from the 3D seismic data survey. This blend was optimised to highlight changes in frequency, and hence colour response, within the reservoir interval of interest. Forward models were then produced using 2 different methods: (1) Simple thinning wedge models. (2) Drawn models with representative geometries and interpreted geological boundaries observed in the seismic data. By adjusting the petrophysical properties used in the model to simulate different geological scenarios it was possible to investigate the impact on the overall frequency response and thus the colours produced in the resulting RGB frequency decomposition colour blend.

Results

Application of the workflow allowed calibration of the frequency decomposition by testing how changing the parameters of a model would be expected to impact the spectral interference colour patterns produced in a resulting FD colour blend. Figures 3 and 4 show examples of models produced. Figure 3 shows results of a classic tuning wedge model such as used by Widess, (1973) to investigate thin bed tuning effects.



Left: *Synthetic seismic wedge models*
Right: *Frequency decomposition colour blend comprising bands of 20, 40, 60Hz in the red, green and blue channels respectively. Note: Whilst changing from a gas to wet sand causes the polarities at top and base sand to reverse, the spectral interference pattern remains unchanged visibly, indicating that thickness is the dominant control for simple two interface cases.*

***Figure 3** – Thinning constant impedance wedge models for **A)** Gas Sand encased in claystones, **B)** Wet Sand encased in claystones.*

Figure 4 shows examples of a simple drawn model based on the well and seismic data at Scarborough-2 location. Model parameters were changed to simulate different scenarios and the impact of the changes on the resulting FD colour blend assessed. Model 1 contains a wet sand in the lower fan whilst model 2 shows the result for a gas sand. In reality the lower fan is gas bearing with 28m gross massive unconsolidated sands of exceptional quality. As predicted the gas sand model shows a closer match to the real FD blend at the well location.

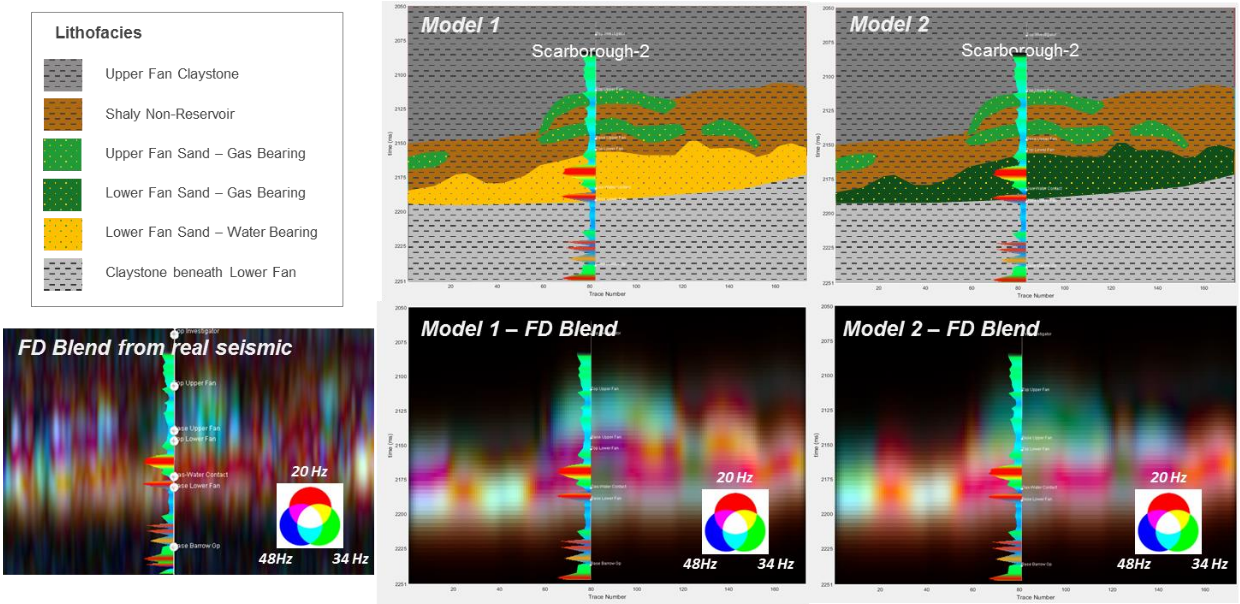


Figure 4 *Example of simple Drawn Model produced to investigate the frequency response for different lithological/fluid configurations.*

The multi-layer models show a greater variability of colour response as compared to the simple wedge models (which did not change when switching between a wet and gas sand model). Since the thickness between interfaces remains constant it is apparent that the ordering of lithologies and the interference between multiple boundaries has a large impact on the composite frequency response in multi-layer models.

Conclusions

Using frequency decomposition colour blending as an add-on to conventional forward modelling workflow offers additional insights into the expected FD spectral response for different geological scenarios in addition to the amplitude and polarity changes which standard seismic forward modelling offers. The workflow aims to bring quantitative understanding to help explain the detail and complexity observed in Frequency Decomposition colour blends, which when used in isolation have been considered a mostly qualitative method for imaging geological features. The main limitation of the workflow is that there are numerous lithological configurations which can produce a similar set of acoustic impedance contrasts, reflectors, and thus resulting FD blend. Therefore it is greatly beneficial to calibrate specific lithological properties using well control. Further work is also required to understand how transitional and gradational boundaries would influence the results. Despite the limitations the modelling workflow may be used to aid in eliminating unfeasible scenarios, reducing risk and adding confidence to interpretations, in addition to gaining a better general understanding of what the colours in an FD blend are likely to represent.

Acknowledgements

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References

Cooke, N., Szafian, P., Gruenwald, P. and Schuler, L. [2014] Forward modelling to understand colour responses in an HDFD RGB blend around a gas discovery. First Break, 32, 87-93.
McArdle, N., and Ackers, M. [2012] Understanding seismic thin-bed responses using frequency decomposition and RGB blending. First Break, 30, 57-65.
O'Halloran, G., and Whittam, D. [2006] BHP WA-1-R HEX03A 3D Seismic Interpretation Report
Widess, M.B. [1973] How thin is a thin bed? Geophysics, 38, 1176-1180.