PROCEEDINGS
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Spectral decomposition calibration and forward modelling for reservoir characterisation

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Abstract

This paper presents a workflow to increase the integration of spectral decomposition and RGB colour blending to aid reservoir characterisation. Case studies are presented to illustrate how spectral decomposition and RGB blending can be applied in a more quantitative manner compared to the current qualitative practise generally used. Techniques for selecting the most appropriate spectral decomposition algorithm and optimising frequency band selection to allow detailed reservoir characterisation are firstly discussed. Increased emphasis is placed on the use of well locations as a starting 'tie' point. By carrying out a blend tie to a well (or multiple wells), in a similar manner to a conventional seismic-well-tie but with spectral decomposition incorporated, the colours in spectral decomposition blend can be better understood and potentially linked to the known underlying geology. This understanding can then be extended away from the well location by use of acoustic impedance based seismic forward modelling with real-world geometries. Population of different model regions to assess which parameters produce a similar response to the real data can then assist in predicting rock property changes. Well data plays a crucial role in generation of synthetic forward models and was used to calibrate and QC the results throughout. The models integrate wireline log data for population of the rock properties (Vp, Vs, Density) producing realistic synthetic results. The resulting models are compared back to the real data to assist interpretation of the seismic response at other locations with no well control. Taking this a step further, fluid substitution is applied to test the sensitivity of the forward models to different fluid scenarios, by doing so allowing prediction of the most likely in-situ case. Results show that more geological information and understanding can be gained by improving the calibration and integration of spectral decomposition with the reflection seismic and well data.

Introduction

Spectral decomposition RGB colour blending is a subjective process which should be varied to suit the specific seismic data and technical objectives at hand. The workflow requires the user to make decisions regarding:

- *the type of decomposition technique*
- *the decomposition parameters in terms of filter length and bandwidth*
- *which frequencies to use as input for the colour blending.*

These choices will impact on the output blend in terms of temporal resolution, frequency resolution and the colour interplay based on the overlap of the selected frequency bands.

Optimisation of blends can be approached qualitatively using a preview data slice to visually assess what parameters best bring out features of interest. In areas where wells have been drilled a more quantitative approach can

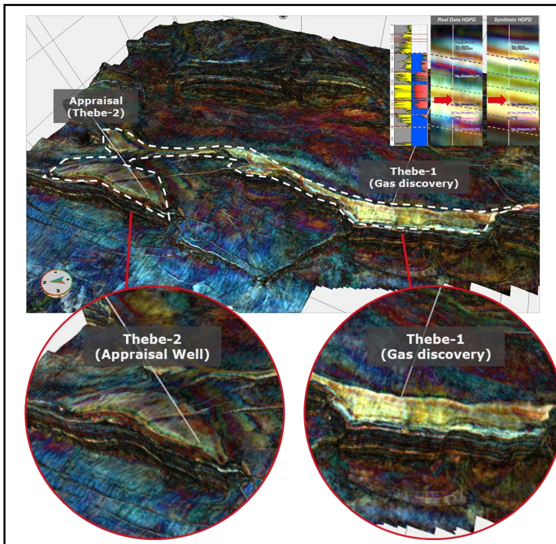

Figure 1 - Spectral Decomposition RGB blend displayed on intra-reservoir surface. The Thebe reservoir is outlined by white dashed line. Note the distinctly different response between the Thebe-1 and appraisal locations. Forward modelling was applied to understand and explain the differences.

be undertaken using forward modelling to understand the link between the resulting colour blends, their parameters, and the known underlying geology of the well location.

Data and Method

Seismic and well data from the Thebe gas field (NW Australia) are used to demonstrate an integrated spectral decomposition workflow with the objective of explaining differences in seismic response between well locations (**Figure 1**). The main workflow steps carried out were:

- 1D well tie of seismic and spectral decomposition blends – enabling correlation and optimization of frequency blends.
- Extension of the result to a 2D section model using geometries from seismic reflectors.
- Linking colour changes in blends to underlying rock parameters
- Testing of different scenarios including fluid substitution

An initial calibration was carried out using frequency analysis (**Figure 2**) and tying of the seismic to the well for both reflectivity and spectral decomposition RGB blend (**Figure 3**). This allowed selection of the best spectral decomposition parameters to highlight reservoir heterogeneities related to lithology, bed thickness and pore-fluids. A simple layer model at the Thebe-1 discovery well location was created using TWT horizon picks based on well markers to split the model into several regions. The regions were then populated with the corresponding well logs for velocities and densities as defined by the associated well-top markers. The reflection coefficients and acoustic impedance model for the layers were generated by using the velocity and density values from well logs as input to Aki-Richards (1980), reflectivity approximation. To create the synthetic seismic, a deterministic wavelet, extracted from the real seismic data as part of the Thebe-1 well tie, was convolved with the reflection coefficients of the model. The entire model building process was carried out in the time domain.
Spectral decomposition and RGB colour blending then were applied to the synthetic reflectivity models using the same parameters as applied to the real data; this result could then be directly compared to the real data result to assist in explaining the meaning of the colours.

The modelling was expanded to a larger area at Thebe-1 and a secondary appraisal location (Thebe-2). At the appraisal location a similar model using the same geological configurations to Thebe-1 was created but adjusted for geometry and thickness variations at the Thebe-2 location, with the aim of explaining the differences observed in the real seismic response. Correlation of reflector events between the two locations was possible as reservoir reflectors are broadly continuous, these were used to separate out the reservoir units at the Thebe-2 location. The Thebe-2 model was populated with the Thebe-1 well log data (as if the well had not yet been drilled, this would be the only well data available). Fluid substitution of these logs was also applied to assess the seismic response to different fluid scenarios.

Result and Discussion

The tie at Thebe-1 allowed for correlation of known geology to the spectral decomposition colour blend, in the same way in which a seismic-well tie links geological interfaces to the seismic reflectivity. A good match between synthetic and real data was achieved at Thebe-1 discovery well location, providing confidence

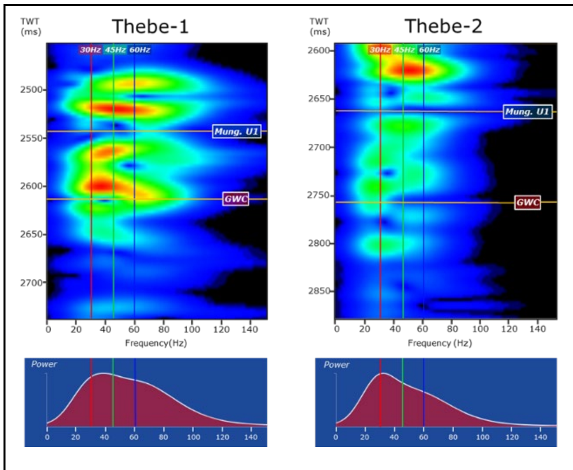

Figure 2: Trace spectrogram showing time-frequency distribution at well locations. Frequency band selection can be tailored around the central frequency at the reservoir interval. In the example the central reservoir frequency of around 45Hz is set as the central (green) band

that forward modelling could be applied robustly. Extending the regions based on interpretation allowed a larger synthetic 2D section to be interactively created (**Figure 4**).

The synthetic model at Thebe-2 created using the Thebe-1 well log data also showed a very good match to the real data in the reservoir interval suggesting similar lithology and fluid configuration to Thebe-1 with different layer thicknesses. Since the only variables that differ

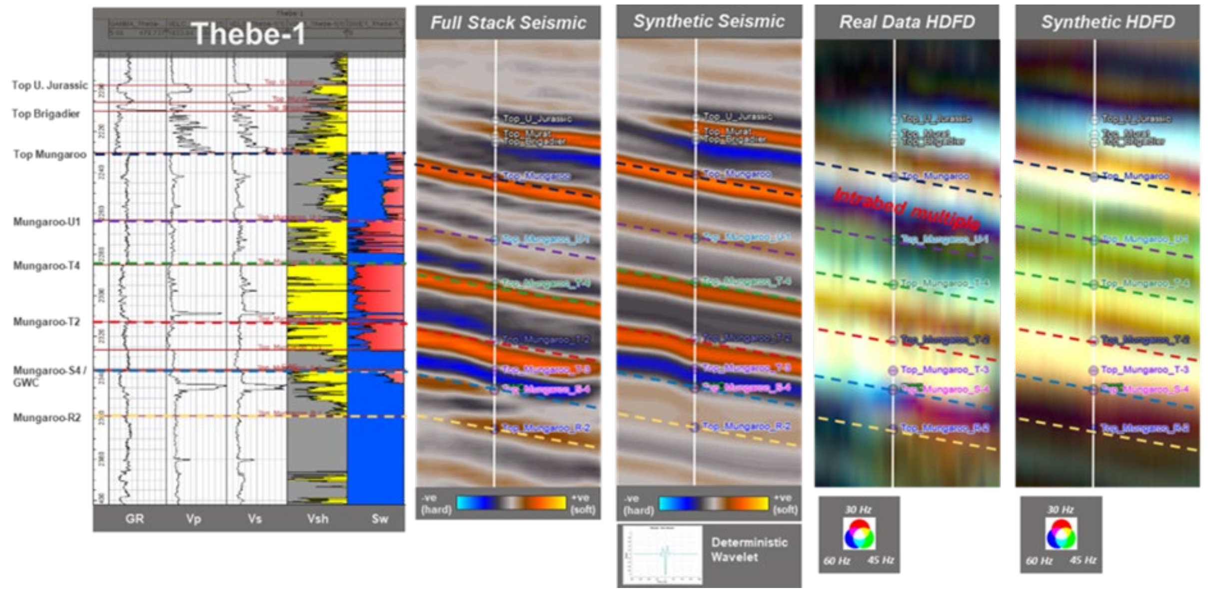

Figure 3: Well correlation at Thebe-1 location. From left to right: well log data, full stack seismic data, synthetic seismic model, High Definition Frequency Decomposition Blend, Synthetic High Definition Frequency Decomposition Blend.

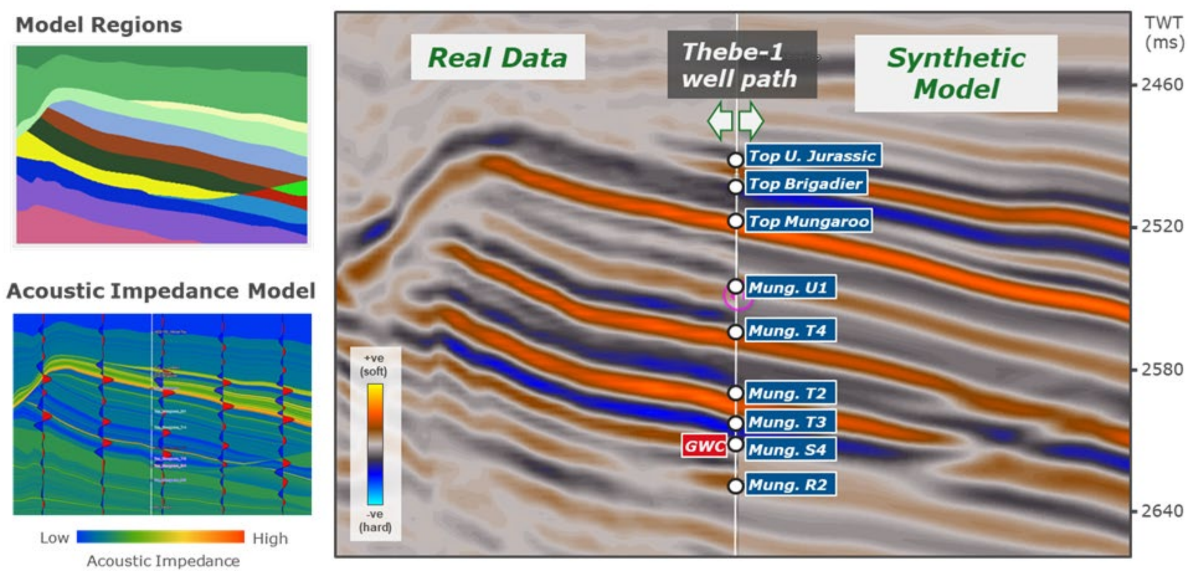

Figure 4 – Forward Modelling at Thebe-1 well location. *Top left)* Model regions created based on well tops and reflectors. *Bottom left)* Regions populated with well log based acoustic impedance values. *Right)* Comparison of real data (left) vs synthetic model (right)

from the Thebe-1 model were the region thicknesses and geometry the results are supportive of the conclusion that interference between the different thickness reservoir layers is a possible causation for the significant contrast in seismic response (amplitude and frequency) between the two locations.

Fluid substitution was carried out on the Thebe-2 model to test the expected impact of a non-hydrocarbon bearing reservoir on the seismic. Using a version of Gassmann's equations based on the ratio of quartz to clay minerals, as demonstrated by Simm (2007), the in-situ reservoir properties at Thebe-1 (i.e. gas) were substituted to test a water bearing case. This produced a significantly different spectral decomposition colour blend result in the substituted reservoir zone which no longer matched the real data (**Figure 5**), supporting that the appraisal location was gas bearing.

Conclusions

- Forward modelling of the spectral decomposition colour blend response allowed for optimization based on the reservoir and greater understanding of how the colours relate to the underlying geology.
- Results showed that the spectral decomposition colour response could be successfully reconstructed from well log derived acoustic impedances.
- Differences in seismic response between the pilot Thebe-1 well and the appraisal Thebe-2 well could be explained as a result of similar geology and fluids but differences in unit thicknesses resulting in different amplitude contrasts and frequency response. This conclusion is supported by the actual drilling results from Thebe-2 appraisal well which confirmed similar quality reservoir with gas in place to Thebe-1.
- The forward modelling results would assist in de-risking this location and can also be used to assist prediction of lithology and fluid at undrilled locations.
- This study illustrates how tighter integration of Spectral Decomposition into an interpretation workflow can increase understanding of the seismic response.
- Correlation of SD colour blends at well locations can be used to improve understanding of the seismic data, by allowing extrapolation of properties away from well locations.

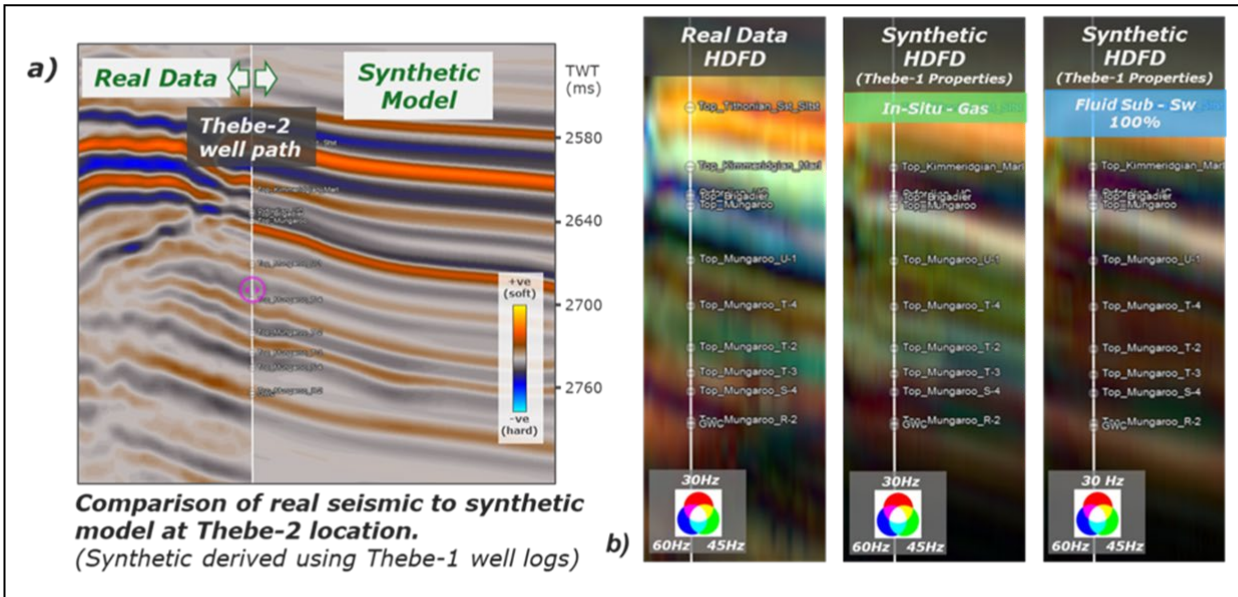

Figure 5 – Forward modelling and fluid substitution at Thebe-2 model location using Thebe-1 log data. Substitution from real data gas reservoir to water bearing shows distinct change in RGB blend

References

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Simm, R., 2007, Practical Gassmann fluid substitution in sand/shale sequences. First Break, **25**, 61-68.

Acknowledgements (Optional)

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