Improved Geological Inference from Seismic Data Using Composite, Colour-blended Seismic Attributes

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Introduction

Combining seismic attributes, such as the outputs of frequency decomposition, with 3 channel (RGB/CMY/HSV) colour blending has become a standard tool in seismic interpretation for highlighting depositional geometries. The techniques are powerful because they convey information in a highly intuitive manner and therefore provide a very efficient mechanism for developing an enhanced understanding of the imaged geology. However, the interpretation of information presented in this way is highly subjective and the results are difficult to calibrate. This is linked with the non-uniqueness of the causes of amplitude variations in seismic reflectivity data. Currently, there is a lot of work being done to determine whether examination of the seismic amplitude frequency spectrum can help resolve some of the ambiguities associated with conventional amplitude analysis.

In this paper we look at additional methods for increasing the understanding that can be gained from frequency decomposition and colour blending of seismic attributes and examine whether extensions to these methods have the potential to allow objective analysis of the images produced for differentiation of fluid and thickness effects from 3D seismic data.

The paper is divided into two sections. Firstly, we look at the application of interpreter guided classification techniques to colour blended images and show, using the example of turbidite channels from the Taranaki Basin, Offshore New Zealand, how this can aid understanding of the distribution of various facies types within a depositional system.

In the second section of the paper we examine the combination of classification and forward modelling techniques for understanding whether variations in seismic response are likely to be due to variations in thickness, fluids or lithology. We will show how the use of a combined thickness and lithology model, based on well data, can be used to examine hypotheses regarding the relationship between the observed 3D seismic response and possible models of a submarine fan system (McArdle and Ackers, 2012).

Classification of RGB blends for seismic facies analysis

RGB blends are a very effective means of highlighting facies changes and depositional geometries imaged within the seismic data. Classifying these facies using a multi-attribute Bayesian technique enables the extent and geometry of the facies to be extracted and a 3D facies model to be created directly from the seismic data.

Attribute analysis of the deepwater turbidite channels in the Taranaki basin highlight signs of internal facies variability within the channels. RGB blending of frequency magnitude volumes highlights the channel core and marginal deposits as well as other potential facies variation, whereas CMY (cyan-magneta-yellow) blending of edge attributes highlights the lateral accretion of the channel along with the evidence of slumping at the edges of the channel (Figure 1). Combining Envelope, Frequency and Dip in a colour blend (Figure 2a) enables definition of all the elements seen in both the RGB and CMY blends; the channel core, marginal deposits and slumping to be visualised in one volume.

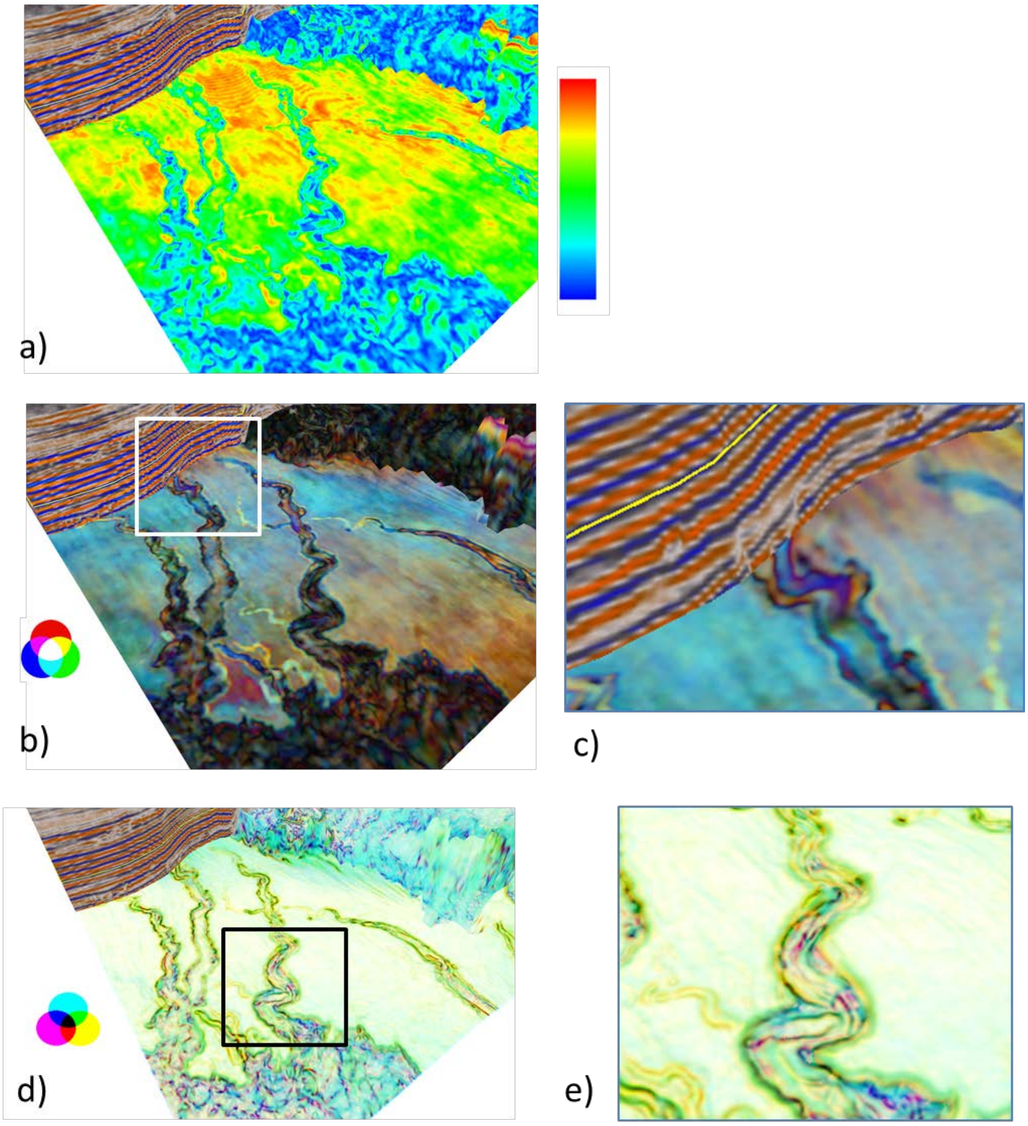

Figure 1 *Turbidite channel system imaged using three forms of attribute analysis. Results are displayed on a mid-channel horizon. a) Instantaneous amplitude (Envelope), b-c) RGB blend of three frequency magnitude responses (Red – 30Hz, Green – 40Hz, Blue – 50Hz), d-e) CMY blend of three edge attributes (Cyan – Dip, Magenta – Structurally Oriented Semblance, Yellow – Tensor).*

Classification of the RGB blend can be achieved using a data driven – interpreter guided process allowing interpreter control over the specification of different facies (based on the geology that can be seen in the blends). The classification itself uses an n-dimensional Gaussian mixture model approach, where the n-dimensions relate to the three components of the RGB blend as well as any other selected attributes. The results show the delineation of the channel core, the marginal deposits and two distinct zones of back fill (Figure 2b and c). From this we can see that the channel core facies is restricted to the base of the main system with some lateral migration but little vertical extension of the facies. The marginal deposit facies are present on both sides of the channel and extend vertically and laterally, and two distinct back-fill facies are seen, one on the lower channel accretion, and one higher up, covering the whole channel belt. Slumping on the top suggests back-fill sediment are finer grained, suggesting a primarily mud filled channel. All this needs to be confirmed with well data and cross-plotting the facies responses with the log data enables us to do this.

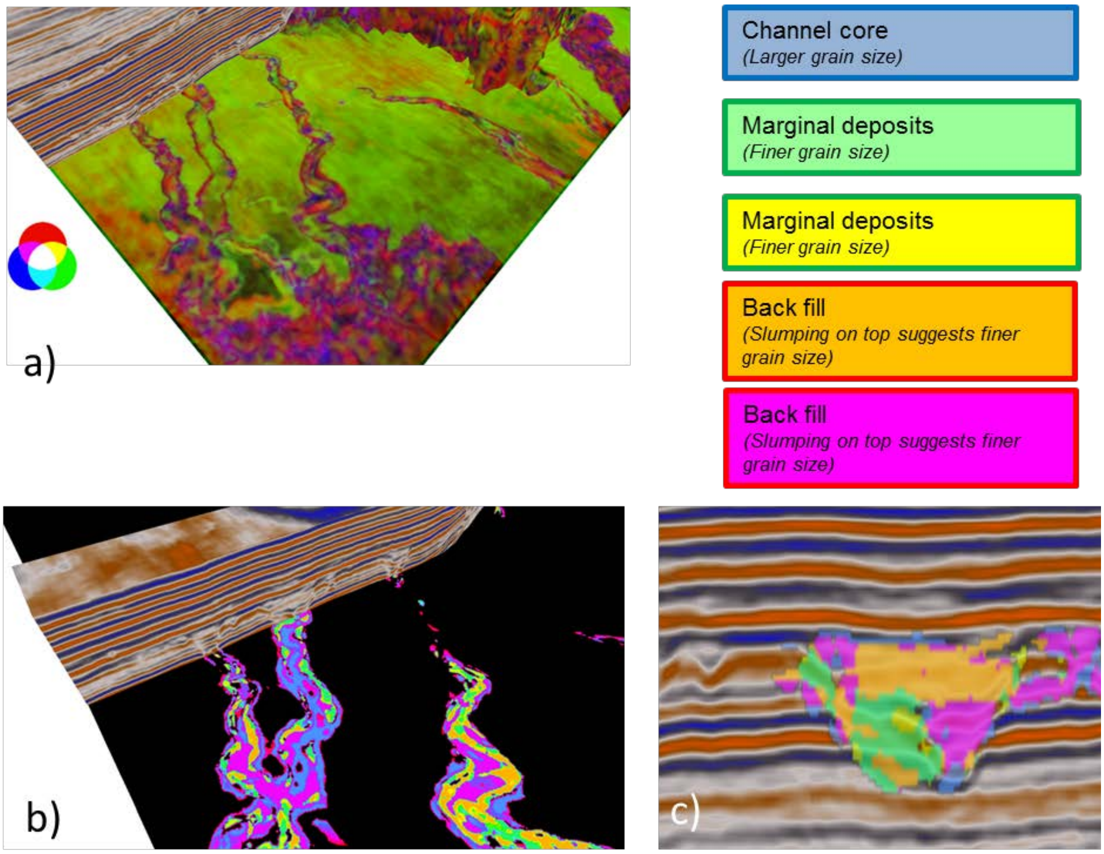

Figure 2 *Facies classification of turbidite system. a) RGB blend of Instantaneous Frequency (Red), Envelope (Green) and Dip (Blue) b-c) Facies classification from the RGB blend showing internal facies variability.*

Classification and forward modelling techniques

Ideally we would like to use seismic attributes to go beyond a phenomenological understanding of geological sequences. For example, the variations seen in an RGB blend of frequency magnitude volumes can be caused by changes in bed thickness or changes in impedance. Forward modelling, based on synthetics derived from well log data, has the potential to help put a quantitative interpretation on the colours seen in the blend. Figure 3 shows the results of forward modelling of a Hermod member submarine fan from the North Sea and illustrates how a thickness model with constant impedance highlights the main geometries of the fan and corresponds closely with the RGB blend extracted from the seismic data. However, varying the impedance values to more closely match the well data provides an extra level of detail in the resulting RGB blend, clearly illustrating that what we see in the seismic response is a combination of both a thickness and an impedance response. This is a first step in differentiating lithological and thickness effects.

Other examples have been investigated and will be presented showing the effects of different density, velocity and thickness characteristics taken from existing well data. We will show how the frequency response varies with these three parameters and discuss the extent to which forward modelling can be used to enable the RGB blends to be used as a predictive tool.

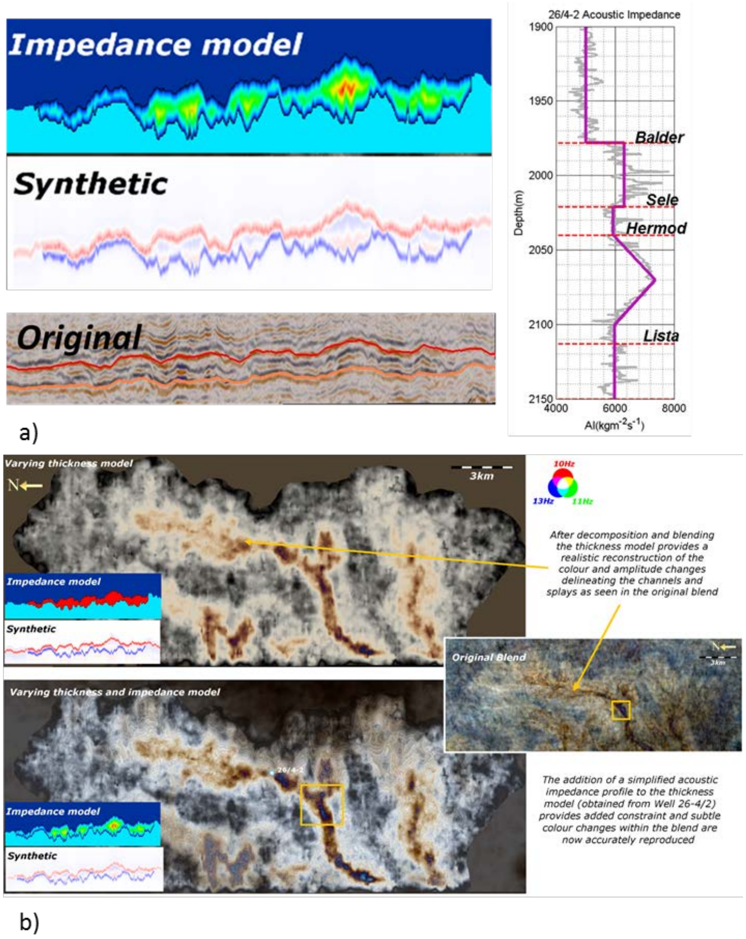

Figure 3 *a) Synthetic of the Hermod sandstone using a varying thickness and impedance model created from the well log, b) RGB blend from frequency decomposition of Hermod synthetic using the variable thickness and variable thickness and impedance models. After decomposition and blending, the thickness model provides a realistic reconstruction of the colour and amplitude changes delineating the channels and splays as seen in the original blend. The addition of a simplified acoustic impedance profile to the thickness model, provides added constraint and subtle colour changes within the blend are now accurately reproduced. (McArdle and Ackers, 2012)*

Conclusions

Frequency Decomposition and RGB blending is a very effective tool for highlighting and extracting depositional geometries but it's use as a predictive tool for estimating thickness, lithology or fluid changes should be approached with caution. This study has shown that variations in impedance and bed thickness contribute to the frequency response in a non-unique manner so that specific RGB colours can mean a number of things. However forward modelling of RGB blends has been effective at reducing the number of possible scenarios. Used in this way RGB blends can be used alongside forward modelling techniques to help predict likely scenarios for thickness, lithology and fluid changes in a reservoir.

References

McArdle, N.J and Ackers, M. [2012] Understanding seismic thin-bed responses using frequency decomposition and RGB blending. *First Break,* 30, 57-65