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Frequency Decomposition and colour blending of seismic data - More than an image

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Introduction:

Frequency decomposition is a technique whereby a seismic signal is broken down into band-limited components in order to facilitate the investigation of frequency dependent phenomena imaged by the seismic data. There are several causes for frequency variations in seismic data, both fundamental and apparent; changes in thickness and tuning effects, lithological and fluid variations causing impedance variation and associated dispersion and attenuation. Several methods can be used for measuring the frequency content of seismic data, such as Fourier Transforms, Wavelet Transforms, Matching Pursuit Decomposition and instantaneous frequency. Each method has relative advantages and all methods are a trade-off between resolution in time and resolution in frequency according to uncertainty principle.

Once the seismic data has been decomposed into its relative components we can investigate each frequency response individually or in combination. A common method for combining multiple frequency responses is by colour blending, so that multiple frequency responses can be merged into a composite image. RGB blending is a form of colour blending that uses Red, Green and Blue colour schemes for each frequency channel respectively. The resultant blend shows a variety of colour and contrast that reflects the complex interplay of frequencies and therefore variations in the phenomena that are the cause of the frequency dispersion. Visually, these RGB blends show elements of, and interactions between, geological systems in stark and vibrant detail (Figure 1). Until recently we had difficulty translating these very clear observations into meaningful quantitative geophysical measurements, but through synthetic modelling we have been addressing this.

Our aim hereto, is to investigate frequency-related phenomena through decomposition and colour blending, so that we can derive information pertaining to reservoir geometry, thickness and petrophysical properties.

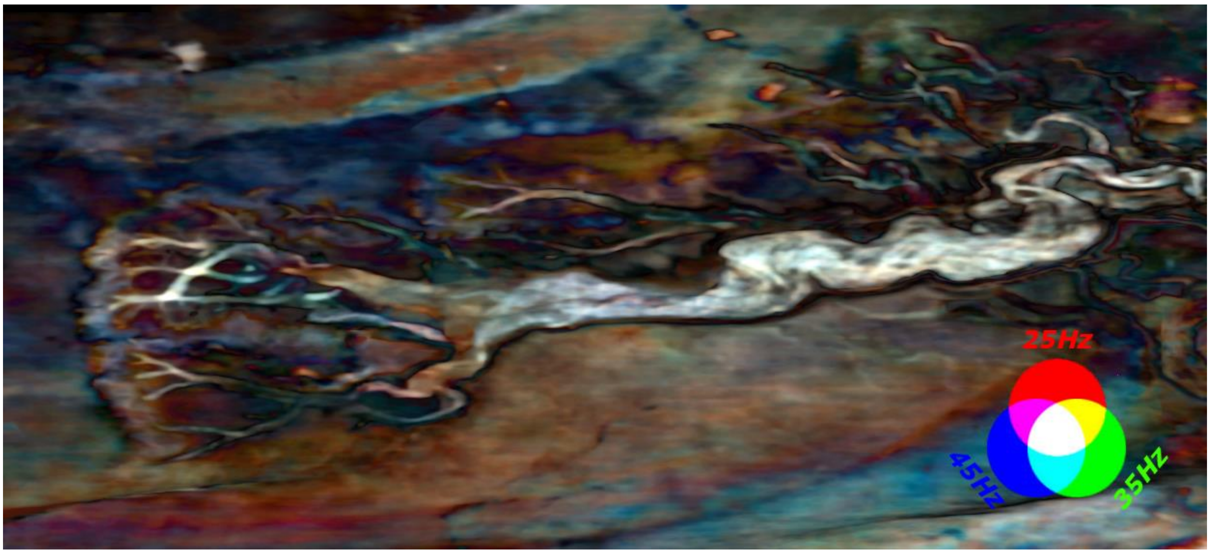

Figure 1: RGB Blend composed of Frequency Decomposition magnitude volumes showing braided channel system, offshore New Zealand. This example, imaged 700ms below seabed, highlights the extraordinary detail we can resolve using these techniques, such that it may be mistaken for satellite imagery.

Synthetic Modelling:

The classical approach to investigate tuning effects is via wedge modelling (Widess, 1973) and the study of frequency responses in relation to tuning is similarly established (Partyka *et al.,* 1998). We have adapted the standard wedge model in order to investigate frequency decomposition response with thickness (Figure 2). RGB wedge models are created to show the complex interference patterns that occur due to the tuning effects of the source and decomposition bands. In simple geological sequences (e.g. those with little seismic interference from surrounding stratigraphy) the RGB wedge model provides a simple proxy measurement of thickness in RGB/decomposition space. The 'calibration wedge' is applicable when the frequency content of the synthetic wedge is well matched to the real seismic signal and the decomposition methods and central frequencies are comparable.

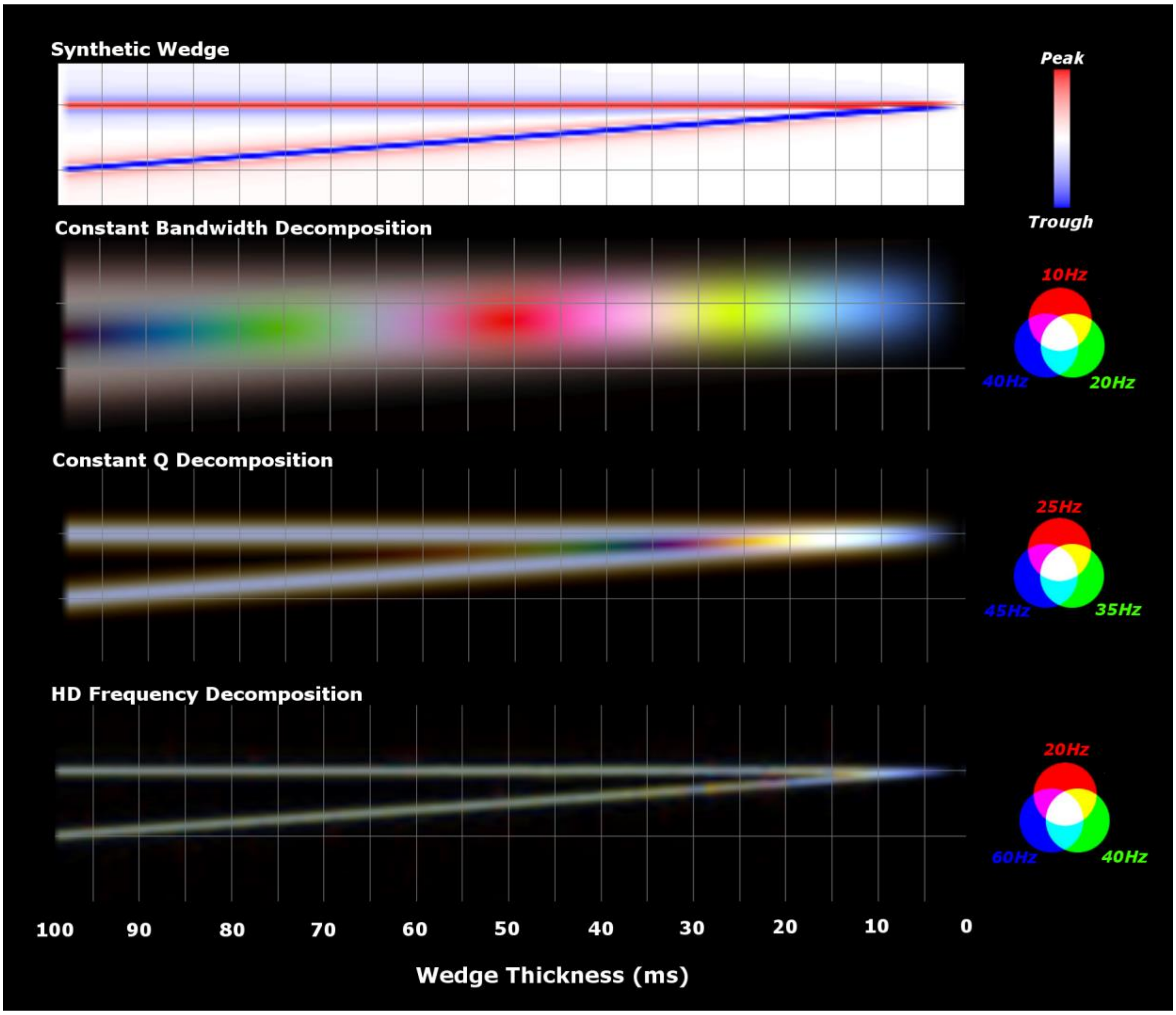

Figure 2: Various wedge model frequency decomposition RGB Blend responses created using different decomposition methods. Notice the variety of colour, contrast and vertical sensitivity obtained by using different techniques and by using different central frequencies. Choosing an appropriate technique and frequencies is dependent not only on the spectral content of the data, but on the imaging and interpretational objectives and the complexity of the seismic sequence.

In complex environments the principle can be extended by building more robust synthetic models, from which sensitivity testing of multiple factors can be considered. This enables the prediction of frequency responses due to intricate and detailed geological systems with subtle lithological variations. Furthermore, by applying well calibration and fluid substitution to the synthetic models we can predict hydrocarbon responses in frequency space in other areas of the blend with a greater degree of certainty and understanding. Figure 3 shows a synthetic model, predicted RGB response and real RGB response for a Palaeocene submarine fan system, Northern North Sea (McArdle & Ackers, 2012) showing that success of this type of forward modelling for lead evaluation.

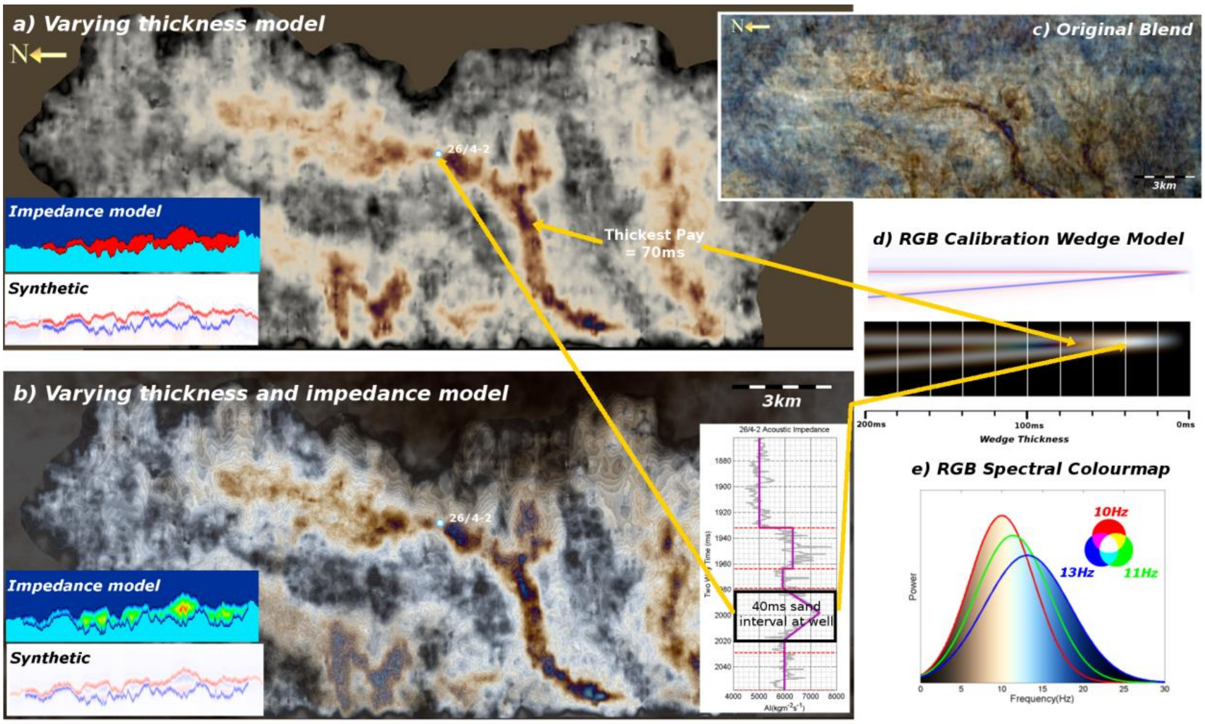

Figure 3: Synthetic model, predicted RGB response and real RGB response for a Palaeocene submarine fan system, Northern North Sea (McArdle & Ackers, 2012). This study was successful in relating thickness and impedance variations to colour and contrast in the RGB blend.

Interpretation and classification from blends:

In addition to the advancements in our understanding of the principles responsible for the very good imaging of geological systems through frequency decomposition, considerable improvement has been made to the way in which we can practically use the output. No longer is an RGB blend just a pretty picture.

One method of extracting information directly is through Interactive Facies Classification (IFC) of the frequency decomposition colour blend. This is a method of unsupervised learning from a pick, group of picks or polygon, usually seeded on a geological feature of interest. An automatic statistical sub classification then occurs, which segments a volume into regions of similar characteristics; these frequency characteristics are defined by geometrical and petrophysical constraints that we have already estimated through forward modelling. The overall result is a classification model distinguishing key sub-surface elements that can be built into a full 3D geological model in a fraction of the time taken by manual interpretation (Figure 4a; Henderson *et al.* 2012).

Another method, Adaptive Geobody delineation, is a direct and semi-automated interpretation technique based on a deformable surface, which can morph and grow to fit a geological feature highlighted in the data. In the context of quantitative interpretation of frequency decomposition blends, contiguous regions within a similar statistical range can be extracted based on interpreter seeding. The interpreter has control over the scale of the geobody and retains the ability to interact with it in a manner that allows it to be matched to a-priori knowledge of a geological environment, whilst remaining faithful to the data (Figure 4b; Henderson *et al.* 2012). During the process of geobody adaption, real-time metrics are computed relating to the volumetric and areal extent of the geological feature.

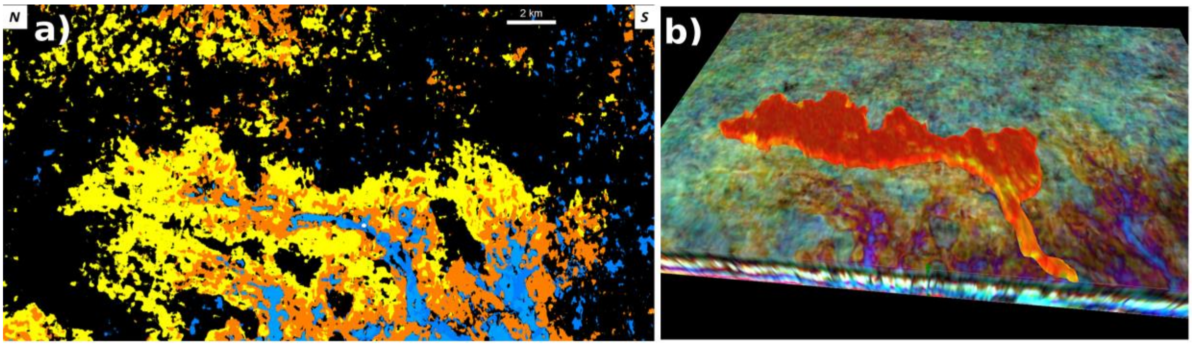

Figure 4: Classification and geobody interpretation of a Palaeocene submarine fan system, Northern North Sea using a frequency decomposition RGB blend to distinguish different parts of the system: a) Classification showing inner channel core (blue), proximal splay (orange) and distal splay (yellow) and b) Adaptive Geobody of proximal splay (Henderson *et al.*, 2012).

Conclusions:

ffA promote a targeted approach to frequency decomposition which enables the appropriate method, frequency range and bandwidths to be considered for given geological feature of interest. Understanding the sensitivities and limitations of a given method is crucial to understanding and interpreting the resulting image, but if done carefully and systematically we can learn a great deal about the geometry and physical properties of the subsurface directly from the interference patterns of frequency responses within RGB Blends. Through synthetic modelling and calibration, classification and interpretation we are able to build detailed geological models from RGB blends with confidence.

Frequency decomposition and RGB blending has moved on from simply pretty pictures and polygon interpretation that we were previously limited to.

References:

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