Integrating Interpretation Expertise and Objective Data Analysis in 3D Interpretation

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Introduction

Volume attribute computation has become an accepted part of mainstream interpretation workflows. Perhaps counter-intuitively, attribute generation is powerful because it creates data sets that show only a subset of the information available in the original seismic. By reducing the information content it is easier to focus on those aspects of the seismic response that help differentiate particular aspects of the imaged geology.

Seismic attributes are often measuring properties of the seismic signal and the trace – to - trace variation in seismic signal that have an opaque relationship to rock properties. Therefore, interpretation of such attributes is generally based on identification of geologically reasonable scenarios. This can be greatly facilitated by examining multiple attributes simultaneously in a spatially co-registered manner either to increase the differentiation between features of interest or to the show the relationship between different types of seismic response. A powerful way of achieving this is the use of colour blending techniques (Henderson et al 2007) (Figure 1). Colour blending is very effective at illuminating the geology, but in doing so creates a complex image in which the information is hard to access other than visually. Accurate extraction of the information we *perceive* within a colour blend is one of the interpretation challenges associated with the improvements in visualisation technology.

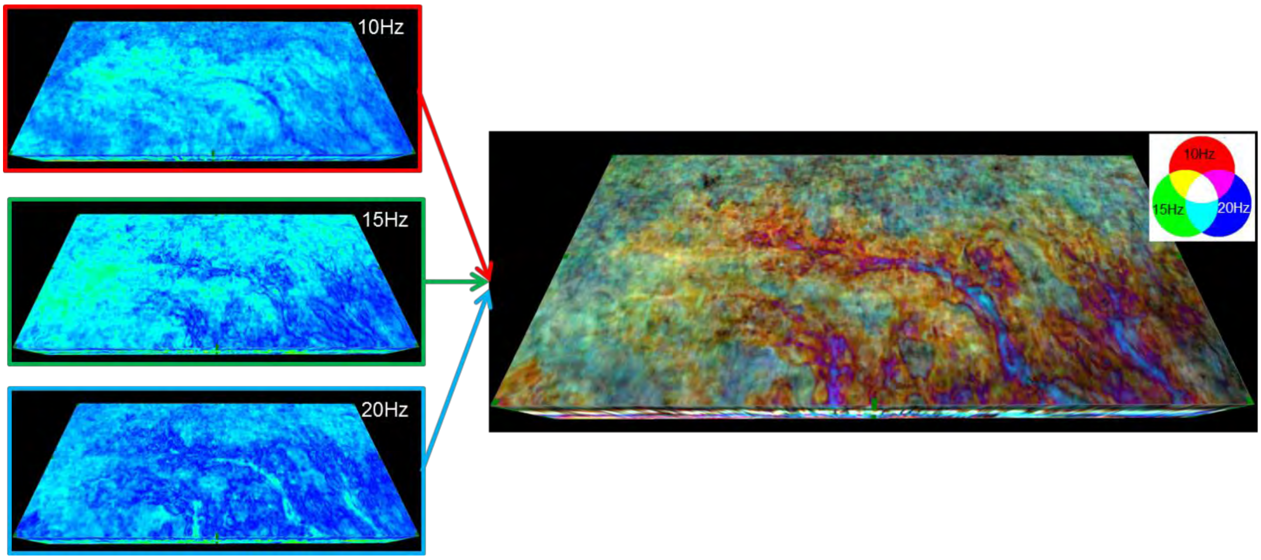

Figure 1. Three magnitude volumes at different central frequencies and the RGB blend created by combining the three volumes, highlighting different elements of the fan system.

Human Perception

What we see in an image is determined by an enormous range of subjective factors. The human visual system is extremely good at connecting or separating elements in an image and compensating for variations in texture, hue and intensity. We are also very adept at recognising and classifying features even when there is substantial variation between individual examples in terms of size and shape whilst at the same time being able to differentiate features on the basis of quite subtle changes. Images of completely different physical entities, from different domains, can have a very similar appearance (e.g. Figure 2). Critically, for our visual analysis to come up with a plausible answer we need to use knowledge and experience to impose a context on the image.

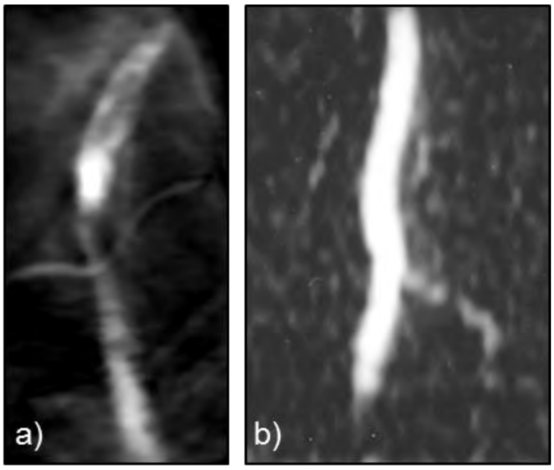

Figure 2. (a) Seismic attribute image of a beach system and cross cutting channel. (b) Lower limb angiogram showing a section of the popliteal artery. With no knowledge of the provenance of the images they could easily both be interpreted as showing anatomy or geology!

Every time we look at an image we are making real time decisions based on assimilating and analysing a vast number of parameters and cues from both the image itself and from past experience. Computing technology is a long way off being able to replicate this and as a consequence, there is always likely to be a significant subjective element to aspects of seismic interpretation.

However, whilst human observers are very good at recognising features in an image we are less good at quantifying what we see. In part this is due to the compensation mechanisms underlying the human visual systems (e.g. Froner et al 2012), which affect how we recognise boundaries. A consequence of this is that substantial inter- and intra-observer differences can arise when manually delineating features seen in an image (Figure 3).

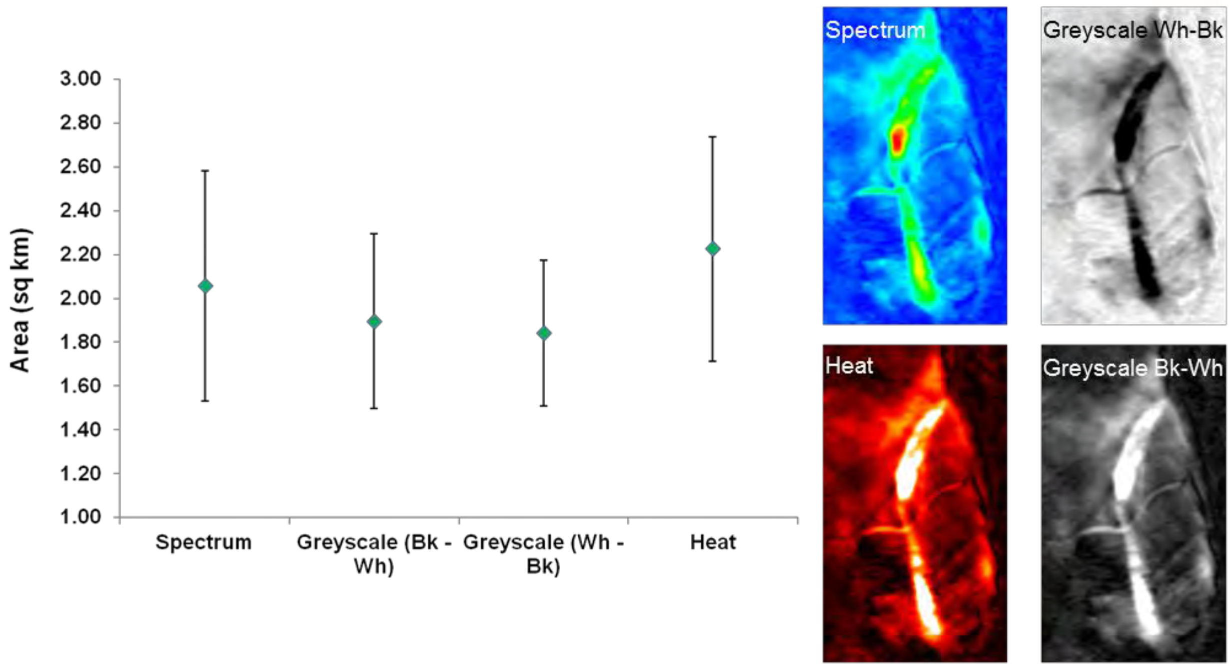

Figure 3. Combined Inter- and intra-operator variability in the area of the beach system as measured by 6 observers from the same data displayed with 4 different colour tables (error bars = 1 std dev of the mean).

Although we are very good at compensating for changes in hue and intensity when determining which parts of an image belong to a given object, the converse is not true in that we perform poorly if asked to decide whether two parts of an image have the same hue and intensity. This can make it difficult to examine the variability within a feature of interest robustly and consistently.

From this simple analysis, it is clear that the main strength of the human observer is to recognise what the images to be interpreted contain and which parts of the image belong to the same geological feature. The strength of objective, numerical analysis is to classify the underlying data into areas of common character and to adapt the guidance provided by the interpreter to the data and thereby facilitate repeatable and accurate measurement. This suggests that we should be looking at developing interpretation technology from a data driven – interpreter guided perspective.

Data Driven – Interpreter Guided Approach

We have applied this perspective to analysis of RGB blended attribute data covering the Hermod fan system on the Norwegian continental shelf. In this analysis two techniques, Interactive Facies Classification and Adaptive Geobodies, that have been designed based on taking a data driven – interpreter guided approach, were applied.

Conceptually, the Interactive Facies Classification (IFC) technique is very simple. The initialisation step is completely interpreter guided and is achieved by manually defining regions on colour blended displays that highlight the features of interest and that are expected to be representative of different facies within the system being investigated.

The data driven part of the workflow comes from the classification. This is based on an analysis of the attribute data comprising the colour blend and utilises a Gaussian Mixture Model approach. The initialisation area(s) can be changed quite easily and in most cases the impact can be seen on a section through the data almost instantly. However, it should be noted that the technique is generally quite robust to small changes in the definition of the initialisation areas.

The IFC gives a very detailed, voxel by voxel, analysis of the input data, and results in a classification of the whole volume. In situations where only one part of the data is of interest, or a more generalised approach is required, the Adaptive Geobodies technique is more suitable.

The Adaptive Geobodies technology (Figure 4) also utilises a classification approach. The data driven – interpreter guided approach embedded in the Adaptive Geobodies technique is much more robust than standard region growing or threshold based techniques. Robustness in the data driven aspect of the technique arises from a combination of factors.

- Variations in the data characteristics representative of the object of interest are accommodated by using multiple picks to define a set of representative data clusters (inclusion picks).
- In situations where the contrast is particularly low or highly variable, external data clusters can be defined to tell the region growing technique which areas to avoid (exclusion picks).
- The classification statistics that constrain the region growing can be derived from up to five different attributes. If the Adaptive Geobody technique is applied to an RGB colour blend then the three attributes that contribute to the RGB blend are automatically included in the classification.

As the geobody grows, the Adaptive Geobodies technique automatically computes a “goodness of fit” measure between the geobody surface position and the data. Where the data suggests there is a strong boundary the geobody surface is ascribed a high confidence value and where there is little indication of a boundary we get a low confidence value.

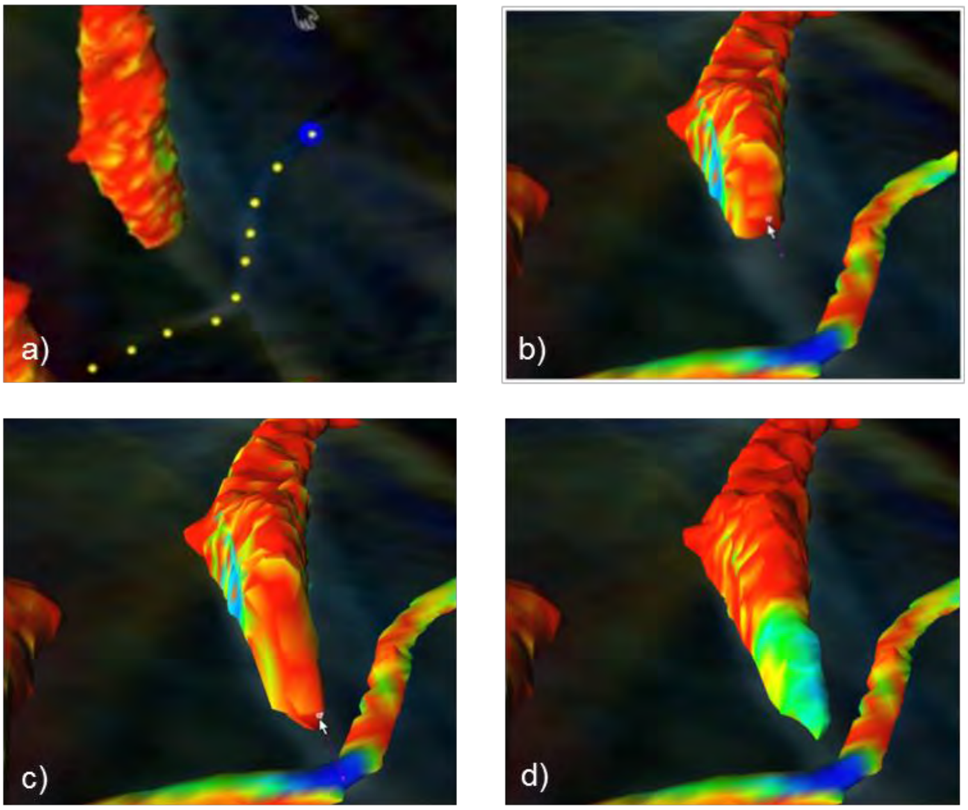

Figure 4. The Adaptive Geobodies workflow. (a) Multiple seed points can be selected to enable the region growing to adapt to varying data characteristics. (b) To manually adjust the geobody interpretation a surface point is selected and (c) a 3D section of the geobody can be dragged to position the surface correctly. (d) The geobody then adapts to the data locally and re-computes the "goodness of fit" parameter (blue: poor fit to the data, red: good fit to the data). (Images courtesy of Lundin Norge AS).

Although the data driven aspects of the Adaptive Geobodies technique are designed to overcome many of the limitations inherent in seismic data, there are still many instances when interpreter guidance is required to produce a geologically reasonable representation of a given geological element. The final level of robustness derives from allowing a high degree of interpreter guidance. This is accommodated in the Adaptive Geobodies technique through providing the interpreter with a simple mechanism for manually deforming the surface of the geobody in 3D. So, for example, if the geobody is not growing into an area into which it is believed to extend, a node point on the surface can be selected and used to drag the surface to where it is interpreted it should be. This 3D surface deformation works by adjusting all the points within a defined radius of influence so avoiding the laborious process of adjusting each point one-by-one.

Once the geobody surface is positioned to where the interpreter thinks it should be, it can be snapped to the optimal position as determined by the local data statistics and the confidence map is updated.

Hermod Submarine Fan System Case Study

The Palaeocene Hermod submarine fan system located in the Norwegian North Sea provides a good example of how a data driven - interpreter guided approach to interpretation can result in an improved understanding of the imaged geology. The eastern-most splay of this system has been investigated using the seismic response in cross-section, isochron maps and an RGB blend of three frequency response volumes, and has been interpreted as a frontal splay complex overlain by a leveed channel, with little erosion of the surrounding Sele Fm. Shale (Figure 5).

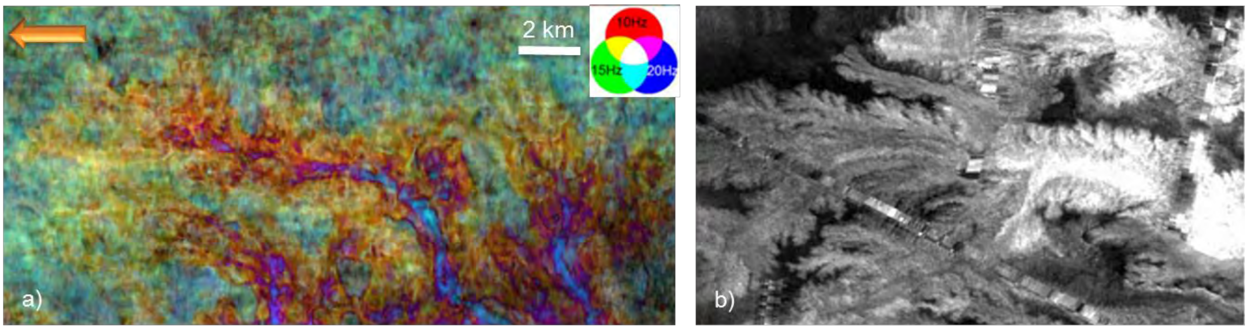

Figure 5: a) RGB colour blending of three frequency response volumes showing the Hermod Mbr submarine fan system, b) Modern day analogy: Splays within a Mississippian submarine fan imaged using side scan sonar.

The Hermod Mbr. sand is of variable thickness, and thins towards the limit of seismic resolution in large areas of the proximal and distal splays. This means standard interpretation techniques on the reflectivity data are inadequate for interpreting the full extent and geometry of the system. Frequency decomposition and RGB blending have proven to be effective at highlighting the fan system (Bryn & Ackers, in press) and the response in the RGB blend can be correlated with known thickness information derived from the well data (McArdle & Ackers, 2012). However imaging the fan in the RGB blend is only half the problem. We need to be able to extract the information from the RGB blend and propagate it through the interpretation and modelling workflow in order to get the maximum value from the data. In order to extract the information that is visible in the blend we utilised two Geological Expression workflows, Interactive Facies Classification and the Adaptive Geobodies technique, to segment the RGB blend.

Using the Interactive Facies Classification technique we were able to specify a region of the fan visible in the RGB blend to determine the facies classes. The application then performs a Gaussian Mixture Modelling analysis and identifies the data clusters within the defined area. All other areas in the data that conform to these clusters are assigned the same class value. The resulting classification (Figure 6) has identified 4 classes, two of which conform to the channel core, one reflects the proximal splays, and the final class identifies the distal splays. The classification simplifies the complex RGB image into a four class segmentation where the geometry and extent of the fan system is immediately apparent. The detailed fingering on the periphery of the fans has been preserved, and the areas of the data where the exact extent of the fans was unclear and hard to determine are now easily visible.

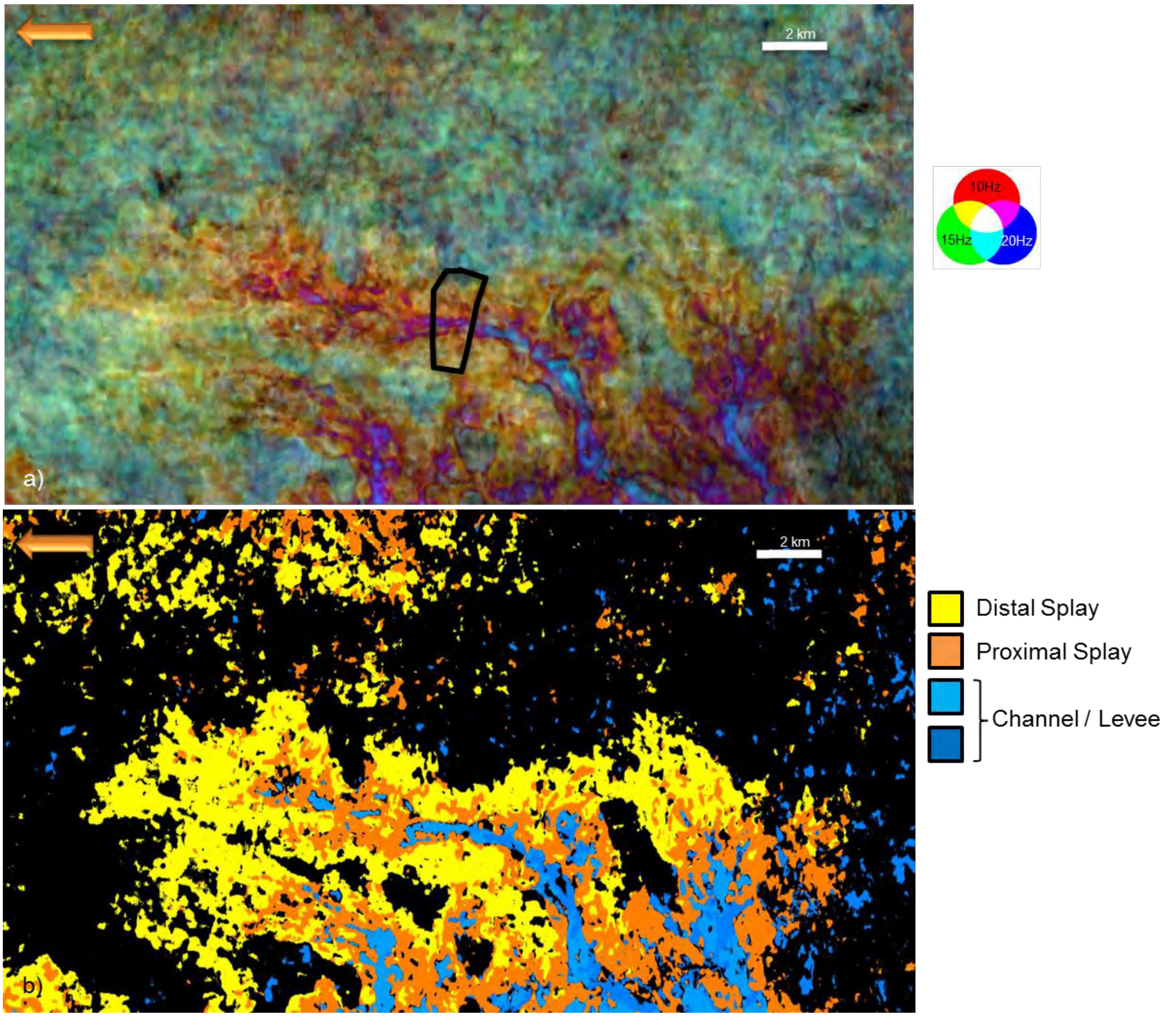

Figure 6: Interactive Facies Classification of the fan system. a) Original RGB blend showing the area selected to determine the classification, b) Classified result showing the different facies of the fan system.

One of the key findings of this result was the close location of the yellow “distal splay” response to the channel core response in the centre of the image (green arrow). On initial interpretation of the RGB blend, this area appears to be associated with the main north trending channel, however all the other distal facies appear at the end of a fan after a zone of orange proximal facies response. This is compatible with the particular distal facies response being associated with a smaller channel/levee located to the north of the western edge of the primary channel and that is trending due east. This would suggest that the main northward trending channel was deposited at a later stage and cuts across the distal edge of the smaller east trending fan. This finding conforms to the known depositional history of the area which indicates a predominant west – east depositional pattern.

These results clearly illustrate how an objective data driven approach but with interpreter guidance can provide detailed and accurate information about the extent, composition, and depositional history of this fan system. However, in an exploration environment these results are too detailed to be used for building a geological model and a more simplified result is required, but one which still honours the variability seen in the data. To achieve this we used the Adaptive Geobodies technique to extract the three main facies of the central channel and fan system.

This approach allows interpolation of the highly detailed boundary geometries resulting in a simplified outline but one which still conforms to the dominant data characteristics. Three Adaptive Geobodies were interpreted, each one building on the previous geobody, so that the three main facies of the fan system were isolated (Figure 7).

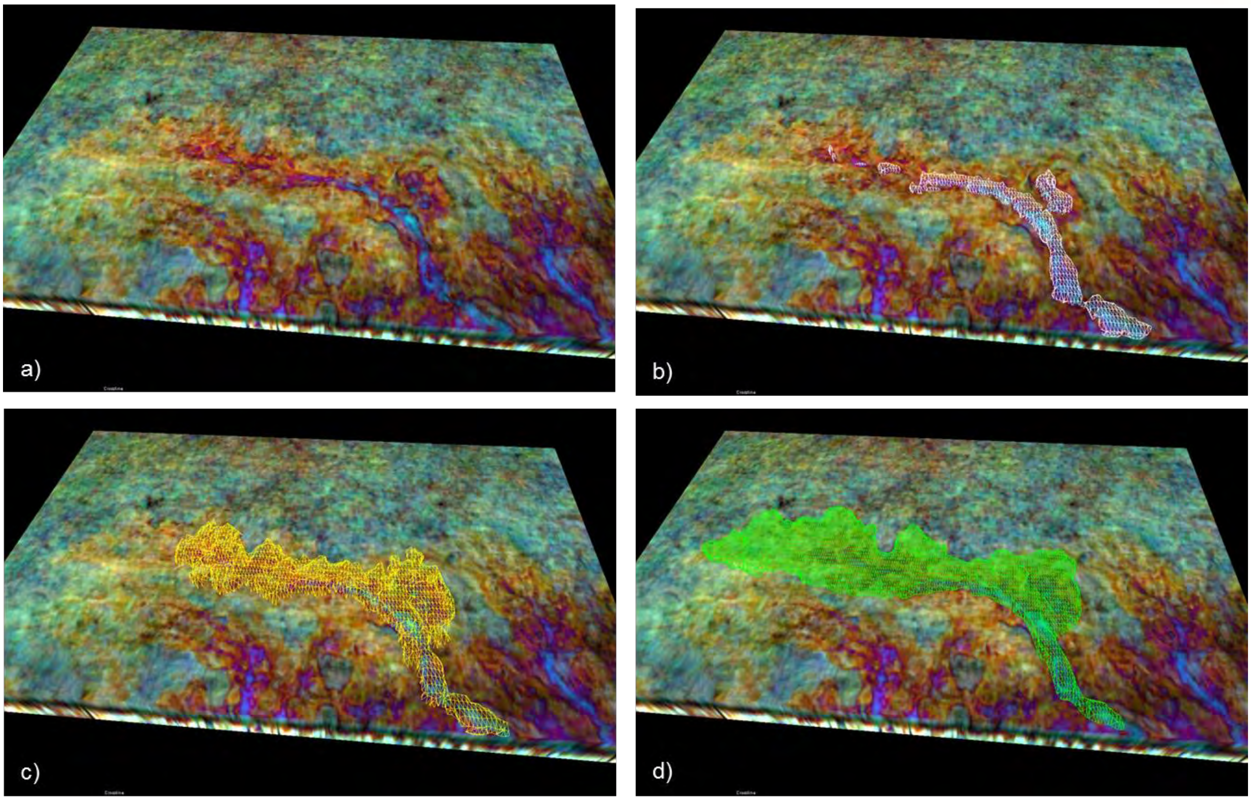

Figure 7: The RGB blend showing the three Adaptive Geobodies extracting the different facies response of the primary fan system. a) input RGB blend, b) Channel/Levee geobody, c) Channel/Levee and Proximal Splay geobody, d) Full fan geobody.

The focus for this interpretation was the largest north trending fan only. The interactive nature of the Adaptive Geobodies enabled control of the data driven tracking so that the distal splay of the minor fan was not tracked and the geobody did not expand into that area as it grew into the distal splay of the fan of interest. Comparison of the three geobodies with the input RGB blend (Figure 8a) shows the boundaries of the geobodies conforming well to the character change in the RGB blend and still retaining a significant amount of geomorphological detail. Comparing the Adaptive Geobodies with the classification achieved using the Interactive Facies Classification (Figure 8b) shows the level of agreement between the two interpretation techniques.

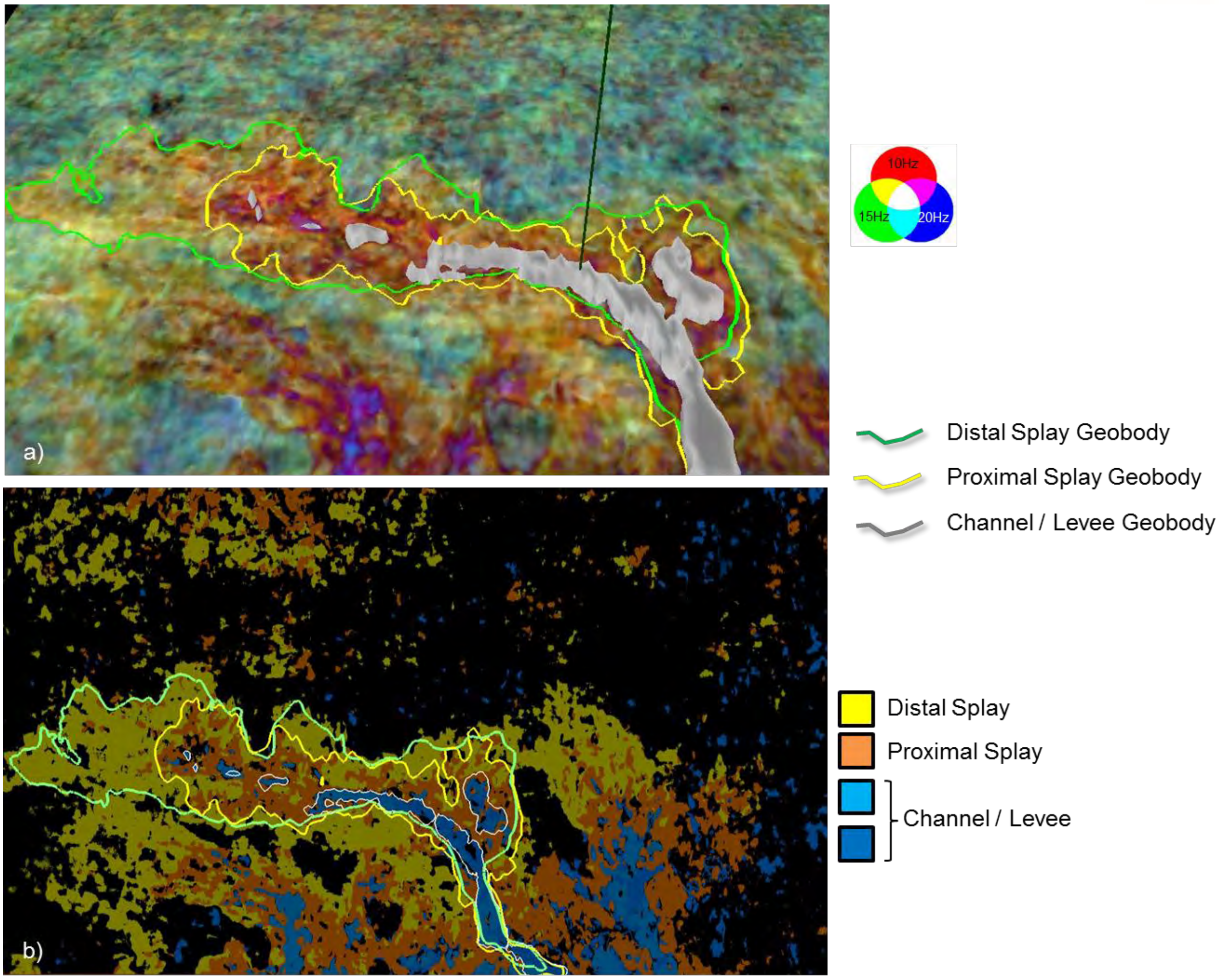

Figure 8: Outline of the Adaptive Geobodies on a) the input RGB blend and b) the Interactive Facies Classification result.

Conclusions

As seismic data gives an abstract and ambiguous representation of the surface, interpretation is always going to rely heavily on the knowledge and experience of the interpreter. With many aspects of attribute analysis we are generating highly detailed geological images that need to be interpreted from a geological rather than a geophysical perspective. As a consequence, to make the most of the information that is available in seismic data we need to better harness the geological experience and expertise of the seismic interpreter. One way of achieving this is interpretation tools that bring objective analysis and subjective interpretation closer together. IFC and Adaptive Geobodies are technologies designed around this approach. As shown in the Hermod case study they can be utilised to give additional insights into complex geology and provide a means of capturing that additional knowledge in a form that can be utilised in later stages of the subsurface workflow.

References:

Bryn, B. & Ackers M. [in press] Unravelling the nature of deep marine sandstones through the linkage of seismic geomorphologies to sedimentary facies – the Hermod Fan, Norwegain North Sea. *IAS Spec. Pub.*, **47**.

Henderson J, Purves SJ and Leppard C. [2007] Automated delineation of geological elements from 3D seismic data through analysis of multi-channel, volumetric spectral decomposition data. First Break **25**, 15 – 21.

Froner B, Purves SJ, Lowell J and Henderson J. [2012]. Perception of visual information; What are you interpreting from your seismic? EAGE Annual Conference, Copenhagen, Expanded Abstracts.

McArdle, N.J. & Ackers, M.A [2012] Understanding seismic thin-bed responses using frequency decomposition and RGB blending. EAGE Annual Conference, Copenhagen, Expanded Abstracts.