Spits, channels and beaches: advanced imaging and delineation of Jurassic and Triassic stratigraphic targets.

Exploration Hot Spots

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Introduction

We present the results of applying advanced 3D seismic analysis methods to a region in the Norwegian sector. The techniques applied were focussed on improving definition and delineation of stratigraphic targets including channels in the Jurassic and landforms and channels in the Triassic.

The complexity of the Jurassic channels in this region makes detailed interpretation on 3D seismic challenging. Similarly, in the Triassic, definition of sand bars and beaches is complicated as they are only partially visible when seismic amplitude is examined. To improve the imaging of these features, we have combined frequency decomposition and seismic attribute analysis techniques with advanced visualisation methods.

Attributes were chosen and tuned to enable the edges and internal architecture of the targeted sedimentary structures to be visualised. In particular, generation of narrow-band instantaneous amplitude volumes to allow detailed analysis of variations in frequency response proved very powerful. By merging these different sources of information, using advanced colour and opacity based co-rendering techniques, composite multi-attribute volumes are created for use in the volume interpretation workflow. The result is a collection of 3D volumes that present rich visual information, clearly delimiting the edges and defining the interior structure of the stratigraphic targets.

In the case of channels, the interpretation of the depositional environment is simplified, whilst additional details of channel structure, overbank deposits and splays are revealed. In the case of spits and beaches, the overall geometries are better defined and by analysing the variation in frequency response, an improved understanding of expected density and thickness variation within these landforms is achieved. Accurate 3D representations of these stratigraphic targets are then extracted as 3D geobodies, which can be used as a basis for subsequent interpretation and reservoir modelling. The delineation methods applied include threshold based segmentation and a new delineation method that has been developed specifically to extract accurate and meaningful representations of geological targets from composite multi-attribute volumes.

We believe that using the described combination of attribute visualisation and delineation techniques, Mesozoic stratigraphy is seen at much higher levels of detail. Our experience has also shown that these methods are applicable to similar settings globally in order to image and extract sedimentary features.

Methodology

We have created and combined a set of seismic attributes that greatly aid delineation and understanding of sedimentary features and potential reservoirs. The workflow is straightforward to apply and comprises data conditioning, attribute generation and combination stages as described below and outlined in Figure 1.

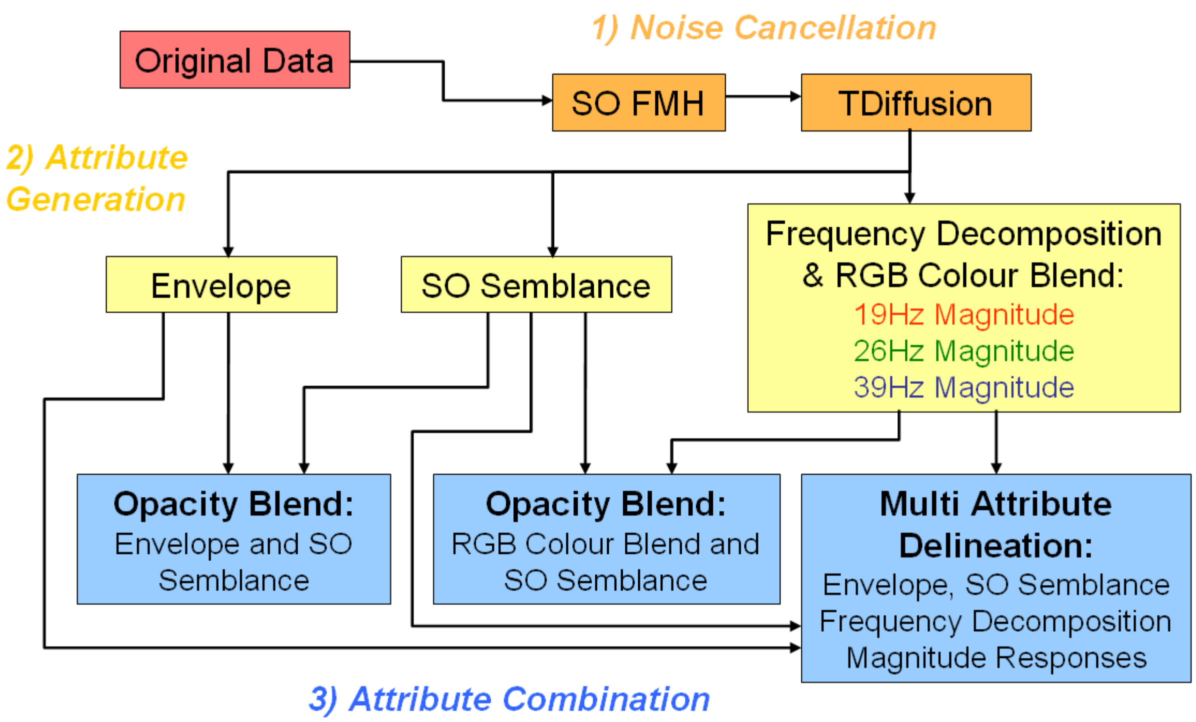

Figure 1: Workflow

Noise Cancellation

The signal to noise ratio of the data is improved through application of a combination of ffA's structurally oriented and adaptive noise cancellation filters. The noise cancellation algorithms are designed to preserve information by aligning the filter with reflectors. Adaptive noise cancellation also preserves reflector edges, such as faults/fractures and stratigraphic terminations, and subtle amplitude variation across the reflectors. Enhancing the image quality by removing noise is important, in order to generate attributes of the highest possible resolution and which have the best chance of capturing subtle stratigraphic details. Figure 2 shows a slice of the data through features of interest, before and after noise cancellation, highlighting the improvement in reflector continuity.

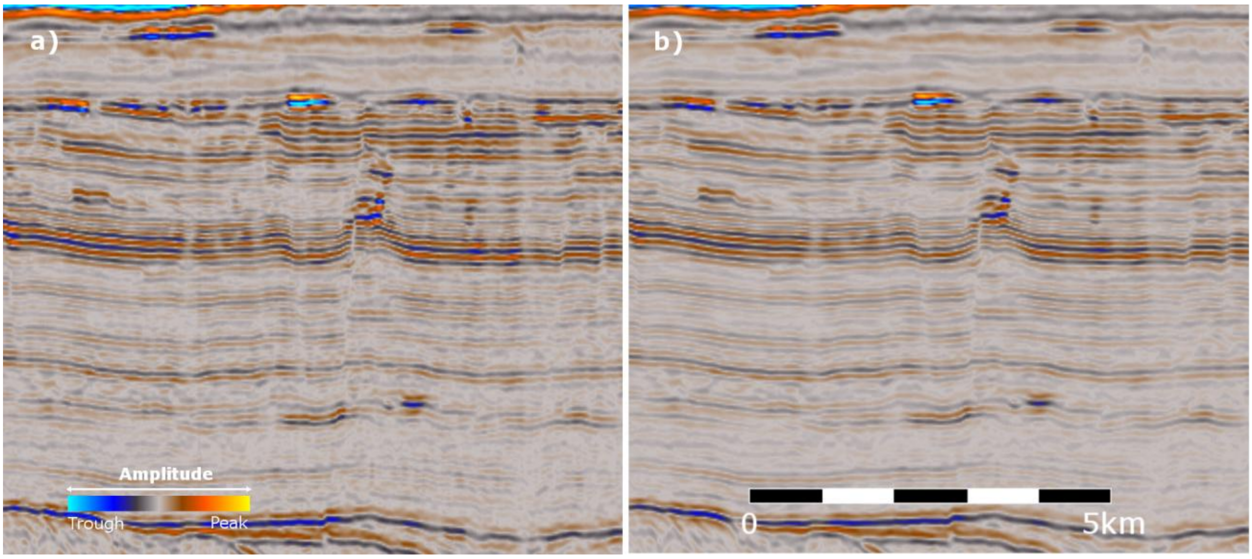

Figure 2: a) Original data versus b) noise cancelled data.

Attribute Generation

As part of ffA's structural and stratigraphic attribute analysis workflows, a Structurally Oriented (SO) Semblance edge attribute and Envelope attribute are generated. SO Semblance is chosen to highlight the edges of channels and very thin spit features, and can also be used to show faulting. Envelope is a trace attribute, and is a measure of reflection strength, which is used to highlight the high amplitude stratigraphic features present in the data set. Figure 3 shows the Envelope and SO Semblance attributes created from the noise cancelled seismic reflectivity volume. Geobodies are created from the Envelope volume by thresholding and carrying out a connected components analysis, with high Envelope values included as geobodies and low values ignored. Envelope bodies are ranked by body size, with very small bodies being omitted from the analysis. Segmentation of the Jurassic channel and Triassic spit systems were carried out independently, by parameterising the body extraction for each system and combining the two body sets as a single volume. The final body volume was populated with Envelope values to show magnitude variation within the extracted features. Figure 4 shows the geobody volume centred at a Triassic beach and spit.

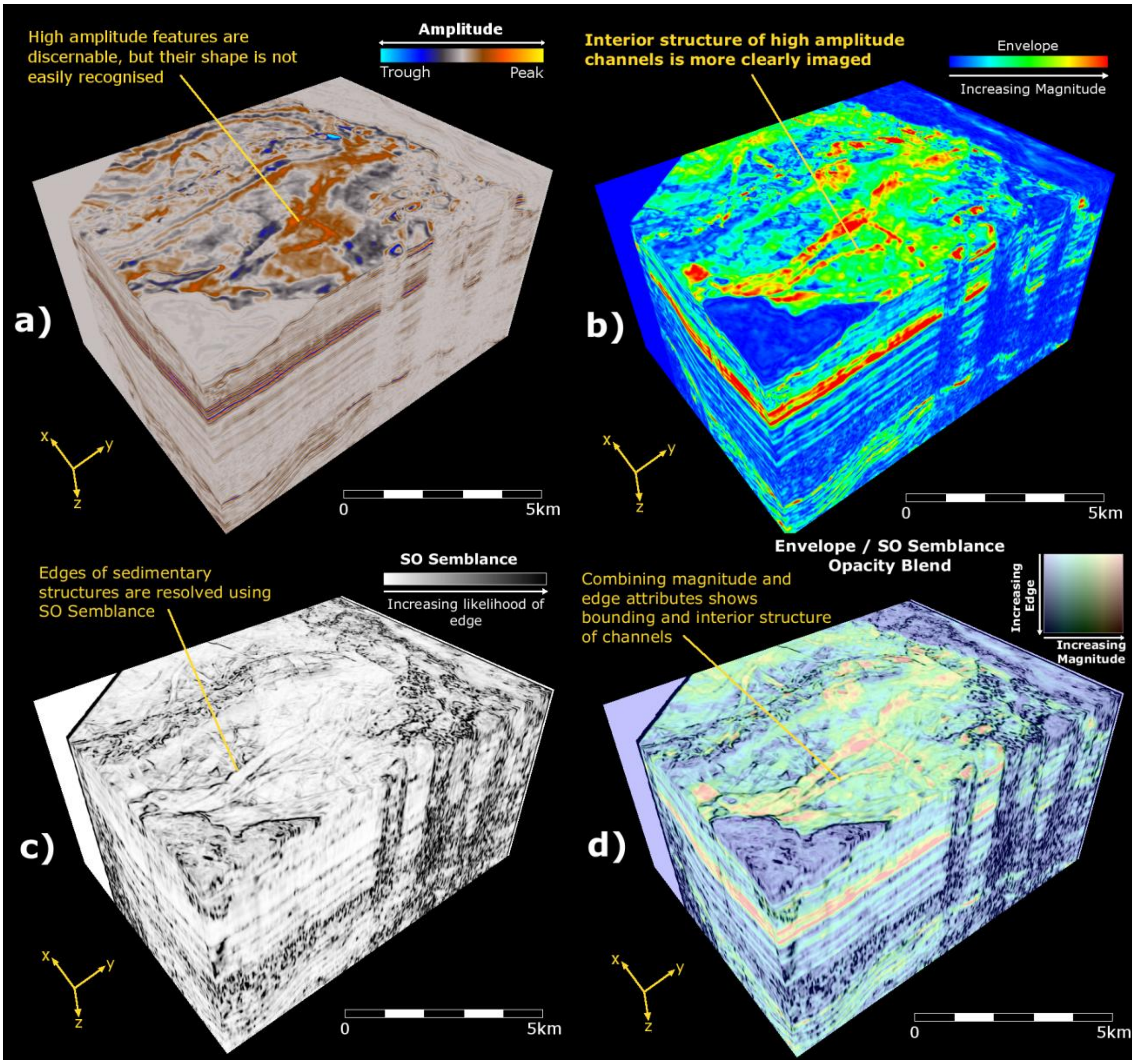

Figure 3: a) Noise Cancelled data b) Envelope c) SO Semblance and d) Envelope / SO Semblance Opacity Blend.

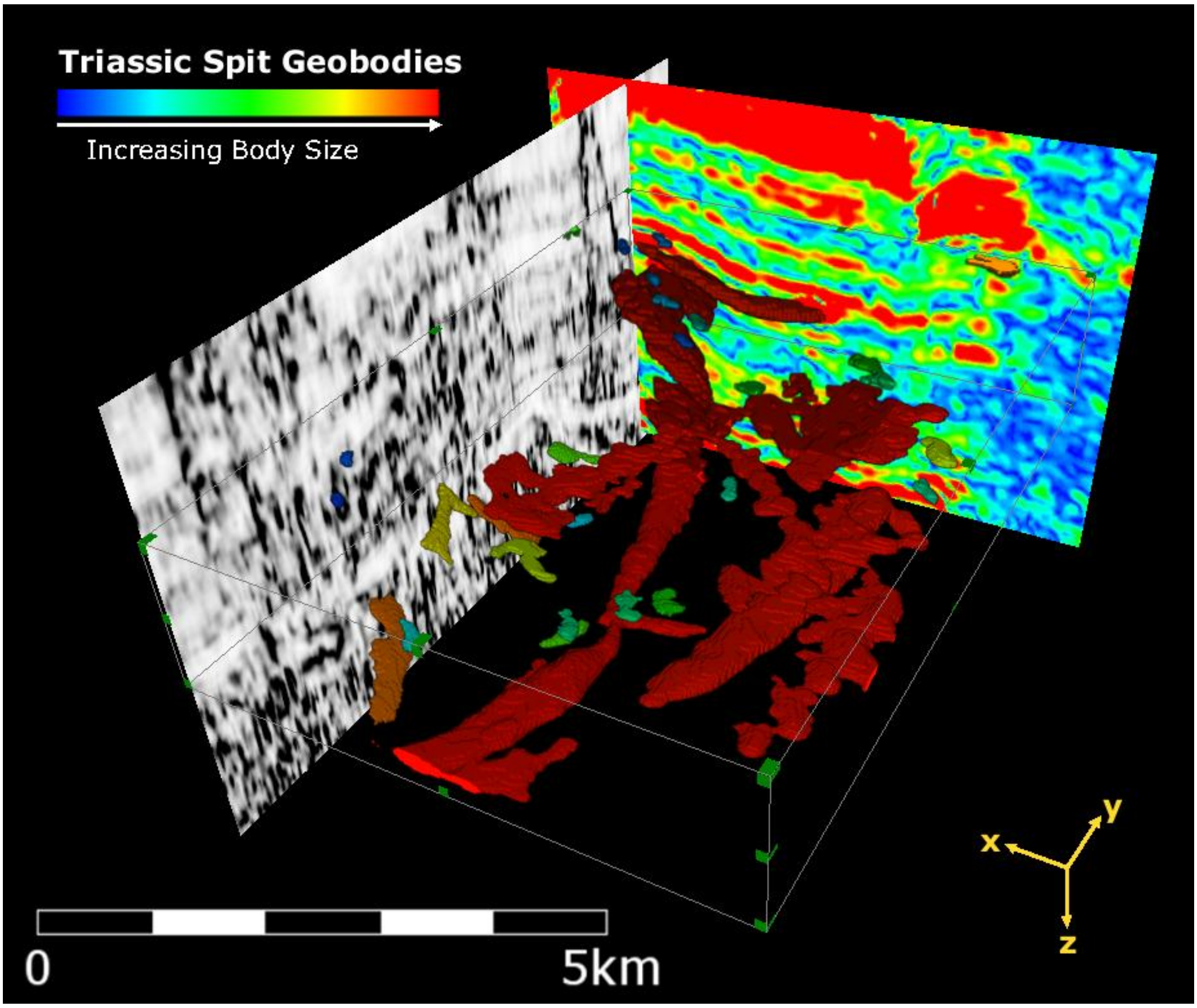

Figure 4: Triassic beach and spit system geobodies.

Opacity Blending

Opacity blending is a visualisation technique in which multiple attribute or colour blended volumes can be co-located and viewed simultaneously by adjusting their relative transparency levels. Opacity blending is most effective when attributes showing different types of feature are used, with complimentary colourmaps. The blend shown (Figure 5) is of SO Semblance, marking edges (greyscale colourmap), with Envelope, highlighting high magnitude targets (spectrum colourmap) and shows the opacity blend successfully highlighting the Triassic landforms and the Jurassic channels.

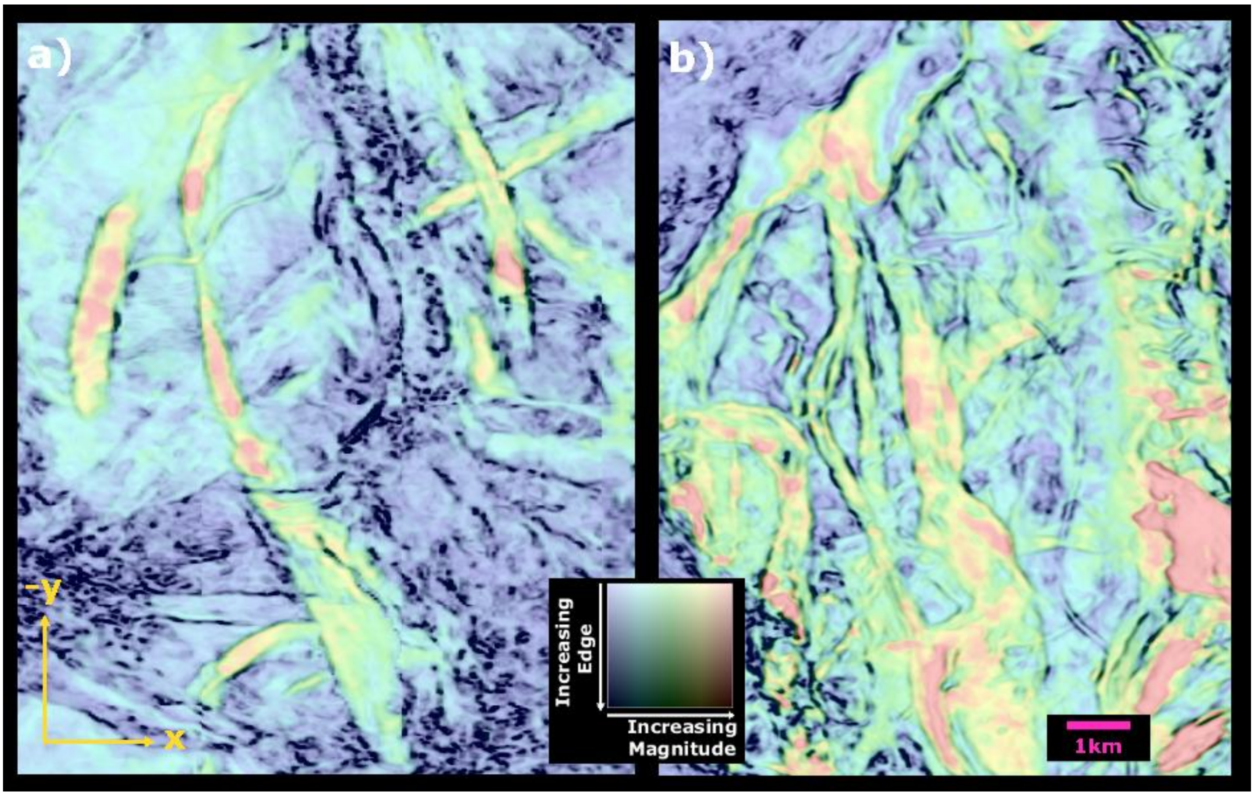

Figure 5: SO Semblance and Envelope opacity blend. a) Triassic spit system b) Jurassic channels.

Frequency Decomposition and RGB Blending

Frequency decomposition is used to generate three band limited magnitude response volumes with discrete central frequencies. The conditioned reflectivity data is decomposed to produce volumes showing the magnitude response at 19Hz, 26Hz and 39Hz. These individual volumes are then normalised and ascribed to each of the red, green and blue channels respectively of the display. The resulting composite RGB image shows variation in colour and intensity that correlates with the change in magnitude response at the different frequencies. Visualisation in this manner can show variations in lithology, bed thickness and porefill, to be seen with high visual contrast. Figure 6 shows individual channels as bright regions of distinct colour, enabling improved interpretation of channel migration and braiding.

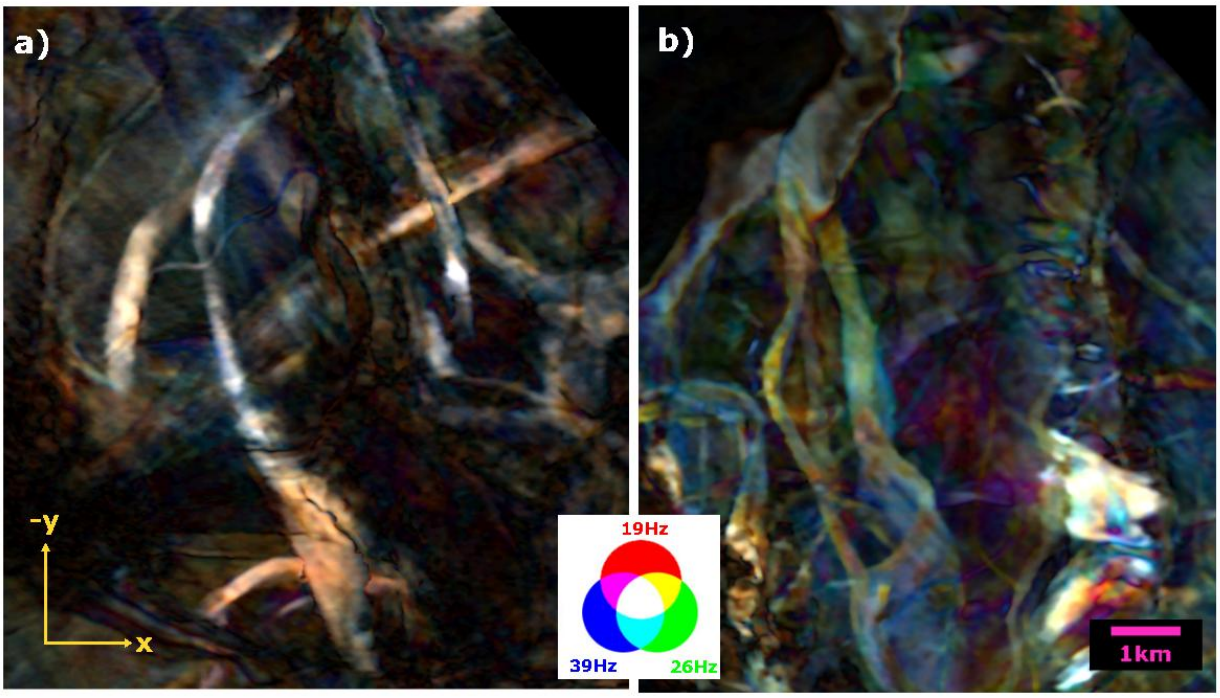

Figure 6: Frequency Decomposition RGB blend showing a) Triassic spit system b) Jurassic channels.

Multi-attribute delineation

The RGB colour blends provide details of the channel system geometry and internal character that are startlingly clear to the interpreter and which greatly aid interpretation. The expression of these systems within RGB blends, although very clear to the eye, is the result of variations in seismic response that are complex and subtle, making practical extraction of these elements as 3D geobodies practically impossible using standard geobody delineation techniques. The geobodies shown in Figure 7 have been extracted with a new geobody delineation system that is designed to track visible structures in RGB blended images, and is semi automatic allowing the interpreter to interactively guide the delineation process. Application of this technique has allowed a user of the system to effectively isolate and extract the different channel segments, shown in figure 7, as independent units.

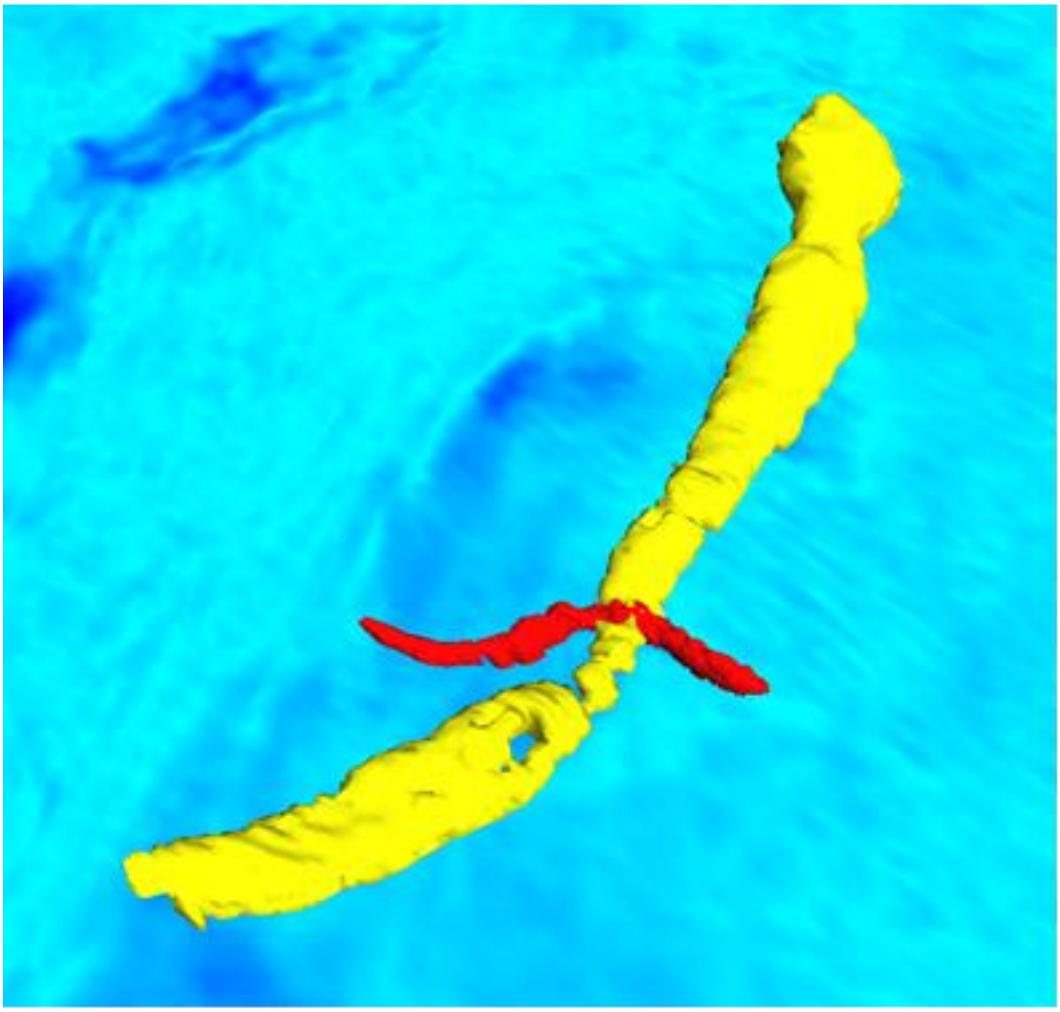

Figure 7: Multi-attribute delineation of 3D Jurassic channels.

Conclusions

A workflow based on new and existing 3D seismic attribute analysis techniques has been used to identify potential reservoirs and sedimentary systems in Jurassic and Triassic stratigraphy from a seismic reflectivity data set from the Norwegian sector [of where]. The workflow is straightforward to apply and has shown details of the imaged sedimentary systems with extraordinary clarity. In particular, combining structural and stratigraphic attributes using opacity blending highlights details on the interior structure and edges of channels, beaches and spits and volumetric frequency decomposition and RGB colour blending enhances subtle, but potentially important, variations in stratigraphy. A new multi-attribute delineation technique was crucial in allowing the channels and spits, which are characterised by complex variations in seismic response, to be delineated as 3D bodies.