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Innovative and Interactive Methods Emphasizing Geological Events through Spectral Decomposition New Zealand Case Study

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Summary

This paper presents how an interactive method in spectral decomposition can facilitate and improve processes in exploration. This study focuses on the Maui field, located offshore New Zealand, in the Taranaki basin. Its aim is to emphasize specific geological features by interactively performing spectral decomposition at different locations on surfaces generated from a Relative Geological Time (RGT) model. This model is obtained thanks to seismic interpretation based on horizon auto-tracking trough a grid (Pauget et al., 2009) and its refinement. It provides a new way to achieve a strata-slicing into the seismic data and allowing a quick and interactive navigation throughout the surfaces. By combining this workflow with the analysis of frequency variations along geological events, it is possible to get an enhanced spectral decomposition of geological features from their averaged spectral signature (low, medium and high frequencies). Each one of these key frequencies was mapped on surfaces and blended into a Red-Green-Blue (RGB) viewer. Such a technique allows the interpreter to better highlight turbidite channels which were then extracted as geobodies with a high rate of confidence.

Introduction

Extracting key frequencies in order to better emphasize geological features through spectral decomposition is very effective but often difficult for complex and large scale geological objects. The frequency picking is commonly done on volumes directly from seismic sections leading to a difficult and uncertain estimate of the frequencies representative of the objects. Although visualization techniques have been drastically improved, geoscientists still make many assumptions resulting in poor imaging and therefore hazardous decisions. This paper shows that picking the frequencies on a dense stack of horizons and obtaining average frequency values removes many uncertainties. It provides a significant improvement in the delineation of subtle geological features. The stack of horizons comes from a Relative Geological Time (RGT) model. This methodology was applied to the Maui field located offshore New Zealand in the Taranaki basin.

Method and Theory

With the common interpretation methods, only a few horizons are picked either manually or using auto-tracking tools. From the few interpreted horizons, attributes can be mapped and analysed to give an approximate overview of the geological features in the seismic dataset.

On the other hand, the Relative Geological Time (RGT) model technique is a comprehensive seismic interpretation method, which can be summarized as a three-step workflow (Figure 1). First, a grid of elementary horizon patches is computed based on signal amplitude. Second, horizons are automatically tracked within the entire seismic volume and relative geological times are assigned to every horizon patch. The seismic interpreter checks the auto-picked horizons and refines them locally until an optimum solution is obtained (Figure 1). Finally, the RGT model is calculated granting access to a dense stack of horizons that allows the interpreter to map various seismic attributes. This leads to a very fine scanning of the seismic volume and to a better tracking of the geological features. Such a method has already been successfully tested on various case studies with different geologies (Gupta et al., 2008; Lemaire et al., 2010; Lacaze et al, 2011; Schmidt et al., 2013; Vidali et al., 2012).

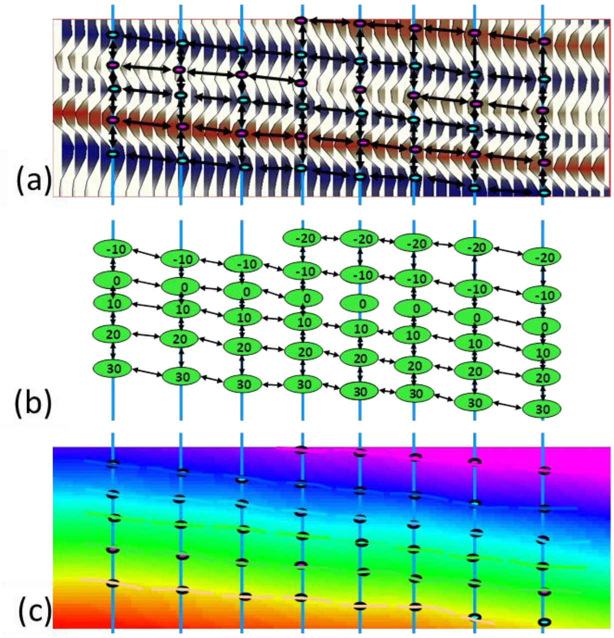


Figure 1*: Workflow of the relative geological time model method. a) Creation of a grid from seismic traces and automatic tracking of horizons. b) Relative geological times assignment. c) Resulted relative geological time model.*

The spectral decomposition method allows defining specific frequencies in order to highlight possible geological targets. In practice, the process consists in the convolution of the seismic trace with a given kernel function associated with the frequency. Several methods based on that simple process are usually applied to seismic data. In the case of the Short Time Fourier Transform (STFT), the trace is convolved with a windowed sine function oscillating at a given frequency. A window length has to be chosen for a required time accuracy. The larger the window, the greater the frequency accuracy will be. In the case of the wavelet transform, the trace is convolved with a wavelet, usually a Ricker or a Morlet wavelet, with a peak frequency corresponding to the required frequency. With the wavelet transform the time precision can automatically be adjusted according to the frequency used. Such a process applied to the entire spectrum of the trace produces a variogram from which remarkable frequencies can be selected. Once they are defined, the same convolution is applied to every trace to generate several spectrally decomposed volumes that are used to produce amplitude maps for RGB blending analysis.

Enhancement of geological features from spectral decomposition analysis

The studied zone is located offshore New Zealand in the Maui High, and represents the Northern horst of the Central Graben. Cretaceous and Paleogene periods consist in a rifting stage linked to a transgression leading to a thin terrestrial to shallow marine deposits. A regional post-rift subsidence occurred during the Paleocene – Eocene epochs, where transgressive sequences can be observed. A subsidence allowed the deposition of the coarse shelf carbonates during the Oligocene epoch. Finally, through the Neogene period, marine and terrigenous rocks were deposited during a regressive propagation of the shelf across the basin.

In the recent years, spectral decomposition has emerged as a technique of choice to enhance the visualization of seismic attributes. It provides very informative maps, especially in clastic successions with sharp impedance contrast such as the turbidite deposits seen in the Neogene deposits of this study (figure 2a). The spectrogram varies a lot from trace to trace and makes locating target from seismic sections challenging. The picked frequencies may indeed not be fully representative of the tracked event on the RGB map. In figure 2, the RGB map clearly shows a channel. The frequencies (43Hz, 56Hz, 69Hz) were extracted from the North-Western part of the channel, which does not appear well delineated in the South-Eastern part.

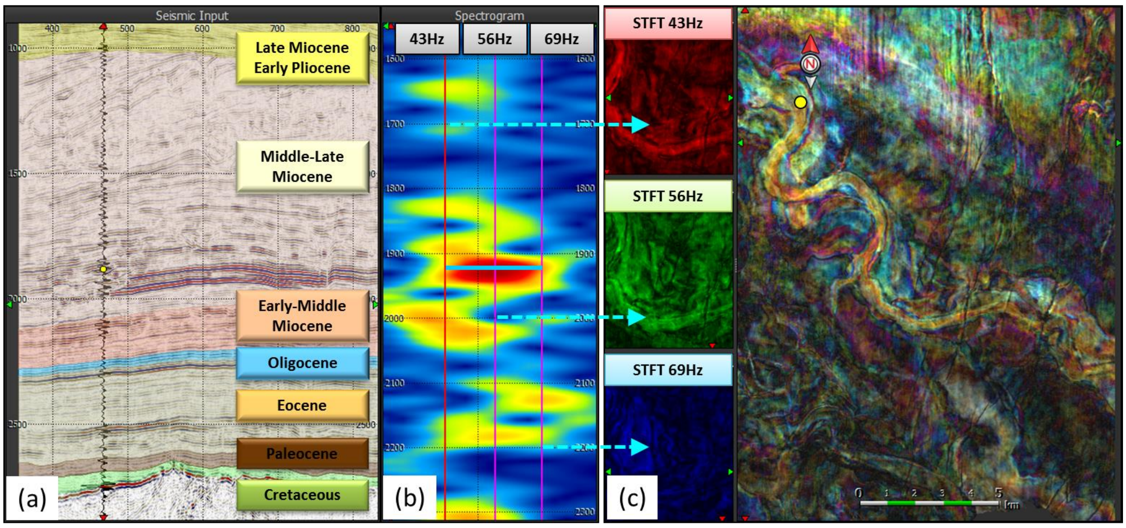
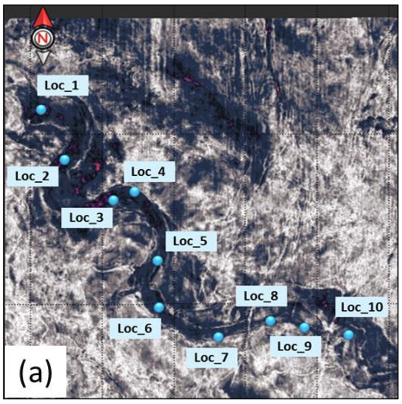


Figure 2*: Conventional spectral decomposition method. a) Turbidite channel in seismic section and stratigraphic units. b) Spectrogram computed at the channel location. c) RGB blending map using spectral decomposition and illustrating channel. The yellow dot represents the frequency picking location.*

Because the RGT model makes available to the interpreters a dense stack of horizons, it is effortless to map amplitude attributes on them to scan the seismic volume. The high interactivity between the horizons and the seismic data allows the interpreters to better track the geological features in terms of spectral signature. We made the assumption that the channel visibility could be improved by analyzing frequencies all along the event. A spectral decomposition was therefore performed at ten locations along the channel (Figure 3a). The table of figure 3b lists the low, medium and high frequencies at each location.



(b)	Low (Hz)	Mid (Hz)	High (Hz)
Location_1	45	56	67
Location_2	42	51	59
Location_3	46	56	66
Location_4	50	57	63
Location_5	33	42	50
Location_6	37	46	54
Location_7	40	50	60
Location_8	44	53	62
Location_9	38	47	56
Location_10	43	51	58
Average Freq.	**41,8**	**50,9**	**59,5**

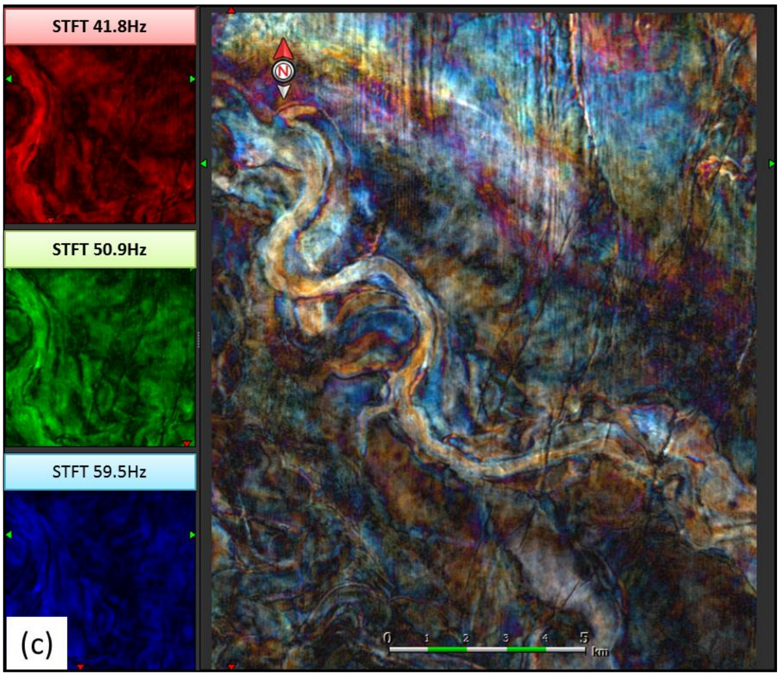


***Figure 3**: Interactive spectral decomposition method a) Turbidite channel in RMS map view and frequency analysis locations. b) Frequency table reporting the low, middle and high values of spectral decomposition at each location and their average values. c) RGB blending map using average values of the spectral decomposition.*

The objective was to compute a set of average remarkable frequencies (41.8Hz, 50.9Hz, 59.5Hz), more representative of the entire channel. The RGB blending map indeed better highlighted the channel, improving its delineation (figure 3c) and therefore its overall modeling (figure 4).

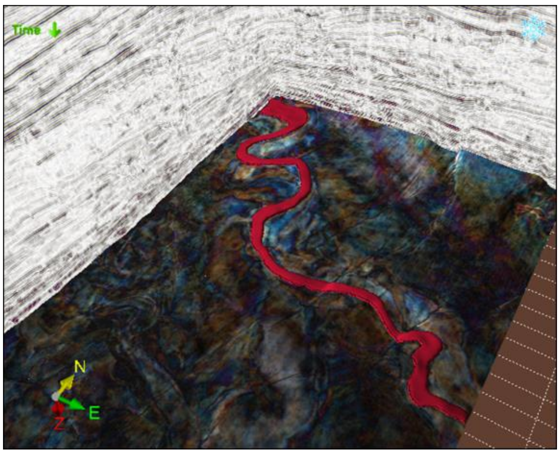


***Figure 4**: 3D view of the extracted geobody representing the channel, based on the interactive spectral decomposition analysis.*

Conclusion

This work presents an innovative and interactive method to perform spectral decomposition. This technique uses a relative geological time model to generate a set of horizons allowing a better identification of geological features. The spectral decomposition was used to highlight a channel on a RGB blending map. The interactive method based on multi-frequency picking showed its benefits in terms of channel delineation and extraction. Indeed, the method gave access to a set of remarkable frequencies, which were characteristic of the entire event and were used for RGB color blending. It was clearly proven for the South-Eastern part of the channel, which could therefore be entirely extracted as a geobody. The next step of this workflow would be to analyse the geobody at reservoir scale and derive geophysical properties using classification techniques as well as volumetric estimates.

Acknowledgments

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