Journal of Engineering and Applied Sciences 13 (12): 4336-4343, 2018
ISSN: 1816-949X

Application of Spectral Decomposition for Evaluation of Fluvial Channel in 'B' Field, Malay Basin, Malaysia

Jamal Emir Jaludin, Lo Shyh Zung and Abdul Ghani Md Rafek
Department of Geosciences, Faculty of Geosciences and Petroleum Engineering,
Universiti Teknologi Petronas, Bandar Seri Iskandar, 31750 Tronoh, Perak, Malaysia

Abstract: Since, the early oil and gas exploration in Malay basin, structural traps such as anticlines have emerged as the primary prospect in almost all fields in Malay basin. The previous exploration in B field focused on the prospect of low-relief anticlines. This research is done to provide a new insight on oil and gas exploration in Malay basin through stratigraphy exploration by using the method of spectral decomposition. Spectral decomposition is applied to the three-Dimensional (3D) seismic data of B field located in Malay basin for stratigraphy exploration and evaluation. Spectral decomposition is used to image the lateral and vertical distribution of channels as well as for hydrocarbon detection in the reservoir. The results of spectral decomposition can be viewed in single component (frequency) or in multi-components display through Red, Green and Blue (RGB) displays. The results are compared with other volume attributes such as variance and sweetness attributes.

Key words: Spectral decomposition, stratigraphy exploration, Short-Time Fourier Transform (STFT), Continuous Wavelet Transform (CWT), exploration, Spectral

INTRODUCTION

Channel system is one of the potential reservoirs for hydrocarbon exploration (Ku *et al*., 2014). The 3D seismic data are easier to interpret subsurface structures and identify channel systems. Seismic attributes generated for the 3D seismic data are useful tool to study hydrocarbon reservoirs. The main purpose of this research is to identify channel systems as well as study the fluid properties of the formation.

B field located in the Northern block of Malay basin. There are 2 wells drilled during the previous exploration which are B-1 and SB-1. The previous exploration focused on of low-relief anticline bounded by a NW-SE major fault. B field has significant channel systems that are not fully evaluated. The petrophysical report from well log data indicates the present of channel features in group E, F and H intervals. The targeted reservoir is F-5 reservoir deposited in tidally influenced coastal plain environments. The lithology of group F interval is predominantly shale interbedded with sandstone and siltstone.

Spectral decomposition technique has developed as a descriptive technique for reservoir characteristics based on frequency spectral decomposition (Li and Zhao, 2014). It decomposed full-band frequency of seismic data into a series of single frequencies. Spectral components tuned to a given thickness often exhibit a high signal-to-noise ratio and thus provide the highest lateral distribution, giving clear images of channels and other stratigraphic features that otherwise might be obscured in broadband data (Li *et al*., 2015). Spectral decomposition has also been widely used for hydrocarbon detection within reservoir (Xiaodong *et al*., 2011).

The spectral decomposition algorithm used in this research are Short-Time Fourier Transform (STFT) and Continuous Wavelet Transform (CWT). STFT is primarily used to delineate lateral and vertical distribution of channel. Red Green Blue (RGB) visualization technique is used to image channel features from the output of STFT. RGB colour blending can help to improve the channel image observed from STFT (Marfurt and Kirlin, 2001; Cao *et al*., 2015). CWT is used to reveal the properties of formation fluids within the targeted reservoir.

MATERIALS AND METHODS

Volume attributes (sweetness and variance): Volume attributes are applied to broadband seismic data. The volume attributes that are used are variance and sweetness. Variance attribute measures the similarity of traces in lateral or vertical windows (Koson *et al*., 2014). Variance attribute is a useful tool to delineate channel features (Pigott *et al*., 2013).

Corresponding Author: Jamal Emir Jaludin, Department of Geosciences, Faculty of Geosciences and Petroleum Engineering, Universiti Teknologi Petronas, Bandar Seri Iskandar, 31750 Tronoh, Perak, Malaysia

Sweetness attribute can also be used to image channel features. Sweetness attribute is useful to identify channel features (Hart, 2008). Sweetness is the value of instantaneous amplitude divide by the square-root of instantaneous frequency. Sweetness attribute can locate hydrocarbon bearing zone. This is because usually oil and gas zones are characterized by traces that have high amplitude and low frequency response (Oyeyemi and Phillips Aizebeokhai, 2015). The volume of variance and sweetness are thoroughly analyzed to determine the channel trap potential within the B field. Equation 1 for sweetness attribute:

$$S(t) = \frac{\alpha(t)}{\sqrt{f(t)}},\ \alpha(t) = \text{instantaneous amplitude}$$

$$\text{and } f(t) = \text{instantaneous frequency}$$

Horizon interpretation and strata grid: Horizon interpretation is done based on the potential area observed in volume attributes. Strata grid is the interval in between two horizons. Strata grid can also be generated from one horizon interpretation and applying time shift.

Spectral decomposition and RGB blending: Spectral decomposition is applied to the broadband seismic data. The seismic data is decomposed into 8 common frequency cubes ranging from 10-80 Hz. There are 2 types of algorithms which are STFT and CWT.

STFT is an algorithm that uses a fixed window approach in which the user sets the time window (Farfour, 2014) . Longer time window helps to delineate the acoustic properties within the reservoir. Shorter time window is useful to delineate small-scale events but the distribution of time slice image is low. CWT has an unrestricted time window and is used for hydrocarbon detection. Both STFT and CWT are applied on each of the strata grids.

RGB Blending is applied by using 3 frequency bands from STFT that image the best channel edges. Each of slices is set to red, green and blue colour, respectively.

RESULTS AND DISCUSSION

Well log interpretation: Figure 1 shows well log correlation of reservoir top F and F-5 at B-1 and SB-1 wells. The depositional environment of group F is tidally influenced coastal plain environment. Based on the well interpretation and previous report there is hydrocarbon accumulation potential within F-5 reservoir at B-1. Gas sand has the response of low gamma ray and high resistivity as hydrocarbon has low radioactive materials and high resistant towards charges flow. Gas sand also has low response at neutron log and density log. This is due to the low hydrogen and high porosity properties of gas sand. The crossover between neutron-porosity (reverse) and density log can be observed in F-5 at B-1.

The gamma ray response in F-5 at B-1 is coarsening upwards or funnel shape. The potential facies are crevasse splay or river mouth bar. It reflects the change of lithology from shale-rich to sand-rich lithology.

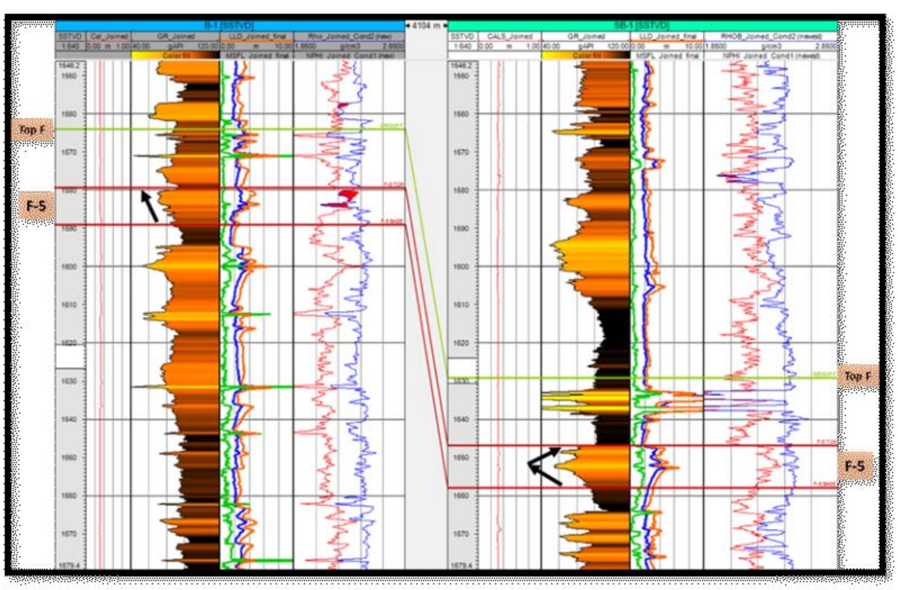

Fig. 1: Well Log correlation of reservoir F-5 at well B-1 and SB-1. Cross-over (red-filled) between neutron and density log indicates the presence of gas at well B-1

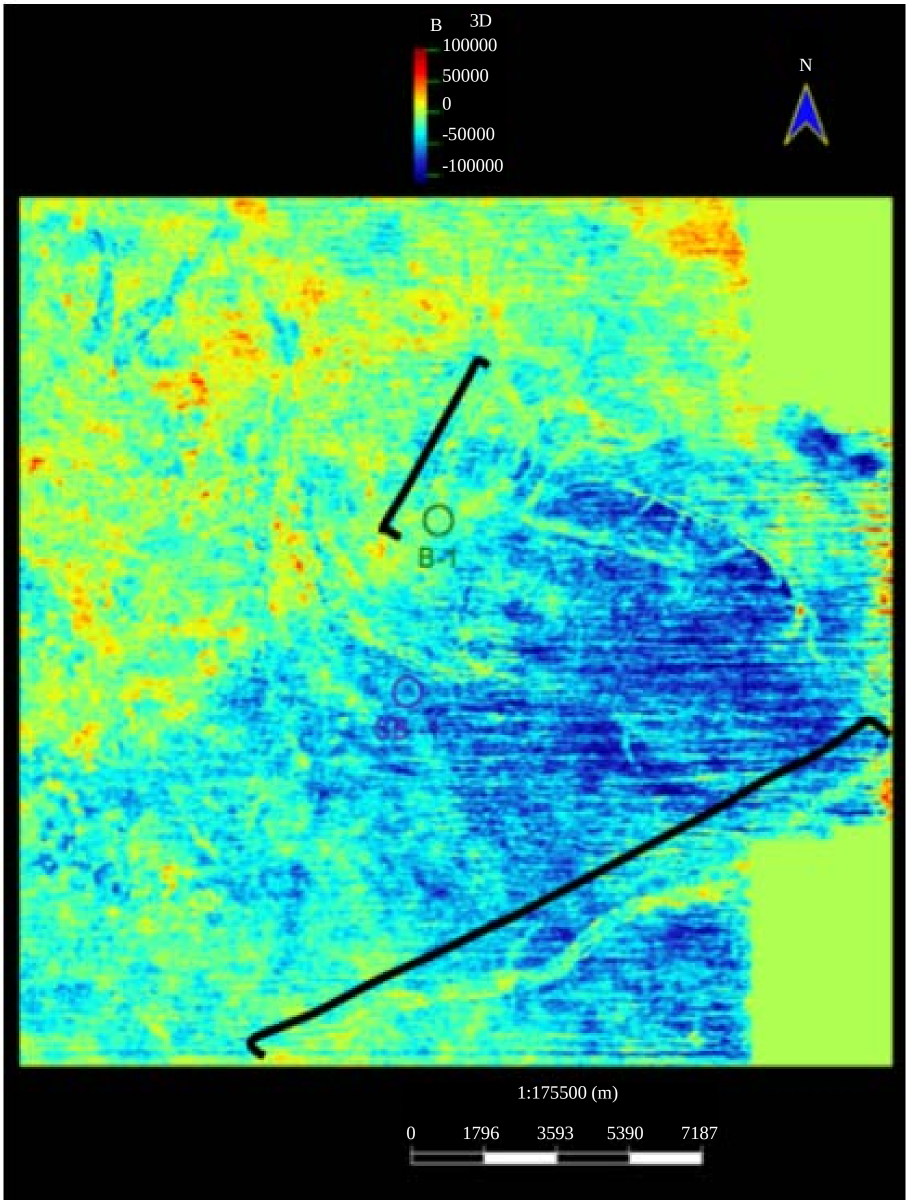

Fig. 2: Horizon slice F-5 of broad seismic data. Black lines mark the subtle channel observed

Meanwhile, at SB-1, the gamma ray response is symmetrical which reflects the progradation and aggradation of clastic sediments.

Post stack 3D data: Figure 2 shows the horizon slice of F-5 using the original seismic data. The full frequency band of the seismic data is in between 10 and 80 Hz. The data is cropped to visualize the study area clearly. Subtle channel images are observed near the well B-1 and in the SSE part of the study area as marked by the black lines. The lateral distribution is very poor because of little to no acoustic impedance contrast between neighbouring traces.

Variance attribute: Variance attribute has better lateral distribution of channel than original seismic data. The main channel is difficult to detect in the Southwest part of the major normal fault. The small-scale channels observed in sweetness is also detected in variance. Overall the spatial distribution of channels observed in variance is almost the same as in the sweetness attribute. There are 2 faults identified by variance attribute which are normal and reverse faults (Fig. 3a).

In term of temporal distribution, variance attribute manages to delineate the channel features from the horizon slice of top F until 25 msec below F-5 (Fig. 3).

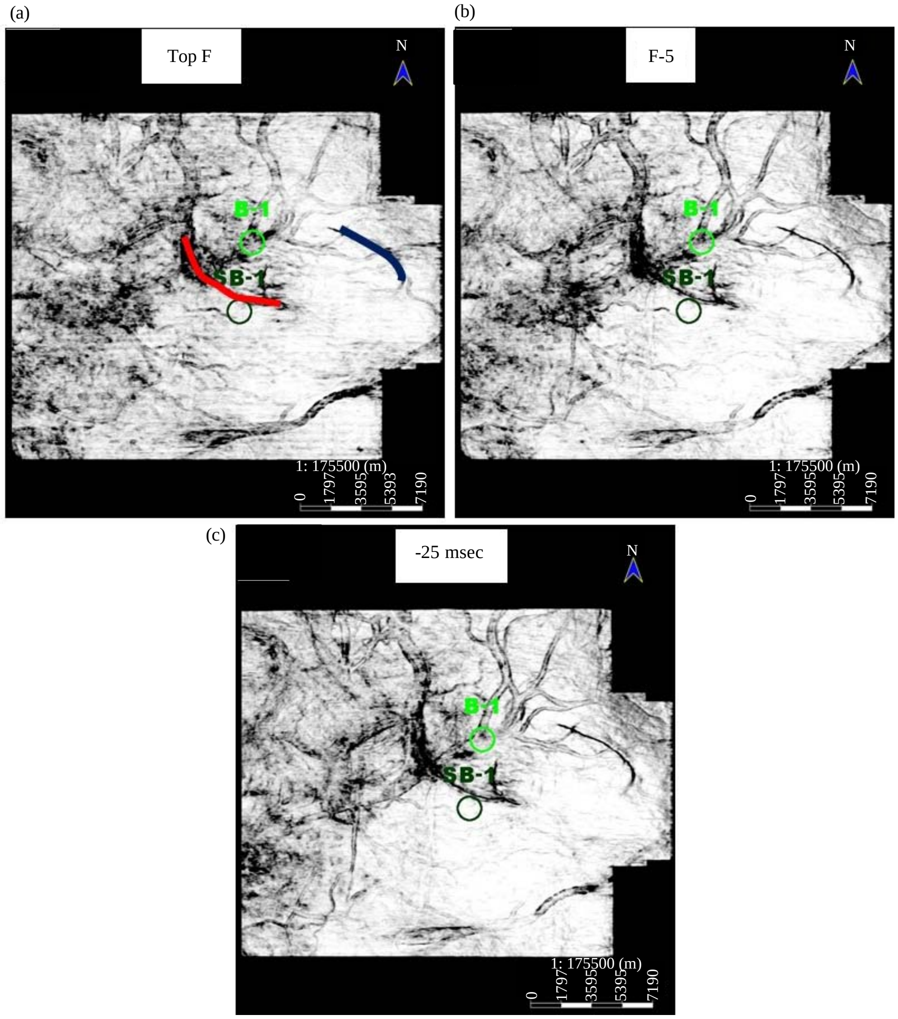

Fig. 3: Horizon slice of variance attribute at: a) Top F; b) F-5 and c) 25 msec below F-5. Fig. 3a) marks the normal (red) and reverse (blue) faults

Sweetness attribute: Sweetness attribute images a much better spatial distribution of channel compared to the original post stack data. This is because sweetness attribute is produced by using the instantaneous amplitude and instantaneous frequency instead of average amplitude and frequency. The channel that penetrates well B-1 is meandering channel with an average width of 450 m. The channel is imaged clearly at well B-1 compared to original seismic data and variance. However, sweetness attribute cannot delineate faults.

Black area in Fig. 4a marks the small-scale channels observed in sweetness attribute. This is because there is little to no lateral lithological contrast at fault planes. Series of small scale channels is identified as marked in the green circle. High sweetness zone within the channel penetrate at B-1 in reservoir F-5 cannot be observed despite the well log and petrophysical data indicating the presence of gas sand.

In term of temporal distribution, sweetness attribute manages to delineate these channels from top F to 5 msec below F-5 as shown in Fig. 4.

Short-time fourier transform: The original post-stack data is decomposed into series of common frequency cubes ranging from 10-80 Hz. The cube of 30 Hz is chosen to be the best output among the 8 cubes. These cubes are then applied to the strata grid. The channel feature that penetrate well B-1 has the best lateral resolution at 30 Hz. The edge of the channel is difficult to detect at higher frequency of 50 and 60 Hz. It can be deduced that thin layers are deposited in the area because low frequency

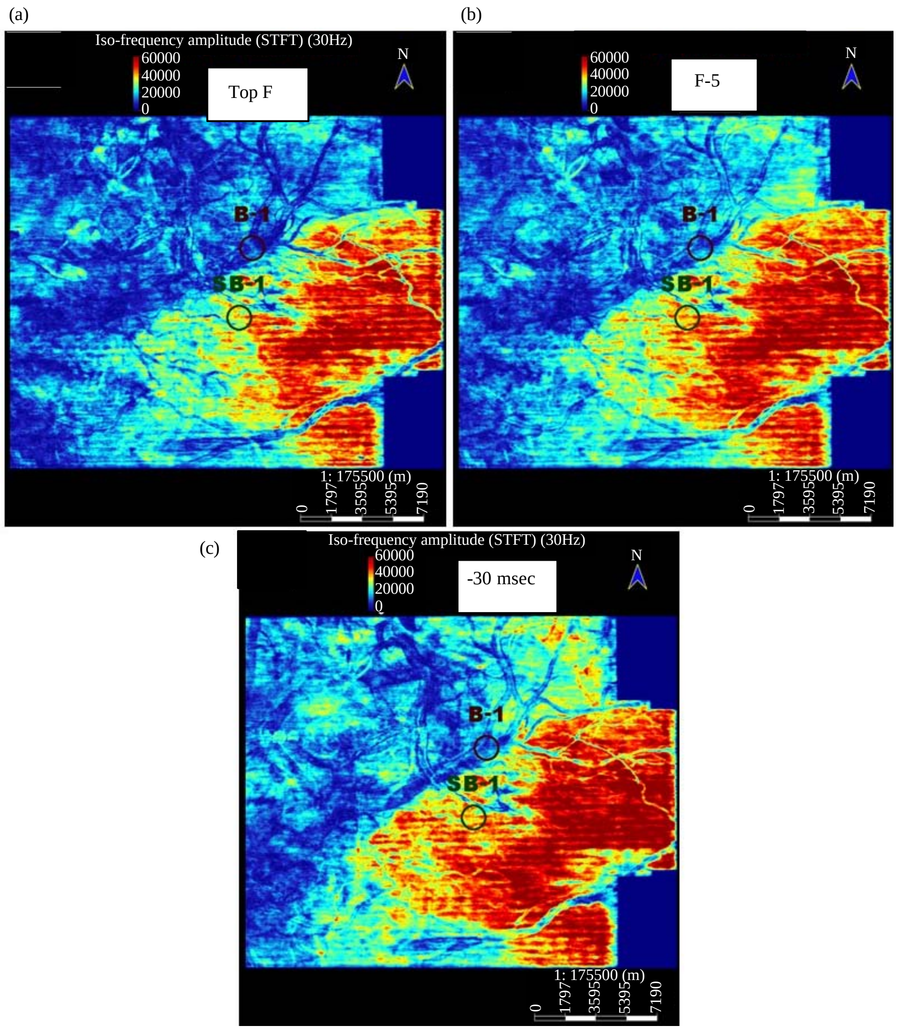

Fig. 4: Horizon slice of sweetness attribute at: a) Top F; b) F-5 and c) 5 msec below F-5. Black rectangle marks the small-scale channels observed in sweetness attribute

corresponds to thick layers meanwhile high frequency corresponds to thin layers (Burnett *et al*., 2003).

The vertical resolution of spectral decomposition generated is analysed. Figure 5 shows that the ISO-frequency of 30 Hz can delineate the channel features from top F horizon to 25 msec below F-5.

RGB blending: Channels image at frequency 30, 50 and 60 Hz are merged using the method of RGB blending. Strata grid of 30, 50 and 60 Hz are assigned to the colourd of red, green and blue respectively. RGB blending help to delineate the lateral and vertical distribution of channel better that STFT. RGB blending manage to delineate channel features from Top F until 35 msec below F-5 horizon (Fig. 6). In summary, spectral decomposition is a better tool for imaging, mapping temporal bed thickness and geological discontinuities compared to the other volume attributes (Partyka *et al*., 1999).

Continuous wavelet transform: Spectral decomposition can also be used for hydrocarbon detection through common frequency cube. The algorithm used to generate common frequency cube is continuous wavelet transform. Common frequency cube can help to identify the sensitive frequency of amplitude attenuation from fluid and thus can be used for identifying hydrocarbon.

Figure 7 shows amplitude attenuation analysis of frequency cubes generated from continuous wavelet transform at reservoir F-5. The analysis shows that the amplitude attenuation is crucial at frequency of 80 Hz. This is because of the accumulation of hydrocarbon

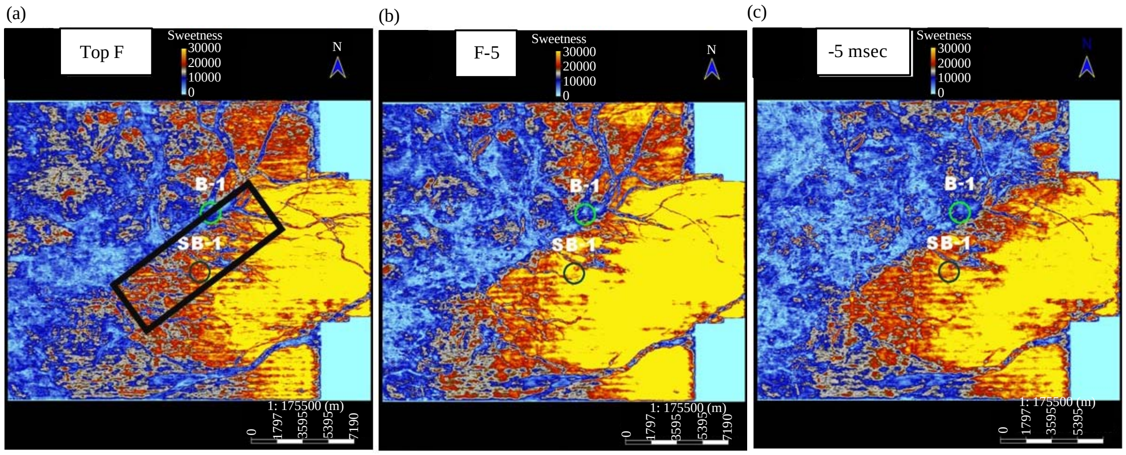

Fig. 5: Horizon slice of 30 Hz STFT at: a) Top F; b) F-5 and c) 30 msec below F-5

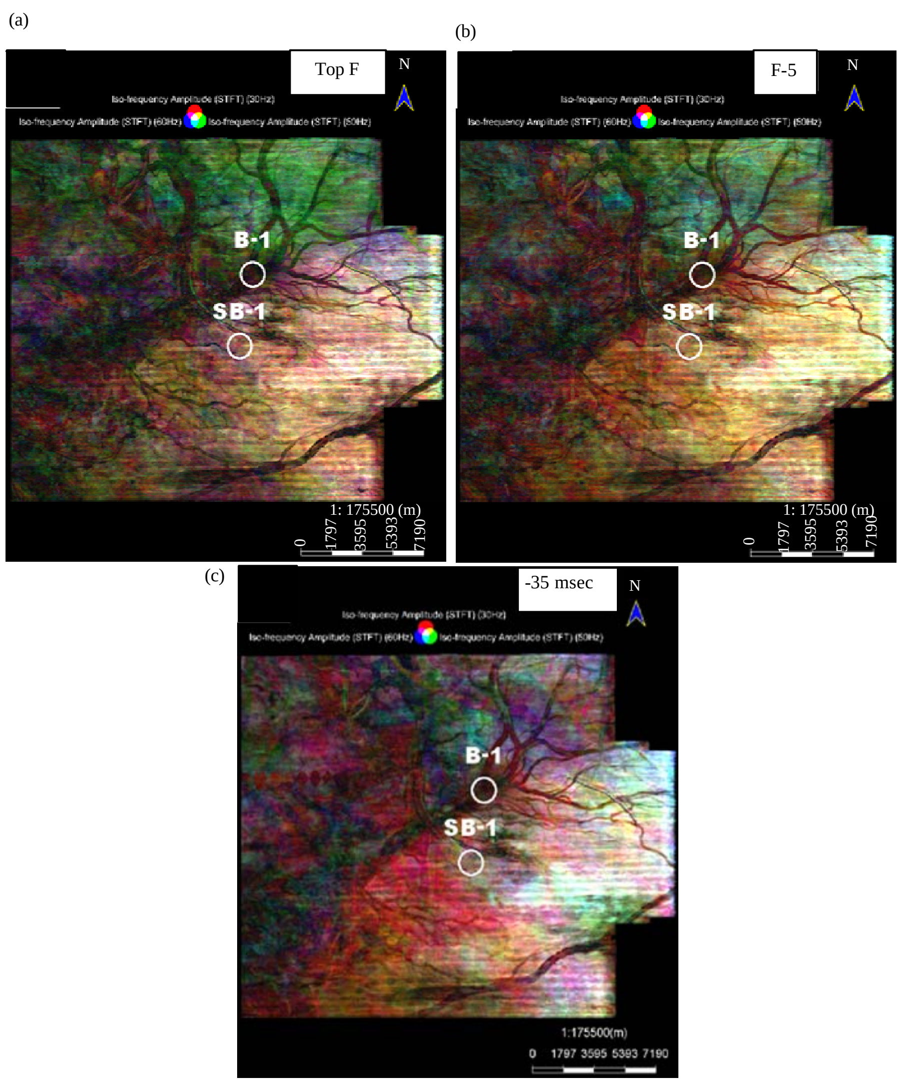

Fig. 6: Horizon slice of RGB blending at: a) Top F; b) F-5 and c) 35 msec below

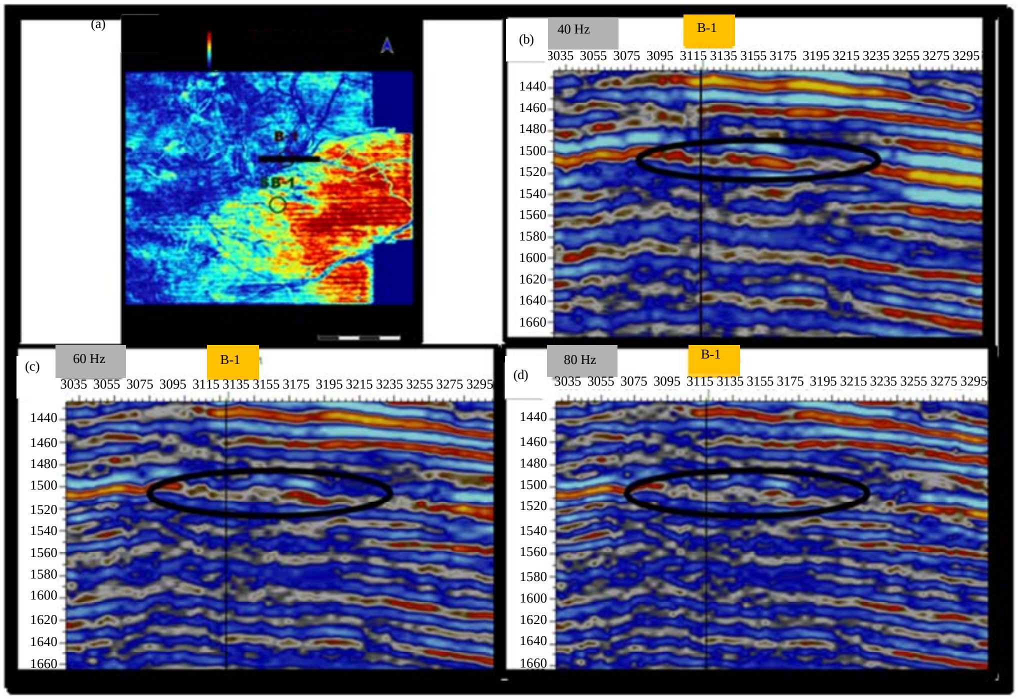

Fig. 7: a) Seismic section view in horizon slice; b) Seismic section at CWT 40 Hz; c) Seismic section at CWT 60 Hz and d) Seismic section at CWT 80 Hz. It can be observed that the amplitude of seismic layer attenuates at higher CWT frequency

within the reservoir. CWT manage to detect hydrocarbon accumulation through amplitude attenuation that sweetness attribute failed to detect.

Gas sand within a reservoir can result low frequency shadow beneath it Barnes (2014). Tai *et al.* (2009) explained that the low-frequency high amplitude events occurred due to the change of velocity between two layers. They stated that velocity change caused by pore fluid results in 4.5 Hz of frequency shift.

CONCLUSION

Horizon slice produced from the original post-stack data has low resolution and thus it is difficult to delineate structural and stratigraphy features. Horizon slice of seismic attribute improved the lateral and vertical distribution of channel features.

Spectral decomposition of STFT is the better tool for delineation of fluvial channel compared to variance and sweetness attributes. STFT has better resolution which could be crucial to map the bed thickness and study the heterogeneity of the reservoir.

Sweetness attribute failed to show high sweetness zone in reservoir F-5 at Bundi-1 despite well data shows the presence of gas. CWT is used to detect amplitude attenuation along the seismic section on F-5 which is caused by the presence of gas sand in the reservoir.

Different types of volume attributes should be analysed together as every attribute has their own ability to reveal geological properties of the study area. In this case study, volume attributes used are variance, sweetness attribute and spectral decomposition to help reveal geological features within the study area.

Based on the results gained through the research, B field has a high potential channel trap. Stratigraphy traps within the field should be further developed for hydrocarbon production in Malay basin.

ACKNOWLEDGEMENT

The researchers would like to acknowledge the Department of Geoscience and Petroleum Engineering of University Teknologi Petronas for their continuous support for this research.

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