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USE OF SPECTRAL DECOMPOSITION ATTRIBUTE IN DETECTING CHANNELS IN TARANAKI BASIN, NEW ZEALAND

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ABSTRACT

Alluvial deposit is considered to be one of the biggest hosts of the petroleum entrapment and also for many nonrenewable resources. Several methods have been introduced to track and delineate the alluvial deposits that show geological features of channels, point bars, flood plains, and crevasse play and so on. The purpose of this paper is to discuss on how spectral decomposition method could be used to enhance geological features of the Taranaki basin emphasizing on stacking channels that widely seen most part of the area. With the introduction of complex traces in early 1970, more seismic attributes have been created and used by seismic interpreters to get better results in interpreting the subtle features of the subsurface. One of the attribute that widely used nowadays is spectral decomposition which was created simply by changing the time seismic into frequency domain using Fourier analysis that cross correlate between predefined sinus and cosines frequencies. Each channel in the survey area stand up more clearly within a specific frequency range where thicker channels shows higher amplitude reading at lower frequency and the thinner layer shows higher amplitude reading at higher frequency. Application of spectral decomposition also helps in determining the channels which were deposited within the incised valleys and helps in recognizing the orientation as well the relative thickness of each channel.

Keywords: spectral decomposition, channels, wavelets.

INTRODUCTION

The study area located at Taranaki basin, approximately 120 km south west offshore New Plymouth that covers around 435.55 Sq. Km with water depth around 200meters (Figure-1). Hector survey which was chosen for this study is one of the prospects in Taranaki Basin which has been penetrated with few wells. Taranaki Basin classified as Cretaceous-Tertiary sedimentary basin where the producing reservoirs are from Eocene Kapuni Group and Oligocene Otarao formation. The basin started to evolve during cretaceous time when sea floor starts to spread around 75 Ma ago and creating the Taman Sea which separating Australia and New Zealand continents (Palmer and Bulte, 1988). The stratigraphy record shows the basin deposited with thicker sediment ranges from Upper Cretaceous to Recent sited on top of Paleozoic and Mesozoic basement rocks.

Taranaki basin undergone extensional phase during late cretaceous - Early tertiary time and it creates normal faults with half grabens which is an essential factor in creating a basin depocenters. The oldest sedimentary rock of the basin dated as Late Cretaceous - Paleocene that creates the Pakawau group. On top of this group sits the Kapuni group sediment which is deposited during Early Paleocene to Early Oligocene. Studies shows that Kapuni group distributed widely in the Taranaki basin and it reaches up to 2000m thick in this basin. The depositional environment indicates terrestrial and parallic characteristics with some transgressive marine siltstone, coal and some back-beach lagoon.

METHODOLOGY

Spectral Decomposition is one of the seismic attribute that used to break time seismic into different frequency bands to identify the thickness of a layer, where the higher frequency spectrum used to determine thinner layers and the lower frequency spectrum identify the thicker layers. Seismic attribute starts to evolve during 1970s when Ansteymanaged to display colors on seismic section while experimenting with the plotter. Anstey and the team crated two variables which is a normal seismic trace that shows the structural view and the auxiliary modulation in color which represents velocity, refection strength, frequency content and other features that could be seen from the color seismic. More stratigraphic features could be extracted and be seen when color attribute was overlaid on grey scaled seismic section. (Satindr Chopra and Kurt Marfurt, 2007).

Seismic attributes became even more famous when Anstey's colleagues Turhan Taner and Fulton Koehler developed sound mathematic framework in 1975 which was used in the attribute computation. This method is based on the real and imaginary part of seismic which can be address as a complex analytical signal. Seismic data refers as the real part and the signal that computed from Hilbert transform is considered as the imaginary part (Figure-2).

The seismic data that we are looking at is only showing the real part of the seismic wave. The real part of the seismic is the projection of the rotating seismic on the real plane which gives the conventional seismic trace. On the other part the imaginary or quadrature trace is projected on the axis perpendicular to the time axis. Below are the two equations that explain the situation that described above.

Seismic trace,

$g(t) = R(t)\cos\theta(t)$

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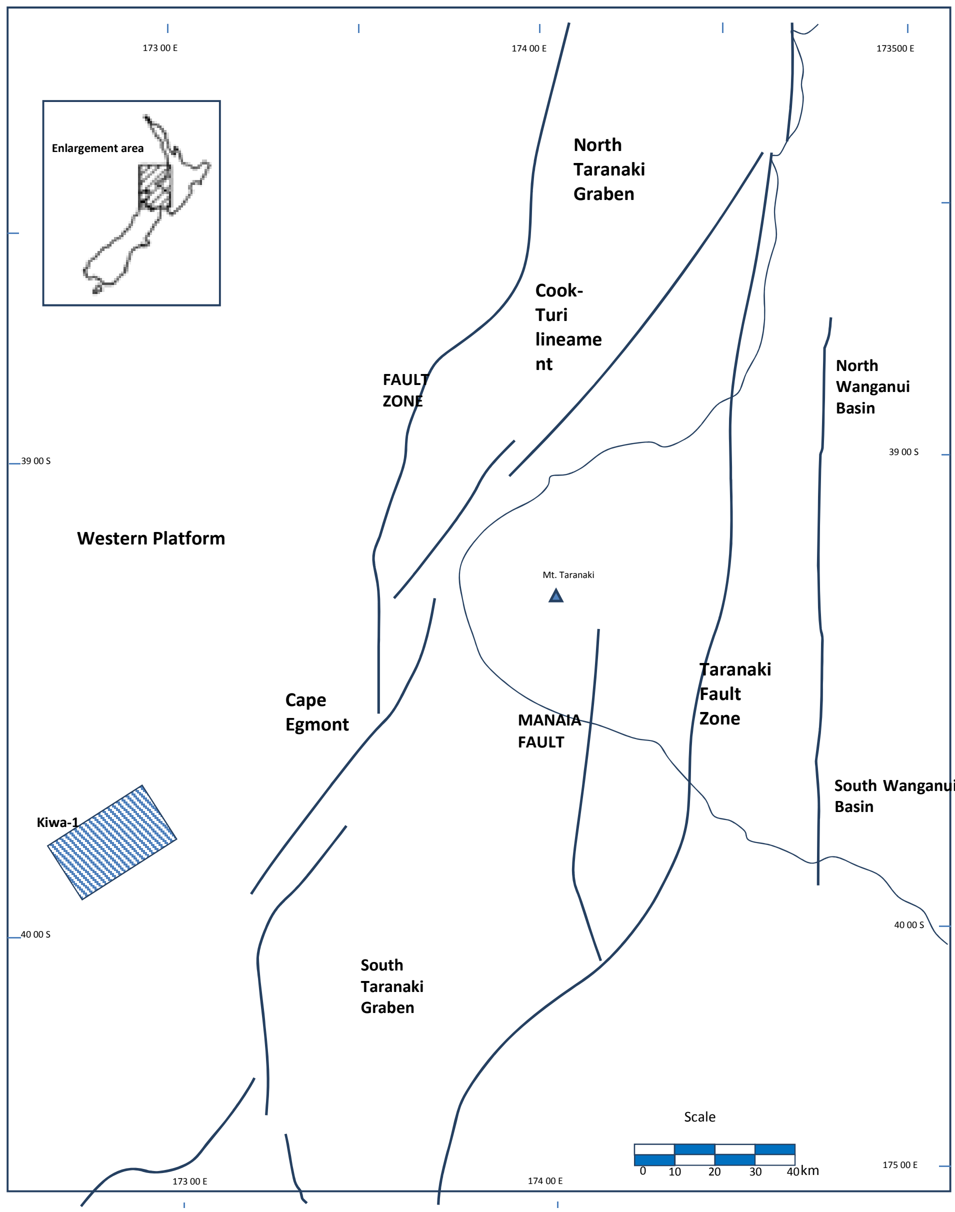

Figure-1. Showing study area located offshore Taranaki. Hector survey which is highlighted in the figure above considered being one of the furthest survey from onshore Taranaki basin.

Quadrature trace,
$h(t) - R(t) \sin \theta(t)$
$R(t)$ = envelope of seismic trace
$\theta(t)$ = phase

Basically the seismic data is representing Sinus and Cosines at predetermined frequencies. Also, they have discovered that these real and imaginary seismic traces can be represented as the kinetic and potential form. The idea came in seismic traces considered as the velocity function (with geophones) or pressure variation (Hydrophones) in considering the path of the seismic waves.

Greg Partyka analyzes his work using Spectral decomposition and noticed the lateral changes of the frequency represent the changes in lithology and sediment bed thickness. He also managed to quantify the amplitude spectra for each frequencies by limiting the analysis window to 100ms. This analysis using short window discrete Fourier transform (SWDFT) eventually became known as spectral decomposition. An article by Satinder chopra and Kurt J. Marfurt, in AAPG Explorer Geophysical corner 2012, explains that the low frequency spectrum volumes tend to show higher signal-to-noise ratio and the same results could be seen in here where the low frequency band shows much clearer features compare to the higher one. This statement indicates different frequency spectrum gives different signal to noise ratio results where low frequency shows higher signal to noise

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ratio comparing to the lower signal to noise ratio at higher frequency. Chopra and Curt suggested that this method mostly used to predict Thin-bed tuning effects, sequence boundary, major changes in lithology and depositional environment and lateral changes in recognizing the faulting.

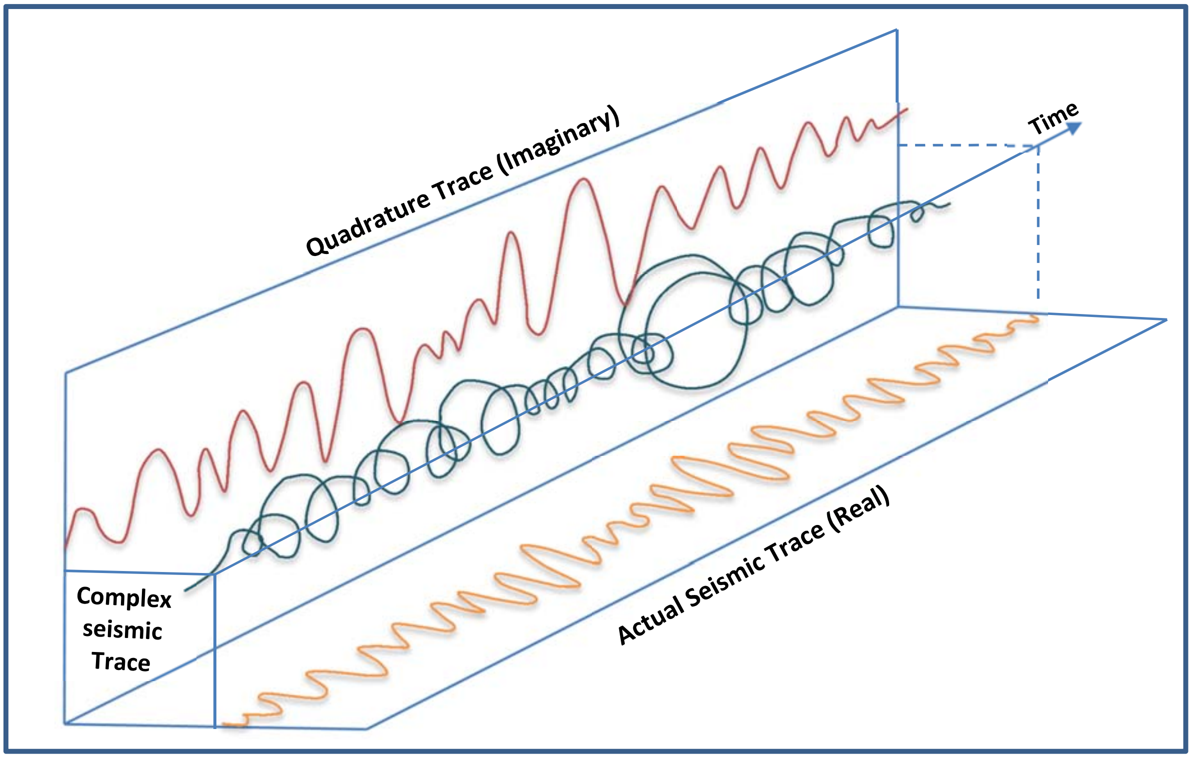

Figure-2. Complex trace diagram that showing real, imaginary and complex traces which give birth to more seismic attribute analysis. Modified after (Taner M.T. and Sheriff R.E., 1977).

DATA ANALYSIS

The case study uses post stack time migrated data to calculate the Spectral decomposition attributes and also for further seismic analysis. The total seismic depth recorded at 6 seconds in TWT. Gabor Morlet wavelet used to breaks seismic data to produce sub bands of frequency spectrum where the bands were subdivided into equal intervals using Octave scale so that the wavelets will have the same shape after stretching or squeezing of each other.

The Spectral composition attribute in this paper refers based on the work that developed by Turhan Taner and his associates at the Rock Solid Images. We could create spectral decomposition from various methods and this papers it is based on the Gabor Morlet wavelets transform method where the seismic data filtered by a series of Gabor-Morlet wavelets to produce a seismic volume with different frequency bands. The filtered amplitude representing an average amplitude and phase of the narrow band. Taner recommended to use frequency band around 7 to 21 sub bands. However in this case, around 10 sub bands have been used to analyze the frequency spectrums. Below equation is used to calculate the sequential series of the bands that will be used to break seismic time into different frequency bands, which was derived from RSA website.

$$G(\omega, t) = \exp(\alpha t^2).\exp(-i\omega t)$$

ω = Gabor-morlet wavelet generated for sequential series values.

RESULT AND DISCUSSIONS

The seismic volume decomposed between 8 to 80 Hz limiting to 10 frequency bands based on the octave scale. The results collected in ten different frequency bands that outputs as 8.0 Hz, 10.3 Hz, 13.3 Hz, 17.2 Hz, 22.3 Hz, 28.8 Hz, 37.1 Hz, 48.0 Hz, 61.9 Hz and 80.0 Hz. Each spectral decomposition band volume slice through at the interval 2.1 seconds where the targeted formation expected to be seen. The time slice result shows number of channels which are visible in most of the other spectral decomposition volumes. However, the same channels projected slightly brighter and dimmer than other spectral volumes and some channels disappear and appears in different spectral decomposition volumes. The stacking channels at the targeted formation clearly seen using lower frequency bands, which is from 8 to 22.3 hz, however once the frequency band reaches the band range between 28.8 to80.0 hz, those channels are no longer clearly visible as this might cause due to the presence of noise in the data. Figure-3 highlights channel features that are not be seen

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clearly at amplitude time slice but manage to see clearly on the spectral decomposition slices. Frequency which is lesser than 22.3Hz able to show the meandering channels with the point bar representing thicker sediments indicated by the larger amplitude values. The Yellow circle in the figure is representing channels that stand out more clearly with low frequencies. Also some feature that identified and marked with the arrow indicates the presence of the thicker sediments within the channel, as this could be the deepest part of the river which is called Thalweg. Most of the features has been vanished from the slice after the 22.3 Hz. The red circle in the other hand is more of an indication of the channels that can be seen clearly with the increased frequency. Low frequency time slices did not shows clear meandering channels at this zone and one of the reason is because the low frequency missed some of the thin bed features that appears below the resolution.

Chantinder and marfurt, 2013 in AAPG memoir presented some similar studies where subtle features reduce in clarify as the frequency band range increases. They testified that when frequency increases more noise is added on to the data which makes the targeted feature hidden within the data.

Bob Hardage (2009) also studied the spectral decomposition and came up with a conclusion that the first octave scale which is from 8 to 18Hz show better quality data for an interpretation. Similar to Bob's result, the research which was conducted on Hector survey reveals that the quality of the time slice deteriorate upon higher frequency. Based on the result

The red arrows also indicating thicker sediment accumulations. It is also pointing out that the spectral decomposition bandwidth from 8 till 17.2Hz is best frequency range for the channels at targeted formation.

Each frequency volume that have been created brings in details of the seismic display that relatively changes according to the frequency where those changes represents information about the thickness, morphology and channel characteristics. Some of the features that could be easily recognized by the decomposed time slice are meandering channels, point bar, bifurcating channels and overlapping channels.

The meandering channel was poorly visible in the complex amplitude time slice and projected much clearly in the spectral 8, 10.3 and 13.3 Hz. The same meandering pattern is not clearly visible after 22.3 Hz. These phenomena explains that the frequency which was decomposed at 22.3Hzor 28.8Hz is closer to the tuning thickness compared to the frequency that less than 22.3 hz. The low frequency images here are also describing the deeper part of the channel and the higher frequency shows the shallower part of the channel.

Figure-4 highlighting the modified sketch that was used by Laughlin 2002, to explain the correlation between frequency and bed thickness. It shows how bed thickness can be identified by different frequency wavelets and their relationship between thin beds tuning within a channel. Part of the channel which was run through by lower frequency captures the thicker beds compared to the higher frequency which captures the thinner beds.

The green color circles that pointing out in Figure-3 considered as the high frequency zone that represent vertically in the Figure-4 by the green wavelet. Also, the thicker channels that pointed in red circle represents as red color low frequency wavelets.

The targeted formation which was deposited during Middle Miocene contains the largest channel networks from braided to meandering river systems. Most of the channels have been recorded in Miocene age and the channels are characterized as incised and stacked with one another representing a common depositional environment that indicates an area with rapid changes in sea level which forms an aggradation and progradation parasequences. Most of the channels in this area relatively straight and gently curved and stacked on one another in filling a valley.

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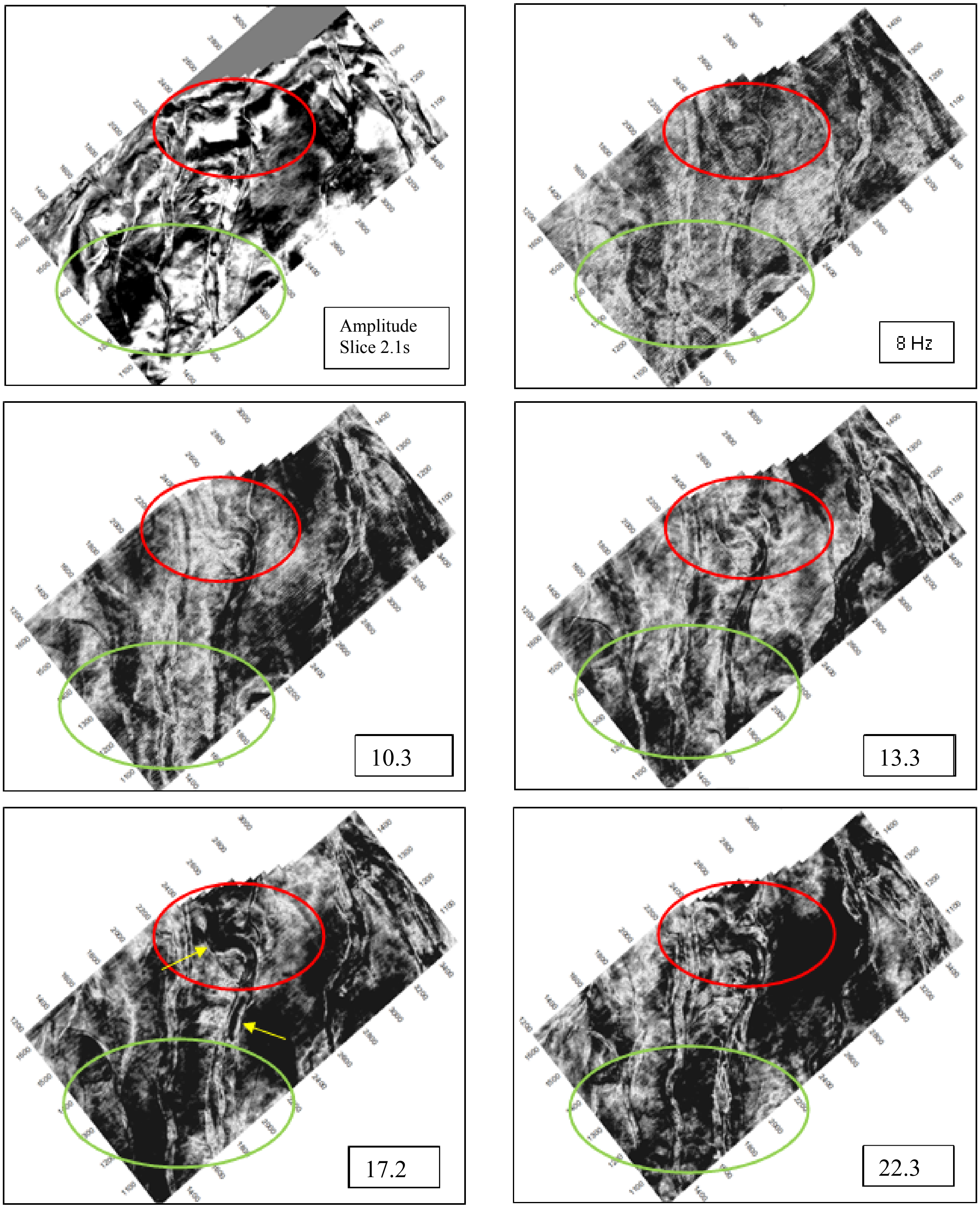

Figure-3. Time slices that created from Amplitude volume and spectral decomposition that ranges from 8 Hz till 22.3 Hz. The yellow circle marking the thicker sediments part and the red circles indicating thinner channels.

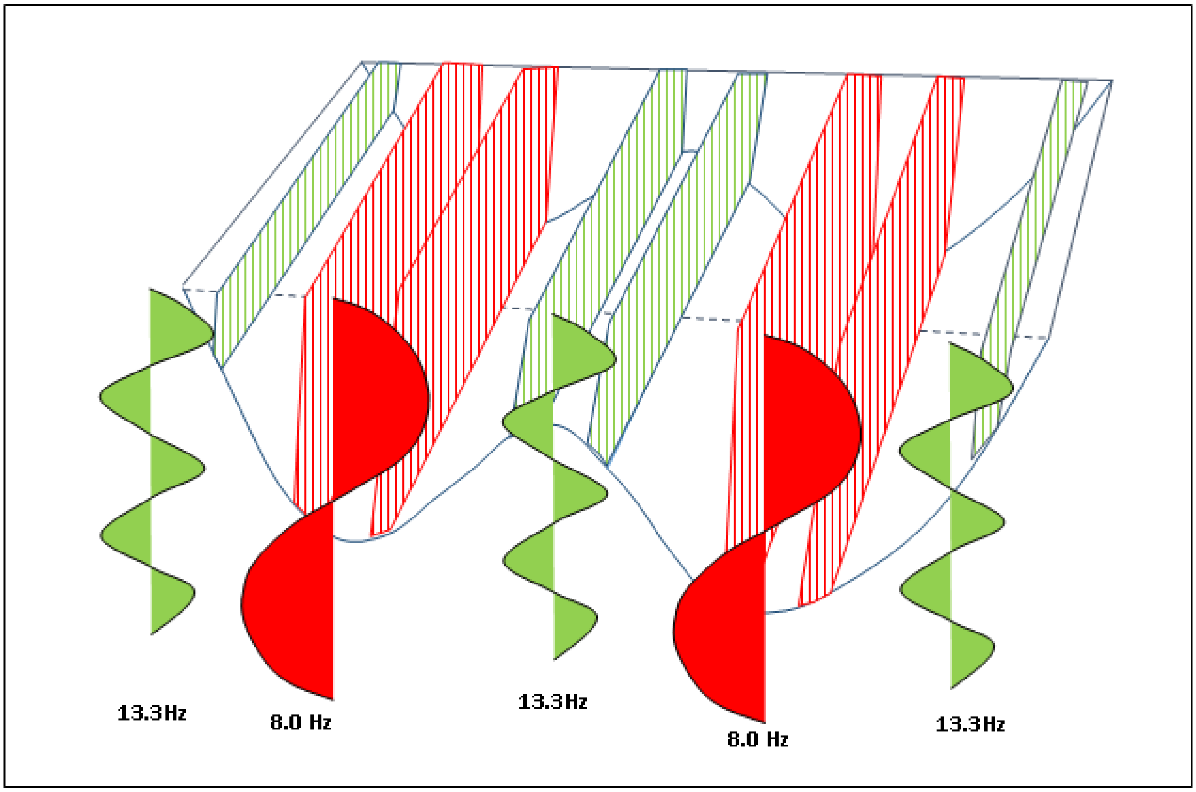

Figure-4. Describing bed thickness with seismic wavelet spectrum showing the correlation between thicker bed with low frequency and thinner bed with higher frequency. The green wavelet represents higher frequency and the red showing lower frequency. Thin bed tuning occurs in the green zone for the higher frequency as well as for low frequency in the red zones.

CONCLUSIONS

Spectral decomposition analysis considered to be one of the tool that helps in recognizing subtle features in more detail specially of the stratigraphic features such as channels, valleys, deltas and so on. Since depositional features varies in bed thickness, the first rule of thumb would be evaluating the bed thickness of the any depositional artifacts. Saying that spectral decomposition should be used widely to analyze the depositional environment. Further it would be best to use more than one attribute to decompose to see the differences and similarities between them before verifying the seismic stratigraphy and the structures.

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