Seismic Resolution Enhacement with Spectral Decomposition Attribute at Exploration Field in Canada

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Abstract—Seismic data that has a high resolution is very important used to describe hydrocarbon reservoirs in detail. In conventional seismic data, the available bandwidth is limited and cannot map the thin layers that seen on well data, therefore, the way to improve the resolution of seismic data is needed. In this research, the method used to improve the resolution of seismic data is spectral decomposition. Spectral decomposition can characterize the seismic response at a particular frequency, and can also be used to filter the data, eliminating signals that are unwanted or increase the quality of data. Spectral decomposition method used is the Continuous Wavelet Transform (CWT). This study had been carried out by implementing CWT in certain wavelet and frequency to analyze the seismic resolution. The various wavelets had been used this study, are Morlet and Gaussian. The various frequencies of 2 Hz, 14 Hz, 20Hz, 25 Hz, 31 Hz, and 51 Hz in 1180 inline. The results obtained from this study show that the use of higher frequency shows better separation. In addition, the application of seismic data in the area of research Penobscot, the best separation of thin layer is in the tuning frequency 51 Hz using Morlet wavelet in 1180 inline.

Keywords— Continuous Wavelet Transform (CWT), Gaussian, Morlet, Spectral Decomposition

INTRODUCTION

Seismic method is a reliable technique for imaging subsurface conditions ranging from the scale of centimeters to kilometers using seismic waves. Through the study of the propagation of acoustic waves into the layers of the earth and where the propagation of seismic waves will be reflected back to the surface and will be received by the recipient, so from the information recorded by the recipient, can learn about the structure, statigrafi and types of rocks of the earth [9]. Seismic data can imagine geological conditions and better image of the subsurface.

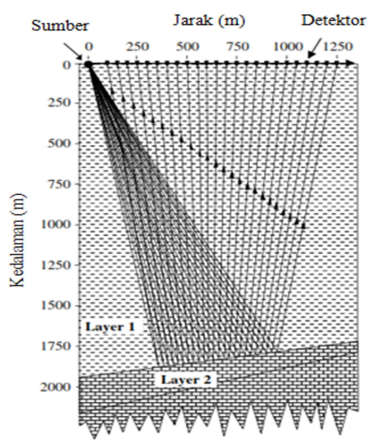

Fig 1. Reflection Seismic Method [7]

Conventional seismic data are usually contaminated by coherent noise. In practice, seismic attribute is effective in extracting the data containing noise becomes more refined [8]. Seismic attribute is a mathematical transformation of seismic trace data which presented ime, amplitude, phase, frequency, and attenuation. Seismic attribute also is expressed as qualitative and descriptive nature of the seismic data can be displayed in the same scale as the original data[1].

Resolution is defined as the ability to separate two appears that is very close toghether. Resolution describes the minimum distance between two reflectors in this case a limit of bedding which can be distinguished by a seismic wave. In a seismic resolution interpretation is divided into two directions of resolution. They are vertical resolution and horizontal resolution. Horizontal resolution plays an important role in determining whether the poor results of interpretation, especially in term of identification of the rock layers. The thin layers can be observed accurately with a high seismic resolution [13].

Seismic data that has a high resolution is very important used to describe hydrocarbon reservoirs in detail. In conventional seismic data, the width of the available frequencies are limited and can not map the thin layers visible on well data. Therefore, needed a method to improve the resolution of seismic data to be able to see the separation of thin layers that will be visible in accordance with the actual situation [11].

In this study using spectral decomposition attribute with Continuous Wavelet Transform (CWT) to improve the resolution of seismic data. spectral decomposition can characterize the seismic respone at a particular frequenct, and can also be used to filter data, eliminating signals that are unwanted or increase the quality of data to produce output amplitude spectrum [10].

The underlying concept of spectral decomposition is based on the fact that a seismic reflection from thin rock layers (at or below the vertical seismic resolution) will give a certain frequency respone characteristics. If the frequency are exploited a thickness on the part of the target zone then it can provide a more detailed picture information compared with conventional seismic processing. By using spectral decomposition, it can be seen spectral amplitude and phase into specific wavelength [14].

The wavelet method is an alternative method to decompose a signal in a time region into a time-frequency region with better resolution [3]. The information that obtained in the wavelet transform is a representation of the signal in the 'time' domain into 'time-frequency' domain. The first proces done choose wavelet 'mother wavelet' and then 'family wavelet' by translating and dilate the mother wavelet. The second process is integrating the multiplication of wavelet with transformed functions [5].

CWT is a convolution process signal $x(t)$ with a window function, window function can be changed at any time and scale changing. Window function is a mother wavelet that become the basic function of the wavelet. Matematically, CWT of a signal x(t) can be solved by the equation :

$$\mathrm{CWT}_x^{\Psi}(\tau, s) = \psi_x^{\psi}(\tau, s) = \frac{1}{\sqrt{|s|}} \int_{-\infty}^{\infty} x(t) \,.\, \psi^* \left(\frac{t-\tau}{s}\right) dt \qquad (1)$$

Where s indicates the scale of value inversely proportional to the frequency (S > 0), τ is time shift that indicates shifting or translational mother wavelet and $\psi^*\left(\frac{t-\tau}{s}\right)$ indicates mother wavelet. By using dilatation/scale parameter and translation parameter which by using a small value s in equation (1), the wavelet is responsible for the localization of high frequencies while s great value then wavelet function vice versa. While the translation parameter (τ) is responsible for the localization span spectral area of the original signal frequency. The larger value of τ, so the greater spectrum area span covered of wavelet transformation [4]

The result of CWT is coefficients that are a function of scale and position. The multiplication of each coefficient with the scale and exact position will produce cconstituents wavelet of the original signal

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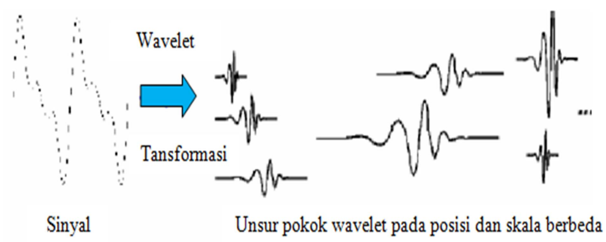

Fig 2. Illustration of transformation with continuous wavelet transforms that produce components wavelet of scale and position

Increasing the resolution of seismic data is one of the uses methods that have evolved to sharpen seismic resolution both vertically and horizontally. The higher the resolution of seismic then the resulting seismic section has a sharper appearance, especially the effect on the two adjacent layers

The addition of the higher frequency components will sharpen (narrowing) peak of wavelet center that will provide increased levels of resolution capable of separating a thin layer, while the addition of the lower frequency components will reduce the formation of sidelobes on wavelet (Figure 3) [6].

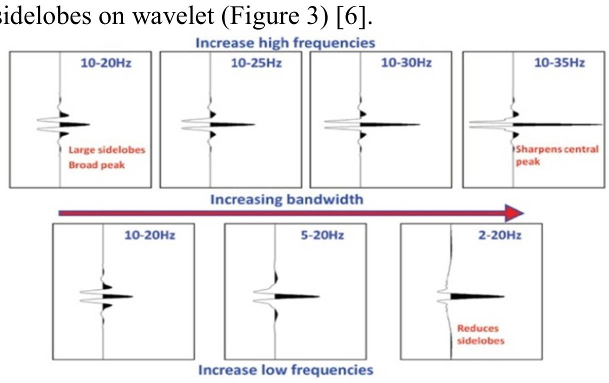

Fig 3. The effect of adding the higher frequency components and lower frequency of the seismic wavelet [6]

In figure 3 shows how the higher frequency of the wavelet will be more narrow, whereas the lower frequency, the number of side lobes on wavelet will be reduced so that the disappearance of the side lobe is contribute a great depictions better at target depth and variation faces large scale and eliminating traces of pseudo high resolution. While Figure 4 shows the difference in a wide bandwidth of the seismic data.

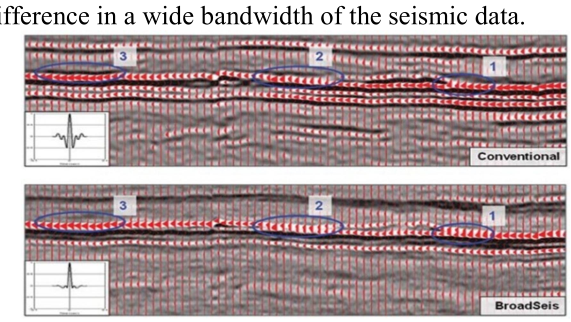

Fig 4. Comparison of seismic data with a wide cross-section of different bandwidth[6]

Figure 4 shows how the pinch-out (Zone 1) and thin bed (Zone 2) on the data broadseis not through the phenomenon of tuning thickness similar to those shown in the conventional seismic data. While broadseis zone 3 on the data did not show any interference side lobe as shown on conventional seismic data.

METHODS

a. Instruments and Materials

The materials used in this study include 3D seismic data at exploration field of Penobscot, well log data, Marker Data, and Check shot data. Instruments used include computer and Opendtect software.

b. Preparations

The preparation stage includes the study of literature and data collection. The study of literature is done by searching for references theories related to the case or the issues to be resolved in the study include the stratigraphic exploration field, seismic methods, seismic attribute, and others, while the collection of data that are collected is seismic data, well log data, Marker data and check shot data.

c. Processing of Data

At this stage of data processing carried out several steps to get the final result of cross-spectral results of spectral decomposition attributes with Continuous Wavelet transform method (CWT), which represents an increasing towards the resolution of seismic data. these stages include :

1. Seismic Interpretation

Seismic interpretation related with the determination of the target zone of the study area. Target zones in this study, after the well seismic tie which is located at a depth of 1992 to 2532 ms and writers here took part in line from the 3D seismic data for interpretation. Inline target zone lies in 1180, is determined by the appearance of seismic layers are very close together so it looks like a reflector alone and based on existence of Bright spot.

2. Making spectral section of CWT

After determining the target zone of the study area, the next running attribute of spectral decomposition with CWT can be done. The parameters included are kind of wavelet and frequency variation. Wavelets used are Morlet wavelet and Gaussian wavelet. In each of the wavelet, put the value of the frequency based on amplitude spectrum generated by the target zone.

d. Step of Discussion

The result of the application spectral decomposition attribute with Continuous Wavelet Transform (CWT) method will be obtained spectral section from the lowest frequency to the highest frequency. Cross-section analysis of the attributes here relates to the separation of thin layers characterized by amplitude anomalies on the seismic section.

e. Conclusion Stage

In the cross-sectional analysis of these attributes will be known on what kind of wavelet and which frequency, thin layers on seismic section that looks are not separate but using this method can be seen separately. Improved resolution is analyzed by looking at the distribution of the amplitude using either a cross-spectral Morlet wavelet or Gaussian wavelet.

RESULTS AND DISCUSSION

Conventional seismic section before implemented CWT method as shown in Figure 5, where inline 1180 is in line passed by the well, which makes the area can describe the distribution of the anomalies well. That seismic section could not provide information about the distribution of any anomalies in the area because of the cross-section of the layer still look thick and form a line one reflector. That is because the data is still contaminated by the noise generated from the interference waves are undesirable, for example surface waves, therefore, be applicable methods of CWT on that section in order to can map the thin layers that exist in the depths of 1992 to 2532 ms. The cross-section is a 2D cross section that gives information that horizontal direction, is cross line which cross line is the path toward y axis at the time of the data and the vertical direction shows the depth in the direction of z-axis in units of ms.

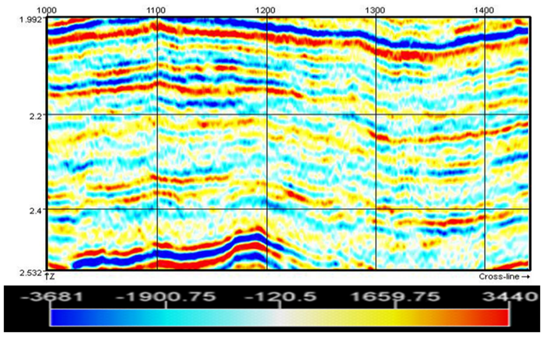

Fig 5. Conventional seismic section in line1180

Amplitude spectrum of seismic data inline cross-section is then determined. At in line 1180, obtained amplitude spectrum as shown in Figure 6. The results of the amplitude spectrum, we can determine the frequencies to be used in research to look at the response of seismic section from low frequency to high frequency.

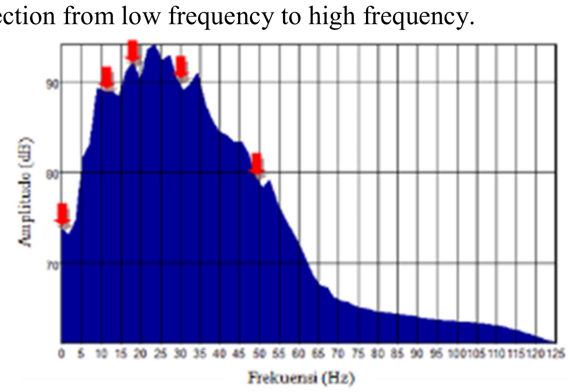

Fig 6. The amplitude spectrum at inline 1180 depth of 1992 to 2532 ms

Based on the amplitude spectrum shown in figure 6 the frequency values obtained from the lowest to the highest that is equal to 2 Hz, 14 Hz, 20 Hz, 25 Hz, 31 Hz and 51 Hz. Determining the value of this frequency based on the frequency value after the peak frequency or called frequency tuning. Tuning frequency is the frequency where the target is clearly visible [2].

In line 1180 cross section (Figure 5) then applied CWT method with a determined frequency either by using Morlet wavelet and the Gaussian wavelet. The results as shown in Figure 7 to Figure 14 based on the low frequency to high frequency. Variations of the used frequency in the study aim to look the response of seismic section from low frequency to high frequency.

The output of CWT section give information about the amplitude spectrum in the area, where the amplitude spectrum generated varies according to that shown by the color legend at the section. Low amplitude is represented by blue color and high amplitude is reprented by red color. Resolution on this research, seen from the distribution of thin layers produced at the section when the frequencies are enhanced. Distribution thin layer is characterized by the spread spectrum amplitude, because based on the reference states that high amplitude showed existence anomaly, then the resolution is here seen from the distribution of high amplitude spectrum are marked in red color. CWT generated cross section, also provides information that shows cross line horizontal direction, which is the path toward cross line y axis at the time of the data and the vertical direction that shows the depth in the direction of z-axis in units of ms.

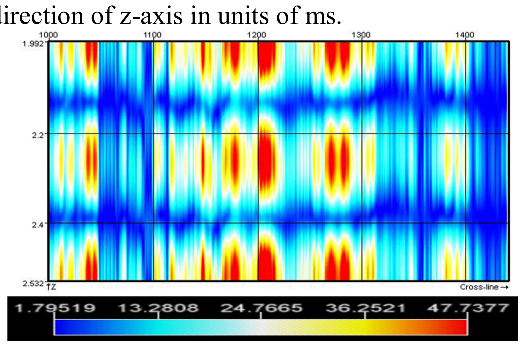

Fig 7. Inline spectral cross-section in 1180 at frequency of 2 Hz with Morlet wavelet

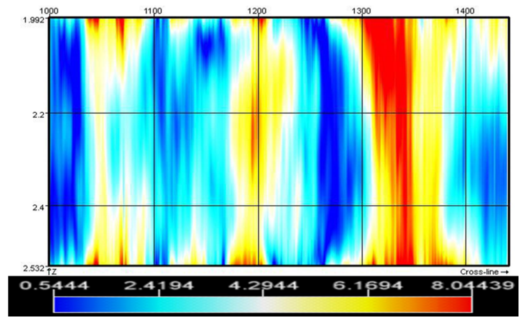

Fig 8. Inline spectral cross-section in 1180 at frequency of 2 Hz with Gaussian wavelet

The results of CWT applications with Morlet wavelet at a frequency of 2 Hz (Figure 7) in the area through which the L-30 wells is inline in 1180, showed that horizon at depth 1992-2200 ms seems not seen the separation between the horizon which is above the horizon its inferior and lateral separation. It also happened at the cross-spectral image with Gaussian wavelet (Figure 8). It also happened at the cross-spectral image with Gaussian wavelet (Figure 8). CWT section generated using Gaussian wavelet shows the highest amplitude seen to accumulate in certain areas, so it can not reveal the spread thin layers in the area. This is because the used frequency is still very low, so the ability to be able to separate the thin layer (resolution) that occur in the target area is still low, it is well known that the relationship between the frequency and resolution of seismic have harmonious relationships. The higher the frequency, resolution is also higher [15].

In Figure 7 and Figure 8, the thin layers are not visible and become one with another thin layer so that the layer of the resulting looks thick and cannot distinguish the actual boundary layer. This occurs because the frequency of a given small so that the energy is distributed below the surface of weak so that cannot map subsurface conditions in detail. This is in accordance with the principle of Huygens [12] which states that any points of bullies who are in front of the main wave front will be the source for the formation of a row of new wave. Number of new energy will be the same as the main energy.

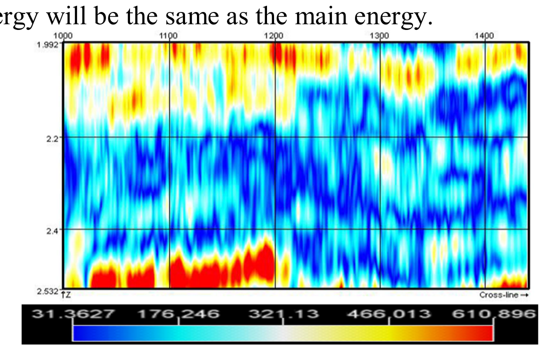

Fig 9. Inline spectral cross-section in 1180 at frequency of 25 Hz with Morlet wavelet

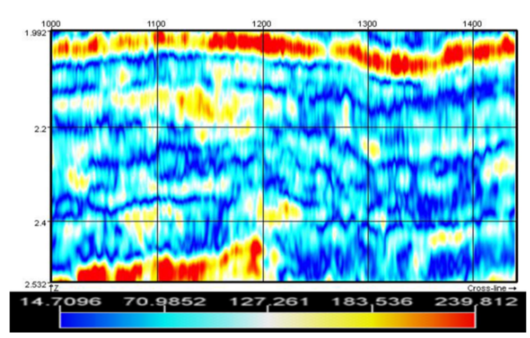

Fig 10. Inline spectral cross-section in 1180 at frequency of 25 Hz with Gaussian wavelet

The Results of CWT at a frequency of 25 Hz with a Morlet wavelet and Gaussian wavelet (Figure 9 and 10), shows that the separation between the horizon which is

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above the horizon beneath it is still slightly visible. At a frequency of 31 Hz, with Morlet wavelet CWT section in the target area shows that the horizon is already beginning to look a separation between the horizon which is above the horizon beneath it, but the separation is still not so contrasting. The ability to be able to carry out the resolution by using a frequency of 31 Hz, it can be said to be higher (better) than the resolution capability with frequency of 25 Hz.

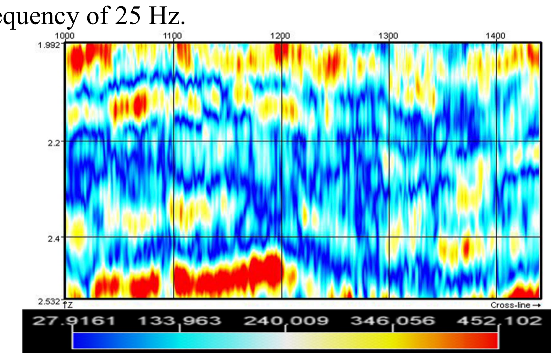

Fig 11. Inline spectral cross-section in 1180 at frequency of 31 Hz with Morlet wavelet

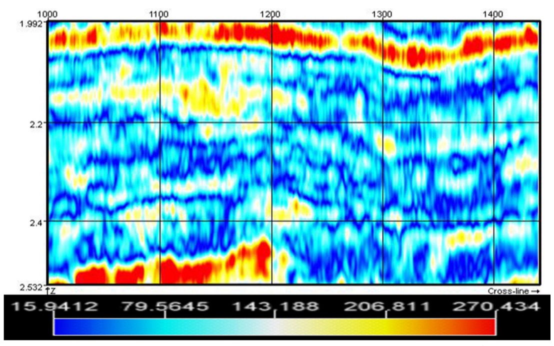

Fig 12. Inline spectral cross-section in 1180 at frequency of 31 Hz with Gaussian wavelet

At higher frequencies at 51 Hz, result of CWT show that the horizon is already evident and clear the separation between the horizons which is above the horizon beneath it (Figure 13). A result with Gaussian wavelet shows the next higher frequency is the frequency of 31 Hz (Figure 12) and 51 Hz (Figure 14), the cross-section visible spectral changes seem very small or tends to stagnation.

Applications of CWT generated at the cross-conventional by using wavelet Morlet produce better resolution at a frequency higher than using wavelet Gaussian while on a cross-CWT with wavelet Gaussian, separation horizon is already visible at a certain frequency and the frequency of the next higher changes tend stagnant. Morlet wavelet show more clearly because Morlet wavelet has a bandwidth greater. The bandwidth is directly related to the resolution, where the higher the bandwidth, the greater the resolution. Wavelet who has a more narrow (very wide bandwidth) would be able to provide reflector very clearly on the interface rocks [4].

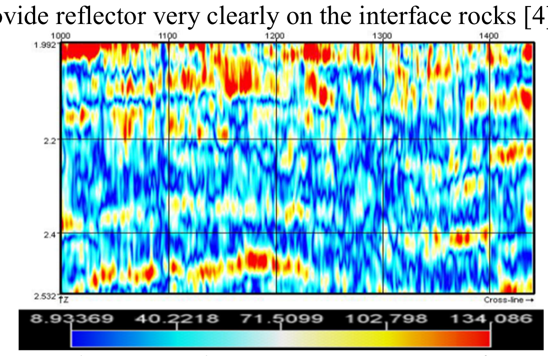

Fig 13. Inline spectral cross-section in 1180 at frequency of 51 Hz with Morlet wavelet

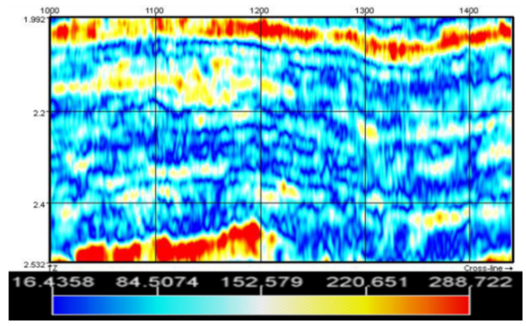

Fig 14. Inline spectral cross-section in 1180 at frequency of 51 Hz with Gaussian wavelet

From the results of a cross-CWT either by using Morlet wavelet and Gaussian wavelet found that the higher the value the sharper the frequency distribution of high amplitude value. This reflects the distribution of the thin layer at high frequencies and the thicker coating is described by a lower frequency. Separation is already evident and obvious, is because the higher the frequency used, so the resolution is happening in the target area are also higher, as it is known that the relationship between the frequency and resolution of seismic have harmonious relationships [15].

CONCLUSION

Results have been obtained in this study, indicate that CWT method is one of the spectral decomposition method that uses wavelet as a window in the time scale. From the results of CWT on seismic data shows that in the target zone, the higher frequency, resolution that provided is also higher. In Morlet wavelet, produced a cross-spectral resolution better at higher frequencies than the Gaussian wavelet. In seismic data in the area of research Penobscot inline 1180, a thin layer separation occurs in the tuning frequency 51 Hz using Morlet wavelet.

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