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Contributed Paper

Geological Delineation Using Shifted Seismic Attributes

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ABSTRACT

Details of geological information might be extracted from seismic data using seismic attributes which illustrate the specific characteristic of the data. Seismic attributes and visualizing techniques have been applied to seismic interpretation workflows. As the objectives, thin channels and fans are captured in the 3D offshore Parihaka and 3D onshore Stratton seismic surveys. The original seismic data are shifted upward and downward using the macro script before mixing together by the Red Green Blue (RGB) blending technique. In Parihaka survey, the architecture of channels, such as point bars and thin channels inside the fan could be highlighted at the time slice of 970 ms, 1120 ms and 1200 ms. In Stratton survey, the channel trend at 1586 ms could be delineated. The well data are confirmed the result from the shifted seismic attribute with the RGB blending technique for the channel detection. The result of spectral decomposition for both Parihaka and Stratton are compared to the RGB blending of shifted attributes. The similar channel trend and fan system could be identified from the RGB blending of spectral decompositions for both datasets, as they could be observed from the RGB blending of shifted attributes. The benefits of this study are to improve the confidence and accuracy of seismic interpretation and geological understanding. The understanding of thin bed connectivity could be useful in the reserve calculation and the economic analysis for hydrocarbon exploration and production.

Keywords: shifted seismic attribute, geological delineation, RGB color blending technique, spectral decomposition, channel and fan detection

1. INTRODUCTION

In general, many oil and gas companies conventionally concentrate on channels and fans geological bodies as the reservoir drilling target, since they are sediment transport pathways. Sand sediments are commonly believed to be deposited in channels and fans, and could potentially be a representative of the hydrocarbon reservoir. Thus, the proper defined and small details captured from the bodies and especially thin beds would provide the more reliable of the geological depositional model resulting in reducing the risks for the oil and gas exploration as a consequence.

Moreover, with good understanding from all above, there is still a limitation and errors in the seismic data itself. The seismic data is band limited missing the data from those low and high frequency ranges. Therefore, various techniques have been developed to overcome these challenges in order to improve the confidence of the seismic interpretations for many decades.

The seismic attribute analysis is one of the tools to guide the seismic interpretation. The seismic attribute is the mathematical expression of seismic data including amplitude, phase, frequency and polarity based on the non-harmonic time signal [1]. There are wide ranges of seismic attribute usage in many studies: signal processing, structural interpretation, fracture analysis, AVO analysis, fluid identification and etc. [2-4].

Spectral decomposition seismic attribute provides an innovative outcomes of utilizing seismic data and the Fourier transform. By Fourier transforming, the seismic data in the time domain is transformed into the frequency domain. The amplitude spectra captures the temporal bed thickness variability while the phase spectra indicate lateral geologic discontinuities.

A simple homogeneous thin bed represents a predictable and/or periodic sequence of notches into the amplitude spectrum of the reflection [5]. The amplitude spectrum pattern from the reflection expresses the correlation between each individual bed acoustic properties that comprise the reflection. The amplitude spectra delineate the thin bed variability via the spectral notching sequence [5]. Thus, understanding the existing and connectivity of unrevealed thin bed under the subsurface is the main highlight on the hydrocarbon exploration, production and economic analysis, as the thin bed could be a potential reservoir.

For the visualization perspective, the RGB color blending technique has been applied to many types for seismic attribute covering such as curvatures, dip and azimuth to highlight the geological features with richer visualizing dimensions, such as channel architecture and faults [6-7]. Each of seismic attribute cube is assigned to each color axis displaying the red, green and blue components into the 3D color space cube.

The methodology of blending shifted seismic cubes are described in this study for the channel and fan delineation using the offshore 3D Parihaka and onshore 3D Stratton seismic data, as the seismic data inputs in the paper. The expected result from shifted attributes with RGB color blending technique should be at least comparable to the spectral decomposition with RGB color blending technique in term of time and the details of capturing geological information. Additionally, it aims to reduce the time in the frequency selection process for spectral decomposition, where the database is normally full up after generating several spectral decomposition cubes as a consequence.

2. MATERIAL AND METHODS

2.1 Dataset Background

Taranaki basin is located in the west coast of New Zealand developed during the extensional breakup of Gondwanaland and later underwent intra-arc and fore-arc basin development [8]. The basin sediment supply is mostly from the Late Cretaceous to Eocene [9]. Taranaki basin is the New Zealand commercial oil and gas field.

The study area is in the south of 3D PSTM Parihaka survey of the permit PEP 51558 represented in the Figure 1 [10]. The area is approximately 220 km^2 covering the inline 2065 to 3096 and the crossline

5580 to 8376 from the time 800 ms to 1500 ms. The inline and crossline spacings are 12.50 m. The seismic cube has the estimated size of 700 MB with the 4 ms sample rate. The frequency content is approximately 10 Hz to 40 Hz.

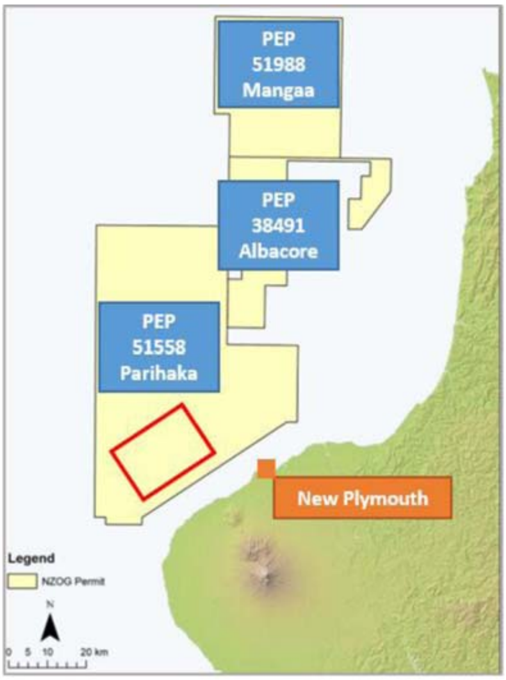


Figure 1. The study area in the red block inside the 3D Parihaka seismic survey locating in the west coast of New Zealand's North Island [10].

The Stratton is located at South Texas, which has the Oligocene Frio formation being the major gas productive interval of the progradational off lapping in the Cenozoic Gulf Coast Basin [11]. The depositional environmental covered the fluvial and deltaic environments. The hydrocarbon was trapped in the structural and stratigraphic traps.

The study area is illustrated in the South Texas as presented in the Figure 2. The seismic data is 3D PSTM having the area coverage of 60 km^2 from the inline 1 to 100 and the crossline 1 to 200 of 2 ms sampling rate. The inline and crossline spacings are 16.764 m. The data have the approximated size of 115 MB, where the frequency content covers a range of 10 Hz to 40 Hz.

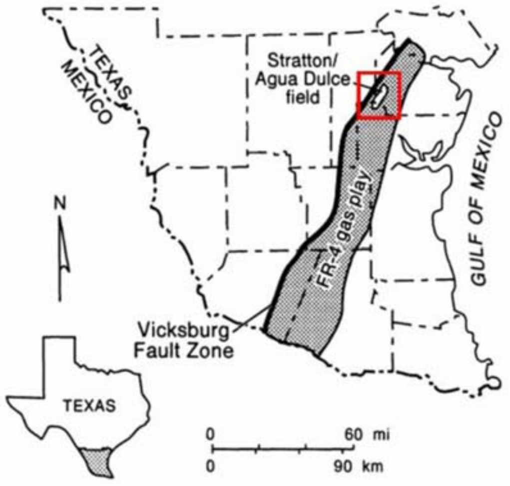


Figure 2. The area of study in the red block inside the 3D Stratton seismic survey locating in South Texas [11].

2.2 Shifted Seismic Attribute

The seismic cube is vertically shifted both upward and downward by the designated number sample (X) using the macro script in the seismic calculator with Schlumberger's software Petrel 2015.5 following these commands by Equation (1) and (2).

$$\text{UpwardShifted} = \text{NameOfCube}\ (0,0,x) \tag{1}$$

$$\text{DownwardShifted} = \text{NameOfCube}\ (0,0,-x) \tag{2}$$

The designated number sample, X, is 1 for both seismic surveys meaning that the entire of Parihaka and Stratton seismic surveys are shifted by 4 ms and 2 ms respectively. The rationale of determining X is described in the RGB color blending section.

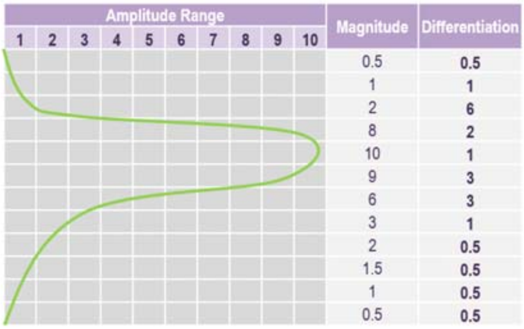
2.3 RGB Color Blending

The RGB color blending technique provides the richer visualizations of geological architecture of channels and fans based on the color spectrum super-position. Each shifted seismic attribute cube is represented to each color axis of the red, green and blue component into the 3D color space cube. The lowest value of each input is assigned to the original position of (0,0,0) of 3D color space cube displaying in a black color, where the highest value of each input is assigned to the maximum value of 255 in the color scale of red, green and blue. The concept of 3D RGB color space vector is mathematically expressed following by the Equation (3) [12]:

$$I_{RGB}(L) = S[I_R(L), I_G(L), I_B(L)], \qquad (3)$$

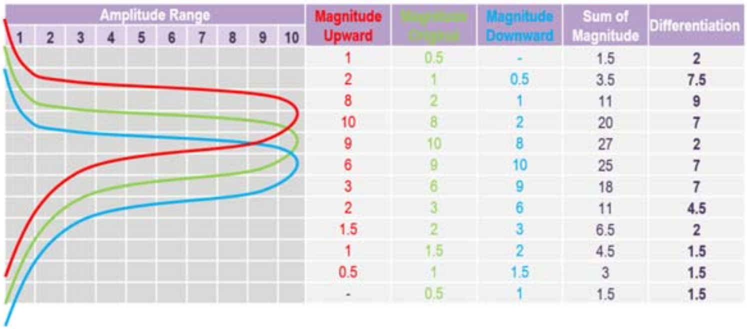
where L= (x, y, z) is the location within the 3D color space cube, I is the color intensity and S is the RGB transformation function. The S function is defined by the magnitude of I_R, I_G and I_B.

A numerical comparison between Figure 3 and 4 illustrates that using the RGB technique with shifted attributes offers a greater differentiation in the term of magnitude contrast over the original seismic data by the super-position concept. However, in case that the magnitude of color intensity, I_{RGB}, is the same in the 3D color space, this technique is still able to visually differentiate by the different color component input contributions of red, green and blue. By applying the minimal number of shifted sample to shifted attributes, the mis-alignment of both upward and downward shifted thin bodies to the original body is avoided ensuring that they are properly superposed.



Magnitude	Differentiation
0.5	0.5
1	1
2	6
8	2
10	1
9	3
6	3
3	1
2	0.5
1.5	0.5
1	0.5
0.5	0.5

Figure 3. The seismic signature shows its magnitude on each position on the grid with their differentiation to the neighboring position.



Magnitude Upward	Magnitude Original	Magnitude Downward	Sum of Magnitude	Differentiation
1	0.5	-	1.5	2
2	1	0.5	3.5	7.5
8	2	1	11	9
10	8	2	20	7
9	10	8	27	2
6	9	10	25	7
3	6	9	18	7
2	3	6	11	4.5
1.5	2	3	6.5	2
1	1.5	2	4.5	1.5
0.5	1	1.5	3	1.5
-	0.5	1	1.5	1.5

Figure 4. The seismic signature shows its sum magnitude from the upward shift, original and downward shift on each position on the grid with their differentiation to the neighboring position.

3. RESULTS AND DISCUSSION

3.1 Results on 3D Offshore Parihaka Survey

At the time slice 970 ms, in Figure 5, the result of RGB blending of shifted attributes captures the meandering channel system features on the top right of the seismic cube indicating by arrows, where the seismic data could not give any geological features in Figure 4. The yellow arrow shows the proximal channel, whereas the red and green arrows illustrate the distal channels flowing in the EW and WE direction respectively. The pink dotted circle represents the location where the channel was splitted into two directions. The edge of channels are clearly determined.

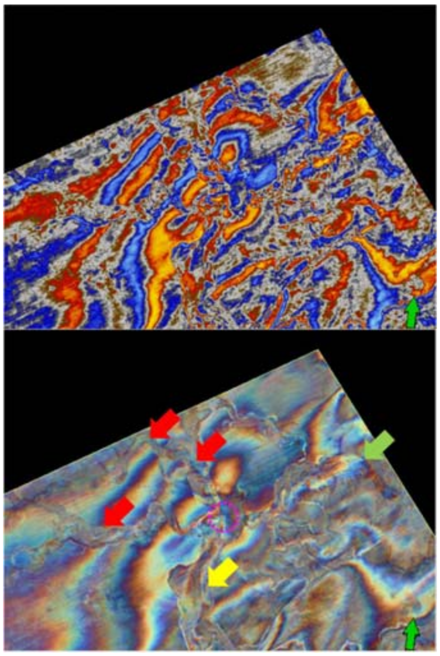


Figure 4: (Top) The Parihaka seismic data at the time slice 970 ms. **Figure 5**: **(Bottom)** The RGB blending of shifted seismic attributes at the time slice 970 ms showing the meandering channel system at the top right. The yellow arrow indicates the proximal channel. The pink dotted circle points out the location where the channel is splitted to the EW and WE direction indicated by the red and green arrows respectively.

At the time slice 1120 ms, the seismic data does not represent any geological body; however, the fan system is enhanced in the red circle in Figure 7. The fan boundary could be determined with the detailed geological architecture of meandering channel system inside the fan in the middle part of the seismic cube as shown in Figure 7. The distal channels could be clearly delineated at the edge of the fan boundary.

Additionally, the channels that are not associated with the fan system are demonstrated by the red arrows. In Figure 10, another channels could be revealed under the fan in the red circle; some point bars could be identified while moving the time slice downward to 1200 ms, but those channels could not be observed from the seismic data as shown in Figure 9. According to this evidence, this geological feature represents the marine regression in this study area.

The RGB blending of 20, 30, and 40 Hz of spectral decomposition is compared to the RGB blending of three shifted attributes at the time slice 1120 ms and 1200 ms. In Figure 8, the fan system and channels that associated to the fan could be seen clearly at the middle of seismic cube displayed by the red circle, and the channels that not associated with the fan are indicated by the red arrows. In Figure 11, the channels are enhanced as in the red circle. Additionally, according to Figure 8 and 11, the exact geological features could be obtained from the spectral decomposition blending including in the fan and meandering channels both associated with and without the fan system.

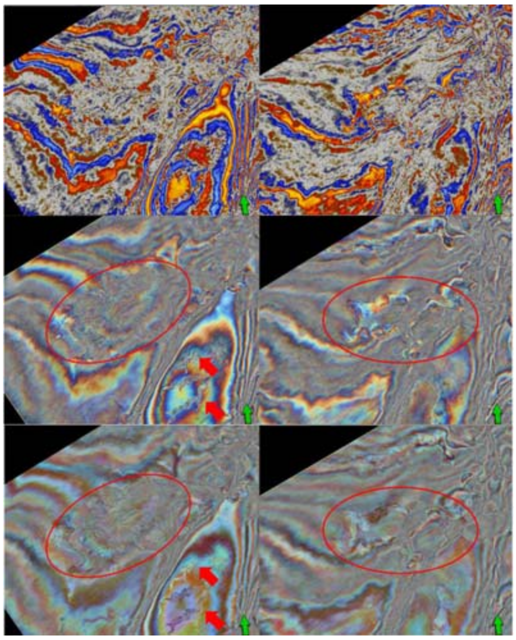


Figure 6. (Top Left) The Parihaka seismic data at the time slice 1120 ms. **Figure 7: (Middle Left)** The RGB blending of shifted seismic attributes at the time slice 1120 ms mapping the fan system in the red circle. The channels that not associated with the fan system are pointed by the red arrows. **Figure 8: (Bottom Left)** The RGB blending of spectral decomposition of 20, 30 and 40 Hz at the time slice 1120 ms mapping the fan system in the red circle. The channels that not associated with the fan system are pointed by the red arrows. **Figure 9: (Top Right)** The Parihaka seismic data at the time slice 1200 ms. **Figure 10: (Middle Right)** The RGB blending of shifted seismic attributes at the time slice 1200 ms highlighting the channels in the red circle. **Figure 11: (Bottom Right)** The RGB blending of spectral decomposition of 20, 30 and 40 Hz at the time slice 1200 ms highlighting the channels in the red circle.

3.2 Results on 3D Onshore Stratton Survey

At the time slice 1586 ms, the seismic data could represent a hot anomaly at the time slice 1586 at the survey center from Figure 12. From the shifted attribute with RGB blening technique, the channels across the survey from east to west and from north to west are revealed interpreting by the red and pink dashed line respectively from the RGB blending of the shifted attributes in Figure 13. This evidence could imply that the formation is in the fluvial system. However, the channel architecture could not be defined due to small channels less than 5 m of thickness [11], where the thickness of channel goes beyond the seismic resolution.

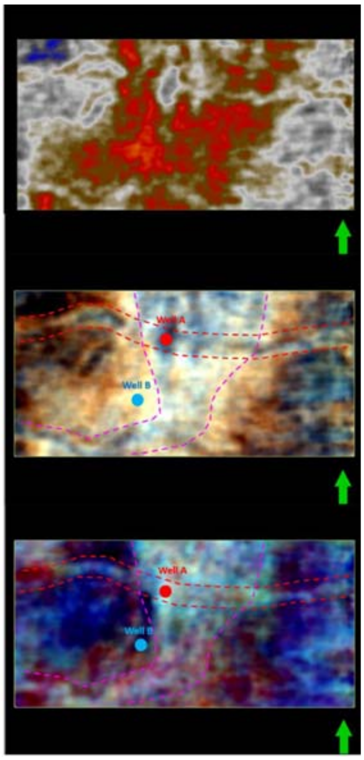


Figure 12. (Top) The Stratton seismic data at the time slice 1586 ms. **Figure 13: (Middle)** The RGB blending of shifted seismic attributes at the time slice 1586 ms uncovering the meandering channel trends capturing by the red and pink dotted lines. **Figure 14: (Bottom)** The RGB blending of spectral decomposition of 20, 30 and 40 Hz at the time slice 1586 ms uncovering the similar channel trends capturing by the red and pink dotted lines.

The RGB blending of 20, 30, and 40 Hz of spectral decomposition at 1586 ms in Figure 14 is compared to the RGB blending of shifted attributes. The similar channel trend could be highlighted.

In this seismic survey, the well data are available on Well A and Well B. Well A is located in the channel while Well B is not, referring to Figure 13 and 14. The gamma ray (GR) log is confirmed that Well A penetrates through the channel by showing the low GR value at 1586 ms while Well B has the high GR value indicating that Well B is not in the channel according to Figure 15.

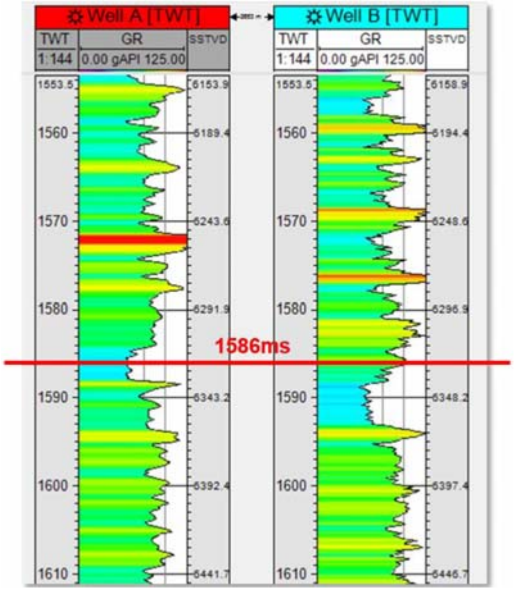


Figure 15. The gamma ray [GR] from Well A shows that Well A penetrates through the channel by having low gamma ray value at 1586 ms, where Well B does not.

3.3 Benefits and Applications

The connectivity of thin bed channel is the key of the reserve calculation, where the connectivity could define the reservoir extension. An inaccurate reserve calculation could lead to the overestimation or underestimation of resources and financial investments on the hydrocarbon exploration and production activities.

For the field development plan, such as the enhance oil recovery process, the effect of water or gas injection is simulated base on the permeability of the reservoir. The permeability is measured of the ability to flow through a media, which is linked to the connectivity. By being awareness of the connectivity of thin bed channels, the reservoir engineer could plan the water or gas injection rate to maximize the hydrocarbon production.

3.4 Performance

The executing shifted seismic attributes consume less time than producing spectral decomposition for both Parihaka and Stratton seismic surveys according to the time record in Table 1.

Table 1. The run time record for shifted seismic and spectral decomposition attributes for Parihaka and Stratton surveys.

Parameters	Survey Name	
	Stratton	Parihaka
Data size (MB)	115	700
Run time of spectral decomposition attributes (s)	12.42	74.11
Run time of shifted seismic attributes (s)	10.13	50.01

Additionally, this method also has a technical limitation to detect the thin body, where the body has the thickness less than 2 seismic samples, since overlapping of the shifted seismic signature will not be occurred.

4. CONCLUSIONS

The shifted seismic attributes with the RGB color blending could be used to delineate the geological features. The meandering channel systems and fan could be captured in both datasets, for example, for the thin layer channels at the distal part from 3D offshore Parihaka survey and the thin bed meandering channels from 3D onshore Stratton survey. The simple and efficient methodology introduces the alternative approach for the geological interpreters to accurately map the hydrocarbon reservoir potentials. The result is compared to the spectral decomposition for the accuracy and efficiency cross check, where the same characteristic of channels and fan could be observed. Ultimately, the benefits of having better understanding on the subsurface information is helpful to estimate and to reduce the risks of hydrocarbon from the exploration to the production in the oil and gas industry.

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