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Contributed Paper

RMS Seismic Attributes with RGB Color Blending Technique for Fault Interpretation

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ABSTRACT

For many generations, the use of seismic attributes has enabled the seismic interpreters to better understand the geological information in the subsurface. The objective of this study is to determine the fault and polygonal fault patterns to aid the structural interpretation inside the 3D Bonaventure seismic survey in Western Australia. In this study, three Root Mean Square (RMS) seismic attributes each with a different number of seismic samples are combined using the Red Green Blue (RGB) color blending technique to highlight the fault patterns using the Petrel platform. As the result, the fault images from the seismic time slices could be captured from the top to the bottom of seismic cube with the adjustment of the RGB color blending transformation function. The stretch and squeeze of RGB color blending functions provide a significant improvement on the fault delineation and visualization, especially at the bottom part of seismic cube, where the signal to noise ratio is usually low. The fault patterns from the RGB color blending technique are directly compared to the results from other structural seismic attributes such as variance, amplitude contrast and chaos at the same seismic time slice. The same fault trends, from the north to south direction, could be determined. The proposed method could be an alternative approach for fault interpretation in terms of t fault delineation and computation time. Finally, the ultimate goal of seismic attribute analysis is to improve the accuracy of seismic interpretation in order to reduce the uncertainty for hydrocarbon exploration and production.

Keywords: fault detection, RGB color blending, RMSseismic attribute

1. INTRODUCTION

Seismic data contain significant geological information regarding the different elastic properties. To produce detailed subsurface models, determining accurate and precise geological information is critical for seismic interpretation purposes. Many seismic interpretation techniques have been used to aid this task including seismic attribute analysis, amplitude versus offset (AVO) analysis [1], self-organizing maps (SOM) [2] and principal component analysis (PCA) [3].

The seismic attribute is a numerical expression of seismic data including amplitude, phase, frequency and polarity

[4]. For decades, geoscientists have been developing wide ranges of seismic attributes from the simple to advanced algorithms. The focus of seismic attribute analysis is to improve the confidence in the seismic interpretation, which reveals the hidden geological information related to stratigraphy, structure, formation properties and fluid responses [5].

One key piece of information for oil and gas exploration is the geological structure, especially faults. Many seismic fault interpretations rely on the seismic discontinuity and chaotic character. The identification of seismic reflector terminations and subtle changes in dip and azimuth allows the interpreter to infer faults. A major difficulty in interpreting faults is the smearing across the discontinuity boundary of the seismic reflector.

The variance seismic attribute is a powerful tool to reveal geological features including faults, reefs, channel edges and splays [6], as it isolates the discontinuities and edges from the seismic data in the horizontal amplitude by computing a normalized population variance [7]. The chaos seismic attribute could also highlight the local seismic signal chaotic character within a 3D window [8], where the geological features such as faults, reef textures and mass transports could be mapped, whereas the amplitude contrast seismic attribute is based on a Sobel-computation of amplitude derivatives in three dimensions of neighboring traces [9] delineating the structure such as faults and salts.

From a visualization perspective, the RGB color blending technique shows geological features with richer visualization [10]. Each seismic attribute cube is assigned to one of the color axes displaying the red, green and blue components in the 3D color space cube. By the default, the minimum value for all elements is located at the origin position, and the maximum value of each component is located at the far end of the 3D color space cube.

For the advance seismic algorithm and high visualization techniques, high-end computational hardware are generally required in order to avoid large computation time. Recently, the RGB color blending technique was successfully applied to the curvature, dip and azimuth seismic attributes to highlight geological features such as faults, unconformities and karst in the seismic time slice [11]; however, there is no study using RMS seismic attribute for fault detection proposes. Thus, this study proposes the methodology of utilizing a conventional seismic attribute, the Root Mean Square seismic attribute, associated to the RGB color blending technique for fault interpretation and analysis without needing the high-end computational hardware.

2. MATERIAL AND METHODS

2.1 Dataset Background

The study area is located in the middle of the WA-365P Block, as a part of the 3D Multi Client Survey (MCS) Bonaventure seismic data at the Exmouth Plateau in Western Australia illustrated in Figure 1 [12]. The area of the seismic survey is approximately 280 km^2 covering the inline locations 3500 to 4500 and the crossline locations 5750 to 7000 from the time of 1500 ms to 3500 ms. The size of seismic cube for this study is 2.26 GB. For the entire survey, the inline and crossline spacing is 12.5 m and 18.75 m respectively with the record length of 6 second and the 4 ms sampling rate.

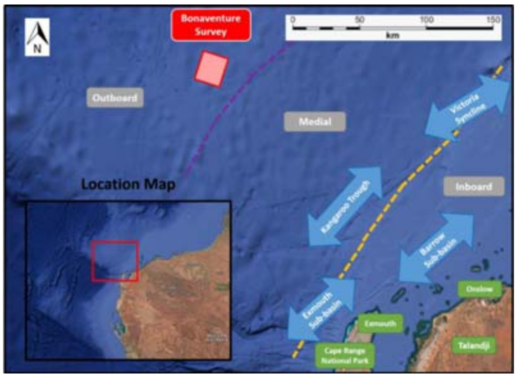

Figure 1. Northern Carnarvon basin location map showing the 3D Bonaventure seismic survey. The basin is divided into three parts where Bonaventure survey is located in the outboard part as indicated by the red box.

The Exmouth Plateau structure, in the western part of Northern Carnarvon basin, experienced north-east striking extensional passive margin tectonism from the Late Triassic to the Early Cretaceous having four major tectonic evolution stages [13]. In stage 1, the intracratonic sediments were deposited prior to Late Triassic. In stage 2, the rifting and extension event occurred, resulting in a major north-south fault trend from Late Triassic to Upper Jurassic [14]. Upper Jurassic to Early Cretaceous (stage 3) was a period of oblique extension. Lastly, in stage 4, the basin has been a passive margin and has subsided from Early Cretaceous until the present [13]. The horst and graben structures are commonly observed throughout the areas shown in Figure 2.

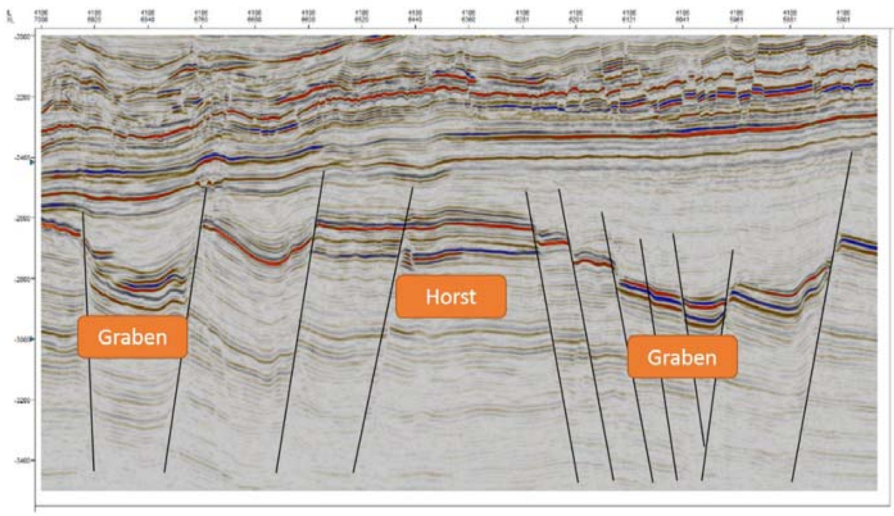

Figure 2. The seismic section of inline 4113 illustrates the horst-graben fault structure in the 3D Bonaventure seismic survey. The black lines are the fault interpretations.

2.2 Hardware Specification and Software

The mobile workstation used to perform this study was a DELL PRECISION Intel® Core™ i7-2760QM with a 2.4GHz CPU and 16.0 GByte RAM with Petrel 2015.4 software by Schlumberger.

2.3Data Conditioning

To sharpen the geological features, edge preserving and noise attenuation filtering were applied as a prerequisite where parameter testing was strongly recommended.

This method is claimed to reduce noise without degradation, including fault expressions in the seismic data [15]. However, with the data conditioning there was a significant trade off of signal to noise ratio.

2.4 RMS Seismic Attribute

The three RMS seismic attribute cubes were generated with a different number of samples from the seismic cube by computing the square root of the summation of squared seismic amplitude over the number of seismic samples following the Equation (1):

$$X_{rms} = \sqrt{\frac{(X_1^2 + X_2^2 + ... + X_n^2)}{n}} \quad , \qquad (1)$$

where X_i is the seismic amplitude of the i^{th} sample, X_{rms} is the amplitude of RMS seismic attribute and n is the number of sample.

2.5 RGB Color Blending

The amplitude response from the RMS seismic attribute becomes boarder with a large number of seismic samples in the operator window than with a smaller number; however, the intensity of the amplitude response from the RMS seismic attribute with a large number of seismic samples in the operator window is less than with the smaller number. Once the three RMS seismic attributes were superposed using the RGB color blending technique, the faults and discontinuities were sharpened and the noise was suppressed.

With the RGB color blending technique, geological features are shown with richer visualization. Each of the RMS seismic attribute cubes was assigned to each color axis displaying the red, green and blue components into the 3D color space cube. The RGB color display was based on the vector of 3D color space cube following by the Equation (2) [10]:

$$I_{RGB}(L) = S[I_R(L), I_G(L), I_B(L)], \qquad (2)$$

where L= (x, y, z) is the location within the 3D color space cube, I_R is the color intensity in the red axis, I_G is the color intensity in the green axis, I_B is the color intensity in the blue axis, I_{RGB} is the color intensity in the red blue green 3D color space and S is the RGB transformation function.

By the default, the minimum value for all elements is located at the (0, 0, 0) position, and the maximum value of each component is located at the far end of the 3D color space cube. With customized settings, i.e. the adjustment of RGB color axis either by stretching or squeezing, there can be a direct impact on the transformation function which enhanced more geological features.

3. Results and Discussion

At time slice 2000 ms, in Figure 3, the seismic amplitude has a highly discontinuous and chaotic pattern. No geological feature or fault could be interpreted at this time slice. Using RMS seismic attributes with the default RGB color blending setting, polygonal fault patterns could be highlighted on the east of the time slice, fault systems could be clearly seen especially at the north using the customized RGB transformation function. Generally, the polygonal faults are very challenging to interpret since the fault truncations occur in a series of patterns. Some polygonal faults were located in Figure 3 in the yellow box. With the proposed technique, the polygonal faults could be observed and easily interpreted in the time splice.

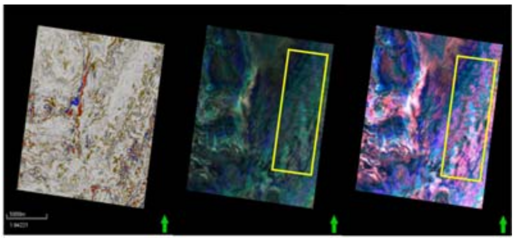

Figure 3. (Left) The seismic time slice at 2000 ms, (Middle) the RMS seismic attributes with default RGB color blending time slice at 2000 ms and (Right) the RMS seismic attributes with customized RGB color blending time slice at 2000 ms. The yellow box is covered the area of polygonal faults that could be interpreted.

Moving downward to the middle of the seismic section at the time slice 2752 ms, the seismic amplitude becomes more homogenous in some parts with the high amplitude contract in Figure 4. The homogeneous parts were interpreted as the horst or graben. The major north-south fault system could be partially interpreted on the seismic time slice at the beginning due to discontinuties of the high and low seismic contrasts as shown by the yellow arrows in Figure 4. The results of RMS seismic attribute with the RGB color blending enhance the major north-south fault system with more number of small faults detected for both default and customized settings. Especially, in the northern part, the minor faults interpreted by the red arrow in the Figure 4 were truncated by major faults where they could not be interpreted from the original seismic time slice.

At the bottom seismic section, the seismic quality and resolution are poor due to energy attenuation, especially high frequency losses leading to the low confidence of the geological interpretations. The seismic reflectors become broader and faults become difficult to interpret from the seismic section. As in Figure 5, at time slice 3200 ms, the seismic contrast and amplitude are relatively low compared to the time slice of 2752 ms and there is no geological feature that could be interpreted in the question marks. The result of RGB color blending with the default setting are very dim in the time slice making the interpretation challenging. However, once the color axis in the 3D color space are customized by stretching and squeezing the color axis, the fault systems are revealed for the entire area as illustrated by the yellow arrows. The series of fault-block details are clearly captured at the south-western part of the area as shown by the red arrows in Figure 5.

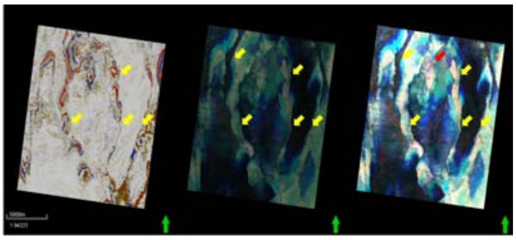

Figure 4. (Left) The seismic time slice at 2752 ms, (Middle) the RMS seismic attributes with default RGB color blending time slice at 2752 ms and (Right) the RMS seismic attributes with customized RGB color blending time slice at 2752 ms. The yellow arrows indicated the faults and the red arrow showed the small details of faults.

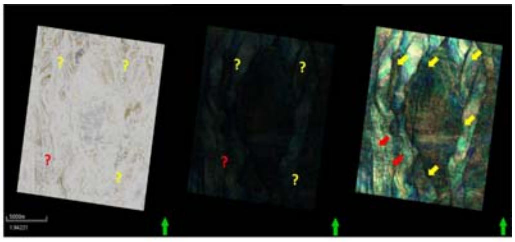

Figure 5. (Left) The seismic time slice at 3200 ms, (Middle) the RMS seismic attributes with default RGB color blending time slice at 3200 ms and (Right) the RMS seismic attributes with customized RGB color blending time slice at 3200 ms. The yellow arrows indicated the faults and the red arrows showed the small details of faults. The yellow and red arrows are the area where the faults could not be interpreted.

The faults in the seismic sections could be seen in the time slice in Figure 6 when the time slice at 3200 ms is displayed with the seismic sections in the 3D plot. The fault images in the time slice are very sharp; however, some faults are blurred in the seismic sections indicated by the yellow arrow for the example. In the time slice, the location where the fault stopped developing could be at the spot represented in the pink arrows.

The result from RMS seismic attributes with RGB color blending technique provides similar results as other structural seismic attributes such as variance, amplitude contrast and chaos as illustrated at time slice 3200 ms in Figure 7. The computation time is approximately equivalent to the time performance by variance, amplitude contrast and chaos seismic attribute according to the Table 1. From the performance observation, the RMS seismic attribute generation with a large number of seismic samples, trends tend to be more complex for the calculation and it takes a longer time to execute than with a small number of seismic samples.

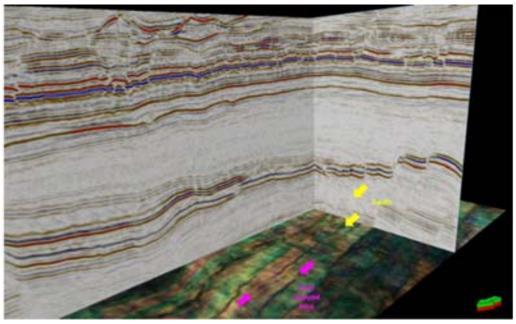

Figure 6. (Left) The seismic time slice at 3200 ms with the seismic section inline and crossline of 3656 and 6719 respectively. The yellow arrows are the interpreted faults and the pink arrows show the location where faults stopped developing further.

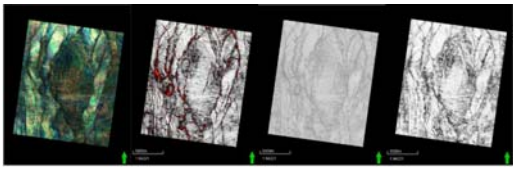

Figure 7. (Left) The RMS seismic attributes with customized RGB color blending time slice at 3200 ms, (Middle Left) the variance seismic attribute time slice at 3200 ms, (Middle Right) the amplitude contrast seismic attribute time slice at 3200 ms and (Right) the chaos seismic attribute.

Table 1. The time taken for each seismic attribute computation.

Seismic Attribute	Time Taken (s)
RMS (Small No. of Seismic Sample in an Operation Window)	10.33
RMS (Medium No. of Seismic Sample in an Operation Window)	12.22
RMS (Large No. of Seismic Sample in an Operation Window)	13.18
Variance	42.81
Amplitude Contrast	63.80
Chaos	474.01

4. Applications and Benefits

The RMS seismic attribute with the RGB color blending technique provides an alternative approach to delineate faults Knowledge of fault structure is very important for hydrocarbon exploration and production, as faults could play a major factor in determining uncertainty ranges on reserve calculations. Even small faults could act as a significant boundary barrier defining the extent of the reservoir. Without agood understanding of fault existence, inaccurate reserve calculations could potentially lead to an overestimation or underestimation of resources and financial investments.

5. Conclusions

The RMS seismic attributes with RGB color blending technique highlights fault patterns, providing an alternative approach to interpreting faults using the Bonaventure seismic survey as an example. This method was able to highlight fault patterns from the top to bottom of the seismic section covering both high and low signal-to-noise ratio areas. Additionally, the challenges of polygonal fault interpretation in this area are overcome using this technique. In terms of visualization, the customized stretch and squeeze capability on the RGB color provides an added capability to identifythe geological information with interpreter preference. The simple expression of the RMS seismic attribute allows an interpreter to manually derive the RMS seismic attribute inside any software through the basic software functionality.

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