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Research paper



Application of Multi Attributes for Feasibility Study of Fractures and Structural Anomalies in Malaysian Basin

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Abstract

There have been lots of efforts to study the geological characteristics and structure of the Malaysian Basin. Faults and fractures are of great importance due to the role they can play affecting different phases of a hydrocarbon prospect life from exploration through production and even abandonment. Carbonate build-ups are another type of significant geological anomalies in the area; because they are proved to be promising prospects. Application of seismic attributes on three dimensional seismic data has been proved to be useful in the study of such features. Each attribute is based on certain property of the seismic data which itself is the result of relevant geological phenomena. In this paper, different seismic attributes that can emphasize on the aforementioned geological anomalies are used in Malaysian Basin. Based on the results and their comparison, it is seen that combination of the results of different attributes can provide a much more convenient outcome.

Keywords: *Seismic Attributes, Fault identification, Carbonate Build-up, Malaysian Basin.*

1. Introduction

Central Luconia gas province is one of the most important explorations and production prospects in Sarawak basin. From the structural point of view, this area is located between a subsidence and faulting zone in the north and tectonic compressional zones in the south from lower to mid-Tertiary. This area shows a low degree of structural deformation. From Oligocene to lower Miocene and then lower to mid-Miocene, there have been some faulting activities that the latter has produced horst and grabens. The horst blocks have been a suitable place for reefal activities and lots of reefal carbonate build-ups have been produced here [1].

The existence of fault and fractures, as well as build-up structures in these carbonates, is of great importance affecting subsurface studies from hydrocarbon accumulation to drilling program to well productivity. The most useful type of data to study such features include three component [2] and three-dimensional seismic data to evaluate the existence and extent of such events. There have been lots of efforts to extract such information from seismic data especially with the help of both pre-stack and post-stack seismic attributes [3], [4], [5], [6]. In this study, the focus is on the post stack seismic attributes. Such attributes that are commonly used in the interpretation of discontinuities provide different information such as similarity of a trace to its neighbors, slope, azimuth, and curvature of layers. De-pending on the characteristics of the subsurface events, the performance of an attribute can be superior to others.

Data used in this study was three-dimensional seismic data from central Luconia, Sarawak covering 437 sq. km. The sampling interval was 2 millisecond (ms) and the total recording time was 5700 ms. Data quality was good and the seismic cube after migration was examined here. Eight seismic attributes were used to study the fault and fractures of the survey area. Comparing the results, the attribute with the better resolution to detect the desired features was selected for further studies. The software used in this study was GVERSE Attributes from LMKR and it should be noted that the attributes applied here may have different commercial names in other industrial programs.

2. Methodology

The seismic attributes used in the study of the faults are those that can detect disruption of the data. Attributes used here are discontinuity, coherence, semblance, dip-magnitude, azimuth, and most positive and most negative curvatures. A brief review of these attributes is given below [7]:

1. Discontinuity shows the dissimilarity of amplitude and phase of reflections between traces. Faults are one of the features causing abrupt changes in seismic data, hence, can be detected using discontinuity attribute.

2. Coherence is, in fact, complementary of the discontinuity. It shows the degree continuity of seismic events. There are different methods for calculating coherence among which the eigenvalues method has been used here. Since the existence of faults results in the low similarity of reflections with the surroundings, areas with low coherency can be an indication of such phenomena.

3. Semblance like coherence is a measure of comparability in seismic data. In this case, as the name suggests, the method used to compute similarity is semblance. Having geological features like channels, faults, and sharp changes in sedimentological facies

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results in a decrease of the similarity of the data; therefore, low semblance.

4. Dip-magnitude computes the slope in different directions in data and considers the highest value as a dip. Consequently, events with different dips can be differentiated with the aid of this attribute. Faults causing layer movement on the fault plane sides can be seen as dipping events on seismic data. Although, it should be considered into account that like other attributes, they are not the only geological events that can produce anomalies in data. Also, strike-slip faults are not accompanied by vertical movements and may not be seen using this tool.

5. Azimuth attribute computes the direction of the maximum dip at each location. It usually accompanies the dip-magnitude attribute. Using this property, dipping events with different orientations can be separated.

6. Curvature quantifies the rate of change of dip and azimuth of seismic events. Since the dip and azimuth change in different directions, curvature produces a series of values including maximum curvature, minimum curvature, Gaussian curvature, most positive curvature, most negative curvature, … among which the last two have shown to be more useful in fault study. Faults usually cause positive curvature on the upthrown and negative curvature on the downthrown side of the fault plane. Hence, they can be seen on the curvature attribute.

3. Results and Discussion

A case study from Malaysian basin illustrates the application of multi-attribute for faults and fractures enhancement in the data. Time slice at 1950 ms of the original migrated seismic cube was chosen for the study purpose as shown in Figure 1. Two events are apparent in data near each other (the green arrow shows a major fault and the yellow box is surrounded by an anticline). To evaluate the significance attributes to differentiate such geological features the study was focused on the selected area shown with the brown box in Figure 1.

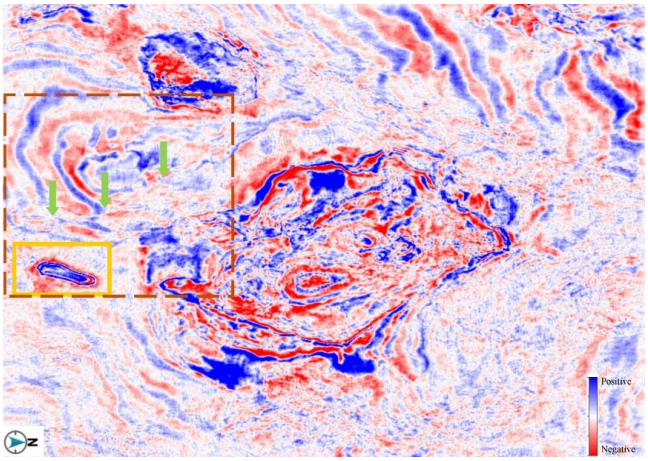

Fig. 1: Time slice from input data at 1950 ms. The green arrows mark a Major fault plane and the yellow box encloses an anticlinal structure. For a more detailed study, the area shown by the brown box is zoomed in following figures.

Figure 2 shows the result of applying the discontinuity attribute on the seismic data at the zoomed part of the same time slice selected in Figure 1. higher similarity of the reflection to its neighbours results in the lower value of this attribute. On the contrary, the presence of abrupt changes in data produces bigger values. In case of a fault in data (green arrows), the colour is black, while for the anticline (yellow box), the values are lower shown by whitish colour. The anticline boundary shows a nearly perfect picture of the anomaly which is the result of discontinuities in the structure.

Coherence is the next attribute applied to data. The result is shown in Figure 3. In this attribute, on the contrary of the previous attribute, the lower similarity results in lower values. Though the fault trend is recognizable, the general resolution of the output data seems lower, compared to Figure 2. However, more details are visible here. For the anticline, coherency has high values (toward white) which confirm the results of the previous attribute; and more details are seen both around and on the structure itself.

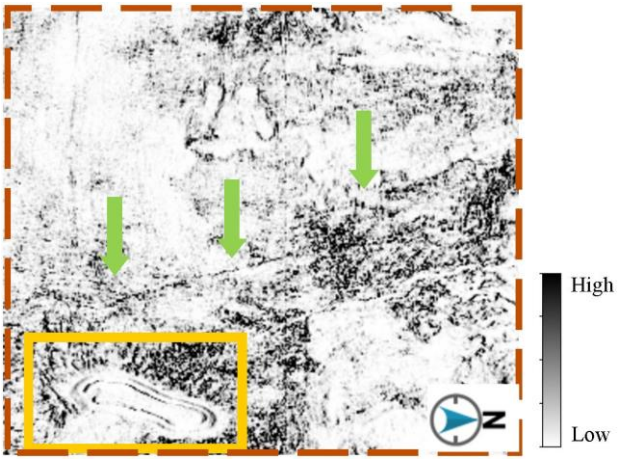

Fig. 2: Result of discontinuity attribute application. Darker colour means higher discontinuity. The fault trend (green arrows) can be clearly identified. The boundary of the anticlinal structure is also adequately located (yellow box).

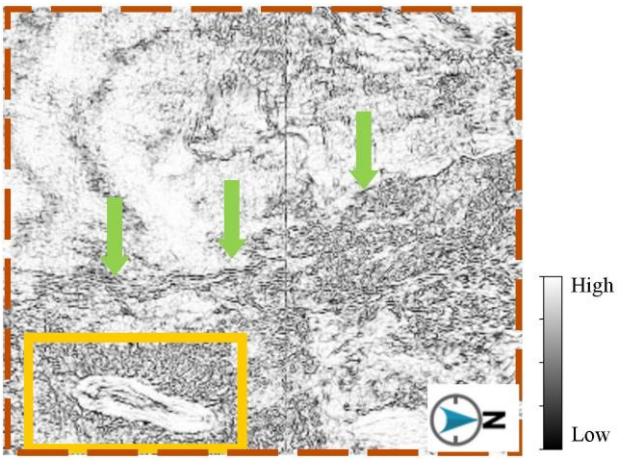

Fig. 3: Data after coherence attribute application. Higher values are shown by lighter colour for comparison purposes. More details have been extracted in addition to the fault trend (green arrows) which can specify how fractured the slice is. For the anticlinal build-up, the boundary is detected; though, it is seen how coherent the inside part is compared to the outside of the structure (yellow box).



Fig. 4: Semblance attribute applied to the migrated seismic data. Higher values are shown by lighter color for comparison purposes. Both the fault trend (green arrows) and the anticlinal structure boundaries (yellow box) are clearer compared to the results of the discontinuity and coherence attributes.

Semblance is the one of the attribute applied to the data (Figure 4). This attribute has the same nature as the coherency, but the meth-

od of calculation is different. In fact, the three attributes are applied to differentiate the similar and dissimilar features in seismic data; those are commonly used interchangeably and called discontinuity attributes in general. Comparing the results with Figure 2 and 3 with Figure 4 demonstrate that the resolution is higher while details are preserved. Both fault and anticline are well preserved by this discontinuity attribute.

Figure 5 shows the application of dip-magnitude attribute that identify the calculation of geological events and the differentiation is done based on the inclination of the structure. The fault is reasonably spotted in this figure with higher dip values. This indicates that the layers on the sides of the fault plane have moved vertically, creating a dipping fault surface. The anticlinal structure is also presented very well as its limbs have high values while near the hinge the color shows lower values.

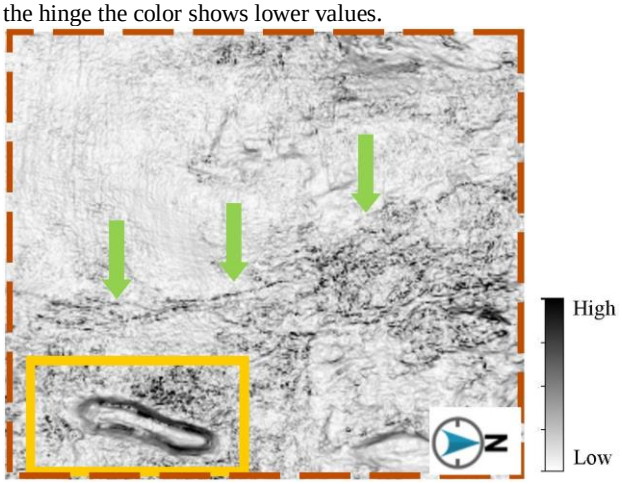

Fig. 5: Application of Dip-magnitude attribute on seismic data. Higher dip values are shown by darker values as the faults tend to usually have steep planes. The fault plane (green arrows) is indicated with higher dip compared to its surroundings. The boundary of the anticlinal structure (yellow box) has also higher dip values as the data is a time slice.

Dip and azimuth attribute usually accompany each other because the azimuth shows the direction of dip at each location (Figure 6). Although the fault plane is not distinguished by this attribute, there are lots of east to west features with a good resolution not well visible by other attributes used till here. It may be because the fault plane is not a straight line so it is not seen as a continuous plane, while those features no matter how small have the same direction. In contrast, the anticline in the section is seen with a high resolution and its hinge is picked easily. The difference between the two limbs is nearly 180 degrees as expected.

The last attribute evaluated in this study is the curvature. Two mostly well-known curvature attributes for discontinuity study are selected: most-positive curvature and most-negative curvature which are shown in Figure 7a and b respectively. As mentioned previously, the upthrown side of the fault has the positive curvature; hence, shown in most positive curvature. On the other hand, the downthrown side is expected to be seen on the most negative data. This result in some relocation of the fault plane when comparing the results of the two curvature attributes as seen in the co-blended attribute (Figure 7c). This phenomenon provides additional information about the layer movement on the sides of the fault plane. In the case of the anticline, the interesting point is the higher resolution of the most-positive curvature attribute compared to the most-negative one. This is obviously a consequence of positive curvature in anticlines. The boundary, of course, is better indicated on the most-negative curvature attribute.

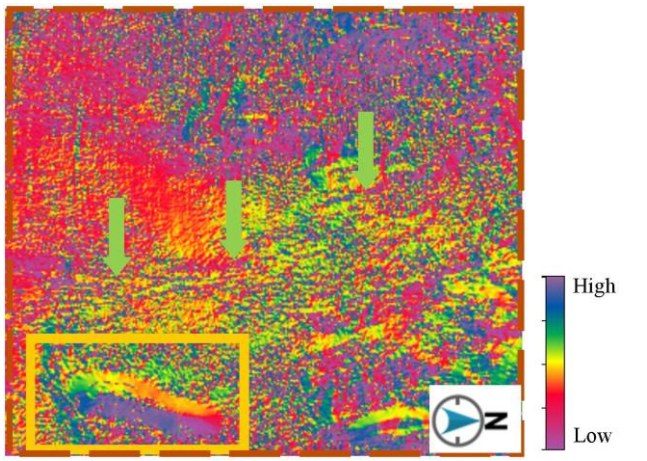

Fig. 6: Azimuth attribute results of the migrated seismic data. As the fault does not have a straight plane, the azimuth is changing along its plane. As a result, the trend cannot be detected by this attribute. For the anticline on the other, azimuth is clearly identifying the whole structure and showing details like the hinge line (yellow box).

Performance of different attributes in this study is summarized in Figure 8. The results show that all attributes used for this case can identify the fault (except the azimuth) with different resolution and details. The anticlinal structure on the other hand is singled out by all attributes and the azimuth can additionally mark the hinge of the structure. Therefore, it was decided to use all the studied attributes for the area of interest and combine the extracted the geological anomalies together.

4. Conclusion

Despite the strength of the seismic attributes in identification of the geological events, they are limited by the fact that each one uses predefined properties of the seismic data derived from its amplitude, phase, and frequency content. Each of such properties is affected by certain geological features, hence can distinguish different values corresponding to such features. Application of various seismic attributes in this paper showed the superior results that any attribute can have compared to others depending on the objective of the study in each case. Simultaneous evaluation of multiple seismic attributes can reveal more details hidden in seismic data benefiting the integration of the information of various categories contained in data to provide a more comprehensive output. As it was seen here, fault trend could be identified by all the applied attributes but the azimuth. In addition, the type of fault can be deducted with knowing the upthrown and downthrown sides of its plane provided by most-positive and most-negative curvatures. For the anticlinal carbonate build-up on the other hand, all attributes provide the information on the boundary of the structure while azimuth can in addition identify the hinge.

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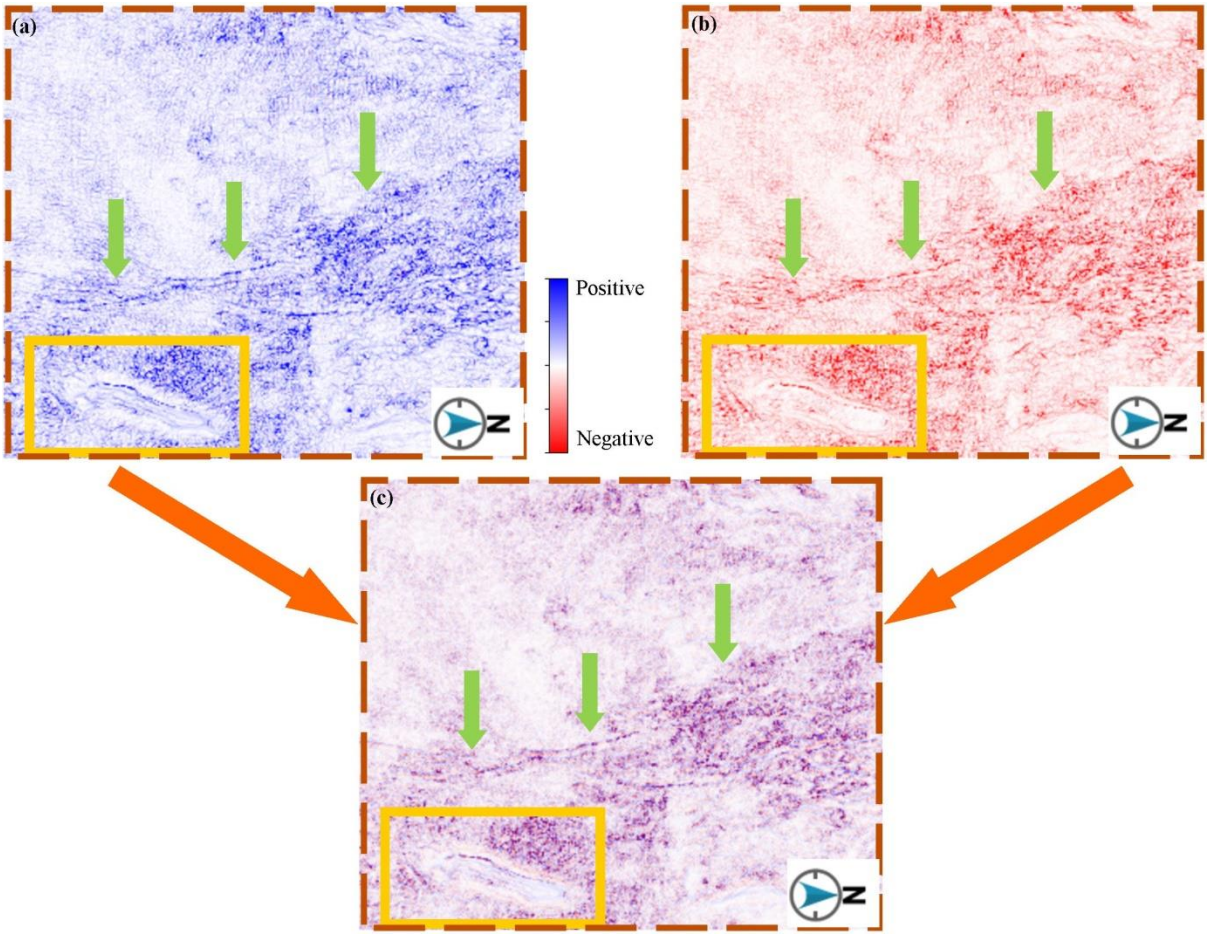

Fig. 7: (a) Most positive, (b) most negative, and (c) co-blended curvature attributes. The fault trend (green arrows) is detected by both methods, though there is a slight difference in the positions. This is the result of having different curvatures at the sides of the fault plane. For the anticlinal structure (yellow box), it is seen that inside the structure the curvature is mostly positive which is consistent with the shape of the anticline.

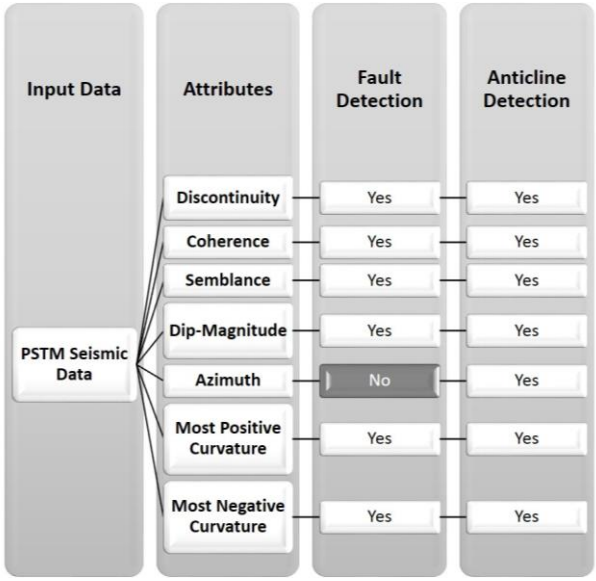

Fig. 8: Summary of the results of the study. Different attributes reveal different information based on what properties are used in their calculations. As in this paper, all attributes could identify the fault trend except azimuth; while azimuth provides more information about the anticlinal structure.

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