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Study on the Delineation of Potential Reservoir in Fractured Basement

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ABSTRACT

Unconventional oil and gas plays are one of Petronas' recent oil and gas exploration priorities. Unconventional reservoirs are those that require specialized production in addition to conventional operations. Therefore, fractured basement reservoir is considered to be one of the unconventional reservoirs with high exploration potential. Seismic identification of basement fractures is a challenge in current research. In the exploration of fractured basement reservoir, the delineation of fault and fracture network is very important. The key factor in the characterization of fractured basement reservoirs is the ability to obtain fractures from seismic data. The purpose of this study is to determine the optimal properties of the base fracture system. In this paper, the response of near and far prestack 3D seismic cube attribute extraction to X-base fracture reinforcement is compared. On the basis of the comparative analysis, the three-dimensional maximum curvature method, the variance edge method, the T * attenuation method and the equal frequency method can help the interpreter identify the possible high fracture areas. The interpretation of any one seismic cube as the best choice for the delineation of fractures is uncertain. However, the results show that in most cases, the application of attributes can be used to delineate the cracks close to superposition. Therefore, the identification of fracture zones can contribute to new exploration projects.

KEYWORDS

Fractured basement; Seismic attributes; 3D Pre-stacks; Reservoir characterization

1. Introduction

In reflection seismology, seismic attribute can be defined as quantify extract or derived data from seismic that can be further analyzed to enhance structures that might be subtle in a traditional seismic image, leading to a better geophysical and geological interpretation of the data (Satinder Chopra, 2007). Seismic attributes is

applied on the surface map of the basement top to boost and elevates the visibility of highly fractured region. Seismic attribute analysis begins by choosing suitable attributes to achieve the objective.

Generally, specific attributes are prescribed for specific objectives. The list of attributes to delineate faults or fractures is:

- 3D Curvature
- Iso-Frequency
- Variance (Edge Method)
- Amplitude contrast
- Dip Guided Variance
- Filter
- Dip deviation
- Dip illumination
- Ant tracking
- Edge Evidence
- 3D Edge Enhancement
- T* attenuation
- Instantaneous frequency
- Instantaneous quality

However not all the listed attributes were used in this research due to unavailability of some license in and not all of those responded positively in term of delineating fracture at least in this case study.

Analysis of pre-stack data as an enhancement in seismic interpretation is now common. This is as the traditional post stack sets are not capable of delineating some features that pre stack might do. This may due to factors like processing, signal to noise degradation, and the result of seismic processing. The idea of the research is the comparison of pre-stack attribute volumes in response to attribute extraction in term of delineating fractures. Analysis of near and far stacks was carried out to highlight its difference in fractures appearance in volumetric attribute cubes extracted over the interpreted basement top of identical depth in both pre-stack cubes. Meanwhile, mid stack data is not available for analysis and analyzing it could be more interesting.

2. Methodology Attribute Influence towards Fractures

Figure 1 summarizes the methodology used in possible reservoir identification, highly fractures distribution of the study area. Figure 2 is showing fractures characterization obtained using seismic volume attribute that is extracted over interpreted basement top from 3D full stacked seismic, with 4 cases study of different

attributes at Z time slice of -2300ms. These four case-studies consist of 3D maximum curvature, variance edge method, t*attenuation and iso- frequency of 25 hz. Each of them has been compared in terms of fracture zone identification.

Similarly, in respond to second objective of the research, fractures identification in 3D pre stacked seismic were obtained also using seismic volume attribute extracted over interpreted basement top in near and far stacked 3D seismic cube with 4 cases study of different attributes. Based on this comparison, the fracture distribution is briefly understood and it help interpreter to identify if the identified fractures are of true fractures. Besides, it also shows the major elevation of the basement top that might influence the reservoir potential from the fracture distribution. Petrel 2018 software was used to apply available attributes to aid on identifying the fractures. The horizon tracking for top of basement completed using manual picking. 3D volume attribute was generated before applying the seismic attributes on the interpreted basement.

3. Results and Discussion

The variance edge method emphasizes on the unpredictability which is their edges and interruptions. It represents trace to trace variability over a particular sampling interval which later produces interpretable lateral changes in acoustic impedance. Thus, similar trace will produce low variance coefficients, while discontinuities have high coefficients. Since faults and fractures are discontinuous and subsequently they become detectable in the trace to trace variability. Thus a fault zone can be indicated by an area having low coherence and high variance values. Fracture trends best delineated through this attribute. The dominant fracture patterns are in NW-SE directions. On the other hand, figure 2a variance highlight structural highs as high variance which is not fault or fractures. So, not all high variance is fault or fractures.

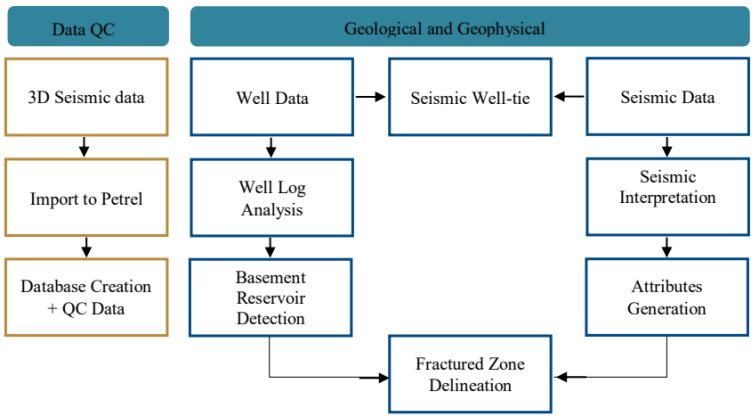

Figure 1. The summarized methodology of the study

Curvature was defined by Roberts (2001) as three-dimensional property of a quadratic surface that quantifies the degree to which the surface deviates from being planar. He also mentioned that it is a second-derivative based method and is sensitive to any noise contamination which may be present in the surface. There are many types of curvature, namely minimum, maximum, most positive and most negative. 3D Maximum Curvature attribute works best in delineating fractures of the X-basement as observed figure 3b. Fracture trends are not clearly visible from this analysis; however, some dominant fracture patterns can be observed in NW area of the attribute map. It could not be the artifacts effect as the attributes extracted along the horizon from the curvature attribute volumes and not from a surface attribute.

The product of t* attenuation attribute volume that includes attribute values called "t*"; therefore, it can be said that larger t* values result from greater attenuation of higher frequencies and the shift of the spectra towards lower frequencies . It is also steered by Najmuddin (2003) that higher t* values indicate higher fracture

intensity or even larger thickness of the fractured layering. The seismic data of Xbasement are quite noisy; therefore, it can be expected that the frequency content of the traces contain noises. In relation to that, some attenuation of frequencies might not be related to true fracturing event. As observed in figure 2c, fractures zone from this attribute do not match the other attribute in term of the fracture densities, there may be some attenuation of frequencies due to layering, interference, multiples in addition to noise related attenuation. Therefore, t* values may contain some uncertainty as a result from the indicated factors.

The Iso-frequency component is a normalized measure of contribution of that specific frequency to the total seismic input at a specific location. Prior to iso-frequency, dominant frequency attributes were generated. The dominant frequency of 25 Hz was used to generate iso frequency volume attribute. The idea is to lease out anomalies to the dominant frequency which could be in this case as fractures. As it can be observed in figure 2d, the areal fracture distribution of this attribute matches to other attributes.

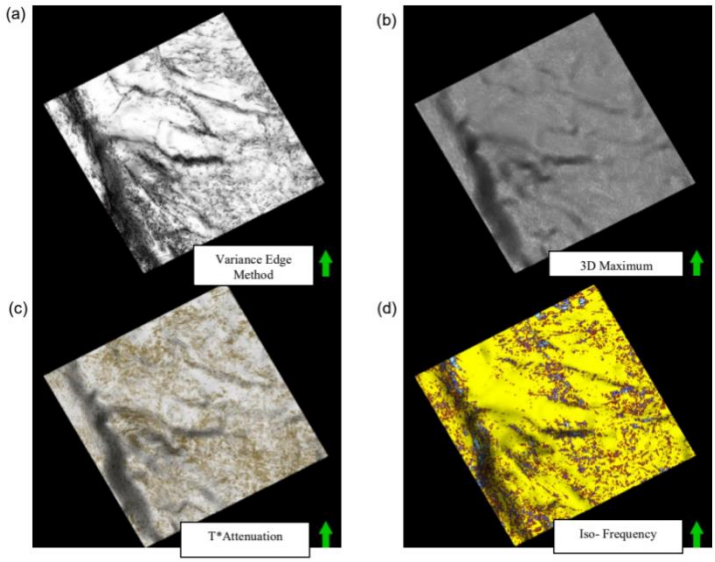

Figure 2. Attribute extraction over the interpreted basement top at Z=-2300ms of four different cases study

On the other hand, comparison between application of seismic attribute in pre and post stack fractures distribution result show significant difference between the number and distribution of identified fault (Figure 3-5). The pre-stack results show distribution of fractures in the potentially reservoir area which have not been identified in post stack analysis in figure 2. This implies the pre stack able to better delineate data missed by the post stack.

Figure 3 comparing 3D Curvature on near and far stack of 3D maximum curvature cube respectively. It can be interpreted that near angle do not appear to show any significant fractures or geological meaning compared to far stack expect for structural features of the basement. On the other hand, similar attribute extraction on far stacked highlight fractures swarm. Comparatively, they show significant difference where in this case, far stack are better in de-mask the fractures.

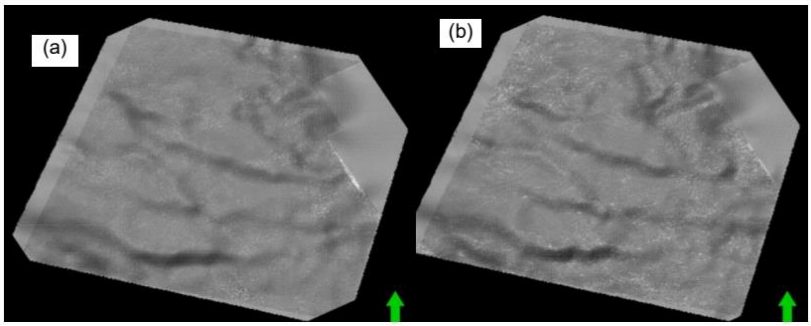

Figure3. 3D maximum curvature extracted over basement top of (a) near and (b) far stacked seismic

In contrast to 3D maximum curvature, extraction of variance edge method attribute in near stacked seismic in figure 4 delineate massive fracture compared to far stack. However, contamination of noises could happen to mask true fractures in the near stack. Despite that, far stacked seismic cube is interpreted to distinguish 'clearer' fractures zone but it could have missed the true fracture of the area. Removing noises in the near stack prior to attribute extraction could improve the interpretation and thus could result in a stronger conclusion comparatively.

Higher t* values indicate higher fracture intensity. In that sense, far stack in figure 5 appear to trace the fractures better. However, that could come with noises etc. masking the true fractures in far stack. Besides, near stacked seismic delineate more confined fracture zones which could be the case where true fracture highlighted dominantly.

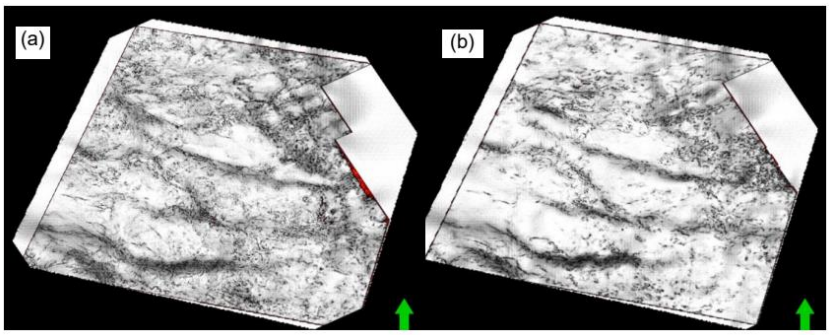

Figure. 4 Variance edge method extracted over basement top of (a) near and (b) far stacked seismic respectively

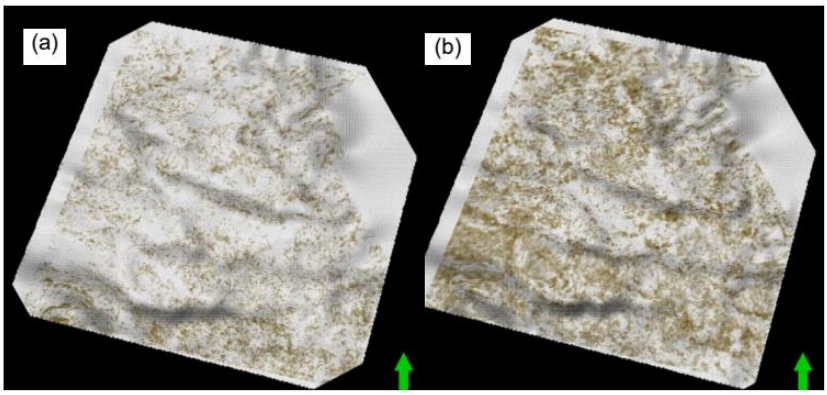

Figure. 5 T*attenuation extracted over basement top of (a) near and (b) far stacked seismic respectively

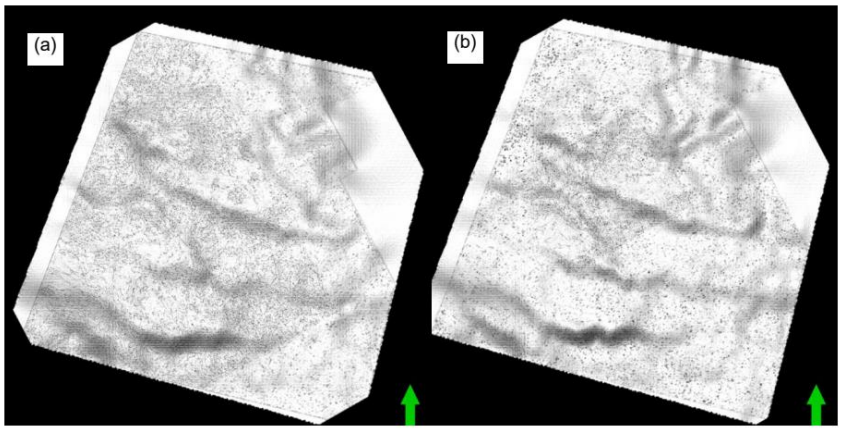

Figure 6. Dip deviation extracted over basement top of (a) near and (b) far stacked seismic respectively

4. Cpnclusions

Unconventional reservoir is one of the focus of PETRONAS in terms of hydrocarbon exploration in the near future. Unconventional reservoirs are mainly a reservoir requiring special operations for recovery outside of conventional operations. Accordingly, fractured basement reservoir is considered as one of the unconventional reservoirs that is highly potential for exploration. Offshore Vietnam-Malaysia, the PreTertiary fractured basement forms an important hydrocarbon accumulation, and is being produced from such reservoirs in Bach Ho field in Chuu Long basin, Vietnam (Nguyen, 2014).

In relation to that, the key factor in characterizing fractured basement reservoir is the ability of capturing those fractures in seismic data. This project marked the step of utilizing the multi-attribute for both academic research and industry application. Via multi- seismic attributes analysis, fractures can be delineated, and the detection could aid the geoscientist and engineers in unconventional hydrocarbon exploration and production phases. Seismic attributes are applied from the currently available attributes, with delineating highly fractured zone as the main goal. In a nutshell, 3D maximum curvature, variance, t* attenuation and iso-frequency are determined as best seismic attributes of all as tools of visualizing and interpreting basement fractures for this case study. As an outcome of this study as well, attribute behavior on near and far stack 3D seismic cube show significant difference. From interpretation, it is inconclusive to nominate either seismic cube as best choice in fracture delineation. But from the research, in most cases near stack delineate fractures better through attribute application tough masked with noises. With that, determined fracture zones can contribute for the new exploration venture.

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