Enhanced Structural Interpretation Using Multitrace Seismic Attribute For Oligo-Miocene Target at Madura Strait Offshore

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Abstract. Geometry is an important parameter for the field of hydrocarbon exploration and exploitation, it has significant effect to the amount of resources or reserves, rock spreading, and risk analysis. The existence of geological structure or fault becomes one factor affecting geometry. This study is conducted as an effort to enhance seismic image quality in faults dominated area namely offshore Madura Strait. For the past 10 years, Oligo-Miocene carbonate rock has been slightly explored on Madura Strait area, the main reason because migration and trap geometry still became risks to be concern. This study tries to determine the boundary of each fault zone as subsurface image generated by converting seismic data into variance attribute. Variance attribute is a multitrace seismic attribute as the derivative result from amplitude seismic data. The result of this study shows variance section of Madura Strait area having zero (0) value for seismic continuity and one (1) value for discontinuity of seismic data. Variance section shows the boundary of RMKS fault zone with Kendeng zone distinctly. Geological structure and subsurface geometry for Oligo-Miocene carbonate rock could be identified perfectly using this method. Generally structure interpretation to identify the boundary of fault zones could be good determined by variance attribute.

1. Introduction

Exploration for Oligo-Miocene target at Madura Strait still reminds to be less activity than the others part of East Java Basin. Some petroleum system issues become obstacle, including trap geometry and vertical migration in case Ngimbang Clastic as source rock. Study area is located at Kendeng Depression which lies between RMKS Fault Zone in the north and Kendeng Thrust in the south. Fault existences become critical to answer some issue regarding hydrocarbon exploration in Madura Strait.
3D seismic as result from seismic reflection was conducted and become useful tool for evaluation process. As known before, seismic reflection has the best accuracy, resolution also the deepest penetration than the other methods.

Furthermore 3D seismic data provides information about multitrace attributes. One of the multitrace attribute used frequently is variance attribute, it can represent geological phenomenon. Variance attribute determines fault clearly and identified its trend both in large or small scale at faults dominated area.

Applying variance attribute on 3D seismic data becomes an excellent step to interpret a horizon that shows continuity or discontinuity of seismic data clearly. Mathematically variance attribute provides 1 or 0 value for the continuity of seismic data. This will enhance interpretation process, so some issues such as geometry, rocks spreading also property and resources quantification will have risks analysis in detail quantification.

2. Location and geology of study area

The study area is within the East Java Basins in offshore Madura Strait (Figure 1). In structural geology terminology, study area is located between strike slip RMKS fault zone fold zone and Kendeng thrust. Kendeng thrust is west-east trend fold thrust belt formed by compression tectonic deformation generating some anticlinorium (Van Bemmelen, 1949). The thrust fault is a shallow tectonic structure involving the basement (Figure 2; Prasetyadi, 2007). This structure zone shows compression effect as a result of Indo-Australian plate subduction beneath the Eurasian Plate.

RMKS fault zone has 15 km to 40 km wide and at least 675 km long from west to east start from Rembang area as west manifest to Kangean and Sakala Islands at eastern Madura Island. At the north part of study area, RMKS fault zone existed and divided into three parts which are west region, center region, and east region (Satyana et al., 2004). Mulhadiono (1984) identified 45 faults and 9 anticlines based on field study at Madura Island as evidence of RMKS uplifting.

The primary source rocks for oil and gas in Madura Strait area are the lacustrine shale of the Ngimbang Formation. The Ngimbang Formation is presently interpreted to be gas-mature within the main Paleogene depocentre along the northern part of the area, although it would have been oil generative during the Miocene to Early Pliocene. The charging is interpreted through the primary migration and secondary migration along fault. The primary reservoir in the study area is Oligo-Miocene carbonate or Kujung I Formation (Figure 3, Modified from Mudjiono and Pireno, 2002). Oligo-Miocene carbonate is reefal buildups that have a thick carbonate section in local high and thinner section in the lower area. As the main traps and seals, not only Major fault of RMKS has contributed to hold hydrocarbon in reservoir, but also minor faults in this structural complex area. In addition, Mudjiono and Pireno 2002 claim that shale in the Tuban Formation provides a regionally extensive seal for Oligo-Miocene reservoir rock to trap the hydrocarbon.

Kujung play has limited data causes of less exploration activity with Kujung Carbonates as reservoir target, but several author believe that local high still possible to be a place for developing carbonate reef. Internal sequence boundary in Kujung generate porosity and permeability to preserves an amount of hydrocarbon.
Figure 1. The location of study area

Figure 2. The geology structure of study area (Prasetyadi, 2007)
3. Methodology

Brown (1990) in Sukmono (2000) defines attribute as the result of derivative from seismic data. All available horizons attribute and formation are not stand-alone attribute, fundamental differentiations found on data analysis from seismic data information and its display result. Time, amplitude, frequency and attenuation are the basic information from seismic data, and that information very suitable for attributes basic classification.

In Azevedo (2009), Volume attributes are computed from processed cubes or from previously computed attribute volumes which are extracted, depending on the mathematical algorithm, trace by trace or considering a group of traces (multitraces). The extraction is performed over a user-defined fixed window, where two horizontal time slice are defined as upper and lower boundaries. Multitrace seismic attributes are also computed inside a fixed vertical window with user-defined limits. In this case, besides the vertical range, the user has to define a bound in the number of traces that will be used to the attribute extraction, according to a mathematical algorithm. The output volume is the result of stacking all the time slices were the attribute computation was kept from each window position in space and time.

4. Results and discussion

Variance attribute seismic was applied to the 3D seismic data at about 1ms to 6000ms. With this range of data, the result expected to enhance seismic image by showing geological phenomenon in particularly fault from the reservoir target (Oligo-Miocene carbonate rock) in the study area. The study area is generally characterized by growth faults and its lies in the boundary of two faults zone. It is hard to identify the boundary from normal seismic data and variance attribute expected to determine

Figure 3. The stratigraphy of study area (modified from Mudjiono and Pireno, 2002)
this boundary. After the boundary already well defined, then we could easily determine Oligo-Miocene carbonate rock geometry.

4.1. Well correlation (Lithostratigraphy)

This study used one cube 3D seismic (1.42 x 10^4 km^2) and three (3) exploration wells (Figure 4). Those data have been correlated in lithostratigraphy to identify each rock formation (well correlation result is shown by Figure 5). The Oligo-Miocene carbonate target rock named by Kujung Lst marked by blue color.

Two wells AA-1 and NN-1 is located at a local high that since early Paleogene already exists. Carbonate reefs grow and clearly identified in both those wells. Grainstone and packestone was the main carbonate lithofacies that found from those two wells. Meanwhile CC-1, lower by position than the two other wells, is dominated by wackestone and mudstone facies and interpreted as talus from main reef body.

Figure 4. Base map of study area.
4.2. Seismic Interpretation

Well to seismic tie was done using the checkshot data from each well. Interpretation has been done for five horizons which interpreted as Basement, Ngimbang (Eo-Oligocene), Kujung Limestone (Oligo-Miocene), Tuban and Wonocolo (Miocene). Figure 6 represents arbitrary line with east west trend through all key wells. Horizons and structures interpretation was conducted to the seismic amplitude having similarity data and it’s also corresponding with well data. Kujung Limestone is shown by high structure or build-up reef penetrated by AA-1 and NN-1 wells. It is distinctly recognized that AA-1 and NN-1 are the build-up body compare to structure which penetrated by CC-1.

![Figure 5. Lithostratigraphy correlation.](image1)

![Figure 6. Horizon interpretation tied to well data](image2)
4.3. Variance Attribute Analysis and Fault Interpretation

Variance attribute was applied to the seismic data to get better geological image and help interpretation process as the main goals. Comparison between seismic section and variance attribute is shown by Figure 7, as north-south trending section passing through AA-1 well that shows corresponding value between continuity-discontinuity with variance value within range 0 (white) to 1 (yellow). Faults are clearly identified by variance section which have red-yellow color. High value of variance indicates intensive fault zone which well known as RMKS and Kendeng fault zone.

![Figure 7](image)

**Figure 7.** The comparison of seismic section and variance attribute

Figure 8 shows the existences structural setting in study area. RMKS fault zone and Paleogene structures forming XX-Ridge with the location of AA-1 and NN-1. RMKS effect could be seen in the north-east part of the seismic section as a basement involved thrust fault. RMKS fault effect is slightly located above Kujung Limestone, it caused Tuban and Wonocolo thicker than surrounding, it also caused Base of Tuban Shale as decollement. Flower structure became the distinguish boundary of uplifted zone and Kendeng zone in southern part including XX-Ridge.

![Figure 8](image)

**Figure 8.** The comparison of seismic section and variance attribute

Figure 9 shows boundary between RMKS fault zone and Kendeng zone as flower structure figure. This figure shows the comparison of seismic data at time 3500 ms and variance attribute at the same time. RMKS fault zone is characterized by high value of variance (red color) represent intensive fault in those areas. Meanwhile Kendeng zone is characterized by low value of variance (grey-white color) without any significant fault shown.

![Figure 9](image)

**Figure 9.** The comparison of seismic section and variance attribute

The flower structure of RMKS fault passed through Kujung Limestone and spouted in Tuban Formation. Recently Kendeng zone in lower position than RMKS fault zone, although in the beginning of RMKS, Kendeng zone was interpreted in the same or maybe higher position than RMKS fault zone. This situation is shown by Figure 10. This figure shows the comparison of time structure map between Tuban and Kujung Limestone. Flower structure distinctly appears spouting in Tuban time structure map, it became a border between high and low area. However, in Kujung Limestone time structure map this structure passed through one area of Kujung limestone which is inverted area of southern part of RMKS fault zone.

![Figure 10](image)

**Figure 10.** The comparison of seismic section and variance attribute
Figure 8. Fault interpretation

Figure 9. Time slicing at 3500 ms for (a) seismic data and (b) variance attribute, (c) flower structure interpretation to define the boundary of RMKS fault zone and Kendeng zone.
Figure 10. The comparison of the existence of RMKS flower structure in time structure map between (a) Tuban and (b) Kujung Limestone

Finally, as the result of structural as well as horizontal interpretation, play concept of hydrocarbon in Oligo-Miocene carbonate can be seen at Figure 11. It is clear that the hydrocarbon source rock in the study area is the shale of Ngimbang Formation, whereas hydrocarbon migrates through RMKS fault and minor fault that formed XX-ridge. Additionally, the main Cap Rock is Tuban Formation that is located on the above of XX-ridge build-up. Moreover, Figure 5 shows that Top Kujung Formation on XX-ridge is reefal build-up, it is totally different with Top Kujung Formation from CC-1 well. This is because CC-1 well is located at RMKS uplift that is formed at the low area before it is uplifted by RMKS fault. It can be seen at Figure 5 that the character of Top Kujung Formation in CC-1 well is siliciclastic dominated. Hence, It is clear that XX-ridge is the ideal place for accumulating hydrocarbon in the study area.
5. Conclusion

Interpretation of the 3D seismic data has been exercised to be more efficient by using variance attribute seismic in particularly fault interpretation. Variance attribute map has proved to be an appropriate tool to determine structural framework. Variance attribute can clearly identify the boundary of two fault zone in this case RMKS and Kendeng fault zone. With references Ngimbang formation as the main source rock in Madura Strait area, then the faults in this case RMKS fault zone become significant media for vertical migration into the Kujung carbonate reservoir. In other perspective, trap geometry cuts by faults can be well identified with this method. Therefore, application of variance attribute become very suitable tools for oil and gas exploration in faults dominated area such as study area.

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