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Sandstone Reservoir Mapping in the "M" Field of the Northwest Java Basin, Based on Seismic Attributes

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Abstract

Hydrocarbon has been discovered and produced in the “M” Field, located in the Cipunegara Sub-basin, Northwest Java Back Arc Basin, from deeper levels of the Baturaja and Talang Akar Formations since early of 2000s. Oil and gas has also been produced in the shallower level of the Upper Cibulakan Formation in this Northwest Java Basin, but in the other sub-basin, not in the “M” Field in the Cipunegara Sub-basin.

Prior to find hydrocarbon in the Upper Cibulakan Formation of this field, the existing of its reservoir should be evaluated. Based on a limited data of 3 wells and a 3D seismic, several seismic attributes mapping has been used to define the reservoir of sandstone.

RMS amplitude, average amplitude, maximum amplitude, energy half-time, and arc length, have been applied in defining the sandstone reservoir. This sandstone reservoir could be considered further in studying the petroleum system in the area.

Keywords: sandstone reservoir, Upper Cibulakan Formation, seismic attribute.

Introduction

Geologically, research area is located in Cipunegara Sub-basin of Northwest Java Basin, as could be seen in Figure 1. Administratively, the study area is under the authority of West Java Province.

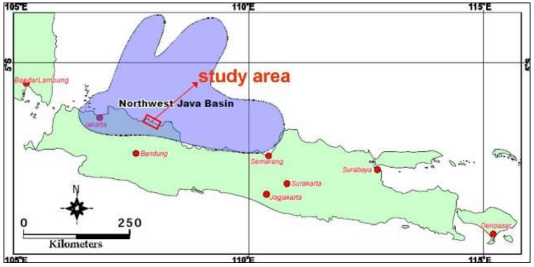

Figure 1: Location map of the research area

Hydrocarbon has been discovered and produced in the “M” Field, located in the northern edge of the Cipunegara Sub-basin, Northwest Java Back Arc Basin, from shallower levels of the Baturaja and Talang Akar Formations, since early of 2000s. These levels had been studied intensively with various attributes (Sukmono et al., 2006).

Oil and gas has also been produced in the shallower level of the Upper Cibulakan Formation in this Northwest Java Basin, but in the other sub-basin, not in the “M” Field in the Cipunegara Sub-basin (see Figure 2).

In the closest area from the studied area, southern edge of the Arjuna Subbasin, Offshore Northwest Java Basin, the Upper Cibulakan Formation is known as Main and Massive Intervals with multiple stacked sandstone reservoirs and hydrocarbon inside them (Purantoro et al., 1994; Butterworth et al., 1995; Posamentier et al., 1998).

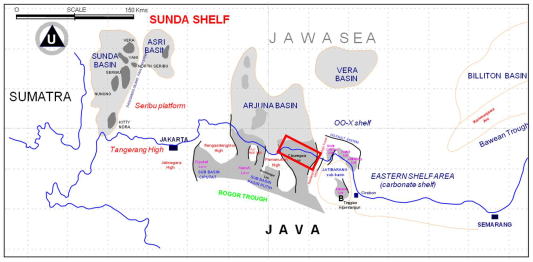

Figure 2: Regional geology of Northwest Java Basin (red square is the research area)

Thus, the objective of this research was to explore the existing of sandstone reservoirs of the Upper Cibulakan Formation in the study area.

Data and Method

Available main data that used in this research are 3 drilled wells and a volume of 3D seismic, as shown in Figure 3.

MSY-1 well was drilled in 2000 and penetrated the Jatibarang Formation or Pre-TAF in its total depth of 2951 mMD. MSY-2 well was drilled in 2003 and penetrated the basement in its total depth of 3107 mMD. MSY-3 is the oldest well that was drilled in 1993 and penetrated the basement in its total depth of 2125 mMD.

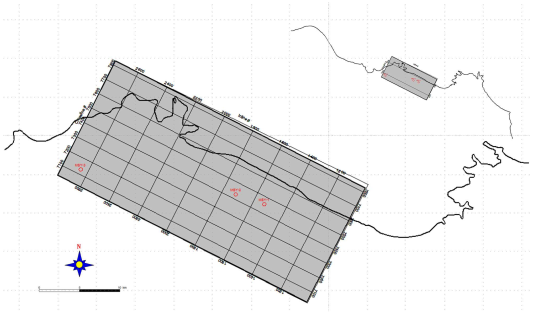

Figure 3: Map of data set

Data of 3D seismic was acquired in 2004-2005 and is down to 2500 ms, consisting of 738 in-lines (in-line 2021 to in-line 2758) and 798 cross-lines (x-line 7032 to x-line 7829).

The methodology of this study is displayed in the flow chart of Figure 4, which is started with the evaluation of both wells and seismic data.

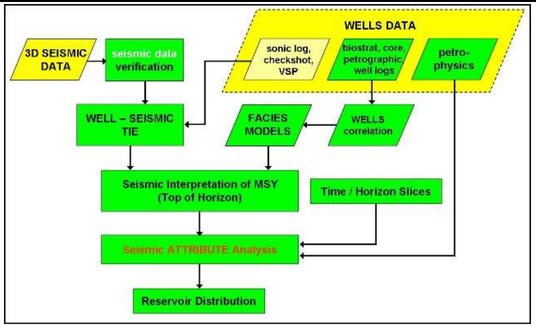

Figure 4: Working flow

All available well data has been analyzed, e.g. biostratigraphy, core data, petrography, and wireline logs. Petrophysical analysis of the MSY sandstone has also been run, while sonic logs and checkshots have been used in integrating wells into 3D seismic volume. In this research, geological evaluation and its result have been used to support and are integrated to the geophysical matter.

Controlled by wells, the seismic interpretation of MSY horizon was done (Figure 5), by picking its horizon top. Due to difficulty in picking top of MSY horizon, easier horizons in the shallower and deeper levels were picked and interpreted earlier, i.e. top of Parigi Formation, top of Upper Cibulakan Formation, and top of Baturaja Formation. MSY horizon is layered between top of Upper Cibulakan dan top of Baturaja Formations.

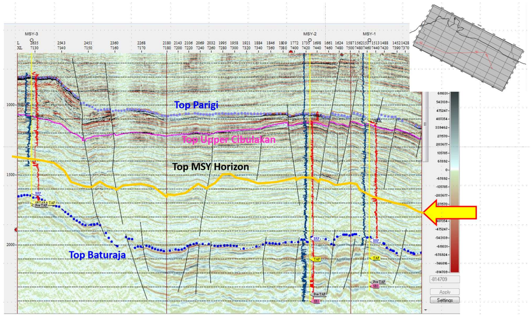

Figure 5: Seismic section

Once the MSY horizon picking was completed, analyses of seismic attributes were applied. The final result is the lateral distribution of the sandstone reservoir. All analyses were performed using 2 main softwares, i.e. GeoGraphix for seismic horizon picking and Petrel for wells correlation and seismic attributes.

Brown (2004) says that seismic amplitude-derived attributes provide stratigraphic and reservoir information, while although frequency-derived attributes are not yet well understood, but there is widespread optimism that they will provide additional useful stratigraphic and reservoir information.

One of the frequency-derived attributes is spectral decomposition. This seismic attribute could be well used in recognizing the lateral distribution of a relatively thin bed reservoir and its fluid. Instead of spectral decomposition, amplitude-derived attributes are used in this study due to the uncertainty of the picked-MSY horizon. Various types of 'window' have been applied in running five amplitude-derived attributes.

RMS (root mean square) amplitude is the square root of sum of the squared amplitudes, divided by the number of live samples as shown in the following formula (Equation 1), where k is the number of live samples.

$$\sqrt{\frac{(\sum_i^n amp^2)}{k}}$$

Equation 1: RMS amplitude

RMS amplitude can map directly to hydrocarbon indications in the data and other geological features which are isolated from background features by amplitude response.

The second amplitude-derived attribute is the average energy, which is the squared RMS amplitude. This attribute is a measure of reflectivity within a time or depth window and can be used to map direct hydrocarbon indicators in a zone.

Average energy is computed using the following formula (Equation 2).

$$(\sum_i^n amp^2)/k$$

Equation 2: Average energy

The third one, maximum amplitude, measures reflectivity within a time or depth window. It returns the maximum positive number in the defined or selected window. It is used to detect positive direct hydrocarbon indicators such as bright spots.

The fourth amplitude-derived attributes is energy half-time, which computes the time or depth required for the energy within a window to reach one-half of the total energy within the entire window. Energy half-time may indicate asymmetric changes in lithology or porosity within a specific zone.

Hybrid attributes are an intriguing combination of amplitude and frequency information (Brown, 2004). One of hybrid attributes which is used in this research is arc length. Arch length is a stratigraphic sequence indicator. It measures reflection heterogeneity, and can be used to quantify lateral changes in reflection patterns. It is calculated using the following formula (Equation 3), where Z is in milliseconds in time domain, or in feet or meters in depth domain.

$$\frac{\sum_{j=i}^{n-1}\sqrt{(amp(j)-amp(j+1))^2+(Z)^2}}{(n-i)\_x\_sample\_rate}$$

Equation 3: Arc length

Interpretation of seismic has been done using 2 different applications, i.e. *GeoGraphic* of Halliburton and *Petrel* of Schlumberger. *GeoGraphix* was used in doing the early steps of subsurface mapping, i.e. horizons picking, including faults defining. Lately, *Petrel* was used to play the various types of amplitude-derived attributes.

Result and Discussion

Based on data of wells, a standard geological evaluation has been done, i.e., sedimentological analysis and biostratigraphical analysis. Only result of these geological analyses is displayed in this paper, not their detail.

Biostratigraphical analysis of 3 wells, MSY-1, MSY-2, and MSY-3, has summarized that the Upper Cibulakan Formation was deposited in the neritic (inner to outer) during Middle Miocene time. Wireline logs interpretation has indicated an intercalation of sandstones and shales, with minor limestones and claystones.

As a result of seismic interpretation, a time structural map of Top MSY horizon has been generated, as shown in Figure 6.

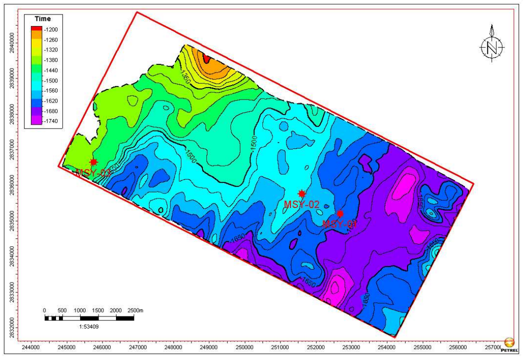

Figure 6: Time structural map of Top MSY horizon

A velocity map is used to convert the time structural map into a depth structural map as shown in Figure 7.

An original velocity map which was taken from the reprocessing seismic volume was used in the beginning; not controlled by wells yet. A "cokriging" facility in the software then was applied in considering depths of wells as the control of the true depths in 3 points. The entire points outside of the wells have been relatively interpolated to the 3 control points.

In the "M" Field, the MSY Horizon is ranging from 1100 m through 1900 m depth. Generally, the horizon is going down from NW to SE. Few closures are recognized in the SE area, e.g. an elongate shape closure in the MSY-2 well, a small closure about 2 km south of the MSY-2 well, and a closure in NE corner of the area.

There are 2 features that possibly could be closures, i.e. the shallower closure in the NW of the area and the deeper one in the SE of the area. Unfortunately, both "closures" have unknown contours that could also be opened to outside of the area.

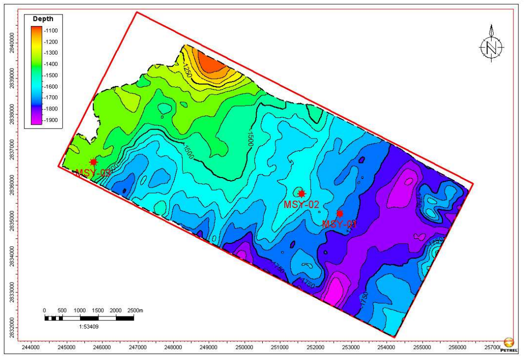

Figure 7: Depth structural map of Top MSY horizon

Five attributes have been selected in trying to define a lateral distribution of sandstone reservoir of the MSY horizon. Four amplitude-derived attributes were run, i.e. RMS amplitude, average energy (window – gross), maximum amplitude (window – selection), and energy half-time (window – distribution). One hybrid attributes (amplitude-frequencyderived) was run, i.e. arc length (window – window).

Several widths of windows of each attribute had been applied to have the most geologically acceptable results. The most acceptable result is the window with 20 ms width (10 ms above and 10 ms below the picked MSY horizon layer), as displayed in the following figures (Figures 8 to 12).

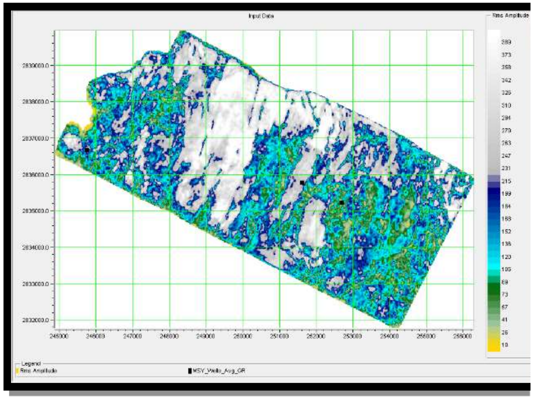

Figure 8: RMS amplitude of MSY horizon

Prior to getting the most acceptable result of window, various widths of windows had been tried in order to have the best one. Some of windows, e.g. 5 ms width (5 ms below the MSY Horizon), 10 ms (5 ms above and 5 ms below the MSY Horizon), 15 ms (5 ms above and 10 ms below the MSY Horizon), 25 ms (10 ms above and 15 ms below the MSY Horizon), and 30 ms (10 ms above and 20 ms below the MSY Horizon).

It is more difficult in, geologically, interpreting the 5 seismic attributes using those widths of windows, than using the most acceptable window of 20 ms width (10 ms above and 10 ms below the MSY Horizon).

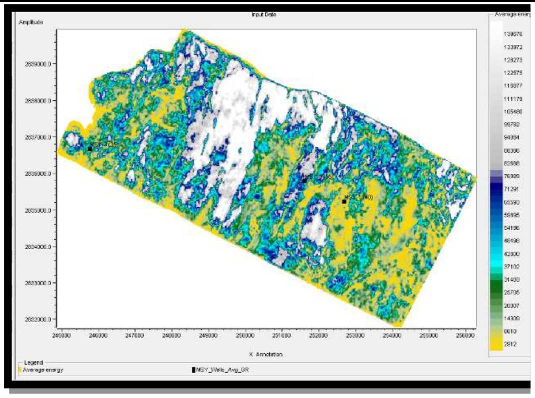

Figure 9: Average energy of MSY horizon

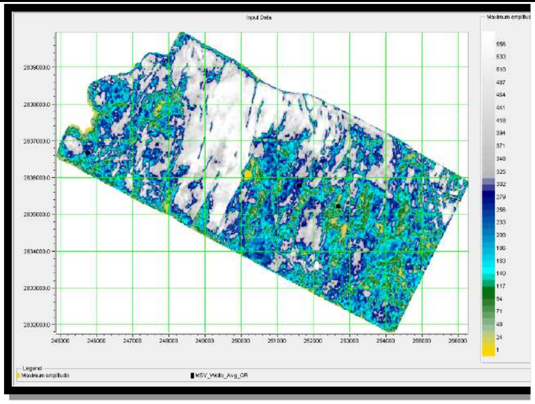

Figure 10: Maximum amplitude of MSY horizon

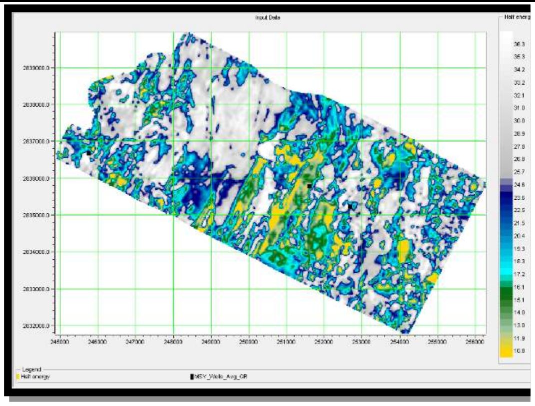

Figure 11: Energy half-time of MSY horizon

By overlaying all 5 seismic attribute maps, a composite map has been generated as shown in Figure 13.

It could be interpreted that sandstone of MSY reservoir is distributed in limited area marked by the yellow arrows in the map of Figure 13 (yellowish or brownish orange in color).

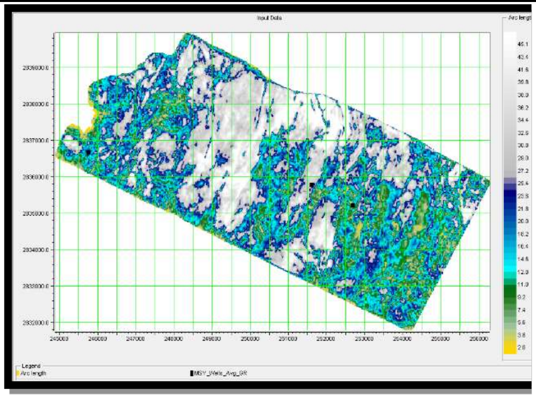

Figure 12: Arc length of MSY horizon

The composite map displays a lateral distribution of MSY sandstone reservoir. It could be interpreted that sedimentation of the MSY sandstone reservoir was directing to the southwest.

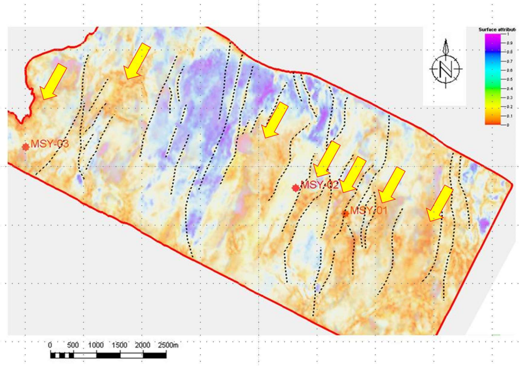

Figure 13: A composite map

Figure 14 shows the composite of attributes map overlaid by the depth structural contours.

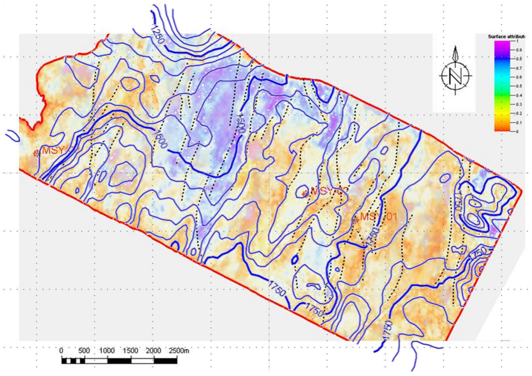

Figure 14: The composite map overlays on its depth structural contours

The accumulation of sandstones is dominantly found in the SE area around the MSY-1 well and between MSY-2 and MSY-1 wells. The MSY Horizon is dipping down from NNW to SSE. Unless stratigraphic trap, no structural trap will be discovered in this area. It means that the area unlikely to be a good prospect for hydrocarbon.

Conclusions

Defining a lateral distribution of MSY sandstone in the area of about 5 km x 10.5 km, based on a limited number of wells and 3D seismic data, has uncertainty. Seismic amplitude-derived attributes could be used in this evaluation, but should be with a note that there is still an uncertainty.

RMS amplitude, average energy, maximum amplitude, energy half-time, and arc length, are possibly not a perfect tool in delineating a sandstone reservoir, but certainly these seismic attributes could decrease the degree of uncertainty.

The MSY Horizon was deposited in the shallow marine or transition zone. All attributes support that this sandstone reservoir was developed from NE (proximal area) to the SW (distal area).

The lateral distribution of MSY Sandstones is spread over the entire area, as supported by the composite map of the 5 seismic amplitude attributes.

The prospective area is in the elongate closure (based on depth structural map) which passes the location of MSY-2 well as a structural play. Second prospect is probably in the smaller closure that located about 2 km south of MSY-2 well.

Finally, the above tools should be integrated with other available data to get a perfect evaluation in exploring hydrocarbon in general.

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