Reservoir Characterization and Volumetric Calculation of Hydrocarbons Reserves in “RRD” Field, Layer Z.2260 Talang Akar Formation, North West Java Basin

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Abstract. “RRD” field is one of the hydrocarbon prospects in North West Java Basin. One of the potential oil reserves in this field was found on Talang Akar Formation Z.2260 layer and indicated by the presence of oil show on drill steam test data. Physical parameters such as acoustic impedance, porosity and hydrocarbon saturation are essential to determine the distribution of reservoir layer. Acoustic impedance can distinguish the reservoir and non-reservoir zone, while porosity and hydrocarbon saturation can be used in the calculation of oil reserves on the layer Z.2260. Model Based Inversion was performed to find out the lithology distribution determined by acoustic impedance. Porosity distribution was identified using crossplot acoustic impedance and porosity analysis while hydrocarbon saturation distribution was determined using cokriging geostatistical analysis. The result shows the existence of sandstone reservoir with acoustic impedance values ranging from 8500–10,000 (m/s)(g/cc) that spreads over 2 zones in the research area of anticline zone A and R. Sandstone with such acoustic impedance range has a porosity value of 8-12% and hydrocarbon saturation 25-50%. The reservoir zone A has value 0.201 (MMbbl) as well as R area 1.689 (MMbbl).

1. Introduction

One role of geophysicist is to hunt for hydrocarbon prospect areas and calculate hydrocarbon reserves in a field using seismic reflection data and well data. This combination will provide both lateral and vertical resolution. In this study we will use seismic data and well data to discover the hydrocarbon prospect areas and calculate the hydrocarbon reserves. The methods of analysis used in this study are seismic inversion, geostatistics, and crossplot.

The seismic inversion method is used to convert a seismic trace into acoustic impedance which is a physical properties of the rock so that it’s easier to interpret into several other physical parameters such as porosity calculation, reservoir layer thickness, and hydrocarbon dispersion pattern. The crossplot analysis of acoustic impedance with ϕ (Porosity) and geostatistics by cokriging is applied to spread the physical value of logs, such as porosity and hydrocarbon saturation, into a volume or distribution map. After obtaining the volume or porosity map and hydrocarbon saturation then this parameter can be used to calculate volumetric volume of hydrocarbon reserves.

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1.1. Regional Stratigraphy

This chapter will discuss the regional stratigraphy and hydrocarbon system in Lower Talang Akar formation. According to Suyono et al (2005)[1], regional stratigraphy in the North West Java Basin, respectively from old to young is described in figure 1.

![Figure 1. Regional stratigraphy of North West Java Basin](image)

Talang Akar Formation is deposited on the Early to End Oligocene Scale and divided into Lower and Upper Talang Akar. Lower Talang Akar is in the delta to fluvial facies which the lithology is sandstone sediment with nonmarine shale; while Upper Talang Akar is in the shallow marine facies which the lithology is seams between limestone, shale, and sandstone. This formation resides in the synrift phase which is precipitated on the Jatibarang Formation.

1.2. Hydrocarbon System in The Lower Talang Akar Formation

Bedrock in the Lower Talang Akar Formation is the Lacustrine Shale formed at a period of syn-rift and developed in two different facies types of many organic material. The second facies are formed during the syn-rift end and developed at the bottom of the equivalent Talang Akar Formation. This bedrock formation is characterized by rough and interbedded nonmarine clastic between sandstones with lacustrine shale.

Reservoir rocks is a rocks that hydrocarbon or water fillings in that have porous and permeable features. The reservoir in Cilamaya Complex is sandstones of Talang Akar Formation and the trap type is a structure trap in the form of a wide anticline dome and an oblique fault block. Migration paths in the North West Java Basin can occur laterally and vertically. Lateral migration is laterally dominated by
channel sands within the Talang Akar Formation which migrating from the South-North. Vertical migration occurs when the direction of primary migration is perpendicular to the layer and fault is the main path for vertical migration. Seal on the Lower Talang Akar Formation is a shale flap insertion inside the formation.

2. Method

2.1. Acoustic Impedance
One of the distinctive acoustic properties in rocks and affecting the reflection of seismic waves is the acoustic impedance. The acoustic impedance itself is influenced by the type of lithology, porosity, fluid content, depth, pressure and temperature. Therefore, acoustic impedance can be used for the identification of lithology, porosity, hydrocarbon and others.

Mathematically, acoustic impedance is the result of multiplication between density and P wave velocity.

\[ \text{IA} = \rho \times v_p \]  

Explanation
\( \text{IA} \): Acoustic Impedance \( \text{(m/s)(gr/cc)} \)
\( \rho \): Density \( \text{(gr/cc)} \)
\( v_p \): P wave velocity \( \text{(m/s)} \)

2.2. Seismic Inversion
Seismic inversion is a technique for constructing subsurface models using seismic data as input and well data as control (Sukmono, 2000)[2], for example predicting the subsurface impedance value of seismic data. The geological model generated by the seismic inversion is an impedance model that represents the sub-surface image of the earth, making it easier to interpret the subsurface conditions.

2.3. Model Based Seismic Inversion
Model based inversion technique involves an acoustic impedance model based on log information to be compared with the seismic data input in an iterative process such that it produces a final model that corresponds to the seismic data and has a relatively minor error (Russell, 1988)[3].

The seismic data model is obtained from the convolution between earth's reflectivity with a seismic (wavelet) source function plus a noise component. In general the form of the equation is given in equation (2):

\[ S(t) = w(t) * R(t) + \text{Noise} \]  

\( S(t) \) is seismic trace and \( w(t) \) is the known wavelet. Noise is assumed to be random and uncorrelated with signal and \( R(t) \) is the reflection coefficient that we look for. The mathematical relationship between model data and seismic data can be calculated using the Generalized Linear Inversion (GLI) method. This method will derive a suitable geological model of least-squares if the geophysical observation data are available. GLI analyzes error between the model and the observed data, and then updates the model to get the smallest error. The nonlinear relationship causes the \( R \) calculation to be done by the iteration process. If the noise component is considered zero, then the equation is written:

\[ S(t) = R(t) * w(t) \]  

Then the trace model is written with the notation \( m(t) \), where at the moment \( R = R_0 \) is formulated as follows:

\[ M(t) = R_0 (t) * w(t) \]  

With \( M(t) \) is trace model, \( R_0 (t) \) is reflection coefficient model and \( w(t) \) is the extracted wavelet. Mathematically, seismic trace and model are written in vector form as follows:

\( M(t) = (m_1, m_2, \ldots, m_3)^T \) = vector of dimensional \( K \) model trace

\( S(t) = (s_1, s_2, \ldots, s_N)^T \) = vektor of dimensional \( N \) seismic trace

With \( T \) is transpose function. The relationship between model trace and seismic trace can be written in the formula:
\( S_i = G(m_1, m_2, \ldots, m_K), i = 1, \ldots, N. \)

With \( G \) is a function that connects the data between the seismic trace and the model. The function of the relationship between the model and the data will issue an output. The GLI method analyzes the error values between model output and seismic trace data. The GLI method of minimizing errors on the model output can be done using the iteration process. Mathematically the iteration process can be written in (5).

\[
S_i = G(M_0) + \frac{\partial G(M_0)}{\partial M} \Delta M
\]

With \( S_i \) is seismic trace data, \( M_0 \) is initial model prediction value, \( M \) shows the true value of the earth model, \( \Delta M \) is \( M - M_0 \), \( G(M_0) \) is synthetic seismogram model, and \( \frac{\partial G(M_0)}{\partial M} \) shows the calculated value change. The error value between \( s(t) \) and \( M(t) \) can be calculated by the following formula:

\[
e(t) = s(t) - M(t)
\]

Equation (6) can be written in the following matrix equation:

\[
e(t) = A \Delta M
\]

With \( A \) is a derivative matrix with dimension \( N \times K \), so the matrix is not a square matrix. Therefore the equation (7) is multiplied by the transpose matrix. So the solution to find \( \Delta M \) is as follows:

\[
\Delta M = [A^T A]^{-1} A^T e(t)
\]

2.4. Porosity

Rock porosity is a fraction of the volume of space between solid particles of rock and total rock volume (Glover, 2000)[4]. Porosity is related to the acoustic impedance as shown in Figure 2. The properties of rock density and velocity are essentially controlled by their matrix and porosity compositions. Speed will decrease if pass through hollow rocks and rocks with high and hard densities also have a large impedance value.

![Figure 2. Relation graph porosity and acoustic impedance.](image)

2.5. Geostatistics

Geostatistics is a statistical technique supplemented by spatial information to estimate the value of a variable at a location that has no value, assuming that on the earth system an adjacent observation value to each other has a greater correlation than observations that are farther away from one another. Spatial relations are measured by the correlation function (variogram) which implies that the further distance between the measured data, the similarity between the two measurements will decrease (Setyadi, 2014)[5].

2.6. Cokriging

Cokriging is a specialized technique in interpolation using two different variables, but is spatially related. By utilizing this spatial relationship, the values of a variable can be estimated from other variables which samples are known. In the case of scattered sample positions (sparse), cokriging is
considered to reduce the uncertainty of the estimation results. In cokriging, the variable to be estimated is called the principal variable, while the variable used to estimate is called the co-variable. We can add a new co-variable (other than the existing one) as long as the spatial relationship between the new co-variable and the main variable is strong enough. Mathematically, cokriging is written in equation (9).

\[ V^*(x_0) = \sum_{i=1}^{n} a_i V(x_i) + \sum_{j=1}^{m} b_j W(x_j) \]

With \( a_i \) being the weight factor for the variable \( V(x_i) \), \( b_j \) is the weighting factor for the variable \( W(x_j) \), \( V(x_i) \) is the sample point value in the principal variable, \( W(x_j) \) is the sample point value on the co-variable, \( V^*(x_0) \) is the estimator of \( V \) at point \( x_0 \), \( m \) is the number of co-variable sample points, and \( n \) is the number of sample points of the principal variable. The relationship between \( a_i \) and \( b_j \) in accordance with the requirements of MVUE (minimum variance unbiased estimate) are:

\[ \sum_{i=1}^{n} a_i + \sum_{j=1}^{m} b_j = 1 \]

(10)

2.7. Calculation of Volumetric Hydrocarbon Reserves

The data required for hydrocarbon volume calculation is the reservoir volume, porosity (\( \phi \)), hydrocarbon saturation (\( S_h \)) in the formation and formation volume factor (\( B_o \)). The reservoir volume depends on the thickness (\( h \)) and area (\( A \)) of the reservoir. The calculation of stock tank oil in place (STOIP) uses equation (11) (Glover, 2000):

\[ STOIP = \frac{7758 \times A \times h \times \phi \times S_h}{B_o} \text{ bbl} \]  

(11)

This equation can be drawn in figure 3.

![Figure 3. Illustration of volumetric calculation reserves hydrocarbon.](image)

2.8. Research Methods

The data used in this research is 3D Post Stack Time Migration seismic data with 461 inline numbers and 461 crosslines. The distance of inline and crossline is 25 m. The extent of this research area is 91.22 km\(^2\).

In this research we used data volume of rms velocity and 11 well data. Well data is used in most processing stages such as tuning thickness analysis, well seismic tie, background modelling, inversion analysis, porosity analysis and hydrocarbon saturation analysis. Here shown the well data used in this research (table 1) and the workflow research is shown in figure 4.
Figure 4. Workflow research

Table 1. Data Available

| No | Well  | Marker | Gamma Ray | RhOB | Resistivity | DT    | PHIE | SWE   | Checkshot |
|----|-------|--------|-----------|------|-------------|-------|------|-------|-----------|
| 1  | DAN1  | ✓      | ✓         | ✓    | ✓           | ✓     | ✓    | ✓     | ✓         |
| 2  | A1    | ✓      | ✓         | ✓    | ✓           | ✓     | ✓    | ✓     | ✓         |
| 3  | A1A   | ✓      | ✓         | ✓    | ✓           | ✓     | ✓    | ✓     | -         |
| 4  | R-2   | ✓      | ✓         | ✓    | ✓           | ✓     | ✓    | ✓     | ✓         |
| 5  | R-5   | ✓      | ✓         | ✓    | ✓           | ✓     | ✓    | ✓     | ✓         |
| 6  | R-8   | ✓      | ✓         | ✓    | ✓           | ✓     | ✓    | ✓     | -         |
| 7  | R-11  | ✓      | ✓         | ✓    | ✓           | ✓     | ✓    | ✓     | -         |
| 8  | R-13  | ✓      | ✓         | ✓    | ✓           | ✓     | ✓    | ✓     | -         |
| 9  | R-14  | ✓      | ✓         | ✓    | ✓           | ✓     | ✓    | ✓     | -         |
| 10 | R-15  | ✓      | ✓         | ✓    | ✓           | ✓     | ✓    | ✓     | -         |
| 11 | R-18  | ✓      | ✓         | ✓    | ✓           | ✓     | ✓    | ✓     | -         |
3. Result and Discussion

3.1. Result of Impedance Acoustic Map
The sandstones distribution pattern is sliced to obtain a lateral cross-section (figure 8). From the result of acoustic impedance slicing, the dispersion pattern between sandstones with shale will be distinguished. The result of this slicing shows that the range of impedance value for sandstone is 8500-10,000 (m/s)(gr/cc).

3.2. Result of Porosity Map
In porosity analysis we use the crossplot method between the acoustic impedance log and the effective porosity log. The point distribution from the crossplot obtained linear trend that is inversely proportional. If the acoustic impedance value is low then the effective porosity value will be high, and vice versa. Figure 5 shows that the effective porosity value is in the range of 8-12%. In Table 2 (Koesoemadinata, 1998)[6], the range of 8-12% is classified as bad to moderate classification. After obtaining an effective porosity map from the crossplot method, we use subtraction between the effective porosity value of the well and the effective porosity value of the crossplot for determining the error value of the well,. The average error rate is 22%.
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Table 2. Porosity Classification

| Porosity % | Classification |
|------------|----------------|
| 0-5        | Ignored        |
| 5-10       | Bad            |
| 10-15      | Enough         |
| 15-20      | Good           |
| >25        | Very Good      |

3.3. Result of Saturation Maps of Water and Hydrocarbons
Hydrocarbon saturation is analyzed using geostatistical method. Based on crossplot result, the spatial correlation between effective porosity log with water saturation log are inversely proportional. The correlation value is -0.727 so geostatistical analysis can be conducted. The water saturation value in the reservoir zone near the well has a range of 50-70% which can be seen in blue to green (figure 6). After the water saturation value of the geostatistical result is calculated, we can calculate the error value by subtraction between the value at the well and geostatistical result. The average error value is 20%.

Using the hydrocarbon saturation formula (Sh = 1 - Sw) then a hydrocarbon saturation map can be made. As shown in figure 7, the hydrocarbon saturation value range in the reservoir zone is 25-50% which can be seen in yellow to red.

Figure 6. Water saturation map in layer z 2260
3.4. OWC Analysis (Oil Water Contact)

The result of OWC determination analysis showed 2 OWC values in region R and A. The OWC in R area is seen from the correlation of well R-8, R-11, R-13, R-14, R-15 and R-18. The lowest limit is seen on well R-15 and obtained OWC value of 2280 m. As for area A, the OWC is seen from the correlation of well A1 and A1A with value of 2410 m. This OWC boundary corresponds to the dispersion of the physical properties of the acoustic impedance. Figure 8 shows the oil-water contact limit value of the blue dotted line in zone A and R zone.
Figure 8. Oil Water Contact on acoustic impedance map overlay structure map in layer Z 2260 and the blue dotted line in zone A and R zone is oil water contact limit value.

3.5. Hydrocarbon Reserves Volumetric Calculation Analysis
Based on porosity distribution map, hydrocarbon saturation map, formation volume factor (1,168), Z.2260 layer thickness and oil-water contact boundary map on RRD field, we obtained table area and bulk volume. The OIP and STOIP calculation of hydrocarbon reserve is shown as follows:

| Zone | Area (km²) | Bulk Rock (MMbbl) | Oil in Place (MMbbl) | STOIP (MMbbl) |
|------|------------|-------------------|---------------------|--------------|
| R    | 3,213174   | 259,692301        | 2,685078            | 1,688728     |
| A    | 0,336941   | 25,521053         | 0,320077            | 0,201306     |
4. Conclusion
The acoustic impedance values of sandstone reservoirs range from 8500 (m/s)(g/cc) to 10.000 (m/s)(g/cc). Map of reservoir porosity value at prospect zone ranges from 8% to 12% and hydrocarbon saturation 25% to 50%. There are 2 hydrocarbon prospect zones (R and A zones):
- Reserves of STOIP zone A of 0,201 ± 0,026 MMbbl.
- Reserves STOIP R zone oil of 1,689 ± 0,012 MMbbl.

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