Analysis of Physical Properties of Rock Reservoirs Using Well Log Method in Determining Reservoir Quality in "JEONA" Field, Central Sumatra Basin

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Abstract. The industrial revolution 4.0 has required collaboration on the oil and gas industry sector. One of the problems is the technology transfer and the increasing of oil reserves supply. It needed to productivity analysis for reservoir rock characterization and subsurface profile that will determine technology transfer. This study was aimed to obtain the hydrocarbon reservoirs quality based on petrophysical parameters. The reservoir zone of JEONA_35 well in 1527.77 - 2067.21 ft. From NPHI and RHOB logs, there is a cross over in 1990 - 2020 ft that interpreted as oil fluid. The PHI is 30 %, Sw is 20 % and Vclay is 10 %. Electrofacies analysis shows that the reservoir zone was located in Bekasap and Menggala Formations (1527.77 - 1889.25 ft). In Bekasap Formation, the gamma ray log pattern is a cylinder block shape and thick from the top until base formation, it deposited in the channel fill distribution with thin sandstones lithology. In Menggala Formation, gamma ray log pattern shows the uptrend bell shape that was deposited in the fluvial - delta distribution with thick sandstone. So, it can be concluded that JEONA_35 reservoir has a good quality with the water saturation is low relatively, so the oil saturation is high relatively.

1. Introduction
Based on the medcom.id website during the Industrial Revolution 4.0 era, the oil and gas industry sector needed collaboration with other industries to increase exploration activities to obtain reserves. The problem in the 4.0 industrial revolution is the need for technology “transfer” and exploring for new reserves while oil and gas reserves are running low [1]. Base on the achievements of upstream oil and gas in semester 1 of 2019 by SKK “Migas”, exploration drilling activities in June 2018 were carried out on 11 wells, while on June 2019 was increased to 18 wells. Oil and gas demand will continue to increase so it is necessary to analyse the productivity of a reservoir rock based on geological data for future operations. One of the activities that can be done is to determine the type of reservoir rock through existing physical properties using the well log method to obtain reservoir characterization in a well. This study was aimed to obtain the quality of hydrocarbon reservoirs based on petrophysical parameters. This research focuses on upstream exploration activities as the beginning of subsurface interpretation for determinate reservoir quality [2]. Tim Tujuh was explained that, exploration activities include geological, geophysical investigations and exploratory drilling or well tests. Geological investigations were carried out to determine rock types, rock age and the potential for oil and gas in an area. Geophysical investigations are used to look at subsurface conditions and look for possible forms of oil
and gas traps. While exploration drilling is carried out to identify the type of fluid in the reservoir [3]. This research was conducted a geological investigation and well test based on wireline logging data including; gamma ray log, NPHI log and RHOB log at JEONA_35 well, Central Sumatra Basin. Thus, it is found that reservoir conditions that allow potentially have hydrocarbon reserves. This determines the technology that must be used to obtain a larger amount of reserves.

2. Theory
2.1. Gamma Ray Log
Williams and Eubank, explained that the gamma ray log was used to measure the natural radioactive activity present in the formation and identification of lithology. High gamma ray values indicate high radioactive content and rock lithology is interpreted as shale. Whereas if the gamma ray value obtained is low, then the radioactive content is small, and the rock lithology is called sandstone (sand). Then, well correlation and the amount of clay volume can also be used using gamma ray logs. Clay volume is a decimal fraction which is showing the amount of shale stone in the formation. Clay volume is obtained from the gamma ray index. In the linear equation, the gamma ray index (IGR) shows the volume of clay. The equation is explained in the equation (1) [4];

\[ I_{GR} = \frac{GR_{log} - GR_{min}}{GR_{max} - GR_{min}} \]  
\[ (1) \]

Where:
- \( I_{GR} \): gamma ray index
- \( GR_{log} \): gamma ray value in formation
- \( GR_{min} \): minimal gamma ray value (clean sand or carbonate)
- \( GR_{max} \): maximal gamma ray value (clay).

2.2. Density Log
Williams and Eubank, explained that log density is one type of porosity log that has relatively shallow depth penetration. The principle of log density is to shoot gamma rays that carry photon particles into rock formations, photon particles will collide with electrons in the formation. The amount of gamma ray energy lost each time collides indicating the electron density in the formation which also indicates the density of the formation. The resulting log density is matrix density (\( \rho_{ma} \)) and bulk-density (RHOB). The porosity density can be calculated using the equation (2) [4];

\[ \phi_D = \frac{\rho_{ma} - \rho_b}{\rho_{ma} - \rho_{fl}} \]  
\[ (2) \]

While for calculating the bulk-density (RHOB) can use the equation (3);

\[ \rho_b = \phi(\rho_{fl}) + \rho_{ma}(1 - \phi) \]  
\[ (3) \]

Where:
- \( \phi_D \): Porosity Density
- \( \rho_{ma} \): Matrix Density
- \( \rho_b \): Bulk Density

2.3. Resistivity Log
Asquith et all was explained that resistivity logs are used to determine hydrocarbon-bearing zones and water-bearing zones and indicate permeable zones and determine porosity. If the hydrocarbon saturation in the pore increases, the water saturation will decrease so that the formation resistivity will increase [5].

2.4. Water Saturation
Based on Harsono explained, saturation is defined as the ratio between the volume of certain fluids (water, oil and gas) to the amount of pore volume. The calculation of water saturation using the
Indonesian equation for water saturation estimation in shaly sand formations. Poupon and Levaux was proposed The Indonesian equation to model the formations in Indonesia which had large volumes of weaning water and the formation of water consisted of freshwater [6]. Poupon, and Leveaux was explained the empirical relationships using the equation (4) [7];

$$\frac{1}{\sqrt{R_t}} = \left[\frac{V_{clay}d}{\sqrt{R_{clay}}} + \frac{\varphi^{m/2}}{a.R_w}\right].S_w^{n/2}$$

(4)

With the value is

$$d = (1 - \frac{V_{clay}}{2})$$ or $$d=1$$

Where:
- $R_t$: formation resistivity
- $m$: cementation factor
- $a$: tortuosity factor
- $V_{clay}$: volume clay
- $R_{clay}$: clay resistivity
- $\varphi$: porosity
- $R_w$: water formation resistivity
- $S_w$: water saturation

2.5. Regional Geology of Central Sumatra

Based on Heidrick and Aulia, stratigraphic units in the Sumatra basin are in Cenozoic rock stratigraphic units (figure 1). The unit consists of five formations namely Pematang, Sihapas, Telisa, Petani and Mina's groups. The unit group is divided into [8];

2.5.1 The Pematang Formation,
The Pematang Formation is directly above the bedrock in the Central Sumatra Basin and consists of two dominant continental facies namely; claystone which has a variety of colours and fine-grained sandstone which are locally interspersed with lacustrine shale stone in organic material. Besides, there are conglomerate sequences, coarse-grained sandstone and various types of claystone. Sediments that have syn-organic characteristics are deposited in separate graben on deep trans dimensional or shallow cracks formed during the regional phase of the Eo-Oligocene.

2.5.2 The Sihapas Group,
The Sihapas group occurs in the transgression phase and covers deposits in Telisa formation. The lowest part of the Miocene Sihapas is shown by an increasingly fine grain size conglomerate, a succession of sandstone grain size from coarse grains to fine grains (Penggala Formation) which is covered by calcarea rocks in the Bangko Formation. The upper part of the Sihapas is formed in transgression of the young Miocene with medium to coarse micaceous sandstone. This happened in Bekasap so that it represented the marginal facies of basinal flakes in the Telisa Formation.

2.5.3 The Telisa Formation,
The Telisa Formation was formed in the oldest until the middle Miocene. The succession of claystone was dominating the formation with interlocking limestone and fine-grained sandstone glauconite. Seawater is affecting the depositional environment that originates from inner, and outer litoral condition. The differences between lithology and fauna were corresponding to the Middle Miocene regression phase in the Neogen cycle. It can show that there is contact between the upper part with the Telisa formation.
2.5.4  *The Petani Formation*,
Sedimentation in Petani formations are monotonous sequences of mudstone shale containing small amounts of sandstone and silt intercalations which indicate the presence of shallow progressive upward and shrinkage of seawater.

2.5.5  *The Minas Formation*,
The presence of eroded erosion covered by a thin layer of gravel, and alluvial sandstone in the Holocene Minas. It is characterizing the peaks of Neogene. This is the nature of disharmony and there is increasing in sediment roughness. So, it shows a considerable increase in the margin of the basin that occurred at the end of the Pliocene period.

![Figure 1. Central Sumatra basin stratigraphy](image)

3. Method
Data processing was performed using Interactive Petrophysics 3.5 software. The research diagram is explained as in Figure 2. The data for this study are wireline logging data such as gamma ray log, neutron log, density log and sensitivity log. Clay volume calculation is used to determine the amount of weaning content in a rock layer. The shale content calculation is based on the gamma ray index where the input parameters are the value of GR clean, GR clay and GR values in wells (see equation 1). Using IP 3.5 software, the log used to calculate porosity are density log, LLD log, VCL and temperature. So, it is known the value of PHIE (effective porosity) and PHIT (total porosity). In petrophysics calculation, effective porosity is used to calculate saturation. Saturation calculations use the Indonesian equation. The cutoff determination is done as a filter to get a clean reservoir zone. The cut off types used are VCL cut off, porosity cut off and Sw cut off. The interpretation of log data is shown in the cut off summary (figure 3).
Figure 2. Processing flowchart
Figure 3. Cutoff Summary IEONA_35 well
Furthermore, electrofacies analysis was carried out to determine the depositional facies and the depositional environment. In this study, electrofacies analysis, was performed based on gamma ray data. Petroleum system information is also used as supporting data in determining the depositional environment. This analysis was carried out on the Formation Formation (shown in the red circle) and Digging (shown in the green circle) (Figure 4).

![Electrofacies Analysis JEONA_35 well](image)

**Figure 4.** Electrofacies Analysis JEONA_35 well
4. Results and Discussion

4.1 Result

Petrophysical calculations using Interactive Petrophysics 3.5 software are shown in table 1.

| Zone Name | Top    | Bottom  | Net   | \( ^{a} \text{Av Phi} \) | \( ^{b} \text{Av Sw} \) | \( ^{c} \text{Av Vcl} \) |
|-----------|--------|---------|-------|--------------------------|-------------------------|--------------------------|
| Bekasap   | 1527.77| 1889.25 | 4.5   | 0.3                      | 0.3                     | 0.2                      |
| Menggala  | 1889.25| 2067.21 | 7.5   | 0.3                      | 0.1                     | 0.1                      |
| All Zones | 1527.77| 2067.21 | 12    | 0.3                      | 0.2                     | 0.1                      |

| Cutoffs Used |
|--------------|
| Phi          |
| Sw           |
| Vcl          |
| PhiSw:PHIE   |
| SwInd:SwInd  |
| VCL:VCL      |
| >= 0.28      |
| <= 0.47      |
| <= 0.35      |

\( ^{a} \text{Av Phi} = \text{average porosity} \\
^{b} \text{Av Sw} = \text{average of water saturation} \\
^{c} \text{Av Vcl} = \text{average of clay volume} \\

4.2 Discussion

Based on table 1, the average clay volume obtained after a cut off of 10%. Worthington and Cosentino was explained about the cut off value category, if the volume of clay obtained is 10% then the other minerals can be sand, limestone and so forth [9]. Then, the average effective porosity after the cut off of the effective porosity is obtained as an effective porosity percentage of 30%. Effective porosity shows the quality of rock pores in passing through the filling fluid. The average water saturation obtained from the cut off calculation is 20%. This value can be said as a pretty good value in determining the quality of the formation of water saturation if the fluid being sought is oil. So that the water saturation value is relatively low, the oil saturation in the formation becomes relatively higher.

The cut off is a limitation of the value given to petrophysical parameters to get a more economical reservoir characterization. The cut off value is based on physical parameter plotting calculations. This value also depends on the cut off value used. in table 1, the VCL cut off is not more than 35%. The amount of volume of clay that is considered economical is not greater than 35% of the volume of clay volume before the cut off. As with effective porosity, the effective porosity cut off is 28%. This means that the amount of effective porosity is given a limit of 28% of the value of effective porosity before the cut off. Whereas the Sw cut off does not exceed 47% of the water saturation value before the cut off. That is, there will be a part of water saturation that is considered uneconomic, so it needs to be discarded.

This research focuses on the formation of Bekasap and Menggala. In Bekasap formation, based on gamma ray log data, the log pattern which is interpreted to be cylindrical with a blocky appearance can be identified deposited in the distributary channel fill area because it shows a thickened log pattern on the top formation and base formation with a sudden beginning and end of the high log. It shows the sedimentation patterns that interpret as aggradation and lithology in the form of thin sandstones. In the formation of Menggala, the gamma ray log shows a log pattern which is interpreted as a bell shape with a grain size appearance that smoothest upward (fining - upward trend). This shows that increasingly towards the top formation there is a decrease in grain size. The Menggala Formation was identified deposited on the area associated with the fluvial portion and delta distribution with a retrogradation deposition pattern. The lithology of the formation of Menggala is still in the form of sandstone but has thick sedimentation.

Based on regional and petroleum stratigraphy from the Central Sumatra basin that was explained by Heidrick and Aulia, in the Central Sumatra basin, almost all hydrocarbons that flow from the lacustrine parent rock to terrestrial are at a young syn-rift age [8]. That show by the presence of some coal in old syn-rift. The reservoir level occurs along with the Pematang group with the best reservoir developed in the delta section with facies in the form of sandstone.
The quality of the sandstone reservoir in the Sihapas group is of good quality and is associated with the fluvial and delta distribution. During the Old-Young Postrift Synrift (Old Oligocene to Young Miocene), this sequence is equivalent to the Sihapas group, including several facies that record, gradual transgression: the Gala Formation is still fluvial, but is overwitten by shallow sea sandstone (Bekasap Formation) and contains gradual facies of clay (Bangko Formation), then forms a part of the cover rock (seal). So that it can be interpreted that both formations have a good hydrocarbon reservoir zone.

5. Conclusion
Based on the analysis conducted in this study, it was concluded that the sandstone reservoir in JEONA_35 well, Central Sumatra basin has good quality. This is shown at an average clay volume of 10 \%, effective porosity of 30 \% and water saturation average obtained of 20 \%. Petrophysical analysis and calculation can be used as an initial step in determining hydrocarbons and subsequent exploration activities. The quality of the reservoir is also a consideration in determining the technology used in drilling the well.

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