Reservoir Characterization Sandstone Reservoir Based on Wireline Log

Mochammad B I Usman and Abdul Haris

1Department of Physics, Natural Science Faculty Indonesia University, Depok, West Java Indonesia

*Corresponding Author: mochammadbimo@gmail.com

Abstract. The hydrocarbon exploration in the sandstone reservoir is still the main interest in Indonesia, in addition to the carbonate reservoir, as the main hydrocarbon reservoirs. To understand the sandstone reservoir characters, this research was conducted to understand the sandstone reservoir behaviour using petrophysics calculation. The characterization of reservoir was conducted by integrating the subsurface data, including ditch cuttings and wireline log. The petrophysics character is used to interpret the geological conditions in the subsurface. The petrophysical analyses used in this research was gained from one well, by calculating the volume of shale (Vshale), porosity, permeability and water saturation. The petrophysics calculation of the reservoir indicate the following parameters: Vshale of 0.51 - 0.091%, Porosity PHIT of 0.17 - 0.2%, PHIE of 0.12 - 0.19%, Permeability of 10.1 - 249.8 mD, saturation water of 0.24 - 0.221%

1. Introduction
A good sandstone reservoir consists of minerals and rock debris originating from igneous, metamorphic or sedimentary rocks with a grain size of 0.0625 – 2 mm. A good reservoir can also contain organic matter within sandstone grains [1]. There are five dominant minerals in sandstone, such as: quartz, feldspar, mica and clay, lithic (rock fragments), and heavy minerals such as: magnetite, hematite, ilmenite, pyrite and zircon. [2].

Petrophysical analysis is an important study to determine the characteristics of a reservoir within a basin. Petrophysical analysis shows several characters including reservoir zones, lithology types, identification of hydrocarbon prospect and its porosity, shale volume, and water saturation.

2. Theoretical background
Petrophysics is a study of the physical and chemical properties of the rocks and their interactions with the fluids (gas, liquid hydrocarbon, and water solution) [2]. The properties of the rock which are needed to understand are shale volume (Vsh), porosity (ϕ), water saturation (Sw), and permeability (k). The properties of the rock are measured and obtained from well logging, both logging after drilling or logging while drilling (LWD).

This analysis is very crucial to understand the physical and chemical properties of the sandstone reservoir. The wireline log which contains a large number of data sets are then analysed using qualitative analysis and quantitative calculation. These analyses can predict and estimate the zone of interest where the hydrocarbon is expected to accumulate. Moreover, the petrophysics calculations are used as the first screening tool of hydrocarbon reserve calculation [1].
Gamma ray log records the radioactivity of the formation. The combination of radioactivity recorded by gamma ray logs comes from the elements of uranium (U), thorium (Th), and potassium (K) [3]. In Figure 2 shows the different response of gamma ray log towards various type of lithologies. The different response is occurred as the radioactivity composition is also different. Sandstones tend to have a small amount of radioactive elements, therefore the gamma ray response is also limited. As a result, the gamma ray log deflect to the left.

2.1. Petrophysics
The purpose of reservoir characterization is to understand the deployment of the rock petrophysical parameters, including porosity, permeability and water saturation. The porosity distribution controls rock permeability and saturation. In sandstone, the porosity is controlled by the diagenesis processes during rock formation.

2.2. Volume Shale (Vshale)
Calculation of Vshale is used to determine the amount of shale in the formation. The presence of shale in the formation will affect the porosity, thus it is very useful mainly for the porosity correction. Shale content can be calculated using the following equation:

$$V_{clay} = \frac{GR_{log} - GR_{min}}{GR_{max} - GR_{min}}$$

where $V_{clay}$ or $V_{shale}$ is the volume of clay or shale, GR min is the minimum gamma ray log (API), GR max is the maximum gamma ray log (API), GR log is the value of GR reading at the certain depth (API).

The calculation of gamma ray values is conducted by creating a baseline, which separate the clean sand and the shally sand. The gamma ray reading which passes the baseline are therefore interpreted as the radioactive-rich shale formation.

2.3. Porosity
Porosity is the ratio of the pore cavity volume pore cavity to the total volume of the rocks. Porosity is expressed in percent (%) and symbolized by $\Phi$. Porosity can be determined by several different log curves.

2.3.1 Porosity Density ($\Phi D$).
The density log is generally used for sandstone reservoirs which contain shale particles (shally sandstone) or complex lithologies. Porosity density is calculated using this following equation:

$$\Phi D = \frac{\rho_{ma} - \rho_b}{\rho_{ma} - \rho_f}$$

where $\Phi D$ is density porosity, $\rho_{ma}$ is density matrix Density (Table 2.1) $\rho_b$ is density bulk formation $\rho_f = $ density fluid ( 1.1 for salt mud, 1.0 for fresh mud, and 0.7 for gas).
2.3.2 Permeability.
Permeability is the capability of the reservoir rocks to pass the fluid through the rock formation pores, without damaging the particles. Permeability can be calculated using this equation:

\[ V = \frac{k.A.\Delta P}{\mu.L} \]  \hspace{1cm} (3)

where \( V \) is Velocity (ml/s), \( \mu \) is Viscosity (cp), \( P \) is Pressure (atm), \( A \) is Area (cm\(^2\)), \( L \) is core length (cm), k is Permeability (Darcy). Based on the classification by Koesoemadinata (1980), permeability can be classified into: tight (< 5 mD), fair (5 - 10 mD), good (10 - 100 mD), and very good (100 - 1000 mD) [4].

2.3.3 Water Saturation (Sw).
Saturation of water (Sw) is the ratio of volume filled with liquid to the volume of total porosity. The general assumption is that the reservoir is initially filled with water and then the oil or gas formed elsewhere moves into a porous formation, replacing water in a larger pore space. But the hydrocarbons replacement could not replace all of the water. In this case, the water is called saturation of residual water or Sw (irr), which indicates that water is left behind due to surface tension on the surface of the grain, contact granules, and in very small gaps. The value varies from 0.05 in a very rough formation with a small water Saturation from the Indonesian Method.

\[ S_w = \left\{ \left( \frac{V_{sh}^{2/3} - V_{sh}}{R_{sh}} \right)^{1/2} + \left( \frac{\phi m}{R_w} \right)^{1/2} \right\}^{-1} R_t^{-1/n} \] \hspace{1cm} (4)

Where:
- \( S_w \) = saturation in the uninvaded zone (metode Indonesia)
- \( V_{sh} \) = volume shale
- \( R_{sh} \) = resistivity shale
- \( R_w \) = resistivity water
- \( R_t \) = true resistivity
- \( \phi \) = porosity
- \( a \) = turtuosity
- \( m \) = cementation
- \( n \) = saturation exponents, ranging from 1.8 to 2.5.

| Lithology | \( \rho_{ma} \) (gr/cc) |
|-----------|------------------|
| Sand      | 2.648            |
| Limestone | 2.710            |
| Dolomit   | 2.876            |
| Anhidrit  | 2.977            |
| Salt      | 2.032            |
3. Method

3.1. Precalc.
The analysis are initiated by doing a calculation, where the temperature changes are calculated in every depth and every well.

3.2. Correction and Normalization
Borehole tunneling affects the reading of the instrument in measuring gamma ray logs and density so that the measurement results need to be corrected. Whereas in gamma ray logs, there is a diversity of values in the gamma ray log due to the generation of tools used during the measurement and the different standard in service companies. Hence, the normalization is needed to equalize the scale of all wells.

3.3. Determination of Flake Volume
Determination of shale volume in this study was carried out with gamma ray log parameters.

3.4. Determination of Porosity
Determination of porosity in this study using log density and neutron log parameters.

3.5. Determination of Permeability
Permeability values are determined using curve regression cross between effective porosity.

![Figure 1. Petrophysical Workflow [5]](image-url)
4. Result and Discussion

4.1. Analysis of Shale Content
Shale volume analysis can be determined through interpretation of the log gamma ray curve, resistivity, or density-neutron. In this study, the interpretation was conducted using the gamma ray and density-neutron curves. The calculation resulted was obtained from two curves. One curve which had the best value was then selected as a reference to analyze the Vshale content in the other wells.

Based on the interpretation, most lithology was interpreted as sandstone, while the shale formations had a very close distance with the sand baseline. Figure 2 of the gamma ray (GR) minimum and maximum histogram shows a good statistical distribution. Finally, the minimum gamma ray values were 46.6 GAPI and 94.8 GAPI, for minimum and maximum gamma rays, respectively. [4]

![Figure 2. Histogram GR Max & Min](image)
Figure 3. Shows that the Vshale composition in the target zone has 0.55-0.6%, indicating fair quality of reservoir zone.

4.2. Porosity
Porosity calculation in this study used the log density-neutron curve using Bateman-Koenan, shown in Figure 4. Moreover, total porosity (PHIT) was gained using the neutron-density curve. The density-neutron value was chosen to calculate both porosities as it had a quite accurate result. This calculation of porosity is 0.2%, indication a fair quality of the reservoir.
4.3. Saturation Water (Sw)

The saturation water analysis indicates that the target has a 0.2% of water saturation. This calculation in figure 5 also indicates that the hydrocarbon saturation reached 80%, which indicating a good fluid content within the target zone.

Figure 4. Porosity Calculation [5]
4.4. Permeability ($k$)
The permeability is varied from tight to good permeability as indicated in Figure 6. This result indicates that the target zone has a variable quality.

Figure 5. Water Saturation [5]
Figure 6. Permeability calculation curve [5]

Table 2. Petrophysical Table.

| Depth (feet) | VShale(%) | Porosity(%) | SW(%)  | Permeability |
|--------------|-----------|-------------|--------|--------------|
| 1573         | 0.51      | 0.17        | 0.24   | 10.1         |
| 1578         | 0.52      | 0.11        | 0.26   | 9.23         |
| 1583         | 0.48      | 0.12        | 0.33   | 6.7          |
| 1588         | 0.5       | 0.09        | 0.32   | 2.8          |
| 1590         | 0.49      | 0.12        | 0.26   | 12.4         |
| 1593         | 0.091     | 0.22        | 0.221  | 249.8        |
5. Conclusion
The petrophysics calculation of the reservoir indicate the following parameters: Vshale of 0.51-0.091, Porosity PHIT of 0.17 - 0.2%, PHIE of 0.12 - 0.19%, Permeability of 10.1 - 249.8 mD, saturation water of 0.24 - 0.221. The production zone is interpreted as a sandstone reservoir. This proven-gas reservoir is needed for further study by combining the porosity calculation from core data, petrography and caliper log calculation.

Reference
[1] Delisatra, G., 2012, Seismic Interpretation & Reservoir Characteristization, Seminar, Yogyakarta.
[2] Harsono, A., 1997, Evaluasi Formasi dan Aplikasi Log, Edisi-8, Schlumberger Oilfield Services, Jakarta.
[3] Hareira, I., 1991, Tinjauan Geologi dan Prospek Hidrokarbon Cekungan Jawa Barat Utara, PERTAMINA UEP III, Jakarta.
[4] Koesoemadinata, 1980, Geologi Minyak dan Gas Bumi, Jilid 1 Edisi Kedua, ITB Bandung.
[5] Paradigm software, 2012, Geolog 7 Software, Paradigm, Houston