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POROSITY ANALYSIS OF WELL LOGGING ON CORE TO UNDERSTAND Sw AND RESERVOIR CHARACTERISTICS IN THE KUJUNG FORMATION OF WELL Y NORTH EAST JAVA

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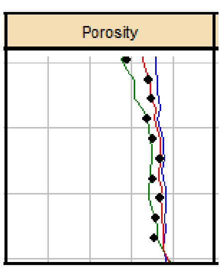
Graphical abstract

Porosity: Log, Core



Abstract

Porosity is the ratio of the volume of porous rock to the total volume of rock multiplied by 100%. Reservoir rocks that have good porosity will affect the volume of oil and gas. The volume of oil, gas and water depends directly on porosity. The study was conducted in the North East Java Basin in the X field, Y well in the Kujung Formation. The objectives are: First, to determine the effective porosity value using porosity calculations with neutron, density, neutron-density models; Second, to determine the comparison of effective porosity values between the results of porosity calculations of neutron models, density models, neutron-density models with core data. The method used is the Well Logging method, using Interactive PetroPhysics software. The results of the calculation of effective porosity in the Kujung Formation from the three models obtained an average effective porosity value between 16.58%-19.95%. Calculation of effective porosity with neutron, density and neutron-density models compared to core data showed a correlation of more than 0.8 so that the calculation results were considered accurate, and could be used for reservoir characteristics and water saturation (Sw). In this area, the determination of porosity is in accordance with the neutron, density, neutron-density model.

Keywords: effective porosity, reservoir, core data, water saturation, fluid.

1.0 INTRODUCTION

Petroleum reservoir porosity is considered one of the most important parameters in hydrocarbon reserve estimation as it determines the effective volume of hydrocarbons stored in the reservoir. Porosity can be determined in the laboratory and can also be determined from logs such as density, neutron, sonic, and Nuclear Magnetic Resonance (NMR) logs. Nuclear Magnetic Resonance (NMR) logs have been used to image fluid-saturated porous media, including reservoir rocks. The petroleum industry quickly adapted this technology for petrophysical laboratory studies and later developed underground logging tools for in-situ reservoir evaluation.

Porosity is a unitless quantity, defined as the ratio of pore volume (Vp) to total rockvolume (Vb). [1] presents an equation for estimating net formation porosity. The porosity has a range of values between 0-1%, where the denser a formation is, the smaller the porosity [2].

Neutron, density, and sonic logs are strong functions of lithology while Nuclear Magnetic Resonance (NMR) logs are not a function of lithology. But NMR Logs can calculate the hydrogen content in fluids, and can measure the actual total porosity [3]. Nuclear Magnetic Resonance (NMR) Logs are one of the reliable methods for determining porosity. Nuclear Magnetic Resonance (NMR) Logs can affect the accuracy of porosity determination from Nuclear Magnetic Resonance

(NMR) Log recording results. Its application in oil-producing areas is that Nuclear Magnetic Resonance (NMR) Logs can be used, because NMR logs can calculate the hydrogen content in fluids (oil, gas, water), which fill the pores of rocks. Furthermore, Nuclear Magnetic Resonance (NMR) Logs can detect porosity values in rocks whose pores are filled with fluids (oil, gas, water).

In exploration both in the field of oiling and groundwater, the porosity parameter is very important, because porosity is the mainvariable to determine the amount of fluid reserves contained in a rock mass [4]. Porosity with geological and stratigraphic information is a necessary step to determinethe characteristics of a reservoir [5, 6]. Thenporosity is also a very important parameter to determine water saturation which is then used to identify the type of fluid [7]. The results of porosity calculations from log dataare validated with core porosity, because it is expected to get almost the same results so that for research on reservoir characteristics and identification of water saturation, accurate research is obtained. Research [8, 9, 10] has successfully conducted log calculations in the Central Sumatra, North East Java and Bintuni basins. Porosity shows how much volume the rock holds hydrocarbons. The greater porosity in the reservoir rock allows the rockto hold more hydrocarbon fluid. In general, the porosity of the rock will decrease with increasing rock depth, because the deeper the rock, the more compact it will be due to the effect of pressure from above.

Looking at the background above, porosity calculations are determined from density, neutron and neutron-density log model data which are then validated with core data. The objectives of this research are: First, to determine the effective porosityvalue in the Kujung Formation of the North East Java Basin in well Y using porosity calculations with neutron models, density models, neutron-density models; Second, to determine the comparison of effective porosity values between the results of porosity calculations of neutron models, density models, deutron-density models with core data.

[11] was the first researcher to study the importance of pore texture on the physical properties of carbonate rocks. Based on pore size, he classified carbonate rocks into permeability estimates. [12] classified carbonate pore types based on pore connectivity and pore size distribution and then found their influence on the physical properties of pores. [13] further classified porosity into interparticle pore space, separate porosity vugs and touch porosity vugs. The three groups have differences in the scheme of connected pores. Because these groups show different permeability-porosity relationships.

This research was conducted in the North East Java Basin in field X of well Y in the Kujung Formation, where the Kujung formation of Early Oligocene to Late Oligocene age mainly consists of limestone,shale, and sandstone layers, and conglomerate sediments with coal inserts.

Well Logging is a technique to obtain subsurface data using measuring instruments inserted into the wellbore, for formation evaluation and identification of rock characteristics in the subsurface [14]. The well logging method produces a relatively high level of data accuracy compared to other methods, so this methodis still the main choice of companies in conducting exploration even though it requires relatively expensive costs [15].

In this study, the effective porosity value was calculated using Interactive PetroPhysics software with single parameter (density model and neutron model) and double parameter (neutron- density model) methods. To determine porosity based on log data, three kinds of logs can be used, namely sonic log, densitylog, neutron log and a combination of neutron log and density log.

Basically, each porosity calculation model has its own calculation characteristics and to validate or determine the accuracy of the porosity value obtained from processing, core porosity data from the well is used. After obtaining the total porosity value from neutron and density we can correct the porosity using data from core porosity [16]. Then it is expected that the porosity of the log data calculation results can match the core data, so that further research in the form of reservoir characteristics and determination of water saturation in relation to fluid type identification can be done accurately.

Some researchers [17, 18, 19, 20, 21, 22, 23] can identify the type of fluid according to the water saturation value. Finding water saturation quantitatively using the equation [24], but the porosity value is still based on the porosity of the log, not the core. So in this study, the core porosity parameter is added. Porosity is also used to predict some log properties [25, 26, 27, 28].

2.0 METHODOLOGY

For the smooth implementation of thisresearch, materials or tools are needed as support, namely: Well Y log data, Well Y core data, IP V3.5 software and laptop. The research period is as follows:

1. Collection of log data and core data for well Y was carried out from 19 September 2022 to 19 October 2022, at the Geological Survey Center, Bandung, West Java, Indonesia 40122.
2. Data processing, carried out from 25 October 2022 to 5 January 2023, at the Geological Disaster Mitigation Laboratory, Geophysical Engineering, University of Lampung, Indonesia, 35145.
3. Data analysis, carried out 6-15 January 2023, at the Geological Disaster Mitigation Laboratory, Geophysical Engineering, University of Lampung, Indonesia, 35145.

2.1 Data Preparation and Collection

The preparation and data collection stage is the stage of collecting the dataneeded in this research. This research datais sourced and owned by the Geological Survey Center in the form of Y well logging data in LAS format. At this stage, pre-calculation is carried out which consists of the stages of well header input, data quality control, depth matching, calculate temperature gradient and calculate Rw value and perform environmental correction.The stages are:

a. Drilling environment correction (Environmental Correction)
   Before processing, the well data used should be corrected first. This is done because during drilling there are several parameters that can affect the reading of the well logging curve, such as borehole

geometry, casing configuration and material, and mud density. So environmental correction is needed to minimize the effect of the borehole.

b. Log Gamma Ray Correction
Gamma rays are absorbed by formationatoms through a process called the photoelectric effect [29]. In gamma ray log correction, the initial step is to inputthe GR log curve, Caliper log curve or borehole diameter.

c. Density Log Correction
In density log correction, the initial stepis to input the RHOB log curve. In the density log, the parameters that are very concerned are drilling mud and caliper data. So that in density log correction requires caliper data or borehole size, and the specific gravity ofdrilling mud (mud weight).

d. Neutron Log Correction
The initial stage in the neuron log correction is to input the neutron log curve. The other parameters considered are caliper data input, temperature value, hole size, bit size, salinity, mud weight, pressure, casing diameter and standoff.

2.2 Data Processing

Data processing uses one well logdata, namely well Y. The log data used is a corrected log curve. Processing is done using the effective porosity from the calculation of the neutron model, densitymodel, neutron-density model.

3.0 RESULTS AND DISCUSSION

3.1 Drilling Environment Correction (Environmental Correction)

Environmental correction is performed to obtain log data that has been corrected from the influence of the drilling environment such as mud density, casing configuration, borehole geometry and borehole effects. Some of these components can affect the reading of the well logging curve. Environmental corrections used in this studyinclude correction of Gamma Ray logs, NPHI logs and RHOB logs using tools from Schlumberger. This correction is done in accordance with the number of drilling runs,where in well Y four runs are done with each depth.

The gamma ray log (GR) correction results are: GR min=0.25 API, GR max=251.10 API. The results of the density log correction (ρ) are: ρ min=1.418 gr/cc, ρ max=2.714 gr/cc. The results of the Neutron Porosity log correction (NPHI) are: NPHI min=0%, NPHI max=100%, and NPHI average=25%.

3.2 Petrophysical Analysis

3.2.1 Calculation of Volume of Shale (Vsh)

Shale volume is defined as the ratio of clay present in a formation. Figure 1, showsthe display curve of the calculation results of Vsh in well Y. Therefore, the calculation of shale volume is carried out to correct the total porosity, so that the effective porosity of thereservoir rock can be obtained [30].

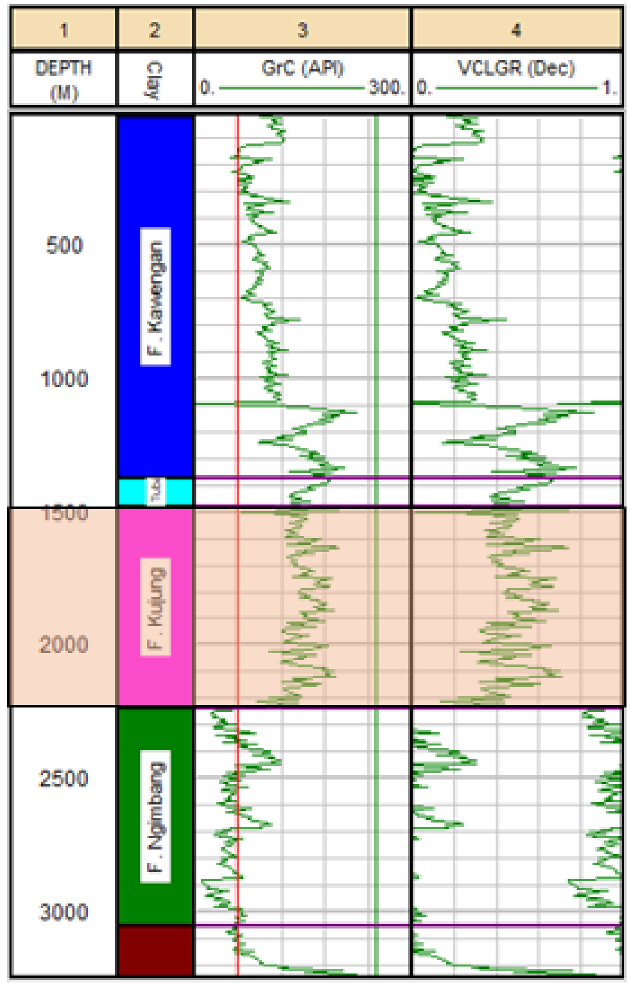


Figure 1. Display curve of calculation result Vsh atwell Y

The calculation of shale volume canuse the gamma ray value according to [31]. The calculation of shale volume (Vsh) in this study uses Gamma Ray log parameters because Gamma Ray logs are basically very sensitive in detecting the content of radioactive elements contained in shale. In calculating the volume of shale, it is necessary to determine the shale baselineand clean sand baseline, namely the zone where it is considered that there is only clean shale (GR max) and clean sand without shale content (GR min). This stage is carried out by selecting the parameters used, namely log gamma ray, neutron resistivity and density with a parameter set in the form of Clay Volume.

In well Y, the average value of Vsh is 0.26 or 26%. The well is divided into four zones which are determined qualitativelybased on the arrangement of rockformations. For the clean sand zone baseline value, the GR value is 60, and the clean shale zone baseline GR value is 250.Vsh Value in Table 1.

Table 1. Vsh value based on formation Y well rock

Formation	Depth (m)	Vsh
F. Kawengan	0 - 1378	0.24
F. Tuban	1378 - 1480	0.50
F. Kujung	1480 - 2238	0.45
F. Ngimbang	2238 - 3052	0.05

3.2.2 Core Data Analysis

This study uses Y well data equipped with core data to validate the porosity value from the automatic software calculation. Core data can be used as a reference in determining rock petrophysics such as porosity. In this case, the porosity value used is the effective porosity value. The following is a table containing core data on well Y. This research has 20 core data as validation of the calculation results. The coredata used in this study will be plotted with the results of the porosity calculation of the neutron, density and neutron-density models.

3.2.3 Porosity Calculation (ϕ)

Porosity is the ratio of pore volume to total rock volume (Schlumberger, 1989). In processing the Y well data to obtain porosity values using IP software, calculations are carried out with 3 different models, namely the neutron model, density model and neutron-density. Each model has its own characteristics and calculation formula. In this study, the calculation is done automatically by IP software processing which must pay attention to several important parameters that affect the results of porosity values.

3.2.3.1 Neutron Model

Based on the calculation of porosity with the neutron model, it shows that the total porosity value is greater than the effective porosity value. The total porosity value (PHIT) in well Y is 0.2257 or 22.57%, while the effective porosity value (PHIE) is 0.1888 or 18.88%. The porosity values in each area are shown in table 2 and explained in figure 2.

It can be seen in table 2 that the results of the calculation of the effective porosity value with the neutron model in the Kujung formation have good porosity quality with a value of 16.58%. This means that there are 16.58% cavities that can be occupied by hydrocarbons in the entire volume of the rock layer. Knowing that the porosity value is quite high, this formation has the prospect of becoming a productive hydrocarbon indication reservoir.

This study also used core data to determine the similarity of log porosity calculations with core porosity. The available core data is only in the depth range of 1501-1507 meters, so the distribution of the neutron model log porosity is plotted together with the core porosity. It can be seen that the results of the core data plot against the porosity curve of the neutron model calculation results show similar results. However, at the initial depth, there is a difference in value between the core calculation and the neutron model calculation from IP software. This could be due to the influence of the drilling environment or other things.

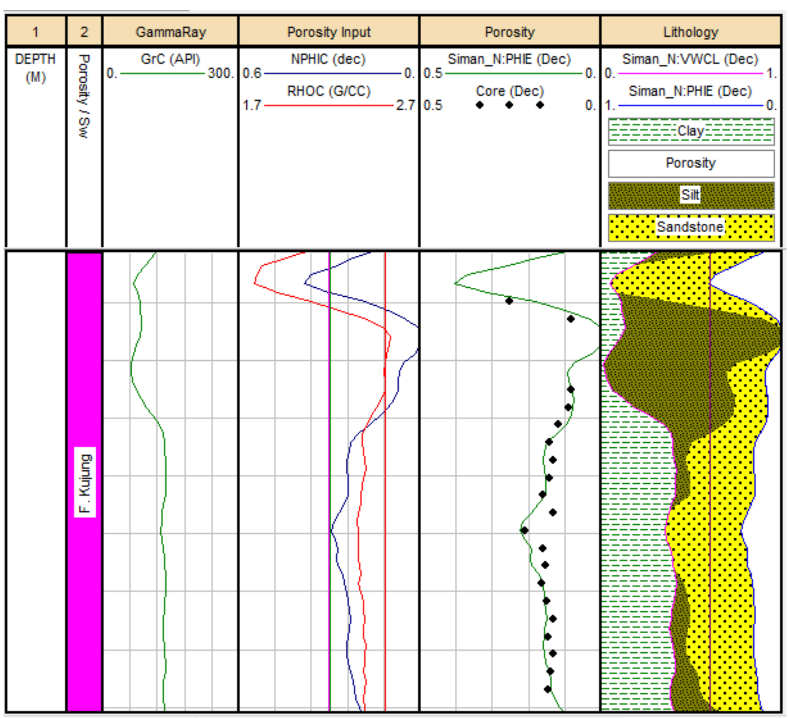


Figure 2. Porosity curve of neutron model with core data 1500-1507 m depth in the Kujung Formation

Table 2. Neutron model porosity values of each formation

Formation	Depth (m)	PHIT (%)	PHIE (%)	Description
F. Kawengan	0 - 1378	30.62	26.57	Special
F. Tuban	1378 - 1480	25.90	18.84	Good
F. Kujung	1480 - 2238	23.02	16.58	Good
F. Ngimbang	2238 - 3052	11.50	10.99	Simply

After obtaining the effective porosity value from the calculation of neutron model porosity, it was validated with core data. To determine the level of similarity of PHIE values from IP software processing with core data, a plot was made. Based on Figure 3, it can be seen that the correlation between the neutron model porosity value and the core porosity data has a fairly goodcorrelation value of more than 0.844.

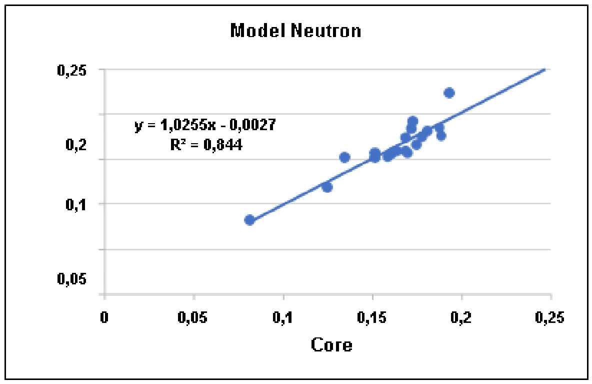


Figure 3. Neutron model with core data plot PHIE result

Table 3 Porosity value of each formation density model

Formation	Depth (m)	PHIT(%)	PHIE (%)	Description
F. Kawengan	0 - 1378	33.24	29.19	Special
F. Tuban	1378 - 1480	27.90	20.83	Very good
F. Kujung	1480 - 2238	26.19	19.74	Good
F. Ngimbang	2238 - 3052	11.17	10.33	Simply

3.2.3.2 Density Model

Based on the porosity calculation of the density model, it shows that the total porosity value is greater than the effective porosity value. The total porosity value (PHIT) in well Y obtained an average value of 0.2350 or 23.50%, while the effective porosity value (PHIE) is 0.1990 or 19.90%. The porosity values in each formation zone are shown in Table 3 and explained in Figure 4.

It can be seen in Table 3 that the results of the calculation of the effective porosity value with the density model in the Kujung formation have good porosity qualitywith a value of 19.74%. This means that there are 19.74% cavities that can be occupied by hydrocarbons in the entire volume of the rock layer. Knowing that the porosity value is quite high, this formation has the prospect of being a productive hydrocarbon indication reservoir.

In this study also used core data to determine the similarity of log porosity calculations with core porosity. The available core data is only in the depth range of 1501-1507 meters only, so the distribution of the density model log porosityis plotted together with the core porosity as shown in Figure 4. After obtaining the effective porosity value from the calculation of the porosity density model which is then validated with core data. To determine the level of similarity of the PHIE value of IP software processing results with core data, a plot is carried out.

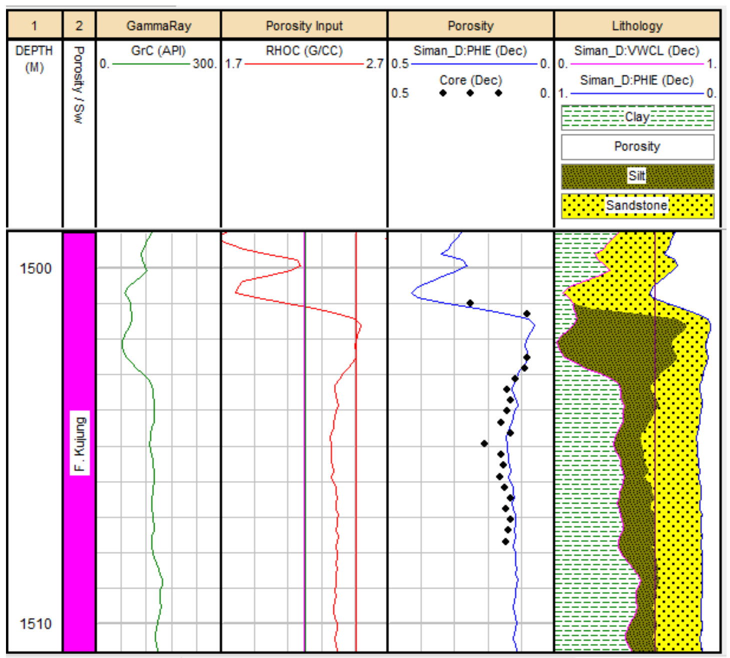


Figure 4. Porosity curve of density model with c o r e data1500- 1507 m depth in the Kujung Formation

Based on Figure 5, it can be seen that the correlation between the porosity value of the density model and the core porosity data has a fairly good correlation value of more than 0.830.

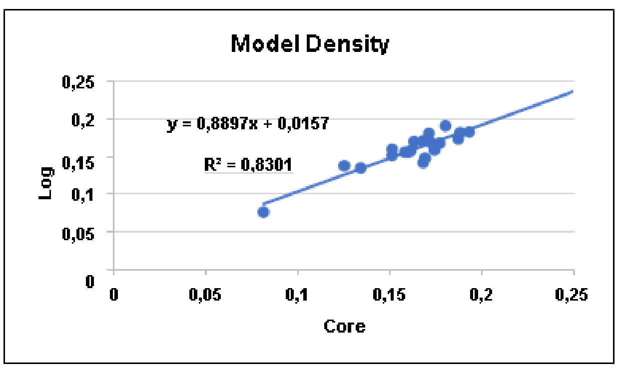


Figure 5. PHIE plot results of density modelwith core data

3.2.3.3 Neutron-Density Model

Based on the calculation of porosity with the neutron-density model, it shows thatthe total porosity value is greater than the effective porosity value. The total porosity value (PHIT) in well Y obtained an average value of 0.2425 or 24.25%, while the effective porosity value (PHIE) is 0.1206 or 12.06%. The porosity values in each zone are shown in Table 4 and explained in Figure 6.

It can be seen in Table 4 that the results of the calculation of the effective porosity value with the neutron-density model in the Kujung formation have good porosity quality with a value of 19.95%. Thismeans that there are 19.95% cavities that can be occupied by hydrocarbons in the entire volume of the rock layer. Knowing thatthe porosity value is quite high, this formation has the prospect of being a productive hydrocarbon indication reservoir.

This study also used core data to determine the similarity of log porosity calculations with core porosity. The available core data is only in the depth range of 1501-1507 meters, so the distribution of neutron-density model log porosity is plotted together with core porosity as shown in Figure 6. After obtaining the effective porosity value from the calculation of the porosity of the neutron-density model which is then validated with core data. To determine the level of similarity of the PHIE value of IP software processing results with core data, a plot is carried out.

Table 4. Porosity value of neutron-density model of each formation

Formation	Depth (m)	PHIT (%)	PHIE (%)	Description
F. Kawengan	0 - 1378	35.55	29.51	Special
F. Tuban	1378 - 1480	28.13	21.06	Very good
F. Kujung	1480 - 2238	26.40	19.95	Good
F. Ngimbang	2238 - 3052	12.64	11.81	Simply

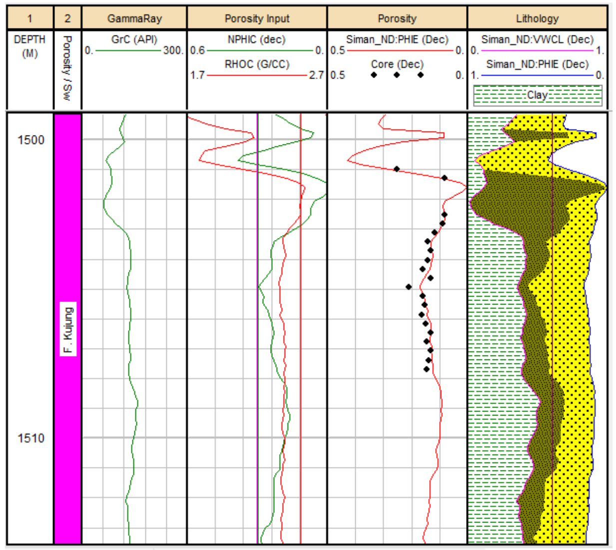


Figure 6 Porosity curve of neutron-density model with core data 1500-1507 m depth in the Kujung Formation

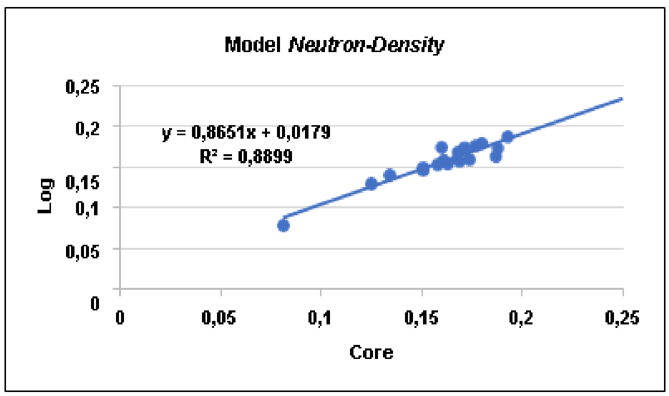


Figure 7. PHIE plot results of the neutron model density with core data

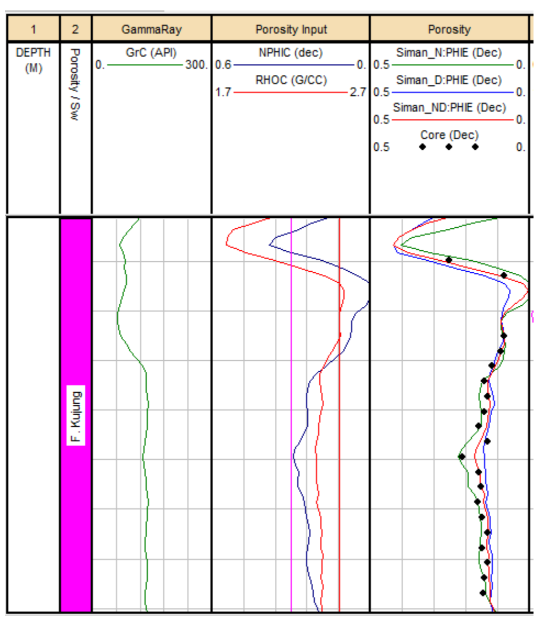


Figure 8. Modeled porosity curves of neutron, density and neutron-density with core data1500-1510 m depth in the Kujung Formation

Based on Figure 7, the graph shows that the correlation between the porosity value of the neutron-density model and the core porosity data has a fairly good correlation value of more than 0.889.

So overall based on the curve plot results of the distribution of log porosity of the neutron-density model, density model and neutron model with core porosity, it can be seen that the effective porosity value (PHIE) in the neutron-density model (red color curve) and density model (blue color curve) neutron model (green color curve) has an effective porosity value that is close to the core porosity value, shown in Figure 8. So, it can be said that the porosity of the three models has a good correlation level with core porosity which is more than 0.8.

In principle, to determine porosity based on log data, three kinds of logs can be used, namely sonic logs, density logs, neutron logs and a combination of neutron logs and density logs. In density logs, if the formation contains little rock matrix, the porosity value will be large. Then the neutron log is a log that detects the content of hydrogen atoms (fluid) in a rock. If the density log and neutron log are combined, it will get good porosity calculation results.

Table 5 Results of effective porosity values of neutron-density, density and neutron modelswith core data

No.	Depth (m)	ϕ Core	ϕ Neutron-Density	ϕ Density	ϕ Neutron
1.	1501.000	0.134	0.140	0.136	0.152
2.	1501.305	0.125	0.130	0.139	0.118
3.	1502.525	0.081	0.079	0.077	0.082
4.	1502.830	0.161	0.158	0.159	0.158
5.	1503.135	0.171	0.173	0.182	0.184
6.	1503.440	0.169	0.157	0.149	0.157
7.	1503.745	0.163	0.154	0.171	0.159
8.	1504.050	0.160	0.174	0.157	0.156
9.	1504.355	0.168	0.161	0.143	0.159
10.	1504.660	0.172	0.173	0.170	0.192
11.	1504.965	0.193	0.187	0.184	0.223
12.	1505.265	0.158	0.153	0.157	0.153
13.	1505.570	0.151	0.149	0.161	0.152
14.	1505.875	0.187	0.163	0.175	0.185
15.	1506.180	0.168	0.168	0.172	0.174
16.	1506.485	0.177	0.176	0.169	0.175
17.	1506.790	0.188	0.173	0.183	0.176
18.	1507.095	0.151	0.146	0.153	0.157
19.	1507.400	0.180	0.179	0.192	0.181
20.	1507.705	0.174	0.159	0.160	0.166

The following are the results of porosity values calculated with the neutron-density model, density model and neutron model shown in Table 5.

Based on Table 5 which shows the results of the calculation of effective porosity with neutron-density, density and neutron models, it can be seen that the porosity value obtained has a value that is almost the same as the porosity of the core. Where from the results of the three porosity model calculations correlated with core porosity data, the calculation of the double parameter porosity model (neutron-density) has the highest correlation value with a value of 0.889 followed by a single parameter, namely the neutron model of0.844 and the density model of 0.830. It can be concluded that the three models are wellused in petrophysical analysis of porosity value calculations, then can be used to characterize reservoirs and determine watersaturation to identify fluid types.

The finding obtained from the results of this research is that we can calculate porosity using only the neutron model or the density model or the neutron density model, because the effective porosity value is the same as the core data porosity. So, the findings obtained from the results of this research are that the effective porosity calculated using the neutron model, density model and neutron density model is in accordance with the effective porosity value of the core data. So the calculation results are considered accurate and the calculation results can be used to characterize the reservoir so that it can help researchers [32, 33, 34, 35, 36]. Apart from that, it also functions to determine water saturation in connection with identifying the type of liquid and will help researchers [37, 38, 39, 40, 41, 42].

3.3 Quality Improvement

Density log tool, neutrons are greatly affected by water in the pores of the rock, its weakness, especially in the hydrocarbon saturated zone. Especially in the hydrocarbon saturated zone. However, if there is core data, it will be very helpful for the weakness (reading log data can be assisted by core data).

Research on porosity needs to be developed, so that it can increase knowledge in the world of oil and gas. To improve the quality of this paper are:

1. Well logs should be supplemented with core data at all target reservoir depths, so that comparisons can be made and the results more accurate.
2. The method on this log well should also be done on log wells in other fields, so that it can add comparison and the results are more accurate. Another reason is that the calculation of effective porosity can use one of the methods from the neutron model, density model and neutron-density model, depending on the available well data.

4.0 CONCLUSION

Based on the calculation results of theeffective porosity value in the Kujung Formation from the three calculation models, the average effective porosityvalue ranges from 16.58%-19.95%.

The calculation of effective porosity with neutron model, density model and neutron-density model compared with core data shows a correlation value of more than 0.8 so that the calculation results are considered accurate, and the calculation results may be used to characterize the reservoir and then determine water saturation in relation to fluid type identification.

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Conflicts of Interest

The author(s) declare(s) that there is no conflict of interest regarding the publication of this paper

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