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Determination of Hydrocarbon Zones Using Logging Data Analysis in A Sandstone Reservoir (Case Study: Structure 'TL' Basin North West Java)

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Abstract - Northwest Java Basin is one of the Indonesian basins that has the potential of hydrocarbon reservoir. A petrophysical analysis plays a role in determining the physical properties of reservoir rocks such as shale volume, porosity, and water saturation zones which is to analyze the hydrocarbon zone possibilities (net pay). A qualitative analysis and correlation of rock lithology study were carried out at seven wells, while a quantitative study was performed by calculating the volume of the shale with a linear method, density-neutron porosity, and water saturation using simandoux equation, then zoning the prospect zones was finally done. Based on the calculation and data analysis, Vsh cutoff value obtained is 23%, the porosity is 10.6%, and water saturation is 71%. Then, the zones of hydrocarbon prospects were recovered, that are the PI-08 wells (9.632 ft - 9.662 ft), PI-10 (9.420 ft - 9.468 ft, 9.475 ft - 9.516 ft, 10.155 ft - 10.175 ft), well PI-11 (9.268 ft - 9.288 ft), well PI-11ST (9.268 ft - 9.927 ft), well PI-12 (9.396 ft - 9.461 ft, 10.047 ft - 10.059 ft), and PI-13 wells (9.356 ft - 9.416 ft, 9.980 ft - 10.000 ft).

Keywords: oil reservoir, hydrocarbon prospects, petrophysical analysis, net pay

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Introduction

Background

Oil and gas exploration is a series of steps to determine and to analyze the existence of oil and gas reserves located below the earth surface in a particular area using geological and geophysical methods. Then, from the geological and geophysical methods, data obtained will be used to determine whether the region will further be analyzed or not. One of such data is logging data, which can be used to determine the physical properties of rocks to fluid content in the subsurface. In addition, interpretation of well log data is a backup method that can be used to evaluate the formation by using recording results of logging tools as the main information.

To know which hydrocarbon prospect zone is in the field "Amor", analyzing the subsurface data such as wireline logs was carried out. These data were analyzed to determine the subsurface petrophysical characteristics of rocks. To confirm the validation of logging analysis, the log data were cross-checked using other data such as core data, mud logging data, formation water analysis, and well test. At the end, the zone that contains hydrocarbon could be obtained. This research determines recommendations for perforation zones based on the results of the petrophysical analysis.

Geological Overview

Northwest Java Basin has been known as a major hydrocarbon reservoir in the Pertamina EP Asset 3 working area, Cirebon. This basin is located among the Sunda Shelf in the north, Bogor-fold increase in the south, Region Appointment Karimun Jawa in the east, and West Exposure of Kepulauan Seribu. Northwest Java Basin is affected by a block faulting trending system of north - south.

The fault is oriented north - south, divided into graben basin or subbasin, with Jatibarang, Pasir Putih, Ciputat, Rangkasbitung, and some basement highs, as Arjawinangun, Cilamaya, Pamanukan, Kandanghaur-Waled, Rengasdengklok, and Tangerang subduction. Regional carefully situations based on the information above were included into the distribution of Rengasdengklok High (Arpandi and Patmosukismo, 1975). The stratigraphy of northern part West Java Basin from the oldest to the youngest are:

<u>Bed rock</u>

The bedrock (basement) consists of igneous rocks (granites) and metamorphic rocks (marble and slate). The basement rocks of Triassic age limestone are from the bottom to the top.

<u>Jatibarang Formation</u>

Jatibarang Formation in some places acts as a potential reservoir rock (Jatibarang structure, spruce, fir blocks down). That reservoir rock of this formation, namely: type "massive" where the porosity and permeability are formed by fractures (fracture porosity). Hydrocarbon accumulations have been tested in the offshore area (Pertamina, 1996).

<u>Talang Akar Formation</u>

Talangakar Formation is unconformably deposited on syn-rift phases over the Jatibarang Formation. Initially, this formation is in fluvio-deltaic facies and marine facies. The lithology of this formation is initiated by interstratified limestone, shale, and sandstone of marine facies. At the end of sedimentation, the Talangakar Formation is marked by the end of the syn-rift sedimentation. The formation was deposited during Oligocene to Early Miocene. The source rock potential well-developed in the Jatibarang Sub-basin (Amril *et al.*, 1991).

<u>Baturaja Formation</u>

This formation was deposited conformably on the Talangakar Formation. Lithologically, this formation is composed of limestone, either in the form of outcrop or growing as reef build-up phase of post-rift that marks the regional cover all clastic sediments.

<u>Cibulakan Formation</u>

The formation is divided into two parts, Upper Cibulakan and Lower Cibulakan Members. The formation is divided based on differences in depositional environment, where the Lower Cibulakan Member is a transition deposition (paralic), while the Upper Cibulakan deposition is neritic. The Cibulakan above is divided into three parts: Massive, Main, and pre-Parigi Units.

<u>Parigi Formation</u>

This formation deposited conformably above the Cibulakan Formation consists of limestone. It is a hydrocarbon-producing zone, with common characteristics as a reefal limestone. In some places, the formation occurs as dolomites.

<u>Cisubuh Formation</u>

The Parigi Formation is overlain conformably by Cisubuh Formation consisting of mudstone with alternating thin sandstone and mudstone at the top of the unit (Noble *et al*., 1997). The main rock comprises alternating shales and clays with sandstones and coal intercalations. This formation is of Late Miocene (N18) in age.

<u>Alluvial</u>

The Cisubuh Formation unconformably underlies alluvial deposits, generally derived from young volcanic sediment with a grain size of sand, clay, and gravel. These deposits are of Pleistocene until Recent (N22 - N23) in age.

Data and Methodology

Data

The data used in this study are:

1. Log data (GR, SP, caliper, density, neutron, resistivity)
2. Core Data
3. *Header* Well
4. Well Test

Methodology

Data management phase includes data collection that was used in this research in the form of subsurface log data of the drilling wells, header logging data, and SCAL data. There are seven wells that were analyzed, namely: PI-08, PI-09, PI-10, PI-11, PI-11ST, PI-12, and PI-13. The analysis of the data was based on well log curve drilling including four processes (Schlumberger, 2009), such as follows.

Clay Types Determination

Determining the type of clay could be obtained by plotting the value DIFFND and RATIOND by the equation:

1. Determining the value of DIFFND

$$DIFFND = [\phi N - \phi N] \quad (1)$$

2. Determining value RATIOND

$$RATIOND = \frac{\phi N}{\phi N} \quad (2)$$

Shale Volume Calculation

Gamma Ray log is the best data to obtain the shale volume, because it can be used to calculate volume of shale in porous reservoir (Asquith and Gibson, 1982). It is based on minimum and maximum readings in each zone of the reservoir. Wherein, the minimum and maximum readings of gamma rays showed zone of clean sand and shale zones. Thus, shale volume fraction was calculated using a mathematical equation. There are several methods that can be used to calculate the content of the shale, as described below:

$$V_{sh} = \frac{GR_{log} - GR_{min}}{GR_{max} - GR_{min}} \quad (3)$$

where:

V_{sh} = Volume of *shale* (V / v)
GR_{log} = Reading Gamma Ray (API)
GR_{min} = Reading Minimum Gamma Ray (API)
GR_{max} = Reading Maximum Gamma Ray (API)

Porosity Calculations

The porosity was estimated from the Neutron-Density cross plot (Krygowski, 2003). The Neutron-Density cross plot method includes the simultaneous completion of the response equation for both logs. The estimation cross plot for a clastic reservoir can be made using the following equation:

$$\phi_{total} = \sqrt{\frac{\phi_N^2 + \phi_D^2}{2}} \quad (4)$$

Where:

ϕ_{total} = Total Porosity (v/v)
ϕ_N = Neutron Porosity (v/v)
ϕ_D = Porosity Density (g/cm^3)

$$\phi_{eff} = \sqrt{\frac{\phi_{Ncorr}^2 + \phi_{Dcorr}^2}{2}} \quad (5)$$

ϕ_{eff} = Effective porosity (v/v)
ϕ_{Ncorr} = Neutron Porosity Corrected Against Shale (v/v)
ϕ_{Dcorr} = Density Porosity Corrected Against Shale (v/v)

Water Saturation Calculation using Simandoux Method

Part of the pore space containing water is called water saturation (S_w). While remaining part filled in with oil or gas namely hydrocarbon saturation or S_h (Harsono, 1997).

For shaly sand formations, Simandoux conductivity was suggested to use the following equation:

$$C_t = V_{sh}\, C_c\, S_w + S_w^n \frac{\phi^m}{aXR_w} \text{ ....} (6)$$

where:

C_t = Total Conductivity
C_c = Dispersed Clay Conductivity

When used in saturation, exponent of n = 2.0, is assumed to form a parabolic equation, which can be written as:

$$Y = bx + CX2 \text{ ....} (8)$$

$$S_w = \left(\frac{0.4 \,.\, R_w}{\phi^2}\right) \cdot \left[\sqrt{\left(\frac{V_{sh}}{R_{sh}}\right) + \frac{5 \,.\, \phi^2}{R_t \,.\, R_w}} - \frac{V_{sh}}{R_{sh}}\right] \text{....} (9)$$

where:

S_w = Water Saturation from uninvaded zone (Archie Method)
R_w = Water formation resistivity in formation temperature
R_t = True resistivity formation (Correction invasion of ILD or LLD)
ϕ = Porosity
V_{sh} = Shale volume
R_{sh} = Shale resistivity

Results

Case Study

The case study took place in the northwestern part of the Java Basin. The available data in this case study gained from seven wells were analyzed and shown in Table 1, while the type of logs used is shown in Table 2.

Shale Volume Calculation

The shale volume (V_{sh}) is needed to be calculated to identify the type of formation between clean formation and gross formation (shaly formation). V_{sh} might affect the value of the porosity and water saturation.

Based on the withdrawal of the maximum and minimum GR line, the data were obtained for the marker Top to 4, *i.e*. 36.41 GAPI and 160 241 GAPI. As for the marker 5 to marker 9 is 21.7 GAPI and 152 502 GAPI.

As an example of shale volume value, the calculation was carried out by using linear equations. GR_{min} and GR_{max} values for the marker Top

Table 1. Availability of Data on the Analyzed Wells

Well	Data Las	*Log Header*	*Core*	*Well Test*	Total Marker
PI-08	√	√		√	10
PI-09	√	√	√	√	10
PI-10	√	√			10
PI-11 ST	√	√			10
PI-11	√	√			10
PI-12	√	√	√		10
PI-13	√	√			10

Table 2. Available of Data Log on Wells Analyzed

Well	Lithology			Porosity		Resistivity		
	GR	SP	CAL	RHOB	NPHI	MSFL	LLS	LLD
PI-08	√	√	√	√	√	√	√	√
PI-09	√	√	√	√	√	√	√	√
PI-10	√	√	√	√	√	√	√	√
PI-11st	√	√	√	√	√	√	√	√
PI-11	√	√	√	√	√	√	√	√
PI-12	√	√	√	√	√	√	√	√
PI-13	√	√	√	√	√	√	√	√

to 4, the PI-13 wells at a depth of 8710 feet are know as follows:

GR_{min} (Top 4) = 36.41 GAPI
GR_{max} (Top 4) = 160 241 GAPI
GR_{min} (5-9) = 21.7 GAPI
GR_{max} (5-9) = 152 502 GAPI
GR_{read} (8710 feet) = 103.43 GAPI
GR_{read} (9350 feet) = 99.0299 GAPI

Calculation:

$$V_{sh} = \frac{103.43 - 36.41}{160.241 - 36.41}$$

$$= \frac{67.07}{123.831}$$

= 0.545 (fractions)

GR_{min} and GR_{max} values for the marker 5 to 9, the PI-13 wells at a depth of 9350 feet are calculated as below:

Calculation:

$$V_{sh} = \frac{99.0299 - 21.7}{152.502 - 21.7}$$

$$= \frac{77.35}{130.802}$$

= 0.6103

From the above calculation, it is obtained that at a depth of 8710 feet the V_{shale} (V_{sh}) value is 0545 (fraction), and a depth of 9350 feet at 0.6103 (fraction).

Calculation of Effective Porosity (φe)

Log types used in the calculation of porosity is neutron-density combination log. The combination of both logs used cross-plot in Figures 1 and 2, so that the values obtained are incorporated into the calculation of the density porosity and neutron porosity.

The data from the cores show that the matrix structure "TL" is quartz. Based on Table 3 the

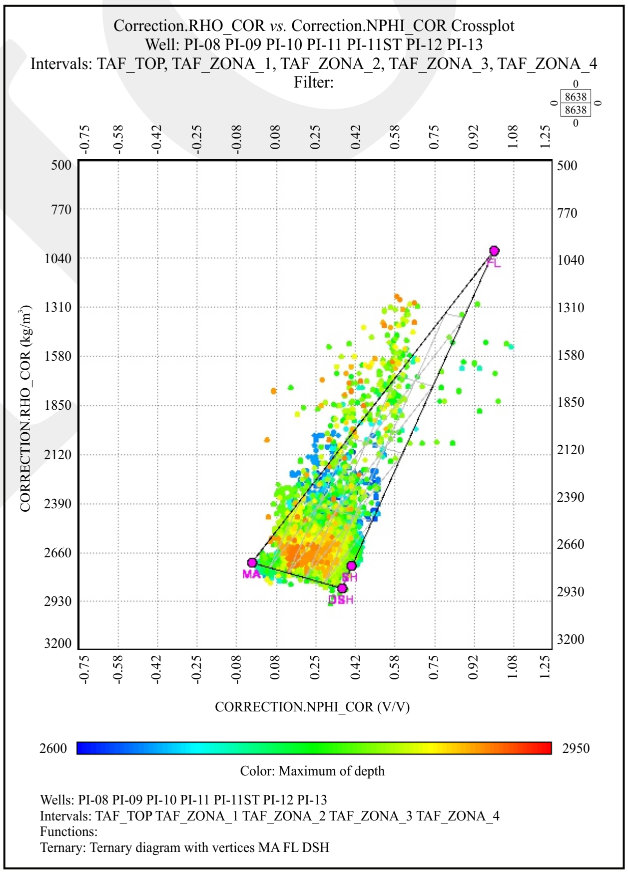

Figure 1. Density-Neutron Crossplot Log in Marker Top-4.

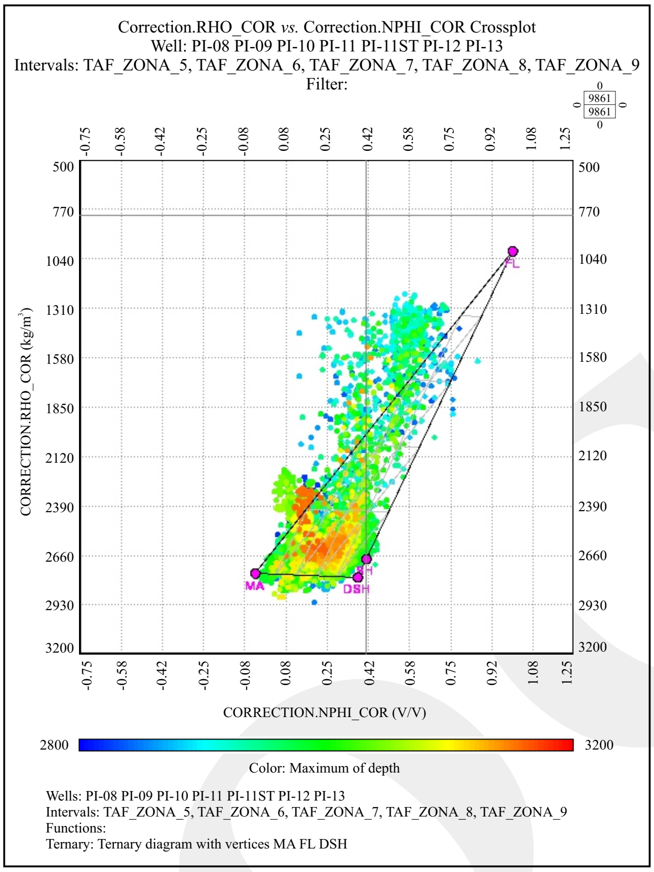

Figure 2. Density-Neutron crossplot Log In Marker 5-9.

density matrix of sandstone (MA) is worth 2650 kg/m^3. The structure of "TL" shows that clay is present in the form of illite based on the values listed in Table 3, that is the obtained initial value of dry shale matrix (DSH). Then, the fluid density value used is 1000 kg/m^3 (freshwater).

The value of the shale rock matrix density (SH) obtained from the cross-plot between neutron density log can be seen in Figures 1 and 2. The Density-Neutron log cross-plot aims to obtain the value of DSH (Dry shale), the value RHOB, and NPHI of shale which could be used to calculate the density-neutron porosity.

Table 3. Response Matrix Tool against Mineral Log (Source: Hughes, 1996)

Lithology	Log RHOB Density (kg/m^3)	Neutron logs NPHI (v/v)
quartz	2650	-0.04 - 0
calcite	2710	0
dolomite	2850 - 2880	0001

In Figure 1, DSH values are obtained by NPHI 0.3 and RHOB 2780, and 0.39 by NPHI SH value and RHOB 2596.25. While in Figure 2, the obtained values for DSH are derived from NPHI 0.24 with RHOB 2780, and NPHI 0.3 with RHOB 2618.75. These values are used in density-neutron porosity calculation. The value differences based on the distinction of parameter used start from the calculation of the volume of shale.

For the calculation, the equation 3.13 Density-Neutron porosity was used. Here is an example of the calculations on PI-13 well depth of 8710 feet, shown as below:

$\rho_{MA} = 2.65$ g/cm^3
$\rho_{log} = 2.5$ g/cm^3
$\rho_{FL} = 1$ g/cm^3
$\rho_{sh} = 2.596$ g/cm^3
$\phi_{Nlog} = 0.369$ v/v
$\phi_{Nsh} = 0.39$ v/v
$V_{sh} = 0.545$

Calculation:

Neutron porosity:

$$\phi_{Ncorr} = 0.369 - \left[\frac{0.39 \text{ x } 0.30 \text{ x } 0.545}{0.45} \right]$$

$$\phi_{Ncorr} = 0.369 - 0.1417$$

$$\phi_{Ncorr} = 0.227 \text{ (fraction)}$$

Density porosity:

$$\phi_{Dcorr} = \frac{2.65 - 2.58}{2.65 - 1} \quad \left[\frac{0.39 \text{ x } 0.30 \text{ x } 0.545}{0.45} \right]$$

$$\phi_{Dcorr} = 0.09 - 0.06$$

$$\phi_{Dcorr} = 0.03 \text{ (fraction)}$$

Effective porosity:

$$\phi_e = \sqrt{\frac{2.27^2 + 0.03^2}{2}}$$

$$\phi_e = \sqrt{\frac{0.0515 + 0.009}{2}}$$

$$\phi_e = \sqrt{0.0303} = 0.163 = 16.3\%$$

Then, the resulted porosity data are plotted in Figures 3 and 4.

Figure 3 indicates the number of R^2 of 0.82, while Figure 4 shows the R^2 value of 0.67. These figures show that the results from the analysis of

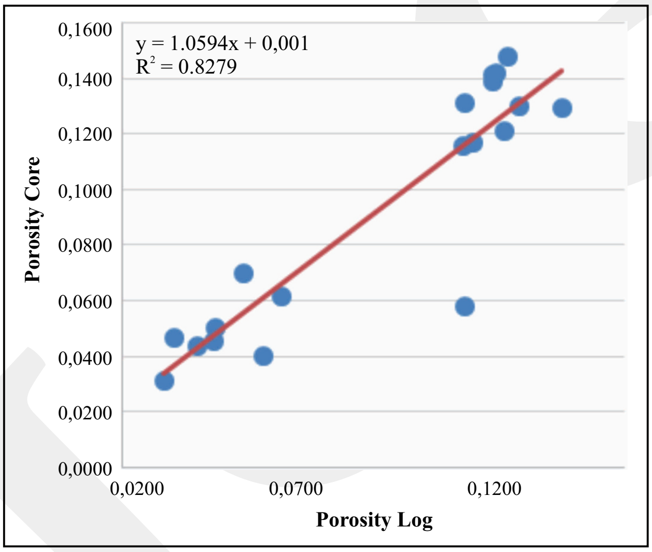

Figure 3. Validation and Core Porosity Log in PI-09 wells (9371 ft - 9390 ft).

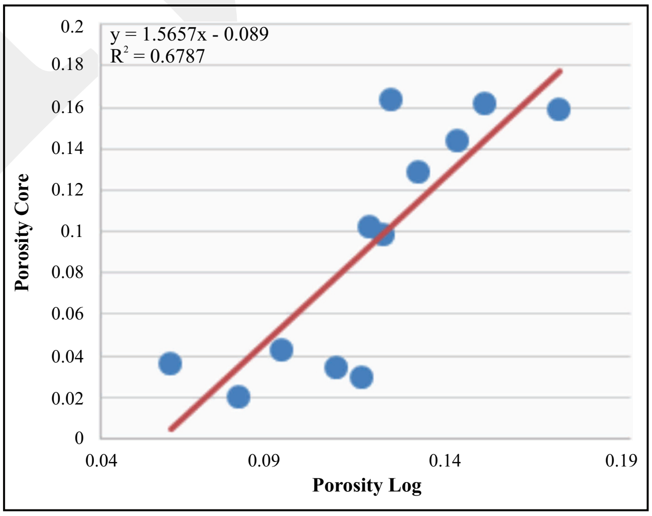

Figure 4. Porosity Log and Core Validation in PI-12 wells (10,029 ft depth - 10,058 ft).

log porosity have a good degree of validation to be used as the petrophysical properties.

Water Saturation Calculation

The calculation of the value of water saturation uses a parameter volume Simandoux shale, shale resistivity, true resistivity, water resistivity, porosity effective, turtoisity constant, cementation factor, and saturation exponent. The use of Simandoux method in the analysis of water saturation calculations is due to the structure of "TL" which is a formation that has a shaly sand lithology.

One method of separate searching for water resistivity values uses the Pickett Plot. This method uses a parameter of true resistivity (RT) and effective porosity. This method is used to find the point where the reservoir has a composition of 100% water fluid. The 5 - 9 marker is used for water zones in the well PI-08 with the interval of 10,358 - 10,369 feet (Figure 5).

The identification of water zone in a qualitative perspective is that the zone has to be porous, and it should be in the deepest well which has been analyzed. While for log analysis, it shows a low value of resistivity log (Figure 6).

To use this method, striker plot values of a, m, and n are required that can be obtained from the SCAL data where a and m are the results of a plot between porosity and formation resistivity factor. N value is obtained from the plot of the saturation of brine and formation resistivity factor (Figure 7).

The graph plots the results of 3 and Chart 4. The obtained values are: a = 1, m = 1.6795, and n= 1.8921. The results of a, m, and n are used on the striker plot to determine the resistivity. Then, eventually the value of RW is obtained (Figure 8).

Based on the Picket plot method, the obtained value of Rw is 0.166 ohmm with a formation temperature of 148 ° C. This value is used for water saturation calculation below.

The example calculation of water saturation using Simandoux method on Well PI-13, depth of 8710 feet can be seen as follows:

ϕ_{eff} = 0.199 fraction
R_w = 0.38 ohmm
V_{sh} = 0.545 fraction
R_{sh} = 3.199 ohmm
R_t = 2.669 ohmm

Calculation:

$$S_w = \left(\frac{0.4 \times 0.166}{0.163^2}\right)\left[\sqrt{\left(\frac{0.545}{3.199}\right) + \frac{5 \times 0.163^2}{2.669 \times 0.166}} - \frac{0.545}{3.199}\right]$$

S_w = 1.00 (fraction)

Based on the validation of data core values of the obtained percent of water saturation, calculation error result in Simandoux method is only about 7.52% (Table 4). Thus, the method is shown to produce accurate results.

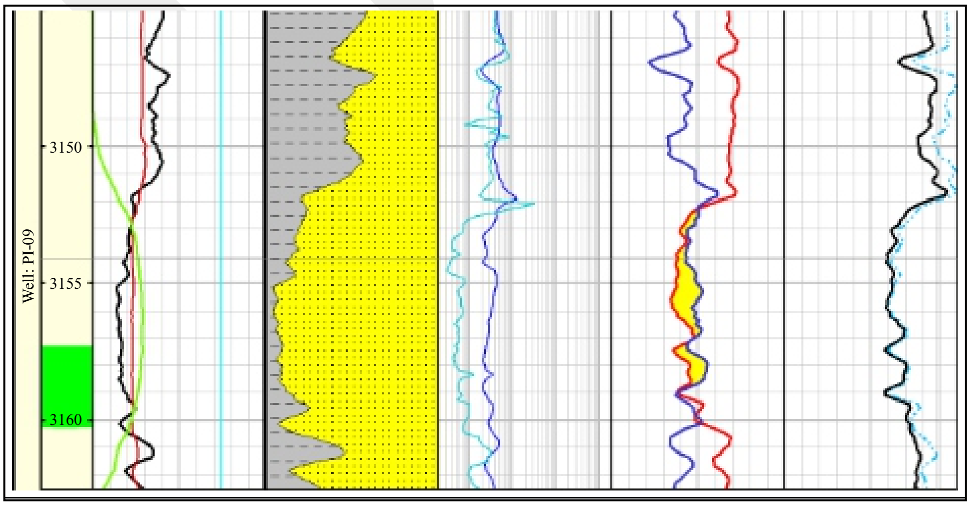

Figure 5. Determination of Water Zone in PI-08 wells (10,358 -10,369 feet).

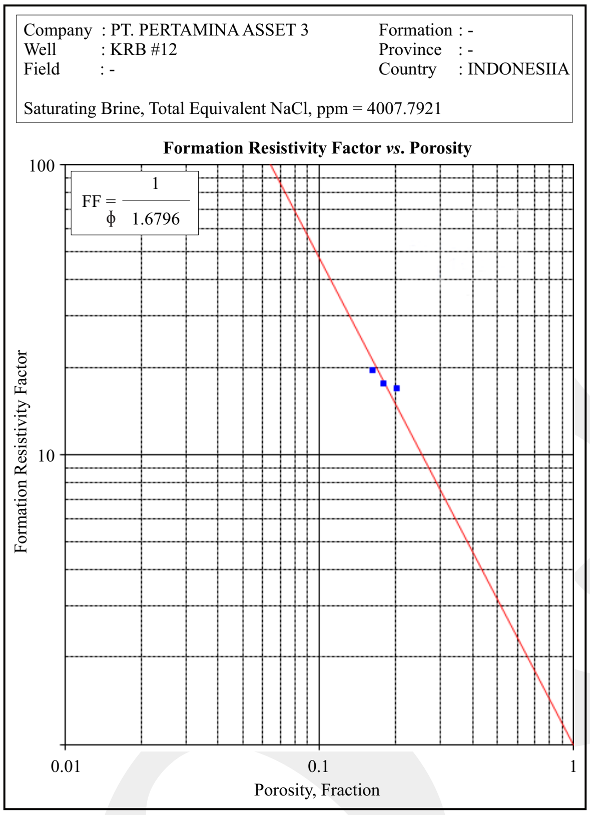

Figure 6. Plot of Porosity Formation Resistivity Factor to Acquire Value of a and m.

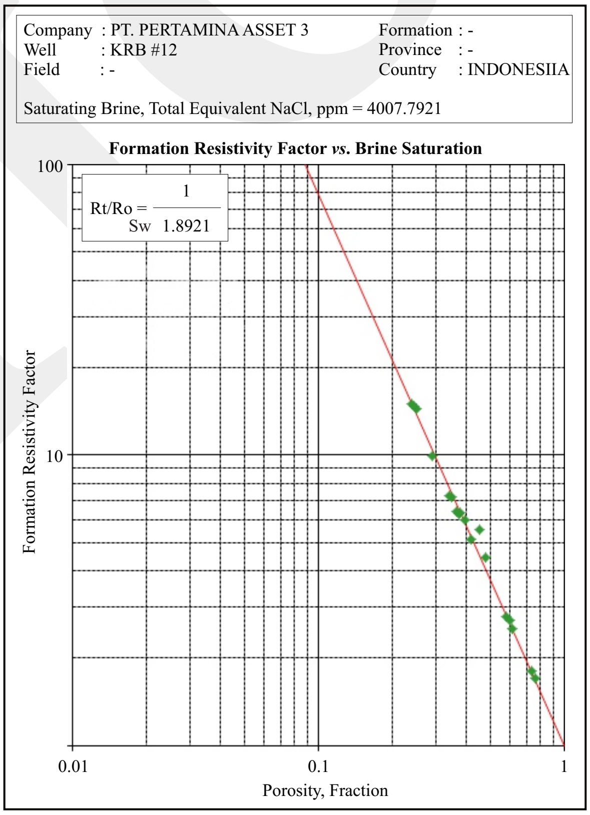

Figure 7. Plot of Water Saturation *vs*. Formation Resistivity Factor for Earned Value n.

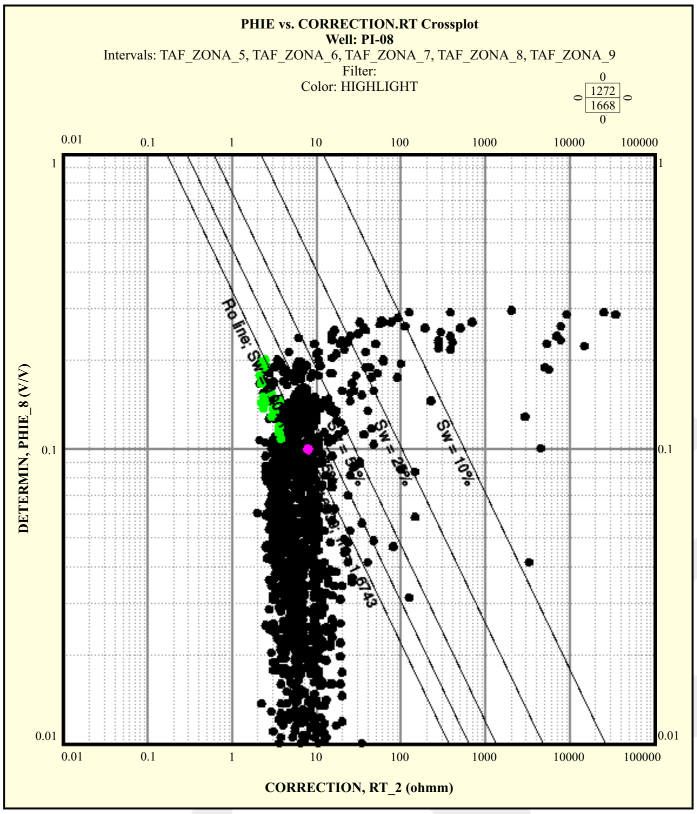

Figure 8. Determining Rw value using picket plot method.

Table 4. Comparison of Methods Saturation Results Simandoux with Core Data PI-09 wells (9,371-9,390 ft)

Depth (Feet)	Air Core Saturation (Fraction)	Water saturation Simandoux (Fraction)
9,371.0	0.65	0.6670
9,373.0	0.75	0.7473
9,374.3	0.76	0.7234
9,376.3	0.75	0.7415
9,377.4	0.75	0.7506
9,379.3	0.76	0.7982
9,380.5	0.67	0.6912
9,382.5	0.61	0.7423
9,383.9	0.65	0.7187
9,384.9	0.65	0.8146
9,387.3	0.77	0.9481
9,392.7	0.42	0.1615
9,394.6	0.45	0.2846
9,397.2	0.44	0.2096
9,400.7	0.54	0.3032
9,402.2	0.43	0.2279
9,403.7	0.52	0.3196
9,406.8	0.66	0.7647
9,390.0	0.51	0.3054
Average	0.62	0.57
% Error		7.52%

Cut-off

Based on the results of log data qualitative interpretation, there are twenty intervals identified as reservoirs. Then, the cut-off value determination of porosity, volume of shale, and water saturation are determined based on the well test data.

To cut-off the porosity and shale volume, porosity and volume values are plotted as the shale, as shown in Figure 9. The test data show that there is a proven proficiency level of the lining of the flow. Thus, the determination of cut-off V_{shale} is determined by looking at the largest value of V_{shale}, while the cut-off determination of porosity can be determined by looking at the value of the smallest porosity in the layer. This indicates that in the biggest V_{shale} and smallest porosity in layer, hydrocarbons can flow. Figure 9 shows a cut-off value V_{shale} of 23% and cut-off porosity of 10.6%.

Figure 10 shows that the blue zone on the cut-off Sw above is analyzed with a zone marker 9 on well PI-08 and PI-09, where the results of well test show that the type of the flowing fluid is water. Thus, the cut-off is carried out under the

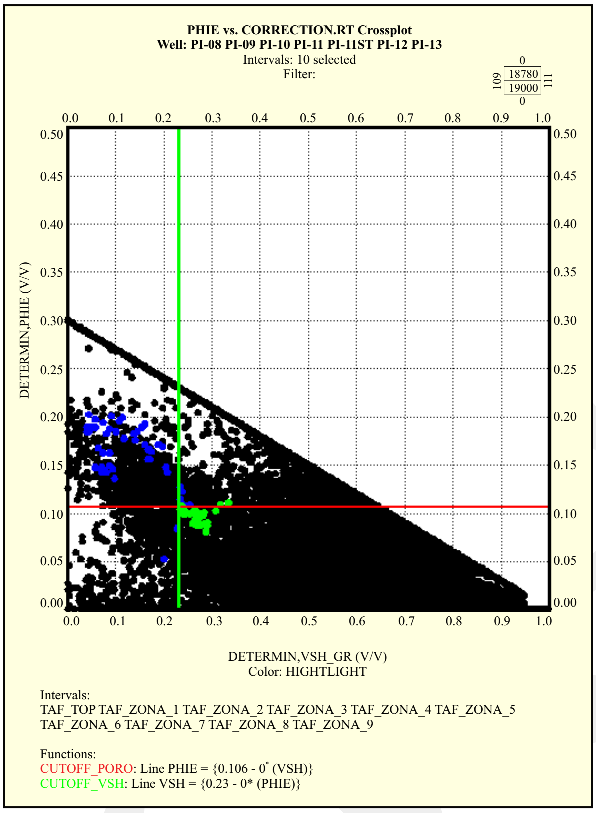

Figure 9. Cut-off the porosity *vs*. V_{sh} based Test Data.

zone. Sw cut-off values are obtained for the structure of "TL" of 71% (Figure 10). These values are applied to all the interval structure of "TL" for subsequent calculation of the pay summary.

Lumping Reservoir (Pay Summary)

Based on the results of the determination of the petrophysical cut-off in the field "Amor", then being carried to seven lumping reservoir wells which were analyzed to see the zones and potential hydrocarbon prospects. The lumping of results, then there are some prospect zones containing hydrocarbons that have not been produced.

On well PI-08, there is one zone recommended to be perforated at intervals of 9,632 - 9,662 ft, where this zone has a thickness of 22 ft of net pay. However, the PI-09 well having no interval is not recommended, because it has no value of net pay.

The PI-10 is a recommended well perforated in the interval of 9,420 - 9,468 ft and has a 6 ft net pay interval 9,475 - 9,516 ft with 12 ft of net pay, and intervals of 10,155 - 10,175 ft with a net pay of 6 ft. Within PI-11, two intervals those are 9,268 - 9,288 ft and 9,921 - 9,947 ft with net pay of 15 ft and 14 ft m respectively, are recognized. However there is only one zone that is recommended to be perforated at the intervals of 9,268 - 9,927 ft, where this zone has a thickness of 11 ft of net pay. In well PI-12, are recommended two intervals, which are 9,396 - 9,461 ft and 10,047 - 10,059 ft with a net pay of 34 ft and 8 ft. Then, well PI-13 within interval of 9,356 - 9,416 ft has 31 ft of net pay interval m and 9,980 - 10,000 ft with 14 ft of net pay.

Recommendations for the zones above are only based on the petrophysical analysis to know the parameters of the shale volume, effective porosity, and water saturation. In this research, the zone which is considered as a hydrocarbon zone is the zone with the thickness of net pay more than 5 ft.

Discussion

Analysis of the structure shows that "TL" is a kind of shaly sand formations. So that, the determination of shale volume uses linear models with Gamma Ray log readings ($I_{sh} = V_{sh}$). As an example at PI-13, shale volume that obtained from the calculation at depth of 8,710 ft is 0.545 and at depth of 9,350 ft is 0,6103. Shale volume will be used for a calculation affecting larger or smaller value of the porosity and water saturation. Shale volume is also used to determine pay zone thickness through the cut off.

In this research, to estimate porosity value is to use a density-neutron calculation method. After obtaining porosity value, then validated the porosity from calculation of density-neutron method and from data cores. The result shows that at PI-09 (at depth 9,371 - 9,390 ft), R^2 value is 0.83, while in PI-12 (at depth 10,029 - 10,058 ft), R^2 value is 0.68. The Figures 1 and 2 show the level of similarity between the porosity of the calculation results with the data core. It indicates that the calculation of the porosity of the equation density-neutron resulted in accurate data and those can be applied to calculate porosity at "TL" structure.

Water saturation calculation within this paper used Simandoux method, because lithology in this structure is shaly sands. Water saturation calculation using Simandoux method shows that at PI-09 well (at depth 9,371 - 9,390 ft) average saturation is 57%, while from core data, average saturation is 62%. Error value between water saturation using calculation and core data is 7.52%. This small error value tends to indicate that the Simandoux method can be applied to calculate water saturation at "TL" structure accurately.

After that, the cut-off value for each item (shale volume, porosity, and water saturation) from well test data is determined. The cut-off value of each item are, for shale volume of 23%, porosity is 10.6%, with water saturation of 71%. The value will be applied to cut-off the data for each item from calculation to all of the reservoirs at the structure of "TL" to get the value of net pay thickness. Then after cutting-off Net Pay thickness for each well is obtained. There are 11 recommended interval zones that have hydrocarbon prospects in the "TL" structure.

Conclusion

From the analysis of logging on the structure of "TL", there are three productive zones, namely Zone 4 (8,881 - 8,904 ft), Zone 5 (9,232 - 9,324 ft), and zone 9 (10,150 - 10,187 ft) which various depths in each well.

Limits to determine the thickness of the reservoir containing hydrocarbons were obtained from the cut off that shale volume is 23%, porosity 10.6%, and water saturation is 71%. Zones that have the physical properties of rocks under these limits are not regarded as productive reservoirs.

The results of the evaluation of the productive zones in the well cutoff value that PI-08 with interval 9,632 - 9,662 ft (Marker 5) obtained 22 ft net pay. PI-09 at the interval 9,917 - 9,944 ft was obtained by dry hole. In well PI-10 which gained three productive zones with the interval of 9,420 - 9,468 ft (Marker 5) obtained 6 ft net pay, interval of 9,475 - 9,516 ft (Marker 5) obtained 12 ft net pay, and the interval of 10,155 - 10,175 Ft (Marker 9) with net pay 6 ft. In wells PI-11 which gained two productive zones with the interval of 9,268 - 9,288 ft (Marker 5) obtained 15 ft net pay, interval of 9,921 - 9,947 ft (Marker 9) acquired net pay of 14 ft. Furthermore, well PI-11ST Interval 9,268 - 9,927 ft (Maker 9) obtained 11 ft net pay. In wells PI-12 there are two zones namely productive interval 9,396 - 9,461 ft (Marker 5) which obtained 34 ft net pay, interval 10,047 - 10,059 ft (Marker 9) acquired net pay 8 ft. In PI-13 wells there are two zones, namely the productive interval of 9,356 - 9,416 ft (Marker 5) which obtained 31 ft net pay, interval of 9,980 - 10,000 ft (Marker 9) acquired net pay of 14 ft.

Based on the correlation analysis of wells, development drilling point coordinates can be carried out to the north. This is due to the discovery of the more productive zones in the north, while the water zone is in the southern area.

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