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Petrophysical Analysis Using Lucia Method

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ABSTRACT: *Parigi Formation Carbonate Reservoir is very well developed in the North West. Java Basin More than hundreds or even thousands of wells in the North West Java area have been drilled penetrate carbonate rock reservoirs, to date hundreds of wells are still producing from the reservoir, which until now was believed to originate from carbonate rock reservoirs which are all located in North West Java the basin, both onshore and offshore. Some subsurface data in the form of geological, reservoir and geophysical data in the northern West Java basin that can be used as supporting data for the study, but in this study it was only used from the fields has complete data such as core rock data and also has complete log data especially the existence of sonic log data which will be very useful in petrophysical analysis in reservoirs has secondary porosity. This research is also useful for determining perforation intervals and There is also the possibility of developing other intervals besides the existing carbonate rock reservoir known. This research is useful for determining perforation intervals and developing intervals in addition to the known carbonate rock reservoirs. By studying reservoir petrophysical analysis carbonate rocks based on log responses and also available core rock data using the method Lucia's classification is expected to be able to solve problems regarding the petrophysics of rock reservoirs carbonate. By using the Lucia classification method to determine the hydrocarbon potential of rock intervals carbonates can be found*

Keywords: *Cibulakan Formation, Lucia Classification, Carbonate reservoir, Petrophysical Analysis*

I. INTRODUCTION

The Cibulakan to Parigi Formation Carbonate Reservoir is very well developed in the Java Basin North West. More than hundreds or even thousands of wells in the North Answerarat area have been drilled penetrating the Carbonate Rock Reservoir, to date hundreds of wells are still producing from the reservoir which until now is believed to originate from Carbonate Rock reservoirs, all of which are located in North West Java Basin is both onshore and offshore.

Although there is a lot of subsurface data in the form of geological, reservoir and geophysical data in the North West Java Basin that can be used as supporting data for studies, in this study it is only used from fields that have complete data such as core rock data and also have Complete log data, especially sonic log data, will be very useful in petrophysical analysis in reservoirs that have secondary porosity.

By studying the petrophysical analysis of Carbonate Rock reservoirs based on log responses and also available core rock data using the Lucia classification method, it is hoped that we can answer questions about the petrophysics of Carbonate Rock reservoirs, so that hydrocarbon potential that may have been overlooked in the Carbonate Rock interval can be discovered. This research is also useful for determining perforation intervals and also the possibility of developing other intervals besides the currently known Carbonate Rock reservoirs.

II. LITERATURE REVIEW

Petrophysical analysis is part of the reservoir characterization process needed to be able to knowing the type of lithology that makes up the reservoir, the distribution of the reservoir vertically and laterally, knowing the petrophysical quantities of each reservoir such as resistivity, porosity and other petrophysical quantities for

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saturation calculations which can ultimately be used to calculating whether the reservoir reserves are economical enough for geophysical exploration activities or hydrocarbon exploitation.

Hydrocarbon reservoirs that are often found in the world generally consist of two types, namely clastic (sandstone) and carbonate (limestone). Petrophysical analysis using the Lucia classification method in carbonate rock reservoirs is still very rare and if there is an attempt to find out in which part of the reservoir the productive zone is located and how it is distributed it is not easy.

Carbonate rock reservoirs (hereinafter referred to as limestone) are produced by deposition in transitional to shallow marine environments. Limestone reservoirs are a type of reservoir rock that is widely discussed by geologists and has an important role in the geological reconstruction of an area. Limestone reservoirs are produced by deposition in transition areas and shallow seas (Badarinadh Vissapragada, et.al 2000), stating that carbonate material contains very high calcite minerals, and because of its unique formation process it can form various kinds of carbonate rocks from Mudstone to Grainstone each of which has its own characteristics. Apart from the reservoir mineral calcite, limestone, like other sedimentary rocks, usually contains clay minerals such as clay and shale. The combination of the presence of various clay minerals and the presence of micro porosity in carbonate rock reservoirs sometimes means that resistivity log readings in limestone reservoirs can be very lower than they should be so that they can be interpreted as reservoirs that do not have potential hydrocarbon content in them.

Not many countries in the world have such a wide variety of carbonate rock reservoirs. Indonesia is one of the countries that has hydrocarbon reservoirs in carbonate rocks with very diverse variations. Based on research results from previous researchers, they generally discuss petroleum geology which includes tectonic settings, stratigraphy and petroleum systems which include source rock and maturation, reservoirs, migration, traps and seals as well as hydrocarbon potential in the area, whereas in this research the emphasis is on log response analysis for Characterization of lithology and productive zones in limestone reservoirs using the Lucia classification method.

III. MATERIAL AND METHODS

The method used in this formation evaluation analysis is by using a method which in petrophysical software is known as a deterministic method. The technique used is to analyze log, core data and a combination of the two

The tools used consist of:

1. Petrophysics Software (Geologist, Interactive Petrophysics).
2. Workstation with specifications min. 16 GB RAM and 64-bit OS.

The method used in this research is focused on finding correlations with the physical properties of the reservoir whose parameters are obtained from cores and logs (Figure 3.1), so the following research methodology and stages are needed:

a. Select a drilling field or well that produces gas, oil or water from the lower Cibulakan carbonate formation reservoir (formerly known as the Baturaja formation) which has core data to study the physical properties related to the amount of oil that has been produced.
b. Study the properties of logs, especially porosity logs, which will be correlated with the physical properties of the reservoir from the core data.

In general, this research consists of three groups of stages, namely:

a. Study of lithological characterization in reservoirs of various carbonate rocks in the area research on megascopic and microscopic core rock analysis as well as log response characteristics for each carbonate rock using the Lucia classification method.
b. Study of the characterization of various carbonate rocks acting as reservoirs and non-reservoirs qualitatively in relation to the presence of grain size of the carbonate rock constituents and the presence

of micro porosity in carbonate rock reservoirs

c. Study on determining parameters for petrophysical calculations validated with measurements on core rock for quantitative characterization of productive zones in carbonate rocks.

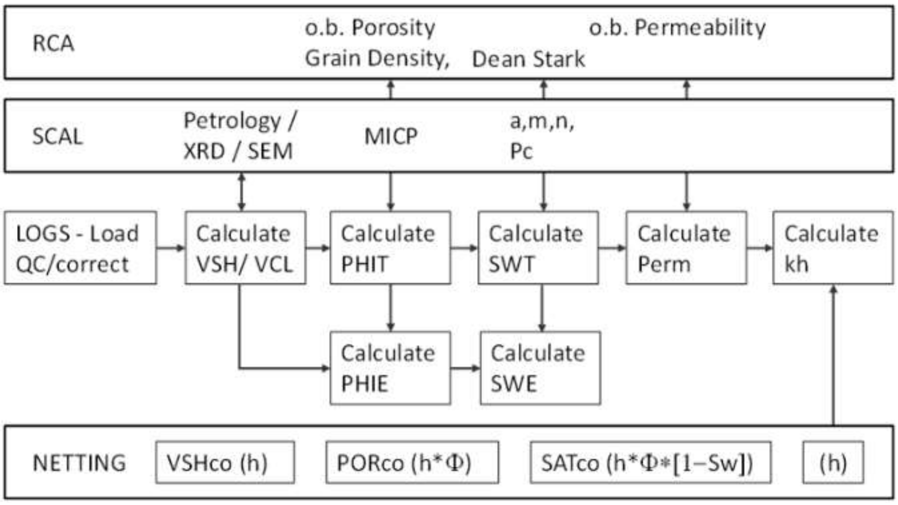

Figure 1: Petrophysical Workflow (Modified from https://www.virtualpps.com,2023)

IV. RESULTS AND DISCUSSION

Making data plots. The first plot is a plot of porosity versus permeability on a classification graph carbonate rocks Lucia, 1995 (Figure 2) to determine the data we have in Class how many of Lucia's carbonate classifications are there? The second plot is the capillary pressure plot (Pc) versus water saturation (Sw) from each class that we get from the first plot (Figure 3).

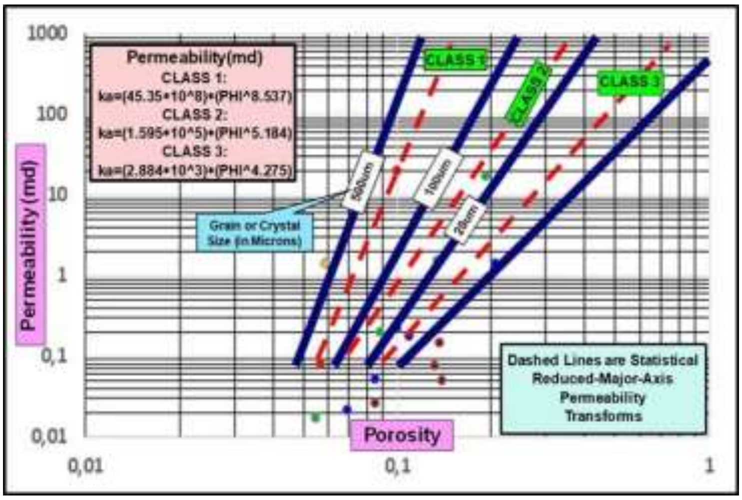

Figure 2 : Class Determination Based on Lucia's Classification (1995)

The stages of data analysis using the Lucia classification application are as follows:

Calculate the water saturation (Sw) and permeability (ka) values based on the data we have obtained.

Previously using the equation from Lucia, 1995 (Figure 4, Phiip is porosity intergranular/intercrystalline, H is the height (in feet) of the free water level or at Pc=0. Based on this equation, we can see that the water saturation value in carbonate reservoirs can be calculated for wells that only have a porosity log without having to have a resistivity log. Figure 5 shows the results of Sw calculations for each class using the Lucia equation without resistivity logs. Thus we can create saturation (isosaturation) distribution map in carbonate rocks using only porosity log data without having to have a resistivity log provided there is data from core analysis at the interval we are analyzing.

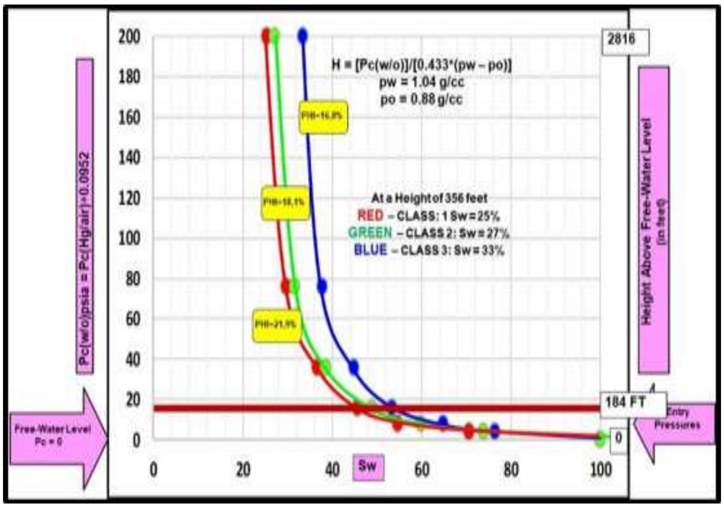

Figure 3: Determination of H for Free Water Level

- **CLASS 1: [100um – 500um]**
  ka = (45.35*10^8) * (PHIip^8.537)
  Sw = (0.02219*H^-0.316) * (PHIip^-1.745)

- **CLASS 2: [20um – 100um]**
  ka = (1.595*10^5) * (PHIip^5.184)
  Sw = (0.1404*H^-0.407) * (PHIip^-1.440)

- **CLASS 3: [<20um]**
  ka = (2.884*10^3) * (PHIip^4.275)
  Sw = (0.6110*H^-0.505) * (PHIip^-1.210)

Figure 4 : Equations for Calculating Sw and ka from Lucia (1995)

Make a plot between Sw versus Porosity at the interval above the free water level (Figure 5), for example the height is 184 ft, which is obtained from the plot between PC versus Sw that has been done previously. From this plot we have an equation that shows the relationship between Sw and porosity, so for each porosity value for each class we can find the Sw value using the relationship equation between the two

Plot Sw values versus depth at the analyzed intervals for Class 1, 2 and 3 of the results calculations using the Lucia equation in Figure 4 and compare the results with Sw the results of calculations using the Archie equation or other equations if the carbonate rock being analyzed is not a clean formation. Determine the interval for each Class as a Hydraulic Flow Unit interval based on Lucia's classification by comparing it to the Sw curve from the Archie equation calculation or others. The Sw curve calculated from Lucia's classification is closest to the curve from other calculations, showing that in this interval it is the HFU Class of the Class curve that is closest to it (Figure 6). For example, in Figure 6 we can see that almost all of the interesting zone intervals are in Class 3 (in blue), because the Sw calculation results from the Lucia equation (blue curve) are closest to the Sw calculation results from Archie (black curve).

Plot the Resistivity Index (RI) versus Water Saturation (Sw) on a log-log scale and compare the results of the plot to the value n (saturation exponent) = 2. The n value is obtained from the equation :

$$n = LOG(Rt/Ro)/LOG(Sw)$$

If the plot results are to the right of the n = 2 line (>2), then the carbonate reservoir is oil wet, whereas if the plot is to the left of the n = 2 line (<2), then the reservoir is water wet (Figure 7).

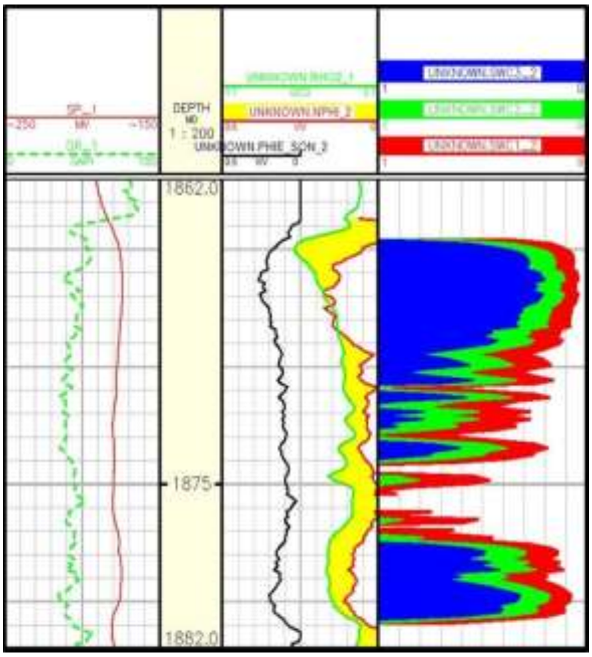

Figure 5 : Sw Calculation Without Resistivity Log

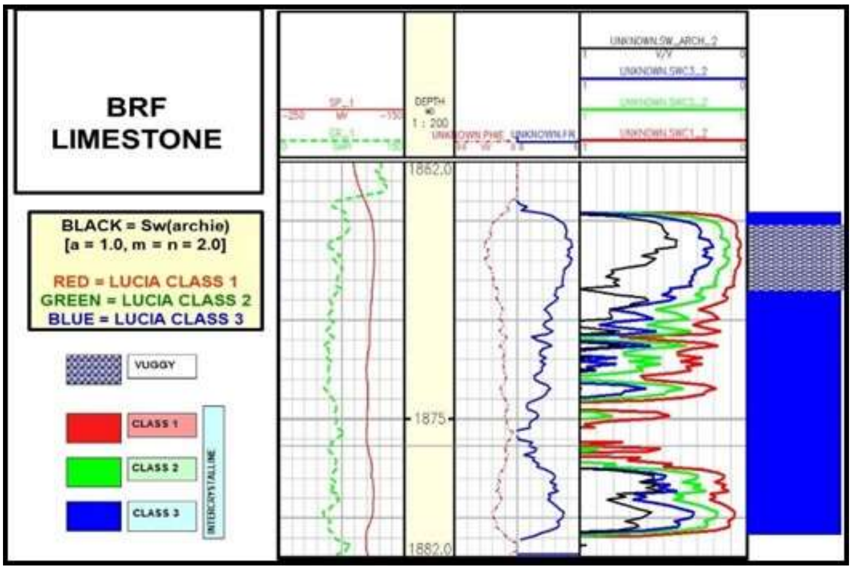

Figure 6 : Plot of Sw versus Depth for Determination of HFU

Determine the Rock Fabric Number (RFN) by plotting the porosity of the sonic log versus permeability, ka (Figure 8). Calculate Swirr for matrix porosity using the Jenning and Lucia, 2003 method equation and sonic porosity:

$$\mathbf{Swirr} = e^{c(\lambda)} * \mathbf{Fsonic}^{d(\lambda)}$$

Where

$c(\lambda) = -co + [c1*\ln(\lambda)]$ $d(\lambda) = -do + [d1*\ln(\lambda)]$ co = 7.163 c1 = 3.063 do = 1.883 d1 = 0.6100 λ = Rock Fabric Number

CLASS 1 λ = 0.5 – 1.0 – 1.5 CLASS 2 λ = 1.5 – 2.0 – 2.5 CLASS 3 λ = 2.5 – 3.0 – 4.

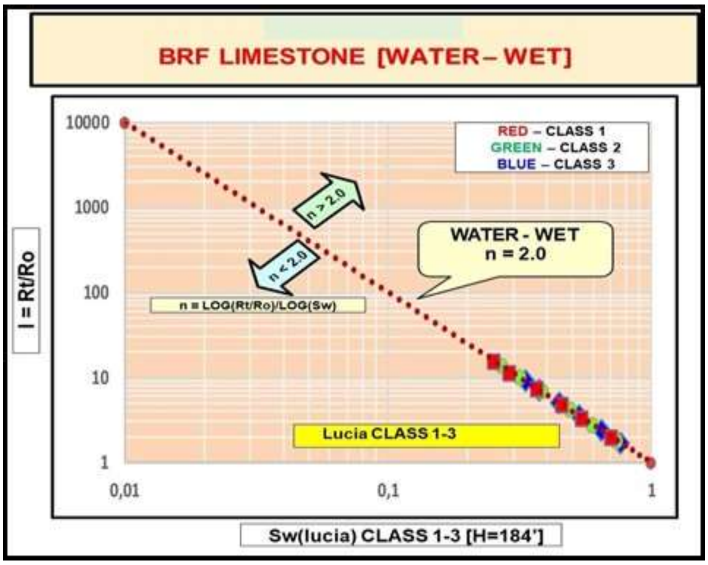

Figure 7 : Determination of Reservoir Wettability

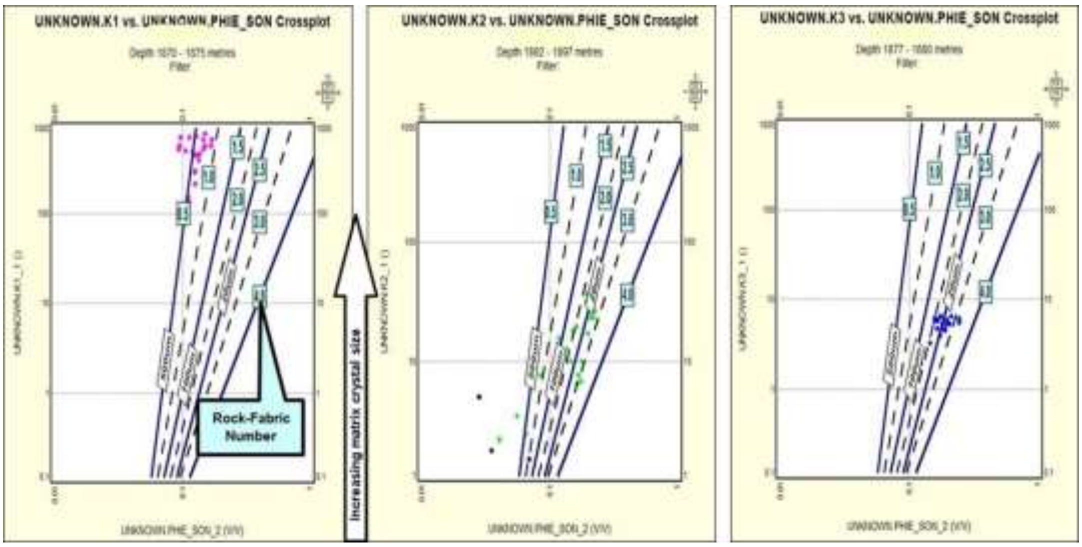

Figure 8 : Plot to Get RFN Value

Calculate the SW matrix with the equation:

Sw(matrix) = [(1/PHIsonic^2)*(Rw/Rt)]^0.5

Calculate Kro and Krw from the porosity matrix using the equation from the Jones, 1945 method as in figure 9

Plot the Kro versus Krw values obtained from the calculation above to get the Swirr value and Sor value as in figure 10

Calculate the Rock Fabric Number (RFN) with the equation:

λ = e^EXP

Where:

EXP = {CO+[DO+ln{Φ}]+ln (Sw)}/{C1+[d1+ln{Φ}]}

co = 7.163 c1 = 3.063 do = 1.883 d1 = 0.6100

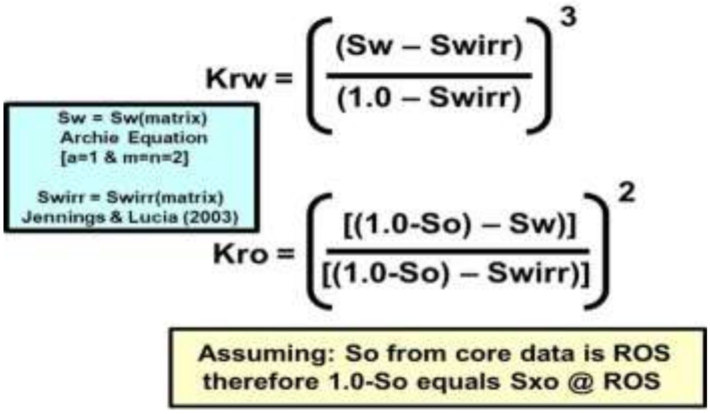

Figure 9 : Jones Equation, 1945 To Calculate Kro and Krw (Asquith, 2017)

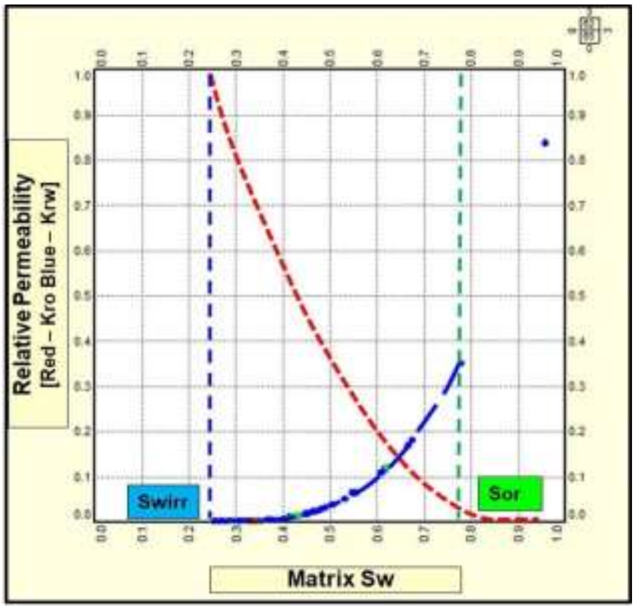

Figure 10 : Plot Kro and Krw to Get Swirr and Sor Values

Plot Rock Fabric Number (RFN) versus depth to obtain the zonation of the carbonate reservoir interval we are analyzing (Figure 11). Based on figure 11 we can see that even though they have relatively the same porosity (black curve) there are actually 3 Classes from the Lucia classification which show differences in the grain size of the carbonates which also shows differences in permeability in these zones, plus 1 (one) zone which is the Vuggy zone which will only be visible if we have a log Image. This can also explain to us why the carbonate reservoirs we have with the same porosity range at the time of production can produce quite significantly different production figures.

Calculate the water saturation in the zone we are analyzing after we know what class the zone is in using the method we have done before, for example in this case the zone is in Class 3, with Lucia's equation for Class 3 we can calculate the Sw value in the reservoir the carbonate. Plot the results of the Sw calculation together with the Sw results of calculations using other equations (Archie as an example), if the Sw value calculated using the Lucia method is greater than or equal to the results of Archie's calculations, then the zone is a hydrocarbon column (Figure 12), however If it is the other way around, then the zone has changed from being a hydrocarbon zone to a water zone, possibly absorbed by adjacent wells or due to the presence of injection wells in the area.

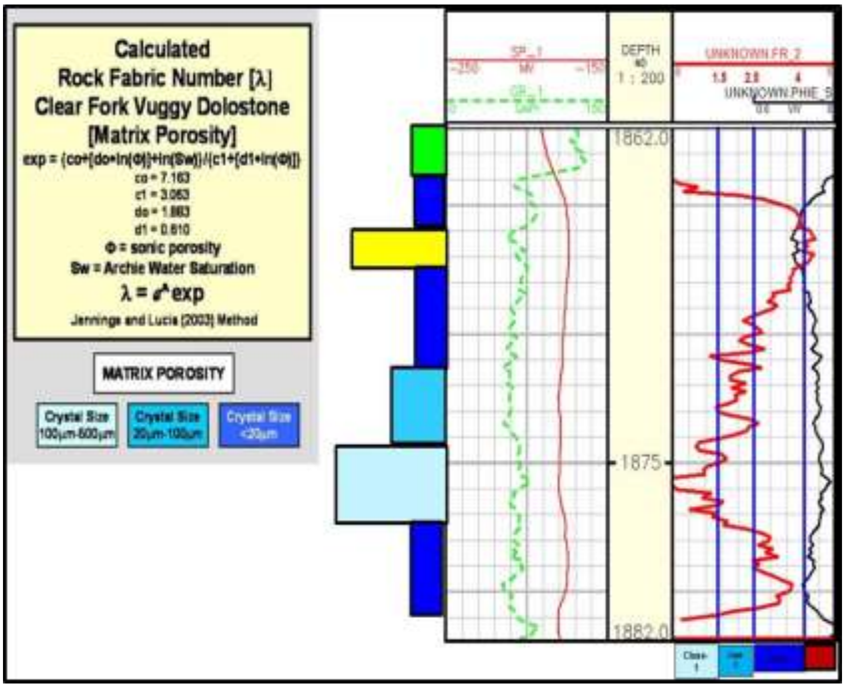

Figure 11 : Plot Rock Fabric Number For Zoning

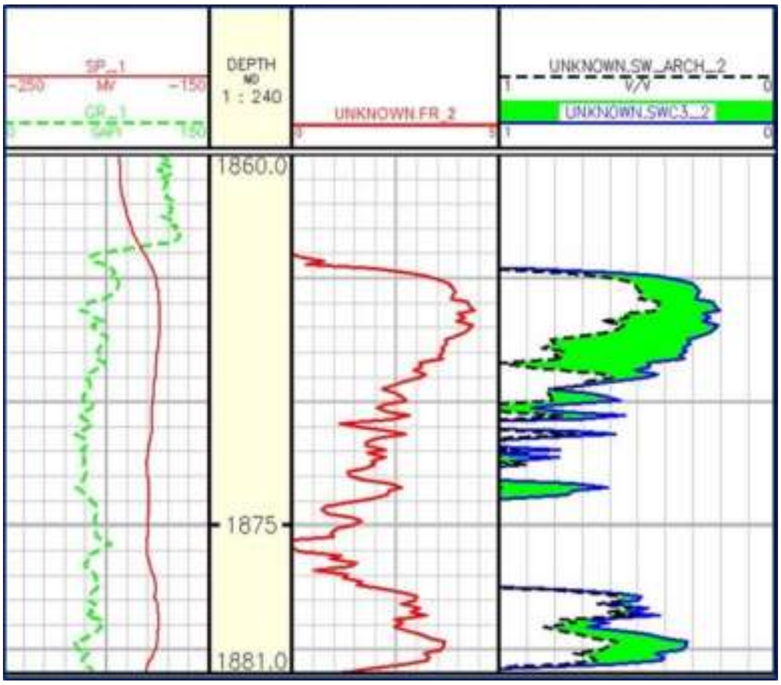

Figure 12 : Thick Transition Zone in Carbonate Reservoirs

This method can also be used to select perforation zones in candidate Work Over or Well Intervention wells to replace CO logs in existing wells

V. CONCLUSION

The conclusions from this research are:

1. Carbonate Rock Reservoirs can be characterized based on log responses after this research is completed
2. Can identify petrophysical parameters in carbonate rock reservoirs, which are usually limestone, which may

be different from limestone reservoirs in general, so that they can be used to calculate the actual amount of saturation of the reservoir and find zones that may have been missed so far.

3. Based on points one and two above, oil and gas potential can be identified from carbonate rock resistivity reservoirs which may have been overlooked so far as proven by production tests in accordance with water saturation calculations using the Lucia classification petrophysical analysis method which has not been widely used in Indonesia in general especially where this research was conducted

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