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Petrophysics of Low Resistivity Reservoir

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ABSTRACT: Low resistivity reservoirs have long been known in the oil and gas industry as reservoirs that have significant potential and contribution to oil and gas production. This reservoir is very unique because of its relatively low resistivity readings (< 5 Ohm) and often other log responses do not show the way carbonate-containing reservoirs do, so they are often overlooked and not considered as potential carbon reservoirs. The low resistivity reading also causes the Water Saturation (Sw) value to be too high, which contributes to why the reservoir is overlooked. Theoretically, the factors that cause low resistivity readings are high clay/shale content, fine grain size, high salinity air formation, presence of microporosity and presence of conductive minerals which affect resistivity log readings in addition to other things such as low structured reservoirs. and there is a significant slope of the layers. Based on statistic reports, generally in low resistivity reservoirs there is a combination of two or more of the causal factors mentioned.

This study aims to identify the characteristics of low resistivity reservoirs in the Upper Cibulakan Formation, West Java Basin, especially from log readings and recognition of what factors support reservoir formation both from the results of core and log analysis as well as selecting combinations for calculating water saturation. From the low resistivity reservoir characteristics, it is hoped that it can be used to find and identify the distribution of similar reservoirs so that potential reservoirs that have been overlooked so far can be identified, discovered and developed which in the end are expected to provide additional contributions both in terms of education and for the oil and gas industry in finding new reserves for oil and gas production in Indonesia.

KEYWORDS: Causative Factors, Low resistivity, Petrophysical Analysis, Reservoir Characteristics.

1. INTRODUCTION

The Miocene low resistivity reservoir is very well developed in the North West Java Basin (Figure 1). More than hundreds of wells in the North West Java area have been drilled and penetrated low resistivity reservoirs both onshore and offshore, until now there are still many wells that are still producing from reservoirs which until now are believed to have only come from shaly sand reservoirs in the field. Cemara, Pegaden and Bojongraong in the onshore area and in the LL field in the offshore area. Although there is a lot of subsurface data in the form of geophysical, geological and reservoir data in the North West Java Basin that can be used as study support data, not only from the Cemara Field but also from data outside the Cemara Field area, until now there are still many questions related petrophysical analysis of the low resistivity reservoir.

By studying the characteristics of low resistivity reservoirs based on log responses and also available core rock data, it is expected to be able to answer questions about the petrophysics of low resistivity reservoirs, so that potential hydrocarbons that may have been missed in low resistivity rock intervals can be found. This research is also useful for determining the perforation interval and also the possibility of developing other intervals besides the shaly sand reservoir which is generally a type of lithology of the low resistivity reservoir.

This research is limited to the low resistivity reservoir of the Upper Cibulakan Formation, North West Java Basin in fields that have log and/or core data that are directly or indirectly related to the presence or indication of the presence of the reservoir or have data to support this research. This research is also limited to petrophysical analysis which uses log and core data as well as production data for validation, does not use other data such as seismic and dynamic pressure data or production performance, and will only display the results from selected wells which will be able to provide an overview as shown.

2. REVIEW OF LITERATURE

Reservoir characterization is needed to be able to know the type of lithology that makes up the reservoir, the distribution of reservoirs vertically and laterally, to know the petrophysical quantities of each reservoir such as resistivity, porosity and other petrophysical quantities for saturation calculations which can ultimately be used to calculate the reservoir reserves, if it is

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economically sufficient for a geophysical exploration or exploitation of hydrocarbons.

Hydrocarbon reservoirs that are often found in the world generally consist of two types, namely clastic (sandstone) and carbonate (limestone). For other reservoirs, such as volcanic rocks, they are 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. Low Resistivity Pay (LRP) and Low Contrast Pay (LCP) are both relatively similar concepts. LCP is a term that is more general in nature and is applied to all conditions where it is difficult to determine whether the formation or the reservoir we find will produce hydrocarbons or water (IHDRC, 2013).

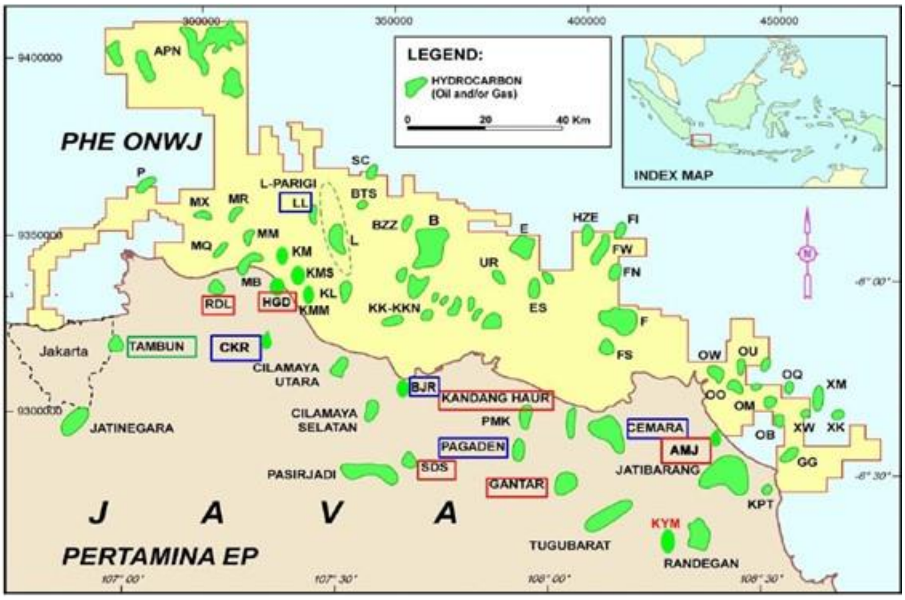

Figure 1. Research Area Location

This may be because there is little difference between the resistivity readings in the reservoir intervals containing hydrocarbons and water, or due to the small contrast in resistivity between the producing layer and the surrounding non-reservoir rock layers, such as shale layers. The absolute value of resistivity in LCP ranges from moderate to high, especially in formations containing fresh water formation water.

Low Resistivity Pay is a special condition of Low Contrast Pay where the absolute value of the reservoir resistivity is also low, generally at a value below 1-2 Ohmm (Gang Wang drr, 2015). Consequently, these reservoirs are often found in areas that have formation water with relatively high salinity (salty water). In extreme cases the resistivity value can be so low that it is very possible to miss the hydrocarbon zone (pay zone), when calculating the water saturation in that zone is very high or even 100%. There are 2 types of low resistivity reservoirs (IHDRC, 2013 and Gang Wang drr, 2015):

• Type 1. Pay, where the results of calculating water saturation (Sw) using the existing resistivity with the Archie equation are less accurate and too pessimistic compared to the actual Sw in the formation. The question then becomes how discover the expansion method of the equation used to obtain the actual Sw value or by modifying the calculation algorithm used from the resistivity, or the possibility of obtaining saturation data in a different alternative way.

• Type 2. Pay, where the results of calculating water saturation (Sw) using the existing resistivity with the Archie equation are accurate but too high. The problem then is how we can understand why the water is effectively immobile and how to develop several possible methods to be able to predict which reservoir rocks will produce hydrocarbons and which will produce water from reservoirs with the same Sw value.

Low resistivity rocks (commonly referred to as shaly sands) are produced by deposition in transitional to shallow marine environments. Shaly sand rock is a type of reservoir rock that is widely discussed by geologists and has an important role in the geological reconstruction of an area. Shaly sand rocks are produced as a result of deposition in transition areas and shallow seas (Gang Wang, drr 2015), stating that the shaly sand material contains very high clay minerals, which can be Ilite, Chlorite or

Montmorillonite, each of which has its own unique characteristics. unique. Besides clay minerals, the shaly sand reservoir usually contains conductive minerals such as pyrite and glaukonite. The combination of various clay minerals and conductive minerals makes the resistivity log reading in the shaly sand reservoir very low so that it can be interpreted as a reservoir that has no potential for hydrocarbon content in it.

Not many countries in the world have low resistivity reservoirs. Indonesia is one of the few countries that has a hydrocarbon reservoir in the shaly sand rock. Previous studies generally discussed petroleum geology which included tectonic settings, stratigraphy and petroleum systems which included source rock and maturation, reservoirs, migration, traps and seals as well as the potential for hydrocarbons in the area, while in this study the emphasis was on log and core response analysis to lithology and productive zone characterization in shaly sand reservoir with low resistivity log readings.

Gang Wang, et.al 2015, based on reservoir property aspects, reservoir size, cation exchange in shally sand, filtrate infiltration during drilling, influence of conductive minerals etc. divides low resistivity reservoirs into 5 types: (a) Low Amplitude Structure; (b) Complex Pore Structure; (c) Additional Electrical Conductivity; (d) Thin Sand-Mud Interbeded; and (e) Reservoir Containing Conductive Minerals.

Meanwhile, Darling and Sneider in Moore (1993) and Geological Perspective of Low Resistivity, stated that there are 7 causes for the formation of low resistivity reservoirs: (a) Bed Thickness: logging cannot read perfectly; (b) Grain Size: the fine grain size contributes a significant Swirr (c) Mineralogy: conductive minerals (such as pyrite, glauconite, hematite, or graphite), or rock fragments that affect the resistivity response; (d) Structural Dip: the slope of the layer gives a significant difference in the response of the resistivity log in conditions where there is an orientation deviation between the log tool and the layer against normal conditions; (e) Clay Distribution: classification as dispersed, structural, or laminated which allows the presence of bound water; (f) Water Salinity: high salinity results in low resistivity readings; (f) Any combination of the aforementioned: usually there is a combination of the factors mentioned earlier

3. PURPOSE AND OBJECTIVES

The purpose of this article is to identify reservoirs that produce low resistivity hydrocarbon and factors that have influence on it with the objective to obtain calculation of aktual saturation to reduce doubt in determining production test on reservoir that contain hydrocarbon with possibilities to delineate wells that will be developed subsequenly in the structure.

4. METHODS

The method used in this study is focused on finding correlations with the physical properties of the reservoir with logs and cores, therefore the following research methodology and stages are needed:

a. Select fields or drilling wells that produce gas, oil or water from the Upper Cibulakan Formation reservoir with low resistivity to study the physical properties related to the amount of oil that has been produced.
b. Study the properties of logs, especially resistivity logs which will be correlated with the physical properties of the reservoir.

Broadly speaking, this research consists of three groups of stages, namely:

a) Study of lithological characterization of low resistivity rock reservoirs in the study area from megascopic and microscopic analysis of core rock and log and core response characteristics for each low resistivity rock in the form of shaly sand reservoir.
b) The study of the characterization of shaly sand rocks acting as reservoirs and non-reservoirs is qualitatively related to the presence of clay minerals and conductive minerals from the reservoir zone which is directly proportional to the cumulative amount of hydrocarbon production produced from the reservoir.
c) The study of determining the parameters for petrophysics calculations is validated by measuring the core for the qualitative and quantitative characterization of productive zones in low resistivity reservoir rocks.

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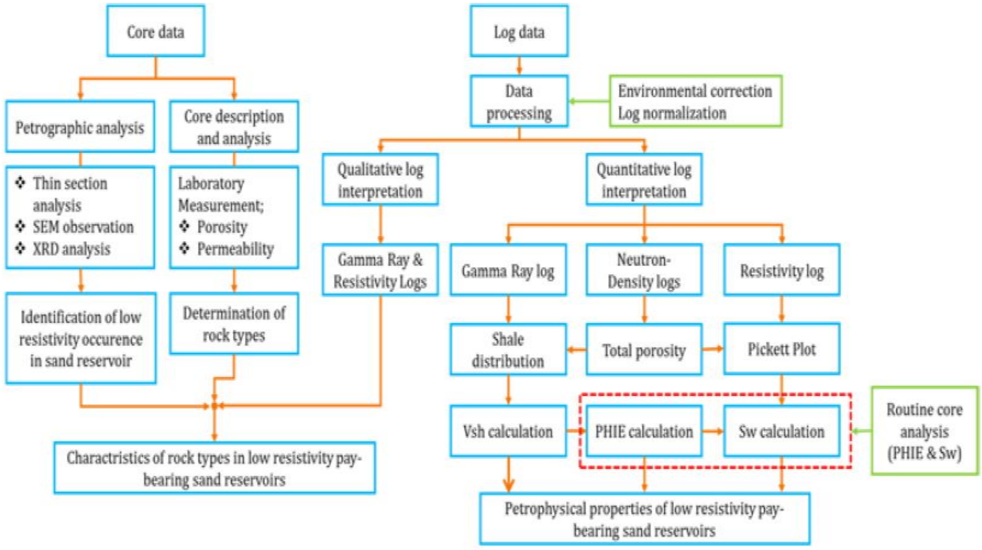

Figure 2. Research Flow and Method

5. RESULT

5.1 Factors Causing Low Resistivity

Reservoir grain size has an effect on reservoir resistivity readings because it can result in high Swirr. Grain sizes in the low resistivity reservoir Cibulakan from petrographic observations based on Wentworth classification are in the medium to very fine range (0.25 to 0.06 mm) in line with the results grain size prediction based on permeability versus porosity plots using a chart from Berg, 1970 which is in the range of 16 to 125 µm or equivalent to 0.02 to 0.125 mm, the difference in the range is due to the limited data used for each observation method but it remains in the same range. The alternation of sandstones with finer grained layers such as clay, silt and/or shale is one of the causes of low resistivity readings, caused by the effect of resistivity readings on the fine and thin layers of the sandstone which is the reservoir. Figure 3 CT Scan results showing the alternation of sandstones with finer grained layers such as Clay, Silt and or Shale

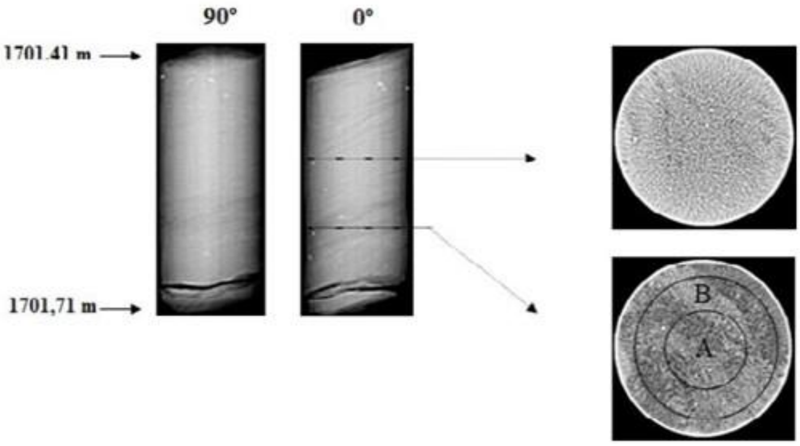

Figure 3. CT Scan showing Sand-Shale alternating, Shale image is brighter than Sand

The presence of clay and/or shale in reservoir rocks, both the amount and/or type of clay, is one of the factors that affect resistivity readings in reservoirs, both normal reservoirs and low resistivity reservoirs. Core analysis results show volume clay in low resistivity reservoirs is in the range of 6 to 21% and the types of clay in these reservoirs are Illite, Kaolinite and Chlorite (Table 1).

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Table 2. Presence Volume and Type of Clay in Low Resistivity Reservoir

No	Depth (m)	Clay Minerals					Glauconite	Carbonate Minerals			Other Minerals				Total		
		Smectite	Ill-Smec	Illite	Kaolinite	Chlorite		Calcite	Dolomite	Siderite	Quarzt	K Felds	Plagio	Pyrite	Clay	Carbonate	Other
1	1695.23			2	4	10	5	-	-	-	70	4	5	-	21	-	79
2	1696			3	5	9	4	-	-	-	71	2	6	-	21	-	79
3	1697.6			2	4	8	5	-	-	-	68	4	8	1	19	-	81
4	1698.3			3	6	8	3	-	-	-	71	3	6	-	20	-	80
5	1699			3	8	10	3	-	-	-	68	tr	7	1	24	-	76
6	1699.6			2	3	5	1	1	-	-	81	1	6	-	11	1	88
7	1700.3			2	3	6	1	35	-	-	48	tr	5	-	12	35	53
8	1701			3	5	8	0.1	1	-	-	78	tr	5	-	16	1	83
9	1701.6			3	4	8	0.1	5	-	-	75	tr	5	-	15	5	80

The presence of the mineral Glaukonite has been widely discussed and is believed to be one of the causes of low resistivity readings in sandstone reservoirs. Glauconite is a Potassium Fero Phyllosilicate mineral (mica group) which has a characteristic green color (Figure 6), brittleness and a very low level of weathering resistance with the chemical formula (K,Na)(Fe3+,Al,Mg)2(Si,Al) 4O10(OH)2. Having a very rich iron and water content, it can be found as individual pellets, granular compositions and intergranular cement. It has densities ranging from 2.4 g/cm3 to 2.95 g/cm3, with an average of 2.67 g/cm3 with a hardness on the Mohs 2 scale. The iron content and Glaukonite are possibly the factors causing the low resistivity readings of the reservoir rock, while the presence of feldspar is due to its It is also radioactive because it is unstable, easily weathered and very easy to turn into clay minerals which is one of the reasons for low resistivity readings. The volume of feldspar present in the reservoir rock ranges from 2.25 to 9.75%, while the mineral Glaukonite ranges from 1.75 to 15.75%

5.2 Petrophysical Parameters

The magnitude of the petrophysical parameters for calculating water saturation is often ignored, log analysts use standard numbers that are commonly used, namely a=1, m=2 and n=2, even though these petrophysical parameter values actually indicate the condition of the reservoir and can explain unusual phenomena in the reservoir. in this case it is a low resistivity reading in a reservoir containing hydrocarbons. Petrophysical parameter values are obtained from the Special Core Analysis (SCAL) where the a and m values are related to the Formation Factor (F) value while the n value is related to the Resistivity Index (RI) value.

From the existing SCAL data, it shows consistency between appearances which can be seen from both the core, petrography, SEM and other analyzes such as XRD regarding the factors that cause low resistivity readings. For example, there is a RI versus Sw curve that curves to the left as an indicator of the presence of significant shale (Figure 8a) and a RI versus Sw curve that curves to the right as an indication of microporosity (Figure 8b). From the data on the formation factor versus porosity after plotting, the value m = 1.56 to 1.76 is obtained, while the value n = 1.7 to 1.9, both of which can be interpreted as the influence of secondary porosity, in this case the dominant microporosity and the presence of water, in this case, trapped in the microporosity.

Another parameter that also affects the calculation of water saturation is the value of Formation Water Resistivity (Rw), the value of Rw is obtained in 2 ways, namely by measuring the resistivity of formation water in the laboratory (Table 4) or using a log to obtain Rwa values such as Rw Sp, Rw Resistivity and Picket Plots. From the two direct and indirect methods above, the value of Rw = 0.12 to 0.37 is obtained . Other data obtained from the results of the Core analysis is Cation Exchange Capacity/CEC (Table 5), this data is needed if we use the Waxman-Smith equation to calculate water saturation (Sw). The available CEC data is very limited (there are only 2 wells), possibly due to the fact that at the time the CEC analysis was carried out there were still limited laboratories that could carry out the work and the price of the analysis was still very expensive.In the discussion of petrophysical analysis, it can be seen that the calculation of water saturation using the Waxman-Smith equation is very dependent on the accuracy of the CEC value obtained from the core because if the CEC value used is inaccurate, the resulting water saturation value becomes very optimistic or conversely too pessimistic. Thus, the calculation of the water saturation value using the Waxman-Smith formula is only carried out on wells that have CEC data, because of the reasons above and also when compared with the water saturation value using other equations the results do not have a significant difference

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5.3 Calculation of Sw

At the beginning of this study Sw calculations used several methods known so far including the Archie method which we are familiar with so far used to calculate saturation in clean sand reservoirs so that there is comparison with other methods

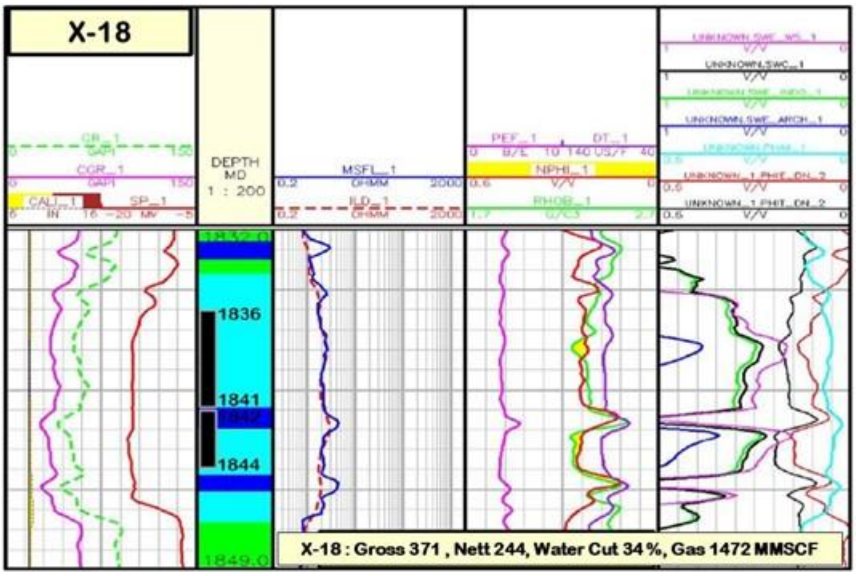

Figure 4. Sw Calculation Results Using Various Methods

After obtaining statistical data from Sw calculations in many wells, the Indonesian equation was chosen as the method used at the beginning of the calculation, then it was corrected using a correction factor which is a collection of factors that cause low resistivity readings and for wells with CEC data the Waxman-Smith equation was used as a comparison.

Figure 4 shows the final results of Sw calculations using the Archie method (in blue), the Indonesian method (green), the Indonesian correction method (black) and the Waxman-Smith method (pink).

6. CONCLUSION

The distribution of low resistivity reservoirs in the North West Java Basin is in the western part (Haurgede, Cikarang, Tambun), the central part (Pegaden, Bojongraong, Sindangdsari, Gantar) to the east (Cemara, Akasia Maju) which are PEP CAs (Onshore) and in CA ONWJ (offshore) as found in the LL structure.The low resistivity reservoir depositional environment is on the inner to outer shelf sedimentation. Reservoir lithology consists of wacke, graywacke, felsphatic graywacke, lithic graywacke, sub litharenite, felsdphatic arenite, lithic arenite and sandy larger foram packstone. Low resistivity reservoirs can be in the form of bell shapes, funnel shapes, serrated and variations of the three, can stand alone or exist between carbonate rocks or are in the armpits of carbonate rocks.The characteristics of low resistivity log reservoirs in the form of low resistivity often give a flat response, low to high effective porosity and generally have low to very low permeability.The low resistivity response is caused by grain size, mineralogy and clay distribution (Moore, 1993) while according to Gang Wang et al, 2015 it is caused by complex pore structures, thin sand-mud interbeded and containing conductive minerals. Spectral gamma ray (SGR) logs are needed to determine the true value of gamma ray (GR) log readings in the Upper Cibulakan Formation (CBA). In general, the SGR value is between 0.66 and 0.98 from the GR value. The high GR value is probably due to the abundance of feldspar minerals in the CBA constituent rocks. The low resistivity response still follows the basic principles of Archie with corrections that depend on variations in the clay/shale content, the presence of water-containing microporosity and the influence of conductive minerals. Regarding points 5 and 6, corrections for clay content can be fulfilled using the available saturation calculation equations (Indonesia, Nigeria etc.), however, if there are other influences that contribute to a decrease in resistivity, additional corrections are required. Corrections are generally in the form of corrections for water that is in micro porosity and conductive mineral content represented by the matrix porosity components in the calculation of the next correction. Regarding point 7, the calculation of shale volume must be as accurate as possible and validated by calculations using other methods and core rock if available. It is highly recommended to obtain saturation calculation parameters

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such as a, m, n from special core analysis (SCAL) data, in addition to obtaining formation factor (F) and Resistivity Index (I) values as well as capillary pressure data from the core analysis. The cutoff resistivity value for hydrocarbons in the Upper Cibulakan Formation which is located onshore is 2 Ohmm for the shally sandstone reservoir and 3 to 4 for calcareous sandstone and carbonate depending on the amount of carbonate minerals, while for offshore it is 1.4 to 1.5 Ohmm depending on the complexity of the the porosity of the reservoir rock. Of the 3 saturation equations used in the calculation of water saturation Sw in the low resistivity CBA reservoir (Indonesia, Modification of Indonesia and Waxman-Smith), the Indonesian equation gives a fairly good value for the RLR caused by the distribution of clay/shale, Indonesian modification of the Indonesian equation gives a fairly good value for the RLR caused by the distribution of clay/shale and other influences, while the Waxman-Smith equation gives a pretty good value if there is a valid CEC value from core rock analysis. Apart from sandstones, in the Upper Cibulakan Formation there is also a low resistivity reservoir in carbonate rocks whose cutoff resistivity value is higher than that of sandstones but still much lower than non-low resistivity carbonate reservoirs. So that more core data and parameters are taken for analysis of Water Saturation quantities such as a, m, n, CEC, F and RI so that the petrophysical analysis carried out becomes more valid. For the industry, verification of the submitted proposals is carried out so that it can be seen directly whether the method used in this research is correct or still requires some adjustments.

7. ACKNOWLEDGEMENTS

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8. CONFLICT OF INTEREST

It is certified that there is no conflict of interest with any individual or group of individual or institution with the present manuscript

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